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Vector Antenna Analyzer FA-VA4

Kit for an easy to use vector antenna analyzer for use in the frequency range 100 kHz to 100 MHz.

Construction and User Manual

First update 8/2017

Vector Antenna Analyzer FA-VA4

Radio Amateurs who build their own antennas, appreciate the value of a vector antenna analyzer. The apparatus presented here as a kit, is characterised by high accuracy, small dimensions and easy handling. It allows one port measurements in the frequency range 100 kHz to 100 MHz with a system impedance of 50 Ohms.

Experimenting with antennas is an essential part of the hobby for many radio amateurs. Measuring SWR and determining impedance values are inseperable. The first can be estimated with the transmitters SWR meter, however, better and more accurate data can be obtained by using an antenna analyzer. Good devices are expensive with less expensive models being somewhat less accurate.
The FA-VA4 closes this gap. It was developed by Michael Knitter, DG5MK and is presented in [1]. This is a full fledged vector antenna analyzer for use in the frequency range 100 kHz to 100 MHz (Table 1).

Vector measurement means that in contrast to a scalar measurement, not only is the SWR determined and displayed but also the value of the base point impedance along with the signbased imaginary part.
The socalled *SOL compensation* from the professional field is used to calibrate the device and allows precise measurements in different configurations.

The FA-VA4 kit consists of an SMD mounted circuit board, the graphics display with backlighting, as well as some mechanical components such as some connectors, push buttons, sliding switches and battery holder along with a fully machined and printed housing. The microprocessor on the board comes preprogrammed.

The requirements for construction can be easily handled by beginners if clean working practices and adherence to the instruction manual are followed.

Building instructions

For construction, the following tools and equipment will be required.

- Temperature regulated 60 … 80 W soldering iron with a fine (pencil) tip, 0.5 … 1 mm solder with flux,
- 100 W soldering iron with flat (chisel) tip,
- Electronics side cutters,
- Flat nose pliers,
- Slot screwdriver,
- Crosshead (Phillips) screwdriver.
- Two 1.5 V batteries type AA for power supply.

Before mounting the board the contents of the kit should be checked against the parts list provided.

Fig. 1: View of a finished FA-VA4 in a switched off state.

Mounting the board

Fig. 2 shows the layout plan with the few components still to be soldered. **These are to be mounted exclusively on the upper side** where the six pin mounting strip for the programmable interface is already located.

First of all the sliding switch S4 should be mounted on the face of the board. It should rest with its underside on the circuit board with the slider able to move horizontally

Table 1: Technical data

Frequency range	0.1 … 100 MHz (1 Hz resolution)
Accuracy	≤ 2 % (f ≤ 50 MHz)
Measurements	Complete impedance values
Measurement range limits*	s ≤ 100, Z ≤ 1000 Ohms
Input	50 Ohms, BNC
Output voltage	Peak to peak = 1 V at 50 Ohms
Power supply	2 × 1.5 V AA batteries
Current drain	49 mA** (110 mA)
Case dimensions	137 mm × 90 mm × 25 mm (L × W × H)
Weight	290 g, incl. batteries

* out of limits less accurate results
** Average value without illumination at 100 MHz and 50 Ohms load resistance, peak value shown in brackets.

(Fig. 3). The simplest way to do this is to make a provisional solder connection using one solder tag on the switch thus allowing for correct alignment whilst heating the solder. When it is in the correct position all the connector tags for the switch along with the two for the housing may be soldered.

Display

An LED backlit LCD screen is used to display measured values. These components are joined together as a single unit and require partial soldering. To do this, the display must be placed on the LED backlight so that there is no gap. **All 6 connections of the two 3 pin display contacts must be soldered to the top of the LED backlight along with the 2 outside pins of the 20 pin connector strip (Figs. 6 and 7)**.
It is advisable to use an appropriate support under the display when soldering to the LED backlight unit to fix both components in the correct position.
The protective film on the display glass screen should be removed before assembly.
To finish, the three socket assemblies are fixed to the contact points on the underside of the display. The upper edge of each socket must sit flush with the back of the

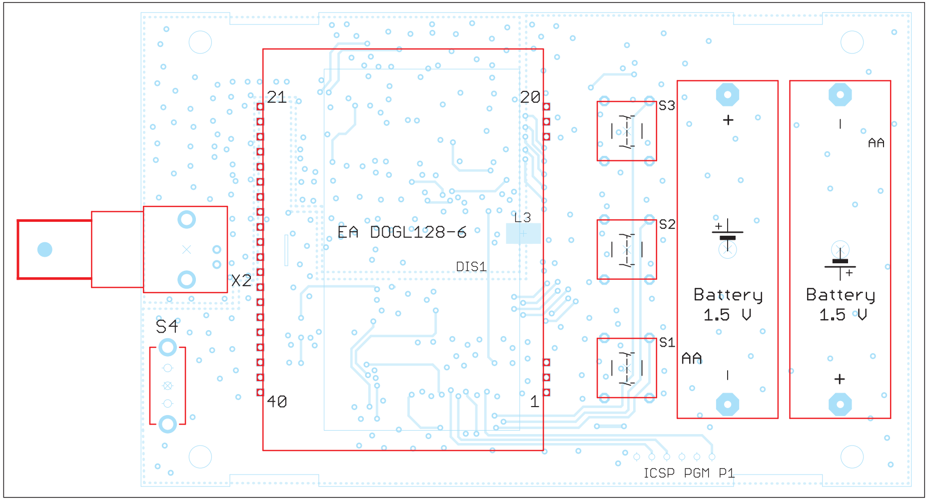


Fig. 2: FA-VA4 layout plan with soldered parts

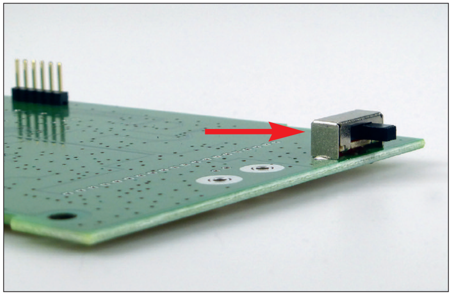


Fig. 3: Slider switch soldered in correct position

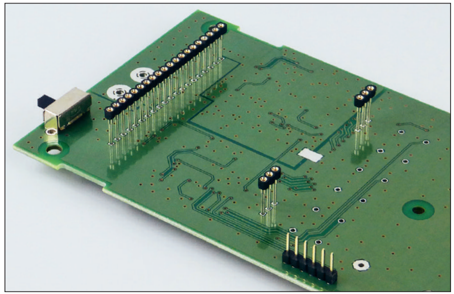


Fig. 4: The three plug connectors for display connection

display after which the whole assembly, display and sockets, must be placed onto the board. The thin ends of the solder tags are pushed fully into their respective holes taking care not to press too hard and that the tags aren't pushed too deep into their holes. Now all three sockets can be soldered on the underside of the board. The display is to be carefully removed while the remaining components are mounted and is then subsequently re-attached. The three mounted socket assemblies are shown in Fig. 4.
After which the three pushbuttons and both the battery holders should be installed. All must have the underside of their housings on the circuit board (Fig. 5). When soldering, some form of compensating support must be used as the socket connections are higher.
The battery holders must be connected to the correct polarity, the spring connection is the negative pole (Fig. 5). The battery holder solder tags are made from spring steel, please use correspondingly robust sidecutters to shorten them.
To finish, the BNC socket must be soldered to the board, set up and aligned horizontally at right angles to the boards edge. The two earth pins should be soldered to the underside of the board using the 100 W soldering iron. The solder must flow well in order to avoid cold spots while at the same time soldering iron usage must be kept to a minimum in order to avoid damaging the insulation on the interior of the socket through overheating.

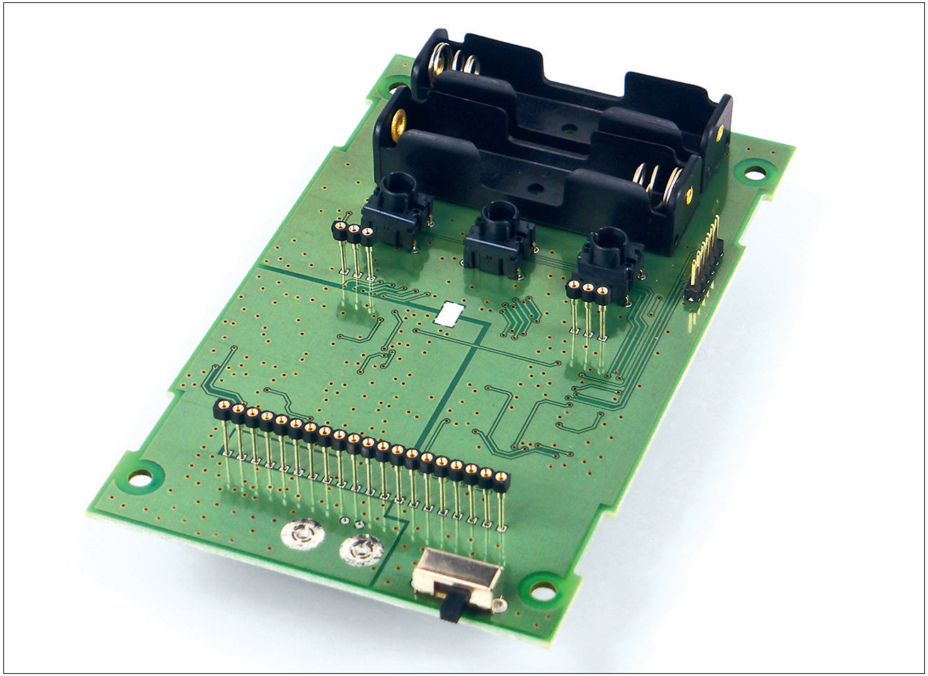


Fig. 5: Mounted pushbuttons and battery holders

Finally use a sidecutter to shorten the two thin pins!

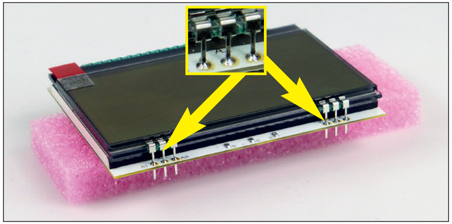


Fig. 6: Display with backlight; shown here the side with the six soldered connections

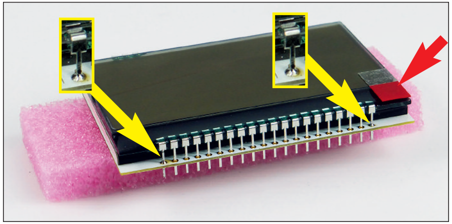
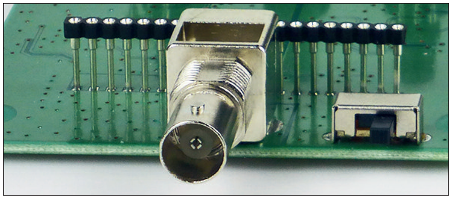


Fig. 7: View of the 20 pin display contact strip after assembly. Solder only the 2 outer pins! Pull the red square to remove the protectiv film from the glass surface.



8: Slider switch in *off* position

Function Test

Before mounting the circuit board into its case a brief test is required. So next first of all, the three caps should be pushed onto the push button switch and the now mounted display plugged into the corresponding sockets. The slider switch should be in the off position (Fig. 8). Lastly two 1.5 V batteries should be attached, making sure of the correct polarity, and the device may be powered up using the slider switch.
The display will briefly show the greetings text, then the FA-VA4 switches to measuring mode. Should the display remain blank then all the previous soldering must be checked and reworked if necessary. When everything is working correctly the slider switch should be turned *off* and the batteries removed from their holder. The fully built board can be seen in Fig. 9.

Assembly into the case

First of all the four rubber feet from the underside of the case are to be fitted, it may help to use some flat nosed pliers to pull on the thin rubber nipple from the inside while slightly twisting the foot into place, after which the excess rubber inside the case should be trimmed with side cutters to around 2 to 3 mm so that it doesn't interfere when the board is screwed into the case.
The board is now inserted, with the socket to the front, into the case subassembly and loosely fixed with four M3×4 cylinder screws in the corners. Then the BNC socket should be fixed using the supplied nut and toothed washer after which the assembly screws may be tightened.
After installation, with due diligence to correct polarity, of the batteries, the case cover should be put on and fixed with four countersunk M3×4 screws. Lastly, the supplied label should be stuck to the underside of the device.
Your FA-VA4 is ready now and can be used in an uncalibrated measuring mode.

General Notes on Use

The FA-VA4 can be used as a measuring device immediately after assembly, it then operates in an uncalibrated mode and the results displayed may be more prone to error than would be the case after correct calibration. This mode can also be selected later from the *Setup* menu, for example if doubts arise about the validity of stored calibration data.

■ Cautions

The FA-VA4 is a sensitive measuring device. **No RF energy must be allowed to reach the measuring socket so as not to destroy the input components.** This could happen if for example an antenna in the immediate vicinity transmits. Likewise, static charges should be kept as far away as possible from the measuring socket. Insulated antenna structures must therefor be earthed before connecting to the device for example by shorting to earth.

Rechargeable batteries should not be used in the FA-VA4 as no deep discharge protection nor charging circuitry is available. Deep discharge can render the rechargeable batteries unuseable or even destroy them. Leaking batteries can likewise severely damage the equipment.

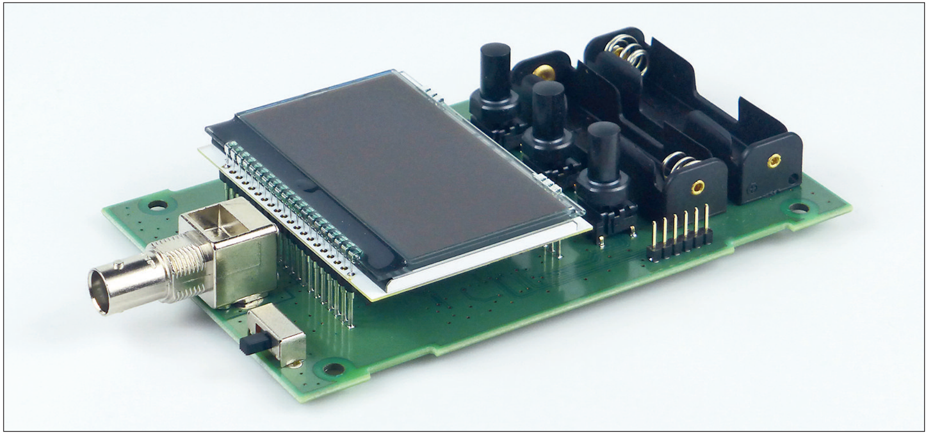


Fig. 9: Completed FA-VA4 board

The FA-VA4 is optimally designed to use 1.5 V AA cells. Used cells must be removed from the device.

For the longest battery life it is recommended to only use the backlight when the display cannot be read. With daylight or outside the display doesn't usually needs backlight illumination.

The number of measurement display cycles should only be as many as are needed to ensure a sufficient repetition rate for the measurement in question. Both parameters have a considerable influence on current consumption and therefore on battery life expectancy, they can be changed in the *Setup* menu.

BNC plugs should be carefully twisted after connecting to ensure no ‘unexpected’ incorrect measurements.

Directions for use

Although the FA-VA4 has a relatively wide range of functions, its operation is fairly intuitive therefore the following guide has the character of a reference book, however the general operating instructions from the previous section are to be considered in each case.
The device cannot be destroyed by incorrect button pressing but may display incorrect, unexpected results. It is recommended therefore that the inexperienced user starts with data from a known measured object and then explores the antenna analyzer step by step, testing different measurement and display modes, and refer to these instructions as necessary.
For precision measurements the subject of calibration (*SOL compensation*) is important and is covered in its own separate section.
The antenna analyzer operates according to the following measuring principles: an internal oscillator generates a signal with a defined frequency, this signal is then passed to the test object (e.g. antenna) via the output socket of the device. Due to the electrical properties of the object under test, the signal will be changed in both amplitude and phase. This change is evaluated to determine the impedance of the test object. All other measured values (e.g. SWR) are mathematically derived from the impedance by the microprocessor.

■ Controls and connectors

The only connection to the analyzer is the test socket. For operation there are three pushbuttons and an on/off switch.
All selected parameters are saved, so that at switching on the device will have the same settings as when it was switched off.
The three pushbuttons have different functions depending on the actual measuring or operating mode. In most cases a function or other selection is called up with the left hand button, the middle and right buttons serve to increase or decrease values through the menulists. The current function is displayed on the display above the buttons.
When in measurement mode a longer press of the left button will call up the menu. The middle and right buttons then allow you to select a menu item which may then be selected or activated using the left button. Other functions of the buttons are explained in a later paragraph.

Switching on the Analyzer

After switching on the FA-VA4 a greetings message will appear on the display under which also the firmware version and to the right of that the battery voltage. The default menu language is *English*.

■ Calibration (SOL compensation)

Every extra plug and additional piece of cable influences the impedance measurement of the test object. This unwanted influence can be completely compensated for by the *Short Open Load* method (shortened to SOL method).
First of all, instead of the test object, three reference elements are measured; *Short* represents a short circuit, *Open*, an open cable end, and *Load*, a resistance in the magnitude of the system impedance (in our case 50 Ohms.) These reference measurements can be easily obtained with acceptable accuracy using three 50 Ohms BNC coax plugs.
In the case of the *Short* element the inner connector and the plug housing are short circuited, for the *Open* element the inner pin remains unconnected, for the Load element there is a small 50 Ohm metal film resistor between the inner connector and the housing. If the materials aren't to hand use the included reference elements (shown in Fig.10 and at page 21).
After calibration has been completed the calculated values are automatically stored in the analyzer so that the correct impedance is determined when the test object is measured.

The analyzer knows two different modes of SOL compensation.

SOL for all frequencies

It is possible to permanently save SOL reference values for the entire measuring range. In this case, with the Short reference element connected, the analyzer runs through the entire frequency range and stores the determined measured values. The same procedure is to be carried out for connected *Open* and *Load* elements. It is recommended to carry out this compensation routine once, after commissioning, for the builtin plug, any permanently attached cable or measuring device and in between times as required. Thereafter the measurement of a test object is possible at any time without further compensation.
The analyzer then uses these reference values as a standard (master compensation), in particular for multi frequency measurements. This function can be accessed via the *Operating Mode → Setup → SOL All Frequencies* (Fig. 12).
Please note: the entire process takes several minutes but may be cancelled, in this case however the resulting measurements will be inaccurate and the calibration procedure should be recommenced at the first opportunity.

Fig. 10: The components for the reference elements BX-240-SOL [2] contains a 50 Ohm termination resistor (made in China) along with two BNC coax plugs (left and right) for the *Short* and *Open* reference elements.
High quality terminations are BTRM-50+ from Mini-Circuits®, PN J01006A1268 from Telegärtner or others.

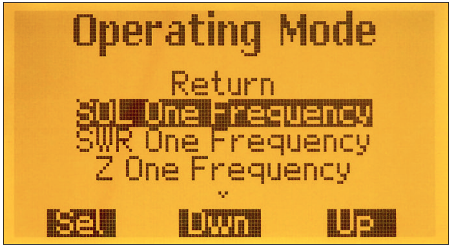


Fig. 11: Menu item for SOL one frequency

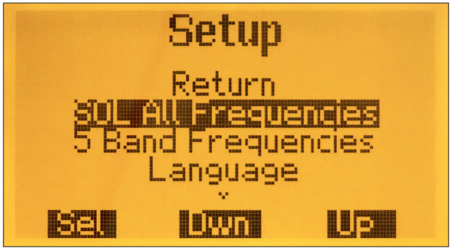


Fig. 12: The Master SOL compensation (for all frequencies) is started in the *Setup* submenu.

SOL for an individual frequency

For all individual frequency measurements it is possible to run through SOL compensation for the actual frequency, (*Operating Mode* → *SOL One Frequency*, see Fig. 11).
The procedure is the same as described above but only applies to the currently set frequency and therefore runs very quickly. This makes it possible to quickly and easily compensate for temporary changes in the measurement setup or parameters as a result of temperature changes or other interference.
For particularly high accuracy it is recommended to perform such compensation before each measurement.

Important: if the measured frequency of the analyzer is changed, the determined SOL reference values for the current frequency are indicated as invalid and the standard values of the master compensation will be used instead for the next measurement. The display shows which reference values are currently being used. For example in Fig. 18 the master calibration is used to measure SWR, which can be seen as a small *solM* to the right of the bar on the right hand side of the display. In case of single frequency calibration the display will show *solf*, in case of no calibration at all it will show *sol-*.

Explanation of the menus

A long press on the left hand button will call up the menu mode. This offers the set-up possibilities contained in Tables 2 and 3 (Figs. 13 to 17).

Operating mode

The operating mode makes it possible to select the measuring and display modes most commonly used in practice.

Single frequency SWR measurement

The indicators become the actual measurement frequency, the standing wave ratio (SWR), the effective impedance resistance (Formula *Z*), the impedance reactance (+j/j), the SWR shown as a bar graph along with the currently used reference values of the SOL compensation, (*solM* for master calibration, *solf* for calibration on an actual frequency, or *sol-* for uncalibrated operation).

Table 2: Possible adjustments in the FAV-A4 operating mode

Menu item	Meaning
Return	Return to the previous mode
SOL One Frequency	SOL compensation of the actual frequency
SWR One Frequency	SWR measurement of the actual frequency
Z One Frequency	Impedance measurement of the actual frequency
SWR Single Sweep	Single run of SWR measurement in the specified frequency range
Z Single Sweep	Single run of impedance measurement in the specified frequency range
SWR 5 Band	SWR measurements of 5 frequencies (5 band measurement)
SWR Cycling Sweep	Cyclic SWR measurement run
Z Cycling Sweep	Cyclic run of impedance measurement
Frequency Generator	RF generator mode
Captured Screens	View of saved measurement results (display contents)
Setup	Call up the setup menu (see Table 3.)

Options in the menu *Setup*

Table 3: FA-VA4 Setup mode

Menu item	Meaning
Return	Return to measurement mode
SOL All Frequencies	SOL compensation over entire frequency range (master calibration)
5 Band Frequencies	Setting the frequency values for 5 band measurements
Language	Select the menu language
Backlight Mode	Settings for the backlight
Delta Frequency	Calibration of the internal frequency
Display Update Cycle	Setting the measurement repeat rate
Reset	Reset all settings to factory default

The actual measurement frequency can be set using the three push buttons. The left button (D/S) selects the decimal place indicated by an underscore line. With the middle or right hand button the values may be increased (+) or decreased (–). For an eventual compensation (*SOL One Frequency*) the corresponding function in the operation mode menu must be selected, (see paragraph *Calibration*). After recording the reference values the analyzer returns to the current measurement mode (Fig. 18).

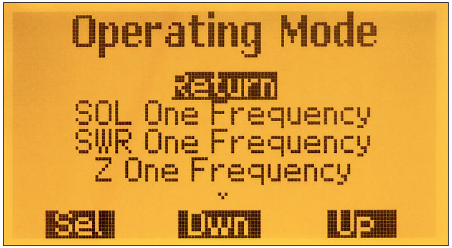


Fig. 13: Operating mode, first screen

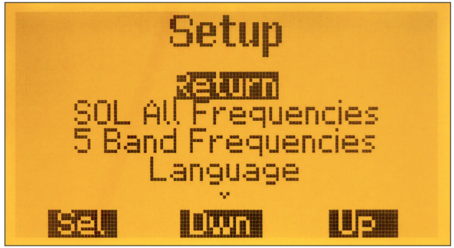


Fig. 16: Setup mode, first screen

Fig. 14: Operating mode, second screen

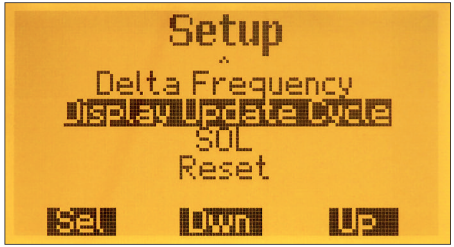


Fig. 17: Setup mode, second screen

Fig. 15: Operationg mode, third screen

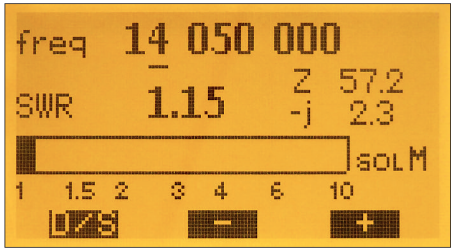


Fig. 18: Single frequency SWR measurement

Single frequency impedance measurement

Displayed are the actual measurement frequency (*freq*.) the complex impedance after effective resistance and reactance, the total impedance resistance (*/Z/*), the corresponding Inductance/Capacitance of the test object, the SWR and the currently used reference values of the SOL compensation (see paragraph *Calibration*).
With regards to the SOL compensation, the sections on *individual frequency SWR* measurement apply (Figs. 19, 21).

Single SWR measurement run

All multi frequency measurements have three different modes which are indicated by a symbol in the upper left corner of the display.

1. **< (small sign):** overview and adjustment of the central frequency. The SWR is displayed above the frequency. In addition a small rectangle indicates the marker position (see Mode **M**). The central vertical line corresponds to the centre of frequency (here 7950 kHz). The operational range extends both left and right according to the selected frequency range (here + or 3200 kHz). Using the middle and right buttons the centre frequency can be increased or decreased by some 100 kHz. At the same time, each button press triggers a new measurement cycle over the defined frequency range.
2. **> (large sign):** overview, marker values and frequency range selection. The SWR is again shown above the frequency. Additionally the small rectangle on the SWR curve indicates the position of the marker (see Mode **M**). Using the middle and right buttons the frequency range may be increased or decreased by a factor of two (within the available frequency/measurement range). At the same time, at each button press a new measurement cycle over the defined frequency range is started. The measured value of the marker frequency is shown in the bottom right hand corner of the display.
3. **M (Marker sign):** View and adjust the marker values over the previous frequency range. The selected frequency of the marker and the corresponding SWR are displayed (without boundary value limitations). The marker itself is again represented by a small rectangle on the SWR curve. Using the middle and right buttons the marker can now be moved along the previously measured curve in a total of 100 steps. In

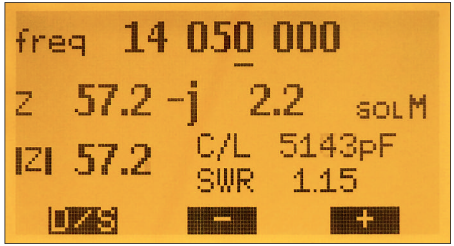


Fig. 19: Single frequency impedance measurement

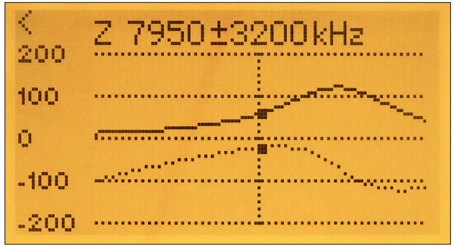


Fig. 20: Single run of impedance measurement

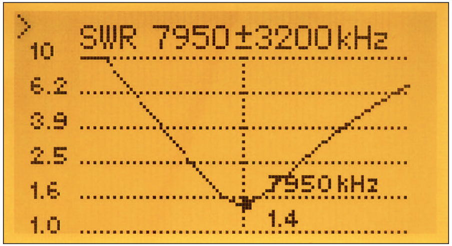


Fig. 21: Single run of SWR measurement

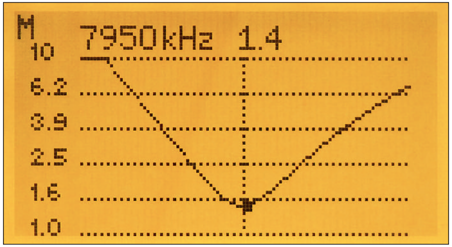


Fig. 22: Marker on 7900 kHz

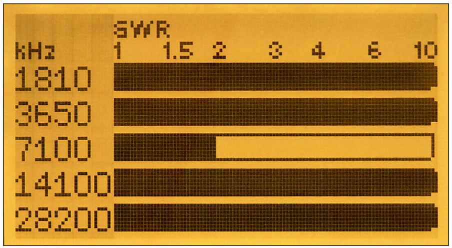


Fig. 23: SWR measurement on 5 frequencies

contrast to the **<** and **>** mode, no new measurement cycle is triggered by button pressing, only the changed marker position, including the corresponding measured value, is displayed. The measured values determined before switching to mode **M** have been 'frozen' and can now be 'traced' using the marker. A new measurement value is only taken again when switching to mode **<** or **>**.

The combination of these three modes makes it easy to 'target' certain frequency ranges during measurements, to intercept values at specific points.

For internal SOL compensation, the unit always uses the reference values from the master calibration.

Single run for impedance measurement

The active resistance (solid curve) and the reactance (dashed curve) are shown above the frequency. All further displays and operating possibilities correspond to the versions in the previous section.

SWR measurement on five frequencies (5 band measurement)

Five SWR values are displayed in the bar graph for five different frequencies. Their values can be defined via the *Setup* menu. In this measuring mode no other options are available. But you can simultaneously observe the practical effects of any changes with multi band antennas.

The internal SOL compensation is always performed using reference values from *SOL All Frequencies* (Fig. 23).

Cyclic continuity for SWR or Impedance measurement

Here the previously described measuring runs are repeated continuously with no need for user intervention. The operation is the same for the single run for measuring SWR and impedance.

HF Generator

The FA-VA4 now operates as an RF generator with a square wave signal output at the measuring socket, with a peak to peak voltage of 1 V_{SS} at 50 Ohms. The current signal frequency is displayed (Fig. 24). The setting is done by means of the three buttons (select the decimal place to be changed with *D/S*, decrease the value with – increase the value with +).

View saved results

All measurement modes allow you to save a view of the current display (display content), to do this briefly press both the left and right buttons simultaneously.
In the subsequent menu, one of five (0… 4) memory locations may be chosen using the middle (*Dwn*) and right (*Up*) buttons and selected with the left button (*Sel*).
The saving to memory takes a few seconds as each pixel is transferred to the EEPROM. Previously stored view data in the selected memory location will be overwritten.
To display these views select *Captured Screens* (*Operation Mode* → *Captured Screens*) and use the plus and minus buttons to select the display memory. On the upper right edge of the display *C0* to *C4* allows identification of the image. Unoccupied memory locations are displayed completely empty. The left button *D/S* allows you to return to the previous test mode (Fig. 25).

Fig. 24: Display view using the FA-VA4 as signal generator; the frequency is selected using the three pushbuttons

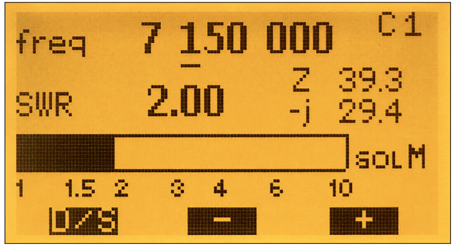


Fig. 25: Stored display view; top right is the memory location number (here *C1*).

Fig. 26: Setting the frequency f_1, to the right the abbreviated *ENT* can be seen; pressing the plus or minus button the frequency value for f_2 is displayed and can be altered and so on for f_3.

Fig. 27: Menu language setting possibilities

■ Setup Mode

The following settings options are included in a separate menu as they are rarely used in practice. They are accessible via *Operating Mode* → *Setup*. The middle and right buttons are used to set up the required option, the left one is used to confirm the selection. After changing a parameter, the analyzer automatically returns back to the last test mode.

SOL All Frequencies

This menu item has already been covered in the *calibration section* (*SOL compensation*).

Frequency values for 5 band measurement

After selecting the menu item (*Operating Mode* → *Setup* → *5 Band Frequencies*), the first of the five frequencies is available for an input or a change (f_1). To do this use the left (*D/S*) button to set the position indicator to the position of the frequency value to be changed and the plus and minus buttons to correct. By jumping from the last point on the left to the first point on the right (1 Hz) the abbreviation *ENT* for 'enter' (input) appears. Pressing the plus or minus key now stores the set value for f_1 and jumps to the frequency input for f_2.

This is repeated up to frequency f_5 (Fig. 26).
Having confirmed the last frequency the analyzer returns to the previous test mode.

Language

This option allows the use of German or English for the menus and measurement displays (Fig. 27).

Display Lighting

The possibilities are *On*, *Off*, and *Auto*. With the automatic option the lighting will turn off after a time, turning on again after some user action (button press). It is recommended to use the device without lighting or, at least, in automatic mode as the current consumption for a graphic display is quite high (Fig. 28).

Correction of the frequency generator

All the internal frequency values are derived from a 27 MHz Quartz crystal. A variation of about a hundred Hertz is not uncommon and can be compensated for using software. To do so a frequency of 27.000000 MHz should be set in the *Frequency Generator* mode. A calibrated frequency counter should be connected to the analyzer output socket and the difference between the measured and adjusted frequency determined. After selecting the menu item *Delta Frequency* press the left button. The value for d_f is then adjusted using the middle and right buttons to the determined difference (27.000000 MHz less measured frequency). Press the *D/S* button again to select the decimal place. Repeated pressing of this button will display the abbreviation *ENT*. If the plus or minus button is pressed now, the FA-VA4 will take the set value as the frequency correction amount. Now the frequency of the analyzer output signal should correspond exactly to the set value. Naturally, in the course of this, changes in temperature may lead to deviations of the quartz frequency, a frequency correction here is at the limits of quartz oscillator stability. In the case of antenna measurements, however, a deviation of a few hundred Hertz or even a kiloHertz is usually noncritical, so the described correction may only be necessary in rare cases (Fig. 29).

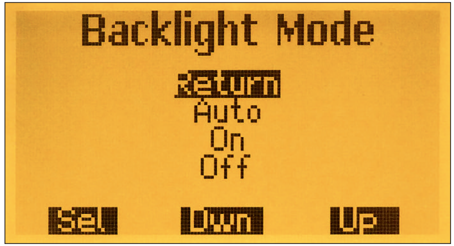


Fig. 28: Settings for display lighting

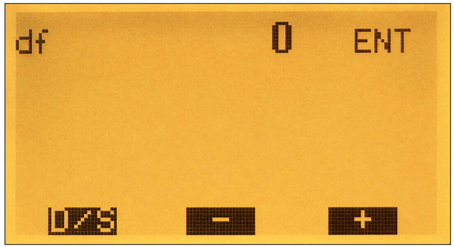


Fig. 29: Input possibilities for the frequency correction factor

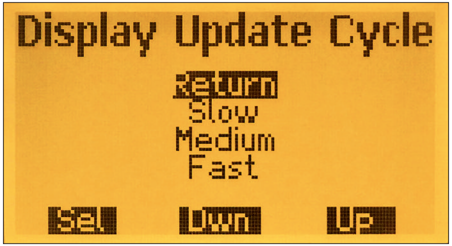


Fig. 30: The display update cycle speed may be selected, *fast*, *medium*, *slow*.

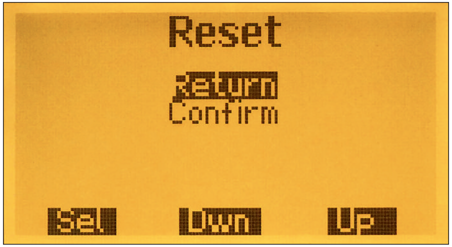


Fig. 31: This menu item allows a complete reset to factory default settings.

Display Update Cycle

For individual frequency measurements there are three options available, *Slow*, *Medium* and *Fast*. The selection has no influence on the measuring accuracy but very much on the energy demands of the device. Outside of the measuring time, the oscillator and other components are switched off and the microprocessor clocked at a lower frequency. A longer display duration (selection *Slow*) therefore results in a lower energy requirement (Fig. 30).

Reset

After selection and confirmation of the menu item, all parameters are reset to the factory settings. The master calibration and all stored display views are cleared from the EEPROM (Fig. 31).

Forced Reset (without menu item)

In the unlikely event of the device becoming unresponsive even when switched off and on again, a forced reset can be carried out without recourse to the menu.
To do this the analyzer must be switched off. Then all three buttons should be pressed and held, then if the power is switched on all parameters should reset to factory default settings and the device work again as per normal. If necessary the language, lighting and frequency settings must be corrected.
However, the forced reset does not clear existing master calibration values nor stored display views. Any existing master calibration values must be declared as valid, to do this select *On* under *Operating Mode → Setup → SOL*.

Tips on measurements in practice

The application possibilities of measuring a complex impedance are very diverse. The measurement examples listed below can therefore only be used to a certain extent. Further explanation of the physical and mathematical contexts can be found in the relevant technical literature.

It is assumed that a master calibration (*SOL All Frequencies*) has been carried out with or without connected cables (depending on the measurement setup). If the setup is later changed e.g. by changing the cable, then the compensation must be carried out again.

On Measurements in General

One must be aware when measuring on antennas, that the FA-VA4 is an 'active' device that generates RF energy and delivers it to the antenna. The power at the BNC socket is about 3dBm.

And is sufficient to cause interference to other stations, therfore the duration of all measurements should be kept as short as possible and tests on frequencies outside of the Amateur Radio bands should be avoided.

Multi Frequency Measurement of Impedance and SWR of an Antenna

The antenna is connected directly to the base point or via a cable previously integrated into the calibration by means of SOL compensation and the analyzer. An overview of the SWR or impedance profile can be generated using the multi frequency measurement. The centre frequency and the frequency range must be set to the range to be measured. A minimum SWR can be 'targeted' via the Marker Mode.

For high quality antennas (e.g. magnetic), increased attention is necessary when taking a measurement. Under certain circumstances, depending on the chosen frequency range the maxima and minima are so narrow that they are not displayed. Here the measurement frequency can only be further limited and the span reduced accordingly.

Measurement of Antenna Impedance and SWR for a single frequency

The antenna is connected directly to the analyzer or via a cable. It is to be decided whether the whole system of antenna and cable or just the antenna is to be measured. If the latter is connected then any cable (usually plug in connectors) must be disconnected. The analyzer must be set to a frequency to measure SWR and or Impedance. The target frequency is then entered. Via the menu item *SOL One Frequency* (see paragraph *Calibration*), the cable is again included for the actual frequency under measurement by successively connecting the test elements (instead of the antenna) as described above. Lastly the cable is connected to the antenna and the actual antenna SWR or impedance is displayed.

The method of tuning an antenna for optimal SWR or resonance depends on the antenna type. For a monoband dipole with Balun this may be achieved by shortening or lengthening the antenna elements. For an antenna with negative reactance (capacitive) the elements are too short, in the case of positive reactance (inductive) then the elements are too long. The aim is to achieve an effective resistance of 50 Ohms with zero impedance (at resonance).

Measurement of Capacitance and Inductance

When using on shortwave the manufacture of a simple adapter of 2.54 mm pin connectors and matching sockets serves to conserve the SOL reference elements (see paragraph *Calibration*). For measurement the mode *Z One Frequency* is used. For the existing measurement setup the target frequency must be set and calibration carried out from the menu item *SOL One Frequency*. The object to be measured is connected directly to the selected setup and the capacitance or inductance at the target frequency can be read on the display.

FA-VA4 as a Dip Meter

If a signal generating source (in our case the analyzer) is loosely coupled in parallel to a resonant circuit, a different energy absorption will be shown through the circuit both at and outside of the oscillators resonant frequency. This change also causes a change to the displayed SWR value.
The loose circuit coupling is usually made inductively; it is sufficient to place the analyzer, with a coil (a wire) connected, close to the resonant circuit. If using a ferrite ring then the wire should be passed through the core, at very low frequencies (f < 1MHz) a test with several windings is helpful.

The SWR multi frequency measurement must be set so that the expected resonant frequency is set as the centre frequency. In order to read the resonant frequency with the highest degree of accuracy the measurement interval should be reduced step by step, this will be indicated by a clear minimum SWR.
It is not always easy to find this minimum as with high Q circuits the margins are very narrow.

Determination of cable resonance and resonant cables

The analyzer makes it easy to determine points of resonance in coax and other RF cables. Connecting an unknown cable to the analyzer, the other end may be open or short circuited. When the cable end is open, points of resonance occur at $^1/_4$, $^3/_4$ etc. of the wavelength of the resonant frequency. With the cable shortcircuited the resonant points are at $^1/_2$, 1, $^3/_2$ etc. of the wavelength of the resonant frequency. Resonance means that the reactance of the impedance is equal to zero, so here we must use the 'Z multi frequency' measurement. For shortwave it makes sense to start with a centre frequency of 15 MHz and a maximum measuring interval. The resonances are indicated at the points at which the reactance crosses the x-axis (absolute zero). This frequency can be easily manipulated in Marker Mode. This method can also be used to make cable resonators for a specific frequency. Thus using the method set out in the following paragraph a rough estimate of the physical length can be made. A slightly long cable may be trimmed until the target frequency resonance is reached.

Determination of cable length and shortening factor

Wavelength and physical length of a resonant cable are linked by the shortening factor. Similar would be comparing the speed of light velocity of a wave in free space to a wave on a cable, the wave on the cable propagates more slowly than in a vacuum. For example RG58 coax cable has shortening factor of 0.66 so the propagation speed is only 198 000 km/s instead of 300 000 km/s.
Length, propagation speed and resonant frequency are linked by the formula

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

N is a factor of $^1/_4$, $^1/_2$, $^3/_4$, and so on, depending on which resonance point is considered and whether the cable is open or short circuited at the other end. If the resonant frequency of a cable is determined from the previous section, the physical length can be determined by using the above equation and the shortening factor for the cable. Conversely the shortening factor with the known physical cable length can also be determined by the above equation.

If you have problems please contact us via support@funkamateur.de.

But now have fun and enjoy building and using the FA-VA4.

shop@funkamateur.de

Appendix

Parts list

Abbreviation	Part description	Quantity	Note
X2	BNC socket	1	
S1 … S3	Pushbutton switches	3	
(S1 … S3)	Knobs for pushbuttons	3	
S4	Slider switch	1	
G1, G2	AA Battery holders	2	
	Graphic display with backlight	1	preassembled but unsoldered
	20 pin connector	1	for display
	3 pin connector	2	for display
	SMD mounted circuit board	1	6 pin connector strip soldered to
	Housing, printed	1	upper and lower cover
	Case rubber feet	4	
	Cylinder (grub) screws M3×4	4	board fixing
	Cross head screws M3×4	4	for case
Construction and User Manual		1	updated in 8/2017
Type label		1	for sticking to the underside
SOL elements	50 ohm termination	1	made in China
	BNC connectors	2	

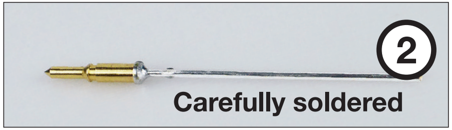
Literature and References:

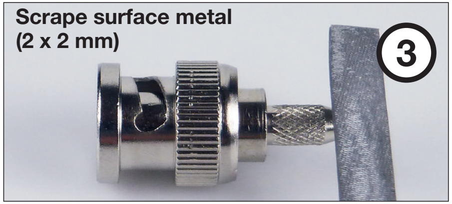
[1] Knitter, M., DG5MK: 100 MHz antenna vector analyzer for everyone. FUNKAMATEUR 66 (2017) H. 3, S. 246–249, H. 4, S. 360–363

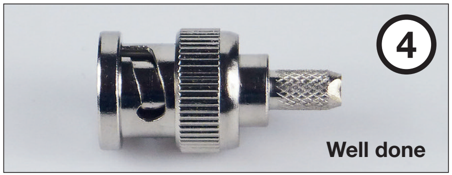
[2] FUNKAMATEUR-Leserservice, Majakowski-ring 38, 13156 Berlin, Germany
www.box73.de → *BX-240-SOL*

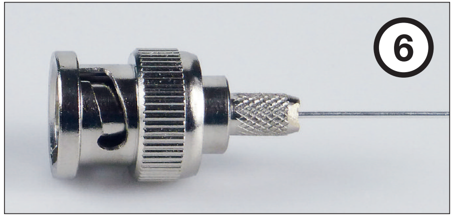
■ OPEN element

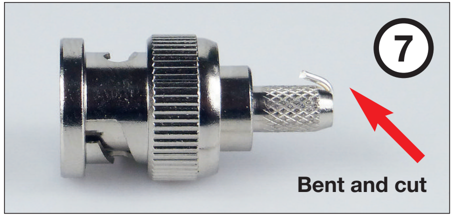
■ SHORT element

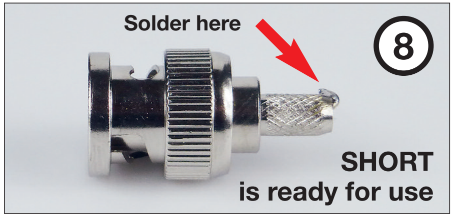












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First update (August 2017)

When disposing of this product, please observe the regulations for the handling of electronic waste. Electronic devices, batteries and components do not belong in household waste. For further information see www.box73.de