Control System and Tests for the 13.2-m RAEGE Antenna at Yebes

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Abstract The RAEGE network is being deployed. The antenna at the Yebes Observatory is the first one in the network, and its construction finished in October 2013. During the construction phase, the remote control system for the antenna and the receivers was developed, and during the commisioning time the software was tested by MT-Mechatronics. As a result, both the control system from MT-Mechatronics and the remote control system by the IGN-CDT were debugged. We have tested the basic functionality of the antenna operated as a single dish telescope. First light at S, X, and Ka band was achieved on February 10th. Afterwards a pointing model for the whole sky was determined, together with an optimum focus position as a function of elevation. Commisioning is not finished yet, and the antenna will be totally delivered to the IGN-CDT in the next weeks. VLBI equipment will be installed within three months, and VLBI observations are foreseen by the end of 2014. In this paper, we provide an overview of the control system and of the main results achieved.

Keywords Antennas, control software

1 Introduction

RAEGE stands for "Red Atlántica de Estaciones Geodinámicas y Espaciales" and refers to a network including four 13.2-m radio telescopes located in Yebes (Guadalajara, Spain), Santa María (Azores islands, Portugal), Flores (Azores islands, Portugal), and Tenerife (Canary islands, Spain). The telescopes will be equipped with receivers at 2, 8, and 30 GHz at a first stage and later will include a wideband receiver. These telescopes were designed by MT-Mechatronics and built by Asturfeito in northern Spain.

The Yebes antenna is the first antenna of the series, and its construction was finished by October 2013. During the construction time, the remote control system for the antenna and the receivers was developed, and during the commisioning time by MT-Mechatronics, the software was tested. As a result, both the control system from MT-Mechatronics and the remote control system by the Instituto Geográfico Nacional – Centro de Desarrollos Tecnológicos (IGN-CDT), at Yebes were debugged.

2 An Overview of the Control System

The Antenna Control Unit, hereafter ACU, is composed of two computers: one which is devoted for the control of the main axes and located in a container on the ground and close by the antenna and a second one which controls the secondary reflector mounted on a hexapod and is located inside the azimuth cabin. Both computers run a real time extension under Windows XP called TwinCAT (by Beckhoff). The antenna can be controlled manually, through a local control panel, and remotely.

The remote control and monitoring of the antenna is achieved using two TCP sockets: one for commands and a second one for monitoring. The specifications for the commands and the monitoring are summarized in a document called the Interface Control Document which was agreed upon by MT-Mechatronics and the

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IGN-CDT at Yebes. All commands are identified by a unique ID and provide an acknowledgement after being received. Although most of them are asynchronous, the acknowledgement provides information about the preprocessing of the command.

Commands allow tracking, superposition patterns on top of the tracking, and movements of the secondary reflector as a function of time and elevation. It is also possible to set the UTC and GST time and DUT1, move the antenna to any azimuth and elevation in the sky, stop it, and load a pointing model. The secondary reflector is operated using a hexapod device and can be positioned in space using six degrees of freedom. Tracking is achieved by sending tables with three columns: time, azimuth, and elevation or time, right ascension, and declination. If the latter mode is used, it is necessary to provide the GST and DUT1. Patterns are possible by loading a superposition table with three columns: time, azimuth offset, and elevation offsets. These patterns may be used to build pointing scans or position switch scans (on–off).

The ACU delivers the status of the antenna every 200 ms through a TCP socket on port 9001. The status is a structure composed of many variables which can be used to obtain a full view of the telescope, including any information regarding the last command sent and even diagnostics in case of malfunction. The timing of the ACU is obtained using an IRIG-B signal from a GPS receiver. The real time extension from Beckhoff guarantees that the time is kept locked to the UTC time provided by the GPS.

The remote control of the antenna, developed by the IGN-CDT personnel, uses ACS, ALMA Common Software, as the communication infrastructure. ACS is an open software framework used in the ALMA intereferometer and implemented by several telescopes in the world. ACS provides an implementation of the component/container paradigm via Common Object Request Broker Architecture (CORBA) and also provides general purpose utility libraries, hiding the complexity of CORBA to the developer.

A radio telescope is a distributed system in which individual components need to send and receive information to and from other components and keep synchronized with them. The ACS provides a powerful communication layer and a distributed component model with components implemented as CORBA objects. Each component exposes its public methods and variables to other components, which may be run in the same host or in different hosts. All communication is done in the Local Area Network. The deployment of components is highly flexible. Physical devices, such as receivers or auxiliary equipment, map into components, which have public and private methods. Public methods allow these devices to be controlled from third-party clients or by other components.

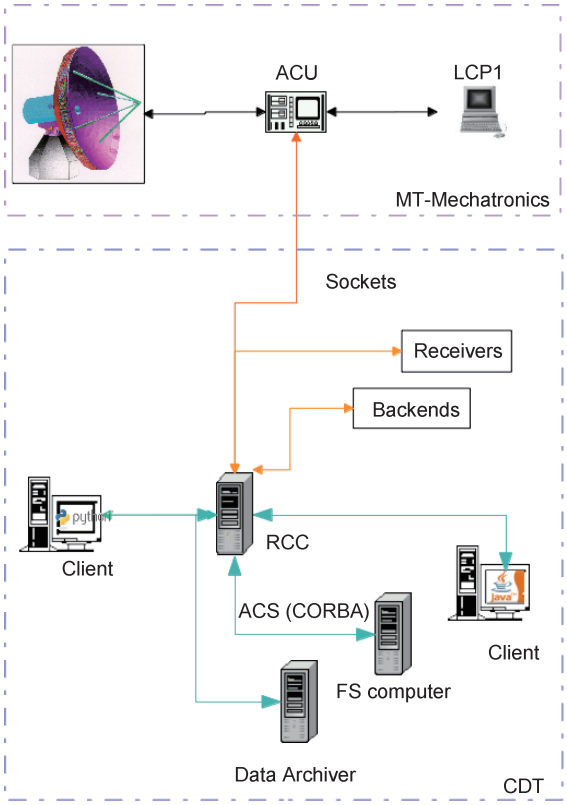

Fig. 1 Overview of the architecture.

Components are implemented using any of the following three programming languages: C++, Java, or Python. Usually C++ is reserved for components which require high speed. This is the case for the lowest level component which communicates with the ACU. IDL is reserved for declaring interfaces. Clients are usually written in Python or Java and can communicate with any component independently of the language in which it is written. All the control software runs on Debian Linux. The 13.2-m radio telescope uses two computers running Linux. Devices are available using embedded or standalone ethernet to serial converters. Receivers

use I2C and a PIC with firmware developed at the IGN-CDT which is addressable via Ethernet.

Our control system provides several monitoring tools, individual graphical applications, and a command line shell which allow full control of the telescope for single dish observations.

For VLBI observations, the communication between the Field System and the control system is done at the Field System computer through shared memory. A C++ component runs in the Field System computer and reads FS local and global variables from the shared memory area and, according to the content of those variables (of which some work as semaphores), commands the antenna and receivers. Information from the antenna is also written onto shared memory by this component so that it is available for the Field System in real time. This method is fast and easy to implement, but it requires that the Field System and the control system, including the ACS, use the same version of the operating system, Debian 6.0.9 ("Squeeze") at the time of this report. In order to decouple the requirements for the FS and the ACS, so that they work in independent computers, we plan to investigate alternatives such as XML-RPC or e-RemoteCtrl (Ettl et al., 2012).

A simple snapshot of the architecture is displayed in Figure 1.

3 Basic Tests

During the comissioning of the telescope and the development of the control software, we performed basic tests to verify the correct behavior of the antenna. These tests included measuring the maximum speed in azimuth and elevation for different position separations, pointing scans at several elevations and tracking of a radio source. The maximum measured azimuth and elevation speed is 12 degrees/second and 6 degrees/second respectively. Acceleration is 6 degrees/second^2. Figure 2 shows the measurement when moving the antenna from azimuth 225 degrees to 45 degrees.

Tracking measurements have also shown that under low wind (less than 4 m/s), tracking errors are below 4 arcseconds peak to peak during a time interval 30 seconds long (see Figure 3).

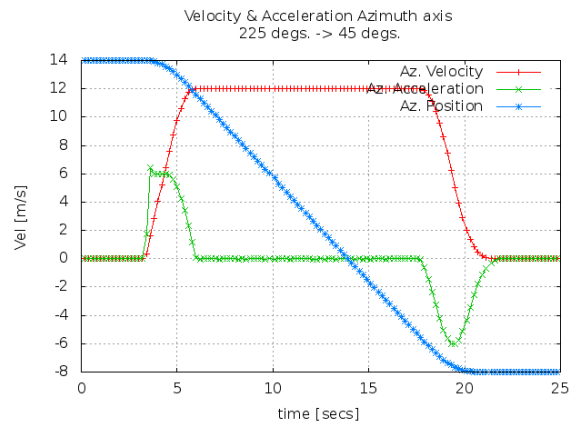

Fig. 2 Azimuth change, velocity, and acceleration versus slew time.

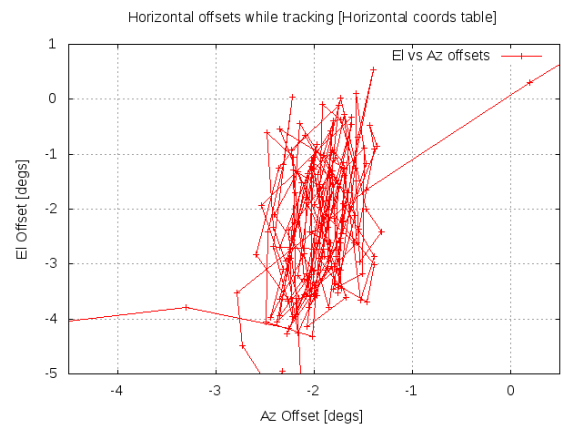

Fig. 3 Elevation versus azimuth while tracking a source for 30 seconds. Wind speed is 3 m/s.

Pointing scans at two different elevations show that the system performs as expected. The length of the horizontal arms depends on the elevation and results in equal arm length when using the source as the center of the reference system. Figure 4 shows the position of the antenna during a pointing scan composed of one azimuth drift and one elevation drift at 52 degrees elevation. It is important to distinguish between azimuth offsets in the encoder reference system and azimuth offsets in the sky, also known as "azimuth collimation" at some telescopes.

Once these basic tests were accomplished, more complex observations were performed. In particular, first light was achieved on February 2014 towards the sun at X band with a warm receiver. Figure 5 shows a

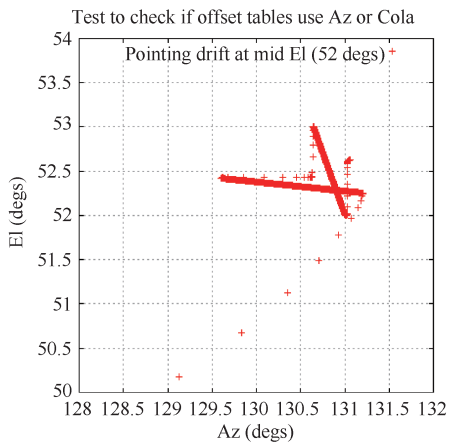

Fig. 4 Pointing scan composed of an azimuth and elevation drift. The azimuth arm is larger than the elevation one, but both have the same length in the sky, when taking the source as the center of the reference system.

pointing drift towards the Sun at S-, X-, and Ka-band under those conditions.

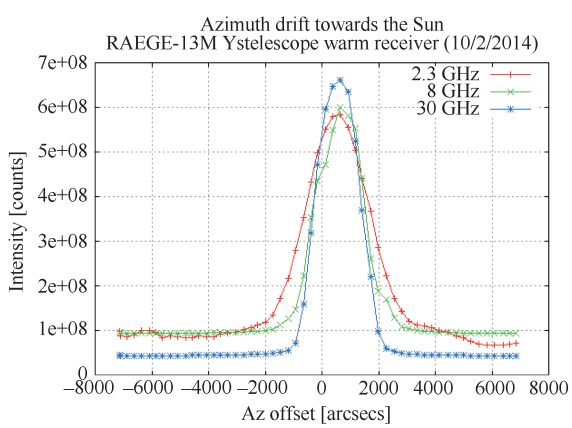

Fig. 5 First azimuth drifts towards the Sun at S-, X-, and Ka-band. The receiver was uncooled.

Later observations have been performed towards Cas A and Tau A with a cooled receiver to estimate the G/T, gain, and SEFD of the telescope. We have also determined a pointing model of the whole sky and optimized the focus position of the antenna in the X, Y, and Z axes.

We estimate an aperture efficiency of 50% and an SEFD of 1300 Jy at X-band. G/T is 43.2 dB/K at X-band. The determination of the gain and SEFD at S band has some uncertainties due to the presence of strong RFI in the band. Ka-band calibration is still preliminary, and some hardware changes are required.

4 Conclusions

The 13.2-m RAEGE antenna will be fully delivered from MT-Mechatronics in summer 2014. During the commissioning time, we debugged part of the MT-Mechatronics software and IGN-CDT remote control system, and as a result, the antenna is fully operational. Small hardware modifications are still pending. The antenna is equipped with a three band receiver, and single dish observations have already been performed. As a result, we already have a pointing model for the sky and an optimum position for the secondary reflector. During VLBI observations, the secondary will be locked to a fixed position. Gain observations are on the way and will be ready in the next month.

The VLBI backend, a DBBC plus a Mark 5B+, will be installed within three months, and VLBI observations are foreseen by the end of 2014.

Acknowledgements

The first light of the 13.2-m radio telescope is the result of the work of the engineers and technicians of IGN-CDT at Yebes, who have performed an excellent job. Without their work, this success would not have been possible.

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