RFID system design using 3D EM simulation tools

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Presentation Outline

- RFID Design Process
- Where does EM simulation fit in, and how can it make the design process more efficient?
  - Tag design
  - System analysis
- What is required of an EM simulation tool?
  - Frontend
  - Solvers
  - Post-processing
- Some real-world examples
RFID Tag Antenna Design Process

- Application? Tag requirements?
- Construction materials?
- ASIC Impedance?

Antenna Specification
RFID Tag Antenna Design Process

Antenna Specification

Parametric study, optimisation.

Build and measure prototypes.

Design requirements met?

Design ready!

EM Simulation
Antenna to System

- The antenna design is only the first step. The antenna is positioned on an object and used in a system, and this introduces additional unknowns which may affect the tag’s performance.

- Antenna unknowns:
  - geometry
  - material properties

- Positioned antenna unknowns:
  - container geometry
  - container material properties
Antenna to System

- Antenna in system unknowns:
  - position and orientation of tag relative to reader
  - effect of group on individual performance (e.g. shielding)
Why EM Simulation?

- RFID tags have to be fast to develop, cheap to manufacture, but are expected to function robustly despite construction tolerances, variations in material properties, on a variety of backgrounds, and all that in a system in a possibly complex environment.

- Using electromagnetic simulation, we can:
  - robustly optimise the initial tag,
  - consider the effects of positioning the tag,
  - check that the whole system will work as envisaged.

- The analysis of complex systems by traditional methods within an acceptable budget and time-frame is unfeasible.

- The only way to ensure that the tag will work not only on its own, but also in its intended environment, is by using EM simulation tools.
EM Simulator Requirements

- General requirements of a modern EM simulation tool:
  - intuitive user interface
  - efficient solvers
  - powerful post-processing
User Interface Requirements

- Intuitive CAD type graphical user interface
- Easy robust parametric construction
- Import from different formats
  - modification, parameterization
- Advanced meshing algorithms
- Powerful macro programming and scripting
Graphical User Interface

- Construct
- CAD Import
- Parameterize
- Integrate
Parameterization

- Critical!
- Should be a fundamental part of construction.
- Should be easy to modify and parameterize imported structures.
- Allows parametric analysis and optimisation.
Solver Requirements

- Choose the right solver for the job.
- Advanced algorithms efficiently using modern hardware give the best performance.
- Parametric sweeps and effective optimisers are essential.
- For systems: co-simulation of 3D EM model and attached circuit.
Choose the Right Solver for the Job

- **Inductive Coupling (125 kHz - 15 MHz)**
  - Very small dimensions
  - Coupling only through magnetic field
  - Tag typically a planar coil
  - Best simulated in the Frequency Domain

- **Microwave Coupling (868 MHz - 5.8 GHz)**
  - Typically a regular antenna
    (e.g. planar folded dipole)
  - Matching network important to keep antenna small
  - Best simulated in the Time Domain
Example: Effect of Placing Tag

- Placing a tag on an object can have a dramatic effect on its properties, and this must be taken into account during its design.
Example: Tag Optimisation

- Will the tag work despite changes in the material properties of the object on which it is placed? A parameter sweep of the permittivity may answer this question.
Chip Effect: Matching Network

- Can consider the effect of a matching network on the antenna behaviour.
- We can e.g. optimise a simple L-C section to allow the antenna to perform best at 900 MHz.

\[ S_{11} \text{ in dB} \]

\[ \text{frequency in GHz} \]
Example: System Simulation

- How is the read range affected if the tag is placed among a group of other tags? Will the transmission to each still be sufficient?

Tag reader, optimized for operation at 900 MHz.
Example: System Simulation

- Shielding effects become apparent for the tags that are further removed from the reader. Or do they?
Transmission Levels
System View: AM-Signal Generator

HF Signal

AM Signal Generator

Input Signal

LF Signals at RFID Tag 3
Example: Complex Environment

- How well will the tag function when placed in a complex environment like a reinforced crate containing cable spools?
Example: Complex Environment

- The tag functions, but there are will be reception nulls from which it cannot be read. Using this information, we can decide on where to position the reader antenna.
Conclusion

- EM simulation is indispensable in RFID design process.
  - Antenna design and system analysis are required.
    - Parameterization is everything.
  - Choose the right solver for the job.
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