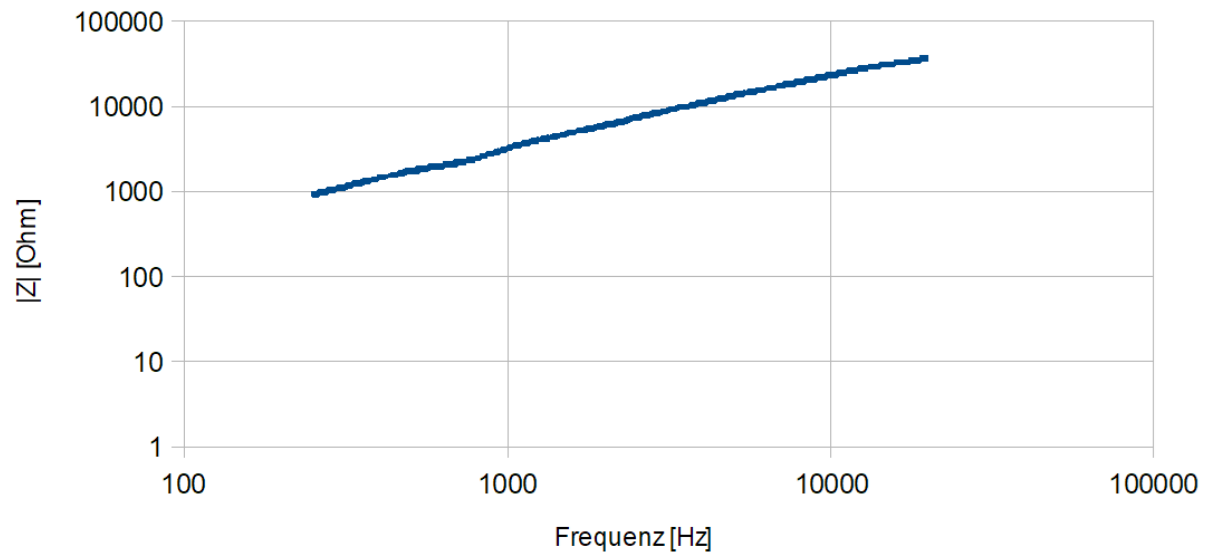


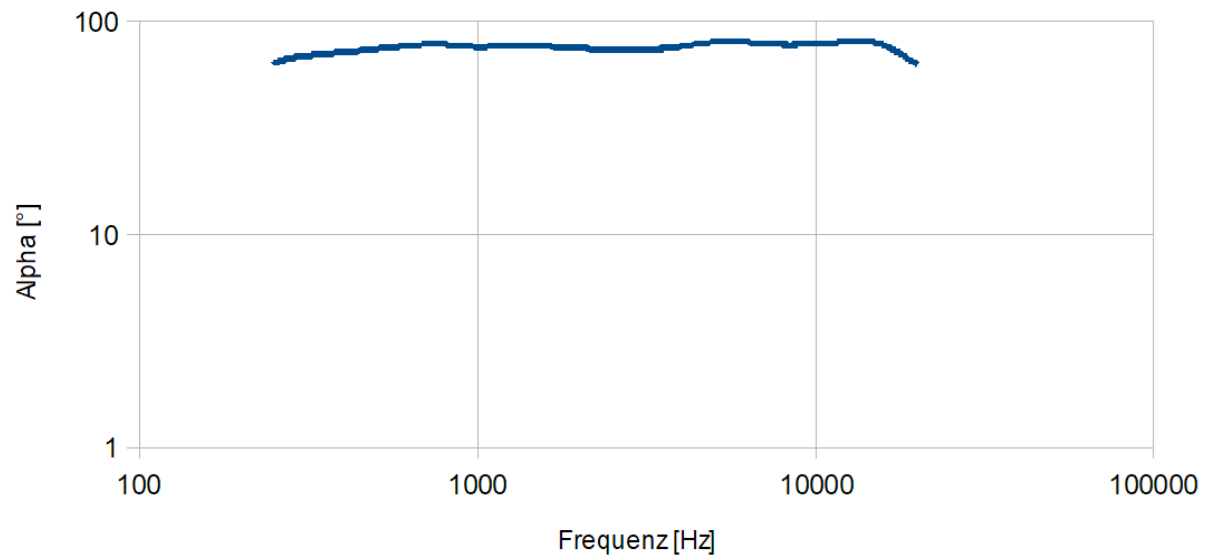
Introduction & Overview

$R1 = 547 \, \Omega$

Impedanz AT420E



Winkel

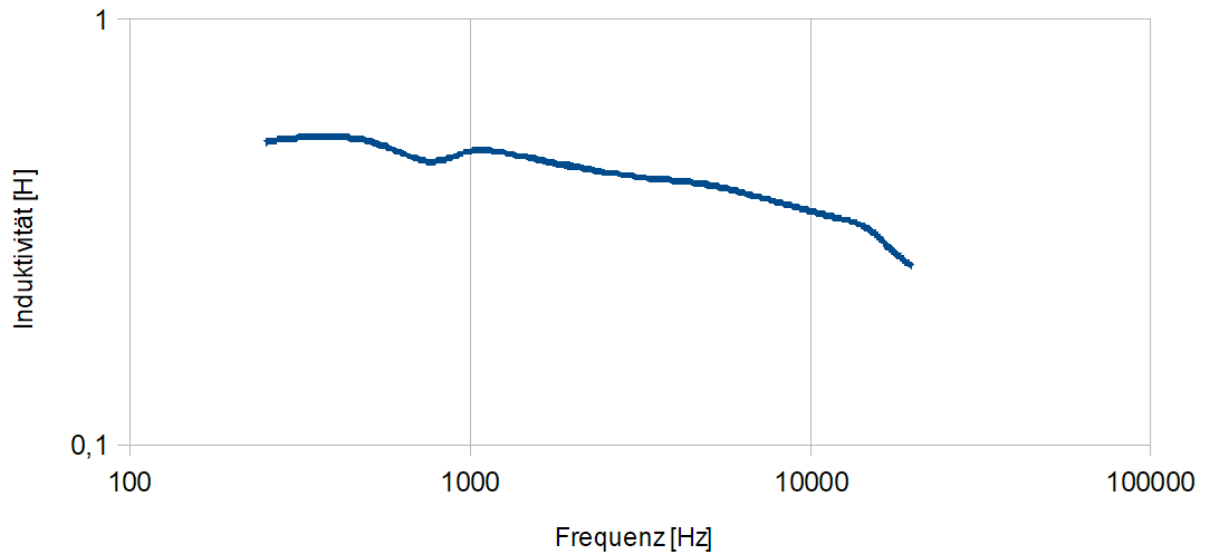


A closer look at the real coil of my MM cartridge AT420E OCC

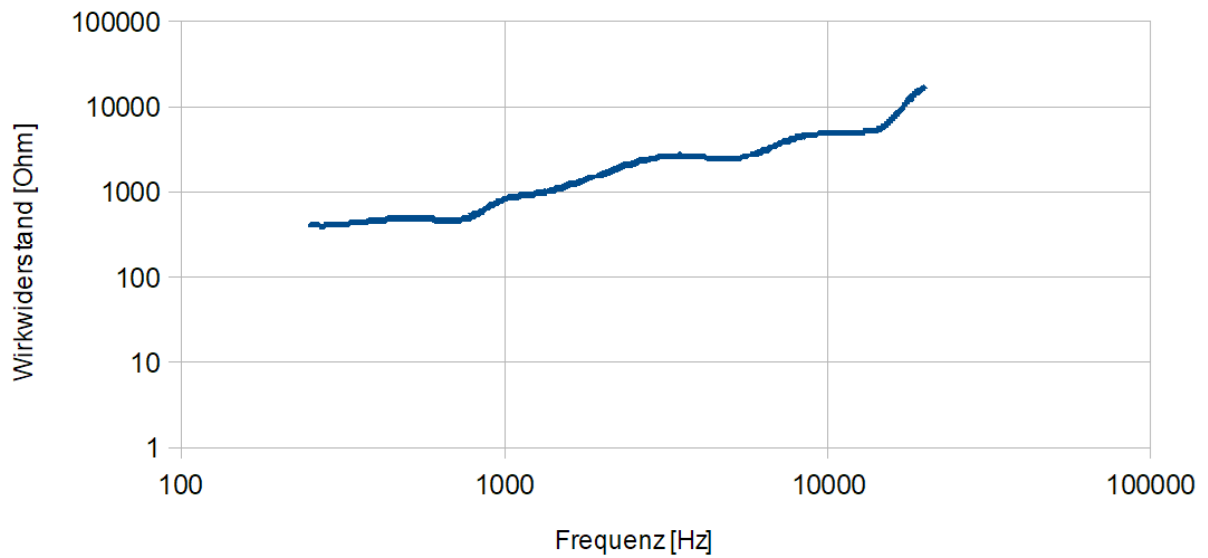
Introduction & Overview

$R1 = 547 \, \Omega$

L_{eff}

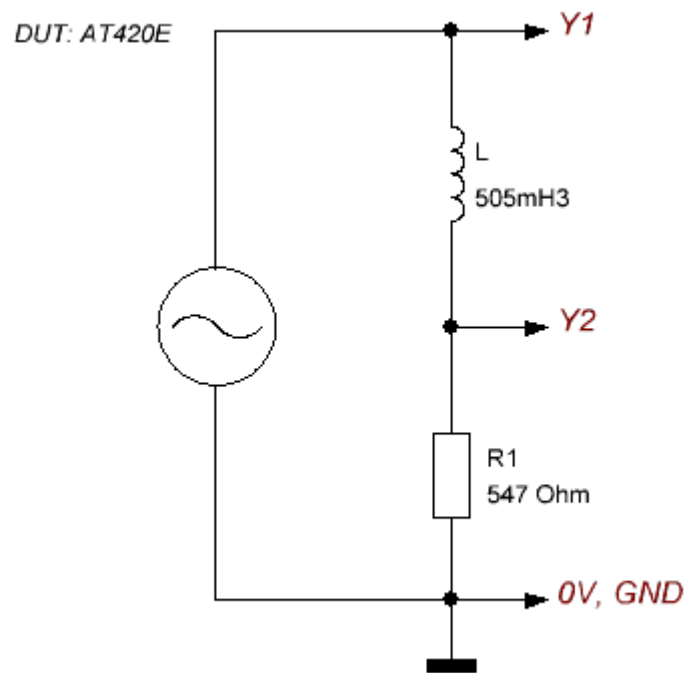


R_{eff}

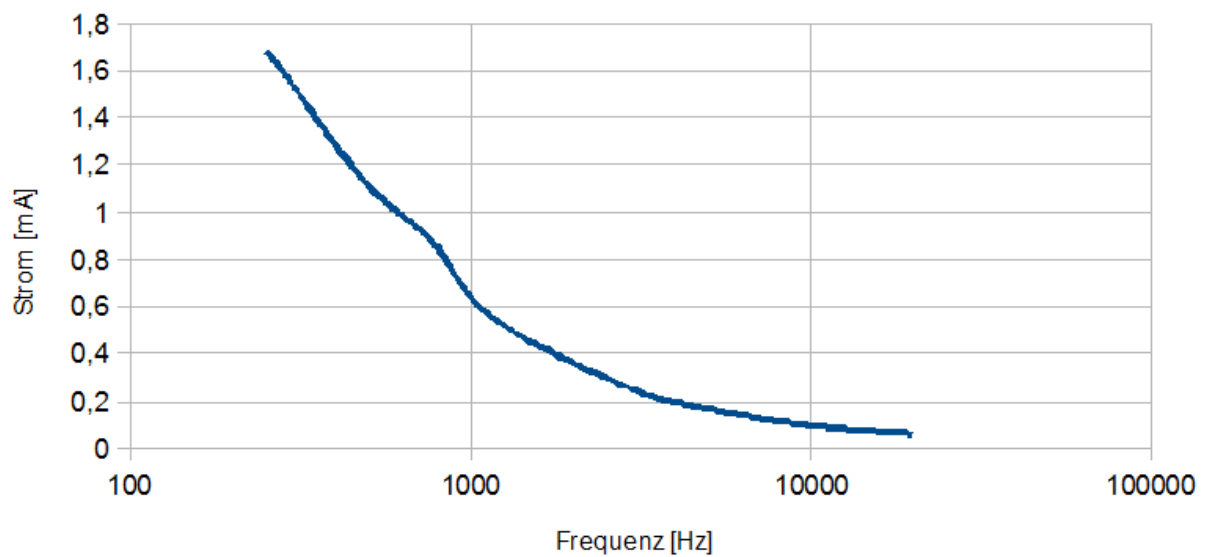


A closer look at the real coil of my MM cartridge AT420E OCC

Introduction & Overview

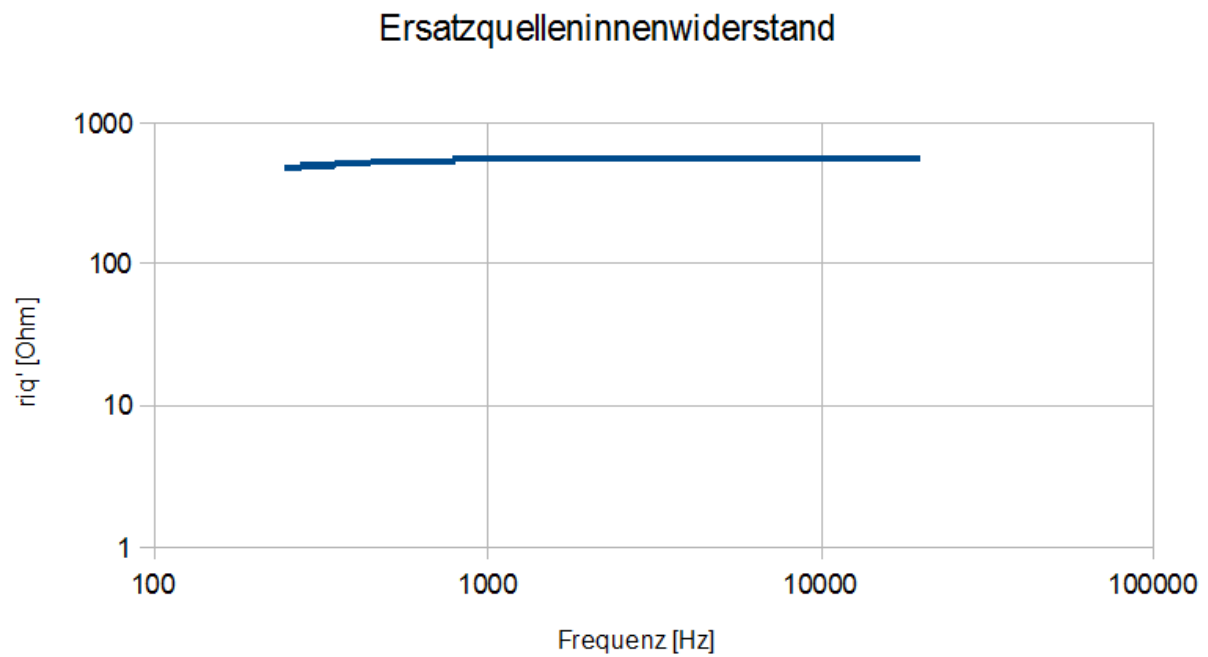
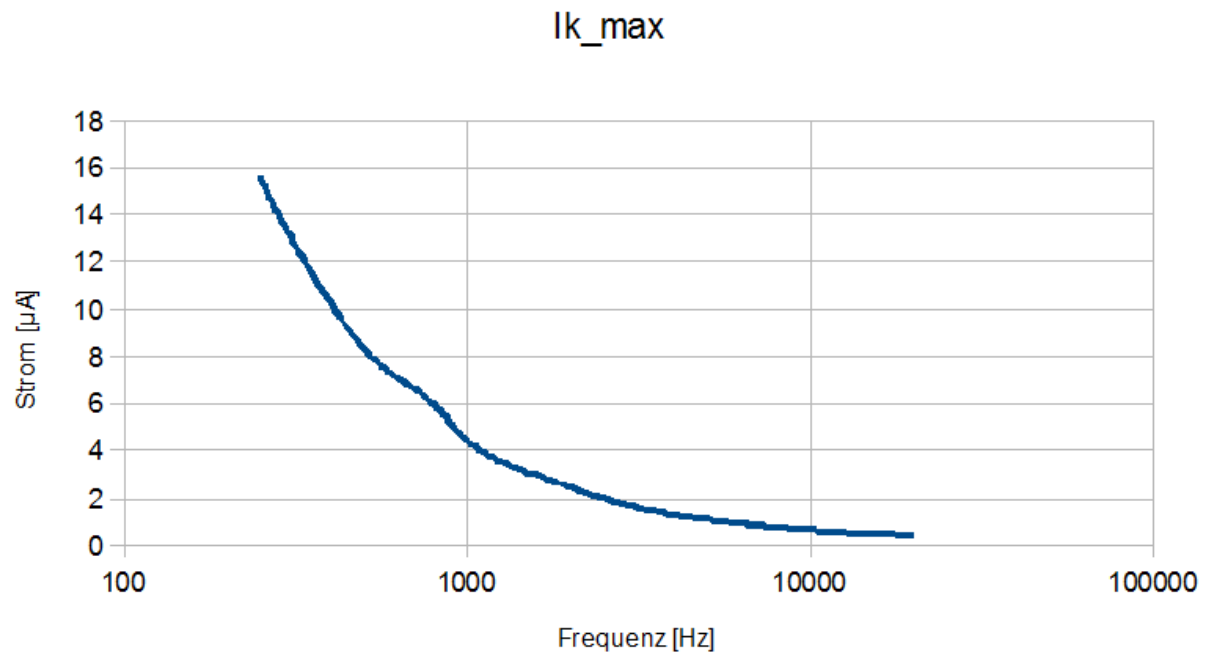


I_mess

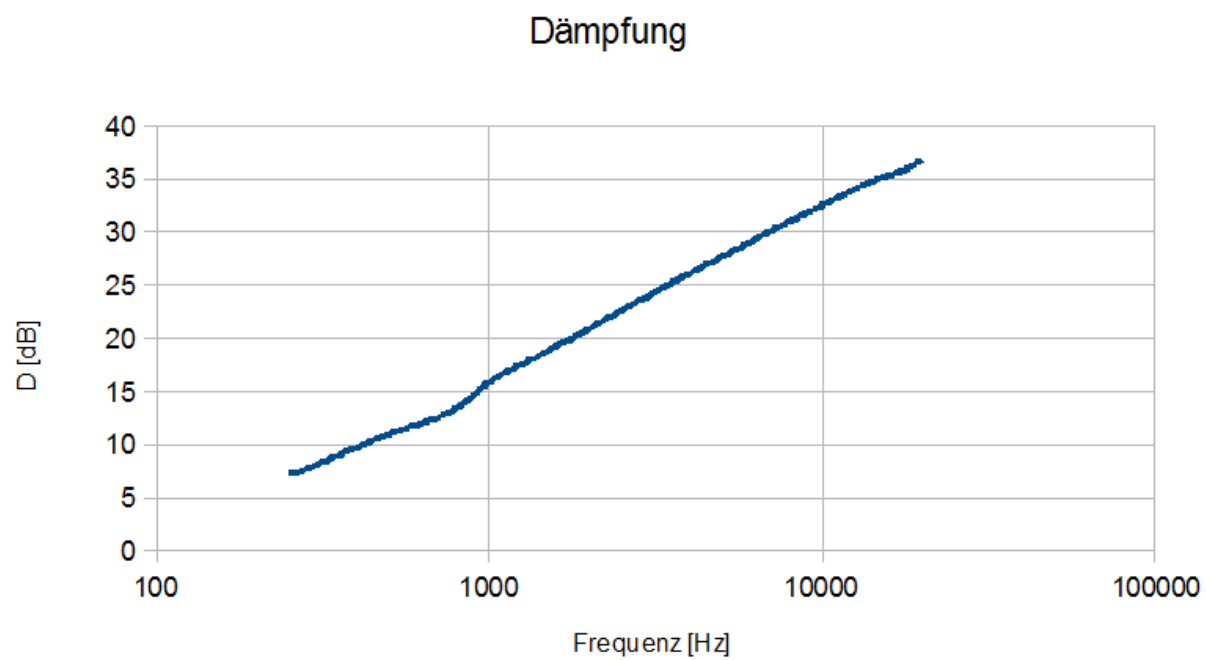


A closer look at the real coil of my MM cartridge AT420E OCC

Introduction & Overview



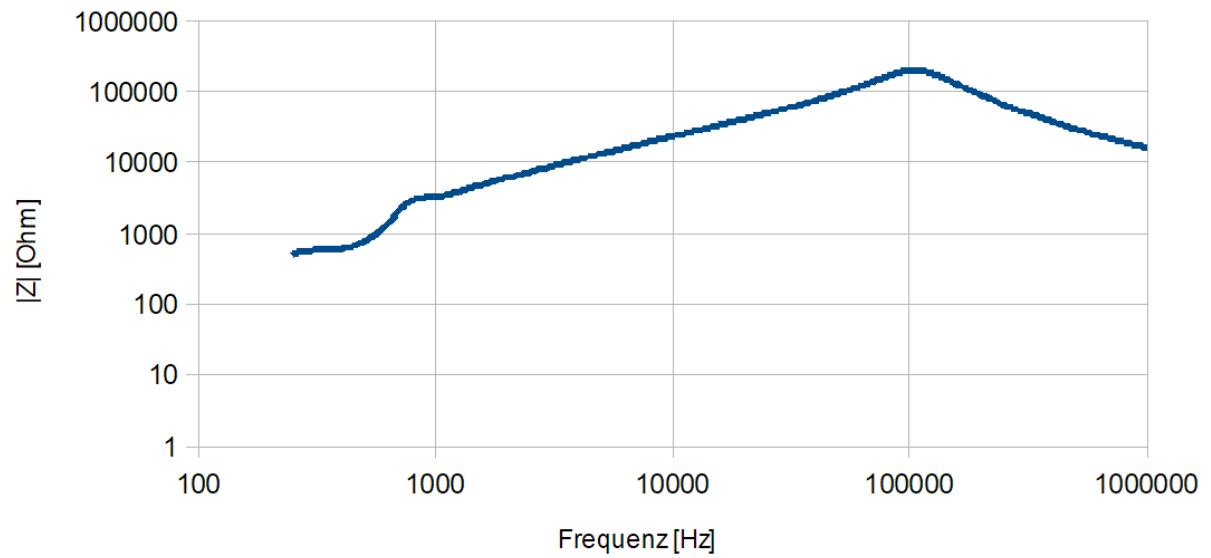
A closer look at the real coil of my MM cartridge AT420E OCC



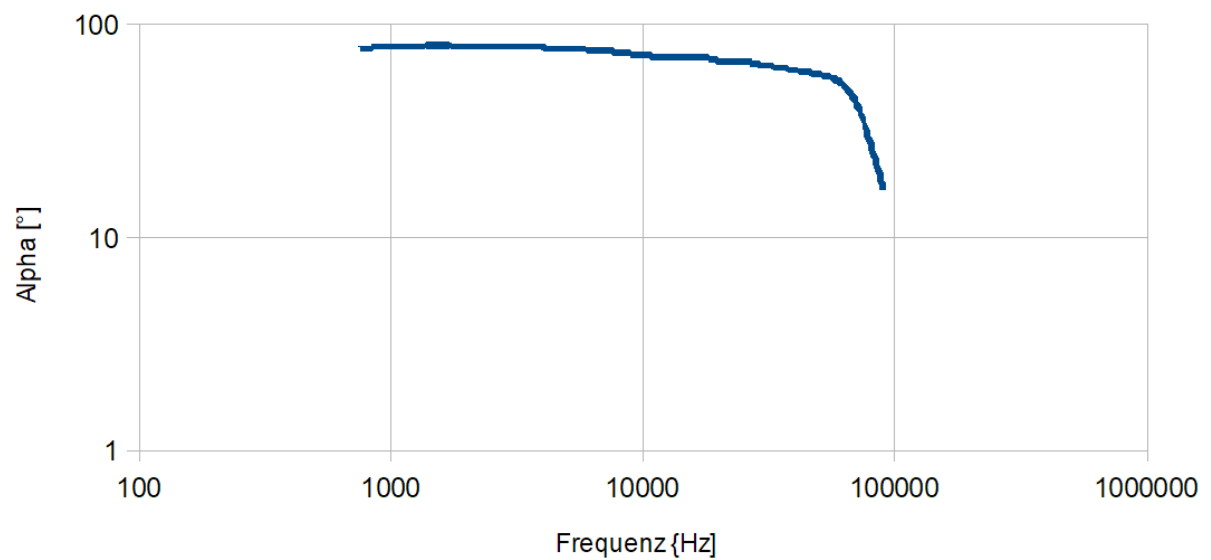
Introduction & Overview

$R1 = 4700\ \Omega$

Impedanz



Winkel

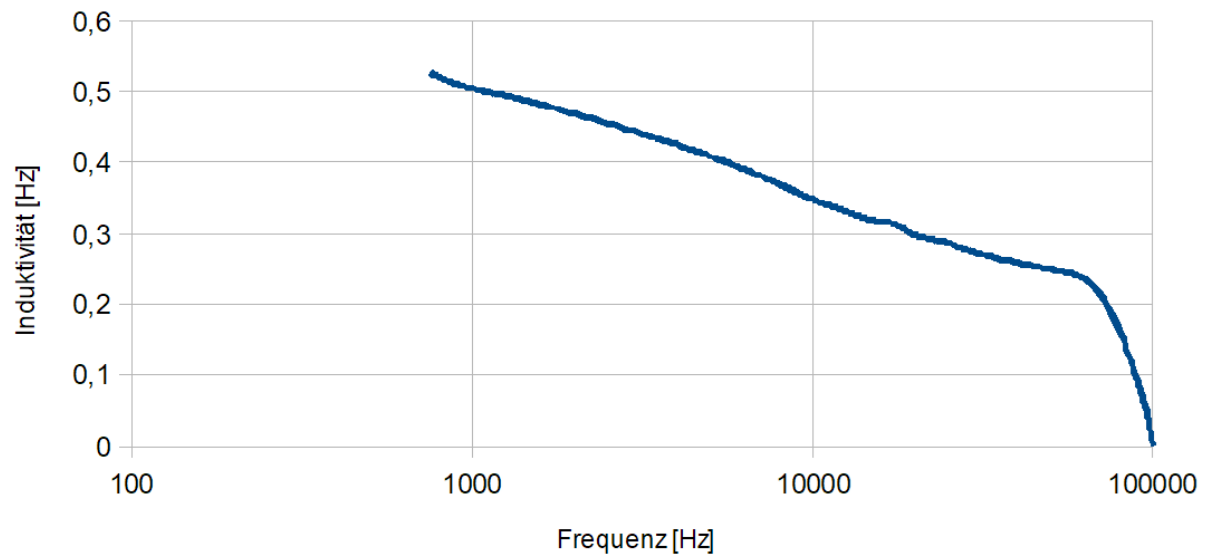


A closer look at the real coil of my MM cartridge AT420E OCC

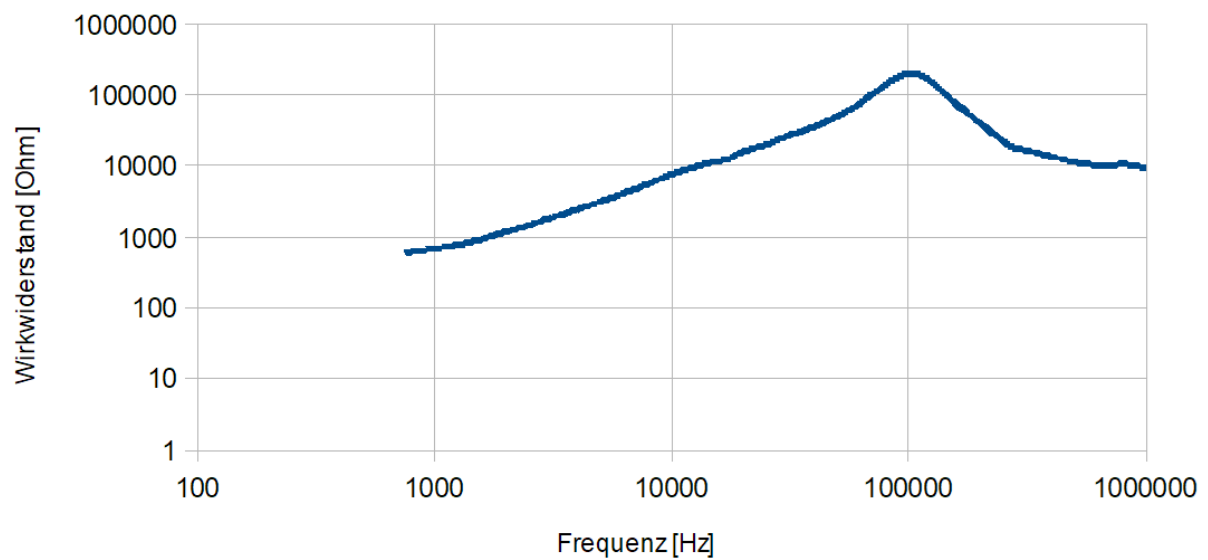
Introduction & Overview

$R1 = 4700 \, \Omega$

L_{eff}

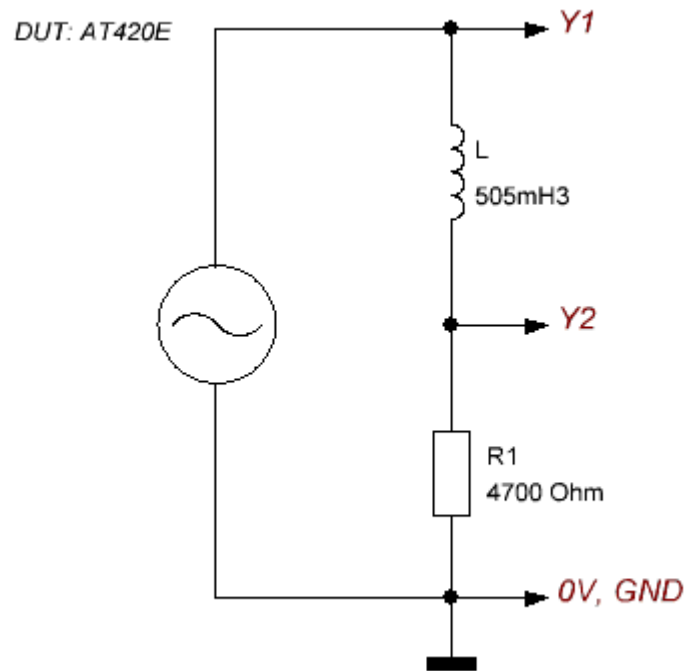


R_{eff}

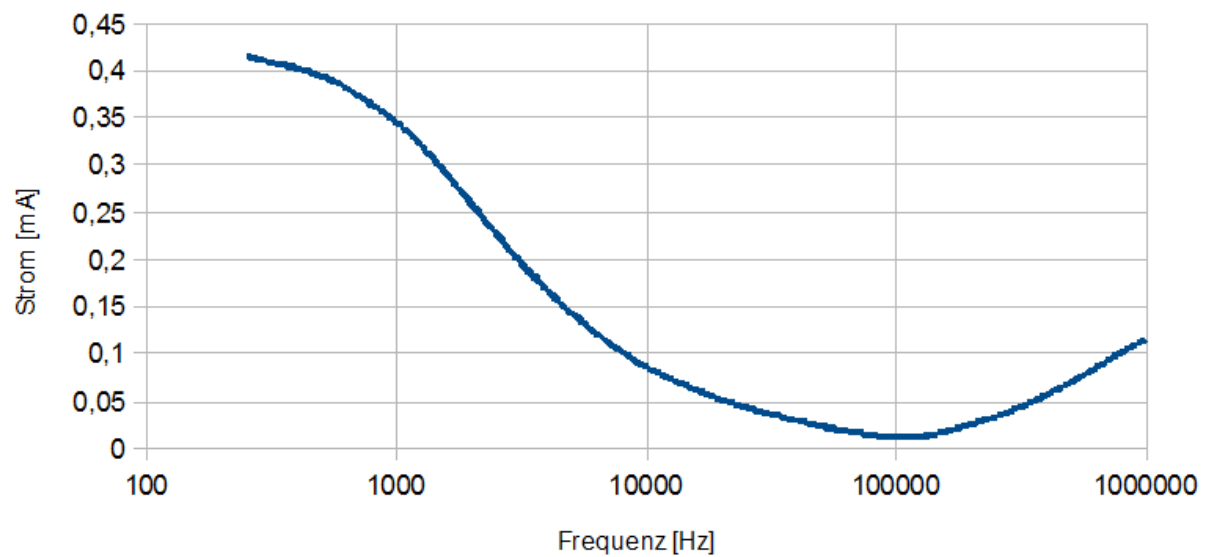


A closer look at the real coil of my MM cartridge AT420E OCC

Introduction & Overview

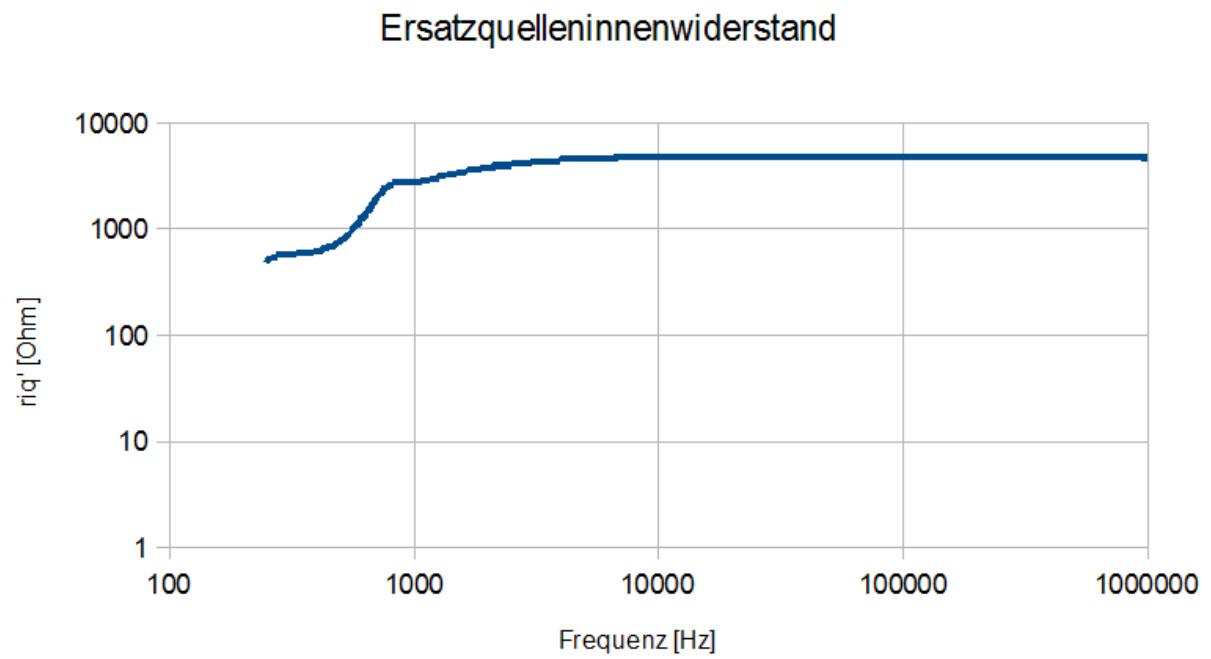
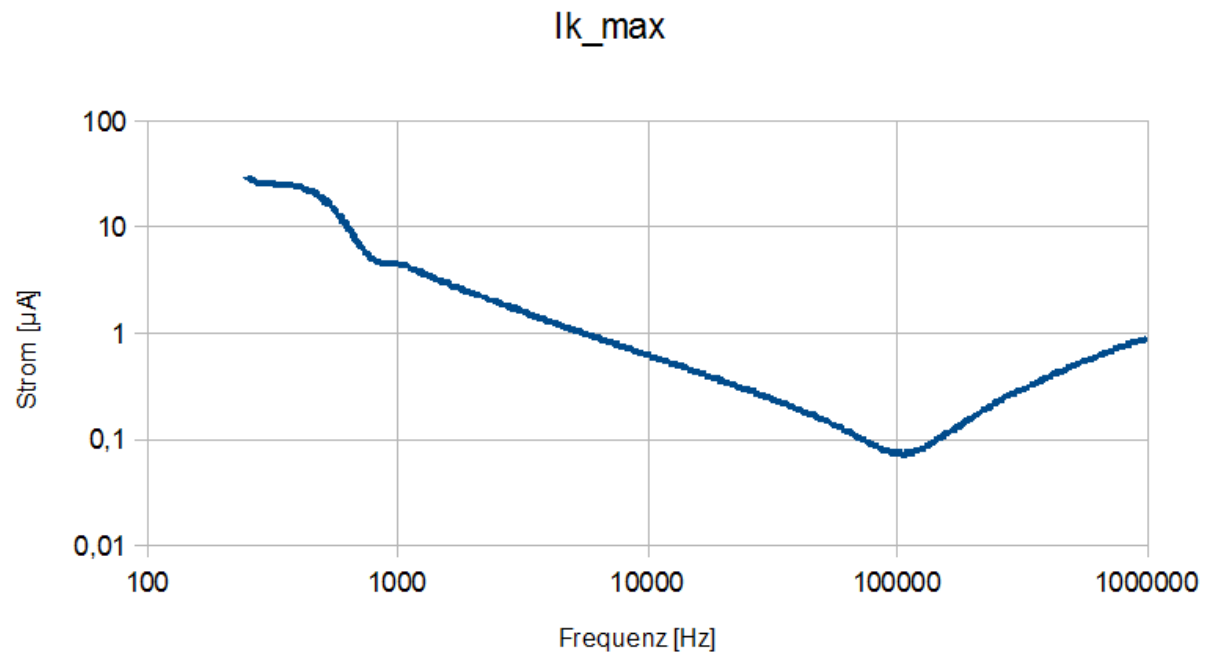


I_{mess}



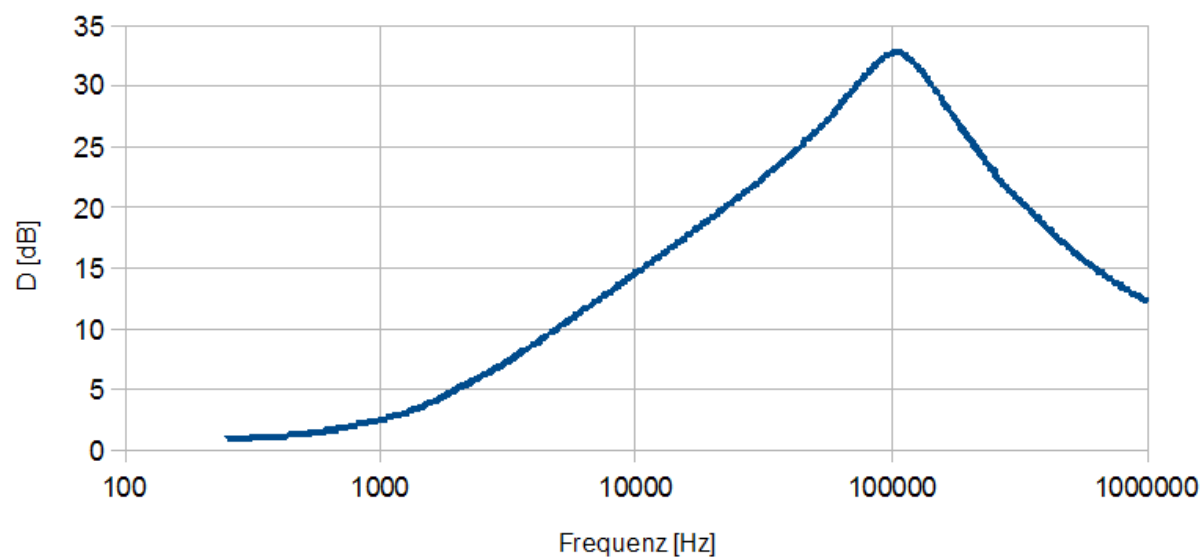
A closer look at the real coil of my MM cartridge AT420E OCC

Introduction & Overview



A closer look at the real coil of my MM cartridge AT420E OCC

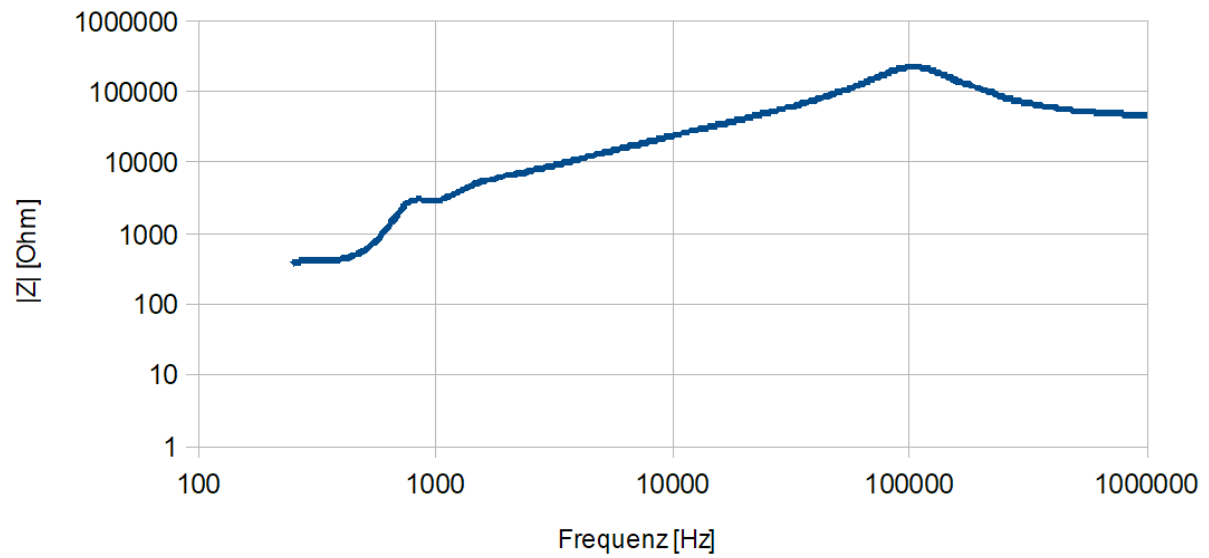
Dämpfung



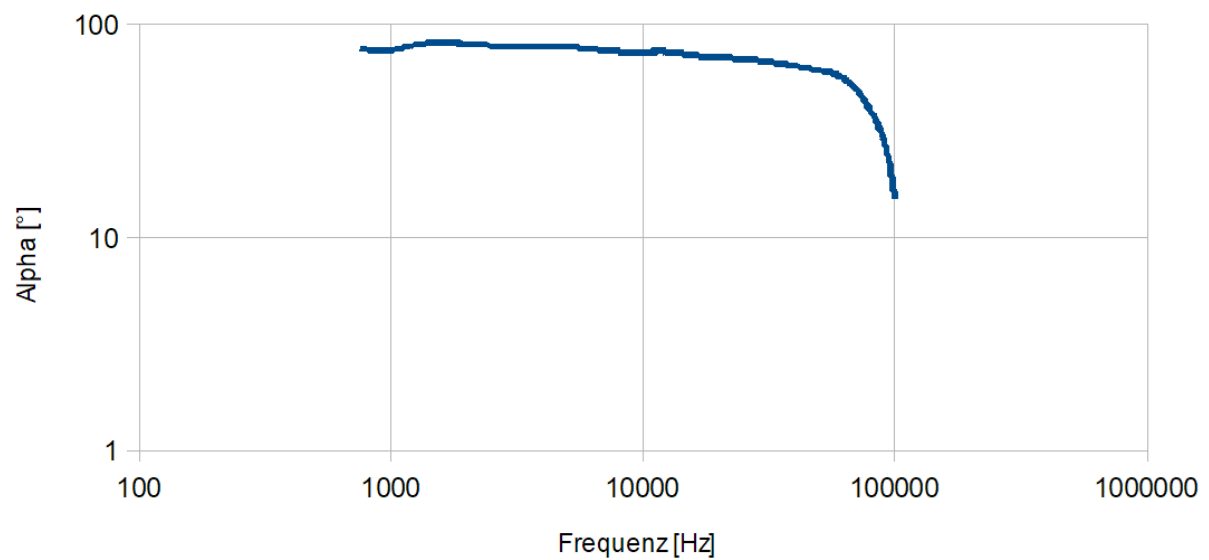
Introduction & Overview

$R1 = 22000\ \Omega$

Impedanz



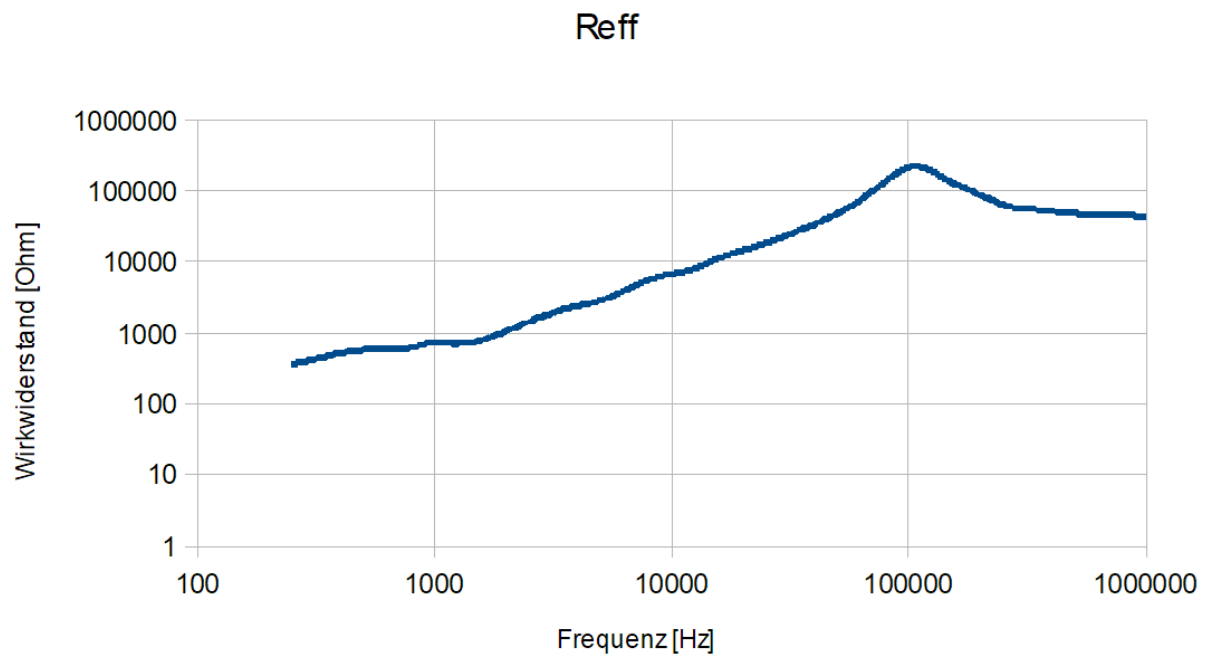
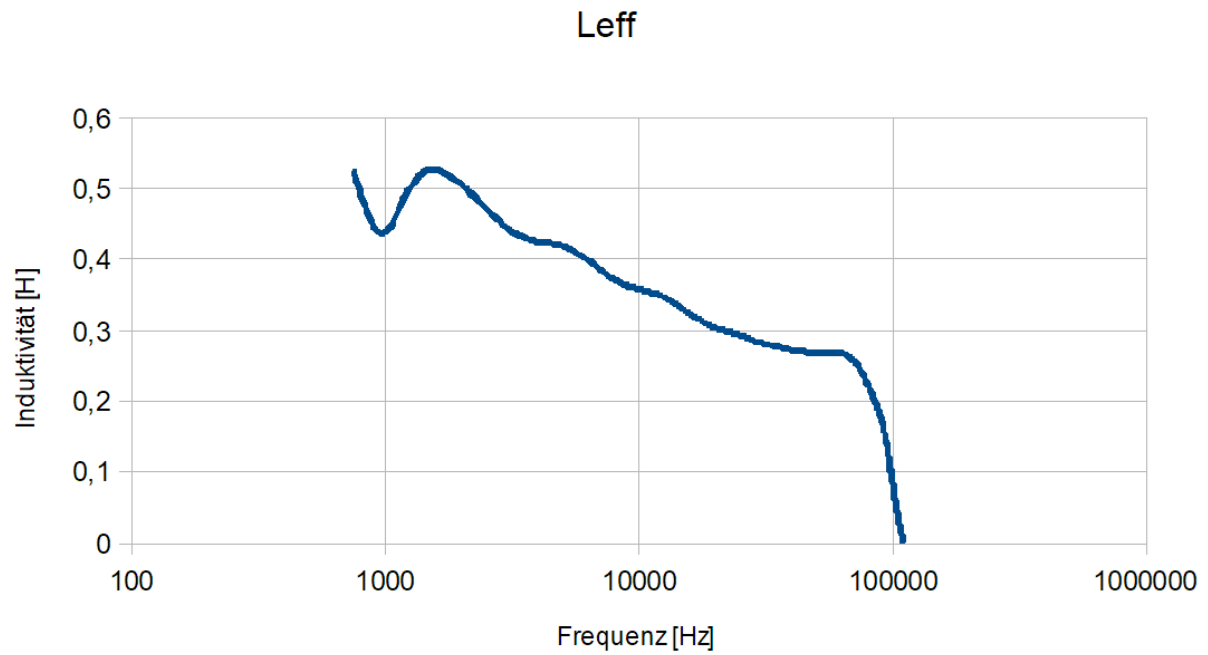
Winkel



A closer look at the real coil of my MM cartridge AT420E OCC

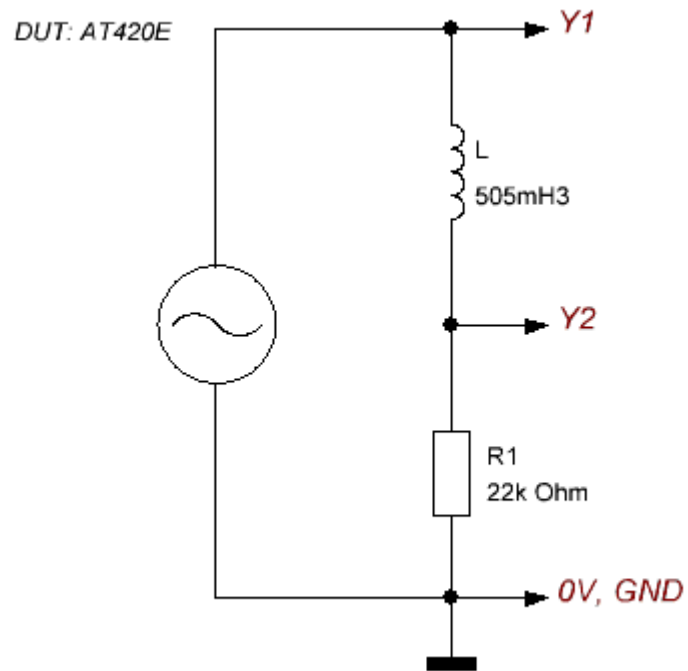
Introduction & Overview

$R1 = 22000 \Omega$

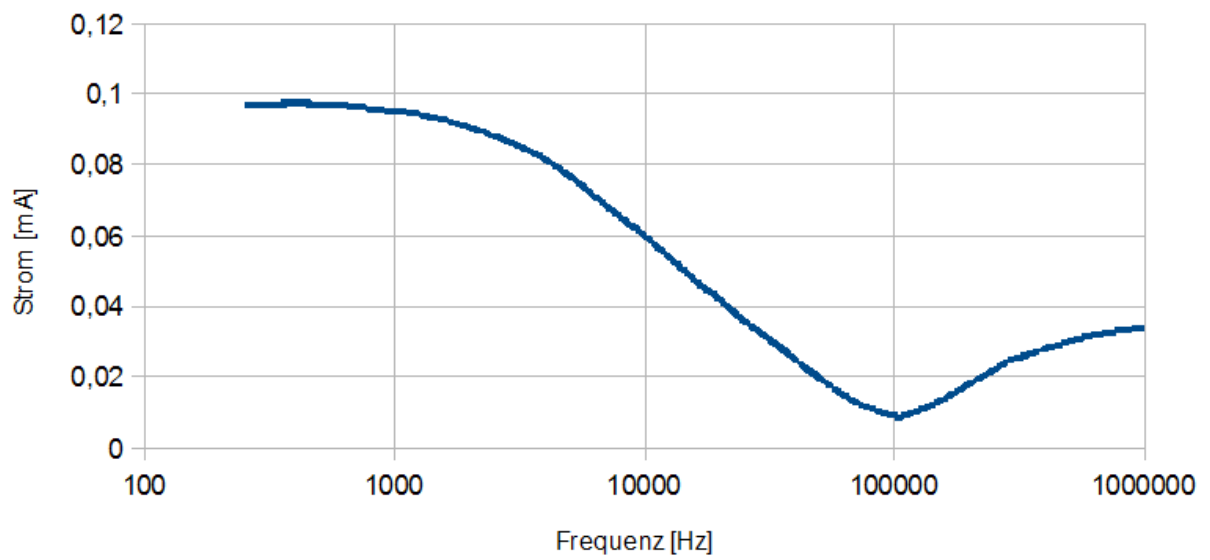


A closer look at the real coil of my MM cartridge AT420E OCC

Introduction & Overview

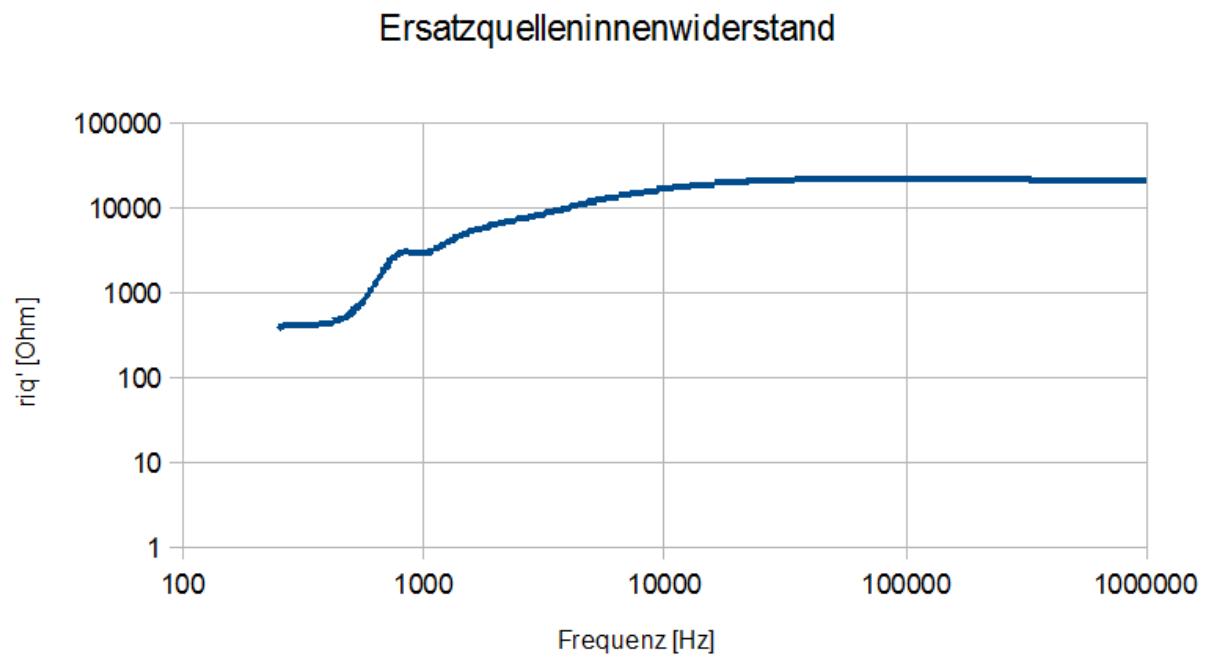
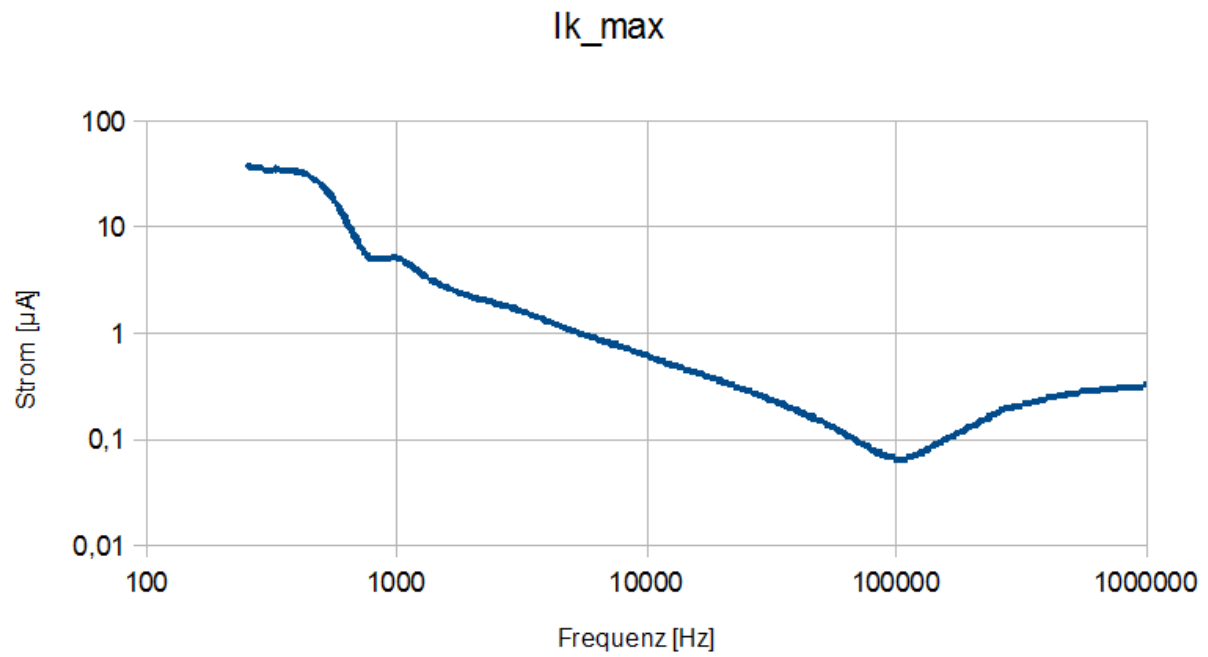


I_mess



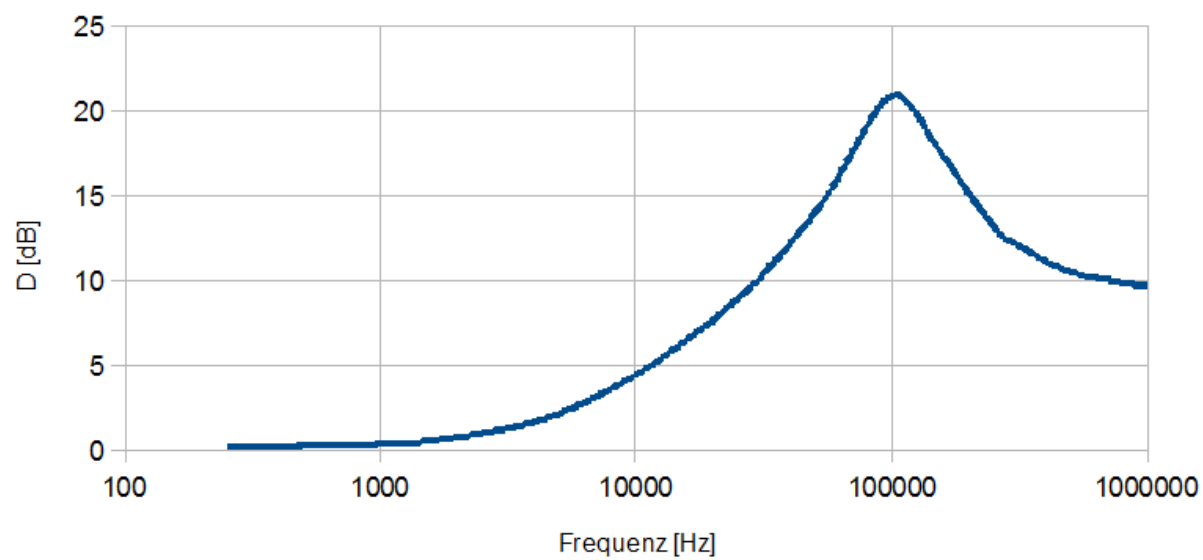
A closer look at the real coil of my MM cartridge AT420E OCC

Introduction & Overview



A closer look at the real coil of my MM cartridge AT420E OCC

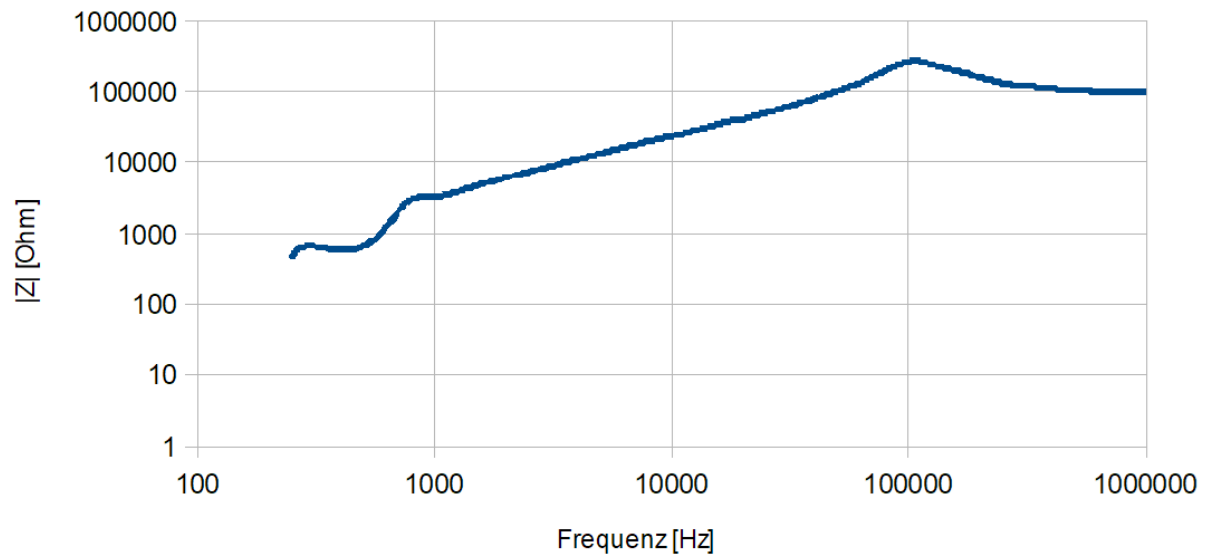
Dämpfung



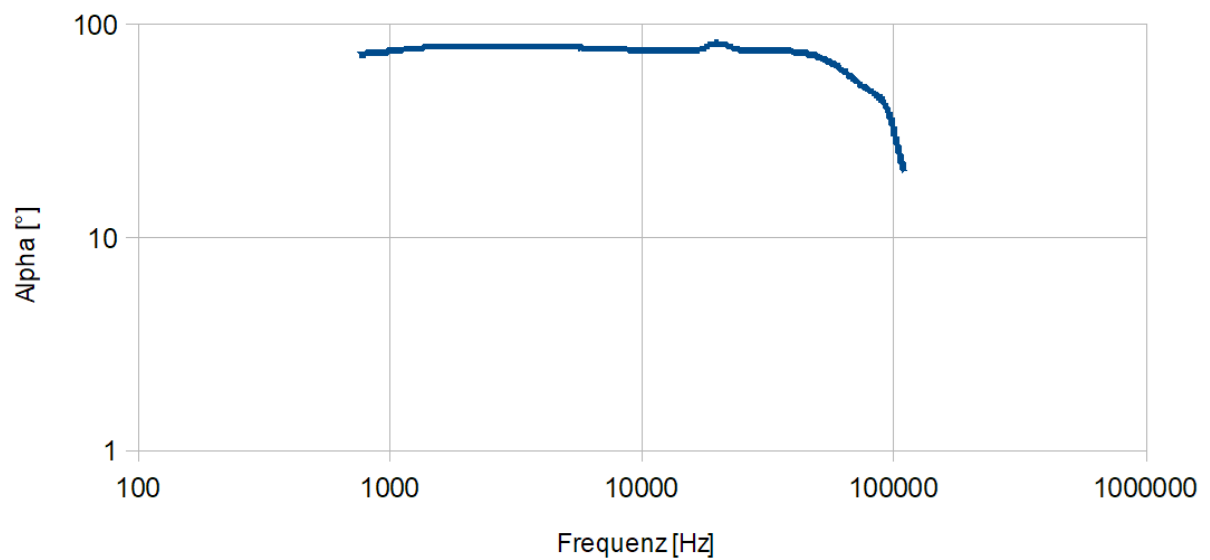
Introduction & Overview

$R1 = 47000\ \Omega$

Impedanz



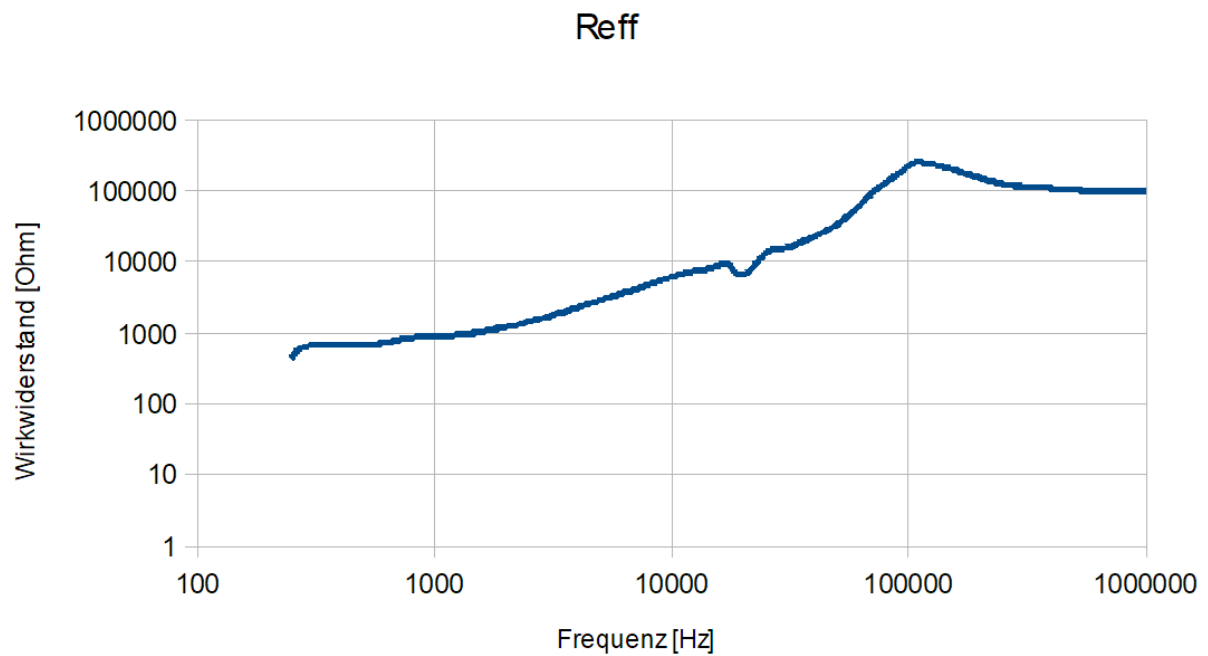
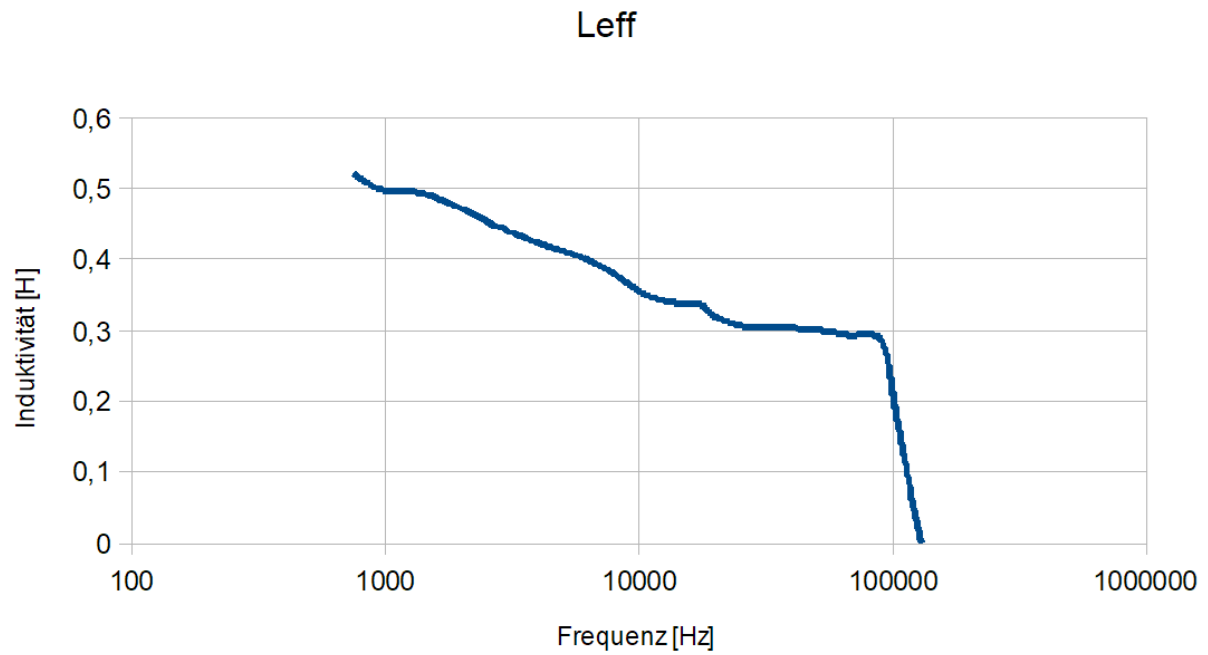
Winkel



A closer look at the real coil of my MM cartridge AT420E OCC

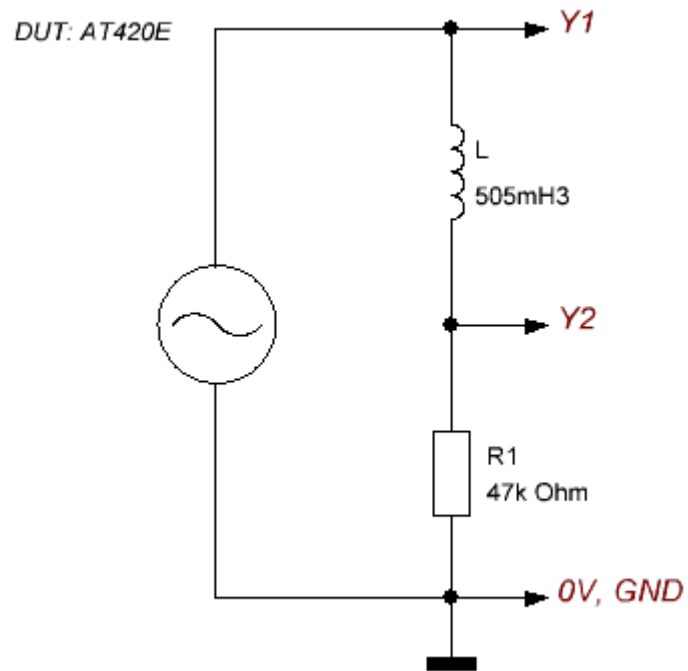
Introduction & Overview

$R1 = 47000 \, \Omega$

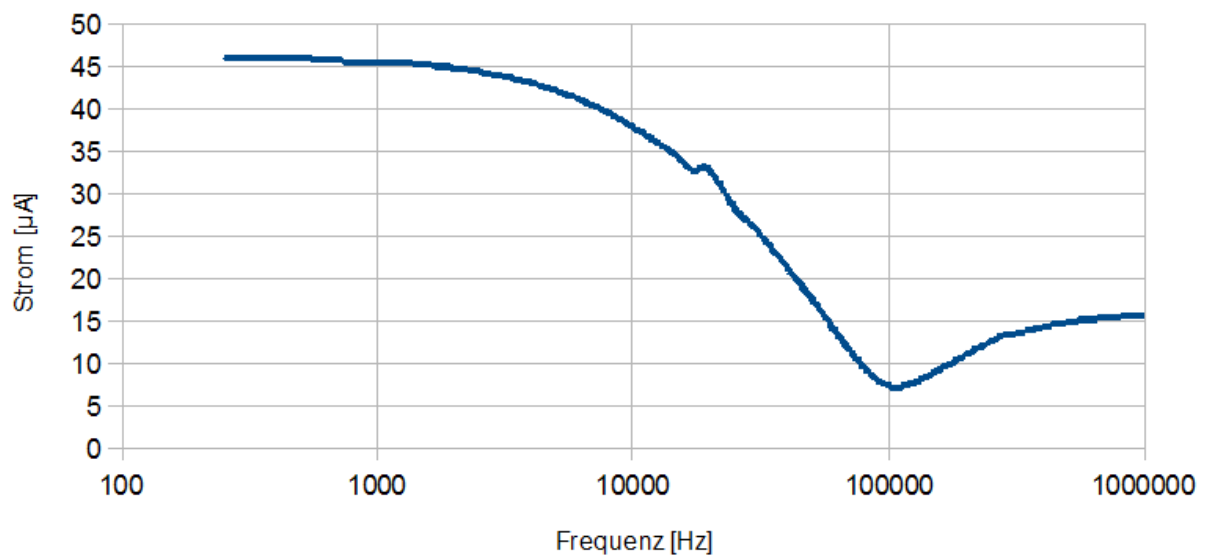


A closer look at the real coil of my MM cartridge AT420E OCC

Introduction & Overview

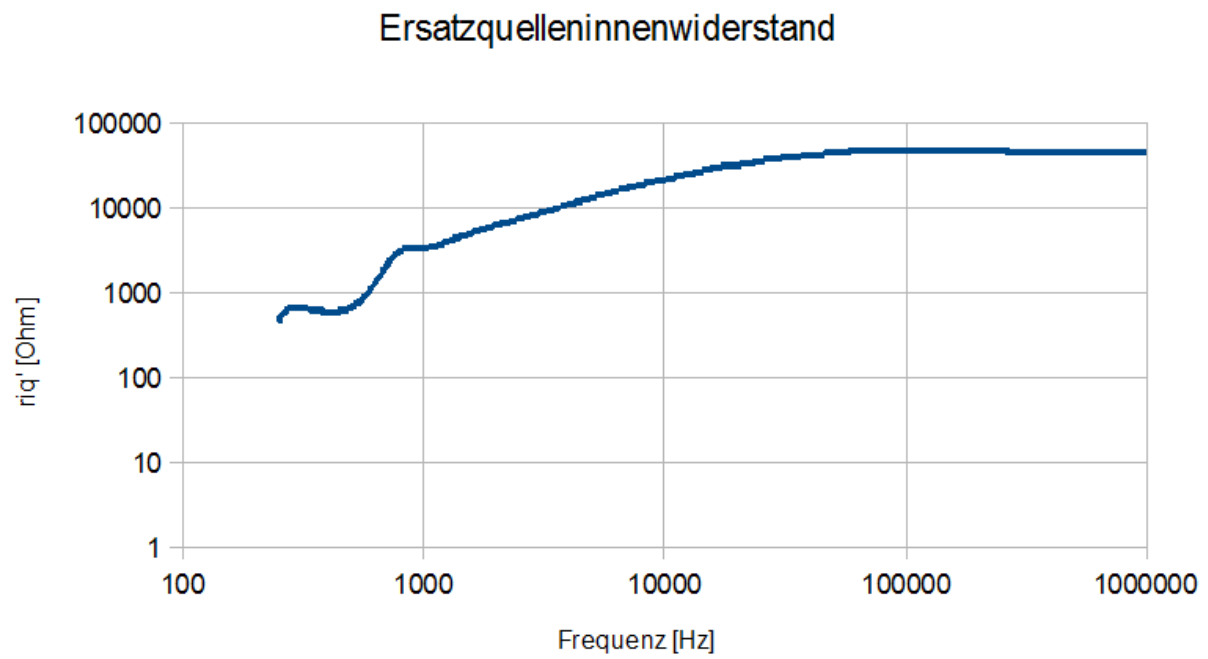
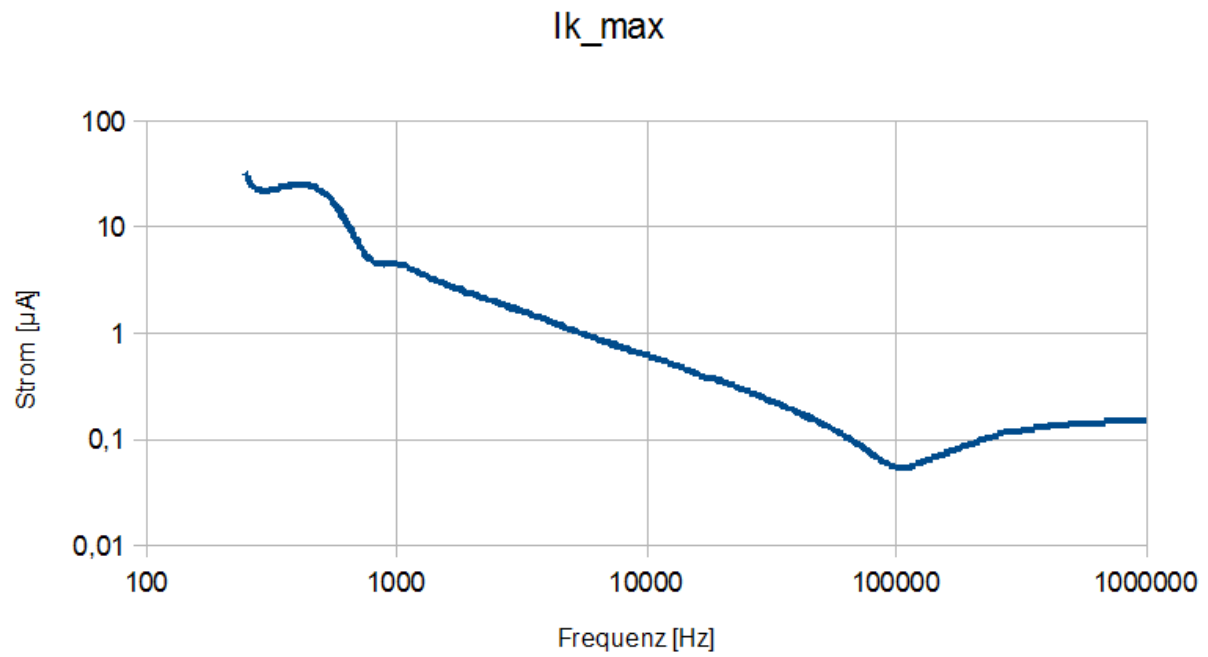


I_mess



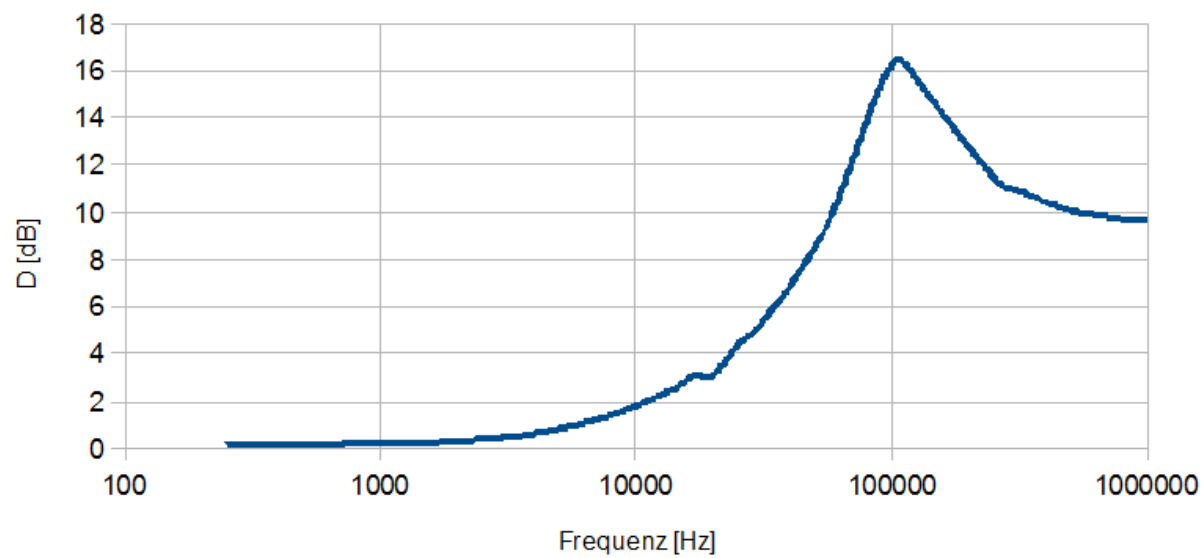
A closer look at the real coil of my MM cartridge AT420E OCC

Introduction & Overview



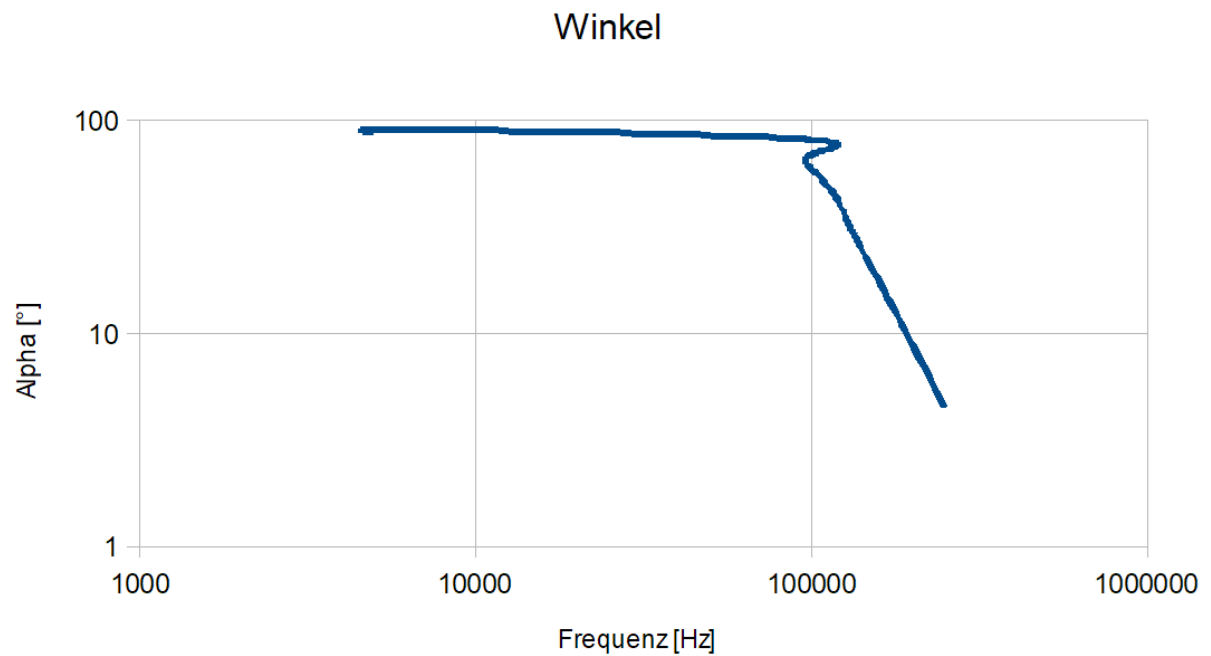
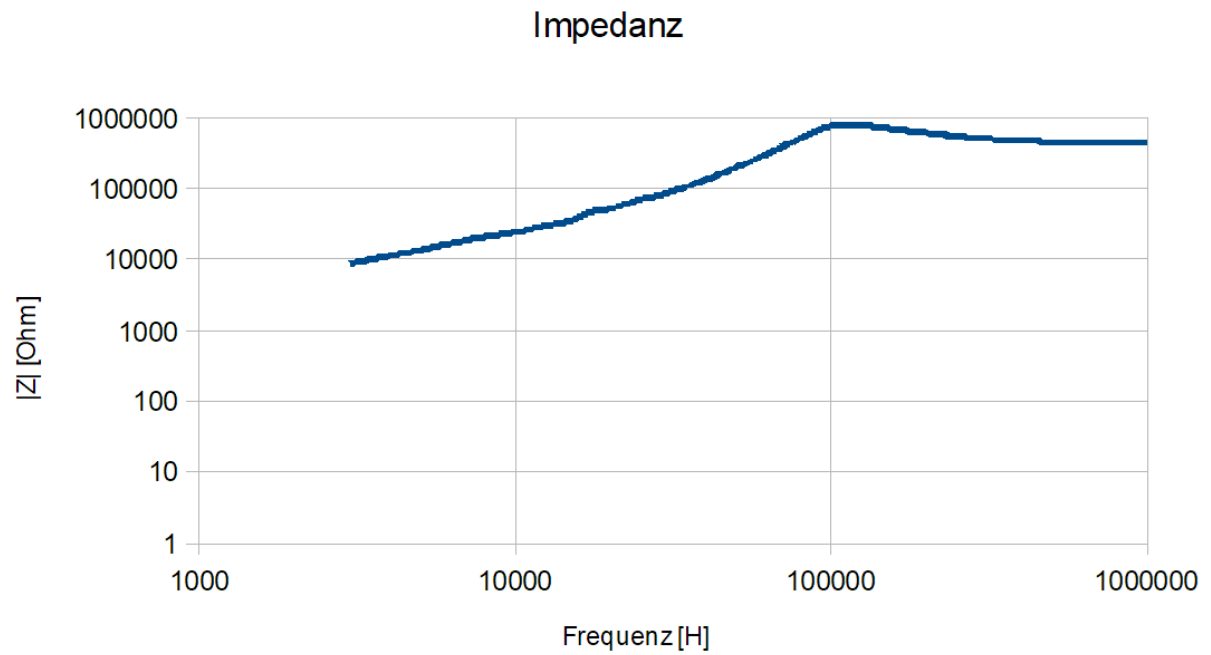
A closer look at the real coil of my MM cartridge AT420E OCC

Dämpfung



Introduction & Overview

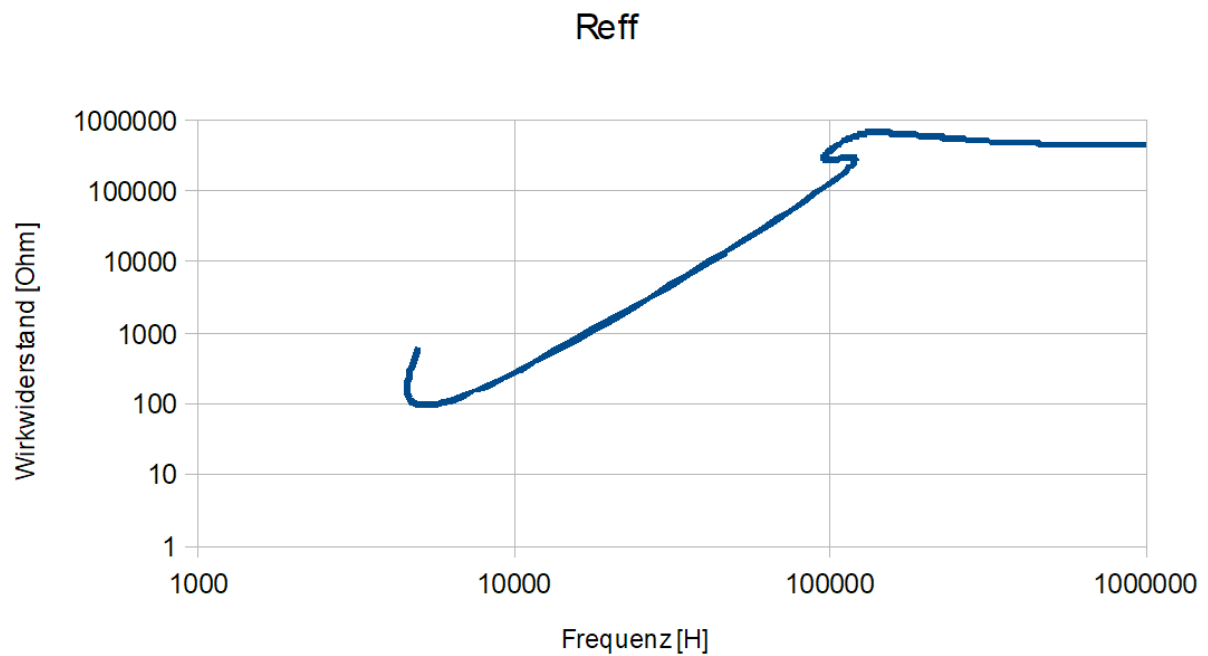
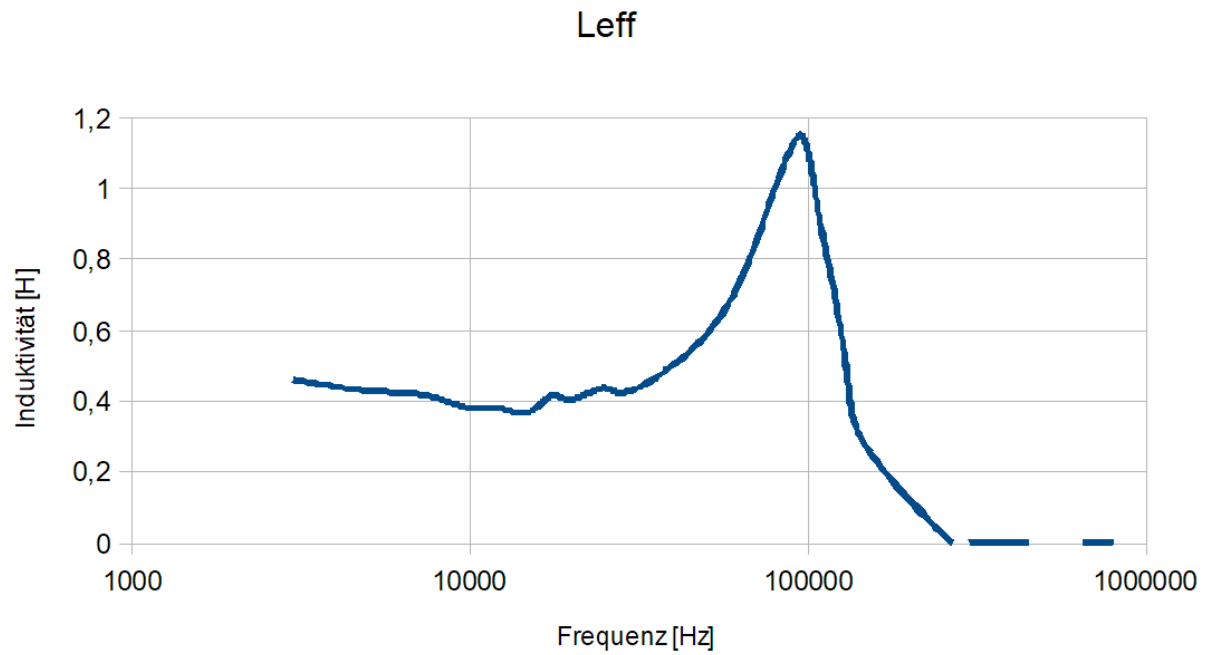
$R1 = 220000 \, \Omega$



A closer look at the real coil of my MM cartridge AT420E OCC

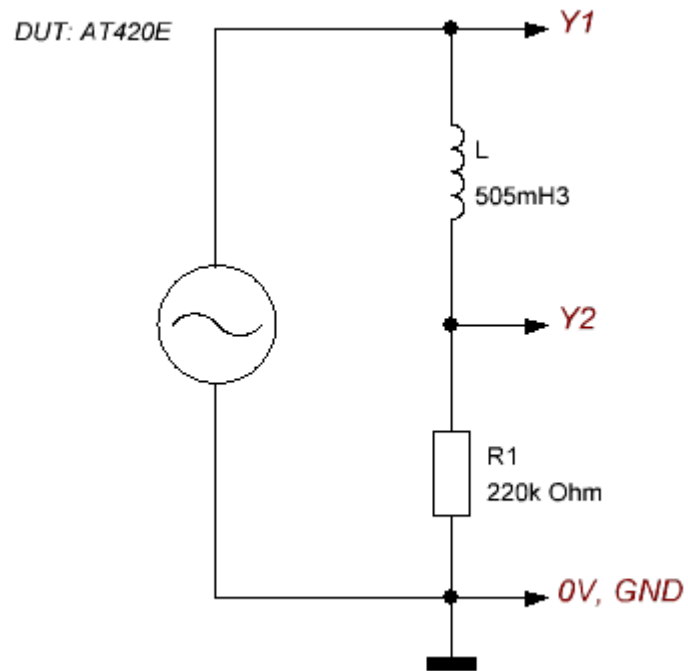
Introduction & Overview

$R1 = 220000 \Omega$

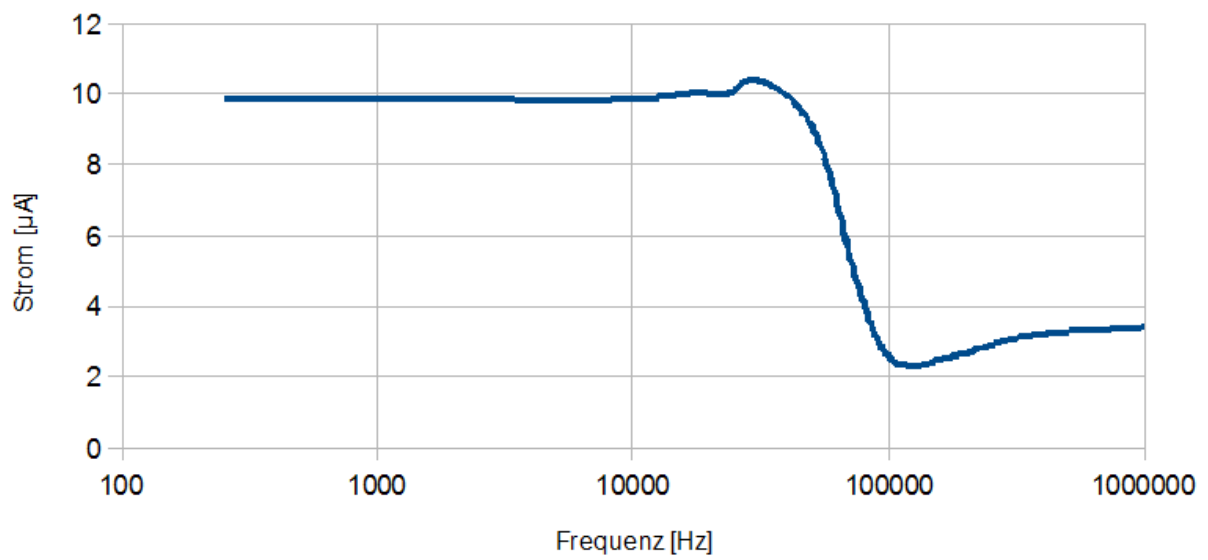


A closer look at the real coil of my MM cartridge AT420E OCC

Introduction & Overview

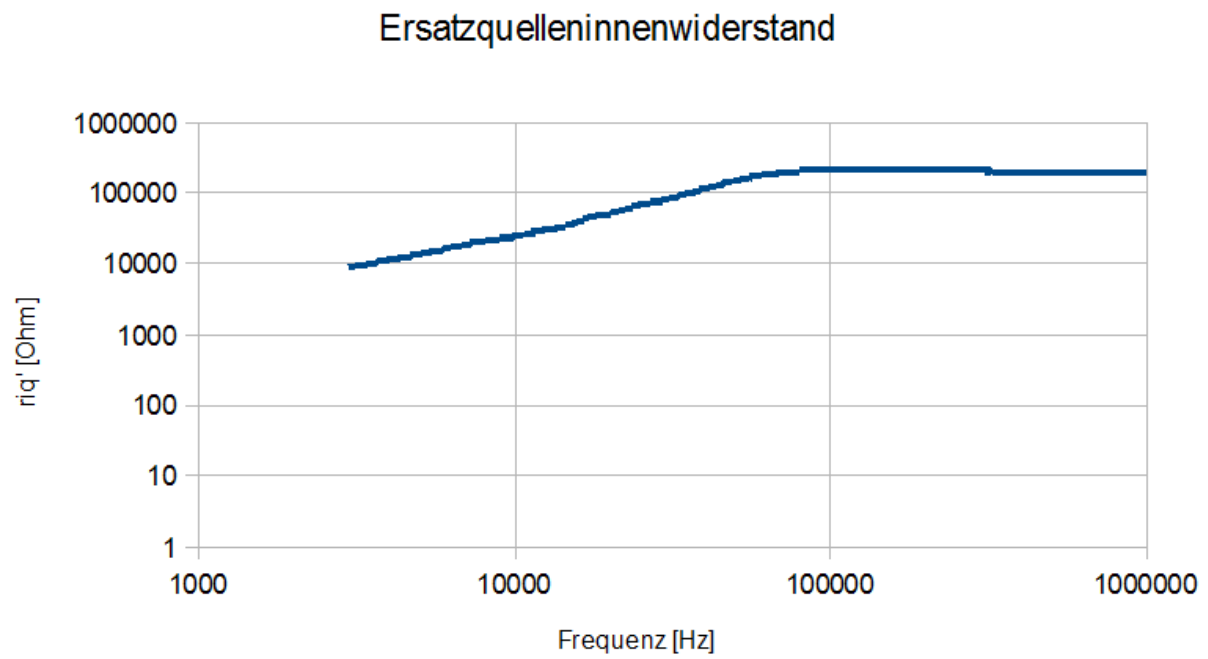
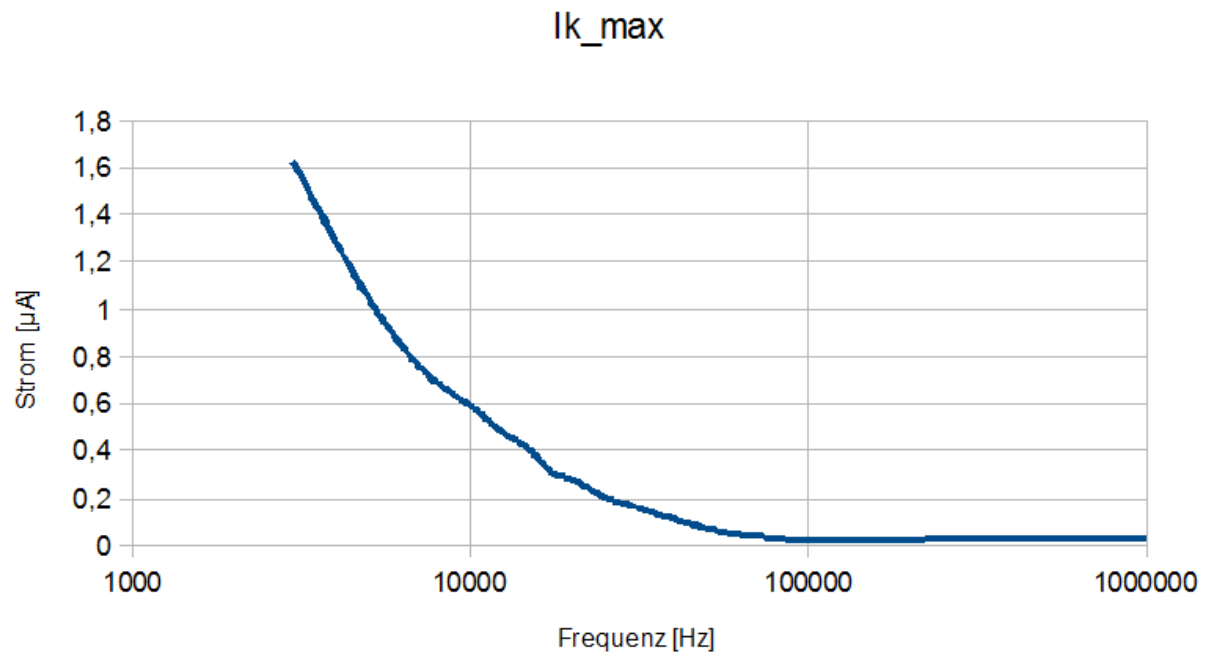


I_{mess}



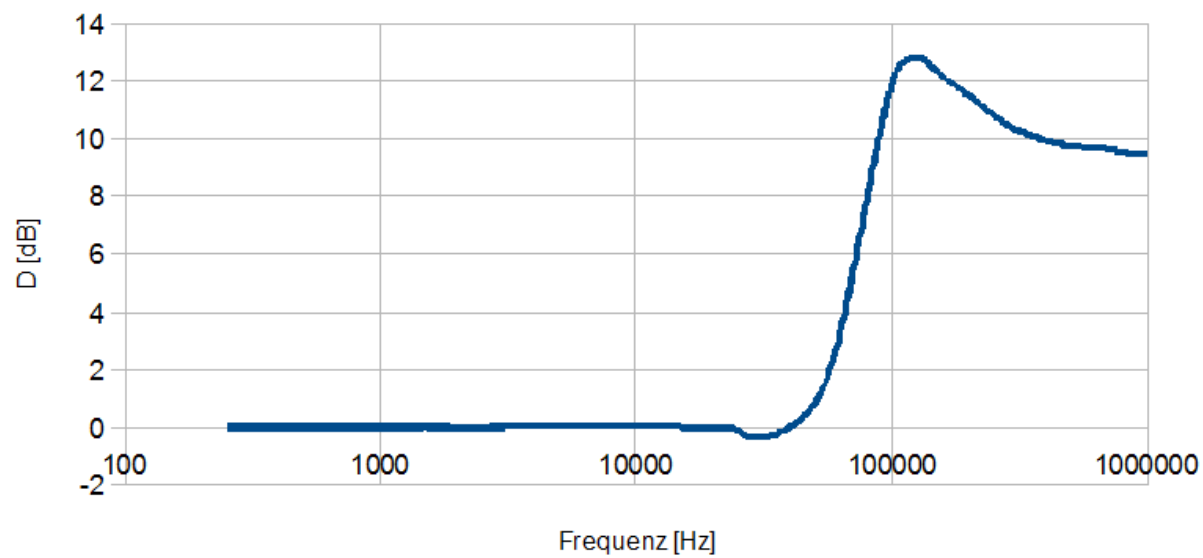
A closer look at the real coil of my MM cartridge AT420E OCC

Introduction & Overview



A closer look at the real coil of my MM cartridge AT420E OCC

Dämpfung

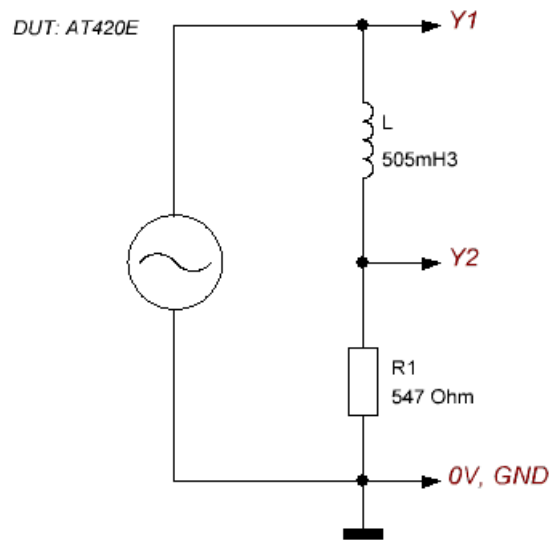


A closer look at the real coil of my MM cartridge AT420E OCC

Introduction & Overview

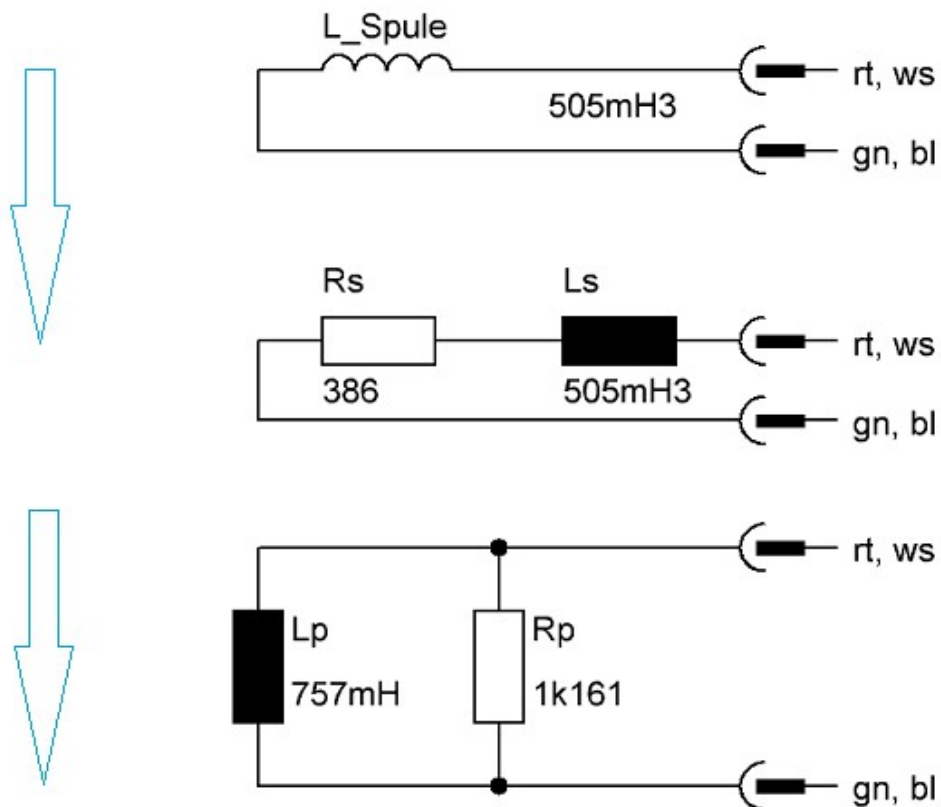
f_{test} :

0Hz, 100Hz, 120Hz, 1kHz, 10kHz, 100kHz



Messgeräte:

Fluke 73, PeakTech 2705, MIC 4070D, LCR-400 Voltcraft, RTC1002 Rohde & Schwartz



A closer look at the real coil of my MM cartridge AT420E OCC

Quellen:

DDS 110 ELV – Funktionsgenerator

A)

<i>f</i>	<i>Ls links</i>	<i>D</i>	<i>Q</i>	<i>ESR</i>	<i>Phi</i>			
100	487,7	1,332	0,751	408	36,8			
1000	485,6	0,237	4,22	724	76,6			
10000	348,6	0,37	2,7	8100	69,6			
100000	32,66	9,52	0,114	195100	6,3	120Hz	496,2mH	Z 1k = 3136 [Ohm]

<i>f</i>	<i>Ls rechts</i>	<i>D</i>	<i>Q</i>	<i>ESR</i>	<i>Phi</i>			
100	485,9	1,305	0,766	399	37,4			
1000	486,4	0,244	4,1	745	76,2			
10000	339,6	0,374	2,67	7990	69,4			
100000	46,23	6,88	0,147	202000	-8,3	120Hz	494,9mH	Z 1k = 3146 [Ohm]

<i>f</i>	<i>Ls</i>
120	495,55
1000	486
10000	344,1
100000	39,445

<i>f</i>	<i> Z </i>	<i>Phi</i>		<i>R s</i>	<i>L s</i>
100	506,326	0,649	37,18	403,5	0,487
1000	3140,722	1,335	76,49	734,5	0,486
10000	23068,712	1,215	69,61	8045	0,3442
100000	200090,855	0,124	7,1	198550	0,0394
[Hz]	[Ohm]	[rad]	[°]	[Ohm]	[H]

B)

We are looking for the inductance of the coil ...

$$R_{dc} = 386 \, \Omega$$

$$|Z| = \sqrt{2} * R_{dc}$$

with

$$f = 172,3 \, \text{Hz}$$

is the value now calculated as (approx.) 500 mH, which corresponds to 100% of the manufacturer's specification!

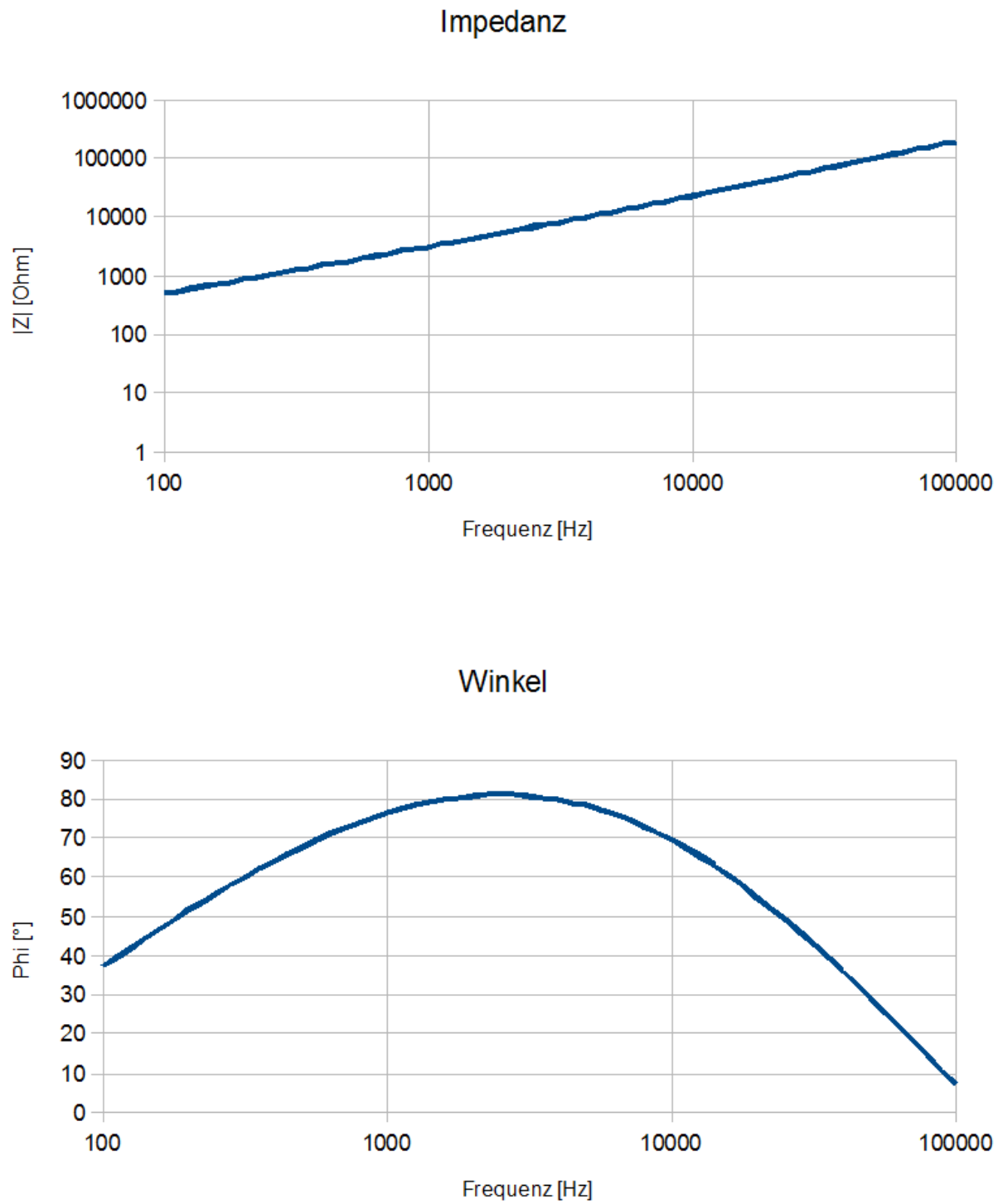
$$L_{tc} = 505,3 \, \text{mH}$$

$$\alpha = 29,32^\circ$$

$$\tan \delta = 1,781$$

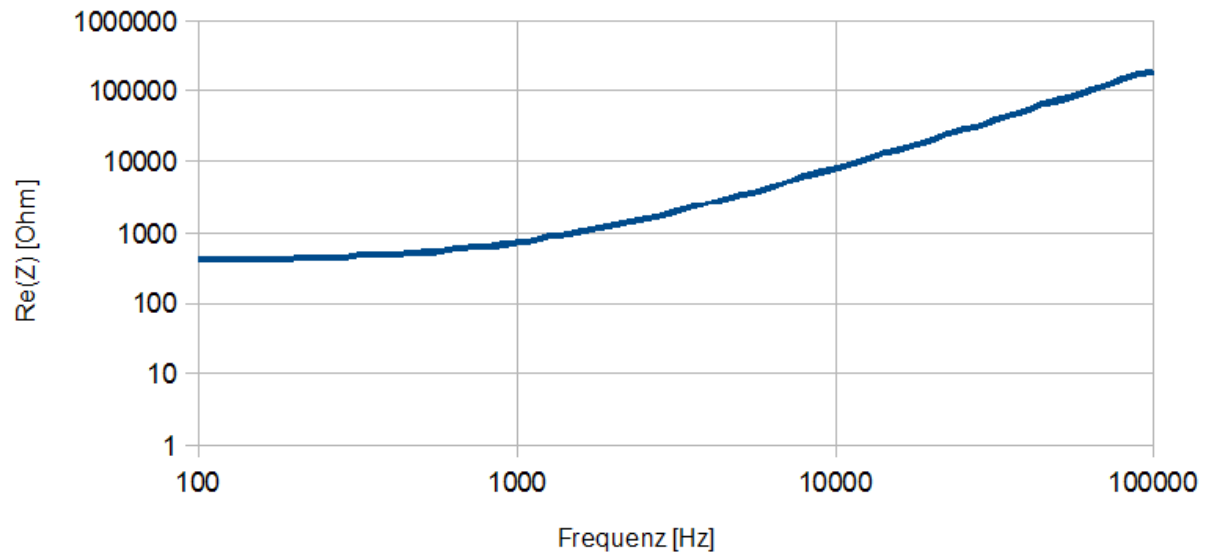
A closer look at the real coil of my MM cartridge AT420E OCC

1a)

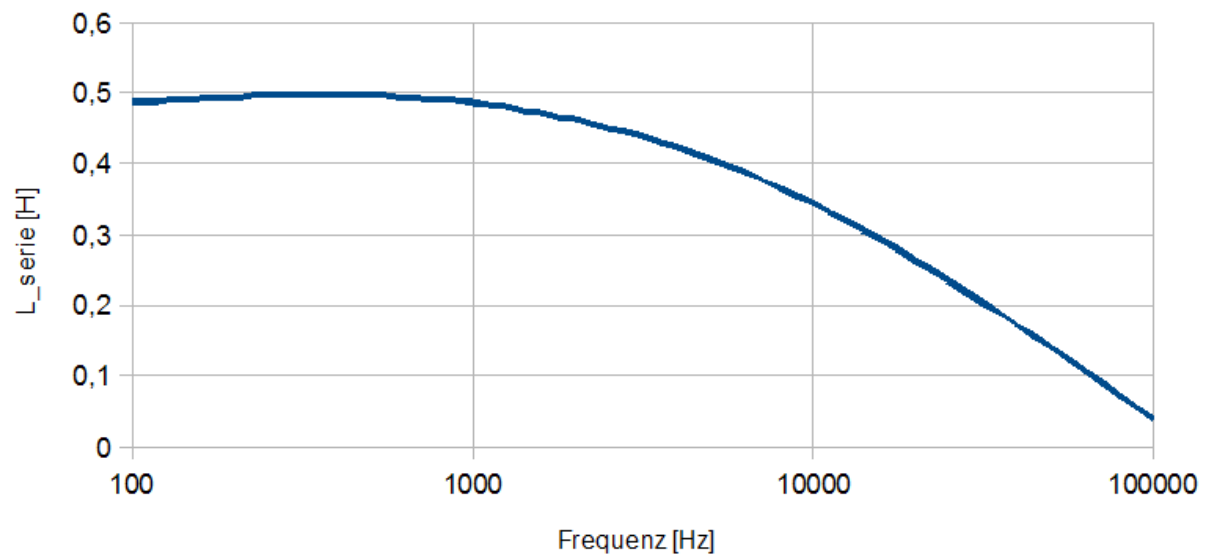


A closer look at the real coil of my MM cartridge AT420E OCC

Wirkwiderstand



Induktivität



A closer look at the real coil of my MM cartridge AT420E OCC

2b)

The following sinusoidal oscillations $U(t) = 1V * \sin(\omega * t + \varphi_0)$, ohmic resistors and two special 1 in 10 probes were used to determine the variables - in order to reduce the capacitive load to a minimum.

f:

250, 300, 500, 750, 1k, 1k5, 3k, 5k, 7k5, 10k, 12k5, 15k, 17k5, 20k, 25k, 30k, 50k, 70k, 90k, 100k, 110k, 130k, 150k, 250k, 300k, 450k, 650k, 800k, 1M ... [Hz]

R1(konstant):

547, 4700, 22000, 47000, 220000 ... [Ω]

The entire determination procedure - the measurement works with “home remedies” and is based on Ohm's law. A step response is not included for the time being for reasons of clarity and hopefully easier general understanding. System identification is classically carried out by means of step excitation; it could be carried out later for completion.

The graphical representation is self-explanatory; the ordinate (Y-axis) is almost always logarithmically divided - i.e. there are double-logarithmic representations. All Y (as a function of X) values are pure calculation values, without eliminating obvious reading errors (inaccuracies during the manual settings for value acquisition) from the two oscilloscoped oscillations.

Introduction & Overview

2c)

Frequenz						Impedanz		min	max
1000	3,17	3,24	x	3,25	x	3,22	0,044	3,176	3,264
5000	13	13,2	13,5	13,3	13,5	13,3	0,212	13,088	13,512
10000	22,7	23,1	23,5	23,1	23,9	23,26	0,456	22,804	23,716
15000	x	32	32,7	32,9	x	32,533	0,473	32,06	33,006
20000	x	40,6	40,7	40,7	x	40,667	0,058	40,609	40,725

1000	75,3	x	75,2	74,1	x	74,867	0,666	74,201	75,533
5000	x	76,4	77,8	77,5	x	77,233	0,737	76,496	77,97
10000	77,9	x	73,5	74,7	x	75,367	2,274	73,093	77,641
15000	x	x	71,5	75,4	x	73,45	2,758	70,692	76,208
20000	64	67,1	69,3	x	x	66,8	2,663	64,137	69,463

547	4700	22000	47000	220000
-----	------	-------	-------	--------

Re(Z)	Re(Z)*	Im(Z)
0,8407	0,4547	3,108
2,9395	2,5535	12,9693
5,8884	5,5024	22,4977
9,2943	8,9083	31,1736
16,0551	15,6691	37,3636
[kOhm]		

L_s
494,654
412,826
358,062
330,762
297,33
[mH]

372,69728

	ideal abw_lin							
Z			Vektor	gamma	beta'vek	Re(vektor)	Im(vektor)	L'
3,2197	3,1983	-0,0214	0,4596	88,5382	76,3258	0,108649733	0,4465729453	71,074
13,2983	15,8792	2,5809	3,8679	31,3296	135,8999	2,777636009	2,6917259538	85,68
23,2555	31,7513	8,4958	10,764	17,4688	147,8639	9,114814603	5,7257183613	91,128
32,5296	47,625	15,0954	18,7071	12,7644	150,6338	16,30329852	9,1737695432	97,337
40,667	63,499	22,832	30,4716	8,3887	148,3582	25,94182708	15,985618983	127,21
phi	beta							
74,864	83,0681	8,2041	<div>472,429</div> <div>[mH]</div> <div>32,871</div>					
77,2295	88,6071	11,3776						
75,3327	89,3034	13,9707						
73,3982	89,5356	16,1374						
66,7469	89,6517	22,9048						

3)

Modeling - from the calculated values $D(f)$, $|Z|(f)$ & $\phi(f)$, formed from the metrologically determined time courses U_e and U_a . The parasitic parallel resonance f_{res} can possibly serve as a starting point. In the arithmetic mean it lies at 107k5Hz, in the approximated model the magnitude and phase agree well, the resonance here falls exactly to 0° . In the crucial frequency range between 1kHz and f_{res} , however, no valid approximation can be achieved in this way.

Examples for L_p , C_p and R_p are:

0,293H – 7,481pF – 198k Ω

0,324H – 6,765pF – 219k Ω

0,394H – 5,563pF – 266k Ω

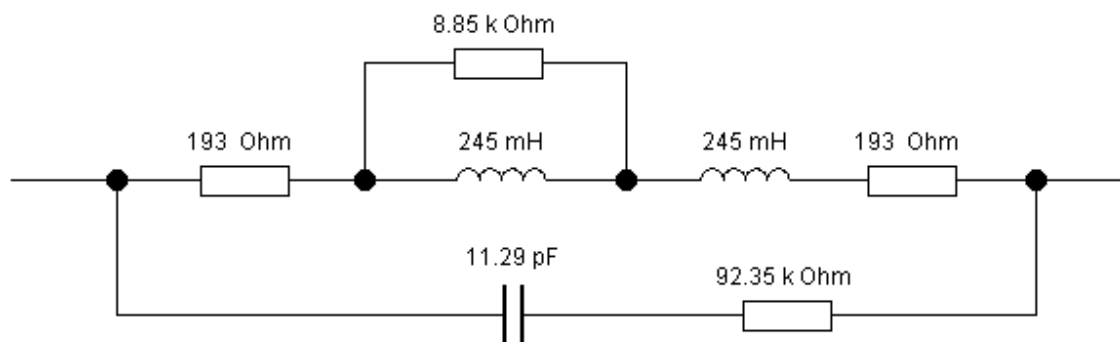
1,161H – 1,888pF – 784k Ω

Since this step will end in a dead end, it is better to start from the attenuation at 20kHz and form a partial model from two resistors and two inductors. This network is supplemented with a global C_p and an R_p . However, this topology cannot fully represent the damping above the resonance; for this purpose, $C||R$ must be transformed into an equivalent series element. In the following, the first, partial network is adapted - all of this together represents the real coil sufficiently accurately.

3a)

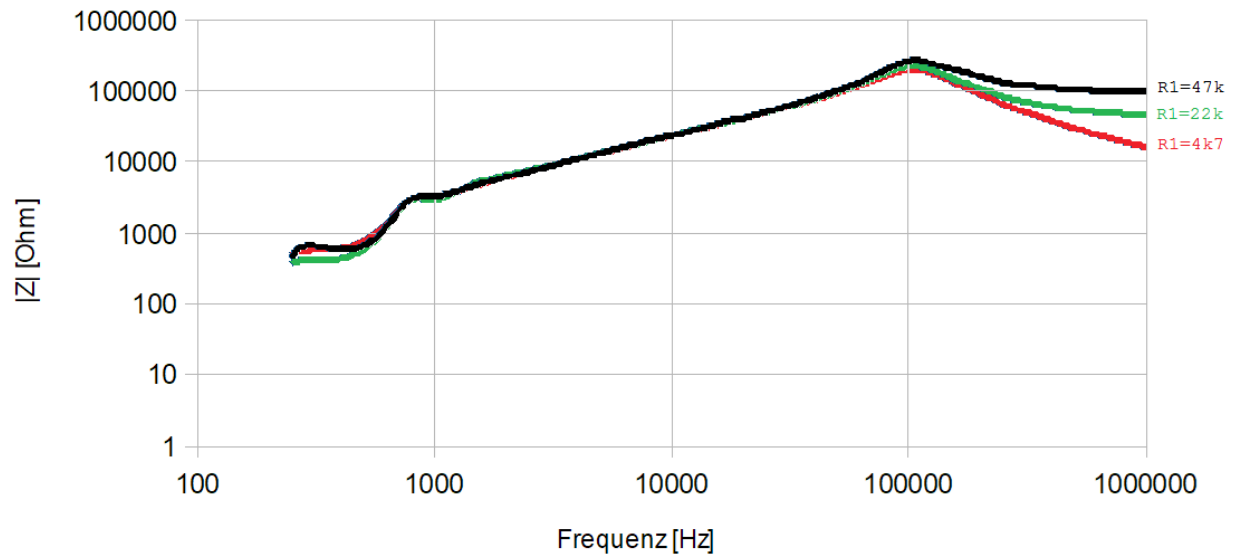
Below is an example of modeling based on 47k Ω as R_{load} .

Exact values are not completely independent of the actual load, but if an upper limit of the validity range is drawn with f_{res} , $R_{load} > 47k\Omega$ also appears to be correctly reproduced.

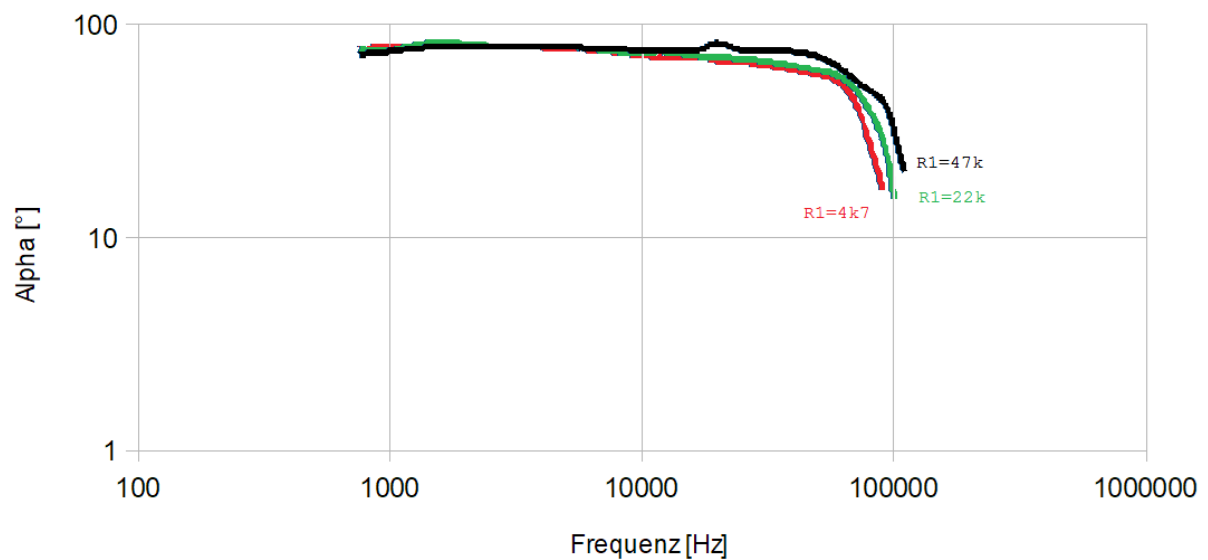


Introduction & Overview

Impedanz



Winkel



A closer look at the real coil of my MM cartridge AT420E OCC

Introduction & Overview

4)

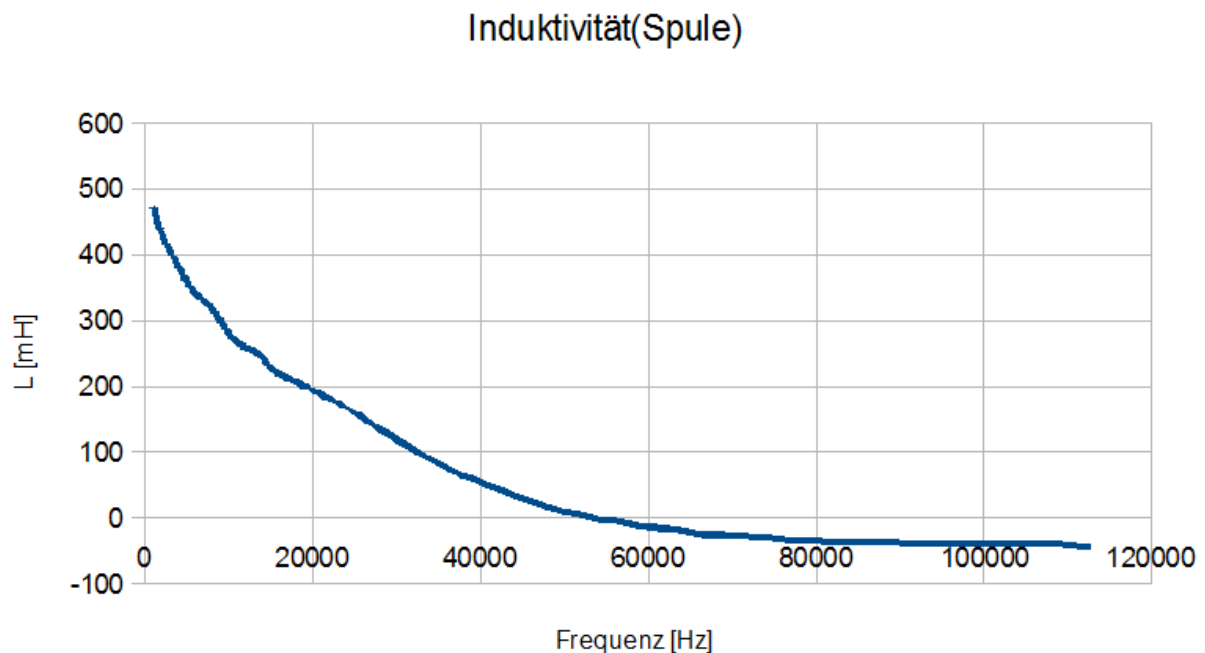
f	I	U_2	$ Z $	ϕ	Re	Im	Re'	$ Z '$	α	Im'	L	C	
1000	7,815	23,9	3,0582	76,32	1,332035	0,7233	2,9714	0,3373	2,9905	1,457765	2,9714	472,913	
2000		44,1	5,643	74,16	1,294336	1,5403	5,4287	1,1543	5,5501	1,361287	5,4287	432,0022	
4000		79,9	10,2239	70,272	1,226478	3,4511	9,6238	3,0651	10,1001	1,262462	9,6238	382,9188	
6000		110	14,0755	65,952	1,15108	5,7358	12,8538	5,3498	13,9227	1,1764	12,8538	340,9576	
8000		142	18,1702	61,632	1,075681	8,6333	15,9882	8,2473	17,99	1,09456	15,9882	318,0751	
10000		167	21,3692	55,44	0,967611	12,1221	17,5982	11,7361	21,1526	0,982638	17,5982	280,0841	
12000		190	24,3122	53,424	0,932425	14,4874	19,5243	14,1014	24,0842	0,945294	19,5243	258,9491	
14000		213	27,2553	51,984	0,907292	16,786	21,4728	16,4	27,0193	0,918549	21,4728	244,1073	
16000		235	30,0704	46,944	0,819327	20,5295	21,972	20,1435	29,8082	0,828787	21,972	218,5595	
25560	47,896	328	41,9706	36,53	0,637569	33,7253	24,9827	33,3393	41,6611	0,643083	24,9827	155,5603	
54000		464	59,373	0	0	59,373	0	58,987	58,987	0	0	0	
112700		328	41,9706	-44,629	-0,778923	29,8692	-29,4849	29,4832	41,6967	-0,785427	-29,4849	-41,6386	
[Hz]	[μA]	[mV]	[kOhm]	[°]	[rad]	[kOhm]	[kOhm]	[kOhm]	[kOhm]	[rad]	[kOhm]	[mH]	[pF]

Finally, the left channel, the left coil of the AT420E OCC MM system, is tested with twelve test points. This time the current is kept constant, now $R_1=100k\Omega$ serves as a series resistor with a constant voltage drop. U_2 is the voltage (peak to peak) at the DUT. The voltage of the source is adjusted so that $I = I_{R1} = I_{DUT}$ is constant. The original voltage is now close to the (maximum) induction voltage occurring in normal operation due to the moving permanent magnet in the air gap. Saturation phenomena of the core material are now excluded.

Quelle:
HAMEG HM8030-6

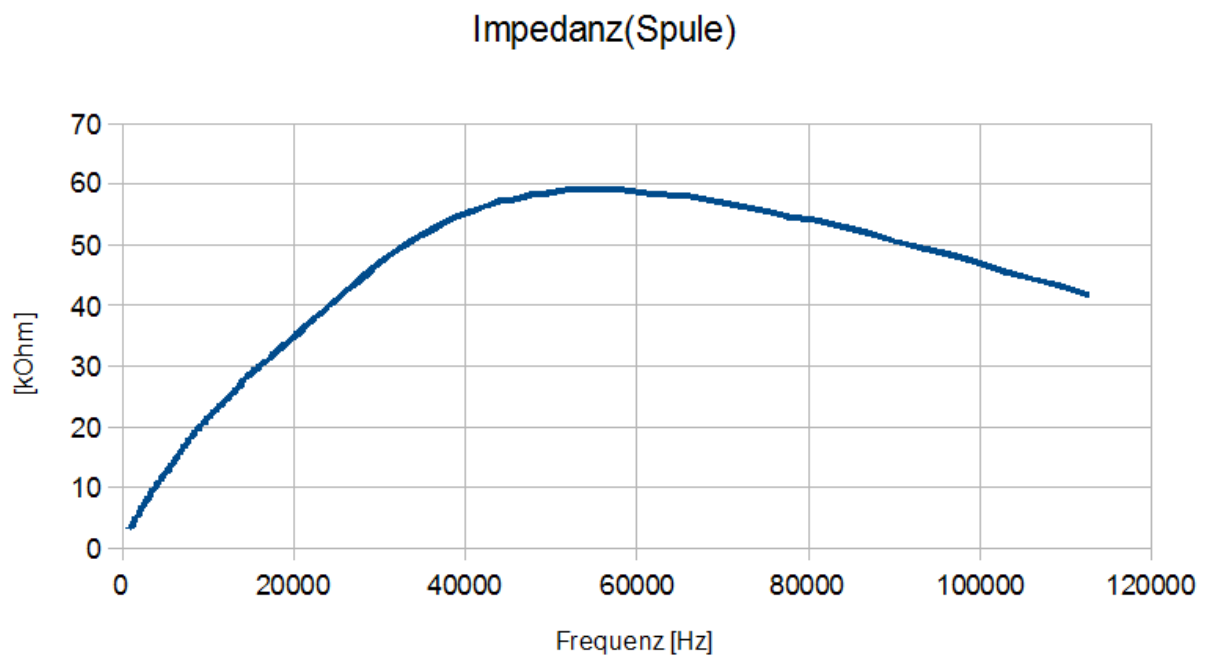
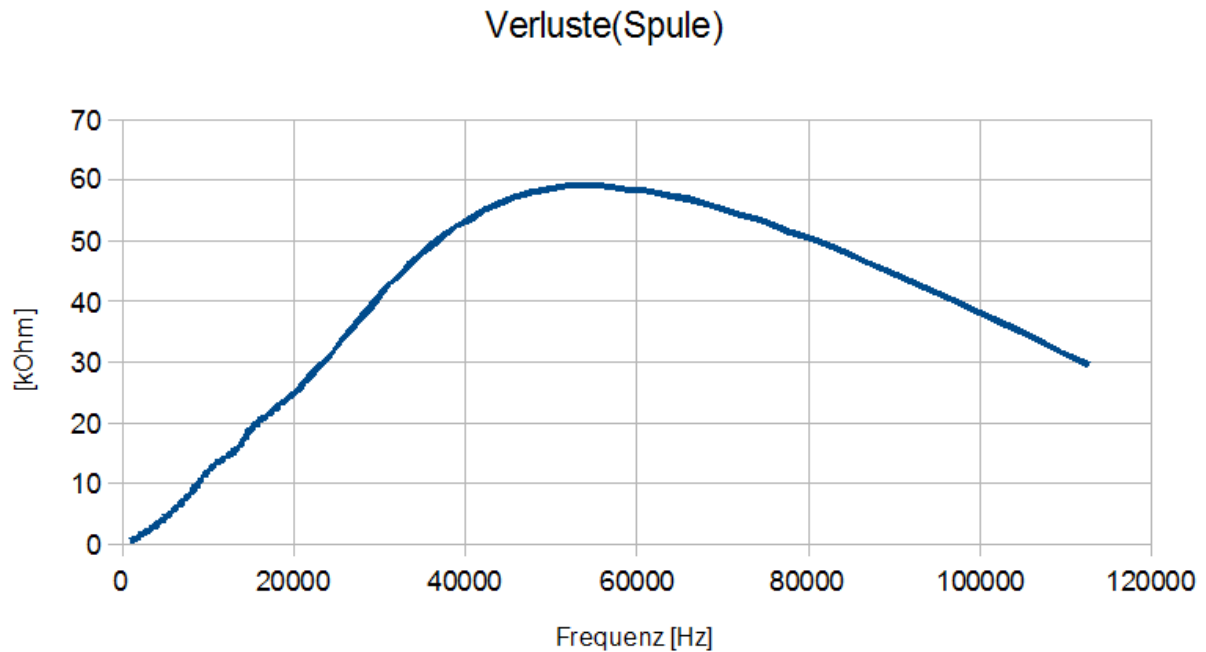
Messgeräte:
HAMEG HM407, FLUKE 73 Multimeter

4a)



A closer look at the real coil of my MM cartridge AT420E OCC

Introduction & Overview

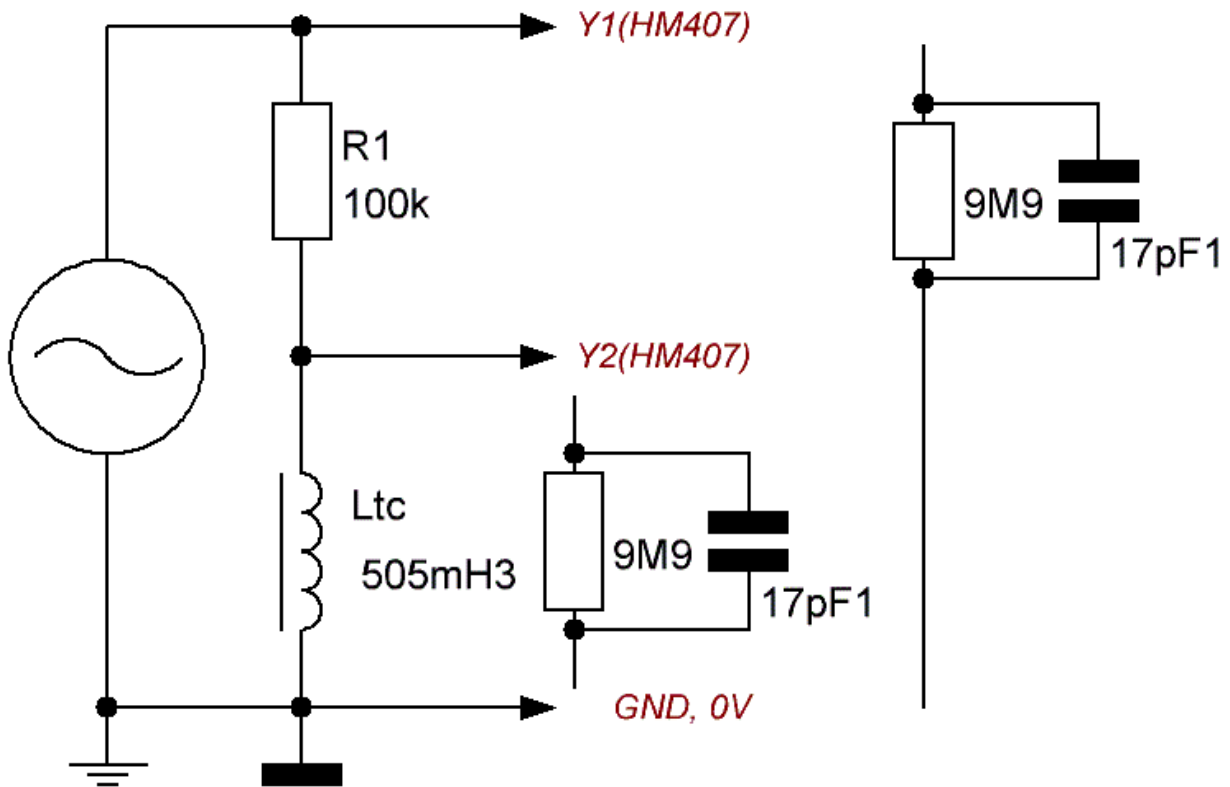


For the sake of clarity, the axes of the graphs are divided linearly. The wire resistance $R_{dc}=386\Omega$ is not included in the losses, expressed as Re' . $|Z|' * e^{j(\alpha)}$ is the pure vector (pointer) of the ideal, but still lossy coil - a frequency-dependent inductance. This is causally related to the laws of induction, electromagnetism. The coil is not ironless. The flux Φ and the flux density B are manipulated.

A closer look at the real coil of my MM cartridge AT420E OCC

4b)

The influence of the measurement setup:

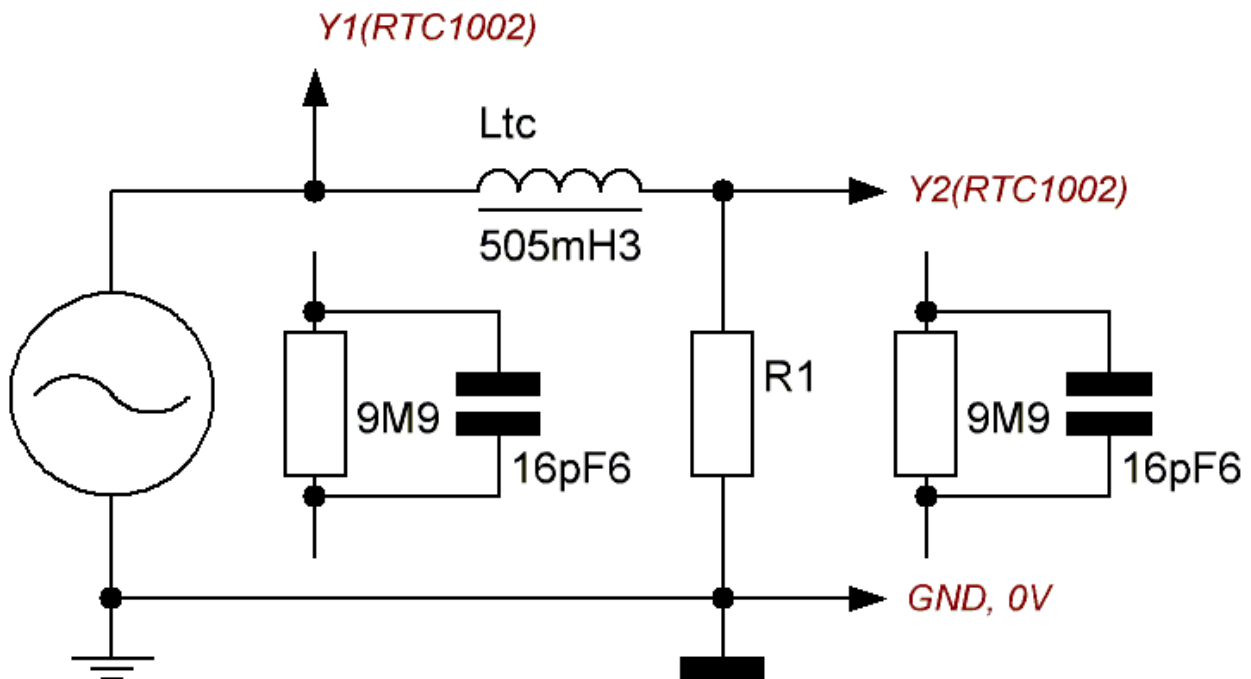


A direct comparison with the first measurements (and determinations) immediately reveals the conspicuous leftward shift of f_{res} . The explanation is obvious. A capacitance-free setup is not possible, especially not with home remedies. In this case, it is the interaction of the probe, the connection terminals, the BNC sockets/plugs, the cables, with the dynamic input resistance of the internal measuring amplifier (and attenuator) of the oscilloscope. This undesirable influence on the existing network (for determining the parameters of the DUT) must be fully compensated for or retroactively eliminated. Even a special recording of the DUT as well as a vector voltmeter or a network analyzer cannot be absolved of external influence; correction calculations must also be carried out here.

The vector (pointer) $|Z| \cdot e^{j(\varphi)}$ contains a global, falsifying C_p of 17pF.

4c)

The influence of the measurement setup:



The above also applies to the first determination method with its measured value recording and different values for $R1$. Although a C in parallel with $R1$ is less invasive here, saturation phenomena of the core must be taken into account with low-resistance $R1$. The resulting current flow may falsify the subsequent calculations. Knowing the maximum induction voltage (of the MM system) and the resulting short-circuit current at the operating point (of an equivalent source model) is a great advantage for the assessment (i.e. classification) of published (or self-made) diagrams.

Equivalent circuit diagrams, whether mechanical or electrical, are almost worthless if they stand alone in a vacuum. Parasitic capacitances are always unavoidable and are representative of all the mistakes that can be made.

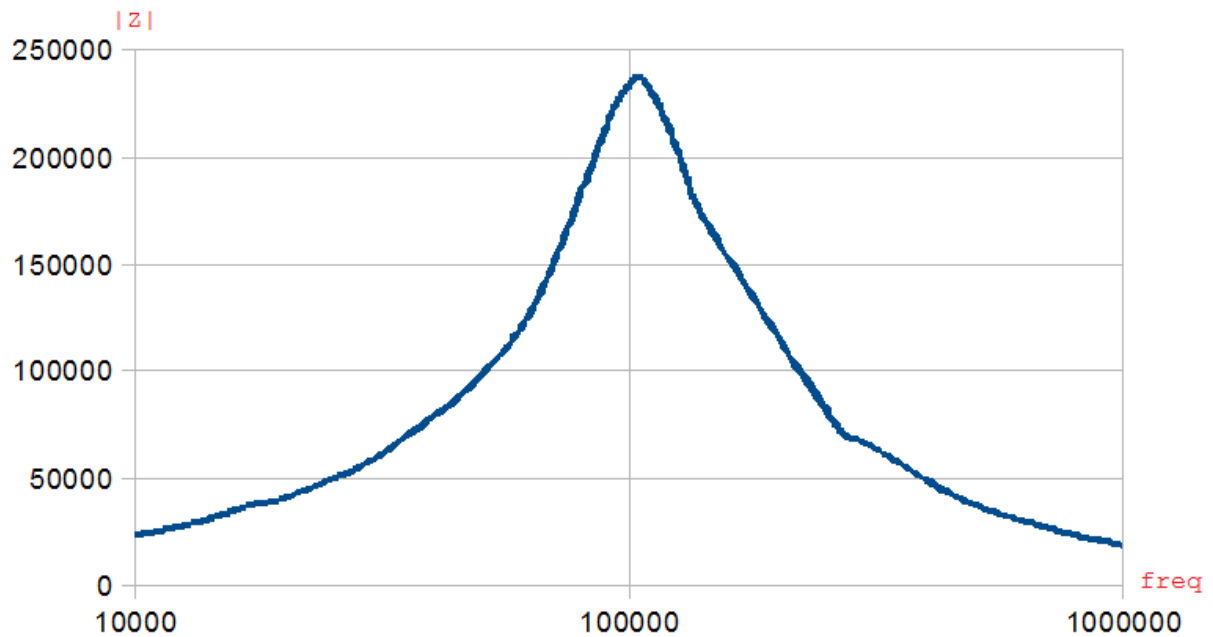
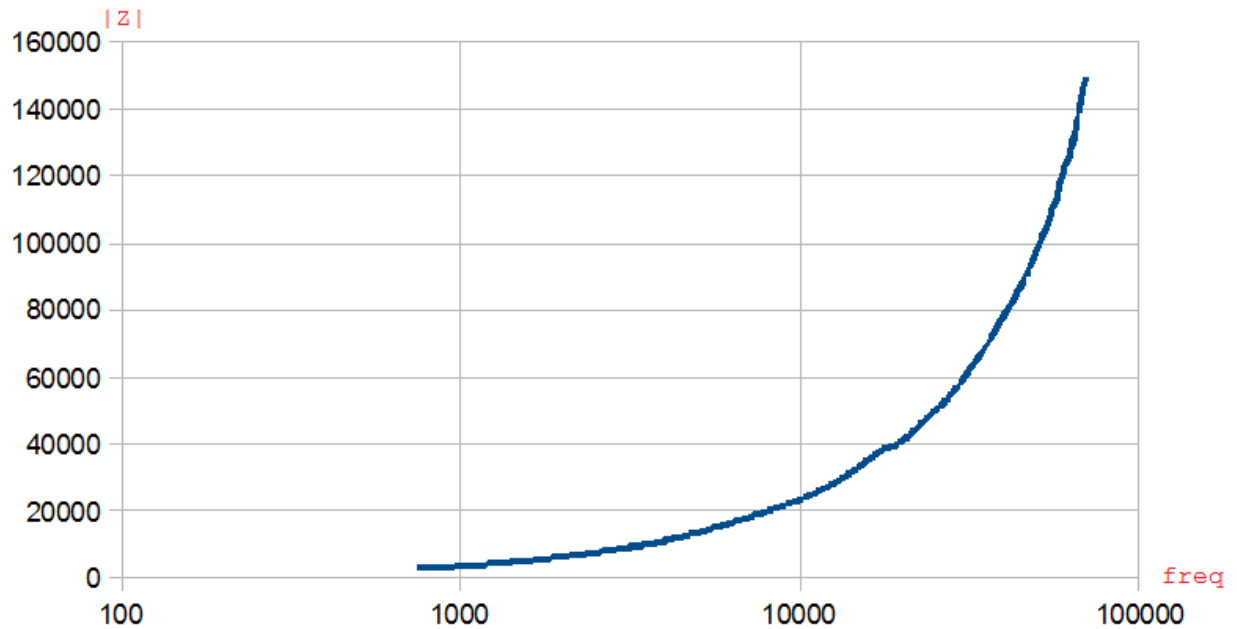
Conclusion:

The determination method and the measuring equipment must always be questioned from a wide variety of directions until a certain level of confidence is finally reached.

Introduction & Overview

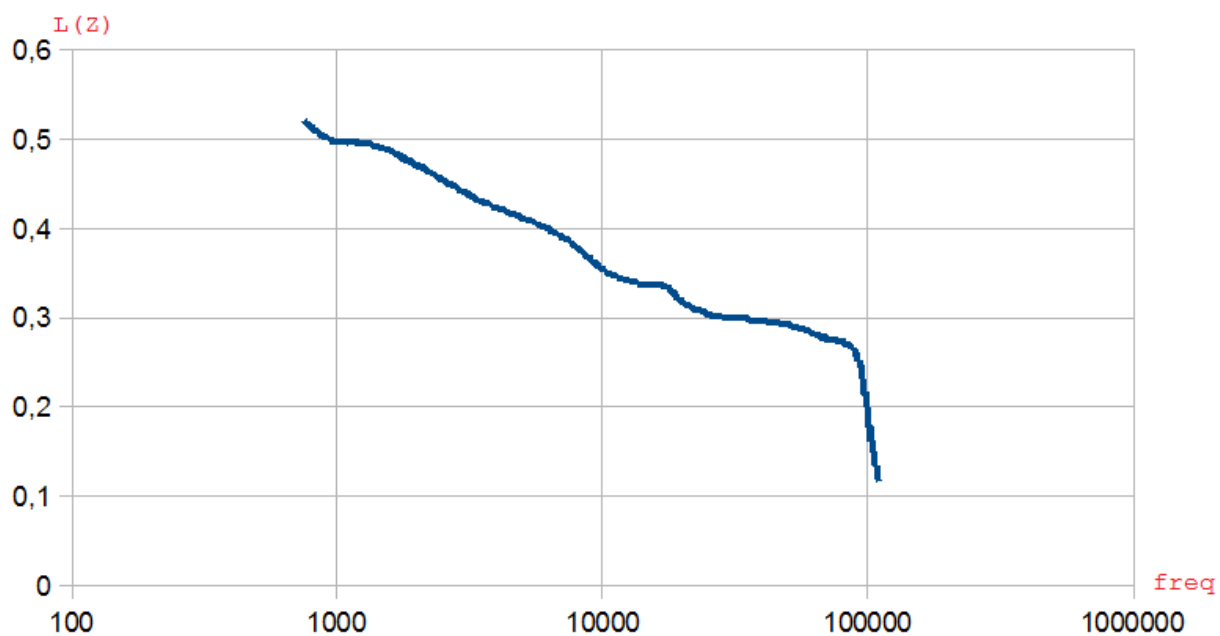
5)

Corrected graphs for the load case with 47k Ω , the influence of the probes was eliminated by a different calculation method:



A closer look at the real coil of my MM cartridge AT420E OCC

Introduction & Overview



A closer look at the real coil of my MM cartridge AT420E OCC

Introduction & Overview

Notes

A closer look at the real coil of my MM cartridge AT420E OCC

Introduction & Overview

Notes

A closer look at the real coil of my MM cartridge AT420E OCC