UNITED STATES DEPARTMENT OF COMMERCE
National Telecommunications and
Information Administration
Washington, D.C. 20230

October 10, 2023

VIA ELECTRONIC FILING

Marlene H. Dortch, Secretary
Federal Communications Commission
45 L Street, NE
Washington, DC 20554

Re: Unlicensed Use of the 6 GHz Band (ET Docket No. 18-295);
Expanding Flexible Use in Mid-Band Spectrum between 3.7 and 24 GHz (GN Docket No. 17-183)

Dear Ms. Dortch:

By this letter, the National Telecommunications and Information Administration (NTIA) submits for the record in the above-referenced proceeding[1] the results of testing by the U.S. Department of Transportation (DOT) regarding the effect on Cellular Vehicle-to-Everything (C-V2X) operations from unlicensed 6 GHz Very Low Power (VLP) portable devices and mobile access points, in those same vehicles trying to receive C-V2X signals. Based upon this testing, NTIA and DOT urge the Commission to set the out-of-band emission (OOBE) limit for VLP portable devices at -37 dBm/MHz (at 5.925 GHz) ***and*** to prioritize unlicensed operations in channels above 6 GHz. This proposal is similar to one previously submitted by industry stakeholders.[2]

NTIA and DOT hope that both C-V2X and 6 GHz unlicensed operations are successful services, but we are concerned that permitting OOBE at -27 dBm/MHz, as contemplated in the *Order and Further Notice*, would cause harmful interference to C-V2X safety operations in the adjacent 5.895-5.925 GHz band where crash-avoidance applications require low latency to provide timely safety alerts to drivers. We also note that, if, in the future, the Commission provides additional in-channel power flexibility for VLP devices operating inside vehicles, then the corresponding OOBE limit to protect intelligent transportation systems (ITS) would need to be reconsidered.

[1] *See Unlicensed Use of the 6 GHz Band*, ET Docket No. 18-295, Report and Order and Further Notice of Proposed Rulemaking, 35 FCC Rcd 3852 (2020) (*Order and Further Notice*).

[2] *See* Letter from Broadcom Inc., Facebook, Inc., Intel Corp., Cisco Systems, Inc. and Qualcomm Inc., to Marlene Dortch, Secretary, FCC (Mar. 1, 2021) (on file in ET Docket No. 18-295, https://www.fcc.gov/ecfs/document/10301179588420/1).

We have attached for your review a DOT technical exhibit describing the C-V2X testing. NTIA encourages the adoption of the proposed rules as soon as possible, but we recognize that the Commission may want additional time for consideration of the C-V2X results being submitted here.

Please let me know if we can provide any further information.

Sincerely,

Charles Cooper
Digitally signed by Charles Cooper
Date: 2023.10.10 13:20:38 -04'00'

Charles Cooper
Associate Administrator
Office of Spectrum Management

U.S. DOT TECHNICAL EXHIBIT[1] ON PROTECTION OF THE V2X 30 MHz (5.895-5.925 GHz) Band

Unlicensed Use of Very Low Power (VLP) Portable Devices and Mobile Access Points in the 6 GHz Band
Report and Order and Further Notice of Proposed Rulemaking
ET Docket No. 18-295; GN Docket No. 17-183[2]

Background: After issuing a Report and Order and Further Notice of Proposed Rulemaking (FNPRM) in 2020 to open the 6 GHz (5.925 – 7.125 GHz) band to Wi-Fi and other unlicensed uses, the Federal Communications Commission (FCC) is working towards finalizing rules that would allow very low powered (VLP) portable devices[3] and mobile access points to use the entire 6 GHz band (5.925 – 7.125 GHz); specifically, including the channels in the lowermost portion of the U-NII-5 band that are directly adjacent to the 5.9 GHz band (5.905 – 5.925 GHz) dedicated for intelligent transportation services (ITS). This Technical Exhibit presents test results demonstrating the potential interference to Cellular Vehicle-to-Everything (C-V2X) receivers caused by out-of-band emissions (OOBE) from VLPs and mobile access points operating inside a vehicle to impact C-V2X communications.

To mitigate the potential for interference from U-NII OOBE, incorporate the rules proposed in the two-part compromise submitted to the FCC by ITS stakeholders in March 2021[4], which requires any device operating under 6 GHz rules to meet an out-of-band emission level of -37 dBm/MHz equivalent isotropically radiated power (EIRP) at 5.925 GHz and to prioritize unlicensed operations in channel above 6.000 GHz (note: the proposed mitigation does not apply to fixed outdoor access points or indoor low power access points).

Importance of Out-of-Band Emission (OOBE) Limits for Transportation Safety

The out-of-band emissions (OOBE) limit proposed in the FNPRM for VLP devices has the potential to bleed emissions into the adjacent 5.895 – 5.925 GHz channels allocated for Cellular Vehicle-to-Everything (C-V2X) transportation safety, which could lead to harmful interference to safety-of-life operations. Deployers plan to transmit basic safety messages for crash-avoidance applications that require low-latency, free-from-harmful-interference in these adjacent channels.

- Without strict emission limits and prioritization criteria for devices operating in the 6 GHz band (5.925 – 7.125 GHz), the proposed rule could lead to VLP portable devices and mobile access points carried inside a vehicle to bleed into the adjacent ITS band when choosing and using immediately adjacent U-NII-5 channels. In particular, OOBE limit of -27 dBm/MHz EIRP proposed by the FCC could affect the 20 MHz channel (5.905 – 5.925 GHz) where deployers have received FCC waivers to begin deploying applications that require low-latency performance for safety-critical transportation services.[5] While testing shows the -27 dBm/MHz OOBE EIRP limit may be acceptable for traditional access points and clients, if that limit is allowed for VLP devices or mobile access points that can be carried inside vehicles, it will impact C-V2X communications due to the continued proximity and insufficient isolation between the U-NII and C-V2X antennas.

---

[1] At the request of the NTIA, the US DOT Office of the Assistant Secretary for Research and Technology prepared this technical exhibit related to US DOT test activities relevant to ET Docket No. 18-295.
[2] Unlicensed Use of the 6 GHz Band, ET Docket No. 18-295; Expanding Flexible Use in Mid-Band Spectrum between 3.7 and 24 GHz, GN Docket No. 17-183: https://www.federalregister.gov/documents/2020/05/28/2020-11320/unlicensed-use-of-the-6-ghz-band
[3] VLP devices can be carried into vehicles and used for mobile hotspots and device-to-device connections to enable streaming media services. Other applications of VLP may include portable gaming systems and virtual reality headsets.
[4] Broadcom, Cisco, Facebook, Intel, and Qualcomm: OOBE-limit-Compr Letter 3 1 2021.pdf (fcc.gov).
[5] *Use of the 5.850-5.925 GHz Band*, ET Docket No. 19-138, First Report and Order, Further Notice of Proposed Rulemaking, and Order of Proposed Modification, 35 FCC Rcd 13440 (2020), petitions for review denied sub nom. Intelligent Transp. Soc'y of America v. FCC, 45 F.4th 406 (D.C. Cir. 2022) (5.9 GHz First R&O).

- U.S. DOT testing shows out-of-band emissions from a portable device operating inside a vehicle at the proposed -27 dBm/MHz OOBE limit on the bottom of the U-NII-5 band (5.925 GHz) does not provide enough protection for ITS services operating in the adjacent 5.905-5.925 GHz channels. Testing shows the *range at which C-V2X devices can effectively communicate was reduced by more than 50% in the presence of OOBE*, particularly in non-line-of-sight scenarios that pose a significant safety threat at intersections. With 300 meters being the ideal range for safety applications to recognize a threat and issue a safety warning, U-NII interference from adjacent channels could reduce that range to as little as 25 meters, such that C-V2X alerts are too late for a driver or automated vehicle to react and stop in time, even at low speeds (less than 25 mph). Additional information on U.S. DOT testing can be found in Attachment 1; the limitations to C-V2X communications range are described in Table 1.
- U.S. DOT test results confirm the conclusions from testing conducted by the Crash Avoidance Metrics Partners, LLC (CAMP) Cellular C-V2X Device-to-Device Communication Consortium (C-V2X Consortium) in 2020.[6] The 5G Automotive Association (5GAA) has also filed concerns that a -27 dBm/MHz OOBE EIRP limit for portable devices does not provide adequate protection to the adjacent 5.9 GHz band.[7] The 2020 FNPRM noted that 5GAA proposed prohibiting VLP operations inside a vehicle from operating in the lowermost U-NII-5 channel.
- While both U.S. DOT and the C-V2X Consortium testing evaluated an OOBE mask representative of U-NII-4 operations in the 5.9 GHz band, the results can be translated to assess the impact of similar OOBE levels generated by portable U-NII-5 devices. As radio emissions are symmetric in nature, the test results from simultaneous operation of U-NII-4 and C-V2X devices in the same vehicle are directly applicable to analysis of U-NII-5 band interference. U.S. DOT is conducting further analysis using a U-NII-5 waveform that meets the flat -27 dBm EIRP OOBE limit in a lab setting; initial results show significant degradation to C-V2X receiver sensitivity.
- The duty cycles used in taking the measurements were shown to be realistic. Popular streaming applications download and buffer data upfront and then have periodic bursts to replenish the buffer. Mobile hotspots, in particular, have very high duty cycles over a span of several seconds. Because C-V2X uses 1 millisecond sub-frames, the U-NII duty cycle does not map directly to the percent of C-V2X sub-frames affected. For a simplified example, a U-NII interferer burst in which 1000 packets of 150 microseconds and 1 millisecond (ms) gap between transmissions will consume 150 ms of airtime over 1150 ms period, which is a duty cycle of 13%. However, each of the 1000 packets would interfere with as many C-V2X sub-frames. Thus, 1000 of the 1150 C-V2X subframes would be interfered with, leading to 87% percent of the sub-frames affected.
- If in future rulemaking proceedings, the Commission provides additional in-channel power flexibility for VLP devices operating inside vehicles, then the corresponding OOBE limits to protect ITS services should be reconsidered.
- Additional data from U.S. DOT testing is available upon request.

[6] See Cellular V2X Device-to-Device Communication Consortium, Task 8: Assessment of Wi-Fi Interference to C-V2X Communications Based on Proposed FCC 5.9 NPRM (Sept. 28, 2020) ("C-V2X Consortium V2V/V2I Report") (attached as Attachment 1), https://pronto-corecdn.prontomarketing.com/2/wp-content/uploads/sites/2896/2020/09/CAMP-CV2X-WiFiInterference-Testing-Results-v6.11.3.pdf.

[7] See, e.g., 5GAA Dec. 9, 2019 *ex parte* letter; 5GAA Jan. 9, 2020 *ex parte* letter; and 5GAA Jan. 24, 2020 *ex parte* letter, all filed in ET Docket No. 18-295.

Proposed Mitigation to Protect Adjacent C-V2X Services

In March 2021, several companies reached a two-part compromise to jointly support VLP operations throughout the entire 6 GHz (5.925 – 7.125 GHz) band, and sent a letter to the FCC encouraging the Commission to implement OOBE and prioritization rules to protect adjacent ITS operations[8]. The proposed compromise is as follows:

1. VLP devices shall comply with an out-of-band emissions level of -37 dBm/MHz[9] EIRP measured using a root mean square (RMS) detector function at 5.925 MHz, and
2. LP devices shall prioritize unlicensed operations in channels above 6.105 GHz[10] [i.e., the top edge of the first 160 MHz wide channel in the IEEE band plan] before beginning operation below 6.105 GHz. Manufacturers shall submit with their application for equipment authorization a declaration that the equipment complies with this prioritization rule.

- **Both parts of the proposed mitigation are essential to protect ITS services.** While prioritization of VLP devices in channels above 6.000 GHz provides enough separation to prevent harmful emissions from bleeding into the 5.905-5.925 GHz channels, in cases when VLP devices are unable to prioritize operations and instead operate in channels directly adjacent to the 5.9 GHz band, they would pose a significant risk to C-V2X with an OOBE level of -27 dBm/MHz instead of the proposed -37 dBm/MHz EIRP measured using an RMS detector function at 5.925 GHz.

[8] Broadcom, Cisco, Facebook, Intel, and Qualcomm: OOBE-limit-Compr Letter 3 1 2021.pdf (fcc.gov).

[9] Major world regions and countries have acknowledged the need to provide additional protection of C-V2X band and have adopted the -37 dBm/MHz parameters for VLPs. The European Union, comprised of 27 countries, adopted a level of -45 dBm/MHz below 5.935 GHz, which may be adjusted to -37 dBm/MHz in 2025 following additional protection studies (See Table 2 in ECC decision 20(01) (Available at: ECC Decision (20)01 (cept.org)) and Table 2 in the Annex to EC 6 GHz harmonisation decision (Available at: 6GHz harmonisation decision: more spectrum available for better and faster Wi-Fi | Shaping Europe's digital future (europa.eu)). Japan has adopted a -37 dBm/MHz level below 5.925 GHz, and Korea has adopted a level of -34 dBm/MHz below 5.925 GHz (Reference available at Countries Enabling Wi-Fi in 6 GHz (Wi-Fi 6E) | Wi-Fi Alliance).

[10] After additional analysis, U.S. DOT and other ITS stakeholders have determined that a lower bound of 6000 MHz is acceptable.

Attachment 1

U.S. DOT C-V2X Test Summary

Beginning in October 2020, U.S. DOT initiated an examination of the C-V2X technology incorporated in the FCC's 2020 decision to reallocate 45 MHz of the 75 MHz within the 5.9 GHz band to non-transportation services, while requiring ITS services to initially operate using Long-Term Evolution (LTE) (4G)-V2X.[11] The intent of this assessment was to test the radio performance of commercially-available C-V2X devices under challenging, "edge" use case conditions—the type of conditions that result in some of the most common and fatal vehicle crashes.

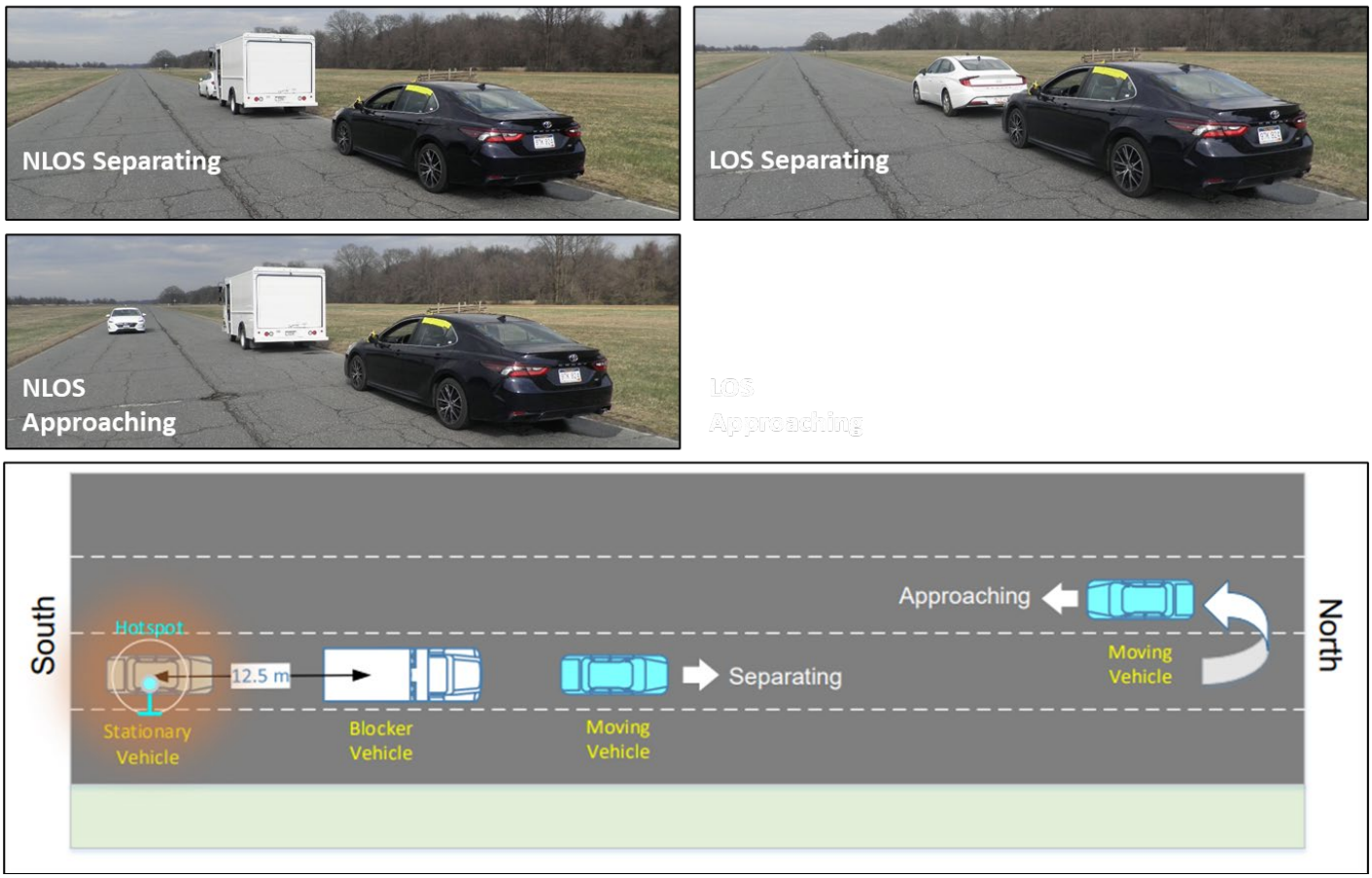
- Pertinent to the 6 GHz ruling, U.S. DOT, in collaboration with industry partners, set out to understand the performance of C-V2X communications in the presence of a portable U-NII hotspot operating inside a vehicle. A closed field test was conducted using two vehicles and a blocking truck to test both line-of-sight (LOS) and non-line-of-sight (NLOS) situations. Both vehicles were equipped with C-V2X devices, with one of the two vehicles containing a signal generator to mimic a U-NII-4 waveform operating in the adjacent unlicensed portion of the 5.9 GHz band (5.815 – 5.895 GHz). While the vehicle equipped with the signal generator remained in place, the other vehicle drove away (shown as separating in the summary statistics below) and toward (approaching) the equipped vehicle at moderate speed (~25-35 mph). Communications performance was measured by tracking the number of packets sent and received between the two C-V2X devices inside the vehicles (Packet Error Rate), along with the time interval between successive packet receipts.
- U.S. DOT testing shows an in-vehicle U-NII device using an 80-MHz waveform at -27 dBm/MHz OOBE will bleed into the adjacent channels and cause significant degradation of V2X performance. When using C-V2X as a sensor, there is a finite amount of time from when the event occurs to when it is presented to the driver. Any additional delay caused by interference will impact the amount of time the system has to sense the safety-critical issue, process a message, and have the driver or automated vehicle react in time. The range at which C-V2X devices can effectively communicate was reduced by more than 50%. In NLOS situations when the communications path was blocked by a truck, the effective range was reduced to as little as 25 meters.

Table 1: V2X Communications Range with Packet Error Rate <= 10%

Line-of-Sight (LOS) vs Non-Line-of Sight (NLOS)	***UNII Interferer OFF***	**UNII-4 Interferer ON (CH 171) (Windows Up)**	**UNII Interferer ON (CH 171) (Windows Down)**	**Worst Case Range Reduction**
LOS	895 m	395 m (approaching) 495 m (separating)	375 m (approaching) 355 m (separating)	**520 m** **(-58.1%)**
NLOS	345 m	215 m (approaching) 35 m (separating)	155 m (approaching) < 25 m (separating)	**190 m** **(-55%)**

[11] https://www.fcc.gov/ecfs/search/search-filings/filing/11202021603352

Test Vehicle Orientations



Test Parameters

Each vehicle was equipped with a C-V2X device set to the following parameters:

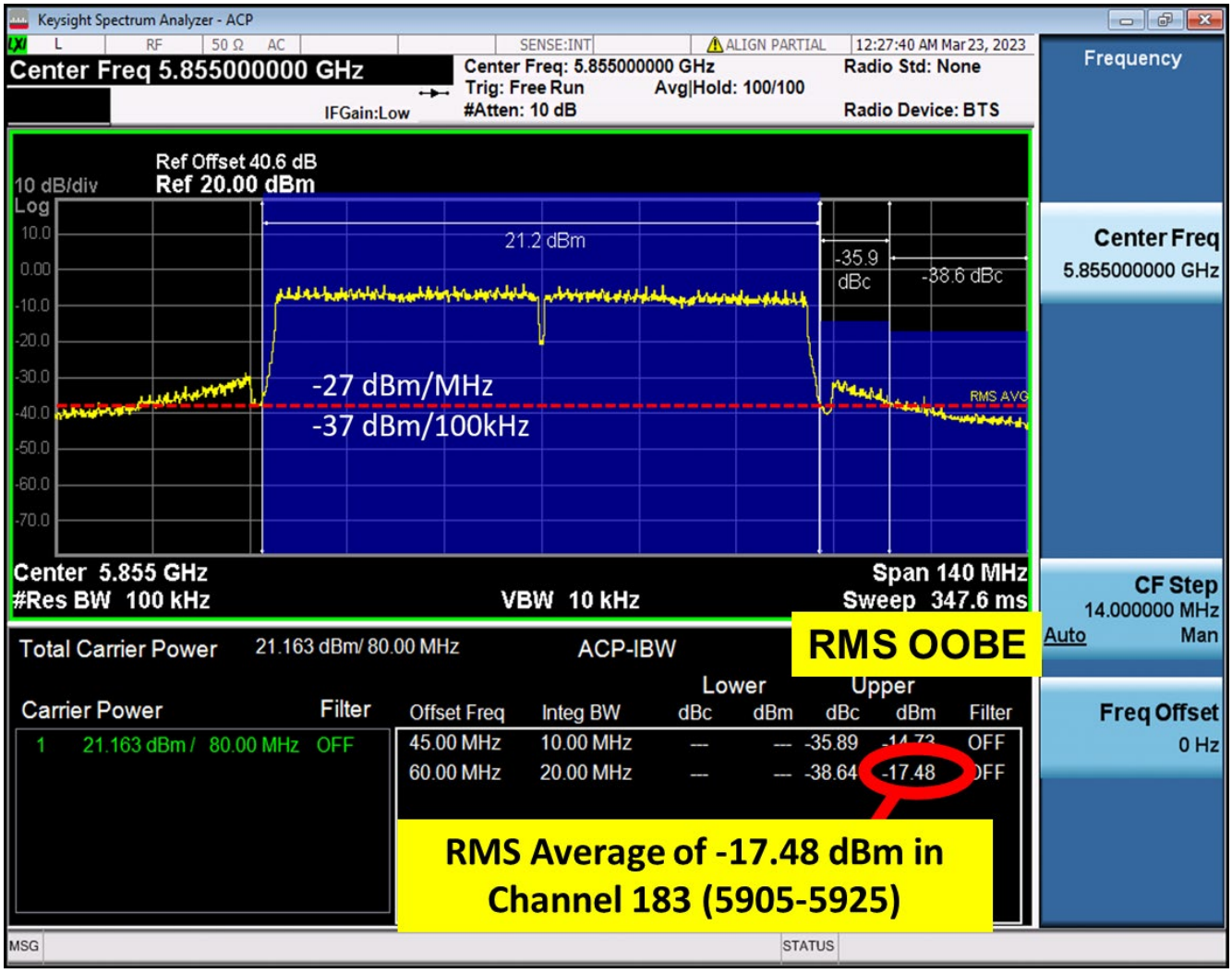
- Channel 183 (20 MHz)
- Transmit Power: 20 dBm
- Message Size: 365 Byte
- Inter-Transmit Time: 100 ms
- Sub-Channel Size: 10

Without access to commercial U-NII-4 or U-NII-5 devices, U.S. DOT used a signal generator to create a U-NII waveform to mimic a mobile hotspot operating in the unlicensed portion of the 5.9 GHz band. The waveform was set to the following parameters:

- 80 MHz (Channel 171) Bandwidth 802.11ac signal
- In-Channel (171) Transmit Power of 21.2 dBm
- Out-of-Band-Emission (OOBE) Power Level in Channel 183 of -17 dBm
- Duty Cycle of 70%[12]

[12] It is important to consider the duty cycle from VLPs and mobile hotspots in terms of seconds when considering the impact to ITS services that require basic safety messages to be transmitted at least nine times per second to provide timely, low-latency information for safety-critical applications.

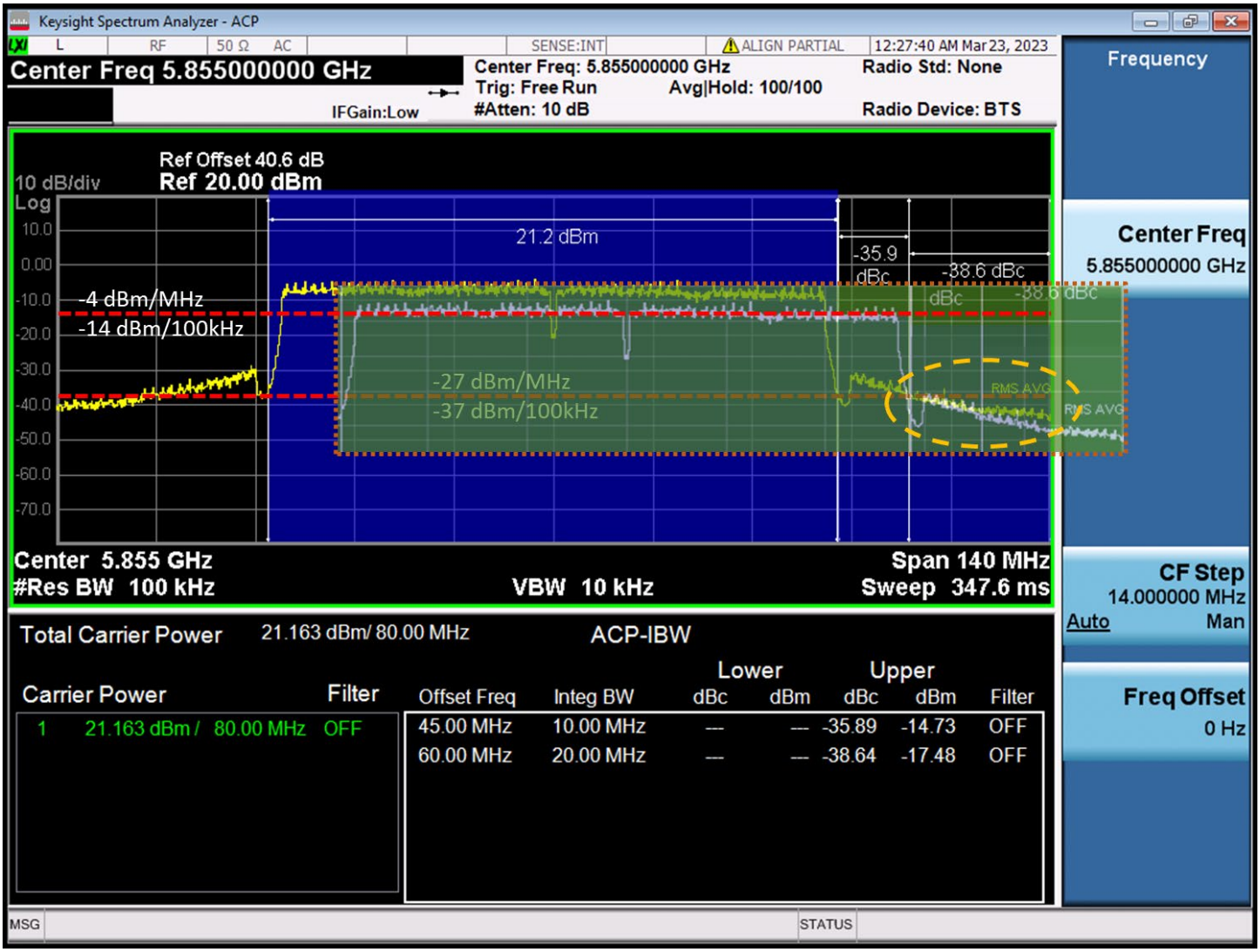
A screenshot of the waveform used in testing is shown in the diagram below. The root-mean square (RMS) measurement of the mobile interferer was -17.48 in Channel 183 (where ITS communicates basic safety messages), which equates to approximately -30.48 dBm/MHz, close to the limit proposed in the 6 GHz order. This is an RMS capture that has a different resolution bandwidth than the U-NII-5 mask but converting it to the same 1 MHz bandwidth results in approximately this limit. This interferer was also verified to conform in Channel 183 to the *overall -27 dBm/MHz limitation proposed by the FCC*[13] and believed to be insufficient (noting the proposed industry compromise of -37 dBm/MHz and prioritizing operation above 6 GHz).



The waveform used in USDOT testing (and shown above) accounts for 10-MHz of separation between the U-NII and Channel 183 where safety-critical C-V2X communications will be present. A U-NII-5 waveform would be directly adjacent to Channel 183 within the ITS band. To show the potential emissions impact from a UNII-5 waveform, an additional graphic is provided below. This graphic shows that even with the power spectral density reduced by approximately 6-7 dB (to align to the proposed power limits of VLPs), there is still expected

[13] Further analysis using a U-NII-5 waveform that meets the flat -27 dBm limit is underway in a lab setting. Initial results show significant degradation to V2X receiver sensitivity.

to be a significant amount of emission in the adjacent channel. U.S. DOT measurements and testing results will be available using the U-NII-5 waveform soon.



Antenna Isolation Measurements

Antenna isolation measurements were recorded to demonstrate the amount of isolation between the C-V2X and signal generator antennas. Testing determined it was impossible to create enough isolation between the two antennas (placed in realistic locations as shown in the pictures below) to prevent harmful interference.

After collecting isolation measurements and identifying the worst-case isolation conditions, the antenna positions used in testing are described below:

- C-V2X antenna mounted on the side mirrors of the stationary vehicle, facing forward with gaffer's tape used to level the antennas on the slanted side mirrors. There were two different C-V2X antennas used between the stationary and moving vehicles.
- U-NII antenna mounted to the side passenger headrest of the stationary vehicle, oriented vertically and slightly off-center towards the driver's side.

Additional Reference Materials

U.S. DOT has conducted extensive research on the impact of out-of-band emissions (OOBE) on ITS operations. These studies provide relevant information on harmful interference from adjacent channels.

- *Analysis of 2016 Proposed Changes to Existing Out of Band Emissions (OOBE) Rules*: Adjacent Channel Interference from Unlicensed National Information Infrastructure (U-NII) Transmissions into the 5.9 GHz Wireless Access for Vehicular Environment (WAVE) Band: Microsoft Word - OutOfBandEmissions Interference Analysis MAY2018.docx (transportation.gov)
- *Preliminary Testing: Out-of-Channel Interference (Out-of-Band Emissions):* oobe-energy-59-safety-band-final-120619.pdf (transportation.gov)
- *Analysis of FCC Phase I Sharing Report: Out of Band Emissions for UNII Adjacent and Next Adjacent Channel Power:* Analysis of FCC Phase I Sharing Report_V02_04 11MARCH2020.pdf (transportation.gov)