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Examination of RF filters for ultralow temperature experiments.

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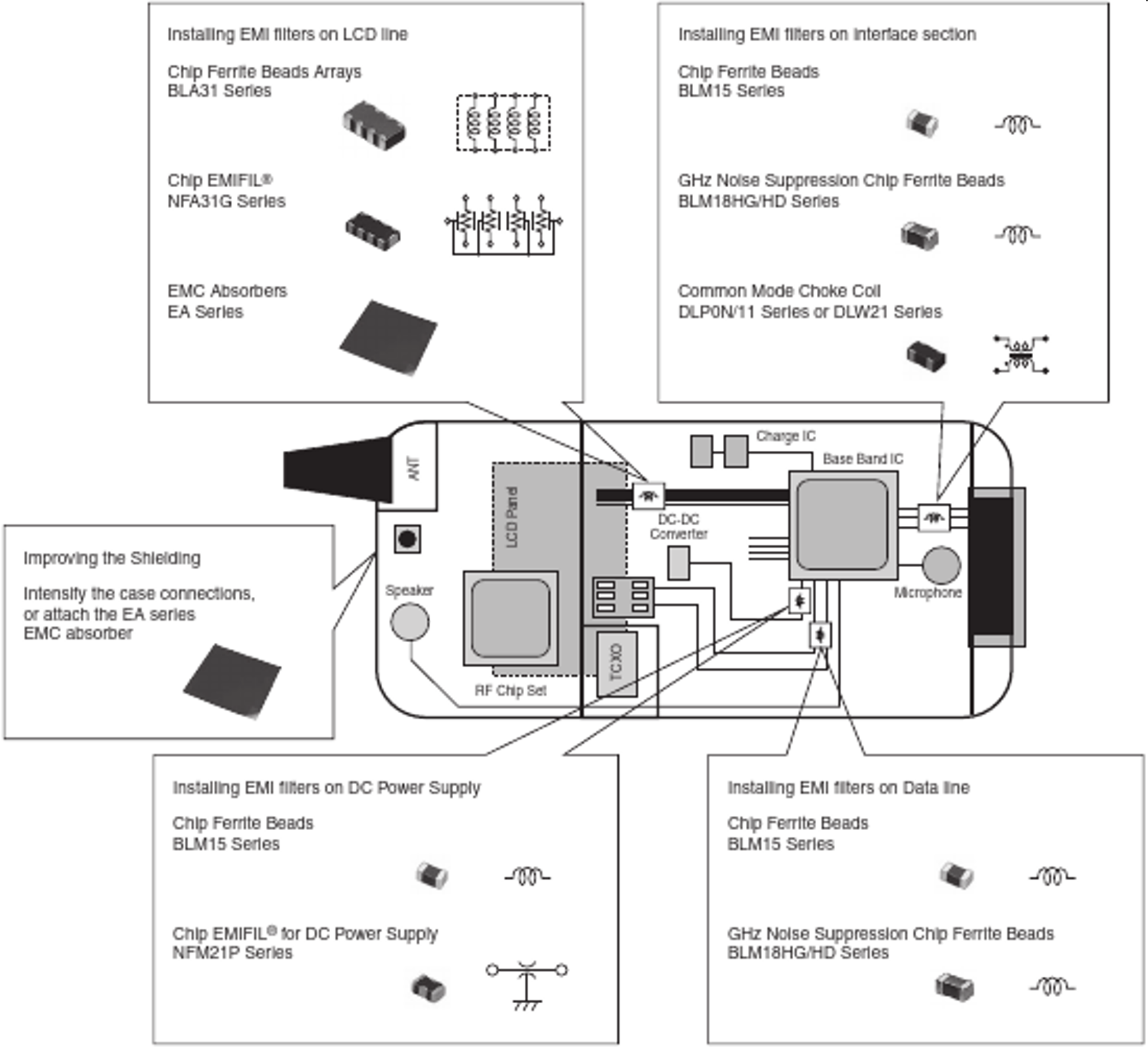

Installing EMI filters on LCD line
Chip Ferrite Beads Arrays
BLA31 Series
Chip EMIFIL®
NFA31G Series
EMC Absorbers
EA Series
Installing EMI filters on interface section
Chip Ferrite Beads
BLM15 Series
GHz Noise Suppression Chip Ferrite Beads
BLM18HG/HD Series
Common Mode Choke Coil
DLP0N/11 Series or DLW21 Series
ANT
LCD Panel
Charge IC
Base Band IC
DC-DC
Converter
Speaker
Microphone
TCXO
RF Chip Set
Improving the Shielding
Intensify the case connections,
or attach the EA series
EMC absorber
Installing EMI filters on DC Power Supply
Chip Ferrite Beads
BLM15 Series
Chip EMIFIL® for DC Power Supply
NFM21P Series
Installing EMI filters on Data line
Chip Ferrite Beads
BLM15 Series
GHz Noise Suppression Chip Ferrite Beads
BLM18HG/HD Series

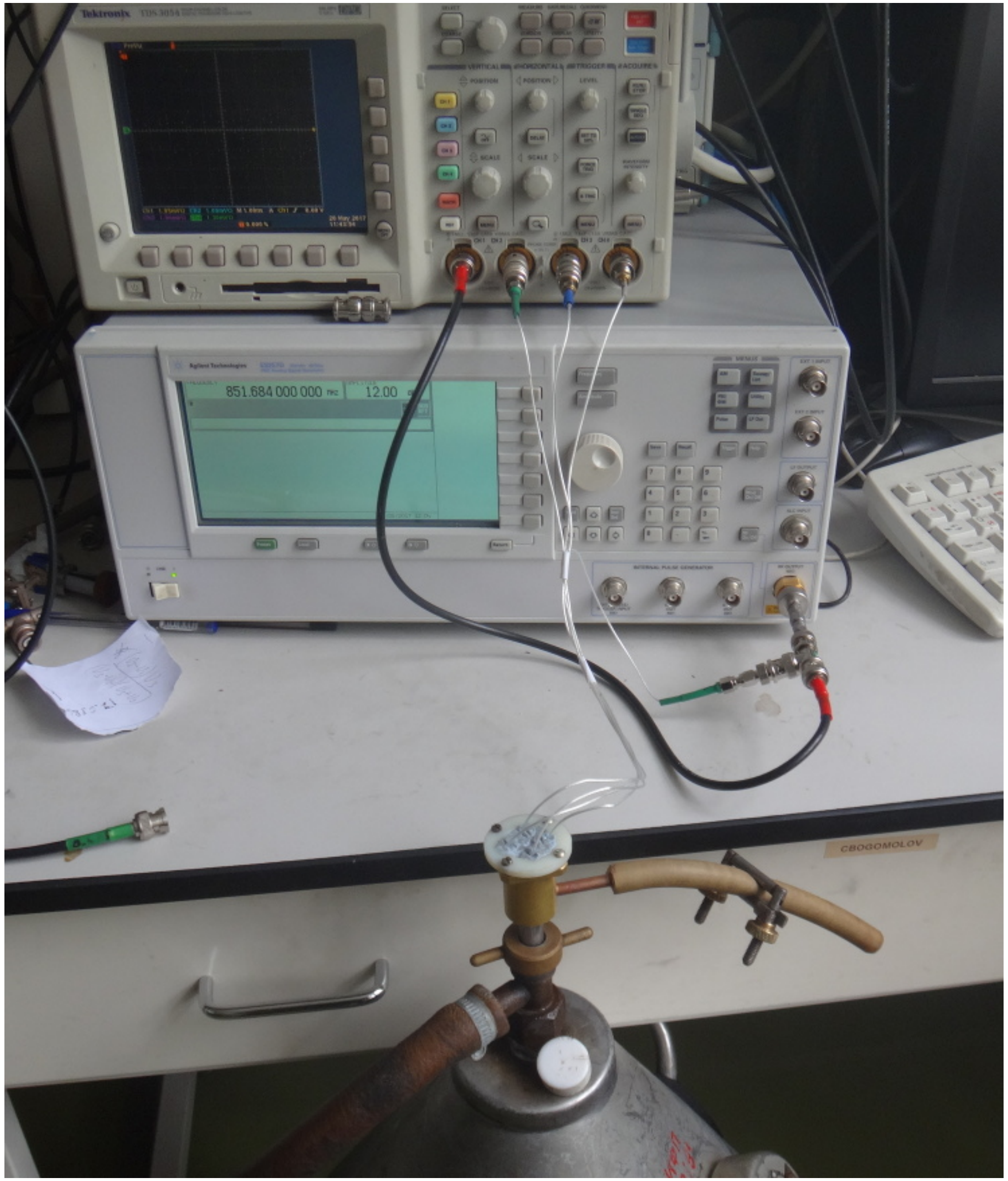
The equipment used

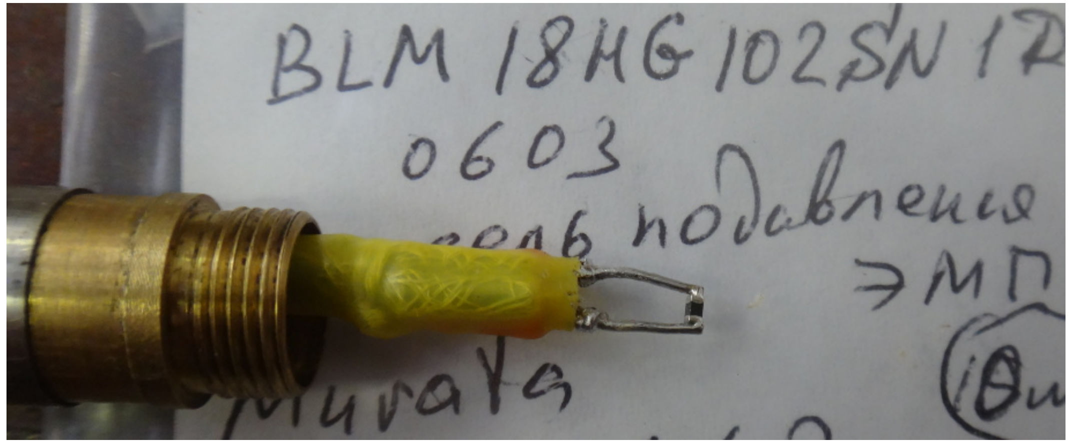
We use top loading insert that operates in a standard liquid helium transport dewar with 12 mm bore. The sample is mounted in a cylindrical copper shielded box at the bottom of the insert.

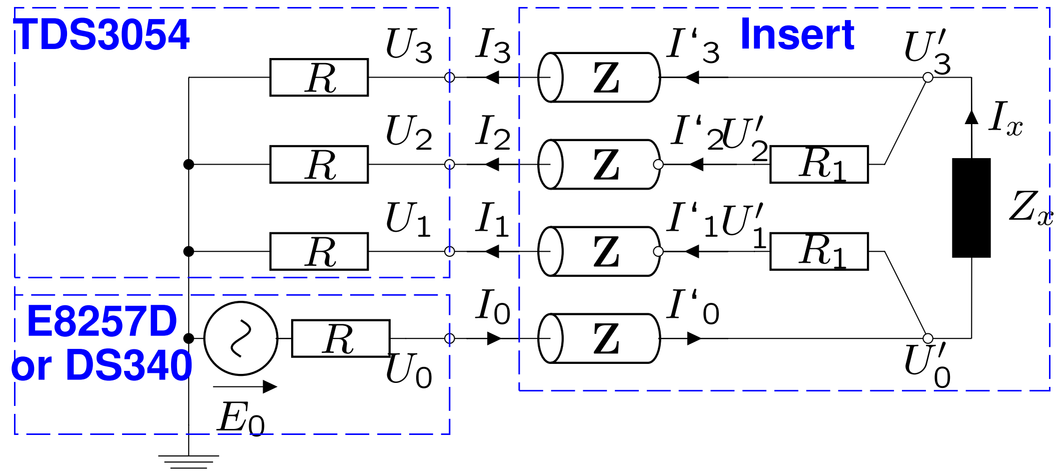
To measure the frequency response of samples we use the 4-channel oscilloscope Tektronix®T with sampling rate of 5GS/s, 500 MHz bandwidth, and simultaneous recording of 10^4 readings per channel with 9-bit resolution. This gives us the ability to find amplitudes and phases of the signals U_1, U_2, U_3 (Fig. 1). The signal U_0 can be used for control and synchronization.

As RF signal source we use Agilent Technologies®PSG CW sygnal generator E8257D (for high frequencies) and Stanford Research Systems®15 MHz synthesized function generator DS340 (for lower frequencies). In our case, characteristics of the oscilloscope are significant. As for the RF source it does not impose any special requirements, and it can be replaced by any appropriate device.

Experimental setup.







R=50 Ω –oscilloscope and oscillator impedances.

R_1=250 Ω –noinductance metal resistors.

Z – impedance of 1.2 meter-long coaxial cable.

Calculation of the filter characteristics

To test filters at liquid He temperatures, we use cables and take into account the retarding effects by introducing a complex transformation matrix $\mathbf{Z}$:

$$\begin{bmatrix} U'_k \\ I'_k \end{bmatrix} = \begin{bmatrix} \cosh(\gamma l) & |Z| \sinh(\gamma l) \\ \dfrac{\sinh(\gamma l)}{|Z|} & \cosh(\gamma l) \end{bmatrix} \begin{bmatrix} U_k \\ I_k \end{bmatrix}, \; k = 0..3.$$

γ –the complex propagation constant, l – cable's length, $|Z|$ – the characteristic impedance of the cable. Using condition $I_k = U_k/R$, k=1..3 we get:

$$U'_k = \left(\cosh(\gamma l) + \frac{Z}{R} \sinh(\gamma l) \right) U_k \equiv a \cdot U_k,$$

$$I'_k = \left(\frac{1}{Z} \sinh(\gamma l) + \frac{1}{R} \cosh(\gamma l) \right) U_k \equiv b \cdot U_k$$

Calculation of the filter characteristics (continuation)

Given that $U_2'-U_3'=I_2'R_1$, and $U_1'-U_0'=I_1'R_1$ we end up with a simple expression for the complex impedance Z_x as function of complex parameters U_1, U_2, U_3, whose amplitudes and phases are determined from the measured signals:

$$Z_x = R_1 \frac{(U_1 - U_2)U_3}{(U_3 - U_2)(U_3 + U_2)} \tag{1}$$

So, we were able to eliminate the characteristics of the cables!

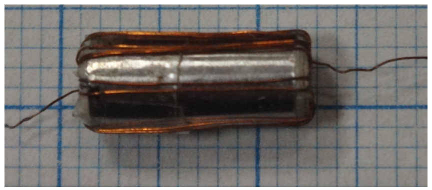
The result does not depend on amplitude U_0 of the testing signal, which allows the usage of simple non-stabilized generators.

Frequency characteristics of various filters

Cryostat for ultralow temperature experiments should be equipped with a multistage filtration system which may consist of EMI filters at room, as well as, liquid He temperatures. One may add also some cryogenic low-pass filters thermally anchored to 1-K pot, to mixing chamber and experimental cell. Our task was to measure characteristics of various filters to evaluate the possibility of their usage in a multi-stage filtration system.

Murata Manufacturing Co., Ltd. “Noise Suppression by EMIFIL ®Application Guide”

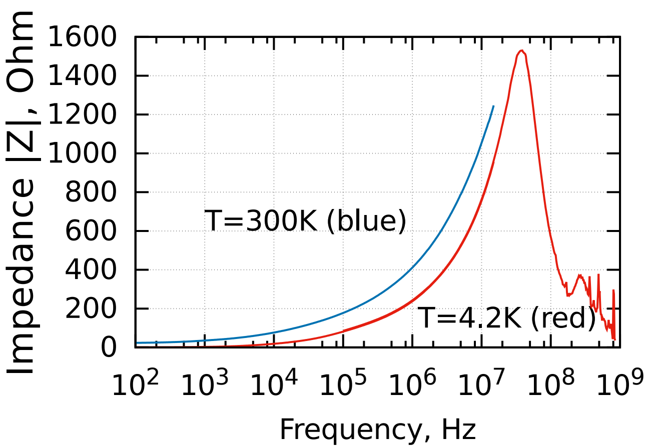
Permalloy-core inductor (handmade)

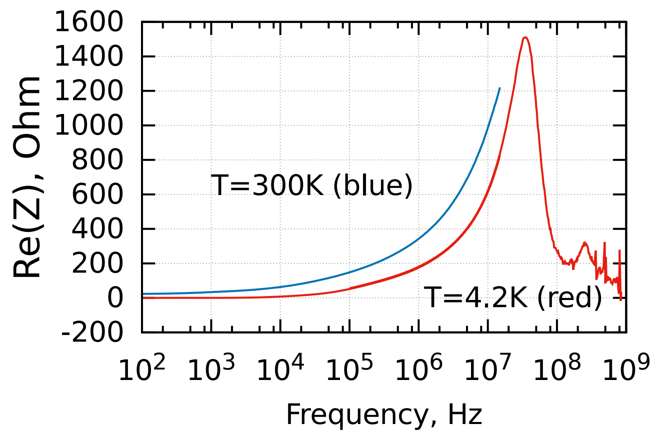


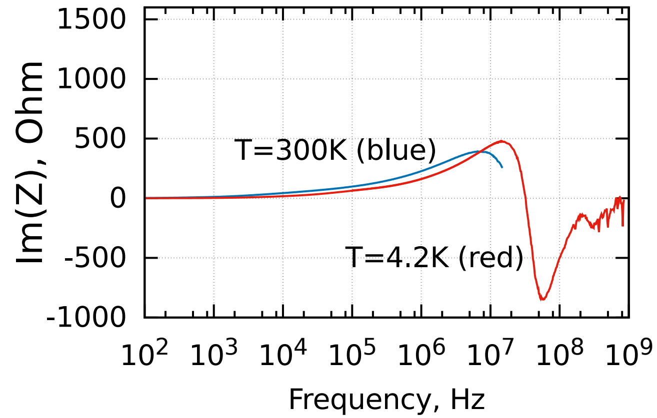
Core geometry: length 11 mm, ID 2 mm, OD 4.5 mm.

Core material: permalloy tape 0.1 mm, annealed.

Winding: NbTi/CuNi, $d = 0.1$ mm, 20 turns, $R_{\text{DC}} = 23\ \Omega$.





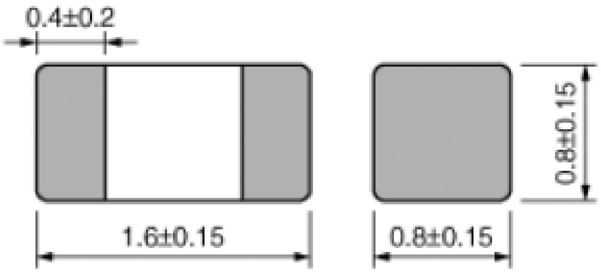


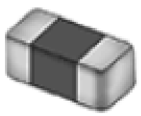
Despite the expected pure reactive behavior of our filter, it is resistive in the range of $10-50$ MHz, which can be explained by eddy currents in permalloy.

Murata® Chip Ferrite Bead EMI suppression filter

BLM18HG102SN1 chip (manufacturer data)

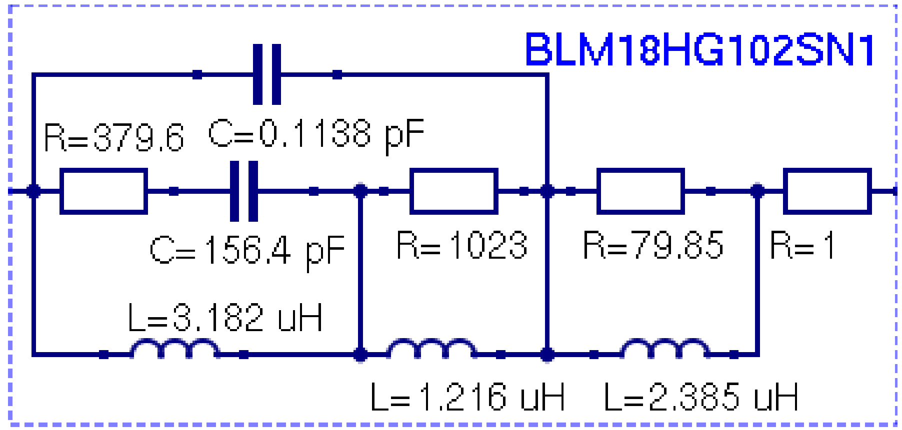
Noise suppression from a few MHz to a few GHz,where the impedance is resistive.





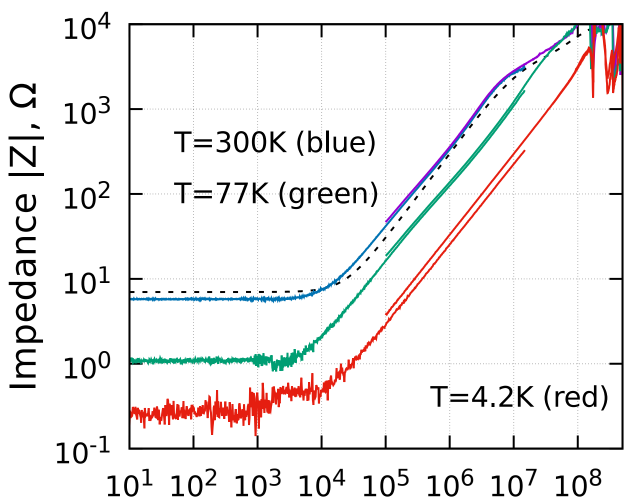
SMD 0603

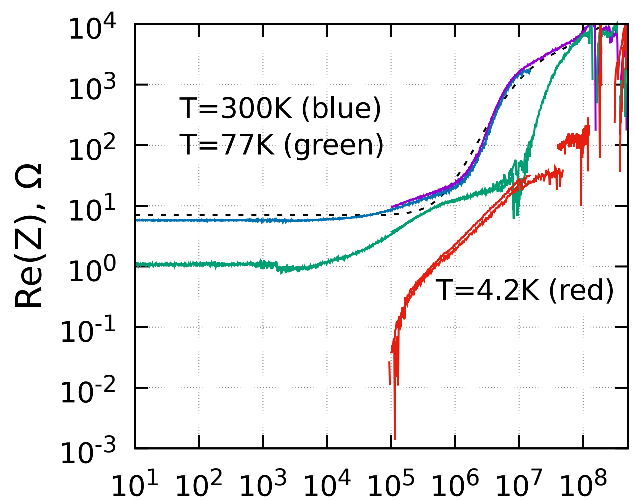
- $R_{\mathrm{DC}}=1.6\,\Omega$
- $R_{\mathrm{100MHz}}=1\,\mathrm{k}\Omega$
- $R_{\mathrm{1\ GHz}}=1\,\mathrm{k}\Omega$

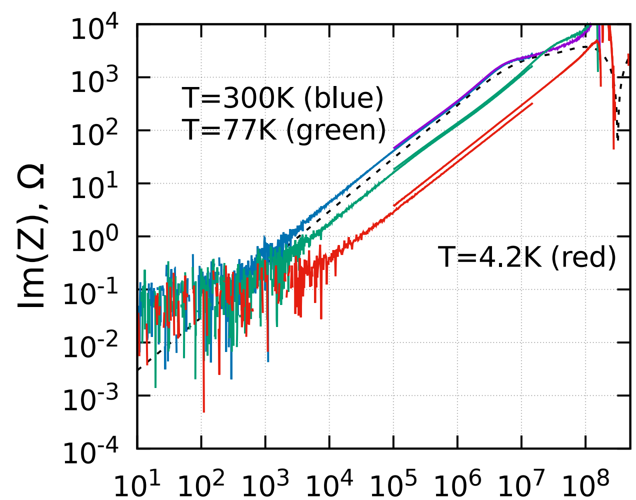


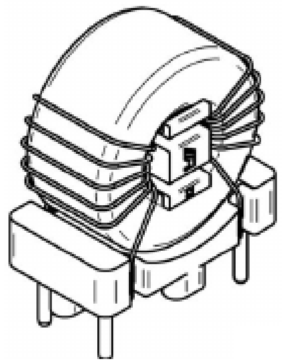
Seven BLM18HG102SN1 chips connected in series (our data)

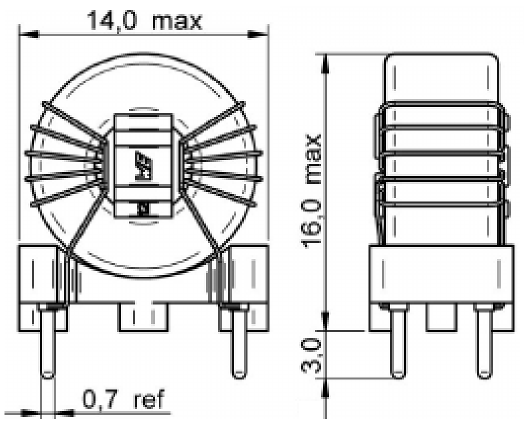
Note the excellent agreement between our data (blue) and calculated according to the manufacturer (dotted).

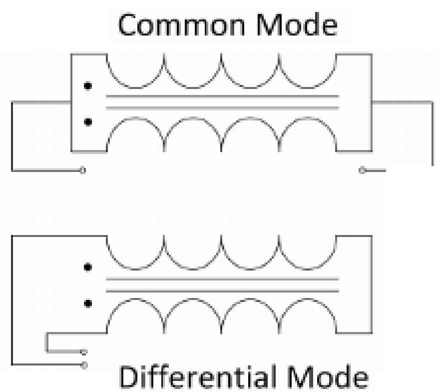


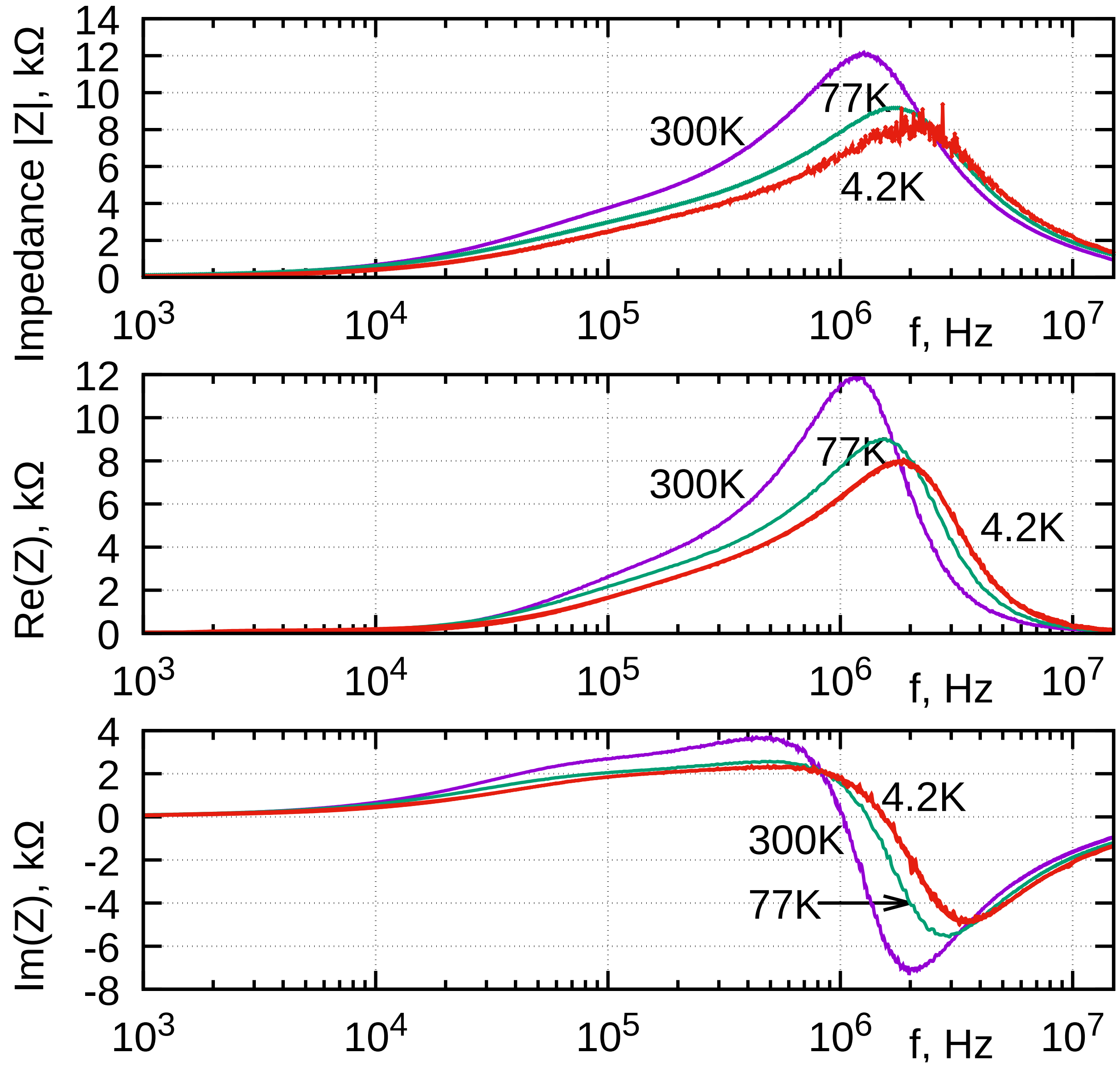


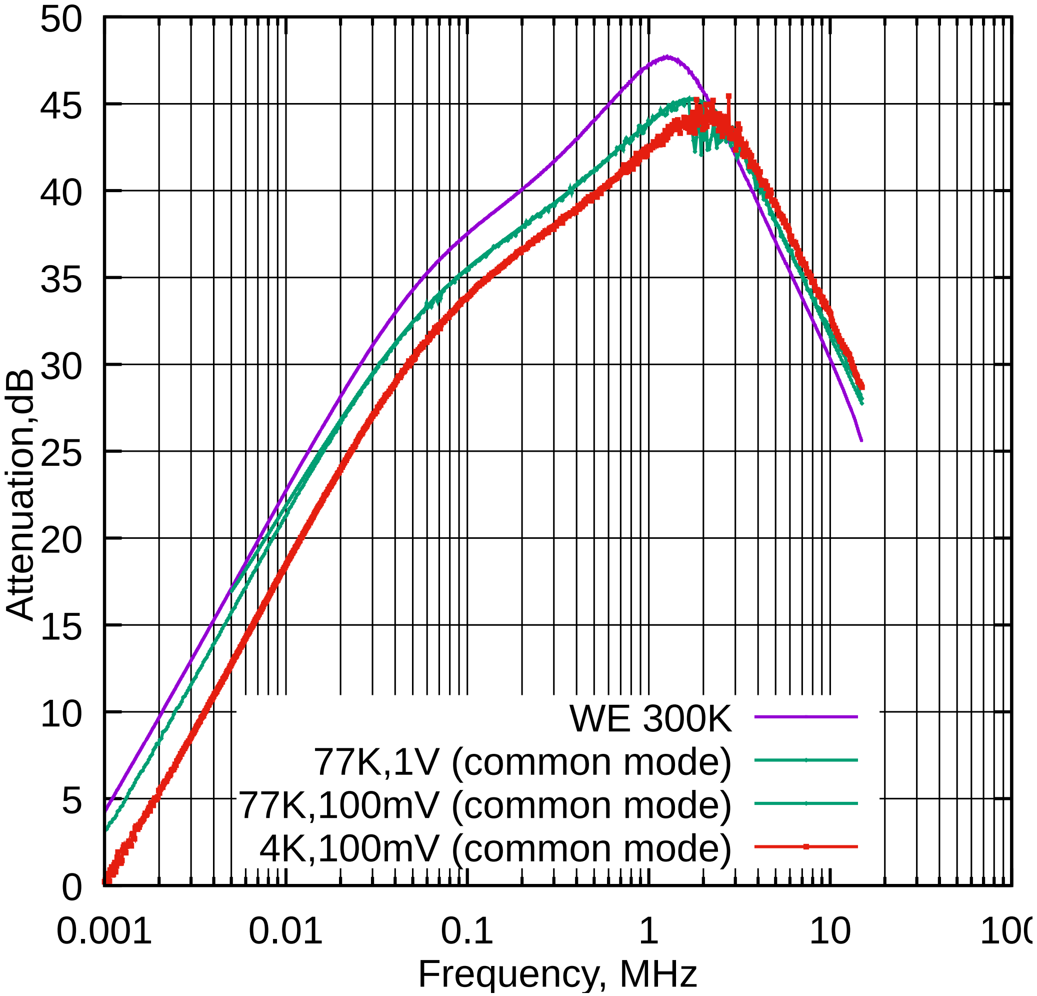


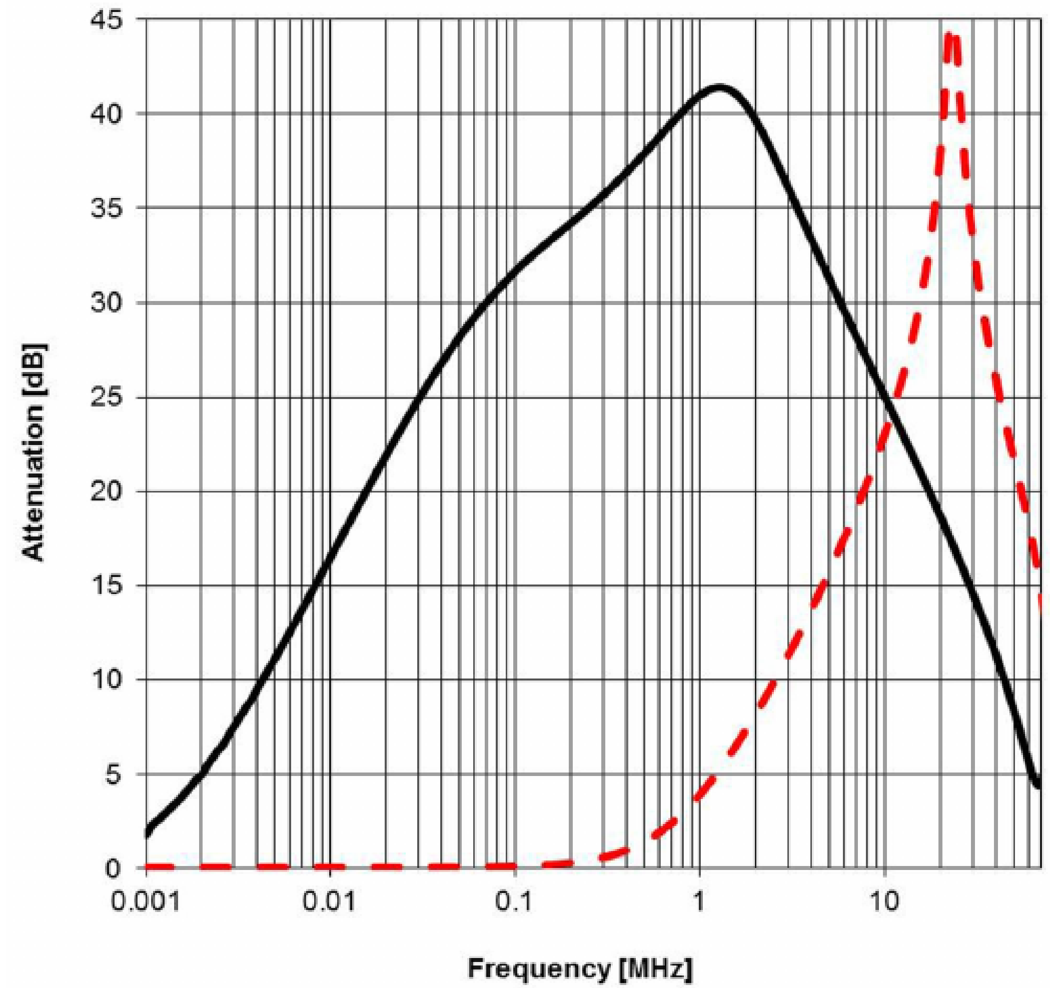



14,0 max
16,0 max
3,0
0,7 ref


Common Mode
Differential Mode


Impedance |Z|, kΩ
300K
77K
4.2K
f, Hz
Re(Z), kΩ
300K
77K
4.2K
f, Hz
Im(Z), kΩ
4.2K
300K
77K
f, Hz





Left: Measured frequency response at 300 K, 77 K and 4K

Right: The graph (from Wurth Elektronik) for 300 K (black line).

The attenuation (in dB) is calculated for a standard 50 Ω load.

Conclusions

We have developed a simple method of measuring the frequency dependence of electrical impedances in a wide (10 Hz-500 MHz) frequency range without usage of expensive network analyzers.

The method enables measurements to be made on samples cooled down to low temperatures.