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Vector Antenna Analyzer FA-VA5

Kit for an easy to use vector antenna analyzer for use in the frequency range 10 kHz to 600 MHz.

Assembly and Operating Manual

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Vector Antenna Analyzer FA-VA5

SUPPORT DEPARTMENT OF GERMAN HAM RADIO MAGAZINE “FUNKAMATEUR”

Radio amateurs who build their own antennas appreciate the value of a vector antenna analyzer. This device is characterized by high accuracy, small dimensions and easy operation. It allows one-port measurements in the frequency range from 10 kHz to 600 MHz and has a USB port for connection to computers.

Experiments with antennas make up a substantial part of the hobby for many radio amateurs.

The measurement of standing wave ratio (SWR) and the determination of the impedance values are inseparable.

The SWR can be estimated when transmitting using a SWR meter, but more extensive and accurate data is obtained using an antenna analyzer.

However, such instruments are often expensive whilst cheaper devices often lack accuracy. The FA-VA5 closes this gap. It is the successor to the successful FA-VA4 which was also developed by Michael Knitter, DG5MK [1].

The VA5 is a full-featured, vector-measuring device with a frequency range of 10 kHz to 600 MHz, (Table 1) offering compact dimensions and a USB port for connection to a computer.

Vectorial measurement means that, unlike a scalar instrument, not only the SWR is measured and displayed, but also the value of the impedance, including the signed imaginary part. The so-called SOL (**Short**, **Open** and **Load**) compensation, originates from professional instruments, and is used for the calibration of the device and provides precise measurements in different configurations.

The FA-VA5's graphic display shows the complex impedance, standing wave ratio, complex reflection coefficient, capacitance and inductance.

An audible SWR indication using the built-in piezo buzzer is also available. The analyser kit consists of an SMD-pre-assembled printed circuit board, a graphic display including backlight, and a USB module in a specially designed enclosure. The microcontroller on the board is already programmed. The USB connection allows not only the interaction of the FA-VA5 with Vector Network Analyzer software installed on the computer (VNWA Application – see the corresponding chapter in this manual) but also permits firmware updates by the VA5 user. The VA5 Menu structure is easily understood by newcomers provided you spend a little time reading relevant instructions in this manual. The VA5 kit includes SOL calibration elements, which are usable up to about 100 MHz. A high-quality calibration kit, covering a frequency range up to 600 MHz, can be purchased at [1].

Technical data

Table 1: Technical data

Frequency range	0.01 MHz … 600 MHz, (resolution: 1 Hz)
Measuring range limits	$SWR \leq 100$, $Z \leq 1000\ \Omega$*
Measurement result	full impedance value (resistance and reactance), including sign
Accuracy	$\leq 2\,\%$ ($0.01\,\text{MHz} \leq f \leq 200$ MHz, $Z < 1000\ \Omega$)
Dynamic range of Return Loss	Mode *Precise*: 80 dB to 200 MHz, 50 dB 200 MHz … 600 MHz Mode *Standard*: 75 dB to 200 MHz, 45 dB 200 MHz … 500 MHz *Fast* mode: 70 dB to 200 MHz, 40 dB 200 MHz … 500 MHz
Frequency stability	0.5 ppm (–30 °C … +85 °C)
Signal processing	24-bit ADC, 16-bit DSP, 32-bit calculation
Power supply	2 × 1.5V AA battery
Measuring input	50 Ω, BNC
Output signal	Squarewave $f = 1$ MHz, $R_L = 50\ \Omega$: $P_1 = 5.6$ dBm (1st harmonic, fundamental) $P_3 = -4.0$ dBm (3rd harmonic) $P_5 = -8.3$ dBm (5th harmonic) $f = 200$ MHz, $R_L = 50\ \Omega$: $P_1 = 4.5$ dBm (1st harmonic, fundamental) $P_3 = -7.2$ dBm (3rd harmonic) $P_5 = -15.3$ dBm (5th harmonic)
Current consumption	38 mA** (65 mA) at 1 MHz, 47 mA** (85 mA) at 200 MHz, Load resistance 50 Ω, lighting switched off, single frequency measurement *Z*
Current real time clock	0.9 µA
Dimensions	127 mm × 86 mm × 23 mm (L × W × H)
Mass	280 g incl. AA batteries

* Measurements beyond that, but possible with less accuracy
** Mean, peak in parentheses

Important

This construction manual was created with great care. All hints and advice contained therein are important for a successful construction! The same applies to the order of the assembly steps.

Any revision of the FA-VA5 Assembly and User manual will be published as a pdf file on *www.box73.de*. Please check this website regularly.

You'll also find videos on assembling and operating the VA5 Antenna Analyzer once these are published.

Building instructions

The following tools are required for assembly:

- temperature-controlled soldering iron 60 … 80 W with pencil soldering tip,
- solder 0.5 ..1.0 mm with flux core
- 100 W soldering iron with chisel-shaped soldering tip,
- PCB side cutter pliers
- flat-nose pliers,
- 3mm slot screwdriver,
- Phillips screwdriver,
- two 1.5V AA batteries (Mignon) for power supply.

Before fitting the board, the contents of the kit should be checked off against the parts list in the appendix.

Fig. 1: View of assembled FA-VA5 – Power switched off

Assembly of the board

The few remaining components to be soldered **are fitted only on the SMD Component (top) side of the motherboard**. The position of the individual parts is shown on the assembly plan (Fig. 2)

Switch and USB Interface board

First, the slide switch S1 is soldered to the topside of the board. It should rest flush on the board with no space underneath, its actuating knob must be horizontal with respect to the board surface (Fig. 3). The easiest way to achieve this is if only one of the solder pins of the switch is soldered first. After that, the switch can still be easily aligned while heating the solder joint. When the correct mounting position is found, all pins and the two housing tags are soldered.

The USB Interface Board is to be soldered directly to the top side of the main board with the supplied mica washer inserted for isolation purposes. The washer must lie flat and be placed exactly between the corresponding soldering surfaces (Fig. 4).

The front edge of the USB socket then projects slightly beyond the main board to terminate flush with the housing shell. Tin one of the relevant solder pads of the main board first, then positioned the USB board including mica washer and fix the USB assembly with some solder. To see if everything fits properly, screw the motherboard with four M3 screws in the housing lower shell and then fit on the upper shell. The USB socket must now sit exactly behind the rectangular cut-out on the left side of the housing. If necessary, the accuracy of fit can now be corrected relatively easily. If everything is correct then continue and solder all 16 solder pads of the USB Board to the main board.

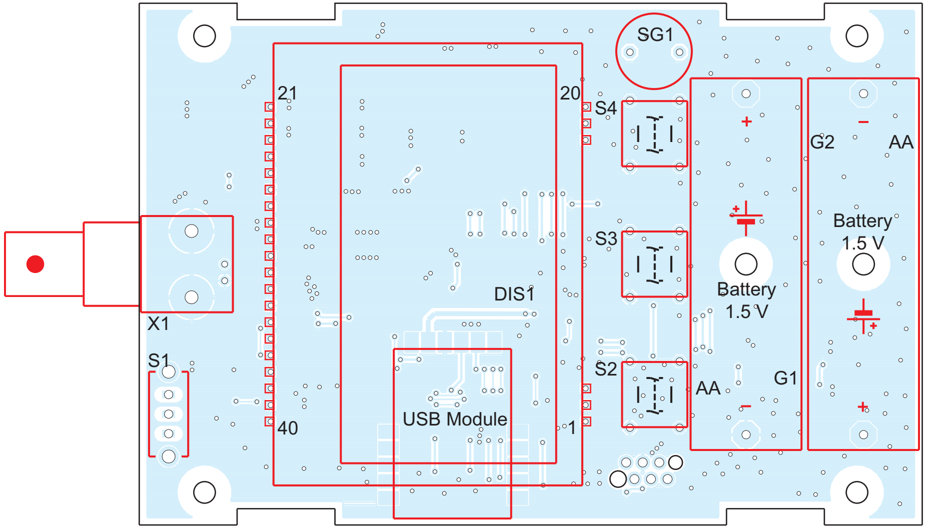


Fig. 2: Assembly plan of the FA-VA5 with components to be fitted

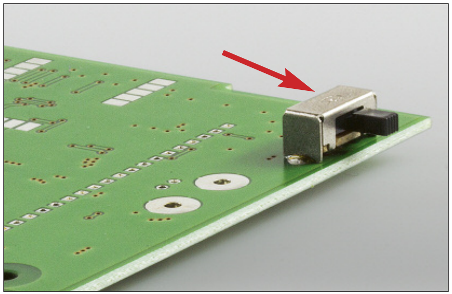


Fig. 3: Slide switch soldered in the correct position. 6-pin header is obsolet

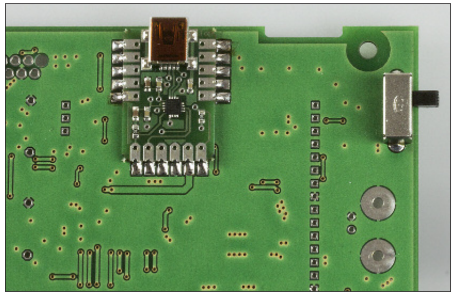


Fig. 4: USB interface board correctly positioned

Display

A graphic LCD display with integral LED backlight is used to display the measured data.

Both components are already delivered assembled as a unit and are only to be soldered in certain places. Caution: Make sure the display is flush with the LED backlight so that there is no gap, then proceed to solder all six connections of the two three-pin display contacts on the back of the backlight (Fig. 5). Also solder the two outer connections of the 20-pin contact strip (Fig. 6).

It is recommended to use a suitable base under the display during soldering in order to fix it flush on the lighting unit.

Caution: The protective film on the glass surface of the display must first be removed before assembling the housing.

If you forget this, you will see a black line on the display that suggests the glass is damaged.

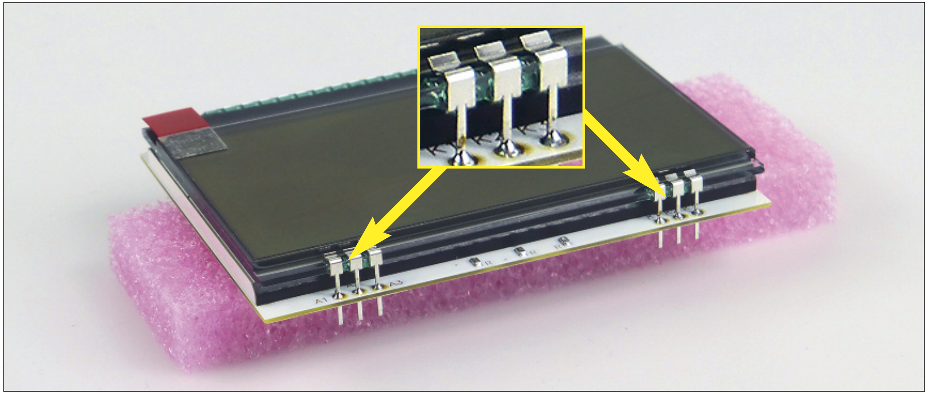


Fig. 5: Display with backlight; all six connections must be soldered on top of the backlight PCB

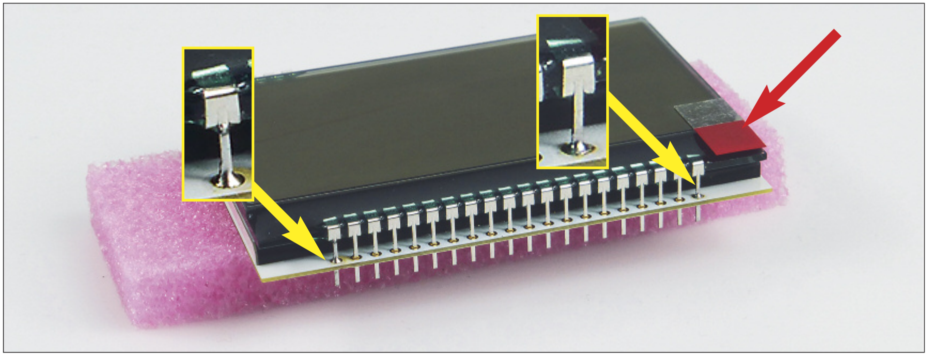


Fig. 6: View of the 20-pin contact strip of the display after assembly. Only the two outer pins are soldered on top of the backlight PCB. Remove the protective film from the display by pulling the red tab.

Socket strips

The three socket strips for contacting the LC display are fitted next. The pre-assembled display can be used conveniently as a gauge for their orientation.

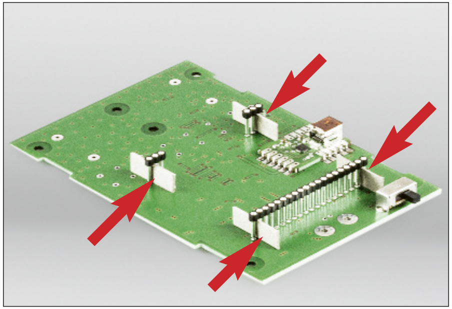


Fig. 7: Four cardboard strips are used for setting the distance between female connectors and the PCB.

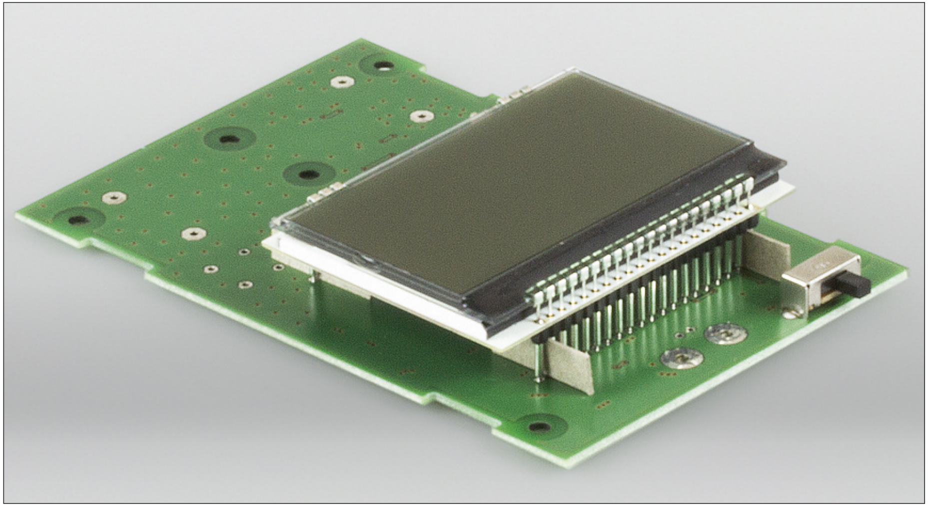


Fig. 8: Main PCB view before soldering the female connectors of the LC display; The cardboard strips must be pulled out after soldering, also the display is removed (unplugged) again before fitting the remaining components. 6-pin header for programming is obsolet

Caution: The lower edge of the plastic body of the socket must have a uniform distance of exactly 7 mm to the board, to ensure that the display eventually sits at the correct height above the main board.
To achieve this, cut the cardboard strip (supplied in the kit) into four parts and place it during soldering as shown in Fig. 7. Before soldering the female connectors, put these strips on the pins of the display. To do this, place it upside down on the work surface and carefully slide the three socket strips onto the display pins. Make sure the socket strips are flush with the display board as the 20-pin strip is prone to bend slightly.
Place the display together with the socket strips on the board. Next the four cardboard strips are inserted (Fig. 8) then turn over whole assembly so you can solder the female connectors on the underside of the board.

The female connectors must be exactly vertical after soldering.

Push-button switch, piezo buzzer, battery holders and BNC socket

The three push-buttons, the piezo buzzer and the battery holders are fitted and soldered next.
Caution: All these components must be mounted so they sit tight on the main board. Remove the protective foil of the

piezo buzzer and locate the positive terminal. Fit this component so the positive pin points in the direction of the battery holder. Next fit the battery holders, observing correct polarity (Fig. 2). Caution: the spring contact is the negative pole. The solder terminals of the battery holders are made of spring steel. Use suitably robust side-cutter-pliers to trim the excess length of the switches, battery holder and buzzer terminals, making sure that these terminals do not touch the housing later.
Finally, fit the BNC socket and solder on the board. Again, this part must sit flush and be aligned horizontally and at right angles to the edge of the board. The two ground pins are to be soldered on the underside of the board with a 100 W soldering iron to ensure the solder flows well in order to avoid cold solder joints. At the same time, the soldering time should be kept relatively short so that the insulation inside the socket is not damaged (Fig. 10). The thin terminals should also be cut after soldering in order to avoid short circuits with the housing.

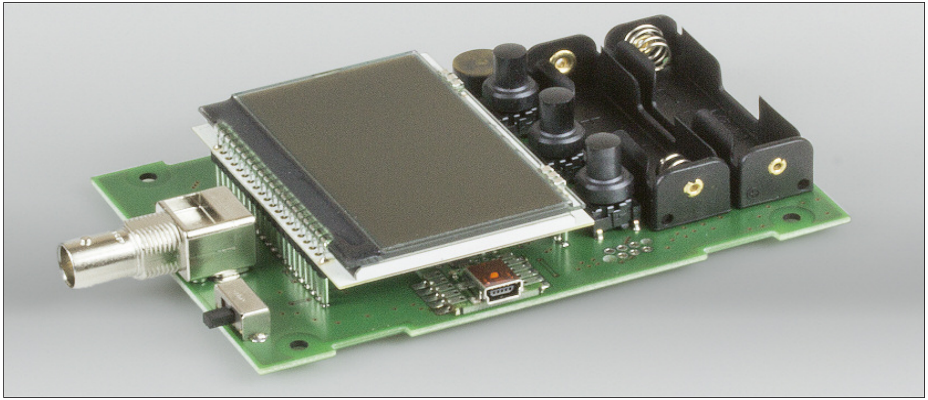


Fig. 9: FA-VA5 Main Printed Circuit Board: fully assembled (6-pin header is obsolet)

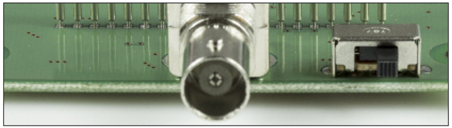


Fig. 10: Slide switch in position *Off*

Functional test and final Assembly

Before installing the board into the housing, a short functional test is required. First fit the three plastic caps on the push-buttons and fit the previously assembled display in the corresponding sockets. Ensure the slide switch is set to the off position (Fig. 10), then insert two 1.5 V batteries with the correct polarity and switch on the device with the slide switch.
The start-up welcome message should now appear briefly on the display, the FA-VA5 then switches to measuring mode.
If the display remains blank, then all solder joints made in the previous steps must be carefully checked and reworked if necessary. Once the functional test is completed, move the slide switch back to the off position and remove the batteries from battery holders. The fully assembled board is shown in Fig. 9.

Installation in the enclosure

First, the four rubber feet are inserted into the lower shell of the enclosure. It is helpful to pull with the flat-nose pliers on the thin rubber nipple on the inside and at the same time to turn the rubber foot slightly. Then cut the protruding rubber nipples to 2 mm with the side cutter (Fig. 11) so that they do not touch the board later. The board is

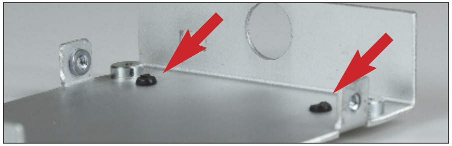


Fig. 11: Cut rubber feet after insertion into the housing

now inserted by sliding the BNC jack into the housing lower shell and the four M3 screws are screwed in at the corners of the board and gently tightened. The BNC socket must then be screwed together with the toothed washer and nut and gently tightened.
To avoid mechanical stresses on the main board, the four fixing screws of the board should be loosened and tightened again, then do the same with the nut of the BNC socket.
Now insert the batteries observing correct polarity. Next the housing cover is fitted and fastened with four M3 countersunk screws.
Finally, attach the Instrument type label to the bottom of the housing! The FA-VA5 is now ready for operation and can already be used in uncalibrated mode.

General notes on operation

The FA-VA5 antenna analyzer can be used as a measuring device immediately after assembly. It then operates in uncalibrated mode and the displayed results are subject to a higher error than is the case after a correct calibration. The uncalibrated mode can always be selected later via the ***Setup*** Menu if, for example, there are doubts about the validity of the stored calibration data.

■ Cautions

Please note the FA-VA5 is a sensitive measuring device. **No RF energy should reach the test socket to avoid destroying the components at the input!** This could happen when transmitting with the antenna connected in close proximity of the VA5. Likewise, static charges must be kept away from the test socket. Isolated antenna structures must therefore be discharged by grounding them first.
Rechargeable batteries should not be used in the FA-VA5 because there is no electronic protection against over-discharge and there is no battery charging facility in the instrument. Deep discharge makes rechargeable batteries useless and can even destroy them. Leaking batteries can also cause damage.
The FA-VA5 is designed to make optimum use of 1.5V alkaline cells. If the battery voltage is less than 2.5 V at switch-on, the display will show a Battery LOW warning. In order to achieve the longest possible battery life, it is advisable to use the display backlight only if it is otherwise impossible to read the display. In daylight or outdoors the backlight is usually not needed. A dimmed brightness setting will also help to save power.
The number of measurements or display cycles should be selected to produce a repeat rate that is sufficient for the measurement in question. These parameters can be changed in the ***Setup*** menu and have a significant influence on the power consumption and thus on the life of the batteries.
It is advisable that BNC plugs should be turned slightly back and forth after the bayonet catch engages to improve contact engagement. Otherwise, under certain circumstances, “inexplicable” measuring errors may occur.

Directions for use

Although the FA-VA5 has a relatively large range of functions, the operation is quite intuitive. Therefore, the following guide has the character of a reference book. However, the general operating instructions in the previous section should always be observed. The instrument cannot be destroyed by pressing buttons the wrong way, and at worst this will provide unexpected or erroneous measurement results. Therefore, it is recommended that less experienced users start-off by measuring some components with known values, then gradually explore the operation of the antenna analyzer by trying out different measurement and display modes. If ambiguity arises please consult this manual.

For precise measurements, calibration (***SOL compensation***) is important. It is therefore detailed in this independent section of the functional description. The antenna analyzer works according to the following principle: An internal oscillator generates a signal with a specified frequency, which is routed via the BNC output socket of the device to a test object (for example an antenna). Due to the electrical properties of the test object, the test signal is changed in amplitude and phase. This change is measured to determine the impedance relative to known component values either directly or through the reflection coefficient (after calibration has been performed). All other values(e.g. SWR) are mathematically calculated from the measured impedance by the built-in microcontroller.

■ Controls and Connectors

The only measurement port on the analyzer is the BNC connector.

For operation, an on / off power switch and three press buttons are available. The Analyzer will always be in the previous measurement mode after power is switched on as all parameters are saved when power is switched off. The three buttons have different functions depending on the selected measuring or operating mode. In general, a function is called up or a selection is made with the left push button. The centre and right buttons are used to reduce or increase numerical values or to move through menu lists.

A rapid change of numerical values (e.g. frequency values for multi-frequency measurements) can alternatively be obtained by pressing and holding the middle or right buttons. At any time, the available functions are displayed on the display above each of the buttons.

A 2-second long press on the left button calls up the menu mode in measuring mode. After that, the middle and right buttons allow you to select a menu item which can then be selected or activated with the left button. Other button functions are explained in the following sections.

This description refers to the firmware version 1.09.

Power Switch-on

After switching-on power on the FA-VA5, a start-up message appears on the display, which includes the firmware version and the current battery voltage. The factory default setting of the menu language is ***English***. The language can be changed to ***German*** by making following button presses:

Long 2-second press on Left Button: → ***Operating Mode*** → Centre button: press 7 × Dwn → ***Setup*** → 1 × Dwn → ***Language*** → 2 × Dwn → ***German*** → left button → Sel.

■ Basic Calibration (SOL Compensation)

Each additional connector and cable affects the accuracy of the impedance measurement on the device under test (DUT). However, these unwanted errors can be fully calibrated out by the **Short Open Load** method (abbreviated to SOL method). Three known calibration elements are measured instead of the test object. The **Short element** applies a short circuit over the BNC socket, the **Open** simulates an open cable end and the **Load element** provides a resistance equal to the system impedance (in our case 50 Ω). During calibration, the software of the FA-VA5 “measures” the reflections of a short circuit (0 Ohm = start of measurement scale) and of an open circuit (Infinity Ohms = end of measurement scale) as well as the reference value Z = 50 Ω at the input (= midpoint of scale). These values are the three defined points of reflection. Due to the physical properties (tolerances) of real components, no absolutely exact values will prevail at the input hence the deviation must be detected and later eliminated from the measurement result. The process of acquisition is called “Calibration”. Without calibration, the measurement result would be subject to a relatively fixed, recurring and frequency-dependent error. During the master calibration, the actual input impedance is automatically measured at intervals of 100 kHz or 1 MHz for all three reflection defined cases, and the calculated correction data is stored permanently in memory. The microcontroller software retrieves and applies appropriate correction factors later whenever calculating the measurement results. If the measuring frequency is between two calibration points, then interpolation of the correction is performed.

Three Calibration elements with acceptable accuracy up to about 100 MHz can be easily made by yourself using three BNC coaxial cable plugs (50 Ω). The **Short**, **Open** and **Load elements** supplied with the FA-VA5 will provide acceptable accuracy up to about 100 MHz. You can easily make your own using three BNC coaxial cable plugs (50 Ω). To make the **Short** calibration **element**, the inner conductor and plug housing are short-circuited, whilst in the **Open** calibration **element** the pin of the inner remains unconnected (see attachment) and the **Load element** has a low-impedance 50 Ω SMD metal layer resistor soldered between the inner conductor and the housing of the plug.

High Quality BNC calibration option

An optional high-quality BNC calibration set, which can be used up to 600 MHz is available from [1]. The load element of this calibration set is individually measured for highest accuracy and the measured data is provided in a printed instruction leaflet. This data is then entered in the FA-VA5 Setup menu (see section Calibration Set Data).

The data supplied for the load element consists of: picosecond delay, ohms resistance, femtofarad parasitic capacitance, and nanohenry parasitic inductance.

In addition the delay values for **Short** and **Open elements** should be entered: this is always –41.66 ps for the open element and always –113.52 ps for the **Short element**.

Fig. 12: The kit contains a set of calibration elements for use in the frequency range up to about 100 MHz, consisting of a 50 Ω Termination from *Telegärtner* (centre) and two BNC coaxial cable connector for making the Short and Open reference elements (see text).

A set of Quality BNC calibration elements usable up to at least 600 MHz including measurement data report is available under order no. BX-245-SOL.

When using the optional High Quality Calibration set, all these values must be entered in ***Setup → Cal/Port Model Master*** and also in ***Cal/Port Model Actual***. Once this data has been entered the master calibration has to be carried out.
Note: When using the VNWA software, these individual values can be loaded via a parameter file. The individual file can be accessed via the link specified on the instruction leaflet supplied with the Calibration kit (CKF file). Loading and using the CKF file is described in the Help for the VNWA software. After completion of the calibration, the correction values are automatically stored in the analyzer so that the correct impedance is determined on subsequent measurements of the test object.

■ Basic Calibration

Three different calibration methods are available for each measurement mode of the analyzer:

No Calibration

This is the factory default condition, it can be accessed through the menu by disabling the calibration. This option can be enabled or disabled and is accessed via ***Operating mode → Setup → SOL. Selecting... "Off"*** sets the "No Calibration mode"

Current calibration

This can be performed for single-frequency mode (Fig. 13) as well as for multi-frequency (Fig. 14) and 5-band measurement mode.
The process affects only the actual single frequency or the frequency range selected and therefore completes very quickly. Current calibration makes it possible to quickly compensate for temporary changes in the measurement setup or the parameters due to temperature or other influences.
Caution! Current calibration values are lost when changing the frequency and when switching off the analyzer.

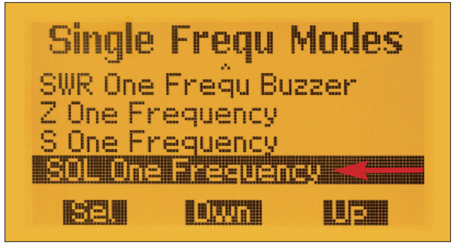


Fig. 13: Menu item for SOL compensation for the actual frequency

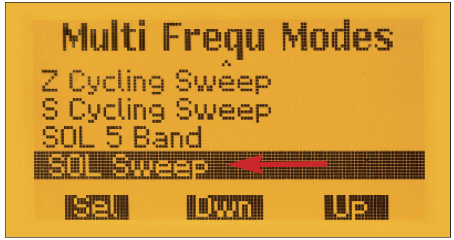


Fig. 14: SOL compensation for the actual Frequencies for a multi-frequency measurement

Master calibration

It is possible to permanently store SOL calibration values for the entire measuring range. The analyzer steps through the entire frequency range with the **Short** calibration **element** connected and stores the measured values. The same process is repeated for the **Open** and the **Load elements**. It is recommended to perform the Master Calibration once directly on either the BNC connector, or at the end of a permanently connected cable or a permanently connected test setup as part of the analyzer commissioning process. Once Master calibration has been performed measurements can be made at any time without new calibration.

This Master calibration function can be accessed via ***Operating mode* → *Setup* → *SOL All frequencies*** (Fig. 15). Master calibration will be selected automatically whenever the current calibration becomes invalid.

Caution: Prior to starting Master Calibration, do make sure that Cal/Port Model Master data for Load, Short and Open (if available) is entered first in Setup, otherwise the Master Calibration will be invalid.

Note: The Master Calibration process takes about 20–25 minutes, but can be cancelled if desired. In this case, however, inconsistent reference values may arise, so this calibration should be repeated at the earliest opportunity.

Which calibration method is actually being used can be seen on the display. Thus, the master calibration is used in Fig. 16 for the SWR measurement, recognizable by the abbreviation M to the right of the bar graph. After single-frequency calibration, there would be a *C* here (for ***Current SOL***), whilst an uncalibrated measurement is indicated as a – (dash character) at this point.

■ FA-VA5 menu system:

Use the left D/S button to enter the menu mode (long 2-second button press). Then there are choices according to Table 2 (Fig. 17 … 19). Within the menu, use the Dwn and Up buttons to move to the desired point and then select it with the Sel button. A new submenu is indicated by a small arrow > pointing to the right. The current selection is inverse and slightly indented.

The system contains three types of menu items: ***Measurement Modes***, ***Functions*** and ***Setup***.

The desired Measurement – Operating mode can always be selected immediately.

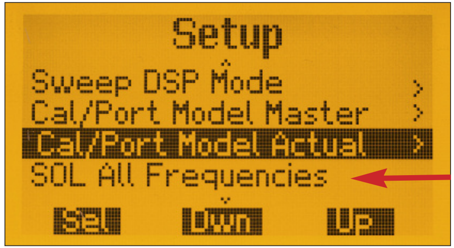


Fig. 15: Starting point of the master calibration

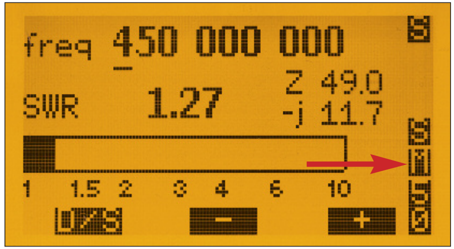


Fig. 16: Master calibration used in this measurement

Table 2: Selection options in FA-VA5 operating mode

Menu item	Meaning
Return	Return to the previous measurement mode
Single frequency modes	SWR, Impedance or Reflection coefficient measurement at current frequency, SWR measurement with sound signal, current calibration
Multifrequency modes	SWR, Impedance or Reflection coefficient measurement within a frequency range (multi-frequency measurement) in the single or cyclic run, 5-band SWR measurement, current calibration
Frequency generator	RF generator mode
LCR Meter	Display of the measured value of Inductance, Capacitance, Resistance and Quality of connected components at a selected measuring frequency
Clock	Displays the call sign, the time and the date
USB	manual USB mode
Data From Memory	Display and Deletion of Saved Measurements Results (Display Data) Recall and Deletion of stored Measurement Presets (Presets)
Setup	Enables the ***Setup*** menu (see Table 3)

All functions, such as setting of the clock time or the SOL compensation etc will go back to the menu from which the function was called by pressing *Return*. All settings, e.g. Backlight Mode or Display Update Cycle, can be selected directly in the corresponding Setup menu.

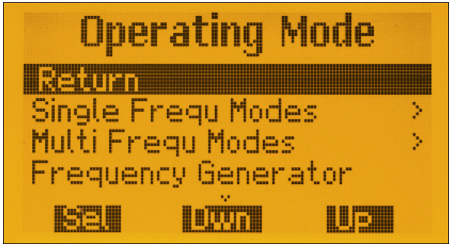


Fig. 17: Operating mode, first part

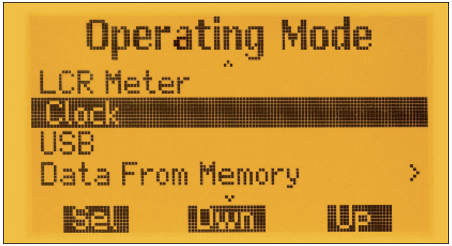


Fig. 18: Operating mode, second part

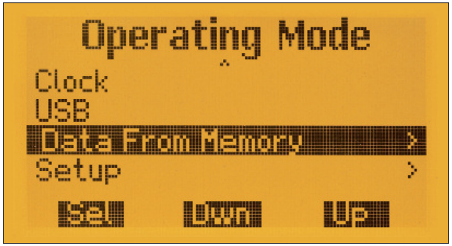


Fig. 19: Operating modes, third part

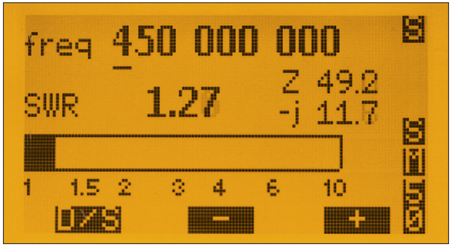


Fig. 20: Single frequency measurement SWR

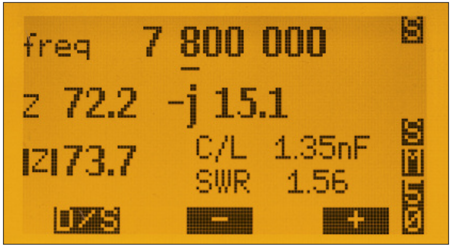


Fig. 21: Single frequency measurement of Impedance

Fig. 22: Single frequency measurement of the Reflection coefficient

■ Measurement Options with the FA-VA5

The Operating mode allows you to select the most commonly used measurement and display settings in practice.

Single Frequency Measurements

The ***Single Frequency Mode*** menu item is the first of the operating mode selections and measures either SWR, impedance *Z* or reflection coefficient *S*.

When selecting **SWR measurement** (Fig. 20) the current measuring frequency (***freq***), the standing wave ratio (SWR), the resistance of the impedance (formula *Z*), the reactance of the impedance (+j/-j) and the SWR are also displayed.

In addition, the reference impedance for the SWR calculation (here 50 Ω), the type of calibration used (see section ***Basic Calibration***) and the impedance model (S or P, i.e. serial or parallel) are shown on the right edge of the display.

The memory indicator S in the upper right corner of the display indicates that all changed values have been stored in the EEPROM of the Analyzer.

When measurement mode ***SWR1 Frequ Buzzer*** is selected, the piezo buzzer provides a beeping noise during the measurement as an acoustic aid, e.g. for antenna tuning. As the SWR decreases, the faster the beeps will sound, making it easy to hear when the lowest SWR is measured. The actual measuring frequency can be set using the three buttons. Use the left button (D/S) to select the point of the frequency to be changed, indicated by the underscore or position indicator. With the middle − or right + button, the value of the selected digit is reduced or increased. You may need to press and hold the button Dwn slightly longer than usual to change the value.

In the **Impedance measurement** (Fig. 21), the bar graph is omitted compared to the SWR measurement. Instead, the equivalent capacitance or inductance of the imaginary part for a serial or parallel replacement element is displayed.

When measuring the **Reflection coefficients** (Fig. 22), the display shows the real and imaginary part (S), the magnitude and phase angle (phi), the reflection loss (dB) and Matching Loss (dB).

Within the ***Single Frequency Modes*** menu item, Current calibration at the set frequency is also possible at any time. After acquiring the reference values, the Analyzer returns to the current measuring mode by selecting *Return*, if necessary.

Multifrequency measurements

The **Multi Frequency Modes** menu item allows the SWR to be measured on five frequency bands. There is also a Sweep mode to measure SWR, impedance Z and reflection coefficient S (multi-frequency measurement). The Sweep mode can be selected as a single or cyclic run.

SWR measurement on five frequencies

In ***SWR 5 Band*** mode (Fig. 23), five SWR values are displayed in the bar graph for five different frequencies.
The actual five frequencies can be entered or changed in the Setup mode via menu item 5 Band Frequencies. Fig. 25 shows an example of setting the frequency f_1. It is analogous to setting the measuring frequency of the Analyzer in Single Frequency Mode. Then press the D/S button repeatedly until the abbreviation Ent is shown to the right of the frequency value. After pressing the + or − button, you can move to f_2, f_3 etc. (see also section Setup). There is no further operating option in this measuring mode. With this measurement mode, you can check and capture the effects of changes made to multiband antennas in one simple measurement. In addition to the use of master calibration, current calibration via the menu item ***SOL 5 Band*** is also possible for this mode (Fig. 24). Prior to performing Current calibration, however, the five required measuring frequencies must have been selected first.

Sweep mode

The Sweep mode (multi-frequency measurement) has three different sub-modes, which are selected via the left button and marked with an icon in the upper left corner of the display. The three sub-modes are indicated with characters **<**, **>** and **M**
Mode 1: this mode is indicated by character **<** and provides changing of the centre frequency. The SWR is displayed above the frequency. In addition, a small rectangle on the SWR curve indicates the position of the marker (see sub-mode **M**). The centre vertical line corresponds to the indicated centre frequency (7300 kHz in Fig. 26). The full frequency range extends to the left and right according to the selected frequency range (here ± 2000 kHz). The middle and right buttons can be used to reduce or increase the centre frequency by 100 kHz. At the same time, a new measuring cycle over the specified frequency range is initiated each time the button is pressed.

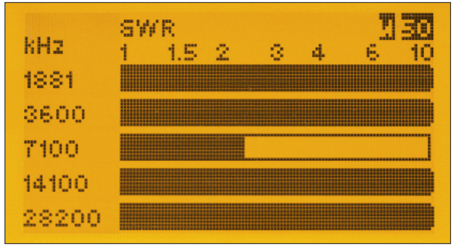


Fig. 23: Simultaneous SWR measurements on 5 programmable frequencies

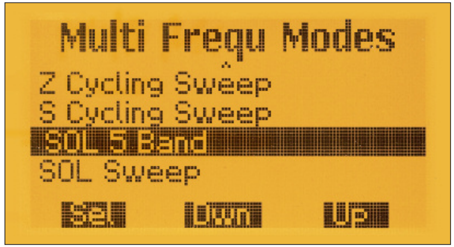


Fig. 24: Additional current calibration option for the mode *SWR 5 frequencies*

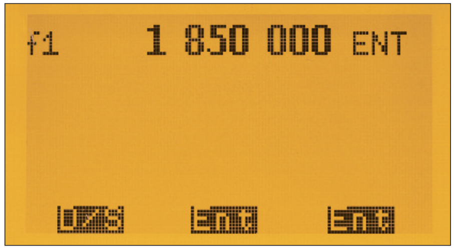


Fig. 25: Selection of frequency f_1

Mode 2: this mode is indicated by character **>** and provides an overview of marker values and changing of the setting of the frequency span. Again the SWR is displayed above the centre frequency. In addition, the small rectangle on the SWR curve indicates the position of the marker (see sub-mode **M**). Using the middle and right buttons, the frequency (sweep) range can be increased or decreased by a factor of 2 (within the available frequency or measuring range see also *Start Frequency Sweep* in the section *Setup*). At the same time, a new measuring cycle over the selected frequency range is started each time the button is pressed. The measured value at the marker frequency is displayed on the bottom right of the display (Fig. 26).

Mode 3: this mode is indicated by character M (marker character) and provides a view and adjustment of marker values over the previous frequency span. The selected frequency of the marker and the associated SWR is displayed (without boundary value limitation). The marker itself is again shown as a small rectangle on the SWR curve. Using the middle and the right button, the marker can now be moved along the previous measurement curve in a total of 100 steps (Fig. 27, see also *Auto SWR* in the section *Setup*).

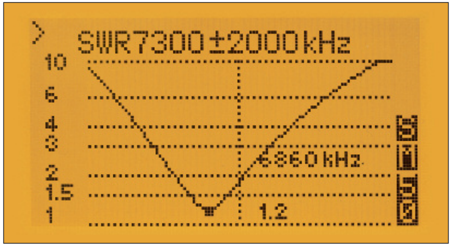


Fig. 26: Multi-frequency measurement of the SWR; the arrow on the top left, pointing to the right shows that an increase or reduction of the frequency span range can be made using the plus or minus buttons.

In contrast to modes **<** and **>**, pressing a button does not trigger a new measuring cycle, but merely displays the changed marker position including the corresponding measured value.

The measured values obtained before switching to mode **M** were "frozen" and can now be "skimmed" using the marker. A new measured value acquisition takes place again when switching to sub-modes 1 or 2 indicated by **<** or **>**. The combination of these three sub-modes thus makes it possible in a simple manner to "approach" target frequency ranges during measurements, to narrow them down and to query specific values at relevant points. For internal SOL compensation, the instrument uses either the calibration values from the master calibration or or uses the current calibration values generated via the menu item SOL Sweep. Prior to performing this calibration, the centre frequency and frequency span must be selected for the current calibration to run correctly.

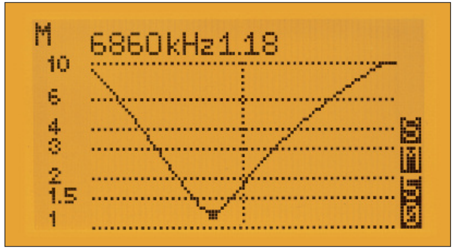


Fig. 27: Multi-frequency measurement of the SWR; The current marker values are displayed.

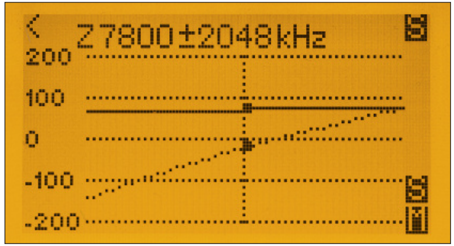


Fig. 28: Example of a multi-frequency measurement the impedance; using plus / minus buttons the centre frequency of the span area changes, as indicated by the arrow on the top left pointing towards the left side.

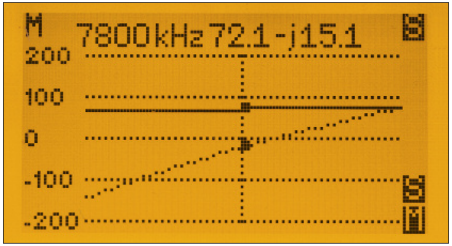


Fig. 29: Example of the multi-frequency measurement the impedance; the real and imaginary parts are displayed next to the marker frequency.

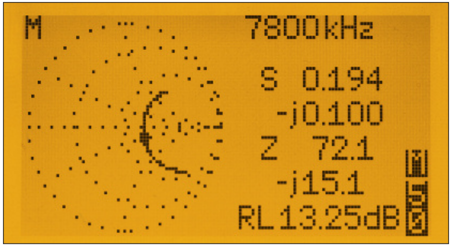


Fig. 30: Example of the multi-frequency measurement the reflection coefficient, the result is a small Smith chart; the real and Imaginary part and other calculated values are displayed below the marker frequency.

Multi-frequency measurements of the impedance and the reflection coefficient are in principle similar as when measuring SWR. The same applies to the operation of the Analyzer (Fig. 28 … 30). In addition to the single pass, which is only triggered again when a measuring parameter is changed on the device, it is also possible to select the cyclic measuring run (Continuous Sweep run). This is automatically restarted by the Analyzer again and again. Changes in the measured values are therefore relatively quickly visible. The disadvantage, however, is a higher power consumption of the device.

■ Additional Operating modes

Frequency Generator

The FA-VA5 operates as a ***RF generator*** with a square wave output signal at the BNC socket after selecting the menu item ***Frequency generator***. Its peak output voltage is about 1 Vpp to 50 Ω. The actual signal frequency is displayed (Fig. 31). The frequency setting is made using the three buttons (choice of decimal point to be changed with D/S, decrease value with − and increase value with +).

LCR Meter

The *LCR Meter* menu item is used to display the results when measuring coils, capacitors and resistors at a chosen measuring frequency. This can be used to determine the suitability of passive components for HF circuits (Fig. 33). Simultaneous quality measurements requires careful calibration of the instrument to obtain good accuracy.

Clock (with Call Sign)

When the menu item ***Clock*** is selected, the set call sign, date and time are shown in the display (Fig. 32).

USB mode (manual switching)

The menu item ***USB*** is also used for manual switching to USB mode (Fig. 34), see also section ***Setup***.

Saved Views, Datasets and Presets

Previously saved Screen views and/or Dataset information can be selected here. All measurement modes allow you to save a screen snapshot of the current display view. To do this, briefly press the left and right buttons at the same time. In the subsequent screen snapshot menu, one of ten memory locations (#0…#9) can be set using the middle Dwn and right-hand Up buttons and selected using the left Sel button. Previously saved views of the selected memory location will be overwritten. The same is possible on a total of 16 memory locations for Dataset records. The latter can be displayed in the view mode or transferred to the PC via USB for documentation purposes (see relevant section). Saving takes a few seconds because all the pixel data of the display contents are transferred to the EEPROM.The same is possible on a total of 16 memory locations for the data of actual measurement results. The latter can be stored as a Dataset and recalled later via USB and transferred to the PC for documentation purposes (see corresponding section).

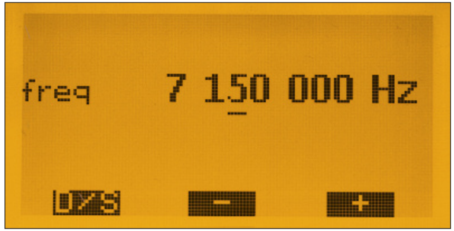


Fig. 31: Screen display when operating the FA-VA5 as an RF generator

Fig. 32: Callsign and time and date displayed

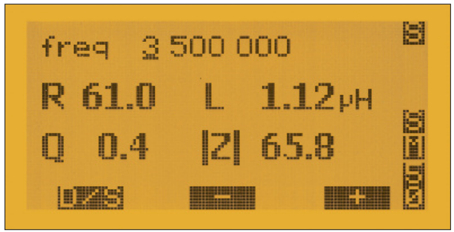


Fig. 33: In the mode LCR meter, the FA-VA5 displays the measured values in a large and clear representation.

Fig. 34: Display after switching to the USB mode

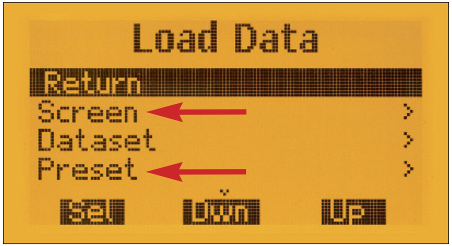


Fig. 35: Access to saved Screens and Presets

Measurement values, saved as a Dataset, cannot be displayed on the FA-VA5 and *Error* is shown instead.

Up to five measurements modes (*Presets*) can also be saved in the same way. For example, it is possible to restore an important or frequently recurring measurement setting quickly from a previously stored *Preset* after switching-on power to the device without incurring a long delay or search (Fig. 35).

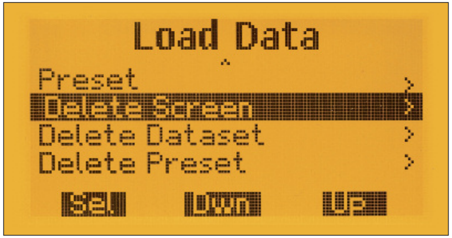


Fig. 36: Menu items for deleting stored Screens, Datasets and Measurement Presets.

If you need this for the current measurement mode, just save the mode using *Save Data* and *Preset* and later call this back up with *Load Data and Preset*.

To see these views, select the menu item ***Data from Memory → Screen*** in ***operating mode*** (Fig. 35). The corresponding display memory can be selected with the Dwn and Up buttons (Fig. 37). Unused memory locations are displayed empty. The left D/S button allows you to return to the previous measuring mode. To visually distinguish from current measurement results, a saved screen view is displayed within a frame (Fig. 38).

To distinguish from current measurement results, a saved Screen is shown within a frame (border) (Fig. 38). A short press on the left button allows you to return to the previous mode.

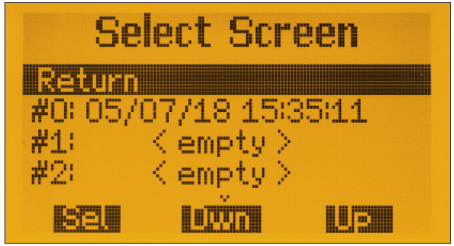


Fig. 37: A saved screen display with timestamp which can be re-called.

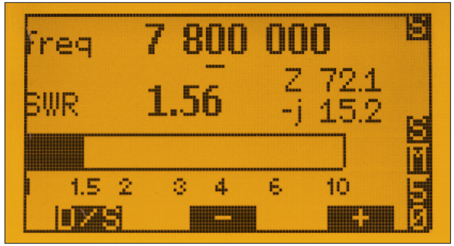


Fig. 38: A saved screenshot is displayed within a surrounding frame.

■ Setup mode

The following Setup options are located in a separate menu as they are less frequently used in practice. They are accessible via ***Operating mode → Setup*** (Fig. 39). The middle and right buttons are used to select the corresponding option, the left button activates the selection.

Language

This option allows the selection of the language used in menus and measured value displays: ***English*** or ***German*** are possible (Fig. 40).

Frequency values for 5-band measurement

After selecting this menu item (***Operating mode → Setup → 5 Band frequencies***), entering or changing of the first of the five frequencies is prompted for ($f_1 - f_5$). To do this, use the left-hand D/S button to set the position indicator to the position of the frequency value digit to be changed, and if necessary, correct this with the plus or minus button. When jumping from the last digit left to the first digit right (1 Hz), the abbreviation Ent for *Enter* appears. Pressing the + or – button will now save the set value for f_1 and jump to the frequency entry for f_2. This is repeated until frequency f5 (page 15, Fig. 25). After confirmation of the last frequency, the analyzer returns to the previous measuring mode.

Clock

The time and date are set here. The FA-VA5 has an internal real-time clock that continues to run after the unit is turned off and is powered by the unit's battery. Power consumption is very low. The date and time are primarily used to ensure a correct timestamp for stored records.
A suitably dimensioned backup capacitor bridges the short time of battery replacement, so normally the clock does not have to be reset.

Fig. 39: Setup mode, first section

Fig. 40: Setup option of the menu language

Table 3: Available Options in Setup mode of the FA-VA5

Menu item	Meaning
Return	Return to operating mode
Language	Selection of the menu language
5 Band Frequencies	Definition of the frequency values for 5-band measurement
Clock	Setup of time and date
Sweep DSP Mode	DSP Setup Fast / Standard / Precise for selecting measuring accuracy and measuring time
Cal/Port Model Master	Input of data from the SOL elements for master calibration
Cal/Port Model Actual	Entry of SOL element data used for current calibration
SOL All Frequencies	SOL compensation over the entire frequency range (Master calibration)
Callsign	Personalization option by entering the call sign
Backlight Mode	Setup of the display backlight options
Display Update cycle	Defines the repetition rate of the measurements
USB Auto Mode	Automatically switches the FA-VA5 to USB mode
Delta Frequency	Calibration of internal TCXO reference frequency
SOL	Option to switch calibration on / off
Z0 Base	Change of reference impedance for SWR calculations
Impedance Model	Switching between Serial and Parallel model
Z Range Sweep	Determines the impedance range for multi-frequency measurements
Start Sweep Mode	Frequency range increment / decrement options for multi-frequency measurements
Auto SWV	Enabling/Disabling of the minimum value Auto SWR marker in multi-frequency SWR measurements. Options are on/off
Firmware	Start of the firmware update
Reset	Reset to factory settings

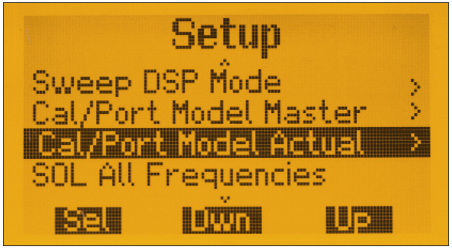


Fig. 41: Setup mode, second section

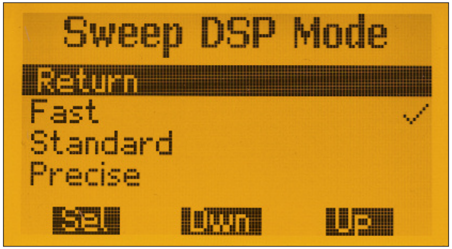


Fig. 42: DSP Setup options

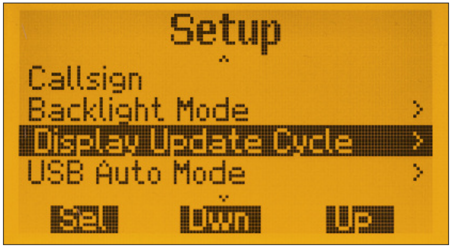


Fig. 43: Setup mode, third section

DSP Setup

In the multi-function ***Sweep DSP Mode*** menu, DSP settings can be made for multi-frequency measurements (Fig. 42). The options are ***Fast***, ***Standard*** and ***Precise***.

Note: More accurate measurement requires longer execution times.

Calibration Set Data

Accuracy of the displayed measurement data, especially at higher frequencies, depends entirely on the SOL calibration set used and how calibration is carried out. The menu items ***Cal/Port Model Master*** *and* ***Cal/Port Model Actual*** allow you to enter appropriate parameters for the master and the current calibration. In practice this data is provided by the manufacturer of the calibration kit and is entered only once. In addition, it is possible to move the measurement plane level by *port extension* by specifying a runtime in picoseconds.

SOL All Frequencies

This item has already been covered in the section ***Basic Calibration*** (***SOL Compensation***).

Callsign

If you want to personalize your FA-VA5, you can use this menu item, e.g. to save your call sign (maximum 9 characters).

Display Backlight

The available options are ***Off***, ***Dim***, ***On***, ***Auto***, ***Backlight Auto Time*** and ***Backlight %***. (Fig. 44 and 45). When Auto is selected, the backlight is switched off after some time, but is switched on again when a button is pressed by the user. It is recommended to set the display backlight to Off or to Auto mode, as power consumption of the graphic display with backlight On is relatively high. The switch-on time of the backlight in Auto mode can be set on seconds via menu item ***Backlight Auto time***. In addition, the FA-VA5 also offers the possibility of working with reduced backlight which will lower power consumption. The mode will then be Dim instead of On. The associated menu item ***Backlight %*** is used to set the brightness setting.

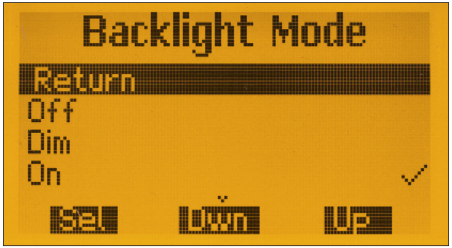


Fig. 44: Backlight options, upper part of the menu

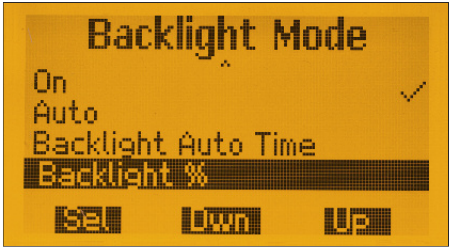


Fig. 45: Backlight options, lower Part of the menu

Fig. 46: The display repetition rate can be set to *Slow*, *Medium* or *Fast*.

Display Update Cycle

For single frequency measurements, the options are Slow, Medium and Fast. The selection has no influence on the measurement accuracy, but has large impact on the power consumption requirements of the Analyzer. Except during measurements, the oscillator and other components are switched off and the microcontroller is clocked at a lower frequency. A longer display duration therefore meets a lower power requirement (Fig. 46).

USB Auto Mode

After connecting to a Personal Computer (PC) via USB cable, the FA-VA5 will be automatically powered from the PC. Whether it also automatically switches to USB mode or has to be switched manually is selected in this menu. (see also description of USB function in section Operating Mode)

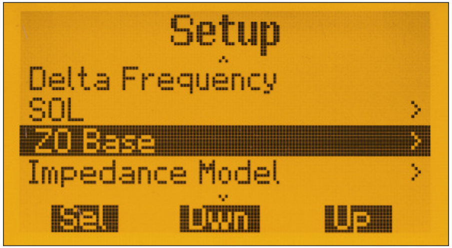


Fig. 47: Setup mode, fourth section

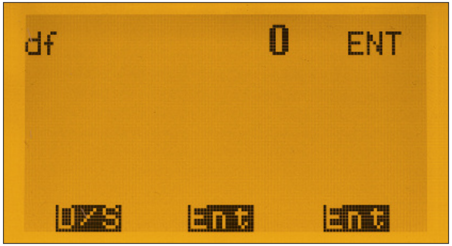


Fig. 48: Input option for the correction of the frequency offset

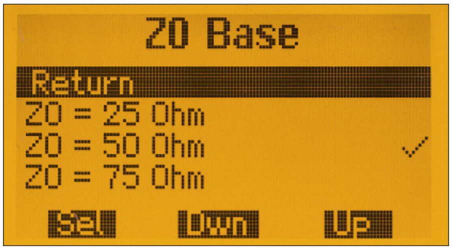


Fig. 49: Selection options for the Reference impedance basis

Delta Frequency

This allows for optional Frequency Correction of the internal oscillator. All internal frequency values are derived from a high quality 26MHz temperature-controlled crystal oscillator (TCXO), which inherently has very little frequency deviation or drift. Any remaining residual deviation can be compensated by software. For this purpose, first set a frequency of 26.000000 MHz in the ***frequency generator*** mode. Then connect a calibrated frequency counter to the BNC output connector of the Analyzer and determine the difference between the measured and the displayed frequency. After selecting the ***Correction Frequency*** menu item, first press the left 0/S button. Then the value for df is set to the determined difference using the middle and right buttons (measured frequency minus 26.000000MHz). The 0/S button is again used to select the decimal place. Repeatedly pressing this button leads to the display of the abbreviation ENT (Fig. 48). When the + or − button is pressed, the FA-VA5 accepts the value set as the frequency correction. Thereafter, the frequency of the Analyzer output signal should be exactly equal to the set frequency. It should be noted, however, that this frequency correction is usually not required for antenna measurements.

SOL = Calibration On / Off

If required, the stored calibration can be switched on / off via menu item ***SOL***. This can be useful if there are doubts about the validity of the stored data, for example.

ZO Base = Reference impedance

SWR measurement values refer to a system impedance Z_0. This reference impedance can be selected via the menu item ***Z0 Base*** (Fig. 49) which is displayed at the right edge of the display during measurement (see section Measurements with the FA-VA5).
Available settings are: ZO = 25 Ohm, ZO = 50 Ohm (default setting) and ZO = 75 Ohm)

Impedance Model

The FA-VA5 can display the impedance in either of the corresponding measurement modes as either a Serial (default setting) or Parallel model. At the same time, the calculation of the equivalent capacitance / inductance of the imaginary part for a serial or parallel equivalent element is performed. The selection is made in the menu item ***Impedance Model***.

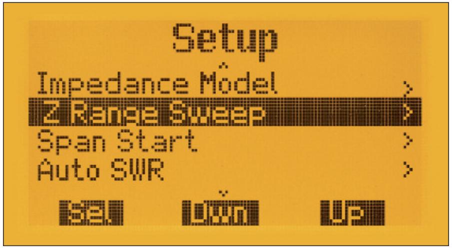


Fig. 50: Setup mode, fifth section

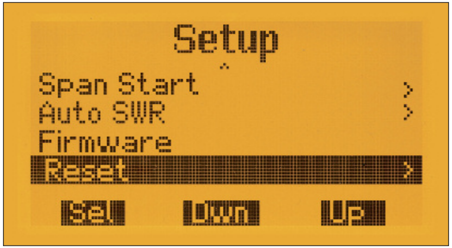


Fig. 51: Setting mode, sixth section

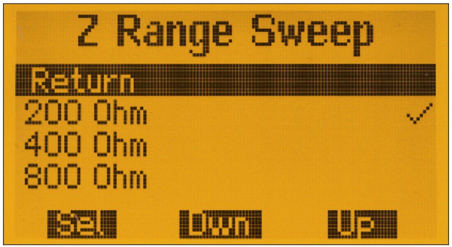


Fig. 52: Maximum values of the impedance for Multi-frequency measurements

Z Range Sweep

The maximum display range for **Z multi-frequency measurements** can be selected here. Either a maximum value of 200 Ω, 400 Ω or 800 Ω can be selected. (Fig. 52). Caution: please note that a maximum value of 800 Ω already deviates relatively far from the system impedance of the device. Measurements of impedances on this scale therefore have a lower accuracy.

Frequency range for multi-frequency measurements

In case of a multi-frequency measurement (see section *Sweeping Mode*, the frequency range is increased or decreased by pressing a button according to a fixed pattern. This selected scheme can be set via the present menu item (Fig. 53).
The selection Start *100 kHz* means that the frequency range can be changed in kilo-Hertz increments in the following steps: 2 – 5 – 10 – 20 – 50 – 100 – 200 – 500 – 1000 kHz etc. With Start 2 kHz one can select steps 2 – 4 – 8 – 16 – 32 – 64 – 128 – 256 – 512 – 1024 kHz etc.

SWR minimum for multi-frequency measurements

With SWR multi-frequency measurements, the marker can be automatically set to display minimum SWR and this value can be

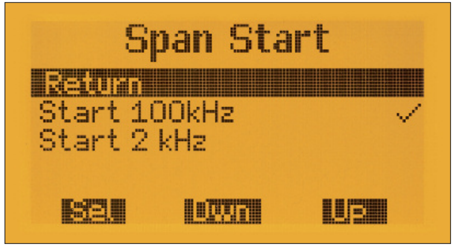


Fig. 53: Selection of the Sweep increment/decrement options of the frequency span for multi-frequency measurements

transferred to the single frequency measurement. To do this, in the *Auto SWR* menu item, select the item *On*. During the subsequent SWR multi-frequency measurement, the marker point automatically jumps to the frequency of minimum SWR after the first pass. If you now switch to the M mode (see section *Sweep Mode*), this frequency is saved and will be automatically used after switching to single measurement. This allows a quick overview and subsequent detailed measurement.

Firmware

Selecting the menu item ***Firmware*** starts the firmware update of the FA-VA5. This is done as follows:

– Connect the FA-VA5 to the PC via USB, read and note the assigned virtual COM port in the Windows Device Manager

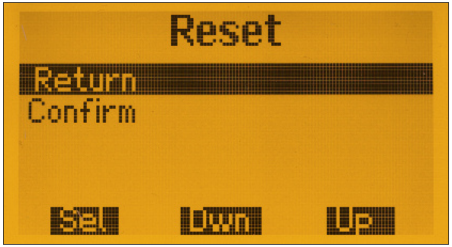


Fig. 54: This menu allows reset to the factory settings.

- Unpack the packed directory containing the update at any point on the PC
- Firmware update starts when selecting this option and the FA-VA5 display starts flashing
- In the unzipped directory on the PC select and then start the batch file named *firmware_update_VA5_Vxxx.bat* (where Vxxx is the actual Firmware version) with a double click. The batch file then prompts to enter the assigned COM port and the display stops flashing and the current data transmission is displayed.

After successfully completing a firmware update, the FA-VA5 must be re-initialized in most cases, as the new firmware will use different memory addresses. This is done by resetting the FA-VA5 to the factory settings (see next section). Then, as a precaution, the master calibration should also be repeated. For each update, there is a *readme* file that lists the software changes and provides installation instructions. These instructions must be followed each time a firmware update is done.

Reset

When this option is selected and confirmed, all parameters are reset to the factory settings and the master calibration and all stored display views are deleted (Fig. 54).

Forced reset

In the unlikely case that the Analyzer suddenly stops responding to operator inputs, and this state persists despite switching off and on again, a Forced reset can be applied without a menu at any time: To do this, switch off the Analyzer. Then press and hold all three buttons at the same time. Now, when the power is switched on, all parameters are reset to factory settings and the device should work as usual. If necessary, correct the language, backlight and frequency settings. Note: a Forced Reset does not erase existing master calibration values or saved display views. Any existing values of the master calibration must be enabled again. To do this, under ***Operating mode → Setup → SOL option "On"*** must be selected. Caution: this step must be performed even if the ***SOL*** menu already displays the status as "***On***", as master calibration is only enabled once it manually set to "***On***" following a Forced Reset.

Tips on measurement practice

Measuring complex impedances poses many options. The measurement examples listed below can therefore only hint at these. Further explanations of the physical and mathematical correlations can be found in specialist literature. It is assumed that a master calibration was performed with or without the cable attached (depending on the measurement setup). If the test structure is changed later, e.g. by replacing the cable, calibration must be carried out again. When making antenna measurements note that the FA-VA5 is an "active" analyzer which generates and outputs RF to the antenna under test.

Therefore, the measurement time should be kept as short as possible to avoid the possibility of causing interference to other users. Tests on frequencies outside the amateur radio bands should be avoided.

Multi-Frequency Measurement of Impedance and SWR of an Antenna

The antenna is connected to the Analyzer directly at the base or via a cable previously included in the calibration by SOL compensation. Using the multi-frequency measurement, an overview of the SWR or impedance curve can be generated. The centre frequency and the frequency span are set as required for the spectrum to be measured. The marker mode can be used to "approach" an SWR minimum.

In antennas with high Q-factors (e.g. magnetic antennas), more attention is needed to obtain accurate measurements. The maxima and minima are so narrow that these may not be displayed depending on the selected frequency span. The answer is to carefully select the centre frequency and to reduce the frequency span (sweep) range accordingly to ensure meaningful results are obtained.

Measuring impedance and SWR of an antenna at one frequency

The antenna is connected directly to the base or via a cable to the analyzer. You will need to decide if the whole system of antenna and cable or only the antenna should be measured. If the latter applies, the cable must be disconnected at the base of the antenna (usually designed as a plug connection).

The analyzer should be set to a single frequency measurement of SWR or impedance. Then the target frequency is entered. The cable is now included in the measurement: remove the feeder cable from the base of the antenna. SOL Calibration should now be done for this frequency via the menu item SOL One frequency for the current frequency by connecting the calibration elements to the end of the antenna cable as previously described in Calibration.

Next, reconnect the cable to the antenna base and the actual SWR or impedance of the antenna can now be measured and displayed. The way of tuning the antenna for optimal SWR and / or resonance depends on the antenna type. For example, a monoband dipole with balun may be tuned by shortening or lengthening the dipole legs. If there is an impedance with negative reactance (capacitive), the antenna is too short. On the other hand, if the Antenna is too long for the measured frequency, a positive reactance (inductive) will be displayed. The aim is to achieve a resistance of 50 Ω and with an imaginary part of the impedance of zero (resonance case).

Measuring Capacitance and Inductance

For measurement of components at frequencies up to 30 MHz, simple adapters made of 2.54 mm pin headers and sockets and matching SOL reference elements has proven to be successful. For the measurement, mode *LCR Meter* is used. The target frequency must be set and then calibration performed using menu item ***SOL One frequency*** for the existing test setup. The measurement object is connected directly to the selected measurement setup and the capacitance or inductance at the target frequency can now be read on the display.

Using the Antenna Analyzer as a dipmeter

If a signal-generating source (in our case the analyzer) is loosely coupled to a parallel resonant circuit, different levels of energy absorption by the circuit occur outside of resonance compared to the resonant frequency of the circuit. This also causes a change in the displayed SWR value. Loose coupling to the resonant circuit under test is usually carried out inductively. It is sufficient to position the analyzer's BNC socket with a one turn coil (one wire) near the resonant circuit. For a toroidal core, a 1 turn link must be added through the toroidal core. At very low frequencies ($f < 1$ MHz) a test with several turns may be needed.

Multi-frequency SWR measurement

The expected resonance frequency should be entered as the centre frequency and a large frequency span selected. Then the frequency span of the measurement should be reduced in several steps in order to be able to read the resonant frequency with the best possible accuracy. It should show a clear SWR minimum. It is not always easy to find this minimum because it can be very narrow in high-quality resonant circuits. The function Auto SWR offers good support here.

Cable resonances and resonators

The analyzer makes it easy to detect resonance points from coaxial and other RF cables. For this, the unknown cable is connected to the analyzer. The other end can be left open or shorted.

When the cable end is open resonances occur at wavelengths of $^1/_4$, $^3/_4$, etc. of the electrical length of the cable (High Z impedance)

When the cable end is shorted, the resonances occur at wavelengths of $^1/_2$, 1, $^3/_2$, etc. of the electrical length of the cable. Resonance means that the reactance of the impedance is zero.

Therefore, a Z-multi-frequency measurement is used here. For the HF range, it makes sense to start with a centre frequency of 15 MHz and a maximum frequency span. The resonances appear at the points where the reactance crosses the x-axis (zero magnitude). The exact frequency can easily be approached in marker mode.

Conversely, this method can also be used to produce cable resonators for a target frequency. For this purpose, the physical length can be roughly estimated using the method of the next section. A slightly longer cable should then be shortened gradually until the target resonant frequency is reached. Wavelength and physical length of a resonant cable are linked by the velocity factor. This is the ratio of the free-space speed of light with the speed of the wave on the cable, because the wave propagates on the cable slower than in a vacuum. For RG58 coaxial cable, for example, the velocity reduction factor is 0.66. The propagation speed is therefore only 198 000 km/s instead of around 300 000 km/s. Length, propagation velocity and resonant frequency are linked by the formula

$$l = \frac{v}{f} \cdot N.$$

N is a factor $^1/_4$, $^1/_2$, $^3/_4$, etc., depending on which resonance point is considered and whether the cable is open or shorted at the other end. If the resonant frequency of a cable is determined on the basis of the previous section, the physical length can be calculated by means of the above equation and using the velocity factor typical for the cable. Conversely, the same formula can be used to determine the velocity factor for a known physical cable length.

VNWA Windows PC Software

The VNWA Windows software developed by Thomas Baier, DG8SAQ, for the SDR-Kits VNWA vector network analyzer can also be used to display the measured values and control the FA-VA5 antenna analyzer. The VNWA application can be downloaded (free for VA5 users) from Ref [2].

Data measured with the FA-VA5 locally can be saved on the computer and can be used for documentation or reference purposes. In addition, the VNWA software can also completely take over the control of the FA-VA5. Together the FA-VA5 and the VNWA application form a fully-fledged measuring station up to 600 MHz.

Controlling the FA-VA5 hardware from the VNWA Application: In the following paragraphs the connection of the FA-VA5 to the PC, as well as the installation and the most important steps for using the software are described. A comprehensive pdf help document in English and German languages for the VNWA Application is available for download from [2].

Setting and usage options beyond the following brief introduction are described in detail in the helpfile, albeit these refer to the VNWA3 hardware. However, the sections of interest in the FA-VA5 (all one-port measurements) are easily identified.

■ PC connection of the FA-VA5

If you have not already done so, you should first connect the FA-VA 5 to the PC via a USB cable to install the driver. The analyzer does not need to be switched on for this because it is powered up via the USB connection. The operating system does not automatically find the correct driver for Silicon Labs on all tested versions of Windows 7 or later. It is therefore recommended to install the driver manually from the link shown on page 38 Ref. [3]. Successful installation of the Silicon Labs driver can be verified via the Windows Device Manager. Connections *COM & LPT* should show that the *Silicon Labs* driver is installed. In the example of Fig. 55, it occupies virtual COM port COM5, as shown. The number of the used COM port should be remembered as it will be needed for the set-up of the VNWA software. If there is a quotation mark shown in Windows Device Manager, the driver has to be downloaded as explained above. (A recent update of WIN10 seems to install a wrong driver, downloading the driver from [4] and installing it fixes this issue).

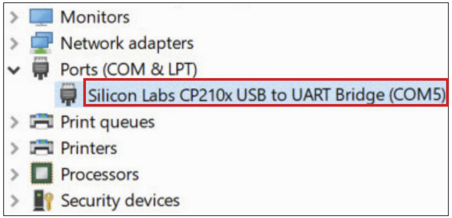


Fig. 55: Section from the display of the Windows Device Manager showing COM port used by by FA-VA5 in USB mode.

■ Installing the VNWA software

The file downloaded from [2] is named *VNWA-installer.exe*. This is an executable file that already contains all the software libraries required to connect the FA-VA5. After the *EXE* file has been downloaded, it must be executed. The subsequent installation is, as usual with Windows software, menu-driven and largely self-explanatory. All the suggested options can be confirmed with the response *Next*. A License key or certificate is not required to operate the FA-VA5. This prompt can be bypassed by ***selecting Next*** or ***Exit***. After installation, the VNWA software must be started. A warning message will be displayed that

does not concern the FA-VA5 and can therefore be confirmed with ***ok***. The same applies to the following warning.
The VNWA entry screen is initially quite simple and uncluttered (Fig. 56). The software at the bottom left of the window will report that no VNWA hardware has been detected. If the existing grid is not clearly visible (depending on the standard window colour of the Windows version), the background colour can be changed via the menu item ***Settings → Diagrams → Display → Grid Options*** and thus adapted to your own taste.

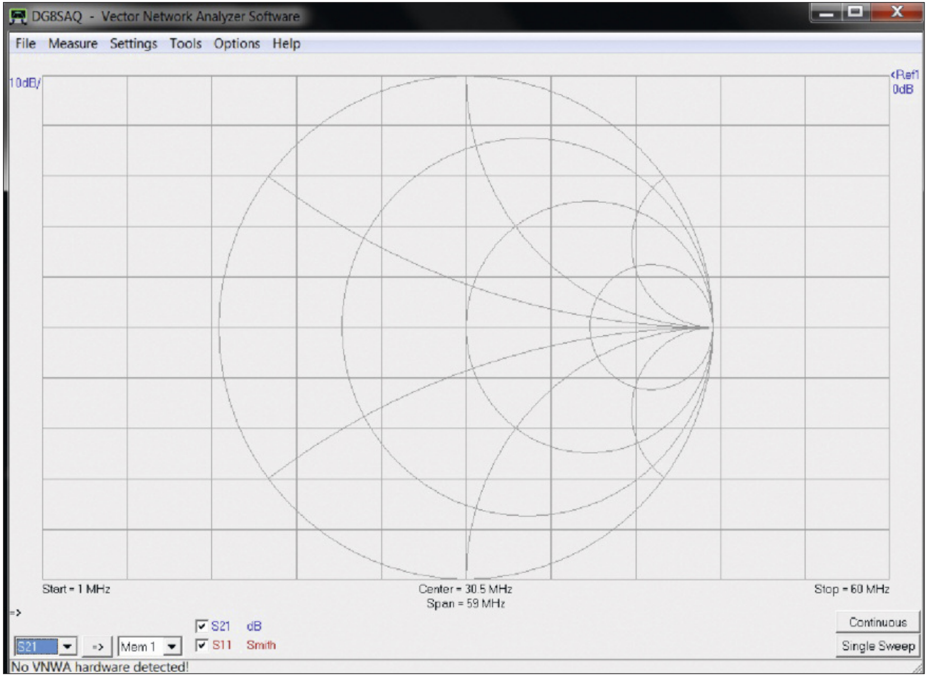


Fig. 56: VNWA Startup screen after installation of VNWA Software

■ Connecting the FA-VA5 to VNWA:

The FA-VA5 must be able to communicate with the PC before you can use *VNWA* software. To do this, put the analyzer in USB mode. If this has not already been changed by the user in the FA-VA5 menu (go to ***Setup → USB Auto Mode***), the analyzer will automatically switch to USB mode when the USB cable is inserted. Otherwise, the USB mode can be manually selected at any time via the Operating menu. Once this has been done, in the VNWA Application under ***Options → Select Instruments → Add to / remove, from the displayed list select → DG5MK Antenna Analyzer***.
Now the FA-VA5 has been added to the list of selectable devices. The actual selection is then made using ***Options → Select Instrument → DG5MK Antenna Analyzer***. Next VNWA still needs to know which COM port was detected by the Windows Device Manager. This is done in the VNWA Application under ***Options → Setup***. A new window opens and the correct COM port is selected from the list in box Port. A successful connection to the FA-VA5 is acknowledged on the top right with the word connected in green and a status line in blue indicating the firmware version of the analyzer (Fig. 57). This com-

pletes the connection of the FA-VA5 to the VNWA software.
Incidentally, the VNWA application "remembers" all settings after closing the program. For this reason, the next time the FA-VA5 is put into operation, it is necessary to plug the VA5 in the same USB port on the Computer **before** using the VNWA program next time. A second important setting is the sweep selection range in the interaction of FA-VA5 and VNWA which is found under ***Settings → Sweep*** (Fig. 58). In addition to some basic settings for multi-frequency measurements with VNWA as controlling software, the second tab of this window allows the import of locally stored data sets of the FA-VA5 as described below.

■ Dataset records Import

After clicking on the second tab in Fig. 58, a window appears as shown in Fig. 59. Here, analogous to the local menu of the FA-VA5, the 16 available Dataset records are listed with their time stamp. By selecting a dataset record with a left-click and then right-clicking the corresponding line of the context menu, the corresponding dataset will now be saved in a file or to Windows *clipboard*. The latter is also possible by double-clicking with the left mouse button. The file path and name of

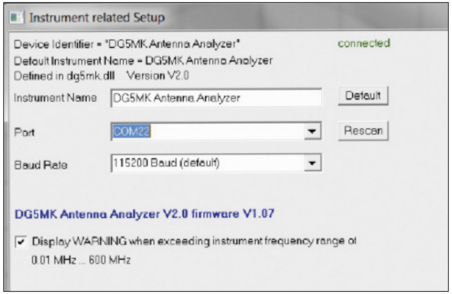


Fig. 57: Example of the FA-VA5 Setup screen in VNWA application

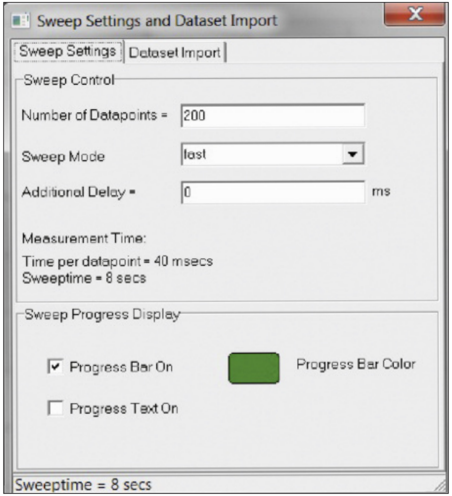


Fig. 58: Setup selection window for the basic sweep (multi-frequency measurements) and data import

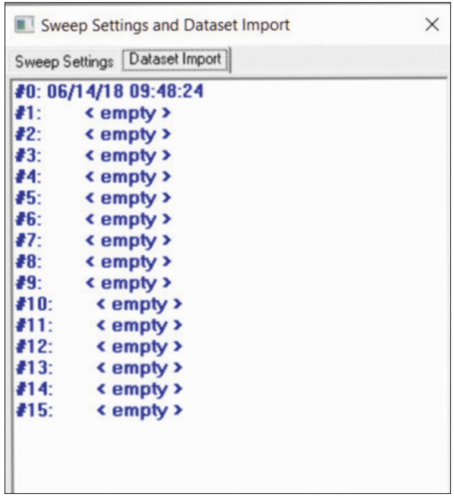


Fig. 59: Selection window for data import; in this example only one record was saved on the FA-VA5

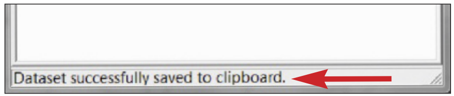


Fig. 60: Section of the selection window for the data import; a successful transmission of the Data to the clipboard is confirmed in the Footer of the window.

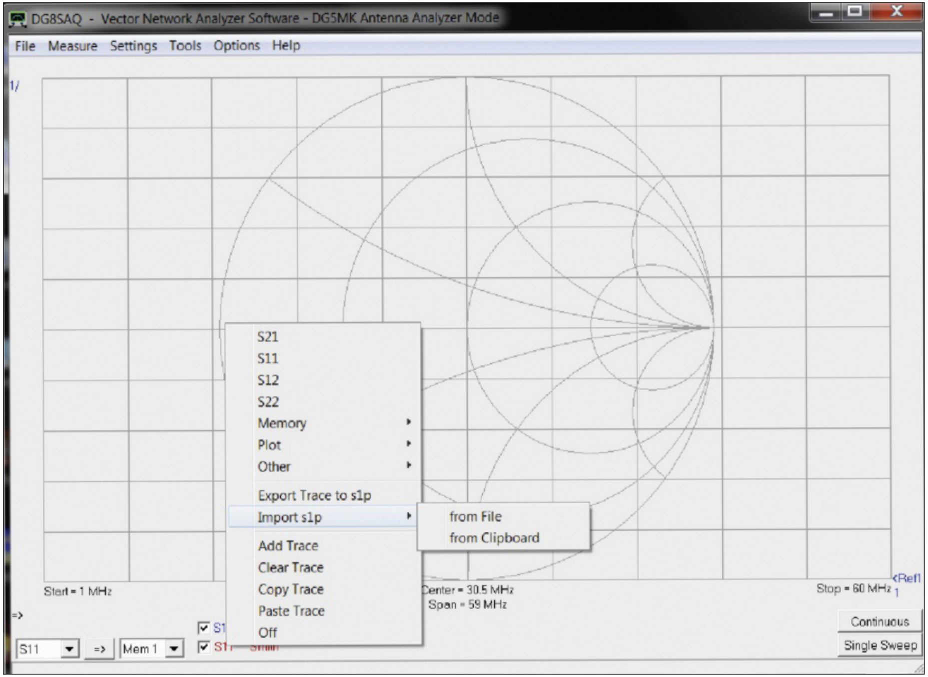


Fig. 61: Selection menu for transferring data from a file or from Windows clipboard into the measured value memory of VNWA

the file can be freely selected. Their format corresponds to the widely used *Touchstone* format, which is also readable with an editor (like Windows notepad).
The following example copies the data to the clipboard. After a double click, the *VNWA* reads the data into the Windows clipboard and confirms the process (Fig. 60). Then the relevant window can be closed. The final step is to transfer the data from the clipboard to the *VNWA* memory. The memory relevant for the FA-VA5 should always be *S11* (see Appendix 1 at the end of the manual). The transmission takes place via a right-click of a displayed S11 output channel (Fig. 61). In the main window bottom left is (for example) a channel *S11 Smith* chart shown in red. By right-clicking directly on *S11* and ***Import s1p → from Clipboard***, the data is loaded into the S11 memory. The graphic display is processed and is displayed in the main window of the program, a popup info-window confirms the read-in process (Fig. 62). For the familiar SWR display, the following quick fix solution is available, which was already anticipated in Fig. 62: double-click on the similarly visible *S21* in blue, in the subsequent window instead of *dB* select the abbreviation *VSWR* and additionally select parameter *S11* instead of *S21*. *VNWA* now shows the locally measured standing wave ratio in the frequency range of the measurement as a blue curve. In the interests of better readability, one or more so-called *frequency markers* may be added. This allows any points of the curve to be "approached" in order to be able to read the measurement frequency and the result accurately. For this purpose, a right click within the grid frame on an empty area is sufficient. This opens a context menu as shown in Fig. 63. Click on Add ***Frequency Marker → Normal***. The *first frequency*

marker is then displayed, shown as a small triangle with an associated digit 1 above. The marker can be moved by left-clicking and holding the mouse button whilst moving the mouse cursor along the trace. In the upper left corner of the main window, among other things, the corresponding frequency and the associated value of the associated SWR are displayed in the same colour as the curve, in this case in blue. In the example in Fig. 63, the frequency marker is at 6.29 MHz, where an SWR value s = 4.46 was measured. The described procedure sounds a bit complicated due to its detailed description. However, after practising the simple process of data transfer a few times, it is unlikely to cause any difficulties. The measurement diagrams shown in VNWA can be saved and printed out. For this purpose the menu item ***File*** → ***Print*** has to be selected in the main window of VNWA. The graphic can then be saved as an image file or output to a printer.

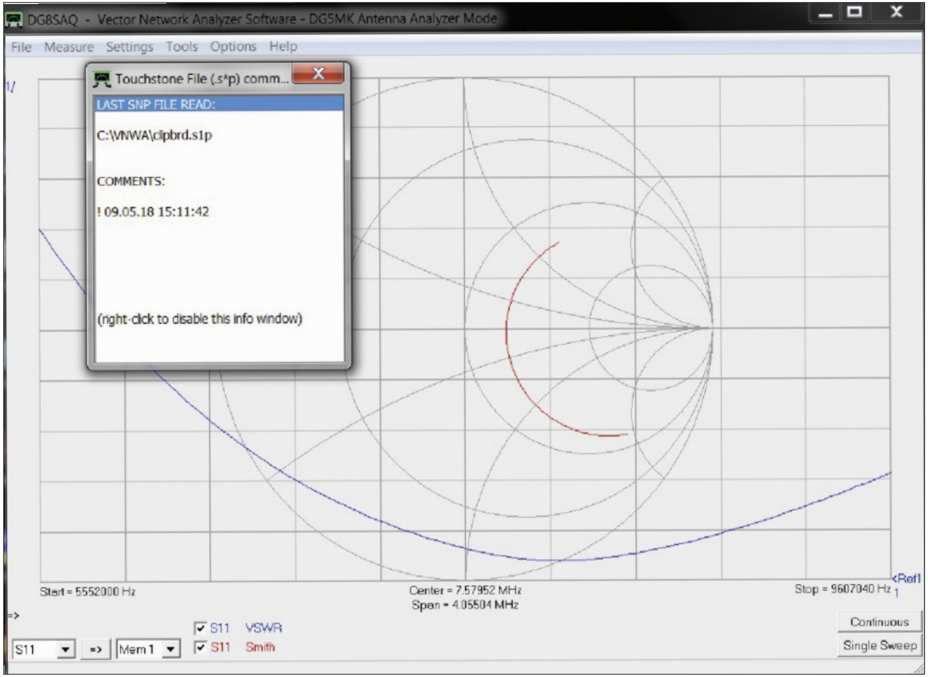


Fig. 62: Main window after importing a data set from the clipboard to the S11-measurement trace

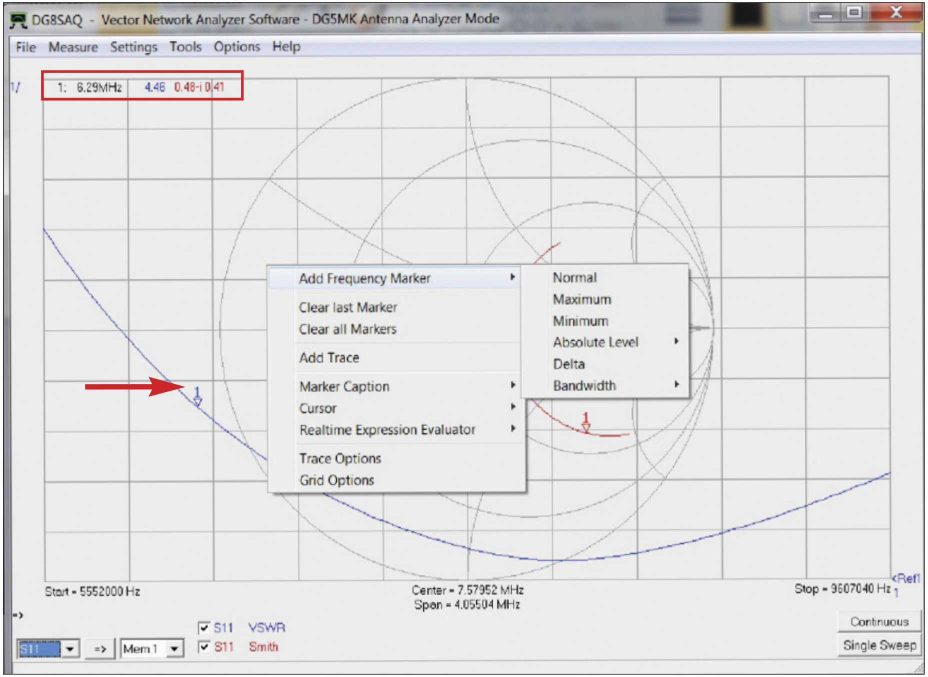


Fig. 63: Context menu when adding a frequency marker; the data of marker 1 (Arrow) can be seen in the upper left corner of the diagram (framed in red).

■ FA-VA5 as USB measuring Front-end

USB measuring Front-end means that the PC software VNWA takes over the entire control and evaluation of a measurement. In simple terms, the FA-VA5 in this case only supplies the requested measurement voltage for a frequency specified by VNWA. Thus, for example, parameters of a multi-frequency measurement, such as the number of measuring points (instead of the locally fixed 100 points) can be specified within given limits. In the following sections, a simplified measurement explains the procedure as an example, with values to be determined for SWR and impedance.

Step 1: Definition of the measuring parameters

First the start and stop frequencies have to be entered. In the main window of VNWA (Fig. 56), this can easily be done by double-clicking on one of the frequencies displayed below the bottom of the Grid: left= Start, middle=centre or right=Stop frequency. The frequency window (*Input*) will open and allows you to enter the start and stop frequency of a multi-frequency pass. Note the decimal point as a division between pre- and post-decimal places. For the example, 6MHz to 10MHz was selected in Fig. 64. Further parameters are device-specific and can be set for the FA-VA5 via the familiar window according to Fig. 58 (***Settings → Sweep***). In addition to the *Number of Datapoints*, one of the three FA-VA5 (***sweep mode***) accuracy levels can be selected: ***fast***, ***standard***, or ***precise***. In addition, another delay per measured value can be set (***additional delay***). This can be useful when measuring low-frequency filters, which have a long settling time. VNWA calculates the resulting time for the multi-frequency measurement. The window can be closed here with the default values and all measurement parameters are now defined.

Step 2: Calibration

Short, **Open**, **Load (SOL) Calibration is mandatory before any measurements**. Otherwise, contrary to the local mode of the FA-VA5, no SOL correction will take place by the VNWA Application. The SOL calibration elements available for the FA-VA5 can be used. For the use of master calibrations and the like refer to the VNWA Help Document [2]. If the calibration set *BX-245-SOL* is used, its individually measured values can be loaded once via a parameter file. This file can be downloaded via the link listed on the instruction leaflet supplied with the BNC Calibration kit. The path and the name of the CKF file can be specified using ***Cal Kit → Load*** as shown in Fig. 65. After confirmation the relevant Calibration Kit parameters are used in the subsequent calibration. Calibration for the specified measuring parameters is done via the menu item ***Measure → Calibrate***. The opening window in Fig. 65 shows the state of the current calibration in the form of red circles, in this case it is *uncalibrated*. By left clicking on the ***Short*** button another window appears, which now asks to connect the **Short** calibration **element** to the FA-VA5. After its connection and confirmation, a measurement cycle starts, the circle turns green, with red M in the middle. Similarly, the calibration for **Open** and **Load** is carried out, the window can then be closed. In the main window of *VNWA*, the abbreviation ***Cal*** should now appear at the bottom left. The advantage of this calibration procedure is that it has now been calibrated exactly to the current measurement configuration in terms of both hardware and measurement parameters. For example, if an extension cable is used, this cable is simply “calibrated in”.

Step 3: Carrying out the measurement

After calibration and connection of the test object, taking the actual measurement is a simple matter. In the main window, click on the ***Single Sweep*** button (bottom right) to start a single multi-frequency measurement. As a result, the measured values are in memory S11. The display settings from the example result in a view as shown in Fig. 66. If you want to continuously track the result of an adjustment on the measurement object, ress the ***Continuous*** button and start repetitive sweep runs. This process can only be ended by pressing the ***Continuous*** button again.

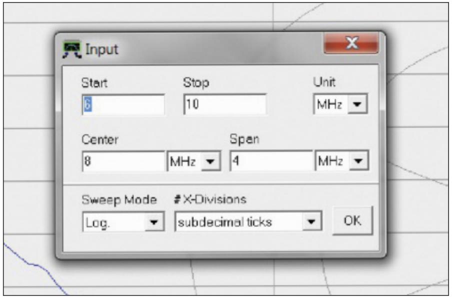


Fig. 64: Double-clicking on the corresponding Span label in Fig. 42 opens this input window for entering the start and stop frequency

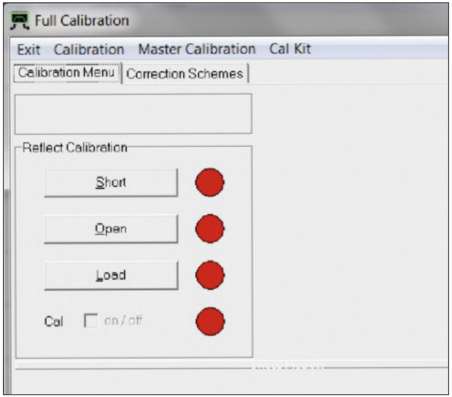


Fig. 65: Calibration window of the VNWA software prior to the start of the calibration process

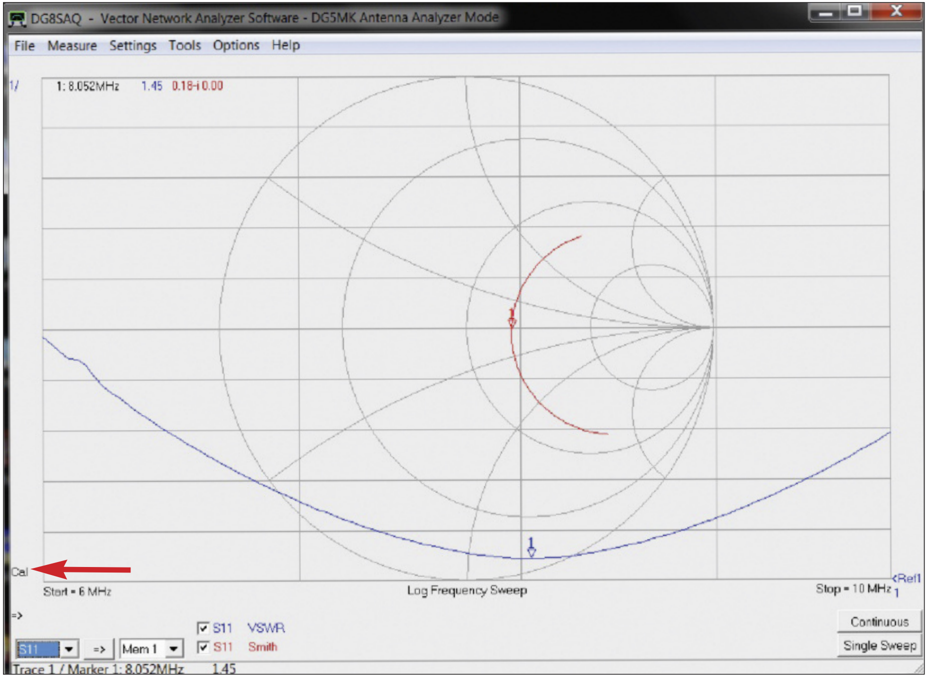


Fig. 66: Result of a measurement run after calibration (arrow).

Step 4: Choice of display and calculation

One of the strengths of *VNWA* is the extensive possibilities for displaying and evaluating measurement results. In total, up to six different traces and their calculation rules can be selected. After double-clicking on the coloured *S11* of an existing trace in the main window of *VNWA* bottom left, a new window opens as shown in Fig. 67. Among other things, it is possible to define in detail which channel (*trace*) should be displayed with which meaning. In the example, the very simple settings according to Fig. 67 apply. Only the value for the SWR calculated from S11 should be displayed in blue. The reflection coefficient is displayed as a red curve in the Smith chart. With regard to the extensive further possibilities, reference is again made to the VNWA Help document [2]. Finally, the final step is meaningful formatting of the selected output traces. In the main window (Fig. 66), colour-coded, top left shows the scale for each trace. On the right side there is, again colour coded, the specification of the reference level or value. Both can be changed in a window which opens by double-clicking on one of the values. The reference level can also be moved by clicking and holding. In the example of Fig. 67, the lowest line in the diagram corresponds to the value s = 1. The next line up means s = 2 etc. The flexibility of the scaling and positioning serves for better readability. As long as scaling and reference levels are known, it does not matter where the curves are positioned in the grid, they can be moved. A handy feature and a good starting point is autoscale, which can be done by left-clicking on the trace scaling factor. This sets the grid scale to sensible values which improves readability. Finally, frequency markers help to better examine individual values along the measurement traces. As mentioned earlier, right-clicking in an empty area within the grid frame will bring up various marker functions. In the example, a marker was set to the resonant frequency f = 8.052 MHz of the DUT (the imaginary part of the reflection coefficient is zero here). The VSWR at this frequency is s = 1.45.

We wish you great success and fun in setting up and operating the FA-VA5 Antenna Analyzer.

shop@funkamateur.de
info@sdr-kits.net

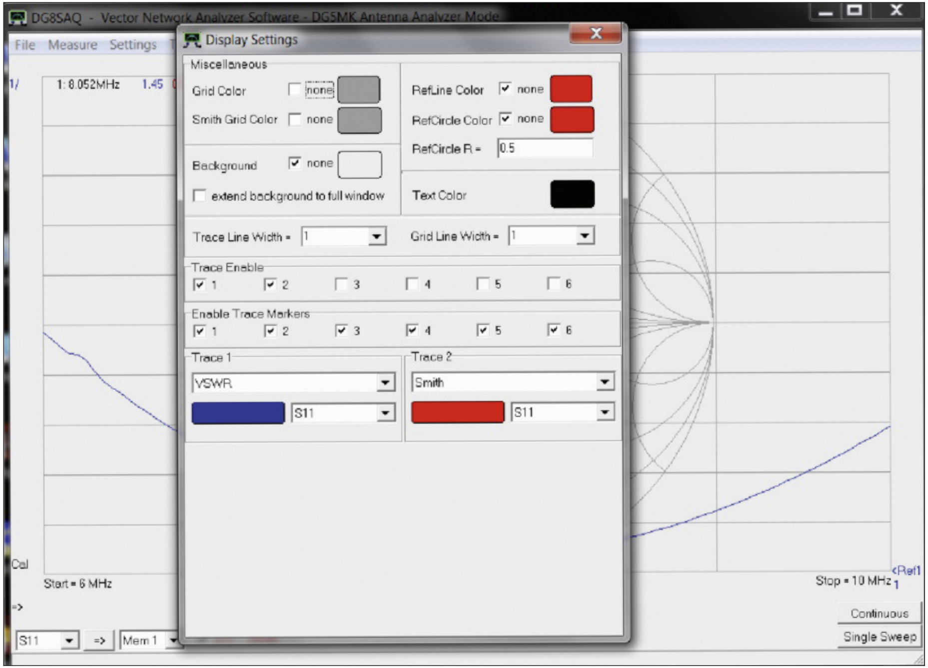
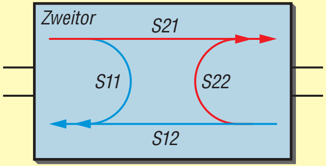


Fig. 67: The menu Display *Setup* offers a high degree of flexibility in the selection of the displayed measurement results; here only two traces are activated.

Scattering parameters



The S11 parameter relevant for the FA-VA5, is part of a group of measured parameters supported by the VNWA software. Related parameters are S12, S21 and S22 (not considered here). The letter S stands for scattering parameters. These describe the behaviour of networks by means of wave amplitudes and phase. A two-port network has one input and one output (e.g., amplifier or attenuator). It is now possible to measure, for example, which portion of a wave is transmitted from the input to the output (S21) or from the output back to the input (S12). Furthermore, the proportion of a reflected wave at the input (S11) or at the output (S22) can be measured. The four parameters S11, S21, S12 and S22 describe a two-port linear network completely and without internal details of the “black box” being known. The software VNWA has been created for the VNWA-3 Vector Network Analyzer hardware, which has a signal output (with reflection sensor) as well as a separate signal input. Therefore, besides S11, also S21 (transmission) can be measured. By interchanging the input and output of the Device under Test (DUT), the remaining two scattering parameters S12 and S22 can be determined. Antennas and other devices have only one port with 2 connecting wires. The antenna analyzer FA-VA5 has therefore only one measuring socket. So only the reflection at the input can be measured (S11). This explains why only the S11 data memory is of interest here. S11 represents a complex reflection factor consisting of real and imaginary parts. From S11, a variety of other parameters such as the standing wave ratio and the impedance Z can be mathematically derived. The presentation of results is often done in a so-called Smith diagram, with the help of which also matching problems and the like can be solved graphically.

References

[1] FUNKAMATEUR reader service, Majakowskiring 38, 13 156 Berlin, Germany, Tel. ++49-30 4466 9472, Fax 9469;
www.box73.de or *www.box73.com*
→ BX-245-SOL
The FA-VA5 Kit and the 600MHz BNC Calibration Kit are also available from SDR-Kits, Office 11, Hampton Park West, Melksham, SN12 6LH United Kingdom. www.SDR-Kits.net

[2] Baier, T., DG8SAQ: VNWA Software. Download link: *http://www.SDR-Kits.net/DG8SAQ/vnwaupdate.php?path=installer&source=Sdr-kits*
Documentation links *https://SDR-Kits.net/DG8SAQ-VNWA-software-documentation-user-guide*

[3] USB UART Bridge Driver Download Page, CP210X: *www.silabs.com/products/development-tools/software/usb-to-uart-bridge-vcp-drivers*

Appendix

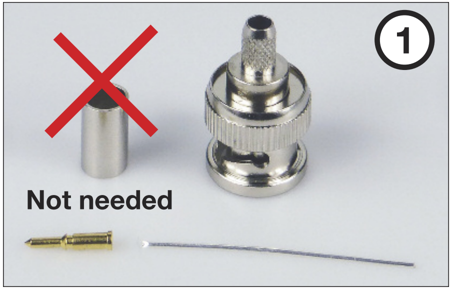
Parts List

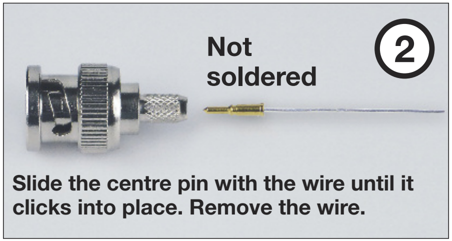
Abbreviation	Component	Number	Comment
X1	BNC socket	1	
S2 … S4	pushbutton	3	
(S2 … S4)	Button for push button switch	3	
S1	slide switch	1	
G1, G2	Battery holder for AA cell	2	
SG1	piezo buzzer	1	
USB	USB module	1	
	Mica washer	1	Fitted between USB module / PCB
	Graphic display pre-assembled with LED Backlight	1	LED backlight requires soldering
	Female header, 20-pin	1	for the display
	Socket strip, 3-pin	2	for the display
	Main PCB SMD-components fitted	1	
	Enclosure	1	consists of upper and lower shell
	Rubber foot	4	
	Cylinder screw M3 × 4	4	for mounting the Main PCB
	Countersunk screw M3 × 4	4	for assembling Enclosure
	Cardboard strip	1	width = 7 mm, for display adjustment
Assembly and User Manual		1	this manual
Type Label – self adhesive		1	Fit on bottom of Enclosure
SOL set	50 Ω Termination	1	Manufacturer is *Telegärtner*
	BNC connector	2	

Version history

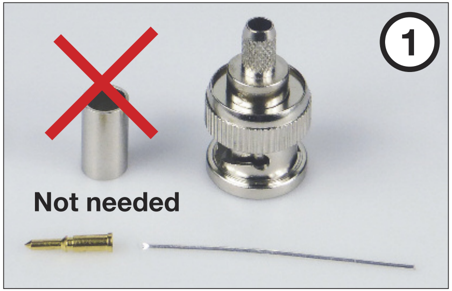
Ver E 1.0	1st edition
Ver E 1.1	table 1, page 11, 12
Ver E 1.2	6-pin header obsolet
Ver E 1.3	New menu functions provided in firmware version 1.09 added in chapters Operation mode and Setting mode.

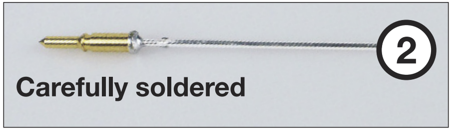
■ OPEN element BX-245

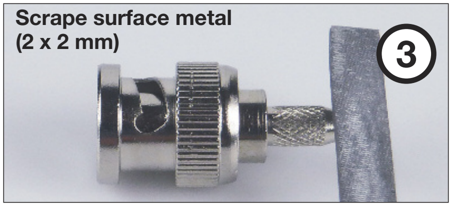


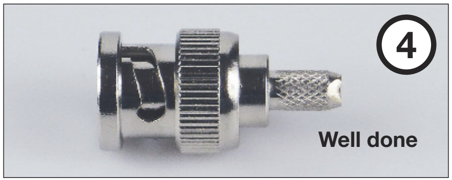


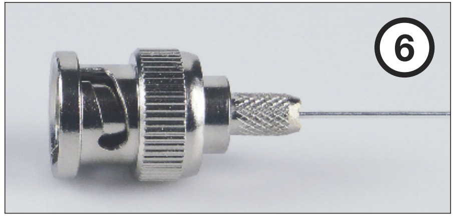
■ SHORT-Element

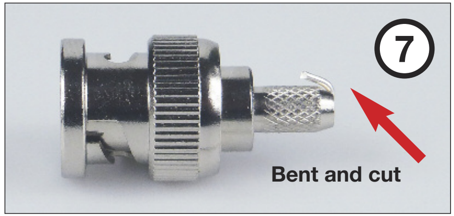


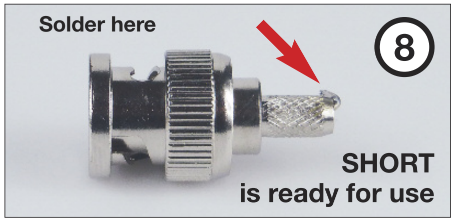












Order no. BX-245

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6th August 2019

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