



**Lumistar LS-28 Family of
Telemetry Range Receivers
(LS-28-DRS, LS-28-QRS & LS-28-R2D3)**

Operations & Maintenance Manual



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1 Introduction

1.1 General Information

As a guide, this manual was developed in accordance with MIL-STD-40051-2A [Preparation of Digital Technical Information for Page-Based Technical Manuals (TMs)] with regard to format and content. This standard establishes the technical content requirements and mandatory style and format requirements for the preparation of technical manuals (TMs) and other types of equipment publications.

This manual has four (4) chapters including this *Introduction*, *System Installation*, *System Operation*, and *System Maintenance*. The Introduction covers Equipment Description, and the Theory of Operation. The System Operation chapter deals with the primary software application and how to use it to control the system. The System Maintenance chapter deals with Preventive and Corrective maintenance and the Performance Testing of the system.

1.1.1 Scope

This is a combined operations and maintenance manual for the Lumistar family of LS-28 telemetry range receiver systems used to support terrestrial flight testing as well as many types of satellite operations. There are two primary variants in the LS-28 family; the *LS-28-DRS¹* is a dual channel unit, while the *LS-28-QRS* is a quad channel receiver. Each variant can support up to four different frequency bands on each channel.

1.1.1.1 Warranty Information

Lumistar warrants all of its products for two years from the date of shipment. This includes all card level products, systems, firmware and Lumistar designed software delivered.

This warranty extends past the original purchaser to the end user of the product. If a product is integrated into a system and delivered as part of an overall system – i.e. Antenna Controller or Decommutation system – Lumistar warrants its components in that system. If a customer buys Lumistar products as part of a government deliverable, the government can exercise the warranty directly from Lumistar.

If a product is found to be defective or fails under normal operating conditions, Lumistar will repair or replace the items at its discretion at no cost to the customer. While Lumistar understands that its customers sometime work in harsh environments and designs for hard use of its products, submersion, exposure to jet blast, or receiving 10 Watts of RF power is not normal operation. Lumistar will be the sole decider of product abuse.

Lumistar's repair philosophy is to cover core costs of non-warranty repair. Lumistar does not typically charge an evaluation fee, and repair costs are kept minimal. Typical repair costs are \$500-\$1,000 for a board level product.

¹ There is also a second variant of the LD-28-DRS, designated the LS-28-R2D3 that has an additional digital demodulator. The –R2D3 is also covered in this manual.

The warranty can be extended at time of purchase for up to 5 years, and the cost is a percentage of the purchase price and whether it is a board or a system being sold.

1.1.1.2 List of Abbreviations & Acronyms

A list of all abbreviations and acronyms used in this document may be found in Appendix A - List of Abbreviations & Acronyms beginning on page 168.

1.2 Equipment Description

The LS-28 is an advanced technology, multi-channel receiver/combiner employing sophisticated fourth generation Digital Signal Processing (DSP) technologies.

1.2.1 LS-28 Characteristics, Capabilities, and Features

The LS-28 supports independent, two or four channel reception² and/or combining of up to four RF bands (including E, S, lower/upper-L, P, K, C, or custom bands up to 5 GHz).

Internal to the LS-28, the RF inputs are processed by the Lumistar LS-27 two-channel, quad band PCI-based tuner card(s) that acquire and downconverts the signals to a 70 MHz intermediate frequency (IF). The IF signals are then digitized by the Lumistar LS-35 two-channel digital multi-mode IF receiver. The LS-35 supports either independent channel, or combined channel operation for diversity reception.

The digital multi-mode demodulation capability of the LS-35 supports multi-symbol PCM/FM, SOQPSK, BPSK, QPSK, OQPSK, AQPSK, PCM/PM, and sub-carrier(s). The demodulated data is bit synchronized and provided as both TTL and RS-422 data & clock outputs (PCM code conversions are also supported). Both Pre-D and Post-D (FM only) combining are available.

Standard features such as eye-pattern and constellation diagram displays, IF spectral displays, bit error reader and onboard 70 MHz test modulator are included. Legacy demodulation of analog NTSC³ FM signals is also included. Since telemetry data is not routed through the system's PCI bus, the LS-28 can process high data rate streams with little or no impact to the processing load of the CPU.

Unlike analog legacy receivers, the LS-28 is a true software-defined radio whose digital implementation is highly flexible and expandable. The unit provides single/dual/tri/quad band operation utilizing Lumistar's LS-27 series dual channel/quad-band down converter in a single PCI slot. The IF receiver/combiner functionality is realized within a single PCI card utilizing a state-of-the-art digital processing engine and can operate as a single or dual channel receiver/combiner.

² Depending on the model number.

³ PAL Video Optional.

The standard LS-28 receiver processes data rates from 10 kbps to 30 Mbps for PCM/FM, 10 Kbps to 20 Mbps for BPSK & PCM/PM, and up to 30 Mbps for QPSK/OQPSK/SOQPSK. Higher data rates are available as an option. The LS-28 sensitivity and adjacent channel interference performance are superior due to the analog IF “SAW” and digital “FIR” filtering method employed to the IF. By using this filtering method, IF bandwidths are optimally set by software as a function of data rate, PCM code, and modulation format, or can be manually selected by the user.

The digital combiner utilizes an enhanced S/N ratio measurement firmware technique to provide a signal-to-noise improvement of at least 2.5 dB when equal signals near threshold levels are applied at the LS-28 inputs. For optimal multi-path avoidance, the combiner can operate at fade “break frequencies” up to 50 KHz. Best source selection can also be performed via software. Because of its digital implementation, the performance of the LS-28 is repeatable, day-after-day, year-after-year, from unit-to-unit. The LS-28 requires no periodic calibration, and life cycle costs are greatly reduced because future upgrades (such as new modulation formats) or an improved DSP algorithm are all implemented via software and/or firmware via an on-site upgrade.

The LS-28 is rack mountable (a rack mounting kit is provided), and is designed for deployment in ground benign environments.

The unit is equipped with two (2) Giga-bit Ethernet RJ-45 ports for remote operation, and the system chassis can support one or two VGA monitor ports.

1.2.2 LS-28 System Components

The LS-28 is made up of a single 4U, 19” wide rack mountable chassis that is populated with both commercial off-the-shelf computer components and custom designed telemetry signal reception and processing cards. All of the RF/IF & other signal inputs and outputs are accessed via a custom designed rear panel for optimum flexibility. The computer components are industry standard IBM PC based and are no different than similar components found in ordinary desk-top PCs. The computer motherboards employ Intel multi-core processors. The LS-28-DRS dual channel system uses a motherboard based processor, for example, whereas the LS-28-QRS quad channel system uses a separate single board computer and a passive backplane. The LS-28 system is compatible with any and all IBM PC display and keyboard/mouse products. The LS-28 system software is hosted on the Microsoft Windows⁴ operating system.

Both the commercial off-the-shelf computer components and custom designed telemetry signal reception and processing cards are described in more detail in the following numbered paragraphs.

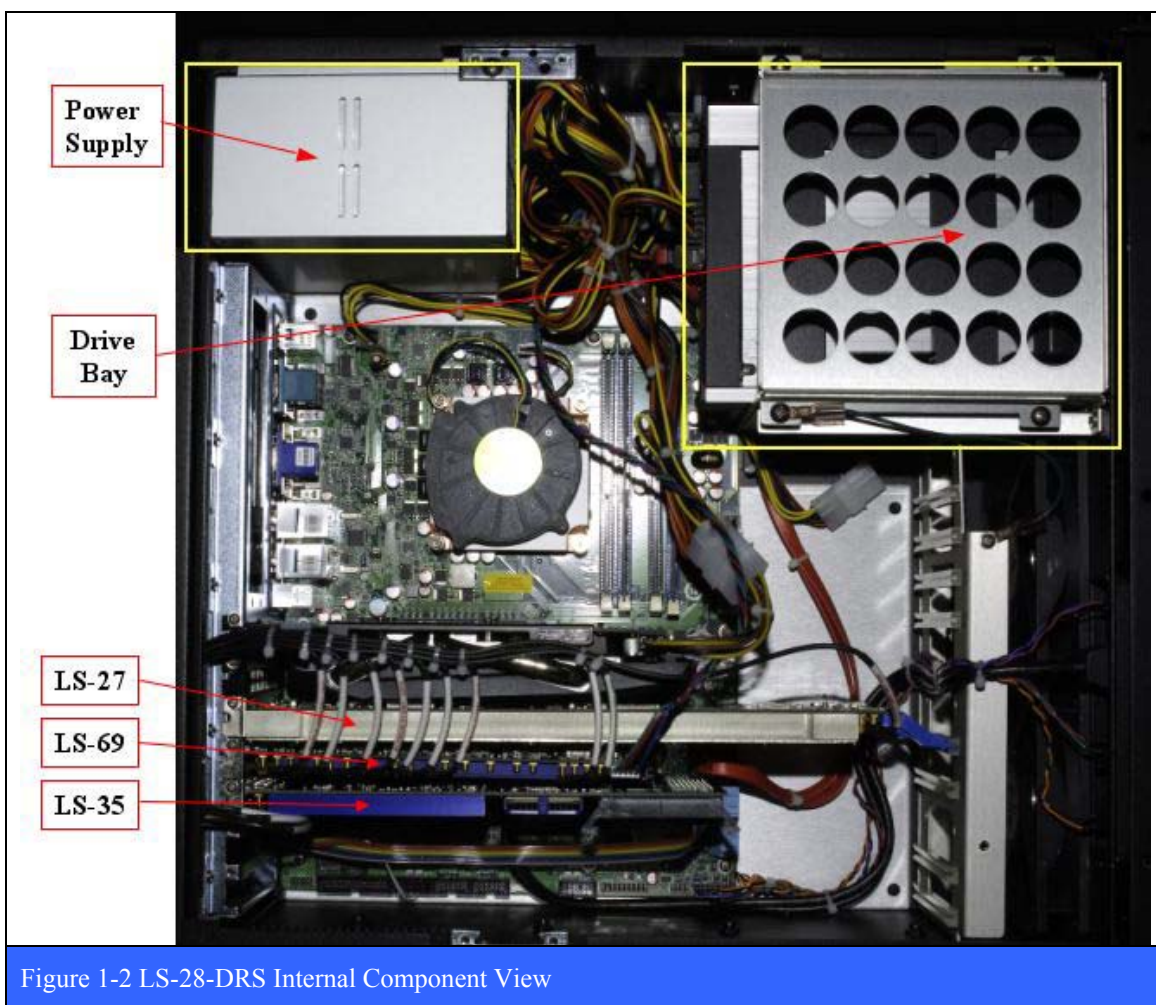
⁴ Either Windows 7, or XP Pro, depending on customer requirements.

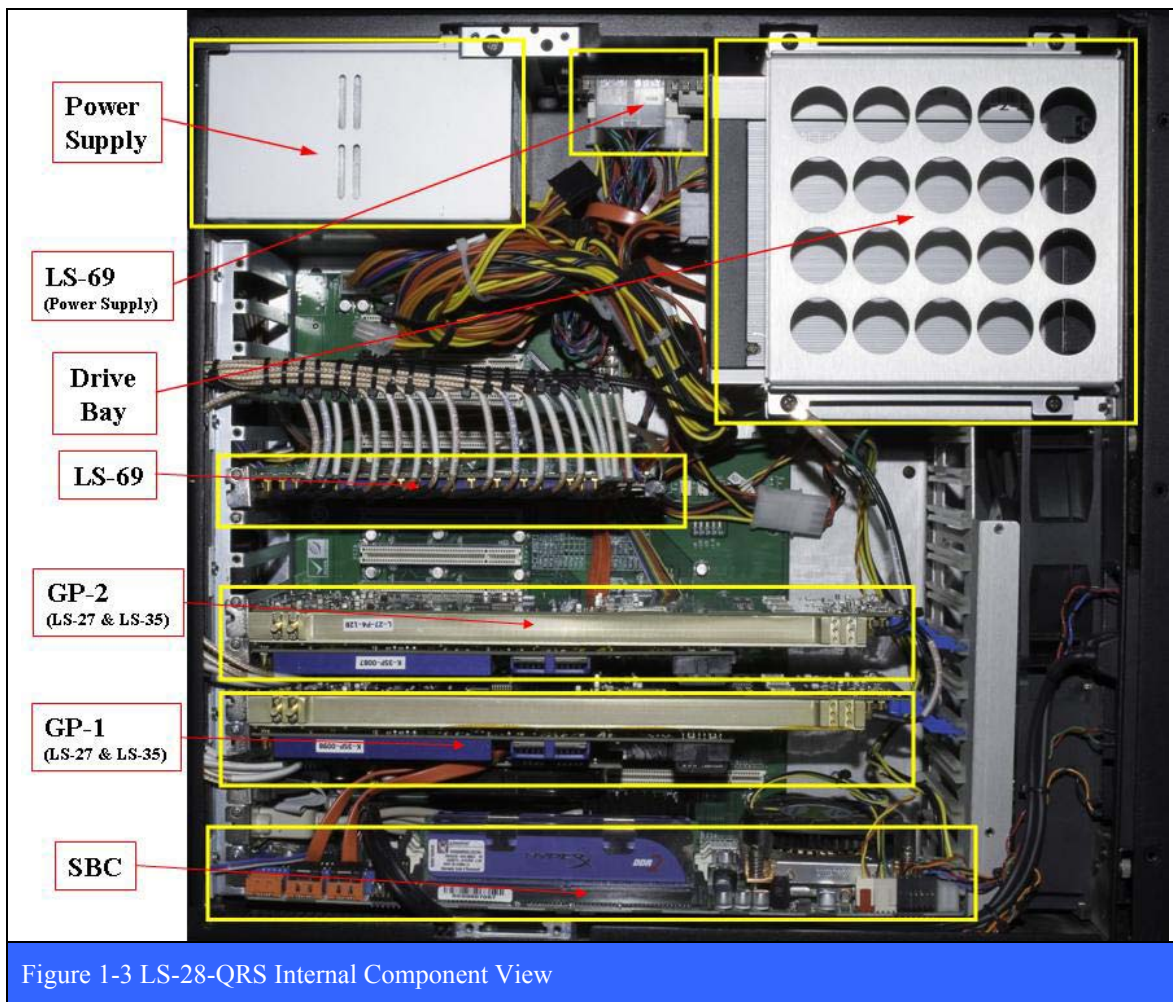
1.2.2.1 LS-28 4U chassis

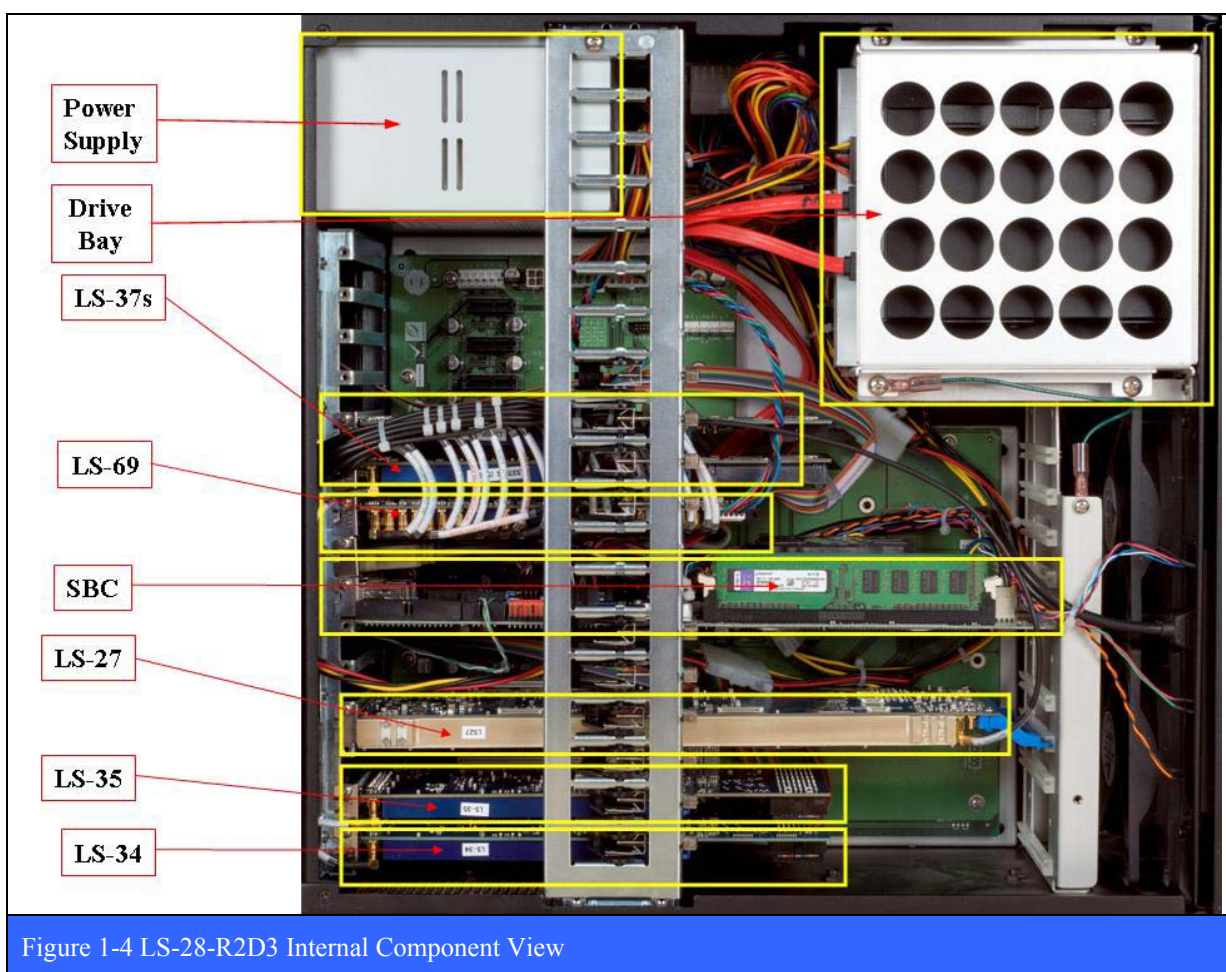
The LS-28 chassis is shown in Figure 1-1. Both the front and rear views are shown. The chassis components include: *Front Panel Assembly*, *System Power Supply*, *SATA Hard Disk and DVD-ROM Drives*, *CPU Motherboard* (or *Single Board Computer*), and *Rear I/O Panel Assembly*.



The internal view of the LS-28-DRS chassis is shown in Figure 1-2 below. Note the location of all of the major components mentioned thus far. The internal view of the LS-28-QRS chassis is shown in Figure 1-3 on page 16. The internal view of the LS-28-R2D3 chassis is shown in Figure 1-4 on page 17.

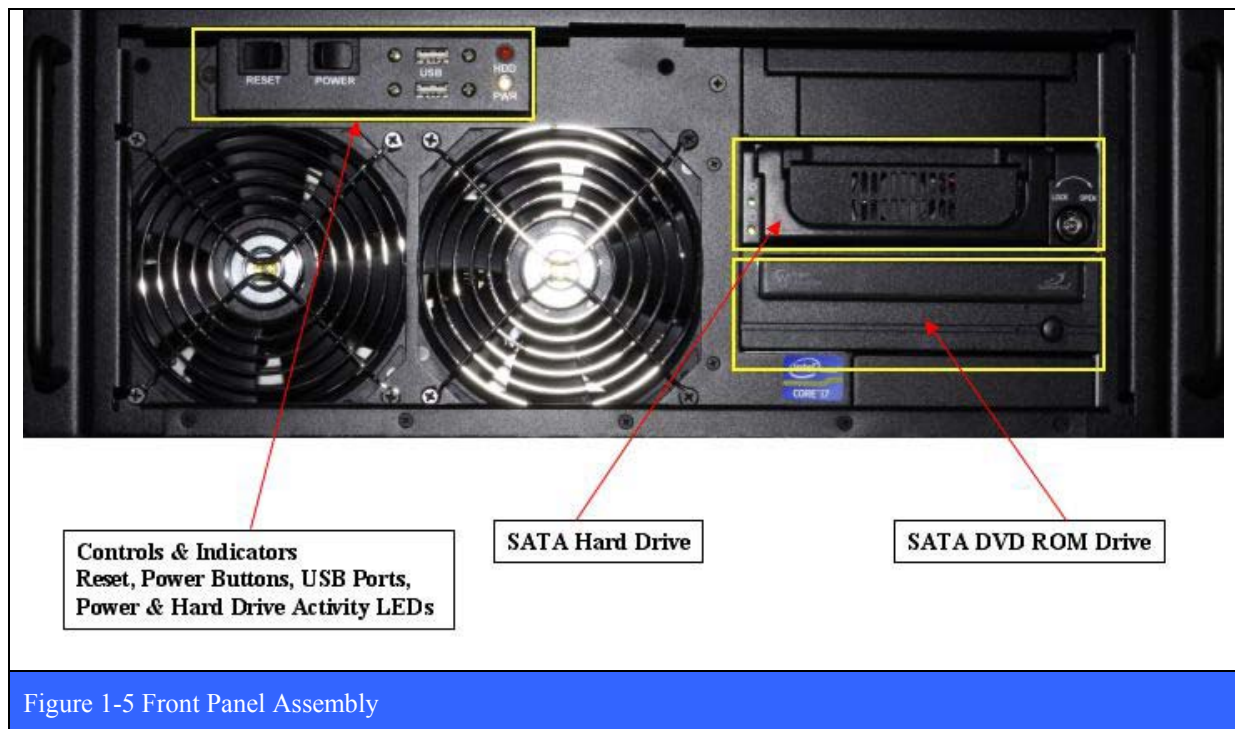






1.2.2.1.1 Front Panel Assembly

The Front Panel assembly includes: a Hinged Door subassembly (not shown) with lock and air filters, controls and indicators (reset & power buttons, USB 2.0 Ports (2 ea) and power and hard disk activity LEDs), 120 mm cooling fans (2 ea), SATA Hard Disk Drive, and SATA DVD-ROM Drive. The drive bay can also accommodate a second 5.25" drive as well as a 3.25" solid state hard drive.



1.2.2.1.2 System Power Supply

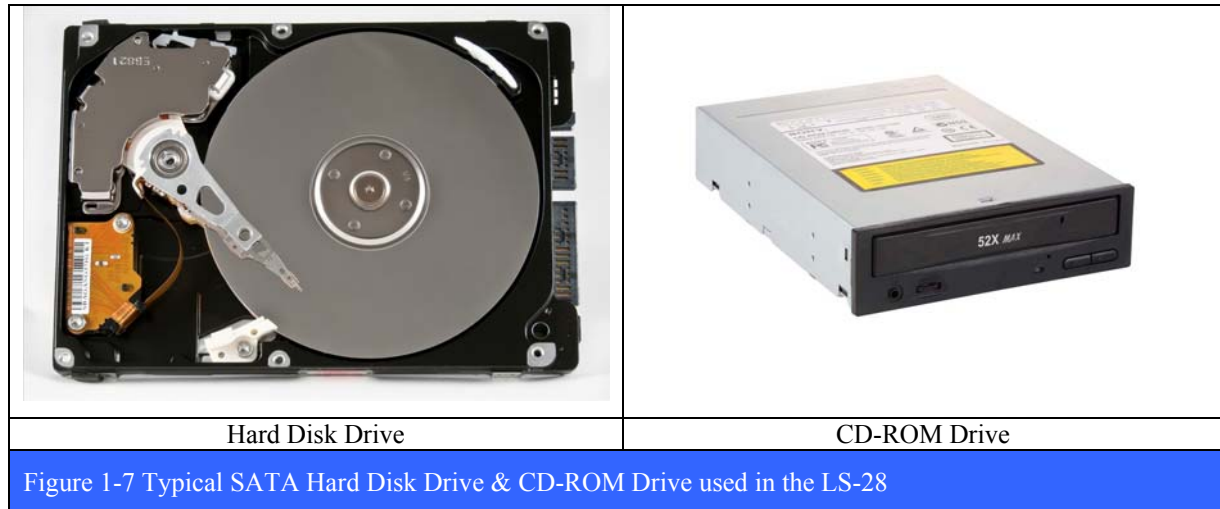
All LS-28 chassis are equipped with a 500+ Watt, ATX style AC power supply similar to the one shown in Figure 1-6 below. The make/model number of the power supply varies as of the date of manufacture. The system power supply converts primary 110/220 VAC to low-voltage regulated DC power for the internal components of the computer as well as all of the custom Lumistar CCAs. The ATX power supply is turned on and off by a signal from the motherboard. It also provides a signal to the motherboard to indicate when the DC power lines are correct so that the computer can begin to boot up. While an ATX power supply is connected to the main AC supply, it provides a 5 V stand-by (5VSB) line so that the standby functions on the computer and certain peripherals remain powered.



Figure 1-6 a typical ATX style System Power Supply used in the LS-28

1.2.2.1.3 SATA Hard Disk Drive & CD-ROM Drive

All LS-28 chassis are equipped with a SATA⁵ hard disk drive and CD-ROM (or DVD-ROM) drive. The make/model number of the drives varies as of the date of manufacture. The size of the hard drive ranges from 500 GB to 1 TB (again, depending on the date of manufacture). Per customer requirement, the system hard drive can have one or two NTFS partitions. The LS-28 chassis is also equipped with a SATA CD-ROM or DVD-ROM drive. Examples of both are shown in Figure 1-7 below.



The Serial ATA (SATA - Serial Advanced Technology Attachment) is a computer bus interface for connecting host bus adapters to mass storage devices such as hard disk drives and optical drives. Serial ATA was designed to replace the older parallel ATA standard (often called by the old name IDE), offering several advantages over the older interface including: reduced cable size and cost (7 conductors instead of 40), native hot swapping, faster data transfer through higher signaling rates, and more efficient transfer through an (optional) I/O queuing protocol. SATA devices communicate via a high-speed serial cable over two pairs of conductors.

⁵ Upon customer request, the LS-28 system can also be configured with a solid state hard drive with a SATA interface.

1.2.2.1.4 CPU Motherboard (LS-28-DRS)

The dual channel LS-28 systems are configured with a multi-core, Intel PCI bus motherboard with integrated graphic⁶. The make/model number of the motherboard and its associated components (CPU/RAM etc.) varies as of the date of manufacture. The motherboard is typically configured with 4 MB of RAM and has a 3 GHz (or higher) multi-core Intel CPU chip installed. A typical example of this motherboard is shown below in Figure 1-8.

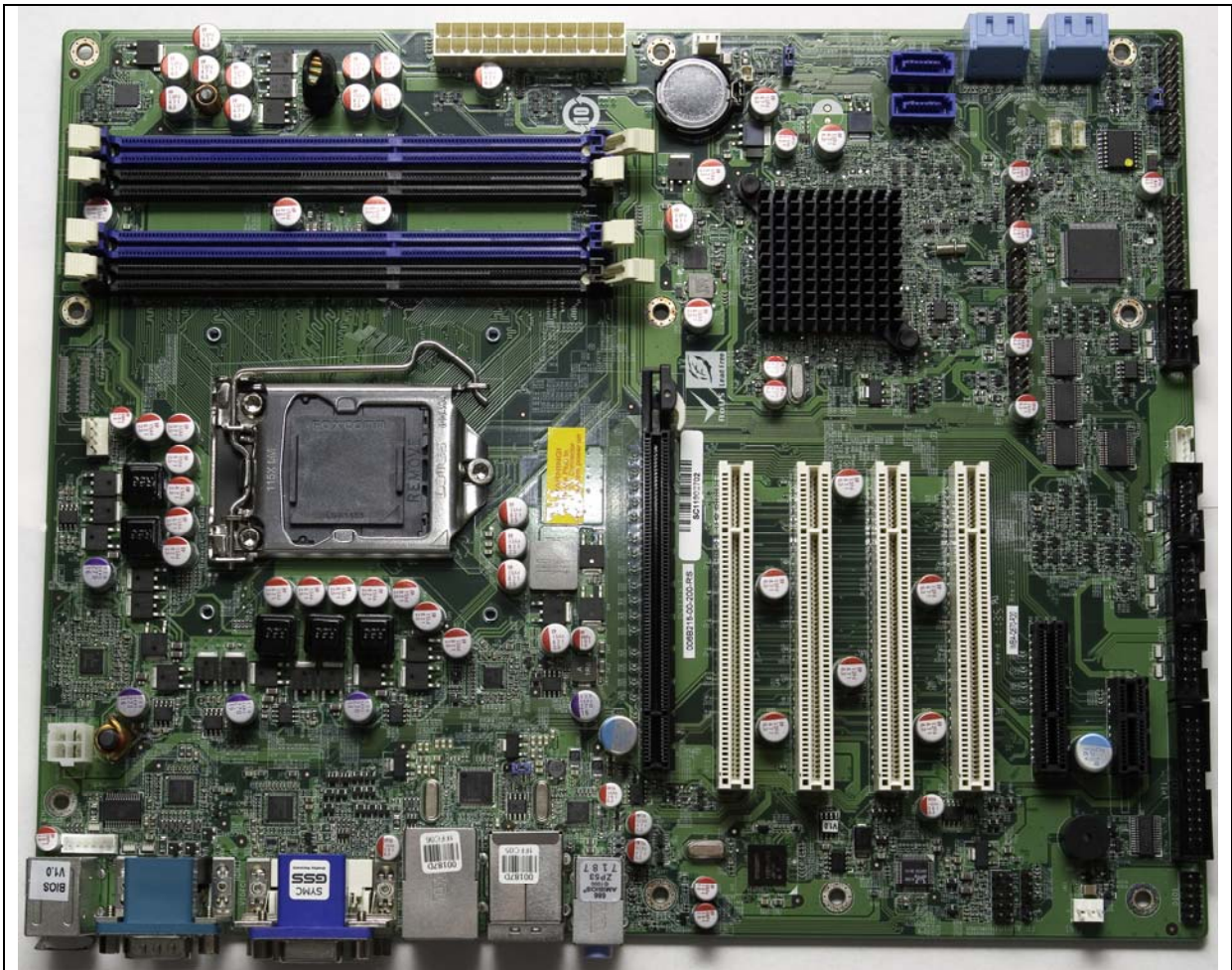


Figure 1-8 a typical CPU Motherboard used in the LS-28-DRS

⁶ Note: The on-board integrated graphic is typically NOT used in favor of a standalone VGA Graphics card with better performance.

1.2.2.1.5 Single Board Computer & Passive Backplane (LS-28-QRS & -R2D3)

The quad channel LS-28 systems are configured with a multi-core, Intel PCI bus single board computer (SBC) and a high slot count (8 PCI slots or greater) passive backplane. The make/model number of the SBC and passive backplane and their associated components (CPU/RAM etc.) varies as of the date of manufacture. The SBC is typically configured with 4 MB of RAM and has a 3 GHz (or higher) multi-core Intel CPU chip installed. A typical example of this SBC is shown below in Figure 1-9, while an example of the passive backplane is shown in Figure 1-10 on page 23.



Figure 1-9 a typical SBC used in the LS-28-QRS & -R2D3

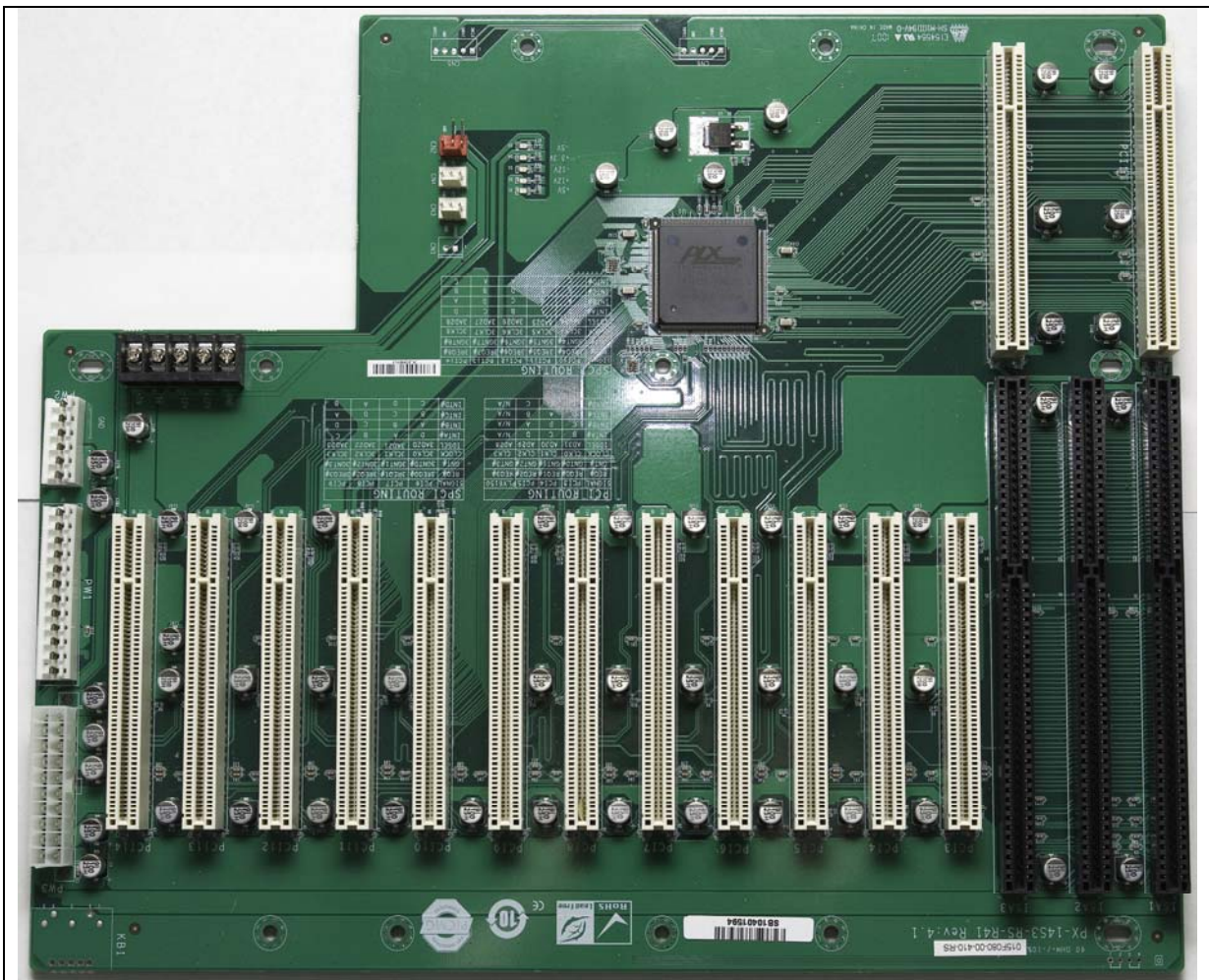


Figure 1-10 a typical Passive Backplane used in the LS-28-QRS

1.2.2.1.6 Dual Monitor VGA Graphic Card

Because the performance of the on-board video graphics found on both motherboard and single board computers is somewhat lacking, both the dual channel and quad channel LS-28 systems use a stand-alone VGA graphics card similar to the one shown in Figure 1-11 below. The make/model number of the VGA graphic card and its associated components (GPU/RAM etc.) varies as of the date of manufacture.



The VGA card supports one or two monitors and is more than capable of producing the horizontal resolution required to support the CCP page graphical user interface preferred by most operators (see paragraph 3.1.1 on page 69 for more information on the CCP page display).

1.2.2.1.6.1 A Cautionary Tail about Using Two Monitors

As previously mentioned, the LS-28 can support two monitors running concurrently. This is a handy feature, especially if one is NOT using the CCP page but is instead using the main LRRS launch banner to invoke individual setup windows and various display widgets (see paragraph 3.2.1 on page 87 for more on the LRRS launch banner). Especially in a quad channel system, the LRRS launch banner can produce a great many separate displays and having the second monitor is very helpful. There is however a serious problem that can arise in such a scenario. If one makes the transition back to a single monitor configuration without first moving all of the open windows on the second monitor back to the first monitor, then after the transition, those open windows will still be on the second monitor, even though there is now only ONE monitor in use. As far as the operating system is concerned, there are still two monitors, and the second monitor still has active windows open on it. The problem is that there is simply NO WAY of getting to them anymore. There is only one monitor plugged in to the system, and it can't see the windows on the second monitor! Therefore, if one intends to use two monitors and then wishes to transition back to a single monitor, first make sure that the second monitor has nothing on it before making the transition.

1.2.2.1.7 Rear I/O Panel Assembly

All signal I/O in the LS-28 is accessible via the Rear I/O Panel assembly. This includes all digital, analog, IF and RF signal types. In addition, all generic computer-related signals are available and include: VGA Video Ports (2ea), Gigabit Ethernet RJ-45 Ports (2ea), and USB 2.0 Ports (2ea)

The digital, analog, IF and RF signal types used in the dual channel, LS-28-DRS are shown in Figure 1-12 below. The names of the signals on the AUX1 & AUX2 connectors are shown in the table below the figure.



The digital, analog, IF and RF signal types used in the quad channel, LS-28-QRS are shown in Figure 1-13 below. The names of the signals on the AUX1 & AUX2 connectors are shown in the table below the figure.

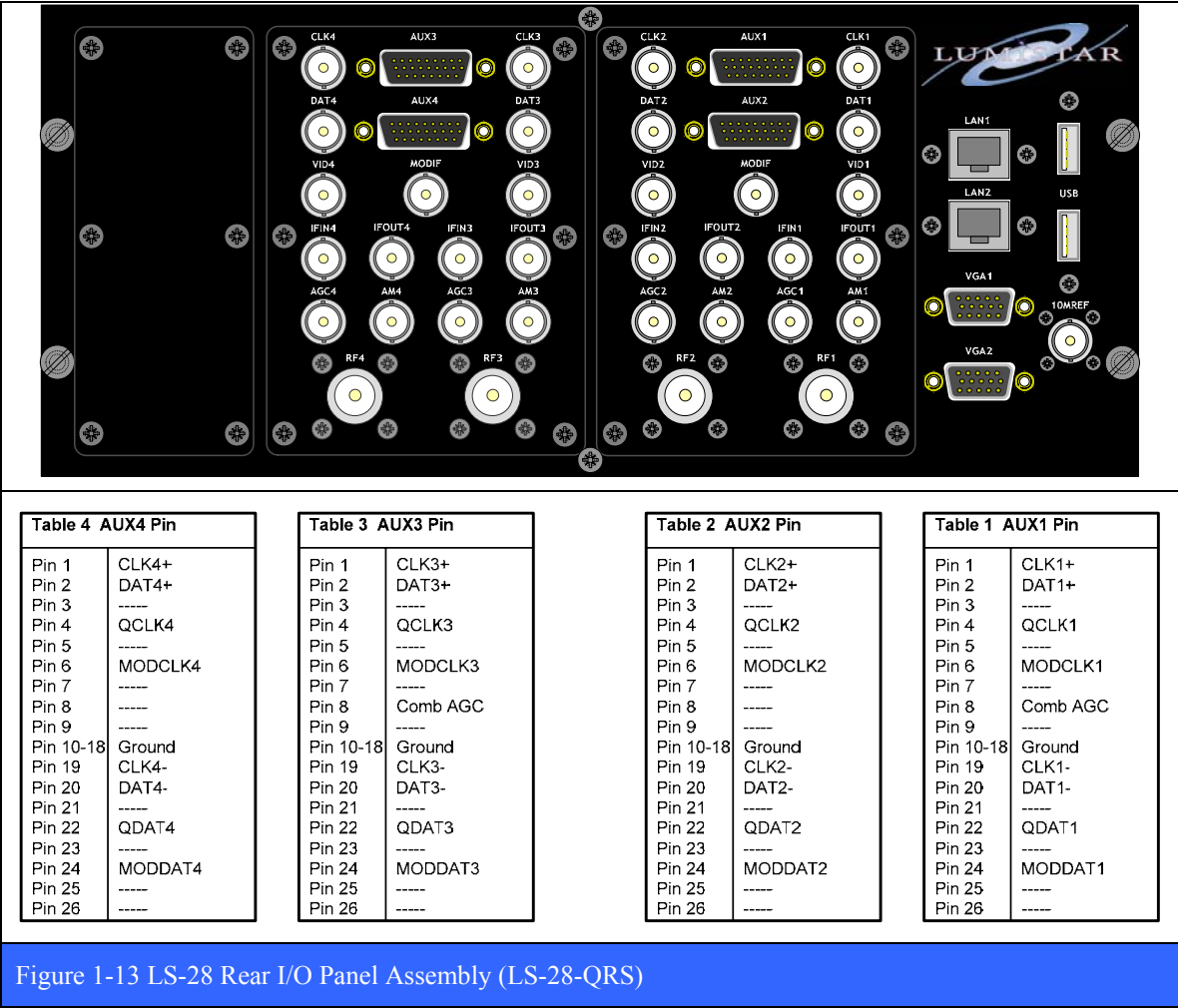
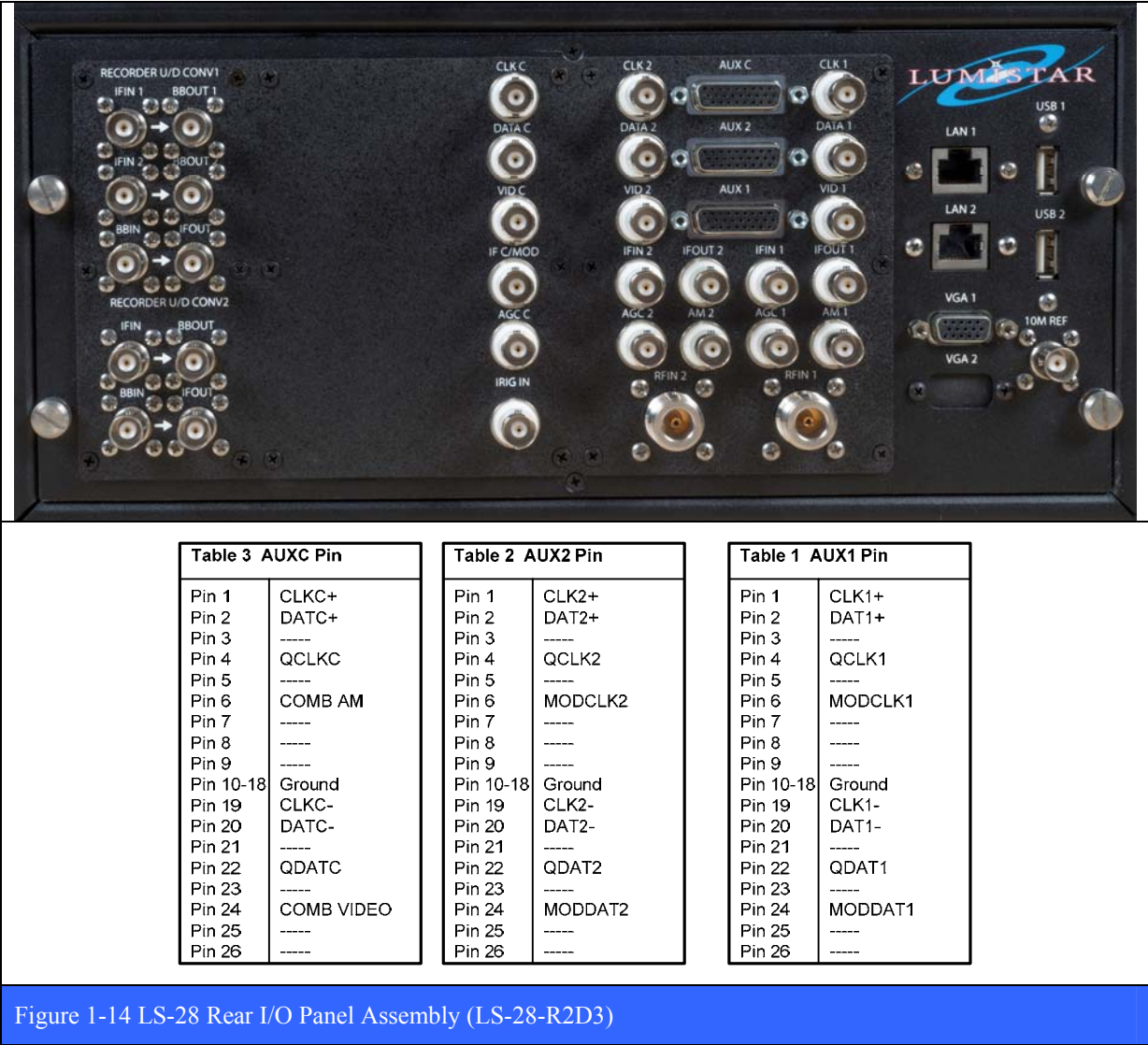


Figure 1-13 LS-28 Rear I/O Panel Assembly (LS-28-QRS)

The digital, analog, IF and RF signal types used in the dual channel/ three demodulator, LS-28-R2D3 are shown in Figure 1-14 below. The names of the signals on the AUX1, AUX2 & AUXC connectors are shown in the table below the figure.



1.2.2.2 LS-28 Custom Circuit Card Assemblies (CCAs)

The LS-28 family of receivers all employ multiple custom designed Lumistar circuit card assemblies which are summarized in the table below. The quantities of each CCA type are included. Each custom CCA are presented in the following numbered paragraphs to familiarize the user with appearance, connectors, etc.

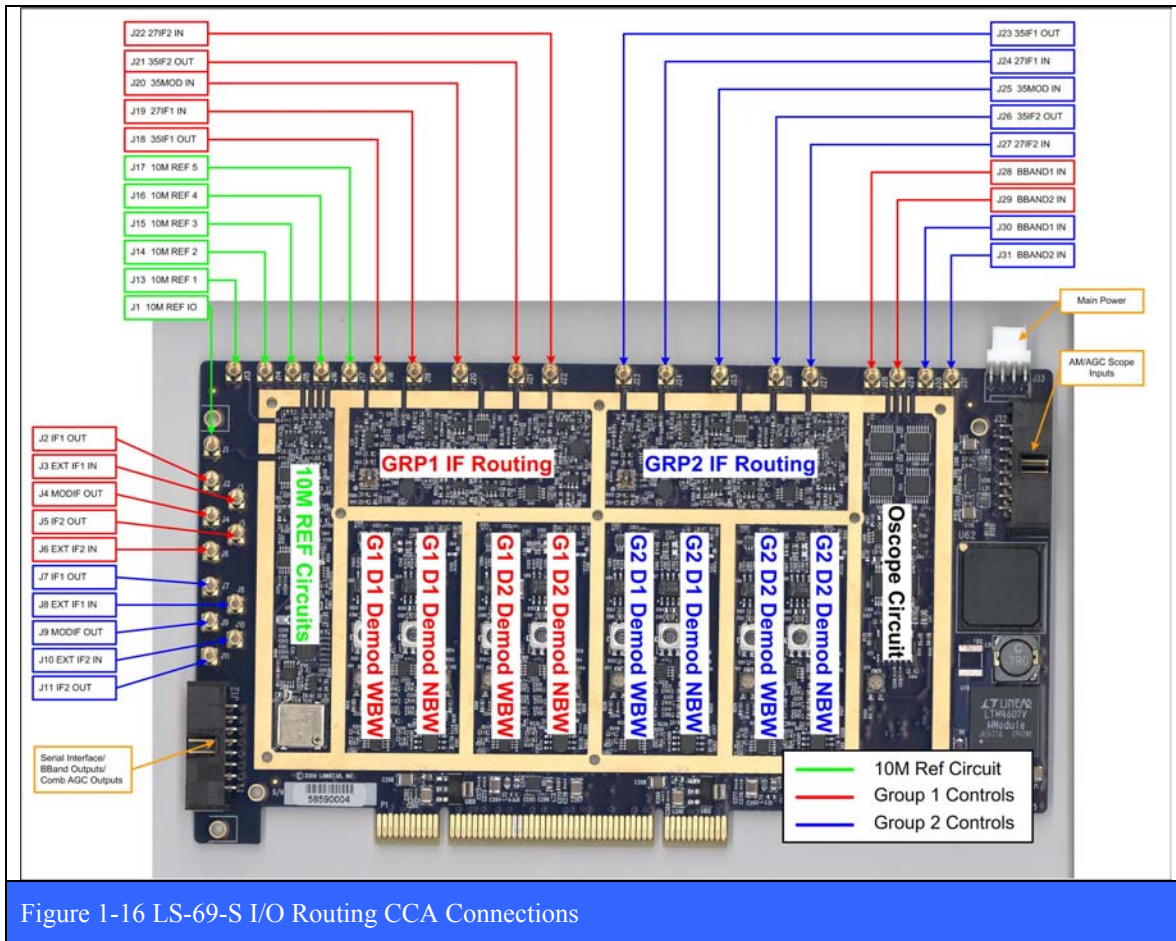
Table 1-1 LS-28 Circuit Card Assemblies		DRS QTY	QRS QTY	R2D3 QTY
LS-69-S	Signal Routing Board	1	1	1
LS-69(PS)	Power Supply Board for LS-69-S	1	1	1
LS-27-P3	PCI Multi-Band 2-Channel Downconverter	1	2	1
LS-35-PCI	Multi-Mode Digital Demodulator/Combiner	1	2	1
LS-34-PCI	Single Channel Multi-Mode Digital Demodulator	--	--	1
LS-37-P95	Two Channel Telemetry Recorder Up & Downconverter	--	--	1
LS-37-P50	Single Channel Telemetry Recorder Up & Downconverter	--	--	1
LS-28-RP2/4	Rear I/O Panel	1	1	1

1.2.2.2.1 LS-69-S I/O Routing CCA

The LS-69-S I/O Routing CCA is shown in Figure 1-15 below. All of the individual I/O signals for the card are shown in detail in Figure 1-16 on page 29. The separate power supply module that powers the LS-69-S is shown in Figure 1-17 on page 29. The LS-69 power supply module is mounted on the chassis side wall between the drive bay and main AC power supply (see Figure 1-3 on page 16).



Figure 1-15 LS-69-S I/O Routing CCA



1.2.2.2.2 LS-27 PCI Multi-Band 2-Channel Downconverter CCA

The LS-27 Multi-Band, 2-Channel Downconverter CCA is shown in Figure 1-18 below. All of the individual I/O signals for the card are shown in detail in Figure 1-19 on page 31.

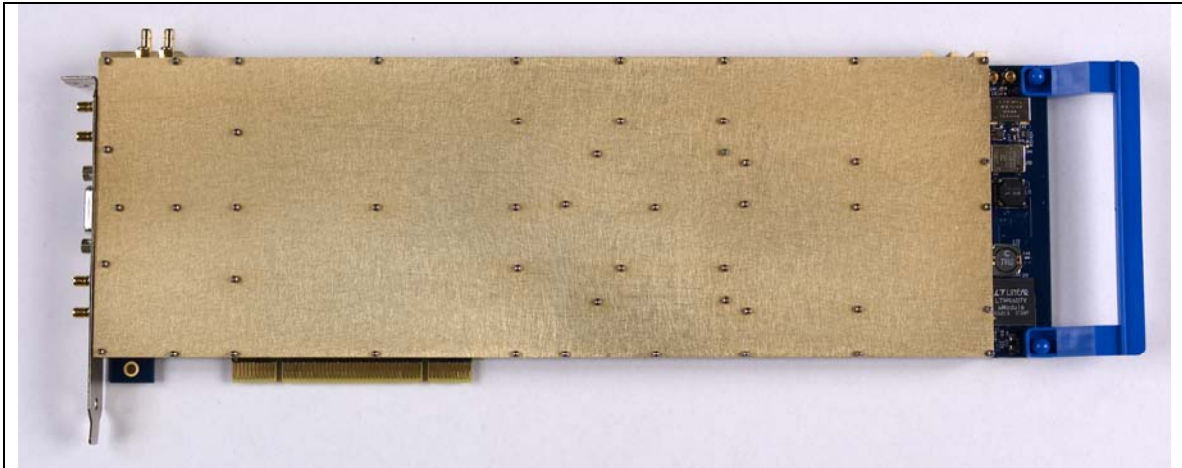
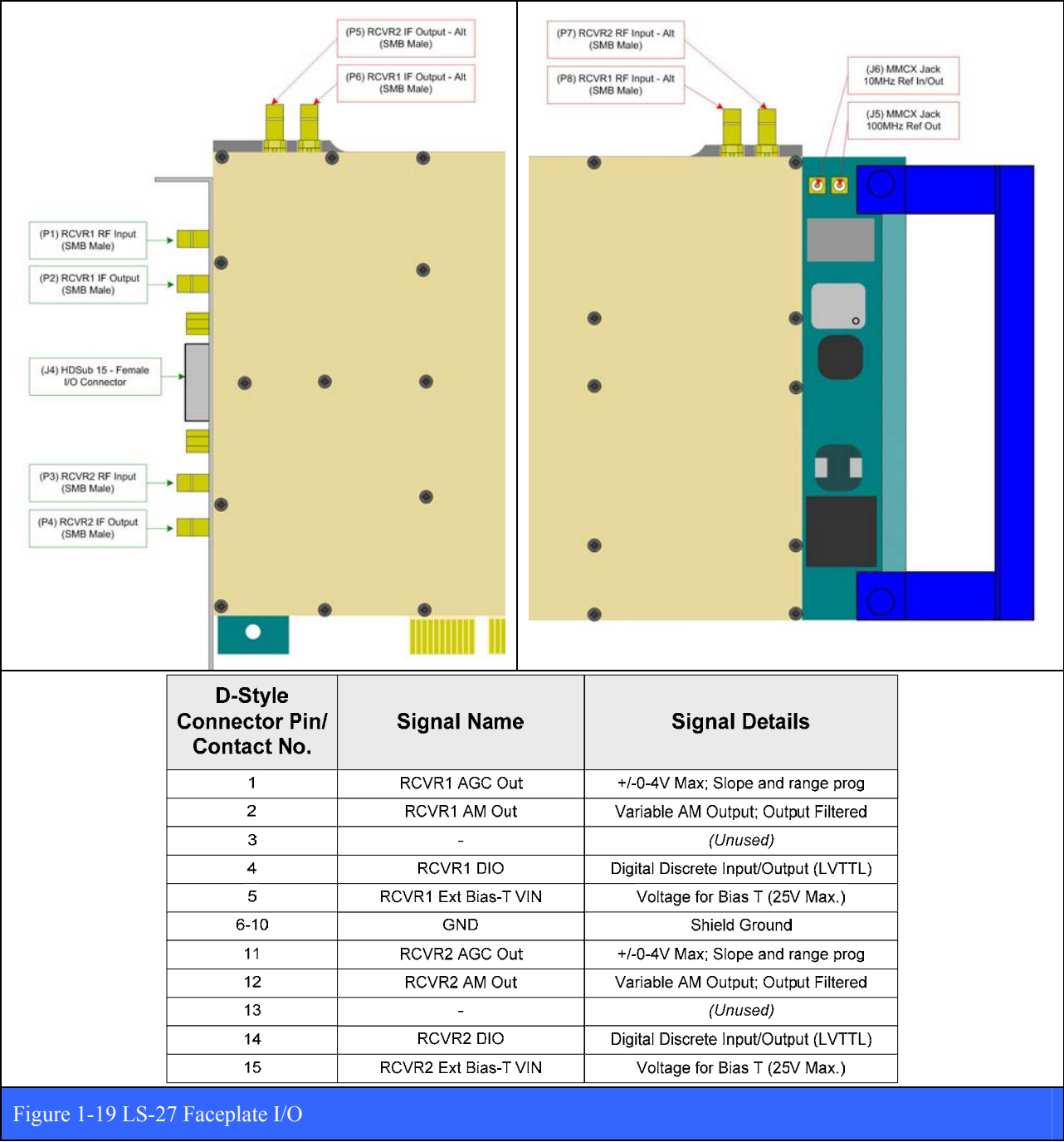


Figure 1-18 LS-27 PCI Downconverter CCA

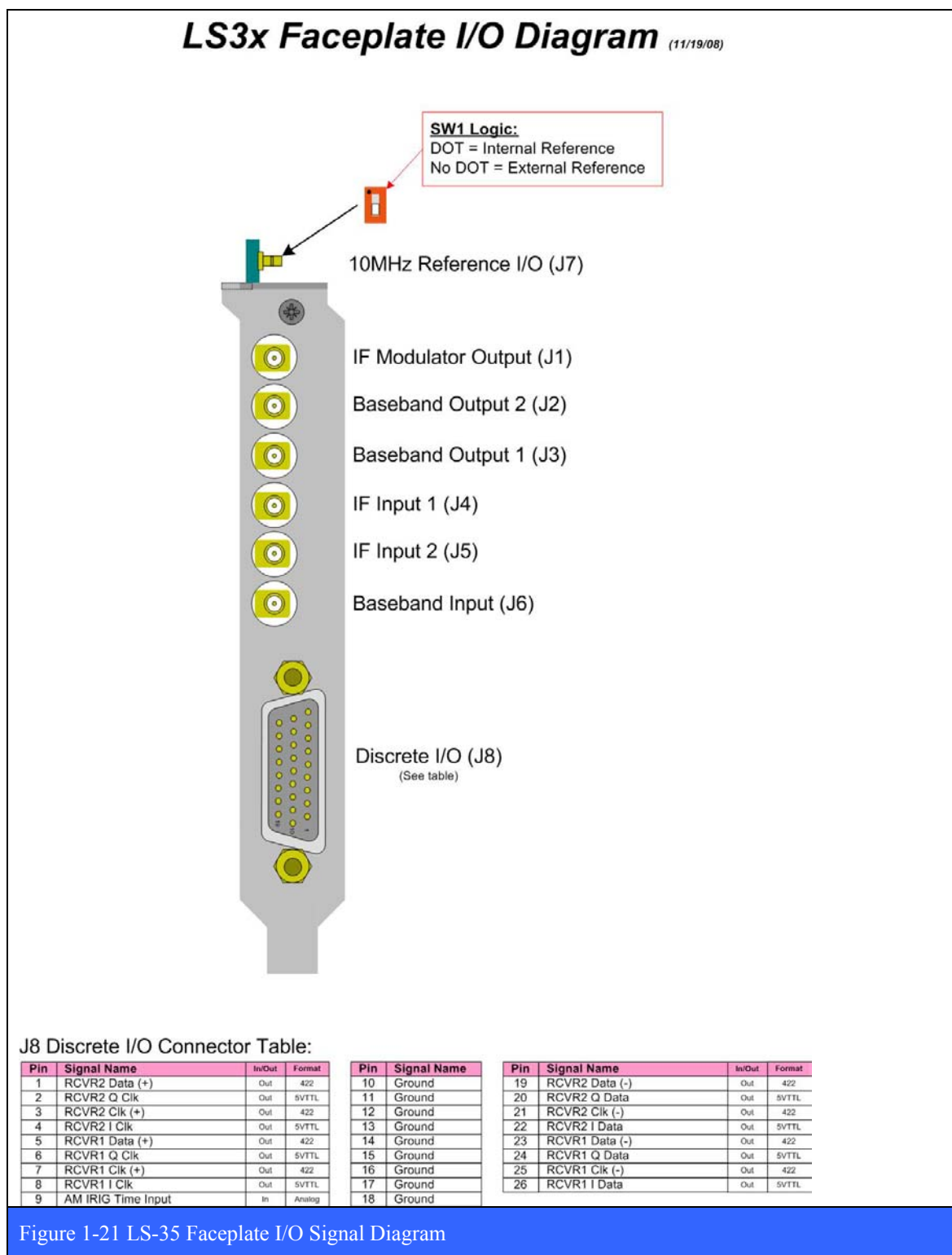


1.2.2.2.3 LS-35 Dual Channel Multi-Mode Digital Demodulator/Combiner CCA

The LS-35 Dual Channel Multi-Mode Digital Demodulator/Combiner CCA is shown in Figure 1-20 below. All of the individual faceplate I/O signals for the card are shown in detail in Figure 1-21 on page 33. The rear I/O connector signals for the card are shown in detail in Figure 1-22 on page 34.



Figure 1-20 LS-35 Dual Channel Multi-Mode Demodulator CCA



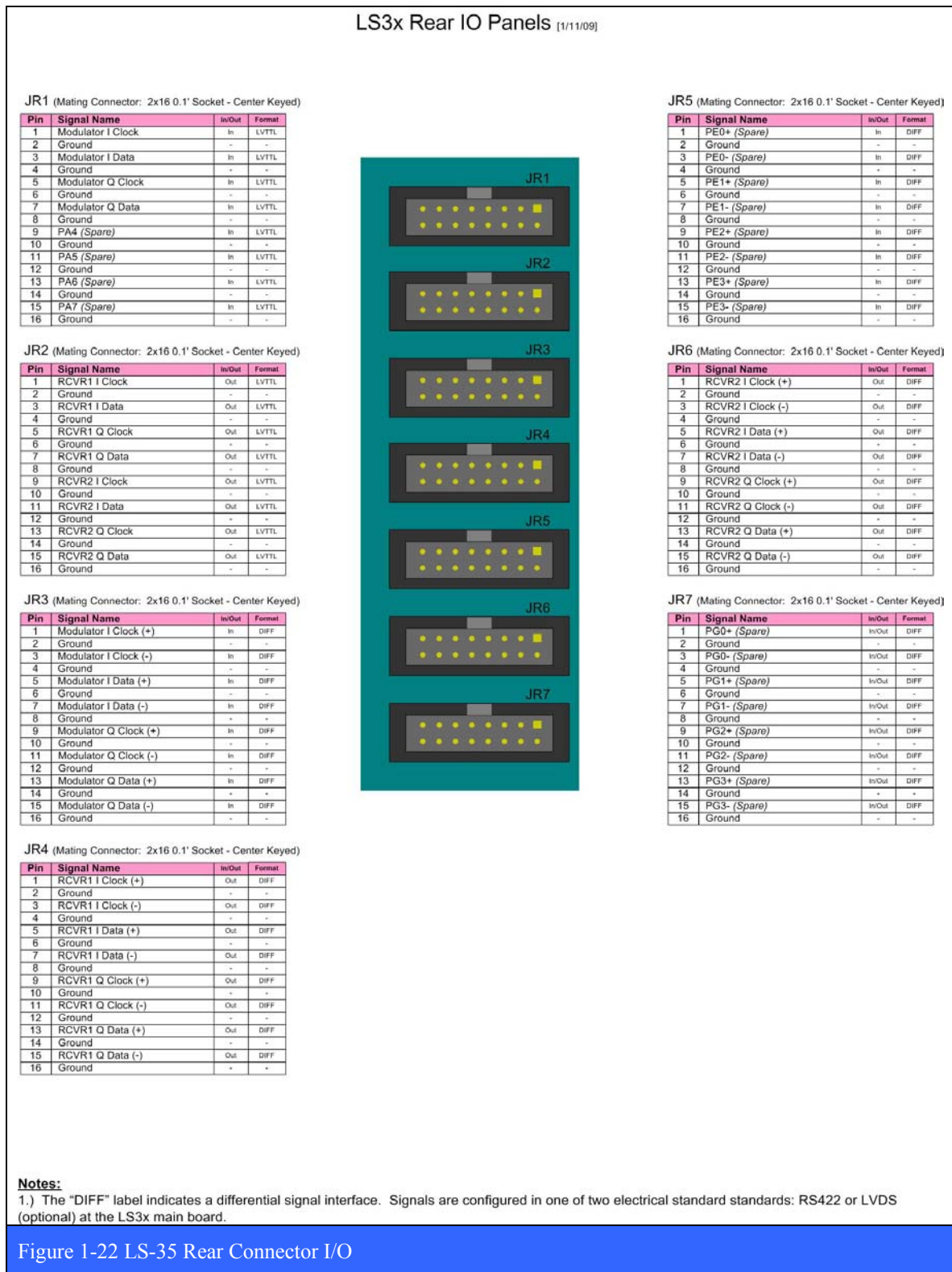


Figure 1-22 LS-35 Rear Connector I/O

1.2.2.2.4 LS-34-PCI Single Channel Multi-Mode Digital Demodulator

The LS-34 Single Channel Multi-Mode Digital Demodulator/Combiner CCA is shown in Figure 1-23 below. All of the individual faceplate I/O signals for the card are shown in detail in Figure 1-21 on page 33. The rear I/O connector signals for the card are shown in detail in Figure 1-22 on page 34. This card is currently used only in the LS-28-R2D3 variant.



Figure 1-23 LS-34 Single Channel Multi-Mode Demodulator CCA

1.2.2.2.5 LS-37-P95 Two Channel Telemetry Recorder Up & Downconverter

The LS-37-P95⁷ Two Channel Telemetry Recorder Up & Downconverter CCA is shown in Figure 1-23 above. All of the individual faceplate I/O signals for the card are shown in detail in Figure 1-21 on page 33. The rear I/O connector signals for the card are shown in detail in Figure 1-22 on page 34.

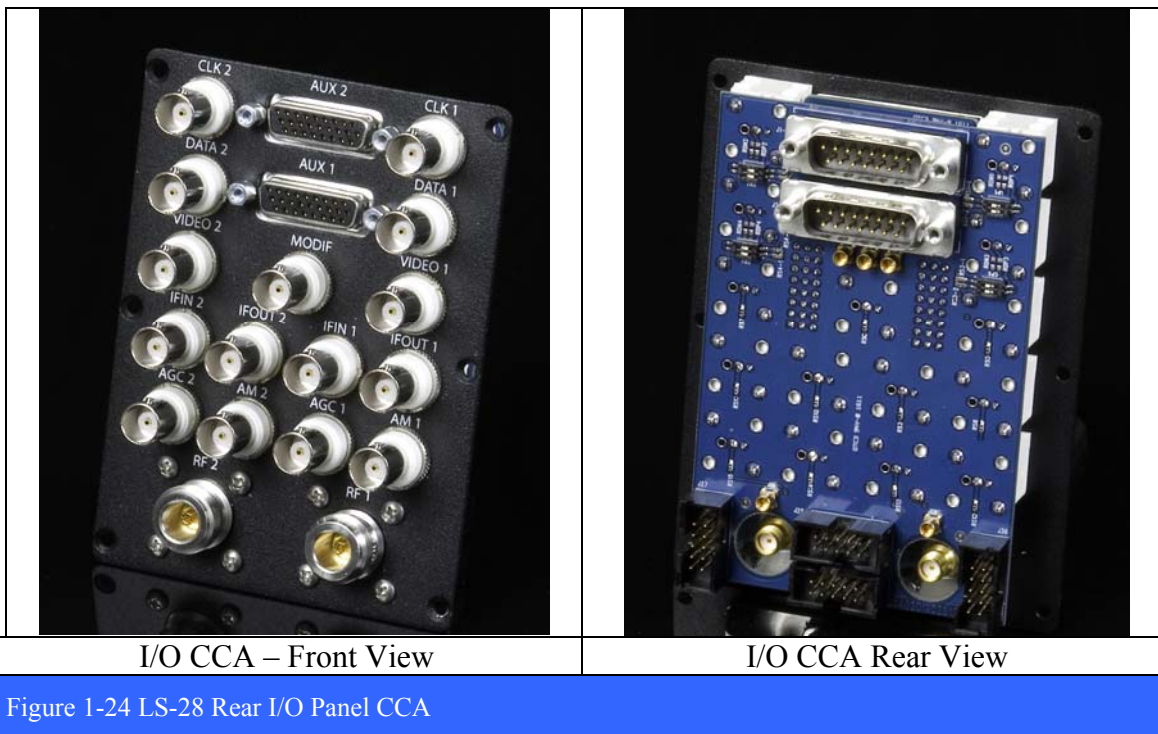
1.2.2.2.6 LS-37-P50 Single Channel Telemetry Recorder Up & Downconverter

The LS-37-P50 Single Channel Telemetry Recorder Up & Downconverter CCA is shown in Figure 1-23 above. All of the individual faceplate I/O signals for the card are shown in detail in Figure 1-21 on page 33. The rear I/O connector signals for the card are shown in detail in Figure 1-22 on page 34.

1.2.2.2.7 Rear Panel I/O CCA

The LS-28 Rear Panel I/O CCA is shown in Figure 1-24 below. Both front and rear views are shown. The I/O CCA is attached to a panel insert as shown in the figure below left. This completed subassembly is then installed into the larger *Rear I/O Panel Assembly* shown in Figure 1-12 on page 25 and Figure 1-13 on page 26.

⁷ The LS-37-P95, LS-37-P50, and LS-34 cards are all physically identical in appearance. The only difference is in the gate-count sizes of the FPGA chip installed on the board.



1.2.3 Differences between Models

The LS-28 has dual channel and quad channel configurations with each channel supporting up to four (4) RF bands. The model numbering scheme for the LS-28 family of receivers is documented in Table 1-2 below.

1.2.3.1 LS-28 Models & Variants

Table 1-2 LS-28 Variants (Model Numbers)	
Dual Channel	
Single Band Configurations	
LS-28-DRS-M1(X)	Multi-Symbol PCM/FM demod format
LS-28-DRS-M2(X)	SOQPSK only
LS-28-DRS-M3(X)	Multi-Symbol PCM/FM, BPSK, QPSK, OQPSK, SOQPSK, and PCM/PM
LS-28-DRS-M4(X)	Multi-Symbol PCM/FM, BPSK, QPSK, OQPSK, SOQPSK, AUQPSK and PCM/PM
LS-28-DRS-M6(X)	Multi-Symbol PCM/FM and SOQPSK
Dual-Band Configurations	
LS-28-DRS-M1(XX)	Multi-Symbol PCM/FM demod format
LS-28-DRS-M2(XX)	SOQPSK only
LS-28-DRS-M3(XX)	Multi-Symbol PCM/FM, BPSK, QPSK, OQPSK, SOQPSK, and PCM/PM
LS-28-DRS-M4(XX)	Multi-Symbol PCM/FM, BPSK, QPSK, OQPSK, SOQPSK, AUQPSK and PCM/PM
LS-28-DRS-M6(XX)	Multi-Symbol PCM/FM and SOQPSK
Tri-Band Configurations	
LS-28-DRS-M1(XXX)	Multi-Symbol PCM/FM demod format
LS-28-DRS-M2(XXX)	SOQPSK only
LS-28-DRS-M3(XXX)	Multi-Symbol PCM/FM, BPSK, QPSK, OQPSK, SOQPSK, and PCM/PM
LS-28-DRS-M4(XXX)	Multi-Symbol PCM/FM, BPSK, QPSK, OQPSK, SOQPSK, AUQPSK and PCM/PM
LS-28-DRS-M6(XXX)	Multi-Symbol PCM/FM and SOQPSK
Quad Band Configurations, P, lower L, upper L and NATO-E band only	
LS-28-DRS-M1PLUE	Multi-Symbol PCM/FM demod format
LS-28-DRS-M2PLUE	SOQPSK only
LS-28-DRS-M3PLUE	Multi-Symbol PCM/FM, BPSK, QPSK, OQPSK, SOQPSK, and PCM/PM
LS-28-DRS-M4PLUE	Multi-Symbol PCM/FM, BPSK, QPSK, OQPSK, SOQPSK, AUQPSK and PCM/PM
LS-28-DRS-M6PLUE	Multi-Symbol PCM/FM and SOQPSK
Quad Channel	
Single Band Configurations	
LS-28-QRS-M1(X)	Multi-Symbol PCM/FM demod format
LS-28-QRS-M2(X)	SOQPSK only
LS-28-QRS-M3(X)	Multi-Symbol PCM/FM, BPSK, QPSK, OQPSK, SOQPSK, and PCM/PM
LS-28-QRS-M4(X)	Multi-Symbol PCM/FM, BPSK, QPSK, OQPSK, SOQPSK, AUQPSK and PCM/PM

Table 1-2 LS-28 Variants (Model Numbers)	
LS-28-QRS-M6(X)	Multi-Symbol PCM/FM and SOQPSK
Dual-Band Configurations	
LS-28-QRS-M1(XX)	Multi-Symbol PCM/FM demod format
LS-28-QRS-M2(XX)	SOQPSK only
LS-28-QRS-M3(XX)	Multi-Symbol PCM/FM, BPSK, QPSK, OQPSK, SOQPSK, and PCM/PM
LS-28-QRS-M4(XX)	Multi-Symbol PCM/FM, BPSK, QPSK, OQPSK, SOQPSK, AUQPSK and PCM/PM
LS-28-QRS-M6(XX)	Multi-Symbol PCM/FM and SOQPSK
Tri-Band Configurations	
LS-28-QRS-M1(XXX)	Multi-Symbol PCM/FM demod format
LS-28-QRS-M2(XXX)	SOQPSK only
LS-28-QRS-M3(XXX)	Multi-Symbol PCM/FM, BPSK, QPSK, OQPSK, SOQPSK, and PCM/PM
LS-28-QRS-M4(XXX)	Multi-Symbol PCM/FM, BPSK, QPSK, OQPSK, SOQPSK, AUQPSK and PCM/PM
LS-28-QRS-M6(XXX)	Multi-Symbol PCM/FM and SOQPSK
Quad Band Configurations, P, lower L, upper L and NATO-E band only	
LS-28-QRS-M1PLUE	Multi-Symbol PCM/FM demod format
LS-28-QRS-M2PLUE	SOQPSK only
LS-28-QRS-M3PLUE	Multi-Symbol PCM/FM, BPSK, QPSK, OQPSK, SOQPSK, and PCM/PM
LS-28-QRS-M4PLUE	Multi-Symbol PCM/FM, BPSK, QPSK, OQPSK, SOQPSK, AUQPSK and PCM/PM
LS-28-QRS-M6PLUE	Multi-Symbol PCM/FM and SOQPSK

1.2.3.1.1 Band Configurations

The LS-28 supports independent two or four channel reception and/or combining of up to four RF bands (including E, S, lower/upper-L, P, K, C, or custom bands up to 5 GHz).

1.2.3.1.2 Channel Configurations

The LS-28 has dual channel (LS-28-DRS) and quad channel (LS-28-QRS) configurations.

1.2.4 System Specifications

The operational and performance specifications for the LS-28 family of telemetry receivers are itemized in Table 1-3 below.

Table 1-3 LS-28 Performance Specifications		
Down-Converter	-DRS, 1 Each	-QRS, 2 Each
RF Input Frequency ⁸	S-band	2200-2400 MHz
	NATO E-Band	2185-2485 MHz
	Upper L-Band	1710-1850 MHz
	Lower L-Band	1435-1540 MHz
	P-band	215-320 MHz
	K-band	680-760 MHz
	N-band	830-1130 MHz
	70 MHz pass thru	70 MHz
Input Level	+10 dBm to threshold	
Maximum Input Level	+28 dBm (self-protection at startup for > +28 dBm)	
Tuner Resolution	50 KHz	
Frequency Accuracy	0.002% max	
Noise Figure	8 dB (Maximum); 5 dB (Typical at threshold)	
IF Filters	Software set by data rate, PCM code and modulation format. User override available. Eight SAW anti-alias pre-filters (0.25, 0.50, 1, 2, 5, 10, 20, 40 MHz). Precision digital FIR filtering employed at demodulation input.	
Phase Noise	Exceeds requirements for ARTM Tier II phase noise (-110 dBm typ. at 100KHz)	
AGC Slope and Range	Programmable over any portion, -4V to +4V, Linear, Pos/Neg	
AGC Time Constants	Selectable: 0.1, 1, 10, 100, 1000 msec.	
RF Input AGC Range	110 dB (+10 to -100 dBm)	
Input Compression	+10 dBm	
IP3	+15 dBm typical (output)	
AM Demodulation	DC to 50 KHz, programmable output vs. AM depth typically 2V p-p for 50% modulation depth	
AM Filtering	32 each lowpass filters, plus Bypass Mode	
Adj Channel Interference	exceeds IRIG requirements, contact Lumistar for more information	
Bias “T” Power Supply	up to +25V, 500 mA	
Pre-D Combiner	-DRS, 1 Each	-QRS, 2 Each
Combiner Type	Digital Combining algorithm based upon measured S/N for each channel	
S/N Improvement	2.5 dB typical (equal RF input levels near threshold)	
Break Frequency	50 KHz minimum for 30 dB fades	
Demodulator Outputs	-DRS, 2 Each	-QRS, 4 Each
Demodulation Formats	Multi-symbol PCM/FM, PCM/PM, BPSK, QPSK, SOQPSK, OQPSK, AQPSK, Analog FM for NTSC/PAL Video, Sub-carrier(s)	
Data Rates	10 kbps – 30 Mbps (Multi-Symbol PCM/FM)	

⁸ Other RF bands available, please consult Lumistar

Table 1-3 LS-28 Performance Specifications		
	10 kbps – 20 Mbps (BPSK, PCM/PM) 1 Mbps to 30 Mbps (QPSK, OQPSK, AQPSK, SOQPSK) (Higher data rates are available, please consult Lumistar)	
Bit Syncs	Two Independent Data/Clock Outputs for each channel CH1/CH2/Combined available (any two at a time) TTL and RS-422 available simultaneously on each channel >3V peak in to 50 ohms	
Code Conversion	NRZ-L, M, S and Bi-Φ L, M, S; DM-M, S; MDM-M, S	
Standard Features		
Internal IF Modulator	Internal 50-90 MHz Modulator for loop-back self-test of the receiver. Power output from 0 to -80 dBm. Formats include PCM/FM, PCM/PM, BPSK, QPSK, OQPSK, SOQPSK and Multi-h CPM, with data rates from 10 bps to 10 Mbps (for FM/PM/BPSK) and 20 Mbps for all QPSK formats and Multi-H CPM. Includes precision calibrated noise feature, output code selection (NRZ-L/M/S, Bi-Phase L/M/S, DMM/S, and RNRZ15), external modulation input, internal PRN pattern generation, adjustable deviation, and Convolutional encoding.	
Multi-symbol PCM/FM	Improves BER performance by approx. 2.5 dB vs. standard PCM/FM	
Constellation Displays	for all PSK formats	
Eye Pattern Displays	for PCM/FM format	
Bit Error Rate Readers	One each per input channel, can be connected to Pre-D combiner	
IF Spectrum Displays	Displays 70 MHz IF Spectrum has typical spectrum analyzer controls and capabilities (such as Span, Averaging, Ref level, max hold, clear/write, etc...). All displays can be captured via Screen-Shot” hardcopy feature, available in JPG file format.	
Optional Features		
	Multimode demodulation formats	
	PCM/FM only (-M1), SOQPSK (-M2), PCM/FM and SOQPSK only (-M6)	
	PCM/FM, BPSK, QPSK, OQPSK, SOQPSK, and PM (-M3)	
	Other demodulation options available, lease consult factory	
	Viterbi decoding (-V2)	
	Sub-carrier (-S2)	
	AQPSK (-A2)	
	Post-Diversity Combining (-O)	
	Viterbi and Reed / Solomon Decoding	
	FPGA upgrade (for additional I/O)	
Environmental		
Operating Temperature	0° to +50° C	
Non-Operating Temperature	-25° to +70° C	
Operating Humidity	0 to 90% (Non-condensing)	
Non-Operating Humidity	Protect from excessive moisture and contamination	

Table 1-3 LS-28 Performance Specifications		
Operational Scenario	Rack mount, ground-based, with sufficient cooling in rack (Option for airborne applications, please consult Lumistar)	
Physical		
Size	4U Rack Mount Chassis (19" W x 23" D x 7" H)	
Weight	40 lbs (18.1 Kg) typical	
Power Supply	115 V/230 V Auto-sensing – 500W	
Computer I/O	Passive SBC backplane, 4 Gbyte RAM typ, Quad-Core Processor, Dual TCP/IP, Dual VGA, USB (2 min), PS2, Windows XP	

1.2.5 System Performance

1.2.5.1 AGC Linearity

The AGC linearity is the accuracy of the AGC output voltage as a function of the input RF signal amplitude. The AGC output voltage of the LS-28 is super-linear with typical residual voltage variations in the 0.1 Volt range. A typical AGC linearity dataset for a dual channel system (LS-28-DRS) is shown in Table 1-4 below. The same dataset plotted graphically can be seen in Figure 1-25 and Figure 1-26 on page 43. The plot shows the -20 dB/Volt slope typically required by most antenna control units (ACUs).

Table 1-4 Typical AGC Output Linearity				
Input (dB) 20MHz IF	AGC 1 (V)	AGC 1 Residuals +/- 2dB max	AGC 2 (V)	AGC 2 Residuals +/- 2dB max
-10	-3.96	0.97	-3.83	-0.23
-20	-3.55	-0.58	-3.34	-0.24
-30	-3.04	-0.32	-2.85	0.04
-40	-2.55	-0.24	-2.36	0.09
-50	-2.05	-0.14	-1.87	0.21
-60	-1.55	-0.02	-1.38	0.30
-70	-1.06	0.02	-0.90	0.38
-80	-0.57	0.08	-0.41	0.43
-90	-0.07	0.22	0.01	-0.99

1.2.5.2 VSWR Characteristics

The Voltage Standing Wave Ratio (VSWR) of the receiver is a measure of how well-matched or mismatched a load is to a resistive source. A well-matched load will carry the signal forward with a minimum amount of reflected power. The VSWR ratio of 1.5:1 is equivalent to 96% of the signal transmitted forward and only 4% of the signal reflected back. The lower the VSWR ratio, the higher the percentage of signal transmitted forward. Return loss is a measure in dB of the ratio of the incident wave to the reflected wave and is equal to $20 \cdot \log(U_{\text{ref}}/U_{\text{inc}})$. A typical VSWR dataset is shown in Table 1-5 below.

Table 1-5 Typical VSWR Performance (multiple bands)								
Channel	Max Freq (MHz)	Max Amp (dBm)	Ref Level (dBm)	Return Loss (dB)	Ref Coef	Mismatch Loss (dB)	VSWR	VSWR Spec
1	2201.2	-37.9	-24.6	-13.3	0.215	0.21	1.5	2.0
2	2216.6	-40.0		-15.4	0.170	0.13	1.4	2.0
1	1783.9	-39.2	-24.0	-15.2	0.175	0.13	1.4	2.0
2	1790.1	-38.4		-14.4	0.190	0.16	1.5	2.0
1	1540.0	-38.8	-24.1	-14.7	0.185	0.15	1.5	2.0
2	1537.9	-38.8		-14.7	0.184	0.15	1.5	2.0

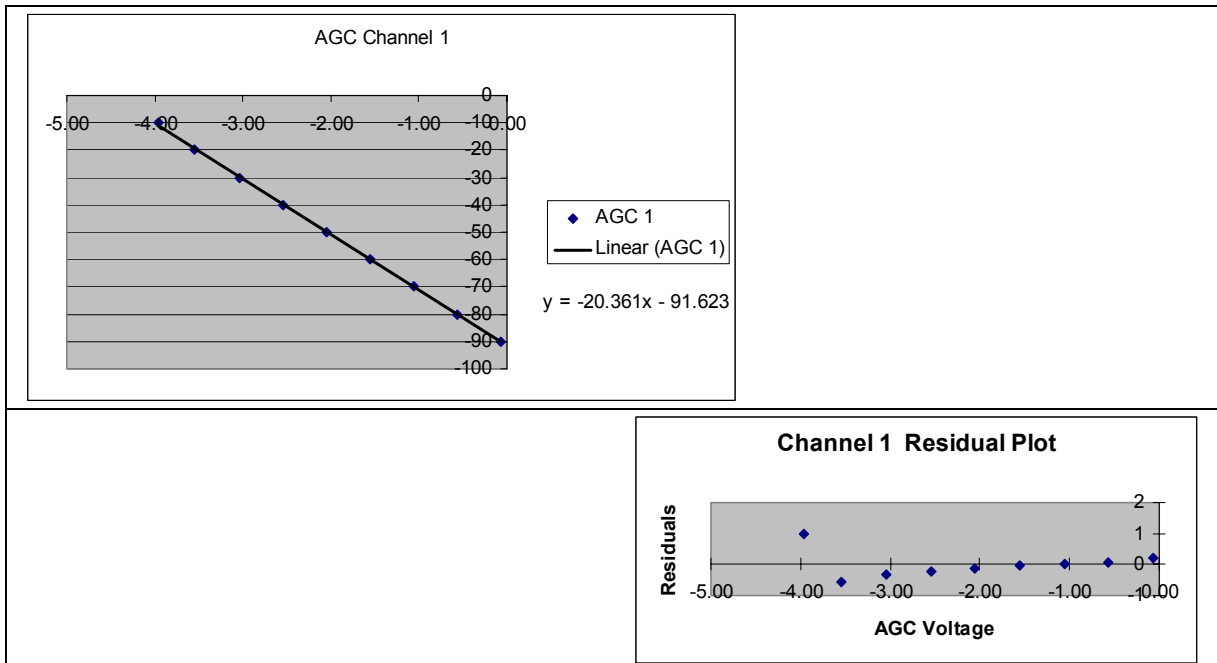


Figure 1-25 AGC 1 - Linearity & Residual Plot

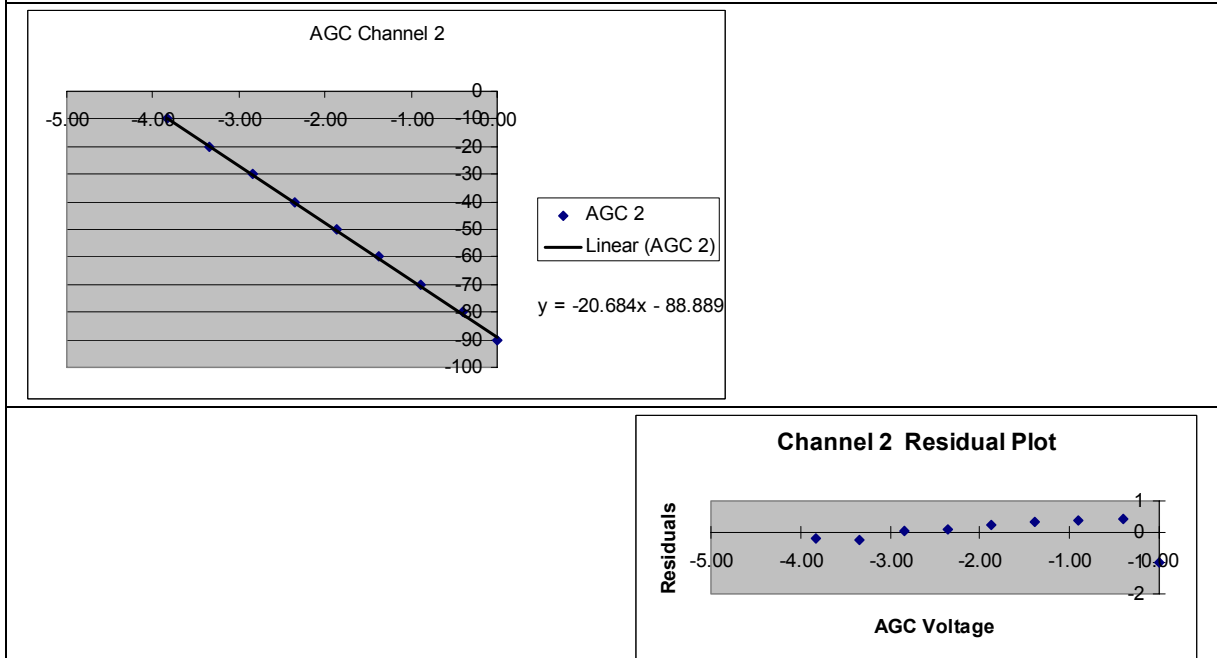
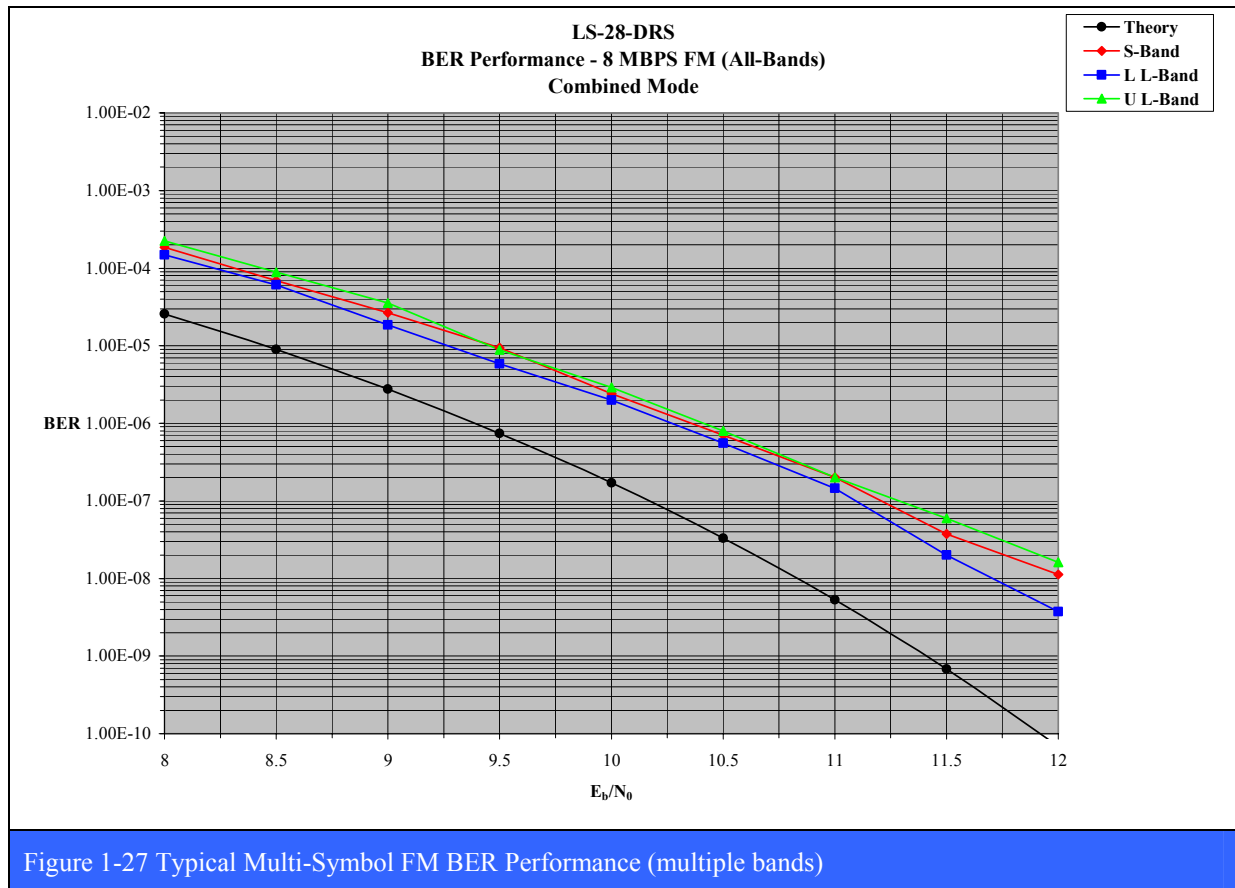
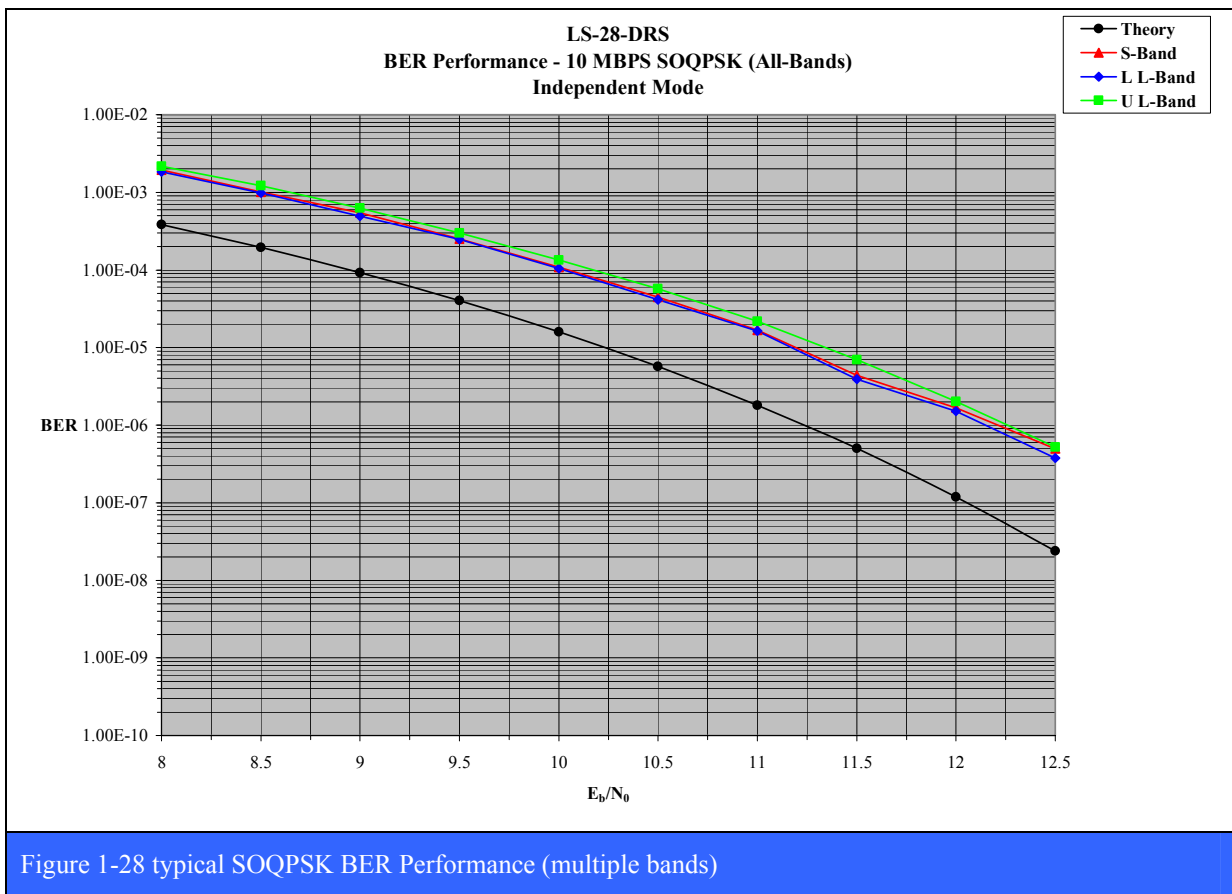


Figure 1-26 AGC 2 - Linearity & Residual Plot

1.2.5.3 BER Performance

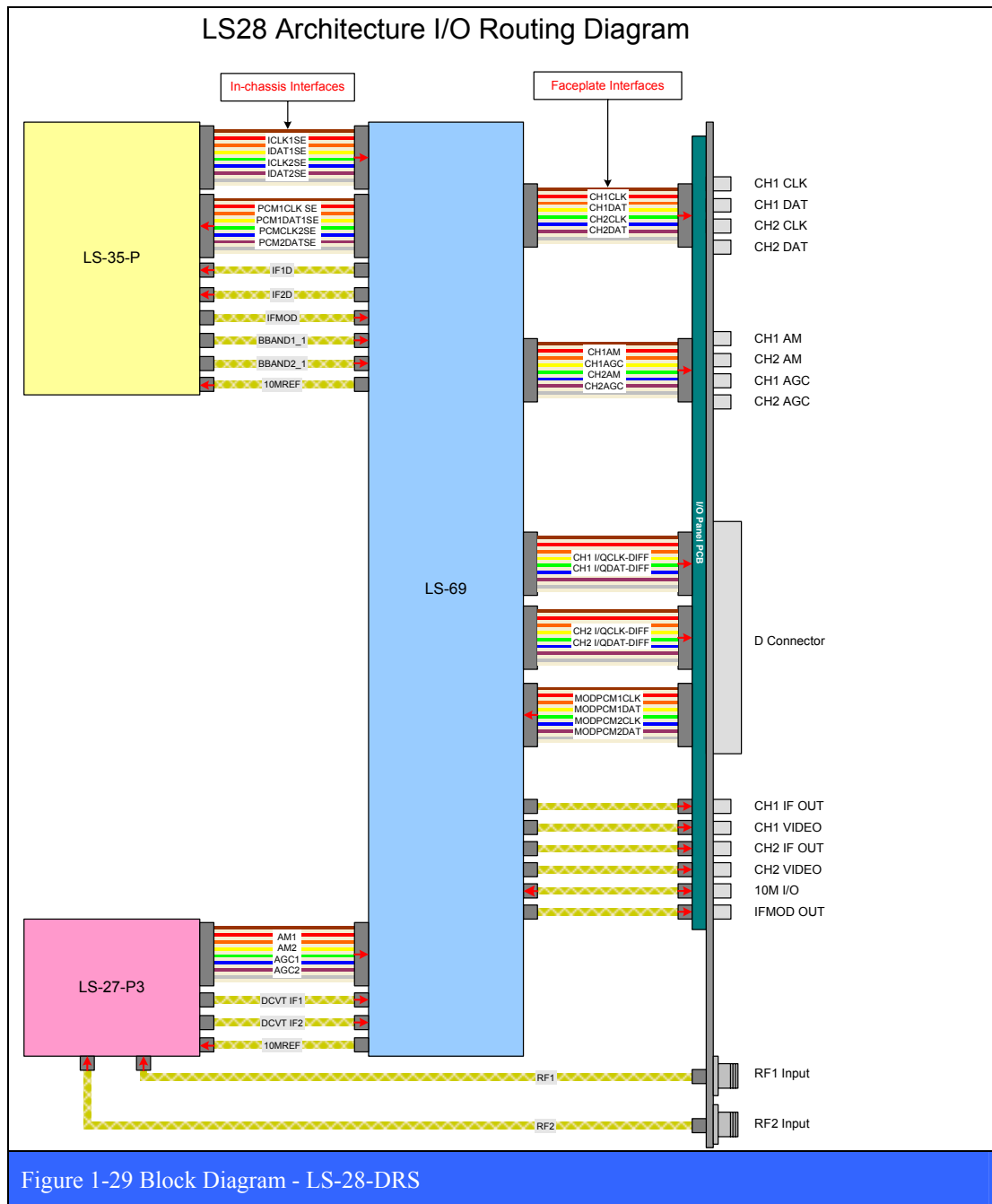
The purpose of this parameter is to show the bit error performance of the receiver in the presence of noise with FM and SOQPSK demodulation. The FM tests were conducted at S-Band (2250.5 MHz), Upper L-Band (1750.5 MHz), and Lower L-Band (1450.5), at a data rate of 8.0 MBPS. The SOQPSK tests were conducted at the same frequencies, at a data rate of 10 MBPS. The BER performance typical for FM modulation is shown in Figure 1-27 below. The BER performance typical for SOQPSK modulation is shown in Figure 1-28 on page 45.

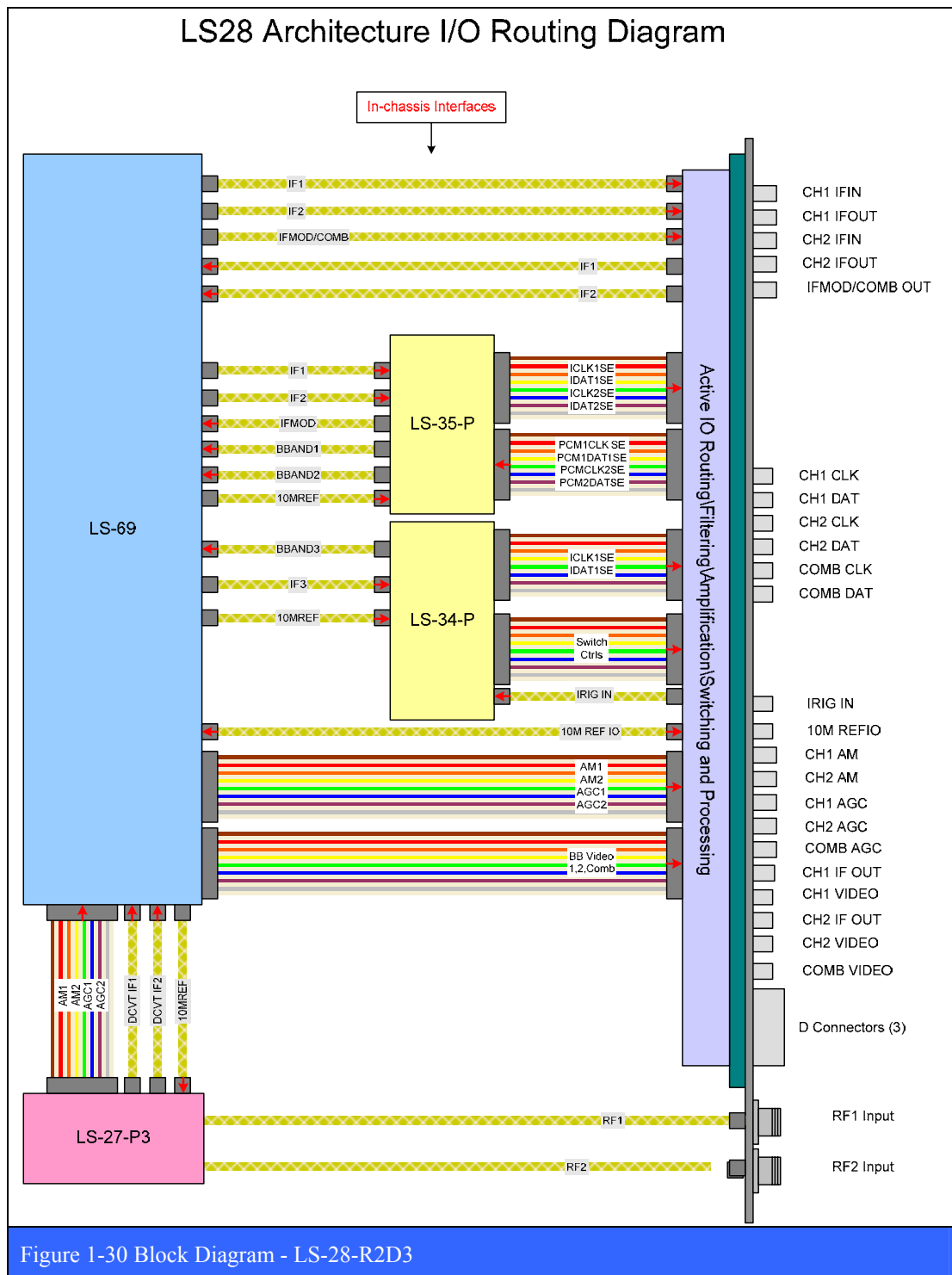


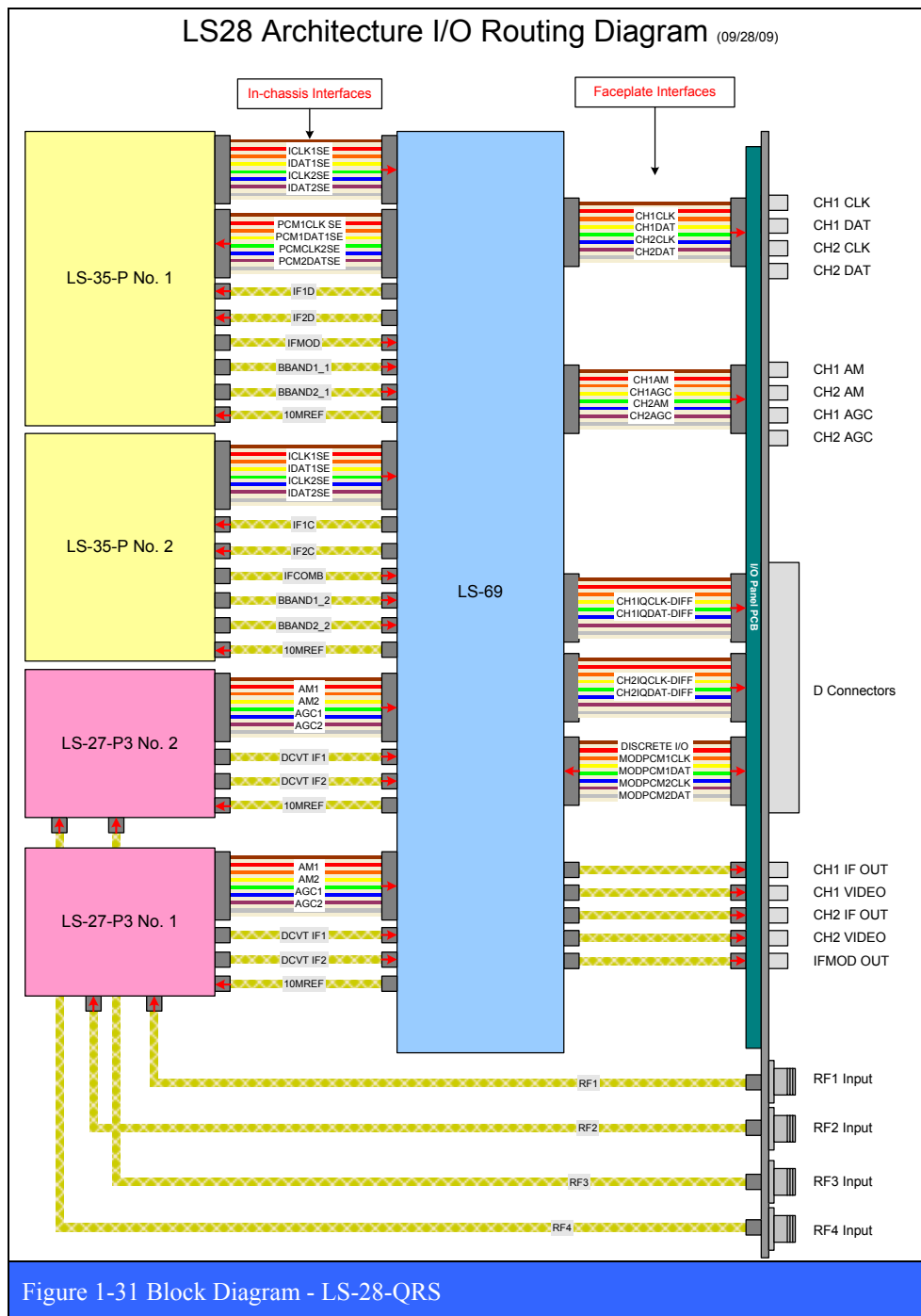


1.3 Theory of Operation

The LS-28 family of receivers all employ multiple custom designed Lumistar circuit card assemblies which are summarized in Table 1-1 on page 28. The way these cards all play together in both the dual channel and quad channel LS-28 systems can be seen in Figure 1-29 below, Figure 1-30 on page 47, and Figure 1-31 on page 48.

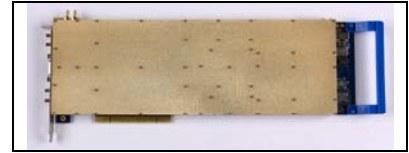






1.3.1 LS-27-P3 PCI 2-Channel Downconverter Board

In order to more clearly understand the operation of the receiver, this section will detail the various stages of the receiver design. These stages are as follows:



- 1st Downconversion
- 1st IF Band-pass Filter
- 1st Local Oscillator
- 2nd Downconversion
- 2nd Local Oscillator
- 2nd IF Filter
- Limiting Amplifier/AM Demodulation/Digital AGC (DAGC)
- Digital Signal Processing Engine (DSPE)

With the exception of the DSPE, each of these sections are physically shielded and isolated from one another to facilitate the greatest EMI/RFI ingress and egress protection allowing the receiver exceptional performance.

For the following sections, refer to the block diagram of Figure 1-32 on page 50.

1.3.1.1 1st Downconversion

The RF input is applied to the 1st downconversion stage. The stage may optionally contain a bias-T which can be used to power an external LNA through the RF interface port. (Contact the factory for further details on this option.) A DAGC section is next in the signal chain for very high level signal protection and compression compensation. This is followed by a low-noise amplifier (LNA) to provide a large amount of gain while maintaining a very low noise figure enhancing the receiver's overall sensitivity. Selectable RF band-pass filters follow the LNA. The RF signal is then mixed with the first local oscillator (LO) which converted to the 1st IF frequency.

1.3.1.2 1st IF Band-Pass Filter

The output of the 1st downconversion stage is sent through one of two 1st IF filter paths based on the selection of high-side or low-side conversion. To eliminate images and limit the overall noise bandwidth to the remaining receiver sections, a 50 MHz band-pass filter is switched into the signal path.

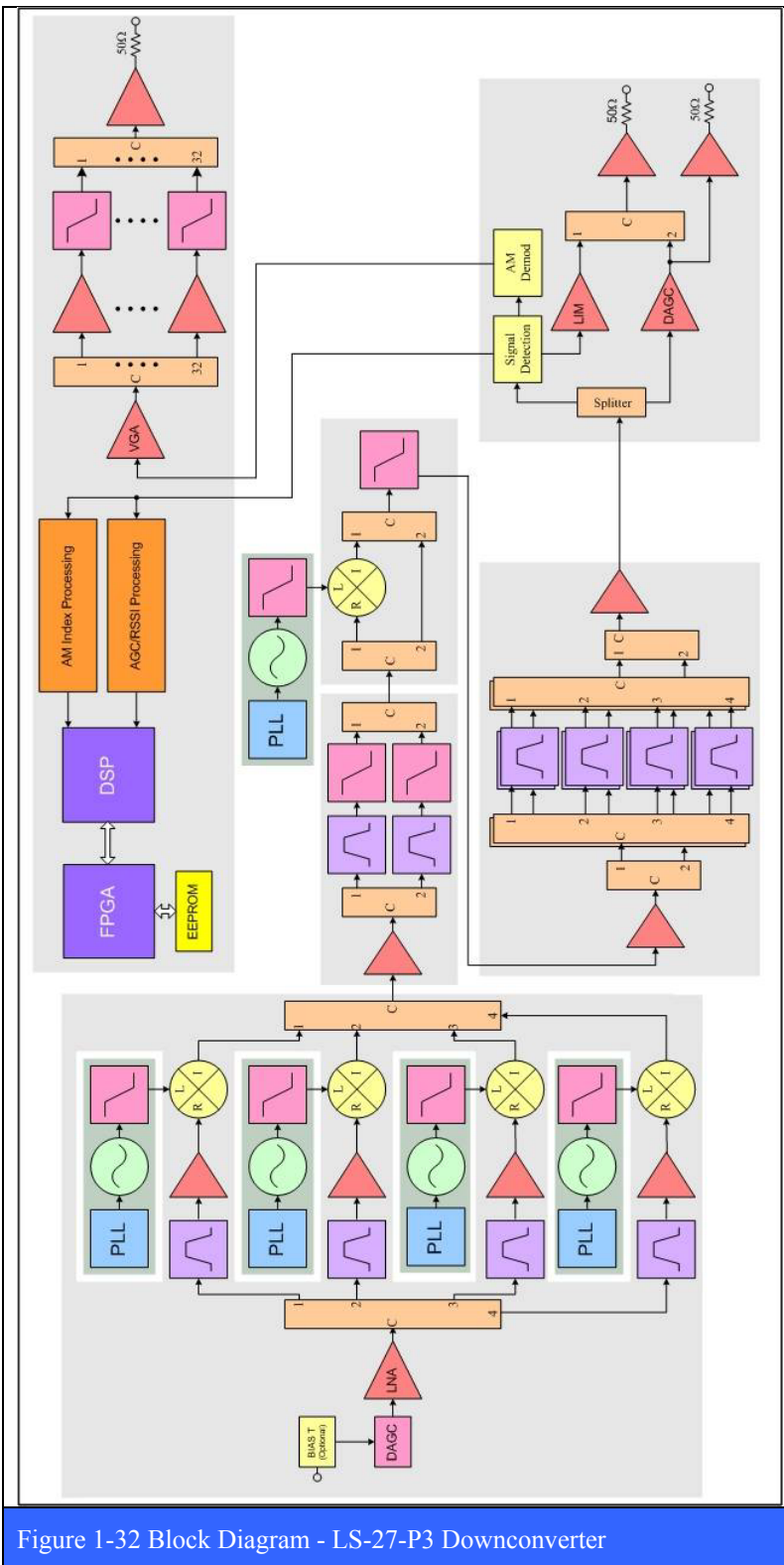


Figure 1-32 Block Diagram - LS-27-P3 Downconverter

1.3.1.3 1st Local Oscillator

In a super-heterodyne design, local oscillators (LOs) are utilized to convert high frequencies to lower, “intermediate” frequencies. The first LO is injected into the mixer of the first down conversion stage to accomplish this task. Mixers can either utilize a sum or difference frequency component to produce IF frequencies. For example, if an RF frequency of 2,200 MHz was to be converted to an intermediate frequency of 250 MHz, a difference component of 1,950 MHz could be injected to the mixer or a sum frequency component of 2,450 MHz could be applied. The difference component LO application is referred to a “low-side” conversion. The sum component application is referred to as “high-side” conversion. Both methods are equally valid and each has its own benefits. The LS-27-P3 design has the ability to utilize either approach and actually switch between the methods when necessary for performance reasons.

1.3.1.4 2nd Downconversion

The receiver designs contain a switching 2nd down conversion stage. Similar to the 1st down conversion stage, it contains a mixer to convert the 1st IF frequency to a second IF frequency of 70 MHz. If the RF frequency band is relatively low, as is the case for P-Band inputs, the on-board processor can bypass the 2nd down conversion stage switching to a single super-heterodyne process. In either case, a low-pass filter is applied to the signal path at the output of this stage to reduce harmonics and low frequency noise from being applied to subsequent stages.

1.3.1.5 2nd Local Oscillator

The second LO is injected into the mixer of the 2nd down conversion stage to provide the second IF frequency of 70 MHz. Like the first conversion stage, the second LO utilizes low-side injection for this conversion. A low-pass filter is applied to the LO output to minimize spurious and harmonic signals from being converted in the 2nd down conversion stage. The 2nd LO is automatically disabled for RF bands that employ a single super heterodyne process.

1.3.1.6 2nd IF Filter

From the output of the 2nd conversion stage, the resulting intermediate frequency is then applied to a group of bandpass filters to minimize noise bandwidth and improve adjacent channel rejection. The 2nd IF stage contains eight IF (SAW) filters centered at 70 MHz and varying in bandwidth from 250 kHz to 40 MHz in approximately octave steps.

1.3.1.7 Digital AGC/Limiting Amplification/AM Demodulation

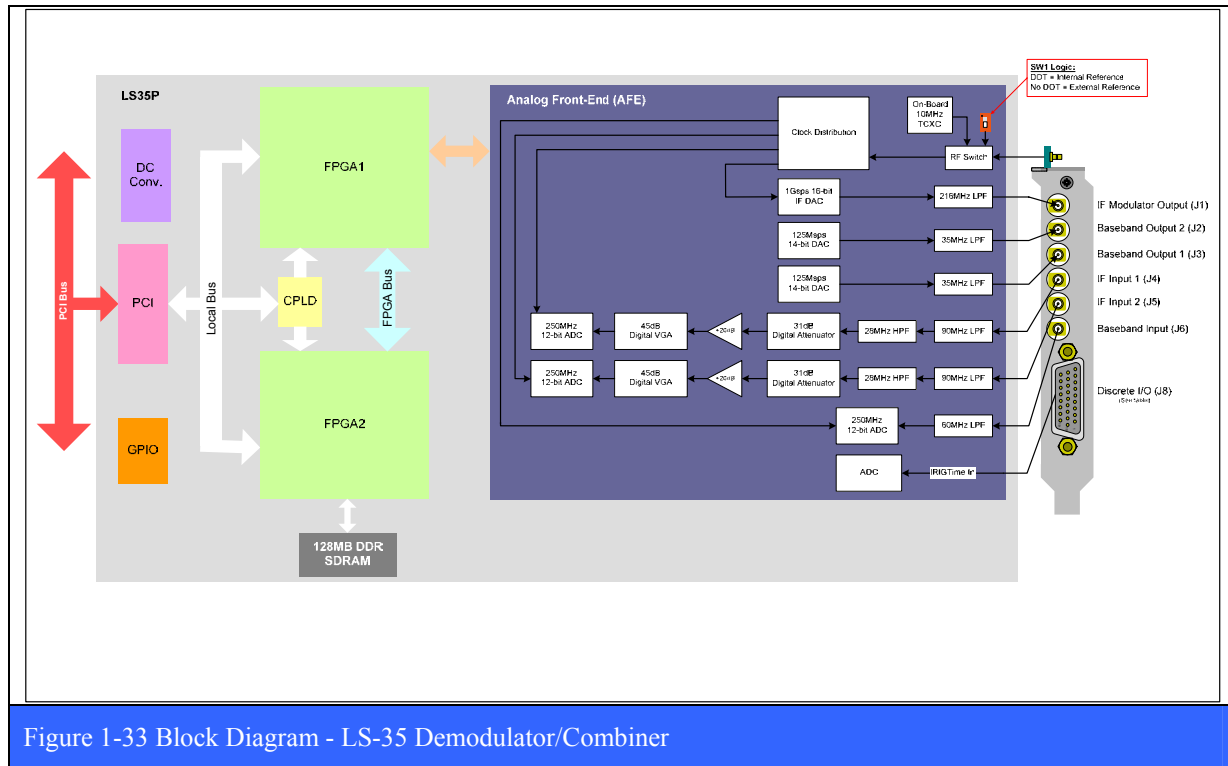
Outputs from the 2nd IF filter stage are routed to the final signal detection, AM demodulation, and gain stage in the receiver. The output stage combines both a limiting amplifier and digital AGC (DACG) section. Included in the design is an AM demodulation stage for antenna tracking applications. The main system gain element provides for 90 to 110 dB of signal gain. Signal level detection is utilized in DAGC controls.

1.3.1.8 Digital Signal Processing Engine (DSPE)

The LS-27-P3 design contains a highly integrated digital signal processing engine (DSPE) which is utilized for linearization, filtering and control applications. This engine is composed of a digital signal processor, FPGA resources, ADCs, DACs and localized memory used to process the signal path parameters. Each of the channels is controlled and monitored as an autonomous receiver. The engine performs “real-time” tasks as well as user software interfaces.

1.3.2 LS-35 PCI Digital Demodulator/Combiner Board

The Lumistar LS-35 Multi-Mode IF Demodulator/Combiner is part of the Lumistar family of digital processing boards used to build programmable telemetry systems. As shown in the figure below, the LS-35 consists of an analog front-end and a 10 million gate FPGA based digital processing engine. The LS-35 can be firmware configured to perform the functions of an IF receiver with multi-mode demodulator, a pre-detection diversity combiner, a bit synchronizer, and a multi-mode modulator for self-test and checkout. The analog front-end performs pre-conditioning of the 70 MHz IF input signal prior to acquisition. Signal conditioning of the receiver and bit synchronizer outputs are also performed in the analog front-end. The digital processing engine is implemented in two large FPGAs and performs the functions of IF reception, multi-mode demodulation, pre-detection combining, bit synchronization, as well as the multi-mode test modulator. The all-digital design and implementation assures a consistent product with high reliability and long-term stability



Like the Chameleon, the LS-35 can take on multiple functional personalities via different firmware loads. The respective functional capabilities within a personality are individually enabled or disabled via a firmware license created at the factory at the time of order. The addition of new functions and capabilities after the product is delivered is a simple matter of updating the firmware license files installed on the target machine where the LS-35 card is

installed. Currently, there are four (4) functional personalities defined for the LS-35. They are respectively designated as; FM-FM, PSK-FM, PSK-PSK, and PM-PSK.

1.3.2.1 FM Mode

The FM-FM functional personality offers two independent PCM/FM multi-symbol demodulators. A simplified FPGA block diagram of this mode is shown in the figure below.

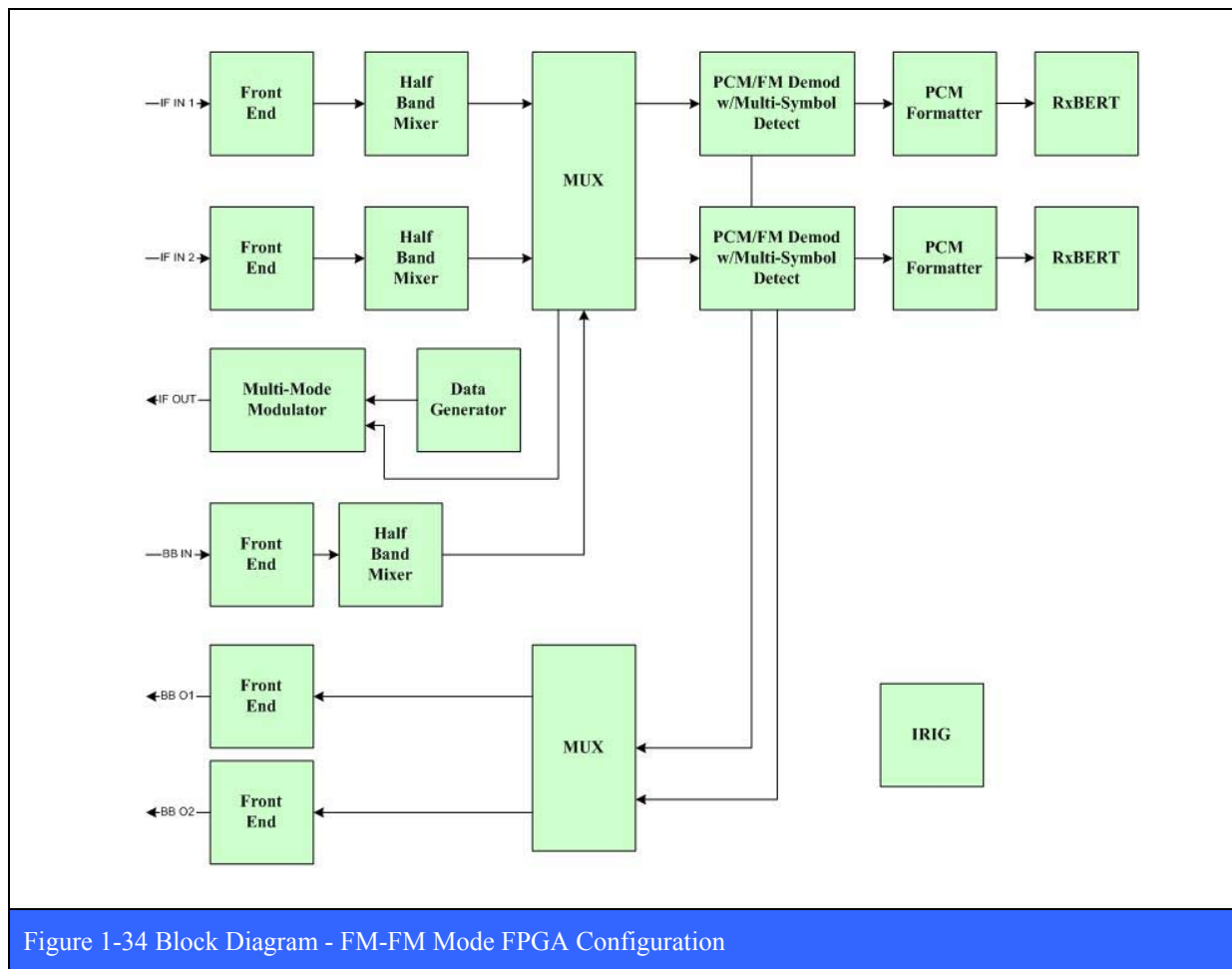


Figure 1-34 Block Diagram - FM-FM Mode FPGA Configuration

1.3.2.2 PSK Mode

The PSK-PSK functional personality offers two independent PSK multi-mode demodulators and a pre-detection diversity combiner. A simplified FPGA block diagram of this mode is shown in the figure below.

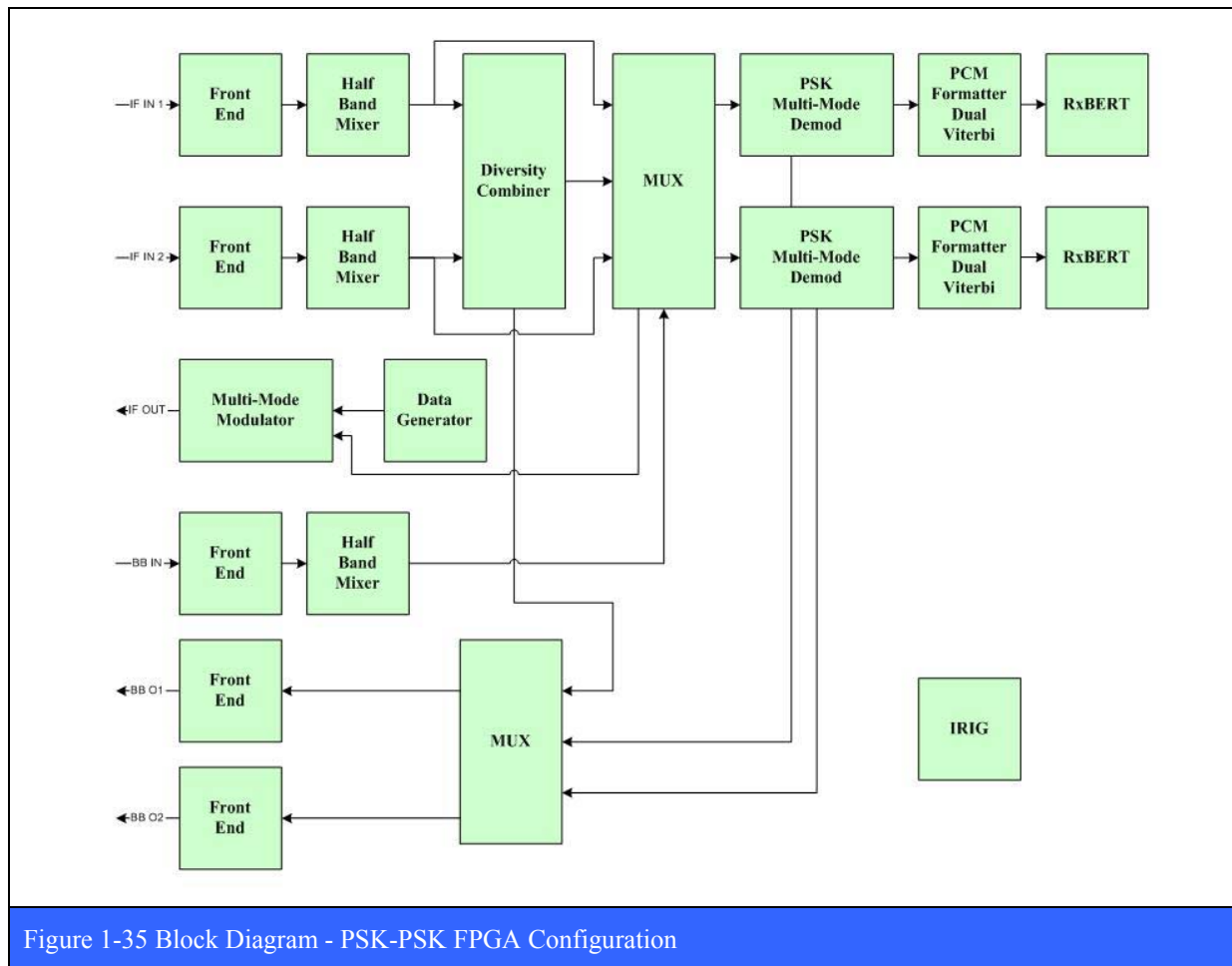


Figure 1-35 Block Diagram - PSK-PSK FPGA Configuration

1.3.2.3 PSK/FM Mode

The PSK-FM functional personality offers one independent PSK multi-mode demodulator, one independent multi-symbol FM demodulator, and a pre-detection diversity combiner. A simplified FPGA block diagram of this mode is shown in the figure below.

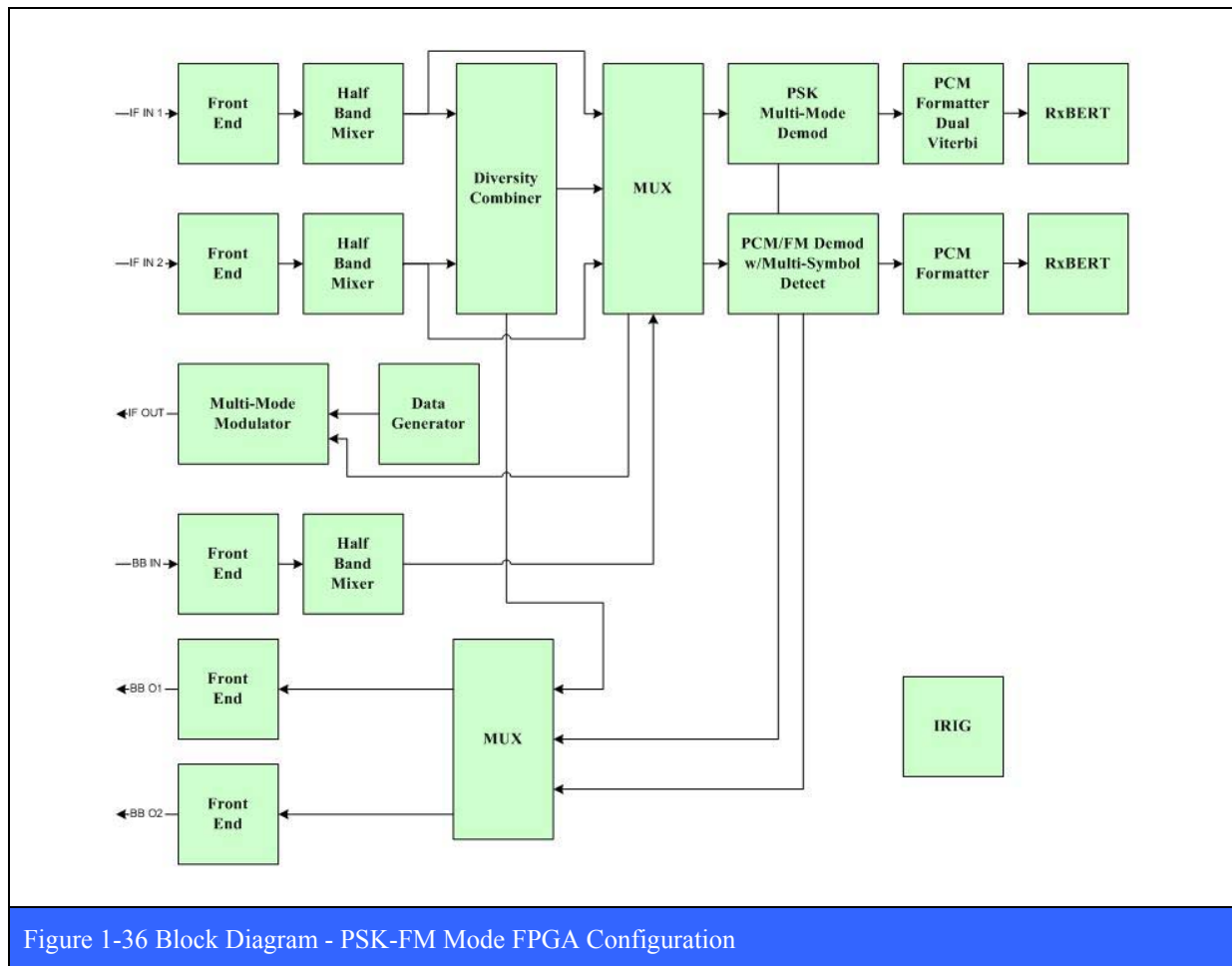


Figure 1-36 Block Diagram - PSK-FM Mode FPGA Configuration

1.3.2.4 PM/PSK Mode

The PM-PSK functional personality offers a single-channel, PM demodulator that is internally coupled to a second PSK multi-mode demodulators used to support various phase modulated sub-carriers. A simplified FPGA block diagram of this mode is shown in the figure below.

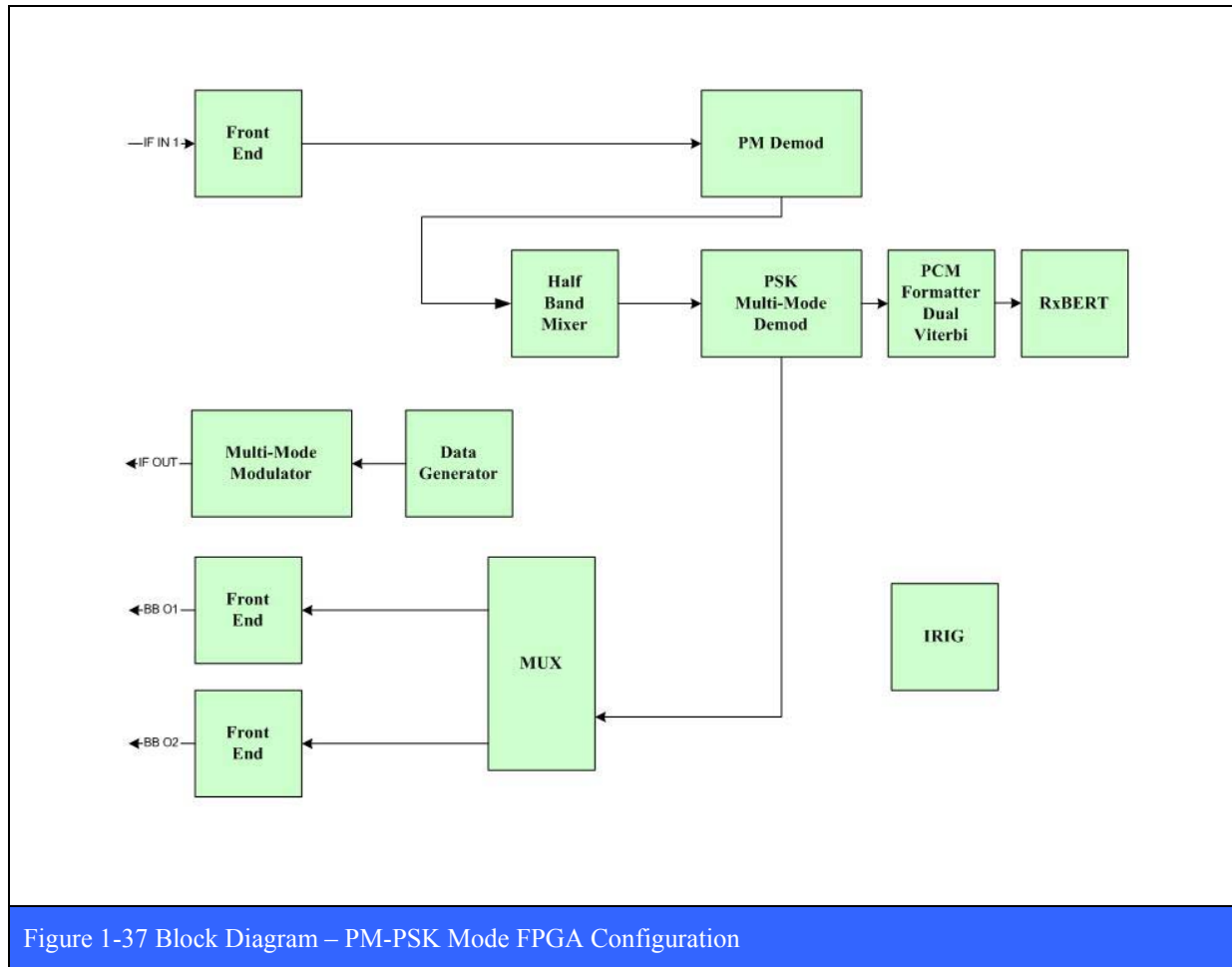


Figure 1-37 Block Diagram – PM-PSK Mode FPGA Configuration

1.3.2.5 Diversity Reception

The LS-35 employs a pre-detection, maximal-ratio diversity combiner. It accepts two IF inputs (typically 70 MHz) that hopefully have independent or complementary fading, usually from separate polarizations or completely separate antennas. The most significant performance improvement from a diversity combiner occurs in a fading environment when the two channels fade independently. When one channel is in a fade, there is a good chance that the other channel will not be in a fade, and so the effect of the fade is completely mitigated. Only when both channels fade does the combined signal fade. A diversity combiner provides the additional performance advantage of providing gain by phase aligning and optimally combining the two signals. Combining prior to demodulation (pre-detection)

makes that gain available to the receiver's tracking process and significantly reduces the chances of the receiver losing lock.

The LS-35 combiner measures the relative phase of the two signals and the Signal-to-Noise Ratio (SNR) of each channel. The phase of the weaker signal is adjusted to match the stronger signal. In a multi-path environment, rapid phase fluctuations occur in the deepest part of the fade. By adjusting the phase of the weak signal to that of the strong signal, the rapid phase fluctuations are mitigated. The amplitudes are adjusted based on the ratio of the two SNR measurements to provide a maximal-ratio combining. This means that if the two signals have different SNRs, then the signal with the lower SNR will be attenuated relative to the signal with the stronger SNR, ensuring that weak or faded signals do not negatively affect the combined signal. Signals with the same SNR will be combined with equal strength.

The combiner operates at baseband and can combine signals of any modulation type. A block diagram is shown below.

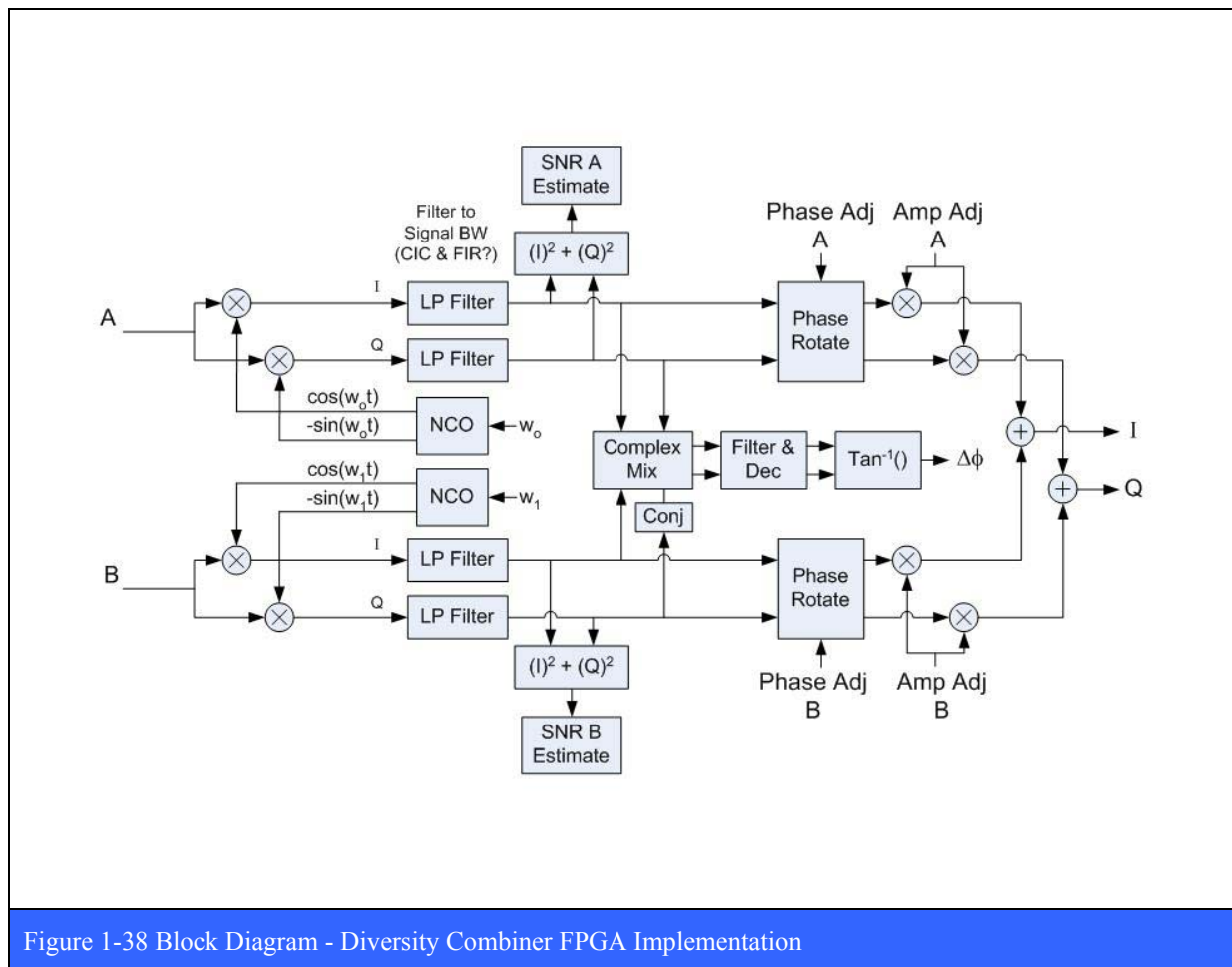


Figure 1-38 Block Diagram - Diversity Combiner FPGA Implementation

Configuration parameters for the combiner are:

- Input Center Frequency
- Signal Bandwidth
- Time Constant – Controls how fast the combiner adapts, fast fade rates work better with a small time constant
- Noise Estimation Mode – Fixed or Auto
- Noise Estimate for each channel when in auto

Status parameters include a read-back of the configuration parameters and the following additional read only parameters:

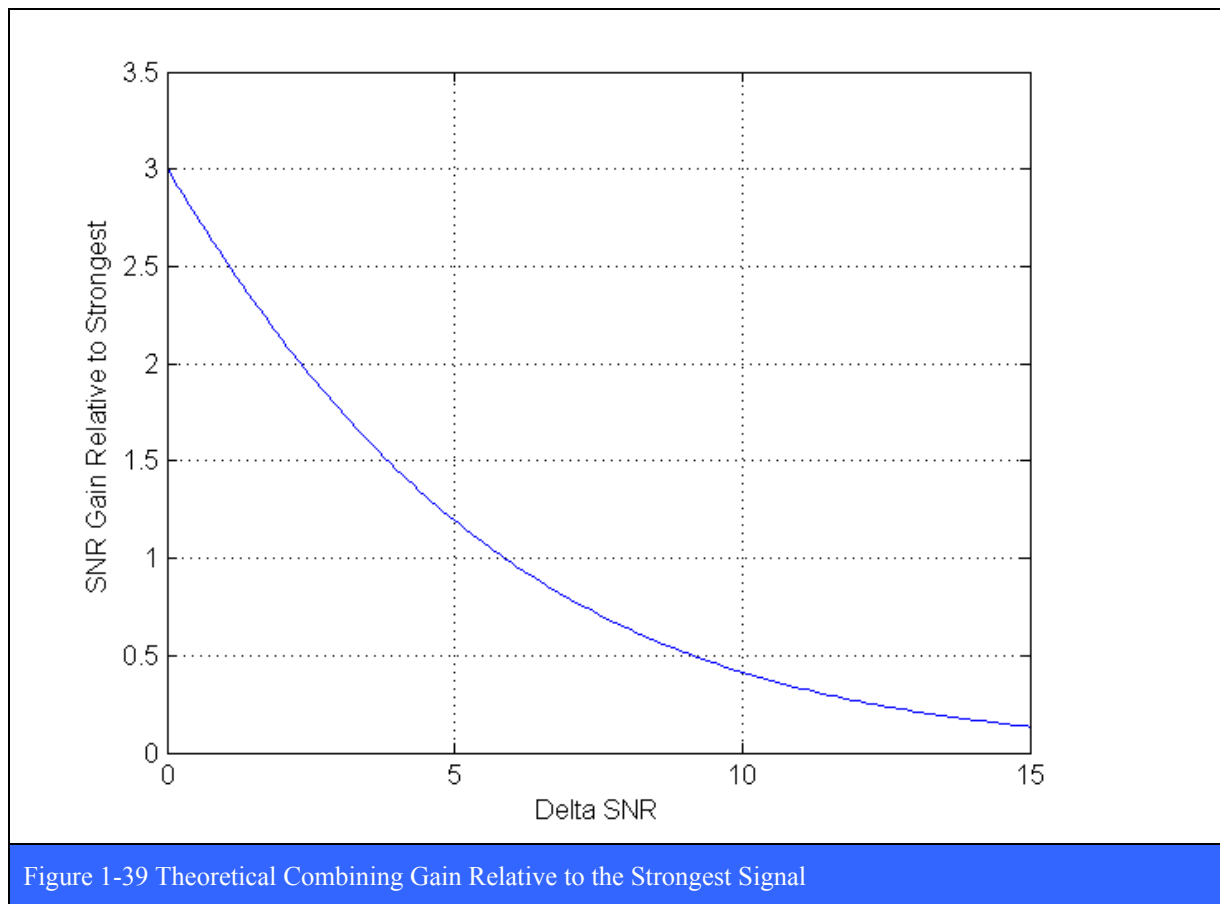
- Noise Estimate for each channel
- SNR Estimate for each channel

Performance:

The theoretical improvement when combining two fading channels with independent additive white Gaussian noise (AWGN) is

$$SNR_{gain} = 10 \cdot \log_{10} \left[1 + 10^{-(\Delta SNR_{dB})/10} \right] \quad (\text{dB})$$

relative to the higher of the two input SNR's. The curve of this improvement is shown below. When the input SNR's are equal (Delta SNR is 0), the improvement offered by combining is 3 dB. When the difference in dB increases to 5.8, the combining gain is reduced to about 1.0 dB.

**Advantages:**

Most legacy combiners use an AGC output as the estimate for the SNR. This works correctly if the noise levels and gains in each channel are identical. However, differences in noise and gains are not uncommon. Differences between channels can be caused by different noise figures of the LNAs and downconverters, different gains of the LNAs and downconverters, different cable lengths and cable losses, and differences in the AGC signal's gain. To get the same operational performance as observed in a laboratory, extreme care must be given during the installation to ensure matching gains and noise figures. But even if the system is properly adjusted during installation, aging of components can cause parameters to change over time, reducing the effectiveness. Measuring the actual SNR is more difficult but it ensures proper combining.

The above implementation makes an instantaneous measure of the signal + noise and an averaged measure of the noise. From these it computes the signal/noise for each channel. The averaged noise measurement can be made prior to operation when no signal is present, or during operation when the signal is present. The measurement prior to operation is generally more accurate as long as the noise does not change during operation. If the noise

measurement is made during operation, the type of modulation can affect the accuracy of the measurement. Constant envelope signals allow accurate noise estimates. PCM/FM, PM, SOQPSK, multi-h CPM are constant envelope signals. BPSK and QPSK are often filtered and then contain a small amount of AM, which make the operational noise measurements less accurate. A noise calibration without signal is recommended for BPSK and QPSK signals.

The combiner implementation is entirely digital, which means that analog component variations are eliminated. This allows the combining gain to come very close to theoretical. The instantaneous signal + noise measurements can be made very quickly and allow accurate combining of signals with very fast fade rates.

Testing:

Accurate testing of a diversity combiner is not a simple task. Static testing to show the strong signal is selected or to show that equal strength signals provide 3 dB of gain are good tests, but do not fully test the performance of a diversity combiner. More realistic tests include a variety of dynamic fade rates with both amplitude and phase fluctuations, and static variations in the gain of each channel (changing the gain does not change the SNR) or the noise figure.

One first tests static performance and compares against the theoretical curve (see Figure 1-39 above). One then tests dynamic performance using two channel simulators that can adjust amplitude and frequency (or phase) of each channel independently based on a stored file. The amplitude of one channel is programmed to have a simple two ray fading profile. The amplitude of the second channel is programmed so that the ideally combined signal should have a constant power level. This provides a resulting signal that should be stable with very predictable parameters, including a constant E_b/N_0 for BER testing. Other fading profiles can also be implemented. The fade rates can be varied from DC to over 10 kHz.

The phase difference between the two channels can be programmed to be continuously varying at a constant rate (a fixed frequency offset) or they can be programmed to more accurately reflect the rapid phase fluctuations that occur in multi-path fading. It is important to measure the performance at a variety of fade rates to ensure that the phase rotations are occurring properly and fast enough to provide accurate combining.

Additional tests are performed to simulate the noise figure and gain variations that can occur in real systems. This can be done by slightly increasing the noise figure or the gain of one channel. Gain only variations should not change the performance because the SNR is not changing. Noise figure only variations change the SNR of that channel and thus do change the ideal combining performance. The change in performance is then compared to theoretical. These tests verify that the SNR estimations are operating properly.

1.3.2.5.1 Combiner Parameters

The primary parameters that drive the combiner functionality are described in the following paragraphs below.

Noise Estimation Mode

As described previously, the combiner in the LS-35 performs dynamic phase and amplitude adjustments based upon the S/N ratio of the two input channels. Key to this process is the accurate determination of the noise component of the input signal. The combiner in the LS-35 has two random-noise estimation modes; AUTO and FIXED. In the auto mode, the combiner employs a proprietary method of measuring the random-noise in the signal. In the fixed mode, the user may independently measure the random-noise component of the signal via some external means and then enter the value using the Fixed Noise Command described below.

Combiner Mode

The combiner in the LS-35 supports multiple combining modes including; Frequency and Polarization diversity. For Spatial or Antenna diversity, choose the Polarization mode. The user may also disable the combiner altogether by invoking the Off command. It should be noted that the particulars of the actual combining algorithm used on the two signals does not change with combiner mode. Rather, these combiner, “modes” are needed in the automation of certain GUI functions. For example, when the user selects the polarization mode, the software will automatically set the tuner frequency of both of the associated downconverters to the same frequency, irrespective to what they were originally set to. In this case, if the second receiver input was set to combiner, for example, then the tuner frequency set for the second downconverter would also automatically be set to the same frequency for the first downconverter. This type of automation is intended to help prevent what might be called, “cockpit error” on the part of the user. By contrast, when the user selects the frequency combiner mode, no such downconverter tuning automation takes place, as by definition, frequency diversity employs two different frequencies.

Signal Bandwidth

As part of the combining process described earlier, the LS-35 measures the S/N ratio of each input channel. Associated with this measurement are bandpass filtering networks with their associated signal bandwidth. In normal operation, the software’s automation sets the bandwidth of these filters automatically based upon parameters such as data rate, modulation type, code format, etc. The advanced user can, however, override these settings and enter a different bandwidth value in MHz by invoking the Signal Bandwidth command. Changing the signal bandwidth value is not recommended however.

Time Constant

The combiner in the LS-35 dynamically phase and amplitude adjusts each channel based upon the S/N ratio of the respective channel. The adjusted channels are then added together in quadrature to form the combined output. This process is dynamic and the computation rate is controllable by the user via the Time Constant command. After invoking the command, the

user is prompted to enter the time constant value in seconds. The default (minimum) value for this parameter is 0.001 seconds. This corresponds to a processing rate of 1000 calculation/adjustments per second. The maximum value for the time constant parameter is 1 second.

Signal Bandwidth Ratio Constant

As described earlier, the LRRS software automation sets the bandwidth of the associated bandpass filtering networks automatically based upon parameters such as data rate, modulation type, code format, etc. The Signal Bandwidth Ratio Constant is part of this calculation, with the default value being set to 1.25. Advanced users may opt to set this constant to some other value. When this constant is changed, the signal bandwidth value displayed will automatically update to a new value.

Center Frequency (Ch1 & Ch2)

The Center Freq Ch1 & Ch2 commands allow the user to change the default 70 MHz frequency value for the incoming carrier signal. For example, one might do this to compensate for a known frequency offset in the input signal that is not caused by Doppler (i.e. the frequency offset is fixed and not changing). In normal operation, the user should not change the carrier frequency from the default of 70 MHz.

Fixed Noise (Ch1 & Ch2)

Used in concert with the Noise Estimation mode command described above, the Fixed Noise Ch1 & Ch2 commands allow the user to independently measure the random noise component of each input signal and enter the noise value in dBm/Hz. After the new noise values have been entered, the user must then initiate a noise calibration cycle by clicking on the Calibrate Fixed Noise button described in the next paragraph. In normal operation this is not recommended to change the noise level, as the combiner's ability to measure the noise-power-per-unit-bandwidth (N_0) is very accurate.

Calibrate Fixed Noise Button

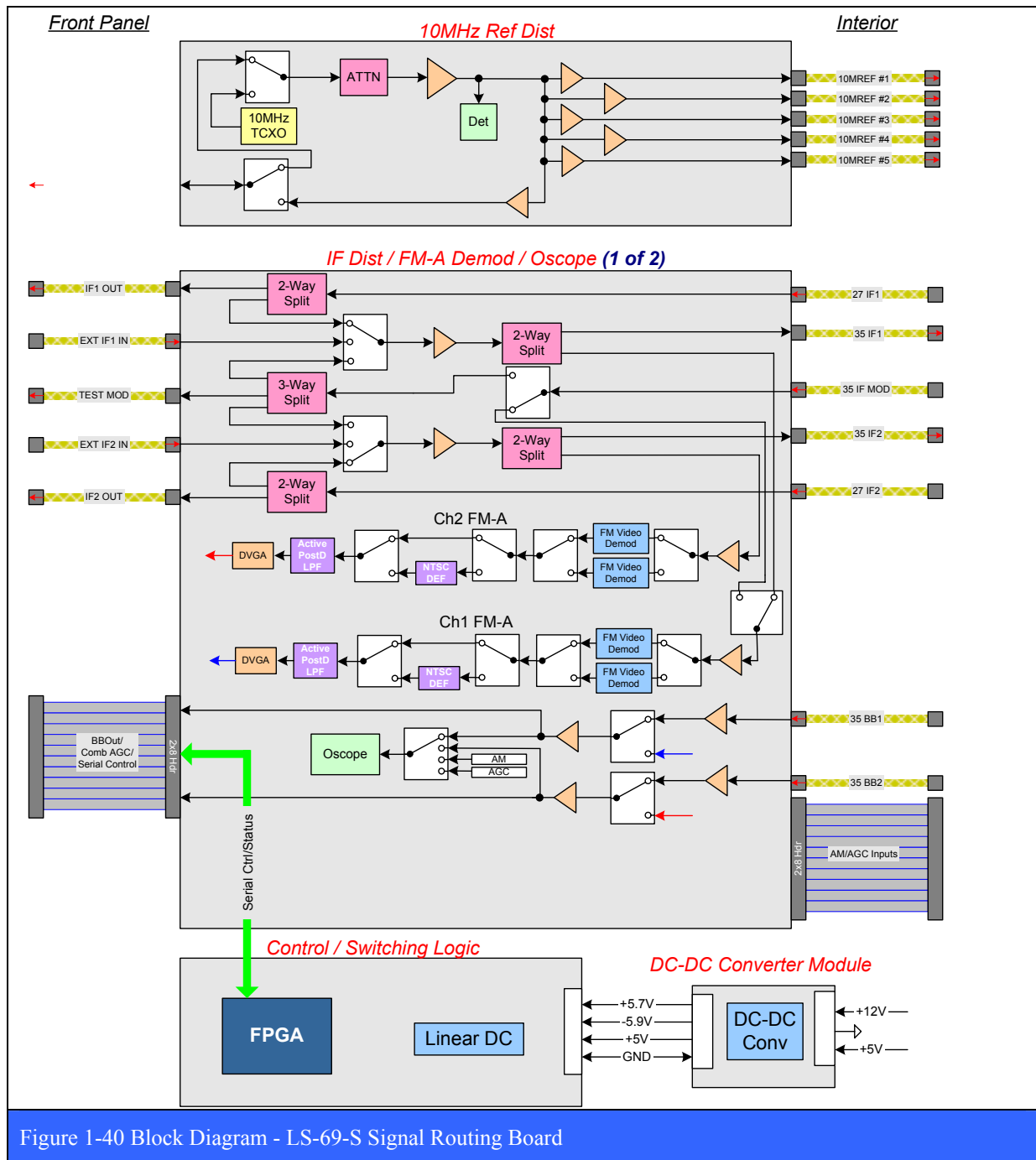
Pressing this button begins a calibration measurement of the noise floor for both input channels.

Reset Button

Pressing this button resets the entire SNR measurement, phase rotation, amplitude adjustment process.

1.3.3 LS-69-S Signal Routing Board

The LS-69-S Signal Routing CCA is the true heart of any LS-28 system. It supports either one or two card groups and provides a plethora of different functions for the LS-28. The block diagram for the LS-69-S is shown in Figure 1-40 below.



The functions performed by the LS-69-S are as follows:

- 10 MHz reference clock distribution, including support for a user supplied external clock reference signal.
- 70 MHz IF signal distribution and switching. This includes the internal loop-back self-test using the on-board 70 MHz IF test modulator.
- Analog FM demodulation & video filtering for multiple channels. This includes the baseband video outputs used to provide the user with an external “Eye Pattern” as well as actual NTSC video.
- Hardware support for the Spectrum and OScope display functionality provided in the LRRS application.
- Routing functions for all baseband signals including receiver AM, RSSI, and baseband video.

Control of the LS-69-S is via one of the host PCs serial ports. Power for the LS-69-S is provided by the LS-69 power supply CCA shown in Figure 1-17 on page 29.

2 System Installation

2.1 General Information

This section provides installation instructions for the Lumistar LS-28 Telemetry Range Receiver/Combiner System. This information includes unpacking and handling instructions, system rack-mount installation instructions, instructions for system storage, and packaging instructions for system transportation or re-shipment.

2.2 Unpacking and Handling

The LS-28 is shipped as a complete unit in the ruggedized shipping and storage container shown in Figure 2-1 below. The receiver chassis, cables, rack-mount installation hardware, software CD and User's Manual are shipped in this container.

Upon receiving the LS-28, open the shipping case and verify that all of the items listed in Table 2-1 are accounted for.



Figure 2-1 LS-28 Shipping Container

Table 2-1 LS-28 Packing List

Item	Description	Quantity
1	LS-28 Chassis	1
2	Chassis roller rails and attaching hardware (mounts to chassis side panels)	2
3	Chassis rack-mount rails and attaching hardware (mounts to equipment rack)	2
4	AC Power Cable	1
5	User's Manual	1
6	Microsoft Windows ⁹ Operating System Software (CD)	1
7	Lumistar LRRS Application Software (CD)	1
8		

⁹ Depending on customer requirements, either Windows 7 or Windows XP Pro

2.3 Installation

The LS-28 is designed to be mounted into any standard 19" equipment rack, and has the capability to be fully extended during operation and maintenance. For installation, perform the following steps.

- Verify that the AC power connection to the equipment rack has been disconnected or is OFF.
- Remove the LS-28 from the shipping case and verify hardware contents against the packing list in Table 2-1 on page 66.
- Install the roller rails on both sides of the LS-28 chassis.
- Install the rack-mount rails on to the equipment rack.
- Using two persons, carefully lift and slide the LS-28 chassis into rack-mount rails.
- Connect the 15-pin VGA connector of an IBM PC compatible monitor to the video input connection (VGA1) in the lower right corner of the rear panel of the LS-28 chassis.
- Connect an IBM PC compatible keyboard cable to the USB connector in the lower right corner of the rear panel of the LS-28 chassis.
- Connect a mouse/trackball cable to the USB connector in the lower right corner of the rear panel of the LS-28 chassis.
- Connect the LS-28 chassis AC power cords to a standard 115 VAC power source.

2.4 Storage and Packaging for Re-Shipment

When storing or transporting the LS-28, care must be taken to not exceed the environmental storage conditions of -20 to +70 degrees C at a relative humidity of 15 to 90%. No special equipment is required for handling the LS-28, although standard and accepted practices and procedures for the handling of electronic instrumentation should be employed to avoid excessive shock and vibration. The steps required for re-packing the LS-28 are basically the reverse of those listed in paragraph 2.3 above.

3 System Operation

The operation of the LS-28 system involves connecting the requisite signals to the rear I/O panel of the unit (see Figure 1-12 on page 25 or Figure 1-13 on page 26) and launching the primary setup and control application (in certain LS-28 systems, because of customer requirements, the primary application launches automatically upon power up of the system). The requisite signals include connecting the system AC power cable and a VGA display monitor and some type of USB Keyboard & pointing device (mouse, track pad, etc.)

3.1 Overview (The LRRS Application & Operating System Environment)

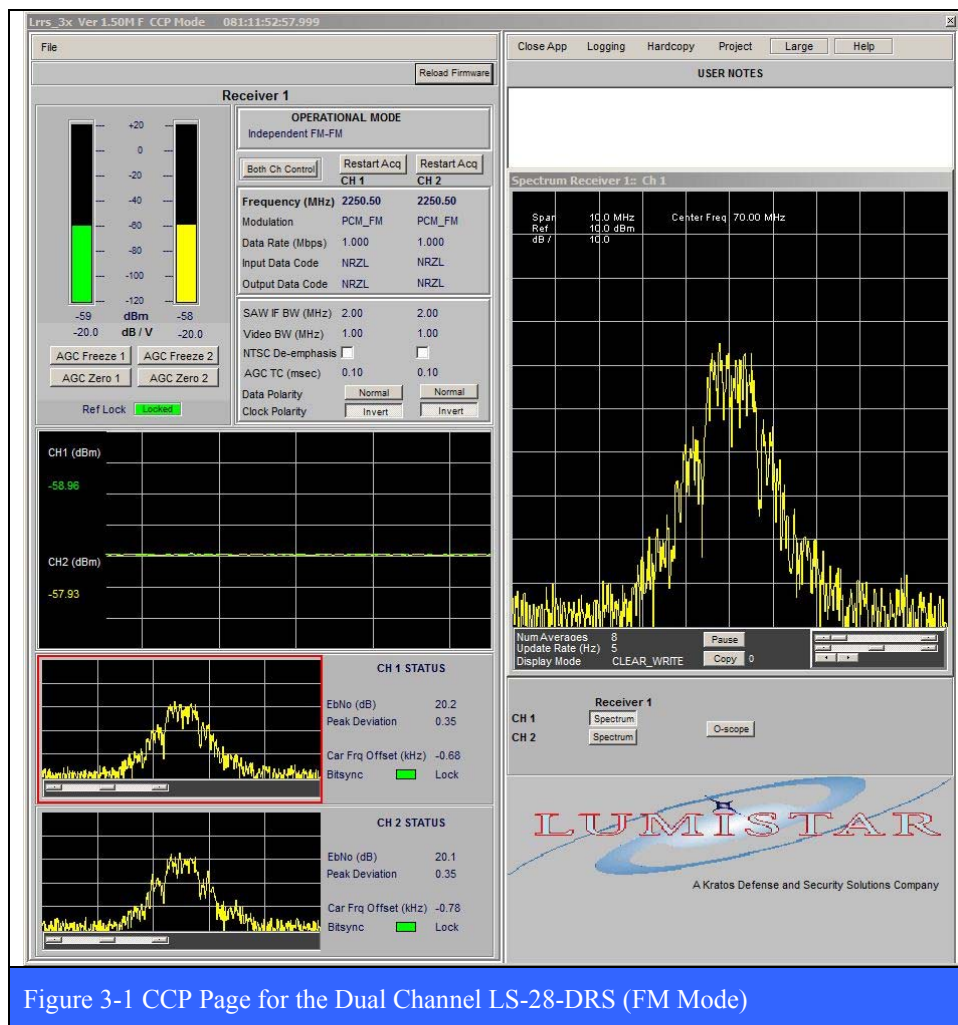
The primary setup and control application of the LS-28 is called the Lumistar Range Receiving System (**LRRS**). The LRRS application was developed to run on either the Microsoft Windows XP Pro, or Windows 7 operating system. The LRRS application is “network aware” and can be operated remotely over the network in a variety of ways. The LRRS application operates in concert with DSP and other firmware elements resident on some of the custom developed Lumistar reception and processing cards installed in the LS-28 system. As such, updates to the system will not only involve new versions of the LRRS application, but also updated firmware as well.

Upon initial delivery of the LS-28 system to a customer, the operating system has been configured with a single user account (User1) and neither the user nor Administrator passwords have been set. Further, the operating system is setup to automatically log on the User1 account, and in some cases, automatically launch the LRRS application. As a general rule, all power management and screen saver functions have been turned off. The operating system will have been updated to the latest security & functional updates as of the date of shipment, but unless otherwise specified, the “automatic updates” feature will have been turned off. No anti-virus programs (3rd party or Microsoft) will have been installed on the system, but prior to shipment, the Microsoft “Malicious Software Removal Tool” (MRT) will have been run on the machine.

3.1.1 The Common Controls Page (CCP)

The primary operator's graphical user interface (GUI), called the *Common Control Page* (CCP), is a full-screen GUI that contain all of the critical displays and controls required to operate the LS-28 during an actual mission test scenario. For the majority of cases, the operator interactions are minimized to button clicks, or single mouse clicks followed by data value entry. The operator is not required to navigate through complex, multi-level GUIs in order to setup and configure the LS-28 for operation.

As there are two flavors of LS-28 (dual channel & quad channel), so there are two variants of the CCP pages. The dual channel CCP page is shown in Figure 3-1 below and is associated with the LS-28-DRS. The quad channel CCP page associated with the LS-28-QRS is shown in Figure 3-2 on page 70



To display the CCP page correctly, the VGA monitor used with the LS-28 must support a minimum resolution of 1440 x 900 (or greater). Any monitor with less than 900 lines of

horizontal resolution will result in the loss of certain portions of the display. Almost all modern flat-panel displays have native resolutions far in advance of the minimums called for here, so there shouldn't be an issue with such displays, but older legacy displays (especially those with 4 x 3 aspect ratios) may not be compatible with the CCP GUI. If this is the case, the CCP page can be turned off (see Figure 3-15 on page 89) and the alternate, multi-tab GUI described in great detail beginning in paragraph 3.2 on page 87 can be used instead. Also, it is preferable to use a VGA display that has a "wide screen" aspect ratio, especially with the LS-28-QRS with its quad channel CCP page display shown in Figure 3-2 below.

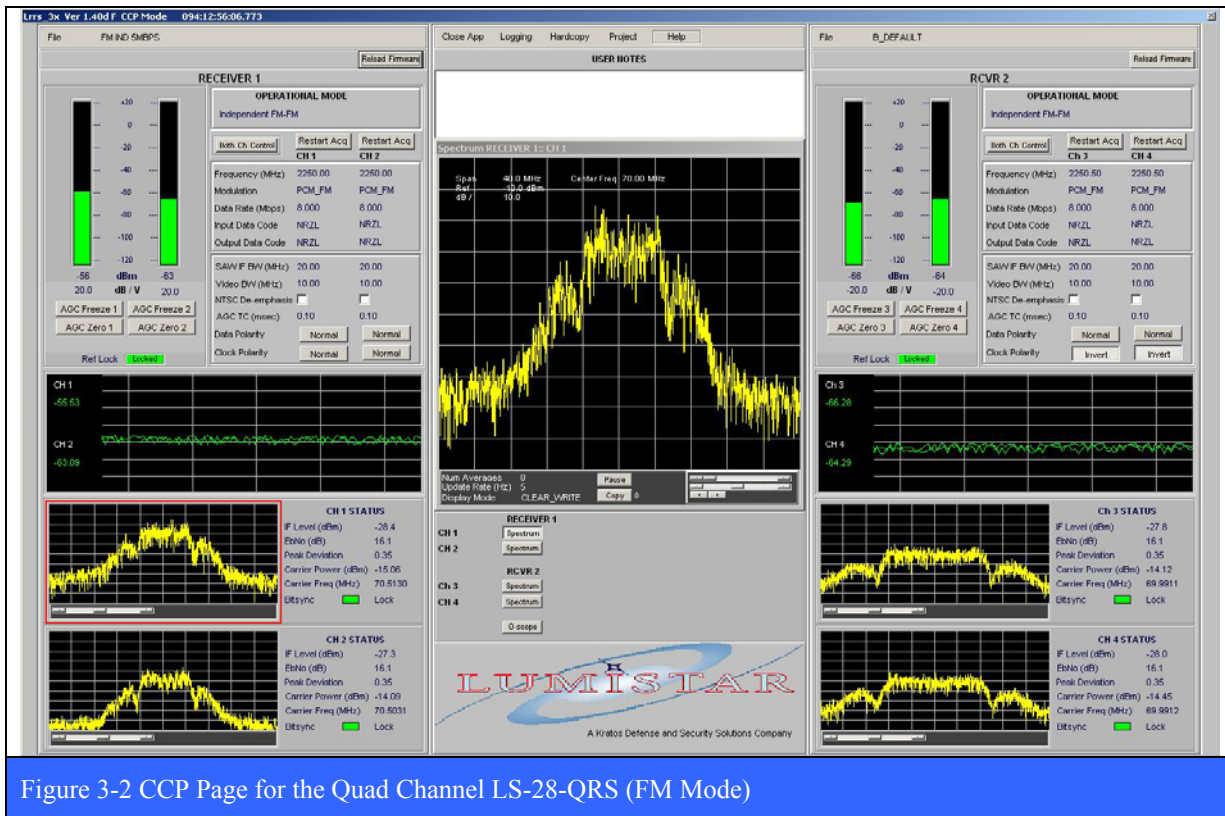
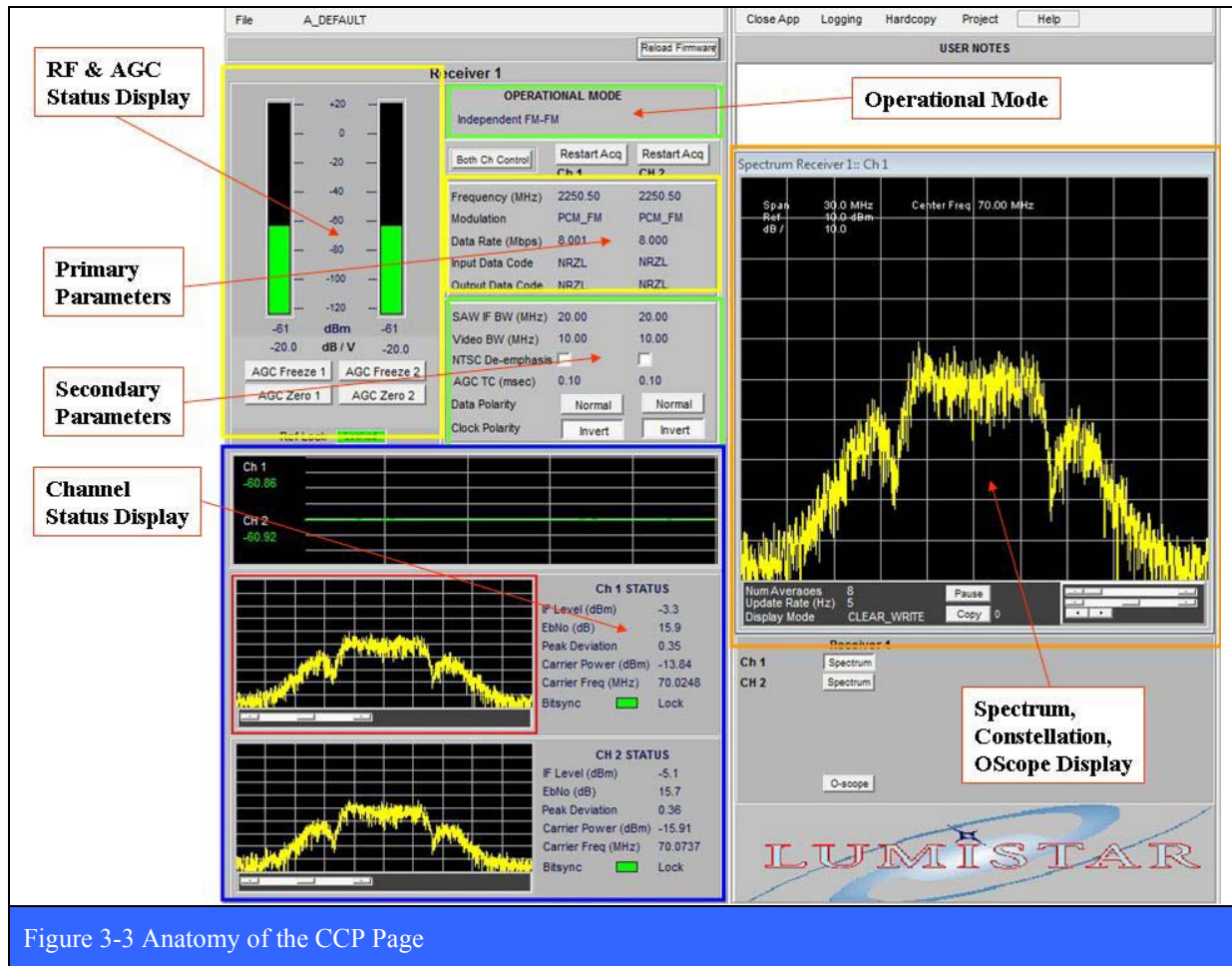


Figure 3-2 CCP Page for the Quad Channel LS-28-QRS (FM Mode)

3.1.1.1 Anatomy of the CCP Page

The CCP page has six different functional areas as shown in Figure 3-3 below. The CCP page shown in the figure is for the dual channel LS-28 configuration. The quad channel LS-28 configuration is similar, and has all of the same functional elements. The functional areas of the CCP page include: *Operational Mode*, *Primary Parameters*, *Secondary Parameters*, *Spectrum/Constellation/Oscope Displays*, *Channel Status Display*, and *RF & AGC Status Display*. Each functional area is described in more detail in the following numbered paragraphs.



Depending on the Operational Mode, the appearance of some of the displays may be different from that shown in the figure above. Any differences are discussed in the individual paragraphs

3.1.1.1.1 Operational Mode

The Operational Mode functional area (see Figure 3-3 on page 71) is where the operator selects what mode the receiver will operate in. The operational modes include *FM*, and/or *PSK* (various types), and whether the two channels in each group in the LS-28 are *Independent* or are *Combined*. The operator selects the receiver mode by placing the mouse cursor in the Operational Mode box and right clicking. The resulting pup-up window is shown below. After the operational mode is selected, the appropriate firmware is loaded into the FPGA on the LS-35 associated with the card group. See paragraph 1.2.2.2.3 on page 32 and paragraph 1.3.2 on page 53 for more details on the LS-35.

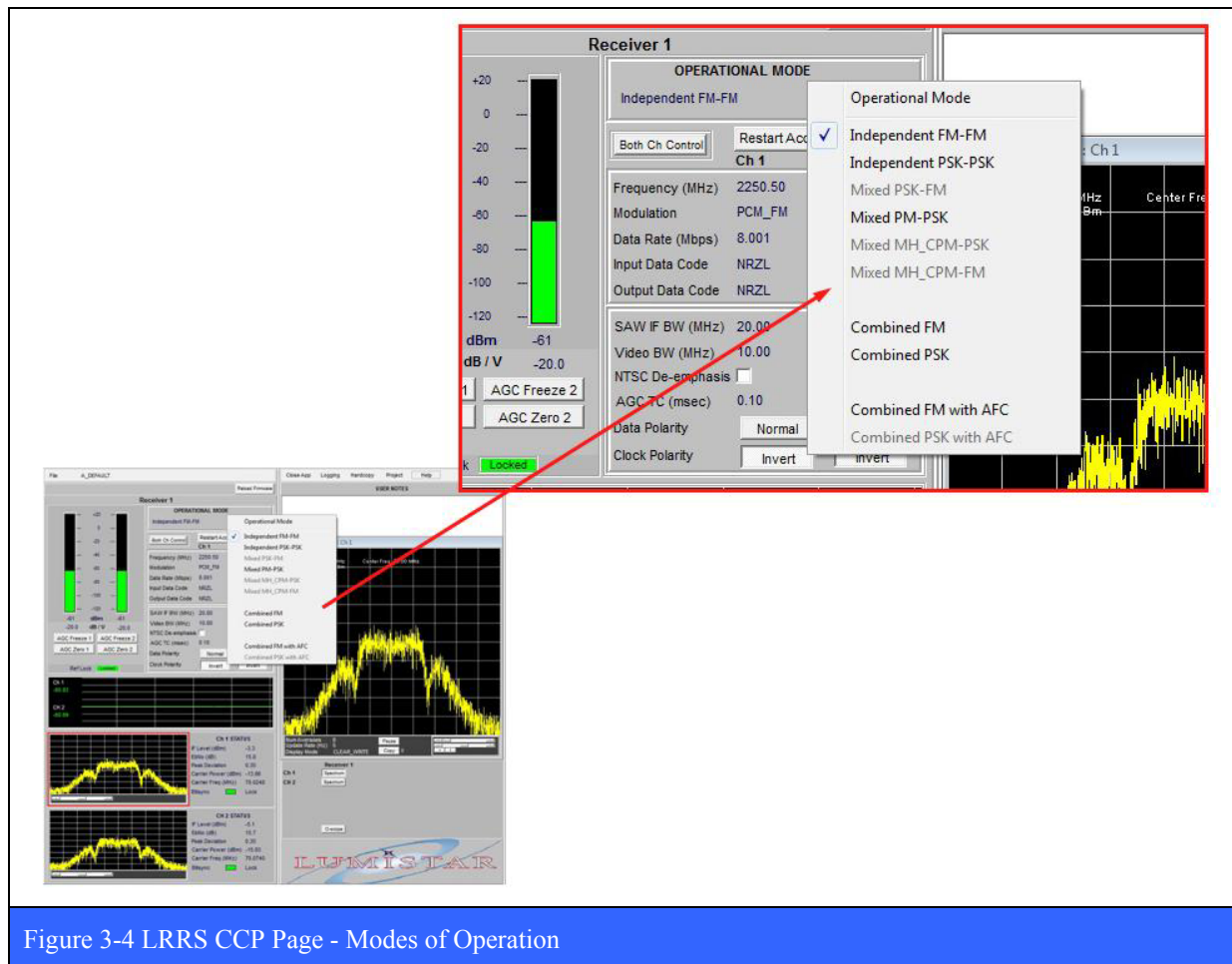
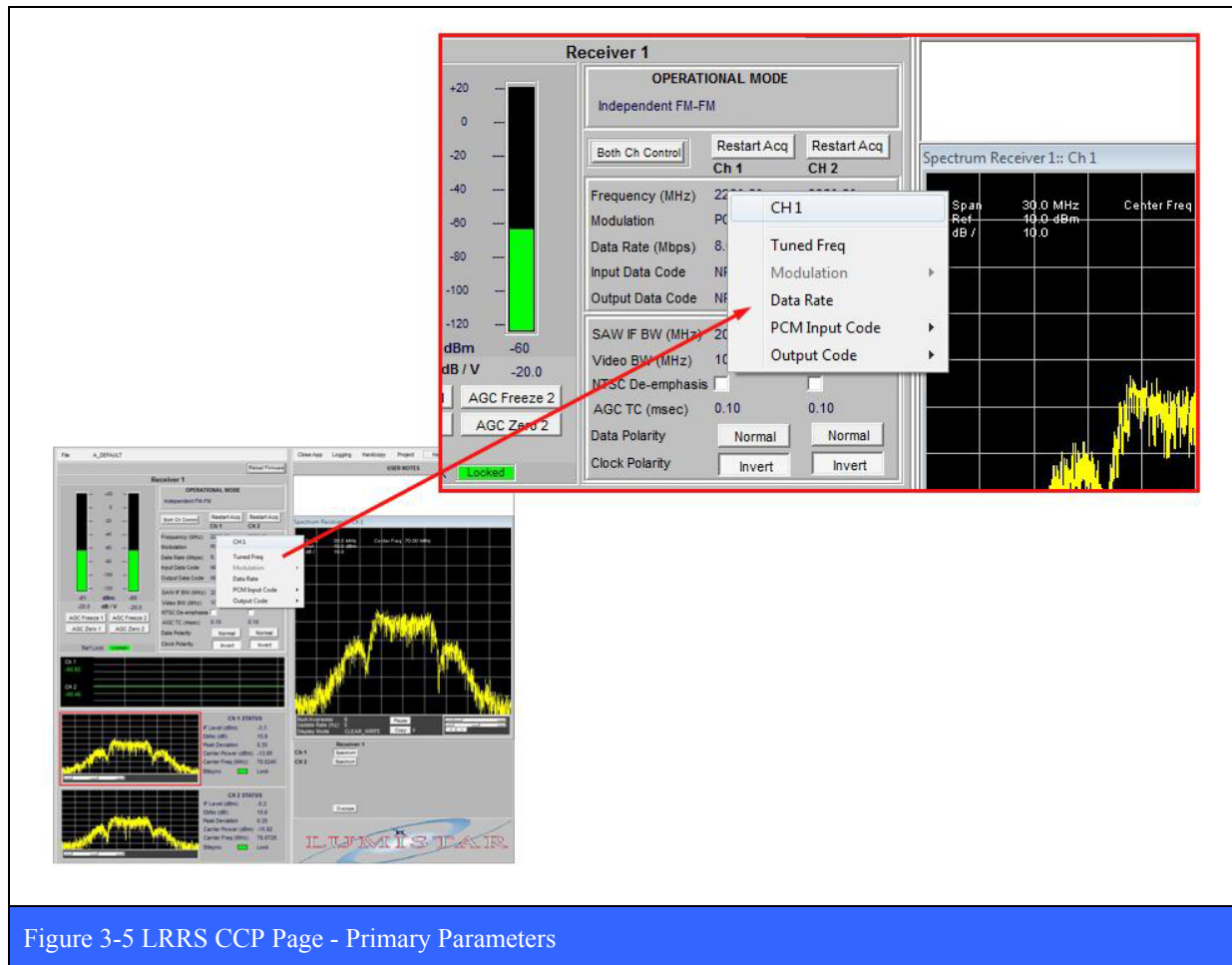


Figure 3-4 LRRS CCP Page - Modes of Operation

3.1.1.1.2 Primary Parameters

The Primary Parameters functional area (see Figure 3-3 on page 71) include: *Tuner Frequency (MHz)*, *Modulation format*, *Data Rate (Mbps)*, and *Data Code*. To change any of these parameters quickly, simply double click on the current parameter value and a dialog box will appear for value entry. Or, one may put the mouse cursor within the box encompassing these parameters and right clicking. The resulting pop-up window for these parameters is shown in Figure 3-5 below.



Modulation

Each multi-mode demodulator in the LS-28 can support a variety of modulation formats. The list of specific formats is determined at the time of purchase via the firmware license file. The complete list of formats include: *FM*, *BPSK*, *QPSK*, *OQPSK*, *DQPSK*, *UQPSK*, *AUQPSK*, *PM*, *SOQPSK-TG*, and *SOQPSK-MIL*. The Modulation item allows the user to specify which demodulation format to use.

Tuner Frequency

The LS-27 multi-band RF downconverter used in the LS-28 concurrently supports up to three of the following five possible frequency bands. The user may also select 70 MHz as an input frequency at any time in addition to the three possible bands.

- 2185.5 - 2485.5 MHz (NATO E-Band)
- 2200.5 - 2399.5 MHz (S-Band)
- 1710.5 - 1849.5 MHz (Upper L-Band)
- 1435.5 - 1539.5 MHz (Lower L-Band)
- 215.5 - 319.5 MHz (P-Band)

To select a receive frequency, click on the Frequency (MHz) item. Enter the frequency in the resulting pop-up dialog box and then click OK. The updated frequency will be displayed in the configuration display area. Note that the supported tuner resolution is 50 KHz, and that entered values will be rounded off the nearest 50 KHz value in the display. Frequency values outside of the ranges specified above will result in an error message with no change in frequency.

Data Rate

The LS-28 supports bit rates from 10 bps to 30 Mbps in the current hardware implementation. To select a Data Rate, click on the Data Rate item. Enter the Data Rate in the resulting pop-up dialog box and then click OK. The updated Data Rate will be displayed in the configuration display area. The operator enters the rate in bps via the **Data Rate (Mbps)** item. Note, if the *Data Rate Entry in Bps* check box in the System Options – Operations tab is UNCHECKED, then the operator may enter the rate in MBPS (not Bps) [see Figure 3-15 on page 89 for more information]. Also note, for quadrature modulation schemes such as QPSK and its variants, the bit rate entered must be twice that of the symbol rate (exception: SOQPSK).

PCM Input Data Code

The bit synchronizer in the LS-28 supports a wide variety of input code types including: NRZ, RZ, Split phase, Miller, and Randomized codes. The **PCM Input Code** item invokes the complete list shown below from which the operator selects.

NRZL, NRZM, NRZS, BIOL, BIOM, BIOS, RZ, DBIOM, DBIOS, DMM, DMS, DMM2, & RNRZ-15.

Demodulator Output Code

The digital demodulator in the LS28 supports a variety of output code types including: NRZL, NRZM, NRZS, BIOL, BIOM, & BIOS. The **Output Code** item invokes the complete list from which the operator selects.

3.1.1.1.3 Secondary Parameters

The Secondary Parameters functional area (see Figure 3-3 on page 71) include: *SAW IF BW*, *AGC TC*, *Video BW*, *NTSC De-emphasis*, *Data Polarity*, and *Clock Polarity*. The Secondary Parameters block has information associated with the down conversion process to 70 MHz as well as the analog FM demodulation performed by the LS-69 card (see paragraph 1.2.2.2.1 on page 28 and paragraph 1.3.3 on page 64 for more information on the LS-69). The default values of many of the secondary parameters displayed are based upon the primary parameters mentioned above in paragraph 3.1.1.1.2 on page 73, as well as the Operational mode. The GUI does allow the operator to change some of the values of these secondary parameters, but this is recommended only for advanced users. Specifically, the secondary parameters that the operator can change include: SAW IF BW (MHz) [second downconverter IF bandwidth in MHz], AGC TC (msec) [automatic gain control time constant in microseconds], and Video BW (MHz) [analog FM demodulated video filter band width in MHz]. To indicate that any of the secondary parameters have been changed from their default values, a double asterisk (**) will be displayed next to the parameter.

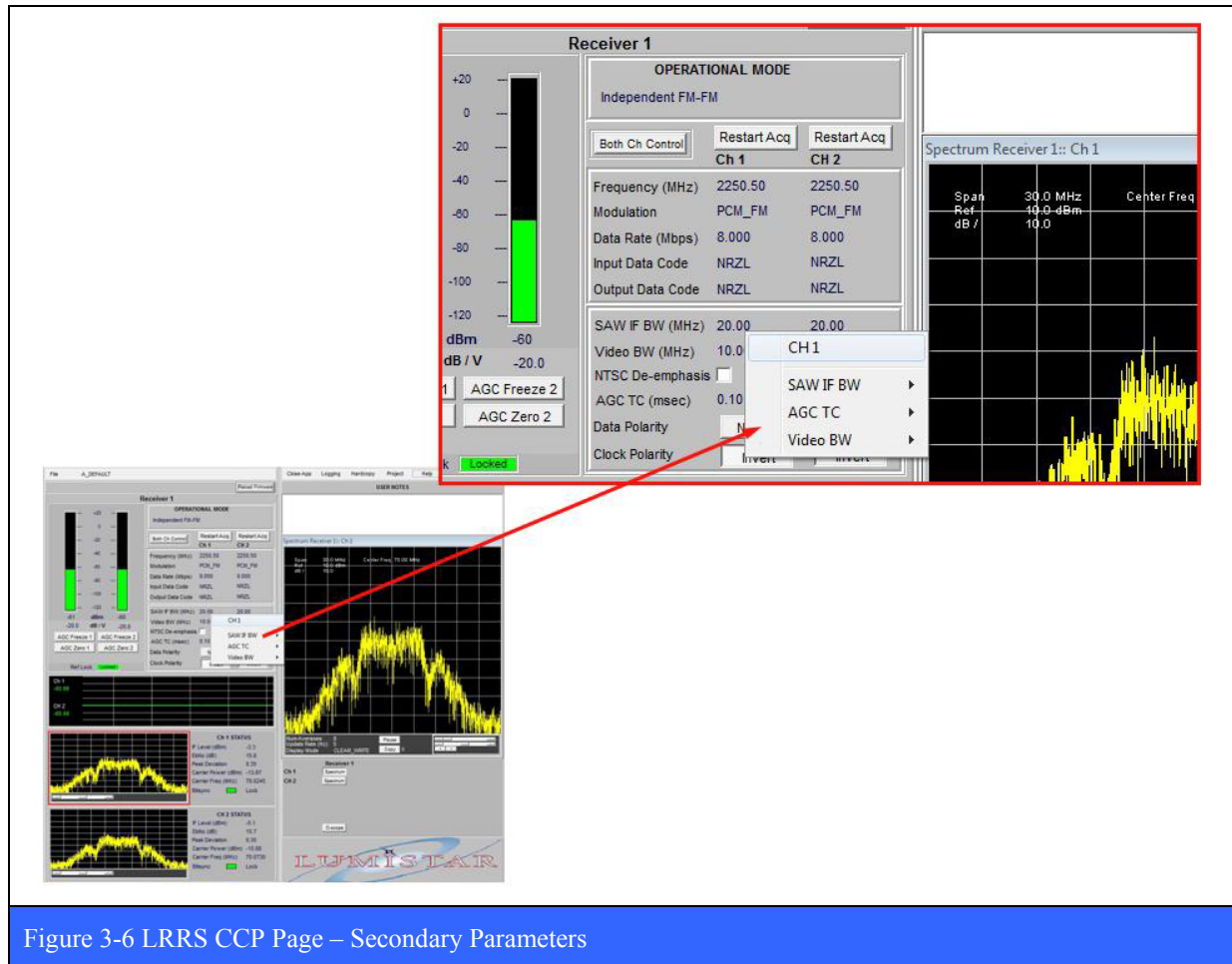


Figure 3-6 LRRS CCP Page – Secondary Parameters

The signal polarity controls consist of two buttons for Data and Clock Inversion. Selecting the Clock Invert button changes the relationship of the rising edge of the clock relative to the data. Selecting the Data Invert button inverts the logic sense of the data.

The NTSC de-emphasis filter is designed to decrease, within a band of frequencies, the magnitude of some (usually higher) frequencies with respect to the magnitude of other (usually lower) frequencies in order to improve the overall signal-to-noise ratio of the analog baseband video outputs of the LS-28.

AGC Time constant, and the associated RSSI voltage, are related as follows. The AGC voltage is produced by a logarithmic amplifier (log amp) in the IF section of the receiver. The log amp has various programmable time constants that allow it to more quickly or more slowly change the absolute receiver gain as a function of RF input level. These time constants vary from 0.1 milliseconds to 1000 milliseconds in decade steps (i.e. 0.1, 1.0, 10.0, 100 and 1000 milliseconds). When using any receiver in an application that requires antenna auto-tracking, the AGC Time Constant must be set to a value that is commensurate with the antenna system's tracking ability. When using the LS28 in a data only application, the value of the AGC Time Constant is typically set to its fastest value, although this has no affect on the quality of the received data.

For example, if the antenna system is a conical scan system with a 30 Hz rotating offset waveguide feed (very common), the AGC Time Constant must be set to 100 milliseconds or slower. If this parameter is set any faster under these conditions, the faster "AGC response" of the receiver will track-out of eliminate the 30 Hz amplitude modulation produced by the antenna, thus rendering the antenna system incapable of auto-tracking. For newer and faster e-scan (electronically scanned, no moving parts) antenna systems, fixed and variable scan rates of 1000 Hz and higher are possible. Experience (and calculation) has shown that a time constant of 10 milliseconds is adequate for a 1 KHz scan rate. It is best to consult with the antenna manufacturer to determine best AGC Time Constant settings in this application.

Legacy analog receivers employ a single AGC Time Constant for both the tracking receiver and data receiver functions (in applications when a single receiver was called upon to do both). In some applications it was not possible to use one receiver for tracking and the other for data only, usually a cost constraint. Realizing that a slower AGC Time Constant required for auto-tracking is not going to be the optimal setting for capturing data (where fast response to drops in signal level is desired), the AGC Time Constant functions for data and auto-tracking have been decoupled. In other words, the AGC Time Constant selection controls the AGC Voltage applied at the rear I/O for interface to the ACU and does not affect the AGC utilized for data only. This is a big operational improvement over legacy receivers.

3.1.1.1.4 Spectrum Display

The Spectrum Display area is shown in the figure below (red rectangle) and is divided into several regions. In the upper portion of the window is the graphical data display area where the spectrum graphs are generated. Also in the upper left portion of the spectrum display are the *Frequency Span (MHz)*, the *Reference Level (dB)*, and *dB/division*. These parameters are controlled in the lower right region below the graphical display via slider or knob controls as shown in the figure. When invoked, addition information associated with Frequency and Amplitude markers are displayed in the upper right portion of the spectrum display. There also two buttons at the bottom of the display. The Pause button freezes the updating of the display until it is pressed again. The Copy button makes a snapshot of the display and saves it as a JPEG file in the C:\Lumistar\LRRS_3X\User\Hardcopies directory. Successive presses of the Copy button will create new snapshots of the widget at different time points.

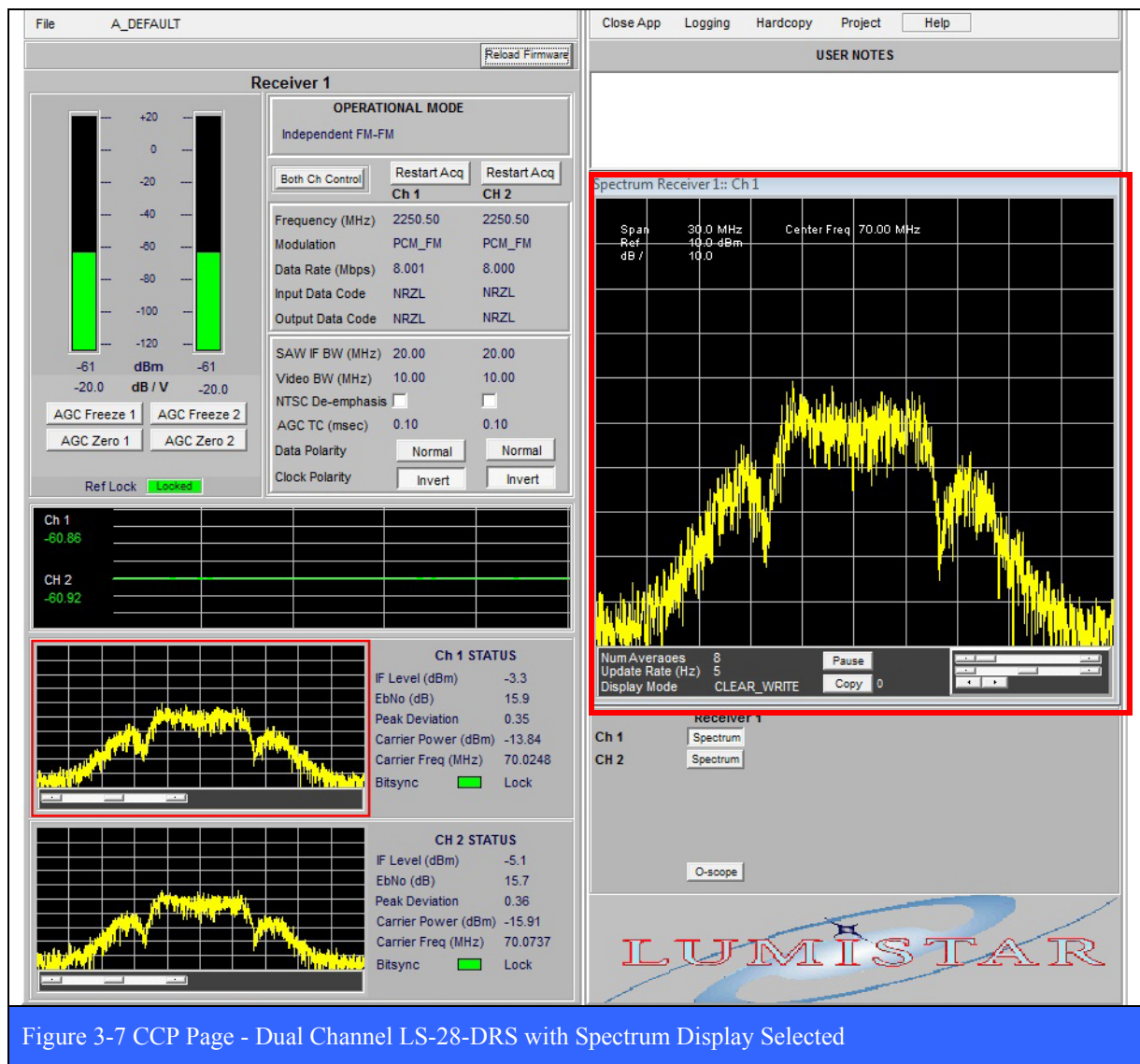


Figure 3-7 CCP Page - Dual Channel LS-28-DRS with Spectrum Display Selected

The **Frequency Marker Delta** mode is shown in Figure 3-46 on page 135 and is represented by two vertical dotted lines. Each marker line advances or recedes in frequency via the slider control shown at the top edge of the display. These two slider controls appear only when the mouse cursor is placed at the top edge of the widget. Note that the two marker frequencies and frequency delta are shown on the display in the upper right corner.

The **Amplitude Marker Delta** mode is shown in Figure 3-47 on page 136 and is represented by two horizontal dotted lines. Each marker line advances or recedes in amplitude via the slider control shown at the left edge of the display. These two slider controls appear only when the mouse cursor is placed at the left edge of the widget. Note that the two marker amplitudes and amplitude delta are shown on the display in the upper right corner.

3.1.1.1.5 PSK Constellation Display

When the LS-28 is in the PSK operational mode, the I/Q Constellation Display becomes available and is shown in the figure below (red rectangle) and has a few simple controls. The I/Q Constellation Display is handy for analyzing the state of quadrature modulation schemes. Figure 3-48 on page 137 shows two examples of the display for SOQPSK modulation (note the display on the right is of a noisy signal). To invoke the controls for the display, simply place the mouse cursor in the lower region and right click. There are two buttons at the bottom of the display. The Pause button freezes the updating of the display until it is pressed again. The Copy button makes a snapshot of the display and saves it as a JPEG file in the C:\Lumistar\LRRS_3X\User\Hardcopies directory. Successive presses of the Copy button will create new snapshots of the widget at different time points.

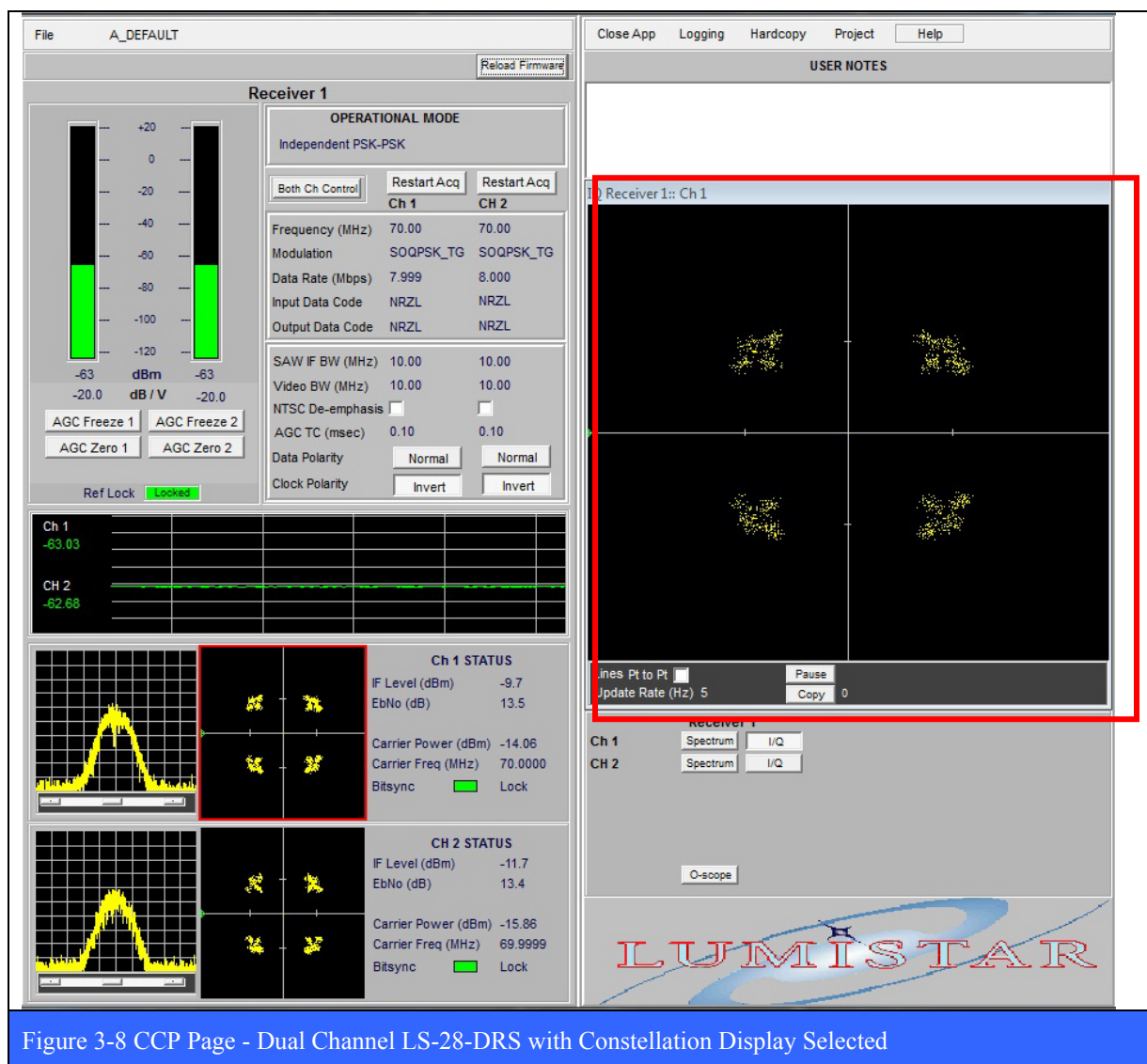
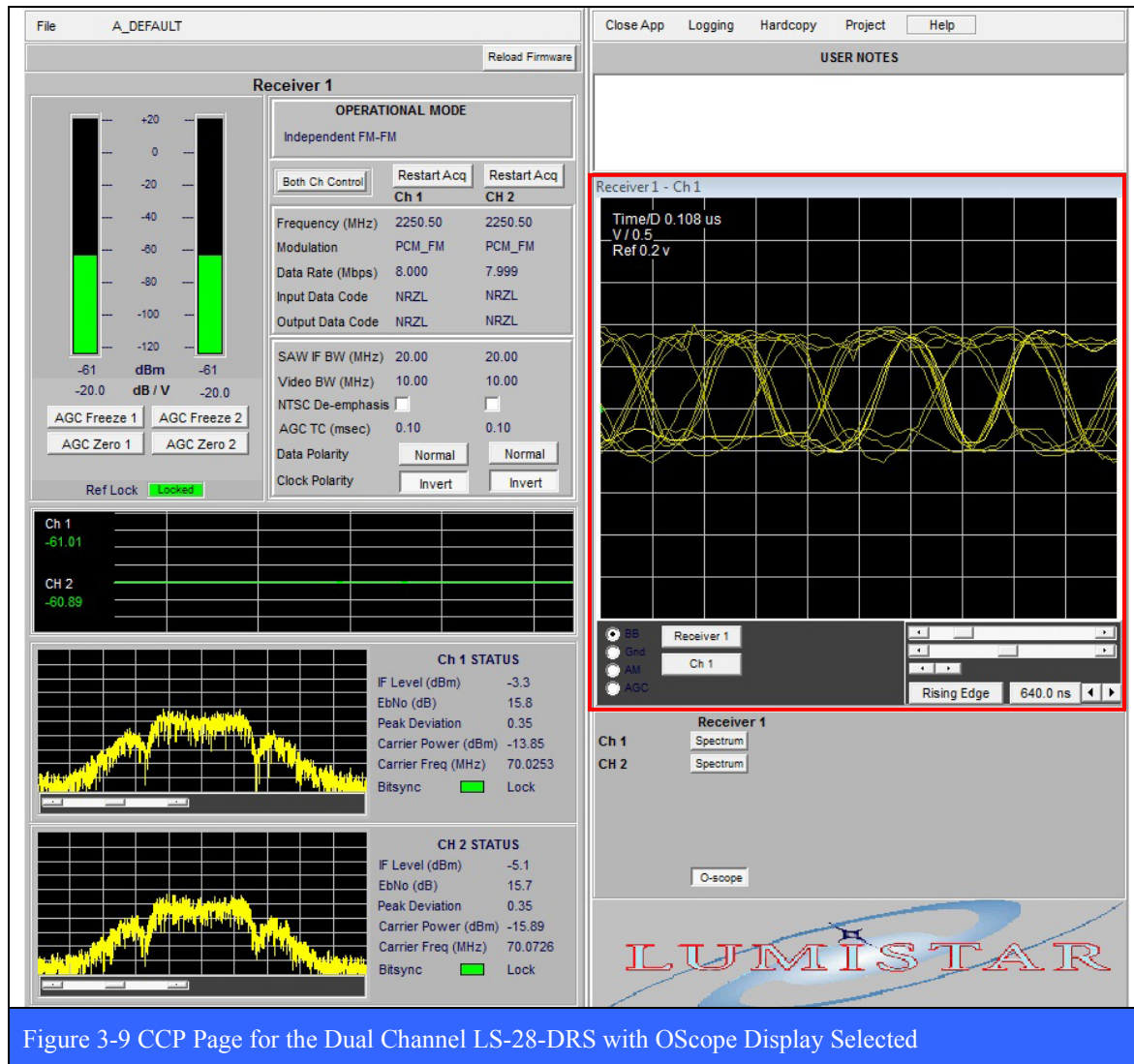


Figure 3-8 CCP Page - Dual Channel LS-28-DRS with Constellation Display Selected

3.1.1.1.6 OScope Displays

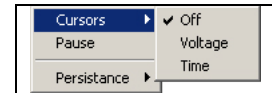
Regardless of the operational mode, the CCP page supports a multi-channel oscilloscope functionality that enables the operator to monitor several important internal signals associated with the operation of the system (red rectangle below). These signals include: *Baseband*, *AM*, *AGC* and a *GND* reference for each receiver channel. For multi-channel systems, the user clicks on the GRP button to select the desired card group, and the CH button to select the desired channel within the group.



Analog waveforms are displayed in the upper portion of the display area, and the controls for the widget are in the bottom portion as shown in the figure below. In the lower right corner of the widget are located the Timebase slider, the Reference Level slider, and the Volts-Per-Division control. Trigger and Timebase controls are also located in the lower right corner of the widget.

Cursor Controls

Select the Cursor Control Mode by right clicking in the upper portion of the time domain display. The Cursor Control Mode has three sub-modes: *Off*, *Voltage*, and *Time*. Each in turn is discussed in the following paragraphs.



Voltage Cursors

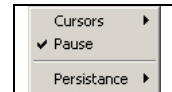
The Voltage Cursor mode is shown in Figure 3-51 on page 141 and is represented by two horizontal dotted lines. Each marker line increases or decreases in voltage via the control shown on the display as indicated in the red square in the figure below. Also note that the marker voltage and voltage delta are shown in the upper right of the display.

Time Cursors

The Time Cursor mode is shown in Figure 3-52 on page 142 and is represented by two vertical dotted lines. Each marker line advances or recedes in time via the control shown on the display as indicated in the red square in the figure below. Also note that the marker time, and time delta are shown on the upper right of the display.

Pause Mode

Select the Pause Mode by right clicking in the upper portion of the time domain display. This will freeze the updating of the time domain display. To resume the dynamic updating of the time domain display, again select the Pause Mode by right clicking in the upper portion of the time domain display. The activation of this mode is indicated by a check mark symbol (v) next to the “PAUSE” item in the menu.



Persistence Control

Select the Persistence Control Mode by right clicking in the upper portion of the time domain display. The Persistence Control has four sub-modes: None, 1.3, 2.7, and 4.0 Seconds. Use the Persistence Control to examine for example the “eye-pattern” of a demodulated datastream. With persistence of the display, successive cycles of a time-varying signal are in essence, displayed one on top of the other, thus creating a temporal layering of successive and often transitory events. An example of this effect is shown right in Figure 3-53 on page 143.

Oscilloscope Trigger Mode

Select the Oscilloscope Trigger Mode by right clicking in the lower portion of the time domain display. The Trigger Mode has two sub-modes: Auto and Normal. In normal mode the oscilloscope only sweeps if the input signal reaches the set trigger condition. Auto mode causes the oscilloscope to sweep, even without a trigger.

Oscilloscope Trigger Slope

Select the Oscilloscope Trigger Slope by clicking Clock Edge button in the lower portion of the time domain display. The Trigger Slope Mode has four sub-modes: Rising Edge, Falling

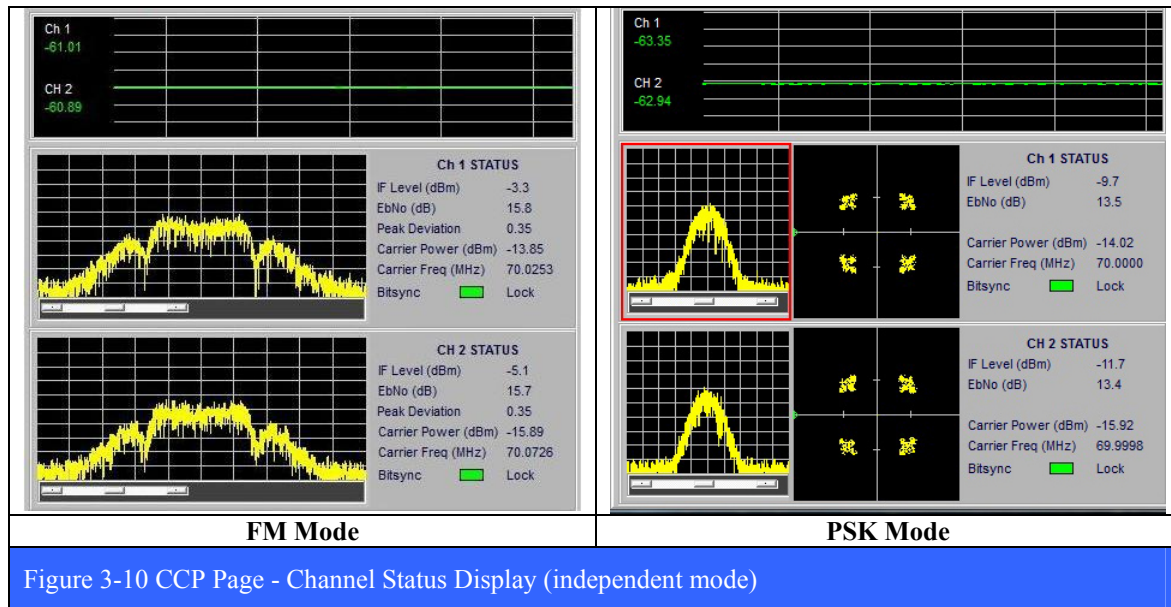
Edge, Either Edge, or Free Run. In the Rising Edge mode, a positive transition (rising edge) will trigger the display. In the Falling Edge mode, a negative transition (falling edge) will trigger the display. For the Either Edge mode, both a rising or falling edge will trigger the display. In the Free Run mode, the trigger conditions (rising/falling edges) are ignored and the display continuously updates.

Oscilloscope Samples

Select the Oscilloscope Sample size by right clicking in the lower portion of the time domain display. The Oscilloscope Sample Mode has two sub-modes: 256, and 512 samples.

3.1.1.1.7 Channel Status Display

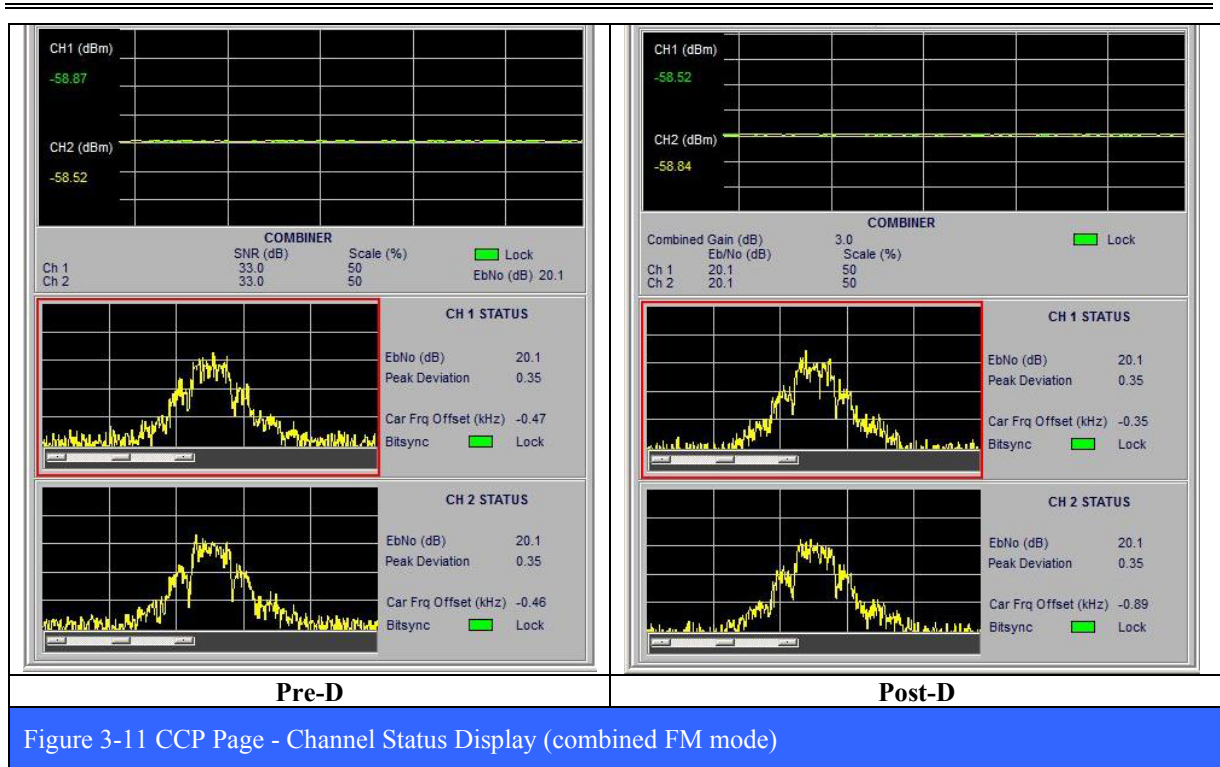
In addition to the primary and secondary parameters described earlier, there are up to six measured parameters associated with the operational state of the demodulator that are displayed in the Channel Status Display functional area (see Figure 3-3 on page 71). These include: *IF Level (dBm)*, *E_b/N₀ (dB)*, *Peak Deviation (FM Only)*, *Carrier Power (dBm)*, *Carrier Freq (MHz)*, and *Bit Sync Lock* status LED. Above the status display area is a scrolling strip chart that displays the time record of the RSSI¹⁰ for both channels of the card group.



When the LRRS application is in one of the **combined** mode, the appearance of the Channel Status Display functional area is slightly different. An example of this is shown below in Figure 3-11 on page 84. The number of parameters displayed is reduced and include: *E_b/N₀ (dB)*, *Peak Deviation (FM Only)*, *Carrier Freq Offset (MHz)*, and *Bit Sync Lock* status LED. Above the status display area is a scrolling strip chart that displays the time record of the RSSI for both channels of the card group. Also included in this area are parameters associated with the combiner performance. They include: channel *SNR*¹¹ (dB) (Pre-D only), channel *E_b/N₀ (dB)*, channel *Combining Percentage (%)*, and *Combiner Lock* status LED

¹⁰ RSSI – Received Signal Strength Indication.

¹¹ SNR – Signal-to-Noise Ratio



3.1.1.1.8 RF and AGC Status

The RF & AGC Status functional area (see Figure 3-3 on page 71) includes: two vertical bar graphs indicating the RF input power level in dBm, the AGC voltage slope value in dB/V for each channel, the Reference Lock status LED for the LS-27 associated with the card group, and four control buttons (two for each channel). Each channel has an *AGC Freeze* mode button, and an *AGC Zero* button.

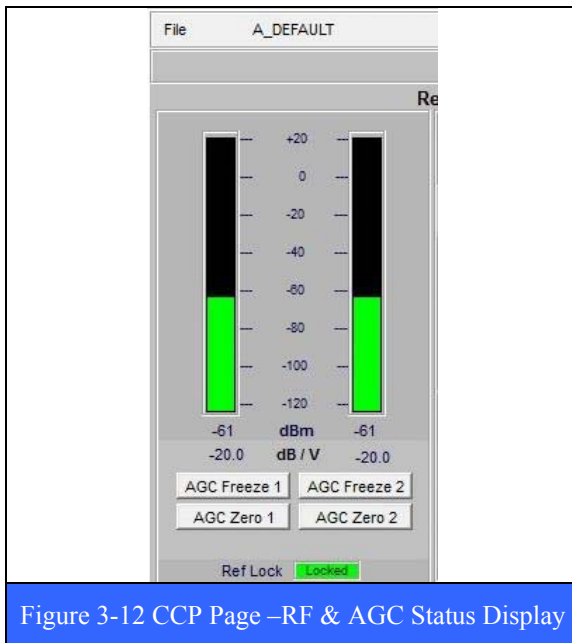


Figure 3-12 CCP Page –RF & AGC Status Display

The nominal condition of the **Ref Lock** LED is Green, while an error condition is indicated with a Yellow color. The Yellow Ref Lock indicates a fatal error with the 10 MHz reference signal input to the LS-27 associated with the card group, and while this error condition is active, the LS-27 will no longer be able to tune correctly.

The **AGC Freeze** function serves to fix the AGC voltage at a given RF power level, thus fixing or freezing the gain of the receiver. This has the effect of placing the receiver out of “Auto AGC mode” and placing it in to a “Linear Gain Mode”. When in AGC Freeze mode, the 70 MHz IF output power will vary linearly as a function of the RF input power (within the limits of the receiver components

linear operating range). This mode is generally employed for system G/T (G over T tests). Note that Lumistar has a stand-alone application that performs the necessary receiver setup, controls and calculations to accurately measure G/T. For more information on G/T tests please consult the Factory.

The **AGC Zero** function is used in many applications where it is required to “zero” or calibrate the AGC voltage by forcing its value to 0 volts for a given fixed RF input level. This zeroing function does not change the slope of the AGC voltage versus RF power, but serves only to force the AGC voltage to 0.00 volts for the power level at the moment the receiver was “zeroed”. This is very useful in setting the total system noise floor, including the additional noise received from an antenna system, and performing “Step Calibrations” to characterize the total dynamic range of the entire receiving system.

A typical example where zeroing of the receiver would be employed is where the noise level received from the antenna is many dB above that of the noise floor of the receiver alone. With the receiving antenna pointed at “cold sky” (no desired RF signal present), the LS-28 receiver would be “zeroed” to produce 0 volts at the system noise floor. If the antenna was then pointed at a signal that was 40 dB greater than the level of the noise floor, then the AGC voltage would change to -2 V (assuming a slope programmed to -20 dB/V and no non-linear

components were in front of the receiver input). AGC zeroing is very useful when an accurate post-mission analysis of logged AGC (or RSSI) voltage versus time is required. By zeroing on cold sky, the user knows where the system noise floor is and can accurately predict the signal levels above the noise floor during the mission.

To set the **AGC Slope**, right click on the value of the AGC Slope (under the vertical input RF power bar graph) and select *Adjust AGC Slope*. A window opens that allows the operator to set the minimum and maximum endpoints of the AGC versus power curve, i.e. the power level and AGC voltage produced at these endpoints. All points in between create a straight line between the endpoints, with dB in the Y axis and Volts in the X axis (or dB/V).

3.1.1.1.9 The Large Status Display Widget

At the top right hand portion of the dual channel CCP page shown in Figure 3-1 on page 69 is the, “LARGE” command button. Clicking on this button in the CCP page will invoke a large graphical display widget that presents the tabular values for channel *Input Power Level (dBm)*, channel *E_b/N_0 (dB)*, *FM Carrier Deviation (%)*, and *Bit Sync Lock Status*. This includes the status of the third demodulator in the –R2D3 variant of the dual channel LS-28-DRS. The exact appearance of this display will depend on the demodulation mode and combiner state that the system is currently operating in. Examples of some of these Large displays are shown in Figure 3-13 below.

<div><div>Large Status 001.1.1.10-10.022027</div><table><thead><tr><th></th><th>dBm</th><th>Eb/No</th><th>LOCK</th><th>DEV</th></tr></thead><tbody><tr><td>CH 1</td><td>-108</td><td>21.1</td><td>YES</td><td>0.35</td></tr><tr><td>CH 2</td><td>-110</td><td>21.2</td><td>YES</td><td>0.35</td></tr><tr><td>COMB</td><td>----</td><td>----</td><td>----</td><td>----</td></tr></tbody></table></div>		dBm	Eb/No	LOCK	DEV	CH 1	-108	21.1	YES	0.35	CH 2	-110	21.2	YES	0.35	COMB	----	----	----	----	<div><div>Large Status 001.1.1.10-05.200473</div><table><thead><tr><th></th><th>dBm</th><th>Eb/No</th><th>LOCK</th><th>DEV</th></tr></thead><tbody><tr><td>CH 1</td><td>-110</td><td>13.5</td><td>YES</td><td>0.00</td></tr><tr><td>CH 2</td><td>-110</td><td>13.5</td><td>YES</td><td>0.00</td></tr><tr><td>COMB</td><td>----</td><td>----</td><td>----</td><td>----</td></tr></tbody></table></div>		dBm	Eb/No	LOCK	DEV	CH 1	-110	13.5	YES	0.00	CH 2	-110	13.5	YES	0.00	COMB	----	----	----	----
	dBm	Eb/No	LOCK	DEV																																					
CH 1	-108	21.1	YES	0.35																																					
CH 2	-110	21.2	YES	0.35																																					
COMB	----	----	----	----																																					
	dBm	Eb/No	LOCK	DEV																																					
CH 1	-110	13.5	YES	0.00																																					
CH 2	-110	13.5	YES	0.00																																					
COMB	----	----	----	----																																					
Independent FM Mode	Independent PSK Mode																																								
<div><div>Large Status 001.1.1.10-10.011010</div><table><thead><tr><th></th><th>dBm</th><th>Eb/No</th><th>LOCK</th><th>DEV</th></tr></thead><tbody><tr><td>CH 1</td><td>-59</td><td>20.0</td><td>YES</td><td>0.35</td></tr><tr><td>CH 2</td><td>-58</td><td>20.0</td><td>YES</td><td>0.35</td></tr><tr><td>COMB</td><td>----</td><td>23.0</td><td>YES</td><td>0.35</td></tr></tbody></table></div>		dBm	Eb/No	LOCK	DEV	CH 1	-59	20.0	YES	0.35	CH 2	-58	20.0	YES	0.35	COMB	----	23.0	YES	0.35	<div><div>Large Status 001.1.1.10-04.010401</div><table><thead><tr><th></th><th>dBm</th><th>Eb/No</th><th>LOCK</th><th>DEV</th></tr></thead><tbody><tr><td>CH 1</td><td>-61</td><td>20.0</td><td>YES</td><td>0.00</td></tr><tr><td>CH 2</td><td>-61</td><td>20.0</td><td>YES</td><td>0.00</td></tr><tr><td>COMB</td><td>----</td><td>22.9</td><td>YES</td><td>0.00</td></tr></tbody></table></div>		dBm	Eb/No	LOCK	DEV	CH 1	-61	20.0	YES	0.00	CH 2	-61	20.0	YES	0.00	COMB	----	22.9	YES	0.00
	dBm	Eb/No	LOCK	DEV																																					
CH 1	-59	20.0	YES	0.35																																					
CH 2	-58	20.0	YES	0.35																																					
COMB	----	23.0	YES	0.35																																					
	dBm	Eb/No	LOCK	DEV																																					
CH 1	-61	20.0	YES	0.00																																					
CH 2	-61	20.0	YES	0.00																																					
COMB	----	22.9	YES	0.00																																					
Combined FM Mode	Combined PSK Mode																																								

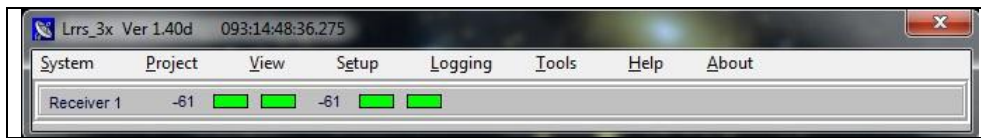
Figure 3-13 Large Status Display Examples

3.2 More User Controls “Behind the Curtain” and “Under the hood”

The CCP page and its controls and displays may satisfy the majority of operational needs for most users, but in certain circumstances, there are just some things that the CCP page alone can’t do. In these scenarios, a GUI with more functional granularity is called for. If the user wishes to, “go behind the curtain,” or look “under the hood” of the LRRS application metaphorically speaking, then the original LRRS launch banner is the place to start.

3.2.1 Main Launch Banner

Start the setup process by double clicking the LRRS icon on the desktop of the computer where the hardware is installed. The resulting window is shown below.



The main LRRS application launch banner has seven commands; *System*, *Project*, *View*, *Setup*, *Tools*, *About*, and *Factory*. Each of these commands will be further discussed in the following numbered paragraphs.

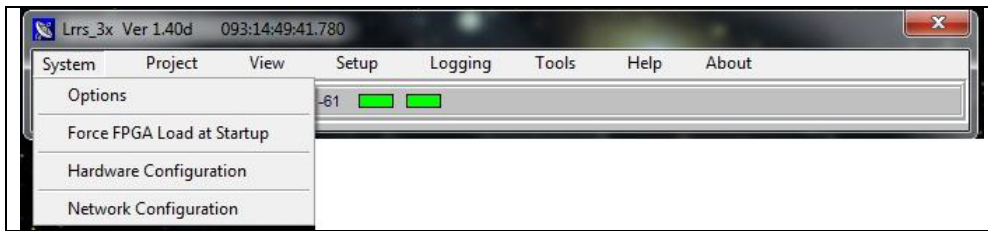
Below the commands are one or more demodulator card status displays. Each demodulator has up to two channels of status that consists of input RF power level (dBm), Carrier Lock indicator and Bit Sync Lock indicator. Green indicated a lock state, Yellow indicates an unlocked state.

Note: When the demodulator is NOT in combiner mode (independent mode), the status for BOTH channel 1 and channel 2 will be shown (see above). When in combiner mode, the status for channel 2 ONLY will be shown.

3.2.1.1 System Command

The main System command has four sub-commands; *Options*, *Force FPGA Load at Startup*, *Hardware Configuration*, and *Network Configuration*.

The **System** command and its associated sub-commands are not typically invoked by the end-user but are rather used in the initial phases of installing and configuring the LRRS application at the factory for the first time. As such, the System commands should only be used with caution and at the direction technical support.



3.2.1.1.1 The System Options sub-command

(System->Options) invokes the multi-tab window shown in Figure 3-14 below. The systems options window has four tabs; *Directory*, *Operations*, *Utility*, and *Unique Card Settings*.

3.2.1.1.1.1 The Directory tab

is shown in Figure 3-14 below allows the user to specify the location of certain LRRS files in directories chosen by the user. Currently the Event Log directory is defined to contain all error logs produced by the application. Future version of the LRRS application may require additional file directories and their locations will also be defined here in the directory tab.

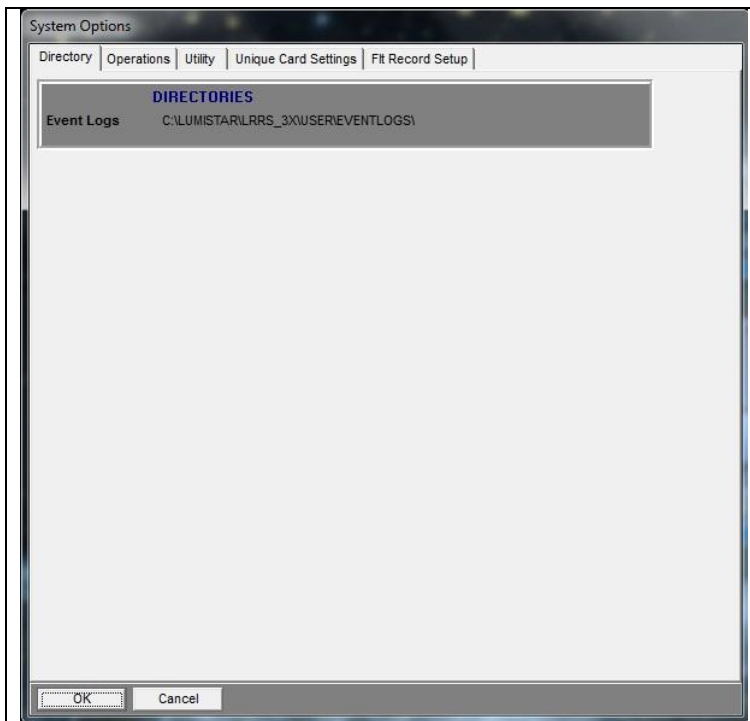


Figure 3-14 System Options Control Window (Directory Tab)

3.2.1.1.1.2 The Operations tab

is shown in Figure 3-15 below allows the user to setup and configure the individual peculiarities of how the LRRS application works. This includes those things that occur automatically upon the Startup of the LRRS application, as well as the Operation and Shutdown of the application. Some default parameter settings are also included for the Receiver on this tab.

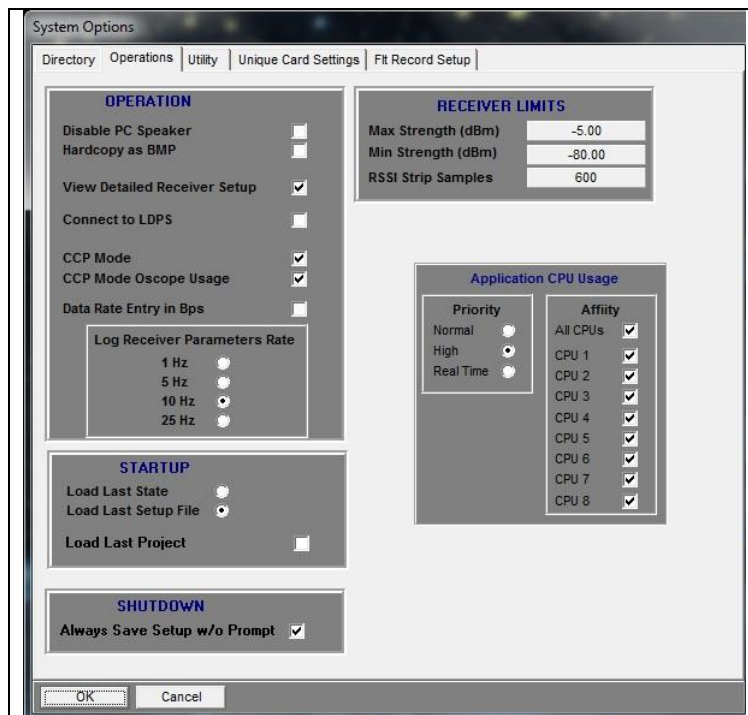


Figure 3-15 System Options Control Window (Operations Tab)

The **Operation** section allows the user to setup and configure the individual peculiarities of how the LRRS application works. The operational configuration for LRRS includes the following features:

- **Disable PC Speaker** – By selecting this option, audio warnings generated by the application will be disabled. The default state of this parameter is off (unchecked).
- **Hardcopy as BMP** – Check this box and all hardcopies made by the application will be saved as Windows BMP files in the hardcopy directory selected in the directory options. Otherwise, the hardcopies will be saved as JPG files. The default state of this parameter is off (unchecked).
- **View Detailed Receiver Setup** - Check this box and both the RF and IF information blocks will disappear from the Operation tab (see paragraph 3.2.1.4.1 on page 99) in the Card Setup Window (see Figure 3-22 on page 100).

- Connect to LDPS – Selecting this option enables a shared memory interface between the LRRS application and the Lumistar LDPS¹² application.
- CCP Mode - By selecting this option, the CCP page GUI will be displayed when ever the LRRS application is launched.
- CCP Mode OScope Usage - By selecting this option, the OScope display feature will be enabled when the CCP page is displayed at application startup.
- Data Rate Entry in Bps - By selecting this option, the operator will be required to enter the data rate in Bits-Per-Second (BPS). If this option is NOT selected, then the operator must enter the data rate in MBPS.
- Log Receiver Parameters Rate – This control allows the operator to select from several different sampling rates when the Receiver Parameter recording function is enabled. The sample update rate include: 1, 5, 10, and 25 Hz.

Below the Operation block is the **Startup** controls for the LRRS application. The Startup configuration for the LRRS application includes the following features:

Load Last State - If this option is selected, then the last valid hardware state (not saved in any setup file) loaded when LRRS was shut down will automatically load when LRRS is started up again. The default state of this parameter is On (selected).

Load Last Setup File - If this option is selected, then the last valid setup file loaded when LRRS was shut down will automatically load when LRRS is started up again. The default state of this parameter is off (unselected).

Load Last Project – If this option is selected, then the last valid mission loaded when LRRS was shut down will automatically load when LRRS is started up again. The default state of this parameter is off (unchecked).

Below the Startup block are the **Shutdown** controls for the LRRS application. The shutdown configuration for the LRRS application includes the following feature:

Always Save Setup w/o Prompt – By selecting this option, when the LRRS application terminates, the state of all hardware settings, including firmware mode, will be automatically saved without prompting the user. The default state of this parameter is off (unchecked).

In the upper right of the Operation tab is the **Receiver Limits** controls. These controls include buttons for: *Max Strength (dBm)*, *Min Strength (dBm)*, and *RSSI Strip Samples*.

- MAX Strength (dBm) – This button sets the numerical value associated with the change of color to indicate that the input RF power level in dBm has exceed the value specified. Once the input RF power level has gone above this level, the color of the

¹² LDPS – Lumistar Data Processing System. A telemetry data acquisition & processing application used to control Lumistar hardware such as decommutators, Digital-to-Analog (DAC) cards, etc. LDPS would be used for example if the user installed a decommutator into a vacant PCI slot in the LS-28 chassis.

vertical bar graph will change to the color specified in the Down Converter Color control (see Figure 3-17 on page 92 – Max Strength Color)

- MIN Strength (dBm) - This button sets the numerical value associated with the change of color to indicate that the input RF power level in dBm is less than the value specified. Once the input RF power level has gone below this level, the color of the vertical bar graph will change to the color specified in the Down Converter Color control (see Figure 3-17 on page 92 – Min Strength Color)
- RSSI Strip Samples - This button sets the numerical value for the number of contiguous data samples included in the RSSI strip chart display widget and on the channel status display in the CCP page.

Below the Receiver Limits controls are the **Application CPU Usage** controls. These controls include *Priority* settings for the LRRS application and individual *Affinity* settings for any/all of the CPU cores found in the systems main CPU.

3.2.1.1.1.3 The Utility tab

is shown in Figure 3-16 below, allows the user to customize the color schemes used for all of the windows and displays used in the LRRS application.

By using the **Colors** controls (shown in Figure 3-17 below), the user may change the LRRS color scheme to just about anything. There are a few default settings that can be used. Select the default colors radio button of interest (currently Browns, Blues, etc) and click the Set Default Colors button and the respective pre selected color scheme will occur. Otherwise, click on the Change Colors button and the menu of various color items will be displayed.

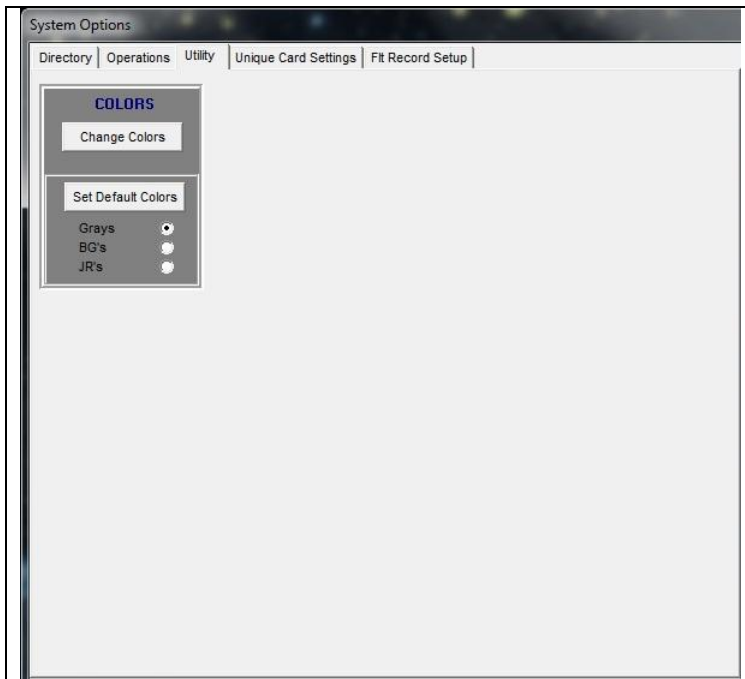


Figure 3-16 System Options Control Window (Utility Tab)

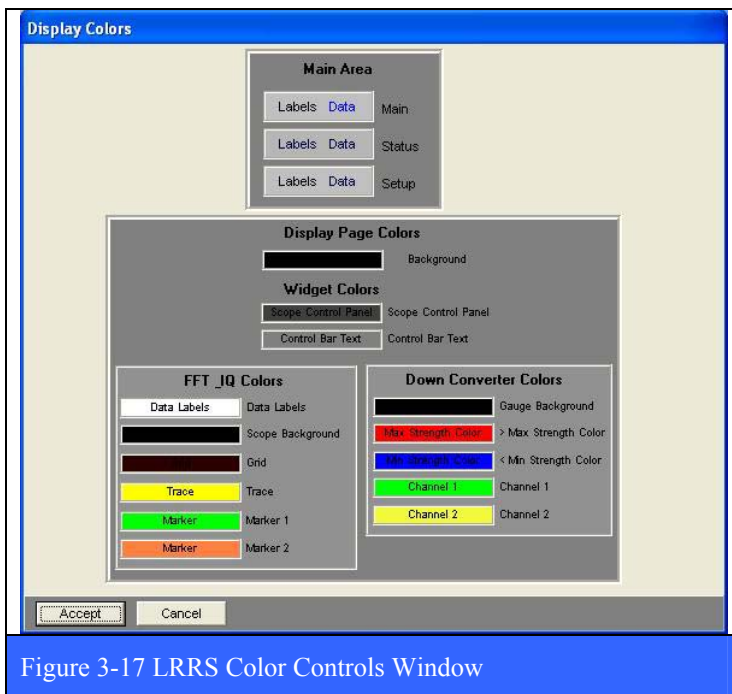


Figure 3-17 LRRS Color Controls Window

3.2.1.1.4 The Unique Card Settings tab

is shown in Figure 3-18 below and allows the user to specify and configure certain hardware and software features within the LRRS application. These include the FFT Controls for customizing the spectral displays, the Bitsync Lock Status controls for specifying certain bit sync behaviors, the IF Auto Settings controls for enabling certain interconnection options for the receivers /and/or downconverters associated with LRRS, and the Downconverter IF Factor parameter used in determining the correct IF bandwidth.

The Spectral displays offer several different types of graphical controls. In addition to the standard “slider” controls shown in Spectrum Display Widget, several additional control configurations are available. To change the type of controls found on the displays, select the appropriate radio button next to the desired option in the **FFT Controls** box. The default control configuration is set to, **Slider Below Scope**.

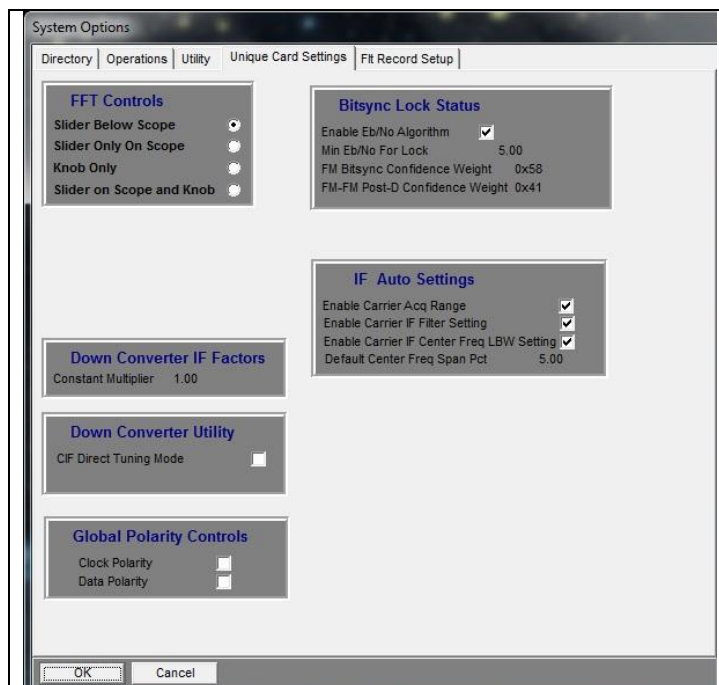


Figure 3-18 System Options Control Window (Unique Tab)

In the **Slider Only On Scope** configuration, the three sliders at the lower right of the display are moved to locations in the upper portion of the display. For example, the frequency span slider on the spectral display appears as a large horizontal scroll bar extending across the entire upper edge of the display. The reference level slider on the spectral display appears as a large vertical scroll bar extending across the entire left edge of the display. The dB/division on the spectral display appears as single up/down arrows in the upper left portion of the display. In the **Knob Only** configuration, the three horizontal sliders at the lower right of the display are replaced by a single

multi-function virtual knob and a parameter selection button. Clicking on the button will cycle through the available adjustment parameters. To make an adjustment, select a parameter and place the mouse cursor on the knob and click and hold the mouse button while rotating the knob with the mouse. For the spectral display, the available adjustment parameters include: Span, dB/Division, and Reference Level. **The Slider On Scope and Knob** configuration is a simple union of the Slider Only On Scope and Knob Only configurations described previously.

The **Bitsync Lock Status** control area has four advanced controls associated with the enhanced bitsync lock detection function. These include: *Enable E_b/N_0 Algorithm* checkbox,

Min E_b/N_0 For Lock value, *FM Bitsync Confidence Weight* constant, and *FM-FM Post-D Confidence Weight* constant. These are advanced controls, and should only be changed at the direction of Lumistar Customer Support. The *Enable E_b/N_0 Algorithm* checkbox is set by default and turns on a special algorithm used to determine the state of the bitsync lock LED. If the E_b/N_0 reported by the demodulator is less than the value set by the *Min E_b/N_0 For Lock* function, then the bitsync lock LED will be Yellow in color. If the E_b/N_0 reported by the demodulator is greater than this same value, then the bitsync lock LED will be Green in color. The enhanced bitsync lock detection function in the LS-28 utilizes a multi-symbol trellis decoder scheme. The *FM Bitsync Confidence Weight* constant, and *FM-FM Post-D Confidence Weight* constant are both associated with error metrics from the trellis and have been established empirically via experiment to their current values (and should NOT be changed).

The **IF Auto Settings** area has four advanced controls associated with the FM demodulators ability to deal with, “ill-behaved data” being received from a conventional Analog FM transmitter. In such a scenario, the ill-behaved data (low transition density – long runs of all ones or all zeros) will have strong DC components present that can, and often do, cause the center frequency of the Analog FM transmitter to randomly drift off frequency. The FM demodulator in the LS-28 can deal with this ill-behaved data scenario. The four controls associated with this function include: *Enable Carrier Acq Range* checkbox, *Enable Carrier IF Filter Setting* checkbox, *Enable Carrier IF Center Freq LBW Setting* checkbox, and *Default Center Freq Span Pct* value. In short, for the special FM demodulation of ill-behaved data to be enabled, all three checkboxes must be set. The *Default Center Freq Span Pct* value is set to a default value of 5% but can be changed to other values as needed.

The **Downconverter IF Factor** control is only used at the factory by Lumistar personnel and should not be changed by the user.

The **Downconverter Utility** control allows for the direct tuning of the CIF-band (400 to 1150 MHz) by selecting the *CIF Direct Tuning Mode* checkbox. When this mode is not checked, the operator instead must enter the actual C-Band frequencies (4100 to 5150 MHz). The Downconverter Utility control only has meaning when the LS-28 is configured with downconverter hardware that supports C-Band frequencies.

The **Global Polarity** controls allow the operator to “Globally” invert the *Clock* polarity, the *Data* polarity, or both for ALL channels on the LS-28. When either of these two checkboxes are unchecked, the operator can still individually invert either the clock and/or data of each channel in the LS-28 from the CCP page or the individual card group setup controls.

3.2.1.1.1.5 The Flt Record Setup tab

is shown in Figure 3-19 below and is used to select and configure seven of the most critical receiver performance parameters for archival recording by the LRRS application. These parameters include: *Time*, *RSSI* [Received Signal Strength Indication], *IF Car Pwr* [IF Carrier Power in dBm], *IF CAR Frq* [IF Carrier Frequency in MHz], *Peak Dev* [Peak FM Deviation – FM mode only], *E_b/N₀*, and *BER* [Bit Error Rate]. This parameter setup is used to select and configure the parameters that will be recorded by the **Logging** Command function described in paragraph 3.2.1.5 on page 126.

Channel 1

	Time	RSSI	IF Car Pwr	IF Car Frq	Peak Dev	E _b / N ₀	BER
Enabled	Y	Y	Y	Y	N	Y	N
Col Width	20	12	12	12	12	12	12
Hdr Line 1	TIME	CH_1	CH_1	CH_1	CH_1	CH_1	CH_1
Hdr Line 2		RSSI	IF Car Pwr	IF Car Frq	Deviation	E _b / N ₀	BER
Hdr Line 3		dBm	dBm	MHz	Pct	dB	
Dec Places	6	2	2	6	2	2	2
Scientific	N	N	N	N	N	N	Y

Channel 2

	Time	RSSI	IF Car Pwr	IF Car Frq	Peak Dev	E _b / N ₀	BER
Enabled	Y	Y	Y	Y	N	Y	N
Col Width	20	12	12	12	12	12	12
Hdr Line 1	TIME	CH_2	CH_2	CH_2	CH_2	CH_2	CH_2
Hdr Line 2		RSSI	IF Car Pwr	IF Car Frq	Deviation	E _b / N ₀	BER
Hdr Line 3		dBm	dBm	MHz	Pct	dB	
Dec Places	6	2	2	6	2	2	2
Scientific	N	N	N	N	N	N	Y

OK Cancel

Figure 3-19 System Options Control Window (Flt Record Setup)

The user selects among the seven parameters to record by entering a “Y” in the Enable row in the left most column in the matrix. The number of characters allocated to each selected parameter is specified in the Col Width row in the matrix. The user may add up to three lines of descriptive labels for each selected parameter by entering text in the Hdr Line 1/2/3 rows in the matrix. The number of decimal places for each selected parameter is set in the Dec Places row in the matrix. Finally, the numeric values may be display in scientific notation by entering a “Y” or “N” in the Scientific row in the matrix. The parameter selection and configuration is performed for both channel 1 and

channel 2.

3.2.1.1.2 The System Force FPGA Load at Startup sub-command

(System->Force FPGA Load at Startup) does what the name implies; it forces the two FPGAs on the LS-35 to load firmware as a result of launching the application (the default is for the application to NOT load the firmware at application startup).

3.2.1.1.3 The System Hardware Configuration sub-command

(System->Hardware Configuration), invokes the setup window shown in Figure 3-20 below. This command is not typically invoked by the end-user but rather in the initial phases of installing and configuring the LRRS application at the factory for the first time. As such, this command should only be used with caution and at the direction technical.

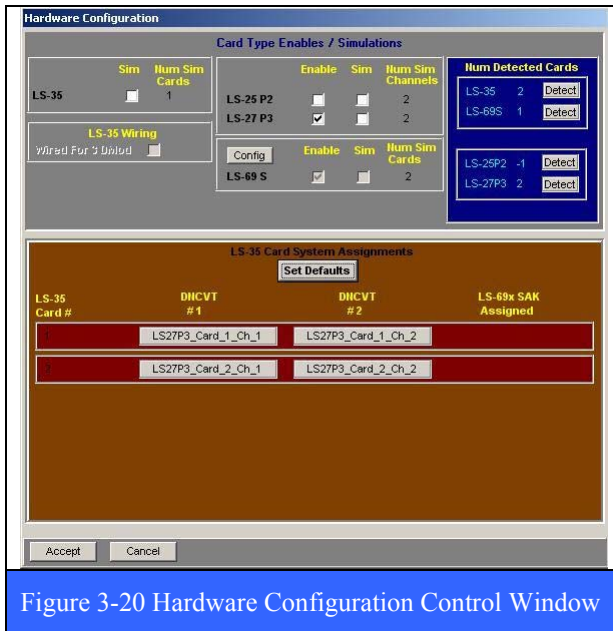
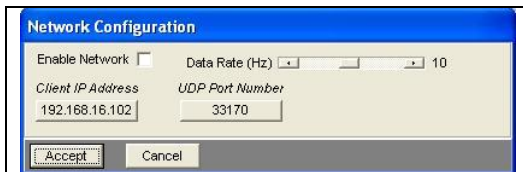


Figure 3-20 Hardware Configuration Control Window

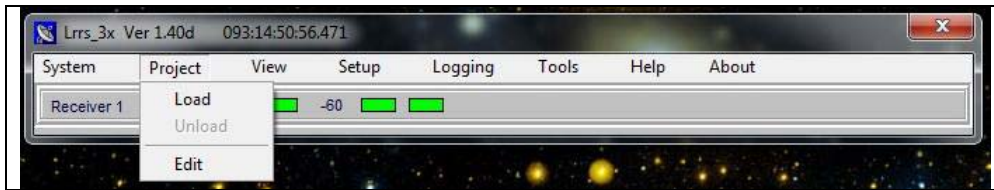
3.2.1.1.4 The System Network Configuration sub-command

(System->Network Configuration), shown below, allows the user to setup and configure the LS-28 for network operation. This is done by checking the *Enable Network* checkbox and entering the *Client IP Address* and *UDP Port Number* by clicking on the respective buttons. The *Data Rate (Hz)* slider controls the update rate of outgoing UDP packets that contain any/all LS-28 system status data.



3.2.1.2 Project Command

The Project command has three sub-commands; *Load*, *Unload*, and *Edit*.



The **Project** command allows the user to create and manage groups of setup files used in configuring the LRRS software and associated hardware. Each of the hardware groups installed in the system can have an individual setup file assigned to them (file extension *.Ls3X). The individual setup file stores all of the configuration and parameter settings for that card group. The Project command allows the user to aggregate all of the individual setup files into one single project file (file extension *.LRPRJ). Thus, to setup an entire system with many card groups installed, the user simply invokes one file, or Project. The user may create many different project files, each supporting a different operational scenario (number of channels, modulation formats, frequencies, data rates, etc.)

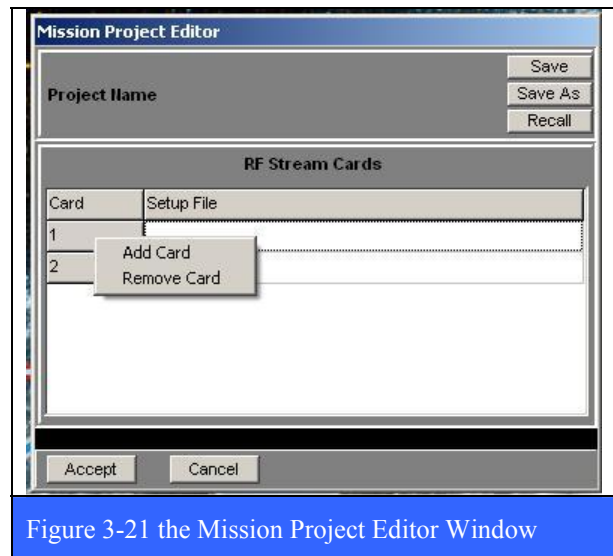


Figure 3-21 the Mission Project Editor Window

3.2.1.2.1 The Project Load sub-command

The project *Load* sub-command invokes a file selection dialog box to appear where the user enters the name of the project file that will be loaded into the system.

3.2.1.2.2 The Project Unload sub-command

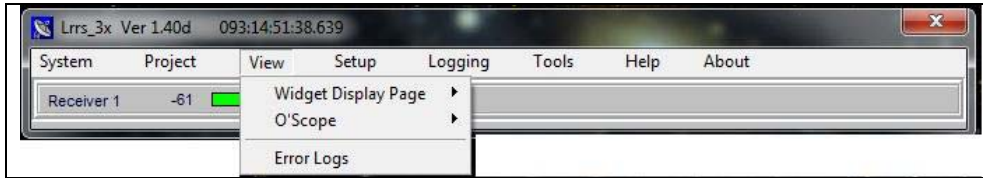
The project *Unload* sub-command unloads the settings invoked when a previously selected project file was loaded into the system.

3.2.1.2.3 The Project Edit sub-command

The Mission Project *Editor* window is shown in Figure 3-21 above. This tool allows the user to define the number of card groups in the LS-28 system, and to enter the file names of each card group hardware setup file (*.Ls3X) into a common Project file (*.LRPRJ) which the user then give a name to with the SaveAs command.

3.2.1.3 View Command

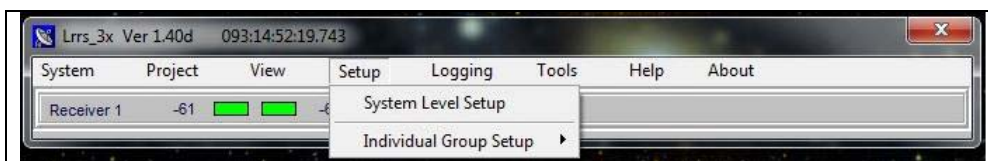
The main View command has three subcommands; *Widget Display Page*, *O'Scope*, and *Error Logs*.



Each card group¹³ installed in the system has a **Widget Display Page** associated with it (see paragraph 3.2.2 on page 134 for more information). When invoked for the first time, the widget display page comes up empty, and is in essence, a blank canvas. To this empty page the user may add graphical objects called “widgets.” These graphical objects include: **Spectral** Displays (see paragraph 3.2.2.1 on page 135 for more information), **Constellation** Displays (see paragraph 3.2.2.2 on page 137 for more information), Received Signal Strength Indication (**RSSI**) strip chart displays (see paragraph 3.2.2.3 on page 137 for more information), and **Status** Displays (see paragraph 3.2.2.4 on page 138 for more information). All are contained within the confines of the Widget Display Page, which may be re-sized by the user. Also, each card group installed in the system has an Oscilloscope display that may be invoked by the user. The **O'Scope** Display (see paragraph 3.2.4 on page 140 for more information) is separate from the Widget Display Page and may be positioned independently on the screen by the user.

3.2.1.4 Card Setup Window

The Setup command has two sub-commands; *System Level Setup*, and *Individual Group Setup*.



The **System Level Setup** command and resulting window aggregates the individual card level status displays and setup controls into a single display suitable for controlling and assessing the state of the entire system at a single glance. The user may resize this window as small, or as large as needed to accommodate viewing from any distance. See paragraph 3.2.3 on page 139 for more information on the System Level Setup window.

¹³ Card Group- Defined as a LS-35/LS-27 pair supporting two channels.

The **Individual Group Setup** command and resulting window allows the user to configure specific card groups¹⁴ and their associated operational parameters with much greater granularity of controls. Invoking this command produces the Individual Group Setup window shown in Figure 3-22 on page 100. The Individual Group Setup window has four tabs: *Operation*, *Outputs*, *Test*, and *Configuration*. Each tab is described in more detail in the following numbered paragraphs.

3.2.1.4.1 Operation Tab

The Operation tab has two sub-tabs. When the Operational mode is set to **Independent** (shown below left in Figure 3-22), the two sub-tabs for the card group are designated CH1 and CH2 (note: the user may change these tab labels). When the Operational mode is set to **Combined**, the two sub-tabs are designated CH2 and Combiner (shown below right in Figure 3-22). In either case, the two sub-tabs allow the user to configure the primary parameters required to receive and demodulate telemetry signals.

3.2.1.4.1.1 Independent Mode

The primary parameters for setup include: *Tuner Frequency (MHz)*, *Modulation format*, *Data Rate (Mbps)*, and *Data Code*.

Tuner Frequency

The LS-27-P3 Multi-band RF Downconverter concurrently support up to three of the following five possible frequency bands. The user may also select 70 MHz as an input frequency at any time in addition to the three possible bands.

- 2185.5 - 2485.5 MHz (NATO E-Band)
- 2200.5 - 2399.5 MHz (S-Band)
- 1710.5 - 1849.5 MHz (Upper L-Band)
- 1435.5 - 1539.5 MHz (Lower L-Band)
- 215.5 - 319.5 MHz (P-Band)

To select a receive frequency, click on the Frequency (MHz) item. Enter the frequency in the resulting pop-up dialog box and then click OK. The updated frequency will be displayed in the configuration display area. Note that the supported tuner resolution is 50 KHz, and that entered values will be rounded off the nearest 50 KHz value in the display. Frequency values outside of the ranges specified above will result in an error message with no change in frequency.

Modulation

Each multi-mode demodulator in LRRS can support a variety of modulation formats. The list of specific formats is determined at the time of purchase via the firmware license file. The complete list of formats is shown right. The Modulation item allows the user to specify which demodulation format to use.

¹⁴ Card Group is defined at a LS-35 multi-mode demodulator and LS-27 downconverter card set.

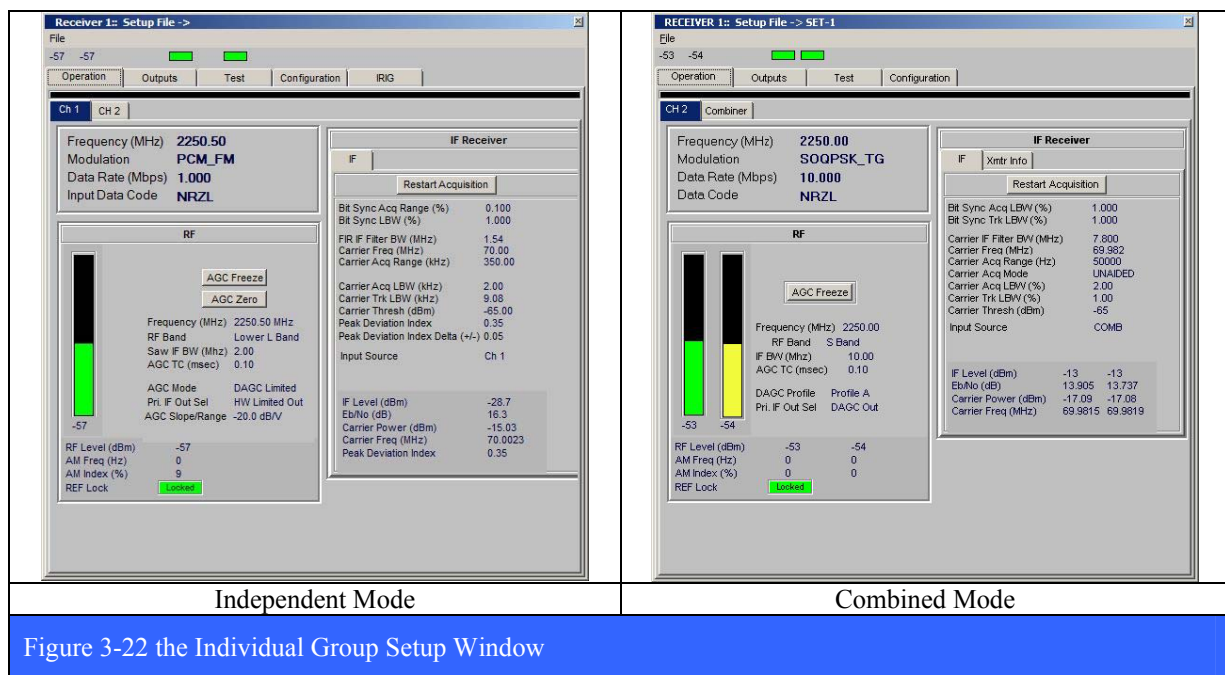
Data Rate

The LS-28 supports bit rates from 10 bps to 30 Mbps in the current hardware implementation. The user enters the rate in bps via the Data Rate (Mbps) item. Note, for quadrature modulation schemes such as QPSK and its variants, the bit rate entered must be twice that of the symbol rate (exception: SOQPSK).

Data Code

The bit synchronizer in LRRS supports a wide variety of input code types including; NRZ, RZ, Split phase, Miller, and Randomized codes. The Data Code item invokes the complete list shown right.

The **RF block** in the lower left portion of the Operation tab has parameter information associated with the down conversion process to 70 MHz, as well as a vertical RF signal power level bar graph. The default values of many of the secondary parameters displayed in the RF block are based upon the primary parameters mentioned above, as well as the Operational mode. The GUI in the RF block does allow the user to change some of the values of these secondary parameters, but this is recommended only for advanced users. Described in more detail below, the secondary parameters in the RF block that the user can change include: *IF BW (MHz)* [second downconverter IF bandwidth in MHz], *AGC TC (msec)* [automatic gain control time constant in microseconds], *DAGC Profile* [digital automatic gain control profile], and *Pri IF Out Sel* [primary 2nd IF output select]. In addition to these changeable secondary parameters, there are also measured parameters such as RF Level (dBm), AM Freq (Hz), AM Index (%), and PLL Lock Status. These measured parameters are displayed at the bottom of the RF block.



IF BW (MHz)

The LS-27-P3 Multi-band RF Downconverter is factory configured to support up to twelve (12) separate IF anti-alias bandwidths. Standard bandwidths include: 500 kHz, 1 MHz, 1.5 MHz, 2.5 MHz, 3.5 MHz, 4 MHz, 6 MHz, 8 MHz, 10 MHz, 12 MHz, 16 MHz, and 20 MHz. At the factory the selected 2nd IF bandwidth values are programmed into a configuration PROM and are used by the LRRS application to populate frequency values in the pop-up list box. Once selected, the IF bandwidth will be displayed in the configuration display area

AGC TC (msec)

The AGC TC (time constant) allows the user to select one of four possible AGC time constants including; 1, 10, 100, and 1000 ms. The selected time constant is displayed in the configuration display area.

DAGC Profile

The LS-27-P3 Multi-band RF Downconverter employed in the LS-28 contains an AGC function which is controlled by a digital signal processing engine. This function provides various AGC “profiles” which respond differently based on the user’s operation scenario. At present, there are two profiles that are implemented: DAGC Limited, and DAGC Linear.

DAGC Linear – Allows essentially no AGC controls over an >80dBm receiver range. In this mode, when RF input signal power is below -25dBm, the output varies directly with the input power. As the input goes up or down by 1dB, the IF output responds in the same manner. When the receiver is exposed to input power levels above -25dBm, attenuation will be added to the input in a linear dB fashion. DAGC Linear is the default condition whenever the LRRS is in Combined mode.

DAGC Limited – Allows the output level to be maintained at a constant level regardless of the input level. This DAGC mode takes full advantage of the AGC Time constant modes, and is the default condition whenever the LRRS is in Independent mode.

Pri IF Out Sel

The LS-27-P3 has the ability to provide two IF outputs. One of the outputs is a permanent “Hardware Limited” output which does not respond to DAGC profiles or the AGC FREEZE mode. The other is the DAGC output which is controllable. Of the two IF outputs provided, one is always a DAGC controlled output. The other is selectable between DAGC Out and the “Hardware Limited” Out mode.

In the **IF Receiver block** (upper right portion of the Operation tab) there can be one or two sub-tabs shown (two if LRRS is in Factory mode). The primary tab of interest is the IF sub-tab. In this sub-tab there are a plethora of secondary parameters that may be of interest to

advanced users. The GUI allows the user to change any of the parameters listed in the table below (this is recommended only for advanced users). In general, the default values are correct for most applications and should not be changes. In addition to these secondary parameters, there are four measured parameters associated with the operational state of the demodulator. These include: IF Level (dBm), E_b/N_0 (dB), Carrier Power (dBm), and Carrier Freq (MHz). Displayed at the bottom of the IF Receiver block, these parameters are continuously measured and updated and are a good indicator of the health of the signal.

Table 3-1 IF Receiver Secondary Parameters		
Bit Sync Acq LBW (%)	1.0 Default	The function of the bit synchronizer is the extraction of clock and data from the demodulated baseband signal. To accomplish this, the LS-28 employs a conventional digital phase lock loop to acquire the clock from the baseband, in much the same way as the carrier is acquired and tracked prior to demodulation. The clock acquisition loop bandwidth is the parameter that controls the gain of the clock acquisition phase lock loop. This parameter also effects how quickly the loop can react as well as how it is affected by noise. The Bit Sync Acquisition Loop Bandwidth is entered as a percentage of the bit rate and is defaulted to 1%.
Bit Sync Trk LBW (%)	1.0 Default	Just as with the carrier recovery functionality in the LS-28, the clock acquisition function of the bit synchronizer operates in two phases; acquisition and tracking. After the clock has been acquired, the bit sync enters the tracking phase. The tracking phase employs the same conventional digital phase lock loop used to acquire the clock, but the loop bandwidth need not be the same. In fact, the clock recovery functionality allows the acquisition and tracking loops to have different bandwidths, with different loop behaviors (i.e. how quickly the loop can react as well as how it is affected by noise). For example, the user may wish to set the acquisition loop bandwidth wider than the tracking loop bandwidth. The Bit Sync Tracking Loop Bandwidth is entered as a percentage of the bit rate and is defaulted to 1%.
Carrier IF Filter BW (MHz)	Calculated based upon multiple factors	After the analog 70 MHz input signal has been digitized, the resulting digital IF is filtered in the front-end of the demodulator via a bank of FIR/CIC bandpass filters (the CIC filters being used for low data rates). The bandwidths of these front-end filters are determined automatically based upon parameters such as modulation type, data rate, code format, FEC utilization, etc.). The Carrier IF Filter Bandwidth item allows the user to override or change the filter bandwidth set by the software. The user enters the IF bandwidth value in MHz. Although the IF filter bandwidth may be changed by the user, it should be noted that the default value is really the optimum and any changes should be made with great care.
Carrier Freq (MHz)	70 MHz Default	The Carrier Frequency parameter allows the user to change the default 70 MHz frequency value for the incoming carrier signal. For example, one might do this to compensate for a know frequency offset in the input signal that is not caused by Doppler (i.e. the frequency offset is fixed and not changing). In normal operation, the user should not change the carrier frequency from the default of 70 MHz.
Carrier Acq Range (MHz)	50,000 Hz Default	In the carrier acquisition phase lock loop, the Carrier Acquisition Range parameter (in Hz) defines the limit of how far the loop may be pulled relative to the center frequency of the loop as the loop tracks the carrier. For example, if the user were to set the range for 100 KHz, then the loop would not track beyond plus-or-minus 50 KHz around the carrier. The default value for the carrier acquisition range is 100 KHz. Setting this parameter too narrow relative to the data rate could frustrate the demodulators' ability to track the carrier in the presence of Doppler. Setting the range too wide could make it possible for the acquisition loop to lock onto a signal other than the intended carrier. For additional information on Doppler frequency shifts, see the Technical Appendix article on this subject.
Carrier Acq Mode (PSK Only)	UNAIDED or FFT	Before any data may be recovered from the input signal, the carrier component of the signal must first be acquired and phase-locked to. The LS-28 demodulator has two modes of carrier acquisition; UNAIDED, and FFT. In the unaided mode, a conventional digital phase lock loop is employed to acquire the carrier. This mode

Table 3-1 IF Receiver Secondary Parameters		
		works well for E_b/N_0 values greater than or equal to 3.0 dB. For signal environments with very heavy Doppler, the FFT carrier acquisition mode can be used. In this mode, a Fast Fourier Transform is performed on the input signal and the carrier location is isolated from the resulting spectrum. It should be noted that the FFT mode is processor intensive and could adversely affect the operation of the host CPU & operating system if multiple card groups are installed in the same chassis and all have FFT mode turned on. In general, heavy Doppler is not very common in terrestrial flight test telemetry scenarios with the possible exception of certain missile tests. Unless heavy levels of Doppler are anticipated, the FFT mode should be avoided.
Carrier Acq LBW (%)	2.0 Default	The carrier tracking loop bandwidth (not to be confused with the carrier acquisition range) is the parameter that controls the gain of the carrier acquisition phase lock loop. This parameter also effects how quickly the loop can react as well as how it is affected by noise and the rate of the Doppler. The Carrier Acquisition Loop Bandwidth is entered as a percentage of the bit rate and is defaulted to 2%.
Carrier Trk LBW (%)	1.0 Default	The carrier recovery functionality in LS-28 operates in two phases; acquisition and tracking. After the carrier has been acquired, the LS-28 enters the tracking phase. The tracking phase employs the same conventional digital phase lock loop used to acquire the carrier, but the loop bandwidth need not be the same. In fact, the carrier recovery functionality allows the acquisition and tracking loops to have different bandwidths, with different loop behaviors (i.e. how quickly the loop can react as well as how it is affected by noise and the rate of the Doppler). For example, the user may wish to set the acquisition loop bandwidth wider than the tracking loop bandwidth. The Carrier Tracking Loop Bandwidth is entered as a percentage of the bit rate and is defaulted to 1%.
Carrier Thresh (dBm)	-65 dBm Default	The color of the carrier lock indicator is determined in part by the value entered by the user for the Carrier Threshold Level. If the carrier level measured by the demodulator is below the threshold level, the carrier lock indicator will never show Green, even if the carrier acquisition phase lock loop has locked onto the carrier. The default value for the carrier threshold is set by the software to -65 dBm. When the carrier level is above the threshold, and the carrier acquisition phase lock loop has not locked onto the carrier, then the color of the carrier lock indicator will be Yellow. In other words, the carrier lock indicator will be Green only when the carrier acquisition phase lock loop has locked onto the carrier, and the carrier signal level is above the threshold.
Peak Deviation Index	0.35 Default	In FM modulation, the carrier frequency is changed, or deviated from the center frequency value by a certain amount (based upon line code and data rate) to indicate either a logic one or logic zero. The IRIG-106 specification states that this amount of frequency deviation, or Peak Deviation Index, shall be 0.35 times the NRZ-L data rate. Thus, for a 1 MBPS NRZ-L data stream, the Peak Deviation of the FM carrier would be 350 KHz. The LS-35 demodulator can handle FM signals with Peak Deviation Indexes from 0.1 to 0.9
Peak Deviation Index Delta (+/-)	0.05 Default	The Peak Deviation Index Delta parameter defines the extremes in frequency over which the LS-35 will attempt to lock, or acquire the signal prior to demodulation. In general, the numerical sum of the Peak Deviation Index and the Peak Deviation Index Delta shall be less than or equal to 1.0 This defines the limits over which the FM demodulator can operate with under/over deviated FM signals.
Input Source	Ch1, Ch2, or EXT	Each demodulator in the LS-28 can receive an input from one of three possible sources. The Input Source parameter allows the user to specify one of these three inputs, or to essentially deactivate the demodulator by selecting the OFF command. The demodulator may be connected to input channels 1 or 2 (CH1, CH2), or the pre-detection IF combiner (COMB).

Restart Acquisition Button

The carrier acquisition process may be restarted at any time by the user by clicking the Restart Acquisition Button. This action restarts the carrier acquisition phase lock loop from its initial condition. One should do this whenever any of the receiver parameters being

discussed in these pages are changed. In fact, it should be noted that simply changing any of the receiver parameters may not have an immediate effect on the state of the carrier acquisition. The acquisition loop may be stuck in a certain state for example. The restart returns the loop to its original state where a new set of initial conditions (resulting from a parameter change) can take effect. The user may also wish to restart the carrier acquisition process whenever there is a change in the signal coming into the receiver. A change in input power level or the appearance of a nearby interferer for example, could be cause to restart carrier acquisition.

3.2.1.4.1.2 Combined Mode

The LRRS application and associated LS-28 hardware supports a two-channel pre-/post-detection diversity combiner that is currently available in the PSK, and FM modes of operation. The Post-D functionality is an optional feature of the LS-28 that is enabled at the time of purchase via the firmware license configuration. As with most LS-28 features, changes or additions to the firmware license configuration may be made at any time after purchase by simply installing a new license file obtained from the factory. In this way, new or additional features can be added to the LS-28 without changing the base hardware.

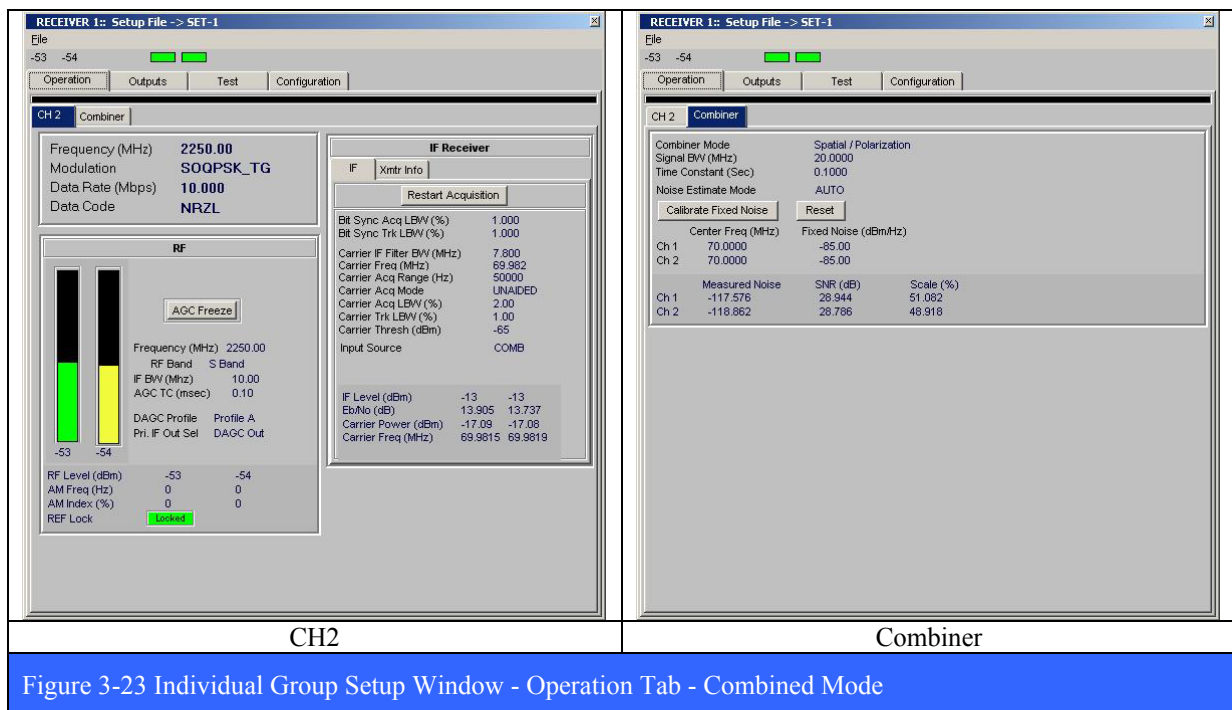
In a telecommunications system, a diversity reception scheme refers to the method of improving the reliability of message reception by utilizing two or more distinct communication channels, each with differing characteristics. Diversity reception plays an important role in mitigating signal fading and co-channel interference typically encountered in telemetry systems. Diversity reception relies on the fact that individual channels typically experience differing levels of fading and interference. Thus, multiple versions of the same signal may be transmitted and/or received and subsequently combined in the receiver. Often, the improvement in signal-to-noise ratio of the combined channel can approach 3 dB (theoretical limit).

The combiner in the LS-28 supports multiple combining modes including; frequency diversity, polarization diversity, and by extension, spatial (or antenna) diversity. In frequency diversity, the signal is transmitted on several different frequency channels, each affected by differing levels of frequency-selective fading. In polarization diversity, multiple versions of a signal are transmitted and received via an antenna with multiple polarizations. With spatial diversity, the signal is transmitted over several different propagation paths. Multiple receiving antennas are employed for each propagation path, with each antenna seeing a different version of the same signal (with differing levels of temporal signal fading).

Irrespective of the diversity mode, the two input signals of the combiner are processed as shown in the figure below. Each signal is dynamically phase and amplitude adjusted based upon the S/N ratio of the respective channel. The adjusted channels are then added together in quadrature to form the combined output. The diagram in the figure below is a highly simplified version of the actual combiner, with the all-important magical details omitted.

To enable the combiner mode, click on the **Configuration Tab** (see paragraph 3.2.1.4.4 on page 122 for more details) of the card setup window for the card group involved. In the User sub-tab, select the Combined radio button in the Operational Mode box. As a result of this, the Accept/Cancel buttons will appear and have a yellow color. Click the Accept button to change the mode to Combined.

When LRRS is in Combined mode, the appearance of the Operation Tab in the card setup window will change as shown in Figure 3-23 below. The Operation Tab now has two sub-tabs; *CARDX CH2* (where “X” is the card group number) and *Combiner*. Both sub-tabs are shown below.



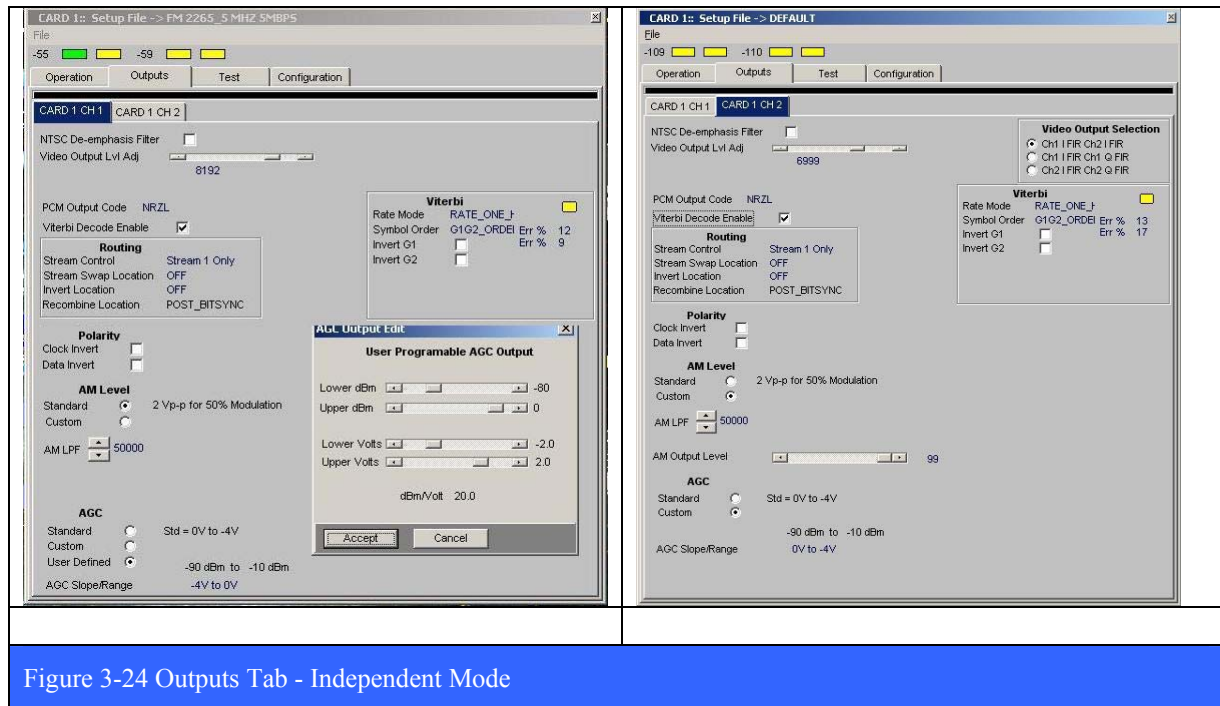
The next step is to set the Combiner Mode that the card group will operate in. Place the mouse cursor beneath the Combiner tab and right-click. The combiner in LRRS supports multiple combining modes including; *Frequency* and *Polarization* diversity. For Spatial or Antenna diversity, choose the Polarization mode. The user may also disable the combiner altogether by invoking the Off command. It should be noted that the particulars of the actual combining algorithm used on the two signals does not change with combiner mode. Rather, these combiner, “modes” are needed in the automation of certain GUI functions. For example, when the user selects the polarization mode, the software will automatically set the tuner frequency of both of the associated downconverters to the same frequency, irrespective to what they were originally set to. In this case, if the second demodulator (CH2) input was set to combiner, for example, then the tuner frequency set for the second downconverter

channel would also automatically be set to the same frequency for the first downconverter channel.

This type of automation is intended to help prevent what might be called, “cockpit error” on the part of the user. By contrast, when the user selects the frequency combiner mode, no such downconverter tuning automation takes place, as by definition, frequency diversity employs two different frequencies. In frequency diversity, the user must enter TWO frequencies in the card setup window and both frequencies are displayed in the GUI (2250.5/2390.5 for example).

3.2.1.4.2 Outputs Tab

Depending on the Operational Mode, the Outputs tab may have one or two sub-tabs. In the Independent mode (shown in Figure 3-24 below), there two sub-tabs; CH1 and CH2. In Combined mode, there is only one tab; CH2. The Channel 1 Output tab has six major areas of control setup. These include: *Video Output* controls, *Data Routing* functions, *Viterbi* FEC controls, *Signal Polarity* controls, *AM Level* and *AGC* controls. Each of these controls are described in more detail in the following numbered paragraphs.



3.2.1.4.2.1 Video Output Controls

The Video Output controls consist of the **NTSC De-emphasis Filter** check box, and the Video Output Lvl Adj slider control. The de-emphasis filter is designed to decrease, within a band of frequencies, the magnitude of some (usually higher) frequencies with respect to the magnitude of other (usually lower) frequencies in order to improve the overall signal-to-noise ratio. The **Video Output Level Adjustment** slider allows the user to change, or vary the voltage level of the video output signal of each channel of the demodulator. Moving the slider control fully to the right produces a maximum voltage of (2 Vpp terminated in 50 Ohms).

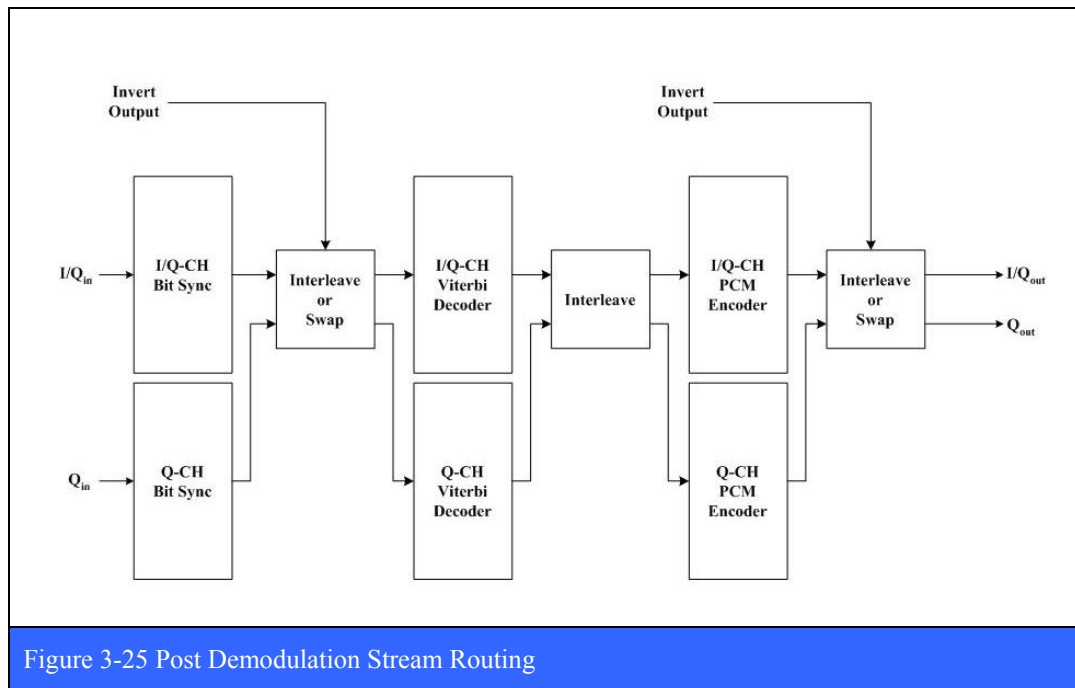
Depending on the Operational Mode, the Outputs tab may have one or two sub-tabs. In Combined mode, there is only one tab; CH2. The channel 2 tab is identical to the channel 1 tab, with the exception of an additional control in the upper right corner of the window. When any quadrature modulation schemes are selected (SOQPSK, etc.), the Video Output

Selection control allow the user to select what video signals are present on the two video output ports on the LRRS (Video 1 and Video 2). Three possible configurations are available and are summarized in the table below.

CH1 I FIR	CH2 I FIR
CH1 I FIR	CH2 Q FIR
CH2 I FIR	CH2 Q FIR

3.2.1.4.2.2 Stream Routing

The Routing section of the Outputs tab allows the user to configure the Stream Routing of the data after demodulation. Because the LS-28 supports quadrature modulation schemes as well as Viterbi decoding error control, the post demodulation signal routing is by necessity somewhat complex. A simplified block diagram of the various signal paths is shown in Figure 3-25 below.



Stream Control

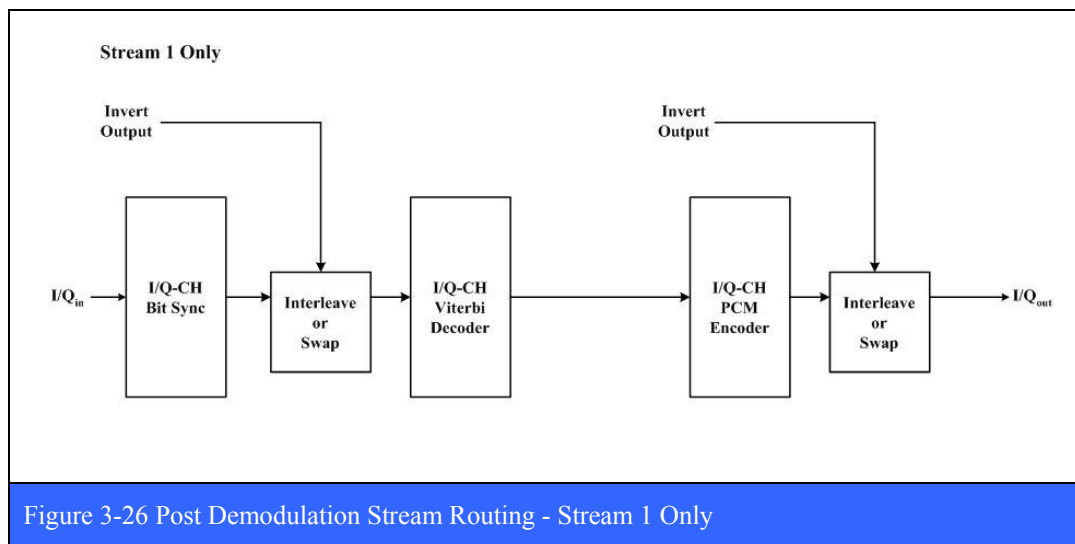
There are two stream control modes; Stream 1 Only (see Figure 3-26 on page 109), and Stream 1 = Stream 2 (see Figure 3-27 on page 110). To invoke the command menu, place the mouse cursor within the Routing area of the Outputs tab and right click. The Stream 1 Only mode is used when the I and Q data streams have been multiplexed together into a single stream. An example of this arrangement is the modulation format SOQPSK. In ordinary QPSK, the I and Q data streams are separate and would be supported by the Stream 1 = Stream 2 mode.

Stream Swap Location

When the stream control mode is set to Stream 1 = Stream 2, as shown in Figure 3-27 on page 110, then the Stream Swap Location command has meaning and allows the I & Q data streams to be swapped or exchanged in several locations. The user may opt to swap the I & Q streams after the bit sync (*POST_BITSYNC*), after the PCM encoder (*POST_PCM_CODING*), or not at all (*OFF*).

Invert Location

The Invert Location command allows the I & Q data streams to be inverted logically in several locations. The user may opt to invert the I & Q streams after the bit sync (*POST_BITSYNC*), after the PCM encoder (*POST_PCM_CODING*), or not at all (*OFF*).



Recombine Location

When the stream control mode is set to Stream 1 = Stream 2, as shown in Figure 3-27 on page 110, then the Recombine Location command has meaning and allows the I & Q data streams to be recombined (interleaved) in a number of locations. The user may opt to combine the I & Q streams after the bit sync (*POST_BITSYNC*), after the Viterbi decoder (*POST_VITERBI*), after the PCM encoder (*POST_PCM_CODING*), or not at all (*OFF*).

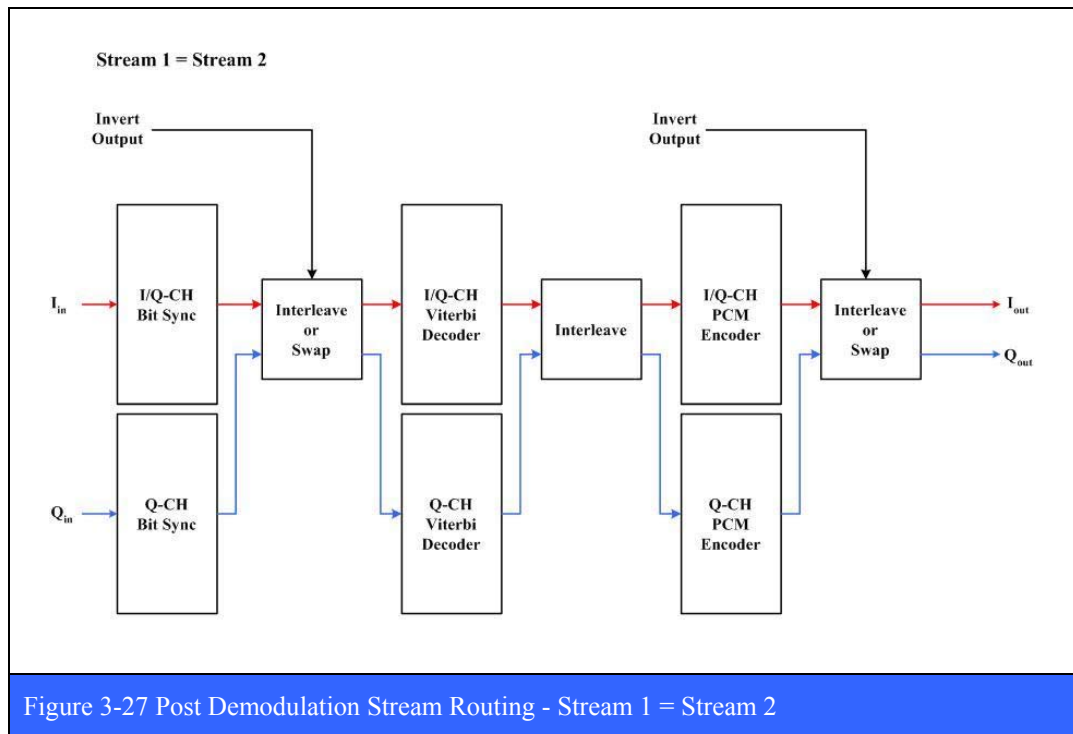
3.2.1.4.2.3 Signal Polarity Controls

Output Clock Polarity

The user has control of the timing relationships between the output data (I & Q) and output clocks (I & Q) by checking the Output Clock Polarity checkbox. The user may opt to align the start of each data bit with either the Rising edge, or the Falling edge of the clock.

Output Invert Enable

The user may opt to logically invert the logic sense of the final data outputs (Post PCM Encoder) by invoking the Output Invert Enable checkbox. This will invert both the I & Q data outputs.



3.2.1.4.2.4 Viterbi Functionality

The setup parameters for the Viterbi decoder functionality are shown in the Viterbi block in the upper right of the Outputs tab. To invoke the setup menu, place the mouse cursor within the Viterbi block and right click. The resulting menu allows the user to enter the requisite parameters necessary to set up the Viterbi decoder for the detection and correction of random errors in the demodulated data. The following paragraphs describe in more detail each of the Viterbi decoder setup parameters.

Viterbi Decoder Enable Checkbox

To enable the error detection/correction features of the bit synchronizer the user must check the Viterbi Decoder Enable checkbox. This turns on the Viterbi decoder function and causes the Viterbi block to appear on the Outputs tab (upper right). The Viterbi Lock indicator turns green when the decoder has locked onto the code sequence. As the decoder detects and corrects errors, the performance of the decoder is displayed as an error percentage for both symbols and bits. In order to successfully use the Viterbi decoder, the original bit stream at the sending end must first be *Convolutional Encoded* prior to transmission.

Viterbi Rate Mode

The Viterbi decoder in the bit synchronizer supports three code rates including; rate 1/2, rate 1/3, and rate 3/4. To select the desired code rate, invoke the Rate Mode command and select the desired rate from the menu. In general, the code rate is a measure of the efficiency of the code. A rate 1/2 code for example produces two output bits for every one input bit. A rate 1/3 code produces three output bits for every one input bit, while a rate 3/4 code produces four output bits for every three input bits.

Viterbi Symbol Order

The convolutional encoder produces pairs of code symbols in a sequential manner. To decode the symbols correctly, the Viterbi decoder must match the temporal order of the symbols it receives. The user selects this order by invoking the Symbol Order command. Two symbol orders are available; G1 followed by G2, and the reverse, G2 followed by G1.

Invert G1/ G2 Checkboxes

The user may also independently invert the logic sense of the G1 symbols, the G2 symbols, or both by checking the Invert G1 and Invert G2 checkboxes.

3.2.1.4.2.5 AM Level Controls

The AM Level control has two sub-modes: Standard, and Custom (radio buttons). The Standard sub-mode produces a 2 Vpp signal into 50 Ohms (at 50% modulation). When the Custom sub-mode is selected, an additional slider control will appear on the configuration display. The AM Output Level slider control allows the user to manually alter the output voltage level of the AM output. Note that no additional feedback is provided in the configuration display as the slider is adjusted. The actual voltage levels of the AM signal will need to be measured via some form of external instrumentation (volt meter, oscilloscope, etc) as the slider is adjusted. Also note that the AM output level is not associated with LRRS, but is included in the setup GUI for those users that intend to use the LS-25 or LS-27 downconverter card(s) in conjunction with an external antenna controller.

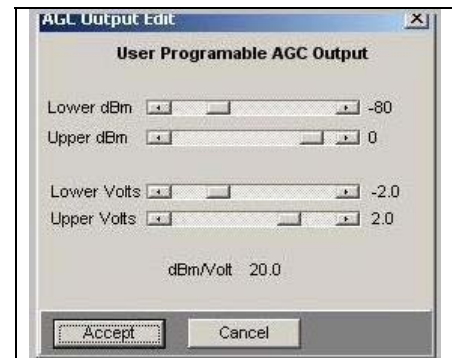
The AM LPF (low pass filter) control allows the user to select the AM filter cutoff frequency from 100 Hz to 50,000 Hz in 100 Hz increment steps. The filtering is applied to the AM signal prior to output.

3.2.1.4.2.6 AGC Controls

The AGC controls has three possible selections; Standard, Custom, and User Defined. In Standard mode, the AGC voltage will vary from 0 volts, to – 4 Vdc over the entire 0 dBm to -110 dBm power level range. In the Custom mode, the user may select an AGC Slope/Range of either Positive Slops, or Negative Slops. The voltage ranges are summarized in the table below. Again, the AGC voltage will vary per the table below over the entire 0 dBm to -110 dBm power level range.

Positive Slope	Negative Slops
-4 V to 0V	0V to -4V
-2V to 0V	0V to -2V
0V to +2V	+2V to 0V
0V to +4V	+4V to 0V
-2V to +2V	+2V to -2V
-4V to +4V	+4V to -4V

The User Defined mode allows the user to specify both starting and ending points for both RF power level and the resulting AGC voltage. When the User Defined mode is selected, the GUI will change and the User Programmable AGC Output widget will appear as shown below. The control has four sliders, two for voltage and two for power level. The user simply sets to starting and ending power RF power levels, and the corresponding AGC voltage levels, and the GUI will calculate the resulting slope in dBm/Volt.



The User Defined AGC mode is a very powerful feature and allows LS-28 to be used with virtually all antenna control units.

3.2.1.4.3 Test Tab

The LS-28 is equipped with a powerful multi-mode IF modulator rich with features and capabilities. The IF modulator is ideal for test and checkout of the various demodulators configured on LS-28 as well as external demodulators. When used in concert with an IF upconverter, the LS-28 may be used to test a wide variety of receivers employing many of the most common modulation formats used in terrestrial and satellite telemetry scenarios. The modulator functionality of the LS-28 also supports some forward error correction coding schemes used in satellite telemetry applications. Perhaps the most powerful feature of the modulator is the built-in noise generator. With the noise generator, the user may add very precise levels of additive white Gaussian noise (AWGN) to the signal. With this feature, the user can create a modulated signal with virtually any signal-to-noise ratio desired. This capability is extremely useful in a variety of testing scenarios including the BER performance of diversity combiners and receivers, and the characterization of error detection and correction hardware.

The specific capabilities of the test modulator are determined at the time of purchase via the firmware license configuration. As with most LS-28 features, changes or additions to the firmware license configuration may be made at any time after purchase by simply installing a new license file obtained from the factory. In this way, new or additional features can be added to the LS-28 without changing the base hardware. Unless specified otherwise by the customer, ALL of the features and capabilities of the modulator are enabled by default.

The Test tab (shown in Figure 3-28 on page 114) has two sub-tabs: *Modulator* and *BER*. The Modulator tab in turn has three sub-tabs: *Primary*, *Secondary* and *Misc*.

3.2.1.4.3.1 Test Modulator Sub-Tab (Primary)

The anatomy of the Primary Modulator sub-tab is shown (shown in Figure 3-28 on page 114). The appearance of the GUI is the same, irrespective of the firmware personality loaded into the hardware. The Modulator sub-tab allows the user to enter the requisite parameters necessary to set up the data and modulation formats needed for testing receivers and demodulators.

The Primary Modulator sub-tab has setup controls for several test functions including the test *Modulator*, *Carrier Sweep* profile controls, two *PCM Encoders*, and the *Transmission (TX) BERT*. To change any of the parameters, the user simply places the mouse cursor over the parameter and right-clicks to invoke an input dialog box.

The Test Modulator parameters are shown in Table 3-2 on page 115. Note; when in Combiner mode, the test modulator is not available for test purposes. Instead, the modulator output is used to provide the 70 MHz reconstructed IF output signal from the combiner. This combined IF is then available for other uses.

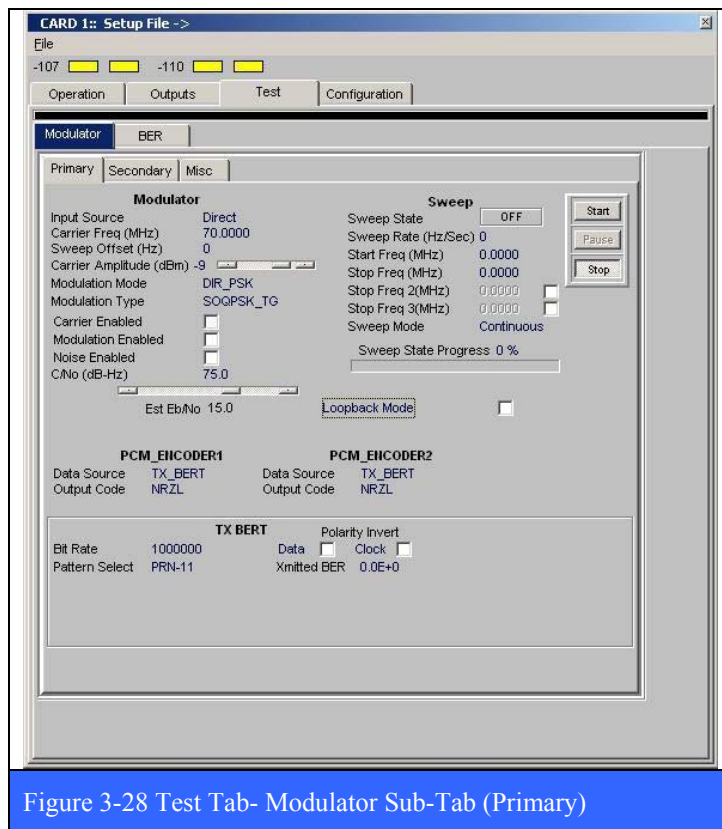


Figure 3-28 Test Tab- Modulator Sub-Tab (Primary)

At the heart of the self-test capabilities within LS-28 is the **Loopback Mode** checkbox. Once invoked by the user, the Loopback Mode automatically engages the *Carrier Enable* and *Modulation Enable* check boxes as well as configuring the internal signal connection paths needed to connect the test modulator output with the inputs to the demodulator(s). When the Loopback Mode check box is engaged, a warning message will appear in the main launch banner of the LRRS application as well as in the header of any open display widget pages. This warning will remind the user that a loopback test is in progress and that no live data is actually being received. The default state of the Loopback Mode is OFF. If Loopback Mode

is active and the LRRS application is re-started, then upon resumption of operations, the Loopback Mode will again be OFF. In other words, the LRRS application can not start up automatically in Loopback Mode and must be invoked manually by the user.

The test modulator **Sweep** parameters are shown in Table 3-3 on page 116. The Sweep function allows the user to dynamically vary the center frequency of the 70 MHz carrier output of the test modulator. The user has control over the starting and ending frequency, as well as several intermediate frequencies in-between, and how fast the frequency changes in rate (Hz/Sec). The sweep may be a single event, or a continuous repeating process. To initiate the sweep, click on the *Start* button. The progress of the sweep is shown in the *Sweep State Progress* bar graph. To interrupt the sweep, click on the *Pause* button. To resume, click the *Pause* button again. To permanently end the sweep, click on the *Stop* button.

Table 3-2 Test Modulator Parameters		
Input Source	Direct or Combiner	The modulator in LRRS produces a 70 MHz IF output signal that is available on the boards face-plate at SMB connector J1. Normally the IF output signal comes from the modulator. However, a second option is available. The output of the pre-detection combiner (if available) is also accessible at connector J1 by invoking the Input Source command and selecting Combiner. The default selection for the input source command is Direct and connects the modulator output to connector J1.
Carrier Freq (MHz)	Value	The Carrier Frequency command allows the user to change the default 70 MHz value of the carrier signal. For example, one might do this to simulate a known frequency offset in the output signal for testing purposes. In normal operation however, the user should not change the carrier frequency from the default.
Sweep Offset (Hz)	Value	If the test modulator is in Sweep mode, this parameter value shows the current frequency value in Hz.
Carrier Amplitude (dBm)	Value	The output power level of the modulator may be adjusted by the user by invoking the Carrier Amplitude command and entering the desired level in dBm. The output power level may be set anywhere between 0 dBm and -80 dBm. The modulator parameter setup GUI also has a slider control for the carrier amplitude.
Modulation Mode	Direct PSK or Subcarrier	The modulator in LRRS can support both direct carrier modulation (DIR_PSK) and subcarrier modulation (SUBCAR). The user specifies one or the other by invoking the Modulation Mode command. The default mode is direct carrier modulation. Selection of certain modulation modes will affect some of the commands available in the modulation parameters menu. The SUBCAR mode for example will enable all of the subcarrier modulation parameters. Note also that the SUBCAR mode will automatically set the modulation type to the PM mode.
Modulation Type	Select from list	The modulator in LRRS can support a variety of formats. The complete list of formats is shown right. The Modulation Type command allows the user to specify which modulation format to use. As new modulation formats are added via firmware update, they will also appear in the list shown right. Selection of certain modulation formats will affect some of the commands available in the modulation parameters menu. For example, the PCM_FM mode will enable the FM Peak Deviation Factor command.
Carrier Enabled	Checkbox (On/Off)	The user may turn on or off the carrier by checking/un-checking the Carrier Enable checkbox. The default setting is disabled. When not checked, no signal will be present on the modulator output (except for the noise floor of the modulator).
Modulation Enabled	Checkbox (On/Off)	The user may turn on or off the modulation of the carrier by checking/un-checking the Modulation Enable checkbox. The default setting is disabled. When not checked, the only signal present on the modulator output will be the carrier (unless it is also disabled).
Noise Enabled	Checkbox (On/Off)	To enable the addition of noise with the modulated signal, the user must select the Noise Enable checkbox. When selected, noise with the C/N_0 level specified by the user is added to the signal. The effect of the added noise to the signal is most easily seen visually by examining the signal's spectrum. The top figure below shows an example of a spectrum (SOQPSK) with a C/N_0 noise level of 75 dB-Hz. In the bottom figure below, the addition of noise can also be seen in the I/Q constellation display of quadrature modulation schemes. Again, the C/N_0 noise level is 75 dB-Hz. Note the spreading out of the four images in the quadrants. In general, the "fuzzier" the appearance, the more noise that is present.
C/N_0 (dB-Hz)	Calculated Value Shown Based on E_b/N_0	Perhaps the most powerful feature of the modulator is the built-in noise generator. With the noise generator, the user may add very precise levels of additive white Gaussian noise (AWGN) to the signal. With this feature, the user can create a modulated signal with virtually any signal-to-noise ratio desired. The user sets the noise level by invoking the C/N_0 command and entering the desired noise in dB-Hz. Noise levels may range between 0 and 110 dB-Hz. The modulator parameter setup GUI also has a slider control for the noise level.
Est E_b/N_0	Slider Control	

Table 3-3 Test Modulator Sweep Parameters	
Sweep State	Toggle On/Off Button
Sweep Rate (Hz/Sec)	Value
Start Freq (MHz)	Value
Stop Freq (MHz)	Value
Stop Freq 2 (MHz)	Checkbox (Enable), Value
Stop Freq 3 (MHz)	Checkbox (Enable), Value
Sweep Mode	Continuous or TBD
Sweep State Progress (%)	Updating Value

To support quadrature modulation formats, the test modulator has two independent PCM data sources. Designated as *PCM_ENCODER1* and *PCM_ENCODER2*, these two data sources can be used to generate a variety of data patters for both the “I” and “Q” channels in a quadrature modulation scheme. Each encoder has a variety of data sources that are shown in the table below. For normal self test, the Data Source defaults to TX BERT.

Table 3-4 Test Modulator Data Source	
INPUT OFF	Turns the data source off
TTL_INPUT_1	Selects the 1 st TTL input
TTL_INPUT_2	Selects the 2 nd TTL input
422_INPUT_1	Selects the 1 st RS-422 input
422_INPUT_2	Selects the 2 nd RS-422 input
TX BERT	Selects the TX BERT as the source
Output Code	Various NRZ & Bi-Phase codes

The operational parameters for the transmission bit error rate tester, or TX BERT, are shown in the table below. In addition to *Bit Rate*, the user may select a number of useful data patters as well as a custom defined pattern with length and pattern value specified by the user. The user may also elect to selectively invert the Data, Clock, or both with the corresponding check boxes.

Table 3-5 Test Modulator TX BERT Parameters	
Bit Rate	Value
Set Bit Error Rate	Value
Prn Pattern	ZERO'S
	ONE'S
	One Zero
	PRN-11
	PRN-15
	PRN-17
	USER
Set User Pattern	Length, HEX Pattern (0xABCD)

3.2.1.4.3.2 Test Modulator Sub-Tab (Secondary)

The Test Modulator Secondary sub-tab (shown in Figure 3-29 below) has four parameter groups that deal with subcarrier and quadrature modulation data issues. These parameter groups include: *FM Peak Deviation Factor*, *PSK PM Mod Index (Radians)*, *Sub Carrier* and *Routing*.

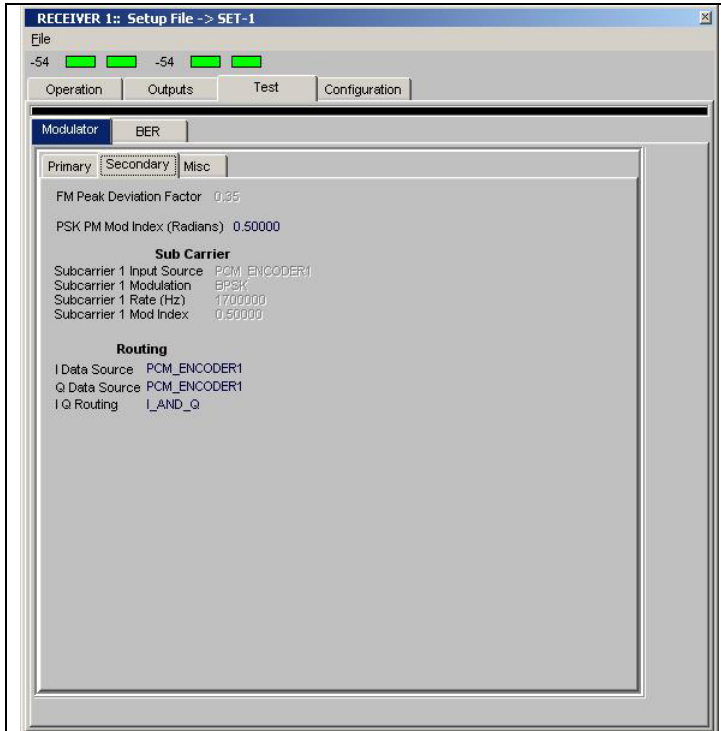


Figure 3-29 Test Tab- Modulator Sub-Tab (Secondary)

When the user selects the FM modulation type, the *FM Peak Deviation Factor* command becomes enabled (not grey). The user may enter the peak FM deviation of the carrier in the range from 0.1 to 0.9, with 0.35 being the default. FM deviation outside this range is not supported by the modulator. The effect of differing levels of FM deviation of the carrier is most easily seen by examining the spectrum of the signal.

When the user selects the PM modulation type, the *PSK PM Modulation Index* command becomes active (not grey) and allows the user to specify the amount of carrier phase deviation to be produced on the carrier. The

user may enter a value up to $\pi/2$ radians (1.5708), with 0.5 being the default. The effect of differing the PM modulation index is most easily seen by examining the I/Q constellation display of the signal.

Subcarrier Modulation Parameters

When the user selects the SUBCAR modulation mode, the subcarrier modulation parameters become active (not grey) and are ready for configuration. The following describe in more detail each of the subcarrier modulation setup parameters.

Subcarrier 1 Input Source

To support the subcarrier modulation mode, two separate, independent PCM data sources are available. Each PCM encoder in turn produces data derived from a number of sources, both internal and external. The user may select from PCM encoder 1 or 2.

Subcarrier 1 Modulation Mode

The subcarrier modulation mode in the LS-28 supports two modulation types; BPSK and QPSK. The user chooses one of these by invoking the Subcarrier Modulation command and making the appropriate selection.

Subcarrier 1 Rate

The user sets the frequency of the subcarrier in Hz by invoking the Subcarrier Rate command and entering the desired frequency. Currently, subcarrier frequencies up to a maximum of 1 MHz are allowed.

Subcarrier 1 Modulation Index

When the user selects the SUBCAR modulation mode, the Subcarrier Modulation Index command becomes active and allows the user to specify the amount of phase deviation to produce on the subcarrier. The user may enter a value up to $\pi/2$ radians (1.5708).

I/Q Routing Parameters

The Routing section of the Secondary Test Modulator sub-tab allows the user to configure the Stream Routing of the data prior to modulation.

I & Q Data Source

To support the plethora of quadrature modulation modes implemented in the LS-28, two separate, independent PCM data sources are available. Each PCM encoder in turn produces data derived from a number of sources, both internal and external. The default for the quadrature scheme sets the I-Channel to PCM_ENCODER1, and the Q-Channel to PCM_ENCODER2. For PCM/FM, BPSK, and SOQPSK, the I-Channel defaults to PCM_ENCODER1, with the Q-Channel being irrelevant.

I & Q Data routing

The data routing functions in the LS-28 Test Modulator determine how the I- and Q-data streams are sent to the modulation stage. By invoking the IQ Routing command, the user may opt to leave the routing unchanged (I_AND_Q), swap the I- and Q-streams (Q_EQUAL_I), or invert the logic polarity sense of the I- and Q- streams (Q_EQUAL_NOT_I).

3.2.1.4.3.3 Test Modulator Sub-Tab (Misc)

The Misc Test Modulator sub-tab (shown in Figure 3-30 below) has three parameter groups that deal with quadrature modulation data issues and FEC (forward error correction) data processing prior to modulation. These parameter groups include: *Misc*, *PCM_ENCODER1* and *PCM_ENCODER2*. The GUI in the Misc sub-tab allows the user to set up the two convolutional encoders, symbol routing and processing, and several miscellaneous functions.

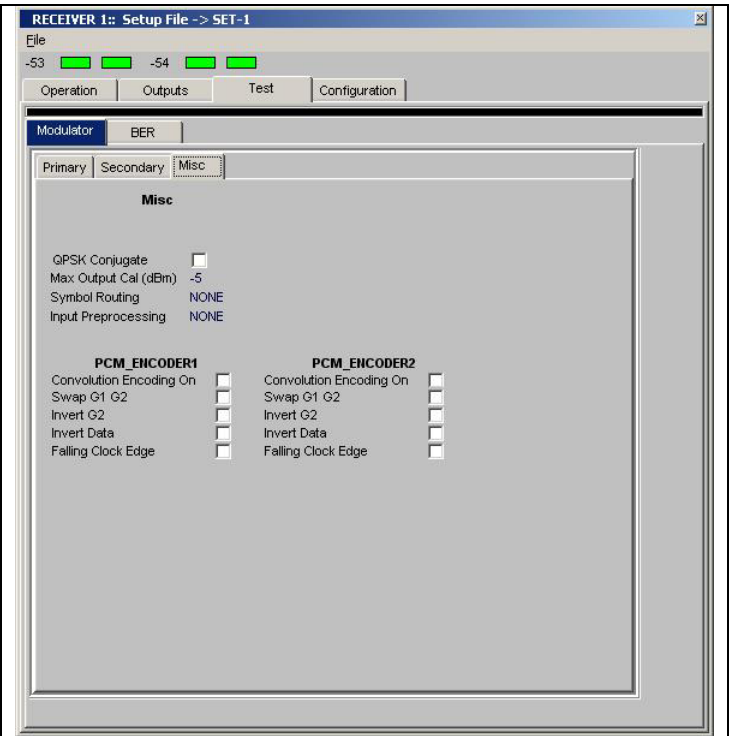


Figure 3-30 Test Tab- Modulator Sub-Tab (Misc)

3.2.1.4.3.4 BER Sub-Tab

The BER sub-tab has setup controls for the reception bit error rate tester associated with each of the two possible channels in the card group. Each RX BERT has its own tab as shown in Figure 3-31 below.

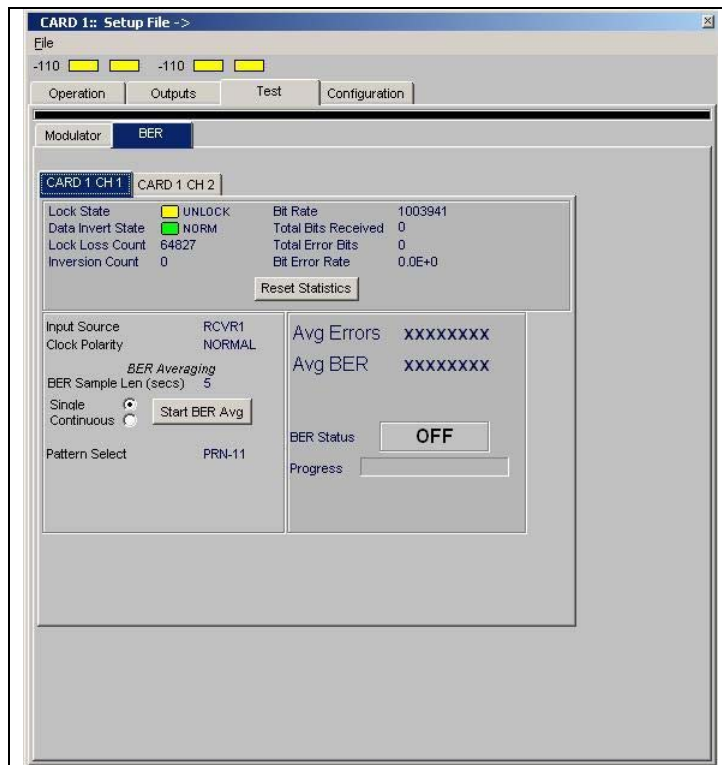


Figure 3-31 Test Tab- BER Sub-Tab

At the top of each of the channel sub-tabs, there is a tabular display area for parameters associated with the BER (bit error rate) function. These parameters are listed in the table below and for the most part, their meanings are self-evident. The *Reset Statistics* button is used to reset the count parameters to a zero value. Note: the initial state of all of the statistics is/can be undefined, thus an initial reset is called for. The *Lock State* indicator shows Green (LOCKED) when the correlator in the BER has detected the PRN pattern specified by the user via the Pattern Select command (see below). The *Data Invert State* indicator shows Green (NORM) when the BER correlator is locked onto the specified PRN pattern, and NOT on the inverted pattern. When the BER correlator

is locked onto the inverted PRN pattern, then the Data Invert State indicator shows Yellow (INV).

Table 3-6 BER Parameter

Lock State
Data Invert State
Lock Loss Count
Inversion Count
Bit Rate
Total Bits Received
Total Error Bits
Bit Error Rate

The BER controls are located in the lower left hand of the BER sub-tab. The controls are listed in the table left. The BER Sample Rate determines how long in seconds the BER counts errors. The Single and Continuous radio button determines if the count interval is a single event, or a continuous, repeating cycle. The Start BER Avg button initiates the counting of errors. For employing a user defined pattern, first set the Pattern Select to USER. This will alter the appearance of the GUI slightly. Then invoke the Set User Pattern command. Enter the length of the pattern followed by the pattern value in HEX.

Table 3-7 BER Commands	
Input Source	RCVR1/2
	OFF
Clock Polarity	NORMAL
	INVERT
BER Sample Rate	Value in seconds
Pattern Select	ZERO'S
	ONE'S
	PRN-11
	PRN-15
	PRN-17
	USER
Set User Pattern	Value; Number of Bits
	Value; Pattern in Hex (0xABCD)

The resultant BER data is displayed in the lower right of the BER tab. The average number of errors (Avg ERRORS), and bit error rate (Avg BER) are displayed along with the BER Status (ON/OFF) and the Progress of the count (in seconds).

3.2.1.4.4 Configuration Tab

The Configuration tab has four sub-tabs: *User*, *License Info*, *DN Converters*, and *Hardware*. Each tab is described in more detail in the following numbered paragraphs.

3.2.1.4.4.1 User Sub-Tab

The User sub-tab (shown in Figure 3-32 below) has five setup blocks: *Operational Mode*, *Receiver Mode*, *Combined Mode*, *Group Designation*, and *Stream Designation*. In the setup blocks with radio buttons, the user may select one, and only one option in the block. A particular mode is available for selection (not grayed out) if that mode was enabled via a firmware license created at the factory at the time of order.

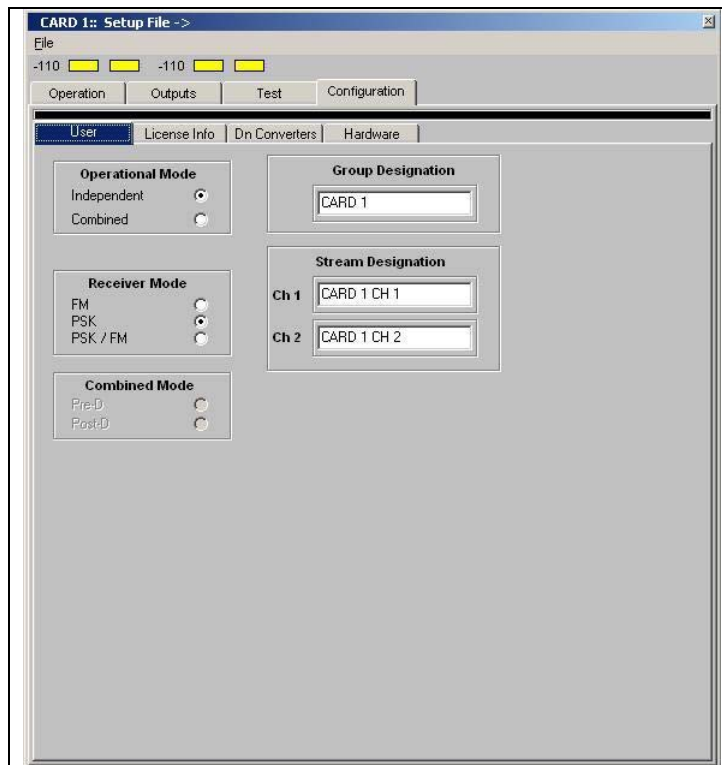


Figure 3-32 Configuration Tab - User Sub-Tab

The **Operational Mode** has two possible choices; *Independent* and *Combined*. The **Receiver Mode** has four possible choices; *FM*, *PSK*, *PSK/FM*, and *PM/PSK*. The **Combined Mode** has two possible choices; *Pre-D* and *Post-D*. (Note: all of this depends on what operational firmware is loaded into LRRS. Depending on the firmware, some of the choices in the Operational, Receiver, and Combined modes may not be available for selection).

The **Group Designation** block allows the user to change the text label associated with the card group. For example, instead of "Card 1," the user may wish to call the card group hardware associated with group 1 "Satellite Channel A," or some other

designation with operational significance to the scenario. Likewise, the **Stream Designation** block allows the user to change the text label associated with each physical channel in the card group.

3.2.1.4.4.2 License Info Sub-Tab

The License Info sub-tab (shown in Figure 3-33 below) has four setup blocks: *Capabilities Licensed*, *Modulations Licensed*, *Hardware ID* and *Firmware ID*.

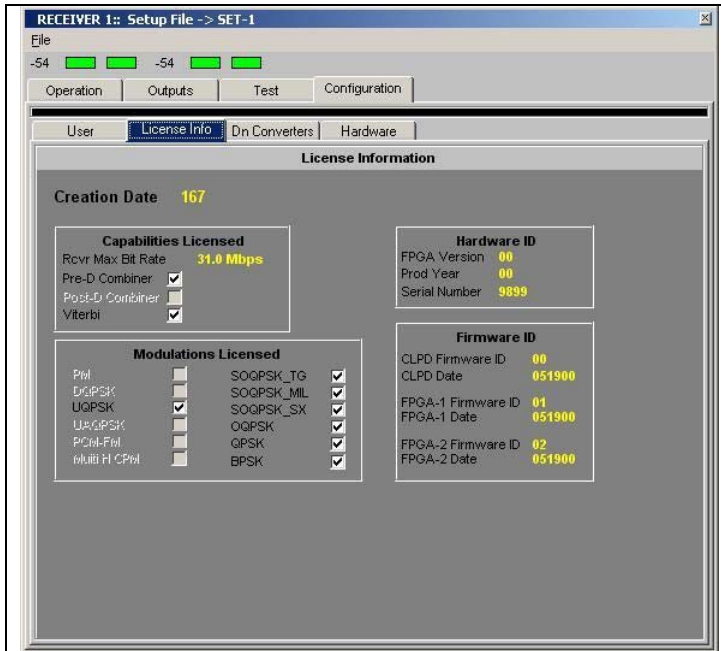


Figure 3-33 Configuration Tab – License Info Sub-Tab

The **Capabilities Licensed** block shows the status of features such as Maximum Receiver Bit Rate, Diversity Combiner modes available, and availability of Viterbi error correction.

The **Modulations Licensed** block shows what modulation formats are enabled for the card group.

The **Hardware ID** and **Firmware ID** blocks show information pertinent to the firmware license files loaded into the demodulator card at the current time.

3.2.1.4.4.3 DN Converters Sub-Tab

The Dn Converters sub-tab (shown in Figure 3-34 below) shows which channels of which LS-27 or LS-25 downconverter are connected to the two input channels of the demodulator associated with this card group. In the example below, channel A of the demodulator is connected to channel 1 of LS-27 card #1, and channel B of the demodulator is connected to channel 2 of LS-27 card #1.

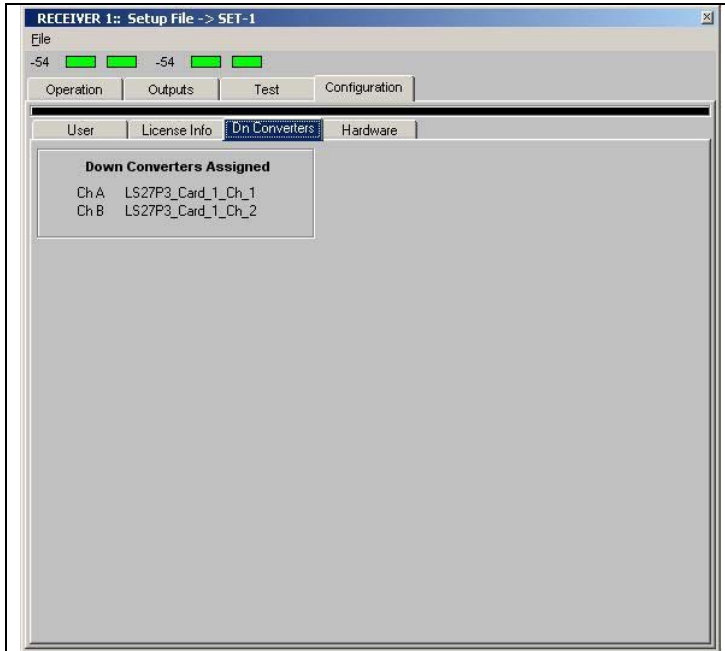


Figure 3-34 Configuration Tab – Dn Converters Sub-Tab

3.2.1.4.4.4 Hardware Sub-Tab

The hardware sub-tab (shown in Figure 3-35 below) displays information pertinent to the *Reference Clock* signal used in the LS-28 configuration. Specifically, the user may select either an *Internal* or *External* reference clock to be used. Perhaps of more importance, the *Reload Firmware* button allows the user to reload the current operational firmware. This may be required under a number of diagnostic or troubleshooting scenarios.

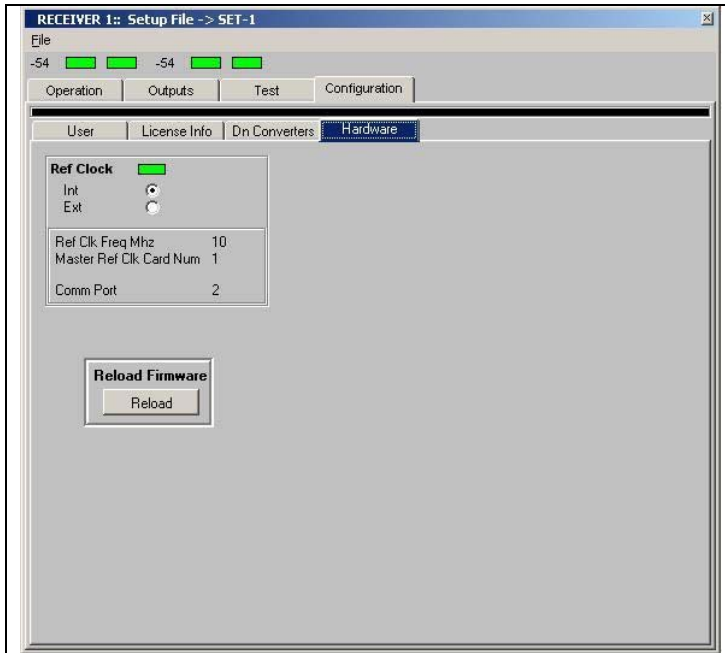
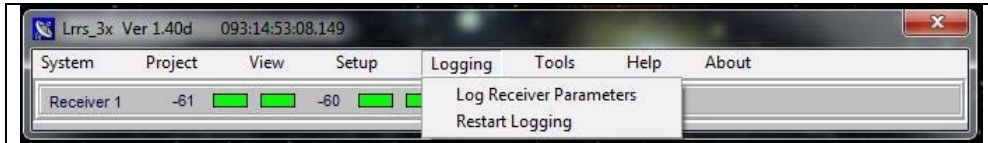


Figure 3-35 Configuration Tab – Hardware Sub-Tab

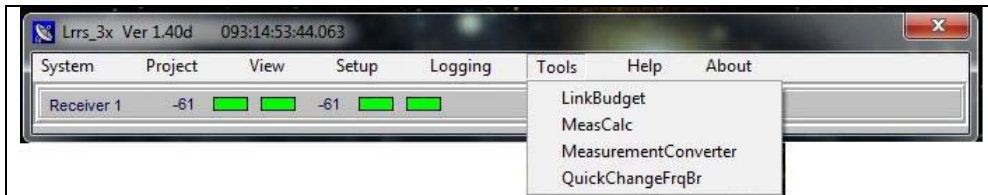
3.2.1.5 Logging Command

The Logging command has two sub-commands: *Log Receiver Parameters*, and *Restart Logging*. The Log Receiver Parameters sub-command initiates the recording of the parameters selected in the **Flt Recorder Setup** tab described in paragraph 3.2.1.1.1.5 on page 95. The Restart Logging sub-command toggles the recording off and on.



3.2.1.6 Tools Command

The main Tools command currently has four sub-commands; *LinkBudget*, *MeasCalc*, *MeasurementConverter*, *QuickChangeFreqBr*. The Tools command offers a variety of handy utilities that are easily accessed via this menu. Each of these tools are described in more detail in the following numbered paragraphs.



3.2.1.6.1 The Link Budget Tool

The Link Budget Calculator is a useful tool for performing a link margin analysis for terrestrial or satellite radio links used in telemetry applications. The user enters the fundamental parameters that describe the link, including range, frequency, transmitter power, bit rate, etc., and the budget for the link is calculated as shown below in the figure. The link budget is a simple accounting of the gains and losses that the signal experiences during its travel from the source to the destination.

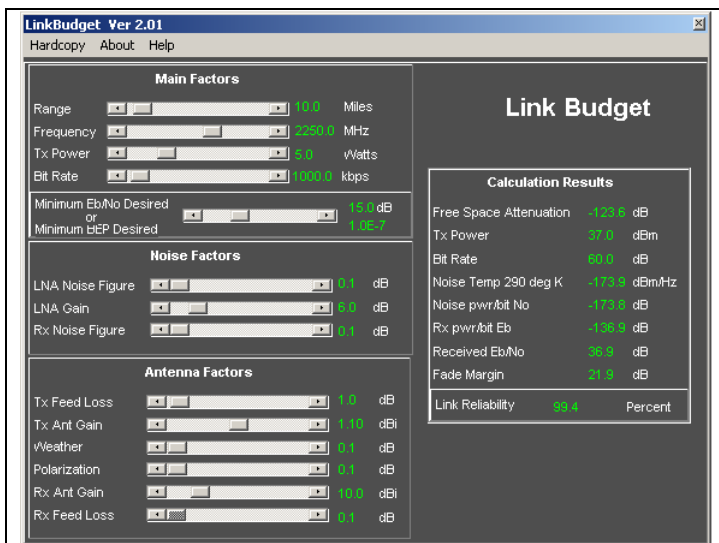
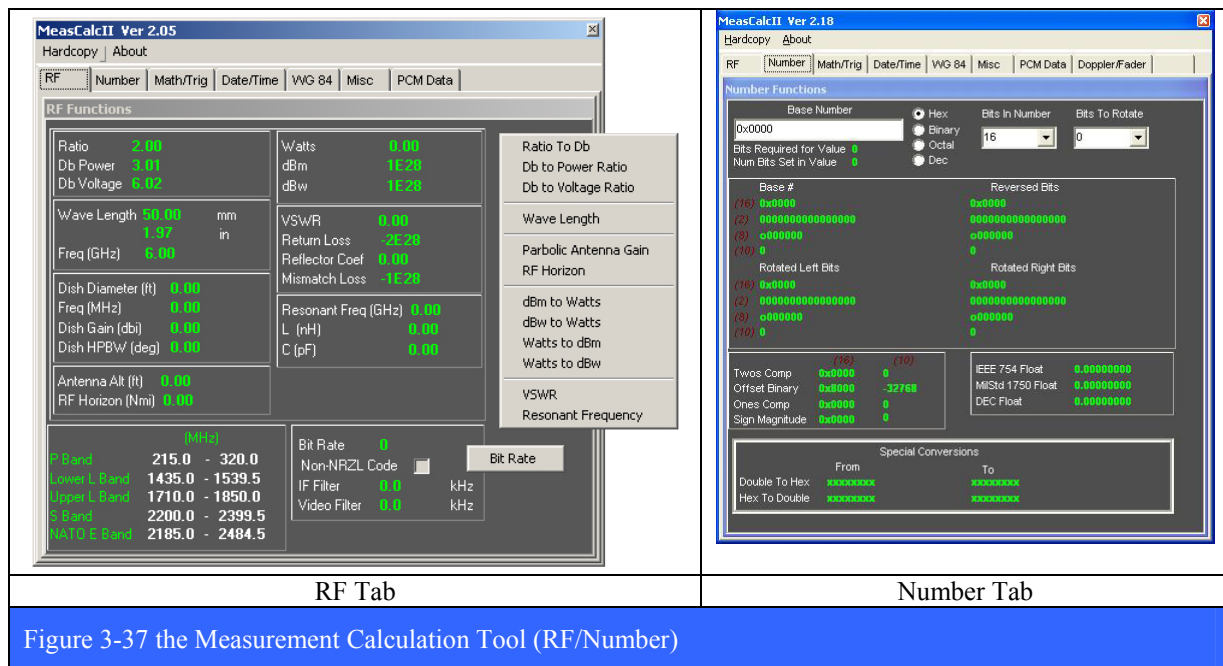


Figure 3-36 the Link Budget Tool Window

3.2.1.6.2 The Measurement Calculation Tool

The Measurement Calculator is a virtual “Swiss Army Knife” of measurement calculations and offers a smorgasbord of handy numerical routines for a variety of different applications. Each application area has a tab containing many different parameters and functions. The user selects a particular parameter or function by right clicking and selecting the item. The specific menus for each of the tabs are shown in the figures that follow.



The measurement calculator has eight tabs across the top of the window that includes: *RF*, *Number*, *Math/Trig*, *Date/Time*, *WG 84*, *Misc*, *PCM Data*, and *Doppler/Fader*. The use of each tab is fairly self-exclamatory and is not described in detail here.

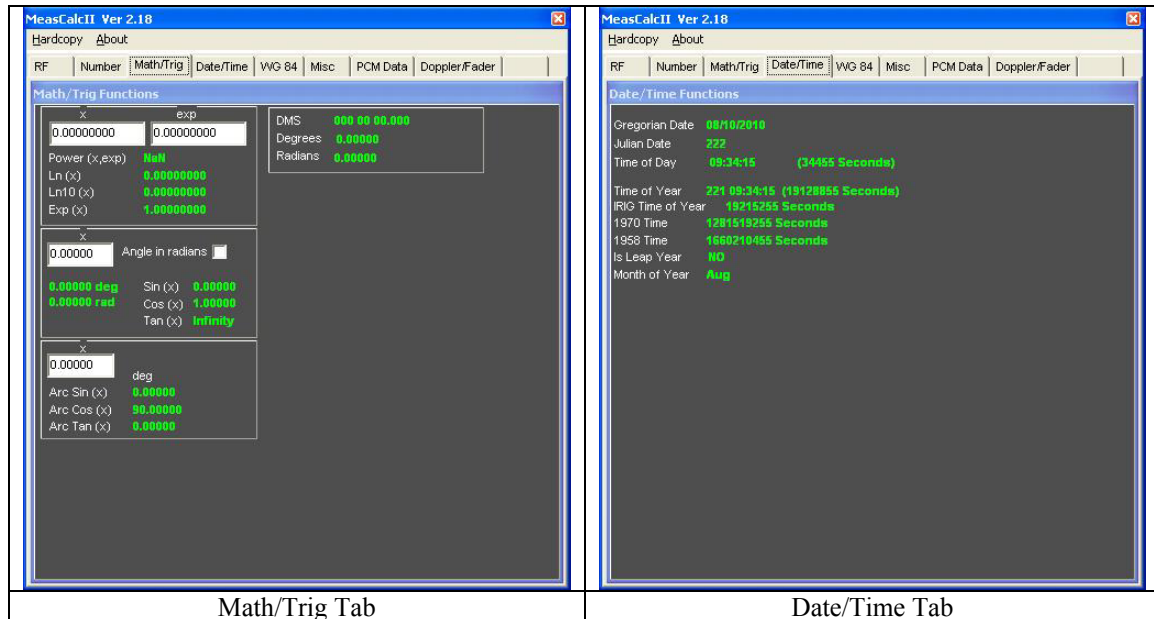


Figure 3-38 the Measurement Calculation Tool (Math/Date)

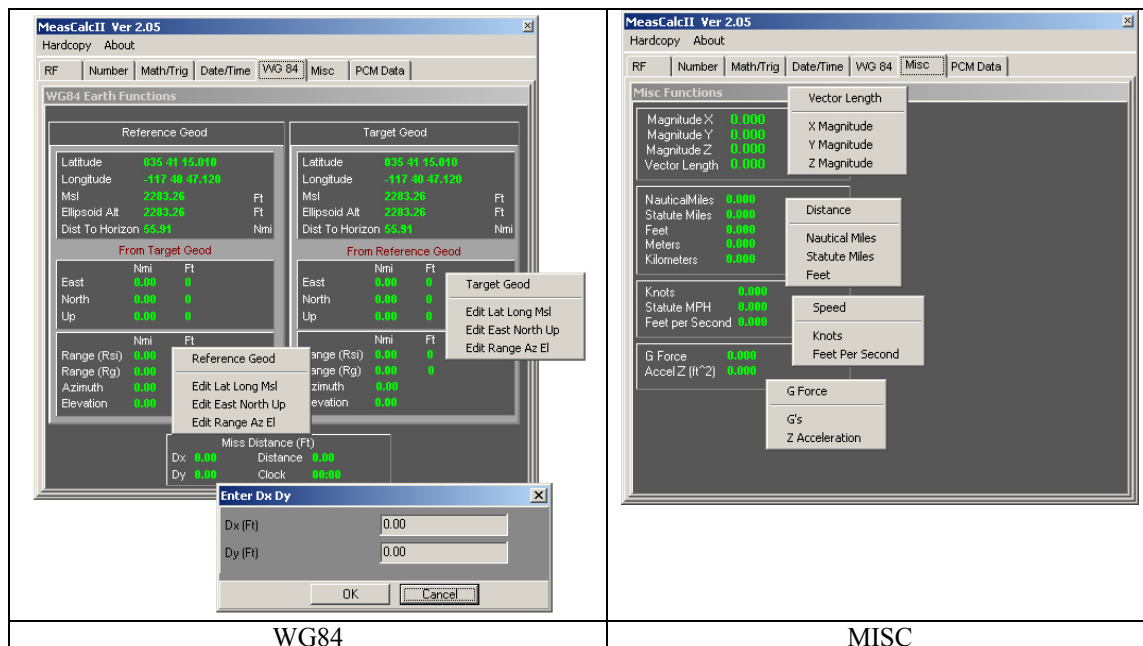


Figure 3-39 the Measurement Calculation Tool (WG84/Misc)

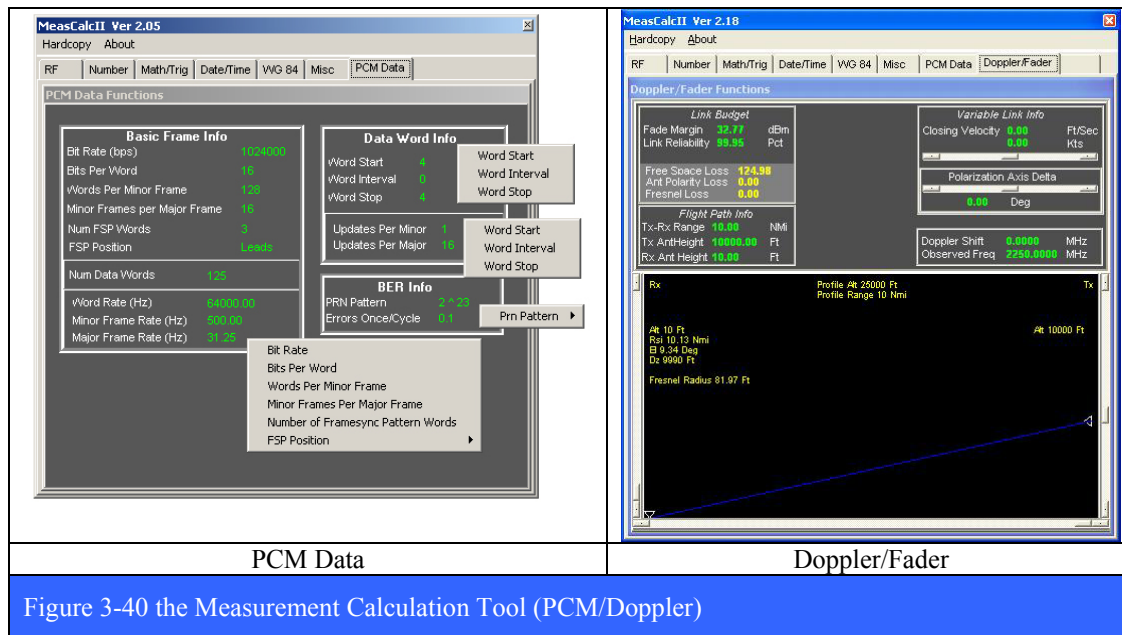


Figure 3-40 the Measurement Calculation Tool (PCM/Doppler)

3.2.1.6.3 The Measurement Converter Tool

The Measurement Converter is another virtual “Swiss Army Knife” of conversion functions for a large variety of physical parameters. Each physical parameter has a tab containing many different units of measure that the user converts to and from. The user selects a particular input and output parameter, and the units of measure for each and then enters the numeric value for the input. The output is automatically calculated as the input value is entered. The specific menus for each of the tabs are shown in the figures that follow.

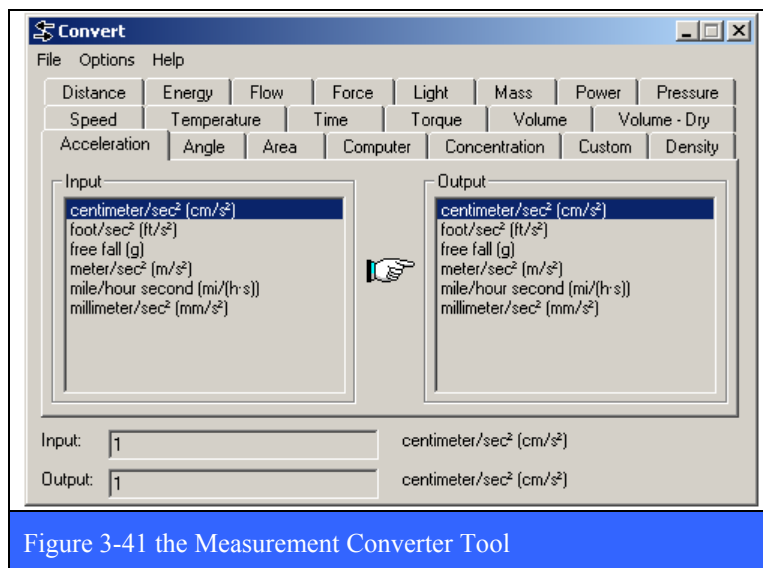
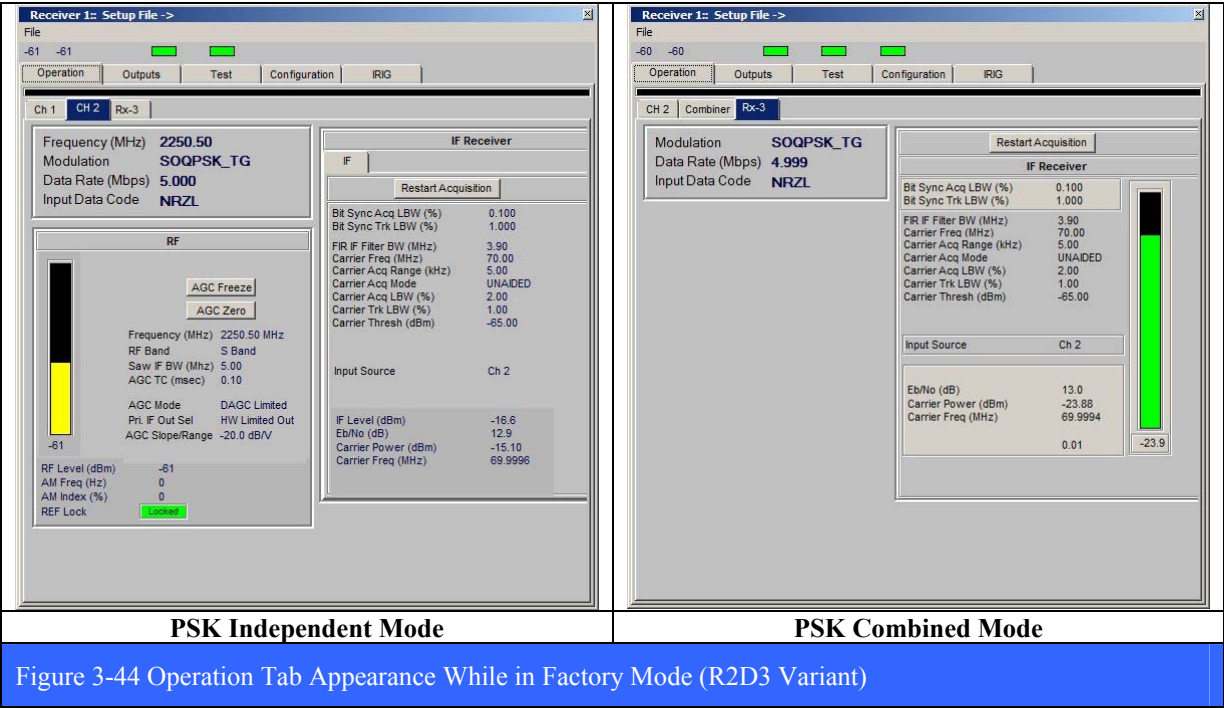


Figure 3-41 the Measurement Converter Tool

3.2.1.6.4 Quick Change Frequency Tool

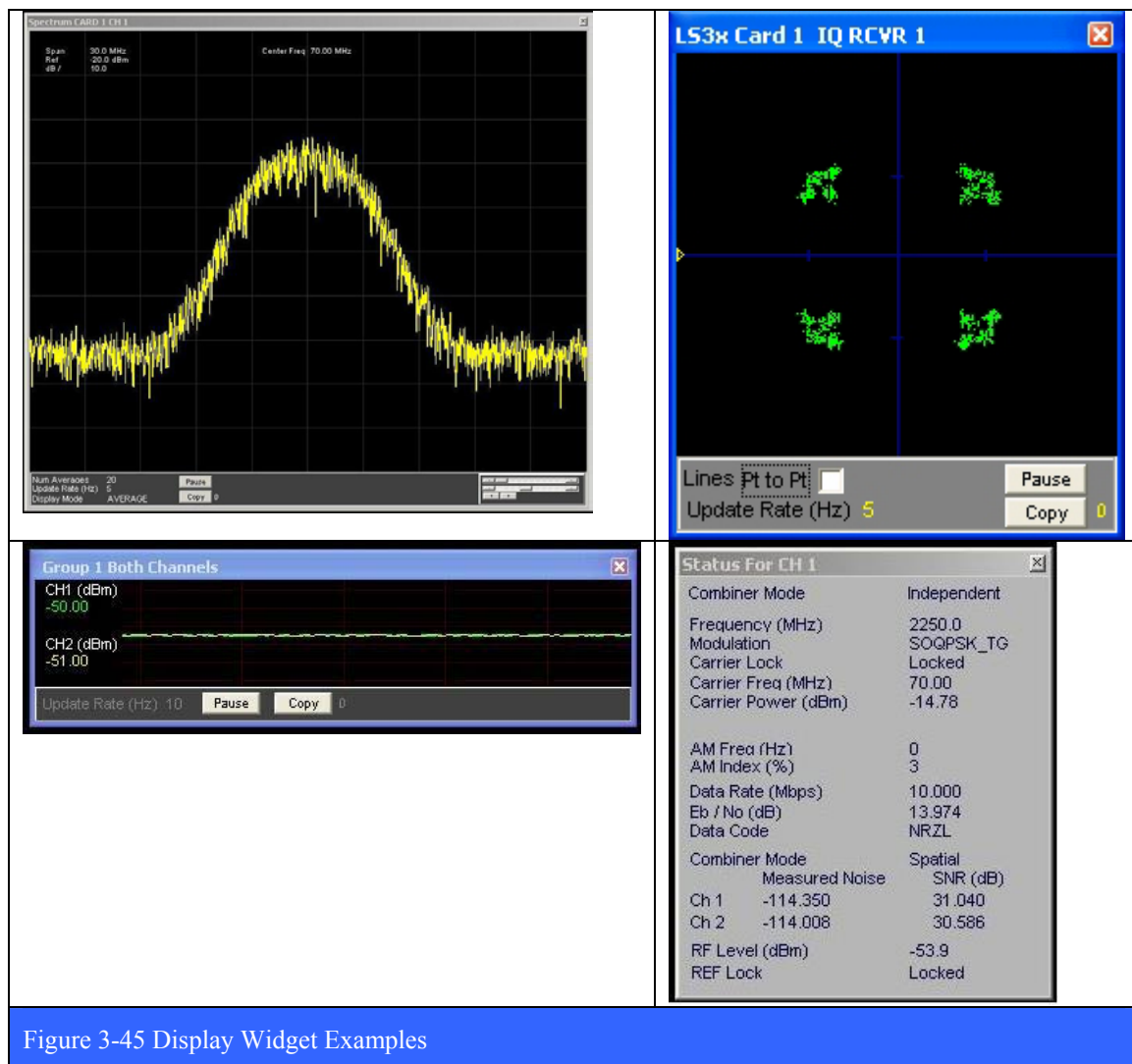
Figure 3-42 the Quick Change Frequency Tool

Also, when the LRRS application is in Factory mode, the appearance of some of the setup windows will be different. An example of this is shown for the –R2D3 variant in Figure 3-44 below.



3.2.2 Widget Display Pages

Each card group installed in the system has a Widget Display Page associated with it. When invoked for the first time, the widget display page comes up empty, and is in essence, a blank canvas. To this empty page the user may add graphical objects called “widgets.” These graphical objects include: Spectral Displays, Constellation Displays, Received Signal Strength Indication (RSSI) strip chart displays, and Status Displays. All are contained within the confines of the Widget Display Page, which may be re-sized by the user. Samples of each display widget type are shown in Figure 3-45 below. Each widget type is described in more detail in the following numbered paragraphs.



3.2.2.1 Spectrum Widget

The Spectrum Display Widget is shown in the figure below and is divided into several regions. In the upper portion of the window is the graphical data display area where the spectrum graphs are generated. Also in the upper left portion of the spectrum display are the Frequency Span (MHz), the Reference Level (dB), and dB/division. These parameters are controlled in the lower right region below the graphical display via slider or knob controls as shown in the figure. When invoked, addition information associated with Frequency and Amplitude markers are displayed in the upper right portion of the spectrum display. There also two buttons at the bottom of the display. The Pause button freezes the updating of the display until it is pressed again. The Copy button makes a snapshot of the display and saves it as a JPEG file in the C:\Lumistar\LRRS_3X\User\Hardcopies directory. Successive presses of the Copy button will create new snapshots of the widget at different time points.

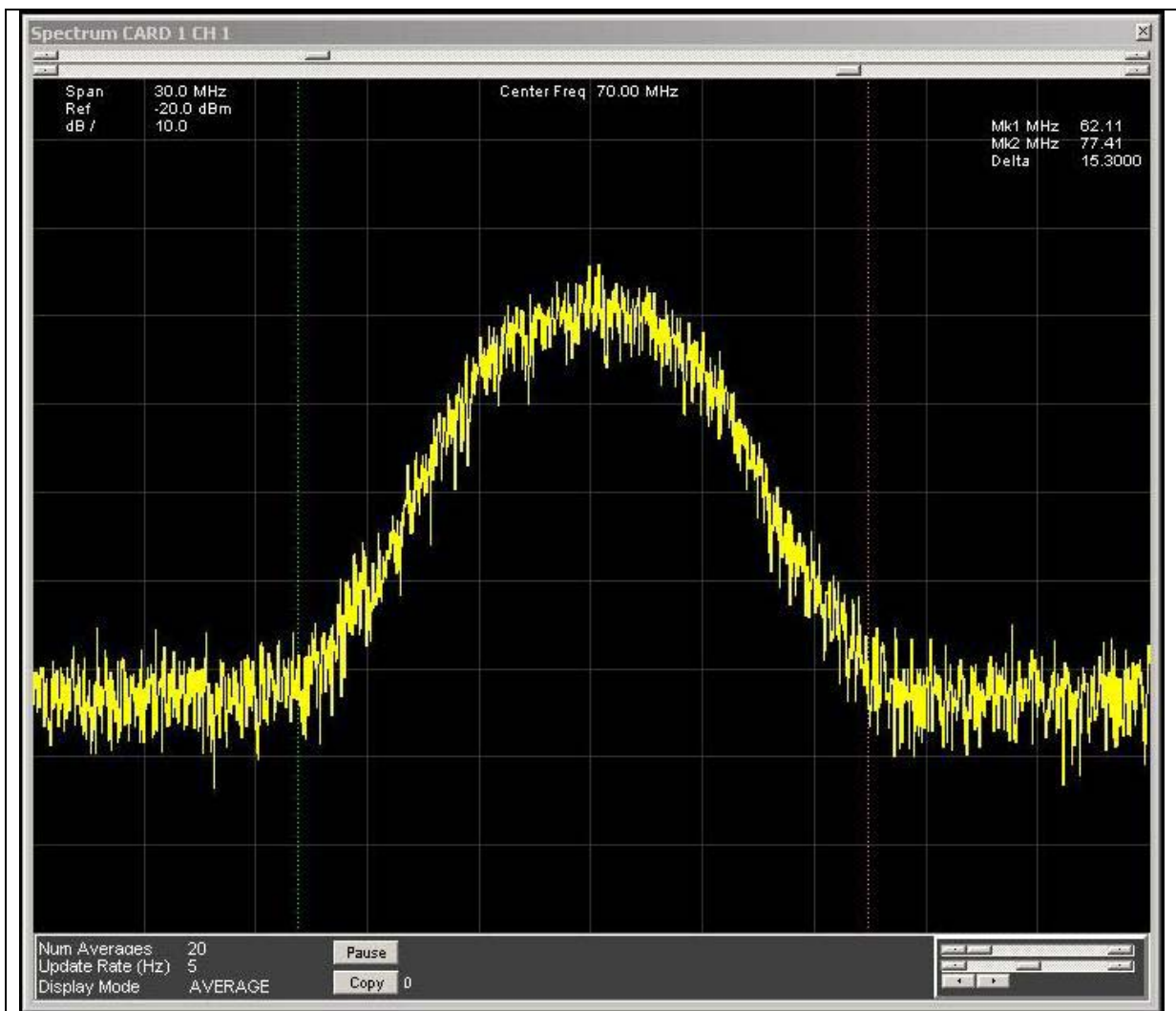


Figure 3-46 Spectrum Display - Frequency Marker Delta Mode

The **Frequency Marker Delta** mode is shown in Figure 3-46 above and is represented by two vertical dotted lines. Each marker line advances or recedes in frequency via the slider control shown at the top edge of the display. These two slider controls appear only when the mouse cursor is placed at the top edge of the widget. Note that the two marker frequencies and frequency delta are shown on the display in the upper right corner.

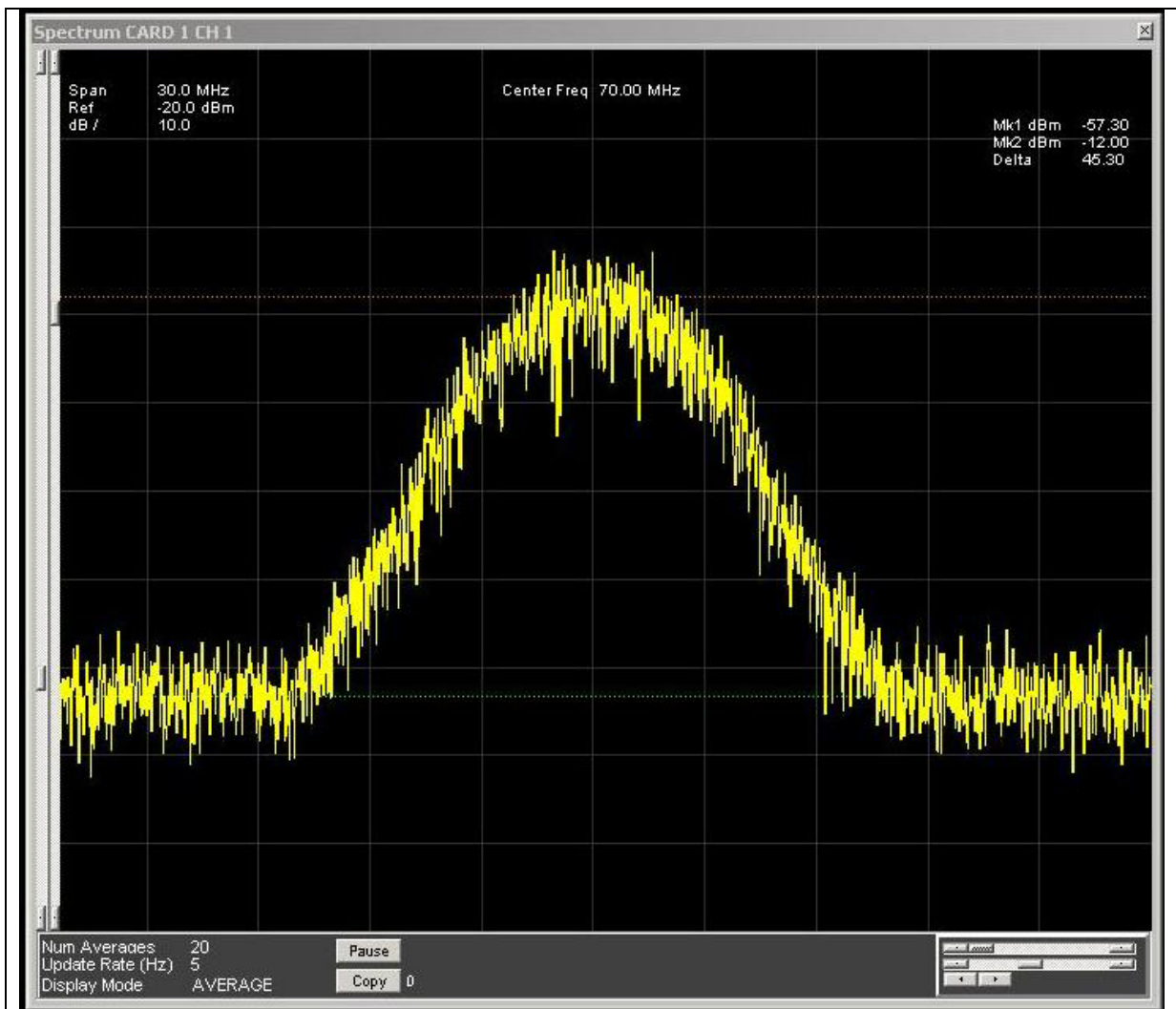


Figure 3-47 Spectrum Display - Amplitude Marker Delta Mode

The **Amplitude Marker Delta** mode is shown in Figure 3-47 above and is represented by two horizontal dotted lines. Each marker line advances or recedes in amplitude via the slider control shown at the left edge of the display. These two slider controls appear only when the mouse cursor is placed at the left edge of the widget. Note that the two marker amplitudes and amplitude delta are shown on the display in the upper right corner.

3.2.2.2 I/Q Constellation Widget

The I/Q Constellation Display Widget is handy for analyzing the state of quadrature modulation schemes. Figure 3-48 below shows two examples of the display for SOQPSK modulation (note the display on the right is of a noisy signal). The widget has a few simple controls. To invoke the controls for the display, simply place the mouse cursor in the lower region and right click. There are two buttons at the bottom of the display. The Pause button freezes the updating of the display until it is pressed again. The Copy button makes a snapshot of the display and saves it as a JPEG file in the C:\Lumistar\LRRS_3X\User\Hardcopies directory. Successive presses of the Copy button will create new snapshots of the widget at different time points.

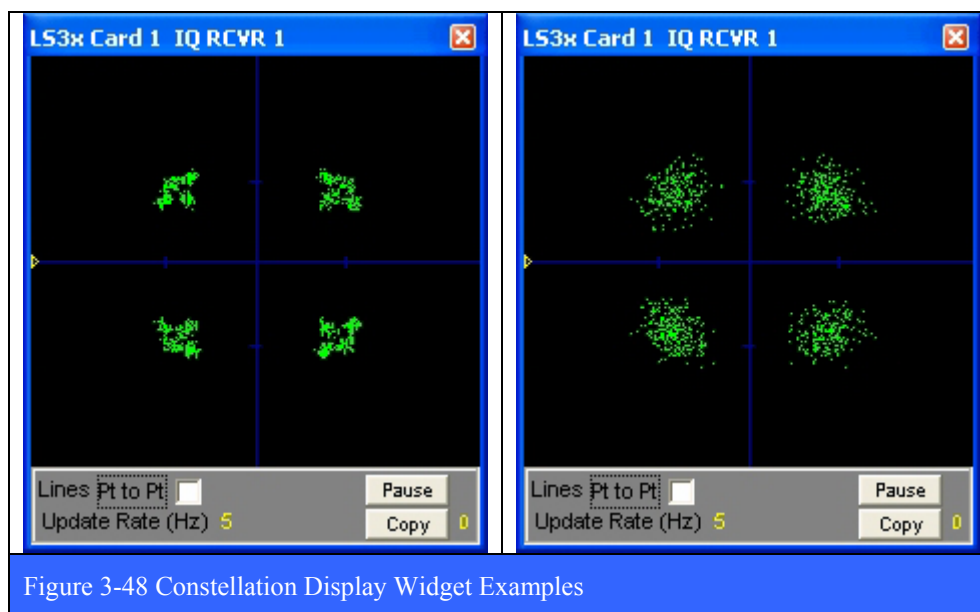


Figure 3-48 Constellation Display Widget Examples

3.2.2.3 RSSI History Widget

The RSSI (received signal strength indicator) Widget presents a horizontal strip chart style graph of the RF signal strength (dBm) as a function of time. Each downconverter channel has this widget available. There is also a two-channel version (shown below) that combines both channels into a single display. The widget has a few simple controls. To invoke the controls for the display, simply place the mouse cursor in the lower region and right click. There are two buttons at the bottom of the display. The Pause button freezes the updating of the display until it is pressed again. The Copy button makes a snapshot of the display and saves it as a JPEG file in the C:\Lumistar\LRRS_3X\User\Hardcopies directory. Successive presses of the Copy button will create new snapshots of the widget at different time points.



3.2.2.4 Status Widget

The Status Display Widget aggregates all of the relevant performance parameters of a demodulator channel into one single tabular display. There are no controls for the widget and it can not be re-sized. Two examples are shown below (FM status on the left, SOQPSK status on the right).

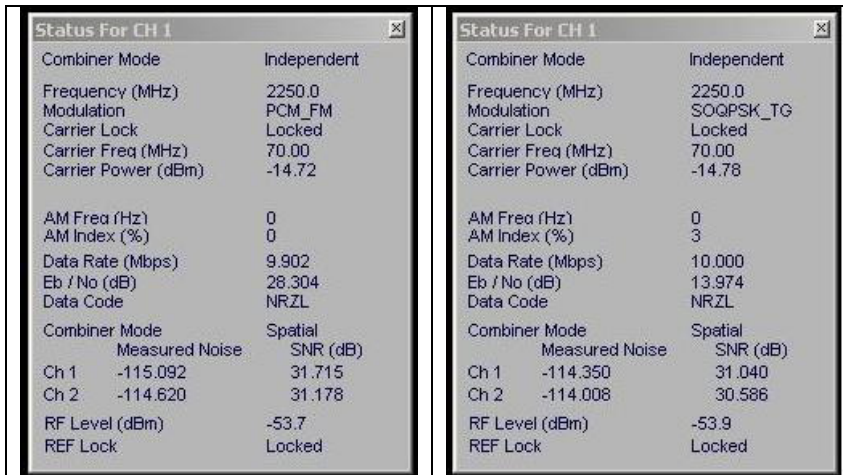
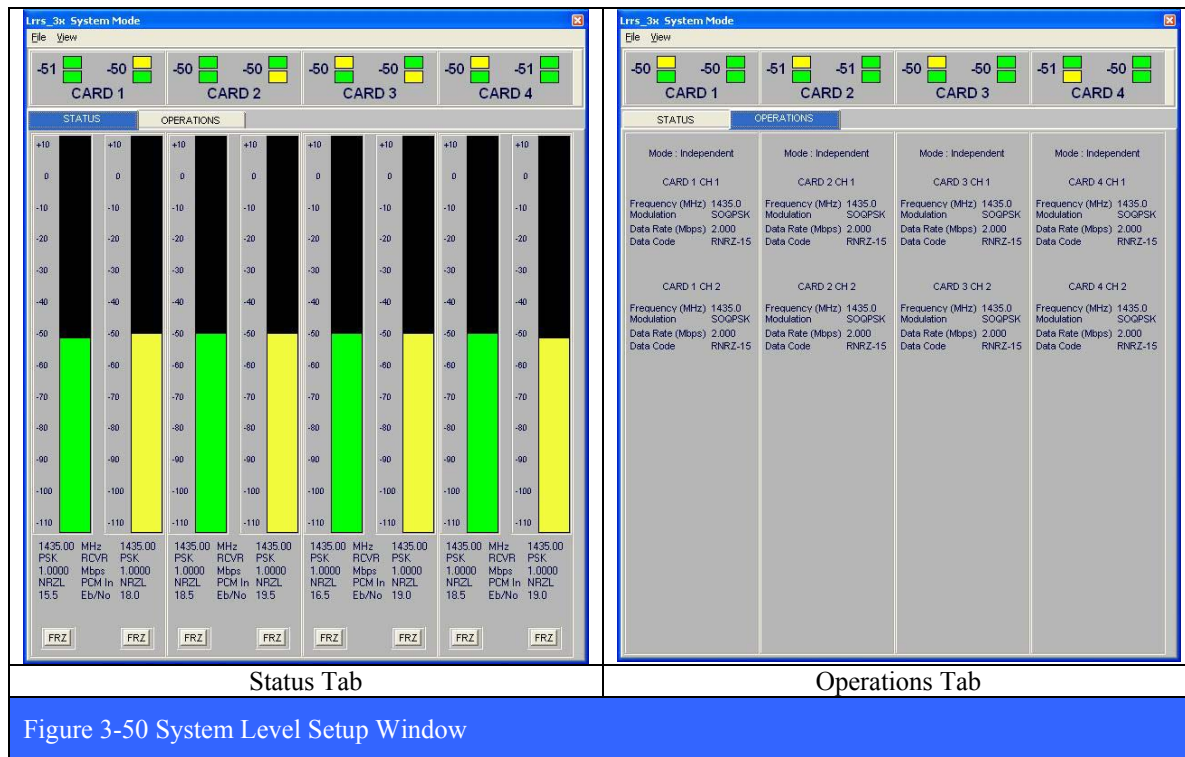


Figure 3-49 Status Display Widget Examples (FM & SO)

3.2.3 System Level Setup

The System Level Setup window aggregates the individual card level status displays and setup controls into a single display suitable for controlling and assessing the state of the system at a single glance. The user may resize this window as small, or as large as needed to accommodate viewing from any distance.

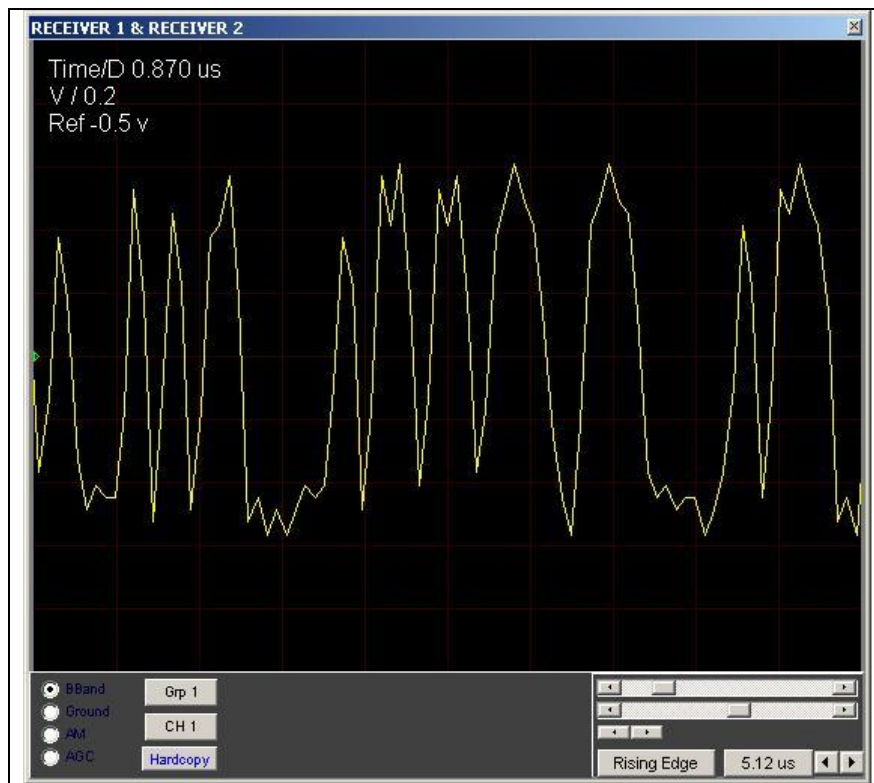


The System Level Setup window has two tabs; *Status*, and *Operations*. The **Status** tab (shown above left) displays a vertical bar-graph representing the RF input power level (dBm) for each channel of the card group. Below the bar-graph for each channel are displayed the following parameters: Tuner frequency (MHz), Modulation format, Data Rate (MBPS), PCM Input Code, and E_b/N_0 . At the top of the Status window, there are indicators for Carrier Lock and Bit Sync Lock for each channel in the group. Green indicates a lock state, Yellow indicates an unlocked state.

The **Operations** tab (shown above right) displays a summary of the primary operational parameters for each card group, and provides the operator the ability to change any of these parameters as needed. The parameters displayed include: Combiner Mode State, Tuner Frequency (MHz), Modulation Format, Data Rate (MBPS), and Data Code. To change any of these parameters, the user simply places the mouse cursor over the parameter and right-clicks to invoke an input dialog box.

3.2.4 The OSCOPE Widget

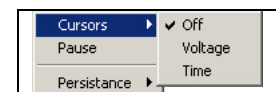
LRRS supports a multi-channel Oscilloscope functionality that enables the user to monitor several important internal signals associated with the operation of the system. These signals include: Baseband, AM, AGC and a GND reference for each receiver channel. For multi-channel systems, the user clicks on the GRP button to select the desired card group, and the CH button to select the desired channel within the group.



Analog waveforms are displayed in the upper portion of the widget, and the controls for the widget are in the bottom portion as shown in the figure below. In the lower right corner of the widget are located the Timebase slider, the Reference Level slider, and the Volts-Per-Division control. Trigger and Timebase controls are also located in the lower right corner of the widget.

Cursor Controls

Select the Cursor Control Mode by right clicking in the upper portion of the time domain display. The Cursor Control Mode has three sub-modes: Off, Voltage, and Time. Each in turn is discussed in the following paragraphs.



Voltage Cursors

The Voltage Cursor mode is shown in Figure 3-51 below and is represented by two horizontal dotted lines. Each marker line increases or decreases in voltage via the control shown on the display as indicated in the red square in the figure below. Also note that the marker voltage and voltage delta are shown in the upper right of the display.

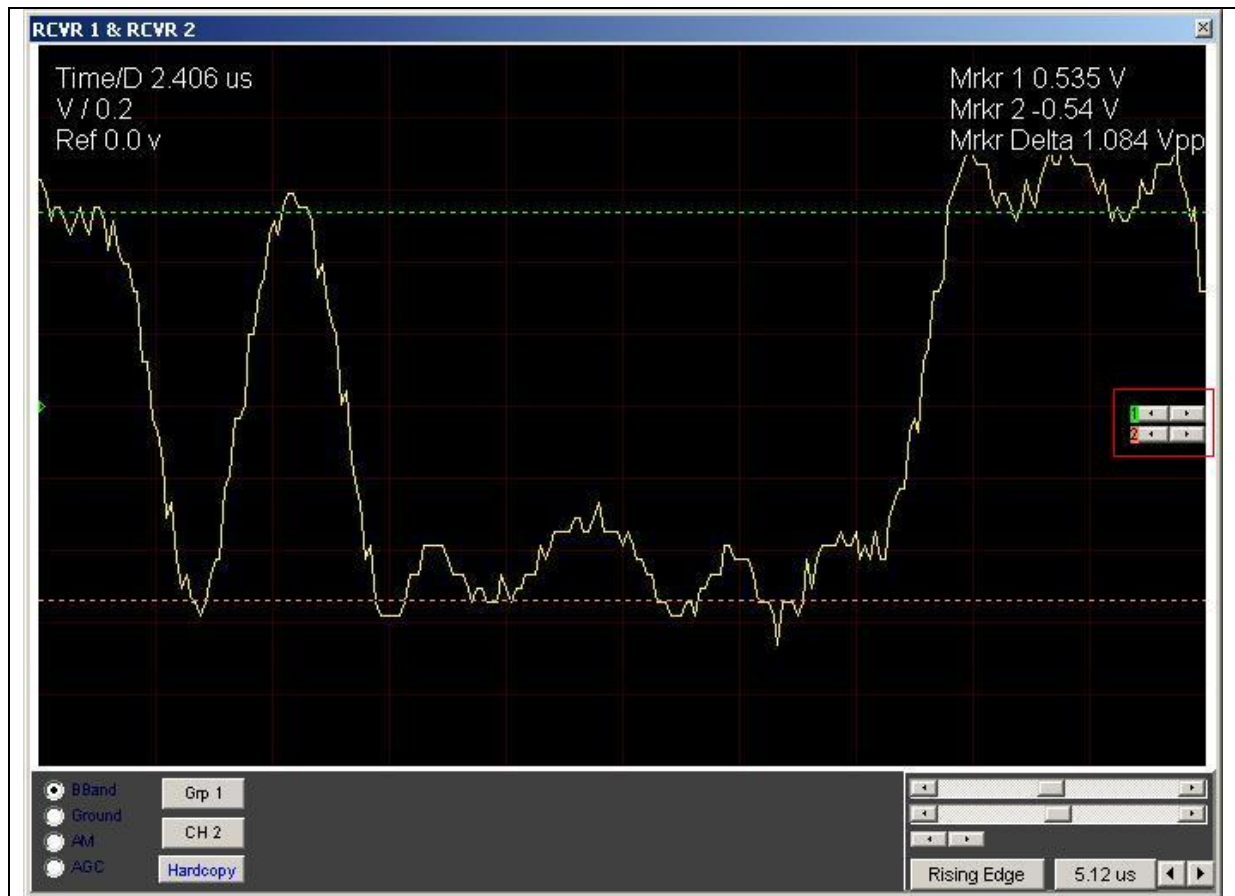


Figure 3-51 OScope Display - Voltage Cursor Mode

Time Cursors

The Time Cursor mode is shown in Figure 3-52 below and is represented by two vertical dotted lines. Each marker line advances or recedes in time via the control shown on the display as indicated in the red square in the figure below. Also note that the marker time, and time delta are shown on the upper right of the display.

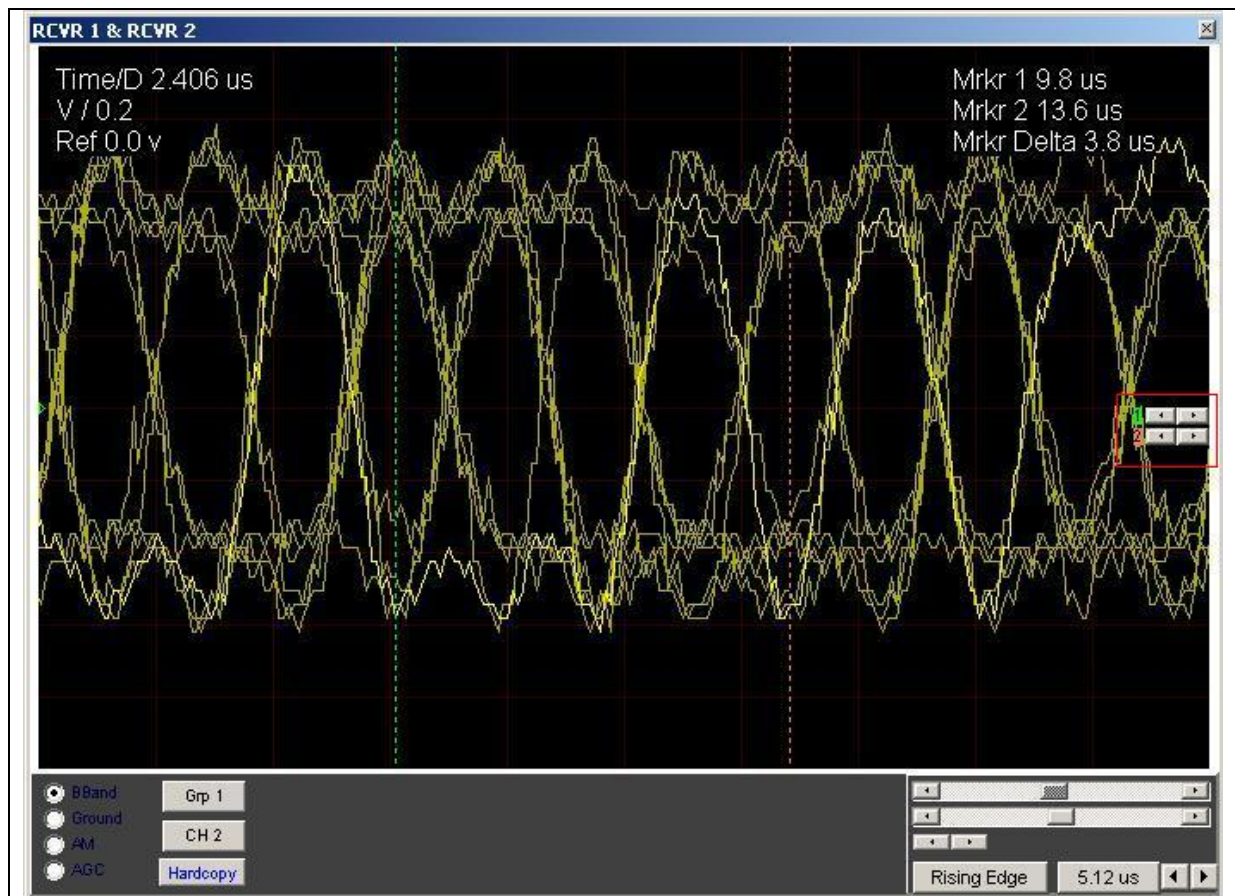
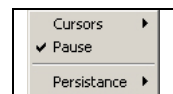


Figure 3-52 OScope Display – Time Cursor Mode

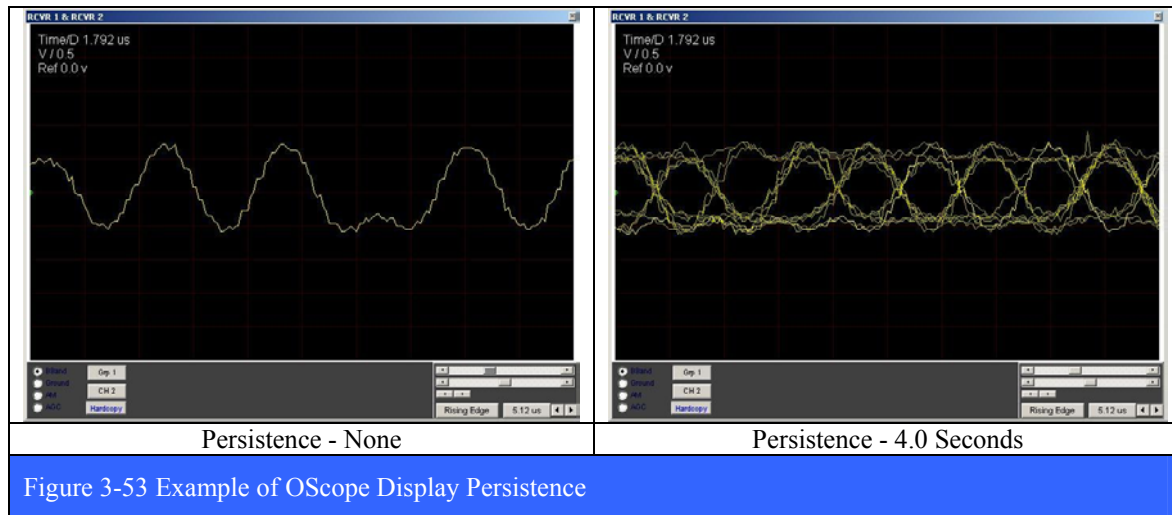
Pause Mode

Select the Pause Mode by right clicking in the upper portion of the time domain display. This will freeze the updating of the time domain display. To resume the dynamic updating of the time domain display, again select the Pause Mode by right clicking in the upper portion of the time domain display. The activation of this mode is indicated by a check mark symbol (✓) next to the “PAUSE” item in the menu.



Persistence Control

Select the Persistence Control Mode by right clicking in the upper portion of the time domain display. The Persistence Control has four sub-modes: None, 1.3, 2.7, and 4.0 Seconds. Use the Persistence Control to examine for example the “eye-pattern” of a demodulated datastream. With persistence of the display, successive cycles of a time-varying signal are in essence, displayed one on top of the other, thus creating a temporal layering of successive and often transitory events. An example of this effect is shown right in Figure 3-53 below.



Oscilloscope Trigger Mode

Select the Oscilloscope Trigger Mode by right clicking in the lower portion of the time domain display. The Trigger Mode has two sub-modes: Auto and Normal. In normal mode the oscilloscope only sweeps if the input signal reaches the set trigger condition. Auto mode causes the oscilloscope to sweep, even without a trigger.

Oscilloscope Trigger Slope

Select the Oscilloscope Trigger Slope by clicking Clock Edge button in the lower portion of the time domain display. The Trigger Slope Mode has four sub-modes: Rising Edge, Falling Edge, Either Edge, or Free Run. In the Rising Edge mode, a positive transition (rising edge) will trigger the display. In the Falling Edge mode, a negative transition (falling edge) will trigger the display. For the Either Edge mode, both a rising or falling edge will trigger the display. In the Free Run mode, the trigger conditions (rising/falling edges) are ignored and the display continuously updates.

Oscilloscope Samples

Select the Oscilloscope Sample size by right clicking in the lower portion of the time domain display. The Oscilloscope Sample Mode has two sub-modes: 256, and 512 samples.

Oscilloscope Timebase Control

Select the Oscilloscope Timebase Control Mode by clicking on the Timebase button in the lower portion of the oscilloscope display. With the timebase control, the user may select fourteen (14) different display timebase settings. The range of timebase settings depends on the sample size selected from the Oscilloscope Samples Control Mode (see above for more details), and range from 640 ns to 0.10 s. The Timebase setting (time/division) is displayed as shown right in the upper left corner of the display area.

4 System Maintenance

4.1 Introduction

This section provides information and instructions for LS-28 system preventative and corrective maintenance. The maintenance concept for the LS-28 consists of sending the system back to the factory in its special shipping case for repair. Lumistar does not recommend the removal and replacement of faulty components in the field due to the sometimes complex cabling issues encountered in removing certain CCAs. The LS-69 for example (see Figure 1-15 on page 28) has approximately thirty (30) interconnecting cables, any one of which when misconnected can cause complete system failure. It is better to leave CCA replacement to the factory.

4.1.1 Test Equipment Requirements

Table 4-1 below lists the special tools and test equipment required for LS-28 maintenance testing and troubleshooting. Equivalent test equipment may be substituted as required.

Table 4-1 Equipment Used for LS-28 Testing & Troubleshooting		
Description	Manufacturer	Model
Synthesized Signal Generator	Hewlett Packard	E4433B
Spectrum Analyzer	Advantest	R3131A
Digital Storage Oscilloscope	Tektronix	TDS-220
Automated E_b/N_0 Test Set with Calibrated Noise Source	Aeroflex	FastBit 100A
Digital Voltmeter	Fluke	72-087
RF Power Meter		
Two-way RF Power Splitter	Mini circuits	15542

4.2 Preventive Maintenance

LS-28 preventative maintenance should consist of periodic visual inspections and alignments/adjustments to detect and correct any deterioration to either the LS-28 systems physical integrity or operational performance. It is recommended that both a visual inspection be performed semi-annually and a performance test be performed either annually or when operational performance dictates.

4.2.1 Visual Inspection

An external visual inspection of the LS-28 should be performed on a periodic basis to avoid any possible malfunctions that may be mechanical or electrical in nature. All LS-28 system components should be visually inspected semi-annually, after any CCA has been removed and re-installed, and after any repairs have been made. Inspection of the unit should include, but not be limited to, the following items:

- Examine the LS-28 chassis for dents, loose or missing screws, scratches and/or marred painted surfaces.
- Check all visible exterior screws for tightness.
- Clean all outer surfaces of the chassis using a dampened cloth (mild detergent can be used).
- Inspect all external connecting cables, connectors and receptacles for corrosion and any loose connections.
- Inspect for frayed or cut insulation at all connecting cables as well as the back shell/cable bracing areas.
- Inspect all connecting cables for any kinks or strain caused by improper installation or placement.
- Tighten all loose mounting nuts.

It is also an excellent idea to visually inspect the internal cabling and card slot seating whenever the system is shipped or transported in its shipping case.

4.2.2 Air Filter Cleaning

Depending on the specific environment that the LS-28 system(s) is installed in, it will be necessary to periodically remove and clean the air filter located on the front door assembly of the chassis. How frequently this is required is dependent on the environment that the unit is installed in. At a minimum, it is recommended that the filter should be removed and cleaned every three months. In dirtier environments with a great deal of airborne dust, this cleaning interval may have to be increased.

To clean the filter, loosen the two captive screws on the filter holder subassembly on the front door and remove the air filter. Clean the filter by rinsing the filter in warm water until the water running through the filter is clear. Air-dry the filter and re-install into the front door.

4.2.3 Hard disk Care

Preventive maintenance of the system hard drive includes periodic checking of the drive with the “CHKDSK” [check disk] operating system feature and if needed, the de -fragmentation of the hard drive with a system utility.

The CHKDSK function on computers running the Windows operating system displays the file system integrity status of the hard disk and can fix logical file system errors. It can also check the disk surface for physical errors or bad sectors and can in some cases repair some physical errors and recover data that is still readable.

To check the system hard drive, locate the “My Computer” icon on the desktop and double click it. This will invoke the system file browser showing all drives installed in the system. Locate the “C-Drive” and right click on it and select “Properties” from the drop-down list. This will invoke the *Properties* window. Click on the “Tools” tab and then click the “Check Now...” button. This will invoke the *Check Disk* dialog box. Select both check boxes under the “Check Disk Options.” These options include: *Automatically Fix File System Errors*, and *Scan for and attempt recovery of bad sectors*. Click the start button and receive a message stating that the activity selected must be scheduled. Indicate that yes, the activity should be scheduled and then re-boot the computer. As part of the boot up process, the CHKDSK function will be performed and any errors on the disk will be reported and an attempt to repair them will be make.

To de-fragment the system hard dive, once again go to the “Tools” tab on the hard drives *Properties* window and click on the *Defragment Now* button. This will invoke the *Disk Defragmenter* window. Click on the “Analyze” button and the tool will analyze the selected drive to see if it needs to be de-fragmented or not. If it does, go ahead and defragment the drive. Warning, on large capacity drives like the one installed in the LS-28, the process of de-fragmentation can take a long time to complete. Be patient.

4.2.4 Operating System Updates

If the LS-28 system is NEVER going to be connected to a network, then it is probably not absolutely necessary that the Windows operating system on the unit be updated to the latest security and functional patches that Microsoft puts out on the second Tuesday of each month via its Automatic Update feature. Before the LS-28 system is first delivered to the customer, it will have been updated to the latest security patch from Microsoft. However, the automatic update function on the operating system will be turned off and it is up to the customer to turn it back on again after delivery of the system.

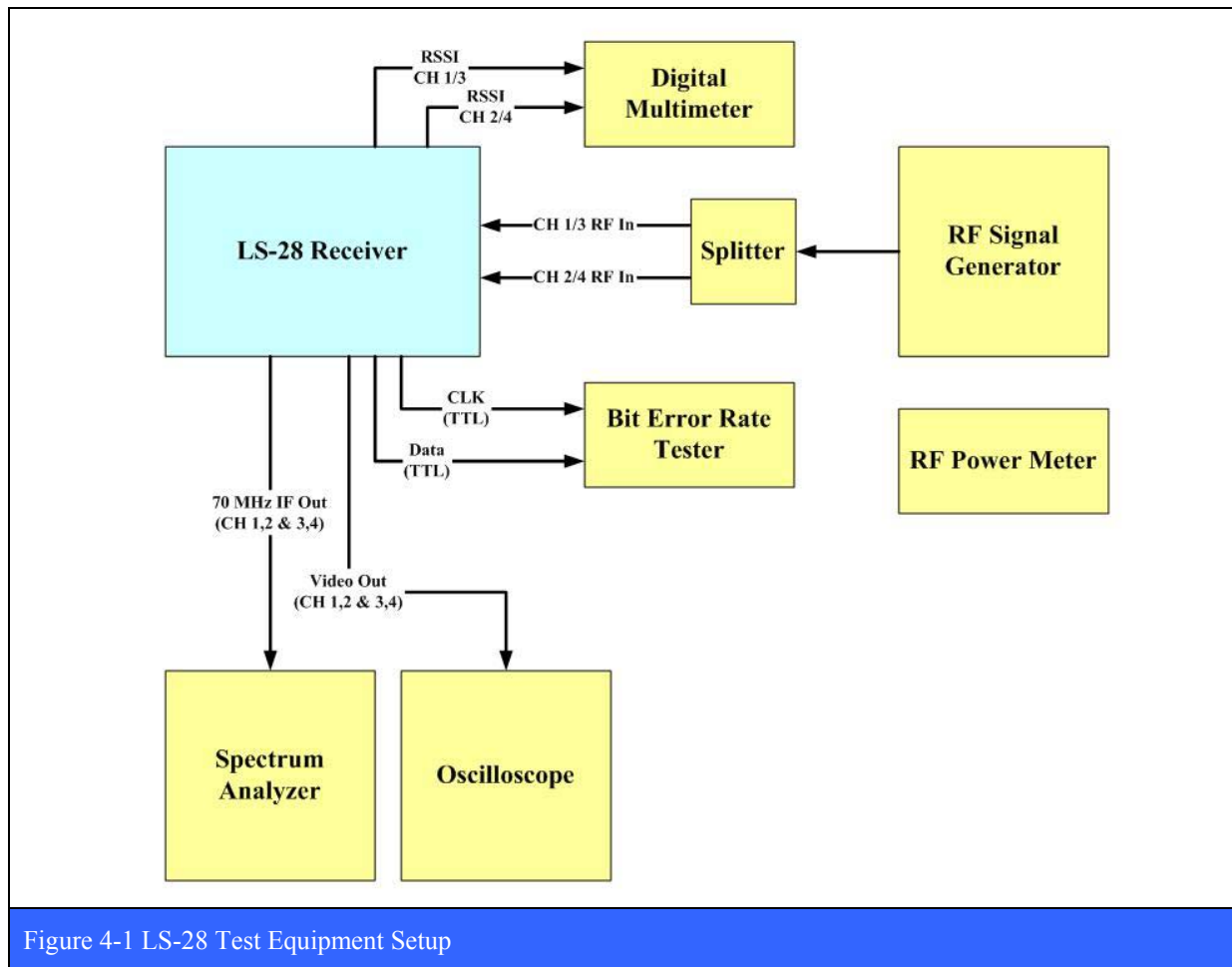
However, if the LS-28 is going to be connected to a network, then it is very highly recommended that the customer does turn on the automatic update feature in the operating system and update the system to the latest security patches. It is also highly recommended that the user periodically runs the Microsoft *Malicious Software Removal Tool* (MRT) and do a complete scan of the system. To run the MRT, open a command prompt window on the

desktop and type MRT followed by return. This program scans the system hard drives for any malicious software (viruses, Trojans, worms, etc.) and alerts/removes the infection in exactly the same way as a third-party anti-virus scanning software would do. There is however a huge difference between the Microsoft MRT and any of the third-party anti-virus scanning software programs. Even though they both do the same function, the third-party tools heavily modify the operating system kernel and other low-level system functions. This may be good for finding computer viruses, but it can, and often is, very bad for the real-time, quasi-deterministic nature of the operating system and how it interacts with third-party hardware like the custom developed Lumistar cards installed in the LS-28 and the LRRS application that talks to them.

Irregardless of the security policies of ones IT department, Lumistar strongly recommends that third-party anti-virus programs **NOT** be installed on the LS-28 system, and that the Microsoft MRT be used instead on a periodic basis.

4.3 Performance Testing

The following tests are designed to verify that the LS-28 system is functional. These tests are also the basis for determining whether or not there has been a major system malfunction, requiring repair actions, including the possible removal and replacement of one or more system CCAs.



The test equipment configuration shown in Figure 4-1 above is used to verify and test the operational and performance characteristics of the LS-28. No specific model numbers for the equipment are specified, but the equipment used should be compatible with testing modern telemetry receivers operating in the 1.4 to 3 GHz frequency band.

4.3.1 Internal Loop-back Test with I/O Signal Verification

The LS-28 is equipped with a powerful multi-mode IF modulator rich with features and capabilities. The IF modulator is ideal for test and checkout of the various demodulators

configured on LS-28. In this test, the operator dismisses the CCP page and from the LRRS launch banner, invokes the test modulator (see paragraph 3.2.1.4.3.1 on page 113). The operator does this for each card group configured in the system. The test modulator is placed in the *Loopback Mode* by checking the checkbox (red circle) in the figure below. The operator then configures the demodulator to match the test modulator settings and then begins checking the various signal outputs on the rear panel assembly (see Figure 4-4 on page 151) using some of the test equipment called out in Figure 4-1 on page 149. The detailed procedure for this test follows below.

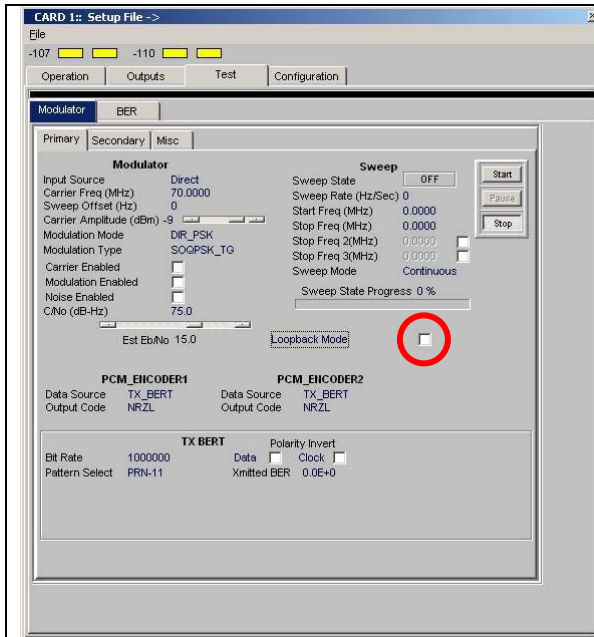


Figure 4-2 Test Modulator Tab - Loopback Mode Checkbox

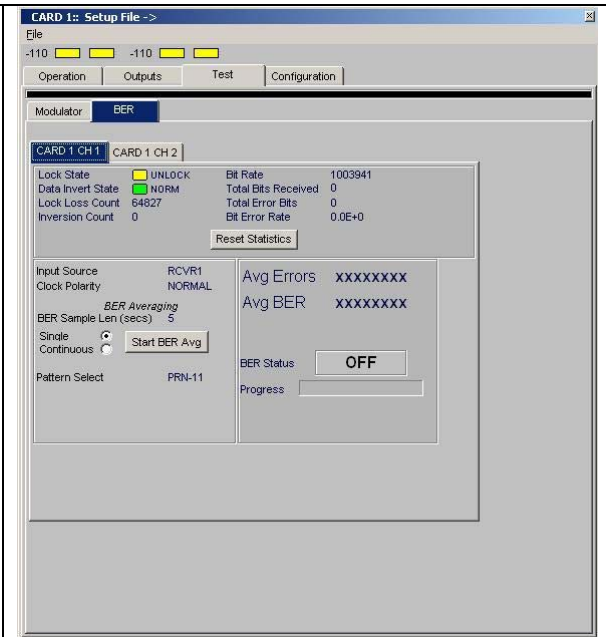


Figure 4-3 Test Tab - BER Sub-tab

Procedure

Step-1

Turn on the LS-28 and after boot up, launch the LRRS application by double clicking on its icon in the desktop.

Step-2

Once the LRRS application has started, dismiss the CCP page (if it is running), and from the main LRRS launch banner, invokes the test modulator (see paragraph 3.2.1.4.3.1 on page 113). Place the test modulator in the Loopback Mode by checking the checkbox (red circle in Figure 4-2 above on page 150). Do this for all card groups configured in the system.

Step-3

On the test modulator tab, set the Tx BERT to a data rate of 1 MBPS using the PRN-11 data pattern. The modulation mode and modulation type should match that set for the demodulator on the Operation tab (see paragraph 3.2.1.4.1 on page 99).

Step-4

On the Operation tab, set the modulation type, data rate, and input code to match the Tx Bert settings from step-3 above.

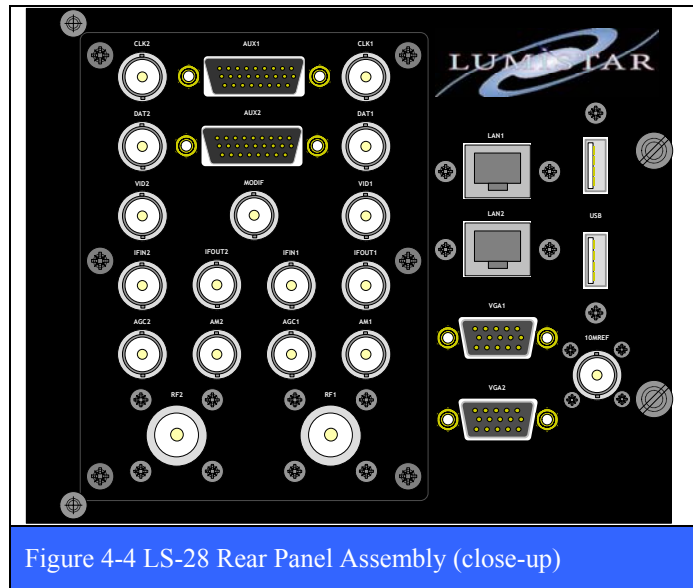


Figure 4-4 LS-28 Rear Panel Assembly (close-up)

Step-5

On the Test Tab, BER sub-tab (see Figure 4-3 on page 150) set up the BERT for a PRN-11 pattern and look to make sure that the BERT is locked up and not taking any errors.

Step-6

Using the test assets shown in Figure 4-1 on page 149, verify all of the digital signals on the rear panel I/O assembly (see Figure 4-4 above) using Table 4-2 below as a guide. Also verify the 70 MHz IF outputs and test modulator (*ModIF*) output with a spectrum analyzer and the Video outputs with an oscilloscope. Do this for all card groups installed in the system.

Step-7

Using an external source of clock and PRN data (from a Bit Error Rate Tester), connect the CLK/Data signals of the BERT to the *AUX1-MODCLK* and *AUX1-MODDATA* signals (see Table 4-2 below). Place the test modulator in the Loopback Mode by checking the checkbox (red circle in Figure 4-2 above on page 150) and then change the Data Source of the PCM_ENCODER1 from TX_BERT to TTL_INPUT_1. Verify that the test modulator (*ModIF*) output signal examined in Step-6 is still present on the spectrum analyzer.

Step-8

Using an external source of clock and PRN data (from a Bit Error Rate Tester), connect the CLK/Data signals of the BERT to the *AUX2-MODCLK* and *AUX2-MODDATA* signals (see Table 4-2 below). Place the test modulator in the Loopback Mode by checking the checkbox (red circle in Figure 4-2 above on page 150) and then change the Data Source of the PCM_ENCODER1 from TX_BERT to TTL_INPUT_2. Verify that the test modulator (*ModIF*) output signal examined in Step-6 is still present on the spectrum analyzer.

Step-9

Repeat steps 7 & 8 for a second card group if one is installed in the system (LS-28-QRS).

Table 4-2 Functional Verification of Outputs and GUI Control		
Connector	Programmed Function for Test	Test
CLK1	Demodulator Clock Output	Verify Signal Present
Data1	Demodulator Data Output	Verify Signal Present
Video1	Analog FM Demodulator Output	Verify Signal Present
IF Out 1	70 MHz IF Output	Verify Signal Present
IF In 1	External 70 MHz IF Input	Select Input, Verify Lock
AM1	Demodulated AM Output	Verify Signal Present, Adjust Amplitude, Note Frequency
AGC1	Downconverter Power Level Signal	Verify Signal Present, Level Changes With Input RF Level
RF1	Microwave RF Input	Verify Signal Detected in GUI
CLK2	Demodulator Clock Output	Verify Signal Present
Data2	Demodulator Data Output	Verify Signal Present
Video2	Analog FM Demodulator Output	Verify Signal Present
IF Out 2	70 MHz IF Output	Verify Signal Present
IF In 2	External 70 MHz IF Input	Select Input, Verify Lock
AM2	Demodulated AM Output	Verify Signal Present, Adjust Amplitude, Note Frequency
AGC2	Downconverter Power Level Signal	Verify Signal Present, Level Changes With Input RF Level
RF2	Microwave RF Input	Verify Signal Detected in GUI
ModIF	Test Modulator 70 MHz IF Output	Verify Signal Present when enabled
AUX1 – MODCLK	Test Modulator External TTL CLK Input	Enable Test Modulator, Select External Data Input, Verify Functionality
AUX1 – DODDAT	Test Modulator External TTL Data Input	Enable Test Modulator, Select External Data Input, Verify Functionality
AUX1 – DAT(+)	Differential Demodulator Data Output	Verify Signal Present
AUX1 – DAT(-)	Differential Demodulator Data Output	Verify Signal Present
AUX1 – CLK(+)	Differential Demodulator CLK Output	Verify Signal Present
AUX1 – CLK(-)	Differential Demodulator CLK Output	Verify Signal Present
AUX1 – QDAT	Demodulator Q Data Output	Verify Signal Present
AUX1 – QCLK	Demodulator Q CLK Output	Verify Signal Present
AUX2 – MODCLK	Test Modulator External TTL CLK Input	Enable Test Modulator, Select External Data Input, Verify Functionality
AUX2 – DODDAT	Test Modulator External TTL Data Input	Enable Test Modulator, Select External Data Input, Verify Functionality
AUX2 – DAT(+)	Differential Demodulator Data Output	Verify Signal Present
AUX2 – DAT(-)	Differential Demodulator Data Output	Verify Signal Present
AUX2 –	Differential Demodulator CLK Output	Verify Signal Present

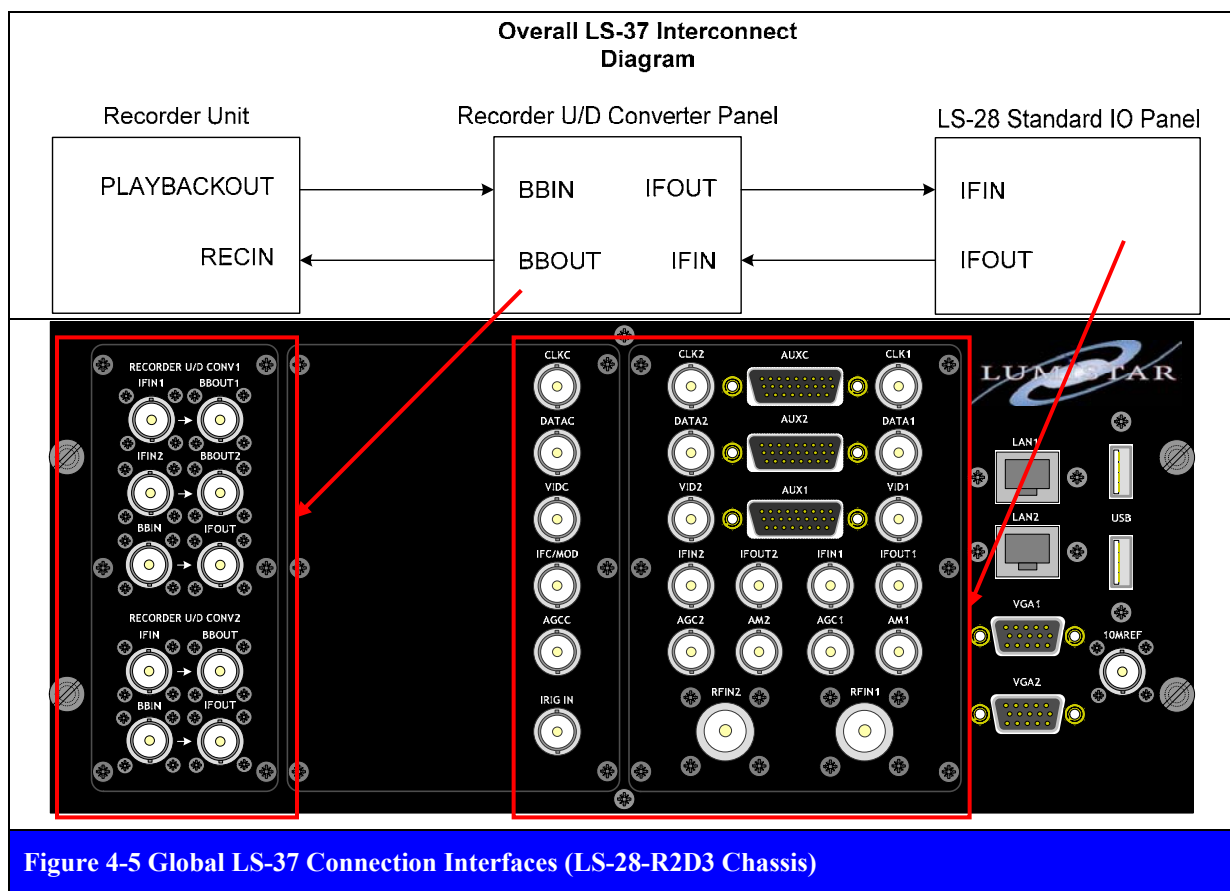
Table 4-2 Functional Verification of Outputs and GUI Control		
Connector	Programmed Function for Test	Test
CLK(+)		
AUX2 – CLK(-)	Differential Demodulator CLK Output	Verify Signal Present
AUX2 – QDAT	Demodulator Q Data Output	Verify Signal Present
AUX2 – QCLK	Demodulator Q CLK Output	Verify Signal Present
10M Ref	10 MHz External Reference Input	Verify Functionality When Signal is Present

4.3.1.1 LS-37 Telemetry Recorder Up & Downconverter I/O Signal Verification (for the -R2D3 Only)

The LS-37 Telemetry Recorder Up/Down-Converter (UDC) is a collection of hardware and software components that together form a system that supports the use of legacy FM, as well as the latest digital telemetry data recorders found on today's test ranges. The hardware elements include: the Lumistar LS-37-P95 and LS-35-P50 Recorder Up/Down Converter PCI cards, and a customized rear panel I/O connector assembly designed to be integrated into the rear panel of the Lumistar LS-28, 4U family of Chassis type receivers. The software element - the LS-37 UDC application and the custom firmware loaded into the FPGA on each LS-37 card, perform the up and down conversion signal processing.

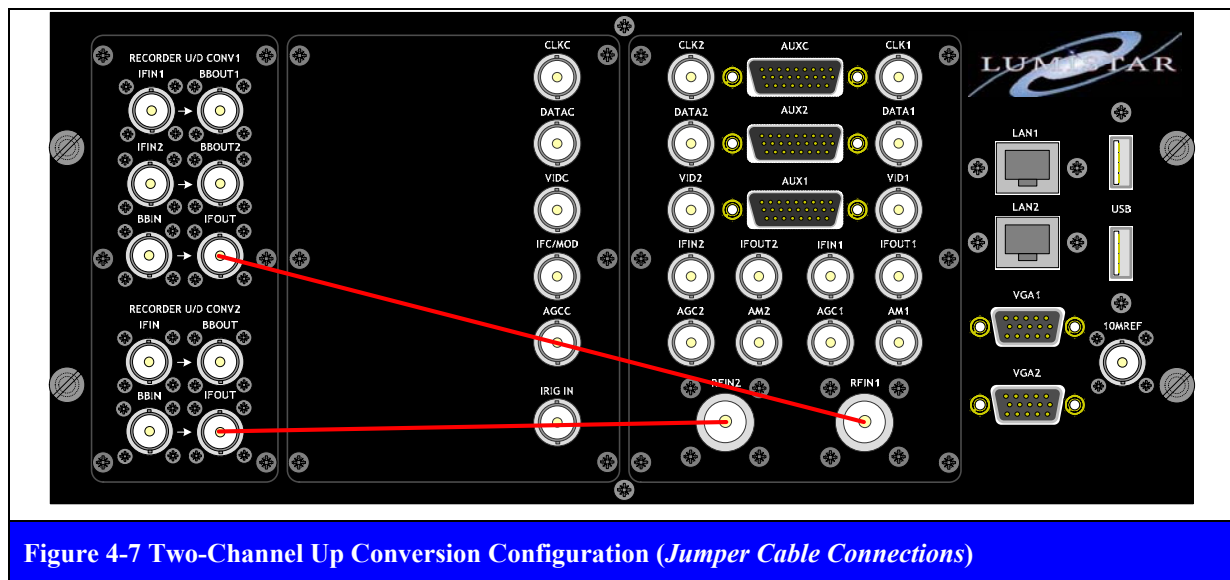
The UDC functionality in the LS-37 is standalone, meaning that there are no internal connections inside the chassis between the LS-37 hardware and the LS-28 radio hardware. All such connections must be made externally via coaxial cabling between the UDC I/O panel and the LS-28 Standard I/O panel as shown in Figure 4-5 below. Specific examples of this external cabling are discussed in paragraphs 4.3.1.1.1 and 4.3.1.1.2 on pages 154 and 155.

The LS-37 configuration in the LS-28-R2D3 is the most common among the many that are possible with this technology. The LS-28-R2D3 is an advanced, multi-mode, multi-band, two-channel receiver/combiner that provides both independent and combined channel output signals. In its most common use scenario, the LS-28-R2D3 ingests the two RF inputs coming from the Left and Right hand feeds of a polarized tracking antenna. It first down converts these two signals to a 70 MHz intermediate frequency (IF), both of which come out the back of the receiver. Next it demodulates each of the two independent IF signals down to both baseband and further down to the final clock and data TTL outputs for each channel. At the same time, it is also diversity combining the two independent 70 MHz IF signals, with the resulting combined 70 MHz IF also coming out the back of the receiver. This combined 70 MHz IF is then demodulated down to both baseband and further down to the final clock and data TTL outputs for the combined channel.



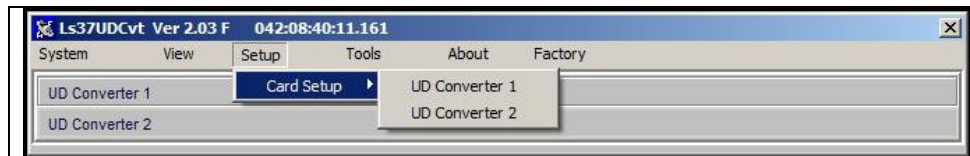
4.3.1.1.1 Three Channel Down Conversion (LH, RH, & Combined)

The first use case of the LS-37 UDC in the Lumistar LS-28-R2D3 involves recording the actual Left Hand, Right Hand, and Combined 70 MHz IF output signals produced by the receiver during an actual mission. In this scenario, the three 70 MHz IF signals are down converted by the LS-37 hardware to some much lower center frequency that is subsequently archived by a recording device. To support this scenario, the IF outputs of the LS-28 must be connected via external coax cables to the inputs of the LS-37 as shown in Figure 4-6 below. Also the three Baseband Outputs of the LS-37 must be connected to the input channels of the recording device.

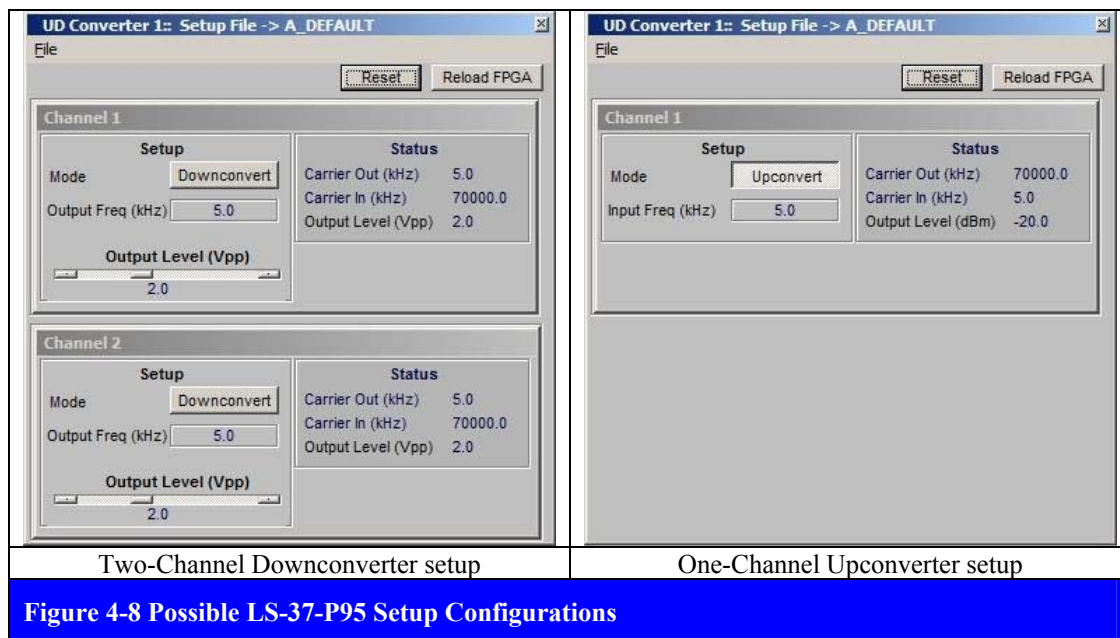


4.3.1.1.3 The Standalone LS-37 Application

After launching the LS-37 standalone application, configure the cards by selecting the Setup command. The Setup command has one sub-command; *Card Setup*. This sub-command in turn will produce a list of all LS-37 cards installed in the system. The typical configuration (shown below) will consist of one LS-37-P95 and one LS-37-P50 card. To setup each card, the user selects the card from the list. The resulting setup windows for the LS-37-P95 are shown below in Figure 4-8. The setup windows for the LS-37-P50 are shown below in Figure 4-9 on page 157.



The LS-37-P95 card can support either two separate down converter channels (each independent of the other), OR one up converter channel. The two channel downconverter scenario is shown below left. The one channel upconverter case (LS-37-P50) is shown below right.

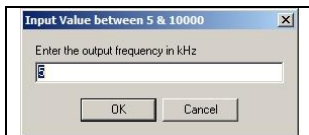


At the top of each card setup window (regardless of mode), are two buttons; *Reset* and *Reload FPGA*. The **Reset** button causes the various software & firmware (FPGA) algorithms involved in up/down conversion to restart to their initial states and begin running. The **Reload FPGA** button does what the name implies; it forces the FPGA on the LS-37 to reload firmware after the application has started running. In general, neither button will ordinarily be invoked by the user during normal operation. They are present in the GUI for

test/troubleshooting scenarios and should only be used as directed by Lumistar customer support.

Below the Reset & Reload FPGA buttons on the card setup GUI are separate *Setup* and *Status* areas. The *Setup* area will have a single button that indicates the current mode state (**Upconvert** or **Downconvert**). This button acts as a toggle – click on it to change the mode. Below the mode button is a numeric display of the frequency currently associated with the mode. In Upconvert mode, the *Input* Frequency (MHz) will be displayed. In Downconvert mode, the *Output* Frequency (MHz) will be displayed. Irregardless of mode, the user may change the frequency value by mouse clicking on the numeric value. This will invoke the list of pre-set frequencies shown right. To select one of the pre-set frequencies, simply click on it. To enter a custom value, mouse click on the *Custom* entry. This will invoke a numeric input box as shown below. Enter a frequency value (kHz) between 50 kHz and 10 MHz and click on the OK button. This will result in the update of the displayed numeric frequency value in the GUI. Also be aware that the numeric *bandwidth* associated with any selected frequency will be 70% of the entered frequency value. Below the numeric frequency display (and only when in Downconverter mode) is a slider bar control that allows the user to set the voltage Output Level (Vpp) of the converted signal. The user may adjust the Output Level between 1.0 Vpp and 3.0 Vpp, with 2.0 Vpp being the default.

- ✓ Custom
- 112.5 kHz
- 150.0 kHz
- 225.0 kHz
- 300.0 kHz
- 450.0 kHz
- 600.0 kHz
- 900.0 kHz
- 1.2 MHz
- 1.5 MHz
- 1.8 MHz
- 2.1 MHz
- 2.4 MHz
- 3.6 MHz
- 4.8 MHz
- 7.2 MHz
- 9.6 MHz



To the right of the Setup area in the GUI is the *Status* area. The Status area has numerical displays for parameters associated with the particular mode. In Upconverter mode, the *Carrier Output* (kHz) frequency (70 MHz), *Carrier Input* (kHz) frequency, and *Output Level* (dBm) are displayed. In Downconverter mode, the *Carrier Output* (kHz) frequency (70 MHz), *Carrier Input* (kHz) frequency, and *Output Level* (Vpp) are displayed.

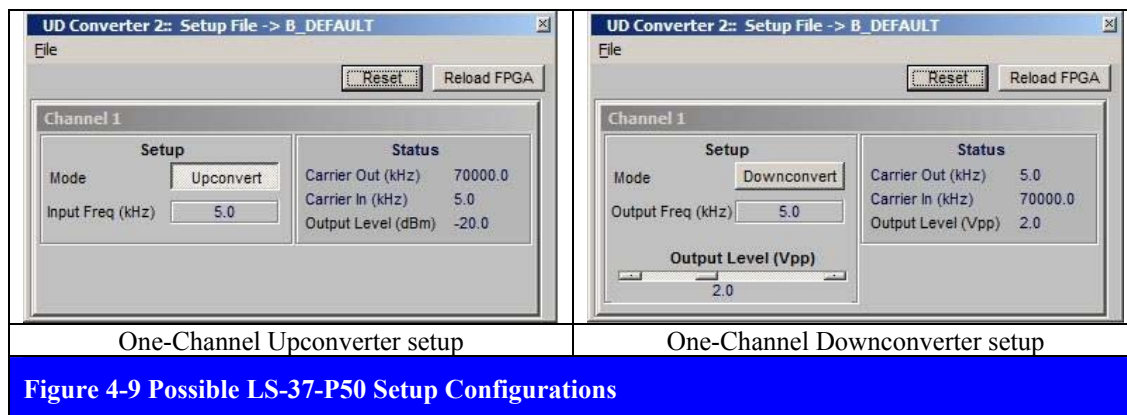


Figure 4-9 Possible LS-37-P50 Setup Configurations

Procedure

(Downconvert Test)

Step-1

Turn on the LS-28 and after boot up, launch the LS-37 application by double clicking on its icon in the desktop.

Step-2

Next launch the LRRS application by double clicking on its icon in the desktop.

Step-3

Once the LRRS application has started, dismiss the CCP page (if it is running), and from the main LRRS launch banner, invoke the Operation tab (see paragraph 3.2.1.4.1.1 on page 99) and set the tuner frequency for both channels in the group to any single frequency that the LS-28 is capable of tuning. Set the modulation mode to Combined FM (a firmware load change may be required), and set the data rate to 1 MBPS.

Step-4

Set up the RF signal generator to output the single frequency set in step-3. Set the output power level of the generator to -50 dBm. Then turn on FM modulation of this carrier frequency. Set the frequency deviation to 350 KHz on the signal generator and FM modulate the carrier with a 1 MBPS data stream using a PRN pattern of ones choosing. Connect the RF output of the signal generator to a two-way power splitter as shown in Figure 4-1 on page 149. Using the RF power meter, measure the output of channel 2 and re-adjust the level to once again be -50 dBm (re-adjust the RF generator output power level as needed). Connect the two output of the splitter to the CH1 and CH2 inputs of the LS-28.

Step-5

Connect the *IFOUT1* and *IFOUT2* [70 MHz IF outputs for channel 1 & 2] signals shown in Figure 4-6 on page 155 to the *IFIN1* and *IFIN2* [70 MHz IF inputs for channel 1 & 2 on the RECORDER U/D CONVTR1 I/O panel] using two BNC jumper cables.

Step-6

From the LS-37 application, set UD Converter 1 to downconvert mode for both channels 1 and 2. Set the Output Frequency (kHz) for both channels to 2.1 MHz. See Figure 4-8 on page 156 for details.

Step-7

Connect the *BBOUT1* [baseband output for channel 1] signal shown in Figure 4-6 on page 155 to the spectrum analyzer (tuned for 2.1 MHz) and inspect the spectral envelope shape. Make sure that the frequency span of the analyzer is slightly wider than the SAW filter value shown in the RF block of the Operation tab (see Figure 3-22 on page 100). Adjust the Output Level (Vpp) slider in the LS-37 GUI and note the effect on the spectral envelope. Repeat this step for the *BBOUT2* signal.

Step-8

From the LS-37 application, set UD Converter 2 to downconvert mode. Set the Output Frequency (kHz) for both channels to 2.1 MHz. See Figure 4-8 on page 156 for details.

Step-9

Connect the *IFC/MOD* [Combined 70 MHz IF output] signal shown in Figure 4-6 on page 155 to the *IFIN1* [70 MHz IF input for channel 1 on the RECORDER U/D CONVTR2 I/O panel] using a BNC jumper cable.

Step-10

Connect the *BBOUTI* [baseband output for channel 1] signal shown in Figure 4-6 on page 155 to the spectrum analyzer (tuned for 2.1 MHz) and inspect the spectral envelope shape. Make sure that the frequency span of the analyzer is slightly wider than the SAW filter value shown in the RF block of the Operation tab (see Figure 3-22 on page 100). Adjust the Output Level (Vpp) slider in the LS-37 GUI and note the effect on the spectral envelope.

**Procedure
(Upconvert Test)**

Step-1

Turn on the LS-28 and after boot up, launch the LS-37 application by double clicking on its icon in the desktop.

Step-2

Next launch the LRRS application by double clicking on its icon in the desktop.

Step-3

From the LS-37 application, set UD Converter 1 to Upconvert mode for channels 1. Set the Input Frequency (kHz) for channel 1 to 2.1 MHz. See Figure 4-8 on page 156 for details.

Step-4

Set up the RF signal generator to output the single frequency set in step-3 (2.1 MHz). Set the output power level of the generator to -30 dBm. Then turn on FM modulation of this carrier frequency. Set the frequency deviation to 350 KHz on the signal generator and FM modulate the carrier with a 1 MBPS data stream using a PRN pattern of ones choosing. Connect the RF output of the signal generator to the *BBIN* [baseband output for channel 1] signal as shown in Figure 4-7 on page 155.

Step-5

Connect the *IFOUT* [70 MHz IF outputs for channel 1] signal shown in Figure 4-7 on page 155 to the spectrum analyzer (tuned for 70 MHz) and inspect the spectral envelope shape.

Make sure that the frequency span of the analyzer is slightly wider than the SAW filter value shown in the RF block of the Operation tab (see Figure 3-22 on page 100).

Step-6

Connect the *IFOUT* [70 MHz IF outputs for channel 1] signal shown in Figure 4-7 on page 155 to the *RFIN1* [RF input for channel 1 of the LS-28] and from the LRRS application GUI, tune channel 1 for 70 MHz input frequency. Note that the system should lock up on this signal and show no errors in the BERT.

Step-7

From the LS-37 application, set UD Converter 2 to Upconvert mode for channels 1. Set the Input Frequency (kHz) for channel 1 to 2.1 MHz. See Figure 4-8 on page 156 for details.

Step-8

Set up the RF signal generator to output the single frequency set in step-7 (2.1 MHz). Set the output power level of the generator to -30 dBm. Then turn on FM modulation of this carrier frequency. Set the frequency deviation to 350 KHz on the signal generator and FM modulate the carrier with a 1 MBPS data stream using a PRN pattern of ones choosing. Connect the RF output of the signal generator to the *BBIN* [baseband output for channel 1] signal as shown in Figure 4-7 on page 155.

Step-9

Connect the *IFOUT* [70 MHz IF outputs for channel 1] signal shown in Figure 4-7 on page 155 to the spectrum analyzer (tuned for 70 MHz) and inspect the spectral envelope shape. Make sure that the frequency span of the analyzer is slightly wider than the SAW filter value shown in the RF block of the Operation tab (see Figure 3-22 on page 100).

Step-10

Connect the *IFOUT* [70 MHz IF outputs for channel 1] signal shown in Figure 4-7 on page 155 to the *RFIN2* [RF input for channel 2 of the LS-28] and from the LRRS application GUI, tune channel 2 for 70 MHz input frequency. Note that the system should lock up on this signal and show no errors in the BERT.

4.3.2 AM, AGC, and RF Signal Strength Indication

The LS28 series receiver front end provides an automatically controlled gain mode (AGC mode) that varies total receiver gain as a function of the RF input power within the IF bandwidth value. This is typically the normal operating mode of the receiver during flight test / telemetry operations. Each channel of the receiver produces an AGC Voltage signal that can provide information relative to the RF signal strength at the input to the receiver channel. The AGC Voltage signal is used internally by the receiver to set the absolute gain of various RF and IF components in the signal path, as well as determine absolute signal path. When the signal level, which typically can vary by 80 dB or more in a normal flight test application, is

very high at the RF input the total receiver gain is alternatively set low to prevent over-driving the components in the receiving chain.

The AGC signal has historically had several uses external to the receiver. The AGC signal can be provided to an external antenna control unit (ACU) for auto-tracking applications in servo controlled antenna systems (usually along with the AM signal). Other uses of the AGC signal include RSSI (received signal strength indicator) wherein the AGC signal is provided to an external “strip-chart” or digital recording device that creates a time varying plot of voltage versus time proportional to receiver signal strength. Note: This RSSI plotting function can also be realized by the internal “Log receiver Parameters” function described in paragraph 3.2.1.5 on page 95.

The AGC signal is linearly proportional to the RF power level at the input to the receiver. The maximum range of the AGC signal provided by the LS28 receiver is from -4V to +4V. The AGC signal can be programmed for a positive slope or negative slope as a function of rising/falling RF power. The linearity ($\Delta\text{db} / \Delta\text{V}$) of the AGC voltage versus RF power is typically within 50 mV of a perfect straight line (see paragraph 1.2.5.1 on page 42). The more linear the AGC voltage versus RF power, the better the auto-tracking performance or accuracy of the RSSI recorded versus time plot (RSSI typically used for post-mission analysis).

Historically, most legacy ACUs would be set up to accept an AGC signal with a fixed -20 dB per volt slope. The receiver AGC signal would provide 0 volts at the minimum RF level (typically at the system noise floor when antenna is receiving nothing but “Cold Sky” signal power) and would provide -4 volts with an RF input of 80 dB above the Cold Sky level. Most legacy analog receivers did not have “programmable AGC”, thus they were usually “factory fixed” to always provide the -20 dB/V slope. Modern ACU and digital receivers (such as the LS28) both provide programmable AGC voltages, so it is important in auto-tracking applications to insure they are working (calibrated) together.

This test verifies the AM and AGC signals on the rear I/O panel (see Figure 4-4 on page 151) as well as the RF signal strength GUI indicators are functioning. The operator uses some of the test equipment called out in Figure 4-1 on page 149. The detailed procedure for this test follows below.

Procedure

Step-1

Turn on the LS-28 and after boot up, launch the LRRS application by double clicking on its icon in the desktop.

Step-2

Once the LRRS application has started, dismiss the CCP page (if it is running), and from the main LRRS launch banner, invoke the Operation tab (see paragraph 3.2.1.4.1.1 on page 99)

and set the tuner frequency to any single frequency that the LS-28 is capable of tuning. Do this for all card groups configured in the system.

Step-3

Set up the RF signal generator to output the single frequency set in step-2. Set the output power level of the generator to -50 dBm. Then turn on AM modulation of this carrier frequency. Set the modulation depth on the signal generator to 50% & the AM frequency to 400 Hz. Set the *AM LPF* setting on the Output Tab (see paragraph 3.2.1.4.2.5 on page 111) to match the 400 Hz modulation. Tune all channels in the LS-28 to this same frequency and using an oscilloscope, verify the presence of the sine wave on all of the AM output signals (AM1, AM2, etc.). Verify control of the AM Output Level by using the slider control to manually alter the output voltage level of the AM output. Note that no additional feedback is provided in the configuration display as the slider is adjusted. The actual voltage levels of the AM signal will need to be measured via the oscilloscope as the slider is adjusted. Lastly, verify that the *AM Freq (Hz)* and *AM Index (%)* parameters shown in the RF block of the Operation tab (see paragraph 3.2.1.4.1 on page 99) are showing values consistent with 50% modulation at 400 Hz.

Step-4

On the RF signal generator, turn off the AM modulation. Verify that the *RF Level (dBm)* shown in the RF block in the Operation tab indicates the correct input power level and that this level is also indicated on the vertical bar graph. Do this for all channels in the LS-28. Using a DMM, measure the AGC signals voltage (AGC1, AGC2, etc.) on the rear I/O panel. Verify that the voltage level changes as the input power level is adjusted up and down on the signal generator.

4.3.3 Receiver Threshold & Combiner Improvement

This test verifies that the LS-28 receiver can produce error-free data when the RF input power levels are just above the threshold level for a given data rate and modulation format, and that when the unit is in combined mode, there is a demonstrable improvement in BER performance (better than 2 dB) at the same threshold input RF power level. In other words, in combined mode, the RF input power level that just begins to produce bit errors will be at least 2 dB lower than the corresponding power level in independent mode that produces the same bit error rate. The operator will use some of the test equipment called out in Figure 4-1 on page 149. The detailed procedure for this test follows below.

Procedure

Step-1

Turn on the LS-28 and after boot up, launch the LRRS application by double clicking on its icon in the desktop.

Step-2

Once the LRRS application has started, dismiss the CCP page (if it is running), and from the main LRRS launch banner, invoke the Operation tab (see paragraph 3.2.1.4.1.1 on page 99) and set the tuner frequency for both channels in the group to any single frequency that the LS-28 is capable of tuning. Set the modulation mode to Independent FM (a firmware load change may be required), and set the data rate to 1 MBPS. Do this for all card groups configured in the system.

Step-3

Set up the RF signal generator to output the single frequency set in step-2. Set the output power level of the generator to -50 dBm. Then turn on FM modulation of this carrier frequency. Set the frequency deviation to 350 KHz on the signal generator and FM modulate the carrier with a 1 MBPS data stream using a PRN pattern of ones choosing. Connect the RF output of the signal generator to a two-way power splitter as shown in Figure 4-1 on page 149. Using the RF power meter, measure the output of channel 2 and re-adjust the level to once again be -50 dBm (re-adjust the RF generator output power level as needed). Connect the two output of the splitter to the CH1 and CH2 inputs of the LS-28.

Step-4

Connect the *IFOUT2* [70 MHz IF output for channel 2] signal shown in Figure 4-4 on page 151 to the spectrum analyzer and inspect the spectral envelope shape. Make sure that the frequency span of the analyzer is slightly wider than the SAW filter value shown in the RF block of the Operation tab (see Figure 3-22 on page 100). Now, briefly disconnect the RF input to channel 2 (or better yet, turn off the carrier on the signal generator) and inspect the resulting spectral display and make sure that there are no spurious signals showing up in-band. If there are any spurious signals, choose a different tuner frequency and start the procedure over again from Step-3

Step-5

Connect the *CLK2* and *DAT2* signals on the rear I/O panel (see Figure 4-4 on page 151) to the clock and data inputs of the external bit error rate tester as shown in Figure 4-1 on page 149. Configure the external BERT to receive a 1 MBPS data stream with the same data pattern set on the signal generator in Step-3.

Step-6

With the 1 MBPS FM signal now applied to both RF channels of the LS-28, verify that the input RF power levels for each channel are shown correctly (-50 dBm) in the RF block of the Operation tab (see Figure 3-22 on page 100). Verify that the Carrier Lock indicator and Bit Sync Lock indicator are Green indicating a lock state (Yellow indicates an unlocked state). Finally, verify that the external BERT is in lock with the PRN pattern and that there are no error being taken.

Step-7

Begin slowly lowering the output RF power level of the signal generator until the external BERT begins taking errors at a rate of 1×10^{-6} BER. On the LS-28, this should correspond to

an input RF power level of approximately -96.5 dBm (for 1 MBPS FM). Make note of the actual signal generator output power level setting.

Step-8

From the main LRRS launch banner, invoke the Configuration tab - User sub-tab (see paragraph 3.2.1.4.4.1 on page 122) and set the *Combiner Mode* to Pre-D. This should immediately result in the BER reported by the external BERT to return to ZERO errors. The combined output for Pre-D is on channel 2 (Post-D combined output is on channel 1).

Step-9

Again, begin slowly lowering the output RF power level of the signal generator until the external BERT again begins taking errors at a rate of 1×10^{-6} BER. On the LS-28, this should correspond to an input RF power level of approximately -99.0 dBm (for 1 MBPS FM). As before, make note of the actual signal generator output power level setting and subtract this value from the value obtained in Step-7 above. The delta in the power level should be at least 2 dB, and it typically 2.5 dB¹⁵.

Step-10

Repeat this procedure for any additional card groups installed in the system.

4.4 Recurring Maintenance

Recurring maintenance includes updating the operational firmware and software that enables the LS-28 to function as a telemetry receiver. These updates are required to enhance and/or add functionality and fix problems that are discovered. These firmware and software updates are distributed to the user in several ways. If no internet connection is available, the user can receive a CD disk upon request. The quickest and easiest way is via the Internet. Periodically, owners of LS-28 systems will receive an email message from Lumistar Customer Support that contains a “web link” to the Lumistar FTP site. The web link is an HTTP hyperlink that points to a web page address and the user simply clicks on the link in the message and is taken to the Lumistar FTP site where a special download area (unique to that specific customer) will have been setup for the update. The user simply clicks a button on this web page and the download of the update begins. The user then takes the update and installs it on the system(s) as directed by Lumistar Customer Support. The different kinds of updates are described further in the following numbered paragraphs.

4.4.1 Updating the Operational Software

The LS-28 operational software/firmware includes the LRRS application, the LS-35 firmware, and the LS-27 DSP firmware. Each is described as follows:

¹⁵ Note: If a combiner improvement of greater than 3 dB is achieved (3 dB is the theoretical maximum), do not despair, the 1×10^{-6} BER at 1 MBPS does not produce that many errors for a given unit of time and the resulting combiner improvement calculation is not that accurate because not enough errors were counted (to be statistically significant, at least 100 errors need to be counted). The remedy, count 100 errors if one has the time, or increase the data rate. Otherwise, this test could take a long time.

4.4.1.1 Updating the LRRS application

When the LRRS application is installed on the LS-28 for the first time, the installer creates a dedicated directory structure on the hard drive of the system. This directory, designated Lrrs_3x, is shown in Figure 4-10 below.

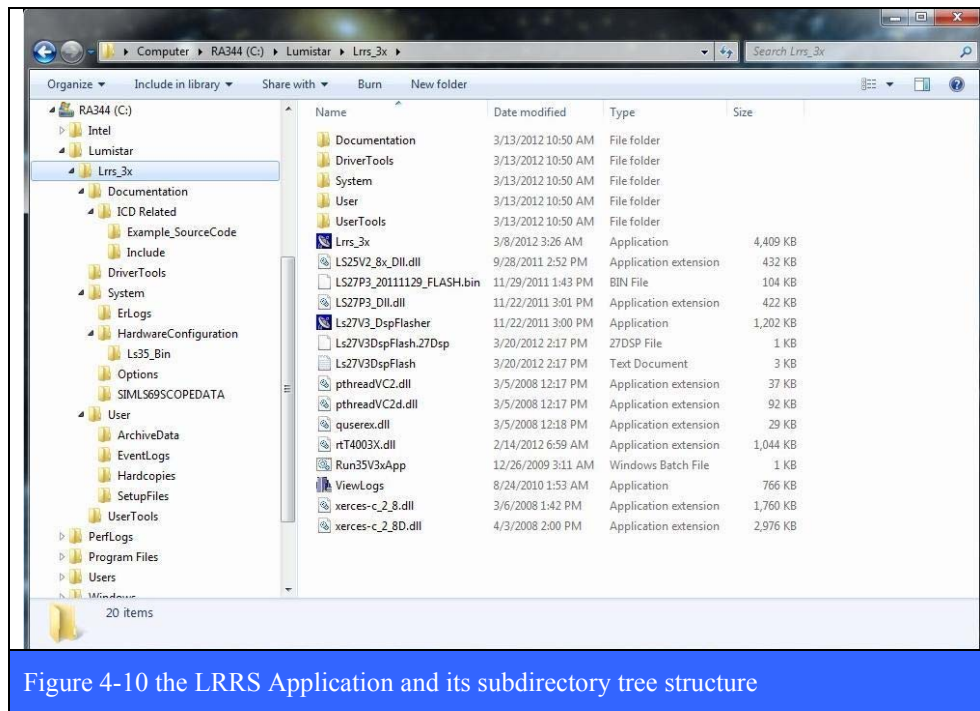


Figure 4-10 the LRRS Application and its subdirectory tree structure

In some cases, the update will consist of a new install program that the user runs on the target machine. The update will automatically change all of the application files in their respective subdirectories. The second form of an update will include individual LRRS files that the user manually copies into select subdirectories of the LRRS directory tree. Specific instructions as to what individual file goes where will be provided by Customer Support along with the update.

4.4.1.2 Updating the LS-35 Firmware Files

Like the Chameleon, the LS-35 can take on multiple functional personalities via different firmware loads. The respective functional capabilities within a personality are individually enabled or disabled via a firmware license created at the factory at the time of order. The addition of new functions and capabilities after the product is delivered is a simple matter of updating the firmware license files installed on the target machine where the LS-35 card is installed. All LS-35 license files are located within the LRRS directory tree in the “Ls35_Bin” subdirectory shown in Figure 4-11 below (red oval). Updating the firmware is a simple matter of replacing the old firmware files with the new files from the update¹⁶.

¹⁶ The user would be well advised to archive the old LS-35 firmware files in a safe place on the system just in case it is necessary to fall back to the previous version for some reason.

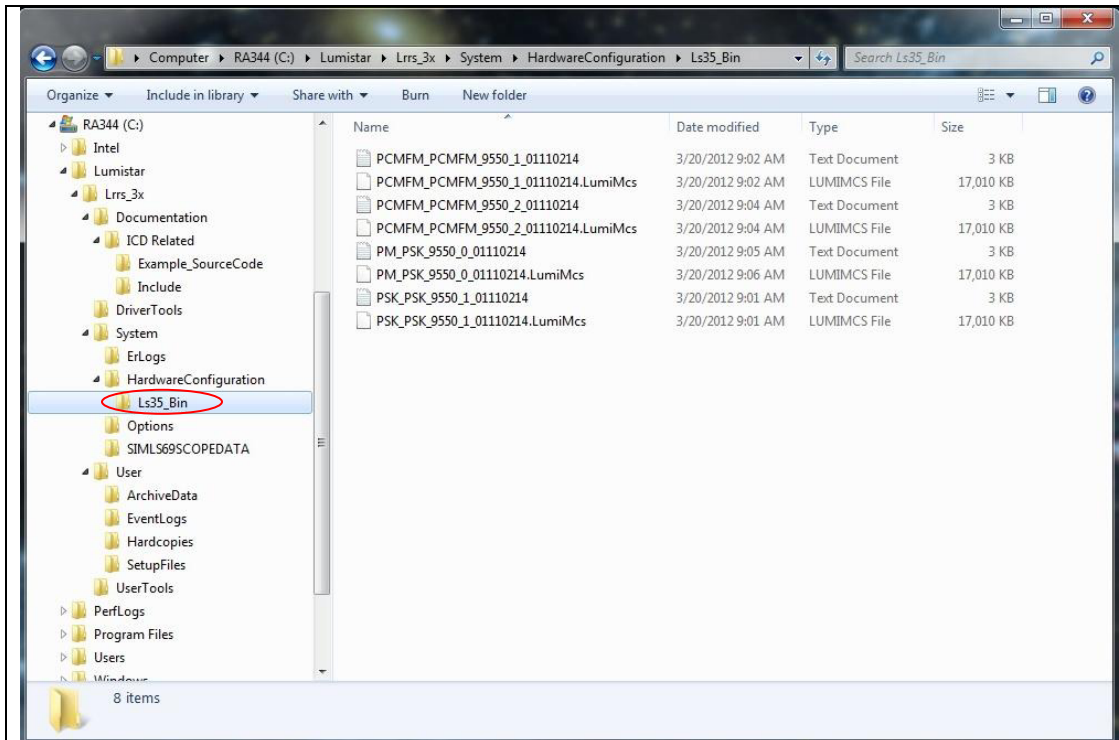


Figure 4-11 the LS-35 Firmware Files & Their Location

4.4.1.3 Updating the LS-27 DSP Firmware

After May, 2011, it became possible to update the DSP firmware in the LS-27 by running a special re-flashing program on the target machine. The re-flashing program (Ls27V3DspFlasher.exe) is located in the LRRS root directory (shown in Figure 4-10), and when invoked, produces the setup window shown left in Figure 4-12 below. From the setup window the user selects the updated DSP File by clicking on the file select button (red square) and entering the file name in the resulting pop-up window (shown below right). The user then checks the *Flash Update Enable* checkbox and then clicks the **Flash DSP** button that appears to begin the update. **It is critically important that this process NOT be interrupted, or else the LS-27 will be turned into a brick and have to be returned to the factory for repair.** Also note, that the LRRS application must not be running at the same time as the re-flashing application is launched.

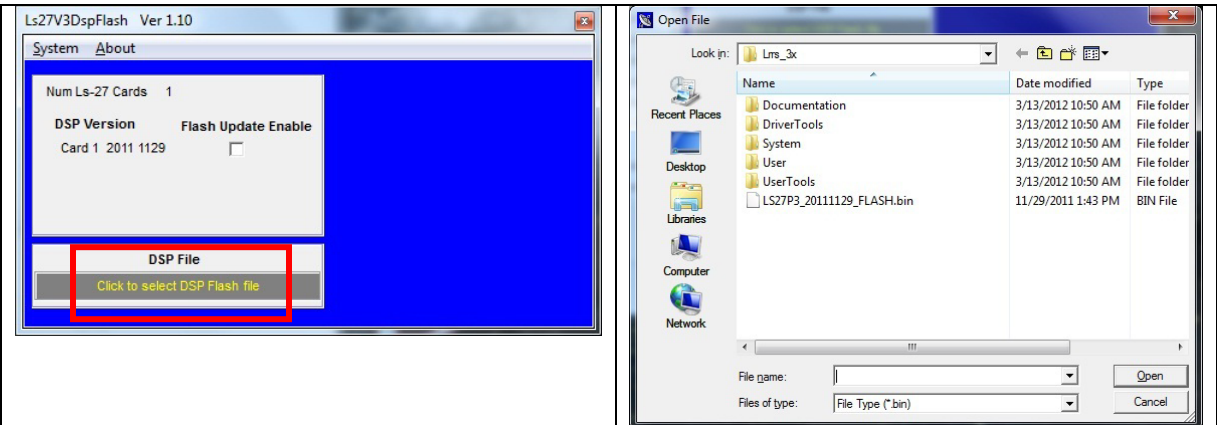


Figure 4-12 the LS-27 DSP Firmware Re-flashing Program

5 Appendix A - List of Abbreviations & Acronyms

The following is a list of abbreviations and acronyms used in this manual.

AC - Alternating Current
ACU – Antenna Control Unit
ADC - Analog to Digital Converter
AGC - Automatic Gain Control
AM - Amplitude Modulation
AQPSK - Asynchronous Quadrature Phase Shift Keying
ATX -Advanced Technology eXtended
AUQPSK - Asynchronous Unbalanced Quadrature Phase Shift Keying
AWGN - Additive White Gaussian Noise
BER - Bit Error Rate
BERT - Bit Error Rate Tester
BIOL – Bi-phase Level
BIOM – Bi-phase Mark
BIOS – Bi-phase Space
BMP - Bit Mapped Photo
BPS - Bits Per Second
BPSK - Binary Phase Shift Keying
BW - Band Width
CCA - Circuit Card Assembly
CCP - Common Control Page
CD - Compact Disk
CHKDSK - Check Disk
CPM - Continuous Phase Modulation
CPU - Central Processing Unit
DAC - Digital to Analog Converter
DAGC - Digital AGC (Automatic Gain Control)
DBIOM - Differential Bi-phase Mark
DBIOS - Differential Bi-phase Space
DC - Direct Current
DMM - Differential Miller Mark
DMM - Digital Multi Meter
DMM2 - Differential Miller Squared (MxM)
DMS - Differential Miller Space
DSP - Digital Signal Processing
DSPE - Digital Signal Processing Engine
DVD - Digital Video Disk
EMI - Electro Magnetic Interference
FEC - Forward Error Correction
FFT - Fast Fourier Transform
FIR - Finite Impulse Response

FM - Frequency Modulation
FPGA - Field Programmable Gate Array
FTP - File Transfer Protocol
GB - Giga Byte
GND - Ground
GPU - Graphic Processing Unit
GUI - Graphical User Interface
HTTP - Hypertext Transfer Protocol
IBM - International Business Machines
ID - Identification
IDE - Integrated Drive Electronics
IF - Intermediate Frequency
IRIG - Inter Range Instrumentation Group
JPEG - Joint Photographic Experts Group
LBW - Loop Band Width
LDPS - Lumistar Data Processing System
LED - Light Emitting Diode
LNA - Low Noise Amplifier
LO - Local Oscillator
LP - Low Pass
LRRS - Lumistar Range Receiving System
LVTTTL - Low Voltage Transistor-Transistor Logic
MB - Mega Byte
MBPS - Mega Bits Per Second
MIL-STD- - Military Standard
MRT - Malicious (Software) Removal Tool
NATO - North Atlantic Treaty Organization
NRZL - Non Return to Zero Level
NRZM - Non Return to Zero Mark
NRZS - Non Return to Zero Space
NTSC - National Television Standards Commission
OQPSK – Offset Quadrature Phase Shift Keying
PAL - Phase Alternating Line
PC - Personal Computer
PCI - Peripheral Component Interconnect
PCM - Pulse Code Modulation
PM - Phase Modulation
PRN - Pseudorandom Number
PSK - Phase Shift Keying
QPSK - Quadrature Phase Shift Keying
RAM - Random Access Memory
RF - Radio Frequency
RFI - Radio Frequency Interference
RNRZ - Randomized Non Return to Zero Level

ROM - Read Only Memory
RSSI - Receive Signal Strength Indication
RX - Receive
RZ - Return to Zero
SATA - Serial Advanced Technology Attachment
SAW - Surface Acoustic Wave
SBC - Single Board Computer
SNR - Signal to Noise Ratio
SOQPSK - Shaped Offset Quadrature Phase Shift Keying
SOQPSK-MIL -- Shaped Offset Quadrature Phase Shift Keying-Military
SOQPSK-TG -- Shaped Offset Quadrature Phase Shift Keying-Test Group
TB - Tera Byte
TC - Time Constant
TCP/IP - Transmission Control Protocol (TCP) and Internet Protocol (IP)
TTL- Transistor-Transistor Logic
TX - Transmit
UDP - User Datagram Protocol
USB - Universal Serial Bus
VAC - Volts AC (Alternating Current)
VGA - Video Graphics Array
VSWR - Voltage Standing Wave Ratio