National Aeronautics and Space Administration

One-meter X/Ka-band Deployable antenna for Small Satellites

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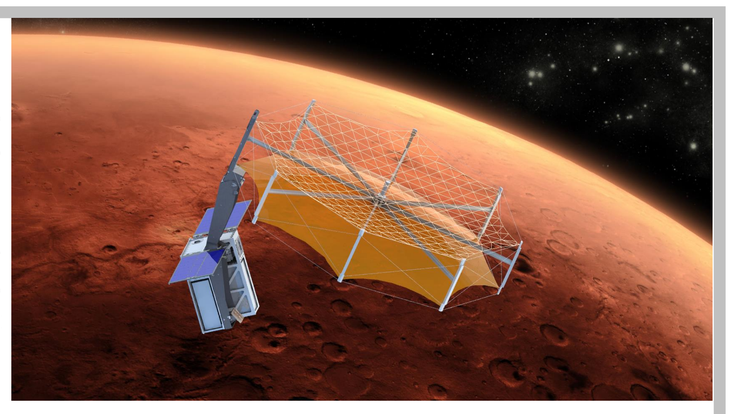
Program: Topical R&TD

Pushing the limits of CubeSats Telecommunication capabilities

The proposed deployable one meter mesh reflector is compatible with 12U-class CubeSat. This antenna is designed for telecommunication and is compatible with NASA's deep-space network (DSN) at X-band (i.e., uplink: 7.145-7.19 GHz; downlink: 8.4-8.45 GHz) and Ka-band frequencies (i.e., uplink: 34.2–34.7 GHz; downlink: 31.8–32.3 GHz).

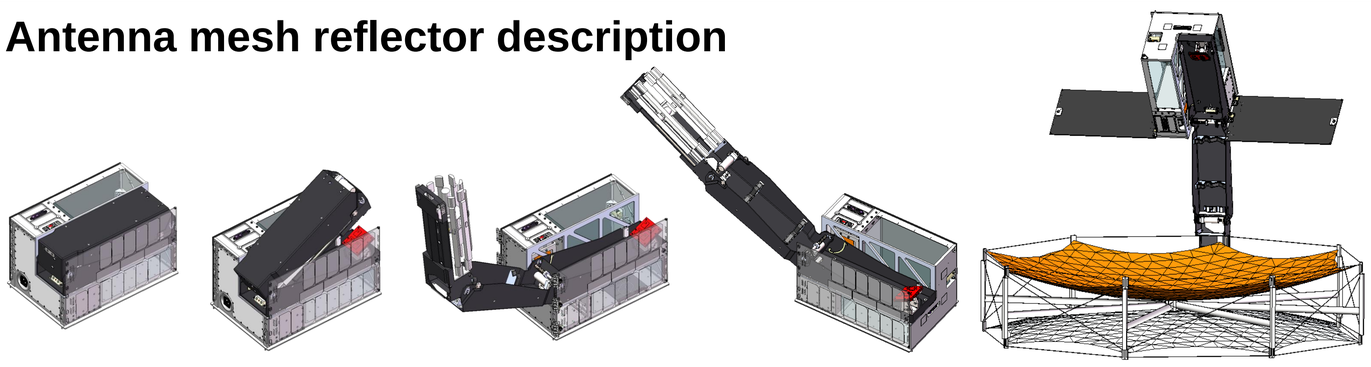
Three right-handed circularly polarized (RHCP) antennas, both transmit and receive, are introduced here: X-band only, Ka-band only, and X/Ka-band. For the X-band only antenna, a gain of 36.1-dBic and 36.8-dBic is achieved at uplink and downlink frequency bands, respectively. This translates into an efficiency of 72% and 62%, respectively. For the Ka-band only antenna, a gain of 48.4-dBic and 48.7-dBic is obtained at downlink and uplink frequency bands which translates to a 62% and 72% efficiency.

This is a significant improvement compared to MarCO's deployable high gain antenna at Ka-band and a significant improvement compared to KapDA at Ka-band. However, it is equivalent to the deployable one meter reflectarray (OMERA) antenna operating at Ka-band which is compatible with 6U-class CubeSats. This adds to the portfolio of JPL's high gain antennas for CubeSat.

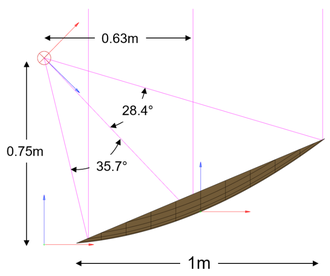


Artist rendering of the one-meter X-band deployable mesh reflector antenna

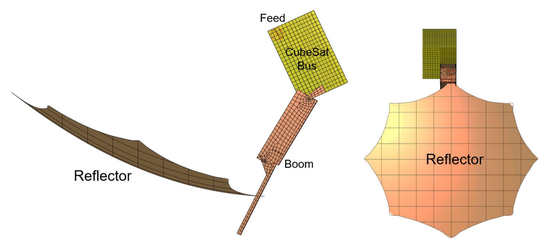
Antenna mesh reflector description



Antenna deployment of the one meter mesh reflector antenna. The mesh reflector is a commercially available technology invented and patented by Tendeg LLC. The boom development is still on-going. Please note that the feeds are fixed to the CubeSat bus to minimize deployment complexity.

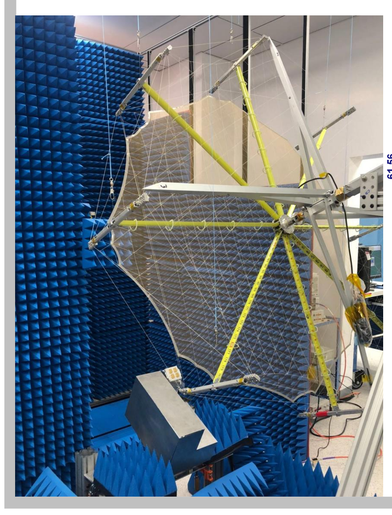


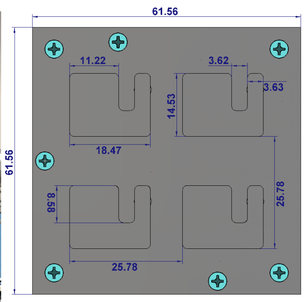
Optical prescription of the deployable off-set mesh reflector antenna.



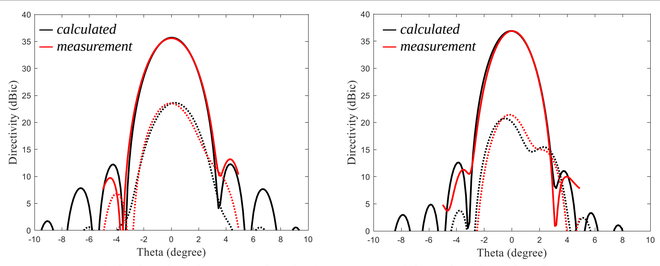
Model used for calculation in TICRA GRASP includes the mesh reflector (with measured data), the boom, CubeSat bus, and feed.

X-band antenna





Dual-band X-band feed with LHCP. Dimensions in mm.

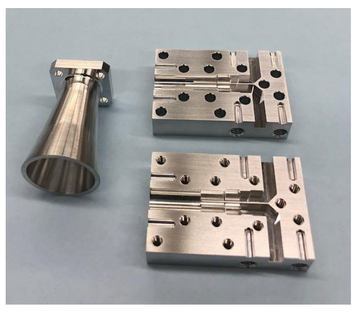


Calculated and measured radiation pattern of the X-band mesh reflector. (Left) Uplink. (Right) Downlink.

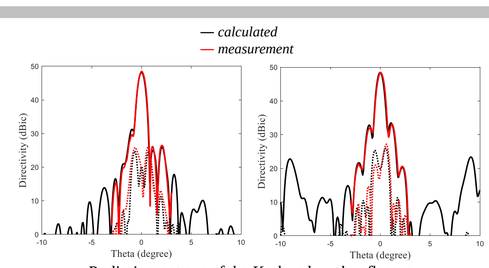
Gain Table at X-band

	Uplink		Downlink	
	Gain (dBic)	**Loss (dB)**	**Gain (dBic)**	**Loss (dB)**
Standard directivity	37.5	-	38.9	-
Taper	37.2	0.3	38.4	0.5
Spillover	36.3	0.9	37.4	1.0
Surface mesh* (30OPI)	36.28	0.02	37.38	0.02
Surface accuracy** (±0.38mm)	36.22	0.06	37.30	0.08
Feed loss	35.92	0.3	37.00	0.3
Feed mismatch (RL=15dB)	35.82	0.1	36.90	0.1
Overall performance	35.82	1.68	36.90	2.00

Ka-band antenna



Multiflare Ka-band feed and Polarizer



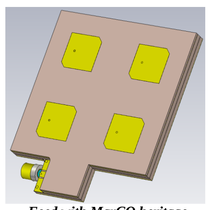
Radiation pattern of the Ka-band mesh reflector. φ = 0 degree. (b) φ = 90 degree. In black: calculated with the measured surface. In red: measured.

Gain Table at Ka-band

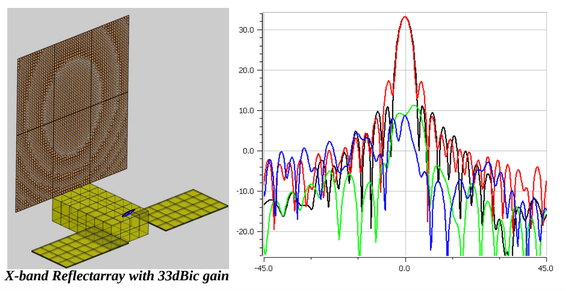
	Gain (dBic)	Loss (dB)
Standard directivity	50.5	-
Taper	49.9	0.6
Spillover	49.5	0.4
Surface mesh* (30OPI)	49.25	0.25
Surface accuracy** (±0.38mm)	48.15	1.1
Feed loss	48.10	0.05
Feed mismatch (RL=15dB)	48.05	0.05
Overall performance	48.05	2.45

X/Ka-band Reflectarray antenna

- **Features:**
  - Compatible with 6U CubeSat
  - X- and Ka-band design for Telecom
  - Transmit only
  - Deployed area: 60cm × 67cm
  - Gain of 32dBic between 8.4-8.45GHz
  - Gain of 43.5.0dBic between 31.8-32.3GHz
  - Co-located feed with identical beam-pointing

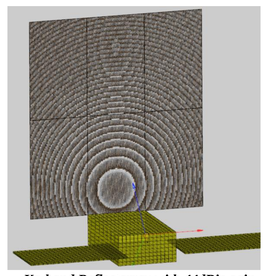


Feed with MarCO heritage

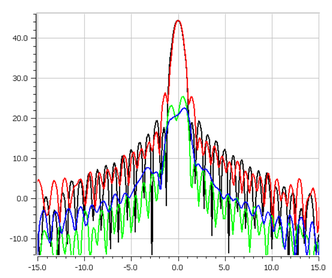


X-band Reflectarray with 33dBic gain

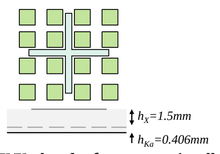
X-band only



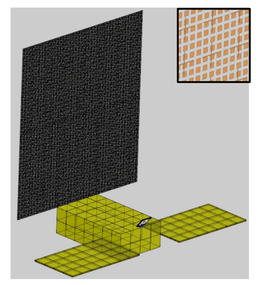
Ka-band Reflectarray with 44dBic gain



Ka-band only



X/Ka-band refectarray unit cell



X/Ka-band Reflectarray with 33dBic gain at X-band and 43dBic at Ka-band

X/Ka-band

Summary

The need for higher data rate for CubeSats is of uppermost importance to push the limit of their capabilities for deep space exploration. This research effort introduces a novel, highly constrained deployable mesh reflector antenna which is currently the largest antenna compatible with 12U-class CubeSat operating at X- or Ka-band. At X-band, a gain of 36.1-dBic and 36.8-dBic is achieved at uplink and downlink frequency bands, respectively. This translates into an efficiency of 72% and 62%, respectively. For the Ka-band only antenna, a gain of 48.4-dBic and 48.7-dBic is obtained at downlink and uplink frequency bands which translates to a 62% and 72% efficiency.

We also designed a dual frequency deployable reflectarray (60cm × 67cm) which provides identical beam pointing using two collocated feeds. A gain of 33dBic is achieved at X-band (i.e. +4dB compared to MarCO) and 44dBic at Ka band (i.e. +2dB compared to KapDA/Raincube). The reflectarray design can tune the antenna beam pointing. Hence, one can imagine using this antenna for telecom at X-band and radar at Ka-band with different beam pointing without changing the structural design of the antenna.

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Patent pending: Chahat *et al.* "High-efficiency dual-band circularly-polarized antenna for harsh environment for Telecommunication", US 2019/0190163A1, Jun. 20, 2019.
Patent: (not funded by this effort) G. Freebury, N. Beidleman, "Deployable reflector," US patent US20170222308A1, Jan. 28, 2016.
Publication: Chahat *et al.*, "One-Meter Deployable Mesh Reflector for Deep Space Network Telecommunication at X- and Ka-band," in press, in *Trans. Antennas Propag.*, 2019.
Publication: N. Chahat *et al.*, "Advanced CubeSat Antennas for Deep Space and Earth Science Missions: A Review," *IEEE Antennas and Propagation Magazine*, Sept 2019.
Book Chapter: N. Chahat *et al.*, "X/Ka-band One Meter Mesh Reflector for 12U-class CubeSat," *Wiley*, in press, 2020.
Book: N. Chahat, "CubeSat Antennas for Deep Space and Earth Science missions," Wiley, *in review*, 2020.

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