C Spire Rural Broadband Consortium Bulletin:

TVWS Database vs Environment

Spectrum Analysis

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Introduction

The C Spire Rural Broadband Consortium recently compared the TV White Space (TVWS) testing, a comparison of the TV White Space database with measured spectrum scans.[1] The comparison indicates the current TV White Space (TVWS) database does not give enough information to use TVWS spectrum without significant testing, time, and cost.

TVWS Spectrum and Database Review

TVWS spectrum is located within the TV broadcast band (primarily 470-614 MHz), making it shared spectrum with TV stations as primary users. Basically, TVWS is TV channels that are unused by TV stations and other operators. Using TVWS requires accessing a TVWS database, certified by the Federal Communications Commission (FCC), that regulates which TV channels are accessible for use at a location. The FCC rules and database are both designed to protect TV broadcast operations by indicating protected service contours. However, those contours do not always reflect the actual service of the broadcaster. This can result in more noise than expected from a TV broadcast signal in a channel identified as "available" by the database.[2] In addition, it appears that not all variables of protected service are adequately conveyed, particularly antenna polarization.

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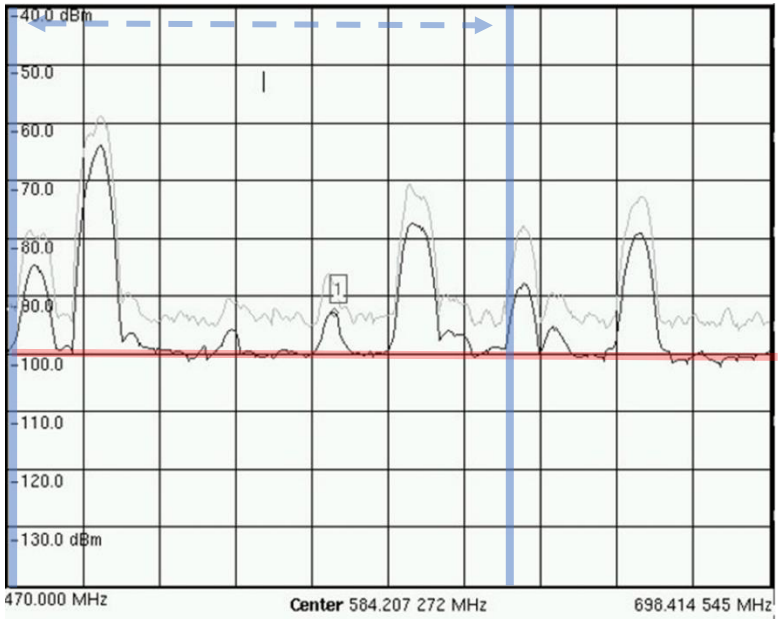
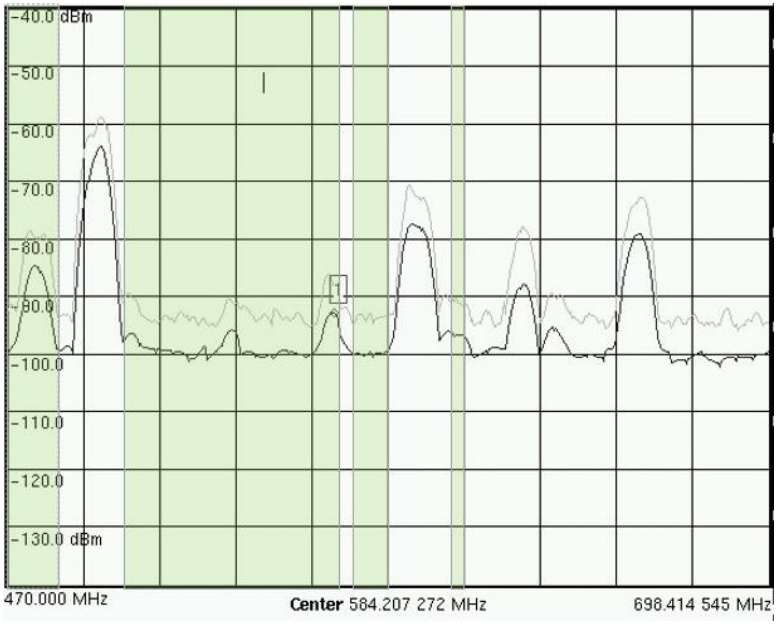
[1] Using TVWS requires accessing a TVWS database certified by the Federal Communications Commission (FCC) that indicates which TV channels are available to use at the location.

[2] Just as it's difficult to hear someone speaking to you in a loud, crowded room, TVWS communication is difficult if other operators are broadcasting on the same frequencies.

Spectrum Scan Analysis

The Consortium performed scans using a spectrum analyzer in six locations throughout Mississippi to determine the availability of TVWS spectrum in those locations. Figure 1 is a screenshot from the spectrum analyzer reproducing the radio frequency (RF) environment as a wave over the frequency range of 470 MHz to 698 MHz. The frequencies potentially available for TVWS are between the two vertical solid blue lines. Any RF received by the analyzer that is above the noise floor of the analyzer (~-100dBm as identified by the red line) is an RF transmission of some sort.[3] For our purposes, these RF transmissions are noise; they would significantly degrade any TVWS operations attempted on the same channels in terms of achievable throughput and coverage. The higher the noise levels, the more TVWS performance will degrade. While the spectrum scans focus on received signals, the TVWS database focuses on the allowable transmission power of a TVWS device. Figure 2 is an overlay where the highlighted green rectangles represent database channels a TVWS device (whether base station or customer equipment) can transmit without worry about interference to a TV receiver.[4] The database does not identify whether those channels are clear and actually usable, only whether someone other than a TV broadcaster is legally allowed to use them. As the tests indicate, this is an important distinction.





[3] The lighter signal represents the maximum received level the spectrum analyzer observed during that time lapse.

[4] Channels available for both full-power and partial-power transmission are indicated by green rectangles. Figures 2-8 are all overlays of permissible power transmissions.

Figure 1: Sample Spectrum Scan

Figure 2: Sample TVWS Database

Figures 3 and 4 are spectrum scans from Fayette, MS, showing the ideal scenario, where channels identified by the TVWS database for TVWS use were also determined to be clear via spectrum scan. Though Figures 3 and 4 look nearly identical, the two figures represent the same area scans at the same azimuths, but with different horizontal and vertical antenna polarizations. This is very significant as today TV broadcasters generally broadcast at a single polarization (often horizontal). This means that signals received from a TV transmitter will be stronger on one polarization than the other at any given location. Scans for both polarizations and multiple azimuths were performed to characterize the spectrum fully. If the TVWS device only uses a single polarized antenna, the clearer polarization can be used. If, however, the TVWS device uses MIMO (multiple input multiple output – basically multiple transmitters interact with multiple receivers on both base station and customer device), both polarizations must be equally clear to enable throughput gains due to this multi-antenna technique. In fact, MIMO gains require very clear spectrum (minimal noise) in order to have throughput gains. The overlaps in both Figure 3 and 4 distinctly show that the database is accurately representing the usable environment in Fayette, MS, as the highlighted green is overlaying the clear spectrum. In the case, TV transmitter polarization does not seem to have a significant impact on the scans, although the transmission at ~624 MHz (circled on both graphs) is slightly stronger for the horizontal versus the vertical polarization scan. Due to this comparison, it can be assumed that the 624 MHz signal is being transmitted using a horizontally polarized antenna. While the database seemingly gives options to specify polarization to determine suggested white space in an area, the information in the database seems to make no distinction between polarizations, indicating the same allowed transmit powers for both polarizations for all the locations tested.

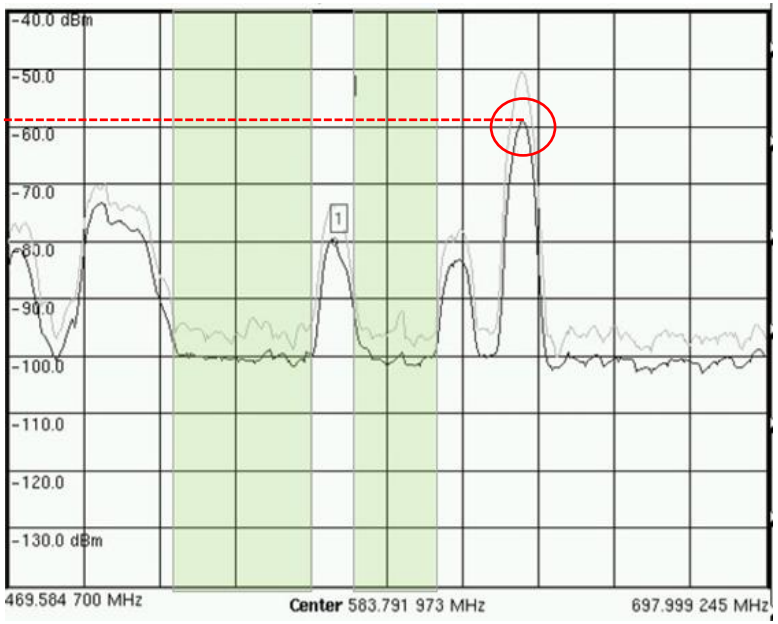


Figure 3: Fayette, MS Spectrum Scan (Horizontal Polarization)

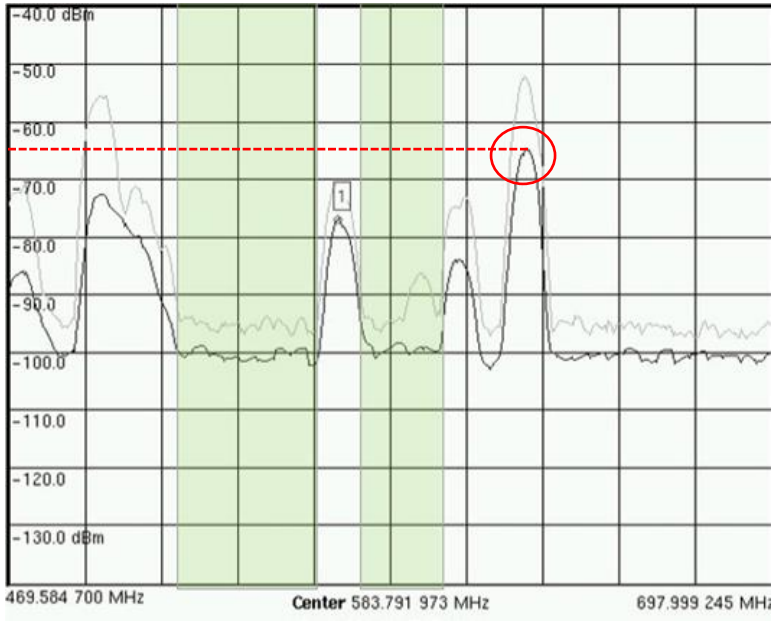


Figure 4: Fayette, MS Spectrum Scan (Vertical Polarization)

Few of the locations tested are as perfectly aligned as those in Fayette. Figures 5 and 6 are spectrum scans taken in Gloster, MS, and represent how significant accurately portraying polarization is. Though both spectrum scans are taken at the same location with the identical azimuths, the noise on each polarization is very different. The database's available channels for TVWS usage are clear in Figure 5, however Figure 6 is littered with noise in those same channels. Likewise, the protected TV broadcast channels are drastically different between polarizations, indicating that there is a preponderance of vertical polarization use. TVWS operations on the database-identified channels should be viable using horizontally polarized antennas. TVWS operations with vertically polarized antennas or MIMO would result in performance degradation (limited coverage and low throughput).

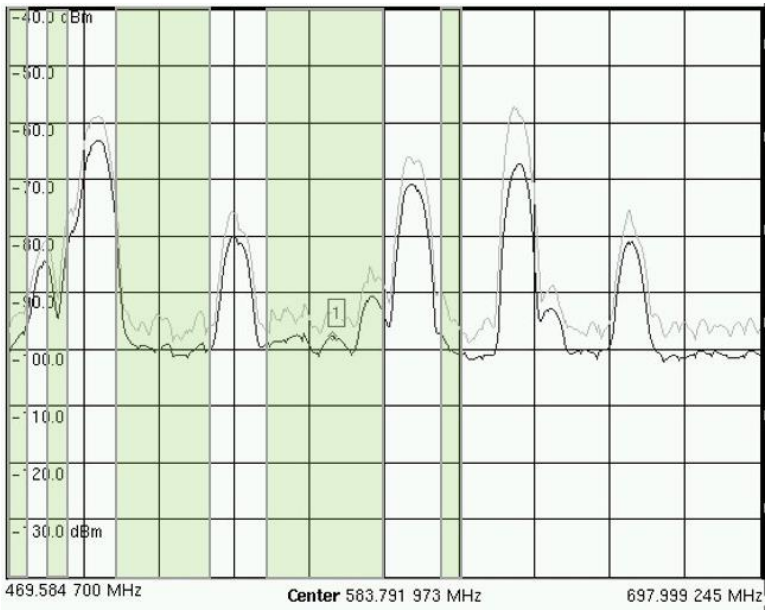


Figure 5: Gloster, MS Spectrum Scan (Horizontal Polarization)

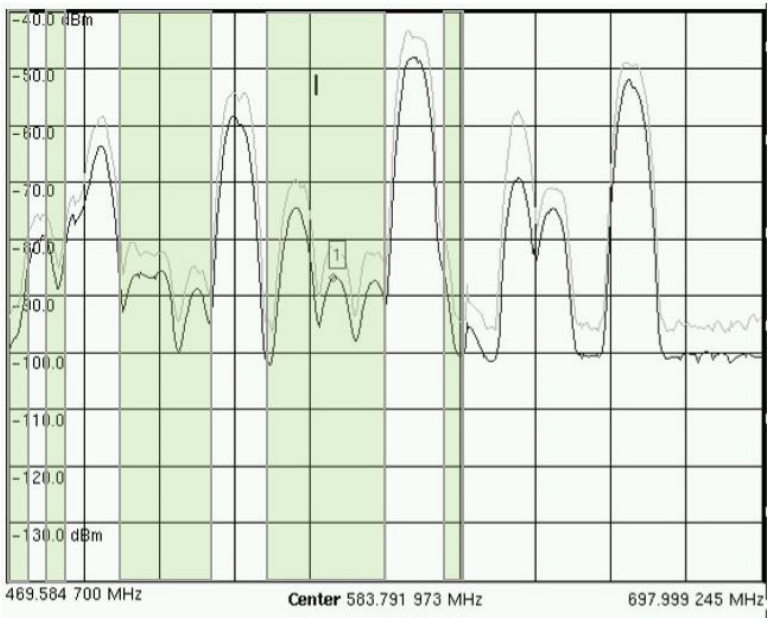


Figure 6: Gloster, MS Spectrum Scan (Vertical Polarization)

The differences in noise levels between polarizations and the discrepancy between clear spectrum and TVWS channel availability is a reoccurring theme with most of the spectrum scans within Mississippi. Figures 7 and 8 are of Hollandale, MS, with an extreme distinction of strong noise on one polarization (vertical) making those channels unusable for MIMO or vertically polarized TVWS operations. Even TVWS operations using only horizontal polarization result in poor performance on most of the "available" channels while using MIMO would be impossible. Most of the remaining spectrum environments analyzed are duplicates of Hollandale and Gloster, where measurements indicate noise within the database's suggested channels and discrepancies between polarizations.

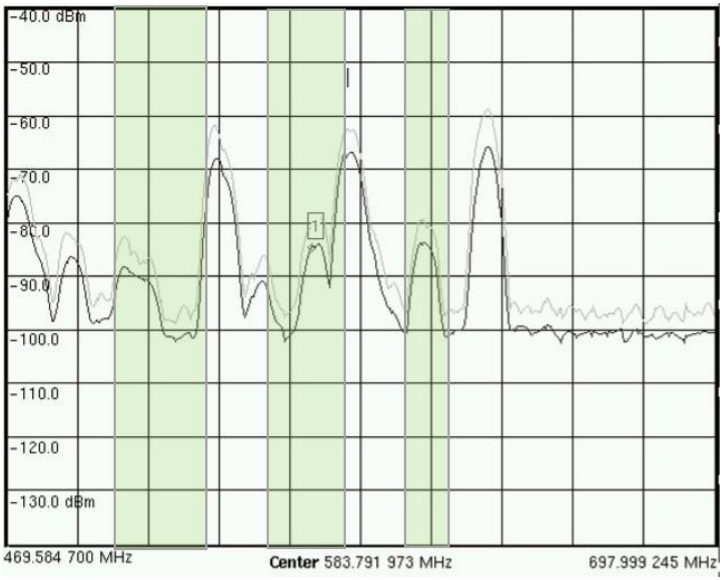


Figure 7: Hollandale, MS Spectrum Scan (Horizontal Polarization)

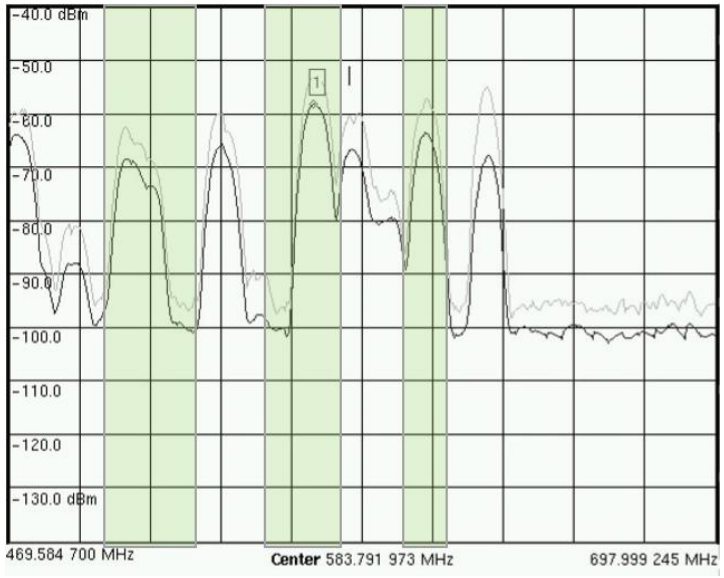


Figure 8: Hollandale, MS Spectrum Scan (Vertical Polarization)

Final Thoughts

After testing in six locations in Mississippi, some trends have started to emerge. The TVWS database is not designed to portray the actual RF environment accurately enough to make TVWS an easily accessible technology. In fact, the database is ambiguous regarding antenna polarization, heights, and even azimuths. Our spectrum scans show that the TV spectrum at various rural test sites is noisier than the TVWS database indicates. A study of what those unexpected noise sources are has not been done, although likely noise sources include TV stations (whose transmissions extend beyond their protected service contour possibly through RF ducting), out-of-band emissions from adjacent bands, harmonics from VHF and FM stations, and other unlicensed operations.

Since many of these noise sources can only be identified in-field, a more accurate database could be developed by ingesting periodic spectrum reports from TVWS equipment and provide recommendations from those reports. This sensing database would provide a more reliable report of usable spectrum and give a sense as to how well each TVWS channel will perform in the field. This would enable more efficient spectrum sharing as well as faster and more cost-effective TVWS deployment by mitigating some resource-heavy processes such as additional tower climbs and spectrum scans. Finally, a sensing database would provide more visibility into the overall availability of TVWS as a tool for rural broadband deployment and elevate its reliability for more pervasive deployment.