W5JH Return Loss Bridge

Assembly and User Manual
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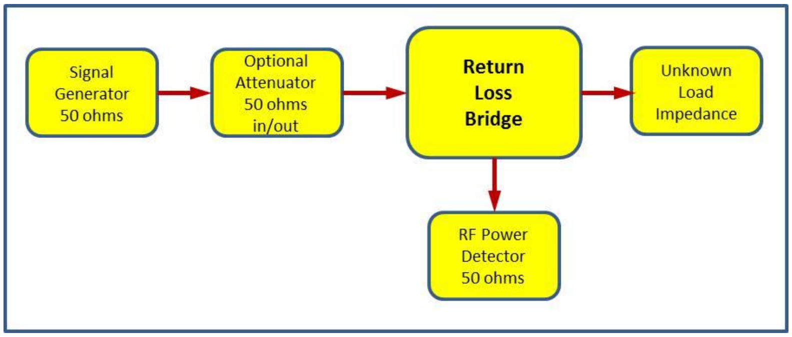
Return Loss Bridge Theory and Description

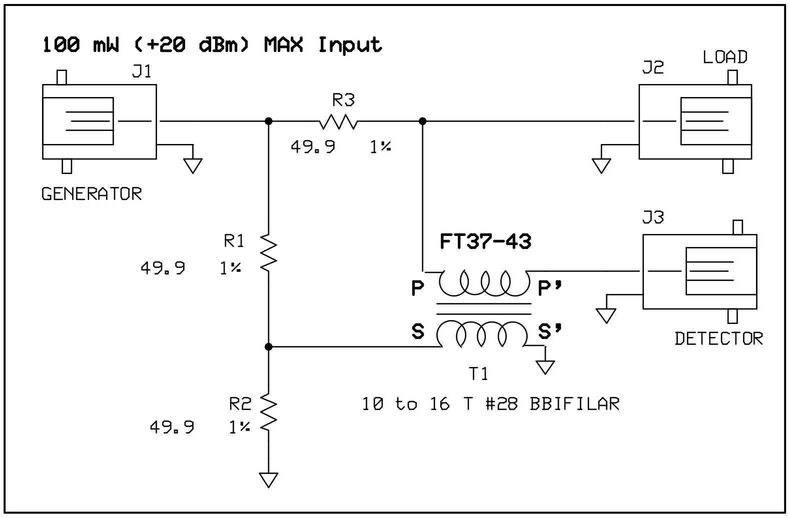
A return loss bridge (hereafter just RLB) is a device that can determine how closely a source of RF power is matched to the load impedance that accepts that power. It performs its task by sampling the signal reflected back from the load impedance. Armed with a measurement of the reflected signal, it's possible to estimate several important RF parameters: the reflection coefficient (Γ, pronounced "gamma"), the standing wave ratio (SWR), and the load impedance itself (Z_L).

If you wished to determine both the resistive and reactive parts of Z_L you would need information about the phase of the reflected signal relative to the source. If, as in the case we're going to discuss, you only have a measurement of the reflected power (which is a scalar quantity) you'll be limited to knowing only magnitude of Γ and the SWR.

You can find references at the end of this document that discuss the theory of operation of the RLB in as much detail as you wish.

Our RLB is just one part of a complete measurement system that consists of an RF signal generator, the RLB, an RF power detector, and the device under test. The block diagram shows how the pieces fit together. The attenuator is needed if the signal generator produces more RF power than can be handled by the RLB without overheating. Our RLB will limited to 100 mW (+20 dBm) or less.





Assembling the Return Loss Bridge, A Pictorial Instruction

<u>Inventory your parts</u>. Verify that you have all of the parts listed in the table below. Parts marked with * are included ONLY in the full kit:

*1 ea, pre-drilled, cast aluminum enclosure (body, cover, 4 screws)
*3 ea, BNC chassis mounting jacks, with nuts, lockwashers, solder lugs
4 ea, SMT resistors, 49.9 ohms, ¼ watt, 1%, size 1206 (three needed, spare is provided)
1 ea, printed circuit board
1 ea, FT37-43 toroid core (a FT37-61 core, *not supplied*, is best for VHF range)
1 ea, 42” length of AWG #28 orange magnet wire (note – NOT heat strippable)
1 ea 24” length of AWG #28 green magnet wire (heat strippable)
1 ea, 6” length of tinned copper bus wire
1 ea, small strip of copper sheet
1 ea, water transfer decal with panel labels

In addition you will need a fine tipped soldering iron and some small diameter (0.020” is fine) rosin core solder, as well as small hand tools.

It is your choice whether to solder on the surface mount resistors before or after you have mounted the circuit board onto the BNC connectors. There’s no great advatage either way. In these photos we’ll assume the resistors are added after mechanical assembly.

<u>Note on Label Decals</u>

The labels decal supplied is the water-slide type, like we used to use on our plastic model airplanes. You can apply the decal before you mount the connectors onto the lid, or wait until the kit is complete. In either case you’ll need to apply a clear protective finish, such as clear Krylon® or clear laquer. Apply two or three light coats, allowing each coat to dry for a few minutes. If you’re applying the decal to a finished kit, be sure to mask over the BNC connectors so you won’t get paint on or inside them.

Prep the surface of the lid by a quick scrub with a steel wool scouring pad, rinse and dry. An alcohol or acetone wipe to remove any oils might also help. Don’t cut the label apart, use it as a continous strip. The lettering is spaced to match the connectors. Soak it in cool water until the film loosens. Check the photo (in a later section) to be sure you’ve got the label facing the right way. Slide the decal onto the lid, align it, and gently blot away the excess water. Allow several hours of drying time before applying the clear overspray.

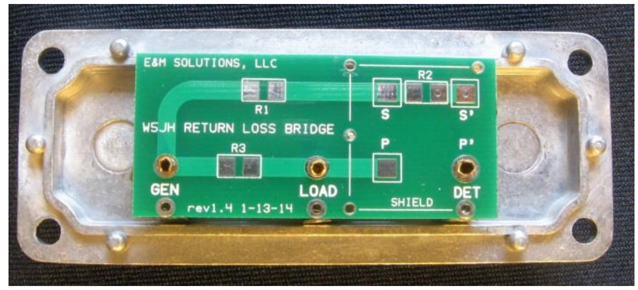
<u>Mechanical Assembly</u>

Your kit may have arrived with the BNC connectors already attached. This was done to ensure that the PCB fits properly onto the solder posts of the BNC connectors.

It’s important that the solder lug of each BNC connector be positioned as shown in the two photos. This is to allow a short piece of bus wire to connect the lug to the ground plane of the PCB.

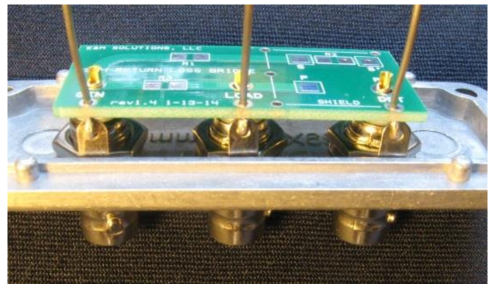
The lugs have been pre-bent so they will fit bewtween the body of the connector and the rim of the box lid, and also so that the mounting nut can be turned without causing the lug to turn.

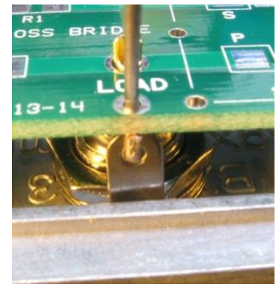
Position all three BNC connectors and their solder lugs as shown, then dry fit the PCB onto the solder posts. When you are satisfied everything fits you may tighten the nuts. It might be necessary to reposition one or two of the connectors if they shift while snugging up the nuts.



<u>DO NOT SOLDER THE PCB TO THE CONNECTORS YET</u>

Cut three pieces of tinned bus wire, each about one inch long. Connect them to the the solder lugs of the BNC connectors. After crimping the wire onto the lugs, be sure to trim the wire so that only the longer sides project above the top of the lug. Otherwise you will not be able to seat the PCB properly in place.





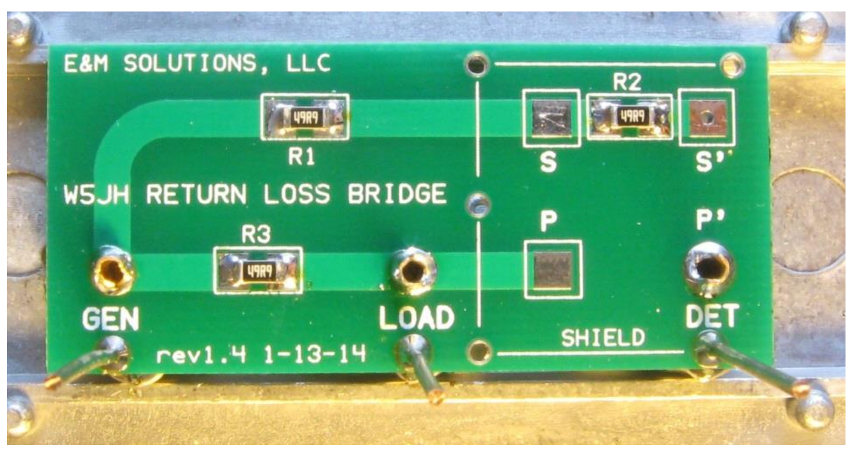
<u>DO NOT SOLDER YET</u>.

Assemble the PCB onto the connectors as shown. The side of the PCB with the silk-screened legend faces away from the underside of the box lid. Make sure the bottom surface of the PCB is seated right against the top of each solder lug.

When you're satisfied with the fit, solder the wires to the lugs and the BNC solder posts to the PCB. The PCB holes are plated through so you need only solder on the top side. Solder the protruding wires to the PCB but leave the excess wire projecting past the PCB surface for the time being. The wire extensions can be used to support the copper shield if you choose to install it.

<u>Installing the Surface Mount Resistors</u>

Many people find it helpful to lightly tin one pad of a surface mount part, hold the part in position and reflow that pad. If the alignment is satisfactory, solder the other pad.

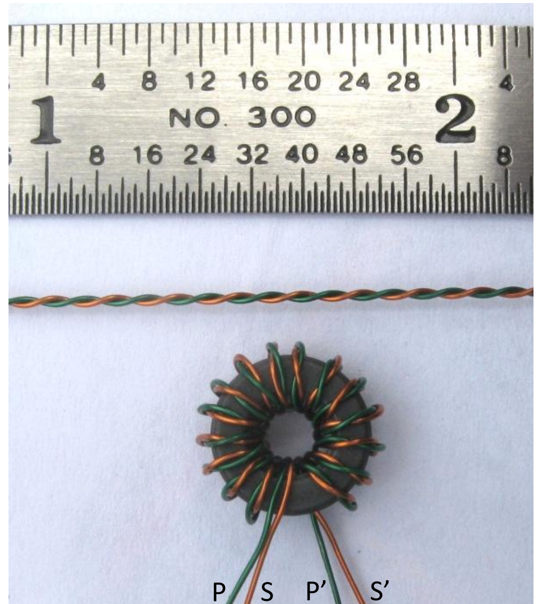


Notice the pad for R2 has a plated through via right in the middle that serves to connect R2 to the bottom side ground plane. It is not necessary to fill that via with solder, but you may if you wish.

Solder all three of the 49.9 ohm, 1% resistors to the PCB. An extra resistor is supplied… just in case ☺

Winding and Installing the Transformer

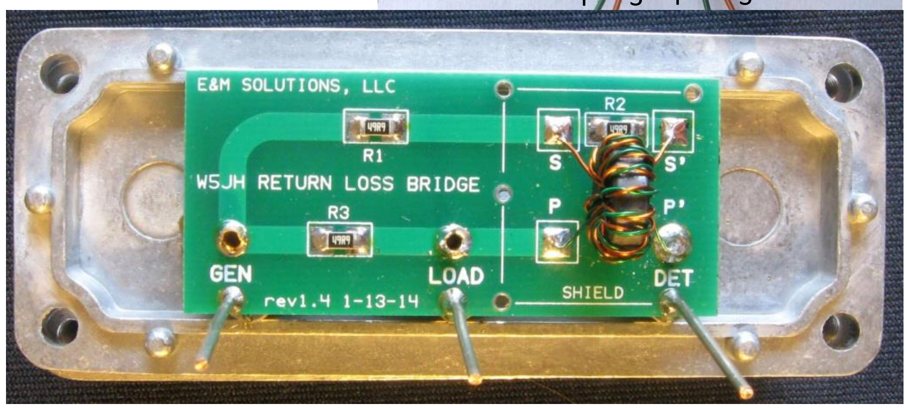
Two kinds of #28 magnet wire are supplied. The orange wire must be scraped or sanded to remove the coating before tinning with solder. The green wire can be stripped and tinned all at once with a little blob of molten solder at the tip of an iron. Enough wire has been provided to wind the transformer at least twice – in case you make a mistake.



Cut two 12" lengths of magnet wire – preferable one length of each color. Twist the two pieces of wire together tightly. Make several twists per inch, as shown in the photo.

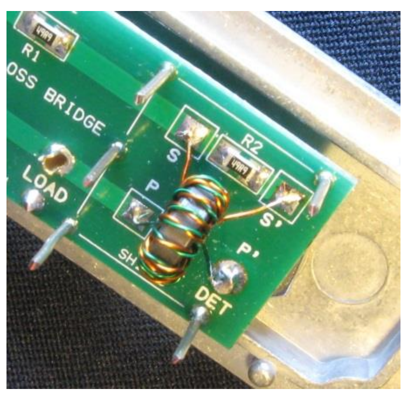
The number of turns is not an absolute. More turns means the transformer will couple well at lower frequencies. Fewer turns means it will have less loss at higher frequencies. About 16 turns will fit on the FT37-43 core. A good compromise is probably 12 to 14 turns. The transformer pictured has 16 turns.

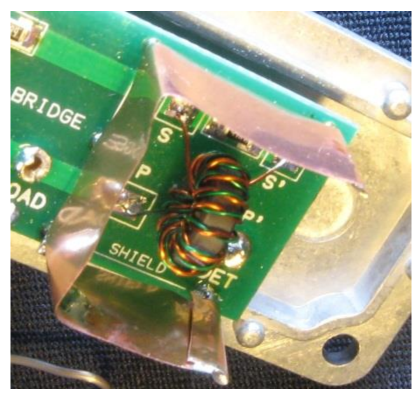
Wind the transformer, then strip and solder tin the leads to within about 1/16" of the core.



One wire will be designated the *primary* winding (**P** and **P'**) the other will be the *secondary* (**S** and **S'**) It makes no difference whatever which is which. If in doubt, follow the picture and solder the transformer to the four marked pads.

Attaching the Shield





Testing has not shown any measureable improvement in performance as a result of adding the shield around the transformer. Nevertheless, you may install it if you wish.

Solder short (about ½") pieces of bus wire into the four holes along the outline of the shield area. The wire still projecting from the **DET** ground connection will also be used. You can snip off the excess wire at the **GEN** and **LOAD** ground pads.

If necessary, trim (scissors will work) the strip of copper to a width of about 1 cm (about 7/16"). Wrap it around the wire posts to form a shield wall. It's not necessary to enclose the top. Solder the copper to the wire posts.

Applying Decals

If you've waited until now to apply the decals, be sure to mask over the exposed parts of the BNC connectors before spraying the clear coat on the cover.

Prep the surface of the lid by a quick scrub with a steel wool scouring pad, rinse and dry. An alcohol or acetone wipe to remove any oils might also help. Don't cut the label apart, use it as a continous strip. The lettering is spaced to match the connectors. Soak it in cool water until the film loosens. Check the photo be sure you've got the label facing the right way. Slide the decal onto the lid, align it, and gently blot away the excess water. Allow several hours of drying time before applying the clear overspray.

You'll need to apply a clear protective finish, such as clear Krylon® or clear laquer. Apply two or three light coats, allowing each coat to dry for a few minutes..

Initial Testing

We will presume you are using the Return Loss Bridge with your PHSNA and AD8307 m power meter. The first test is to make sure that a signal is getting to and through the RLB.

Turn on your PHSNA and set it to output a 10 MHz signal. Connect the output of you PHSNA to the RF input of your power meter. Leave the **LOAD** port unterminated for the time being. Jot down the dBm level of the direct signal from the PHSNA.

Now connect the PHSNA output to the **GEN** port of the RLB, and the **DET** port to the RF input of the power meter. In a perfect world the new RF level would be exactly 12 dBm below the direct signal noted above. You'll probably see about 12.3 to 12.5 dB less than the direct signal. Anything more than a 13 dB drop is probably evidence of a problem. Jot down the level you measure with the **LOAD** port unterminated.

If you have a shorted BNC connector available, connect that to the **LOAD** port. The RF level should be about the same (with tenths of a dB) as with the unterminated port.

Now we'll measure the directivity of the RLB. Connected a matched 50 ohm dummy load to the **LOAD** port of the RLB. The measured RF level should drop dramatically. The difference between the matched level and the open/shorted level is the directivity of the bridge. A drop of 35 dB is pretty good, 40 db or more is excellent.

If all of these tests are satisfactory, congratulations, you have a working Return Loss Bridge. Button up the case with the four machine screws.

CAUTION – ***The resistors in the RLB are rated ¼ watt. DO NOT apply more than 100 mW or so of RF power to the GEN port. To use the RLB with a transmitter, even a QRP or QRPp one, you'll need some attenuation between the transmitter and the RLB.***

For example, if you wanted to excite the bridge with a 5 W (37 dBm) QRP transmitter, you need about 20 dB of attenuation. That would get you down to a safe 50 mW or so. Remember that the 20 dB attenuator has to be capable of dissipating almost the entire 5 W.

References:

The ARRL Handbook for Radio Communications, 2006 ed, pages 25.32 – 25.33

Return Loss Bridge Basics
http://www.sglabs.it/public/Eagle_RLB150.pdf

QRP SWL Homebuilder
http://www.qrp.pops.net/RF-workbench-3.asp

SiversIMA VSWR Return Loss Converter
http://www.siversima.com/rf-calculator/vswrreturn-loss-converter/

Manual Return Loss Measurements
http://www.wetterlin.org/sam/Reflection/ManualReturnLoss.pdf

Measuring Impedance with a Return Loss Bridge
http://www.wetterlin.org/sam/Reflection/RL_To_Impedance.pdf

Below are several copies of the top side PCB pattern, inverted for use with toner transfer method.
Be sure to verify that the print is to the actual size of 1.95” x 0.875”

Use 0.062” two-sided copper clad material, 1 or 2 ounce cladding. The reverse side should be a solid copper plane, except for isolation margins around the three large holes that accept the BNC connector solder pins.