Instruction manual IEEE802.11b/g (2.5GHz) antenna and cable test set External Sensor

Contents

General Description

Introduction

This test set is designed to measure accurately the VSWR of antennas or other RF loads referred to 50 Ω for VSWR < 1:2. It will also determine feeder loss by measuring the effective mismatch of a cable when the far end is in a short circuit.
The test set is used in combination with any WLAN transceiver or any other transmitter capable of delivering 15 to 20 dBm (30 to 100mW) of RF power over the desired range.
There is one analog readout, displaying the measuring bridge unbalance voltage.
There is one control, to set the meter to "Full scale" at the measurement frequency when the bridge is unbalanced.
Power supply for the indicator is from an internal 9 Volt battery, that is switched ON by a switch in the Sensitivity control. Power used is approximately 12mA.

Technical data

Frequency coverage
Bridge: 144MHz to 2500MHz

Impedance
50 Ω

Maximum RF Input level
Never exceed an RF Input level of 23dBm (200mW), or damage to the measuring bridge will occur.

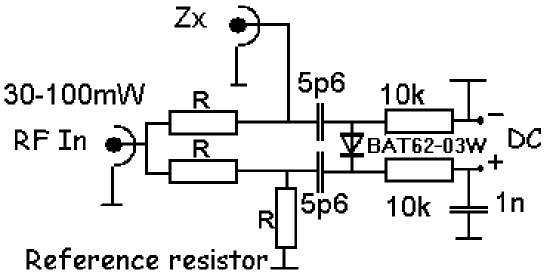
RF level at measurement connector
6dB below RF input level
i.e. 14dBm with an input of 20dBm from a standard Access Point

Measurement connector
'N' type socket

Power Consumption
12mA from 9 Volt battery

General

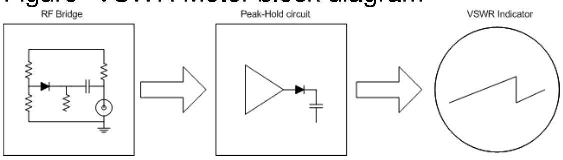
Figure "RF Bridge Circuit Diagram"



Udc = (RFin/2) * (Zx-50)/(Zx+50)
Where RFin is the peak value of the RF input signal.

The test set utilises an RF bridge circuit to compare the device under test with a precision 50Ω resistor as shown in Figure "RF Bridge Circuit Diagram". The antenna under test is connected to the test bus as Zx.
The DC Output voltage of this bridge is connected to an Analog Peak Voltmeter through a variable voltage divider.
Note that when Zx = R = 50Ω, there is no output from the bridge and as Zx starts to differ from R, the output (DC) increases and finally when Zx is open or short circuit, reaches a maximum of Rfin / 2. This output voltage is proportional to the reflection coefficient of the device under test and after suitable processing is displayed as VSWR on a meter.
To realise the maximum accuracy of the bridge, great care is required in its assembly.

Figure “VSWR Meter block diagram”

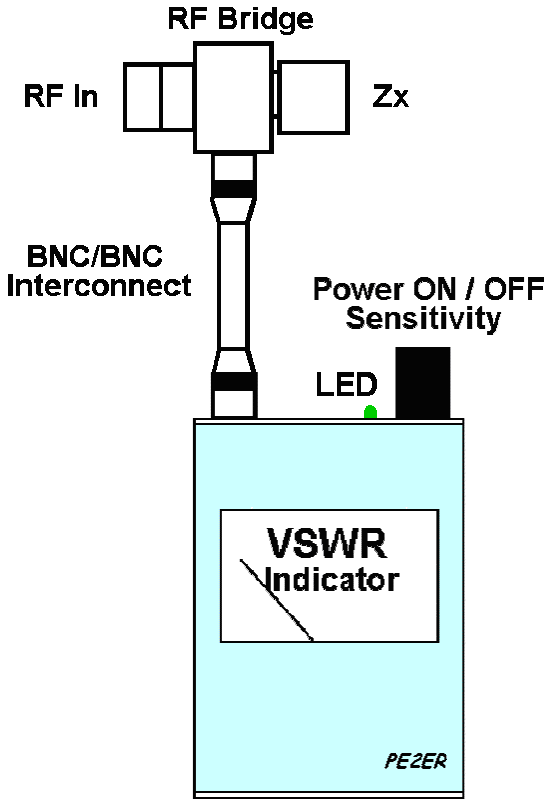


The RF Bridge its DC output voltage is passed to a peak-hold circuit via a potentiometer. This circuit captures the peak voltage during the short transmission burst (typically 0,5ms) of IEE802.11b/g equipment.

The peak-hold circuit makes the indicator have a fast-attack, slow release behaviour.

Due to variations in output power and frequency of IEEE 802.11b/g equipment with, the needle may vibrate. This is due to the Direct Sequence Spread Spectrum (DSSS) modulation technique.

Connections and controls



RF Bridge connectors
RF In: Female-N
Zx: Male-N
DC Out: Female BNC

Indicator connector
DC In: Female BNC

Operating Instructions

Initial Instructions

Connect the SWR Bridge to the indicator with the shielded BNC/BNC interconnect cable.

Switch the meter ON by the power switch on the front of the meter housing. The indicator needle should deflect to full scale and slowly settle to SWR 1:1 to indicate correct operation. If battery condition is unsatisfactory (Green LED does not illuminate brightly, needle does not deflect or settle to SWR 1:1), replace the internal 9 Volt Alkaline battery with a new one.

Connect the RF Generator (IEEE802.11b/g Access Point) to the N-connector **RF in** on the RF bridge.

VSWR

1. Set up the generator to transmit at the desired operating frequency (Channel).
2. Make sure that **nothing** is connected to the test bus (Zx) receptacle on the RF Bridge.
3. Apply RF power to the bridge and adjust the VSWR meter needle to the SET position using the Sensitivity control. NOTE: Due to variations in output power and frequency of IEEE 802.11b/g equipment with, the needle may vibrate. This is due to the DSSS modulation technique.
4. Attach device under test to the test bus connector using, if necessary, a short piece of suitable coaxial cable and connectors.
5. Read the VSWR meter.
6. Determine the ´loss in potential range´ from the following table:

VSWR 1 : x	Open cable Insertion Loss	Loss in potential range
1,00		**0,0 %**
1,10	**13,2 dB**	
1,20	**10,4 dB**	
1,30	**8,8 dB**	
1,40	**7,8 dB**	**2,0 %**
1,50	**7,0 dB**	
2,00	**4,8 dB**	
2,50	**3,7 dB**	**5,7 %**
3,00	**3,0 dB**	
3,50	**2,6 dB**	
4,00	**2,2 dB**	**13,4 %**
4,50	**2,0 dB**	**16,8 %**
5,00	**1,8 dB**	**20,0 %**

Note: Best prototype antenna measurements are obtained with the RF Bridge Zx port connected directly to the antenna, without the use of coaxial cable or adapters.

Line Loss

1. Set up the generator to transmit at the desired operating frequency.
2. Make sure that **nothing** is connected to the test bus (Zx) receptacle on the RF Bridge.
3. Apply RF power to the bridge and adjust the VSWR meter needle to the SET position using the set control just below the display.
4. Attach device or cable under test to the test bus connector using, if necessary, a short piece of suitable coaxial cable and connectors.
5. Read the VSWR meter.
6. Determine the ´Open cable insertion loss´ from the table above.

Field Strength

1. Attach an antenna to the test bus (Zx) receptacle on the RF bridge
2. Set the **Sensitivity** control to maximum sensitivity (Fully clockwise).
3. Determine the relative field strength by reading the VSWR meter. Reduce sensitivity using the control as required.

Precautions

Certain precautions should be observed to obtain accurate results on antenna systems:

1. It is essential when measuring an antenna, as distinct from a system, to attach the supplied cable direct to the base connector of the antenna. This ensures the highest accuracy by eliminating the effect of long lossy cables between the antenna and test set.
2. When needing to know the loss of a cable accurately, it is necessary to perform two or three measurements not only at the frequency (channel) of interest but either side of this frequency (channel) to average out any resonant effects on the cable.
3. When making any measurements, especially at UHF and SHF, it is necessary to minimise use of co-axial adapters, as these items can introduce a large degree of uncertainty in any VSWR measurement. Use only precision adapters, cables and connectors for accurate measurements.
4. It is inadvisable to operate the test set in the vicinity of high powered transmitters as enough power may enter the test set, via the antenna under test, to influence the measurement.

Calibration

Offset

The electrical null position of the indicator (power switch in ON, Sensitivity control fully counter-clockwise) should be near equal to the mechanical null position (power switch in OFF) and corresponding to the VSWR 1:1 mark on the instrument.

NOTE: The instrument must be in horizontal position for this test (flat on table).

If required, adjust the mechanical null position with the lever inside the instrument.

If required, adjust the electrical null position with the potentiometer on the peak-hold circuit board.

NOTE: The instrument needs to be disassembled for these adjustments.

VSWR

The accuracy of the VSWR meter scale should be checked every 12 months by attaching a generator and calibrated dummy load (Zx = 50Ω at 2,4GHz) to the test set. If the reading is not within specification (VSWR below 1:1.1), the instrument must be checked and re-calibrated.

Battery replacement

When the LED does not illuminate brightly with the power switch in ON, or after switching the unit ON the indicator needle does not deflect to full scale and settle to SWR 1:1, replace the internal 9 Volt Alkaline battery with a new one.

1. Place the power / sensitivity switch in position OFF
2. Open the battery compartment on the rear of the indicator unit.
3. Gently pull out the 9 Volt battery and replace the battery with a fresh 9 Volt Alkaline battery.
4. Insert the 9 Volt battery.
5. Gently put the battery compartment lid into place.

Some useful formulae relating to VSWR

Let S = VSWR (< 1).
Γ = voltage reflection coefficient.
Pi = incident Power.
Pr = reflected Power.
Pt = transmitted Power.

$$S = \frac{1+\Gamma}{1-\Gamma}$$

$$\Gamma = \frac{S-1}{S+1}$$

$$\frac{Pr}{Pi} = \Gamma^2 = \frac{S-1}{S+1}^{2}$$

$$\frac{Pt}{Pi} = 1 - \Gamma^2 = \frac{4S}{(S+1)^2}$$

Let S max = Maximum VSWR when S1 and S2 combine in worst case

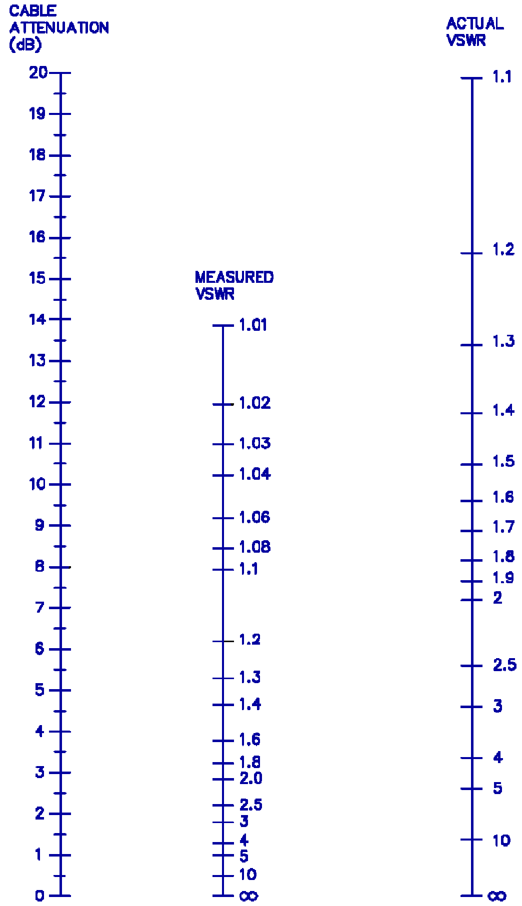
and S min = Minimum VSWR when S1 and S2 combine in best case

then:

$$S\max \approx S1S2$$

$$S\min \approx \frac{S2}{S1}\ (S2 > S1)$$

Figure "Nomograph for correction of VSWR for cable attenuation".



Antenna Theory

Antenna Voltage Standing Wave Ration (VSWR)

Of all the antenna parameters, the VSWR is probably the one most readily measured. Indicating the ratio of antenna impedance to the characteristic impedance of the co-axial feeder, it is possible to use the VSWR figure to calculate the percentage transfer of power to the antenna. If it can be assumed that the antenna meets the necessary mechanical and environmental requirements, the polarisation is correct and the design such that the required coverage can be achieved, then a knowledge of the antenna VSWR across the frequency band of interest will enable performance calculations to be made.

VSWR influence on potential range

Table 1 shows the power transferred to the antenna for various values of VSWR, the power loss in dBs and the percentage loss in potential system operating range. From the table it can be seen that for a VSWR of 2:1, the percentage of power transferred to the antenna is 89% and the reduction in potential range against a perfect match of 1:1 is approximately 6%. If the VSWR increases to 1:5, then the reductions in range potential will rise to approximately 25%. These figures emphasise the importance of maintaining the antenna VSWR at the initial system design value.

Table 1

VSWR	% Power to antenna	Power loss in dBs	% loss in potential range
1	100	0	0
1.5	96	0.18	2.02
2	89	0.51	5.7
2.5	82	0.88	9.65
3	75	1.25	13.4
3.5	69	1.6	16.85
4	64	1.94	20.00
4.5	60	2.25	22.86
5	56	2.55	25.46
6	49	3.1	30.00
7	44	3.59	33.86
8	40	4.03	37.15
9	36	4.44	40.00
10	33	4.81	42.5

Cable Loss influence on potential range

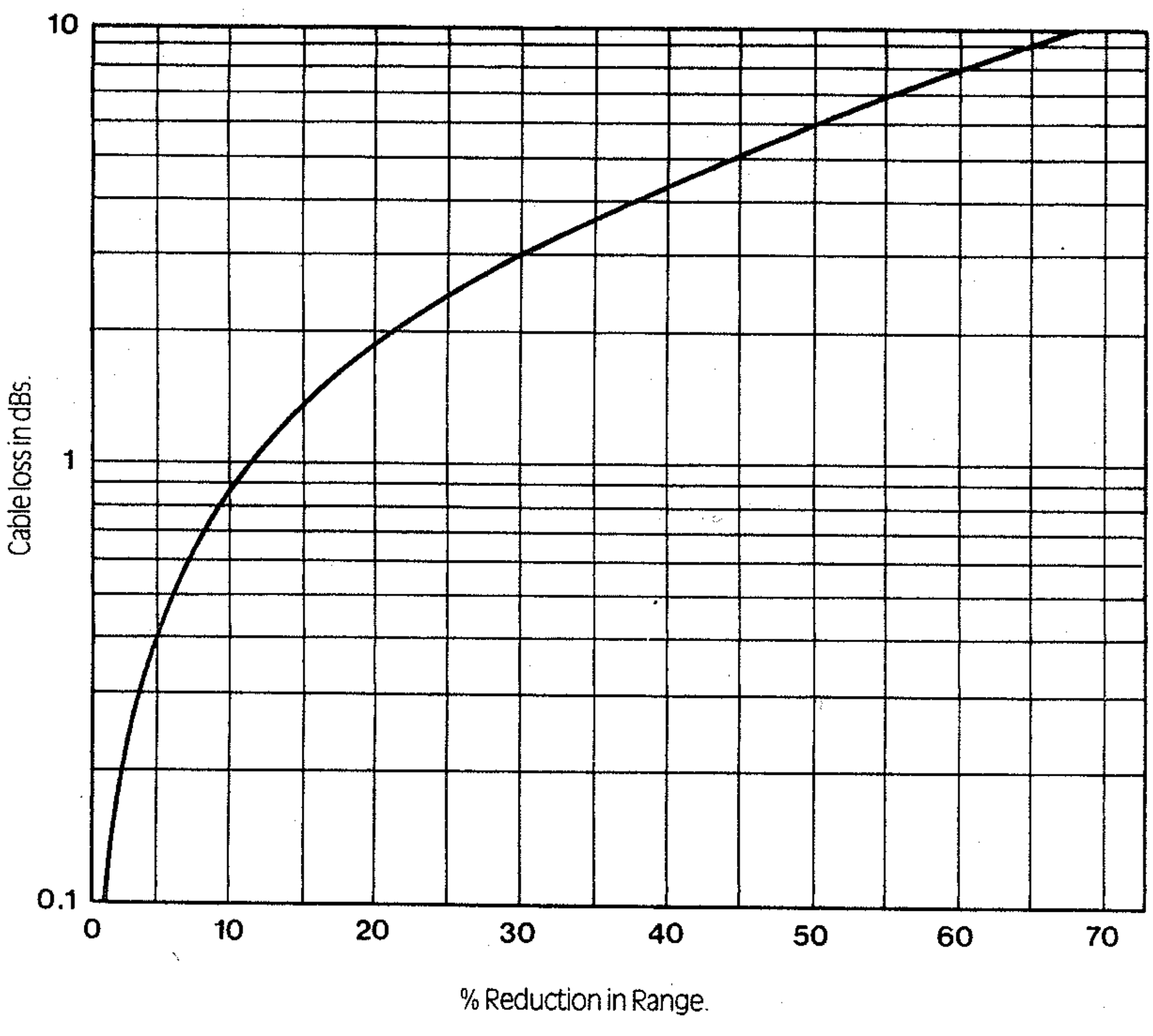
By performing a cable attenuation measurement, or from the manufacturers' specification, it is possible to obtain a nominal value of attenuation for any cable length and then obtain a figure for the reduction in range potential from Figure "% Reduction in range" below.

Figure "% Reduction in range".

Total System performance

The effect of the combination of VSWR and cable attenuation on a system performance can be determined by combining the effect of VSWR from table 1 and cable attenuation.

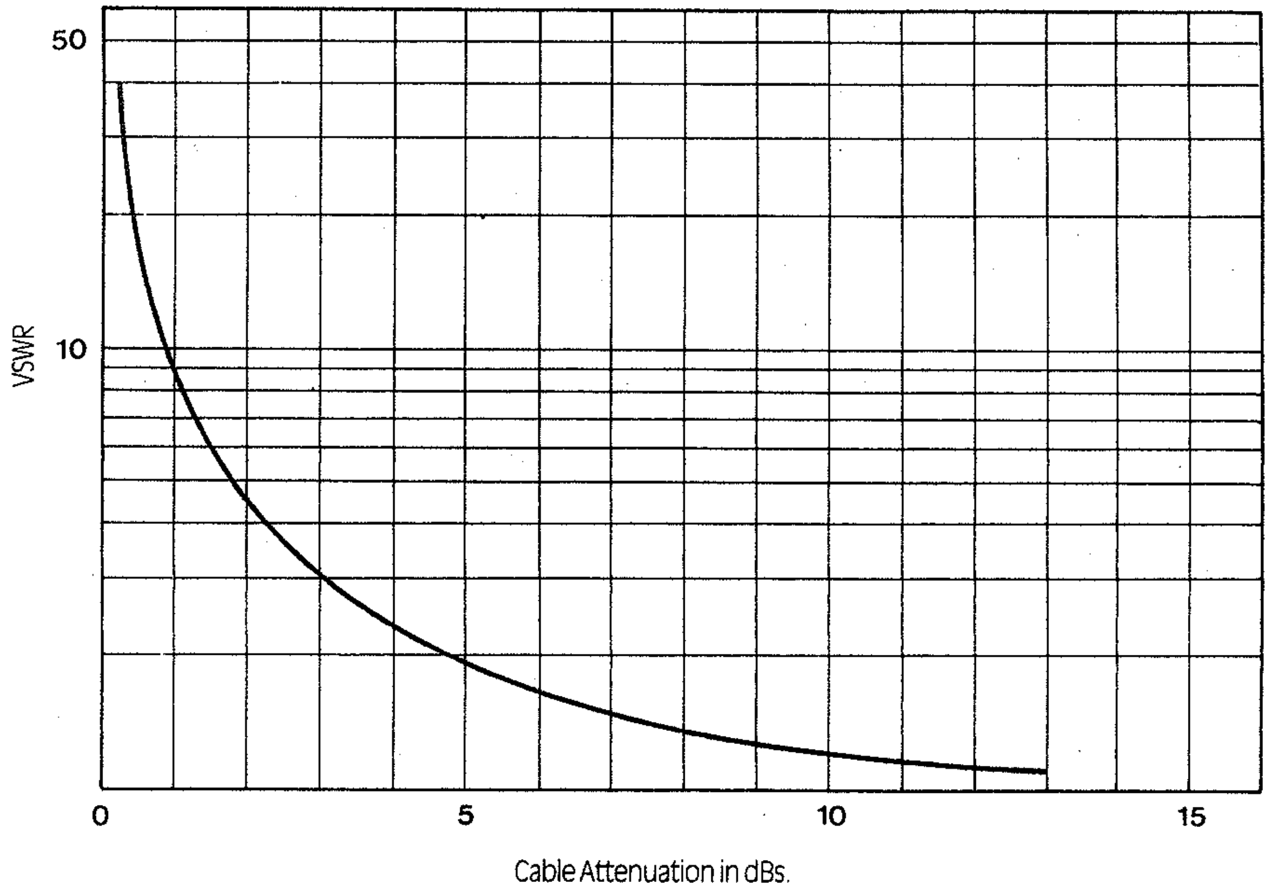
For example, a VSWR of 1: 2.5 gives a power loss of 0.88dB. Combined with a cable loss of 1.5 dB, the reduction in potential range will be 25% according to the table.



Cable loss influence on VSWR

Apart from its effect on range potential, the attenuation of the co-axial feeder can mask the true VSWR of the antenna to which it is connected. An extreme example of this effect is shown in Figure "VSWR masked by Cable attenuation", which gives the apparent VSWR of a short circuited cable against increasing cable attenuation. This is an extreme case, but with some Rx only antennas having a VSWR of 5:1, it can be seen from this figure, that 10 meters of RG-58C/U would give sufficient attenuation at 145 MHz to make a short circuited antenna appear to be acceptable.

Figure "VSWR masked by Cable attenuation".



Measuring prototype antennas

When building and measuring a prototype antenna, you may encounter problems originating from radiation coming from measurement equipment and cables.
The problems caused by resonating equipment and/ or cables may include:

- Change in input impedance at resonance
- Change in frequency of resonance.
- New resonances appearing.
- Change in efficiency.
- Change in radiation pattern.
- Equipment breaking from the power put into it, especially other electronics
- Distortion of transmitted signal.

The problem of changing the pattern is by far the hardest to crack.

The problem is different in prototyping to in final, installed use. Installation used here in its most general term, like installing antennas on towers and buildings and installation of antennas on or inside equipment.

There are two approaches to fixing this problem in installed antennas.

- Install the antenna, taking into account the radiation due to cables, masts, things near the installation etc. Leave the antenna unbalanced and use it.
- Balance the antenna well, so the environment can be ignored to a certain extent.

In prototyping there are several approaches possible, like:

- Prototype in the place where the installed antenna will go. Build what works best there.
- Balance the antenna in prototyping, and then later balance the system with the installed antenna.
- Construct an environment similar to the environment that the antenna will be installed in.

In general antenna designers need to know if their antennas are radiating or not radiating because of the items they are connected to. One way is to balance the antenna with a BALUN and observe.

Without building a BALUN you can make some estimates to see if there is a problem.

Here are some methods that can tell you if your antenna system is well balanced.

- Look for a series of narrow resonances spaced in regular periods of frequency.

If you have a series of resonances like this it is quite likely that you have a lossy transmission line causing them, not the antenna.

- Short wire

Suspecting that the antenna in question is balanced, attach a λ/4 wire to the feed-point. If you have incorporated a BALUN, place it between the BALUN and the generator. Trail this wire in a different axis to that of the antenna. E.g. if the antenna is in XY plane, align it to YZ or XZ plane.

If the resonance moves in frequency you may have a problem. After trying λ /4 try smaller lengths, if these still have an effect then the cable current is large.

- Move the items behind the feed through 90 deg

Move the items attached behind the feed or the BALUN through 90 deg into another axis. If the resonances change a lot then you have a problem. If the pattern changes then you can't be sure that it's not just because the items you've moved is not just re-radiating differently in it's new position. You should only try this if you've predicted that your antenna should stay balanced if the feed is moved, many antennas are considered to be balanced (or close to balanced) only if they are fed from a certain direction.

- Check the radiation is in the polarisation you expect

This is fairly obvious, if the opposite polarisation is radiating more than the one you think should be radiating then there is probably a problem.

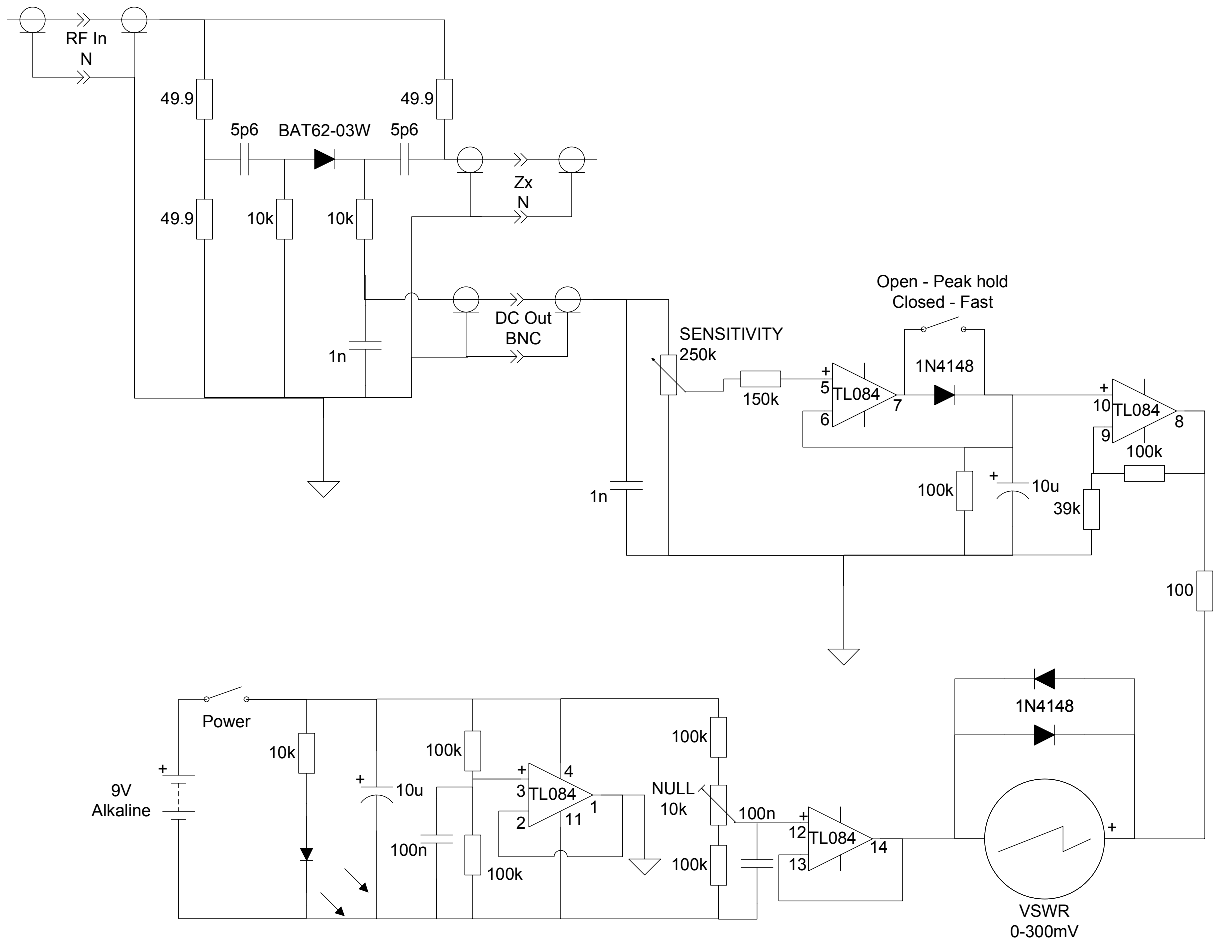
- Add a loss mechanism

For this test, you need to use broadband Radio Absorbing Material (RAM)
Apply the RAM around the feedline upto the feed-point and around the apparatus attached to the feed. If the bandwidth increases then there is cable radiation, the extra bandwidth is caused by the RAM absorbing the energy. Look for large changes in the bandwidth (like 3dB – 2x). Using ferrites ferrules is an extension of this method.

- Us Antenna Simulation software

Simulate the antenna installation including the feed, look at the current on the feed.
Try simulating the antenna with the feed removed.

Electrical diagram



***Peak hold** / **Fast** switch optional