Printed conductive layer for 3D-RFID-transponder-antennas for future identification applications in smart packaging

Ralf Zichner[1] *and Reinhard R. Baumann*[1,2]

[1]Fraunhofer Institute for Electronic Nano Systems (ENAS)
Department Printed Functionalities, Chemnitz, Germany
[2]Chemnitz University of Technology, Institute for Print and Media Technology

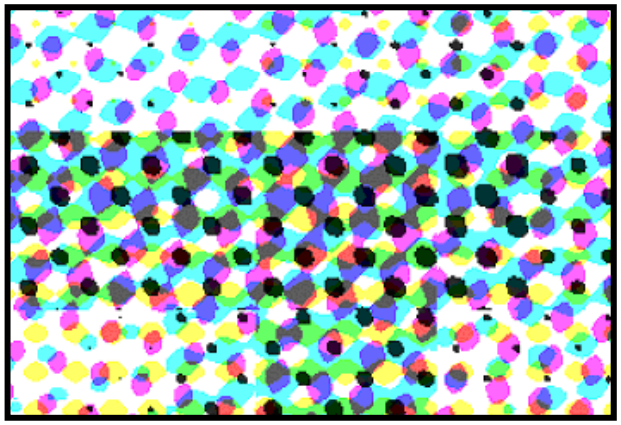
Outline

- Printing of Conductive Layer
- Basics: Printed Antenna & RFID
- 3D-RFID-Transponder-Antenna
- Conclusions

Printing of Conductive Layer

Printing of color inks for visual applications

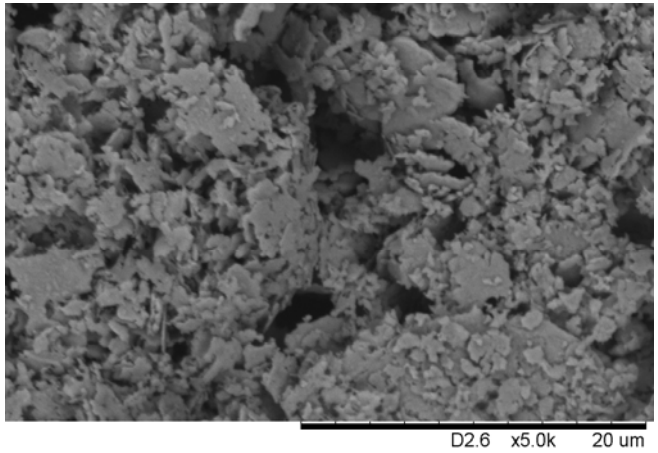
screen dot patterns



http://www.newspaperscanada.ca/sites/default/files/imagecache/homeslide_560x264/news/images/iStock_000010849371Small_18.jpg

Printing of conductive inks for electronic applications

Ag flake based “closed” layer



Printing of Conductive Layer → Inks

Printing starts with the ink and there chemistry!

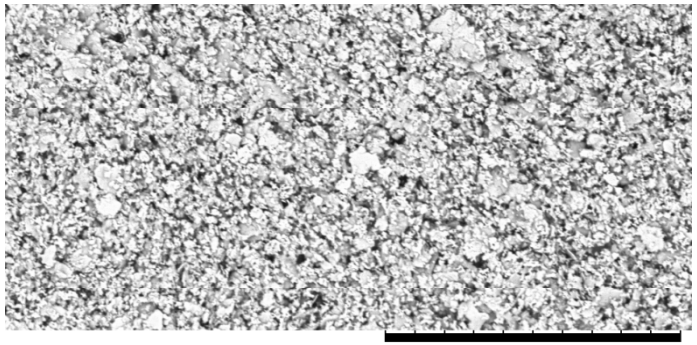
Standard Inks for Printed Antenna Manufacturing:

- Silver
- Copper
- Silver + Copper
- Aluminium
- Zink
- Gold

Screen Printing Inks

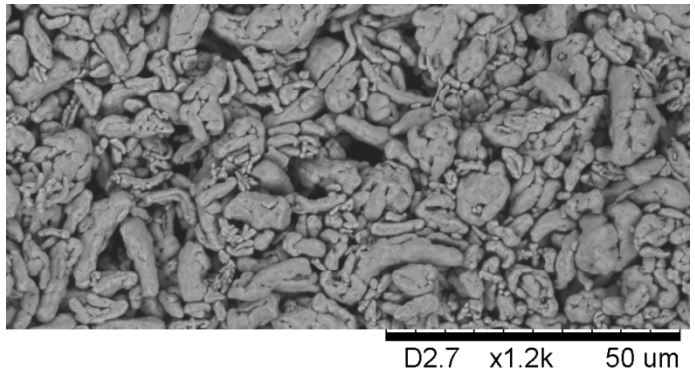
Silver

e.g. CRSN2442 (SunChemical)



Copper

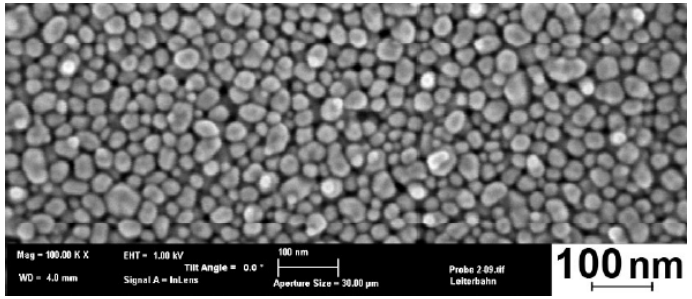
e.g. CB200 (DuPont)



Inkjet Inks

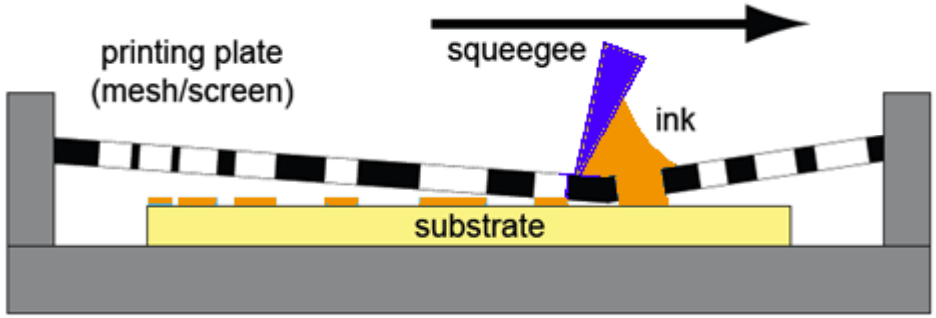
Nano-Silver-Particle

e.g. CSD 32 (Cabot)

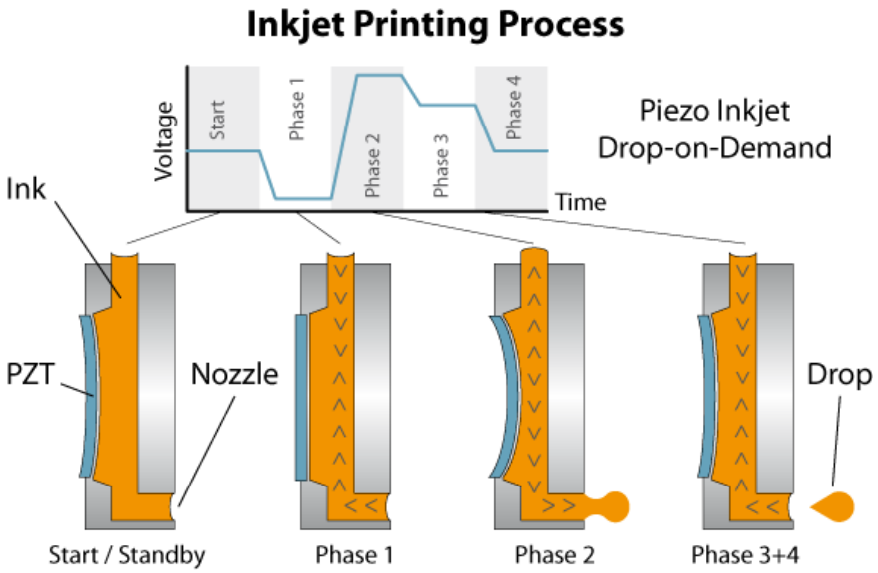


Printing Technology

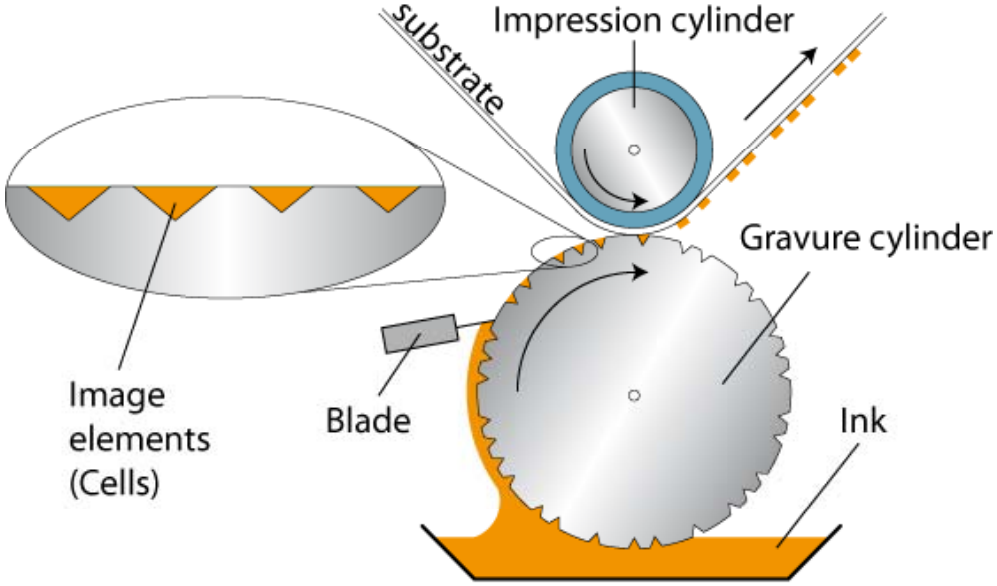
Screen Printing



Inkjet

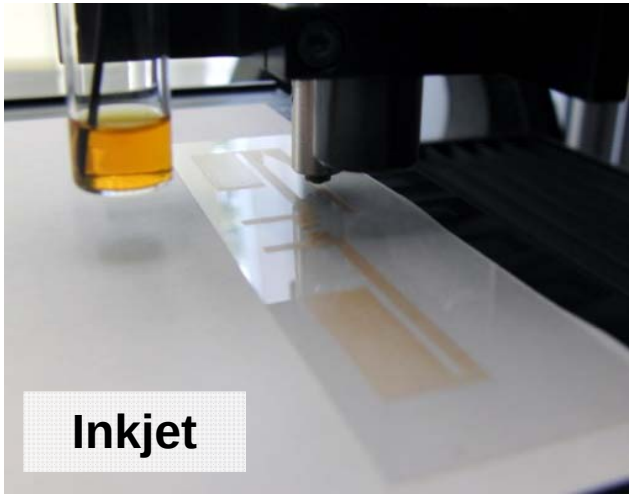


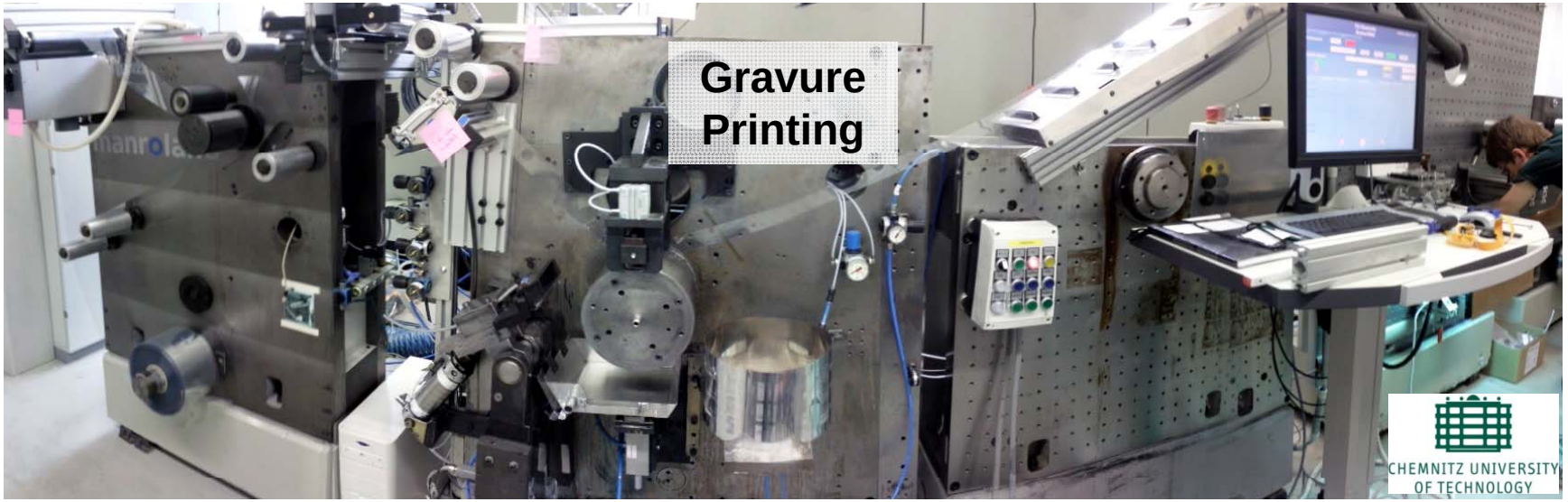
Gravure Printing



Fraunhofer ENAS

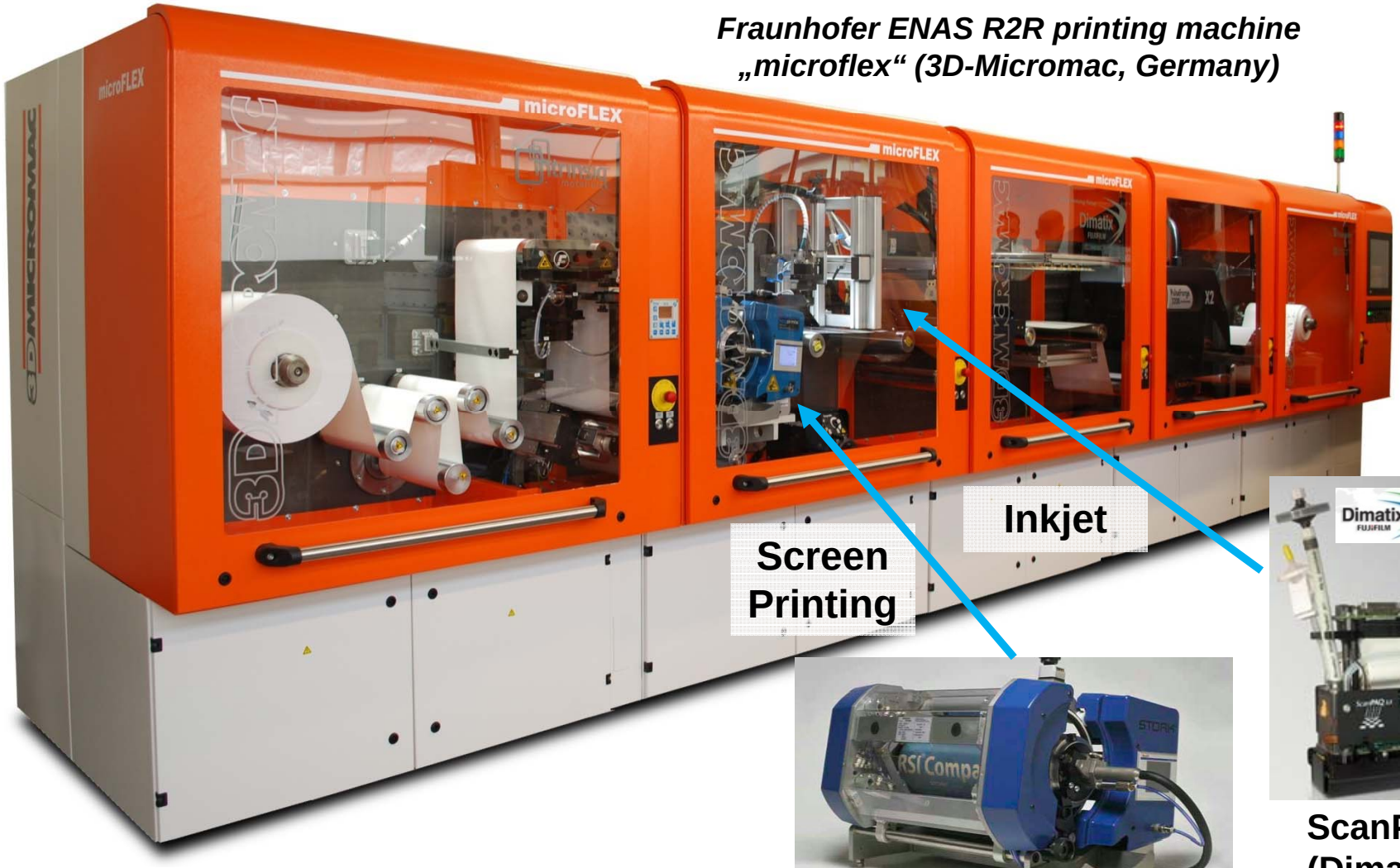
Printing Technology lab scale





Printing Technology fab scale

Fraunhofer ENAS R2R printing machine „microflex“ (3D-Micromac, Germany)



RSI Compact (Stork)

ScanPAQ (Dimatix)

Outline

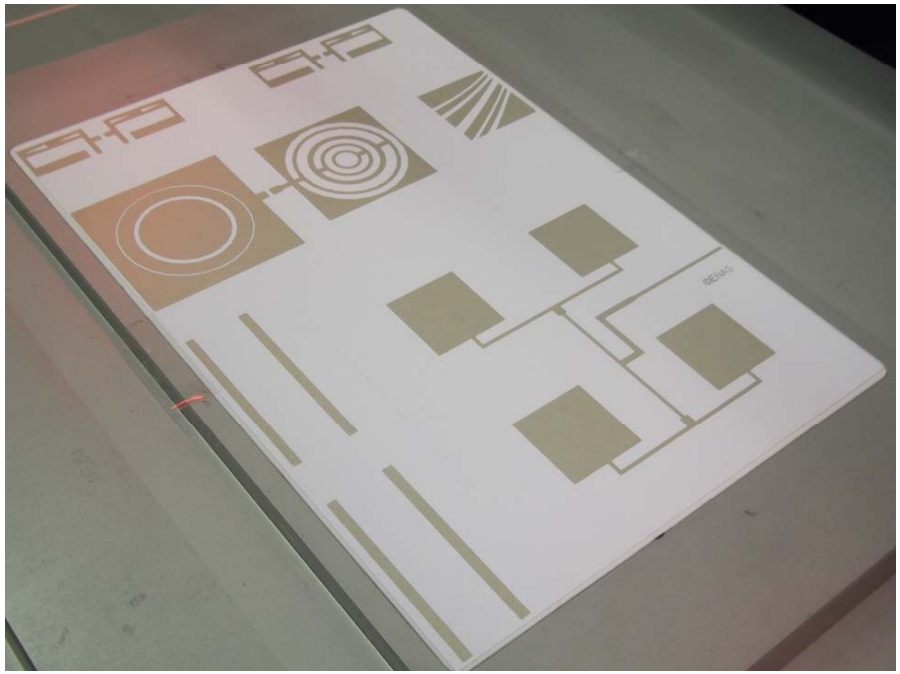
- Printing of Conductive Layer
- Basics: Printed Antenna & RFID
- 3D-RFID-Transponder-Antenna
- Conclusions

Printed Antenna Technology Basics

Printed Antenna = Printed Conductive Layer (Single or Multi Layer)

Printing Technology = Additive Technology

→ printing conductive inks/pastes onto different substrates
(flexible substrates: foil, paper, fibers, … ;
solid substrates: glass, plastics, PCB, …)



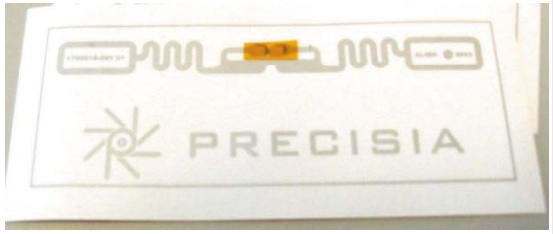
Printable Antennas:
- Dipoles
- Patch Antennas
- Slot Antennas
- 3D Antennas
- …

State of Art of Printed Antennas

Development Status → low industrial use right now!

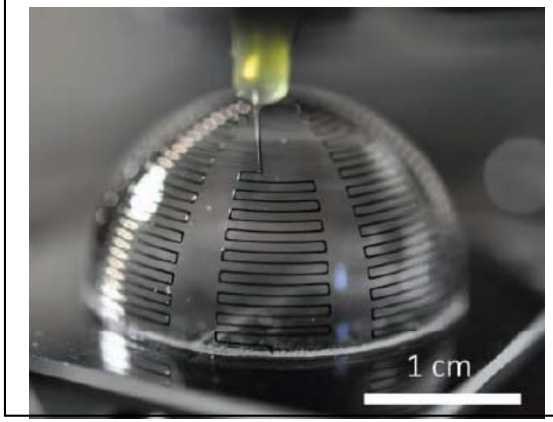
Reasons:
- low knowledge about antenna behavior in dependence of printed manufacturing **(Excepted Fraunhofer ENAS)**
- challenge: up scaling printed antenna manufacturing from lab to fab

Precisia, LLC
USA
Printed UHF-RFID-Transponder-Antenna



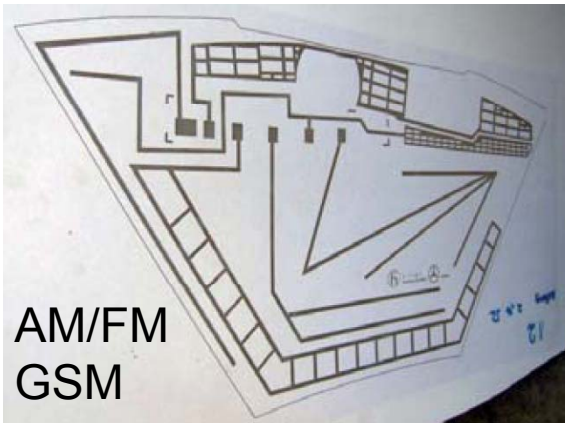
http://news.thomasnet.com/fullstory/RFID-Tag-Manufacturing-Process-incorporates-printed-antennas-452420

J. J. Adams @ all.
"**Conformal Printing of Electrically Small Antennas of Three-Dimensional Surfaces**", Advanced Materials 2011, XX, 1-6



Prof. Dr.-Ing. Gunter Hübner
Stuttgart Media University

First Test of "Printed Antennas for Automotive Applications"



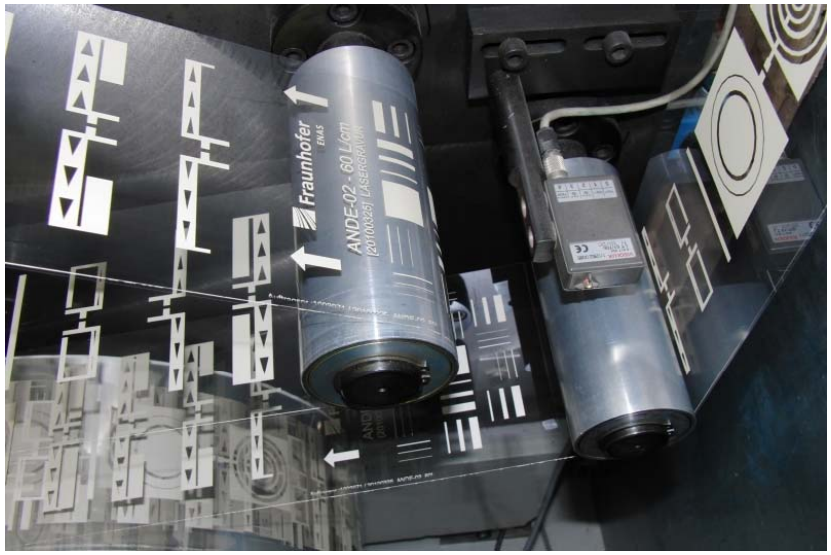
http://www.hdm-stuttgart.de/international_circle/circular/issues/08_01/ICJ_01_35_huebner_petersen.pdf

Motivation of printed Antennas

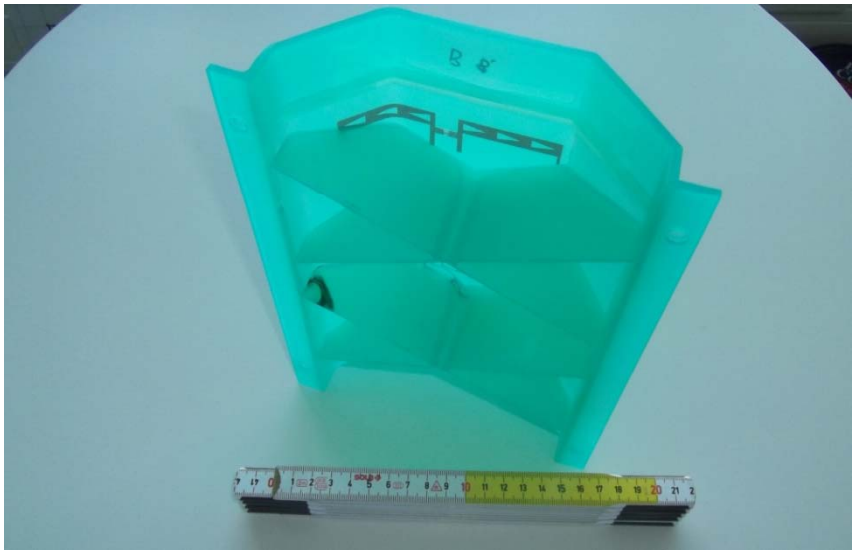
Why Printed Antennas?

Cost efficient manufacturing

Development on new flexible and integrated antenna systems



R2R gravure printed antennas on PET



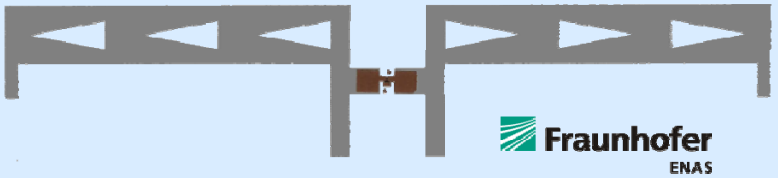
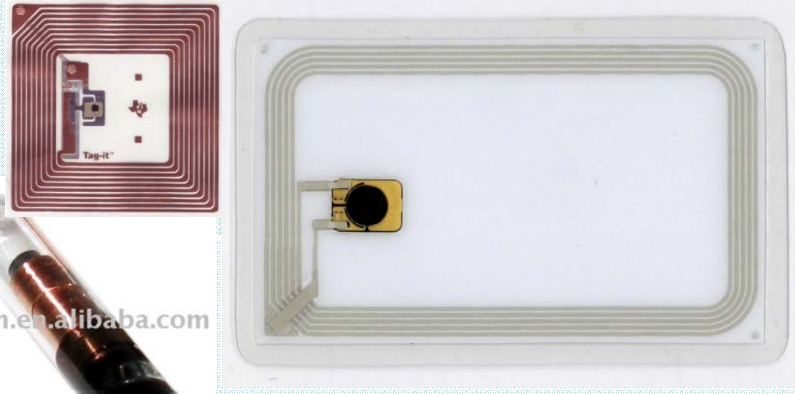
Printed antenna integrated into an injected molded component

How to make a custom-designed printed antenna

Step:	Input Parameter:
1. Antenna Design	- addressed resonance frequency, wave impedance and directivity - **permittivity and permeability of the dielectric material [e.g. paper] and the surrounding material depending on the application [e.g. packaging content]** - conductivity of the used printing ink/paste - layer thickness of the printed conductive layer
2. Simulation	- antenna design - **size and shape of the dielectric material and surrounding material** - addressed wave impedance, conductivity of the used printing ink/paste, layer thickness of the printed conductive layer
3. Manufacturing	- final antenna design - **printing technology (lab & fab) and the knowledge about it**
4. Measurement	- printed antenna

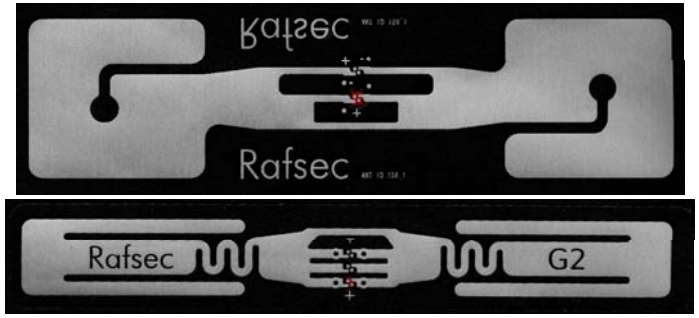
RFID Communication Basics

LF/HF versus UHF/SHF-Passive RFID-Transponder

	RFID resonance frequency	coupling	antenna design	antenna layer thickness
SHF	5.8 GHz	electro-magnetic		*< 1 µm*
UHF	868 – 928 MHz	electro-magnetic		*200 nm – 9 µm*
HF	13.56 MHz	magnetic		*> 20 µm*
LF	125 kHz	magnetic		*Copper wire > 100 µm*

State of the Art Far-Field RFID Tagging

868 MHz (EU), 928 MHz (China & USA)



http://www.upmrfid.com/rfid/upm_upm-rfid

http://www.bm-tricon.com/images/gross/lesestation_kl.gif

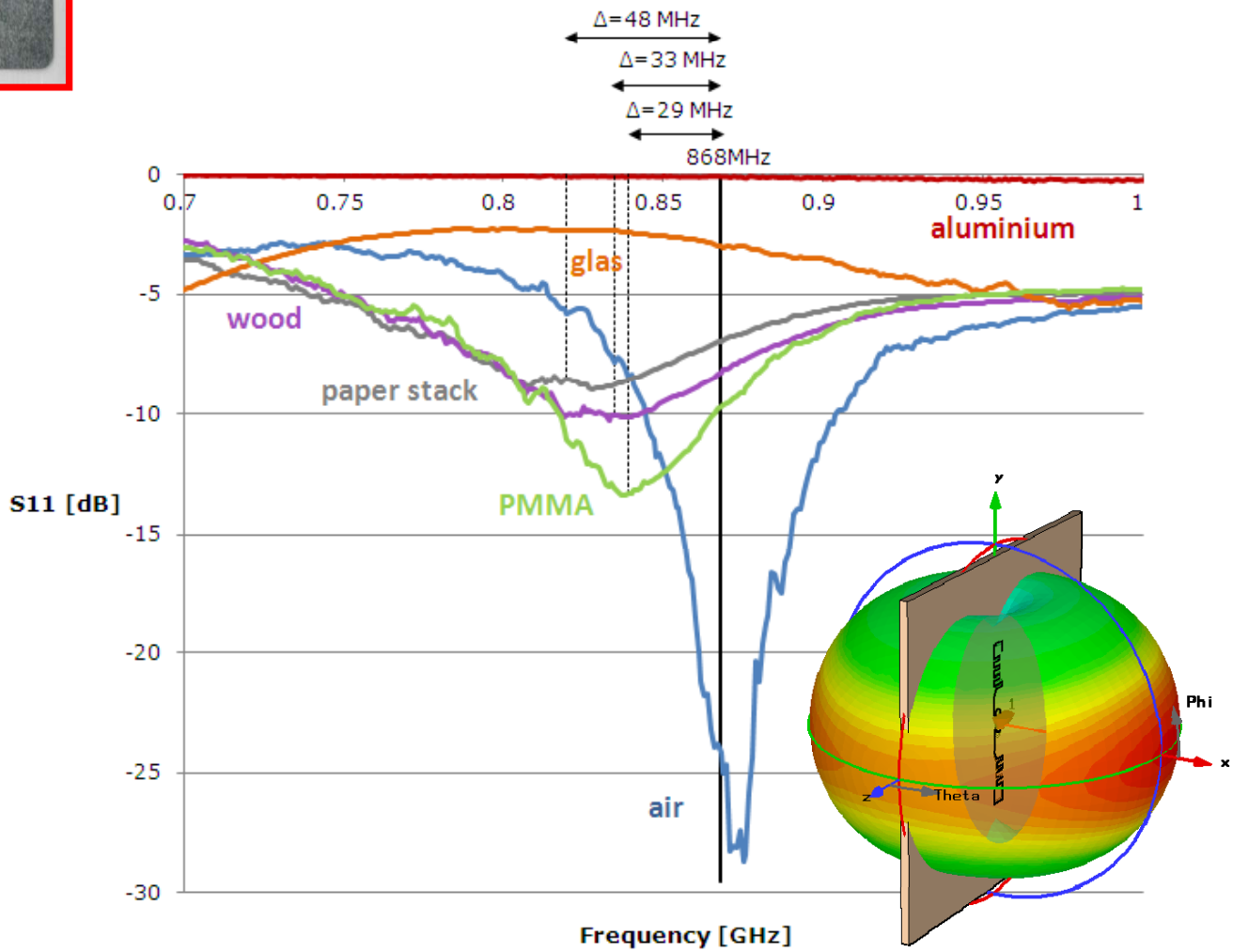
Reading Distance: 0.5 – 8 m
Reading Reliability: 10 – 90 %

©METRO Group www.future-store.org

www.ics-ident.de

Performance of a standard UHF-Transponder in different environments

Antenna characterization in an anechoic chamber



Outline

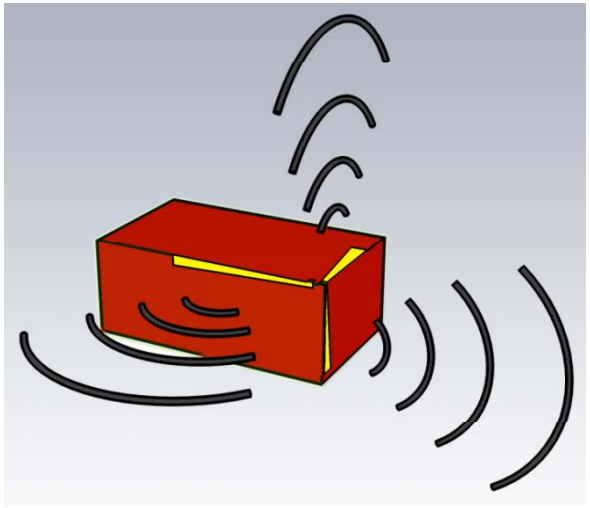
- Printing of Conductive Layer
- Basics: Printed Antenna & RFID
- 3D-RFID-Transponder-Antenna
- Conclusions

Advanced Printed Antennas
→ 3D RFID Transponder Antennas @ 5.8 GHz

…, Radio Frequency Identification (RFID) Transponder, …

RFID frequencies: 125 kHz, 13.56 MHz, 868 – 928 MHz, 2.45 GHz, **5.8 GHz**, 24.125 GHz

SPONSORED BY THE
Federal Ministry of Education and Research



→ *Multidirectional communication*

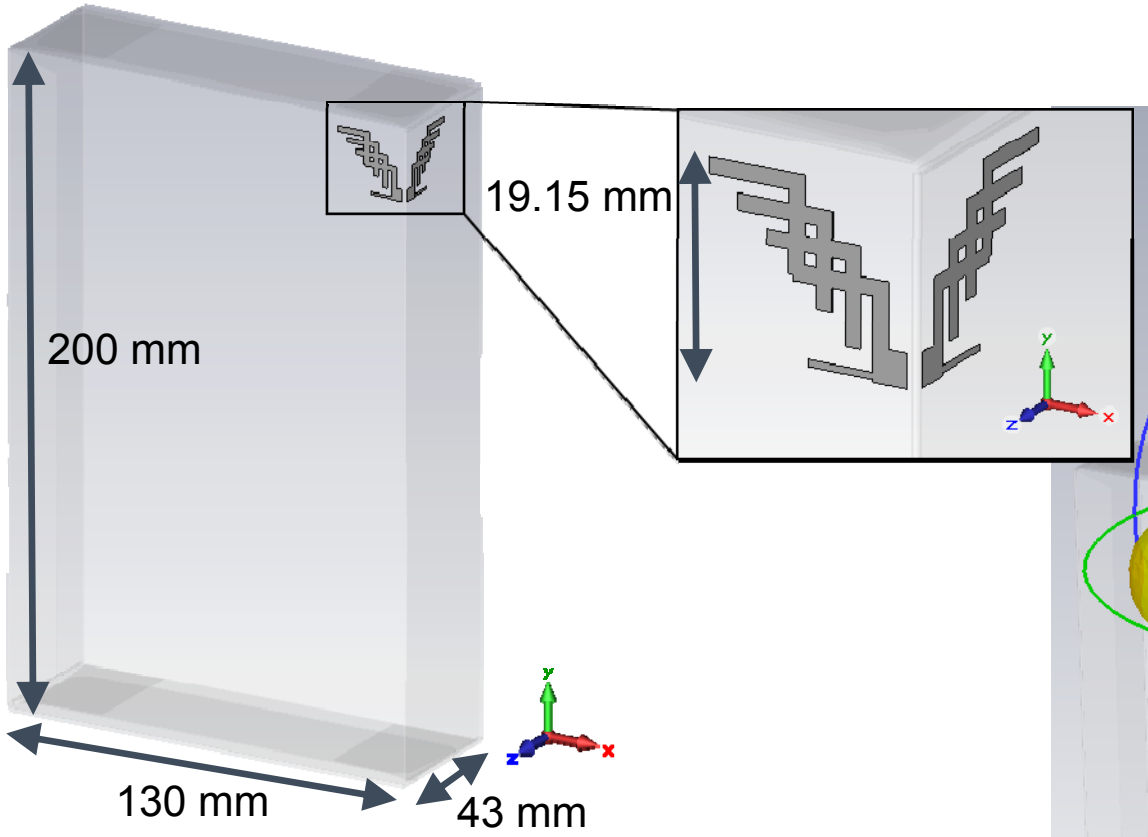
Why printed 3D Antennas @ 5.8 GHz?

→ increasing communication quality
→ increasing read reliability
→ increasing read- / write range (> 10 m)
→ high frequency bandwidth → Bulk Reading
→ low cost manufacturing

<u>Multidirectional 3D Antennas for</u>

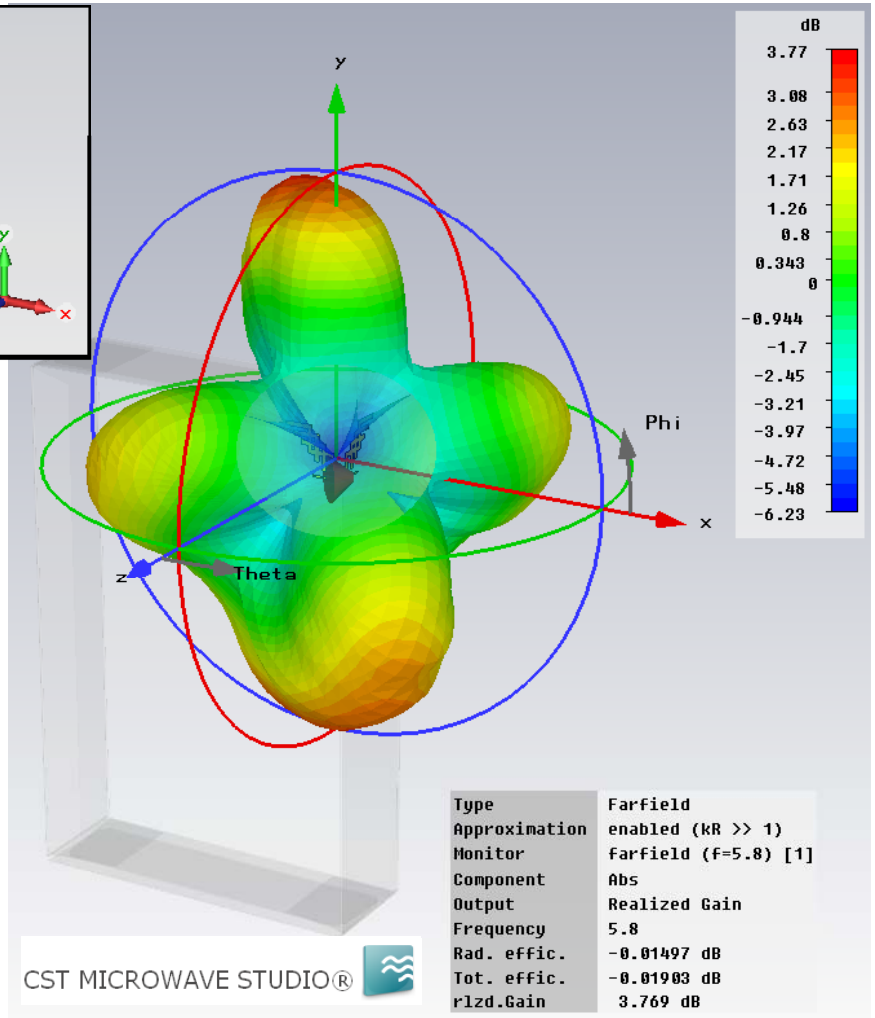
- the future internet of things
- logistic applications

3D RFID Transponder Antennas Design @ 5.8 GHz for Smart Packaging Applications

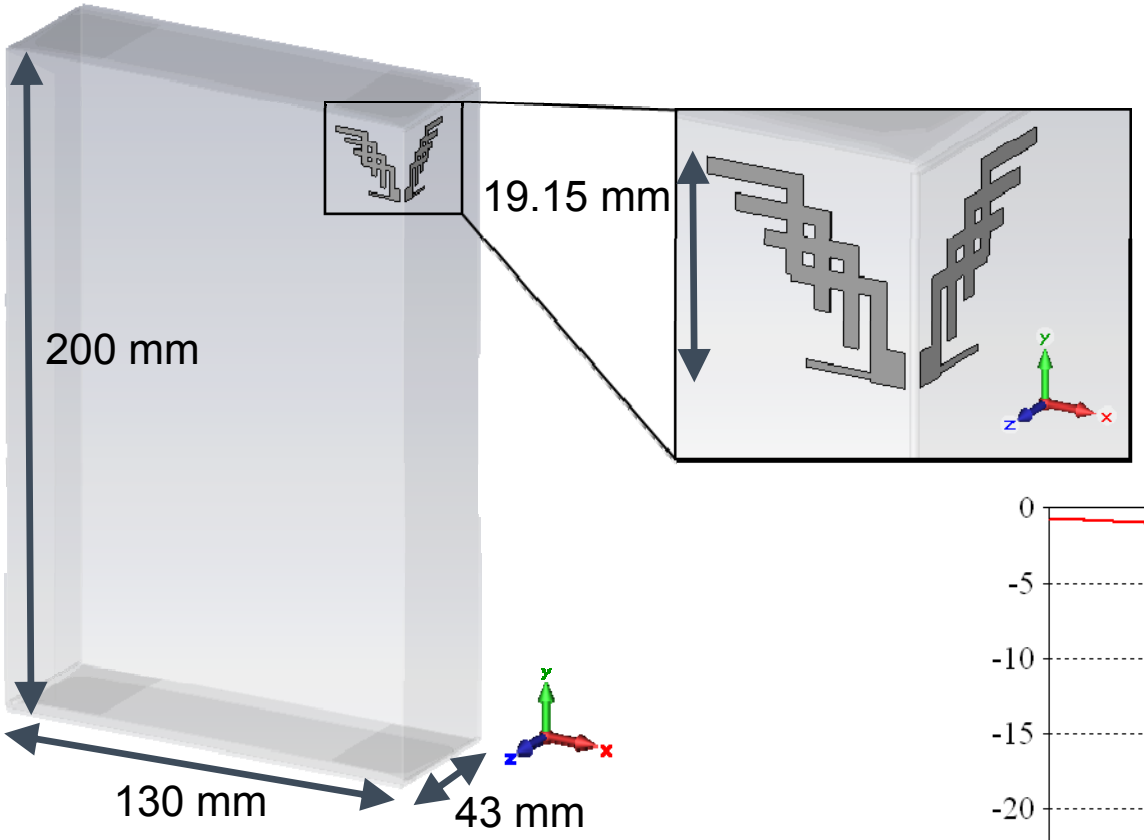


Product-Packaging

Simulated radiation characteristics:



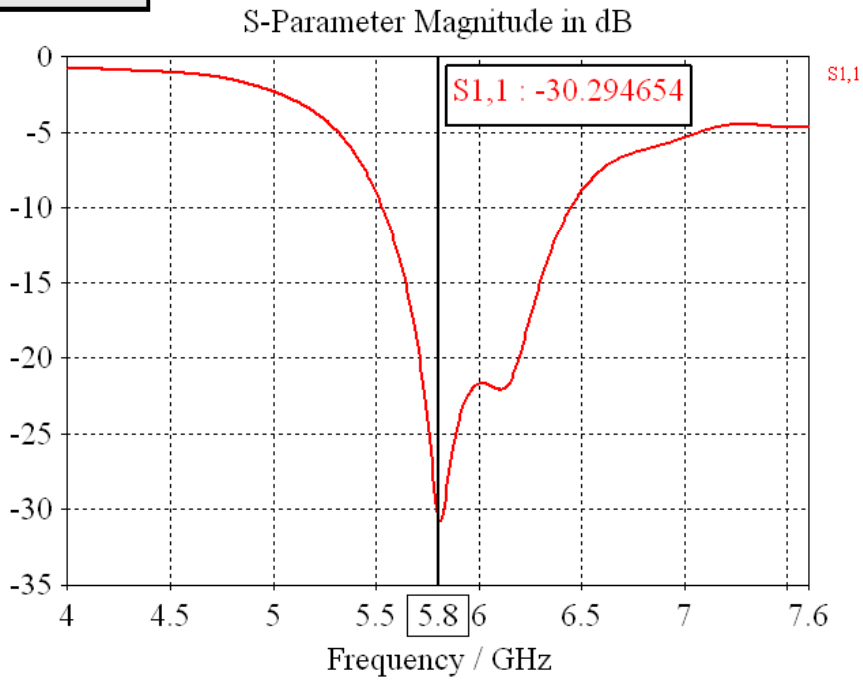
3D RFID Transponder Antennas Design @ 5.8 GHz for Smart Packaging Applications



Product-Packaging

CST MICROWAVE STUDIO®

Simulated Scattering Parameter:

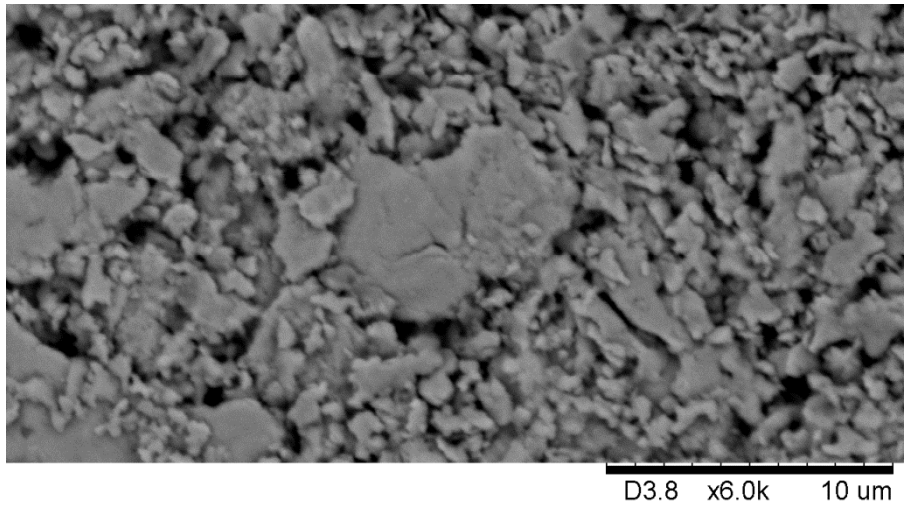


Antenna Printing → lab Scale

Screen Printing Parameters:

- 195 mesh screen
- Silver ink „CRSN2442“ (SunChemical)
- Substrates: a) cardbox paper
- Drying: vakuum oven
  (Heraeus Thermo Scientific VT6060P)
  @ 110 °C, 200 mbar, 20 minutes

Sheet fed Screen Printer EKRA E2XL



Layer thickness (avg) [µm]	Surface roughness [µm]	Surface resistance [Ω/□]	Electric conductivity [S/m]
5.3	1.9	0.059	3.2*10^6

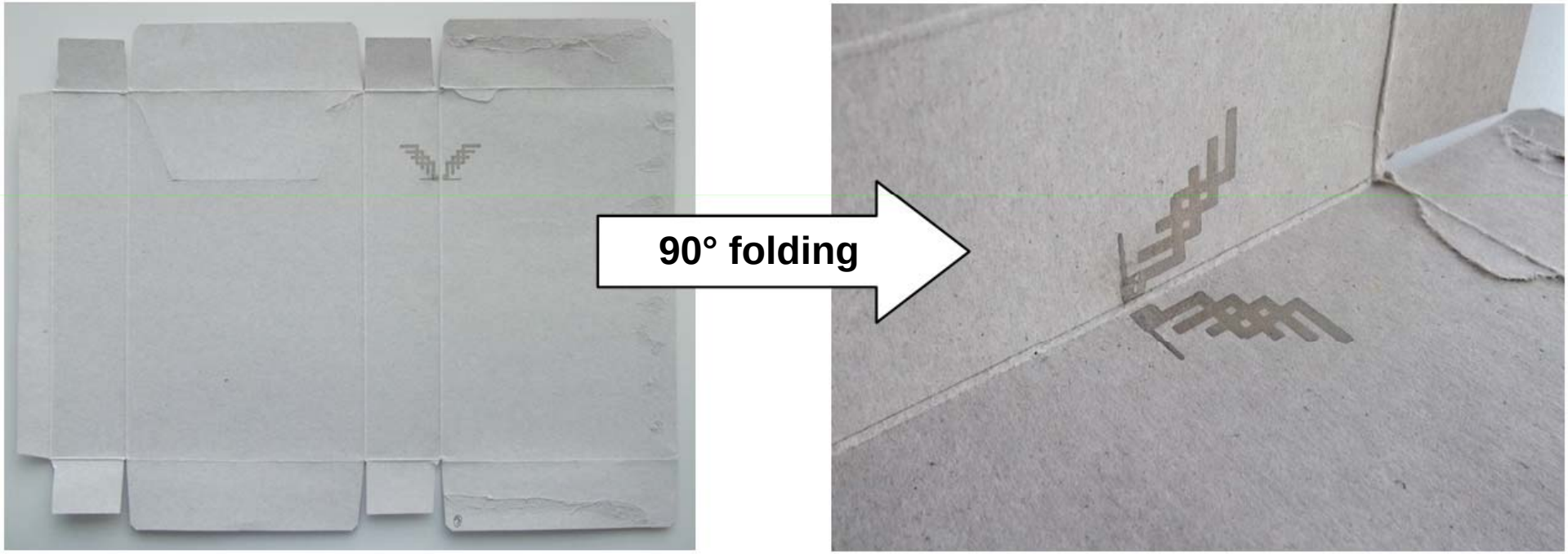
3D Antenna manufacturing → lab Scale

SPONSORED BY THE
Federal Ministry of Education and Research

Printed 3D Antenna manufacturing:

- planar printing (e.g. screen printing on paper substrate)
- folding

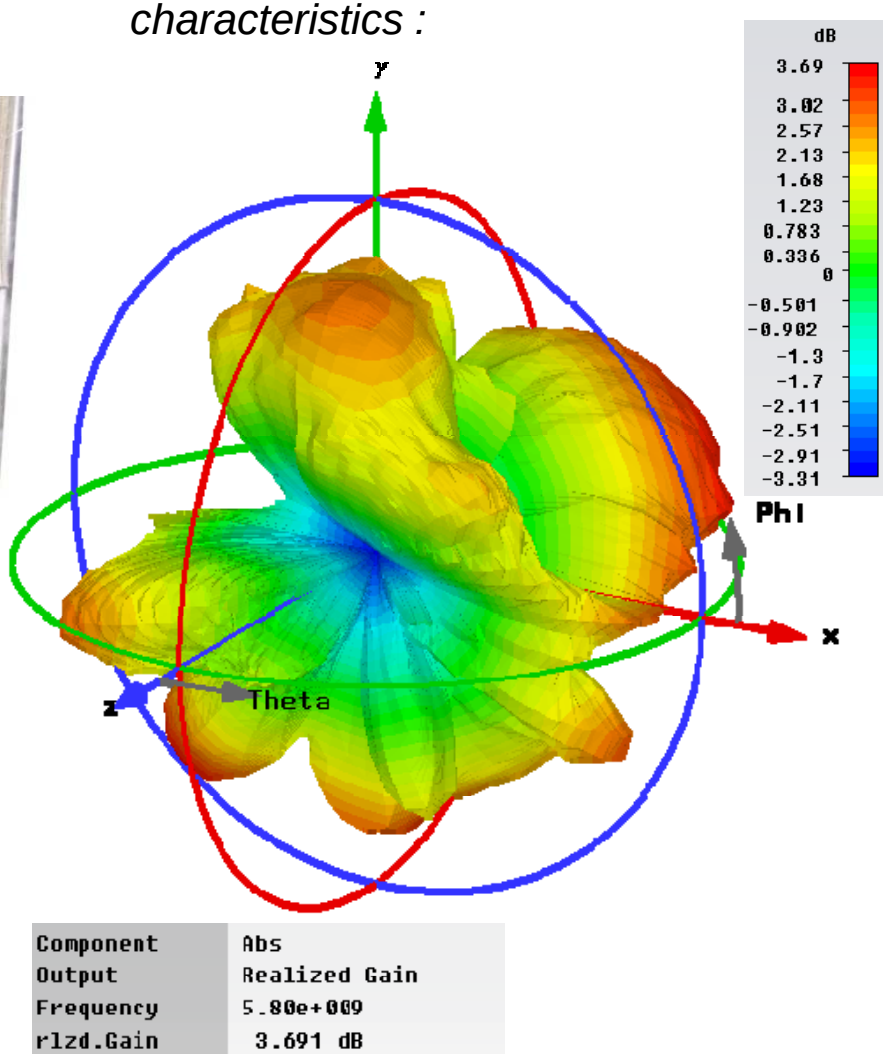
→ 3D antenna structure



3D Antenna Characterization

Measurement setup in an anechoic chamber:

Measured antenna radiation characteristics :



Advanced Printed Antennas: lab → fab → *Future fab*

Future: *Printed antenna manufacturing using a large-format packaging press*

http://www.parfumtrends.com/de/hugo-boss-bottled-night-edt-100-ml.html

Cyan *Magenta* *Yellow* *Black* *Silver (Antenna)*

Conclusions

➢ To realize highly functional printed antennas for identification applications the knowledge about:

✓ How to design a full application including the manufacturing of a specific antenna!

✓ How to print! → lab to fab!

is necessary.

”RFID is Nothing Without the Right Antenna!”

45th International Circle Conference 2013

Thank You for Your Attention

Contact: ralf.zichner@enas.fraunhofer.de