

Appendix 5

Base Station Radio System

Appendix 5

Contents

1.0	Base Station Modules
2.0	Radio Command Unit (RCU)
2.1	Overall Description
2.3	Baseband Module
3.3.1	Overall Description
2.3.2	Circuits and Function
2.3.2.2	DSP and Memory
2.3.2.2	Digital I/O, RCB, RS-232 and Timer
2.3.2.3	Codec and Clock Generation
2.3.2.4	FPGA and Seismic Data Bus
2.4	Clock Generator and Splitter Module
2.4.1	Overall Description
2.4.2	RF Splitter Sub-Module
2.4.3	Clock Reference Generator Sub-Module
2.4.4	RCU and DRU Versions
2.5	Power Amplifier Module
2.5.1	Overall Description
2.5.3	Power Amplifier Sub-Module
2.5.3.1	DC Null
2.5.3.2	RF Attenuation
2.5.4	Linearizer Sub-Module
2.5.4.1	Linearizer Operation
2.5.4.2	Instability Detection
2.5.5	Control Sub-Module
2.5.5.1	Feedback Coupler
2.5.5.2	Transmit/Receive Switching
2.5.5.3	Dallas Temperature Sensor
2.5.6	MHU Power Conditioning & Current Sensor
2.5.7	RF Transmission Specifications
2.6	Power Supply Module
2.6.1	Inputs
2.6.2	Outputs
3.0	Data Receive Unit (DRU)
3.1	Overall Description
3.2	Concentrator Module
3.2.1	Specifications
3.3	RF Module
3.3.1	Overall Description

- 3.3.2 RF Modules in RCU and DRU
 - 3.3.2.1 Use in RCU
 - 3.3.2.2 Use in DRU
- 3.3.3 Dual Synthesizer
- 3.3.4 RF Receiver
- 3.3.5 ADC

- 4.0 Masthead Unit (MHU)**
 - 4.1 Circuits and Functions
 - 4.1.2 Power Conditioning
 - 4.1.3 TX/RX Switching
 - 4.1.4 Low-Noise Amplifier and Band-Pass Filter
 - 4.1.4.1 Low-Noise Amplifier
 - 4.1.1.2 Band-PassFilter

- 5.0 Signals & Connections**
 - 5.1 RCU
 - 5.3 RF Module
 - 5.4 Baseband Module
 - 5.5 Buses
 - 5.6 Concentrator Module
 - 5.7 Power Supply Module

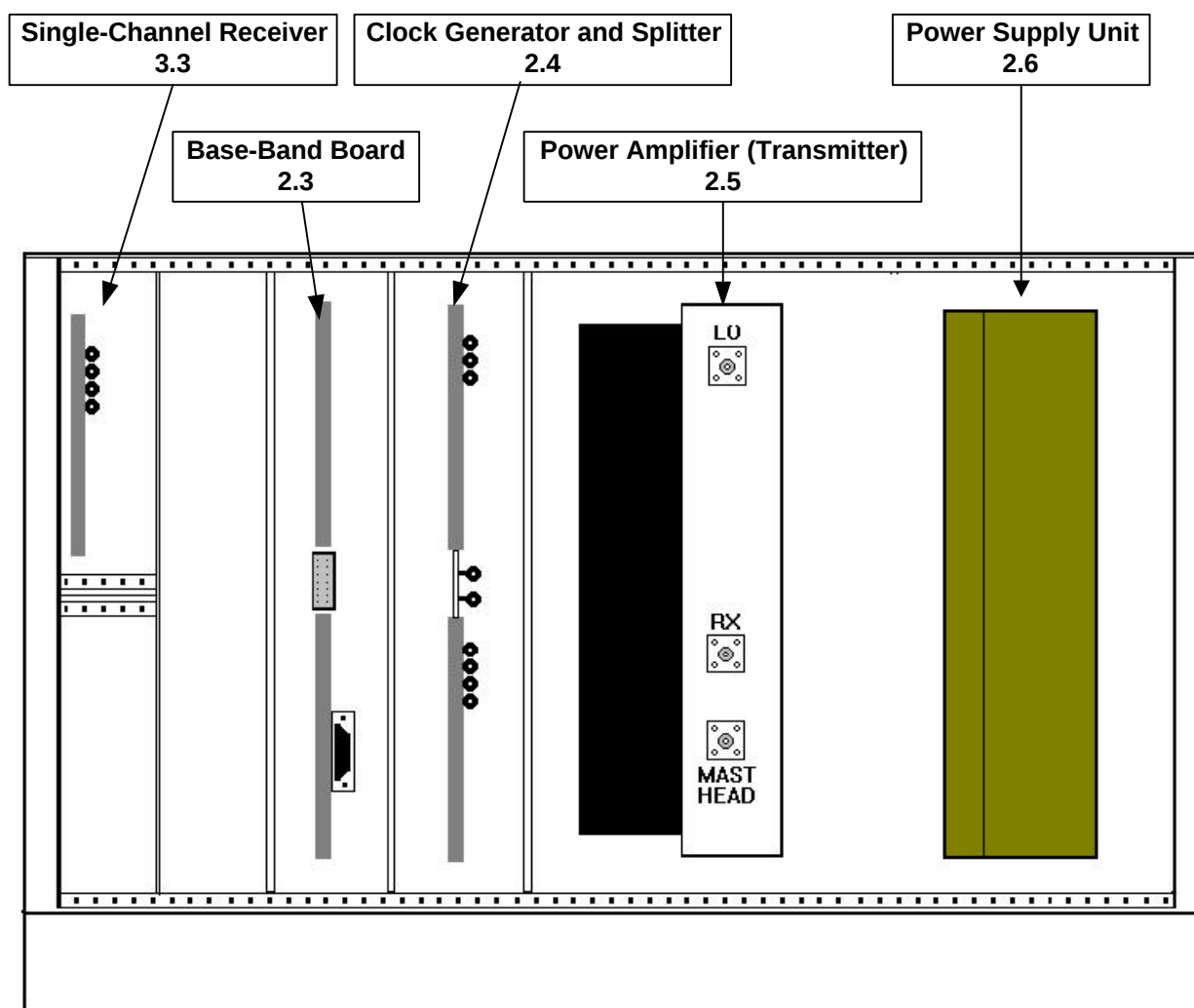
1.0 Base Station Modules

The Base Station, which is part of the Central Recording System (CRS), comprises three principal modules: The Radio Command Unit (RCU), the Data Receive Unit (DRU) and the Mast-Head Unit (MHU). The Central Recording System also contains the Recording Computer.

2.0 Radio Command Unit (RCU)

2.1 Overall Description

Figure 1 shows the names and locations of the various modules in the RCU, together with the Section of this text in which they are described.



Front View of Radio Command Unit

Figure 1

The Radio Command Unit is a Base Station module which houses a single-channel transmitter for the Command downlink and a single-channel receiver for Command uplinks. The unit also houses the Master Frequency Reference Generator for the System and provides distribution of both the Master Frequency Reference and the received RF to multiple Data Receiver Units (DRU).

The RCU interfaces with the Recording Computer and the DRUs via a Radio Control Bus (RCB), and provides an interface to the Recording Computer's data bus for single-channel seismic data capture.

2.3 Baseband Module

There is one baseband board in the RCU and up to twelve in the DRU. Each baseband module formats data and commands received from its corresponding RF board.

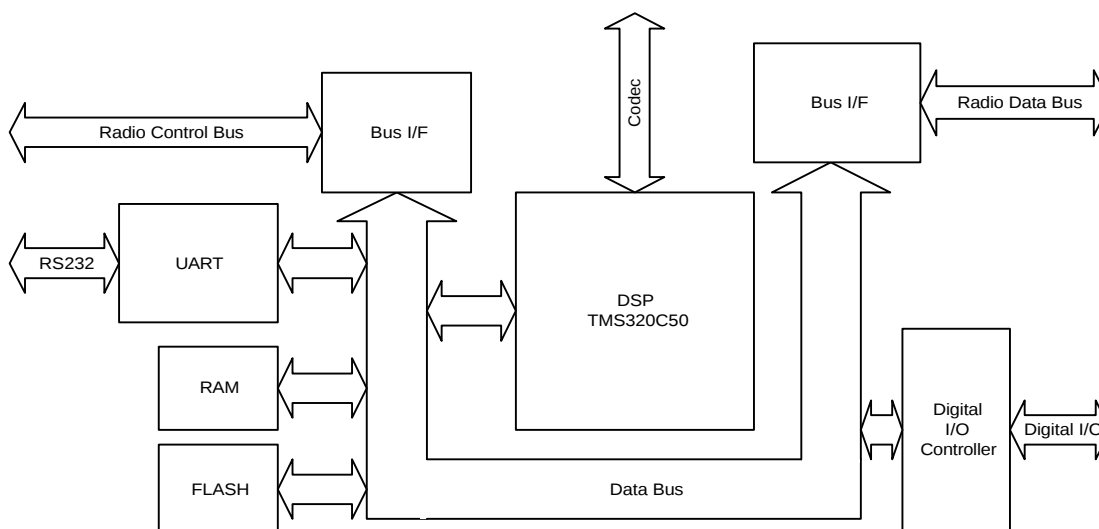
2.3.1 Overall Description

The Command baseband module is shown in block form in figure 2. It provides all digital processing for both the Power Amplifier Module and the Command Receiver in addition to performing recorder control functions.

The module receives command and configuration information from the Control Interface Board through the Radio Control Bus, and passes Command Unit status information back to the Control Interface Board.

The Command Base-Band module consists of four separate sub-modules:

DSP and Memory;
Digital I/O, RCB, RS232 and Timer;
CODEC and Clock Generation; and
FPGA and Seismic Data Bus.



Command Unit Base-Band Module - Block Diagram

Figure 2

2.3.2 Circuits and Functions

2.3.2.1 DSP and Memory

The DSP is a single digital signal processor (type TMS320C50) with ancillary memory and peripherals. This DSP has 16-bit address lines and 16-bit data lines. Its clock is 40.00 MHz, which is obtained from the Clock Generation sub-section.

There are four 64k X 4 RAM ICs which are used for memory. In addition, a Flash Memory contains configuration information for the DSP.

DSP outputs include:

- 16 data bits (D0 to D15) which go to the Universal Serial Controller (USC),
- CODEC-DACDATA connected to the CODEC sub-section, and
- Control and clock signals for the FPGA, USC, Timer and UART.

2.3.2.2 Digital I/O, RCB, RS-232 and Timer (See Schematic ---)

The USC (type A16C30V10VSC) interfaces with the DSP through the 16-bit data lines (D0-D15).

A Master to Slave signal is placed on the RCB to interface with the Command Unit and the DRUs.

U35 and associated components form the timer circuitry using the crystal oscillator X2, at a frequency of 32.768 kHz.

Inputs to the Digital I/O circuits from the Command Transmitter board include:

- Cartesian transmitter instability detector,
- VSWR alarm indicator, and
- Transmitter Temperature indicator.

Digital outputs include:

- Synth Serial Data and Synth Serial Data clock to the Synthesizer of the Command RF board.
- Cartesian loop gain reduction and Cartesian loop dc null control signals to the Cartesian Linear Transmitter of the Command Transmitter board.

U36 is a Universal Asynchronous Receiver and Transmitter (UART) which provides an RS232 link for test purposes.

2.3.2.3 CODEC and Clock Generation (See Schematic ---)

The CODEC U32 provides A/D conversion of the up-linked I and Q signals to CODEC serial data. This serial data is routed to the Command Base-Band board for processing.

The CODEC also performs A/D conversion of the CODEC serial data (from the Command Base-Band board) into I and Q Base-Band signals. These I and Q signals are sent to the Power Amplifier Module for modulation and transmission.

The CODEC clock is 7.68 MHz, and is derived from the 61.44 MHz VCO and the Divide by Eight Counter, U21.

The P-CLK signal for the DSP is 40 MHz. A jumper selection at Jumper Point JP9, permits selection of 40 MHz from either X1 (the internal oscillator) or from the 40 MHz Master Clock from the RF Splitter board.

This sub-section takes the RX-I and RX-Q signals from the Command Receiver board and converts them to CODEC serial data to be sent to the DSP for processing.

The A/D conversion involves converting the CODEC-DACDATA from the DSP to TX-I and TX-Q Cartesian Base-Band signals to be fed to the Cartesian Linear Amplifier on the PA Linearizer board.

Phase-Control (PH-CTL) signal is also fed to the PA Linear Amplifier to maintain a phase balance between the I and Q signals.

2.3.2.4 FPGA and Seismic Data Bus (See Schematic ---)

U3 is a Field-Programmable Gate Array (FPGA) which contains the I/O and digital logic functions and also provides the interface between the DSP and the Control Interface Board.

2.4. Clock Generator & Splitter Module

2.4.1 Overall Description

The two main sub-modules within this board are the

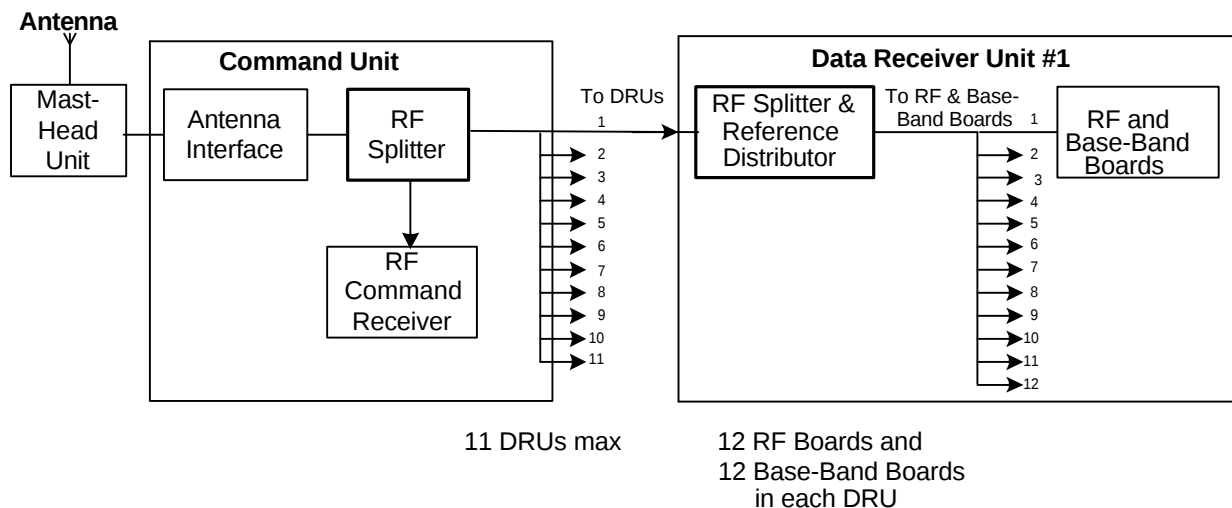
RF Signal Splitter and the
Reference Generator.

There are two versions of the Clock Generator & Reference module: one in the RCU and the other in each DRU.

- The Command Unit contains a module which splits the received RF signals 12 ways, for distribution as shown in figure 3.

This module generates a 40 MHz controlled-reference clock which is fed to the Command Receiver and to up 11 DRUs.

- Each DRU contains a module which serves:
 - to split the Reference Clock two ways for distribution to the RF and Baseband boards within the DRU and
 - to split received RF signals twelve ways for distribution to RF boards within the DRU.



Received RF Signal Path showing Distribution Functions of RF Splitter

Figure 3

As shown in figure 3, the antenna feed to the RCU version of this module comes from the Mast-Head Unit via the antenna interface, whilst the antenna feed to the DRU version comes from the RF output of the Command Unit splitter.

2.4.2 RF Splitter Sub-Module

Figure 4 shows that the RF splitter stages consist of

- antenna feed,
- filter,
- power division and
- twelve 12 dB gain stages.

The band-pass filter on the splitter board ensures that no in-band intermodulation is produced by out-of-band energy.

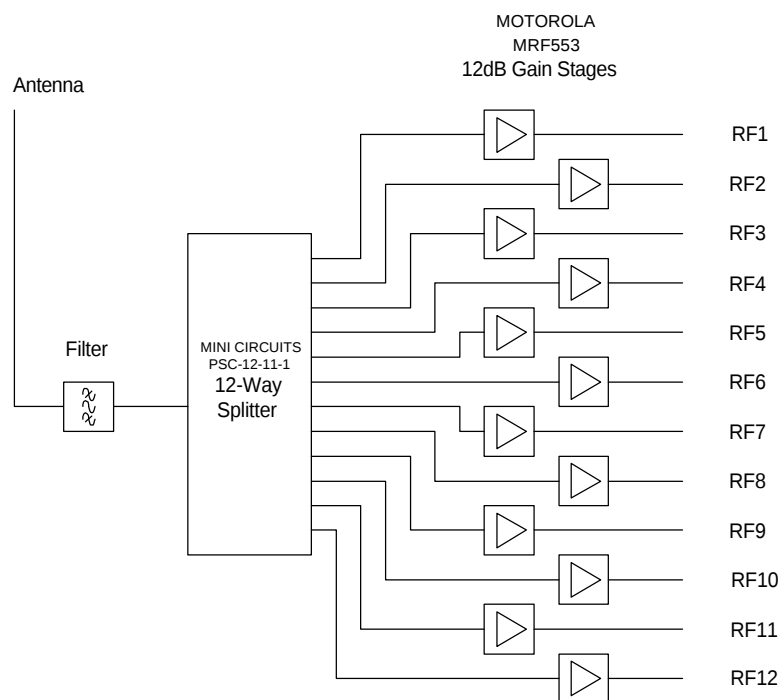
The filtered signal is fed into a 12-way splitter. In order to compensate for the insertion loss of this splitter, a 12 dB (nominal) gain stage is present in each RF output path. This results in 12 RF outputs of a level nominally identical to the RF input level – giving a 0dB gain stage.

2.4.3 Clock Reference Generator Sub-Module

Figure 5 illustrates the differing reference clock configurations of the CU and the DRU splitter variants.

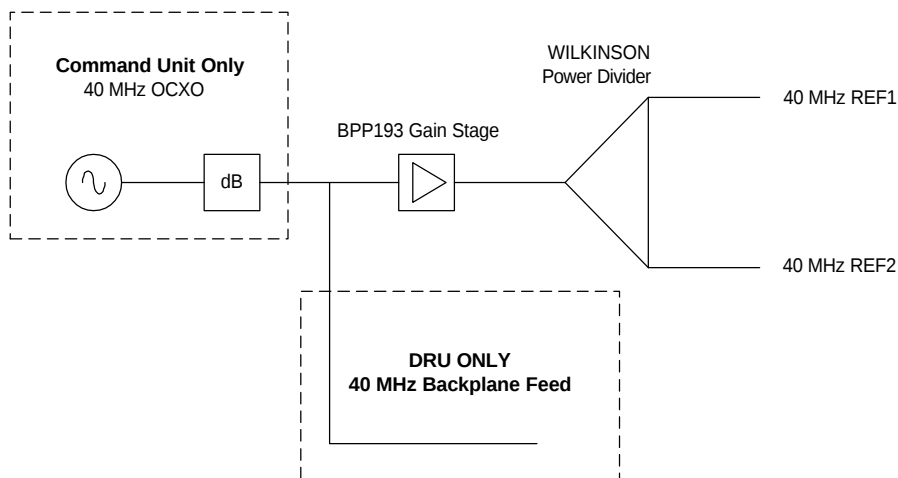
In the CU model an on-board highly-stable oven-controlled oscillator provides the reference signal. The DRU model does not possess this oscillator and requires the clock signal to be sourced from the backplane.

The gain stage provides an output of approximately +17 dBm which, when split through a tuned Wilkinson power divider, results in a nominal +13 dBm signal at both 40 MHz reference points. The CU RF board uses one of the reference signals and the second is used by any connected DRU.



RF Splitter Stages

Figure 4



Reference Generator

Figure 5

2.4.4 RCU & DRU Versions of Clock Generator & Splitter Modules

As has been shown in figure 5, there are two versions of this module. Physical differences are detailed in Table 1.

Component	Radio Command Unit	Data Receiver Unit
Reference oscillator	40 MHz present	Not present
Oscillator link	Pins 1 & 3 linked	Pins 2 & 3 linked
Handle colors	Blue	Black

Clock Generation & Splitter Board: CommandUnit/Data Receiver Unit Differences

Table 1

2.5 Power Amplifier Module

2.5.1 Overall Description

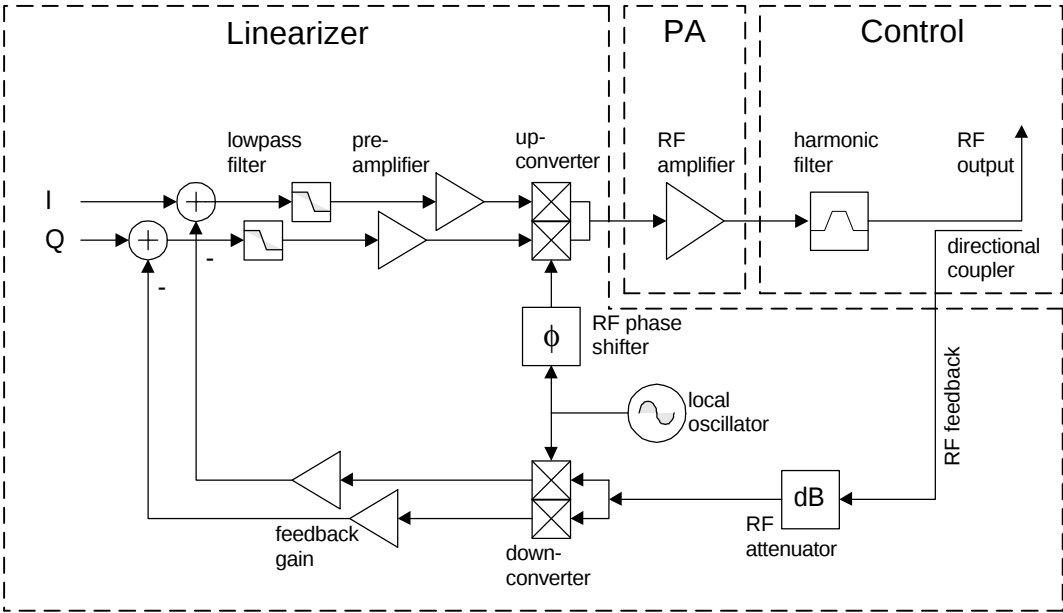
This module comprises the transmitter that feeds RF to the antenna for downlinking commands to the Remote Units, and is illustrated in figure 6.

The module contains three separate sub-modules, all located on the same board:

Power Amplifier	A three stage power amplifier which provides the RF forward-path gain and final output drive for the RCU transmitter.
Cartesian Linearizer	RF and baseband processing sub-module which provides direct up-conversion of the quadrature baseband input signals, while simultaneously correcting for non-linearities in the power-amplifier.
Control Section	This sub-module provides a 20 dB (nominal) RF feedback path to the Cartesian Loop Linearizer as well as transmit-receive switching and MHU (masthead) power supply conditioning. Also incorporated are: A temperature sensor, Non-volatile parameter storage, Masthead connection status and VSWR indication.

2.5.2 Dedicated Channel

The RCU downlink requires a single 20 kHz dedicated channel. The transmission of a pilot on this channel provides a means of waking up the remote units and frequency locking them to the CRS high-stability reference.

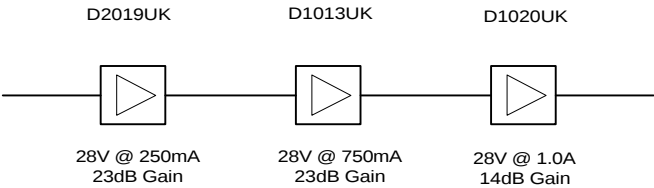


Linearized Power Amplifier - Block Diagram

Figure 6

2.5.3 Power Amplifier Sub-Module

The PA sub-module comprises the main RF amplifier and provides the forward-path gain and final output drive. This board consists of three ‘Semelab’ device stages, shown in fig. 7.



PA Device Line-Up

Figure 7:

Each device is individually tuned for gain and return loss. The whole line-up is tuned to achieve a gain of approximately 60dB.

2.5.3.1 DC Null

During operation of the PA, a steadily rising carrier component exists on the output spectrum, this being a result of carrier up/down-converter feed-through. It can be seen at baseband as a dc component superimposed on the I and Q signals.

This represents an unwanted tone in the output spectrum, and is removed by sampling the magnitude of dc component at start of transmission and removing it from the resulting dc component 30 seconds after transmission.

2.5.3.2 RF Attenuation

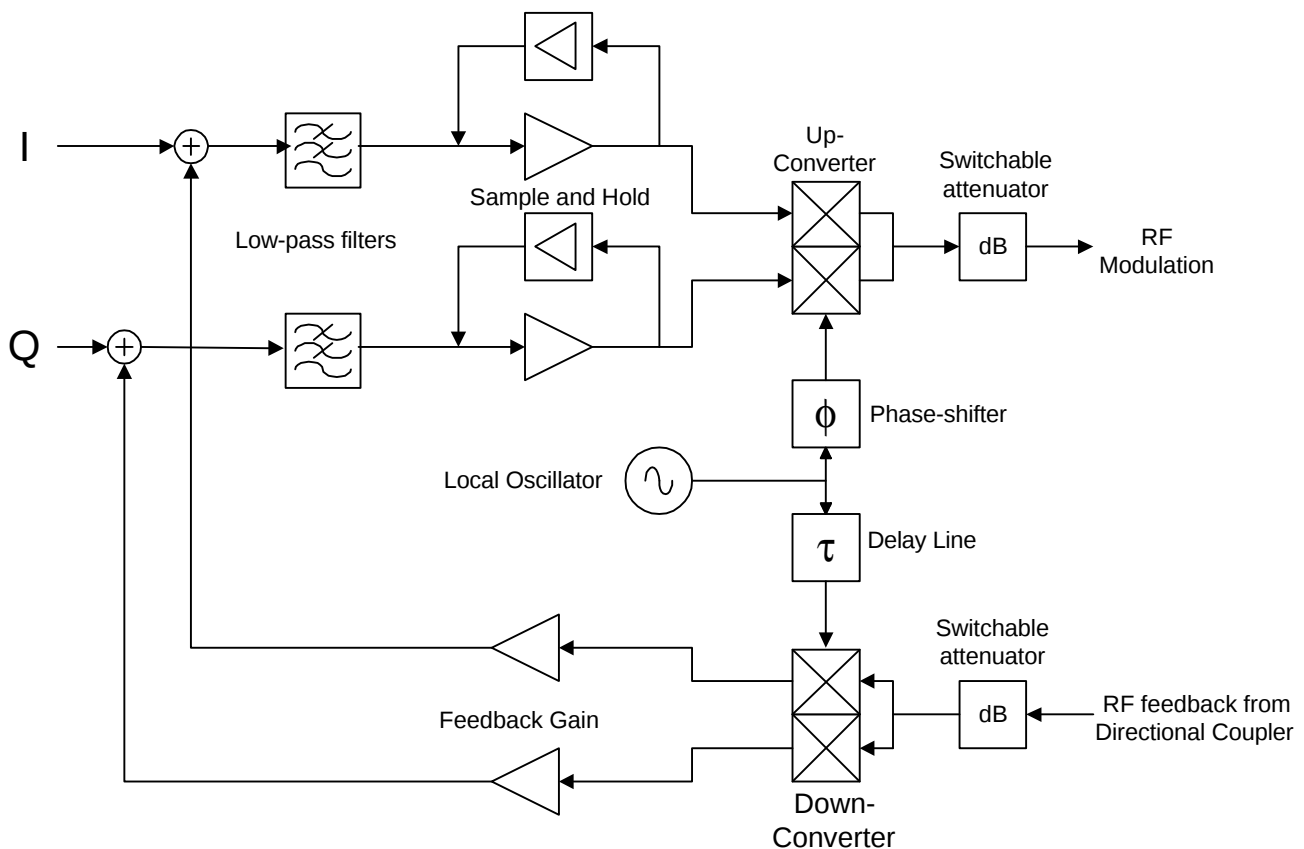
Transmitted power can be varied by a series of switchable attenuators situated in the Up- and Down-Converter paths (figure 8), and is also controlled by the feedback gain elements.

Increasing the feedback gain reduces the overall output power.

To maintain linearization, the attenuator situated in the Up-Converter path must be changed in the opposite direction to the attenuator in the Down-Converter path..

2.5.4 Linearizer Sub-Module

The basic layout of the linearizer is shown in fig. 8.



Linearizer – Block Diagram

Figure 8

2.5.4.1 Linearizer Operation

A fraction of the transmitted RF signal is fed back from the output by the directional coupler (figures 6 & 8), and is then attenuated to reduce the signal to a level suitable for input to the down-converter.

The signal is split as shown and down-converted, with two carriers of 90° phase difference yielding the I and Q baseband signals.

Feedback gain is provided by low-noise operational amplifiers (CLC428), and the signal is then subtracted from the modulation input.

The forward path signal is low-pass filtered and pre-amplified at baseband. The baseband signal is then up-converted with a phase-shifted version of the local oscillator to ensure that the input and feedback signals are exactly 180° out of phase.

2.5.4.2 Instability Detection

To monitor loop stability during operation, a circuit is provided which measures output spectrum energy around 200 kHz above the carrier.

Any instability causes high frequency components to appear in the output spectrum and correspondingly at baseband level.

A high-pass filter is used to isolate these higher frequencies which are then fed through an amplitude detector.

When the amplitude reaches a preset dc detected level, an instability error is flagged.

2.5.5 Control Sub-Module

The Control Sub-Module is shown in figure 9.

It provides RF feedback from the PA sub-module to the linearizer sub-module, and controls transmit/receive switching.

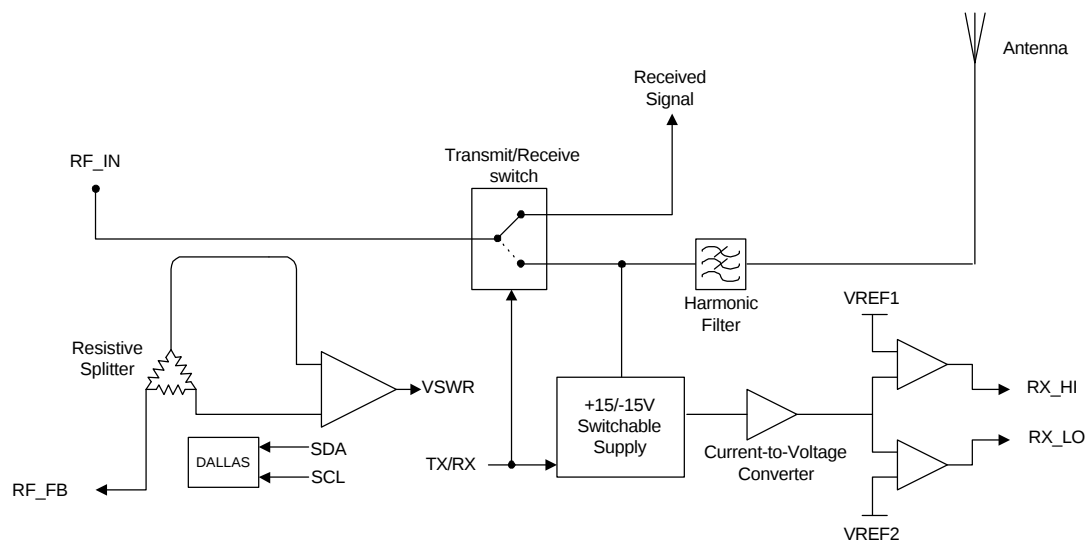
Another function of this sub-module is to provide data storage of temperature-sensing and amplifier-characterisation information by use of a Dallas temperature sensor and non-volatile memory device

2.5.5.1 Feedback Coupler

The Control Sub-Module provides a 20 dB-coupled path. A portion of the output signal, roughly 20dB down, is sampled providing the feedback signal for the linearizer. A VSWR detection circuit enables coupled and direct powers to be compared.

2.5.5.2 Transmit/Receive Switching

PIN diodes are used to direct signals from the antenna in receive and to the antenna during transmit.



Control Sub-Module – Block Diagram

Figure 9

The diodes may be biased + (RX) or – (TX) by transistor switching between the two voltage rails.

The RF path is determined by the biasing of the PIN diodes which, in conjunction with matching circuitry, act as RF quarter wavelength sections. These sections have the ability to behave as open circuits or as 50Ω lines depending on the bias voltage.

The bias voltage also supplies masthead power via a dc-coupled link through the Masthead coaxial cable.

2.5.5.3 Dallas Temperature Sensor

The Dallas sensing device provides a temperature measurement system, with one-second acquisition time, the data being read as an integer byte. It also incorporates 256 bytes of non-volatile memory for storing details unique to the individual amplifier – such as phase control voltages, phase, image balance settings, serial number and revision details.

2.5.6 MHU Power Conditioning & Current Sensing

A dc supply rail powers the MHU (masthead unit) via the PA/Masthead coaxial cable.

The masthead's own internal TX/RX switching is biased from this cable and, in Receive, a low-noise amplifier with a 30 dB gain is powered.

The MHU is biased by either a positive or negative supply depending on the logic condition of the TX/RX line.

In Transmit, the supply rail is negative, and the pin diodes in the RX path are biased to present an open-circuit to RF, thereby ensuring that RF signal follows the TX path.

In Receive, the supply rail is positive, and the RX path is enabled by positively-biased pin diodes thereby allowing received RF to follow the RX path.

Current sensing is provided to monitor the presence and status of the MHU.

When the MHU is in Transmit mode, the current drawn is approximately 50 mA.
When the masthead is in Receive mode, the current drawn is approximately 450 mA.

Two comparator circuits are employed to give a logic low signal when MHU current is less than 50 mA or greater than 500 mA.

The current sensor operates by using a current-to-voltage circuit which monitors the voltage dropped across a very low-value resistor network. An operational amplifier provides a DC output between 0 and 5 V depending on the current drawn. This is fed into two level-set comparators, which provide the logic signals.

2.5.7 RF Transmission Specifications

All output powers are defined at the masthead antenna connector.

2.5.7.1. RF Output Power

Mean: 10 W (+40 dBm +/- 1dB) available at antenna connector

2.5.7.2 RF Gain

60 dB $\pm$ 1 dB nominal

2.5.7.3 Supply Voltage

+ 28V $\pm$ 0.5 V @ 4.0A

2.5.7.4 Input Impedance

50 Ω nominal

2.5.7.5 Third order Intercept Point

55 dBc min.
(Measurement: two tones with 10 kHz spacing: 38 dBm per tone)

2.5.7.6 Harmonics

-70 dBc, 10 W cw output

2.5.7.7 Spurious

-70 dBc, 10 W cw output

2.5.7.8 VSWR

Stable into 5:1 loads, all angles

2.6 Power Supply Module

2.6.1 Inputs

240 V ac, 50/60 Hz or
120 V ac, 50/60 Hz

2.6.2 Outputs

Dc output voltages are given in Table 1.

Voltage (V dc)	Current (A dc)	Line Regulation For 10% change (%)	Load Regulation For 10-100% change (%)	Max Ripple %
+5	4	< 0.2	< 0.5	< 0.5
+15	4	< 0.5	< 5	< 2
-15	4	< 0.5	< 5	< 2
+28	10	< 0.5	< 5	< 2

PSU Output DC Voltages

Table 2

3.0 Data Receive Unit (DRU)

3.1 Overall Description

The DRU (Data Receive Unit) receives, demodulates, and decodes all seismic-trace data from the seismic sensors and supplies this data through a Concentrator to the Recording Computer.

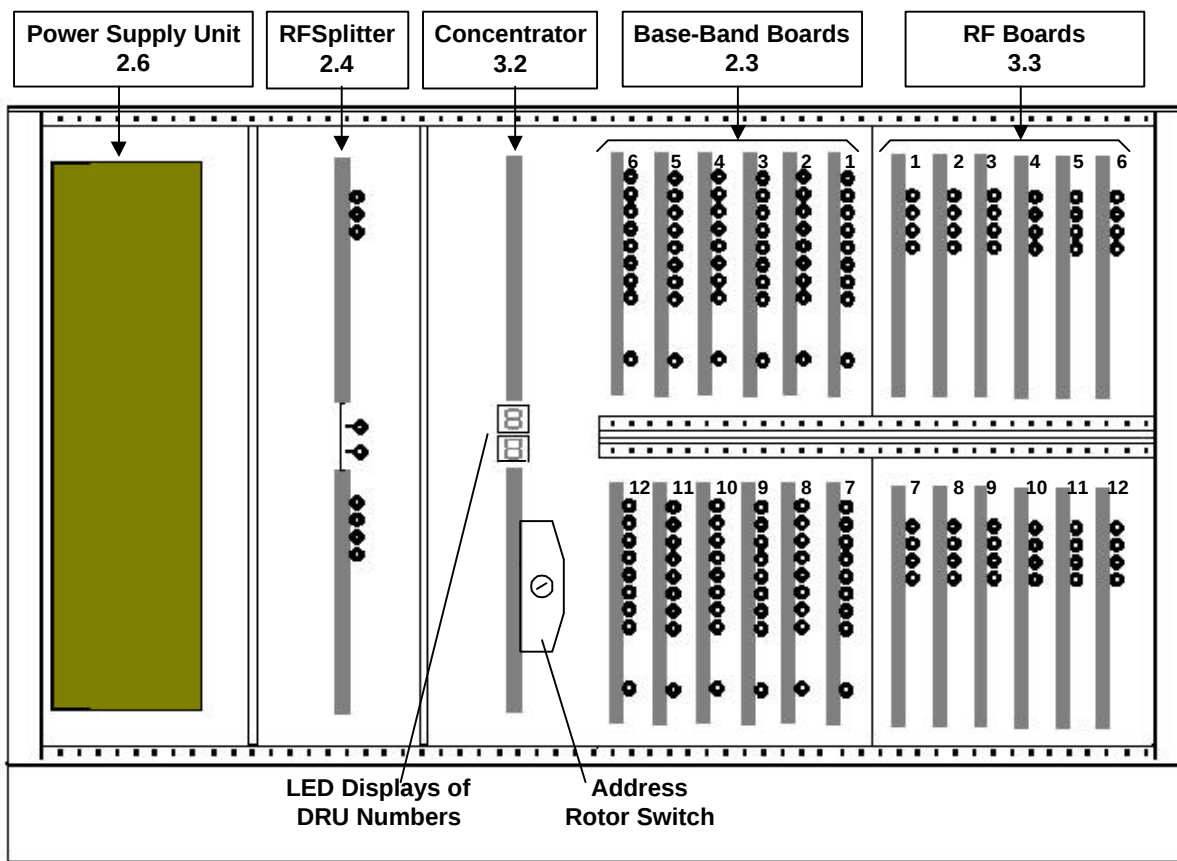
Figure 10 shows the names and locations of modules within each DRU, together with the section of this text in which they are described:

3.2 Concentrator Module

Each DRU contains one Concentrator board which collects 8 channels of seismic data from each of the 12 data receiver board pairs (RF and Baseband boards).

The data are buffered and formatted for collection in multiplexed form over the Radio Data Bus (RDB) by the Radio Data Interface board in the recording module (RDB). The Radio Data Interface is under control of the Recording Computer.

A simplified functional diagram is shown in figure 11, and a block schematic in figure 12.



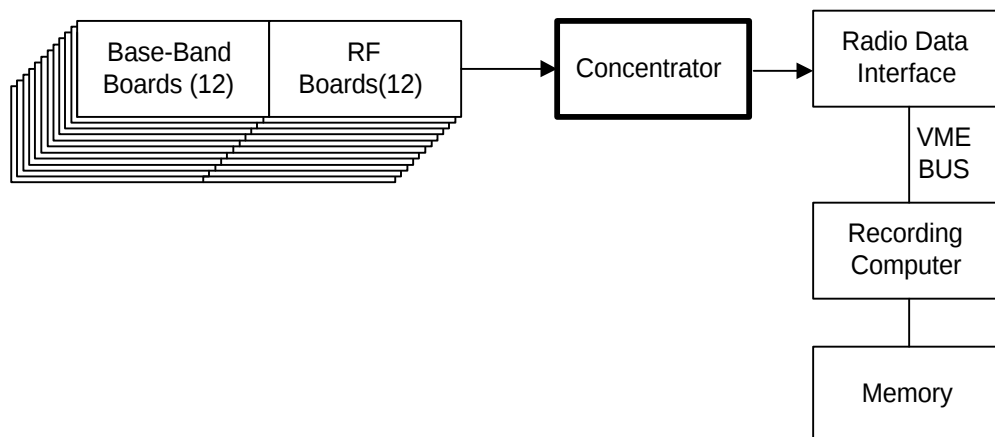
Front View of Data Receiver Unit (DRU)
Figure 10

The Concentrator polls each of the RF boards in the DRU in turn, waiting for all boards to have data ready for collection. The Concentrator then clocks data out of each RF Board, with each channel represented as two 16-bit words, into a FIFO buffer on the back-plane bus. The recording computer then clocks this data onto the VME bus, with each 32-bit word represented as two 16 bit words

The Concentrator module determines which channels the DRU receives. On the front of the Concentrator board there are two numeric LED displays and one rotor switch (figure 10). The switch is used to set the DRU address from 0 to15.

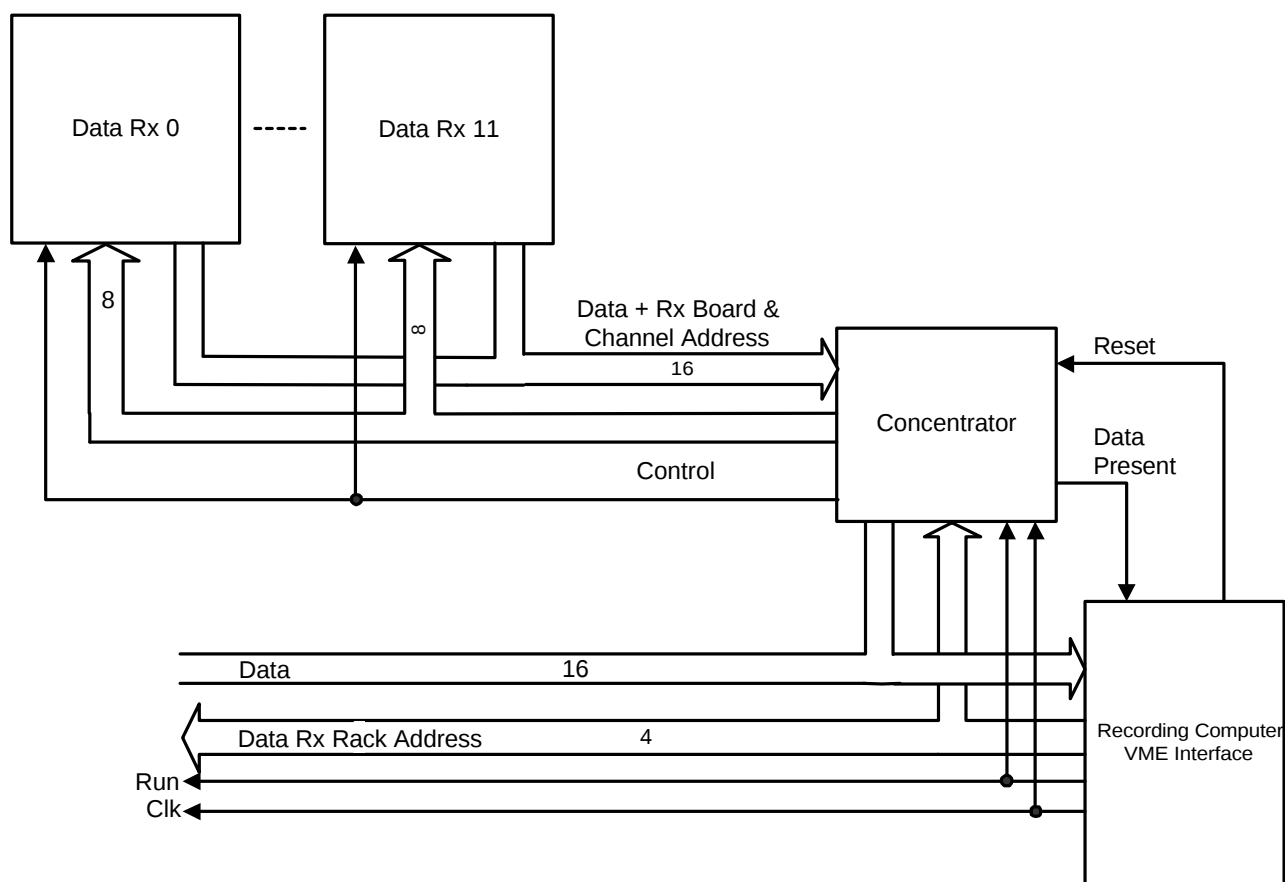
Addresses 0 -10 are used for normal recording,
Addresses 11-14 are not used, and
Address 15 is used for single channel recording only.

The DRU address is displayed on the Concentrator numeric LED, address 0 being displayed as DRU 1, address 1 as DRU 2, etc.



Simplified Received Data Transfer

Figure 11



Concentrator Module - Block Schematic

Figure 12

3.2.1 Specifications

3.2.1.1 Gain & Noise

- Gain: For each signal path, 0 dB nominal (independent of the number of properly terminated outputs).
- Noise: For each RF signal path < 20 dB.

3.2.1.2 Maximum Input Power

- RF input: +10 dBm, 1 dB compression.

3.2.1.3 Third Order Intercept Point

- RF input: ≥ +36 dBm.

3.2.1.2 Reference Signals

- 40 MHz Oscillator: Stability < 1 ppm (used in CU splitter card only)
- 40MHz ref. output #1: Level 13 dBm
- 40MHz ref. output #2: Level 13 dBm
- 40 MHz ref. input: Input level 13 dBm (used in DRU splitter board only).

3.3 RF Module

3.3.1 Overall Description

The RF module provides the RF receive chain for uplinks from remote units to the CRS. This board is used in two racks:

- One RF module board is used in the RCU, and
up to 12 RF module boards are used in each DRU. Each of these RF boards is used in
conjunction with an associated DRU board, also located in the DRU.

The module contains an ac-coupled direct-conversion receiver suitable for 16QAM data. The board also incorporates the RF synthesizer, which is used in both the receiver and the command unit transmitter.

Principal functions are summarized as follows:

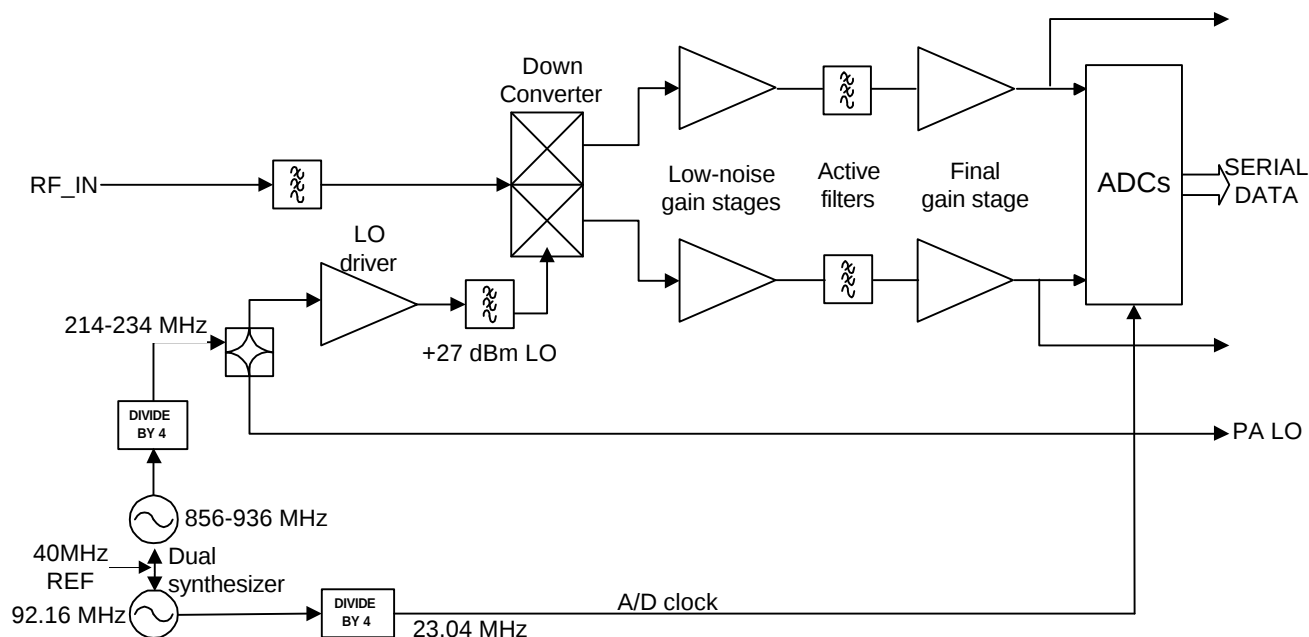
- RF Receiver

The receiver provides linear direct down-conversion from the RF channel frequency to quadrature baseband outputs.
- Dual Synthesizer

One synthesizer provides a Local Oscillator (LO) for both the receiver sub-module and the command transmitter module. The other synthesizer provides the clock for the ADCs. The synthesizer reference is derived from the CRS high-stability source.

ADC

The ADC (Analog to Digital Converter) serves to digitize the received baseband I and Q signals. The resulting data are output serially.



RF (Receiver) Board

Figure 13

3.3.2 RF Module in RCU and DRU

3.3.2.1 Use in RCU

When used in the radio command unit, the Baseband I and Q signals are output, and the ADCs are not used.

In this mode, the receiver receives a single 20 kHz channel, which is digitized by the RCU Unit baseband module (reference Section 2.3). It should be noted that the dual-synthesizer. In the RF module is programmed by the Baseband board.

The LO signals are used by the receiver down-conversion process and output to the RCU Power Amplifier (Transmitter) module.

3.3.2.2 Use in DRU

When used in a DRU, each RF module is used in conjunction with its own associated baseband module in the DRU.

Each RF module is used to receive up to 8 contiguous 20 kHz channels,

The analog to digital converters (ADC) operate at a sampling rate of 180 kHz to convert the baseband I and Q signals and output the result as a serial data stream to the DRU Baseband board.

The DRU Baseband board programs the dual synthesizer. The LO signals are used only by the receiver down-conversion process.

3.3.3 Dual Synthesizer

The dual synthesizer package enables the clock signals of both the down-converter LO and the ADC to be derived from the single oven-controlled stable source provided by the CRS splitter.

Serial programming of the LMX2332 enables 10 kHz steps from 216.01 to 213.99 MHz to be synthesized. The synthesizer design employs an 856-936 MHz VCO running at four times the RF down-conversion frequency. As can be seen in figure 13, a divide-by-four stage reduces the LO signal frequency to the required band.

The RF LO is fed into a Wilkinson power divider

One output of this divider supplies a nominally 0 dBm LO for use by the PA module.

The other output is fed through an amplifier to a Semelab D2081UK, which provides a +27 dBm LO. This LO is used by the high third order intercept-point down-converter (Mini-Circuits JSIQ-234DH1).

The ADC clock is derived in a similar manner, with the VCO constructed from discrete components and again running at four times the required frequency. A 92.16 MHz signal is produced which is fed into a divide-by-four stage, whose output is a square wave which serves as the ADC clock.

3.3.4 RF Receiver

The RF board provides the RF receive path for the command data up-link. As previously stated, demodulation is achieved through an ac-coupled direct conversion.

The RF signal received by the antenna, after passing through the low-noise amplifier of the MHU and the 0 dB-gain stage of the splitter module, is band-pass filtered and fed into the down-converter. This received signal is then mixed with the +27 dBm LO, producing the I and Q baseband signals. The I and Q signals are then fed into a low-noise gain stage, with a voltage gain of about 10.

The baseband signals next pass through an active filter chain, with a roll-off from 80 to 140 kHz.

The final stage involves amplitude and phase balancing, followed by another low noise gain stage.

If the RF module is in the RCU, the I and Q signals are fed directly to the baseband board via 50Ω coaxial.

If the module is in a DRU, the I and Q signals are connected directly to the ADC.

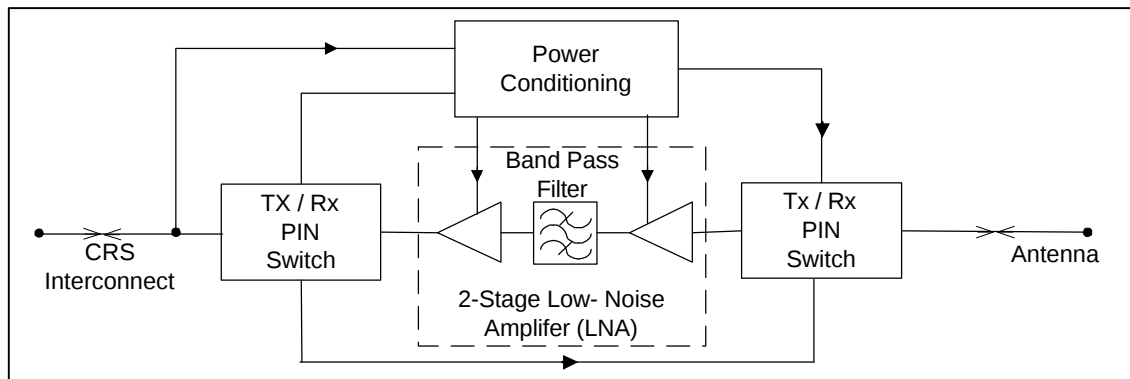
3.3.5 ADC

The I and Q baseband signals are dc-coupled into the ADC16471 ADCs, which operate in a master/slave configuration. Both I and Q output signals are multiplexed together on a single serial data line.

4.0 Masthead Unit (MHU)

Figure 14 is a simplified functional diagram of the Mast-Head Unit, showing the four main sub-modules:

Power conditioning
TX/RX switching
Band-pass filter
Low-Noise Amplifier (LNA)



Masthead Unit – Functional Diagram

Figure 14

4.1 Circuits and Functions

4.1.2 Power Conditioning

The dc supply for the masthead unit is routed through the command unit coaxial cable.

When the command unit is in Transmit (TX) mode, the supply voltage on the coaxial is -15 V .
When the command unit is in Receive (RX mode), the supply voltage on the coaxial is $+15\text{V}$.

Biasing of the low-noise amplifier (LNA) FET devices is provided by an LT1261CS, which ensures the drain supply is switched off until the gate voltage is valid. This results in the gate voltage being sufficiently high to keep the FET switched off during power up, thereby preventing unsaturated operation and excessive current draw.

A comparator circuit monitors the magnitude of the gate voltage and only applies the drain when the gate has reached approximately -1 V .

4.1.3 TX/RX Switching

The polarity of the supply voltage controls the combination of pin diode switches (MACOM MA504-30), in the RF path.

When supply voltage is +15 V (RX), the only RF path which does not appear as an open circuit is the Low-Noise Amplifier/Band-Pass Filter. This stage is therefore able to amplify and filter the incoming signal..

When the supply voltage is –15 V (TX), the Low-Noise Amplifier/Band-Pass Filter stage appears as an open circuit to RF, and is therefore by-passed by the transmission signal.

4.1.4 Low-Noise Amplifier and Band-Pass Filter

4.1.4.1 Low-Noise Amplifier

The masthead unit provides the first gain stage of the receiver chain and has a very low noise and high dynamic range characteristic.

The gain stages are provided by two Philips FET1905s. As can be seen from figure 1, a two-stage line-up is used with the high-rejection Band-Pass Filter (BFP) between the stages.

4.1.4.2 Band-Pass Filter

The masthead receive path includes the high rejection Band-Pass Filter connected between the two low-noise gain stages. The purpose of this filter is to remove any out-of-band spurious signal which could give rise to inter-modulation products within the received band.

5.0 Signals & Connections

5.1 RCU

5.1.1 Connectors

External connectors to the Power Amplifier Command Transmitter are defined in table 1.

Connector Name	Description
H1	LO input - 5-way D-type Combo RF insert
H2	I & Q and data line inputs - 15-way D-type
H3	Power and RF input/output - 9-way D-type Combo RF & power inserts
H4	Power and signal lines - 9-way D-type

External Connectors

Table 1

5.1.2 Internal Interfaces

Table 2 lists the internal interface signals, which are present between the Power Amplifier and the Linearizer sub-modules.

Signal Name	From	To	Type	Description
RF_MOD	CLT	PA	RF	Low power RF input to PA
RF_FB	PA	CLT	RF	Feed back signal for linearizer
RF_OUT	PA	CB	RF	RF power output
TX_EN	LB	PA	Data	Transmit enable

Internal Interfaces

Table 2

5.1.3 External Interfaces

Table 3 shows the signal interfaces between the Power Amplifier board and the rest of the Command Unit.

Signal	Direction	Type	Description
-15V	In	Power	-15V Power supply
+28V	In	Power	+28V Power supply to Control Board
+28V	In	Power	+28V Power supply to PA (4.0 A)
AGND	In	Power	Analog ground
TX_RF	In/Out	RF	Transmitter RF output / Receiver RF input via Masthead
I_IN_AC	In	Analog	Baseband I channel input
AGND	In	Power	Analog ground for Linearizer board
Q_IN_AC	In	Analog	Baseband Q channel input
SHDN	In	Digital	Enables PA (from DSP) – used for CLT dc-nulling
5dB_UP	In	Digital	HCMOS power control, up converter: 5dB step
5dB_DOWN	In	Digital	HCMOS power control, down converter: 5dB step
10dB_ATT	In	Digital	HCMOS power control: 10dB step
15dB_ATT	In	Digital	HCMOS power control: 20dB step
PH_CTL	In	Analog	Cartesian loop phase control
DC_NULL	In	Digital	Cartesian loop dc null control
INSTB	Out	Digital	Transmitter instability detector
VSWR	Out	Digital	VSWR alarm indicator
+15V	In	Power	+15V power for Cartesian loop
TX_RX	In	Digital	Switches between Tx & Rx mode
TX_EN	In	Digital	Disables the PA during a DC Null operation.
SCL	In	Digital	Temperature sensor data clock
SDA	In/Out	Digital	Temperature sensor bi-directional data line
RX_I_HI	Out	Digital	Indication of masthead unit condition connection/status
RX_I_LOW	Out	Digital	Indication of masthead unit condition connection/status
RX_RF	Out	RF	Received RF from Tx/Rx switch
LO_TX	In	RF	Local oscillator input 0dBm

External Interface Signals

Table 3

5.1.4 Voltage Inputs

240 V ac, 50/60 Hz or
120 V ac, 50/60 Hz

5.1.5 Voltage Outputs

Dc output voltages are listed in Table 4.

Voltage (Volts dc)	Current (Amps dc)	Line Regulation For 10% change (%)	Load Regulation For 10-100% change (%)	Max Ripple %
+5	4	< 0.2	< 0.5	< 0.5
+15	4	< 0.5	< 5	< 2
-15	4	< 0.5	< 5	< 2
+28	10	< 0.5	< 5	< 2

PSU Output DC Voltages

Table 4

5.2 Reference Generator & Splitter Board

5.2.1 External Connections

Table 5 lists the signals which constitute the interfaces between the Splitter Board module and the Radio Command Unit or Data Receiver Unit.

Signal	Direction	Description
RF_IN	In	RF input signal
RF1	Out	RF1 Split signal
RF2	Out	RF2 Split signal
RF3	Out	RF3 Split signal
AGND	In	Analog ground
DGND	In	Digital ground
+5V	In	Logic supply rail
40MHZ_IN	In	40MHz Reference signal (DRU only)
-15V	In	Supply monitor input rail
+15V	In	RF Supply rail
+28V	In	Supply monitor input rail
RF4	Out	RF4 Split signal
RF5	In	RF5 Split signal
RF6	Out	RF6 Split signal
RF7	Out	RF7 Split signal
AGND	In	Analog ground
RF8	In	RF8 Split signal
RF9	Out	RF9 Split signal
RF10	Out	RF10 Split signal
RF11	Out	RF11 Split signal
DGND	In	Digital ground
+5V	In	Logic supply rail
-15V	In	Supply monitor
Continued overleaf		

Signal	Direction	Description
+15V	In	RF Supply rail
RF12	Out	RF12 Split signal
40MHZ_REF#1	Out	40MHz Reference signal
40MHZ_REF#2	Out	40MHz Reference signal

External Interface Signals

Table 5

5.3 RF Module

5.3.1 Connectors

The connectors for the RF module are defined in Table 6.

Connector Name	Description
H1	Connector to back plane - DIN41612M 60 + 4 plugs (pins and coax inserts)

Connectors

Table 6

5.3.2 Inputs

Table 7 defines the external input signals for the RF module.

Signal	Connector	Type	Description
+15V	H1: A-C15	Power	Power supply
-15V	H1: A-C14	Power	Power supply
+5V	H1: A-C8	Power	Power supply
DGND	H1: A-C7	Power	Digital ground
AGND	H1: A-C9;A-C10;A-C12;A-C13	Power	Analog ground
S_CLK	H1: A-C20	HCMOS	Synth. serial data clock
S_DATA	H1: A-C21	HCMOS	Synth. serial data
S_LE	H1: A-C22	HCMOS	Synth. load enable
(CU)REF	H1: A-C11	RF	+13dBm reference input
(DRU)REF	H1: B2	RF	+13dBm reference input
RX_RF	H1: B31	RF	Received signal input
DOE	H1: A-C26	HCMOS	ADC's data output enable
FSI	H1: A-C23	HCMOS	ADCs frame sync input

External Inputs

Table 7

5.3.3 Outputs

Table 8 defines the external output signals for the RF board.

Signal Name	Connector	Type	Description
SDO	H1: A-C24	HCMOS	ADCs serial data output
SCO	H1: A-C25	HCMOS	ADCs serial clock output
(CU)I_RX	H1: B2	Baseband	Baseband I channel output
(CU)Q_RX	H1: B5	Baseband	Baseband Q channel output
TX_LO	H1: B28	RF	0 dBm LO output CU transmitter

External Outputs

Table 8

5.3.4 Indicators

Indicators on the RF module are defined in table 9.

Indicator Name	Color	Description
LED1	Yellow	+5V analog supply (internally generated)
LED2	Yellow	+12V analog supply
LED3	Yellow	-5V analog supply (internally generated)
LED4	Yellow	+5V analog supply (internally generated)
LED5	Green	Synthesizer Lock Detect

Indicators

Table 9

5.3.5 Internal Connections

Internal connections within the RF board are defined in table 10.

Signal Name	From	To	Type	Description
F_CLK	Synth	ADC	Digital	ADC 20.48 MHz clock
LO +27dBm	Synth	RX	RF	Local oscillator for Command Receiver

Internal Interface Signals

Table 10

5.4 Baseband Module Board

5.4.1 Power Signals

These signals are described in Table 7.

Signal Name	Direction	Connector	Type	Description
AGND	In	P1:A1,C1,A3,C3,A4,C4,A6,C6 A9,B9,C9,A10,B10,C10,A12,B12,C12,A13,B13,C13,A27,C27,A29,C29,A30,C30,A32,C32	Power	Analog Ground
DGND	In	P1:A7,B7,C7 P2:A1,B1,C1	Power	Digital ground
+5V	In	P1:A8,B8,C8	Power	Power supply 5V +/- 5%
+15V	In	P1:A15,B15,C15	Power	Power supply 15V +/- 5%

Power Signals

Table 11

5.4.2 Analog Signals

These are described in Table 12.

Signal Name	Direction	Connector	Type	Description
40 MHz	In	P1:A11,B11,C11	Analog	40 MHz Clock at +13 dBm
RX_I	In	P1:B2	Analog	I input from receiver 2.8 V p-p into AC coupled input
RX_Q	In	P1:B5	Analog	Q input from receiver 2.8 V p-p into AC Coupled input
TX_I	Out	P2:C32	Analog	I output from transmitter 0.7 to 3.5 V
TX_Q	Out	P2:C32	Analog	Q output from transmitter 0.7 to 3.5 V

Analog Signals

Table 12

5.4.3 Digital Control Signals

These signals are defined in Table 13.

Signal Name	Direction	Connector	Type	Description
S_CLK	Out	P1: A20	HCMS	Synthesizer Clock
S_DATA	Out	P1: A21	HCMS	Synthesizer data
S_LERF	Out	P1: A22	HCMS	RF Synthesizer enable LOW = Enable, HIGH = DISABLE
IN#1	In	P2:C2	TTL	Spare input
IN#2	In	P2:C3	TTL	Spare input
IN#3	In	P2:C4	TTL	Spare input
IN#4	In	P2:C5	TTL	Spare input
OUT#1	Out	P2:C6	HCMS	Spare Output / Data Detect LED
LED	Out	P2:C7	TTL	LED Output
20DB_ATT	Out	P2:C14	HCMS	Transmitter 20 dB Attenuator LOW = Switch in, HIGH = switch out
10DB_ATT	Out	P2:C15	HCMS	Transmitter 10 dB Attenuator LOW = Switch in, HIGH = switch out
5DB_DOWN	Out	P2:C16	HCMS	Transmitter 5 dB Down Attenuator LOW = Switch out, HIGH = switch in
5DB_UP	Out	P2:C17	HCMS	Transmitter 5 dB Up Attenuator LOW = Switch in, HIGH = switch out
T_SCL	Out	P2:C18	TTL	Temperature sensor Clock
TX_EN	Out	P2:C19	HCMS	Transmit enable LOW = enable, HIGH = Disable
TX_RX	Out	P2:C20	HCMS	Transmit/receive switch LOW = Receive, HIGH = Transmit
RX_I_HI	In	P2:C21	TTL	Masthead over current LOW = Over current, HIGH = Current OK
RX_I_LO	In	P2:C22	TTL	Masthead under current LOW = Under current, HIGH = Current OK
T_SDA	In/Out	P2:C23	TTL	Temperature sensor data
VSWR	In	P2:C24	TTL	Max VSWR exceeded (TBD - VSWR exceeded)
INSTB	In	P2:C25	TTL	Transmitter unstable LOW = Unstable, HIGH = not unstable
DC_NULL	Out	P2:C26	HCMOS	Transmitter DC Null LOW = Null, HIGH = Normal transmit
SHDN	Out	P2:C28	HCMOS	Shut down Cartesian Loop LOW = Disable, HIGH =enable Cartesian Loop

Digital Control Signals

Table 13

5.5 Buses

5.5.1. Radio Control Bus

The Radio Control Bus consists of an RS485 interface, and is used to control the command unit base-band board.

The various input and output signals are described in Table 14.

Signal Name	Direction	Connector	Type	Description
DID	Input	P1:A16	Analog	Spare
DIDR	Output	P1:B16	Analog	Spare
TZ+, TZ-	Input	P1:A17,B17	RS485	Message Trigger (Differential)
MS+,MS-	Input	P1:18,B18	RS485	Master - Slave signaling (Differential)
SM+,SM-	Output	P1:A19,B19	RS485	Slave - Master signaling (Differential)

Radio Control Bus

Table 14

5.5.2 Radio Data Bus

The radio data bus is used to output seismic data received over the radio link.
The inputs and outputs are differential with each path of the differential signal having TTL Logic levels.

The various signals handled by this bus are described in Table 15.

Signal Name	Direction	Connector (P2)	Type	Description
VA0+,VA0-	In	A2,B2	Differential	Address bit 0
VA1+,VA1-	In	A3,B3	Differential	Address bit 1
VA2+,VA2-	In	A4,B4	Differential	Address bit 2
VA3+,VA3-	In	A5,B5	Differential	Address bit 3
VCLK+,VCLK-	In	A6,B6	Differential	Clock
VRUN+,VRUN-	In	A7,B7	Differential	Run signal
VDP+,VDP-	Out	A8,B8	Differential	Data Present
VD0+,VD0-	Out	A10,B10	Differential	Data bit 0
VD1+,VD1-	Out	A11,B11	Differential	Data bit 1
VD2+,VD2-	Out	A12,B12	Differential	Data bit 2
VD3+,VD3-	Out	A13,B13	Differential	Data bit 3
VD4+,VD4-	Out	A14,B14	Differential	Data bit 4
VD5+,VD5-	Out	A15,B15	Differential	Data bit 5
VD6+,VD6-	Out	A16,B16	Differential	Data bit 6
VD7+,VD7-	Out	A17,B17	Differential	Data bit 7
VD8+,VD8-	Out	A18,B18	Differential	Data bit 8
VD9+,VD9-	Out	A19,B19	Differential	Data bit 9
VD10+,VD10-	Out	A20,B20	Differential	Data bit 10
VD11+,VD11-	Out	A21,B21	Differential	Data bit 11
VD12+,VD12-	Out	A22,B22	Differential	Data bit 12
VD13+,VD13-	Out	A23,B23	Differential	Data bit 13
VD14+,VD14-	Out	A24,B24	Differential	Data bit 14
VD15+,VD15-	Out	A25,B25	Differential	Data bit 15
CONN	In	A26	Digital	Unit connected forward
RET	Out	B26	Digital	Unit connected return

Radio Data Bus

Table 15

5.5.3 RS232

Signal Name	Direction	Connector	Type	Description
GND	in	H4 pin 5	Power	RS232 Ground
RXD	Out	H4 pin 2	RS232	RS232 Receive Data
TXD	In	H4 pin 3	RS232	RS232 Transmit Data
DTR	In	H4 pin 4	RS232	RS232 Data Terminal Ready
DSR	Out	H4 pin 6	RS232	RS232 Data Set Ready
RTS	In	H4 pin 7	RS232	RS232 Ready To Send
CTS	Out	H4 pin 8	RS232	RS232 Clear To Send

RS232 Signals

Table 16

5.6 Concentrator

5.6.1 Connectors

The connectors for the Concentrator are defined in Table 17.

Connector Name	Description
H1	Connector to Data Receive Unit back plane DIN41612 Type C (96 way male)
H2	Connector to Data Receive Unit back plane DIN41612 Type C (96 way male)

Connectors

Table 17

5.6.2 Inputs

Table 18 defines the input signals for the Concentrator module.

Signal Name	Connector	Type	Description
+5V	H1, pins 2a, 2b, 2c H2, pins 2a, 2b, 2c	Power	Main 5V supply
+15V	H1, pins 9a, 9b, 9c H2, pins 9a, 9b, 9c	Power	Main +15V supply
-15V	H1, pins 8a, 8b, 8c H2, pins 8a, 8b, 8c	Power	Main -15V supply
DGND	H1, pins 1a, 1b, 1c, H2, pins 1a, 1b, 1c	Power	Digital ground
AGND	H1, pins 3a, 3b, 3c 4a, 4b, 4c 6a, 6b, 6c 7a, 7b, 7c H2, pins 3a, 3b, 3c 4a, 4b, 4c 6a, 6b, 6c 7a, 7b, 7c	Power	Analog Ground
Continued Overleaf			

DRxD0	H1, pin 14c	TTL	Seismic data input bit 0
DRxD1	H1, pin 15a	TTL	Seismic data input bit 1
DRxD2	H1, pin 15b	TTL	Seismic data input bit 2
DRxD3	H1, pin 15c	TTL	Seismic data input bit 3
DRxD4	H1, pin 16a	TTL	Seismic data input bit 4
DRxD5	H1, pin 16b	TTL	Seismic data input bit 5
DRxD6	H1, pin 16c	TTL	Seismic data input bit 6
DRxD7	H1, pin 17a	TTL	Seismic data input bit 7
DRxD8	H1, pin 17b	TTL	Seismic data input bit 8
DRxD9	H1, pin 17c	TTL	Seismic data input bit 9
DRxD10	H1, pin 18a	TTL	Seismic data input bit 10
DRxD11	H1, pin 18b	TTL	Seismic data input bit 11
DRxD12	H1, pin 18c	TTL	Seismic data input bit 12
DRxD13	H1, pin 19a	TTL	Seismic data input bit 13
DRxD14	H1, pin 19b	TTL	Seismic data input bit 14
DRxD15	H1, pin 19c	TTL	Seismic data input bit 15
DRxP	H1, pin 13b	TTL	Data Rx present High: Card fitted Low: Card not fitted
DRxDP	H1, pin 13c	TTL	Data Rx data available High: Data available Low: Data not available
DRxO	H1, pin 14a	TTL	Data Rx data o/p buffer overflow ¹ High: Buffer overflow Low : Buffer OK
40MHz In	H1, 5a, 5b, 5c	Analog	40.0MHz clock at +13 dBm
VA0+	H2, pin 10a	Differential	RDB Rack address bit 0
VA0-	H2, pin 10b	Differential	RDB Rack address bit 0
VA1+	H2, pin 11a	Differential	RDB Rack address bit 1
VA1-	H2, pin 11b	Differential	RDB Rack address bit 1
VA2+	H2, pin 12a	Differential	RDB Rack address bit 2
VA2-	H2, pin 12b	Differential	RDB Rack address bit 2
VA3+	H2, pin 13a	Differential	RDB Rack address bit 3
VA3-	H2, pin 13b	Differential	RDB Rack address bit 3
VClk+	H2, pin 14a	Differential	RDB I/F data clock Data is clocked into recording computer on rising edge.
VClk-	H2, pin 14b	Differential	RDB I/F data clock
VRun+	H2, pin 15a	Differential	RDB I/F Run control High: During data transfers Low: Otherwise
VRun-	H2, pin 15b	Differential	RDB I/F Run control
Vreset+	H2, pin 17a	Differential	Concentrator reset
Vreset-	H2, pin 17b	Differential	Concentrator reset
/DRxRdy	H1, pin 14b	TTL	Data receiver ready for DMA data transfer Low: ready, High: Not ready
BIB_EN	H1, pin 20a	TTL	Enable RCB slave master output, wire-or from DRUs Active Low

External Input Table 18

5.6.3 Outputs

Table 19 defines the output signals for the Concentrator board.

Signal Name	Connector	Type	Description
VDP+	H2, pin 16a	Differential	Data present flag High: Data available for reading Low: No data available
VDP-	H2, pin 16b	Differential	Data available flag
VD0+	H2, pin 18a	Differential	RDB Data bit 0
VD0-	H2, pin 18b	Differential	RDB Data bit 0
VD1+	H2, pin 19a	Differential	RDB Data bit 1
VD1-	H2, pin 19b	Differential	RDB Data bit 1
VD2+	H2, pin 20a	Differential	RDB Data bit 2
VD2-	H2, pin 21a	Differential	RDB Data bit 2
VD3+	H2, pin 22a	Differential	RDB Data bit 3
VD3-	H2, pin 23a	Differential	RDB Data bit 3
VD4+	H2, pin 24a	Differential	RDB Data bit 4
VD4-	H2, pin 24b	Differential	RDB Data bit 4
VD5+	H2, pin 25a	Differential	RDB Data bit 5
VD5-	H2, pin 25b	Differential	RDB Data bit 5
VD6+	H2, pin 26a	Differential	RDB Data bit 6
VD6-	H2, pin 26b	Differential	RDB Data bit 6
VD7+	H2, pin 25c	Differential	RDB Data bit 7
VD7-	H2, pin 26c	Differential	RDB Data bit 7
VD8+	H2, pin 27a	Differential	RDB Data bit 8
VD8-	H2, pin 27b	Differential	RDB Data bit 8
VD9-	H2, pin 28b	Differential	RDB Data bit 9
VD10+	H2, pin 27c	Differential	RDB Data bit 10
VD10-	H2, pin 28c	Differential	RDB Data bit 10
VD11+	H2, pin 29a	Differential	RDB Data bit 11
VD11-	H2, pin 29b	Differential	RDB Data bit 11
VD12+	H2, pin 30a	Differential	RDB Data bit 12
VD12-	H2, pin 30b	Differential	RDB Data bit 12
VD13+	H2, pin 29c	Differential	RDB Data bit 13
VD13-	H2, pin 29d	Differential	RDB Data bit 13
VD14+	H2, pin 31a	Differential	RDB Data bit 14
VD14-	H2, pin 31b	Differential	RDB Data bit 14
VD15+	H2, pin 32a	Differential	RDB Data bit 15
VD15-	H2, pin 32b	Differential	RDB Data bit 15
/DRxReq	H1, pin 10a	TTL	Data Receiver DMA request Low: Request High: No request
DRxCk	H1, pin 10b	TTL	Clocks data out of the buffer on Data RF board on rising edge and into FIFO on the falling edge.
DRxA0	H1, pin 10c	TTL	Address line 0 for channel data
DRxA1	H1, pin 11a	TTL	Address line 1 for channel data
DRxA2	H1, pin 11b	TTL	Address line 2 for channel data
DRxA3	H1, pin 11c	TTL	Address line 3 for channel data
DRxA4	H1, pin 12a	TTL	Address line 4 for channel data
Continued Overleaf			

DRxA5	H1, pin 12b	TTL	Address line 5 for channel data
DRxA6	H1, pin 12c	TTL	Address line 6 for channel data
DRxA7	H1, pin 13a	TTL	Address line 7 for channel data

External Outputs

Table 19

5.6.4 Bi-directional Signals

Table 20 lists the external bi-directional interface signals for the Concentrator.

Signal Name	Connector	Description
SM#1+	H1 pin 31a	To SMU (SM2 buffered from DRUs)
SM#1-	H1 pin 31b	To SMU (SM2 buffered from DRUs)
MS#1+	H1 pin 30a	From SMU, (buffer to DRUs)
MS#1-	H1 pin 30b	From SMU, (buffer to DRUs)
SM#2+	H1 pin 20b	From DRUs (buffer to SMU)
SM#2-	H1 pin 20c	From DRUs (buffer to SMU)
MS#2+	H1 pin 21b	To DRUs (MS1 buffered from SMU)
MS#2-	H1 pin 21c	To DRUs (MS1 buffered from SMU)
SM#3+	H2 pin 21b	Termination input for SM2
SM#3-	H2 pin 20c	Termination input for SM2
MS#3+	H2 pin 21b	Termination input for MS2
MS#3-	H2 pin 21c	Termination input for MS2

External Bi-Directional RCB Interface Signals

Table 20

5.7 Power Supply Module

5.7.1 Inputs

240 V ac, 50/60 Hz or
120 V ac, 50/60 Hz.

5.7.2 Outputs

DC output voltages are summarized in Table 21.

Voltage (V dc)	Current (A dc)	Line Regulation For 10% change (%)	Load Regulation For 10-100% change (%)	Max Ripple %
+ 5	50	< 0.2	< 0.5	< 0.5
+15	8	< 0.5	< 10.0	< 2.0
-15	8	< 0.5	< 10.0	< 2.0

PSU Output Voltages

Table 2