RAPTOR X®

UNLICENSED WHITE SPACE

BROADBAND VHF/UHF
NETWORKING SYSTEM

User Guide

- System Design
- Installation
- Operation
- Maintenance

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METRIC SYSTEMS

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FCC Regulatory Information

FCC ID: 2ABCU-50739

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Any changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.
Part 15 TV Band Device Notice

This equipment has been tested and found to comply with the rules for TV bands devices, pursuant to part 15 of the FCC rules. These rules are designed to provide reasonable protection against harmful interference. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

(1) Reorient or relocate the receiving antenna.
(2) Increase the separation between the equipment and receiver.
(3) Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
(4) Consult the manufacturer, dealer or an experienced radio/TV technician for help.
Caution: Exposure to Radio Frequency Radiation.
To comply with FCC RF exposure compliance requirements, for fixed configurations, a separation distance of at least 40 cm must be maintained between the antenna of this device and all persons.
This device must not be co-located or operating in conjunction with any other antenna or transmitter

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RaptorX User Manual

Part Number 50739 Series

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Revision History

DATE OF REVISION	REVISION LETTER	DESCRIPTION OF CHANGES	PAGES CHANGED
9/30/14	Rev.1.06.2	BETA MANUAL RELEASE	
3/3/15	Rev.1.07A	NEW MANUAL UPDATE	ALL

Metric Systems Corporation (MSC)

Standard Hardware One (1) Year Warranty

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1 Introduction

1.1 Manual Overview

This manual provides the professional telecommunications engineer or craft person with the required information and procedures necessary to successfully design, deploy and operate a RaptorX White Space Broadband Radio network.

This Manual is organized into four (4) chapters:

1. Overview of the RaptorX hardware, embedded capabilities and tools to allow you to design, deploy and operate RaptorX White Space Radio equipment.
2. Spectrum Coordination and Equipment Registration. This section will show how to determine what TV band channels are available to support your network application and how each RaptorX is registered with the FCC via RaptorX's certified database supplier to operate on available channels
3. System/Network Design. This segment of the Manual provides the necessary technical and practical information to successfully design, deploy and operate multiple RaptorX Radio nodes in various network configurations.
4. Technical Reference section addresses system operations and maintenance procedures.

1.2 Documentation Conventions

Description	Represents	Example
Italic	Specify something	*Registration mode*
'Single quotes'	Field name	'Register Device'
"Double quotes"	Reference to new term	"Channel List"
Underline	Definition	UHF - Ultra High Frequency
Bold	For emphasis	Then before you …
(Text in parenthesis)	Additional clarification	(The red field)
*Asterisk text	Special note	*Registration requires a name

1.3 Abbreviations and Terminology

Abbreviation	**Definition**
White Space	VHF or UHF TV channels that are no longer in use in a given geographical area
TVBD	(TV band devices)An FCC term denoting a wireless device which operates in unlicensed TV band spectrum
Half Duplex	A wireless protocol that uses a single wireless or dual wireless channels to communicate with another station, e.g. Tx on VHF or channel 13; Rx on UHF channel 14.
TDD	Time Division Duplex; a media access protocol that subdivides an epoch of time, i.e. a second, into discreet elements to transmit or receive information packets from one to many stations
Full Duplex	A wireless protocol that uses two independent channels for simultaneous two way communications.
Simplex	A wireless protocol that transmits while the other side listens. Streaming video is a "most-of-the time transmit
FCC Database Provider	An FCC certified vendor that provides White Space equipment with registration services and geographically available operating channels.
Base Station	The RaptorX unit that accesses the FCC Database.
Remote Station	RaptorX unit that accesses the Base Station

2 RaptorX Overview

RaptorX is an *unlicensed* broadband half-duplex Tx/Rx Networking Radio System operating in high VHF TV channels 7-13 (174 MHz -216 MHz) and authorized UHF channels 14-35 (470 MHz-599 MHz) and UHF channels 39-51 (620-698 MHz) bands. The primary technical mission of the RaptorX suite is to support industrial, commercial, and governmental backhaul and edge network transport applications. The RaptorX features an adaptive suite of robust transmit modulation formats along with full legal conducted RF power output capability (27.8 dBm) to take full advantage of locally available TV band spectrum. *MSC offers a variety of antenna types to support Omni, Sector and Directional applications. With the appropriate antenna the maximum FCC EIRP transmit power of 36 dBm (4 Watts) is available. While in the Rx mode, higher gain antennas can provide additional passive gain to extend range and coverage area.*

2.1 System Benefits and Capabilities

- Extended range, beyond horizon operation, and superior in-structure operation
- Easily integrates with existing public and private wireless systems
- Provides new and enhanced revenue opportunities to service and venue operators.

2.2 Operational Capabilities

- Maximum legal EIRP support for both VHF high band channels (7 to 13) and UHF channels (14 to 35 and 39 to 51);
- High system margin supports VHF and UHF operation to 20+ miles;
- Fixed or dynamically-adaptable payload rates of 1 to 6 mbps;
- Half-duplex, single frequency or dual frequency operations;
- Tx/Rx diversity advantage: separate Tx and Rx antenna options for extended range and custom coverage requirements;
- SafariView: RaptorX's integrated HTML-based systems Operations, Administration and Maintenance application is accessible via front Ethernet ports or short range secure wireless connection using a standard web browser (Mozilla, Safari, Apple 4, Internet Explorer);
- User-configurable to support:● multiple network and link topologies;● single channel point-to-point,● multiple-channel point-to-point,● chained point-to-point relay links,● ad hoc-based mesh nets and ●point-to-multipoint;
- Bandwidth scalable – two or more available White Space channels can be bonded (channel aggregation) to increase link payload capacity and provide high-link reliability via spatial diversity;
- Two-channel MIMO operation provides superior operation in urban or natural clutter environments.

2.2.1 Optional System Features

FEATURES	DESCRIPTION
Separate ports	Provisions for separate Tx and Rx ports enabling the RaptorX to operate in a MIMO configuration (1 x 1) for enhanced operation in a cluttered environment (urban, forested, refineries, etc.)
System Clock	Provision for external high stability system clock used for single frequency network operation
Antenna-common	A common antenna will serve multiple RaptorXs in a channel aggregation configuration serving industrial wireless internet service provider (WISP)applications
Antenna-separate	Separate Tx and Rx antennas support the RaptorX capability for spatial and frequency diversity configuration useful for extending range, shaping coverage footprints and increasing overall system reliability.

2.3 The RaptorX Hardware Suite

The basic RaptorX Hardware Suite consists of three (3) purpose-specific component shelves which are user-configured to support single or dual-channel White Space operation:

- Network Shelf – common to single and dual channel configurations (See Figure 1.0)
- Channel Expansion Shelf – provides an additional VHF/UHF Channel (See Figure 3.0)
- Redundant Power Shelf (See Figure 1.0) provides power to network and expansion shelves.

2.3.1 A RaptorX Single White Space Channel Configuration includes one

(1) RaptorX Network Shelf contains the local network processor and a single channel White Space VHF/UHF broadband radio. Figure 1.0 below shows user indicators, controls and physical interfaces. Figure 2.0 shows the rear view of a single channel stack. Figure_____ shows a basic site single channel configuration.

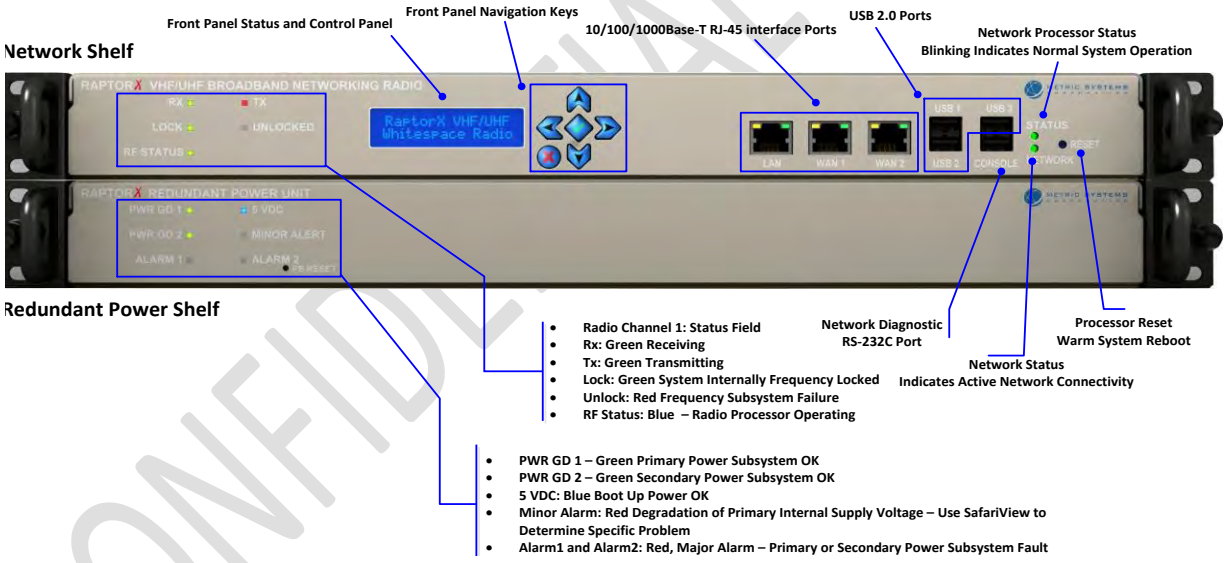


Figure 1.1 Single Channel System (Front View) illustrating user indicators, controls and physical interfaces.

The *front view* ergonomics of all RaptorX equipment are designed to provide the user and installer with the minimum required indicators and controls to monitor, operate and maintain system operation following equipment registration.

2.3.1.1 Network Shelf Front Panel Descriptions

ITEM	DESCRIPTION/FUNCTION
Tx/Rx Field	
Rx: Green	RaptorX is in receiving (Rx) mode
Tx: Green	RaptorX is in transmitting (Tx) mode
Lock: Green	Tx/Rx frequency internally locked
Unlock: Red	Subsystem Failure
RF Status: Blue (blinking)	Tx/Rx processor operational; no blinking or "off" indicates major alarm
Front Panel Status and Control Panel Display and Navigation Keys	Allows selection of available channels following valid registration
	Allows setting of maximum available power based on antenna type and transmission line loss
	Permits engaging of local or remote antenna-aiming application (See Chapter 3)
	System self-test
	Enables and displays results of local and remote equipment self-test
	Enables maintenance mode for depot equipment: calibration, diagnostics and repair. Password protected.
Network Ports	One (1) local LAN port (See Chapter 4) (10/100/1G)
	Two (2) WAN ports (See Chapter 4) (10/100/1G)
	Three (3) USB ports are powered to support 250 MHz from each port, if required.
Network Diagnostic Port	For factory and depot use only.
Network Processor Status: Blue (blinking)	Indicates the RaptorX is connected to a valid IP network and can reach RaptorX's FCC database site.
Network Status	Password controlled for factory and certified professional use only.
Processor Reset	Processor reset performs a warm reboot on the network processor and TV band transceiver.

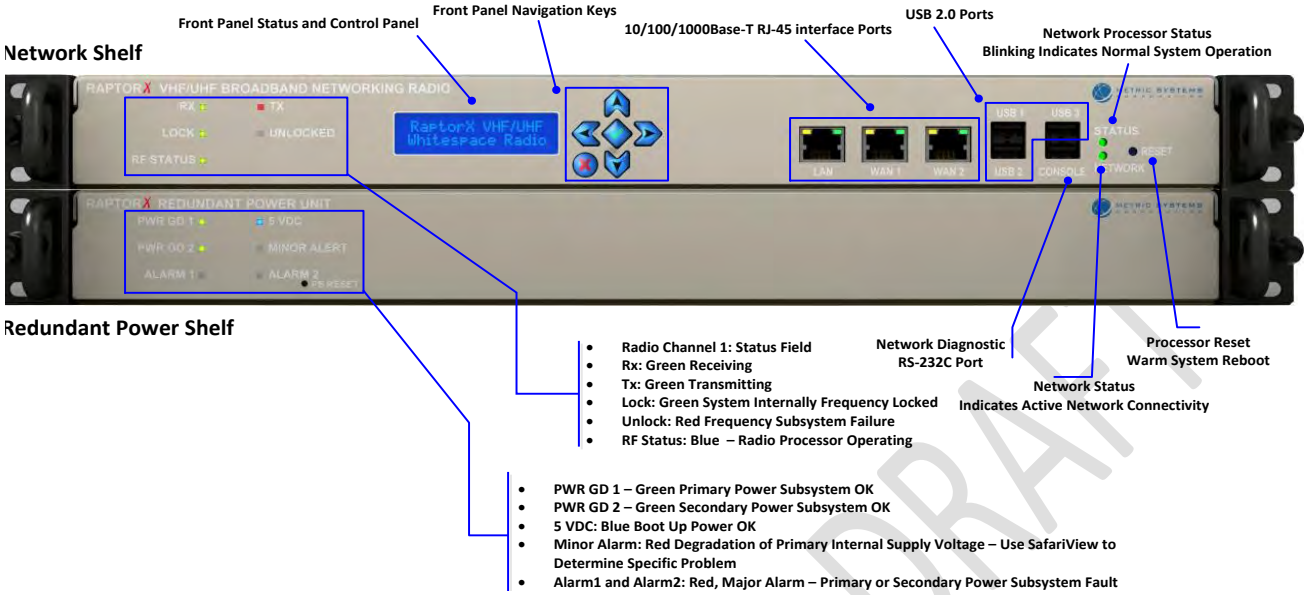


Figure 1.2 Single Channel System (Front View)

2.3.2 RaptorX Redundant Power Supply Shelf Indicators and Controls

POWER SUPPLY ITEM	DESCRIPTION/FUNCTION
PWR GD1 - Green	Indicates primary power supply operating nominally
PWR GD2 - Green	Indicates secondary supply operating nominally
5 VDC- Blue	Indicates processor power operational
5 VDC - Red	Indicates system power parameter(s) are out of tolerance. Use SafariView or Front Panel display to define problem.
Alarm 1 or Alarm 2 - Red	Primary or secondary power subsystem failure

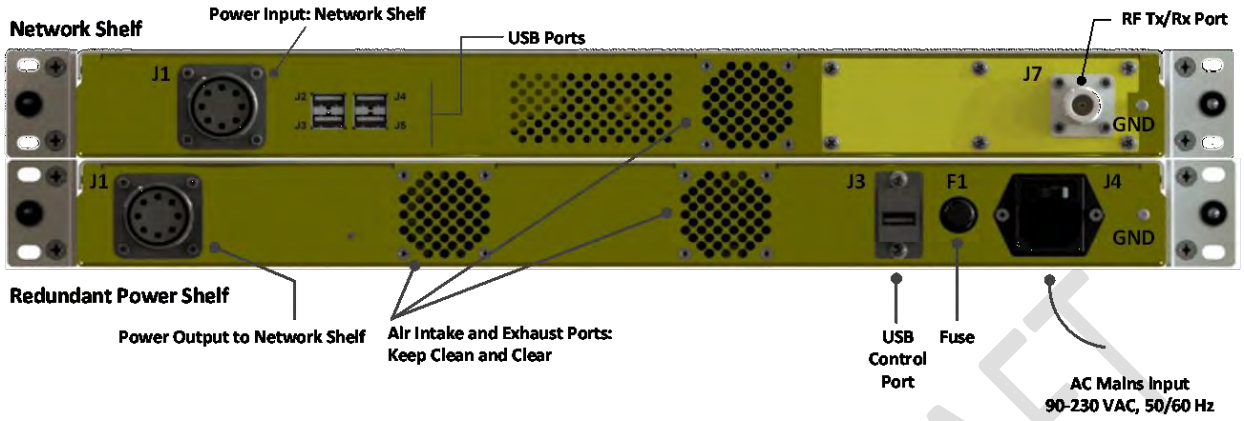


Figure 1.3 Single Channel System (Rear View)

2.3.3 RaptorX Single Channel System (Rear Views)

NETWORK SHELF ITEM	DESCRIPTION
J1:Power Input	DC Input: 12 and 28 V DC
J2,3,4,5: USB 2.0 Ports	Port J2 interconnects to J3 on Power Shelf
J7:RF Tx/Rx Port	VHF/UHF output
GND	Connect to local site ground

REDUNDANT POWER SHELF ITEM	DESCRIPTION
J1:Power Output	To Network Shelf
Air Intake and Exhaust Ports	Keep clean and clear
J3:USB Control Port	Connects to J2 on Network Shelf
F1:Fuse	Connect to local site ground
J4: AC Mains Input	AC Power Input: 90-230 VAC, 50-60 Hz
GND	

2.3.4 RaptorX Dual Channel Expansion Configuration

A Dual Channel RaptorX is configured by adding one Channel Expansion Unit. Each Channel Expansion Unit (Shelf) is controlled by the Network Shelf and contains one VHF/UHF White Space Tx/Rx unit. The Expansion Unit RF front panel controls and indicators are identical to those on the Networking Radio Shelf

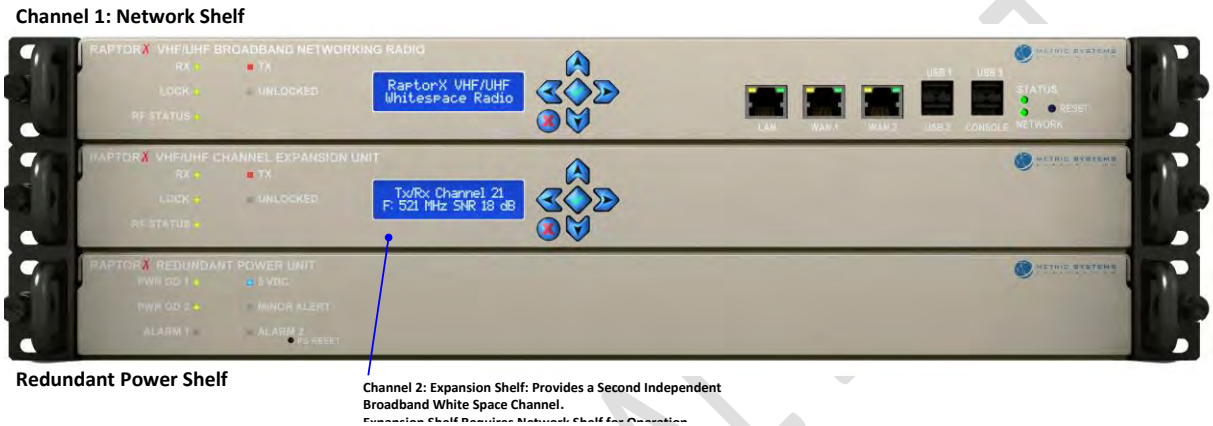


Figure 1.4 RaptorX Dual Channel System (Front View)

2.3.4.1 Utilization of the Expansion Shelf (See Figures_____)

Use of the Channel Expansion Shelf provides the following system benefits and capabilities:

- Increased link throughput capacity; nearly twice the rate of a single channel link
- Fault-tolerant point-to-point link protection; connection is maintained in the event of a channel propagation failure or a hardware failure
- Spatial frequency and diversity
- Wide area multiple sector point-to-multipoint networks
- Back-to-back add-and-drop relay nodes for low latency long range relay chains

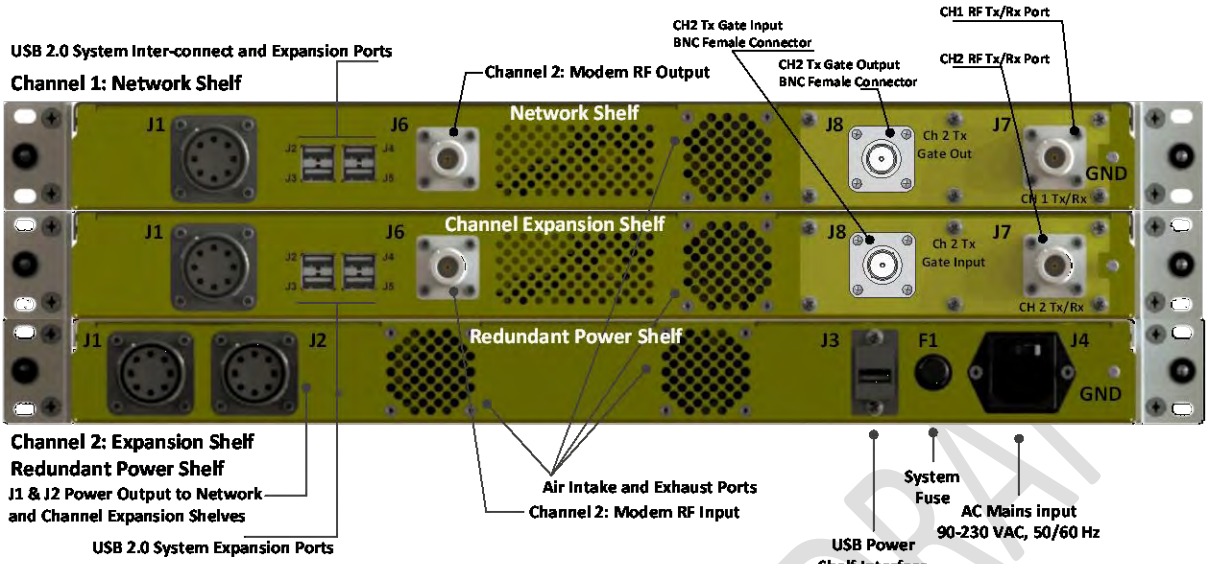


Figure 1.5 RaptorX Dual Channel System (Rear View)

2.3.5 RaptorX Dual Channel System using Channel Expansion Shelf Interfaces

CHANNEL EXPANSION INTERFACES	DESCRIPTION
J1 Power Input- Mil-style	DC input from Redundant Power Shelf
J 2,3,4,5- Standard ISB	USB 2.0 System Expansion Ports
J6- Type N Female	Channel 2: Modem RF Input
J7-Type N Female	Channel 2: RF Tx/Rx Output Port
J8 BNC Female	Channel 2: Tx Gate Input BNC Female Connector
Air Intake and Exhaust Ports	Keep clean and clear

2.4 Accessing VHF/UHF TV Band Spectrum/Getting Started

See Figure 5.Registering the RaptorX, which shows the registration configuration of a RaptorX connected to the internet.

The RaptorX only becomes operational when successfully registered with the RaptorX's designated FCC certified database provider, IConnectiv. (http://iconectiv.com/spectrum-mgmt/white-spaces/index.html)

Each RaptorX has been registered for two (2) years with Iconnectiv.

It is the operator's responsibility to assure continued registration, either directly with a certified database provider or through an MSC Service Plan.

2.4.1.1 To access the Registration page insert the IP address: 192.168.1.1 into your web browser/URL line.

2.4.1.2 Insert required device and location information. Click *Registration*.

2.4.1.3 Upon a successful registration a list of available White Space channels will be returned.

2.4.1.4 Select the appropriate TV channel to complete registration and activate the Tx subsystem of the RaptorX.

2.4.1.5 The remaining sections will describe in detail the *Registration process*. The RaptorX will automatically validate and re-register the unit every 24 hours.

3 Registration Overview

3.1 The RaptorX TV Band Device (TVBD) has two status modes:

"Unregistered" and "Registered".

3.1.1 When valid registration settings are detected

an attempt is made to load the configuration. Upon successfully loading, an automatic check is performed to determine the mode (see definitions below) and that the appropriate form fields are displayed for the proper mode.

3.2 Unregistered mode:

All fields (excluding address 2) under Device, Location, Contact, and Registrant must be completed with valid information (see pg. 7). Once completed the device must be registered by clicking the 'Register Device' button. If an error is caught registration will fail and a notification with the appropriate error(s) will be shown. In the event of an error the device will stand-by for correct input before successfully switching to registered mode.

3.3 Registered mode:

Upon successful registration, a list of available white space channels is returned in the "Channel List" drop-down menu and the device prompts to select a channel. When a channel has been selected the device does an additional check with the FCC database to ensure it is still available and proceeds with the channel registration. At any point the user may choose to refresh the 'Available Channel' list or 'Unregister' the device by clicking the desired button.

3.4 Radio Transmission:

After successfully registering a radio to a channel frequency the final step is to enable radio transmission. To do so, fill out all input fields under the Radio Information and set Enable Radio to the Yes Option. If the device should enable the radio on startup, check the

appropriate box as well. Click the 'Apply Changes' button to commence RaptorX radio operations.

3.5 To change any information after registration

the device must first be in the unregistered state. ***To do so, simply click the Unregister button.***

3.6 Completing the RaptorX Registration Form

When filling out the fields to register the RaptorX they are automatically scanned for errors1 when attempting to register the device. If any errors are caught they are displayed and marked along with the appropriate error message. Below is an example of some errors as well as a brief explanation of what to enter for each field.

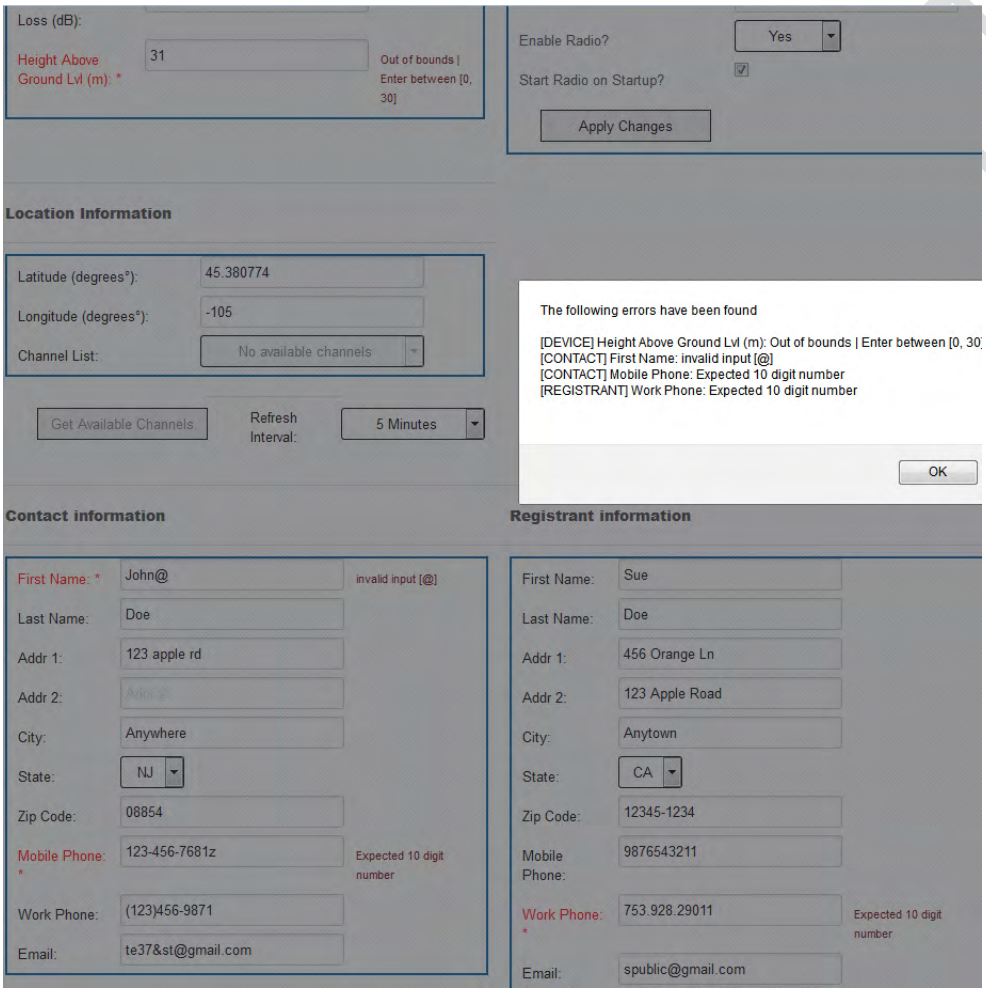


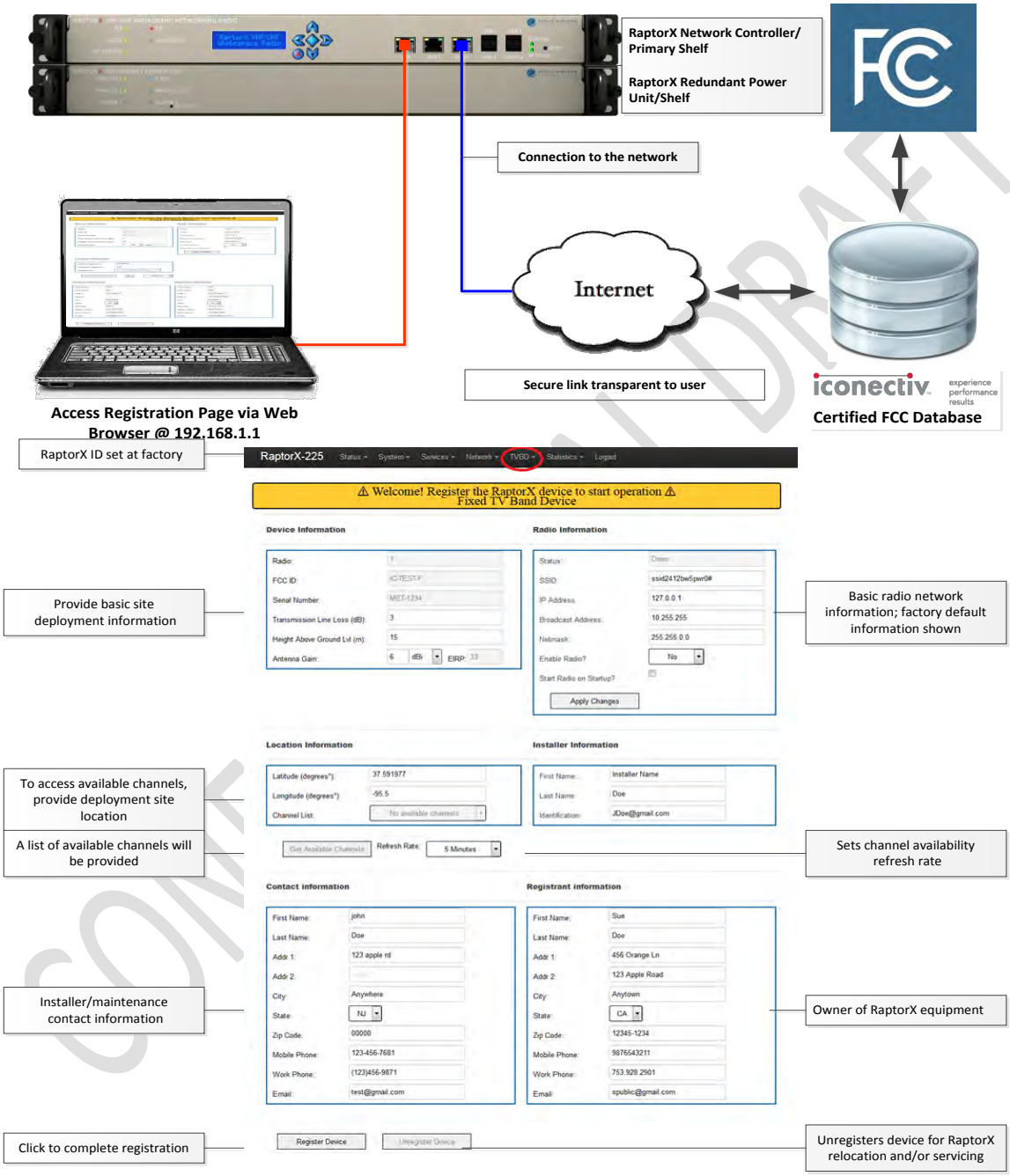
Figure 1.6 RaptorX Registration Form

1 – Error Descriptions

1. Syntax – Invalid characters appear or the format is wrong
2. Out of Bounds – Input is not in the correct range (too high or too low)
3. NIL Input - No Input in a field
4. Channel Registration – The TV channel is not valid for registration
5. Device Registration – Registration failed
6. Radio Registration – The radio settings were not successfully applied

3.7 Registering the RaptorX

Figure 1.7 RaptorX Registration Configuration Set-Up



3.7.1 [DEVICE]

Radio: The device radio number | **This is locked into the RaptorX at manufacture**
FCCID: The device FCC ID | **This is locked into the RaptorX at manufacture**
Serial Number: The device serial number | **This is locked into RaptorX at manufacture**
Antenna Gain: The antenna gain power (dBi/dBd) | **Expected: [-15, 15]**
Transmission Line Loss: Measured transmission line loss (dB) | **Expected: [0, 10]**
Antenna height above ground level (HAGL): (m) | **Expected [0, 30]**
EIRP: The Effective Isotropic Radiated Power output | **Locked into RaptorX, MAX=36**

3.7.2 [LOCATION]

Latitude: The latitude up to six decimal places (degrees) | **Expected: [-90, 90]**
Longitude: The longitude up to six decimal places (degrees) | **Expected: [-180, 180]**
Channel List: The list of available TV channels | **Determined by geolocation**

3.7.3 [RADIO]

Status: The radio status | **Will display 'Up' or 'Down' dependent on operation mode**
SSID: The broadcast SSID | **Accepts all characters except [><&\"=/]**
IP Address: The radio IP Address
Broadcast Address: The radio Broadcast Address
Subnet mask: The radio subnet mask

3.7.4 [CONTACT/REGISTRANT]

*The *contact* form information should be that of the owner of the device.
*The *registrant* form information should be that of the installer's for troubleshooting.
*The *contact* and *registrant* can be the same in some cases
*Fill out the forms with the appropriate corresponding label information. No special cases.

3.7.5 [MISC]

Refresh Interval: How often the registered channel and list of available channels are checked for availability (refreshed). Recommended period: 5 minutes
Enable Radio: Enable or disable the corresponding radio unit; either Radio 1 or Radio 2
Startup?: Enable or disable the corresponding radio unit when the device starts up (If enabled, the RaptorX will begin sending *beacon packets* to alert other RaptorX nodes operating on a common channel within the network.)
Get Available Channels: Refreshes the list of available TVBD channels
Register Device: Uses the information to register the RaptorX
Unregister Device: Unregisters the RaptorX.

The RaptorX must be unregistered when:

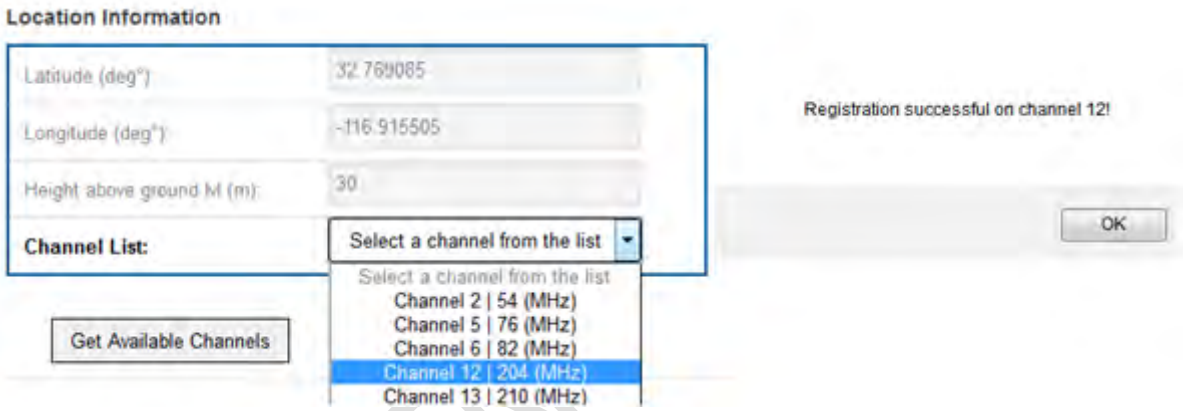
- **RaptorX is moved beyond 50 meters**
- **It is being repaired or undergoing firmware enhancements.**

3.8 Selecting an Available Channel

3.8.1 Upon a successful registration:

3.8.1.1 All the fields are locked and prevented from being modified;

3.8.1.2 TV channel list is available with the geographically available channels. To assign the device to an available channel simply select the desired channel from the drop-down list.



3.8.1.3 While the RaptorX is registered the list of available channels can be refreshed at any point by clicking the 'Get Available Channels' button.

3.8.1.4 After registering a valid TV channel the radio is now ready for operation. To begin, complete the 'Radio Information' form and ensure the 'Enable Radio' option is set to "Yes". Click on 'Apply Changes', the RaptorX device will complete the registration and start radio operation on the appropriate TV channel. In the sample above we have selected TV Channel 12, center frequency 204 MHz

3.8.1.5 If any issues occur go back to the first step and follow the instructions carefully.

3.8.1.6 To unassign a channel but keep the RaptorX registered simply select the first option in the drop-down list that reads 'Select a channel from the list' (colored grey).

3.8.2 Unregistering the RaptorX

3.8.2.1 When the device is in *registered* mode the 'Unregister Device' button becomes enabled

3.8.2.2 If the device needs to go into the *unregistered* mode the user must press the 'Unre20gister' button

3.8.2.3 Unregistering the RaptorX will send it back to *unregistered* mode after successfully dropping the registered channel followed by completely unregistering the device.

*To change any fields the device must be in *unregistered* mode.
*Unregistering the device will allow changes to all form information

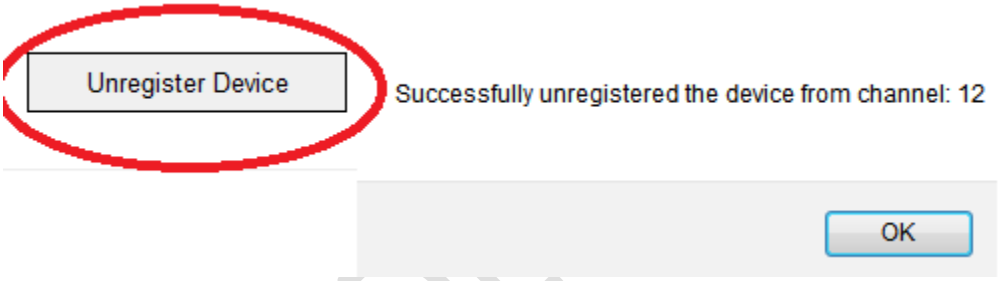


TABLE 1		
Frequency Range	TV Channel Number	Center Frequency (MHz)
VHF High Band 174-216 MHz	7	177
	8	183
	9	189
	10	195
	11	201
	12	207
	13	213
UHF Low Band 470-611 MHz	14	473
	15	479
	16	485
	17	491
	18	497
	19	503
	20	509
	21	515
	22	521
	23	527
	24	533
	25	539
	26	545
	27	551
	28	557
	29	563
	30	569
	31	575
	32	581
	33	587
	34	593
	35	599
UHF High Band 614-698 MHz	39	623
	40	629
	41	635
	42	641
	43	647
	44	653
	44	659
	46	665
	47	671
	48	677
	49	683
	50	689
	51	695

Appendix 1 Communications Protocol between the TVBD and the Certified FCC Database

1. *What communication protocol is used between the database and the TVBD?*

The TVBD connects to the iConectiv database using HTTP over SSL/TLS. The protocol used over this transport layer is specified by the IETF Protocol to Access White Space (PAWS) Draft-12 specification.

2. *How are communications initiated?*

The TVBD initiates communication with the iConectiv database by sending first sending an INIT_REQ message containing a Device Descriptor. The Device Descriptor element contains the device serial number, manufacturer ID, and model ID, which in the US is FCC ID.

3. *How does the TVBD validate messages from the database?*

The identity of the iConectiv database is validated through verification of the iConectiv SSL certificate through standard third-party certificate authority mechanisms, ensuring the communications are secure and authentic between the TVBD and the database.

At the application layer both the TVBD and database only handle messages that conform to the PAWS protocol specification. One additional message validation feature included in PAWS is the ability for the TVBD to correlate a response with a specific request by comparing the message's ID field with the ID field of the request that was sent.

4. *How does the device handle failure to communicate or authenticate the database?*

If the TVBD has never communicated with or authenticated the database, then it will not begin operation. If once operating, experiences a communication or authentication failure, then it will cease operation at 11:59 PM on the following day.

5. *How does the database validate messages from a TVBD?*

The database validates messages from the TVBD by checking the serial number and FCC ID received in the Device Descriptor data element in every message versus a table of valid client devices that is populated when the device is manufactured. The list of valid serial numbers is communicated from device manufacturer to iConectiv via "out-of-band means," such as email or telephone.

6. *What encryption method is used?*

SSL/TLS standard encryption is used to encrypt packets send between TVBD and database.

7. *How does the database ensure secure registration of protected devices?*

In this document, we interpret "protected devices" to mean entities authorized by the rules for protection from TVBDs, e.g., Temporary BAS, MVPD, Licensed and Unlicensed Microphones.

iConectiv provides a public interface that is available to entities authorized for protection under CFR Title 47 Part 15 Subpart H. The iConectiv registration system requires entities seeking protection to register for an account on the iConectiv site before they can create protected contours. Once a user creates an account, they can create new and view previously created registrations via the iConectiv registration site.

iConectiv maintains two parallel registration sites. The first, production registration site, is available to entities seeking protection from operational TVBDs. The second, test and integration site is available to those device manufacturers looking to integrate with the iConectiv database and to FCC and test laboratories looking to test functionality of a TVBD operating in conjunction with the iConectiv database. The test and integration site is provided so as to not corrupt data in the live production site with records used for testing only.

The two registration sites can be accessed via these addresses:

1. Live production registration site: https://spectrum.iconectiv.com/main/reg/
2. Test and integration registration site:: https://spectrum.iconectiv.com/dev/reg/

Testers should note that while a device is being tested for certification, it will be connecting to the iConectiv test and integration server. To test the TVBD for operation in conjunction with registered protected entities, the tester must register for protection on the test and integration server (#2) listed above.

Appendix 2 Logging

When the RaptorX successfully executes certain operations (registering channel, checking channel availability, etc.) the output of the execution is sent to a log file. This log file can be displayed on the "Radio Logging" page.

The output of the logs is the most recent N lines of the log file where N is the number in the drop-down selector outlined in red below. If the entire log is needed there is a "Download Log" button which will securely download the log file for the radio(s).

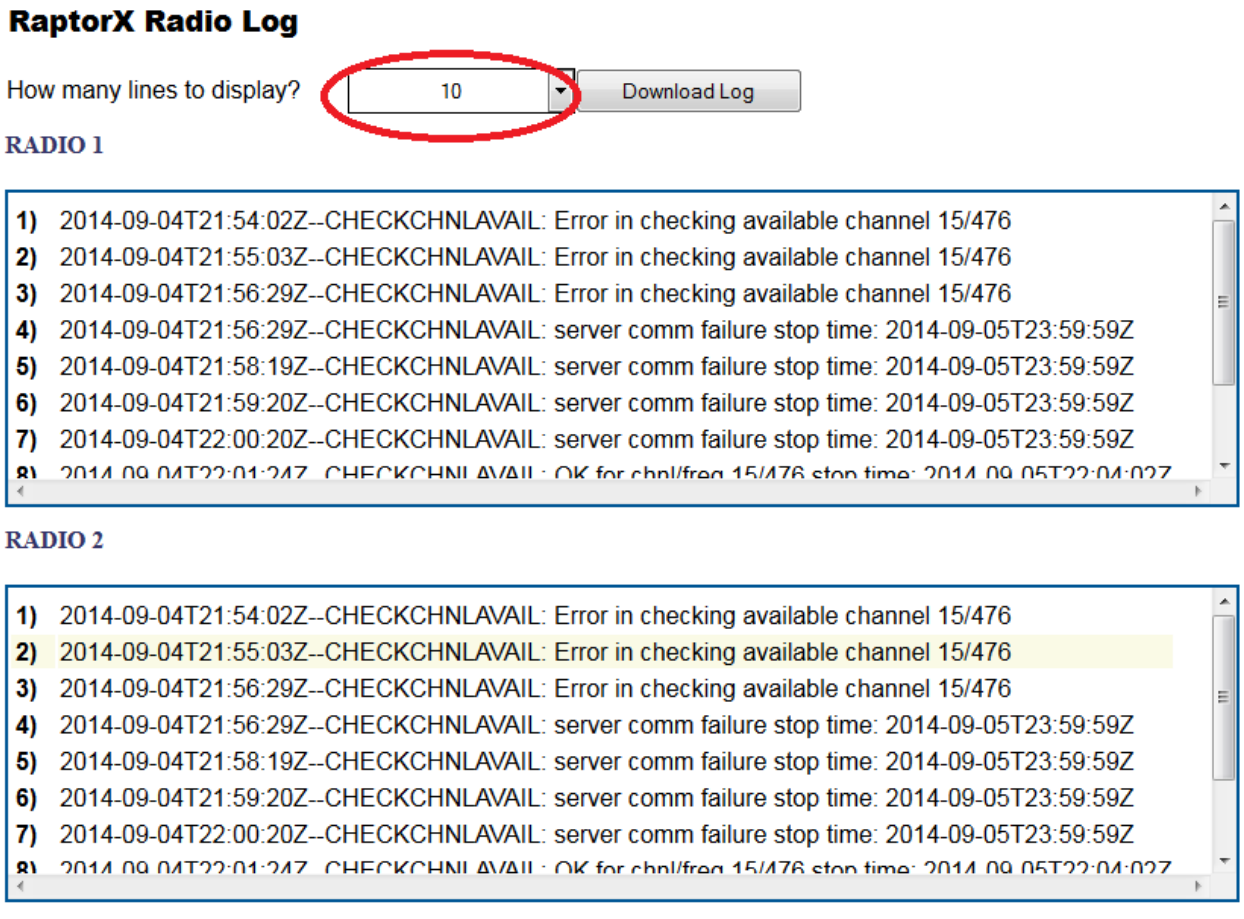


Figure 1.8 Professional Installation Single Channel Point-to-Point Link

The figures below illustrate the process of registration and database maintenance between Base and Remote Units:

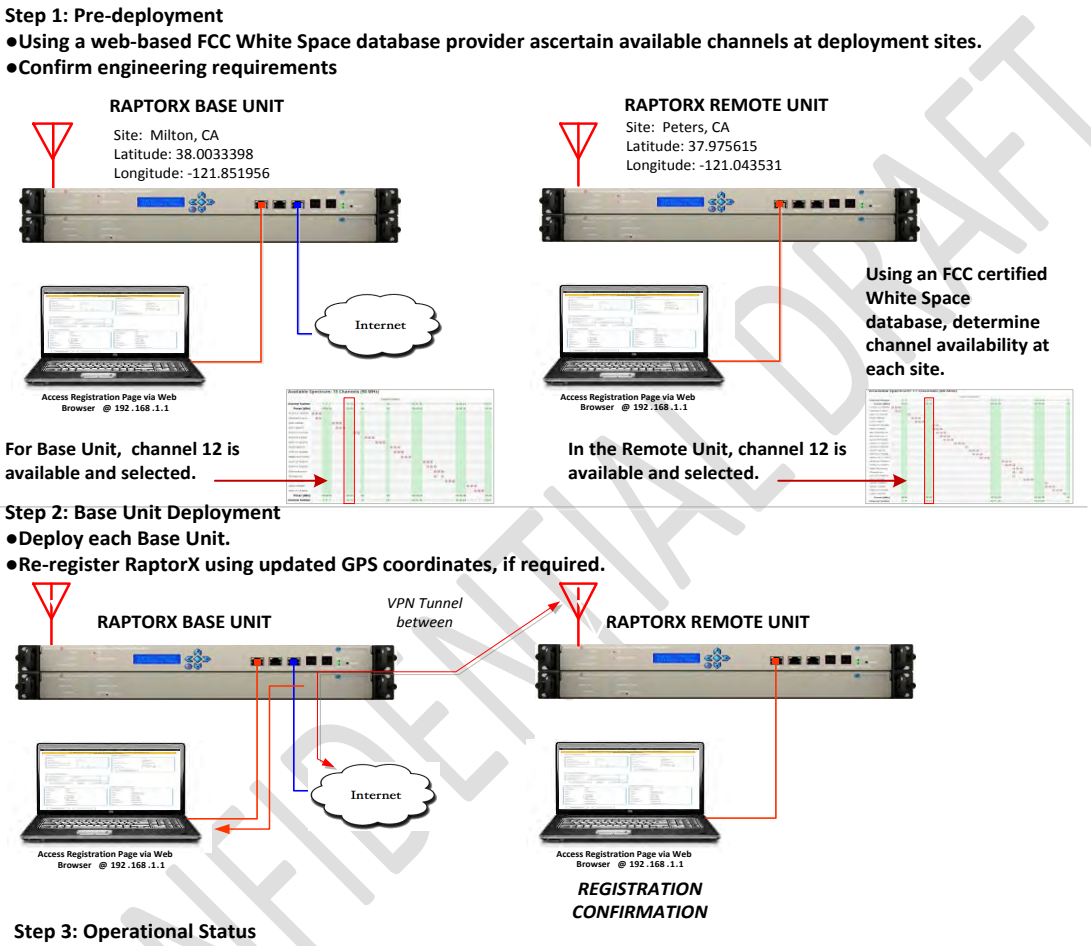


Figure 1.9 Professional Installation Dual Channel Point-to-Point Link

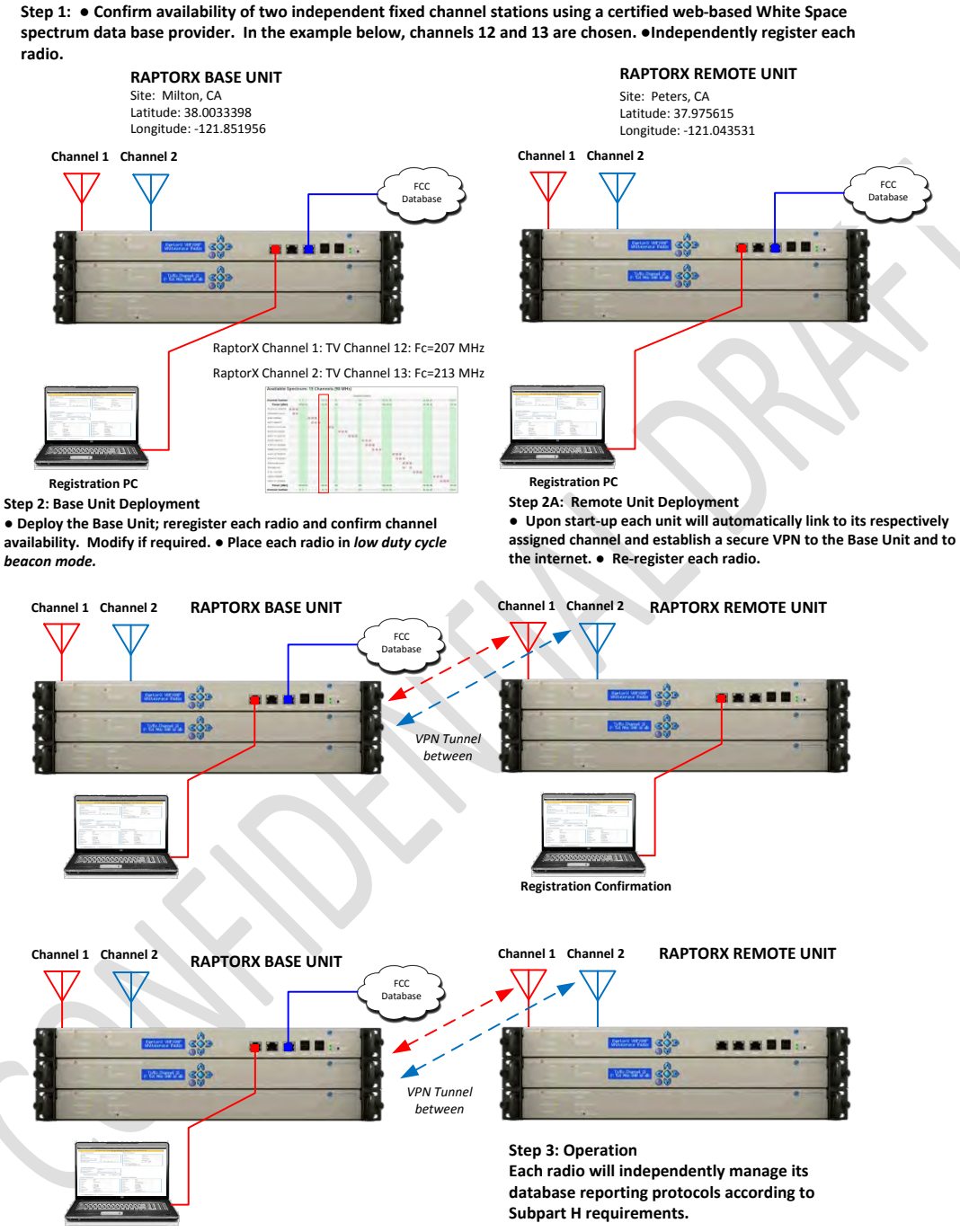
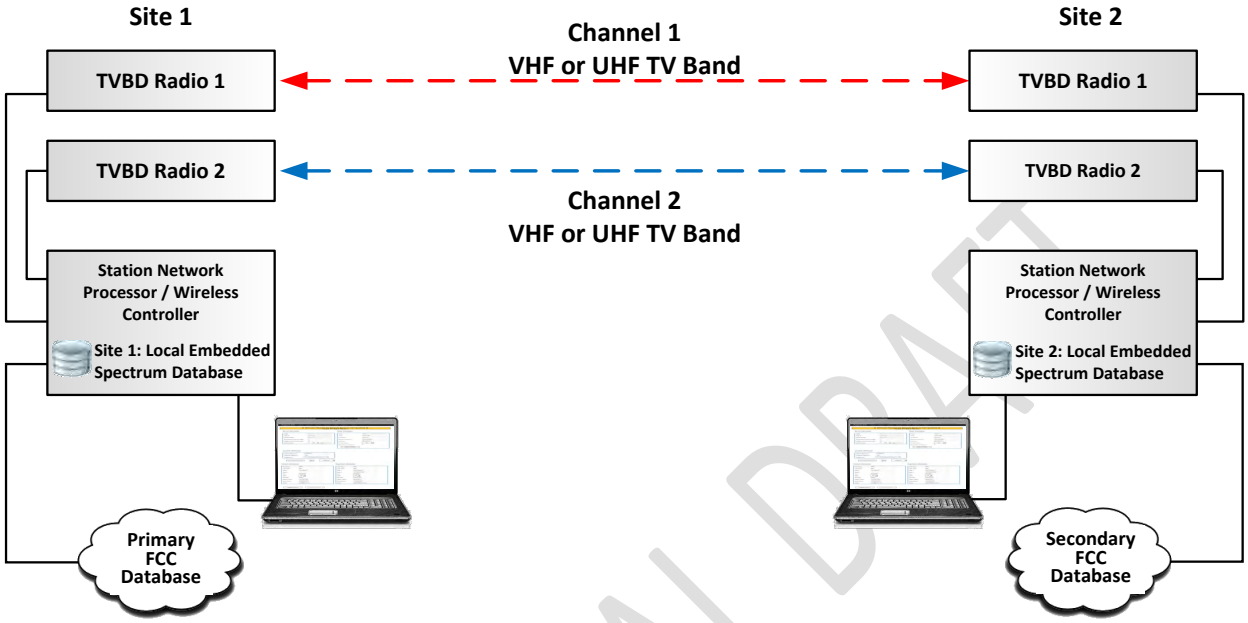


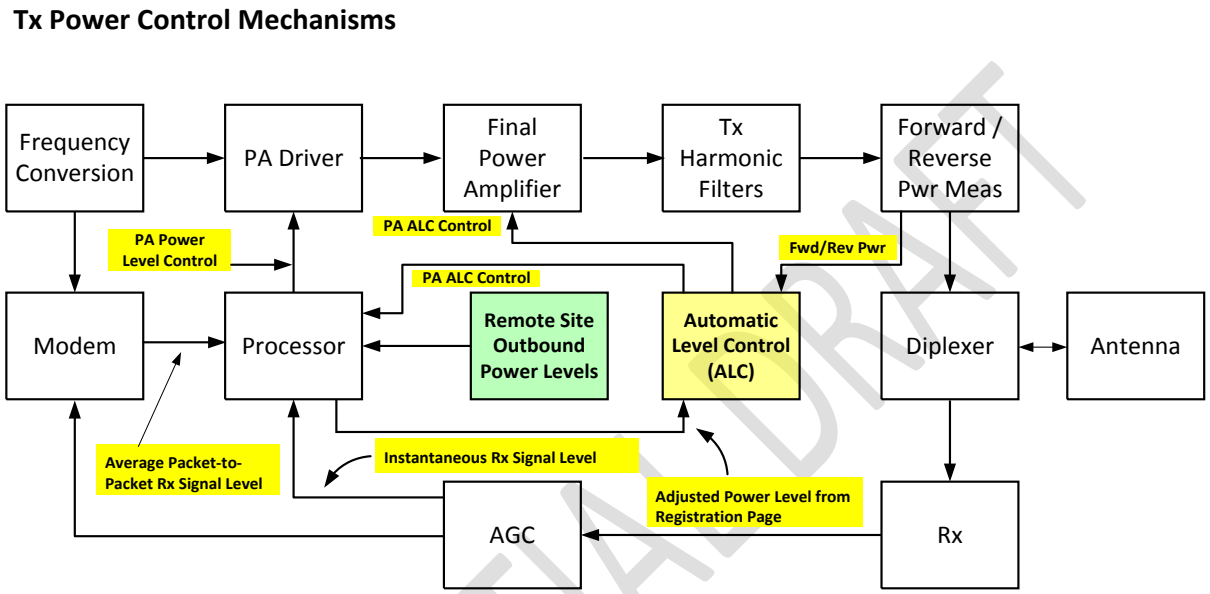
Figure 1.10 Registration Process for Dual Channel System



RaptorX offers the ability to establish a multi-channel station using a RaptorX Network Shelf containing one VHF/UHF Tx/Rx unit and adding an additional channel via a Channel Expansion Shelf. In this configuration, the Station Network Processor provides network control and registration management for each station.

The Registration page provides the capability to register up to two (2) local stations. Once registered, the Controller independently manages each radio. A spectrum fault in any radio does not affect the remaining radio. The capability of utilizing a standby database link is shown above. This capability will ensure un-interrupted operation in the event access to the primary IP connection is lost.

Figure 1.11 Tx Power Control Mechanisms



Tx Power Control is used to meet the following objectives:

- Adjust and maintain output power to a level not to exceed 36 dBm EIRP under any situation.
- This objective is accomplished with the following process:
    - On the Registration Page, entering the isotropic gain of the antenna (See Page 4). The processor calculates the Tx attenuation factor required to maintain Tx conductive power and EIRP within the required regulatory framework.
- Maintaining the minimum adequate EIRP to maintain required service levels
- Figure 4 above shows the Functional Block Diagram of a RaptorX Tx/Rx device and associated power control lines.
- Figure 6 illustrates compliance with FCC Regulation 15.709 (a) (2) Sub Part H. The minimum required for adequate Rx signal levels to maintain link connectivity. This requirement is met by controlling outbound Tx Power based on Rx RSSI and required SNR to maintain a given BER rate. For example, say a link using QPSK requires an average SNR of 9 dB to maintain a BER of 10^{-6}. If the measured SNR is 15 dB where the excess is attributable to excess Rx energy, a power reduction protocol packet will be sent to the far end instructing the transmitter to lower its power by 1dB increments to arrive at a nominal Rx level.

Figure 1.12 Test Set Up

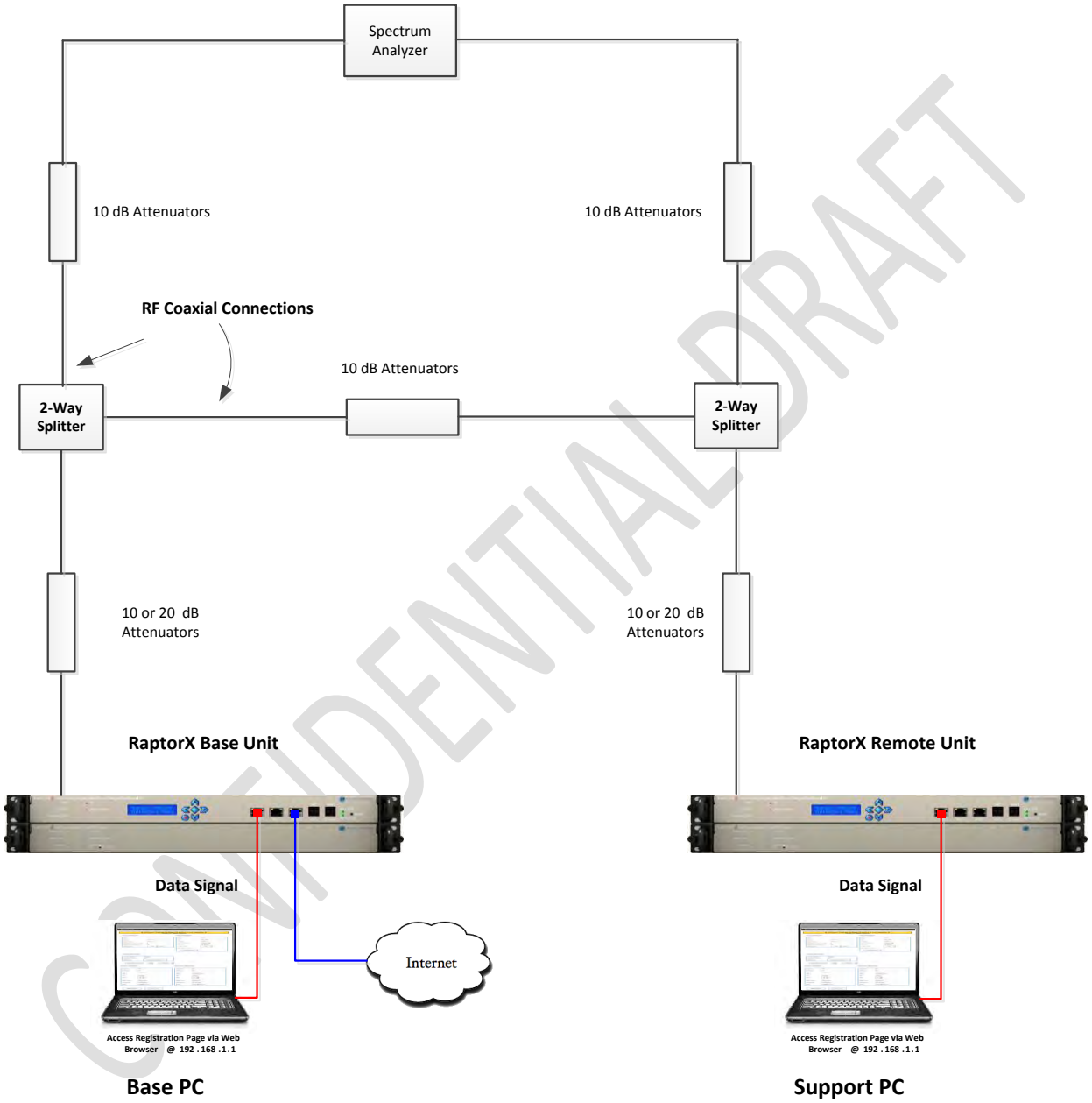


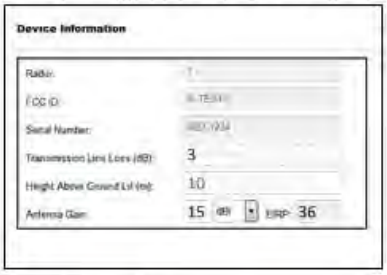
Figure 1.13 Test Procedure Paragraph 15.709 (a) (2)

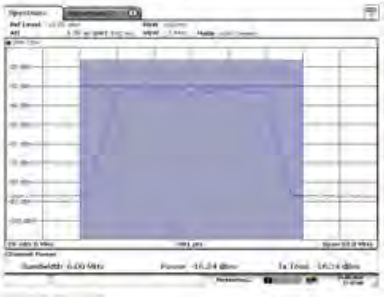
Test Procedure Paragraph 15.709 (a)(2)

Measurement Objective:
Show that the Tx conducted PSD limit for fixed devices is reduced by one dB for each dB that the maximum directional gain of the transmit antenna exceeds 6 dBi to maintain an EIRP of 36 dbm.

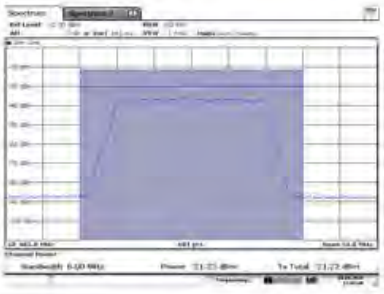
EUT Nominal Maximum Conductive Output Power Calculation
Nominal Maximum Conductive Output Power : 28.77 dBm
i.e. 12.6 dBm/100 KHz Band + 10*Log10(4.14 MHz/100 KHz) Where 4.14 MHz is the measured 99% occupied bandwidth and 12.6 is max PSD in any 100 KHz band segment within a 6 MHz band

Case 1, Antenna Gain 15 dBi, TL Loss 3 dB
Tx Conductive Power is automatically reduced by a minimum of 4.77 dB to an Conductive output of 24 dBm



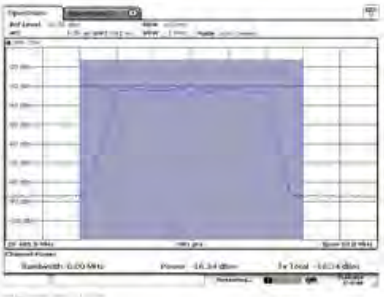


Measured PSD @ 6 MHz= -16.34 dBm which represents 28.77 dBm

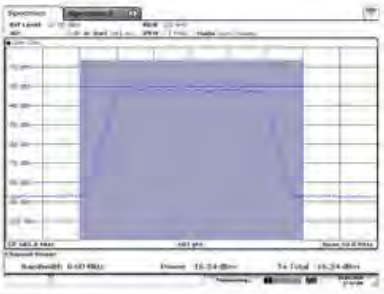


Measured PSD @ 6 MHz= -21.22 dBm represents 4.88 dB reduction in conductive output as required by Paragraph 15.709 (a)(2) for an effective conductive output of 23.55 dBm

Case 2, Antenna Gain 6 dBi, TL Loss 2 dB
Tx Conductive Power is maintained at a Conductive output of 28.77 dBm

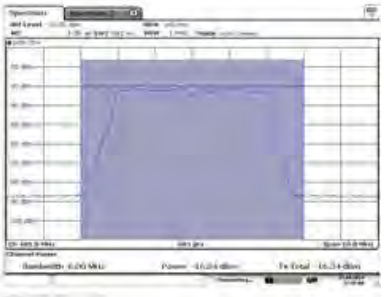


Measured PSD @ 6 MHz= -16.34 dBm which represents 28.77 dBm

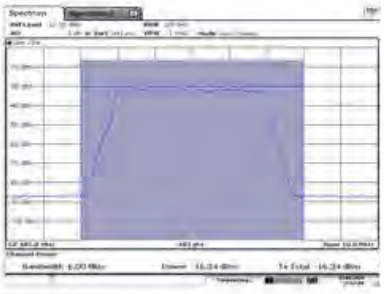


Measured PSD @ 6 MHz= -16.34 dBm represents 0 dB reduction in conductive output as required by Paragraph 15.709 (a)(2) for an effective conductive output of 28.77 dBm

Case 3, Antenna Gain 0 dBi, TL Loss 4 dB
Tx Conductive Power is maintained at a Conductive output of 28.43 dBm



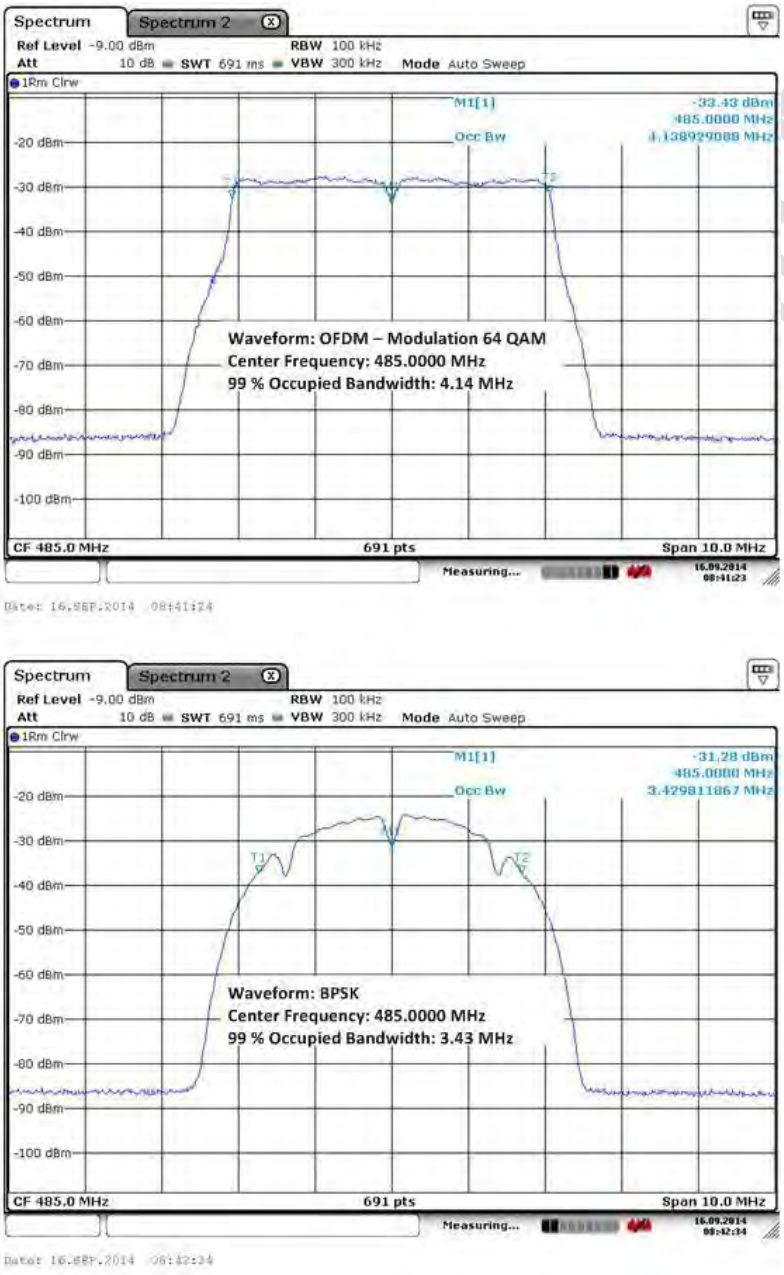
Measured PSD @ 6 MHz= -16.34 dBm which represents 28.77 dBm



Measured PSD @ 6 MHz= -16.34 dBm represents 0 dB reduction in conductive output as required by Paragraph 15.709 (a)(2) for an effective conductive output of 28.77 dBm

Figure 1.14 RaptorX Tx Waveform Occupied Bandwidth

RaptorX Tx Waveform Occupied Bandwidth



4 RaptorX Network Design Process

This section describes the process and tools required to design White Space Station networks in several steps. Intermediate steps common to all professional radio system deployment will be left to the professional designer and installer.

4.1 Tools Needed:

- Access to internet
- Intended site parameters, i.e. possible available antenna location heights (establishing channel availability and network band plan)
- Spectrum Analyzer
- PC with web browser

4.2 Step 1:

- Determine as accurately as possible the latitude and longitude of each probable antenna site. Use these coordinates on the Google Spectrum Data Base https://www.google.com/get/spectrumdatabase/index.html to determine available White space channels at the site of each planned White Space antenna.
- Enter latitude and longitude, along with device type. Fixed for RaptorX and maximum antenna height, 30 meters (98.4 feet). Click search for available channels.
- You will be provided with all available channels for that site.

Site	Latitude	Longitude	# of Available Channels (excluding Channels 2-6)	Available Hi Band VHF Channels	Available UHF Channels
Greenleaf, WI	44.31356	-88.09611	20	7-9, 13	14-19,32-35,44-47,51
McKenzie County, ND	47.77910	-103.41576	34	13	16-35,39-51
Reno, NV	39.53087	-119.81390	4	10,11	39,41
Kuparuk Oil Field, AL	70.05186	-150.06762	42	7-13	14-35,39-51
Permian Basin, TX	31.93900	-102.2276	12	11-13	14,16,28,34,44,45,47,48

Table 2: Example of Available Channels per Google White Space Database

https://www.google.com/get/spectrumdatabase/index.html

4.3 Step 2:

Selecting Available Channels to Use (using an RF Planning Tool)

Several general guidelines should be used here:

- Choose a channel/frequency (see frequency chart) that will provide you with sufficient signal and fade margin to provide 99% worst case reliability expectation over the path and range in which you will operate.
- RaptorX uses an adaptive modulation process that works to maximize data throughput for a range of Rx signal levels vs local noise levels.

4.4 RaptorX RF System Design Parameters

4.4.1 Tx Subsystem:

- OFDM/QAM Max RMS average Tx conductive output power: 28.8 dBm (.76 Watt) (99% occupied bandwidth)
- BPSK/QPSK Max RMS average Tx conductive output: 28 dBm (.631 Watts) (99% occupied bandwidth)
- Transmission line loss power compensation: 2.0 dB max, automatically calculated at time of FCC registration.
- 99% signal bandwidth: 4.2 MHz
- Only FCC–approved antennas must be used with the RaptorX. Please contact RaptorX@metricsystems.com if you intend to use an antenna other than our standard models.

4.4.2 Rx Subsystem:

- Rx Sensitivity vs Nominal Data Throughput vs Modulation Mode

Sensitivity	Data Throughput	Modulation Rate
-85 dBm	1.5 mbps	BPSK
-80 dBm	2.0 mbps	QPSK
-77 dBm	2.5 mbps	QAM16
-70 dBm	4.0 mbps	QAM64

Table 3: Rx Sensitivity vs Modulation Rate (local noise floor less than, or equal to, -89 dBm)

4.4.3 Channel Bonding and Aggregation - RaptorX supports bonding of multiple White Space channels to increase data throughput and provide link redundancy in the event a link is lost or degraded.

4.5 Antennas:

The RaptorX is certified to operate with the following VHF and UHF antennas to fit various deployment scenarios. When you register the RaptorX you will be required to include on the Registration Application the chosen antenna, including the height and latitude and longitude center. This information will be used to automatically configure the RaptorX to provide peak link performance. (See appendix for antenna details.)

- VHF Directional Antenna (9dBi)
- UHF Log Periodic Antenna (10.15 dBi)
- UHF High Gain Semi-Parabolic Antenna (16 dBi)

4.5.1 Transmission System (Transmission Line + EMP Protectors)

- We recommend that a Low-Loss LMR-600 coaxial cable with waterproof connectors be used.

4.6 Basic Examples:

- Point-to-Point: VHF link
- Point-to-Point: UHF Link

VHF POINT-TO-POINT LINK BETWEEN ONEIDA AND GREENLEAF SYSTEM DESCRIPTION

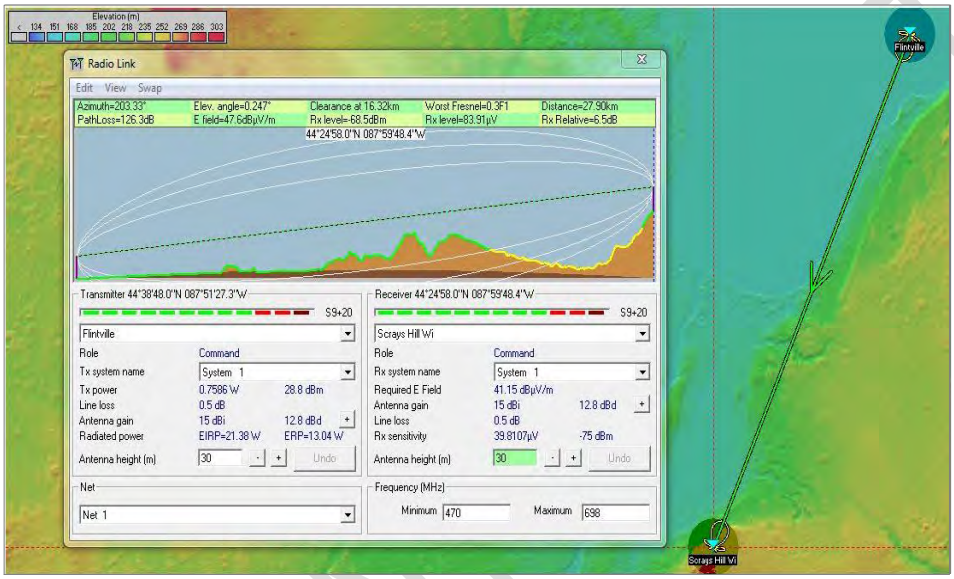
- Site 1/Oneida: Lat: 44.31366 Long:
- Site 2/Greenleaf: Lat: Long:
- Antenna Type: Kathrein DRV VHF-TV Panel Antennas, 174-230 MHz
  - Gain dBd = 7, Gain dBi = 9.15
- Link Range: 13.5 Miles/21.76 Km
- Minimum System Margin Required: 6 dB for 32 QAM
- Planned throughput: 2DS1s (2 x 1.544 mbps): 3.088 mbps
- See Figure 2 for Path Profile, Rx Signal Level and Margin and available VHF and UHF Channels for each site.

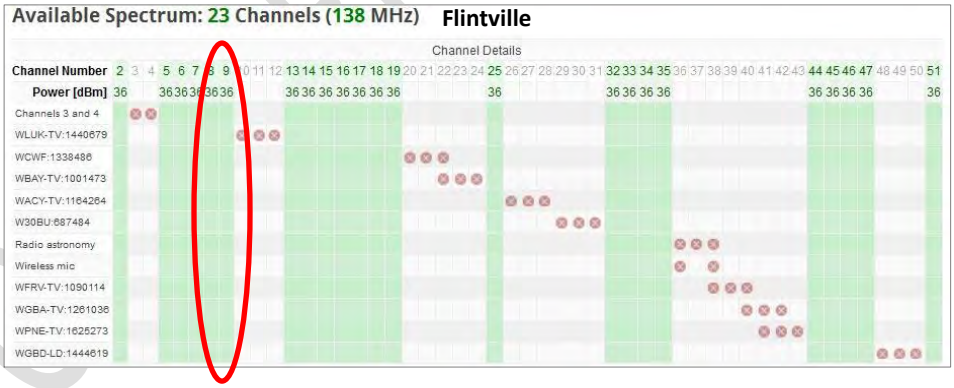
UHF POINT-TO-POINT LINK BETWEEN SCRAYS HILL AND FLINTVILLE SYSTEM DESCRIPTION

- Site 1/Scrays Hill: Lat: Long:
- Site 2/Flintville: Lat:` Long:
- Antenna Type: Kathrein High Gain 15 dBi Parabolic Directional Antennas
- Range: 17.3 Miles (27.9 km)
- Minimum System Margin: 6.5 dB
- Planned Throughput: 2 DS1s (2 x 1.544 mbps): 3.088 mbps

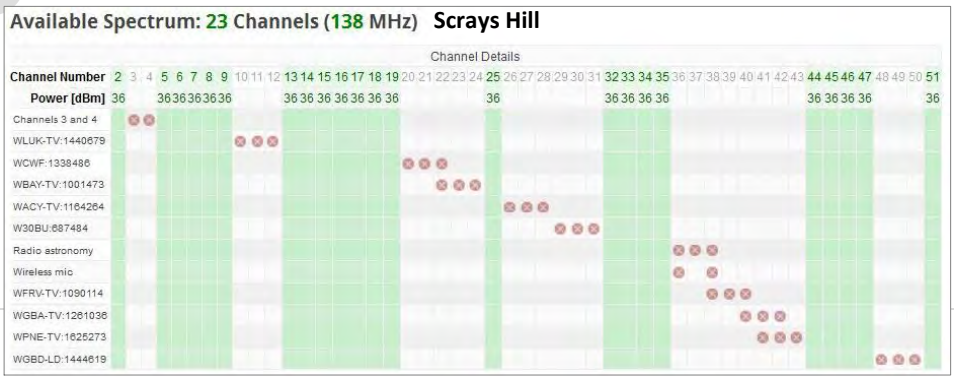
Figure 1.15 Common Available Channels VHF Hi-Band: 2 Channels (8,9)

Antenna Height: 95 feet
Range: 13.5 miles (21.76 km)
Tx Ant Gain: 6 dBi; Antenna Gain: 9.15 dBi
Rx Ant Gain: 9.15dBi





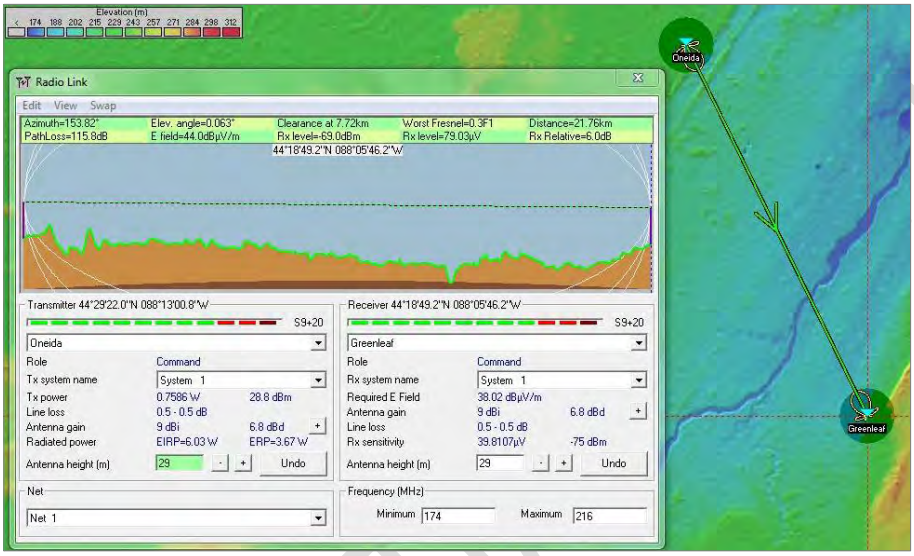
Available White Space Channels (shown in green) at Flintville Site

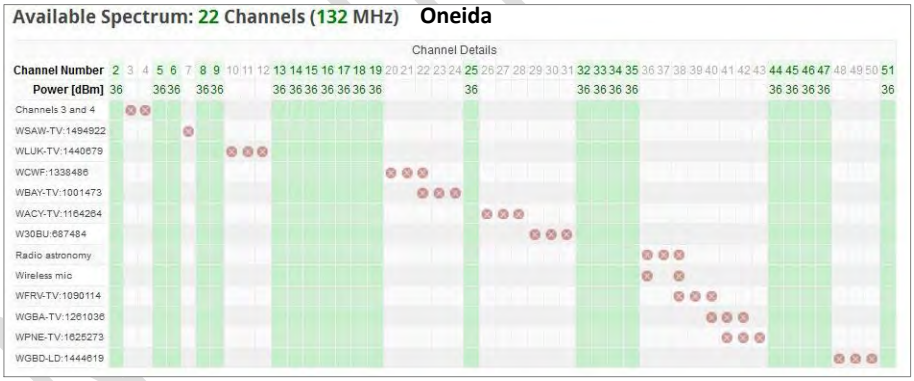


Available White Space Channels (shown in green) at Scrays Site

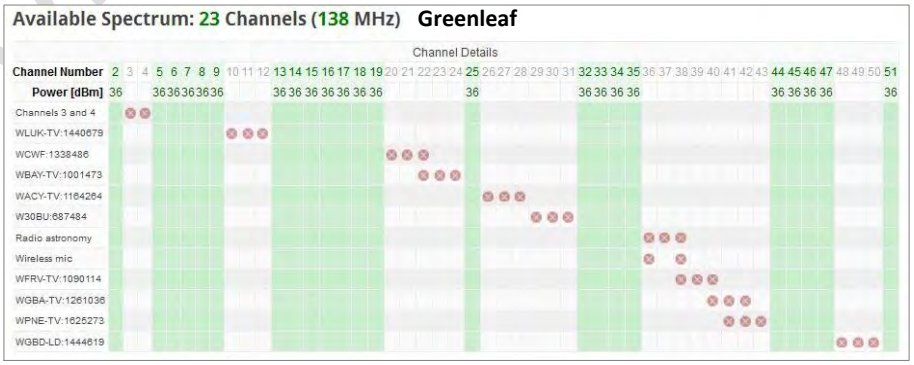
Figure 1.16 UHF White Space Point-to-Point Link

Common UHF Channels Available: 17 (Channels 13-19,25 ,32,35,44-47,51)
Antenna Height: 98”
Range: 17.3 miles (27.9 km)





Available White Space Channels (shown in green) at Oneida Site



See Page 4 for Path Profile Rx Signal Level and Expected Margin and available3 UHF Channels for each antenna site. In each case for these sites the system designer has a number of deployment channels to choose from.

5 Summary

The major new elements in designing with White Space spectrum are:

- **Channel Selection via an on-line database, choosing from an available channel list an appropriate channel(s) in which to operate.**
- **Evaluating link performance using an RF System Planning application, e.g. Pathlink 5 or Radiomobile.**

5.1 Provisioning RaptorX Radios:

FCC-certified RaptorX radios, as shipped, are not pre-configured to operate at any channel. The radios per FCC, Part 15 Subpart H Rules must be successfully registered via the internet with a certified FCC Database Provider. Metric Systems Corporation has contracted with iconectiv.com (http://iconectiv.com/spectrum-mgmt/white-spaces/index.html)for this service.

Equipment Configuration:

A basic RaptorX node consists of three (3) components.

a. RaptorX Network Controller Shelf, also called Primary Shelf. The Primary Shelf acts as the core controller of the local RaptorX node. It consists of three elements,
   - a powerful Linux-based power PC processor;
   - an adaptive waveform modem that automatically selects the best modulation to utilize to maximize performance over the RF path
   - and a very linear frequency agile transmitter receiver assembly.

b. Channel Expansion Shelf or Secondary Shelf which provides an additional independent White Space channel. This shelf is controlled through RaptorX's Primary Shelf.

c. The Redundant Power Unit Shelf maintains system operation in the event an individual system power fails, whether provisioned as a single or dual channel configuration.

Figure 1: Single Channel RaptorX System Front and Rear Panel Interfaces

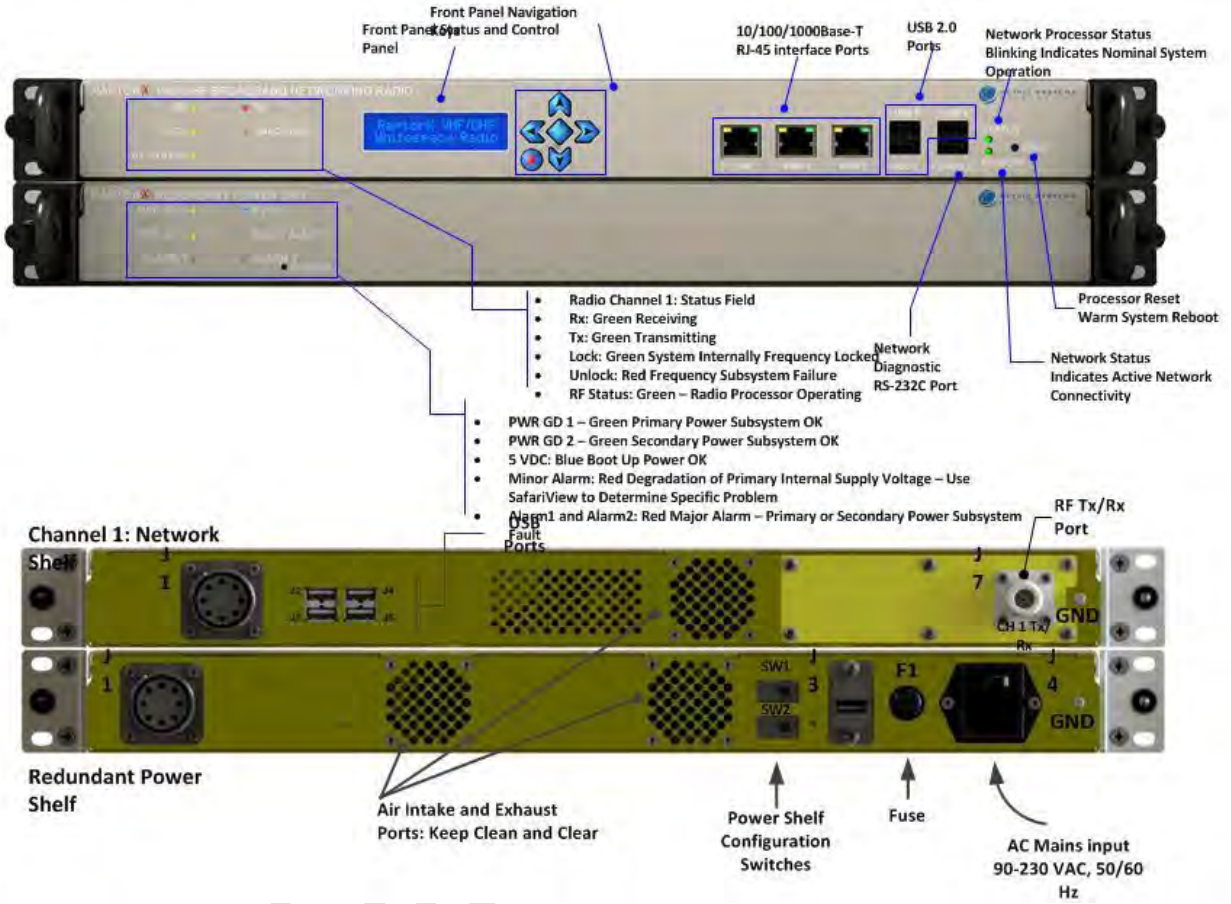


Figure 2: Dual Channel RaptorX System Front and Rear Panel Interfaces

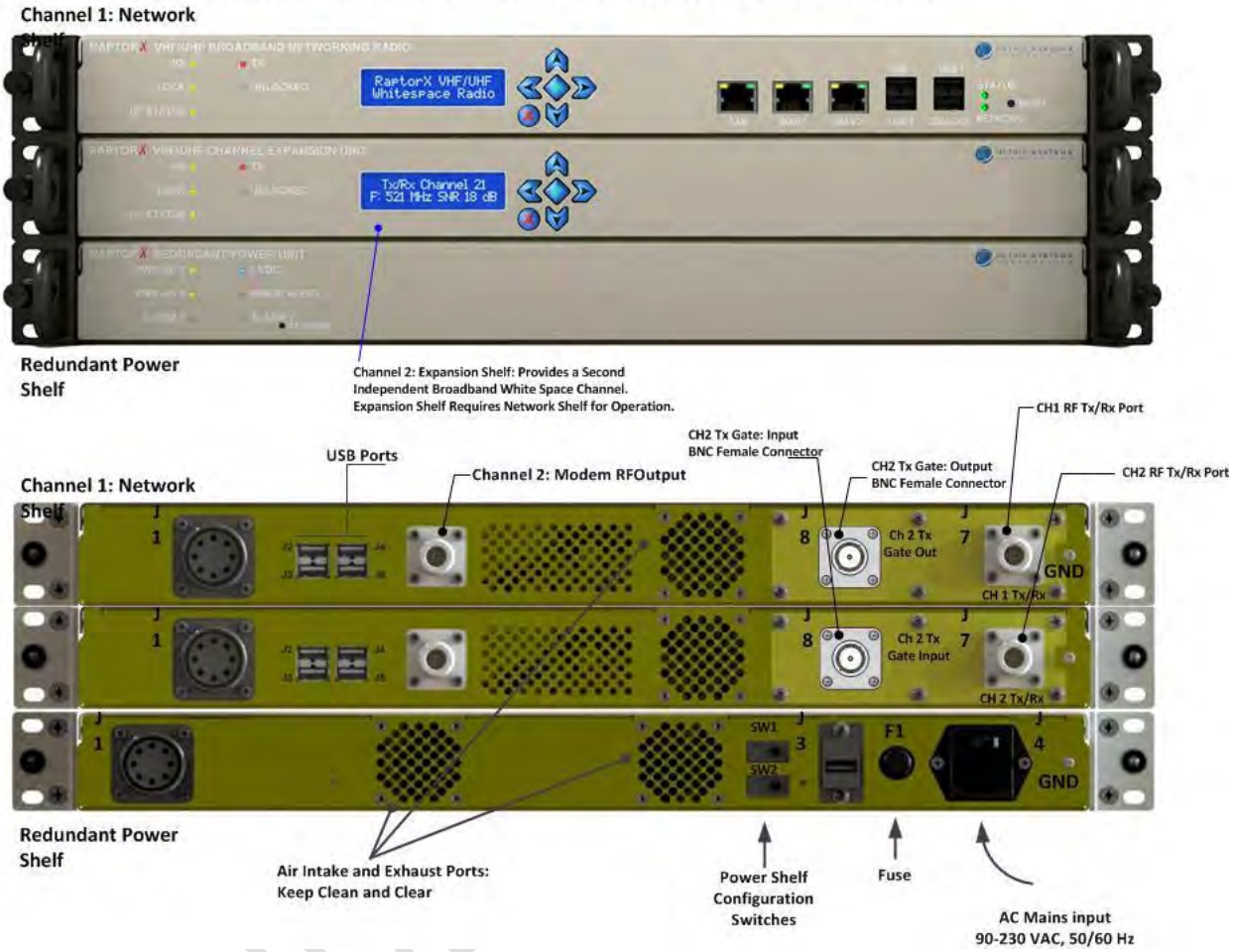


Figure 3: Typical RaptorX Antenna Configurations

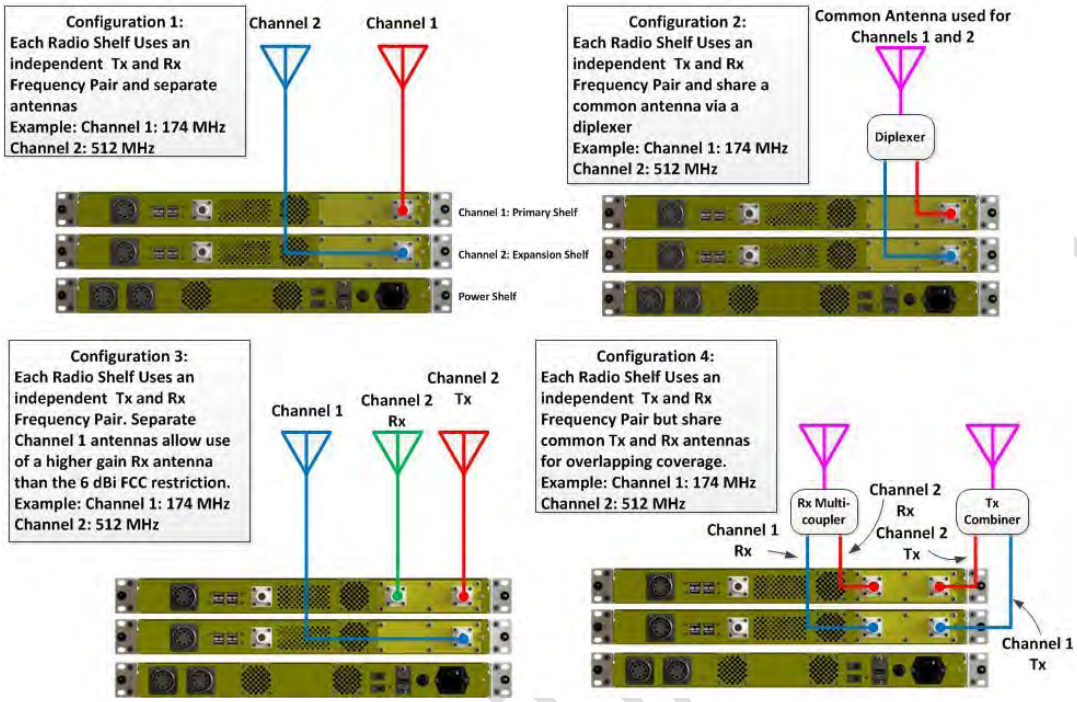


Figure 4: Rear Dual Channel with Antennas

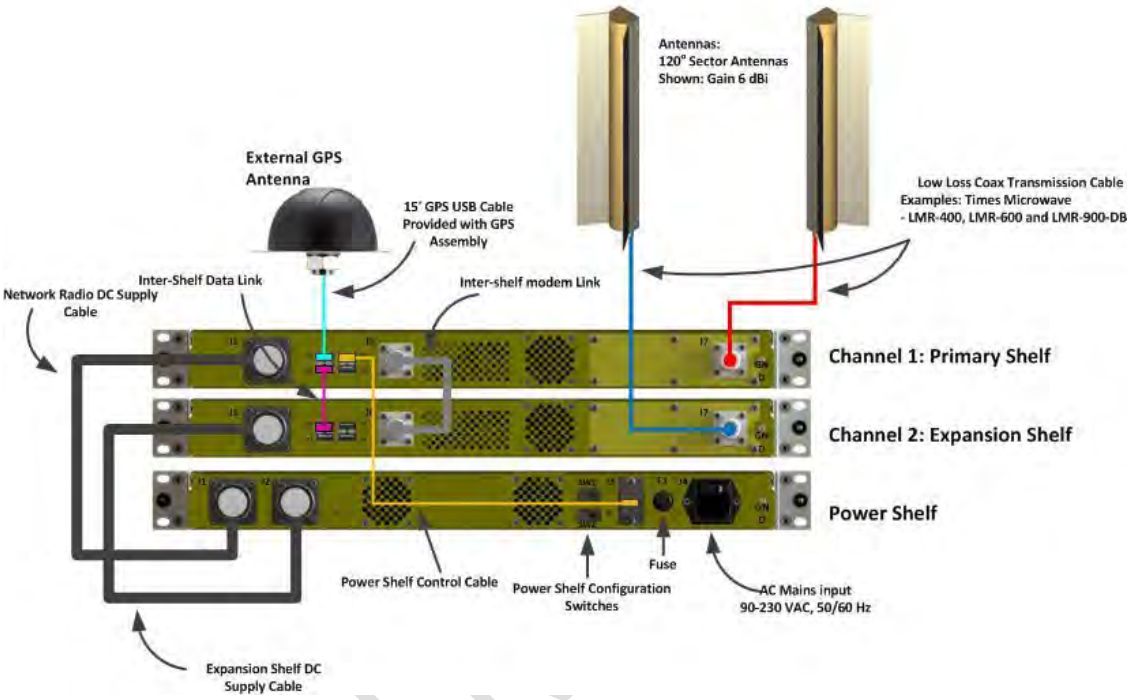
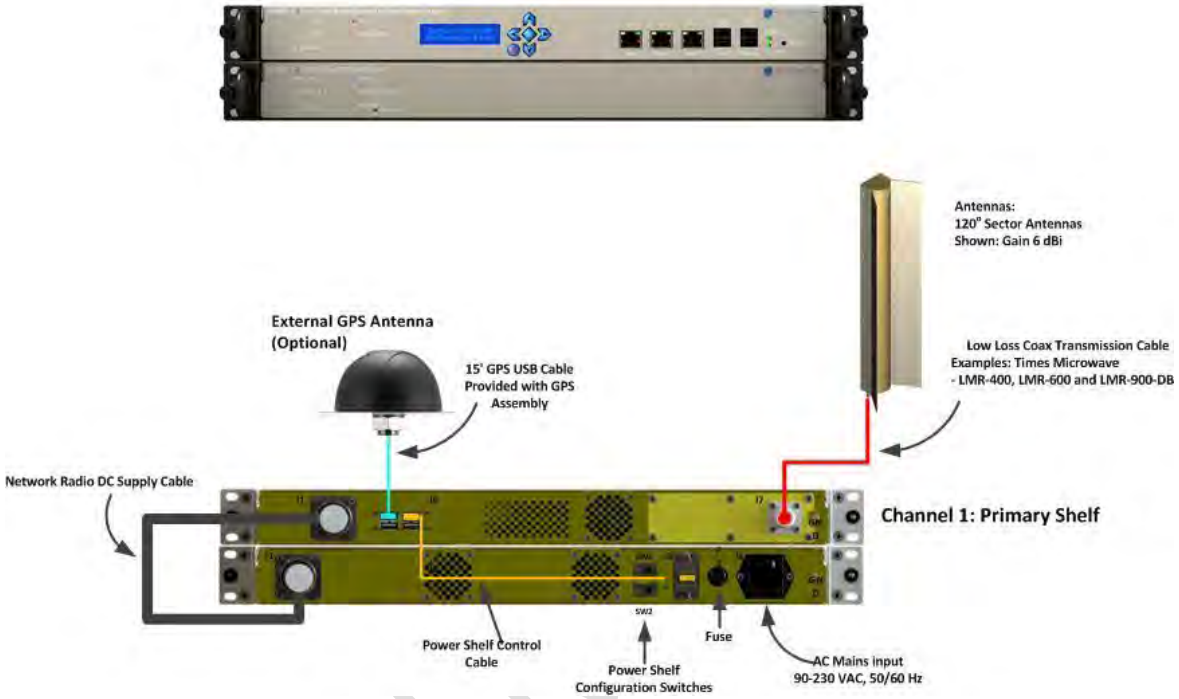


Figure 5: Rear Single Channel with Antennas



6 Technical Reference

6.1 RMA Procedure

RETURN MATERIAL AUTHORIZATION PROCEDURE

1. To **request a return material authorization** (RMA) number, contact Metric Systems Corporation at (760) 560-0348 or email us at info@metricsystems.com. When calling, please be prepared to provide the following information:

   - Your name, company, telephone and fax numbers and e-mail address;
   - Part and/or model number (if applicable) of the system components to be returned;
   - Reason for return and repair disposition authority.

   A **purchase order number** will be requested at the time we issue an RMA number. Note: non-warranty costs can be incurred through shipping damage, misuse or product misapplication. It is assumed that the user has protected the returned component from EMI/EMP and environmental damage. The user will be billed for items found to be defective due to the above factors.

2. Once an RMA number has been issued, ship the product to be returned to the following address:

   Metric Systems Corporation
   3055 Enterprise Court
   Vista, CA 92081
   Attn: RMA Number _____

3. For out-of-warranty repairs, you are responsible for paying all freight expense, any applicable import and/or export duties and taxes. You are responsible for delivering the returned product safely and undamaged to MSC.

4. On receipt of the product returned under an RMA number, an e-mail will be sent to you confirming receipt of product and quantities received.

5. All products returned under warranty will be repaired or replaced at the sole discretion of Metric Systems Corporation with new or equivalent materials.

Customer Information email us at info@metricsystems.com			
Bill To:		**Ship To:**	
	Company Name		Company Name
	Street Address		Street Address
	City, State, Zip Code		City, State, Zip Code
	Contact		Contact
	Phone		Phone
	Fax		Fax
	E-mail address		E-mail address

Purchase Order, Warranty and General Instructions			
Your PO# for Repair Authorized by (if no PO provided)		**Method of Payment**	
Original PO number(s) under which the Unit(s) were shipped		**Service Contract if Any**	

Product to be repaired

Item #	Qty	Model/Part No.	Serial Number	Symptom or Problem
1				
2				
3				
4				

Your Special Instructions

IMPORTANT NOTICE: By submitting the product described above to MSC for repair, Customer acknowledges and agrees that it shall pay the amount charged by MSC for the repairs immediately upon receipt of written notice (or proforma invoice) from MSC setting forth the date of completion of repairs and the total amount due. If the amount due remains unpaid ninety (90) days after delivery of such written notice to Customer, MSC at its option, shall have the right to retain the product or dispose of such product. MSC may retain the proceeds of any sale of product as payment for the costs associated with the repair and disposition of the product plus reasonable costs of storing the product ("Costs"). By submitting the product to MSC, Customer further agrees that it waives any obligation of MSC to take any actions, other than those actions set forth herein, prior to retaining or disposing of the product. Upon the written request of Customer, MSC will submit to the Customer any amount obtained from the disposition of the product in excess of the Costs.