DELIVERING WIDE-AREA BROADBAND SERVICES

IN WILDERNESS AND RURAL TERRAIN

USING VHF/UHF WHITE SPACE SPECTRUM

WHITE SPACE: AN ALTERNATIVE TO MICROWAVE AND SATELLITE BACKHAUL

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RaptorX Unlicensed VHF/UHF Broadband
Carrier Class Wireless Radio

Application Note: E915 FCC ID #: 2ABCU-50739

OVERVIEW

The challenge of delivering wide-area terrestrial broadband services in forested areas like the Marcellus Shale region in the Appalachian basin is difficult and expensive using microwave and satellite-based equipment. Topographically, the terrain is some of the most rugged and harshest of global plays. The geography ranges from gently rolling hills to wetlands to steep vertical rock barriers, making the use of line-of-sight and microwave links a challenge. Seasonal variation of natural ground clutter and obstructions affects signal reliability. Currently, nearly all field communications are supported through Satcom, licensed/unlicensed microwave, and where available, 4G/LTE broadband systems. This approach, while satisfying basic requirements for voice and data, constrains operational efficiencies by limiting reliable implementation of additional value-added requirements such as video, real-time streaming of well data and wide-area environmental monitoring systems. This article focuses on presenting the corporate communications engineer and IT professional with the benefits and advantages of using unlicensed VHF/UHF spectrum called White Space. This paper will conclude with basic deployment and use scenarios applicable to the ever-increasing, tetherless connectivity requirements of the entire oil and gas production stream.

Unlicensed White Space Spectrum- What is the value?

On September 23, 2010, with the change from analog to digital TV, the U.S. FCC opened for unlicensed secondary use, 270 MHz of prime VHF (54-60, 76-88 and 174-216 MHz) and UHF (470-602, 620-698 MHz) spectrum.

The physical properties of this broad spectrum band offer the communications engineer the reach and coverage capabilities unattainable with microwave-based systems. The use of TV band VHF/UHF spectrum enables the realistic deployment of a broad range of security, M2M and analysis systems previously uneconomical.

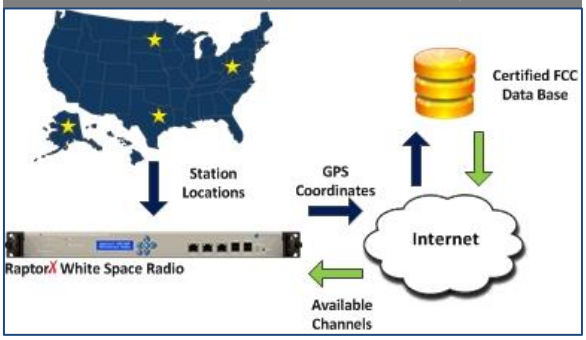
Table 1 shows the TV White Space bands in the U.S., along with available spectrum, and conservative estimate of digital payload bandwidth as a function of current practical technology. The FCC allocates available White Space channels geographically and sets equipment conformance rules to avoid interference with existing over-the-air TV reception. Available use channels are made available via FCC-certified database suppliers.

The links below to the iConectiv.com and Google Spectrum FCC-certified databases provide White Space channels available on the basis of latitude, longitude or place name. As expected, the number of available White Space channels increases as distance from urban areas increases.
http://www.iconectiv.com/spectrum-mgmt/white-spaces/index.html

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

Figure 1 illustrates the basic channel acquisition process for a fixed White Space broadband radio station. Each White Space radio station acts as a spectrum acquisition server querying an FCC-approved database for available channels based on latitude and longitude.

FIGURE 1. WHITE SPACE EQUIPMENT CHANNEL ACQUISITION



White Space Propagation Benefits

The core advantage of using White Space spectrum is superior propagation as compared to operating in the 900 MHz, 2.4 and 5.8 GHz bands. Additional benefits include minimizing equipment count required to extend operation into areas and supporting applications requiring costly satellite or public carrier transactionally-priced services.

Propagation advantages range from longer range, better coverage in forested and wetland regions matched with superior near and beyond horizon performance.

White Space Band	North American TV Channels	Frequency Range (MHz)	Available Spectrum (MHz)	Estimated Payload Bandwidth * (Mbps)
VHF- High Band	2,5,6	54-60, 76-88	18	72
VHF - Low Band	7-13	174-216	42	168
UHF	14-35, 39-51	470-602, 620-698	210	840

Table 1. U.S. Unlicensed TV band spectrum estimated payload bandwidth based on 4 bits per hertz payload coding rate

The White Space Propagation Advantage Example

An end-to-end (point-to-point, or multi-point) wireless White Space communications system, operating in the VHF/UHF range versus microwave (1 GHz and higher) will have a marked advantage in operating range and ability to penetrate natural and man-made ground clutter. Current licensed, cellular LTE systems operating in the 470 and 700 MHz band in the U.S. and internationally, take advantage of improved UHF propagation physics in urban and rural areas to push through and establish viable communications in high rise, dense urban complexes, and extended range suburban/rural areas.

VHF/UHF Broadband operation provides the communication planner with three intrinsic system propagation benefits over microwave spectrum (900 MHz and above):

1. ***A 4-5X range extension over microwave***
2. ***Superior clutter and structure penetration***
3. ***Near and beyond horizon capability, especially in the high VHF and low UHF bands.***

All of which make the use of White space spectrum a serious alternative propagation option in the environs of the Marcellus Shale Play and rugged terrain regions.

Network Example

To appreciate the inherent operational benefits of VHF/UHF spectrum in a varied topology we have constructed a broadband peer-to-peer ad hoc mesh network model using the RaptorX VHF/UHF White Space Radio System interconnecting five (5) actual production pads in mid-central Clinton County, PA. The basic model shown in **Figure 2** contains 10 viable pad-to-pad broadband links; each link providing a payload bandwidth of 2-3 DS1s to each site. **Tables 2 and 3** present the results of each link evaluated (using a Longley-Rice Propagation Model in an 80% forested region) for sustained reliability on the basis of Rx signal level, fade margin and spectrum availability. For example, in **Figure 3**, Link 1-2 between Pads 1 and 2, runs 6.5 miles uphill grazing about 1 mile of tree line, with site antenna heights of 60 feet (20 m) and an antenna gain of 6 dBi at each site, each White Space band provides a usable broadband link with a 10 dB fade margin. **Table 2** below shows, in comparison, that unlicensed operation in the 2.4 to 8 GHz spectrum presents a margin deficit which would require taller antennas and/or higher gain antennas, or a diversity system to overcome inherent path loss to achieve equivalent operation, thus increasing capital and labor deployment costs.

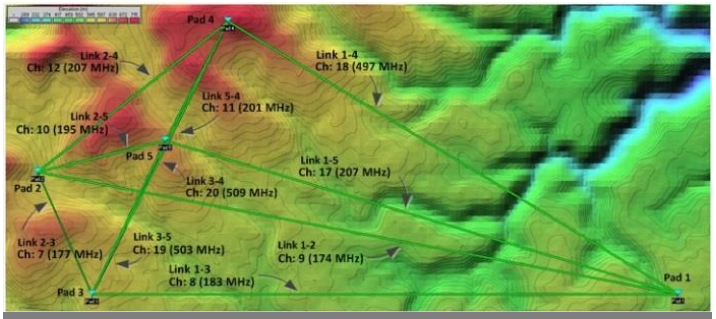


Figure 2. Five production pads in Clinton PA interconnected in a broadband ad hoc mesh network operating over non and near line-of-sight paths using locally available White Space VHF and UHF spectrum.

Figure 3. 10 km grazing path between Pads 1 and 2 @ 174-216 MHz

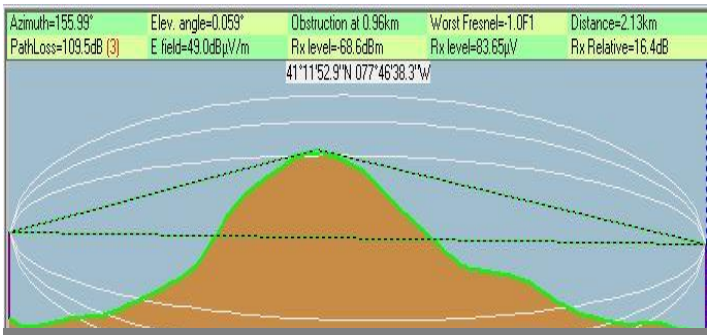


Figure 4. Non-Light-of-Sight path between Pads 2 and 3 @ 174-216 MHz

Figure 4 illustrates the ability of VHF and low end UHF transmissions to propagate over or reflectively around path obstructions. The path between Pads 2 and 3 is obscured by gently rolling hills spanning approximately .5 Km or .3 miles obscuring an otherwise line-of-sight path. Path analysis shows that the combined VHF ground-wave and air-wave provide a potential 16.4 dB fade margin, sufficient for sustainable high payload bandwidth operation.

Tables 2 and 3 list available unused TV channels at each pad and RF propagation performance between adjacent pads contrasting VHF/UHF and microwave performance. In all cases VHF/UHF performance provides additional margin and thus reliability.

					White Space Band Signal Margin (dB)			Microwave Spectrum Margin (dB)		
Link #	Node-to-Node	Range (km)	Range (miles)	Propagation Mode	LO-Band	Hi-Band	UHF	2.4 GHz	5-6 GHz	7-8 GHz
1	1-2	10.34	6.45	Grazing	22.9	15.4	8.0	9.6	20.7	32.9
2	1-3	9.30	5.80	LOS	25.6	19.3	13.8	6.3	2.4	4.5
3	1-4	8.34	5.20	LOS	40.0	27.1	18.1	6.4	1.7	3.5
4	1-5	8.49	5.29	LOS	37.2	24.7	15.8	4.1	4.0	5.9
5	2-3	2.13	1.33	NLOS	37.6	17.2	9.4	40.5	60.1	67.6
6	2-4	3.86	2.41	1 km Graze	32.9	20.7	2.5	24.4	42.1	48.9
7	2-5	2.08	1.30	Grazing	39.5	27.8	7.9	22.4	37.9	45.1
8	3-5	2.70	1.68	LOS	41.6	36.8	32.5	12.3	8.9	6.2
9	3-4	4.84	3.02	LOS	38.4	34.1	28.4	16.4	6.7	1.2
10	4-5	2.14	1.33	LOS	44.6	39.3	30.5	17.0	10.0	8.4

Table 2. Clinton PA White Space network showing usable inter-pad links, propagation mode and point-to-point signal design margin.
RED TEXT INDICATES SIGNAL MARGIN DEFICIT.

			Available White Space Channels				
Site	Lat	Long	LO-Band	Hi-Band	UHF	Total Available Spectrum (MHz)	Potential Payload Bandwidth (Mbps)
Pad 1	41.19814	-77.66617	3	5	15	138	552
Pad 2	41.21552	-77.78767	3	6	17	156	624
Pad 3	41.19802	-77.77731	3	7	17	162	648
Pad 4	41.23701	-77.75148	3	5	16	144	576
Pad 5	41.22001	-77.76347	3	6	17	156	624

Table 3. Clinton PA Pad coordinates along with available White Space channels and potential internode network payload rate.

Potential payload capacity (in megabits per second) should be used as a guide to estimate potential transport capability of each link, based on total available White space spectrum at each pad.

Deploying the Network and Building a Bandplan

Currently, each of these pads is an actual production site. For now, let us assume we are commencing a multi-well development process. As well site development progresses, a suite of voice, data and video services is required. **Table 4** below presents the Payload Bandwidth estimation required to sustain as development progresses. Our goal here is to show that when White Space middle mile wireless systems are integrated with third-party communications services, i.e. satellite, common carrier (4G/LTE), point-to-point microwave and fiber, the RaptorX White Space network solution advantage provides an economical bridge integrating edge devices into a unified infrastructure solution at higher efficiencies and lower cost.

Completing the physical design of the network we need to determine which TV channels are available at each pad. This can be done by accessing one of several FCC-certified databases.

The iConectiv or Google databases previously cited are used to determine available channels at each pad. Entering coordinates from **Table 3**; the iConectiv database will return available channels, normally at the zip code center of the target county. **http://www.iconectiv.com/spectrum-mgmt/white-spaces/index.html#details_tab**

The Google spectrum data base can also be used: **https://www.google.com/get/spectrumdatabase/index.html**

See **Table 5** for available channels at Pad 1. **Figure 1** summarizes the deployment concept of broadband mesh network interconnection in five (5) pad sites over a 222 square mile area. As a rule of thumb, the lower channels were chosen for meeting the near and non-line-of-sight critical paths; higher UHF channels for near or clear line-of-sight and/or tree level paths.

Table 4 — **Estimated Next Generation Well Site Minimum Connectivity for Full Enterprise Reach-Out**

WELL SITE DEVELOPMENT STAGE	COMMUNICATION SERVICE REQUIREMENTS	NEXT GENERATION ESTIMATED MINIMUM BANDWIDTH REQUIRED (Mbps)	USE PERIOD	WHITE SPACE CHANNELS REQUIRED
Site Selection, Well Pad Preparation and Drilling	Drilling pad coverage area may range from 2-10 acres Broadband internet with support for: • Security Video • Voice connectivity • Corporate networking • Contractor networking; wire trucks, man camps, etc. • Independent Cell Coverage	2-8 DS1s	1-12 Months	TWO(2) - THREE(3)
Well Completion	Pad Coverage • Video, Sensor Security • Smart Phone • Secure Unlicensed Wireless for PC and Tablets	1-2 DS1s	4-12 Months	1
Production	• Cell Coverage • Secure PC/Tablet Coverage • Security	1-2 DS1s	Up to 40 years	1
Aqua Renew	• Cell Coverage • Environmental Monitoring	1-DS1	3 Months	1
Well Site Reclamation	• Continuous sensor monitoring	< 1-DS1 1.544 mbps	6 months	1

Place	Beech Creek, PA
Coords	(41.19814, -77.66617)
HAAT	115.0 m, (117.9 m antenna HAAT)

Total Available: 138 MHz - 23 channels							
Low VHF: 18 MHz - 3 channels							
2	✓	3	⊘	4	⊘	5	✓
6	✓						
High VHF: 30 MHz - 5 channels							
7	✓	8	✓	9	✓	10	⊘
11	✓	12	✓	13	⊘		
UHF: 90 MHz - 15 channels							
14	⊘	15	⊘	16	⊘	17	⊘
18	✓	19	✓	20	✓	21	⊘
22	✓	23	⊘	24	⊘	25	⊘
26	⊘	27	⊘	28	⊘	29	⊘
30	⊘	31	⊘	32	⊘	33	⊘
34	✓	35	✓	36	🎤	37	⊘
38	🎤	39	✓	40	✓	41	⊘
42	⊘	43	⊘	44	✓	45	✓
46	⊘	47	✓	48	✓	49	✓
50	✓	51	✓				

Table 5. Available Channels at Pad 1
Green indicates an available channel. Small microphone icons at channels 36 and 38 designate reserved channels for wireless microphone use.

Wide-Area Long Distance Coverage

White Space spectrum also provides for superior reach-out in point-to-multi-point and ad hoc mesh applications. For servicing multiple locations from a central point, e.g. Wi-Fi range extension, SCADA and VoIP and video. Figure 5 clearly shows the advantage of VHF/UHF propagation over WiFi in the play area examples. The wide-area coverage provided by the low and high VHF/UHF channels provides superior coverage over 900 MHz, 2.4 and 5.8 GHz systems allowing reach out to lowlands and terrain depressions, covering greater range and terrain variations.

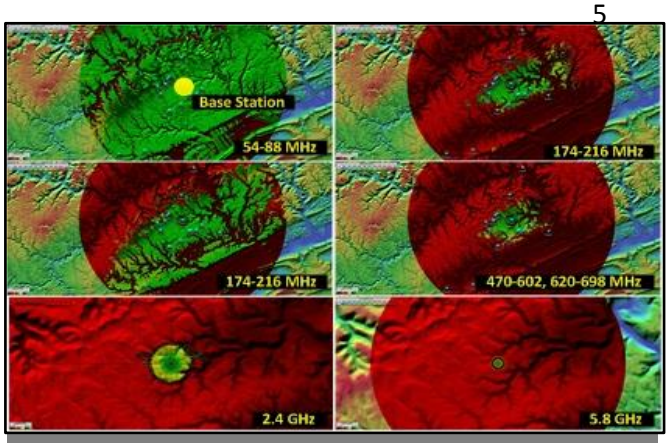


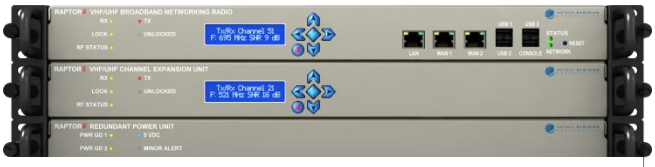
Figure 5. A sequential montage showing the superior coverage of White Space bands over a 12.4 mile (20 km) 80% forested area. Yellow dot is center of production area. Base station antenna height 60 feet. Remote site height 15 feet. Total area coverage 22.4 x 10 miles (36 x 16 km). 2.4 GHz plot show 7 miles (11.3 km) coverage radius.

The Raptor✗ VHF/UHF Wireless Networking Equipment Suite enables the design and deployment backhaul and infrastructure networks to support a wide range of edge services including LTE/4G, WiFi, and M2M, at ranges and situations unattainable with conventional unlicensed and licensed microwave solutions.

Equipment Description

The basic Raptor✗ Broadband Radio Suite consists of:

- **Primary Shelf** – Single Channel maximum power **White Space Broadband** Radio (174 to 698 MHz VHF/UHF) (top shelf)
- **Channel Expansion Shelf** adds an independent VHF/UHF channel to enhance payload data rates and system redundancy (middle shelf)
- **Power Supply Shelf** to provide uninterrupted power to all shelves (bottom shelf).
- **VHF/UHF Antennas** to meet coverage and range needs.



Raptor✗ Unlicensed VHF/UHF Broadband Radio.
FCC ID #: 2ABCU-50739

EXPERIENCE THE BENEFITS OF OPERATING IN WHITE SPACE SPECTRUM WITH RAPTOR✗, THE INDUSTRY'S LEAD CARRIER CLASS WHITE SPACE NETWORK RADIO. CLICK HERE FOR RAPTOR✗ DATA SHEET:
http://www.metricsystems.com/products-2/raptorx-vhfuhf-broadban

SUMMARY
The additional availability of nearly 270 MHz of unlicensed spectrum and equipment will provide every sector of the energy industry with additional spectrum resources to enhance the security and operational effectiveness of each link of the production chain. In addition, low cost, high resolution, wide-area sensor coverage, and wide-area environmental coverage will provide a quantitative basis to address uncertainty in watershed monitoring.

REFERENCES

AGENCIES AND RELATED LINKS

- **U.S. Federal Communications Commission/ www.fcc.gov**
- **FCC CDBS (Consolidated Database System) https://licensing.fcc.gov/prod/cdbs/forms/prod/cdbs_ef.htm**
- **FCC ULS (Universal Licensing System) *uls-gis.fcc.gov***
- **FCC EAS (Equipment Authorization System) ("white" list) *https://apps.fcc.gov* › *FCC E-filing***

Temporary BAS (Broadcast Auxiliary Service) links:

- **https://www.google.com/get/spectrumdatabase/**
- **http://iconectiv.com/spectrum-mgmt/white-spaces**
- **http://spectrumbridge.com/tv-white-space/**
- **https://www.federalregister.gov/articles/2003/03/17/03-4176/broadcast-auxiliary-service-rules**

ITU PUBLICATIONS

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