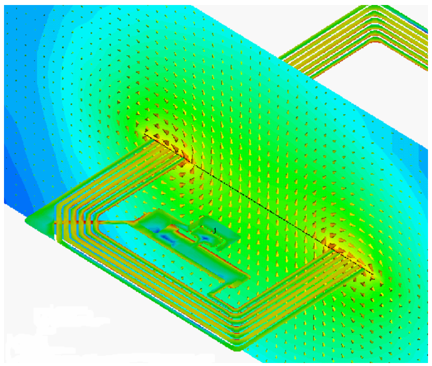
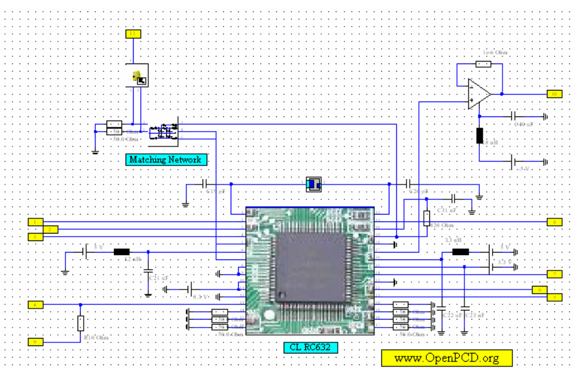
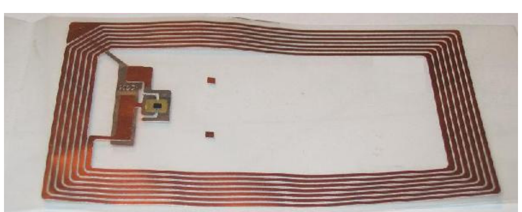
Application Note on RFID Simulations







- Overview
- Operating Principles
- Inductive Coupling
- Microwave Coupling
- Coupling to Circuit Simulation
- Customer Application
- Summary

Franz Hirtenfelder/ CST GmbH

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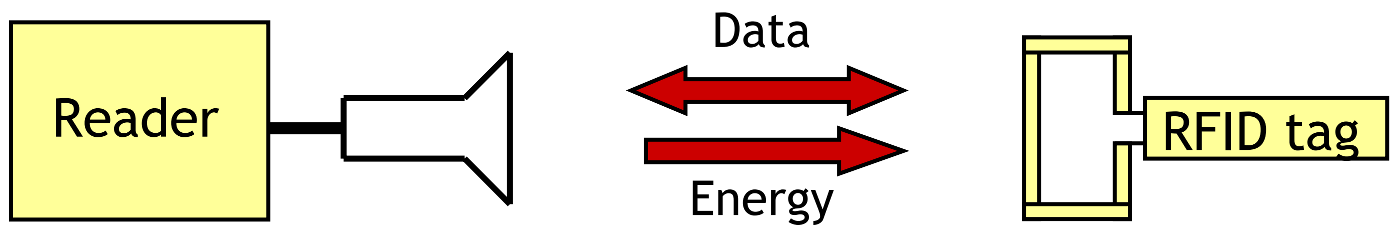
Overview

Radio Frequency IDentification

- Fundamental tool for Automatic Identification: authentication, ticketing, access control, supply management, parking, payment, vending, surveillance
- Advantages:
  - Contains more information than e.g. Barcodes
  - Can be read/write
  - Contactless ID (in contrast to phone or bank cards)
  - May become cheap mass product (e.g. in supermarkets)

General Principle



Typical characteristics of RFID:

- Tag is a passive device, energy is transmitted from reader
- Distance mm to 10m (typically ~20 cm)
- Contains silicon chip, can be read only or read/write
- Responds with modulated signal
- Mostly printed (planar) structures

Frequencies

125/134 kHz	Animal identification, industrial applications, very robust, low data transmisstion (64 bit)
7.4 - 8.8 MHz	Electronic Article Surveillance (EAS)
13.56 MHz	"Smart Labels" widely used for product/article ID
868 - 928 MHz	Logistics,…
2.4 GHz	Vehicle identification, electronic toll collection
5.8 GHz	electronic toll collection in Europe

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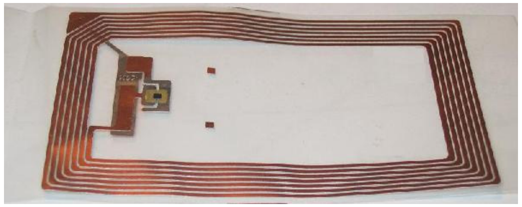
Operating Principles

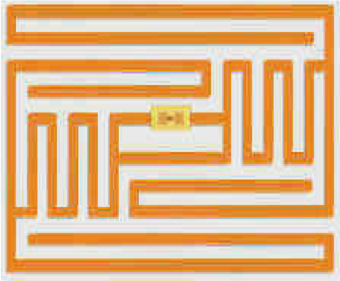
- Inductive Coupling (125 kHz – 15 MHz)

  - Very small dimensions compared to l
  - Coupling only through magnetic field
  - Tag typically a planar coil



- Microwave Coupling (868 MHz – 5.8 GHz)

  - typically a regular antenna
    (e.g. planar folded dipole)
  - Matching network important to keep
    antenna small



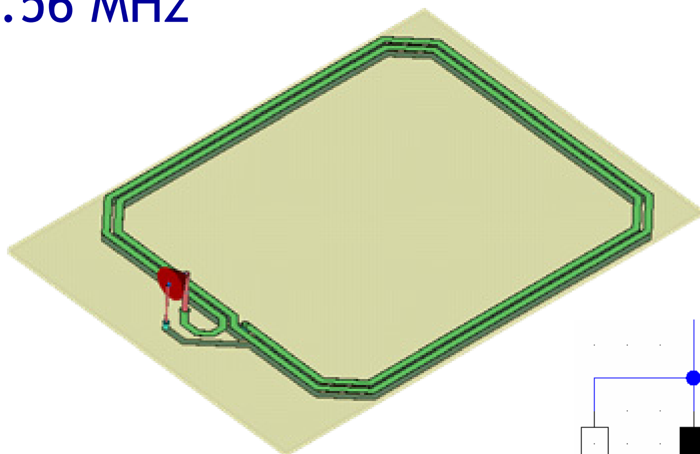
Inductive Coupling

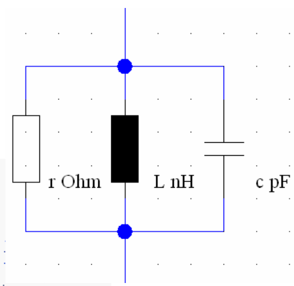
RFID tags are mostly planar coils with small dimensions compared to l

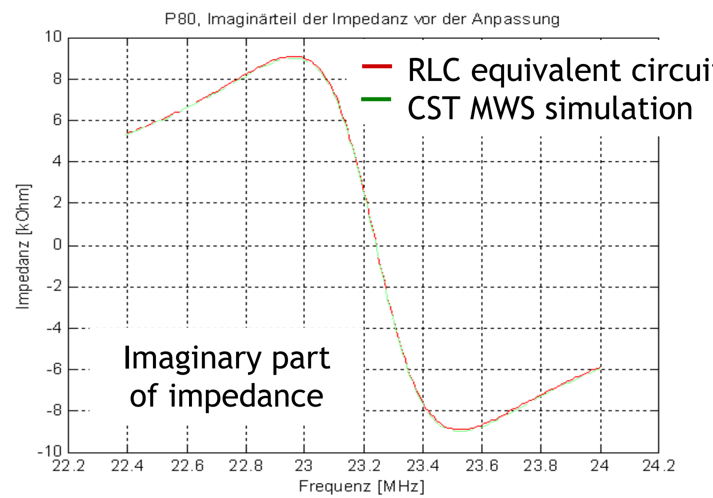
⇨ Hexahedral or tetrahedral F-Solver are typically most suited.

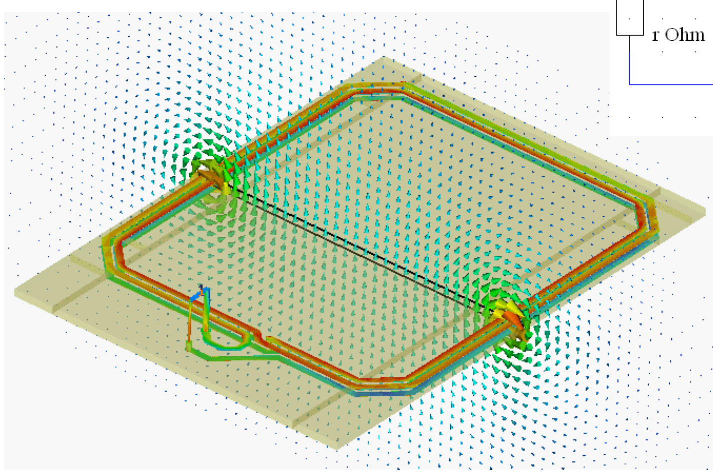
Simple Example for 13.56 MHz

At 13.56 MHz Measurement: (7.15 + 398i) W
Simulation: (7.0 + 395i) W







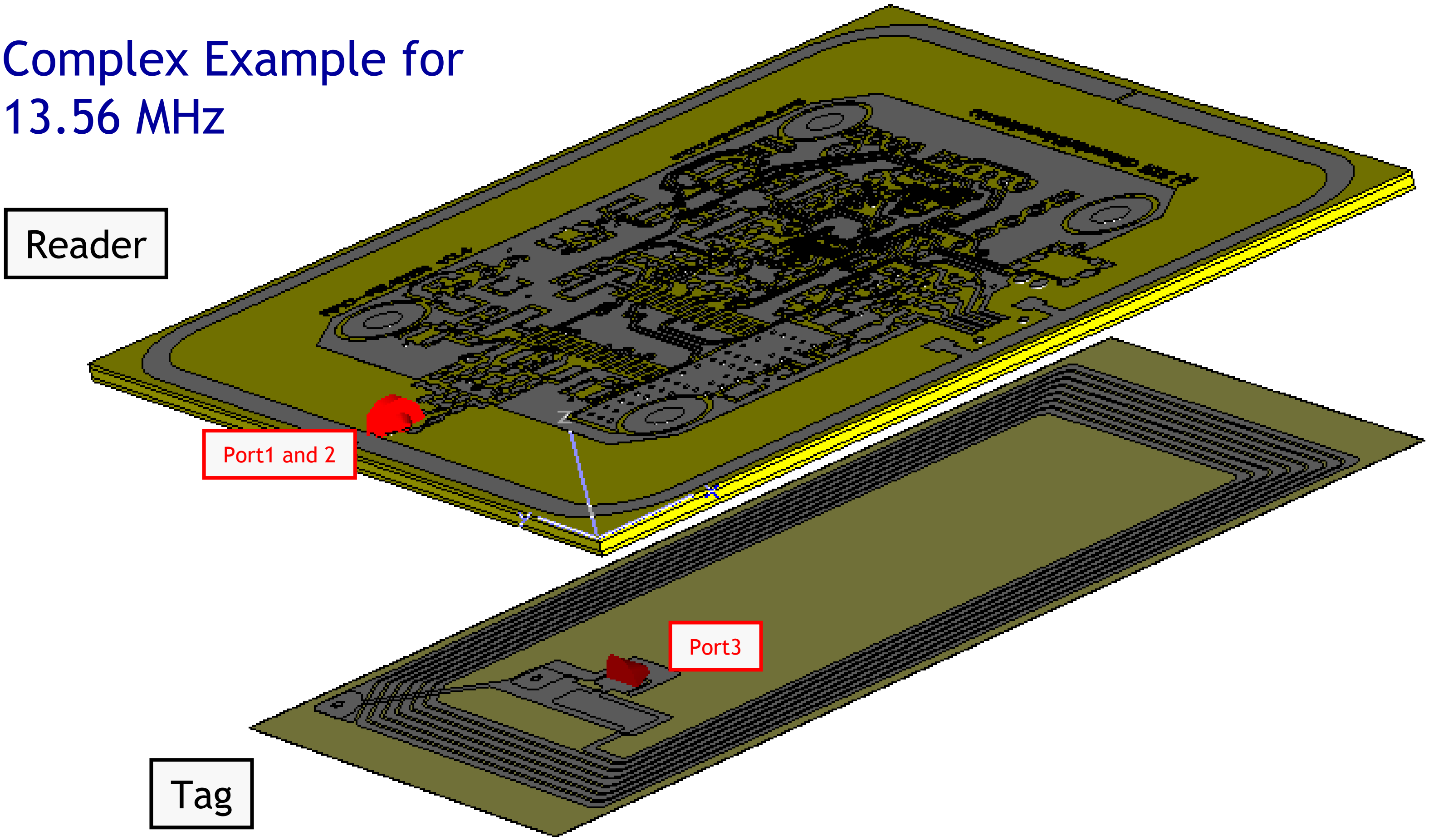


RLC parallel equivalent circuit fits broadband to simulation results

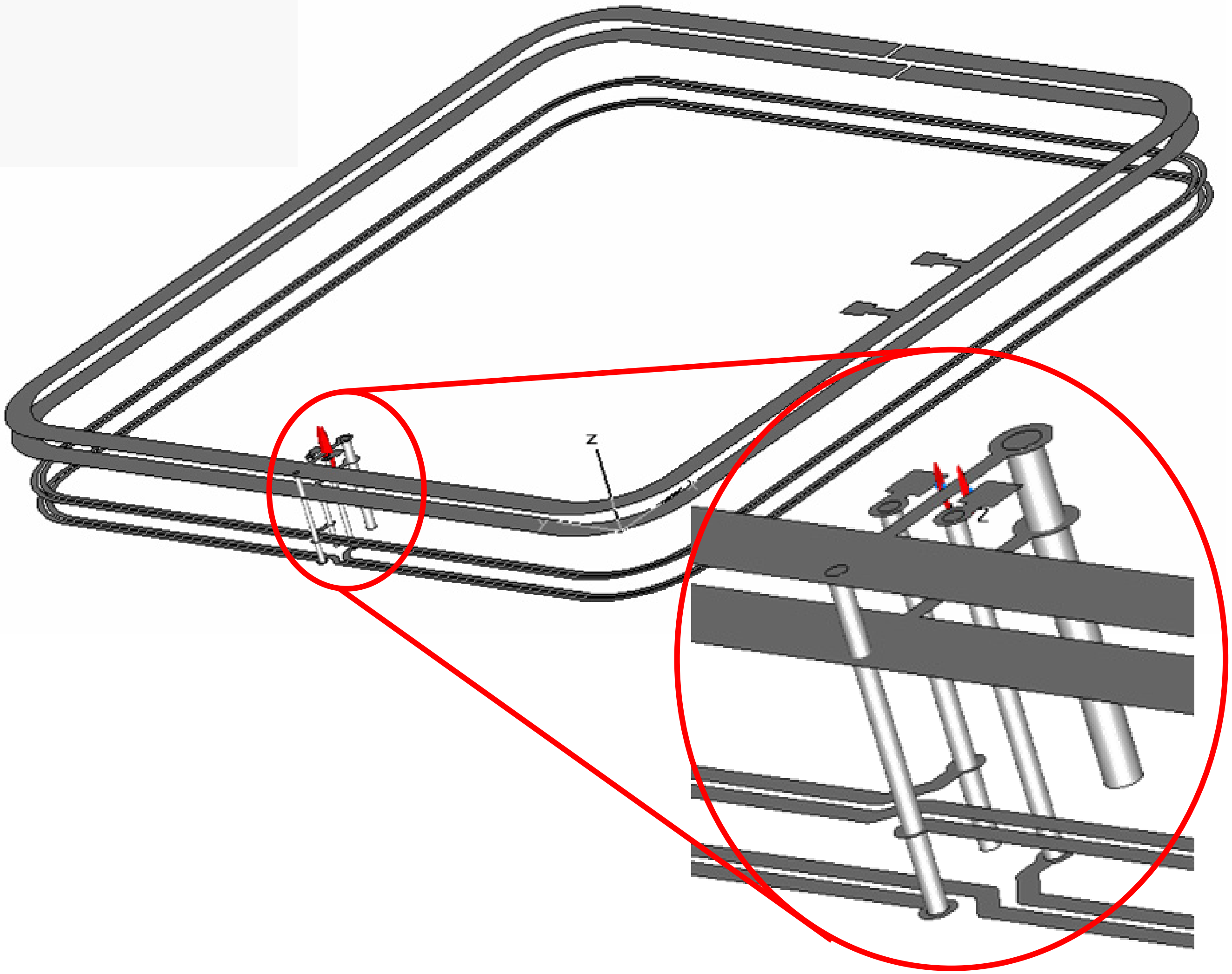
with courtesy and permission of Legic Identsystems AG

Reader &Tag
Inductive Coupling: 13.56 MHz

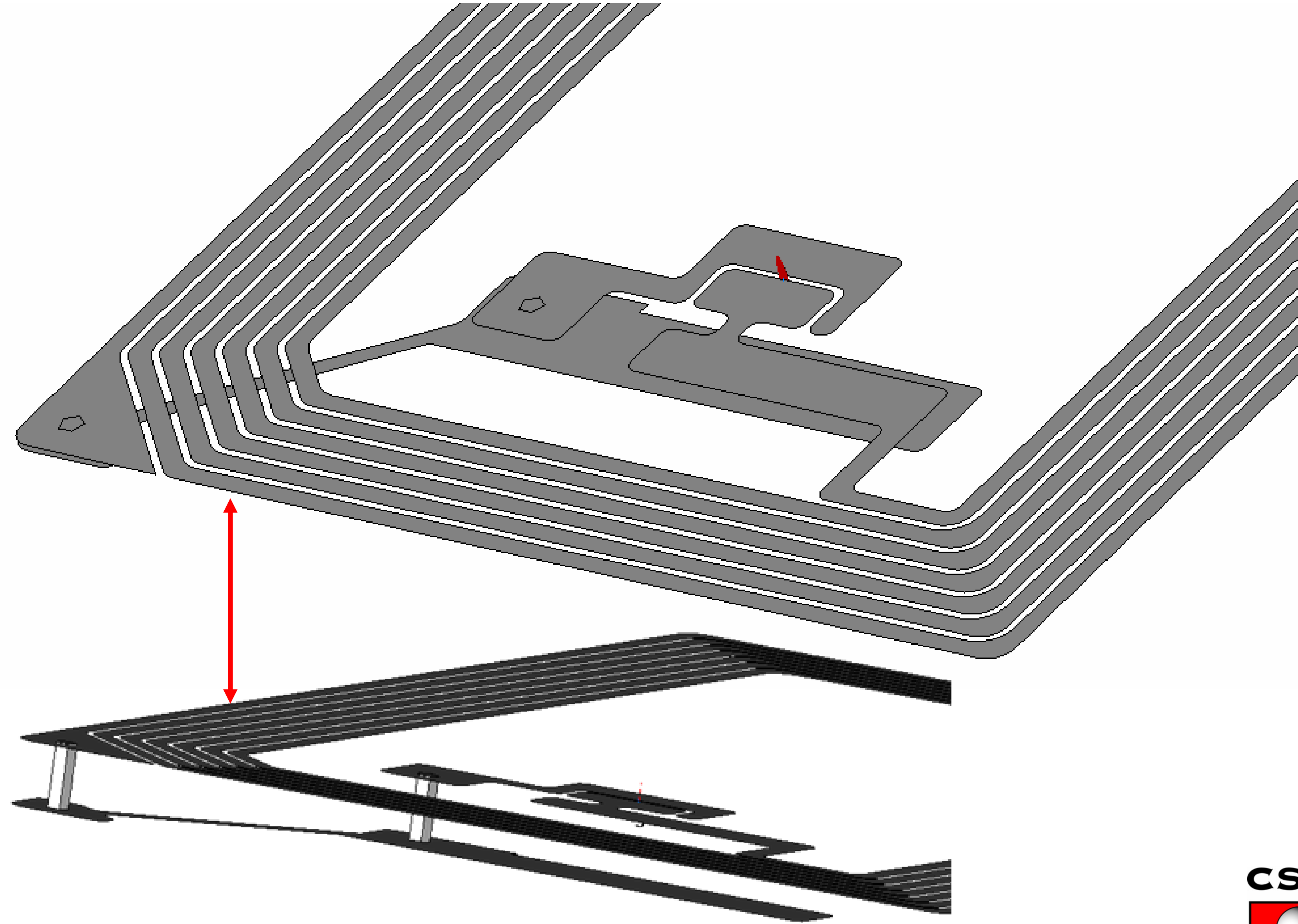
Complex Example for
13.56 MHz



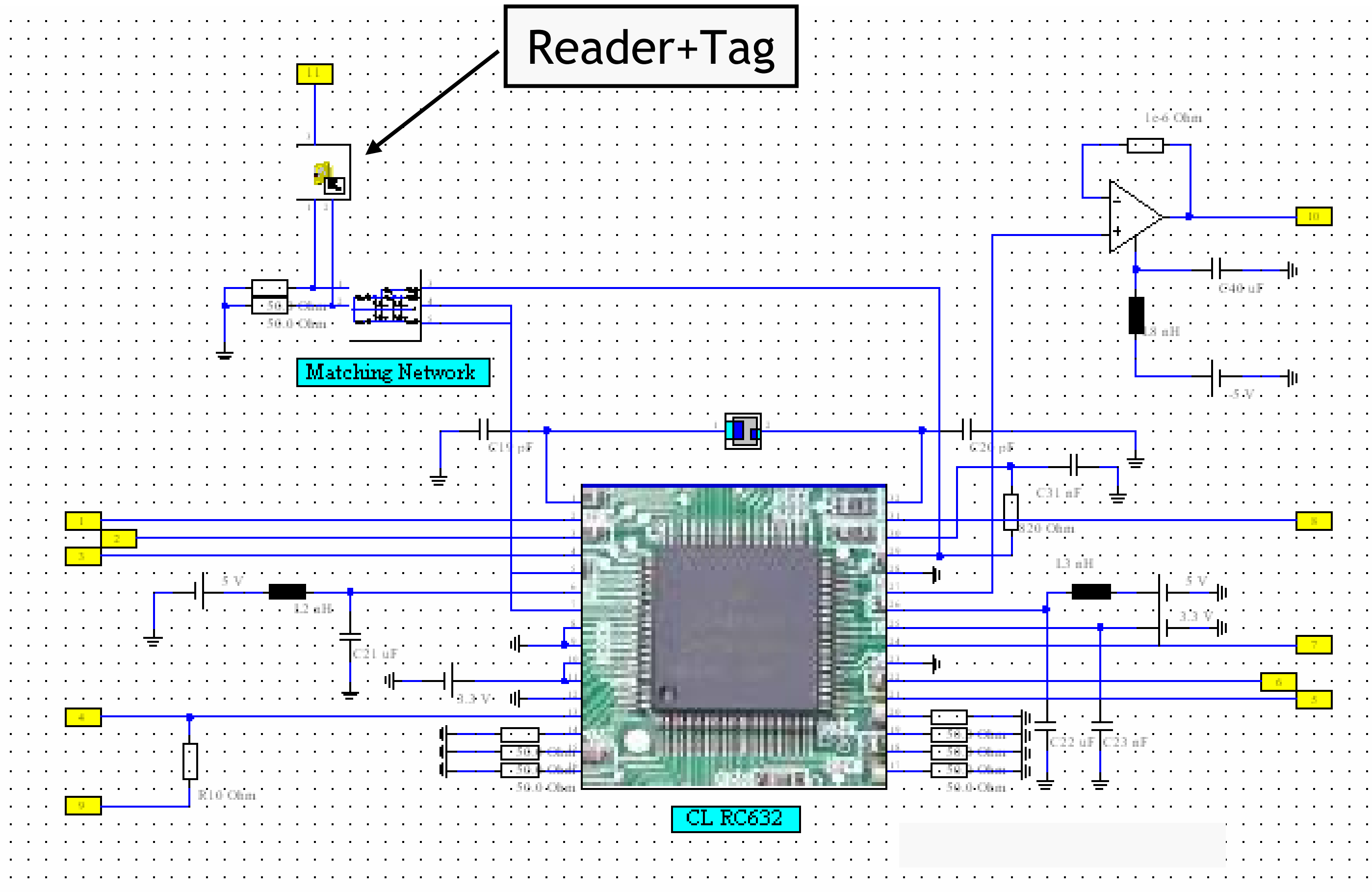
Close-Up look at Reader-feeding



Close-Up look at Tag



Circuit in CST DESIGN STUDIO



Simulation of a realistic multi-tag / reader environment

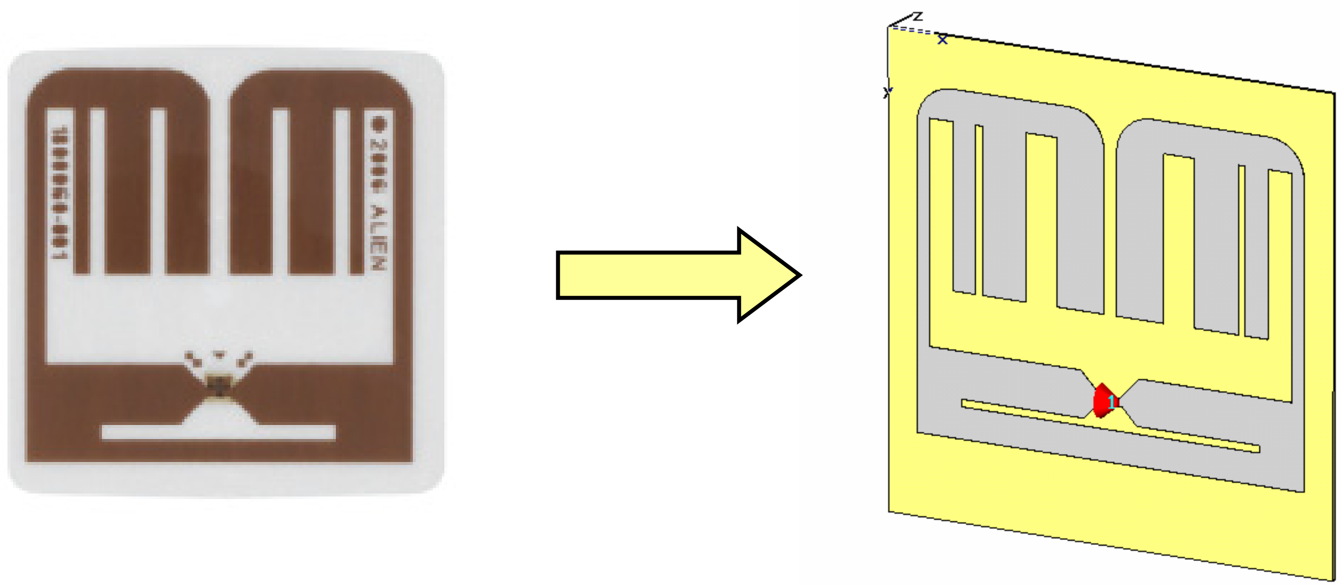
- Design of Tag and Reader
- Microwave coupling (900 MHz)
- 3D EM Simulation with CST‘s „Complete Technology“ using Time-Domain and Frequency Domain solvers
- Coupling to circuit analysis with CST DESIGN STUDIO™

MicroWaveCoupling: TAG

SMALL FORM FACTOR TAGS

GEN 2 1X1

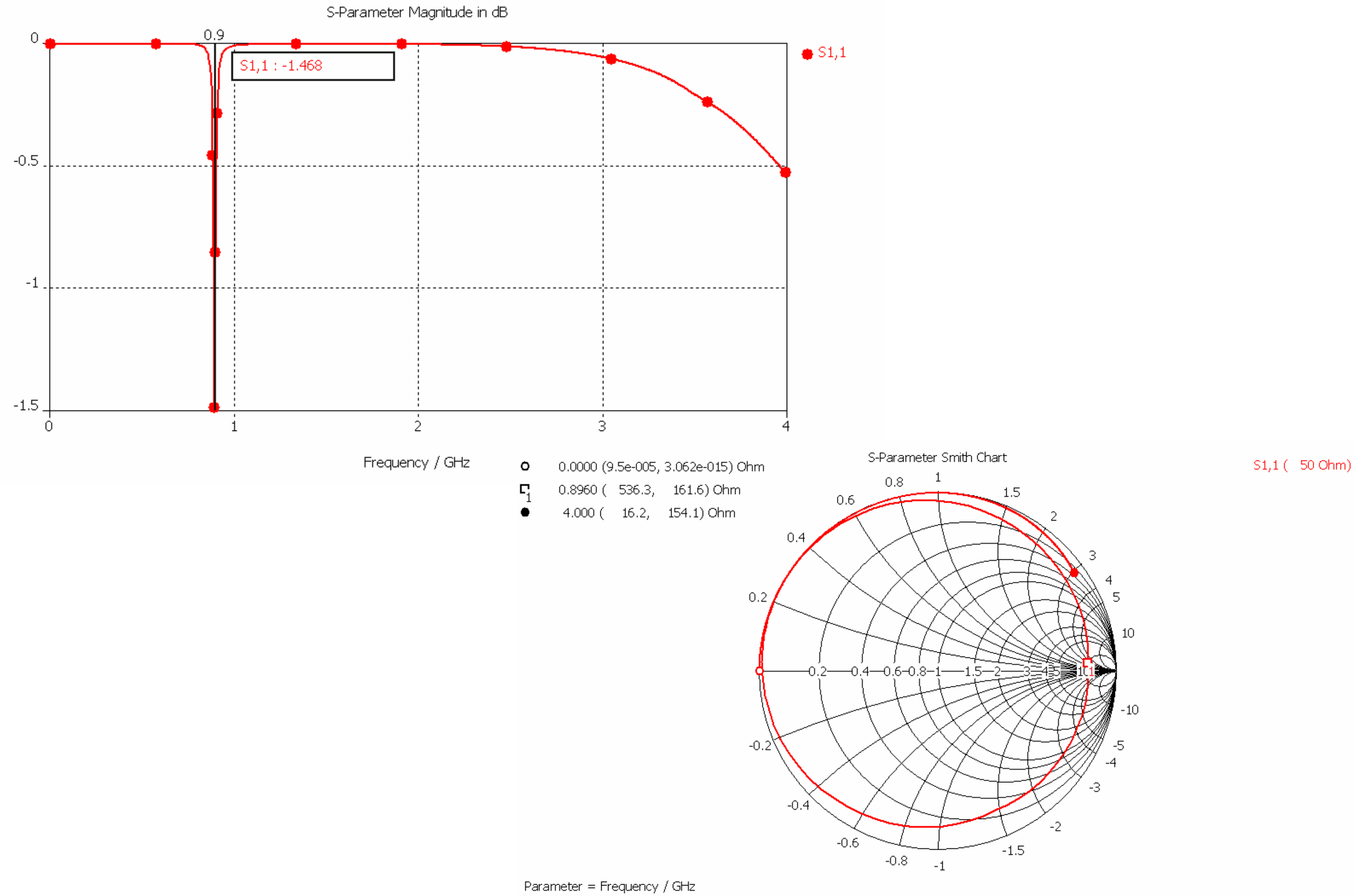
- Optimized for operation from 902 to 928 MHz
- Small form factor tag optimized for plastic packaging such as pharmaceutical pill bottles
- Near-field and far-field communication modes
- 25.4mm x 25.4mm



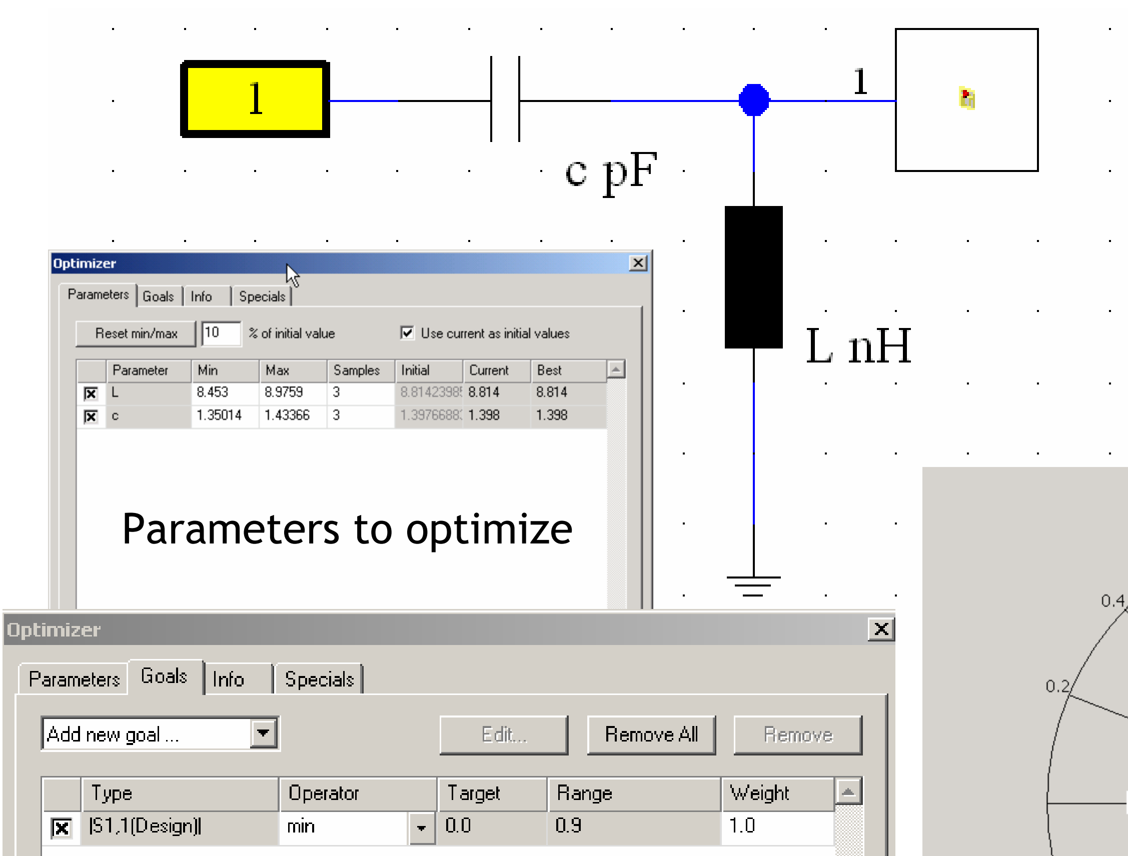
http://www.alientechnology.com/docs/Gen2_TagFam_datsht.pdf

S-Parameter

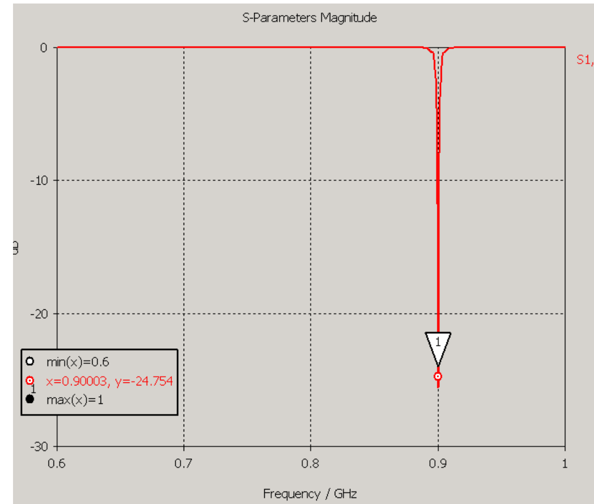
$|S_{11}|$ in dB, unmatched

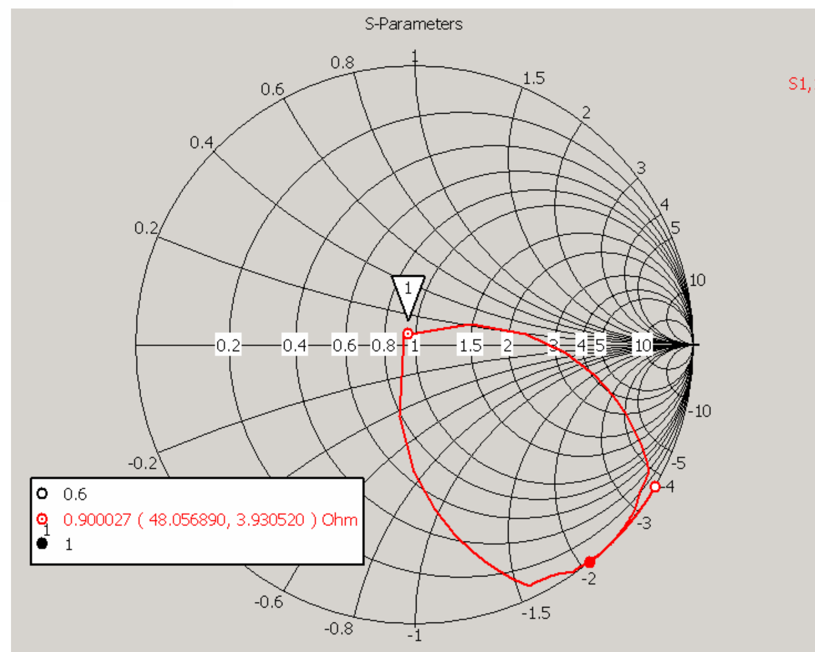


Matching Network in DesignStudio™



Goal definition





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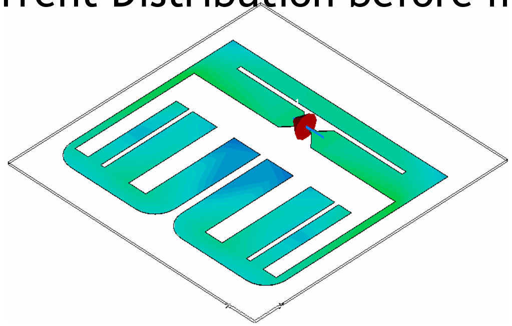
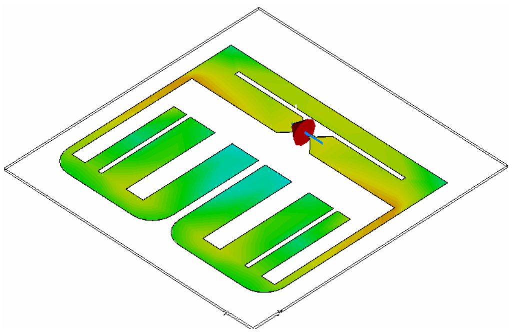
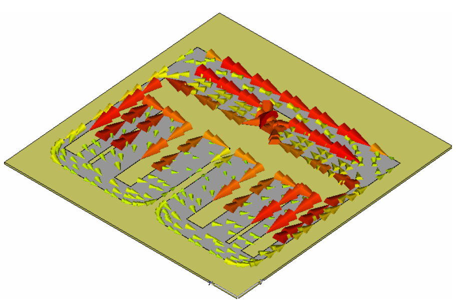
Surface-Current and Farfield f=900 MHz

Current Distribution before matching

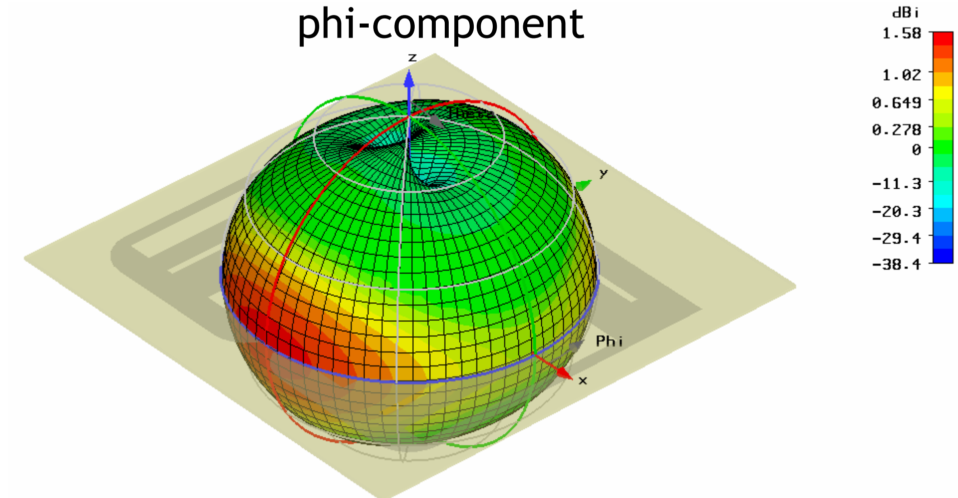


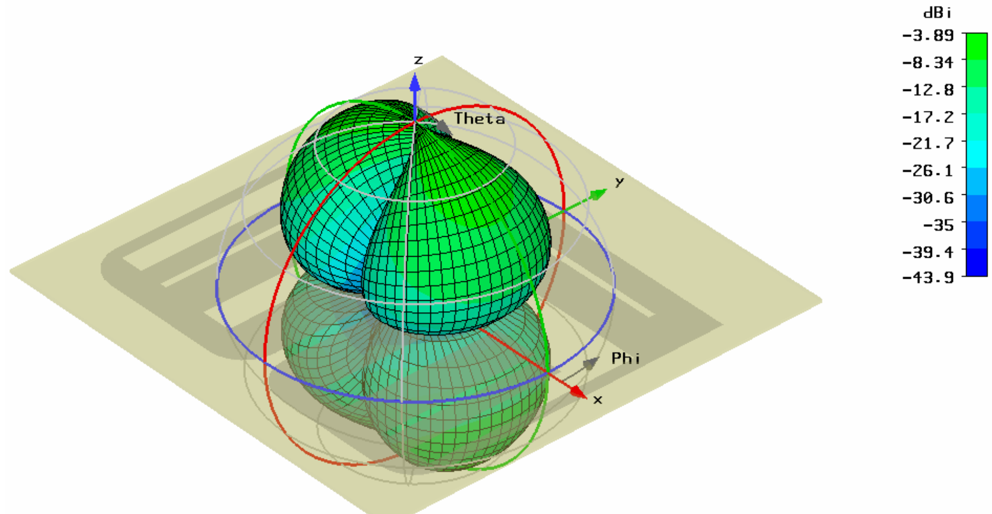
Current Distribution after matching





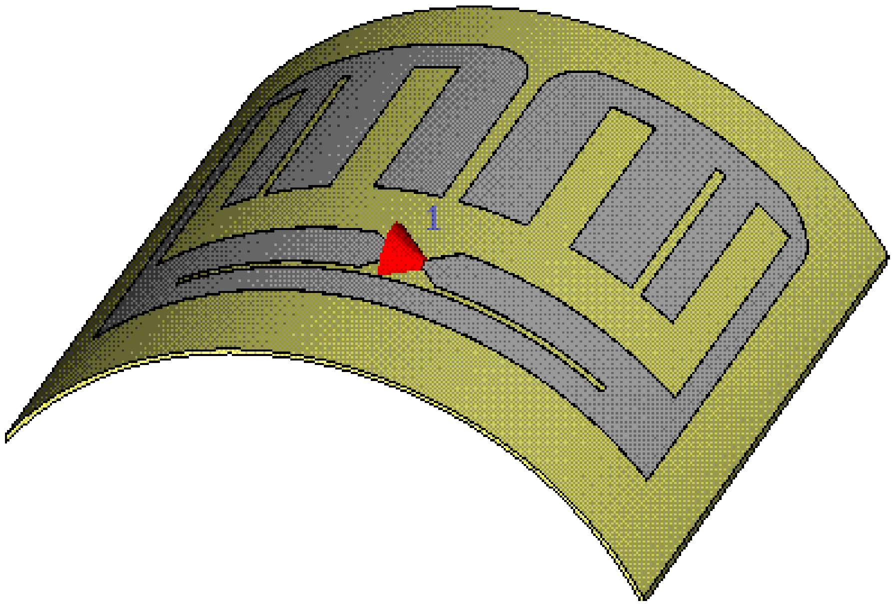
phi-component



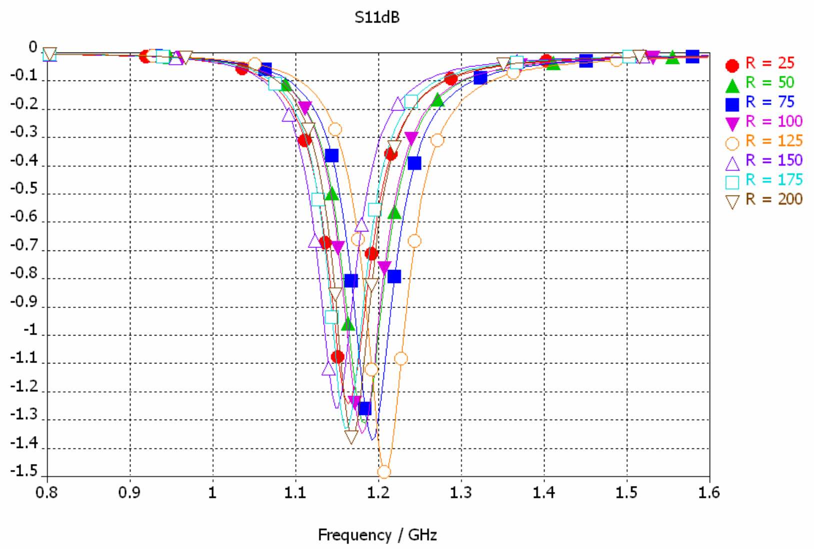


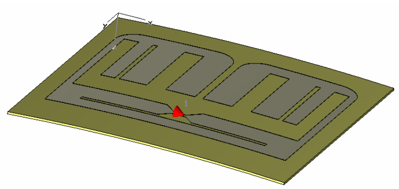
theta-component

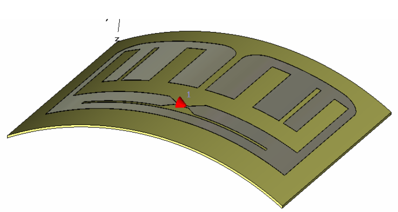
Parameter Study of a warped Tag



The impact on S-Parameters and farfields are investigated for warped tags. The conformal radius is varied in a range of 25 – 200 mm

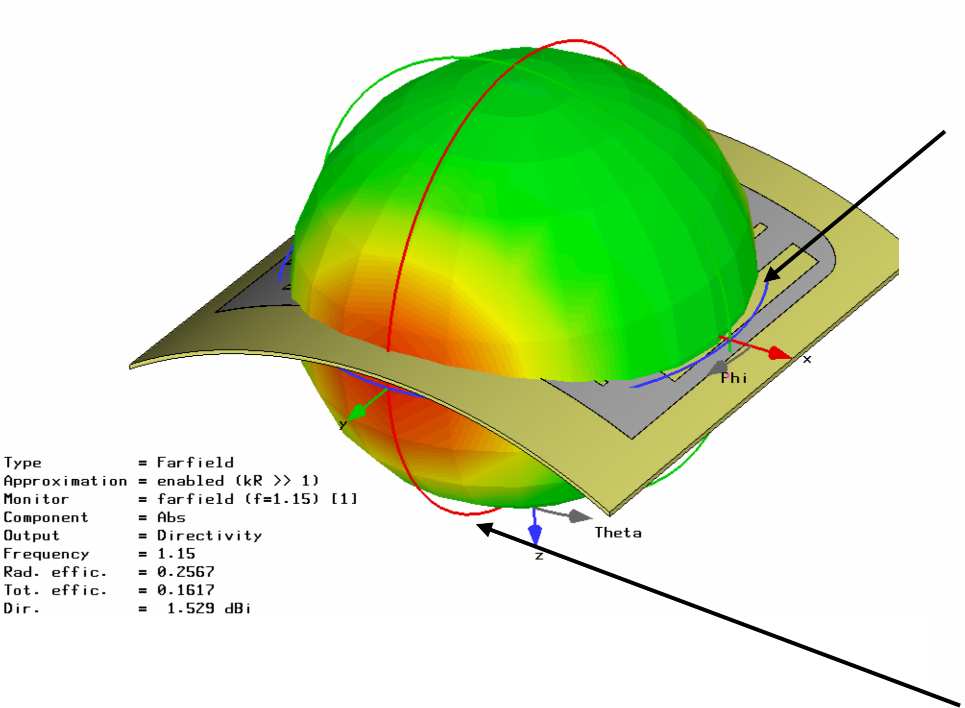


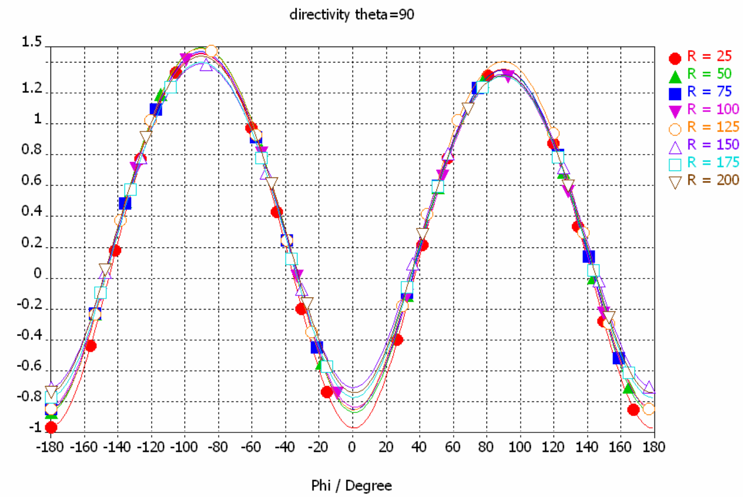


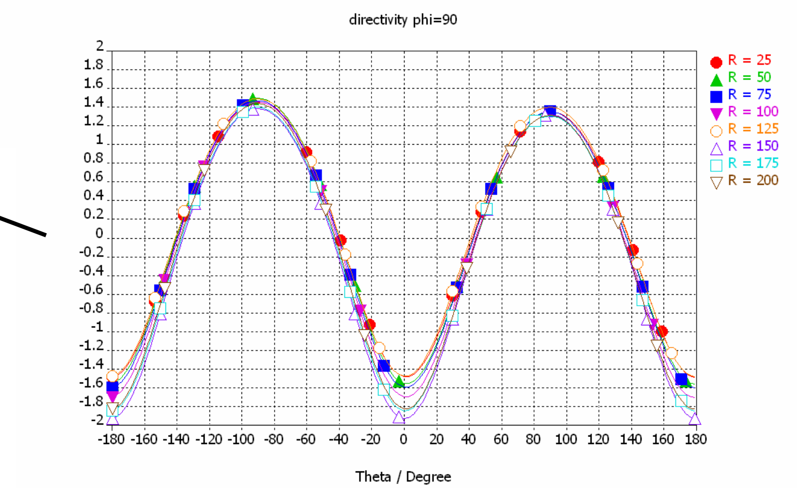


Parameter Study of a warped Tag

Farfield at 1.15 GHz







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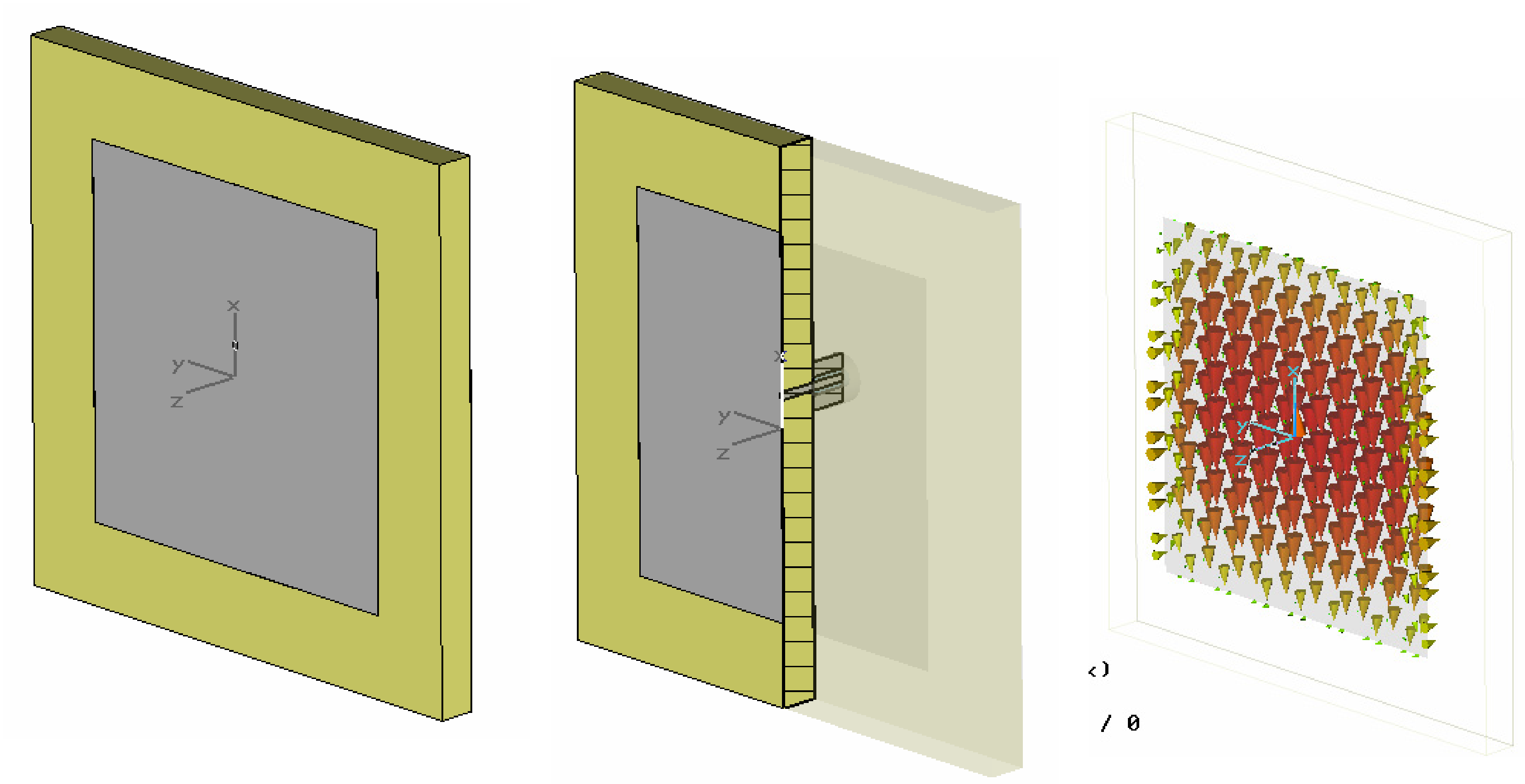
Geometry of the Reader

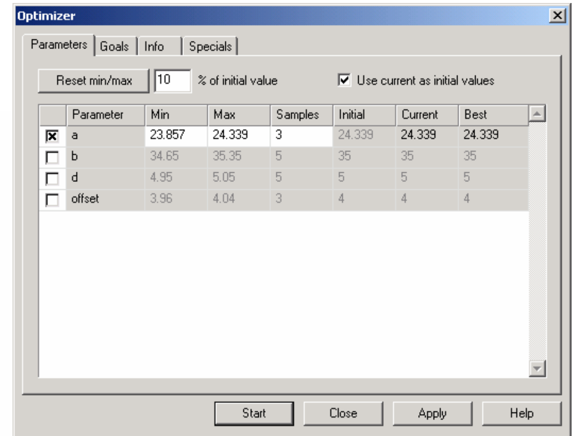
A simple, vertically polarized patch-type reader antenna was used as reader antenna. The feed is designed as a simple coax-connector line.

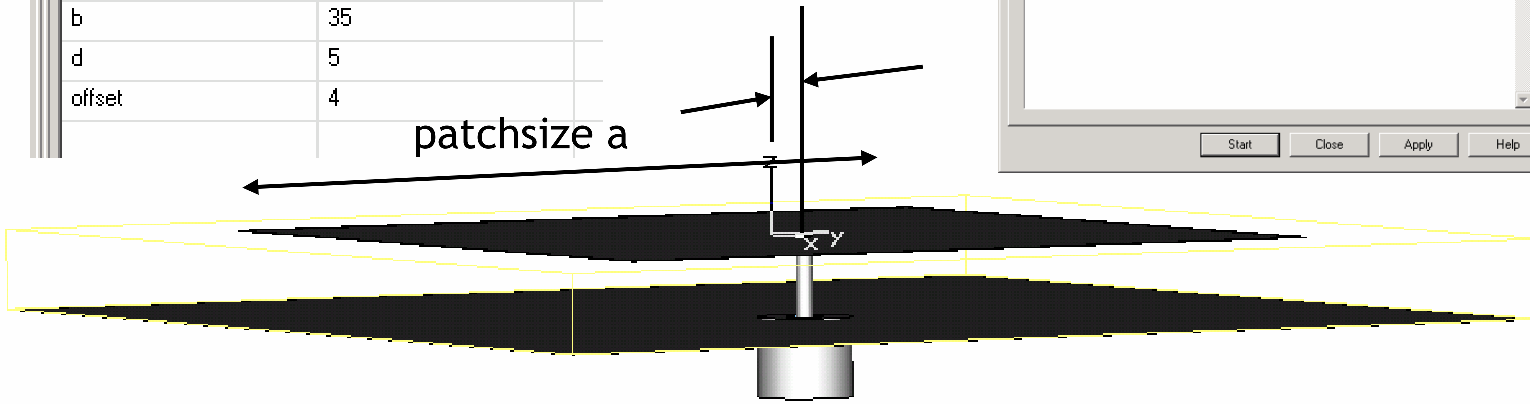


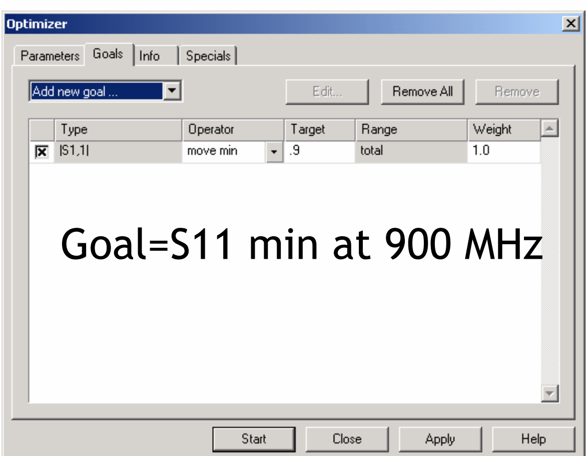
Reader: Optimization

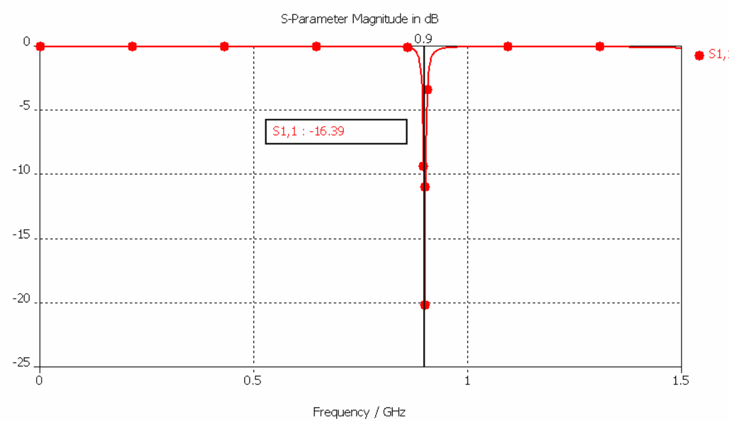
Parametric model setup

Name	Value	D
a	24.339	
b	35	
d	5	
offset	4	





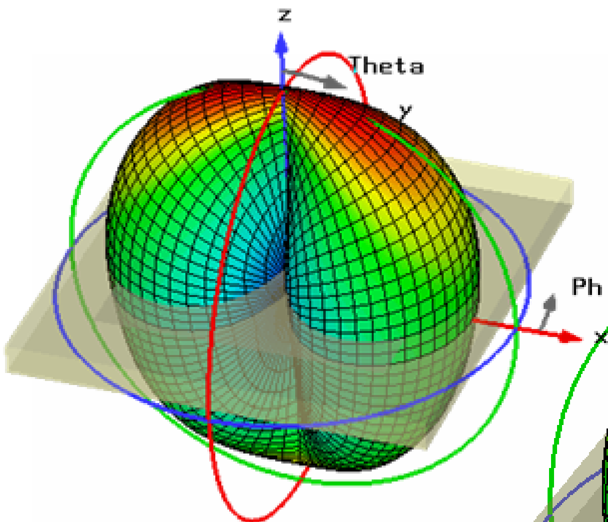


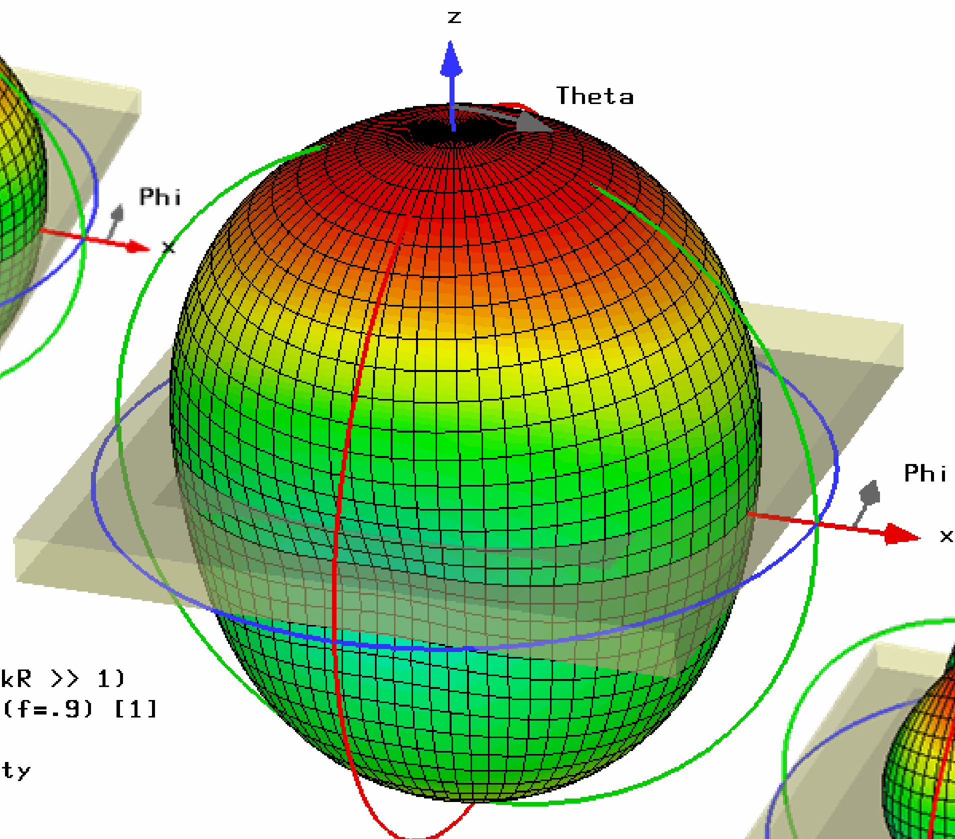


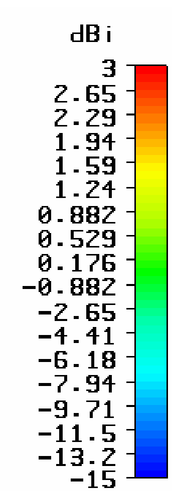
Reader: Directivity

f=900 MHz

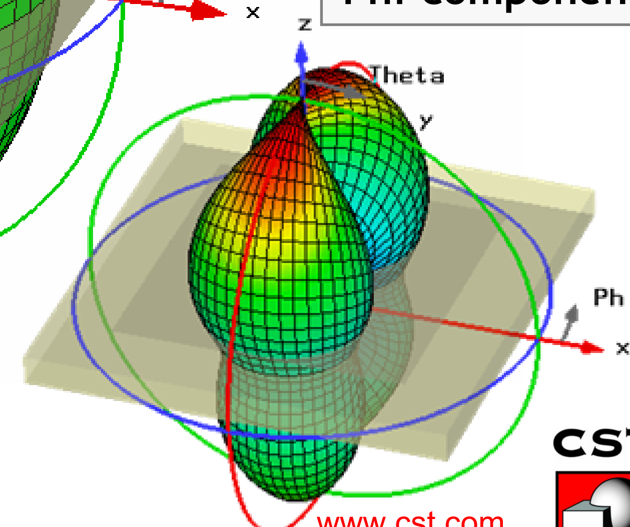
Theta-component







Phi-component




```
Type           = Farfield
Approximation = enabled (kR >> 1)
Monitor        = farfield (f=.9) [1]
Component      = Abs
Output         = Directivity
Frequency      = 0.9
Rad. effic.    = 0.9912
Tot. effic.    = 0.9628
Dir.           =  3.449 dBi
```

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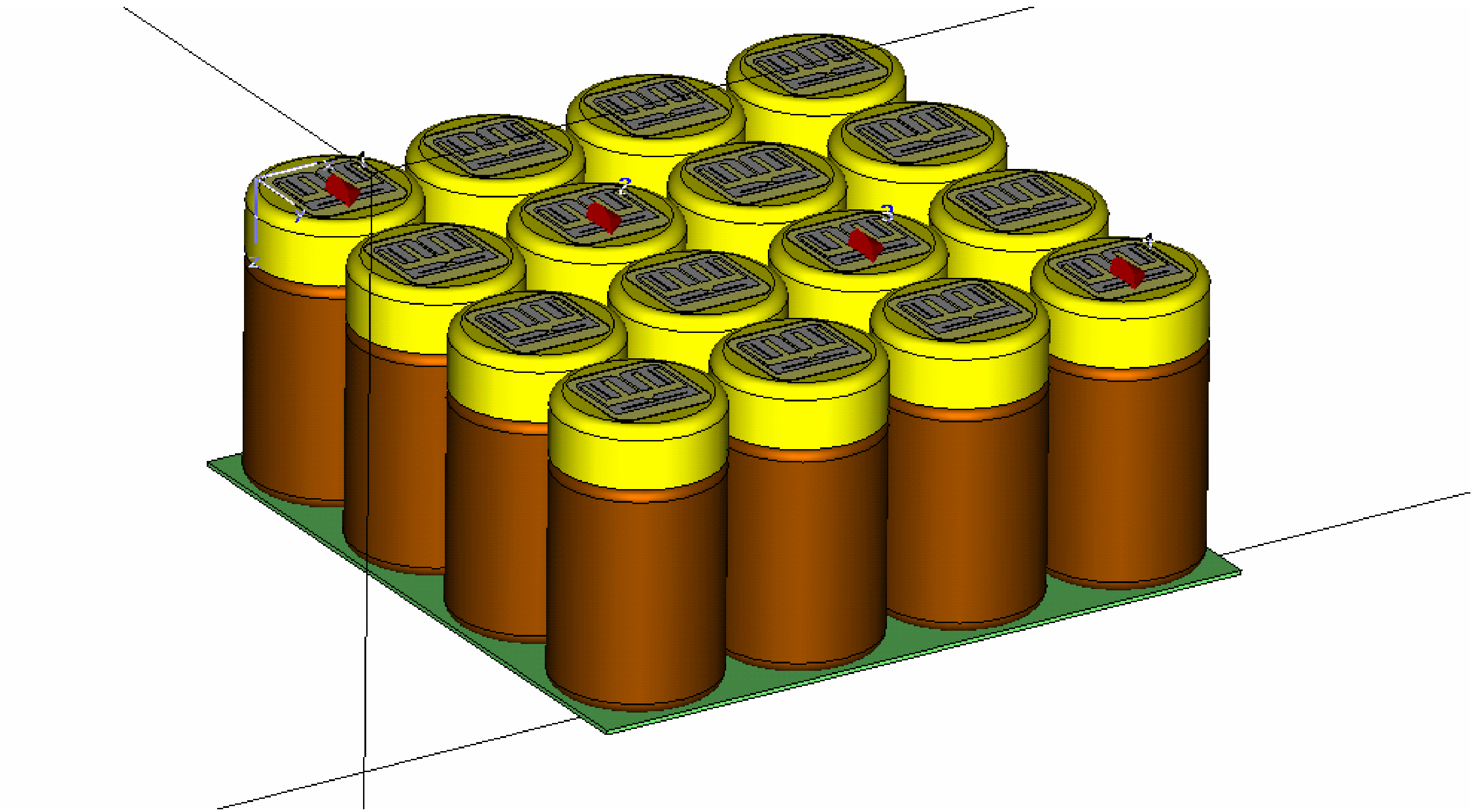
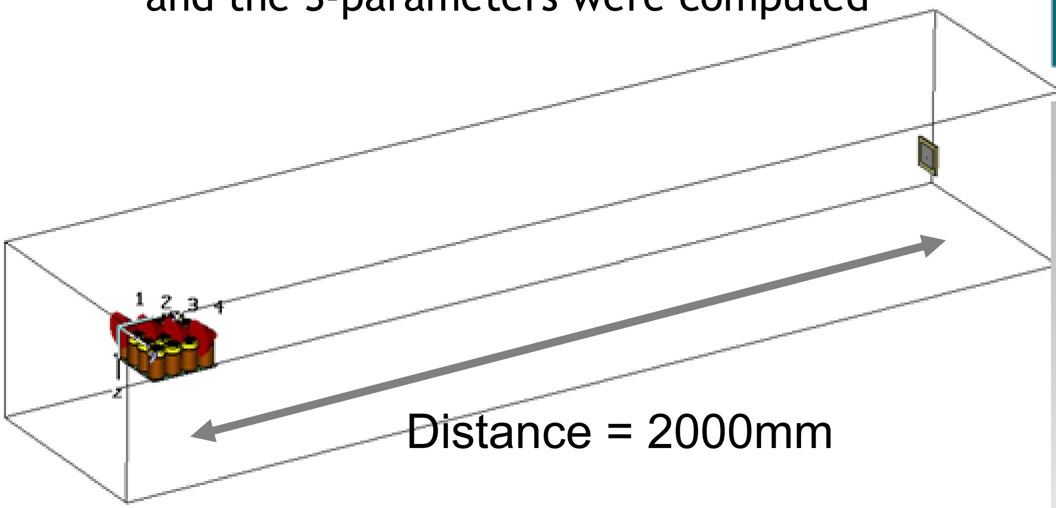
Tags on medical pill-boxes

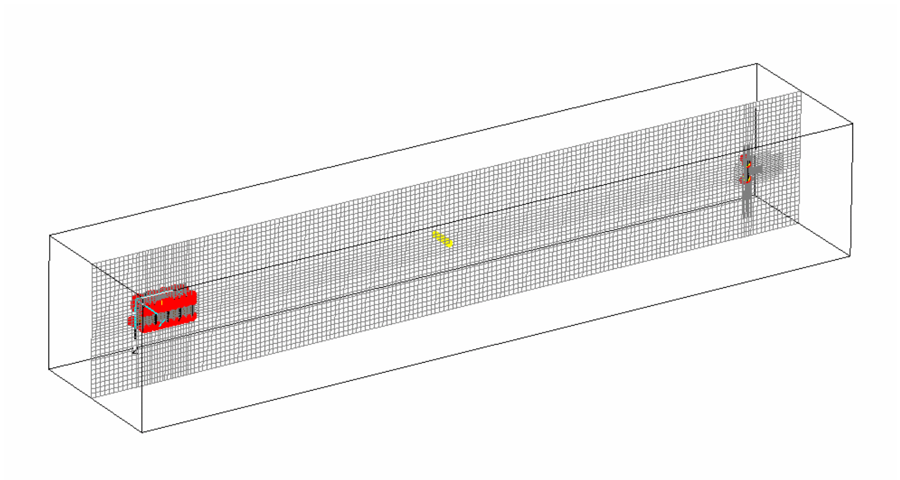
For a more realistic scenario, an ensemble of tags were placed on the lids of a set of pill-boxes



Assembly

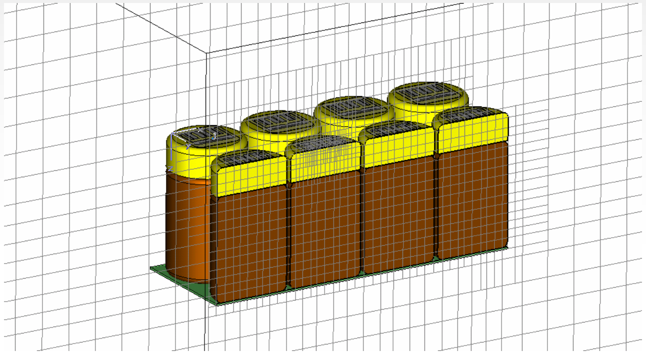
Tags and reader are positioned some distance apart and the S-parameters were computed





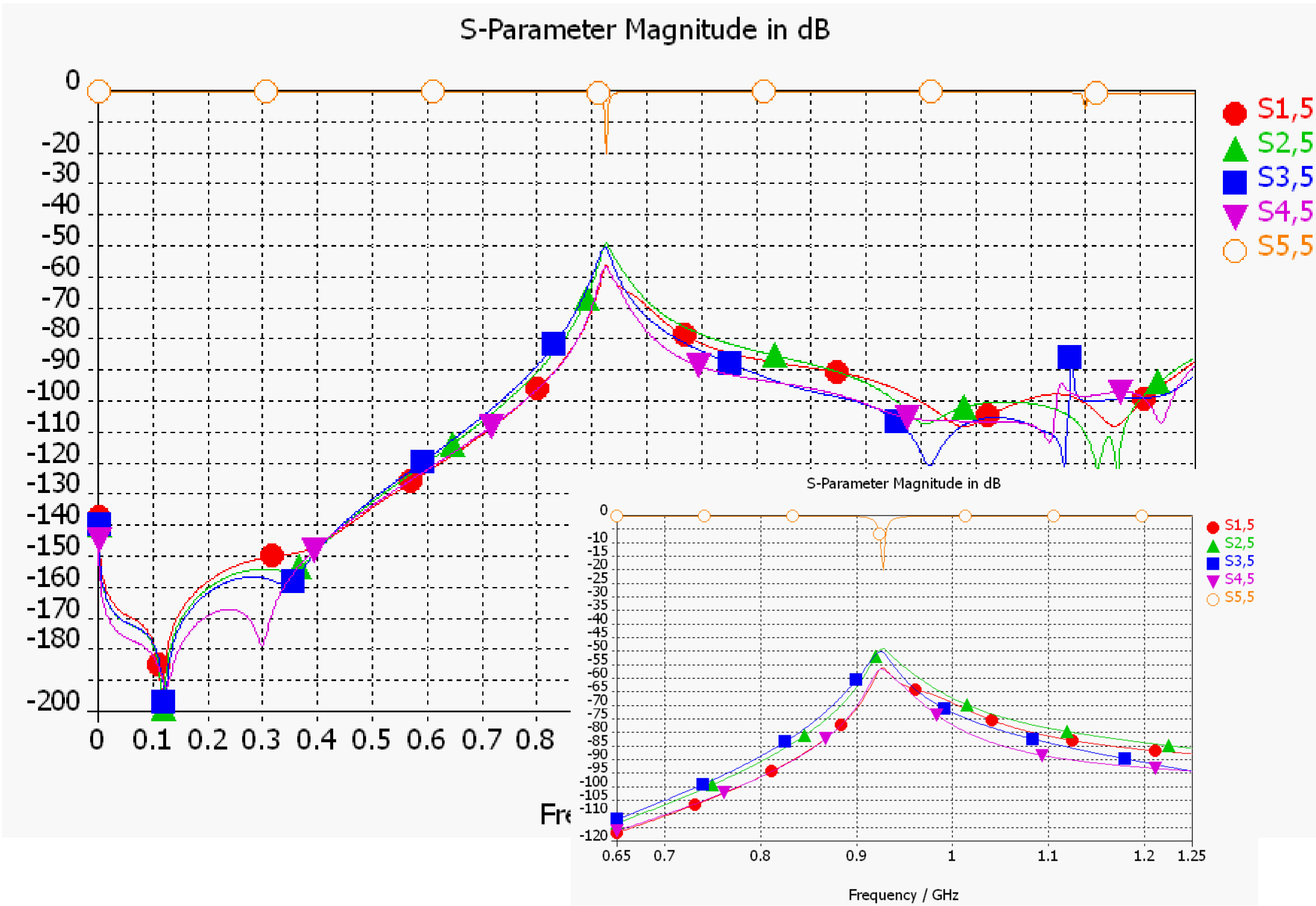
CST MICROWAVE STUDIO®

- **Advanced CAD modelling**
  full parameterization
- **Transient Analysis**
  2.2h on 32bit machine, 400MB
- **PBA + Subgrid**
  Optimized runtime



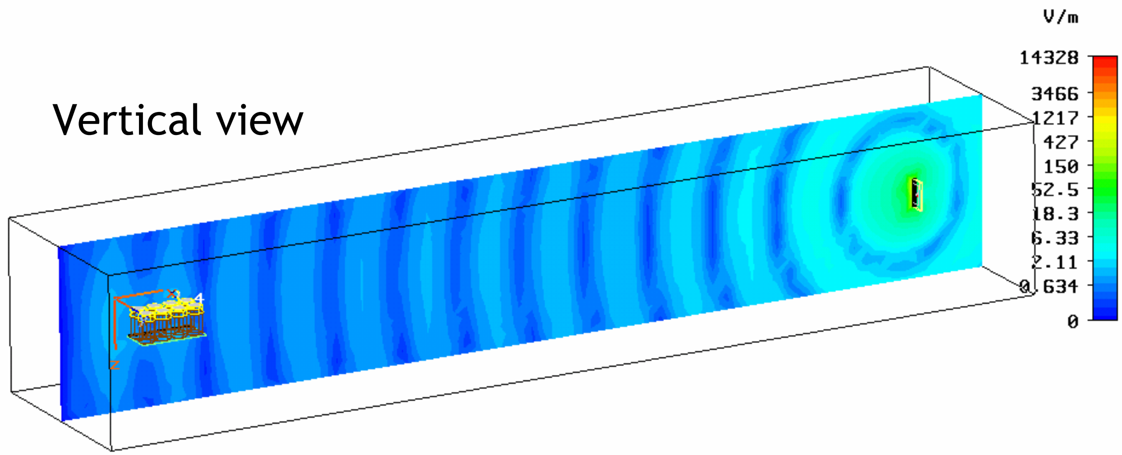
S-Parameter

|S| in dB



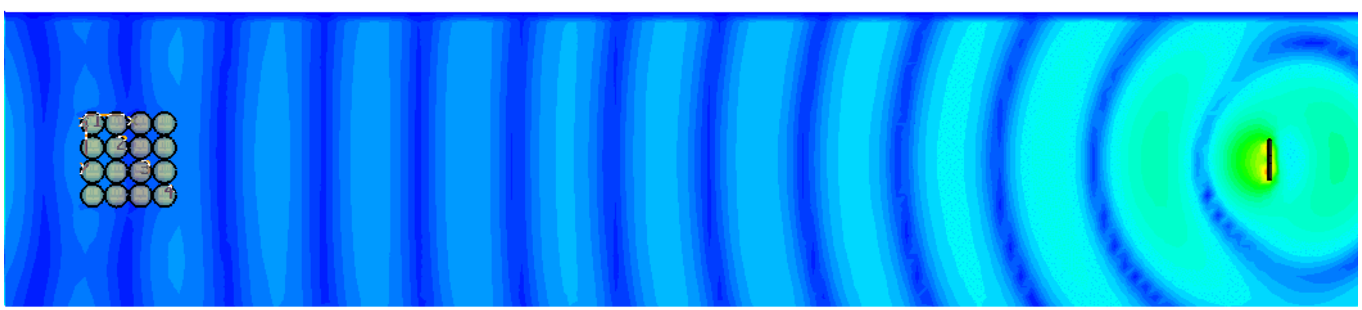
E-Field > e-field (f=900) MHz

Vertical view




```
Type          = E-Field (peak)
Monitor       = e-field (f=.9) [5]
Component     = Abs
Plane at y    = 75.7
Frequency     = 0.9
Phase         = 67.5 degrees
Maximum-2d    = 12624.8 V/m at 2080.7 / 75.7 / 45.72
```

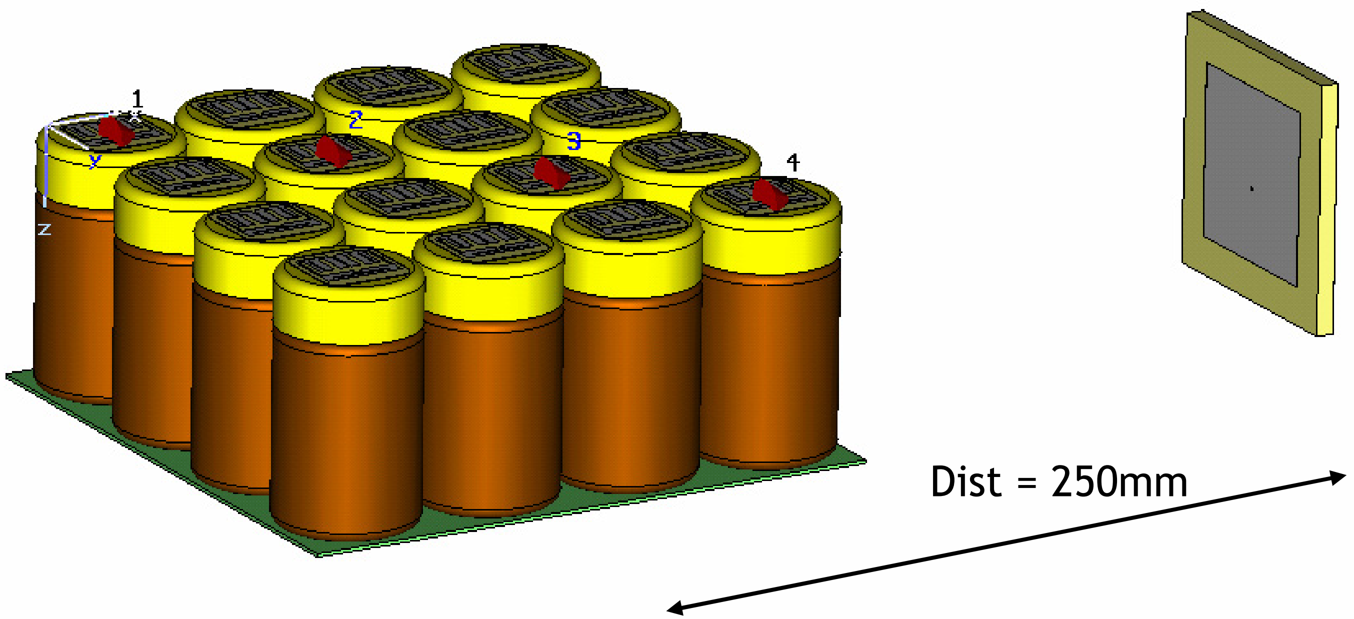
Animated top view



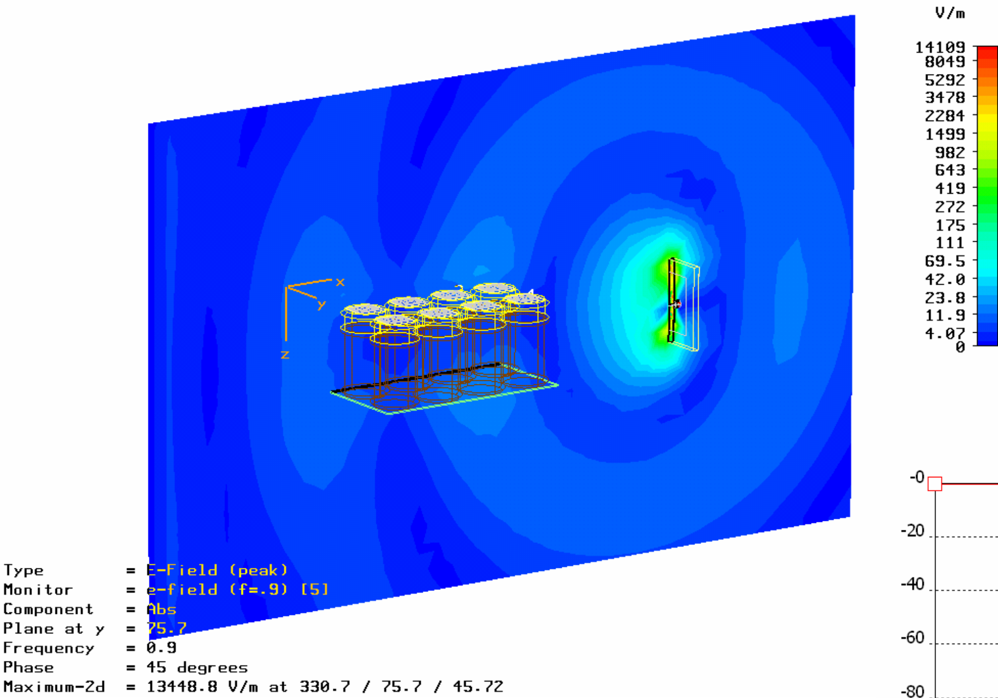
CST - Computer Simulation Technology

Simulation of tags and reader

Broadband S-parameters are computed for a modified distance between Reader and Tag reduced to 250 mm. The reader is fed by an AM-signal, the deformed signal waveforms at the tag-ports can be observed

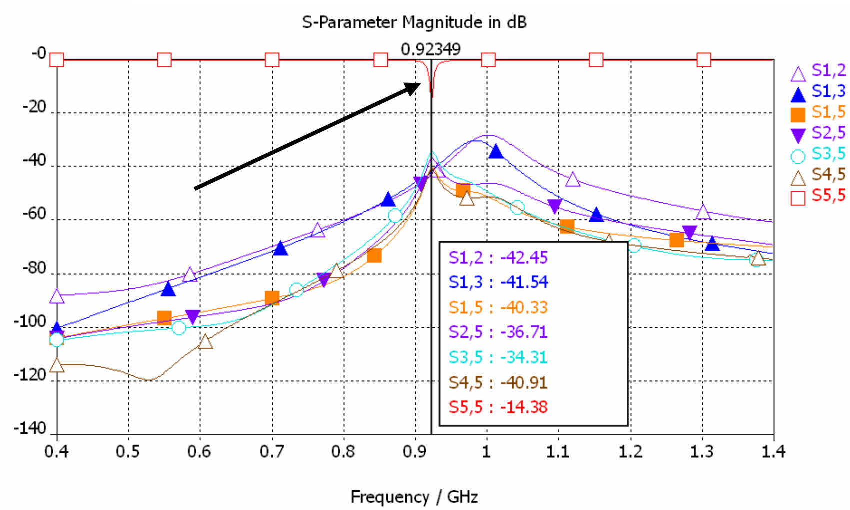


Simulation of tags and reader



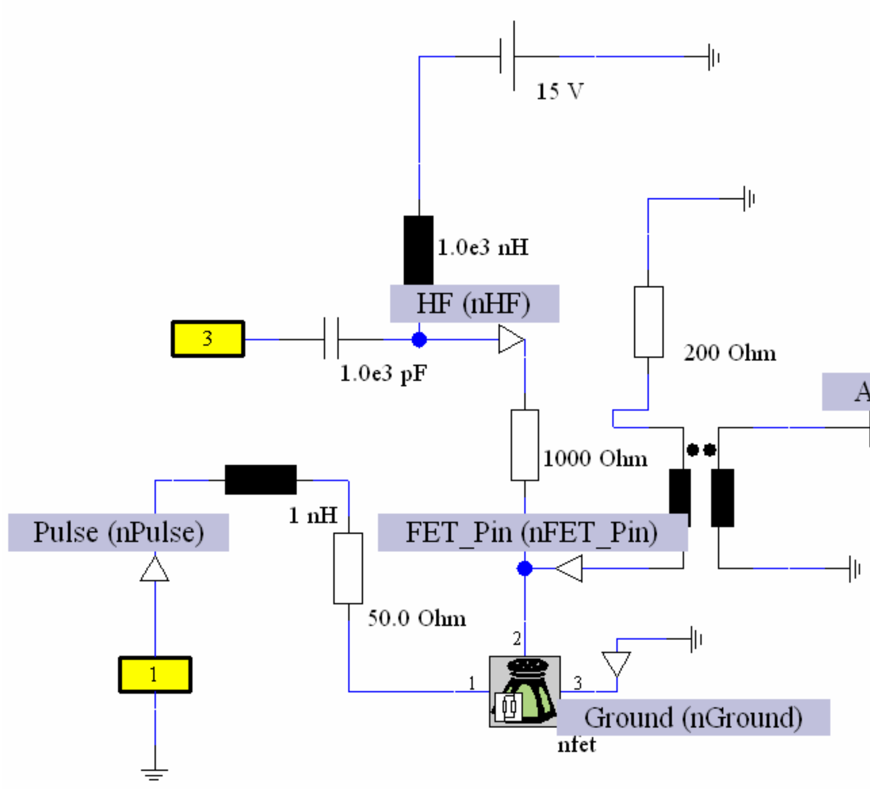
E-Field (f=900 MHz)

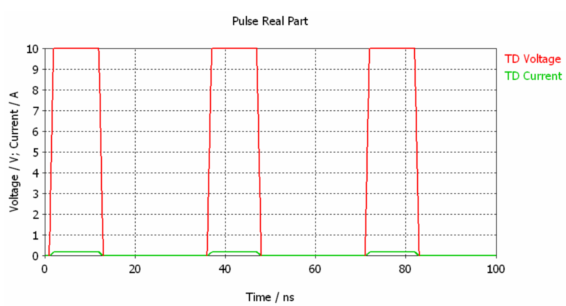
S-Parameters

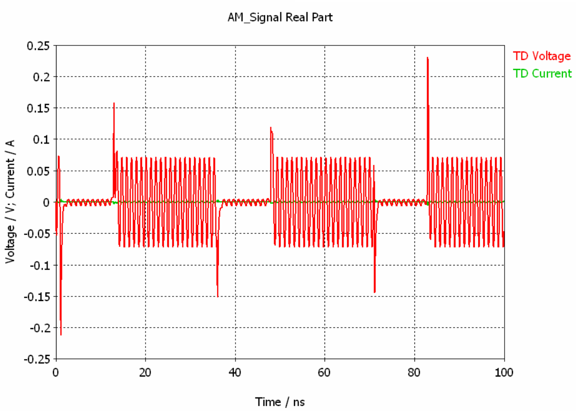


At 923 MHz the reader shows the best match. The HF-Signal for the AM-Generator is set to this frequency.

AM Signal Generator in DesignStudio



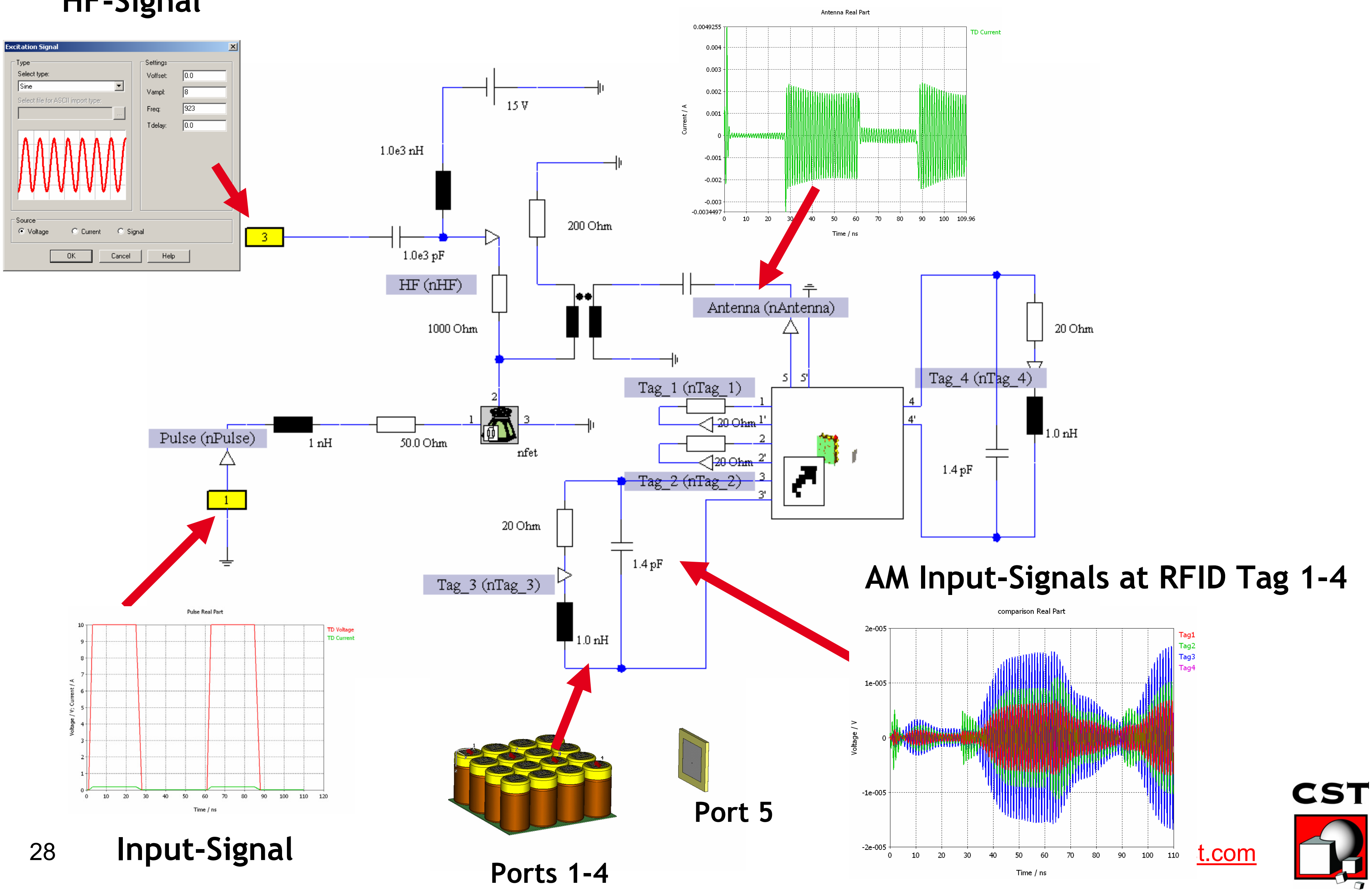




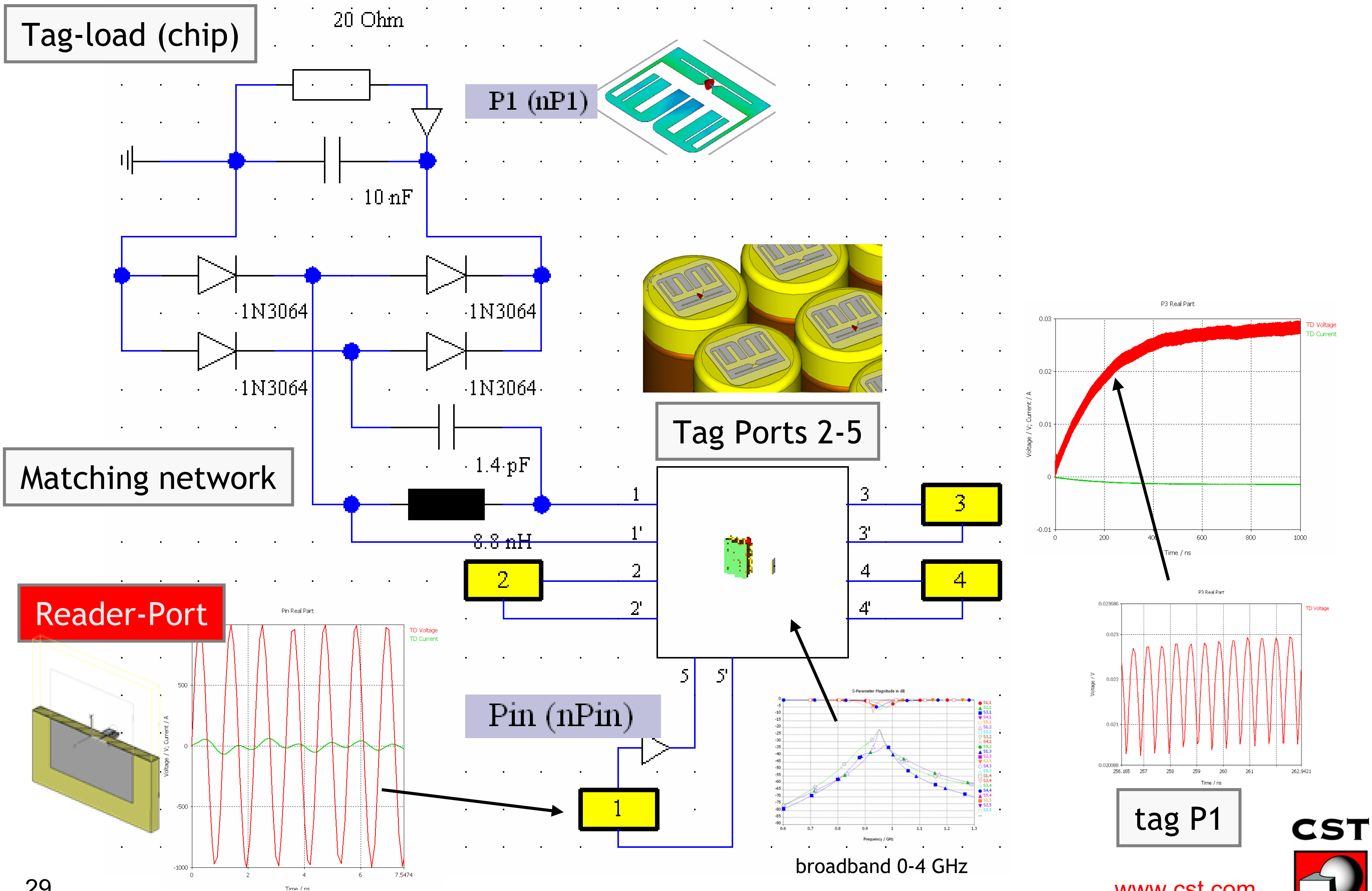
AM-SignalGenerator + RF-IDs

HF-Signal

AM Input-Signal at RFID Reader-Antenna



Generating the DC-Volatge at the tag



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METRO Group & Checkpoint

Logistical Application

METRO Group

Checkpoint

Side horizontal illumination

Towards minimum axis of the tag

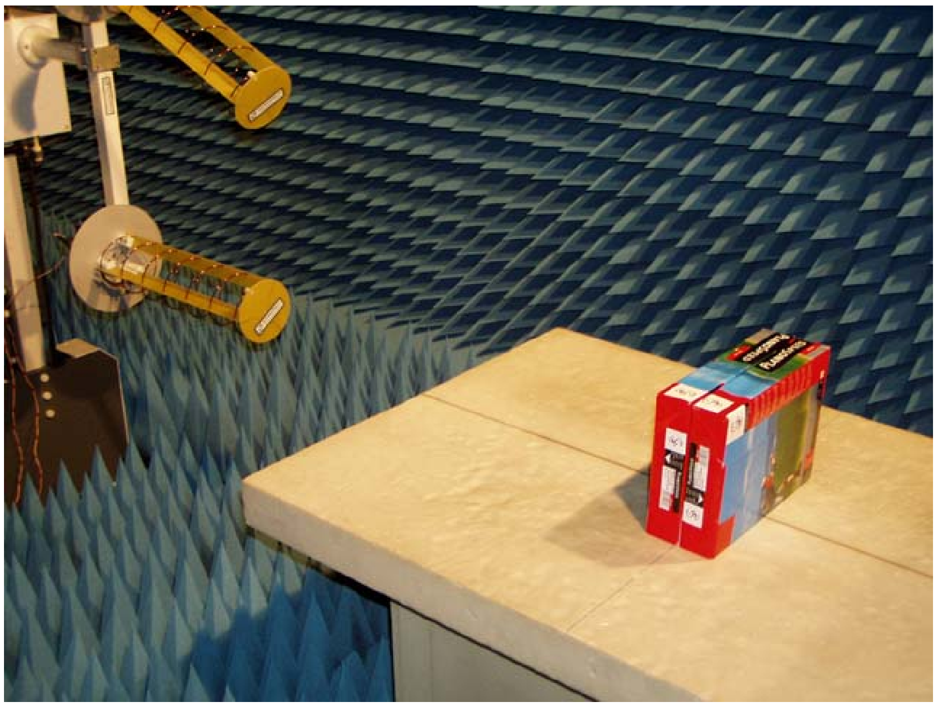
Tags are between the boxes

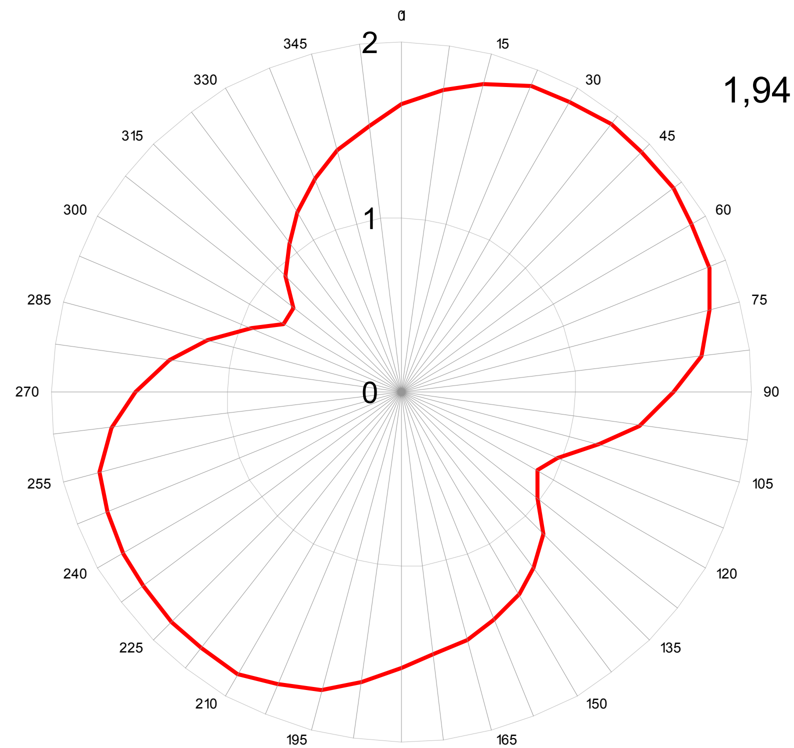
Front horizontal illumination

Tags are between the boxes

Label Orientation and Detection

Illumination: Horizontal Front





Tag is embedded between the paper stacks
with it's axis along the axis of the paper stacks.

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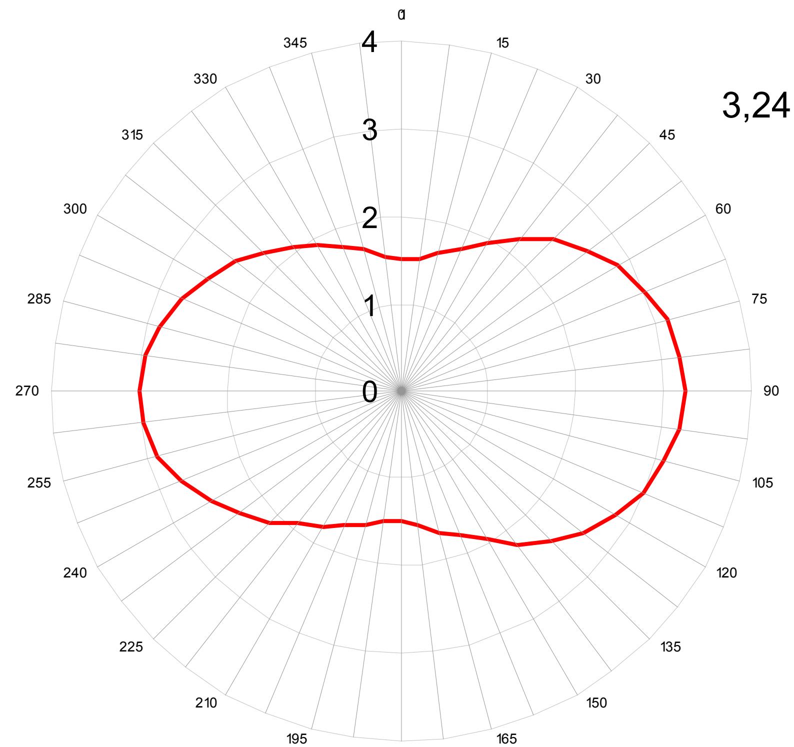
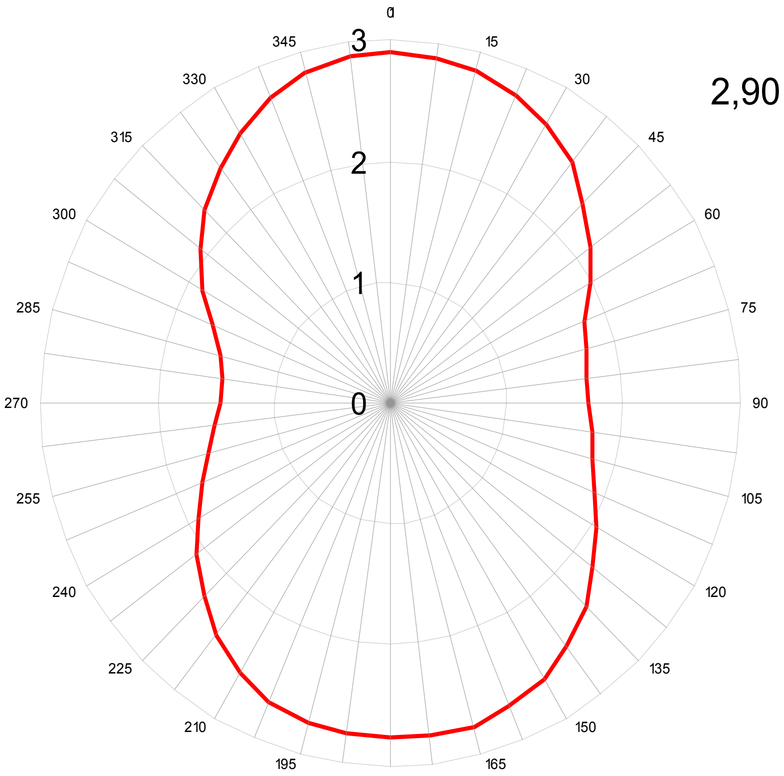
Label Orientation and Detection

Illumination: Vertical Front

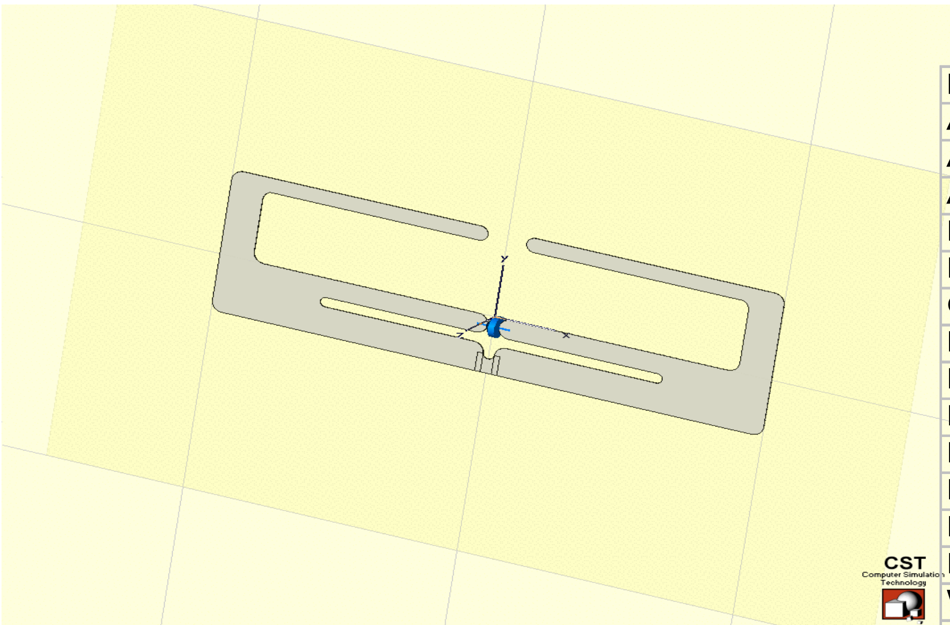


Label Orientation and Detection Illumination: Flat Side



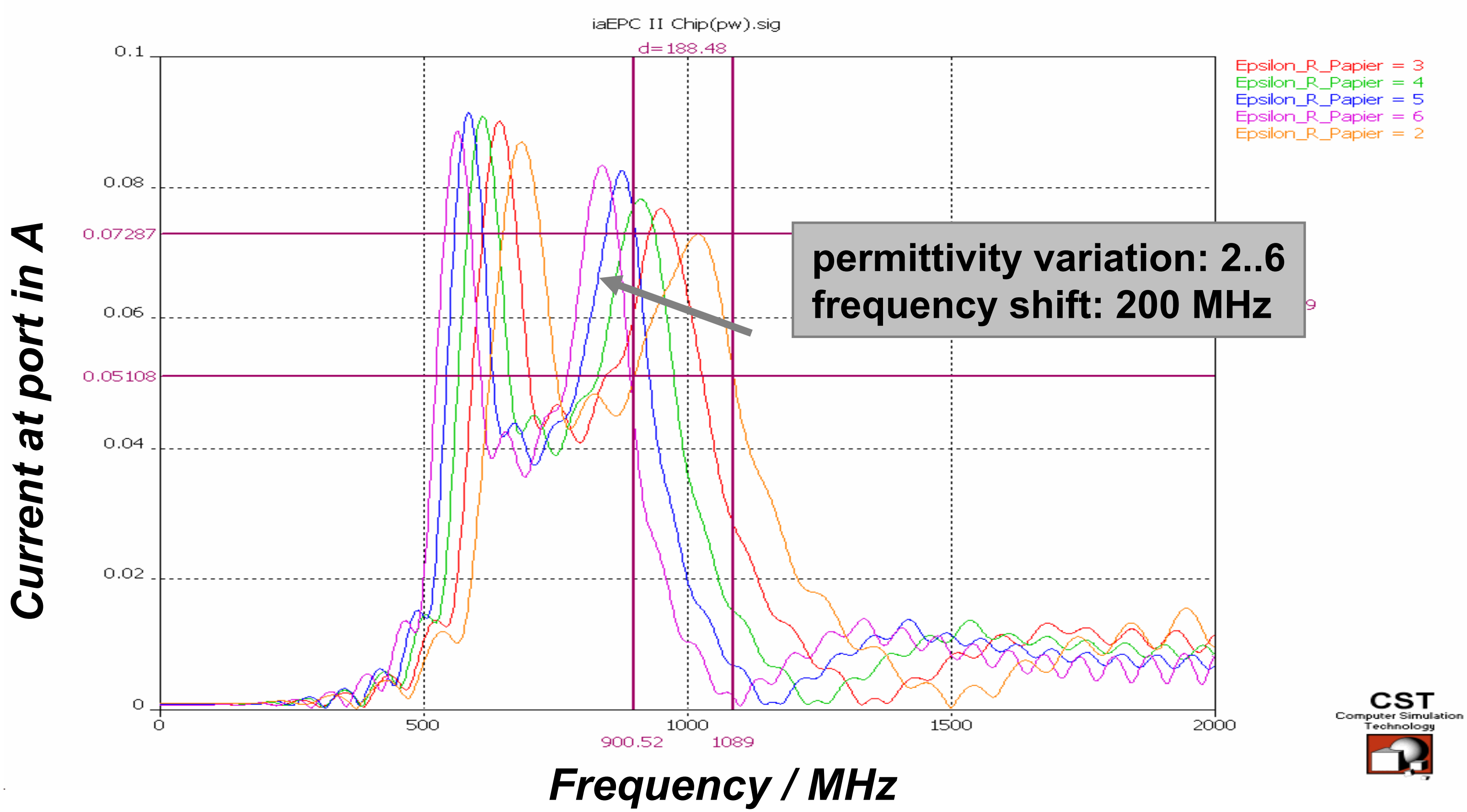
Tag Design

Parameter Studies on Permittivity Variations



Material	Eps_r min	Eps_r max
Acryl	2,1	4,5
Aluminum Oxide	4,5	26,0
Aramid / Kevlar	1,6	4,0
Dacron / Polyester	2,8	8,1
Duroid / Teflon	2,0	6,2
Glass, soda lime	3,6	8,5
Nylon / Polyamide	2,8	11,0
Paper	2,0	6,0
Plexiglas - Polymethyl Methacrylate	2,8	11,0
Polycarbonate	2,7	3,5
Polyvinyl Chloride - PVC	2,3	12
Porcelain	4,4	11,0
Rubber	2,0	18,0
Water / distilled	77	87
Wood	1,2	8,5

Permittivity Variation



Tag on a cardboard, DIN A4 with 4mm thickness.

Material Parameters and Volume

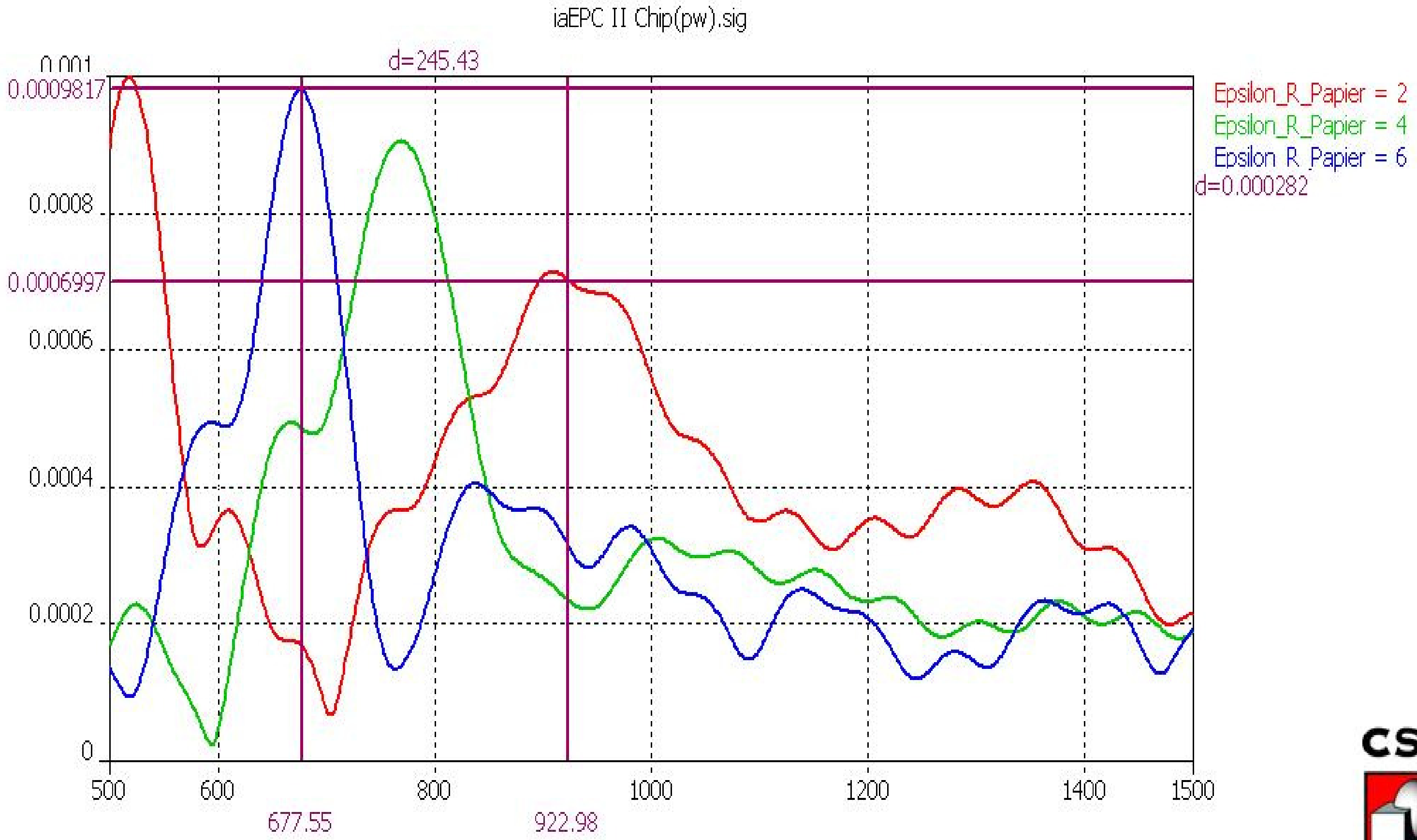
Simulated Scenario

label is on the middle of a dieletric volume of **1000** cm^3 / 1 liter.

Permittivity ranges from **2 – 6** (typical paper) in three steps.

1) The volume is a cubus of : 100 x 100 x 100 mm.
2) The volume is a card board: 500 x 500 x 4 mm
3) The volume is a bar : 330 x 60 x 50 mm

Frequency shift for Cubus

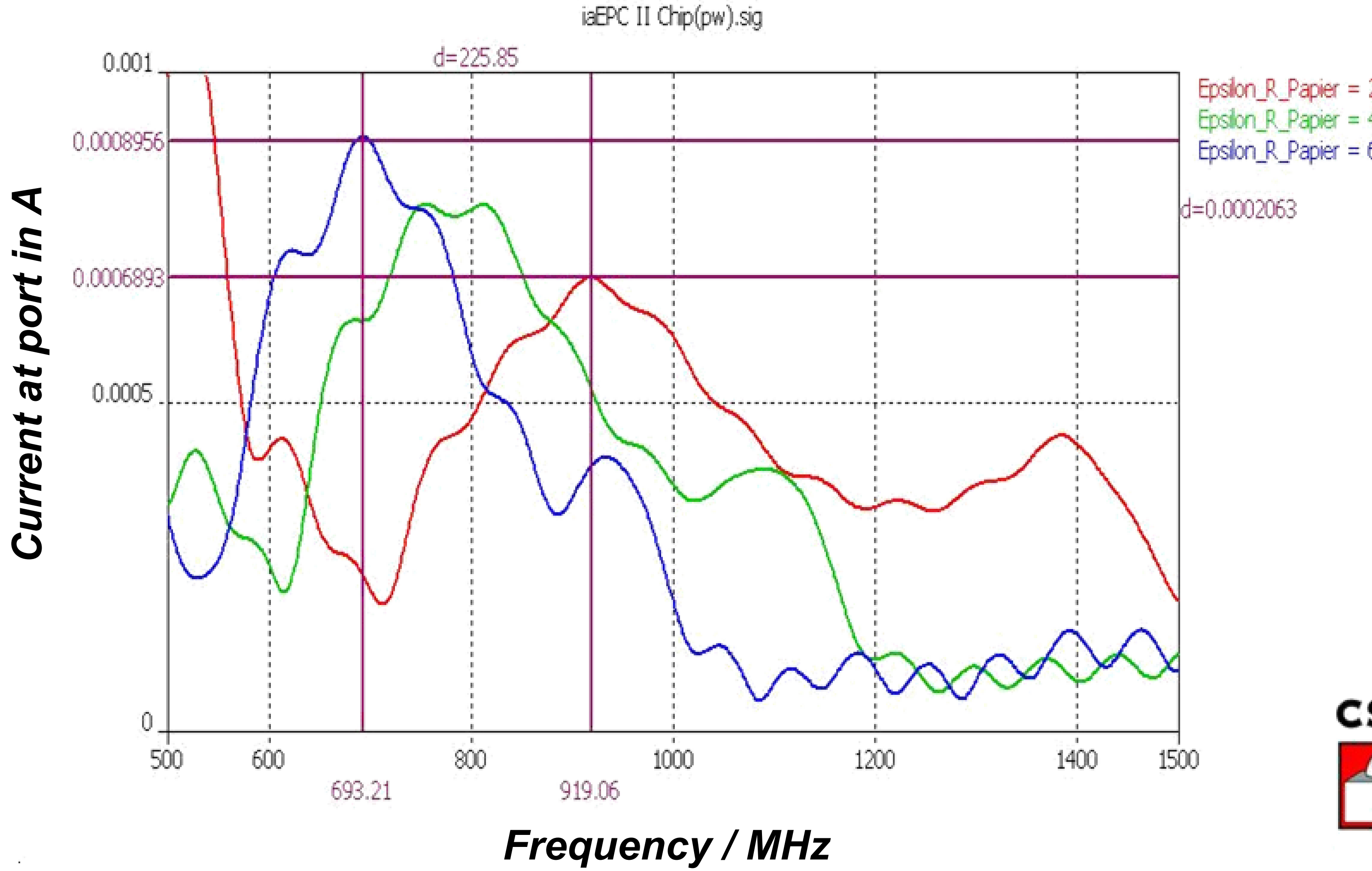


Current at port in A

Frequency / MHz

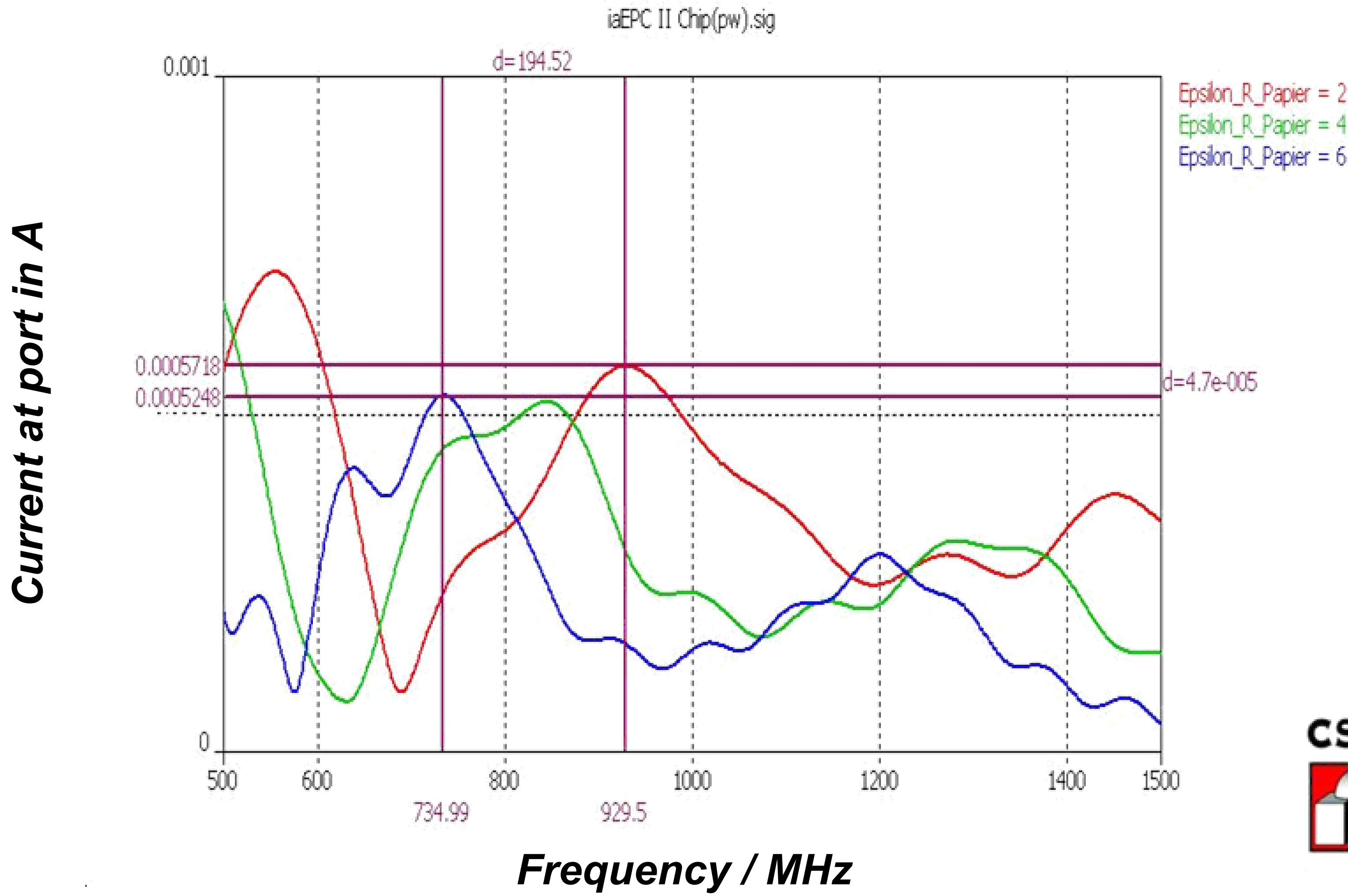
Frequency shift for a bar

330 x 60 x 50 mm



Frequency shift for a card board

500 x 500 x 4 mm



Summary

- CST RFID is a general concept using different technical principals
- complete technology approach offers best solution for each case
  - CST MWS Frequency Domain / CST EMS for inductive type
  - CST MWS Transient for microwave type
- Coupling between CST DS and CST MWS allows easy combination of circuit and 3D EM analysis, e.g. for
  - Tag matching networks
  - Reader circuits (using the new Transient solver in CST DS)