LEADER TEST INSTRUMENTS

MODEL LIM-870

ANTENNA IMPEDANCE METER

INSTRUCTION MANUAL

LEADER ELECTRONICS CORP

Reconstructed by PE2ER

1. General
The Leader LIM-870 Antenna Impedance Meter is basically a capacitor type SWR (standing Wave Ratio) bridge. Both arms of the bridge have been made variable. It is possible to measure radiation resistance and resonant frequency of an antenna, transmission line impedance, approximate standing wave ratio and optimum receiver input.
The LIM-870 may be operated from any low power RF source not exceeding ½ Watt. The wide frequency range and portability of a transistor dip meter such as the Leader LDM-815 make it ideal for use with the Antenna Impedance Meter.

A build-in RF amplifier reduces the RF Input power needed for the bridge, to improve frequency accuracy.

2. Specifications

Antenna Impedance	0-1000 Ω
Frequency	1.8 – 150 MHz
RF Power input	0.5 Watt maximum

3. Panel Controls
Antenna Impedance Ohms Dial
This dial controls a double variable capacitor that is used to balance the bridge and determine antenna impedance in the range **0 to 1000 Ω**.

Amplifier power switch
This switch controls the power to the build-in RF amplifier.
It has the following settings: **RF AMP OFF – ON** and **BATT. CHECK**

Indicator
The indicator shows relative RF Bridge unbalance, or voltage of the internal 9 Volt battery.

RF In
The original LIM-870 has two binding posts to feed the antenna impedance bridge with RF power.
The modified LIM-870 has a BNC type input.

Antenna
The original LIM-870 has two binding posts to connect the antenna to the impedance bridge.
The modified LIM-870 has a SO-239 type antenna socket and two grounded binding posts.

Mode switch
The mode switch determines mode of operation in the original LIM-870. It has two positions **Direct** and **AMP**. In position **Direct**, the internal RF Amplifier is bypassed.
The modified LIM-870 has no mode-switch; the RF Amplifier can not be bypassed.

4. Circuit Description

The LIM-870 consists of a two-stage transistor RF amplifier, followed by an RF bridge. See Figure 1. This bridge compares the Antenna Under Test to a reference 50 Ω resistor. An indicator shows the relative unbalance of the bridge. When the indicator has a zero indication, the two legs of the bridge are balanced and the unknown antenna impedance Z_x can be read from the capacitor dial.

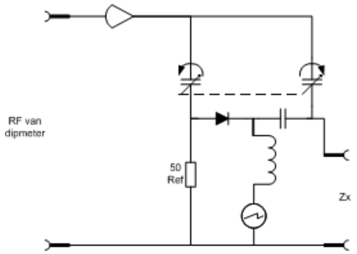


Figure 1.

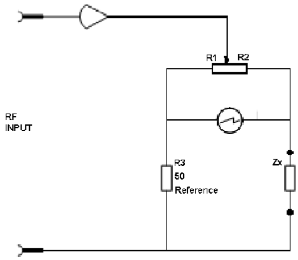


Figure 2.

The operation of the Antenna Impedance Meter may be understood by referring to the fundamental bridge shown in Figure 2. Here, the variable impedance of the capacitor is shown in the form of a variable resistor consisting of R1 and R2.

The indicator voltage is given by the following formula:
$U_{IND} = U_{R3} – U_{Zx} = U_{RF}\ x\ (R_3 / (R_1+R_3) - Z_x/ (R_2 + Z_x))$

Voltage across the indicator is zero when the voltage over R3 and Zx are equal and in phase. When the bridge is balanced, $U_{IND} = 0V$
$U_{RF}\ x\ (R_3 / (R_1+R_3) - Z_x/ (R_2 + Z_x)) = 0$

This means that:
$(R_3 / (R_1+R_3) - Z_x/ (R_2 + Z_x)) = 0$ and hence $R_3 / (R_1+R_3) = Z_x/ (R_2 + Z_x)$

Form this, it is clear that $Z_X = R_3 \times \frac{R_2}{R_1} = 50\Omega \times \frac{R_2}{R_1}$

Resistor R3 has a fixed value of 50 Ω, Z_x can be determined by the ratio of R_2/R_1; the position of the dial on the variable capacitor in the LIM-870 Bridge.

5. Precautions in operation

Excessive input power will damage the RF amplifier and possibly the RF bridge diode and resistor. Never se more power than needed to get full deflection on the indicator. With the mode switch in position **DIRECT**, RF Input power must be limited to ½ Watt. With the mode switch in position **AMP**, the bridge must only be connected to a low power VFO or dip meter.

6. Operation

The LIM-870 can be operated from any low power RF source, not exceeding ½ Watt. The LDM-815 transistor dip meter makes an excellent driver for it. The LIM-870 and LDM-815 can be screwed together back-to-back to form a compact fully integrated antenna test set.
However, a VFO or an even higher powered transmitter may be used if the coupling is decreased sufficiently to prevent overload of the LIM-870.
At frequencies above 15 megacycles, a one turn loop is usually sufficient for obtaining maximum output from the transistor dip meter. For lower frequencies, a two or three turn loop will be required. The position of the loop generally need only be at a point which produces approximately full scale reading on the Antenna Impedance Meter while the impedance dial is set near the expected impedance and while the Antenna terminals are left open. Because the variable capacitor is linear, nulls towards the high end of the scale will not appear as sharp as those at the lower end. In this case, it may be necessary to increase the coupling to the transistor dipper. For best accuracy of frequency measurements, it is advisable to listen to the transistor dip meter beat against some standard frequency while the instruments are set at the measured reading point.

In the following discussion, the RF source will be referred to as generator. Unless otherwise stated, the null is considered as zero meter reading and it must be kept in mind that this is not obtainable unless the measured impedance is resistive which in the case of an antenna or any other circuit made up of inductance and capacitive resistances, means it must be resonant at the frequency concerned. Incomplete nulls indicate the measured impedance is reactive.
Before discussing antenna measurements, data on the readings of transmission lines will be first presented because they clearly indicate special characteristics of these lines and because certain definite length of lines will be used with some measurement procedures.

Transmission lines – Quarter wave lines

To determine the electrical length of the quarter wave line, connect the line to the antenna terminals of the antenna impedance meter. When using twin lead, do not let it lie on the ground, the floor, or on any metallic objects but see it hangs clear. The case of the instrument should be ungrounded. Set the impedance dial to zero and leave the end of the line open. By varying the generator frequency, find the lowest frequency at which the null occurs. This may be approximated by the standard formula:

$$F_{(MHz)} = 75 \times V_p / L_{(m)} \quad \textbf{or} \quad F_{(MHz)} = 246 \times V_p / L_{(ft)}$$

Where:

F = Frequency in Mega Hertz
V_p= Velocity of Propagation (of the transmission line)
L = Length (of the transmission line, in meter or feet)

The frequency indicated by the generator is the that at which the line is one-quarter wavelength long, since the quarter wave open line will appear as a short circuit at its input terminals.

Shift the generator frequency to any odd number of times the frequency just found and the null will again occur because the above characteristic holds a true at odd quarter wavelengths.

Now, as of general interest, leaving the generator set at the original frequency, connect a non-reactive resistor equal to twice the line surge impedance at the end of the quarter wave section. Rotate the LIM-870 dial until a new null is noted. He generator frequency may have to be slightly retrimmed during this operation. The resistance reading found will be half that of the line surge impedance:

$$Z_S = \frac{Z_O^2}{Z_R}$$

Where:

Z_O = Line Surge Impedance (Transmission Line Property)
Z_S = Input Impedance (Measured with LIM-870)
Z_R = Load Impedance (Terminating resistor)

Transmission lines – Half wave lines
Connect the line to the instrument as above but this time short the end of the line. With the LIM-870 dial set at zero, find the lowest frequency at which the null occurs. This will be the half-way frequency of the line, since the half-wave line will repeat whatever is connected at its far end, which in this case is the short-circuit. Any multiple length of the half wave will produce the same result.
Now connect a non-reactive resistor of any value within the range of the LIM-870 at the far end of the line. Rotate the dial for the new null, slightly readjusting the generator frequency if required. The indicated value shown on the impedance scale should be that of the test resistor, because as already shown, a half wave line will repeat its load.

Transmission lines – Surge Impedance
Connect a section of line, open at its far end, to the LIM-870 and find the frequency at which it is one-quarter wavelength long, as described above. With the generator frequency left set, connect a non-reactive resistor at the far end of the line and find the new null by rotating the impedance dial. Using this reading, the line impedance may be calculated from

$$Z_O = \sqrt{Z_S \times Z_R}$$

Where:

Z_O = Line Surge Impedance (Transmission Line Property)
Z_S = Input Impedance (Measured with LIM-870)
Z_R = Load Impedance (Terminating resistor)

The inverted impedance may fall outside the range of the instrument if the test resistor value is too far different from that of the line impedance. A Different size test resistor must then be employed. Suggested resistor values when the line impedance is approximately known are 30 or 100 Ω for lines near 50 or 70 Ω, 50 or 200 Ω for these near 100 Ω, and 200 or 600 Ω for those near 300 Ω.

Antenna resonance and resistance
It may seem strange to consider finding antenna resonance by any other means that the dip meter method when a transistor dip meter is already on hand to use with the Antenna Impedance Meter. However, there are cases where a reading by the dip meter method is difficult to obtain, especially when the antenna is of low Q, or when the element diameter is large. In other situations it may be physically impractical to reach the point at the antenna required for accurate measurement. It is also often impossible to obtain sufficient coupling to a long wire or low frequency antenna, even if it were accessible for measurement. The LIM-870 may be employed directly at the antenna or at a convenient point removed from the antenna. Resistance and resonance measurements may be made in one operation because the antenna impedance is resistive at resonance.

Occasionally reference to the standard antenna formula will materially aid in correlating readings. From the following data it will become apparent that the LIM-870 will be used in several different ways, either separately or in other combinations to achieve the same paramount end result of getting the antenna tuned up and the transmission line matched up for optimum results. The procedure to follow is a matter of convenience and depends upon the problems in each individual case,

Antenna – half wave dipole
If the centre of the antenna is within reach when it is in normal position, the LIM-870 may be connected directly at the centre, as shown in Figure 6. The centre of the antenna must be open in order to connect it to the instrument. The leads at this point should be absolutely no longer than is necessary to make the connection. The binding post can be screwed down tight on the connecting leads and will be sufficient to hold the instrument. In any event, do not support the instrument by holding the case by hand because this will produce serious unbalance. The frequency range to employ at the generator may be ascertained by first approximating the antenna frequency according to the standard formula:

$$F_{(MHz)} = 150 \times {}^{0,95}\!/\!_{L_{(m)}} \quad \text{or} \quad F_{(MHz)} = 492 \times {}^{0.95}\!/\!_{L_{(ft)}}$$

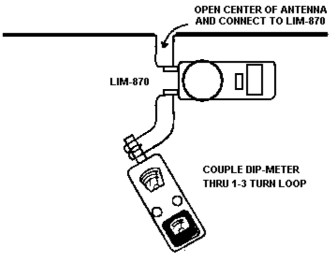


FIGURE 6

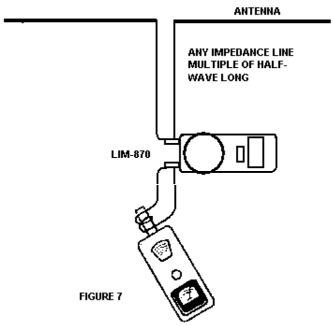


FIGURE 7

Set the LIM-870 dial near 50 Ω and vary the generator frequency until the best null is indicated. Then rotate the impedance dial until the complete null is realised. The generator frequency may have to be slightly readjusted before the complete null is found. The antenna resistance will then be indicated by the dial reading of the LIM-870 and the antenna resonance frequency will be that at which the generator is now set.

Resistance readings will vary between 10 and 100 Ω being mainly dependent upon exact height above ground and upon nearby elements or other objects. Tests on half-wave antennas at various heights above ground have indicated close adherence to the standard curves of resistance versus height when the measurements were made under similar conditions. Do not expect indoor antennas to behave in the normal manner as their characteristics vary to a surprising extent.

At frequencies above 50 MHz, the readings are apt to be effected by the presence of the instrument at the centre of the antenna and/ or the presence of the person making measurements. Readings will then have to be obtained at a point removed from the immediate proximity of the antenna. This will also be necessary when an antenna is inaccessible for direct readings. It was demonstrated earlier that a half wave line repeats its load as seen from the sending end. Thus a half wave line or any multiple thereof may be connected to the centre of the antenna and the measurement may be made at the lower end of the line. See figure 7. These readings will then be a duplicate of those obtainable directly at the antenna, regardless of line impedance as long as the line is an exact half wave of the antenna frequency.

Now the question may arise as to how the correct half wave length may be determined in view of the fact that the antenna resonant frequency is one of the unknowns to be measured. Although measurements of existing antennas may be desired, it is recommended that the antenna system be tuned or adjusted to a prescribed frequency in order to assure peak performance. This will generally be the eventual step anyway and it will simplify remote readings because the half wave line may be first cut to the specific frequency using the antenna impedance meter method, described earlier, following which the antenna may be trimmed to the correct frequency according to the readings obtained with the instrument at the lower end of the line. The best procedure for existing antennas is to calculate the antenna frequency approximately by the standard formula and than use this as the basis for ascertaining the frequency for the half wave line. The alternative method is to use a line of impedance near that of the expected value of the antenna resistance. The mismatch will probable not be too great and the error will be slight. If the antenna is within reach and if a dip meter measurement is possible, the frequency may be found accordingly. It is obvious that this will apply mainly when the resistance only is to be read or when the resonant frequency is to be confirmed.

The half wave line should run at a right angle away from the antenna for a distance of at least a quarter wave length to minimise unwanted coupling to the antenna. If open wire or twin lead is utilised, twist the line about one turn every two feet (half a meter). This will tend to cancel out line unbalances to ground which may affect the reading, particularly since the LIM-870 is in itself an unbalanced device. The case of the instrument should always be insulated from ground and it should be placed so as to minimise capacitance between the case and nearby grounded objects. Line unbalance may be checked by reversing the connections at the antenna terminals. Little change, if any, should be noted in the readings. With high frequency antennas it is usual best to employ a line several half waves long to reduce the effect of personal body presence. If the LIM-87o should read above zero when the antenna or line is connected to the instrument, and when no generator signal has yet been applied, most likely RF energy is being picked up from some nearby broadcast station or other high power source. This has been experienced with several cases involving 3.5 MHz antennas. Often just reversing the line is sufficient to drop reading down to zero. If this does not rectify the situation, about the only other remedy is to wait for the interference to cease. By using headphones in the phone jack of the LDM-815, the interfering signal may be identified.

Antennas – Folded dipoles

Measurements may be made in the same manner as with the normal dipole. See Figure 8. If any frequency check is to be made with the dip meter method, the open centre must first be shortened. Resistance readings of folded dipoles will generally run between 150 and 350 Ω. In some cases it may be possible to obtain a second null in the 500 Ω region at a slightly different frequency. This is due to the following. Refer to Figure 9. The overall length A determines the natural period of the antenna. However, each half of the antenna, sections B and C, are lines quarter wave long at a frequency which may differ slightly from the overall frequency depending upon the height above ground or upon the presence of other elements. With open wire or tubing this is usually not pronounced and is of little consequence but with a folded dipole made of twin lead, this effect will be quite apparent with a wider frequency difference due to the velocity of propagation factor of the twin lead. The frequency of the quarter wave sections being about 86% lower from that of the overall natural period. The net result of this situation narrows the frequency versus impedance response and the twin lead folded dipole then no longer embodies as broad a characteristic as that of the open wire type. The correct antenna impedance meter reading will be the one found at the higher frequency. The usual suggested method of altering this situation is that of inserting a fixed capacitor in series with each short end.

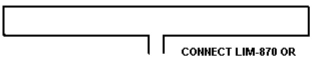


Figure 8

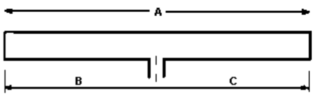


Figure 9

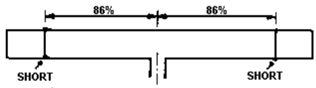


Figure 10

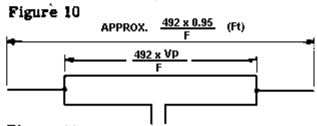


Figure 11

The capacitance depends upon frequency, being approximately 7 pF per meter. An alternative method which is more practical is to connect another short across each section at approximately 86% of the distance from the centre as shown in Figure 10. The quarter wave sections will then be each nearly tuned to the overall natural period of the antenna and the impedance characteristic will be broadened.

A corrected twin lead folded dipole may be easily and accurately set up trough the employment of the LIM-870. First cut a length of twin lead to an electrical length of a half wave at the desired frequency, using the instrument as described earlier. Then place permanent shorts across each end of the line and the at exact centre open one side of the line for the feed point. Now add equal lengths of wire at each end of the twin lead so that the total length of antenna will be slightly longer than the calculated formula. See Figure 11. Then using the antenna impedance meter, connect it directly or remotely to the centre, trim the end wires equally until resonance is indicated at the desired frequency. If remote measurements are to be made and if the half wave line to be used is made of the same type twin lead, its length will naturally be the same as that of the section installed in the antenna. The properties of this antenna will be approximately the same as those of the ordinary dipole.

Antennas – harmonic Antennas
Antennas made up of any multiple lengths of half waves may be measured at the desired operating frequency by connecting the LIM-870 either directly or remotely at any high current point. As an example, Figure 12 indicates the correct points when using a three half wave antenna. The resistance readings will be only for that at the particular point of measurement. Resonance for this antenna when measured at X_1 will be that of the third harmonic, while readings taken at the centre point X will be those of the fundamental or any odd number harmonic. Readings of other harmonics may be made at points determined by the theoretical location of current loops.

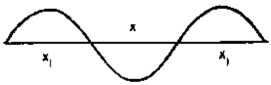


Figure 12

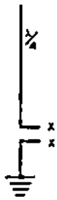


Figure 13

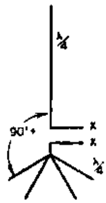


Figure 14

Antennas – Quarter wave vertical and ground-plane antennas
Connect the LIM-870 or half wave line at the normal feed point between the base of the antenna and ground or radials as the situation may require. See Figure 13. The resistance reading will be approximately 35 Ω. Since the resistance at the feed point of the ground-plane antenna may be raised by dropping the radials to form a larger than 90° angle with the vertical element, the LIM-870 is a handy device for determining the correct angle for the desired resistance in any specific case. See Figure 14. The limit obtainable is about 70 Ω at which point the radials will be folded all the way down so they too are vertical and the system then resolves into a form of coaxial antenna. Resonance of the vertical antenna may be adjusted by varying the length of the vertical portion and that of the radials if involved.

Antennas – Mobile Antennas
Quarter wave mobile antennas may be measured for resonance and resistance in the same manner as employed with the vertical antennas. See Figure 15. The average antenna of this type will have about 45 Ω resistance providing a sufficient close match for a 50 Ω line. Base or centre loaded antennas may be likewise checked. Resistance readings will be in the 20 to 35 Ω region. Refer to Figure 16. By correctly proportioning the antenna length in the ratios of L and C, the system may be adjusted so the feed point will have a resistance value to match either 50 or 70 Ω line. The correct adjustment may be determined according to readings found with the LIM-870.

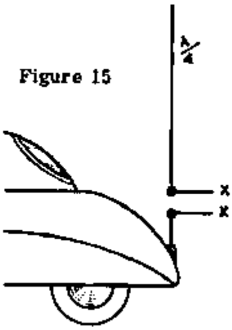


Figure 15

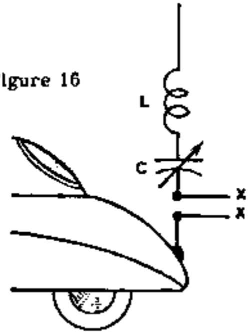


Figure 16

Antennas – Parasitic Beams

Connect the LIM-870 or half wave line at the centre of the driven element as with any half wave antenna. Resistance readings will usually lie between 10 and 100 Ω, being dependent upon the exact spacing and tuning of the other elements. Resonance will also be dependent to some extend upon these factors which will make it difficult to calculate exactly the length of the half wave if needed for remote measurements. For this situation, the antenna system may be tuned to a prescribed frequency with the line cut accordingly as previously suggested. However, in most cases the centre driven element will be accessible, so the instrument may be used directly. Occasionally one or two slightly different frequencies may be indicated by the LIM-870. This is due to reflections from other elements and must be analysed in each individual case. With the beam correctly tuned, only one frequency will be indicated by a complete null at the true resonance frequency. As already stated, partial nulls indicate reactive impedance which will be the incorrect point to consider. It has been found generally good practice to resonate the driven element while the reflector is set at a length about 5% longer than this element and the director set about 5% shorter. The beam adjustment may then be left set since only little improvement will usually be gained over this arrangement by retuning the parasitic elements through the customary lengthy process of checking against field strength readings. But, if finite adjustments of the other elements is desired, it is suggested that the LIM-870 be employed as a means of initially tuning the driven element. The parasitic elements may then be tuned in their usual manner with occasional checks being made for antenna resonance. This latter step may be made with the LIM-870 used as SWR meter as will be subsequently explained.

Adjusting Q Bars

Q bars, as quarter wave transformers, often used as a matching device between an antenna and a transmission line, may be adjusted by connecting the LIM-870 at the line end of the bars, with the other end being connected to the antenna. The spacing between the bars should then be adjusted to obtain the necessary impedance. They must first be cut to the correct length and the antenna must be resonant at the frequency to be used.

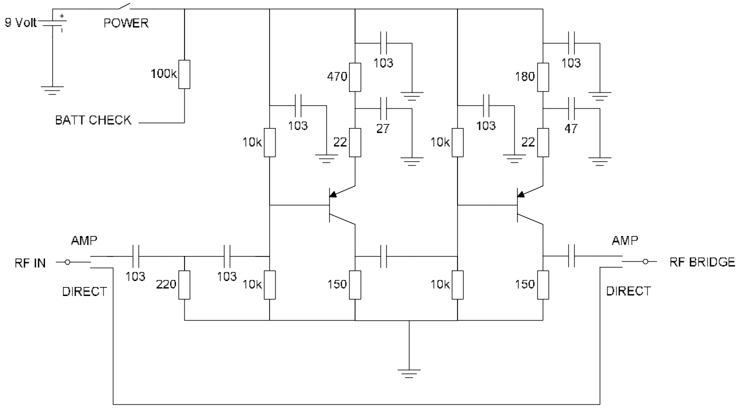
Standing Wave Ratio
If the meter indicates a complete null when the LIM-870 is inserted into the transmission line with the dial set to desired impedance, the indicated SWR will be unity or 1:1. Ratios higher than 1:1 may be determined if the line is a multiple of a half wave long at the resonant frequency involved and if the antenna is resonant. Just rotate the LIM-870 dial while slightly adjusting the generator frequency if required, until the null is found indicating the resistance of the termination. The SWR may then be determined by:

$$SWR = \frac{Z_{LOAD}}{Z_{LINE}}$$

The instrument itself may be calibrated for various ratios but the readings will be inaccurate unless the above conditions prevail. Lines of other lengths will reflect impedance different than that found at the termination and this impedance will be reactive particularly if the antenna is not resonant. The same difficulty of obtaining an accurate reading of SWR other than 1:1 may be found with many current type of SWR meters. As with other measurements, the ideal procedure is to tune up an antenna to a prescribed frequency while matching the line. This may be readily done with the LIM-870 connected at the sending end of the line. In order to avoid confusing nulls, due to line resonances, it is suggested that the length of the line be held shorter than one wave length. Set the instrument dial at the line impedance and vary the generator frequency near that calculated for the antenna, until a null is observed. If this occurs at a point other than at the desired frequency, adjust the antenna until resonance is obtained at the correct frequency as indicated by the LIM-870 null. If the null is incomplete and a variable matching device is being used, it should be adjusted until a complete null is realised at the resonant frequency.
When a matching system such as the T match is employed, an antenna will be affected by these changes. If no variable matching arrangement is used, and if the line is otherwise correctly terminated at the resonant antenna, the meter will indicate a complete null and the SWR will be unity.
Stress is again placed on the fact that the unity ratio cannot be obtained unless the line is not only terminated by an impedance equal to its own impedance, but also that this impedance must be resistive which in turn is not possible unless the antenna is resonant at the frequency involved. When the complete null is realised indicating a 1:1 ratio, the length of the transmission line should be altered by $^1/_8$ or ¼ wavelength to verify the reading. If the SWR has been correctly adjusted to unity, no change should be noted in the meter null.

Receiver input impedance
Connect the LIM-870 to the receiver input terminals and tune receiver to the frequency at which the impedance is to be determined. Set the generator at the same frequency and rotate the impedance dial until the complete null is found. Retrim generator frequency if necessary. As with antennas, the input circuit must resonate at the frequency employed in order to read the resistive component. If the input circuit is tightly coupled as it is on many sets, two impedance readings at slightly different frequencies will be noted. One reading will be low between 10 and 20 Ω and the other reading will be anywhere from 50 to 500 Ω. The reason for this is that the reactance of the coupling loop between the generator and the input side of the LIM-870 reflects upon the tuned input circuit of the receiver, the very low impedance reading being evidenced at this point. Although the loop reactance may be tuned out, moderate accuracy may be had by relying upon the higher reading.

7. Schematics



8. How this manual came about

This manual is based on the Heatkit manual for the AM-1 antenna impedance bridge, adapter for the LIM-870 by PE2ER.