The Antenna Noise Bridge: A Forgotten Tool

By Joseph J. Carr

Modern radio receiver design is especially exciting to an old radio hacker like myself. Having cut my teeth on a Knightkit regenerative SW radio and an elderly Hallicrafters S-20R, and then graduating to the might SX-28A (with a WW II surplus BC-342 along with way), I find modern designs extremely exciting. We can now buy performance that matches the top-dollar Collins 51J4 and R-390 models of yesteryear for about the same price as medium-grade receivers cost a generation ago. While the newcomer who is trying to raise $500 for a receiver might not believe it, that translates to a tremendous price deflation.

In the "good old days" we used nonresonant long-wire antennas. Given receiver performance of the day, there was little incentive to upgrade to single-band resonant antennas. When we wanted to improve performance we added preselectors and other electronic gimmicks but left the antennas alone.Today, receiver performance is usually so good that we now look to the antenna to effect further improvement.

The Forgotten Instrument

Because shortwave listeners can not legally use a transmitter to test antennas, using the VSWR meter as a check of antenna performance is out. However, the SWL can use an antenna noise bridge for a variety of measurements on r-f circuits. The noise bridge is perhaps the most overlooked test instrument that a hobbyist—and especially the SWL—can own.

Over the years several companies have produced noise bridges, mostly for the amateur radio market—among them—Omega-T, Palomar Engineers and others. More recently, the Heath Company has introduced the Model HD-1422 (Fig. 1). Over the years I have used noise bridges for a variety of radio tests and measurements, especially in the hf region. Contrary to popular belief, those applications are not limited to the testing of antennas, which is the main job of the noise bridge.

A noise bridge can be used to measure impedance in r-f circuits at frequencies up to 30 MHz and will give relative indications up to 100 MHz. Impedance consists of resistive and reactive components; the reactance can be either capacitive or inductive, but is zero for a perfectly resonant circuit or antenna. A good noise bridge will measure reactive components as well as resistive.

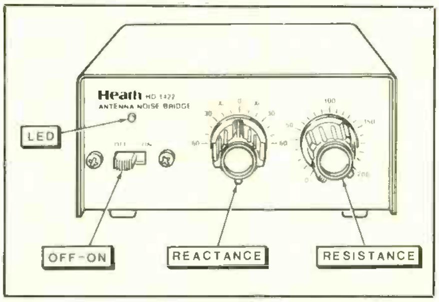

Fig. 1. Heath's HD-1422 noise bridge.

Figure 2 shows the internal details of the HD-1422. Note that the bridge circuit consists of four arms. The inductive arms form a "trifilar" wound transformer over a ferrite core with the input winding of *T101*. A signal applied to the input is injected into the bridge circuit. The "Measurement" arm consists of series circuit *R1/C1*, a 200-ohm potentiometer and a 120-pF variable capacitor. The potentiometer is used to set the range of the resistive component (0 to 200 ohms) of impedance, the capacitor the reactance component.

Capacitor *C2* in the UNKNOWN arm of the bridge is used to balance *C1*. With *C2* in the circuit, the bridge is balanced when *C1* is approximately in the center of its range. This arrangement accommodates both inductive and capacitive reactances, which appear on either side of the "zero" point, which is the mid-range capacitance of *C1*. When the bridge is in balance, the R and C settings reveal the impedance across the UNKNOWN terminals (e.g. your antenna).

Zener diodes normally operate in the reverse-bias mode, which produces a large amount of noise because of the avalanche process inherent in the zenering operation. While that noise is a problem in most applications, in a noise bridge it is highly desirable, and the richer the noise spectrum, the better. The spectrum is enhanced somewhat in the HD-1422 because of the 1-kHz square-wave modulator that chops the noise signal. An amplifier boosts the noise signal to the level needed in the bridge circuit.

The detector used in the noise bridge is your hf receiver. An AM receiver is preferable, but an SSB receiver with a wide i-f bandwidth is also useful. Although it is quite easy to use your ears to detect the noise null that indicates bridge balance, it is best to use a receiver with an S meter. Thus, the best receiver to use is an AM hf model that is equipped with an S meter. If your antenna lacks an S meter, you can use an old-fashioned (analog) ac voltmeter across the receiver's speaker output. Since antennas are not always convenient to ac power, you might consider adding "battery-powered" to the list of attributes required of the receiver.

Adjusting Antennas

Perhaps the most common use for the antenna noise bridge is finding the impedance and resonant points of an hf antenna. To make this measurement, connect the RECEIVER terminal of the HD-1422 to

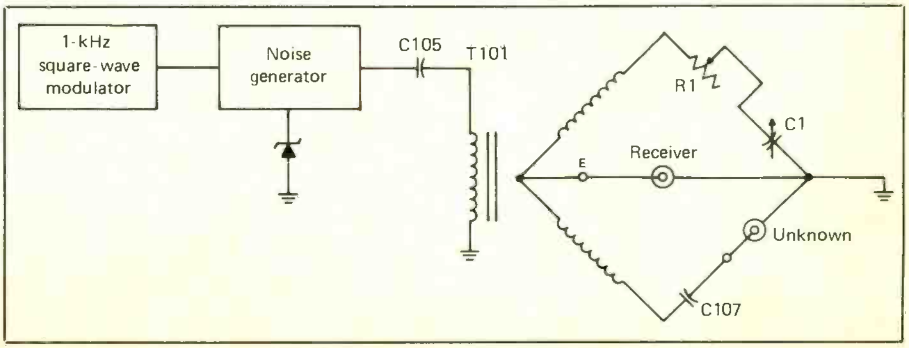

Fig. 2. Internal details of HD-1422.

the ANTENNA input of the hf receiver through a short length of coaxial cable as shown in Fig. 3.

The Coax length should be as short as possible, and the characteristic impedance should match that of the antenna feedline. Next, connect the antenna's coaxial feedline to the ANTENNA terminals on the HD-1422. You are now ready to test the antenna.

Finding Impedance. Set the noise bridge's RESISTANCE control to the antenna feedline impedance (usually 50 or 75 ohms for most amateur antennas) and the REACTANCE control to mid-range (zero). Now tune the receiver to the *expected* resonant frequency (F_{exp}) of the antenna. Turn on the noise bridge and look for a noise signal of about S9 on the S meter. This will vary on different receivers.

Adjust the RESISTANCE control (R) on the bridge for a null (minimum noise as indicated by the S meter). Next, adjust the REACTANCE control (C) for a null. Repeat these adjustments until you obtain the deepest possible null, as indicated by the lowest noise output on the S meter. Because there is some interaction between the two controls, it is important that you trim both repeatedly until no lower reading can be obtained.

A perfectly resonant antenna will have a reactance reading of zero ohm and a resistance of 50 to 75 ohms. Real antennas may have some reactance (the less the better), and a resistance different from the ideal 50 or 75 ohms. Impedance-matching methods can be used to transform the actual resistive component to the 50- or 75-ohm characteristic impedance of the transmission line. If the resistance is close to zero, there is most likely a short circuit on the transmission line. Conversely, if the resistance is close to 200 ohms, the line most likely has an open circuit.

A reactance reading on the X_L side of zero indicates that the antenna is too long, while a reading on the X_C side of zero indicates an antenna that is too short. An antenna that is too long or too short should be adjusted to the correct length to obtain optimum performance.

To determine the correct length, you must find the Actual Resonant Frequency, or A.R.F. To do this, reset the REACTANCE control to zero, and then *slowly* tune the receiver in the proper direction—downband for too-long and upband for too-short—until the null is found. On a high-Q antenna the null is easy to miss if you tune too fast. Don't be surprised if the null is out-of-band by quite a bit. The percentage of change is given by dividing the expected resonant frequency (F_{exp}) by the A.R.F. and multiply by 100: Change = $(F_{exp} \times 100\%)/\text{A.R.F.}$

Resonant Frequency. Connect the antenna, noise bridge and the receiver in the same manner as above. Set the receiver to

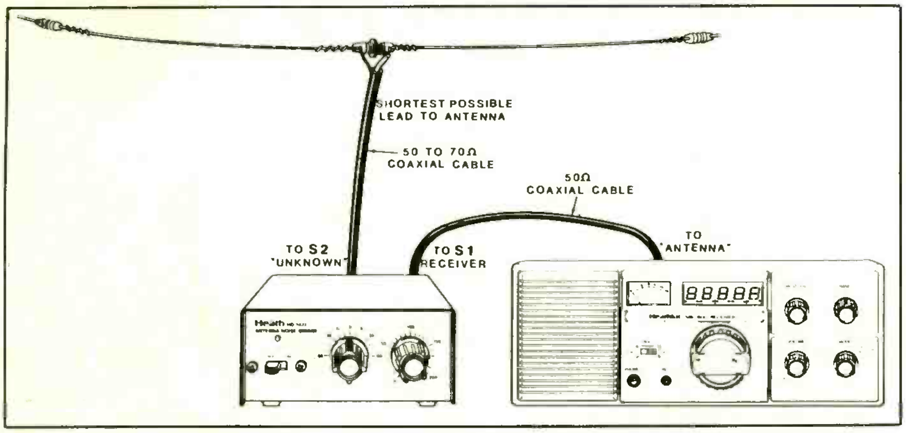

Fig. 3. Finding the impedance and resonance points of an hf antenna with a noise bridge is accomplished with setup shown.

the expected resonant frequency—468/F for half-wavelength types and 234/F for quarter-wavelength types. Set the RESISTANCE control to 50 or 75 ohms, as appropriate for normal antenna and transmission-line impedance. Set the REACTANCE control to zero. Turn on the bridge and listen for the noise signal.

Slowly rock the REACTANCE control back and forth to determine on which side of zero the null appears. Once the direction of null is determined, set the REACTANCE control to zero, and then tune the receiver towards the null direction, which is down-band if null is on the X_L-side and up-band if it is on the X_C side.

A less-than-ideal antenna will not have an exact 50- or 75-ohm impedance. So some adjustment of the R and C controls must be made to find the deepest null. You may be surprised at how far off some dipoles and othe types of antennas can be if they are not in "free space" (close to the Earth's surface).

Nonresonant Antenna Adjustment

Antennas can operate on frequencies other than their resonant frequency if you know its impedance (R and X components) and provide a matching network to provide impedance transformation. After setting up the receiver and noise bridge as in the first case above, tune the receiver to the desired operating frequency. Find the nulls for R and X, and note the scale readings. The X readings are not the reactance in ohms, but rather the capacitance (0 to 60 pF). You can now calculate the normalized reactance at 1 MHz as follows: $X_C = X = [159{,}155/(68 - C)] - 2340$ and $X_C = X = 2340 - [159{,}155/(68 + C)]$. Then plug the *X* value into $X_F = X/F$, where *F* is the desired frequency in MHz.

Other Jobs

The Heath HD-1422 noise bridge can be used for a variety of jobs, such as finding the values of capacitors and inductors, characteristics of series and parallel tuned resonant circuits, and adjusting transmission lines.

Transmission Line Length. Some antennas require antenna feedlines that are either quarter- or half-wavelength at some specific frequency. Use the HD-1422 to find these lengths as follows:

(1.) Connect a short-circuit across the UNKNOWN terminals of the HD-1422 and adjust R and X for the best null at the frequency of interest (both will be near zero);

(2.) Remove the short-circuit;

(3.) Connect the length of transmission line to the UNKNOWN terminal—it should be longer than the expected length;

(4.) For quarter-wavelength lines, shorten the line until the null is very close to the desired frequency. For half-wavelength lines do the same thing, except shorten the line at the far end for each trial length.

Transmisssion Line Velocity Factor. The velocity factor (usually expressed by the letter "V") is a decimal fraction that tells how fast the radio wave propagates along the line relative to the velocity of light in free space. For example, coaxial cable with a foam dielectric has a velocity factor of 0.80, which means that radio signals travel along the line at 0.8 times the velocity of light.

Since all radio wavelength formulas are based on the velocity of light, you need the V value to calcute the physical length needed to equal any given electrical length. For example, a half-wavelength piece of coax has a physical length of $(492 \times V)/F_{MHz}$ feet. Unfortunately, the real V value is often quite different from the published value. You can use the HD-1422 to find the actual value of V for any given sample of coaxial cable as follows:

(1.) Select a convenient length of the coax more than 12 feet in length and install a PL-259 coaxial connector on one end and short-circuit the other end.

(2.) Accurately measure the length of the cable in feet (either cut off the shorted end to the nearest foot, or convert the spare inches to tenths of a foot—don't forget to reconnect the short circuit.

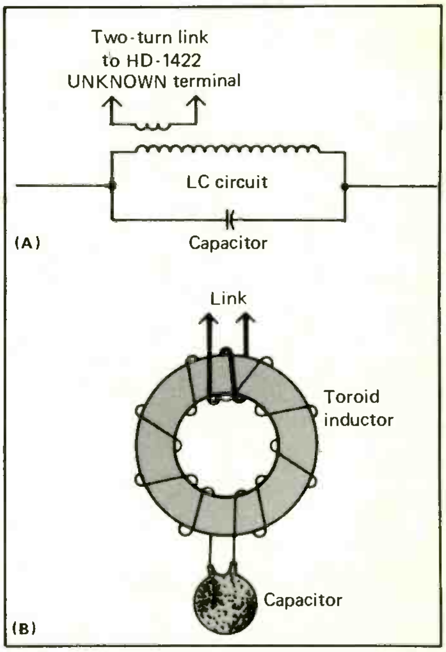

Fig. 4. Making measurements in a parallel-resonant circuit requires loop coupler. Different approaches are required for axial and toroidal coils.

(3.) Set the HD-1422's RESISTANCE and REACTANCE controls to zero.

(4). Adjust the receiver for deepest null. Use the null frequency to find velocity factor V = FL/492, where *V* is velocity factor (a fraction); *F* is frequency in MHz; and *L* is length in feet.

Tuned-Circuit Measurements

An inductor/capacitor (LC) tuned "tank" circuit is the circuit equivalent of a resonant antenna, so there is some similarity between the two measurements. You can measure resonant frequency with the noise bridge to within ±20 percent or better if care is taken. This accuracy may seem poor, but it is better than one can usually get with low-cost signal generators, dip meters, absorption wavemeters and the like.

Series Tuned Circuits. A series tuned circuit exhibits a low impedance at resonance and a high impedance at all other frequencies. Start by connecting the series tuned circuit under test across the UNKNOWN terminals of the HD-1422. Set the RESISTANCE control to a low resistance value, close to zero ohms. Set the REACTANCE control at mid-scale (zero mark). Next, tune the receiver to the expected frequency, and then for the null. Make sure the null is deepest by rocking the R and X controls for best null. At this point, the receiver frequency is the resonant frequency of the tank circuit.

Parallel Resonant Circuits. A parallel resonant circuit exhibits a high impedance at resonance and a low impedance at all other frequencies. The measurement is made in exactly the same manner as for the series resonant circuits, except that the connection is different. Figure 4 shows that a two-turn "link" is needed to inject a noise signal into the tank circuit. If the inductor is a toroidal type, the link must go through the hole in the doughnut-shaped core and then connects to the UNKNOWN terminals of the noise bridge. After this, do exactly the same as you did for the series tuned circuit.

Capacitance and Inductance

The HD-1422 noise bridge comes with a 100-pF mica test capacitor (CTEST) and a 4.7-μH test inductor (LTEST), which are used to measure inductance and capacitance, respectively. The idea is to use the test components to form a series-tuned resonant circuit with an unknown component. If you find the resonant frequency, you can calculate the unknown value. In both cases, the series tuned circuit is connected across the UNKNOWN terminals of the HD-1422, and the series-tuned procedure above is followed.

Inductance. To measure inductance, connect the 100-pF CTEST in series with the unknown coil across the UNKNOWN terminals of the HD-1422. When the null frequency is found, find the inductance: L = 253./F^2, *L* is the inductance in microhenrys (μH) and *F* is the frequency in megahertz (MHz).

Capacitance. Connect LTEST across the UNKNOWN terminals in series with the unknown capacitance. Set the RESISTANCE control to zero, tune the receiver to 2 MHz, and readjust the REACTANCE control for null. Without readjusting either noise bridge control, connect LTEST in series with the unknown capacitor and retune the receiver for a null. Capacitance is now C = 5389/F^2, where *C* is capacitance in picofarads (pF) and *F* is frequency in megahertz (MHz).

Conclusion

The Heath HD-1422 noise bridge is an easily constructed kit of simple but good design. It is also an immensely useful tool. I recommend that all radio hobbyists who listen or experiment in the medium-wave and high-frequency shortwave bands purchase and use one of these instruments. ME