THE ACTIVE SURFACE FOR THE NOTO RADIOTELESCOPE

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ABSTRACT

In this paper a solution, realized on the 32m antenna of the Noto radiotelescope and completed at the beginning of 2002, to overcome the degradation of antenna efficiency due to gravitational deformation of the structure is presented. This new setup allows an increase of the operative frequency and eliminates the elevation dependance of the antenna efficiency. The electromechanical actuators as well as the structure of their connecting network will be described, together with panels alignement tools and first results obtained.

INTRODUCTION

Large parabolic antennas have the antenna efficiency that is strongly affected by gravity effects on the mechanical structure. Primary mirrors of large antennas are formed by a lot of aluminum panels that can be aligned in a parabolic shape at a specific elevation. As the antenna moves to point at different positions on the sky the mirror deforms loosing its ideal shape and consequently the antenna gain reduces. A way to overcome this effect is moving panels, recovering the ideal parabolic shape at every elevation. This can be done because gravity induces repeatable deformations so they can be measured and compensated.
This upgrade has been installed at the 32m dish of the Noto (Siracusa, Italy) radioastronomy observatory (Fig. 1) operated by Consiglio Nazionale delle Ricerche - Istituto di Radioastronomia (Bologna, Italy).

Fig. 1. 32m Parabolic radiotelescope at the Noto observatory

The aim to provide our telescopes with electromechanical actuators, dates back to first 90s [1]. Each actuator will move the corner of four near panels in the normal direction to the local surface. The amount of the movement for each "four corners" has stored in an a priori matrix of deformation where the raws are elevation values and the columns are the movements of the actuators. The amount of "four corners" actuated is 244 and the building elements for this kind of active surface are:
1) a matrix of deformation
2) an actuator
3) a communication network between actuators
4) a software to remotely command the network and to interface the active surface system with the antenna station computer.
The item one was available from either measured data or finite element analysis from which we also derived the stroke of the actuators: a maximum deformation of ±5mm, at the extreme elevations 0° and 90°, and with respect to the alignement at El=45°.
A first prototype of actuator was realized in 1995 [2] enabling us to make experience on various aspects of the actuation. In 1999 the funding was available to start with the realization phase of the system and also to change the old panels with new ones of better manufacturing accuracy (0.1mm rms).

THE ACTUATOR AND THE ACTUATORS NETWORK

In order to achieve a very reliable device we avoid all is not strictly necessary in order to fulfil the wanted requirements. Maintenance reasons guided us to use motors without brushes and, in order to avoid the emission of interference signals generated by the motor controller/driver, the electronics was put in the actuator box. In this way long cables carrying switching signal are avoided.
Another constraint we faced was that the active surface system is implemented on an already erected antenna, so the actuator body is forced to have a fixed height in order to be inserted in the antenna structure frame.
The actuator is made by a moving part including a stepper 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 (fig. 2).

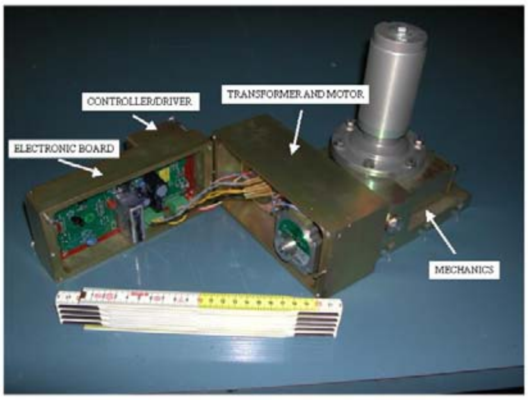

Fig. 2 The electromechanical actuator

Two connectors are provided, one input connector carrying the 48VAC supply and the RS485 communication line and an output connector that transfers these signals at the next actuator in the network. The electrical transformer secondaries allow, together with the dc circuitry in the electronics boards, to derive the dc power supply both for the controller and the driver. The step motor controller/driver is a commercial device, and it is mounted on the other side of the electronics box so that a thermal contact with the cover gives a good heat exchange, keeping the controller chip at less than 10^{o}C above the external temperature.
A lot of tests were performed on the prototype as well as on the final release actuator, such that loading test, environmental and temperature test, reliability test, communication test, and EMC test. These gaves us a strong feeling on the reliability and performance of the actuators.
The actuator is also provided with a simple system to check the eventuality the motor looses steps: a cam, mechanically connected to the motor shaft, passes in front of a photocell every motor round generating a pulse until the actuator reaches the position. The number of generated pulses and the commanded motor rounds are compared in order to check their matching. The following specification can be summarized:

Table 1. Actuator specification

Weight	8.5kg
Dimension	295x184x203mm
Stroke	13mm
Peak positioning accuracy	±0.015mm
Axial operating load	250kg
Radial operating load	100kg
Axial survival load	1000kg
Radial survival load	700kg
Speed	0.36mm/sec
Power supply	48VAC
Communication	RS485
Outside operating temperature range	-10^o ÷ 60^{o}C
Operating power consumption min/max	16/23VA
Stand by power consumption	4VA
Lifetime	20 years

All the 244 actuators were then connected together forming the actuator network to be mounted on the antenna. This network has been tested for some months before to proceed to the installation. The block diagram showing how the network is organized can be seen in fig. 3.
Each junction box has two input connectors, one for 220VAC and one for RS485, and 12 output connectors, each one routing both the 48VAC and RS485, merged in a same cable, to five actuators positioned along a radial line. Each radial line is arranged like a bus. The master computer has stored the "four corners" deformations vs elevation and manages the whole system issuing commands to the actuators. The commands must be regarded like "address + position".
The host computer, located in the control room, receive the antenna elevation from the antenna control computer and send it to the master. Moreover, the host computer runs the monitoring software which is devoted to check continuously the status of the network, and permits manual control of individual actuator. The monitoring software allows to start a zero procedure by means of which all actuators are commanded to a mechanical reference position clearing the step counter. Less than 30msec per actuator are required to address, command and receive back the status of the individual actuator. Fig. 4 is a picture of the computer panel commands showing the dish and the actuators location. To get the desired surface position it's not necessary to command all the actuators at the same time, but it is enough to command group of them in such a way the surface is recovered before the antenna commanded position is reached. For comparison, all actuators moving simultaneously should require a worst case power of 5.6KVA (244 x 23VA); it could be demonstrated that with a communication time of 50msec 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 power of 1.1KVA: this is a good advantage with respect to the power consumption and the size of an UPS unit.

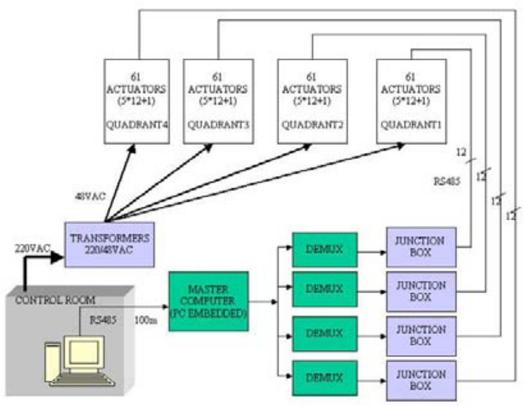

Fig. 3 Block diagram of the actuators network

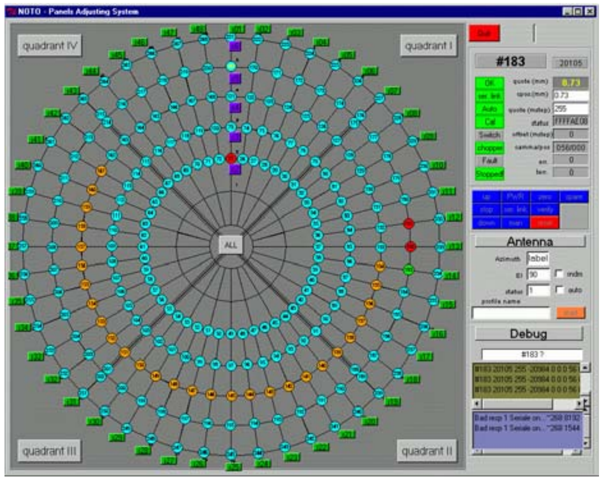

Fig. 4 Monitoring panel

ANTENNA ALIGNEMENTS AND PRELIMINARY RESULTS ABOUT THE ANTENNA EFFICIENCY

The alignement of panels and actuators made use of a theodolite and specific tools designed and constructed in house (fig. 5 and 6). The alignements was done with the antenna stowed at the zenith position. The actuator is regulated by three translations and one rotation in order to position a surface plate on the theoretical parabolic shape. This is done by two levels and an hollow corner cube mounted on a surface plate. The level guides the tilting whereas the corner cube, together with the theodolite, the translations. With respect to the ideal shape the translations are aligned within 1mm, the tilting within 20 arcmin.
After mounting all panels they have to be aligned on the nominal parabolic surface. By using the theodolite one panel corner of four is properly aligned (see the target in fig. 6) so it is regarded like a reference point to align the other three corners. These are put on the same plane and inclination of the reference by using four micrometers, one for each panel corner, two levelmeters, acting on two orthogonal coordinates, and a plane mirror sighted by the theodolite. The readings of the tools are done remotely. Once the primary reflector is aligned, readings at different elevations are done in order to refine the alignement and enabling us to get an rms value of the best fit parabola: nothing better of 180 microns was reached.

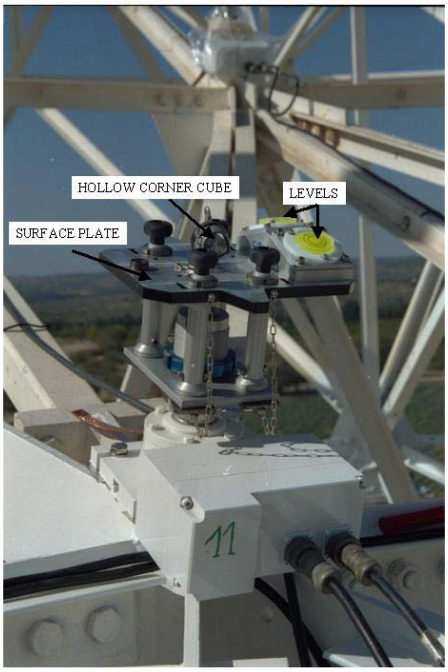

Fig. 5 Actuator alignement tool

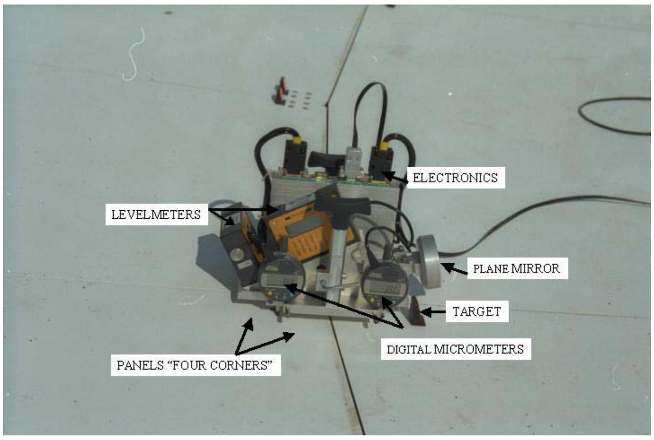

Fig. 6 "Four corners" panels alignement tool

Measurements on sky were then performed at 22GHz by pointing DR21. In fig. 7a and 7b a comparison of antenna efficiency with and without using the active surface system is showed and represents a first preliminary result.
The antenna gain was acquired maximizing the pointing for each elevation, optimizing the subreflector position at El=45^o and keeping it fixed at all elevations. The antenna efficiency was then calculated taking into account the atmosphere correction. The alignement residuals applied in fig. 7b were those ones measured at El=45^o, a more flat curve we will obtain applying direct measurements at the various elevations, above all at El < 45^o. In order to do that a photogrammetry measurement of the dish is programmed.

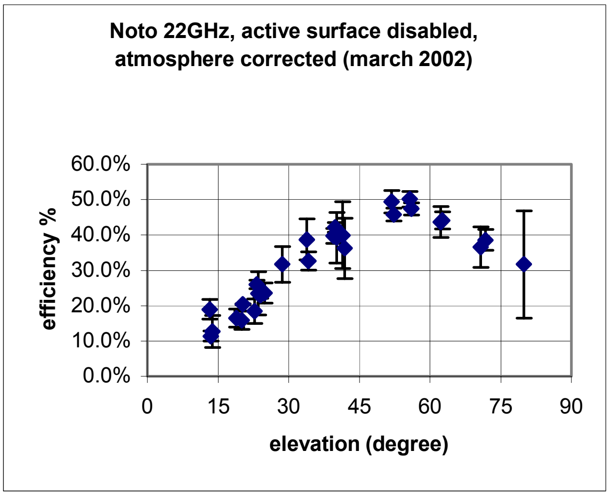

Fig. 7a Antenna efficiency without active surface

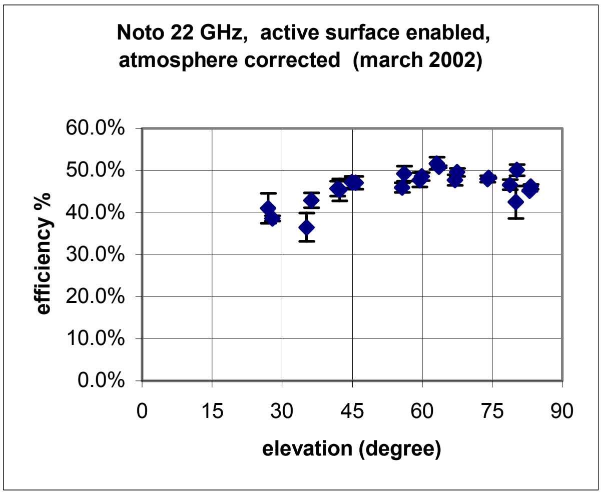

Fig. 7b Antenna efficiency with active surface

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