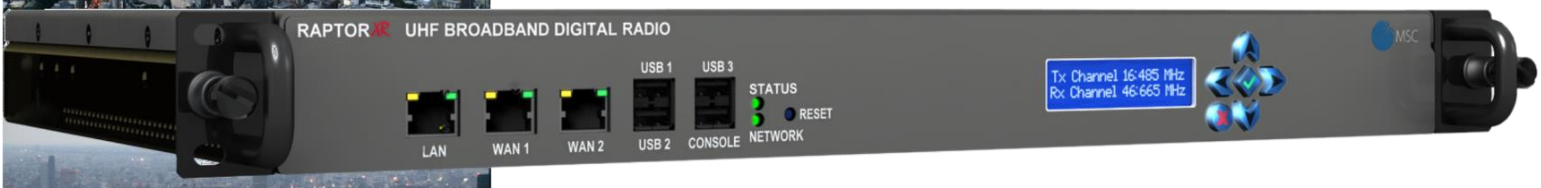
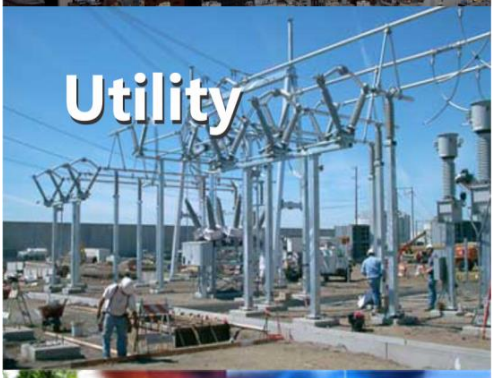
RAPTOR XR®

BROADBAND VHF/UHF
NETWORKING SYSTEM

UNLICENSED WHITE SPACE





User Guide

- System Design
- Installation
- Operation
- Maintenance

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REV. 1.10
05/02/17

FCC Regulatory Information

FCC ID: 2ABCU-50911-U

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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Patents

The RaptorXR employs techniques and methods incorporated in Metric Systems Corporation's U.S. and Canadian patents listed below. The use of this technology provides the user with a robust and versatile system to meet the stringent requirements of a dynamic frequency allocation broadband wireless system.

ITEM	S/N	TITLE
1	6,952,563US	Method and apparatus for adaptively setting frequency channels in a multi-point wireless networking system
2	7,013,345US	Method and apparatus for wireless networking
3	7,089,014US	Wireless communication system control apparatus and method
4	2,417,931CA	Method and Apparatus for Adaptively Setting
5	2,444,643CA	Method and Apparatus for Wireless Networking
6	2,444,805CA	Wireless Communication System Control

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RaptorXR User Manual

Part Number 50739.1.P Series

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Revision History

DATE OF REVISION	REVISION LETTER	DESCRIPTION OF CHANGES	PAGES CHANGED
09/30/14	Rev.1.06.2	BETA MANUAL RELEASE	
03/3/15	Rev.1.07A	NEW MANUAL UPDATE	ALL
04/30/15	Rev. 1.07B	UPDATE	ALL
07/01/15	Rev. 1.08	UPDATE	ALL
10/5/16	Rev. 1.09	UPDATE ILLUSTRATIONS etc	ALL
04/28/17	Rev.1.10 FCC	UPDATE	ALL

Metric Systems Corporation (MSC)

Standard Hardware One (1) Year Warranty

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B) that MSC will have sole control of the defense of such suit and all negotiations for its settlement or compromise; and
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1 Introduction

1.1 Manual Overview

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

This Manual is organized into eight (8) sections:

1. Manual Overview- preview, documentation conventions, terminology
2. RaptorXR Overview of the hardware, embedded capabilities and tools to allow you to design, deploy and operate RaptorXR White Space Radio equipment.
3. Getting Started
4. Accessing VHF/UHF TV Band Spectrum
5. RaptorXR Network Design Process-
6. Database Registration This section will show how to determine what TV band channels are available to support your network application and how each RaptorXR is registered with the FCC via RaptorXR's certified database supplier to operate on available channels
7. Customer Service – RMA procedures
8. Technical Appendices

8.1 Appendix A – Antenna specification sheets

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8.2.1 FCC SDR Request Information

8.2.2 RaptorXR UHF Band Plan Table

8.2.3 Minimum Signal Requirements

8.2.4 Technical Overview/Theory of Operations

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
Available channel	A channel which is not being used by an authorized service and is acceptable for use by the RaptorXR at its geographic location.
Base Station	The RaptorXR unit that accesses the FCC Database.
Conductive Output Power Limit	Average power output of the RaptorXR into a 50Ω load as measured over a 6 MHz bandwidth
CR	Code Rate- defines error correction level
Duplex Band Split Channel Spectrum	Low Band channels: 14-34; 473-602 MHz High Band channels: 40-51;626-698 MHz
EIRP	Effective Isotropic Radiated Power - defined as conductive power + antenna gain in dBi. The maximum EIRP of a fixed White Space device is 36 dBm.
EIRP for less congested areas	Geographic areas where at least half of the TV channels are unused. In these areas EIRP is 40 dBm (10 Watts).
FCC Database Provider	An FCC certified vendor that provides White Space equipment with registration services and geographically available operating channels.
Fixed Device	A White space device that transmits and/or receives signals at a specific fixed location, using available channels from an authorized White Space database.
Fixed Station Antenna Requirements	Transmit antenna height shall not exceed 98.4' (30 m) above ground level
Full Duplex	A wireless protocol that uses two independent channels for simultaneous two way communications.
GI	Guard Interval- a short time between packets
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.
Independent White Space Database Providers	Several firms provide RaptorXR registration and database services. These firms provide secure, local channel availability information over the course of a 24 hour availability period where channel availability is re-checked. If a channel becomes unavailable the RaptorXR will automatically relocate to an available channel.
Operating Channels	Channels used by the RaptorXR
OTA	Over the Air

OTAP	Over the Air Programming
PAWS	Protocol to Access White Space Databases
RaptorXR Network Initiation	The process by which RaptorXR devices send encrypted control parameters to one or networked RaptorXRs to initiate communication.
Remote Station	RaptorXR unit that accesses the internet through a designated Base Station
Receive Diversity Mode Option	RaptorXR Diversity Mode Option provides extended range and reliability in highly reflective environments, e.g. mountainous and urban areas. The diversity mode provides a nominal 5 dB overall system improvement.
Registration Fee	A nominal Registration Fee is required per White Space device. This fee is paid directly to the Database Supplier, e.g. Google, Microsoft, Spectrum Bridge, Iconectiv, etc. See section 4 for more information.
Simplex	A wireless protocol that transmits while the other side listens. Streaming video is a "most-of-the time" transmit protocol
Spectrum Sensing	The patented process by which the RaptorXR scans available channels for noise, signal quality and other White Space systems.
System Planning Software	RF Propagation simulation software is a highly recommended prediction model to simulate and verify path and performance expectations. Radio Mobile uses the irregular terrain model.
System Margin	A systems design allowance in dB to allow reliable operation
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
TVWS	(TV band devices) An FCC term denoting a wireless device which operates in unlicensed TV band spectrum
Television Bands	VHF TV channels 2-4 (54-72 MHz), 5-6 (76-88 MHz), 7-13 (174-216 MHz); UHF TV Channels 14-36 (470-611 MHz) and Channels 38-51 (614-698 MHz)
White Space	VHF or UHF TV channels that are no longer in use in a given geographical area and are available for unlicensed use.

2 RaptorXR Overview

RaptorXR is an unlicensed broadband full-duplex Tx/Rx Fixed Wireless Networking Radio System operating in what the FCC calls White Space spectrum. This spectrum spans the high VHF TV channels 7-13 (174 MHz-216 MHz) and authorized UHF channels 14 to 35 and 40-51 ~~(470 MHz-698 MHz)~~. The primary technical mission of the RaptorXR suite is to provide reliable backhaul and edge network transport applications in a wide variety of urban and rural environments. The RaptorXR features an adaptive suite of robust OFDM transmit modulation formats to maximize user throughput. ~~*MSC offers a variety of antenna types to support Omni, Sector and Directional applications*~~. *With the* approved *antenna the maximum FCC EIRP transmit power limit of* 12-13 dBm *is attainable.* ~~*While in the Rx mode, higher gain antennas can provide additional Rx gain to extend range and coverage area.*~~

2.1 System Benefits

Combining operation in White Space spectrum with the RaptorX (Half-Duplex Radio) provides the following benefits and capabilities as compared with microwave-based systems operating in the 900 MHz, 2.4 and 5.8 GHz bands.

- Extended Range: up to 4 times further reach than 2.4 GHz; 16 times the reach of 5.8 GHz systems
- Through foliage: RaptorXR links can penetrate through treed areas with much less attenuation than 2.4 and 5.8 GHz systems.
- Non-Line-of-Sight and beyond horizon: RaptorXR systems offer superior operation in highly reflective and refractive environments.
- Superior outdoor to indoor and indoor operation: RaptorXR offers extraordinary outdoor to indoor transmission capability and outstanding in-structure connectivity due to lower through wall attenuation.
- These characteristics make the RaptorXR an ideal system solution for a variety of outdoor and indoor backhaul transport needs, including:
    - Fiber to last mile requirements
    - Forested small cell backhaul
    - Cable TV to sub-division transport
    - T1 backup links
    - Critical fault-tolerant and redundant backup links
    - Easily deployable Carrier Class Wifi within building and challenging terrain situations.
- The superior propagation and broadband capabilities of the RaptorXR offers operators and end-users new and enhanced revenue opportunities.

2.2 Operational Capabilities

- ~~Maximum legal EIRP (nominally 36 dBm; 40 dBm in remote areas) support for both VHF high band channels (7 to 13) and UHF channels;~~
- High system margin supports VHF and UHF operation to extended distances
- Manually or dynamically-adaptable full-duplex payload rates of 6 to 31 mbps+;
- Diversity Option (DIV.1): provides an additional system gain up to 4 dB;
- SafariView: RaptorXR's integrated HTML-based systems Operations, Administration and Maintenance (OAM) application is accessible via front Ethernet ports, local short-range secure wireless connection, or remotely, 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;
- Scalable Bandwidth to take advantage of Multiple Channel operation. (See Figure 1.4) 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 frequency and spatial diversity provides superior operation in urban or natural clutter environments.
    - Output power adjustable ~~from 0 to 25 dBm~~

2.3 Operating and Technical Specifications

GENERAL	
Standard Frequency Range	
VHF~~-High-~~Band (P/N RaptorXR 50739.1.P.174)	174-216 MHz
UHF Low-Band (P/N RaptorXR 50739.1.P.470)	470-602 MHz Low Band Model
UHF High-Band (P/N 50739.1.P.620)	626-698 MHz High Band Model
Frequency Tuning Steps	1 kHz
Unit Weight:	Single Shelf: 6.88 lbs. (3.12 kg)
Shipping Weight	Single Shelf: 10.2 lbs. (4.63 kg)
Dimensions:	14.2 in. D x19 in.W x 1.78 in.H (360.6 mm x 428.6 mm x 45.2 mm)
Operating Temperature	Standard: -10°C to +65°C

Over-the-Air Data Rates	Can be set either manually or automatically. See Section 5 for details

MINIMUM Rx SPECIFICATIONS (6 MHz Tx Bandwidth) (Also see Full Table page 24)

Modulation Mode	Signal Level (dBm)	Minimum Required C/N (dB)	Over-the-Air (OTA) Full-Duplex Link Rate (Mbps)
4 QAM - OFDM	-91	3.1	11.62
16 QAM – OFDM	-84	9.1	20.74
64 QAM – OFDM	-76	18	31.10
Adjacent channel rejection (6 MHz channel VHF/UHF)		>40 dB (100 kHz off-channel)	
~~Average conductive RF power output per 6 MHz channel~~		~~VHF: 23 dBm~~ ~~UHF: 25 dBm~~	

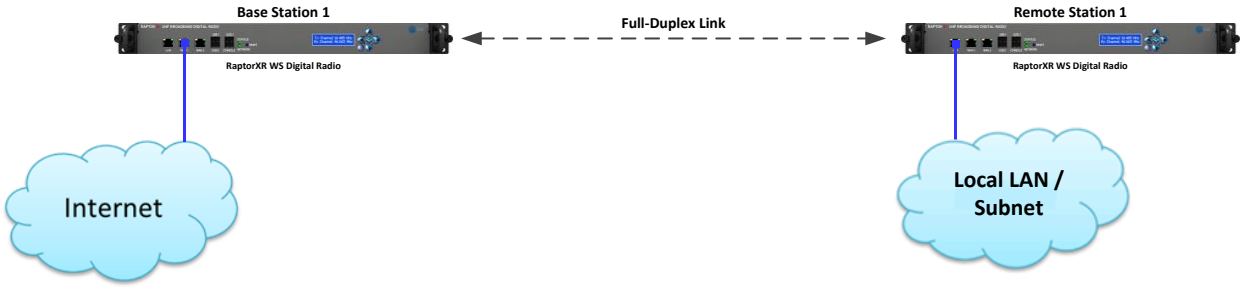


Figure 1.1: Basic RaptorXR Point-to-Point Backhaul Configuration

POWER	
AC Input	110/240 V AC 50/60 Hz
Maximum Power Consumption:	60 Watts
SECURITY	
Encryption	128/256-bit Advanced Encryption Standard (AES)
Authorization and Accounting	Protects against unauthorized administration/maintenance and over-the-air access
System access/authentication capabilities	Multi-factor authentication. Remote access token-based authentication
System access/authentication capabilities	Integrated firewall and Information Assurance tools
NETWORK ARCHITECTURE	
VLAN	Supports multiple laws; static and dynamic
	System Integrity Logs
Firewall	Robust rule support and encrypted download
Dynamic ad hoc network	Adaptive, self-forming, self-healing network
Network Size	Limited only by available RF channels
Network capabilities/single channel	Point-to-point, point-to-multipoint and mesh
Network capabilities/ dual channel	Point-to-point, multipoint, and mesh
Maintenance/diagnostics	Over-the-air programming, integrated web-based administration, monitoring and reconfiguration
System logs	System, security, authentication, information flow, traffic monitoring and intrusion detection.
Network timing	Multiple network timing protocol options (NTP)
FREQUENCY STABILITY	Internal ±1.5 ppm
STANDARD ANTENNA INTERFACES	Common Tx/Rx antenna
ANTENNAS	Directional, Omni or Sector

2.3.1 Optional System Features

FEATURES	DESCRIPTION
Diversity Option P/N: DIV.1	Separate Tx and Rx antennas support the RaptorXR capability for spatial and frequency diversity configuration. Provides up to 6 dB of system margin for extended range and reliability in difficult NLOS urban and rural applications.
GPS Location and Frequency Stabilization Options P/N: GPS.1	Provides the user with the ability to automatically and accurately provide the database provider with site location within ±50 meters and altitude. Enables provider a highly stable frequency reference to the RaptorXR's RF subsystem to enable single channel use for outbound broadcast and critical time of arrival applications.

2.3.2 Factory Default Configurations

FACTORY CONFIGURATION		
	BASE	**REMOTE**
Units	**Low Band**	**High Band**
Tx Frequency Down Link (MHz))/CHANNEL	**473/14**	**629/40**
Rx Frequency Up Link (MHz)/CHANNEL	**629/40**	**473/14**
Tx Bandwidth (MHz)	**5**	**5**
Constellation	**4 QAM (QPSK)**	**4 QAM (QPSK)**
Useful Data Rate (Mbps)	**3.110**	**3.110**
Full Duplex Rate	**6.220**	**6.220**
Code Rate (CR)	**1/2**	**1/2**
Guard Interval (GI)	**1/4**	**1/4**
Maximum Conducted Power Output (dBm)	6-7	6-7
EIRP (dBm) with 10.15 dBi antenna Tx Output Power to Antenna Adjusted to meet Maximum Allowable EIRP	12 dBm	12 dBm From Page 8 of Test Report
PASSWORD	**RaptorXR**	**RaptorXR**

2.3.3 Theory of Operation

- The RaptorXR system is a broadband full-duplex software-configurable radio capable of operating in the High VHF 174 to 216 MHz TV band and the UHF TV bands 470-602 MHz and the 626 to 698 MHz spectrum.

- Platformed in a lightweight 19" 1U rack, the RaptorXR enables the network engineer to deliver penetrating broadband coverage to a wide range of backhaul and edge applications.

- RaptorXR's key performance element is the ultra-linear adaptive constellation digital modulator. The digital modulator converts the incoming IP packets into error-corrected data streams which are converted via a highly integrated software-controlled Tx subsystem into VHF or UHF digital waveforms. Figure 1.15 below illustrates the 5 MHz RaptorXR waveform used in domestic (US) White Space applications.

- Ultra-Sensitive High-Dynamic Range Broadband Receiver

  RaptorXR's proprietary broadband receiver technology optimizes operation in high signal urban and RF co-site areas, while providing operation over an 80 dB-dynamic range. In some cases, an external Rx filter may be required if operation is close to high power, adjacent channel TV transmitters.

- Ultra-Linear Broadband UHF Amplifier

  RaptorXR's Power Amplifier provides an ultra-clean low adjacent channel noise amplified signal to Raptor's low loss UHF TV band Duplexer. The power amplifier's efficiency allows the system designer to bond and aggregate channels to increase effective useful throughput and redundant link operation.

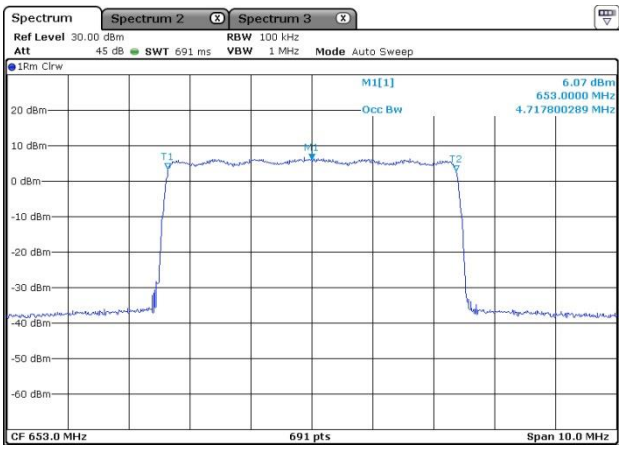


FIGURE 1.A: 5 MHz Waveform

- Broadband UHF Duplexer

  Full-duplex wireless operation requires, at minimum, two simultaneous clear channels. In the RaptorXR one channel is called the Downlink Channel which provides a broadband link from the Base Station to the Remote Station, using channels in the low band segment of the duplexer. Conversely, the Remote Station (Uplink) communicates with the Base Station on high-band channels. Table 5, page 58 provides a table of the low band and high band channels. ~~The high efficiency duplexer transitions from low band to high band in primarily unavailable channels.~~

- Linux-Powered Multicore Network Processor

  The R1020 RaptorXR Network Processor provides the user/operator with multiple Ethernet and USB interfaces. The Ethernet interfaces are easily configured via Raptor's internal web page. The USB ports can support a wide range of Linux-based applications. The RaptorXR is configured to support TP Links USB WiFi dongle. The R1020's encryption core supports a wide range of open source encryption standards. Please contact Metric Systems for additional information on specific application requirements.

2.4 The RaptorXR Hardware Suite

The basic RaptorXR Hardware Suite consists of a Wireless Network Shelf and a Broadband Antenna

- Network Shelf – combines the RaptorXR software defined radio with versatile software defined Network Processor and Network Interface Suite.
- The RaptorXR Single Link White Space Channel Configuration includes one (1) RaptorXR Network Shelf containing the local network processor and a single channel white space VHF/UHF broadband radio. Figure 1.1 below shows user indicators, controls and physical interfaces of the Single Channel System. Figure 1.2 shows the rear view of a Single Channel stack.

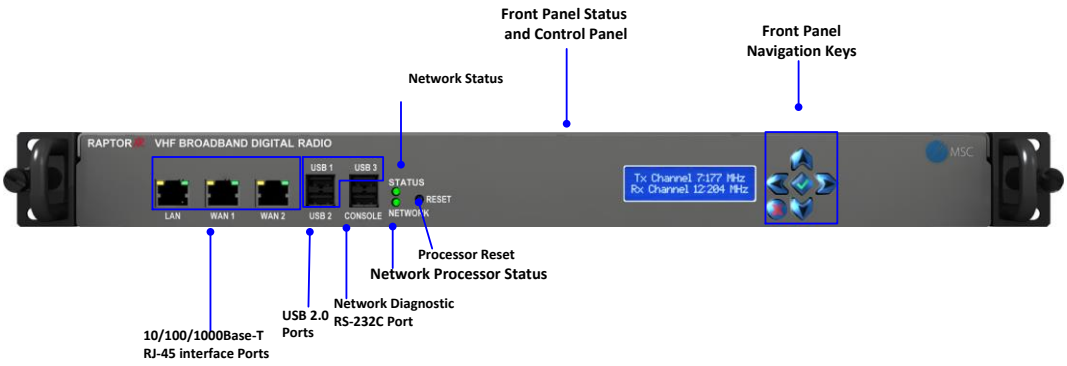


Figure 1.2 Single Link System (Front View) illustrating user indicators, controls and physical interfaces.

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

2.4.1 Network Shelf Front Panel Descriptions

ITEM	DESCRIPTION/FUNCTION
Front Panel Status and Control Panel Display and Navigation Keys	Allows selection of available channels following valid registration process Allows setting of 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	Indicates the RaptorXR is physically connected to an external network Ethernet line. Yellow and green LEDs indicate inbound and outbound Ethernet packets transmission. Password controlled for factory and certified professional use only.
Network Processor Status: Blue (blinking)	Indicates processor and internal components are operating Provides indication of local connectivity to its (possible) adjacent RaptorXR unit and to the core network gateway.
Network Status	Indicates the RaptorXR is connected to a valid IP network and can reach RaptorXR's FCC database site.

Processor Reset	**Processor reset performs a warm reboot on the network processor and TV band transceiver.**

2.4.2 RaptorXR Single Link (Rear Views)

Figure 1.3 Single Link System (Rear View)

NETWORK SHELF ITEM	DESCRIPTION
J1:Power Input	DC Input: 12 and 28 V DC
J3:RF Tx/Rx Port	Tx/Rx Antenna Type N Female
Dual Exhaust Fans	Keep Clear & Clean

2.4.3 RaptorXR Single Link System (Rear Views)

Figure 1.4 Single Link Diversity System (Rear View)

2.4.4 RaptorXR Single Link Diversity System (Rear Views)

NETWORK SHELF ITEM	DESCRIPTION
J1:Power Input	DC Input: 12 and 28 V DC
J3:RF Tx/Rx Port	Tx/Rx Antenna

	Type N Female
J5 RF Tx/Rx Port	Tx/Rx Antenna
	Type N Female
Air Intake and Exhaust Ports	Keep Clear & Clean

2.4.5 RaptorXR Dual Link Relay Configuration

A Dual Link RaptorXR System is configured by adding an additional Network Shelf... Each independent Shelf contains one VHF or UHF White Space Tx/Rx unit.

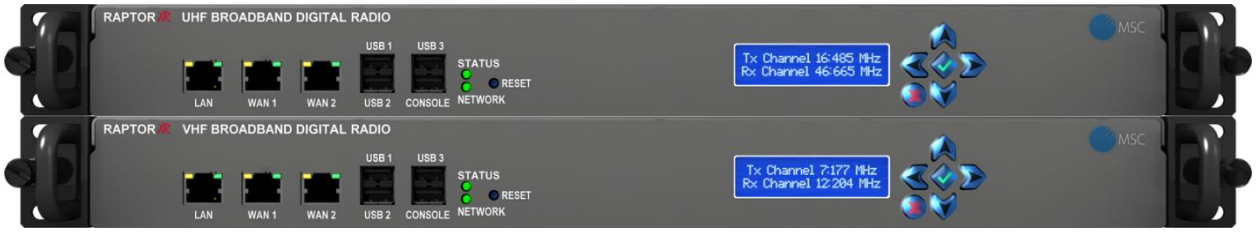


Figure 1.5 RaptorXR Dual Link System (Front View)

2.4.5.1 Benefits of Dual Link System (See Figure 1.6)

Use of the Dual Link System 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

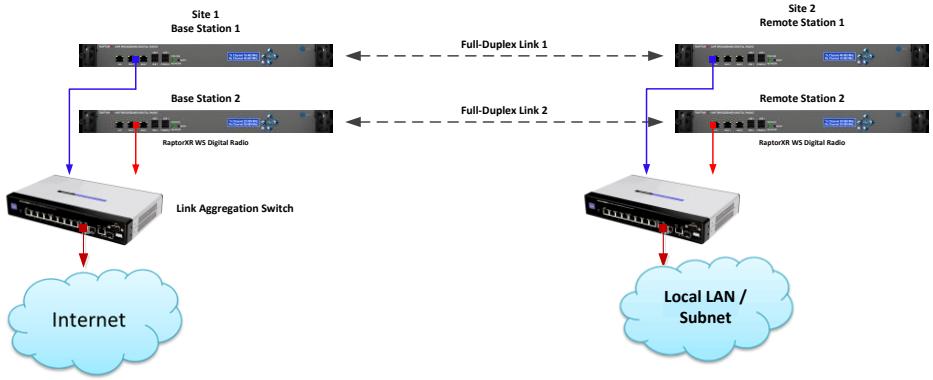


Figure 1.6 Dual Link System

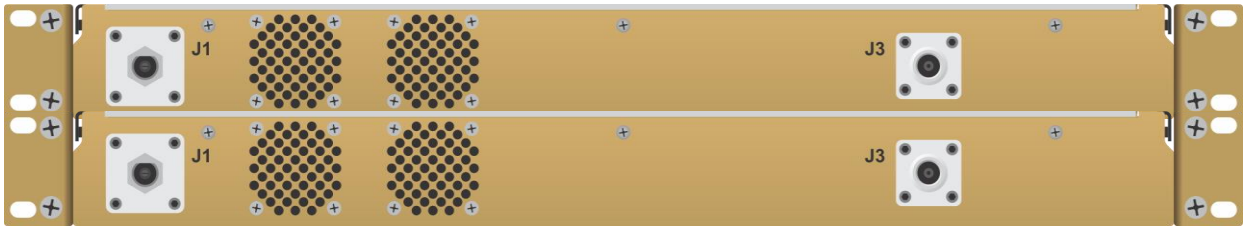


Figure 1.7 RaptorXR Dual Link System (Rear View)

2.4.6 RaptorXR Dual Link System using Channel Expansion Shelf Interfaces

CHANNEL EXPANSION INTERFACES	DESCRIPTION
J1 DC Power Input- Mil-style	DC input from Power Supply
J3 RF Tx/Rx Output	Tx/Rx Antenna, Type N Female
Air Intake and Exhaust Ports	Keep clean and clear

3 GETTING STARTED

Implementing a RaptorXR or network consists of three inter-related stages:

- DESIGN
  - Selecting operating channels via an FCC approved data base. (See below and page
  - Analytically validating that an operating link can be established (See page
- DEPLOYMENT
  - Locally registering and verifying RaptorXR operation (See page
  - Deploy RaptorXRs to respective sites (Base or relay)
  - Setting the RaptorXR link to an operational full-duplex rate. (See page
- COMMISSIONING
  - Testing the effectiveness of a link with actual data is possible with RaptorXR's embedded video server.
  - Accessible via RaptorXR's web page, streaming videos at various payload rates can be selected, transmitted and monitored for path effectiveness.

~~3.1~~ EXAMPLE

~~This section describes the basics of setting up a Point-to-Point RaptorXR link. The example uses actual locations and path design. For your particular application use local GPS coordinates. This process will allow you to set up and confirm system operation prior to deployment. It is assumed that all RaptorXR equipment, antennas and support accessories are available. Mobile IP is a free radio link design application. It uses recently digitized topographic maps with land coverage.~~

~~STEP 1: Selecting available White Space Channels (examples of GPS coordinates)~~

~~Using Google spectrum database: https://www.google.com/get/spectrumdatabase/index.html~~

~~STATION 1: Location: Pine Creek, MT Latitude: 45.52N Longitude -110.6253~~

- ~~Channels Available (total): 21 (126 MHz)~~
- ~~VHF High Band:~~
- ~~UHF: 14,15,16,17,18,30,31,32,33,34,35,43,44,48,49,50,51~~

~~STATION 2: Location: Carbella, MT Latitude: 45.25582N Longitude: -110.802~~

- Channels Available (total): 25 (150 MHz)
- VHF High Band: 7,12
- UHF Channels: 14,15,16,17,25,29,30,31,32,33,34,35,43,33,48,49,50,51

In this example the range between sites is 20 miles (32 mm). The Google database indicates VHF High Band channels available at Carbella, but not at Pine Crest. We will choose the lowest UHF channel available in the UHF low band spectrum (channels 14-35) and the lowest available high band channel (channels 39-51).

From the database we will select Tx channel 14 for the Carbella to Pinecrest link;

And channel 42 for the uplink channel from Pinecrest to Carbella.

The figures below show the path statistics between each station: Key System Parameters are:

Point-to-Point Range: 32.55 km/20.35 miles
Tx EIRP Power: 3.55 Watts (35.5 dBm EIRP) (Maximum 4 Watts, 36 dBm EIRP)
Predicted Rx Signal Level: 70.7 dBm (using Langley-Rice model)
Projected Full-Duplex Data Rate: 30 mbps
Minimum Required Antenna Height: Pinecrest: 50 feet; Carbella: 40 feet

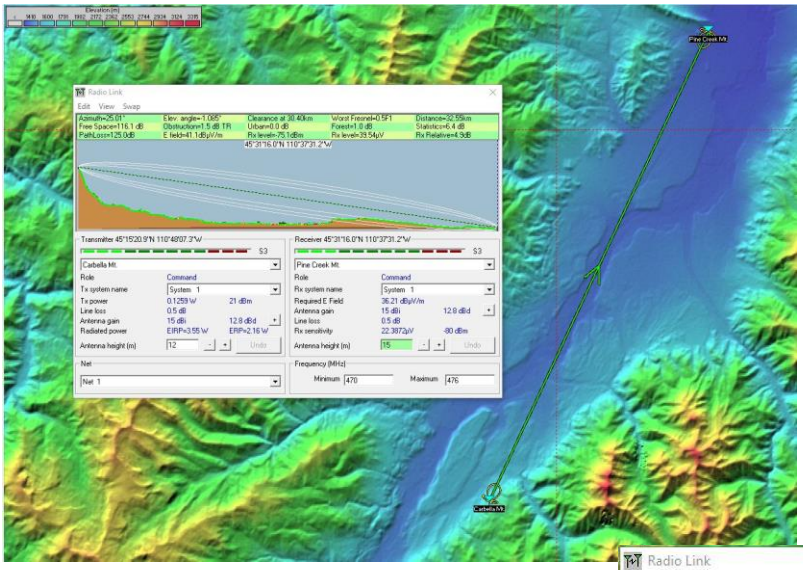


Figure 1.8 Topological and Point-to-Point profile between Carbella and Pinecrest.

This design clearly shows how a reliable link is established between two points, using available White Space channels.

Practical aspects of the design include antenna polarization (horizontal recommended for rural, vertical for urban) and additional losses in the transmission system.

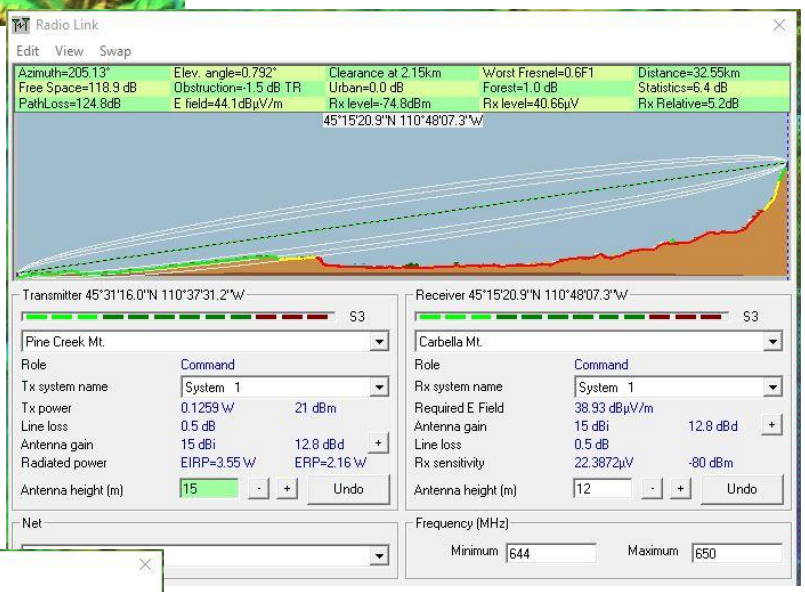


Figure 1.9 Point-to-Point profile of Pinecrest-to Carbella link. Minimum Pinecrest Antenna Height: 15 meters (50 feet.)
Antenna type: Kathrein PR-TV,15.5 dBd gain

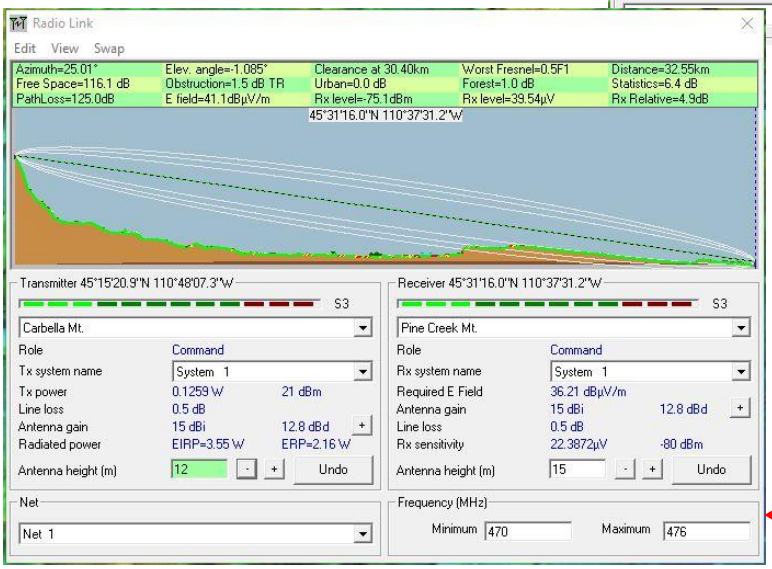


Figure 1.10 Point-to-Point profile of Carbella-to Pinecrest link. Minimum Carbella Antenna Height: 12 meters (40 feet.)
Antenna type: Kathrein PR-TV,15 dBd gain

4 Accessing VHF/UHF TV Band Spectrum

See Figure 1.7, Registering the RaptorXR, which shows the registration configuration of a RaptorXR connected to the internet.

The RaptorXR only becomes operational when successfully registered with the RaptorXR's designated FCC certified database provider, Spectrum Bridge
http://whitespaces.spectrumbridge.com/whitespaces/home.aspx

Each domestic (U.S.) RaptorXR has been registered for one (1) year with Spectrum Bridge.

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

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

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

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

4.4 **Select the appropriate TV channel to complete registration and activate the Tx subsystem of the RaptorXR.**

4.5 **The remaining sections will describe in detail the Registration process. The RaptorXR Database Registration Engine will automatically validate and re-register the unit every 24 hours.**

5 RaptorXR Network Design Process

This section describes the process and tools required to design a RaptorXR White Space network. Intermediate steps common to all professional radio system deployment will be left to the professional designer and installer.

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

5.1 Operating Channel Selection via an on-line secure database

5.2 Need to evaluate and predict link performance using an RF System Planning application, e.g. Pathlink 5 or Radio Mobile.

5.3 RaptorXR certified 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 Spectrum Bridge.com (http://Spectrum Bridge.com/spectrum-mgmt/white-spaces/index.html)for this service.

5.4 Tools Needed:

- Access to internet
- Site parameters, i.e. GPS coordinates, intended Antenna Height
- Spectrum or Signal Analyzer
- PC or mobile device with appropriate browser.

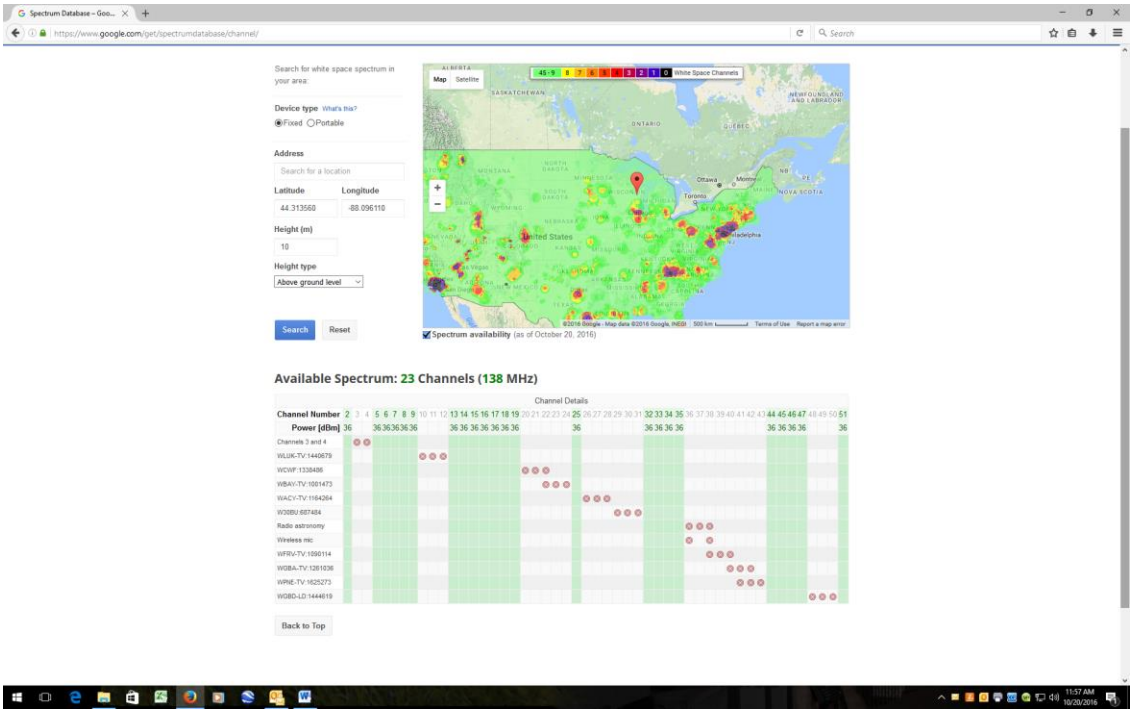
5.5 Step 1:DETERMINE LAT/LONG

- 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 RaptorXR 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 1: Example of Available Channels per Google White Space Database

Figure 1.11 https://www.google.com/get/spectrumdatabase/index.html



5.6 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.
- RaptorXR uses an adaptive modulation process that works to maximize data throughput for a range of Rx signal levels vs local noise levels.
- Radio Mobile, a semi-professional RF planning tool, can be downloaded from http://www.cplus.org/rmw/english1.html. It is ideal for nearly all RF planning. If you find it of value, please contribute.

5.7 Step 3: Manually Setting Full Duplex Data Rate

The shipped default Useful Data Rate (UDR) of all RaptorXR radios is 3.110 mbps per link direction (half-duplex) or 6.220 mbps full-duplex.

The RaptorXR has the capability of providing a high-end rate of 39.586 mbps full-duplex. The Useful Data Rate (UDR) is a two- step process:

1. Using the Front Panel or the SafariView radio control page (see Fig…..)

   Select: *New Modulation Waveform Code Rate and GI parameters*. The local transmitter will automatically enable the remote Rx to sync to the higher (lower) rate.

2. If you are satisfied with resulting operation click, *Apply*: and the new rate will be "locked" for that link direction. The reverse link can be remotely modified. It is not necessary that each link have the same rate.

To maintain link reliability the RaptorXR uses an AI algorithm which monitors channel C/N. If the algorithm senses the channel performance degrading it will attempt to maintain communication by first increasing power, lowering transmission rate, automatically moving to a new preassigned channel or entering into a channel scan mode to discover a suitable pre-available channel.

RaptorXR Single Channel Useful Data Rates as a Function of Code Rate (CR) and Group Interval Setting

For full-Duplex Useful Rate add up-link and down link rates;
e.g. Up-link Rate 3.110 Mbps (QPSK, CR=½,GI=¼,
Down-link Rate 5.184 Mbps (QPSK, CR=¾,GI=1/8)
Total Full-Duplex Rate: 8.394 Mbps
Note Rate can vary a few percent due to signal-path, Processor andf Traffic Load

5 MHz Useful Data Rates

Modulation	Code rate	Guard interval			
		1/4	1/8	1/16	1/32
QPSK	1/2	3,110	3,456	3,659	3,770
	2/3	4,147	4,608	4,879	5,027
	3/4	4,665	5,184	5,489	5,655
	5/6	5,184	5,760	6,099	6,283
	7/8	5,443	6,048	6,404	6,598
16-QAM	1/2	6,221	6,912	7,318	7,540
	2/3	8,294	9,216	9,758	10,053
	3/4	9,331	10,368	10,978	11,310
	5/6	10,368	11,520	12,197	12,567
	7/8	10,886	12,096	12,807	13,195
64-QAM	1/2	9,331	10,368	10,978	11,310
	2/3	12,441	13,824	14,637	15,080
	3/4	13,996	15,551	16,466	16,965
	5/6	15,551	17,279	18,296	18,850
	7/8	16,329	18,143	19,211	19,793

5 MHz Useful Data Rates per Waveform, Code Rate (CR) and Guard Interval (GI) settings

6 MHz Useful Data Rates

Modulation	Code rate	Guard interval			
		1/4	1/8	1/16	1/32
QPSK	1/2	3,732	4,147	4,391	4,524
	2/3	4,976	5,529	5,855	6,032
	3/4	5,599	6,221	6,587	6,786
	5/6	6,221	6,912	7,318	7,540
	7/8	6,532	7,257	7,684	7,917
16-QAM	1/2	7,465	8,294	8,782	9,048
	2/3	9,953	11,059	11,709	12,064
	3/4	11,197	12,441	13,173	13,572
	5/6	12,441	13,824	14,637	15,080
	7/8	13,063	14,515	15,369	15,834
64-QAM	1/2	11,197	12,441	13,173	13,572
	2/3	14,929	16,588	17,564	18,096
	3/4	16,796	18,662	19,760	20,358
	5/6	18,662	20,735	21,955	22,620
	7/8	19,595	21,772	23,053	23,751

6 MHz Useful Data Rates per Waveform, Code Rate (CR) and Guard Interval (GI) settings

7 MHz Useful Data Rates

Modulation	Code rate	Guard interval			
		1/4	1/8	1/16	1/32
QPSK	1/2	4,354	4,838	5,123	5,278
	2/3	5,806	6,451	6,830	7,037
	3/4	6,532	7,257	7,684	7,917
	5/6	7,257	8,064	8,538	8,797
	7/8	7,620	8,467	8,965	9,237
16-QAM	1/2	8,709	9,676	10,246	10,556
	2/3	11,612	12,902	13,661	14,075
	3/4	13,063	14,515	15,369	15,834
	5/6	14,515	16,127	17,076	17,594
	7/8	15,240	16,934	17,930	18,473
64-QAM	1/2	13,063	14,515	15,369	15,834
	2/3	17,418	19,353	20,491	21,112
	3/4	19,595	21,772	23,053	23,751
	5/6	21,772	24,191	25,614	26,390
	7/8	22,861	25,401	26,895	27,710

7 MHz Useful Data Rates per Waveform, Code Rate (CR) and Guard Interval (GI) settings

8 MHz Useful Data Rates

Modulation	Code rate	Guard interval			
		1/4	1/8	1/16	1/32
QPSK	1/2	4,98	5,53	5,85	6,03
	2/3	6,64	7,37	7,81	8,04
	3/4	7,46	8,29	8,78	9,05
	5/6	8,29	9,22	9,76	10,05
	7/8	8,71	9,68	10,25	10,56
16-QAM	1/2	9,95	11,06	11,71	12,06
	2/3	13,27	14,75	15,61	16,09
	3/4	14,93	16,59	17,56	18,10
	5/6	16,59	18,43	19,52	20,11
	7/8	17,42	19,35	20,49	21,11
64-QAM	1/2	14,93	16,59	17,56	18,10
	2/3	19,91	22,12	23,42	24,13
	3/4	22,39	24,88	26,35	27,14
	5/6	24,88	27,65	29,27	30,16
	7/8	26,13	29,03	30,74	31,67

8 MHz Useful Data Rates per Waveform, Code Rate (CR) and Guard Interval (GI) settings

Table 2: Single Channel Useful Data Rates as a Function of Code Rate and Group Interval Setting

Table 3: Carrier to Noise (C/N) vs Useful Data Rate and Minimum Signal Required

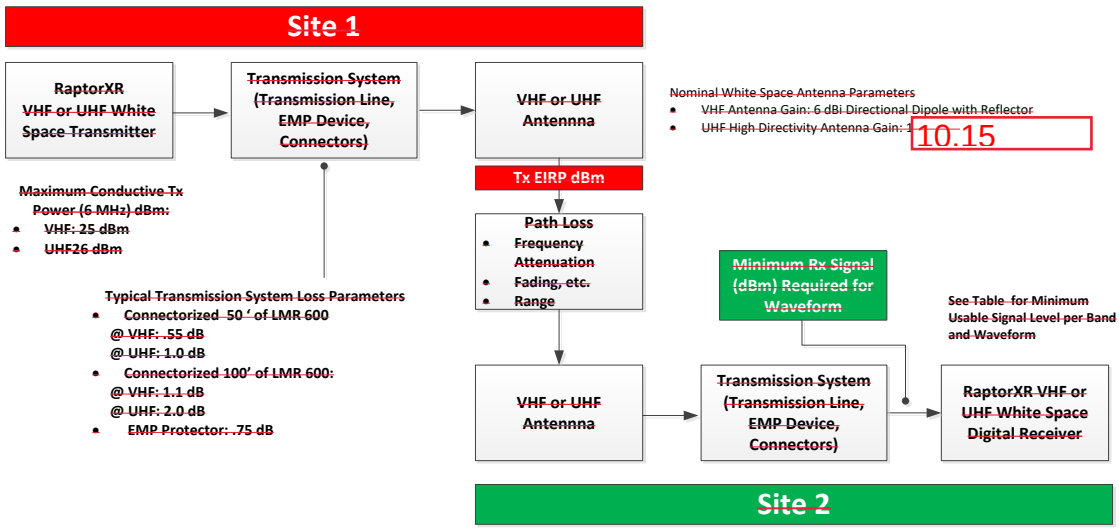
		Required C/ N for BER = 2 x 10^{-4} after Viterbi QEF after Reed-Solomon			Bitrate (Mbit/s) Bandwidth = 5 MHz Guard Interval			
Modulation	Code Rate	Gaussian Channel	Ricean Channel (F1)	Rayleigh Channel (P1)	1/4	1/8	1/16	1/32
QPSK	1/2	3.1	3.6	5.4	3.110	3.456	3.659	3.770
QPSK	2/3	4.9	5.7	8.4	4.147	4.608	4.879	5.027
QPSK	3/4	5.9	6.8	10.7	4.665	5.184	5.489	5.655
QPSK	5/6	6.9	8.0	13.1	5.184	5.760	6.099	6.283
QPSK	7/8	7.7	8.7	16.3	5.443	6.048	6.404	6.598
16 -QAM	1/2	8.8	9.6	11.2	6.221	6.912	7.318	7.540
16 -QAM	2/3	11.1	11.6	14.2	8.294	9.216	9.758	10.053
16 -QAM	3/4	12.5	13.0	16.7	9.331	10.368	10.958	11.310
16 -QAM	5/6	13.5	14.4	19.3	10.368	11.520	12.197	12.567
16 -QAM	7/8	13.9	15.0	22.8	10.868	12.096	12.807	13.195
64-QAM	1/2	14.4	14.7	16.0	9.331	10.368	10.978	11.310
64-QAM	2/3	16.5	17.1	19.3	12.441	13.824	14.367	15.080
64-QAM	3/4	18.0	18.6	21.7	13.996	15.551	16.466	16.965
64-QAM	5/6	19.3	20.0	25.3	15.551	17.279	18.296	18.850
64-QAM	7/8	20.1	21.0	27.9	16.329	18.143	19.211	19.793

NOTE 1: Quasi Error Free (QEF) means less than one uncorrected error event per hour, corresponding to BER = 10^{-11}

NOTE 2: The net bit rates after Reed-Solomon decoder are also listed.

5.8 System Margin Examples

System Margin Examples



5.9 Link Budget Calculation

Link Budget Calculation	
Down Link (Base to Remote)	**Up Link (Remote to Base)**
1. Operating Frequency (MHz):	Operating Frequency (MHz):
2. Tx Power (dBm):	Tx Power (dBm):
3. Transmission System Loss	Transmission System Loss
• EMP Protector: • Coax Cable Loss: • Connector Loss:	• EMP Protector: • Coax Cable Loss: • Connector Loss:
4. Antenna Gain (dBi):	Antenna Gain (dBi):
5. Tx EIRP (dBm):	Tx EIRP (dBm):
Down Link Path Loss	**Up Link Path Loss**
• Range Miles:	• Range Miles:
• Path Loss P_L = 36.6 + 20 log (F_{MHz}) + 20 log (d_{miles})	• Path Loss P_L = 36.6 + 20 log (F_{MHz}) + 20 log (d_{miles})
Up Link Rx Power	Downlink Rx Power
Rx = Tx EIRP + Rx Ant Gain – Path Loss	**Rx = Tx EIRP + Rx Ant Gain – Path Loss**
Rx signal must be greater than minimum signal (as required in 5.9 System Margin Table)	

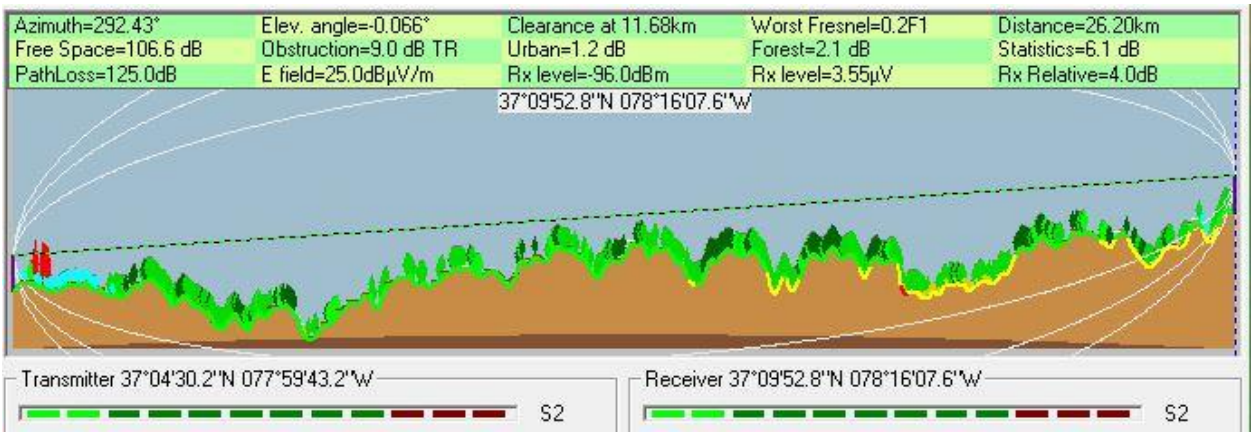


Figure 1.12 VHF System Gain and Margin

VHF Example:

System Gain and Margin calculations

- VHF @ Channel 8, 183 MHz
- PEIRP = Po (dBm) + VHF Tx antenna gain (6 dBi) = **31 dBm**
- Rx Antenna gain: 6 dBi, Rx System sensitivity: **-104 dBm**
- VHF system gain @ 183 MHz= 31 dBm + 6 dBi + -104 dBm = **141** dB @ **QPSK;**
    - CR: ½; GI: 1/8, FFT = 8K
- System at each site introduces a 2 dB loss; SG = 141 – 4 dB = **137 dB**
- Path with loss of **125.0 dB** provides an excess system margin of **12 dB.**
- The Radio Mobile program indicates a **4 dB** margin with the ability to take into consideration multipath, environmental effects and Tx/Rx antenna height.

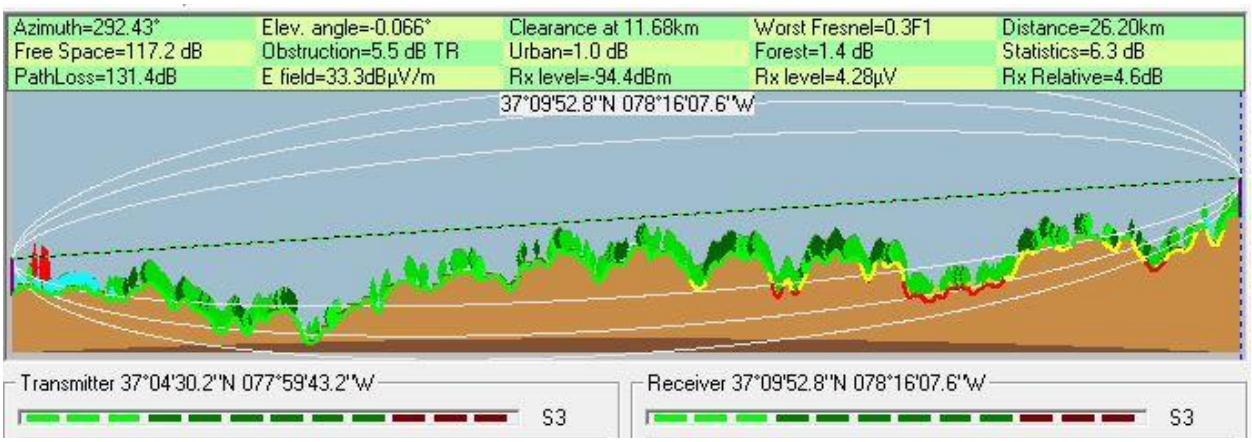


Figure 1.13 UHF System Gain and Margin

UHF Example:

System Gain and Margin Calculations:

- UHF @ Channel 46, 665 MHz
- PEIRP = Po (dBm) + UHF Tx antenna gain (10.15 dBi) = **36 EIRP dBM**
- Rx antenna gain: 10.15 dBi; Rx system sensitivity for 64 QAM: **100.4 dBm**
    - CR = ½; GI = 1/8; FFT: 8K
- UHF System Gain @ 665 MHz = 36 EIRP dBm (Tx radiated power) + 10.15 dBi (Rx antenna gain) + -100.4 = **146.55 dB**
- Let us say additional losses from system implementation, environmental and multipath characteristics degrade the system margin by 6 dB, yielding an estimated margin of **140.5 dB.**
- Again, using Radio Mobile (see Figure) a **131.4 dB** propagation loss is predicted over a 26.2 km (16.375 mi) path over a deciduous broadleaf forest.
- Thus system margin is:
    - System Gain – Propagation Loss = System Margin
    - 140.5 dB – 131.4 dB = **9.1 dB**

This is the minimum acceptable one-way system margin. An additional _____dB of Rx margin can be achieved with the PR-TV ParaReflector Antenna.

5.10 System Margin Table

TABLE 4: SYSTEM MARGIN TABLE

RaptorXR Single Channel VHF/UHF Radio System (5 MHz CR: 1/2 GI: 1/4)

Tx Band width (MHz)	Tx Wave-form	UHF/ VHF Bands	Tx Freq. MHz	Min Required Rx Power (dBm)[1]	System Gain (dB)*	Req C/N (dB)	Useful Data Rate (Mbps)	Full Duplex Rate	Code Rate (CR)	Guard Interval (GI)	Number of OFDM Carriers (FFT)
5	QPSK	VHF	183	-104.0	141.0	3.1	3.110	6.220	1/2	1/4	8K
5	QPSK	UHF	473	-105.2	158.4	3.1	3.110	6.220	1/2	1/4	8K
5	QPSK	UHF	656	-105.4	158.6	3.1	3.110	6.220	1/2	1/4	8K
5	16QAM	VHF	183	-99.5	136.5	9.1	6.221	12.442	1/2	1/4	8K
5	16QAM	UHF	473	-105.2	158.4	9.1	6.221	12.442	1/2	1/4	8K
5	16QAM	UHF	656	-105.6	158.8	8.8	6.221	12.442	1/2	1/4	8K
5	64QAM	VHF	183	-104.7	141.7	13.7	9.331	18.662	1/2	1/4	8K
5	64QAM	UHF	473	-100.7	153.9	14.1	9.331	18.662	1/2	1/4	8K
5	64QAM	UHF	656	-100.4	153.6	13.6	9.331	18.662	1/2	1/4	8K
5	64QAM	VHF	183	-86.2	133.35	20.1	19.793	39.586	7/8	1/32	8K
5	64QAM	UHF	473	-92.0	145.15	20.0	19.793	39.586	7/8	1/32	8K
5	64QAM	UHF	656	-94.0	147.0	20.0	19.793	39.586	7/8	1/32	8K

***UHF TX = EIRP 36 dBm; Rx Ant: 17.15 dBi; VHF = EIRP 31 dBm; Rx Ant: 6dBi**

5.10.1 NOTES:

- System Gain = Tx EIRP (Far End dBm) - minimum sensitivity for QEF BER of 10^{-11} + Rx Antenna-gain dBi
- Nominal VHF conductive output power of 25 dBm with a nominal 6 dB Tx and Rx directional gain antenna for an EIRP of 31 dBm.
- Nominal UHF conductive output power of 26 dBm with a 10 dBi antenna
- QEF = Quasi error-free means less than one uncorrected error event per hour corresponding to BER = 10^{-11}
- Effective Tx Antenna system gain and Rx Antenna System gain are adjustable. For example: If one is using a 15 dBd (17.15 dBi) Directional Antenna, upon registration and selection of this antenna the spectrum database will determine whether to limit EIRP power to either 36 dBm EIRP or 40 dBM EIRP (22.85 dBm). The RaptorXR will compensate for inline transmission losses. Thus on the Tx channel, maximum power limits are observed, but the Rx is using the full antenna gain, in this case 17.15 dBi.

[1] Actual sensitivity is affected by local in-band and adjacent channel noise. A 10 dB margin on all links is recommended for sustainable reliability.

5.11 Antennas

The RaptorXR is certified to operate with the following VHF and UHF antennas to fit various deployment scenarios. When you register the RaptorXR 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 RaptorXR to provide peak link performance. (See Section 6.2 for antenna details.)

- VHF –TV Panel Antenna -174-230 MHz (P/N K523157)
- UHF-TV Log Periodic Antenna 470-862 MHz (P/N CL 1469B)
- ~~UHF High Gain Semi-Parabolic Antenna - 470-862 MHz (P/N AUPRTV862)~~
  ~~Rx mode only. Tx automatically limited to EIRP of 36 dBm.~~
- ~~UHF- Corner Reflector Sector Antenna – 470-800 MHz (P/N ARS800EU~~)

5.12 Transmission System (Transmission Line + EMP Protectors)

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

6 RaptorXR Data Base Registration and Channel Selection Procedure

This guide supports pre-deployment procedure required of RaptorXR VHF/UHF Radio Units for proper registration with the Spectrum Bridge Database to comply with FCC: CFR47 PART 15 SUBPART H Database Registration Requirements. FCC rules require that all White Space radios securely access an FCC-certified database via the internet to verify channel availability. In this instruction, RaptorXR units designated as a "BASE" have a direct connection to the internet. Units described as a "REMOTE" do not have a direct connection to the internet, thus require a secure radio link to a "BASE" in order to access the internet. The "BASE" provides secure routing services to transport traffic to and from the internet for the "REMOTE" unit. Both the BASE and the REMOTE units need to be independently registered prior to channel assignment and/or site deployment. Sections 3.4 to 3.11 provide detailed descriptions of FCC requirements and RaptorXR set up and registration procedures.

6.1 Configuration and Registration Instructions Prior to Deployment

6.1.1 Setup the units as illustrated in Figure 1.5A. The registration process requires that RaptorXR units be setup together and connectivity be established between the two units. If required, individual units can be configured and tested separately. When configuring the REMOTE units, FCC requires that it be permanently connected to a BASE station via a virtual radio link. REMOTE units require a temporary direct connection to the internet to be independently registered prior to operation or testing.

6.1.2 Once the units are setup per Figure 1.5A,.apply power to both units and to any additional required equipment (e.g. laptop, switches, routers, spectrum analyzer, etc.). Allow all equipment to fully boot and enter normal operation. At a minimum, please allow all equipment to stabilize for 15-30 minutes.

6.1.3 Use the Spectrum Bridge website to determine the available channels each deployment site. Establish an internet connection to the desktop or laptop pc. Open an internet browser window. Type the following URL in the search bar and press enter: http://whitespaces.spectrumbridge.com/whitespaces/home.aspx

6.1.4 Click the "Enter Location" button on the bottom left of the page. A window will open for you to enter the proposed antenna coordinates and click the Apply button. A new map of the requested area opens and the available channels are shown on the right side of the page.

6.1.5 Record the site coordinates and desired available operating channel on the Raptor XR Radio Configuration Worksheet. Do this for each unit that is to be configured. A REMOTE unit's Tx channel must be available at both the BASE and REMOTE locations. Multiple BASE and REMOTE radio units need to be independently registered each at their independent deployment locations.

6.1.6 Disconnect the temporary internet connection from the desktop or laptop pc and reconnect to each respective RaptorXR as shown in Figure 1.5A.

6.1.7 Configure each RaptorXR Unit for operation by opening a browser window on the desktop or laptop pc that is connected as described in the Setup Diagram. If registering a REMOTE unit connect a temporary internet connection as described in the setup diagram. Type the units IP address in the search bar and hit enter. This will take you to the RaptorXR Radio browser page.

6.1.8 On the left side of the page go to the SYSTEM ADMIN tab and select SYSTEM CONFIGURATION from the popup menu.

6.1.9 Login using the following information:
Username: root **Password: mscadmin (lowercase)**

6.1.10 Displayed across the upper part of the page are a series of menu tabs. Go to the TVBD tab and select TVBD1 from the dropdown menu.

6.1.11 Enter in all the required information in the appropriate fields. See the RaptorXR Radio Configuration Worksheet for the unit specific information. The FCC ID and SERIAL NUMBER are fixed and cannot be changed. Enter the coordinates of the operating site location in which the unit will be deployed. Enter antenna height, gain, and transmission line loss in the device information box. Next enter in the CONTACT and REGISTRATION information (all fields must be filled in). Next enter in the INSTALLER information. The installer information is from the person/company setting up the unit for operation in the field. Once all the information is typed in, click the REGISTER DEVICE button at the bottom of the page.

6.1.12 The unit will now verify the correct information was entered and request registration from the FCC database over the internet. If successful, the page will ask you to select an operating channel from the CHANNEL LIST field in the location box. The channel list will only show the available channels for the geo-location coordinates entered for that unit. Once registered location coordinates cannot be changed without unregistering the unit. Units can switch to another available channel at any time. Select an operating channel from the list.

6.1.13 You are now registered to that channel. Next select the YES option in the ENABLE RADIO field in the Radio Information box. Click the START RADIO ON STARTUP checkbox and then click the APPLY CHANGES button. This turns the unit's radio on and enables the selected channel for normal operation.

6.1.14 The Unit is now set up and registered to the FCC Database for operation on the selected channel. If the Unit is equipped with a second radio channel (Expansion Shelf) go to the TVBD menu tab and select TVBD2 from the drop down menu. Repeat steps 6 thru 12 to register the second radio. The second radio (TVBD2) must have the same location coordinates as the TVBD1 radio since they are in the same stack and will be installed at the same location. Select a different operating channel for the unit's second radio.

Repeat the above configuration and registration instructions for each RaptorXR Radio Unit to be deployed and tested.

6.2 Procedure for Unregistering a RaptorXR and Relocating to Another Location

6.2.1 TVBD Units are only authorized to operate at a specific geo-location using available data base channels. To relocate a Unit to another location you must first **unregister** the Unit. This requires the Unit be directly connected to the internet. See setup diagram in Figure 1.12A,

6.2.2 Follow steps 3.1.7 thru 3.1.10 described above to navigate to the TVBD Configuration page. The TVBD page will automatically detect current registration and available channels. Scroll down to the bottom of the page and click " UNREGISTER DEVICE". The Unit will now unregister itself from the FCC Database. Once successfully unregistered, the device will automatically turn off the associated radio.

6.2.3 At the new location enter the NEW location coordinates and any other information that has changed pertaining to the NEW location (i.e. antenna height, gain, transmission line loss). Verify all other information is correctly filled in then click the REGISTER DEVICE button at the bottom of the page. Select the new operating channel from the available channel list when prompted. The Unit is now registered to a new location and channel.

6.2.4 Activate the radio by clicking APPLY CHANGES in the radio information box. Be sure to select YES in the ENABLE RADIO field and select the START RADIO ON STARTUP option before clicking APPLY CHANGES.

6.2.5 The Unit will now begin normal operation on the new channel and location.

6.2.6 If the Unit is equipped with a second radio then repeat steps 3.2.2 thru 3.2.5 selecting the TVBD2 tab this time from TVBD drop down menu.

6.2.7 Repeat the Unit Relocation Instructions for additional Radio Units.

6.3 Instructions for Checking Available Channels using the Google Spectrum Database or the Spectrum Bridge Database.

Identifying available White Space channels for the continental United States or its possessions is done by using the Google Spectrum Database or the Spectrum Bridge website's CHANNEL AVAILABILITY feature.

6.3.1 On a Desktop or Laptop computer with a direct connection to the internet, open an internet browser window and type URL below to access the

Google Spectrum Database https://www.google.com/get/spectrumdatabase/index.html

or the

Spectrum Bridge home page.
http://whitespaces.spectrumbridge.com/whitespaces/home.aspx

You must type the entire URL.

6.3.2 Now click the CHANNEL AVAILABILITY link or the map in the middle of the page. You can click anywhere on the map to view channel availability at that location or you can click the ENTER LOCATION button on the bottom left of the page and enter the specific GPS coordinates in the popup window and click the APPLY button. The new location is displayed on the map and the available channels are on the right of the page.

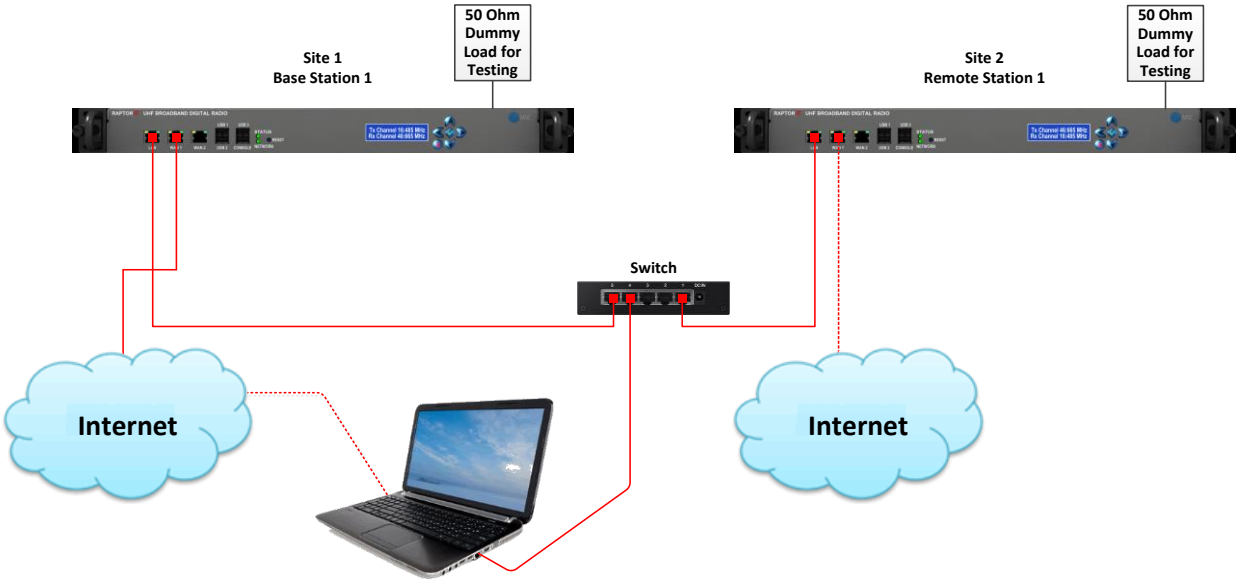


Figure 1.14Set Up Configuration for Registration

6.4 The RaptorXR TV Band Device (TVBD) has two status modes:

"Unregistered" and "Registered".

6.4.1 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.

6.5 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 detected 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.

6.6 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.

6.7 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 RaptorXR radio operations

6.8 To change any information after registration

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

6.9 Completing the RaptorXR Registration Form

When filling out the fields to register the RaptorXR they are automatically scanned for errors2 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.

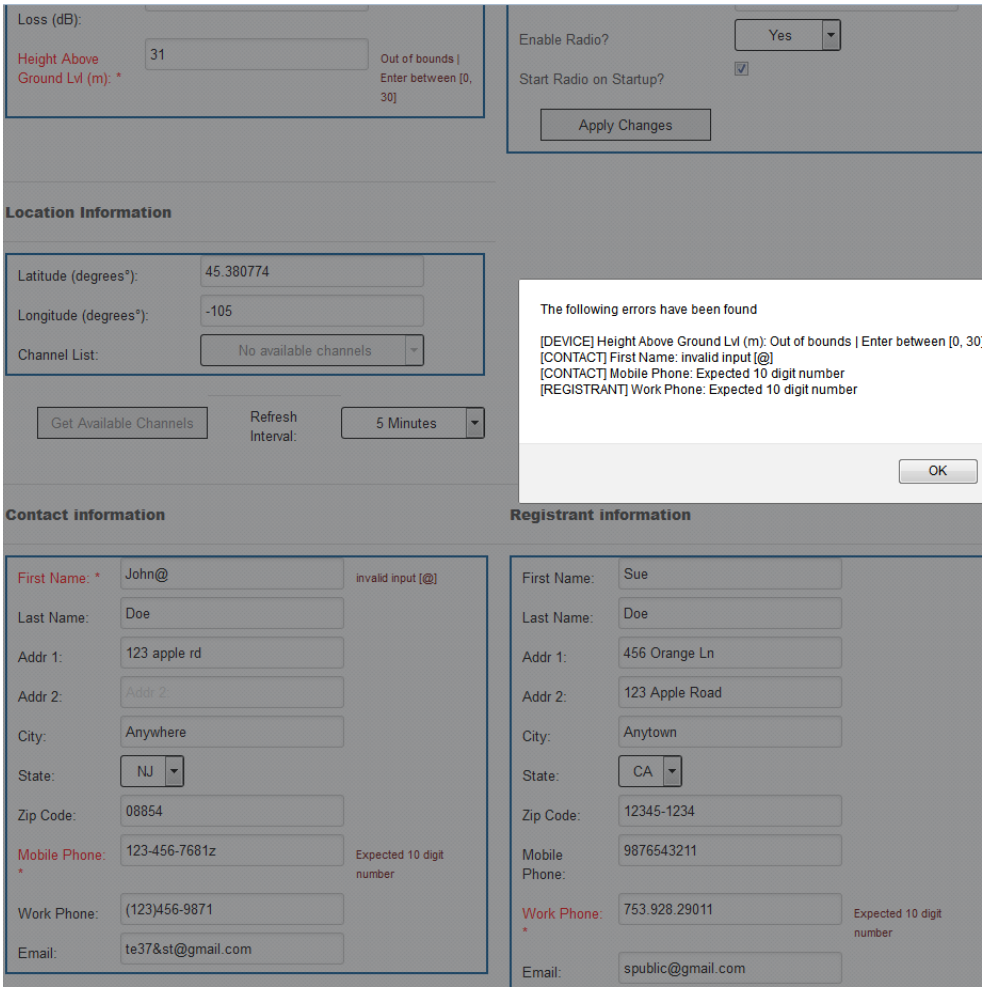


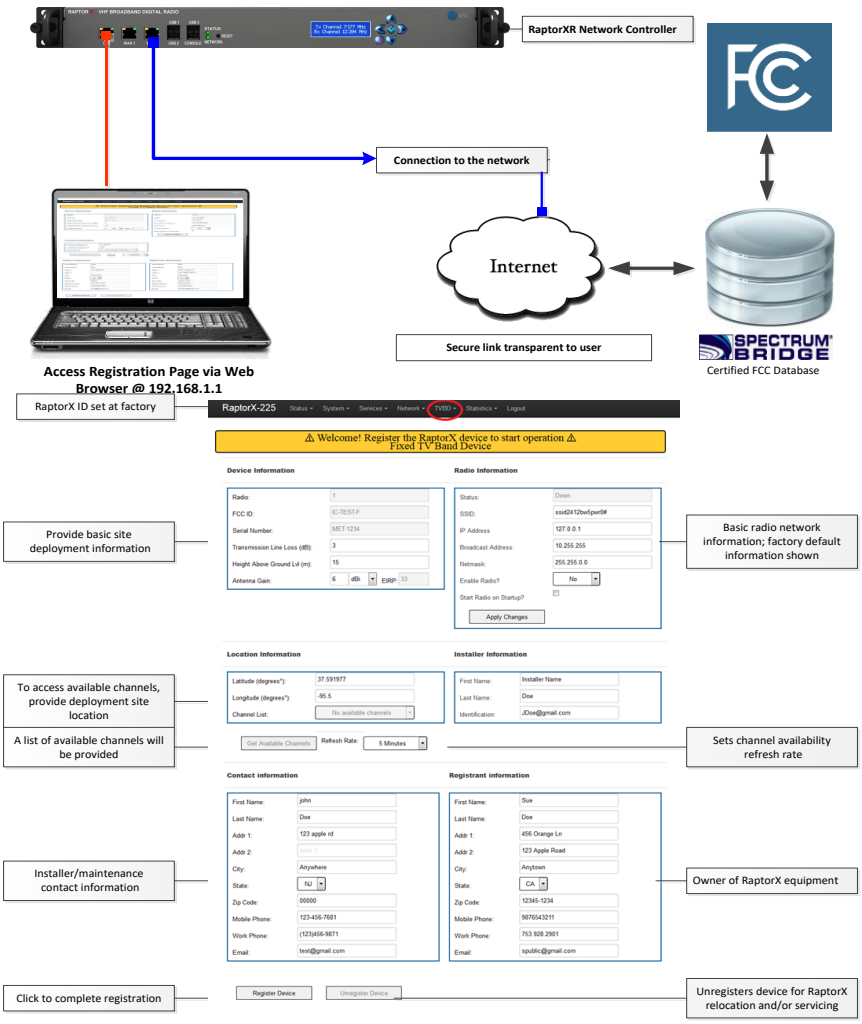
Figure 1.15 RaptorXR Registration Form

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

6.10 Registering the RaptorXR

Figure 1.16 RaptorXR Registration Configuration Set-Up



6.10.1 [DEVICE]

Radio: The device radio number | **This is locked into the RaptorXR at manufacture**
FCCID: The device FCC ID | **This is locked into the RaptorXR at manufacture**
Serial Number: The device serial number | **This is locked into RaptorXR 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 RaptorXR , MAX=36**

6.10.2 [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**

6.10.3 [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

6.10.4 [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.

6.10.5 [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 RaptorXR will begin sending *beacon packets* to alert other RaptorXR 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 RaptorXR
Unregister Device: Unregisters the RaptorXR

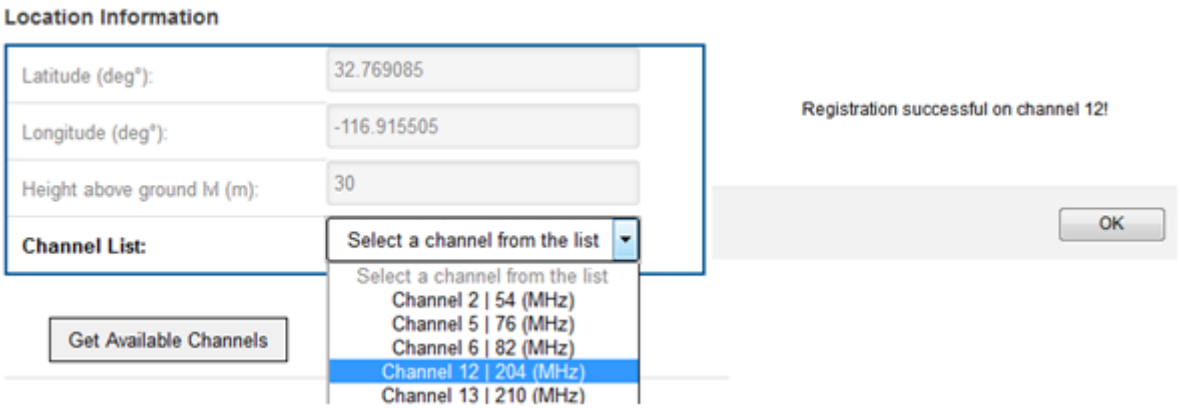
The RaptorXR must be unregistered when:

- **RaptorXR is moved beyond 50 meters from its current operating location.**
- **It is being repaired or undergoing firmware upgrades.**

6.11 Upon a Successful Registration:

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

6.11.1.2 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.



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

6.11.1.4 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 RaptorXR 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

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

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

6.12 Unregistering the RaptorXR

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

6.12.2 If the device needs to go into the *unregistered* mode the user must press the 'Unre57gister' button

6.12.3 Unregistering the RaptorXR 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

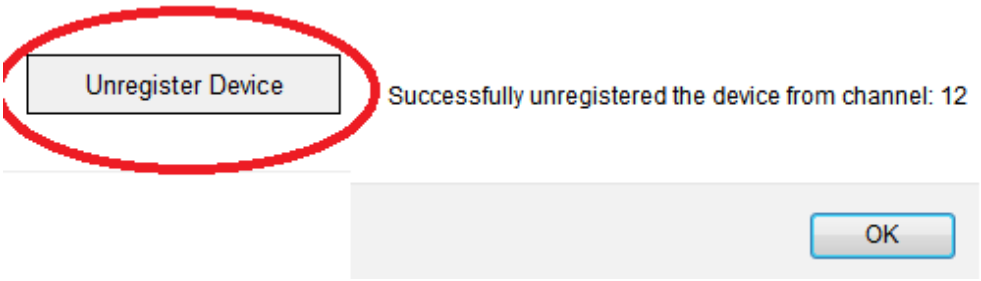


TABLE 5: VHF		
Frequency Range	**TV Channel Number**	**Center Frequency (MHz)**
VHF Low Band 177-189 MHz Channels 7-9	7	177
	8	183
	9	189
Channel 10 – Band Split	10	195
VHF High Band 201-213 MHz Channels 11-13	11	201
	12	207
	13	213

TABLE 6: UHF		
Frequency Range	**TV Channel Number**	**Center Frequency (MHz)**
UHF Low Band 470-599 MHz Channels 14-35	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
Channel 36-39 Band Split	39	623
UHF High Band 629-698 MHz Channels 40-51	40	629
	41	635
	42	641
	43	647
	44	653
	45	659
	46	665
	47	671
	48	677
	49	683
	50	689
	51	695

6.13 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 Spectrum Bridge 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 Spectrum Bridge database by 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 the FCC ID.

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

The identity of the Spectrum Bridge database is validated through verification of the Spectrum Bridge 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 to Access White Space) 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 Spectrum Bridge via "out-of-band means," such as email or telephone.

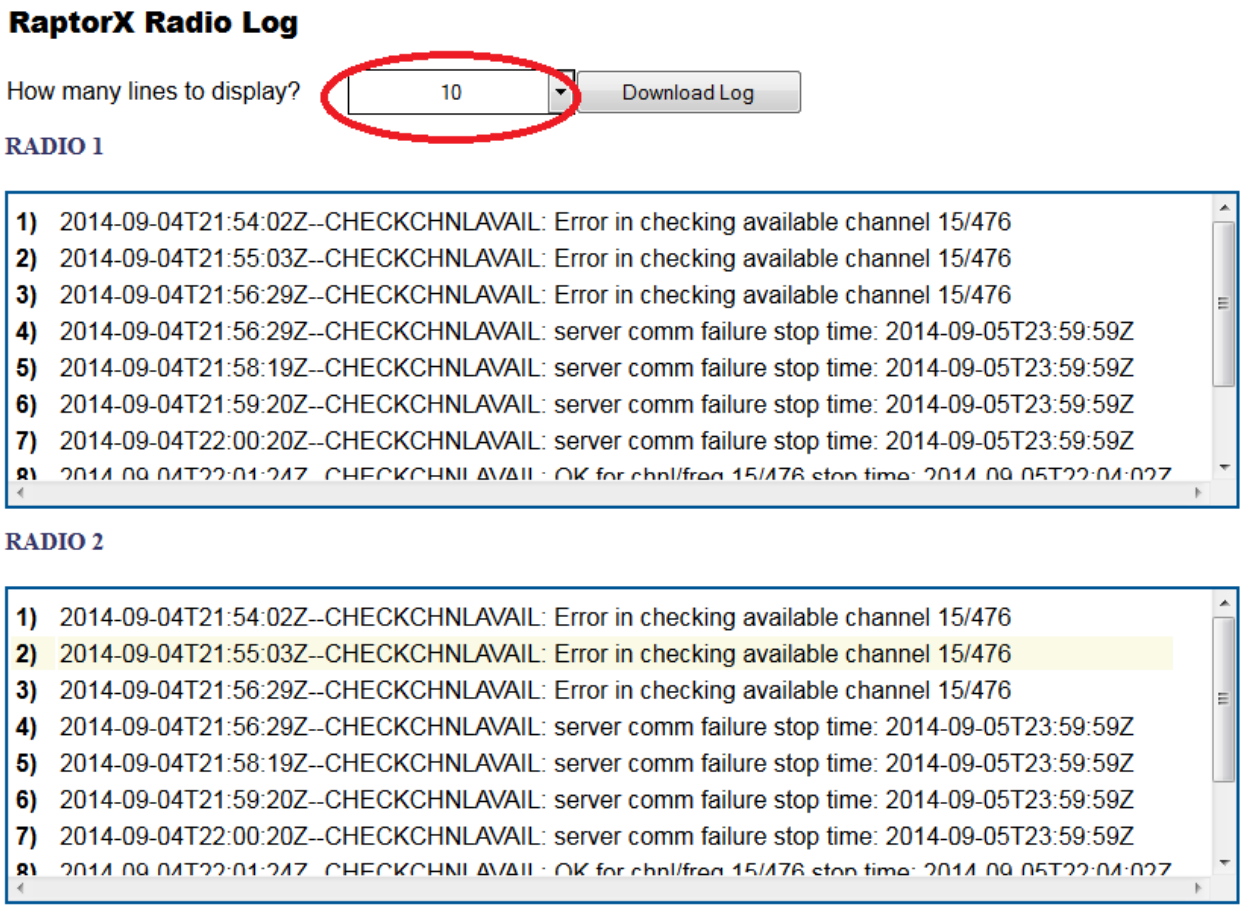
6. *What encryption method is used?*

SSL/TLS standard encryption is used to encrypt packets sent and received between the TVBD and database.

6.13.1 Appendix 2 Logging

When the RaptorXR 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).



6.13.2 Recommended Depot Configuration for end-to-end system testing and alignment

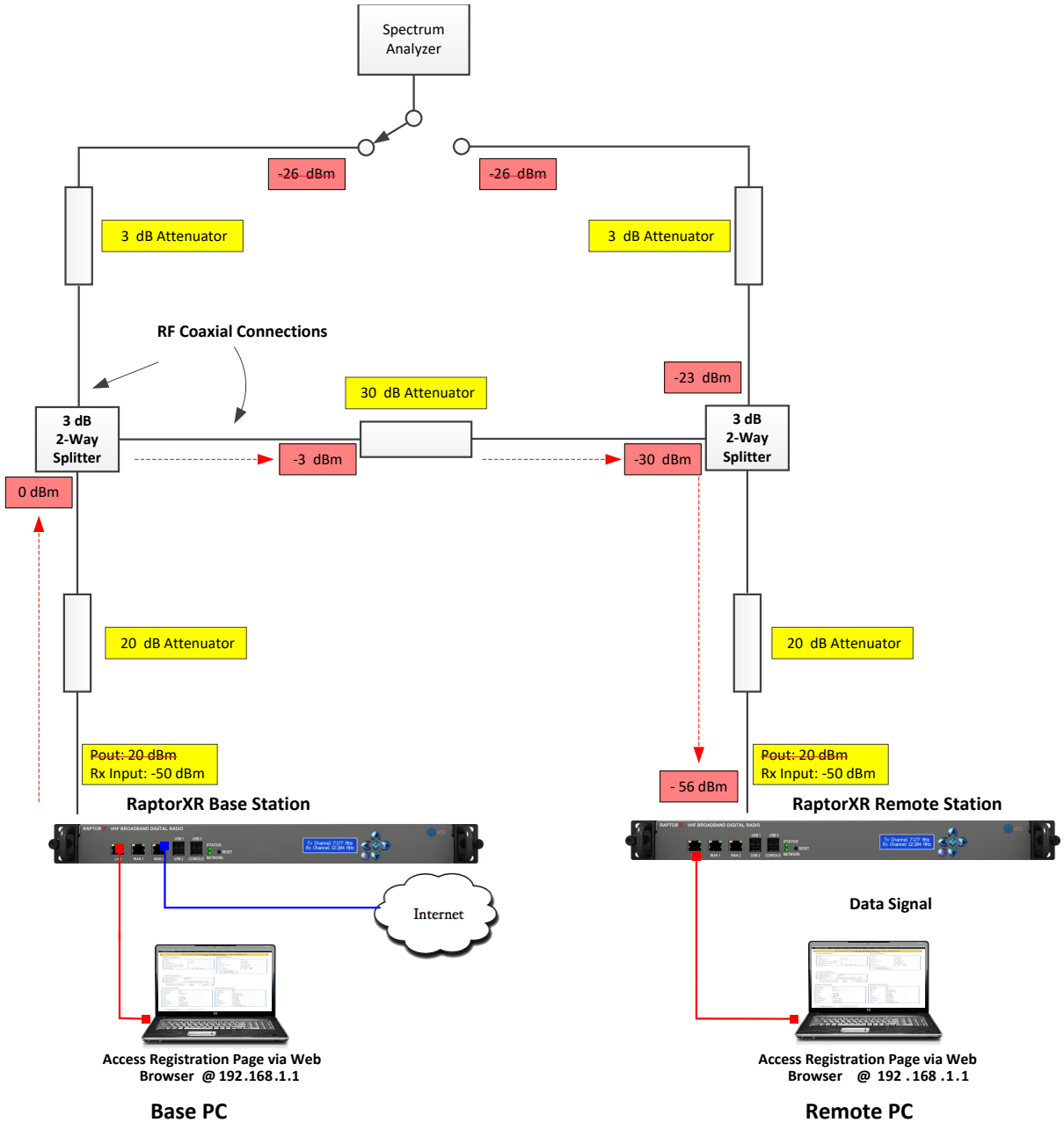
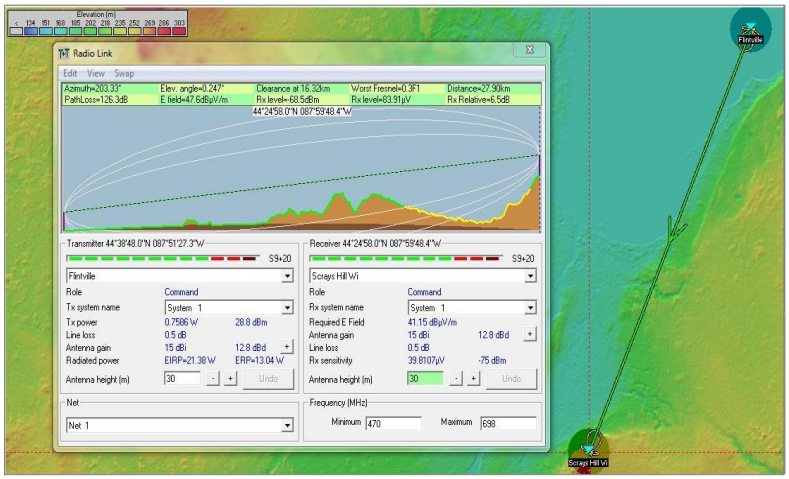
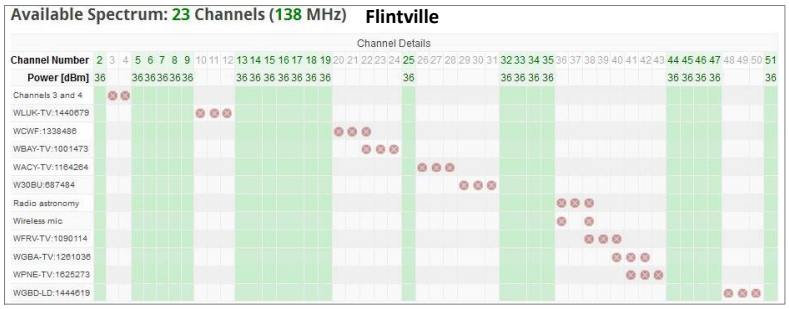


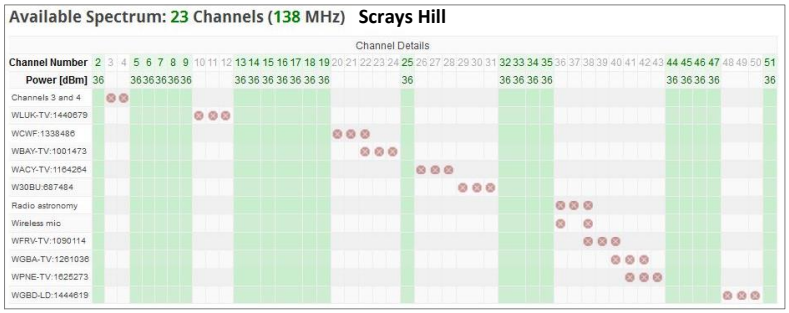
Figure 1.17 Recommended depot configuration for end-to-end system testing

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





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

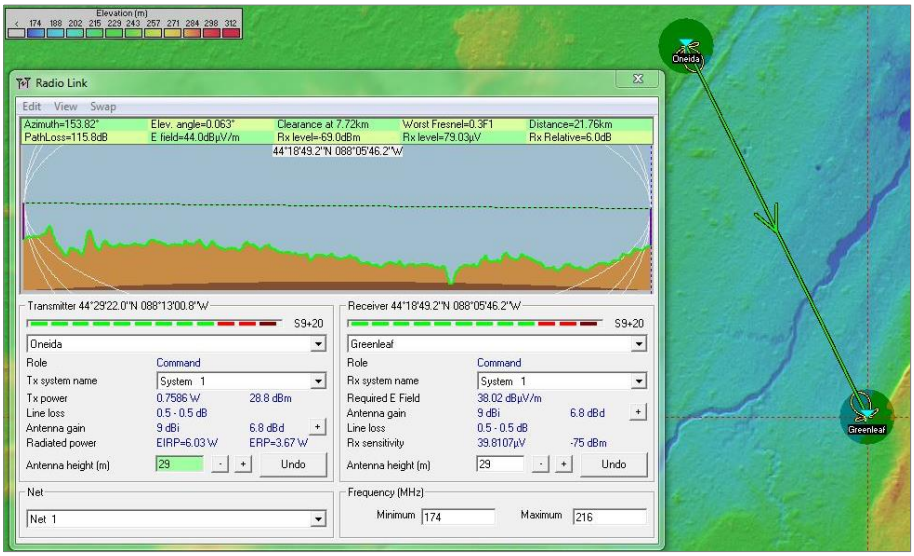


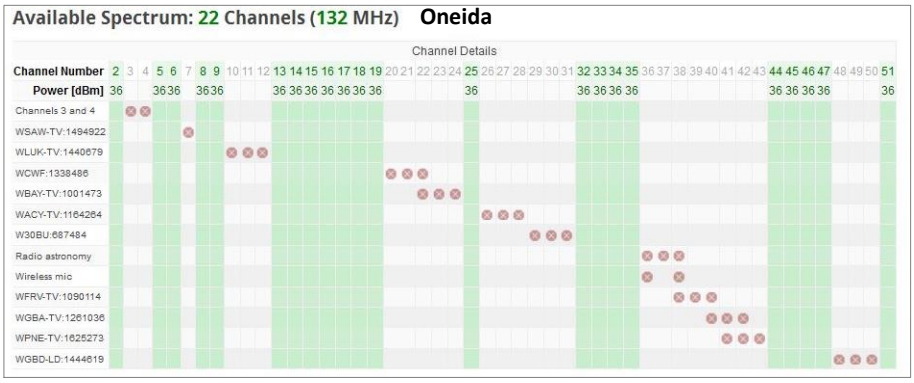
Available White Space Channels (shown in green) at Scrays Site

Figure 1.18 Common Available Channels VHF Hi-Band

~~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~~

6.13.4 Common Available Channels UHF White Space Point-to-Point Link (17Channels: 13-19,25 ,32,35,44-47,51)





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

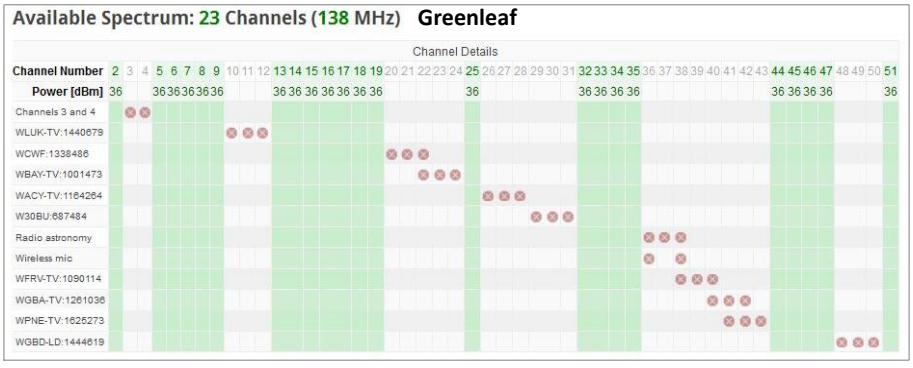


Figure 1.19 UHF White Space Point-to-Point Link
~~Antenna Height: 98”~~
~~Range: 17.3 miles (27.9 km)~~
~~EIRP: 36 dBm, Rx Antenna Gain: 15 dBi~~

6.14 Provisioning RaptorXR Radios:

FCC-certified RaptorXR 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 Spectrum Bridge.com (http://Spectrum Bridge.com/spectrum-mgmt/white-spaces/index.html)for this service.

7 Customer Service

7.1 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.

Figure 2 RMA Form

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.

8 Technical Appendix A

8.1 RaptorXR Recommended Antenna Specification Sheets

- Directional Log Period AUPE862)

8.1.1 UFH-TV Log Period Antenna AUPE862 /Page 1 of 2

KATHREIN
SCALA DIVISION

CL-1469B

UHF-TV LOG-PERIODIC ANTENNA
8 dBd gain
470–862 MHz (Channels 14–69*)

The Kathrein Scala Division CL-1469B is a ruggedly built, linearly polarized log-periodic antenna designed for professional UHF-TV transmit and receive applications.

Like all Kathrein Scala Division antennas, the CL-1469B is made of the finest materials using state of the art electrical and mechanical designs resulting in superior performance and long service life. The rugged fiberglass radome protects the antenna from icing and assures stable pattern and gain performance under adverse environmental conditions.

The CL-1469B may be used stand alone or in arrays for higher gain, increased side-lobe suppression, or custom azimuth patterns.

*The CL-1469B covers all 6, 7, and 8 MHz UHF-TV channels worldwide (bands IV/V).

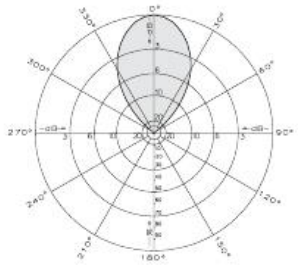
(Shown horizontally polarized)

Specifications:

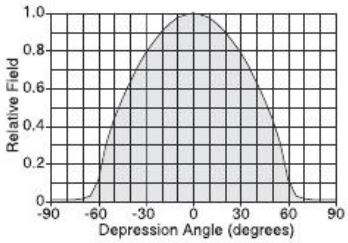
Frequency range	470–862 MHz (broadband)*
Gain	8 dBd
Power gain	6.31
Impedance	50 or 75 ohms
VSWR	< 1.5:1
Polarization	Horizontal or vertical
Front-to-back ratio	>35 dB
Maximum input power	100 watts, type "N" 75 ohm connector 250 watts, type "N" 50 ohm connector
Azimuth pattern	52 degrees (half-power)
Elevation pattern	72 degrees (half-power)
Connector	N female (50 or 75 ohms)
Weight	22 lb (10 kg)
Dimensions	29 x 17 x 12 inches (737 x 432 x 305 mm)
Equivalent flat plate area	2.78 ft² (.258 m²)
Wind survival rating*	100 mph (160 kph)
Shipping dimensions	31 x 20 x 14.5 inches (787 x 508 x 368 mm)
Shipping weight	28.0 lb (12.7 kg)
Mounting	Mounting kits available for masts of 2.375 to 4.5 inch (60 to 114 mm) OD.

See reverse for order information.

* Mechanical design is based on environmental conditions as stipulated in EIA-222-F (June 1996) and/or ETS 300 019-1-4 which include the static mechanical load imposed on an antenna by wind at maximum velocity. See the Engineering Section of the catalog for further details.



Azimuth pattern (E-plane)



Elevation pattern (H-plane)

10276-C

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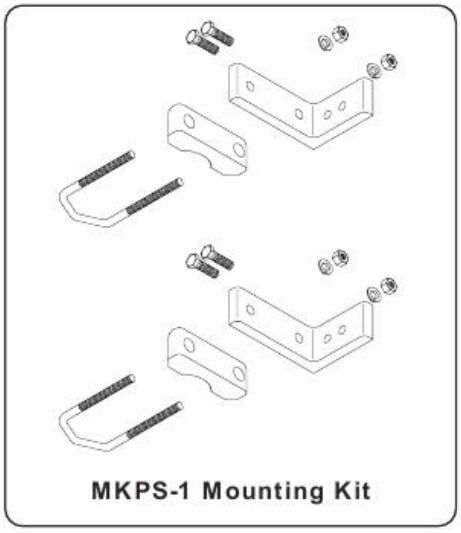
Email: broadcast@kathrein.com Internet: www.kathrein-scala.com

UFH-TV Log Period Antenna AUPE862 /Page 2 of 2

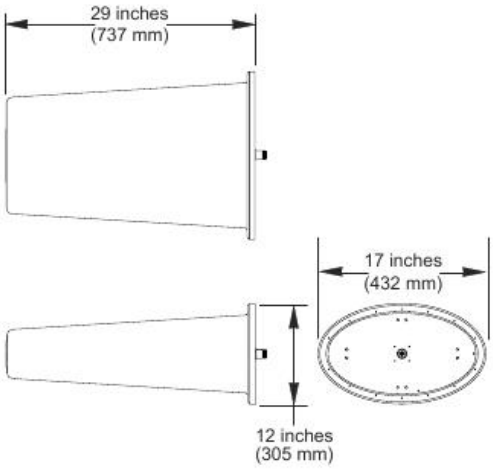
KATHREIN
SCALA DIVISION

CL-1469B

UHF-TV LOG-PERIODIC ANTENNA
8 dBd gain
470–862 MHz (Channels 14–69*)



MKPS-1 Mounting Kit



(Shown horizontally polarized)

Mounting Options:

Model	Description
MKPS-1 (shown)	Mounting Kit for 2.375 inch (60 mm) OD mast.
MKPS-2	Mounting Kit for 2.875 inch (73 mm) OD mast.
MKPS-3	Mounting Kit for 3.5 inch (89 mm) OD mast.
MKPS-4	Mounting Kit for 4 inch (102 mm) OD mast.
MKPS-5	Mounting Kit for 4.5 inch (114 mm) OD mast.

Order Information:

Model	Description
CL-1469B/50	Antenna with 50 Ω N connector
CL-1469B/75	Antenna with 75 Ω N connector
Note:	*Requires mounting kit at additional cost (see listing above).*

All specifications are subject to change without notice

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8.2 Appendix B

8.2.1 RaptorXR UHF Band Plan

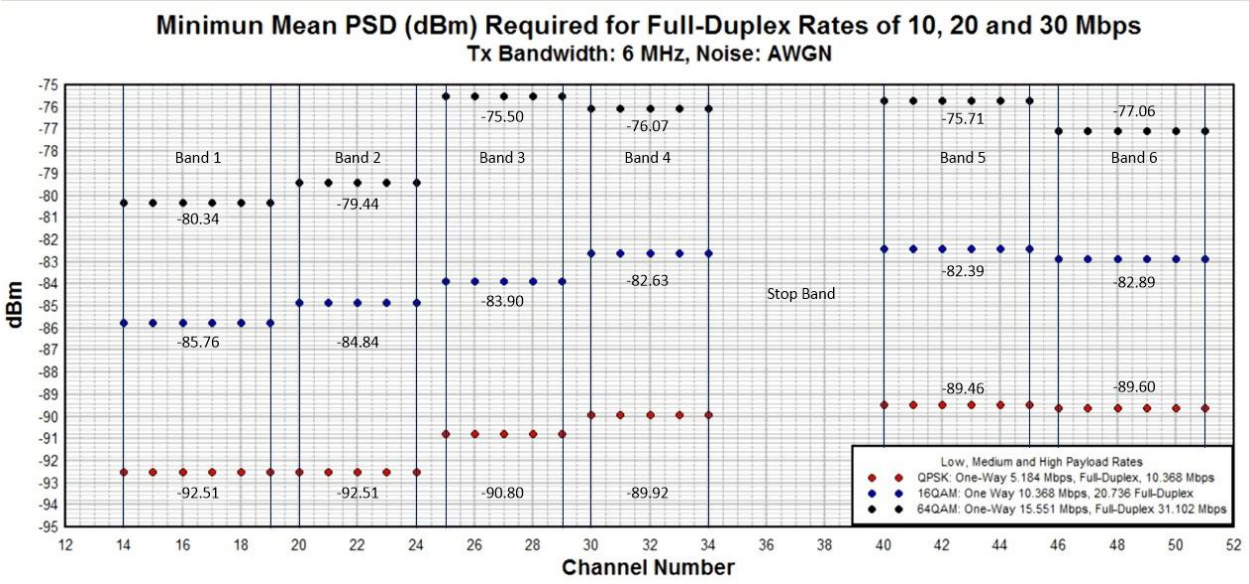
RaptorXR UHF Band Plan

FCC TV White Space UHF Channels

	Lower Adjacent Channel Total BW=6 MHz					Upper Adj. Channel Total BW=6 MHz			
	Lower Adjacent Channel (LAC) (BW=5.9 MHz)			Lower Band Edge (LBE) (BW=100 KHz)	Operating Channel (BW=6 MHz)	Upper Band Edge (UBE) (BW=100 KHz)	Upper Adjacent Channel (UAC) (BW=5.9 MHz)		
Channel Number	LAC Start Freq (MHz)	LAC Center Freq (MHz)	LAC Stop Freq MHz	LBE Center Frequency (MHz)	Center Frequency (MHz)	UBE Center Frequency (MHz)	UAC Start Freq MHz	UAC Center Freq (MHz)	UAC Stop Freq MHz
Band 1									
14	464	466.95	469.9	469.95	473	476.05	476.1	479.05	482
15	470	472.95	475.9	475.95	479	482.05	482.1	485.05	488
16	476	478.95	481.9	481.95	485	488.05	488.1	491.05	494
17	482	484.95	487.9	487.95	491	494.05	494.1	497.05	500
18	488	490.95	493.9	493.95	497	500.05	500.1	503.05	506
19	494	496.95	499.9	499.95	503	506.05	506.1	509.05	512
Band 2									
20	500	502.95	505.9	505.95	509	512.05	512.1	515.05	518
21	506	508.95	511.9	511.95	515	518.05	518.1	521.05	524
22	512	514.95	517.9	517.95	521	524.05	524.1	527.05	530
23	518	520.95	523.9	523.95	527	530.05	530.1	533.05	536
24	524	526.95	529.9	529.95	533	536.05	536.1	539.05	542
Band 3									
25	530	532.95	535.9	535.95	539	542.05	542.1	545.05	548
26	536	538.95	541.9	541.95	545	548.05	548.1	551.05	554
27	542	544.95	547.9	547.95	551	554.05	554.1	557.05	560
28	548	550.95	553.9	553.95	557	560.05	560.1	563.05	566
29	554	556.95	559.9	559.95	563	566.05	566.1	569.05	572
Band 4									
30	560	562.95	565.9	565.95	569	572.05	572.1	575.05	578
31	566	568.95	571.9	571.95	575	578.05	578.1	581.05	584
32	572	574.95	577.9	577.95	581	584.05	584.1	587.05	590
33	578	580.95	583.9	583.95	587	590.05	590.1	593.05	596

34	584	586.95	589.9	589.95	593	596.05	596.1	599.05	602
Band Stop (Channels 35-39)									
35	590	592.95	595.9	595.95	599	602.05	602.1	605.05	608
36	596	598.95	601.9	601.95	605	608.05	608.1	611.05	614
37	602	604.95	607.9	607.95	611	614.05	614.1	617.05	620
38	608	610.95	613.9	613.95	617	620.05	620.1	623.05	626
39	614	616.95	619.9	619.95	623	626.05	626.1	629.05	632
Band 5									
40	620	622.95	625.9	625.95	629	632.05	632.1	635.05	638
41	626	628.95	631.9	631.95	635	638.05	638.1	641.05	644
42	632	634.95	637.9	637.95	641	644.05	644.1	647.05	650
43	638	640.95	643.9	643.95	647	650.05	650.1	653.05	656
44	644	646.95	649.9	649.95	653	656.05	656.1	659.05	662
45	650	652.95	655.9	655.95	659	662.05	662.1	665.05	668
Band 6									
46	656	658.95	661.9	661.95	665	668.05	668.1	671.05	674
47	662	664.95	667.9	667.95	671	674.05	674.1	677.05	680
48	668	670.95	673.9	673.95	677	680.05	680.1	683.05	686
49	674	676.95	679.9	679.95	683	686.05	686.1	689.05	692
50	680	682.95	685.9	685.95	689	692.05	692.1	695.05	698
51	686	688.95	691.9	691.95	695	698.05	698.1	701.05	704

8.2.1.1 Minimum Signal Requirements



8.2.1.2 Technical Overview/Theory of Operation

RAPTORXR – Broadband TVWS Backhaul SDR Radio System

TECHNICAL OVERVIEW

The RaptorXR Communication Mission

The RaptorXR VHF/UHF Broadband Digital Wireless System

The mission of the RaptorXR is to provide our customers with the ability to reliably deliver in outdoor and indoor environments needed backhaul and edge wide-area coverage and broadband capacity unattainable using licensed or unlicensed microwave based systems.

This mission is accomplished via the RaptorXR, a software configurable full-duplex digital radio system, utilizing locally available VHF/UHF TV channels called TV White Space.

With the RaptorXR nearly any conceivable mesh network can be implemented - ranging from basic long-range point-to-point to highly survivable back-haul networks covering very wide service areas.

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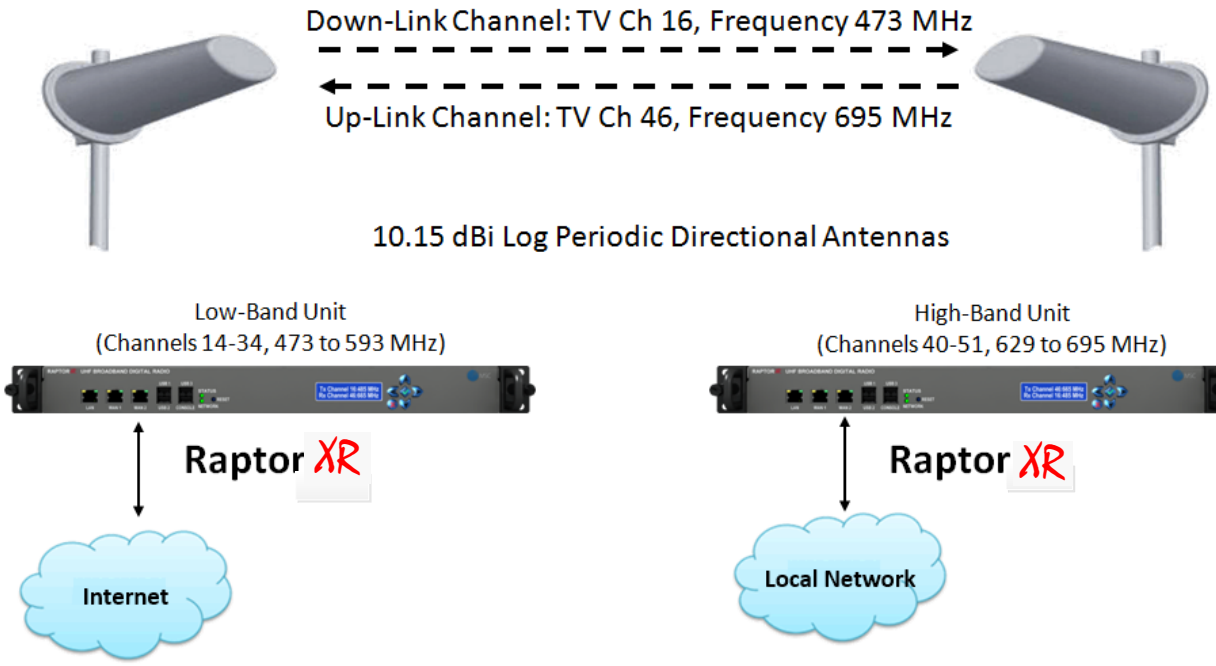
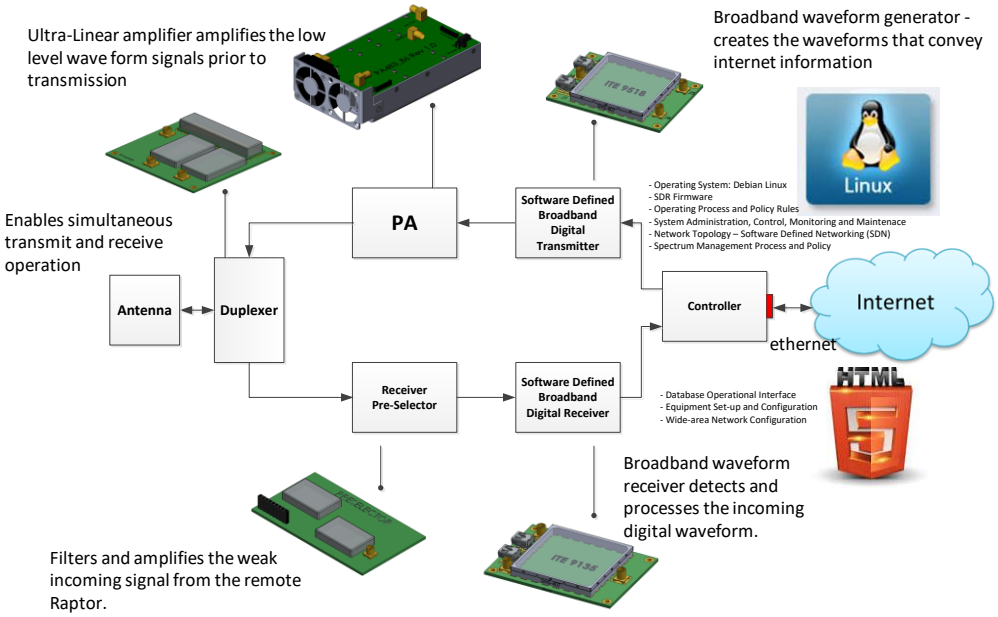
Basic Point-to-point VHF or UHF link - two channels required – one low band down-link channel and one uplink high-band channel.



RAPTOR TECHNOLOGY OVERVIEW



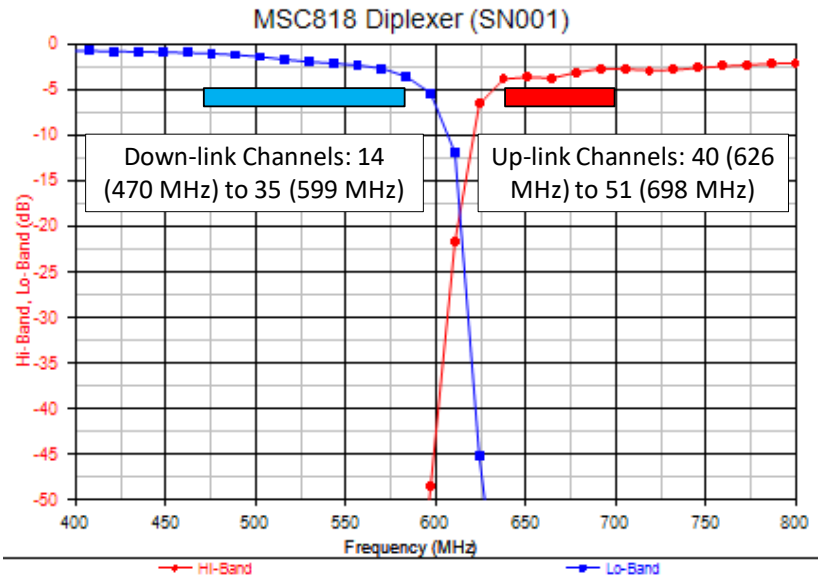
All Raptors – Base Stations and Subscriber Stations follow the same architecture. Software radio components driven by an open systems OS followed by wide band amplifiers.

This architecture enables reusable software and common parts leading to a consistent manufacturing process.

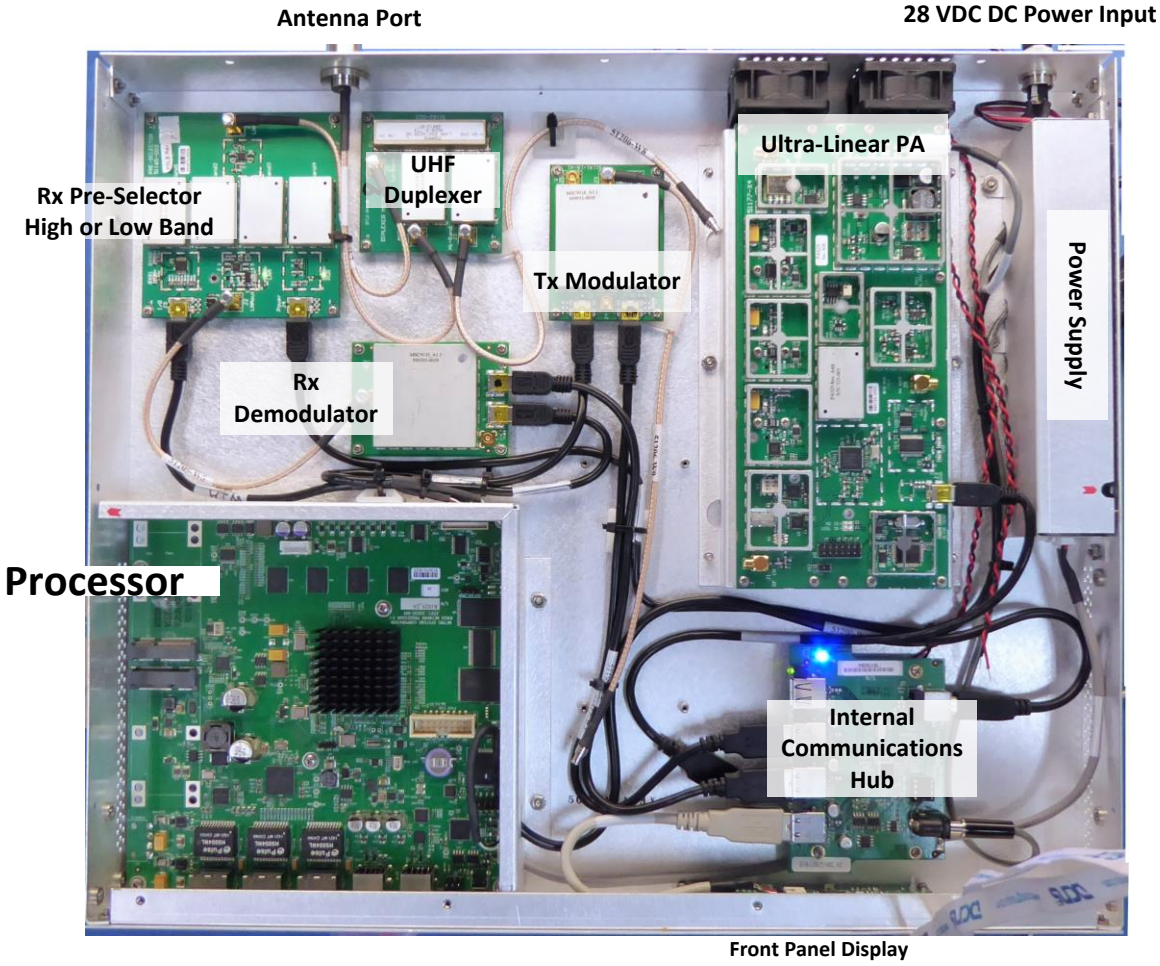
RaptorXR Point-to-Point Bandplan and Duplexer Response

6: UHF Duplexer Table		
Frequency Range	TV Channel Number	Center Frequency (MHz)
UHF Low Band 470-599 MHz Channels 14-35	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
Channel 36-39 Band Split	39	623
UHF High Band 629-698 MHz Channels 40-51	40	629
	41	635
	42	641
	43	647
	44	653
	45	659
	46	665
	47	671
	48	677
	49	683
	50	689
	51	695

RaptorXR Diplexer Performance (400 – 800 MHz)



RaptorXR Internal Sub-Systems



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