RESILIENT SPECTRUM SHARING AMONG NON-GEOSYNCHRONOUS SATELLITES

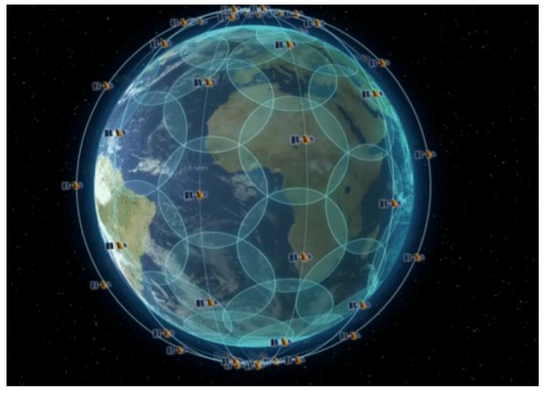
PI: Jon Peha, Co-PI's: Alex Hills, Marvin Sirbu
BS & MS Students: Yuxuan Ni, Sean Pogorelc, Eric Tang
PhD Student starting in 2024: Ganghui Lin

OUR RESEARCH QUESTIONS

- Our general questions
  - How big is the problem of in-line events?
  - What technologies and coordination strategies address the problems of in-line events most effectively?
  - What spectrum policies incentivize use of effective technologies and coordination strategies?
- As applied to
  - Interference from NGSO satellite constellations to GSO satellites
  - Interference from NGSO satellite constellations to other NGSO satellite constellations
- Under a wide variety of conditions, technologies and assumptions

SATELLITES AND SPECTRUM SHARING

- GSO satellites and constellations of NGSO satellites will operate in the same spectrum bands
  - Including Ku, Ka, V bands
- Sharing between NGSO and GSO: Primary-secondary
  - NGSO satellites not allowed to cause unacceptable interference to GSO satellites
  - NGSO satellites must accept interference from GSO satellites without claiming protection
- Sharing between NGSO constellations.
  - Recent FCC Order requires that NGSO constellations within the same processing round split bandwidth when there is interference risk, unless they agree to do otherwise
- What is the risk of harmful interference, and how should it be mitigated?



IN-LINE EVENTS

- There is potential for harmful interference during "in-line events"
  - Ground station for satellite system 1 and ground station for satellite system 2 are collocated (or reasonably close)
  - Ground stations, satellite from system 1 and satellite from system 2 form a line (or are sufficiently close to linear)
    - System 1 ground station points to system 1 satellite, and system 2 satellite falls within its beamwidth

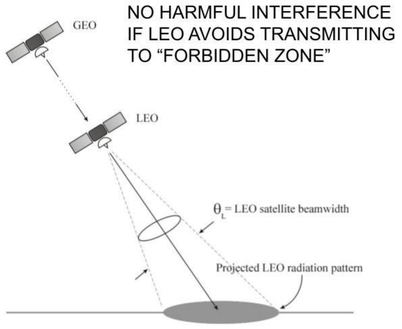
NGSO TO GSO INTERFERENCE

- We analyzed likelihood of in-line events between a GSO satellite and different NGSO satellite constellations
  - Approximation of OneWeb
    - 648 satellites, 1200 km, polar orbits (90 degree inclination)
  - Approximation of SpaceX
    - 4236 satellites, 550 km altitude, orbital inclinations of 53, 70 and 90 degrees

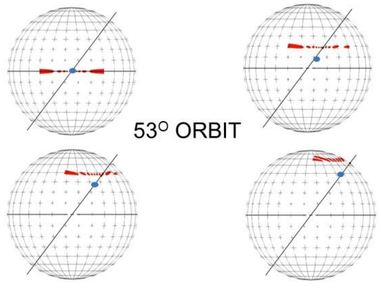
System	Probability	Minutes/day	Hours/day
OneWeb	11.82%	170	2.8
StarLink	17.43%	250	4.2

Assuming:

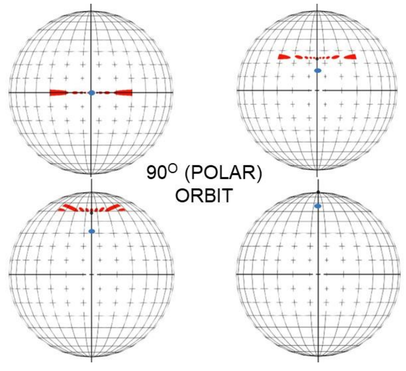
- Mid-latitude GEO earth station (45° look angle)
- Small GEO antenna (TVRO with 10° beamwidth)
- Not considering side lobes



NO HARMFUL INTERFERENCE IF LEO AVOIDS TRANSMITTING TO "FORBIDDEN ZONE"

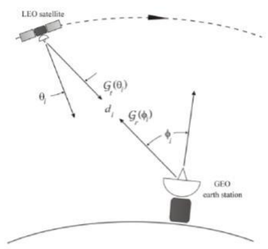


A satellite's forbidden zone (shown in red) shifts as the satellite moves along its orbit



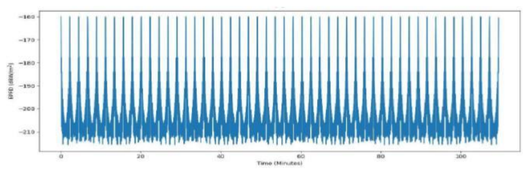
INTERFERENCE FROM LEO SIDELOBES

- Even when a LEO satellite is not transmitting towards a GEO ground station, the LEO's sidelobes can cause interference
- A constellation's aggregate interference depends on
  - satellite altitude,
  - number of satellites in constellation,
  - sidelobe transmit power,
  - antenna diameter, …



RESULTS OF SIDELOBE ANALYSIS

- Consider constellation resembling OneWeb
  - 588 satellites: 12 orbital planes, 49 satellites per plane
  - Satellites at 1200 km
  - - 20 dB side lobe
  - GEO ground station with 60 cm antenna placed at equator



- Sidelobe interference varies over time, with peak every 2.3 minutes as satellite flies over ground station.

MUST DECREASE SIDELOBE AS CONSTELLATION GROWS LARGE

- As the number of satellites increases, the number of satellites in locations that cause interference increases, so max sidelobe must be decreased.

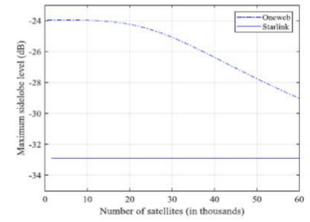
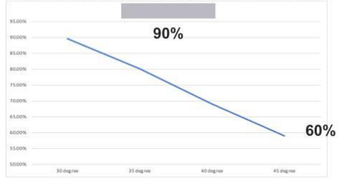


FIGURE 6. Maximum permissible side lobe level (dB) for OneWeb and Starlink Group 1 Ku-band constellations vs number of satellites in each constellation.

IN-LINE EVENTS ARE OFTEN POSSIBLE

- Could a satellite at given location be in an in-line event?
  - Yes if there is a point on earth that would experience an in-line event if served by this satellite and a satellite from another constellation that is sufficiently close.
- Consider 2 constellations similar to OneWeb & SpaceX
- What fraction of "SpaceX" satellites could be in an in-line event as function of "OneWeb" min elevation angle?



"SpaceX" assumed to min elevation angle of 30 degrees.

INTERFERENCE FROM ONE LEO CONSTELLATION TO ANOTHER

- We have developed analytical tools to determine when two satellites from different LEO constellations can experience an in-line event with a ground station at any location on earth.
- We have developed software that simulates satellite orbits and uses this analysis to identify in-line events
- Initially, can be used to quantify risk of harmful interference from in-line events in the absence of mitigation
- Then, can be used to experiment with mitigation strategies for in-line events.

MITIGATION IS POSSIBLE

- There are a variety of ways to mitigate the effects, including "look-side," i.e. changing which satellites serve which ground stations

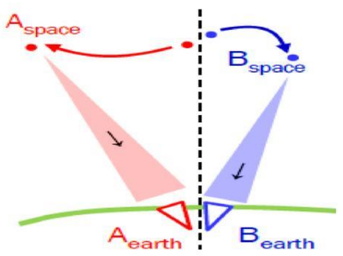


Figure from FCC TAC, 2017

SUMMARY

- NGSO satellites are often in a position where in-line events are possible
  - Both with GSO satellites, and with other NGSO satellites.
  - So the risk of harmful interference must be managed for both
- NGSO sidelobe interference must also be managed
  - Aggregate interference matters for very large constellations
- In-line events can be avoided in multiple ways
  - Interference with GSO systems can be prevented if NGSO satellites avoid communications to ground stations in the "forbidden zone"
  - Interference with NGSO systems can be prevented with approaches such as band splitting and look aside
- Research continues on mitigation strategies

REFERENCES

- Some of what was presented here is written up, and available for anyone interested
  - "Feasibility of Using Beam Steering to Mitigate Ku-Band LEO-to-GEO Interference," *IEEE Access,* by Hills, Peha & Munk. https://ieeexplore.ieee.org/iel7/6287639/6514899/09828023.pdf
  - "Controlling Antenna Sidelobe Radiation to Mitigate Ku-Band LEO-to-GEO Satellite Interference," *IEEE Access,* by Hills, Peha, Munk & Pogorelc. https://ieeexplore.ieee.org/abstract/document/10177750