

Specifications

and Operator Manual

Active Preselector RAP1



Ausgabe: 1.3

Created: 18.06.2022

Specifications

Dimensions (W x H x D):	75 mm x 28 mm x 130 mm (without connectors / control elements)
Frequency range:	0 MHz (about 1 kHz) ... 30 MHz
Frequency deviation tuning:	$\leq 5\%$ of tuning frequency
Attenuation loss:	0 dB (0 / 0.5 MHz - 30 MHz), -2 dB (0 – 0.5 MHz)
Level accuracy:	± 3 dB
IP3 (Input):	$\geq +20$ dBm (10 MHz) $\geq +25$ dBm (10 MHz) from serial number 521
Maximum input level:	- 6 dBm (with 0 dB attenuation set, version A and B) 0 dBm (with 0 dB attenuation set, from version C) +8 dBm (maximum attenuation set)
Intrinsic noise power density (output):	≤ -159 dBm/Hz (10 MHz, 0 dB attenuation loss)
Power supply:	+9.0 ... +15.0 V- / max. 250 mA
Connectors:	BNC 50 ohm, hollow pin 2.1 mm, SMA
Maximum cable length from control unit to antenna:	depends on HF cable, max. 10 ohm DC resistance
Weight:	≤ 500 g
Environmental conditions:	0 ... +50 °C ambient temperature, $\leq 90\%$ 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!

Safety precautions

Please always keep the following safety precautions in mind!

Never connect the device to any other voltage than indicated in the specifications. Under no circumstances should the device come into contact with the mains voltage of 230 V ~!

It is essential to observe the lightning protection regulations for the outdoor operation of electrotechnical systems! When connecting an antenna outside the protected area (e.g. your house), it must be professionally provided with lightning protection. The HF bypass must be equipped with overvoltage protection. In case of lightning hazard, immediately take the antenna out of operation and disconnect it safely from other devices (remove HF connection)!

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!

Always provide a safe placement on a flat, straight and solid base of sufficient carrying capacity! Always transport the device either in solid cardboard or wooden boxes (e.g. the delivery packaging), or transport it by firmly gripping the housing! The device may cause injury in the event of a fall due to its own weight!

Never expose the device to mechanical stress due to impact, pressure, vibration or shock which exceed a normal level.

If you notice any damage to the device, immediately take it out of operation (remove 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!

1 Operator Manual

1.1 Introduction

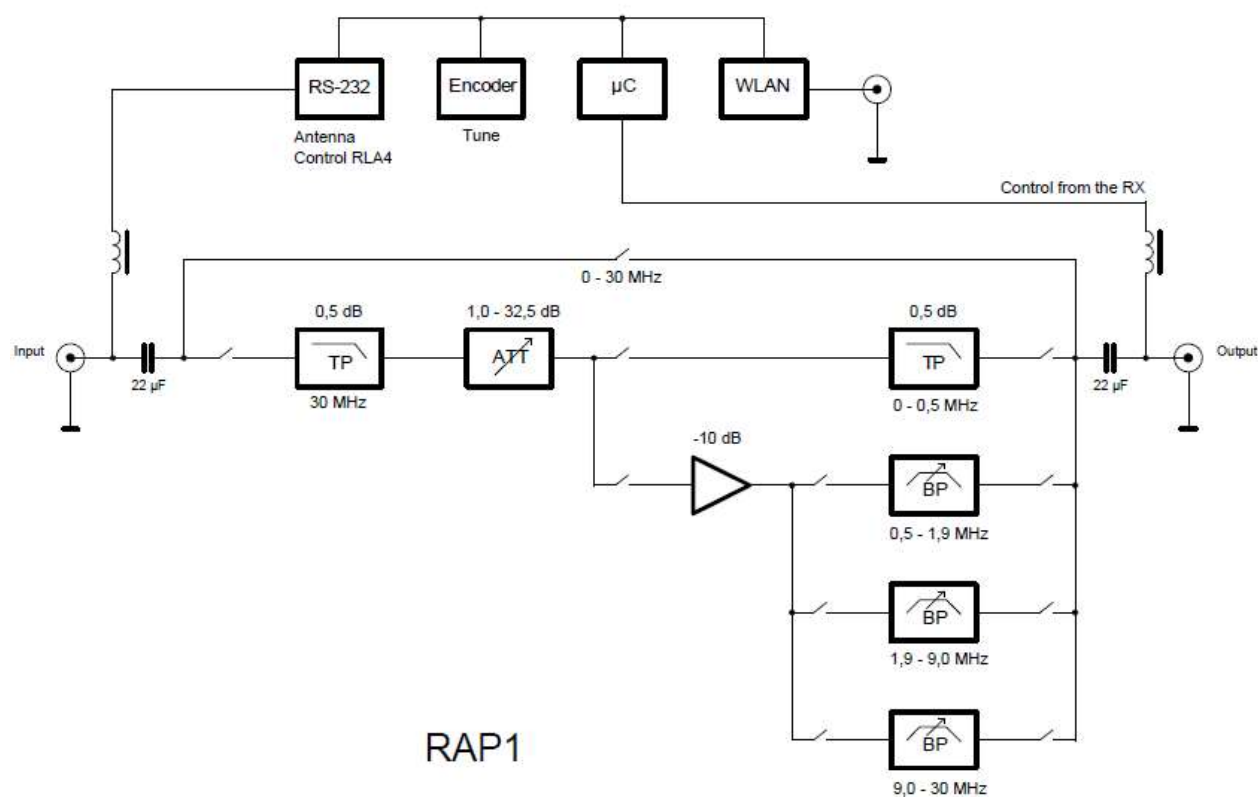
The RAP1 active preselector can be used to filter RF signals in the frequency range up to 30 MHz. The main field of application is the pre-filtering of antenna signals for forwarding to a receiver. The receiver thus contains lower sum levels (especially when using broadband antennas). This puts less load on the receiver's input circuitry (reducing possible distortion such as inter- or cross-modulation). Wideband or hard limiting receivers ("SDR") without or with only low RF selection benefit the most from the reduction of the sum level. The possible necessary use of an attenuator can be reduced or even avoided altogether and the receiver can thus be operated with maximum sensitivity.

Further possible applications arise in measurement technology and general RF signal processing, e.g. to improve the output signal of signal generators (attenuation of harmonics and / or low-frequency interference signals).

The RAP1 can be internally upgraded with an RSW4 control unit (version B and D). The unit is used for remote power supply and control of antennas RLA4. It also allows remote feeding of suitable active antennas via the coaxial cable with approx. 8 V and max. 250 mA. The current flowing to the antenna is measured and displayed and can be used as an indicator for proper operation or short circuit / interruption of the RF line.

In addition to single-knob operation on the device, the RAP1 can also be controlled remotely via a wireless connection (WLAN). For this purpose, the preselector has a WiFi-compatible (IEEE 802.11 b/g/n) transceiver (station) for establishing a connection to an access point. Control can then be performed by means of suitable applications (e.g. for smartphone, tablet or personal computer) from any terminal connected to the access point.

The block diagram shows the structure of the signal processing with the filter's switching options. Attention, the given dB values are attenuations (negative attenuation = gain).



1.2 Filter characteristics

A preselector only allows a specific frequency band of the signal at the input to pass through to the output. Ideally, the passed signal is not altered (no change in level, no addition of other signals such as IM distortion or noise.) The bandwidth and the mid-band of the transmitted signal should be adjustable within the widest possible limits.

The RAP1 meets almost all requirements. However, the bandwidth is not adjustable. It is fixed by the internal filter circuit and is mainly dependent on the set mid frequency. The filter design utilized operates rather broadband (predominantly inductively coupled 2-circuit bandpass filters). The average bandwidth is about 15 - 20% of the filter frequency. Thus, in normal operation, retuning is rarely required unless the receiver is tuned over large ranges (e.g., an amateur radio band is always fully passed). In addition, in receivers with a spectrum display, a sufficiently large area is visible next to the receiving frequency without attenuation. Nevertheless, the filter effect is sufficient in most cases for a good attenuation of distant interference frequencies (other amateur or broadcast bands, discrete and broadband interference from industrial and household appliances, ...).

To achieve the filter function over a frequency range of up to 30 MHz, 4 different filter circuits are implemented:

- Low-pass filter 0 – 0.5 MHz: Fixed filter with lower cut-off frequency by 2 serial 22 μ F capacitors
- Bandpass filter 0.5 – 1.9 MHz
- Bandpass filter 1.9 – 9 MHz
- Bandpass filter 9 – 30 MHz

Furthermore, the complete bypass of the filters for a frequency range of 0 – 30 MHz (min., typically up to over 100 MHz) is possible.

All switching and tuning processes of the filters are carried out automatically by a microprocessor control (μ C). The operator simply specifies the desired tuning frequency.

The level difference between input and output is 0 dB nominal attenuation in the passband (approx. 2 dB in the range 0 – 0.5 MHz). This requires the use of an amplifier to compensate for the filter damping that is always present (hence the term "active" preselector). The amplifier also has another important task: It matches the input quite accurately and broadband to the required 50 Ohm impedance of the BNC connector.

This is important because the filter circuits have very different and frequency-dependent impedances. However, the preselector is often connected at the end of long cables from the antenna. At this point, an exact impedance termination is necessary to avoid interference (jacket waves) and influencing of the antenna properties. The RAP1's amplifier decouples the antenna with coax derivation from the following steps and thus simplifies the connection of antennas.

The output of the preselector is coupled directly to the filters via a passive matching circuit. Thus, the output impedance is not ideal 50 ohms and it is frequency dependent. **The filter effect depends on the devices connected to the output!** Therefore, the connection from the RAP1 to the connected device should always be kept as short as possible. The reception device should have an accurate and broadband input impedance of 50 ohms!

The range from 0 – 0.5 MHz (low-pass filter) does not have an amplifier and therefore always has a certain basic attenuation (approx. 2 dB). The output and input of the preselector are connected via the filter, so changes at the output (impedance of connected devices) are not decoupled from the input.

The bandpass filters in the ranges from 0.5 – 30 MHz have different attenuations within their respective tuning range. In order to still ensure the nominal attenuation of 0 dB is largely stable, the built-in amplifier has a corresponding gain reserve. An additional attenuator that can be switched in steps of 0.5 dB reduces the amplification to such an extent that just 0 dB of attenuation is achieved over the entire circuit (input to output of the RAP1).

The attenuator is controlled automatically, as are the filter circuits. This means that when the frequency setting is adjusted, the appropriate value for securing the set attenuation is also specified in each case. In doing so, the RAP1 always tries to keep the attenuation constant regardless of the frequency, as long as it is technically feasible. Only if the set attenuation value cannot be realized at the current filter frequency, an

adjustment to the possible maximum or minimum value is made.

Exception: When switching from bandpass filter operation (0.5 - 30 MHz) to lowpass operation (0 - 0.5 MHz), the RAP1 remembers the attenuation set in the bandpass range and restores it when switching back from lowpass to bandpass (as far as possible).

The nominal attenuation can be changed manually (or via WiFi) by the user. The adjustment range is 31.5 dB. The value currently required by the filters (controlled by the microprocessor) and the available overall gain of the amplifier are also taken into account. **The adjustment range is therefore only 0 – 31.5 dB in special cases!** Rather, it ranges from the current internal filter attenuation to the total possible attenuation of the attenuator + gain. Negative values, i.e. an amplification from the input to the output, are also possible. Example:

- Overall gain of the amplifier: 10 dB.
- Current attenuation of the band filter at the set frequency (used by μC): 6 dB.
- Total gain value not required (current reserve): 4 dB.
- Adjustment range of the attenuator: -4 dB ... 27.5 dB.

The amplification reserve that is not required can therefore be used to increase the antenna level if required.

However, more often (e.g. on powerful antennas, broadband active antennas with high output level, ...) the use of the attenuator's reserve will be necessary. The largely very advantageous use of an active circuit (amplifier) in the RAP1 also has a disadvantage: The amplifier generates additional distortions (IM) and in particular it has a modulation limit (maximum level that can be processed, see Specifications).

If the level at the input causes clipping, the attenuation value must be increased. It is not always easy to see whether any overmodulations are being caused in the RAP1 or in the connected receiver. The RAP1 does not have an overmodulation indicator. Therefore, the levels must be assessed in the receiver. An existing receiver attenuator could be used for this purpose. **However, the goal is always to use as little attenuation as possible in RX and, if necessary, to attenuate the level in RAP1.**

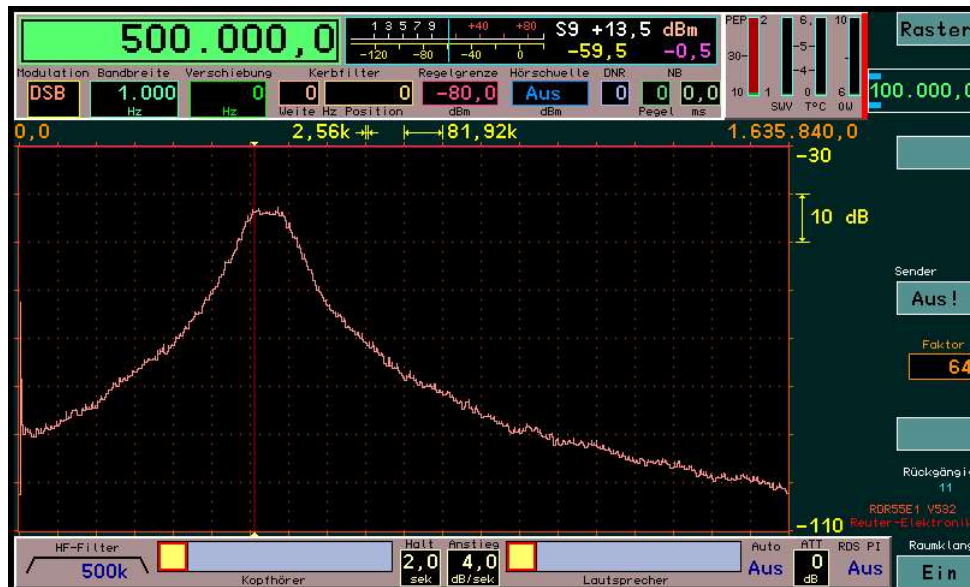
The attenuator can also be used in the 0 – 0.5 MHz range (without amplifier, always at least 2 dB attenuation of the filter).

Caution! Even when the attenuator is switched on, there is an upper limit for the permissible input level, which can be lower than the limit at 0 dB + attenuator value (limited by overvoltage protection diodes and the maximum permissible input power of the attenuator)! **Exceeding this limit will destroy the device! If necessary, connect external attenuators and / or overvoltage protection devices to the input of the RAP1!**

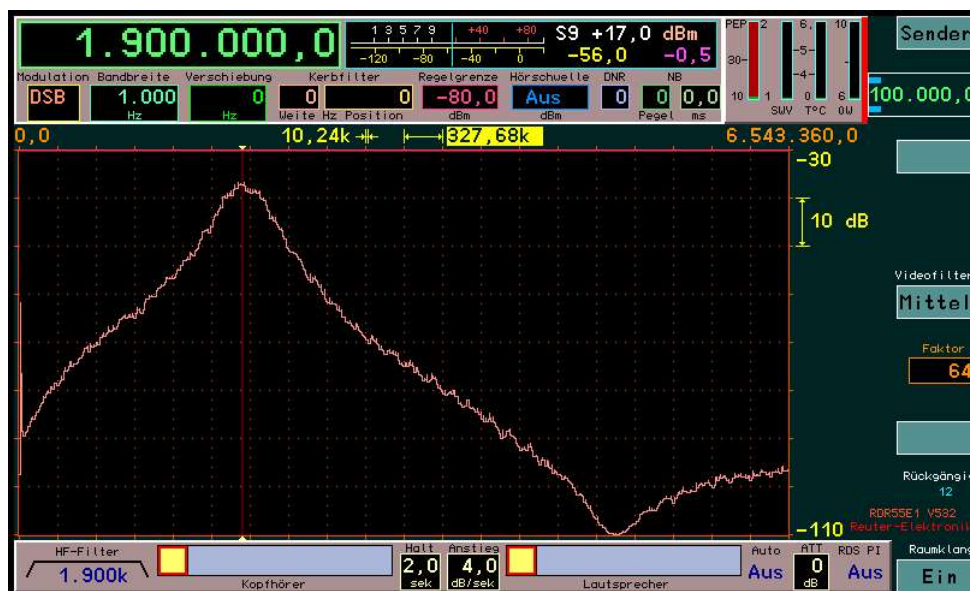
When the filters are switched off (range 0 – 30 MHz), neither the attenuator nor the amplifier can be used. The signal is switched directly to the output via 2 22 μF isolating capacitors (direct current isolation from any antenna remote feed).

Finally, some images to clarify the possible filter curves in the different areas. Depending on the tuning within the respective range (lower to middle to upper end), slightly different curves result (supercritical ... critical ... subcritical coupling of the 2-circuit filter). The transitions when switching from one range to another are particularly significant. It can sometimes be more advantageous to tune the RAP1 slightly off the actual reception frequency (place the signal outside the center or even "on the edge") if this results in an internal band switchover with a possibly more advantageous filter curve.

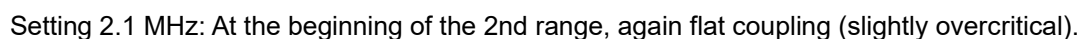
(The curves were recorded with a digitally generated broadband noise ("shaky" curve) in real time on an RDR55 equipped with 4 pieces of 16-bit ADC.)

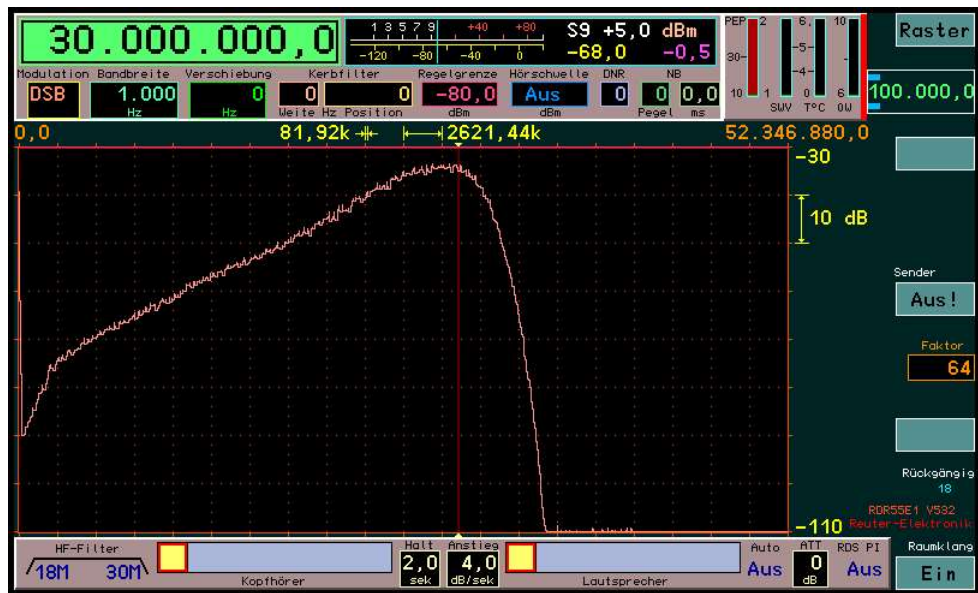


Setting 0.5 MHz: The filter curve (slightly overcritical coupling) is just under 500 kHz with the left side.

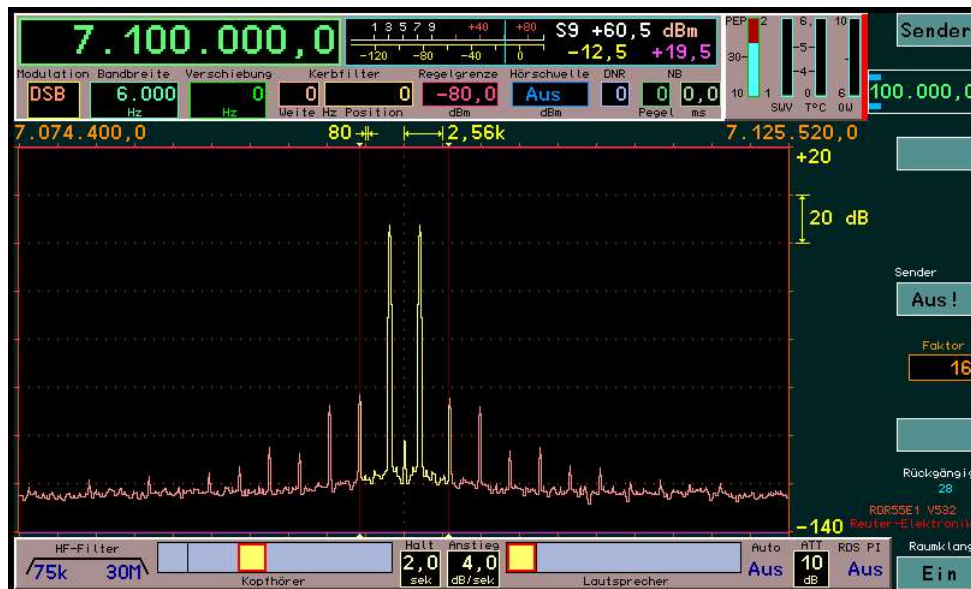


Setting 1.9 MHz: The filter curve (end of the 1st range, subcritical coupling) is steepened in the higher-frequency range by an additional notch filter and is therefore almost symmetrical in the linear frequency representation.





Setting 30 MHz: The filter curve becomes relatively wide above approx. 15 MHz (decreasing quality of the components used). A steep low-pass filter works at the upper end (RDR55 receiver), so that the upper edge can no longer be displayed correctly in the spectrum.



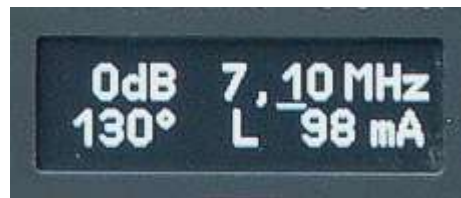
Intermodulation at 7.1 MHz: Despite active amplification and relatively small filter components as well as fully electronic tuning (using many switched semiconductors), the RAP1 only generates a small amount of IM (IP3 of the measurement in the picture approx. +23 dBm). As long as the downstream receiver does not have a significantly higher IP3, it is very unlikely that the reception will be impaired by the IM distortions of the RAP1.

1.3 Operation

The RAP1 is set using a rotary knob. A small OLED display is used to show the values. The knob is actually a high-quality optical pulse encoder. It also has a push function. Every actuation of the rotary encoder is evaluated by a microprocessor (μC) and processed to the corresponding control of the device.

In addition, all device functions can be controlled via the WiFi interface. To do this, the RAP1 must be logged into a WiFi access point. The RAP1 can then be operated via any device connected to this access point (usually "IT technology" in the local network or Internet).

The set values of the RAP1 are shown on the display. A cursor (horizontal line below the display value) shows which value can currently be adjusted using the rotary encoder. The cursor can be moved by pressing and then rotating the rotary knob.



Caution! For devices without antenna control (RAP1A/C version), only the WiFi connection status (here "L" for connected to the access point) and the 1 mA digit of the current display (always 0, since antennas cannot be fed) are displayed in the bottom line!

The following display digits can be selected with the cursor and changed with the rotary knob:

- 0.01 MHz frequency digit: Changing the filter center frequency in 10 kHz steps.
- 0.10 MHz frequency digit: Changing the filter center frequency in 100 kHz steps.
- 1.00 MHz frequency digit: Changing the filter center frequency in 1 MHz steps.

Note: When setting a frequency below 0.51 MHz by moving back the 0.01 MHz digit by one step, "0-0.5 MHz" is displayed and the low-pass filter is switched on. If the frequency is moved back by more than 0.01 MHz (regardless of the increment), "0-30 MHz" is displayed and all filters, as well as amplifiers and attenuators are bypassed. In this case it is also not possible to change the attenuator value, "0dB" is always displayed.

- 1 dB attenuator digit: Changing the attenuator setting in 0.5 dB steps.

Note: Due to the fact that only 4 display digits are available, the "dB" unit of measurement is not displayed for a setting with a 0.5 dB digit. Example: Changing the value from 0 dB to 0.5 dB: Display "0 dB" → "0.5dB".

- 1° digit of antenna control (only RAP1B/D devices): Change of antenna orientation by 1°.
- 10° digit of antenna control (only RAP1B/D devices): Change of antenna orientation by 10°.

- 1 mA digit: Changing the power consumption of the display (brightness control).

Note: The mA value shown is not the current of the display, but the current to the antenna. This value is not adjustable.

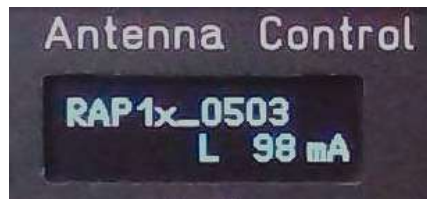
Caution! The service life of the display decreases with increasing brightness! Set the brightness only as high as absolutely necessary for reading.

In addition to the knob to carry out all settings, only the on / off switch is present. All settings made are saved when the device is switched off and restored when it is switched on again.

1.4 Remote control via WiFi

Remote control requires the RAP1 to log into an access point such as a WiFi router. Bidirectional control is then possible via an application on an IT device that is also connected (changes to the device are displayed in the app and vice versa).

The designation of the RAP1, under which it can be found in the network, is "RAP1x_nnnn" (from firmware Vx3 "RSW34_nnnn"), whereby the serial number of the device with 4 digits (i.e. possibly leading zeros) must be used for "nnnn". (It is specified on the nameplate.) This designation is always displayed briefly when the device is switched on:



As an application for remote control from a Windows PC, the user interface "RLFA_Vxx" (xx = version) from V05 can be used to control antennas (download on the product page of the RAP1, below at "Software"). The operation corresponds to the description in the appendix. When connected to a preselector RAP1 (as of firmware Vx3 always specify "RSW34_xxxx" with "xxxx" = serial number incl. leading zeros in the Setup!) additional control elements appear. They have the following functions:

- **"Frequency MHz" window:** Display and input window for the RAP1's frequency setting. When changes are made to the RAP (rotary knob), the current setting is displayed here. A frequency can be entered in the window (click / tap). As long as the input mode is active, the font appears red and changes made directly at the RAP1 (rotary knob) are not displayed. The input in MHz can be made with any decimal places. It is completed by pressing "Enter" and then sent to RAP1. Too many / too few decimal places are automatically adjusted to 2 digits, too large / too small values are limited to the possible maximum / or minimum value.

- **Arrow up / down to the right of frequency:** With each click / tap the frequency is increased or decreased by 1 in the marked position. Overflows up and down are taken into account in the other digits (change of the total frequency value). Clicking / tapping an arrow key for a longer time generates continuous counting.

- **Black bar under frequency:** Highest value digit that is changed when clicking / tapping the arrow keys. The bar can be moved below the two decimal places or to the 1 MHz digit.

- **"Zero Out" button:** Clicking / tapping the button sets all digits to the right of the current input location (bar) to zero.

- **"Bypass 0 - 30" button:** Clicking / tapping the button switches the RAP1 to bypass mode.

- **"0 - 0.5" button** Clicking / tapping the button switches the RAP1 to the lowpass range.

- **"Attenuator dB" window** Display and input window for the attenuation setting of the RAP1. The function corresponds to the window for frequency input.

- **Arrow up / down to the right of attenuation:** Changing the attenuation in individual steps. The function corresponds to the arrow keys for frequency change. It is always possible to change only the least significant digit in steps of 5 (0.5 dB).

- **"Max" and "Min" buttons:** Clicking / tapping a button sets the attenuation setting to the current maximum or minimum possible value according to the current filter setting of RAP1.

Note: The operating elements for controlling a possibly connected RLA4 antenna are always visible and functional. However, they have effect only on devices RAP1 version B and D (change of degree setting and output of control signals to the antenna).

2 Upgrades / Software Updates

2.1 Hardware Versions RAP1C and RAP1D

The device versions A and B allow remote control via WiFi connection to a PC or a receiver / transceiver of the RDR5x series. Version B, for its part, can remotely feed and control an RLA4 antenna connected to the "ANT" input via the coaxial cable.

All newer versions of the RDR5x devices can also feed and control RLA4 (and RFA1) antennas directly. Like the RSW control units, they apply supply voltage and control signals to the coaxial cable at the antenna input.

The preselector RAP1 has been extended so that it can evaluate these control voltages of the coax cable coming from the RX. This allows it to process the signals to set the frequency and reception direction for RLA or RFA antennas. These signals can thus be used for remote control of the RAP1 without a WiFi connection having to be active.

Caution! Remote power supply via the RF cable from the RX is not possible! The RAP1 always requires its own power supply!

To remote control the RAP1 without WiFi directly via cable from a RDR5x, the RDR must be set to the value "RAP" in the Setup dialog under item "Antenna Control". (You may have to update your RDR5x software for this). A set value for direction control of an RLA4 antenna then appears in the user interface of the device.

This value is transmitted via the coaxial cable to the RAP1 and appears in its display. In addition, the RAP1 transmits this value further to an RLA4 antenna connected to its input (RAP1B/D version only). The function corresponds to connecting the antenna directly to the RDR5x and setting it to "RLA" in the Setup. If the value is changed at the RAP1B/D, it is also transmitted to the antenna. However, "reverse transmission", as with remote control via WiFi, is not possible.

In addition to the set value of the RLA4, the current frequency is also transmitted to the RAP1 (from version RAP1C). So if the frequency is changed on the RDR5x, the RAP1 will be retuned automatically (like via an active WiFi connection). Again, "reverse transmission" is not possible when changing the frequency setting on the RAP1 (but also locked via WiFi). Frequency changes are not transmitted to a possibly reacting antenna (for example, an RFA1). Connecting a frequency-selective antenna via another frequency-selective preselector is pointless anyway. (However, the RFA1 can also be remotely powered and controlled directly from an RDR5x without an intermediate preselector).

Advantages and disadvantages of the two remote control options:

- WiFi:
 - Fast data transmission.
 - No interference with the RF reception signal.
 - Receive back the RLA4 setting when changes are made to RAP1 for display in the RDR5x.
 - RDR5x access point must be switched on (power consumption, load on RF environment).
 - RAP1 must be within WiFi range of the RDR5x, or connected via external network.
- Coaxial cable:
 - Slow data transmission.
 - No feedback from setting changes on the RAP to the RDR5x.
 - RF interference possible due to data transmission via RF line.
 - Low power consumption.
 - No need to use the 2.4 GHz WiFi range.
 - Distance RDR5x -> RAP1 limited only by cable resistance.

The current firmware for the devices is

- RAP1C: RAP1C_Vx4.BIN
- RAP1D: RAP1D_Vx4.BIN

Other changes from RAP1A/B:

- The network name is now "RSW34_xxxx" (xxx = serial number).
This makes the control with an RDR5x receiver / transceiver fully compatible with the RSW3 and RSW4 antenna control units. For WiFi remote control of the RAP1, the setting "RSW" can be selected in the Setup dialog of an RDR5x. If the connection is established successfully (see appendix), both the remote frequency control and the direction control of an RLA4 (version D devices only) are performed from the user interface of the RDR5x.
- Switching the remote power supply.
RAP1 device version D allows for remote feeding of antennas. Usually a RLA4 is connected (power supply and direction control). The following other options exist:
 - ➔ Turning the setting beyond 0° to the left: Switching off the supply voltage (display "Off!"). If an active antenna is not connected or is not to be operated, the voltage can be switched off. When connecting passive antennas with galvanic connection, this can prevent unwanted current flow through the antenna.
 - ➔ Rotate the setting beyond 180° to the right: Switchover to supply voltage 12 V (display "12 V"). This enables a feeding possibility for any active antennas with demand of 12 V and not more than 200 mA current. (There is an internal shutdown at currents greater than approx. 220 mA). To reach 12 V at the input of the RAP1D, a supply voltage of min. 12.5 V must be connected. Otherwise, the available remote supply voltage is reduced by the corresponding value (approx. 0.5 V below supply voltage).
 - ➔ Press the button for min. 3 s when the cursor is on a position of the degree display: The remote power supply and control of an antenna is completely switched off. The display disappears. To switch on again, press the button again for at least 3 s.
- Increase of the allowable input level without attenuator (setting 0 dB) up to 0 dBm.
The amplifier in RAP1C and D can handle a bit more level without running into the limit. This means that an attenuation setting greater than 0 dB is required less frequently. However, in the extended range from -6 dBm to 0 dBm, distortion (IM) also increases. If possible (maximum sensitivity not required), some attenuation should always be selected to reduce the load on the amplifier and filter circuit.
- Fast switching option between filter operation and filter bypass.
If the knob is pressed for longer than min. 3 s and is not turned (turning always triggers the cursor shift in the display), the RAP1 switches the operating mode. When the attenuator and filters are bypassed, "-----" is shown in the display.

Caution! Even with remote control from the RDR5x, "forced switching" to bypass is possible. In this case (as well as when the lowest or highest possible filter frequency is exceeded) "0-30MHz" is displayed. This makes it possible to distinguish on which device (RAP or RDR / PC) this operating mode was switched on. **The RAP1 always has priority!** As long as it is manually switched to bypass, no change is possible from the RDR5x or PC!

- Switching off the WiFi transceiver.
Normally, the WiFi transceiver is always active and waiting for a connection option to an external control device. This consumes power and puts a strain on the 2.4 GHz radio range. The transceiver can be permanently deactivated by moving the cursor to the display position of the current connection status. The status and thus the entire WiFi transceiver can be switched off by pressing the button for at least 3 s (letter disappears). The setting is stored permanently, even after the RAP1 is switched off. To switch on again, the cursor must be moved to the now empty position and the button must be pressed again for at least 3 seconds.

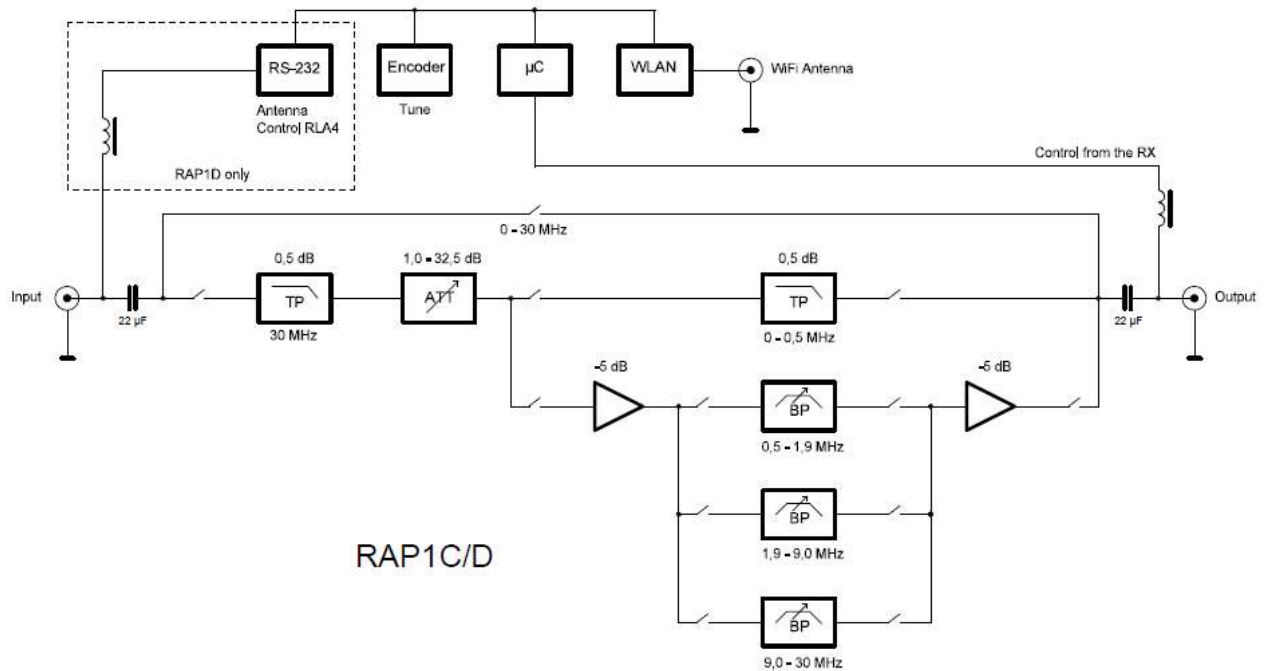
2.2 Firmware Vx5 / circuit extension

The firmware RAP1C_Vx5 (without antenna control) and RAP1D_Vx5 (with antenna control) contains the following changes:

- Omission of the UDP connection via WiFi

The RAP1 can now be remotely controlled exclusively via TCP/IP connections (or the cable to the RX). The required data is explained below. This allows the device to be controlled from any source (IT devices or appropriately created software).

From serial number 521 the circuit of the RAP1 contains an additional amplifier at the output. The gain at the input was reduced accordingly.



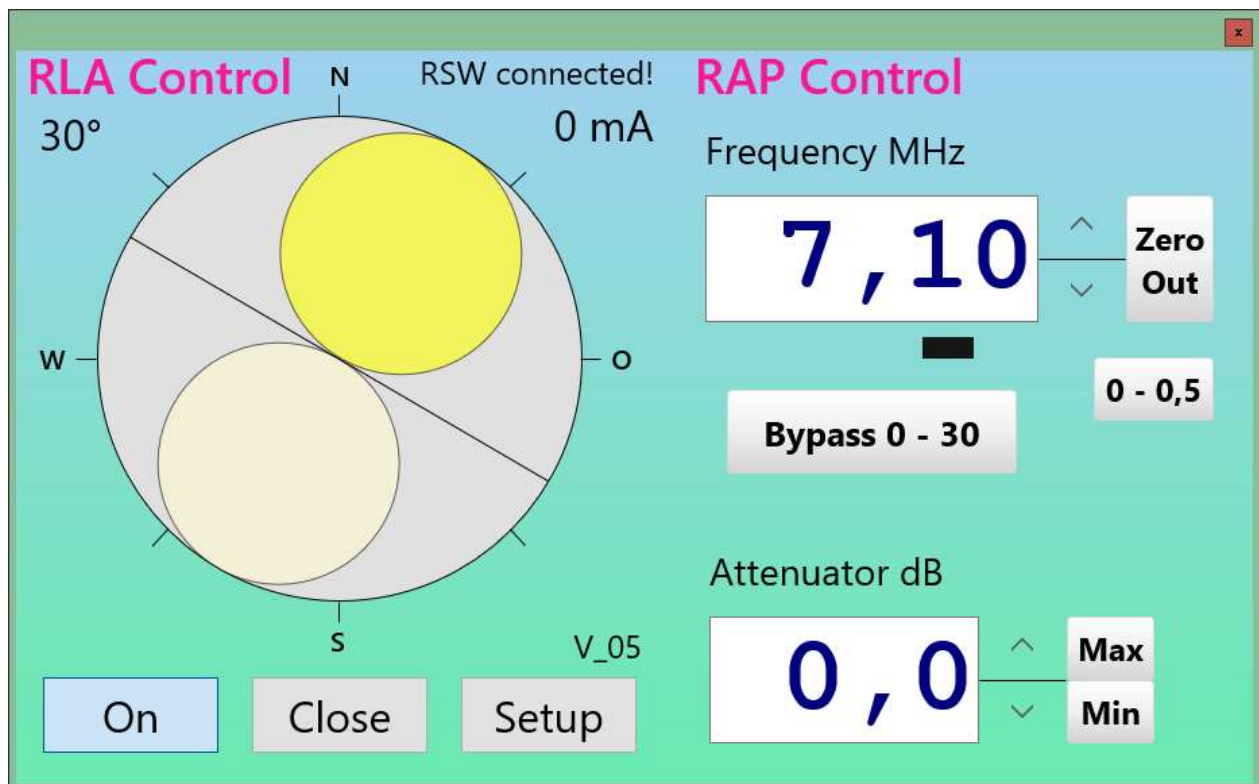
The use of the additional amplifier enables the following advantages:

- Reduction of the levels at the filter components. This increases the IP3 by min. 5 dB.
- Decoupling of the filter circuit and exact matching of the output impedance to 50 ohms even in the range 0.5 - 30 MHz.

Appendix: WiFi connection with an access point and Windows software RLFA_Vxx

The RAP1 has a network controller with corresponding software ("TCP/IP Stack") and a 2.4 GHz transceiver for establishing network connections via a WLAN ("WiFi"). It can be controlled via such a connection as well as by direct operation on the rotary knob. That is, frequency and attenuation can be changed and the directional setting of an RLA4 can be controlled remotely. Due to the standardized IP connection, control by any suitable software is possible via any available connection (e.g. Internet).

In addition to device-specific software (e.g. user interface of the RDR52), remote control software for Windows-compatible PCs is available for the RAP1: RLFA_Vxx.EXE (xx = 2-digit version number). It allows the adjustment of the RLA4 and the RAP1 by remote control. Below follows the description of the software with control of the RLA4. The additional operating elements of the RAP1 are included in the operating instructions of the RAP1 (see above).



After opening the file RLFA_Vxx.EXE the program window appears. It contains the graphic replica of the antenna diagram of the RLA4 as well as some displays and buttons. The degree indicator on the top left and the power display on the top right correspond to the displays on the RAP1. A text box above the current display shows the current connection status between the software and the RAP1. The buttons in the lower area can be used to switch the RLA4 on or off (corresponds to turning the RAP1 all the way to the left until "Off" appears or turning to the right on a degree display), the program can be ended or another window for further settings ("Setup", see below) can be opened.

The antenna diagram can be rotated within the circle by clicking with the mouse (or tapping on devices with a touchscreen) and then dragging it to a desired position. The two reception lobes of the RLA4, stylized here as a circle, indicate the direction of the maximum reception. The degree indicator on the top left (or that on the display of the RAP1) always refers to the right, darker side of the reception diagram. Its maximum (point of contact with the gray circle of the compass direction) corresponds to the degree indicator.

Note: If the RLA4 is set up with its main receiving direction facing north, when the degree display is set to 0°, the antenna diagram shows the correct direction. However, the sometimes large deviation of the actual antenna diagram from the ideally displayed diagram in the software or the degree display should be observed. Without the employment of a correction table for the exact assignment of the actual reception diagram to the displayed diagram, the RLA4 can only be used for direction finding purposes to a very limited extent.

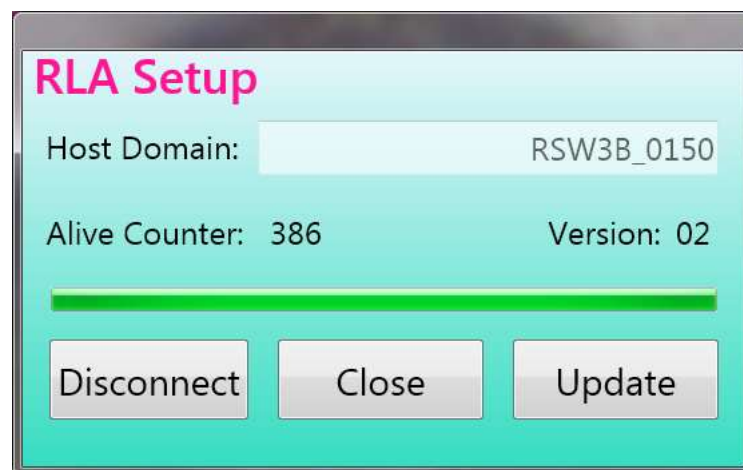
The alignment of the maximum reception is not so necessary with the RLA4, because the reception lobes are very wide and even larger deviations hardly result in a reduction in the reception level. Rather, the exact positioning of the zero point (minimal reception) is important to suppress signals from very specific directions (attenuation of unwanted transmitters or interference). In the diagram, the zero point is displayed by the line between the circles. The line is always located at a 90° angle to the main reception direction.

The diagram can be rotated very quickly in the program window, much faster than the RLA4 can actually react (relatively slow transmission of the control words from the RAP1 to the antenna). For this reason, intermediate steps are omitted in the case of a fast rotation, and the then valid data is only transferred when the desired position is reached (stopping the rotation by releasing the mouse button or lifting the finger). The diagram and the degree indicator always display the position reported by the RAP1 and that is actually transferred to the antenna. Delays during data exchange (for instance, because of a slow internet connection) can lead to jerky movements.

An exact and sensitive adjustment can be achieved with the computer mouse's scroll wheel. Moving the scroll wheel one step exactly advances the antenna position by one level. This corresponds to the operation as with the RAP1's rotary encoder of the antenna (its operation is also displayed by rotating the directional diagram and updating the degree indicator within the program). Please note that a position step does not exactly correspond to a 1° change in direction, but approx. 0.776° (the RLA4 has 232 steps for 180° rotation). However, there is no representation of decimal places within the degree indicator due to the anyway existing inaccuracy of the real antenna diagram.

Setup

To set the connection parameters from the RLFA_Vxx.EXE program to the RAP1, another window can be opened with the "Setup" button.



Caution! As of version V04, "**RSW34_nnnn**" with nnnn=serial number must always be inserted in the window for the device name!

When the antenna is connected (note "RLA connected!" at the top right of the main program window), an "Alive Counter" (activity counter) counts the data that is constantly exchanged between the program and the control unit (at least 2 data packets per second). To the right of this, the firmware version contained in the RAP1 is displayed (see below under "Update").

By pressing the "Disconnect" button, the connection to the RAP1 can be disconnected. The counter then stops, the name of the button changes to "Connect" and the input field for the network name of the RAP1 becomes active. This state is also present when the Setup window is opened if there is no connection to the RAP1.



In the text field "Host Domain" (called "RSW Name_S/N" in newer versions) the address under which the RAP1 can be reached by the program must be entered. Depending on how it is coupled with other devices (computer, router, ...) (see below) and the connections via which the program can access these devices (LAN connection, Internet, WiFi Direct, cellular network, ...) different possibilities exist. 2 basic variants exist:

1. The RAP1 and the computer on which the RLFA_Vxx program is started are located in a common network with free access between the devices. Example: Home or corporate network under Windows.

In this case the RAP1 can be addressed directly with its name in the network. The designation is always made up of the word "RSW3B" (from software version 3 "RSW34") with the following underscore "_" and the four-digit serial number of the device. This is indicated on the type plate on the bottom of the housing and is briefly shown on the display when it is switched on (when the power supply is connected). The serial number must always be entered with 4 digits, i.e. with shorter numbers with leading zeros.

2. The RAP1 and the computer on which the RLFA_Vxx program is started are in separate networks. The connection is established via various media and is usually secured by protection software (firewall) in such a way that no arbitrary access from one network to the other is possible. Example: Remote control via the internet.

In this case, additional preparations must be made to make the RAP1 or its network "visible" for the program. Various options and additional software exist for this purpose, which cannot be described in more detail here. In principle, all of these variants enable the program or the computer on which it is running to use an address or a name with which the RAP1 can be accessed. This address / name must then be entered in the Setup.

Example: Access via port sharing in the router of the network in whose WLAN access point the RAP1 has logged in.

In this case, the RAP1 has been connected to a WLAN router and all computers that are also connected to this router have direct access via the name of the RAP1 (variant 1). If the router is connected to the internet (e.g. via DSL), other computers on the Internet cannot normally access the network or the devices in it (meaning the RAP1 and other computers).

In order to "forward" a connection from the internet to the RAP1, the router must explicitly allow this connection(s) for certain addresses (ports). This so-called port forwarding can be configured in any conventional router. Please utilize the router's documentation for this process. The following variables must be set:

- The device to be accessed via the forwarded ports. The RAP1 is listed in the router either under its designation "RAP1" (possibly with attached additions such as version and serial number), or under the designation "espressif" (the name of the RAP1 network processor).
- The port or ports to be forwarded. For the RAP1 this is only one port number: 55556.

- The protocol(s) with which the RAP1 can be accessed via the forwarded port. The protocols "TCP" and "UDP" must be enabled for the RAP1. Depending on the router, this can be achieved with one setting (both protocols can be selected in the port forwarding dialog at the same time), or you have to set up port 55556 for each protocol individually.

After confirming these settings, the RAP1 can be accessed via the internet. To do this, the IP4 address of the router that contains the port release and the RAP1 is logged in must be entered within the RLFA_Vxx.EXE program. This address is displayed within the router configuration program if it is connected to the internet.

The problem with variant 2 consists in the automatic changing of this "public IP address" each time the router is reconnected to the internet. This means that every time this happens, you would have to look up the address and enter it in the remote control software again. There are many ways to avoid this problem. For example, it is common to use a "DNS service" that always assigns a unique designation to the router, regardless of the current IP address. The router manufacturer often offers a service like this, e.g. "MyFritz" for the widespread Fritz Box router. After setting up this service, the designation assigned to the router can be permanently entered in the Setup of the program.

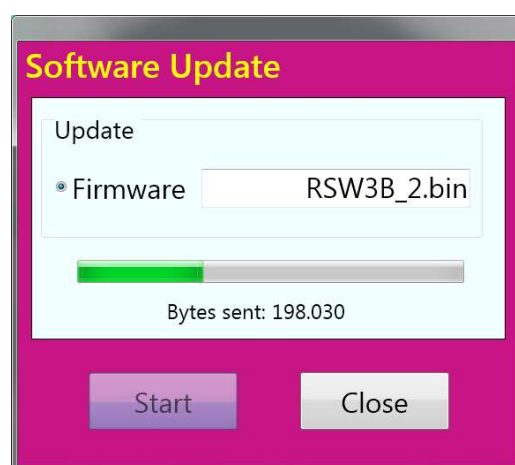
Pressing the "Connect" button initiates the establishment of the connection to the RAP1. The green progress bar shows the progress. If the connection is successful, the button name changes to "Disconnect" and the Alive Counter begins to count. The version number appears on the firmware display.

If the progress bar completes to the end without a connection being established, the attempt is terminated and the Setup window remains in the disconnected state. In this case, it must be checked whether all the necessary conditions for establishing a connection are met (RAP1 switched on, logged into a WLAN, access to this WLAN from the program possible, correct address / correct designation entered in the Setup, ...).

The software access to the RAP1 occurs according to the motto: "First come, first served!" As soon as any device (PC) has established a data connection with the RAP1 ("S" in the RAP display), it has exclusive control and other devices can no longer access it. Only after the connection has been closed (in the Setup dialog or by closing the application) can another one get access. Only a single instance of the RLFA_Vxx program should be started on each device. The control of several RAP1 from one device is only possible by changing the connection according to the set value in the Setup.

Firmware Update

The RAP1 contains integrated software ("firmware") that controls its function and connection via WiFi. If there is a connection, this firmware can be updated from the RLFA_Vxx.EXE program. To do this, press the "Update" button in the Setup. Another window opens.



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 .BIN and be located directly in the folder of the program file RLFA_Vxx.EXE. If there are several such 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 RAP1.

Caution! The transmission can only take place if the RAP1 is connected to the software (see above) and the control works correctly (the antenna diagram reacts and the alive counter in the Setup is moving)!

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. After a few seconds, the connection must be re-established in the Setup, if this has not already been done automatically. The update can then be retried. In the event of multiple cancellations, the reliability of the connection between the program and RAP1 must be checked or established (perfect and largely delay-free operability of the RAP1).

Caution! Only start the update if you have direct manual access to the control unit! Depending on the changes in the firmware or in the event of serious data errors, it may be necessary to disconnect the RAP1 from the power supply and reconnect it. In addition, the network data (names, addresses, password ...) may have changed so that the WiFi connection of the RAP1 must be set up again (see below).

The successful end of the transmission is reported with a message window. An automatic reset then takes place in the RAP1 and the device starts with the new firmware. Now the connection between the program and the RAP1 must be re-established (this can also occur automatically, please wait a few seconds). The Update window must be closed and the old connection must be interrupted in the Setup window with the button "Disconnect". The button now called "Connect" allows the connection to be re-established as specified in the description of the Setup window. The software version of the new (previously transferred) firmware must now appear in the version display (corresponds to part of the name of the firmware's BIN file).

Note: The version number always contains the consecutive version number of new firmware in the 2nd digit. The first digit changes with each successful update between 2 different digits / letters (depending on device and firmware version) to detect a successful re-transfer of the firmware. The first digit always alternates between the digit 5 and the letter D at the RAP1.

If the old version number appears again, there were errors while transferring or restarting the RAP1. In this case, the update must be repeated. If a connection is no longer possible, there may be various errors:

- The connection between the program and RAP1 was interrupted by one of the devices involved. For example, the restart of the RAP1 requires an automatic or manual re-establishment of its WiFi connection (see below), or the connection of the computer with the program RLFA_Vxx.EXE to the internet was interrupted by the computer or the internet access device (router, mobile device, ...) and must first be re-established again.
- No valid (not originally downloaded from the manufacturer) or incorrect (data error, virus attack, ...) BIN file was transferred. In the vast majority of cases, the RAP1 recognizes faulty data, aborts the transmission and starts again with the old firmware. Executable new, but possibly defective firmware can still be started and can permanently disable the function of the RAP1 if there are errors. In this case, the device must be sent to the manufacturer for basic reprogramming.

Connection of the RAP1 to a WiFi access point

For remote control of the RAP1, it must be connected ("logged in") to an access point (also called hotspot, access point or similar) according to WiFi standard in the 2.4 GHz band. Such an access point can e.g. be a WLAN router, a suitably configured personal computer, a smartphone, a WiFi-capable radio unit or the like. From this device, which provides the access point, the further connection to the control software (e.g. RLFA_Vxx.EXE or user interface of the RDR52) takes place as described above.

To log in to the access point, the RAP1 uses a secure connection according to "WPA2-PSK". This requires the specification of a password with which the access point allows WLAN subscribers (stations) to log in. The participant (in this case the RAP1) must know the name ("SSID") of the access point in which it wants to log in and query it to be allowed to participate in the network using the password. If the access point grants participation (it "authenticates" the station), the requester is logged in as a station and can now exchange data via the network.

Note: The access point must be configured so that it actually grants the request of the RAP1 with the correct password and does not e.g. deny it by blocking his MAC address or the like (see notes further below).

The RAP1 does not have the option (keyboard or similar) for alphanumeric entry of names and passwords. For this reason, certain simplifications and / or restrictions regarding the selection of access points must be observed.

1. Simplified / automatic login using the "WPS push button" method.

Many access points (especially routers) allow stations to log in using this method. The access point must be switched to this mode (usually automatically limited to 2 minutes), in which case it then transmits its authentication data (name and password) to all requesting stations. They therefore have all the data to be able to log in. The access point (or its operator) can then decide whether it really wants to authenticate the logged-in stations (e.g. the RAP1) or exclude it from participating in the network (e.g. unknown stations, spies and hackers).

Caution! Depending on the RAP1's firmware, it can be displayed in the list of stations found via WPS with the designation "RAP1" (possibly followed by further numbers) or as "espressif". This device must remain in the list of allowed devices.

To connect the RAP1 to the access point using the WPS push button, proceed as follows:

- Disconnect the RAP1 from the power supply, connect the antenna to the "WiFi" socket.
- Start the WPS push button method within the access point (Physical button on the router or button in configuration software). Wait a few seconds.
- Press the rotary knob on the RAP1 as far as it will go and establish the power supply (switch on with the knob).
- Release the rotary knob immediately after the display shows.

The top line of the display (where attenuation and frequency normally appear) now shows: "Search AP ...". When the connection to the access point has been successfully established, the display shows: "AP:" followed by the name of the access point (only the first 9 characters are visible). In the access point, the WPS authentication is canceled and the device found is displayed in the list of logged-in stations. An "L" appears in the RAP1's display between the degree and the current display to indicate successful login. As a check, the power supply can be briefly interrupted and restored (without pressing the rotary knob!). After a short time, the "L" must appear on the display again and the device RAP1 or espressif must be shown as connected in the access point configuration software. Now the RAP1 automatically logs into this access point each time it is switched on (if accessible).



2. Logging into a suitably configured access point

If there is no possibility of connection using the WPS method, the RAP1 can only connect to access points that use a specific password. It is called: "1234567890". Such a password is of course not secure, if only because it is publicly displayed here. This method only makes sense if an access point is used that does not allow any connections other than those to the RAP1. An example are the receivers / transceivers of the "RDR" series (if equipped with firmware for remote control of the RAP1, such as the RDR52). An otherwise isolated PC (no connection to other devices) with a WiFi radio module can be configured accordingly and used with the RLFA_Vxx.EXE application to control the RLA4. **Not recommended due to high power consumption and strong EMC pollution of the environment!**

To log the RAP1 into an access point with the password 1234567890, proceed as follows:

- Follow the steps as described for the WPS method (without starting the WPS on the router).
- After the "Search AP ..." message appears, turn the rotary knob **to the right** (min. approx. 90°).
- Press the knob again and release it immediately.
- The message "Scan APs ..." appears.
- The RAP1 now searches for all access points within radio range.
- After a while, the name of the first access point found appears.
- You can display the list of all the access points found by turning the rotary knob.
- Select the desired access point and briefly press the rotary knob.

If the access point allows the connection (authenticates the password 1234567890), the connection is established permanently and the "L" appears on the display of the RAP1 to indicate successful login.

If the control software (program RLFA_Vxx.EXE or user interface of the radio unit) has access (permanent connection, see above) to the RAP1, an "S" appears in the display instead of the "L". Remote control of the RAP1 is now possible in this state. Control by rotary knob is always active as well, operations on the RAP1 are transmitted for display in the control software (not for frequency).

Instructions for successfully connecting the RAP1 to a WiFi router

The WPS push button method is standardized and should work with any router equipped with it. However, there are many different brands with many different setting options for the WLAN. Some of these can prevent a successful connection via WPS. Due to the large number of options, no general procedure for configuring the router can be given. There is also no guarantee that every device can be configured appropriately! But here are some tips on settings that should definitely be observed:

- WiFi radio channel: **MUST** (!) Be set to the 2.4 GHz band. "Auto" or similar is possible and should work. If a particular channel is to be used, identify a channel that is not used very often (there is often a graphic view of the channel assignment). A channel in the range of 8 to 13 is recommended.
- WiFi standard: 802.11 b. The "b" is important, combinations like "b+g+n" are also possible. "a" or "ac" or "a+c" usually do not work (but can be tried after successful login).
- Security / WPA encryption: WPA2 (CCMP). WPA (TKIP) or similar should also work. Stronger encryption such as "Enterprise" etc. do not work.
- WLAN access: "Allow all new WLAN devices" or similar setting. New devices must not be blocked (select "All devices may communicate with each other" or similar). Turn off the MAC filter. (Can be reactivated after successfully finding the RAP1 / espressif. Allow the MAC of the new device beforehand!)
- Activate WLAN coexistence if necessary.

Please note: After making adjustments to the settings, it is often necessary to click the "Apply" or "Save" button or similar, so that these settings are not lost when changing the router menu (call up WPS).

Control via TCP connection

Caution! The exchange of self-generated data via the WLAN connection of the RAP1 represents an unauthorized intervention in the operating principle of the device! Possible damage to hardware and software due to faulty / harmful data is not covered by warranty or guarantee!

The information about the data logs is provided without any guarantee of proper functioning when used in externally created software! There is no support for the development of software or other assistance than contained in this document.

The TCP connection is based on the server-client principle. For this purpose, the RAP1 provides a TCP server that permanently waits for connection requests from a TCP client from the network. As soon as a connection request with correct addressing (IP address and port) arrives, it is confirmed (socket connected) and the server is ready to transfer data. Only one connection can be established. Further connection requests are ignored / rejected until the existing connection is disconnected again. An existing

connection is indicated with "S" in the display.

As soon as a connection to a client has been established, the RAP1 sends a status data packet to the client approx. 2 times per second. Whenever a change is made to the device (operation of the rotary knob, overcurrent or interruption fault message), a packet is sent immediately. Likewise when the setting is changed by receiving a control data packet (immediate feedback on the successful processing of the control instructions).

The following data packets are sent:

Current, frequency and attenuator

1. Byte	2. Byte	3. Byte	4. Byte	5. Byte	6. Byte	7. Byte	8. Byte
0x0D	0x08	Strom	0x0D	0x0A	FREQ low	FREQ high	ATT

Current: Current measured value in mA.

FREQ low + high: Low and high byte frequency (16 bit word) in 1 kHz resolution.

ATT: Attenuator in 0.5 dB.

Note: The current measurement is subject to large tolerances and is mainly used to detect a short circuit (current > approx. 200 mA) or an interruption (current = 0) of the antenna line.

Direction control RLA (RAP1D version only)

This data packet can be sent in a single TCP packet, or together with the settings data packet (which then contains 11 bytes).

1. Byte	2. Byte	3. Byte
0x0D	0x09	POS

POS: Direction control in 232 steps. Level 0: Switched off, step 231: 180°.

Note: The directional adjustment of the RLA4 takes place in 232 steps within a rotation angle of 180°. The directional adjustment is subject to large tolerances and is non-linear in large parts of the rotation range.

The RAP1 expects the following data:

Version request firmware

1. Byte	2. Byte	3. Byte
0x0D	0x12	0x00

The RSW responds to this message with a special data packet containing the version number and location of the programmed firmware:

1. Byte	2. Byte	3. Byte
0x0D	0xFF	Version

Version: Bit[6..0]: Version number, Bit[7] location: 0 = primary memory, 1 = secondary memory.

Note: After each successful reprogramming, the memory location is altered. This means that valid firmware is always available, even if errors occur during data transmission.

Frequency adjustment

1. Byte	2. Byte	3. Byte	4. Byte
0x0D	0xB0	FREQ low	FREQ high

FREQ low + high: Low and high byte frequency (16 bit word) in 1 kHz resolution.
Values smaller than 500 kHz or larger than 30,000 kHz switch the RAP1 to 0 - 30 MHz. The value 500 kHz switches the RAP to 0 - 0.5 MHz.

Setting attenuator

1. Byte	2. Byte	3. Byte
0x0D	0xB4	ATT

ATT: Attenuator in 0.5 dB.

Setting receiving direction RLA4 (RAP1D version only)

1. Byte	2. Byte	3. Byte
0x0D	0xB2	POS

POS: Direction control in 232 steps. Level 0: Antenna switched off, step 231: 180°.

Further notes on controlling the RAP1 via WLAN

The programming for the data exchange of the RAP1 is done internally via a hardware-specific TCP/IP stack with associated API using standard interfaces ("sockets"). Software to establish a connection with the RAP1 must be done via these sockets. For this purpose, there are corresponding APIs for the control computer used, e.g. "INDY" for PCs. The user interface "RLFA_Vx" (see above), for example, was created with it under the Windows operating system.

Software development for TCP/IP with sockets offers many possibilities and thus also many "pitfalls". Here are some hints for successful control of the RAP1:

- ➔ After logging the RAP1 into the network, a client socket must be configured that contains the IP address of the RAP1 (possibly easily determined automatically via the name "RSW34_nnnn") and the port number 55556.
- ➔ The socket is to be connected with the corresponding command (usually "Connect" or similar) with IP address and port of the server socket in RAP1.
- ➔ After successful connection, data can be taken from the client socket (data coming from RAP1) and sent through it (data to control the RAP1).
- ➔ The connection should be maintained as long as data is to be exchanged for the foreseeable future (usually until the program is terminated).
- ➔ Depending on the API, operating system and other settings of the program environment, there are many ways to organize the data transfer. Often small amounts of data are first collected and then sent in a larger package, and so on. (e.g. functions "Nagle" or "A-MPDU" or "A-MSDU"). This can lead to longer delays in transmission or fragmentation of data packets. Such functions should be disabled or minimized as far as possible.
- ➔ Several data packets according to the above list can be sent within one transmission (this then usually results in only one TCP packet). However, it must be guaranteed that complete instructions of correct length are always present in a package. Incomplete data / splitting of an instruction to several data packets lead to blocking of the connection.
- ➔ The data log of the RAP1 contains other instructions that are not documented here (e.g. for firmware update).

Caution! Never send data to the RAP1 other than the data specified above! Other data can lead to the cessation of the function up to the complete (irreversible) deletion of the firmware in the device!