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Low Frequency Wire Grid Reflector for Space

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Low Frequency Wire Grid Reflector for Space

Objective:

Is a 1-km diameter reflector for operation at 0.1 to 3.75 MHz feasible given current launch capabilities?

Approach:

Design a minimum mass paraboloid wire mesh reflector anchored by small maneuverable satellites.

Wire Size and Spacing

- The reflectivity of a conducting sheet is a function of its 'sheet resistance'.
- The resistance of a cell depends on its length (more length, more resistance) and its width (more width, less resistance).
- The resistance of the wire edges of the cell is a function of the resistivity (rho), wire diameter and the skin depth (delta).
- The directivity (forward gain) of a paraboloid wire reflector depends on the cell size in wavelengths.
- The cell size therefore puts a limit on the wire resistance, which is shown in the graph.

Reflectivity of a sheet:

$$\Gamma(R_s) = \frac{R_s - R_0}{R_s + R_0}$$

For 95% and R0 = 377Ω, Rs <= 10Ω.

Resistance of a grid cell LxW in size:

$$R = R_s \frac{L}{W} \simeq R \leqslant 10\,\Omega$$

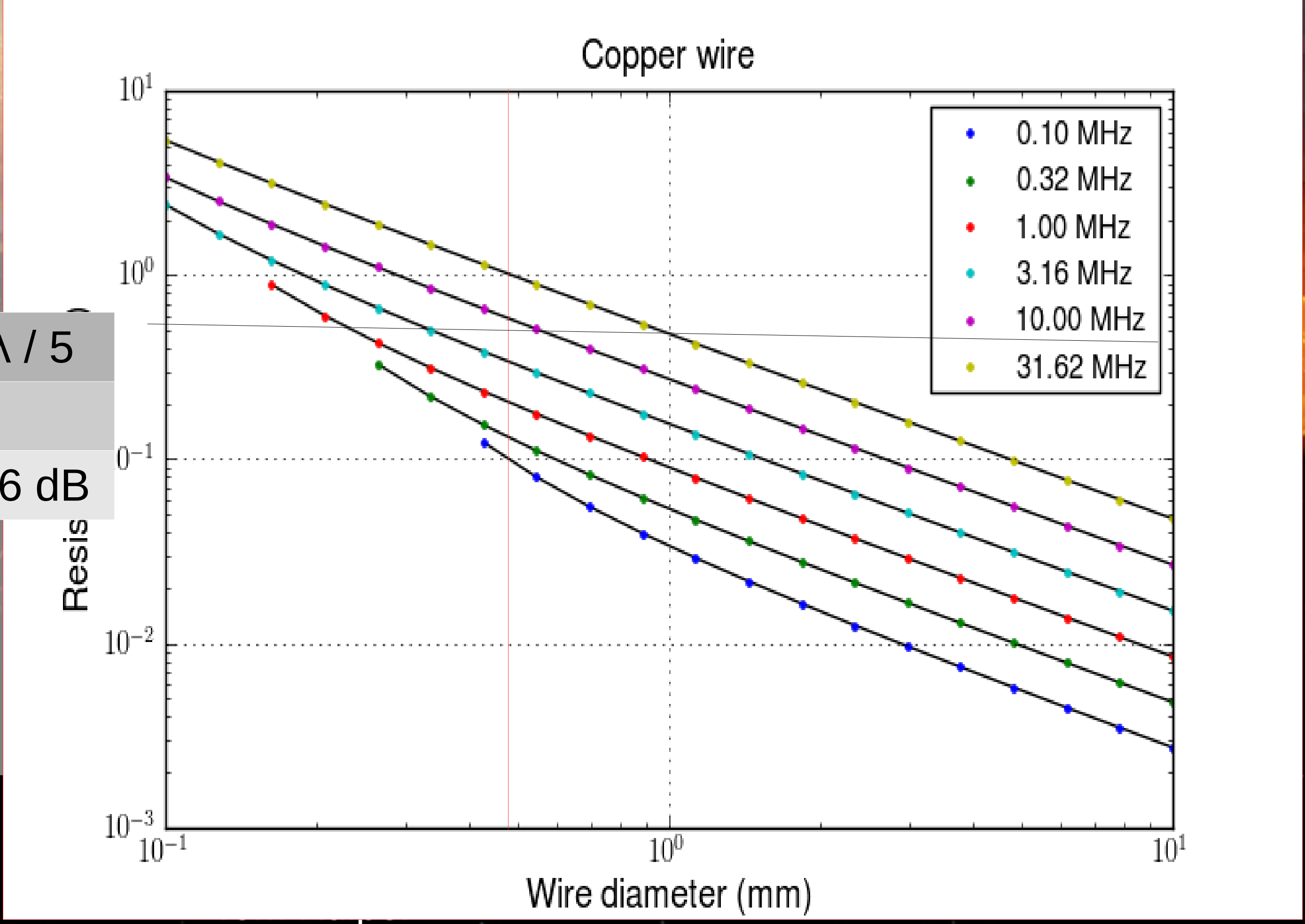
Resistance & Skin Depth:

$$R(d) = \frac{\rho}{\pi\delta(d-\delta)}$$

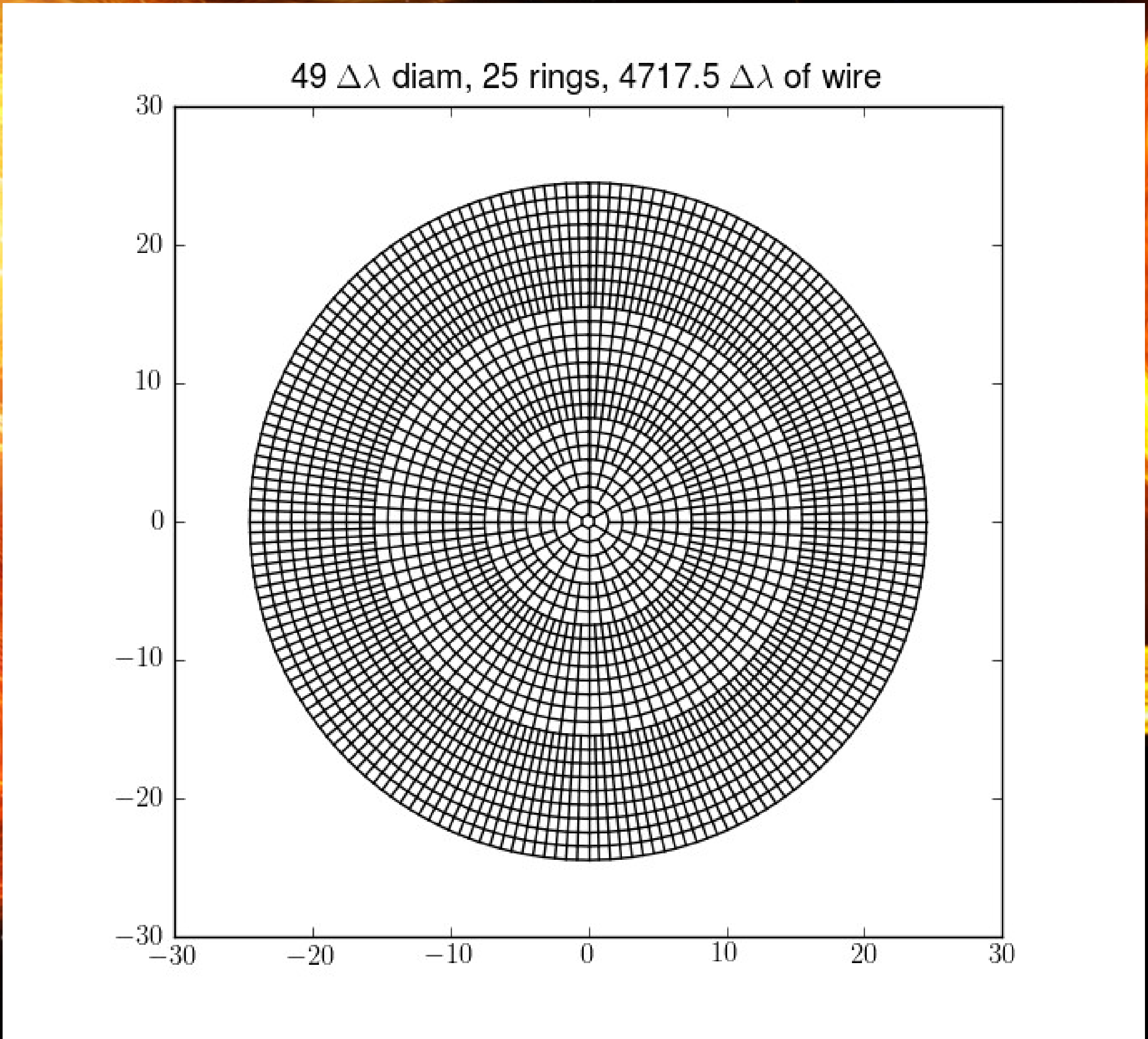
Cell size:

spacing	λ / 2	λ / 4	λ / 5
reflectivity	0.6	0.9	
directivity	31 dB	28 dB	26 dB

3.75 MHz (80 m wavelength) requires a cell size of 20 m which implies a wire 0.5 mm in diameter.



Wire Arrangement

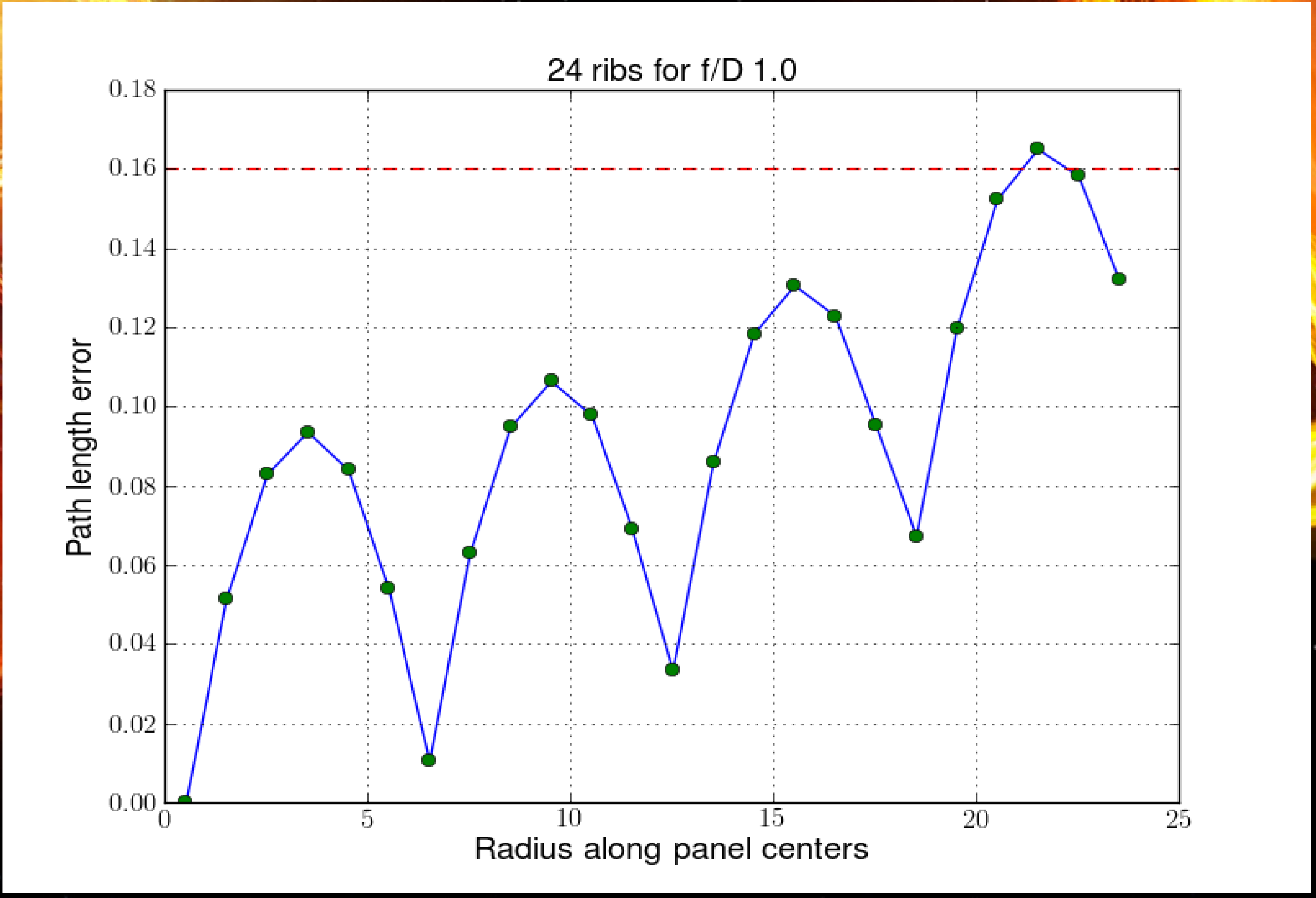


Anchoring

f/D	0.25				0.6		1.0	
anchors	6	7	8	9	4	5	4	5
r.m.s. error	0.16	0.12	0.08	0.06	0.29	0.10	0.18	0.06
max. error	-0.30	-0.26	-0.16	-0.15	-0.56	-0.14	-0.35	-0.08
err. radius	6.5	12.5	2.5	8.5	18.5	2.5,4.5	18.5	var.

Radial

Azimuthal



The error units are in wavelengths

The radius is in units of cells.

Mass of the Mesh Paraboloid

Mesh Mass

Wire length: 4717.5 x 20 m = 94.35 km
Cross-section area = $\pi \times 0.0025^2\ m^2 = 2 \times 10^{-7}\ m^2$
Volume = $0.018\ m^3$
Density of copper = $8940\ kg\ m^{-3}$
Mass = 169.7 kg

Anchor Mass

Number of anchor satellites = 96
Mass of a 2U Cubesat = 4.5 kg
Mass = 430 kg

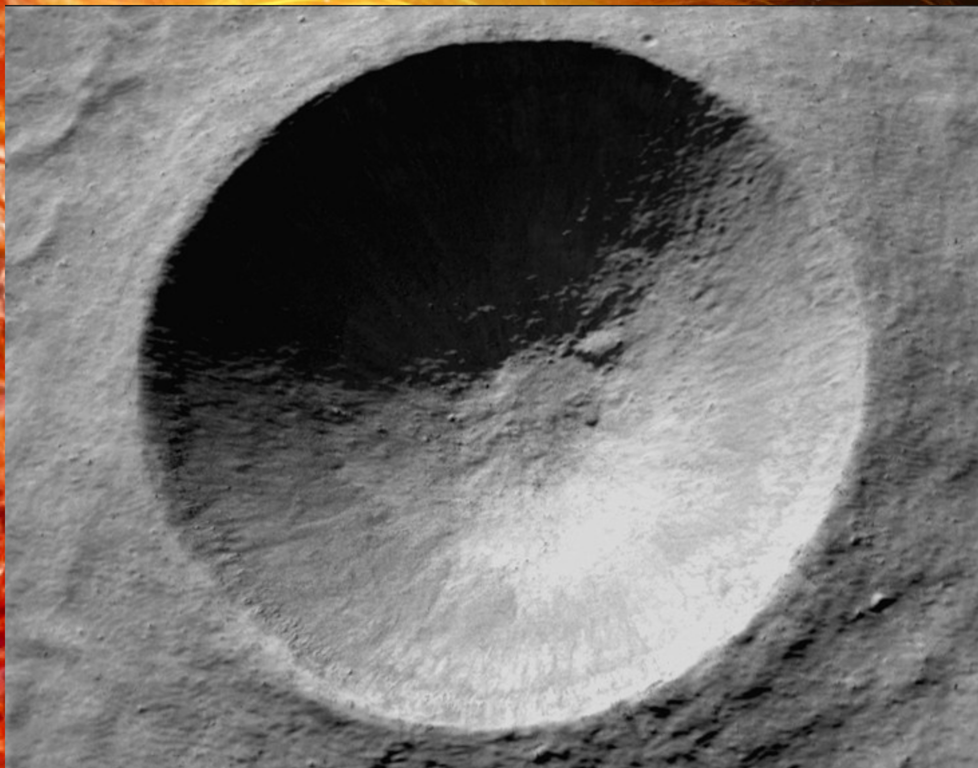
Launch Capacity to LEO

Light : up to 2000 kg
Medium: 2000-20,000 kg
Heavy: 20,000 to 50,000 kg

Escape Velocity

To LEO: 9.3 km/s
To the Moon: 11.2 km/s

Another Approach to Anchoring



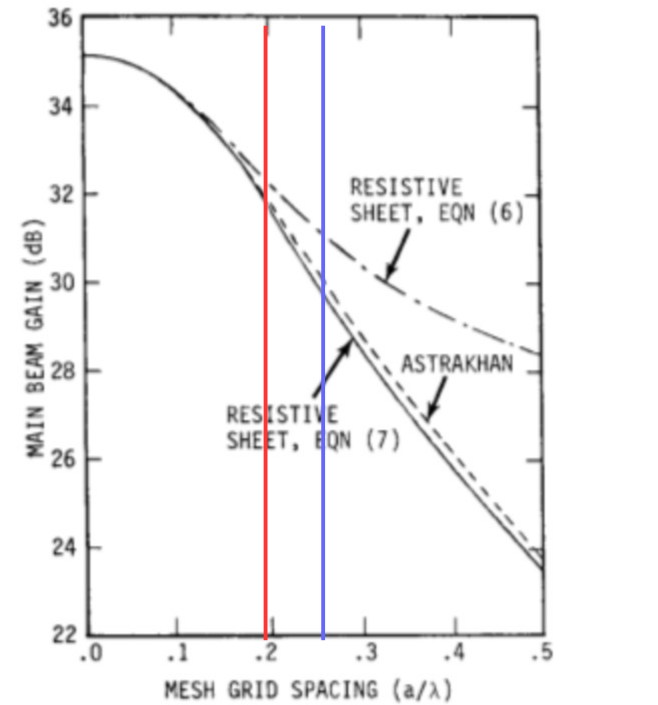
Linne Crater, 2.2 km diameter

Courtesy of Gregg Hallinan

Conclusion

It can be done!

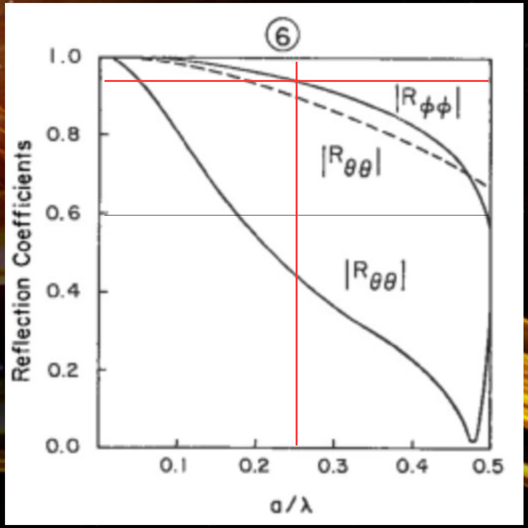
Backup: Parabaloid Mesh Gain



Gain of a 20λ paraboloid as a function of mesh grid size. (f/D = 0.4, cos θ feed, r_0 = 0.002 λ.)

D. C. Jenn *et al.*, *IEEE Trans AP*, **37**, 1484 (1989)

Backup: Wire Mesh Reflectivity



D. A. Hill and J. R. Wait, *Can. J. Phys.*, **54**, 353 (1976).