DVAC CONCEPT DESCRIPTION:

OFFSET GREGORIAN DISH — DVAC-1
PRIME FOCUS DISH — DVAC-2

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Outline

1. Dish Verification Antenna China in General
2. DVAC Design Principle
3. DVAC-1 Main Specifications
4. DVAC-1 Concept Design
5. DVAC-1 Main Specification Budget
6. DVAC-2 Specs
7. DVAC-2 Concept Design
8. DVAC-2 Specification Budget

1. DVAC General

Potentially three types of reflector antenna could be used:

- **Prime focus reflector antenna**
- **Dual symmetric reflector**
- **Dual offset reflector**

1. DVAC General

➢ Prime focus reflector antenna

A prime focus reflector antenna has advantage of the simplest optical design, a symmetry helps the mechanical design and low cost. But disadvantages are:

- ✓ **impossible to simultaneously optimize aperture efficiency and noise temperature;**
- ✓ **lower efficiency and higher side-lobe due to larger blockage;**
- ✓ **mechanically difficult to accommodate multiple feeds and a PAF at the primary focus.**

1. DVAC General

- **Dual symmetric reflector antenna**
  - ✓ **Aadvantages**
    - **Shaping produce high aperture efficiency and low noise T;**
    - **Feed spillover pointing to sky further reduce noise temperature;**
    - **Symmetry helps with mechanical design and cost.**
  - ✓ **Disadvantages**
    - **Subreflector has to be small to reduce aperture blockage, limiting the low frequency performance;**
    - **Small subreflector requires high gain (narrow beam) feeds, limiting use of broadband feeds with wide angle illumination;**
    - **Lower frequency feed and PAF to be at the primary focus, requiring a feed interchange mechanism, difficult to accommodate two feeds at the primary focus.**

1. DVAC General

➢ Dual offset reflector antenna

✓ Advantages

- Shaping produce high aperture efficiency and low noise T;
- No blockage design further enhances aperture efficiency and reduces wide angle sidelobes;
- Feed spillover pointing at the sky can further reduce the noise temperature;
- Mechanically easy to accommodate multiple feeds at the secondary focus and a PAF at the primary focus.

✓ Disadvantages

asymmetry increases the complexity of mechanical design leading to higher costs.

1. DVAC General

JLRAT propose two concept designs for the SKA dish.

Dish Verification Antenna China #1 (DVAC-1) refers to an offset Gregorian dish;

DVAC-2 refers to an axis-symmetric dish (prime focus reflector antenna).

1. DVAC General

Reference

- ***SKA Dish Verification Antenna: Executive Summary***
- ***SKA Dish Verification Antenna System Functional Specifications***
- ***Requirements_spreadsheet_v1_20100929(1)***

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Main specifications and Concept Design

2. Design Principle

- Excellent performance
- Low cost
- Ease of transportation and installation
- Minimal routine maintenance
- Long lifetime

DVAC CONCEPT DESCRIPTION:

OFFSET GREGORIAN DISH — DVAC-1

3. Main Specifications for DVAC-1

Antenna Type	Offset-Gregorian Antenna , Diameter 15m
Mount Type	EL over AZ (AZ：Gear，EL: Screw)
Frequency Band	0.3GHz ~ 10GHz
Frequency Band Switch Manner	Switching Feeds within 30s
Surface Accuracy of Main Reflector	≤1.2 mm RMS (at night, under low wind) ≤1.25mm RMS (Wind 7m/s , ΔT=5ºC) ≤1.75mm RMS (Wind 20m/s , ΔT=7ºC)
Pointing Accuracy	≤10 arcsec RMS (at night and no wind) TBC (at daytime, with wind)
Antenna Aperture Efficiency (%)	≥ 55%
First Sidelobe Level	≤-18dB

3. Main Specifications for DVAC-1

Polarization	Dual-LP/Dual-CP
Travel Range	AZ：±270° , EL：15° ~ 85°
Slew Rates (Max)	AZ：3° /s, El：1° /s
Acceleration (Max)	AZ：3° /s^2, El：1° /s^2
Wind Velocity	Drive to stow :70 km/h Survival: 160 km/h (at El=54°)
Design Lifetime	≥ 30 years

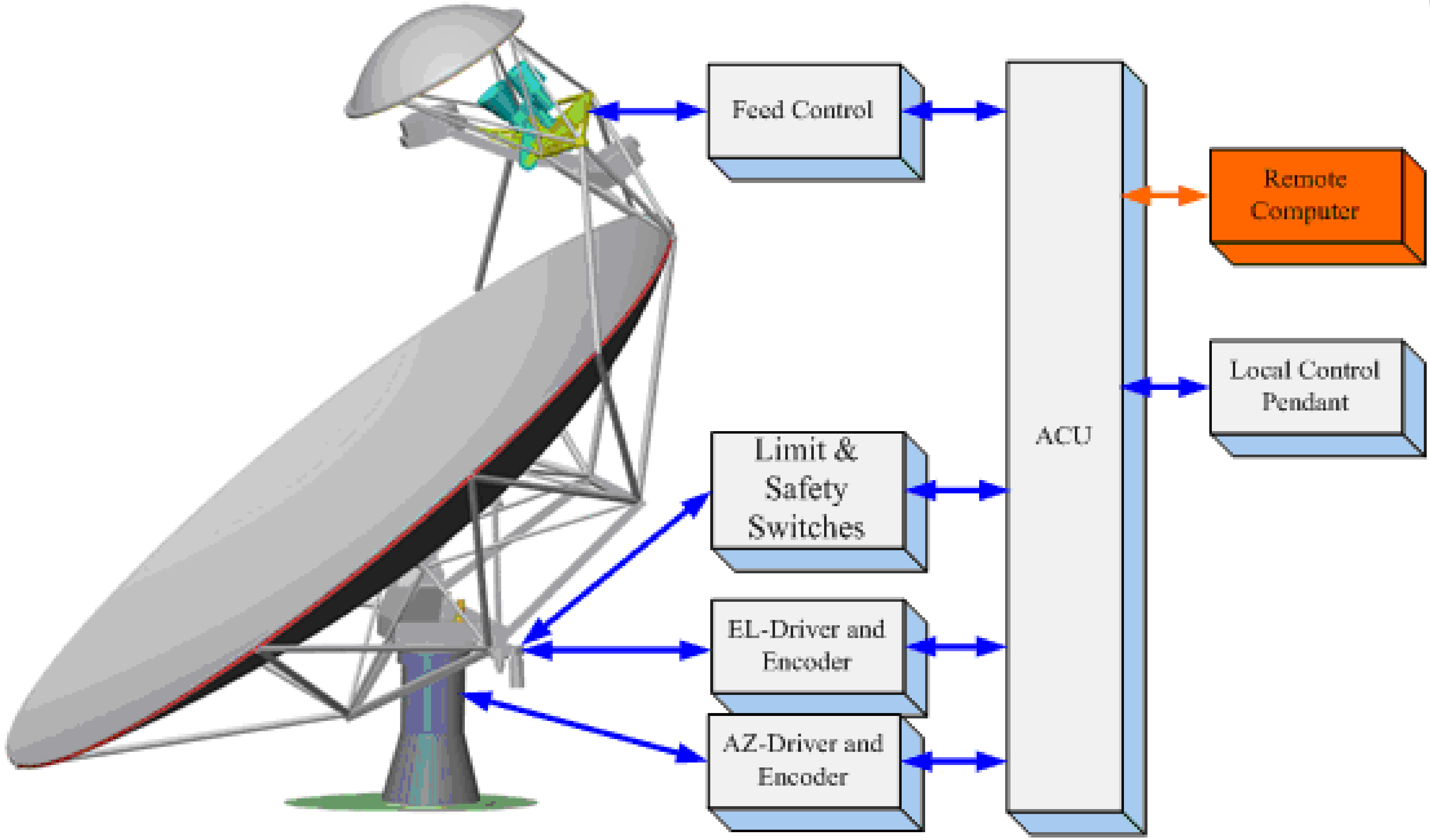
4. Concept Design

Main Attractions of DVAC-1 Design

- Offset-Gregorian Antenna
- Wide Band Feed (WBF)
- Integrated Modular Design
- Integrated Main Reflector Surface (Single Panel)
- Sealed and Lubricated Driving Devices
- Mature Technology

4. Concept Design

Design and Manufacture



Block Diagram of 15 Meter Antenna System

4. Concept Design

(1) Microwave Optical Design

(2) Structure Design

(3) Servo Control Design

4. Concept Design

(1) Microwave Optical Design

- ➔ Feed Design
- ➔ Main and Sub Reflector Curve Design

4. Concept Design

(1) Microwave Optical Design

➔ Feed Design

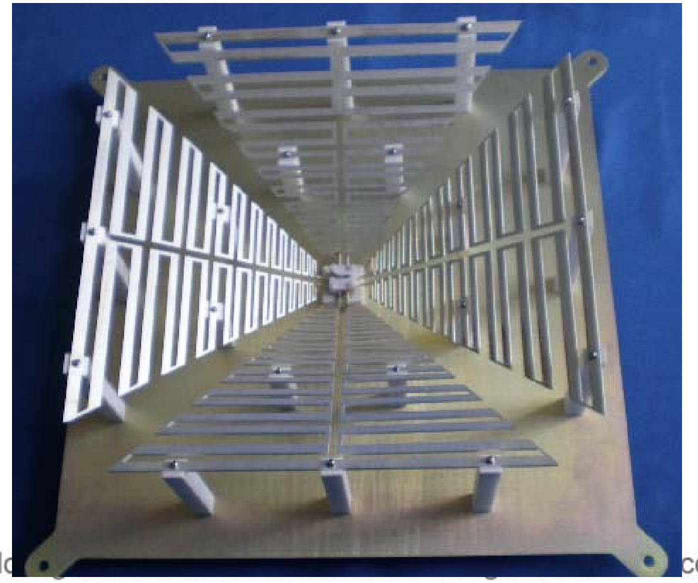
Operating frequency: 0.3GHz~10GHz (33 octaves)

⬇

two wide-band feeds (WBF)

WBF advantages:

- Bandwidth of several octaves;
- Dual linear or circular polarization
- Constant phase centre
- Equal E- and H-plane beamwidth



4. Concept Design

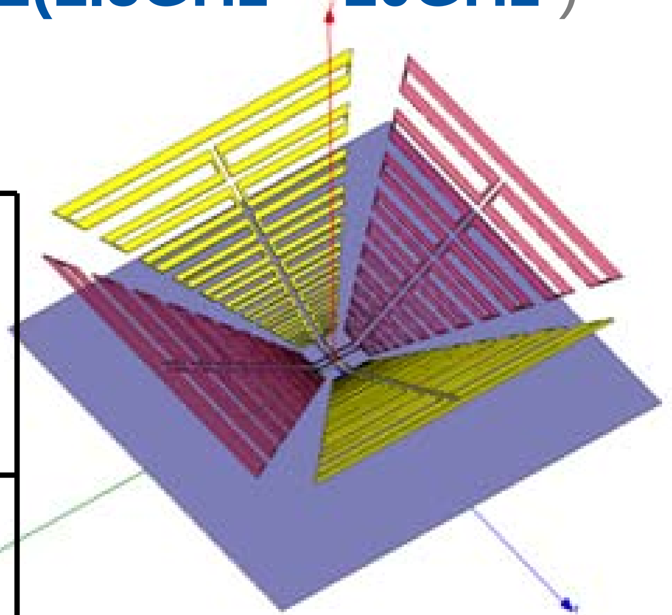
(1) Microwave Optical Design

➔ Feed Design

Feed 1(0.3GHz ~ 1.5GHz) and Feed 2(1.5GHz ~ 10GHz)

Eleven Feed

Frequency (GHz)	Length×Width×Height (mm)	Weight (kg)
0.3~1.5	1040×1040×350	20
1.5~10	250×250×120	8



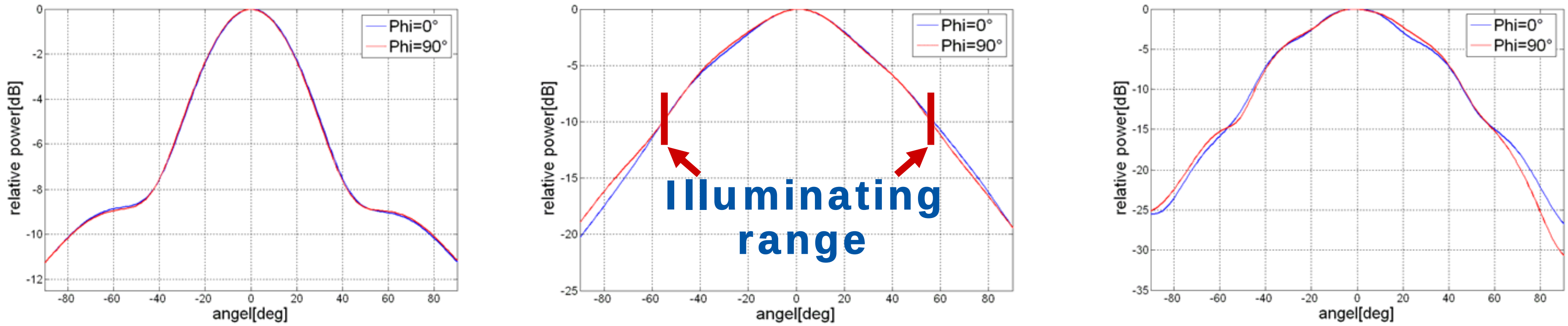
Simulation Model

4. Concept Design

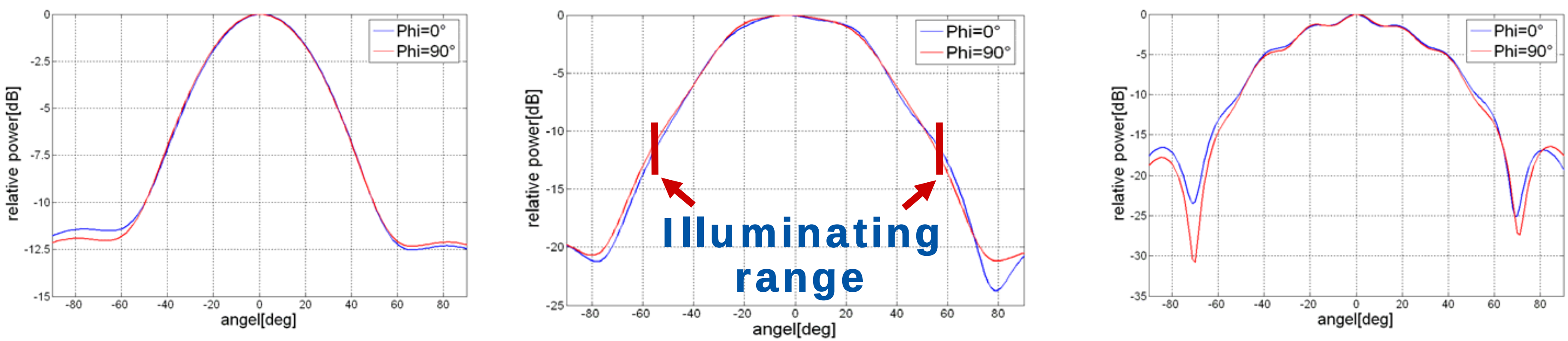
(1) Microwave Optical Design

➔ Feed Design

Subreflector Edge Taper: -9 ~ -15dB



Radiation Patterns of Feed1 at 0.3, 0.9 and 1.5GHz

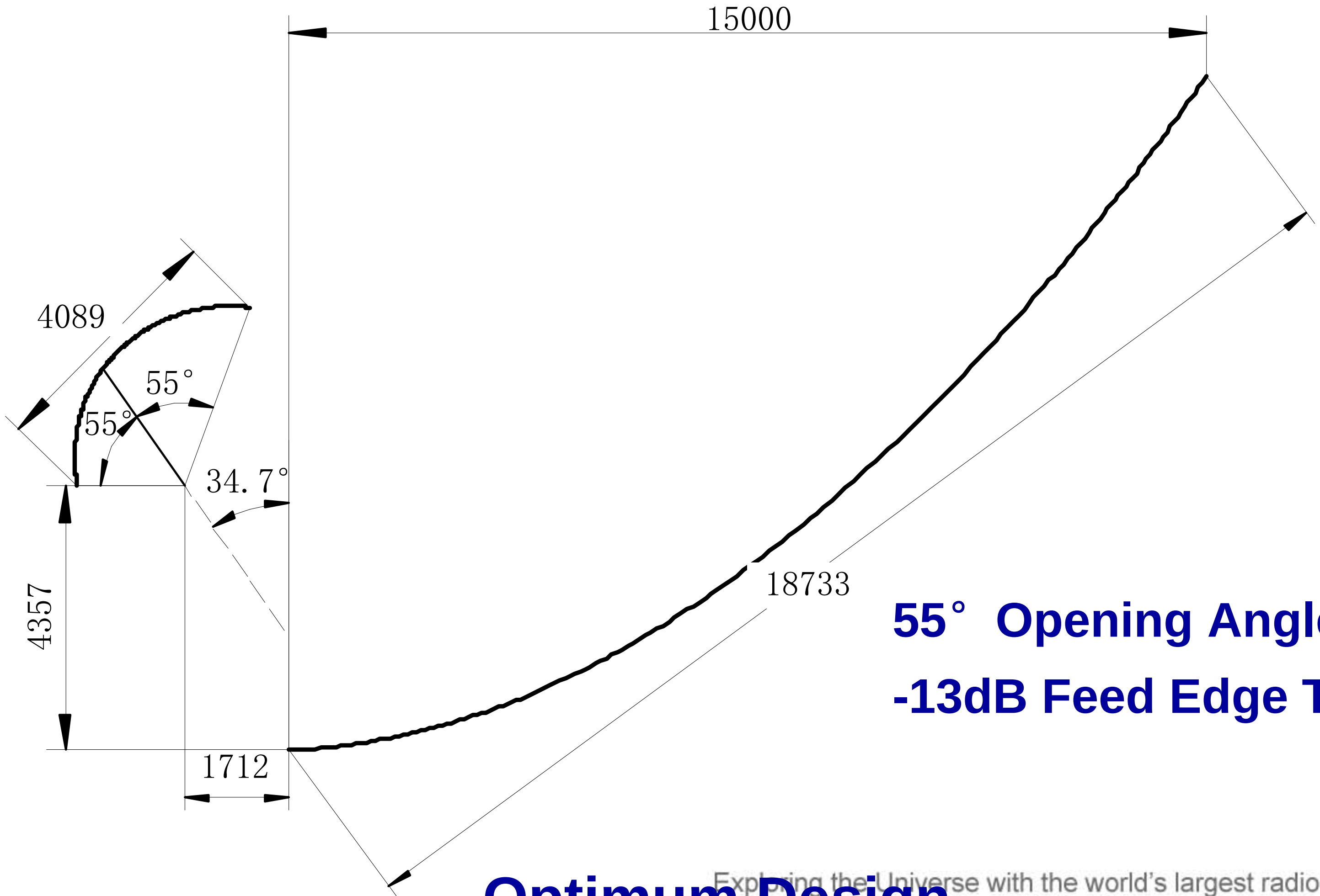


Radiation Patterns of Feed2 at 1.5, 6 and 10GHz

4. Concept Design

(1) Microwave Optical Design

➔ Main and Sub Reflector Curve Design



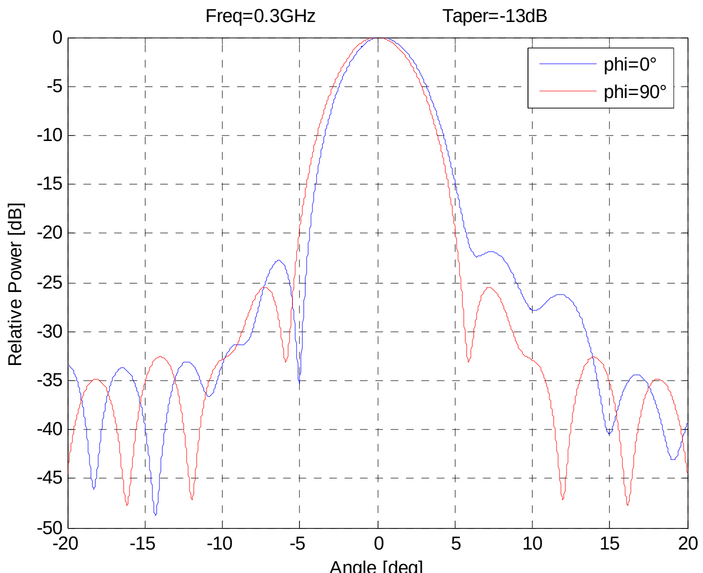
55° Opening Angle

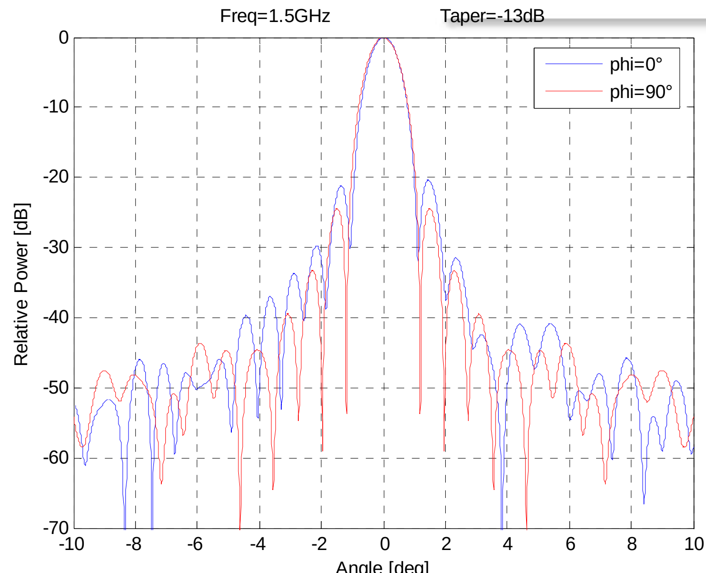
-13dB Feed Edge Taper

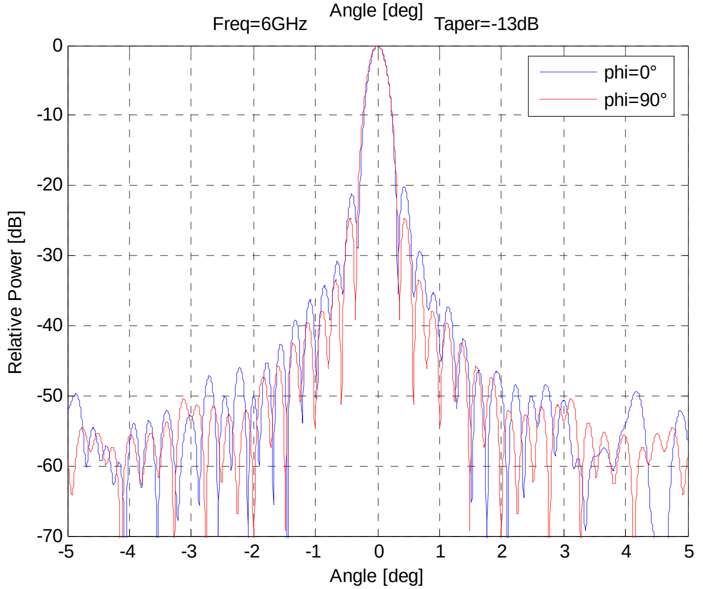
Optimum Design

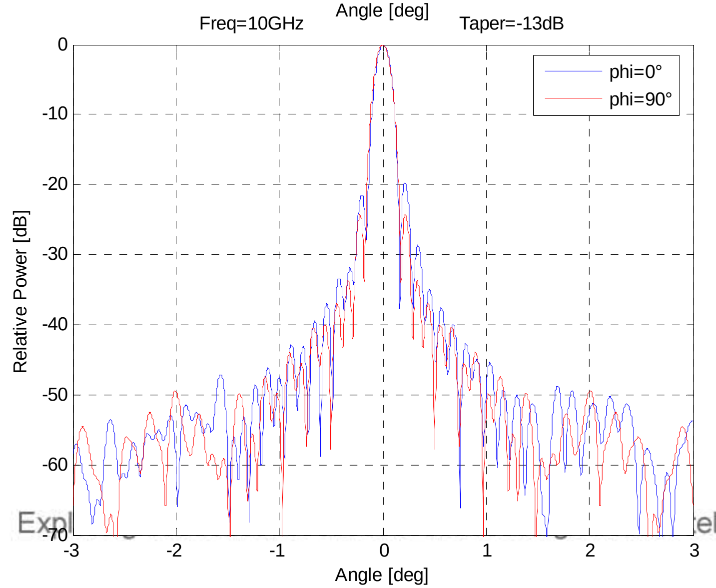
4. Concept Design

(1) Microwave Optical Design





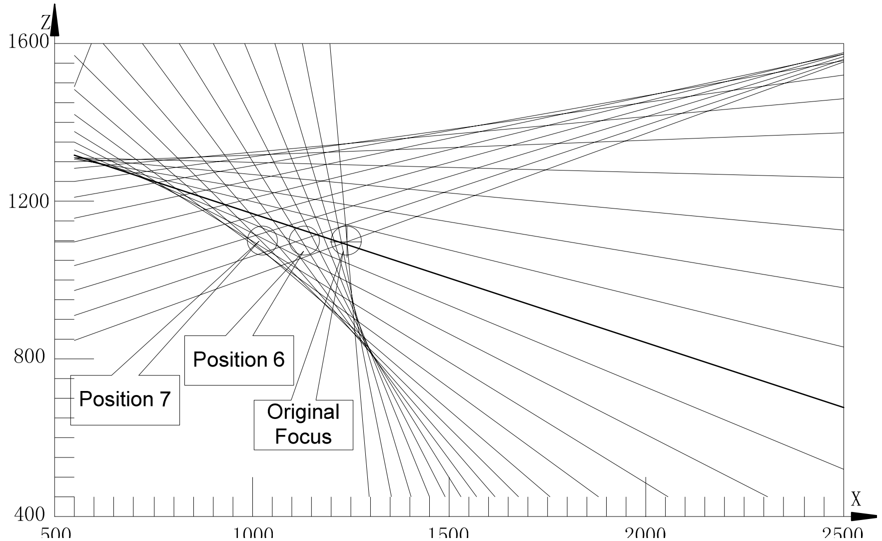


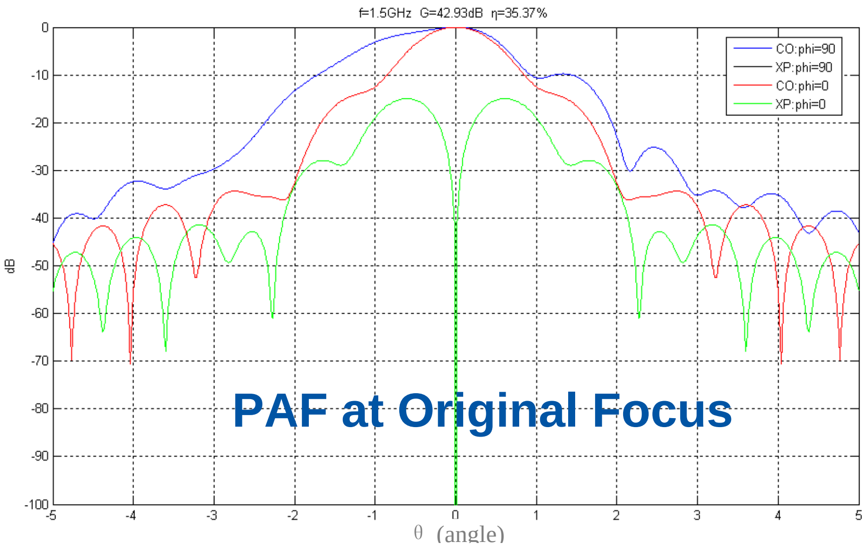


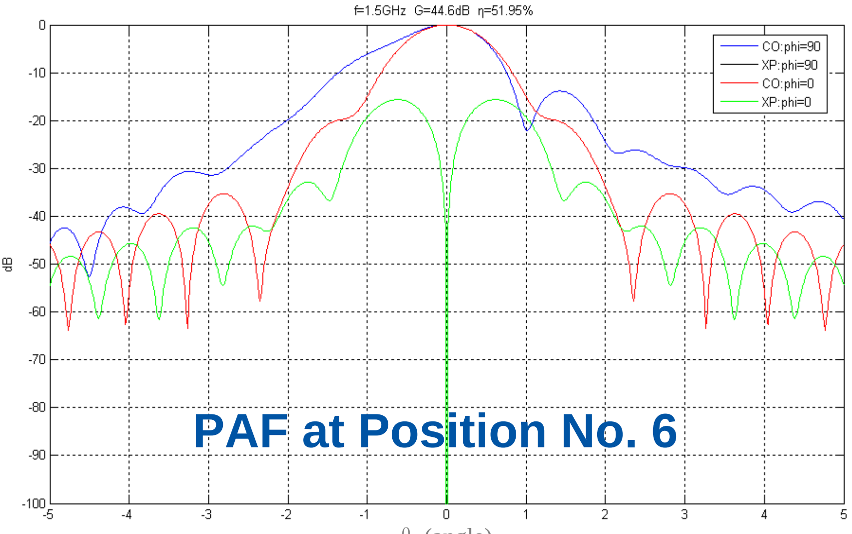
4. Concept Design

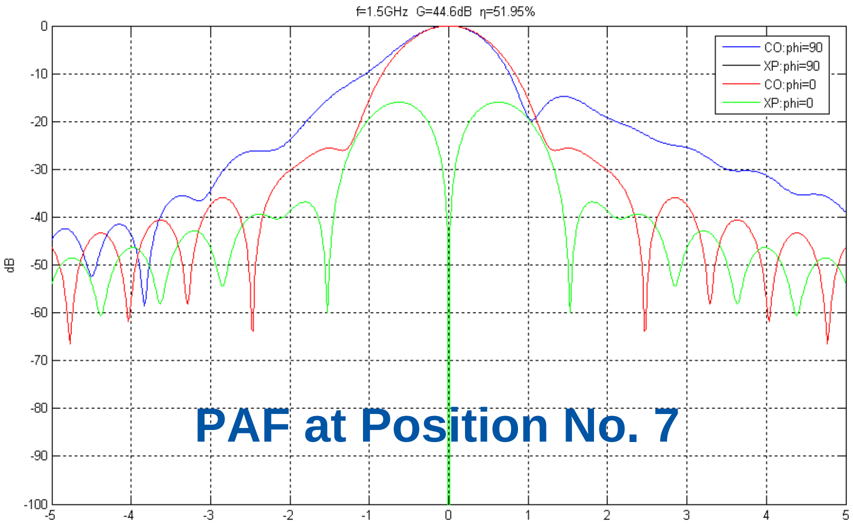
(1) Microwave Optical Design

Radiation Performance of Antenna with PAF at Prime Focus



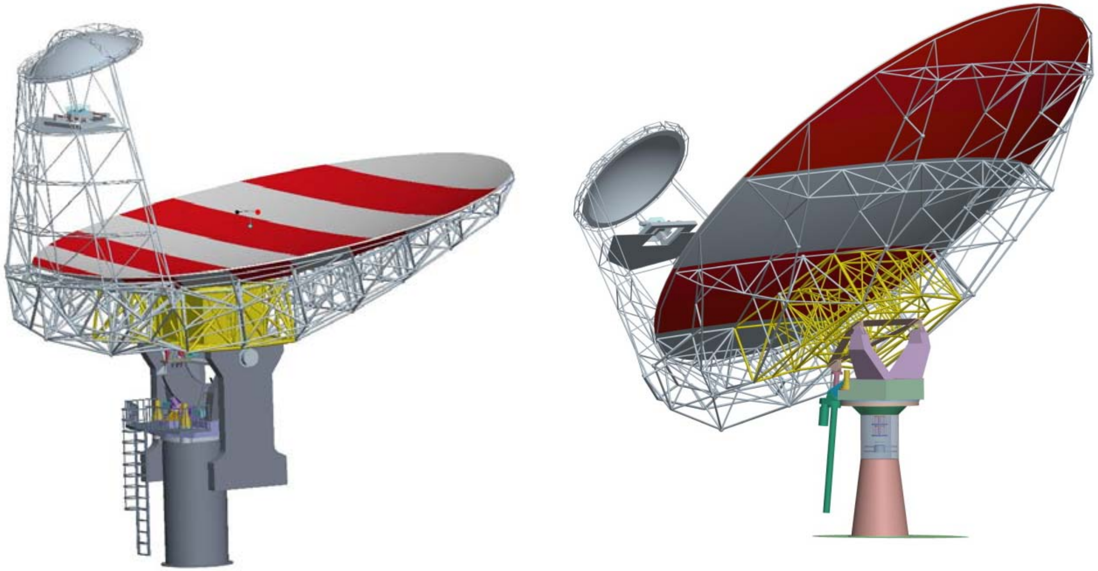




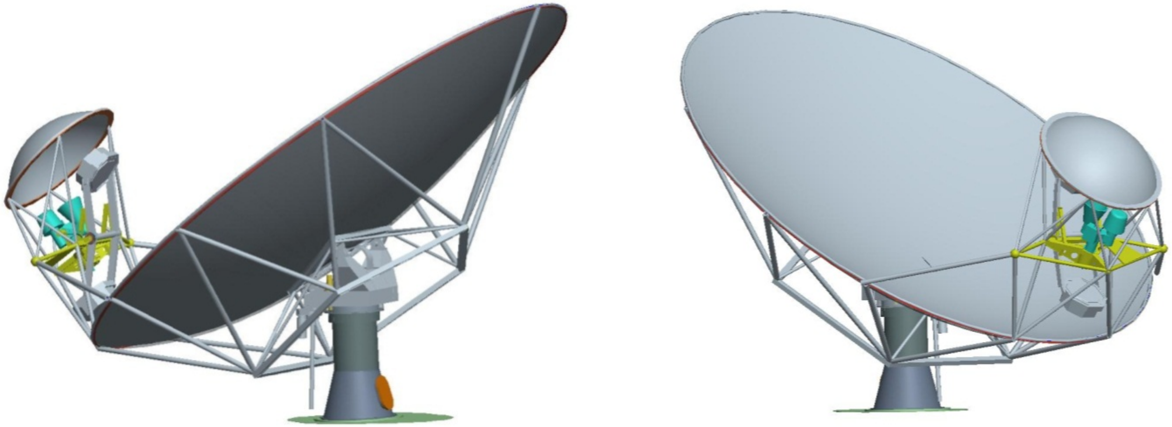


4. Concept Design
(2) Structure Design

Initial Design



Current Design



- Single Panel
- Simple Structure
- Light Weight
- Low Cost
- Fast Installation

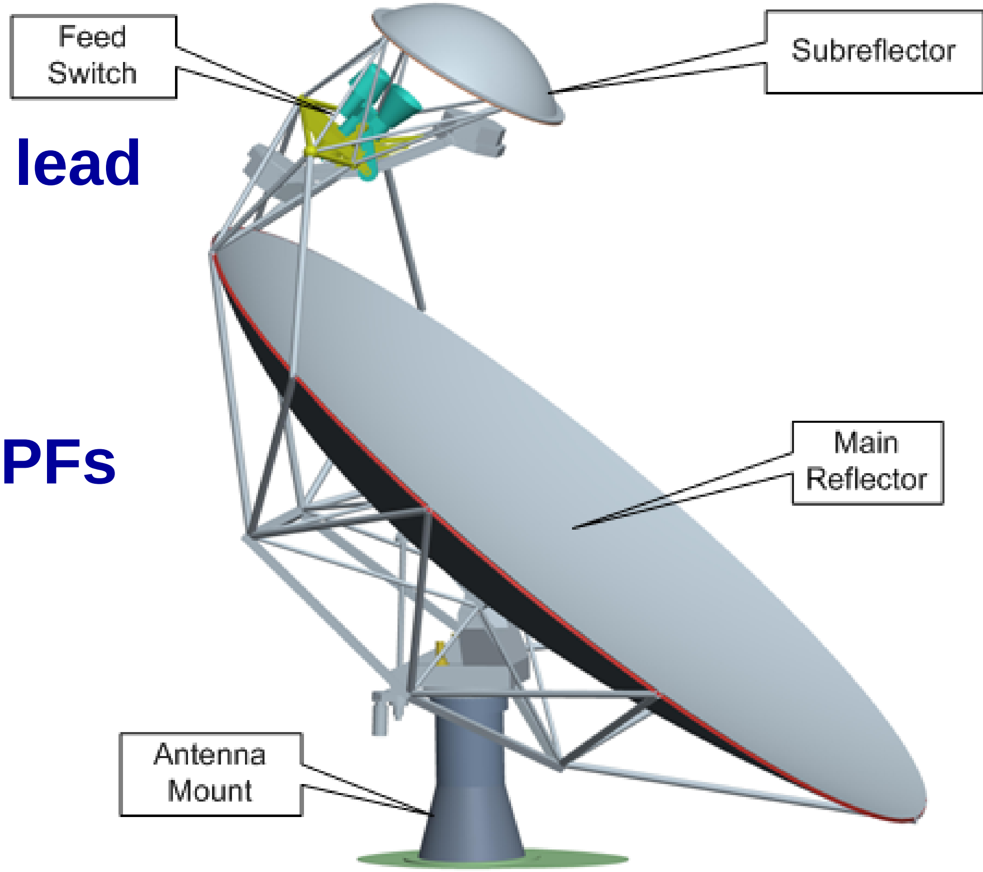
4. Concept Design

(2) Structure Design

- Reflector Design
- Mount Design
- Structural Mechanics Analysis

4. Concept Design
(2) Structure Design

- Single integrated main reflector
- Minimal spar structure
- Turning head design with a lead screw elevation actuator
- Support and interchange mechanism for a PAF and 3 SPFs or 2 WBFs.

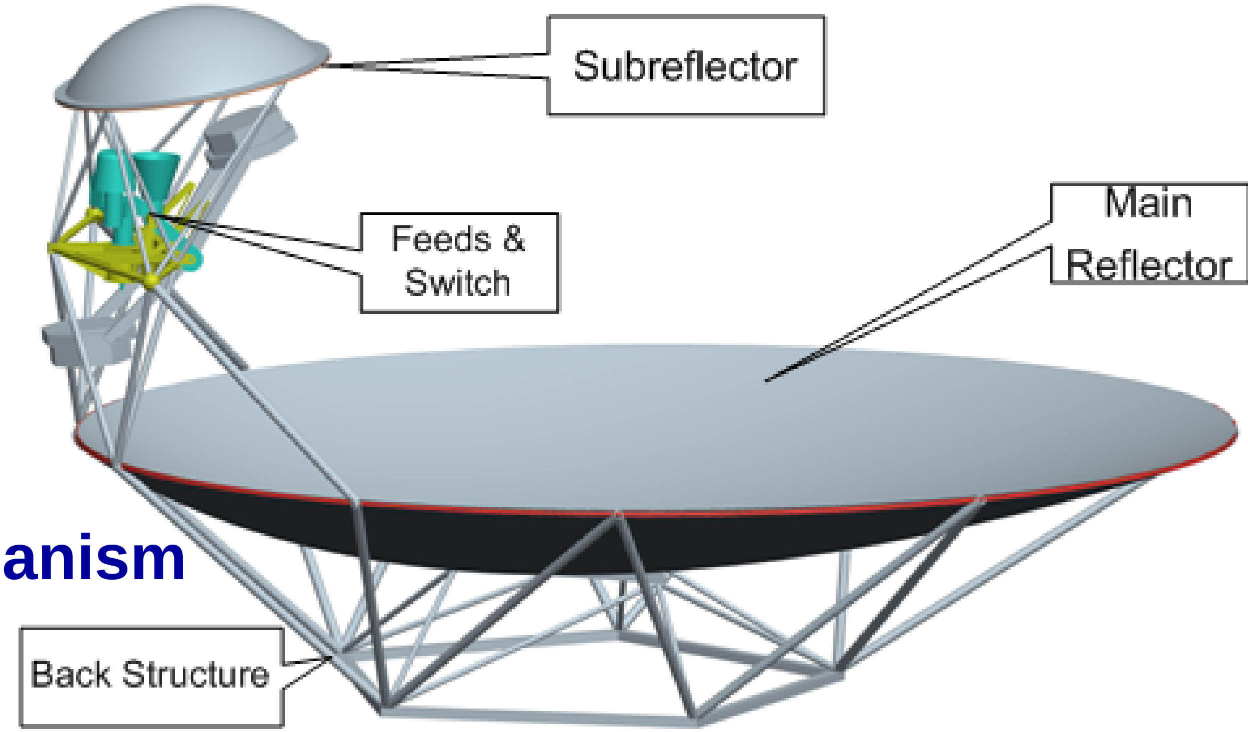


4. Concept Design

(2) Structure Design

➔ Reflector Design

- Main reflector
- Back structure
- Subreflector
- Feed switch mechanism



4. Concept Design

(2) Structure Design

➔ Reflector Design — Main reflector

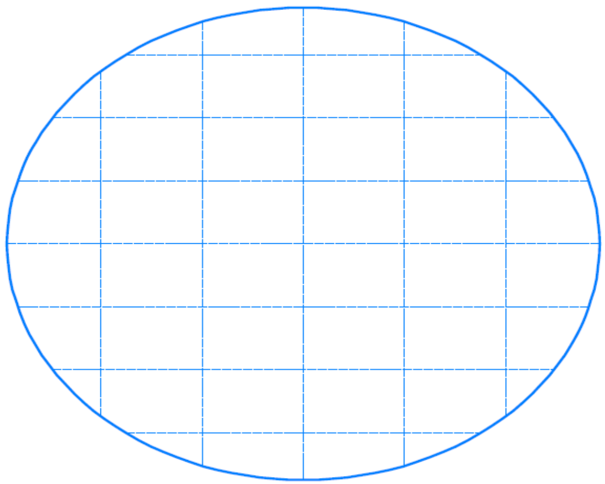
✓ Design 1: Aluminum sandwich structure

Single aluminium panel

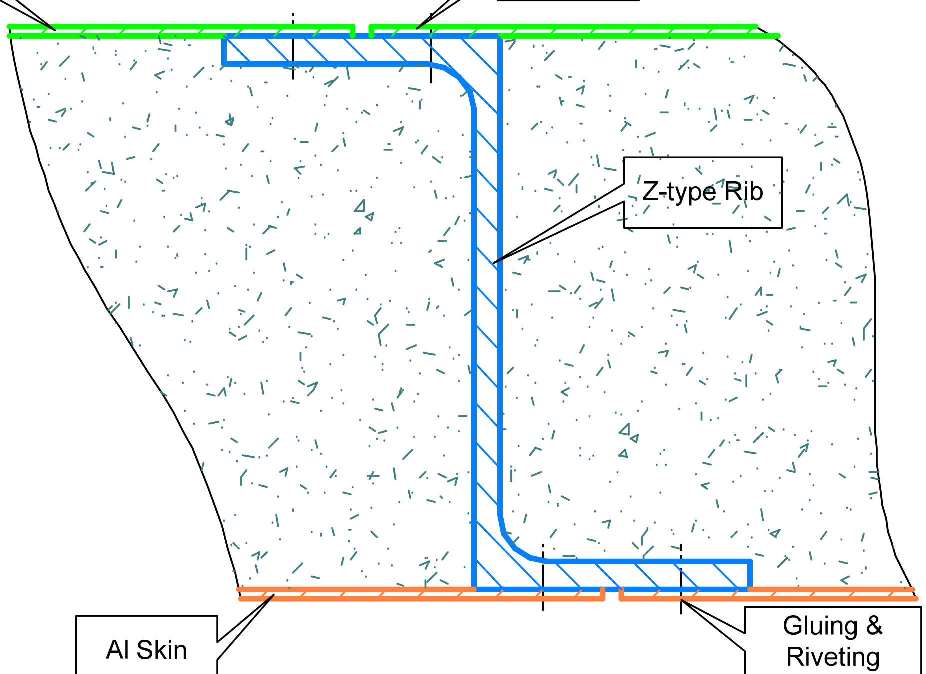
Skins: 2mm (upper)/1mm (lower) in thickness, 2m in width

Skin and ribs are glued through negative pressure method on mould

Surface accuracy σ ≤0.8mm



Rib Configuration



4. Concept Design

(2) Structure Design

➔ Reflector Design — Main reflector

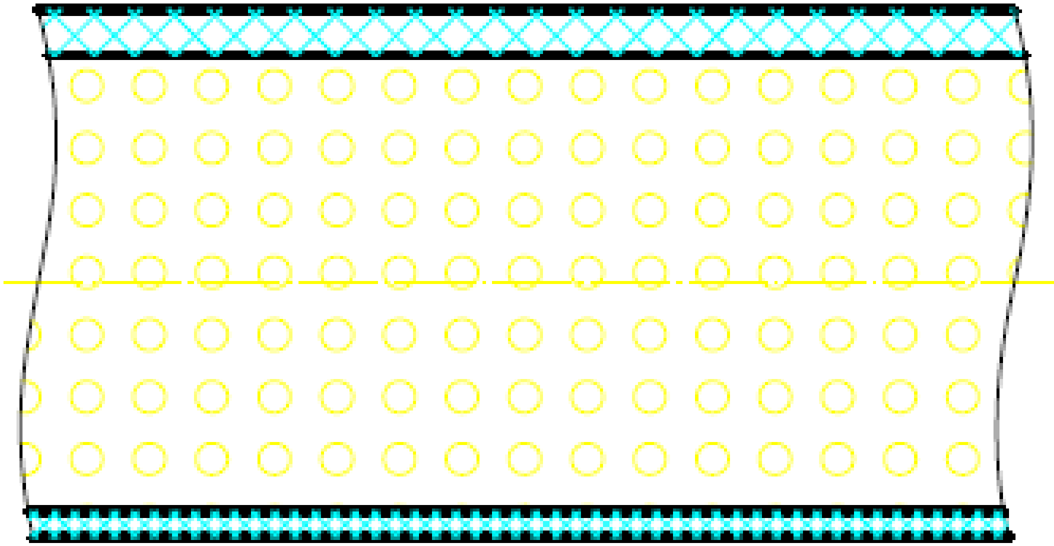
✓ Design 2: Carbon fibre sandwich structure

Single carbon fibre panel

Carbon fibre skins: 1.5mm (top)/1mm (bottom) in thickness

Polyurethane foam: in the middle

Surface accuracy $\sigma \leqslant 0.8$mm



4. Concept Design

(2) Structure Design

➔ Reflector Design — Back structure

The backup structure is based on US TDP design with some modifications (some details see to DVAC-1).

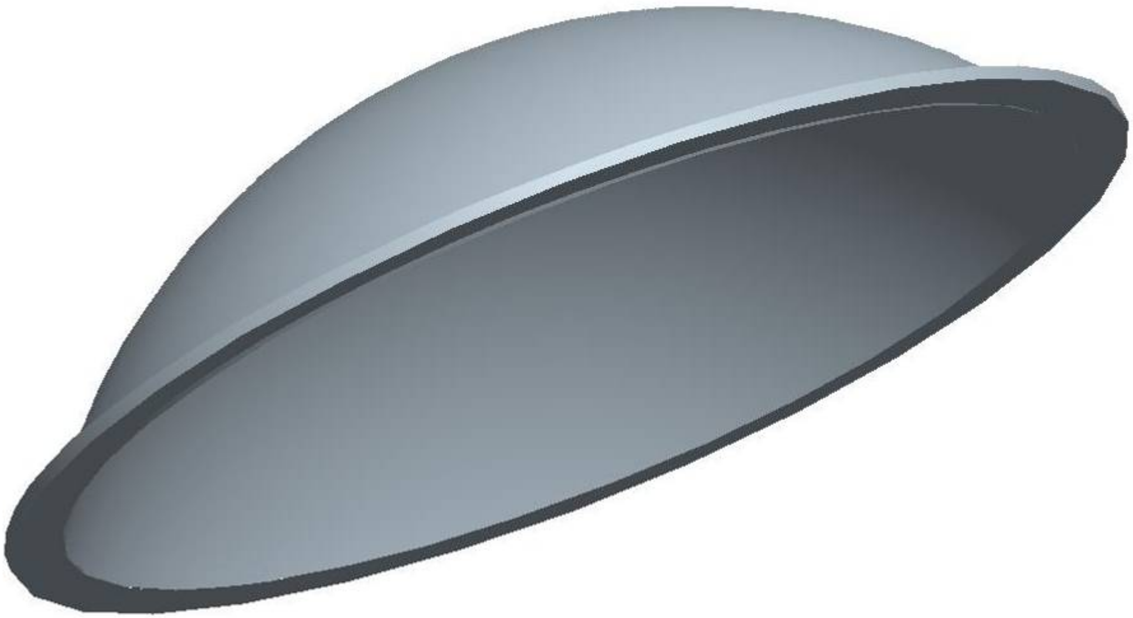
escope

4. Concept Design
(2) Structure Design

➔ Reflector Design — Subreflector

Magnesium material, 30% lighter than aluminum alloy.

Surface accuracy σ ≤0.25mm

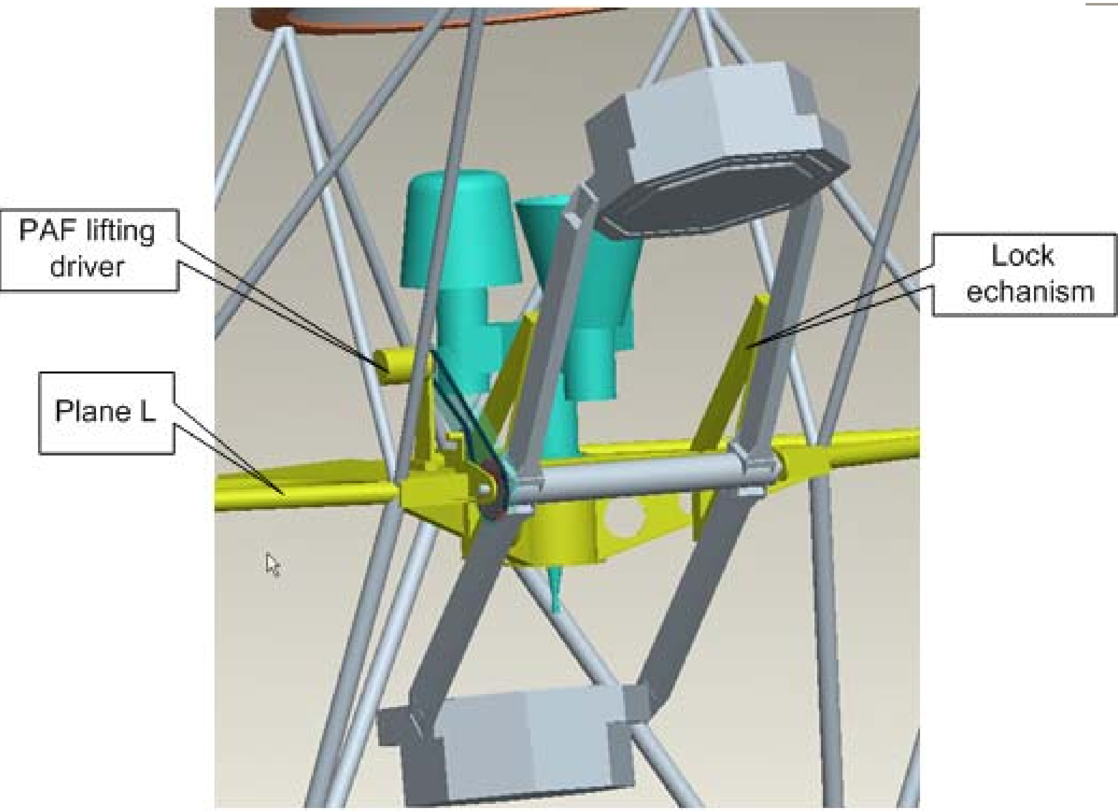


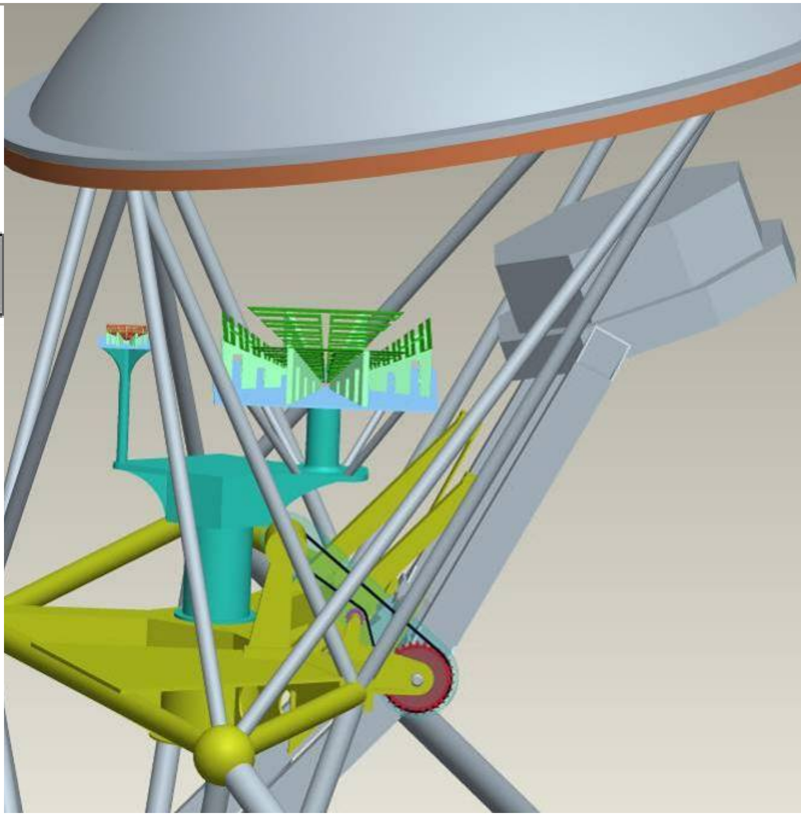
rgest radio telescope

4. Concept Design

(2) Structure Design

➔ Reflector Design — Feed Switch Mechanism

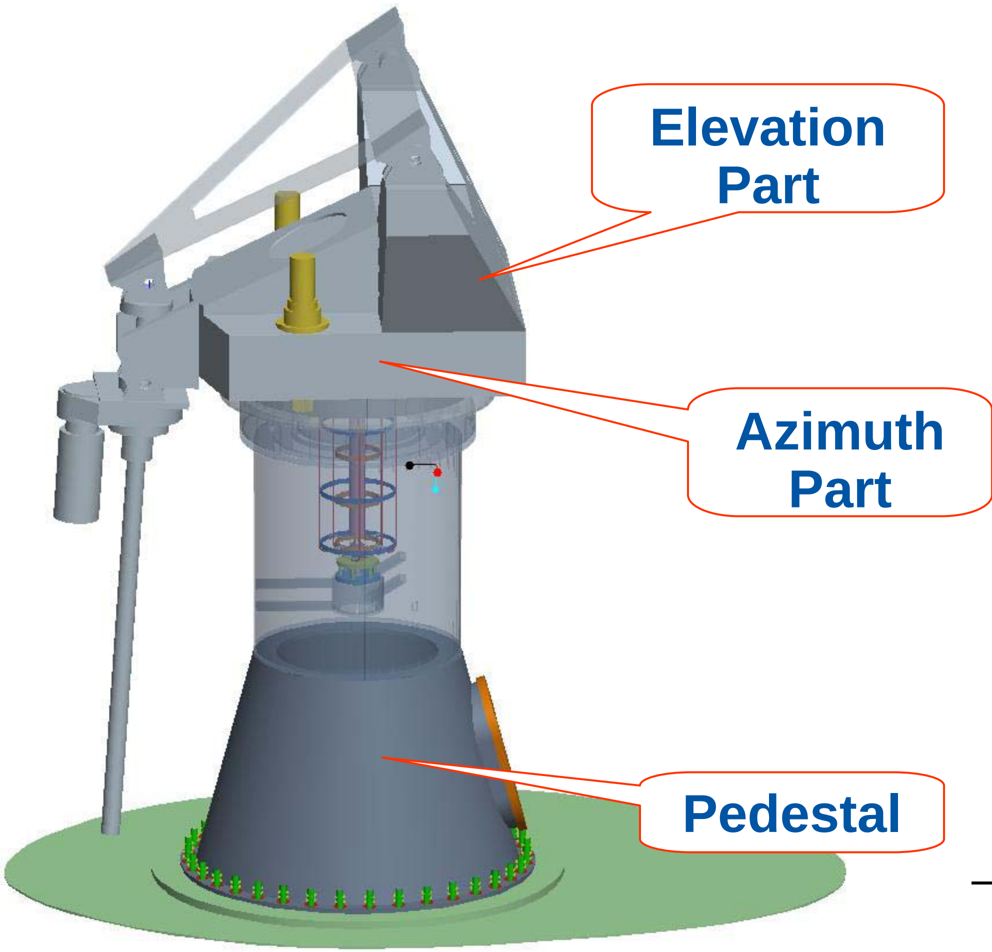


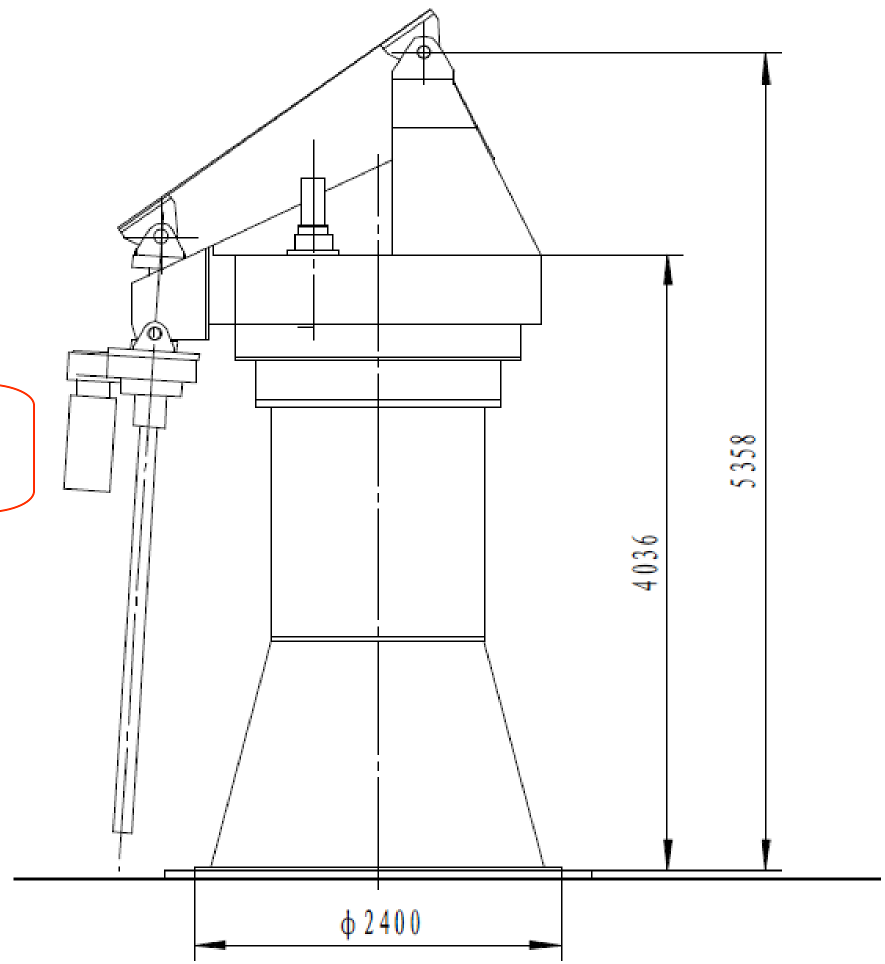


4. Concept Design
(2) Structure Design

SKA SQUARE KILOMETRE ARRAY

➔ Mount Design



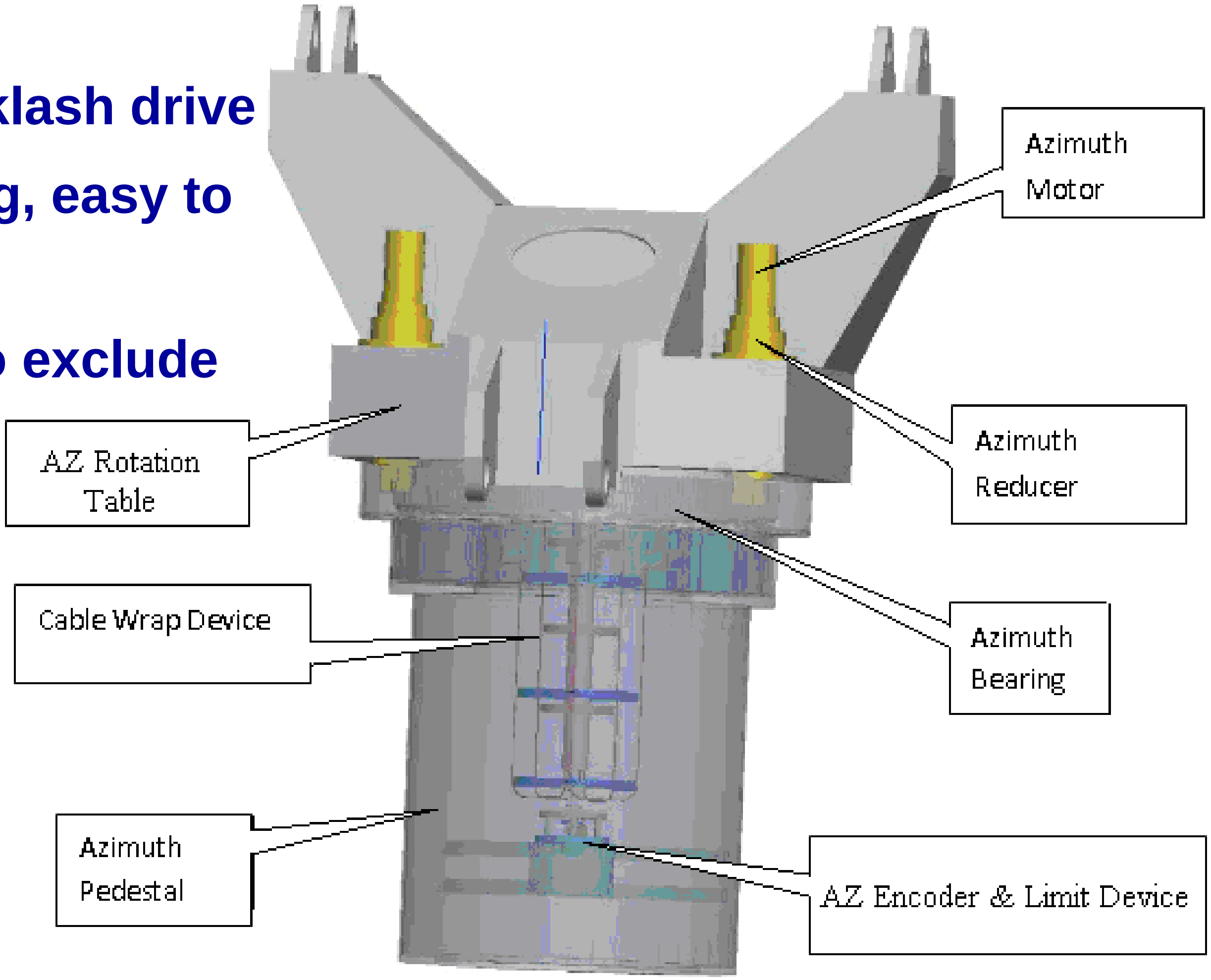


4. Concept Design

(2) Structure Design

➔ Mount Design — Azimuth part

- Dual-motor anti-backlash drive
- External gear bearing, easy to maintain
- Seal cover is used to exclude dust and sand

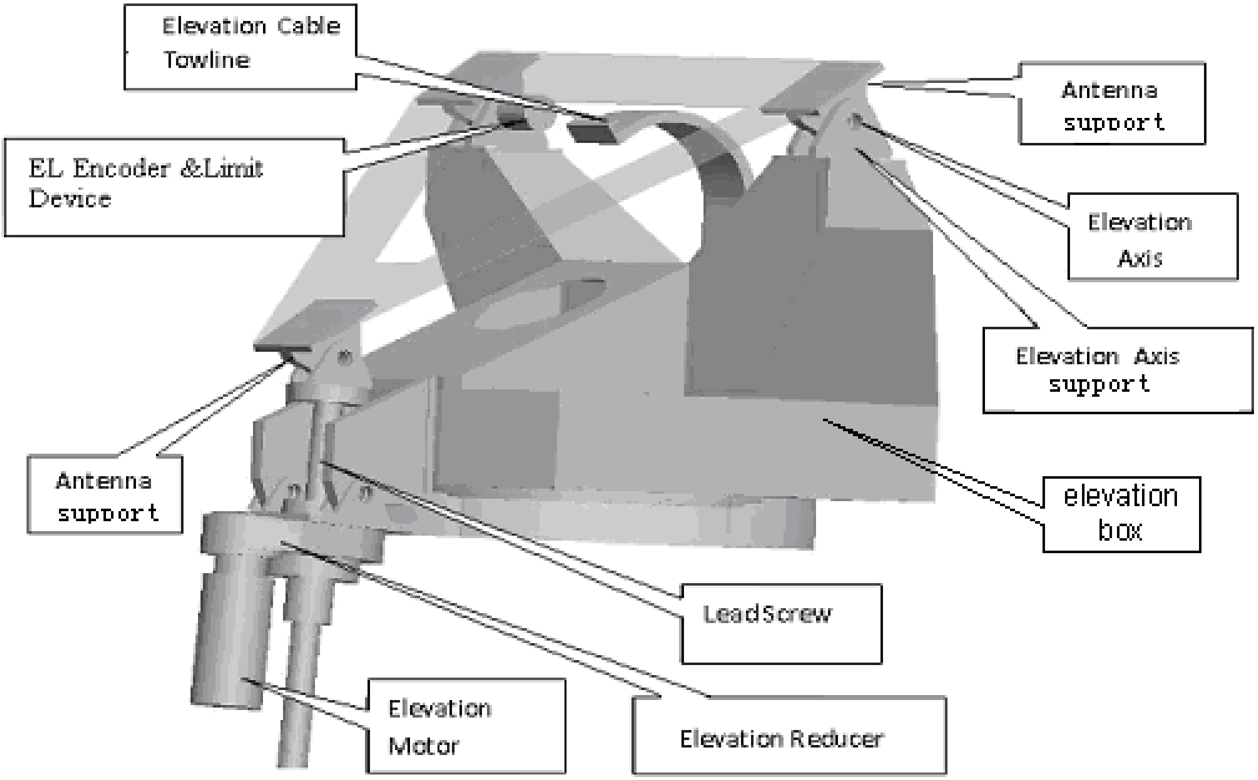


4. Concept Design

(2) Structure Design

→ Mount Design — Elevation part

A planetary reducer with a ball screw drive is used for the elevation part without a counterweight.



telescope

4. Concept Design

(2) Structure Design

➔ Mount Design

- A flexible-axis drive technique is adopted for Az and El encoder mechanism.
- A double-layer ring structure is used for AZ cable wrap.
- A modular design for all rotating parts.
- A Line-Replaceable Unit (LRU) design is applied to reducer, motor, encoder and limit device, azimuth cable wrap, and elevation lock device. Not only for ease of replacement and maintenance, but also suitable for batch production.

4. Concept Design

(2) Structure Design

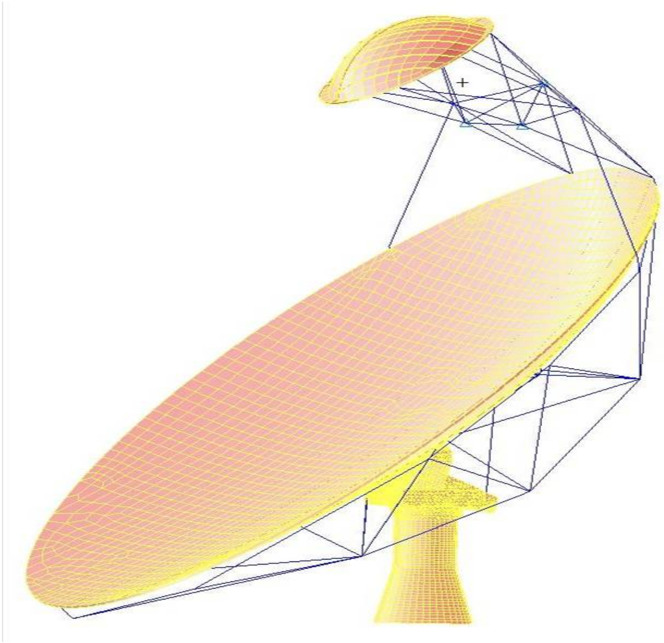
Weight of Dish

ITEM	WEIGHT (aluminum, Kg)	WEIGHT (carbon fibre, Kg)
Reflector	7250	7050
Mount	11250	11250
Total weight	18500	18300

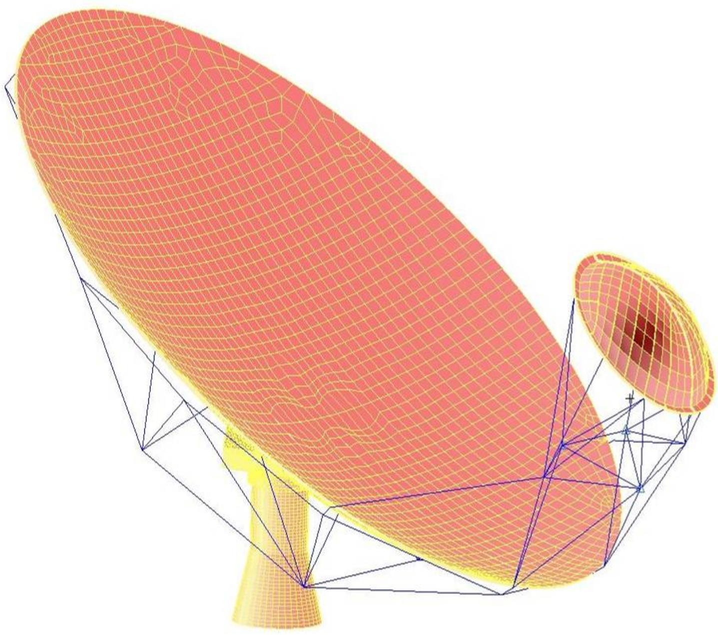
4. Concept Design
(2) Structure Design

➔ Structural Mechanics Analysis

- Finite Element Model



EL=10°



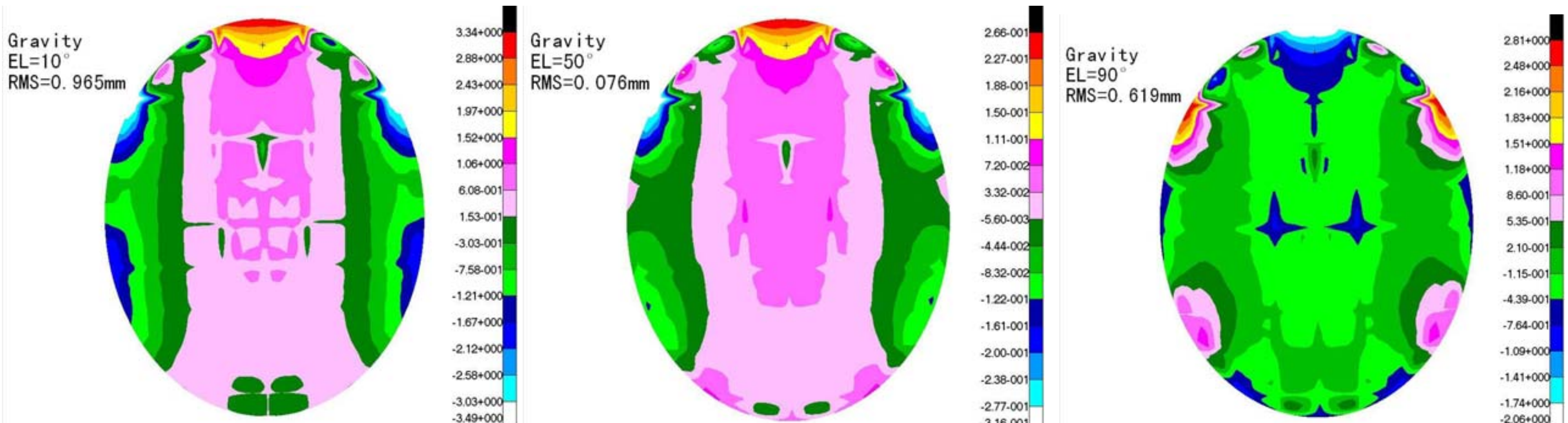
EL=90°

4. Concept Design

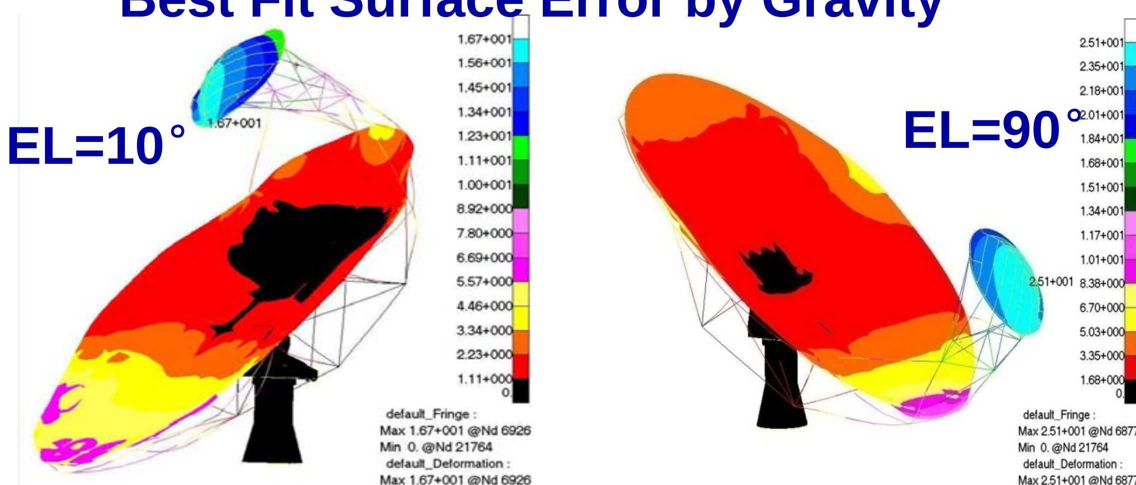
(2) Structure Design

➔ Structural Mechanics Analysis

➢ Reflector Surface Deformation by Gravity



Best Fit Surface Error by Gravity



argest radio telescope

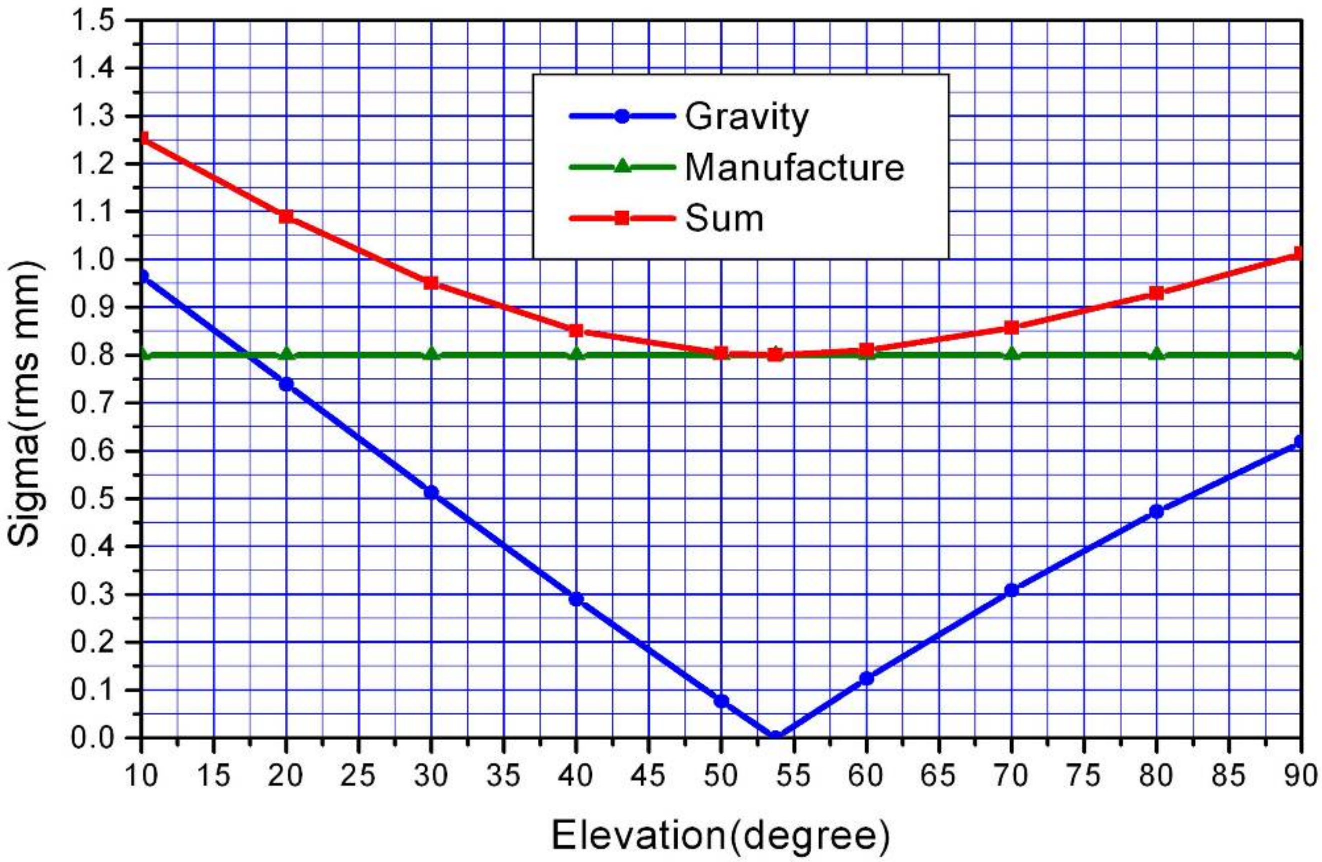
4. Concept Design

(2) Structure Design

➔ Structural Mechanics Analysis

➢ Reflector Surface Deformation by Gravity

Less than 1.1 mm from 15 to 90 degree

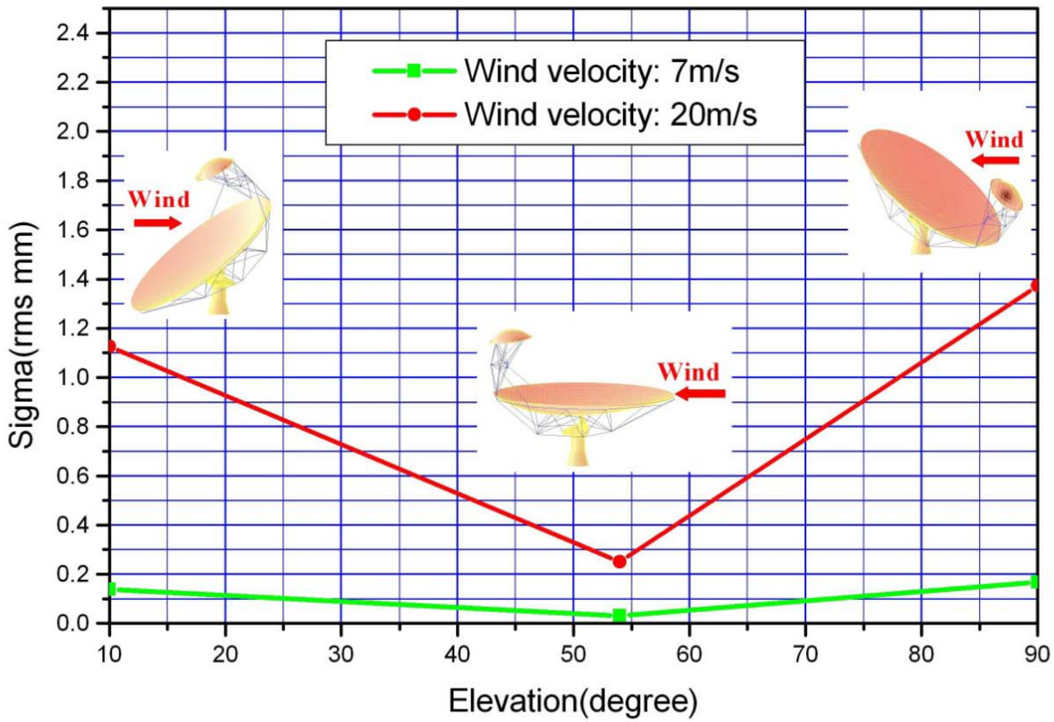


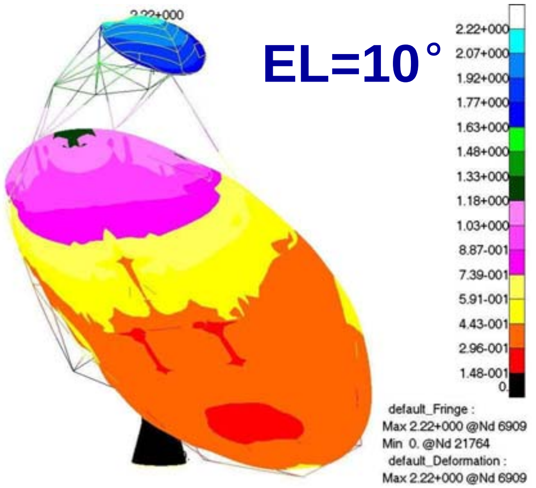
4. Concept Design

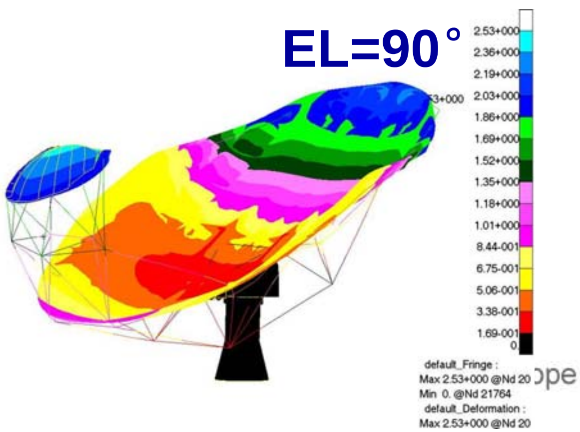
(2) Structure Design

➔ Structural Mechanics Analysis

➢ Reflector Surface Deformation by Wind







4. Concept Design

(2) Structure Design

Structural Mechanics Analysis

- Reflector Surface Deformation by Temperature

Temperature Difference	2° C	5° C	7° C
Surface Error (r.m.s. mm)	0.081	0.203	0.284

4. Concept Design

(2) Structure Design

➔ Structural Mechanics Analysis

➢ Strength Analysis

Elevation (degree)	Wind speed (m/s)	Gravity	Max. stress (MPa)	Safety coefficient
10°	20	√	77.4	4.5
54°	20	√	80.3	4.3
90°	20	√	150	2.3
54°	45	√	150	2.3

4. Concept Design

(2) Structure Design

Structural Mechanics Analysis

- Antenna Modal Analysis

Order	1	2	3	4	5
Resonant frequency (Hz)	2.42	3.25	4.61	4. 82	4.89

4. Concept Design

(2) Structure Design

➔ Structural Mechanics Analysis

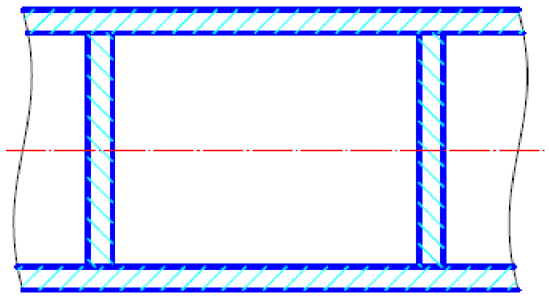
- **Conclusion**

The analysis results show that the structural performance of antenna can meet the SKA requirements

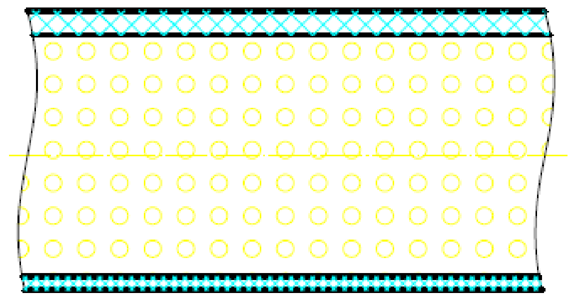
4. Concept Design

(2) Structure Design

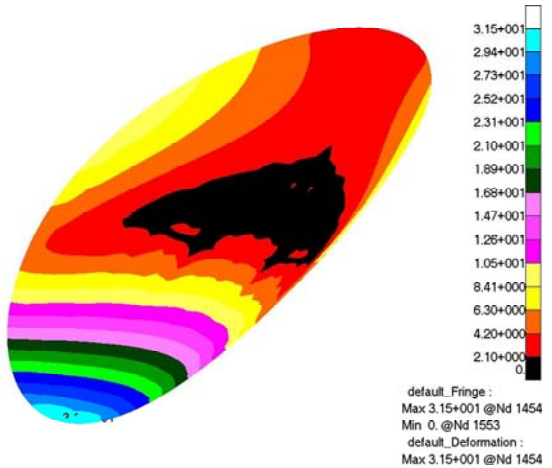
➔ Investigation of Main Reflector Types



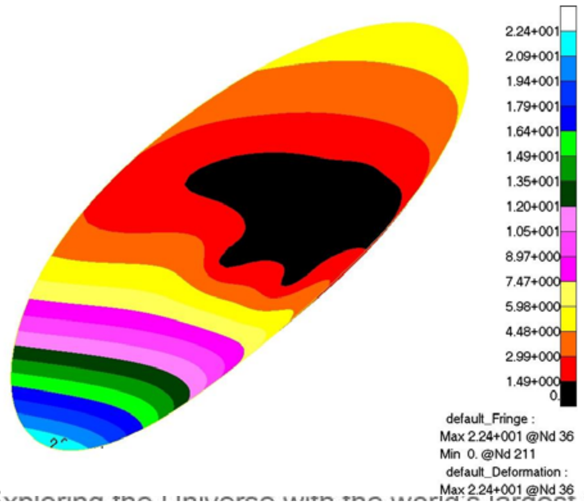
Aluminum Sandwich Structure (83mm thick, 2mm/80mm/1mm)



Carbon Fibre Sandwich Structure (82.5mm thick, 1.5mm/80mm/1mm)



Deformation of Aluminum Structure



Deformation of Carbon Fibre Structure

4. Concept Design

(2) Structure Design

Investigation of Main Reflector Types

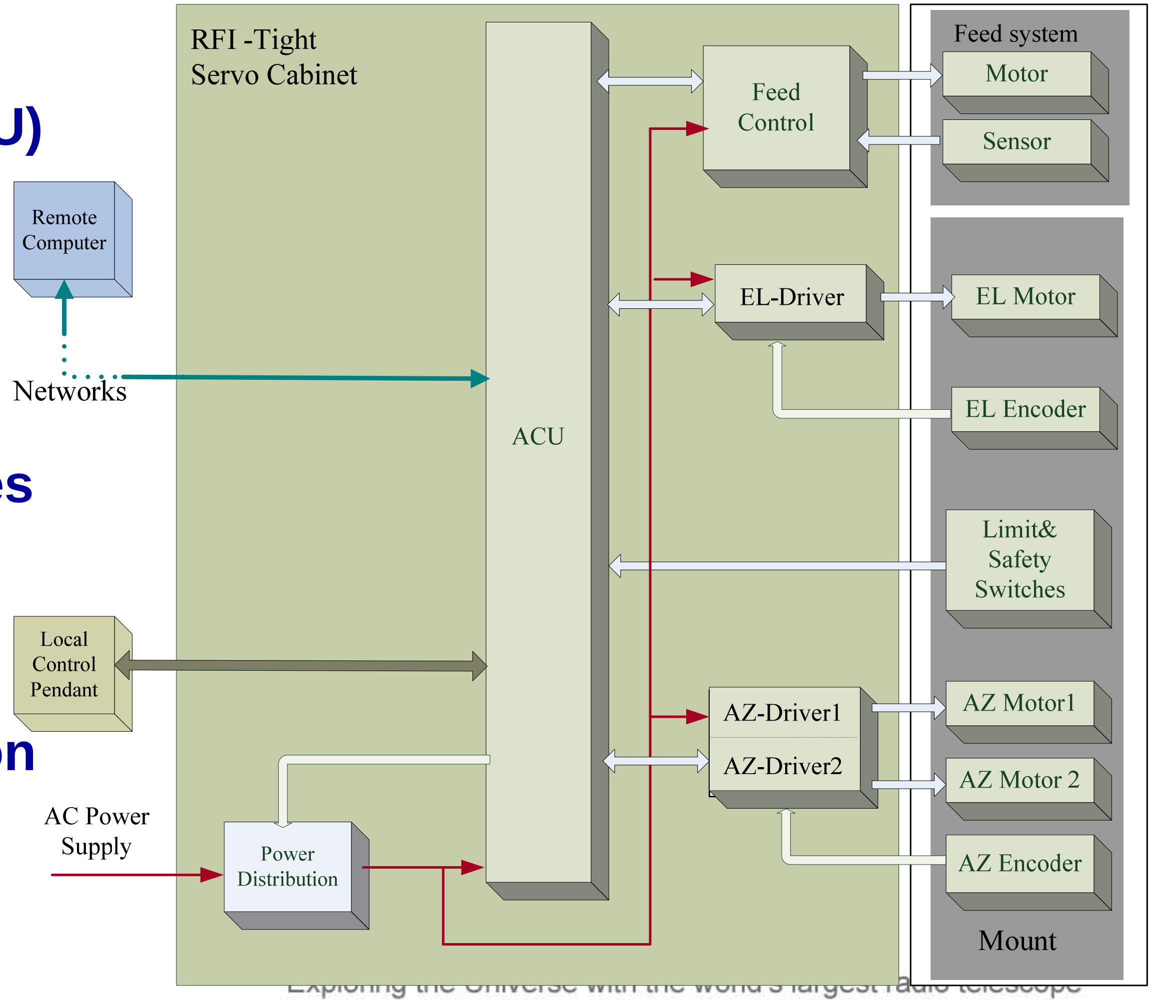
Type	Name	Total thickness (mm)	Weight (t)	Maximum Deformation (mm)	Surface Error (rms， mm)
1	Aluminum sandwich structure	83	2.1	31.5	3.877
2	Carbon fibre sandwich structure	82.5	1.9	22.4	1.629

Surface accuracy of type 2 is better than that of type 1

4. Concept Design

(3) Servo Control Design

- Antenna control unit (ACU)
- Feed Control
- Antenna drivers
- Motors
- Power distribution devices
- Encoders
- Local control pendant
- Limit and safety protection device



4. Concept Design

(3) Servo Control Design

Main features of control system

- Mature Product
- State-of-the-art components
- Fully digital control system
- Very high reliability
- Modular design, easy for maintenance
- Brushless motors, no maintenance
- Spare part available

4. Concept Design

(3) Servo Control Design

- **STANDBY**

  Power-on default operation mode or return-on-fault mode

- **PRESET**

  Moving to predefined position

- **RATE**

  Moving at user-defined constant velocity

- **PROGRAM TRACK**

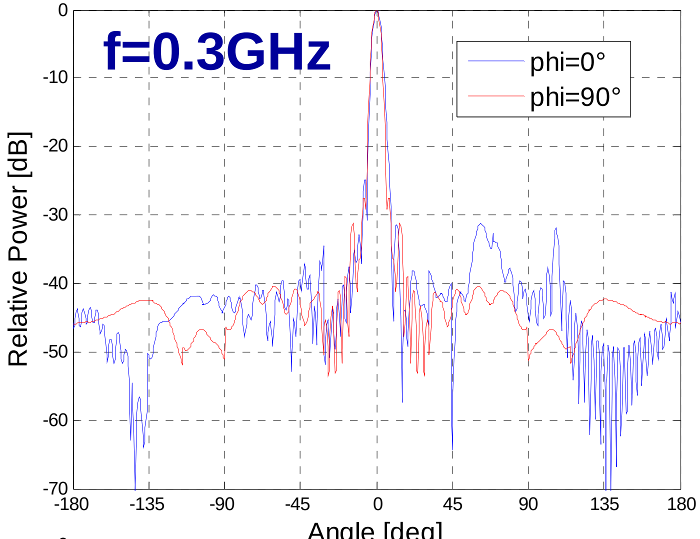
  Tracking of an object along a pre-defined path

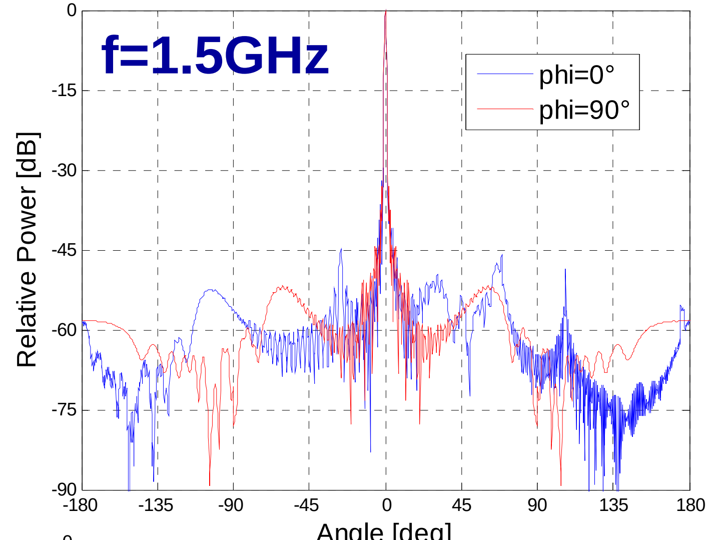
- **STOW**

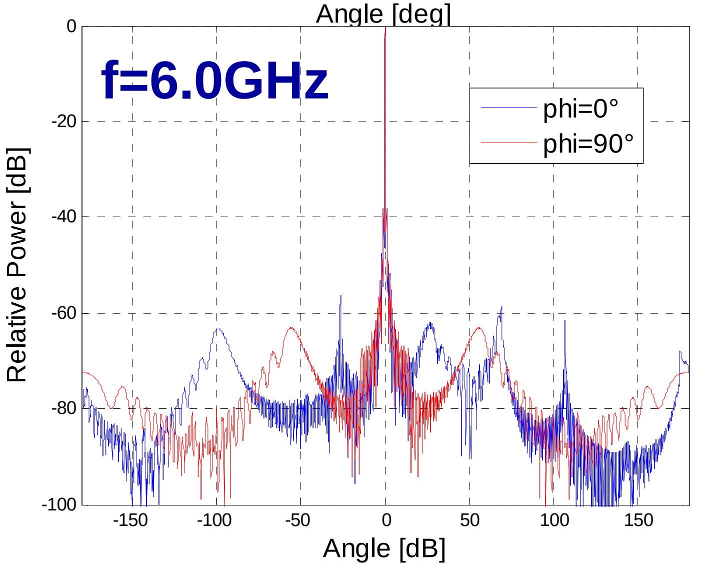
  Automatically rotating to preset stow position and locking stow pin

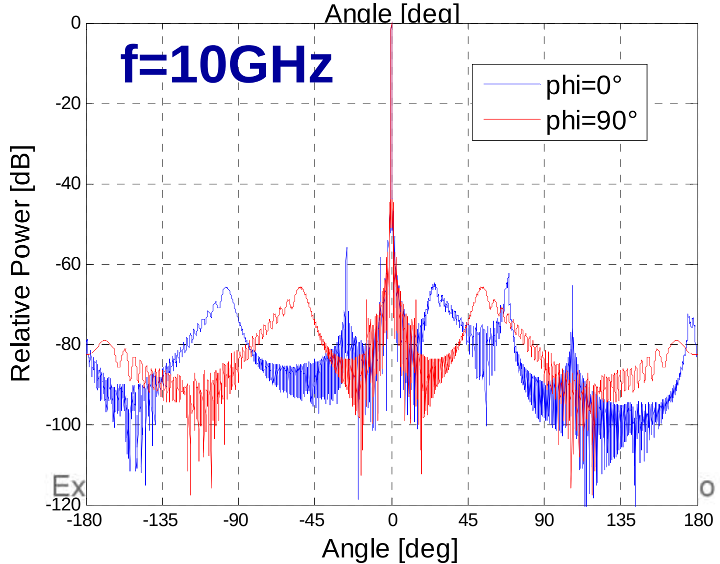
5. Main Specification Budget

(1) Full Radiation Pattern Calculation









5. Main Specification Budget
(1) Full Radiation Pattern Calculation

Frequency (GHz)	First sidelobe (dB)	
	0° plane	90° plane
0.3	(-22.77, -21.87)	(-25.51, -25.51)
1.5	(-21.22, -20.38)	(-24.37, -24.37)
6	(-21.21, -20.13)	(-24.64, -24.64)
10	(-21.35, -19.73)	(-24.24, -24.24)

First sidelobe: less than -19.73dB

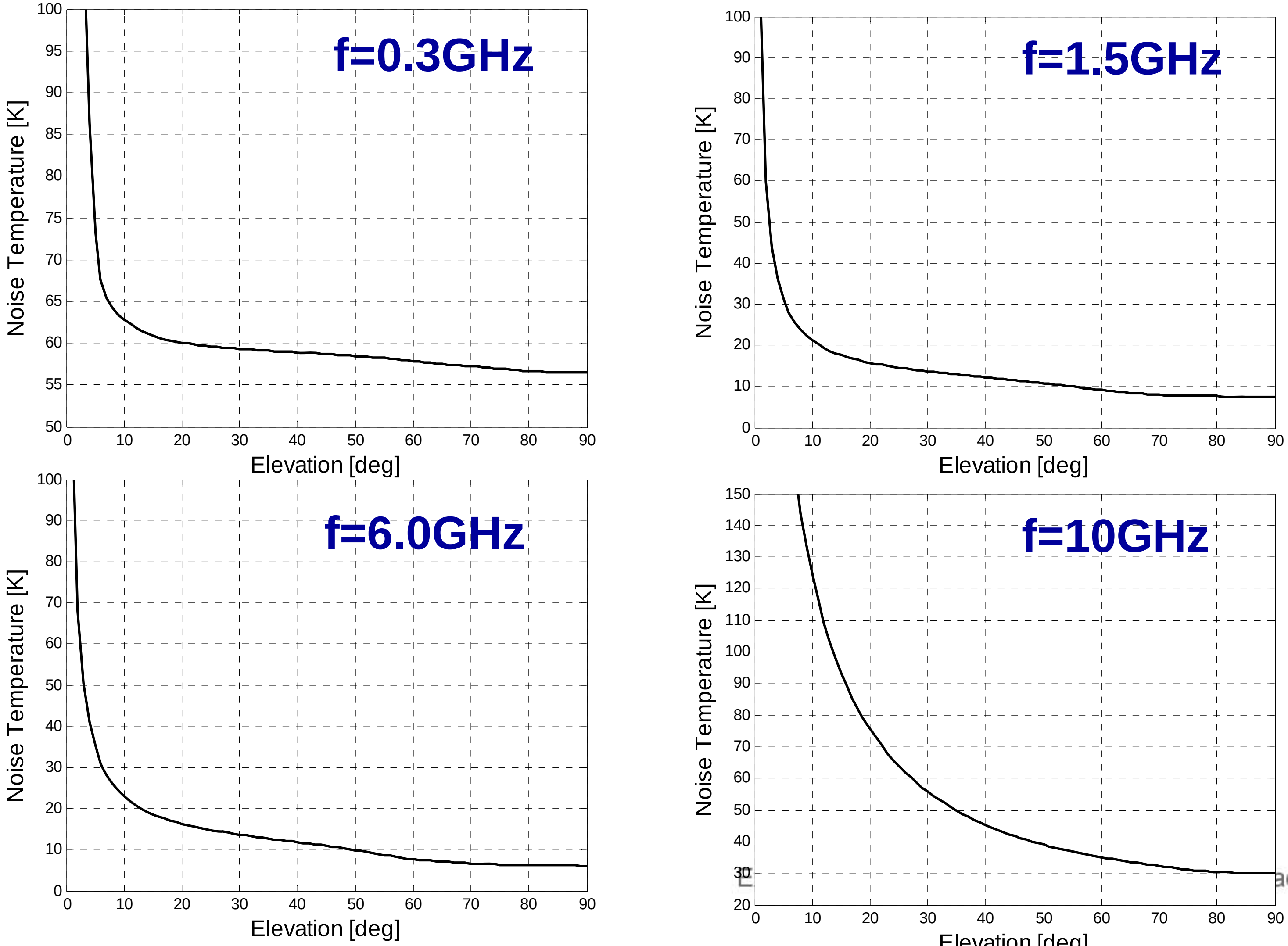
5. Main Specification Budget

(2) Antenna Aperture Efficiency

Frequency (GHz)	$\eta_1 \ \eta_2$	η_3	η_4	η_5	η (%)
0.3	0.71	1	0.95	0.98	66
0.9	0.76	1	0.95	0.98	71
1.5(feed 1)	0.78	0.99	0.95	0.98	72
1.5(feed 2)	0.77	0.99	0.95	0.98	71
6	0.81	0.91	0.95	0.98	69
10	0.81	0.78	0.95	0.98	59

Antenna aperture efficiency: more than 59%

5. Main Specification Budget
(3) Noise temperature



5. Main Specification Budget

(4) Pointing accuracy

Error source (r.m.s.)	Error (arcsec)	Residual error (arcsec)	Modification method
Verticality of the azimuth axis	10	3	Pointing model
Azimuth-Elevation non-orthogonality	3	3	-
Azimuth bearing run-out	4	4	-
Adjust error of sub-reflector and feed	3	3	-
Gravity deformation	11	2	Lookup table
Thermal deformation	<1	<1	
Wind deformation	-	-	
Servo error	5	5	
Uncertain error	3	3	
Total error (RMS)	8.7 arcsec (at night and windless)		

DVAC CONCEPT DESCRIPTION:

PRIME FOCUS DISH — DVAC-2

6. DVAC-2 Specifications

Antenna Type	Prime Focus Antenna, Diameter 15m
Focal length / Diameter ratio (f/D)	0.4
Mount Type	AZ-EL-POL mount（AZ, POL：Gear，EL: Screw)
Frequency Band	0.3GHz ~ 10GHz
Frequency Band Switch Manner	Switching Feeds within 30s
Surface Accuracy of Main Reflector	≤1.1 mm RMS (at night, under low wind) TBC(at daytime, with wind)
Pointing Accuracy	≤10 arcsec RMS (at night and no wind) TBC (at daytime, with wind)
Antenna Aperture Efficiency (%)	≥ 50%
First Sidelobe Level	≤-20dB

6. DVAC-2 Specifications

Polarization	Dual-LP/Dual-CP
Travel Range	AZ：±270°，EL：15° ~ 85°
Slew Rates (Max)	AZ：3° /s, El：1° /s
Acceleration (Max)	AZ：3° /s², El：1° /s²
Wind Velocity	Drive to stow :70 km/h Survival: 160 km/h (at El=90°)
Design Lifetime	≥ 30 years

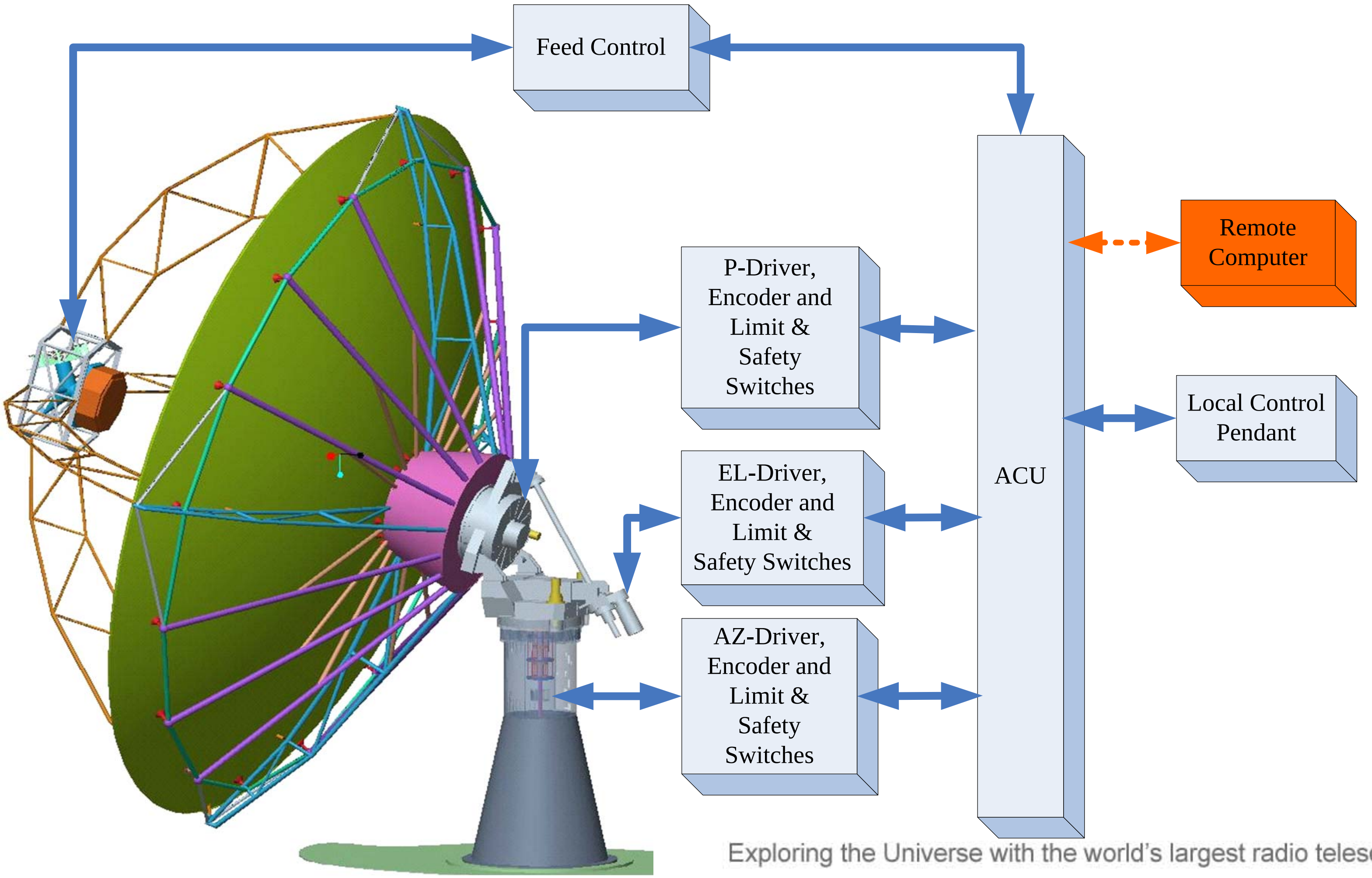
7. DVAC-2 Concept Design

Main Attractions of DVAC-2 Design

- Wide Band Feed (WBF)
- Integrated Modular Design
- Integrated Main Reflector Surface (Single Panel)
- Sealed and Lubricated Driving Devices
- Mature Technology

7. DVAC-2 Concept Design

Design and Manufacture



7. DVAC-2 Concept Design

(1) Microwave Optical Design

(2) Structure Design

(3) Servo Control Design

7. DVAC-2 Concept Design
(1) Microwave Optical Design

- ➔ Feed Design
- ➔ Main Curve Design

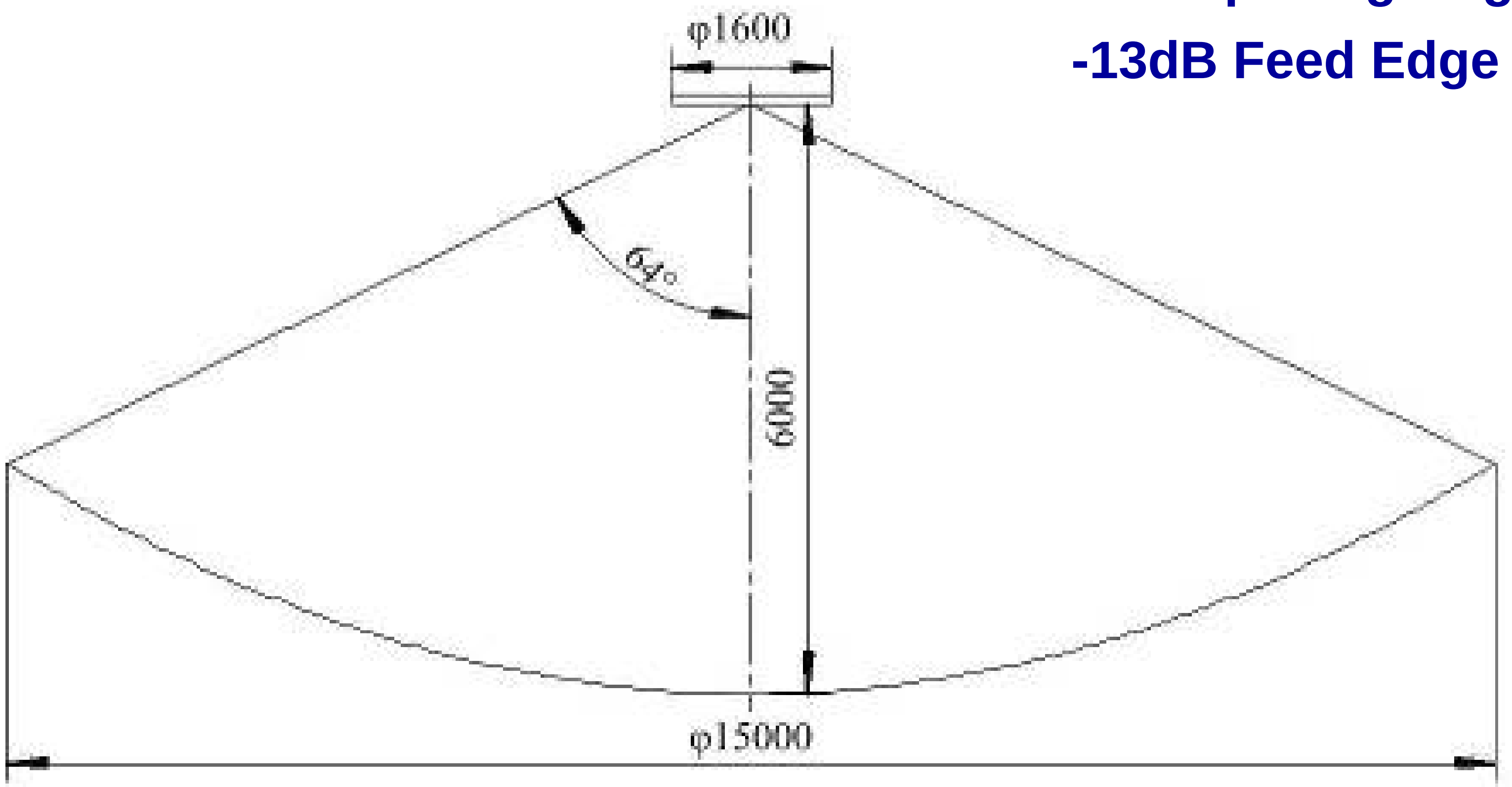
7. DVAC-2 Concept Design
(1) Microwave Optical Design

➔ Main Curve Design

F/D =0.4

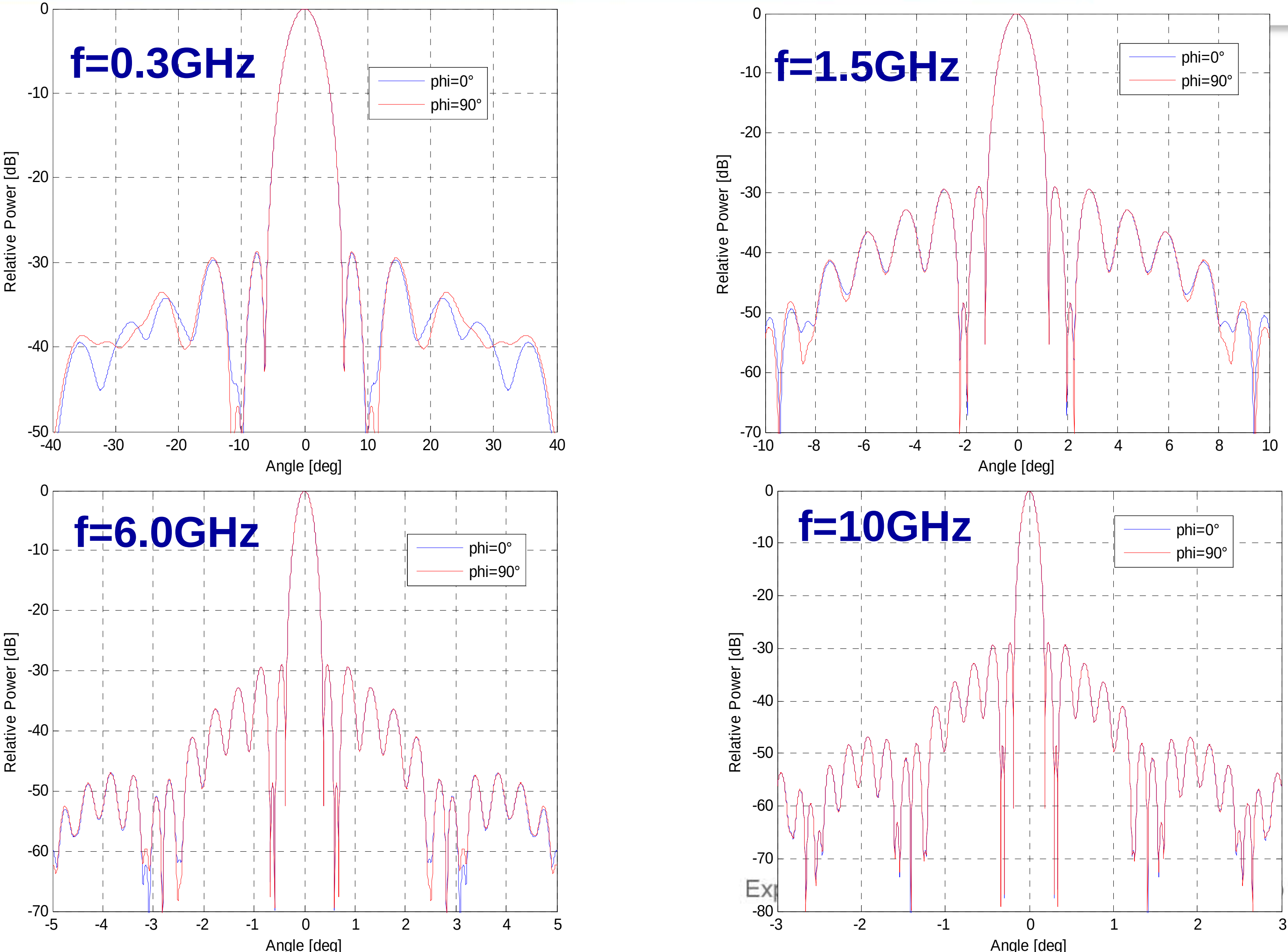
64° Opening Angle

-13dB Feed Edge Taper



7. DVAC-2 Concept Design

(2) Microwave Optical Design

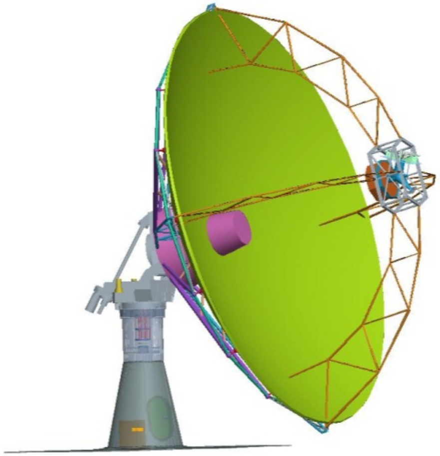
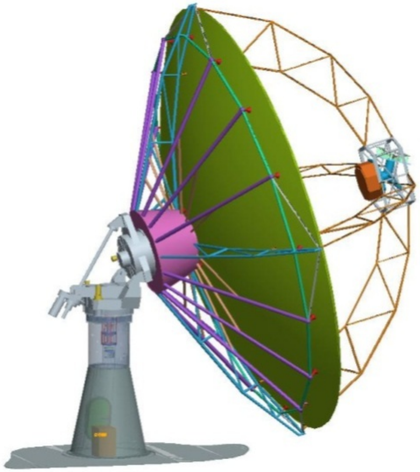


7. DVAC-2 Concept Design
(2) Structure Design

Old Design →


New Design →

- Single Panel
- Simple Structure
- Light Weight
- Low Cost
- Fast Installation

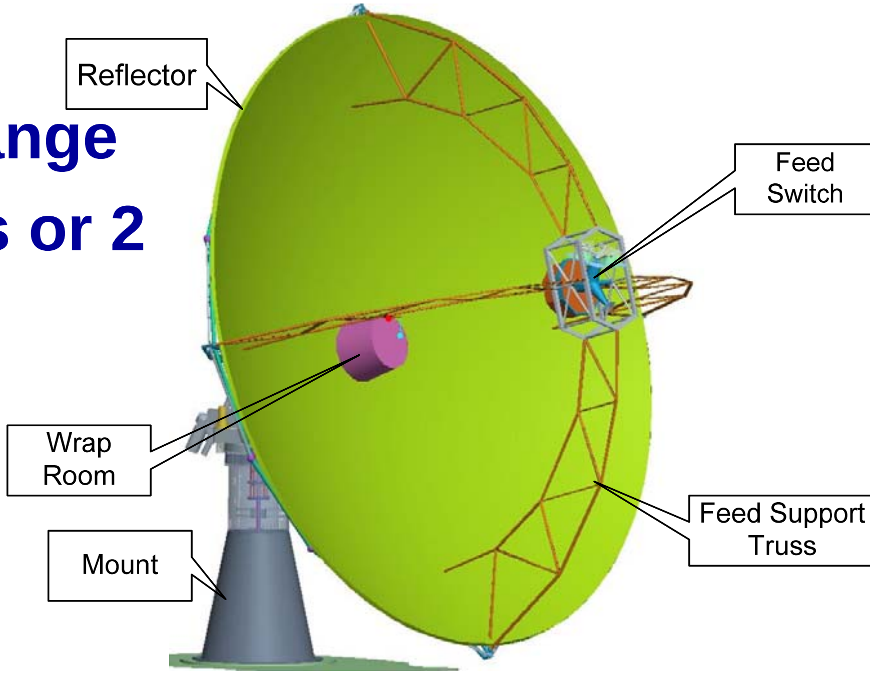
7. DVAC-2 Concept Design

(2) Structure Design

- Reflector Design
- Mount Design

7. DVAC-2 Concept Design
(2) Structure Design

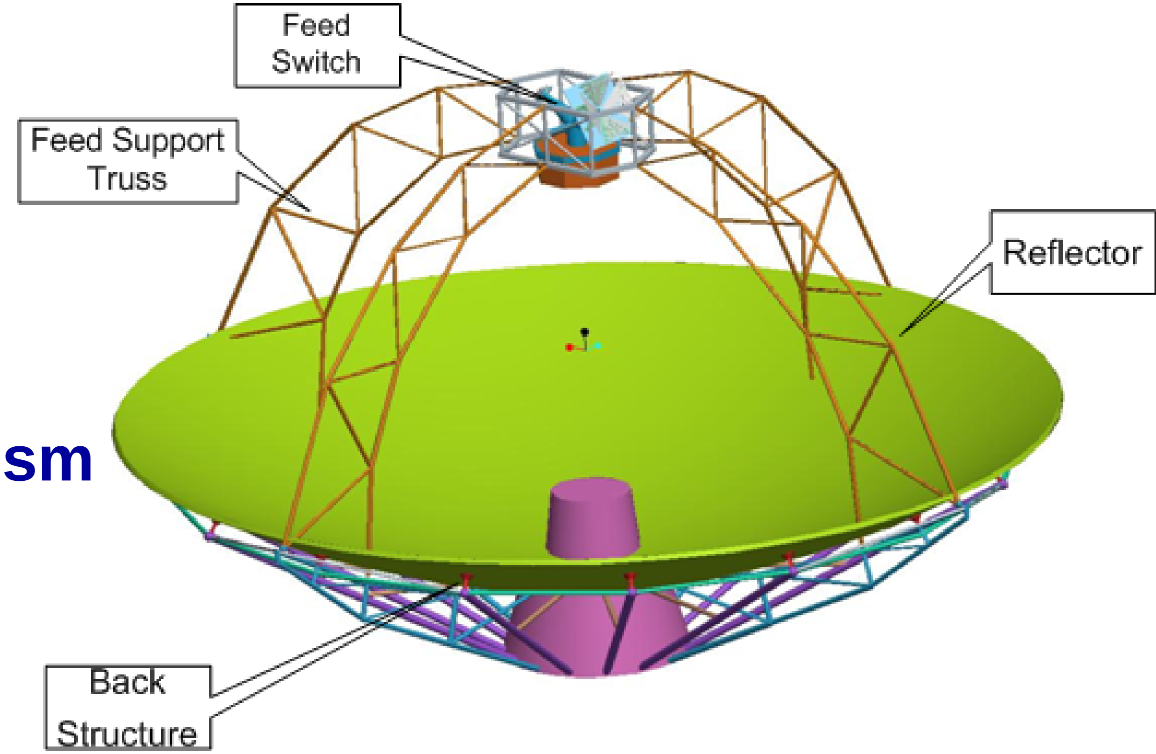
- Single integrated main reflector
- Minimal spar structure
- Turning head design with a lead screw elevation actuator
- Four support legs and interchange mechanism for a PAF and 3 SPFs or 2 WBSPFs.



7. DVAC-2 Concept Design
(2) Structure Design

➔ Reflector Design

- Main reflector
- Back structure
- Feed switch mechanism



7. DVAC-2 Concept Design
(2) Structure Design

➔ Reflector Design — Main reflector

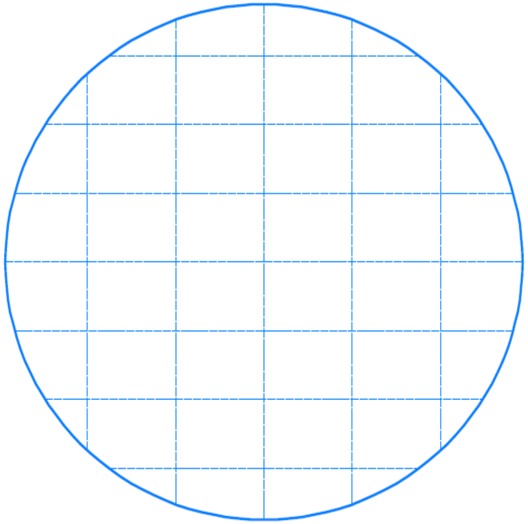
✓ Design 1: Aluminum sandwich structure

Single aluminium panel

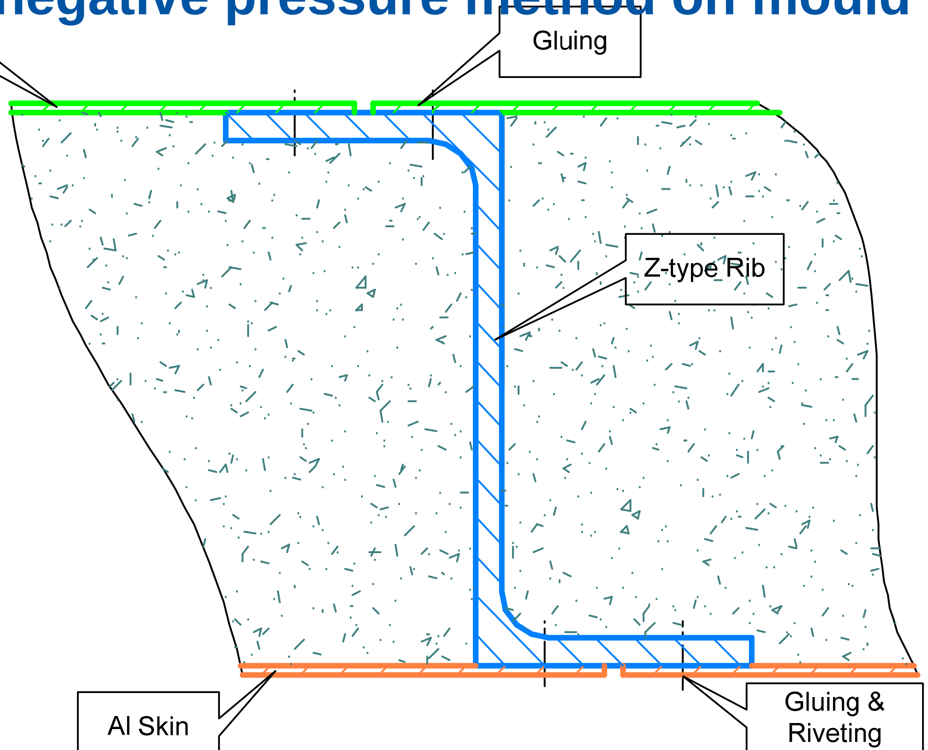
Skins: 2mm (upper)/1mm (lower) in thickness, 2m in width

Skin and ribs are glued through negative pressure method on mould

Surface accuracy σ ⩽0.8mm



Rib Configuration



7. DVAC-2 Concept Design
(2) Structure Design

➔ Reflector Design — Main reflector

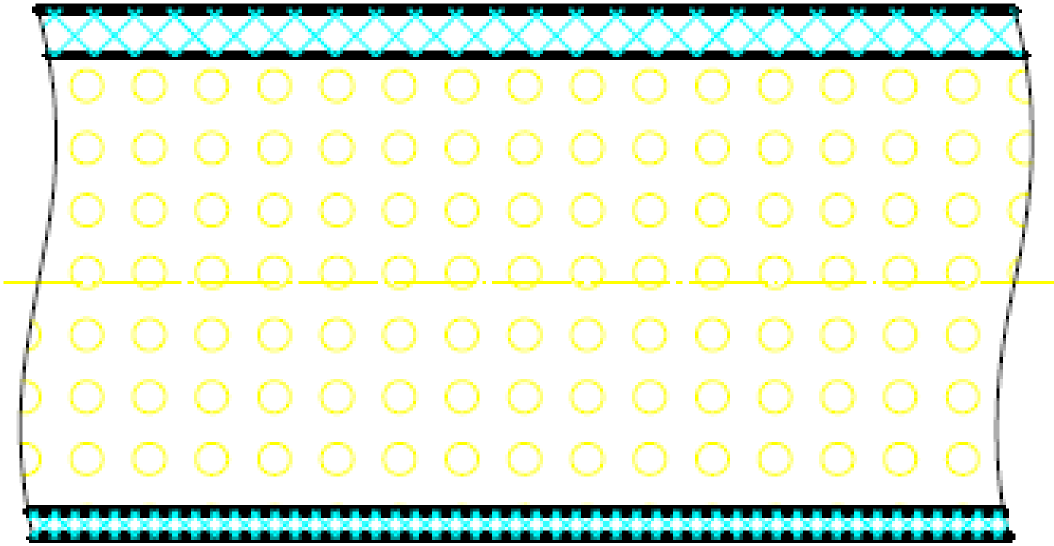
✓ Design 2: Carbon fibre sandwich structure

Single carbon fibre panel

Carbon fibre skins: 1.5mm (top)/1mm (bottom) in thickness

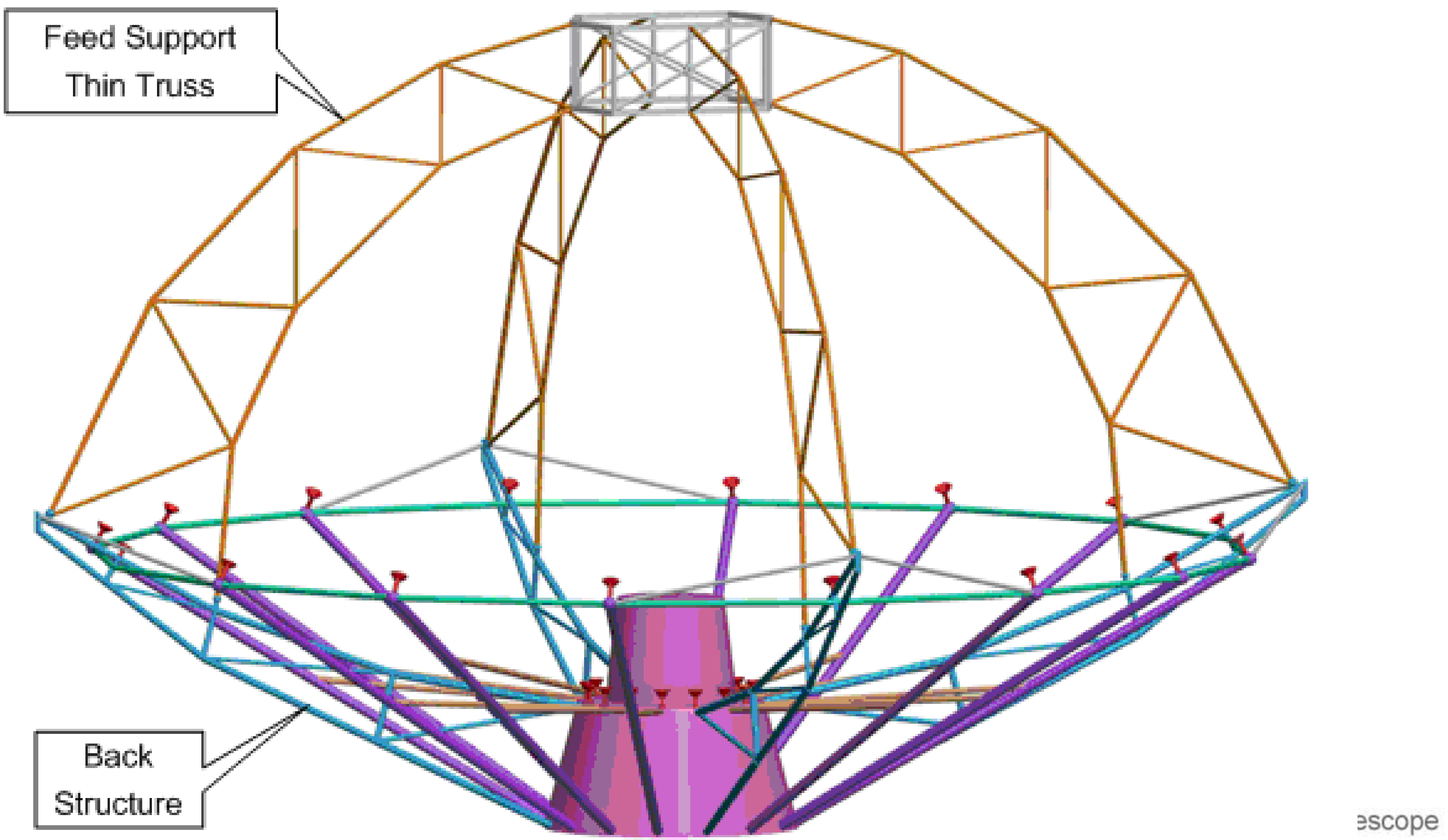
Polyurethane foam: in the middle

Surface accuracy σ ≤0.8mm



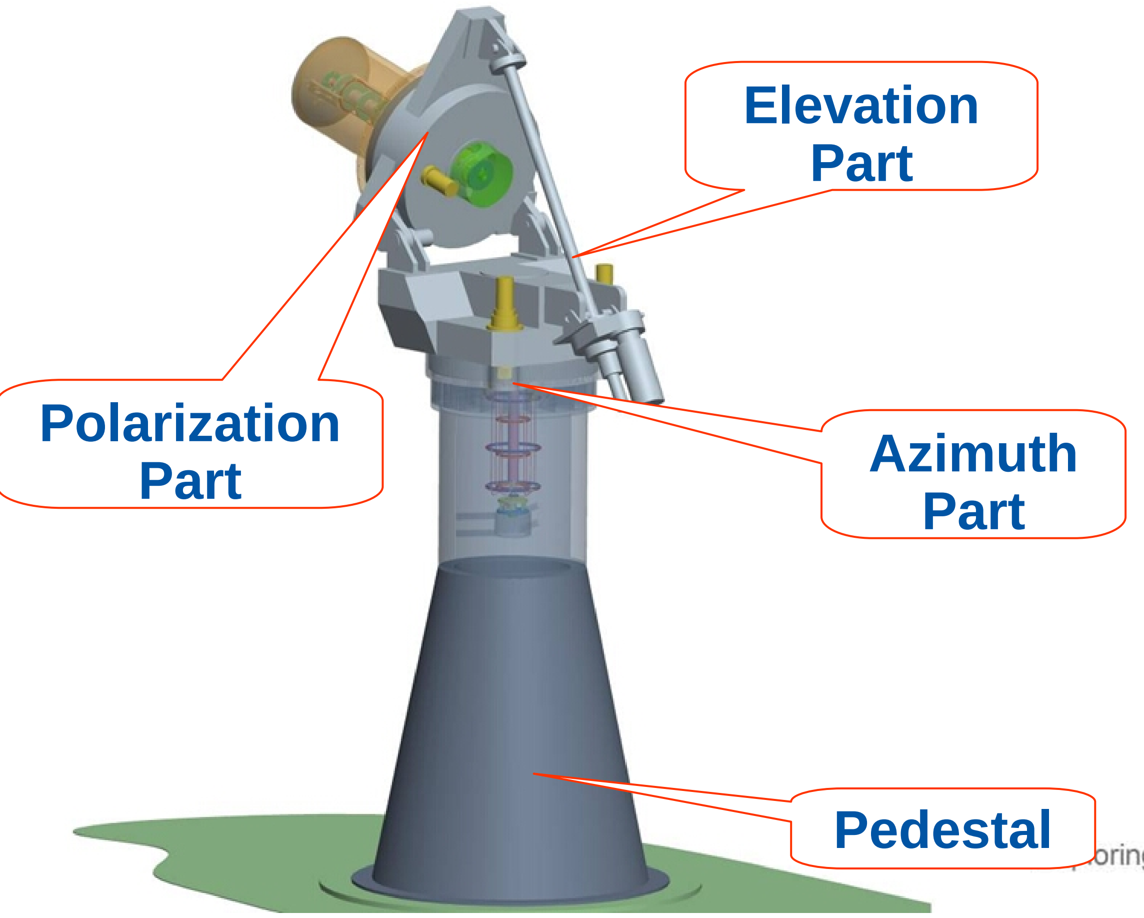
7. DVAC-2 Concept Design
(2) Structure Design

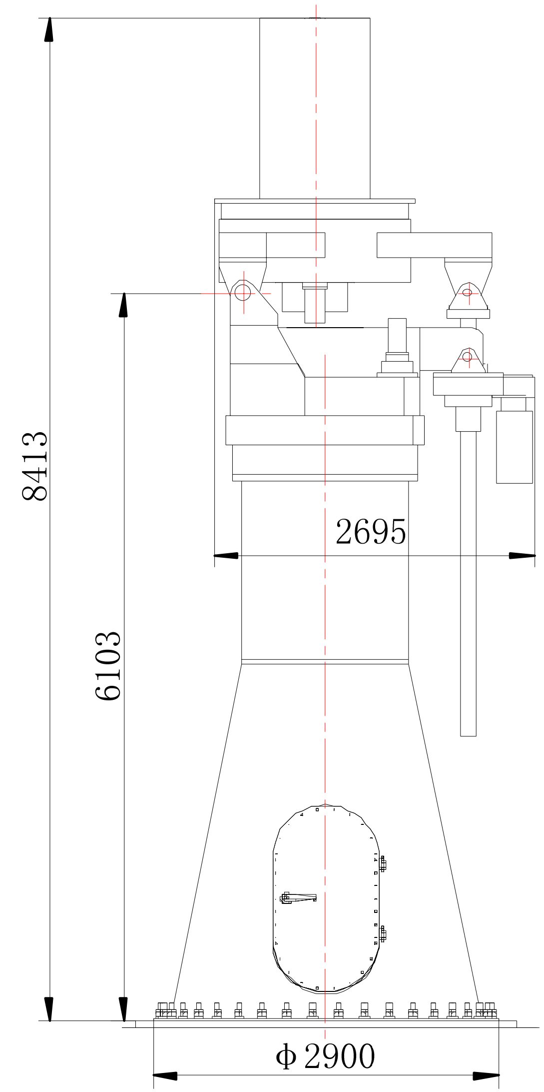
➔ **Reflector Design — Back structure**



7. DVAC-2 Concept Design
(2) Structure Design

➔ Mount Design

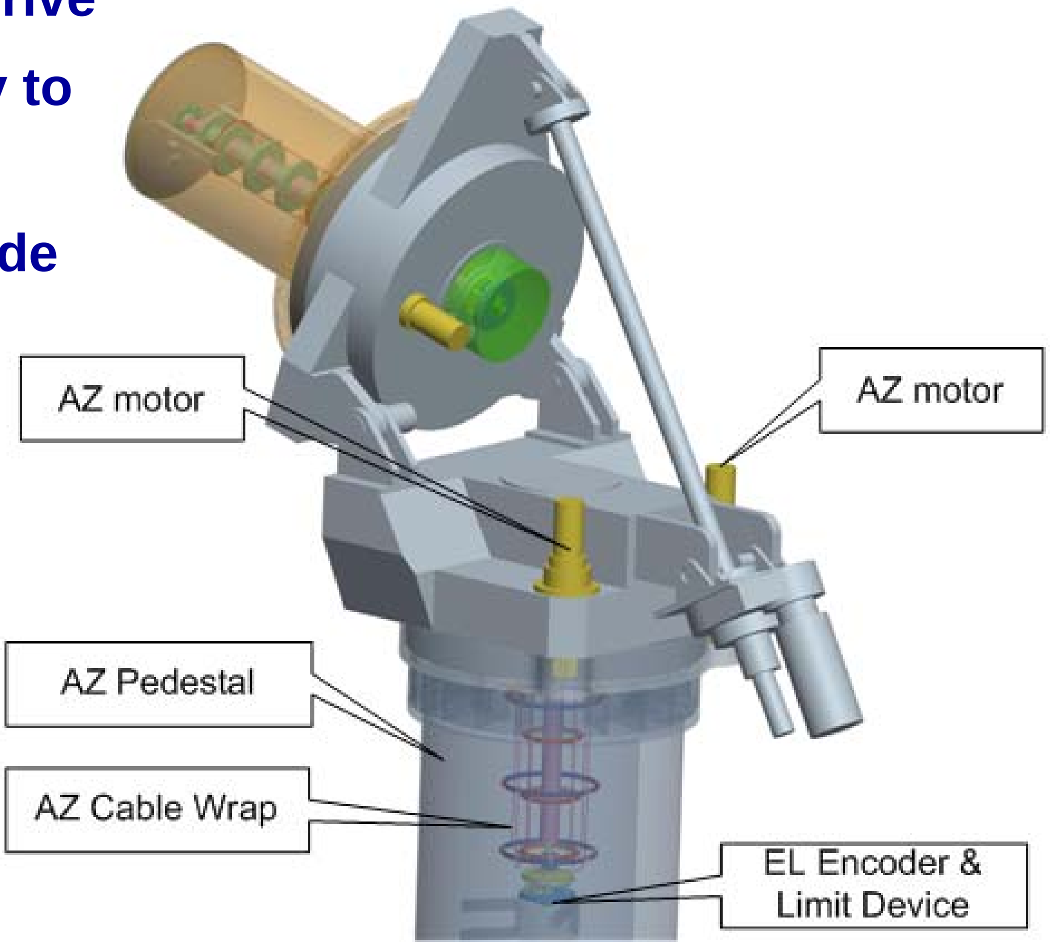




7. DVAC-2 Concept Design
(2) Structure Design

➔ Mount Design — Azimuth part

- Dual-motor anti-backlash drive
- External gear bearing, easy to maintain
- Seal cover is used to exclude dust and sand

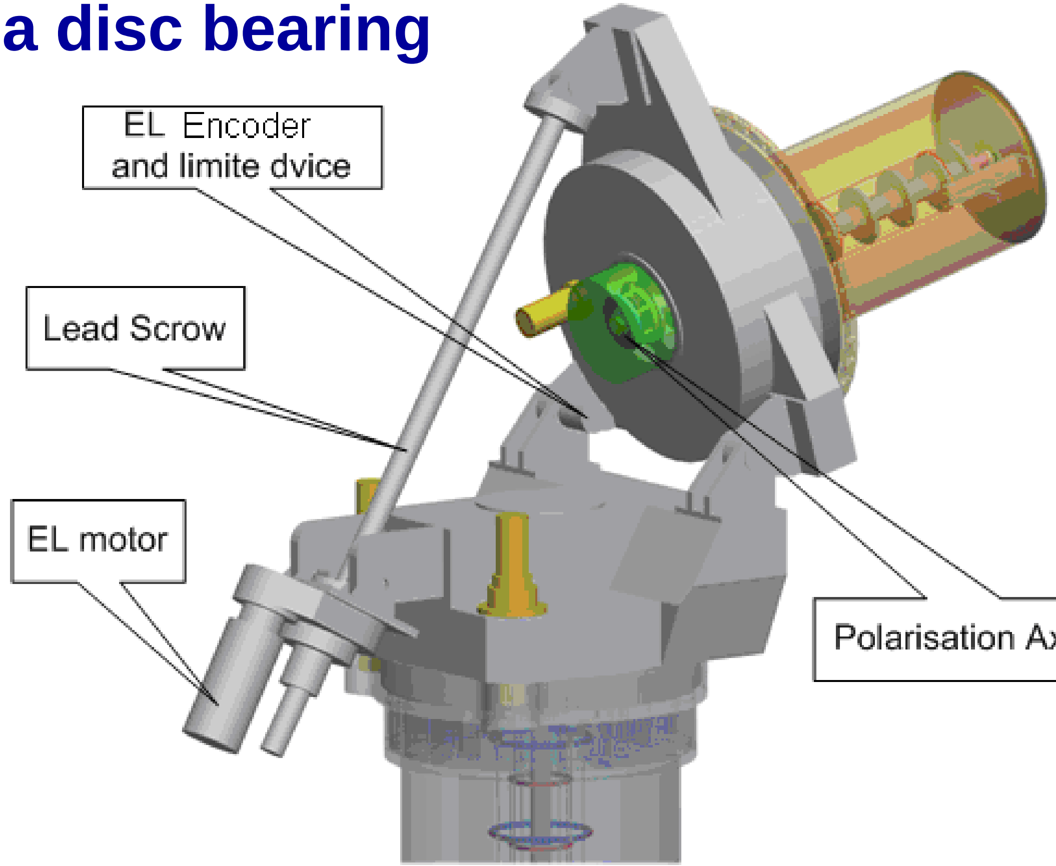


7. DVAC-2 Concept Design
(2) Structure Design

➔ **Mount Design — Elevation and polarization part**

Elevation part: a planetary reducer with a ball screw drive

Polarization part: a disc bearing



7. DVAC-2 Concept Design
(2) Structure Design

Mount Design

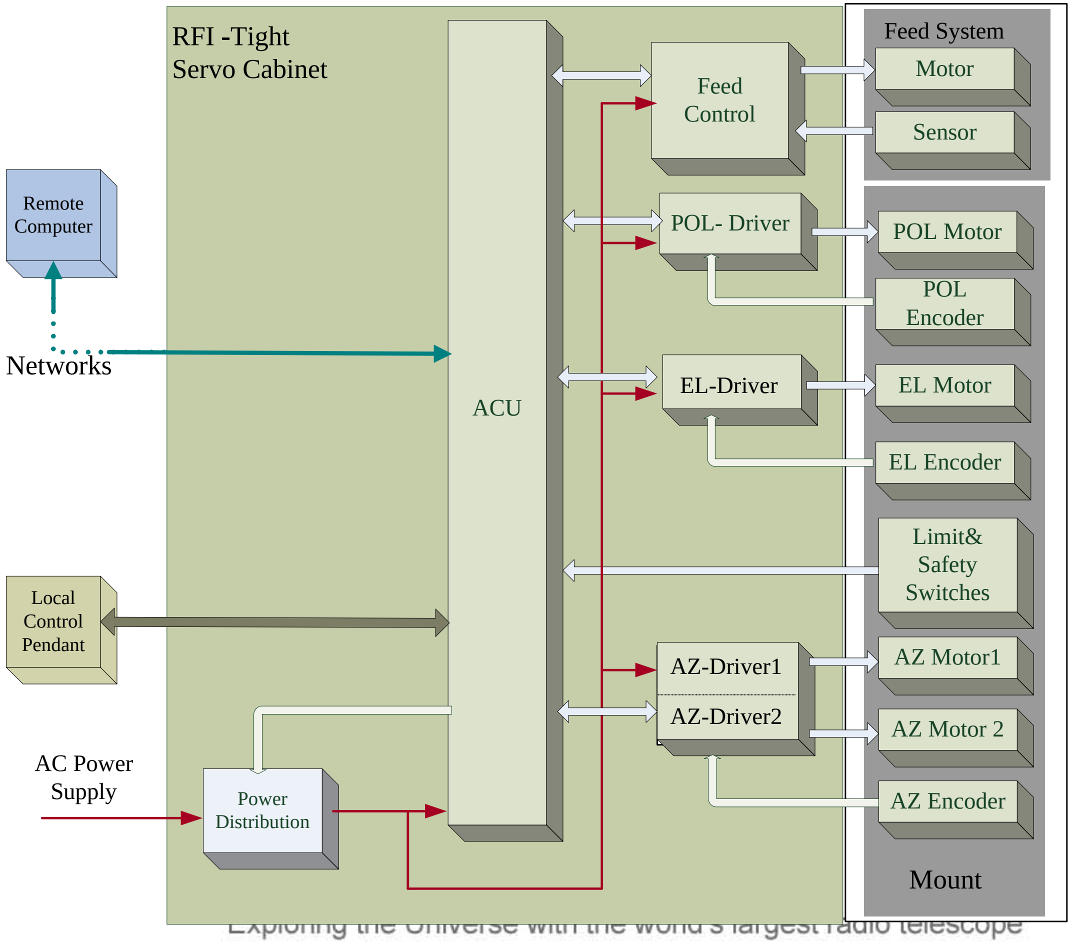
- A flexible-axis drive technique is adopted for Az and El encoder mechanism.
- A double-layer ring structure is used for AZ cable wrap.
- A modular design for all rotating parts.
- A Line-Replaceable Unit (LRU) design is applied to reducer, motor, encoder and limit device, azimuth cable wrap, and elevation lock device. Not only for ease of replacement and maintenance, but also suitable for batch production.

Weight of Dish

ITEM	WEIGHT (aluminum, Kg)	WEIGHT (carbon fibre, Kg)
Reflector	6800	6550
Mount	12500	12500
Total weight	19300	19050

7. DVAC-2 Concept Design
(3) Servo Control Design

- Antenna control unit (ACU)
- Feed Control
- Antenna drivers
- Motors
- Power distribution devices
- Encoders
- Local control pendant
- Limit and safety protection device



7. DVAC-2 Concept Design
(3) Servo Control Design

Main advantages of the control system

- Mature Product
- State-of-the-art components
- Fully digital control system
- Very high reliability
- Modular design, easy for maintenance
- Brushless motors, no maintenance
- Spare part available

7. DVAC-2 Concept Design
(3) Servo Control Design

- **STANDBY**

  Power-on default operation mode or return-on-fault mode
- **PRESET**

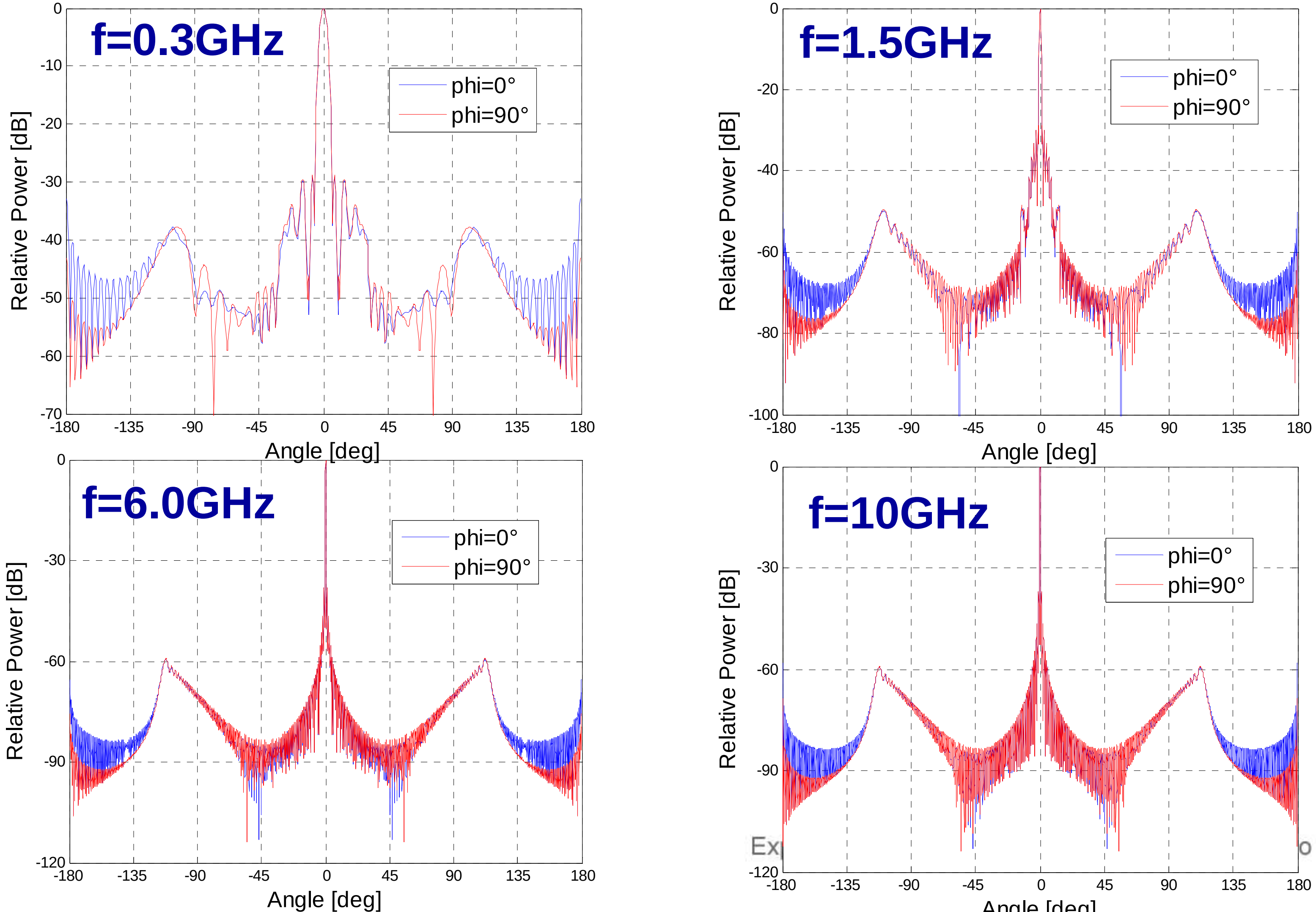
  Moving to predefined position
- **RATE**

  Moving at user-defined constant velocity
- **PROGRAM TRACK**

  Tracking of an object along a pre-defined path
- **STOW**

  Automatically rotating to a preset stow position and locking stow pin

8. DVAC-2 Specification Budget
(1) Full Radiation Pattern Calculation



8. DVAC-2 Specification Budget
(1) Full Radiation Pattern Calculation

Frequency (GHz)	First sidelobe (dB)	
	0° plane	90° plane
0.3	(-28.2, -28.2)	(-28.2, -28.2)
1.5	(-28.5, -28.5)	(-28.5, -28.5)
6	(-28.7, -28.7)	(-28.7, -28.7)
10	(-28.9, -28.9)	(-28.9, -28.9)

First sidelobe: less than -28dB

8. DVAC-2 Specification Budget

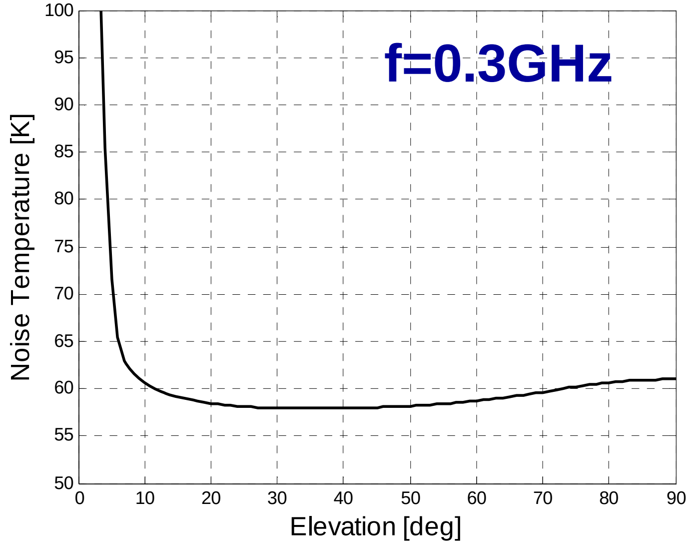
(2) Antenna Aperture Efficiency

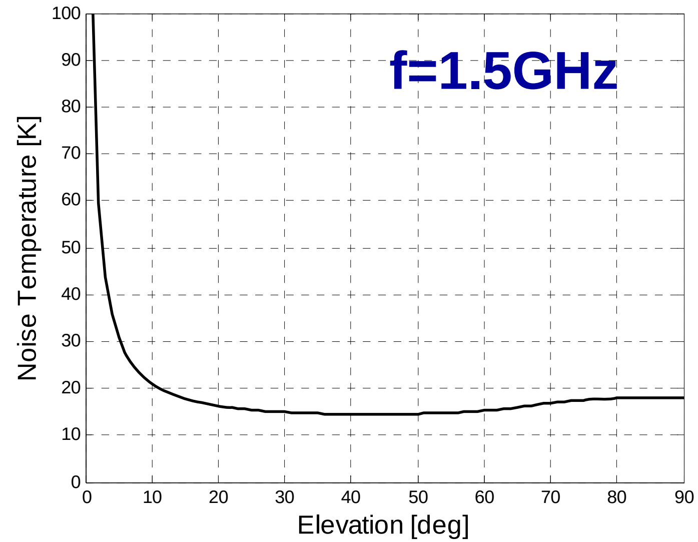
Frequency（GHz）	$\eta_1 \ \eta_2$	η_3	η_4	η_5	η (%)
0.3	0.74	1	0.95	0.98	69
0.9	0.71	1	0.95	0.98	66
1.5(feed 1)	0.70	1	0.95	0.98	65
1.5(feed 2)	0.72	1	0.95	0.98	67
6	0.70	0.93	0.95	0.98	60
10	0.68	0.81	0.95	0.98	51

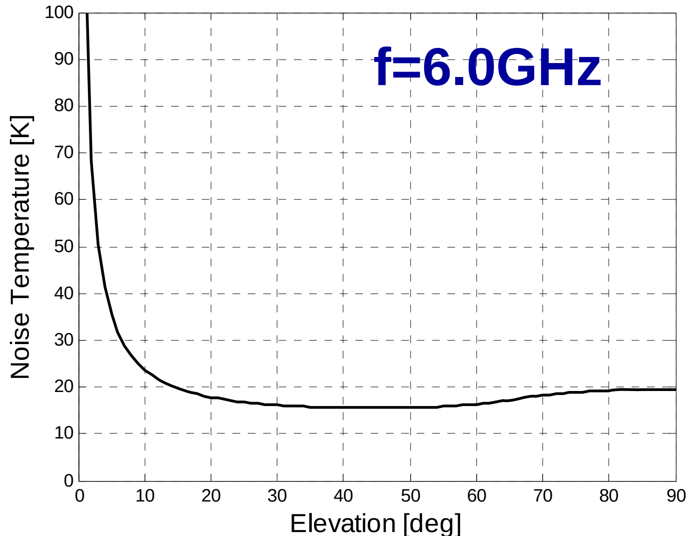
Antenna aperture efficiency: more than 50%

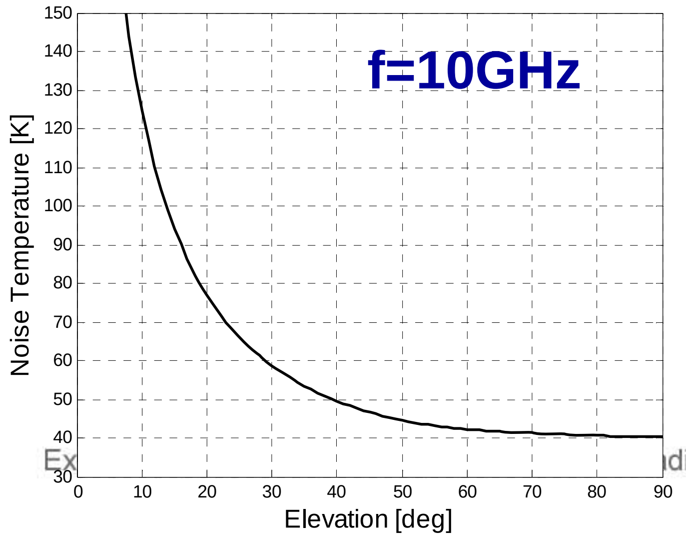
8. DVAC-2 Specification Budget

(3) Noise temperature









8. DVAC-2 Specification Budget

(4) Pointing accuracy

Error source (r.m.s.)	Error(arcsec)	Residual error(arcsec)	Modification method
Verticality of the azimuth axis	10	3	Pointing model
Azimuth-Elevation non-orthogonality	3	3	-
Polarisation-Elevation non-orthogonality	3	3	
Azimuth bearing run-out	4	4	-
Adjust error of feed	3	3	-
Gravity deformation	9	2	Lookup table
Thermal deformation	<1	<1	
Wind deformation	-	-	
Servo error	5	5	
Uncertain error	3	3	
Total error(RMS)	9.2arcsec(at night and windless)		

Thank You

END