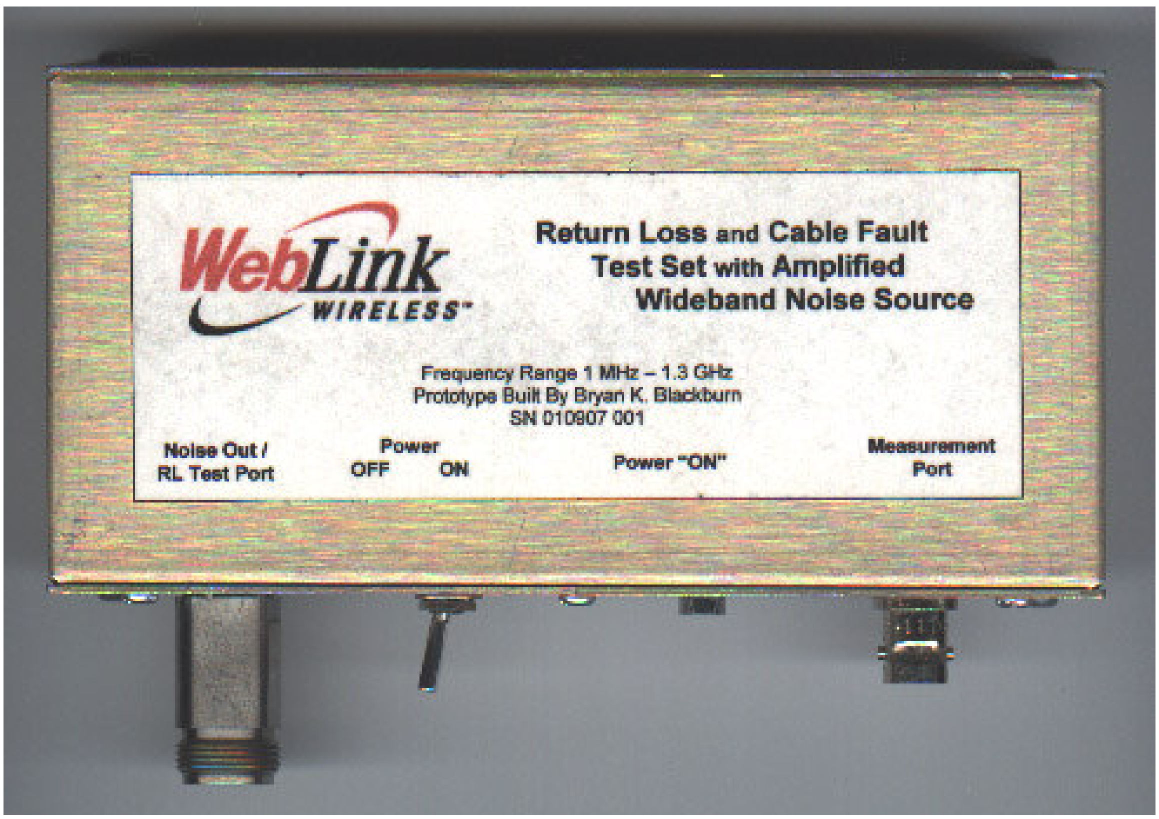
Preliminary Users Manual for the
Self Contained Return Loss and Cable Fault Test Set with Amplified Wideband Noise Source



Self Contained Test Set

About This Test Set

This test set was built especially for WebLink Wireless as a demo of what is possible for antenna system testing.

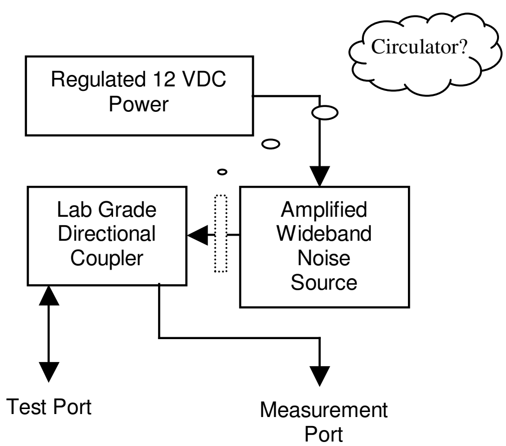
The test set makes possible several measurements that are difficult if not impossible to make without specialized test equipment, usually costing thousands or tens of thousands of dollars more than this measurement solution.

Measurements Possible

A few of the measurements made possible by this test set are: Return Loss, Frequency Domain Reflectometry (FDR or distance-to-fault), amplifier noise figure and gain, and cable velocity of propagation, to name a few. Other tests include filter bandpass measurements and tuning, isolater testing, antenna pass/fail tests, cable assembly losses, and more.

What's Under the Hood

Inside the box is an amplified wideband noise source, a laboratory grade directional coupler, and a regulated 12 VDC supply.



RL Test Set

The amplified wideband noise source output directly feeds the coupler input. The coupler output port is brought to the test set front panel as an 'N' connection, and is labeled 'Noise Out / RL Test' port. The coupler 'coupled' port is also brought to the front panel to a 'BNC' connector and is labeled the 'Measurement' port.

Notably missing is any protection from applied RF at the coupler test port. Several protections are possible, but all have their own drawbacks. An attenuator is the simplest protection, but comes at a cost of a proportional required increase in noise power, which also requires more battery power.

A circulator has no attenuation cost to the noise source, but is expensive and bandwidth limiting.

Caution!

This Prototype Test Set DOES NOT have ANY internal protection against applied high RF signal levels! DO NOT connect to any antenna or active device if potential exists for RF levels greater than 100mW to be present!

Although the internal coupler is very robust, there is no isolator between the coupler and the wideband noise source! (I didn't have one small enough.)

All The Noise

Noise Source

All materials produce noise proportional to their temperature. This is referred to as thermal noise. Thermal noise is white noise. Just as white light is light of all colors, white noise is noise power equal at all frequencies.

The noise in this test set is generated by a special noise diode. The noise output from the diode spans from a few hertz to many GHz, and is amplified by a series of high gain MMIC amplifiers. The bandwidth of the amplifier and that of the inline coupler is the primary limiting factor for the bandwidth of available noise output.

Since the power is equal at all frequencies, the measured power will be proportional to the measurement bandwidth. Each time the measured bandwidth is doubled, the noise power will increase by 3 dB. This is important since we are using the noise source as a signal generator. In order to obtain the highest available dynamic range of RL measurement, we must use a wide resolution bandwidth.

Useful Noise

Since the noise output is constant over all frequencies to over 1 GHz, we are able to use the noise source as a signal generator for such tests as return loss and frequency domain reflectometry.

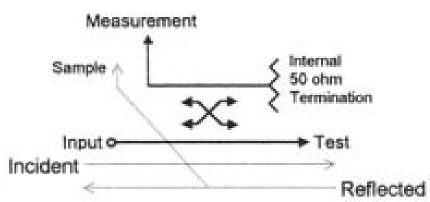
It is also possible to use noise for testing the bandwidth and tuning of band-pass filters by injecting the noise into the filter and measuring the output with the spectrum analyzer. This as well as the ability to perform RL tests on the filter.

Another interesting possibility is to use the noise source as the basis for measuring the noise figure of an amplifier. Although this may not be practical due to the need of a good accurate and calibrated spectrum analyzer, and the need to assess the true ENR of the noise source. (Which can be done with an accurate and calibrated spectrum analyzer!) Is the COM120 good enough for this? Not likely. The COM120 has a quoted accuracy of ±2 dB. Which means that the worst-case final result could be off by the same amount. This measurement uncertainty is significant for low noise amplifier characterizations.

Reflection Measurements

Directional Coupler

The directional coupler in the test set is a signal separation device. It provides a sample of the power traveling in one direction only. The coupler has four ports, an input port, a test port, and the measurement sample port. The fourth port is internally terminated in a precision 50-ohm load.



Directional Coupler

An incident signal applied to the input port of the coupler is passed to the test port unattenuated (less the insertion loss). Any signal reflected by the device under test will be passed back through the coupler to the input port. A sample (20 dB down), directionally isolated from the incident signal, will also be present at the measurement port.

When compared to the incident signal, This directionally isolated reflection sample provides the basis for calculating reflection coefficient, return loss, SWR, and impedance.

Reflection Coefficient

Reflection coefficient is the most basic of reflection measurement values, and is simply the ratio of reflected power to incident power. This number varies from zero for a perfect match to one for a total mismatch. If your spectrum analyzer offers a choice between linear and log displays, and most do not, you will be able to read this value directly from the screen. The symbol for reflection coefficient is ρ (magnitude only) or Γ (magnitude and phase).

Return Loss

The logarithmic expression of the reflection coefficient is the return loss, and its value is given in decibels. A return loss of 0 dB represents a total mismatch, and one of 40 dB or more, a near perfect match. Since spectrum analyzers are usually calibrated in decibels, reflection measurements are read from the screen directly in return loss. The abbreviation for return loss is RL, R.L. or R/L. Use the following equations to convert between return loss and reflection coefficient:

$$RL = -20\log_{10}|\rho|$$

$$\rho = 10^{\left(\frac{RL}{-20}\right)}$$

Impedance

For every measured value of, Γ there is a corresponding value of impedance. The two are directly related; their relationship in a 50-Ohm system is shown by the equation:

$$Z = 50\frac{1+\Gamma}{1-\Gamma}$$

To find reflection coefficient from impedance:

$$\Gamma = \frac{\frac{Z}{50}-1}{\frac{Z}{50}+1}$$

Remember that Z is the symbol for complex impedance, a value that includes magnitude and phase.

SWR

Reflected signals on a transmission line form standing waves on the line. Every half-wave along the line, high-voltage and low current points occur. Halfway between the high-voltage points will be low-voltage, high current points. The ratio of these voltages or currents is the Standing Wave Ratio or SWR. SWR is also related to return loss, impedance, and reflection coefficient, as shown by the equations:

$$SWR = \frac{1+10^{(-RL/20)}}{1-10^{(-RL/20)}}$$

$$SWR = \frac{1+\rho}{1-\rho}$$

And:

$$SWR = \frac{Z}{50}$$

Reflected Power

Since power is proportional to I^2 (or E^2), the power reflected will be proportional the square of the reflection coefficient, or:

$$P_{reflected} = \rho^2 P_{forward}$$

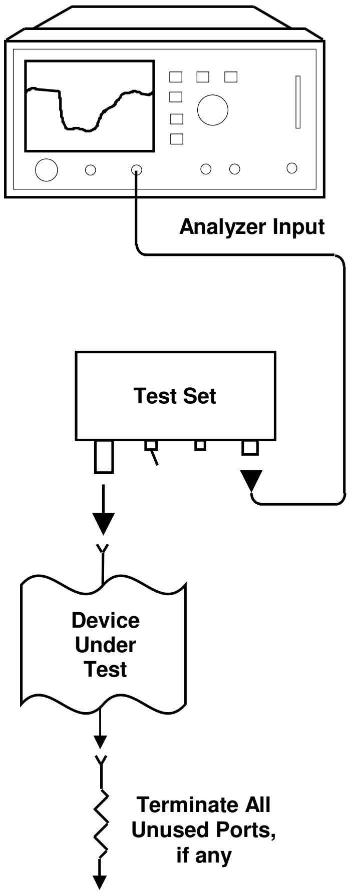
For example, a source impedance of 50 Ω, and load impedance of 100 Ω, produces an SWR of 2:1 and a reflection coefficient of 0.3333. The square of 0.3333 is 0.1111, or 1/9, fractional. This means that eight-ninths of the power indicated by an in-line wattmeter would actually be delivered to the load.

The remaining one-ninth is reflected from the load. The reflected power is reactive power (volt-amperes), and is not actually dissipated.

Return Loss Test Setup

Spectrum Analyzer

Make connections as shown in the diagram, apply power to the spectrum analyzer and turn on the test set. Leave test port open i.e., unconnected, at this time.



For most WebLink Wireless applications, using the IFR COM-120, set up as follows (other service monitors or spectrum analyzer types… Improvise!):

- Set the center frequency to 920 MHz.
- Set the span to 10 MHz per division.
- Note that these settings result in a 3 MHz resolution bandwidth.
- Attenuation to 0 dB.
- Set the input port to ‘Antenna’.
- Set the reference level to place the displayed line near the top of the screen.
- Turn on peak hold and minimum hold functions.

Now momentarily turn off the Test Set. The difference between the two displayed lines is the return loss measurement range of the Test Set at this frequency and span setting. If you are not using a COM-120, you can use a grease pencil to trace these lines on the screen. Some spectrum analyzers offer normalization functions. If available, these are far more accurate and useful for setting up a reference and for measuring results. Use it if you have it!

The measurement range at this frequency should be about 40 dB.

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Adaptors and Jumpers

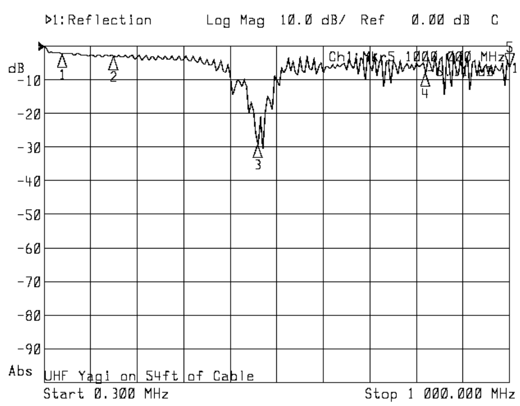
If an adapter or jumper cable must be used between the test port and the device under test (or DUT), connect it now. Keep in mind that the test set will add any mismatch in the adapters or jumpers to your reading, effectively *limiting* the measurement range of the test setup. A single, average quality adapter can limit the measurement range of the test set to as little as 20 dB. Jumpers longer than 1/20λ become *a part of* the DUT, no longer just a jumper! It is always best to avoid using adaptors or jumpers whenever possible.

Testing

Once connected and set up as described above, the spectrum analyzer will display the return loss of anything connected to the test port of the set. Since return loss is a measure of the *reflected* power from the device under test, a lower trace on the analyzer display indicates a better impedance match to 50 ohms. Since spectrum analyzers are calibrated in decibels, and since return loss is a logarithmic expression, the analyzer reads return loss directly.

Interpreting Results

When the test set is connected to an antenna feedline, the displayed plot or return loss measured is that of the same quality of match a transmitter or receiver "sees" when connected to the transmission line. The results are a composite signal of the return loss of the antenna, the cable, any connectors, any losses, and a standing wave pattern related to the length of the cable between the test set and the antenna and the match at the end of the cable (the antenna). And finally, all the interactions between all the above. Whew! For most purposes, this reading is enough to determine whether or not there is a problem. If the RL reading seems poor, increase the span of the spectrum analyzer (or vary the center frequency up *and* down) enough to see if there is a composite wave from the antenna and cable. Poor RL with no wave pattern may indicate an open or shorted cable (careful: the pattern may be very difficult to see with a short antenna cable).



Wide sweep of a good antenna and feedline

An SWR reading of 1.5:1 is equal to a return loss reading of 14 dB. In most cases, this is the value that manufactures specify as a minimum performance level for their antennas. The usable bandwidth of such an antenna is the span between the 14 dB points.

Cable Tests

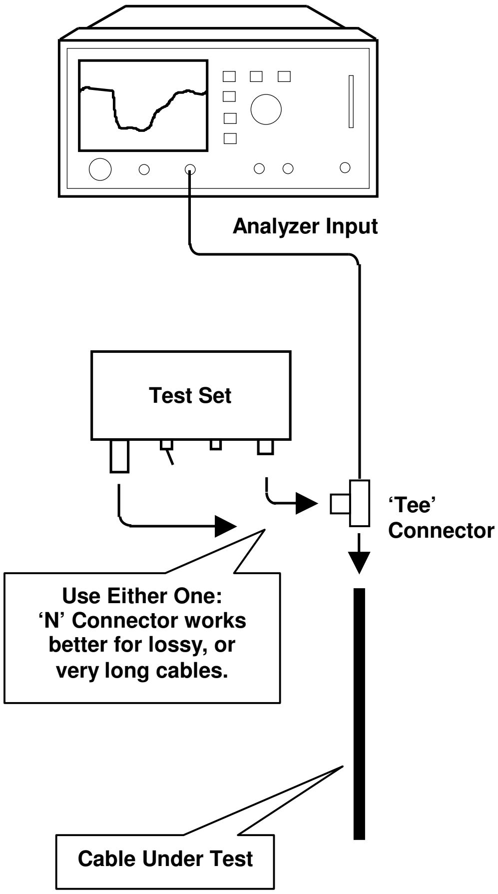
Transmission Line Basics

Remember that an open quarter wavelength of cable at any chosen RF frequency will reflect power 180 degrees out of phase back to the source. It will "appear" shorted. A spectrum analyzer in parallel with an RF source would read a weak signal. If the cable is lengthened to one-half wavelength, power will be reflected 360 degrees out of phase, which is actually in phase with our source but delayed by one cycle. The line will "appear" open (which it really is). Our spectrum analyzer would show a strong signal. (The incident and reflected signals are added together, and the measured signal will be about 3dB higher than the applied signal, minus cable losses.) Each time we lengthen the cable by a quarter wavelength, this cycle will repeat. Losses in the cable will reduce the reflected power measured on each successive peak and dip. These losses will be proportional to the cable losses at a particular frequency, times two. The losses should be small, but they will be there. (Excessive losses at higher frequencies can indicate problems such as water in the transmission line!)

Frequency Sweeping

Okay. So what? Well, what if instead of changing the cable length, we change the frequency? Say we have a cable of some length that is a multiple of one-quarter wavelength at a frequency of 10 MHz. Our signal generator and spectrum analyzer in parallel set to same frequency at the source will read a low or null signal, 180 degrees out of phase. As the frequency of the signal generator is increased, the wavelength of the cable remains unchanged. Yet because we are at a higher frequency, you could say that the cable "appears" longer to the new source frequency. At some higher frequency, say around 20 MHz, the cable will be a multiple of a half-wavelength, and our analyzer will read the in phase signal at a peak. Lets keep going, nulls are easier to find than peaks (trust me!). Increasing the frequency further to 30 MHz results in a null reading.

What have we done? We have revealed a ripple pattern whose frequency of repetition is directly related to the length of the cable under test. Or, more to the point, the distance to the largest abrupt impedance change… the end of the cable, possibly the fault, or the problem! Now let’s look at the same data graphically.



Setup Make connections as shown at left using *very* short cables or even better, direct connections. Reflections from the test leads will appear in the test results, the shorter the cables, the less effect they will have on your measurements!

Set the spectrum analyzer as before, choosing some lower frequency than the …

Blah, blah, blah. I'm going to bed.