EMC Analysis for VCC Cubesats

Introduction and Summary of Results

The Virginia CubeSat Constellation (VCC) is a collaborative, student-led project, of four Virginia Universities: University of Virginia (UVA), Old Dominion University (ODU), Virginia Tech (VT), and Hampton University. Supported by NASA through the Virginia Space Grant Consortium as part of NASA Undergraduate Student Instrument Project (USIP) program, the project will launch three similar CubeSats into low Earth orbit from the International Space Station, and transmit data to ground stations on the UVA, ODU, and VT campuses for less than two years. The primary mission is to collect atmospheric data to improve deorbit predictions.

Radio operating licenses have been requested from the FCC as follows:

	Lower frequency [MHz]	Center frequency [MHz]	Upper frequency [MHz]	Bandwidth [kHz]
UVA	401.030	401.040	401.050	20
ODU	401.070	401.080	401.090	20
VT	401.110	401.120	401.130	20

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, as were the ITU SNS and MIFR databases. These are documented in later sections of this report.

Table 1 summarizes the identified relevant operators with whom coordination actions were taken, and the outcome of the coordination efforts. Details for each are provided in later sections of the report, and in Appendices at the end of the report.

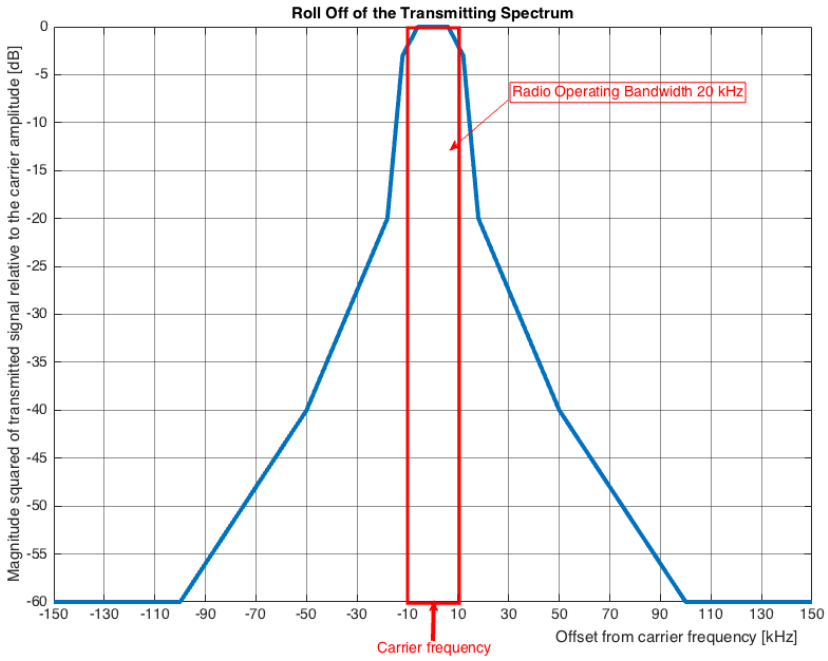
Operator	Action	Outcome
NOAA GOES	EMC Analysis Completed	No objections, Coordination Complete, NOAA concurs with VCC analysis. VCC agrees to not more than 3 years of operation.
National Radio Quiet Zone	NRAO Evaluation	No objections, Coordination Complete
GHG	Contacted GHG, supplied data.	No objections, Coordination Complete
Spire	Contacted Spire	No objections identified, Coordination in progress.
Kepler Communication	Contact Kepler	No objections identified, Coordination in progress.

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

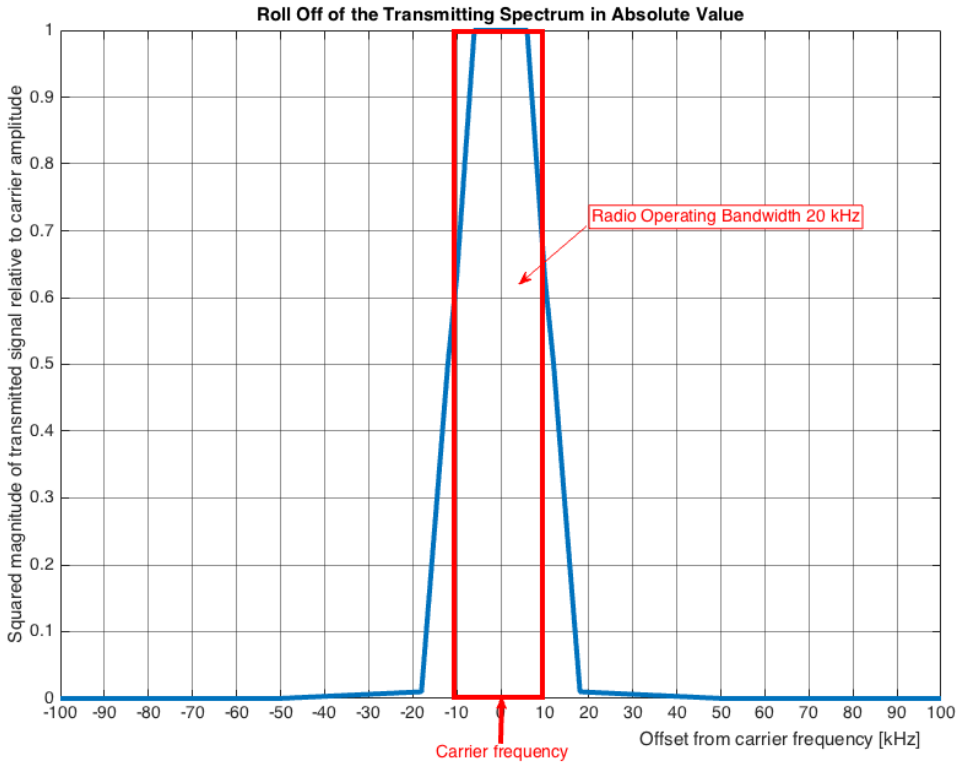
In the downlink (CubeSat to ground station) the Lithium-II radios with broad beam antennas will provide a transmit power of 3.9 W EIRP. According to AstroDev, the manufacturer of the radio, the roll off of the transmitting spectrum is:

- -3 dB at 12 kHz;
- -20 dB at 18 kHz;
- -40 dB at 50 kHz;
- -60 dB at 100 kHz.

This is shown in the following figure:



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



In the uplink (ground station to CubeSat), a Universal Software Radio Peripheral (USRP) B200 software defined radio from Ettus Research will be used with directional antennas and power amplifiers to deliver a transmit power of 13.98 dBW (25 W). A similar roll-off characteristic for the transmitting spectrum is assumed in the uplink, which can be easily implemented as a digital root-raised cosine (RRC) filter in the B200 USRP.

Power Spectral Density Analysis

Downlink:

Considering the total power of the transmitting signal to be approximately uniformly distributed over the operating bandwidth of 20 kHz, this results in a power spectral density (PSD) of 1.9 W / 20 kHz = 79.49 x 10^{-5} W/Hz or -40.23 dBW/Hz.

The out-of-band power of the transmitting signal is radiated through the 0 dBi CubeSat antenna mostly in the adjacent 20 kHz bandwidth to the left and to the right of the operating band. The out-of-band PSD at frequencies located beyond 100 kHz away from the carrier frequency is attenuated by 60 dB relative to the in-band frequencies resulting in an out-of-band PSD of -40.23 - 60 = -100.23 dBW/Hz for these frequencies.

The out-of-band frequencies of the transmitted signal will be further attenuated by propagation pathloss from the VCC CubeSat orbiting in low Earth orbit at 400 km, to the GOES satellite orbiting in geosynchronous orbit at 35,768 km. The minimum value of the corresponding pathloss for 401 MHz band with a wavelength of 0.748 m is 175.48 dB, and corresponds to the minimum distance of 35,468 km between the VCC CubeSat and a GOES satellite. Thus, the out-of-band

PSD at a potential satellite receiver operating in a bandwidth that is 100 kHz away or more from the operating bandwidth of the CubeSat radio is -100.23 - 175.48 = -275.81 dBW/Hz, equivalent to -255.81 dBW per 100 Hz.

Uplink:

Considering that the in-band power of the transmitting signal is approximately uniformly distributed over the operating bandwidth of 20 kHz, this results in a power spectral density of 25 W / 20 kHz = 1.25 x 10^{-3} W/Hz or -29.03 dBW/Hz.

The out-of-band power of the transmitting signal is radiated through a 13.80 dBi Yagi ground station antenna mostly in the adjacent 20 kHz bandwidth to the left and to the right of the operating band. The out-of-band PSD at frequencies beyond 100 kHz away from the carrier frequency is attenuated by 60 dB relative to the in-band frequencies resulting in an out-of-band PSD of 13.80 -29.03 - 60 = -75.23 dBW/Hz for these frequencies.

The out-of-band frequencies of the transmitted signal will be further attenuated by propagation pathloss from the VCC ground station to the GOES satellite orbiting in geosynchronous orbit at 35,768 km, which for the 401 MHz band (0.748 m wavelength) is equal to 175.58 dB. Thus, the out-of-band PSD at a potential satellite receiver operating in a bandwidth that is 100 kHz away or more from the operating bandwidth of the CubeSat radio, is -75.23 - 175.58 = -250.81 dBW/Hz, which is also equivalent to -230.81 dBW per 100 Hz.

The interference analysis calculations are summarized in the following table:

	Downlink CubeSat → Ground Station	**Uplink** Ground station → CubeSat
Peak transmit power [**dBW**]	2.80	13.98
In-band radiated PSD [**dBW/Hz**]	– 40.23	– 29.03
Transmitting spectrum roll off at frequencies >100 kHz away from VCC bands [**dB**]	– 60.00	– 60.00
Transmit antenna gain [**dBi**]	0	13.80
Path loss to DCS receiver [**dB**]	–175.48	–175.58
Out-of-band PSD at DCS receiver [**dBW/Hz**]	–275.81	–250.81
Interfering signal power at DCS receiver in reference bandwidth [**dBW per 100 Hz**]	–255.81	–230.81

Domestic Operator Search

From the FCC OET and FCC International Bureau databases, lists of satellite systems using the 401 to 402 MHz band was 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, 401 to 401.2 MHz

Search Criteria: All Services, Frequency Range = 400.8 MHz through 401.7 MHz, Box Search: Start Coordinates = 24° 33' 18" N 81° 46' 43" W End coordinates=47° 36' 28" N 122° 20' 6" W, Currently Licensed and Pending Facilities

OET Experimental Licensing System Database

Callsign: WI2XSC	**File Number:** 0039-EX-CN-2017	**Licensee:** Blue Origin	**FRN:** 0024940371	**Issue Date:** 02/06/2017	**Expiration:** 02/01/2019	**Radio Service:** XT	**Status:** Granted

Site Address:	**State:** TX	**County:** CULBERSON	**Mobile Coordinates:** 31° 25' 23" N, 104° 45' 26" W

Frequency: 401.20000000 M **Comment:** Experimental, out of Band

Callsign: WJ9XNY	**File Number:** 1452-EX-ST-2017	**Licensee:** The Boeing Company	**FRN:** 0001583483	**Issue Date:** 10/17/2017	**Expiration:** 04/17/2018	**Radio Service:** XT	**Status:** Granted

Site Address: Fixed operations within 1 kilometer radius	**State:** OR	**Fixed Coordinates:** 45° 44' 54" N 119° 47' 38" W	**Mobile Coordinates:** 45° 44' 54" N, 119° 47' 38" W

Frequency: 401.00000000 - 415.00000000 M **Comment**: Expired

Site Address:	**State:** WA	**Fixed Coordinates:** 45° 42' 24" N 121° 27' 30" W

Frequency: 401.00000000 - 415.00000000 M **Comment**: Expired

Site Address: Boardman Bombing Range	**State:** OR	**Mobile Coordinates:** 45° 44' 54" N, 119° 47' 38" W

Frequency: 401.00000000 - 415.00000000 M **Comment**: Expired

Callsign: WL9XGW	**File Number:** 0656-EX-ST-2017	**Licensee:** The Boeing Company	**FRN:** 0001583483	**Issue Date:** 06/05/2017	**Expiration:** 12/06/2017	**Radio Service:** XT	**Status:** Granted

OET Experimental Licensing System Database			
Site Address: Fixed operations within 1 kilometer radius	**State:** OR	**Fixed Coordinates:** 45° 44' 54" N 119° 47' 38" W	**Mobile Coordinates:** 45° 44' 54" N, 119° 47' 38" W
Frequency: 401.00000000 - 415.00000000 M **Comment**: Expired			
Site Address:	**State:** WA	**Fixed Coordinates:** 45° 42' 24" N 121° 27' 30" W	
Frequency: 401.00000000 - 415.00000000 M **Comment**: Expired			
Site Address: Boardman Bombing Range	**State:** OR	**Mobile Coordinates:** 45° 44' 54" N, 119° 47' 38" W	
Frequency: 401.00000000 - 415.00000000 M **Comment**: Expired			

Callsign: WL9XGW	**File Number:** 1646-EX-ST-2017	**Licensee:** The Boeing Company	**FRN:** 0001583483	**Issue Date:** 12/19/2017	**Expiration:** 06/07/2018	**Radio Service:** XT	**Status:** Granted

Site Address: Fixed operations within 1 kilometer radius	**State:** OR	**Fixed Coordinates:** 45° 44' 54" N 119° 47' 38" W	**Mobile Coordinates:** 45° 44' 54" N, 119° 47' 38" W
Frequency: 401.00000000 - 415.00000000 M **Comment**: Expired			
Site Address:	**State:** WA	**Fixed Coordinates:** 45° 42' 24" N 121° 27' 30" W	
Frequency: 401.00000000 - 415.00000000 M **Comment**: Expired			
Site Address: Boardman Bombing Range	**State:** OR	**Mobile Coordinates:** 45° 44' 54" N, 119° 47' 38" W	
Frequency: 401.00000000 - 415.00000000 M **Comment**: Expired			

Table 2: IB Licensing System Files, 401 to 401.2 MHz

International Bureau Filing System Database						
Callsign: E940536	**File Number:** SESMOD2013093000856	**Applicant:** ORBCOMM License Corp.	**FRN:** 0004379202	**Grant Date:** 12/16/2013	**Expiration:** 05/17/2020	**Status:** ATPN **Sub-System:** SES

Site: 1	**Description:** CONUS	**City:** OCILLA	**State:** GA	**County:** IRWIN	**Coordinates:** 31° 30' 3" N, 83° 11' 58" W
Frequency: 00000137.00000000-00000401.00000000 **Comment**: Does not Overlap					

International Bureau Filing System Database

Callsign: E940537	**File Number:** SESMOD20130930000854	**Applicant:** ORBCOMM License Corp.	**FRN:** 0004379202	**Grant Date:** 12/17/2013	**Expiration:** 05/17/2020	**Status:** ATPN **Sub-System:** SES

Site: 1	**Description:** CONUS	**City:** ST. JOHNS	**State:** AZ	**County:** APACHE	**Coordinates:** 34° 27' 21" N, 109° 33' 17" W

Frequency: 00000137.00000000-00000401.00000000 **Comment**: Does not Overlap

Callsign: E940538	**File Number:** SESMOD20130930000855	**Applicant:** ORBCOMM License Corp.	**FRN:** 0004379202	**Grant Date:** 12/16/2013	**Expiration:** 05/17/2020	**Status:** ATPN **Sub-System:** SES

Site: 1	**Description:** CONUS	**City:** EAST WENATCHEE	**State:** WA	**County:** DOUGLAS	**Coordinates:** 47° 33' 4" N, 120° 10' 30" W

Frequency: 00000137.00000000-00000401.00000000 **Comment**: Does not Overlap

International Operator Search

From the ITU Space Network Systems Online (SNS), a list of satellite systems using the 401 to 402 MHz frequency range is shown in Table 3. For each satellite system, the Comment column in the table indicates an assessment of the impact of the VCC CubeSats' operation on the system.

Table 3: List of Satellite Systems from ITU SNS, 401 to 401.2 MHz with USA, CAN or MEX ADM/ORG.

ADM	ITU ID	Satellite Name	BR IFC ID	Center Freq. (Mhz)	Min Freq. (Mhz)	Max Freq. (Mhz)	Bandwidth (Khz)	Status	Comment
CAN	113540650	GHGSAT-D	2773	402	401	403	2000	Active	Coordination Complete; No Expectation of Interference
CAN	108540431	JC2SAT	2640	402	401	403	2000	Active	CSA and JAXA. On Hold Indefinitely.
CAN	118545050	KELYPSIS	2871	401.5	401	402	1000	Active	**Kepler Communications Coordination in Progress**
CAN	117545422	MULTUS	2874	401.075	400.15	402	1850	Active	Inuvik Canada ground station beyond our footprint. No Impact.
USA	108540735	OSTM	2682	401.245	400.25	402.24	1990	Active	DORIS instrument, uses 401 as an auxiliary frequency
USA	117545411	ARKYD-6A, ARKYD-6B	2870	401.5	401.43	401.57	140		Redmond Washington ground station beyond our footprint, out of band. No Impact.
USA	110540475	CUCU, ISS-CUCU	2865	400.575	400.15	401	850		SpaceX CRS UHF Communication Unit on ISS; Beyond our footprint, out of band, No Impact
USA	113540068	DOVE1	2759	401.3	401	402	1000	Demised	No impact
USA	113540069	DOVE2	2759	401.3	401	402	1000	Demised	No impact

ADM	ITU ID	Satellite Name	BR IFC ID	Center Freq. (Mhz)	Min Freq. (Mhz)	Max Freq. (Mhz)	Bandwidth (Khz)	Status	Comment
USA	113540400	DOVE3	2766	401.3	401	402	1000	Demised	No impact
USA	113540401	DOVE4	2766	401.3	401	402	1000	Was Never Deployed	No impact
USA	113540399	INSIGHT	2764	397.5	390	405	15000	None	Note 1
USA	115545100	MARCO	2823	397.5	390	405	15000	None	Note 1
USA	116545103	MARS 2020	2831	397.5	390	405	15000	None	Note 1
USA		MRO		405		405	405000		Note 1
USA		MSL		410		410	410000		Note 1
USA	117545328	LEMUR-2-3	2867	401.5	401	402	1000	Active	**Spire, coordination in progress.**
USA	113540070	MER-R	2757	401.5856	401.4356	401.7356	300		Note 1, Out of Band
USA	107540739	NPOESS	2831	402	401	403	2000	Inactive	No impact
USA	108540735	OSTM	2682	401.25	400.25	402.25	2000	Inactive	No impact
USA	117545438	RAINCUBE	2875	400.795	400.78	400.81	30	Active	Pasadena CA ground station beyond our footprint. Out of band. No impact.
USA	117545438	RAINCUBE	2875	401.15	401.135	401.165	30	Active	Pasadena CA ground station beyond our footprint. Out of band. No impact.
USA	95540430	USASAT-30A	2842	401.5	401.47	401.53	60		Out of Band
USA	113540648	USASAT-30F	2788	401.5	401	402	1000	Active	Fairbank AK Ground station beyond our footprint. No impact.
USA	117545385	USASAT-NGSO-ASTC-2	2872	401.675	401.6	401.75	150		Out of Band
USA	113540040	USOCEAN	2757	401.25	401.2385	401.2615	23		Out of Band
USA		USPOJOQUE		401.7455	401.512	401.979	467	Inactive	No Impact
USA	112540309	UST4WP	2734	401.05	401.04676	401.05324	6.48		Entry 6 years old.

Note 1: *The Mars missions use highly directional ground based antennas and our satellites will transit quickly if at all, across these highly directional antennas, in roughly 4 seconds maximum.*

National Radio Quiet Zone Coordination

The University of Virginia ground station in Charlottesville, VA, lies just inside the Eastern border of the National Radio Quiet Zone (NRQZ), so evaluation for impact on the operation of the National Radio Astronomy Observatory (NRAO) was required. The NRAO performed an evaluation, and found no concerns with the operation as planned. See Appendix 1 for correspondence supporting this.

NOAA Coordination

NOAA conducts operations of the GOES system in the range of 401 to 402 MHz. Carmelo Rivera at NOAA was contacted, and an analysis of compatibility of VCC operations with NOAA operations, was provided. Mr. Rivera replied Sept. 12 that they will probably not have a problem with operation, and on September 24, he forwarded a letter from Fred Mistichelli, NESDIS. See Appendix 2 for correspondence showing their recommendations for concurrence with the VCC position of no interference. This recommendation is conditional on limiting the VCC activity to 3 years or less, which is compatible with our plan to operate for 2 years or less.

GHG Coordination

GHGSat operates in the range from 401 to 403 MHz. Carrie Rhoades at GHG was contacted, and she stated that there would be no impact on their operations. See Appendix 3 for a letter from GHG confirming this position.

Spire Coordination

Coordination discussions are ongoing with George John, Lead Legal & Regulatory Counsel Spire Global, Inc. See Appendix 4 for the latest communication from Spire.

Kepler Coordination

Kepler Communications operates in the range from 401 to 402 MHz. They have ground stations in Toronto, Canada; Svalbard, Norway; and New Zealand. VCC operation was reviewed with Nick Spina, Director Launch & Regulatory Affairs at Kepler Communications. His focus was on potential interference by VCC satellites transmissions, with the receiver at the Toronto ground station. Discussion ongoing.

Conclusion

There is no expectation at this time that VCC experimental satellite and US earth station operations will interfere with any known systems.

Appendix 1 Evaluation Letter from NRAO

NATIONAL RADIO ASTRONOMY OBSERVATORY
POST OFFICE BOX 2
GREEN BANK, WV 24944-0002
NRQZ OFFICE TELEPHONE (304) 456-2107 FAX (304) 456-2276
HTTP://WWW.GB.NRAO.EDU/ NRQZ@NRAO.EDU

July 11, 2018
Page 1 of 1
NRQZ ID: 11510_06JUN2018

Christopher P. Goyne
570 Edgmont Road
Charlottesville, VA 22904

Application Reason/Purpose	Coordination of tabled assignment
File/Docket/Assignment #	ULS 0240-EX-CN-2018 / NG-214748 / J1417835
Applicant Name	University of Virginia (UVA)
Call Sign	2XMR
Site Name or Loc	Charlottesville
Nearest City/State	Charlottesville, VA
N Latitude	38 01 57
W Longitude	78 30 40
Ground Elevation (m) / AGL (m)	166 / 13
Frequency (MHz)	401.0300 – 401.0500
Emission Designator	20K0G1D
Transmitter Power Out W / ERP	25 Watts / 688.3 Watts
Antenna 1 Type (Gain dBi) / Orientation (degT)	Not provided / ND
Previous NRAO Coordination No.	None – New frequency assignment
Current NRAO Coordination No.	NRQZ ID 11505_06JUN2018 (NTIA assignment) NRQZ ID 11510_06JUN2018 (ULS assignment)

Dear Applicant:

The National Radio Quiet Zone (NRQZ) has evaluated these facilities to determine the interference impact on our highly sensitive radio astronomy operations.

The National Radio Astronomy Observatory (NRAO) site located at Green Bank, Pocahontas County, WV, has no objections to this frequency assignment.

The Sugar Grove Research Station, formerly the Naval Radio Research Observatory (NRRO), located at Sugar Grove, Pendleton County, WV has no objections to this frequency assignment.

This letter constitutes coordination of assignment in the National Radio Quiet Zone as required by the FCC Rules and Regulations 47CFR1.924(a).

If I may be of assistance, please feel free to contact me.

Sincerest regards,

Paulette W. Woody
NRQZ Office Administrator
PWW:pww

cc: Mal Tran, FCC; Mike Miller for applicant file: 11510.docx

This concurrence remains valid provided the data contained within is consistent with the applicant's filing at the Commission. Any discrepancy in system parameters, such as geographical coordinates (Latitude, Longitude, AMSL), antenna height above ground level (AGL), antenna gains or directivity (orientation), channel (operating frequency or frequency bands), emission type, and power requires re-coordination. If the Commission has questions regarding the validity of this or any concurrence, please direct inquiries to nrqz@nrao.edu or 304-456-2107

Appendix 2 Evaluation Letter from NOAA

On Tue, 25 Sep 2018 08:47:17 -0400, Carmelo Rivera - NOAA Federal wrote:

Mike,

I concur.

Regards,
Carmelo

On Mon, Sep 24, 2018 at 10:51 PM, Mike Miller <mlmiller@sterksolutions.com> wrote:
Hi Carmelo,

This is very positive I feel. Do you concur, as recommended by Fred / NESDIS?

Thanks,

Mike
415 385-3842

On Mon, 24 Sep 2018 08:44:36 -0400, Carmelo Rivera - NOAA Federal wrote:
Please see the comments below and the recommendation from our satellite division.

v/r,
Carmelo

---------- Forwarded message ----------
From: **Alfredo Mistichelli - NOAA Federal** <alfredo.mistichelli@noaa.gov>
Date: Mon, Sep 24, 2018 at 3:34 AM
Subject: VCC 401-403 MHz interference analysis
To: Carmelo Rivera - NOAA Federal <carmelo.rivera@noaa.gov>
Cc: "Hall, Nathan T" <nhall@alionscience.com>, Al Wissman <Al.Wissman@noaa.gov>
Carmelo,

We have reviewed the technical specifications of the GOES-R UHF receiver in more detail, and made the following conclusions on the VCC coordination analysis:

Potential Impact to GOES DCS

- Their interference analysis (attached), shows acceptable RFI impact to GOES DCS
  - The only issue is the GOES-R satellite receive antenna gain (13.8 dBi) was not included in their static calculations; however, that wouldn't have a significant impact when you consider the frequency separation between the VCC signals and the GOES DCPR passband
  - Their analysis cites NOTE 1 within the ITU-R Recommendation SA.1164-2, which states,

> NOTE 1 – The single-entry interfering signal power thresholds in Table 1 are the permissible levels of interfering signal power that fall within the specified reference bandwidth.
>
> Accordingly, the total power in interfering signals that are narrower than the reference bandwidth should be considered in frequency sharing analyses.In cases where the interfering
>
> bandwidth exceeds the reference bandwidth or does not fully overlap the passband of a specific receiver under study, the available frequency dependent rejection should be applied
>
> in conjunction with the specified permissible interference levels.

- Frequency separation between VCC signals (401.04/401.08/401.12 MHz) and the filter within the GOES DCPR receiver (401.7 – 402.4 MHz) is enough to ensure no potential for interference (see attached figure)
- Regarding the potential for high levels of VCC interference signal power to drive GOES receiver LNAs into nonlinearity, we have confirmed there are no potential issues

Given all of the above, if you do decide to concur with VCC, we plan to track this agreement (along with all other future agreements with 401-403 MHz smallsats) in order to continually evaluate the potential for aggregate interference to GOES DCS.

Potential Impact to ARGOS

- DCS system use on NGSO MetSat/EESS systems is allocated to the bands 401 – 401.2 MHz and 401.3 – 401.7 MHz (as stated in ITU-R Recommendation SA.2045)
- The future NOAA Argos A-DCS satellite, scheduled for launch in FY2021, will use the 401 – 401.2 and 401.3 – 401.7 MHz bands

- Preliminary dynamic analyses, which evaluated the potential for interference from VCC uplinks/downlinks to the future Argos A-DCS links in 401 – 402 MHz, showed that the ITU-R Recommendation SA.2044 protection criteria is met
  - These analyses assumed VCC's stated duty cycles for their uplinks/downlinks
    - Uplinks: 2 passes taken per day, average transmit time per pass of 1.6 minutes
    - Downlinks: 2 passes taken per day, average transmit time per pass of 6.6 minutes

Given all of the above, there is concern that, should more and more smallsat constellations use the 401 – 401.2 and 401.3 – 401.7 MHz bands, by the time the Argos A-DCS satellite launches in 2021, the RF signal environment in those bands will have an adverse impact on the satellite's operation.

NESDIS Recommends we concur conditionally for a limited period of time, not to exceed 3 years, with conditions to not interfere with NOAA satellite operations. This should include stop buzzer POCs for the VCC missions (use me for the Gov side if you want). Due to the aggregate smallsat use of this band for smallsat TT&C it is recommended VCC transition out of the band by 2021.

Please note the ITU-R Recommendations cite above are no longer drafts, and have been approved by SG7. They still need to go through the ITU comment period to Administrations before coming into in force status and published.

Please call me if you'd like to discuss.

--
Regards,
Fred Mistichelli

Electronics Engineer
US Department of Commerce (DOC)
National Oceanic and Atmospheric Administration (NOAA)
National Environmental Satellite, Data and Information Service (NESDIS)

Office of Chief Information Officer

-

Satellites (OCIO-S)
1335 East West Hwy, SSMC-1 (Rm. G1-101)
Silver Spring, MD 20910-3283

(O)
(301) 713-1647
(C) (202)-308-5016

Appendix 3 GHGSAT Coordination Letter

--------- Forwarded message ---------
From: <carrie.herzog@ghgsat.com>
Date: Fri, Sep 14, 2018 at 9:46 AM
Subject: Re: FCC Frequency Coordination for VCC
To: Erin Puckette <ep2hk@virginia.edu>
Cc: Stephane Germain <stephane.germain@ghgsat.com>, Marcela Arias <mam@ghgsat.com>, Mike Miller <mlmiller@sterksolutions.com>

Hi Erin,
We have completed our analysis.
We believe that your operations will not interfere with GHGSat's Operations.
Given this information, we consider this coordination as complete.
Thank you,
Regards,

Carrie Herzog
Data Processing and Operations Specialist
GHGSat Inc.
3981 St-Laurent, Suite 500
Montréal, QC H2W1Y5>
Tel : +1-514-847-9474 x218

Appendix 4 Latest Communications with Spire Global

---------- Forwarded message ---------
From: **George John** <george.john@spire.com>
Date: Tue, Sep 25, 2018 at 6:24 AM
Subject: Re: UVA Cubesat Project - Licensing Coordination
To: Erin Puckette <ep2hk@virginia.edu>
Cc: Robert Sproles <robert.sproles@spire.com>

Don't worry about it. We know it's a rigorous process!

Talked to the engineering team and they are kindly requesting you submit the full spectral mask for uplink and downlink for the range of 150MHz -1700MHz. They also need to know your transmit duty cycle for both up and downlink.

Thanks,
George

On Mon, Sep 24, 2018 at 7:56 PM Erin Puckette <ep2hk@virginia.edu> wrote:
Hi George,

Sorry for the delay, I've been at vibration testing. For the markers given, the spectral density will be insignificant for all but 402.7 MHz. The roll off value there would be on the order of -128.861 dB.

Let me know if you need anything else.

Erin Puckette