New Modeling & Evaluation Approach for Capacitive Occupant Detection in Vehicles

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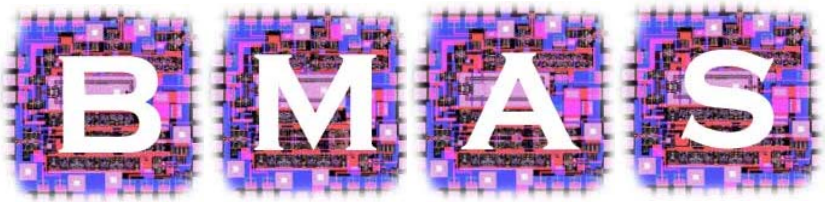
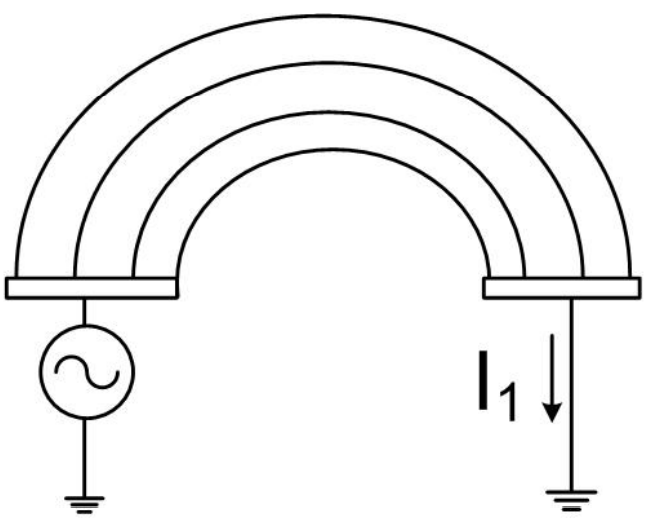


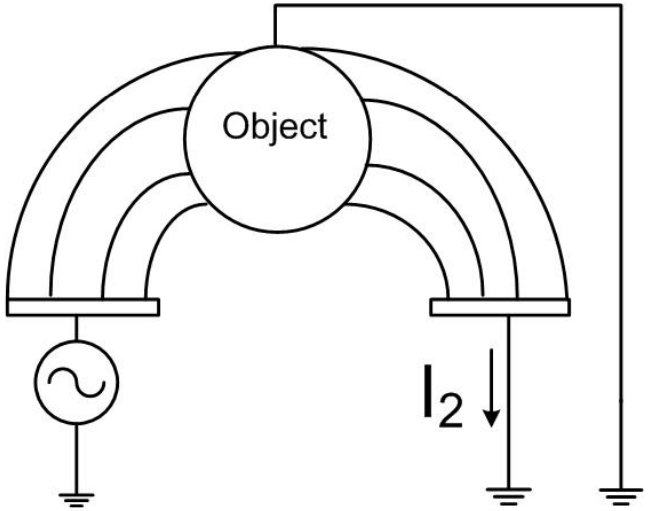
Outline

- Introduction
- Sensor Model
  - Human passenger
- Electrode variation method
  - FEM simulation
- Outlook on further activities

Introduction - Application

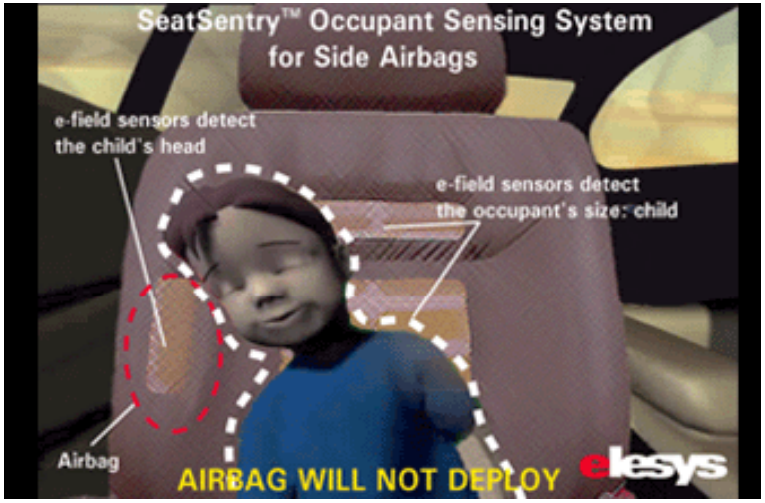
- Contactless sensing methods are needed to improve automotive safety standards.
- Information about occupancy status can be used for triggering safety devices → smart air bag system.
- Capacitive sensors can detect: Different passenger postures, child-sized passengers and child seat positions. [1],[2]

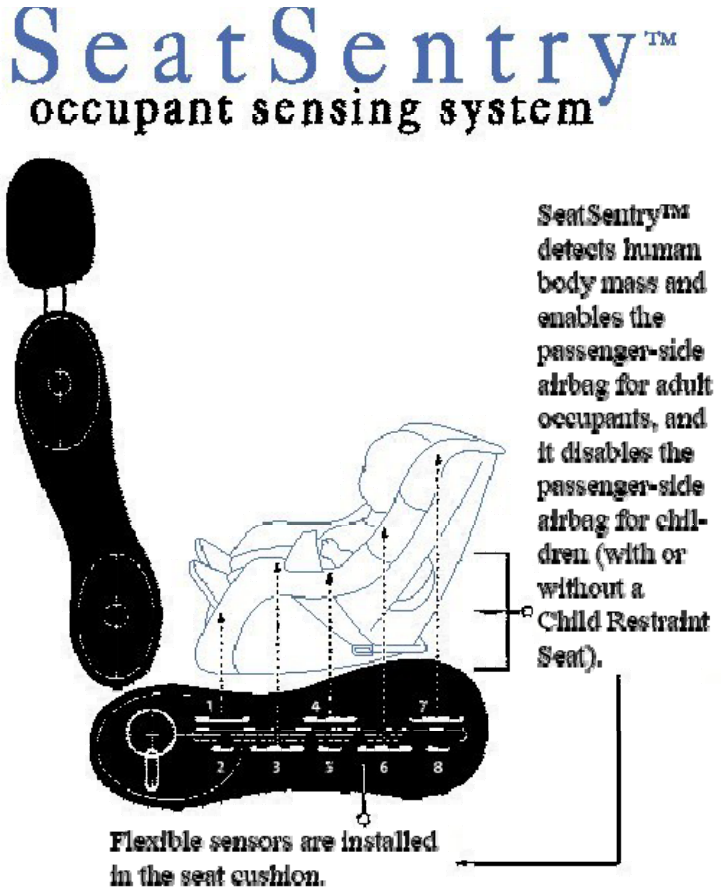




Introduction - Examples

- Child sized occupant protection methods using capacitive sensors.





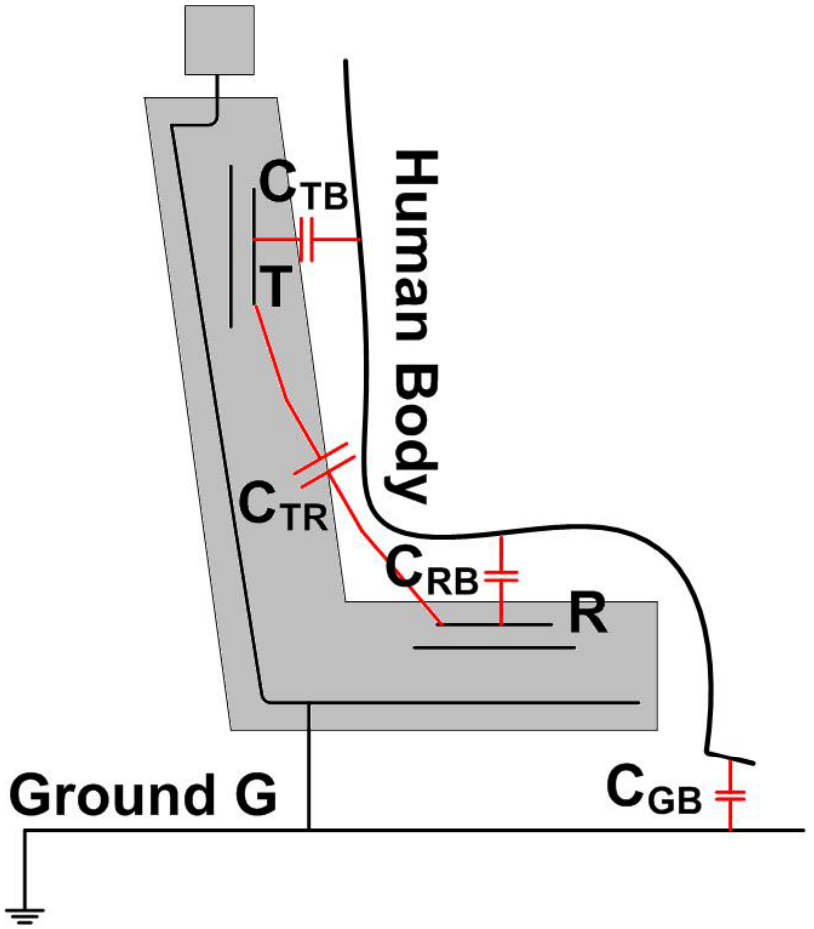
References: [4],[5] and [6]

Introduction - Problem Description

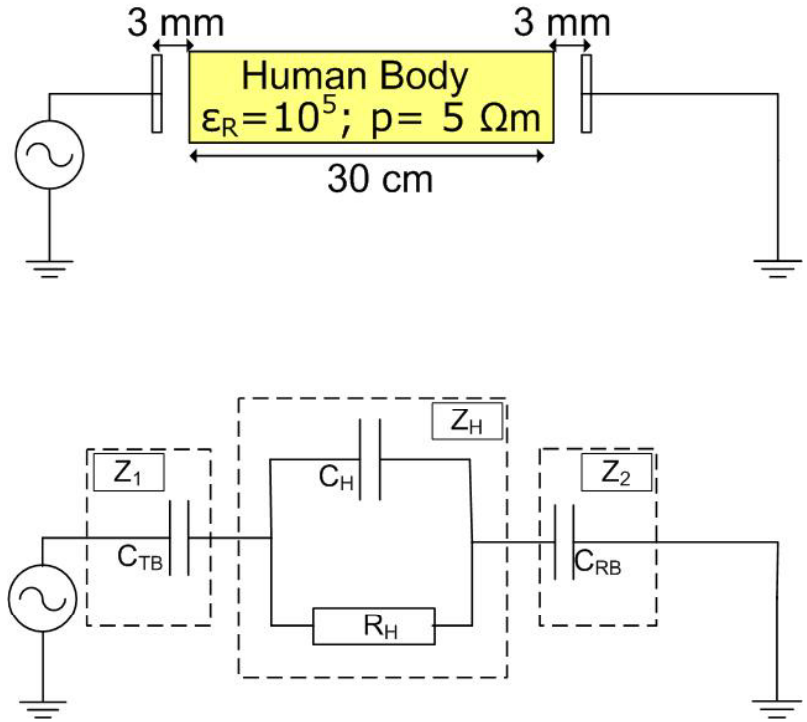
- Questions:
  - How human passengers are influencing sensed capacitances?
  - How can the sensed signal be inverted in order to give the correct occupancy status?
- Answers:
  - Human Body model; Sensor model.
  - Model parameter evaluation method.

Sensor Model

- T represents transmitter and R receiver electrodes placed on a vehicle seat.
- Possible current pathways are modeled by the capacitances C_{TB}, C_{TR}, C_{RB} and C_{GB}.



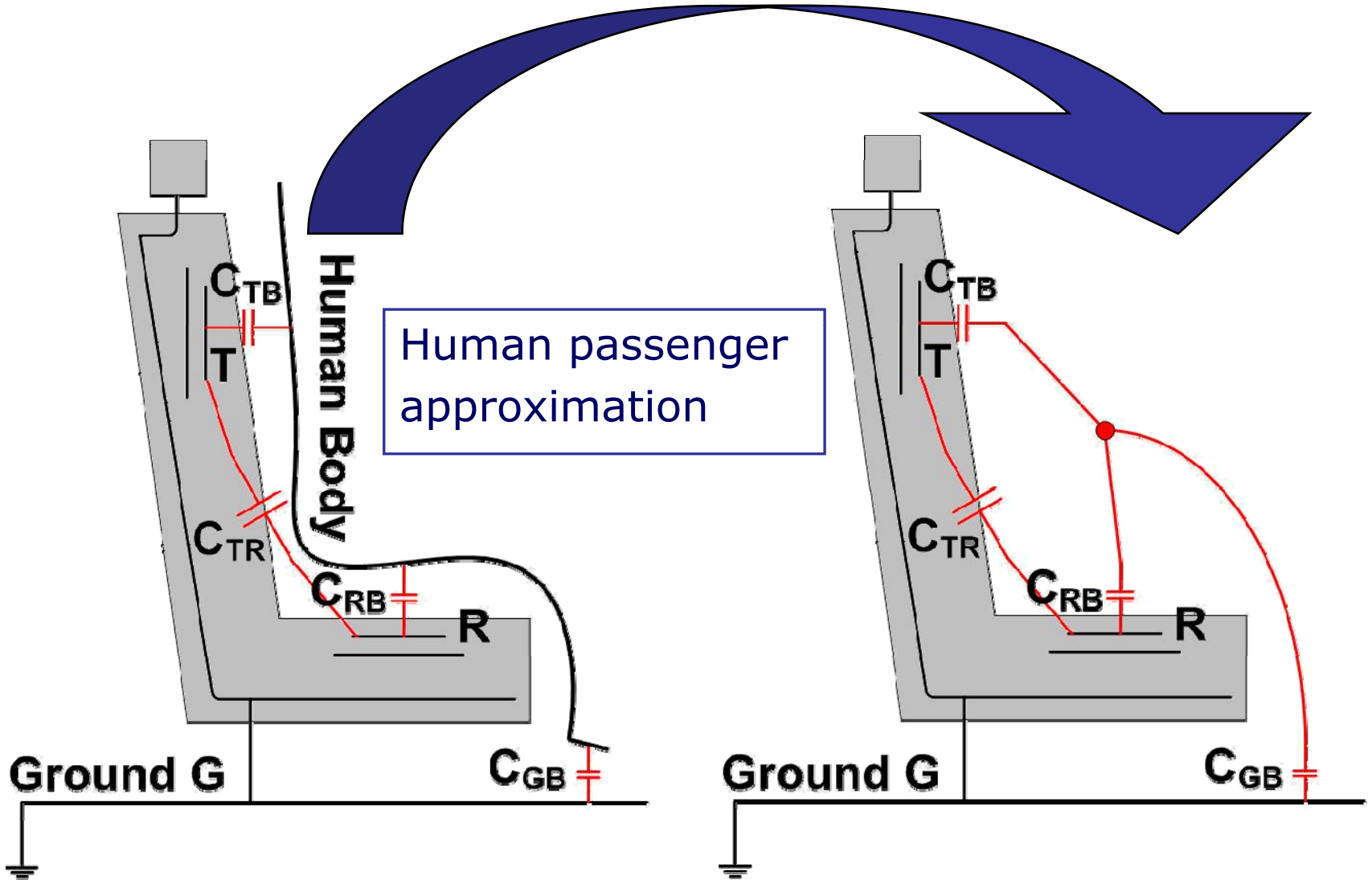
Sensor Model – Human Body



Frequency [kHz]	10
ε_R	10^5
P [Ωm]	5
Electrode area [cm²]	10
Distance [mm]	3
Length [cm]	30
$C_{TB} = C_{RB}$ [pF]	2.9
C_H [pF]	2933
R_H [kΩ]	1.5
$Z_1 = Z_2$ [MΩ]	5.5
Z_H [kΩ]	1.5

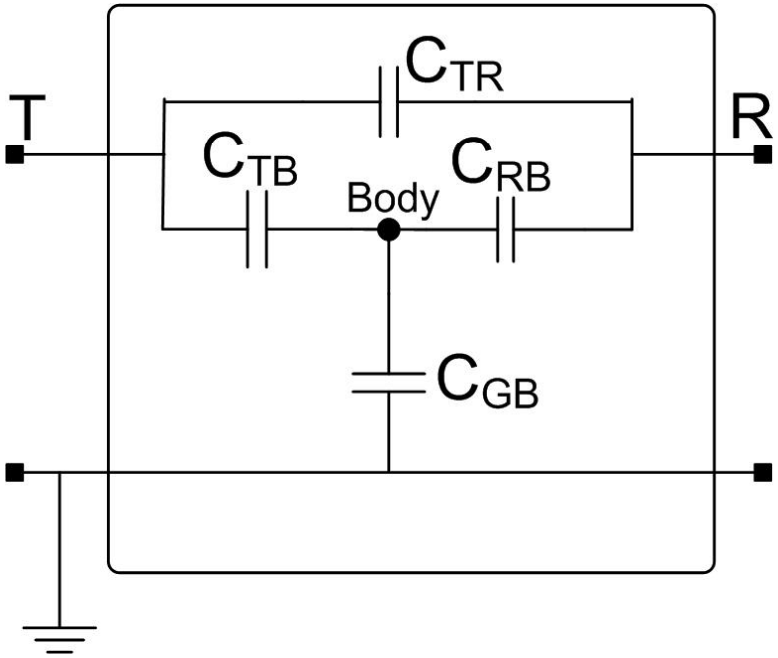
- For 10 kHz sensor signals human body impedance can be neglected compared to the coupling impedances.

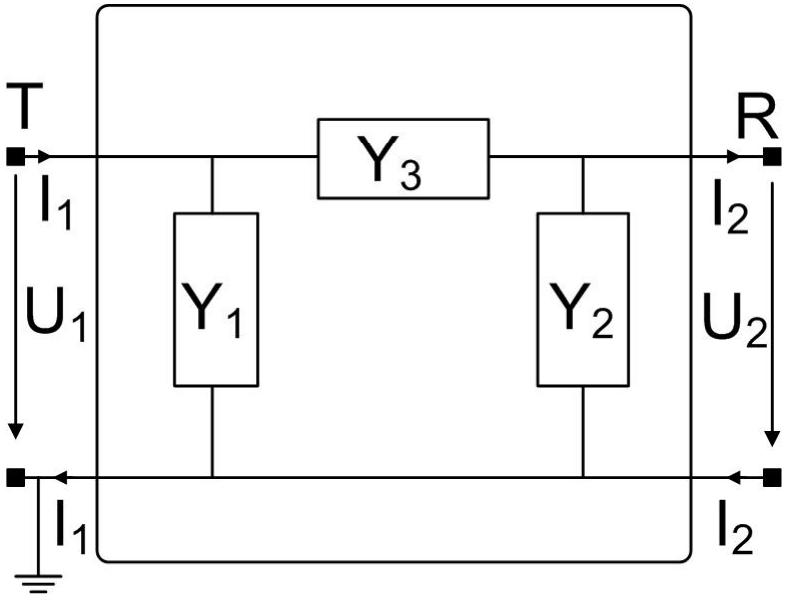
Sensor Model – Human Body



Sensor Model

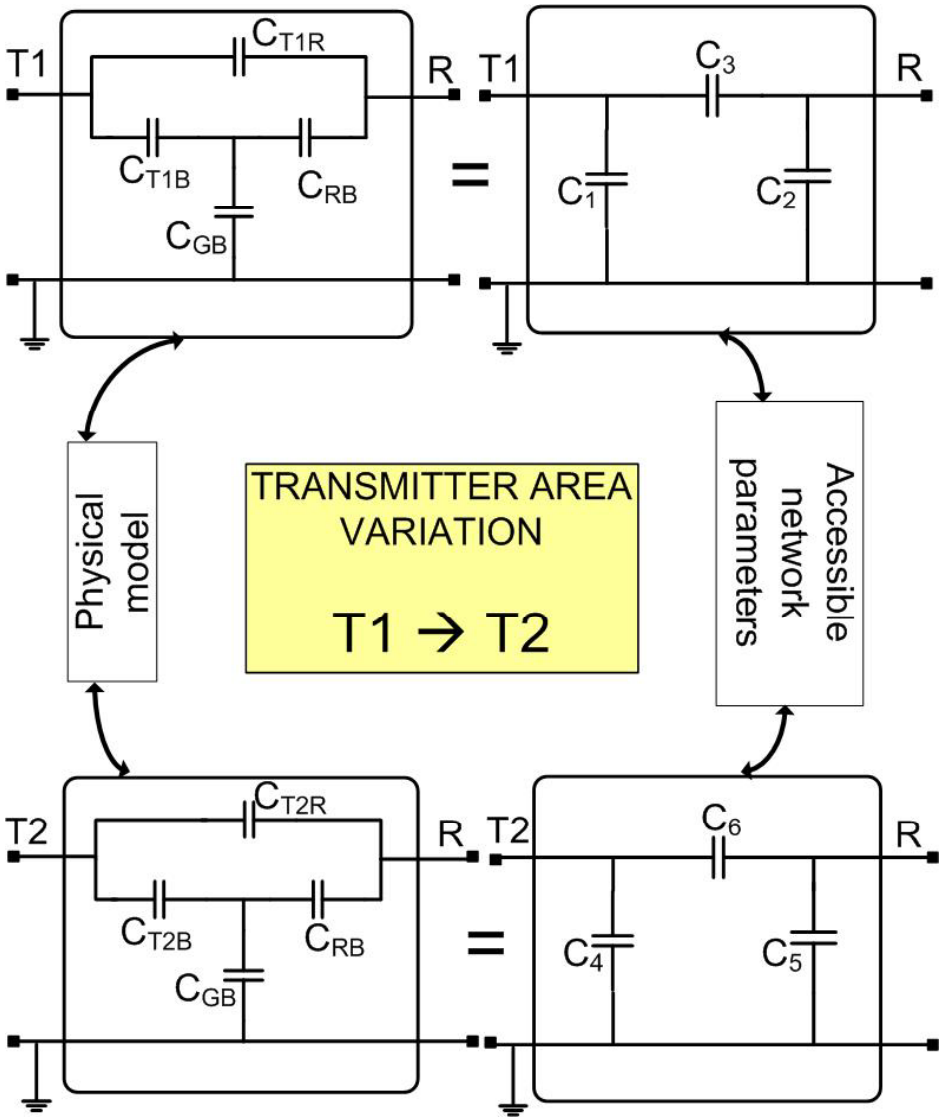
- Sensor model has the form of a bridged T-network.
- Idea: Measured signals are related back to model parameters (C_{TB},..). Decision about the occupancy status is based on model parameters. → Case of maximal sensor information.
- Problem: Only three independent parameters are accessible by measurements!





Electrode Variation Method

- Further Problems:
  - Parameters are passenger dependent.
  - Parameters cannot be fixed without restrictions.
- Solution:
  - If one cannot fix one parameter at least able to change some model parameters independently from each other.



Electrode Variation Method

- Result: Set of six equations for six unknown parameters.

$$\frac{1}{C_{T1B}} = \frac{C_2}{C_1}\left[\frac{C_1 + C_2 - C_4 - C_5}{C_1C_5 - C_2C_4}\right]$$

$$\frac{1}{C_{RB}} = \frac{C_1 - C_4 + C_2 - C_5}{C_5C_1 - C_4C_2}$$

$$\frac{1}{C_{GB}} = \frac{1}{C_1 + C_2}\frac{C_B}{(C_5C_1 - C_4C_2)}$$

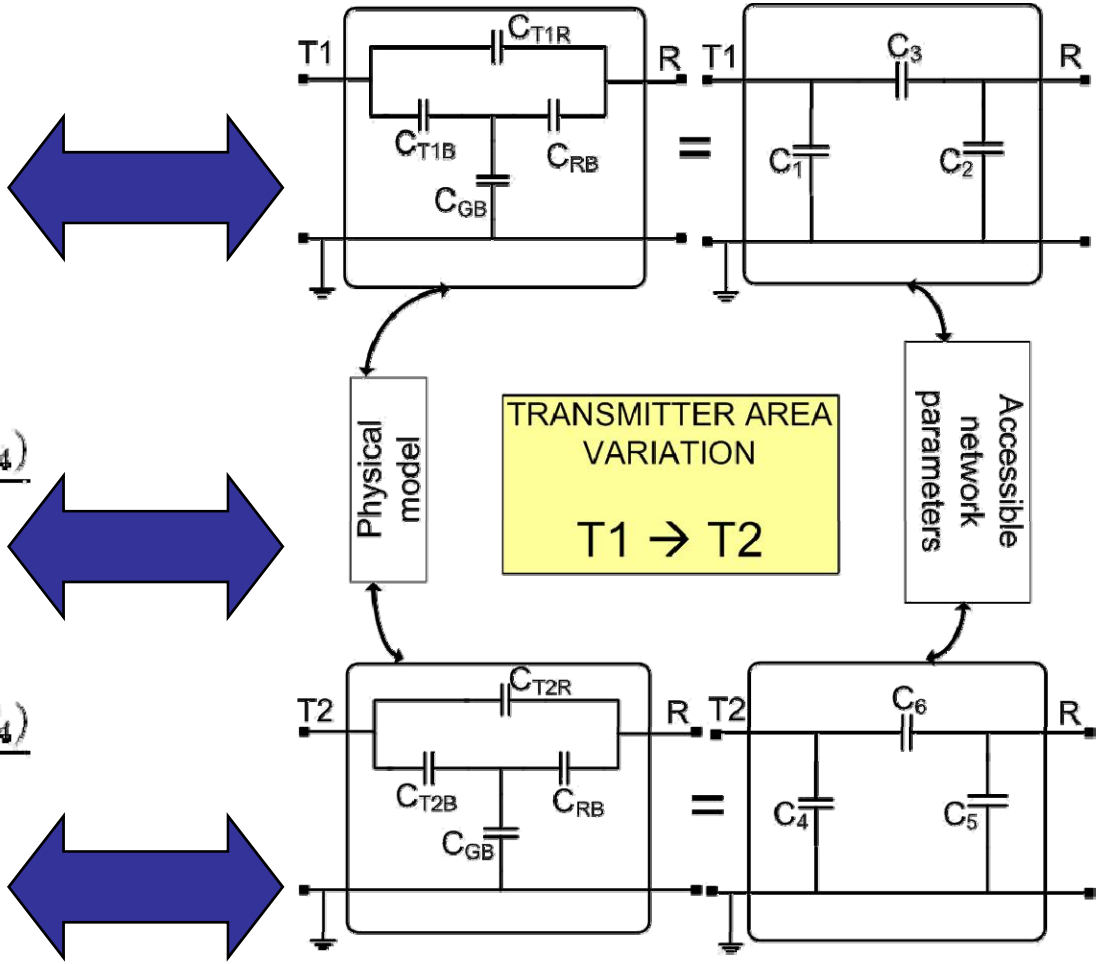
$$\frac{1}{C_{T1R}} = \frac{(C_1 + C_2)^2 - (C_1 + C_2)(C_5 + C_4)}{C_3C_A - C_1C_B}$$

$$\frac{1}{C_{T2B}} = \frac{C_5(C_1 - C_4 + C_2 + C_5)}{C_4(C_5C_1 - C_4C_2)}$$

$$\frac{1}{C_{T2R}} = \frac{(C_1 + C_2)^2 - (C_1 + C_2)(C_5 + C_4)}{C_6C_A - C_4C_B}$$

$$C_A = (C_1 + C_2)^2 - (C_1 + C_2)(C_5 + C_4)$$

$$C_B = C_1C_5 + C_5C_2 - C_1C_2 - C_2C_2$$

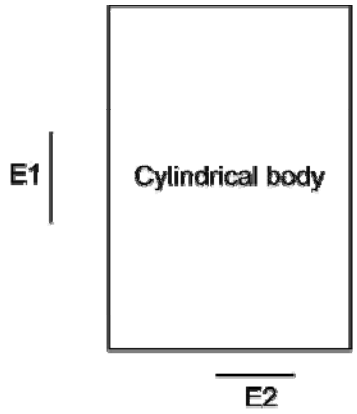


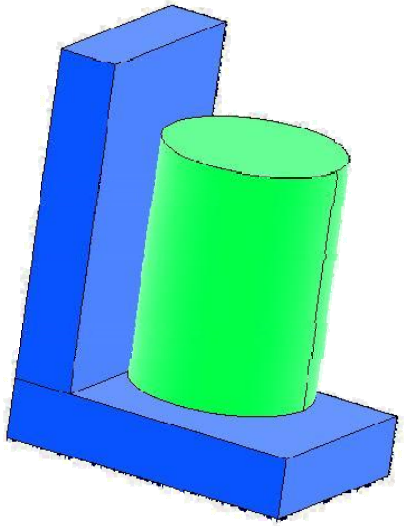
Electrode Variation Method

- Variation of the transmitter is changing only C_{TR} and C_{TB}.
- C_{GB} and C_{RB} are not influenced by a transmitter variation.
- FEM simulation

Simulation input data

Electrode Area T1 [cm^2]	2400
Electrode Area T1 [cm^2]	1200
Electrode Area T1 [cm^2]	2400
ε_R Seat	3
Base area of the body [cm^2]	2827
Height of the body [cm]	80
Electrode to body distance [cm]	15



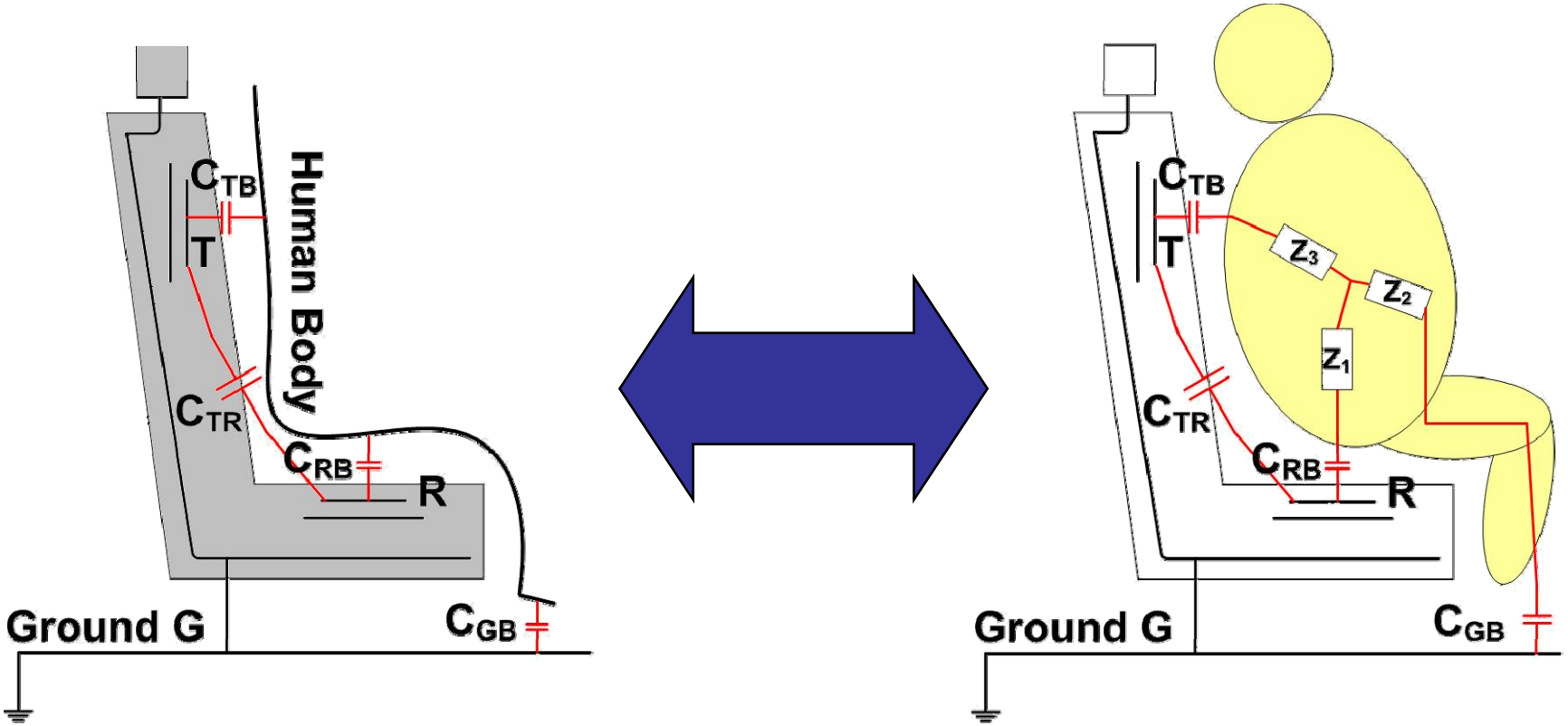


Simulation results

Parameters	Step 1 (T1)	Step 2 (T2)	Step 2 / Step 1
C_{TB} [pF]	11.2	8.1	0.723
C_{RB} [pF]	13.8	13.9	1.007
C_{TR} [pF]	0.3	0.2	0.667
C_{GB} [pF]	62.5	63.5	1.016

Outlook

- We will focus on MHz frequency range in order to sense human impedances.
- Sensor models need to be developed including permittivity and conductivity of human tissue.



References

- [1] Kazunori Jinno, Masahiro Ofuji, Takashi Saito and Saikichi Sekido; *Occupant Sensing Utilizing Perturbation of Electric Fields*; SAE paper collection; Occupant Detection and Sensing for Smarter Air Bag Systems, 167-180, 2004
- [2] Christian Marschner; *Messverfahren zur Eliminierung von Erdungseinflüssen bei kapazitiven Detektoren und ihre Anwendung zur Sitzbelegungserkennung in Kraftfahrzeugen*; PhD – thesis at munich university of technology, 2004
- [4] http://www.elesys-na.com/content.cfm?page=2 , 08.09.2008
- [5] http://www.elesys-na.com/content.cfm?page=37 , 08.09.2008
- [6] http://www.elesys-na.com/content.cfm?page=38, 08.09.2008

Thank you for your attention!