# Gerhard Hoffmann:  Experiments With Decoupling Capacitors

V1.0.0  may. 2007

This text  is the result of some time spent well while waiting for the VHDL compiler to finish its thing.

The setup is a W&G TSA-2 spectrum analyzer 100 Hz to 180 MHz with tracking generator and minimum loss pads for conversion from 75 to 50 Ohm. The test board has a 50 Ohm stripline and lots of nearby ground vias. The traking generator and the spectrum analyzer have together a 25 Ohm impedance that is shorted by the device under test. The measured loss is an indication of the qualtity of the short. Port cables are not long, so transformation effects can be ignored at these moderate frequencies. Cable attenuation and empty board have been normalized out.

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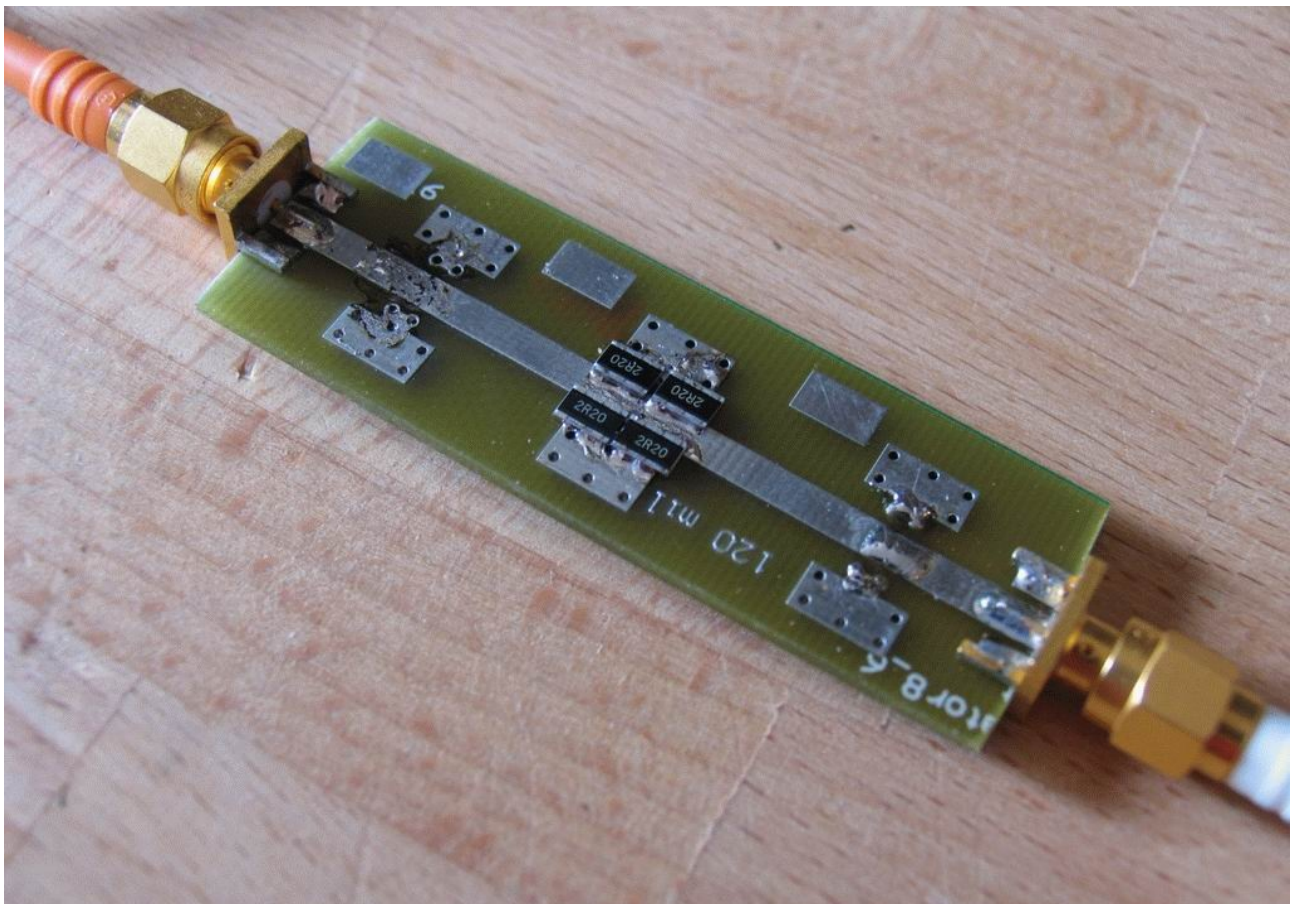
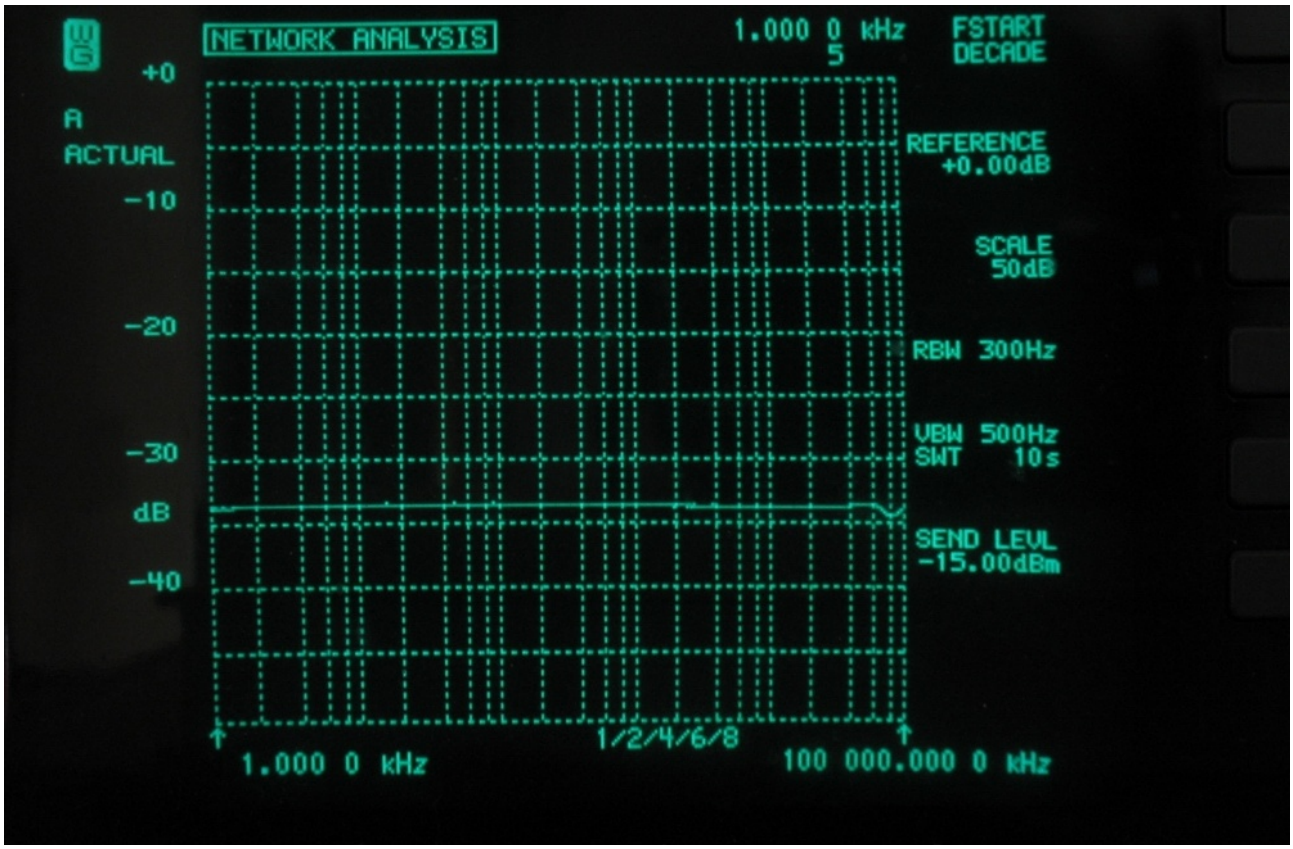
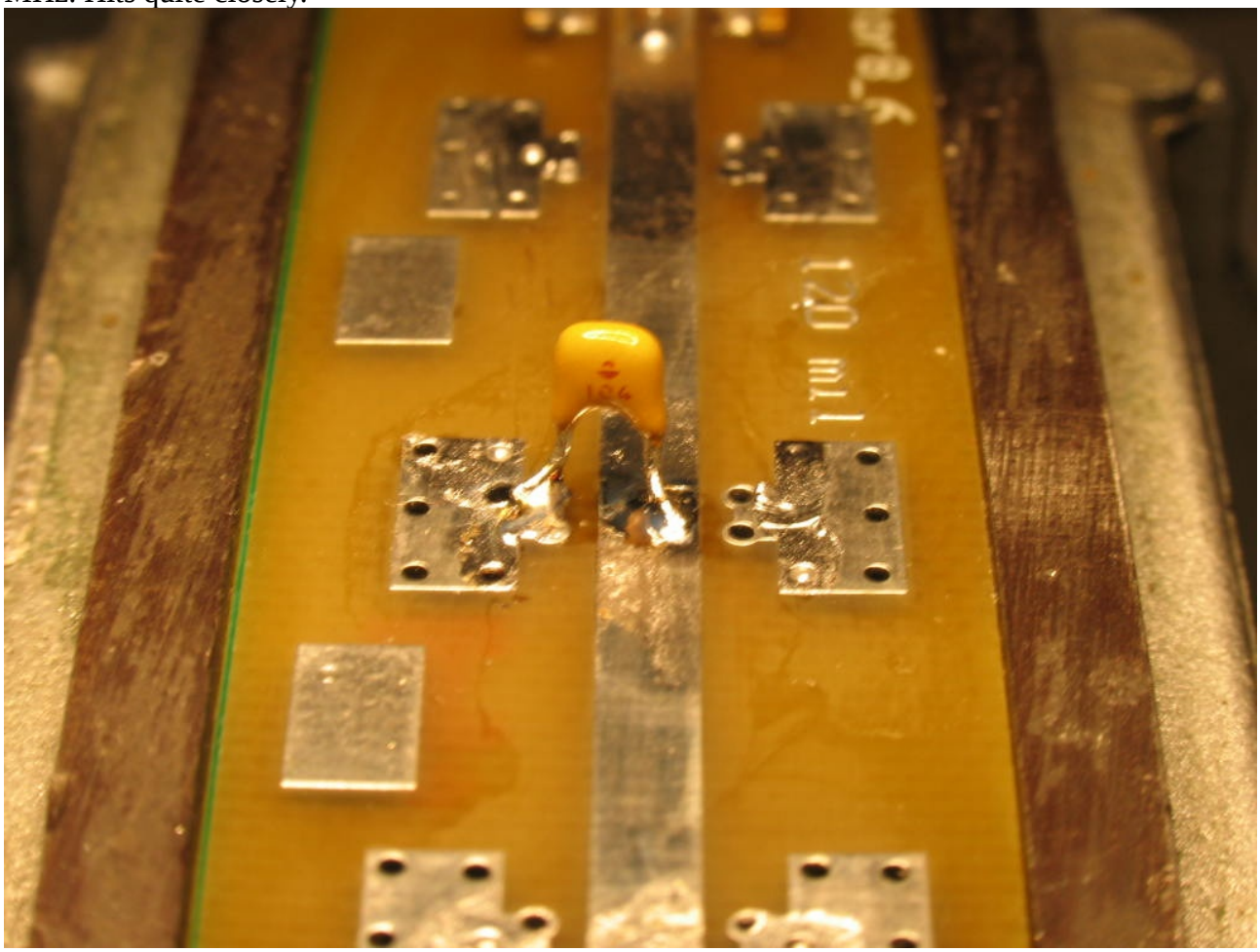
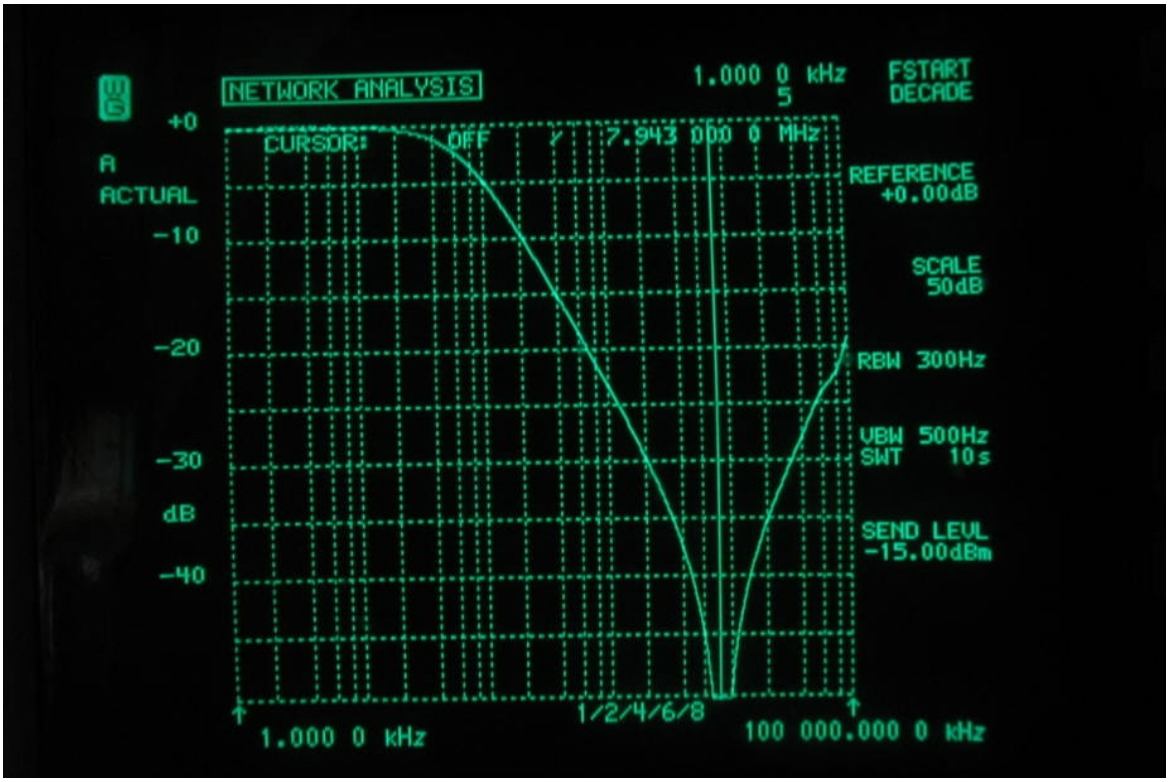



As a reality check, first 4 resistors, 2R20 each or 0.55 together.
They have a 1218 form factor, i.e. thick and short. We expect an attenuation of 0.55 / (25 + 0.55) = 21e-3 voltage-wise or 33.34 dB. Measured loss is 33.6 dB. That looks OK .

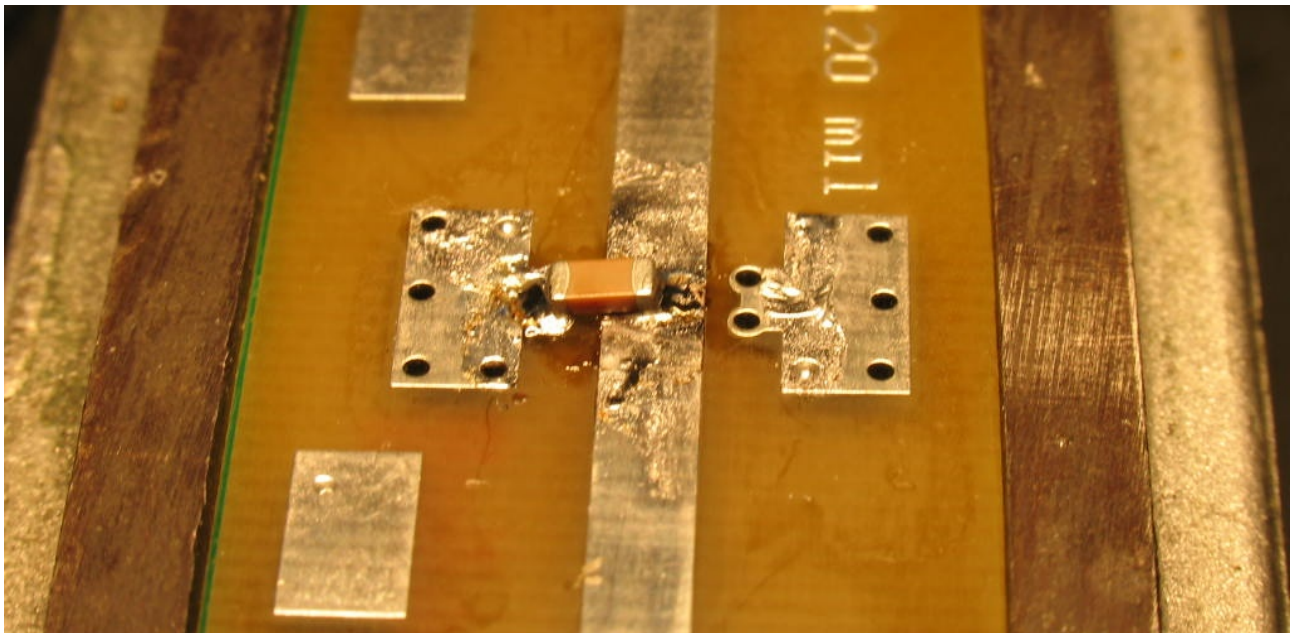


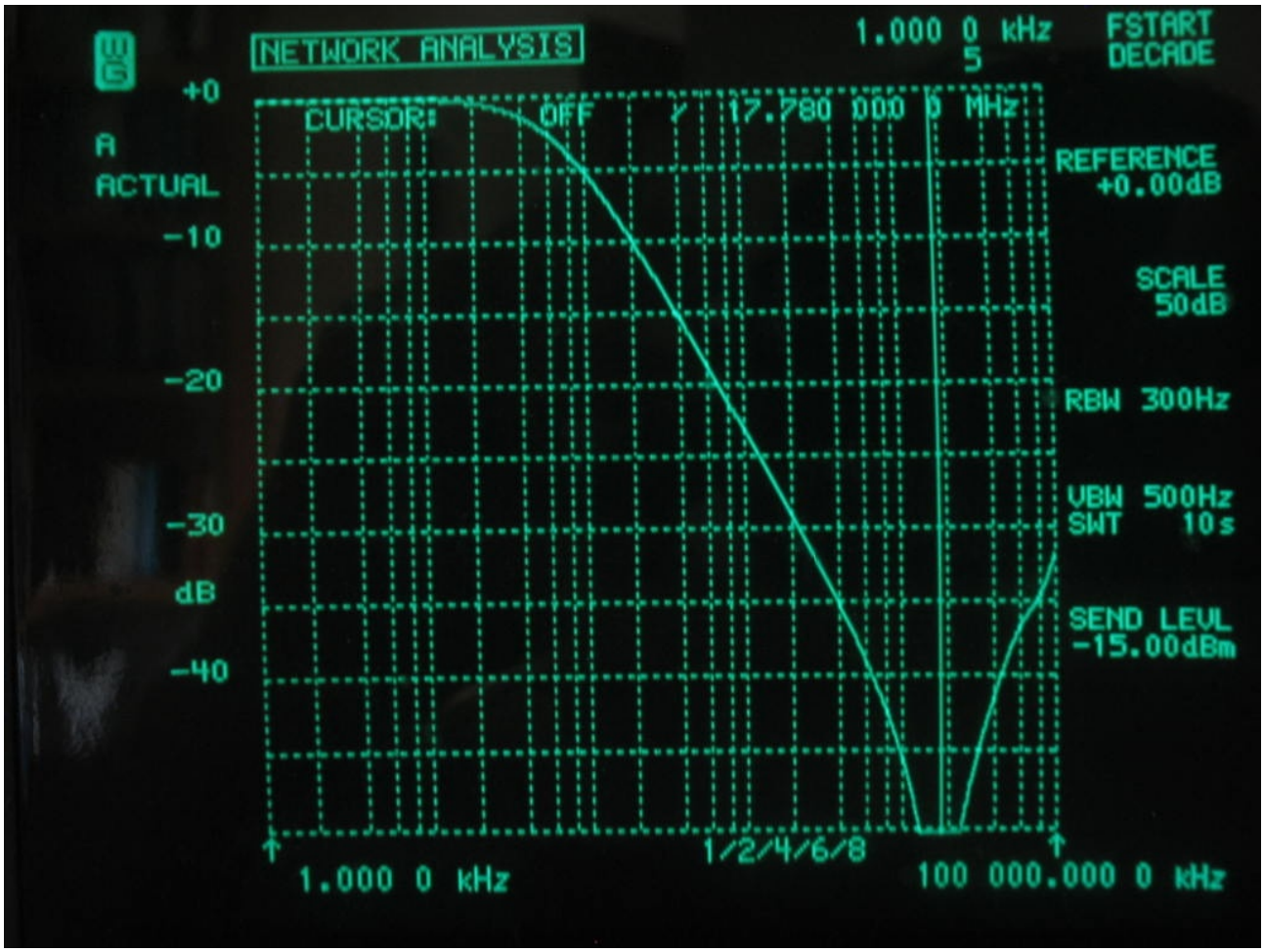
now a leaded 100 nF ceramic capacitor. The rule of thumb is that 100 nF leaded resonates at 7 MHz. Hits quite closely.



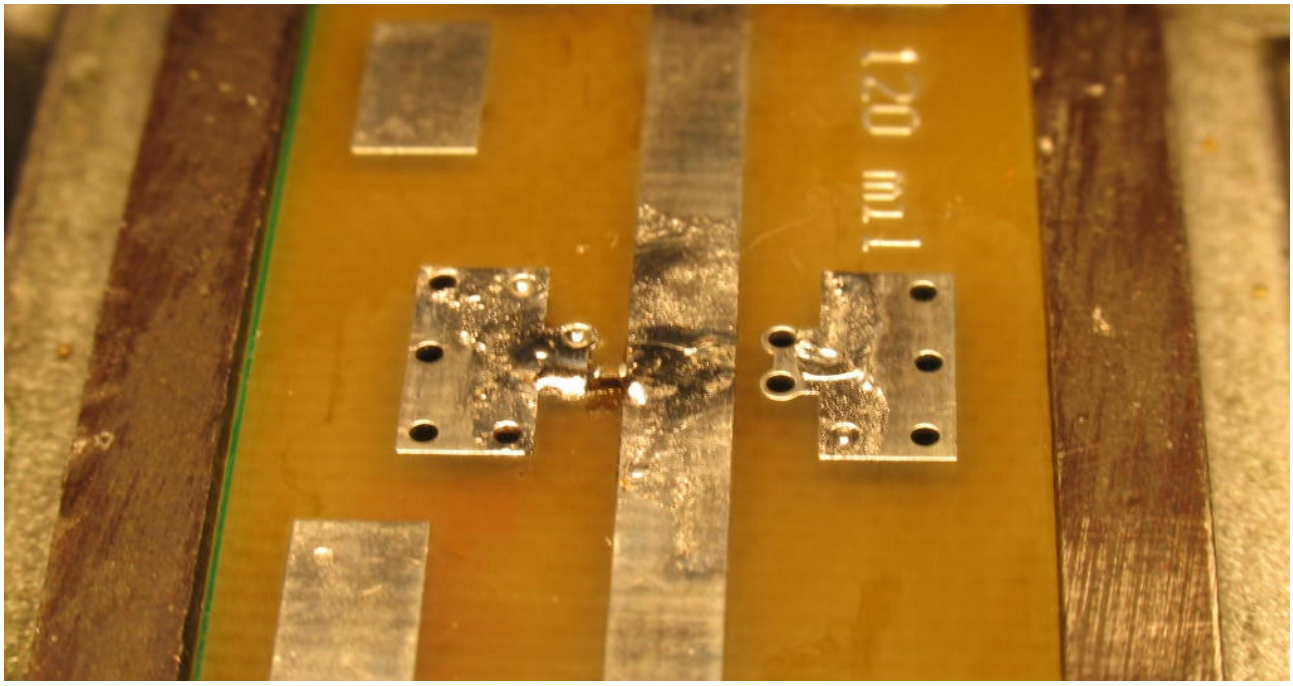


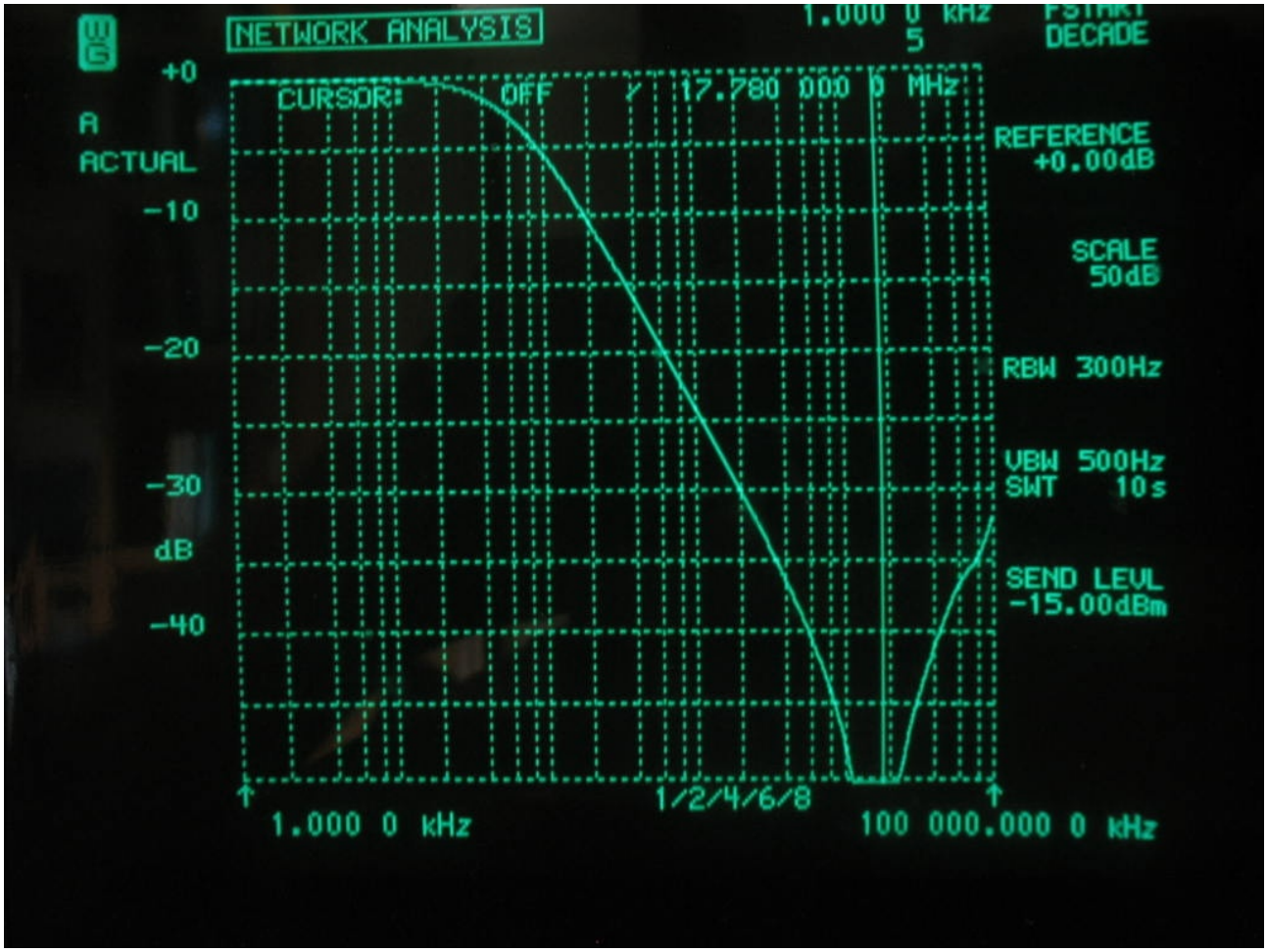
Next: 100 nF 1206



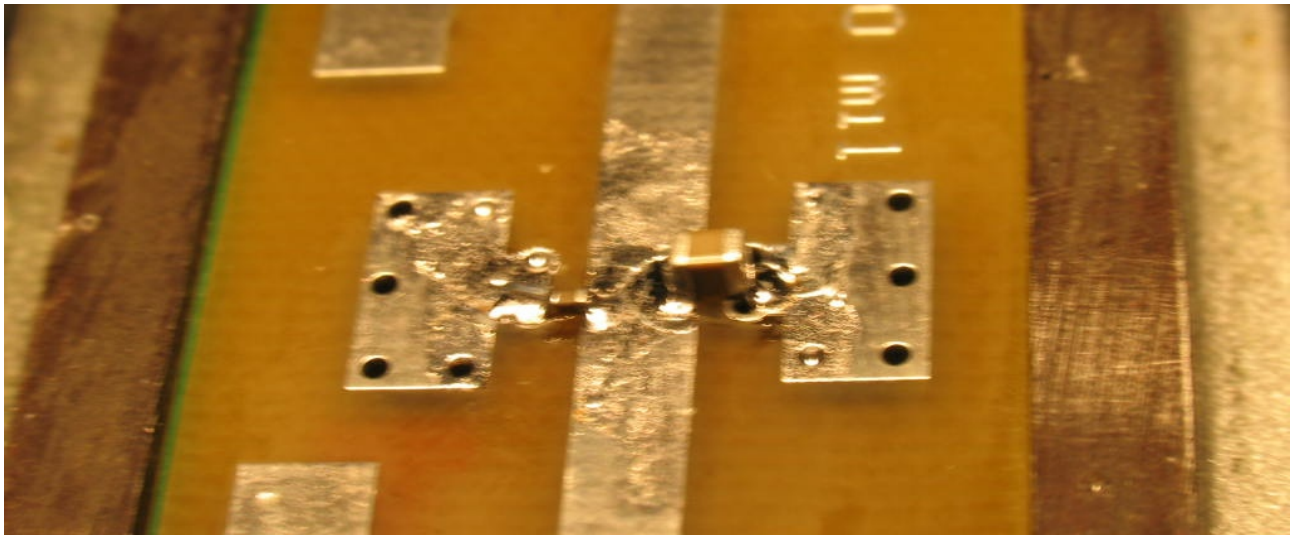


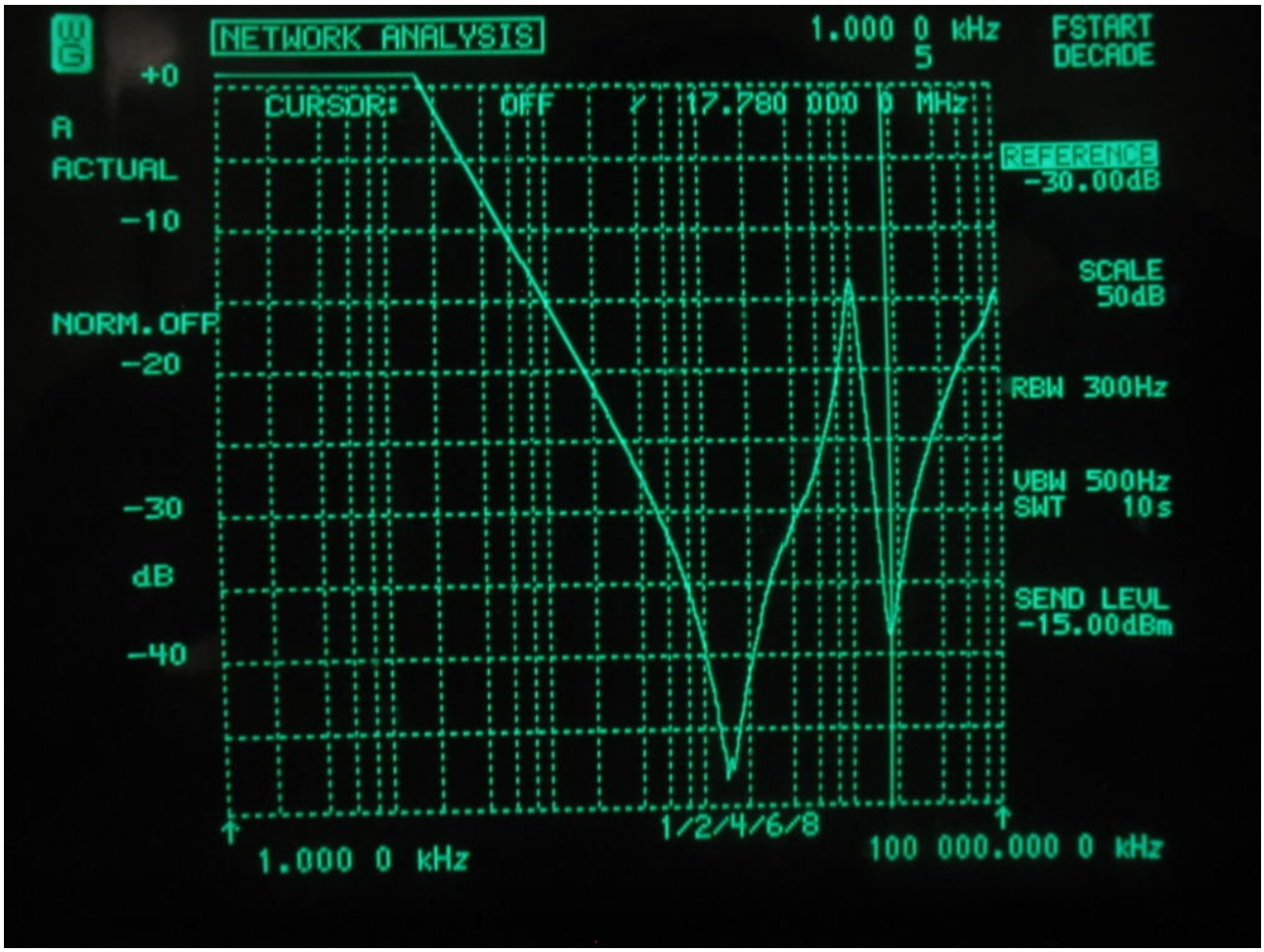
Lets try 100 nF 0402. That does not buy us much. At 1.5 mm, the board is simply too thick and the via is too long.



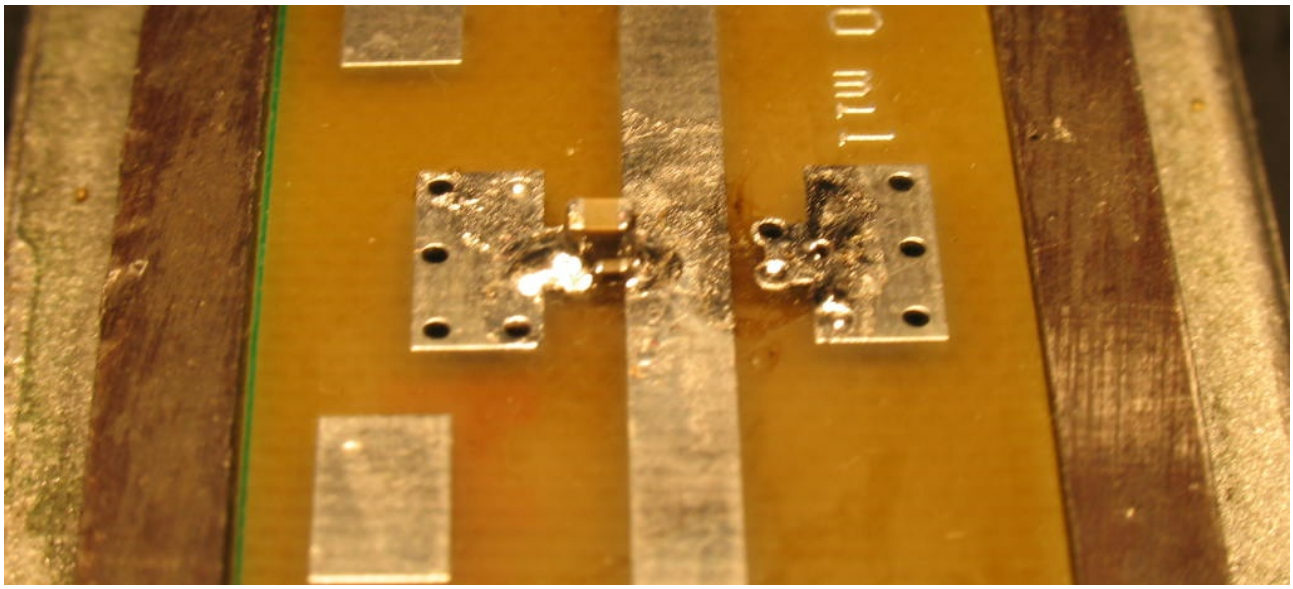
Now the bigger caps: 22uF 0805 Murata.
I leave the 100 nF 0402 on the board to see what happens.



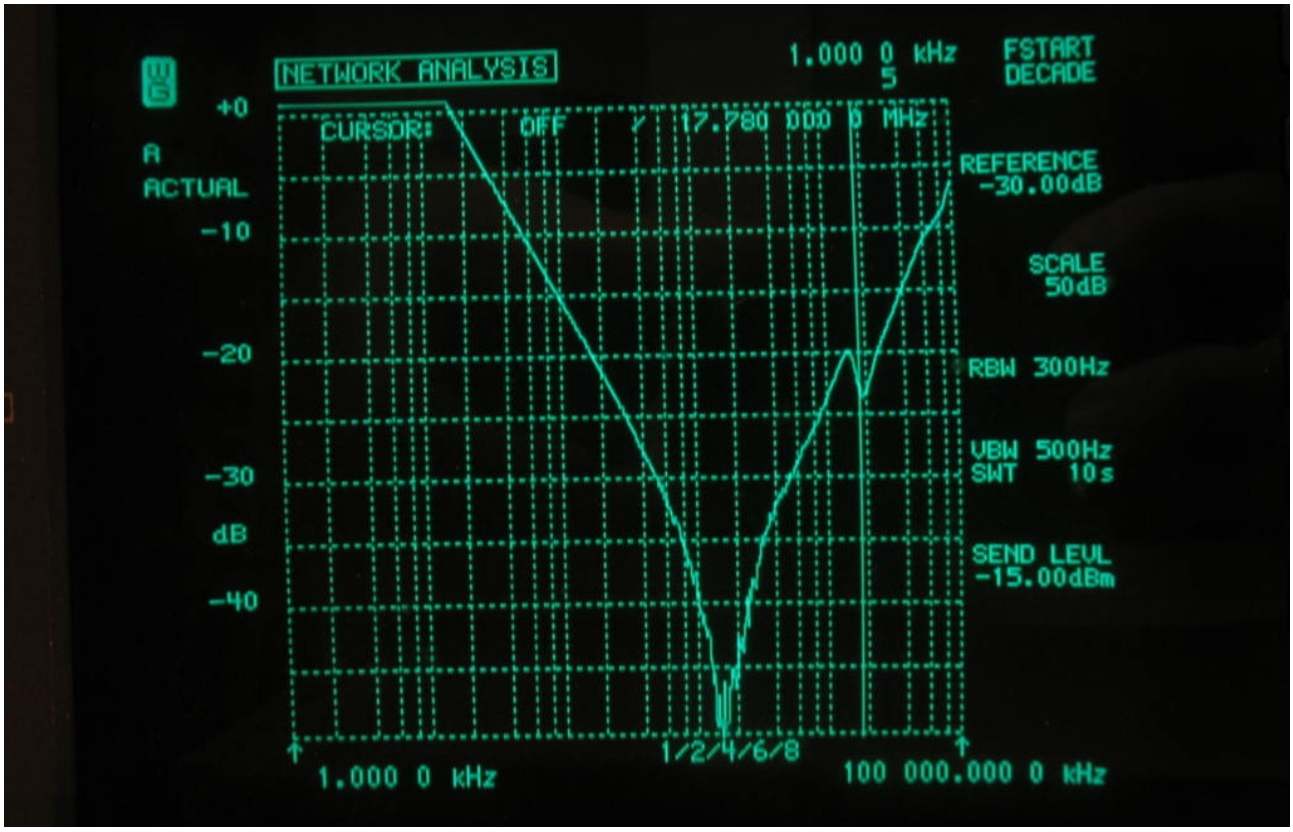



At 80 MHz, things are much worse than before. Parallel resonance.

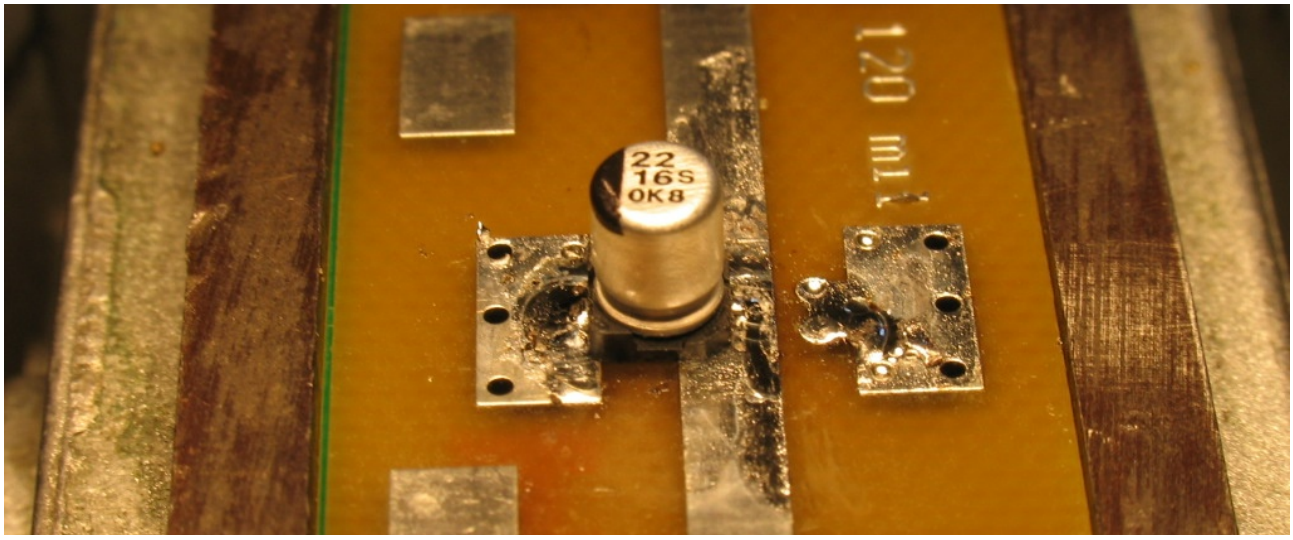
22u 0805 close to 100 nF 0402 with half the vias.



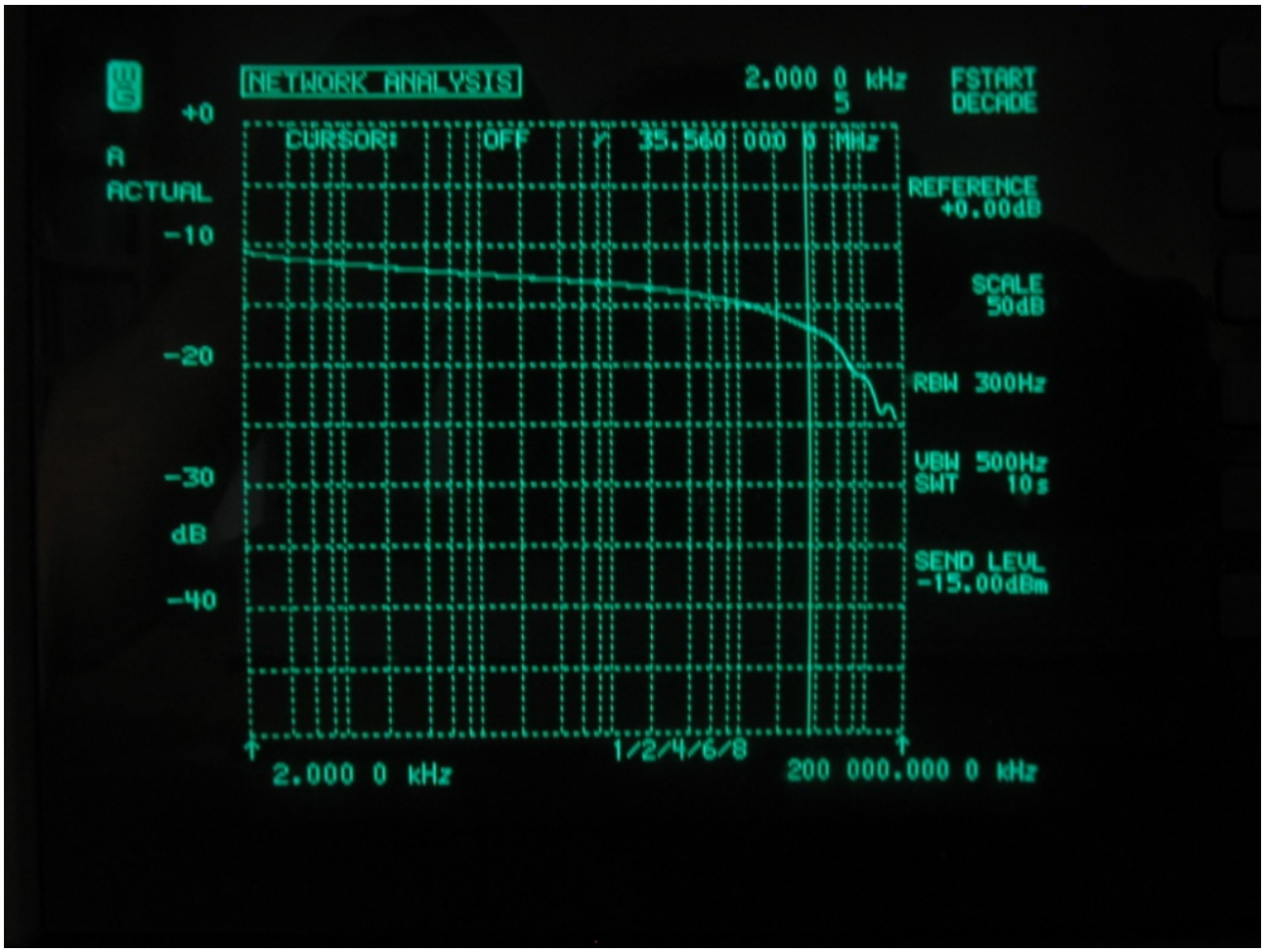
.. and this is the response.  The notch is ~ 75 dB down.



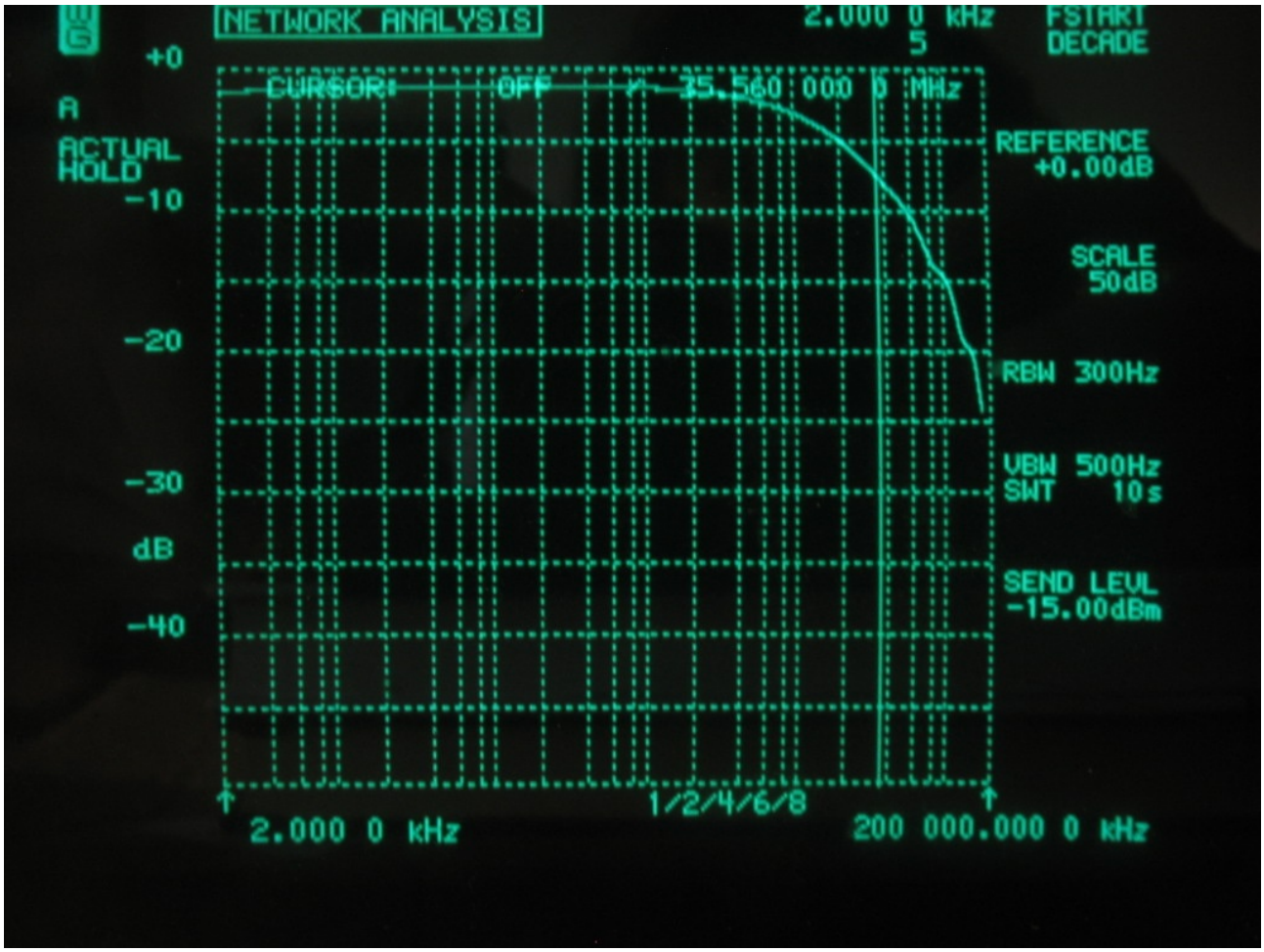
Alu SMD 22uF 16V 4mm dia 5 mm high, no bias.
Manufacturer logo similar to Moto-M or BatMans head in a box
You'll recognize it when you see it. I don't want no war.



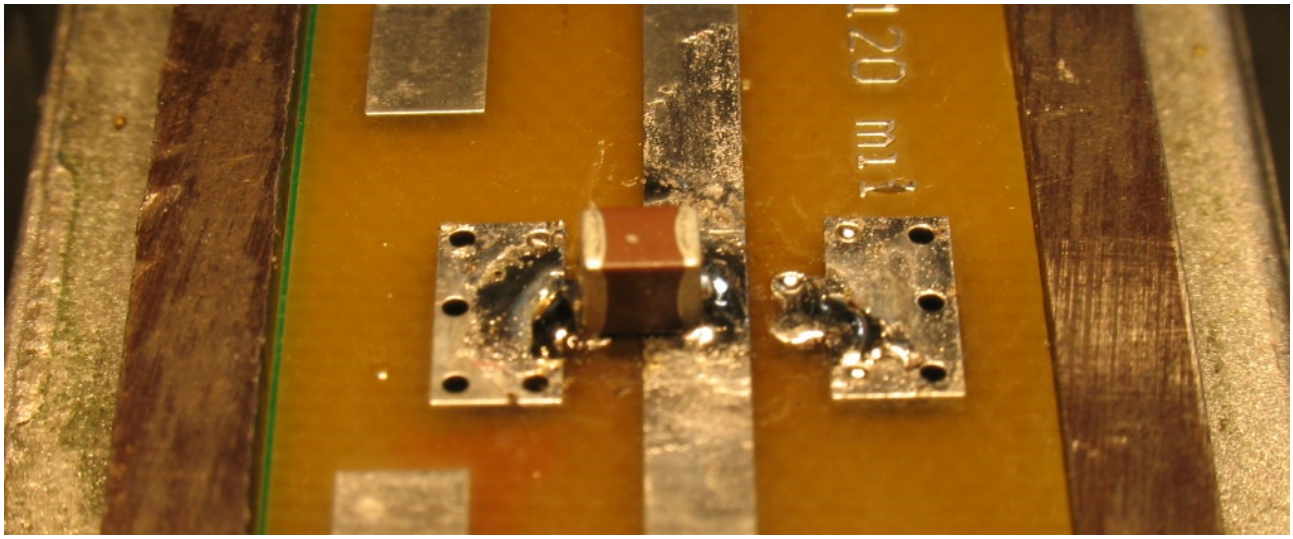

That's embarrassing. Picture taken at room temperature.

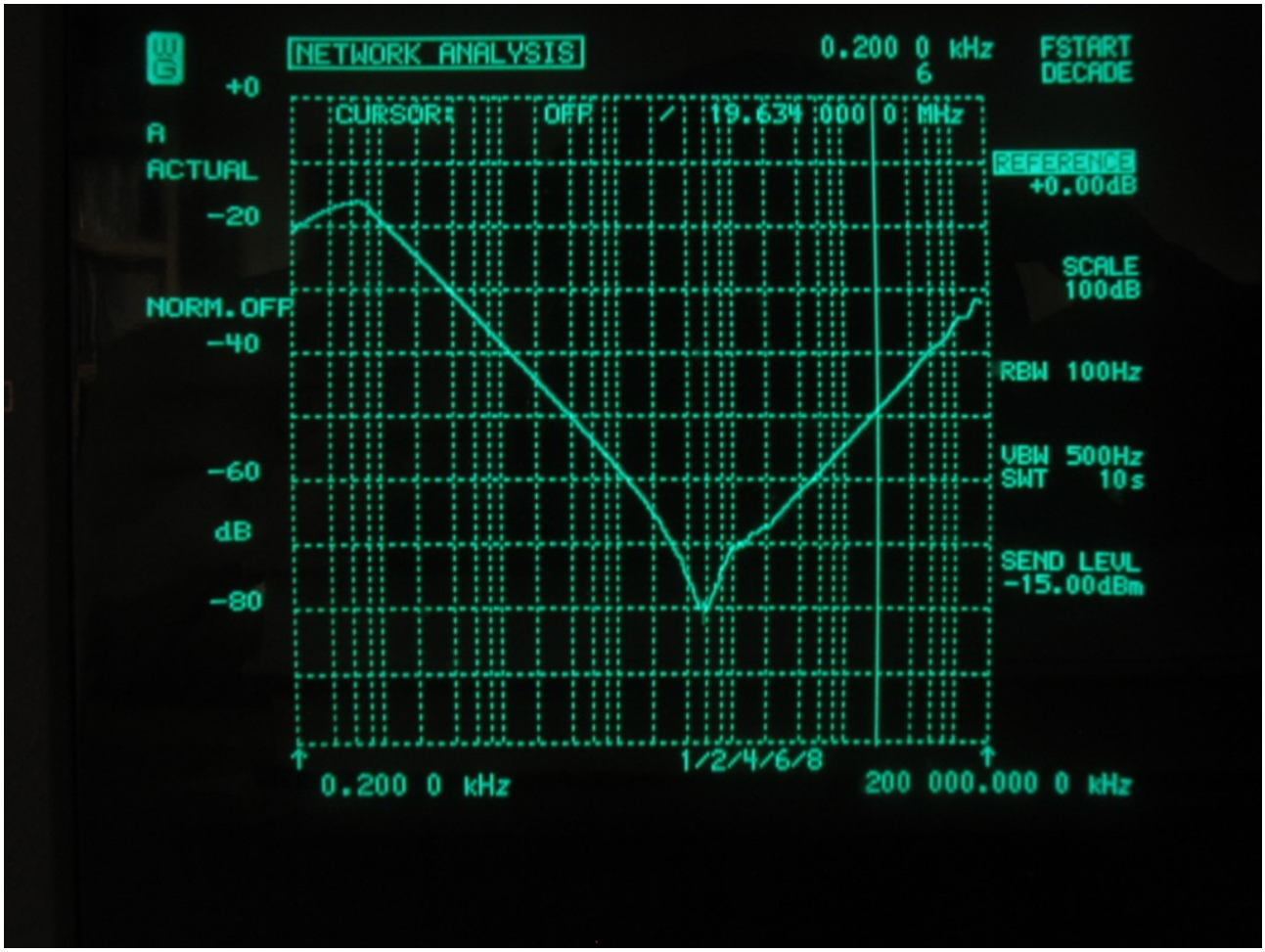


Now let's apply some freeze spray.
This adds insult to embarrasment. About as good as no capacitor at all.
(but heating to 105 degC does not fare much better than room temp.)



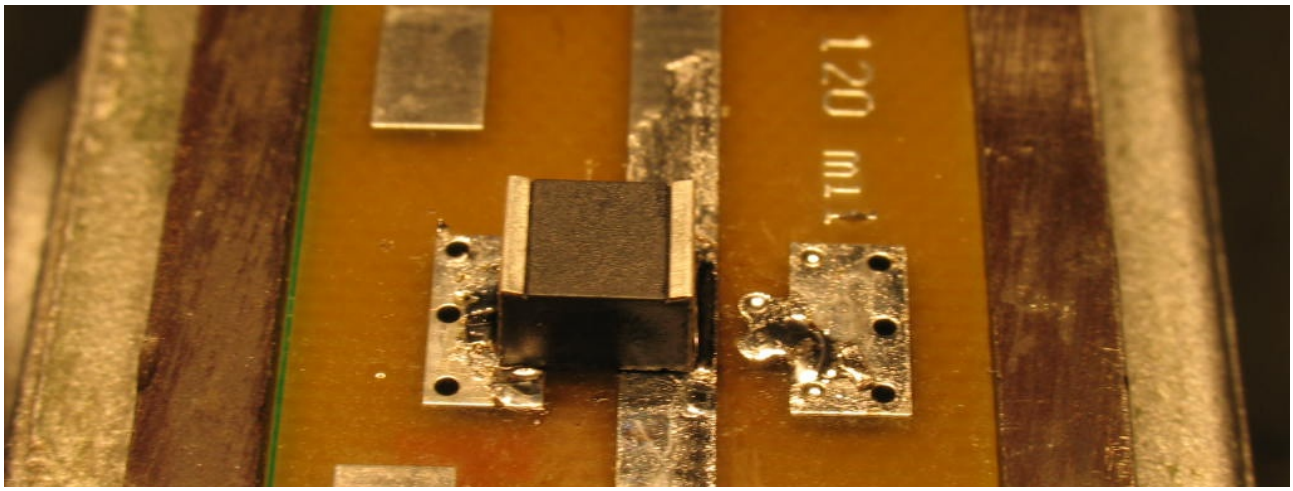
The next one looks better.
TDK C3225 X5R 0J107MT
100 uF 6.3V ceramic multilayer 1208

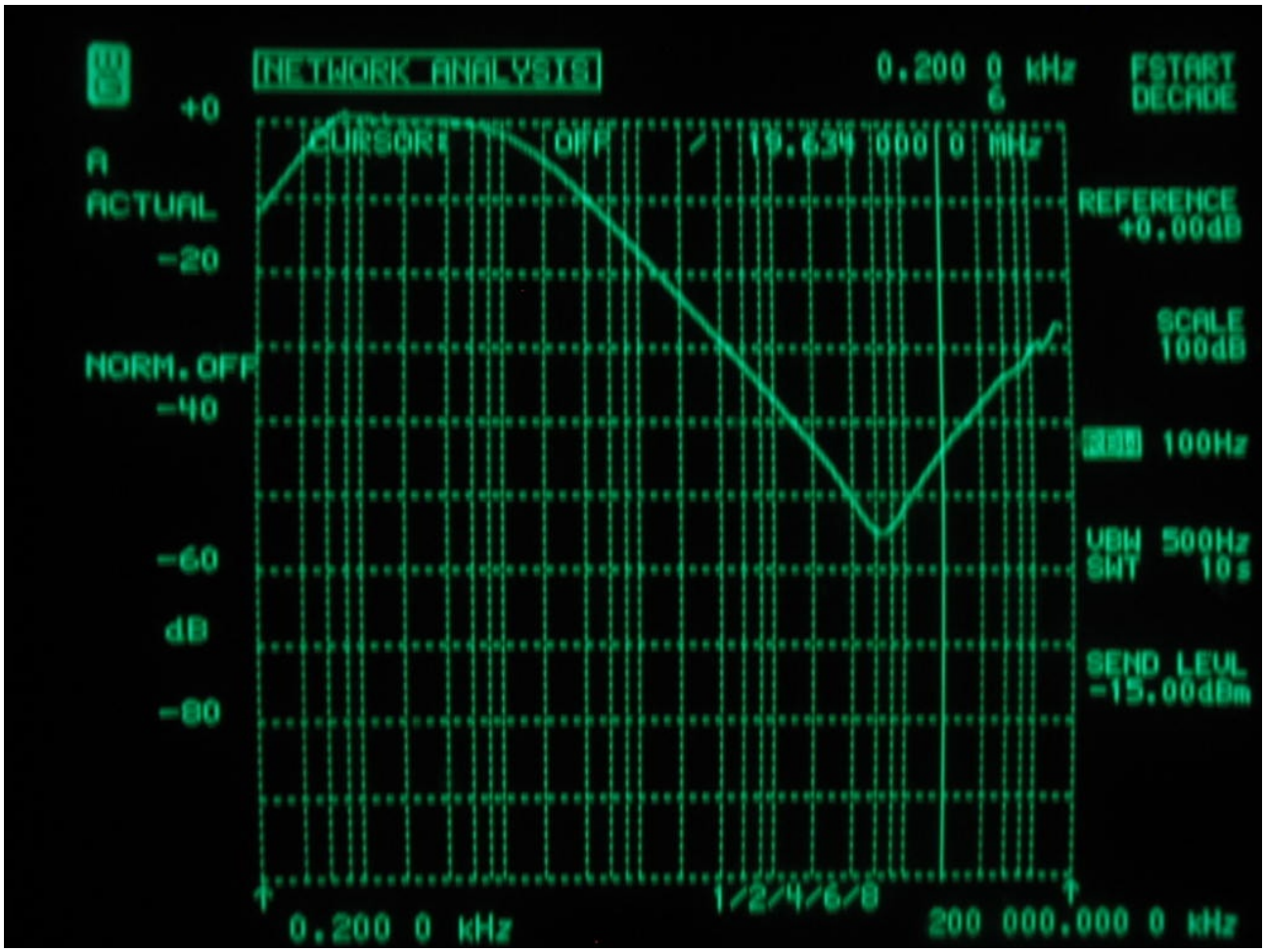




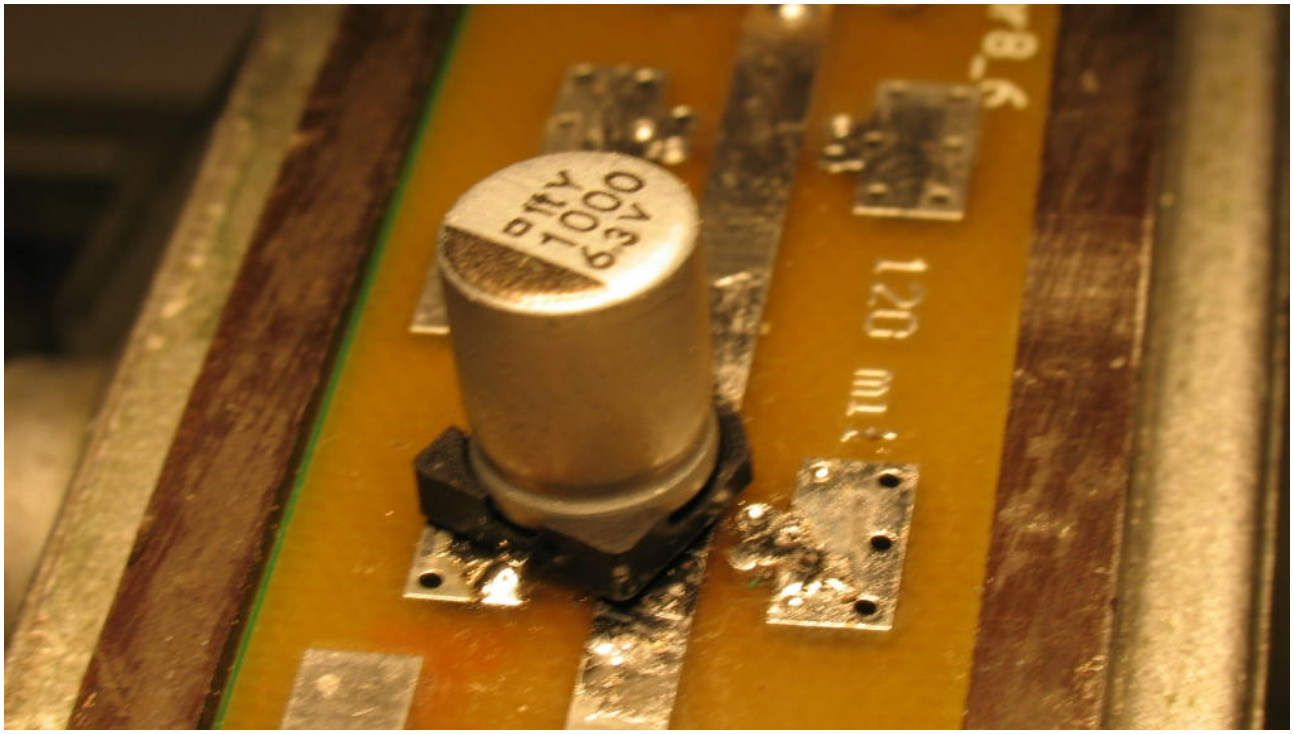

I couldn't decide what to snip off, so I changed the vertical scale to 100 dB and added a decade on the frequency range. response change was barely visible between freeze spray and 105 decC hot air. The decline below 400 Hz is probably the lower cutoff of the Spectrum analyzer and the tracking generator. Perhaps I should have re-normalized.

and now: SMD 2220 470nF 63V foil, polyester by Wima
The foil capacitors may have their merits, but wideband decoupling is not one of them.
(but the scale is 100 dB now)

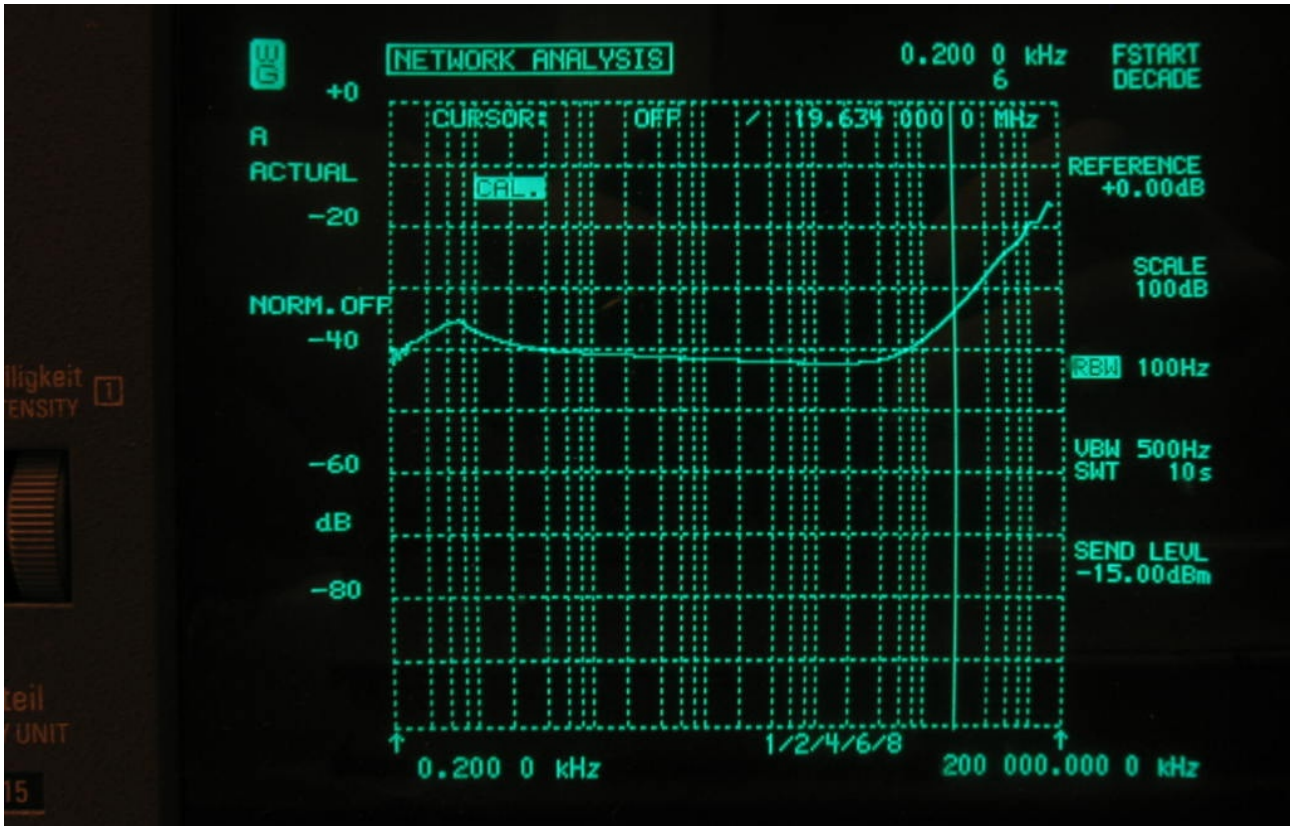




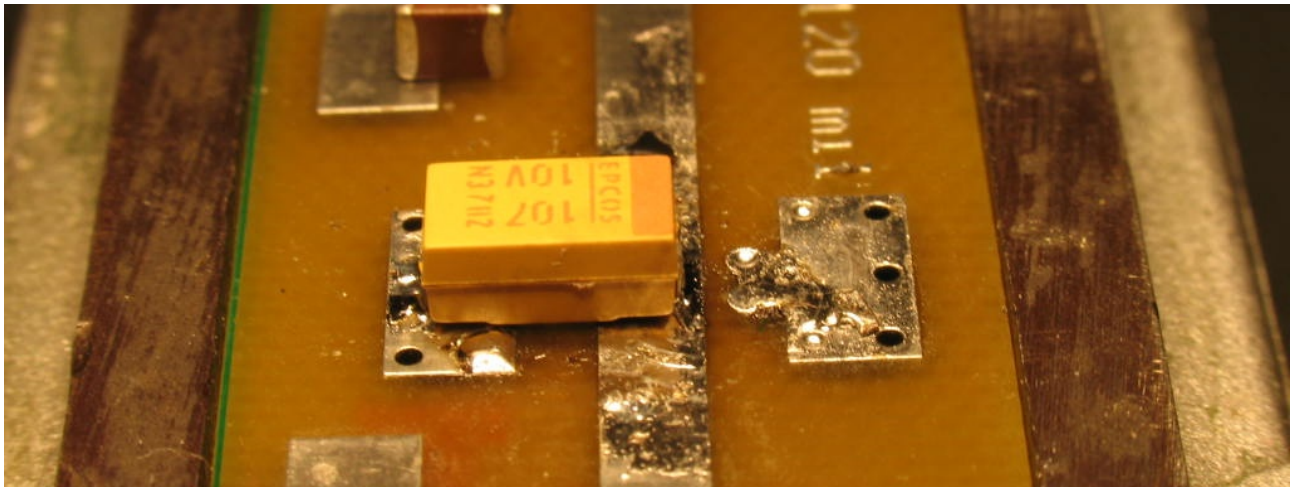
1000 uF 6.3V NipponChemi "Low ESR" 0.3R
8 mm dia, no bias

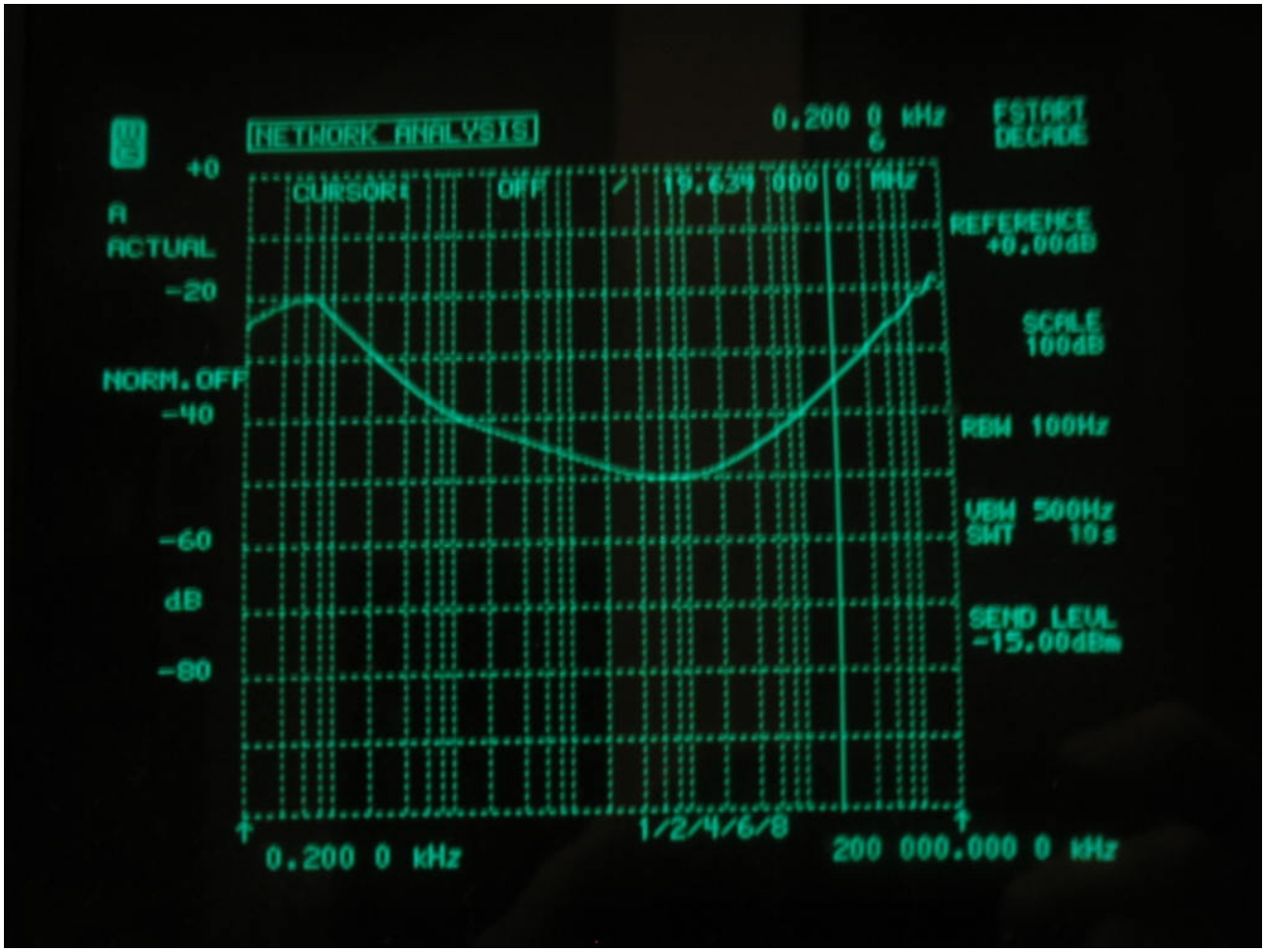


The RF side is not so pretty, but then this is a 1 MilliFarad electrolytic. Does a good job at the low frequency end. The horizontal section gets 2 or 3 dB worse if cap is deep frozen, but it's not that complete failure like the BatCap. All in all, I like it.

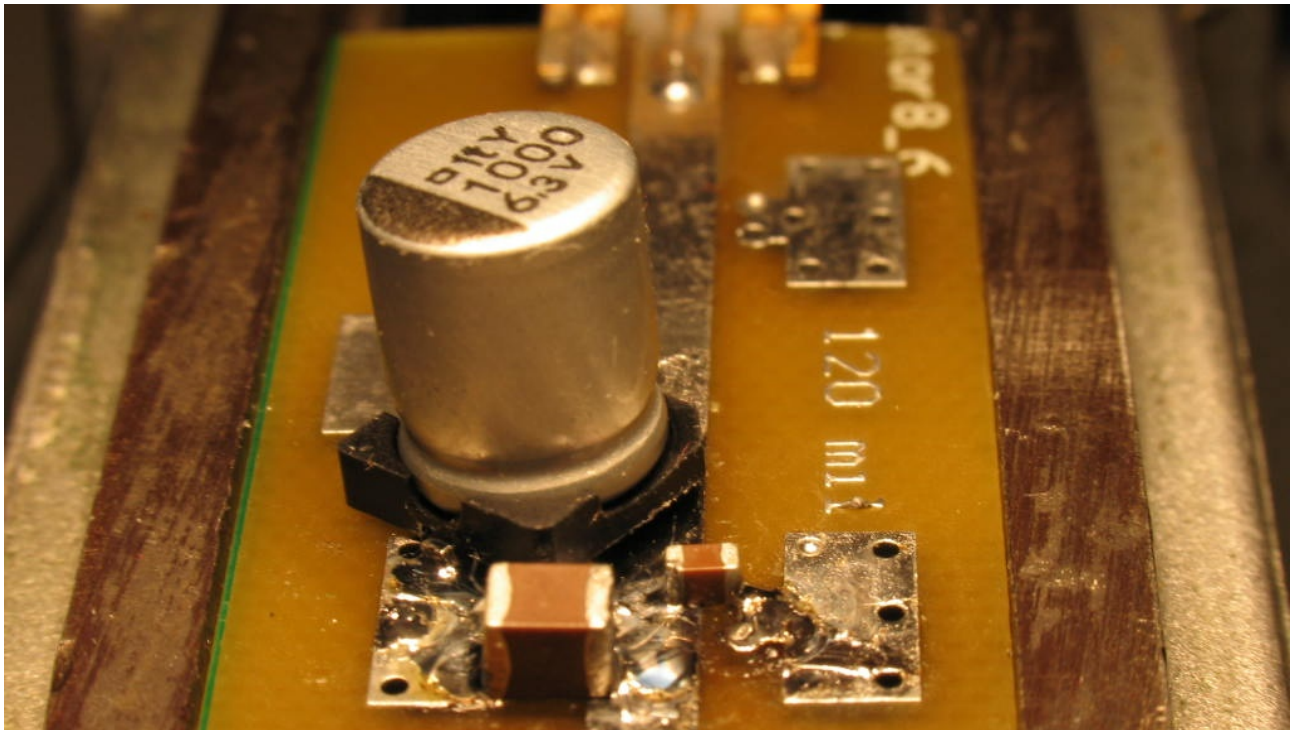


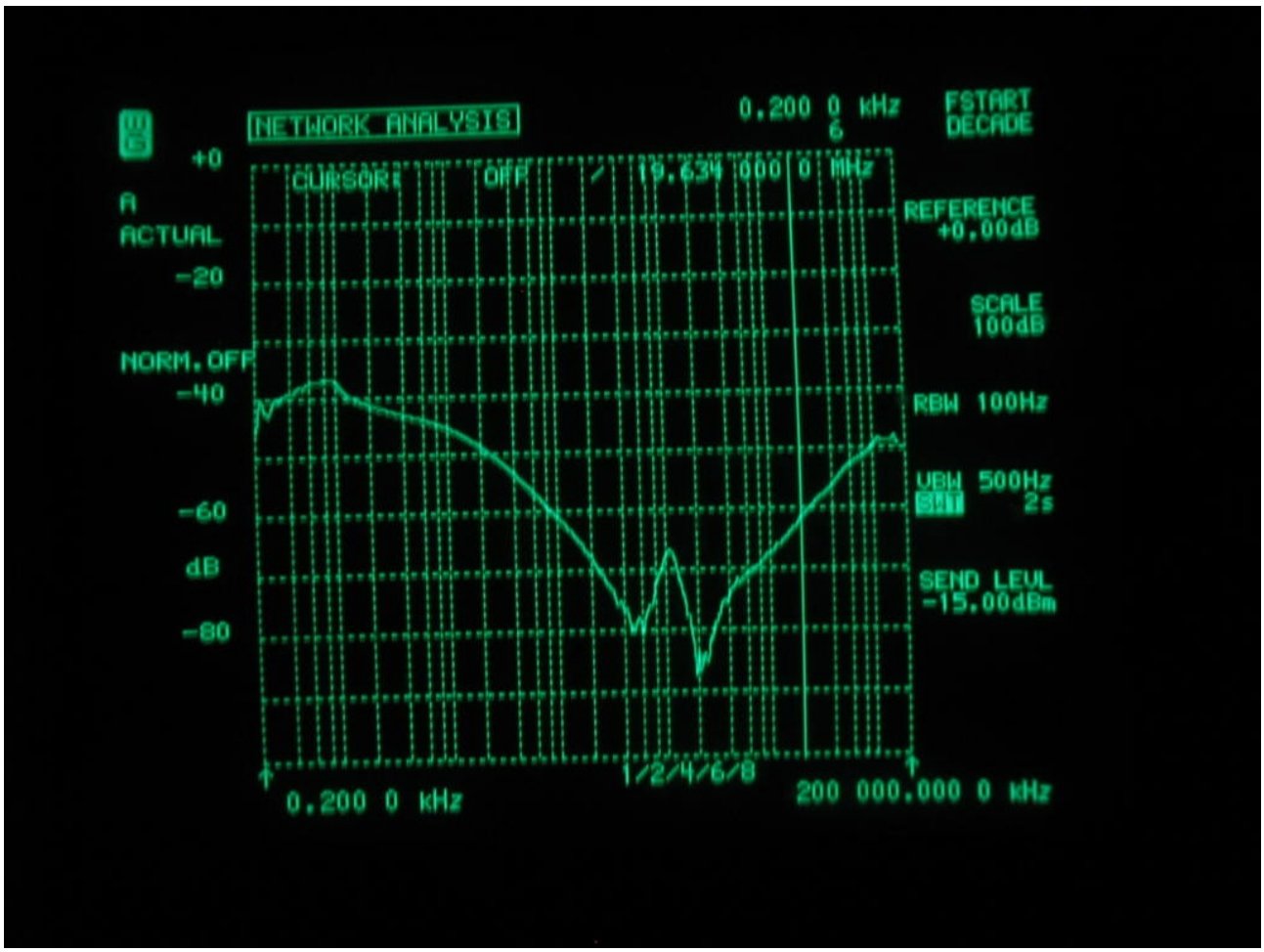
100 uF tantal. Above 2 MHz, it's simply too large, mechanically.
Does not make me like tantals. The brown capacitor in the background is not connected.



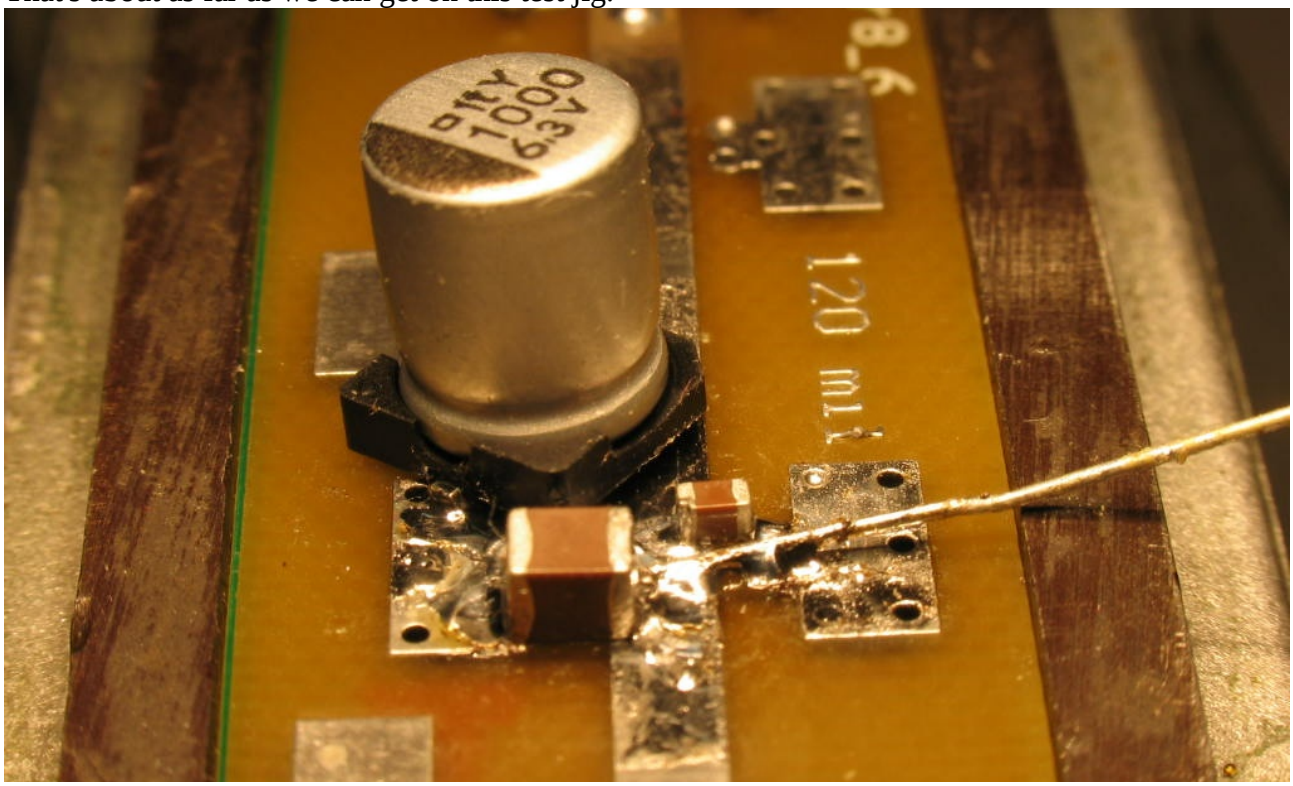



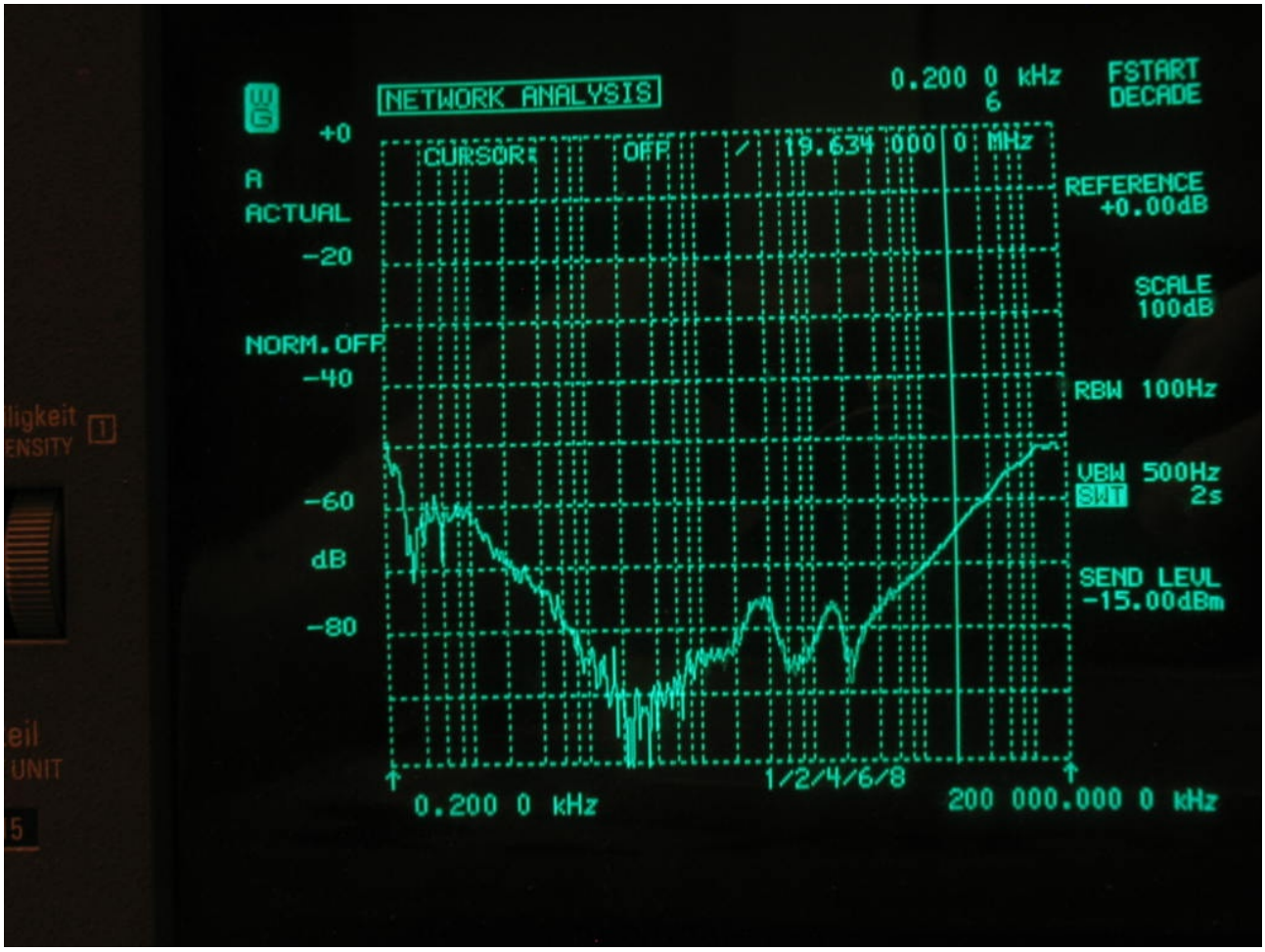
1000uF electrolytic + 100uF 1208 ceramic + 10 uF 0805 ceramic
There are resonances, but at this level, it's OK.



Adding more small ceramics helps nothing. We try a single short.
1000 uF electrolytic + 100 uf MLCC + 10 uF MLCC + wire short
We can still see the series resonance of the 10 and 100 uF ceramics at 2.5 and 0.7 MHz.
That's about as far as we can get on this test jig.

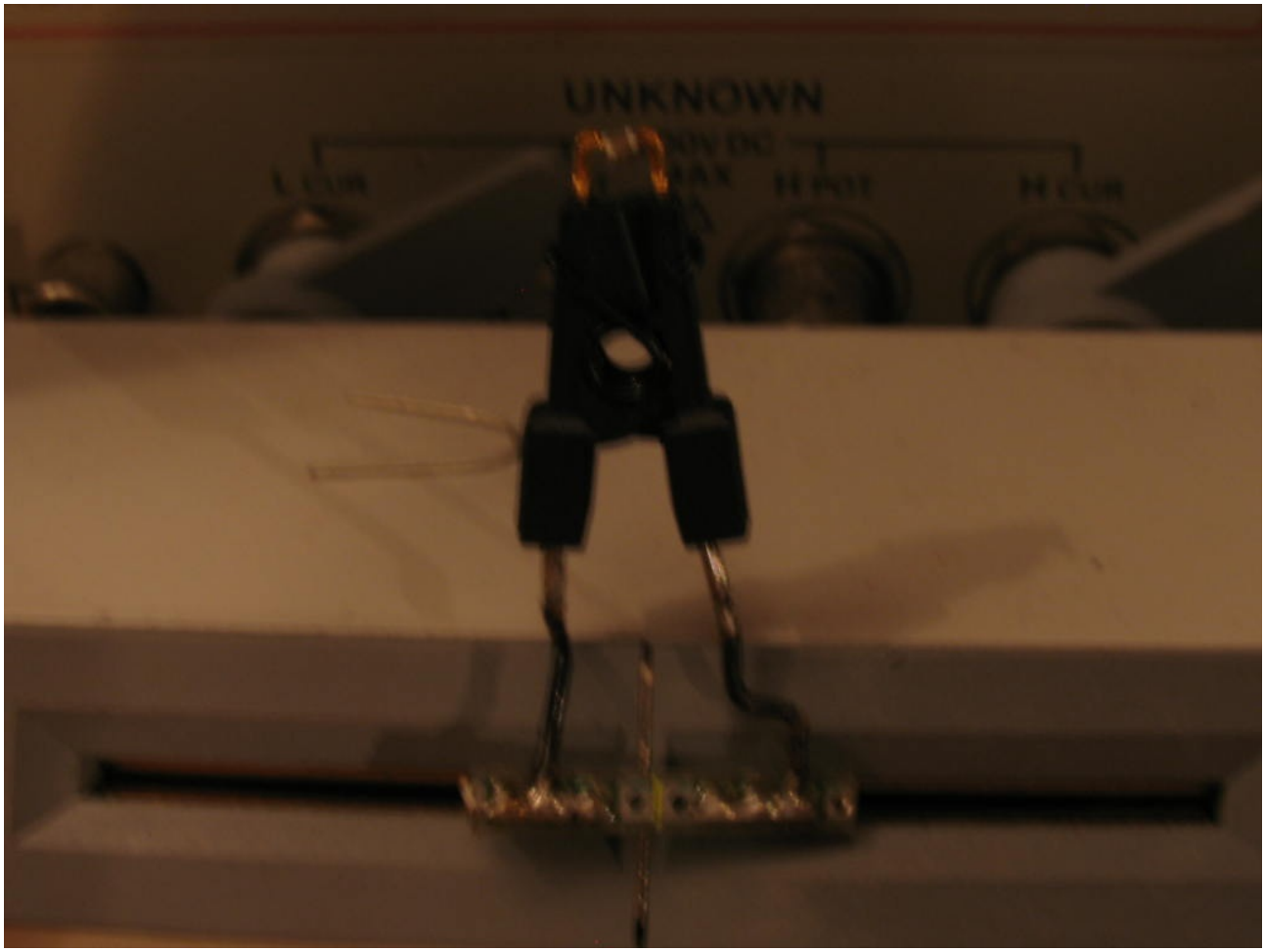


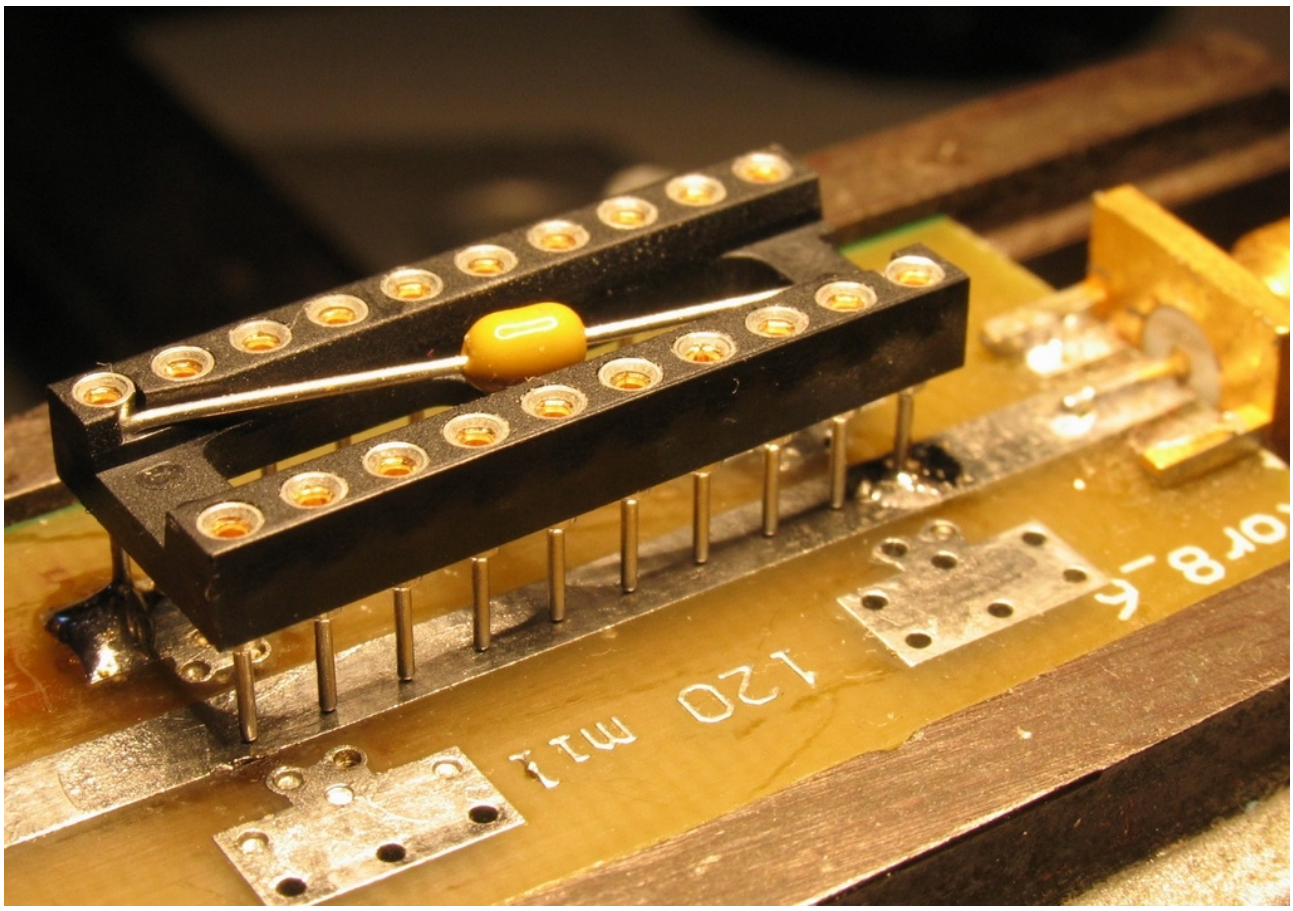



This is what a HP4274A multifrequency LCR meter thinks about the
22uF 0805 capacitor if it is attached with 2 * 30 mm of wire:

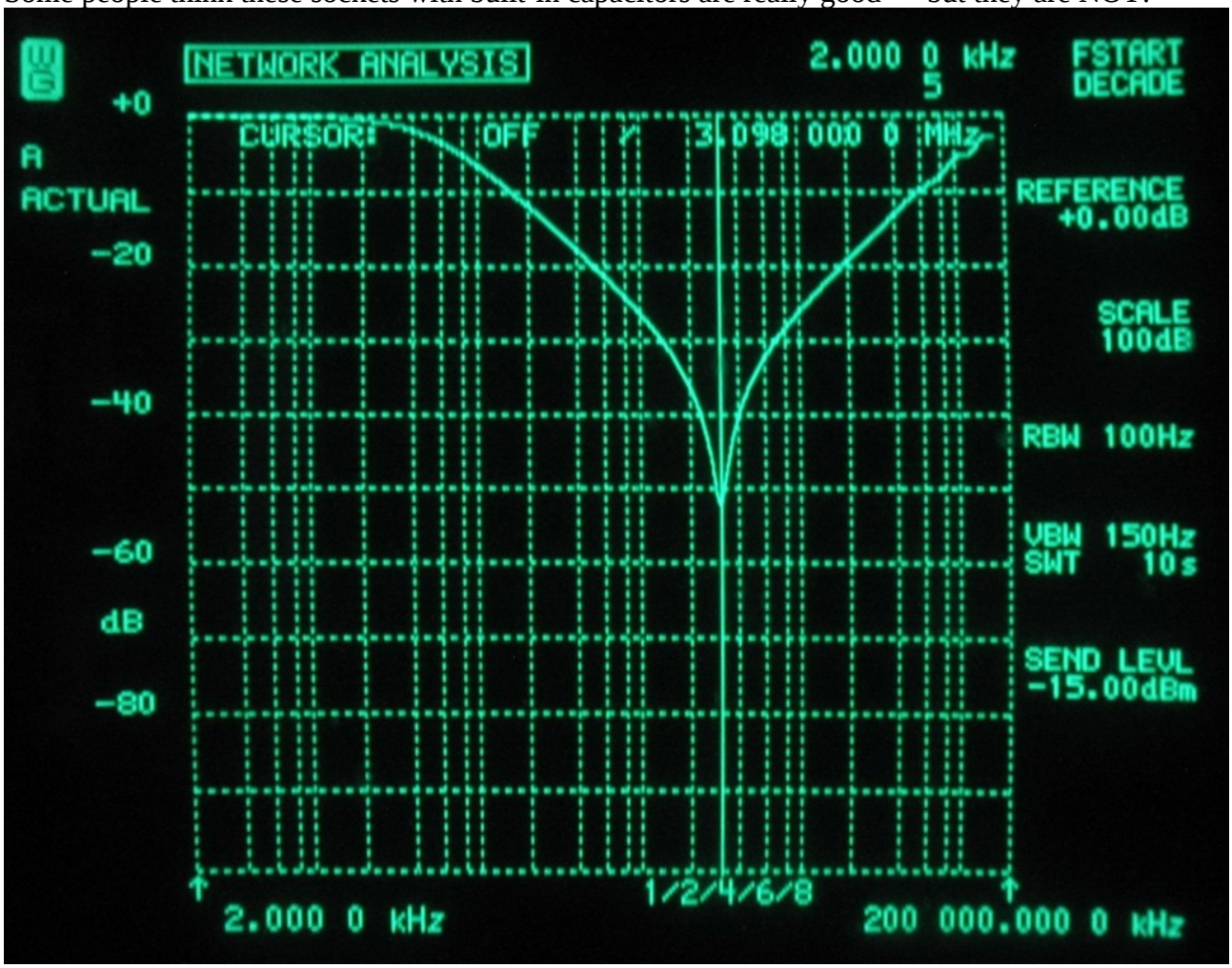
| | | |
|---|---|---|
| 100 KHz | 14.1uF | Q=2.1 |
| 40 KHz | 11.81uF | Q=5.4 |
| 20 KHz | 11.9uF | Q=9 |
| 10KHz | 12.5uF | Q=11.4 |
| 4KHz | 14.06uF | Q=10.7 |
| 2KHz | 15.89uF | Q=9 |
| 1KHz | 18.03uF | Q=8.4 |
| 400 Hz | 20.92uF | Q=8.6 |
| 200 Hz | 22.7uF | Q=9.3 |
| 100 Hz | 23.79uF | Q=10.2 |

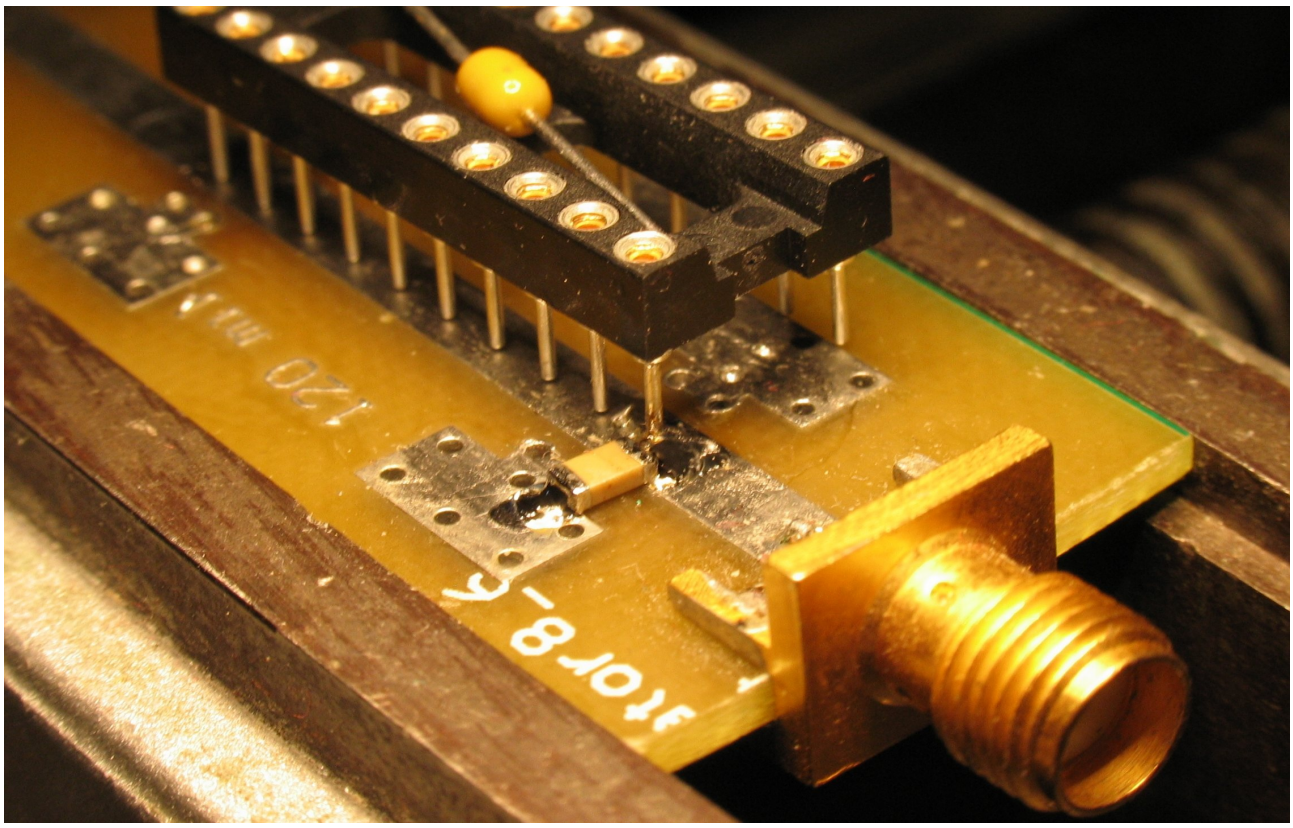
The 60 mm of wire make quite a mess. Now think if you trust C measurements on those multimeters with unknown frequency and long cables.





Some people think these sockets with built-in capacitors are really good --- but they are NOT!





Adding a 100nF / 0805 capacitor adds a resonance.