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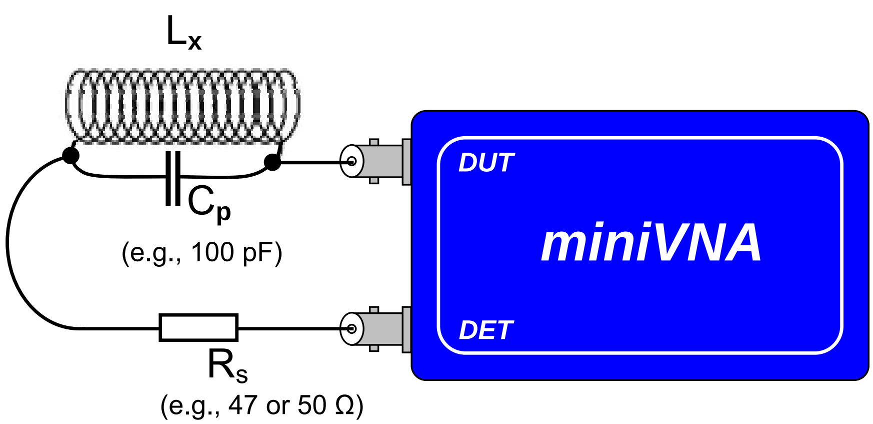
“A fool with a tool is still a fool”

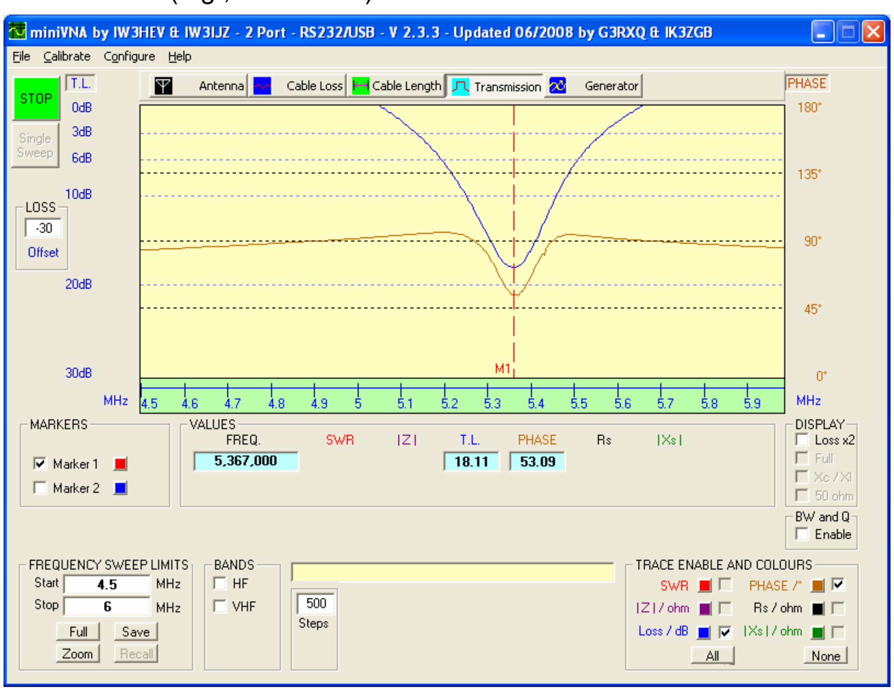
Measurements of an antenna loading coil by Frank F/N4SPP

I have constructed a center-loaded mini-dipole, and used two of those to create a 2-element mini yagi beam antenna. See “antenna projects” on my website According to on-line calculators for airwound coils (e.g., here), these loading coils (32 windings of #22 AWG insulated hook-up wire tightly wound, coil length 5 cm) should have an inductance of about 8.14 μH (assuming the PVC core and the wire insulation have negligible effect). I made an additional coil to verify this. I tried three different methods: parallel- and series-resonance with my miniVNA antenna analyzer, and parallel-resonance with my dipmeter.

Parallel-Resonance Method by Gerd, DO1MGK

For the parallel-resonance methods, I placed a 100 pF (±5%) capacitor across the coil to create an LC-circuit. I added a 50 Ω series terminator resistor to the LC-circuit, as I thought that the analyzer doesn’t like low impedance loads (OK, I actually used 27 Ω). My miniVNA antenna analyzer in transmission-mode found a resonance frequency of 5.34 MHz, see phase plot below.





Phase plot for parallel LC-circuit, miniVNA in transmission mode

Using the formula below (or plugging the numbers into an on-line calculator, e.g., here), the inductance of the coil is 8.9 µH. Not so bad compared to the calculated/predicted value of 8.14! Twentyfour years of professional engineering experience has taught me that anything within ±20% is within engineering accuracy!

$$f_{res} = \frac{1}{2\pi \cdot \sqrt{LC}} \quad \Leftrightarrow \quad L = \frac{1}{C \cdot (2\pi \cdot f_{res})^2}$$

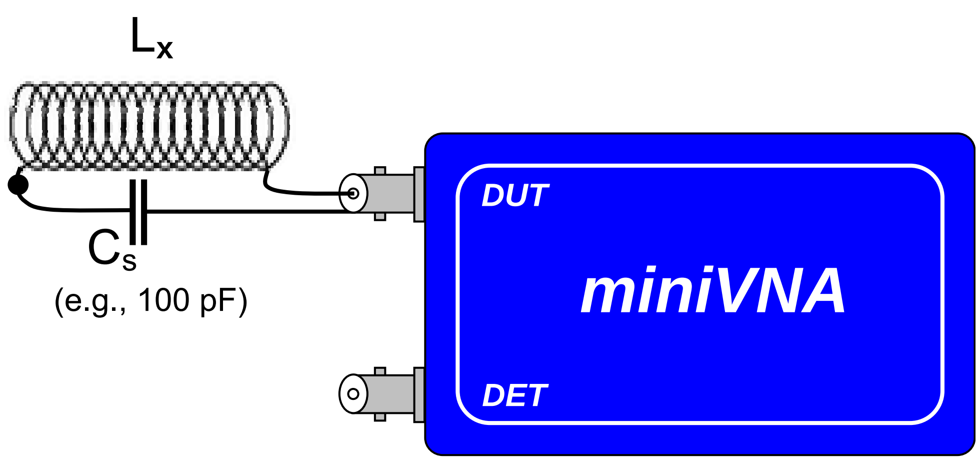
The Quality "Q" of the circuit (including series resistor, parallel or series capacitor!) is the ratio of the resonance frequency f_{res}, and the bandwidth between the two frequencies at which the phase angle is 45 degrees from the phase at the resonance frequency (f_{res} lies between these two frequencies). Let's call these frequencies f_1 and f_2. Then:

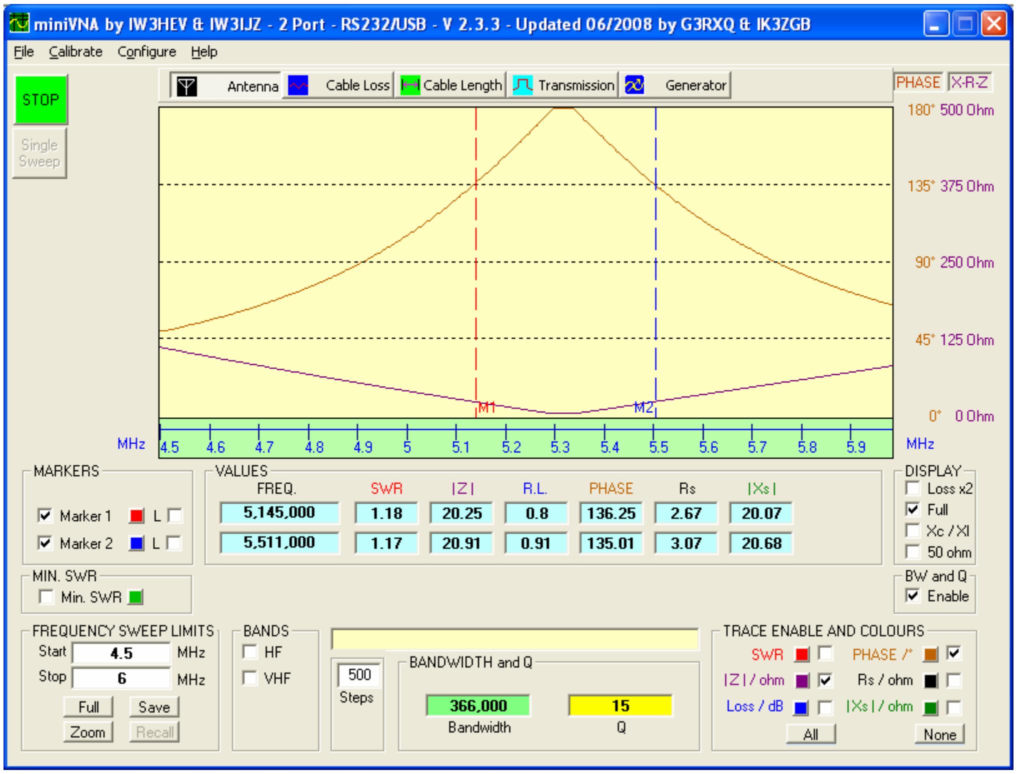
$$Q = \frac{f_{res}}{f_2 - f_1}$$

Note that capacitors typically have poor tolerances with respect to their nominal value. When new, ceramic disk caps typically have +80/-20% tolerance, milar polyester typ. ±5 or ±20%, tantalum typ. ±10 or ±20%, metalized polypropylene typ. ±5, ±10, or ±20%, electrolytic typ. ±20%, etc. A handy overview of capacitor markings is here.

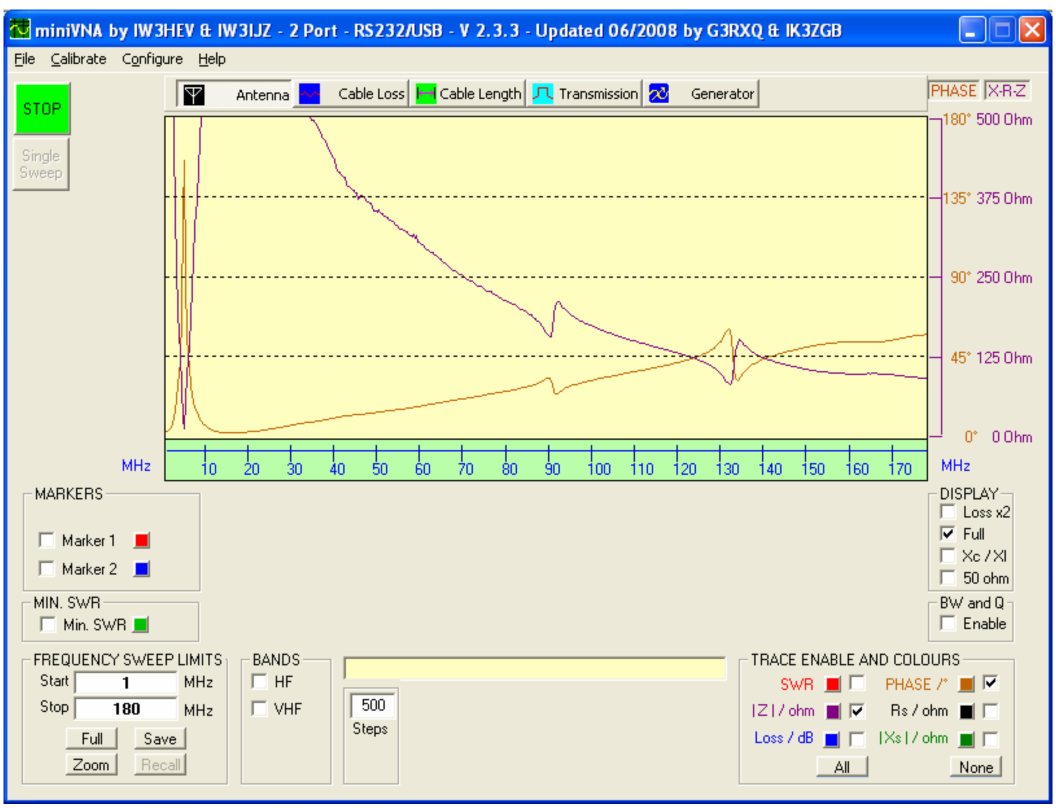
Series-Resonance Method by Gerd, DO1MGK

Next I tried the antenna analyzer in antenna-mode, with the L and C in series, without the series resistor. Based on the phase plot immediately below, resonance is at about 5.31 MHz which translates to 9.0 µH. Slightly different from the above parallel-resonance method. The full-sweep plot below it, shows some phase "dips" and "reversals" at (much) higher frequencies. I guess they may be related to resonances due to stray capacitance of the coil, wiring of the test setup, etc?



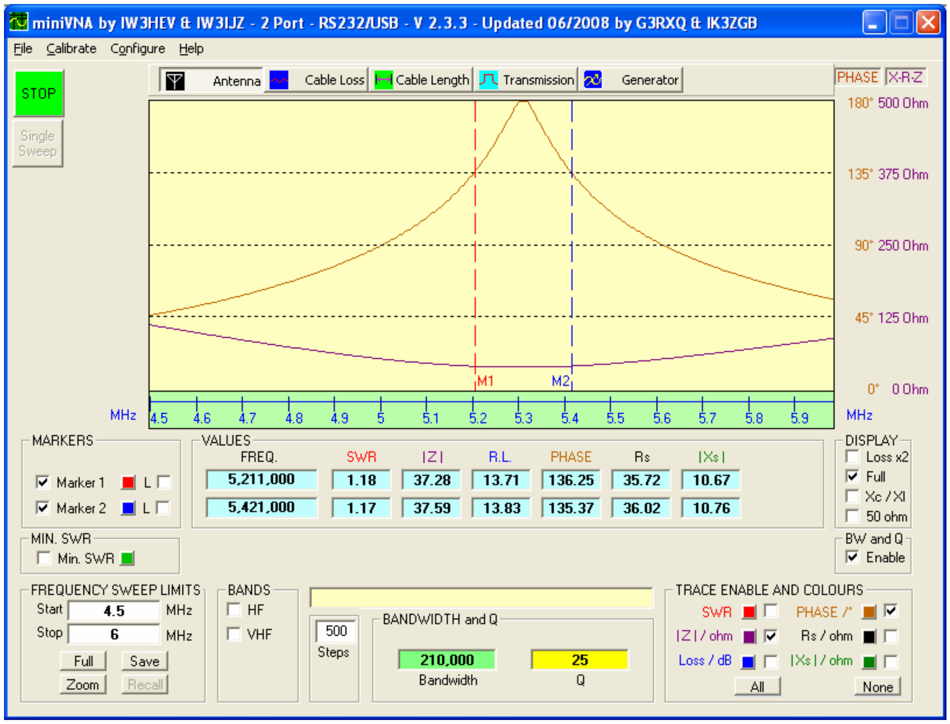


Phase plot of series LC-circuit without series-resistor
miniVNA in antenna mode (4.5-6 MHz sweep)



Phase plot of parallel LC-circuit, miniVNA in antenna mode (full sweep)

Finally I tried the same LC-configuration, but this time with the series resistor. Found the same resonance frequency (to be expected), but the Q seems to have gone up when the series resistor was added???

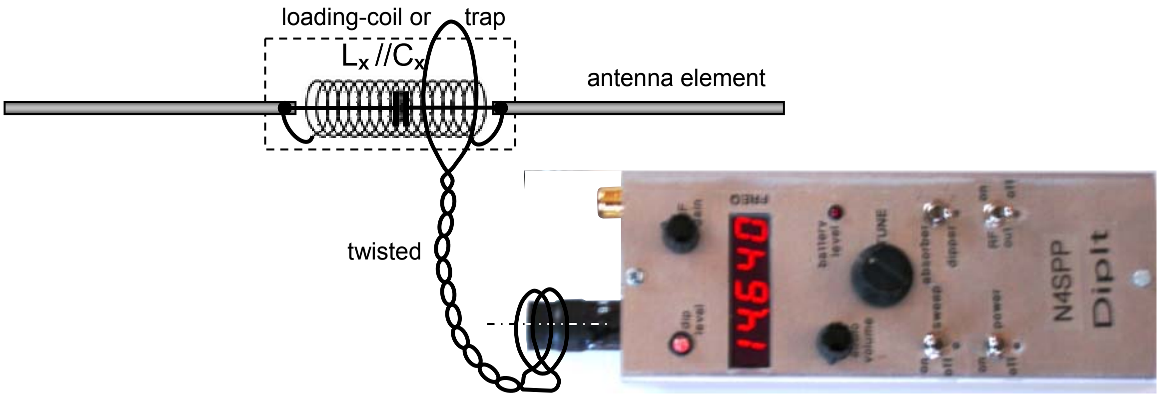


Phase plot of series LC-circuit with series-resistor (miniVNA in antenna mode)

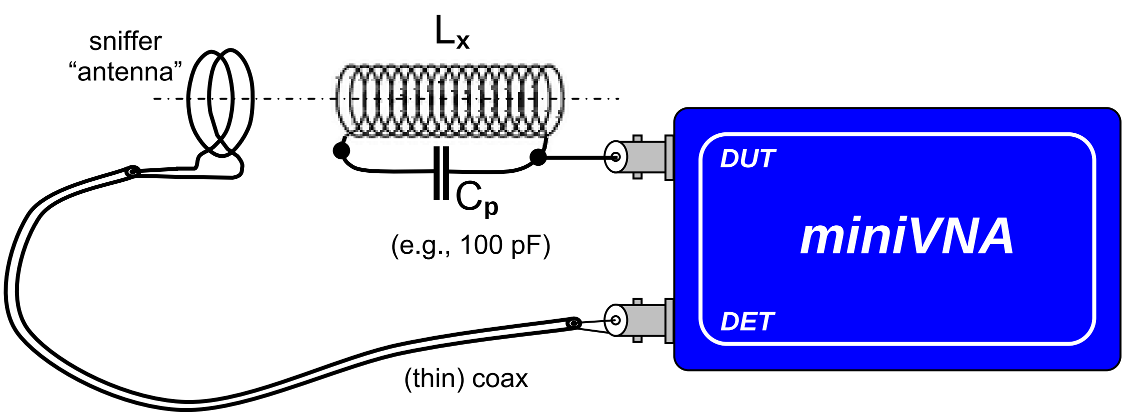
Classical Dip-Meter Method

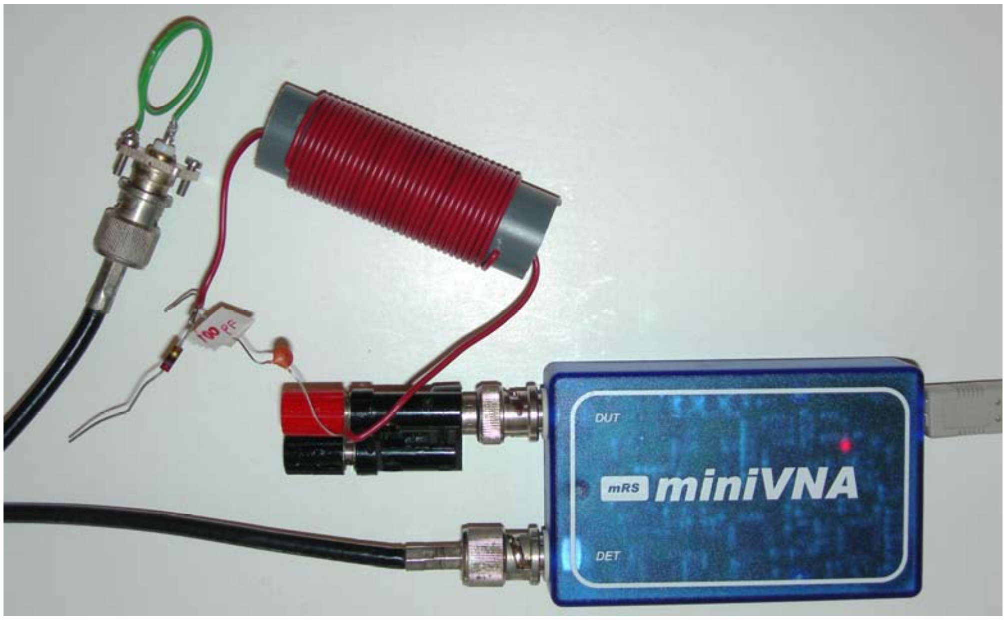
To double-check, I used my fancy dipmeter with digital frequency read-out (DipIt kit from QRPprojects) to determine the resonance frequency. Also found a sharp dip at 5.34 MHz (dipmeter's excitation coil coaxially aligned with my test coil). Inserting a fiberglass fishing pole (my dipole is made up of two such poles) into the coil did not cause the resonance frequency f_{res} to shift. A good thing! You cannot determine the Q of the coil with this method. Also, the resonance frequency shifts with the level of coupling (i.e., distance) between the test coil and the dipmeter's excitation coil. So the results are operator-dependent.

(e.g., 100 pF)



Sniffer-Dipper Method by Gerd, DO1MGK

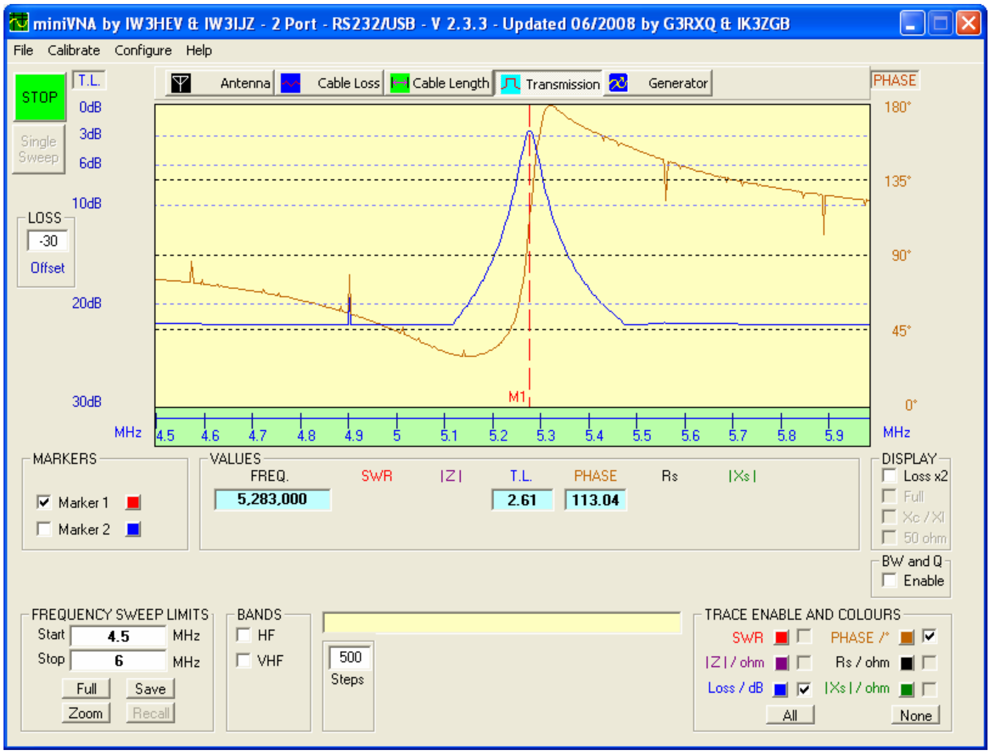




The two screen shots below show the phase and loss traces for my test coil with this test method. Note the -30 dB “loss offset” setting. Analyzer is in “transmission” mode. The difference between the two plots is that the phase traces are mirror-imaged. I ran this test twice, the second time with reversed polarity of the sniffer coil: just turned the sniffer-coil 180 degrees about its lateral axis, such that the flux it captures from the test coil enters the opposite side of the sniffer coil. This is the same as measuring at the opposite end of the test coil without changing the orientation of the sniffer coil. Obviously should not make a difference, and it doesn’t.

The same resonance frequency is obtained as with the classical dipmeter method. So, no need to buy a dipmeter if you already have a miniVNA!

Note that you cannot use the above formula to determine the Q of the coil with this method: the phase-vs-frequency plot depends on the coupling (i.e., distance) between the test coil and the “sniffer coil”. As with the classical dipmeter, the resonance frequency also tends to shift with the level of coupling.


miniVNA by IW3HEV & IW3IJZ - 2 Port - RS232/USB - V 2.3.3 - Updated 06/2008 by G3RXQ & IK3ZGB
File Calibrate Configure Help
STOP
Single Sweep
T.L.
0dB
3dB
6dB
10dB
LOSS
-30
Offset
20dB
30dB
MHz
Antenna
Cable Loss
Cable Length
Transmission
Generator
PHASE
180°
135°
90°
45°
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M1
4.5 4.6 4.7 4.8 4.9 5 5.1 5.2 5.3 5.4 5.5 5.6 5.7 5.8 5.9
MARKERS
Marker 1
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VALUES
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DISPLAY
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Start 4.5 MHz
Stop 6 MHz
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Save
Zoom
Recall
BANDS
HF
VHF
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TRACE ENABLE AND COLOURS
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PHASE /°
|Z| / ohm
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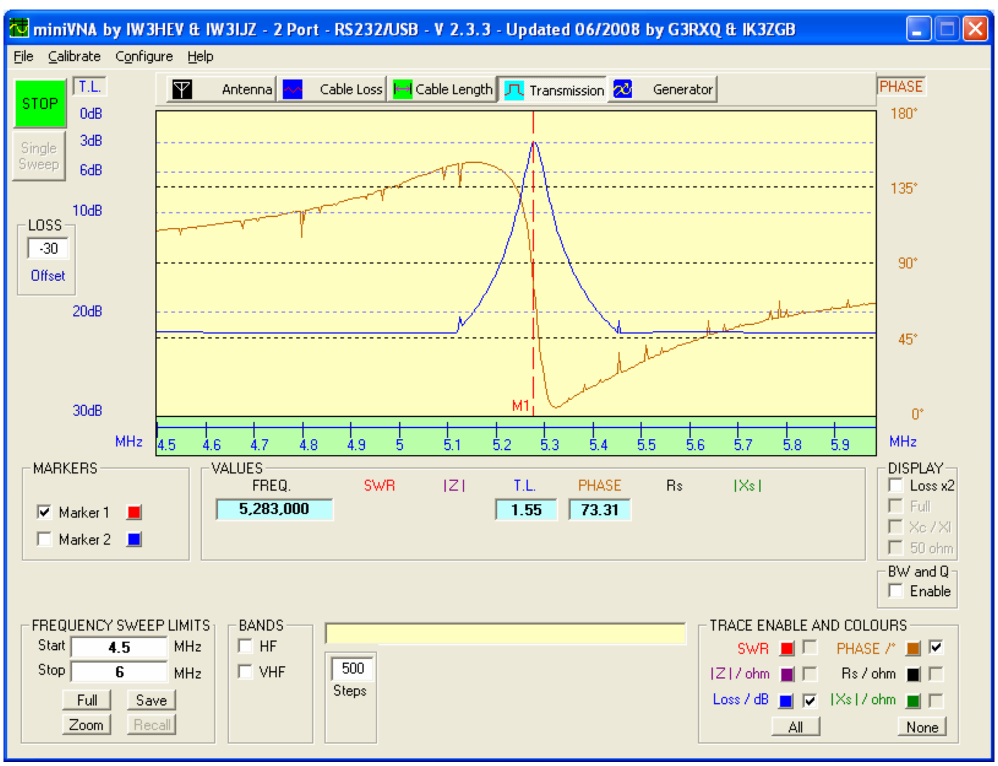
Loss / dB
|Xs| / ohm
All
None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PHASE /°
|Z| / ohm
Rs / ohm
Loss / dB
|Xs| / ohm
All
None

The techniques discussed above can be also be used to characterize parallel LC-circuits such as antenna “trap” filters that are used in many antenna designs. Note that traps do not have the same function as loading coils. Traps have high impedance (infinite in the ideal case) above their resonance frequency **TBC**, whereas series LC-circuits have low impedance at their resonance frequency **TBC**. That is, traps blocks frequencies above the resonance trap’s resonance frequency from the part of the antenna radiating element that is beyond the trap (looking from the antenna feed point).

If L_x and C_x are the (parallel) elements of the L/C trap, C_p is the additional parallel cap, f_{res1} is the resonance frequency of the trap without C_p, and f_{res2} is the resonance freq of the trap plus C_p, then:

$$f_{res1} = \frac{1}{2\pi \cdot \sqrt{L_x \cdot C_x}}$$

$$f_{res2} = \frac{1}{2\pi \cdot \sqrt{L_x \cdot (C_x + C_p)}}$$

After determining f_{res1} and f_{res2} with one of the methods discussed above, we can solve for C_x:

$$C_x = \frac{C_p \cdot (f_{res1})^2}{(f_{res2})^2 - (f_{res1})^2}$$

Once C_x is found, the standard resonance formula can be used to determine L_x.