DEVELOPING ANTENNA STRUCTURES FOR KAT7

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INTRODUCTION

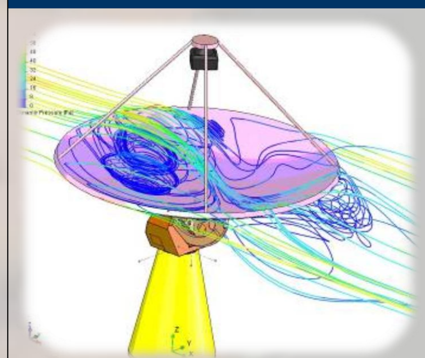
MeerKAT has been designated as a Precursor for the SKA, and will be a world-leading centimetre wavelength radio telescope in its own right. MeerKAT will develop technologies for the mid-band SKA, and will perform preparatory science for the SKA. KAT-7 is a 7-antenna prototype array that is already testing early technology developments.

For KAT7 composite dishes have been developed in South-Africa in collaboration with BAE Land Systems Dynamics. This is a one piece reflector that is moulded on site. The main advantages of the one piece reflector are that it is structurally a more efficient structure and that, once the manufacturing process has been qualified, there is no alignment of panels as the required accuracy on the dishes is an inherent property of the fabrication technique. The KAT7 dishes was an optimization/ improvement on the XDM dish that was constructed at HartRAO (shown to the right).

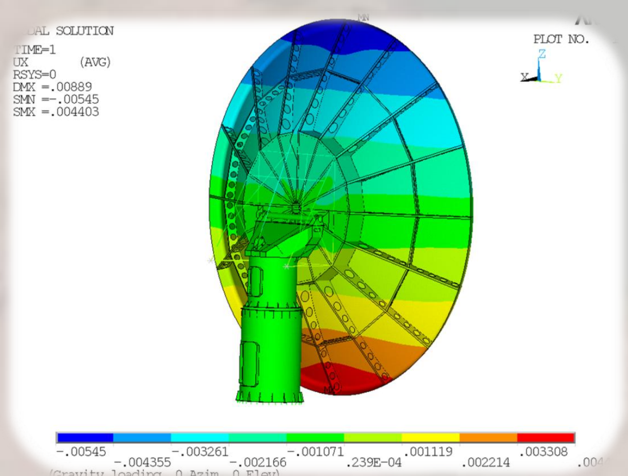
MAIN SPECIFICATIONS for KAT7 and MeerKAT

	KAT7	MeerKAT
Pointing Accuracy (deg)	25" RMS (target 15)	15" RMS
Surface Accuracy (mm rms)	1 mm	<1 mm
Upper Frequency Limit (GHz)	8 GHz	15 GHz
Wind (Operational) km/h	36	36
Wind (Marginal Operation) km/h	45	45
Wind (Drive to Stow) km/h	55	55
Wind (Survival) km/h	160	160
Azimuth Rotation speed (deg/s)	2	2
Elevation speed (deg/s)	1	1
Diameter	12	12
F/D	0.38	
Lowest Natural Frequency (Hz)	3+	3+
Feed/Cryo Mass (kg)	75kg	+-300kg
Mount /Type	Alt-Az PF	Alt-Az PF or Offset Gregorian

ANALYSES

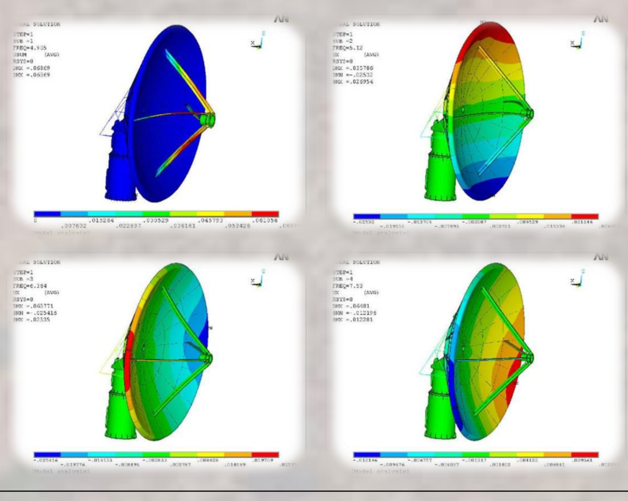


CFD Analyses were used to determine Pressure Coefficients (Cp) on dish surface in order to determine the wind loading at various wind speeds. The antenna was designed to meet specification at wind speeds of 36 km/h, it will stow at wind speeds of 50 km/h and will survive wind speeds of 160 km/h, provided it is in the stow position.

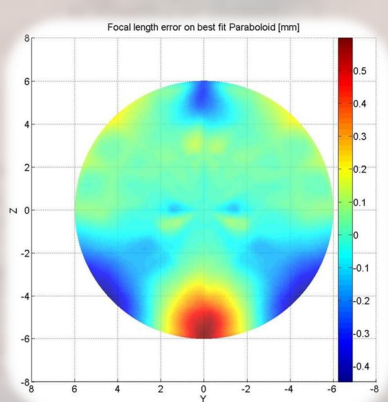


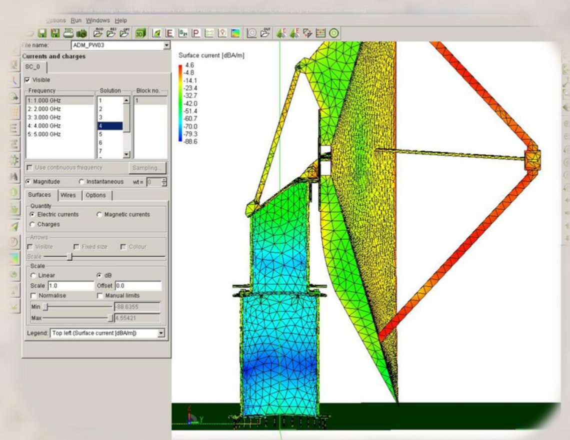
Gravity, thermal and wind loading were applied in order to determine antenna performance (surface accuracy, pointing accuracy, structural integrity). Thermal loading was determined by monitoring thermocouples that were moulded into the XDM composite dish front and rear.

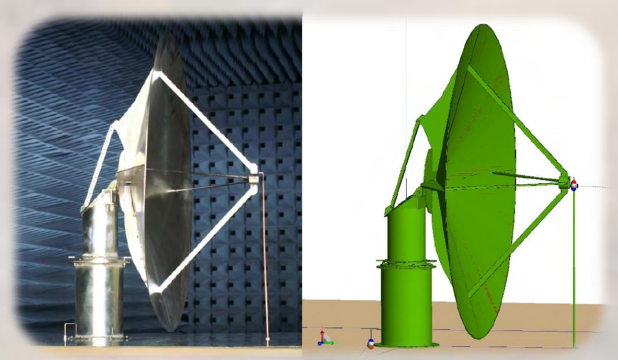
The lowest natural frequency (by analyses) was improved to 4.91 Hz. This is an excellent result considering that some optical telescope structures have modes below this. Structures above 1.3 Hz can typically be excited by wind, so coupling with wind is not a risk (GBT has a lowest natural frequency of 1.8 Hz).



Mode number	Freq [Hz]
1	4.91
2	5.12
3	6.36
4	7.53



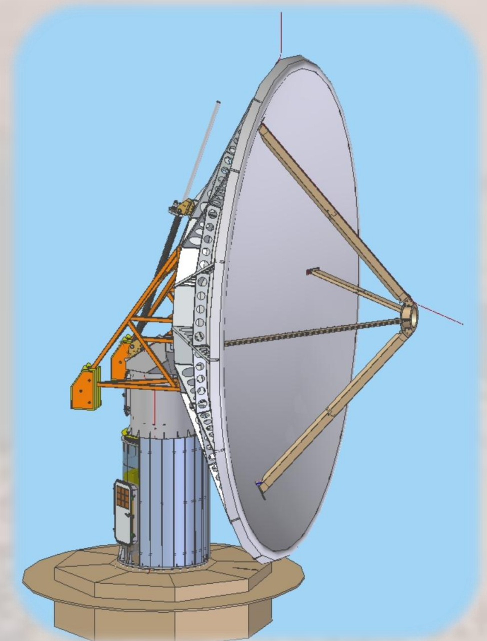




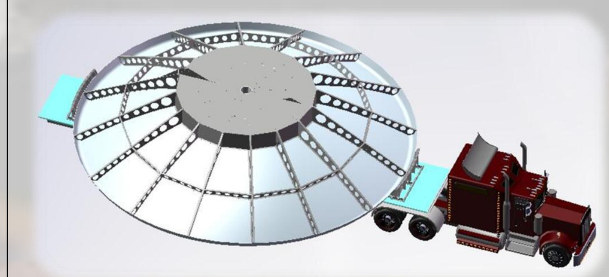
Modeling in FEKO and scale model experiments to qualify the analyses results were used to define a custom lightning protection design. This is crucially important for a dish that is not fully metallic. This led to a fundamental understanding of current flows on the structure and the magnetic fields associated with these.

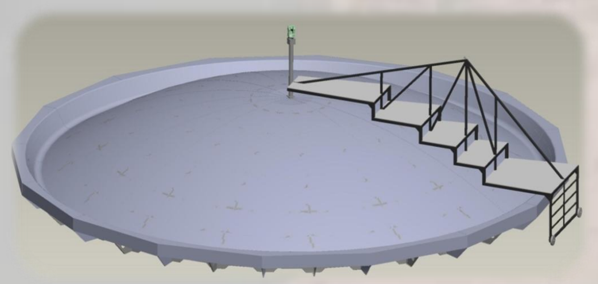
DETAIL DESIGN

Standard System Engineering process was followed: Concept Design, (followed by PDR), Detail Design (including tooling), followed by CDR and manufacturing. Various improvements have been made to the XDM design.

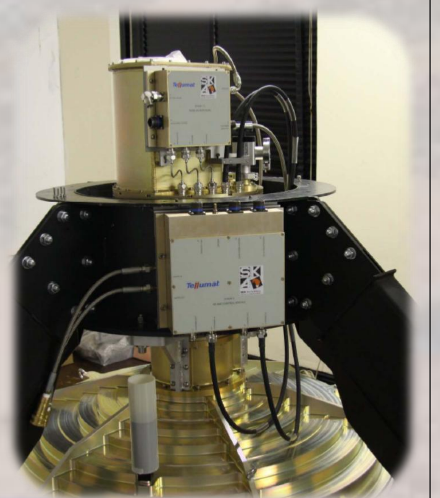


- Mould
  - Pattern Aluminium (KAT7) vs. Wood (XDM)
  - Mould Setup/Conditions (thermal control on KAT7)
  - Improved surface accuracy (by design and process)
- Analyses and Design
  - Thermal design improved (thin open sections / dish)
  - Increased lowest natural frequency
  - Improved surface accuracy (by design and process)
  - Feed displacement reduced
  - Improved control system
  - Better pointing (by design and process)
  - Dish shape optimized (for single pixel feed)
  - Cone Deflector improved detail
  - Feed leg shape optimized (including structural)
  - RFI/Lightning protection design improved



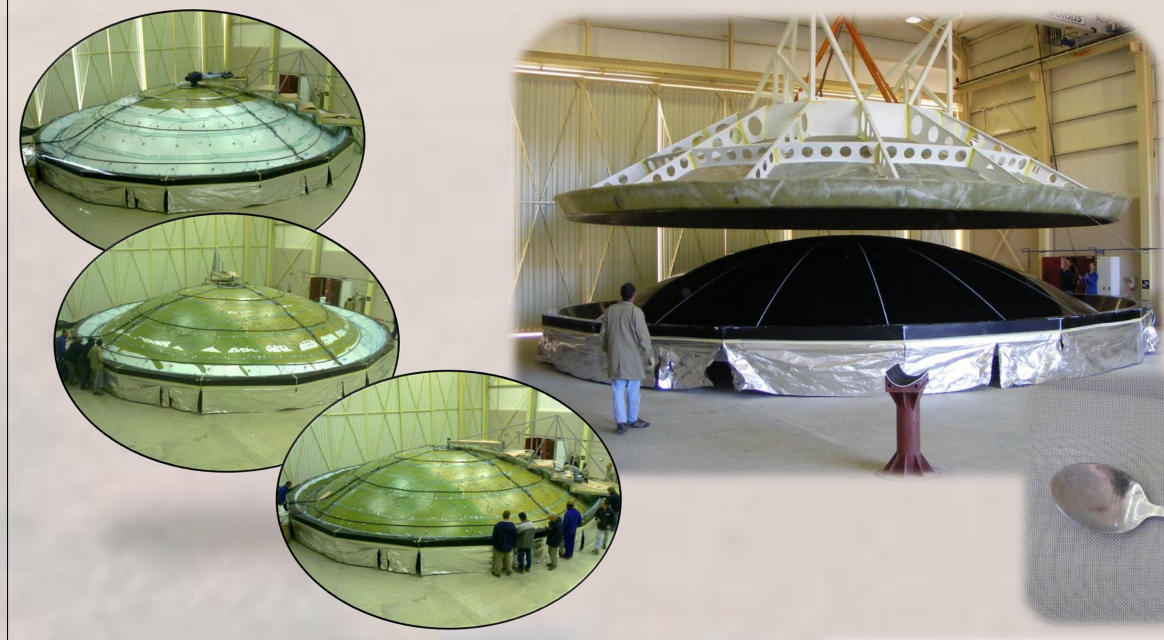


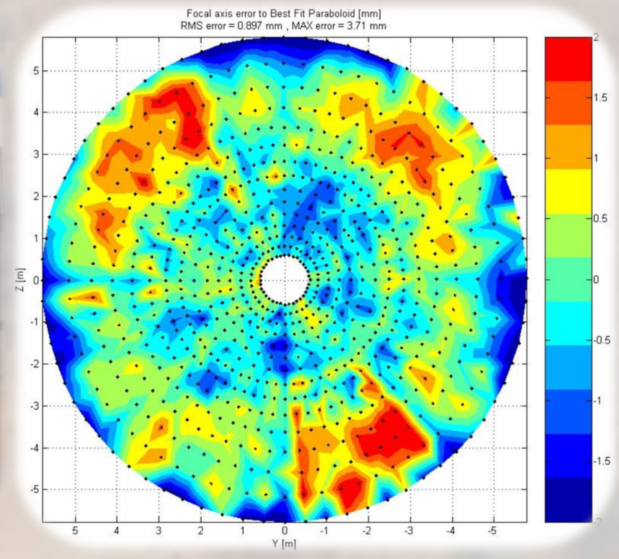
MANUFACTURING and OFF-SITE INTEGRATION



Apart from the primary reflector structure, all manufacturing was done off-site. Integration prototypes were used to minimize site work. The dish shed on site provides a controlled environment to work in. For MeerKAT a possibility is to integrate antennas as far as possible in the shed and then transport to site, since fixed access platforms and an overhead crane will significantly reduce the amount of time to assemble antennas (compared to cherry pickers).

MANUFACTURING (MOULDING) of DISH ON SITE





The composite dishes were moulded on site on a mould that was built and set up to an accuracy of 0.5 to 0.6 mm RMS. Once the process was streamlined, a dish was moulded every 2 weeks. The plot above shows the measurements on one of the dishes using photogrammetry – the achieved RMS surface accuracy was 0.9mm. After moulding, the backing structure was glued on and the dish was transported by means of a custom built trailer to site (6km) where it was installed.

The metallic layer is a fine mesh moulded on the surface of the composite – the mesh size and wire thickness was selected to allow operation to 15 GHz without performance degradation when compared to aluminium panels – this was verified on test panels prior to making the decision to use mesh (aluminium flame spray was also an option).

INSTALLATION and ACCEPTANCE TESTING