

RADIO-TELESCOPE RT-16 CONTROL SYSTEM

Gatis Gaigals, Inese Lībiete, Dmitrijs Bezrukovs, Normunds Jēkabsons

Engineering Research Institute "Ventspils International Radio Astronomy Centre"
of Ventspils University College, Inženieru 101, Ventspils, LV-3601, LATVIA

In article in short are described radiotelescope RT-16 construction, mechanisms and available working equipment for development of antenna control system. More detailed are described changes in power supply and motor feed, shown current motor feed and control system hardware connection schematics. In detail is described and shown developed control system structure and purpose of functional blocks.

As a result of work radiotelescope RT-16 is now in operating state equipped with new modern control system. First successful observations are made.

Key words: RT-32, RT-16, radio-telescope, NASA Field System, VLBI.

1. INTRODUCTION

Till recent time Engineering Research Institute "Ventspils International Radio Astronomy Centre" of Ventspils University College (VIRAC) in Irbene (Latvia) for radioastronomic observations and related research did use radiotelescope RT-32 which is good condition and operating state 32 m parabolic antenna. Currently it is used for all research areas: very long basis radio astronomy (VLBI), ionospheric research, geodesy, space debris and solar observations. In 2013 VIRAC is planning to launch first Latvian satellite "Venta-1". As there is need to ensure receiving signals as backup ground station from "Venta-1" and because RT-32 radioastronomic research load is increasing, it was clear, that for some tasks smaller radiotelescope will be better suited. Luckily, in territory of VIRAC in Irbene for applications is available one more similar construction radiotelescope – the RT-16 which is 16 m parabolic antenna and which from early 1990s till last year was in non operating state. In 2009 VIRAC started the European Social Funds (ESF) Attraction of Human Resources to Science, the project Nr. 2009/0231/IDP/1.1.1.2.0/09/APIA/VIAA/151 "Technologies for receiving, transmitting and processing the signals related to artificial Earth satellites". Beside other in project planned objectives, there was planned to prepare RT-16 for radioastronomic observations, in particularly, for ionospheric research and, if there will be need, for satellite signal receiving.

Most challenging task in preparation of RT-16 for radioastronomic observations was development of control system (CS) for RT-16 taking in account current implementation of CS for RT-32 and the fact that there was no documentation for any RT-16 equipment, cabling, device or construction.

2. DESCRIPTION OF FACILITIES

2.1. Support construction and mechanisms

Support construction and mechanisms are well described in (Bezrukov 2011). Only short description here is present to show overall picture.

A special reinforced concrete tower is created around all mechanisms and equipment – in opposite, for example, well known 100 m Effelsberg telescope (Grahl 1973), RT-16 (and RT-32 too) in Irbene is

not open type. Originally power supply and motor feed equipment were deployed in basement, while central room on 1st stage was used to deploy control equipment.

Transmission of RT-16 has gear-boxes with two motors (larger and smaller) attached at each main rotation axle: larger motors are used for fast antenna movement during the tracking target change, smaller – to follow the target in the sky. Each gear-box has two exit axles as part of simple mechanical backlash compensation mechanism; tension between axles depends from wind speed.

2.2. Power supply and motor feed

Originally on RT-16 amplidyne technology was used to feed the motors. The amplidynes itself were controlled by differential amplifiers based on vacuum tube technology. During the research, development and renovation amplidynes were replaced with DC converters (SIEMENS SIMOREG), but only for smaller motors. Larger motors currently are not used because currently there is no need for such fast antenna movement which can ensure larger motors. To control DC converters there are at least two different remote control variants: Ethernet via help of additional communication extension board or the built-in front panel G-SST1 interface.

2.3. Sensors and transducers

Originally on RT-16 there were many sensor systems for speed and position control. In working condition currently are tachogenerators for speed control, optical position sensors RS-50 for angular position control and transducer system.

At RT-16 there are six tachogenerator boxes, each box contains two tachogenerators with common output axle. Tachogenerators are placed directly on motor axles and on each movement axle exit before backlash compensation mechanism. Signals of motor axle tachogenerators as speed feedback are connected to DC converters.

At RT-16 there are four optical position sensors RS-50 – a couple for each movement direction. They input axles are connected to antenna main axles with a 1:4 gear-boxes. On output RS-50 has 14 bits binary negative logic Gray code.

Horizontal movement transducers consists from end position switches (three at each end position), sector switches and horizontal movement speed limit switch, which can be used to slow down antennas movement short before reaching movement end position.

Vertical movement transducers consists from end position switches (four at each end position) and 90⁰ elevation switch, which is used to show to the operator the position when it is safe to fix the antenna in vertical position with help of special rod.

3. RESULTS AND DISCUSSION

3.1. Support construction and mechanisms

During investigation of RT-16 detailed construction and mechanics drawings were created to form documentation and to ease maintenance. Drawings examples are shown in (Bezrukov 2011).

3.2. Power supply and motor feed

During investigation of RT-16 detailed power supply and signal cabling schematics were created to form documentation and to ease CS development and debugging. Schematics examples are shown in (Bezrukov 2011).

Early experiments with both vertical and horizontal movement motors were made with scheme of motor control shown in Fig. 1 (Bezrukov 2011).

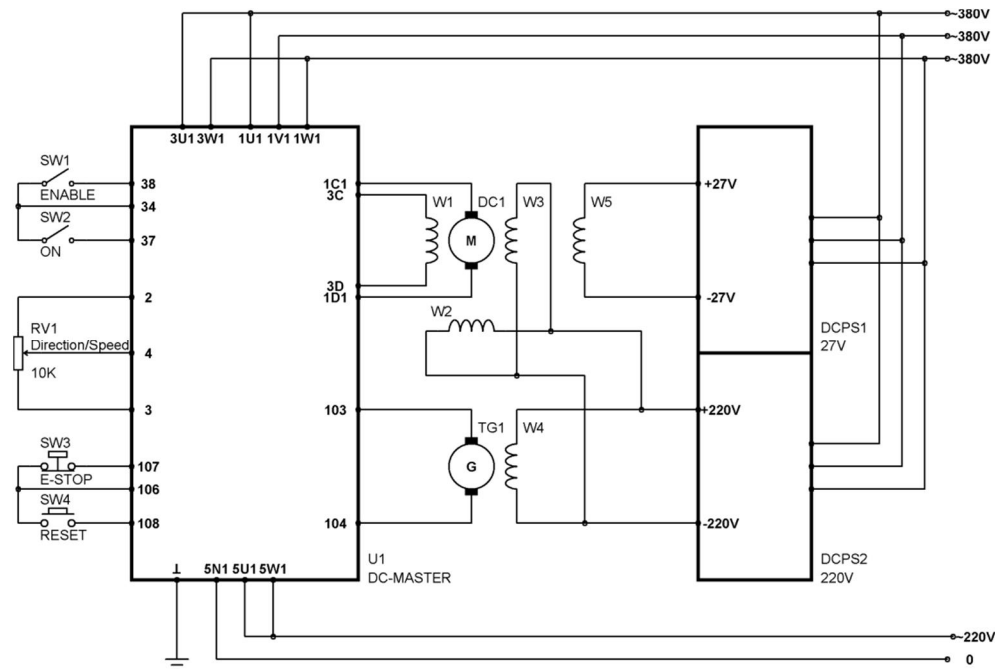


Fig. 1. Schematic of motor control during early experiments:

- U1 – DC converter; DC1 – DC motor; G1 – tachogenerator attached to DC1;
- W1 – excitation winding of DC1; W2 – winding for main electromagnetic brake of the gearbox;
- W3 – DC1 brake reset winding; W4 – excitation winding of TG1;
- W5 – winding for gearbox electromagnetic clutch of DC1; SW1 – “Enable operate” switch;
- SW2 – “On/Off” switch; SW3 – “E-Stop” loop push-button; SW4 – DC converter reset push-button;
- RV1 – potentiometer for setting the motor rotation direction and speed;
- DCPS1 – 27 V DC power supply; DCPS2 – 220 V DC power supply.

During research and tests was found that there is no need for quite powerful stabilised 220 V DC power source DCPS2 as it was originally. It was replaced with two power sources: one small power stabilised 220 V DC power source for tachogenerator exciting windings, second – unstabilised 185V DC power source for main electromagnetic brake and motor brake reset windings. After upgrading analogue tachogenerators to digital encoders, 220 V DC power source can be removed from system. Currently used improved schematic of motor control is shown in Fig. 2 (power chokes and RF filters are omitted). As seen in Fig. 2, a safety loop was added to avoid damages to staff and antenna. Safety loop for each movement direction is created by serial connection of normally closed end position switches and circuit breaker safety push-buttons. To ensure operation in manual and automatic (computer control) modes, an operation mode switch SW5 was added to schematic.

DC converters were programmed to ensure appropriate working and to provide remote control via built-in G-SST1 interface and USS protocol. Built-in G-SST1 as remote control interface was chosen not only because it is less expensive in implementation, but because serial interface makes less interference to received signals.

For radioastronomic observations very important is to reduce overall electromagnetic (EM) noise from any electric equipment, but DC converters are very noisy. Because EM interference from motors feed or power supply wiring is hard to plan, DC converters are placed in metal cabinet and all power and motor feed shielded cables are fitted with chokes and RF filters.

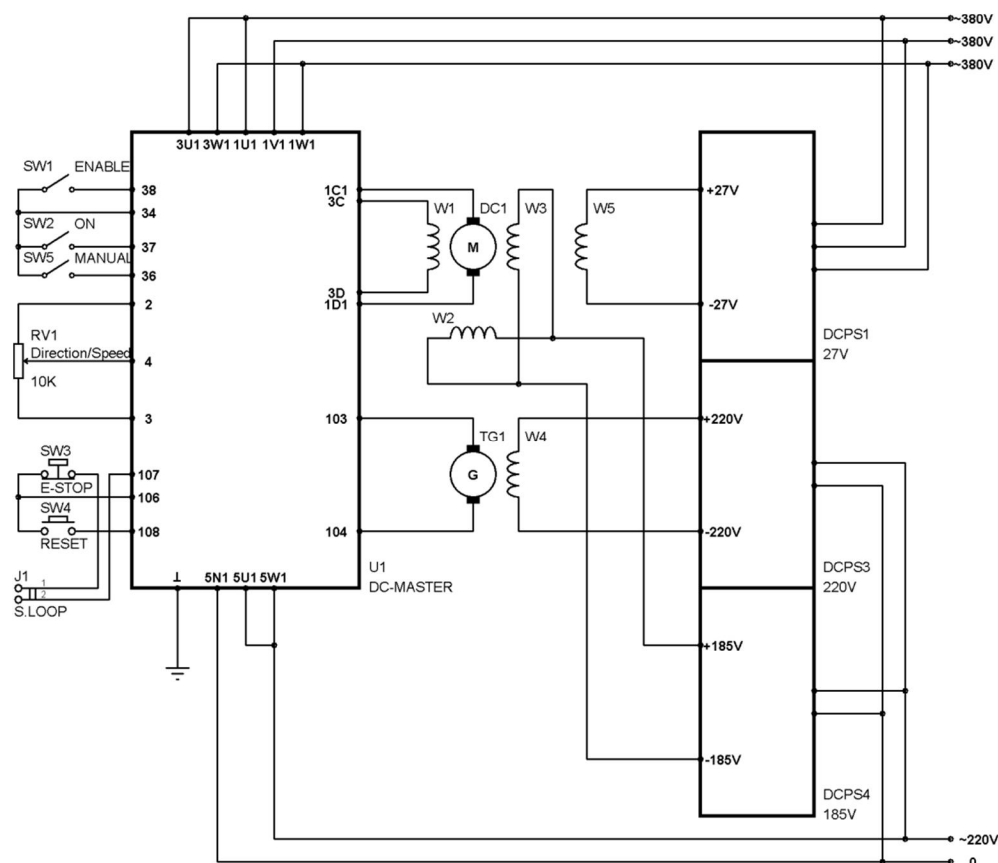


Fig. 2. Simplified current schematic of motor control:

SW4 – DC converter working mode switch; J1 – safety loop connector; DCPS3 – 220 V DC power supply; DCPS4 – 185 V DC power supply.

3.3. CS hardware

3.3.1. Sensors back-end

As sensors back-end two different self-made boards were developed and made. One board is *Atmel* microcontroller based board with USB interface; second one is simple multiplexer board with parallel interface. Both computer-connected sensor back-end boards are connected to sensors and transducers via optocouplers. Both boards can be used in same time to make sensors back-end redundant.

Atmel microcontroller board as single board for optical sensor reading was developed first. During it debugging was found, that more reliable system should consist of simple interconnection board with connectors for unified modules. Unification of modules will allow exchange them between different boards and create different configurations of sensor back-ends. Second version of Atmel microcontroller board currently is in development.

More simple multiplexer board was developed because during experiments was found that USB interface realisation on standard PCs is not stable enough. But on modern computers a special parallel interface card should be added since nowadays PCs normally do not have parallel interface. After installing RF filters USB communication come stable.

3.3.2. Human front-end

As human front-end an ordinary PC is used. That allows reducing of front-end costs, simplifies development of antenna CS software and ensures remote control of human front-end hardware on demand. On control PC a Linux based OS is installed – a Debian OS with pseudo real-time kernel extension. To control DC converters via RS-232 and USS protocol a PC with a couple of serial interfaces is taken.

During experiments was found that for improved overall system stability optical isolation of serial interfaces is preferable. Schematic of CS implementation hardware connections is shown in Fig. 3.

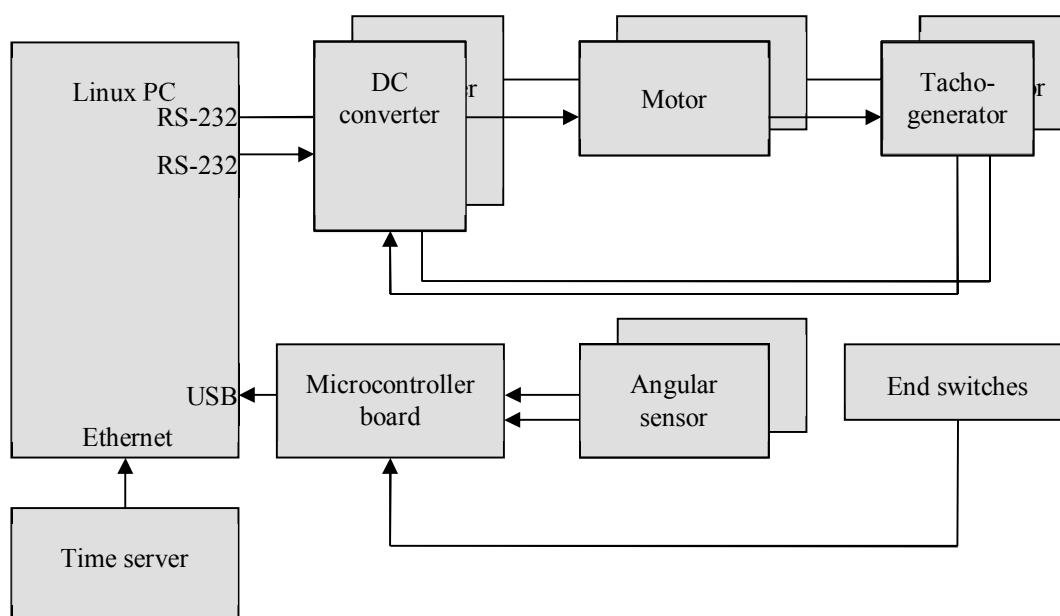


Fig. 3. Schematic of CS implementation hardware connections.

3.4. CS software

RT-16 CS software (called *rt16main*) is based on one used at RT-32 but is made more modular to allow implement new functionality – it is an attempt to create a universal control software which could be easily expandable for use in wide variety of radio astronomical observations. Structure diagram of *rt16main* is shown in Fig. 4.

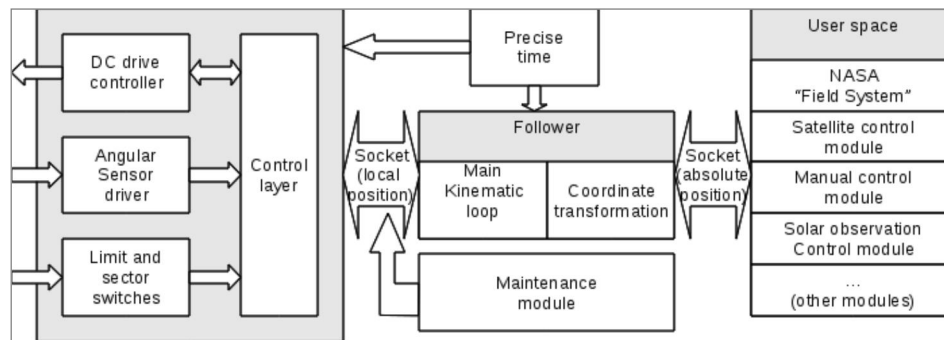


Fig. 4. Structure of *rt16main*.

As seen from Fig. 4, *rt16main* is divided into separate blocks. Each block represents CS layer with its own purpose. Two near layers communicate via TCP/IP socket; each module can be executed with its own priority. There are:

- local hardware control (LHC) layer;
- astronomical calculations (AC) layer;
- user space (US) layer.

Such server-client approach allows not only ease system maintenance but also provides easy client implementation of other software packages (particularly, automated control through standard VLBI software NASA “Field System”) and remote connection of clients for control or maintenance.

Precise time module shown in Fig. 4 is not middle layer application – it is a GPS precise time server to ensure operation of LHC and AC layers in real time. Maintenance module is special exception – it is planned for testing and development purposes and can connect to any layer software.

3.4.1. LHC layer

LHC software contains locally available hardware drivers: microcontroller board, parallel interface board and DC converters connectivity code. This layer reads sensor data and delivers data to middle layer; it receives DC converters control data and delivers data to DC converters. Drivers do not make any calculations; they only convert data from local hardware interface specific representation to *C* data types and *vice versa*.

In overall following data is transmitted to AC layer:

- antenna pointing angular coordinates in antenna angular sensor RS-50 units;
- transducers data;
- actual speed of motors;
- actual working parameters of motors.

To avoid damages to antenna, there is functionality to check angular sensors returned coordinates against limits set in software – so called soft limits functionality in opposite E-stop functionality realized by DC converters and safety loops.

Currently *rt16main* LHC layer is developed and runs in testing mode.

3.4.2. AC layer

AC layer is made by two modules:

- astronomical module;
- motor control module.
- At each loop the astronomical module performs the calculations of the antenna coordinates and angular speeds based on instant antenna angular motion and known geographical coordinates of the radiotelescope in following steps:
 - calculations of apparent equatorial coordinates at the current epoch are performed taking into account the precession, the nutation and the aberration;
 - apparent equatorial coordinates are transformed to local topocentric horizontal coordinates with a following coordinate correction taking into account the refraction and RT-16 pointing model parameters;
 - antenna pointing coordinates and angular speeds for motor control module are calculated.
- The drive control module is controlling the DC converters. A two closed feedback loops – one for the angle and other for the angular speed are implemented in software for both of axles. At each software loop:
 - on input module receives:
 - current position and angular speeds from LHC layer;
 - calculated antenna position and calculated angular velocity from astronomical module;
 - module calculates output data for DC converters using preset PID control model.

Currently *rt16main* AC layer is transferred from RT-32 to RT-16 adding TCP/IP connectivity.

3.4.3. US layer

User space programs do whole experiment control operating as client for AC layer. The NASA Field System (FS) can be one of such a user space programs example.

The FS main structure consists of different software modules communicating with each other through shared memory (Fig. 5.). Modular design of FS provides several features that are useful for adapting or customizing it for a particular station. The most fundamental of these is that it is organized into station independent and station dependent parts.

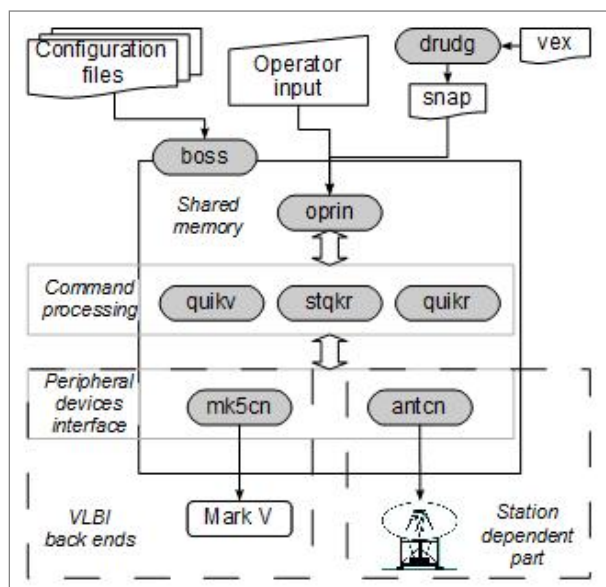


Fig. 5. FS structure.

The station-independent part of code provides the basic FS operation and support for the VLBI back-ends, like *mk5cn* module for automated MarkV control during observation sessions.

The station-dependent modules can be customized to support different hardware and antenna interface that is present in the particular site. Most important is antenna control module (*antcn*), which is the customizable module, used for data passing between FS and existing antenna drive system controller. In order to operate RT-16 under control of FS a site-dependent *antcn* module had to develop.

The design of the *antcn* program code is such that once it is properly implemented at a station, the antenna has certain standard features from the FS point of view. Once these features exist, control of the antenna from a schedule and for pointing and sensitivity measurements can be carried out in a station independent fashion (Himwich 1993).

The Field System interacts with *antcn* by scheduling it in different modes, determined by the first "run parameter". The possible modes are:

- 0 - Initialization;
- 1 - New Source Request;
- 2 - New Offset Request;
- 3 - On-source Status With Error Logging;
- 4 - Direct Antenna Communication;
- 5 - On-source Status Without Error Logging;
- 6 - Reserved for Field System Focus Control;
- 7 - Additional Information Logging;
- 8-99 - Reserved for Future Use;

- 100-32767 - Available for Site Specific Functions.

Considering the requirements of FS (Himwich 2001) a US layer client module that translates instructions of FS to RT-16 (and *vice versa*) is made. Currently are implemented all important *antenn* run modes 0, 1, 2, 3, 4, 5, 7. Other US layer modules can be written in similar way.

3.5. Test observations

As AC layer is not finished yet, it is possible to point RT-16 only to fixed coordinates in sky. To check out overall system state and currently written code, in 21/11/2012 were made observations of GPS satellites in transient mode. Experiments were successful and signals from GPS satellites were observed (Fig. 6.).



Fig. 6. Received GPS satellite down-converted signals in transient mode:
on left – before entering RT-16 antenna pointing maximum;
on right – entering RT-16 antenna pointing maximum.

4. CONCLUSION

1. During investigation of RT-16 detailed documentation is formed containing construction and mechanics drawings, power supply and signal cabling schematics, maintenance and repair related information.
2. At RT-16 available sensor and transducer system is researched to form prerequisites for control system (CS) development.
3. Two different sensor back-end boards developed and made, upgraded version of unified microcontroller based board is in development. Unified optoisolator boards are developed and made to ensure decoupled connection of transducers and optical sensors to CS back-end.
4. DC converters are programmed to ensure appropriate working and control using their front panel RS-232 interface and USS protocol.
5. On a regular PC as CS human front-end a Debian OS is installed and kernel is patched to ensure real-time software support.

6. Three layers universal modular client-server type CS software is developed to ease different hardware control and different user application implementation. US layer application – a NASA FS *antenn* module is done, LHC layer software is under tests, AC layer software translation from RT-32 to RT-16 and upgrade has to be finished.
7. Successful observations in transient mode of GPS satellite were made using RT-16 under control of developed control system.

Acknowledgements

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