More on the MDT 14MHz Anomaly

From the measured input VI phase data it is clear that the voltage is taken as the reference and the phase angle of the current is reported. The phase diagram can be broken down into four quadrants as shown in Figure 1.

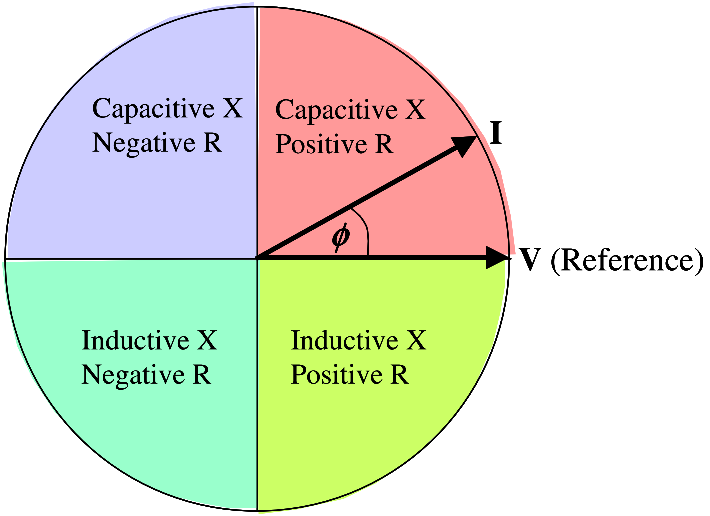

Figure 1. Input VI Phase Diagram

Positive angles (up to 180°) represent capacitive reactance, up to 90° having a positive series resistance while between 90° and 180° the resistance is negative. Negative angles represent inductive reactance, and again up to 90° having a positive series resistance while between 90° and 180° the resistance is negative. When this is imported to the phase v. frequency diagram we get the situation shown in Figure 2.

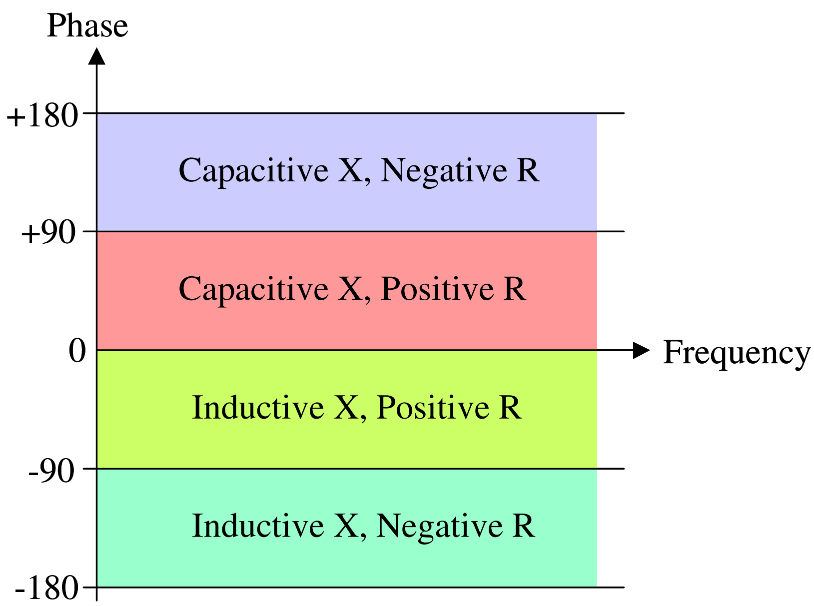

Figure 2. Input VI Phase v. Frequency Diagram

Considering the MDT as a negative resistance device we can forget about the secondary as an output and just consider it as a means to adjust the primary input characteristic. We find that the greatest anomalous phase (i.e. magnitude greater than 90°) occurs on the bare MDT with no load resistor, just the scope probe of 10MΩ. The phase v. frequency diagram is shown in Figure 3 for the secondary shunted by various values of capacitance.

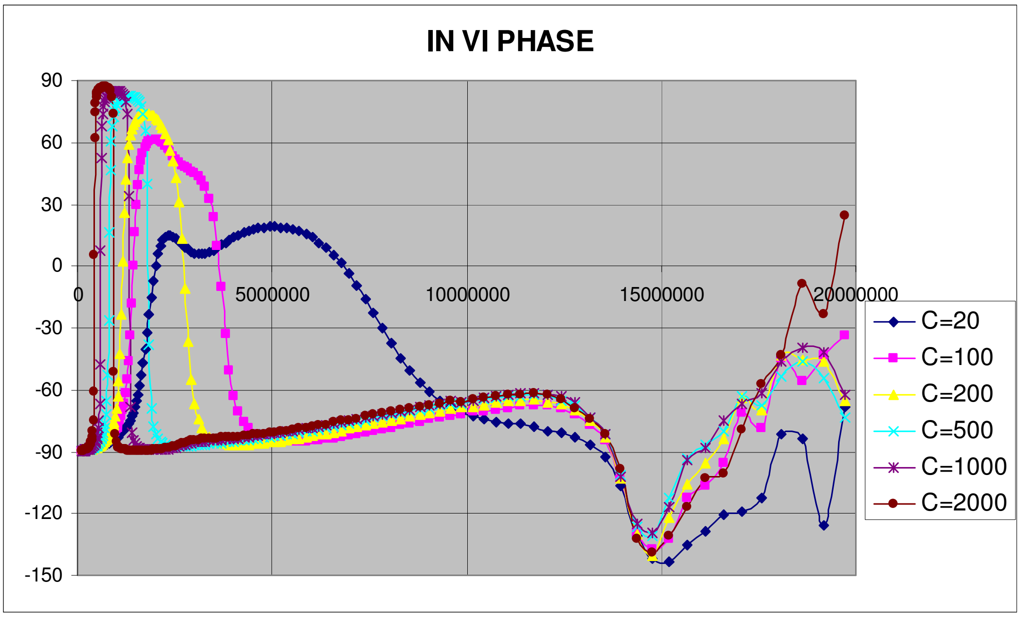

Figure 3. VI Phase Diagram for Bare MDT

All the curves start near -90° indicating inductive reactance with near zero resistance. The low frequency swing through zero towards +90° and capacitive reactance is the secondary LC resonance, but interestingly at higher frequencies the curves swing negative again into the inductive regime. The anomalous region occurs around 14MHz where the phase goes below -90° indicating negative resistance in series with inductive reactance. This is the area of interest, shown on an expanded frequency scale in Figure 4.

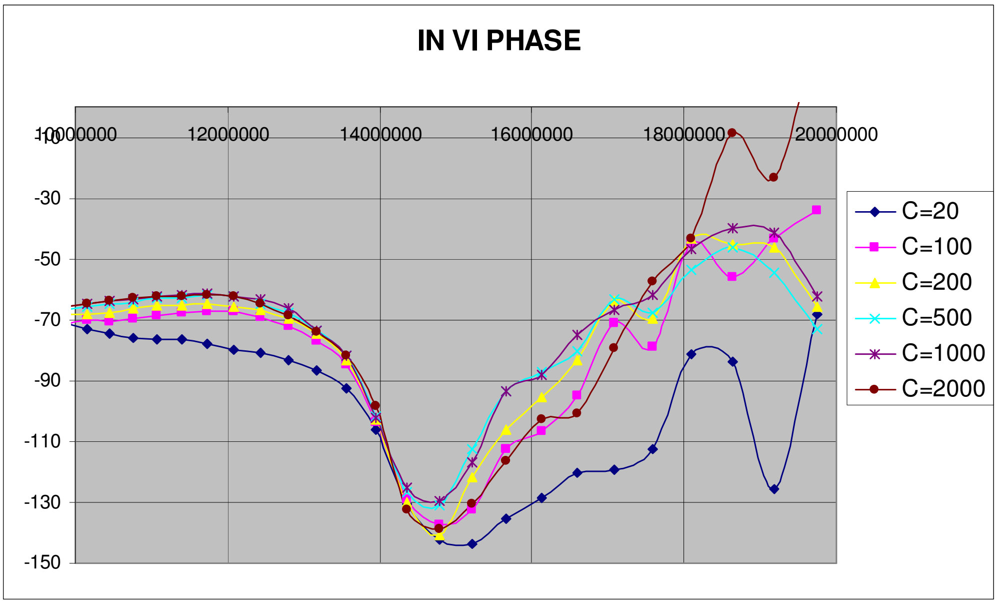

Figure 4. Expanded Phase Diagram

The phase goes beyond the -90° point by an incredible further 40 to 55°, so it's not a case of measurement inaccuracy just tipping the result over the -90° position. There is some definite cause for the apparent OU, and hopefully that can be discovered to useful effect.

When we look at the input voltage as shown in Figure 5 we see that this remains at sensible levels, but the input current in Figure 6 is another story.

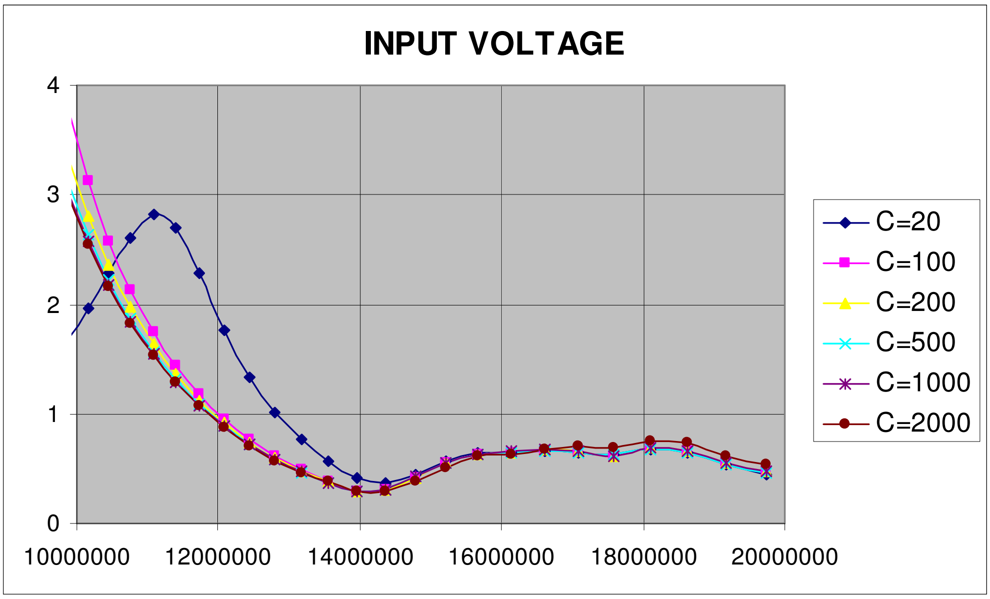

Figure 5. Bare MDT Input Voltage

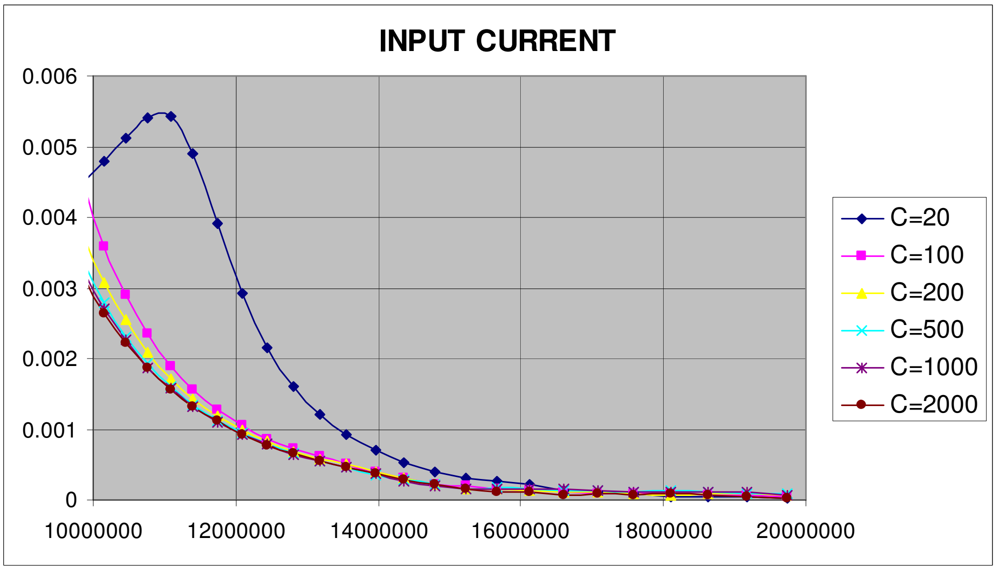

Figure 6. Bare MDT Input Current

Above 12MHz input current rolls off with increasing frequency so at some point it would be expected that the measurements become noisy. This is apparent in Figure 4 where the phase gets noisy above 16MHz, but that noise cannot account for the phase passing through -90° point near 14MHz. It may be noted that the maximum phase excursion occurs for C=20pF whereas that has the highest input current, so low current amplitude alone cannot account for the anomalous effect. It is possible that there is some systemic effect associated with low current and one way to discover whether this is true is to repeat the measurements at a higher input voltage level, hence higher currents. If the phase v. frequency diagram remains the same then we can rule out low current being the cause.

Looking now at the actual negative resistance values and their associated reactance we get the charts of Figures 7 and 8.

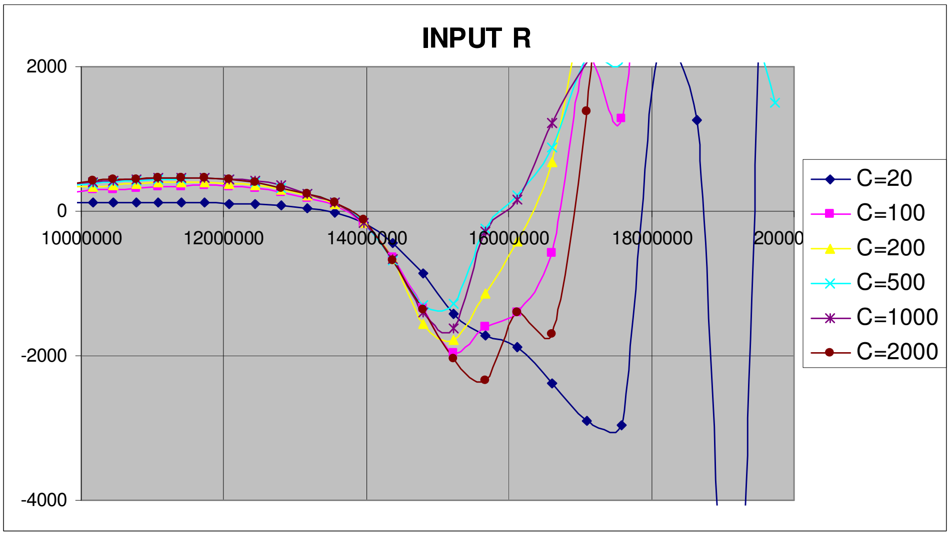

Figure 7. Bare MDT Input Resistance

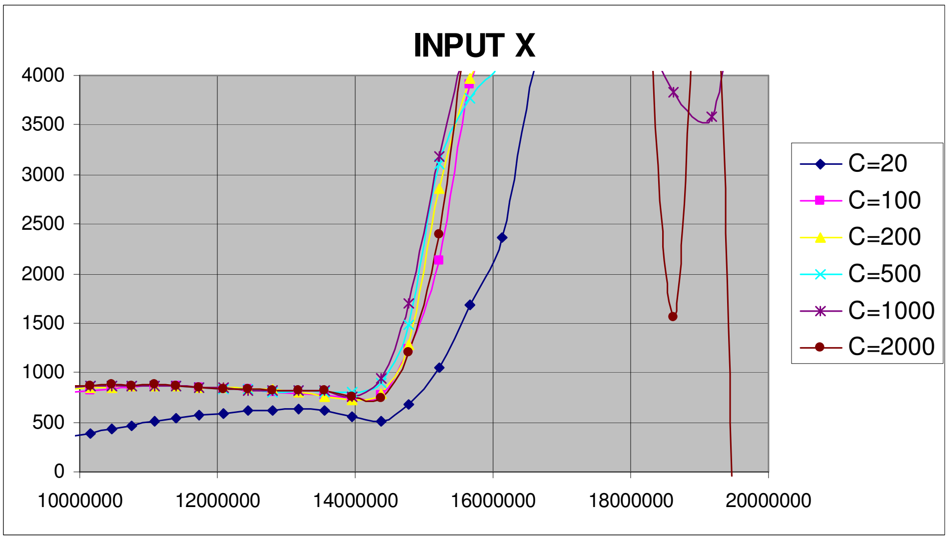

Figure 8. Bare MDT Input Reactance

The positive reactance can be converted to the inductance values in Figure 9.

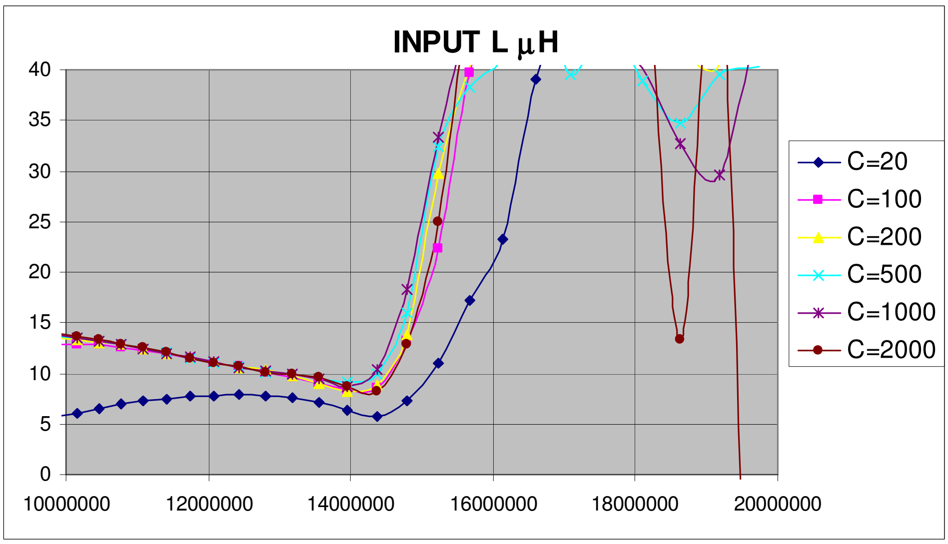

Figure 9. Bare MDT Input Inductance

Taking 15MHz as the optimum frequency where the negative R is near maximum, we see that the input inductance is about 20μH (ignoring the 20pF case). This would resonate with a 5.6pF capacitor, so it would seem sensible to shunt the input with a trimmer, loosely couple a 15MHz signal and see whether there is any evidence of high Q or even self-oscillation. If neither then it could be concluded that the apparent negative resistance is an artefact.

For comparison with the above charts for the bare MDT, the shielded MDT results are given here.

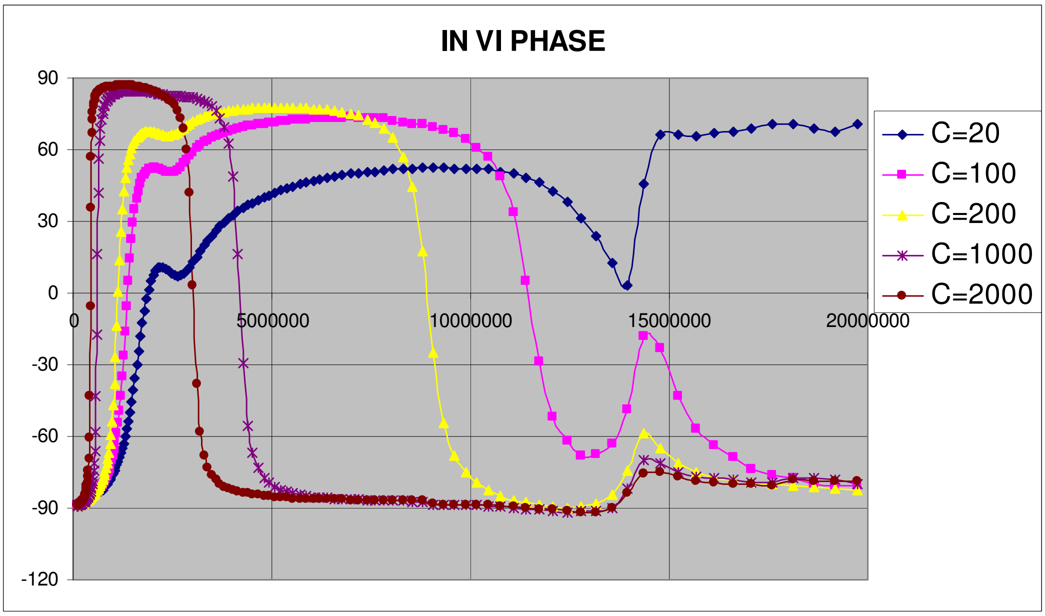

Figure 10. Shielded MDT Phase Diagram

The phase just tips below -90° by about 2° for the two highest values of shunt capacitance as seen in the expanded chart Figure 11. This could be just measurement inaccuracy.

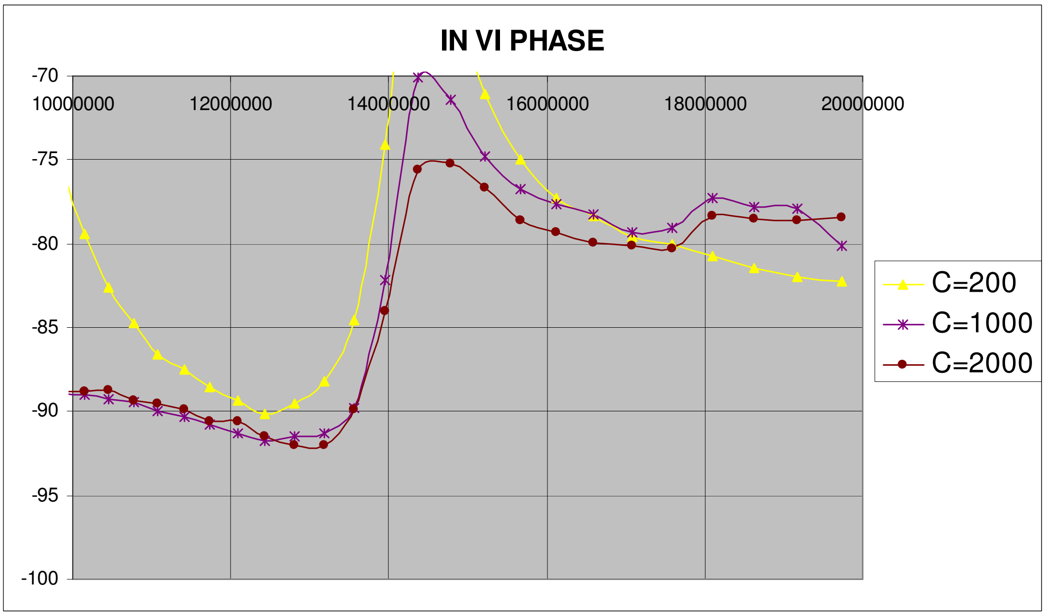

Figure 11. Expanded Phase Diagram

This produces only small values of negative R, Figure 12, peaking at 13MHz.

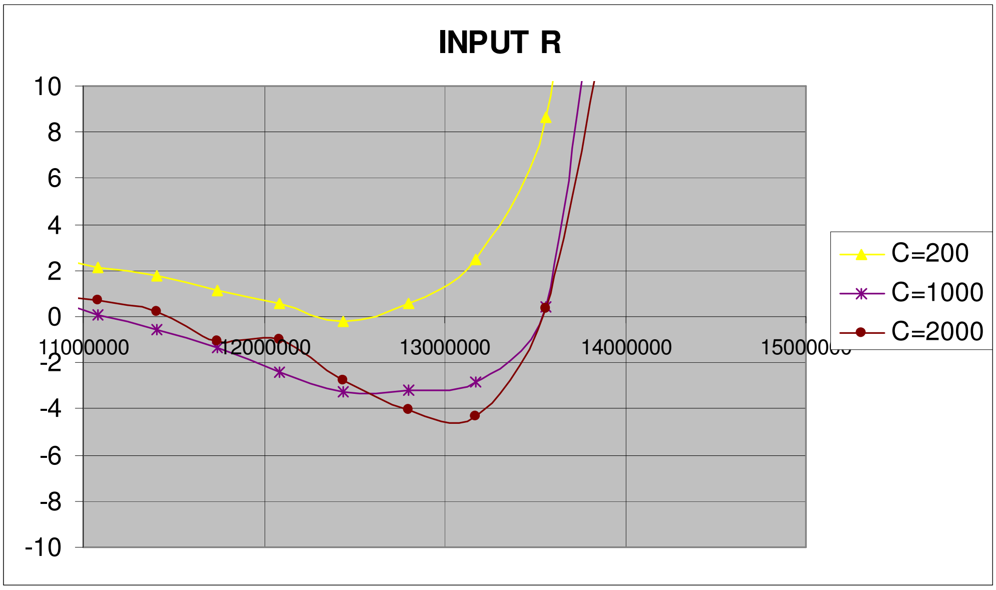

Figure 12. Shielded MDT Input Resistance.

Input inductance is also low being just a few micro-henries.

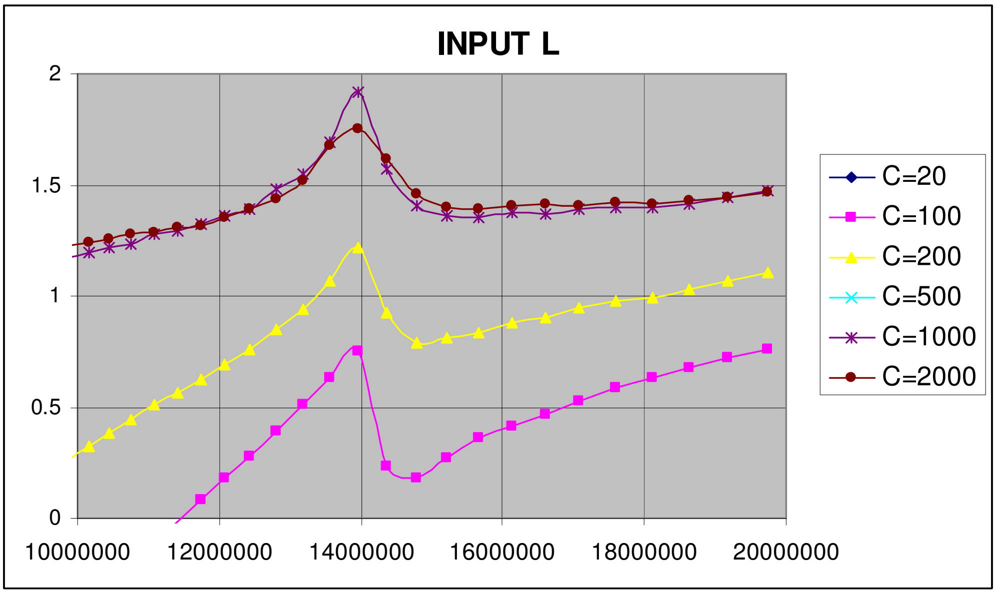

Figure 13. Shielded MDT Input Inductance

These charts do indicate some sort of resonance at 14MHz that could be responsible for the anomalous results. Whether this is internal to the MDT or external and within the measurement set-up remains to be seen. However the fact that the large phase anomaly seen on the bare MDT (which has leakage flux) is almost eliminated on the shielded MDT (where the leakage flux is minimised) does suggest that the measurement could be affected by leakage flux. Could it be that the probe across the low value non-inductive resistors used for input current measurement is seeing an induced error voltage from leakage flux, or even the resistor itself? It should be easy to determine if that is the case simply by changing the orientation of the isolator and repeating the measurement.