

ANSYS MAXWELL SIMULATIONS FOR WIRELESS POWER APPLICATIONS

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AGENDA

- Introduction to Ansys Maxwell
- Introduction to ICEPAK
- Simulation steps of WE Qi A10 WPCC coils (inductance, R_{AC} , field distribution, coupling) with Ansys Maxwell
- Thermal simulation of a WE Qi A10 WPCC coil
- Comparison between measurements and simulations

INTRODUCTION

ANSYS Maxwell

- high-performance software package that uses finite element analysis to solve electromagnetic problems
- is integrated into the Ansys Electronics Desktop (AEDT), together with all the other ANSYS Electromagnetic Tools
- solves the electromagnetic field problems by solving Maxwell's equations in a finite region of space
- geometries can be created directly inside Maxwell or imported from external CAD tools (e.g. SolidEdge)
- this presentations shows the workflow of a 3D simulation of a Qi-coil with Ansys Maxwell

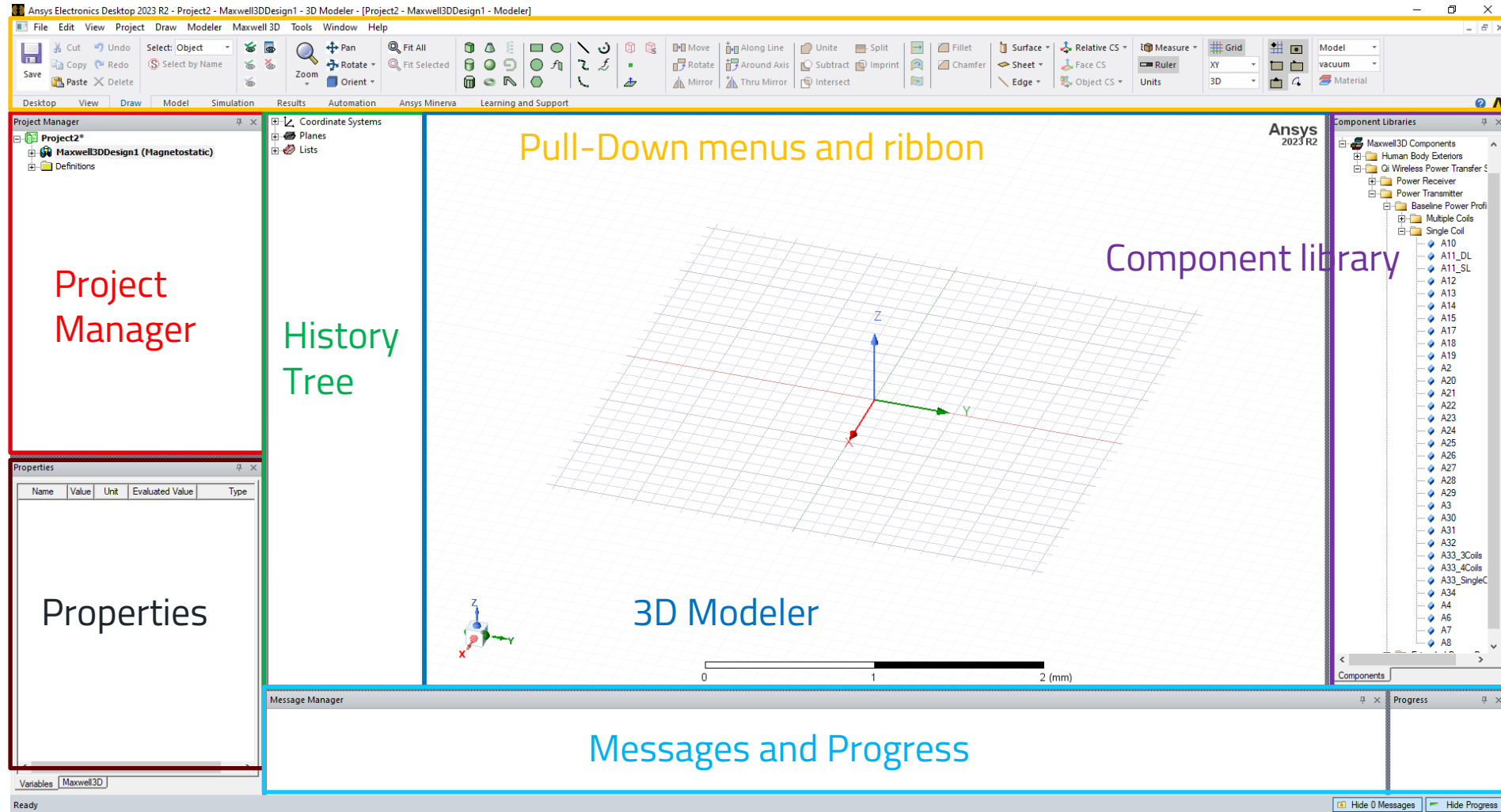
INTRODUCTION

Ansys ICEPAK

- is a computational fluid dynamics (CFD) software for predicting and managing thermal performance in electronic devices
- simulates airflow, temperature and heat transfer for electronic devices
- supports conjugate heat transfer analysis, modeling conduction, convection and radiation in steady-state and transient modes
- is closely integrated with the AEDT
- is used by WE to simulate the wireless power coils at a certain AC current flowing through the respective coil

ANSYS MAXWELL 3D SIMULATION

Ansyz Electronic Desktop: Graphical User Interface



WPC Qi A10 DESIGN

- A10 design due to the Qi 1.3 Standard :

Inductance:

$$L = 24 \mu\text{H} \pm 10 \%$$

Ferrite Material: Mn-Zn or Ni-Zn with at least 0.5 mm thickness

Shield should extend at least 2 mm beyond the outer diameter of the primary coil

Primary Coil

The Primary Coil is of the wire-wound type, and consists of no. 17 AWG (1.15 mm diameter) type 2 litz wire having 105 strands of No. 40 AWG (0.08 mm diameter), or equivalent. As shown in Figure 15, the Primary Coil has a circular shape and consists of multiple layers. All layers are stacked with the same polarity. Table 13 lists the dimensions of the Primary Coil.

Figure 15. Primary Coil of Power Transmitter design A10

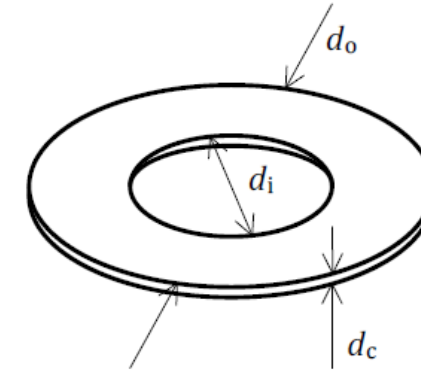


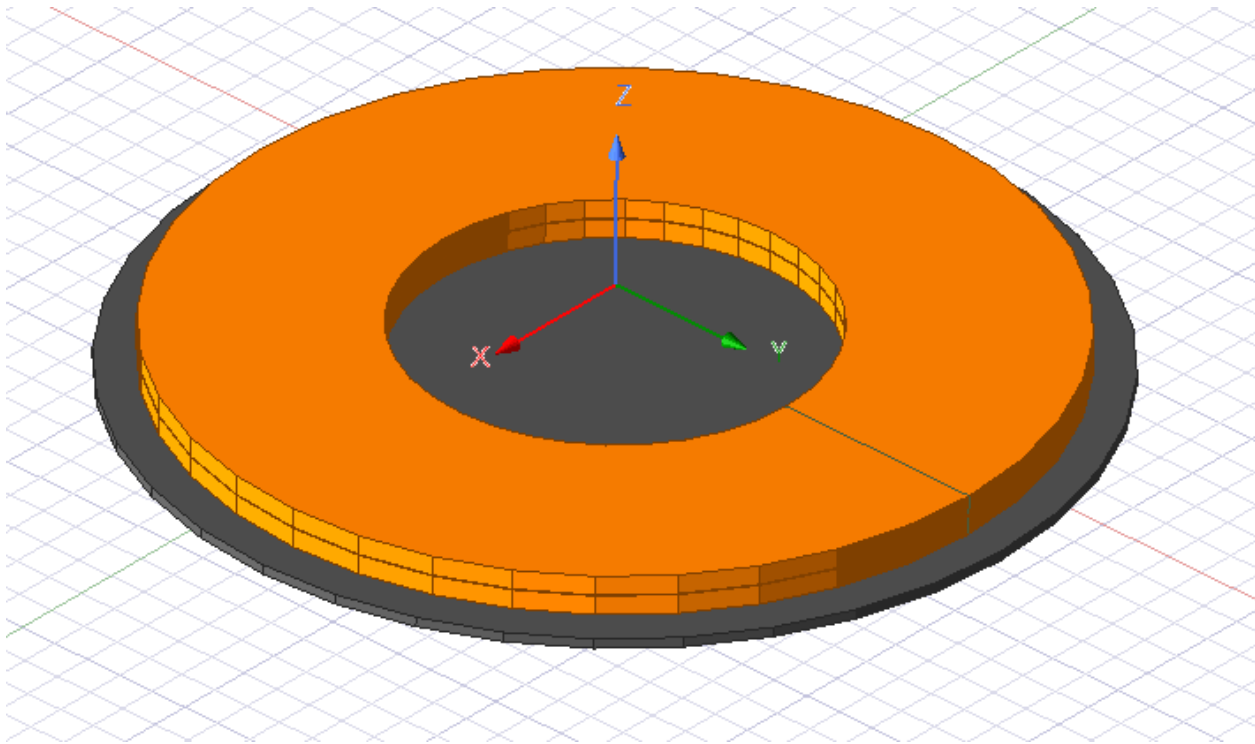
Table 13: Primary Coil parameters of Power Transmitter design A10

Parameter	Symbol	Value
Outer diameter	d_o	$43^{\pm 0.5}$ mm
Inner diameter	d_i	$20.5^{\pm 0.5}$ mm
Thickness	d_c	$2.1^{+0.5}$ mm
Number of turns per layer	N	10
Number of layers	—	2

SIMULATION WORKFLOW: 3D MODEL

Make your 3D model in Ansys or choose a Qi design from the component library (doubleclick on the Qi-Design -> it will be loaded into the modeler screen)

Example: Qi A10 Design from the component library (corresponding WE coil 760308101410):



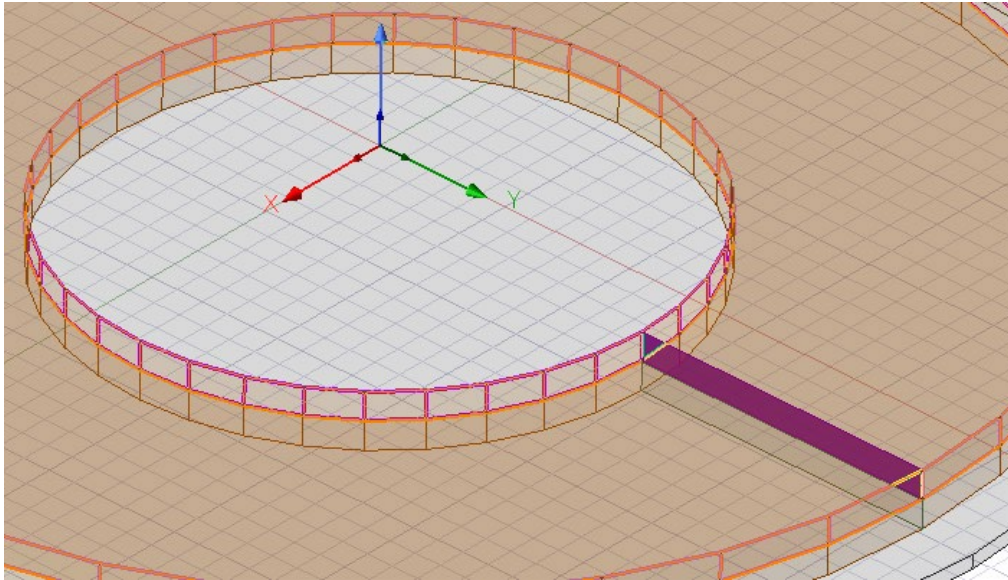
Consists of:

Grey cylinder (material: ferrite)
2 discs (1 for each layer,
material copper)
two cross sections, 1 for each
layer of the coil)

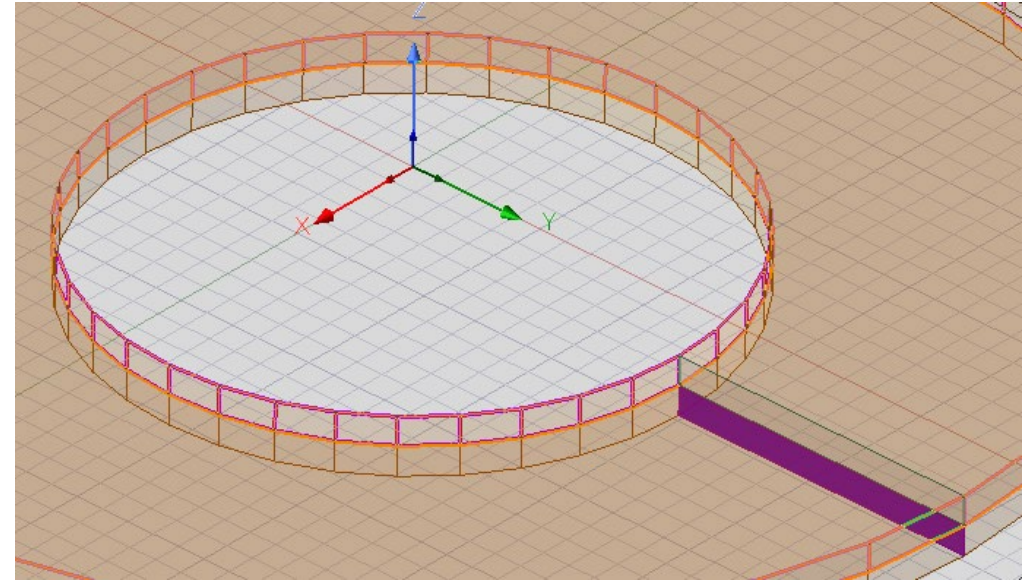
3D SIMULATION WORKFLOW: CROSS SECTION AND EXCITATION

If you made your own model, the cross sections have to be added and the materials have to be defined in the properties window (is already done if you choose the model from the library):

- Cross section layer 1:

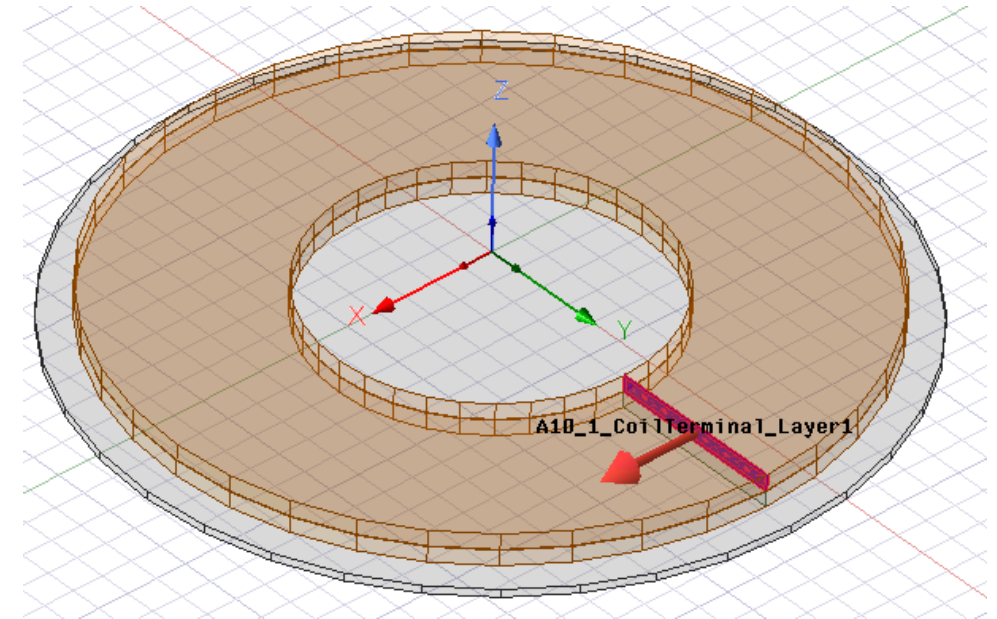
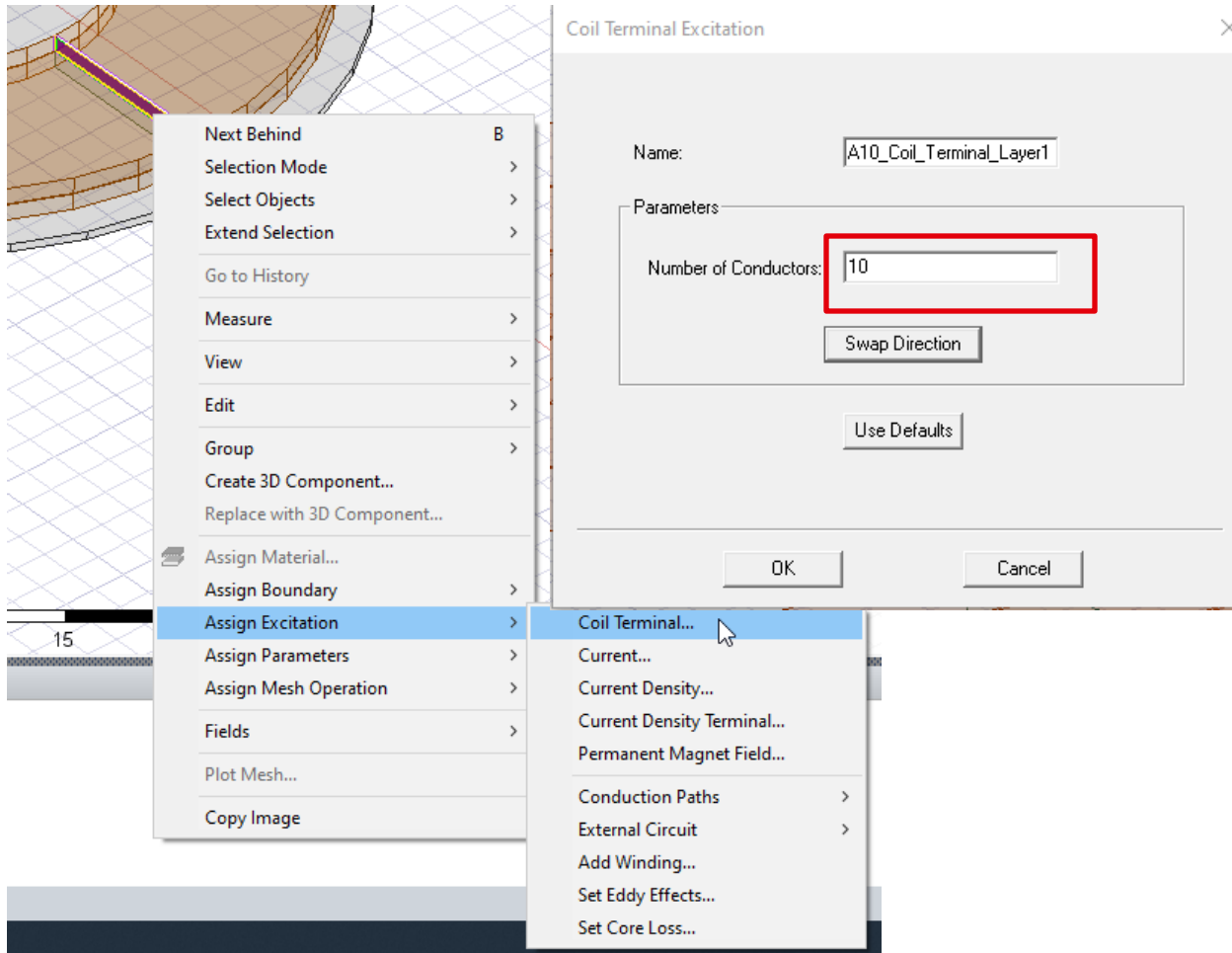


- Cross section layer 2:

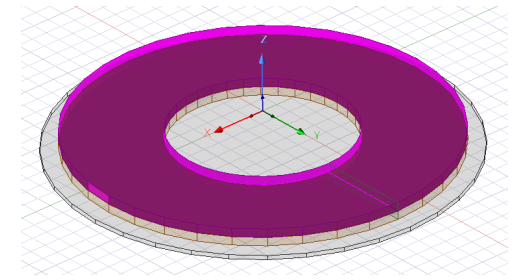


3D SIMULATION WORKFLOW: CROSS SECTION AND EXCITATION

Define Excitation on both cross sections: Right click on the cross section -> Assign Excitation -> Coil Terminal 1/2



3D SIMULATION WORKFLOW: MATERIAL PROPERTIES (COPPER)



Define materials (and colors) at the properties window, first select the part, where the material has to be defined by clicking on it, go to Material -> Edit -> choose needed material (e.g. copper) and go to View/Edit materials:

Properties

Name	Value	Unit	Evaluated Value
Name	Coil_Layer_1		
Material	"vacuum"		"vacuum"
Solve Inside	Edit...		
Orientation	"femite"		
Model	"vacuum"		
Group	Model		
Display Wi...	☐		
Material A...	☐		
Color			
Transparent	0		

Select Definition

Materials | Material Filters

Search Parameters
Search by Name
copper

Search Criteria
☒ by Name ☐ by Property
Relative Permittivity

Libraries ☒ Show Project definitions ☐ Select all libraries
[sys] Materials

Name	Location	Origin	Relative Permeability	Bulk Conductivity
copper	SysLibrary	Materials	0.999991	58000000
coming_glass	SysLibrary	Materials	1	0
cyanate_ester	SysLibrary	Materials	1	0
diamond	SysLibrary	Materials	1	0
diamond_hi_pres	SysLibrary	Materials	1	0
diamond_pl_cvd	SysLibrary	Materials	1	0
Dupont Type 100 HN Film (tm)	SysLibrary	Materials	1	0
Duroid (tm)	SysLibrary	Materials	1	0
epoxy_Kevlar_xy	SysLibrary	Materials	1	0
femite	Project	Materials	1000	0.01
femite	SysLibrary	Materials	1000	0.01
FR4_epoxy	SysLibrary	Materials	1	0
gallium arsenide	SysLibrary	Materials	1	0

View / Edit Material

Material Name: copper
Material Coordinate System Type: Cartesian

Properties of the Material

Name	Type	Value	Units
Relative Permittivity	Simple	1	
Relative Permeability	Simple	0.999991	
Bulk Conductivity	Simple	58000000	siemens/m
Dielectric Loss Tangent	Simple	0	
Magnetic Loss Tangent	Simple	0	
Core Loss Model	None		w/m^3
Mass Density	Simple	8933	kg/m^3
Composition		Litz Wire	
- Wire Type		Round	
- Strand Number	Simple	105	
- Wire Diameter	Simple	0.08	mm

View/Edit Material for

☒ Active Design
☐ Active Project
☐ All Properties

Physics:

☒ Electromagnetic
☒ Thermal
☒ Structural

View/Edit Modifier for

☐ Thermal Modifier
☐ Spatial Modifier

Material Appearance

☒ Use Material Appearance
Color:
Transparency: 0

Notes:

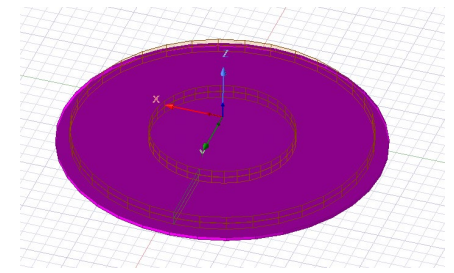
Calculate Properties for:

Reset OK Cancel Validate Material

Define Composition: Litz wire, wire type, strand number and wire diameter

3D SIMULATION WORKFLOW: MATERIAL PROPERTIES (FERRITE)

Go to Material -> Edit -> choose needed material (e.g. ferrite) and go to View/Edit materials:



Properties

Name	Value	Unit	Evaluated Value
Name	Shielding		
Material	"vacuum"		"vacuum"
Solve Inside	Edit...		
Orientation	"vacuum"		
Model	☒		
Group	Model		
Display Wi...	☐		
Material A...	☐		
Color			
Transparent	0		

Select Definition

Materials | Material Filters

Search Parameters
Search by Name
ferrite

Search Criteria
☒ by Name ☐ by Property
Relative Permittivity

Libraries ☒ Show Project definitions ☐ Select all libraries
[sys] Materials

Name	Location	Origin	Relative Permittivity	Relative Permeability	Bulk Conductivity
ferrite	SysLibrary	Materials	12	1000	0.01
FR4_epoxy	SysLibrary	Materials	4.4	1	0
gallium_arsenide	SysLibrary	Materials	12.9	1	0
GE GETEK ML200/RG200 (tm)	SysLibrary	Materials	3.9	1	0
GIL GML1000 (tm)	SysLibrary	Materials	3.12	1	0
GIL GML1032 (tm)	SysLibrary	Materials	3.2	1	0
GIL GML2032 (tm)	SysLibrary	Materials	3.2	1	0
GIL MC5 (tm)	SysLibrary	Materials	3.2	1	0
glass	SysLibrary	Materials	5.5	1	0
glass_PTFEreinf	SysLibrary	Materials	2.5	1	0
gold	SysLibrary	Materials	1	0.99996	41000000
graphite	SysLibrary	Materials	1	1	70000
HDPE elastic	SysLibrary	Materials	2.3	1	0

View / Edit Material

Material Name: ferrite
Material Coordinate System Type: Cartesian

Properties of the Material

Name	Type	Value	Units
Relative Permittivity	Simple	12	
Relative Permeability	Simple	3000	
Bulk Conductivity	Simple	0.01	siemens/m
Dielectric Loss Tangent	Simple	0	
Magnetic Loss Tangent	Simple	0	
Core Loss Model		None	w/m^3
Mass Density	Simple	4600	kg/m^3
Composition		Solid	

View/Edit Material for:
☒ Active Design
☐ Active Project
☐ All Properties
Physics:
☒ Electromagnetic
☒ Thermal
☒ Structural

View/Edit Modifier for:
☐ Thermal Modifier
☐ Spatial Modifier

Material Appearance
☒ Use Material Appearance
Color:
Transparency: 0

Notes:

Calculate Properties for:

Reset OK Cancel

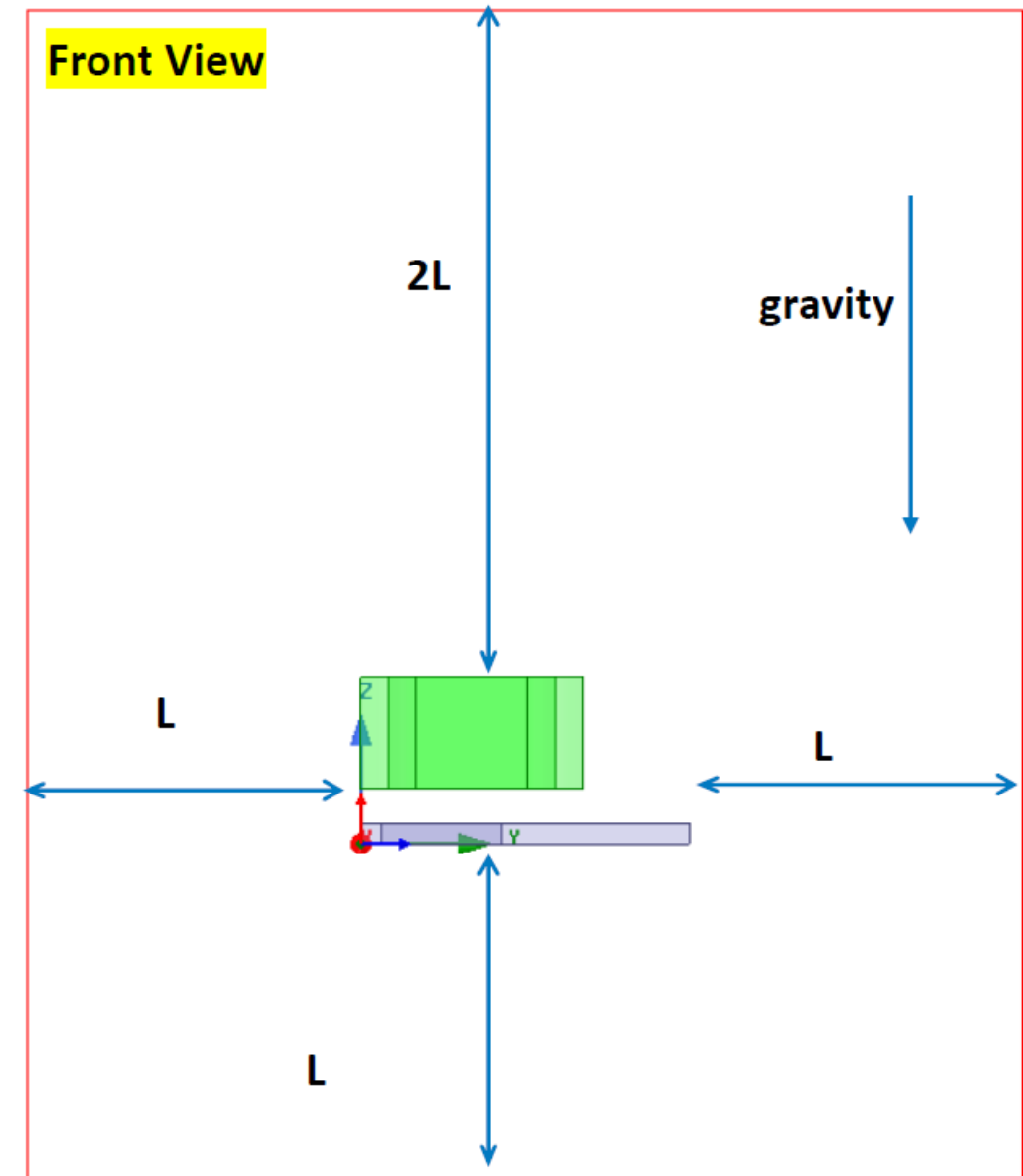
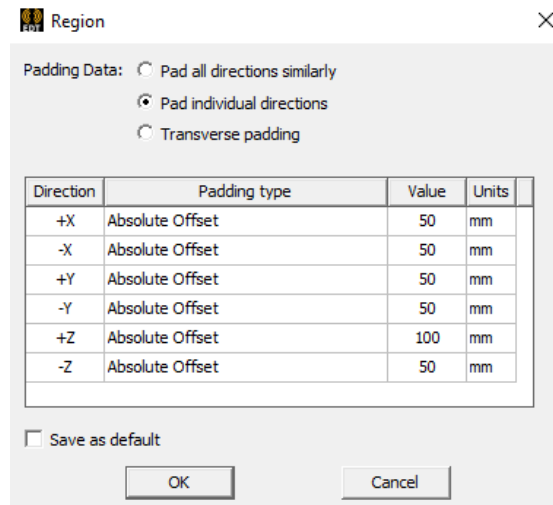
Validate Material

Relative permeability: ~ 3000

SIMULATION WORKFLOW: REGION SIZING

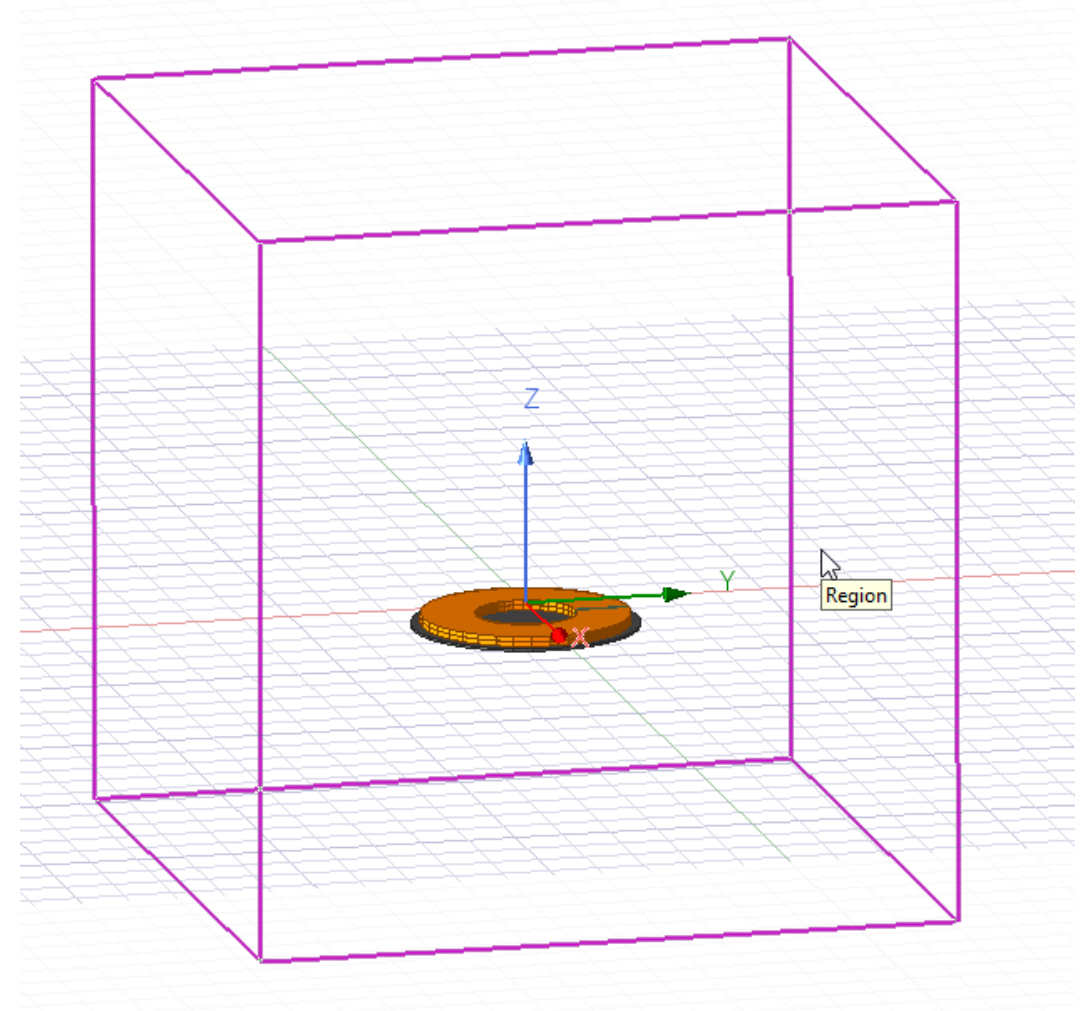
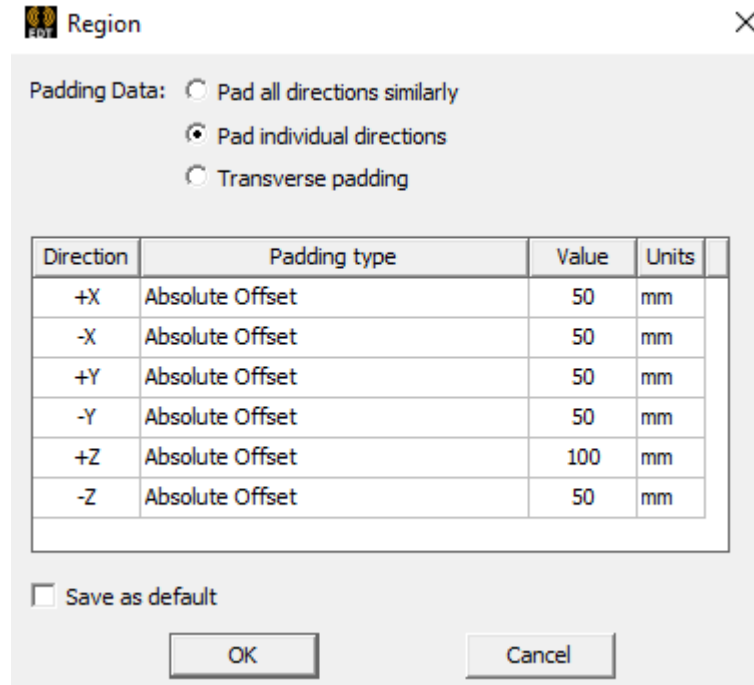
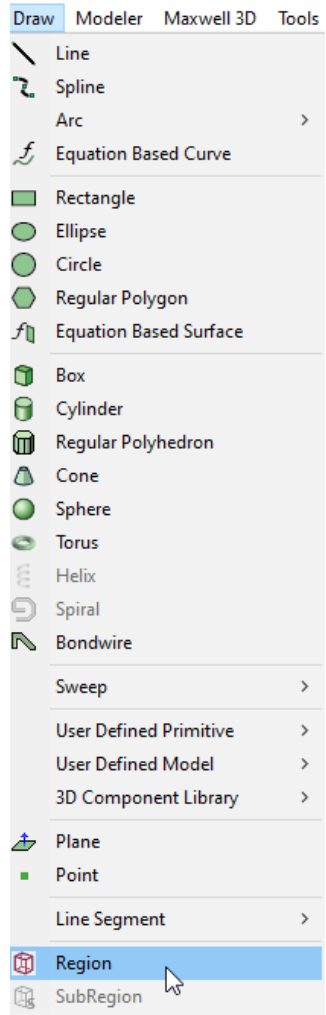
- Rules of thumb recommended by Ansys:
- Top (against gravity): At least $2L$
- Sides and below: at least L
- Where L is the largest dimension of the unit in 3 directions

In this case: $L \sim 50$ mm



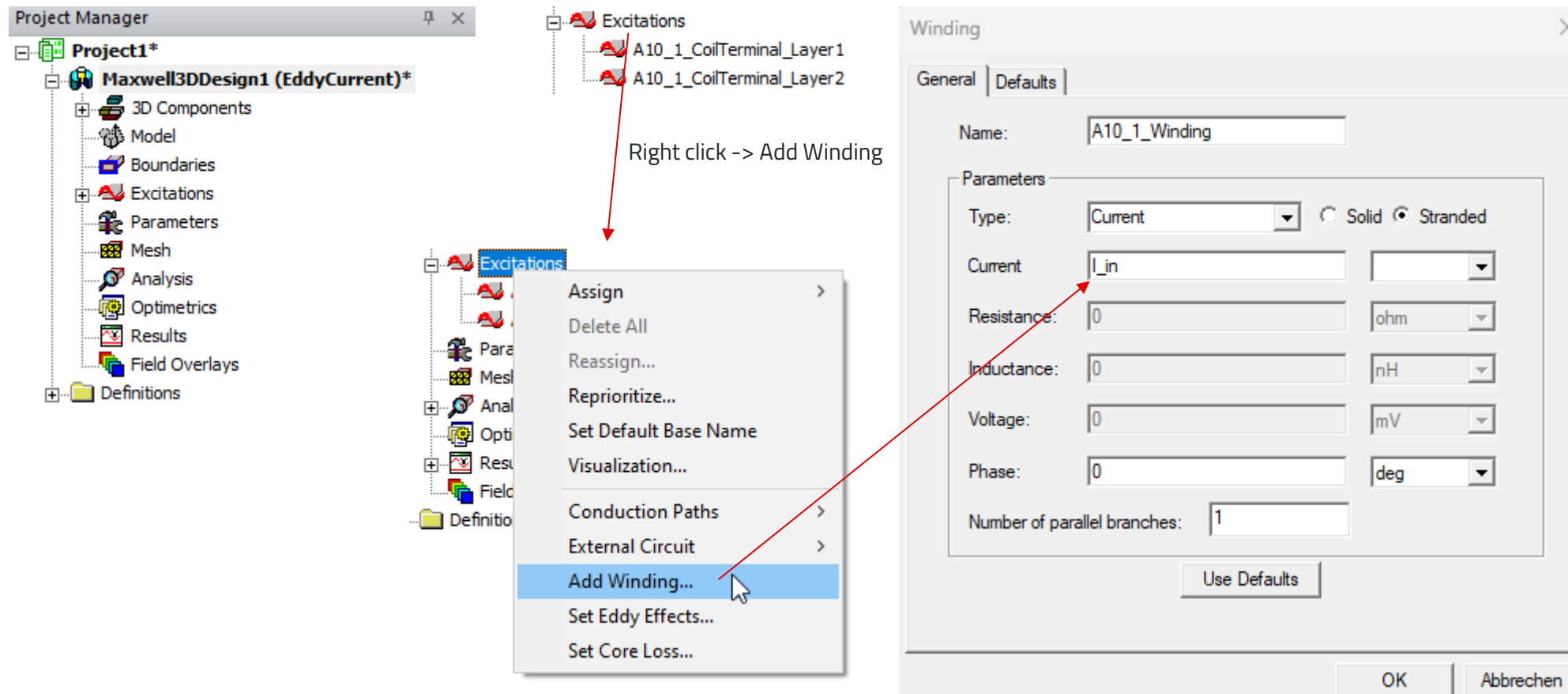
3D SIMULATION WORKFLOW: DEFINE THE REGION

The space, in which the electromagnetic field has to be calculated, is called the region, it is defined as default as vacuum



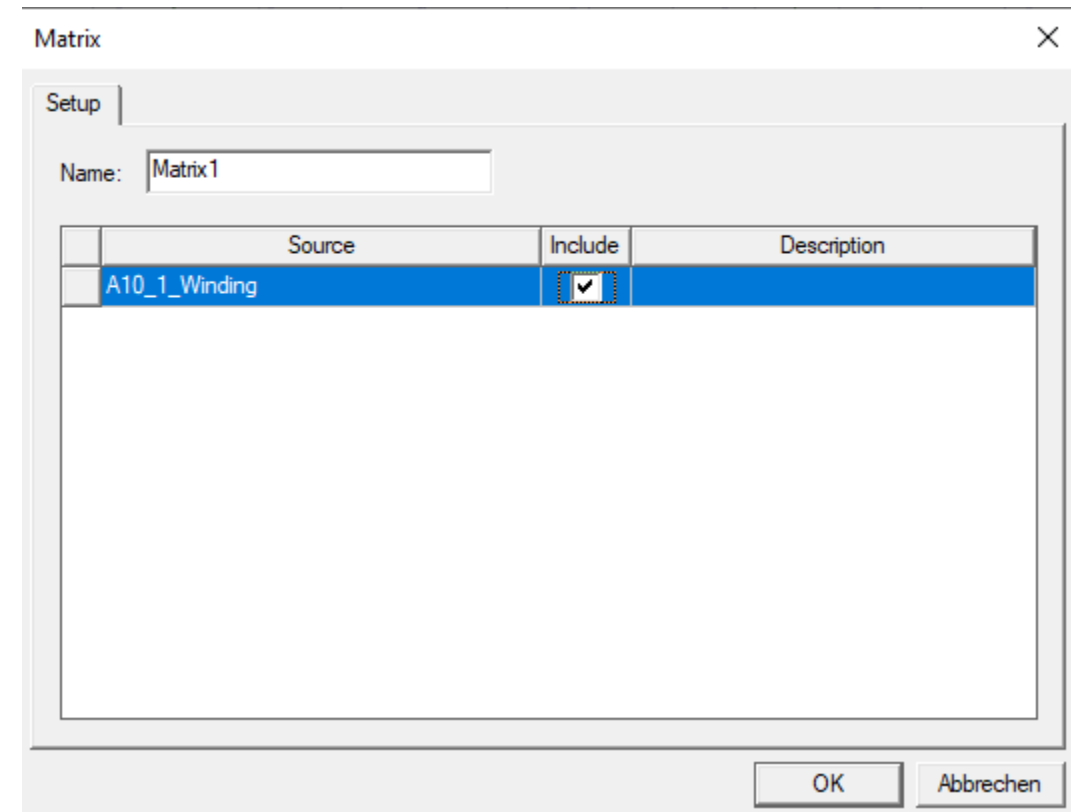
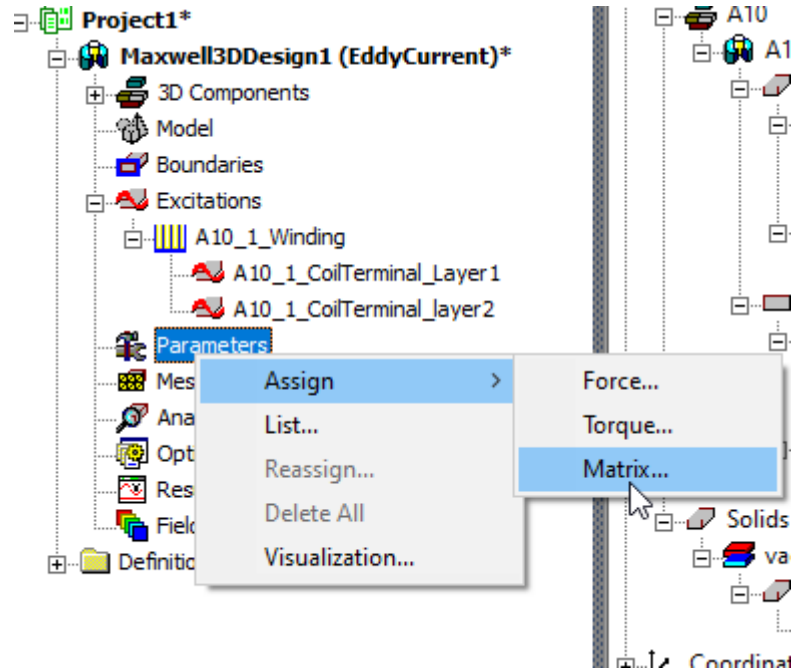
3D SIMULATION WORKFLOW: SETTINGS

- Some settings have to be made at the Project Manager: Excitations, Parameters, Analysis and Results
- Excitations: Define the variable I_{in} for the AC amplitude variable



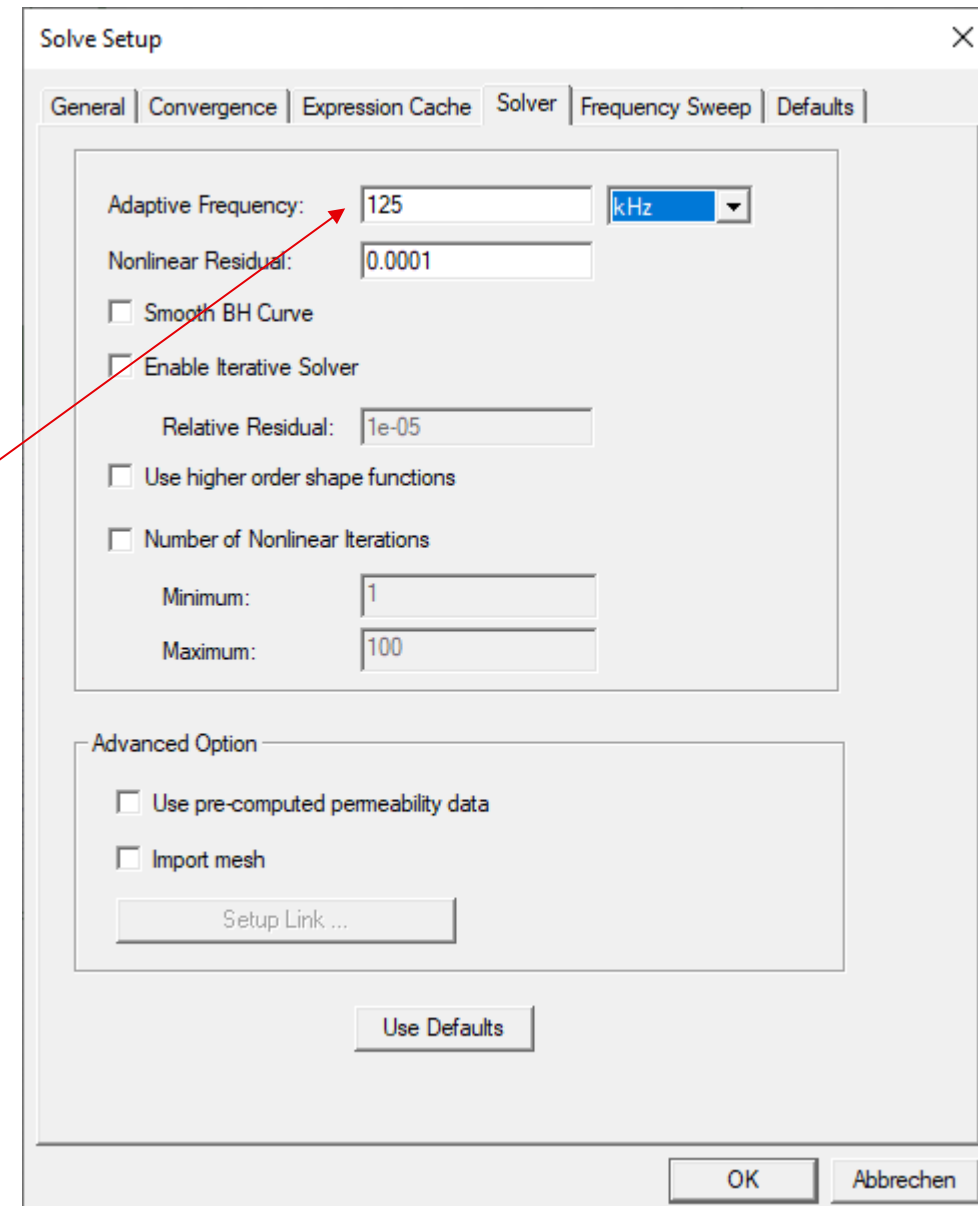
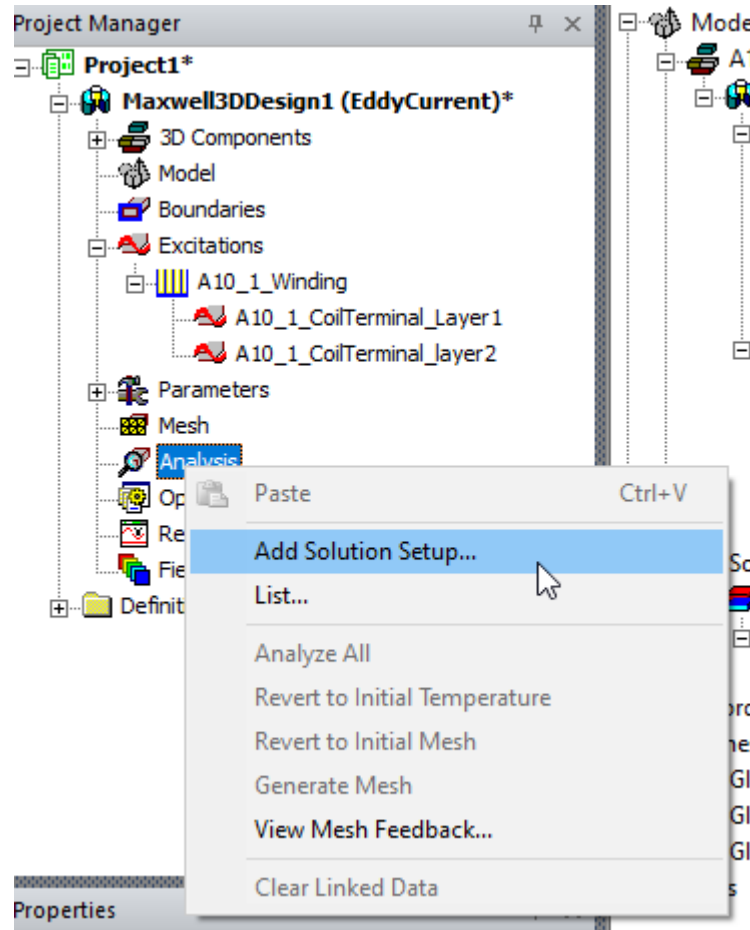
3D SIMULATION WORKFLOW: SETTINGS

- Parameters:

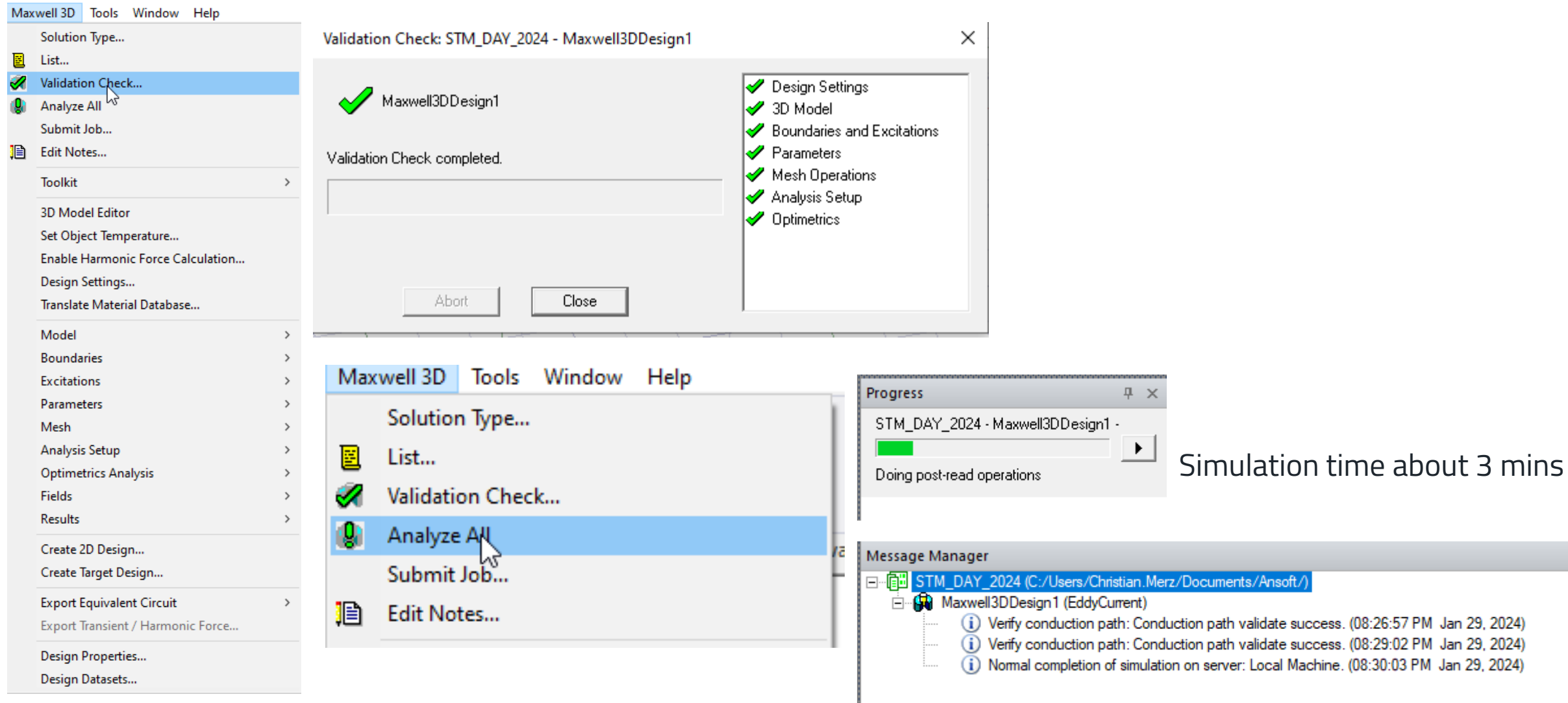


3D SIMULATION WORKFLOW: SETTINGS

■ Analysis:



3D SIMULATION WORKFLOW: VALIDATION AND ANALYZATION



The image displays the Maxwell 3D software interface during a simulation workflow. The main menu bar includes Maxwell 3D, Tools, Window, and Help. The Tools menu is open, showing options like Solution Type..., List..., Validation Check..., Analyze All, Submit Job..., and Edit Notes... The Validation Check dialog box is open, titled "Validation Check: STM_DAY_2024 - Maxwell3DDesign1". It shows a green checkmark and the text "Validation Check completed." The dialog box also lists the following items with green checkmarks: Design Settings, 3D Model, Boundaries and Excitations, Parameters, Mesh Operations, Analysis Setup, and Optimetrics. The Analyze All option in the Tools menu is highlighted. The Progress window shows the simulation progress for "STM_DAY_2024 - Maxwell3DDesign1" with a green progress bar and the text "Doing post-read operations". The Message Manager window shows the simulation results, including "Verify conduction path: Conduction path validate success" and "Normal completion of simulation on server: Local Machine".

Maxwell 3D Tools Window Help

Solution Type...
List...
Validation Check...
Analyze All
Submit Job...
Edit Notes...

Validation Check: STM_DAY_2024 - Maxwell3DDesign1

Maxwell3DDesign1

Validation Check completed.

Design Settings
3D Model
Boundaries and Excitations
Parameters
Mesh Operations
Analysis Setup
Optimetrics

Abort Close

Maxwell 3D Tools Window Help

Solution Type...
List...
Validation Check...
Analyze All
Submit Job...
Edit Notes...

Progress

STM_DAY_2024 - Maxwell3DDesign1

Doing post-read operations

Simulation time about 3 mins

Message Manager

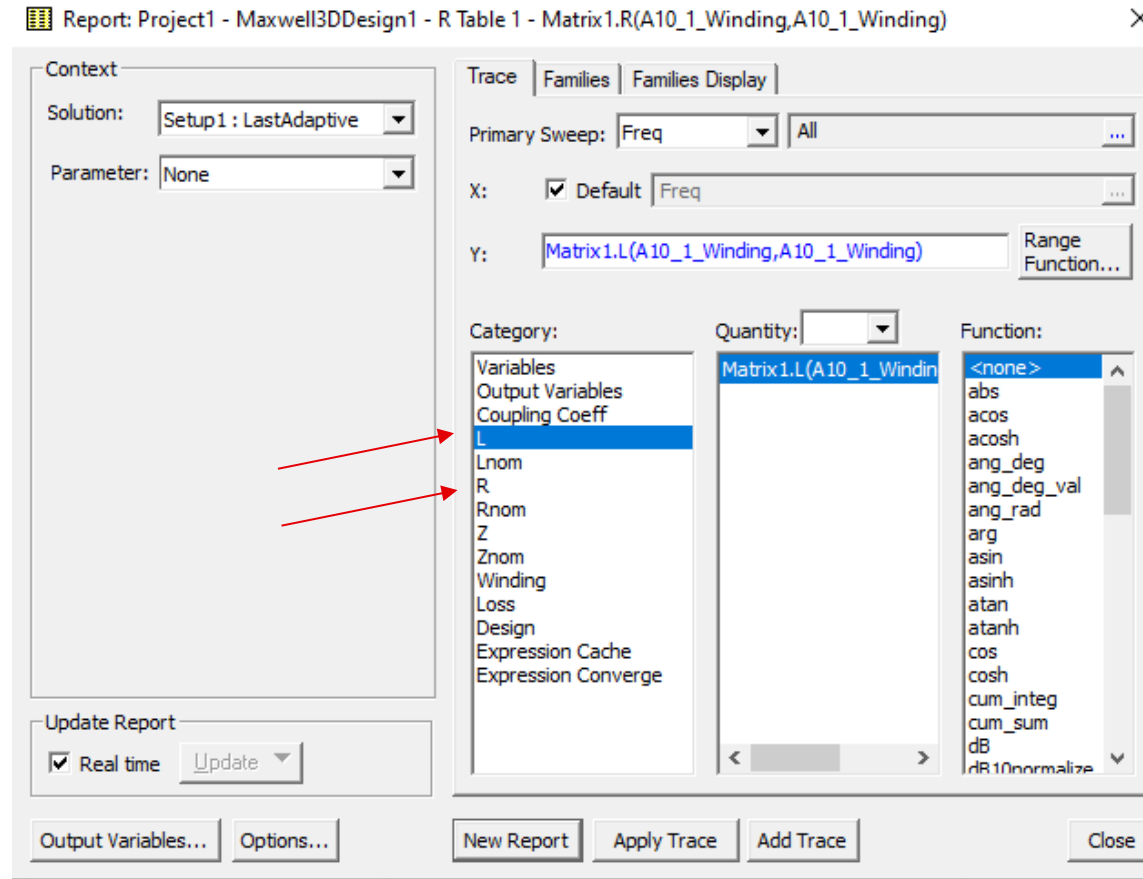
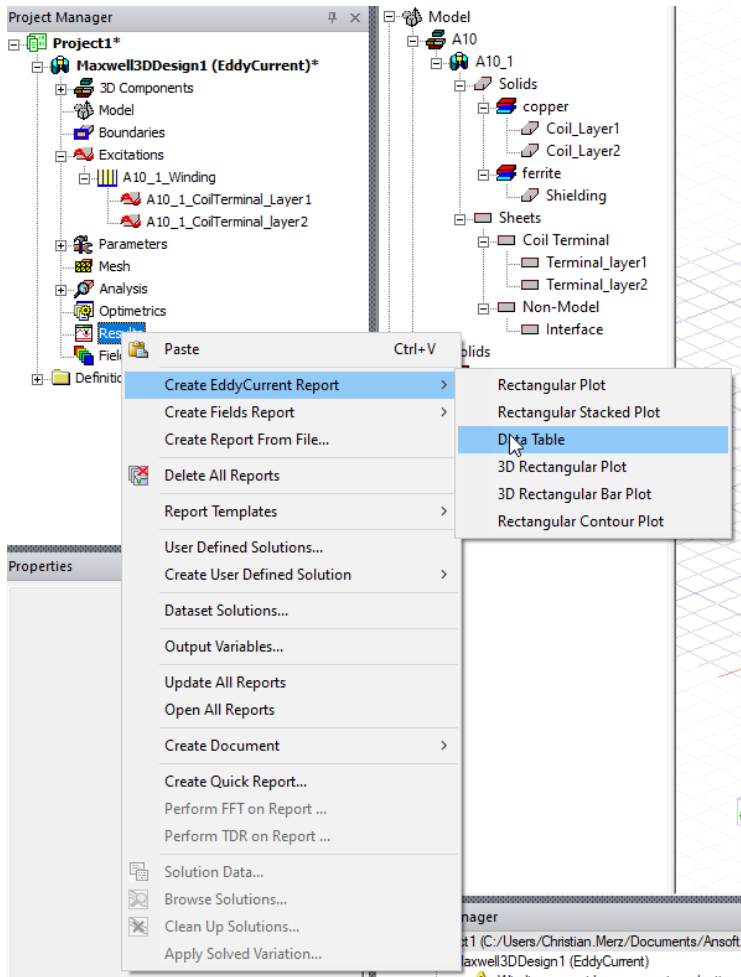
STM_DAY_2024 (C:/Users/Christian.Merz/Documents/Ansoft/)

Maxwell3DDesign1 (EddyCurrent)

- Verify conduction path: Conduction path validate success. (08:26:57 PM Jan 29, 2024)
- Verify conduction path: Conduction path validate success. (08:29:02 PM Jan 29, 2024)
- Normal completion of simulation on server: Local Machine. (08:30:03 PM Jan 29, 2024)

3D SIMULATION WORKFLOW: SETTINGS

Results:



3D SIMULATION: INDUCTANCE AND R,AC

Inductance

Freq [kHz]	Matrix1.L(A10_1_Winding,A10_1_Winding) [uH] Setup1 : LastAdaptive
125.000000	23.752755

A10 coil in the datasheet: $24 \mu\text{H} \pm 10 \%$ @ 125 kHz

Deviation between simulated and nominal value: only 1%

R,ac

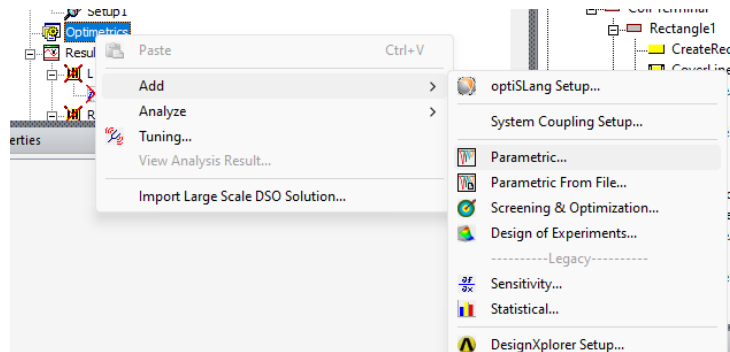
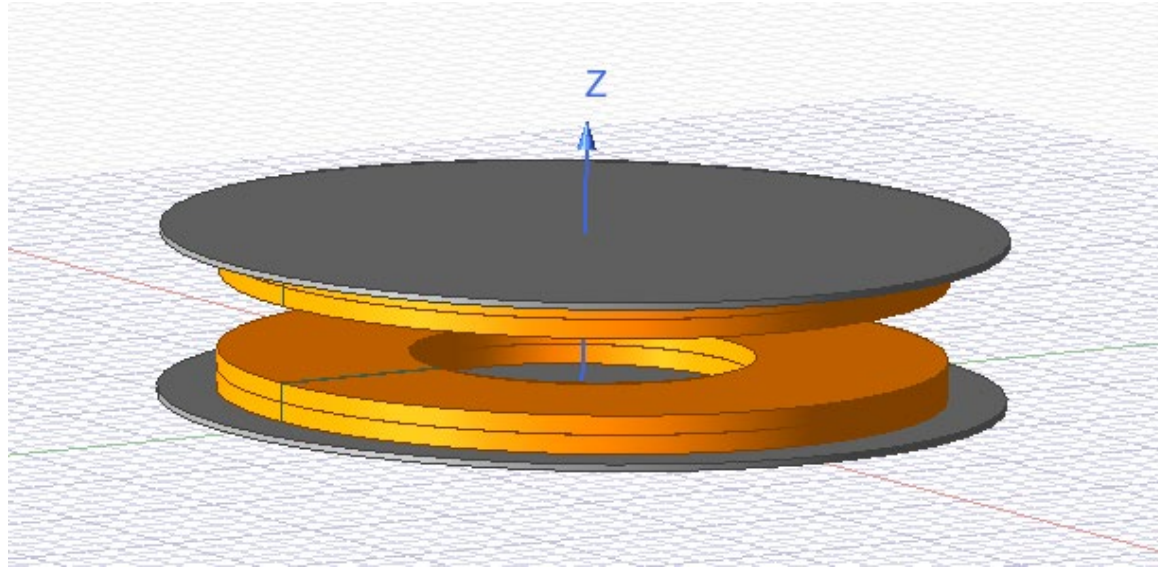
	Freq [kHz]	Matrix1.R(Winding1,Winding1) [mOhm] Setup1 : LastAdaptive
1	125.000000	92.091459

Measured value with LCR-Meter @ 125 kHz: 96 m Ω

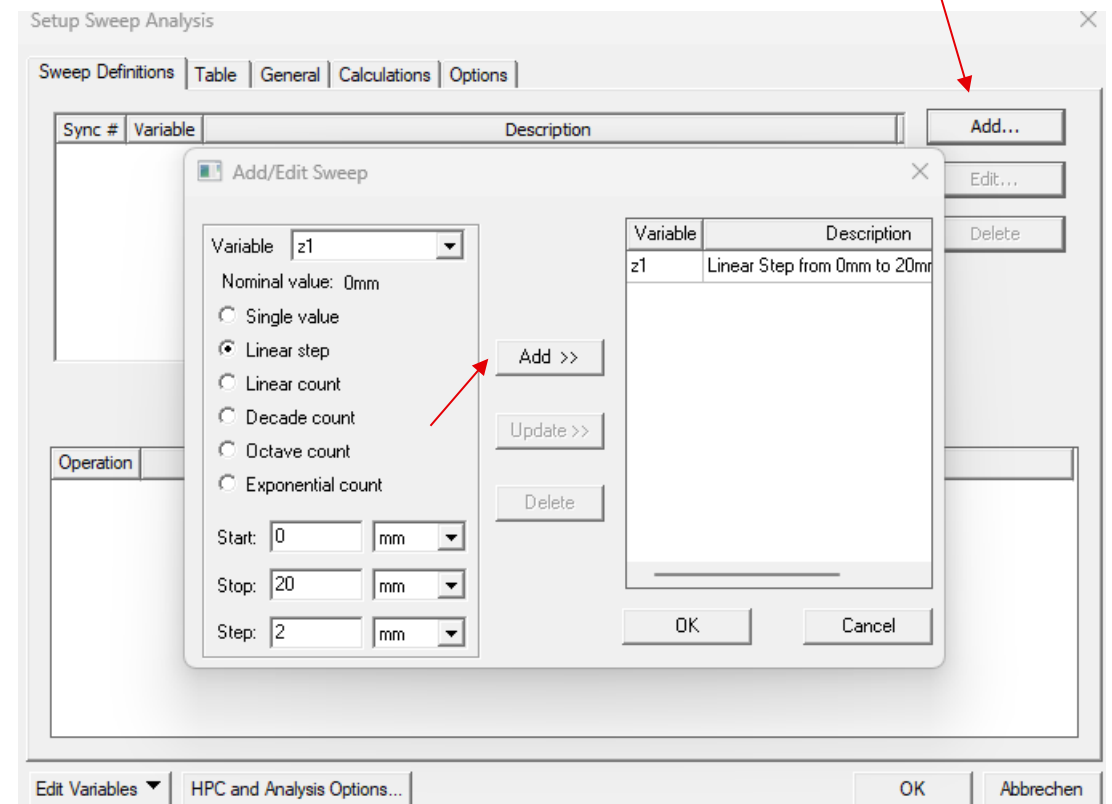
Deviation between simulated and measured value: only 4%

SIMULATION: COUPLING BETWEEN TWO IDENTICAL COILS

The A10 Coil has been copied and flipped above the other coil, the coupling factor in dependence of the vertical misalignment has been simulated

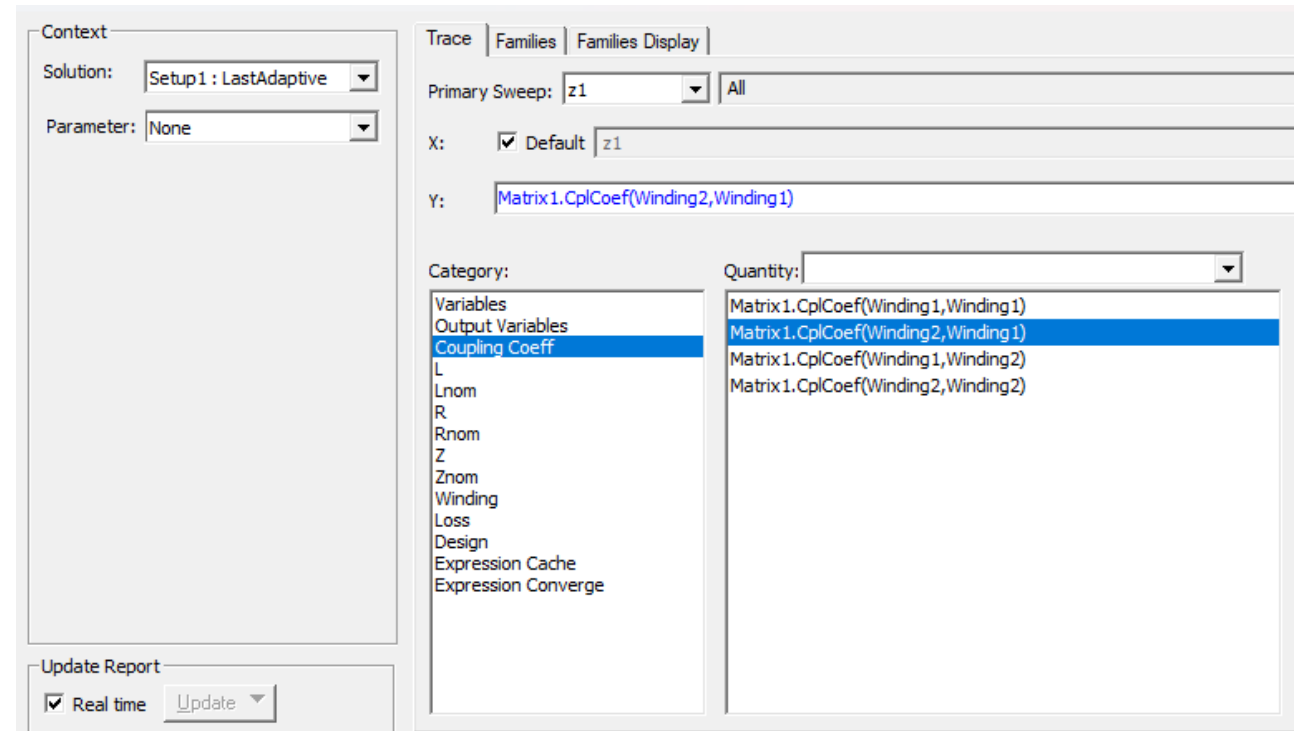
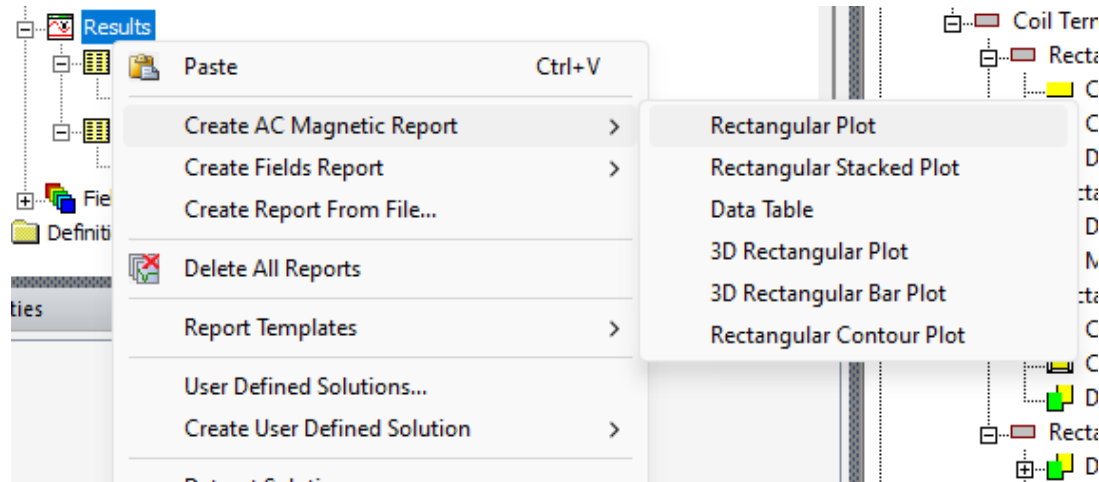


Vertical distance variable: z1



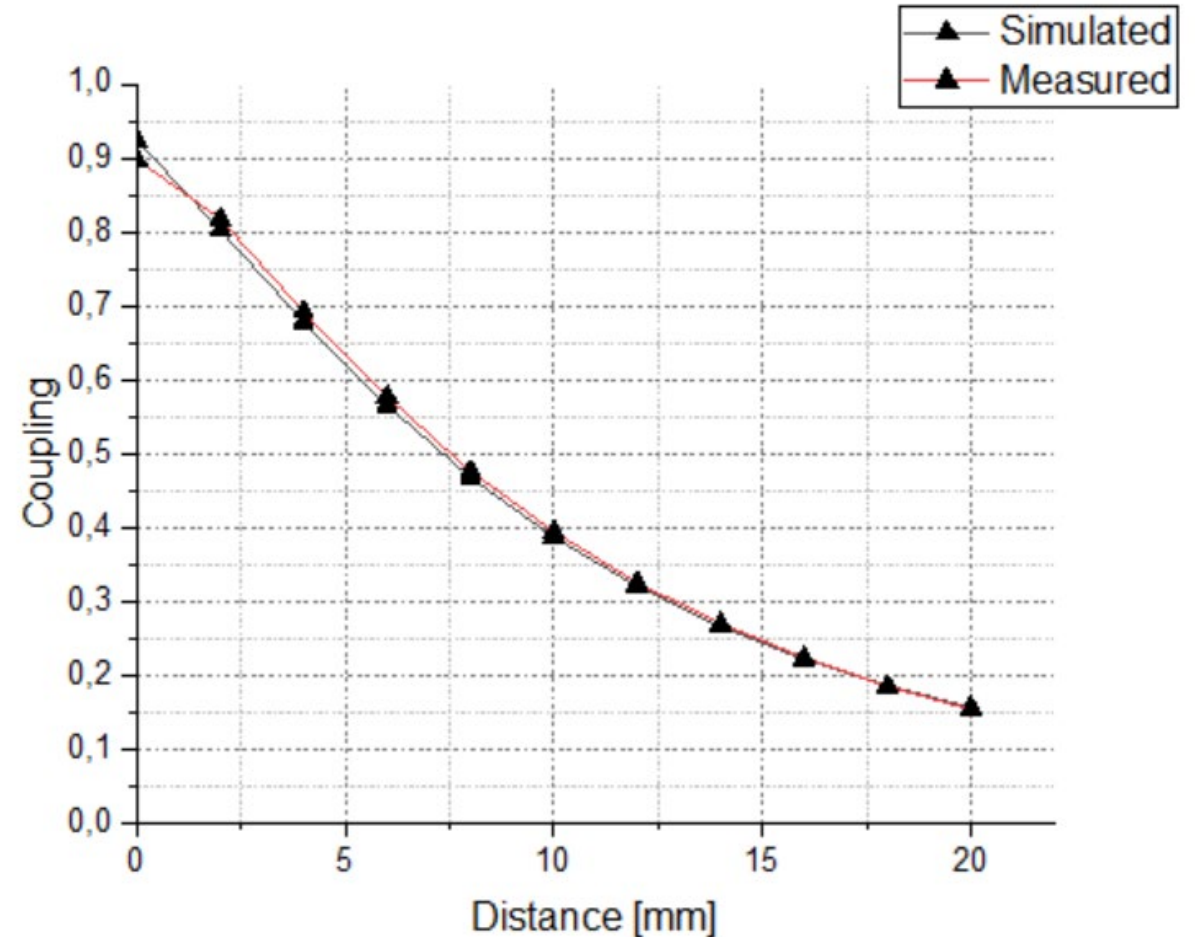
SIMULATION: COUPLING BETWEEN TWO IDENTICAL COILS

The A10 Coil has been copied and flipped above the other coil, the coupling factor in dependence of the vertical misalignment has been simulated



SIMULATION: COUPLING BETWEEN TWO IDENTICAL COILS

The A10 Coil has been copied and flipped above the other coil, the coupling factor in dependence of the vertical misalignment has been simulated



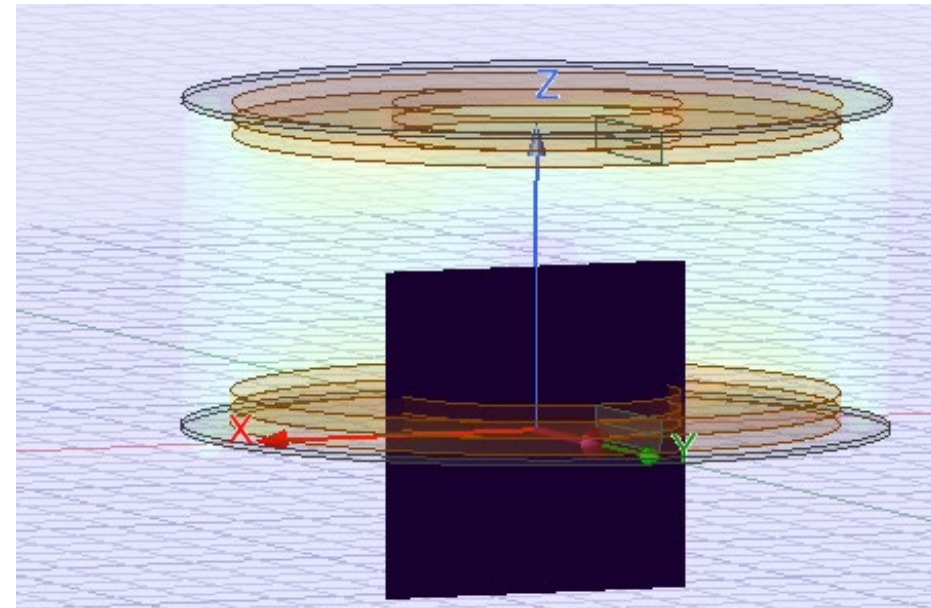
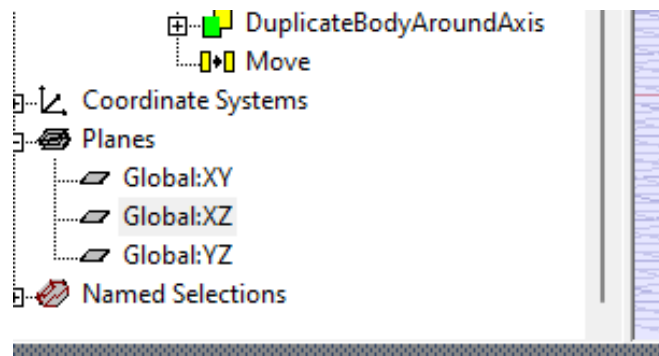
$$k = \sqrt{1 - \frac{L'_1}{L_1}}$$

Variation of 0.5%-3 %

SIMULATION: MAGNETIC FIELD BETWEEN TWO IDENTICAL COILS

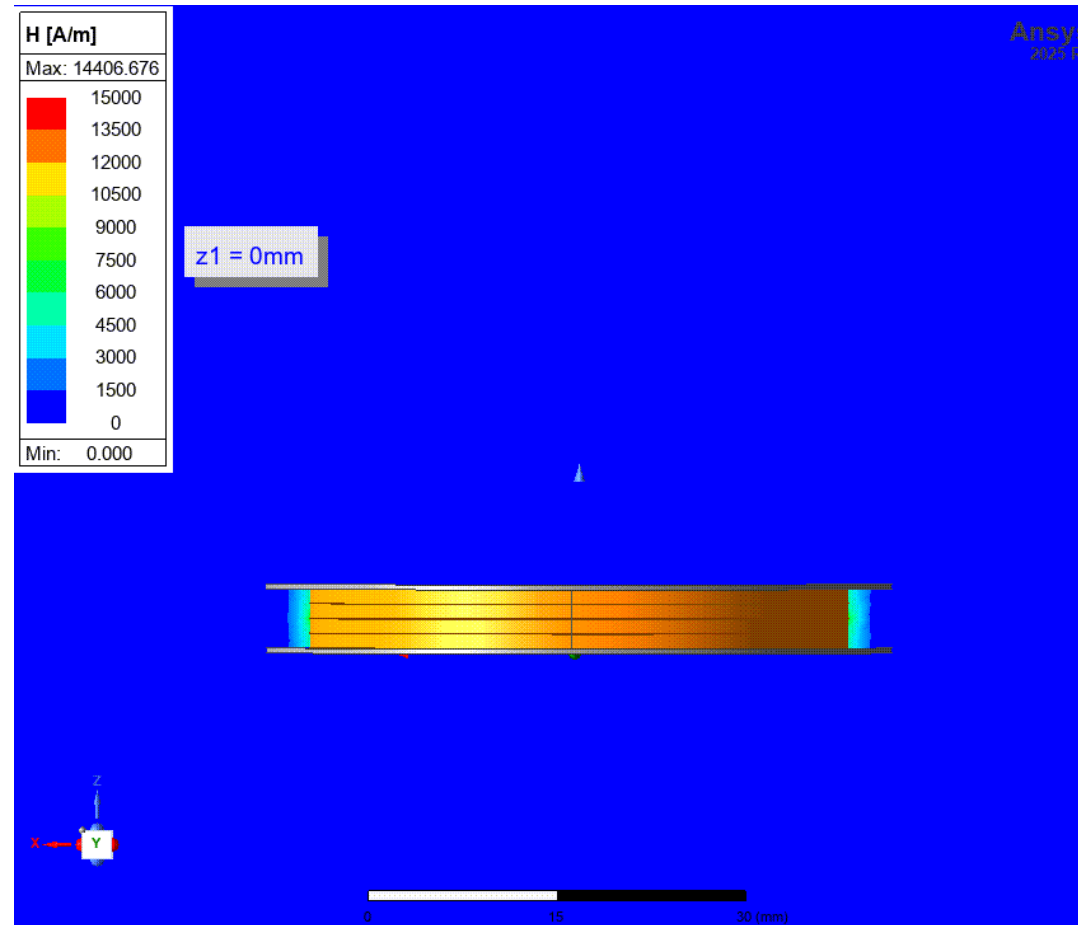
Absolut Value of the magnetic field H [A/m] has been simulated at the distances between 0 – 20 mm

1. Select a geometry, in which the field distribution should be shown (e .g. XZ plane)



SIMULATION: MAGNETIC FIELD BETWEEN TWO IDENTICAL COILS

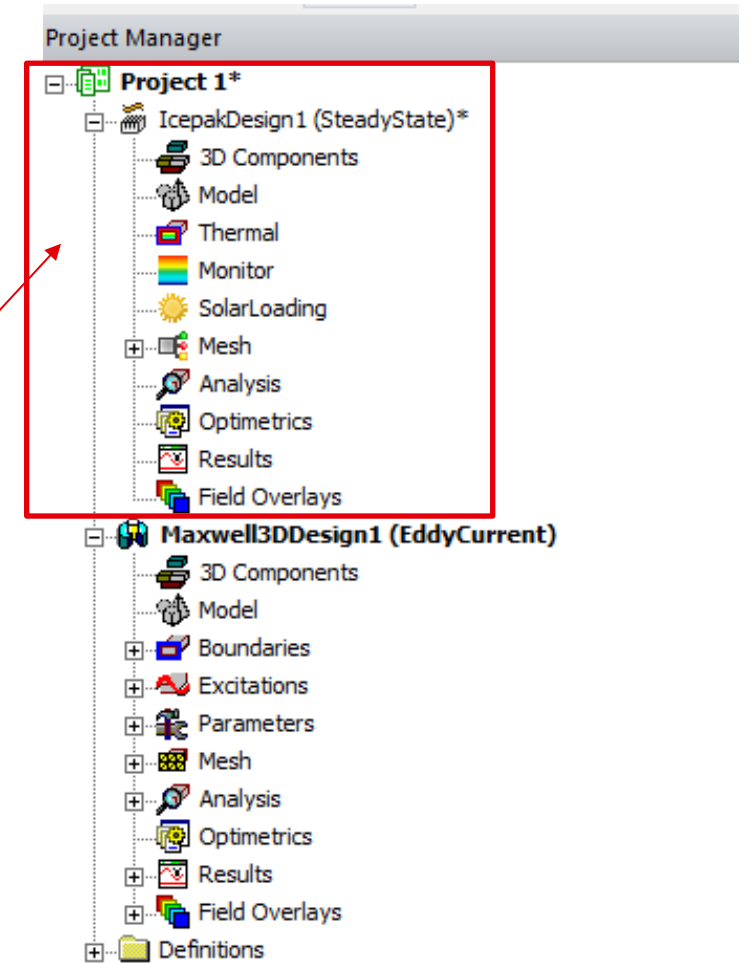
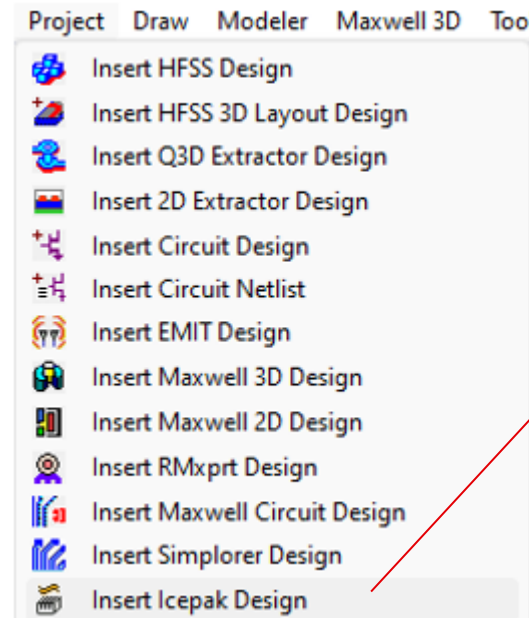
Absolut Value of the magnetic field H [A/m] has been simulated at the distances between 0 – 20 mm



ICEPAK MODULE

Workflow of the ICEPAK Module

1. After the 3D design is done and simulated, the ICEPAK module has to be inserted
Projects -> Insert ICEPAK Design

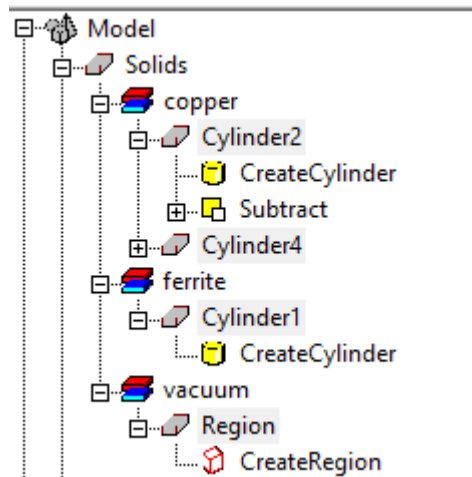


ICEPAK MODULE

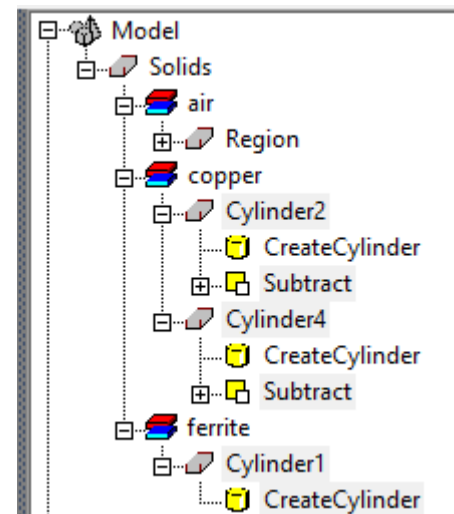
Workflow of the ICEPAK Module

2. Copy the model of the 3D design into the ICEPAK history tree

Maxwell 3D Design History Tree



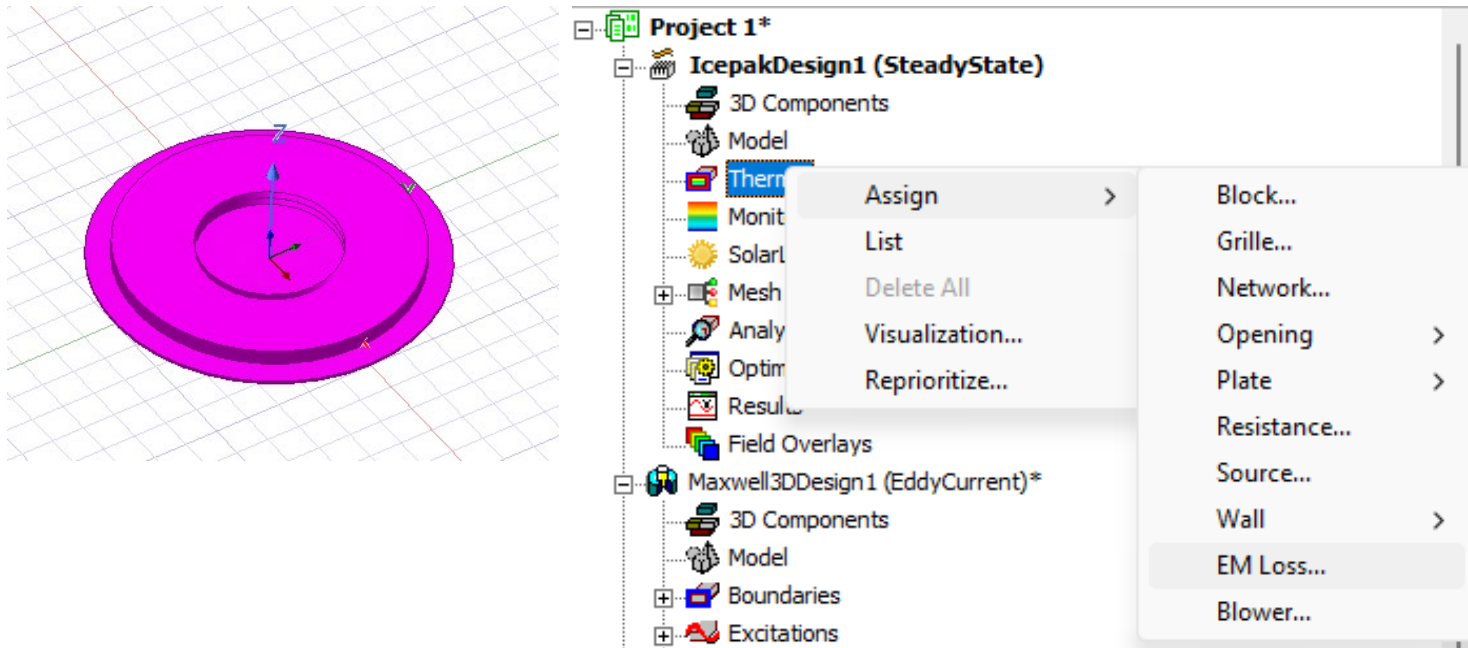
ICEPAK History Tree



ICEPAK MODULE

Workflow of the ICEPAK Module

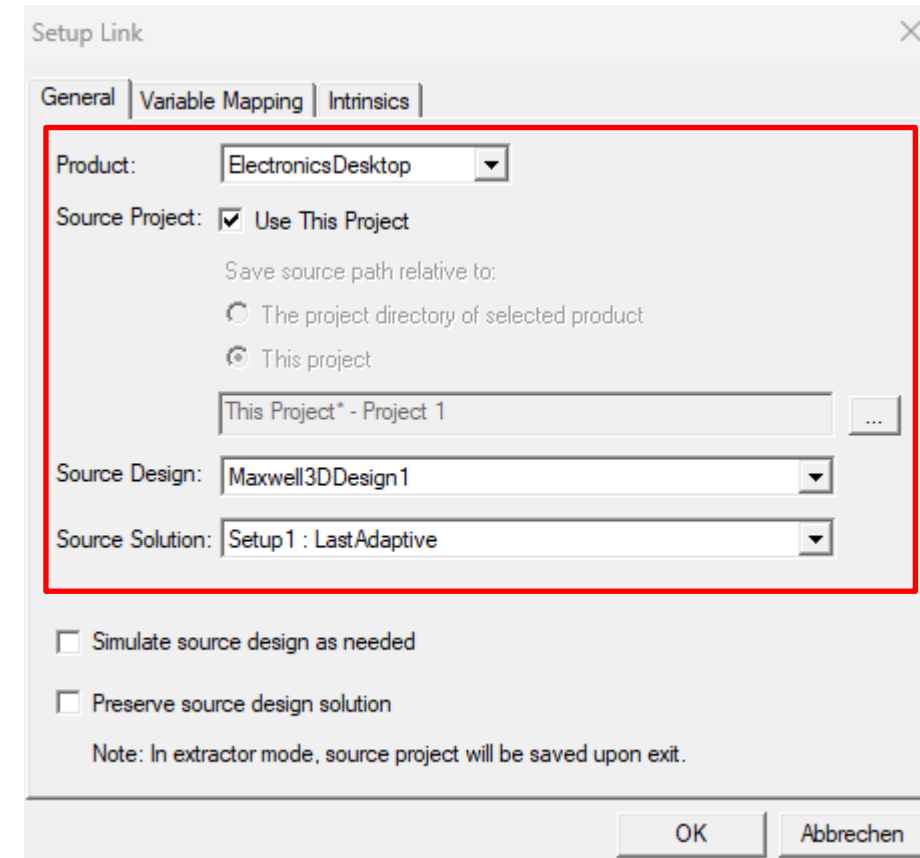
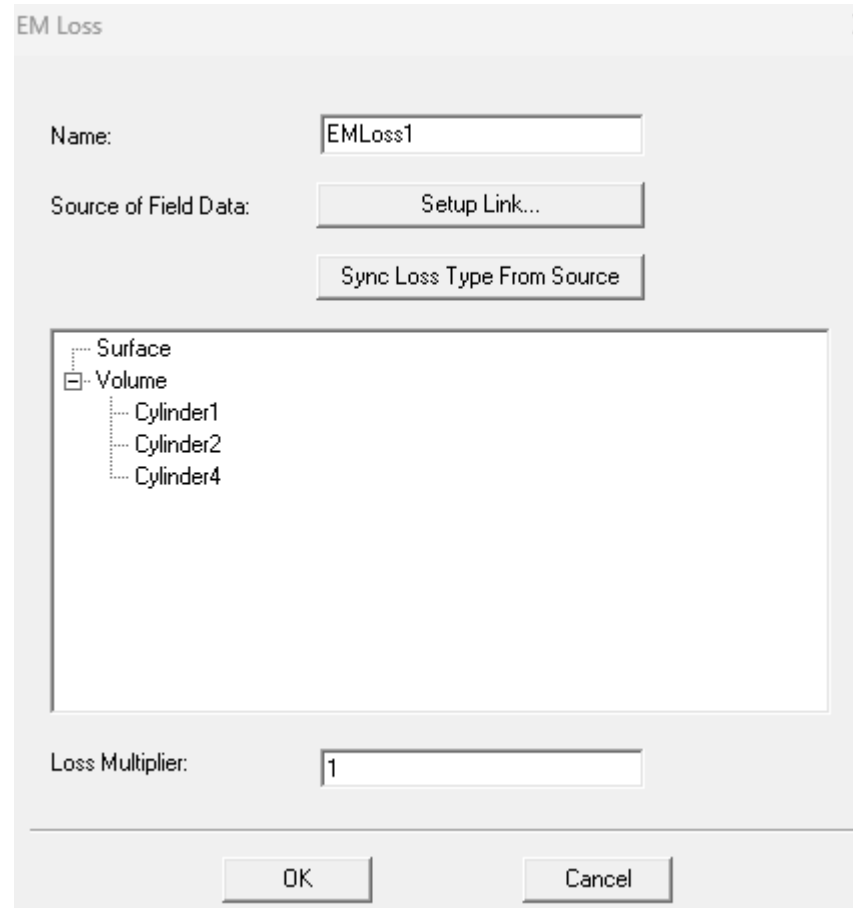
3. Define EM Loss Settings -> Mark the 3d Model and go to Thermal -> Assign -> EM Loss



ICEPAK MODULE

Workflow of the ICEPAK Module

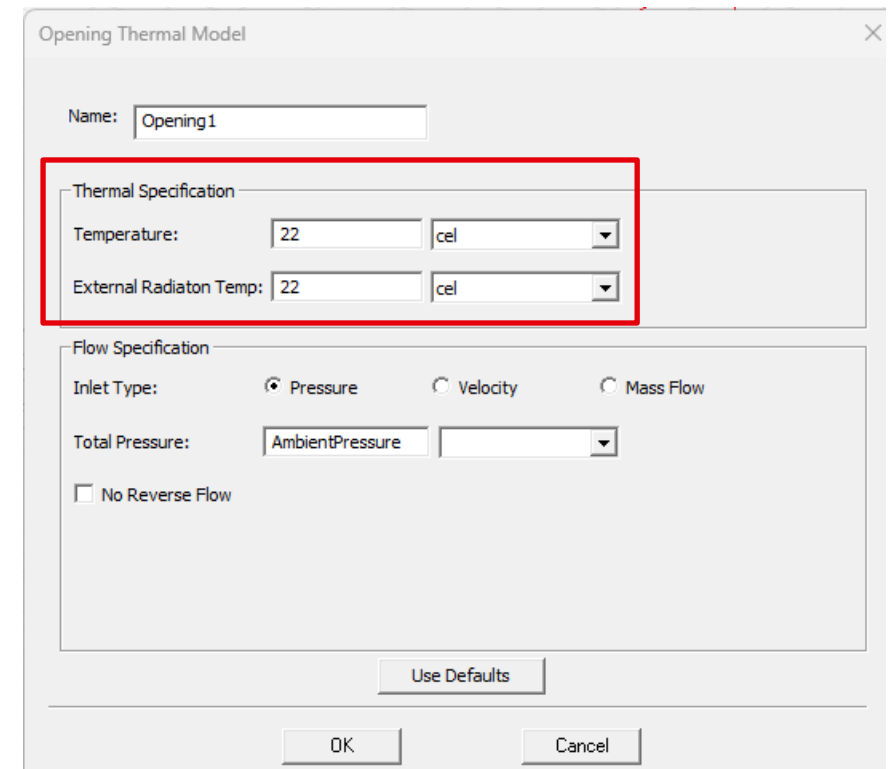
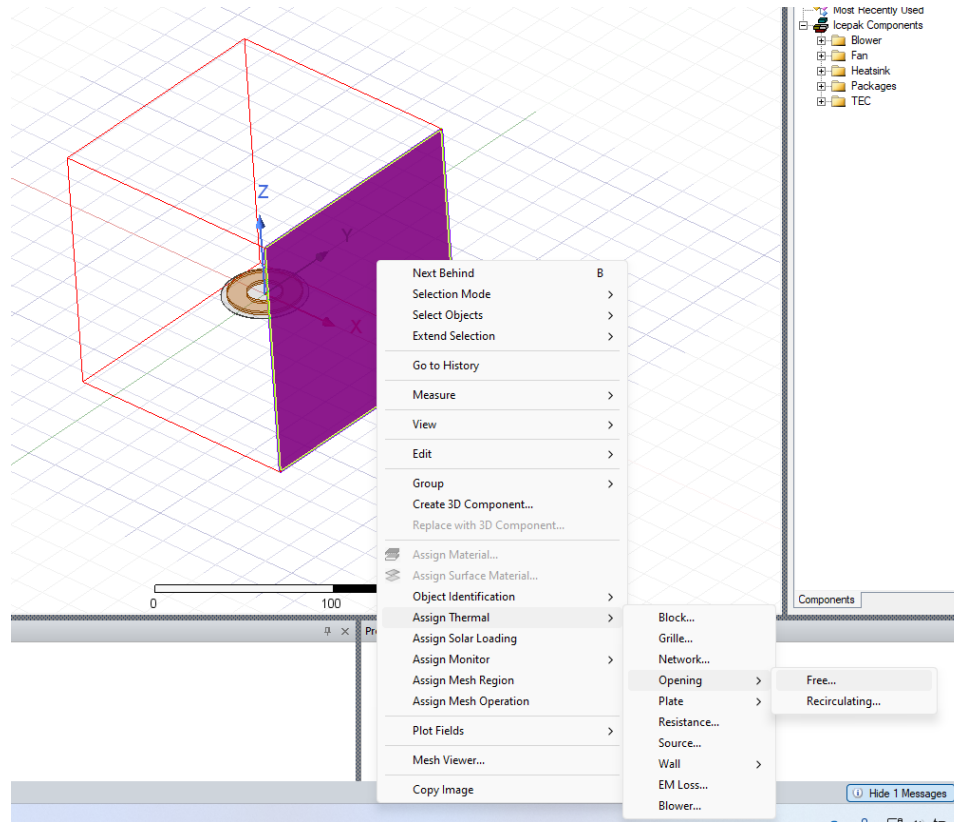
4. Setup the Link between ICEPAK and the 3D design



ICEPAK MODULE

Workflow of the ICEPAK Module

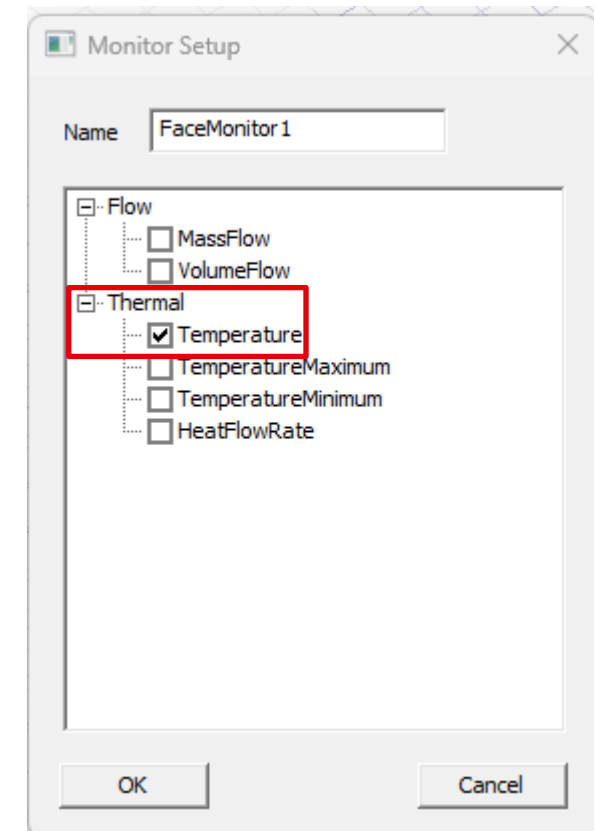
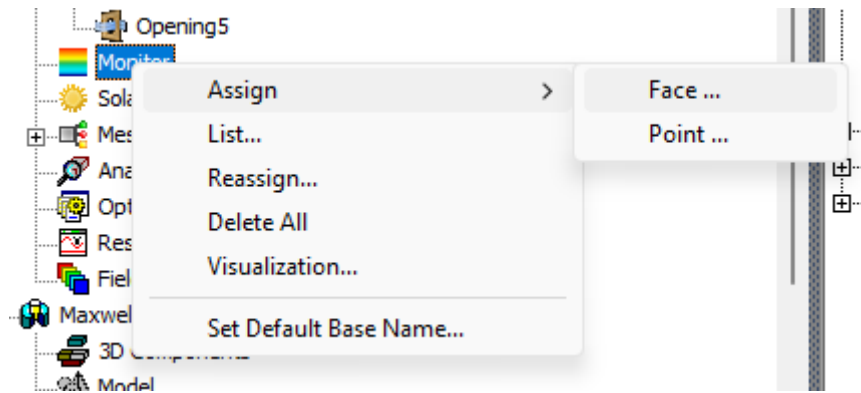
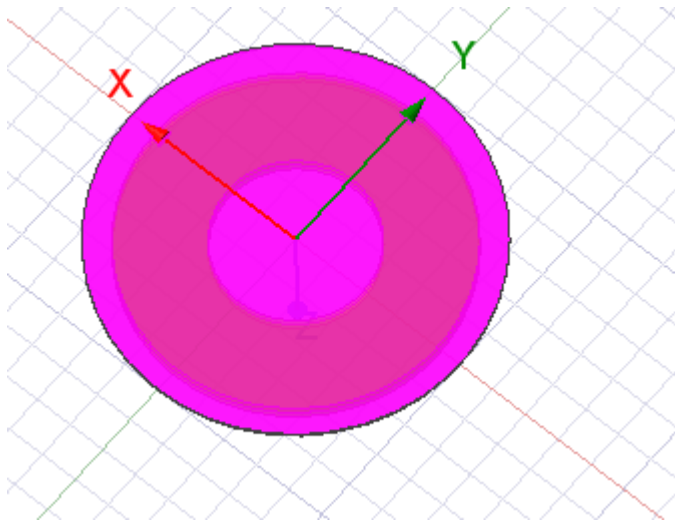
5. Define openings at all faces of the region except bottom) -> mark faces (push F) and right click on assign Thermal-> opening -> free -> define ambient temperature



ICEPAK MODULE

Workflow of the ICEPAK Module

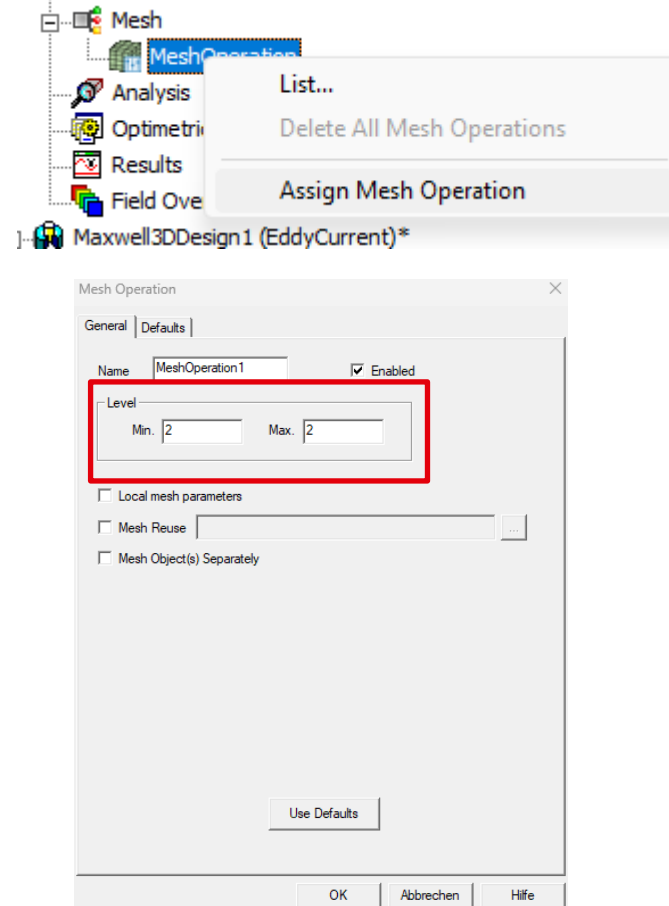
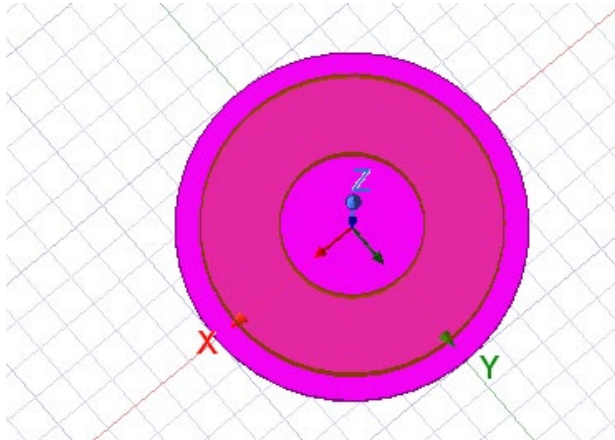
6. Assign temperature monitor -> mark the surface of the ferrite -> click on Monitor -> Assign -> Face -> Monitor Setup Temperature



ICEPAK MODULE

Workflow of the ICEPAK Module

7. Define Mesh -> Mark Coil -> Assign Mesh Operation -> Min, Max value 2



Purpose of the mesh:

Icepak is based on finite volume method

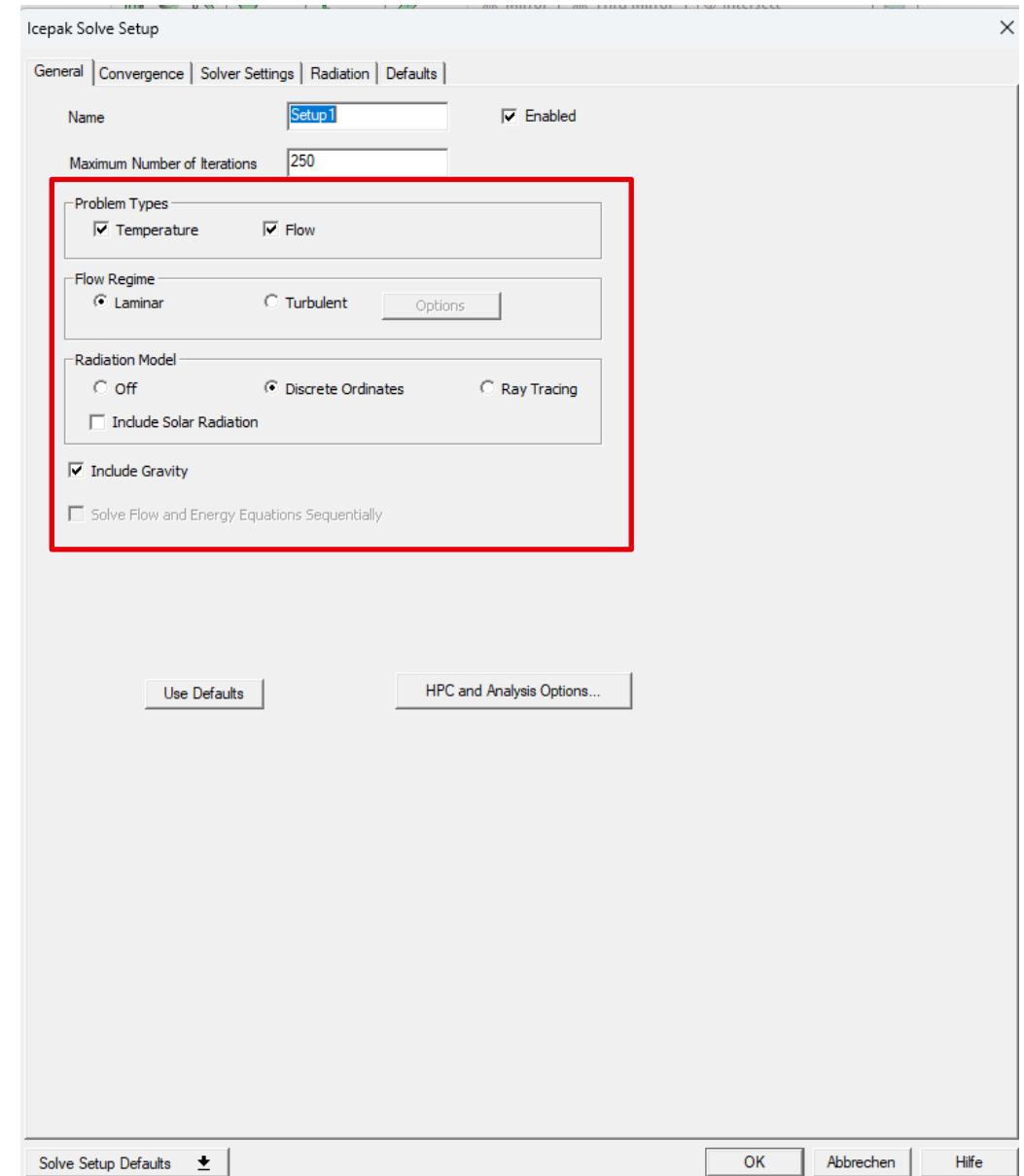
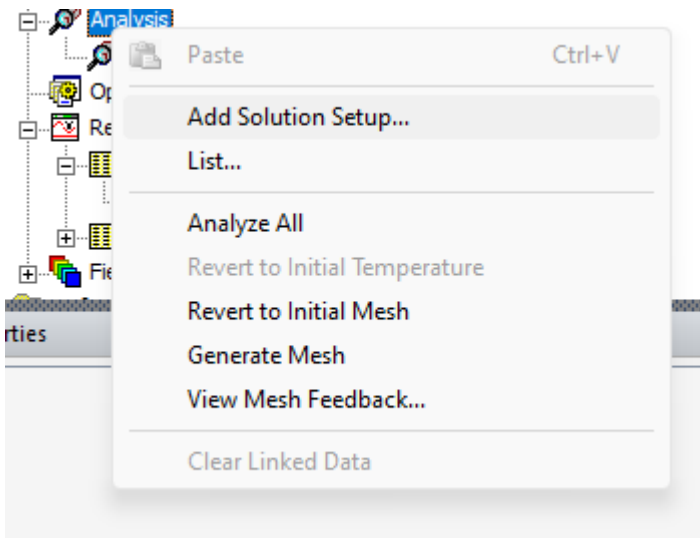
Domain is discretized into a finite set of volumes

➔ The assignment of mesh operating levels improves the meshing near complex or bended geometry in comparison to the default meshing

ICEPAK MODULE

Workflow of the ICEPAK Module

7. Analysis -> Add solution setup



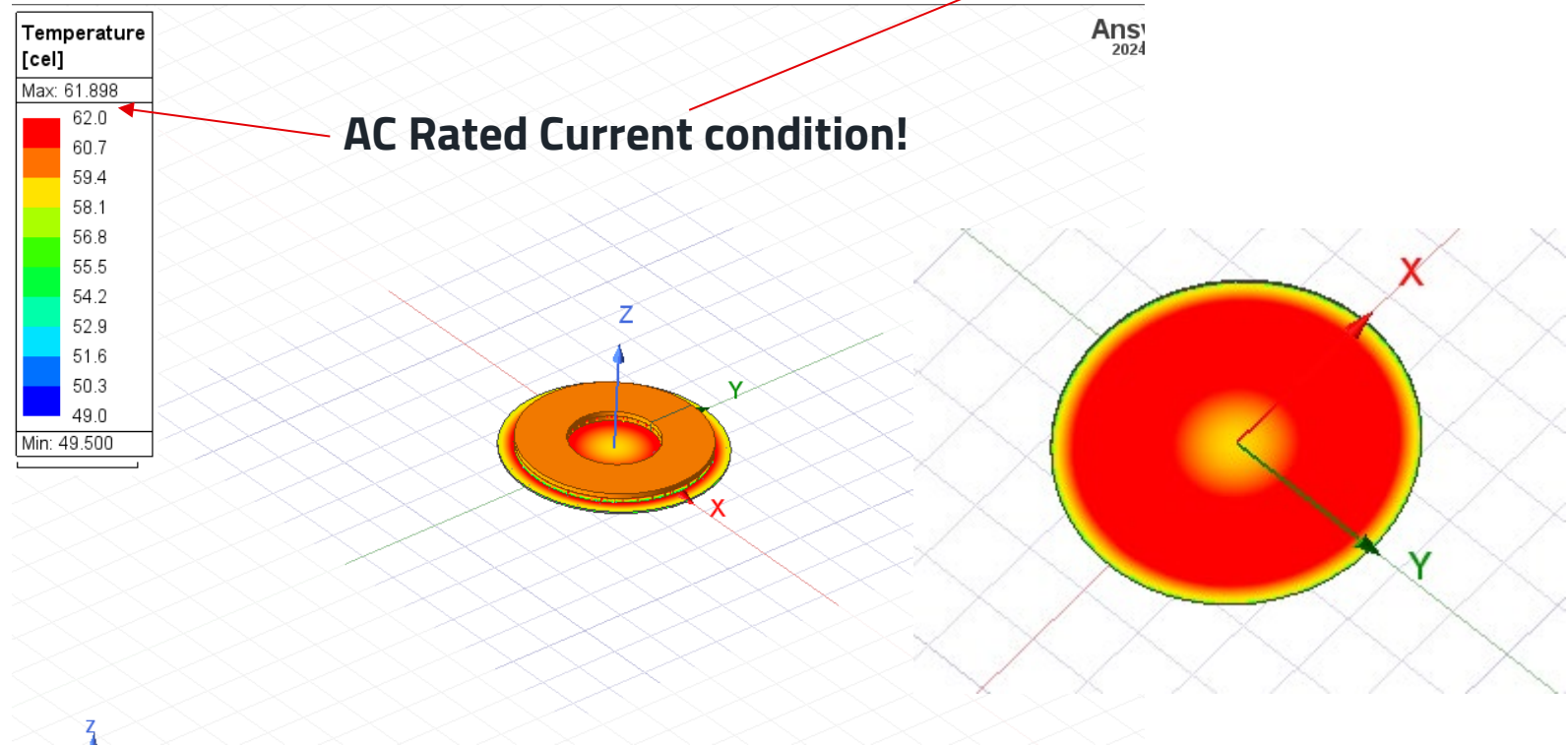
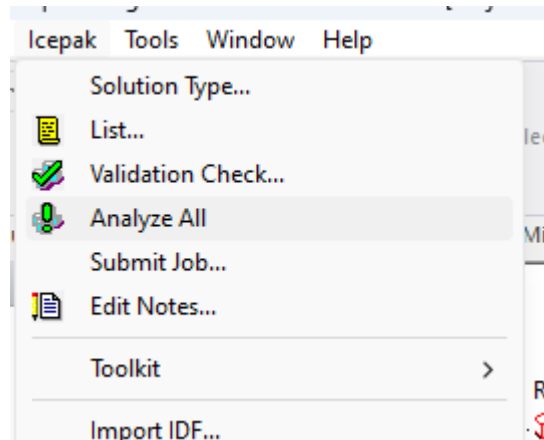
ICEPAK MODULE

Workflow of the ICEPAK Module: Validation of the measurement result

8. Start simulation → ICEPAK → Analyze all

Measured Value: 3.7 A RMS

For 5A amplitude (Variable I_in) (~ **3.5 A RMS**) @ 125 kHz
Ambient Temperature 22 °C



RESULTS

Comparison of simulated and measured results: 3 Examples

Coil	IR,AC (RMS) [A] simulated	IR,AC (RMS) [A] measured	Deviation [%]
760308101410	3.5	3.7	5
760308101304	5.3	5.2	2
760308101141	5.7	5.8	2

THANKS FOR YOUR ATTENTION

Questions?

Contact: wirelesspower@we-online.com