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The Active Surface System on the Noto Radio Telescope

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Abstract. The antenna efficiency of large parabolic antennas is strongly affected by the effect of gravity on the mechanical structure. The parabolic shape is ideal at the elevation of the panel's alignment but as the antenna points to different positions on the sky the mirror deforms, loosing its ideal shape and consequently reducing the antenna gain. A way to overcome this effect is moving panels, recovering the ideal shape at every elevation. This can be done because gravity induces repeatable deformations, so they can be measured and compensated. In this paper we describe a solution to overcome this effect, realized on the Noto radio telescope and completed at the beginning of 2002. This new setup allows an increase in the operating frequency and eliminates the elevation dependence of the antenna efficiency. The electromechanical actuators are described, as well as the structure of their connecting network , together with panel alignment tools and first results obtained.

1. Introduction

Primary mirrors of large antennas are formed by hundreds of aluminum panels, aligned in a parabolic shape at a specific elevation. At other elevations, gravity-induced deformations increase the root-mean-square (rms) surface error and consequently the antenna gain is reduced. The concept we followed to overcome this effect is moving panels, recovering the ideal parabolic shape at every elevation.

The goal of providing our telescopes with an active surface dates back to the early '90s (Orfei et al. 1993; Zacchiroli et. al 1995). An electromechanical actuator will move the corners of four adjacent panels in the direction normal to the local surface. The amount of the movement for each point and for each elevation is stored in a matrix, or calculated in a polynomial form, known from either measured data or finite element analysis, together with the results of the panel alignments. In 1999 funding was available to start the realization phase of the system to be installed at the 32m dish of the Noto (Siracusa, Italy) radio astronomy observatory, operated by Consiglio Nazionale delle Ricerche - Istituto di Radioastronomia.

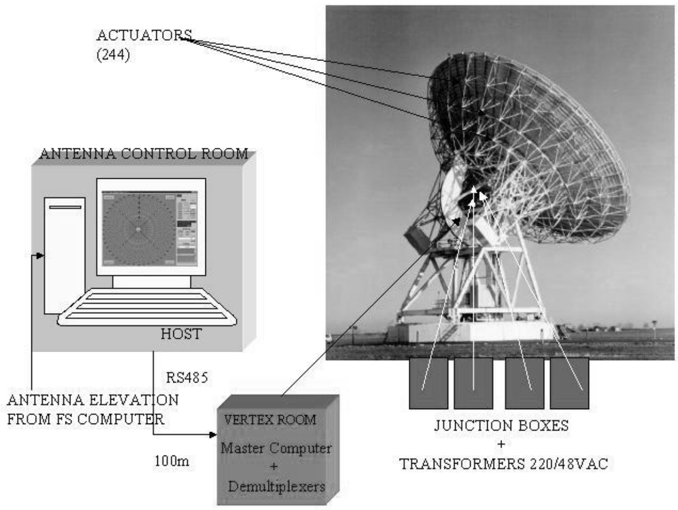

Fig. 1. The active surface system

2. The Active Surface System

In Fig. 1 a schematic picture shows the whole system. 244 actuators are mounted on the antenna backup structure, each supporting a panel "four corner" point. They are organized in 48 radial lines with 5 actuators each (there is an exception near the four quadripode leg extremities where one more actuator is placed) and each radial line acts like a bus where the five devices are hung. In principle the bus structure avoids blocking of the actuators in the line if one of them fails, but if that does happen, the five/six-actuator radial structure avoids loosing too much surface if the whole radial line fails, allowing maintenance to be postponed until after the observation is finished. Each group of twelve radial lines connects to a junction box where the RS485 communication and the 48V AC actuator power supply are merged in the same cable: the 48V AC is obtained from the 220V AC primary line.

A master computer, an embedded PC board, manages the network, addressing each actuator to be moved by routing the message through 4 de-multiplexers (Fig.2). The message can be most simply regarded as "address + position".

The master computer stores the deformations in a polynomial form and moves the panels according to the antenna elevation, issued by the host computer located in the antenna control room. The host computer receives the antenna elevation information from the Field System computer and runs a Tcl/Tk program (Fig.3), monitoring the actuator network. This checks sequentially each actuator, returning its status, monitors the actual position of the surface and, when requested, aids the maintenance of

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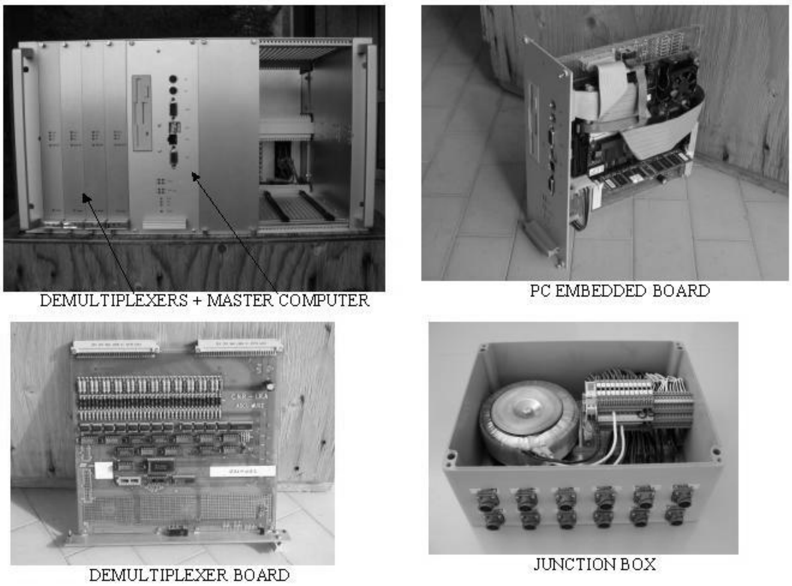

Fig. 2. Master computer/demux rack and junction box

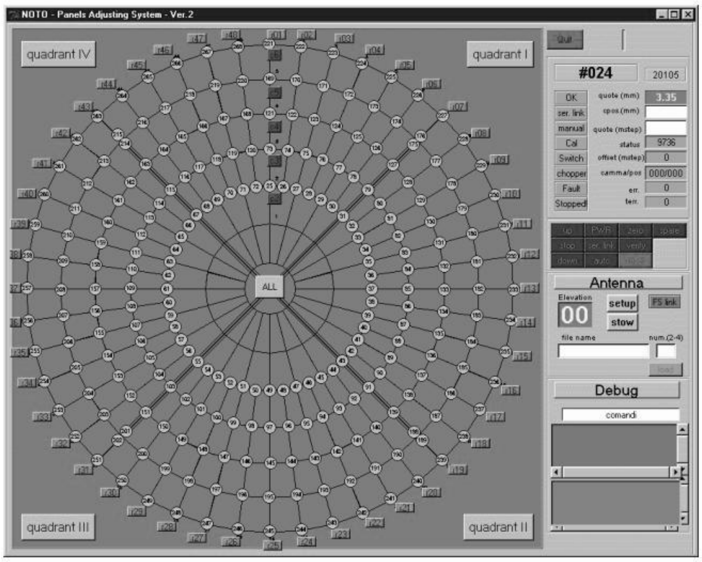

Fig. 3. The active surface monitoring program

the system allowing manual addressing of each actuator individually. The program can also broadcast particular commands to all actuators, for example in the starting procedure where all actuators are moved to a mechanical zero reference position. Since less than 30 msec per actuator are needed to address, command and receive back a status response, the network is refreshed every 7 seconds.

The system is such that it can be easily duplicated to serve bigger antennas, maintaining the same performance. The speed of each actuator is fast enough to position the primary mirror surface well within the slewing time of the antenna and it is not necessary to have all actuators moving at the same time. It could be demonstrated that, with a communication time of 50 msec per actuator (a conservative value), a velocity of 0.36mm/sec and managing a convenient time delay between actuators, about 50 actuators will be moving simultaneously, corresponding to a worst case requested power of 1.1kVA (see Table 1): this is an advantage for the power request for supplying the active surface system and the size of an UPS unit.

3. The Actuator

The complete actuator and its parts are shown in Fig. 4. The electromechanical part consists of a step motor and a reduction gear connected to a pre-loaded ball screw. A linear slide, with a slithering bearing, is mounted in order to avoid radial loads on the ball screw. We avoided using motors with brushes in order to enhance the maintainability and reliability of the system. The electronics is part of the actuator in order to avoid the emission of interference signals generated by the motor controller/driver. In this way, long cables carrying switching signals are avoided.

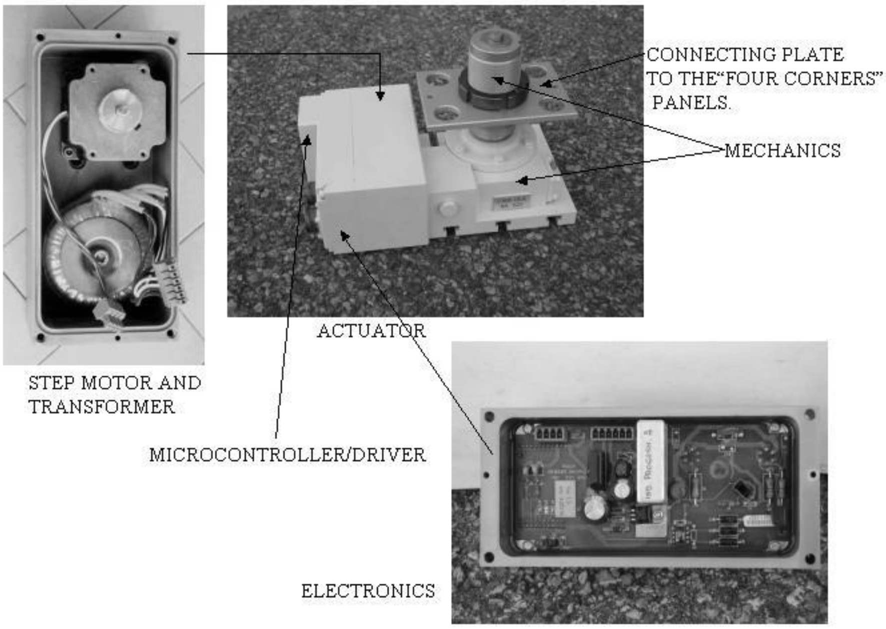

Fig. 4. The electromechanical actuator

The controller/driver is a commercial device able to independently manage the movement of the actuator when it recognizes its address. The remainder of the electronics derives DC supplies from the 48V AC and incorporates a simple mechanism to detect if the step motor loses steps. The tests we extensively performed on many individual actuators (loading, temperature, environmental, communication, EMC etc.) and on the network allow us to write down the specifications reported in the following table.

Table 1. Table 1. Actuator Specification

Weight	8.5 kg
Dimension	295 × 184 × 203 mm
Stroke	13 mm
Peak positioning accuracy	±0.015 mm
Axial operating load	250 kg
Radial operating load	100 kg
Axial survival load	1000 kg
Radial survival load	700 kg
Speed	0.36 mm/sec
Power supply	48 V AC
Communication protocol	RS485
Operating temperature range	-10° / 60° C
P consumption min/max	16/23 VA
Stand by power consumption	4 VA
Lifetime	20 years

The operating loads reported are relative to panel weight plus 80km/h wind. The survival loads are the maximum load we tested, corresponding to the survival wind specification of the antenna. They do not represent a destructive load.

The peak accuracy is relative to the whole stroke (±6.5mm) and is partly limited by the backlash of the gear and partly by the non-linearity of the mechanical system. If the surface correction needs less than half of the stroke available, and this is the case, the accuracy is better than the value reported.

The operating temperature range tested was larger than reported in the table, but it is a safe range, taking into account that the microcontroller is a $0^o \div 70^o$C device.

4. System installation and preliminary results

The upgrade of the Noto dish surface started in August 2001 and lasted until January 2002. At the same time as the installation, it was decided to weld parts of the backup-structure joints and to replace all panels with new ones with better manufacturing accuracy (0.1mm rms). After mounting all the actuators and cabling the network, they were aligned using a theodolite together with a custom tool designed in-house. It is composed of a reference surface plate, a hollow corner cube sighted by the theodolite and levels.

Then the new panels were mounted and each four-corner point was aligned using the theodolite. This corner will be the reference, with respect to which the other three will be aligned. This local alignment allows putting each four-corner point on the same plane with an accuracy better than 50 microns, a performance not achievable by aligning each corner using the theodolite. To do this, another custom tool has been designed in-house as well. Fig. 5 shows the tools.

Fig. 6 shows the actuators and panels mounted.

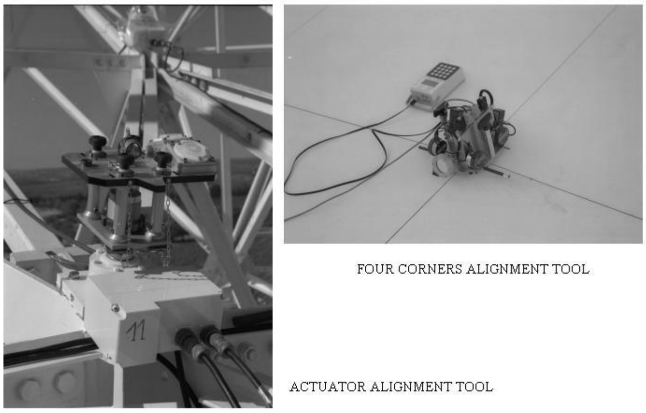

Fig. 5. The alignment tools

Fig. 6. Installing the aligning the system

After completing the alignment procedure the results of subsequent readings gave an rms best-fit parabola no better than 180 micron at elevation=45^o.

In Fig. 7 a preliminary measure on sky is shown. It was performed at 22GHz by pointing at DR21. A comparison of antenna efficiency with and without using the active surface system shows that the active surface is working. The antenna gain was measured by optimising the pointing for each elevation and keeping fixed a sub-reflector position optimized at El=45^o. The antenna efficiency was then calculated, correcting for the atmosphere. It should be noted that the alignment residuals applied for the surface correction were those measured at El=45^o; a flatter curve should be obtained by applying direct measurements made at various elevations, especially at El<45^o. In order to do this a photogrammetry measurement of the dish has been done and results will be merged with theodolite data. The maximum value of the efficiency at 22GHz is consistent with that which could be calculated from the known surface accuracy. The limitation comes from the sub-reflector surface rms, which is high.

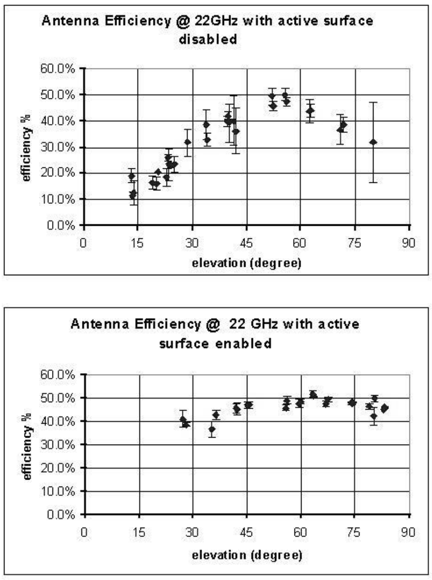

Fig. 7. Active vs no active surface comparison

5. Conclusions

These good preliminary results encourage us to continue with measurements at higher frequencies. After getting photogrammetric data, new measurements will be made both at 22 and 32 GHz. This latter receiver will be mounted on the primary focus of the antenna, allowing us to measure the efficiency and avoiding the surface degradation factor due to the sub-reflector. Work on a new 43GHz receiver is also in progress and this will provide another interesting test when the sub-reflector surface is upgraded. Moreover, it could be demonstrated that with 0.1mm rms panels, a 0.1mm rms sub-reflector and reaching an accuracy around 0.1mm rms in reading the primary mirror surface (photogrammetry or holography) the maximum operating frequency will increase to near 86GHz. This will allow us to refurbish an already erected antenna, designed for centimetric wavelengths, to near millimetric. Of course, as the operating frequency increases we will face the requirement of enhancing the pointing accuracy.

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