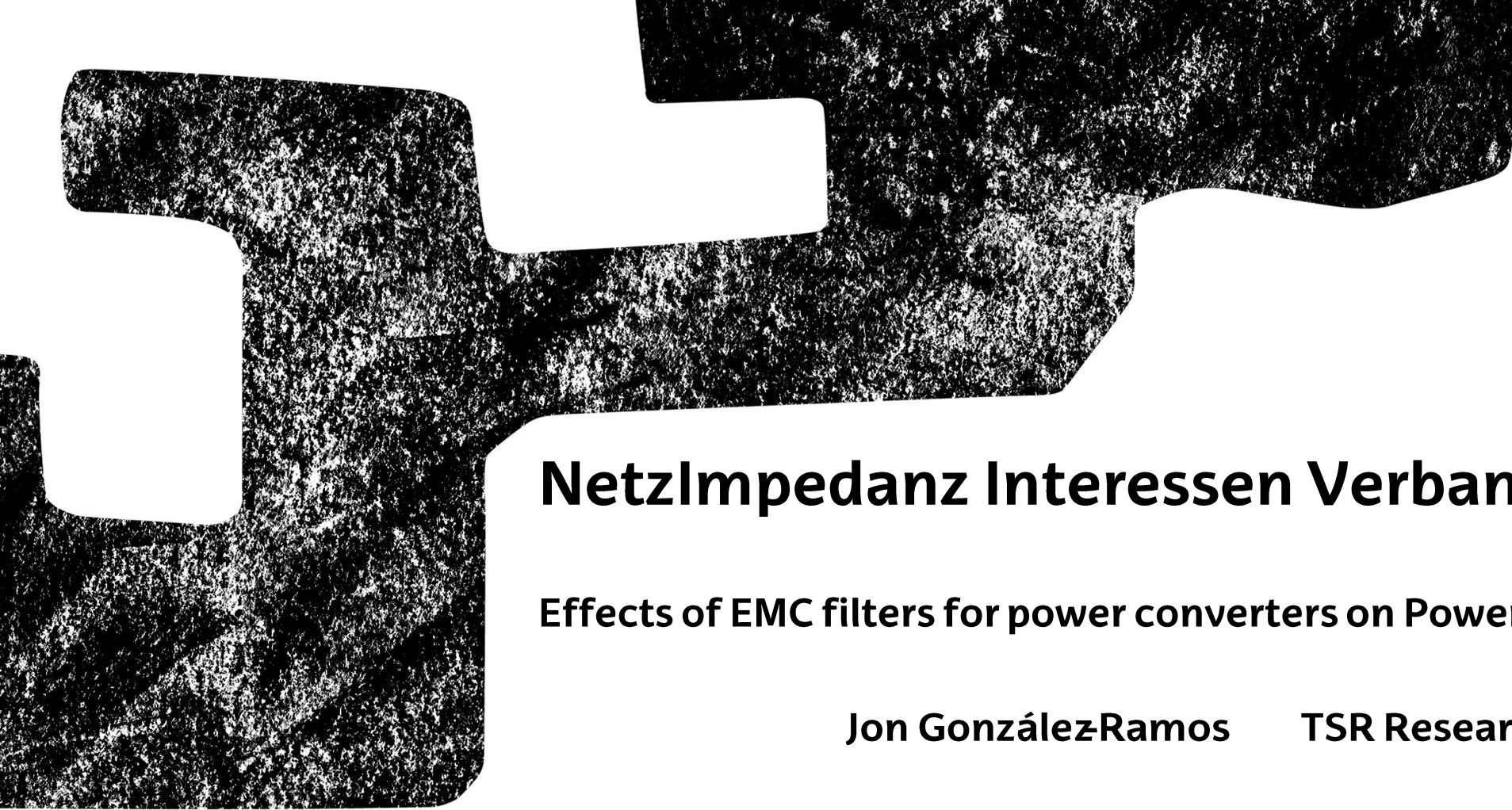




NetzImpedanz Interessen Verband

Effects of EMC filters for power converters on Power Line Communications

Jon GonzálezRamos TSR Research group

25th March 2021



Universidad
del País Vasco

Euskal Herriko
Unibertsitatea

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Table of contents

- Context & Objectives
- Methodology & Measurement setup
- Results
- Conclusions

Context & Objectives

Power Converters

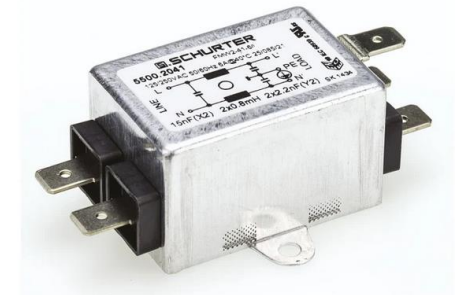
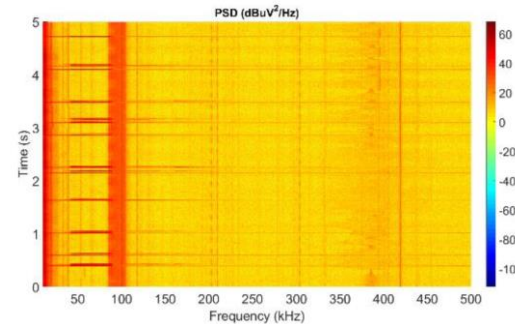
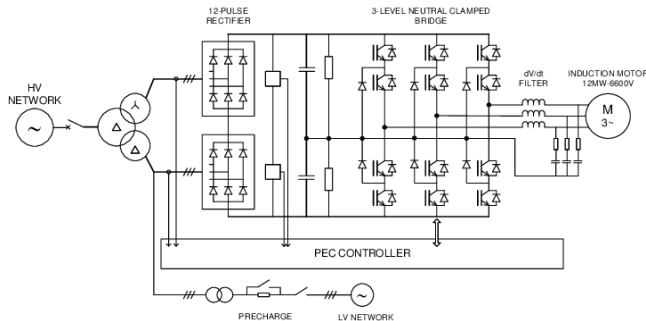
imply

Electromagnetic interference

- Differential-mode noise of hundreds of kHz

solution

Passive filters



- ❑ ... but **passive EMC filters** imply undesired effects on NB-PLC
 - ✓ Notching effects due to parallel and/or series resonances

Analysis of the potential influence of EMC filters on NB-PLC signals

Measurement setup & Methodology



f(kHz) 42 89 97 144 151 198 206 253 261 308 315 362 370 417 424 471

Measurement setup & Methodology

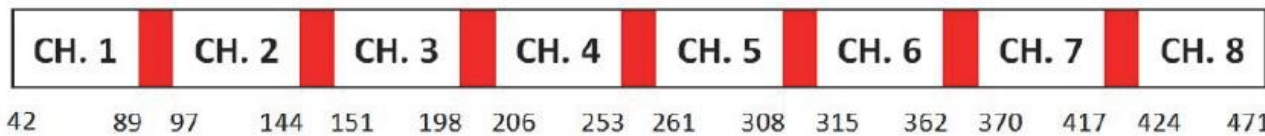
- Two different parameters calculated:



f(kHz) 42 89 97 144 151 198 206 253 261 308 315 362 370 417 424 471

Measurement setup & Methodology

- Two different parameters calculated:
 - ✓ Signal attenuation due to EMC filters



Measurement setup & Methodology

- Two different parameters calculated:
 - ✓ Signal attenuation due to EMC filters
 - ✓ Frame Error Rate (FER) vs Signal to Noise Ratio (SNR) curves



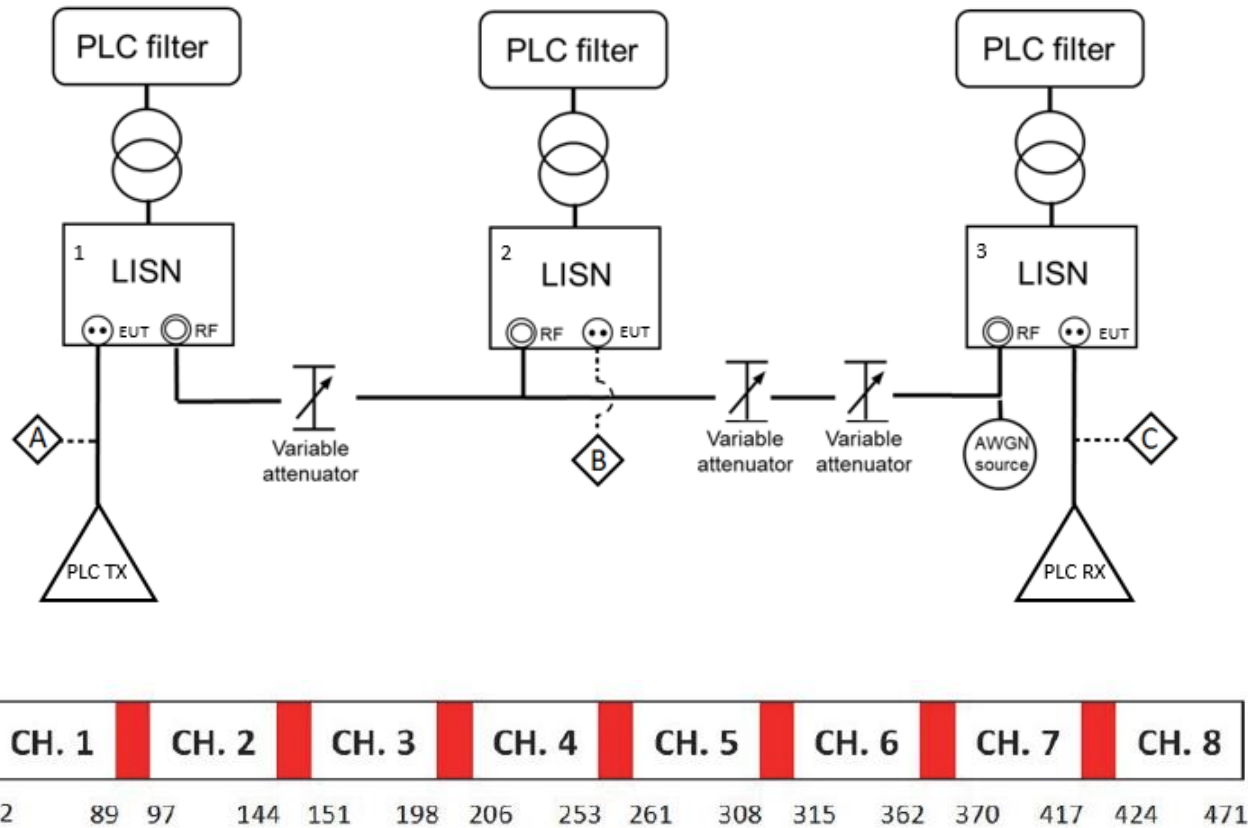
Measurement setup & Methodology

- Two different parameters calculated:
 - ✓ Signal attenuation due to EMC filters
 - ✓ Frame Error Rate (FER) vs Signal to Noise Ratio (SNR) curves
 - SNR threshold for a FER of 5%



f(kHz) 42 89 97 144 151 198 206 253 261 308 315 362 370 417 424 471

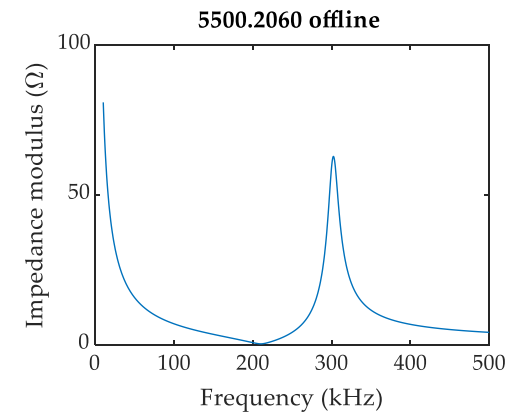
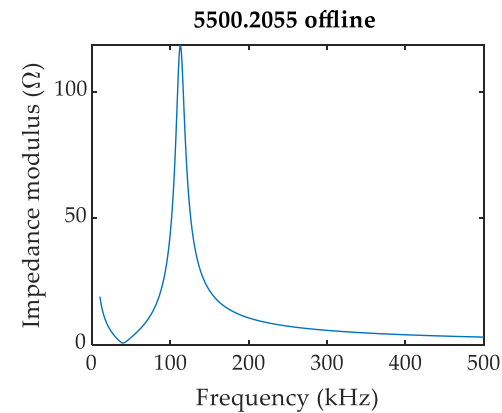
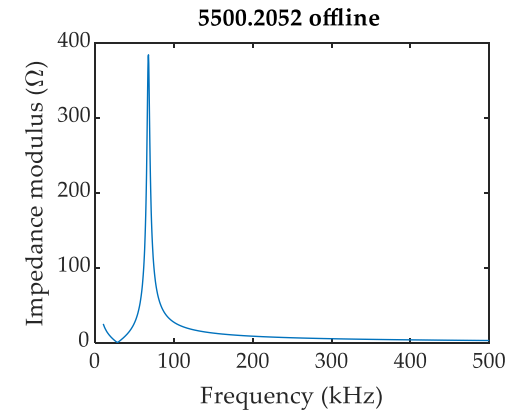
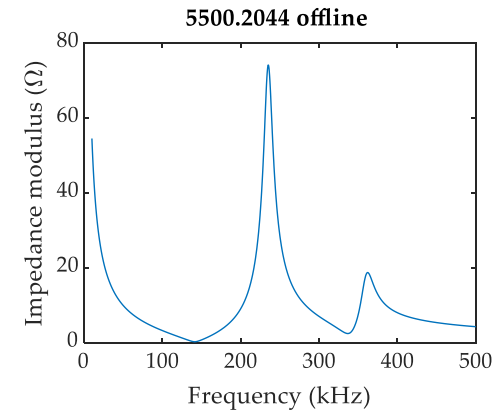
Measurement setup & Methodology



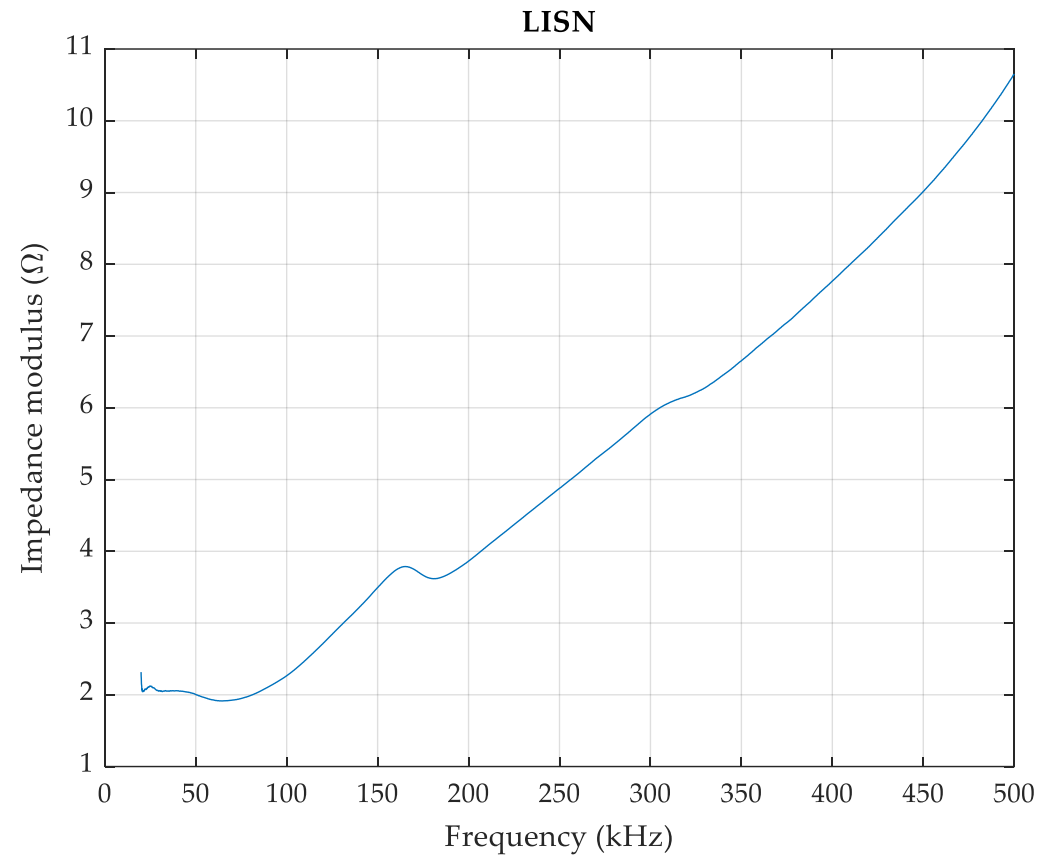
- Two different parameters calculated:
 - ✓ Signal attenuation due to EMC filters
 - ✓ Frame Error Rate (FER) vs Signal to Noise Ratio (SNR) curves
 - SNR threshold for a FER of 5%

Results. Impedance measurements

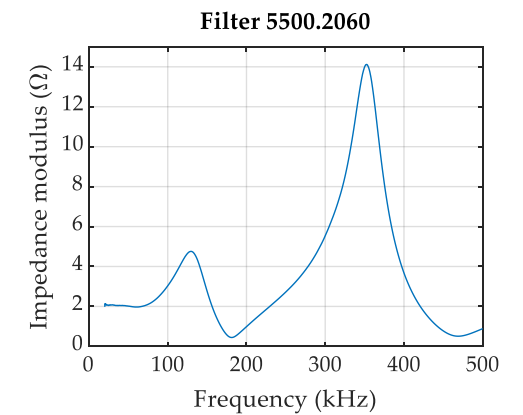
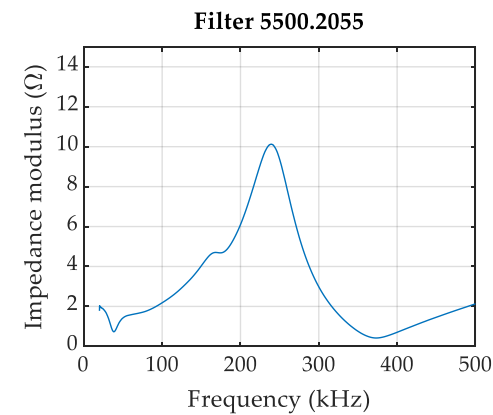
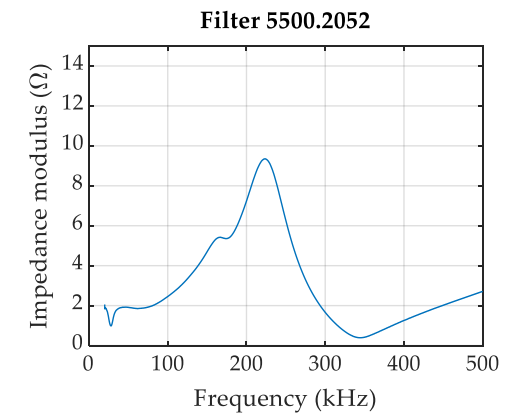
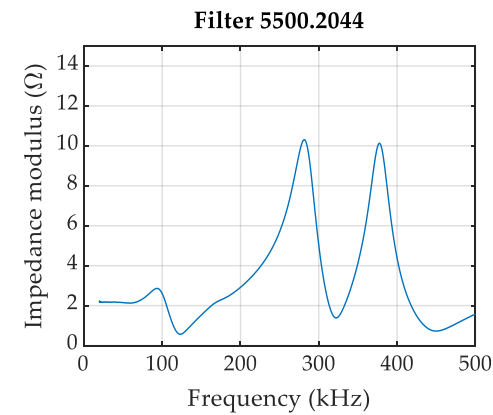
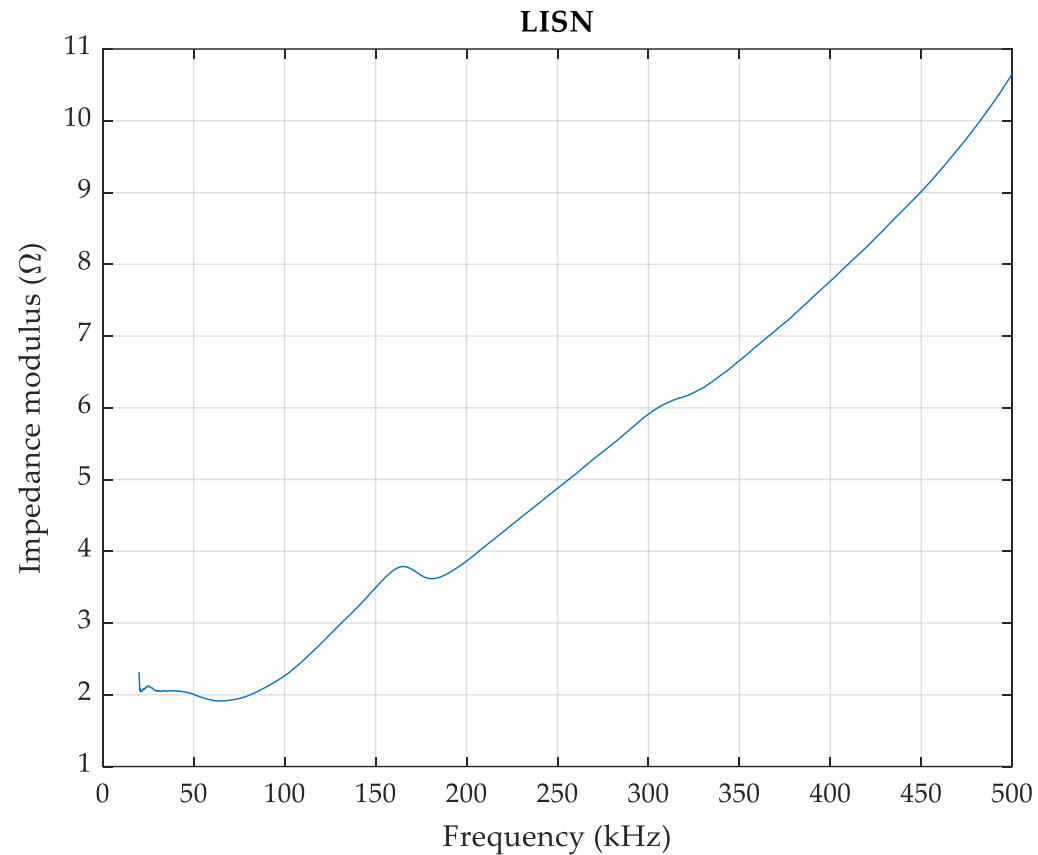
EMC filters show a wide range of impedance values along the PLC frequency band



Results. Impedance measurements



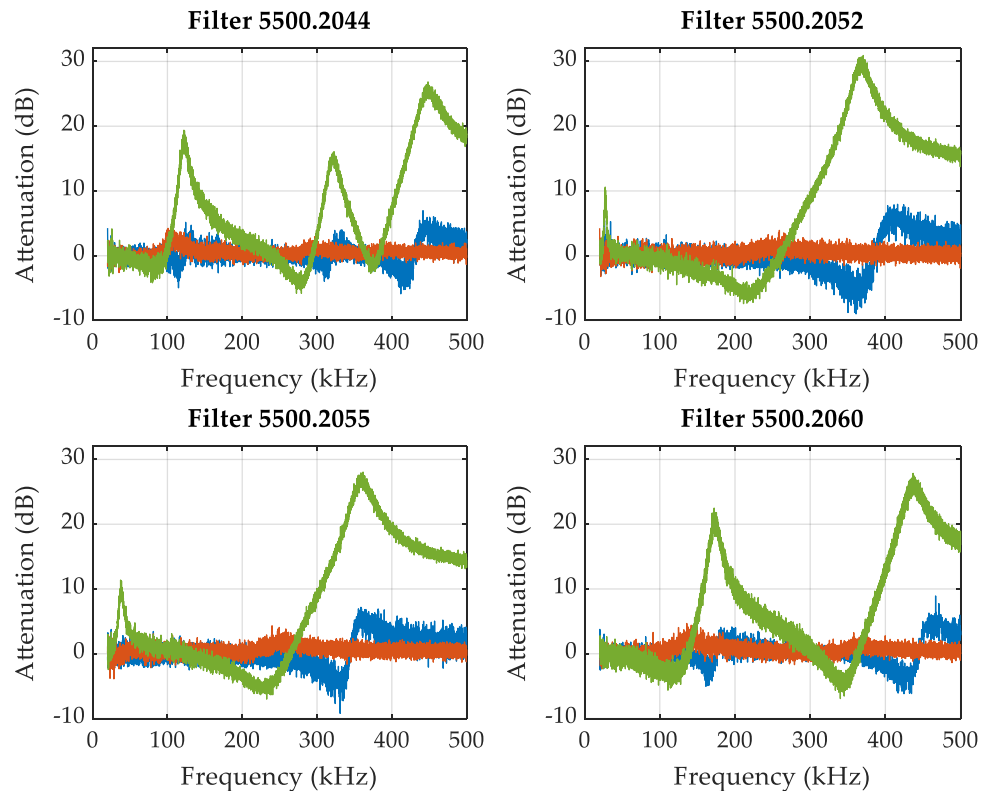
Results. Impedance measurements



Results. Attenuation due to EMC filters

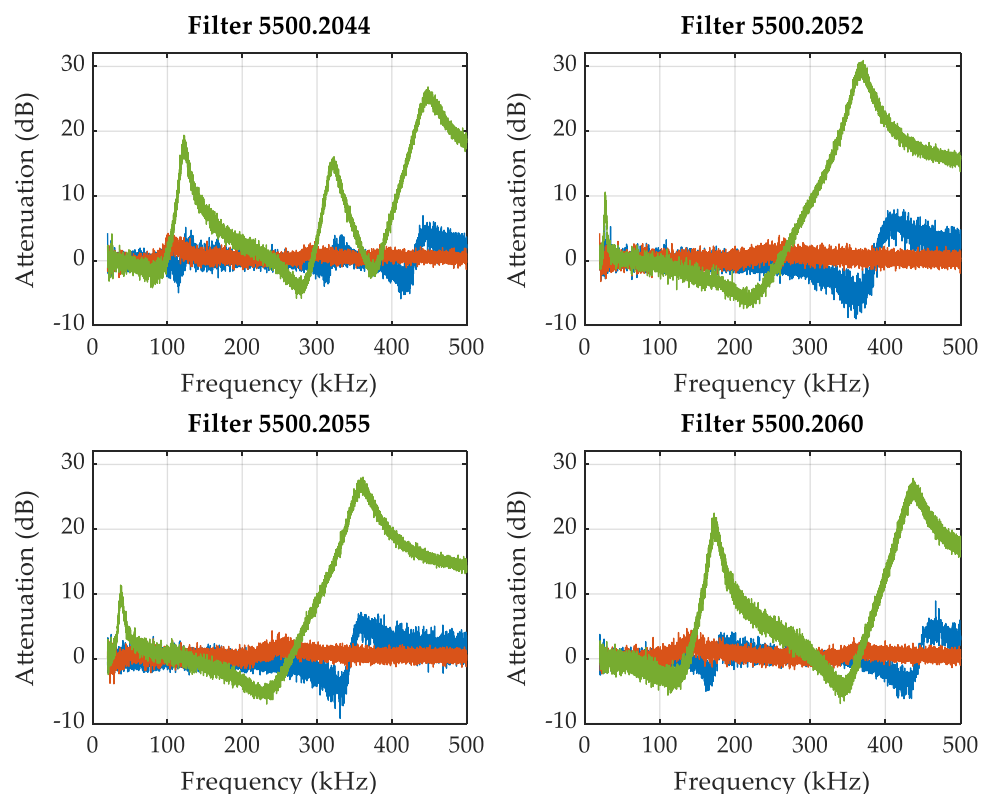
Blue line: EMC filter connected at A
Red line: EMC filter connected at B
Green line: EMC filter connected at C

- Very low attenuation when connecting filters at A and B



Results. Attenuation due to EMC filters

Blue line: EMC filter connected at A
Red line: EMC filter connected at B
Green line: EMC filter connected at C



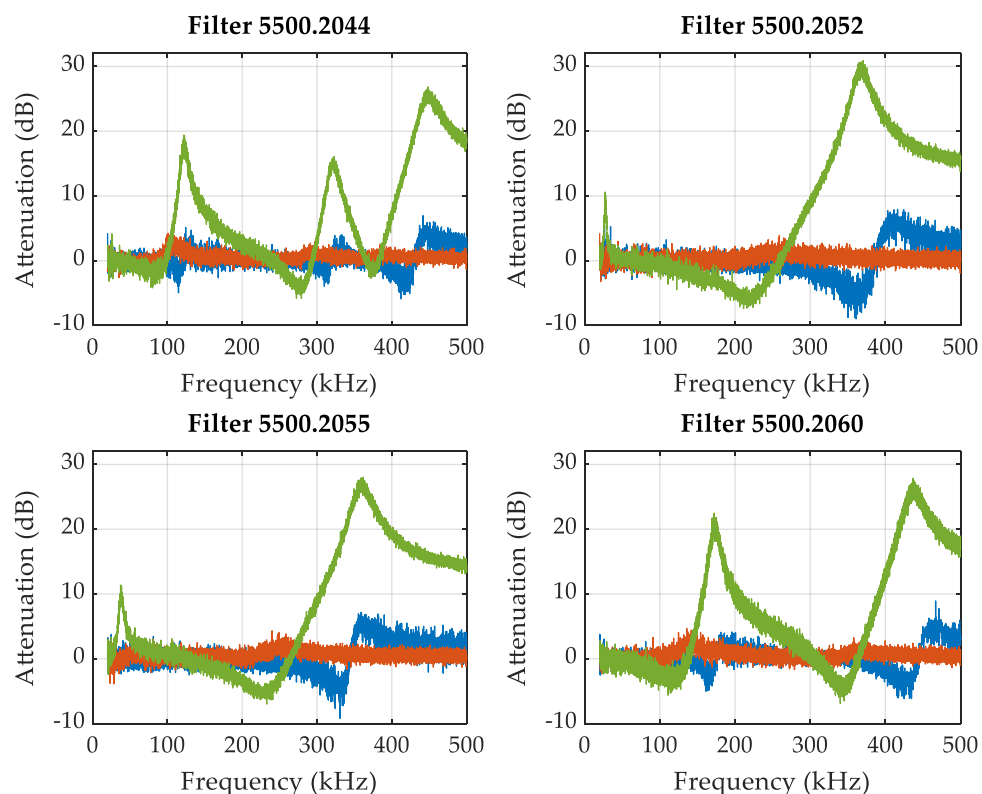
- Very low attenuation when connecting filters at A and B

		Attenuation of 5500.2044 (dB)		Attenuation of 5500.2052 (dB)		Attenuation of 5500.2055 (dB)		Attenuation of 5500.2060 (dB)	
Channel		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
CH 1		-1.11	0.85	0.14	0.65	2.34	1.45	-0.78	1.03
CH 3		4.81	1.49	-3.30	0.85	-1.99	0.86	15.23	4.16
CH 4		0.77	1.23	-4.38	1.46	-4.49	0.84	6.66	1.55
CH 5		-0.24	3.65	6.05	3.13	5.62	3.48	2.23	1.47
CH 6		9.76	4.65	20.91	4.99	21.42	4.78	-2.92	1.10
CH 7		6.22	5.25	24.20	3.04	20.76	2.21	11.84	5.22
CH 8		23.04	2.33	17.35	0.92	15.76	0.72	23.57	2.06

Attenuation when connecting filters at C

Results. Attenuation due to EMC filters

Blue line: EMC filter connected at A
Red line: EMC filter connected at B
Green line: EMC filter connected at C



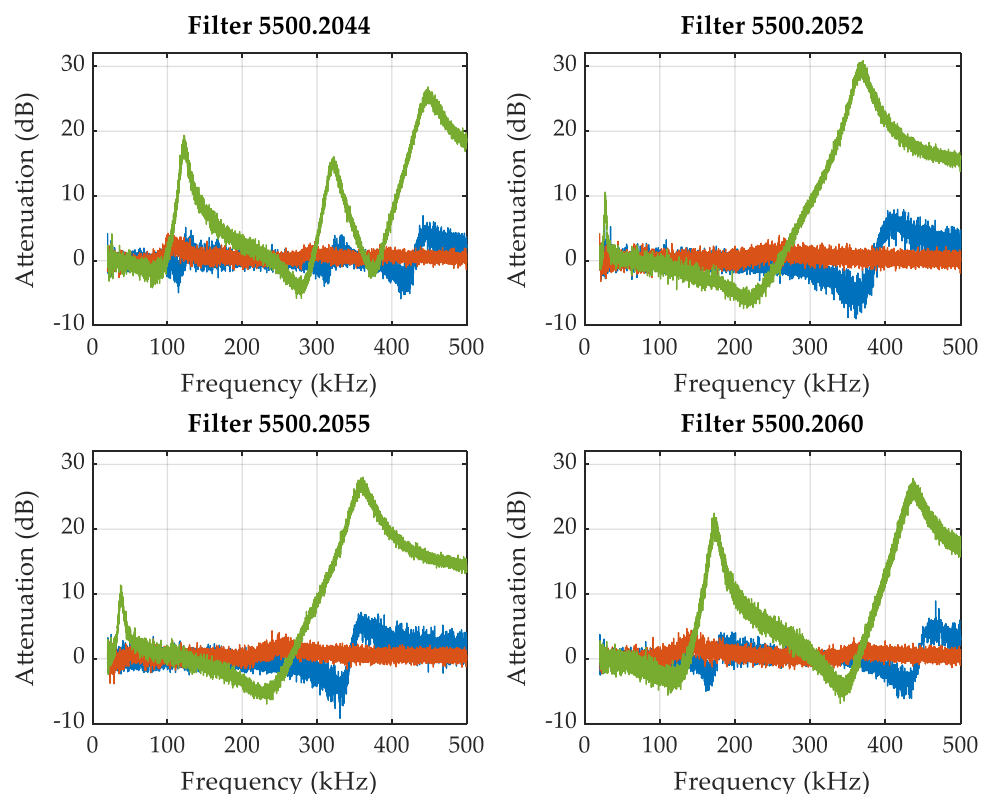
- Very low attenuation when connecting filters at A and B
- High attenuation at some frequencies when connecting filters at C

	Attenuation of 5500.2044 (dB)		Attenuation of 5500.2052 (dB)		Attenuation of 5500.2055 (dB)		Attenuation of 5500.2060 (dB)	
Channel	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
CH 1	-1.11	0.85	0.14	0.65	2.34	1.45	-0.78	1.03
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Attenuation when connecting filters at C

Results. Attenuation due to EMC filters

Blue line: EMC filter connected at A
Red line: EMC filter connected at B
Green line: EMC filter connected at C

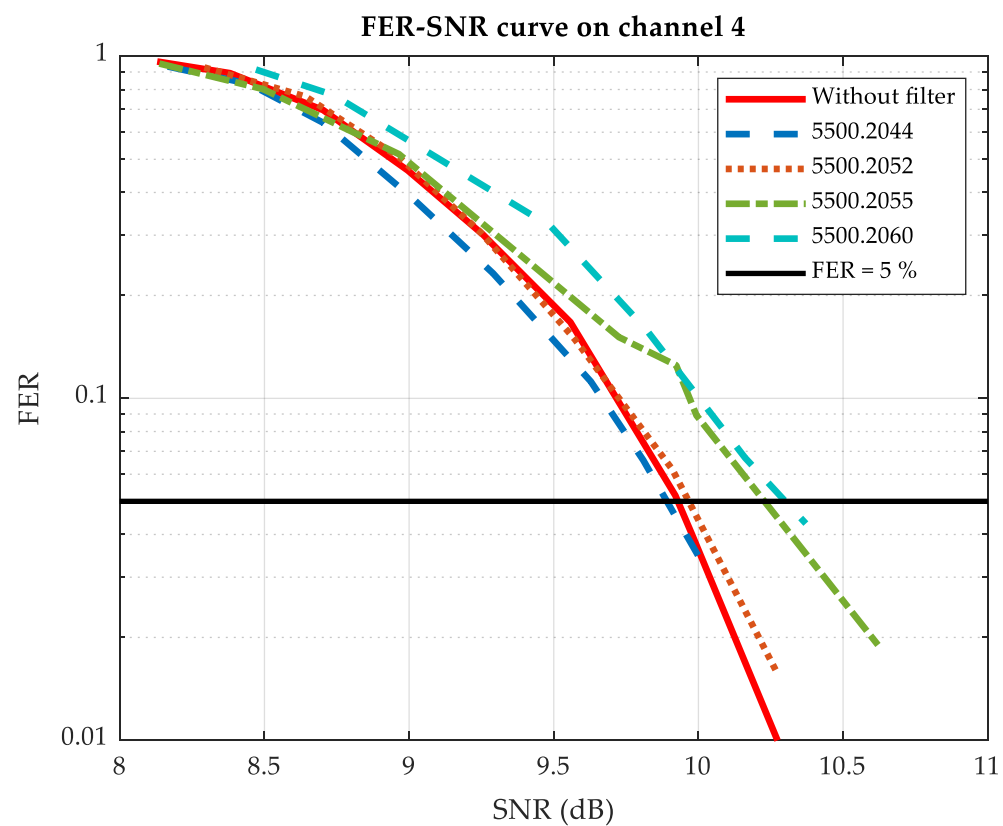


- Very low attenuation when connecting filters at A and B
- High attenuation at some frequencies when connecting filters at C
- Parallel/series resonances → Negative attenuation

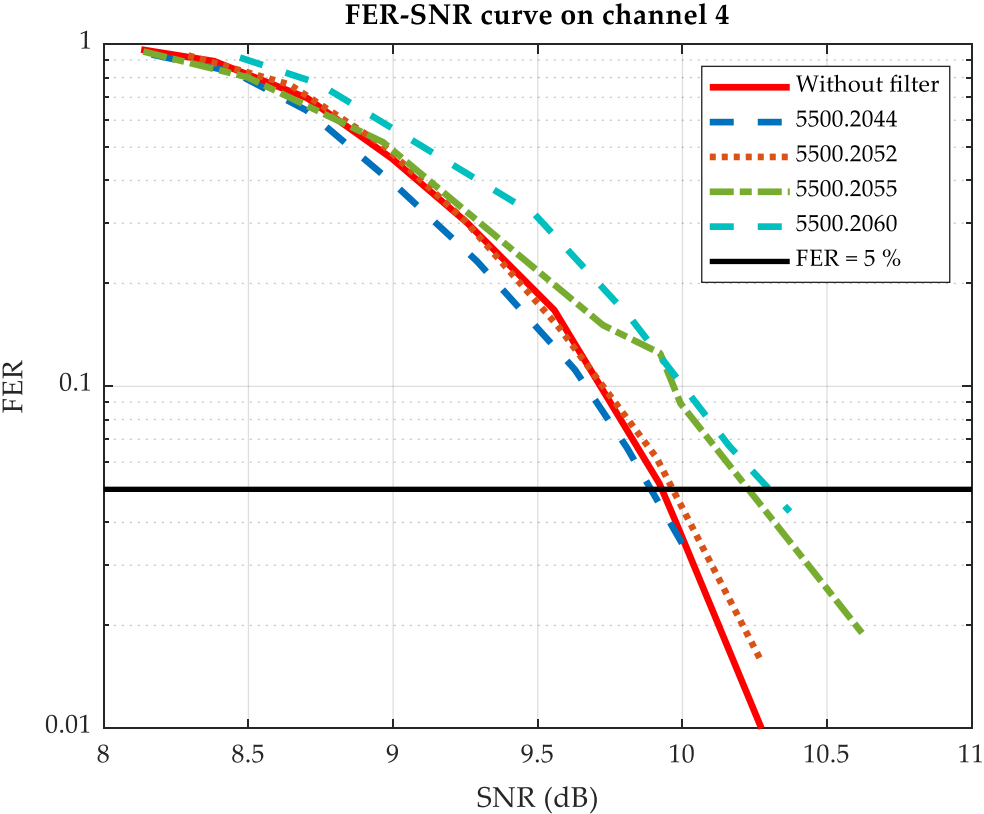
	Attenuation of 5500.2044 (dB)		Attenuation of 5500.2052 (dB)		Attenuation of 5500.2055 (dB)		Attenuation of 5500.2060 (dB)	
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CH 8	23.04	2.33	17.35	0.92	15.76	0.72	23.57	2.06

Attenuation when connecting filters at C

Results. FER-SNR curves

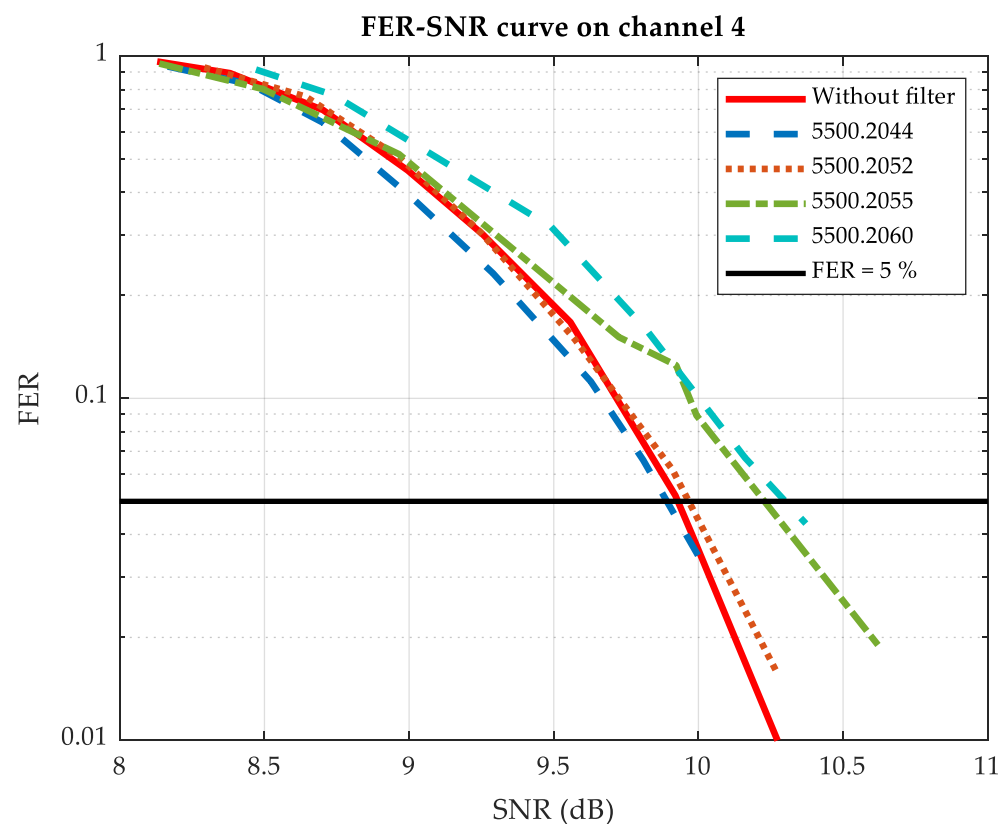


Results. FER-SNR curves



SNR (dB) for FER = 5 %					
Channel	Without filter	5500.2044	5500.2052	5500.2055	5500.2060
CH 1	11.0	10.9	10.9	10.6	10.9
CH 3	10.5	10.5	10.5	11.1	10.6
CH 4	9.9	9.9	10.0	10.3	10.3
CH 5	10.2	9.8	9.8	9.9	10.2
CH 6	10.5	10.5	10.7	10.3	10.8
CH 7	10.0	9.7	10.1	9.8	9.5
CH 8	11.0	11.4	11.1	10.5	10.4

Results. FER-SNR curves



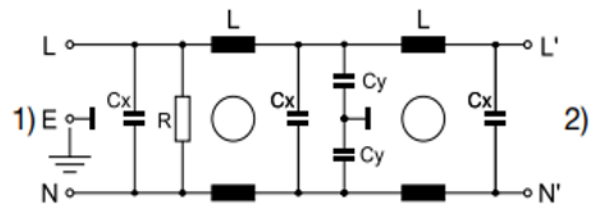
Similar thresholds in the absence of a filter and when the EMC filters are connected

Channel	SNR (dB) for FER = 5 %				
	Without filter	5500.2044	5500.2052	5500.2055	5500.2060
CH 1	11.0	10.9	10.9	10.6	10.9
CH 3	10.5	10.5	10.5	11.1	10.6
CH 4	9.9	9.9	10.0	10.3	10.3
CH 5	10.2	9.8	9.8	9.9	10.2
CH 6	10.5	10.5	10.7	10.3	10.8
CH 7	10.0	9.7	10.1	9.8	9.5
CH 8	11.0	11.4	11.1	10.5	10.4

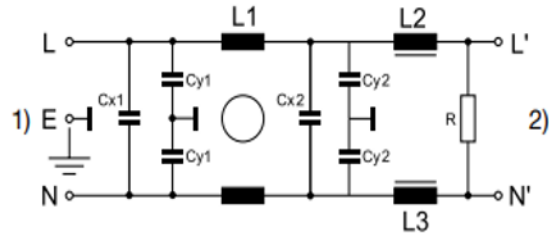
Maximum difference: 0.6 dB

Results. Filters reversed

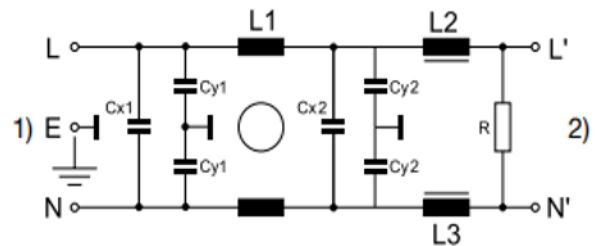
5500.2044



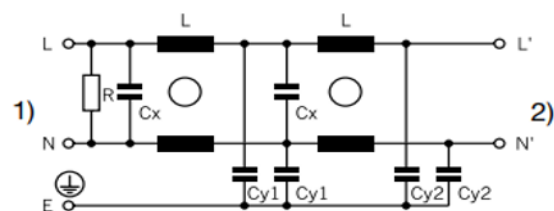
5500.2052



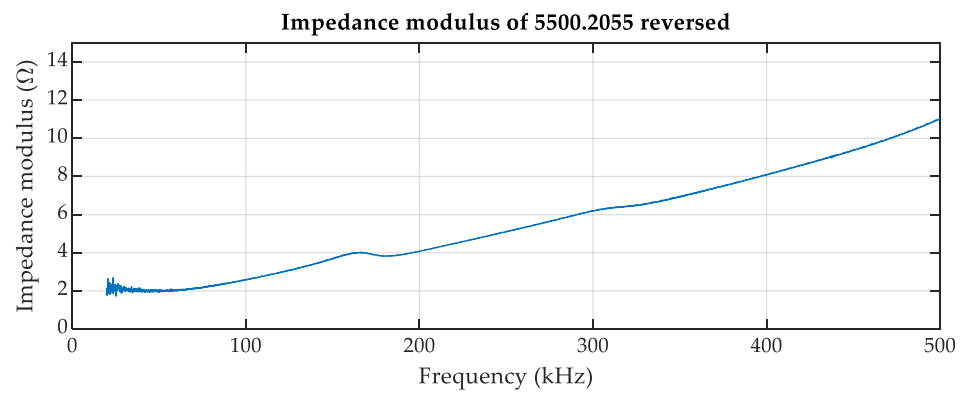
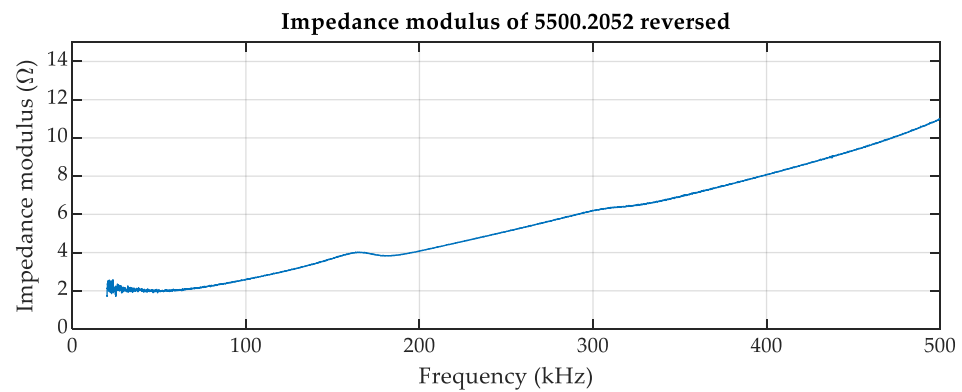
5500.2055



5500.2060

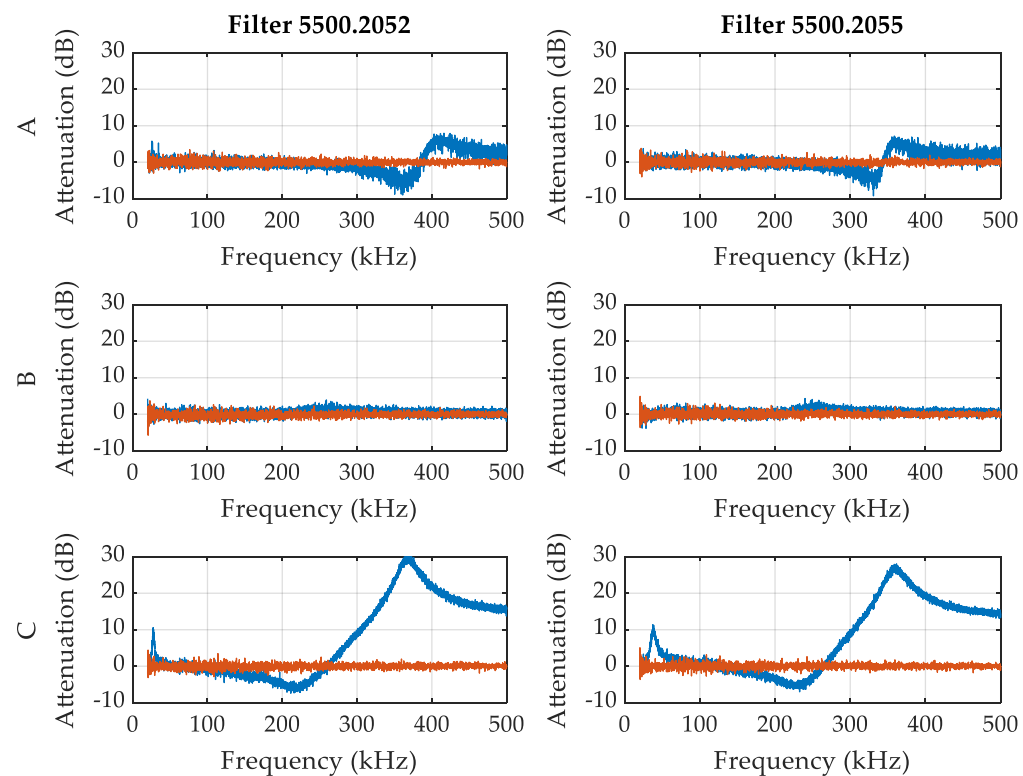
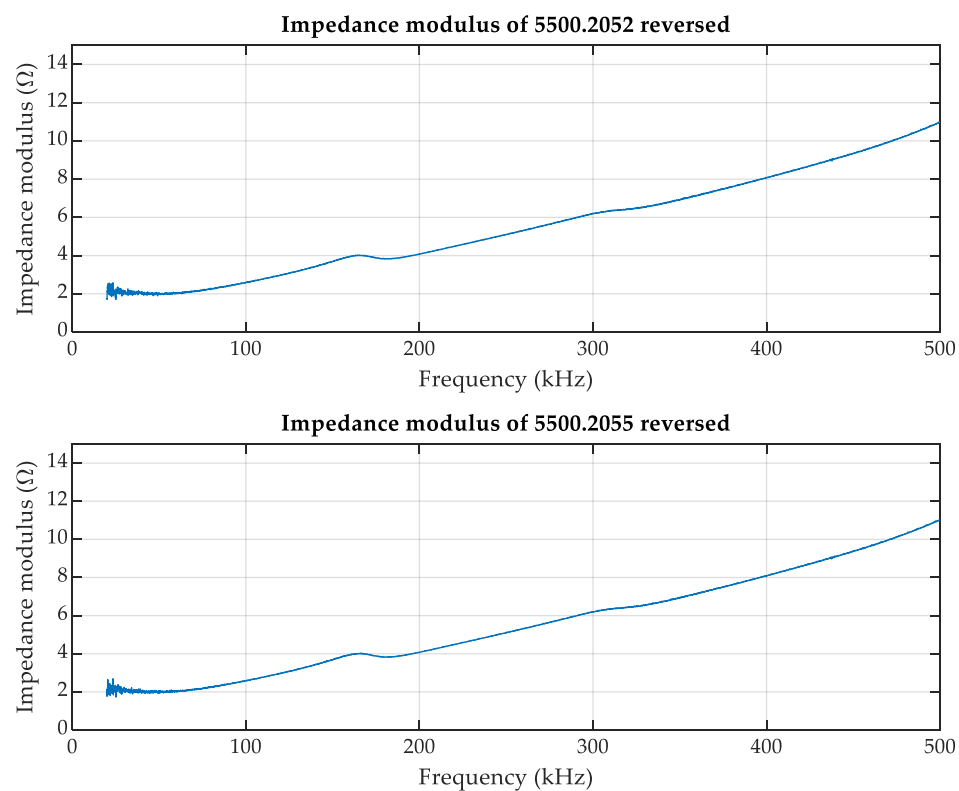


Results. Filters reversed



Results. Filters reversed

Blue line: EMC filter connected
Red line: EMC filter connected reversed





Conclusions

- Potential effects of EMC filters on NB-PLC were analyzed
- EMC filters:
 - ✓ Introduce impedance variations
 - ✓ Introduce high attenuation when connected near the receiver
 - Due to the capacitive interface of the filters with the grid
 - Might cause communications to fail
 - ✓ Do not introduce abrupt variations in the channel characteristics → SNR thresholds not affected