Microsoft | Airband Initiative

TV WHITE SPACES

WHERE TO BEGIN AND BEST PRACTICES

With the FCC ruling on the definition of high-speed broadband, it is clear to Service Providers that the 900MHz ISM band, the "go to" band for NLOS for the last decade, is now becoming extremely challenging. Beyond the technology available today, this band has only 26MHz of total spectrum that is shared between several wireless services commonly found in the residential market. This means it is not a viable solution heading into the future.

The TV White Space (TVWS) band is very effective in rural markets. In fact, the more rural the market is, the better this band performs. This is because of the nature of the band and the fact that it is shared with analog TV station services.

The TVWS band, like all bands, has its specific characteristics and introduces two significant new factors that Service Providers did not have to worry about before:

1. Interference from transmitters that are significantly more powerful than those the broadband industry is accustomed to working around.
2. A database management system to ensure all the band users behave properly.

The TV Broadcast industry runs extremely powerful transmitters at heights that can impact broadband at very long distances. As a Service Provider, you are used to contending with peers that use similar transmit power to you, so interference is present; but in the TVWS band, noise from the TV industry can actually be destructive to all available channels. This means that testing in your service area is key to understanding where and how the band can be used for your services. The good news about analog TV stations is that they are not new and the legacy broadcasters are slowly leaving the market. This means that the more rural your market is, the better the band usability will be.

The database that provides channel availability, and to which all systems need to connect, is a new element in the Service Provider business model. The TVWS band is the first band to be impacted by this database access situation, but will not be the last one. Shared spectrum is a new reality that we all must understand and learn to work with. The new CBRS band will also work with database access. There is a finite amount of spectrum accessible to all wireless users and sharing will become the standard in the future. The positive side to the database system is that, over time, it will provide a very powerful tool for predicting noise level in service areas.

Redline has been active in TVWS for years. With more radios deployed in the U.S. than any other country, we are well aware of the benefits and challenges of the band. From our engineering group to field experts, we have developed best practices and methodologies to address the usage and usability of this band in a way that will minimize our customers' investment and ensure commercially viable deployments.

Redline had its very first field trial with this band five years ago. Since then we have done countless field trials and pilots, and have been involved in some of the largest deployments in the U.S. The Redline team responsible for our participation in the Microsoft Airband Initiative program, and leading Redline's involvement in the TVWS band, have developed some guidelines to help our customers:

1. Available channels vs. usable channels

a. The database tells you what channels you can use, but not if the RF environment is usable.
b. Always test for RF noise i.e. run proper spectrum sweep for all the areas you are considering, and do it at "production" heights.

2. TV station interference

a. TV broadcasts at megawatts of transmission power, at hundreds of feet above ground level, and carries a very, very long way. Assume that you will have to deal with it to some extent.

3. Noise floor in the band

a. The band is also impacted by industrial area noise; high-power electric motors, SCADA operations, LMR systems. TV broadcasters are the most significant noise contributor, but not the only one.

4. Higher is not always better

a. We are accustomed to look for height in the broadband wireless industry. In TVWS, height is not always the best solution; sometimes it is easier to deal with an obstruction than interference. While using the cover of foliage will negatively impact the link budget, it may save you from more destructive interference from high-power noise sources.
b. In mountainous areas, you must leave the top of the mountains to the broadcast industry and use the slopes above villages to serve those customers.

5. Leverage MIMO in more ways that just dual polarity

a. TV broadcasters and most other noise generators rarely use MIMO and thus may only affect one polarity. In this case, use two single polarity antennas on the same pole so you can benefit from MIMO gain due to diversity and uncorrelated signals.

6. Tools to use before purchasing any equipment

a. The Cavell, Mertz & Associates Google Earth FCC Info plug-in. This tool will show you the TV broadcasters in your service area, **http://www.fccinfo.com/fccinfo_google_earth.php**
b. TV Fool website, **https://www.tvfool.com/**. This website can be used to understand where you can get off-air TV. If your service area indicates poor off-air TV coverage, then it's a good indication that TVWS will work well in that area.
c. Nominet Channel Search engine: **https://usa.wavedb.com/**. Nominet is the database administrator Redline has selected for its radio. Their site provides very valuable information.

7. Using the Nominet Channel Search Results:

a. Go to "How to check Channel Availability for TVWS Devices", click on "Channel Search" and select "TV White Space".
b. Enter coordinates of tower site with Ellipse antenna height 30m (maximum is 98ft AGL).
c. Record the list of fixed channels that are available in your service area by taking a screen capture or copying into an Excel spreadsheet.
   i. Example screen capture from Nominet website, Redline starts at TV channel 14.

Available Channels with Power Limits

Channel	TVWS Equipment		
	Fixed	Mode1	Mode2
2	40dBm	x	x
3	36dBm	x	x
4	40dBm	x	x
5	40dBm	x	x
6	36dBm	x	x
10	40dBm	x	x
11	40dBm	x	x
12	40dBm	x	x
14	40dBm	20dBm	20dBm
15	32dBm	20dBm	20dBm
16	40dBm	20dBm	20dBm
17	40dBm	20dBm	20dBm
18	40dBm	20dBm	20dBm
33	24dBm	20dBm	20dBm
34	40dBm	20dBm	20dBm
35	40dBm	20dBm	20dBm
36	36dBm	20dBm	20dBm
40	40dBm	20dBm	20dBm
19	x	16dBm	16dBm
21	x	16dBm	16dBm
25	x	16dBm	16dBm
26	x	16dBm	16dBm

d. 'X' beside a channel number means that channel is not available for that service area.

The power levels are the maximum allowed power for the channel; however, based on FCC restrictions the maximum EIRP RDL-3000 will meet is 21dBm total RF power (18dBm per RF chain) plus 11dBi antenna gain minus 0.5dB cable loss is 31.5dBm EIRP based on current antennas available in the market today.

Using the above print-out you can also determine the number of contiguous channels available in your service area. In the above example, channel 14 through to channel 17 represents a 24MHz channel size.

If you happen to be using temporary keys on the RDL-3000's you will need to convert between TV channels to center frequencies, see table below. Note that RDL-3000 R4v1 does not support TV channels 36, 37 and 38 and RDL-3000 R4v2 does not support channels 38 through to channel 51 due to this part of the spectrum being re-allocated to LTE band 71.

Channel	Center Frequency (MHz)	RDL3000 R4v1 470-698 MHz	RDL3000 R4v2 470-614 MHz
14	470	Y	Y
15	476	Y	Y
16	482	Y	Y
17	488	Y	Y
18	494	Y	Y
19	500	Y	Y
20	506	Y	Y
21	515	Y	Y
22	518	Y	Y
23	524	Y	Y
24	530	Y	Y
25	536	Y	Y
26	542	Y	Y
27	548	Y	Y
28	554	Y	Y
29	560	Y	Y
30	566	Y	Y
31	572	Y	Y
32	578	Y	Y
33	584	Y	Y
34	590	Y	Y
35	596	Y	Y
36	602	N	Y
37	608	N	Y
38	614	N	N
39	620	Y	N
40	626	Y	N
41	632	Y	N
42	638	Y	N
43	644	Y	N
44	650	Y	N
45	656	Y	N
46	662	Y	N
47	668	Y	N
48	674	Y	N
49	680	Y	N
50	686	Y	N
51	692	Y	N

8. RF survey

a. An RF survey is a critical step before determining if TVWS will work in your service area. Spectrum sweeps can be done with standard spectrum analyzers. Ideally you will test at base station antenna height. If this is not possible, then elevate as high as possible. But remember, the noise you measure will only get worse as you elevate the antenna.

b. If you do not have a spectrum analyzer, our TVWS radio has a built-in spectrum sweep feature, just use the default setting for the sweep. Once completed, highlight the data and copy to an Excel spreadsheet. The radio will keep the last sweep unless it is power cycled, or a new sweep is run.

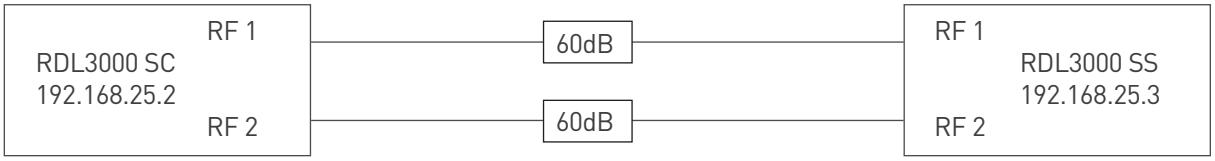
i. Steps to the site survey.

ii. Model the area to be tested with a RF propagation software. This will help you understand the area where LOS and NLOS conditions can be tested. (*Redline can assist with startup assumptions in Radio Mobile. See end of document).

iii. Visit the Redline training page at **http://rdlcom.com/products/training-and-certification/** and watch the video on TVWS and radio configuration.

iv. Procure two radios and proper feature key and antennas.

v. Configure the radio and test indoor with 60dB of attenuation.



vi. Start testing outdoor with one radio at 100ft. (tower side) and a second one at average house installation height.

1. Start testing in close proximity and LOS to validate configuration and installation.
2. Progressively increase distance and LOS condition. The objective is to develop an understanding of the system limits in your specific environment.
3. Keep documenting performance (noise, Rx signal) for both radio chains. This will help you understand the noise level and pattern and refine your modeling assumption.

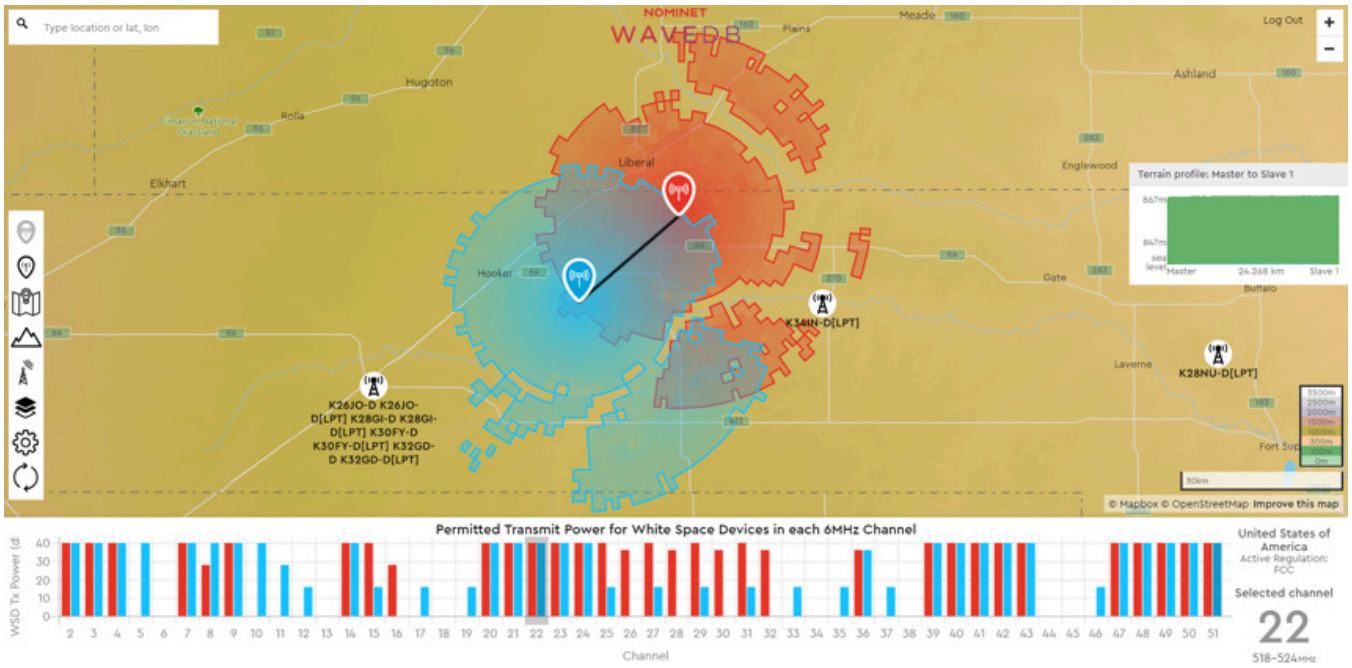
NOMINET WaveDB PLATFORM

Nominet's Global TVWS Platform is a production-grade cloud-based system designed which utilises worldwide datasets and can be localised for different regulatory rulesets. Nominet have also developed a set of sophisticated mapping, planning, and wide-scale spectrum investigation tools.

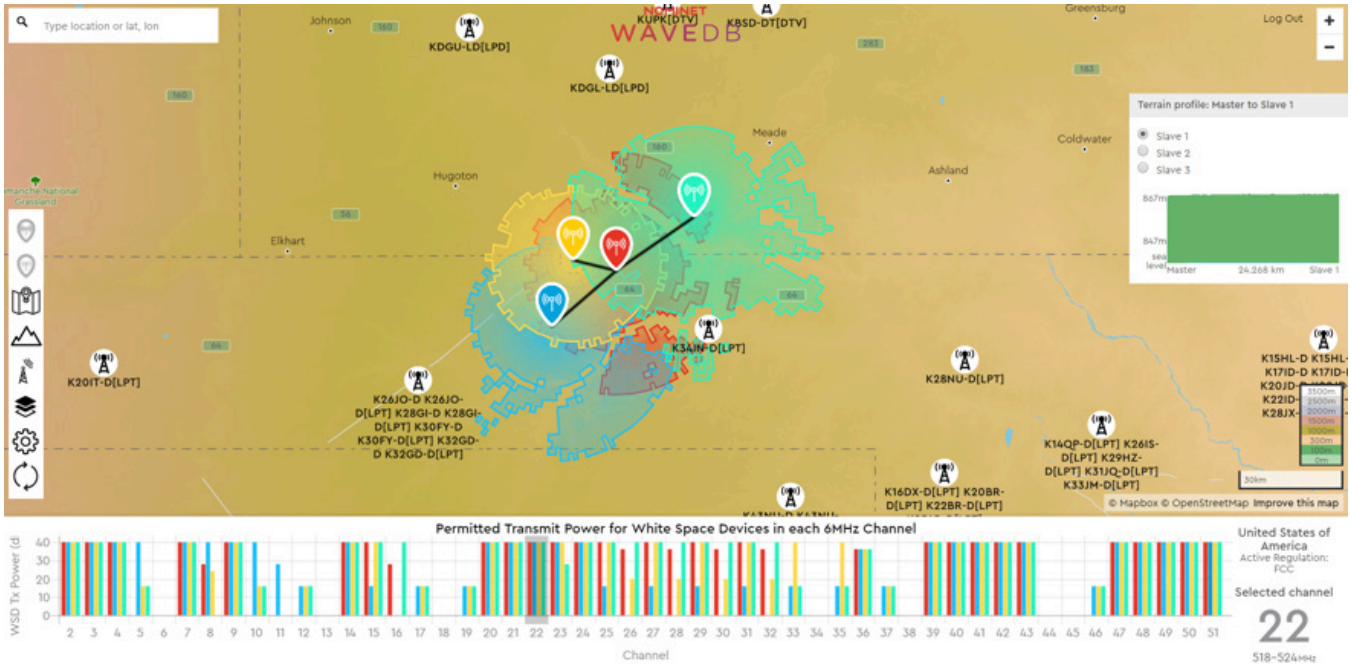
Nominet's WaveDB Platform has been designed to support the planning of TVWS deployments and investigate spectrum availability. Nominet provides several platforms; **https://usa.wavedb.com/** offers basic channel availability searches, more sophisticated mapping and design can be carried out **http://welcome.wavedb.com/** . Below details Nominet's basic WaveDB-Explore solution that is accessed via welcome.wavedb, additional features are available (WaveDB-Explore Pro and WaveDB-Explore Max).

WaveDB-Explore

In each map the red marker indicates the location of the TVWS base station and the light blue one marks the location of the CPE. The histogram graph under the map indicates the maximum EIRP power allowed to the TVWS stations on each channel. The red bars indicate the power limits for the base station, and the light blue ones are for the CPE.



The settings bar allows for changes in height AGL (ft) for both the base station and the CPE devices.
The box on the right side shows the link distance and the terrain profile of that link.
Additional CPEs can also be mapped, as indicted below by the yellow and green markers.



Please note: WaveDB-Explore, WaveDB-Explore Pro and WaveDB-Explore Max incur a subscription fee.
Contact: ***hannah.webb@nominet.com***

Synchronizing

To control intra-interference it is strongly recommended to GPS synchronize all sectors. Before you enable this feature ensure the antenna system you are using has an integrated or external GPS antenna. For the GPS synchronization to work correctly the Ellipse or base station GPS system needs to see at least 5+ satellites. For this to be possible the top of the sector antenna with an integrated GPS antenna or external GPS antenna has clear view of the sky. Confirm this is possible by doing a GPS survey using a handheld GPS.

Ensure all the following Ellipses or base station's Advance Wireless parameters are set the same:

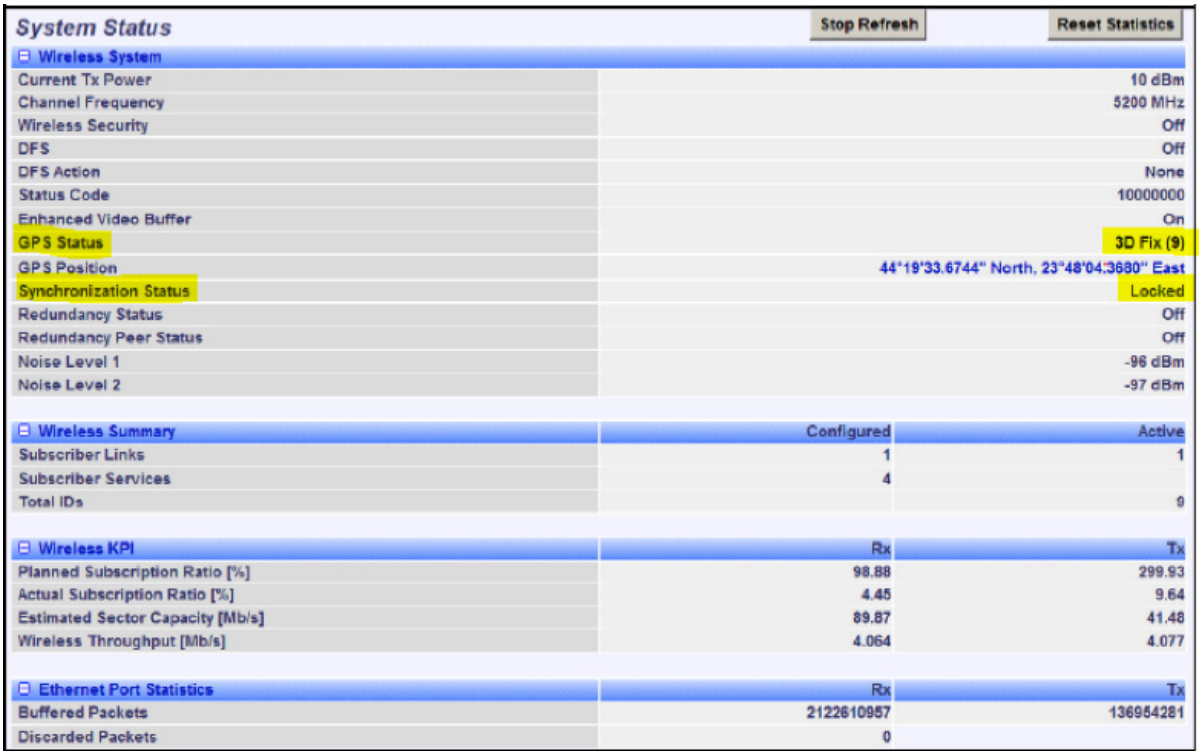
- Max Distance
- Channel Size
- Cyclic Prefix
- Management MCS
- Fixed Frame
- DL Ratio

If any of the above parameters are changed run "apply and save" then reboot for parameter changes to take effect.

Under advance wireless parameters GPS Antenna Type is set to "passive" for integrated GPS antenna typically and "active" external GPS antenna. Passive means GPS antenna does not requires a bias voltage. External means GPS antenna has a built-in amplifier and requires a bias voltage to operate. The bias voltage is supplied on the center conductor of the GPS antenna connector. If this parameter is changed "apply and save" then reboot for parameter change to take effect.

All synchronized Ellipse or base stations must achieve sync "Locked" status, 3D Fix. This can be checked under Systems Status under Wireless System:

To determine the number of satellites the GPS system is seeing is by the number in parenthesis's beside "3D Fix".



System Status | Stop Refresh | Reset Statistics

Wireless System	
Current Tx Power	10 dBm
Channel Frequency	5200 MHz
Wireless Security	Off
DFS	Off
DFS Action	None
Status Code	10000000
Enhanced Video Buffer	On
GPS Status	3D Fix (9)
GPS Position	44°19'33.6744" North, 23°48'04.3680" East
Synchronization Status	Locked
Redundancy Status	Off
Redundancy Peer Status	Off
Noise Level 1	-96 dBm
Noise Level 2	-97 dBm

Wireless Summary	Configured	Active
Subscriber Links	1	1
Subscriber Services	4	
Total IDs		9

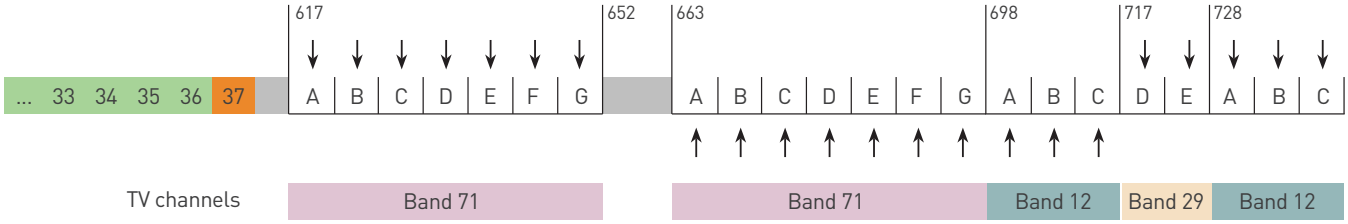
Wireless KPI	Rx	Tx
Planned Subscription Ratio [%]	98.88	299.93
Actual Subscription Ratio [%]	4.45	9.64
Estimated Sector Capacity [Mb/s]	89.87	41.48
Wireless Throughput [Mb/s]	4.064	4.077

Ethernet Port Statistics	Rx	Tx
Buffered Packets	2122610957	136954281
Discarded Packets	0	

If the Ellispe or base station loses 3D Fix it will go in holdover for 10min. During that time the Ellipse or base radio will stop transmitting.

Supported TVWS Channels

The current TVWS RDL3000 radios R4v1 operates from 470 to 698MHz; however, an installed notch filter blocks channels 36, 37, and 38. The new TVWS RDL3000 radios R4v2 will operate from 470 to 614MHz. The smaller range is due to T-Mobile purchase of upper part of the 600MHz spectrum called Band 71. Below is a diagram of this band:



For more information on the FCC ruling go to **http://www.spectrumgateway.com/600-mhz-spectrum**.

It is important to keep this future band limitation in mind when planning your TVWS deployments. The table below shows the differences in supported TV channels between the two TVWS RDL-3000 models.

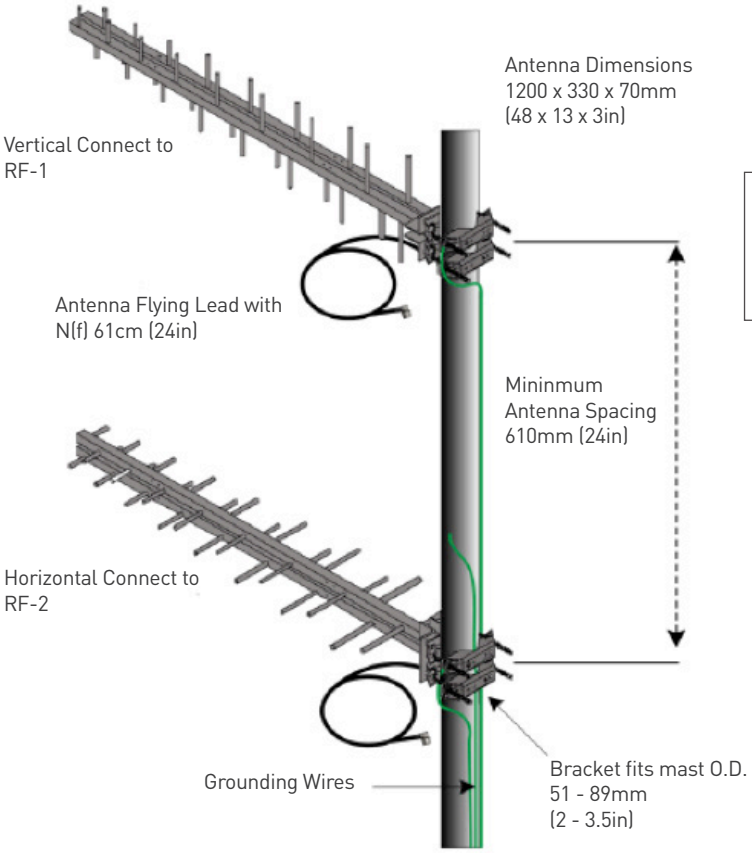
Channel	Name	RDL3000 R4v1 470-698 MHz	RDL3000 R4v2 470-614 MHz
14	470	Y	Y
15	476	Y	Y
16	482	Y	Y
17	488	Y	Y
18	494	Y	Y
19	500	Y	Y
20	506	Y	Y
21	515	Y	Y
22	518	Y	Y
23	524	Y	Y
24	530	Y	Y
25	536	Y	Y
26	542	Y	Y
27	548	Y	Y

Channel	Name	RDL3000 R4v1 470-698 MHz	RDL3000 R4v2 470-614 MHz
28	554	Y	Y
29	560	Y	Y
30	566	Y	Y
31	572	Y	Y
32	578	Y	Y
33	584	Y	Y
34	590	Y	Y
35	596	Y	Y
36	602	N	Y
37	608	N	Y
38	614	N	N
39	620	Y	N
40	626	Y	N
41	632	Y	N
42	638	Y	N
43	644	Y	N
44	650	Y	N
45	656	Y	N
46	662	Y	N
47	668	Y	N
48	674	Y	N
49	680	Y	N
50	686	Y	N
51	692	Y	N

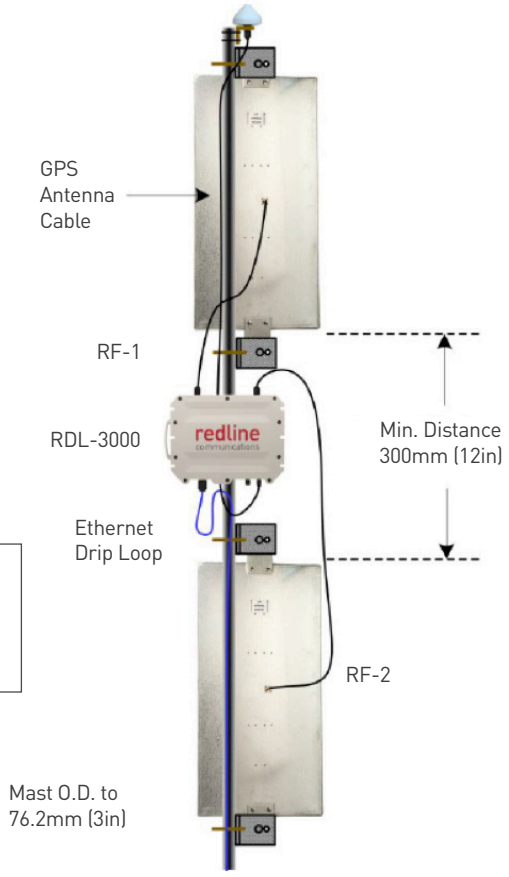
Antenna Spacing

When installing Log-P antennas on opposite pols (V&H) ensure the minimum antennas spacing is 24".

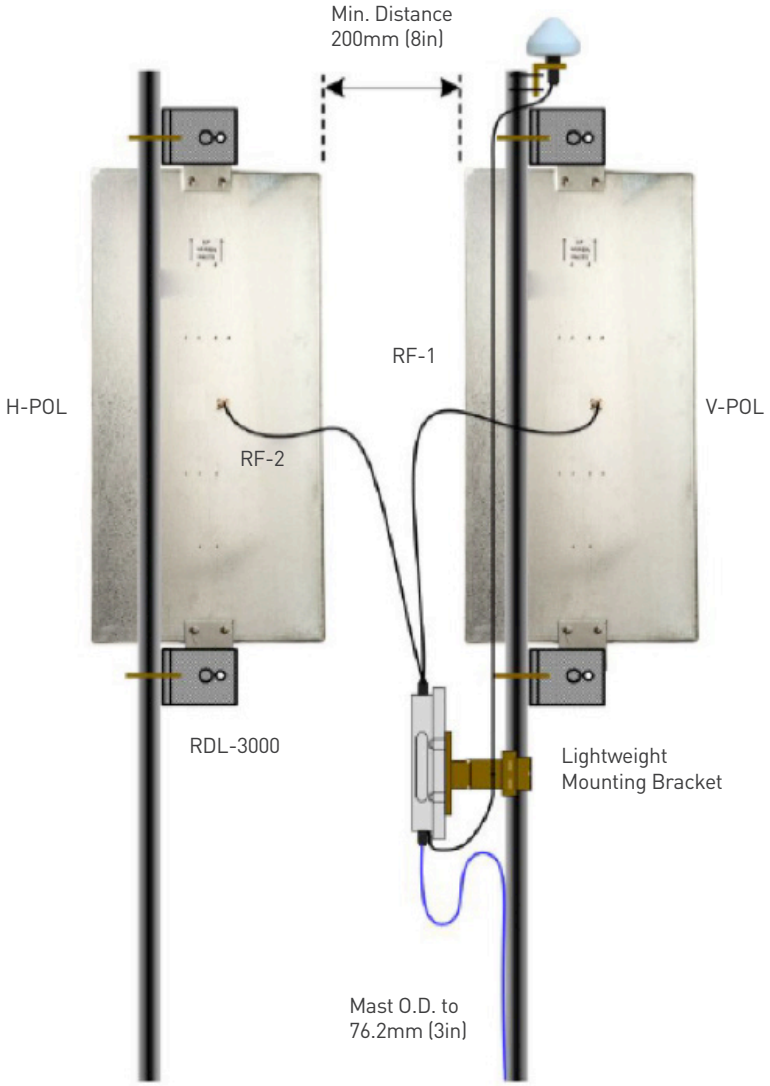
Enterprise RF: Mounting Directional UHF Log-P Antennas



When installing Log-P antennas on the same pol (V&V) ensure the minimum antenna spacing is 48".



When installing sector antenna panels on opposite pols (V&H) vertically on a tower/ mast ensure the minimum spacing is 12".



When installing sector antenna panels on opposite pols (V&H) horizontally on a tower/ mast ensure the minimum spacing is 8".

When installing sector antenna panels on the same pols (V&V) horizontally on a tower/ mast ensure the minimum spacing is 16".

Radio Mobile Startup Assumptions:

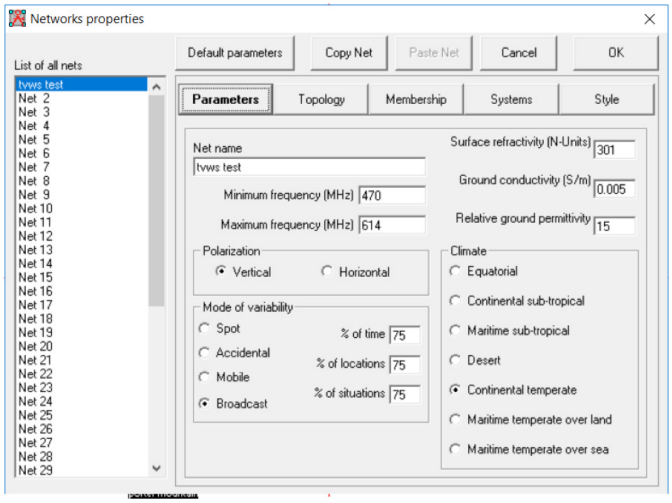
Redline's Advanced Services uses professional grade design tools, but given that Radio Mobile is a free RF propagation tool designed by, and for, the Amateur Radio ("ham radio") community and commonly used by the ISP, we want to provide guidance around that platform.

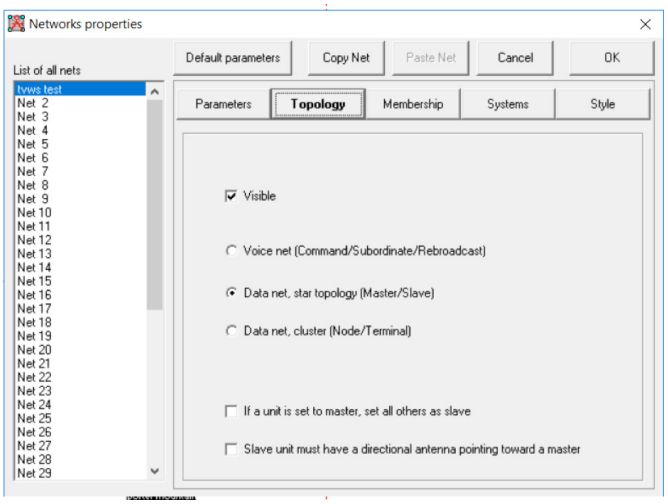
This section is not an endorsement or training on the platform but guidance for those who would already use it.

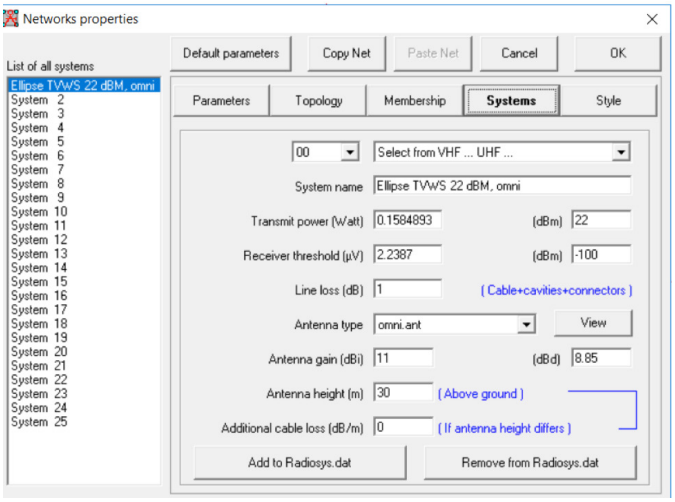
This guidance is offered to provide a baseline of the TVWS coverage without any consideration for the RF noise in a specific environment. The tool could then be used, along with guidance, to help predict the expected Rx signal but does not provide expected capacity.

The following screen shot provides guidance on parameters that have, so far, proven helpful in assessing the coverage.

Network properties configurations:





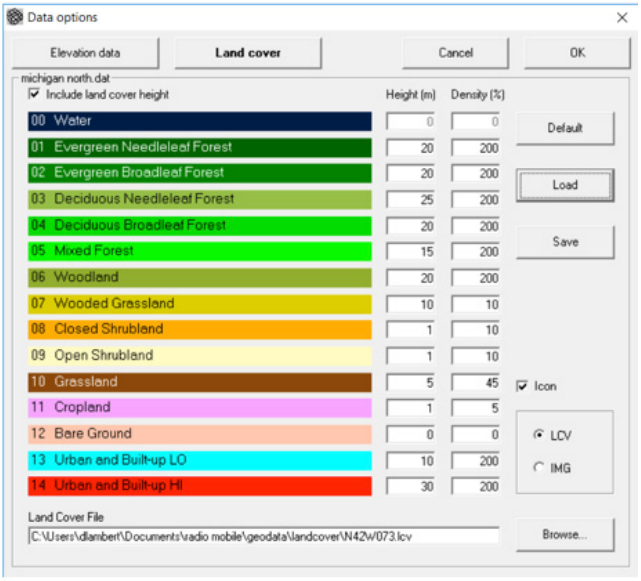


Land cover data:

The values on the right represent what would be used for northern Michigan, Wisconsin and like regions.

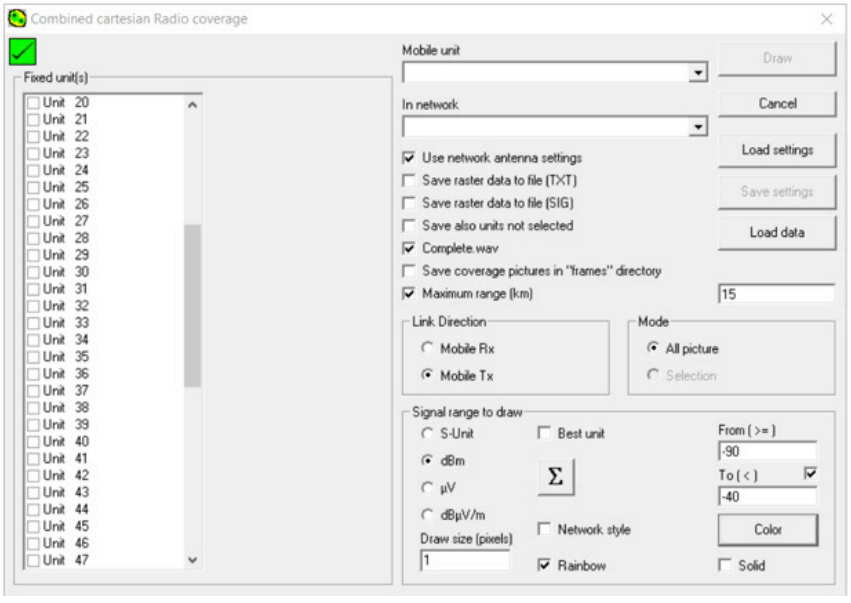
Adapt the tree height for your region but keep the density of tall obstructions to 200%.

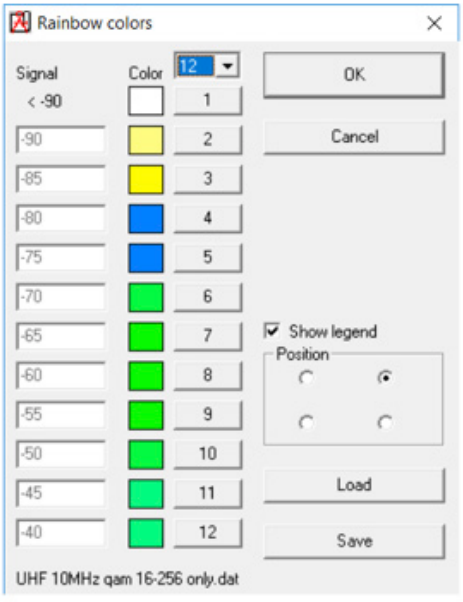
As a rule, be conservative and overestimate the height and density of the obstruction.



Combined Cartesian radio coverage:

Over time we have found that this coverage model provides fair assessment. The Combined Cartesian model also allows for more than one tower site to be considered at a time. The screenshot below provides the assumption to use in this model, the result would deliver an estimated Rx signal coverage for a 4 channel system and represent the modulation change from QAM 256 (green), QAM 64 (blue) and QAM16 (yellow). Considering the accuracy, or lack thereof, of the SRTM datum freely available, the typical noise and obstruction loss, we don't recommend plotting for the lower modulation.





Results

The following pictures identify the Rx signal level and coverage area for a site in both the 5.4GHz band and the TVWS band. In both cases the values represented are based on ideal noise conditions.

The pictures are all based on the same area to provide a more graphical view of the advantages of TVWS in NLOS scenario.

It is interesting to note that the Redline Virtual Fiber™ platform delivers the same capacity or bits/hertz regardless of the frequency band used. This way, a 10MHz channel in the 5.4GHz band and a 10MHz channel in the TVWS band will both deliver in excess of 50Mbps for the same modulation. The TVWS radio will do it over longer distance and through more obstruction.

In all three pictures below, the channel size is set to 10Mhz wide and the color arrangement identify the changes in modulations as per this chart:

- Green: QAM 256 range
- Blue: QAM 64 range
- Yellow/orange: QAM 16 range

While Redline's Virtual Fiber does support lesser modulation, BPSK and QPSK have been ignored in these pictures as they are less interesting to the Service Provider in terms of overall capacity and payload.

Figure 1: 5.4Ghz, 50M tower & 8M remote

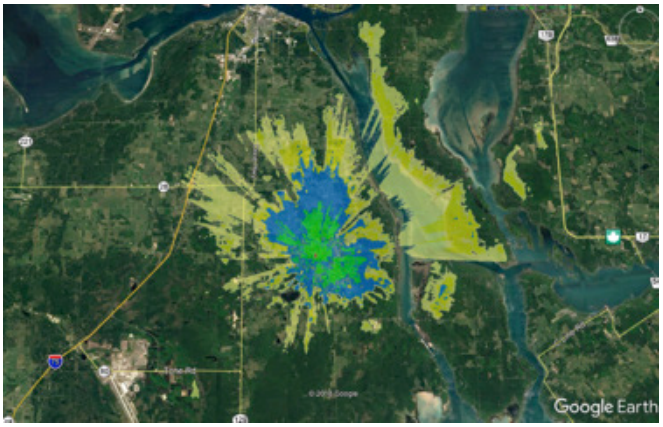


Figure 2: TVWS 18dBm Tx, 30M tower & 8M remote

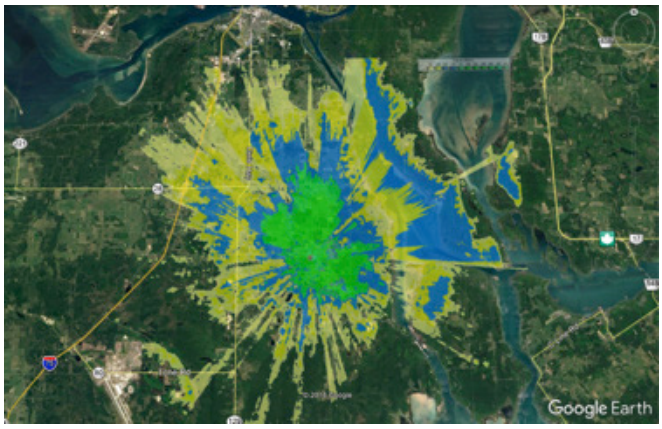


Figure 3: TVWS 23dBm, 30M tower & 8M remote

EDX TOOL ASSUMPTIONS:

Network Properties Configuration:

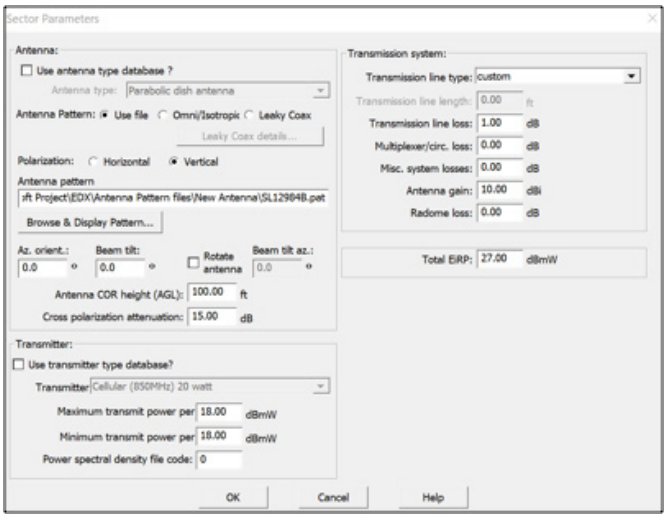
The following are the link budget assumptions to do initial analysis:

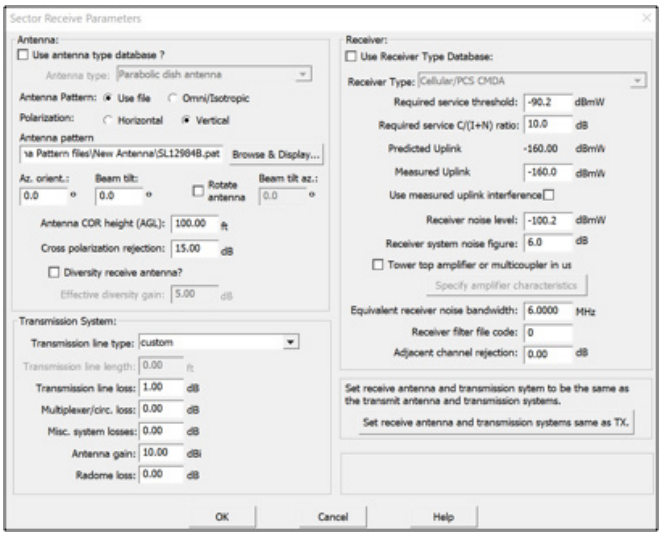
Redline Base Station Parameters

- Transmit power: 18dBm
- Antenna Gain: 10 dBi
- Transmission Line Loss: 1dB
- EIRP: 27 dBm
- Antenna Height: 100ft AGL
- Antenna H-Beamwidth: 90 degrees
- Azimuth: 0, 90, 180, 270
- Anderson 2D model used for EDX simulation
- 30m resolutions Terrain and Clutter data used for simulation

Redline CPE Parameters

- Transmit power: 18dBm
- Antenna Gain: 11 dBi
- Transmission Line Loss: 1dB
- EIRP: 27 dBm
- Antenna Height: 20ft AGL
- Antenna H-Beamwidth: 65 degrees





FREQUENTLY ASKED QUESTIONS

What are the rules around using the TVWS band?

- First off, Service Providers should make sure to review the rules thoroughly, as for any other band, to ensure their TVWS implementation abides by the FCC provision and amendment of Part 15 (FCC Document FCC-15-99A1.PDF). This document can be found on the FCC Website at the following address: **https://www.fcc.gov/document/fcc-adopts-rules-unlicensed-services-tv-and-600-mhz-bands**.

Really? Can you make it simple?

- You owe it to your business to stay abreast of FCC rulings as any complaints can result in you being fined.
- The ruling, as it applies to the broadband industry, is set to ensure proper power setting based on distances and elevation. The document referred to above has detailed charts on EIRP and distance.
- Generally speaking, the antenna cannot be more than 30M AGL and 250M HAAT. Most vendor are controlling the power output not to exceed the TX power limit.
- Furthermore, the database will also assist in enforcing the rules by not providing a list of available channels to radio outside of the physical installation limits.
- Again, please take the time to become familiar with the rules.

What is the license fee for the band?

- There are no licenses for the band. It is license exempt . The novelty is the database "policing" the various users of the band: TV broadcasters, broadband industry, wireless microphone, etc. These databases are certified by the FCC and every vendor gets to make a choice of with whom it wants to certify their radios. In Redline's case, we have elected to use Nominet a database operator: **https://usa.wavedb.com/**

If the band is not licensed, why do I have to pay to use it?

- Nominet, like all the database operators, is a business like yours. As such they are not subsidized or otherwise funded by the government. The fee you are paying is to ensure the Nominet database is kept operational.

I want to buy your radio but will shop the database myself.

- This is not possible. The FCC certification for the radio is required to be done with the radio AND database connection. So for you to be using another database a Nominet implies that Redline would need to recertify its radio with a second database. While this is all relatively easy to say, the costs and engineering associated make this quite prohibitive.

How does this database work? What do I have to do?

- The primary function of the database is to protect the TV transmission and reception from noise pollution from the broadband industry. In this role, the database validates antenna heights and provides a list of available TV channel (White Spaces) that can be used. It will not make the channel selection nor the channel bonding decision. This will be your responsibility and will be done on the radio Gui.
- Outside of ensuring that the network has an open port for the radios to reach the database, there is nothing else to do on your part; just point the radio to the database and click on the channel(s) you want to use.
- The radios need to have access to the internet, through your network, to reach the database. No proxy can be used.

How do I know what channel to use?

- You will do this the same way for any other license exempt product: run a spectrum sweep, identify a list of RF positions that are acceptable then overlay this with the available TV channel from the database to pick the channel(s) best suited for your market. While it seems complicated, it is all simplified by being done from the radio Gui.

Will your radio have further reach than the other products we have worked with?

- You should not count on that. The law of physics and RF propagation work in the same way for all vendors. The RSSI and noise level will be quite similar from vendor to vendor. What you will notice thought are variations in link stability, performance and capacity.
- What this translates into is simple: Radio XYZ gave you 5Km of reach but barely any capacity. The Redline radio, the only MIMO solution on the Market, will also reach the 5Km mark but will deliver far better capacity and link margin.
- If you have already played with TVWS, share with us the TX, RSSI, antenna gain and noise level observed and we will be able to tell you what the Redline solution will deliver.

What speed will I get?

- Since NLOS performance varies for every single link, providing performance guidance can be misleading to you. We can say that in LOS, the TVWS version of our Virtual Fiber™ RDL-3000 carries the same performance as our other Virtual Fiber bands in 2, 3 & 5GHz: at QAM 256 7/8 and 20MHz channel, the radio will deliver about 160Mbps aggregate. Of course, you will not likely see this in NLOS but it is quite frequent to hit QAM 64 and QAM 16 in real life. In fact, when we model RF conditions, we only pay attention to QAM 256 / 64 / 16 and ignore the lower modulations. The objective of radios is to deliver broadband services so lesser modulation is far less interesting to you. Typical measure speeds are from 10Mbps to 45Mbps download speeds. The actual speed measured will depend on the modulation and channel size the link is using.

Why is your radio getting more capacity?

- Redline's Virtual Fiber platform is the only MIMO platform in this band. This alone provides tremendous advantage as there are 2 radio chains to work with and deal with noise/obstruction.
- Further to this, Virtual Fiber has the most advanced MIMO A implementation. This comes from the fact that Virtual Fiber is not based on a chipset and limited in development but rather Redline's entire intellectual property. Redline owns every part of the radios "DNA" and this has been able to optimize it. In MIMO A, Redline can take advantage of STBC (Space Time Block Coding) on the TX side and MRRC (Maximal Ratio Receiver Combining) on the Rx side to achieve MIMO gain of close to 12dBi on its link budget. So, for the same RF environment, Redline gets a much higher link budget, hence more stability and capacity.
- One other unique feature of the VF radio is the use of a very linear OFDM amplifier and tight filter mask. This result in a flat power curve i.e. the radio TX does not drop with increase modulation but remains at maximum level for all modulation. In real life, this means that Redline will keep high modulation further away than any other radio, maximizing the capacity to the edge of the base station reach.

Why is Redline different?

- Simply said, there are three types of vendors in the TV White Space market today:

  1 - Those that came from the serial modem and SCADA market.

  - Already have radios in the band but no broadband experience.
  - OFDM and wide channel operations are just not this simple to develop. Just ask any of the failed WiMax vendor from 10 years ago.

  2 - The TVWS startup.

  - No legacy to deal with, but building a radio from the ground up.
  - Just as above, not that simple. Most turn to some form of 802.11 chipset.
  - Using chipset can be limiting on the feature side as you cannot do more than what the chipset is built for.

  3 - The there is Redline.

  - Publicly traded, mature radio vendor.
  - Virtual Fiber™ is not new but the 5th generation of intellectual property.
  - No chipset but dual FPGA i.e. we can make it anything we want.
  - Virtual fiber exists in multiple frequencies, so development for TVWS also goes to the 2,3 & 5GHz version and vice versa. This gives Redline a much wider financial scope when undertaking development.

Should I synchronize the Ellipse base stations?

- In many instances synchronizing traffic will alleviate intra cell noise and allow higher throughput. This is especially useful when collocating Sector and /or using lesser quality antenna on sector radio. With 600MHZ frequency, OFDM transport and MIMO, the solution propagates very nicely, which can be challenging with radios in close proximity.
- Another interesting use case for synchronization is with close proximity CPEs, where wide beam antenna such as flat panel and Yagi antenna may cause self interference with one another

Can I re-use a channel on the same base station?

- While this is feasible in theory, it would require antenna with higher lobe isolation factor than currently available. From what we have seen of current antennas, it would be difficult to consider channel re-use.

How many CPE can I connect to a Sector (AP)?

- Virtual Fiber uses a connection-oriented environment and uses a scheduler to ensure all users have proper time allocation to transmit. Currently the scheduler, hence the radio, can support up to 120 simultaneous connection or CPE/client. This was done to accommodate the industrial SCADA requirement. It is doubtful that the ISP community would connect this many customer as the individual capacity would be very low.

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