<u>EISCAT's High Power HF radar</u>

Technical description and user instructions

MTR, 20190805

This describes the hardware and software used to operate the high power HF radar as of about 2016, using Array-3 as an array of 12 receiving antennas, and one or more transmitters in Array-1 for transmission. The physical frequency range is thereby limited to 5.4 to 8.0 MHz. The 12 receiving antennas on Array-3 are the 6 east-west-aligned rows of 6 crossed full wave dipoles. The 12 specially-modified coaxial switches (S23 which is the name used in various documentation figures and on the cables used to control these switches) have an N-connector output connected to the inner conductor from Array-3 whenever that switch is in the position connecting the transmitter to Array-2. See the document '**TRswitch_instructions.odt**' and .pdf on how the coaxial switch was modified.

Twelve equal length (ca. 70m) RG213 coaxial cables connect each S23 Rx/Tx switch output to the receiver hardware inside the transmitter hall, on the south wall between Tx1 and Tx3. After passing through some isolating coaxial relays (isolator), pin-diode receiver protector switches (RxProt) and low pass (LP) filters, the signal goes to 6 USRP-200N receivers, each of which has two input

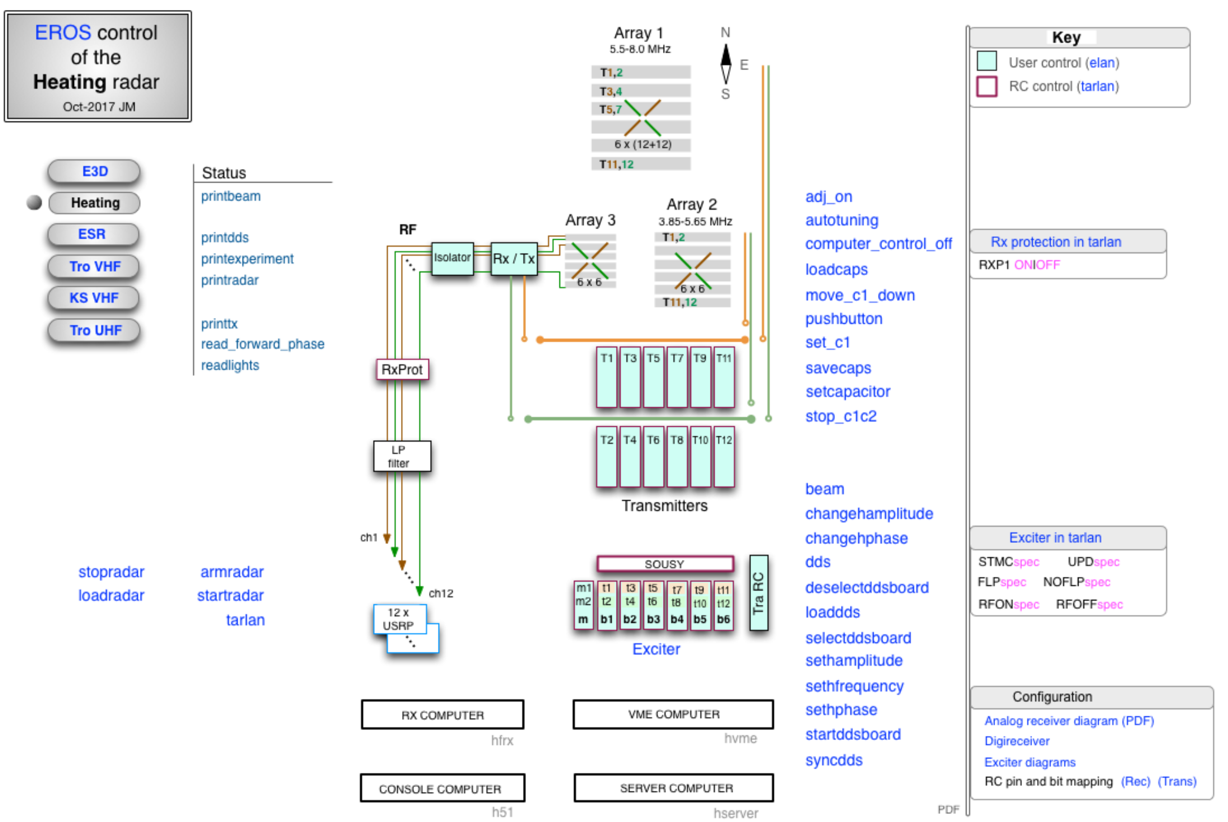


Figure 1 Schematic diagram of the Heating system, showing some of the EROS commands used to control various parts of the hardware (from http://www.sgo.fi/~jussi/eiscat/erosdoc/index.html)

channels RF1 and RF2, giving 12 channels. Fig.1 (from Jussi Markkanen) shows these items schematically. The rest of the hardware in the transmitter hall is shown in Figure 2.

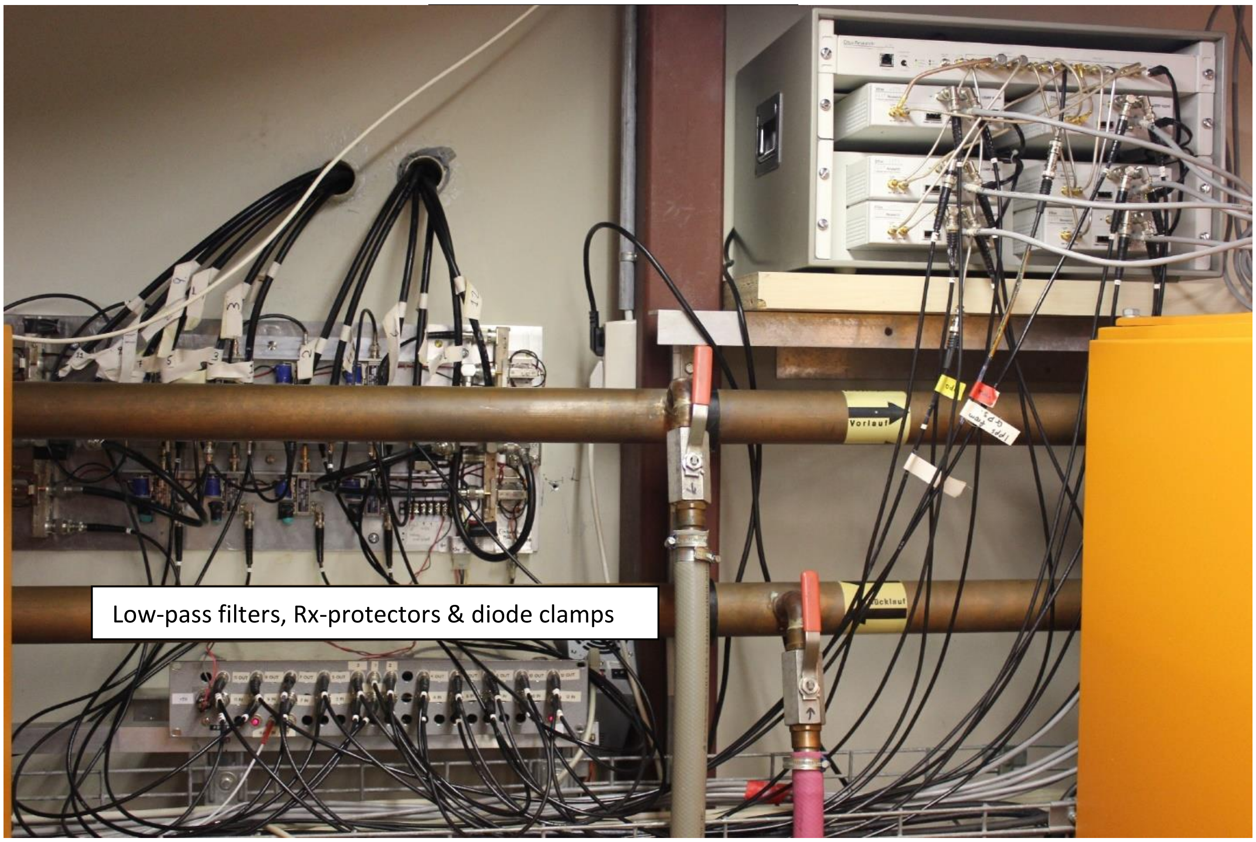


Figure 2 Receiver hardware: Rx-isolator, Rx-protector, and USRP receivers on south wall of transmitter hall, between Tx1 and Tx3.

Several protective measures have been built into the system, to ensure that the USRP receivers and associated hardware are not damaged by too high HF radio wave levels from the heating transmitters. First there are the modified **Tx/Rx coaxial switches** which make the connection to the inner conductor of the 10cm aluminium coax to/from Array-3 only when the connection from the transmitter is made to Array-2. However, transmission on Array-2 during the radar operation are not desirable because that array is so close to Array-3 that the RF levels are very high, and furthermore they are mostly on the wrong frequency range for radar use. So there is an interlock system which disconnects the receiving antennas from the receiver system, called the **receiver isolator**, whenever any transmitter is not connected to array-1. This system is a set of 12 coaxial relays mounted on a plate on the wall of the transmitter hall where the RG213 cables come in (see Fig.2).

The individual items and their controls are now described individually in more detail.

<u>Slow Tx/Rx coaxial switches</u>

See the document '**TRswitch_instructions.odt**' and .pdf on how the original coaxial switch was modified to provide a receiver signal.

These switches are under pushbutton control. The Eros command for transmitter 1 is:
pushbutton t1 a3 (or a2 or a1). When the transmitter is not connected to a3, the receiver port is automatically connected to that antenna row. Fig. 3 shows one of the coaxial switches, with the N-connector for the receiver output.

Receiver Isolator coaxial relays

All 12 isolator relays receive a common enable/disable signal. The function is to isolate all the antenna rows from the receiver whenever any transmitter is not connected to array-1. The interlock logic is done by a hardware modification in the 'coax-Zentrale' rack. In addition, an enable signal must be given from EROS with the command '**pushbutton t0 cn**' or '**hall cn**', where **cn** is Guttorm's way of commanding 'coax relay on' and **cf** disables the relay. This cn command sends 24Vdc via the '**receiver isolator controller card**' (see Fig.3 and schematic in Fig. A1) in the 'coax-Zentrale' rack to the relay board on the wall at the other end of the transmitter hall. This controller card disables the 24Vdc if any transmitter is not in position Array-1. The philosophy behind this relay is that it is a much more robust relay than the later pin diode switch so that the rather large RF voltages induced (10's of volts) on an array-3 antenna row by any transmission on the nearby array-2 or another part of array-3 will not damage the pin-diode switches or the USRP. Transmissions on array-1 are off course allowed and desired in a radar mode, that array being further away and distributed over a larger area.

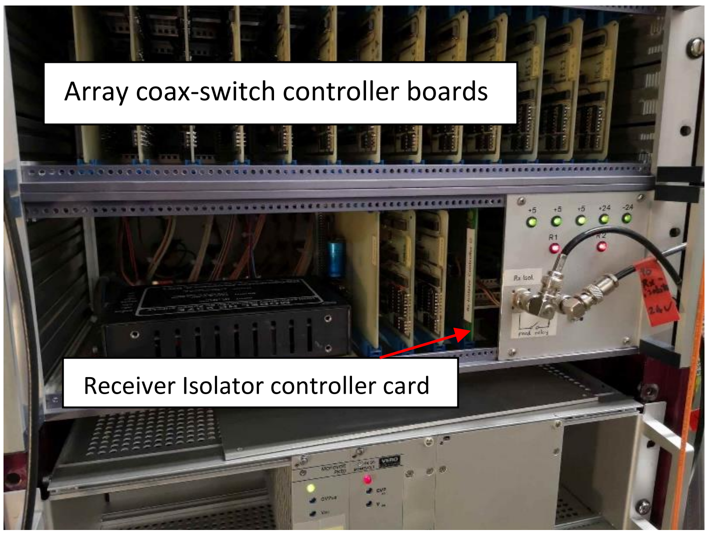


Figure 3 Receiver Isolator controller card in 'Coax-Zentrale' rack, with BNC input and output for the 'cn' / 'cf' control signal.

Receiver Protector

After the isolator relays, the signals go to pin-diode switches which are controlled by a single radar-controller bit via an optical fibre interface for radar operations. The switches are of type Mini-Circuits ZX80-DR230+ absorptive SPDT, with data sheet [ZX80-DR230+.pdf](). The TARLAN command is:

'**RxP1 ON**' or **OFF**

The receiver protectors and the following low-pass filters and diode clamps are inside a re-used 17" rack unit shown in Fig.4.

Figure 4. Rack unit containing receiver protectors, low-pass filters and diode clamps.

Low-pass Filters and diode clamps

After the receiver protectors anti-aliasing filters remove components above 10.7 MHz. Each channel has a Mini-Circuits BLP-10.7+ low pass filter installed (see Figs. 4 and A.4). The characteristics are described in data-sheet BLP-10.7+.pdf. They are followed by two back-to-back signal diodes to clip any high voltage signals before going to the USRP's via output BNC's on the front.

Notching stubs (optional)

When the HF radar is to be used simultaneously with some heater transmitters for heating, as in some PRAM experiments, then the heater wave may be too strong for the receiver system. The heating frequency would normally be different from the HF radar frequency and then the heater frequency can be attenuated by about 20-22 dB using a quarter wave coaxial cable as a stub. This open-ended cable acts as a notch filter, but has a relatively wide bandwidth such that the HF radar frequency is also likely to be attenuated, but somewhat less (like 3 dB for a radar frequency of 7.953 MHz with a stub cut for 6.2 MHz). Twelve stubs were made for the July 2019 PRAM experiments, and a typical transfer characteristic is shown in Fig. A. 5 They are joined to the output signal BNC's from the rack using a BNC T-piece.

USRP receivers

The input to each USRP should not exceed 2Vpp, which is why we put the protective measures above in place, with the diode clamps being the final device. Each USRP is started using the GNU Python script **thor.py**.

The EROS command is: usrp <command name>

These commands are still under development

Appendix

The schematic layout of the receiver isolator, receiver-protector and associated circuitry are shown in these sketches (Figures A.1-A.3):

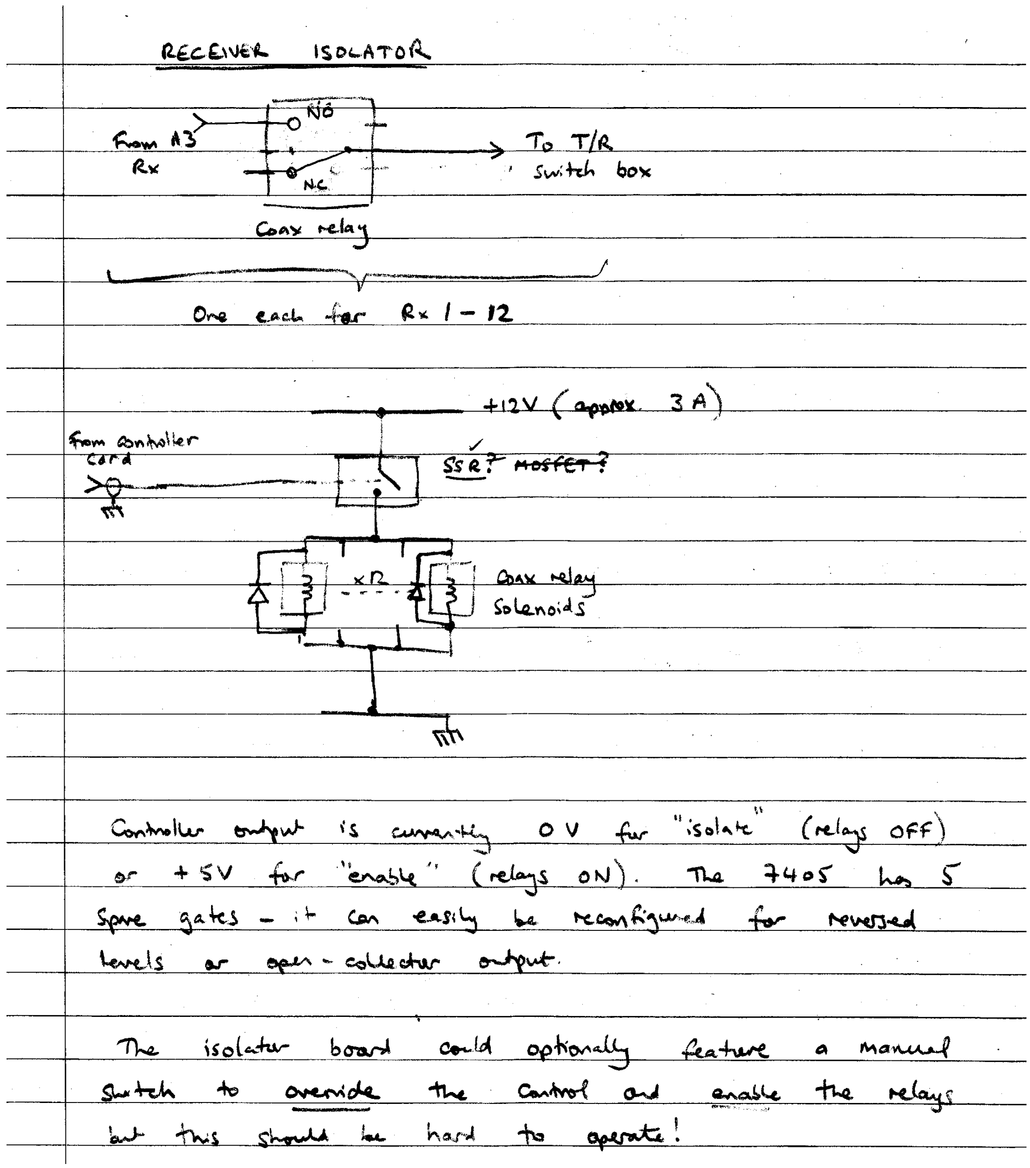


Figure A. 1 Receiver Isolator circuit.

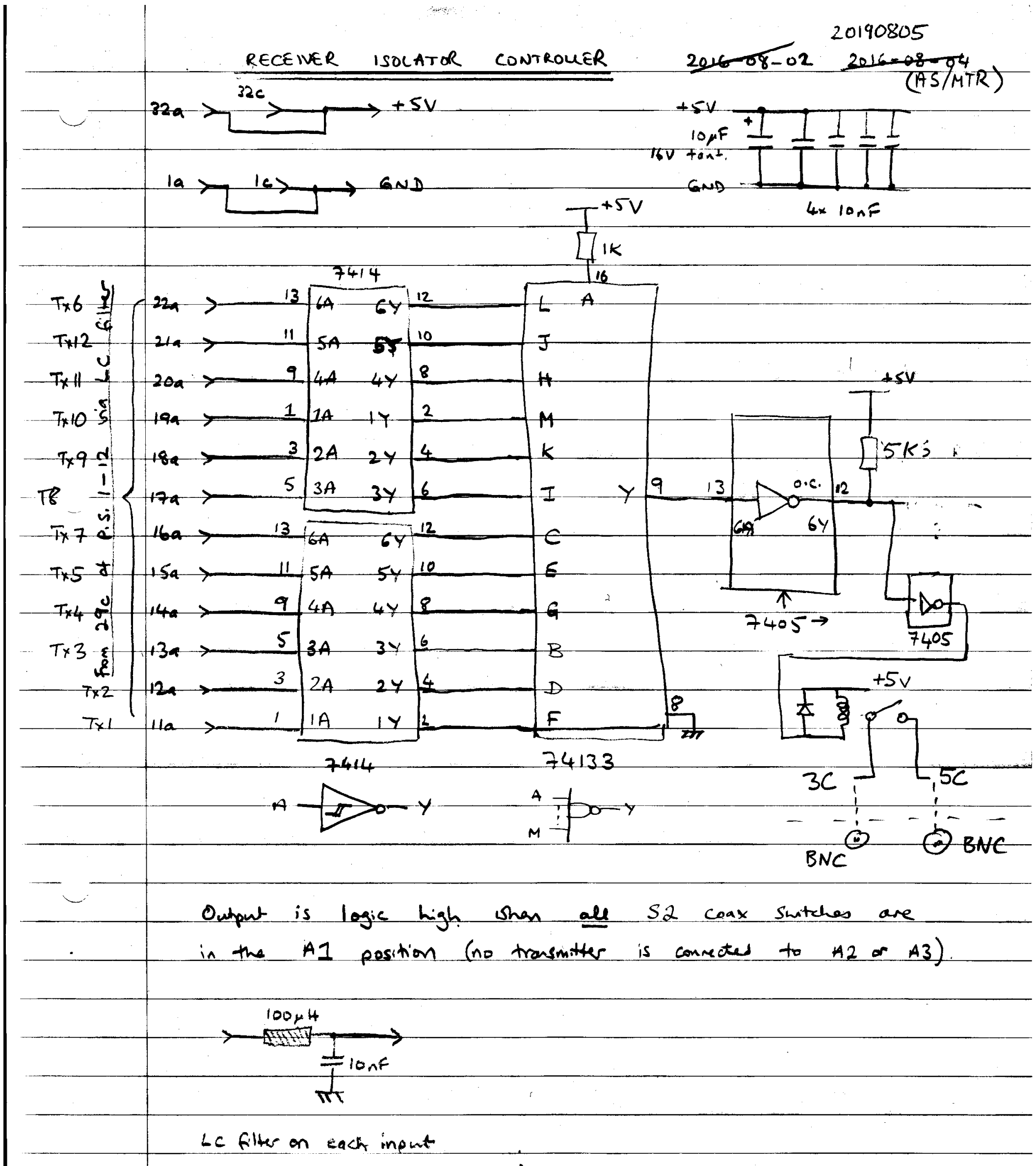
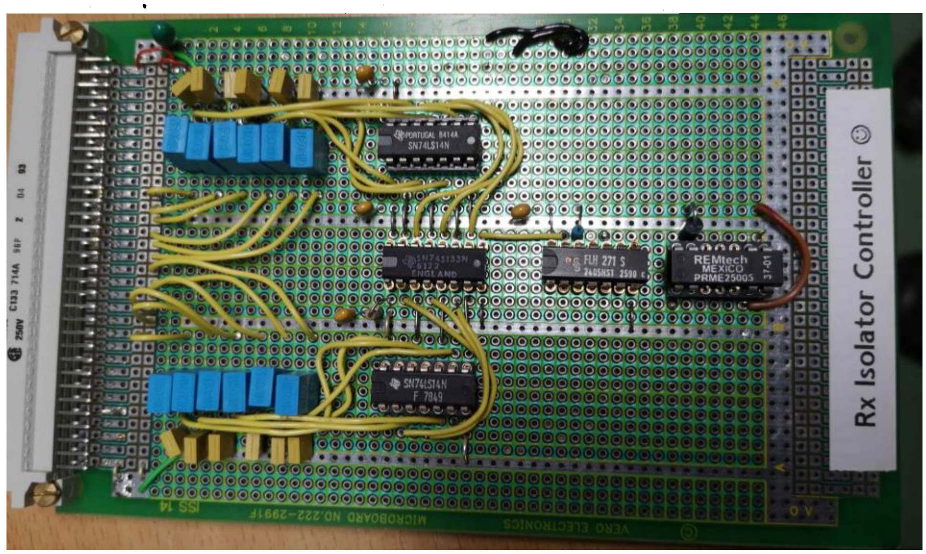
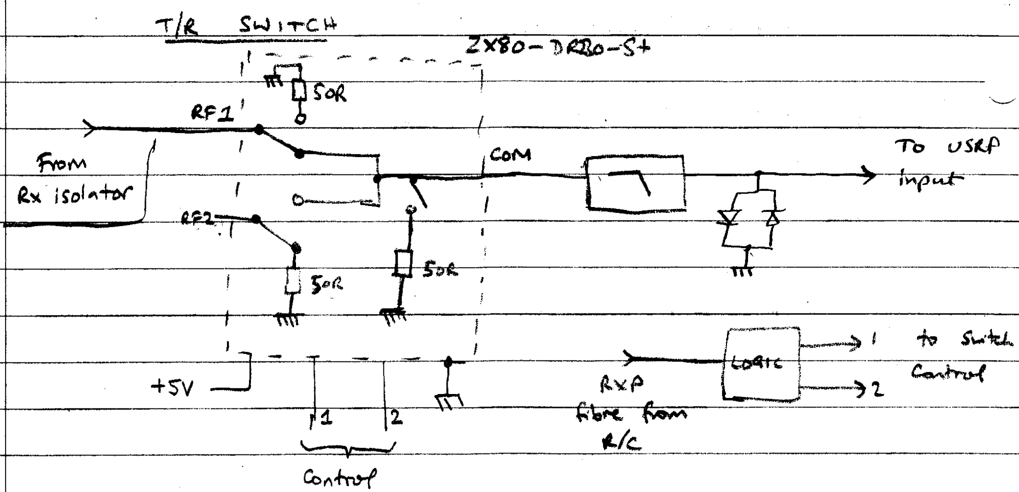


Figure A. 2 Receiver Isolator Controller, schematic and PC board





The ZX80-DR230-S+ Control inputs should be switched as follows:

Mode	"State"	Control I/Ps 1	2
Rx enabled	3	H	L
Rx protected	1	L	L

Power supply and Control inputs should be well filtered to avoid noise coupling into the signal path or modulating the signal, or coupling between signal paths.

Later we might want to add Tx sampling via the RF2 input. This would change the Rx enabled mode to use State 2. It would make sense to route all 12 pairs of control inputs to a common point so this change can be made easily!

BUT – 1. Power handling of ZX80-DR230-S+ may be an issue when antenna is terminated in an internal load!

2. The T/R switch does not address the issue of 'pram' type combined heating/radar experiments where the Txs may still be on during radar reception.

→ may need notch filters, unless signal levels are low enough – should measure these!

Figure A. 3 Receiver protector (T/R) switch (solid state)

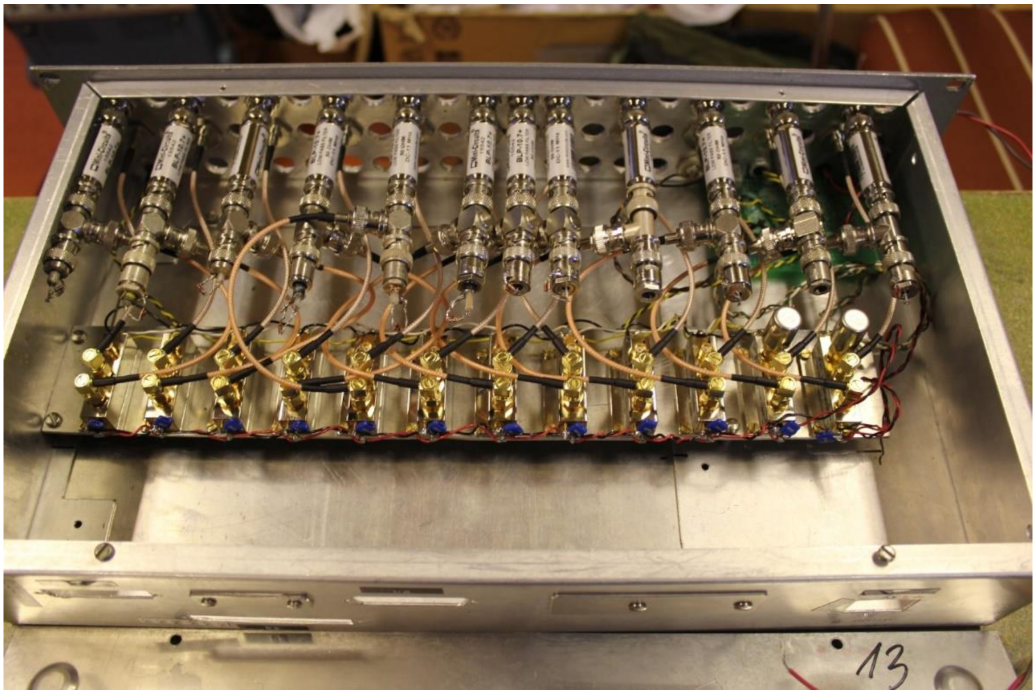


Figure A. 4 Receiver Protector and low-pass filter box.

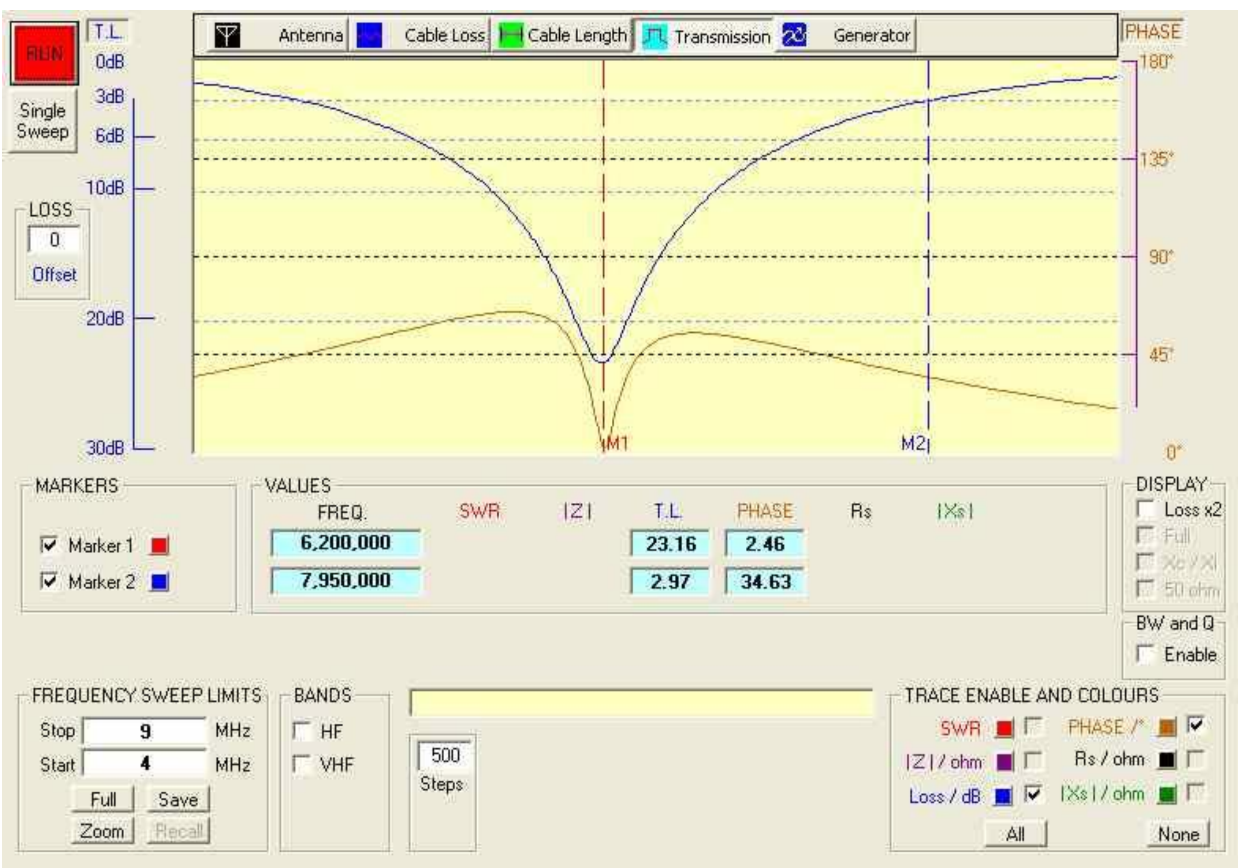


Figure A. 5 Transmission curve for a quarter wave stub for 6.2 MHz, measured with MiniVNA network analyser.