



TV White Spaces

FAQ and Engineering Best Practices

Microsoft Airband Initiative

TVWS Overview:

What is TVWS?

Television white spaces (TVWS) refers to frequencies in the very high frequency (VHF) and ultra-high frequency (UHF) television bands not assigned or otherwise used by broadcasters or by any other licensed services. With the assignment of channels to broadcasters varying by location, not all the allocated channels are assigned to broadcasters in any given market, giving rise to “white spaces” in which a channel that is not assigned for broadcast may be available for other purposes. TVWSs are a great example of spectrum sharing; regulators allow TVWS devices to transmit on these unassigned channels without the need of a license (unlicensed spectrum) as long as they leverage a Federal Communications Commission (FCC) mandated TVWS database which protects TV broadcasters and other licensed users from harmful interference.

What use cases are best for TVWS?

TVWS can be used to provide broadband connectivity and telemetry for Internet of things (IoT) solutions. IoT encompasses a range of high- and low bandwidth applications that leverage the propagation characteristics of TV white spaces. This includes a full range of applications used for public safety, transport, energy grids, agriculture, healthcare, and the environment. TVWS have the capability of providing high speed broadband Internet. Wireless Internet solution providers (WISPs) and other types of ISPs frequently use 5GHz deployments in low density areas; TVWS can be deployed in conjunction with 5GHz and other mid-band links to increase the coverage area and to cover the missing spots that cannot be addressed by 5GHz and other mid-band links due to non-line of sight (NLOS) and distance limitations.

Is there a special IoT radio for telemetry applications that is different and cheaper than a full band TVWS radio?

Yes, Microsoft has developed a triple band Long Range Wireless Area Network (LoRaWAN) IoT radio which is capable operating in the high VHF, UHF and upper ISM bands. This is a narrow band, low power and long-range radio primarily targeted for telemetry applications.

Does TV White Spaces affect licensed operations?

TVWS does not affect licensed operations. All TVWS radios in the United States need to be certified by the FCC and they need to be connected to the TVWS database, which controls what channels can be used and at what maximum power levels. TVWS databases only give TVWS devices access to unassigned TV channels.

What is the difference between available channels vs usable channels?

The TVWS database provides the list of unassigned channels that can be used by TVWS devices (per the FCC's regulations). However, not all available channels are usable as they may be polluted and have a high radio frequency (RF) noise. Because of this, it is fundamental to run a proper spectrum scan in all the areas where you are considering deploying this technology.

Do we have frequency reuse with TVWS?

Yes, TVWS devices have frequency re-use. Some vendors allow frequency reuse of $N=9$ and others like Adaptrum with their new 'Network Sync' capability allow a reuse of $N=3$.

What technology standard are you using for TVWS?

All vendors use proprietary technology usually derived from the 802.22 and 802.11 down-banded Wi-Fi standards. Adaptrum is manufacturing a baseband chip which leverages the 802.11af standard, a published IEEE .11 standard that was designed specifically for devices operating on TVWS.

Are TVWS radios from different manufacturers interoperable?

Not yet. All vendors use proprietary technology and therefore cannot interoperate. Adaptrum is producing a baseband chip based on the 802.11af standard. Ideally, different radio and hardware vendors will adopt the 802.11af standard, which would pave the way to interoperability, but we are not there yet.

What is the extent of mobility support?

While current TVWS devices are used for fixed connections, the FCC does not preclude mobility for TVWS systems. If a TV white space radio manufacturer supports mobility, there would be nothing in the FCC regulations stopping it, if the devices operated in personal-portable mode and the database query obligations were followed.

Devices and Pricing:

Who are the TVWS equipment vendors?

There are many vendors of TVWS. Major vendors include 6Harmonics and Adaptrum. Radwin has announced plans to release a TVWS product during the first quarter of 2020.

What are the website links for TVWS vendors?

- 6Harmonics: <http://www.6harmonics.com/>
- Adaptrum: <https://adaptrum.com/>
- Radwin: <https://www.radwin.com/>

What is the current pricing of TVWS equipment?

Please contact the Microsoft Airband Team or the equipment vendor for pricing.

What does a total cost of ownership (TCO) analysis of TVWS and mid band radios say about cost comparison?

Microsoft has worked with t3 Broadband on a Total Cost of Ownership (TCO) analysis in which we compared TV white space technologies with other Wi-Fi type technologies operating on the 5.x GHz bands. The analysis confirms that TV white space technology is the most cost-effective solution on a cost per household *passed* standpoint (coverage). With current average prices of TV white space customer premises equipment (CPE) compared to 5.x GHz, the cost per household *connected* is at the advantage of TV white space technology only in low housing density areas (≤ 15 houses or 36 people per square mile) at current average CPE pricing levels. With a rapidly evolving TV white space hardware landscape, we can expect this competitive advantage to expand to more dense population areas when TVWS CPE pricing falls in the \$300-\$600 range. Another very interesting outcome of the study is that, in the case of hybrid network deployments, mounting TV white space base radios at the same time as 5 GHz on the same tower reduces TCO of TV white space installation by approximately 85%. The 5 GHz layer will be used for capacity while the TV white space layer can be used for coverage including a larger coverage area where the 5 GHz links cannot reach as well as coverage on locations that cannot be addressed by 5 GHz due to non-line-of-sight requirements.

Is there currently support or work going on toward channel aggregation or channel bonding? In the future?

Yes, there are multiple vendors working on advanced features for the TVWS radios. Most vendors already provide channel bonding (using contiguous channels as a single piece of spectrum) capabilities. Some vendors allow 2 channels bonding, while others already provide 4 channel bonding. 2x20MHz channel aggregation will be available on the Radwin equipment during the first quarter of 2020. Later releases of the TVWS equipment are expected to allow up to 4x20MHz channel aggregation.

Regulation and Database:

How does the TVWS database work?

The FCC has regulations allowing unlicensed access to TV white spaces. Under those regulations, certified TV white spaces devices operate under the control of a TV white spaces database.

TV white spaces databases are cloud based services that perform two basic duties for the regulator: (1) providing TV white spaces devices access to broadcast spectrum that is not assigned to a broadcaster or another licensee; and (2) protecting incumbent licensees from interference. The FCC certifies both white spaces databases and devices that are used to access TV white spaces spectrum.

To access TV white spaces spectrum, a TV white spaces device contacts a TV white spaces database over the Internet and requests a list of channels at its specified location (as determined through professional installation or geolocation capabilities, such as global positioning system (GPS).

Examples include: a TV white spaces base station radio able to reach the Internet over a fiber backhaul connection; an in-home access point able to reach the Internet over a cable modem connection; or even a Wireless Fidelity (Wi-Fi) device able to reach the Internet over a 4G Long Term Evolution (LTE) connection.

Depending on their operating characteristics and intended uses, the FCC will designate such devices that directly contact TV white spaces databases as either 'fixed devices' or 'mode two personal portable devices.'

Once it connects with the TV white space database, the TV white spaces device reports its location and the TV white spaces database then communicates which channels can be used by that TV white spaces device at that particular location.

The TV white spaces device will only transmit on channels specified by the TV white spaces database. If no channels are returned by the database, the TV white spaces device cannot transmit until it is given another list of channels. Once the device receives a list of channels, it selects the channels to begin transmitting on.

Client devices designated by the FCC as either fixed devices or mode one personal-portable devices will be under the control of devices with direct contact to the TV white spaces database. The client devices will be in listen only mode and will only begin transmissions upon hearing an enablement signal from the base station, access point, or other device with direct contact with a TV white spaces database.

TV white spaces devices with direct connections to the Internet are required to re-contact the TV white spaces database at specified time intervals (or if moved from their current location) for lists of new TV white spaces channels. The activity is invisible to the user and requires no action by the consumer.

How can I know the TVWS channel availability at any location?

In the United States, Nominet has a free tool that can be used to check the TVWS channel availability at any specific location using geographic coordinates. This tool can be accessed using the following link:

<https://usa.wavedb.com/channelsearch/tvws>

Can the TVWS Database be used for designing a TVWS network?

The TVWS database cannot be used as a design tool. However, Nominet has a paid service that incorporates channel availability, TVWS link simulations, coverage maps, population studies and link budget. If you want additional information, please visit <https://www.nominet.uk/wavedb-register/>

Is there a procedure for feeding usable channel information back into the Nominet database based on local measurements?

Unfortunately, there is no direct way of reporting back this information to the FCC channel database.

What does the TVWS database service cost?

The cost of service for the Nominet US TVWS database is \$1 per device (Base Station or CPE) per month, paid by the TVWS radio manufacturer to Nominet.

The TVWS database says certain TV channels are off limits, but the spectrum analyzer shows that these channels are not being used. Why can't I use these channels?

Even though these are unused channels, the FCC's TVWS regulations preclude you from using them. In time, we hope to be able to show the FCC that these unused channels could be dynamically used, just like other white spaces.

What is the power limitation in using TVWS?

For fixed TVWS devices, the maximum effective isotropic radiated power (EIRP), which is the power radiated by the antenna, cannot exceed 40 decibels relative to a milliwatt (dBm) (10 Watts) for less congested areas and 36 dBm (4 watts) for all other areas. According to the FCC, less congested areas are those where at least half of the allocated television channels within the intended band of operation (low VHF, high VHF, or UHF) are unused for broadcast services and available for white space use, and where a fixed white space device is sufficiently separated from protected operations.

How does your BS connect with the TVWS database (Nominet)?

The radio vendor provides a software key for each radio to connect to the Nominet TVWS database. Once the radio is connected to the database via the Internet, it provides to the database its location and the database returns the list of channels available as well as the maximum operating power level at that location.

Planning and Deployment:

How easy is it to install and commission TVWS?

Installation of TVWS equipment is simple and straightforward if all the steps suggested by manufacturers are followed. Commissioning a TVWS radio is like commissioning any other radio on the 3.x GHz, CBRS and 5.x GHz bands.

How high can the radiation center be for TVWS?

The radiation (rad) center for TVWS antenna installation depends on the regulation of TVWS. In United states the maximum allowed rad center is 100 meters for less congested areas and 30 meters for all other areas. According to the FCC, less congested areas are those where at least half of the allocated television channels within the intended band of operation (low VHF, high VHF, or UHF) are unused for broadcast services and available for white space use, and where a fixed white space device is sufficiently separated from protected operations.

What range and throughput performance should we expect with TVWS?

As with any wireless technology, the answer to this question will vary significantly based a variety of conditions, including whether the link is line-of-sight or non-line-of-sight, the presence and intensity of interference from other co-channel or adjacent channel transmitters, and other factors. The throughput is a factor of RF parameters, the number of TVWS channels used and geographic conditions. Different TV white space radio models deliver different performance, so it's always a good idea to test different radios prior to determining which to deploy. Current (4 x 6 MHz channels) TVWS radios can deliver a throughput of up to 186 Mbps (8 MHz TV channels in Europe, Africa, and Asia also allow channel bonding up to 24MHz) and we are seeing typical range of a TVWS base station radio at about 7 miles (less or more distance depending on signal quality and other factors). TVWS signals can travel great distances under good radio conditions and we have closed links out to almost 25 miles in maritime applications. Like all radio signals, the farther they go the weaker they get, and the throughput decreases.

What is a spectrum scan? How does one perform such a scan?

A spectrum scan is a measurement of the signal level (without injecting any additional RF signal) within a specific range of frequencies at a particular location using a spectrum analyzer such as an [RF Explorer](#) and an antenna.

Why is a spectrum scan required?

Since TVWS operates in an unlicensed spectrum band by making use of unused TV channels, it is always important to perform a spectrum scan to validate the quality of the available channels. The quality will depend on the amount of RF noise on each channel; RF noise can be defined as any RF energy that is not the desired signal.

What is RF ducting?

RF ducting or atmospheric ducting is an undesired effect of radio waves that makes them travel further than expected as they refract on the upper layers of the atmosphere and they tend to follow the curvature of the earth. When RF ducting occurs, TV signals can interfere with distant TVWS signals operating on the same channel, far beyond the broadcaster's protected contour. In this instance, a TVWS database would report the channel as available for TVWS transmissions, but it cannot be used as a practical matter.

What are RF ducting mitigation techniques?

Below we present are a few techniques that might work to help mitigate atmospheric ducting. These techniques are not mutually exclusive and can be used in combinations.

Reducing the antenna height: If the links permits and the desired coverage area is not compromised, it is recommended to lower the antennas height when interference is present.

Using more directional antennas: Using antennas with a narrower beam width reduces the amount of RF signals the antenna sees while increasing the gain of the signals within the antenna's beam width angle.

Down tilt the antenna: The angle of arrival of the ducted signal is usually close to the horizon. A small down tilt might help to keep the undesired signals out of the TVWS radio. A good starting point is to place the 3 decibel (3dB) point on the antenna pattern on the horizon as you generally won't lose any signal to the subscribers.

Switching channels: If there is availability of other TVWS channels in the area, then changing the channel is the best solution as it only requires a configuration change in the radio.

Network planning: If there are multiple vertical assets options, sometimes changing the path of the signal is the best option. We should avoid pointing the signals towards the source of interference as much as possible.

What are TVWS design best practices?

Designing TVWS follows the same steps as any RF Design. Since TVWS operates on unlicensed spectrum, we need to design carefully to have a successful network deployment. Here are some of the steps required to have successful TVWS design:

- Identify areas with widespread households and low population density
- Review the channel availability at the desired locations
- Perform a detailed spectrum scan to understand the RF conditions
- Conduct RF propagation, coverage and capacity studies

What do we do if the VHF and UHF bands are unusable?

TVWS is a tool in the toolbox. If the TVWS channel availability is not good and the RF conditions are not favorable, consider evaluating other frequencies and technologies such as 5 GHz, Citizens Broadband Radio Service (CBRS) and other mid-band technologies, as well as the 900 MHz band.

How many antennas will be used to have TVWS link?

TVWS radios with multiple input multiple output (MIMO) capabilities require 2 antennas on the base station side and 2 antennas on the client side; on both base and client radios the two antennas can be replaced with a single dual polarization antenna. For radios without MIMO capabilities a single antenna is needed on both the base station and the client side.

What kind of antennas can be used for TVWS deployment? Who makes the antennas?

There are different types of antennas used for TVWS, including directional and omni antennas. Although directional antennas concentrate the energy and they usually have a higher gain, the selection of the antenna for a TVWS link depends on multiple factors. Some TVWS equipment providers sell their own antennas while others work in a partnership with a specific antenna manufacturers. Some of the vendors include:

- MARS Antennas: <https://mars-antennas.com/>
- KP Performance Antennas: <https://www.kpperformance.com/>
- MTI Antennas [Products \(mtiwe.com\)](https://www.mtiwe.com/Products)
- 6Harmonics: <http://www.6harmonics.com/products/>

What is the Signal to Noise Ratio (SNR) and Radio Frequency (RF) conditions where we can still assure a certain grade of service (GoS) and throughput?

The minimum SNR to establish a link is 10dB. For further reference please refer to vendor modulation and coding schemes (MCS) tables.

What tools can you use to perform RF propagation modeling on any tools?

There are different tools that can be used for RF propagation modeling. Some of the tools include SignalPro, Planet, Radio Mobile, Nominet WaveDB and Tower Coverage. Radio Mobile is widely used and it is free for the amateur radio community (<http://radiomobile.pe1mew.nl/>). Nominet WaveDB is also a good alternative for TVWS specific propagation modeling (<https://www.nominet.uk/wavedb-register/>).

What does TVWS network management application look like? Is there a web-client to monitor Base Station (BS) and Client Premise Equipment (CPE) for channel utilization?

Different vendors have different types of network management. Almost all TVWS vendors use web-based management. Some vendors, like Adaptrum, use cloud-based network management.

How easy is it to install and commission TVWS?

Installation of TVWS equipment is simple and straightforward if all the steps suggested by manufacturers are followed. Commissioning a TVWS radio is like commissioning any other radio on the 3.x GHz, CBRS and 5.x GHz bands.

Resources regarding TVWS and RF design:

- [Dynamic spectrum and tv white spaces](#)
- [Microsoft White Spaces Database](#)
- [White Space, the next internet disruption: 10 things to know](#)
- [Whitespaces Microsoft spectrum](#)
- [Nominet | Getting started with TV White Space](#)
- [Dynamic Spectrum Alliance](#)
- [Signal-to-noise ratio](#)
- [What is a signal-to-noise ratio?](#) | [Atmospheric duct](#) | [Tropospheric propagation](#) | [Spectrum analyzer](#)
- [Federal Communications Commission](#)