Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band	)	ET Docket No. 02-380
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	)	

Summary

Shared Spectrum Company agrees with the Commission's suggestion that unlicensed devices can operate in the TV band without causing significant interference to existing TV receivers in the Notice of Inquiry released December 20, 2002 in this proceeding. Specifically, the "listen-before-talk" approach described in Note 39 could reliably detect the proximity of any TV transmitters and could be used by the unlicensed device to find unoccupied channels.

The Commission should allow Unlicensed Devices to operate within the TV bands provided that they:

- Are capable of detecting TV signals at levels 25 dB below thermal noise (10 dB NF and 6 MHz bandwidth). When the Unlicensed Device detects a TV signal, then it is not allowed to use the channel. A similar measurement using a different threshold value would be used to insure that adjacent channel interference didn't occur.
- Transmit less than 1 mW using a near-omni directional antenna with a waveform with approximately uniform power density over the 6 MHz TV channel.
- Use a fence type method around the TV reception areas to transmit at higher power levels (up to 5 W).

Shared Spectrum believes that the Probing Spectrum Access Method described herein would provide the most productive results in the long term. The Commission should prepare to issue experimental secondary licenses for system testing and demonstrating of new equipment reflecting this approach with the goal of defining, on the basis of the data derived therefrom, a set of appropriate criteria for the issuance of certifications for future operation of new secondary systems on an unlicensed basis.

1 Introduction

Shared Spectrum is a newly formed company developing broadband wireless equipment optimized for secondary spectrum markets applications. As noted by the Commission[1], there is no equipment on the market now with the flexibility and capability to facilitate the use of available spectrum for a broad range of services. Our goal is to offer technology and equipment to fully realize the potential of the secondary spectrum market as rapidly as possible. The technology to accomplish this could be fielded in a few years, but regulatory issues (technical and spectrum availability) now limit its development.

Shared Spectrum has conducted extensive spectrum occupancy surveys that indicate that spectrum utilization is low in most bands, even in urban areas. We believe that the problem is access to spectrum, and not of spectrum shortage.

Shared Spectrum believes that advances in broadband wireless network technology being developed by the Department of Defense along with the Commission's Spectrum Policy Task Force's recommendations will provide a profound improvement to wireless communications over the next few years. These advances enable current and future wireless systems to avoid causing interference and to be tolerant of interference. The Task Force's concept of Interference Temperature enables dynamic, adaptive spectrum use that would solve the spectrum access problem. These new developments will lead to a very large increase in the widespread availability of high capacity wireless communications in both urban and rural regions and provide a significant cost reduction due to reduced spectrum acquisition costs. We applaud the Commission's forward thinking on this issue.

Shared Spectrum is developing adaptive methods to control transmitter power that would enable secondary use to maintain a specified Interference Temperature at the Primary transceiver. We believe our progress in this area can contribute significantly to the practical implementation of the Interference Temperature concept introduced in the SPTF report.

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[1] *Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets*, FCC 00-402, Para. 4.

2 "Listen-Before-Talk" Spectrum Access Method

2.1 Description

In the Listen-Before-Talk" (LBT) Spectrum Access Method, the Unlicensed Device measures the received power level on the channel of interest. If the received power level is less than a threshold value for a certain time period, then the channel is assumed vacant and is used.

In the broadcast bands, the fundamental LBT assumption is that the TV signal strength within the region where the Unlicensed Device might cause interference to the TV receiver is close in value to the TV signal strength measured by the Unlicensed Device (Figure 1). If the TV signal strength at the Unlicensed Device is less than the minimum TV reception value[2], then TV receivers within a certain distance[3] are not using the channel and the Unlicensed Device can use the channel without causing interference.

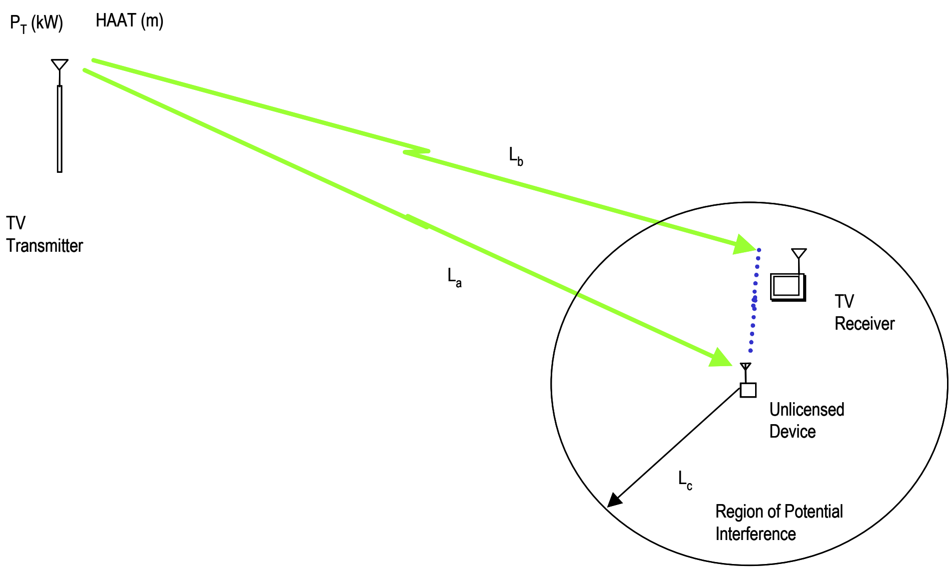

Figure 1 Unlicensed Device operates on a non-interference basis in the TV band.

The challenge with the LBT approach is that the TV transmitter-to-Unlicensed Device propagation loss will be different than the TV transmitter-to-TV receiver

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[2] The "Effective Grade B Level", i.e. the Grade B level signal for analog TV and certain field strength values for DTV.

[3] Defined to be the "Region of Potential Interference".

propagation loss. Terrain blockage, building blockage, and multi-path effects will cause the two propagation losses to be different (Figure 2). This difference is largely a function of the distance between the Unlicensed Device and the TV receiver, and on the obstacles in close proximity to the Unlicensed Device and the TV receiver.

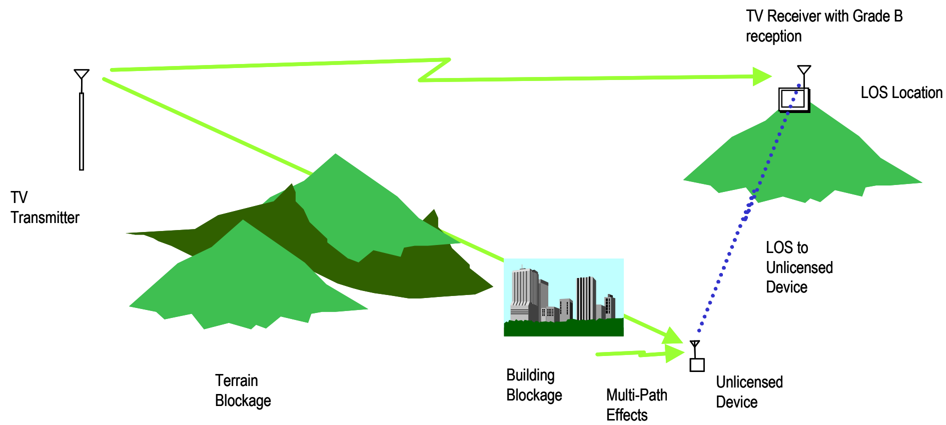

Figure 2 In some cases, the TV transmitter-to-Unlicensed Device propagation loss will be different than the TV transmitter-to-TV receiver propagation loss due to terrain blockage, building blockage, and multi-path effects.

2.1.1 Terrain Blockage Propagation Effects

The terrain blockage propagation effects can be estimated using the Longley-Rice computer model and terrain elevation information.[4] Figure 3 shows the terrain contours of a region centered on the state of Virginia used for the following calculations. This area contains a wide variety of terrain including mountainous regions and relative flat areas.

[4] FCC OET Bulletin 69, Longley-Rice Methodology for Evaluating TV Coverage and Interference, July 1997.

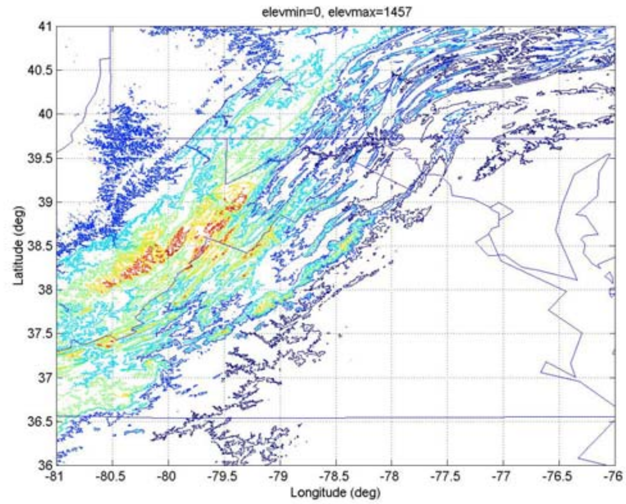

Figure 3 Terrain contours of a region centered on Virginia used for TV propagation loss estimates.

Figure 4 shows the locations of several representative TV channel 36 transmitters along with their transmit power and antenna height as obtained from an older FCC data base. Also shown are two hundred test reception points equally spaced along 0.1^{o} of longitude (approximately 8 km) that represent potential Unlicensed Device and TV receiver locations. Each used an antenna height of 3 meters. The test reception point location was selected randomly to be within the scenario area, and many such locations were examined as part of this study.

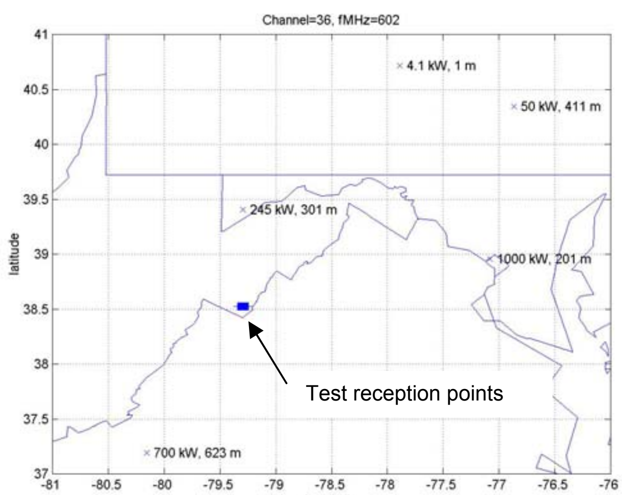

Figure 4 Channel 36 TV broadcast stations and test reception locations.

Figure 5 shows the received power level at the test reception points from the two strongest TV stations at this position. The horizontal axis is the distance from the first reception point to the other reception points. At the 2 km position, one of the TV station's signal level is above the "Effective Grade B" limit and then within a few hundred meters distance drops more than 30 dB to a value below the noise level. Many of the randomly selected test reception points included 10-30 dB type drops within a few hundred meters distance. Large propagation changes in less than 100 meters distance changes were rare.

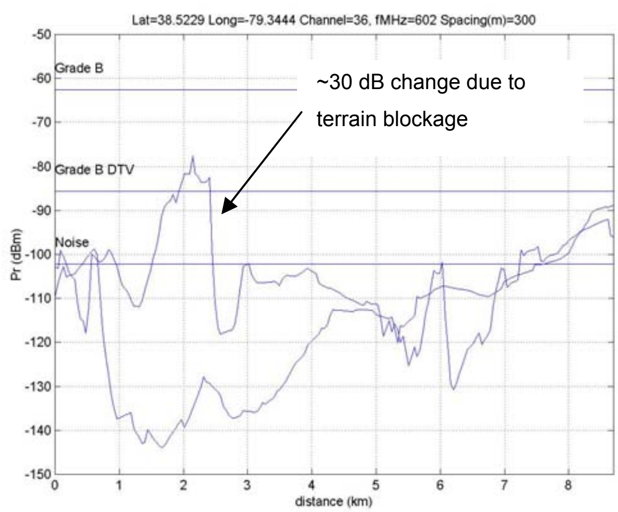

Figure 5 Received power level from two TV stations at different test point locations.

2.1.2 Building Blockage Effects

Propagation losses due to building penetration and shadowing have been measured extensively. A survey of the literature indicates that shadowing losses are approximately 10 dB and building penetration losses are approximately 10 dB to 20 dB.[5] These losses are not as large as the terrain blockage effects.

2.1.3 Multipath Propagation Effects

We assume that in conditions with high propagation losses, that the multi-path effects can be described by Rayleigh statistics.[6] In this case, fading due to multipath

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[5] See for example W.J. Tanis and G.J. Pilato, "Building penetration characteristics of 880 MHz and 1922 MHz radio waves" IEEE Veh. Technol. Conf. Proc., 1993, pp 206-209.

[6] Mobile Communication Design Fundamentals, Second Edition, W.C.Y. Lee, Wiley and Sons, 1993.

with amplitude loss greater than 20 dB occurs less than 1% of the time. These losses are not as large as the terrain blockage effects.

This type of fading is not stationary due to the dynamic changes in the propagation environment. If the Unlicensed Device sampled the signal multiple times or slightly varied the center frequency, then the probability that multiple measurements would have large multipath propagation losses is much less than 1%.

2.2 Determining the Threshold Value and Maximum Unlicensed Device Transmit Power Level

Two methods can be used to mitigate the uncertainty in the differential propagation losses described above.

2.2.1 Unlicensed Device Threshold Level

One method is to reduce the threshold where the Unlicensed Device determines that the channel is available from the minimum TV reception level[7] to a lower signal level. Figure 6 shows typical values of the power levels of interest based on recent FCC generated information.[8] The minimum DTV signal strength is –81 dBm, which is approximately 15 dB above the thermal noise level.

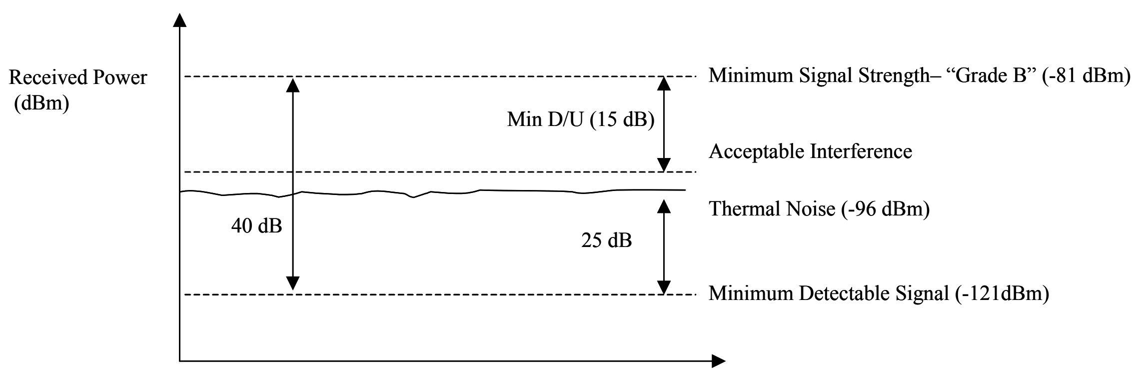

Figure 6 The use of non-linear detection algorithms provides 40 dB of differential propagation loss allowance (Minimum Signal Strength – Minimum Detectable Signal).

We believe that if the Unlicensed Device is limited to detecting TV signals at the noise level, then the TV transmitter-to-Unlicensed Device propagation loss will be large

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[7] The Effective Grade B level.

[8] Table 3, FCC OET Bulletin 69, Longley-Rice Methodology for Evaluating TV Coverage and Interference, July 1997.

enough compared to the TV transmitter-to-TV receiver propagation loss that a significant number of interference "events" will occur.

However, we believe that if the Unlicensed Device can detect TV signals below the noise level, then the probability of interference "events" is greatly reduced. Figure 6 shows that if a method to provide 25 dB of additional sensitivity was used, then 40 dB of differential propagation loss could exist, and the Unlicensed Device could more reliably detect the presence of TV signals and, thus, avoid "interference events".

Detecting signals below the noise level can be done using techniques used by military direction finding (DF) equipment. Figure 7 shows a feature detector's performance (output SNR versus input SNR) for different integration times and a 1.25 MHz BW BPSK signal[9]. The feature detector allows reliable detection (output SNR ~ 10 dB) of signals with –25 dB input SNR if a long integration time is used. The long integration time (~ 1 sec) and high computation load are not critical in most Unlicensed Device applications because they are not mobile scenarios and the above signal measurement needs to made very infrequently.

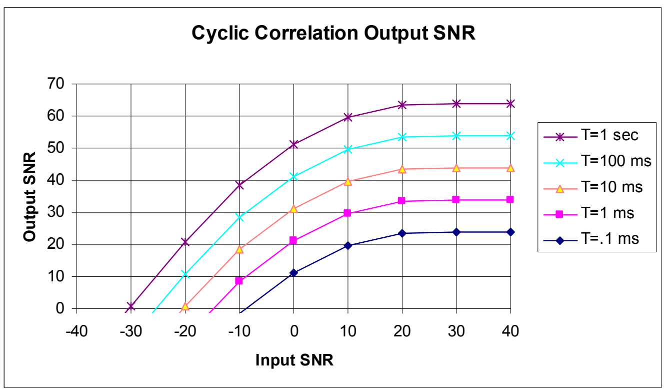

Figure 7 Input SNR vs. Output SNR using a second order non-linear detector against a 1.25 MHz BW BPSK signal with a 1.25 MHz noise BW.

2.3 Unlicensed Device Interference Range

The other method to mitigate the uncertainty in the differential propagation is to limit the Unlicensed Device to a low transmit power level. If the Unlicensed Device's signal can propagate with large amplitude over large distances (10's of kms), then the

[9] While the DTV signal does not use BPSK modulation and has a different bandwidth, these results are representative.

probability of the terrain blockage causing the TV transmitter-to-Unlicensed Device propagation loss to be different than the TV transmitter-to-TV receiver propagation loss becomes high. In about half the cases of our study, there was a 40 dB change in propagation across the 8 km distance used for the test reception points in the simulation. The number of cases with 40 dB changes over shorter distances was much less. Thus, we believe that the Unlicensed Device's "interference range" needs to be limited to approximately 1 km for the LBT method to work well.

Figure 8 shows the received power versus range for a 1 mW transmitter using an obstructed terrain propagation model[10] and in free-space. The power level of thermal noise with a 10 dB NF and 6 MHz bandwidth is shown. We believe the joint probability of the Unlicensed Device being at a location with line-of-sight for several kilometers and having unusually high propagation loss to the TV transmitter is low. Thus, the obstructed propagation model is most applicable, and the 1 mW transmitter power limit would limit the interference range to less than 1 km.

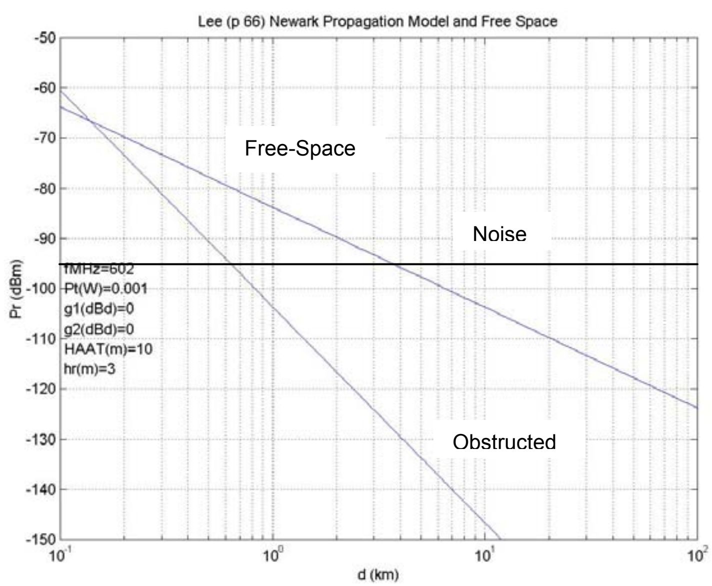

Figure 8 Received power versus distance (in km) of a 1 mW transmitter at 602 MHz (channel 26) signal in obstructed conditions and in free-space.

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[10] Mobile Communication Design Fundamentals, Second Edition, W.C.Y. Lee, Wiley and Sons, 1993.

3 Probing Spectrum Access Method

The Probing Spectrum Access Method (PSAM) uses multiple Unlicensed Devices to collaboratively determine each node's maximum transmit power to avoid interference with TV receivers. This method overcomes the dominant weakness of the LBT Method, which is that it can only be used at very transmit power levels (< 1 mW). The Probing Spectrum Access Method would allow a networked system to operate at high power levels (watts) and would enable long-range (~15 km) wireless communications in the TV bands.

3.1 Description

To allow high transmit power levels, PSAM determines an Unlicensed Device's maximum transmit power level by estimating the propagation loss (including antenna gains) to certain locations or to all TV receiver nodes in the area. Propagation models could be used, but inaccuracies and uncertainties would require prohibitively conservative transmit power levels to avoid interference.

The PSAM approach is shown in Figure 9 (left) where a sparse fence of "receive-only"[11] nodes is located along the perimeter of the TV receiver area to be protected. Each Unlicensed Device's node sends a brief, very low power "probe" signal to the receive-only nodes using a unique code, the received signal levels are measured in parallel, and the received amplitude is returned to the Unlicensed Device node if it exceeds a threshold. The propagation loss for each path is then found by comparing the received value (or a threshold value if no message was returned) to the probe transmit power level. The propagation loss to all of the TV receiver nodes is then assumed to be equal to or greater than the minimum of the loss to the small number of receive-only nodes.

A simulation of this process shows this assumption works well and that only a few receive-only nodes are required. Using an allowable interference of –100 dBm to the TV receiver receivers and six receive-only nodes, the maximum Unlicensed Device transmit power at many distant locations surrounding a TV transmitter was determined. Then the interference caused by the Unlicensed Device system to a large number (100) of TV receiver nodes randomly located near the broadcast transmitter was found. The simulation uses the Longley Rice propagation model and digital terrain maps of West Virginia to provide realistic propagation estimates in "hilly" terrain.

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[11] These nodes receive-only in the frequency band of interest but transmit in another band.

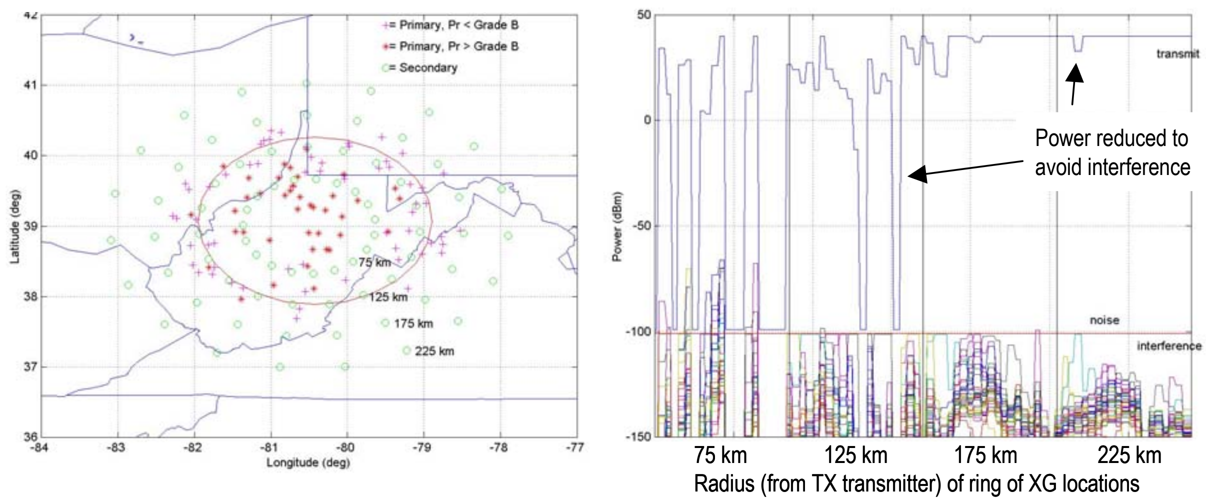

Figure 9 (Left) Propagation loss to a large region is estimated by measuring propagation loss to few "receive-only" nodes. (Right) Simulation results show the Unlicensed Device's transmit power and resulting interference to all TV receivers versus distance from the TV receiver TX.

Figure 9 (right) shows the Unlicensed Device transmit power versus Unlicensed Device node location and the multiple lower curves show the interference to all of the TV receiver nodes. The Unlicensed Device locations were in four rings spaced 75 km, 125 km, 175 km and 225 km from the TV transmitter. In the 75 km ring, the Unlicensed Device power is often set at very low values (low values indicating minimal spectrum sharing) and the interference values occasionally exceed the -100 dBm noise level. In this case the algorithm made mistakes because more receive-only nodes are required at close ranges. At these close distances, a the LBT rule would be used (not implemented in this simulation) to prohibit Unlicensed Device operation. At larger ring distances (125 km, 175 km, and 225 km) large transmit power values occur more frequently and there is no interference, indicating that spectrum sharing would be useful.

3.2 Probe Waveform

The probe waveform must be transmitted at very low power to avoid causing unacceptable interference, and must be readily detectable by the Unlicensed Devices. Using spreading and special waveforms, this can be accomplished.

4 Recommendations

Our analysis indicates that the Commission should allow Unlicensed Devices to operate within the TV bands provided that they:

- Are capable of detecting TV signals at levels approximately 25 dB below thermal noise (10 dB NF and 6 MHz bandwidth). When the Unlicensed Device detects a TV signal, then it is not allowed to used the channel. A similar measurement using a different threshold value would be used to insure that adjacent channel interference didn't occur.

- Transmit less than 1 mW using a near-omni directional antenna with a waveform with approximately uniform power density over the 6 MHz TV channel.
- Use a fence type method around the TV reception areas to transmit at higher power levels (up to 5 W).

The Probing Spectrum Access Method should be pursued. The first step in implementation of that policy would be the issuance of experimental secondary licenses for the conduct of experiments and demonstration to establish appropriate criteria for the issuance of equipment certifications on a system basis to permit general use of such equipment on an unlicensed secondary basis. Initial tests would use the TV bands, but on the basis of those results, could later be expanded to other appropriate spectrum bands.

Respectfully submitted,

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