Application Note #5

Measuring Return Loss with an
oscilloscope and a Return Loss Bridge (RLB)
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An RF return loss bridge (RLB) is a wide band bridge which can be used to check the impedance of antennas, coaxial cables, and filters, etc. The ARRL Handbook defines return loss as "*a measure of how closely one impedance matches a reference impedance in phase angle and magnitude. If the reference impedance equals the measured impedance level with a 0° phase difference, it has a return loss of infinity.*"

For Ham radio applications This impedance is usually 50 ohms. The INPUT port is normally connected to a test frequency (an RF oscillator or tracking generator from a spectrum analyzer). The DET (detector) is usually connected to an oscilloscope or spectrum analyzer. A RLB is ideal for measuring filter response because return loss measurements are a more sensitive measure of pass band response than insertion-loss measurements.

Figure 1 Return Loss Bridge

An RF Return-Loss Bridge

Fig. 1 The RLB-I (internal reference – three ports) is a high performance RLB. It is carefully designed specifically for Ham radio applications. It uses a wide band 1:1 miniature SMD 750MHz transformer. The bridge reference resistors are precision 50 ohm SMD devices. The circuit board employs computer optimized 50 ohm strip line technology.

How to measure return loss with an oscilloscope

Fig. 2 To measure return loss, apply the output of the signal generator to the RF INPUT port of the RLB. It may be necessary to attenuate the generator output to avoid overloading the device under test

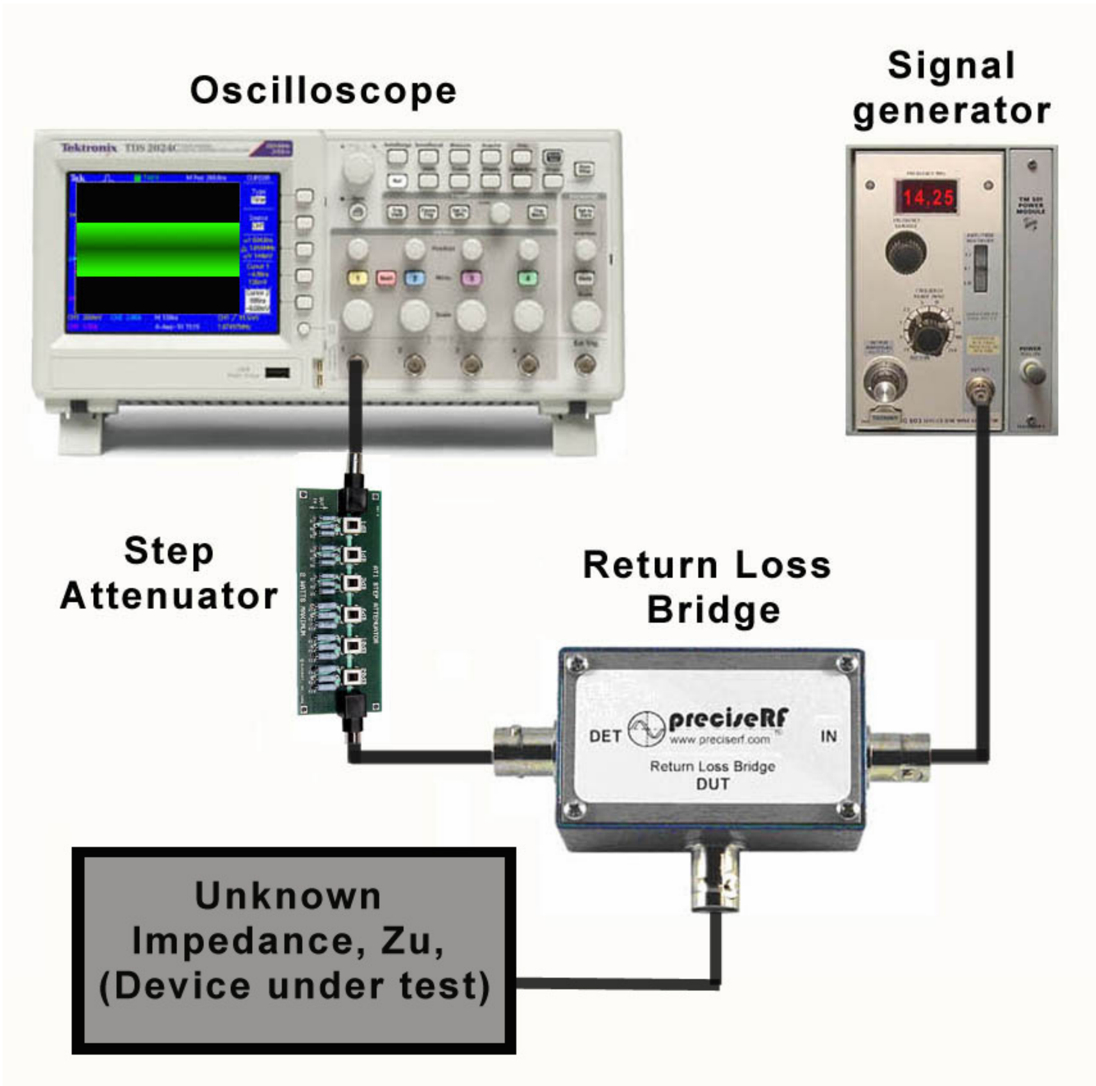

Figure 2 Return loss measurement

Connect the bridge DETECTOR port to an oscilloscope through a step attenuator and leave the (DUT) port of the bridge open circuited. Set the step attenuator for a relatively high level of attenuation and note the oscilloscope deflection.

Now connect the unknown impedance, of the device under test, to the bridge DUT port. The scope reading will decrease. Adjust the step attenuator to produce the same reading obtained when the DUT port was open circuit. The difference between the two measurements is the return loss, measured in dB (as taken from the attenuator setting).

By way of operation, the reference internal impedance (50 ohm) is compared to the DUT impedance. If the impedances are exactly equal, than the detector output will be essential zero (0). In practice this never happens. Most bridges have residual return loss from 30-40 dB (1000-1 to about 10,000) providing equivalent SWR measure.

The unknown impedance measured by this technique is not limited to amplifier inputs. Coax cables attached to load, an antenna, a filter, or any other fixed impedance device can be characterized by return loss.

Return loss is measured in dB, and it is related to a quantity known as the voltage reflection coefficient. Where RL = return loss, dB ρ = voltage reflection coefficient [p]. The relationship of return loss to SWR is:

RL=-20 log[p]

[p]=10^(-RL/20)

Where RL = return loss, dB
P = voltage reflection coefficient.

The relationship of return loss to SWR is:
SWR=(1+10^x)/(1-10^x)

Where x=-RL/20
For example if RL=20dB

Return Loss versus VSWR

Return Loss	VSWR	Reflection	Mismatch Loss	Reflected Power	Forward Power
(dB)	Coefficient, Γ	(dB)	(%)	(%)	
1	17.39	0.891	6.868	79.43	20.57
2	8.72	0.794	4.329	63.10	36.90
3	5.85	0.708	3.021	50.12	49.88
4	4.42	0.631	2.205	39.81	60.19
5	3.57	0.562	1.651	31.62	68.38
6	3.01	0.501	1.256	25.12	74.88
7	2.61	0.447	0.967	19.95	80.05
8	2.32	0.398	0.749	15.85	84.15
9	2.10	0.355	0.584	12.59	87.41
10	1.92	0.316	0.458	10.00	90.00
11	1.78	0.282	0.359	7.94	92.06
12	1.67	0.251	0.283	6.31	93.69
13	1.58	0.224	0.223	5.01	94.99
14	1.50	0.200	0.176	3.98	96.02
15	1.43	0.178	0.140	3.16	96.84
16	1.38	0.158	0.110	2.51	97.49
17	1.33	0.141	0.088	2.00	98.00
18	1.29	0.126	0.069	1.58	98.42
19	1.25	0.112	0.055	1.26	98.74
20	1.22	0.100	0.044	1.00	99.00
21	1.20	0.089	0.035	0.79	99.21
22	1.17	0.079	0.027	0.63	99.37
23	1.15	0.071	0.022	0.50	99.50
24	1.13	0.063	0.017	0.40	99.60
25	1.12	0.056	0.014	0.32	99.68
26	1.11	0.050	0.011	0.25	99.75
27	1.09	0.045	0.009	0.20	99.80
28	1.08	0.040	0.007	0.16	99.84
29	1.07	0.035	0.005	0.13	99.87
30	1.07	0.032	0.004	0.10	99.90
31	1.06	0.028	0.003	0.08	99.92
32	1.05	0.025	0.003	0.06	99.94
33	1.05	0.022	0.002	0.05	99.95
34	1.04	0.020	0.002	0.04	99.96
35	1.04	0.018	0.001	0.03	99.97
36	1.03	0.016	0.001	0.03	99.97
37	1.03	0.014	0.001	0.02	99.98
38	1.03	0.013	0.001	0.02	99.98
39	1.02	0.011	0.001	0.01	99.99
40	1.02	0.010	0.000	0.01	99.99