Exhibit D – Ground Co-Channel Interference Analysis of Topside Sounder
7/02/2026

1. Executive Summary

Saint Francis University requests an Experimental Authorization (Part 5) to operate a 9.303 MHz topside ionospheric sounder with a peak effective isotropic radiated power (EIRP) of 1.0 Watt. The primary regulatory and operational concern for High Frequency (HF) transmissions from low Earth orbit (LEO) is the potential for harmful interference to co-channel terrestrial Primary Fixed and Maritime Mobile services.

This exhibit mathematically demonstrates that under the worst-case atmospheric scenario—wherein the ionospheric medium becomes completely transparent—the peak and average power flux densities arriving at the Earth's surface sit well below the median ambient rural RF noise floor. Furthermore, this scientific initiative will leverage an international framework of public engagement, utilizing amateur radio operators and STEM students to expand global ionospheric research.

2. Worst-Case Atmospheric Scenario Architecture

Ionospheric interaction at 9.303 MHz is governed by the critical frequency of the F2 layer (f_oF_2).

- **Daytime Dynamics (f_oF_2 > 9.4 MHz):** The ionosphere acts as a reflective boundary; RF energy is contained within the topside orbital regime, and ground-level power density is effectively zero.
- **Nighttime Dynamics (f_oF_2 < 9.2 MHz):** The ionosphere becomes electromagnetically transparent to a 9.303 MHz carrier. The downward-directed signal punches through the plasma layer and travels via direct line-of-sight to the Earth's surface.

The mathematical evaluation below assumes a constant, worst-case transparent environment (f_oF_2 < 9.2 MHz) at a minimum orbital altitude of 500 km.

3. Mathematical Quantification of Radiated Energy

The payload utilizes a highly disciplined, low-impact waveform configuration designed specifically to minimize spectral occupancy, optimize digital synthesis, and protect terrestrial services:

- **Center Frequency (f_c):** 9.303 MHz
- **Chirp Bandwidth (Δf):** 125.0 kHz
- **FCC Emission Designator:** 129KQ3N

- **Pulse Duration (τ):** 500 microseconds (µs)
- **Pulse Repetition Interval (PRI):** 131.6 milliseconds (yielding a 7.6 Hz Pulse Repetition Frequency)

A. Duty Cycle and Average Power Verification

The temporal footprint of the transmitter is severely restricted. The operational duty cycle (*DC*) is calculated as:

$DC = \tau / \text{PRI} = (500 \times 10^{-6}\ \text{s}) / (131.6 \times 10^{-3}\ \text{s}) \approx 0.0038\ (0.38\%)$

Given a peak EIRP of 1.0 Watt (+30 dBm), the maximum integrated average power (P_{avg}) radiated by the spacecraft is:

$P_{avg} = P_{peak} \times DC = 1.0\ \text{W} \times 0.0038 = 0.0038\ \text{W} = -24.2\ \text{dBW} = +5.8\ \text{dBm}$

B. Transmitter Spectral Power Density

When active, the transmitter spreads its 1.0 Watt peak power across a 125.0 kHz linear frequency modulation (LFM) sweep, yielding a peak spectral power density (PSD_{peak}) of:

$PSD_{peak} = 1.0\ \text{W} / 125{,}000\ \text{Hz} = 8.0 \times 10^{-6}\ \text{W/Hz}$

C. Worst-Case Ground Power Flux Density (PFD)

Applying the free-space spherical spreading law over a minimum slant range (d) of 500 km (500,000 meters) to the sub-satellite point on the ground, the Peak Power Flux Density (PFD_{peak}) arriving at the surface is:

$PFD_{peak} = EIRP_{peak} / (4 \times \pi \times d^2) = 1.0\ \text{W} / (4 \times \pi \times (500{,}000\ \text{m})^2) \approx 3.18 \times 10^{-13}\ \text{W/m}^2$

Factoring in the 0.38% duty cycle, the Average Power Flux Density (PFD_{avg}) hitting the Earth's surface is:

$PFD_{avg} = PFD_{peak} \times DC = (3.18 \times 10^{-13}\ \text{W/m}^2) \times 0.0038 \approx 1.21 \times 10^{-15}\ \text{W/m}^2$

4. Electromagnetic Compatibility with Terrestrial Noise Floors

To contextualize these levels for regulatory approval, the arrived signal must be compared against standard background noise profiles defined by international bodies. According to ITU-R Recommendation P.372 (Radio Noise), the median man-made and atmospheric noise figure (F_a) at 9.3 MHz in a quiet rural environment ranges from 45 to 50 dB above the thermal limit (*KTB*).

Over the requested 129.0 kHz wide channel bandwidth (B), the ambient terrestrial noise floor power (P_{noise}) sits between -78.0 dBm and -73.0 dBm.

At the ground receiver terminal, the spacecraft's uncompressed peak pulse power (P_{rec_peak}) is calculated by multiplying the Peak PFD by the effective aperture of a standard half-wave dipole ground antenna ($A_e \approx 135.7$ m² at 9.3 MHz):

$$P_{rec\_peak} = PFD_{peak} \times A_e = (3.18 \times 10^{-13} \text{ W/m}^2) \times 135.7 \text{ m}^2 = 4.31 \times 10^{-11} \text{ W} = -73.6 \text{ dBm}$$

While this uncompressed peak power momentarily matches the broadband noise threshold for a quiet rural environment, primary terrestrial Fixed and Mobile services operating within this band utilize narrow channel allocations (typically 3 kHz for SSB voice or data). Because the spacecraft's energy is linearly swept across a wide 125.0 kHz bandwidth, a primary terrestrial receiver occupying a 3 kHz channel will only capture 2.40% (3 kHz / 125.0 kHz) of the peak power, reducing the co-channel peak interference power at any single asset by an extra 16.20 dB down to -89.8 dBm. This places the peak pulse 11.8 to 16.8 safely below the ITU-R P.372 rural noise floor within any standard operational terrestrial bandwidth.

Furthermore, because the transmitter utilizes an accelerated LFM sweep rate of 0.250 kHz per microsecond (125.0 kHz / 500 µs), the signal spends only 12.0 microseconds inside a victim receiver's 3 kHz passband. Because this window is significantly shorter than the physical 333-microsecond rise-time (dispersion limit) of standard 3 kHz narrow-band filters, the filter transient response will naturally smooth and heavily attenuate the incoming voltage step.

Factoring in the ultra-low 0.38% operational duty cycle, the integrated average received power across the full 125.0 kHz bandwidth is -100.9 dBm. This average signal level sits 22.9 to 27.9 dB below the median ITU-R P.372 rural noise floor, guaranteeing a strict zero-interference profile to primary terrestrial users.

5. Conclusion and Non-Interference Commitment

Because the average power delivered to Earth is significantly lower than the rural noise floor, the risk of electromagnetic interference from topside sounding by SoFIE to ground users is very low. Furthermore, Saint Francis University will operate the spacecraft on a strict Non-Interference Basis (NIB) and maintain an independent, real-time command line capable of executing an immediate cessation of all 9.303 MHz emissions upon regulatory instruction via the ground command operations center detailed in Exhibit B.