A Simple Wideband Return Loss Bridge Revisited
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This article is a revised and expanded version of a shorter article originally published in Nerg news, (the newsletter of the Melbourne North East Radio Group) December 2005.

Since first having the details of my Return Loss Bridge published in Nerg News I have had quite a bit of interest expressed by a number of Hams in more information and or some follow up on the uses for such a device.

I know for some people including too much of the theory can be a turn off, however some people really want to see these sorts of things (and I am one of them) so if you just want to get down to the construction bits I suggest you skip ahead a couple of sections.

What is Return Loss and what has it got to do with a Bridge?

While most Ham's have heard of VSWR, and used a VSWR (or just SWR) meter the number of Hams who know what Return Loss is or have used a Return Loss Bridge (or RLB for short) is surprisingly small. Surprising because a RLB is a very simple but powerful tool that can be at least as useful as a VSWR meter. Do not be confused by the bridge bit of the name a VSWR meter is also often referred to as a VSWR Bridge, a Return Loss Bridge is just a tool for measuring Return Loss.

Put very simply Return Loss gives a relative measure of the amount of power returned (or reflected and "lost") from a load, to that power offered forward to, or incident on, that load. Return Loss is usually measured in dB and for example a Return Loss of 20dB means that the reflected power is 20dB down on the total power incident, ie if the forward power was 100 Watts the reflected power would be 1 Watt. So a return loss of 20dB indicates a reasonably good match. For those that want to think in terms of VSWR, a 20 dB return loss is equivalent to about a 1.2:1 VSWR., suffice to say the bigger the value of the Return Loss the better is the match, and the less power is being "lost" to reflections.

Note there is some potential confusion about the use of a sign on the Return Loss some say it should always be negative because the reflected power is always less than the forward power and so you should show the sign, and others say because it is always negative that you can leave off the minus sign in a similar way that the ratio bit of a VSWR is often neglected, others define it as being positive. It is always however the same absolute value. Ie. In common use a 14 dB Return Loss is the same thing as -14dB Return Loss, just as a VSWR of 1.5 is the same as a VSWR of 1.5 : 1. The ARRL Antenna Handbook, which I take as a standard reference, goes so far as to force Return Loss as a positive number by explicitly putting a negative sign in the equation for it just so that it will cancel out. They do at least mention that some people define it as a negative. As an example of this the Belden Company, of coax cable fame, subscribes to the show the negative school. The important thing to remember is no matter who is saying it, that the reflected wave is always less than the forward wave by an amount equal to the number part of the Return Loss.

For the purposes of this article I will stick with the ARRL version, which has a minus sign in the Return Loss equation, but not in the numbers it produces.

Table 1. below illustrates the relationship between Return Loss and VSWR. I have also included the reflection Co-Efficient and the Equivalent Load pure resistance values that would apply.

Refl Coeff	Return Loss (dB)	VSWR	Equiv Resistive Load (50 Ohm system)		Refl Coeff	Return Loss (dB)	VSWR	Equiv Resistive Load (50 Ohm system)	
1.000	0	Infinity	Open	Short	0.089	21	1.196	59.785	41.817
0.891	1	17.391	869.548	2.875	0.079	22	1.173	58.629	42.641
0.794	2	8.724	436.212	5.731	0.071	23	1.152	57.619	43.389
0.708	3	5.848	292.402	8.550	0.063	24	1.135	56.734	44.065
0.631	4	4.419	220.971	11.314	0.056	25	1.119	55.958	44.676
0.562	5	3.570	178.489	14.006	0.050	26	1.106	55.276	45.227
0.501	6	3.010	150.476	16.614	0.045	27	1.094	54.676	45.724
0.447	7	2.615	130.728	19.124	0.040	28	1.083	54.146	46.171
0.398	8	2.323	116.143	21.525	0.035	29	1.074	53.679	46.573
0.355	9	2.100	104.994	23.811	0.032	30	1.065	53.266	46.935
0.316	10	1.925	96.248	25.975	0.028	31	1.058	52.900	47.259
0.282	11	1.785	89.244	28.013	0.025	32	1.052	52.577	47.550
0.251	12	1.671	83.545	29.924	0.022	33	1.046	52.290	47.810
0.224	13	1.577	78.845	31.708	0.020	34	1.041	52.036	48.044
0.200	14	1.499	74.926	33.366	0.018	35	1.036	51.810	48.253
0.178	15	1.433	71.629	34.902	0.016	36	1.032	51.610	48.440
0.158	16	1.377	68.834	36.319	0.014	37	1.029	51.433	48.607
0.141	17	1.329	66.449	37.623	0.013	38	1.025	51.275	48.757
0.126	18	1.288	64.402	38.818	0.011	39	1.023	51.135	48.890
0.112	19	1.253	62.638	39.912	0.010	40	1.020	51.010	49.010
0.100	20	1.222	61.111	40.909	0.000	Infinity	1.000	50.000	50.000

Table 1. Reflection Coefficient, Return Loss, VSWR, and Resistive load Equivalences

All the relevant formulae for calculating these quantities can be readily found either on the web or in places like references 2 and 3. The only important ones we need here now are the simple ones:

$$RL = -20 \times Log|\rho|$$

and

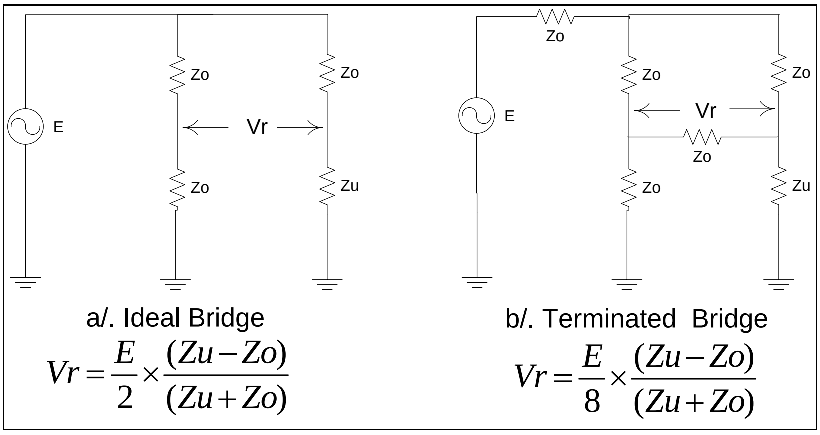
$$|\rho| = \left|\frac{Zo - Zu}{Zo + Zu}\right|$$

Where
ρ = Reflection Co-Efficient, and |ρ| = the magnitude of the Reflection Co-Efficient
RL = Return Loss in dB
Zo = The reference impedance, or that of the transmission line, in Ohms typically 50 Ω.
Zu = The unknown Impedance in Ohms

The straight line brackets in the above indicate that the Reflection Co-Efficient and the various impedance terms above are actually vector or complex quantities that have both a magnitude and a phase. For our purposes here, because Return Loss is not a vector quantity we only need to worry about the magnitudes, which is just as well as they are the simplest to understand, and measure. From here on in this article unless otherwise stated you should assume that when I mention the Reflection Co-efficient, I am referring to the magnitude only.

Return Loss Bridge Basics and the Importance of Being Balanced

The Return Loss Bridge presented here is based on the classic bridge circuit shown in figure 1. If you look at figure 1a., the ideal case, it is relatively easy to see that if the top two impedances marked Zo are equal then the voltage Vr will equal zero or null when Zu is equal to Zo. Usually the impedances Zo are all equal to the characteristic impedance of your transmission line, (typically 50 Ω in the Ham coax case) and Zu is connected by a bit of transmission line you can see that this null will occur when the load, say an antenna, is also equal in impedance to this value. A bit of maths can take this further still and show that in fact in this case, that the voltage Vr is equal to the Reflection Co-efficient multiplied by a constant value. If we measure this voltage in a logarithmic way (ie. In dB) then the difference between this value with a particular value of Zu, and the value with a known Reflection Co-efficient (typically open or short where Reflection Co-efficient is one) the constants will cancel out and the resultant will be the value of Return Loss in dB for that Zu.



a/. Ideal Bridge

$$Vr = \frac{E}{2} \times \frac{(Zu - Zo)}{(Zu + Zo)}$$

b/. Terminated Bridge

$$Vr = \frac{E}{8} \times \frac{(Zu - Zo)}{(Zu + Zo)}$$

Figure 1. Basic Bridge Circuits

Many simple SWR meter and RLB designs are based on this ideal Figure 1a. circuit, often using a diode detector to measure Vr. The problem with this ideal circuit is that it is very difficult to provide the ideal required add ons ie the detector measuring Vr must be both perfectly balanced and have infinite impedance, and the signal source must have zero output impedance. While a simple diode detector can have reasonably high impedance at least at some frequencies it is not infinite, and making it balanced and sensitive at low levels is also difficult. For these reasons many of these simple bridges only give reasonable results when used at significant power drive levels, this in turn causes problems with resistor wattages. A clear indication of problems with this simple design is seen when comparing measurements made relative to a short and an open. Both short and open should ideally give a Reflection Co-efficient of 1, ie. an equal result, however with some simple designs there can be considerable differences between the two measurements and usually neither is correct.

An alternative slightly more complicated approach is used in the design here based on figure 1b., the so called terminated bridge. Here you can see that the source has a real output impedance, and the detector has a real input impedance. This arrangement is more complex to analyse but it can be shown (Ref 4. for example) that, so long as all the impedances Zo are equal the equivalent results for Vr being a measure of the Reflection Co-efficient, all-be-it with a different (smaller) constant multiplier, can be obtained.

The requirements for the figure 1b. case are much easier to satisfy. Most signal generators have a 50 Ω unbalanced output, and getting some sort of sensitive 50 Ω unbalanced receiver or detector is not hard. The only problem left is the connection of the unbalanced detector to the balanced bridge. It cannot be directly connected without unbalancing the bridge and losing accuracy, so some sort of Balun is required. Note that the Zo resistor across Vr , and the one in series with the voltage source, are not physically present in the RLB circuit they are the signal generator's output impedance and the detector's input impedance, in this case as reflected through a Balun. The only thing we need then is a good 1:1 Balun and to ensure that what is on one side of the bridge is exactly duplicated on the other, ie it is symmetrical. Put another way great care needs to be taken that the only difference between the reference termination and the unknown side of the bridge is the unknown, or what you want to measure, itself. For example many RLB designs terminate the reference side of the bridge directly with a soldered in 50Ω resistor. While at lower frequencies this doesn't make much difference, as the frequency goes up the differences in impedance between that soldered in resistor and say an exactly equal value resistor, but connected via a BNC plug and socket, starts to make a difference. The purist may say that the bridge is only telling the truth that the connector is not perfect and you should measure it, usually however you only want to measure what is connected by the connector, so by balancing it out it can be removed from the measurement. The design here for this reason uses connectors to bring out both the reference and unknown ports. This also gives increased flexibility to the uses for the bridge. Similarly many designs get over the need for a balanced detector by just using a simple diode arrangement directly across the bridge and even neglecting the inaccuracies caused by the small voltage drop across the reference. The design here instead uses a 1:1 balun, this means we can use a normal unbalanced tuned receiver as the detector, which means measurements can be made at much lower power levels, and there is much less likelihood of getting misleading results caused by the signals of say the local broadcast station being detected by the diode rather than the actual test signal.

Circuit Details.

There are many designs for RLB's available in places like Reference 2 and 3 and on the web and the only claim to any sort of originality here is the combination of components, the layout, and perhaps the construction of the balun used. The RLB presented here is relatively simple to build, costs very little, helps to prevent interference on the bands, and the prototype gives good results measured on all the Ham bands up to at least 70 cm. The RLB here consists of four resistors, a homemade balun, some connectors, a few bits of PCB, some short lengths of coax, and a box.

The circuit of the RLB is shown in Figure 2.

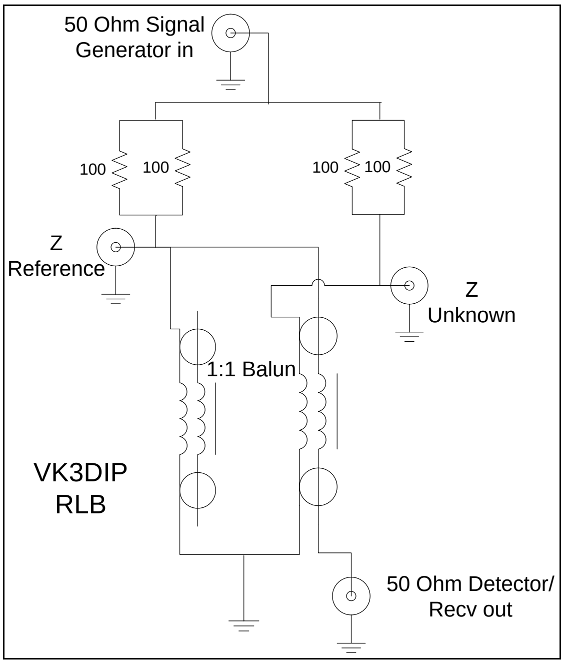


Fig 2. the RLB circuit.

As can be seen the four 100 Ω resistors are used in two parallel pairs to give 50 Ω each. I used 1% surface mount resistors to minimise lead inductances etc. This will however limit the maximum power that can be applied to this RLB but as I intend it only for use with a signal generator, probably via an external attenuator, this is not a problem.

The signal source is connected at the top, and the calibrated receiver or similar detector is connected at the bottom. The two ports in the middle are interchangeably the unknown and reference ports. The 1:1 balun used as indicated in the circuit is a little bit different to what you would normally see and needs a bit more explanation.

Caution, as you will see from figure 2 in this RLB the particular design of Balun used here means that there is a DC short across all ports save the Signal generator one. A DC only short across the receiver/detector might cause some problems if you are using a transceiver as the receiver which had say a DC feed on the antenna connector or some switching voltage present. Similarly if you want to measure an unknown which may have a DC level on it, say the input stage of a pre-amplifier you will need to ensure DC isolation. This will not be a problem for most people but it is worth checking your Receivers manual etc. before taking any risks.

The Bridge Balanced to Unbalanced Transformer (Balun)

There are commonly two types of baluns used by Amateurs called choke/current baluns or transformer/voltage baluns. I don't want to get into the relative merits of each, as there are lots of opinions on this in the Amateur literature, suffice to say here I have used a configuration that is a bit of both. If you just look at the right hand half of the balun it can be seen to be a conventional ferrite choke type, ie. A short length of coax with ferrite beads along its length. The problem with just this alone is that while the impedance of the current path on the coax outer surrounded by ferrite back to earth is quite high it is not infinite and it is only across one side of the bridge. Thus to balance this high impedance we have on the other side of the bridge an identical high impedance to earth formed by an identical piece of coax and ferrite. Note only the outer is actually used on this second piece of coax. This extra balance item also makes the Balun equivalent to a voltage or transformer action balun. This can be more easily seen if we forget about the fact that we are using coax and as I am using standard two hole (ie figure 8 style) ferrite balun formers think of it as simply three (one turn) windings on a transformer connected as per a normal one to one transformer balun. This arrangement gives bits of both worlds leading to a Balun that is usable over a number of frequency decades. It is this Balun frequency response which is the biggest contributor to the bandwidth of this particular RLB.

Construction

Construction starts with making the single most complex piece of the RLB, the Balun. The Balun is made using four, two hole, ferrite formers taped together into one bigger former, with short lengths of thin coax through the holes soldered onto small bits of PCB at each end as shown in figure 3. to make the “windings”. This can also be seen in Photos 1,2,3,and 4 which show the Balun in various stages of construction.

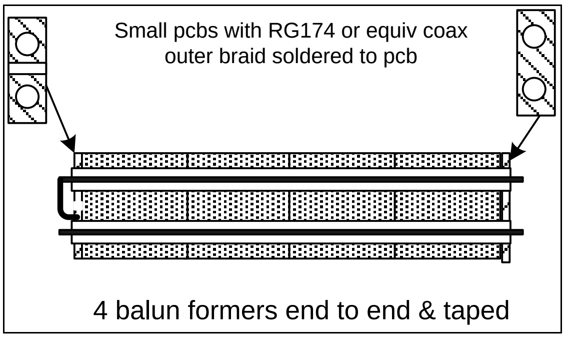


Fig. 3 Balun construction.

Photo 1, The pieces to make the Balun. Note I used small lengths of Teflon Coax to prevent problems with the inner melting while soldering. Normal RG174 should work also be careful when soldering.

Photo 2. Partially assembled. Note outer braid of coax is taught, and holds the formers together.

Photo 3. Formers wrapped in tape , I used clear tape just so you could see the formers, but other should work just as well. Also note I had to trim down the end pieces of PCB a bit to fit. The end shown is the end that goes to the resistors so that one centre conductor is bent over to connect to the other side and the other centre conductor is cut off flush.

Photo 4. Close up of resistor end of balun. Note I also had to cut a couple of notches in the PCB to fit the ends of the BNC connectors. You won’t need to do this if you use a bigger box.

The rest of the construction uses another small bit of PCB to hold the resistors as per Figure 4. I used a small hand drill with a milling bit to make it. You could also have a version with slightly poorer upper frequency performance, but better power handling, by not using this board and just soldering pairs of 100 Ω 0.25/0.5 W resistors directly between the various terminals. Obviously the shorter you can make the leads in this case the better.

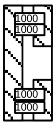


Fig 4. Resistor board.

In my case I fitted the RLB into a small diecast aluminium box, which I understand may not still be available in this size. See "getting the bits" later. If you don't have one of these exact boxes the next size up is still available and you won't have quite as much trouble as I had squeezing the RLB in. At worst you may have to have slightly larger pieces of PCB . I cannot however comment on what might be the effect on performance, as I haven't had any feedback from people who have gone down this path to date.

The final assembly is as per Figure 5. and Photo's 5,6, and 7

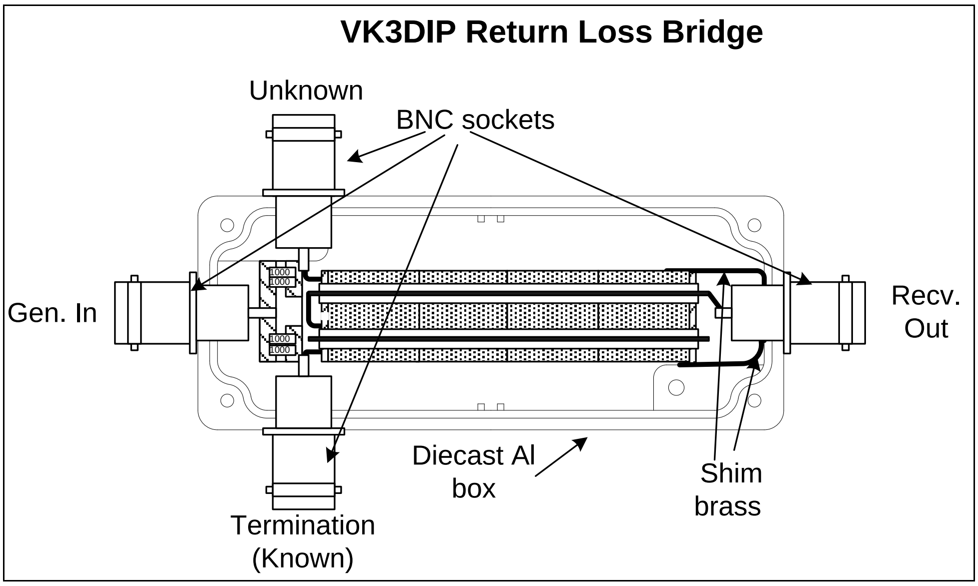


Figure 5 fitting it together.

Photo 5. Balun inserted in box. BNC connectors were put in first then balun soldered at Reference/Unknown end first. Balun then hinges at this point and can be swung down to mate with the brass shim and the receiver BNC.

Photo 6. Close up of the Reference/Unknown end.

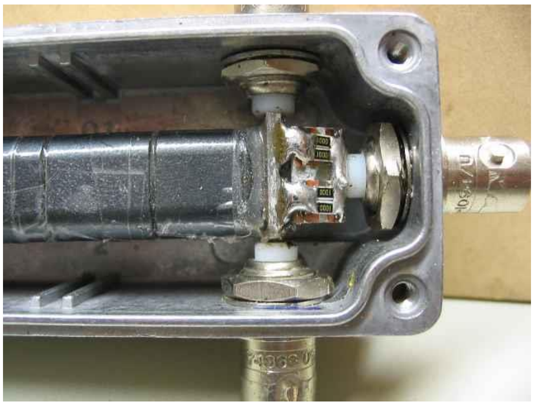


Photo 7. The resistance board added.

Testing it out.

The prototype was tested for directivity, which here is simply a measure of the difference between the balanced and maximally unbalanced states of an open and/or a short on the unknown port. This effectively is the maximum Return Loss that can be measured with the RLB. The result should be infinite but in practice a result over 40db is good enough enabling measurements down to an equivalent VSWR of 1.02 : 1 as shown in Table 1.. The results obtained from the test setup shown in Figure 6. are shown in Graph 1. For interest these results were obtained using two identical cheap coax ethernet terminators. The two curves on Graph 1. show the measurement relative to an open circuit and a short circuit.

These results show that the RLB is quite useable with a greater than 40 dB value obtained over the full range of Ham bands up to and including 70cm. The RLB is particularly good over the VHF 28 to 144 MHz bands where directivities in the high fifties closer to sixty were obtained. This compares very well to equivalent commercial models of RLB’s

The very good agreement between the Open and Short cases demonstrates that as well as the RLB being well balanced that the impedances seen at the source and receiver ports are close to 50 Ω. This is in part due to judicious use of the fixed attenuators. I placed the 12 dB at the Receiver end because I was less sure of its input impedance, whereas the Signal Generator I used is known to be a reasonable 50 Ω source.

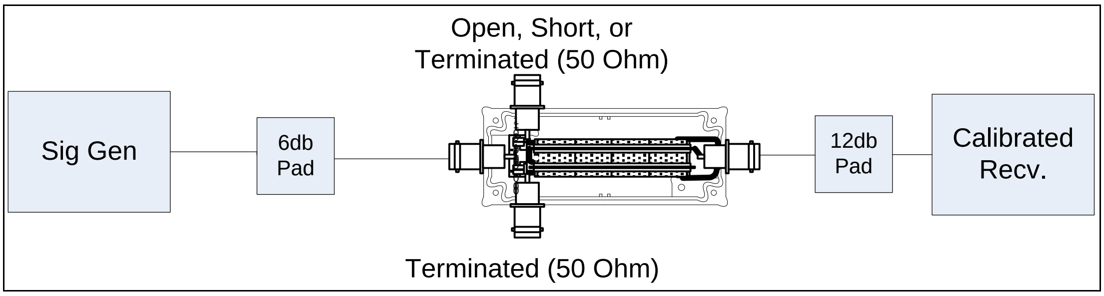
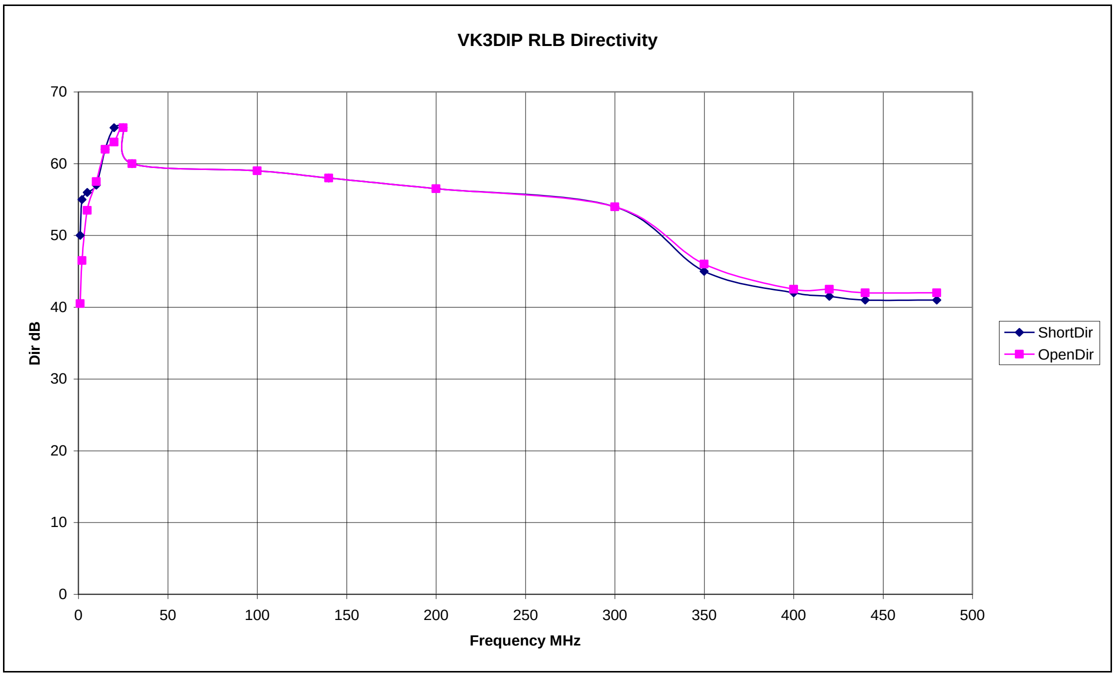


Figure 6. The test setup, the pads are to minimise effects of varying loading and frequency changes of the impedances of the signal generator and the receiver.



Graph 1. Measured directivity of the prototype showing usable directivity up to at least 70cm.

Note: The testing done here was with my own far from Lab standard equipment at a relatively small number of discrete frequencies. A sweep using a spectrum analyser or network analyser might find some dips and bumps that I didn’t happen to spot.

Some Return Loss Bridge Accessories

In Photo 8. you will see the RLB along with some of the various accessories I use with it.

Photo 8. RLB and Accessories

1/. Attenuators, Fixed and Switched Variable.
Photo 8 item 1 shows a number of fixed attenuators, I use this set for many things, it is made up of 1, 2, 3, 6, 12 dB values. This combination ensures I can make up any value from 1 to 24dB in 1dB steps. Some of these came from surplus, but the others can now be purchased for quite reasonable prices from Jaycar. As well as these fixed attenuators I also use some switched (not shown) ones as the case requires. These are either home made or ratted from dead signal generators.

2/. Terminators - Matched, Open, and Short
Shown in Photo 8 item 2 is a set of special BNC terminators, one each of open, short, and terminated (ie 50 Ω), also shown here is how 50 Ω terminators can also be combined with that ex LAN staple the BNC tee connector to produce a known 25 Ω load or 2:1 VSWR, which is about 9.5dB Return loss. I tried various versions of these and if you don't have access to commercial ones the best I found was to get some surplus ethernet (ie computer networking) 50Ω terminators and use those as the basis. There was considerable variation between the many different "brands" of terminators so test what you find before you rely on them. The best ones I found were those shown which have a green plastic top on basically a standard crimp BNC connector with what looks like a 1 watt 50 Ω metal film resistor in the body. The green cap can be easily removed to get access to the resistor. To produce the open circuit just snip off or otherwise disconnect the end of the resistor lead connected to the outer of the connector, and the short circuit is made by removing the resistor entirely and replacing it with a bit of wire connected to a bit of brass shim across the body of the connector. I got my versions of these terminators from Rockby Electronics who had them for 30cents each.

3/. Broadband Detector
Photo 8 item 3/. is a home-made broadband diode detector. This was made yet again utilising one of the cheap Ethernet terminators mentioned above by removing the resistor and replacing it with a hot carrier diode. One end of the diode goes to the centre pin and the other to a feed-through capacitor attached to the connector body by a small extension made out of brass shim. A digital or otherwise multimeter is connected to the end. The BNC tee piece is used as shown to make it either a 50 Ω (or other) terminated style detector or by itself as a high impedance detector. I could calibrate this but as I mainly use it for relative measurements I haven't needed to yet.

A much better solution for this would be something like an AD8307 integrated circuit logarithmic detector from Analog Devices which gives a 93 dB range at greater than 500Mhz. An even better one would be one based on the AD8302 which adds phase detection as well and works up to 2.7 GHz, even though it does have a slightly lower dynamic range. It's a pity it is so difficult to get these bits in one offs in Australia, as with the one IC AD8302 and this RLB you could basically have the main parts of a Vector Impedance Meter/ Network Analyser.

4/. Variable R/X Widget

This RLB isn't only useful for measuring return loss. By just connecting a variable impedance to the reference port the RLB can be used as a simple impedance bridge. I just tweak a couple of components connected to a BNC connector at the reference port until I get a null at the receiver port. The tweaked impedance on the BNC is then just removed from the RLB and placed on a RLC meter or equivalent for measurement at a few Kiloherz or other more manageable frequency. Of course if just using a resistor your multimeter will do fine. Photo 8. Item 4 shows a case of a 500 Ω pot, and a 100 Ω trim pot in series with a trim capacitor.

5/. Broadband Amplifier.

One of the problems with a Broadband Diode Detector is correctly detecting deep nulls. Or more correctly differentiating deep nulls from small dips. As the diode output tends to drop of rapidly at the low end this can be a problem. You can of course use more power but if you want to do measurements over a broad range of frequencies you may not have suitable transmitters for this, you also run into power dissipation problems. To help with this I have made up a small box with basically a hybrid IC as used in TV antenna masthead/distribution amplifiers which basically gives me some 16dB gain fairly flat from a nominal 30 to 870Mhz with usable gain either side extending its usefulness. Photo 8 item 5/. The impedance is a nominal 75 Ω but the datasheet (and my tests) show it working fine at 50 Ω using some of the fixed attenuators to give a clean 50 Ω to the RLB.

This is a good example of where using Return Loss to work out what happens is easier than VSWR. If we just connected say the 75 Ω directly to the 50 Ω system, then from Table 1 looking up the equivalent load resistance column we could see that this would be a 14 dB Return Loss. (also a 1.5:1 VSWR as expected) if we added now a 6 dB fixed attenuator then this would simply add 12 dB (twice the attenuation because the forward wave passes through it once, and once again for the reflected wave on the way back) to the Return Loss giving 26 dB which again Table 1. shows as an equivalent load resistance of 55 Ω and a VSWR of 1.1:1. A 12dB attenuator adds 24 dB to the Return Loss and leads to a 51 Ω equivalent impedance and a 1.025 : 1 VSWR. In practice it works even better than this as the nominal 75 Ω of the amplifier was actually lower than this. How do I know, simple I measured it with my RLB.

6/. Known Coax Lengths and Connectors.

Photo 8 item 6 is just one example of the miscellaneous bits of coax and connectors that can be used with the RLB. The item shown is useful for connecting to items under test at lower test frequencies. One of the very useful items in this class is a bit of coax a multiple of half waves long at the measurement frequency. This comes in handy when measuring impedances as it saves having to calculate the actual value at the load or antenna using a smith chart or equivalent computer program.

7/. Other Bits not shown.

As well the above there are a number of items of test equipment that fit in well or are required with the RLB.

A low power transmitter or one with a power attenuator on its output can be used as a signal source but a good Signal Generator is much more friendly with simple control of levels and usually well known output impedance characteristics.

The Diode detector and amplifier above can be used with the RLB but a tuned receiver will work much better at exploring deep nulls while rejecting the local broadcast band station. Any receiver with a good S meter can be used, but few Ham band models have a true 50 Ω input impedance, so here again the fixed attenuators come in handy. A Calibrated Receiver, a Frequency Selective Voltmeter, or even a Spectrum analyser, would be better still each having better known impedance characteristics, built in attenuators, and higher dynamic range, but few Hams can run to these.

Something that a number of Hams have is an Oscilloscope. The Oscilloscope, (with either attenuators, or a parallel 50 Ω load using a BNC tee piece for impedance matching) makes a very nice detector when used within its frequency range. It can also show if you are getting any distortion or unwanted signals coming in.

Finally the holy grail of RLB use is the Network Analyser, or Vector Network Analyser, this does it all, being the signal generator and the detector giving both magnitude and phase of the reflection co-efficient. While there are some home made versions of these out there they are still very complicated beasts. Maybe if AD8302's and equivalent DDS ic's get more readily available to the Ham community here this will change.

Getting the bits

Resistors - I got the surface mount resistors from Rockby Electronics Cat 27556
Ferrite Baluns - Two Balun formers in a packet from Jaycar Cat LF1220.
Box - The 36x90x30 box I used originally came from Dick Smith Cat H2230, and you may be able to find the same thing at other suppliers. Some people may have difficulty with this small size so using the next size up diecast box such as the Jaycar Cat HB5062 will both make things a bit more roomy to work in and a bit more commonly available.
PCB, and BNC Connectors - Most places such as Dick Smith, Jaycar and Rockby have these.
Coax - In my case came from the junk box, You might have to get a bit creative with the Teflon coax, if that's what you decide to use, as the only commonly available to Hams source I can find to this would be either the local club hamvention for surplus/ second hand, or cutting up the Wi-Fi extension cable sold by Jaycar Cat WC7802.
Fixed Attenuators – Make them yourself or see Jaycar Cat LT3053 and similar.
Ethernet Terminators – Most computer swap meets, or Rockby Cat 12984

What can you do with this Return Loss Bridge

1/. Measure Return Loss, Magnitude of the Reflection Coefficient, and VSWR

Measuring Return Loss is straight forward with two basic techniques that can be used. Which is easiest will depend in part on the actual signal generator and or receiver you use.

The first method I find simplest if you have a reasonable Signal Generator with good variable output level/attenuation, but are perhaps using a normal Ham receiver or un-calibrated diode detector. In this method the first thing you do is set the equipment up more or less as per figure 6 and with a Short or Open connected to the unknown port, and the reference terminated with the 50 Ω load, set the output level of the Signal Generator such that it is on the frequency of interest and there is a well recognisable level indication on the receiver, say S 9 on the meter. The absolute level doesn't really matter just that you can tell easily when you are there, and that you have noted both this level and the setting on the Signal Generator that produces this. The open or short termination is now replaced with the unknown you wish to measure, and the output from the Signal Generator increased (assuming here that the unknown is better than an open or short) until the reading on the receiver is back to the original say S 9. The difference in level of the Signal Generator before and after is the Return Loss, which if as usual the Signal Generator output level is calibrated in dB's will be in dB's.

The second method is similar to the first but here instead of starting with the Open or Short we start with the Unknown Connected and set the value, then connect the Open or Short, and increase the attenuation between the RLB and the detector until we are back where we started. I find this works best if your detector is a bit deaf as you set the first level which is the lowest such that you know you can detect it.

Obviously any combination of these two extremes also works basically you are simply getting a measure of the difference between the Open or Short and the Unknown case. Remember however bigger number means better match.

Given the Return Loss, getting the magnitude of the Reflection Co-Efficient, or VSWR is either a case of just looking up Table 1, or calculating then using some computer program or equivalent.

Remember this works whether you are using an antenna on the end of a transmission line, or the input of a gee-whiz pre-amplifier you are building. This is something that would be impossible in the normal VSWR case due to the power levels you would have to be using.

Sometimes you don't need to measure the actual value of Return Loss just to maximise the value (ie minimise VSWR, minimise reflected power, get the best match, etc.). As an example of this, say you are trying to optimise the input to an amplifier stage, you can just connect it to the RLB and tweak its input matching until you get a minimum (null) on the receiver.

2/. Measure Coax Losses

Given a length of coax that you want to measure the losses of, the line loss is found by connecting it to the RLB with the reference port terminated in 50 Ω, and the line open circuited at the end. The Return Loss is then measured as per 1/. above. With no losses in the coax there will be no difference between the open circuited coax connected to the RLB and the open circuit terminator connected. For practical cable with losses we have the case similar to the impedance matching using attenuators mentioned earlier, ie the coax losses will be half of the measured improvement in Return Loss. Remember the factor of two is because of the power having to travel once along the line from the RLB to the open circuit at the end of the coax and once as the reflection all the way back.

3/. Measure Coax, Physical and Electrical Length

Connect a shorted termination to the reference port, so we are not really measuring return loss but more using the bridge aspect, and short the end of the piece of coax to be measured and connect it to the unknown port. Now as you sweep the frequency from your signal source you should notice that the output on the receiver/detector (ie. amplitude,) goes from peaks to nulls. The nulls will correspond to frequencies where the electrical length of line is a multiple of a half wave at that frequency, and the peaks will be when the line is an odd multiple of a quarter wave at that frequency. At the half waves the short at the end is being repeated at the unknown port and balancing the short at the reference port. At the odd quarter waves the short is transformed to an open at the unknown port and this maximally unbalances the bridge. If we want to find the physical length and we know the cable velocity factor then you measure the frequency difference between two adjacent nulls (or two adjacent peaks if that is easier to see) and then cable physical length (ignoring losses) will be given by:

$$L = 150 \times \frac{Vf}{\Delta F}$$

Where:

L = Physical Length in Metres, Vf is the Coax Velocity factor as a fraction, and ΔF = Frequency difference in MHz of adjacent nulls.

Note the nulls must be adjacent for this to work, ie, next to each other frequency wise with no other null in between, this ensures that the difference in the multiples of half waves is one.

For example if you measure nulls to be at exactly 10 MHz, and the next at 20 MHz then the frequency difference will be 10 MHz so that if the cable velocity factor is 0.67 then the physical length is:

150x0.67/10 = 10.05 Metres.

You can work back the other way if you know the physical length to get the velocity factor of a piece of cable from:

$$Vf = \frac{L \times \Delta F}{150}$$

For example you measure your cable to be physically exactly 10 metres long and the nulls are exactly 10 MHz apart then the Velocity factor will be 10x10/150 = 2/3 = 0.66667

The accuracy of these values can be improved by using an average value for the frequency difference, ie. if you find three nulls and the differences are 10.1 Mhz and 9.9 Mhz then the average value of 10Mhz will give a better result.

For short pieces of coax it is probably simpler to use the same set up with shorted cable and short reference and just find a single null and use:

$$L = N \times 150 \times \frac{Vf}{F}$$

Where:
N = the whole number multiple of half wavelengths in the cable, F = the frequency of a Null in MHz.

You need to first estimate what multiple N is of course but you can usually get a reasonably good idea of this whole number by using typical cable velocity factors and measured length.

This approach also works well for cutting a length of coax to a specific electrical length. In this case it is simpler to have the coax open circuited where the nulls will now correspond to odd multiples of quarter waves and the peaks be half waves.

For example if you wanted a piece of coax exactly one quarter wavelength electrically long at a particular frequency then you roughly calculate the length based on published coax data add a bit just in case and connect it to the unknown port with the other end open. The Signal generator is set to the frequency of interest and with the reference port shorted, you cut bits off the coax until you get a null on the receiver/detector. If you never get a null then the safety margin you added at the start must not have been enough and/or the cable is not as per the published specifications for velocity factor.

4/. Measure the Impedance of an Antenna/Load/Component

There are several methods for calculating impedance using a RLB, the simplest is if you can measure both magnitude and phase of the reflection co-efficient, but as that requires more complex test equipment than most Hams have access to (or one of those elusive AD8302's) , other more complicated methods have been found to get around this. All of these methods rely on doing a second measurement using either an added known resistor in series with the unknown, or changing the effective system impedance series. These all require some quite complex calculations or playing with smith charts to get a result and often even when you are done you still do not get the sign of the reactance. Further description of these methods is well beyond the scope of this article, but have a look at references 5/. and 6/. if you are interested.

A simpler method that I use uses the RLB as a normal bridge by replacing the reference terminator with a variable component such as the items shown in Photo 8 items 4. Using this method the unknown is connected up and the reference is replaced with one of these R X widgets and the values adjusted until a null is achieved ie. at the frequency under test the impedance of the item under test will be exactly the same as the tweaked value of the reference. This is basically using the RLB as a classic impedance measurement bridge. In the classic bridge case a lot of the work required to build one is spent in calibrating the scales on the variable components and trying to get the range of values required. In my case it may take a little longer to take a measurement, and may occasionally require a soldering iron to add some more C or to replace the variable C with some variable L, but no up front calibration is required. Instead once the null has been achieved I simply disconnect the BNC connector with the widget from the RLB and connect it to either a multimeter if I was using a single resistor, or some form of audio or other RLC measuring device. One I find works particularly well in this case is a PC soundcard version (Reference 7/.). The only tricks are; 1/. That you need to get your LCR meter to measure in Ohms for resistances, Farads for Capacitors, and Henries for Inductors, then you can convert them into reactances at the particular frequency of interest if you need them. 2/. That if you want to measure an impedance at the other end of a bit of coax you can either use a smith chart or a computer program substitute like the ARRL TLW program, or again as I have mentioned before use a piece of coax that is an electrical multiple of a half wave at the frequency of interest.

This later technique can also be used to work out the impedance of a bit of unknown coax by measuring off an electrical quarter wavelenth as per 3/. above and then terminating it with a known resistance, and measuring the effective impedance at the bridge.
The coax impedance can then be found from:

$$Zo = \sqrt{Rk \times Rm}$$

Where:
Zo = Coax characteristic impedance, Rk = the known test terminator value at the end of the coax, Rm = the measured value at the port, all in Ohms.

5/. Use it as a Hybrid Combiner

The RLB described here is also identical to a Hybrid Combiner. Hybrid Combiners are used to combine the signals from two Signal Generators (connected to the Source and Receiver ports of the RLB) to one signal at the Unknown port. The Circuit here is such that neither Signal Generator output will effect the other one, and the output impedance will be a clean 50 Ω one. This sort of setup is common when doing two tone inter-modulation testing etc. of receivers.

6/. Do Network Analysis

If you happen to have a Network Analyser or a Spectrum Analyser then you probably already know the sorts of things you can do with them and a RLB.

Conclusion.

Hopefully having read this article you are motivated to rush out and build one of these, and are asking how did I ever survive without one. But perhaps more realistically you will keep this in mind as a possible construction project that you could try out one rainy weekend that is about as cheap and simple as they come. Also, while I have described a lot of things you can do with this bridge, I am sure that Hams out there can think up many more useful things it can do. So not bad for something with no active components and just of a couple of resistors and a balun eh.

73 Paul VK3DIP

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