COMSOL CONFERENCE 2017 ROTTERDAM

Determination of NFC-Antenna Operating Distance by Comsol Multiphysics® Simulation of Planar Transformer Modeling

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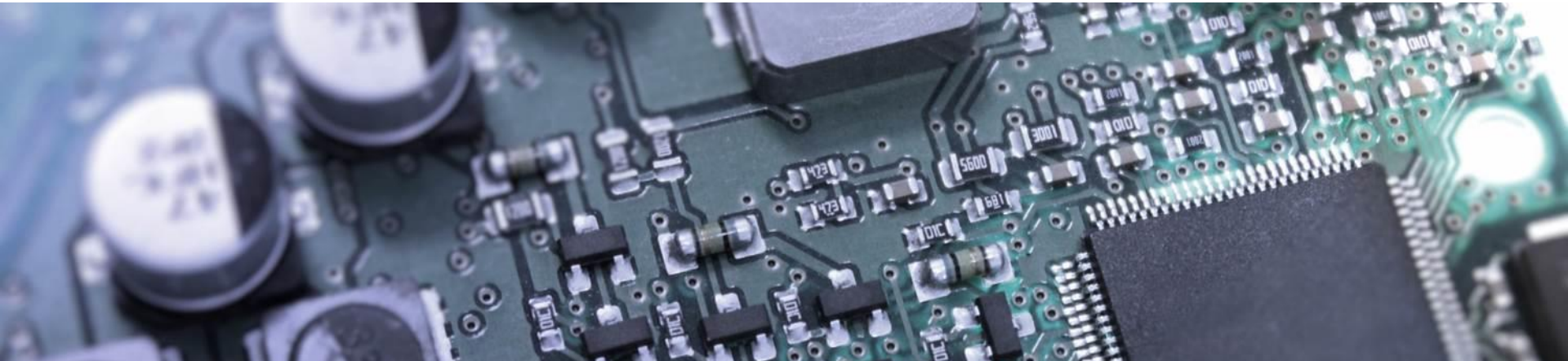
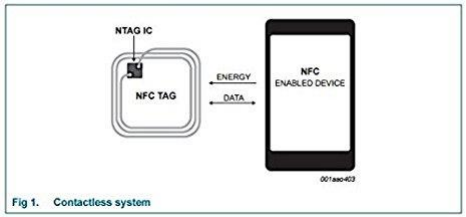


Outline of the Talk

- Overview of RFID/NFC System & Problem Definition
- Why Planar Tranformer Modeling?
- Modeling of Planar Transformer (3D-Model)
- Frequency Domain Simulation of NFC-Antenna & Tag
- Simulation Results
- Conclusions

Overview of NFC System / Problem Definition



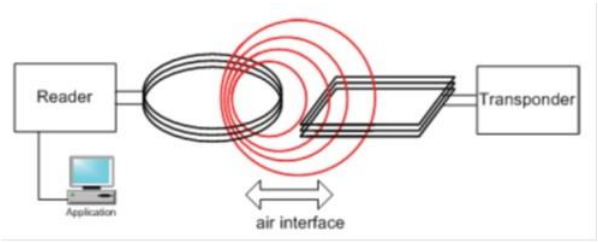
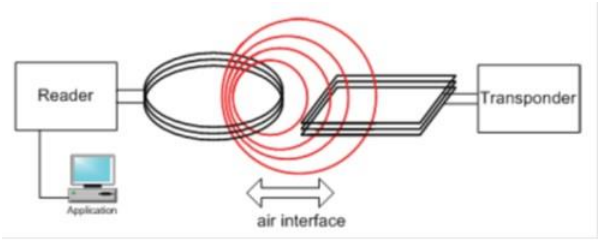


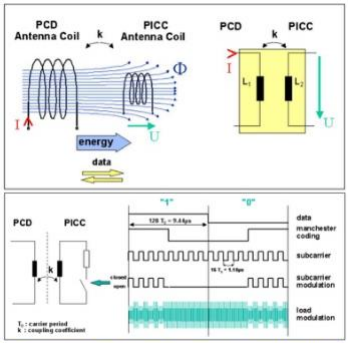
Fig. Overview of RFID/NFC-System

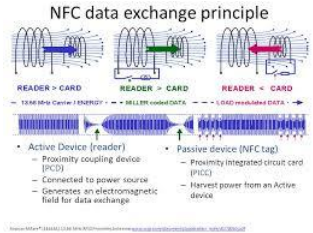
- For an well tuned NFC-Reader-Antenna Operating Distance depends on size, geometry/contour of both Reader/Tag-antenna besides other factors.
- For the keyless entry into the car in car door handle project this operating distance is given as 3 to 4 cm.
- Without the time consuming experiment with real H/W and/or S/W Prototypes this cannot be tested.
- Theoretical/simulation based method is needed for the estimation of NFC-antenna operating distance.

Why Planar Transformer Modeling?

- NFC-Reader Antenna & Ref. Tag can be viewed as an inductively coupled (transformer) system
- Reader and Tag Antenna coils are similar to the primary & secondary windings of transformer resp.
- Energy is transferred from reader antenna (PCD) to tag (PICC) coil (transformer principle)
- If Tag (PICC) gets sufficient energy/voltage through coupling the NFC-based communication is initiated/data transfer state is enabled.
- Tag antenna when properly aligned above the reader antenna- it is similar to a planar transformer.



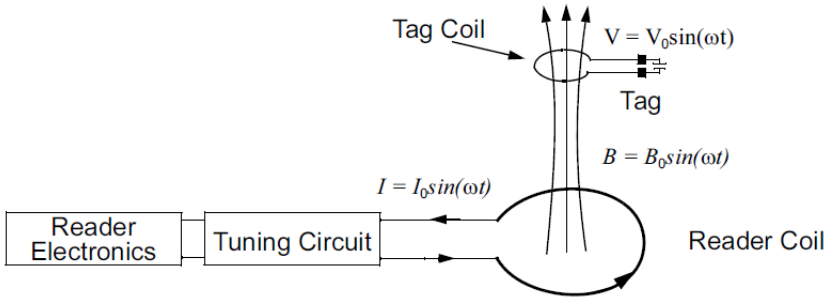


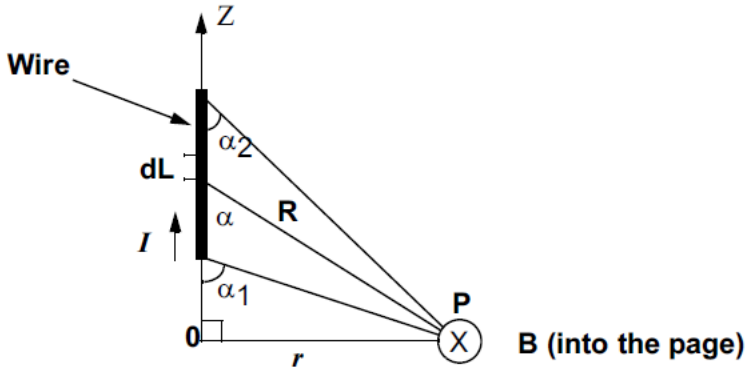


http://www.nxp.com/documents/application_note/AN78010.pdf

Reader Antenna & Ref. Tag (Coupled) System

Well Tuned Reader Coil enhances Power & Data Transfer





Matching Circuit will adjust the Q-factor and enhance the Power efficiency and Data Transfer Rate to/from the Antenna Coil

$$L_a = 4W_m / I_0^2, \quad R_a = \mathrm{Re}(Z)$$
$$Q = (\omega L_a)/R_a$$
$$I_{rms} = I_0/\sqrt{2}, \quad W_m = L_a I_{rms}^2/2$$

$$B = \mu_0 \mu_r I(\cos\alpha_2 - \cos\alpha_1)/4\pi r$$
$$B = \mu_0 \mu_r I/2\pi r, \text{for } \alpha_2 = 0°, \alpha_1 = 180°$$

$$\psi_{mf} = \int B \cdot dA, \quad L_a = N\psi_{mf}/I$$

$$\delta = 1/\sqrt{\pi f \mu \sigma}, \quad R_a = l/(\sigma A_{active})$$

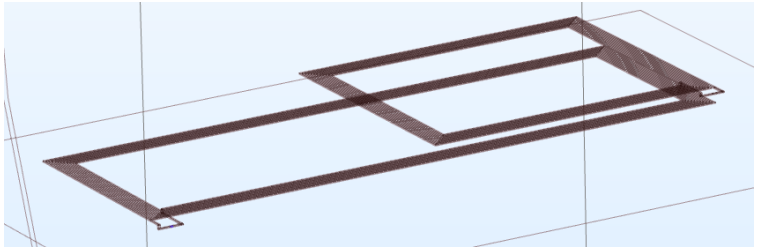
Modeling of NFC-Reader-Antenna & Reference Tag

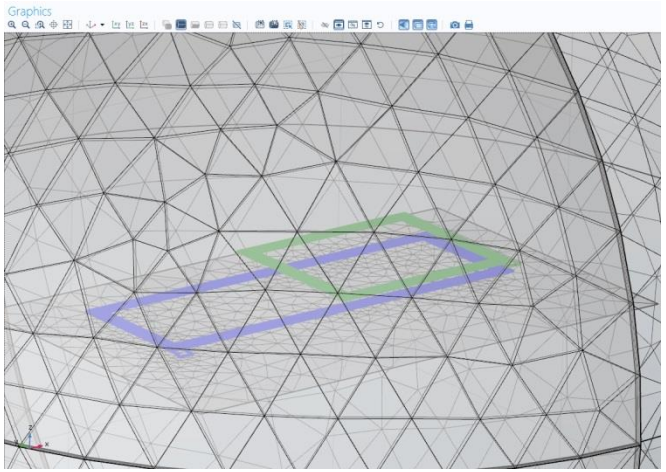
Model Building Steps:

- Geometry 1
  - Work Plane 1 *(wp1)*
    - Plane Geometry
      - Polygon 1 *(pol1)*
    - View 2
  - Extrude 1_ToplayerSpiralAssembly *(ext1)*
  - Block 2_TopLeftExtXtor *(blk2)*
  - LeftVert_column_Block 1.1 *(blk11)*
  - TopVertDownProj_InnerColumn_Block 1 *(blk1)*
  - Block 3_MidTopLongXtor 1 *(blk10)*
  - Block 4_TopXtorCol1_notOK *(blk4)*
  - Union 2_TopLayerNFCCoil *(uni2)*
  - Block 5_TopXtorCol1_LP *(blk12)*
  - Difference 2_NFCBigBottomReaderCoil *(dif2)*
  - Block6_NFC_BottAntCoil_LP *(blk13)*
  - Work Plane 2 *(wp2)*
    - Plane Geometry
      - Polygon 1 *(pol1)*
      - Mirror 1 *(mir1)*
    - View 3
  - Extrude2_ToplayerSpiralAssembly 1 *(ext2)*
  - Extn_midCol2right_Block *(blk9)*
  - Block3_TagCoil_RightLongXtor 1 *(blk3)*
  - Block 5_TagCoil_CentralLongLeftXtor *(blk5)*
  - Extn_downCol2right_Block *(blk14)*
  - Block 7_ThinXtor_Long_NotLP *(blk7)*
  - Union 3_Top_NFC_TagAntCoil *(uni3)*
  - Block 15_ThinXtor_Right_NotLP 1 *(blk15)*
  - Difference 3_XtorLP_TopTagCoil *(dif3)*
  - Block 16_BottomTagCoilTop_LP *(blk16)*
  - Move 1_30mmx30mm_TopTagCoil *(mov1)*
  - Work Plane 3_RectArea4HfieldPlot *(wp3)*
    - Plane Geometry
      - Polygon 1 *(pol1)*
    - View 4
  - Sphere 1_Air *(sph1)*
  - Form Union *(fin)*

- Materials
  - Air_Dom_Sph_out_insideWall *(mat1)*
  - Cu_NFCBottom_Coil_Dom *(mat3)*
  - Cu_TopTagCoil_Movable_Dom *(mat4)*
  - Material 5_Coil_CuBound *(mat5)*
  - Material 9_TagCoil_LP_CuBound *(mat9)*
  - Air_GF_LP_Dom *(mat7)*
  - Cu_2Side_LP_TopTagCoil_bound *(mat8)*
  - Cu_2Side_LP_BottomNFCAnt_bound 1 *(mat13)*
  - Air_BottomNFCReader_LP_4Bound *(mat10)*
  - Air_boundary_TagCoil_LP *(mat11)*
  - Air_boundary_remain *(mat6)*
  - Air_boundary_remain 1.1 *(mat12)*

- Mesh 1
  - Size
  - Free Triangular 1
  - Swept 1
    - Distribution 1
  - Free Tetrahedral 1
    - Size 1
  - Free Tetrahedral 2
    - Size 1





Modeling of NFC-Reader-Antenna & Ref. Tag …

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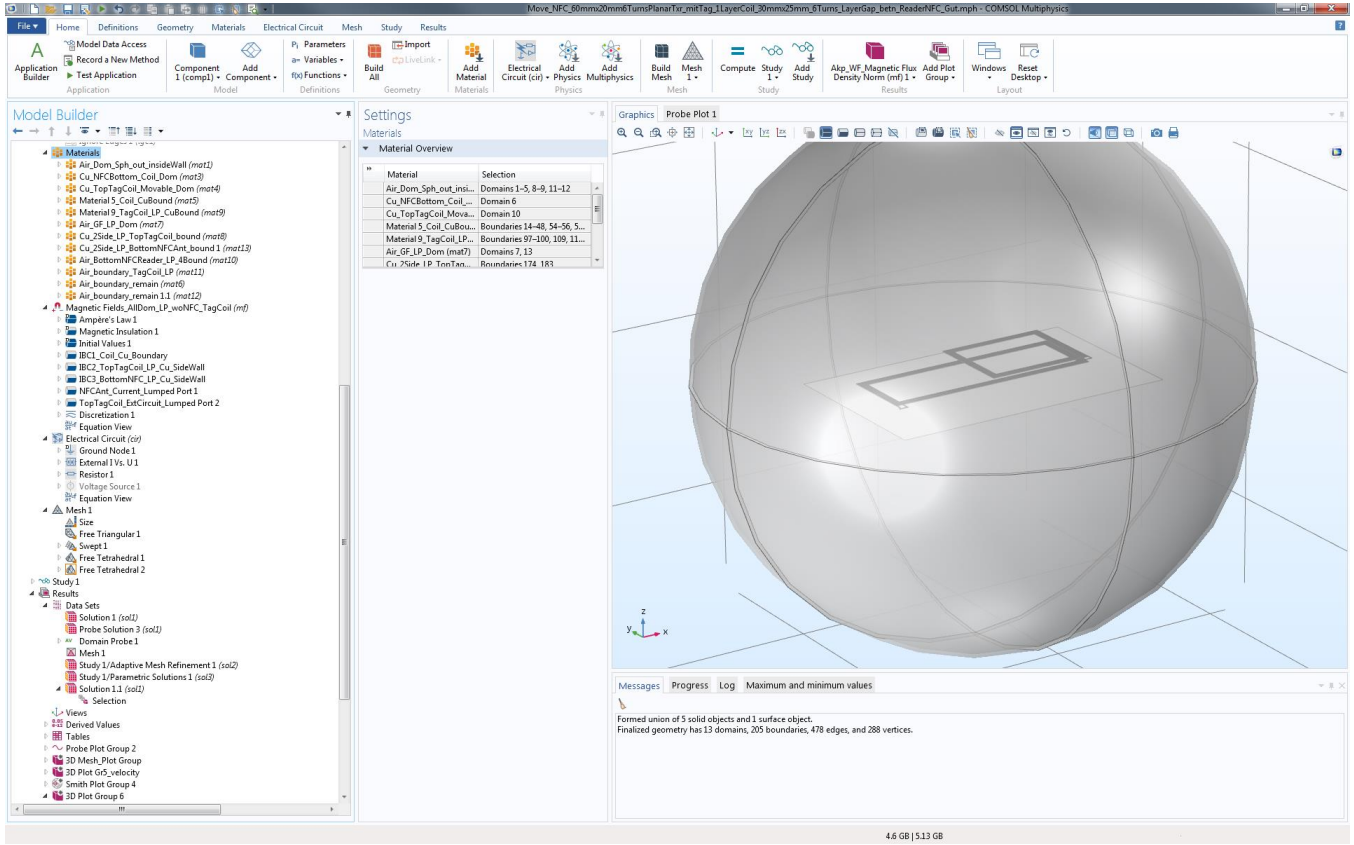
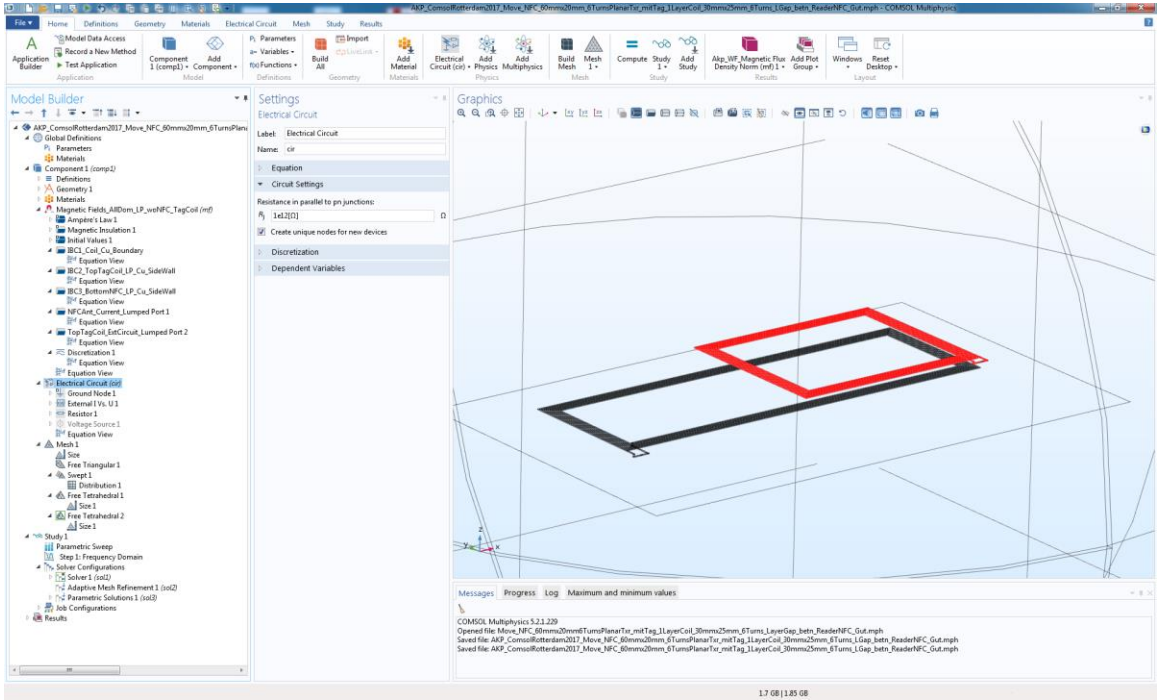


Simulation of NFC-Reader & Tag Antenna

MF-Physics Interface:

- Magnetic Fields_AllDom_LP_woNFC_TagCoil *(mf)*
  - Ampère's Law 1
  - Magnetic Insulation 1
  - Initial Values 1
  - IBC1_Coil_Cu_Boundary
    - Equation View
  - IBC2_TopTagCoil_LP_Cu_SideWall
    - Equation View
  - IBC3_BottomNFC_LP_Cu_SideWall
    - Equation View
  - NFCAnt_Current_Lumped Port 1
    - Equation View
  - TopTagCoil_ExtCircuit_Lumped Port 2
    - Equation View
  - Discretization 1
    - Equation View
  - Equation View
- Electrical Circuit *(cir)*
  - Ground Node 1
  - External I Vs. U 1
  - Resistor 1
  - Voltage Source 1
  - Equation View



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    - Equation View
  - NFCAnt_Current_Lumped Port 1
    - Equation View
  - TopTagCoil_ExtCircuit_Lumped Port 2
    - Equation View
  - Discretization 1
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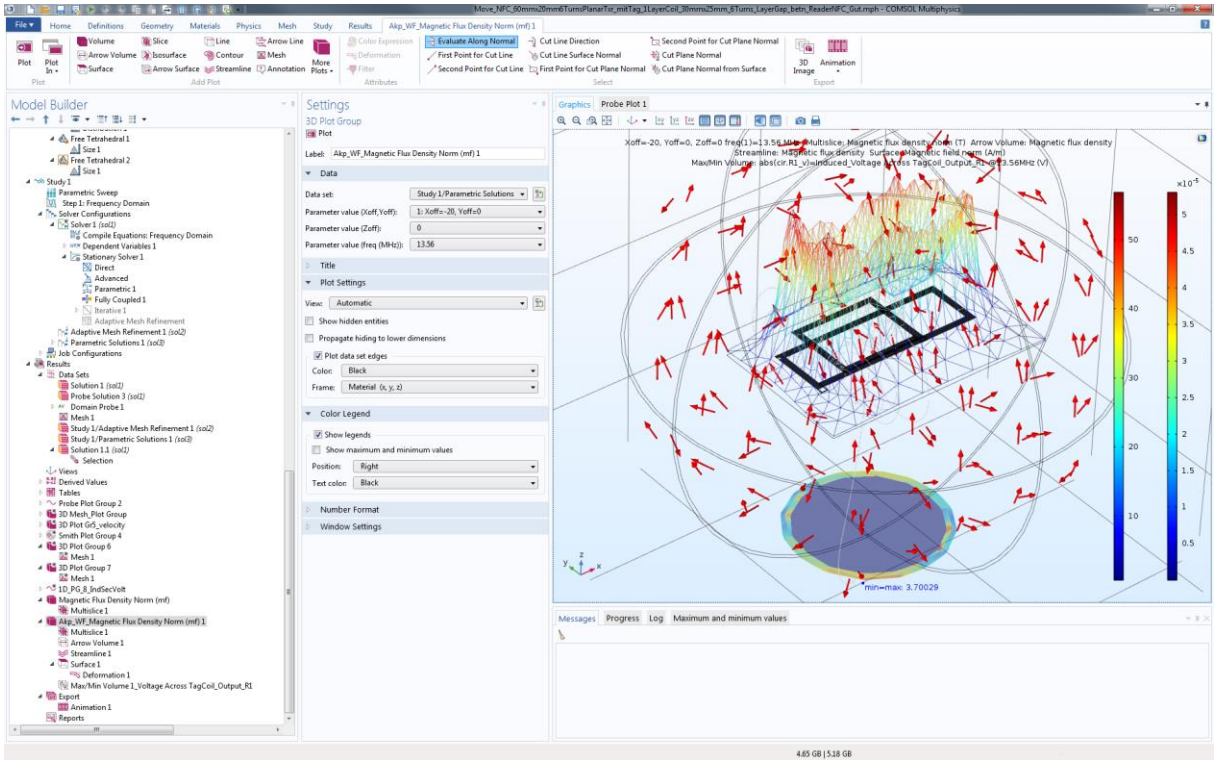


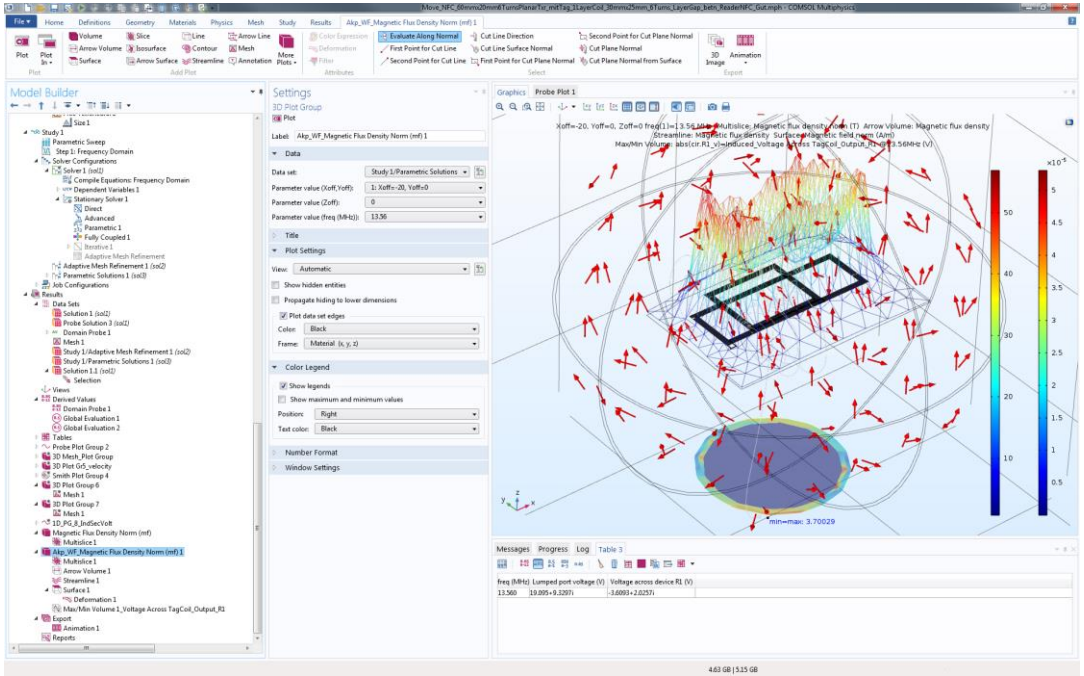
Simulation Results (Inductively Coupled Antennas)

Voltage induced on the Ref. Tag coil varies at different locations for following parameters:

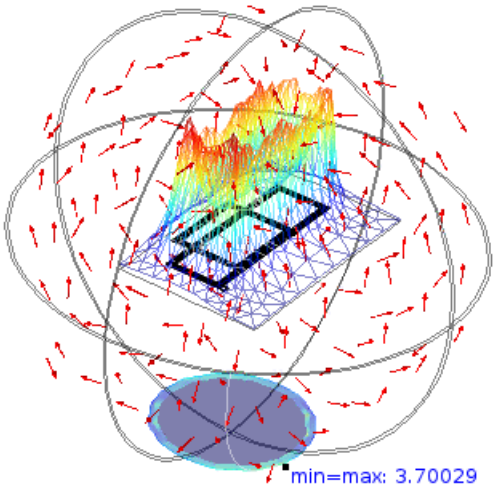
$$Z_{off\_vertical} = 30\ mm,$$
$$X_{off\_horizontal} = -20\ mm \text{ to } +30mm$$

Min & Max Voltages induced on the Ref. Tag coil at different locations for *I*_reader_antenna = 100 mA:

$$V_{Tag\_induced\_min} = 3.62\ Volt,$$
$$V_{Tag\_induced\_max} = 4.13\ Volt$$



Simulation Results (Induc. coupled Reader & Ref. Tag Antenna)



For different horizontal locations Xoff (-20 mm to 30 mm) induced voltage on Tag coil varies from 3.62 V to 4.13 V

Conclusion:

- ✓ 3D-Model of NFC-Reader-Antenna and Reference Tag-Coil were built and simulated using Comsol frequency domain tool.
- ✓ NFC-Reader-Antenna and Reference Tag-Coil were modeled as the primary & secondary windings of planar transformer coupled through aircore and operating at 13.56 MHz frequency.
- ✓ The distance (z-direction) between the reader antenna and tag-coil was varied and the induced voltage/energy across the Tag is evaluated/simulated.
- ✓ If the Induced voltage/energy across the Tag-coil exceeds certain predetermined value, the corresponding distance is considered as the operating distance for the reader antenna.

Thank you very much for your attention!