

Characterization of UHF RFID Sensor Tags with EM Coupled Passive Sensors

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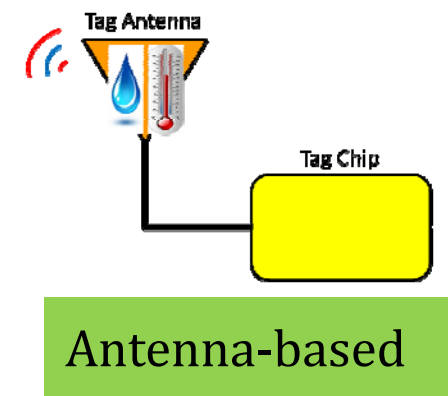
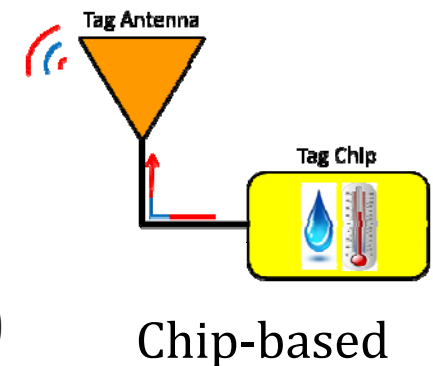
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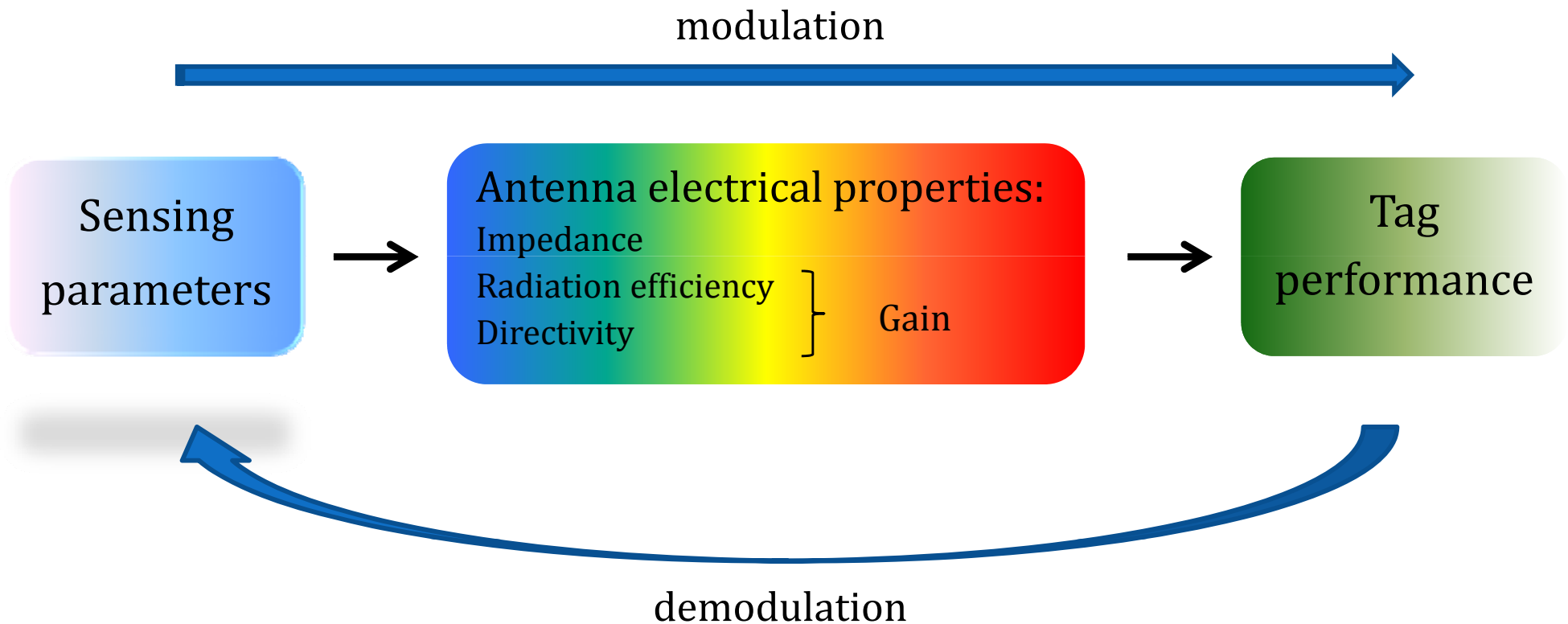
Related Works

- UHF RFID tags with sensing functionality
 - Chip-based sensor tags
 - ❖ Good compatibility with traditional sensors
 - ❖ High-precision measurements of the sensing parameters
 - ❖ High cost and probably short lifetime (if with assistant of a battery)
 - Antenna-based sensor tags
 - ❖ Application-dependent designs
 - ❖ Low-precision measurement, single event login
 - ❖ Low cost and long lifetime



Related Works

- Antenna-based passive UHF RFID sensor tags



Previous Work

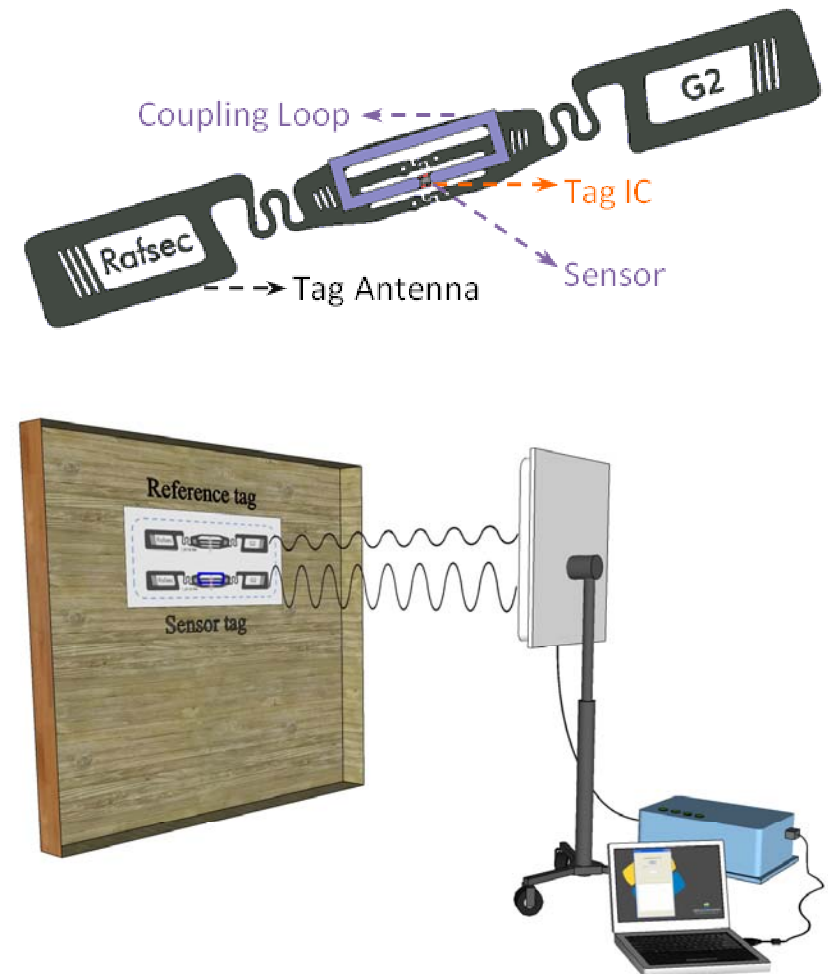
- Electromagnetically (EM) coupled UHF RFID sensor tags

- ❖ Twin tag setup

A sensor tag and a reference tag.

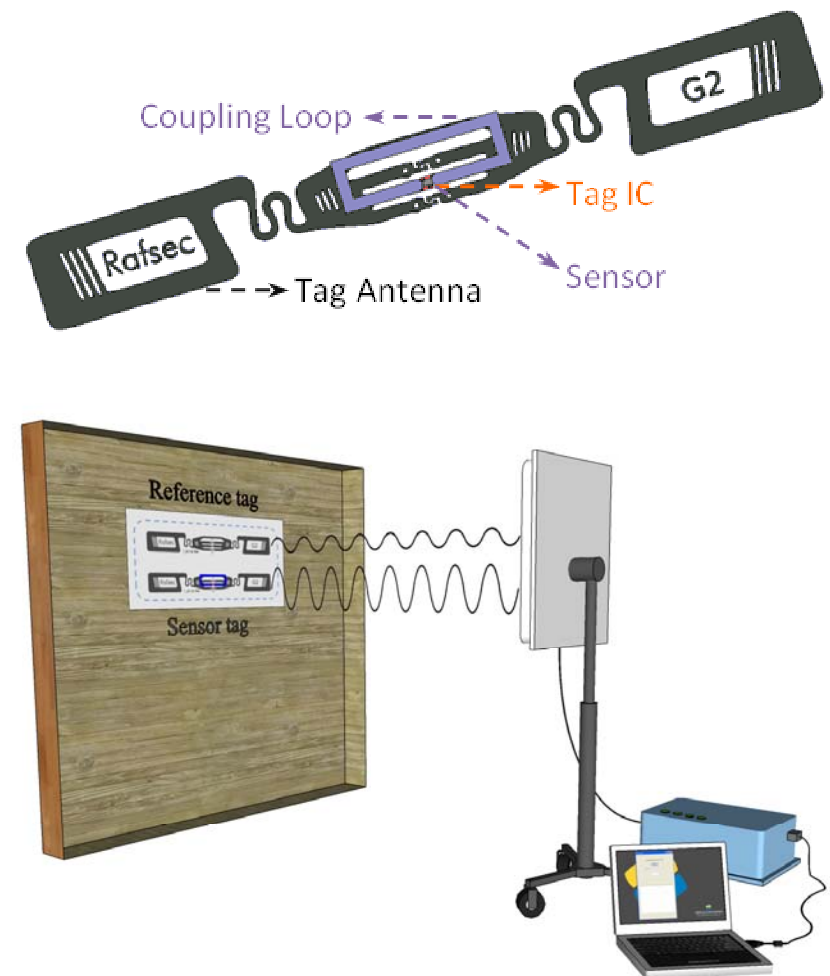
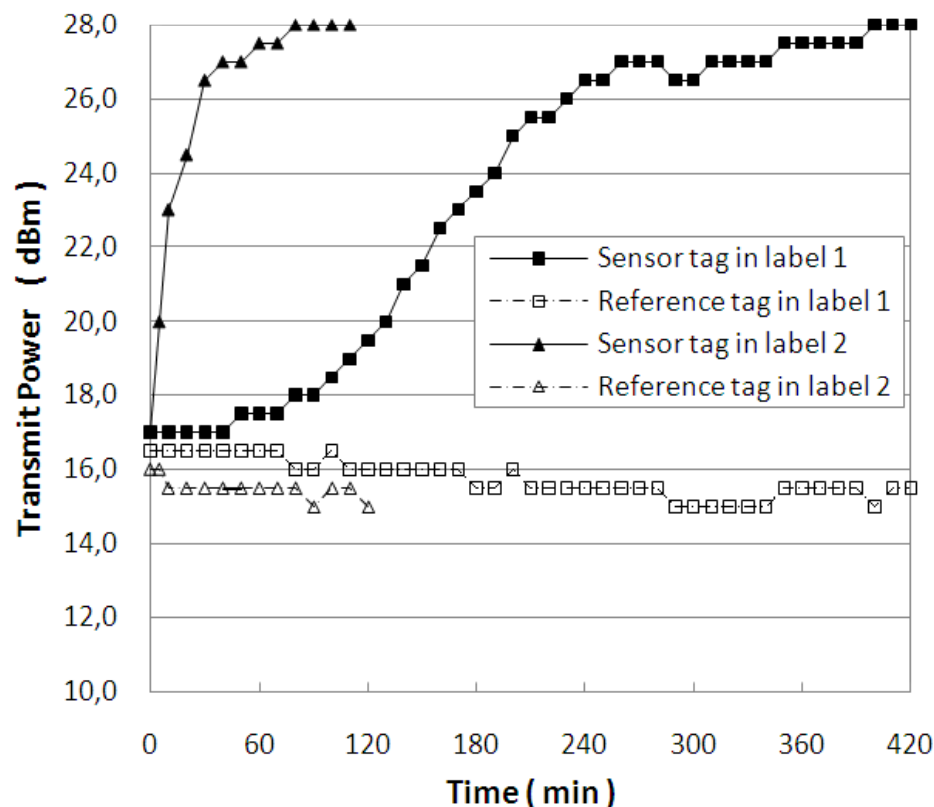
- ❖ Differential power readout

Two identical RFID tags are applied within the same sensor label and they are always interrogated at the same reading distance, thus allowing for the differential power readout.



Previous Work

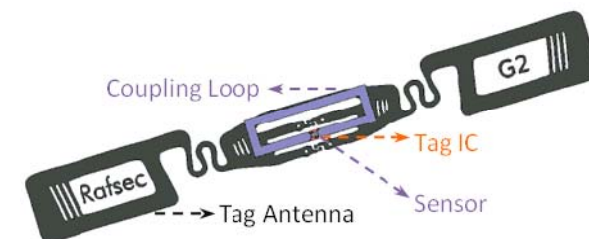
- Electromagnetically (EM) coupled UHF RFID sensor tags



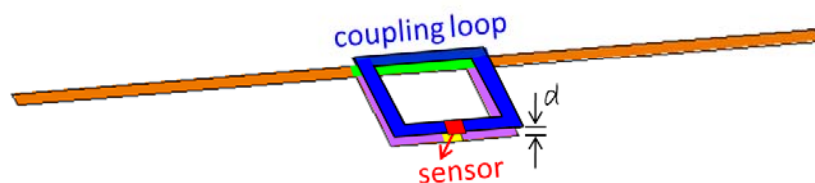
Present Work

- Two analytical models are proposed for EM coupled UHF RFID sensor tags.
- The models are validated by comparing the calculated results from the models with the results from full-wave simulations.
- The models can be used for analyzing and predicting the behavior of the EM coupled sensor tags.
- The analysis of the considerations during the design of the EM coupled sensor tags are also provided with the aid of the proposed models.

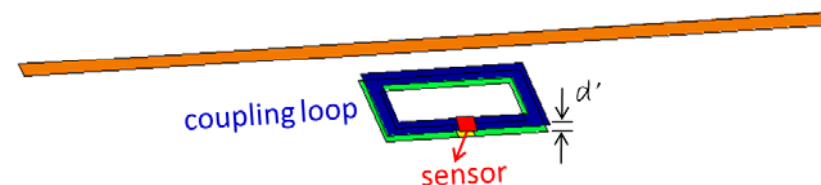
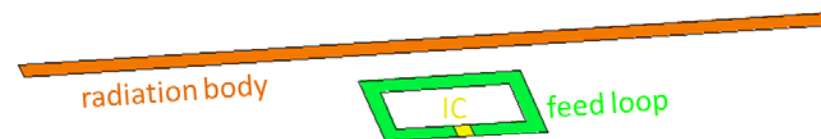
Analytical models



❖ Shunt/series inductors matched dipole

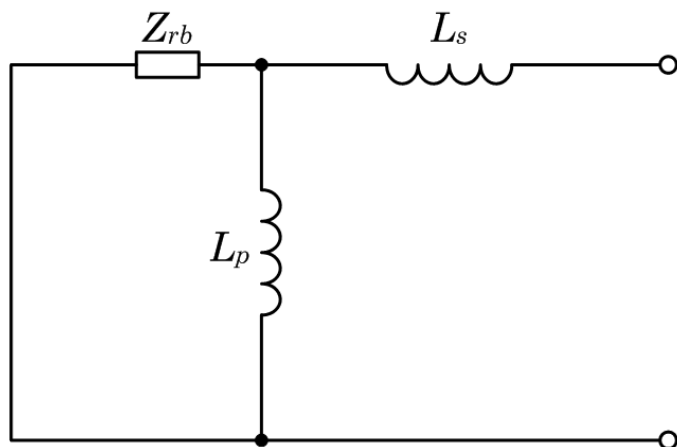


❖ Inductively coupled dipole



Analytical models

❖ Shunt/series inductors matched dipole

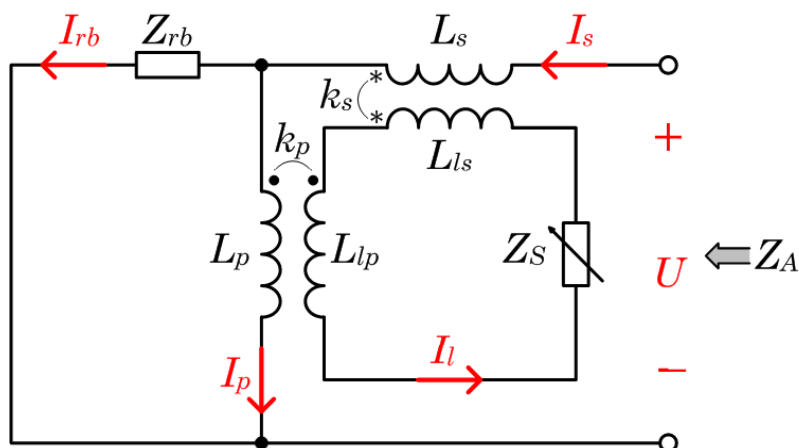


$$Z_{A0} = \frac{Z_{rb} Z_{L_p}}{Z_{rb} + Z_{L_p}} + Z_{L_s}$$

$$RadEff_0 = 1$$

$$\leftarrow Z_{A0} \quad R_{r0} = R_{A0} \cdot RadEff_0 = R_{A0}$$

$$R_{l0} = R_{A0} \cdot (1 - RadEff_0) = 0$$



$$Z_A = \frac{U}{I_s} = \frac{U_{L_p} + U_{L_s}}{I_s} = Z_{L_s} + A Z_{L_p} + B (Z_{M_p} + Z_{M_s})$$

$$RadEff = \frac{P_{rad}}{P_{rad} + P_{loss}} = \frac{|1 - A|^2 R_{rb}}{|1 - A|^2 R_{rb} + |B|^2 R_S}$$

$$R_r = R_A \cdot RadEff$$

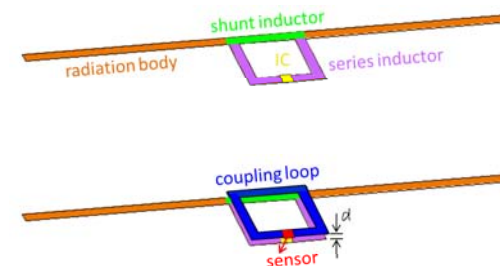
$$R_l = R_A \cdot (1 - RadEff)$$

where

$$A = \frac{T Z_{rb} + Z_{M_p} Z_{M_s}}{T Z_{rb} + T Z_{L_p} - Z_{M_p}^2}$$

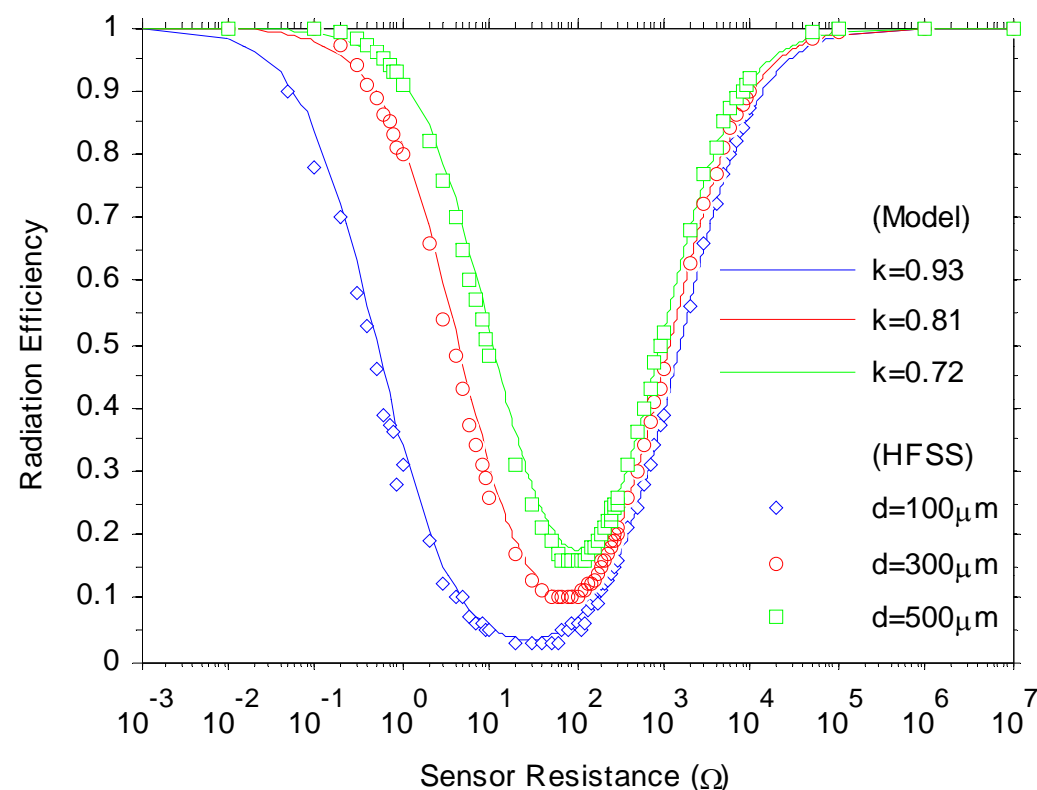
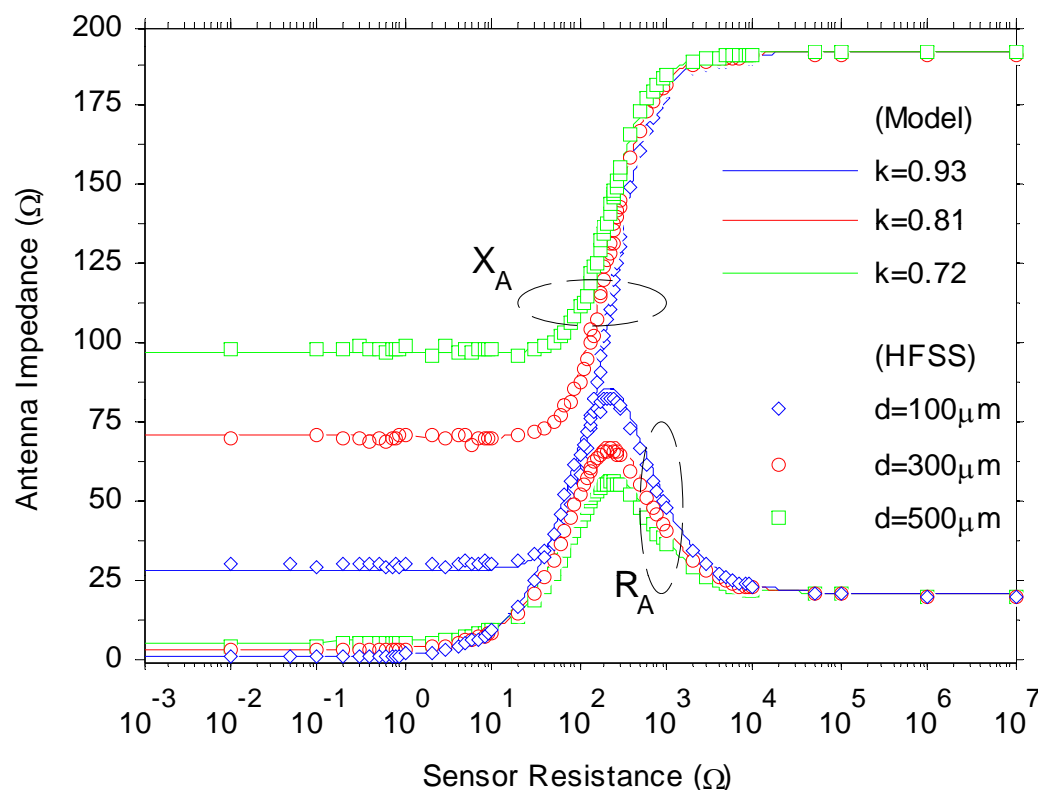
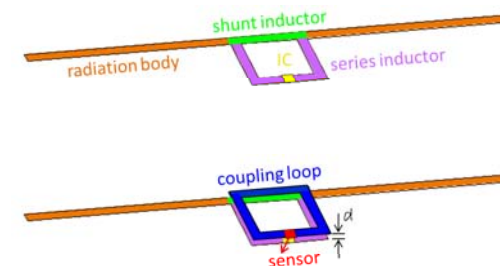
$$B = -\frac{1}{T} (A Z_{M_p} + Z_{M_s})$$

$$T = Z_{L_{lp}} + Z_{L_{ls}} + Z_S$$



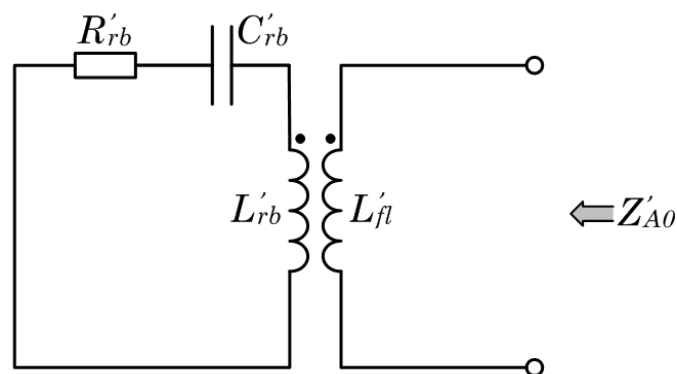
Analytical models

❖ Shunt/series inductors matched dipole



Analytical models

❖ Inductively coupled dipole

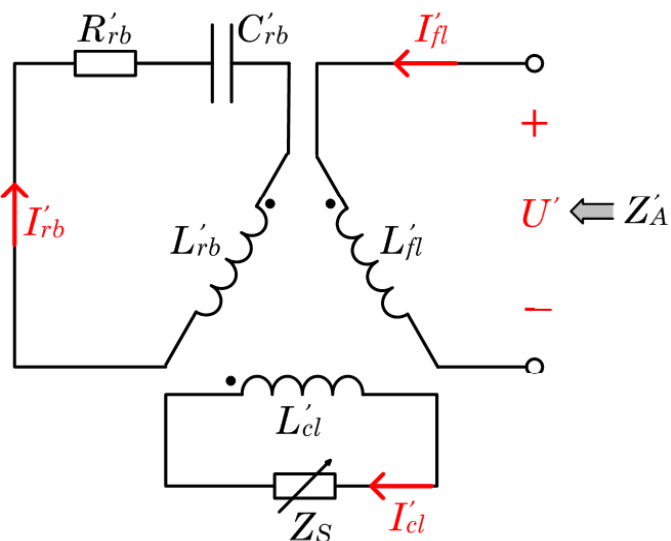


$$Z'_{A0} = Z'_{L'_{fl}} - \frac{Z'^2_{M'_{rb,fl}}}{Z'_{rb}}$$

$$RadEff'_0 = 1$$

$$R'_{r0} = R'_{A0} \cdot RadEff'_0 = R'_{A0}$$

$$R'_{l0} = R'_{A0} \cdot (1 - RadEff'_0) = 0$$



$$Z'_A = \frac{U'}{I'_{fl}} = Z'_{L'_{fl}} + A' Z'_{M'_{rb,fl}} + B' Z'_{M'_{fl,cl}}$$

$$RadEff' = \frac{P'_{rad}}{P'_{rad} + P'_{loss}} = \frac{|A'|^2 R'_{rb}}{|A'|^2 R'_{rb} + |B'|^2 R_S}$$

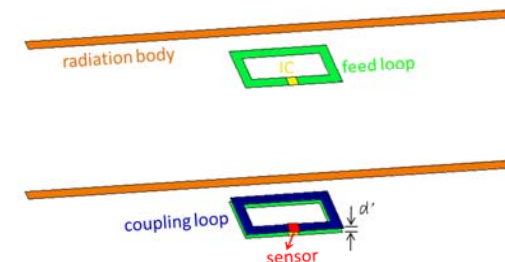
$$R'_r = R'_A \cdot RadEff'$$

$$R'_l = R'_A \cdot (1 - RadEff')$$

where

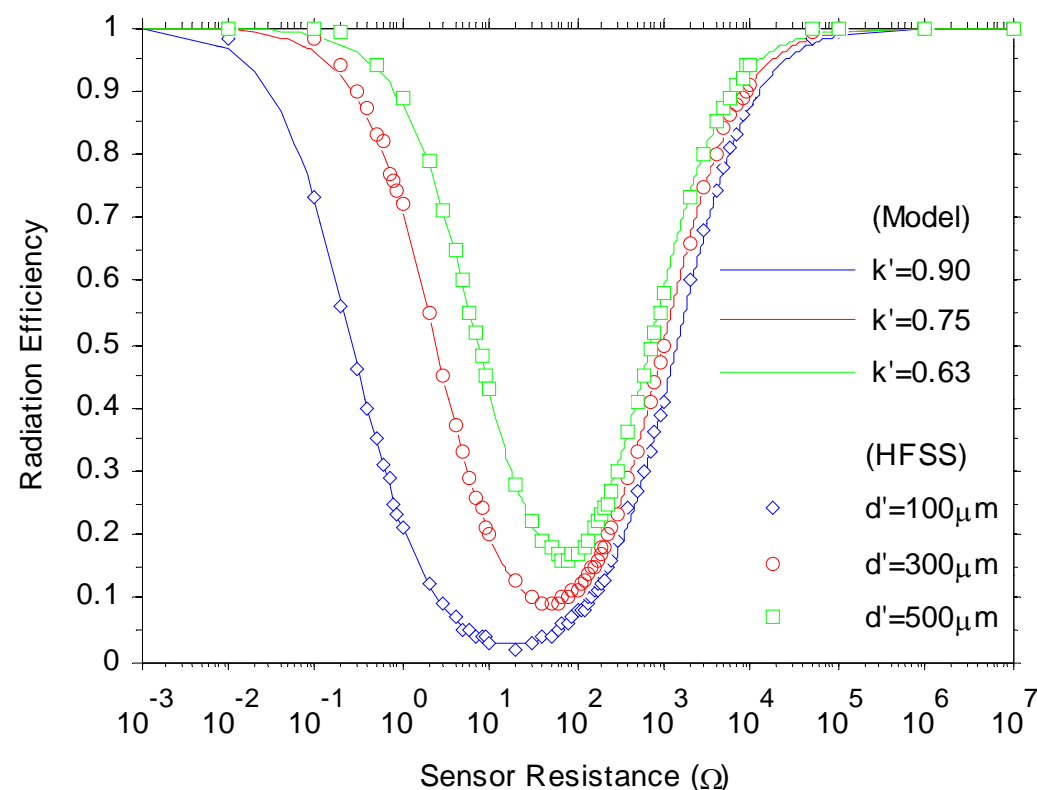
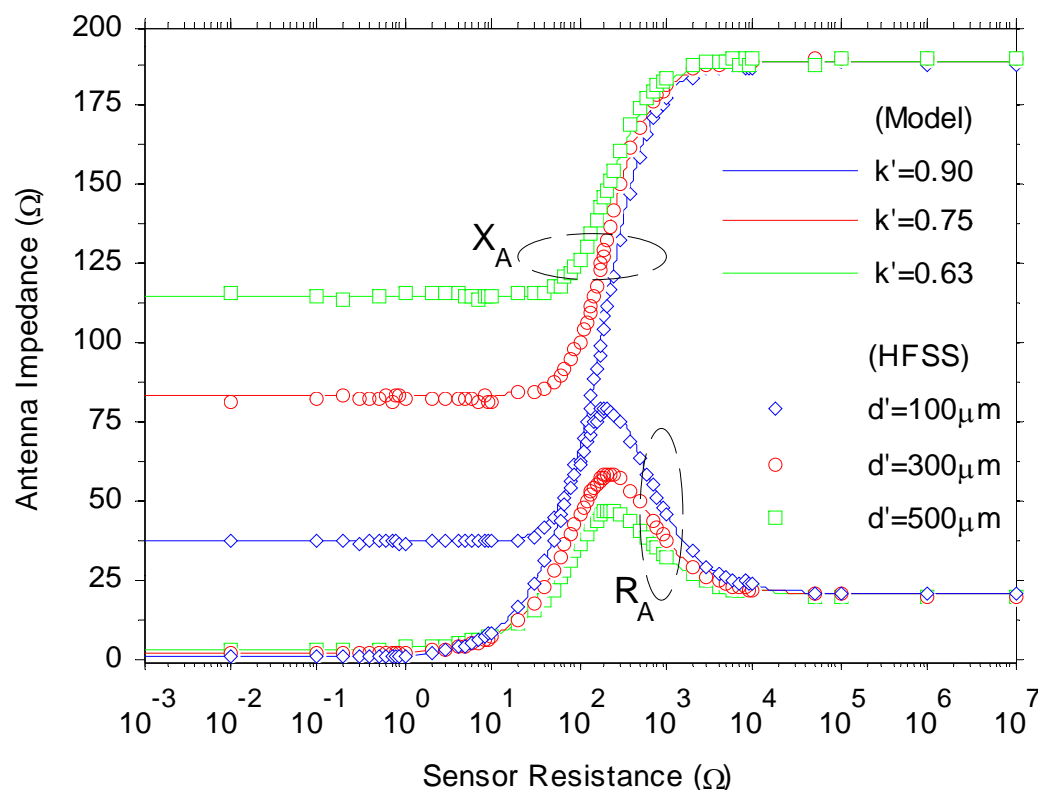
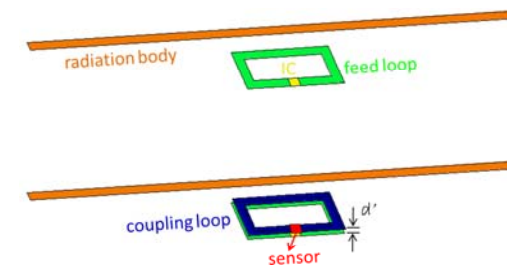
$$A' = \frac{Z'_{M'_{fl,cl}} Z'_{M'_{rb,cl}} - Z'_{M'_{rb,fl}} (Z'_{L'_{cl}} + Z_S)}{Z'_{rb} (Z'_{L'_{cl}} + Z_S) - Z'^2_{M'_{rb,cl}}}$$

$$B' = \frac{Z'_{M'_{rb,fl}} Z'_{M'_{rb,cl}} - Z'_{rb} Z'_{M'_{fl,cl}}}{Z'_{rb} (Z'_{L'_{cl}} + Z_S) - Z'^2_{M'_{rb,cl}}}$$



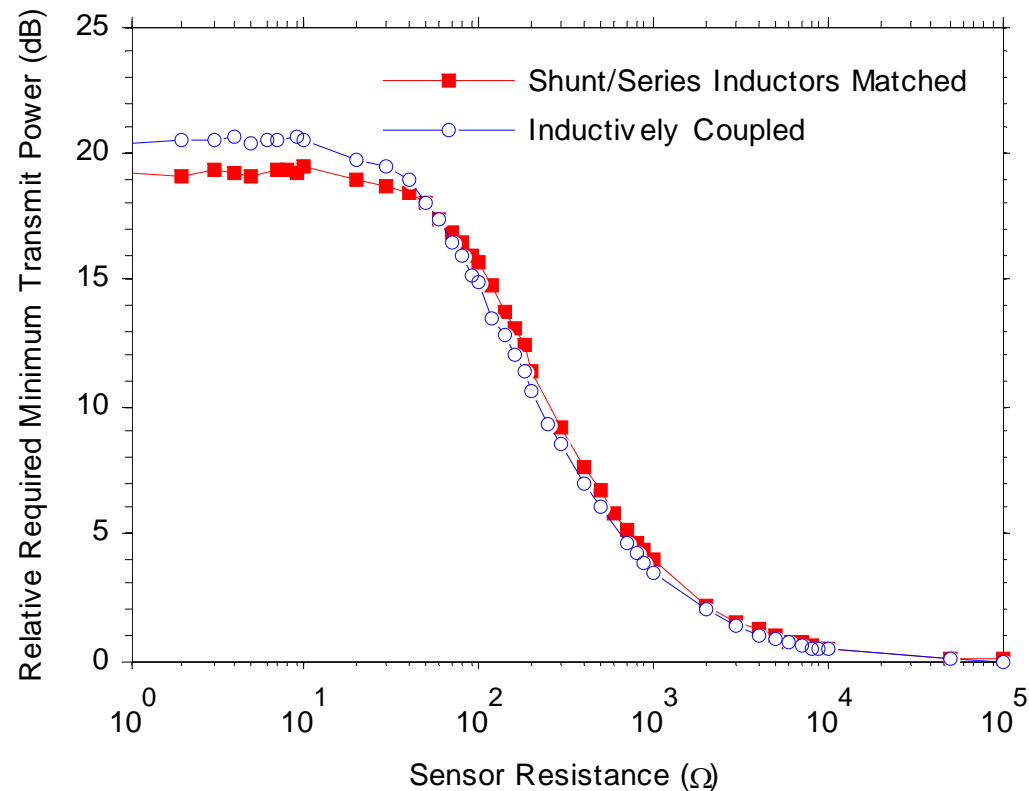
Analytical models

❖ Inductively coupled dipole



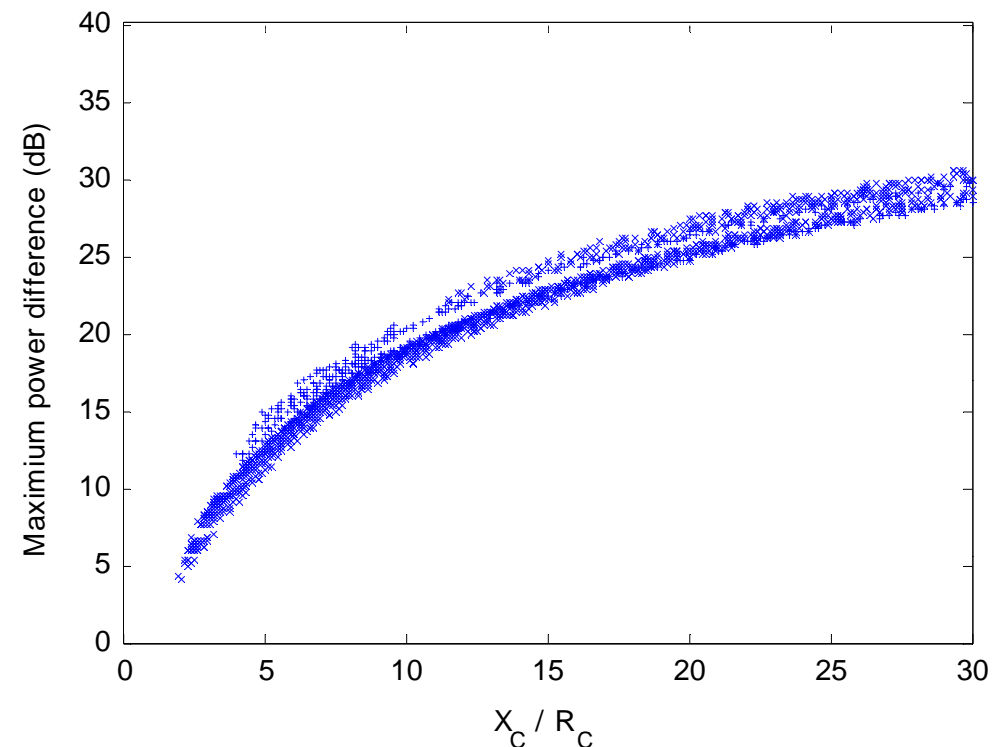
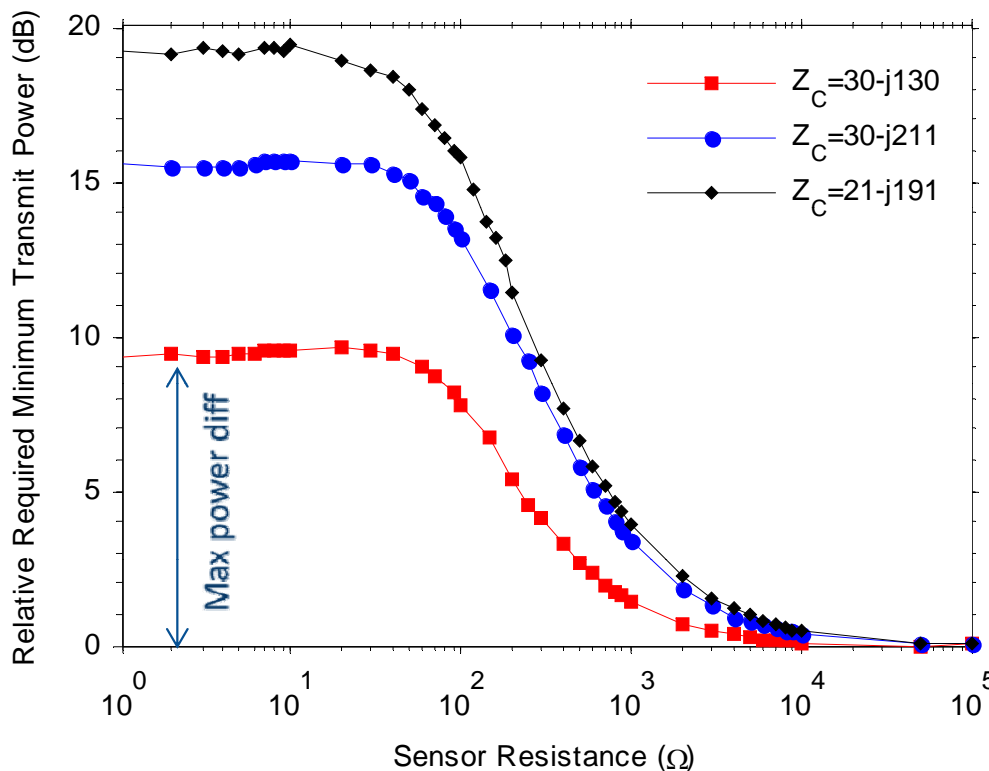
Design considerations

❖ Different types of antennas



Design considerations

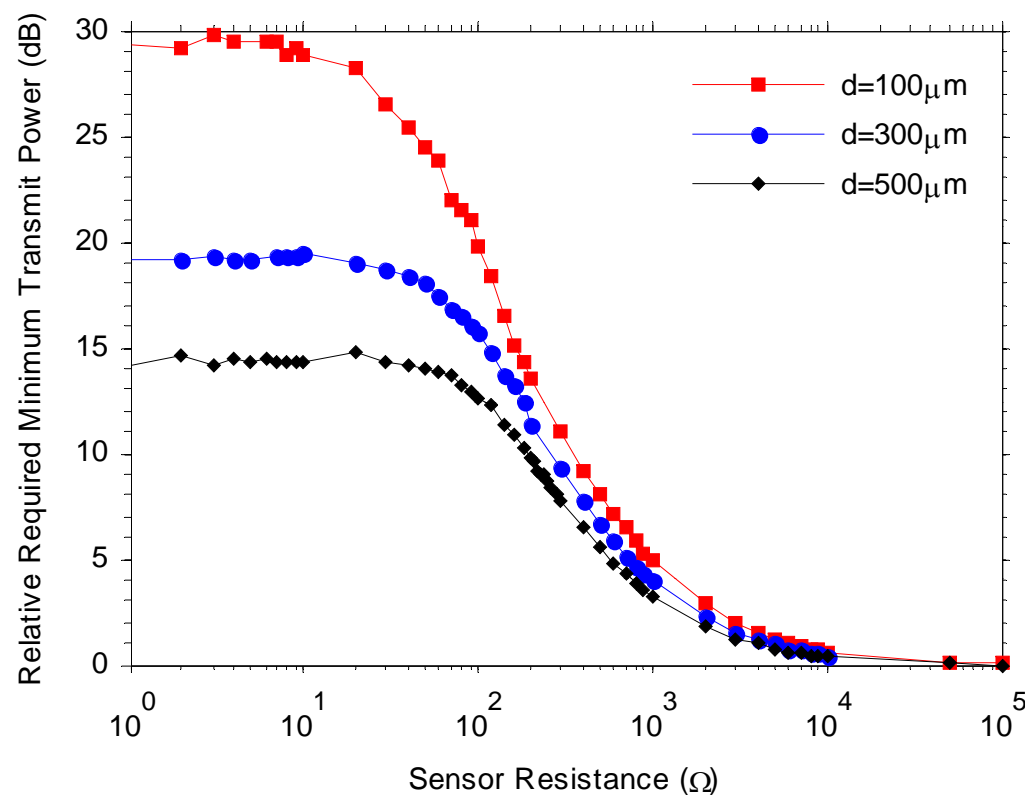
❖ Different types of chips



- One of the advantages of the EM coupled sensor tags is the easy assembly of sensors into commercial tags.
- The commercial tags have many kinds of chips which have different chip impedance.

Design considerations

- ❖ Various distance between coupling loop and tag antenna



Conclusions

- Analytical models are proposed for EM coupled UHF RFID sensor tags;
- The models can be used to analyze and predict the EM coupled sensor tags' performance through time-efficient circuit-level calculations rather than tedious full-wave simulations.
- The models can be a useful tool when constructing the EM coupled sensor tags, for choosing a proper tag and optimizing the sensor tag performance.
- The performance of an EM coupled sensor tag is related to tag antenna structure, the tag chip impedance and the distance between the antenna and the coupling loop.

Thank you for your attention!