AT Technical Memo: AT/40.3.1/103

Parkes 64m balance – a recalibration

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We thank JE Reynolds for helpful discussions and feedback.
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Outline:

This Memo extends the work done by M. Kesteven in 2002 on the balance and wind-loading of the Parkes 64-metre dish in its Zenith axis, as recorded in Technical Memos AT/39.3/112 and AT/40.3.1/102. It is intended to confirm and improve upon the earlier results by using larger weights for calibration, producing more easily observed effects. The tests were done at short notice when the opportunity and favourable conditions presented themselves.

Previous work:

M. Kesteven's AT/39.3/112 paper was based on work carried out much earlier (perhaps early 2001) by Harry Fagg. The calculations in the paper are based on the test weight having been placed in the cabin, however anecdotal evidence seems to point to the load being placed on the lower edge of the dish surface. If this is the case the results in AT/39.3/112 may be questioned.

Method:

The opportunity was taken to run these tests during a teacher's workshop tour of the dish. The teachers were given "dish-rides" in two large groups and were organised to sit still and maintain their positions, tightly grouped and centred at a known point for the duration of the test. Holding currents were measured at zenith angles of 2 and 59.5 degrees while driving currents were also recorded using MoniCA. The tests were done with two separate groups of teachers (with rough approximations of their total weight) and then twice more with a "bare dish". All of the tests were done with the dish nominally facing into the wind. Wind conditions were gentle and consistent (also monitored using MoniCA) and a further "bare dish" test was carried out after a 180 degree rotation in Azimuth to place the wind at the rear of the dish.

A rough manual sighting was also made from a distance to approximate the antenna elevation angle at which the centre of teacher-mass was equal in height from the ground to that of the elevation bearing.

Test Results:

Data recorded with MoniCA between 10:00 and 13:10 on 15/5/2015 was retrieved and in addition to this, spot currents were read off the live Servo screen and recorded manually. The average values in the table below are from processed MoniCA data and are the average current measured at 2 second intervals for the duration of the period held.

Holding I at 88 degrees elev. (A)	Holding I at 30.5 degrees elev. (A)	Notes
12.92	2.0	13 People On Board (POB)
13.01	2.20	13 POB
12.96	**2.1**	13 POB (average)
12.84	1.76	14 POB
13.2	2.0	14 POB
13.0	**1.88**	14 POB (average)
14.5	3.6	0 POB
14.77	3.43	0 POB
14.63	**3.51**	0 POB (average)

14.46		0 POB (av) (side wind)
15.34	**4.53**	0 POB (av) (wind behind dish)

Estimated total weight of 13 POB group =~900kg

Estimated total weight of 14 POB group = ~1050kg

During the "driving down" phase of the 13 POB test the mass of teachers was centred on the 6th step (counting towards the outer edge of the dish). In all other groups and phases of the test the group was centred on the 4th step. For simplicity the calculations below are as if in all cases the load was centred on the 4th step.

The 4th step is approximately 3.76m from the outer edge of the dish.

A rough sighting was taken of the antenna geometry to determine the Zenith angle required to draw a horizontal line between the elevation bearing and the 4th step on the dish surface. This angle was found to be ~28 degrees.

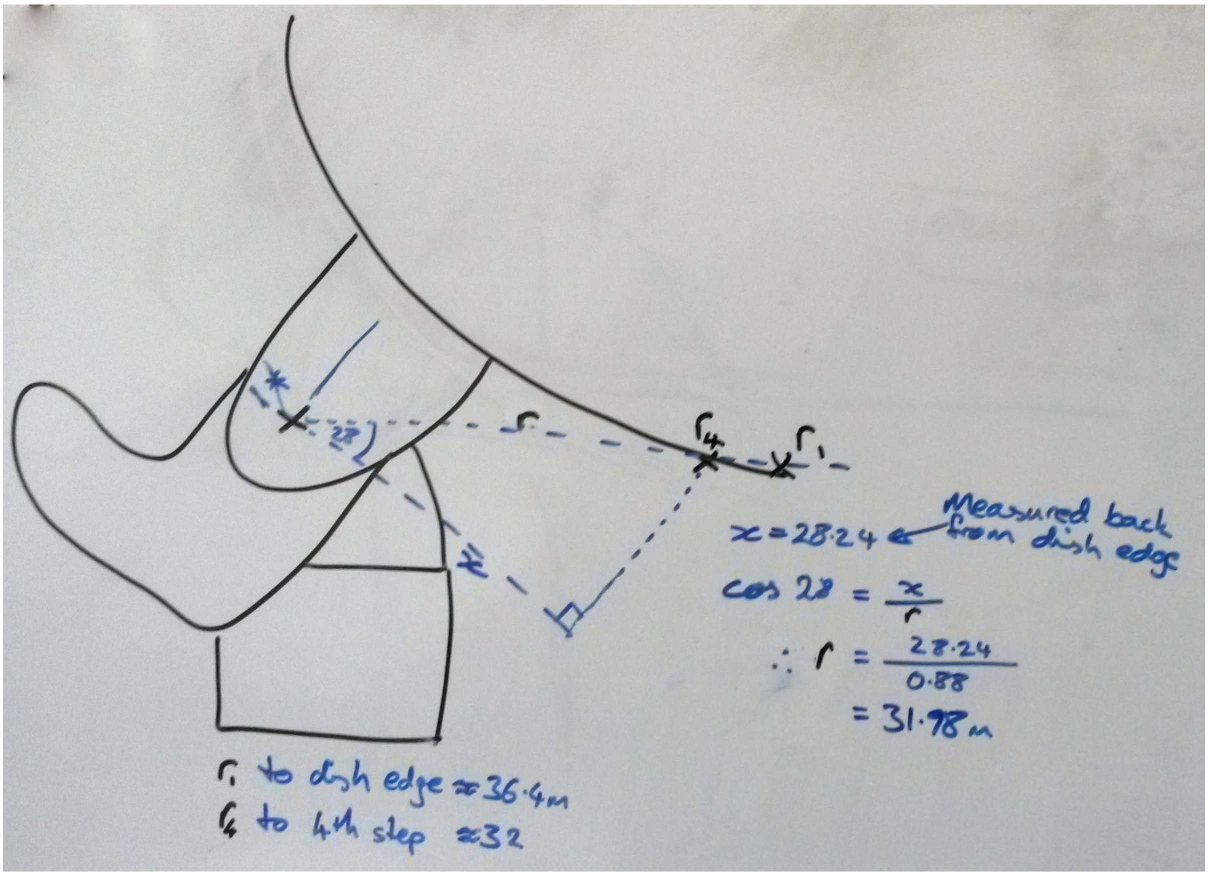


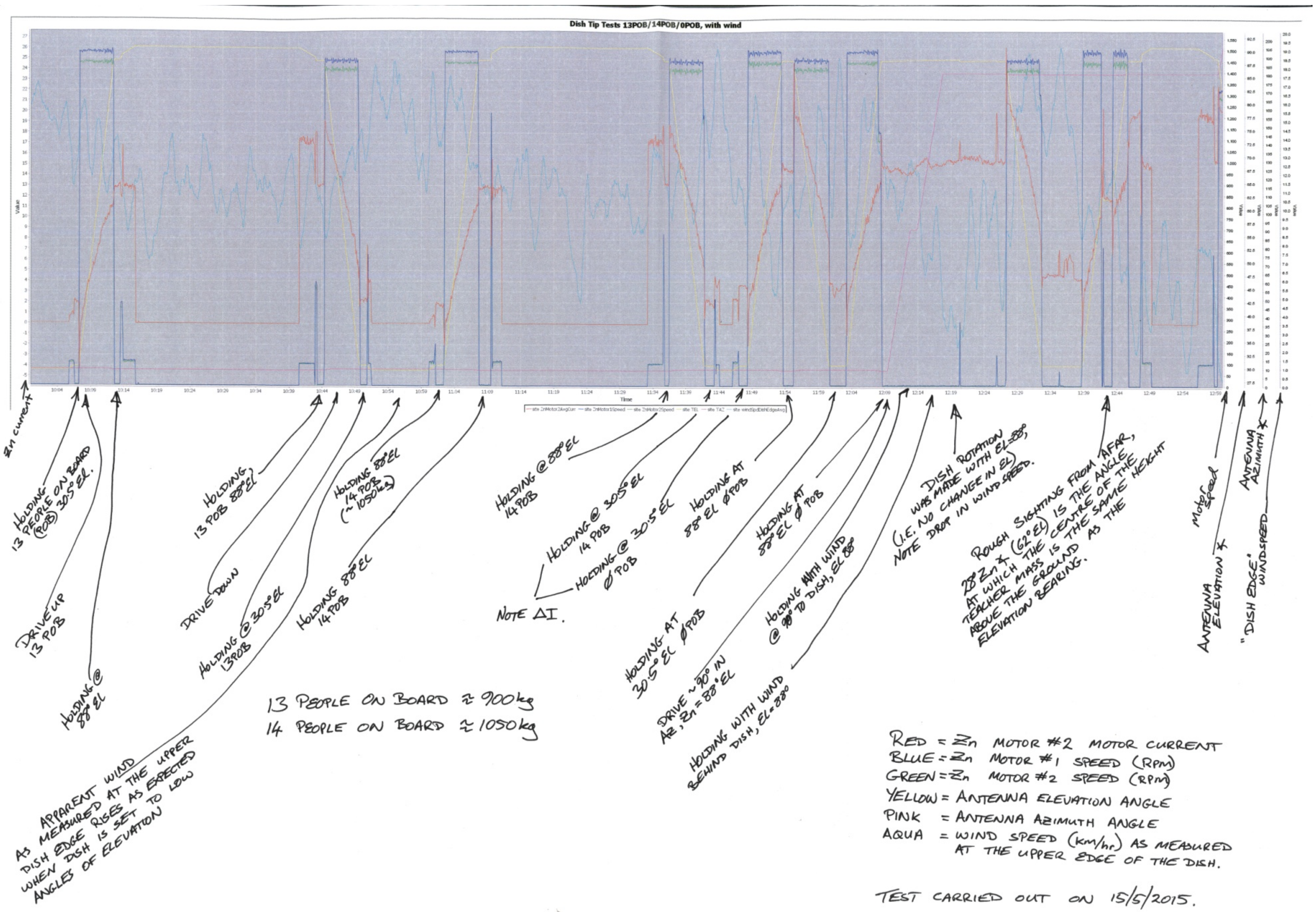
Figure 1: Sketch showing calculation of r_1 (dish edge)and r_4(step #4)

The tabulated results were mostly as expected:

- High currents when holding near zenith,
- Low currents while holding near the horizon.
- Weight added at the edge of the dish surface reduces the holding current near the horizon.
- Wind speed and direction with respect to the antenna's position have an effect on the holding currents

The sense of the change in current measured with the wind in front of the dish, as compared to behind it though, was not as expected. This may be explained by the significant drop in wind speed at the time of the azimuth dish rotation.

The L-band multibeam, S/X, and K-Ku receivers were installed in the cabin at the time of the test.



13 PEOPLE ON BOARD ≈ 900kg
14 PEOPLE ON BOARD ≈ 1050kg

RED = Zn MOTOR #2 MOTOR CURRENT
BLUE = Zn MOTOR #1 SPEED (RPM)
GREEN = Zn MOTOR #2 SPEED (RPM)
YELLOW = ANTENNA ELEVATION ANGLE
PINK = ANTENNA AZIMUTH ANGLE
AQUA = WIND SPEED (km/hr) AS MEASURED AT THE UPPER EDGE OF THE DISH.

TEST CARRIED OUT ON 15/5/2015.

Figure 2: Annotated MoniCA chart showing Drive currents, Drive speeds and telescope orientation

Calculations:

In AT memo AT/40.3.1/102 M Kesteven concluded that the centre of mass of the entire telescope tipping structure was quite near the elevation bearing, and offset laterally. He modelled the torque of this lateral load with:

$$T.\cos(El_0\text{-}El),$$

Where:

- El_0 allows for the difference between the antenna elevation and the elevation of the offset load (centre of mass), and
- T is the peak (maximum) turning moment (torque) about the elevation bearing.

The value of El_0 was estimated to be 105.5° and the geometrical meaning of El_0 is shown in his Figure 2.

The change in torque at a given antenna elevation for a weight placed at a known point on the down-side of the dish is:

$$dT = m_4.r_4.\cos(El_4\text{-}El)$$

while for a weight in the cabin:

$$dT = m_c.r_c.\cos(El)$$

Where:

- m_4 is the added mass centred on "step #4" on the dish,
- m_c is the added mass in the cabin,
- r_4 is the distance from the centre of the added mass on the dish ("step #4") to the elevation bearing,
- r_c is the distance from the elevation bearing to the cabin.
- El_4 is the antenna elevation at which "step #4" has the same vertical height as the elevation axis (62 degrees),
- El is the elevation angle of the antenna.

So the change in torque resulting from adding 14 teachers (m=~1050kg) at a distance of r=32m at an antenna elevation angle of 30.5 degrees is:

$$1.05\text{x}32\cos(62\text{-}30.5)=28.65 \text{ tonne-m}$$

The difference in holding currents in the above circumstances was measured as 3.51A-1.88A=1.63A which results in a calibration factor of:

$$T_{cal}=28.65/1.63=17.6\text{tonne-m/A}$$

Calculating for 13POB at 88 and 30.5 degrees elevation, and 14POB at 88 degrees elevation yields 15.5, 17.4, and 18.5 tonne-m/A respectively.

So the four cases give an average of:

T_{cal}=17.3tonne-m/A (+/- 0.6tonne-m/A)

The equivalent weight change in the cabin for the same change in torque is then given by equating:

$$m_c r_c \cos(El)=m_4 r_4 \cos(El_4-El)$$

whence;

$$m_c= m_4 r_4 \cos(El_4-El)/ r_c \cos(El)$$

$$=930kg$$

The calculations above also give us a convenient conversion factor for the weight in the cabin that will produce the same torque (and therefore Drive Current) as a given weight on step #4 of the dish:

$$m_c=0.89m_4$$

and for a weight m_1 at the dish edge:

$$m_c=1.01m_1$$

So the addition of 930kg to the focus cabin causes a reduction in the holding current (at the horizon) of 1.63A, giving us a cabin-weight to Drive-current ratio of:

930kg/1.63A =570kg/A

The value for T_{cal} (found above) is about 12% higher than the value determined by M. Kesteven in AT/39.3/112.

However if, as we speculate, the test load in this previous measurement (Kesteven, AT/39.3/112**) was located at or near the rim of the dish, and not in the focus cabin, we may recalculate a value for T_{cal} from this earlier measurement of 17.3tonne-m/A, which is consistent with the result reported here.**

Conclusions:

1. The bulk of the data was gathered with the dish facing into the wind. This is the "safe" mode of operation for the antenna but it has the overall effect of elevating the holding currents at all antenna elevations. While an attempt was made to quantify the effect of the prevailing wind into the face of the dish during the test, the results were corrupted by an apparent drop in wind speed (as measured at the edge of the dish) during this phase of the test.
   I have consequently ignored the influence of the frontal wind loading in this paper but note that this will have the effect of artificially raising the observed holding currents. This is of little consequence in the discussion of torque and the calculation of the cabin-weight to drive-current ratio but will I think make a significant contribution to the discussion as to whether the antenna balance should be more in favour of the counter weight at the horizon.

   More work should be done to gather wind neutral results, or to calculate a suitable offset to apply to the results found here.

2. The effect on torque of placing a weight in the cabin as compared to the lower outer edge of the dish (while at 30.5 degrees elevation) is very similar and well within the errors associated with these calculations so the results found in AT/39.3/112 may not be questioned on the basis of where the load was placed at the time of the experiment.
3. Recalculated for my test elevation of 30.5 degrees, Kesteven's results yield:

   $$\Delta m = 533 kg/A$$

   This is within 7% of the result from my data:

   $$\Delta m = 570 kg/A$$

   This variance could be explained by a simple 7% over estimation of the combined weight of the 14 participating teachers, however it is interesting to note that the same calculation for the 13POB case also yields $\Delta m = 570 kg/A$