SMPS Mains Leakage Current-Induced Errors In Unbalanced Audio Interconnects.

Cheap SMPS supplies which are typically bundled with DACs etc are known to have high levels of nasty mains leakage common-mode current compared to medical grade SMPS and traditional linear supplies. I will show here the effect this balancing current can have on the signal at the cable end, when the balancing current is forced to flow through the RCA cable shield and when the shield impedance, including connectors, isn't low (sub-Milliohms @ DC), allowing for R*i and L*di/dt voltage drops seen as signal. This is known in the literature as "SCIN -- SCreen Induced Noise". The way the measurement was set also allowed to measure the effect of the balancing current flow right through the PCB GND-Plane/Tracks in the Audio Interface, producing again some R*i and L*di/dt drops.

Setup :
- Analyzer : REW running on a Laptop with earth-grounded supply (the PE return path for the leakage current), USB-GND (where the Audio Interface is attached to) is at PE potential.
ADC : RME Adi-2 Pro FS (a DAC+ADC unit), USB connected, 44.1kHz, Analog In set to +4dBu (so dB values shown in the plots are close to being actual dBV units).

Supply of the Audio Interface :

- Stock SMPS of the Adi-2 Pro, a standard construction with high amounts of leakage current,
- Inserted medical isolated DC/DC (12V->15V) Converter (TRACO model # THM 30-1213) with low leakage and small coupling capacitance to mains,
- Input GND of the DC/DC is brought to a binding post so it can be connected, for example, to the secondary side to have the full common-mode current as without DC/DC, or to divert it to PE via another path (see specifics below),

Analog Input to the ADC is via 1/4" TS to RCA adapter, either directly shorted with a 50R BNC (via adapter) or with the DUT (el-cheapo RCA cable) in between.

Measured entity is the zero-signal shorted (50R) input noise floor spectrum.

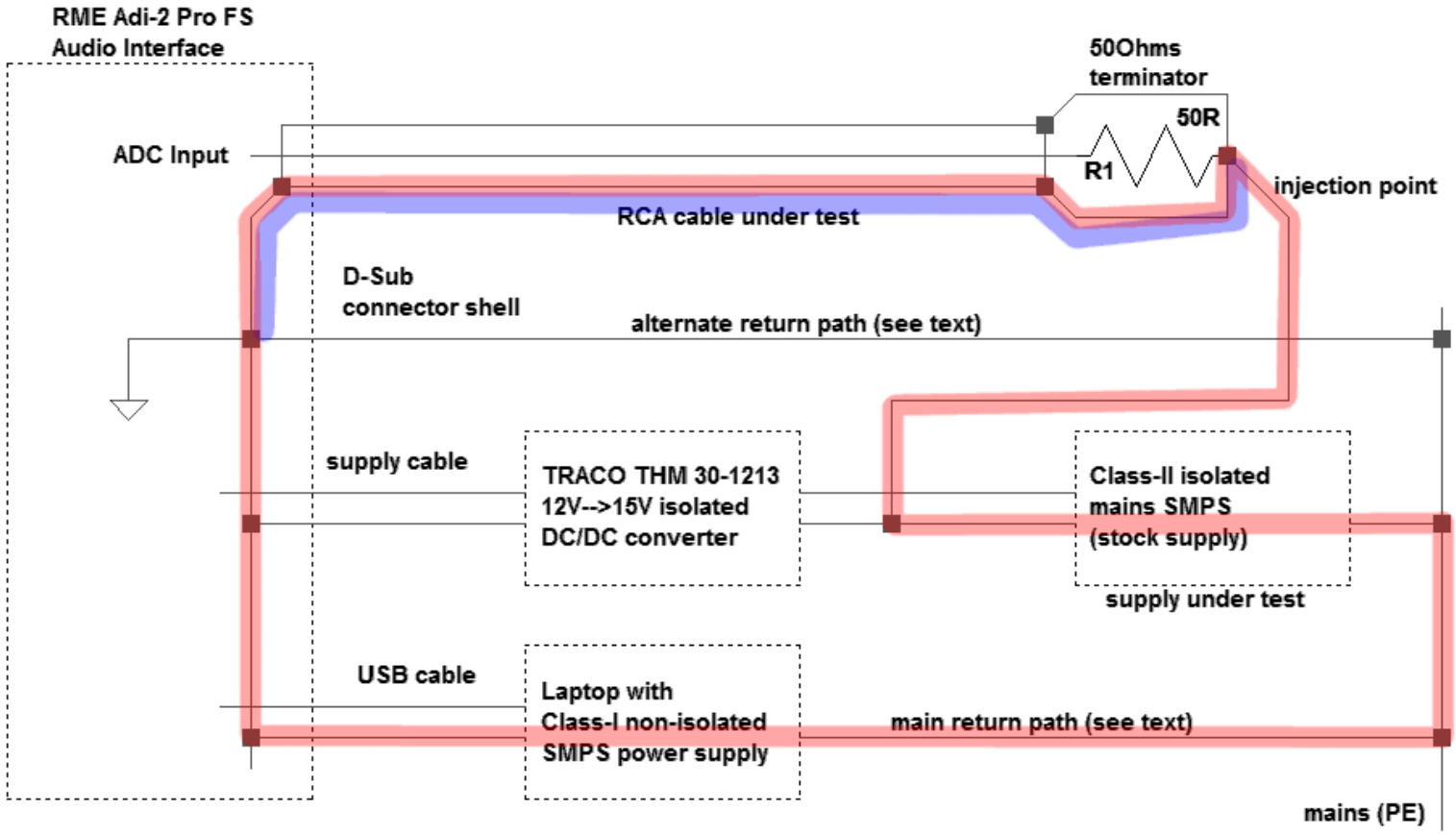
In the experiment I will vary the route of the balancing current of the stock supply from *right through* the cable shield and the RME analog electronics GND to several ways of bypassing this current around the cable and device, plus reducing it in the first place.

It was found that for the specific SMPS and RCA cable used the shield current induced noise was significant and could lead to wrong interpretations when the goal is to measure the true output noise of a grounded source, without precautions taken to shunt the balancing current away or reduce it by a better isolating supply.

In the complementary application, like a "floating" DAC feeding a grounded amp via unbalanced interconnect, the same error voltage is present at the amp input. Not necessarily resulting in apparent audible buzz in the speaker/phones, but there is a chance that it still affects perceived sound quality. Controlling your balancing current paths and reducing current levels in an unbalanced listening/measurement setup seems worthwhile at any rate.

February 2019, KSTR

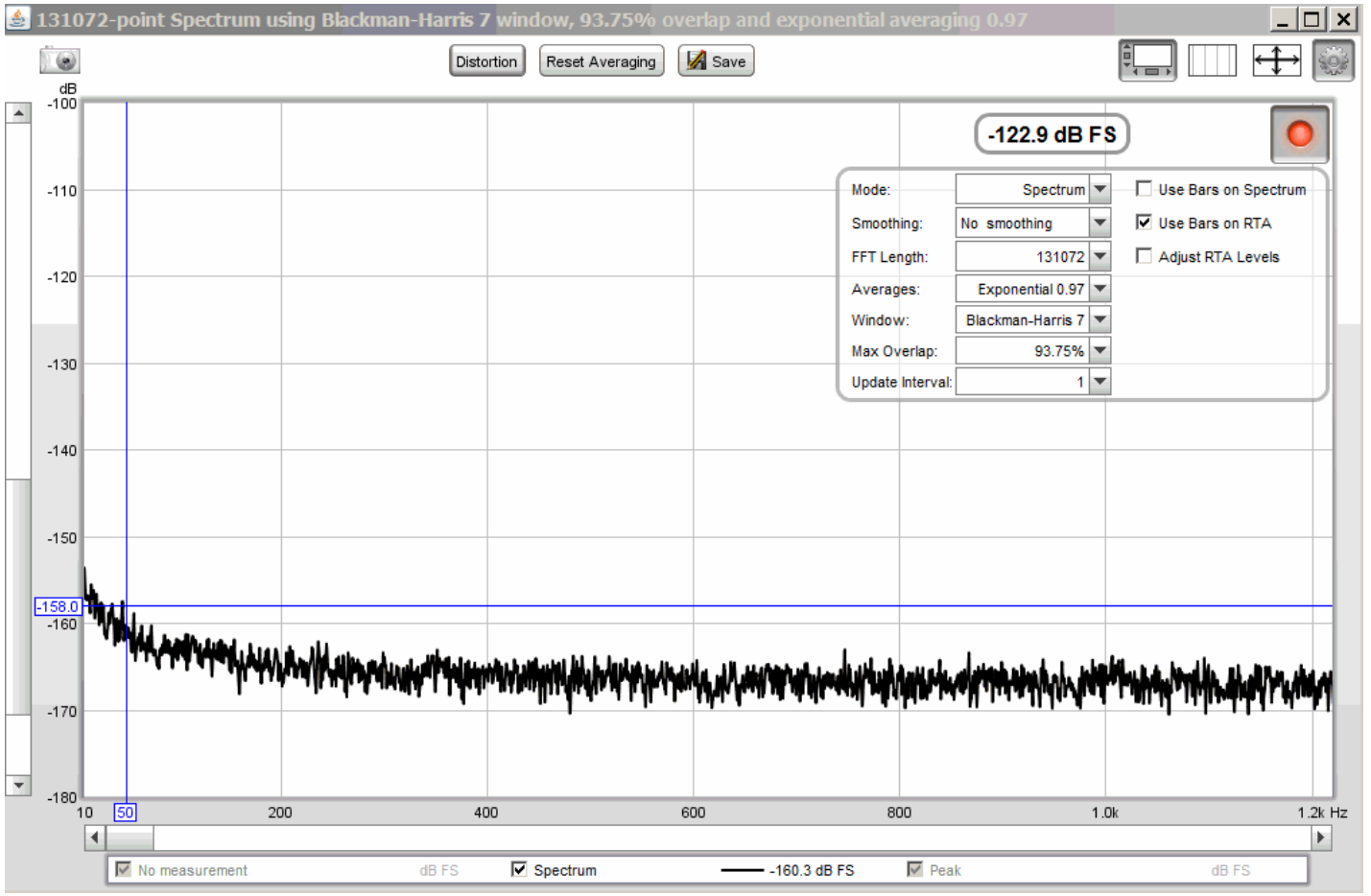
Setup :



The setup shown is what was used for the relevant measurement #4 (note: alternate path not used) and the balancing current path is highlighted in red. Highlighted in blue is the relevant part of it, the shared path with the audio GND/shield connection where any voltage drop along it appears 1:1 as error signal at the ADC input.
Note that the error signal developed along the relevant section of the path is the same when injection point and return connection are swapped (Laptop running off of battery, no mains connection. Alternate path used instead -- as injection entry point as noted).

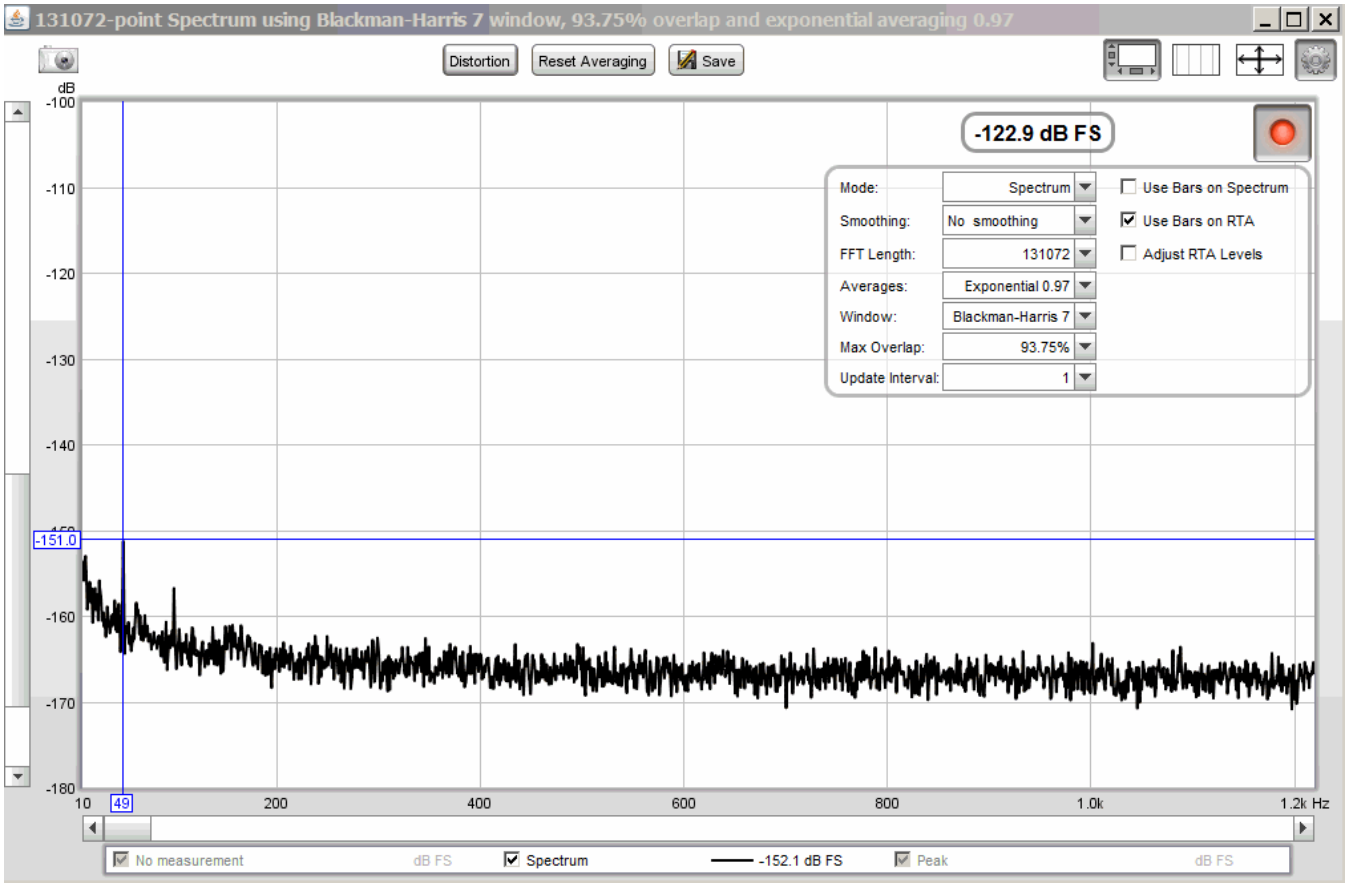
For the other measurements different return paths were used, please refer to the corresponding description of the test.

1) Noise Baseline, 50Ohm shorted Input:



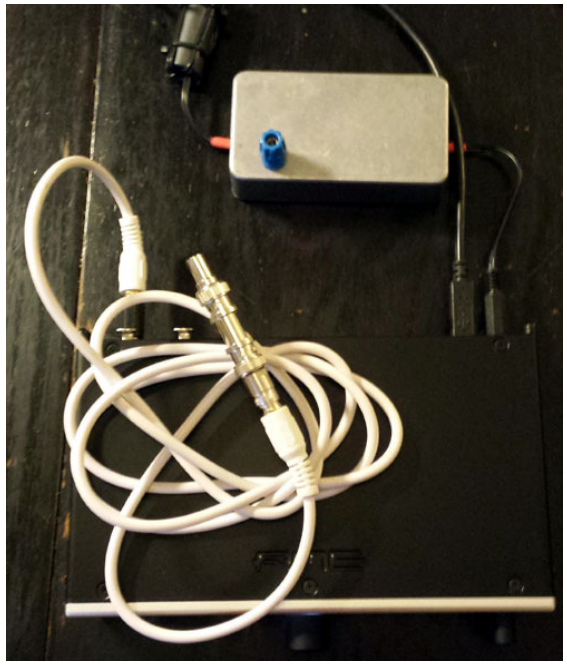
There is no balancing current at all in the audio path, and the little balancing current that is left (due to the inserted DC/DC) is routed directly from the entry point (far right) to the USB cable. No shared path, the spectrum is as free from mains-related noise as it gets.

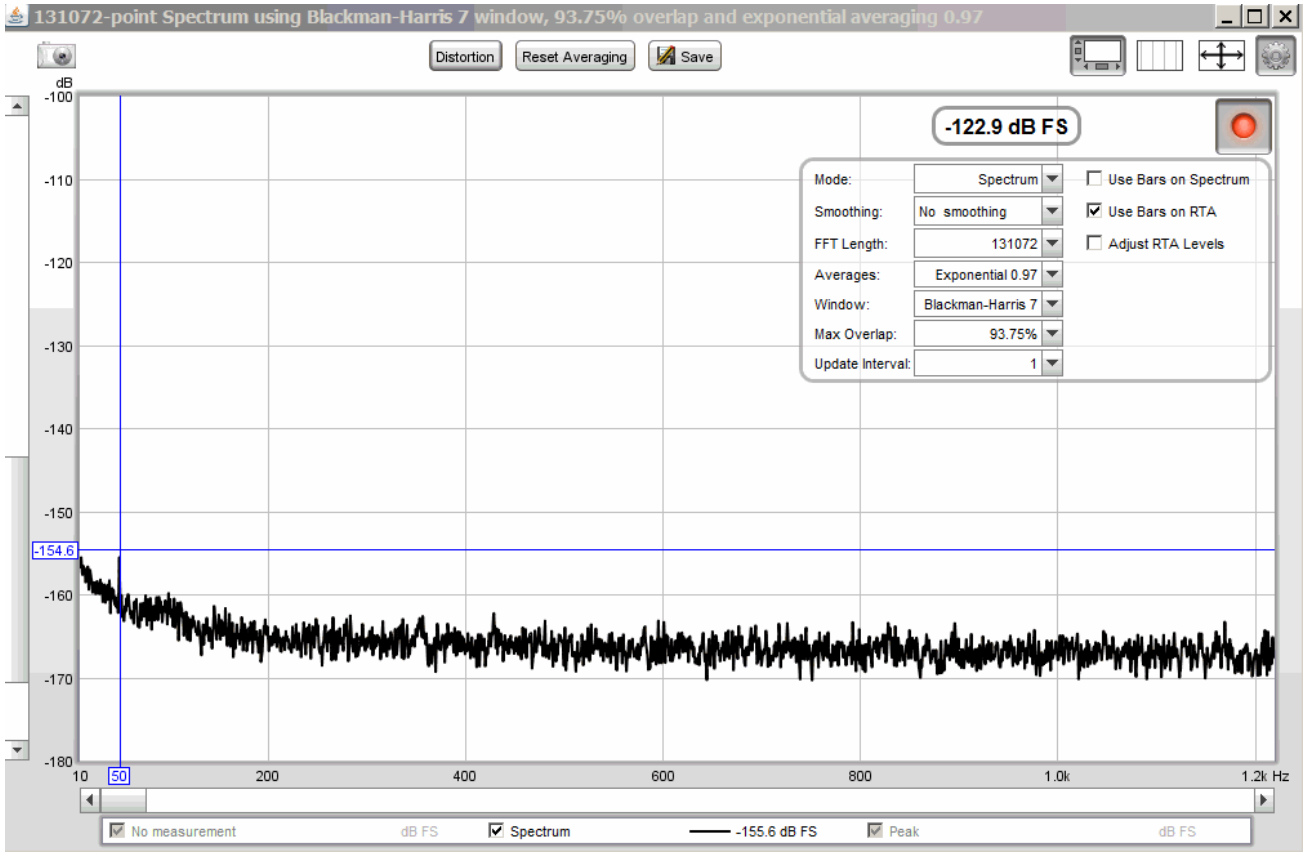
2) Input shorted with 50Ohms, and SMPS balancing current **injected** into the interface:



The original leakage current from the stock supply is injected to the adapter shield via the red cable from the binding post at the encased DC/DC (from where goes to output GND of the original supply). The current flows though the GND inside the audio device all the way from left to right (where it returns via the USB cable).
The Adi2-Pro FS shows an excellent performance here, some totally irrelevant spikes appear at 50Hz and 100Hz.

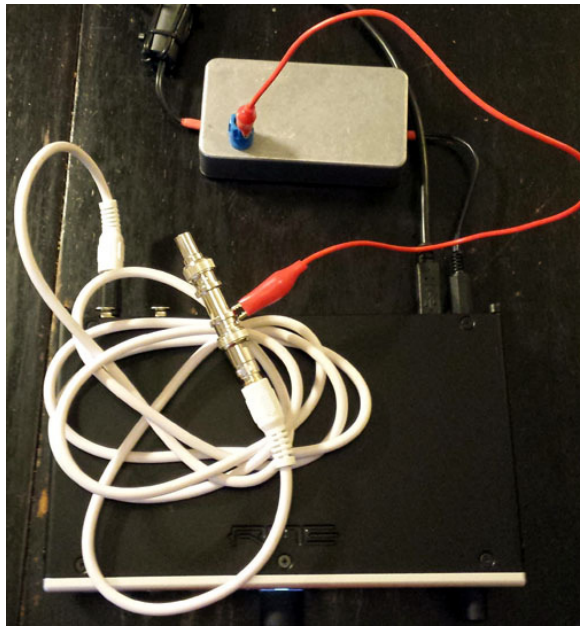
3) Noise floor with 50Ohms terminated cable (1.5m, cheapest kind):

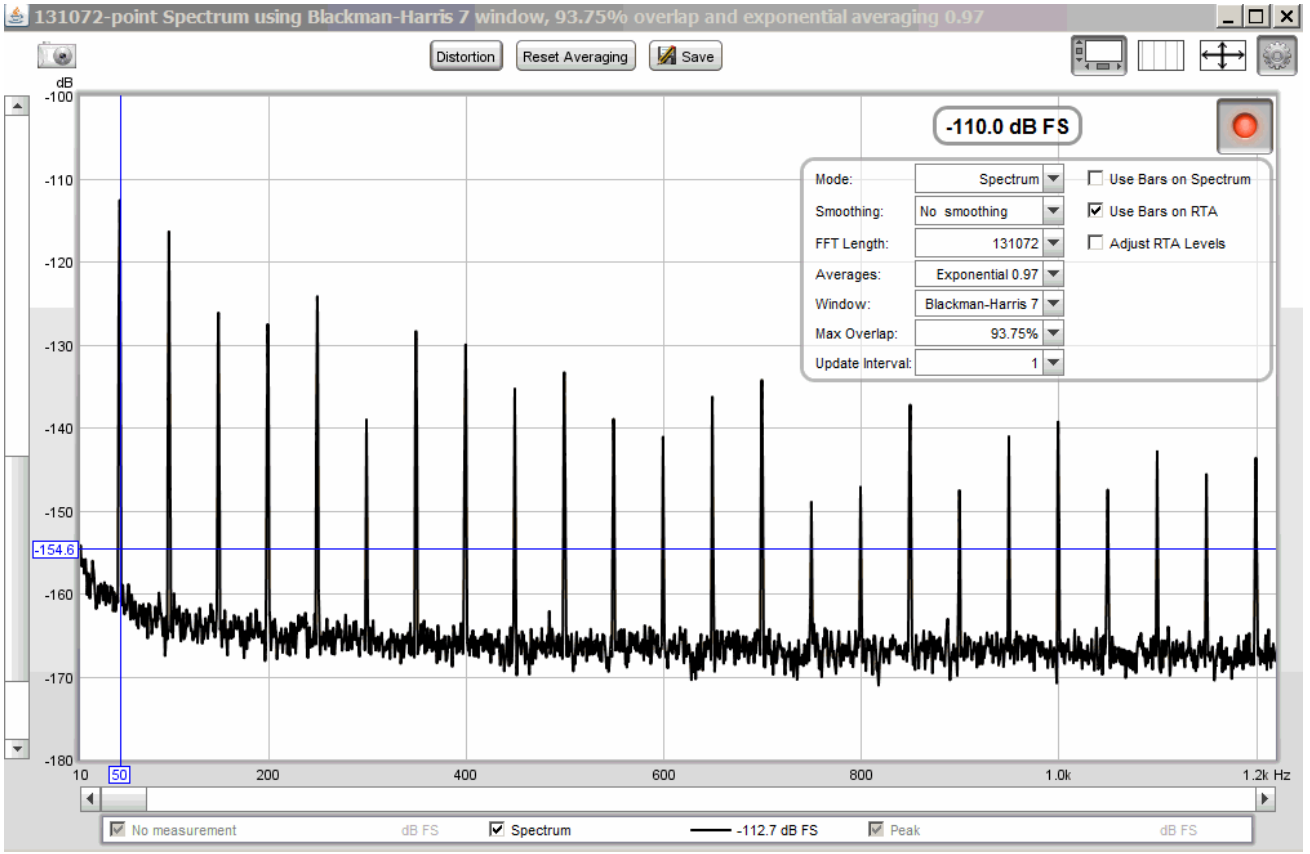




A tiny spike at 50Hz, that's all. No effective difference from the cable to the directly 50R-shorted input.

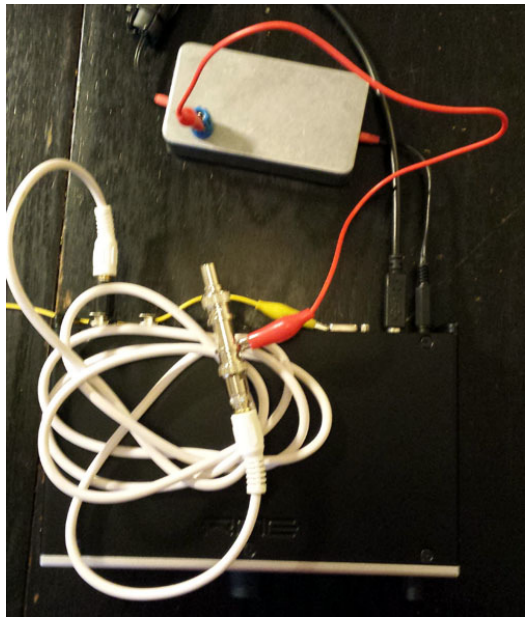
4) Input shorted with 50Ohms, and SMPS balancing current **injected** in the interface **+ cable**:

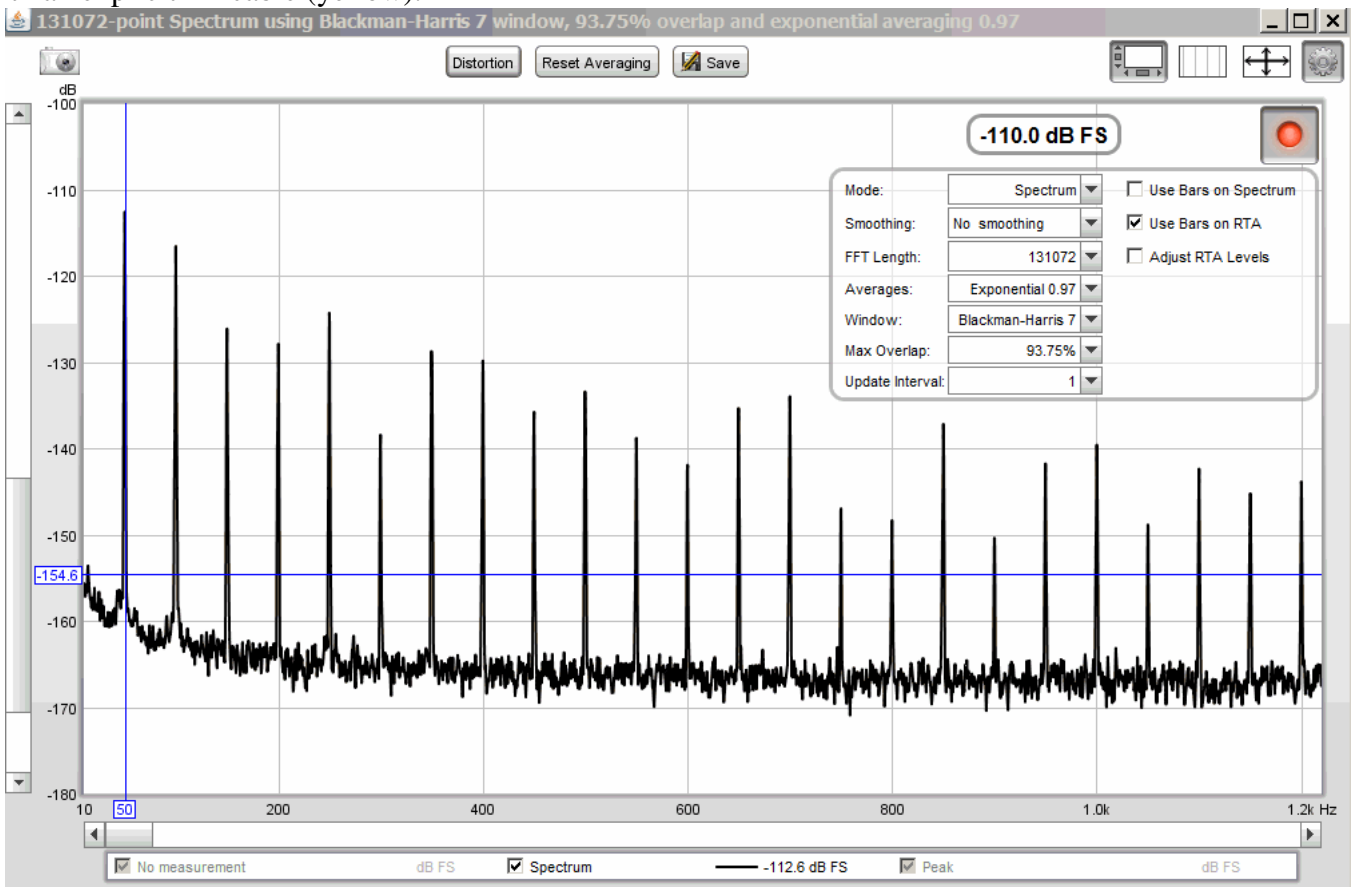




Like in 2) the original SMPS leakage current is forced to flow along the cable shield into and through the RME, returning to the supply via the PE connection the USB cable provides. The spectrum speaks for itself, at least a 40dB boost for the mains noise caused just alone by the R*i and L*di/dt drops along the shield of this (rather bad) cable! Shield current induced noise does matter.

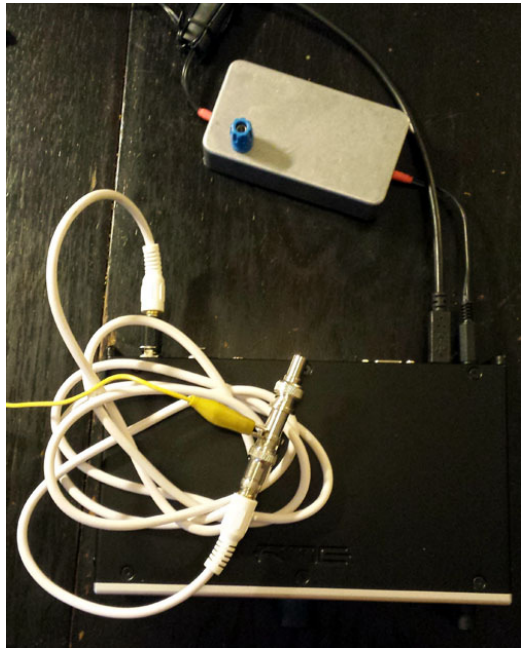
5) Confirmation of measurement 4)
To confirm the result with a second, different measurement, the setup was changed as follows:
- Laptop running off of its battery, no PE connection, fully floating.
- PE connection thus routed differently with an explicit PE cable (yellow).

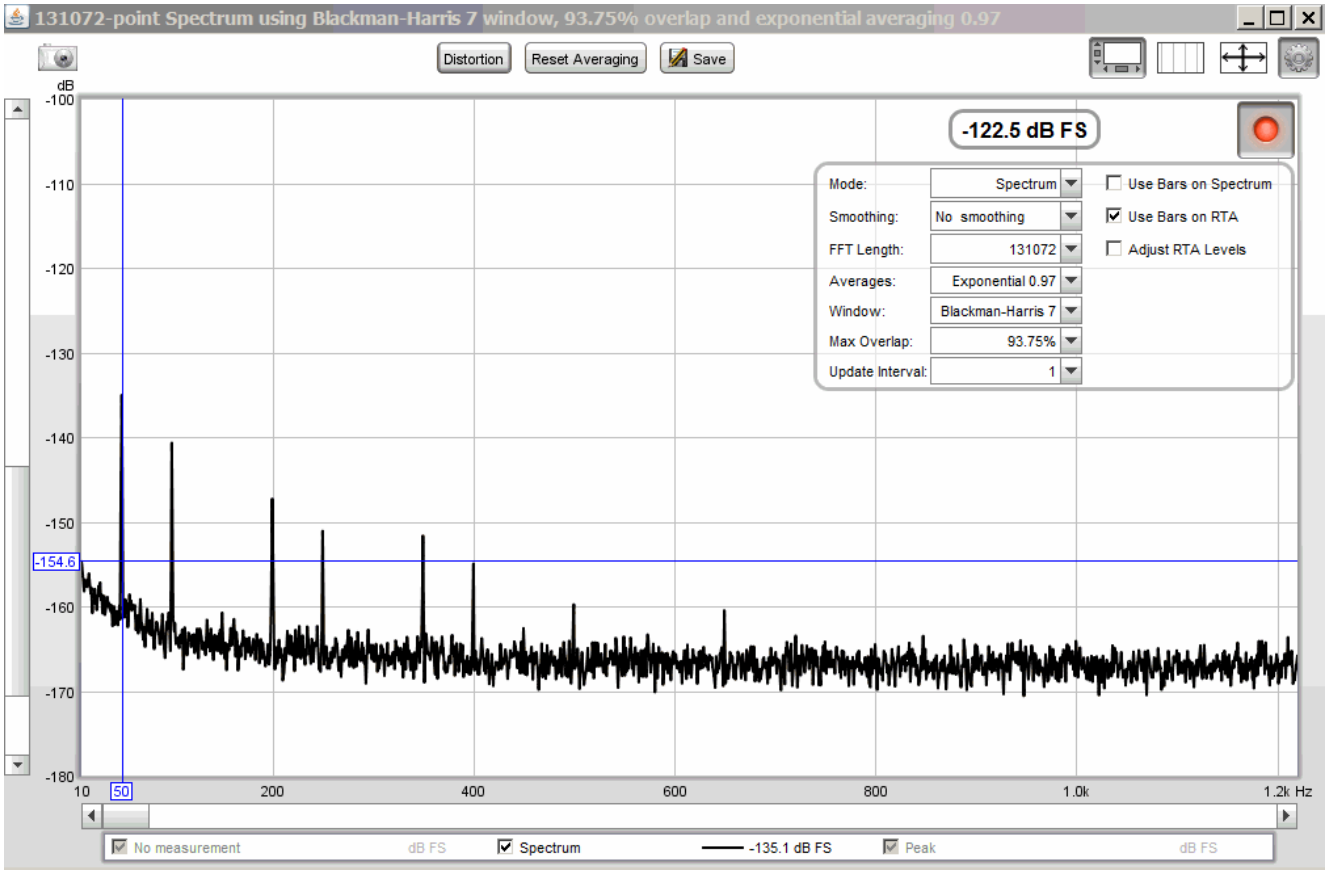




No difference to 4).
This was additionally confirmed in a 5b) measurement (not shown) with red and yellow cables swapped (signal cable at PE, and RME Sub-D being the entry point for the current.

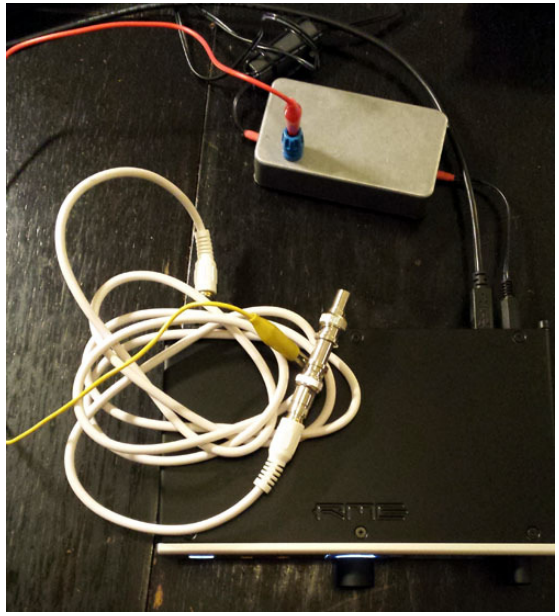
6) Input shorted with 50Ohms, and SMPS balancing current **reduced** but still injected in the interface **+ cable**:
This simply is the 5b) setup with the injection cable removed, and the balancing current greatly reduced by the isolated DC/DC converter.

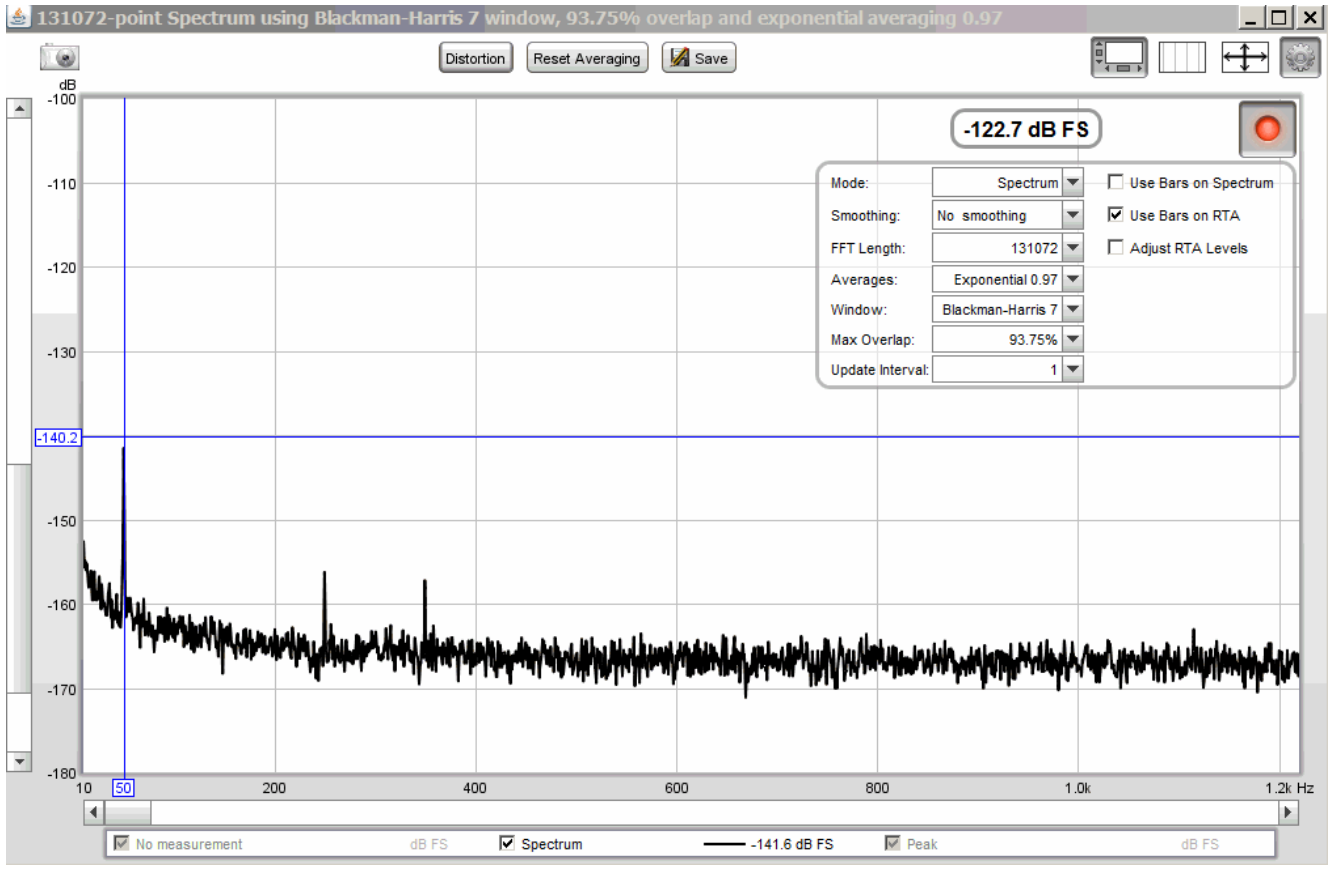




While not exactly perfect, a significant reduction of at least 20dB is seen in the mains noise spectrum.

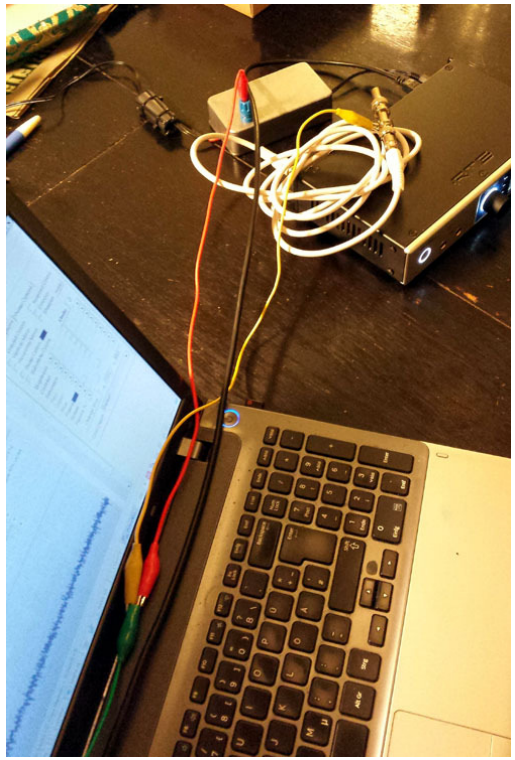
7) Input shorted with 50Ohms, and SMPS balancing current **removed**:
This final measurement shows the effect to 6) when the original SMPS's leakage current is fully shunted away from the path with an extra PE connection (red and yellow cables going to PE at the left -- outside of the picture)

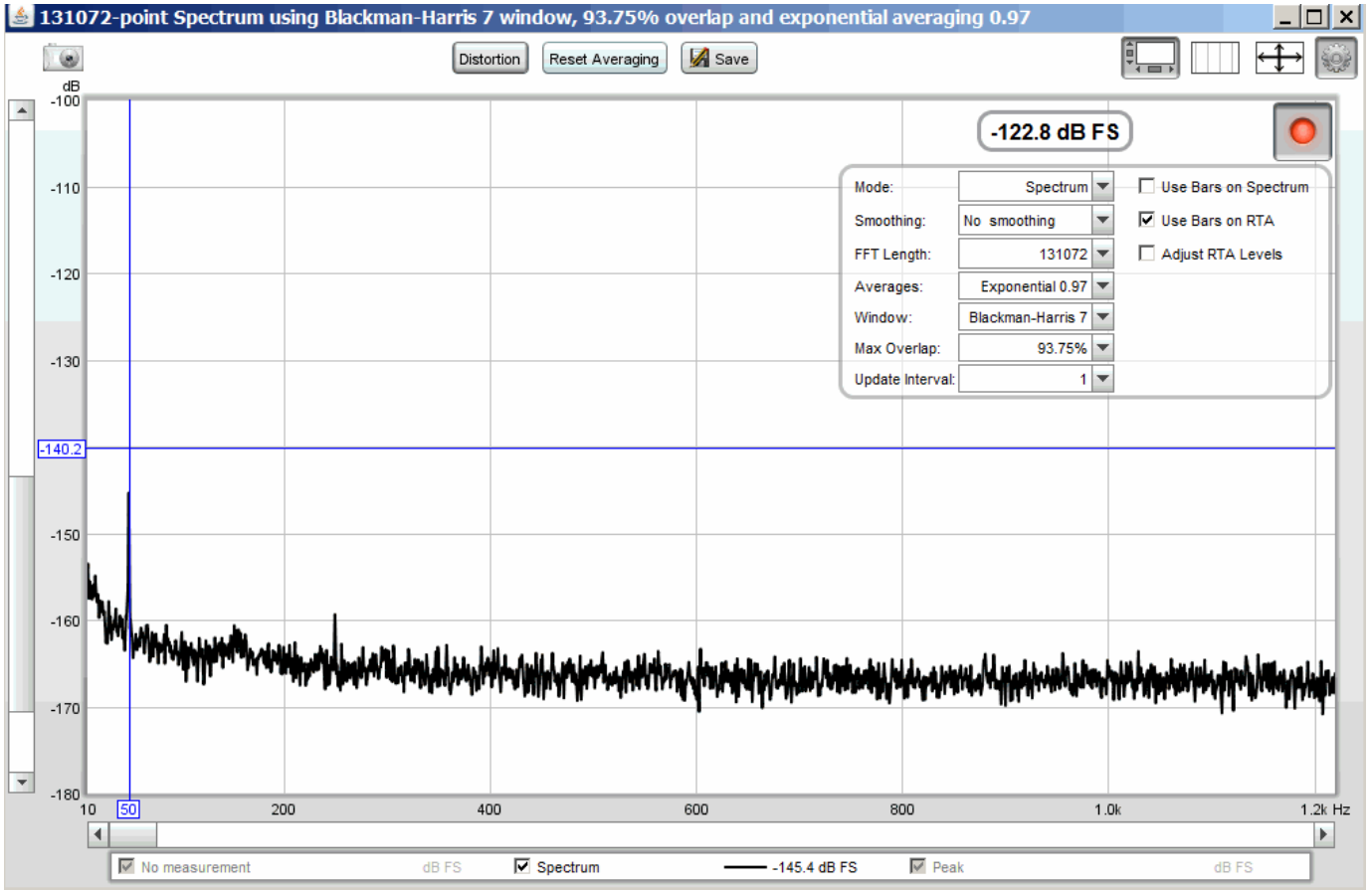




While not as good as a truly floating input end of the cable (measurement 3) this result is very acceptable in absolute terms. The residual seen is most likely from a different root cause...

... as confirmed by the following spectrum, obtained after bundling the cables:





350Hz component is now in the noise, the remaining lowered a bit.