Measurement of a 10 Metre Composite Radio Dish Surface Shape Between 2008 and 2010

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Abstract

A composite radio reflector (the MkII) was molded at the Dominion Radio Astrophysical Observatory (DRAO) in 2008. The MkII was built as a demonstrator for the International Square Kilometre Array (SKA). Since 2008, the MkII has been used to test a prototype Phased Array Feed (PHAD). This PHAD demonstrator puts a substantial load on the structure. The MkII telescope has also been used to investigate composite thermal and weathering issues. The surface shape of the main reflector were recorded in 2008 and again in 2010 using a laser scanner. These data are compared. Some interesting results are presented.

1 Introduction

In 2008, a one piece 10 metre composite radio telescope was built at the DRAO in Penticton BC Canada. This telescope was built as a second proof of concept after the 2007 construction of the MK1, a closely similar composite radio telescope. The design and construction of the MkII are outlined in reference [2]. Figure 1 shows the telescope mounted and looking at the sky. The 10m reflector surface is molded from composite material in a single piece using the Vacuum Infusion Process (VIP). The radio reflective layer is embedded inside the structure but close to the molded surface so that the shape of the mold is accurately reproduced in the shape of the reflective layer. The structural beams, made from carbon fibre reinforced composite material, are bonded directly to the backside of the dish surface. The resultant structure is very stiff, capable of easily handling 160kph frontal winds, and very light at only 1000kg. Through measurements of the surface after molding using a laser tracker, the RMS best fit error was found to be 0.54mm before the PHAD feed and feedlegs were added. This result easily meets the mid-frequency requirement for the SKA. With the PHAD and feed legs added, and the telescope looking straight up the RMS best fit error was 0.75mm as measured in 2008. The next question is, how stable is the structure and what can we learn by measuring it again two years later?

Figure 1: The MkII 10m one piece composite radio reflector

2 First Dish Measurement Oct 2008

Based on earlier work which showed an excellent correlation between holography measurements and physical surface measurements (ref [1]), the dish shape was recorded using a laser tracker instead of the more usual holography due to the simplicity of the former method. The laser tracker data was reduced by one of us (Gray), which included spatially interpolation onto a regular grid. Figure 2a and 2b shows two plots of the residuals between the surface as measured and best fit parabolas. Table 1 lists the best fit parameters for the three data sets shown in the paper. The RMS value for the fit in Figure 2a was 0.66mm and for 2b it was 0.75mm. Beginning with Figure 2, we take note of some of the features in the data. First, the 4 diagonal directions of the dish surface show a general depression, while the cardinal directions have the highest positive values. These data were collected with the telescope looking straight up (reflector horizontal); negative values are then downwards, while positive values are up. The negative distortion in the dish surface in the diagonal directions is induced by the fairly heavy (350kg) prototype phased array feed, which currently sits on the feed legs that connect to the rim of the dish (see Figure 1). Second, there is a general grid-like feature visible in the data, oriented at 45 degrees in Figure 2. This feature is real, and results from a small ripple in the mold surface created by the underlying support structure of the mold. Third, there are two bands of noise in the data between 5 and 6 o'clock, and between about 7 and 8 o'clock in Figure 2b. The source of this noise has not yet been found, but we are confident that this noise is instrument related and not actually in the dish surface. And fourth, the hole in the data at the dish centre is due to limitations in the field of view of the laser tracker.

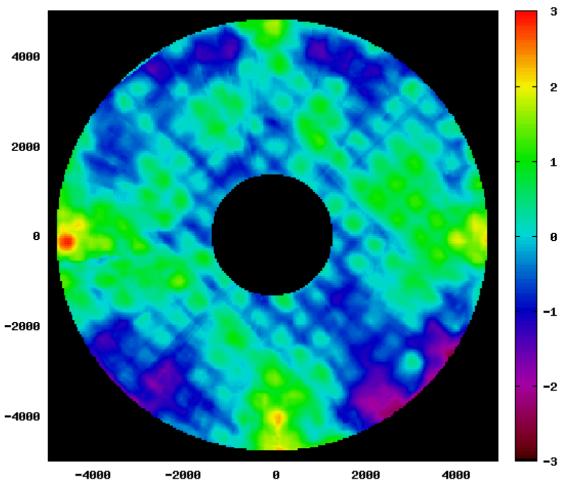

Figure 2a, MkII Surface residuals Oct 22 2008
Scale in mm for all plots

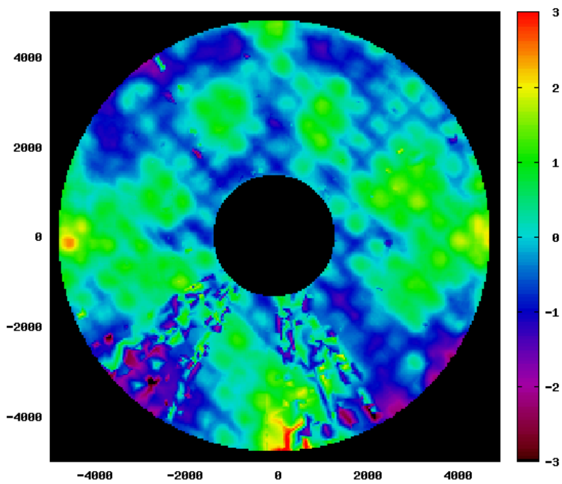

Figure 2b, MkII Surface residuals Oct 30 2008

3 Second Dish Measurement November 2010

In November of 2010, a third set of data were collected from the same dish. Test conditions were set to be the same as the October 2008 data collections with the telescope pointing straight up and the same laser tracker employed. The other variable, temperature, was not identical, but similar. Figure 3 shows the residuals between the laser tracker data and a best fit parabola. Table 1 gives the parameters for the parabola and shows an RMS value of 0.78mm for this fit. The RMS value is virtually identical to the fit done on Oct 30th 2008, although slightly higher than the Oct 22nd data set. Figure 4 is an attempt to compare the November 10 2010 data with the October 2008 data. Figure 4 simply represents the 2010 residuals subtracted from the 2008 residuals. What we see is that the dish compares well with the 2008 data, with it being everywhere within $^{+}_{-}1$mm of the older data. We can also see a radial pattern clearly outlining the support beams in Figure 4a; a pattern that is less evident in Figure 4b. There are also two bands of noise in the data introduced from the 2008 data set which obscures the area around the lower left feed leg in Figure 4b. One complication with the method of data comparison in Figure 4 is that the fit parabolas are not the same between the 2008 and the 2010 data sets. In an attempt to correct this Figure 5 was plotted. Here the data were corrected by adding the difference of the of the best fit parabolas. The result is interesting. Now the differences between 2008 and 2010 are more clearly defined. Figure 5a (Oct 22 2008 minus Nov 2010) has a circumferential ripple with a magnitude of about 0.5mm which is probably due to thermal effects. Figure 5b shows a smaller thermal ripple than 5a, but has some un-accounted-for noise around 5 and 7 o'clock. If both 5a and 5b are taken together, the common trend is for the difference between 2008 and 2010 to be under 1mm except for a very local area right where the feed legs attach to the dish rim.

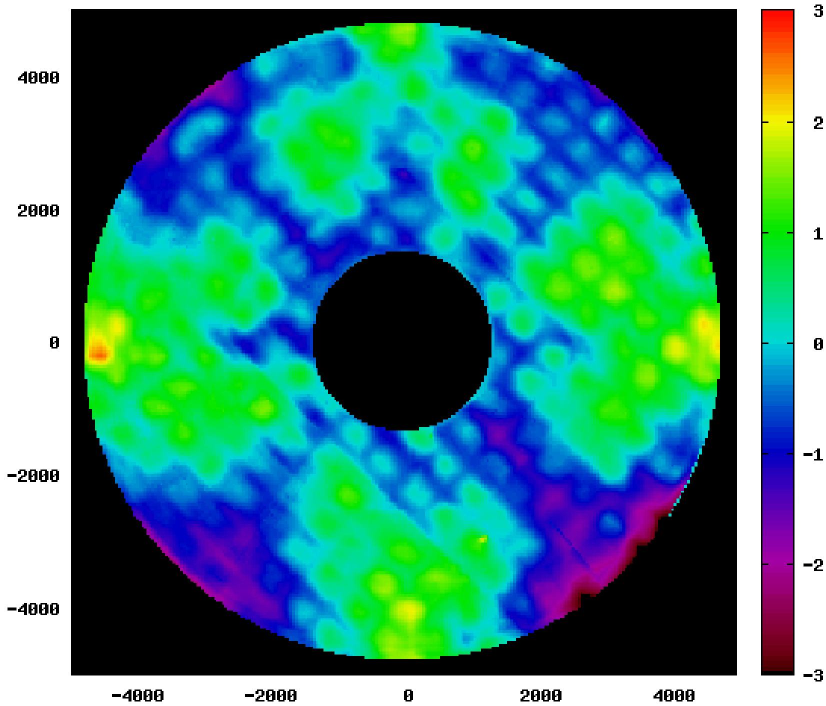

Figure 3: Surface Residuals, November 10, 2010. Scale in mm.

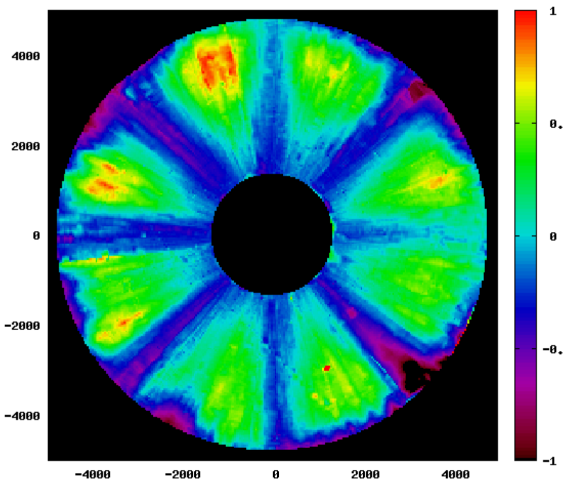

Figure 4a: Nov. 2010 minus October 22 2008

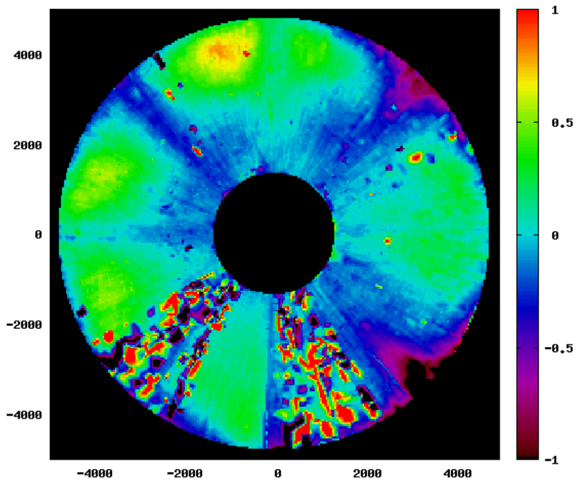

Figure 4b: Nov. 2010 minus Oct 30 2008

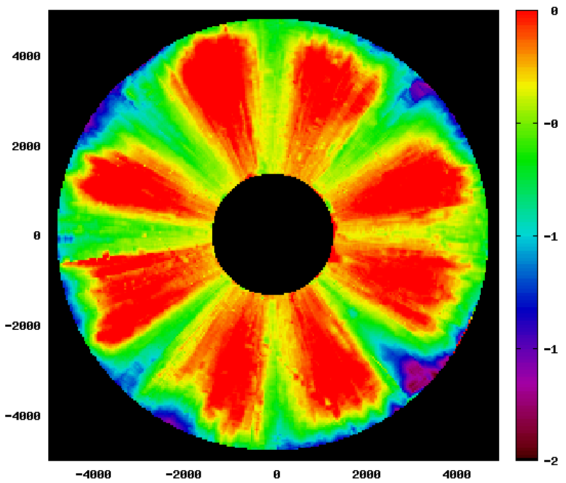

Figure 5a, Oct 22 corrected

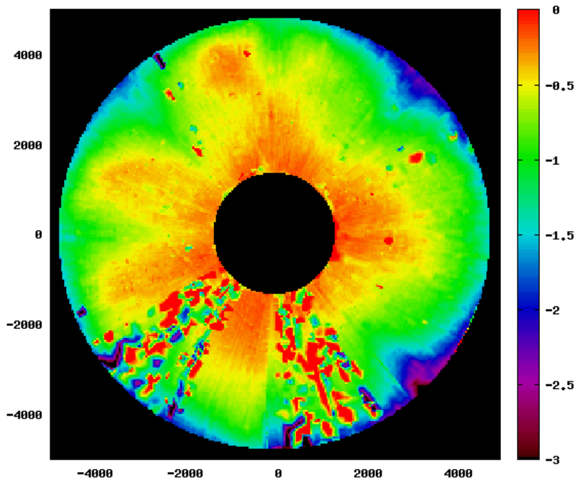

Figure 5b, Oct 30 corrected.

4 Conclusions

Measurements of the dish shape in 2008 and again in 2010 show that the dish has a smoothness which allows it to easily meet the SKA mid-frequency target. It is clear that some ripple has transferred from the mold itself, an error which will be reduced with an improved production mold. Elastic distortion from the feed leg load, is evident but can be mitigated on future models through various means such as strengthening the beams that run out to the feed leg attachment points. Comparisons between these two dates also show very little difference in the surfaces. Everywhere the differences are under 1mm in amplitude except for a small region directly adjacent to the feed leg attachment point at the rim of the reflector. Further study is needed to understand the cause of this distortion and this work is being carried out now. Alternate materials and construction techniques are being investigated to minimise these distortions and several look promising

Table 1:

Description	**Figure #**	**Focal Length**	**RMS**	**Amb. Temp.**
2008 Oct 22, data minus best fit parabola	2a	4488.5mm	0.66mm	11.8°C
2008 Oct 30, data minus best fit parabola	2b	4486.0mm	0.75mm	7.07°C
2010 Nov 10, data minus best fit parabola	3	4490.9mm	0.78mm	2°C

5 References

1. D. Chalmers, "Composite Applications for Radio Telescopes Metrology Results for 1'st 10m Reflector Mounted on Positioner", *NRC-CART Internal Memo #4* , October 2007.
2. D. Chalmers, G. Lacy "Composite Applications for Radio Telescopes (CART): The MkII Reflector Results", *SKA Memo 106,* January 2009