Development of Satellite Radio Frequency Interference Models for Mega Constellations

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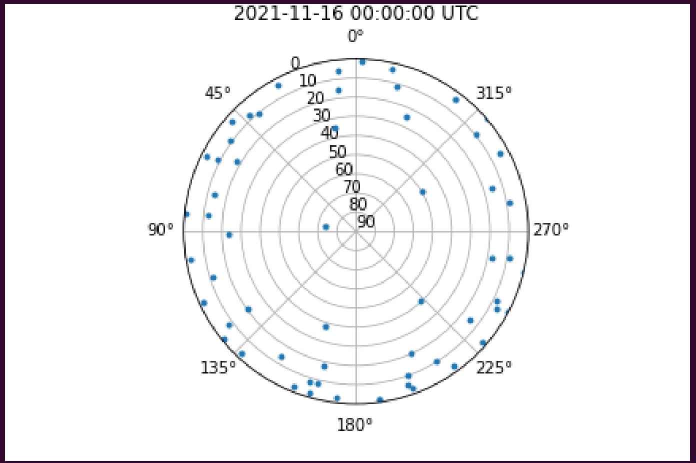
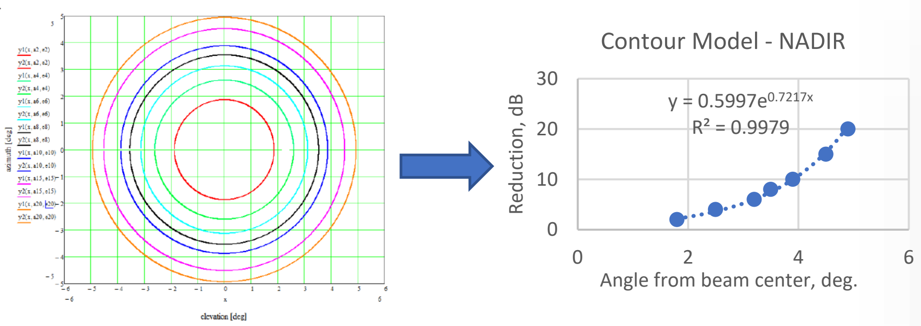


In this poster, I discuss the first steps taken towards comprehensive modeling of signals owing to satellite constellations. As it has the most available design parameters (largely from FCC filings), I am using Starlink as a test case. Starlink is currently operating, largely, in the 10.7-12.7 GHz range.

Methods



I take the beam contour plot from the 2016 Starlink FCC filing and create an exponential function to represent it.

I use python libraries (Skyfield and geopy) to download Starlink TLEs, model the orbits of said TLEs above a test site (in this case, the Chajnantor Plateau, home of ACT, Simons Array, and neighbor to ALMA). Then, I calculate the distance from each satellite's subpoint to the observer location.

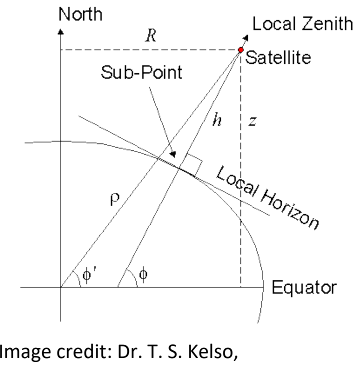


Image credit: Dr. T. S. Kelso, https://celestrak.com/columns/v02n03/

Three-Step Model:

Step 1: Assess positions of satellites accurately without loss of accuracy due to TLE decay

Status: TLEs have known issues with positional error, but for the purposes of modeling RFI estimates, they provide enough accuracy.

However, simulations must make use of archival TLEs, or fully simulated satellite constellations, due to the decay of TLE accuracy with time (more so for these low-Earth orbit satellites).

TLE support has been implemented; archival TLEs will be implemented in long-term simulated runs.

Step 2: Determine pointing strategies and band occupation fractions

Status: This is currently an area of weakness for the model. Starlink design strategies suggest a demand-based model wherein a satellite's beam will point to wherever a customer is; however, customer information isn't public record.

Thus, in my preliminary calculations, I assume a beam at the satellite's subpoint, and present figures in the dB reduction of the signal power. This will be replaced upon more direct observations of Starlink signals.

Step 3: Use signal information and beam location to determine strength of RFI signal

Status: While only represented in dB reduction, these results do provide a basis by which to understand the effect distance has on received signal. That is, significant events tend to only happen at high zenith (i.e., a beam pointed close to the observing site). While spurious emissions have not yet been characterized, one could assess Starlink presence in data through reverse engineering this process. The most helpful information, of course, would be the service addresses of any local customers.

Future steps:

- Finalize model representation of Step 2
- Direct observations to assess:
  - Spurious emission
  - Band occupation
  - Beaming strategy
- Couple model with instruments to assess science impact

Input is welcome!

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Works Cited:
Starlink 2016 FCC Filing, SAT-LOA-20161115-00118
Software Credits:
Skyfield: https://ascl.net/1907.024
Geopy: https://github.com/geopy/geopy