
Loop and Dipole Antennas Measurements

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Background.

David Jefferies mentioned his idea for the Zagi antenna to Johnny Johnstone, and described the simulations made by Dan Handelsman to explore the concept. The reports of these simulations appeared in the March 2004, issue of *antenneX* (now in Archive VI). It was decided to make versions of these Zagi antenna elements for careful measurements. These measurements will be reported in a future article.

Initial attempts to make measurements of antennas about 30-50cms long in the open laboratory were not very successful, both on account of reflection and absorption by nearby objects in the lab, and also because the laboratory contained a plethora of interfering signals, which varied over time. See **Figure 1**.

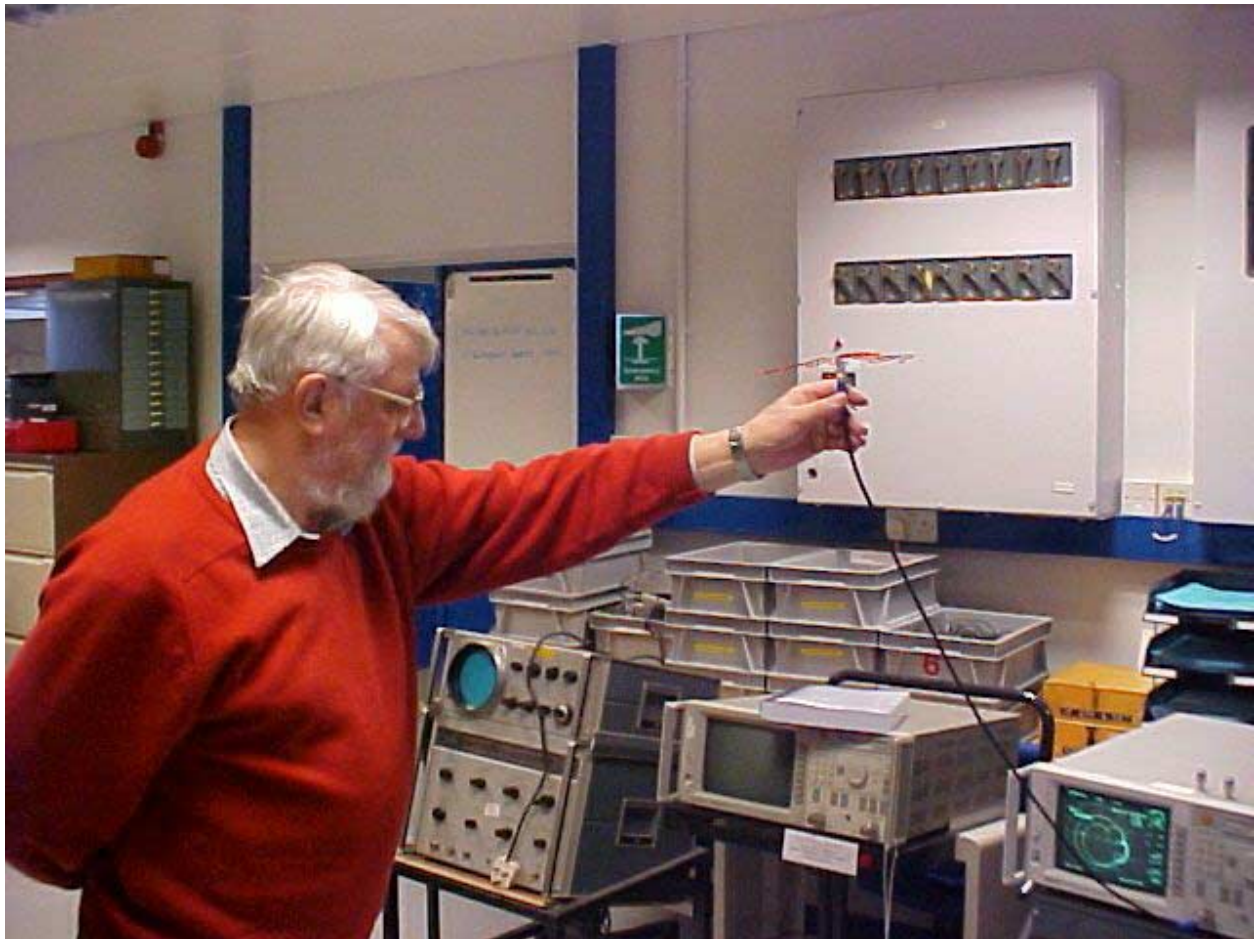


Fig. 1

Johnny Johnstone suggested that we try to make careful measurements on simple structures in a quiet environment first, before trying to interpret any of the behaviours observed for the Zagi elements.

Therefore, the measurement site was moved to a screened damped room, with 20cm thick tapered absorbers on the walls. See **Figure 2**.

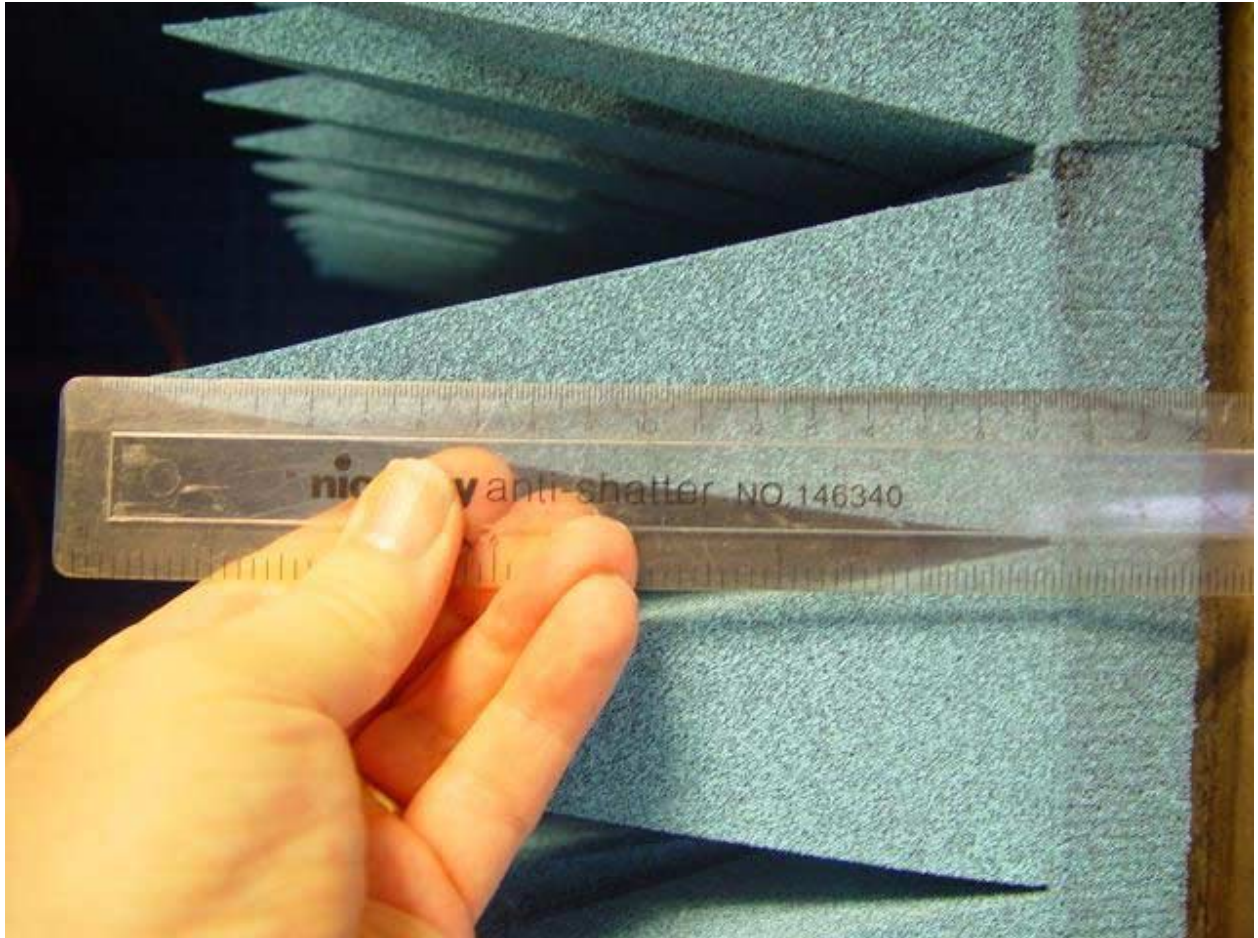


Fig. 2

It is believed that this room is quite a good anechoic environment at frequencies above about 1500MHz (1.5GHz) where the absorber materials are 1 wavelength thick. Measurements on simple loops and dipole antennas are reported in this present article, to illustrate some of the snags, difficulties, and ameliorative measures which allow reasonable measurements to be made on these kinds of antenna elements down to several tens of MHz in this screened damped chamber. It will be seen that the results are much better than the measurements made in the open lab. The exercise also gives us a good idea of the hazards real antennas have to face when installed in their operating environments, and also indicates the variations from the idealised NEC model which a real antenna installation may experience.

Some of the experimental plots reported in this article are compared with NEC results provided by Dan Handelsman, for which we are very grateful.

Dipole measurements.

First, we constructed a simple wire dipole by soldering two 125 mm lengths of tinned copper wire to a BNC connector. The wire diameter, as measured with an electronic micrometer, was 1.4 mm plus or minus 0.05 mm. The overall length of the dipole was 256 mm plus or minus 2 mm, with a gap at the feed of 6 mm plus or minus 1 mm. The HP 8714C network analyser used for these measurements was calibrated using the supplied cal kit. **Figure 3** shows the resulting trace



Fig. 4

Various wiggles[1] are seen on this broadband sweep, which turns out to be due to cable and room resonances. The dipole couples more strongly to the cable and the room at the higher frequencies, but the room itself is better damped at these higher frequencies. At the lower frequencies the room resonances are more lightly damped, but the antenna is not very efficient and so couples less well to them. We notice the reduction in the sizes of the wobble loops at the high frequency side of resonance after the antenna is moved into the damped, screened room. But it is clear that the cable is coupling to the dipole.

Note that the trace on the SMITH chart plot runs clockwise around the chart from lower to higher frequency.

The dipole was then isolated from the feed, to some extent, by using a ferrite clamp placed around the coaxial cable just behind the feed point. This is a first attempt at suppressing the outer sheath currents. We didn't attempt to make a resonant balun as we wanted to be able to sweep the frequency over several orders of magnitude. We then observed the SMITH chart sweep shown in **Figure 5**, with resonance at 547.6 MHz and impedance at resonance 72.6 ohms. Compared to **Figure 4**, we observe a 2% reduction in indicated resonant frequency and a 6% increase in resistance at resonance. We are beginning to appreciate the quantitative effects of the cable coupling.



Fig. 5

Finally, the sweep range was set to 1MHz to 801MHz, and the cable was suppressed with five additional ferrite sleeves as shown in **Figures 6, 7, and 8**. The cable length is 2 metres, and so the ferrite beads are spaced every 500 mm which is about a wavelength (in free space) at the resonant frequency of the half-wave dipole. The trace shown in **Figure 9** was then obtained, with resonance at 546.8 MHz and impedance at resonance of 72.25 ohms. This represents an additional change of minus 0.15% in resonant frequency and of minus 0.5% in resistance at resonance. The curve looks smooth and very much what we see in the NEC prediction (figure 10). The resonant frequency corresponds to a free space half-wavelength of 274.3 mm compared to our dipole of length 256 mm, which is 93.3% of the half-wavelength, in line with the expected theoretical shortening. The equivalent NEC prediction is shown in **Figure 10**, courtesy of Dan Handelsman. *Thanks, Dan.*



Fig. 6

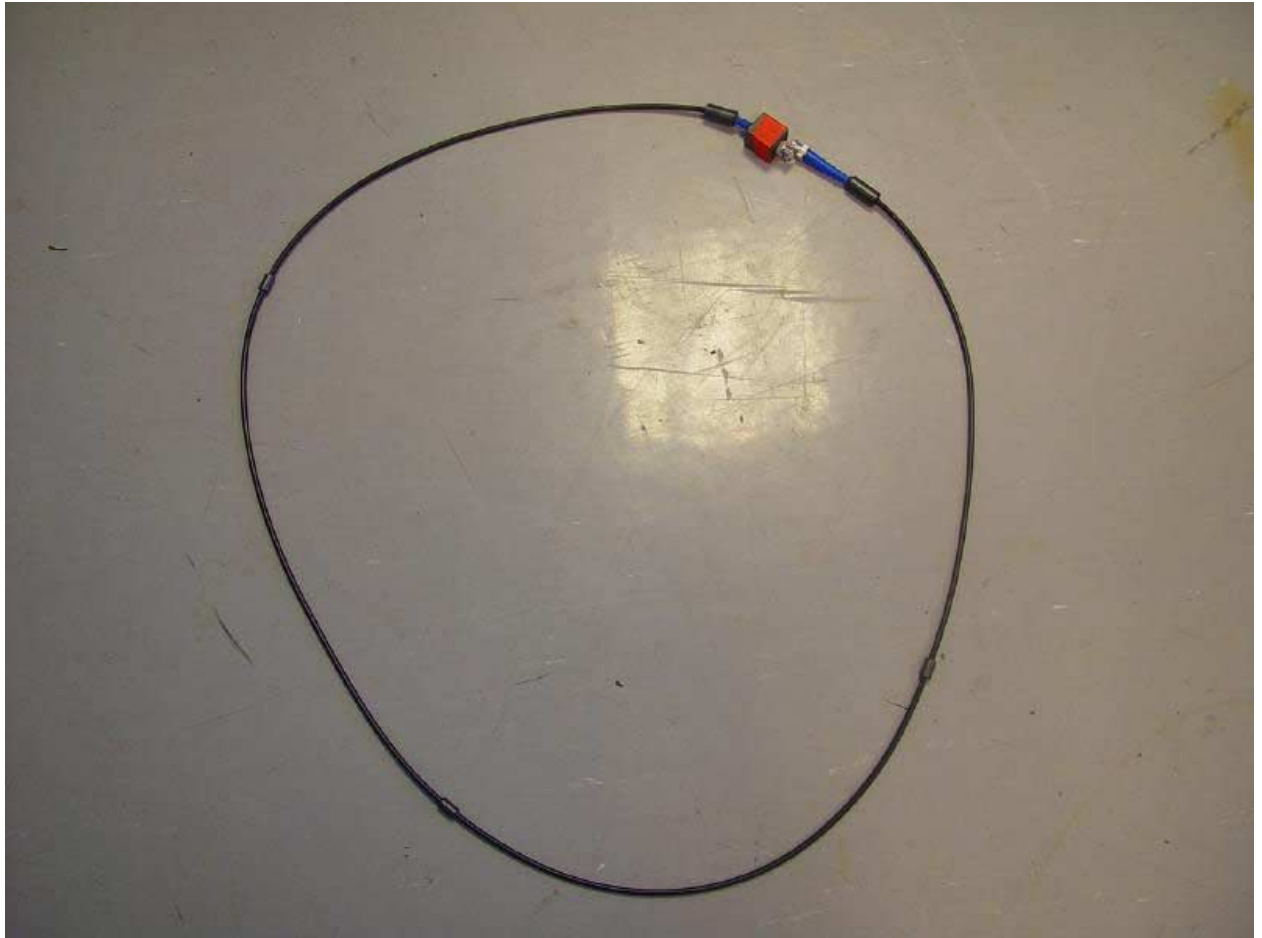


Fig. 7

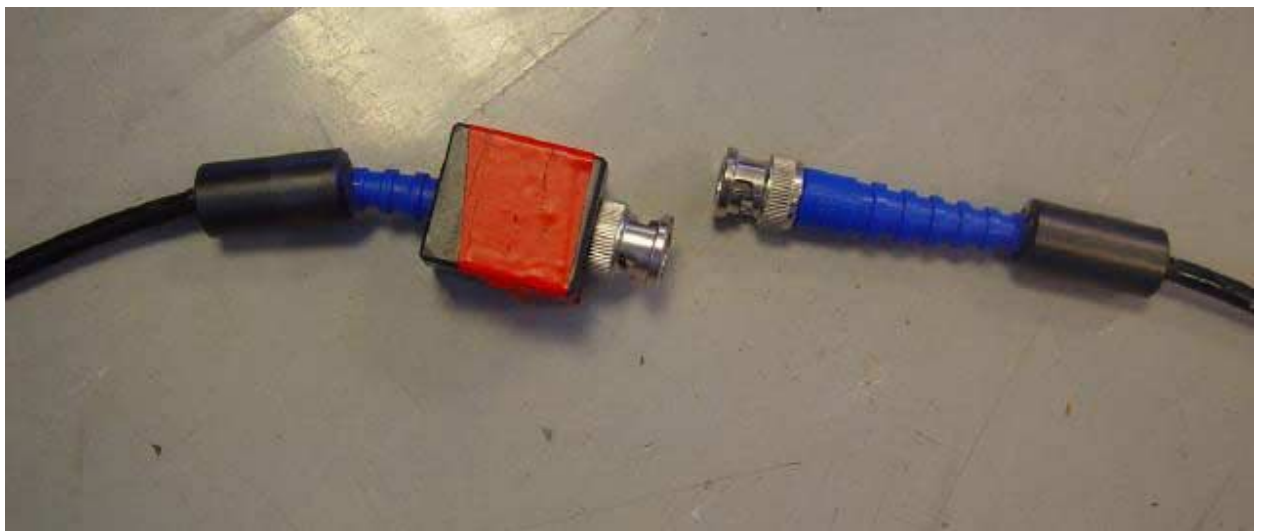


Fig. 8



Fig. 9

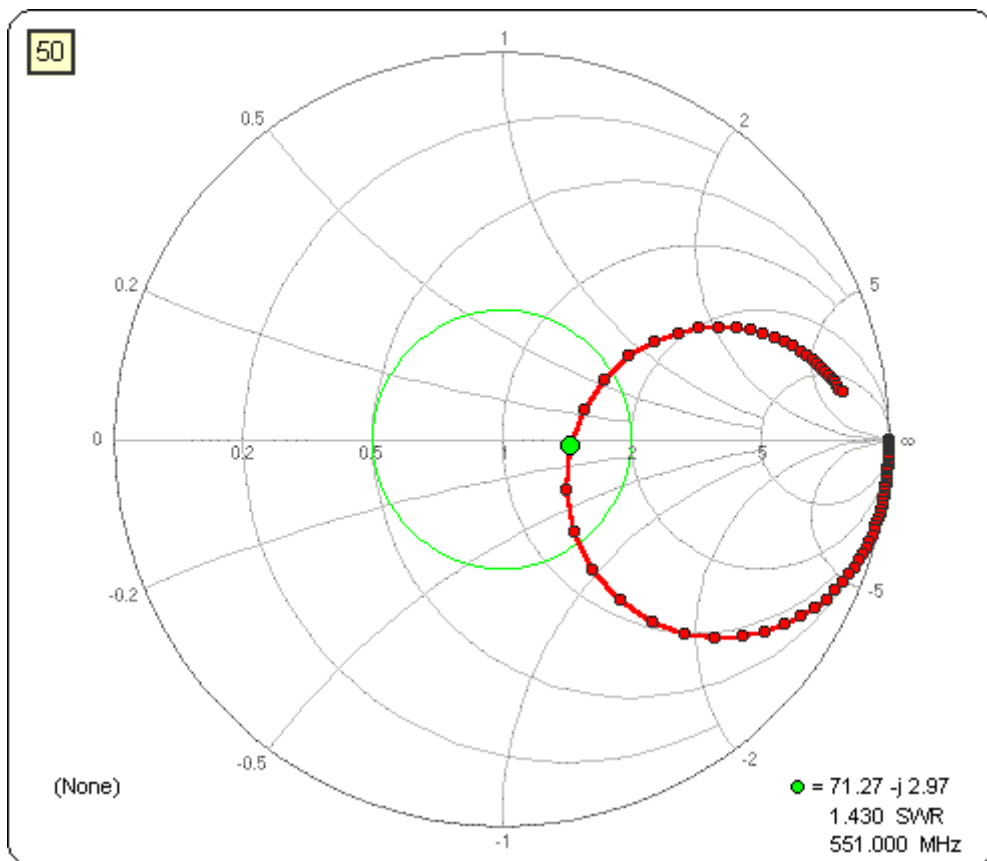


Fig. 10

Experimental estimates of the bandwidth of this dipole, made by examining the point at which the resistive part of the impedance equals the reactive part, give a $R=X$ bandwidth measurement of around 13%, which is what we expect for a thin wire dipole.

Loop measurements.

The equivalent measurements were then made on a loop antenna. The suppressed cable was used. A photo of the loop is shown in **Figure 11**; its circumference was 500mm plus or minus 2mm. A photo of the junction between the loop wire and the BNC socket is shown in **Figure 12**. The NEC simulation for an approximation to this loop is shown in **Figure 13** (thanks Dan) and the experimental SMITH chart trace is shown in **Figure 14**.



Fig. 11

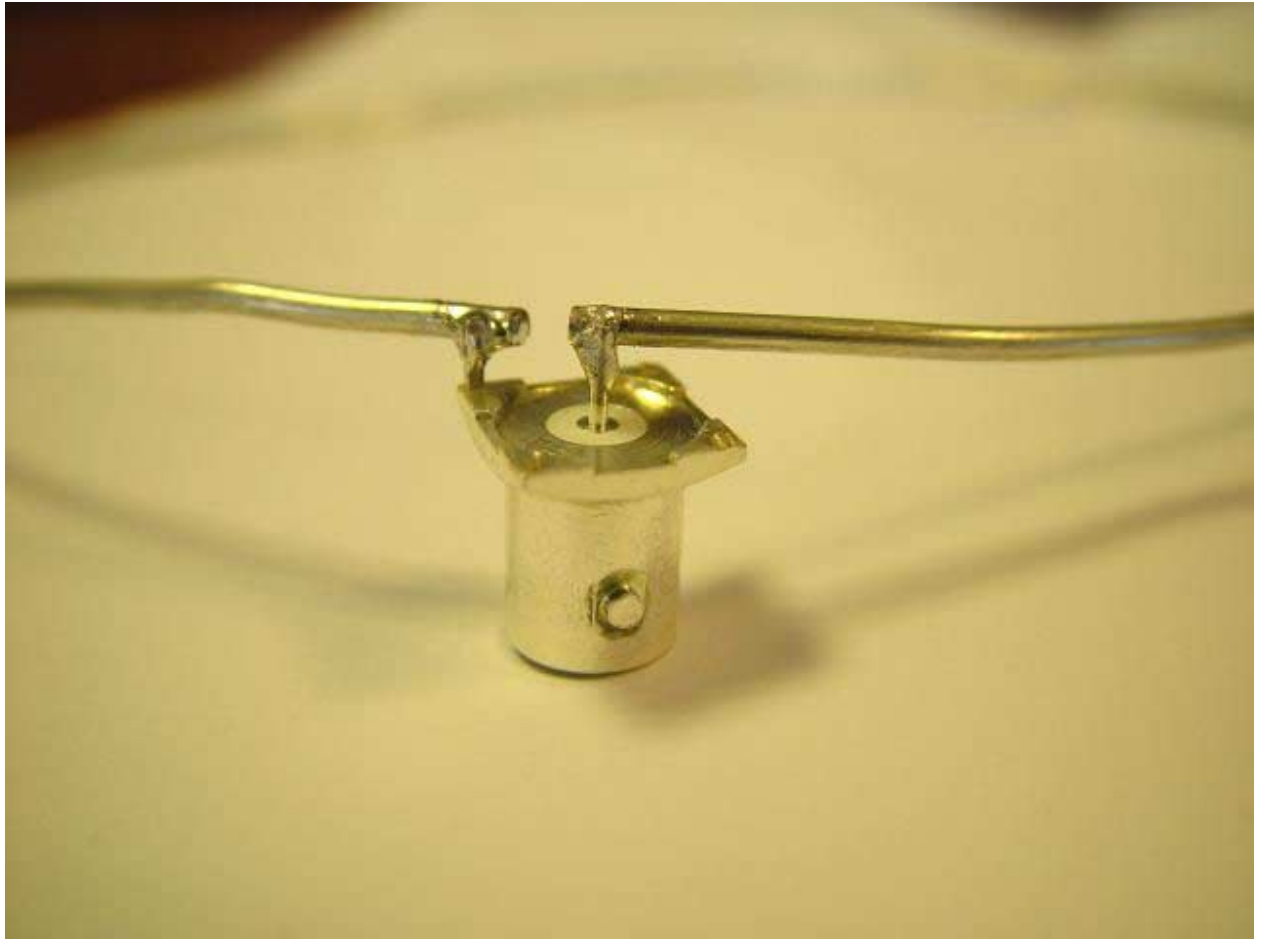


Fig. 12

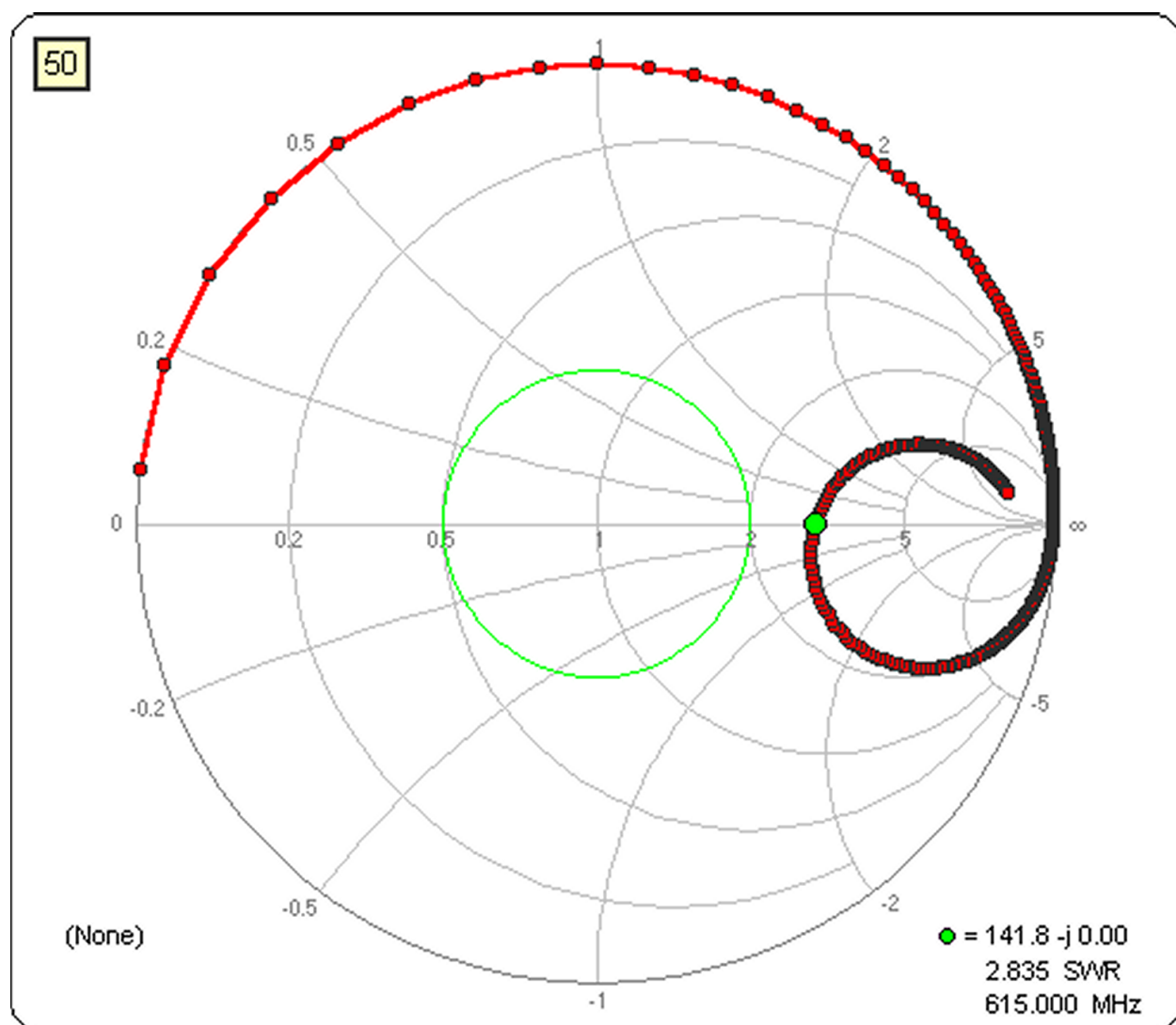


Fig. 13



Fig. 14

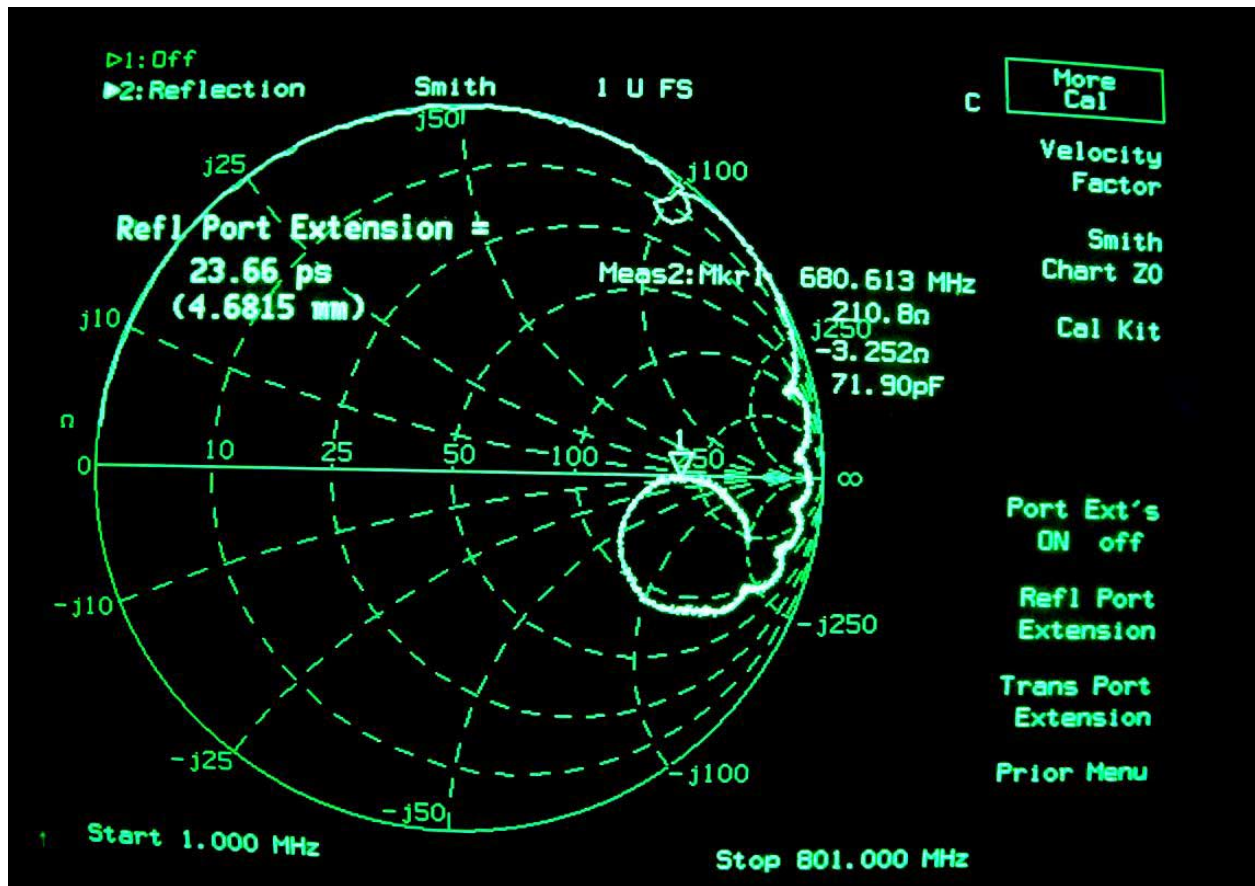


Fig. 15

When the cable is not fully suppressed, as in **Figure 15**, we see the room resonances and the cable resonances. These appear at various frequencies above about 35MHz. After suppression, the experimental trace and the simulation are in reasonable overall agreement. However, we now know that this antenna couples to the room at lower frequencies, and so we assume that the room damping and cable damping both absorb power from the loop. If we look carefully at the experimental traces in **Figures 14 and 15**, we see that the trace departs from the $R=0$ periphery of the SMITH chart. This indicates that with suitable tuning and matching circuits we might be able to couple appreciable amounts of power to the antenna above about 60MHz, where the antenna circumference is a tenth of a wavelength. This leads us to have some confidence in the theory article that we wrote about intermediate-sized loop antennas in December 2003, *antenneX* (now in Archive VI).

There are some differences between the simulation and experiment in the antiresonant and resonant frequencies and their associated impedances. This is not surprising, for at antiresonance the impedance is very sensitive to small values of shunt capacitance and the precise location of the driving point reference plane. Also, the model is of an octagonal loop which has a different ration of area to circumference to the one measured, so it is not surprising that we see a difference in the resonant frequency.

Nevertheless, these dipole and loop measurements give us some confidence in being able now to make sensible measurements on wire and plate Zagi elements, using the screened and damped room method and our suppressed cable. It is intended to go further and measure coupling between two dipoles and between two loops in this environment. We don't expect to get into the far field region at the lower frequencies, so it is not likely that we will be able directly to resolve

the issue about the radiation efficiency of intermediate-sized loops. It is, however, pleasing to see how accurately we can come to the simulations, using a room that many people would say was not anechoic at the frequencies used. Just the fact that other laboratory radiation and scattering sources are excluded is a great step forwards.

As far as the dipole measurements are concerned, we have some confidence that using these techniques we can measure to better than 1% in resonant frequency and better than 2% in resistance at resonance. It may be that the actual accuracy is rather better than this, but in a practical installation more precision will be nugatory on account of the coupling to nearby objects, masts, guys, feeds, buildings, and trees. Also we have not considered the effect of the ground, whose properties will be time-dependent as the weather changes.

There are some more detailed and considered views of these experiments, with links to a number of other pictures, posted at

<http://www.ee.surrey.ac.uk/Personal/D.Jefferies/loop.html>

There, we discuss the niceties of network analyser port extensions and the effects of stray capacitance and inductance at the feed-antenna junction.

Summary.

To summarise, the purpose of this report and these measurements was twofold: to establish sensible agreement between dipole measurements and simulations for our experimental setup, and to investigate the loop antenna over a wide frequency range. This will now give us confidence in the parallel measurements, which we are making on Zagi antenna elements at about the same frequency range and in the same room.

Those people who had asked the question “just how accurately can measurements on antennas be made in the laboratory” now have some measure of an answer. For this reason we thought it would be a good idea to publish these intermediate results in *antenneX* magazine. –30–

Footnote:

[1] The author used the slang word "wibble" here to mean spurious features on the SMITH chart plot of the antenna impedance, caused by coupling to cable and room resonances, and to be ignored.



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Johnny Johnstone started his career in electronics working as an OB engineer in the BBC, a good introduction to the realities of engineering. After a spell of this he joined the BBC Engineering Training dept as a Technical author, writing about all aspects of Broadcast engineering. He was also active in writing technical articles and a book about FM. He then moved to the BBC design department and worked on TV and sound equipment, finally becoming Head of the RF section. On retirement, Johnny founded the R&D group of a mobile radio RF outfit and submitted a Ph.D. thesis on Transmission line filters. Current interests include RF measurements and antennas.

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