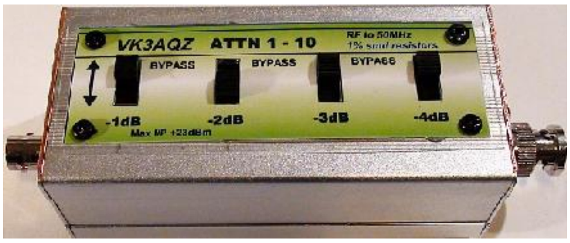
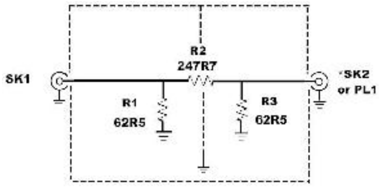




VK3AQZ ATTENUATOR KITS ATTN1-10, ATTN10-50, and ATTN20dB

Introduction and description.

RF attenuators are very useful additions to the radio amateur's workshop.

Various important RF measurements can be made with the use of a signal generator, good RF power meter, and a set of good attenuators.

In order to make reasonably accurate measurements, such as receiver sensitivity, a good quality well shielded signal generator is required capable of producing an accurately known, very low level signal.

For a modern receiver, this may well be down below 0.05uV, or -135dBm.

A commercial signal generator capable of producing such a low level signal accurately to within a dB or so, is a costly instrument.

However, a low cost generator can be used with a set of external attenuators and a power meter to achieve a sufficiently low enough signal to make reasonably accurate low level measurements, such as receiver signal to noise ratios.

Most hobbyists and radio amateurs can obtain, or build, a low cost signal source for such measurements.

Switched attenuators can be constructed using readily available parts with quite good performance into the lower VHF region. Single stage attenuators can be also constructed with good accuracy well into the UHF region.

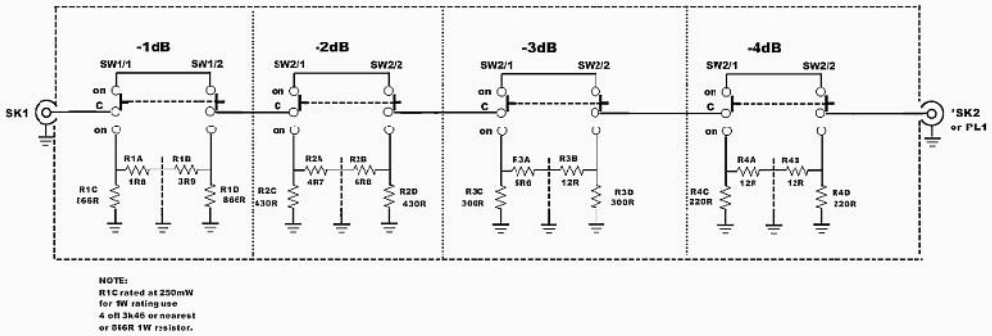
An accurate RF power meter can be used to confirm the performance of attenuators.

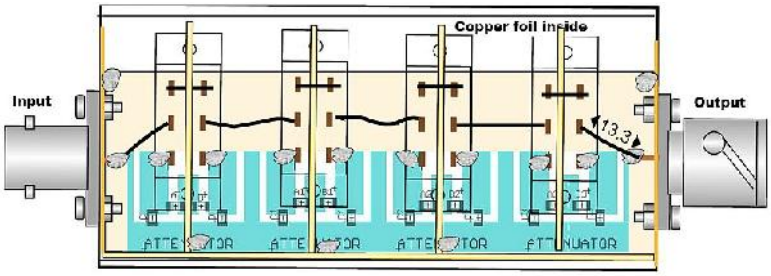
The RFPM1 power meter is sufficiently accurate for amateur radio and hobbyist use.
Cost of the RFPM1 is considerably less than a good quality laboratory meter making attenuator measurements and tests affordable for radio amateurs and hobbyists.

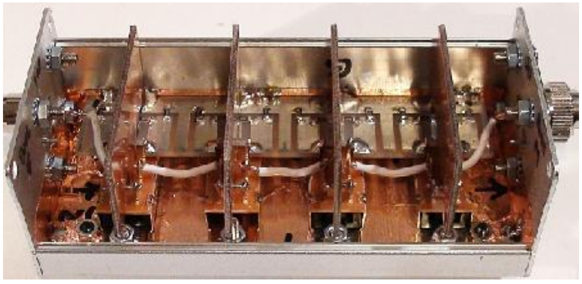
The VK3AQZ attenuators are easily constructed kits which can be a useful addition to the RFPM1 RF power meter kit.

There are 3 models currently available. All 3 attenuators are 50 ohm and configured as PI sections.

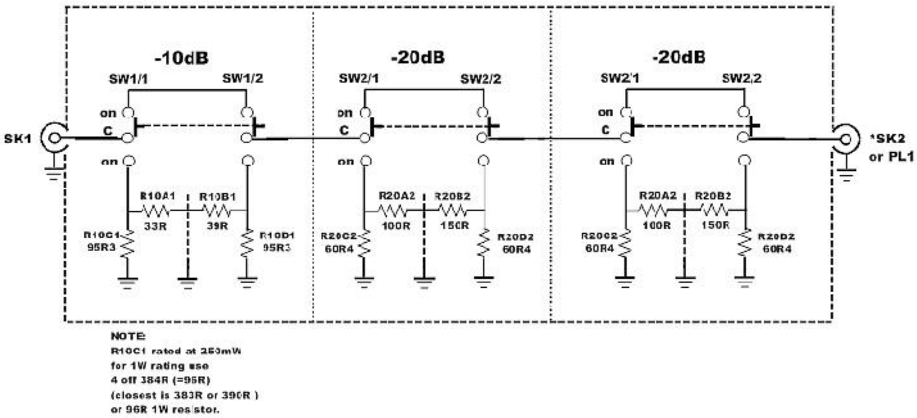
The **ATTN1-10** is a 4 section switchable RF attenuator which provides 1dB steps by selection of various combinations of the 4 sections. The 4 sections are 1dB, 2dB, 3dB and 4dB. Operating all 4 sections provides 10dB of attenuation

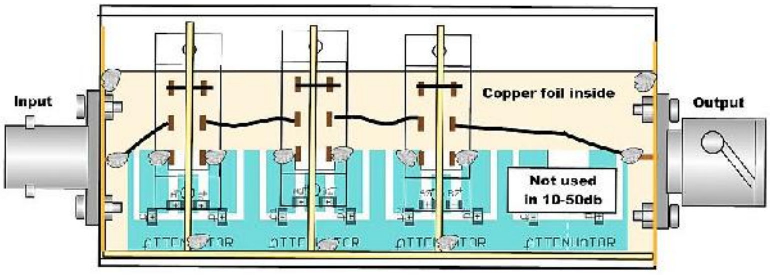






The **ATTN10-50** is a 3 section switchable RF attenuator which provides 10dB steps by selection of various combinations of the 3 sections. The 3 sections are 10dB, and 2 equal sections of 20dB. Operating all 3 switches provides 50dB of attenuation. With the simple shielding used, the amount of attenuation in one unit is limited to a maximum of 50dB.
Additional internal sections could be used but the leakage might be too high. For higher levels of attenuation, it is recommended that separate units be cascaded.





NOTE: the 10-50 attenuator uses the 1-10dB case and PCB but only 3 switches are fitted.
(this does allow for an additional stage if desired).

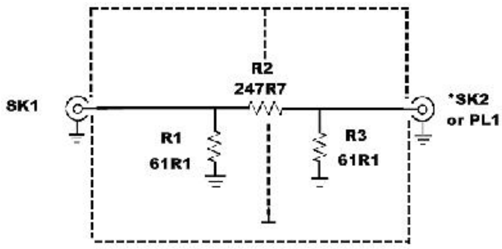
For both the above switchable attenuators, 1% SMD resistors and shielding provide around 2% accuracy upto 50MHz. The attenuators can be used beyond 50MHz but the accuracy will begin to fall. The series arms of the 2 attenuators consist of 2 resistors in series so as to improve the isolation. A shield can be inserted between the slide switch tags to increase the shielding.

The input power handling ability of these 2 attenuators is 300mW due to 1206 size resistors used. However builders may wish to use larger or parallel resistors, in the shunt arm of the first section to increase the power handling ability.

The **ATTN20dB** is a single section 50 Ω, RF attenuator providing 20dB of attenuation. The ATTN20dB is capable of handling 16W of input power due to the use of high power SMD resistors.

The prototype accuracy was around 0.2dB well into the VHF band and around 1dB at 440MHz.

The 20dB attenuation will drop a 16W signal down to 160mW, which is within the power handling of the switchable attenuators.



The attenuator is a 50 ohm PI section. The calculated values for 20dB attenuation are: R1 = 61.11 Ω, R2 = 247.5 Ω, and R3 = 61.11 Ω.

The parallel combination of standard values is: R1 = 61.07 Ω, R2 = 247.71Ω, and R3 = 61.08 Ω.

With these values, the calculated attenuation is 20.01dB, input return loss of 72.5dB and an output return loss of 78.7dB. The input and output Z calculates to within a small fraction of 50 Ω.

Once the attenuator is constructed, resistance measurements across the input or output can be used to trim the total resistance to be close to 50 ohms. Small amounts of R can be added if the values are above 50 ohms, and resistors can be replaced with higher values if the reading is below 50 ohms.

Bear in mind that the actual RF resistance may be different to the DC resistance. So RF measurements should be made prior to altering the values. When making RF attenuation measurements, you need to ensure the source and load impedance of the attenuator is 50 ohms resistive. If they are not, then the attenuation will not be close to the calculated value of 20dB.

Kit contents and tools.

Before starting to assemble the kit, check that all the components have been supplied.

Refer to the “Component list” for details.

Assuming all the components are there, and correct, you can commence the assembly process.

You will need the following tools:

For the SMD components you will require a soldering iron with a fine tip, a pair of fine SMD tweezers, a small fine pointed pick (toothpick or similar) for holding down the components, and some fine solder. Small dobs of glue or double sided tape can also be used to temporarily hold components in place. A piece of solder wick will be handy for removing excess solder. A flux pen can sometimes help if the solder has insufficient flux. Fine gauge solder can have virtually no flux over short segments.

Soldering temperature should be around 190 degrees C. This is just above the Tin Lead Eutectic point for 60/40 solder.   However most non industrial irons cool significantly once the solder melts, and in order to maintain the solder melt, you may need to set the dial as high as 350 degrees or so, depending on the size of the joint. Where you may be soldering copper sheet, you may need to go even higher depending on the quality of soldering iron.

A pair of SMD test probes would be handy.

For the remainder of the kit, a soldering iron with normal tips, a pair of fine tipped side cutters, small and medium sets of pliers, a pair of sturdy scissors, a set of cross head and flat blade screwdrivers of various sizes, a 3mm nut driver.

Some self closing Tweezers would be handy.

A 12 V PC fan running from a battery or plug pack maybe suitable for blowing away fumes if the soldering rate is low enough.

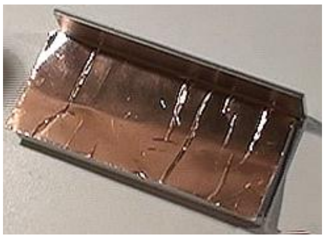
Tools

Test equipment

Useful SMD probes

Assembly.

Assembling the switched pads (applies to both versions)

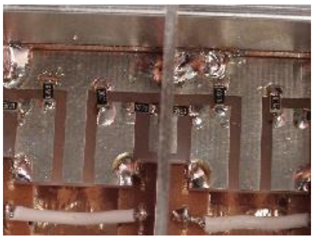


1. Lay a length of adhesive backed copper foil in the case side with the switch cut outs. Trim the areas around the cut out with a small blade or tool.
Approx 12mm of foil needs to be run up the wider side of the case. The PCB edge will need to be soldered to this section. Refer to the video for more details.

2. Mount the slide switches to the case using 3mm x 10mm countersunk screws.
Also at this stage you can attach the label. Note which end is the 10dB section and 20dB section and mount the label accordingly. Use 3mm x10mm dome screws with washers and nuts to hold the label down.
NOTE: The 10-50 attenuator has only 3 sections and 3 switches but uses the same 4 section 1-10dB case and printed board. The last section is left unused. This allows you to add an extra section if desired.

3. On each switch, the 2 terminals at the top of the switch, (the bypass position) are connected together using a short length of copper wire.

4. Also connect short lengths of insulated wire between the centre switch terminals of each switch (the poles) as per the wiring diagrams and video. These are the white insulated pieces shown in the photo.

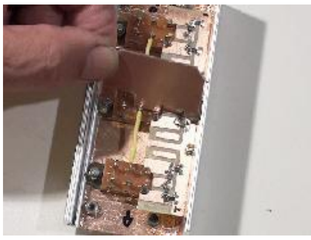


5. With the PCB in a suitable holder, solder the appropriate SMD pad resistors in place in each of the sections on the PCB. Check you have the 10dB resistors on the correct section by laying the PCB in the case over the switch and referring to the label on the front.
Working upside down can result in the pads not matching the label. So take particular care of the PCB orientation relative to each switch and label.

6. Once all the resistors are in place, and checked with a meter, fix the PCB onto the lower switch terminals as per the drawings.
In 3 locations along the earth edge of the PCB, make 3 solder connections to the copper foil stuck to the upright side of the case.

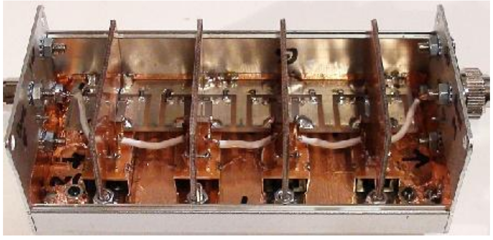
7. Fix a short piece of copper foil to each end plate across the lower half of the connector location. This foil will contact the foil in the case section completing the connector flange earth to the case earth.
Fit the input and output connectors and attach the end plates to the case ends. Use a short 3x6 mm screw in the connector hole next to the PCB. A longer 10mm screw fouls with the PCB. The assembly video illustrates this part of the assembly. Solder the copper foil on the connector flange to the foil in the case with a small blob of solder where convenient.

8. Connect the centre terminal of the connectors to the middle terminal on the end switches as per the diagrams.



9. Place the shields over the centre of the switches and solder to the back section and the PCB earth track. Check that the copper wires on the switch tags are not shorted to earth.

10. Fit the upper case section. That completes the attenuator ready for testing.



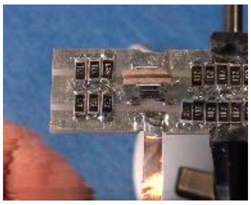
Assembling the ATTN20dB

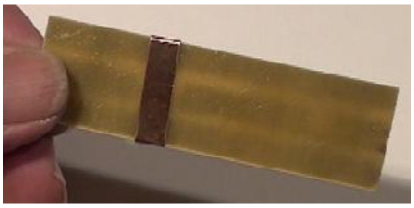
1. Commence by mounting the resistors on the larger PCB. Follow the diagrams and video. Leave sufficient space between the end resistors and the connector end pads. Keep the resistor ends away from the PCB edges to allow clearance for the slots in the case. Please note that the kit may contain 2512 size 820R, 2k7 and 27k resistors depending on supply. The assembly video shoes the smaller 1206 size for these resistors.

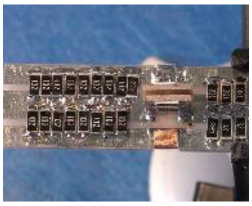
2. Mount the series resistors on the small PCBs. These are single sided boards.2 resistors on one PCB and 3 on the other. Before you mount the small PCBs, you may want to measure the total resistance of the input section and the output section. They should read close to 61 ohms. If you try to measure them after the small PCB is soldered in place, the presence of the series arm will effectively join the 2 end sections via the common ground resulting in a different reading.
And in the same manner measure the resistors on the small PCBs. Here one will be different to the other. One has 2 off, 1k in parallel reading 500 ohms and the other has an additional 27k across the 2 resistors to give 491 ohms.

3. Mount the small PCBs upright on the main PCB as per the diagrams and video. Don't forget to solder both ends of both PCBS to complete the circuit across the gap.

4. Connect a copper strip between one side of the PCB and the other via the underside of the main board. See photos below and video. Keep the bend tight so that the edge of the PCB can still enter the case slots.



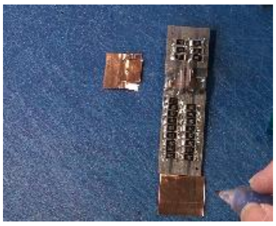
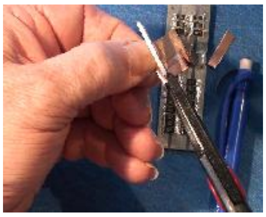
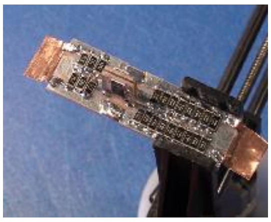




5. Take a piece copper foil as per the video. Cut a square piece which is the width of the PCB. Mark out 2 segments which line up with the earth strips on the PCB and cut as per the video. These 2 narrow strips are soldered to the PCB earth strips at the end of the PCB.

The uncut section of foil is folded down so as to be clamped between the connector flange and the case.
This needs to be done at both ends of the PCB.

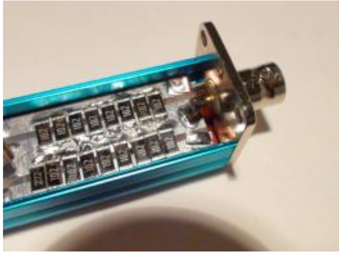
Excess foil can be neatly trimmed off once the connectors are attached.

6. Slide the PCB with the foils at each end, into the slots in one half of the metal case.
Attach the female end connector to the end of the case using 2 countersunk 3mm short screws.
Do not over tighten, and keep straight so as not to cross thread the screw. Do the same at the other end with the other connector.

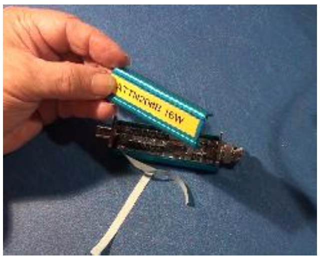


7. Connect the centre conductor of the connectors to the PCB centre tracks using a length of copper wire.

9. Do a quick check for shorts then fit the upper half of the case. You will need to loosen the screws holding the connectors to the lower half of the case so that the upper case can be slipped into the gap. When fitting the screws into the case be careful to keep the screw straight and not cross thread it. The screw should turn fairly easily. If there is too much resistance then the screw is most likely cross threading. So turn back and try again. Also, check the alignment of the case thread with the connector flange hole. Pushing on the side of the case can help to align the screw with the thread in the case.

10. The assembly is now complete. You can now attach the identification label. The female end is the input to the attenuator and can handle 16 watt. The other end has less resistors and can handle only around 1 watt. In order to help reduce the possibility of connecting the attenuator around the wrong way when using more than 1 watt, you might want to draw direction arrows on the label or some method of highlighting the 16 watt end of the unit (i.e. red tape or paint spot, etc.)



TESTING

1. Check the input and output connectors for short circuits and continuity through the switched attenuators when all switches are bypassed. You can also check the resistance reading across the input and output connectors with a multimeter. The resistance readings here will be dependent on the total value of resistance formed from the 3 arms of the pads. The output shunt resistor will be in parallel with the series combination of the series arm resistor and input shunt resistor.

The tables below show readings taken on prototypes. Small variations are due to resistor tolerances. For example, when several sections are selected, the tolerance variations may add or subtract depending on the directions of the variations. Note that all the readings are taken with no loads on the connectors.

2. The next test you can do is to measure the actual attenuation at RF using a signal generator and power meter.

Due to the construction, the actual attenuation of each section will vary depending on it's location in the case. The last section may show more or less depending on how much leakage or shunt capacitance exist in and around that section. Some of these variations can be cancelled out with small pieces of copper strips but you will need a good power instrument or network analyser plus lots of patience, to flatten out the attenuator response. Alternatively, you may draw up a response chart for each section. Some commercial attenuators come with a calibration chart showing the response of the attenuator at different frequencies as it is quite difficult to eliminate such things as self resonant frequencies of resistors, stray capacitance, and small values of inductance.

Multimeter readings on input and output connectors.

NOTES: Measurements taken without any loads.

	INPUT R	OUTPUT R
ATTN20dB	50.8 ohms	50.5 ohms

ATTN1-10	INPUT R	OUTPUT R
1db	432 ohms	433 ohms
2dB	217 ohms	217 ohms
3dB	148.6 ohms	148.7 ohms
4dB	117.9 ohms	118.1 ohms
5dB	96.8 ohms	97.2 ohms
6dB	84.3 ohms	84.2 ohms
7dB	75.6 ohms	75.4 ohms
8dB	69.1 ohms	69.1 ohms
9dB	64.3 ohms	64.5 ohms

ATTN10-50	INPUT R	OUTPUT R
10dB	60.6 ohms	60.6 ohms
20dB	50.5 ohms	50.5 ohms
30dB	49.9 ohms	49.7 ohms
40dB	49.5 ohms	49.5 ohms
50dB	49.8 ohms	49.5 ohms

APPLICATIONS

Attenuators, although simple, can be very useful when carrying out various tests on RF equipment.

One of the most common usages is for dropping signal levels by specific amounts into circuits under test.

Signal generator output levels can usually be set by the generator controls. However the lower cost generators do not have accurate output level setting. Accurate attenuators between the generator and circuit under test can be used to obtain more accurate levels.

The more accurate the attenuator, the more accurate the overall measurement can be.

There are many examples of attenuator use. One good example is the measurement of receiver sensitivity.

One method of assessing a receiver's sensitivity, say in the AM mode, is to feed a modulated signal of known level into the receiver input and measure the resulting audio signal to noise ratio (S/N). The most common AM/SSB/CW specification is the input signal, in µV, which produces an audio output which is 10dB above the "no input" noise output.

To carry out this test, the receiver's audio output signal is fed into a meter which is calibrated in dB, and the audio output level is set for some reading of noise without an RF input.

A generator is then fed into the receiver and the level adjusted until the meter reading increases by 10dB. The generator level is noted and this level, in µV, is the 10dB S/N sensitivity of the receiver. A good receiver may have a 10dB S/N sensitivity of around 0.2µV. This is a level of around -121 dBm.

If you have a low cost generator the output level cannot usually be set to such a low level due to leakage around the generator's output level control.

This is where a good set of switchable attenuators become very useful.

The generator output can be set at some reasonably high level which can be measured with a power meter or oscilloscope. A typical figure might be 0dBm, or 1mW into 50 ohm.

The generator output is then fed into a series of well shielded attenuators totalling some 130dB and switchable down to 1dB steps. The attenuators are then adjusted till the receiver output has increased by 10dB above the no input noise level as measured on the dB meter across the output. The amount of attenuation introduced between the generator and receiver can then be used to find the sensitivity. A dBm to µV look up chart, or web based calculator can then be used to find the sensitivity in µV.

I have included a video illustrating this measurement and the documentation supplied with the attenuator kits contains a suitable look up chart for dBm to µV conversion.

<u>References:</u>

1 Drew Diamond, VK3XU. "An Attenuator Set for Receiver Sensitivity Measurements" Amateur Radio, WIA, August 1999 pp 22-24.

2 Denton Bramwell, K7OWJ. "An RF Step Attenuator". QST, June 1995. p 33.

3 Jim Rowe. "Digital RF Level & Power Meter" Silicon Chip, Oct. 2008, pp 30-42

4 Websites:http://chemandy.com/calculators/matching-pi-attenuator-calculator.htm
http://www.microwaves101.com/encyclopedia/calcattenuator.cfm
http://www.rfcafe.com/references/calculators/attenuator-calculator.htm1
and many more using Google search.

First issue 22/1/2014
Updated: 22/7/2014 The ATTN20db small vertical double sided PCB replaced with 2 single sided pieces to reduce cross coupling at UHF.
Updated: 24/7/2014 New photos of ATTN1-10 attenuator.
Updated: 29/7/2014 ATTN20dB information update.

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