ADVANCES AND INNOVATION IN MICROWAVE ANTENNAS FOR CUBESATS

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Visionary Solutions

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Application of Microwave Antennas in CubeSat Payload

- **Communication and Data Transport-**
  High Data Rates and Small Available Aperture in CubeSats favors higher frequencies (compared to UHF, ...)

- **Active Remote Sensing (Radars, Sensor Instruments-**
  Large aperture required to achieve the beam footprint on ground or intended target (clouds, aerosol, ice, terrain, pressure..)

- **Passive Remote Sensing and Specialized Instruments-**
  Microwave, mmWave and THz radiometers, sounders

Antennas for CubeSats- Requirements and Critical Constraints

-Size and Form-factor (Stowage)

-Mass and Mechanical Stability

-Extreme Temperature Variation (Dimensional Stability), Material selection

--Minimum Interaction with Satellite Structure/Payload

- Electromagnetic compatibility and immunity (EMC, EMI..), Electrostatic charging

- High power handling capability (multipaction, ionization breakdown)

-High Radiation Efficiency

- Tolerant of radiation environment (applicable to active antenna arrays)

-High Reliability in Deployment; Robust

- Low Cost, Large Scale Production Capability

Electromagnetic Spectral Bands For Space to Earth, Intersatellite Links and Radars/Sensors

Applications of CubeSat Transmitters

Communications
Data Transport
Inter-Satellite Links (ISL)
Sensor/Radar
Other emerging uses

Radar And Sensor Bands

S band (3.2 GHz)
L band (1.25 GHz)
X band (8-8.5 GHz)
Ka band (35-36 GHz)
V band (65-71 GHz)
W band (93-95 GHz)

Communication and Data Transport Bands

RF

- VHF/UHF (30-1000 MHz)

Microwave

- S (2-2.5 GHz)
- X (7.1-8.5 GHz)
- Ku (12-16 GHz)

Millimeter waves and Terahertz

- K (17.2-21.2 GHz)
- Ka (25.5-27.5 GHz, 31-33 GHz), 35.5 GHz
- Q (37.5-42.5 GHz)
- E/V/W (71-76, 81-86 GHz)
- Terahertz (Between 100 and 1000^+ GHz)

Types of Antennas Suitable for CubeSats and other SmallSat Platforms

PLANAR ANTENNAS

- Printed Circuit
  - Patch Arrays
  - Slot Arrays
  - Metasurface antennas

APERTURE TYPES

- Horns and Feeds
- Quasi-optical antennas (Lens, Optical Components)

ARRAYS AND DISTRIBUTED ANTENNAS

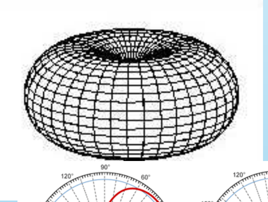
- Active Electronically-Scanned Arrays (AESA)
- Phased Arrays

REFLECTOR TYPE

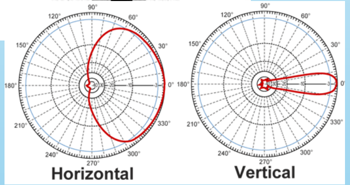
- Offset Cassegrain and Prime-Focus Antennas
- Deployable Reflectors
- Reflectarray systems

Types of CubeSat Antenna Beam Patterns and Characteristics Commonly Needed or Used

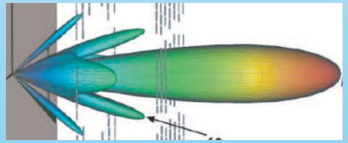
-Omnidirectional (Narrow or wide beam), Isotropic

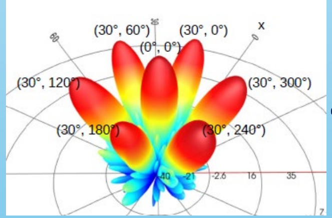


-Sectoral Coverage (high aspect ratio of beam widths)



-Narrow, pencil beam

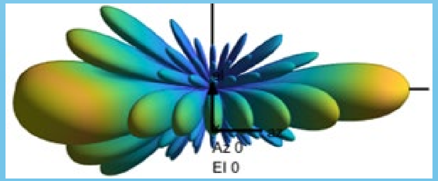




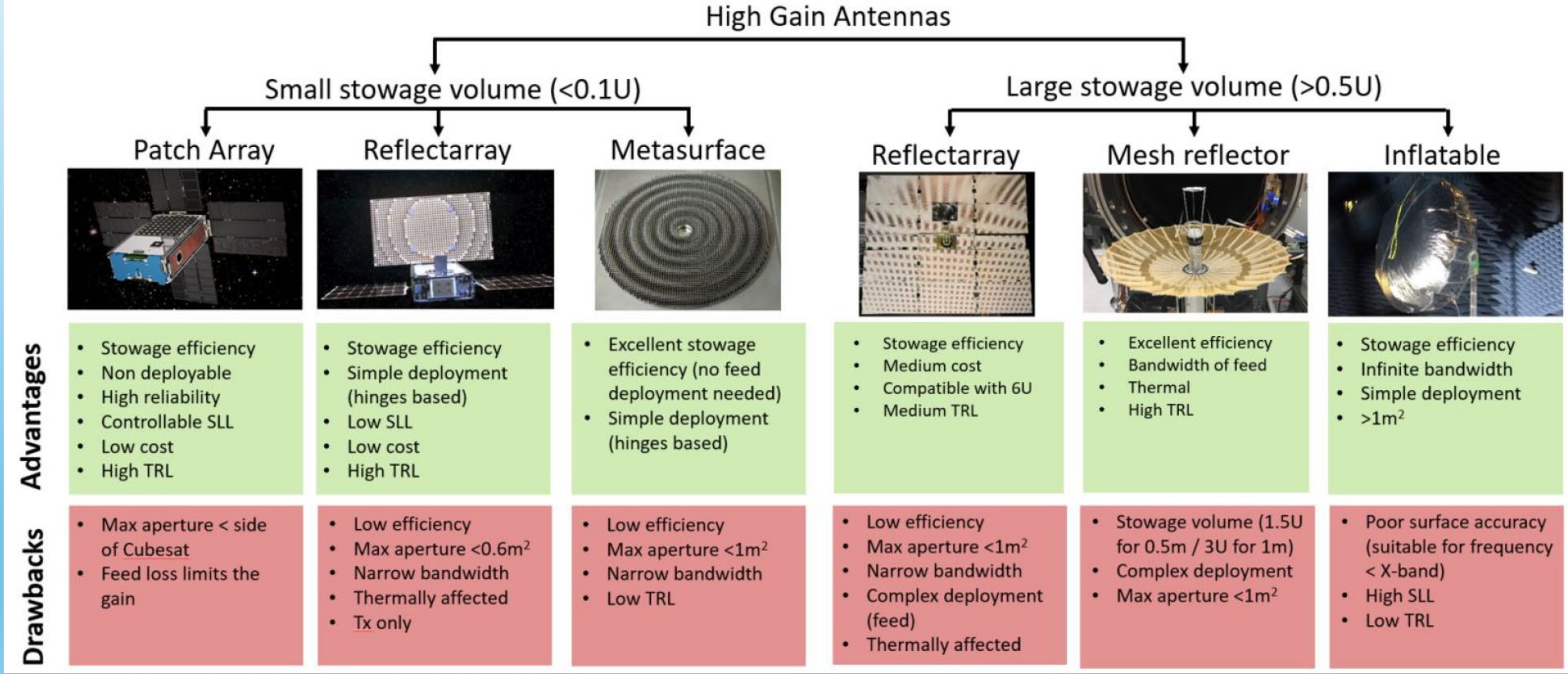
-Shaped-Beams, Multiple Beams

-Reconfigurable beam pattern

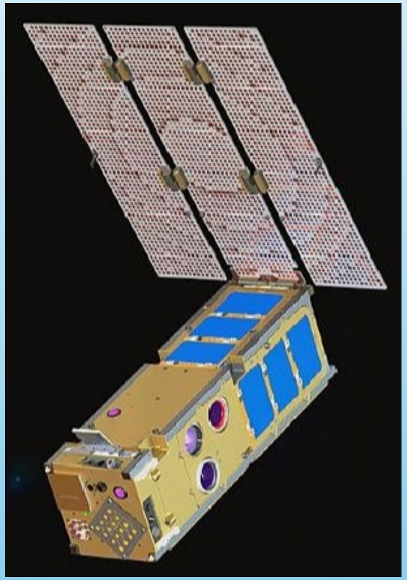
-Steerable Beam(s)



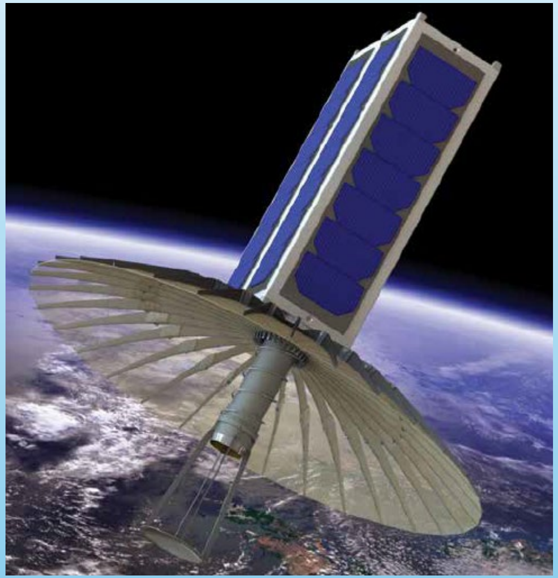
Comparison of Various High Gain Antenna Types for CubeSats



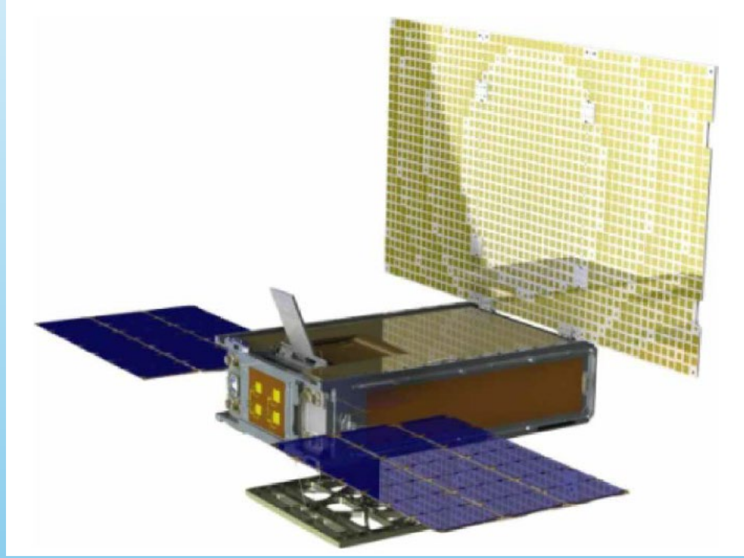
Past Accomplishments and Current Commercial Art



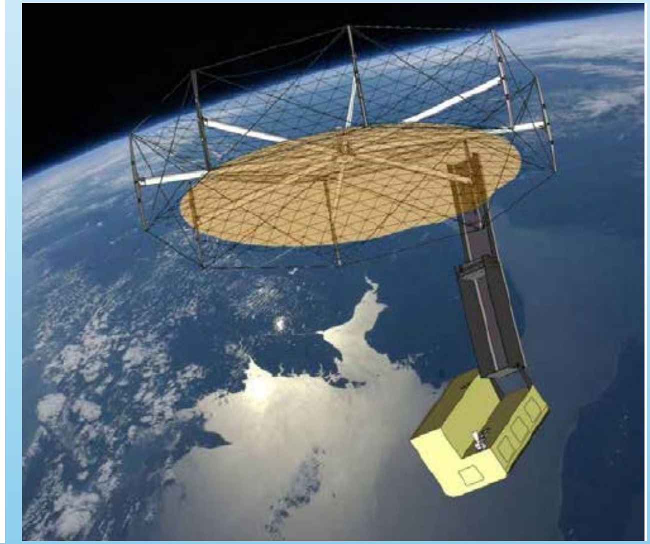
Reflectarray-26 GHz (deployed)- ISARA)



Deployable reflector- RainCube

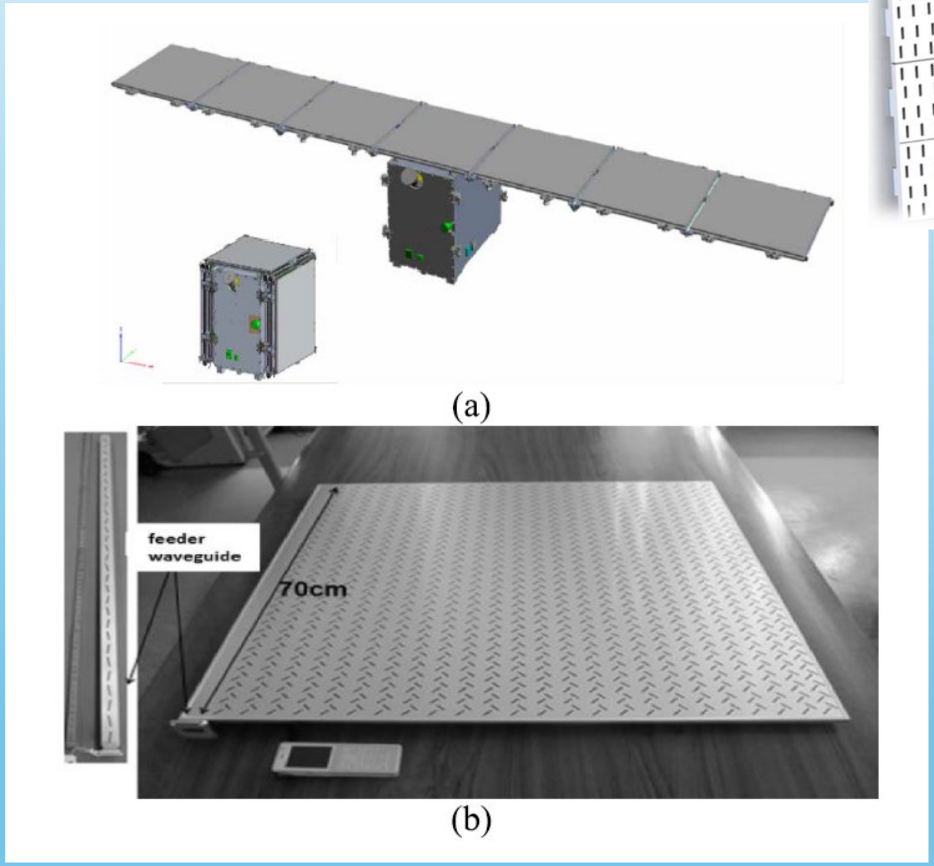


Reflectarray 8 GHz- deployed- MarCo

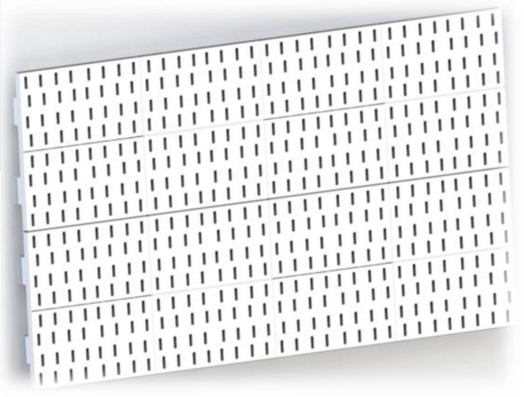


Large (1-meter) Ka-band (35.75 GHz) deployable reflector (fits in 3U)

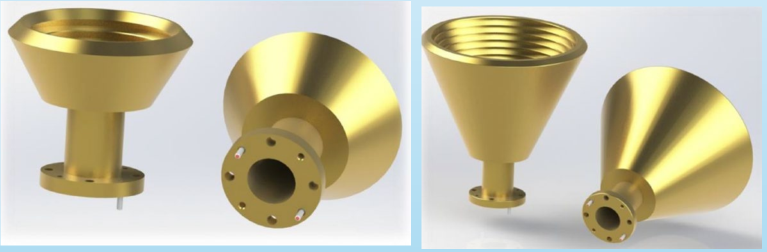
Past Accomplishments and Current Commercial Art



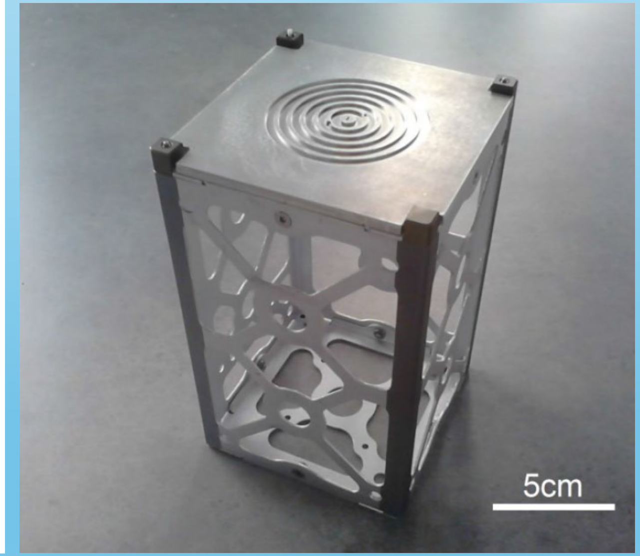
X-band Deployed Slot Array, Circular Polarization



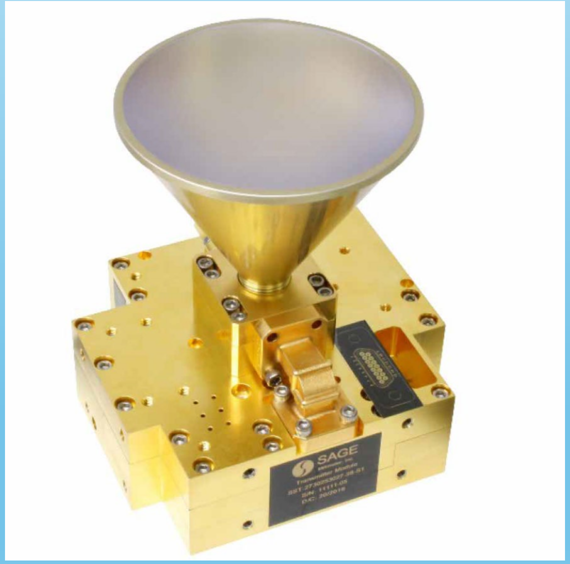
Slot Array, 35 GHz



Horn Antenna

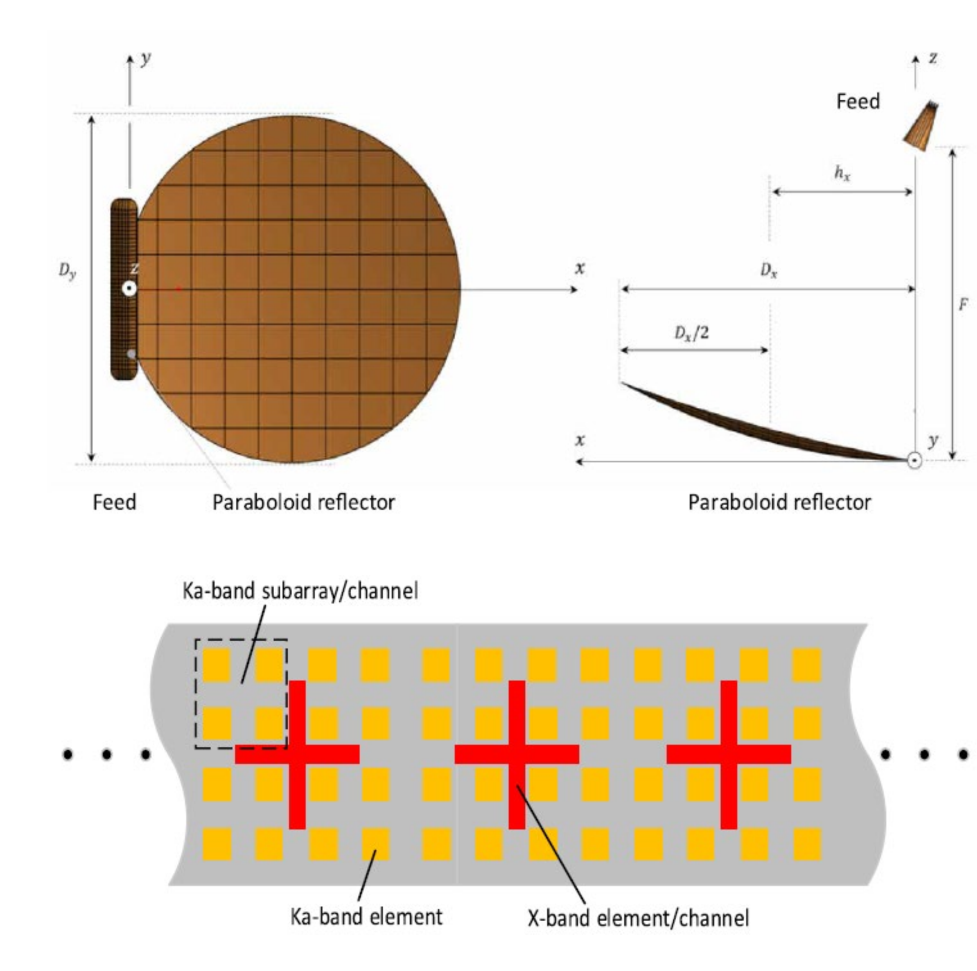


V-band (60 GHz) Bull's Eye antenna

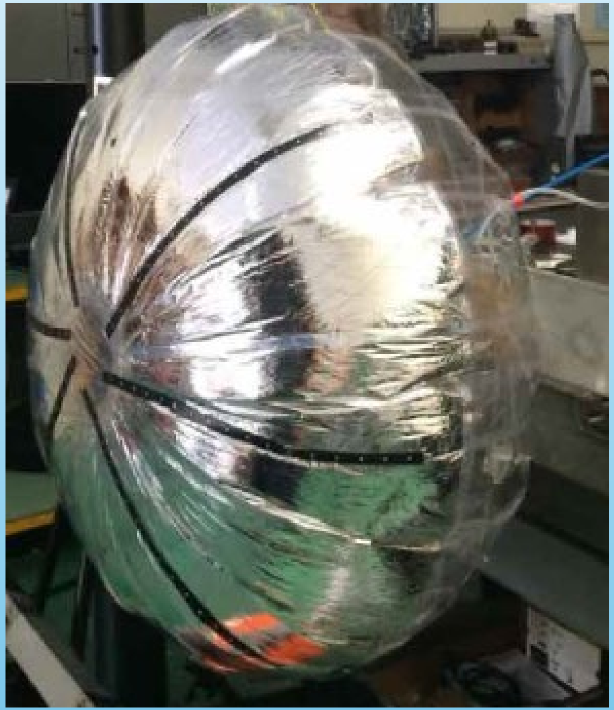


Dielectric-loaded horn- Ka band

Past Accomplishments and Current Commercial Art



Dual-band (X and Ka) Reflector-based Antenna System

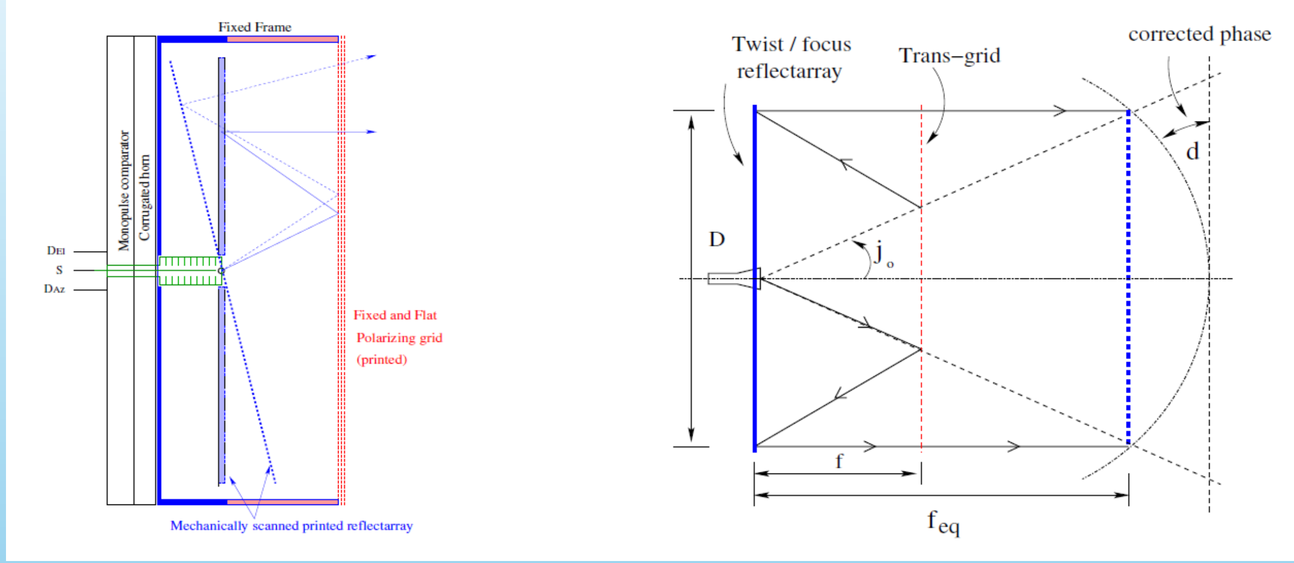


Inflatable X-band antenna prototype for CubeSats

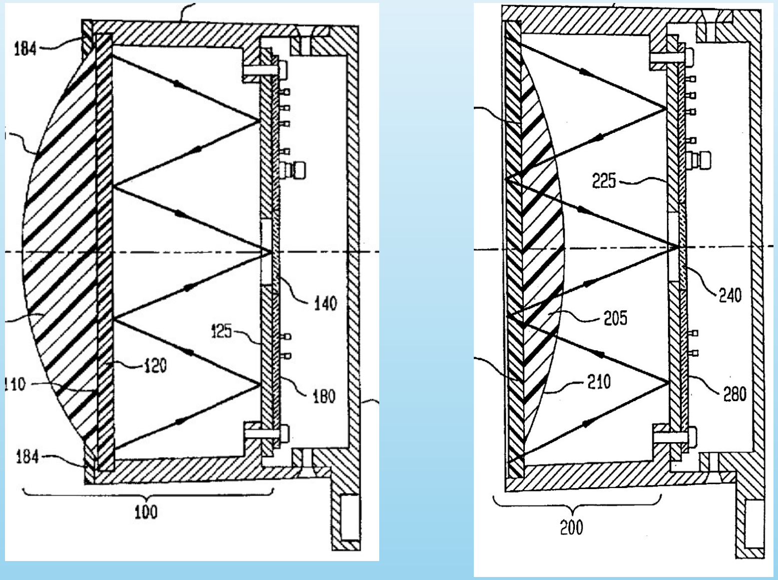
Highlights and Features of Proposed Antennas

Enhancements and Improvements	Advances, Innovation and Added Features
Low profile (thin, conformal)	- Gapwave waveguide structure - Slot array antennas
Low SWaP-C	- Folded Optics and “folded” apertures (horns) - Additive Manufacturing (3-D printed antennas)
Higher Overall Efficiency	- Gapwave waveguide structure (low RF loss) - Improved, advanced printed circuit board materials - Advanced Optics
Low-cost Manufacturing Method	- Additive Manufacturing (3-D printed antennas)
Standardization for CubSat Architecture	- Availability as COTS products for most bands
Novel Application-specific capabilities	- Beam forming and scanning capabilities (AESA) - Multi-band performance
Higher RF Frequency of Operation	- Greater bandwidth, data rates; Higher resolution - Application-specific performance (sensors, radars)

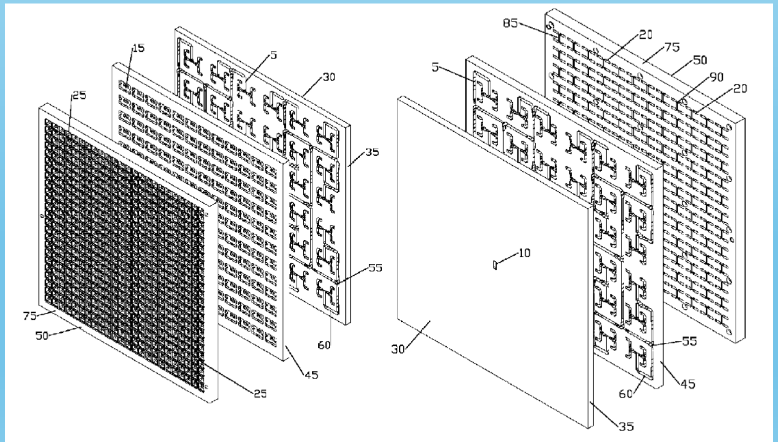
Examples of Innovative Microwave and Millimeter-wave Antennas for CubeSats



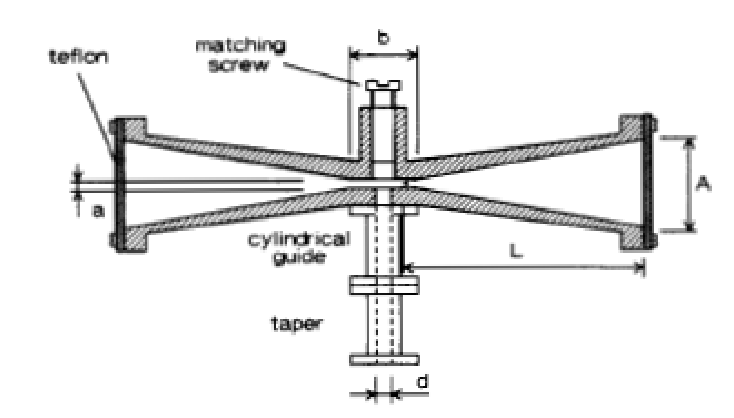
Folded-optics Antenna (scannable)



Folded-optics Lens-Feed Antenna



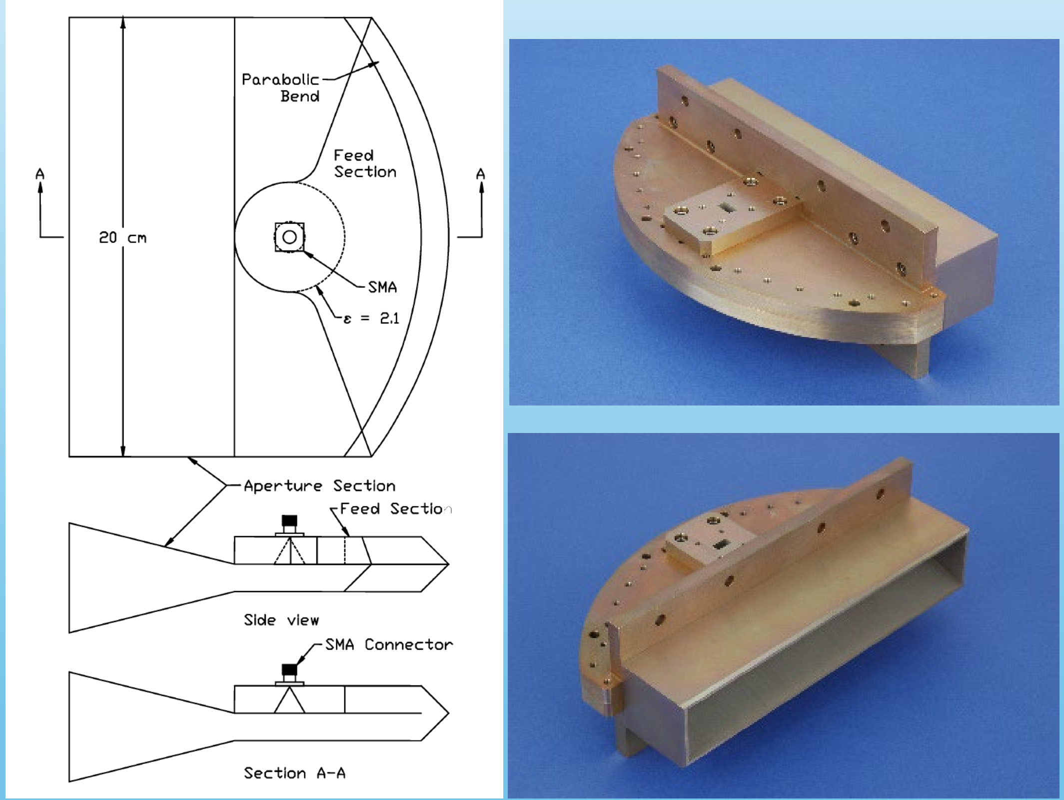
Flat Panel Array Antenna



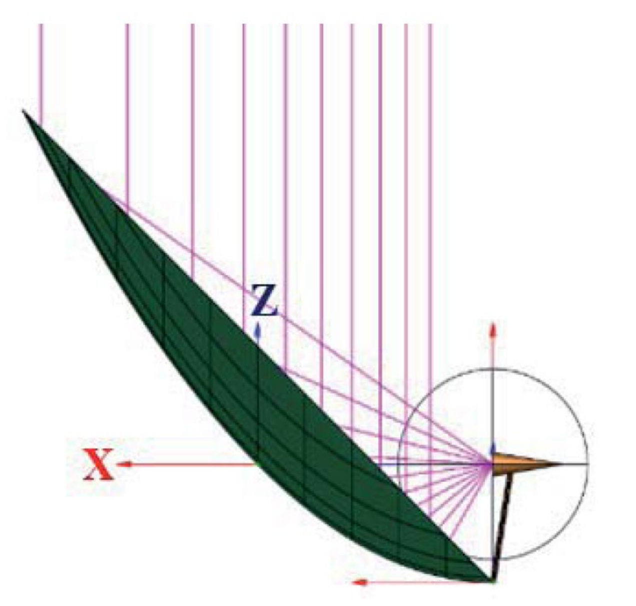
Omni-directional Antenna

Examples of Innovative Microwave and Millimeter-wave Antennas for CubeSats

Designs and Concepts for Antennas for Future CubeSat Mission



Folded Horn Antenna for Sectoral Beam Pattern

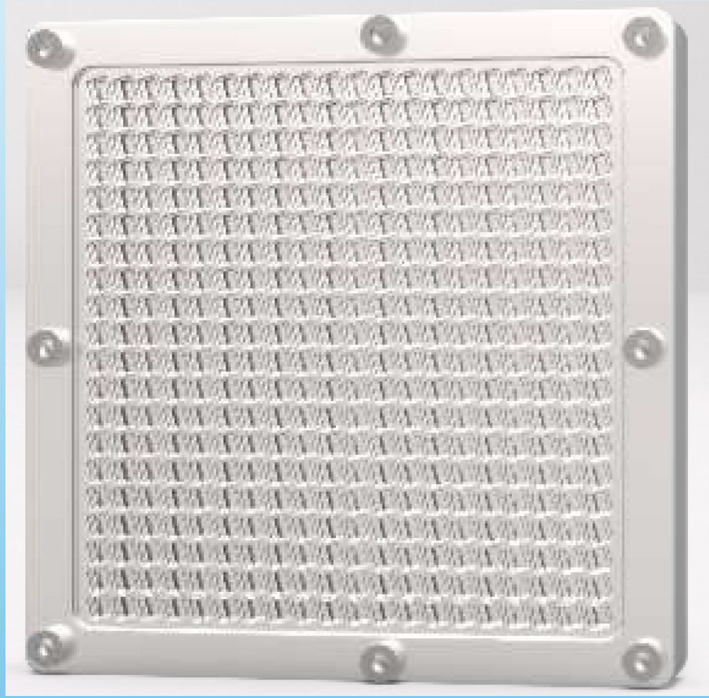


Compact Offset Reflector Antenna for CubeSats (1U)

Additively Manufactured Metal only RHCP Ka band Metasurface antenna

Examples of Innovative Microwave and Millimeter-wave Antennas for CubeSats

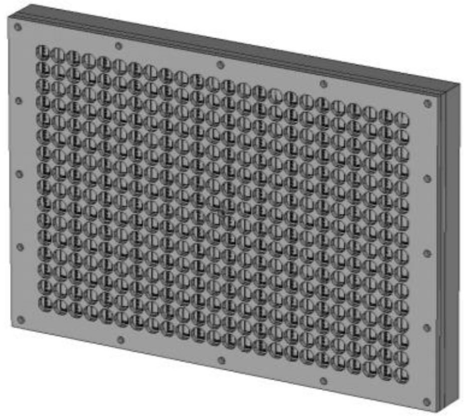
“Gapwave” waveguide technology for high performance flat array antennas



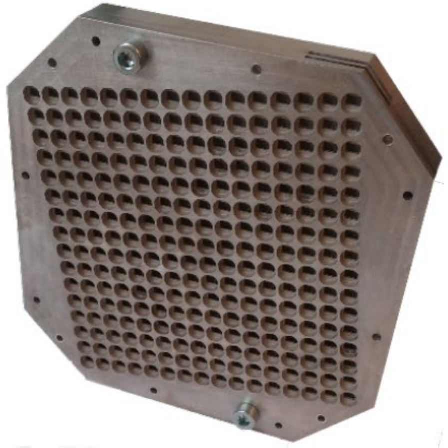
Gapwave V-band flat panel array

Size	~93 × 93 × 15.8mm
Frequency range	57 - 66 GHz
Gain (mid band)	32.5 dBi
Connecting flange type	WR15

2×6-port Slot Array Antenna with 8×4-slot Subarrays



Size (mm)	110 × 74 × 10
Frequency range (GHz)	57 – 66
Boresight gain (Low band) (dBi)	34.1
Boresight gain (Mid band) (dBi)	34.9
Boresight gain (High band) (dBi)	35.4
Boresight E-plane HPBW (deg)	2.4 – 2.8
Boresight H-plane HPBW (deg)	3.6 – 4.2
Maximum angle in E-plane (deg)	+/- 6
Maximum angle in H-plane (deg)	+/- 3
Output flange	WR15



Technical specifications

Size (mm)	80x80x10
Frequency range (GHz)	57 – 66
Gain (Low band) (dBi)	31.8
Gain (Mid band) (dBi)	32.5
Gain (High band) (dBi)	33
Half power beam width (deg)	3.8 – 4.1
Front-to-back ratio (dB)	30
ETSI compliance	Class 2
Output flange	WR15

Active and Passive Beamforming Architectures for Scannable and Agile Beam Antennas

Active Electronically Steered Arrays (AESA) and Phased Arrays

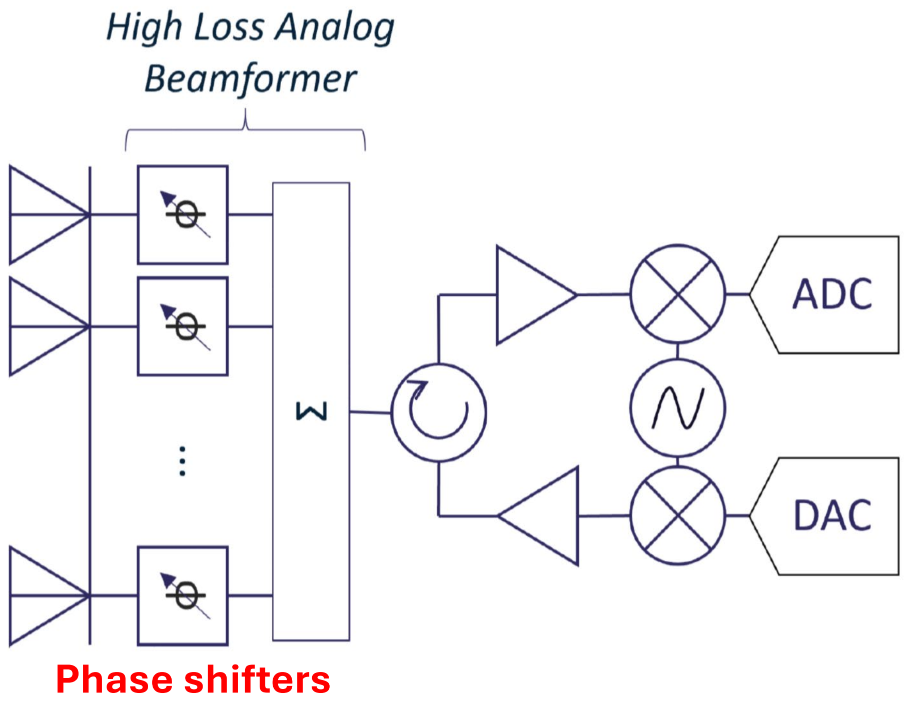


Fig. 3: Passive Beamforming Architecture (after [3])

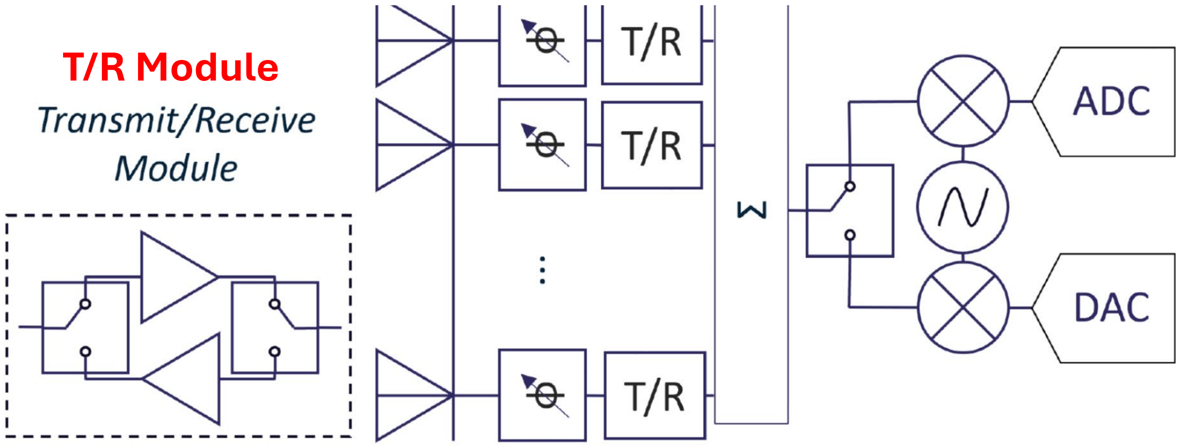


Fig. 4: Active Beamforming Architecture (after [3])

Conclusions

Thank you for your attention

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