Driveline and Chassis Technology

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Frequency Domain modeling of Inductive Position Sensor with Finite Element Tools

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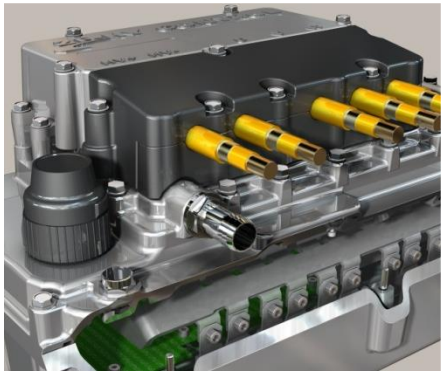

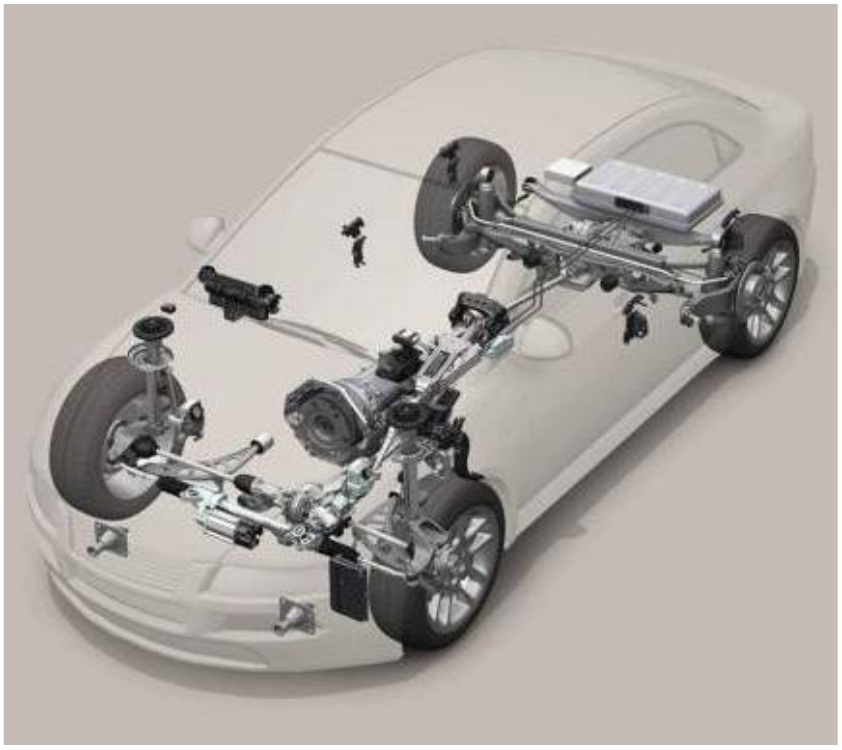

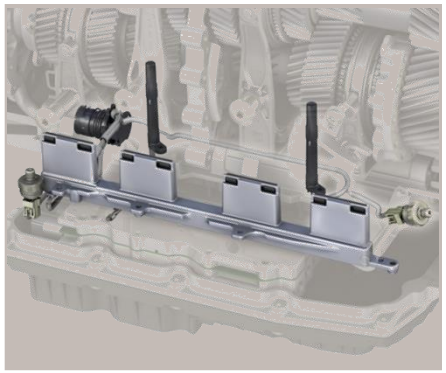

Contents

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- Structure of Inductive Position Sensor
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Why Inductive Position Sensors?

- **Automotive Electronics must work in extreme weather conditions, e.g. dust, humidity, vibration and wide temp range -40°C to +90°C**
- **Non-contact type & low cost solutions needed**
- **Resistive/Capacitive Sensors will be unsuitable**
- **Hall Sensors with Magnets were usually used**
- **They have some problems, e.g. magnet fixing with adhesive/glue, B(remanence) changes with temp, compensation needed, not so cheap etc.**

Inductive Position Sensors

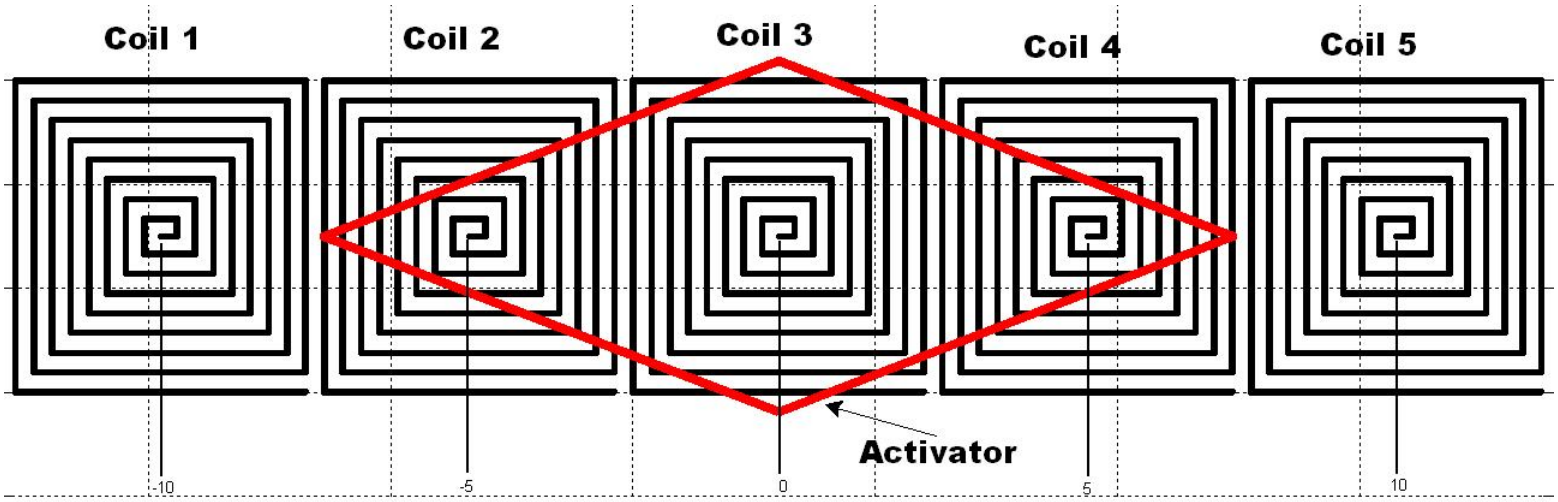


Figure: Inductive Position Sensor

- **Planar coils are fabricated directly on the PCB**
- **Double layers coils are often needed**
- **Other shapes e.g. rectangular, trapezoidal, circular, elliptical are also possible**

How does it work?

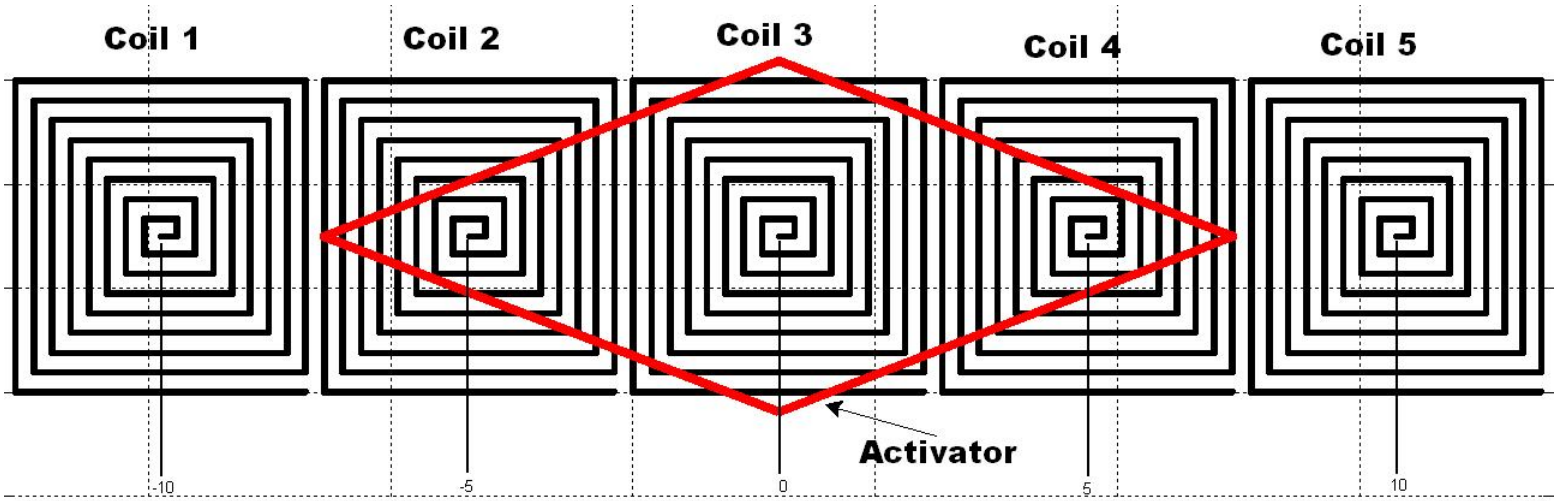
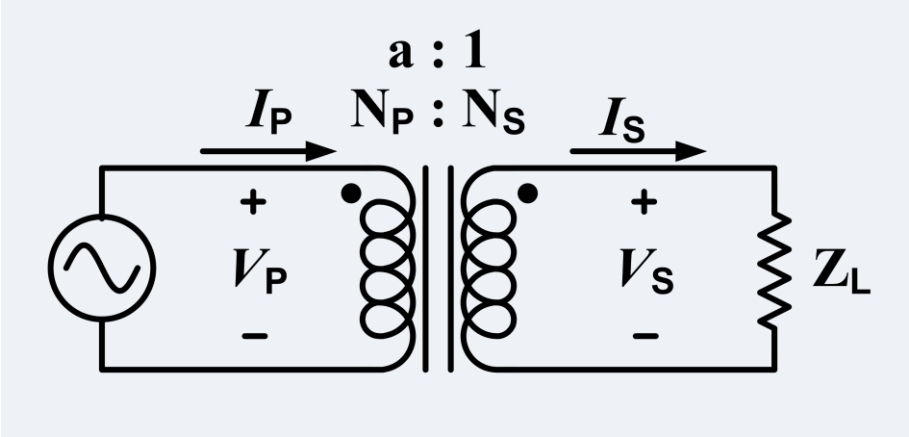


Figure: Inductive Position Sensor

- **Activator is a very thin Rhombus shape Cu-plate**
- **Slides horizontally over the coils (fixed vertical gap)**
- **Multiple coils‘ inductances are affected due to Cu-Activator (eddy current‘s effect)**

Modeling of Inductive Pos. Sensor



$$V_p = I_p R_p + L_p \cdot dI_p/dt - M \cdot dI_s/dt,$$
$$M \cdot dI_p/dt = I_s(R_s + Z_L) + L_s \cdot dI_s/dt$$

$$V_p/V_s = I_s/I_p = Np/Ns = a,$$
$$M = K_{coupl}\sqrt{L_p L_s},\ a = \sqrt{L_p/L_s}$$

$$I_s = aI_p,\quad V_p = (L_p - aM)dI_p/dt$$

$$aM = K_{coupl} L_p,\ V_p = (1 - K_{coupl})L_p\, dI_p/dt$$

- **Inductive position sensor can be viewed as a leaky (*air core*) and loosely coupled transformer**
- **Planar coils behave like a primary and activator is like a shorted secondary winding with one turn.**

Freqency Domain Modeling

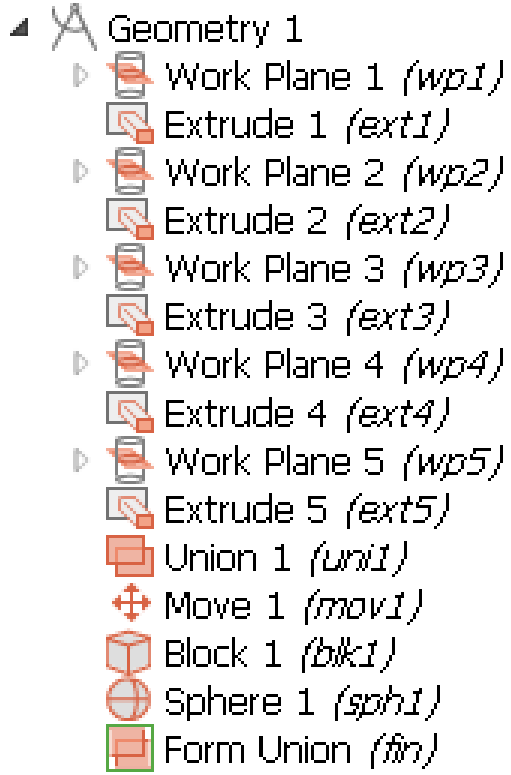
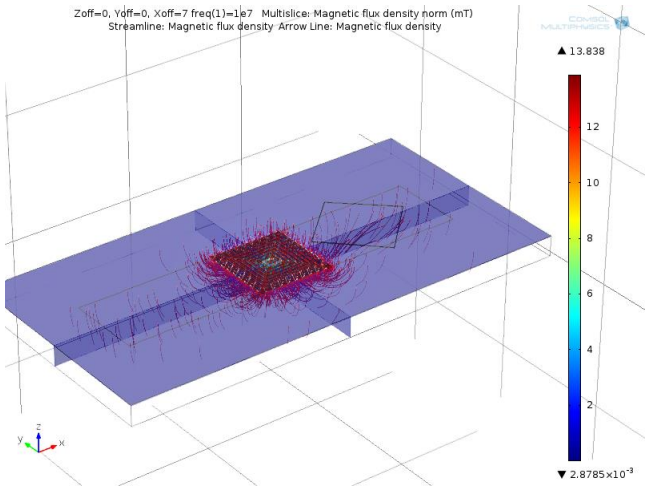
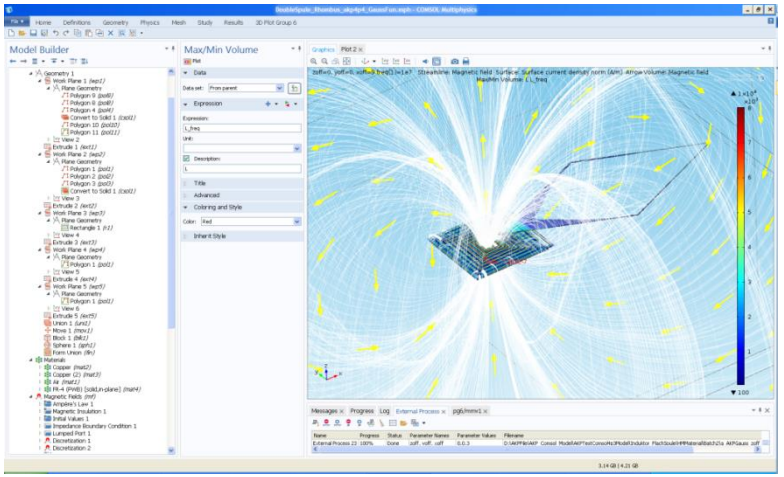
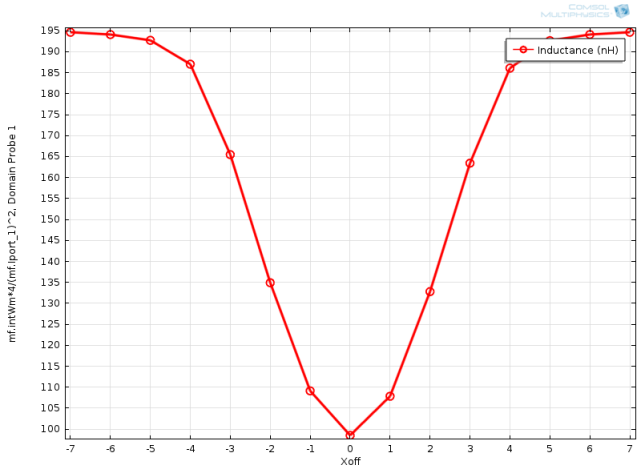


Figure: Geometry building steps of planar coil with activator element in Model Builder.

Simulations Results (single & double layer)







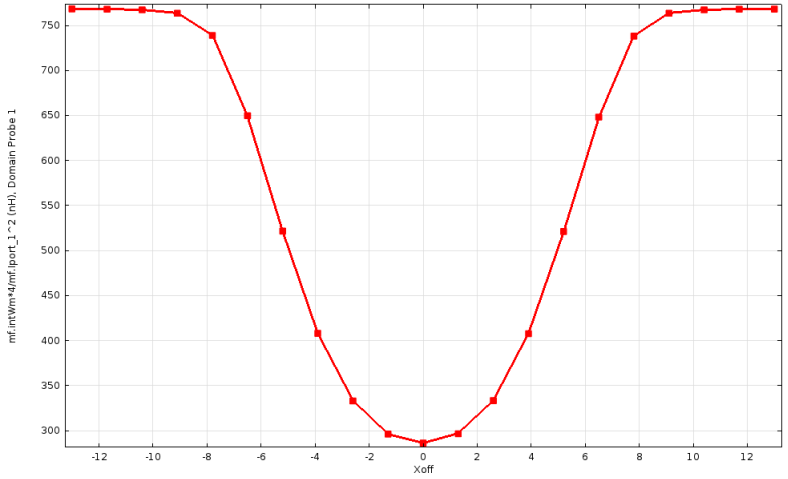
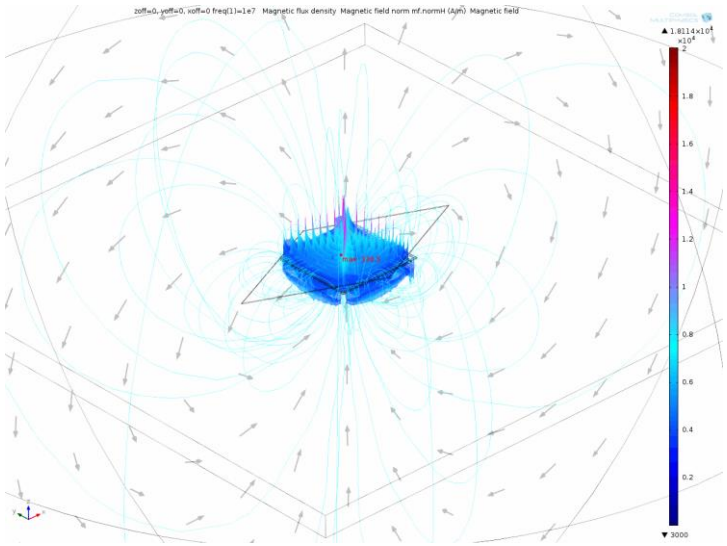
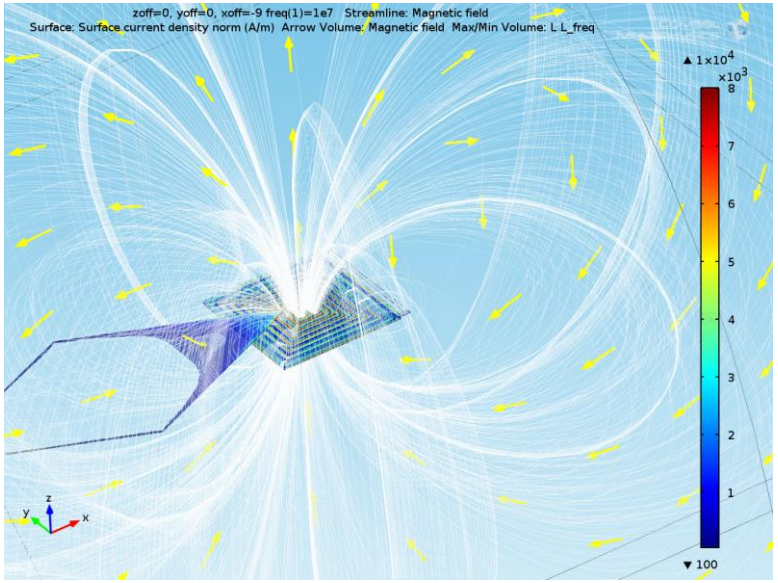
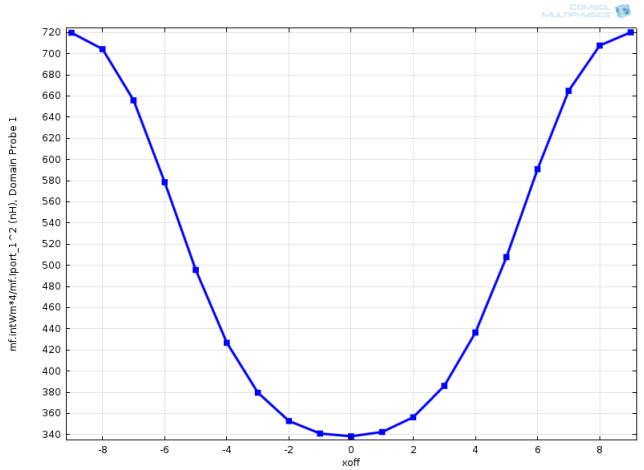


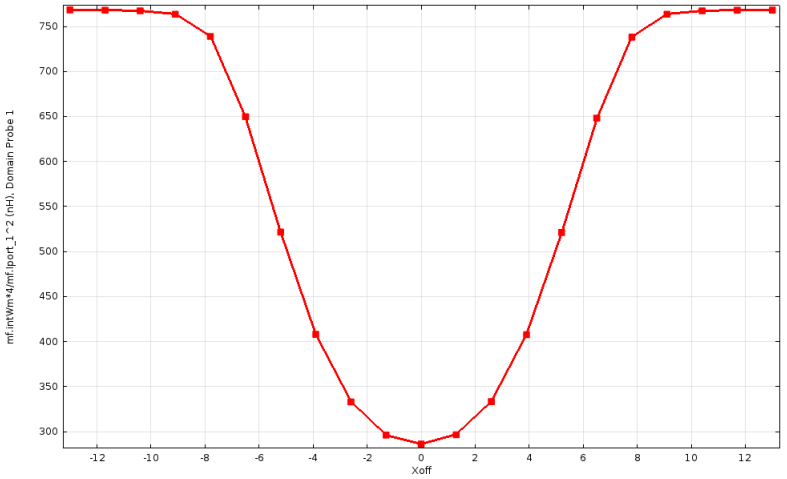
Figure: Cu-activator's X-off position (mm) vs. Inductance (nH) graph for a single (left-bottom) & double layer (right-bottom curve) planar coil.

Simulations Results (2-layer Coils)





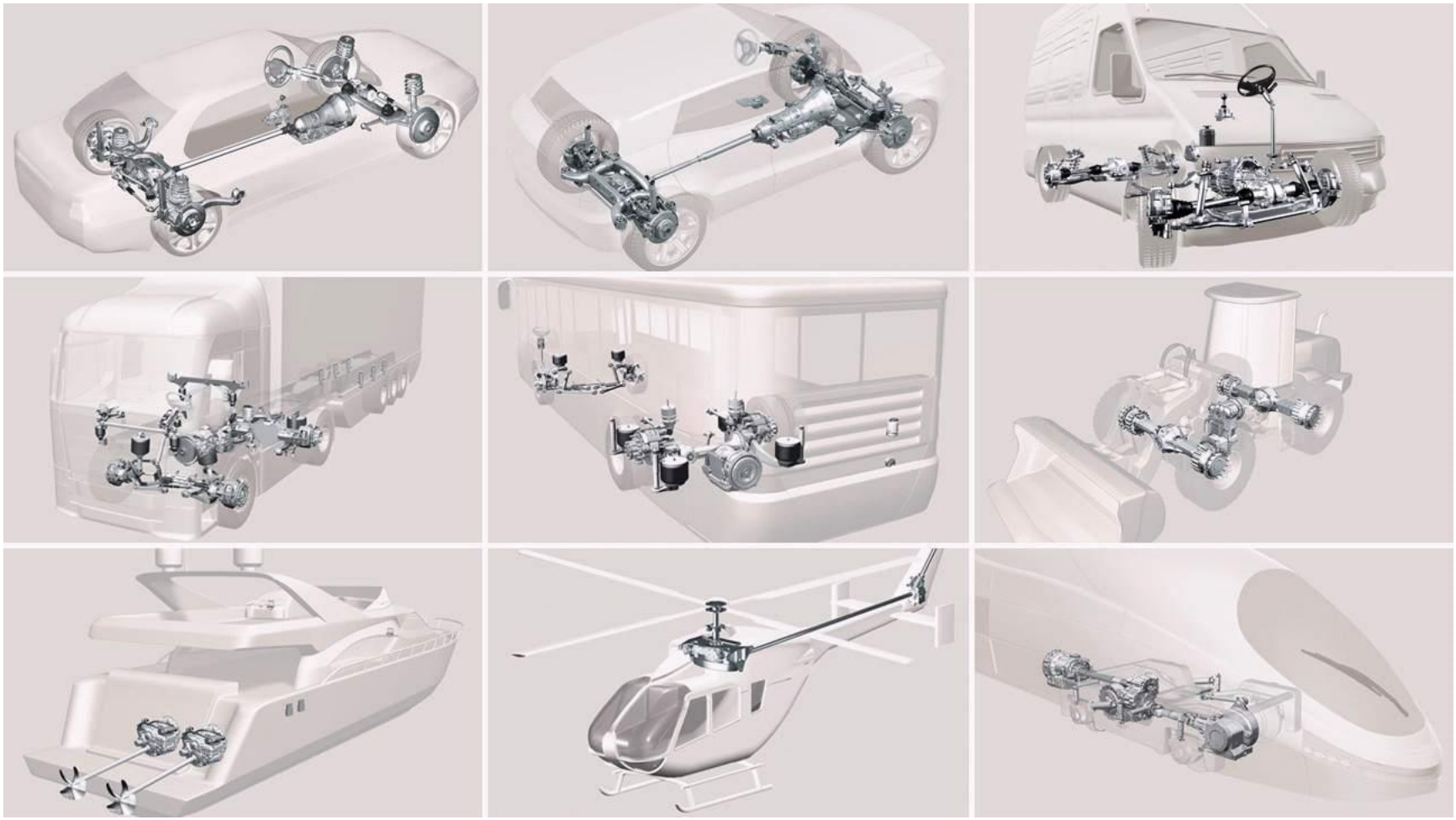




Conclusion

- ✓ **Inductive position sensor was modeled as a leaky/loosely coupled (*air core*) transformer with a shorted secondary winding (one turn) and operated at MHz frequency.**
- ✓ **Multiple coils‘ inductances are influenced (reduced) by the Cu-Activator element**
- ✓ **Xoff-position vs. Inductance curve (single/double layer) of planar coil looks like an inverted Gaussian function**
- ✓ **Sensor‘s sensitivity is dependent on operating frequency and shape, size, location (both horizontal & vertical) of the activator element over the coil**
- ✓ **The results have been implemented in the development of an automatic gear shifter module of a leading German car**

Thank you for your Attention!



Comsol Simulations of Inductive Position Sensor