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Brainstorming: Best Frequency Band for GRAND-like experiments

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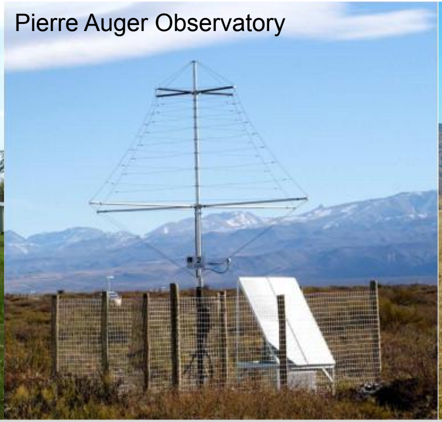

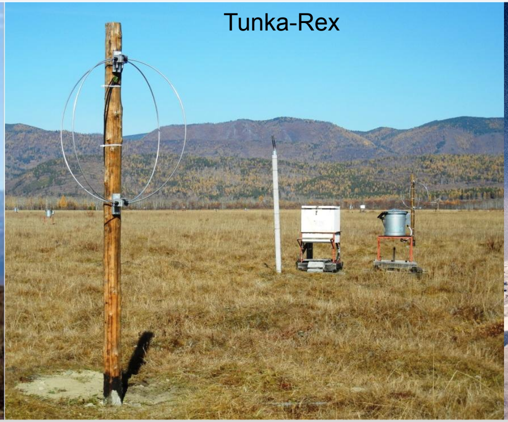

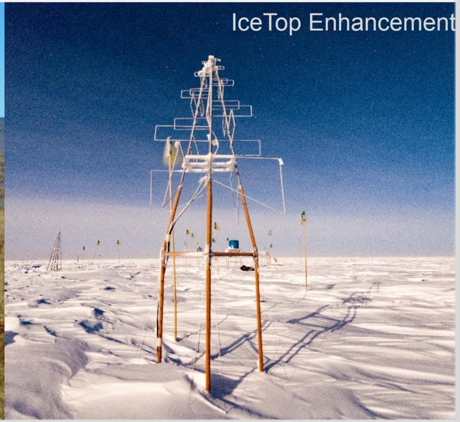

What is the optimum frequency range?

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- Signal-to-noise ratio?
- Density of instrumentation?
- Mechanics?
- Cost?
- RFI-quietness?

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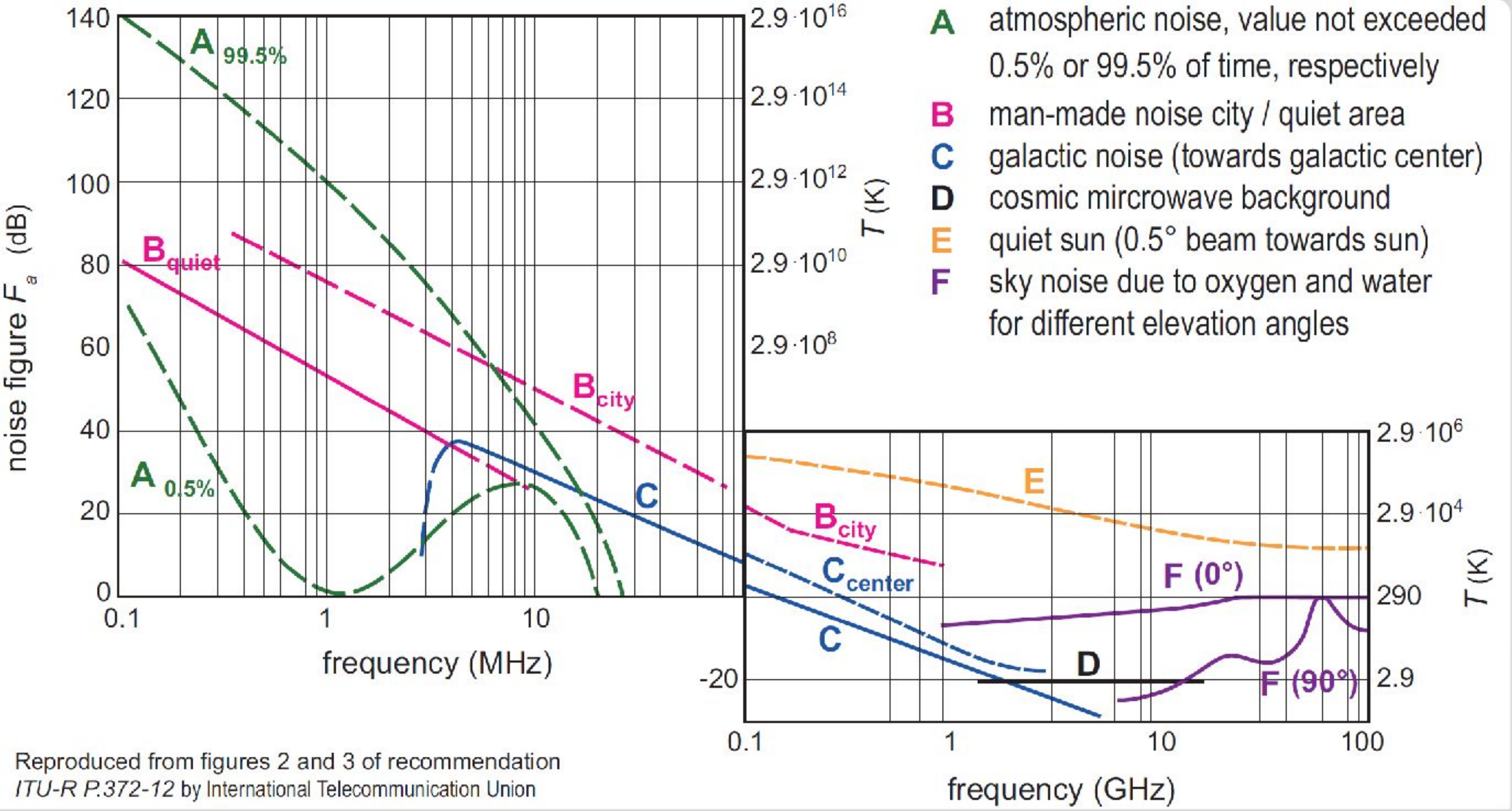

Reproduced from figures 2 and 3 of recommendation *ITU-R P.372-12* by International Telecommunication Union

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Shower LDF as function of frequency

A. Balagopal V., et al.
EPJ C 78 (2018) 11

For < 100 MHz:

signal beyond Cherenkov cone

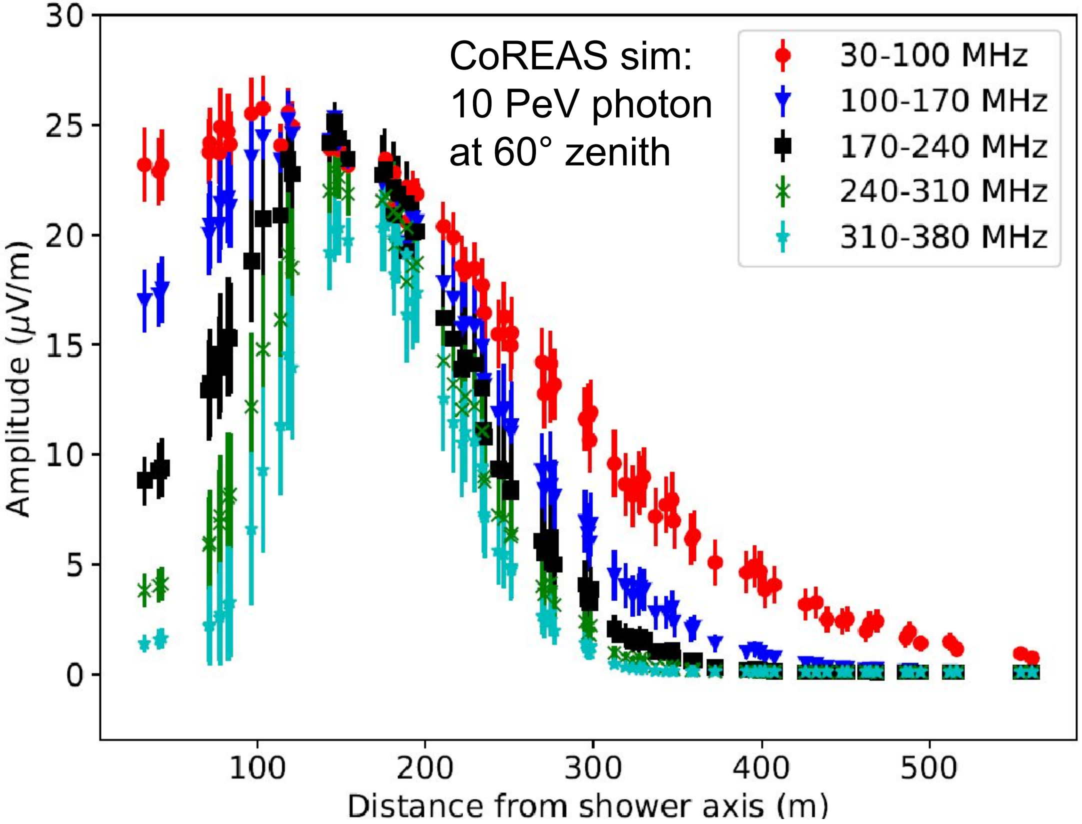
For < 200-300 MHz:

signal inside of Cherenkov cone

For > 300 MHz:

signal only on Cherenkov cone

 Band should start at 200 MHz or lower, but may extend beyond



Caveat: not sure if neutrino induced showers are different.

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Lower frequencies have wider beam

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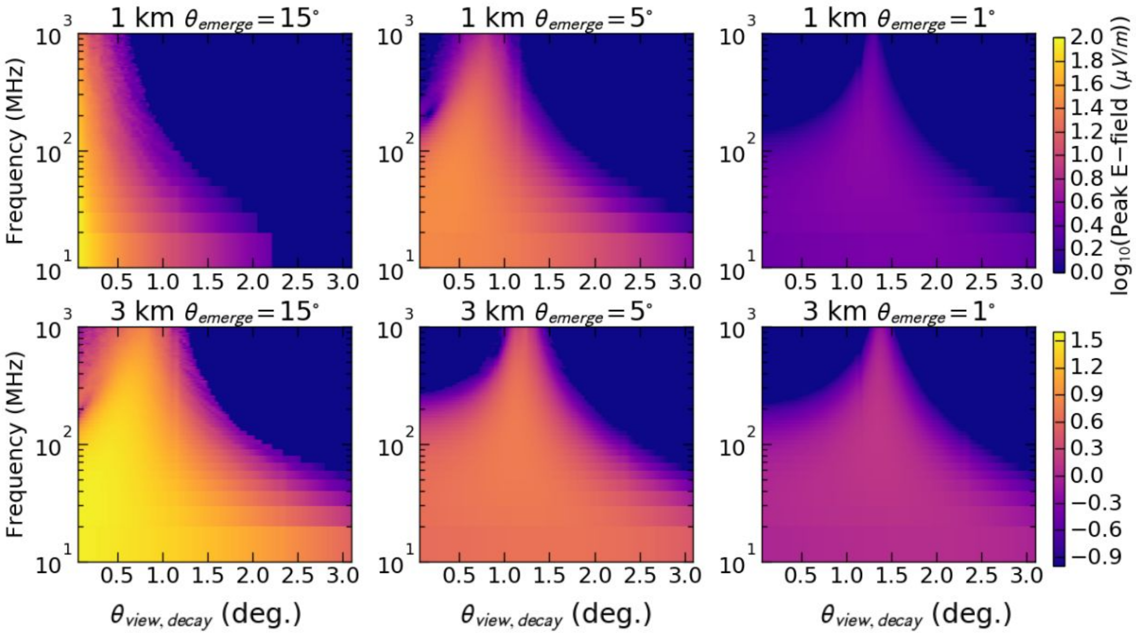

- Larger aperture at low frequencies for given antenna spacing

BEACON ICRC 2019

Lower frequencies better for BEACON?

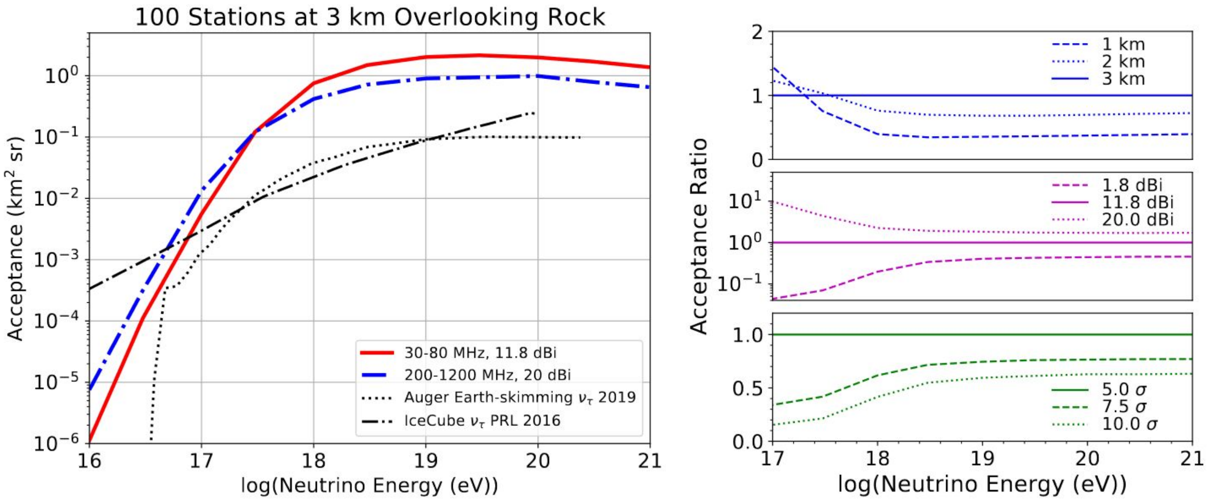

Figure 3: (left) The acceptance of BEACON in two different frequency bands compared with the acceptance of Auger to Earth-skimming tau neutrinos [14] and IceCube to tau neutrinos [15]. Each station comprises 10 antennas with a trigger threshold of 5σ. (right) The ratio of the acceptance of a 30-80 MHz detector for different elevations (top), phased array gains (middle), and trigger thresholds (bottom) relative to the design.

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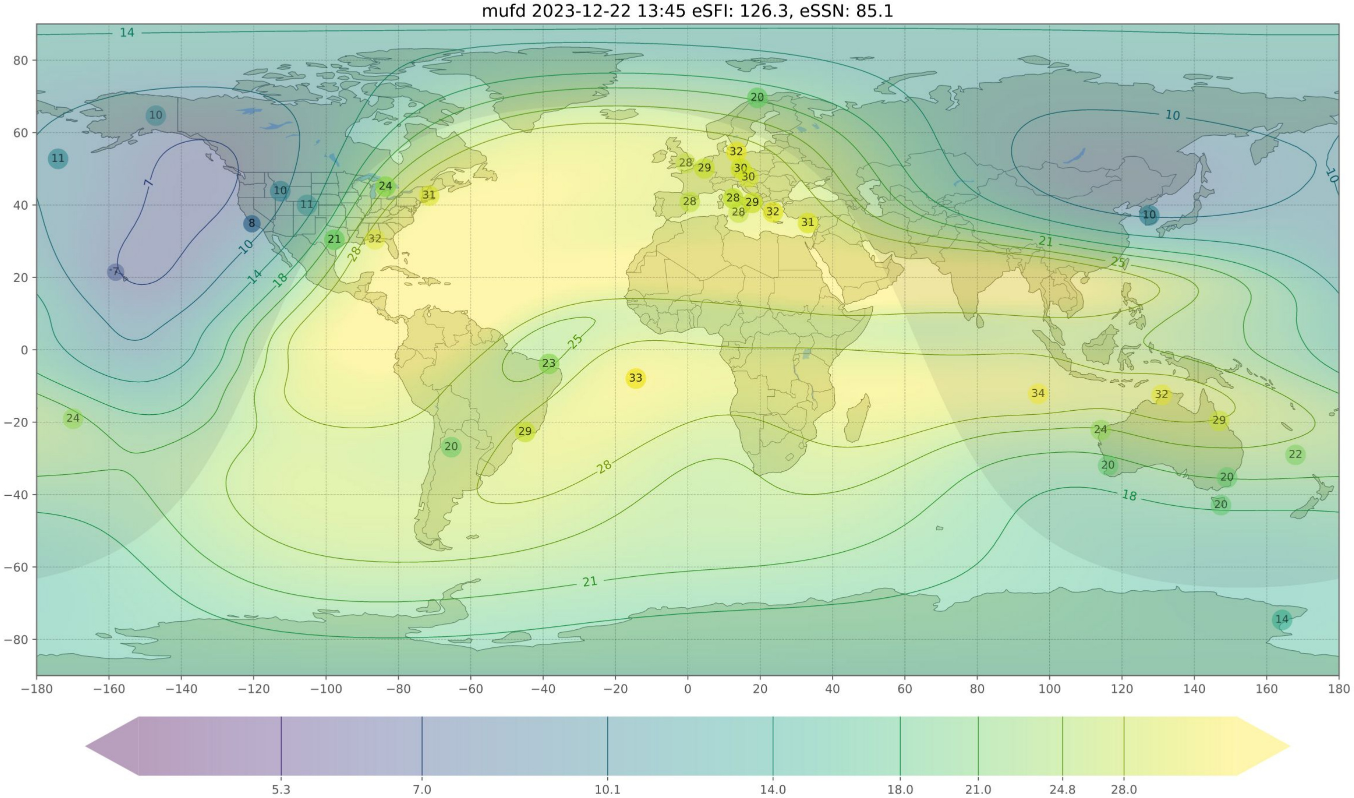
Below ~30-40 MHz ionosphere becomes relevant: https://prop.kc2g.com/



Noise consideration: Example SKALA v2

- system noise of 40 K exceeds Galactic Noise (sky) for frequencies larger than 400 MHz; thermal noise of sky (2.7 K of CMB) totally negligible; thermal noise of ground (~ 300 K) suppressed by antenna pattern
- if 300 K thermal noise of ground would be fully picked up by an antenna more sensitive to the horizon, than thermal noise would already dominate at frequencies larger than 150-200 MHz

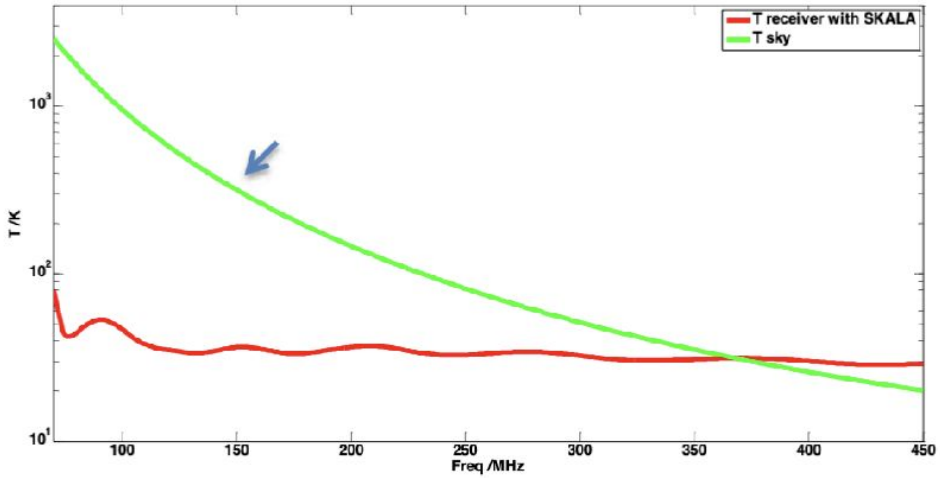
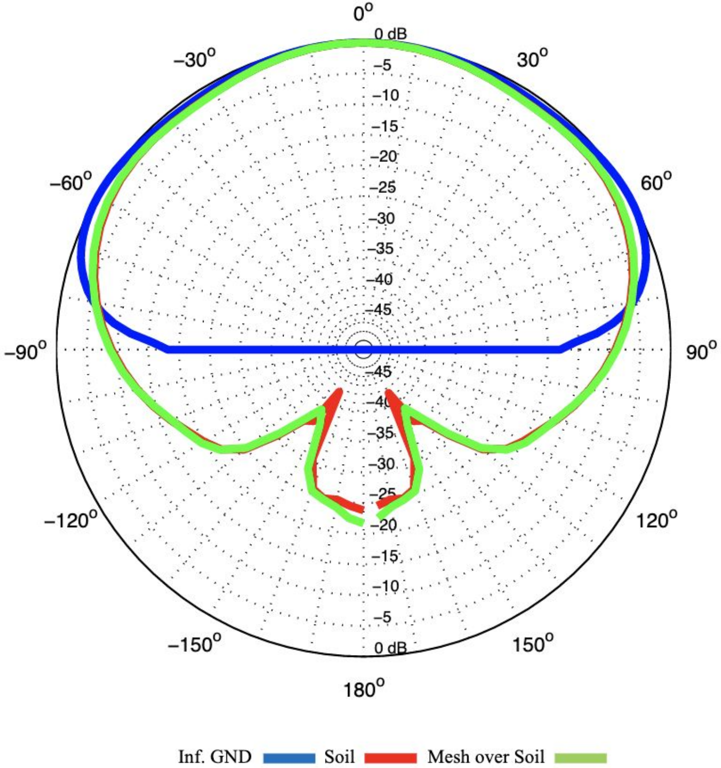


Fig. 9. Receiver noise temperature versus sky noise.

E. de Lera Acedo, N. Drought, B. Wakley and A. Faulkner, "Evolution of SKALA (SKALA-2), the log-periodic array antenna for the SKA-low instrument," *2015 International Conference on Electromagnetics in Advanced Applications (ICEAA)*, 2015, pp. 839-843, doi: 10.1109/ICEAA.2015.7297231.

H-plane cut - 150 MHz



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Thoughts about low vs. high frequency range

Pro **low** (< 100 MHz) frequencies

- enables sparser arrays as radio footprint extends significantly beyond Cherenkov angle
- simpler and cheaper electronics
- small local structures of ground should have lower impact on systematic uncertainties
- easier time-synchronization for beam-forming/interferometry

Pro **high** (> 100 MHz) frequencies

- lower Galactic noise □ better signal to noise ratio until f_{max} when thermal noise dominates
- smaller antenna structures facilitate deployment
- lower antenna height above ground suffices to avoid ground effects
- potential to exploit commercial 5G hardware? lowest 700 MHz, though?

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