Antennas

More on HF magnetic loops and impedance measurements

PHOTO 1: HP4085 vector impedance meter. The meter on the left indicates Zmag in ohms while the right hand meter indicates Theta in degrees.

RF CONDUCTORS. In the September Antennas I described a loop antenna tuned by a capacitor that consisted of two aluminium plates fixed on hinges at the ends of the copper loop. One of the issues with this design was how to reduce the RF resistance across the capacitor hinges. The mechanical arrangement of these hinges, although made of brass, would probably present a relatively high RF resistance, which I said could be circumvented using coax cable braid.

The advantage of braid in this application is its flexibility. Some people question the effectiveness of braid at radio frequencies. The argument is that each strand of the braid weaves in and out and back and forth across the braid. Currents must either follow that inductive weaving path, or jump from strand to strand where strands touch. There are, of course, many individual strands in parallel, so overall inductance should be low. Tinned copper braid is probably best because oxidation between various strands of bare untinned copper braid may degrade performance.

Having said that, most coaxial cables for RF applications have a braided outer conductor to give them flexibility. The better grades use tinned braid. Very high performance low-loss coaxial cables use a solid outer conductor.

Copper strip is the best type of RF conductor because has the greatest surface area for a given amount of copper. Due to the skin effect, RF currents tend to flow along the outside surface of a conductor. Copper strap has a large, smooth surface area to take full advantage of this effect.

The disadvantage of copper strap is that it is not flexible and is unsuitable for bonding straps across the hinges of our loop capacitor. G8JNJ [1] tried thin sheet brass (obtained from a model shop) to make the bonding straps on the capacitors of his loop antenna. While brass does not have the conductivity of copper, he does report that it seemed to improve the Q slightly compared to using copper braid, although no actual figures are supplied. Another type of material that might be suitable for this purpose is phosphor bronze strip (used in door draught excluders).

MAKING COPPER STRIP. If you have difficulty in finding a source of copper strip for parts of a loop made from copper tubing (other than the capacitor hinge bonding strip mentioned above) you can make it from readily available 22mm or 15mm copper pipe. A short length of heavy duty strip suitable for fixing the SO239 socket to the loop can be made by flattening a short length of 22mm copper pipe in a vice. Smaller and thinner copper straps for making the shunt match connection to the loop can be made from flattened 15mm copper pipe. The edges of the flattened pipe are then filed down until it breaks into two thin strips.

OTHER COMMENTS ON THE LOOP. One of the oddities of the model shown in **Figure 1** is that the nulls in the sides of the azimuth plot are not very deep compared with a free space dipole. Measuring the nulls of the real loop using a selective level meter resulted in nulls of –20dB on one side and –11dB on the other; the cause of this asymmetry at the time of writing is unknown. The coax feed to the loop should be routed vertically down from the loop to the ground to get the best SWR and to minimise common mode currents on the coax. A current choke would also be of some help in this regard.

G8JNJ suggests making the capacitor plates teardrop shaped. This would give a smaller minimum capacitance and make the angular movement of the plates relative to frequency more linear.

RF MEASURING INSTRUMENTS. Many of you are aware my main interest is RF measuring instruments and their uses. For many years, the most popular and practical instrument for measuring the most useful of parameters, impedance, was the R±jX noise bridge.

There are times when measurements accuracies greater that provided by the standard noise bridge are required, particularly when the results have to be committed to print. I had used the 3-meter instrument [2] to good effect for many years but what was really needed was some sort of standard. Over a period of time, I acquired two old commercial instruments capable of making precision measurements.

The first was a General Radio 1606 Impedance Bridge, which I bought in 1985. This instrument comprises a precision bridge with variable calibrated components. As with all bridges of this type the bridge is energised using a signal generator. The bridge measures

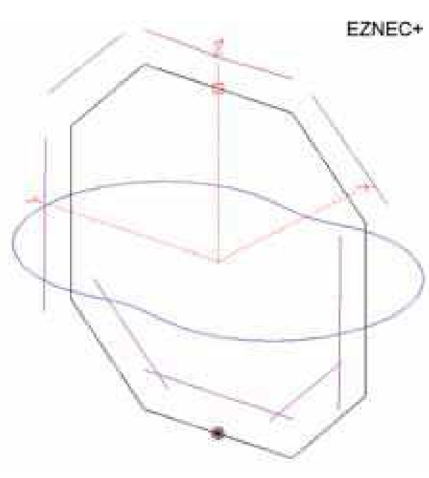

FIGURE 1: *EZNEC 5* free space model of the G3LDO magnetic loop antenna showing current distribution (red) and azimuth radiation diagram (blue).

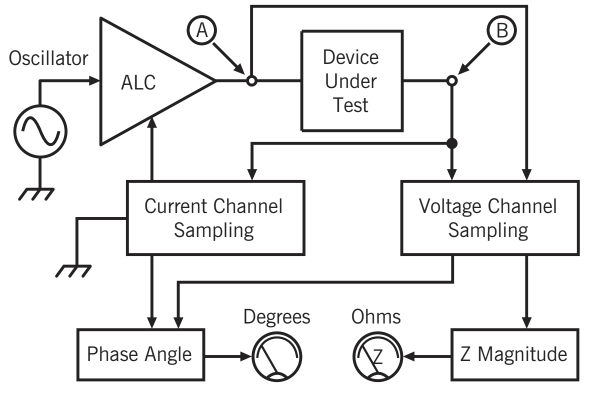

FIGURE 2: Simplified block diagram of the HP 4085 vector impedance meter. The device under test is connected to terminals A and B.

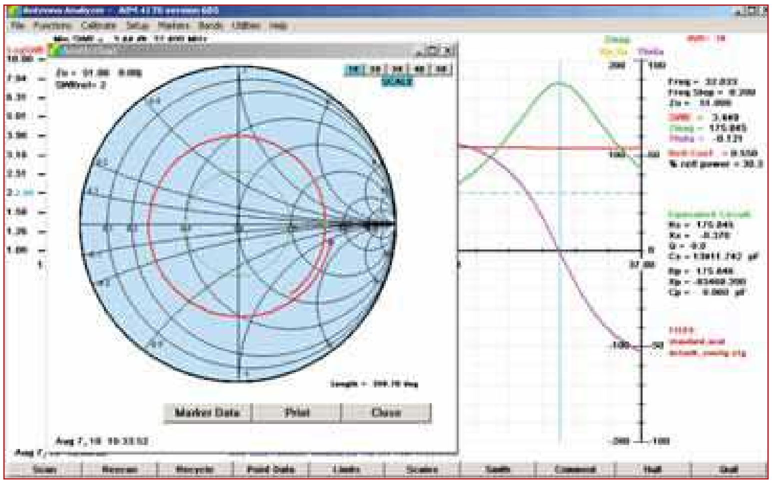

FIGURE 3: An AIM 4170 display showing a Smith chart superimposed on swept frequency graph, the result of measuring a 200Ω resistor over a three metre length of RG58.

the impedance presented to the UNKNOWN socket by adjusting calibrated components for a dip (or null) in a detector, usually a communications receiver with an S-meter. The impedance (R±jX) is measured on the dials of the bridge-calibrated components at the point of maximum dip.

While the GR 1660 gave good results, its weight of 10.5kg (23lb) together with an appropriate signal generator and communications receiver represented a lot of equipment for making an impedance measurement.

Later, I obtained a HP4085 vector impedance meter at a radio rally. At 17.6kg (39lbs), this instrument is heavier than the GR 1660 but has the advantage of being self-contained with its own signal generator supplying test signals from 0.5 to108MHz. This instrument doesn't have calibrated bridge components and a null detector. Instead, it measures impedance directly by comparing the ratio of voltage and current injected into the circuit or antenna under test. An automatic level control circuit (ALC) holds the current constant so that the impedance magnitude is directly proportional to voltage. Phase angle is measured by detecting the phase relation between the voltage and current waveforms. Impedance is read out directly on two meters, one showing impedance magnitude and the other phase as shown in **Photo 1** and **Figure 2**.

It measures the impedance using a probe and presents these measurements in terms Zmag/Theta. In the days when this instrument was state of the art (circa mid 60s), HP provided a slide rule calculator to convert these polar coordinates into the more familiar R±jX format.

VECTOR IMPEDANCE ANALYSERS. These instruments have been around for some time now (the first I heard of them was in the September 2004 Technical Topics). Vector impedance analysers are now commercially available. There is the miniVNA from Mini Radio Solutions and the AIM 4170, designed by Bob Clunn, W5BIG, which was reviewed in *RadCom* **[3]**.

I bought an AIM 4170 early in 2007 after being inspired by it during a visit to Dayton. It has been used for the analysis of antennas and baluns in Antennas columns since August 2007. It is very intuitive to use with only occasional recourse to the instruction book being necessary.

A length of feeder acts as an impedance transformer, the ratio of which varies with frequency. This means that the impedance you measure at the end of the feeder will generally not be the feed impedance of the antenna if you are using one of the instruments described earlier. There is an exception and that is when the feeder is an electrical half wavelength long. In this case the transmission line theoretically acts as a 1:1 transformer but note the measurement described below.

One of the features of the AIM 4170 is its ability to calibrate the feeder between the instrument and the device under test, which circumvents the problem described above.

The AIM 4170 performs a number of parameter measurements over a given swept frequency range; the most well known being SWR and impedance. This latter parameter is given in Zmag/Theta and/or the more familiar R±jX. It will also plot Reflection Coefficient and Return Loss; it'll even do all these parameters at the same time if so desired. Mind you, if you try to display them simultaneously the display gets a bit messy so in practice I generally stick with just SWR and impedance.

The AIM 4170 also has Smith chart display. This is a useful feature for checking the accuracy of this type of instrument. The display shown in **Figure 3** is Smith chart superimposed on a swept frequency graph, being the result of measuring a 200Ω resistor (one that came with the calibration pack) over a three metre length of RG58.

The green circle is a SWR 2:1 marker. It can be seen that the actual plot (shown in red) is a smooth circle showing a tendency to spiral towards the centre as the frequency is increased; an effect caused by coax cable loss. Any errors with measurements will cause irregularities in the smoothness of this plot.

In the background plot of Figure 3, you can see a green marker placed over the point where Theta is zero. This is the half wavelength point away from the 200Ω load. The data to the left of the display shows the Zmag and Rs both 175.8Ω. At a full wavelength, it was 158Ω. I had not appreciated how much the cable attenuation would affect the divergence from the 1:1 transforming ratio but it is obvious when you think about it.

I have only just scratched the surface of what this instrument can do. If you wish to know more then I recommend you attend the RSGB 2010 Convention on Sunday 10 October **[4]** where Ian Wade, G3NRW, is giving two presentations on the AIM 4170 antenna analyser. The first will cover the basics of antenna measurement, and the second will illustrate the use of the 4170 as a design tool.

Live demonstrations of the AIM 4170 will be the main feature of the presentations, and will include tuning a 4m ground plane, trap tuning, designing a 160/80m trap dipole, measuring quartz crystal parameters, using the Smith chart, quarter-wave stub tuning and measuring the impedance at the antenna feedpoint. The final demonstration will show how to control the analyser remotely via a Wi-Fi link, allowing you to tune your antenna while standing in the garden (or on the roof or at the top of the tower). The presentations will be based on the material at G3NRW's website **[5]**.

REFERENCES

[1] http://g8jnj.webs.com
[2] *The Antenna Experimenter's Guide*, Second Edition, Peter Dodd, G3LDO.
[3] *RadCom* July, 2007
[4] RSGB Convention: www.rsgb.org.uk/rsgbconvention
[5] http://homepage.ntlworld.com/wadei/aim4170.htm