Operator's Manual

Direct Digitizing Black Box Receiver

RSR200

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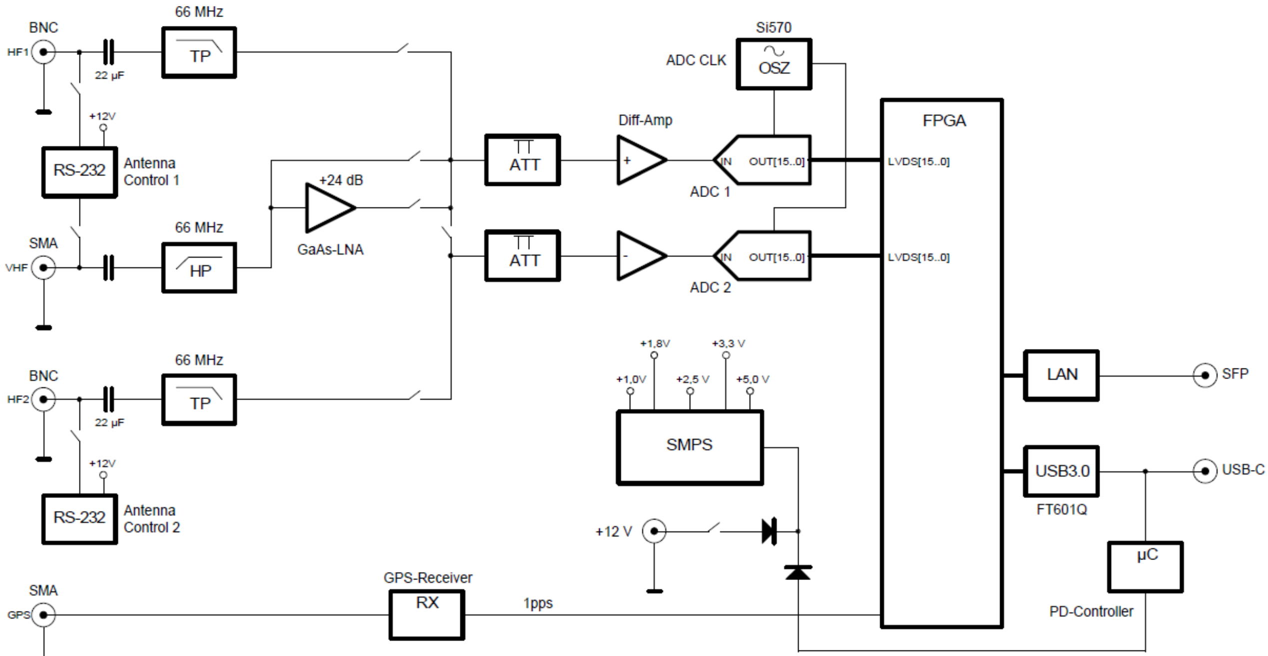
Content

1. Overview

The Reuter Software defined Receiver “RSR200” is a receiver for high-frequency signals in the 1 kHz to approx. 250 MHz range. It works on the principle of direct digitization of the received signals and forwarding of the generated data stream to a personal computer (PC). The PC then undertakes the processing of the signals via software (“SDR”: Software Defined Receiver).

The RSR200 is a broadband receiver designed primarily for generating high-frequency data streams with a large real-time bandwidth. This allows the SDR (PC) to monitor and analyze a large frequency range without any loss of information compared to other technologies (”Scanner”: Processing of only narrow frequency ranges staggered over time).



RSR200B

The analogue signals fed in at the inputs are digitized after filtering and amplification by two analogue-to-digital converters (ADCs): each with 16-bit amplitude resolution. The ADCs can be operated with an adjustable clock rate of 70 - 200 MHz. The digital output signals are fed into a highly integrated programmable circuit (“FPGA”: Field Programmable Gate Array). This pre-processes the data and controls various interfaces for transmission to a PC.

The maximum possible data rate of the interfaces determines the maximum real-time bandwidth that can be processed. The RSR200 provides 2 interfaces for data transmission:

– USB: Maximum 3200 Mbit = 100 MSp/s with 2x16 bit I/Q resolution. Practically achievable max. approx. 85 MSp/s.

– LAN: 1 Gbit Ethernet / 1000 Mbit FX (fiber optic): Practically achievable max. approx. 30 MSp/s with 2x16 bit I/Q and UDP protocol.

There are 3 signal inputs available:

– HF1: 0 - 66 MHz, digitization with ADC (channel) 1 and / or channel 2

– HF2: 0 - 66 MHz, digitization with channel 2

– VHF: 66 - 150 MHz, digitization with channel 1 and / or 2

HF1 and VHF are only switchable, not simultaneously usable, their signals always go to channel 1. Channel 2 can also digitize these signals. The signals generated by both channels can be combined in various ways (see below description DSP → Selector switch for setting the operating modes).

Both channel’s data streams can be routed individually or completely independently of each other to the output interfaces. Each interface can output the signal from channel 1, channel 2 or both channels simultaneously.

Both channels have adjustable (1 dB step width) amplifiers and attenuators at the HF inputs. An additional preamplifier with approx. 24 dB gain can be connected for VHF input.

Both channels have a remote feed/control unit for active antennas or other upstream active units (preselectors or similar). The remote power supply units can supply a maximum of 200 mA and a maximum of 12 V. Control signals can be output for active antennas RLA4 and RFA1/2, as well as for preselectors RAP1 (depending on the firmware and DLL version).

The USB and LAN output interfaces are intended for direct connection to a powerful personal computer (PC). The high data rates generated require a connection without the interposition of inhibiting routers, hubs, switches or similar. The RSR200 is designed to reliably maintain the necessary data flow. Control information is transmitted directly in the signal data stream. Data faults / delays therefore not only lead to interruptions in data processing, but also to malfunctions of the control system.

2. Safety precautions

Please always keep the following safety precautions in mind!

The device is intended for connection to a direct current low voltage. Only use safe power sources such as tested / certified power supplies or fused batteries.

Never connect the device to a voltage other than that specified in the specifications, especially never to mains voltage! The device tolerates polarity reversal (reversal of + and – pole) and overvoltage only in the specified voltage ranges and only for a short time. Disconnect it immediately from the power supply if it has switched itself off or has not switched on due to reverse polarity or overvoltage.

Disconnect the device from the power supply (pull the plug!) if you want to loosen any fastening screw or do any work outside the intended use on the device! The device contains no user-serviceable or user-replaceable parts (e.g., light bulbs or fuses).

The device is intended for indoor use. Avoid excessive moisture, never put liquid filled containers on top of the unit! Should moisture (e.g. spilled drinks) accidentally get on or even get into the device, immediately disconnect the power supply and send the device back to the supplier for inspection!

Observe the permitted temperature range for starting up the device! Do not switch the device on or off again if this range is exceeded or fallen below! The device heats up during operation and gives off this heat via the housing surface. Always set it up so that there is a gap of at least 10 cm between the rear wall and the side walls and other objects! Never place sources of heat such as candles or heaters directly next to, under or on the device! Do not operate the device in direct sunlight!

Always provide a safe placement on a flat, straight and solid base of sufficient carrying capacity! Transport the device only in either solid boxes or crates (for example the shipping container), or transport it by firmly grasping the sides with both hands! The unit can cause an injury in case of a drop under its own weight!

Do not expose this equipment to mechanical stress caused by impact, pressure, vibration or shock which exceed that commonly used in the home with the use of electronic devices! The control elements are sensitive to pressure or impact. Never operate a control element with a force that exceeds the required level.

If you notice any damage to the device, take it out of service immediately (disconnect the power supply)! If necessary, send it to the supplier for repairs.

Would you like to dispose the device due to damage or because you do not use it anymore, send it back to the supplier or return it to your local waste collection center. Never dispose of the appliance elsewhere, such as household waste. It pollutes our environment!

Only use soft, lint-free and dry cloths to care for and clean the device. Do not use aggressive solvents, but at most a slight moistening swab with distilled water or a damp piece of cloth or microfiber! Make sure that no moisture reaches the inside of the device!

3. First steps

After you have received the device and carefully read the operator manual (especially the above safety precautions!), you can now put it into operation.

3.1 Unpacking and first-time operation

Please unpack the device carefully and place it on a hard, flat surface. If you have just moved the device from a cooler to a warmer environment, please leave it switched off for a while to avoid any possible condensation moisture. By placing a hand on the top cover, you may decide whether the unit has reached approximately ambient temperature.

The following accessories are always included with the device:

- USB cable for connection to a personal computer.
- GPS antenna ("GPS mouse") with long cable and SMA connector.
- Power supply cable with hollow pin plug for connection to a power source.

Plug the provided (or an equivalent) USB cable with the USB-C plug into the “USB3.0” socket. Insert the plug on the other end of the cable into a suitable socket on a PC that complies with at least the USB 3.0 standard. If the PC asks which driver should be used for the new USB device (if no suitable one is found), direct the Windows installation wizard to the “FTDIBUS3” file in the USB driver directory suitable for your PC (can be downloaded from the RSR200 website under “Software”). Further information can be found in section 5.2 “USB interface”.)

Note: If you use a cable suitable for “Power Delivery” (PD) and connect the RSR200 to a PD host-capable port (capable of supplying power), the RSR200 is switched on immediately. The following steps to establish the power supply can then be omitted.

Connect the power supply cable. The coaxial DC plug (“hollow pin” for 2.5 mm pin) must be plugged into the RSR200’s “+12 V” socket. The **positive pole** must be on the **middle connection**. It is marked as a red wire at the other end of the cable. At this end, the cable can be connected to pole terminals or fitted with plugs suitable for the power supply unit (e.g. “banana plugs”). The power supply (power pack or accumulator or similar) must be able to supply at least the current specified in the specifications.

The quality of the power supply has a major impact on the reception performance of the RSR200. Interference, e.g. from insufficiently suppressed switching power supplies or unfavorable grounding conditions (the negative pole in the device is connected to ground) can significantly reduce the potential performance of the RSR200!

When the supply voltage is applied, the “PWR” LED lights up. Blue if the polarity is correct, red if the polarity is incorrect. If the polarity is incorrect, disconnect the supply voltage **immediately** and restore the correct polarity! The RSR200 can now be switched on using the toggle switch on the front side. The color of the “PWR” LED changes to cyan (turquoise). If the RSR200 is supplied via USB-PD, the LED lights up green and the “LAN” LED magenta (violet) (or white if there is also an Ethernet connection, see below).

If the RSR200 is to be operated with GPS-corrected frequency setting, connect the provided GPS antenna to the device’s “GPS” connection.

To receive different HF signals, suitable antennas must be connected to the “HF1” and / or “HF2” and / or “VHF” inputs. Observe the permissible input levels according to the specifications!

The RSR200 is now ready for operation and is already supplying data to the USB port (and if necessary to the LAN port, see description “LAN interface”). A suitable SDR program must now be started on the PC to process this data. All further explanations refer to the use of the “HDSDR” program from version V2.81.

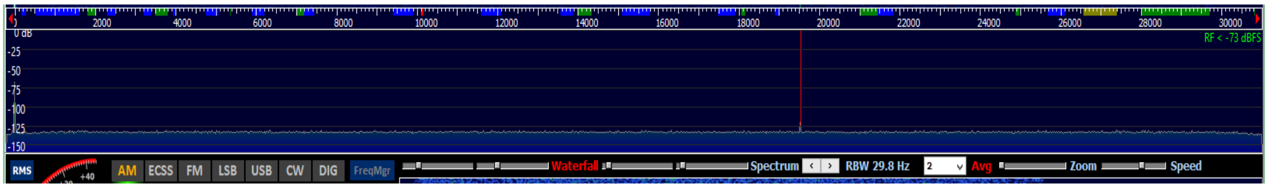
3.2 General information on operation

The RSR200 outputs its data to USB and LAN ports with very specific properties (protocols). These must be taken into account by the PC or the SDR program running on it and received accordingly. There is a connection program for the RSR200 that receives the data and makes it available to other software (the SDR programs) according to a certain standard. This standard was defined for the “Winrad” program. The connection program is provided in the form of a DLL (Dynamic Link Library). The SDR program executes this DLL and uses its functionality to receive the data and control the hardware. The file “ExtIO_RSR200Bxxx.DLL” (xxx corresponding to the current version) is used for the RSR200. The following explanations refer to version “ExtIO_RSR200B100”, for changes see section “Updates” for newer versions.

The current ExtIO*.DLL has to be copied into the directory of the SDR program. Depending on the version, additional files may be required:

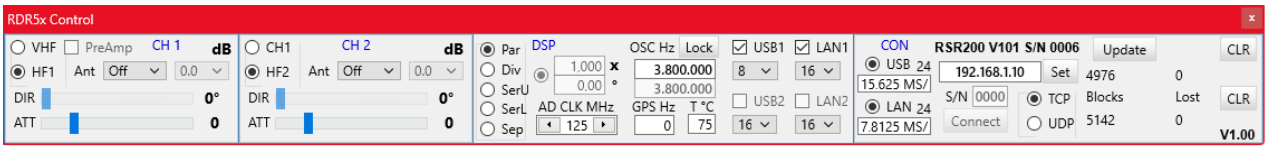
- FTD3XX.dll
- cc32c260mt.dll (only for V100)
- borlndmm.dll (only for V100)

These files can be downloaded together with the ExtIO*.DLL from the developer's website. After copying them into the directory of the SDR program (or any other directory), the program can be started. In the program, the ExtIO*.DLL must be selected as the source for the reception data (for HDSDR via “Options [F7] → Select Input”). If the SDR program is successfully connected to the RSR200 hardware via the DLL, the reception signals appear in the SDR program.



HDSDR via USB with >30 MHz signal bandwidth.

The main settings, such as reception frequency or demodulator and reception bandwidth, are adjusted in the SDR program (see its corresponding manual). However, particular hardware settings are only adjustable via the RSR200's own user interface. This user interface is contained in the ExtIO*.DLL and can be displayed by the SDR program.



The RSR200 is controlled via 4 panels:

- **CH 1:**

  - VHF/HF1 selector switch: Selection of the reception signal digitized in channel 1.

  - PreAmp: Switchable preamplifier for the VHF input.

  - Ant: Selection of remote power supply/control for channel 1 (on HF1 and VHF). Selectable in version 1.00: “Off“ or “+12 V“. The “HF1/VHF” LED indicates the presence of DC voltage at the inputs.

  - DIR: Direction setting of a RLA 4 antenna connected to HF1 or VHF (not available in V1.00).

  - ATT: Attenuation setting for channel 1. Values above 0 (dB) result in attenuation of the input signals, below 0 dB amplification.

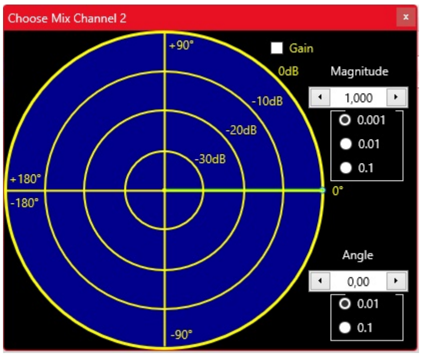
- **CH2** : As CH 1. The input selector switch allows the channel to be switched from channel 1 (same signal as selected for this channel) to HF2. The selected remote power supply / control is always switched to HF2. The “HF2“ LED indicates activation.

- **DSP:**

  - Selector switch for adjusting the signal processing:

  - Par: Parallel addition: The 16-bit data streams of the two ADCs are combined to form a 17-bit data stream. This results in a theoretical increase in SNR of 3.01 dB (practically achievable are around 2 dB). Channel 2 must be switched to signal input “CH1“ for this purpose. (When switched to “HF2”, both data streams are also added together. However, an improvement in the SNR can only be achieved if “HF1“ or “VHF“ and “HF2“ receive exactly the same signal).

  - Div: Diversity: The data stream from channel 2 is added to data stream 1 with adjustable amplitude and phase. If different signals are fed to the two inputs HF1 and HF2 (“antenna diversity”), certain signals can be boosted or attenuated by interference. A dialog window can be opened to set the amplitude and phase (button to the right of “Div”):



The green pointer can be dragged at the tip (small green dot) with the mouse and dropped in the IQ data space. The distance to the center corresponds to the amplitude (correct: magnitude of the complex signal), the angle to the x-axis corresponds to the phase. If the signal in channel 2 is smaller than that in channel 1, a digital amplification can be switched on via “Gain”. The separately adjustable attenuators in channels 1 and 2 can also be used to influence the signal.

Proceed as follows to attenuate a specific (interference) signal (main application of diversity):

– Check the level ratios of the signal in both channels (possible by switching the channels for the selected interface with operating selection “Sep“, see below). The reception of the interference signal should be slightly stronger in channel 2 than in channel 1 (otherwise switch on “Gain”).

– Position the tip of the pointer approximately on the level circle at whose attenuation the levels in channel 2 are brought to those of channel 1 (highest attenuation occurs at exact amplitude equality).

– Now move the pointer on this circle around the center point (phase change). At a specific phase, the signal is attenuated to the maximum. Try also adjusting the amplitude slightly to find the exact point of maximum attenuation.

– Use the adjustment controls for magnitude and angle for fine adjustment.

The achievable suppression values are highly dependent on the signals at the inputs. Observe the general instructions on antenna diversity (sensible selection and arrangement of antennas, etc.).

  - SerU / SerL: Serial addition: Channel 1 is interleaved in time with channel 2 with a shift of ½ clock period. The combined data stream is filtered at twice the clock frequency. This corresponds to a virtual doubling of the ADC clock frequency. It is possible to select whether the upper (“SerU”) or the lower (“SerL”) sideband of the resulting spectrum is processed further. The result is an increase in the SNR corresponding to the parallel addition and an attenuation of unwanted aliasing signals corresponding to the selected sideband. The practically achievable attenuation is approx. 30 dB.

  - Sep: Separate processing of data from channel 1 and channel 2. Both channels work completely separately from each other (practically 2 devices in one). Their signals can be fed to different interfaces for forwarding to one or two PCs.

- AD CLK MHz:

Clock frequency of the ADC (both channels always work with the same AD clock frequency). The frequency can be set in steps of 1 MHz. Select a clock frequency at which the ADCs operate at the minimum required clock rate (calculate/observe aliasing signals). Adjusting the clock rate is critical (brief interruption of signal processing and interface data transmission) and can lead to malfunctions under certain circumstances. Only use this setting if absolutely necessary.

Caution! High clock frequencies lead to increased current consumption and thus heating of the RSR200. Observe the internal temperature of the device and reduce the clock frequency or switch off the device if the temperature rises above 80°C!

- Osz Hz / Lock:

Display of the mixed frequency (controlled by the SDR program) generated in the RSR200 to produce the output spectrum. The data streams of the two channels are mixed with this frequency and the correspondingly frequency-shifted spectrum is forwarded to the interfaces. Channel 2 always runs parallel to channel 1 with the exception of the “Sep” operating mode selection. The frequency can also be entered manually. The “Lock” switch can lock the frequency so that it can no longer be controlled by the SDR program (useful if the program frequently makes unnecessary adjustments).

- GPS Hz

Display of the deviation of the ADC clock frequency determined by the GPS receiver (with antenna connected) from the set value. The value is used as a correction value for each frequency setting.

Note: The RSR200 has a very low-noise main oscillator for generating the ADC clock frequencies. The disadvantage of such high-quality signal-technological (short-term stable) oscillators is their often not particularly high frequency stability against temperature changes, copy scattering and aging. These gradual changes can be compensated for by a correction value. This requires an exact measurement of the current frequency. This is possible with stable reception of the GPS signal down to a deviation of 1 Hz. The correction is not made by directly influencing the oscillator (PLL or similar), so that its spectral purity is completely preserved.

- T °C:

Core temperature of the FPGA in the device. It should not exceed 80 °C at peak times and should not exceed 75 °C permanently. Otherwise, reduce the ADC clock frequency or switch off the device.

- USB1, LAN1, USB2, LAN2 and associated selection menus:

The interface at which the data of the respective channel is output is selected here (USB* / LAN*: Interface; *1 / *2: channel). The associated selection menu determines the decimation (divider factor for reducing the data rate compared to the ADC clock rate). Low decimation results in high bandwidths, but also high data rates to be transmitted. Only set the data rate so high that no or very little data is lost (see below).

Caution! In principle, several data streams can be forwarded to the interfaces. However, the original version of the ExtIO_RSR200B100.DLL connection program according to the “Winrad standard” only allows forwarding to a single SDR program. Parallel processing of several data streams requires special software.

- **CON:**

- USB xx / USB data rate display:

Is activated automatically if a functional USB connection (min. standard 3.0) is detected when the software is started. The number after “USB” indicates the bit width of the IQ data transfer. It is normally set automatically to 16 or 24, depending on the selected ADC clock frequency and decimation for USB. It can be forcibly set to 16 by double-clicking with the mouse (reduction of the bit rate on the interface in the event of faulty data transmission). 24 bit transmission results in better signal quality compared to 16 bit. The display below “USB xx” shows the sample rate resulting from the selected settings. This is usually also displayed in the SDR program; please check if these match (otherwise the spectrum in the SDR program does not match the spectrum actually generated by the RSR200).

- LAN xx / LAN data rate display:

The same as with USB if a functioning network connection is found when switching on.

- “RSR200 ...” display:

Displays the version number of the firmware in the device transmitted by the RSR200 to the software and the serial number of the device.

- IP address display and “Set“ button:

IP address under which the RSR200 is accessible in the network. This address is permanently stored in the device. The RSR200 always activates its network connection (SFP port) with this fixed IP address after it is switched on. It can be changed in the user interface, transferred to the RSR200 with the “Set” button and saved there. This address will then be used the next time the device is switched on.

Caution! Choose the address carefully! The software (ExtIO*.DLL) can only establish a connection via LAN if the PC (Windows...) can access this address in the network. Please note the further explanations on operating the RSR200 via network connection (see below).

- S/N and “Connect” button:

You can enter the serial number of an RSR200 under which the device is to be found in the WAN (home network, Internet, ...) here. Press the “Connect” button to search for the RSR200 within the network via DNS. A network connection is established when the device is found. Please note the further explanations on operating the RSR200 via network connection (see below).

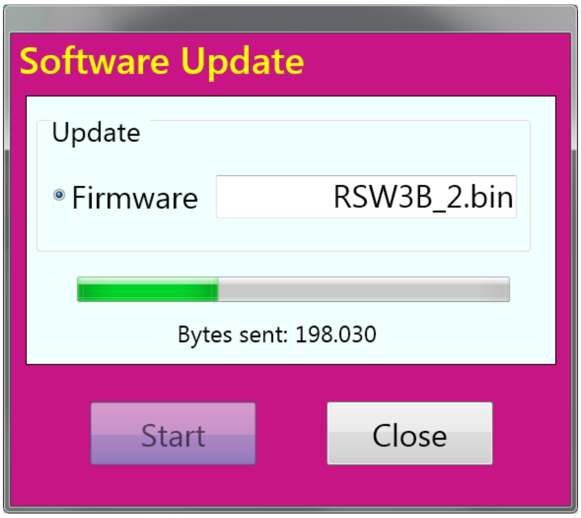
- TCP / UDP selection:

Selection of the transmission protocol used for data transmission in the network. TCP allows the detection of data errors and, if necessary, the retransmission of incorrectly received data. However, this requires higher computing power from the PC and can, at high data rates, lead to the connection being terminated completely for a short time (additional data and “negotiations” are conducted in the background via the network interface). UDP does not check the data and thus enables higher data rates. Because of this, individual data may occasionally be missing. With stable connections, however, this happens very rarely and minor data losses are usually hardly noticeable within the SDR program.

- “Update“ button:

Opens a dialog for updating the RSR200’s firmware. If the data connection is active (counter for USB and / or LAN is running), the data for the update is also transmitted within the signal data. The update speed therefore depends on the data rate settings. The following is recommended:

- USB1 only, decimation 16 (slow), 8 (normal) or 4 (fast, stable connection required!).
- AD CLK approx. 110 - 120 MHz, maximum 125 MHz!
- Switch off signal processing in the SDR program (“Stop” or similar).
- Stable operation of the PC (do not switch on power saving mechanisms or similar) and the RSR200 (no power supply failure, do not switch off, do not disconnect USB, ...).



The "Firmware" field is initially empty. With a double click / tap on it, the program searches for transferable files. These files must always have the extension .Bit and be located directly in the ExtIO*.DLL folder. If there are several *.Bit files in the folder, the first one that can be found (depending on the arrangement of the files in the folder) is used. To avoid confusion, there should always be only one update file in the folder, namely exactly the (new) firmware to be transferred.

Pressing the "Start" button starts the transfer to the RSR200.

Caution! Transmission may only take place if the RSR200 has an error-free data connection to the PC (error counter in "CON" is not running).

The progress of the transfer is indicated by the green progress bar and the count of the transferred bytes. If an error message appears (transmission could not be started or was canceled due to long interruptions in the connection), the Update window must be closed. Once an error-free connection has been re-established, the update must be **repeated immediately** until it has been successfully completed. Do not exit the SDR program and do not switch off the RSR200 until the update is successful!

Caution! Aborted updates can lead to total failure of the RSR200! In this case, the firmware can only be restored by basic firmware reprogramming at the manufacturer.

If the new firmware was loaded without errors, it will be run after restarting the RSR200 (switch off/on again, exit the SDR program first!). The version number in the "CON" panel of the user interface shows the firmware version.

- Displays "Blocks" and "Lost" with "Clear" buttons:

  The interface's data transfer (USB at the top, LAN at the bottom) occurs in blocks of a specific size. The blocks are numbered consecutively. The arriving blocks are counted and compared with the numbering in the software. The number of blocks since the interface was started and any errors that have occurred (no data errors, only numbering errors) are displayed. The error counters can be reset with "Clear".

  Note: The quality of a data connection in terms of its ability to transmit the required data rate can be assessed by observing the counters (if active at all, how often errors occur). Rare errors are normal. However, as soon as the error counter continues to count more frequently (once every few seconds or more often), the interface cannot transmit the data fast enough. In this case, reduce the data rate (ADC clock frequency, decimation, switch to 16 bits) or change the interface (USB instead of LAN). The maximum possible data rate is also very dependent on the PC and its configuration (operating system, other running programs, firewalls / virus scanners, ...).

  Caution! Individual errors are not a problem for the signal data of the ADC. However, errors in control data (control of the RSR200 via the user interface's panels) and especially during firmware updates can have devastating consequences. Do not operate the interfaces at data rates that cause frequent errors.

- Display "Vxxx" at the bottom right:

  The version of the ExtIO*.DLL that provides this user interface.

4. Specifications

Dimensions (W x H x D):	135 mm x 53 mm x 110 mm (without connectors / control elements)
Frequency range (-3 dB):	1 kHz … 66 MHz (HF1 and 2), 66 … 150 MHz (VHF)
Clipping limit (ATT = 0 dB):	0 dBm (HF1 and 2), +5 dBm (VHF, PreAmp off)
Input level max:	+13 dBm
Inherent noise:	< -156 dBm/Hz (HF1 / 2), < -150 dBm/Hz (VHF, PreAmp off)
Jitter main clock oscillator:	< 0.5 ps RMS (12 kHz … 20 MHz)
Temperature drift main clock oscillator:	< 5 ppm (0 … 80 °C, without GPS correction)
Intermodulation distance IM3:	> 82 dB @10 MHz (HF1 / 2), > 76dB @100 MHz (VHF without PreAmp), 1 dB with full modulation
Amplification PreAmp:	24 dB @100 MHz
Noise level PreAmp:	< 2.0 dB @100 MHz
Input IP3 PreAmp:	> +12 dBm @100 MHz
Level of inaccuracy:	± 3 dB
Power supply:	+9.0 … +15.0 VDC / max. 0.8 A (min. +12.0 V, if antenna remote control is to be used)
Connectors:	BNC 50 Ohm, hollow pin 2.5 mm, SMA female
Weight:	< 600 g
Environmental conditions:	0 ... +40 °C ambient temperature, <=90 % rel. Humidity non-condensing, indoor application
Compliance:	CE according to DIN EN 55013, EN 55020, EN 60065 RoHS / WEEE Directive, ear-Reg. 27676700

All specifications are subject to design changes!

5. Notes on RSR200 operation

5.1 Data rates / bandwidths / reception ranges

The RSR200B is a high-speed digitizer that can provide large signal bandwidths. The theoretical upper limit results from the maximum possible data rate of the USB interface. It is operated at 100 MHz with a 32-bit word width. This theoretically results in a bit rate of 3.2 Gbit. That corresponds to 100 MSp/s at 16-bit word width of the IQ data. The division into data blocks and the insertion of control information into the data stream reduces the possible sample rate.

The minimum possible sample rate results from the minimum possible ADC clock frequency of 70 MHz and the highest possible decimation rate of 16. This results in 4.375 MSp/s. This data rate is almost always too high to transmit over a slow network (Internet, WiFi, ...).

Caution! In the first version V10x of the firmware and the ExtIO_RS200B10x.DLL, the RSR200 is only intended for direct connection via cable to a PC interface.

The variable ADC clock frequency is an outstanding feature of the RSR200 for flexible adaptation to existing or desired reception conditions. For this purpose, the theoretical principles of converting analog signals into digital signals / data must be observed. These are in particular the so-called “Nyquist theorem” and all related effects such as mirroring / convolution, aliasing, oversampling, bandwidth limitation, etc. For the RSR200’s effective operation, it is strongly recommended that you consult the relevant basic literature.

When operating the RSR200, particular attention must be paid to the position of the “Nyquist zones”, which depend on the ADC clock frequency. These are the areas that can be digitized “in a row” without signal interference (“aliasing”) occurring. To achieve this, the corresponding zone must be filtered out using analog filters at the RSR200’s input.
Any signal from another zone that reaches the ADC input is received in the same way as the signal in the desired zone (with different attenuation according to the zone order). The Nyquist zones each have a bandwidth of half the ADC clock.

Example: ADC clock rate = 100 MHz Zone 1: 0 – 50 MHz, Zone 2: 50 – 100 MHz, Zone 3: 100 – 150 MHz, …

If signals from zone 1 are to be received, all signals above 50 MHz must be blocked (low pass). A bandpass of 50 - 100 MHz is required for reception in zone 2. Etc. It should be noted that the filters can never be “square-wave filters”, even with the greatest effort, i.e. they have a limited slope. A Nyquist zone can therefore never be fully utilized, the attenuation of the desired signals already begins at its limits and signals from the respective neighboring zone appear. The filter’s attenuation at the frequencies of the unwanted zones determines how strong the interfering signal within the desired range is.

For the RSR200’s effective operation, it is therefore essential to use filters that match the clock frequency before the inputs (or only feed in signals that do not contain frequencies in interfering zones, e.g. from measurement generators or resonant antennas with high out-of-band signal suppression). Or, and this is the advantage of the RSR200, the ADC clock frequency can be adapted to the given possibilities (existing filters, antennas, ...).

Example 1: The RSR200’s integrated low-pass filters (HF1 and 2). The filters are sufficient to achieve good attenuation of the alias signals within the HF range (1st Nyquist zone = “baseband”). At the standard ADC clock frequency of 125 MHz, the next reception range (2nd Nyquist zone) is 62.5 - 125 MHz. Frequencies around 125 MHz ±30 MHz are mapped to the 0 - 30 MHz range. The frequency 125 MHz - 30 MHz = 95 MHz (closest to the actual reception range) is mapped at 30 MHz and appears attenuated by approx. 75 dB. Conclusion: As long as there are no extremely strong FM signals at HF1 / 2 (antenna issue!), this attenuation should be sufficient for almost all reception situations.

Tip: Changing the ADC clock frequency shifts the range mapped after 0 - 30 MHz to other frequencies (always around the multiples of the clock frequency). For example, if an ADC clock of 140 MHz is selected, no FM frequencies can be mirrored within the HF range.

Example 2: The RSR200’s integrated high-pass filter (VHF). In the VHF range, the filter is sufficient to achieve good attenuation of low-frequency alias signals coming from the HF range. As in example 1, a 30 MHz signal is mirrored at 95 MHz. There, it appears with approx. 72 dB attenuation.

The next highest alias signal within the VHF range is 125 MHz + 30 MHz (3rd Nyquist zone) = 155 MHz. It is fully passed through the VHF input and appears with only approx. 5 dB attenuation (frequency response of the VHF input + system attenuation at higher aliasing orders) at 95 MHz.

This clearly underlines the requirement that **bandpass filters** must always be used for interference-free digitization in higher order Nyquist zones. Because of this, at least one low-pass filter (together with the built-in high-pass filter to form a band-pass filter) would have to be used before the VHF input so that all frequencies above the clock frequency are sufficiently suppressed in the example.

When digitizing in even higher Nyquist zones, the requirements become more stringent. In this case, the high-pass filter at VHF is no longer sufficient, as it only attenuates the 1st zone.

Example 3: Digitization of the DAB range from 174 - 240 MHz. The bandwidth is 66 MHz. According to the Nyquist theorem, the ADC clock must be greater than twice the bandwidth to be captured. A frequency for AD CLK of at least 132 MHz is therefore necessary. However, this would require a bandpass filter with a rectangular filter curve. For realistic filters, the ADC clock must be increased. However, it must also be ensured that the desired reception range fits completely into a Nyquist zone. With e.g. 150 MHz AD CLK, the 3rd zone would be at 150 - 225 MHz, i.e. it could not fully cover the DAB range. If 166 MHz is selected, the 3rd zone is 166 - 249 MHz and therefore quite symmetrically within the desired reception range. The closest Alias signals are 158 MHz (174 MHz - 166 MHz = 8 MHz below the ADC clock) and 258 MHz (1.5 AD CLK - 240 MHz = 9 MHz above 1.5 times the ADC clock). The bandpass filter to be provided for the DAB range must therefore be quite complex if all possible alias signals are to be well suppressed.

Use of SerL and SerU: In order to mitigate the requirements for anti-aliasing filters, especially in the VHF range, the RSR200 has a special operating mode: “Ser” (serial connection of the two ADCs). This means that the sampling times of the ADCs are shifted against each other so that the input signal appears to be sampled at twice the frequency (serially one after the other). This also doubles the width of the Nyquist zones and significantly reduces the requirements for the necessary filters.

Caution! Only a limited temporal accuracy can be achieved while using the ADC’s serial mode of operation. Even deviations in the sampling times in the femto-second range (1 fs = 0.001 ps) reduce the possible attenuation of the original (narrow) Nyquist zones compared to the ideal (doubled) zones. Approx. 30 dB attenuation can be achieved within the RSR200.

The doubled data rate from the ADCs must be set back to the original ADC clock in a decimation stage. In order to meet the Nyquist condition again, filtering is necessary (maximum bandwidth 0.5 AD CLK). The letter “U” (Upper) or “L” (Lower) after the “Ser” operating mode indicates whether high-pass or low-pass filtering is used. This allows you to select whether the possible suppression of alias signals in the Nyquist band takes place “to the right” (higher frequencies) or “to the left” (lower frequencies) of the utilized Nyquist band.

Example 4: Reception of the 4 m band at 70 MHz at the VHF input. Selected ADC clock frequency 160 MHz (reception of 70 MHz within the 1st Nyquist zone). The next higher-frequency alias frequency is 90 MHz (0.5 AD CLK - 70 MHz, 2nd zone); it is received without attenuation. The requirements for a filter to sufficiently attenuate the VHF signals are therefore high. If the “SerL” operating mode is selected, the lower (here the 1st) Nyquist zone is passed through and the upper zone is suppressed. The VHF signals are therefore attenuated by approx. 30 dB and the requirements for the filter are significantly reduced.

Note: This is a fictitious example by deliberately selecting an unfavorable clock frequency (but in some cases there is no other way). In example 4, the selection of 120 MHz AD CLK would be more favorable because the next highest clock frequency is only at 170 MHz. But even then, selecting “SerU” (the useful signal is now in the “upper” 2nd zone) would result in favorable conditions because the lower sideband (1st zone) is now attenuated. The lower-frequency alias signal at 50 MHz (70 MHz - 0.5 AD CLK) is already attenuated by the VHF high-pass filter, but now by approx. 30 dB more. Despite the use of a higher zone (normally a bandpass filter is required!), the high-pass of the VHF input is now sufficient for normal reception (the higher-frequency Alias signals must still be suppressed by an additional low-pass if the antenna provides them).

Caution! The filtering of the adjacent Nyquist band in the “Ser” operating modes is not infinitely steep. The 3 dB bandwidth (useful band) or max. suppression (attenuated band) is approx. 10% next to the respective Nyquist limit. As the reception frequency approaches the limit, the attenuation of the useful signal increases and the suppression of the alias signal decreases.

Further notes: As shown, the RSR200 allows a very flexible design of the reception ranges with different signal quality characteristics or requirements for filtering the input signals. If the reception ranges are to be utilized with the widest possible bandwidth, proceed as follows:

- Check which frequency ranges are to be received at which input and which signals are actually supplied by the antennas used.
- Identify the necessary ADC clock frequency and the resulting position of the Nyquist zones that enable continuous reception of the desired range.
- Check to what extent the RSR200's integrated signal filtering options are sufficient for interference-free reception of the desired range (sufficient attenuation of the signals otherwise supplied by the antennas outside this range).
- If necessary, switch appropriate filters before the respective signal input.

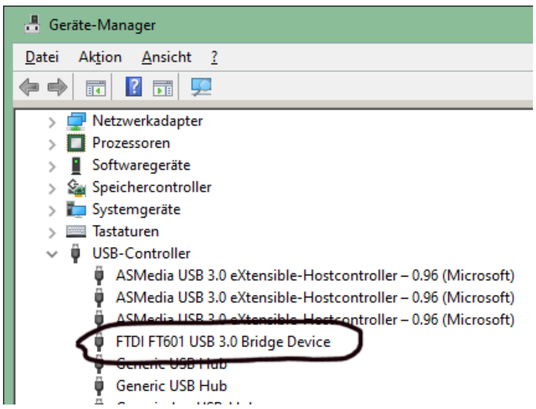
Caution! The inputs HF1, HF2 and VHF are switched to the ADC with limited attenuation of the respective switched-off channel. There is also only limited crosstalk attenuation between the components of the various channels on the device's circuit board. Strong signals at one input can therefore also appear undesirably in channels that are switched to another input. In this case, disconnect the interfering input.

5.2 USB interface

A standard PC with a USB3.x port requires short computing times to read the blocks from the interface and forward them to the software. Furthermore, this process can always be interrupted briefly by the operating system due to high PC loads.

Tests on an Intel i7 8 Core / max. 4 GHz PC with Windows 10 showed a stable data rate of approx. 85 MSp/s under ideal conditions (no other USB interface used, no other program active, no SDR program either, only the user interface). After starting HDSDR, approx. 70 MSp/s are still possible. This makes the USB interface the first choice when it comes to large bandwidths.

The RSR200 uses an interface circuit from FTDI (FT601Q). This requires a USB driver on a Windows PC to establish the USB connection. FTDI circuits are widely used and the appropriate driver is often already installed on the PC. If Windows asks for a driver, or if the existing one is not working, the drivers can be downloaded from the RSR200 product page on our website (select the appropriate version). The driver must then be specified in the Device Manager (new driver for "unknown device" or similar). The successful installation is displayed as follows (or similar) after connecting / switching on the RSR200:



5.3 LAN interface

A 1 Gbit connection is provided for the network. Under the above conditions, a maximum stable data rate of approx. 950 Mbit via TCP or UDP can be achieved. For this purpose, the PC must be connected directly to the RSR200 via a 1 Gbit network connection and no other network connections may be active.

Caution! **In the first version V10x of the firmware and the ExtIO_RS200B10x.DLL, the network connection is not fully active. Only use the USB interface initially.**

An SFP module is required to connect the LAN interface. These are available with a normal RJ-45 port for use with standard patch cables, or with a fiber optic connection (various standards possible). It must meet the respective specifications for at least 1000 Mbit transmission rate. The module must be plugged into the "SFP 1000" slot and locked. When connecting via fiber optic cable, an SFP slot or other connection suitable for the cable must also be available on the PC at the PC end. Furthermore, "media converters" can be used to convert the SFP module to RJ-45.

5.4 Notes on reception

5.4.1 Remote control of active antennas

The RSR200B contains two control units for remote control of the RLA4 and RFA2 antennas, as well as the RAP1 preselector and any antennas with a 12 V supply (max. 200 mA!). The control units also provide the necessary operating current for the antenna ("remote power supply"). The RAP1 always requires its own power supply (can be the same as that of the RSR200). The first control unit can be switched to input HF1 or VHF (selection in the control panel "CH 1" according to the selected signal input). Control unit 2 is always permanently connected to HF2.

If the control units are switched off ("Off" selection), they are completely disconnected by means of an optoelectronic relay. If an active antenna is selected, the remote power supply and the necessary control signal for Rxxx devices are connected to the input via isolating filters (inductor with 400 µH inductance).

Caution! The possible interference of low-frequency signals due to the isolating inductance must be taken into account! Do not use a remote power supply / control if 400 µH inductance is not sufficient for your planned reception operation!

Caution! The operating current of the antennas is taken directly from the power supply of the RSR200 (socket "+12V" or USB-PD). Ensure that the power supply used is sufficiently powerful (operating current of the RSR200 plus power consumption of all antennas)!

Remote control of the Rxxx devices is carried out using digitally coded signals directly via the HF line from the RSR200 input to the device. Information on the direction control (RLA4 and RAP1) or resonance quality (RFA2) is taken directly from the control panels (slider above "ATT"). RFA2 and RAP1 are also supplied with information about the current reception frequency. The information is supplied by the SDR program ("Tune" setting or similar) via the ExtIO*.DLL to the RSR200 and on to the devices. This ensures the "automatic synchronized tuning" functionality.

Transmitting the control signals directly via the HF line is a convenient option for remote control (no additional lines required). However, it also has disadvantages:

- Relatively slow. Data is transmitted at 125 bit/s, so each data packet takes over 0.1 s to transmit. The antenna therefore "lags" behind the control commands, especially with fast tuning. Input settings that require signal transmission to the antenna only slowly.

- The control signals are superimposed on the reception signals. They are noticeable in the signal, especially at low reception frequencies. The interference spectrum extends up to approx. 10 kHz, beyond which it can modulate onto the received signals.

Caution! The RSR200 has a very low cut-off frequency (approx. 200 Hz). The 125 Hz control signals therefore generate a high additional modulation of the ADC. With high pre-amplification (small values for ATT) and / or high HF input levels, the ADC can be overloaded. In this case, increase the attenuation (set the ATT higher). Pay attention to any additional digital amplification ("Magnitude" value > 1.000 in "Div" operating mode) and reduce it if necessary!

Note: The active antennas RLA4 and RFA2 (and many others) provide quite high reception levels. Further amplification (ATT < 0) is never necessary. Rather, the attenuation should be increased until the inherent noise of the RSR200 just (not yet) begins to affect weak signals.

5.4.2 Antenna diversity

The RSR200B's hardware offers the possibility of linking signals from two antennas (without the need for an SDR program to achieve that) in such a way that destructive (attenuating) or constructive (amplifying) interference of signals of the same frequency occurs. Same-frequency signals means the reception of the same signal via different channels. In the RSR200, these are the HF1 and HF2 inputs with the antennas connected to them.

The main application of diversity reception is the selective suppression of unwanted signals. To do this, the signals must be brought to exactly the same level and phase shifted by exactly 180° (inversion) before linking (addition). If this is only successful for the unwanted signals without the desired received signals fulfilling this condition, the interfering signals are strongly attenuated and the desired signals hardly at all. The more the selected antennas support these conditions, the more successful the differentiation between unwanted and wanted signals will be.

The RSR200 itself makes it possible to adjust the level and phase for reception channel 2 in order to achieve the necessary level equality and phase inversion when added to channel 1. (A rough adjustment of the levels is also possible using “ATT” in both channels). Very precise setting is necessary for high suppression values (high accuracy of the matches). Channel 2 can therefore be set digitally with a resolution of 0.001 in the range from 0.001 to 8x gain and 0.01° in the range from 0° to ±180° phase angle.

Caution! These setting ranges result in a total of 288 million possible combinations!

To find the most suitable combination to achieve the maximum possible attenuation, the selection is made in 2 steps:

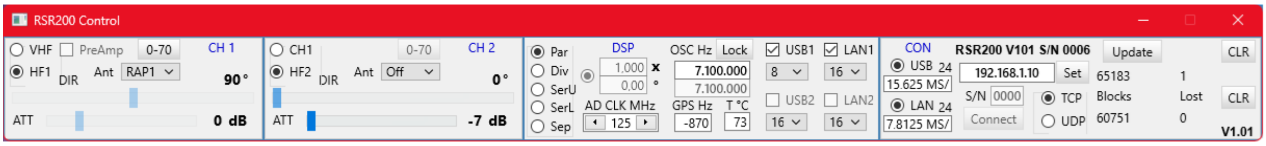
> - Rough selection using the pointer for the required (polar) coordinates in the two-dimensional magnitude-phase space. This selection is made using the mouse with the pixel resolution of the diagram (“target circle”). Observe the spectrum in the SDR program and search for the point at which the level of the signal of interest is lowered. By making small variations around the point found, you can identify the pixel on the “target circle” that enables the greatest possible reduction. Depending on the frequency, approx. 30 dB (up to approx. MW) to 20 dB (SW) are possible. If none is found, the levels of the signals must be better adjusted (antennas, attenuators, possibly switching on “Gain” in the diagram, ...).

Note: In “Sep” operating mode, the RSR200 allows you to switch the view of both individual channels. To do this, set the check mark for the selected interface alternately for channel 1 and 2. The level of the signal to be hidden should be slightly higher in channel 2 than in channel 1 (align antennas, set attenuator). If this is not possible, it may be a maximum of 18 dB lower, then use digital “Gain” in Diversity.

- Fine adjustment with the “Magnitude” and “Angle” sliders. The exact point of highest suppression can be selected here with reciprocal adjustment (adjust step widths if necessary). At low frequencies without large fluctuations, up to 60 dB can be achieved; the point of highest attenuation is very “sharp”. As the frequency increases, the possible attenuation and “sharpness” of the setting decrease.

5.5 Updates

5.5.1 Version 1.01



Version 1.01 contains the following enhancements:

– Control of the devices RLA4, RFA1/2, RAP1 when connected to the inputs HF1, HF2 or VHF.

The design of the CH 1 and CH 2 panels has changed. The “Ant” selection menu can now be used to select one of these devices in addition to the “+12 V” remote power supply:

- Slider “DIR”: With RLA4 and RAP1, this can be used to remotely control the reception direction of an RLA4 (connected directly or to the input of the RAP1). The slider can be moved quickly with the mouse and can be finely adjusted using the cursor keys on the keyboard. Adjustment is possible in 232 steps from 0° - 180°.

- Button „0-70“: If “RAP1” is selected, this can be used to switch on the preselector bypass. The RAP1’s display then shows “0-30MHz” (it is only designed for this range). However, the bypass can pass the entire range that can be received with HF1 or HF2 (useful up to approx. 70 MHz).

To update the device, the file “RSR200B101.BIT” must be transferred to the RSR200. Follow the instructions for the software update exactly (observe instructions for “Update” button in “CON” panel)! After successful transfer, the SDR program used must be closed and the RSR200 switched off. After switching on again (wait a few seconds), the new firmware is active.

The new firmware can only work with the corresponding ExtIO*.DLL. For firmware version RSR200B101, specify the file ExtIO_RSR200B101.DLL in the utilized SDR program.

Caution! Do not use a DLL in the SDR program that does not match the firmware of the RSR200! The RSR200 can then only operate to a limited extent or not at all. In particular, never carry out an update if the firmware and ExtIO*.DLL are different! This could completely erase the RSR200 memory. The device can then only be made operational again after (chargeable) reprogramming by the manufacturer.

Note: Whether the RSR200 firmware and the DLL used in the PC match can be easily recognized by the version numbers displayed in the CON panel. The firmware version displayed after “RSR200” must correspond exactly to the DLL version displayed at the bottom right (the separating dot is meaningless). If the versions do not match, immediately configure the SDR program to use the correct DLL!

5.5.2 Version 1.0A

This is a “beta version” (not yet fully released version) for testing and eliminating the following peculiarity:

- If input HF2 is overloaded, strong signal distortions occur.

Input HF2 possesses special signal processing at the digital level (“behind” the ADC) to implement the “antenna diversity” functionality. It is always active when the “Div” operating mode is selected in the “DSP” panel. It is also active when “Sep” is selected, because in this case channel 2 is also routed via the diversity circuit (then set to magnitude 1.000 and phase 0.00).

Up to firmware version 1.01, the diversity circuit reacts very sensitively to clipping. As of V1.02 (tested as of V1.0A), an additional limiter is installed which limits higher levels to a maximum of the level required for full modulation (clipping limit). This only causes the unavoidable distortions caused by clipping, but no additional distortions.

Additional indicators have been integrated into the input circuit panels for channels 1 and 2 to make it easier to recognize clipping on the RSR200 in general. The normally green “Ov” (overload) field turns red as soon as the reception level is only approx. 0.5 dB below the clipping limit. The circuit operates with the ADC clock frequency, thus also enabling the detection of very short pulses in the ns range. However, detected full modulation or clipping is displayed in red for at least 0.5 s.

Note: If the clipping indicator of a channel lights up red frequently or even permanently, reduce the input level. Distortion-free signal processing is not possible when clipping!

The input level can be reduced using the attenuator (“ATT” set to higher values).

Caution! In the “Div” operating mode, a digital amplification can be set “behind” the ADC (magnitude > 1.000). This amplification generally reduces the analog clipping limit that is actually possible “before” the ADC. Only select digital amplification if absolutely necessary, e.g. for very low levels of the signal source connected to input HF2!

Also observe the notes on the use of remote-controlled antennas. Remote control is carried out directly via the HF cable and thus superimposes the received signals with the control signals. At high sum levels (broadband reception signals) and / or high pre-amplification (ATT < 0), the additional antenna control signals may cause clipping. In this case, reduce the pre-amplification (set ATT to higher values).

The controllable devices RLA4, RAP1 and RFA2 are active devices (integrated amplifiers) that deliver such high levels that pre-amplification is never necessary in the RSR200. Rather, the use of attenuation (ATT > 0) or the interposition of a preselector is necessary, especially with the RLA4 (broadband high levels).