The Impact of Mega-Constellations on Radio Astronomy

Samuel Thé, MIT Haystack Observatory, samthe@mit.edu
Frank D. Lind, MIT Haystack Observatory, flind@mit.edu
Daniel Sheen, MIT Electrical Engineering and Computer Science, dsheen@mit.edu
Aleks Pop Stefanija, MIT Haystack Observatory, alekspop@mit.edu

MIT HAYSTACK OBSERVATORY

BACKGROUND

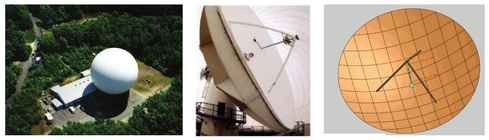
The rapid growth of LEO satellite constellations is transforming global connectivity, bringing internet access even to remote regions. However, many of these areas host radio telescopes that depend on extremely low levels of radio interference. As satellite deployments rise, observatories face increasing RFI exposure from both intentional and unintended emissions [1], threatening sensitive observations and demanding new strategies for coexistence [2].

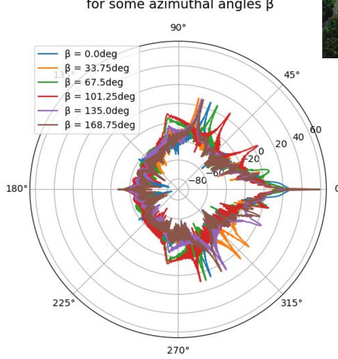
This work presents recent observations of satellites both in their downlink band and in radio astronomy protected band, using both the WESTFORD antenna at MIT Haystack Observatory, and the BigDish antenna on MIT campus. Our work focused on the 1.42 GHz band containing a hydrogen emission line and the 10.69GHz, at the edge of the satellites downlink band.

WESTFORD ANTENNA

The WESTFORD antenna [3] is part of the MIT Haystack Observatory, located in Westford MA. This 18.3m radio telescope is used mainly for geodetic VLBI by NASA and is part of a global VLBI network.

The antenna is currently used for our measurement and simulation works, thanks to a precise modeling of its gain pattern.





Parameter	Westford
primary reflector shape	symmetric paraboloid
primary reflector diameter	18.3 meters
primary reflector material	aluminum honeycomb
feed location	primary focus
focal length	5.5 meters
antenna mount	elevation over azimuth
antenna drives	electric (DC) motors
azimuth range	$90° - 470°$
elevation range	$4° - 87°$
azimuth slew speed	$3°\ s^{-1}$
elevation slew speed	$2°\ s^{-1}$
	Frequency range 2–14 GHz
T_{sys} at zenith	40–70 K
aperture efficiency	0.25–0.60
SEFD at zenith	1800–4500 Jy

ADDING 1420 MHz TO WESTFORD

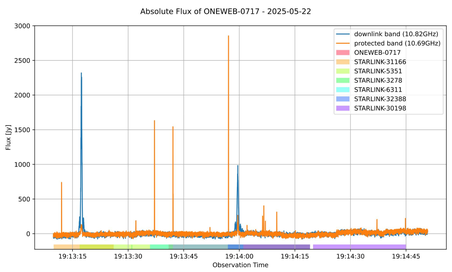
In addition to the VGOS system, a 1.420 GHz feed was designed and positioned at an offset from the Westford focal point to enable observations in the protected band between 1.400 and 1.427 GHz.

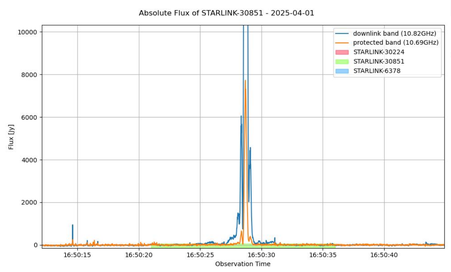
- Dual channel RH/LH Circular polarization
- 41.1 dBi Gain
- ~35 K Tsys
- Filtered for 1.400 to 1427 MHz (~70MHz 3dB Bandwidth)
- designed to operate in tandem with 6m BigDish on MIT Campus

RESULTS

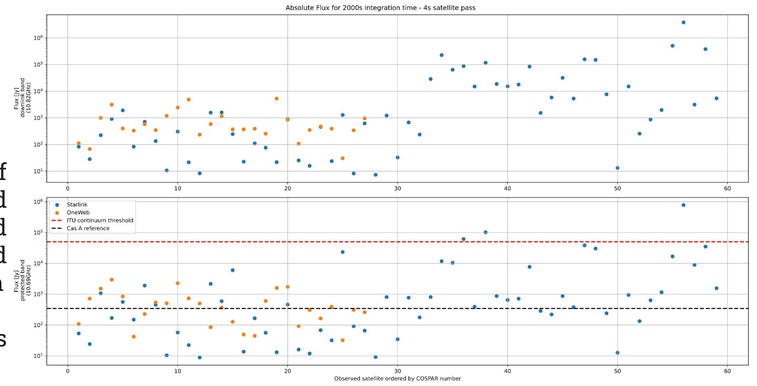
The survey is centered on two experiment setups:

- Joint observation of satellite transits in downlink band (10.82GHz) and radio astronomy protected band (10.69GHz);



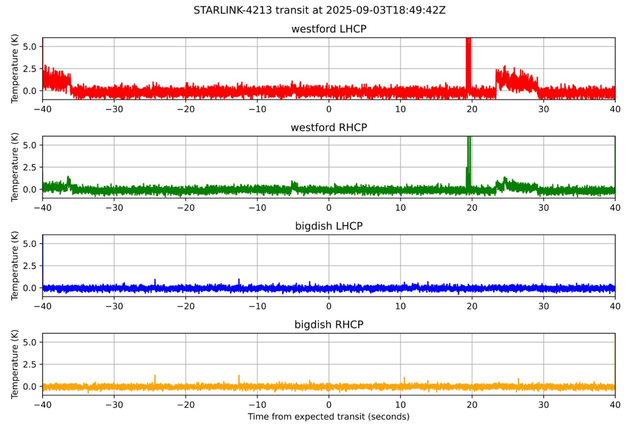


Above: Flux of OneWeb (left) and Starlink (right) passes, in downlink band (blue) and protected band (orange) with ITU thresholds.



Right: Flux of satellites observed in donlink band (top) and protected band (bottom) with ITU thresholds and Cas A as comparison.

- Observation of Starlink transits at 1.42 GHz, using the Westford and BigDish antennas at the same time. The use of two separated antennas enables the rejection RFI local to either telescope site.



CONCLUSION

- The protected bands being essential for radio astronomy, it is important to survey and measure the impact of mega-constellations on our systems.

ACKNOWLEDGEMENTS

This work has been supported in part by the National Science Foundation under the SpectrumX center award 2132700 and by the SWIFT program 2029670. Additionally, we would like to thank the staff at MIT Haystack Observatory for their efforts to implement and operate the instrumentation used for this work.

REFERENCES

[1] Bassat et al., Bright unintended electromagnetic radiation from second-generation Starlink satellites, A&A, 2024
[2] Nhan et al., Towards Spectrum Coexistence: First Demonstration of the Effectiveness of Boresight Avoidance between the NRAO Green Bank Telescope and Starlink Satelittes, AAS, 2024
[3] Poirier and Burns, Westford Antenna 2019-2020 Biennial Report.