Institute of Applied Astronomy
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Receiver module Power, Control and Monitoring system for RT-32 and RT-13 radio telescopes

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Introduction

IAA RAS accumulated a decades of experience of developing, using and repairing radio astronomical receivers of RT-32 radio telescopes. Analyzing this experience gave us some ideas how to enhance Power, Control and Monitoring of radio astronomical receivers. These ideas were implemented during several cycles of modernization of RT-32 receivers. In last years these ideas proved their effectiveness.

Base principles

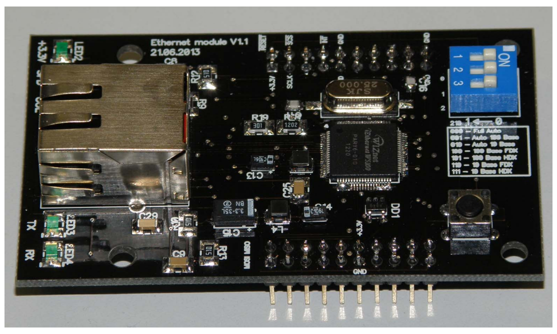
- Data interchange via Ethernet. (Given proper screening and cables – no RFI.)
- The more we know – the better. (All key parameters such as voltages, currents, temperatures, pressures must be measured at key points.)
- Remote control and remote monitoring.

Ethernet

- Provides data interchange.
- Easy, cheap, reliable, trustworthy, lots of software and hardware.

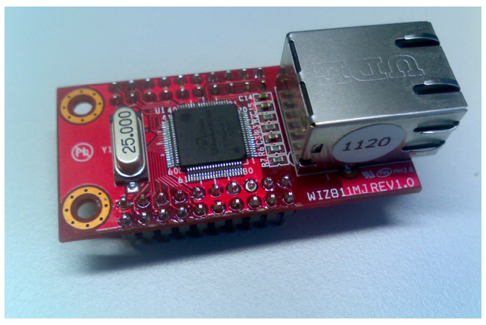
Versatile Ethernet module based on W5100 was developed.

IAA RAS v1.1



- SPI only
- **Manual**/auto 10/100 BASE FDX/HDX
- Tx, Rx, FDX, Link, COL, SPD LEDs

Wiznet WIZ811MJ Rev1.0



- SPI, direct, indirect
- **Auto** 10/100 BASE FDX/HDX
- FDX, Link LEDs

Compared to Wiznet WIZ811 factory assembled module we sacrificed high speed interfaces. High speeds produce more dangerous high frequency RFI. Control and monitoring requires low speeds. In order to minimize RFI we used manual speed control. If in AUTO mode RFI is a problem there is a possibility to manually switch to lower speed. A number of signal LEDs was installed to make network diagnostics easier. PCB design includes special features to reduce RFI.

Sensors

- We used our experience with RT-32 radio telescope receivers to determine key parameters and key points in receiver circuits.
- All sensor circuits designed to make minimal or no impact to circuit measured.
- Sensor sensitivity must be enough to detect changes which will affect the receiver performance.

During modernization of S/X receivers of RT-32 radio telescope special high-sensitivity current and voltage sensors were introduced to LNA power sources. These proved themselves as very effective tools for LNA diagnostics. LNA failure often results in noticeable change in it's current consumption. The most important that we could determine LNA failure almost in no time what provides faster repair.

RT-13 receivers also incorporates similar sensors, but such a sensors are placed in almost all circuits. This allows us detect failures in receiver units and even failures of critical parts within receiver unit, LO for example.

Remote control

Remote control not only allows operator to control receiver module from control building in order to carry out routine checks and observations. It also allows specialist at IAA conduct experiments targeted to find what failure happened to receiver unit or study receiver behavior under some circumstances. This possibility is real time and money saver. Specialist can determine failure without taking time and money to travel to observatory. Sometimes local stuff only need instructions how to repair. But even in the case if specialist involvement is necessary he goes to observatory totally prepared, with all parts and equipment needed.

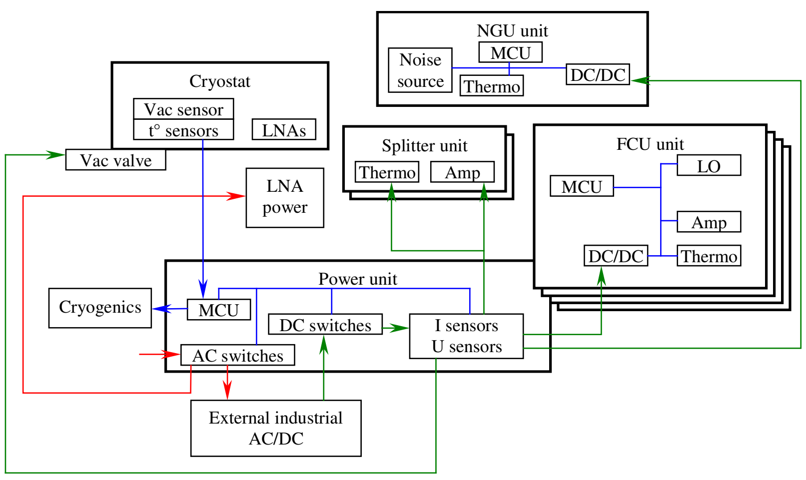
All control software and hardware are automation-friendly. Virtually, there is a possibility that radio telescope can operate unmanned for some time. Some failures can be detected automatically and people responsible alerted.

Monitoring

Some hardware failures not just happen instantly. They developing for some time allowing to predict future failure and replace or repair hardware before it fails.

We have developed software tools that store data from receiver module's sensors into log files. Analyzing these log files allow us to predict some failures of receiver module equipment. Also it allows us to improve receiver itself by better understanding its characteristics under different environmental factors.

PCM - Power, Control and Monitoring system design



The picture above shows block diagram of newest UWB (Ultra Wide Band) VLBI2010 compatible receiver module for RT-13 radio telescopes. This receiver module incorporates 8 sub-receivers. Each one can be tuned individually to sub-band in H (4 receivers) and V (4 receivers) polarization.

Each receiver unit contains PCM board with low frequency MCU. This MCU controls all unit's circuits, DC/DC converters, switches, thermostats, etc. There are number of different voltage, current and other sensors. All data are gathered to MCU memory via I^2C bus. Versatile Ethernet module provides communication with control and monitoring software running at MRCC (Main Radio telescope Control Computer).

All units are powered with 24V voltage from single industrial AC/DC converter. Each unit can be powered separately with dedicated smart switch. Each power line has sensors for voltage and current. In order to produce voltages and currents powering devices inside receiver unit DC/DC converters used. Critical voltages and currents also measured, for example LO and amplifiers. Digitally controlled via I^2C bus UHF attenuators are widely used. Sensitive UHF circuits enclosed in digitally controlled thermostats.

Great flexibility of power system allows us to switch off some parts of receiver we don't need at the moment. This not only saves energy, but also decreases equipment heating and prolongs its lifetime.

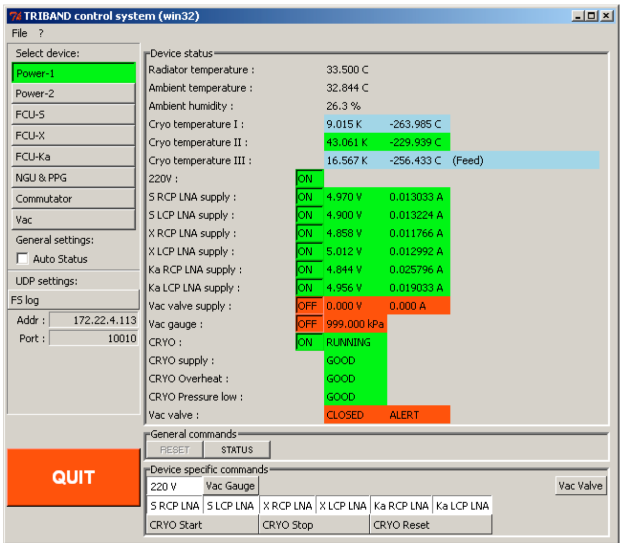
MCU Software

Each receiver unit has low speed Atmel AVR MCU. The choice is dictated by low RFI level and high reliability. Firmware is developed using AVR Assembler. Careful programming and interrupt management provides fast and reliable operation. Most data from sensors transferred raw and calculations done at MRCC. MCU performs calculations needed for unit functioning only.

Data interchange protocol

A UDP-based data interchange protocol is developed. It provides fail safe reliable data transfer. A datagram incorporates field for instruction code followed by 4 byte data field. The protocol developed is versatile enough to fit requirements for any receiver unit of RT-13 and RT-32 radio telescopes and simple enough to be easily programmed for MCUs.

MRCC Software

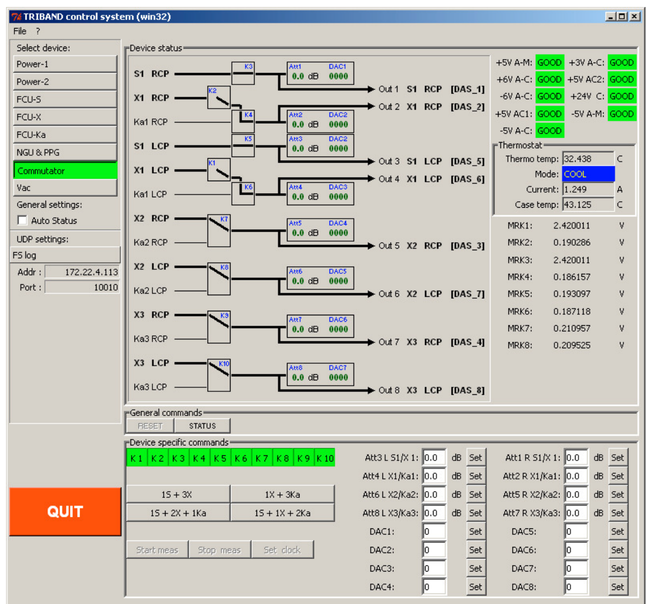


Graphic interface software developed using Python 2.7 and TkInter 8.3 extension.

Software implements "user friendly" concept. Flexibly adjustable color alerts are widely used. It helps operator to rapidly recognize failures. Thresholds for different colors are easily programmed by changing values in dedicated configuration file. Moreover some default values can be programmed, for example, typical PCal attenuator level.

Color indicators also used to help maintain technological cycles (see left). For example cryogenics must be started when certain pressure is archived in cryostat chamber by vacuum pump. When this pressure is archived the background color of pressure indicator turns from red to yellow. When cryostat chamber is vacuumed enough pressure indicator color turns green and this means that vacuum valve should be closed and vacuum pump should be stopped.

There are software limitations programmed and potentially harmful actions can't be done without confirmation.



Interactive graphic representation of receiver block diagram is used to help user understand current configuration. Particulary, picture at the right represents interface window for Commutator unit of Triband S/X/Ka receiver module. This unit also incorporates secondary radiometric DAS, which provides us with alternative tool to measure T_{sys} and other key parameters of receivers. An algorithm was developed which represent current connections in "block diagram" style. This is very helpful during diagnostic experiments carried out in order to determine what part of the single receiver failed.

Current version of control and monitoring software is engineer-targeted. This means there are lots of functions, lots of parameters to change, lots of indicators. This situation can cause complications during observations and routine checks done by operator due to confusion. To eliminate this we plan to separate engineer and operator versions of interface program. Engineer version is to be password protected and allows full access to all functions with low safety limitations. This version targeted to complex diagnostic and scientific research. Operator version is simplified, highly safe, designed for observations and routine receiver measurements. Operator version also will be highly automated, capable to perform some technological or maintenance cycles in unmanned mode.

Conclusion

Power Control and Monitoring system developed provides power, control and monitoring functions for carrying out radio astronomical observations, routine checks, telemetry and monitoring. Sensors sensitivity and placement allows to use PCM system as powerful scientific tool to research receiver characteristics and improving performance of RT-13 and RT-32 radio telescopes. Power Control and Monitoring system provides great possibilities for automation, unmanned operation and predicting failures.