

Simulation of Conducted Emissions from Transport Power Electronics

Design evaluation and improvement guided by
simulation

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Agenda

- Overview
- Circuit topology
- Model parts
- Test set-up
- Test vs simulation
- Layout change
- Original versus re-layout comparison
- Conclusions
- Questions



OUR MISSION

Invent and scale breakthrough technologies to optimize how humanity uses energy

Turntide Transport

Vehicle Electrification

Turntide provides electrification and powertrain components that electrify fleets faster, with less risk, and higher performance safety.



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From mini excavators to forklifts, we offer simple drop-in solutions to help you get an EV to market quickly and easily.



Agriculture

We'll deliver the intelligence, efficiency, and controls you need to build industry-leading vehicles, from tractors to combines, for years to come.



Material Handling

We offer electrification solutions to help warehouses and distribution centers increase the productivity of their autonomous mobile robots (AMRs) and automatic guided vehicles (AGVs) by minimizing downtime and taking advantage of opportunity charging.



Performance Sports Cars

We offer proven high-performance electrification components and solutions to de-risk your vehicle electrification programs.



Trucks / Buses

We offer a range of highly reliable electrification solutions, from high-power electric traction drives to low-power pumps fans and hotel loads, to help you deliver your emissions targets.



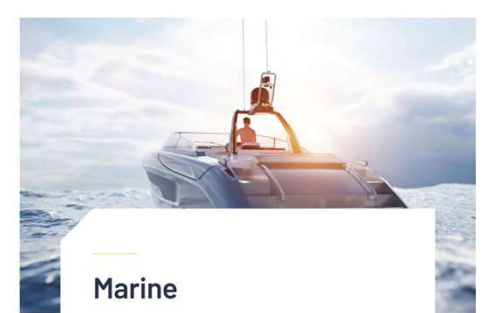
Light passenger vehicles 2,3,4 wheelers

Our electrification solutions for two, three, and four wheel light passenger vehicles ensure quality, reliability, and efficiency.



Rail

We provide high-performance electrification components for rail solutions to provide a path to carbon reduction.



Marine

We've helped world-class manufacturers electrify their marine vehicles.

Overview

Switch mode power supply simulation (SMPS)

Conducted emissions from a 'bad' SMPS based on a topology used in an automotive inverter were simulated, including parasitic effects of the PCB and components.

Comparison of original against measurement

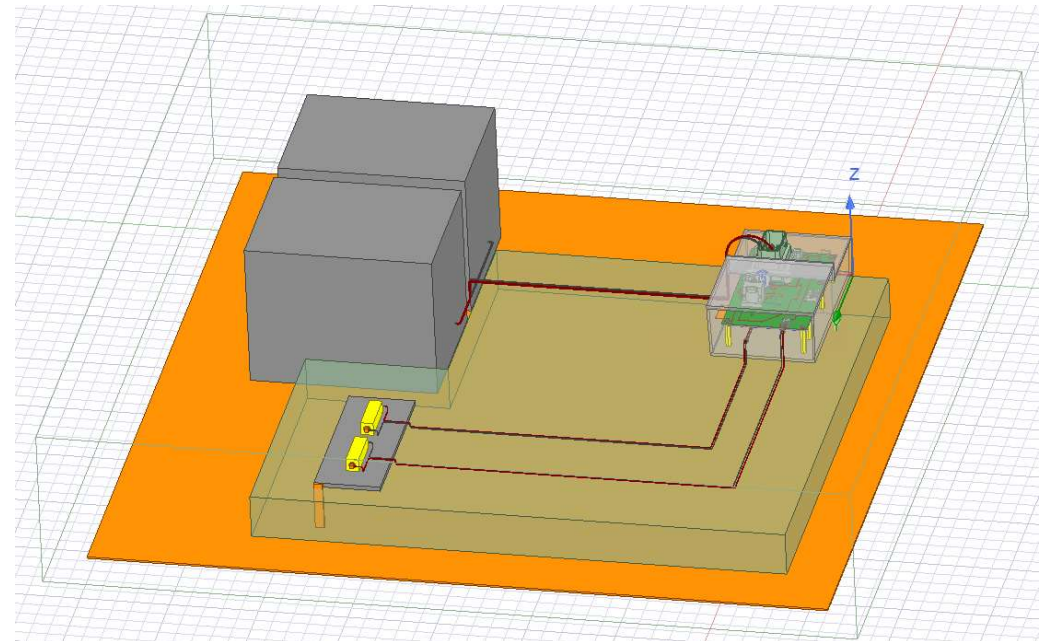
A physical equivalent was built and tested. Simulation and experiment were compared.

Trial of improvements in simulation

The model was used to trial a PCB layout change.

Comparison of improved design against measurement

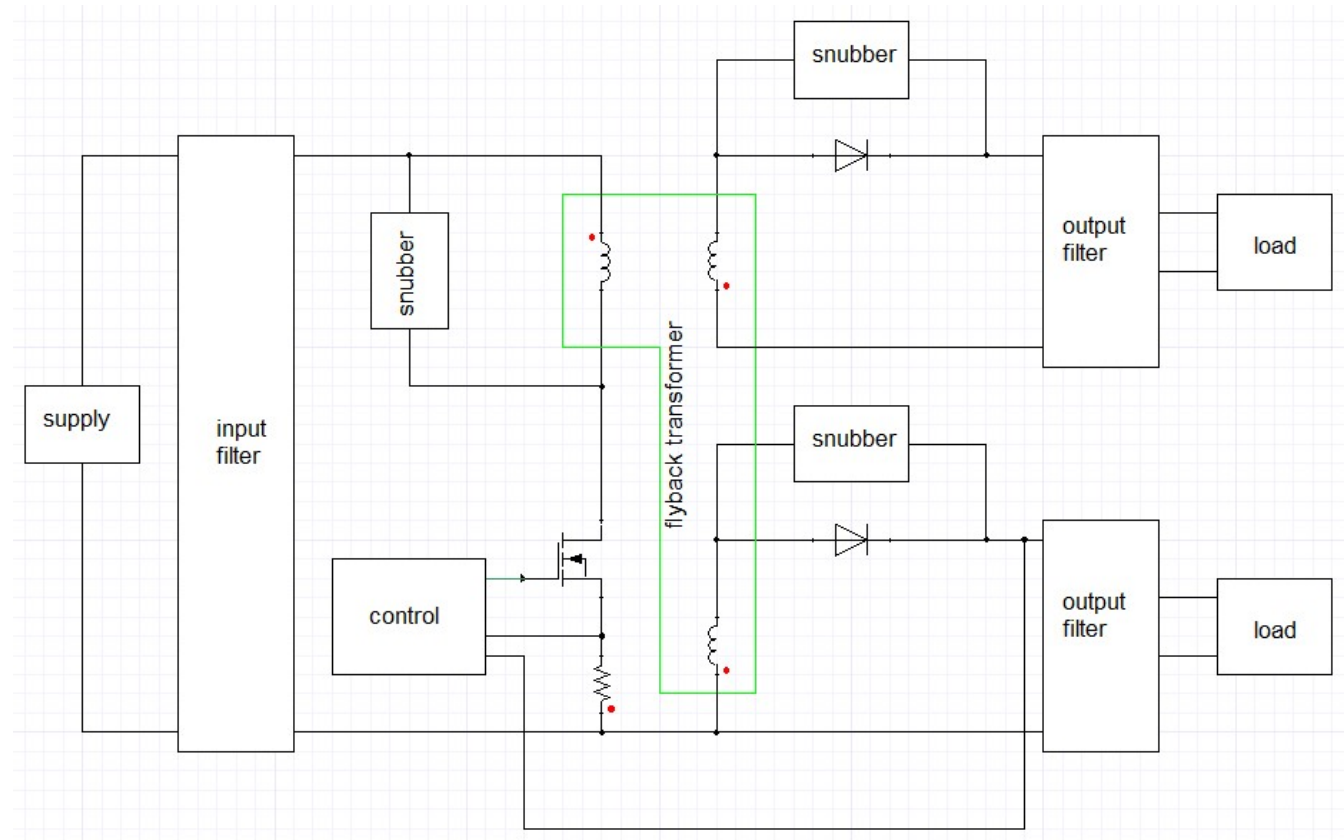
The improved design was built and tested. Simulation and experiment were compared.



Circuit topology

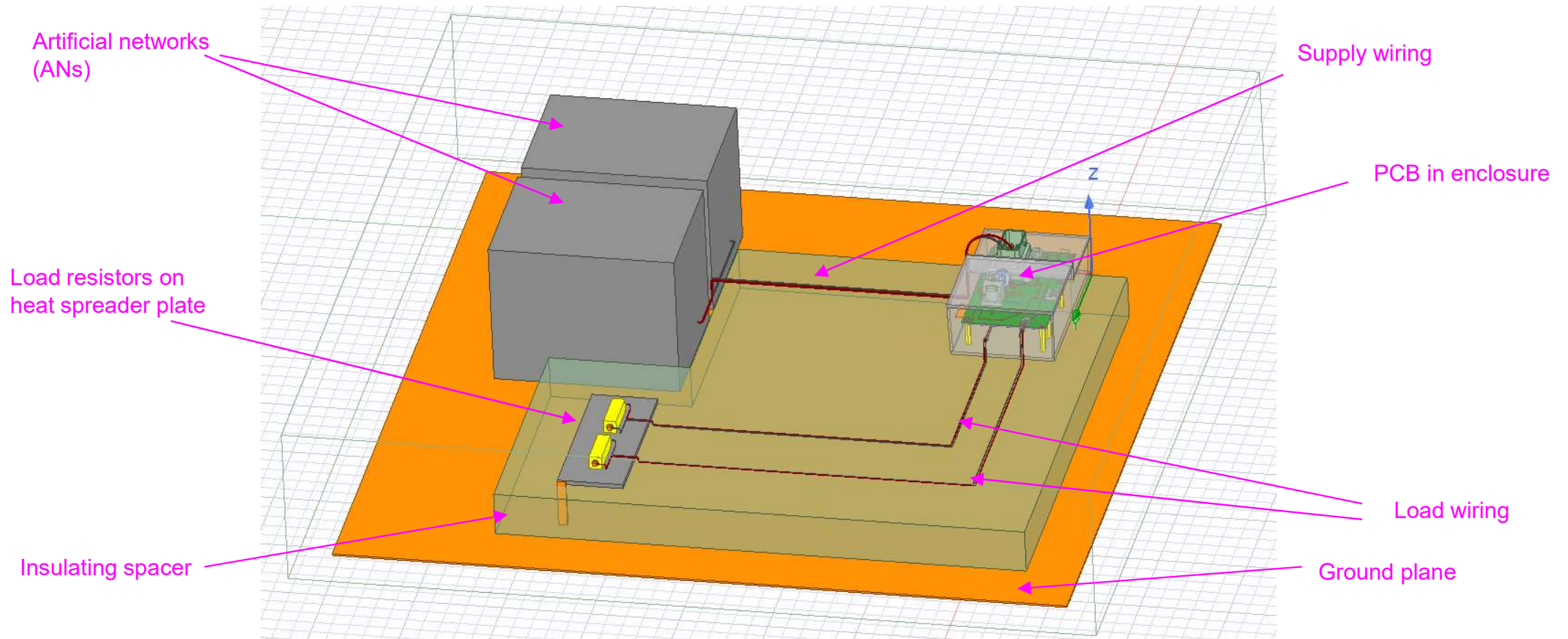
Flyback converter

- Low voltage vehicle battery input
- One isolated, one non-isolated output
- ~15W output total



Complete model

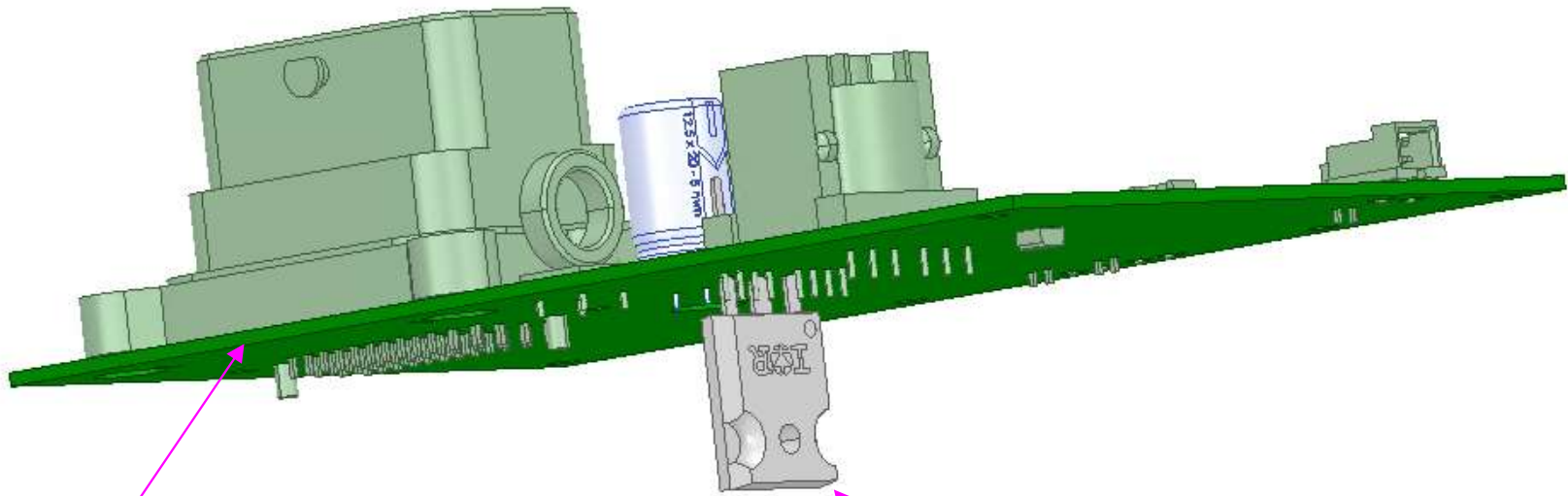
The complete model included a CISPR 25 conducted emissions set up.



PCB model

PCB exported from PCB layout software.

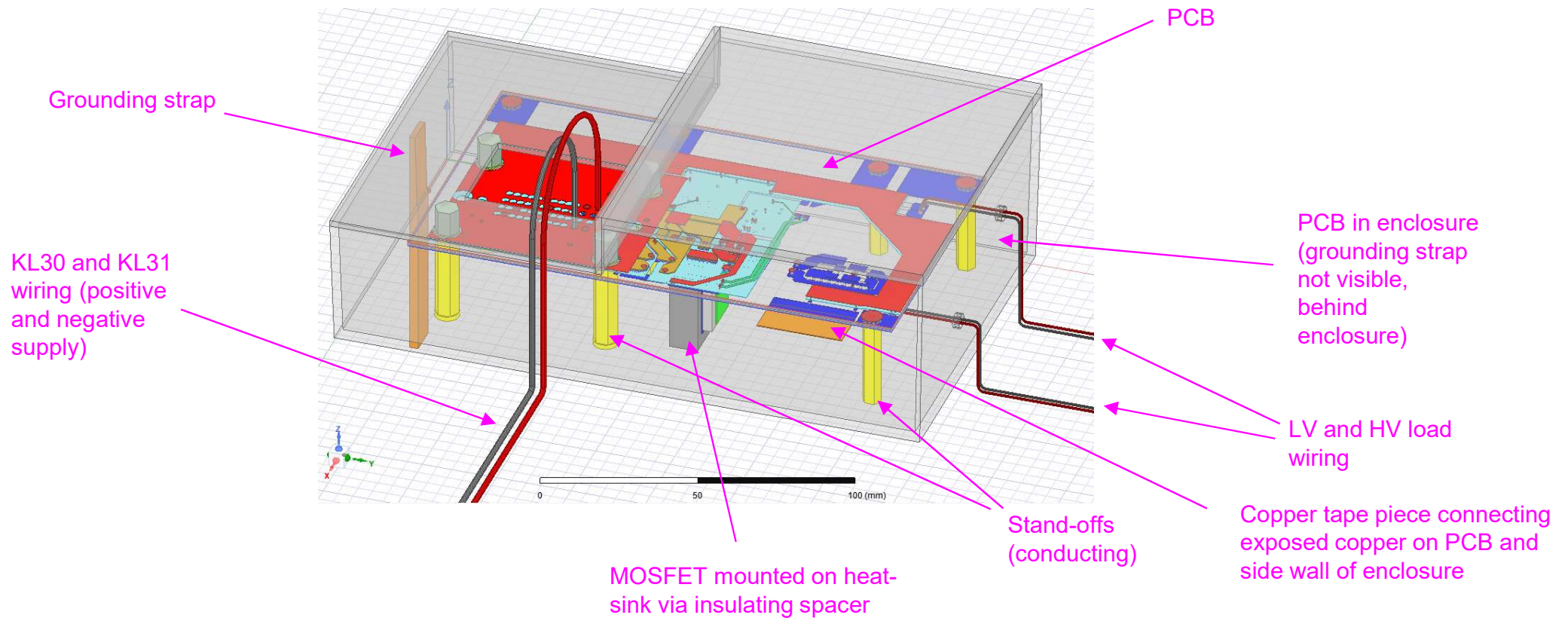
Design was altered to use a through-hole FET to exacerbate emissions by capacitive coupling between FET tab and chassis via insulating spacer.



Mechanical CAD of PCB exported from layout software, showing component positions.

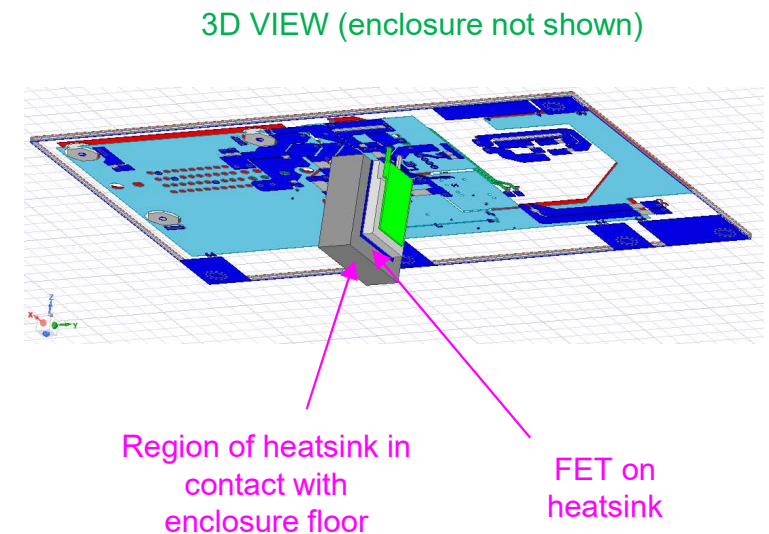
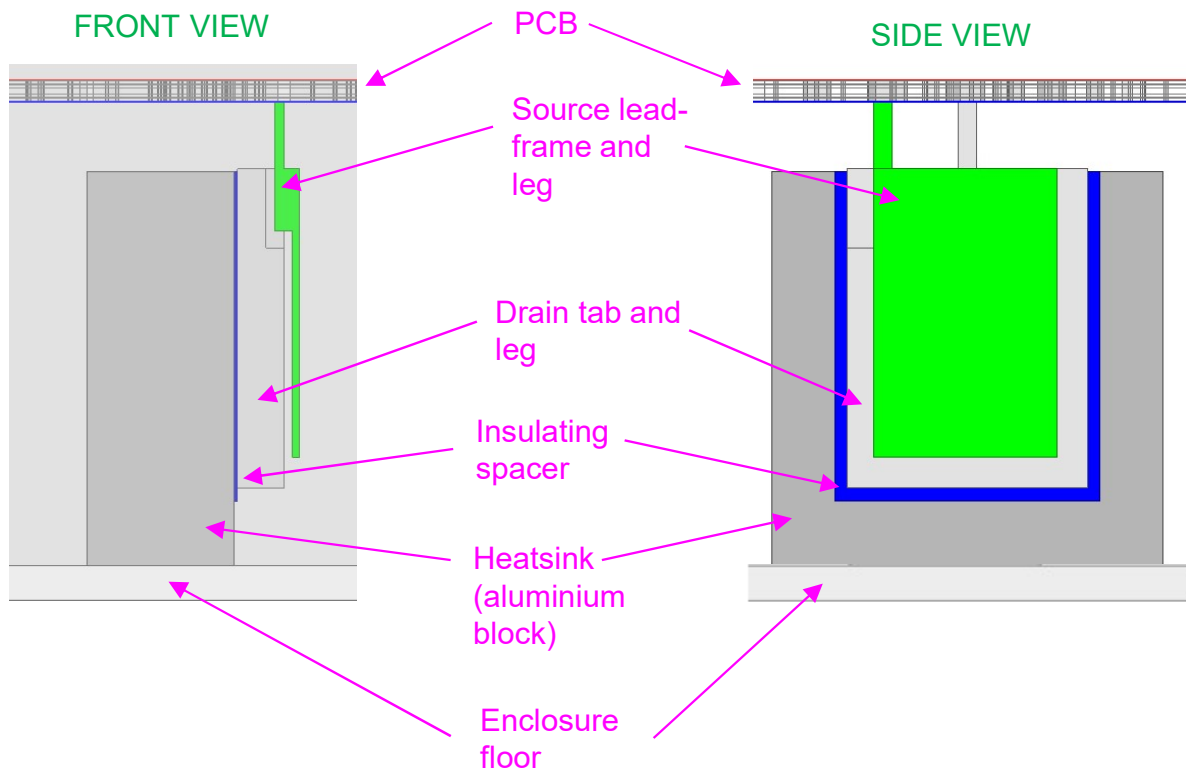
Through-hole FET

PCB in enclosure



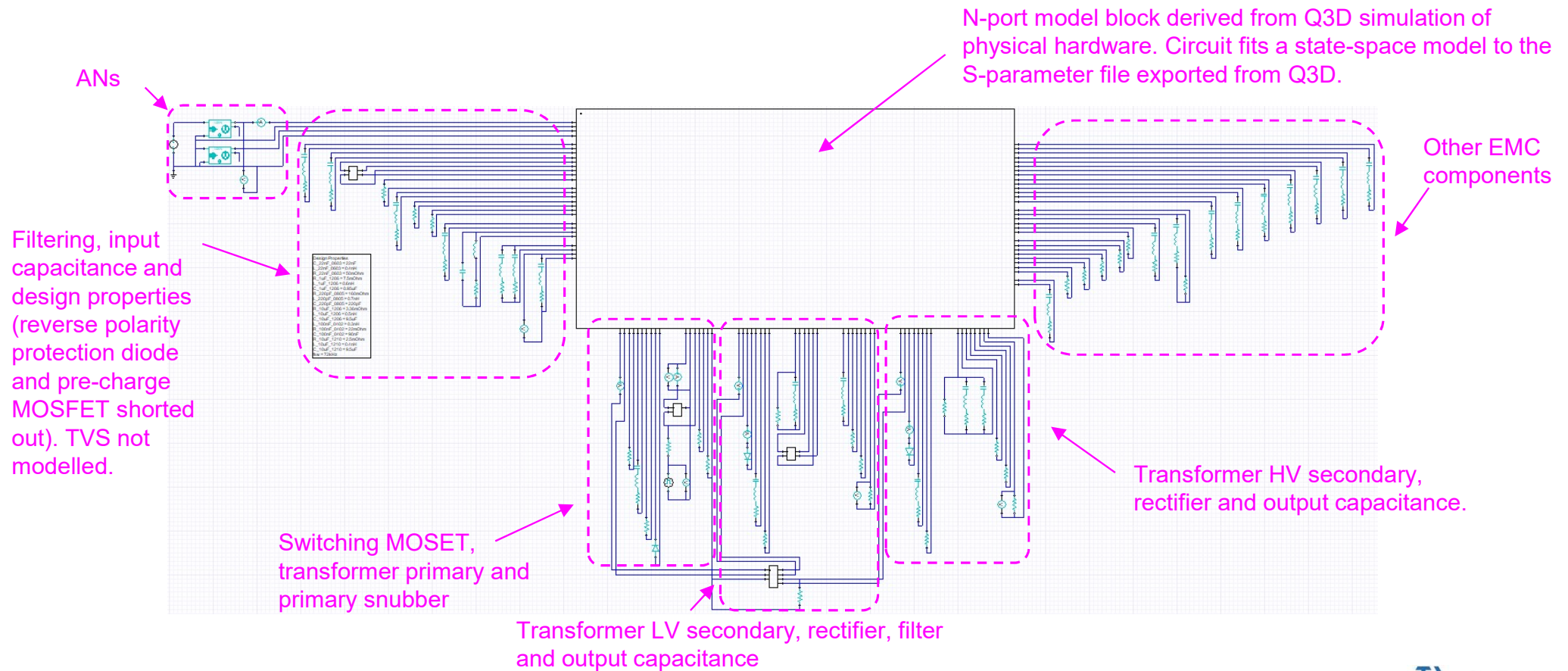
FET mounting on heat-sink

FET mounted on aluminium block via insulating spacer for heat-sinking - bad for EMC given capacitive coupling of switching node with enclosure!



Circuit model

All lumped component and finite element analysis derived models incorporated into a circuit simulator.



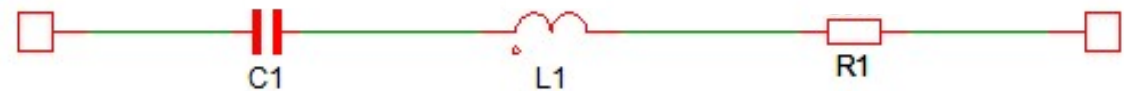
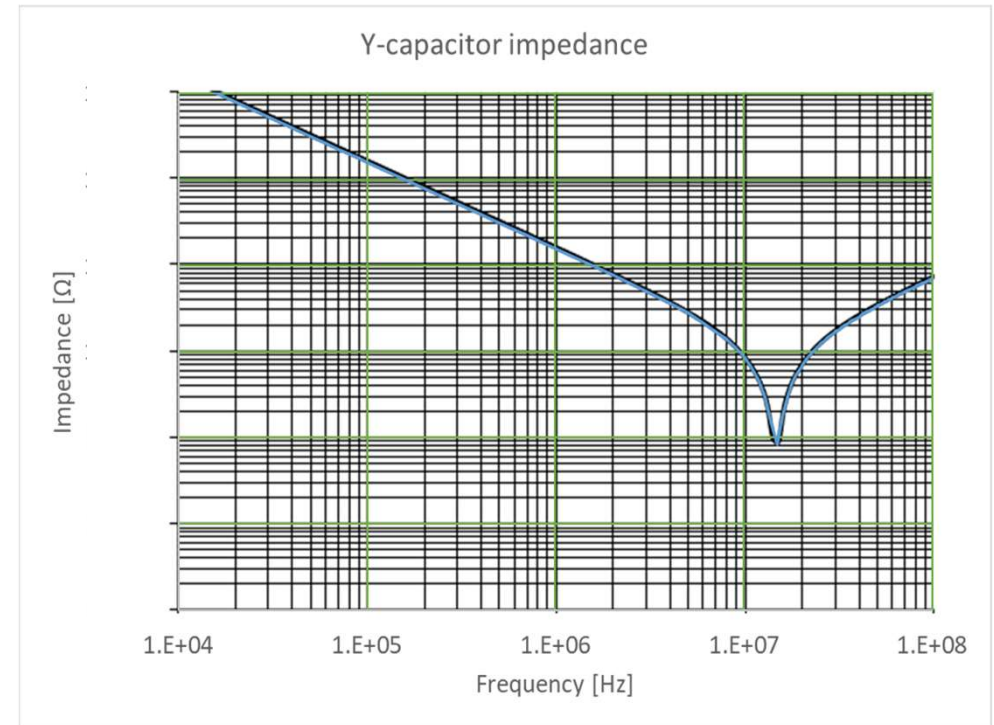
Capacitor models

Component parasitic effects included

All capacitors were modelled using a series R-L-C model to include parasitic inductance and ESR.

Model fitting

The model parameters were adjusted to match manufacturer data.



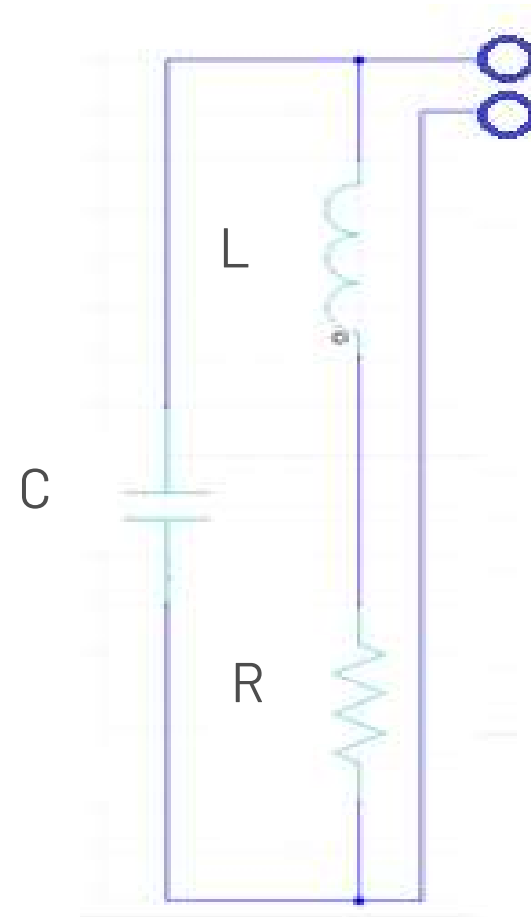
Inductor models

Component parasitic effects included

All filter inductors were modelled using a series R-L parallel C model to include parasitic capacitance and series resistance.

Model fitting

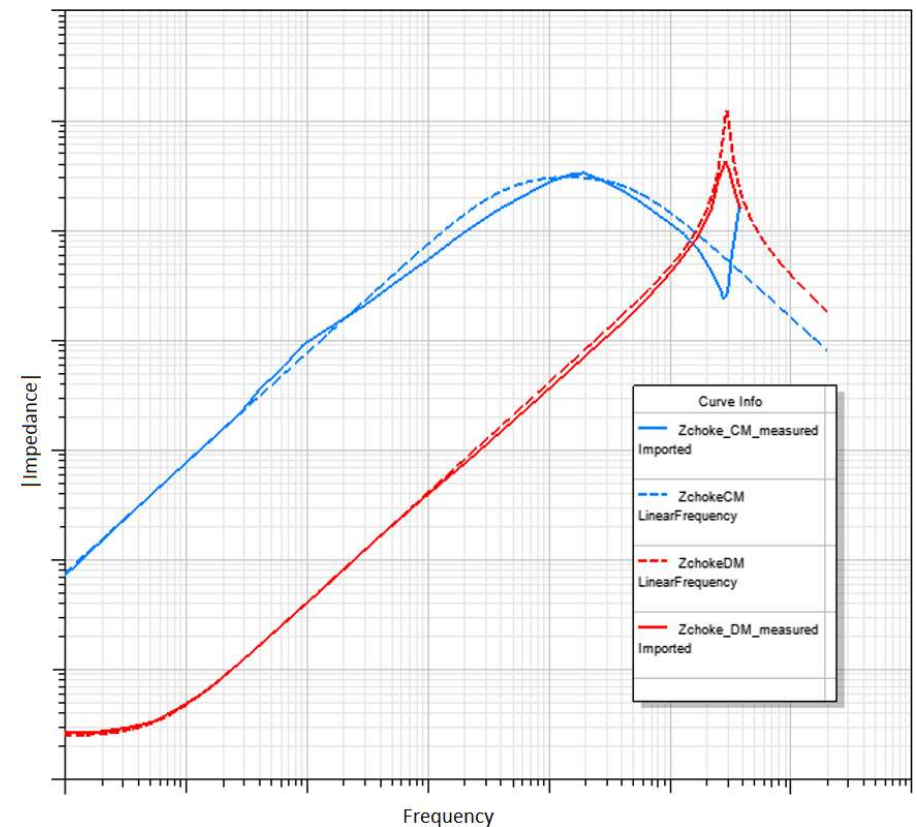
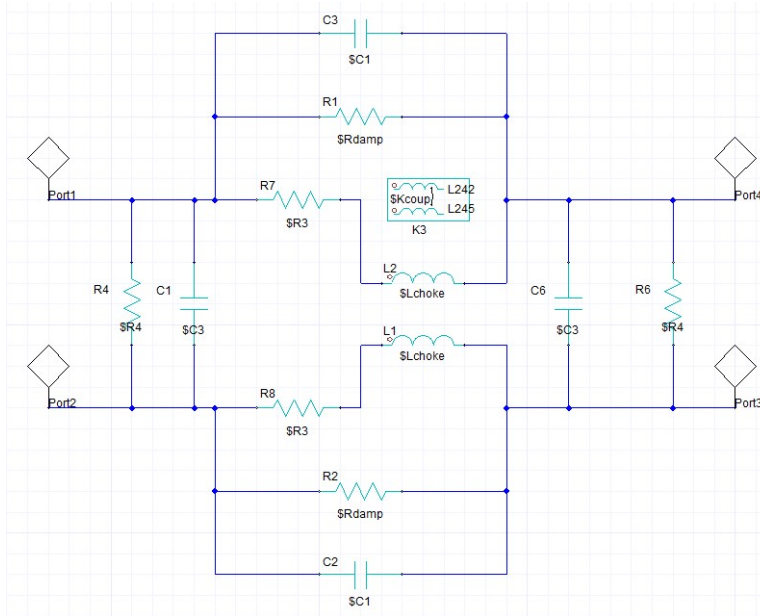
The model parameters were adjusted to match manufacturer data on DC resistance and self resonant frequency (SRF). No attempt was made to model the increase in resistance with frequency resulting from skin effect.



Common-mode choke models

Frequency dependent impedance

The frequency dependent common mode and differential mode impedance of the common mode chokes used in the design was modelled using simple equivalent circuits, based on the manufacturer model, fitted to manufacturer data and/or measured data.



Transformer model

Magnetising and leakage inductance

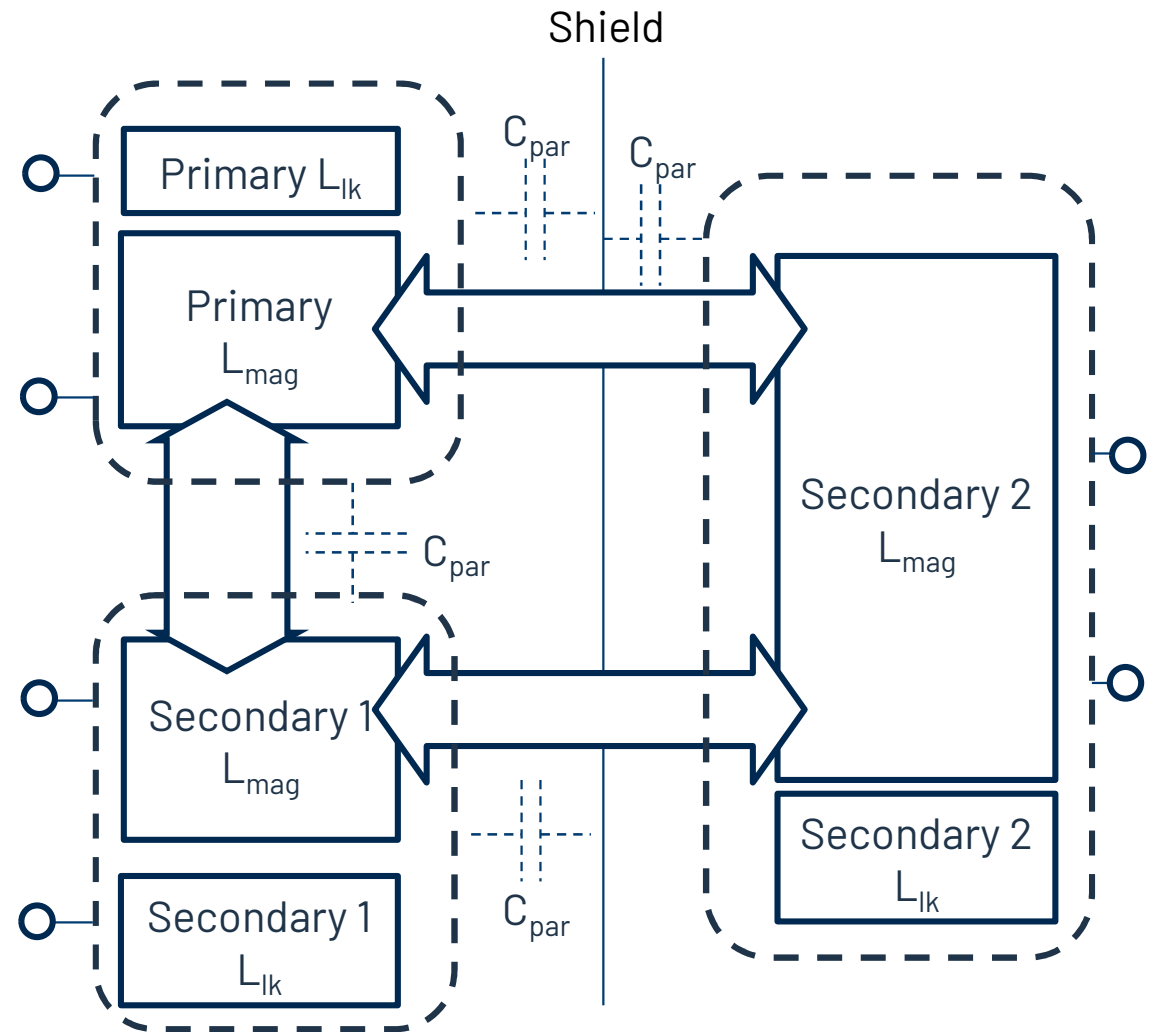
Magnetising and leakage inductances were extracted using Ansys PEmag and Maxwell.

Parasitic capacitance

Inter-winding and winding to shield capacitance was extracted using Ansys PEmag and Maxwell.

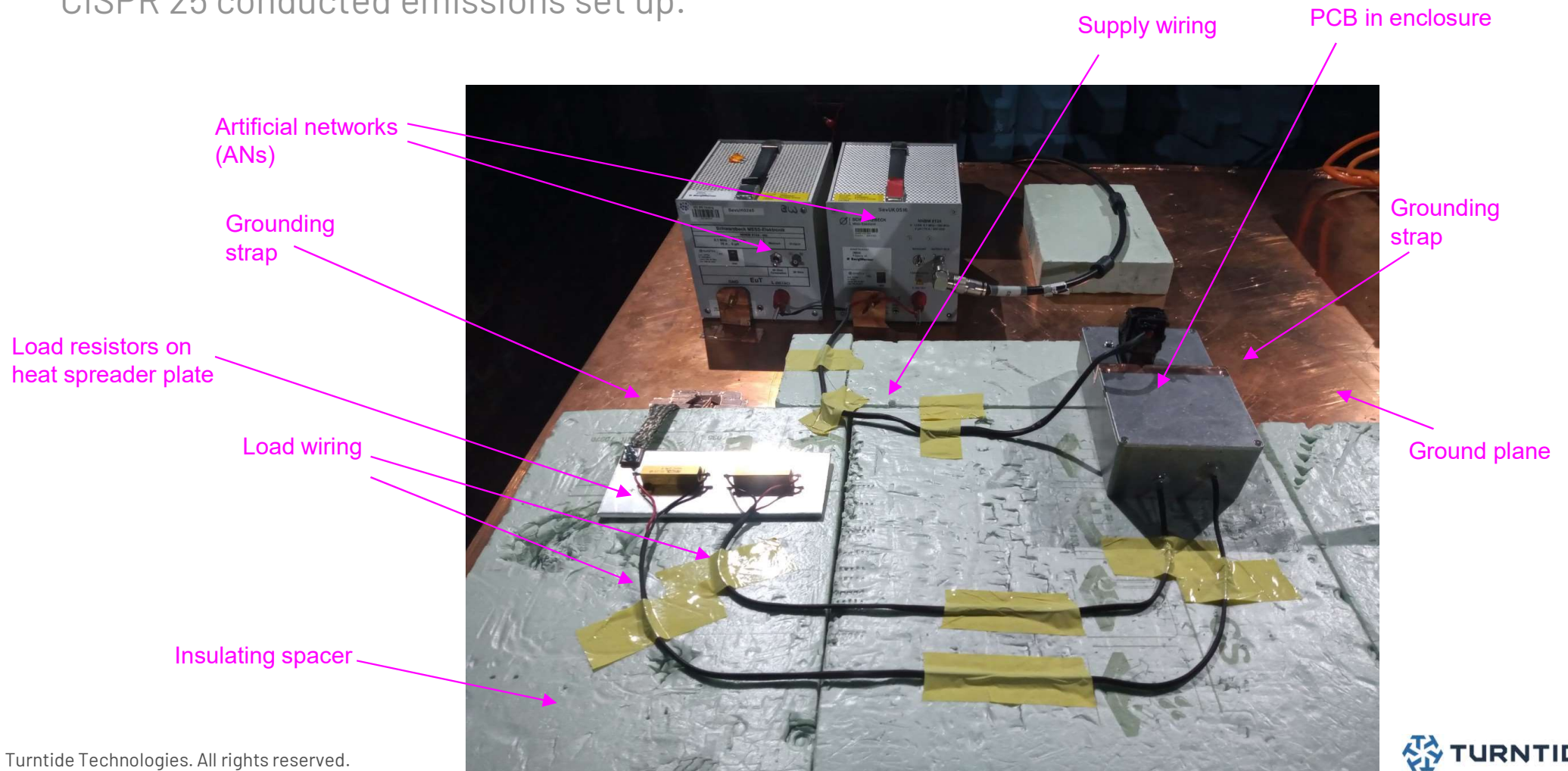
Model complexity trade-off

A coupling factor of 1 was used between windings, with inductance and capacitance split to obtain a trade-off between lumping everything together and its real-life distributed nature.



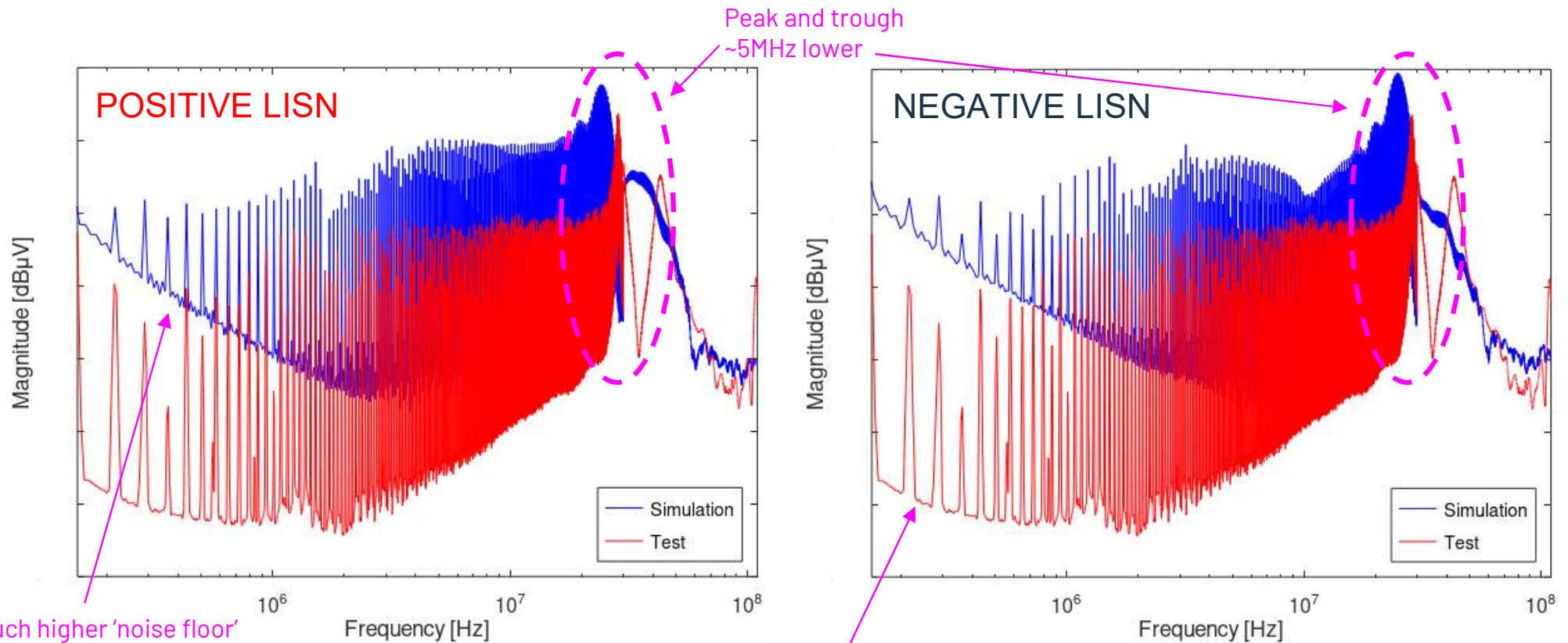
Test set-up

CISPR 25 conducted emissions set up.



Test versus simulation - EMI

Test / simulation comparison

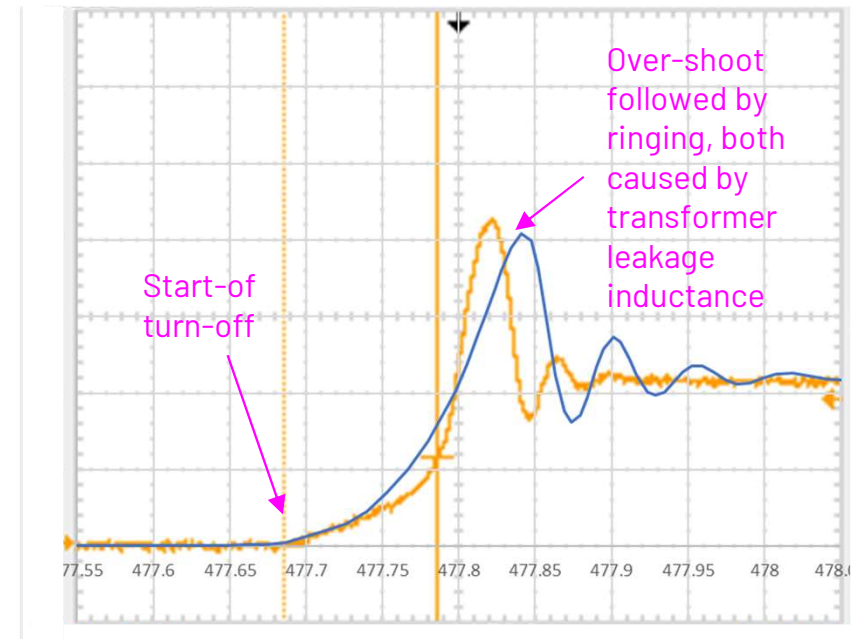
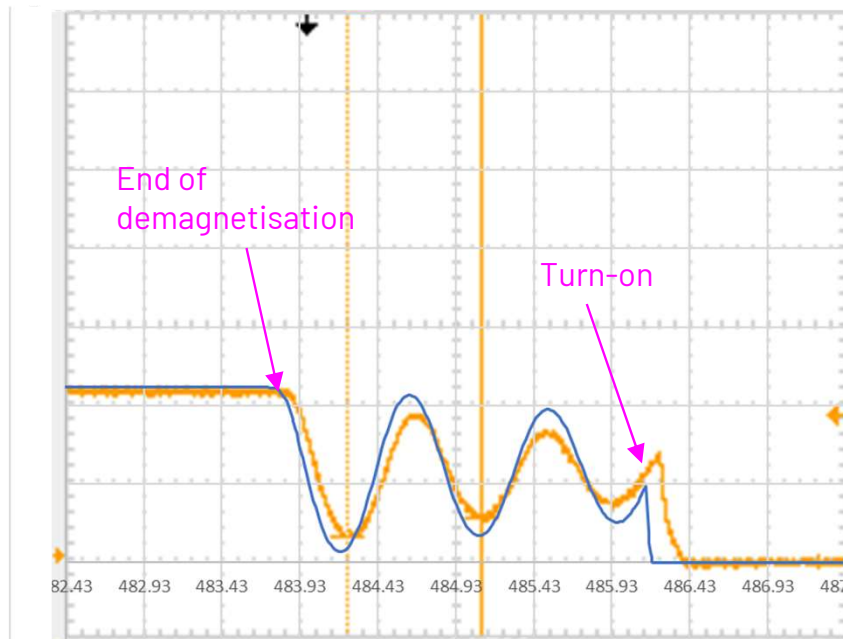


Much higher 'noise floor' resulting from post-processing parameters.

Peaks are spaced at the switching frequency, which was set in simulation to match test, given known potential for inaccuracy in control IC timing.

Test versus measurement – switch node voltage

Overshoot and ringing at the switch node captured - some mismatch but in the right 'ball-park'

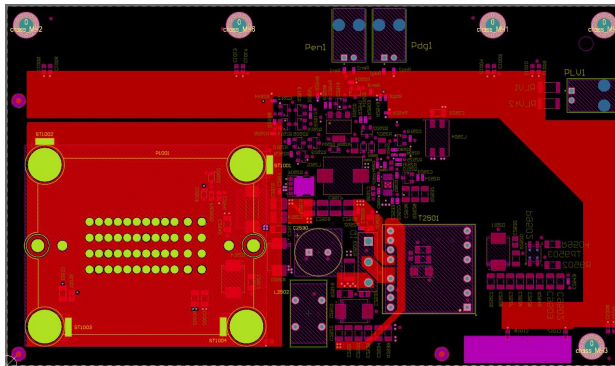


Layout change

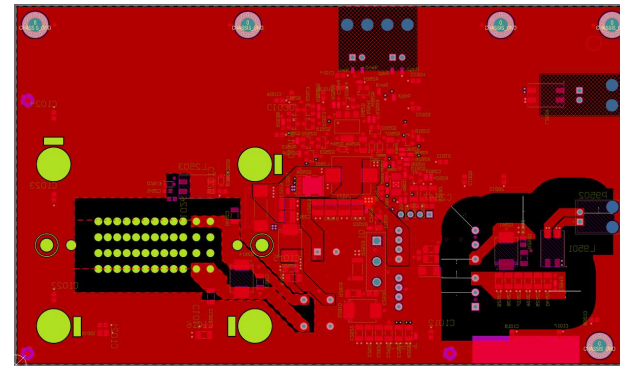
Layout changed to increase 0V reference coverage, stitch 0V plane to chassis via multiple capacitors and cut away planes around connectors to give clear boundary.

Top

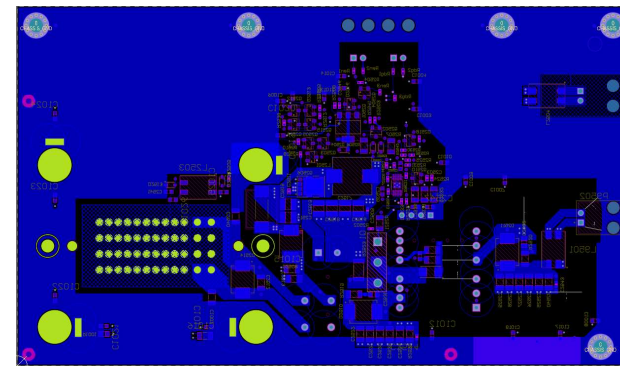
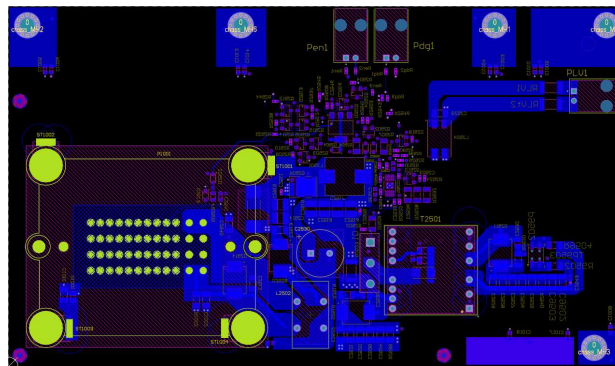
Before



After



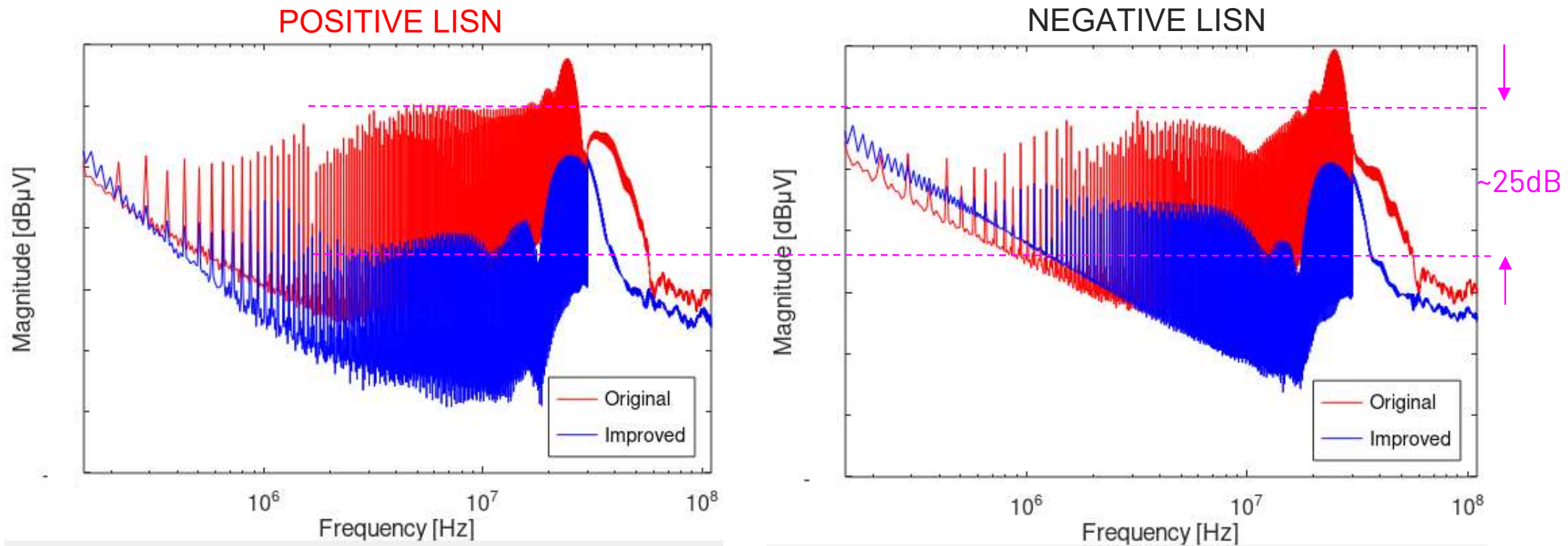
Bottom



Layers 2-5
not shown.

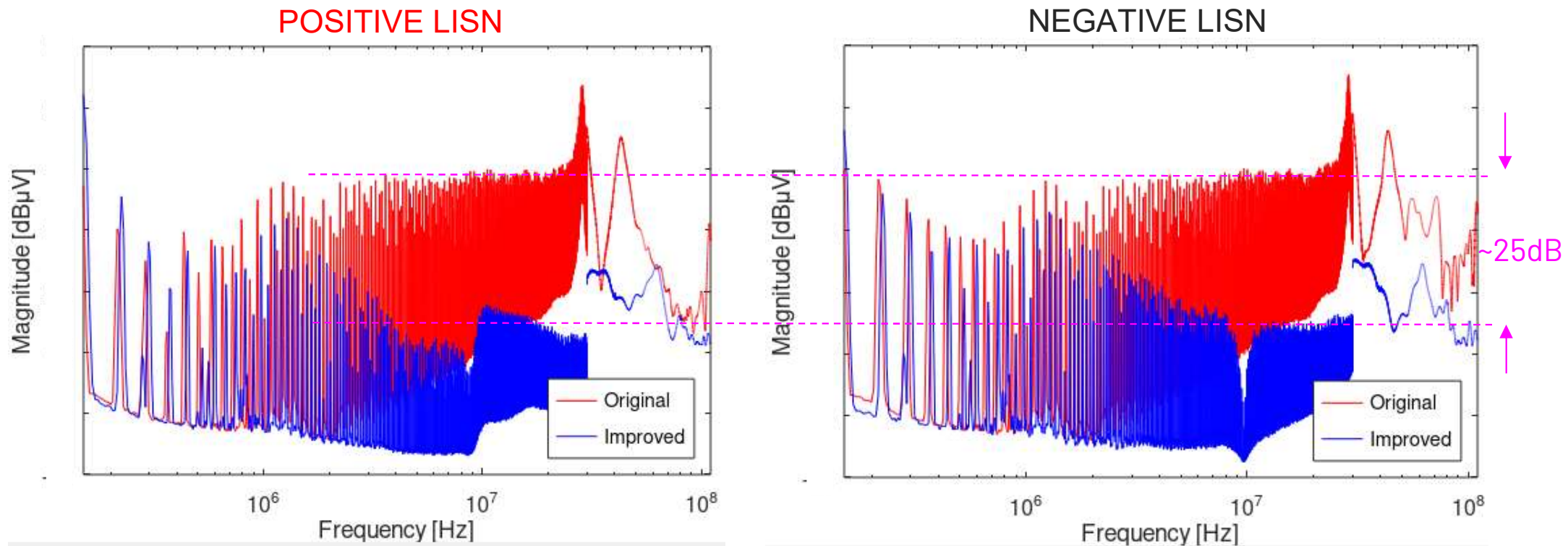
Original versus re-layout – simulation

Simulated conducted emissions for original and improved layout.



Original versus re-layout - test

Tested conducted emissions for original and improved layout



Conclusions

Filter simulation and optimisation

An outline of a method used to simulate conducted emissions from a switch-mode power supply inside an enclosure given. The model gives a method of like-for-like comparison of designs through simulation, before going to prototype test.

Match between simulation and measurement

The match between simulation and measurement requires further investigation, however the presence of emissions is represented and the reduction in emissions offered by an alternative layout is indicated.

Further work

Work in progress to better understand the discrepancies between experiment and test and to extend the methodology to other aspects of EMC such as conducted immunity.

Q & A

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