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NanoVNA SMD Tweezers

Build this tweezers probe for connecting to and measuring SMD components with a NanoVNA.

As an MF/HF/VHF circuit design hobbyist I have long wished to own inexpensive instrumentation that I could use to measure passive RF surface mount device (SMD) components at the intended frequency of operation. One slick but pricey handheld commercial instrument has a mechanical design based on the tweezers concept. For two pin passive RCL SMDs with exposed pins on opposite ends of the chip the tweezer probe concept permits a quick and easy connection method by simply clamping the tweezer contacts onto the component terminals. However a significant disadvantage of at least one commercial instrument that uses the tweezer concept is its frequency of measurement is 10 kHz or less.

The tweezer probe concept can also be useful for component identification, since most L/C SMD chips do not have any markings. If they become separated from the original packaging they cannot be visually identified. A tweezer probe accessory for a frequency agile L/C meter can provide a convenient method for measuring the value and frequency dependent characteristics of an unmarked chip.

The recent development and marketing of an inexpensive, handheld portable, battery powered vector network analyzer (VNA) instrument has opened up a whole new measurement horizon for the RF design hobbyist on a budget. Known as the nanoVNA, it offers measurement bandwidth capability up into the UHF region, which is more than sufficient for the measurement of components intended for most HF and VHF applications. Internet links for some informative sources are provided in the notes.

This article describes the design, construction and use of a low cost tweezers probe for the nanoVNA that adapts the nanoVNA for measuring LCR RF passive SMDs across a user specified swept frequency range up to 150 MHz. Supplementary info is provided at **www.arrl.org/QEXfiles**.

Figure 1 shows the nanoVNA with the tweezers connected to the channel 0 (CH0) port via a 2 W SMA dc - 6 GHz coaxial fixed attenuator, (**https://www.aliexpress.com/**), which provides improved measurement accuracy in some cases. The cable connected to the CH1 port is not used for this application and is left terminated with a 50 Ω resistive load. The calibration box that is shown above the nanoVNA is used for providing reference standards

Figure 1 — NanoVNA tweezers connected via 6 dB attenuator.

for tweezer probe calibration, and to also provide a range of LCR tight tolerance SMD references for performing measurement comparison checks. Accuracy examples are reported in **www.arrl.org/QEXfiles**.

NanoVNA Tweezer Construction

Following several failed attempts to obtain an inexpensive tweezer design that would be reasonably practical for a hobbyist to make, and that would also stand the test of time, I settled on the design shown in **Figures 1 to 7**. This design meets my requirements, and continues to work as described after making hundreds of measurements.

Figure 2 shows the specialty parts needed for making a pair of tweezers. All the parts were purchased online. The total cost for the pair of tweezers including cable, spade terminals, one 6 dB attenuator and one 90° SMA adapter was less than $20. I built two tweezer probes to have a spare available, and because there was very little additional cost to make a second probe. Additional supplies not shown are tiny cable zip ties, shrink tubing, hot glue (or equivalent bonding agent), parts needed for the reference box, and general electronic shop supplies.

The SMA-to-SMA RG178 coaxial cable jumper **[2]** shown in **Figure 2** is one meter long. I purchased a prefabricated 2 m long SMA cable, and cut it in half to provide two 1 m coaxial leads needed for the pair of tweezers. A very important feature of the RG178 coax that it uses a PTFE dielectric, which can withstand soldering temperatures without melting. With its small diameter and stranded center conductor RG178, it is sufficiently flexible for this purpose. Although the photos show the cables with female SMA connectors, a cable with male connectors would be a better choice because it would permit direct connection to the nanoVNA without the need for an adapter (although a 90° male-to-female adapter is recommended). Also the cost would be slightly lower.

The tweezers **[3]** have tips made of material that seems similar to PTFE (they are described by the seller as ceramic) and can also withstand soldering temperatures. The tips appear to have good RF insulation characteristics.

I purchased the gold flashed spade terminals **[4]** as a lot of 10. The extra quantity purchased proved to be a wise choice as a few were wasted in the process of learning how to attach them to the tweezer tips.

The preparation of the two cable ends are created by bisecting the coaxial jumper to make the pair of leads is shown in **Figure 3**. As shown, I removed about two inches (5 cm) of jacket. I threaded the center conductor through the braid at the edge of the jacket. Then I stripped about a quarter inch of dielectric off the ends exposing the center conductors for soldering to the spade terminals.

Figure 4 shows the spade terminals attached to the tweezer tips, which I found to be a bit of a tricky procedure. I slid the spade lug onto the tip with the point of the tip extending underneath the small tab that pokes out the back of the lug. I tightened the wire clamps of the lug around the tweezer

Figure 2 — NanoVNA tweezers assembly parts.

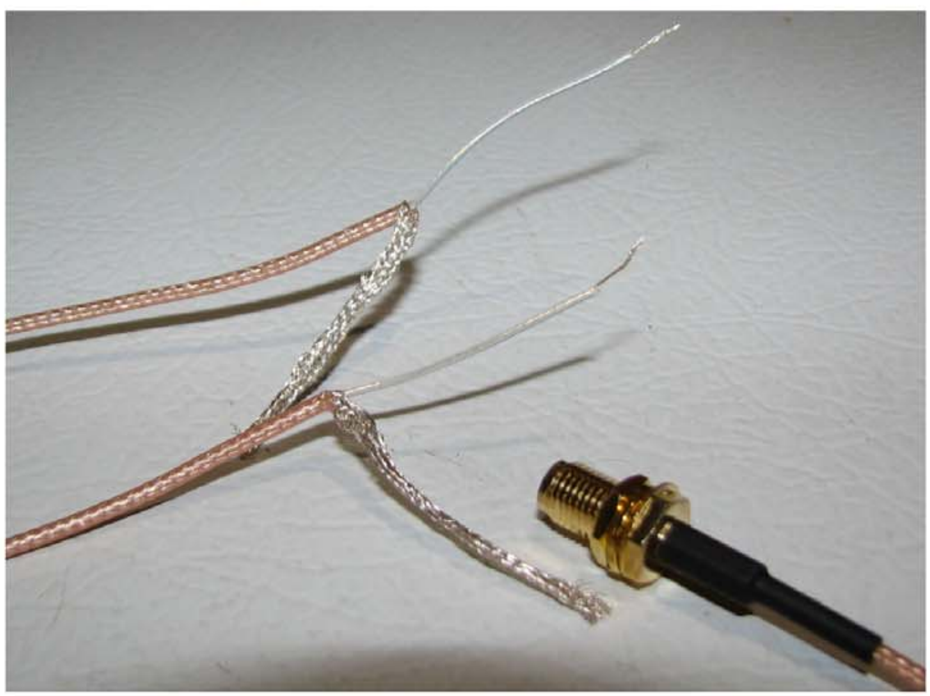

Figure 3 — Dissected cable tweezer connection end preparations.

Figure 4 — Spade lug contact mounted on tweezer tips.

tips with pliers. Then I aligned the tips of the spades so that they became flush with tweezer closer. I then curved the spades towards each other so that only the ends of the spades touched each other when the tweezers were closed. Finally, I applied solder as shown to stiffen the spade backs and to create a form around the tips. I found at this stage that it is pretty easy to pull the spades off the tweezer tips, however, don't despair. Once I attached the cable and applied a small drop of fast setting glue to the clamp area I found that the spades were held in place. The main objective at this point is to have the lugs aligned and attached with a good fit. **Figure 5** is a more detailed view of the spade lug attached to the tips.

Figure 6 shows the attachment of the prepared cable end. The outer conductor is soldered to one terminal and the center to the other. Here strain relief is very important. I used a tiny nylon cable tie to secure the cable jacket to the terminal on the shielded side.

Once I soldered the center conductor to the second terminal, I slid heat shrink tubing over the center conductor and then shrank it to secure the dielectric to the spade terminal. This prevents the flexing of the center conductor wire at the solder connection during tweezer usage. Without this strain relief I found that the wire would break off after only a few dozen measurements due to insufficient bending radius metal fatigue.

Figure 7 shows the completed tweezers. I applied hot glue to secure the cable to the hinge end of the tweezers to keep the cable clear of the work area. As a final step to secure the tips, I carefully applied a small drop of quick setting Super Glue® to the wire clamp ends of the terminals and allowed it to set with the tips elevated to ensure the glue would not migrate down onto the spades.

A 90° adapter for connection to the nanoVNA is recommended to reduce leverage strain on the nanoVNA port 0 connector. A side benefit is that the 90° adapter helps prevent the rotation of the nanoVNA screen away from the direct view of the user while the probe is being shifted into position for clamping onto the device under test (DUT).

Loose Component Testing Tray

During the early proof of tweezer concept evaluation, I discovered that to prevent loss of parts, a tray with a perimeter wall was needed to place loose SMD components into for measurement. It is pretty easy to have a chip catapult away from the tweezer tips thus a testing tray is essential. An inverted screw-on plastic food container lid about 10 cm (4") in diameter with a 1.5 cm (5/8") threaded lip, as shown in **Figure 8**, was found to serve the purpose quite well. It is important to place stick-on rubber feet on the flat top as shown in **Figure 9**. The rubber feet are necessary to stop the lid from sliding around on the desktop.

At the onset of this development effort I

Figure 5 — Spade lug contacts installed and aligned.

Figure 6 — Cable connections to spade lugs with strain relief.

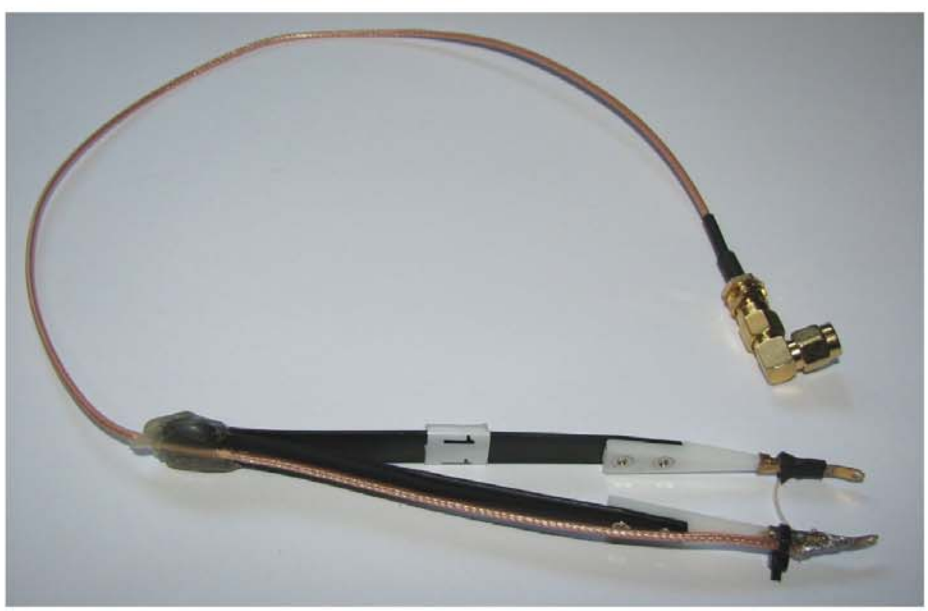

Figure 7 — Tweezers assembly complete showing cable strain relief points and 90° adapter.

Tweezer Tip Calibration and the RF Reference Plane

Those already familiar with the calibration of the nanoVNA will be familiar with the use of the factory supplied coaxial connector references consisting of OPEN, SHORT and LOAD (OSL) SMA components. It is presumed here that owners of nanoVNA instruments will already be familiar with the touch screen menu selections and calibration procedures. Detailed calibration instructions can be found on the nanoVNA user group internet web site; **https://groups.io/g/nanoVNA-users/**. In general following a RESET to clear previous calibration data, the calibration procedure consists of connecting the OSL terminations in sequence to the CH0 RF bridge port, usually via a short coaxial test lead. This enables the nanoVNA to measure and save the resulting complex impedance value data for the OPEN, SHORT, and ideal 50 Ω resistive LOAD for each frequency step within the defined spectrum segment. The device under test (DUT) is then connected to the **same point** used for the OSL terminations. Once the DUT is connected, the MPU cyclically measures the DUT impedance for each frequency step and updates the data record about once per second. By correcting for the previously saved calibration reference data, the MPU mathematically determines the complex impedance of the DUT for each frequency step and updates the user's screen display accordingly. The obtained accuracy of the measurement is mainly dependent upon the RF impedance bridge range of measurement limitations, the calibration accuracy, computational accuracy and the quality of the connection to the DUT. Of significance is the common test connection point that is used for both the calibration OSL references and the DUT. This very significant connection point is the **reference plane.**

For the nanoVNA tweezer probe described here, the reference plane is formed by the tweezer contact tips. To perform the OSL calibration it is necessary to connect the tweezer tips sequentially to open, short and load terminations. This is similar in concept to the familiar procedure for calibrating with the usual SMA coaxial reference plane and the factory provided SMA component reference terminations. To facilitate tweezer probe calibration the reference box shown in **Figure 12** and described in the main text of this article was developed.

Figure 8 — Loose SMD component measurement tray with initial sol calibration references.

carefully glued the 0805 SMD OSL (Open / Short / Load) reference resistors (**Figure 8**) to the inside of the tray for calibrating the tweezers. This was difficult to do and took several attempts as the glue has a tendency to insulate the chip contacts but ultimately it provided the basic essentials needed to prove that the tweezer concept would work okay with the nanoVNA .

Although this simplistic approach is all that is basically needed to calibrate the tweezers, a proper reference box is a much better solution. I made my first reference box by simply soldering chips down onto a prototype board with 0.1 inch spaced isolated pads.

The dark hole that appears near the center of the tray is the test cavity for measuring inductors that will be described in more detail in the next section. The electrical tape patch on the bottom that appears in **Figure 9** is used to attach the bottom plate for the test cavity. The bottom plate consists of a 0.25 inch disk of very thin but rigid plastic sheeting obtained by the use of a paper punch.

Inductor Testing

Details of inductor testing are in the **QEXfiles** webpage. **Figure 10** is a digital microscope view of the underside of the inductor package, which illustrates its vulnerability. The extremely fine copper wire leads are totally exposed, and can be easily broken if rubbed by the tweezer tips. Thus it is necessary to ensure tweezer tip contact is limited to the wrap around ends of the solder terminals. This is very difficult to ensure unless the part is reasonably well fixed in place so that it cannot move around or roll over.

If used with care the test cavity near the center of the test tray (**Figure 8**) can be used to hold 0805 size inductor chips with the wrap around terminals exposed for relatively safe tweezer connection. **Figure 11** shows that when the chip is placed into the cavity upside down the wrap around contacts become exposed. Although the chip remains loose, its range of movement is quite restricted. The cavity consists of a hole slightly larger than 2.5 mm in diameter that was made with a 7/64" drill bit. **Figure 9** shows that the hole is capped on the bottom so that the part cannot fall through.

Using a 1/4" drill bit I manually shaved off the sharp edge of the cavity entrance at an angle (i.e., chamfered) to about half way through the thickness of the tray material. The resulting sloped circular edge guides the tweezer tips towards the wrap around terminals on the exposed chip base. Thus, when upside down in the cavity, the top hat of the chip is pretty much blocked by the 2.5 mm hole diameter near the bottom while the wrap around terminal surfaces are exposed by the chamfered cavity entrance.

It is important when using this method for inductor testing that a magnification hood (or equivalent) be employed to provide a clear view. Before grasping the wrap around terminals with the tweezer spade tips one must ensure the chip is placed properly within the cavity, see **Figure 11**, and that the spade tips make contact only to the ends of the chip away from the vulnerable coil wire. After a bit of practice this is quite easy to do, however it may take a few tries to get a good solid connection. The quality of the connection can be determined by watching the nanoVNA real time display for a steady and proper inductance trace near the Smith chart upper half circumference.

Figure 9 — Bottom of measurement tray with adhesive rubber feet.

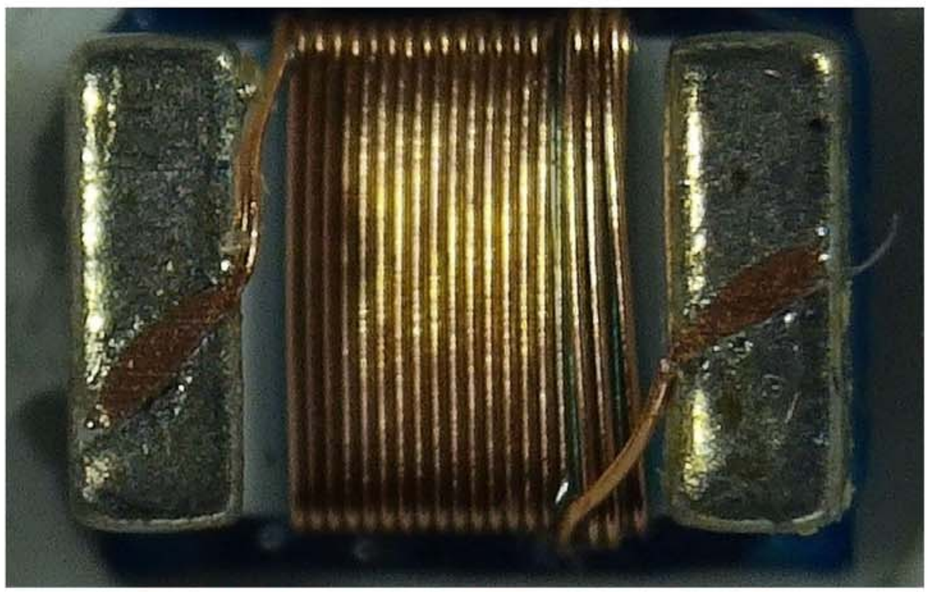

Figure 10 — Microscopic view of 0805 inductor coil vulnerability.

Reference Box Construction

The reference box (**Figure 12**) is based on a professionally manufactured version 2 PCB board design (seems I always find room for improving my initial PCB artwork designs that isn't apparent until the first prototype is tested). The board fits into an economical die-cast aluminum box. The PCB provides stray coupling isolated footprint pads for mounting an array of close tolerance SMD 0805 size passive components. The values of the reference positions are clearly labeled with large silk screen fonts. A proper reference box similar to the one shown here is recommended as in addition to providing a set of comparison reference components. It also provides a tutor platform for gaining experience with using the nanoVNA tweezers. The reference box described here provides footprints for mounting 19 passive RLC components. Three of the pads are used for mounting the components that form the OSL calibration references. The additional 16 are used for mounting tight tolerance RLC components that have a wide range of values. The reference box schematic and details are on the **QEXfiles** web page.

The provision of the die-cast aluminum enclosure protects and stabilizes the PCB during use. The PCB, which can be used as a template to mark the holes for drilling, is mounted with 1/2" standoffs. **Figure 13** shows stick-on rubber feet installed on the bottom of the box to prevent it from sliding around, and also to protect desk top surfaces. The rubber feet by 3M are my favorites as they seem to stick to a surface better than most alternatives.

A parts list intended as a guideline for the reference box to help with parts procurement identification details is available from **QEXfiles**. A PCB manufacturing Gerber file package is also provided for those who may wish to procure a batch of boards. To avoid possible disappointment, I recommended that the PCB files be checked with a Gerber viewer prior to ordering for confirmation of file integrity and for taking a close look at the design details. I have a limited supply of boards available for purchase for those who just want a single board and do not

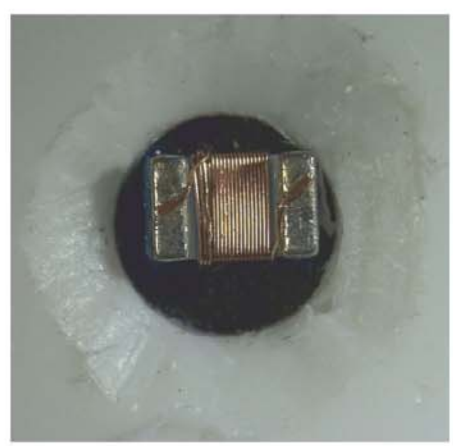

Figure 11 — 0805 SMD inductor upside down in test cavity with contacts exposed.

Figure 12 — Assembled component reference box.

Figure 13 — Rubber feet on bottom of reference box.

wish to have a batch manufactured. Should a local area interest group wish to share the shipping costs, a batch purchase from an online PCB manufacture would typically prove to be the most economical source.

NanoVNA Tweezer Calibration

The tweezer calibration process is fundamentally the same as the calibration procedure for making coaxial cable connection measurements. The only difference is the use of the tweezers for making the OSL reference connections to the reference SMD devices within the reference box instead of connecting the factory supplied SMA coaxial references. For further details regarding the calibration reference plane see the **Sidebar 1**.

The calibration procedure for the use of the nanoVNA tweezers is relatively convenient compared to the steps needed for conventional SMA connection calibration. Using the tweezers it is very easy to quickly switch between the three OSL references. Once the tweezer calibration is completed the calibration and setup data can be saved in one of the nanoVNA memories for future convenience, just as is done with coaxial connections.

Prior to calibration, the frequency spectrum segment for measurement must be decided upon. The nanoVNA is designed to provide 101 frequency steps per sweep. For tweezer calibration any spectrum segment between 50 kHz and 150 MHz can be specified. Although it can be convenient to sweep a wide spectrum segment, if it is too wide the gaps between the resulting large frequency steps may result in a failure to make measurements at some important frequencies of interest. For example if set for a wide 50 kHz to 150 MHz sweep the resulting 1.5 MHz step size could be too large to properly measure components intended for use in a relatively narrow bandwidth circuit.

For this article it is apparent that calibration should be done for at least two sweep ranges. A range of 50 kHz to 150 MHz would cover the HF and VHF segments in roughly 1.5 MHz steps, and a range of 50 Hz to 15 MHz would cover the LF to MF to HF segments up to the 20 meter band with roughly 150 kHz steps. These two ranges will be used here with some minor exceptions as found necessary for particular cases.

Any of the 5 nanoVNA memory locations can be used for storing calibration and display setup settings. Here, memory 1 will be used for storing the wider 50 kHz to150 MHz sweep setup data, and memory 2 for the narrower 50 kHz to15 MHz low frequency segment. Memory 0, which is automatically loaded as default during power-up, was left available for the more conventional coaxial connection VNA applications. Consequently it is important to remember that for this article, each nanoVNA power-up cycle for tweezer testing will require using the menu to recall the tweezer data and settings from either memory 1 or 2 as needed. For the clearest component value readability it is desirable to have the SMITH trace values shown in the top right corner of the screen, (see the Figures in the QEXfiles), away from the Smith chart circle clutter. The trace FORMATS functions will provide the top right display of the component value once LOGMAG trace 0 is disabled after calibration as recommended below. For starters all traces must be set to channel 0 and the scales set as shown. It may be desirable to change the scale and the stop/start frequencies as required to match DUT characteristic ranges. Initially the nanoVNA menu selections should be set as follows:

DISPLAY>TRACE:
Trace 0, Yellow: LOGMAG; scale 10/
Trace 1, Blue: REACTANCE; scale 200/
Trace 2, Green: SMITH; scale 1/
Trace 3, Red: RESISTANCE; scale 200/

Note: All traces must be set to channel 0.

STIMULOUS>
START
50K
STOP
150M (or 15M for the low band)

The following checks and procedures help ensure successful calibration and measurement accuracy. Confirm that all the SMA connector retaining nuts are snug. This is very important, because the nuts can work loose thus should be checked periodically. There are somewhat pricey torque wrenches available online designed specifically for tightening SMA connectors to proper torque specification.

To minimize hand effect capacitive coupling to the tweezer tips grasp the tweezers quite high, with thumb and index finger, around the mid point of the tweezer arms.

Hold the tweezers vertical, i.e. perpendicular to the calibration box PCB while alternately connecting to the OSL reference chips as directed by the nanoVNA firmware calibration function steps.

To reduce screen clutter during calibration, traces 1 and 3 should be disabled so that only the trace 0, LOGMAG, and trace 2, SMITH trace remain.

To calibrate from the menu top, select CALIBRATE > RESET then sequentially connect the tweezers to the OSL references while tapping the OPEN > SHORT > LOAD menu items, then select DONE. Confirm the calibration accuracy as follows:

When connected to OPEN check that the trace is just a small dot is at the right hand intersection of the Smith chart outer circle and the zero reactance horizontal center line.

When connected to SHORT check that the trace is just a small dot and is located at the left hand intersection of the Smith chart outer circle and the horizontal zero line.

When connected to LOAD check that the trace small dot (not a small circle) is in the center of the Smith chart circle.

While connected to the LOAD reference ensure the LOGMAG return loss trace is more negative than –40 dB across the entire spectrum sweep width.

NanoVNA tweezers measurement examples are on the **QEXfiles** web page.

Known Limitations

The tweezers may not be reliable when the measurement is influenced by inductor self resonance especially when the amount of stray self capacity is minuscule. If the reactance trace is curved at the test frequency the apparent inductance measurement result may be higher than the actual coil inductance. An error may possibly be due to a lowered self resonance frequency caused by stray capacity from the testing platform. Practically speaking this may not be a significant limitation since inductors are most commonly used in circuits that operate far below the self resonant frequency.

PC Software USB Port Control Enhancement

Personal computer USB port nanoVNA control freeware can be used to obtain large screen swept frequency response views of the measurements. Two apps that are particularly good are *NanoVNA-Saver* and *NanoVNA-App* **[5]**. The control software can streamline the measurement results acquired via the nanoVNA tweezers by providing swept frequency views of a large number of frequency-dependent passive component characteristics. Using the acquired data from the nanoVNA, the powerful PC software almost instantly calculates a large number of characteristics such as Return Loss, SWR, Quality Factor, Impedance Z, Complex Impedance, series equivalent values, parallel equivalent values and Admittance. Most parameters can be graphically viewed across the frequency spectrum segment of interest. In addition to providing excellent large screen views of component characteristics the screens and associated data can be captured for documenting measurement results. The nanoVNA screen captures shown In the **QEXfiles** page were obtained using the aforementioned apps.

Conclusion

The nanoVNA instrument adds a new dimension of low cost but powerful testing capability to the radio amateur's RF electronics workshop. It can provide a means to measure passive LCR component complex impedance values across user defined segments of frequency spectrum. The nanoVNA Tweezers accessory provides a convenient means for connecting the nanoVNA to SMD passive component packages for determining complex impedances and related values at user specific frequencies within the 50 kHz to 150 MHz range.

The nanoVNA Tweezers and associate components reference box can be an effective educational platform for those who wish to experiment with VNA component measurement and analysis. The measurements provide real-time views of component frequency-dependent characteristics. The use of the tweezers with the reference box can provide experience with many of the nanoVNA menu settings. The measurement results may enhance user knowledge and understanding of the RF characteristics of passive SMD components.

Under personal computer control additional characteristic parameters of interest can be obtained by running freely available advanced PC apps. The apps used to control the nanoVNA via the USB port can acquire the measurement data from a nanoVNA while employing a simple, time efficient tweezer connection to the SMD chips. This provides a convenient method for comparing component characteristics.

I wish to express my gratitude to Dr. James Koehler, VE5FP for our discussions that led to the development of the easy to construct test cavity for inductor measurement and for his ongoing support in general.

*Tom Alldread, VA7TA, was interested in electronics since grade school. In his teens, he repaired radio and television sets. He obtained his amateur radio license in 1965, and upon graduating from technical college obtained his commercial radio operator certification. He graduated from the Capitol Radio Engineering Institute Engineering Technology program. Tom worked in the telecommunications industry as a microwave, multiplex and VHF radio equipment maintenance technician, an instructor, an engineering standards and design specialist, and in the Middle East as adviser for long distance network operations management. Now retired, Tom and his wife Sylvia, VA7SA, live on Vancouver Island. Tom, is a member of The Radio Amateurs of Canada, enjoys operating CW, designing equipment, and supporting emergency communications. He was net manager for the SSB/CW 20 meter Trans-Canada Net (***www.transcanadanet.com***). His interests include microcontroller development projects associated with amateur radio. Tom won second place in the Luminary 2006 DesignStellaris contest and first place in the 2011 Renesas RX contest. Other hobbies include computing, RVing, hobby farming and bicycling.*

Useful internet links

https://groups.io/g/nanoVNA-users/.
https://zs1sci.com/blog/nanoVNA saver/.
http://www.gunthard-kraus.de/fertig_NanoVNA /English/.
https://hexandflex.com/2019/08/31/getting-started-with-the-nanoVNA-part-1/.
https://hexandflex.com/2019/09/15/getting-started-with-the-nanoVNA-part-3-pc-software/.

References

[1] **https://www.coilcraft.com/getmedia/ac56eabb-8678-4ca2-9604-c609886d68c1/Doc1287_Inductor_specifications.pdf**.

[2] SMA male connector RG178 cable 100cm; **https://www.aliexpress.com/item/32566647516.html?spm=a2g0s.12269583.0.0.2d483d67o6TRJA?)**

[3] Ceramic tweezers insulated straight tip ESPLB; **https://www.aliexpress.com/.**

[4] 2.8 mm male spade terminals, gold tone; **https://www.aliexpress.com/**.

[5] **https://github.com/NanoVNA-Saver/nanoVNA-saver**, and **https://github.com/OneOfEleven/NanoVNA-H/tree/master/Release**.