Structurally reconfigurable modular inflatable reflectors

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Outline

- Introduction
- Motivation
- Challenges
- Objectives
- Approach
- Results and Discussions
- Further Work
- Conclusion
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Introduction – High gain antennas (HGA)

- Include reflectors and reflect-arrays.
- Directional radiation minimizes losses.
- Enable high data-rate communication.

JPL's Ka Band reflector
(Chahat et al., 2018)

Introduction - Reflectors

- **Larger surface area to volume ratio among HGA's.**
- **Better packing efficiency among deployable HGA's.**

Antenna Technology	Surface Area (m^2)	Mass (kg)	Stowed Volume (m^3)	Packing efficiency
Deployable parabolic reflectors	1.0	1.5-2	0.04	5:1
Foldable reflect-arrays	1.0	0.6 – 0.8	0.05	3:1

Comparison of HGA technologies for 1 m^2 reflective surface area (Chandra, 2015)

Introduction - reconfiguration

- Reflector curvatures can be reconfigured.
- Reconfiguration enhances reflector performance.
- Can be used to correct shape errors.
- Can assist with antenna fine pointing.

Motivation

Enhance deep space CubeSat communications by:

- **High gain reflector design.**
- **Co-operative reflector systems between CubeSats.**

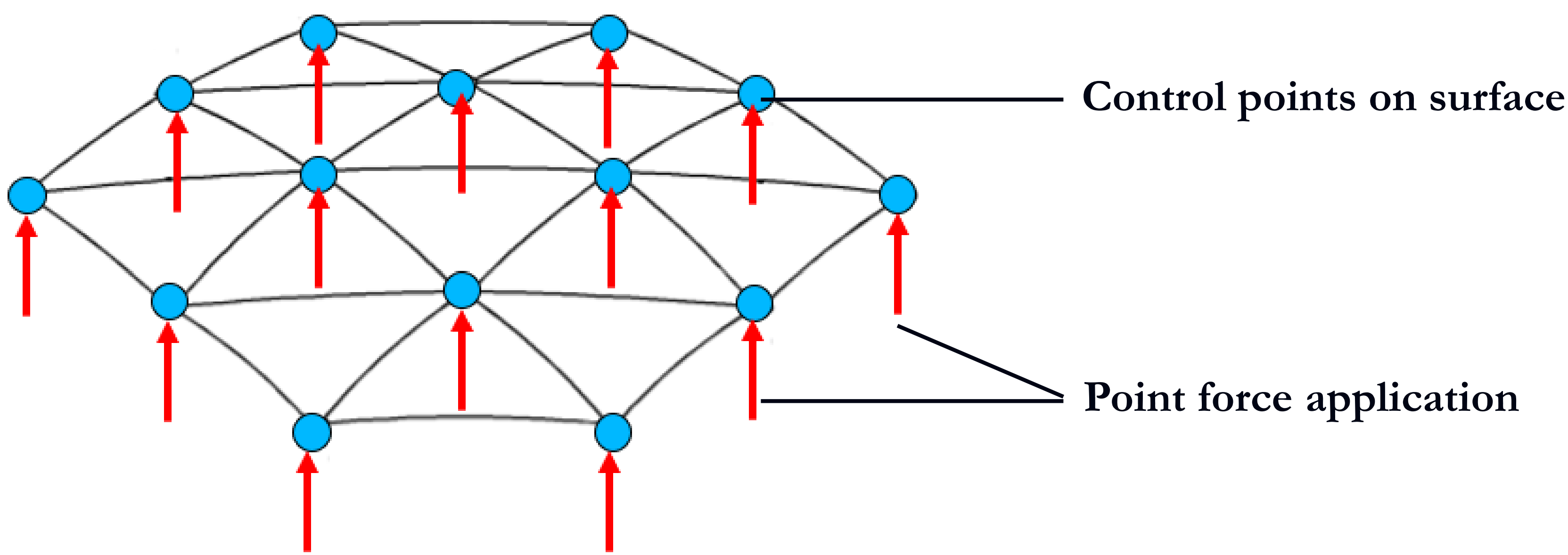
Frequency band	Minimum required gain (dBi)
X - band	28
Ka - band	42

Interplanetary mission reflector gain requirements.

Related Work

Reconfiguration has been attempted using:

- **Piezo based linear actuators.** (Datahvili, 2017)
- **Shape memory alloys.** (Kalra et al., 2018)



Challenges

- Mechanical actuators are bulky.
- Large number of actuators are required.
- Can be mechanically complex.
- Metallic actuator parts cause signal interference.

(Datashvili et al., 2010)

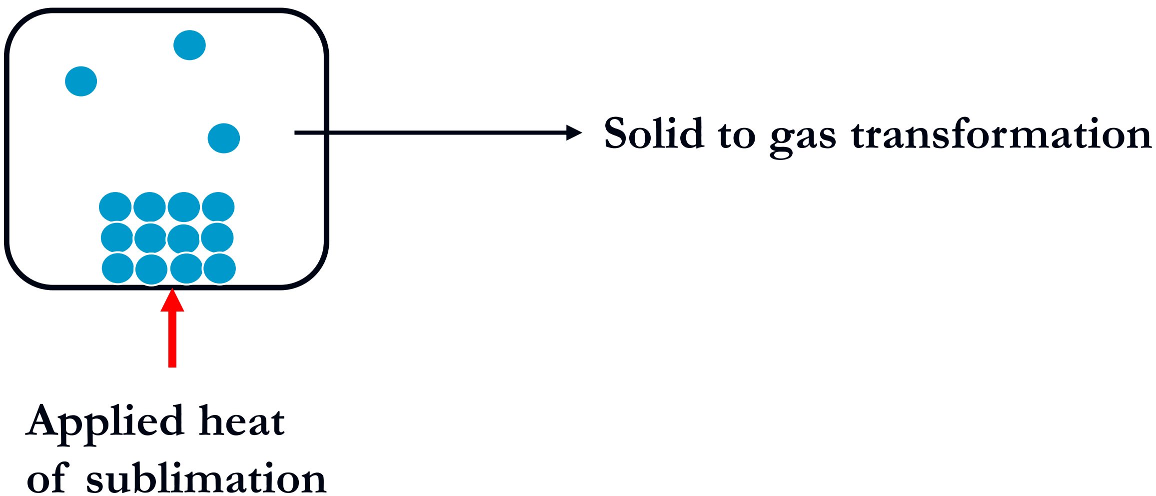
Objectives

- **To develop a pneumatic actuation mechanism.**
- **To design a reflector based on this mechanism.**
- **Numerically analyze structural behavior.**
- **Develop a reflector design using the mechanism.**

Approach

Chemical sublimate gas generation

- Sublimates undergo solid to gas transformation.
- Pressure of gas able to inflate a membrane in space.



Sublimate gas pressure control

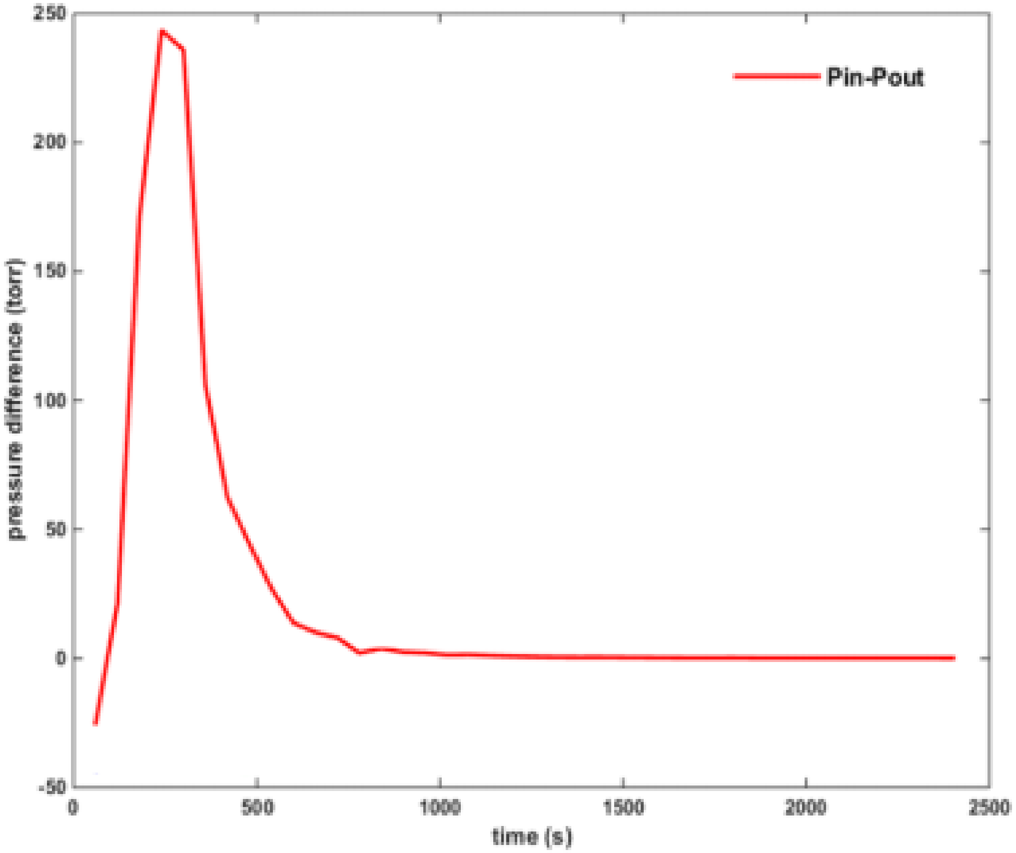
- **Pressure controlled by ambient pressure and temperature shown.** (Babuscia et al., 2014)

$$\frac{dm}{dt} = \alpha \sqrt{\frac{M}{2\pi RT}} (p_{eq} - p)$$

p – internal pressure
T– ambient temperature
R – Gas constant
M – molecular mass
p_{eq}- Vapour pressure
m- mass of generated gas

- **At constant temperature, pressure reaches equilibrium**

Sublimate gas pressure measurement



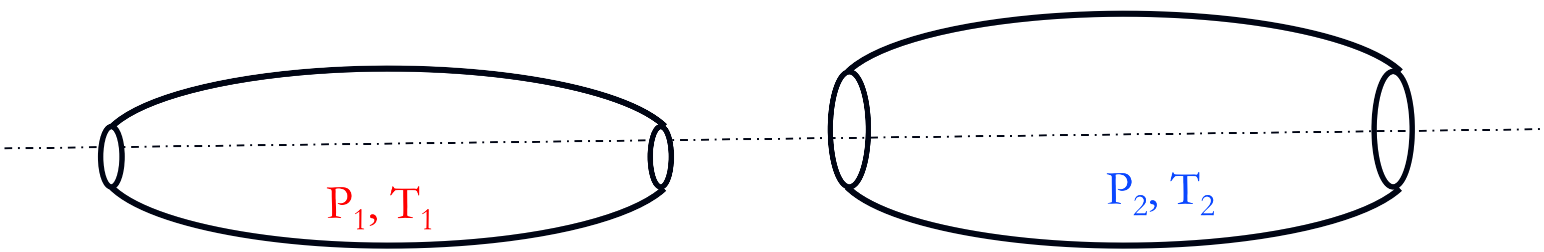
Benzoic acid gas pressures at room temperature vacuum
(Chandra, 2015)

- Sublimate benzoic acid yields a final stable pressure of 0.38 Pa at room temperature.

Sublimate gas membrane inflation

Pneumatic actuator

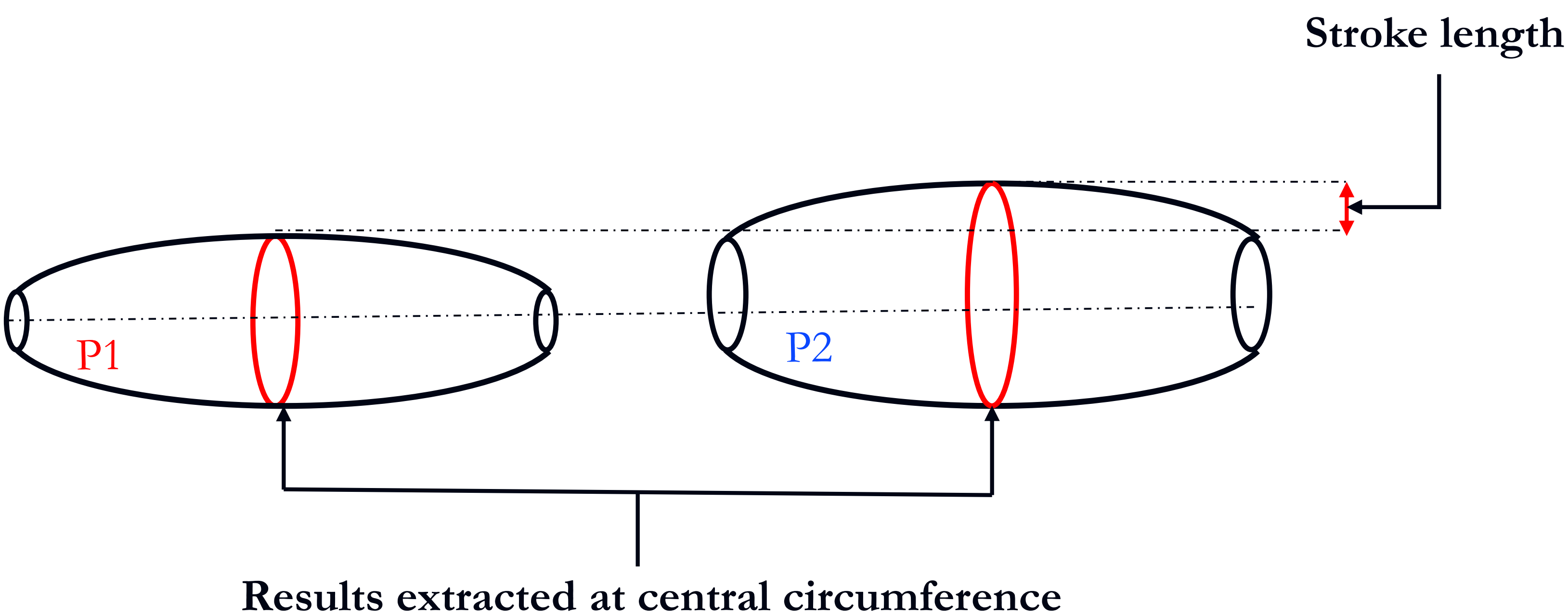
- Sublimate incorporated into a Mylar membrane unit to form actuator.



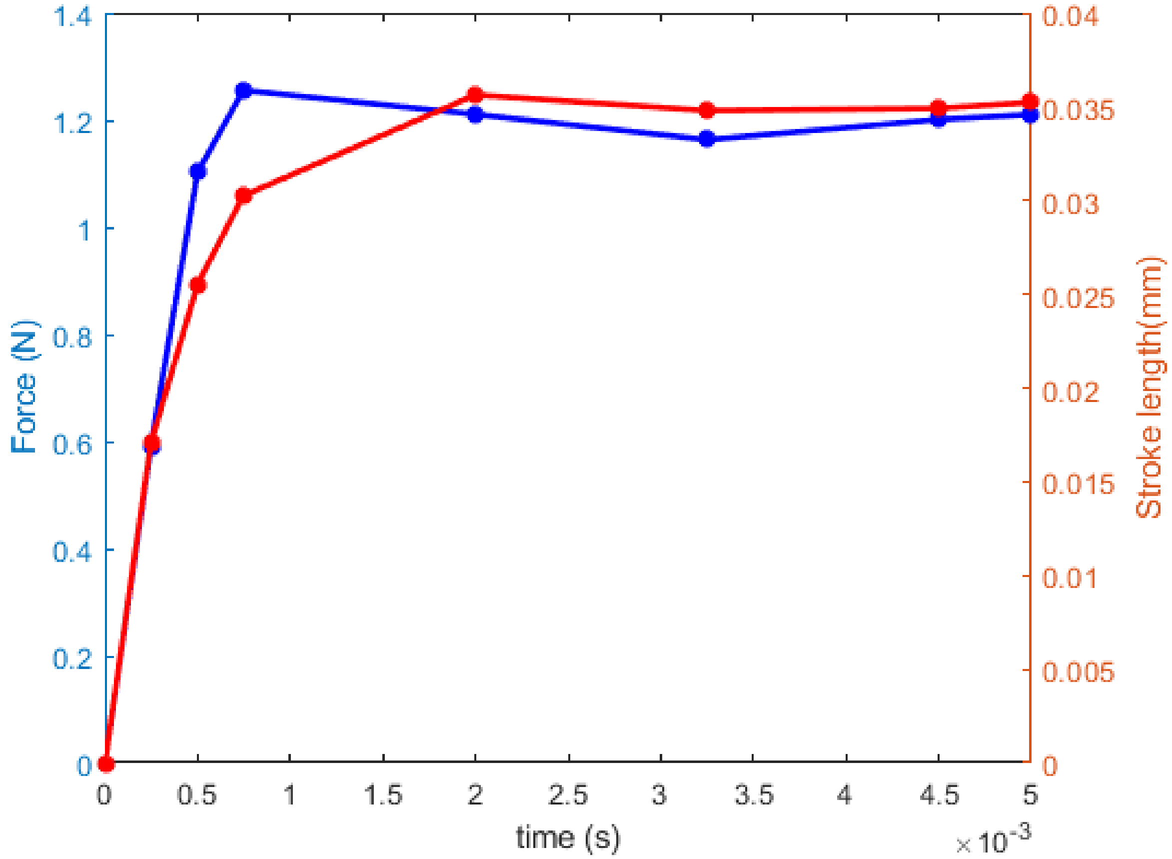
Mylar membrane changing pressure state with temperature

Actuation stroke length

- Numerical analysis carried out using LS-Dyna.
- Stiffness and deflection behavior simulated.



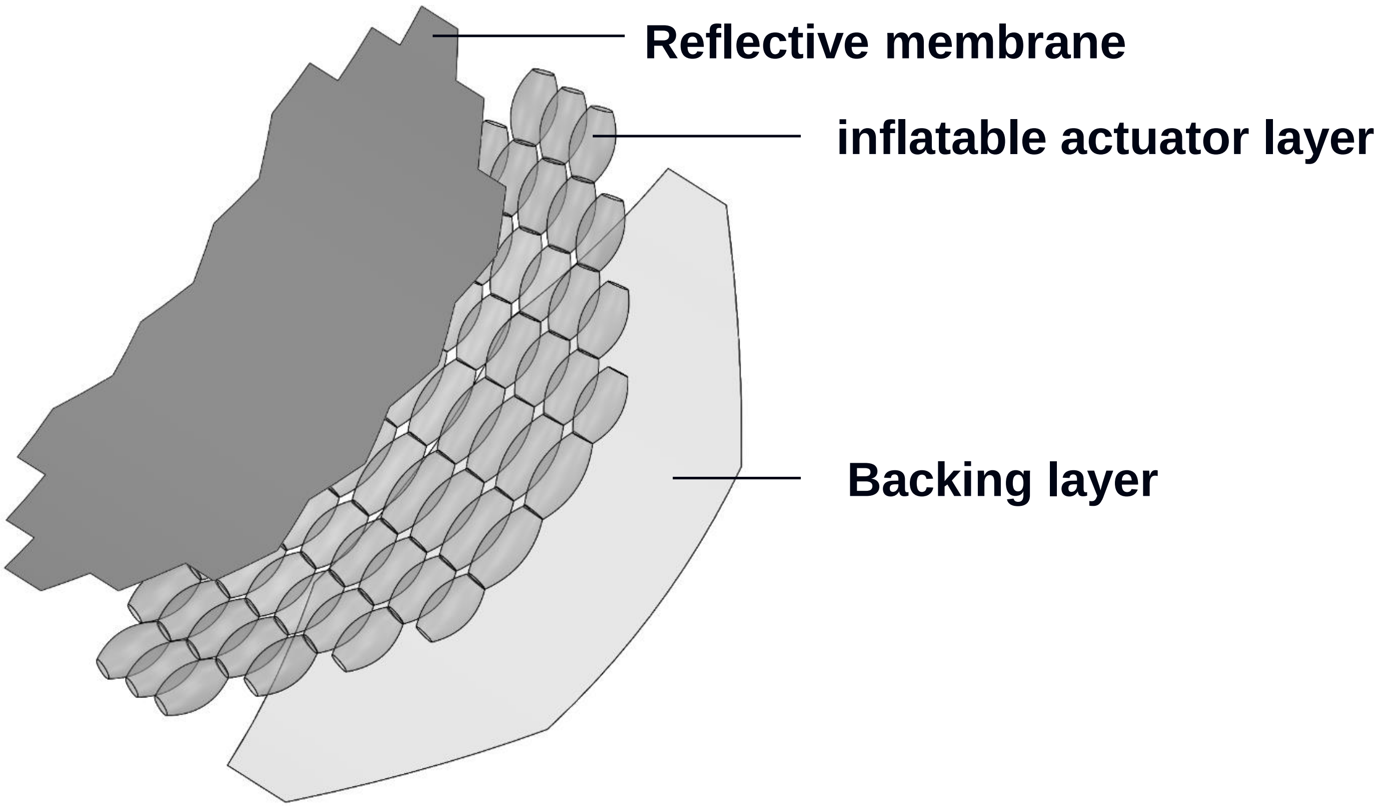
Numerical Results



Force and stroke length during inflation

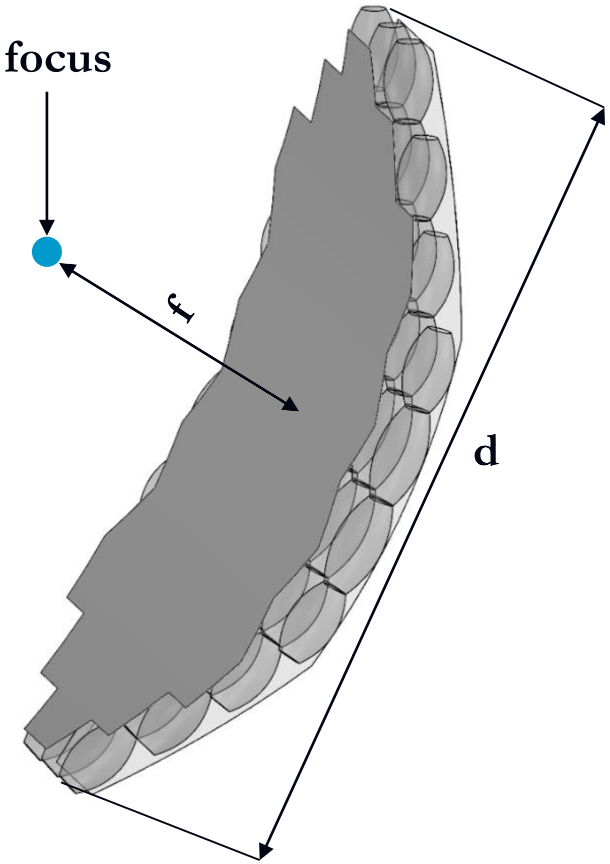
Composite inflatable reflector

- **Multiple units to form reflector structure** (Chandra et al., 2018)



Composite inflatable reflector

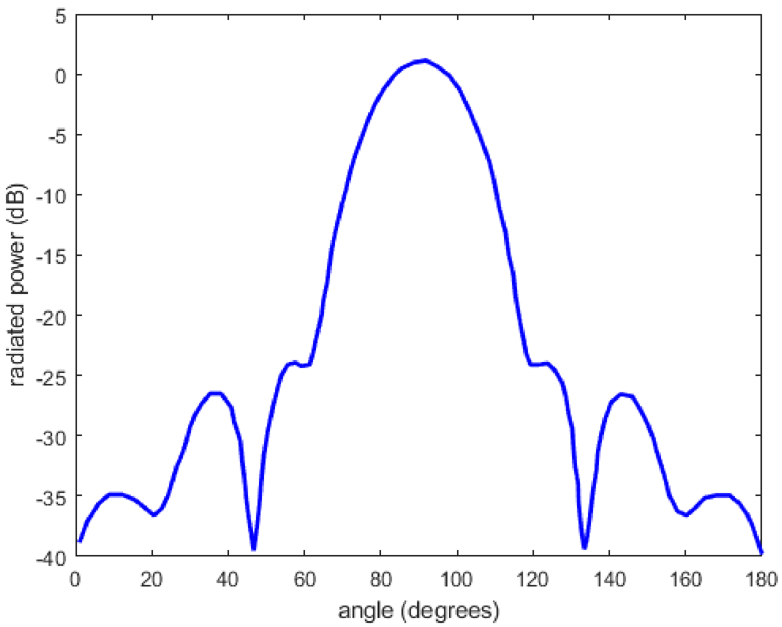
- **Inflatable units can be used to modulate f/d ratios.**
- **Patterned inflation can be used to obtain desired geometry**



Further Work

- Work underway to understand how focal length/ distance ratios change with actuation.

- Radiation pattern analysis would be done for each case.



Radiation pattern for 1 m reflector

Conclusion

- **A pneumatic actuation mechanism has been developed.**
- **Force and stroke length data show actuation feasibility.**
- **A methodology towards application to parabolic reflectors has been proposed.**

Thank you

References

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