EMC Analysis for SOARS Beacon

Introduction and Summary of Results

The SOARS program is aiming to create a space tracking infrastructure with the use of transmitting, low-swap Beacons on orbit that are tracked with a distributed ground station network. For initial on orbit testing, the project will launch a flight beacon as a hosted payload on the rocket body. The primary mission is to establish comms with the beacon, monitor long-term health of the hardware, and validate the distributed ground station network.

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

	Lower frequency [MHz]	Center frequency [MHz]	Upper frequency [MHz]	Bandwidth [kHz]
Uplink	400.019	400.030	400.041	22
Downlink	400.618	400.620	400.622	4

This report provides a domestic and international electromagnetic compatibility study of the uplink and downlink 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 operators with whom coordination actions were taken, and the outcome of the coordination effort. Details for each are provided in later sections of the report.

Operator	Action	Outcome
Eritek, Inc	Reached out for Coordination	No objections, coordination complete.
TCOM	Reached out for Coordination	Contract that operations supported has expired, therefore no further use of spectrum. Coordination complete.

Power Flux Density

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

The transmitter for downlink provides no greater than 5.6 dBW EIRP. The flight unit transmitter's spectrum was measured and found to have the following signal roll off:

- -3 dB at 3.5 kHz;

- -20 dB at 5 kHz;
- -40 dB at 9 kHz;
- -50 dB at 220 kHz
- -60 dB at 600 kHz.

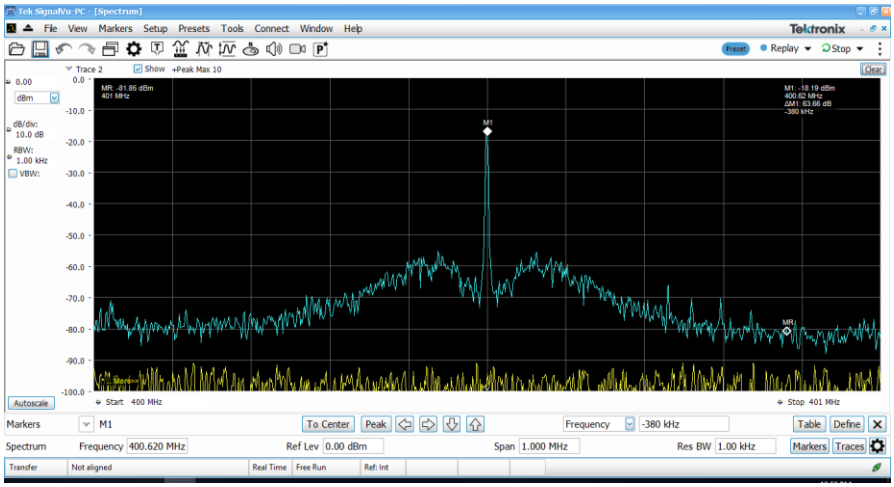

Figure 1 Measured Output Spectrum of Beacon

Figure 1 represents the rolloff for both the uplink and downlink.

The uplink uses the same transmitter, with a larger amplifier. The total EIRP of the uplink system is 34.7 dBW, center beam. The extra bandwidth requested in the application for the uplink signal, is to allow for doppler compensation on the ground, allowing the center frequency and spectrum to slide around inside the bandwidth.

Power Spectral Density Analysis

Downlink:

Considering the total power of the transmitting signal to be approximately uniformly distributed over the operating bandwidth of 4 kHz, this results in a power spectral density (PSD) of 3.63 W / 4 kHz = 0.0009 W/Hz or -30.42 dBW/Hz.

The out-of-band power of the transmitting signal is radiated through a fairly omni directional path antenna whose gain of 3 dBi is included in the previous EIRP measurement. The out-of-band PSD at frequencies located beyond 9 kHz from the carrier frequency is attenuated by 40 dB relative to the in-band frequencies resulting in an out-of-band PSD of -30.42 - 40 =
-70.42 dBW/Hz.

GEO Interference:

The out-of-band frequencies of the transmitted signal will be further attenuated by propagation pathloss from the SOARS beacon orbiting in low Earth orbit at 450 km, to a notional 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 175.5 dB, and corresponds to the minimum distance of 35,318 km. Thus, the out-of-band PSD at a potential satellite receiver operating in a

bandwidth that is 9 kHz away or more from the operating bandwidth of the beacon is -70.42 - 175.5 =
-245.92 dBW/Hz.

Earth Surface Interference:
For a potential receiver on the ground, the closest approach would be the beacon directly overhead at a separation of the altitude of 450 km. This translates to a free space path loss of 137.6 dB. Thus, the out-of-band PSD for a notional ground receiver operating in a bandwidth 9 kHz or greater away from the operating frequency of the beacon is -70.42 – 137.6 =
-208.02 dBW/Hz.

Uplink:

GEO Interference
Considering that the in-band power of the transmitting signal is approximately uniformly distributed over the instantaneous operating bandwidth of 4 kHz, this results in a power spectral density of 2951 W / 4 kHz = 0.738 W/Hz or -1.32 dBW/Hz.

The out-of-band power of the transmitting signal is radiated through a fairly directive Yagi antenna whose gain is included in the previous EIRP measurement. The out-of-band PSD at frequencies beyond 9 kHz away from the carrier frequency is attenuated by 40 dB relative to the in-band frequencies resulting in an out-of-band PSD of -1.32 - 40 = -41.32 dBW/Hz for these frequencies.

The out-of-band frequencies of the transmitted signal will be further attenuated by propagation pathloss from the ground station to a notional satellite orbiting in geosynchronous orbit at 35,768 km, which for the 401 MHz band (0.748 m wavelength) is equal to 175.6 dB. Thus, the out-of-band PSD at a potential satellite receiver operating in a bandwidth that is 9 kHz away or more from the operating bandwidth of the beacon is -41.32 - 175.6 =

-216.92 dBW/Hz.

Interference to Earth Surface Receivers

The minimum elevation of the antenna is 20 degrees, and the consequent off-beam derating of the antenna gain from the radiation pattern diagram is 7 dB. The resulting EIRP is 26.2 dBW or 417 W. Considering that the in-band power of the transmitting signal is approximately uniformly distributed over the instantaneous operating bandwidth of 4 kHz, this results in a power spectral density of 417 W / 4 kHz = 0.104 W/Hz or -9.81 dBW/Hz.

The out-of-band PSD at frequencies beyond 9 kHz away from the carrier frequency is attenuated by 40 dB relative to the in-band frequencies resulting in an out-of-band PSD of –9.8 - 40 =

-49.8 dBW/Hz

The interference analysis calculations are summarized in the following table:

	Downlink Beacon → Ground Station	**Uplink** Ground station → Beacon
Peak transmit power [**dBW**]	5.6	34.7
In-band radiated PSD [**dBW/Hz**]	-30.42	-1.32
Transmitting spectrum roll off at frequencies >9 kHz away from freq bands [**dB**]	-70.42	-41.32
Path loss to GEO receiver [**dB**]	175.5	175.6
Out-of-band PSD at GEO receiver [**dBW/Hz**]	-245.92	-216.92
Path loss to Earth Surface [**dB**]	137.6	(Based on distance from ground station)
Out-of-band PSD at Earth surface [**dBW/Hz**]	-208.02	-49.8

Frequency Analysis

The space element of the SOARS system has a 5.6 dBW EIRP. The resulting maximum ground Power Flux Density is -118.4 dBw/m^2/4kHz as seen on the ground at the closest approach. The ground station has a 20 degree elevation mask which yields a maximum exclusion radius of 2,700 km, extending to the US and Canada. A Power Flux Density analysis was completed to understand the observed surface power density. The received PFD at Earth surface will never exceed – 118.4 dBW/m^2/4kHz.

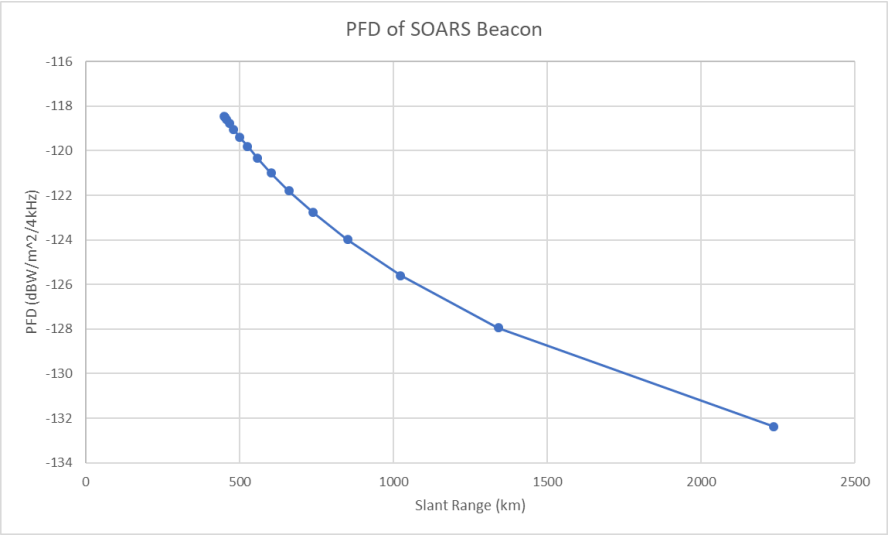

Figure 2 PFD over Range

Domestic Operator Search

From the FCC OET and FCC International Bureau databases, lists of satellite systems using the 400 to 401 MHz band was collected and shown below in Table 1 and Table 2.

Search Criteria: Frequency Range = 400 MHz through 401 MHz, Computed Box Based on Point/Radius: Center = 38° 57' 51.7" N 77° 22' 45.2" W, Radius = 249 Miles, Currently Licensed and Pending Facilities

OET Experimental Licensing System Database

Callsign:	File Number:	Licensee:	FRN:	Issue Date:	Expiration:	Radio Service:	Status:
WJ2XSM	0380-EX-CN-2018	Eritek, Inc	0027511377	12/03/2018	12/01/2020	XT	Granted

Site Address:	State: V A	Mobile Coordinates: 39° 6' 56" N, 77° 33' 49" W Distance from Center: 14.4 Miles Azimuth from Center: 316.6°

Frequency: 400.00000000 - 406.00000000 M

Site Address:	**State:** VA	**Mobile Coordinates:** 39° 7' 12" N, 77° 25' 55" W **Distance from Center:** 11.1 Miles **Azimuth from Center:** 345.3°

Frequency: 400.00000000 - 406.00000000 M

Callsign: WJ2XRV	**File Number:** 0634-EX-CN-2018	**Licensee:** TCOM, L.P.	**FRN:** 0005393228	**Issue Date:** 10/11/2018	**Expiration:** 10/01/2020	**Radio Service:** XC	**Status:** Granted

Site Address: 190 TCOM Dr	**State:** NC	**County:** PASQUOTANK	**Fixed Coordinates:** 36° 13' 50" N 76° 7' 50" W **Distance from Center:** 200.6 Miles **Azimuth from Center:** 159.7°	**Mobile Coordinates:** 36° 13' 50" N, 76° 7' 50" W **Distance from Center:** 200.6 Miles **Azimuth from Center:** 159.7°

Frequency: 400.00000000 - 450.00000000 M

Table 1

International Bureau Filing System Database

Callsign: E191359	**File Number:** SESREG20181008004983	**Applicant:** Kuhn Communications, Inc.	**FRN:** 0008463440	**Status:** AFP **Sub-System:** SES

Site: Walnut Bottom	**Description:** Central PA -Cumberland, Franklin, & Perry Counties	**City:** Walnut Bottom	**State:** PA	**County:** CUMBERLAND	**Coordinates:** 40° 9' 0" N, 77° 40' 0" W	**Distance from Center:** 83.2 Miles **Azimuth from Center:** 349.5°

Frequency: 00000370.00000000-00004200.00000000

Callsign: E940535	**File Number:** SESMOD2013093000853	**Applicant:** ORBCOMM License Corp.	**FRN:** 0004379202	**Grant Date:** 12/12/2013	**Expiration:** 06/12/2020	**Status:** ATPN **Sub-System:** SES

Site: 1	**Description:** CONUS	**City:** ARCADE	**State:** NY	**County:** WYOMING	**Coordinates:** 42° 31' 29" N, 78° 22' 57" W	**Distance from Center:** 251.2 Miles* **Azimuth from Center:** 348.3°

Frequency: 00000137.00000000-00000401.00000000

Table 2

From this survey, the PSD from the SOARS ground station to the location of these systems was computed according to Table 3.

Licensee	Frequency (MHz)	Separation (km)	Path Loss (dB)	PSD (dBW/Hz)	Comment / Resolution
Eritek, Inc	N/A	23.2	111.82	-174.62	No risk of interference. Eritek is not using this spectrum.
Eritek, Inc	N/A	17.9	109.56	-172.36	No risk of interference. Eritek is not using this spectrum.
TCOM	N/A	322.8	134.68	-197.48	No risk of interference. This experimental RF link was in support of a government contract that is no longer active.
Kuhn Communications	370-4200	133.9	127.04	-189.84	No risk of interference. Entry in database is typo. The actual range of their operation is 3700-4200 MHz.
ORBCOMM	400.15-401	404.2	136.64	-203.44	No risk of interference. Spectrum roll-off is 50 dB plus addition 7 dB rejection due to azimuth-specific mask of 25 deg elevation when pointed near ORBCOMM ground station. Resulting signal is below theoretical noise floor.

Table 3

International Operator Search

From the ITU MIFR database, a list of satellite systems using the 400-401 MHz frequency range is shown in Table 4. No impacts were found in the planned area of operation.

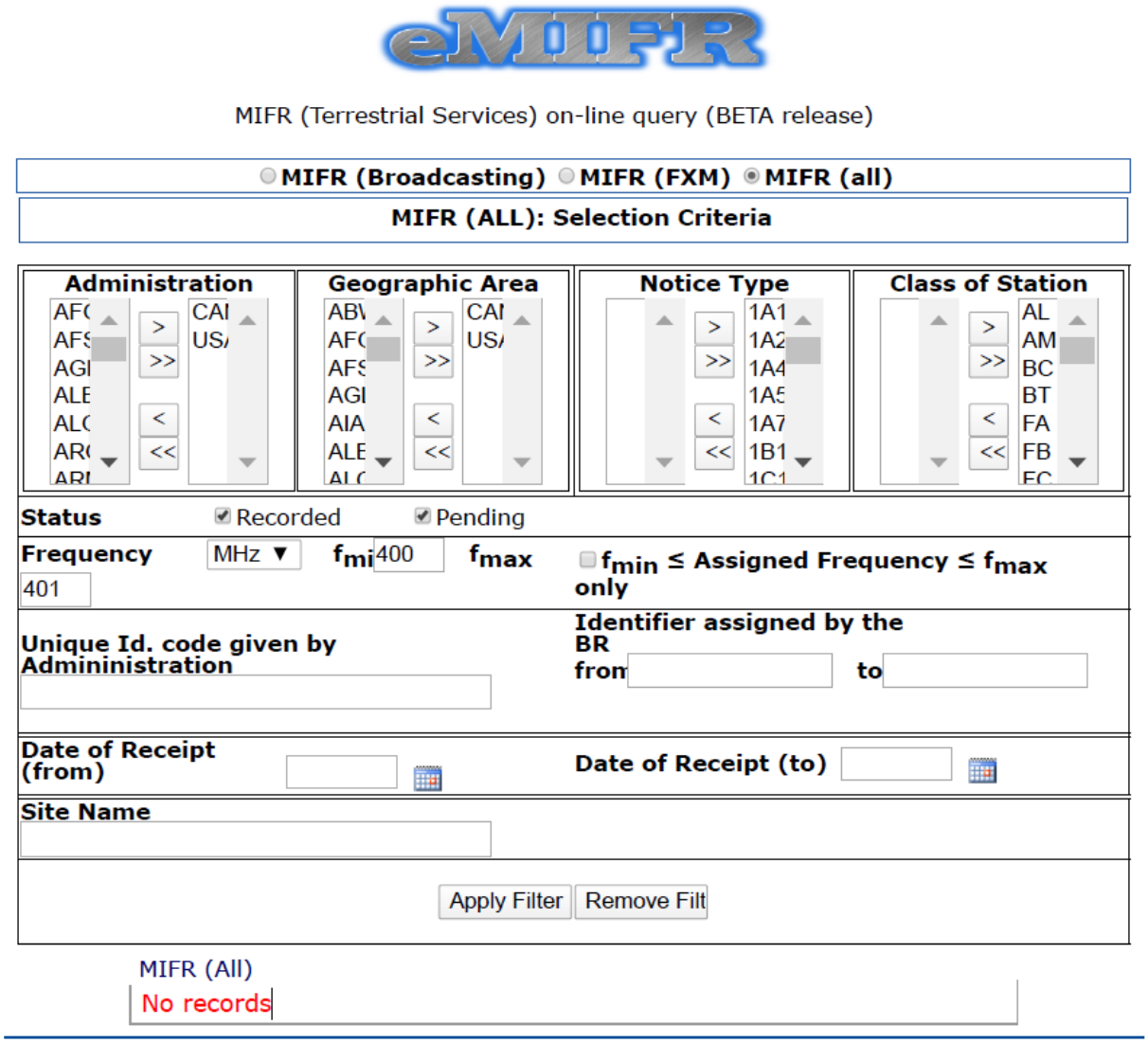

Table 4

Coordination

Eritek Coordination

Eritek is not and as of 1/21/20 has no plans to operate in this frequency range. See Attachment 1 for email correspondence stating this.

TCOM Coordination

TCOM's experimental license is only in support of US Government contract number W56KGY-18-C-0006. This contract ended in 2019 and therefore there is no possible risk of interference and no need for coordination. See Attachment 2 for summary of phone calls confirming this.

Conclusion

The experimental satellite and US earth station pose no risk of creating harmful interference with any known, licensed system.

Attachment 1 – Eritek Coordination Email

On 1/21/2020 3:10 PM, Joel Brotman wrote:

Alex,

Thank you for contacting me, I am the correct person. Although we have the experimental license, we are not and have not used the system. At this point we have no plans to use it.

Joel

Joel Brotman
VP Operations
Eritek Inc.
703-574-5323

From: Alex Witko
Sent: Monday, January 20, 2020 1:52 PM
To: Joel Brotman
Subject: Spectrum Coordination Request

Mr Brotman,

My name is Alex Witko and I am an electrical engineer at Tiger Innovations. We are in the process of setting up an experimental RF system and based on paperwork you filed with the FCC (File number 0380-EX-CN-2018), there is a chance we could cause interference with your system or you could cause interference with ours. I would like to exchange some of the parameters of our system with yours to ensure this does not happen. If you are the correct person to talk to about this, please let me know when you would be available to talk. If there is someone else in your organization that would be better suited to discuss this with me, please let me know what their contact information is.

Respectfully,

Alex Witko
Electrical Engineer
Tiger Innovations, Inc
(703) 435 2980 x110

Attachment 2 – TCOM Coordination Phone Calls

Phone call #1 was at 10:30 EST on 1/24/20 between Thomas Frank (listed government POC on TCOM FCC filings) and Alex Witko (Tiger Innovations engineer).

Summary:

Thomas Frank indicated he was no longer the responsible POC for contract W56KGY-18-C-0006 and that Will Kwon was the correct POC. Thomas Frank provided contact information.

Phone call #2 was 10:40 EST on 1/24/20 between Will Kwon (government POC) and Alex Witko (Tiger Innovations engineer).

Summary:

Will Kwon confirmed he is the correct POC for government contract number W56KGY-18-C-0006. Will Kwon indicated that contract's Period of Performance was from 2018-2019 and was no longer active. With the contract complete, no further use of the experimental RF link is expected, and thus possess no risk for interference.