EMC Analysis for 1HOPSAT-TD Mission

Introduction and Summary of Results

Hera Systems Incorporated will launch 1HOPSat-TD, a nanosatellite, into low Earth orbit in Q4 2019, and transmit data to the 4.5 meter and 3 meter C-band (IEEE 802.11n) ground stations at the University of Santa Clara, in Santa Clara California, for a maximum of 6 months, demising within 3 years after launch. The primary mission of the 1HOPSat-TD satellite is a technology demonstration of Earth imaging capability.

The 1HOPSat-TD C-band frequencies are not allocated for use in Earth observation, therefore we provide this EMC analysis verifying that no interference will be caused to authorized operations by the C-band, 802.11n, downlink, with center frequency of 5745 MHz.

This report provides a domestic and international electromagnetic compatibility study with the existing users, as required by the FCC. The FCC OET and FCC International Bureau databases were searched. These are documented in later sections of this report.

Table 1 summarizes the identified relevant operators, with comments on each. Details for each are provided in later sections of the report, and in Appendices at the end of the report.

Operator	Action	Comment
Broadcomm, Inc. File number: 0726-EX-ST-2019	No action taken due to expired license.	License expired 05/20/2019
SpiderCloud Wireless, Inc. File number: 0005-EX-CR-2019	No action appears to be needed. See outcome.	This license appears to be related to indoor femtocell testing operations. No interference should be expected.
General Atomics Aeronautical Systems, Inc. File number: 0496-EX-CR-2017	No action taken. See Outcome.	The licensed radius of operation is 306 miles from our ground station, well outside Hera's 1HOPSat-TD half-power beamwidth radius of 156 miles.

No other stations were identified in database searches that would overlap our transmission footprint. Note here that the ground station in Santa Clara, CA is at the top of northern extreme of our orbit latitude range. Accordingly, stations more than ~252 km south of Santa Clara will never see signal levels above those of the half-power beamwidth level. The relatively tight beamwidth of the satellite antenna, together with the precision of the attitude control, limits the footprint of the beam.

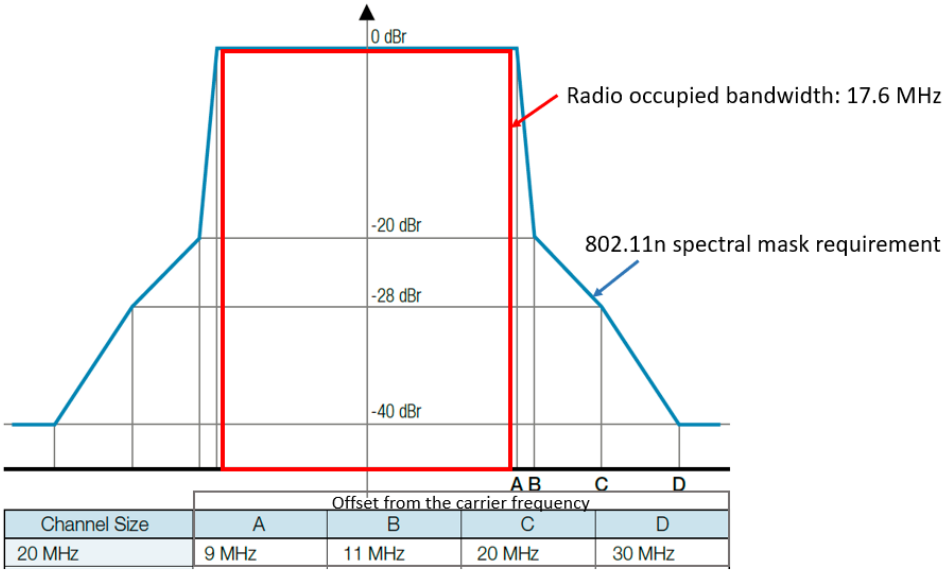
Power Flux Density at Earth Surface, In Band and Out of Band

In the downlink (1HOPSat-TD CubeSat to Santa Clara University ground station (SCU-GS)) a Doodle Labs™ 802.11n Wi-Fi radio with a helical antenna will provide a transmit power of 5.89 W (7.7 dBW) EIRP. According to Doodle Labs, the manufacturer of the radio, and the IEEE 802.11n standard, maximum occupied bandwidth of the single 20MHz subchannel used by Hera Systems is 17.8 MHz. By definition, this means that only 1% of the transmitted energy lies outside the frequency range of 5736.1 MHz to 5753.9 MHz .

the roll off of the transmitting spectrum is:

- -20 dBr at Fc +/- 11 MHz;
- -28 dBr at Fc +/- 20 MHz;
- -40 dBr at Fc +/- 30 MHz;

This is shown in the following figure:



Channel Size	A	B	C	D
20 MHz	9 MHz	11 MHz	20 MHz	30 MHz

Figure 1 Spacecraft Transmitter Power vs. Frequency Rolloff

Converting the transmitting spectrum roll off in absolute units provides the following plot:

Power Spectral Density Analysis

Considering the total power of the transmitting signal to be approximately uniformly distributed over the operating bandwidth of 20 MHz, this results in a power spectral density (PSD) of 0.8 W / 20 MHz = 4 x 10^{-8} W/Hz or -73.98 dBW/Hz.

The out-of-band power of the transmitting signal is radiated through the 10.4 dBi helical antenna mostly in the adjacent 20 MHz bandwidth to the left and to the right of the operating band. Per manufacturer specification, the out-of-band PSD at frequencies beyond 20 MHz away from the carrier frequency is attenuated by 45 dB relative to the in-band frequencies resulting in an out-of-band PSD of 10.4 -73.98 - 45 = -108.58 dBW/Hz for these frequencies.

The out-of-band frequencies of the transmitted signal will be further attenuated by propagation pathloss from the 1HOPSat-TD orbiting in low Earth orbit at 555 km, to any user on the Earth's surface. The pathloss for 5745 MHz band with a wavelength of 0.052 m is 162.5 dB, and corresponds to the minimum distance of 555 km between the 1HOPSat-TD and Earth. Thus, the out-of-band PSD at a potential satellite receiver operating in a bandwidth that is 20 MHz away or more from the operating bandwidth of the 1HOPSat-TD radio is -108.58 – 162.5 = -271.08 dBW/Hz, equivalent to -251.08 dBW per 100 Hz.

The interference analysis calculations are summarized in the following table:

Parameter [Units]	**Value**
Peak transmit power [**dBW**]	0.8
In-band radiated PSD [**dBW/Hz**]	-73.98
Transmitting spectrum roll off at frequencies >20 MHz away from 5745 MHz bands [**dB**]	– 45.00
Transmit antenna gain [**dBi**]	10.4
Path loss to SCU-GS [**dB**]	–162.5
Out-of-band PSD at the SCU-GS [**dBW/Hz**]	-271.08
Interfering signal power at SCU-GS receiver in reference bandwidth [**dBW per 100 Hz**]	-251.08

Table 1 Interference Analysis Calculation Summary

Domestic Operator Search

From the FCC OET and FCC International Bureau databases, lists of satellite systems using the 5735 to 5755 MHz band were collected and shown in Tables 1 and 2 below. None of these operations are expected to have interference for reasons cited in the Comments associated with each.

Table 1: OET Experimental Licensing System Files, 5735 to 5755 MHz

Search Criteria: Frequency Range = 5735 MHz through 5755 MHz, Computed Box Based on Point/Radius: Center = 37° 21' 02.6" N 121° 56' 03.4" W, Radius = 250 Miles, Currently Licensed and Pending Facilities

OET Experimental Licensing System Database							
Callsign: WO9XMB	**File Number:** 0726-EX-ST-2019	**Licensee:** Broad Comm, Inc.	**FRN:** 0007283856	**Issue Date:** 05/09/2019	**Expiration:** 05/20/2019	**Radio Service:** XT	**Status:** Granted
Site Address:	**State:** CA	**Mobile Coordinates:** 38° 34' 42" N, 121° 29' 40" W **Distance from Center:** 88.0 Miles **Azimuth from Center:** 15.6°					
Frequency: 5735.00000000 M 5755.00000000 M							
Site Address:	**State:** CA	**Mobile Coordinates:** 36° 34' 46" N, 121° 45' 17" W **Distance from Center:** 54.1 Miles **Azimuth from Center:** 169.4°					
Frequency: 5735.00000000 M 5755.00000000 M							
Site Address:	**State:** CA	**Mobile Coordinates:** 37° 7' 39" N, 121° 39' 4" W **Distance from Center:** 21.9 Miles **Azimuth from Center:** 134.6°					
Frequency: 5735.00000000 M 5755.00000000 M							
Site Address:	**State:** CA	**Mobile Coordinates:** 38° 56' 13" N, 119° 56' 22" W **Distance from Center:** 154.2 Miles **Azimuth from Center:** 44.1°					
Frequency: 5735.00000000 M 5755.00000000 M							
Site Address:	**State:** CA	**Mobile Coordinates:** 38° 35' 24" N, 121° 18' 10" W **Distance from Center:** 92.2 Miles **Azimuth from Center:** 21.7°					
Frequency: 5735.00000000 M 5755.00000000 M							
Site Address:	**State:** CA	**Mobile Coordinates:** 37° 57' 33" N, 121° 17' 28" W **Distance from Center:** 54.8 Miles **Azimuth from Center:** 39.7°					
Frequency: 5735.00000000 M 5755.00000000 M							
Site Address:	**State:** CA	**Mobile Coordinates:** 35° 21' 57" N, 120° 51' 0" W **Distance from Center:** 149.6 Miles **Azimuth from Center:** 155.9°					
Frequency: 5735.00000000 M 5755.00000000 M							
Site Address:	**State:** CA	**Mobile Coordinates:** 35° 8' 37" N, 120° 38' 29" W **Distance from Center:** 168.4 Miles **Azimuth from Center:** 154.3°					
Frequency: 5735.00000000 M 5755.00000000 M							

Site Address:	State: CA	Mobile Coordinates: 34° 16' 56" N, 119° 17' 42" W Distance from Center: 258.2 Miles* Azimuth from Center: 144.3°

Frequency: 5735.00000000 M 5755.00000000 M

Site Address:	State: CA	Mobile Coordinates: 34° 3' 53" N, 117° 39' 4" W Distance from Center: 330.5 Miles* Azimuth from Center: 132.1°

Frequency: 5735.00000000 M 5755.00000000 M

Site Address:	State: CA	Mobile Coordinates: 34° 14' 11" N, 117° 39' 32" W Distance from Center: 322.0 Miles* Azimuth from Center: 130.7°

Frequency: 5735.00000000 M 5755.00000000 M

Site Address:	State: CA	Mobile Coordinates: 34° 23' 30" N, 118° 32' 33" W Distance from Center: 278.9 Miles* Azimuth from Center: 136.1°

Frequency: 5735.00000000 M 5755.00000000 M

Site Address:	State: CA	Mobile Coordinates: 34° 8' 52" N, 118° 8' 40" W Distance from Center: 306.7 Miles* Azimuth from Center: 135.0°

Frequency: 5735.00000000 M 5755.00000000 M

Callsign: WC2XLR	File Number: 0496-EX-CR-2017	Licensee: General Atomics Aeronautical Systems, Inc.	FRN: 0006976740	Issue Date: 12/01/2017	Expiration: 12/01/2020	Radio Service: XT	Status: Granted

Site Address: 25500 East Avenue R-8	State: CA	County: LOS ANGELES	Fixed Coordinates: 34° 33' 49" N 117° 40' 46" W Distance from Center: 306.2 Miles* Azimuth from Center: 127.7°

Frequency: 5750.00000000 M

Callsign: WI2XQP	File Number: 0005-EX-CR-2019	Licensee: SpiderCloud Wireless, Inc.	FRN: 0019587807	Issue Date: 03/01/2019	Expiration: 03/01/2022	Radio Service: XT	Status: Granted

Site Address: 475 Sycamore dr	State: CA	County: SANTA CLARA	Fixed Coordinates: 37° 24' 38" N 121° 54' 47" W Distance from Center: 4.3 Miles Azimuth from Center: 15.7°	Mobile Coordinates: 37° 24' 38" N, 121° 54' 47" W Distance from Center: 4.3 Miles Azimuth from Center: 15.7°

Frequency: 5735.00000000 - 5840.00000000 M

Assessment of expectation of interference, for each operator found:

Case 1, Broad Comm, Inc.:

License expired.

Case 2, General Atomics Aeronautical Systems, Inc.:

No interference would be expected due to low signal levels arriving at Earth from space in the spectrum user's area of operations which is >306 miles (>492 km) away, well beyond the half-power beamwidth (HPBW) of the 1HOPSat-TD antenna at 152 km radius.

Signals from the spacecraft would be less than -295 dBW/Hz.

To see this as interference, General Atomics would have to point a very high-gain dish antenna toward the 1HOPSat-TD spacecraft, viewing the beam pattern from a steep side angle (roughly 45 degrees off the main beam), and track the spacecraft location with the dish to see signals at interfering levels. Even if General Atomics did this, this wort-case alignment geometry might only occur once every few days for a period of a few minutes. Typically, the 1HOPSat-TD spacecraft will be pointing more Northerly, further reducing signals that could be seen by General Atomics.

Case 3, SpiderCloud Wireless, Inc.:

The SpiderCloud facility is only 4.3 miles from main-beam pointing location of 1HOPSat-TD. Even so, to see interference, SpiderCloud would have to point a high-gain dish toward the 1HOPSat-TD spacecraft, and track the spacecraft location with the dish to see signals at interfering levels. Signals from the spacecraft would be in the range of -271.08 dBW/Hz at the location of the SpiderCloud facility.

Table 2: IB Licensing System Files, 5735 to 5755 MHz

IBFS Ground Station Search Parameters: Latitude=37° 21' 02.6", Longitude=121° 56' 03.4", Radius=250 miles, Frequency Lower=5735 MHz , Frequency Upper=5745 MHz

This search returned no results.

TBD Dave you show 2500 km in this search criteria. Previously you used 250 miles. It would be best to be consistent. I expect you meant to write 250 miles in the above.

Discussion of Coordination

No coordination is deemed necessary for reasons previously discussed.

Conclusion

There is no expectation at this time that the 1HOPSat-TD will interfere with any known systems.