3D MODELING OF 3-PHASE CM CHOKE AND DM POWER INDUCTOR FROM BLUEFERRITE

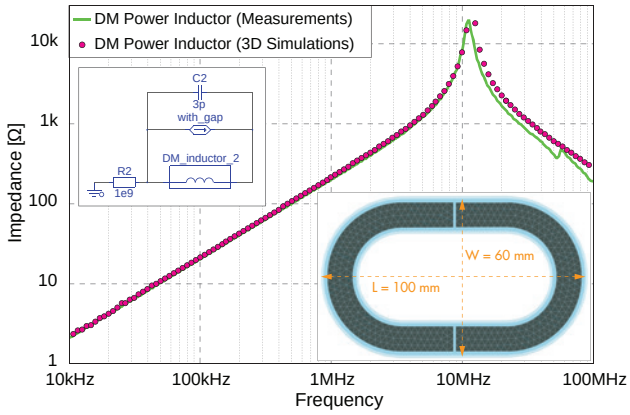
Introduction

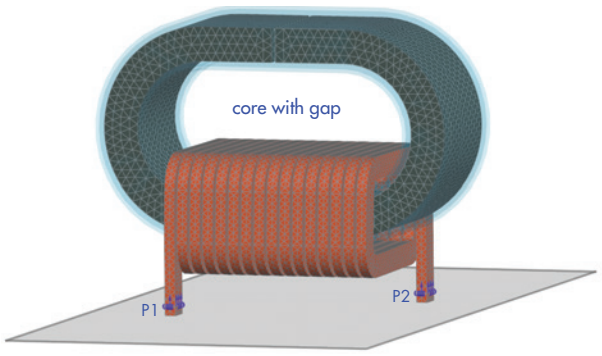
This application note presents the results of a collaborative project between EMCoS LLC and company Dovitech GmbH, focusing on the 3D simulation of 3-Phase Common Mode (CM) Choke and Differential Mode (DM) Power Inductor which are represented with flat-wire windings on oval-shaped nanocrystalline cores. The study demonstrates applicability of EMCoS Studio software package, which provides advanced simulation capabilities for accurate modeling of such components enabling detailed prediction of 3D field coupling effects.

Modeling of Blueferrite Components and Impedances Calculation

The 3D simulation models for component impedance simulation and radiated field distribution were constructed in EMCoS Studio environment. Frequency-dependent material (μ initial ≈ 30k) was used to model the oval core for 3-Phase CMC, while for DM Inductor effective permeability μ'≈100 was defined. These models were calculated and analyzed using the direct full-wave Method of Moments (MoM) solver, TriD. The simulation results were subsequently compared with measured data for various winding connection modes to validate the accuracy of the models. All related measurements were conducted in EMCoS Research Laboratory.

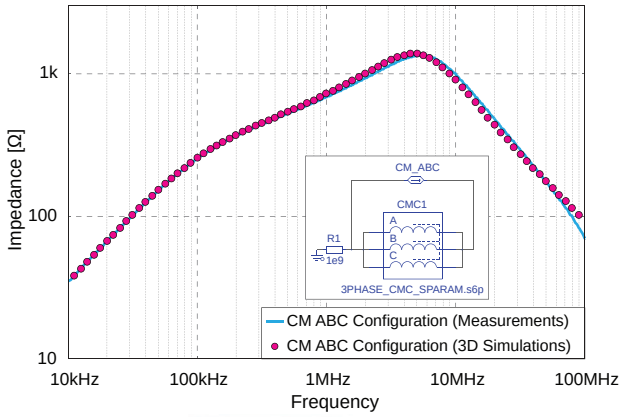
Simulation and Measurement of DM Power Inductor Impedance

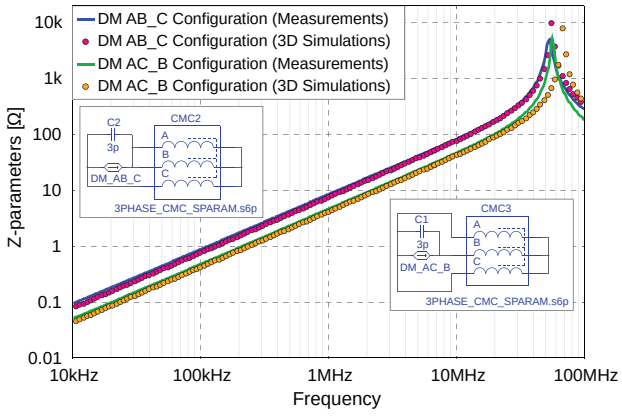


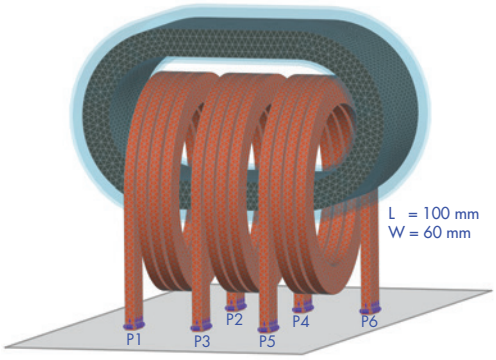


DM inductor is represented with 16 turns of flat copper wire with cross-sectional area around 17 mm²

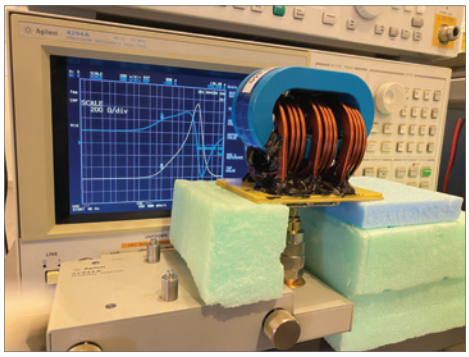
Simulation and Measurement of 3-Phase CM Choke Impedances in Different Connection Modes

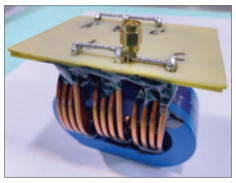


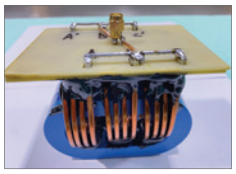




CMC with 3 windings, each has 4 turns of 22.5 mm² flat wire







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Application note was prepared in cooperation with Dovitech GmbH

Blueferrite

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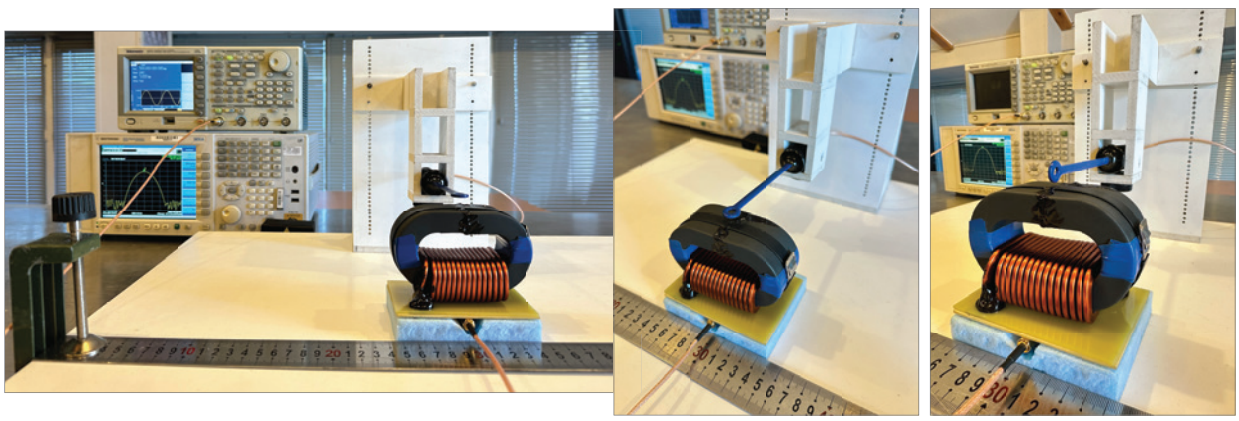
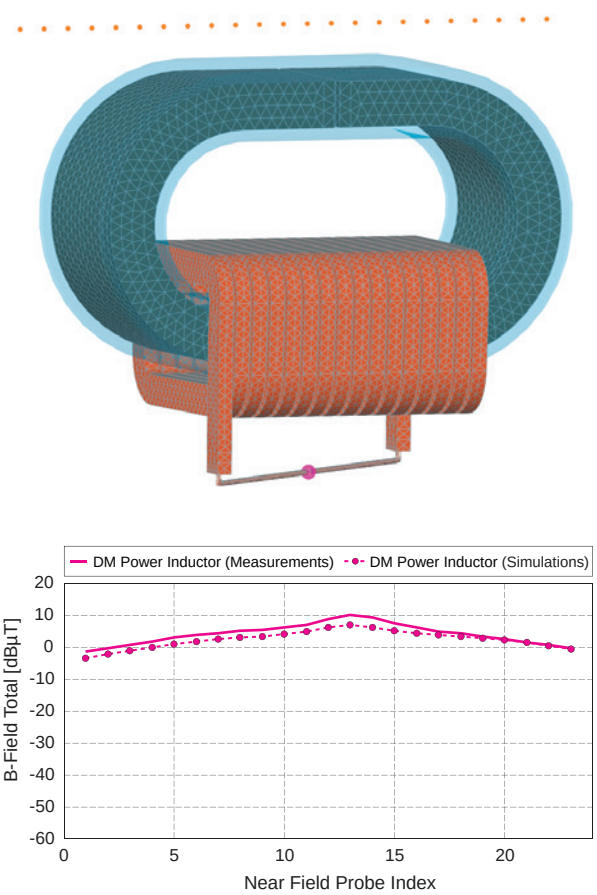
Radiated B-Field from DM Power Inductor

Observing the radiated B-field distribution around filter components provides valuable insights into field leakage and coupling effects, which is very important for selecting the appropriate samples and their placement for specific applications. The 2D and 3D distribution plots for the total B-field at a frequency of 500 kHz are presented below for the DM Power Inductor. As shown in the plots, the simulation results align closely with the measured data, further confirming the reliability and accuracy of the EMCoS Studio simulations.

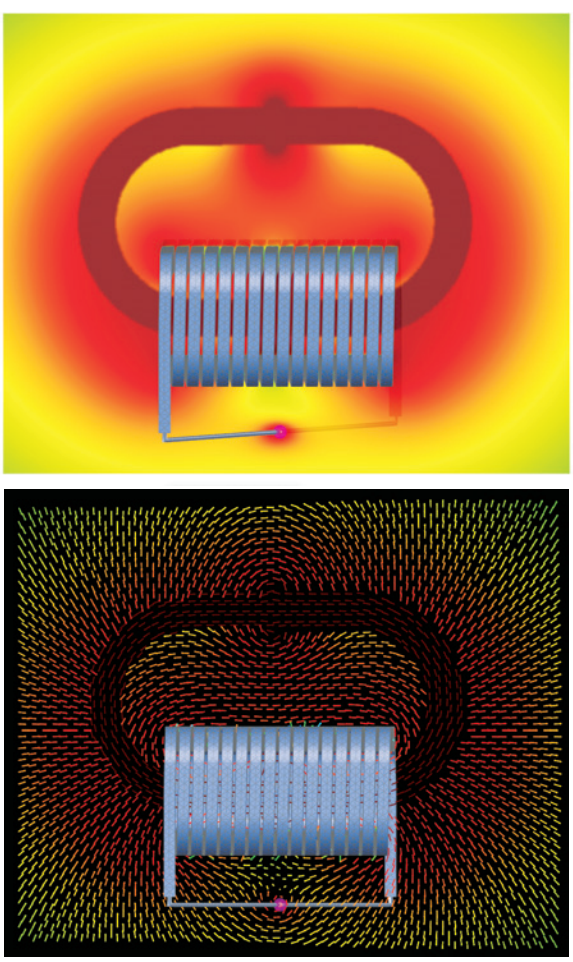
Measurements of Radiated B-Field from DM Power Inductor



Comparison of Radiated B-Field, DM Power Inductor (500 kHz)



B-Field Distribution, DM Power Inductor (500 kHz, min level = -45 dBµT; max level = 20 dBµT)



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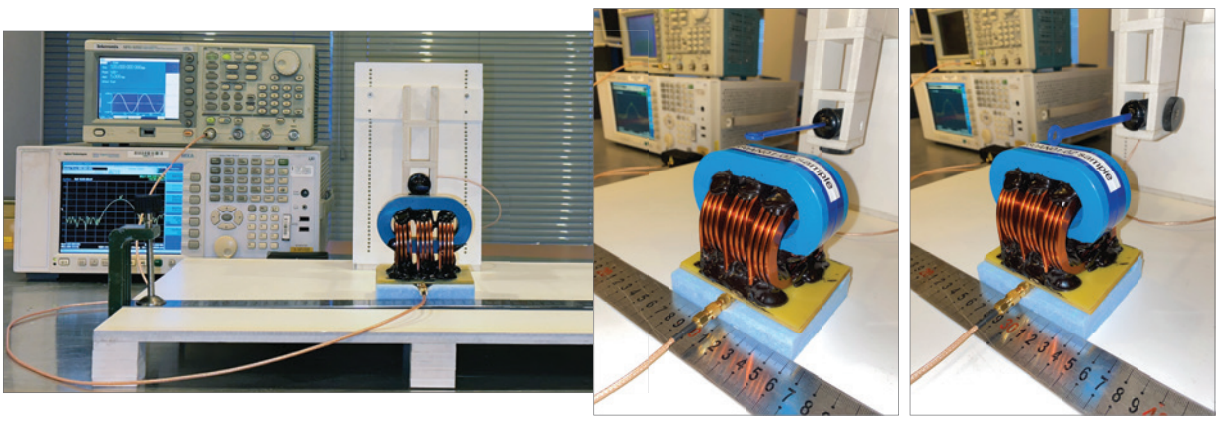
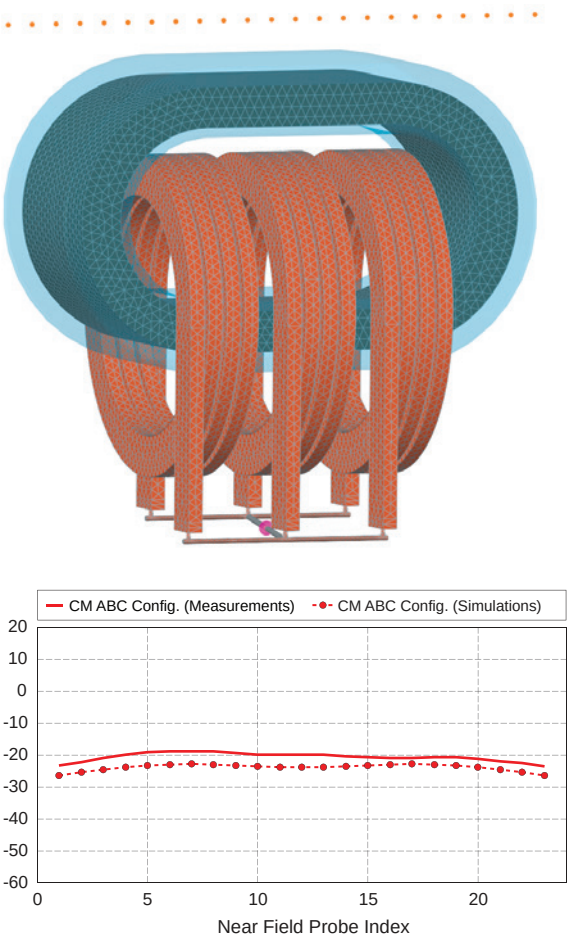
Radiated B-Field from 3-Phase CM Choke (CM ABC Configuration)

The 2D and 3D distribution plots for the total B-field at a frequency of 500 kHz are presented below for the 3-Phase CM Choke, considering CM ABC configuration of the winding connection mode. Magnetic near field measurements were performed and compared with the corresponding simulations. The results demonstrate a good correlation between the simulated and measured data.

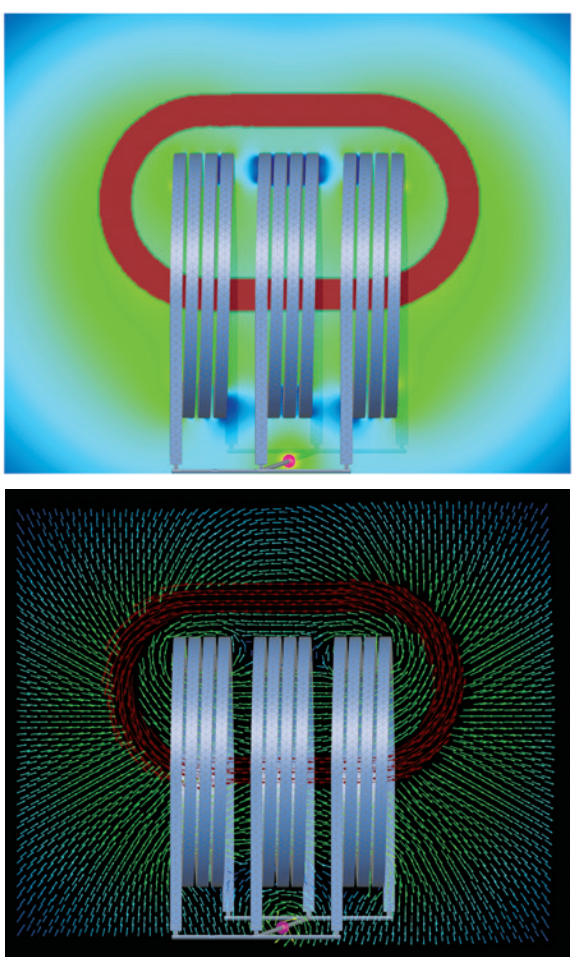
Measurements of Radiated B-Field from 3-Phase CM Choke



Comparison of Radiated B-Field, 3-Phase CM Choke (CM ABC Configuration, 500 kHz)



B-Field Distribution, 3-Phase CM Choke (500 kHz, min level = -45 dBµT; max level = 20 dBµT)



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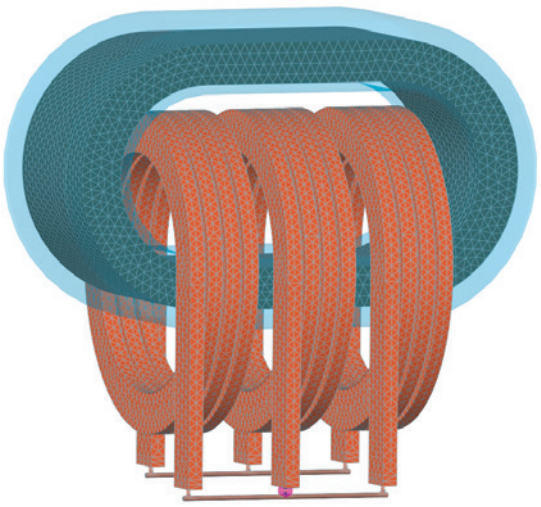
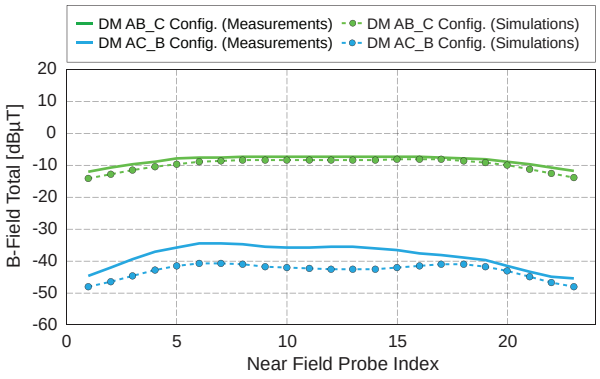
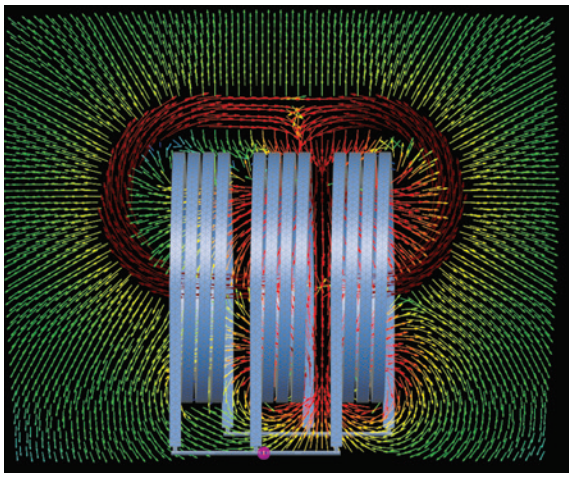
Radiated B-Field from 3-Phase CM Choke (DM AB-C & AC-B Configurations)

The analysis of the measurement and simulation results, along with the visualization of B-field distribution using color/arrow plots, provides valuable information about field leakage when the 3-Phase CM Choke is considered with different winding connections in differential mode (CM ABC, DM AB-C, and DM AC-B configurations). It is shown that when the component is considered with the DM AC-B winding connection mode, the level of field leakage is significantly lower compared to the other connection modes. The same effect can also be seen from the impedance curves.

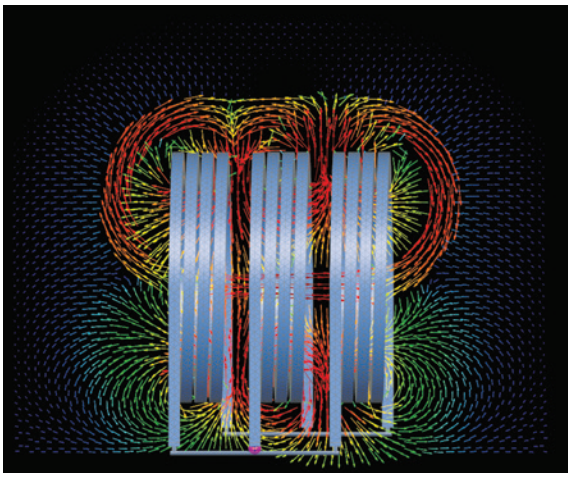
Comparison of Radiated B-Field, 3-Phase CM Choke, DM AB-C & DM AC-B Configurations
(500 kHz; min level = -45 dBμT; max level = 20 dBμT)







3-Phase CM Choke (DM AB-C Configuration)



3-Phase CM Choke (DM AC-B Configuration)

Conclusions

- The detailed simulations of the radiated B-field distributions for various filter components have been validated by comparison with measured data, confirming the reliability and precision of EMCoS Studio 3D full-wave MoM solution
- The 3D field color/arrow plot distribution provides a comprehensive visualization of the electromagnetic field distribution around the simulated components, offering detailed insights into the behavior of radiated fields, field leakage, and the coupling effects associated with the design of the component. This type of plot is an essential tool for analyzing the electromagnetic compatibility performance of power inductors, chokes, and other components in various operating conditions
- This study highlights the effectiveness of using EMCoS Studio for the simulation and optimization of power inductors and chokes and other components, providing EMC engineers with powerful tools to predict and mitigate electromagnetic field coupling effects in their products

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