

EMC Analysis Out of Band, CAPSat

Introduction and Summary of Results

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

	Lower frequency [MHz]	Center frequency [MHz]	Upper frequency [MHz]	Bandwidth [kHz]
Uplink	402.65	402.675	402.70	50
Downlink	401.15	401.175	401.20	50

This report provides a domestic and international electromagnetic compatibility study with 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. From these queries, it was determined that coordination efforts are required with NOAA, GHGSat, and JC2Sat. Additionally, a radio station in Monterey Mexico was identified to be registered in the ITU MIFR database operating at a center frequency of 402.95 MHz. This station will hereafter be referred to as “the Monterey station”.

It should be noted that a search of public records available online from the Instituto Federal de Telecomunicaciones (IFT), the official telecommunications regulatory agency of Mexico, yielded no licenses issued at the frequency 402.95 MHz in the state of Nuevo León where the Monterey station is located. Though it is possible that records of past licenses may be incomplete, as the IFT only recently replaced its predecessor in 2013, the lack of any active licenses on file (as well as the 26-year time gap since the station was registered in the MIFR) suggests the possibility that the Monterey station may no longer be in operation.

All coordination efforts have been approved, and the ground station operations for CAPSat are not expected to interfere with the Monterey station.

Table 1 summarizes the identified relevant operators with whom coordination actions were taken, and the outcome of the coordination effort. Details for each effort are included in the appendix.

Table 1: Summary of Coordination Efforts

Operator	Action	Outcome	Artifact
NOAA	Requested Coordination	Coordination Approved	Appendix Figure #1
GHGSat	Requested Coordination	Coordination Approved	Appendix Figure #2
JC2SAT	Requested Coordination	Mission Cancelled	Appendix Figure #3

Power Flux Density at Earth Surface, Out of Band, Monterey Station

The FCC requested an analysis for potential interference of the uplink (Ground station to CubeSat) Earth surface operations.

This section analyzes the potential for interference with operation of the radio station in Monterey, Mexico. See Appendix Figure 4 for more information.

Monterey Station Parameters

Center Frequency: 402.95 MHz

Bandwidth: 16.0 kHz

EIRP: 17.8 dBW

Radius of Operation: 25km

Power Spectral Density at Maximum Radius of Operation:

The Laboratory for Advanced Space Systems at Illinois (LASSI) operates a ground station located in Urbana, IL, at the Electrical and Computer Engineering building at the University of Illinois. The ground station uses an Ettus Research N210 software defined radio, operating at 50W output power, with an M2 401CP14 antenna having max gain of 11.5dBi, cable loss of 7.4 dB, which will provide an estimated transmit power of 128.82W EIRP. According to preliminary tests conducted on the radio by students at the University of Illinois, the roll off of the transmitting spectrum at 50W power output will yield operational maximum power settings as follows:

- -3 dB at 10 kHz;
- -20 dB at 25 kHz;
- -40 dB at 50 kHz;
- -60 dB at 140 kHz,
- -80 dB at 240 kHz, which just reaches the lower limit of Monterey Station Bandwidth

In the uplink (ground station to CubeSat), an Ettus Research N210 SDR will be used with directional antennas and power amplifiers to deliver a transmit power of 21.1 dBW (128.82W). This analysis assumes the receiver in Mexico is in the middle of the beam at the highest gain point, even though the elevation of the antenna is always 10 degrees or above.

Power Spectral Density Analysis

Uplink:

Considering that the in-band power of the transmitting signal is approximately uniformly distributed over the operating bandwidth of 50 kHz, this results in a power spectral density of $128.82\text{ W} / 50\text{ kHz} = 2.58\text{ W/Hz}$ or 4.12 dBW/Hz .

The out-of-band power of the transmitting signal is radiated through a 401CP14 11.5 dBi Yagi ground station antenna mostly in the adjacent 25 kHz bandwidth to the left and to the right of the operating band. The out-of-band PSD at 240 kHz away from the carrier frequency is attenuated by -80 dB relative to the in-band frequencies, resulting in an out-of-band PSD of $11.5\text{ dBic} - 4.12\text{ dBW/Hz} - (80\text{ dB}) = -72.62\text{ dBW/Hz}$ for these frequencies.

The out-of-band frequencies of the transmitted signal will be further attenuated by propagation pathloss from the CAPSat ground station to Monterey station by a distance of 1,959km, which for the 401 MHz band (0.748 m wavelength) is equal to 150.3 dB.

Pathloss Calculation:

$$FSPL = 20 \log_{10}(d) + 20 \log_{10}(f) + 20 \log_{10}\left(\frac{4\pi}{c}\right) - G_t - G_r$$

Thus, the out-of-band PSD at a potential satellite receiver operating in a bandwidth that is 240 kHz away from the operating bandwidth of the CubeSat radio, is $-72.62 - 150.3\text{ dB} = -222.92\text{ dBW/Hz}$.

The interference analysis calculations are summarized in the following table:

Table 2: Summary of Interference Analysis at Monterey Station

	Uplink Ground station: Monterrey Mexico
Peak transmit power [dBW]	17.8 dBW
In-band radiated PSD [dBW/Hz]	4.12 dBW/Hz
Transmitting spectrum roll off at 240 kHz away from CAPSAT bands [dB]	-80 dB
Transmit antenna gain [dBi]	11.5 dBi
Path loss to DCS receiver [dB]	150.3 dB
Out-of-band PSD at Monterey receiver [dBW/Hz]	-222.92 dBW/Hz

Appendix

Figure 1: NOAA Coordination Approval

From: [Kunde, Richard Joseph](#)
To: ["Carmelo Rivera - NOAA Federal"](#)
Bcc: [Hardy, Brian Patrick](#); ["Eric A"](#)
Subject: RE: FCC Licensing Issue - SpaceICE CubeSat Mission
Date: Friday, September 14, 2018 9:31:00 AM

Carmelo,

Thank you very much for looking into this. It means a great deal to our student teams. We appreciate your coordination efforts!

Sincerely,
 RJ Kunde
 University of Illinois

From: Carmelo Rivera - NOAA Federal <carmelo.rivera@noaa.gov>
Sent: Wednesday, September 12, 2018 7:42 AM
To: Kunde, Richard Joseph <rjkunde@illinois.edu>
Subject: Re: FCC Licensing Issue - SpaceICE CubeSat Mission

RJ,

I haven't heard anything back from them but we have steered others to the 402.6 - 402.9 MHz band since that shouldn't cause us a problem so I will give the go ahead on this one.

Regards,
 Carmelo

On Tue, Sep 11, 2018 at 5:02 PM, Kunde, Richard Joseph <rjkunde@illinois.edu> wrote:

Hi Carmelo,

Just touching base on this, have you received any word from your analysts?

Thank you,
 RJ Kunde

From: Carmelo Rivera - NOAA Federal <carmelo.rivera@noaa.gov>
Sent: Thursday, August 30, 2018 7:24 AM
To: Kunde, Richard Joseph <rjkunde@illinois.edu>
Subject: Re: FCC Licensing Issue - SpaceICE CubeSat Mission

RJ,

I will pass this on to our analysts and see what they say.

Figure 2: GHGSat Coordination Approval

From: carrie.herzog@ghgsat.com
To: [Kunde, Richard Joseph](#)
Cc: [Stephane Germain](#); [Marcela Arias](#); [Alpine, Eric Luke](#)
Subject: RE: CubeSat FCC License Question
Date: Friday, September 14, 2018 8:48:23 AM

Hi RJ,
We have completed our analysis.
We believe that CAPSat and SpaceICE will not interfere with GHGSat's operations.
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

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Figure 3: JC2Sat Mission Cancellation

From: [Ng, Alfred \(ASC/CSA\)](#)
To: [Kunde, Richard Joseph](#)
Subject: RE: JC2SAT FCC Licensing Question
Date: Wednesday, September 12, 2018 8:06:42 AM

Dear Richard:

The project JC2Sat was terminated by the management of JAXA and CSA following the difficulty to secure a launch opportunity. We reached the CDR stage and it was terminated at that point onward.

Let me know if you have any other question.

With regards,

Alfred Ng

Directeur adjoint, Sciences & technologies spatiales
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From: Kunde, Richard Joseph <rjkunde@illinois.edu>
Sent: September-11-18 5:02 PM
To: Anton de Ruiter <aderuiter@ryerson.ca>
Cc: Ng, Alfred (ASC/CSA) <alfred.ng@canada.ca>
Subject: RE: JC2SAT FCC Licensing Question

Anton,

Thank you for making the introduction!

Dr. Alfred Ng, do you happen to have any additional information on JC2Sat's status?

Thank you,
RJ Kunde
University of Illinois

From: Anton de Ruiter <aderuiter@ryerson.ca>
Sent: Wednesday, September 5, 2018 7:56 AM
To: Kunde, Richard Joseph <rjkunde@illinois.edu>

Figure 4: ITU MIFR Database Results - Monterey Station



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eMIFR

MIFR (Terrestrial Services) on-line query (BETA2 release)

☐ MIFR (Broadcasting)
 ☐ MIFR (FXM)
 ☒ MIFR (all)

MIFR (ALL): Selection Criteria

Administration	Geographic Area	Notice Type	Class of Station
AFG ▲ ▼ AFS ▶ ◀ AGL ▶▶ ◀◀ ALB ◀ ▶ ALG ◀◀ ▶▶ ARG ▼ ▲ ADM ▼ ▲	ABV ▲ ▼ AFG ▶ ◀ AFS ▶▶ ◀◀ AGL ◀ ▶ AIA ◀◀ ▶▶ ALB ▼ ▲ ALC ▼ ▲	▲ ▼ ▶ ◀ ▶▶ ◀◀ ◀ ▶ ◀◀ ▶▶ 1A1 1A2 1A4 1A5 1A7 1B1 1C1	▲ ▼ ▶ ◀ ▶▶ ◀◀ ◀ ▶ ◀◀ ▶▶ AL AM BC BT FA FB FC

Status
☒ Recorded
 ☒ Pending
 ☒ Not published

Assigned Frequency

☐ $f_{min} \leq \text{Assigned Frequency} \leq f_{max}$ only

Unique Id. code given by Administration

Identifier assigned by the BR
 from to

Date of Receipt (from)

Date of Receipt (to)

Site Name

MIFR (All) IFL: 092021336

Administrative			
Administration	MEX	Intent	RECORDED
Unique identification code given by the administration		Modification Type	
Identifier assigned by the BR	092021336	Amendment Type	RECORDED
Fragment	NTFD_RR	Provision	RR11.9
Notice Type	1B1	Resubmission	False
Date of Notification		Address Code	A
		Signed Commitment	False

Date of Receipt	15	Jul	Hours Of	0000-2400
	1992		Operations	
Date of Expiry				
Date of Entry into the MIFR	15	Jul		
	1992			
Operating Agencies		124		

Emission Characteristics				
Assigned Frequency (MHz)	402.95	Nature of Service	CV	
Reference (carrier)		Frequency deviation (MHz)		
Frequency		Energy dispersal (kHz)		
Class of Emission	F3EJ-	System Type Code(s)		
Bandwidth Code	16K0			

Station and Site Information				
Site Name	MONTERREY	Region	2	
	NL	Geographical Area	MEX	
Class of station	ML	Geographical coordinates	100°18'00" W - 25°19'00" N	
Station Type	RX	Altitude of site above sea level (m)		
Geographical Type	POINT	Radius (km)		
Zone ID				

Operations				
Operation 1				
General Characteristics				
Power Type	Y	Polarization		
Power to the Antenna (dBW)	10	Antenna Directivity		
Radiated Power (dBW)	17.8	Azimuth of Maximum Radiation (°)		
	E	Maximum Effective Antenna Height (m)		
Maximum Antenna Gain (dB)		Height of Antenna Above Ground Level (m)		
Maximum Gain Toward the Local Horizon (dB)		Elevation Angle (°)		
Gain Type		Beamwidth (°)		
Maximum Power Density (dBW/Hz)		Reference Antenna		

Receiving Station Information				
RX1				
Site Name		Geographical Type	CIRCLE	
Geographic Area		Zone ID		
Region	2	Geographical coordinates	100°18'00" W - 25°19'00" N	
		Radius (km)	25	

Findings Information				
Publication History				

BR IFIC	Date of Publication	Special Section	Publication part	Addendum	Corrigendum
2047	6 Oct 1992	2047	1		
2054	24 Nov 1992	2054	2		

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