

Exhibit C - Interference Study

Interference and Electromagnetic Compatibility Study

The experimental Swarm satellite network, which includes 3 satellites and 2 US earth stations¹, employs the 137-138 MHz band for space to earth and earth to space links, consistent with the US and International table of frequency allocations. To demonstrate compliance with an experimental systems obligation to operate on a non-interference basis with other authorized operators in the bands, this report provides a three part electromagnetic compatibility study with the existing authorized users. Specifically, the report includes: 1) a study of compatibility with terrestrial services, 2) a study of compatibility with other satellite systems, and 3) a study of compatibility with radio astronomy services.

Statement for Terrestrial and Aeronautical Mobile System Compatibility

ITU Radio Regulations impose power flux density (PFD) limits that trigger coordination for certain terrestrial (fixed and mobile) and aeronautical mobile systems in the 137-138 MHz band and adjacent 138-143.6 MHz band². In summary the PFD thresholds that trigger coordination are as follows:

- Terrestrial Services: -125 dBW/m²/4KHz
- Aeronautical Mobile (R): -125 dBW/m²/4KHz
- Aeronautical Mobile (OR): -140 dBW/m²/4KHz

Figure 1 shows a plot of the expected PFD at Earth's surface for all angles of arrival at the operational orbit altitude. Note that due to the antenna gain pattern, the PFD at Earth's surface diminishes significantly as the satellite elevation increases towards 90 degrees. The gain pattern is optimal for communications at elevations 10 to 60 degrees where the majority of ground access time occurs.

¹ The three satellites for which an authorization is sought will transmit only when within line of sight of two US earth stations, one in Los Altos CA, and one in Atlanta GA, when commanded by the ground station. No other earth stations will transmit to the three satellites.

² ITU RR Appendix 5, Annex 1, article 1.1.1 and 1.1.2

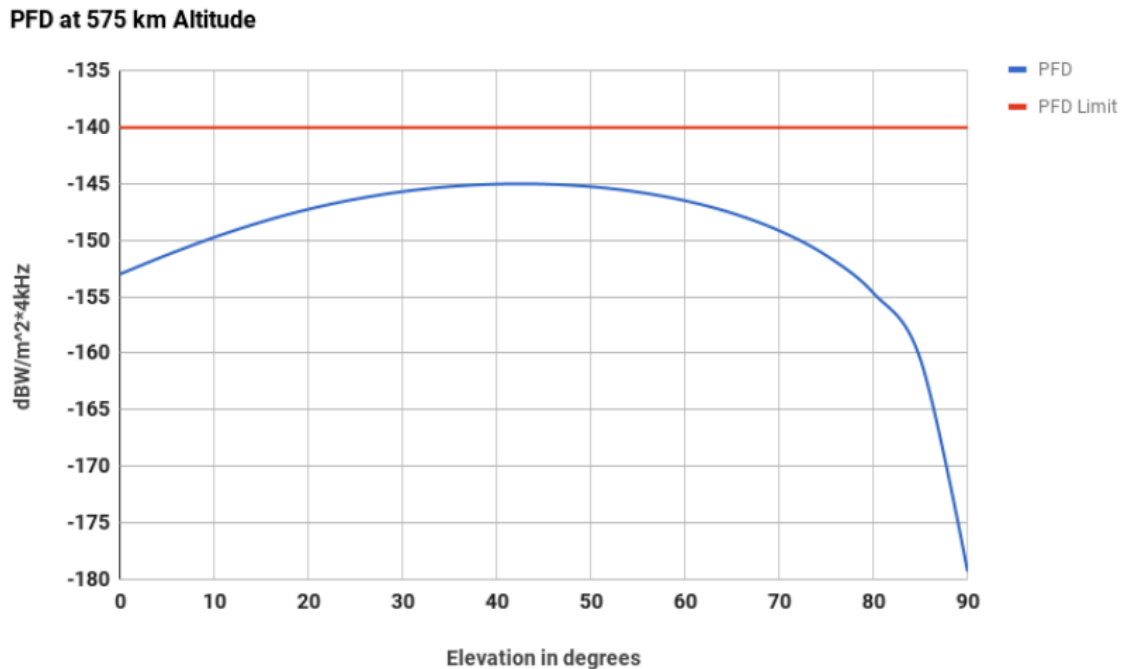


Figure 1. PFD at Earth's surface produced by a satellite transmission

In summary, the power flux density (PFD) at the Earth's surface produced by the Swarm satellites will not exceed -145 dB(W/m²) in any 4 kHz band at any angle of arrival, which is under the threshold for coordination with both terrestrial services and aeronautical mobile (R or OR) and therefore does not trigger a coordination requirement.

Statement of Satellite Service System Compatibility

From the ITU Space Network Systems Online (SNS), a list of satellite systems using the 137-138 MHz band was collected and shown in Table 1. For each satellite system, the table indicates the administrative jurisdiction, service areas, frequency overlaps, and ultimately a disposition for a coordination requirement. Most satellites have either no frequency overlap with Swarm satellites, have no area coverage overlap, or have no apparent earth stations in the USA. In addition, a search of the FCC IBFS for the 137-138 MHz band show that only Orbcomm is licensed for a space system using these space services links within the United states. In summary, only Orbcomm Satellites, and NOAA N require some form of coordination for operations in the USA. Swarm will seek consent from both the NTIA and Orbcomm regarding those systems.

The Interference Protection Criteria (IPC) for meteorological satellites³ in the 137-138 MHz band is -136 dBW per 150 kHz. This IPC is applicable for the NOAA N and NOAA KLM satellites. There is no frequency overlap with NOAA KLM and therefore no interference is expected. The NOAA N earth stations may have an isotropic gain as high as 10 dBi⁴ and in this case the signal power from a Swarm satellite into a NOAA N ground receiver could reach -132.8 dBW exceeding the IPC. This however will be a rare situation where a Swarm satellite is transmitting at the same time the NOAA N earth station is pointed in the direction of the Swarm satellite (given a 10 dBi antenna has some directionality). In fact, potential interference conjunctions above -136 dBW/150 kHz IPC is estimated to occur less than 0.00037% of the time which meets the IPC limit of less than 0.0063% of the time (as specified by the previously referenced ITU recommendation.) This is estimated as follows⁵: The Swarm transmissions will occur less than 0.069% of the time daily over each ground station. The NOAA N satellite may transmit up to 3.3% of the time daily in the same area. A 10 dBi earth station antenna has a 6 dB beamwidth of approximately 72 degrees, which is about 16% sky coverage. This results in a potential interference conjunction exceeding -136 dBW into the earth station receiver no more than 0.00037% of the time. Therefore the experimental Swarm satellite system meets the IPC for NOAA N and coordination should not actually be required. Note that this estimate assumes the worst case scenario that the satellites share a similar orbit and equatorial crossing time and anything otherwise would yield a smaller conjunction percentage.

There are two other satellite systems shown in the tables below deserving additional attention, IMDC and SI-SAT-BILIKIKI. In each of these two cases there is potential frequency overlap and the USA is a designated coverage area in the ITU notices. However, none of these systems have launched yet, and no US licenses or applications were submitted to the FCC as of December 2017. The IMDC system is a single satellite by the company Innovative Solutions In Space in the Netherlands. It appears there will only be an earth station in the Netherlands. The SI-SAT-BILIKIKI is a planned large Mobile Satellite Service constellation by Pangea Networks LLC. Pangea Networks is a US based company but filed their satellite system notification through the Solomon Islands administration. the status of their launch authorization licensing and construction progress is unknown by Swarm, and Pangea has no space system licensing within the United States.

³ ITU R-REC-SA.1027-5, Table 1, Sharing Criteria at 137-138 MHz, Interfering signal power (dBW) should not exceed -136 dBW per 150 kHz more than 0.0063% of the time.

⁴ The ITU SNS for NOAA N shows receive antenna type ND with up to 10 dBi isotropic gain.

⁵ Swarm transmissions: 2 second duration * 10 contacts * 3 satellites / 1440 minutes/day = 0.069%,

NOAA transmissions: 12 minute duration * 4 contacts * 1 satellite / 1440 minutes/day = 3.3%,

NOAA earth station antenna sky coverage: $\text{PI} \cdot (72 \text{ deg beamwidth} / 2)^2 / \text{PI} \cdot (90 \text{ deg})^2 = 16\%$

In these tables, red-colored boxes indicate frequency overlap between the respective system in the row and the Swarm satellites. Green rows indicate some level of coordination or additional consideration is required for the system.

Table 1: List of Satellite Systems in the ITU SNS, transmitting 137-138 MHz

Satellite	Country	Service Area	Freq Overlap (max freq shown)	Coordination requirement	Notes
AGILE	Italy	XVE Kenya ES	138	None	Equatorial NGSO, no orbital access to USA.
ATS-5	USA	GEO NC ES	...137.365	None	GEO, no frequency overlap
EUTELSAT-48E	France	GEO Belgium ES	...137.230	None	GEO, no frequency overlap
IMDC	Nether lands	XAA, Netherland ES	137.9-138 E-S, S-E	None	Not launched yet? No US license/stations Innovative Solutions In Space
IMP-J	USA	AK, NC ES	...137.995	None	Inactive, 1970's
LEOTELCOM-1	USA	XAX (world)	...137.325	Orbcomm Consent	No frequency overlap
LEOTELCOM-2	USA	XAX	...137.928	Orbcomm Consent	To be coordinated with Orbcomm
LEOTELCOM-5	USA	XAA	...137.655	Orbcomm Consent	No frequency overlap
MCSCS	China	XAA (world)	...137.525	None	No frequency overlap
METEOR-3M	Russia	XAA	...137.975	None	deactivated March 2006
METOP	France	XAA	...137.1	None	No frequency overlap
NOAA N	USA	XAA	...137.932	NTIA consent IPC met	To be coordinated w/ NTIA IPC met
NOAA-KLM	USA	XAA	...137.793	None	No frequency overlap
RS-D2	India	IND (India)	...137.550	None	No area or frequency overlap
SAUDISAT-1C	Saudi Arabia	ARS (Saudi Arabia)	...137.525	None	No area or frequency overlap
SAUDISAT-2	Saudi Arabia	ARS	...137.513	None	No area or frequency overlap
SEO BHASKARA-1	India	IND	...137.990	None	No area overlap, 1980's
SEO BHASKARA-2	India	IND	...137.990	None	No area overlap, 1980's
SI-SAT-BILIKIK I (300 satellites)	Solomon Island	XAA	137-138 (1 MHz)	None	Not launched yet No US license/stations Pangea Networks
SROSS-1	India	IND	...137.690	None	No area or frequency overlap 1990's

Radio Astronomy Service Protection

Pursuant to the ITU Radio Regulations 5.208A, Swarm's satellites meet the ITU recommendations⁶ to avoid interference with the nearby Radio Astronomy Service (RAS) band (150.05-153 MHz). The satellites transmit only in the 137-138 MHz band and out of band emissions are minimized by digital modulation techniques and filtering with at least 85 dB spectral roll-off⁷ at 150 MHz resulting in a power flux density (pfd) at Earth's surface not exceeding -265 dB(W/(m² · Hz)) thereby meeting the RAS protection criteria of -259 dB(W/(m² · Hz))⁸.

The experimental ground stations share the same frequency and out of band suppression characteristics. Ground stations will be positioned at a distance or otherwise obstructed such to prevent line-of-sight observations by a Radio Astronomy site using the 150.05-153 MHz band⁹ and resulting in a signal attenuation that meets the RAS interference protection criteria. In addition, the frequency of transmissions from the Swarm earth stations is much less than 2% of the time¹⁰ which also meets the RAS protection criteria¹¹.

Conclusion

The experimental satellites and US earth stations pose no risk of creating harmful interference with any known system with the exception of Orbcomm. As represented above, Swarm satellite transmissions are compliant with the frequency allocation tables and meet PFD based protection criteria for terrestrial systems and RAS as well as meteorological satellite systems. Swarm will seek specific consent from Orbcomm to mitigate any potential for interference with their system.

⁶ ITU Radio Regulations, Resolution 739 (Rev. WRC-15) and Recommendation ITU-R M.1583.

⁷ Measured performance at 150 Mhz is -86 dBc within the limits of the test equipment and likely exceeds this performance in the RAS bands. -80 dBc occurs at 3 Mhz from the carrier.

⁸ As specified in ITU-R M.1583, the protection criteria is -238 dB(W/m²) in a 2.95 MHz reference bandwidth and as recommended in ITU-R RA.769-2 Table 1, the threshold for harmful interference is -259 dB(W/(m² · Hz)) at a center frequency 151.525 MHz.

⁹ Recommendation ITU-R RA.769-1 specifies "above about 40 MHz sharing may be practicable with services in which the transmitters are not in direct line-of-sight of the observatories".

¹⁰ The experimental transmissions are at a maximum of 2 second durations 30 times per day (~0.069% of the time). This accounts for 3 satellites with up to 10 contacts each per day.

¹¹ ITU RR 2016, Resolution 739, article g, and ITU-R RA.1513-2, article 2.