CAMP LLC

Cellular V2X Device-to-Device Communication Consortium

CELLULAR V2X DEVICE-TO-DEVICE COMMUNICATION CONSORTIUM

C-V2X Performance Assessment Project

Task 8: Assessment of WiFi Interference to C-V2X Communication Based on Proposed FCC 5.9 GHz NPRM

April 15, 2020

List of Acronyms

Abbreviation	
SEM	Spectral Emissions Mask
OOBE	Out of Band Emissions
C-V2X	Cellular Vehicle to Everything
U-NII-4	Unlicensed National Information Infrastructure (U-NII) radio band (5850 MHz -5895 MHz) proposed by the FCC NPRM
ITS	Intelligent Transportation Systems
3GPP	3G Partnership Project
VA	Variable Attenuator
TX	Transmitter
PRX	Primary Receive
DRX	Diversity Receive
HPA	High Power Variable Attenuator
RMS	Root Mean Square
MCS	Modulation and Coding Scheme
HARQ	Hybrid Automatic Repeat Request

Task 8: Technical Scope

- Evaluate the interference from Wi-Fi operations in the U-NII-4 band to C-V2X (3GPP Rel-14, mode 4) safety communications on Channel 180 and Channel 183 based on proposed rules in the January 2020 FCC 5.9GHz NPRM
- Period of Performance: February 01, 2020 – May 31, 2020

CH 180 : 5895 MHz – 5905 MHz
CH 183 : 5905 MHz – 5915 MHz
U-NII-4(proposed) : 5850 MHz – 5895 MHz

Task 8: Testing Categories

- Wi-Fi Interference Source Characterization - Completed
- Bench Testing - Completed
- Field Testing – V2V & V2I Scenarios – Not Started

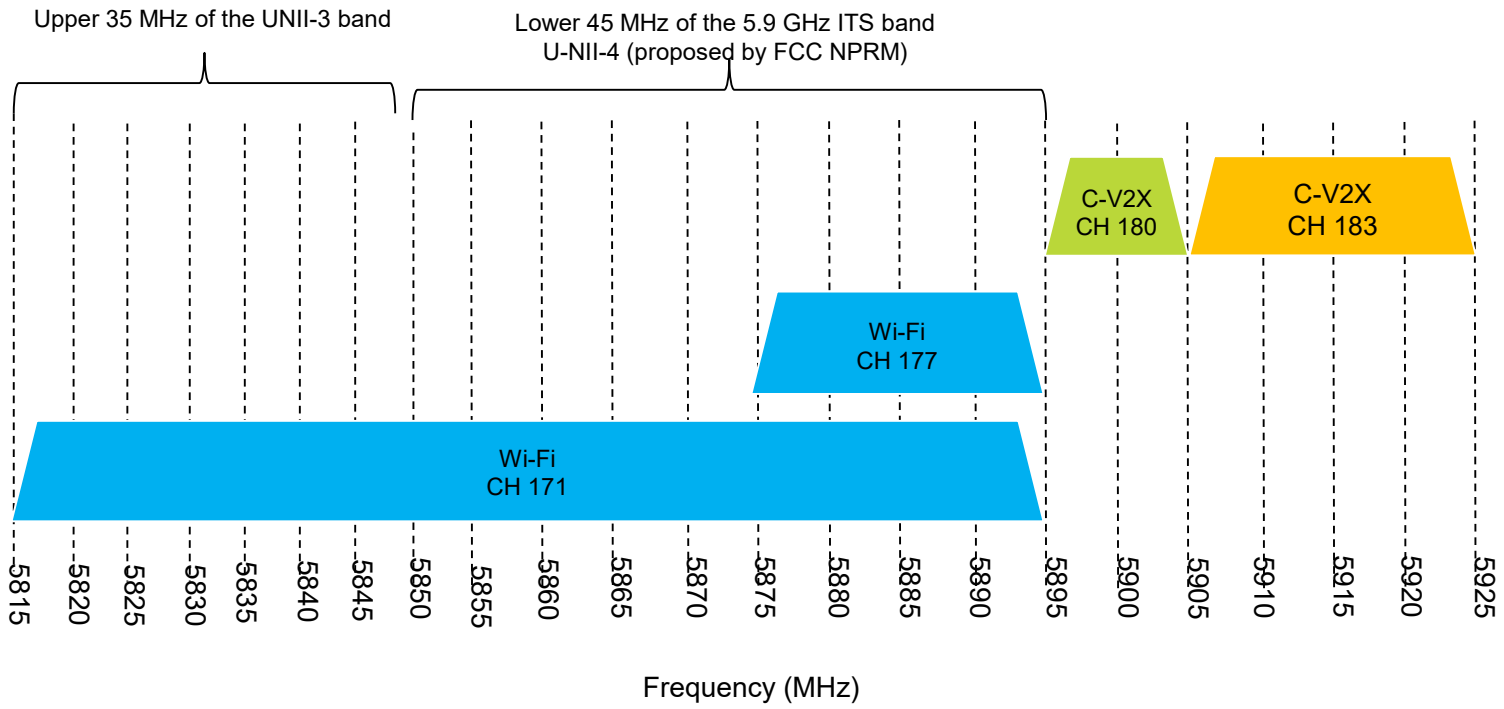
Objective Test Description

Aimed at understanding Wi-Fi interference to C-V2X system performance in CH 180 and CH 183 under these system factors:

- C-V2X Device Parameters
  - Channel bandwidth – 10 MHz (CH 180) and 20 MHz (CH 183)
  - Sub-Channel Size 10 RBs
  - 365 byte, MCS 11, 2 sub-channels, supporting V2V messages
  - 1400 byte, MCS 7, 5 sub-channels (10 MHz BW) or 10 sub-channels (20 MHz BW), supporting I2V messages
- Wi-Fi OOBE Proposal Submissions to FCC Docket
  - Proposal 1 (Link , Outdoor Operation)
  - Proposal 2 (Link, Indoor Operation)
- Wi-Fi Parameters
  - 20 MHz (CH 177) and 80 MHz (CH 171) Bandwidth Wi-Fi 802.11ac signal

Proposal 1: https://www.fcc.gov/ecfs/filing/1030974615271
Proposal 2 : https://ecfsapi.fcc.gov/file/10309096401111/5GAA Comments (3-9-2020).

Wi-Fi and C-V2X Channels Used



C-V2X Device Parameters

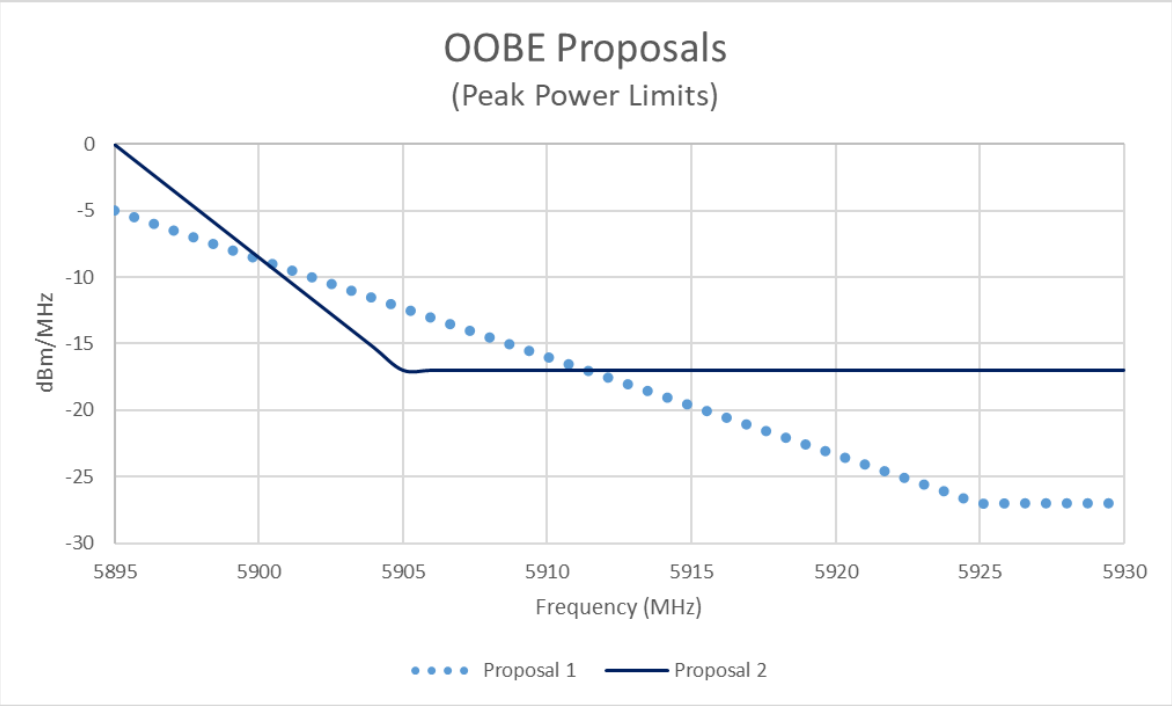
	20 MHz (CH 183)		10 MHz (CH 180)	
Packet Size	MCS	Num Sub Channels	MCS	Num Sub Channels
365	11	2	11	2
1400	7	10	7	5

Sub-Channel Size = 10 Resource Blocks (RB)
HARQ Enabled

Note1: The parameters are subject to change pending future implementations and/or standards recommendations
Note2: Please see Appendix for C-V2X Device used for testing

Wi-Fi Interference OOBE Proposals

- Proposal 1 (Link)
  - Linearly drawn to match
    - -5 dBm/MHz at 5895 MHz
    - −27 dBm/MHz >= 5925 MHz
  - Outdoor Operation
- Proposal 2 (Link)
  - Linearly drawn to match
    - 0 dBm/MHz @ 5895 MHz
    - -17 dBm/MHz @ 5905 MHz
    - -17dBm/MHz > 5905 MHz
  - Indoor Operation



- Note
  - All Masks drawn for Peak Levels

Proposal 1: https://www.fcc.gov/ecfs/filing/1030974615271
Proposal 2 : https://ecfsapi.fcc.gov/file/10309096401111/5GAA Comments (3-9-2020).pdf

Wi-Fi Interference Sources

- 802.11ac U-NII-3 Devices Modified to work in U-NII-4 band
  - 20MHz U-NII-4 operation to asses impact to CH 180
    - Wi-Fi CH 177 (5875 MHz – 5895 MHz)
  - 80MHz U-NII-4 operation to assess impact to CH 183
    - Wi-Fi CH 171 (5815 MHz – 5895 MHz)

- Signal Generator with Generated 802.11ac waveform
  - Maximize OOBE to the extent possible under allowed proposals
    - 20 MHz (CH 177) waveform targeted for Proposal 2 mask
    - 80 MHz (CH 171) waveform targeted for Proposal 1 mask

Wi-Fi Interference Device Characterization

- Characterize OOBE emissions of the Wi-Fi interference sources w.r.t the OOBE proposals being considered. Namely:
  - Proposal 1
  - Proposal 2

- Characterize interference (rms power) in CH 180 and CH 183 from U-NII-4 operation for the different proposals

Interference Device Characterization Procedure

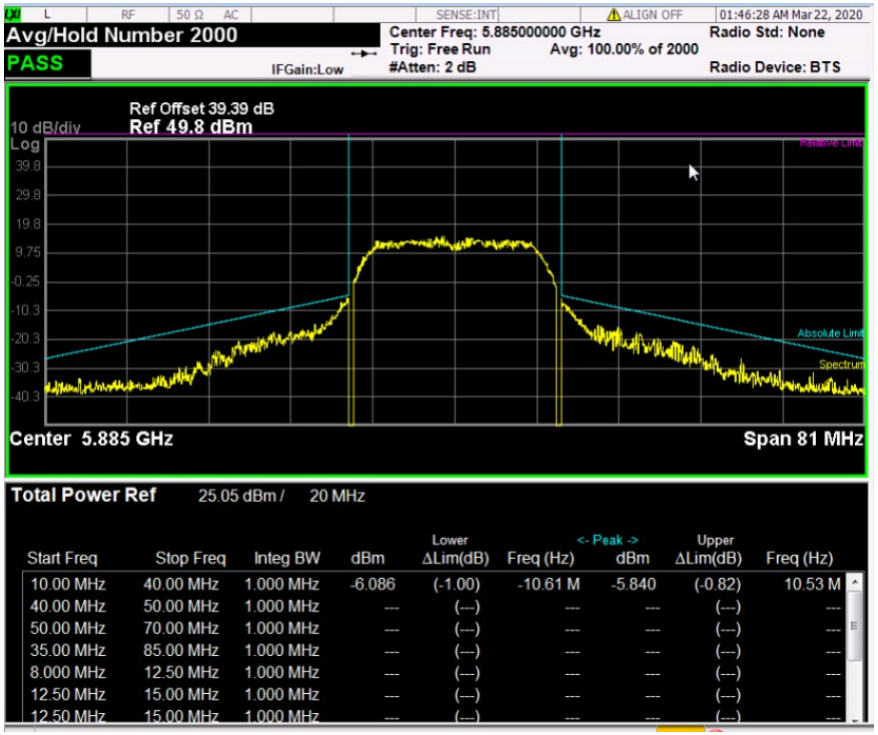
- Configure the interference device to comply with the OOBE proposal for each test
- Verify that the OOBE meet the Spectrum Emission Mask (SEM) on the spectrum analyzer (as per Slide 8)
  - In addition, setup the spectrum analyzer with the following key settings: Res BW: 1 MHz, Max Hold, Peak Detector, RF Burst Capture
- Set the Tx power of the interferer to maximum possible power while still meeting the SEM under test
- Note interference (rms power) in CH 180 and CH 183

Device Characterization

Wi-Fi Interferer	Wi-Fi BW (MHz)	OOBE Proposal
802.11ac Devices	20	Proposal 1 (Outdoor)
802.11ac Devices	80	Proposal 1 (Outdoor)
802.11ac Devices	20	Proposal 2 (Indoor)
802.11ac Devices	80	Proposal 2 (Indoor)
Generated 802.11ac Waveform	80	Proposal 1 (Outdoor)
Generated 802.11ac Waveform	20	Proposal 2 (Indoor)

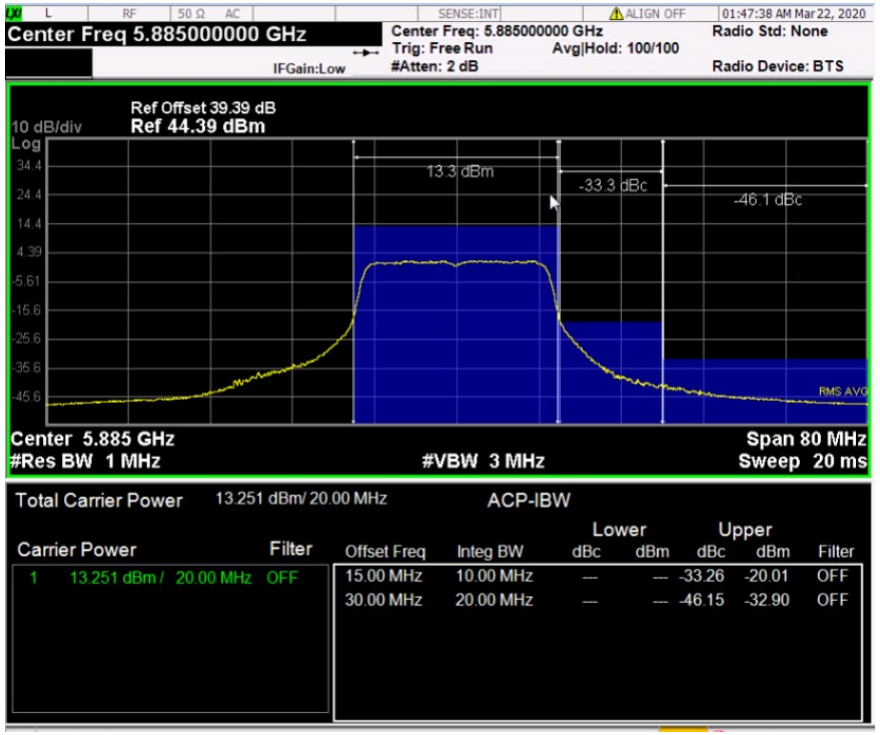
802.11ac Devices, CH 177 (20 MHz) – TX Power Adjusted to Meet Proposal 1 Mask

OOBE - Proposal 1 SEM (Proposed)



Key Settings: Res BW: 1 MHz, Max Hold, Peak Detector

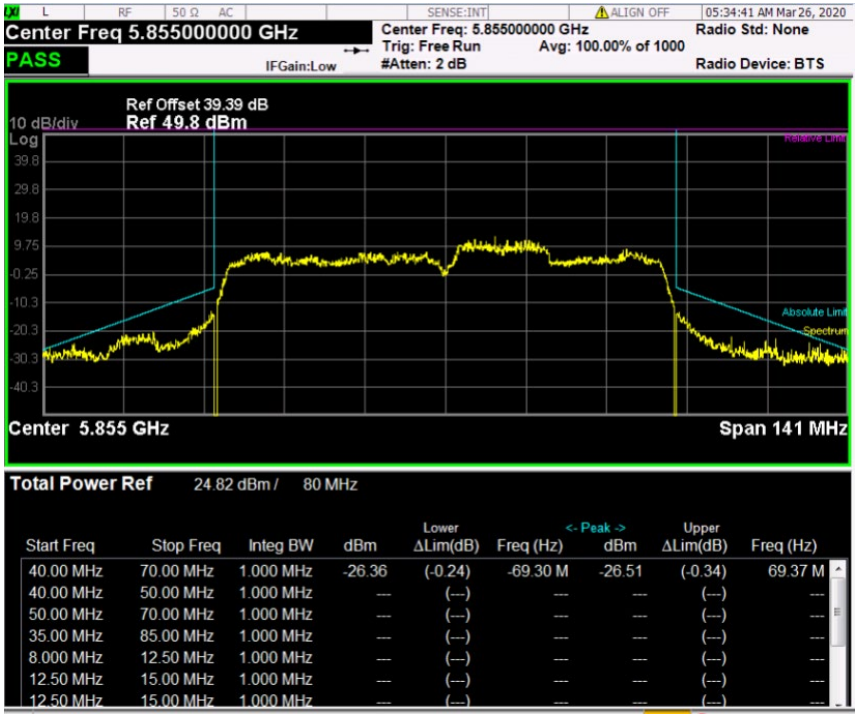
Average RMS Power measured in CH 180 and CH 183



Key Settings: Avg Detector, RMS Avg

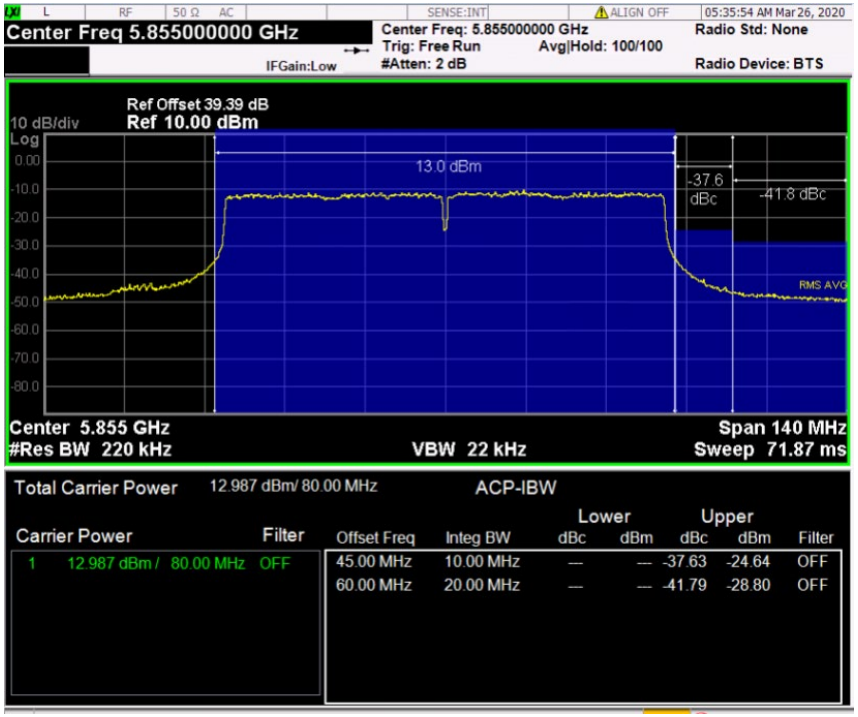
802.11ac Devices, CH 171 (80 MHz) – TX Power Adjusted to Meet Proposal 1 Mask

OOBE - Proposal 1 SEM (Proposed)



Key Settings: Res BW: 1 MHz, Max Hold, Peak Detector

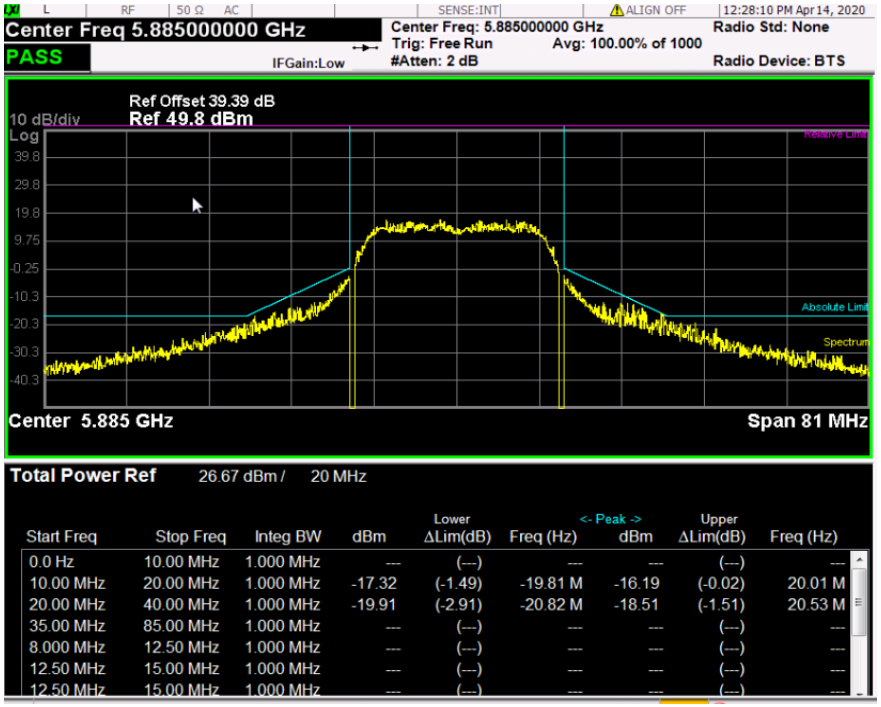
Average RMS Power measured in CH 180 and CH 183



Key Settings: Avg Detector, RMS Avg

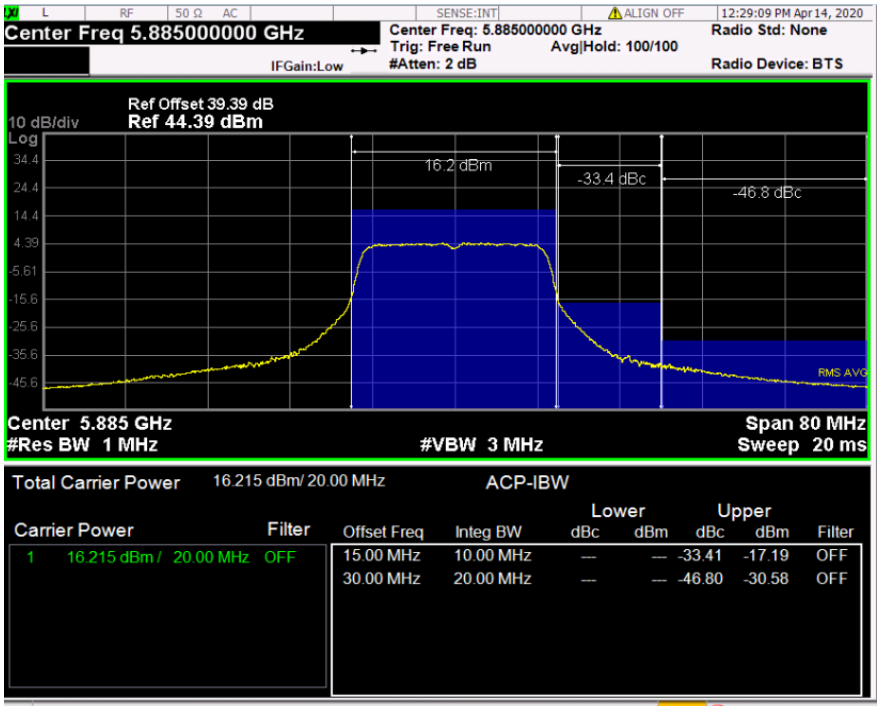
802.11ac Devices, CH 177 (20 MHz) – TX Power Adjusted to Meet Proposal 2 Mask

OOBE - Proposal 2SEM (Proposed)



Key Settings: Res BW: 1 MHz, Max Hold, Peak Detector

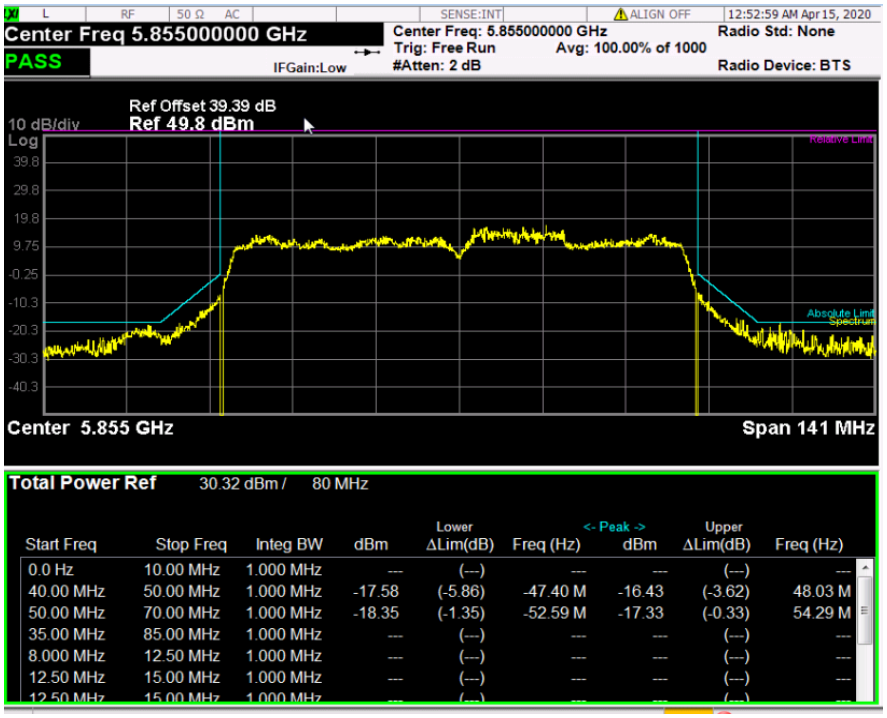
Average RMS Power measured in CH 180 and CH 183



Key Settings: Avg Detector, RMS Avg

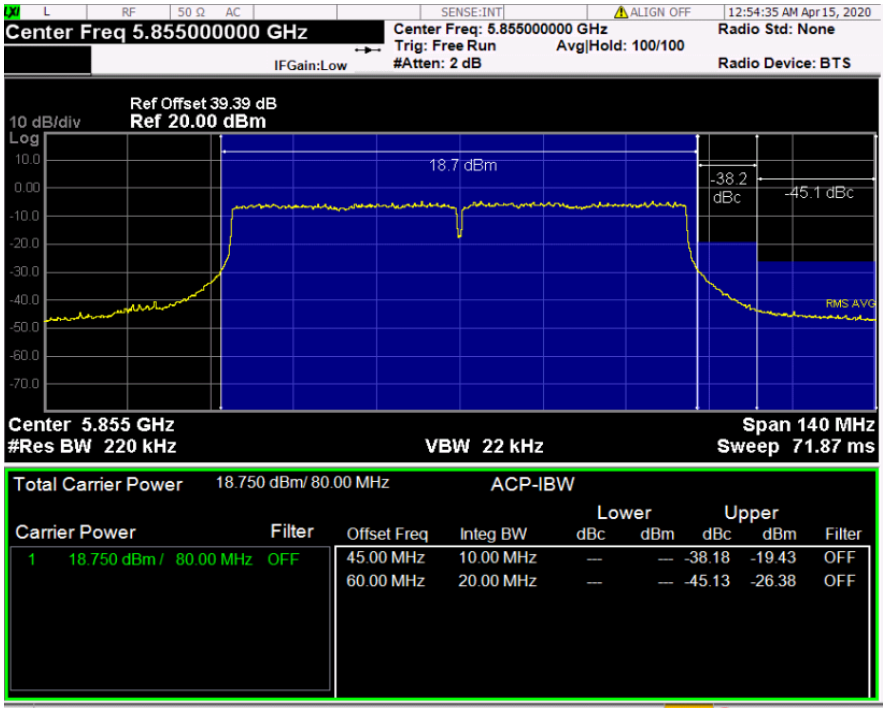
802.11ac Devices, CH 171 (80 MHz) – TX Power Adjusted to Meet Proposal 2 Mask

OOBE – Proposal 2 SEM (Proposed)



Key Settings: Res BW: 1 MHz, Max Hold, Peak Detector

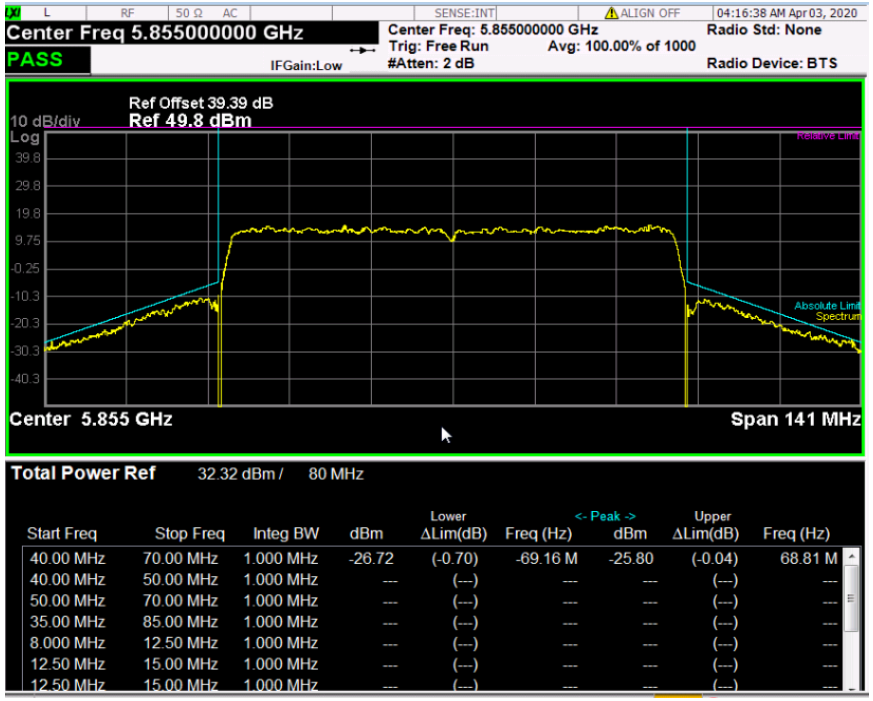
Average RMS Power measured in CH 180 and CH 183



Key Settings: Avg Detector, RMS Avg

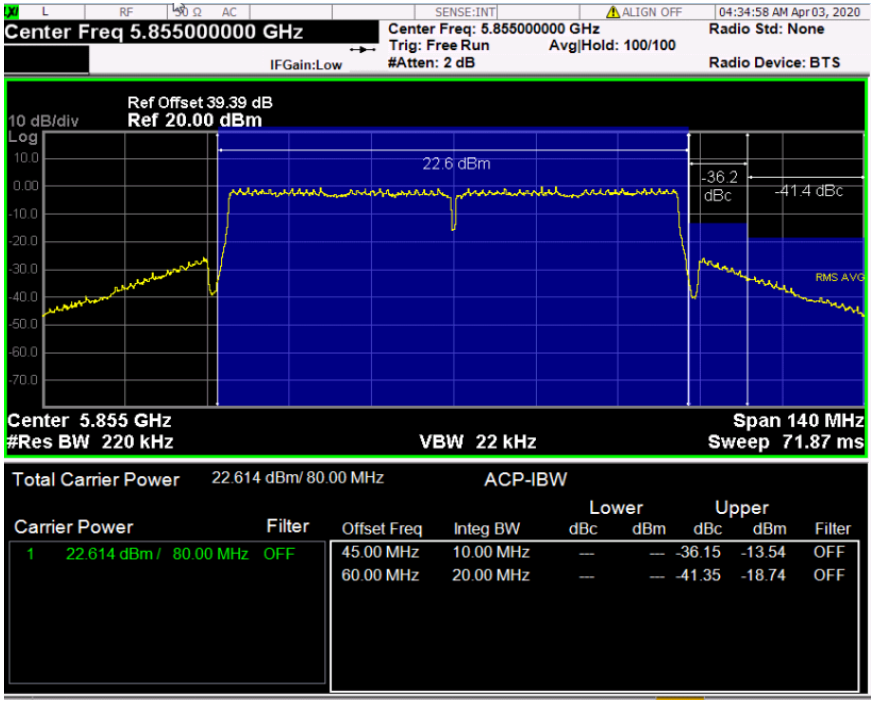
Generated 802.11ac Waveform, CH 171 (80 MHz) – TX Power Adjusted to Meet Proposal 1 Mask

OOBE - Proposal 1 SEM (Proposed)



Key Settings: Res BW: 1 MHz, Max Hold, Peak Detector

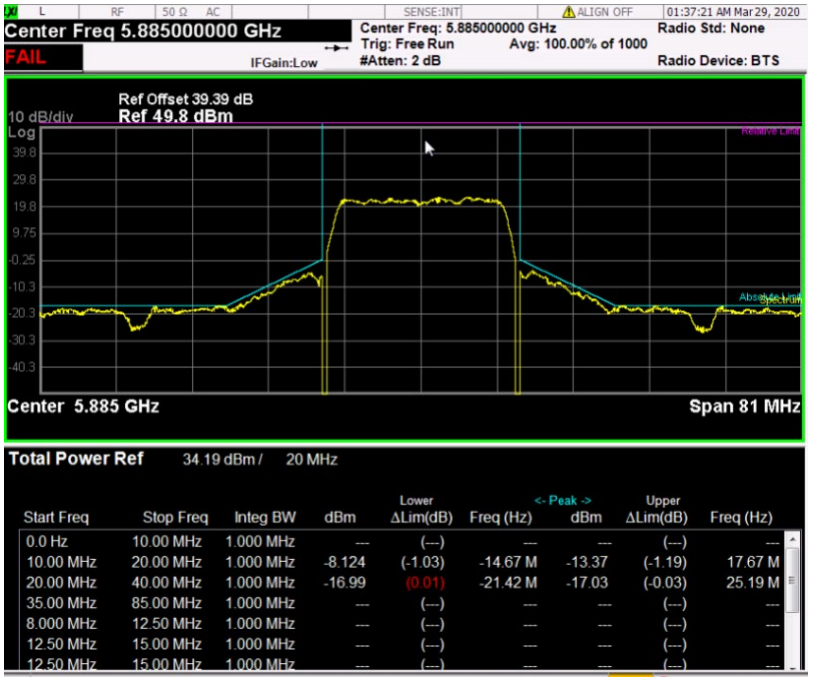
Average RMS Power measured in CH 180 and CH 183



Key Settings: Avg Detector, RMS Avg

Generated 802.11ac Waveform, CH 177 (20 MHz) – TX Power Adjusted to Meet Proposal 2 Mask

OOBE – Proposal 2 SEM (Proposed)



Key Settings: Res BW: 1 MHz, Max Hold, Peak Detector

Average RMS Power measured in CH 180 and CH 183

Key Settings: Avg Detector, RMS Avg

Interference (RMS Power) Summary

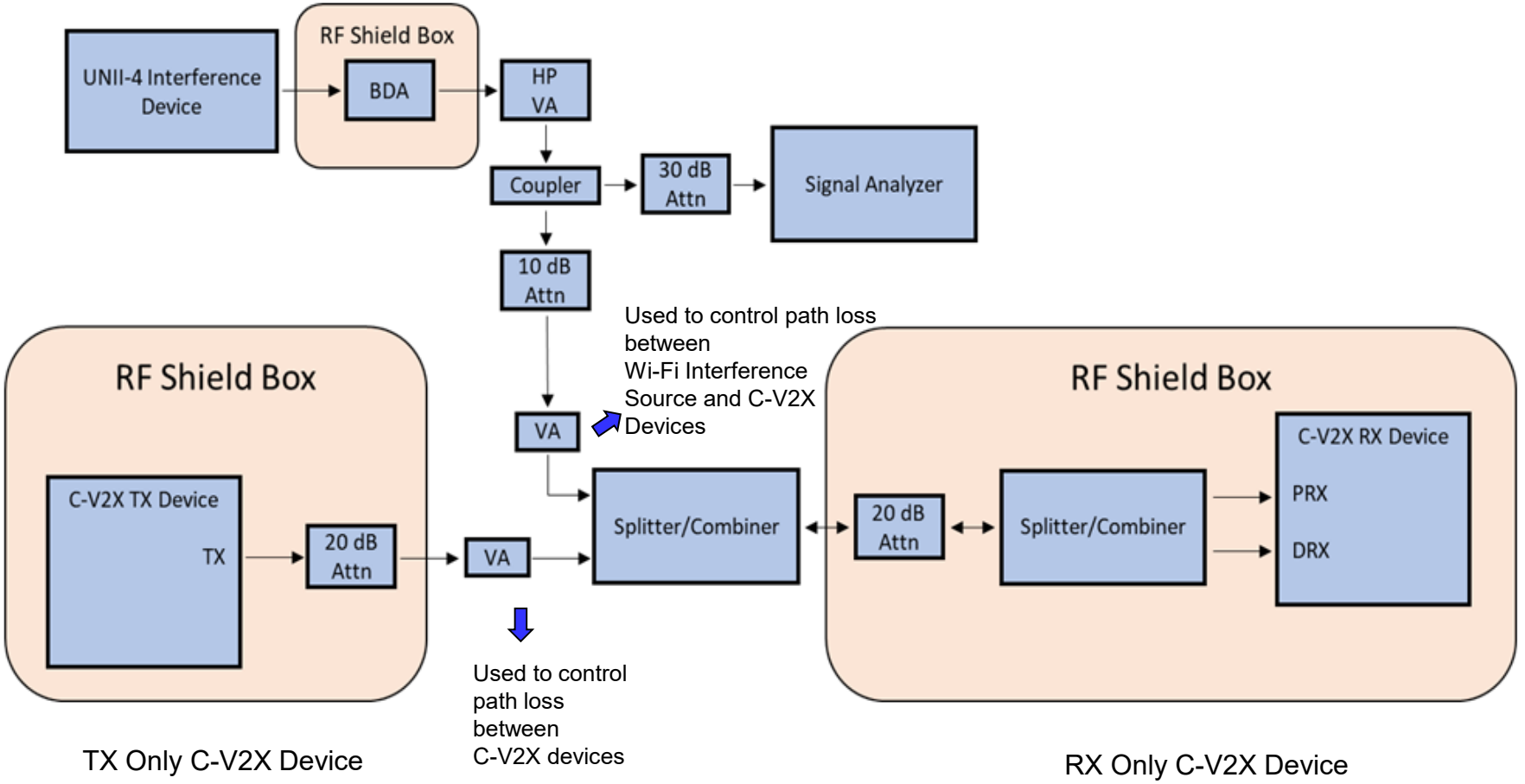
Interferer Profile	In band RMS Power (dBm)	RMS Power Measured in CH 180 (dBm)	RMS Power Measured in CH 183 (dBm)
CH 177 (20 MHz), 802.11ac Devices, Proposal 1 Mask	13.25	-20.01	-32.99
CH 171 (80 MHz), 802.11ac Devices, Proposal 1 Mask	12.99	-24.64	-28.80
CH 177 (20 MHz), , 802.11ac Devices, Proposal 2 Mask	16.2	-17.2	-30.6
CH 171 (80 MHz), 802.11ac Devices, Proposal 2 Mask	18.75	-19.43	-26.38
CH 171 (80 MHz), Generated 802.11ac, Proposal 1 Mask	22.61	-13.54	-18.74
CH 177 (20 MHz), Generated 802.11ac, Proposal 2 Mask	24.31	-9.67	-16.84

- Since the 20 MHz 802.11ac Wi-Fi Device Operation causes more interference to Channel 180 as compared to 80 MHz operation, it is used as the interference bandwidth in the following tests when assessing impact to CH 180.
- Similarly, 80 MHz 802.11ac Wi-Fi operation of Wi-Fi devices is chosen as the interference bandwidth for CH 183 testing.
- For Generated waveforms, the same configuration is used for both CH 180 and CH 183.

Bench Testing Objective

- Characterize impact to baseline sensitivity of the C-V2X receiver under test from Wi-Fi interference at varying path loss/isolation from the C-V2X receiver
- Sensitivity is defined as min RX power (dBm) required to maintain PER below 10% threshold for configuration under test

Bench Testing Setup



Bench Testing Procedure

- Baseline Sensitivity of the configuration under test is determined by turning off the interference and adjusting the path loss between C-V2X transmitter and receiver
  - For each path loss setting between C-V2X transmitter and receiver, PER is determined over 10,000 packets
- Wi-Fi Interference is introduced at the receiver for varying levels of path loss between Wi-Fi interferer and C-V2X receiver [60 dB to 110 dB in 10 dB steps]
- For each path loss setting between Wi-Fi interferer and C-V2X receiver, the sensitivity for the C-V2X configuration is determined
  - For each path loss setting between C-V2X transmitter and receiver, PER is determined over 10,000 packets
- Tests are repeated for different interferer proposals

Bench Test Scenarios

Interferer Profile	C-V2X Channel	C-V2X Packet Size (bytes)
20 MHz CH 177, 802.11ac Devices, Proposal 1 Mask	CH 180	365
20 MHz CH 177, 802.11ac Devices, Proposal 1 Mask	CH 180	1400
20 MHz CH 177, 802.11ac Devices, Proposal 2 Mask	CH 180	365
20 MHz CH 177, 802.11ac Devices, Proposal 2 Mask	CH 180	1400
80 MHz CH 171, 802.11ac Devices, Proposal 1 Mask	CH 183	365
80 MHz CH 171, 802.11ac Devices, Proposal 1 Mask	CH 183	1400
80 MHz CH 171, 802.11ac Devices, Proposal 2 Mask	CH 183	365
80 MHz CH 171, 802.11ac Devices, Proposal 2 Mask	CH 183	1400
20 MHz CH 177, Generated 802.11ac Waveform , Proposal 2 Mask	CH 180	365
20 MHz CH 177, Generated 802.11ac Waveform , Proposal 2 Mask	CH 180	1400
20 MHz CH 177, Generated 802.11ac Waveform , Proposal 2 Mask	CH 183	365
20 MHz CH 177, Generated 802.11ac Waveform , Proposal 2 Mask	CH 183	1400
80 MHz CH 171, Generated 802.11ac Waveform , Proposal 1 Mask	CH 180	365
80 MHz CH 177, Generated 802.11ac Waveform , Proposal 1 Mask	CH 180	1400
80 MHz CH 171, Generated 802.11ac Waveform , Proposal 1 Mask	CH 183	365
80 MHz CH 171, Generated 802.11ac Waveform , Proposal 1 Mask	CH 183	1400

Selected Results*

*See Appendix for individual test results

Wi-Fi Devices v/s Generated Waveform Proposal 1 Mask, C-V2X CH 180

	Wi-Fi Devices		Generated Wi-Fi Waveform	
Isolation / Path Loss (dB)	10% PER CH180 365 bytes (dBm)	10% PER CH180 1400 bytes (dBm)	10% PER CH180 365 bytes (dBm)	10% PER CH180 1400 bytes (dBm)
Baseline	-99.35	-98.35	-99.35	-98.35
110	-99.35	-98.35	-100.35	-98.35
100	-99.35	-98.35	-99.35	-98.35
90	-99.35	-98.35	-98.35	-97.35
80	-98.35	-96.35	-92.45	-92.45
70	-93.35	-88.45	-83.45	-83.45
60	-85.45	-80.35	-73.25	-73.25

Note: Yellow Highlight shows the range where significant impact from interference starts to be noticed. For example, for the Wi-Fi Devices, 365 byte packet at 70dB isolation, the sensitivity of the C-V2X receiver is reduced by 6dB which in practical terms might mean up to 50% range in LOS conditions

Wi-Fi Devices v/s Generated Waveform Proposal 1 Mask, C-V2X CH 183

	Wi-Fi Devices		Generated Wi-Fi Waveform	
Isolation / Path Loss (dB)	10% PER CH183 365 bytes (dBm)	10% PER CH183 1400 bytes (dBm)	10% PER CH183 365 bytes (dBm)	10% PER CH183 1400 bytes (dBm)
Baseline	-98.25	-95.15	-98.25	-95.15
110	-98.25	-95.15	-98.25	-94.25
100	-99.25	-95.15	-98.25	-93.25
90	-98.25	-95.15	-98.25	-94.25
80	-99.25	-94.25	-97.25	-93.25
70	-96.25	-93.25	-91.25	-87.25
60	-93.25	-89.25	-82.35	-78.15

Wi-Fi Devices v/s Generated Waveform Proposal 2 Mask, C-V2X CH 180

	Wi-Fi Devices		Generated Wi-Fi Waveform	
Isolation / Path Loss (dB)	10% PER CH180 365 bytes (dBm)	10% PER CH180 1400 bytes (dBm)	10% PER CH180 365 bytes (dBm)	10% PER CH180 1400 bytes (dBm)
Baseline	-99.35	-98.35	-99.35	-98.35
110	-99.35	-98.35	-99.35	-98.35
100	-99.35	-98.35	-99.35	-98.35
90	-98.35	-97.35	-97.35	-96.35
80	-96.35	-93.35	-89.35	-89.35
70	-91.35	-86.45	-80.35	-80.35
60	-82.25	-76.25	-72.25	-70.15

Wi-Fi Devices v/s Generated Waveform Proposal 2 Mask, C-V2X CH 183

	Wi-Fi Devices		Generated Wi-Fi Waveform	
Isolation / Path Loss (dB)	10% PER CH183 365 bytes (dBm)	10% PER CH183 1400 bytes (dBm)	10% PER CH183 365 bytes (dBm)	10% PER CH183 1400 bytes (dBm)
Baseline	-98.25	-95.15	-98.25	-95.15
110	-97.25	-94.25	-99.25	-94.25
100	-98.25	-94.25	-99.25	-94.25
90	-97.25	-94.25	-98.25	-94.25
80	-98.25	-93.25	-97.25	-93.25
70	-96.25	-86.35	-90.25	-86.35
60	-91.25	-77.15	-80.25	-77.15

Bench Testing Summary

- C-V2X receiver sensitivity in CH 180 can be impacted by U-NII-4 Wi-Fi operation when path loss to interferer is less than 90dB
- C-V2X receiver sensitivity in CH 183 can be impacted by U-NII-4 Wi-Fi operation when path loss to interferer is less than 80dB
- Proposal 2 is expected to provide additional level of protection to C-V2X operation in CH 180 and CH 183 as it proposes to restrict U-NII-4 Wi-Fi to indoor operation

Note: Field testing to further characterize interference is planned.

Next Steps

- Execute Field Tests to collect empirical data from the field

Appendix

Test Results for Individual Scenarios

Interpreting the Results

- Calculated Interference Power in CH 180 is total power in 10 MHz . (Path loss + Avg rms power measured in CH 180)
- Calculated Interference Power in CH 183 is total power in 20 MHz (Path loss + Avg rms power measured in CH 183)
- Interference power is not uniformly distributed in CH 180 and CH 183. Refer to Wi-Fi device characterization for details.
- 365 byte messages use only 2 sub-channels = 20 RB = 3.6 MHz bandwidth
- 1400 byte messages use 5 subchannels for CH 180 and 10 sub-channels for CH 183

802.11ac Devices, CH 177 (20 MHz), Proposal 1 Mask , C-V2X CH 180

C-V2X: (MCS 11, 365 bytes, 2 sub-channels), (MCS 7, 1400 bytes, 5 sub-channels, 2 segments)

Interference Duty Cycle : ~90%

Interference CH 180 RMS avg power before isolation: -20 dBm (-30 dBm/MHz)

Isolation / Path Loss (dB)	CH 180 Calculated Interference Avg Power at RX (10 MHz) (dBm)	10% PER CH180 365 bytes (dBm)	10% PER CH180 1400 bytes (dBm)
Baseline		-99.35	-98.35
110	-130	-99.35	-98.35
100	-120	-99.35	-98.35
90	-110	-99.35	-98.35
80	-100	-98.35	-96.35
70	-90	-93.35	-88.45
60	-80	-85.45	-80.35

802.11ac Devices, CH 171 (80 MHz), Proposal 1 Mask , C-V2X CH 183

C-V2X: (MCS 11, 365 bytes, 2 sub-channels), (MCS7, 1400 bytes, 10 sub-channels)

Interference Duty Cycle : ~90%

Interference CH 180 RMS avg power before isolation: -28.80 dBm (-41.80 dBm/MHz)

Isolation (dB)	CH 183 Calculated Interference Avg Power at RX (20 MHz) (dBm)	10% PER CH183 365 bytes (dBm)	10% PER CH183 1400 bytes (dBm)
Baseline		-98.25	-95.15
110	-138.80	-98.25	-95.15
100	-128.80	-99.25	-95.15
90	-118.80	-98.25	-95.15
80	-108.80	-99.25	-94.25
70	-98.80	-96.25	-93.25
60	-88.80	-93.25	-89.25

802.11ac Devices, CH 177 (20 MHz), Proposal 2 Mask , C-V2X CH 180

C-V2X: (MCS 11, 365 bytes, 2 sub-channels), (MCS7, 1400 bytes, 5 sub-channels, 2 segments)

Interference Duty Cycle : ~90%

Interference CH 180 RMS avg power before isolation: -17.2 dBm (-27.2 dBm/MHz)

Isolation (dB)	CH 180 Calculated Interference Avg Power at RX (10 MHz) (dBm)	10% PER CH180 365 bytes (dBm)	10% PER CH180 1400 bytes (dBm)
Baseline		-99.35	-98.35
110	-127.2	-99.35	-98.35
100	-117.2	-99.35	-98.35
90	-107.2	-98.35	-97.35
80	-97.2	-96.35	-93.35
70	-87.2	-91.35	-86.45
60	-77.2	-82.25	-76.25

802.11ac Devices, CH 171 (80 MHz), Proposal 2 Mask , C-V2C CH 183

C-V2X: (MCS 11, 365 bytes, 2 sub-channels), (MCS7, 1400 bytes, 10 sub-channels)

Interference Duty Cycle : ~90%

Interference CH 180 RMS avg power before isolation: -26.38 dBm (--39.38 dBm/MHz)

Isolation (dB)	CH 183 Calculated Interference Avg Power at RX (20 MHz) (dBm)	10% PER CH183 365 bytes (dBm)	10% PER CH183 1400 bytes (dBm)
Baseline		-98.25	-95.15
110	-136.38	-97.25	-94.25
100	-126.38	-98.25	-93.25
90	-116.38	-97.25	-94.25
80	-106.38	-98.25	-94.25
70	-96.38	-96.25	-92.35
60	-86.38	-91.25	-87.25

Generated 802.11ac Waveform, CH 171 (80 MHz), Proposal 1 Mask , C-V2X CH 180

C-V2X: (MCS 11, 365 bytes, 2 sub-channels), (MCS7, 1400 bytes, 5 sub-channels, 2 Segments)

Interference Duty Cycle : ~60%

Interference CH 180 RMS avg power before isolation: -13.54 dBm (-23.54 dBm/MHz)

Isolation (dB)	CH 180 Calculated Interference Avg Power at RX (10 MHz) (dBm)	10% PER CH180 365 bytes (dBm)	10% PER CH180 1400 bytes (dBm)
Baseline		-99.35	-98.35
110	-123.54	-100.35	-98.35
100	-113.54	-99.35	-98.35
90	-103.54	-98.35	-97.35
80	-93.54	-92.45	-92.45
70	-83.54	-83.45	-83.45
60	-73.54	-73.25	-73.25

Generated 802.11ac Waveform, CH 171 (80 MHz), Proposal 1 Mask , C-V2X CH 183

C-V2X: (MCS 11, 365 bytes, 2 sub-channels), (MCS7, 1400 bytes, 10 sub-channels)

Interference Duty Cycle : ~60%

Interference CH 183 RMS avg power before isolation: -18.74 dBm (-31.74 dBm/MHz)

Isolation (dB)	CH 183 Calculated Interference Avg Power at RX (20 MHz) (dBm)	10% PER CH183 365 bytes (dBm)	10% PER CH183 1400 bytes (dBm)
Baseline		-98.25	-95.15
110	-128.74	-98.25	-94.25
100	-118.74	-98.25	-93.25
90	-108.74	-98.25	-94.25
80	-98.74	-97.25	-93.25
70	-88.74	-91.25	-87.25
60	-78.74	-82.35	-78.15

Generated 802.11ac Waveform, CH 177 (20 MHz), Proposal 2 Mask , C-V2X CH 180

C-V2X: (MCS 11, 365 bytes, 2 sub-channels), (MCS7, 1400 bytes, 5 sub-channels, 2 Segments)

Interference Duty Cycle : ~55%

Interference CH 180 RMS avg power before isolation: -9.7 dBm (-22.7 dBm/MHz)

Isolation (dB)	CH 180 Calculated Interference Avg Power at RX (10 MHz) (dBm)	10% PER CH180 365 bytes (dBm)	10% PER CH180 1400 bytes (dBm)
Baseline		-99.35	-98.35
110	-119.7	-99.35	-98.35
100	-109.7	-99.35	-98.35
90	-99.7	-97.35	-96.35
80	-89.7	-89.35	-89.35
70	-79.7	-80.35	-80.35
60	-69.7	-72.25	-70.15

Generated 802.11ac Waveform, CH 177 (20 MHz), Proposal 2 Mask , C-V2X CH 183

C-V2X: (MCS 11, 365 bytes, 2 sub-channels), (MCS7, 1400 bytes, 10 sub-channels)

Interference Duty Cycle : ~55%%

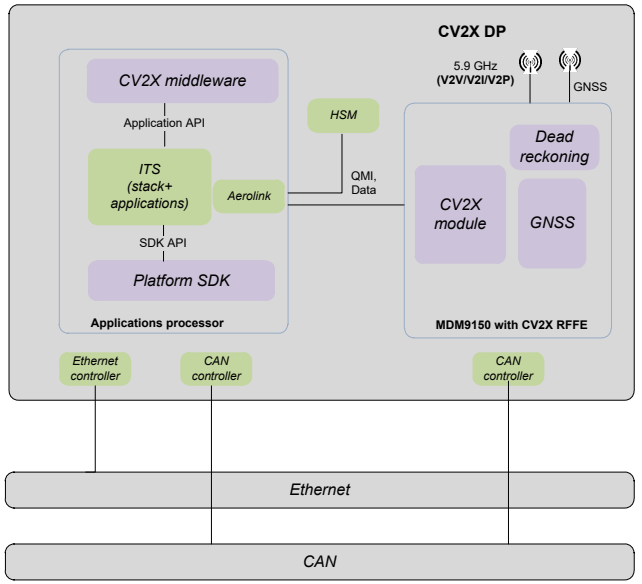
Interference CH 180 RMS avg power before isolation: -16.84 dBm (-29.84 dBm/MHz)

Isolation (dB)	CH 183 Calculated Interference Avg Power at RX (20 MHz) (dBm)	10% PER CH183 365 bytes (dBm)	10% PER CH183 1400 bytes (dBm)
Baseline		-98.25	-95.15
110	-117.84	-99.25	-94.25
100	-116.84	-99.25	-94.25
90	-106.84	-98.25	-94.25
80	-96.84	-97.25	-93.25
70	-86.84	-90.25	-86.35
60	-76.84	-80.25	-77.15

Devices Used

C-V2X Development Platform (RRv1)

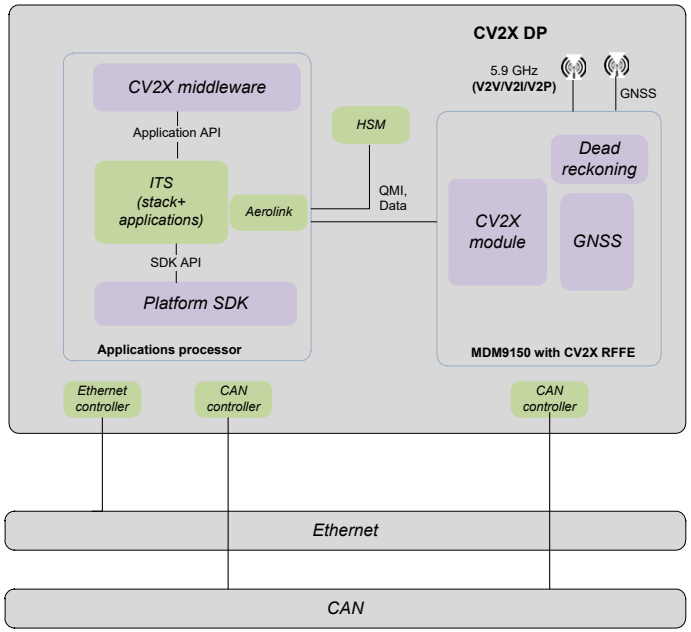
- Objectives
  - Serve as early OBU or RSU for C-V2X evaluation, trials and demonstration
  - Enable ITS stack vendors to port their stack and applications to function over the C-V2X PC5 Direct Communications



- Description
  - Platform consists of APQ 8096 (Applications Processor) and C-V2X 3GPP Single Channel Radio MDM 9160
  - Platform SDK to enable ITS stack vendors
  - Evaluation units supplied by Qualcomm come pre-loaded with ITS stack and applications from Savari
    - V2V Applications: FCW, EEBL, IMA, LTA, BSW, LCW
    - V2I Applications: SPAT/MAP etc.
  - Test Applications built using Platform SDK are also available for PC5 evaluation independent of ITS stack
  - CAN Functionality
    - Provides Multiple CAN buses and Multiple Options to connect to the Vehicle CAN Bus
  - Optional C-V2X Middleware to enable V2I, V2P, V2N Applications

C-V2X Development Platform (RRv1)

Component	Description
Processor	Automotive Snapdragon820 (APQ8996) 1200 MHz ARM A7 (in MDM9150)+B2
Memory	2 GB (APQ)
Storage	64 GB + 2 GB, microSD slot
Radio	PC5 Mode 4
GNSS	Multi-constellation Qualcomm QDR3 Dead Reckoning XTRA + Time injection
Operational Temperature	“-40 to 85C”
Other Interfaces	USB 3.0 OTG, USB Host, 3x 1 Mbps CAN, 1000BT Ethernet, RS232
Standards	3GPP Rel 14, IEEE 1609.3, ETSI ITS G5, SAE J2735, SAE J3161 (draft)
Security	IEEE 1609.2 (Via Savari & OnBoard Security)
Wireless Connectivity	Automotive QCA6574AU - Wi-Fi: 2.4 GHz, 802.11n, 2 x 2 - Bluetooth 4.2 + BLE



Wi-Fi Devices

- 802.11ac Wi-Fi Router
  - QCA AP161 Development Platform
    - QCA 9984 5GHz Radio

Test Equipment

- Vector Signal Generator
  - R&S SMBV 100

- Signal Analyzer
  - Keysight MXA 9020A