Analysis of FCC Phase I Sharing Report Out of Band Emissions for UNII Adjacent and Next Adjacent Channel Power

Introduction.

The FCC released their **Phase I Testing of Prototype U-NII-4 Devices** (TR 17-1006) in October of 2018. That report contains a wealth of information that FCC did not analyze; this information provides insight into the potential for sharing between Unlicensed National Information Infrastructure (U-NII) devices and other users of the band, including those using it for transportation safety. This white paper examines a subset of the adjacent channel information available from that report in order to assess the potential for interference to the immediately adjacent channel and the next adjacent channel.

The proposed rules would allow unlicensed national information infrastructure (U-NII) devices to operate directly adjacent to Dedicated Short Range Communications (DSRC) channel 180 and only 10 MHz away from Long Term Evolution (LTE) Cellular Vehicle to Everything (LTE-C-V2X) in the band below these channels. In the band above these channels, FCC proposes that U-NII operate immediately adjacent to LTE C-V2X and 20 MHz from DSRC channel 180. Figure 1 illustrates the proposed band plan in the NPRM.

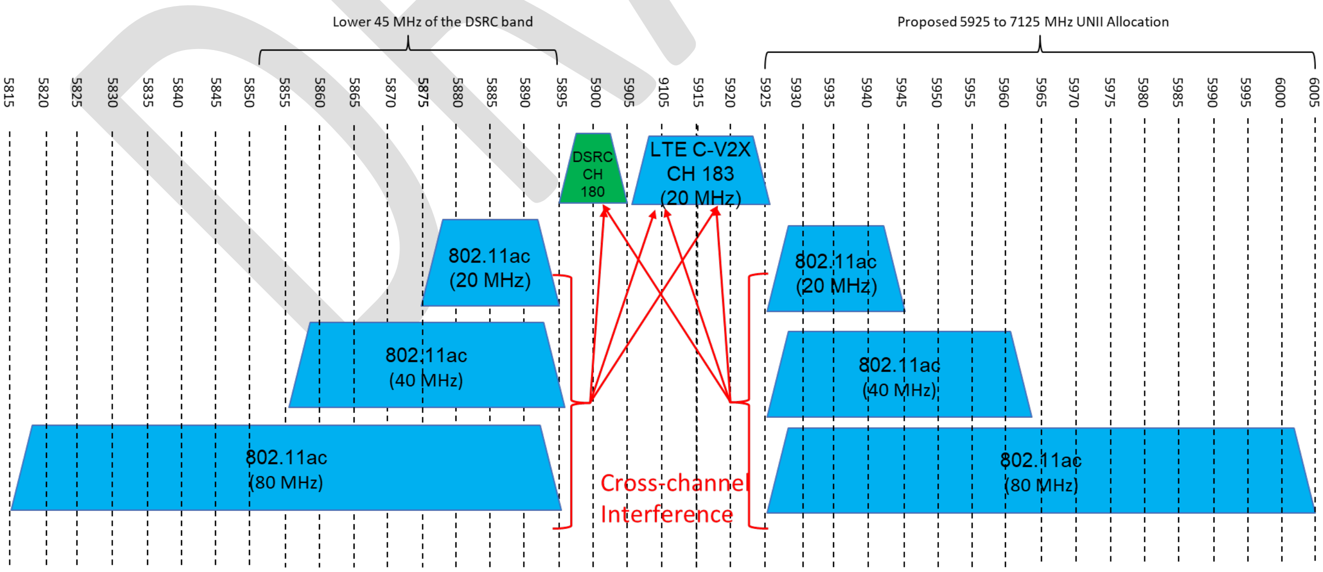

Figure 1. Proposed Channel Configuration

Process

The FCC's Phase 1 report provides Out-of-Band Emissions (OOBE) from the U-NII devices and DSRC devices tested. Appendix B.2 addresses both average channel power (ACP) and Out of Band Emission (OOBE) test results. Figure 2 is a copy of Figure 125 from the FCC **Phase I Testing of Prototype U-NII-4 Devices**.

The FCC report offers all the details of the test configuration. US DOT will not repeat that information here. What US DOT does describe is the OOBE into both the adjacent 10 MHz channel and the 20 MHz channel above that, as well as the OOBE into the 10 MHz and 20 MHz channels below per Figure 1, which represent the two V2X channels of interest. To be clear, the goal is to understand the impacts of surrounding the proposed safety band with U-NII devices that meet current regulatory emission regulations. In looking at Figure 2:

- Marker 1R is the power at 5875 MHz while 1Δ is the integrated power from 5875 MHz to 5895 MHz.
- Marker 2R is the power at 5855 MHz while 2Δ is the integrated power from 5855 MHz to 5875 MHz.
- Marker 3R is the power at 5895 MHz while 3Δ is the integrated power from 5895 MHz to 5915 MHz.

Since the FCC did not specifically integrate the power in the proposed revision to the Safety Band, US DOT interprets what the FCC provides. For the analysis, US DOT looked at the power leakage into DSRC channel 180 and LTE C-V2X channel 183 from a U-NII interferer both above and below these two bands.

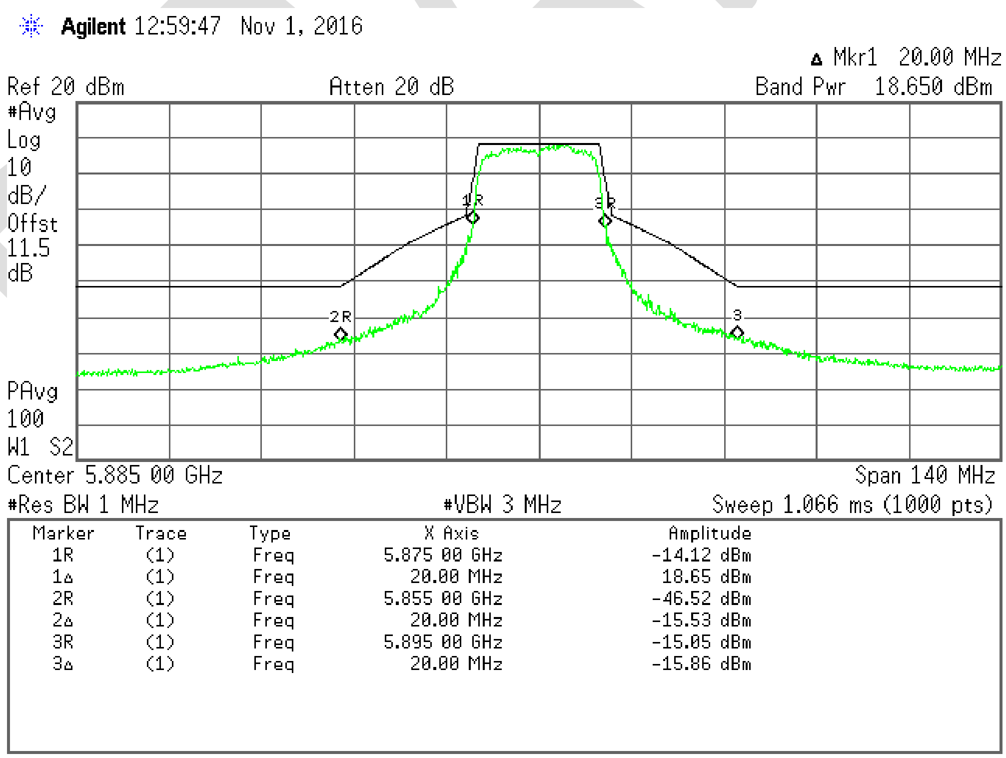

Figure 2. Figure 125 from the FCC Phase I Testing of Prototype U-NII-4 Devices

Since we know the energy in the 20 MHz below channel 177, we will use that as the basis to determine the process for calculating the power present.

Using a discrete integration technique, we can now analyze the area under a curve with a series of rectangles, trapezoids, etc. and then complete a Riemann summation to estimate integration. By extending this process to infinitely thin rectangles, the Riemann summation converges to the integral definition. Starting with a single set (see figure 3), we know the fixed locations of the edge of the 20 MHz channel and the point 20 MHz below that:

- 5875 MHz -14.12 dBm
- 5855 MHz -46.52 dBm

These are the points at the center top of the rectangles shown in Figure 2.

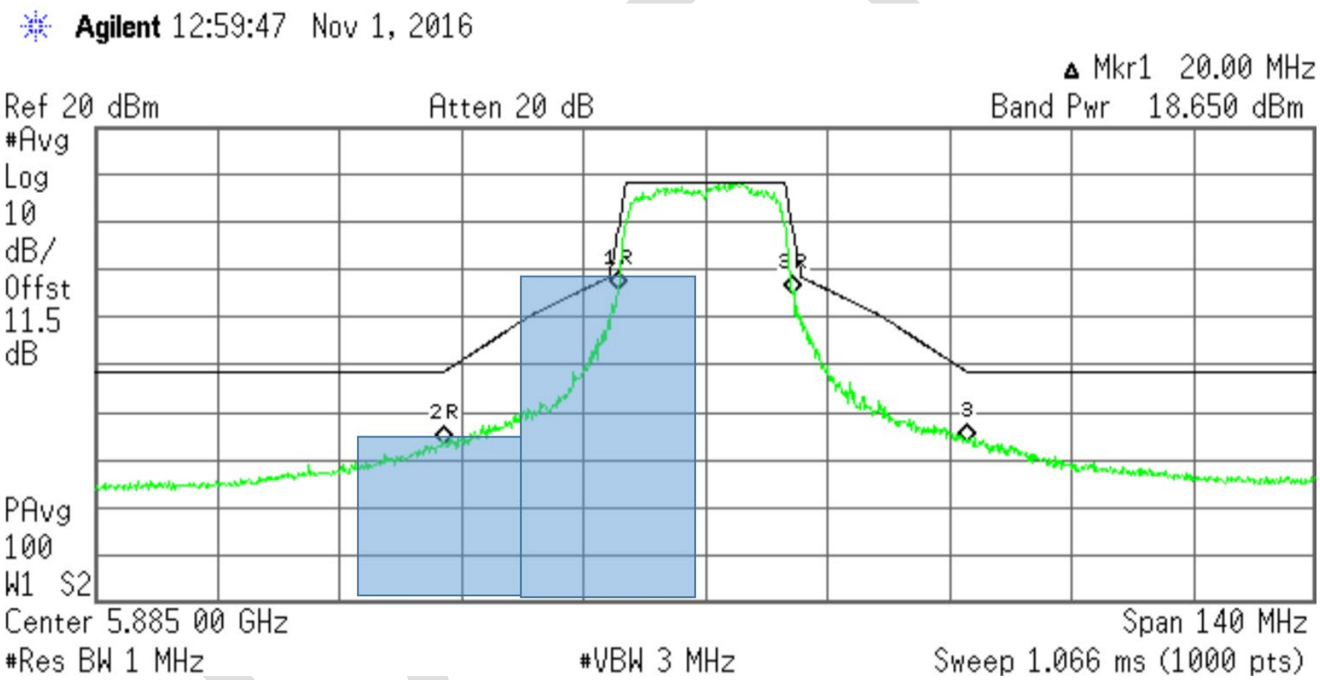

Figure 3. Visual description of a numerical integration technique.

The power indicated corresponds to dBm per the bin of the frequency over which it was measured. Thus:

At 5875 MHz, -14.2 dBm is -14.2dBm/1 MHz since the resolution bandwidth is set to 1 MHz.

-14.2 dBm = 3.87e-2 mW/1 MHz

Similarly, at 5855 MHz, -46.52 dBm is -46.52dBm/1 MHz

-56.52 dBm = 2.23e-5 mW/1 MHz

Using a trapezoidal summation to ensure only the power within the band is considered:

$$\sum_{n=1}^{L-1} \frac{H(n) + H(n+1)}{2} * \Delta f$$

Given that there are only two points in this summation (L=2), the summation becomes:

$$\frac{H(5875) + H(5855)}{2} * 20\ MHz$$

$$\frac{3.87e - 2mW/1MHz + 2.23e - 5mW/1MHz}{2} * 20\ MHz = 0.387\ mW\ or - 4.12\ dBm$$

This is a large overestimate due to the large spacing between the points used. However, as we reduce this spacing, the error decreases, ultimately converging on the true value with an infinitely small spacing. Byy reading points from Figure 2, using on the order of 30 rectangles, the calculation comes out to -16.2 dBm, within a dB of the measured -15.53 dBm, which is sufficient for a first interpretation.

We could delve further and define further areas, but to keep it simple, we use this approximation with the understanding that to obtain a precise value, we would need to take the device back to a lab and re-measure the power spectrum. While that step should be taken, it is important to note how much information is in the Phase 1 report that the FCC did not analyze. Figures 125 through 164 offer insight into adjacent channel energy with multiple devices and multiple Modulation Coding Schemes (MCS). In formulating a new band plan, the FCC will need to analyze this type of information to determine the amount of energy present in the proposed limited safety band to assess the impact to safety.

It is possible to step through all the Phase 1 plots and provide data for our approach. We used Python to further analyze figure 125 as well as figure 129 (a 40 MHz channel) and figure 130 (an 80 MHz channel). In each case, US DOT used the summation of the three previously measured bands of known power to ensure the summation was accurate prior to integrating over the proposed bands. Table 1 provides the critical information. Figure 4 provides the same information through an illustration.

Table 1. Results of discrete integration of data available from FCC Phase I Testing of Prototype U-NII-4 Devices.

	Energy in DSRC Channel 180	**Energy in LTE C-V2X Channel 183**
20 MHz U-NII below proposed new safety band	-14.25	-31.31
20 MHz U-NII above proposed new safety band	-38.98	-16.19
40 MHz U-NII below proposed new safety band	-13.88	-18.97
40 MHz U-NII above proposed new safety band	-27.37	-15.95
80 MHz U-NII below proposed new safety band	-18.9595	-23.3333
80 MHz U-NII above proposed new safety band	-29.999	-18.78

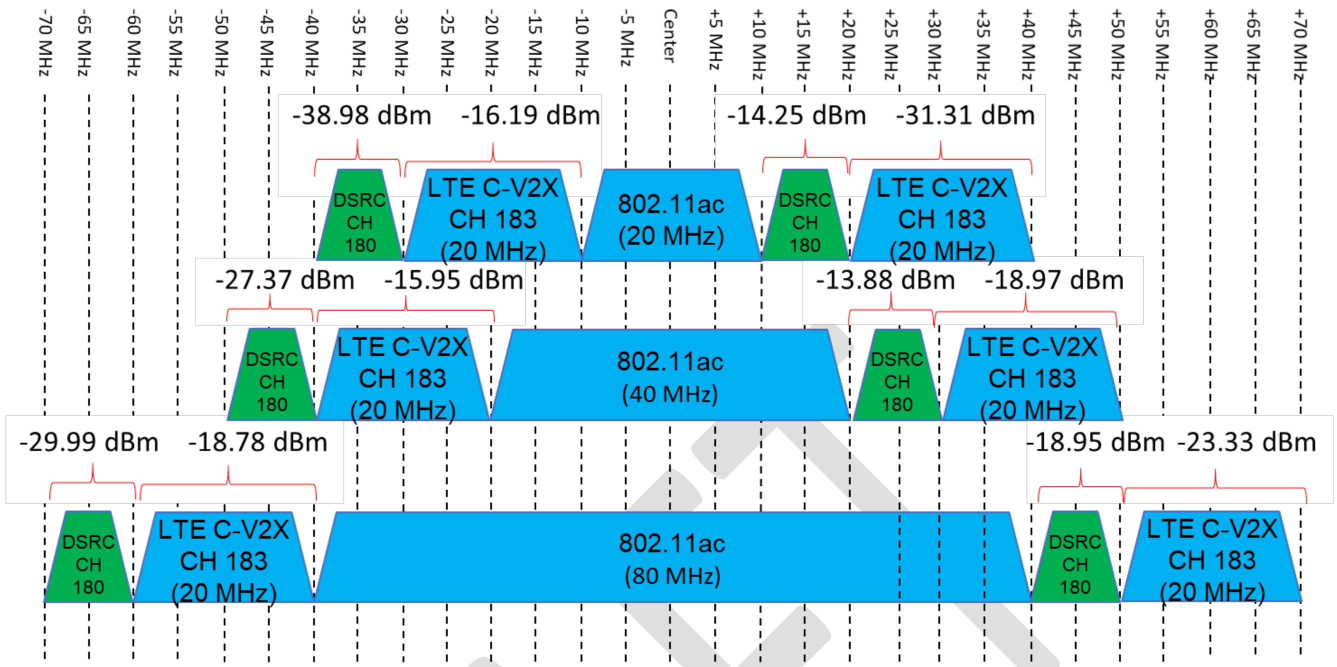

Figure 4. Visual presentation of Table 1.

It should be noted that accuracy in this analysis in the absence of raw data is limited by the accuracy of reading data points from the plot and, while we used a program to ensure these were as accurate as possible, the accuracy should not be assumed to be better than 1 dB. This is especially true for the energy in channel 183 from an 80 MHz U-NII device directly above the channel (the lower right value in table 1). The power in this band is dominated entirely by the entrance power to the band that occurs in the middle of an extremely sharply sloped region. When translated to a linear scale, this is amplified further. The result is that errors in reading points from the plot in this region are amplified in the final summation. However, even in this worst-case scenario for this analysis, the estimated value is still within 2dB of the measured value of the spectrum analyzer in all measured cases, and less than 1dB in most cases.

Observations

It is important to note that the 10 MHz and 20 MHz channels proposed for transportation safety critical applications could see interference from above and below if both proposed allocations become regulation. This analysis does not consider combining these two potential interference sources but it is important to note that actual interference is likely to be worse than suggested by the values provided here.

Interference into adjacent channels is dominated by the portion of the channel closest to the interfering source. LTE C-V2X monitors sub-channels for energy/use and can identify sub-channels that are not seeing as much energy and prioritize those. Although this would work well in an underloaded channel, in a channel near capacity, the devices must transmit at the channel edge or the channel will be underutilized. Note that LTE C-V2X also uses a technique that automatically retransmits data within 15 *m*sec of the original transmission (known by the acronym HARQ)which may aid in reducing interference at the cost of channel efficiency. Both techniques (sub-channel selection and HARQ) may create more reliability in the communication link, but it is unclear if that is sufficient to support low-latency and high availability data flows. This is particularly true in a high vehicle density environment.

It is also worth noting that LTE C-V2X is synchronous while U-NII is asynchronous. We currently do not know how well the C-V2X devices will avoid collisions if the OOBE interference is a randomly time-gated signal. For example, the interference may only occupy sub-frame (SF) 7 for several frames, leading an LTE C-V2X device to think SF 8 is free and schedule itself there. But nothing is forcing the UNII device to use SF 7 and it may transmit within SF 8 on the next LTE C-V2X frame.

DSRC looks at energy across the channel, utilizing the time domain to avoid collisions, and may suffer more from adjacent channel interference. Similar results are found in the US DOT's white paper, **Impairing Safety from Changes in the Safety Band: Introduction from Unlicensed** Users (included as Appendix B.1). The results provide the analysis of adjacent channel interference and quantify the impact to the cooperative-ITS safety transmissions.

Conclusion

Using the U-NII channel bandwidths that were presented in the FCC's Phase I sharing report, US DOT examined potential OOBE interference into the adjacent 10 MHz and 20 MHz channels that the FCC has suggested could serve all transportation low-latency, high availability needs. It is clear, based on material available to the FCC, that there is insufficient evidence that these safety critical channels will be clear of interference from U-NII devices. The full impact will not be known unless a full technical assessment is completed. The FCC has not adequately analyzed data it has available to ensure the purpose for establishing spectrum to support transportation will be available for that purpose.