WIPE COST IC 1301

Electromagnetics and emerging technologies for pervasive applications: Internet of Things, Health and Safety

LCIS

Chipless RFID, State of the art and Current Developments

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EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

Agenda

- INTRODUCTION
- RFID SYSTEM COMPONENTS
- TAG CLASSIFICATIONS
- CHIPLESS CODING CLASSIFICATION
  - CODING BY PROCESSING UNIT
  - CODING WITH EMS
  - USING RF ELEMENTARY PARTICLE (REP)
- VOLUME CODING : THID
- MEASUREMENT - CHIPLESS READER
- FUTURE DIRECTIONS
- CONCLUDING REMARKS

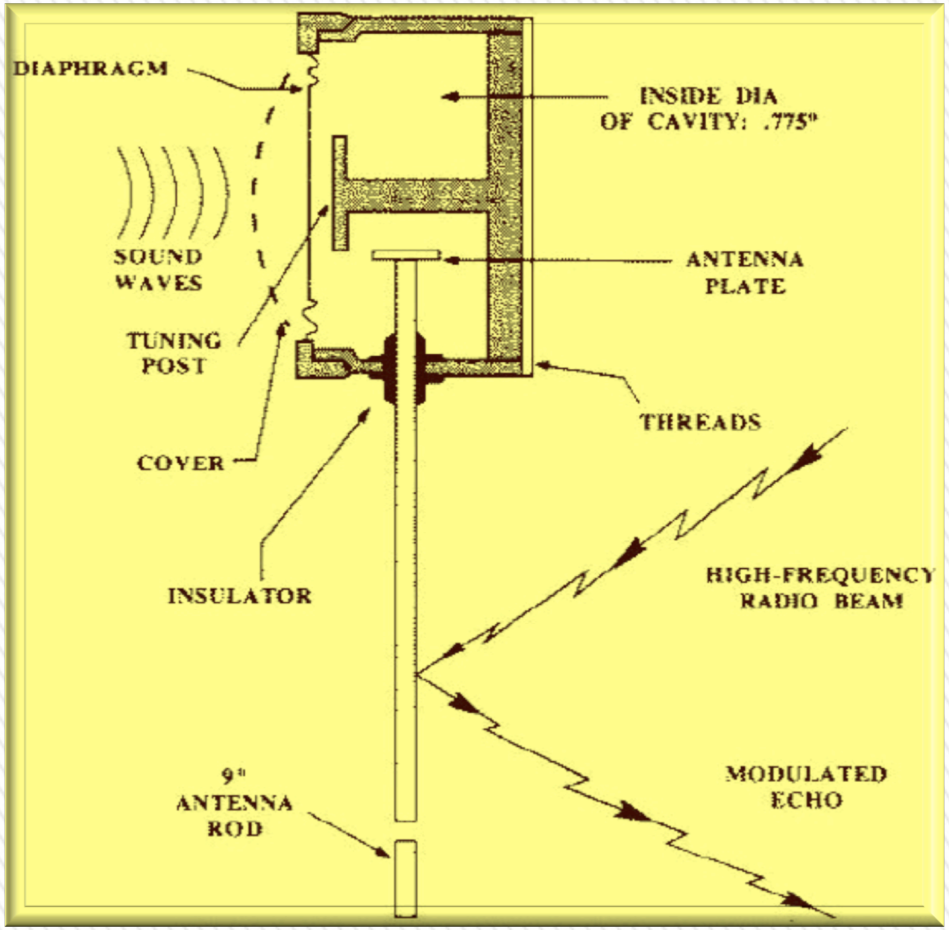
The spirit of RFID : The Thing

designed by Léon Theremin

Tiny capacitive membrane (microphone) connected to a small λ/4 antenna

Passive cavity resonator, became active @ 330 MHz.

Sound waves caused the microphone to vibrate, turn modulated reflected radio waves



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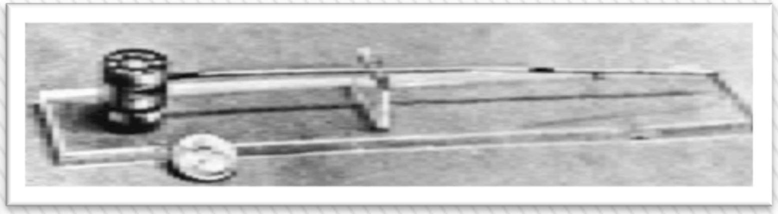
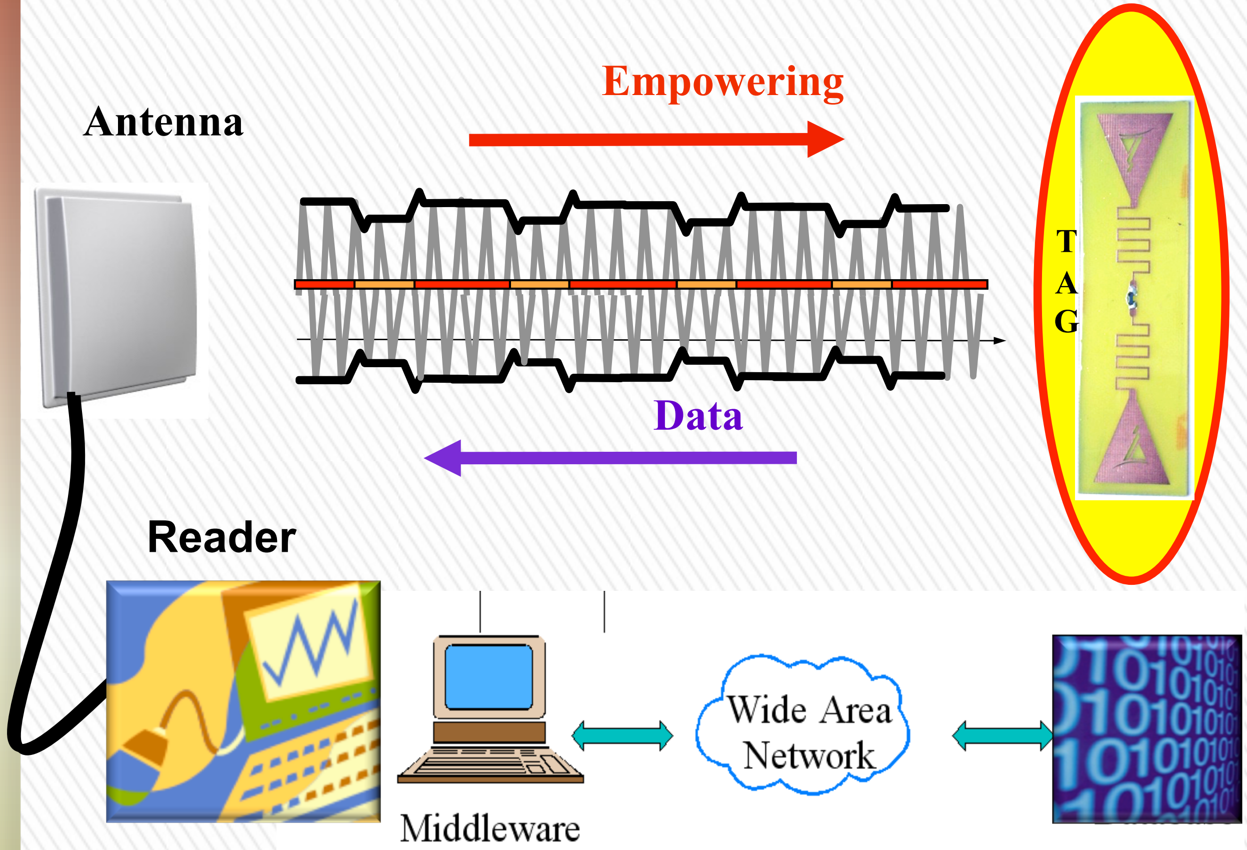
The Thing : 1945 The Great Seal Bug

The device was embedded in a carved wooden plaque of the US Great Seal . On August 4, 1945, Soviet school children presented it to U.S. Ambassador A. Harriman, as a « gesture of friendship ». It hung in the ambassador’ s Moscow residential office until it was exposed in 1952 during the tenure of Ambassador G. F. Kennan. The existence of the bug was accidentally discovered by a British radio operator who overheard American conversations on an open radio channel as the Russians were beaming radio waves at the ambassador's office. The CIA found it after an exhaustive search of the American Embassy, and P. Wright, a British scientist and former MI5 counterintelligence officer, eventually discovered how it worked.

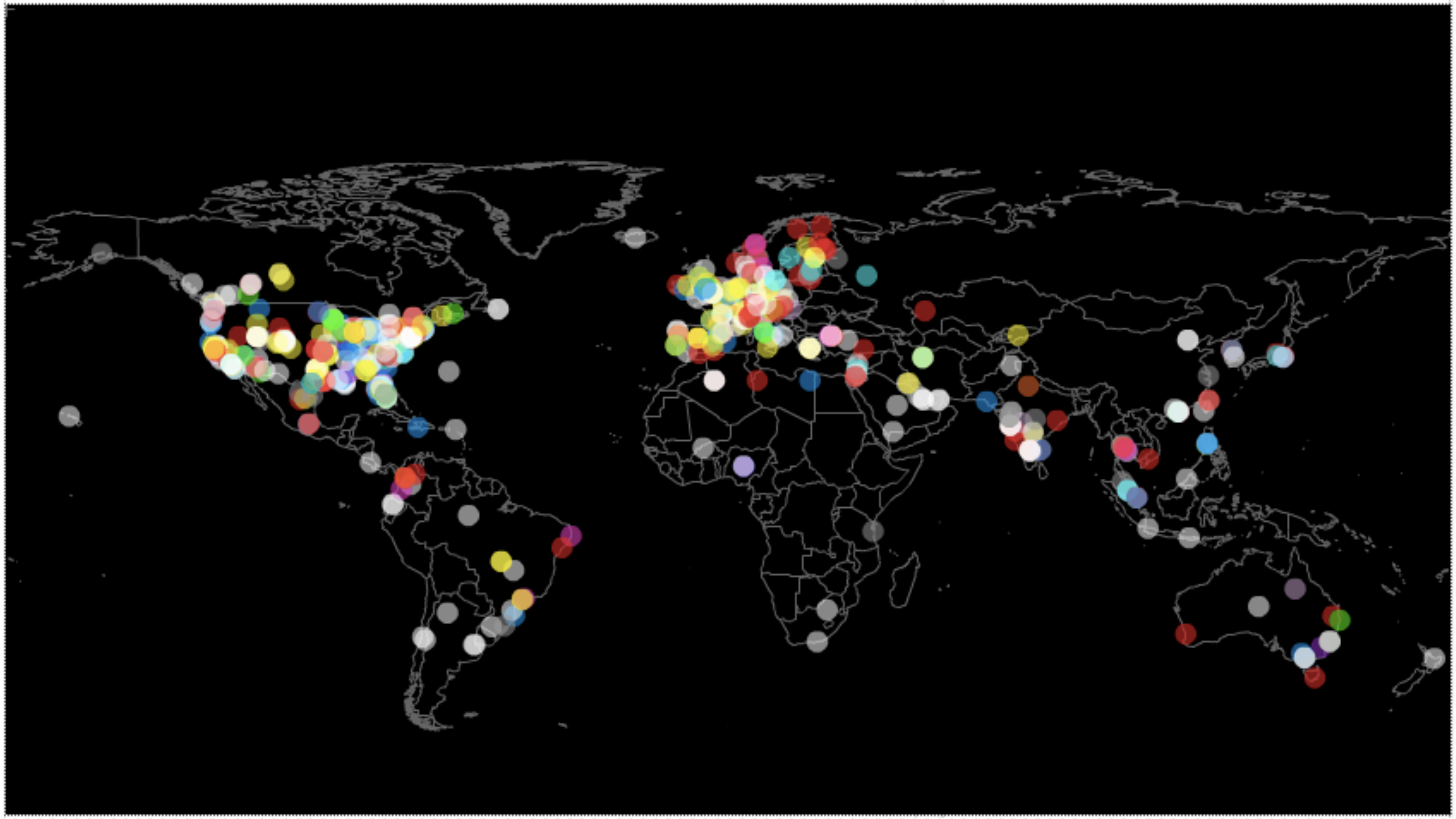


RFID SYSTEM COMPONENTS

RFID System Elements



RFID Deployments Worldwide



Source : http://www.rfidjournalevents.com/map.php

Thousands of Study Cases

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The Latest RFID Case Studies

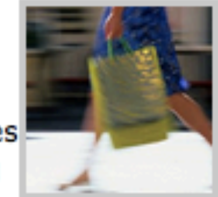
Show 30 latest new/modified case studies

City and County of Denver, roads, USA — 16 Oct 2015

The City and County of Denver, Colorado, with more than 6,100 lane-miles of roadway, has licensed CDO Technologies' CDO RoadTag to better track street cut data. Denver Public Works has purchased rugged Radio Frequency Identification (RFID) ...

View

Levi Strauss & Co, item level, USA — 16 Oct 2015



Levi Strauss & Co. has been innovating since the birth of the first pair of jeans in 1873. They continue to uncover new avenues for progress, including exploring ways to engage and inform consumers online and in stores. This comes through ...

View

Other new or recently modified RFID Case Studies

- Generation Tux, item level, USA
- Poltrona Frau, leather, Italy
- Sibley Memorial Hospital, tracking and safety, USA
- Outside Lands Music Festival, people,

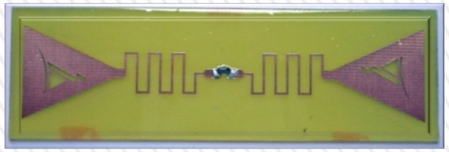
Case studies	4863
Companies covered	4940
Company slideshows & audio	770
Countries covered	124
Last updated	October 16, 2015

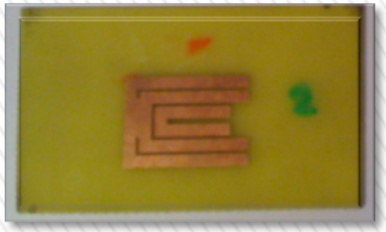
Classification of RFID tags

RFID Tags

Hardware | Signal&Software

- **Power**
  - Passive
  - Semi passive
  - Active
- **Com. Range**
  - Long range
  - Short range
  - NFC
- **Data Proc.**
  - IC based
  - Chipless
    - Printed
    - SAW Based
    - RF Circuits
    - THZ/volume
- **Program.**
  - Read
  - WORM
  - R/W
- **Protocol**
  - Tag Driven
  - Reader Driven





Challenging Optical Barcode

EAN-13 : 13 characters world-wide bar code (retail goods).

The concept of the optical barcode was introduced in 1948 by **Bernard Silver**

EAN-13 : 13 characters world-wide (retail goods).
the first 2 or 3 : country code (manufacturer is regist
The country code is followed by 9 or 10 data. And a checksum digit
2-digit and 5-digit supplemental may be added (total of 14 to 17 digits).

Example: Assume the barcode data = 001234567890X

1. 0 + 2 + 4 + 6 + 8 + 0 = 20
2. 20 * 3 = 60
3. 0 + 1 + 3 + 5 + 7 + 9 = 25
4. 60 + 25 = 85
5. 85 + X = 90 (modulo 10), therefore X = 5 (checksum)

Data Capacity of Optical Barcode

Data Matrix is a high density 2 dimensional matrix style bar code symbology that can encode up to 3116 characters from the entire 256 byte ASCII character set. The symbol is built on a square grid arranged with a finder pattern around the perimeter of the bar code symbol.

Symbology	Worst Case	Best Case
DataMatrix	1 error in 10.5M	1 error in 612.9M
PDF417	1 error in 10.5M	1 error in 612.4M
Code 128	1 error in 2.8M	1 error in 37M
Code 39	1 error in 1.7M	1 error in 4.5M
UPC	1 error in 394K	1 error in 800K

f h 4 5 3 4 f

C O D E 3 9

0 22334 54545 3 45

Friendly use

Data Matrix is a high density 2 dimensional matrix style bar code that can encode up to 3116 characters from the entire 256 byte ASCII character set. The symbol is built on a square arranged with a finder pattern around its perimeter.

Thanks to http://datamatrix.kaywa.com/

QR Code

From Denso-Wave in 1994 in Japan

Version 1, 21×21, 10-25 caractères,

Version 2, 25×25, 20-47 caractères.

Version 3, 29×29, 35-77 caractères.

Version 4, 33×33, 67-114 caractères.

Version 10, 57×57, 174-395 caractères.

Version 40, 177×177, 1 852-4 296 caractères.

Version 3, 29×29, 35-77 caractères.

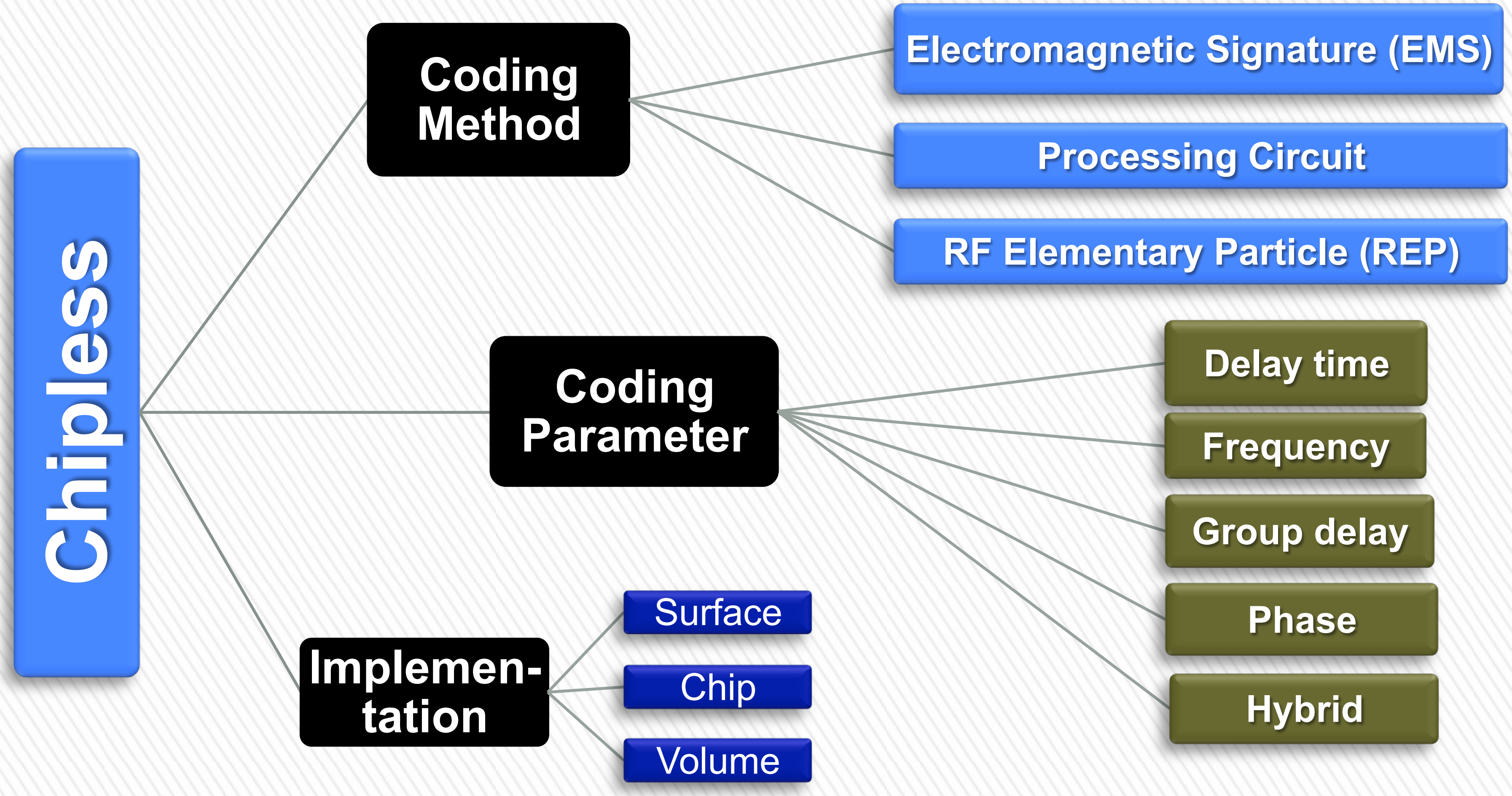
Version 4, 33×33, 67-114 caractères.

Version 10, 57×57, 174-395 caractères.

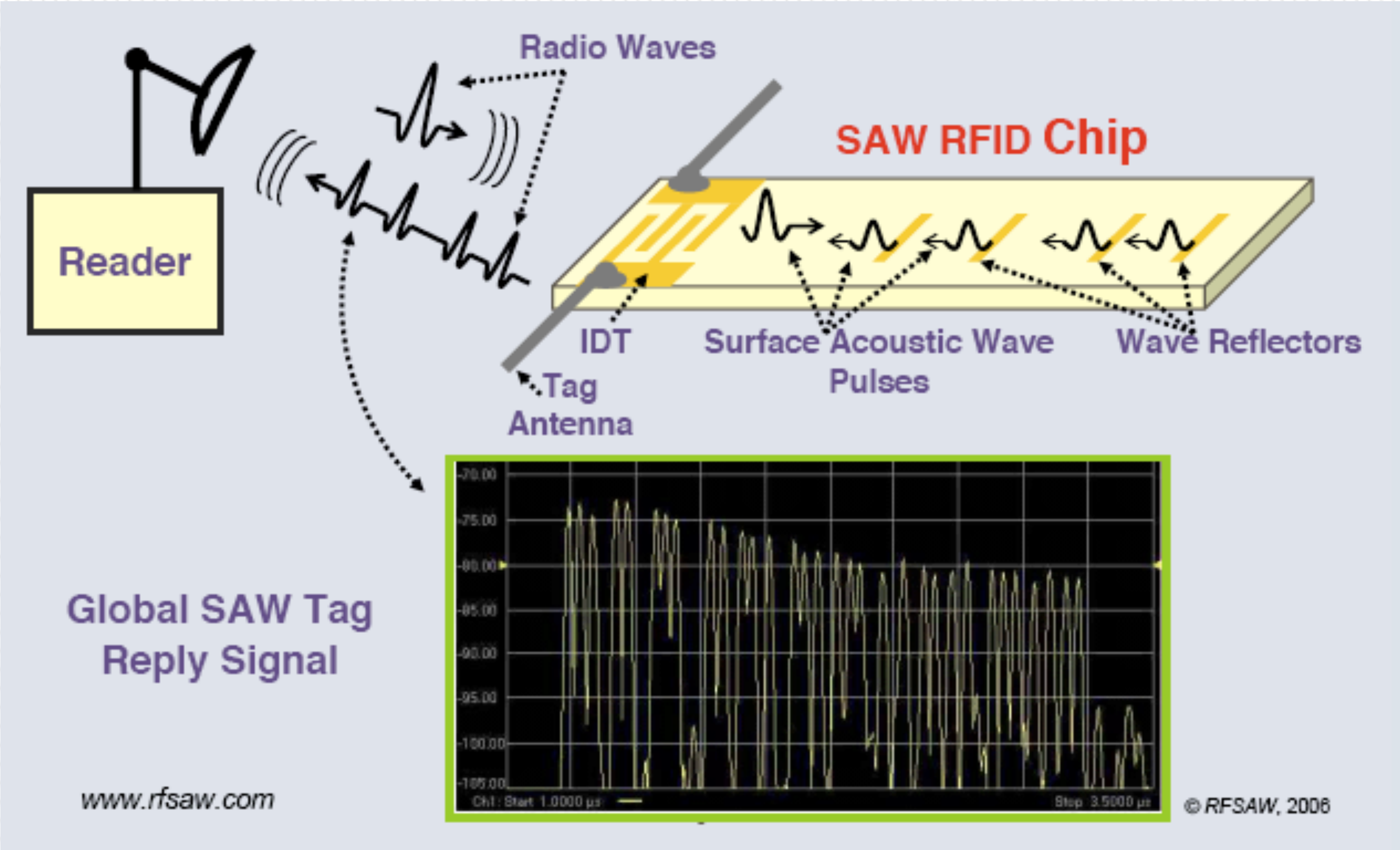
Version 40, 177×177, 1 852-4 296 caractères.

CHIPLESS TECHNOLGIES

Coding Techniques Tentative Of Classification

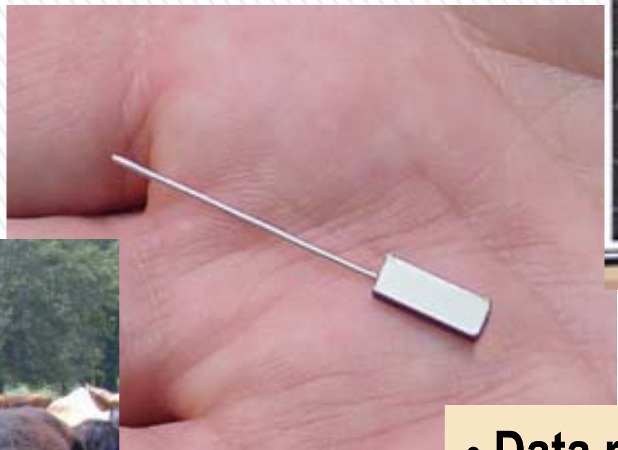


Processing Circuit : SAW



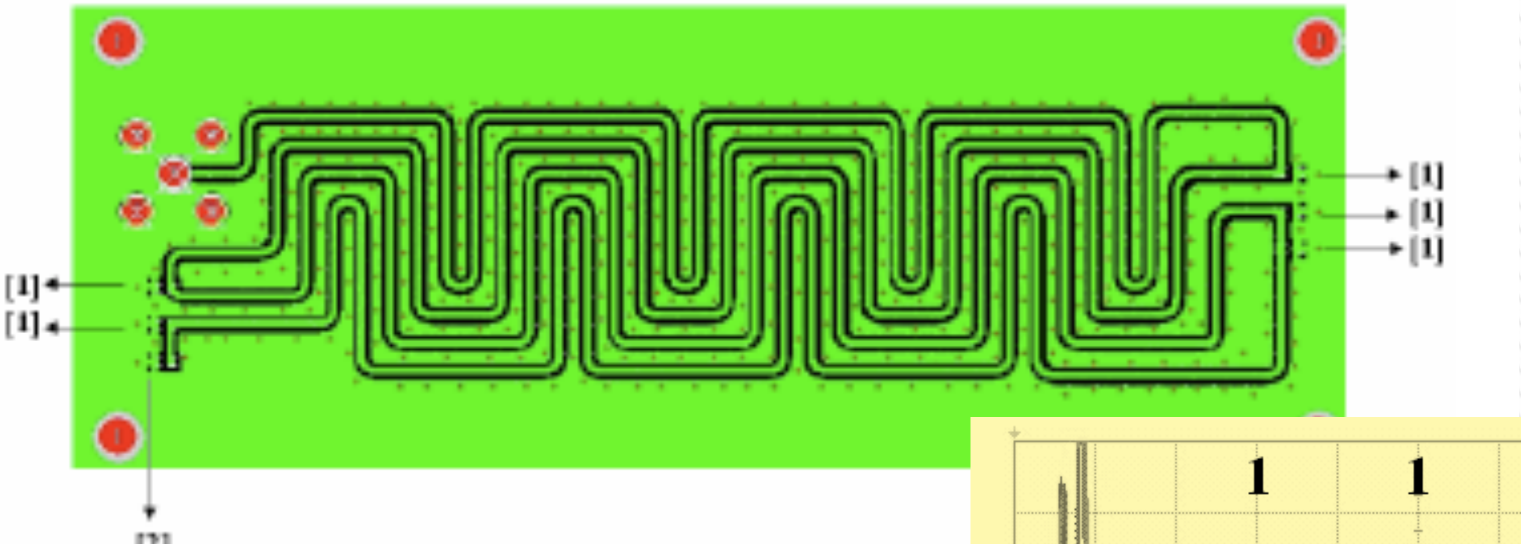
SAW Tag Features

- Low Power, 2.45 GHz Reader
- Longer Read Range
- Automatic ID and Location
- Read Multiple Tags in Field
- Size Compatible with Ear Tag

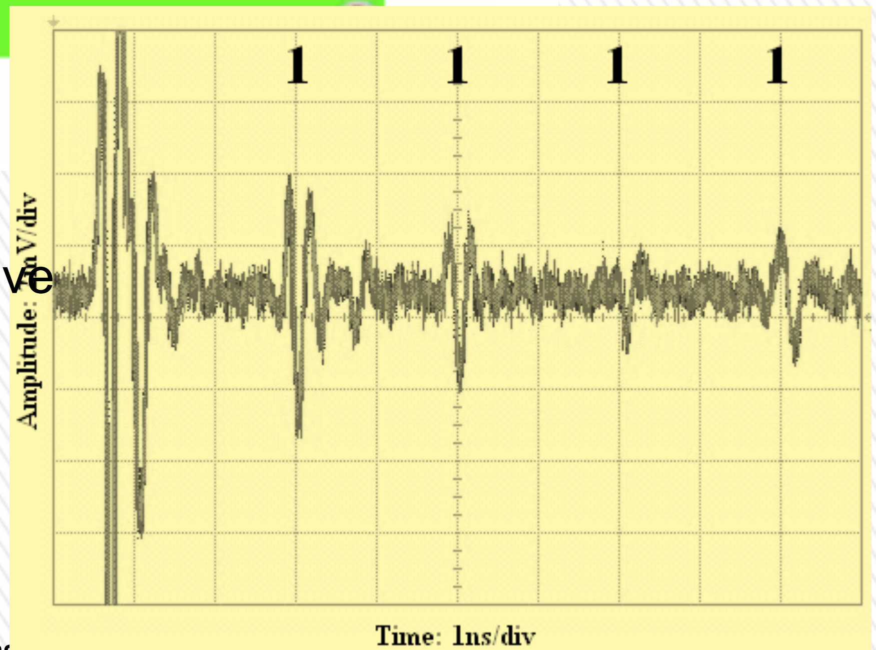


- Data range from 32 to 256 bits
- Robust error detection
- Anti-collision
- Fundamentally low cost (in high quantity)
- Single SAW tag is legal worldwide
- Passive Read of Range and Temperature

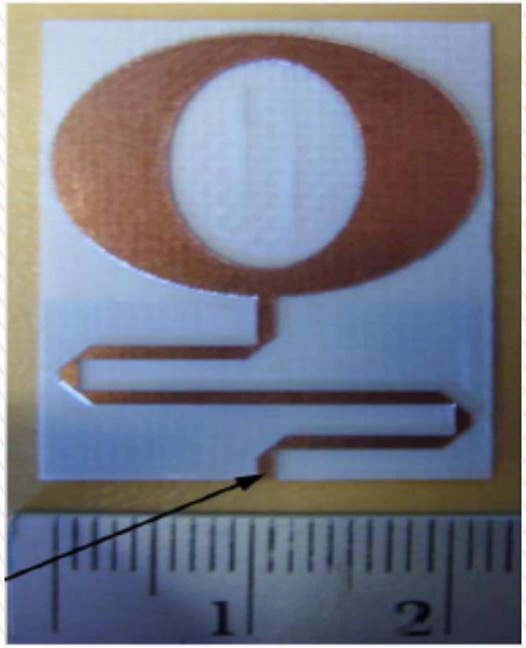
Processing Unit: Delay Line on RF Substrate



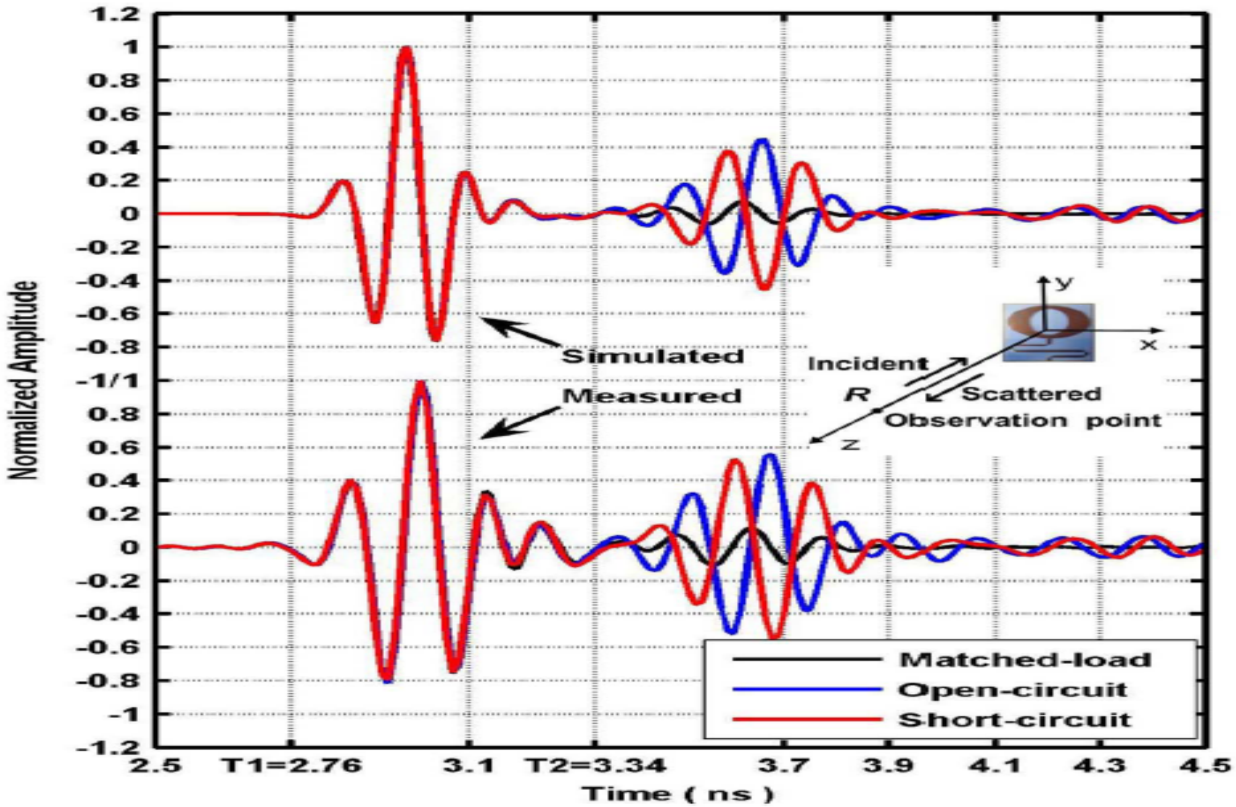
Each TR line 180mm length, 1 bit TR-line
4 bit and 8 bits are realized!!
Capacitors are either soldered or planar passive capacitors with bulk size are used
Pback is -70 dBm,
power 20 dBm @2.45GHz
Substrate Rogers 4350, Gt = 2.2 dBi,



Processing Unit with Loads

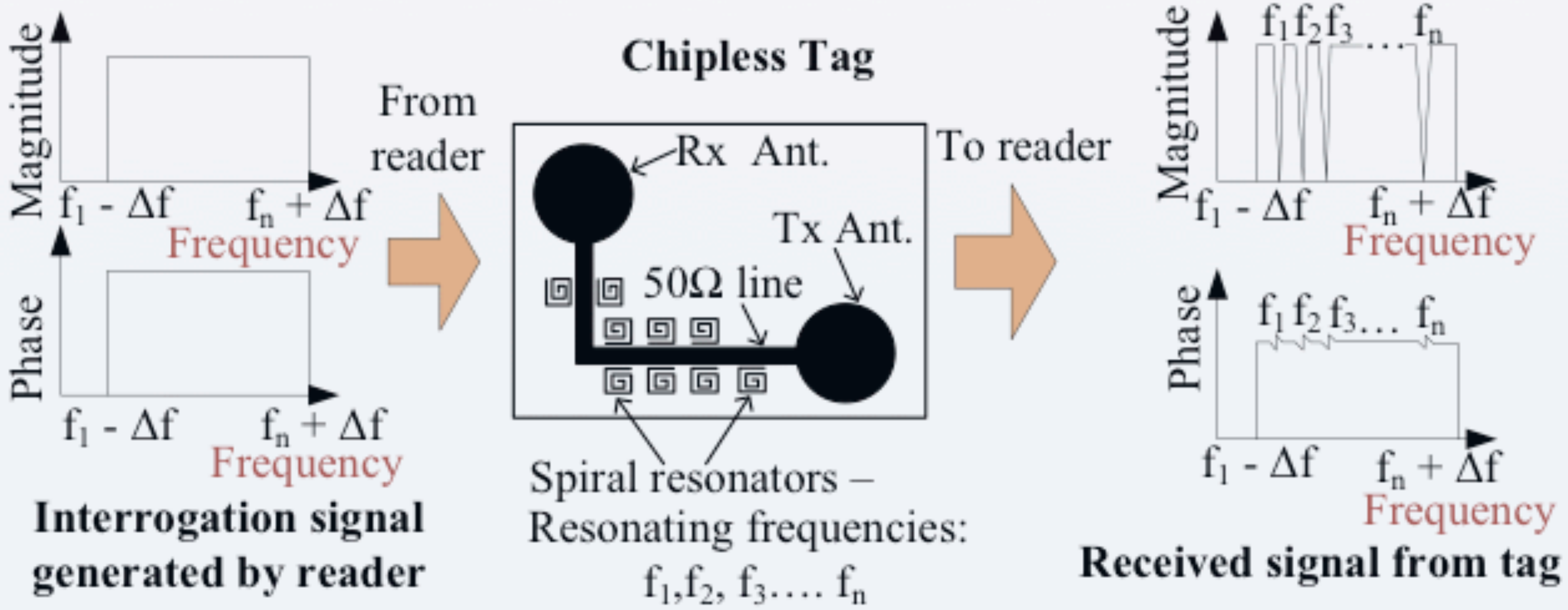


Terminated with loads here



*S. Hu, C. L. Law, and W. Dou, "Balloon-Shaped Monopole Antenna for Passive UWB-RFID Tag Applications" IEEE Antennas And Wireless Propagation Letters, VOL. 7, 2008

Processing Unit : Multiresonator

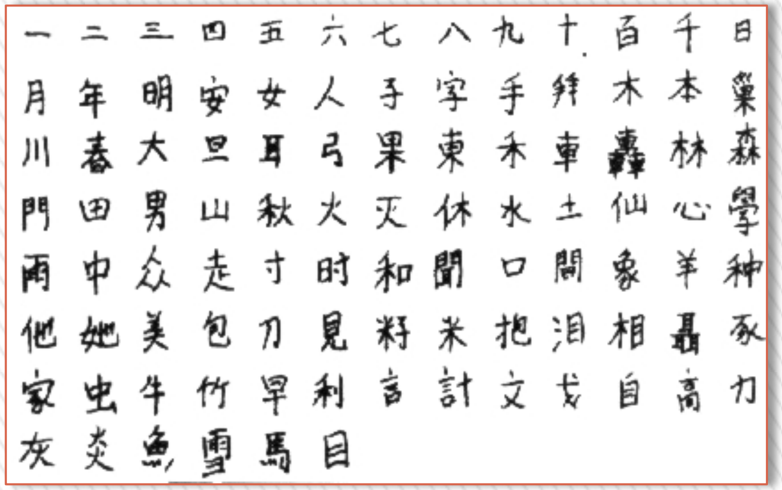


Courtesy : Nemai Karmakar

Electromagnetic Signature (EMS)

- Using metallic letters for identification application allows :
  - visual identification (in line of sight)
  - RF identification (none line of sight)

- The diversity of alphabets in the world is a richness from EM point of view.



- The EM response of a letter depends on its parameters (Size, Font…).
  - Several letters form “words”, having new EM signature

EMS Simulation

Letter Generation

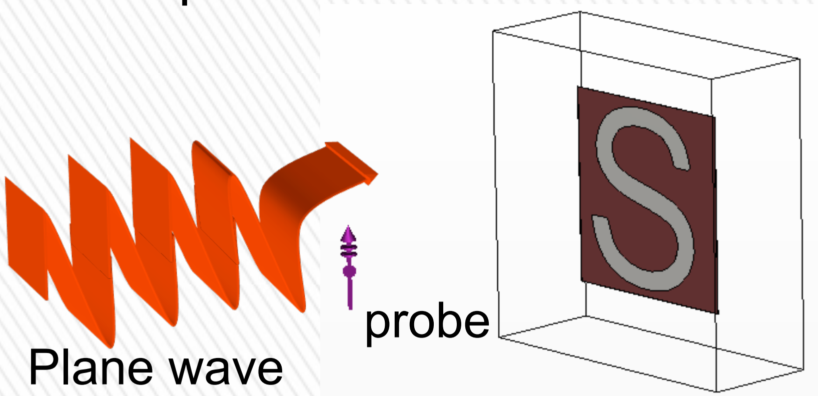
Letter design → CAD software → .dxf → Electromagnetic Simulation → CST Microwave Studio

EM Simulation

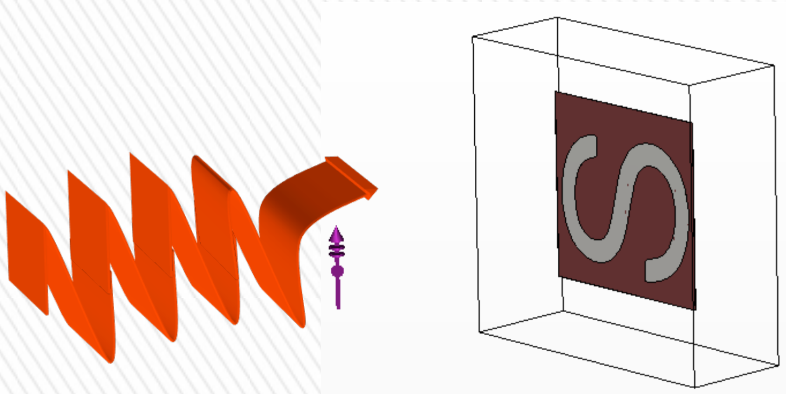
- Boundaries : open add space
- Plane Wave excitation
- RCS probe

Kapton, εr=3.5, tand=0.004, t=0.1mm

Copper, 17µm



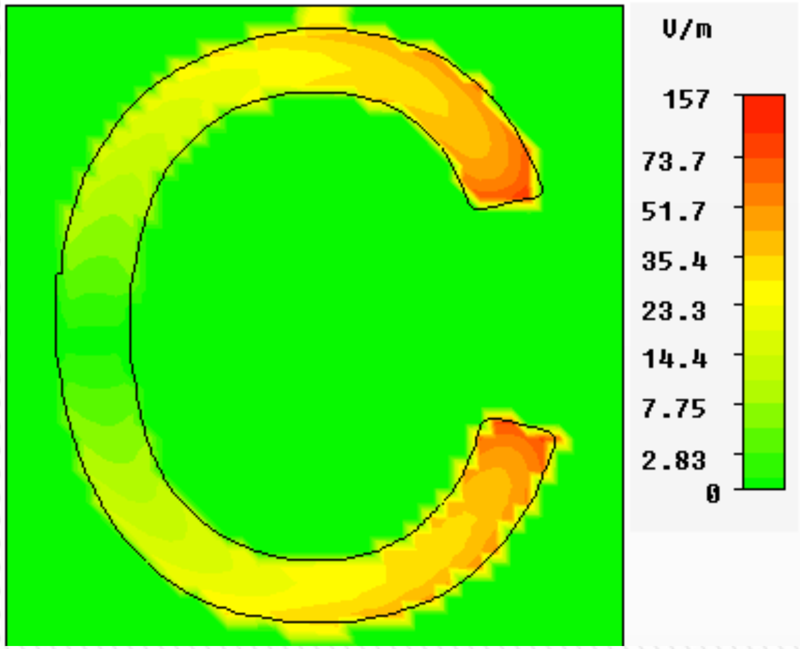
Vertical polarization



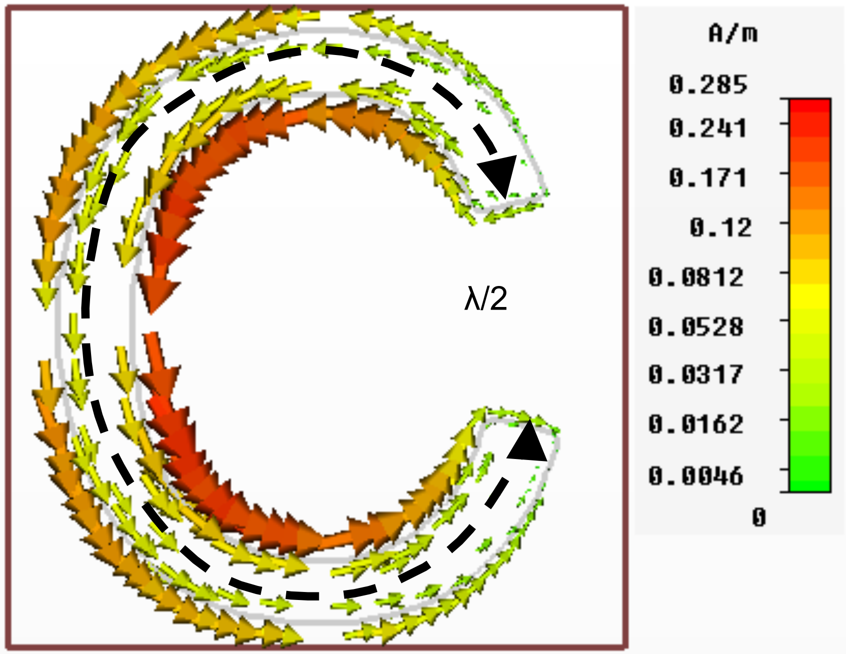
Horizontal polarization

Response of Letter C : EMS

- Way of radiation for letter "C" of 48mm height



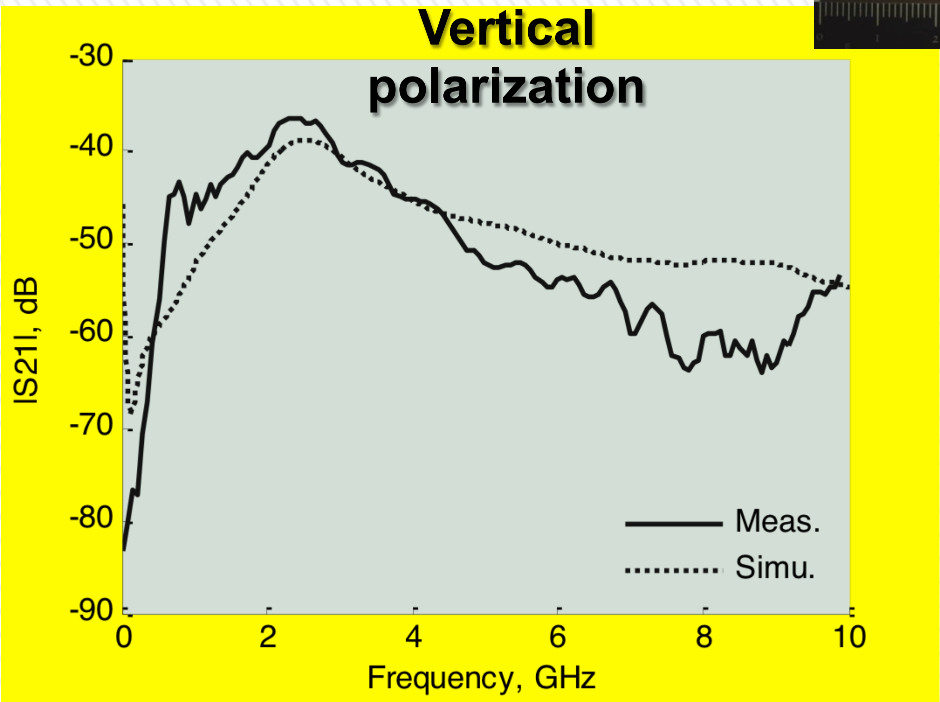
field intensity

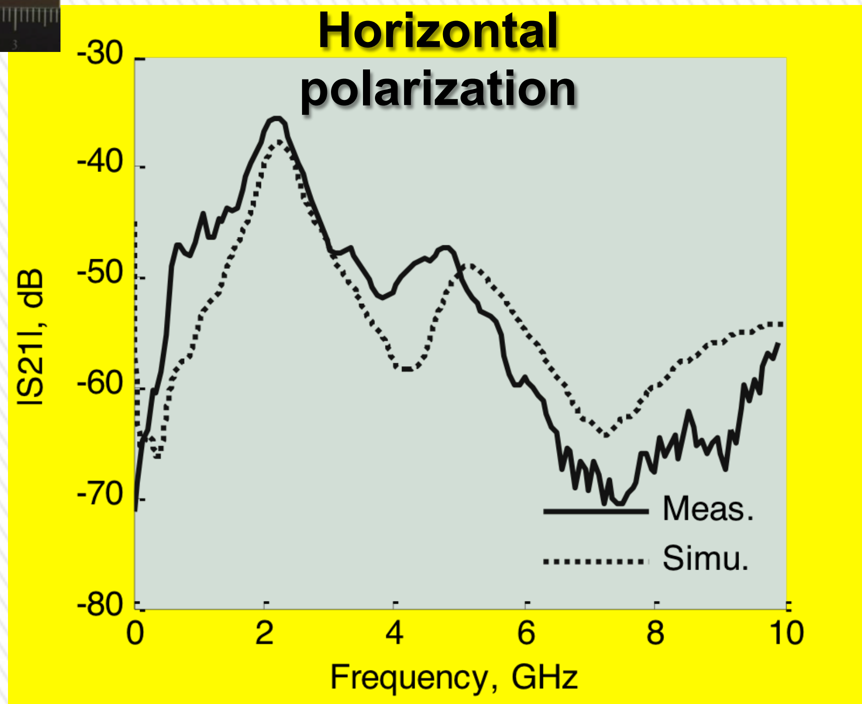


Surface current

λ/2 resonance @ 1.29 GHz

Experimental Validation For "F"





- **Simulation results are obtained with CST using a RCS probe**
- **The Radar Equation is applied to get |S21|**

24mm Alphabet lookup Identification

A	B	C	D	E	F	G	H	I	J	K	L	M
5.52	4.84	2.4 7.9	4.94	2.6	3.67 6	2, 4.74 8.4	6	5.45	4, 8.56	4.28 5.74	3.92 8	3.86
N	**O**	**P**	**Q**	**R**	**S**	**T**	**U**	**V**	**W**	**X**	**Y**	**Z**
6	5.1	4.4	4.5	4.82	2.54	3.96	5.4	5.5	3.86 8.1	4.22	4.62	2.88

- lookup table Vertical polarization

A	B	C	D	E	F	G	H	I	J	K	L	M
4.64	8.21	5.70	5.2	8	3.67	4.6	3.2	Out range	4, 8.36	4.02	4 7.45	2.27
N	**O**	**P**	**Q**	**R**	**S**	**T**	**U**	**V**	**W**	**X**	**Y**	**Z**
2.75	5.03	8.4	5.17	4 Min 5.82	8		2.57 7.5	3.1 4	2.21 Min 7.2	4.69 5.5	4.56	8

- lookup table Horizontal lpolarization

Application to Arabic Alphabets

ص	ش	س	ز	ر	ذ	د	خ	ح	ج	ث	ت	ب	أ
2.71 5.34	2.60 4.55 6.27	3.17 6.24	3.74 7.62	4.81	8.44	5.52	8.37	7.70	2.50 5.04 9.00	2.84 5.13	3.56 3.93	3.83	Ø
ي	**و**	**ه**	**ن**	**م**	**ل**	**ك**	**ق**	**ف**	**غ**	**ع**	**ظ**	**ط**	**ض**
3.35	5.16	6.49	3.88	5.24	3.02 6.14	3.24 7.26	3.29	3.52	2.80 9.01	3.07 5.38 8.44	3.86 5.05 7.01	4.03 5.95	2.69 3.45

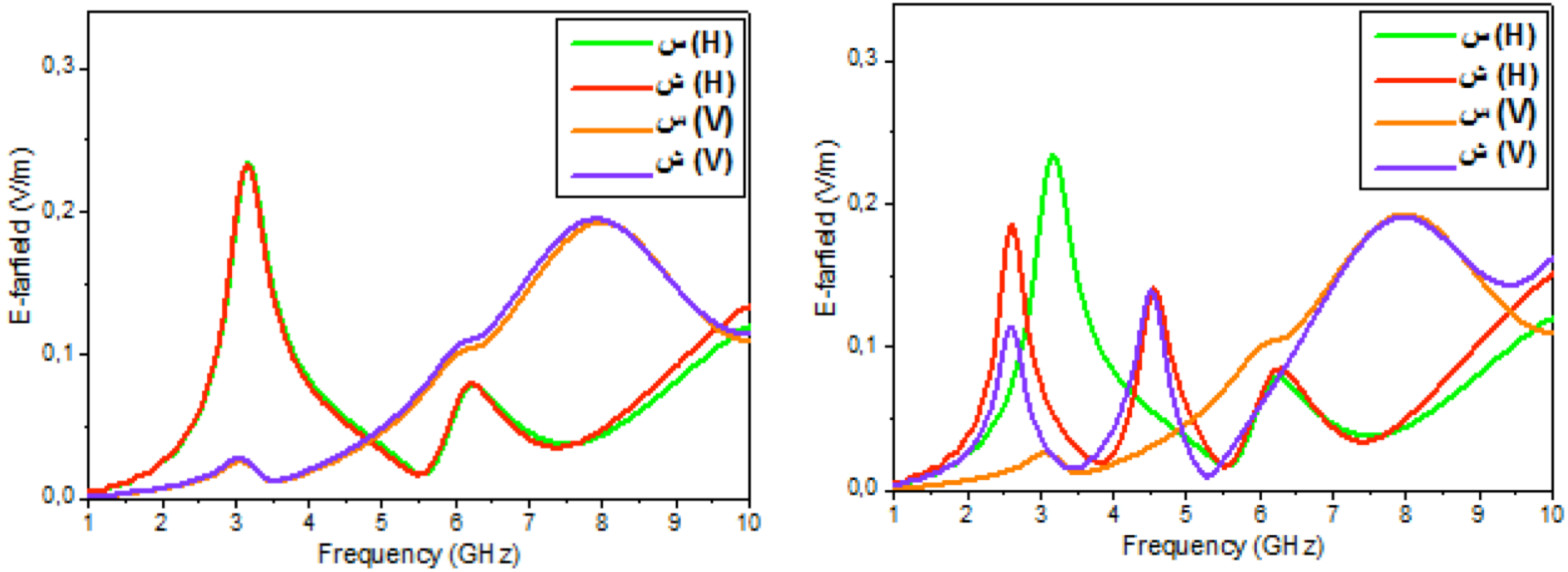
Lookup table for 24mm-height alphabet using horizontal polarization

.

ص	ش	س	ز	ر	ذ	د	خ	ح	ج	ث	ت	ب	أ
2.60 7.98	2.60 4.51 7.95	3.07 6.10 7.97	3.74	4.85	4.28	5.59	2.92 7.06	3.11	2.52 5.15	2.49 7.92	3.66 8.64	7.87	6.12
ي	**و**	**ه**	**ن**	**م**	**ل**	**ك**	**ق**	**ف**	**غ**	**ع**	**ظ**	**ط**	**ض**
3.30 5.99 8.71	5.23	6.31	3.76 7.80	3.35	3.01 6.22	3.22 6.55 7.99	3.25 7.24	7.82	2.89 4.87	3.16 5.59	3.84 5.32	4.10	3.37 6.08 8.61

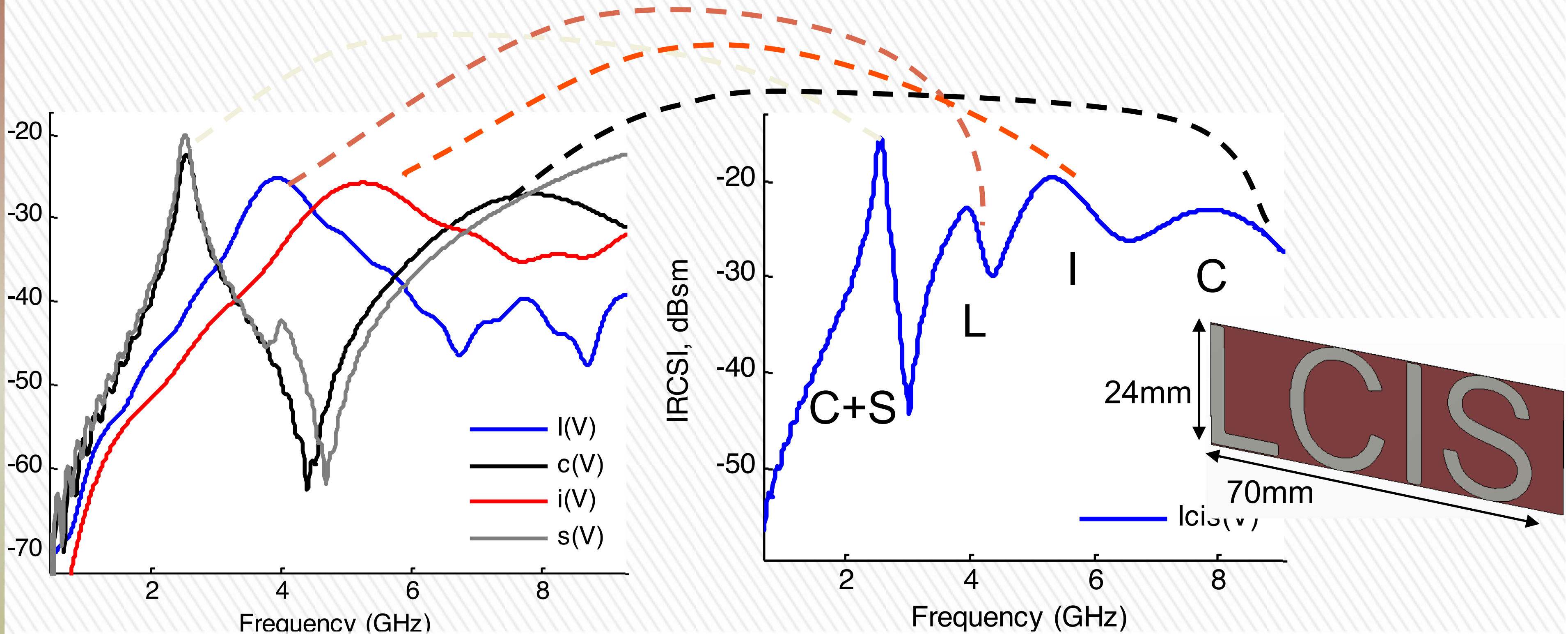
Lookup table for 24mm-Height alphabet using vertical polarization.

Adapting the Letter Shape



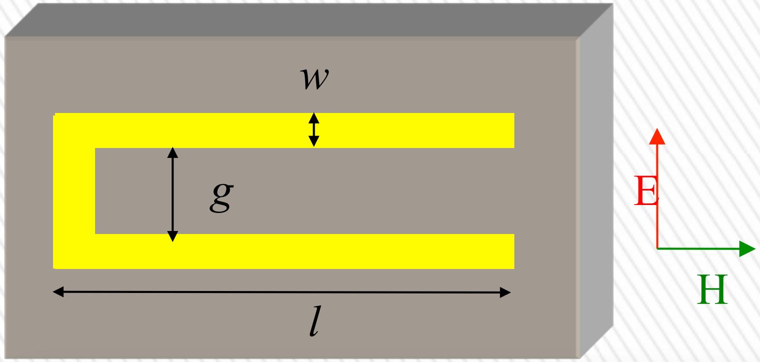
(a) (b)

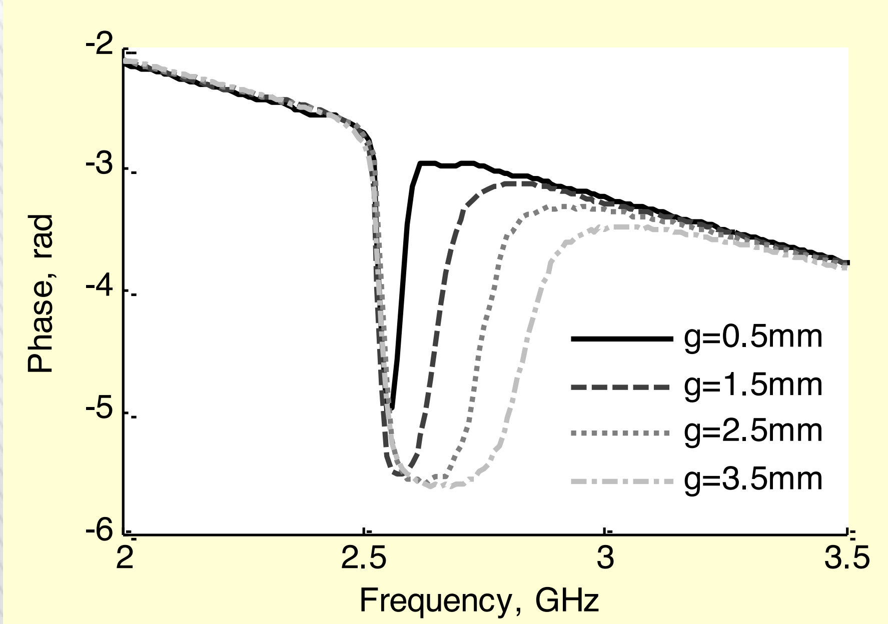
Identification of Words

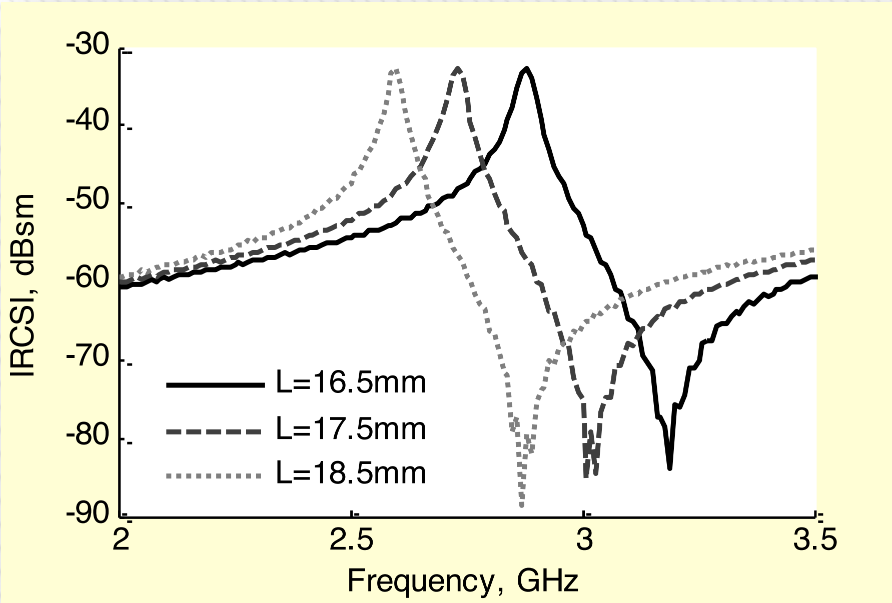


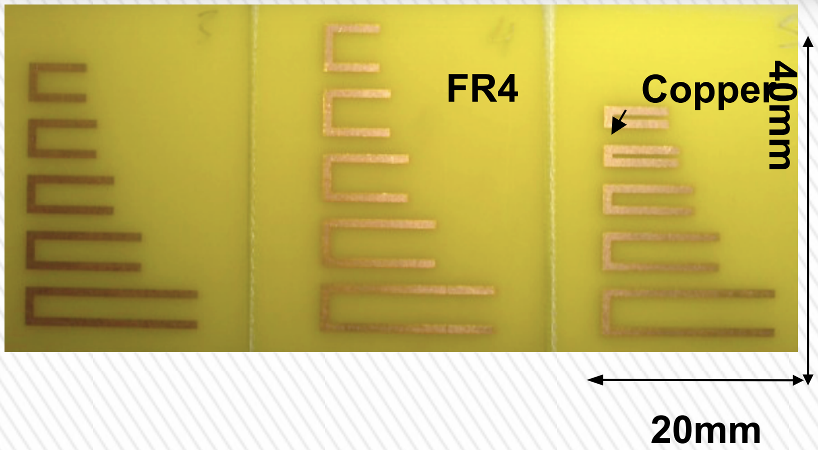
- **The EM signature "LCIS" depends on the presence of all the letters**
- **But whatever the position of the letters in the word. 1 possibility among 24 (4!) to find the right one.**

RF Coding Particule: C-Cell

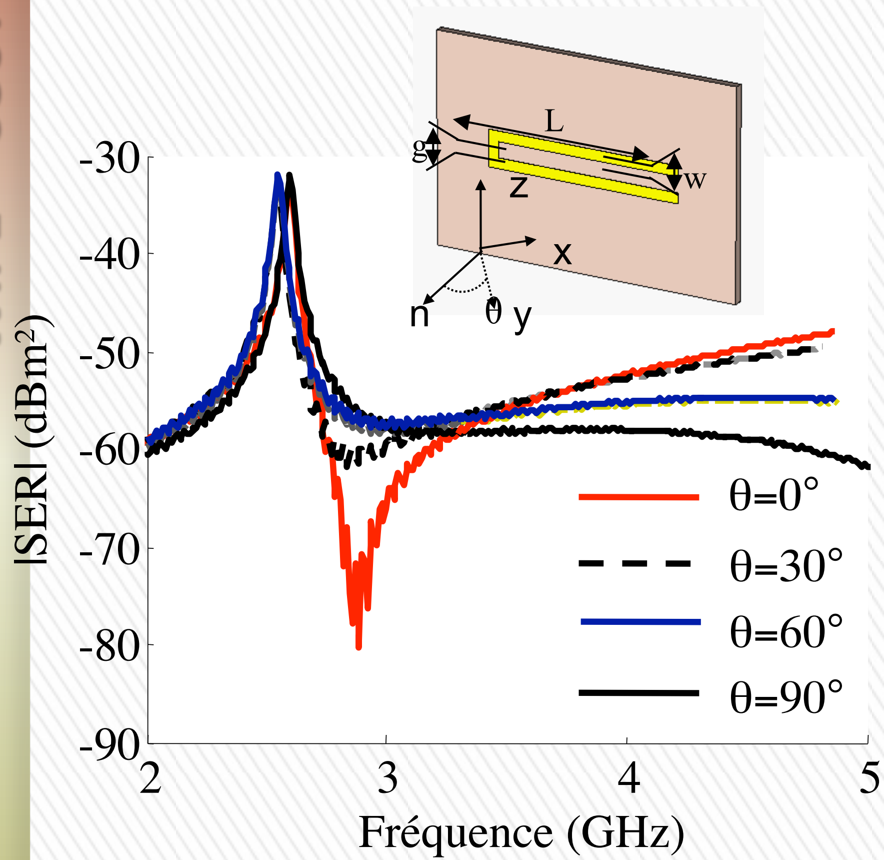


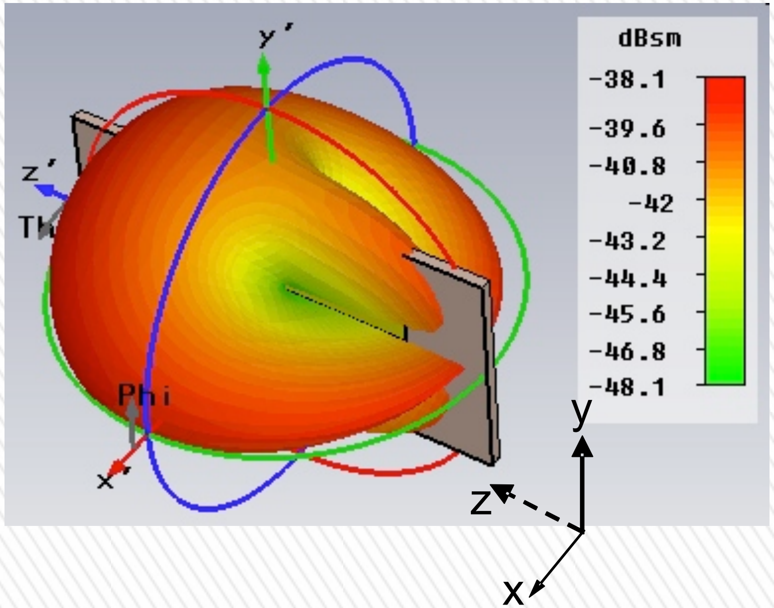






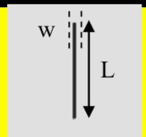
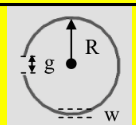
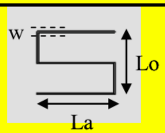
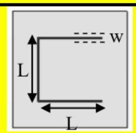
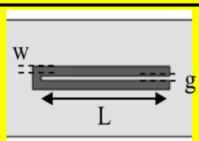
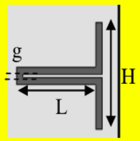
C-Cell Re-Radiation



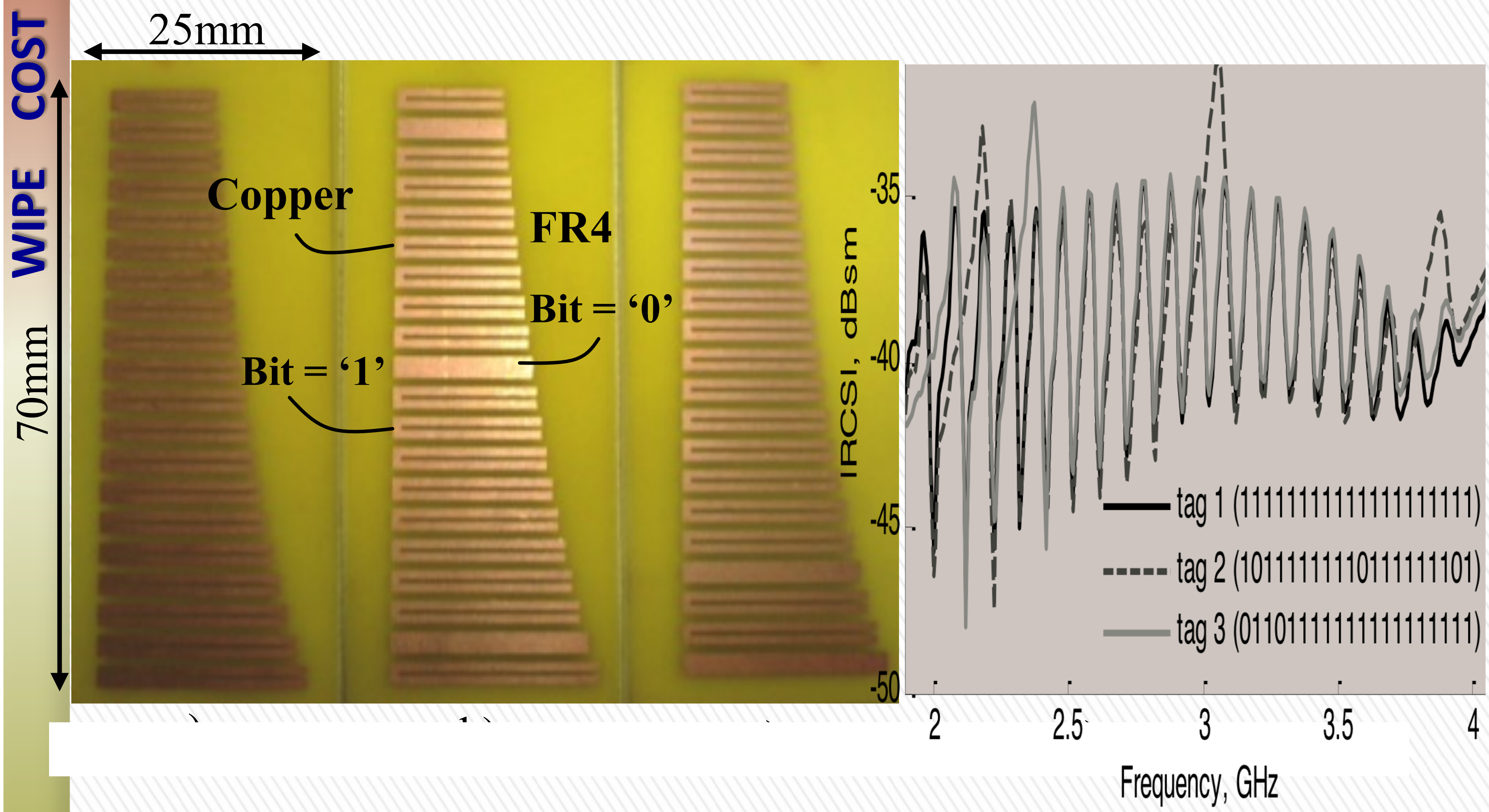


Selectivity 30 MHz for g = 0.5 mm & L = 20 mm. RCS : -30 dBm²

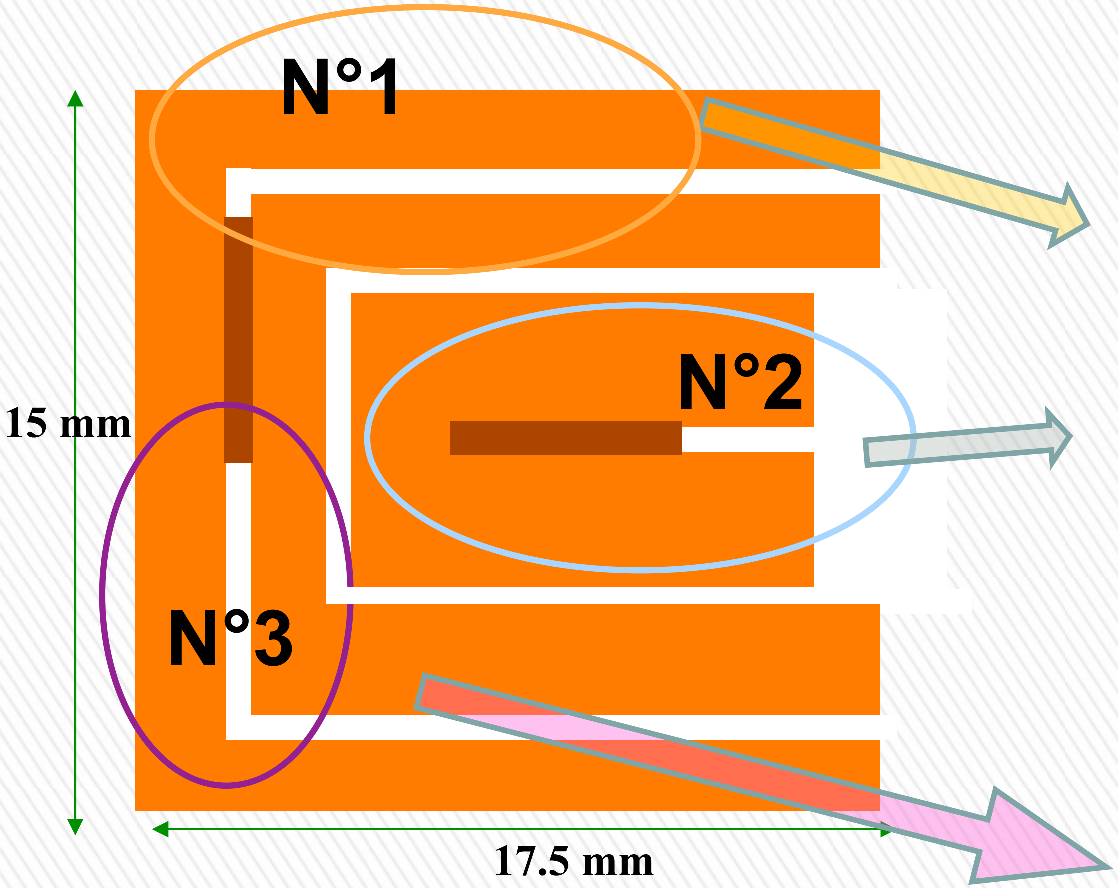
Selectivity & Reflectivity

Type	Shape	Dimensions (mm)	BW-3dB	Maximum size in wavelength	RCS (dBsm)	Frequency of the 1st higher order mode
Shorted dipole		L=34 w=0.5	452MHz (15%)	λ/2	-21.35	8.94 GHz
Single circular SRR		R=5.4 g=1.6 w=0.5	72MHz (2.4%)	λ /6.3	-25	8.95 GHz
S-like		La=10 Lo=10 w=0.5	84MHz (2.8%)	λ /6.8	-21.9	>10 GHz
C-like (L=g)		L=12.1 w=0.25	120MHz (4%)	λ /8.5	-22.9	8.32 GHz
C-like (g=0.5 mm)		La=16 w=1	28MHz (0.9%)	λ /4	-31.4	8.95 GHz
C-like extended		L=13.3mm, H=15mm, g=0.5mm	32 MHz (1.1%)	λ /6.67	-22.5	6.73 GHz

20 Bits Chipless Tag



Coding Particule: Double-C



Freq. (GHz)	Code for N°1
2.40	00
2.45	01
2.50	10
2.55	11

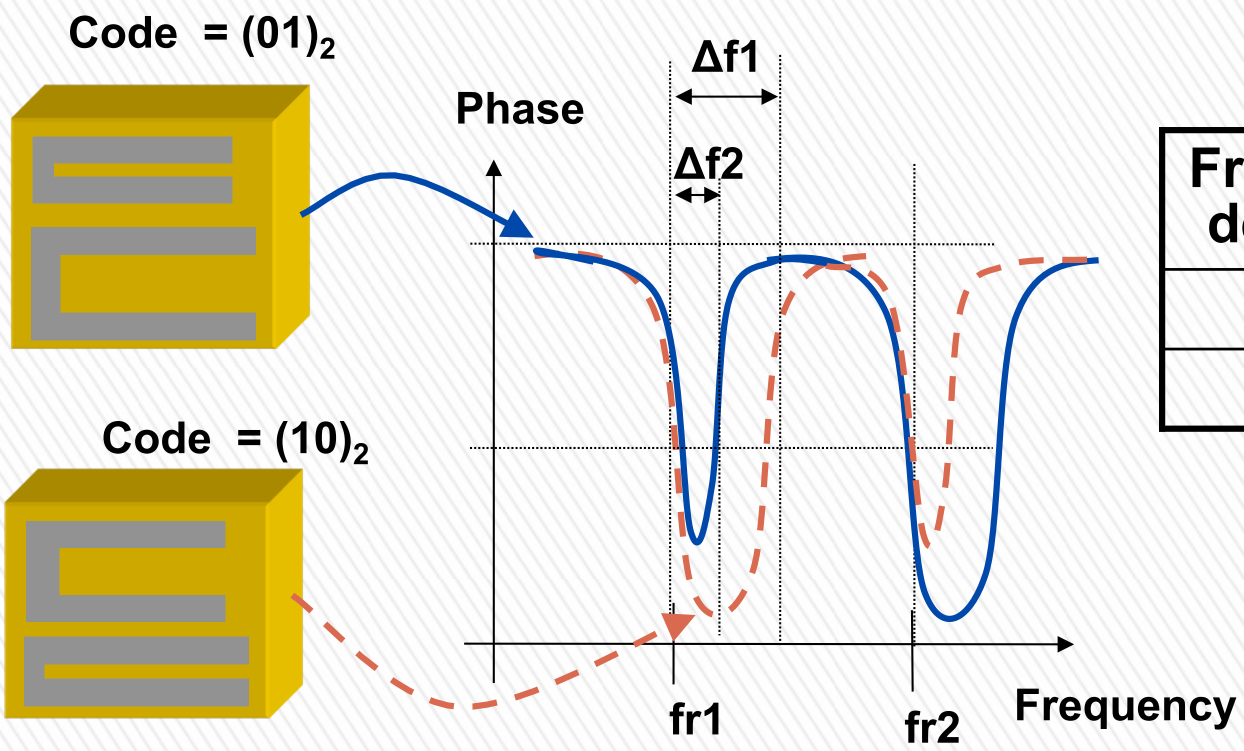
Freq. (GHz)	Code for N°2
4.0	00
4.4	01
4.8	10
5.2	11

Freq. (GHz)	Code for N°3
2.0	00
2.1	01
2.2	10
2.3	11

code “110110” : resonances : 2.55, 4.4, 2.2 GHz

Bits/cm² = 2.3

Using the Phase for Coding



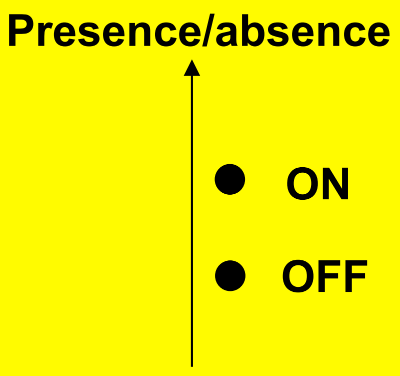
Frequency deviation	Binary Code
Δf1	0
Δf2	1

Coding due to phase deviation for fr1

Hybrid Coding : Efficiency Enhancement

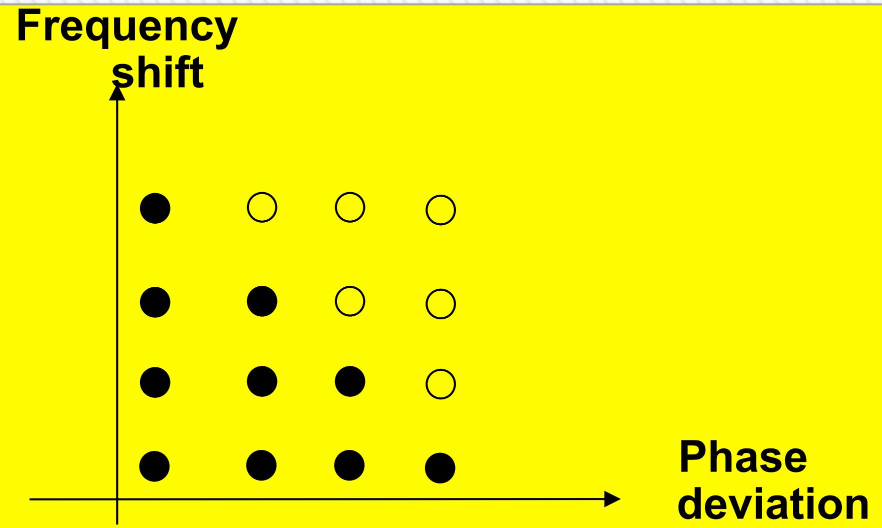
Hybrid technique to Increase the Coding Efficiency

- Frequency Position
- Phase deviation



Constellation in frequency domain for OOK case

1 resonator ⇔ 1bit

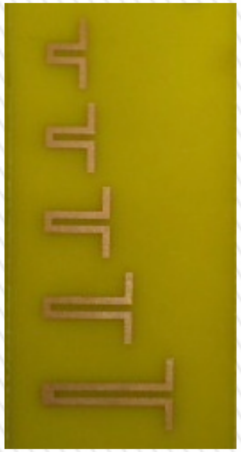


Constellation in frequency and phase domains (PFS K)

1 resonator ⇔ N bits

Hybrid Coding : Coding Efficiency

Tag C having 5 resonators



K=5

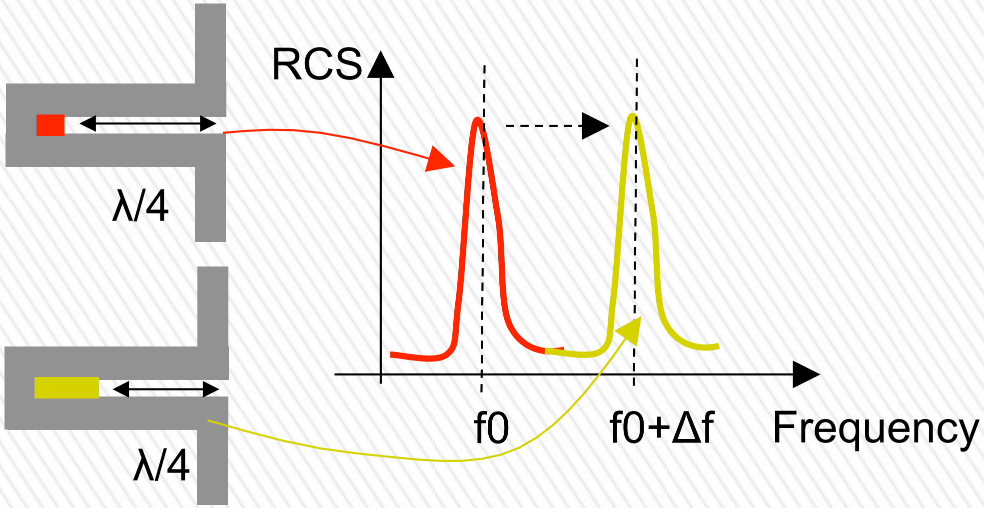
BW = 1000MHz

Δf = 100MHz

N=100000

C= log2(N)=16.6 bits

Frequency Shift Encoding



Coding Capacity Calculation

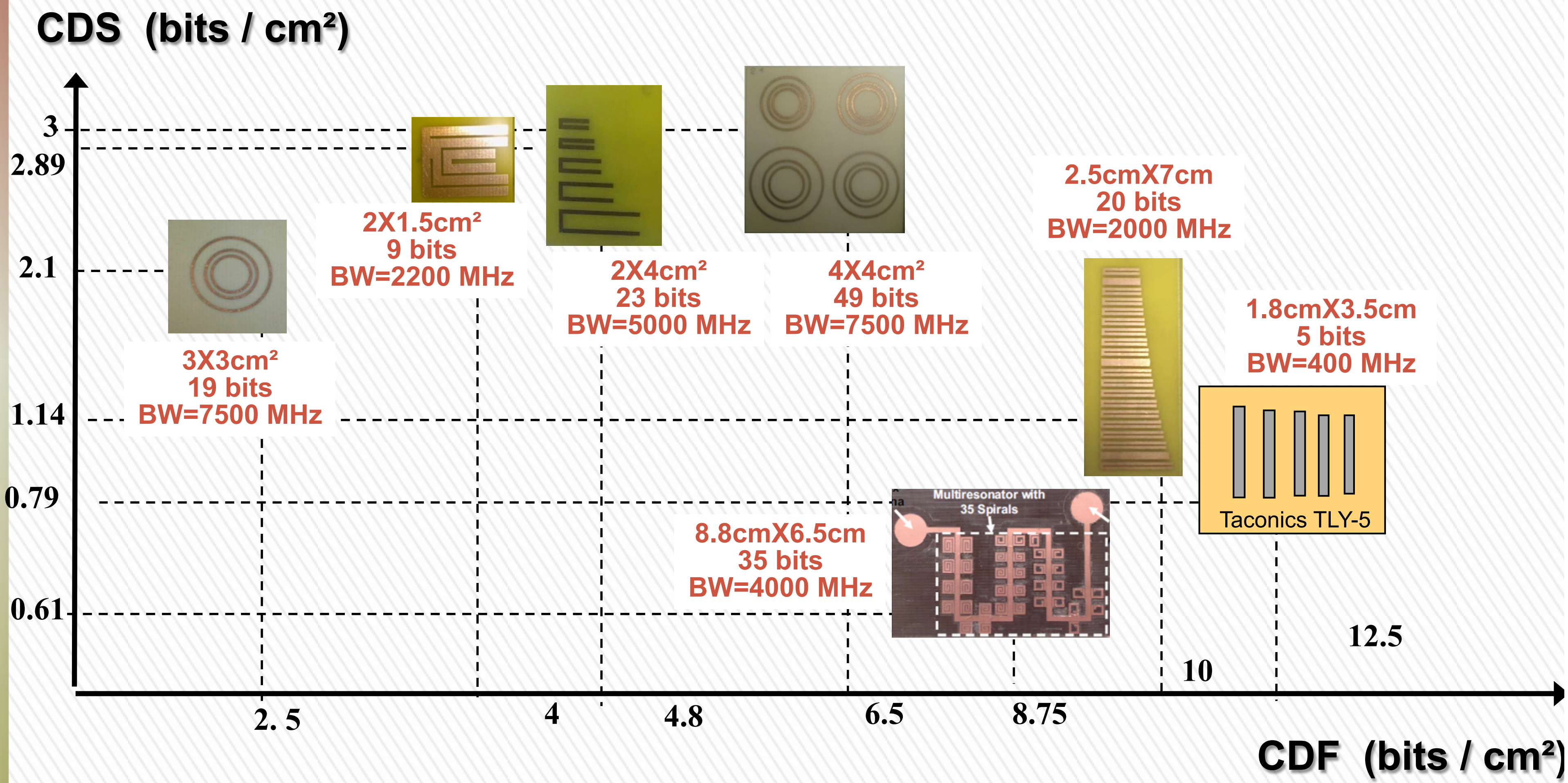
$$N_{tot} = \left[\frac{BW}{\Delta f} + 1\right]^K$$

Coding Capacity (bits)

For K=23, BW = 350MHz,

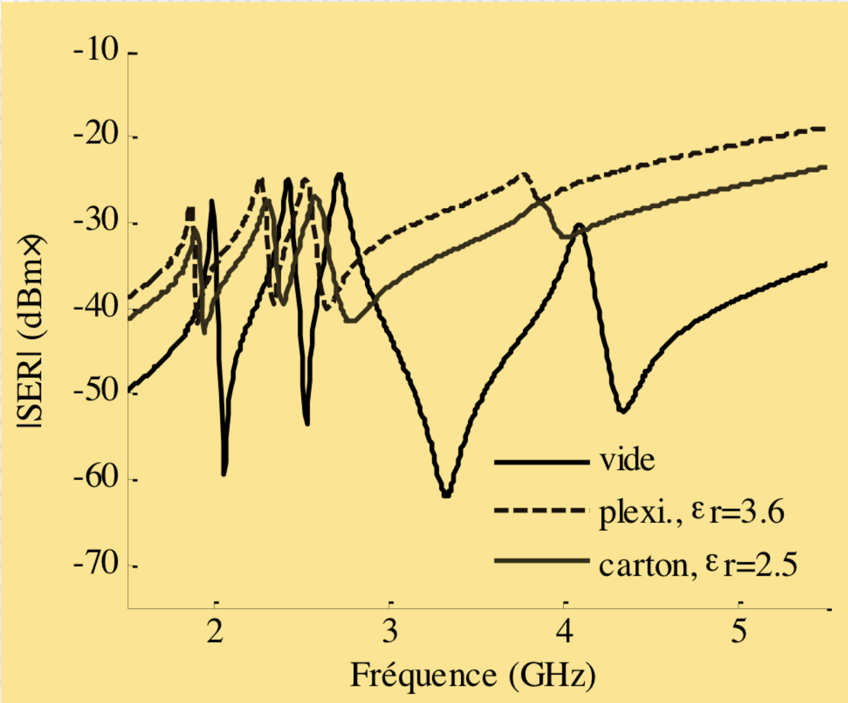
Δf = 50MHz, C= 69 bits !!

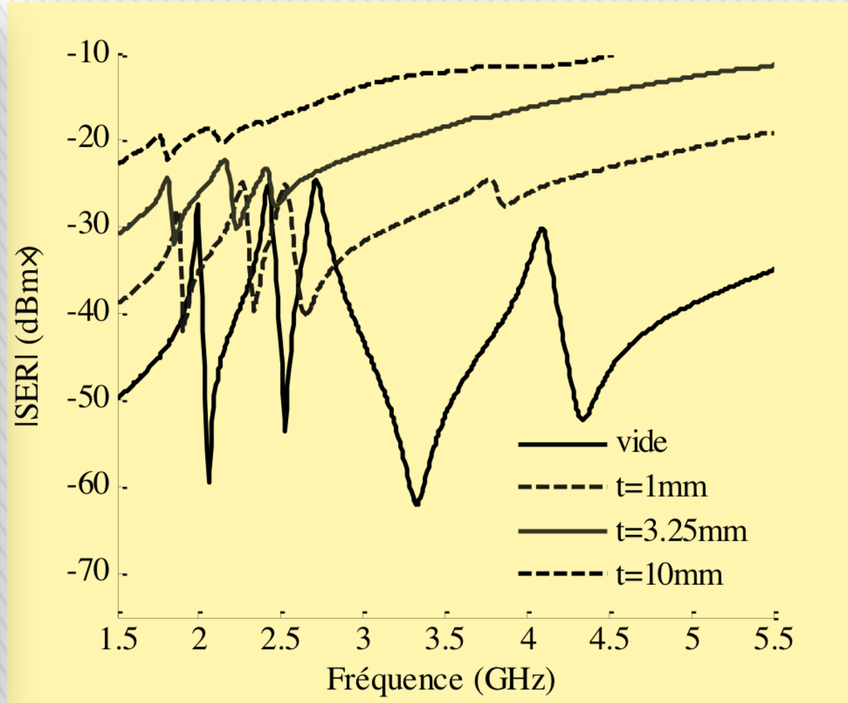
Comparing Coding Capacity



Robustness

» **Frequency detuning**



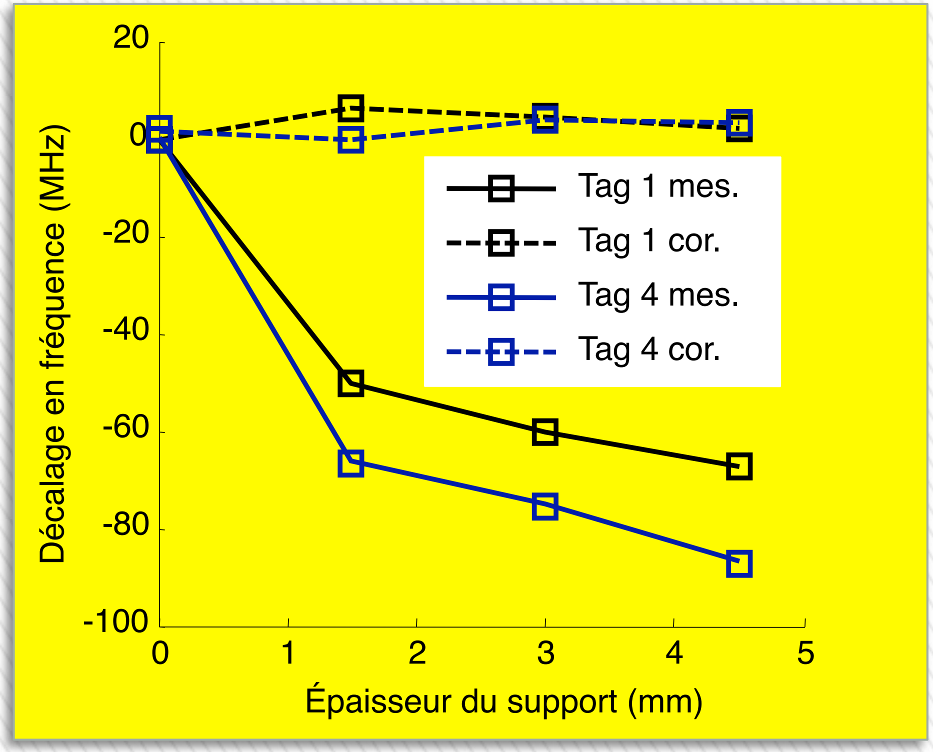


On 1mm substrate

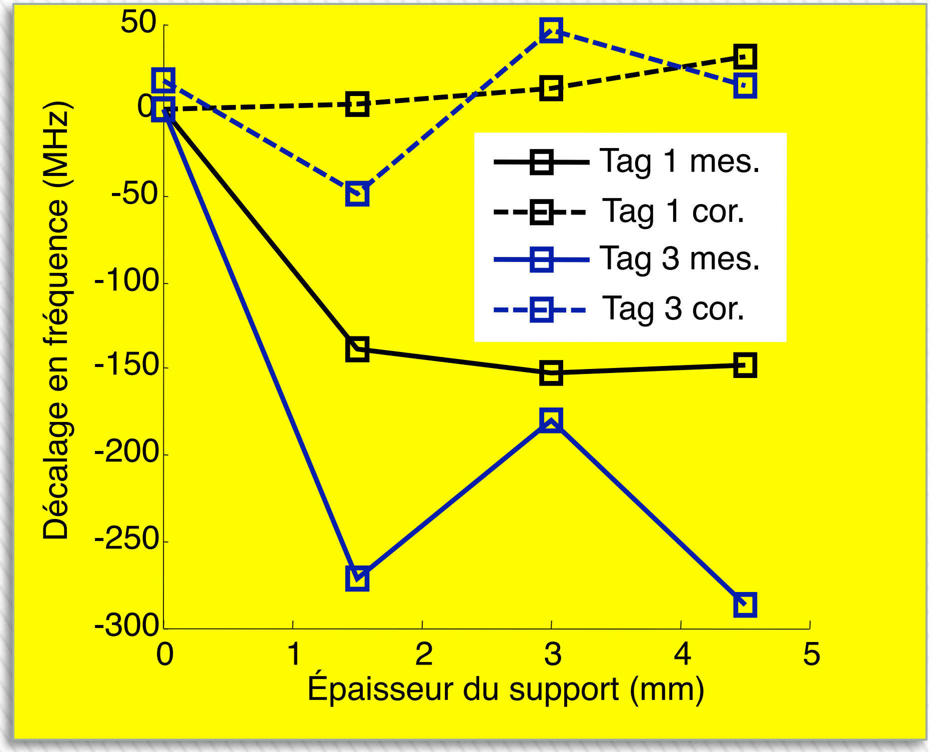
On substrate of ε_r =2.5

Detuning Compensation

- One resonator is used as substrate sensor
  - @ 2.73 GHz in this figure

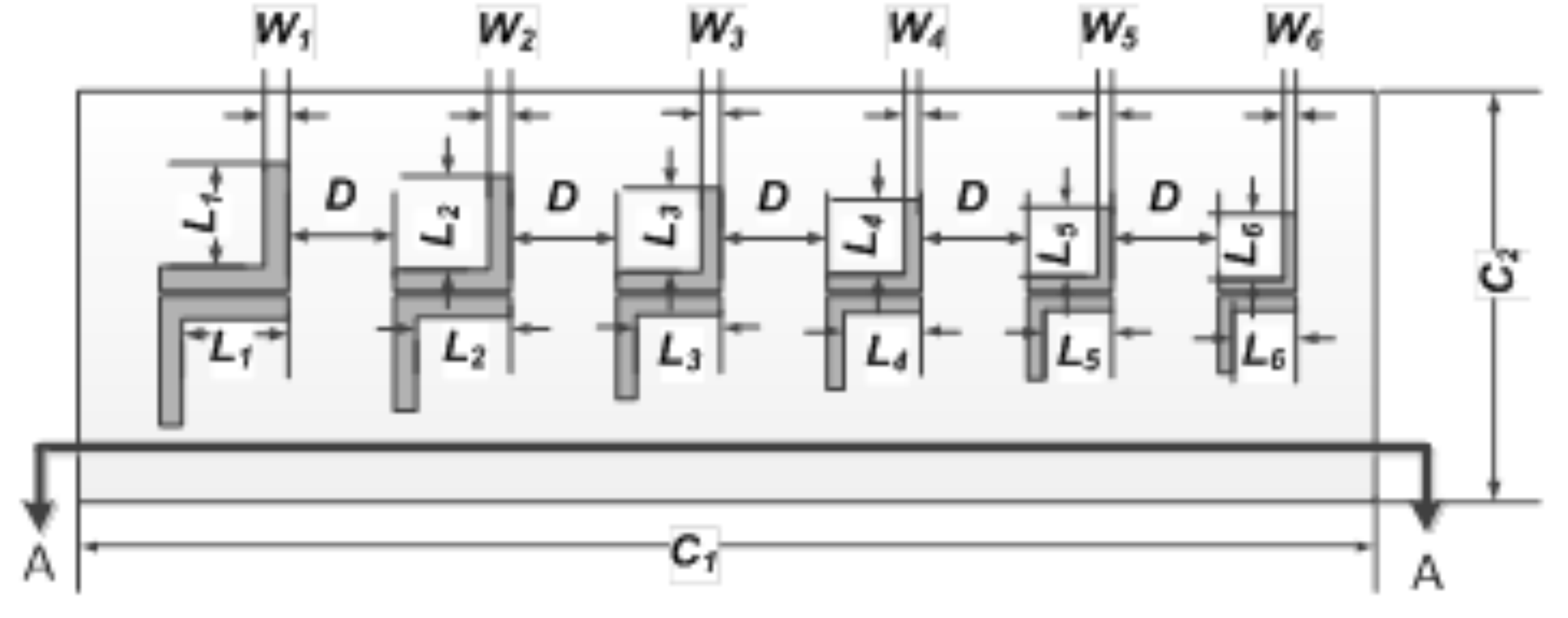


Mode 1 (2-2.4 GHz)



Mode 4 (4-5.5 GHz)

« Cooperative » Depolarizing Tag

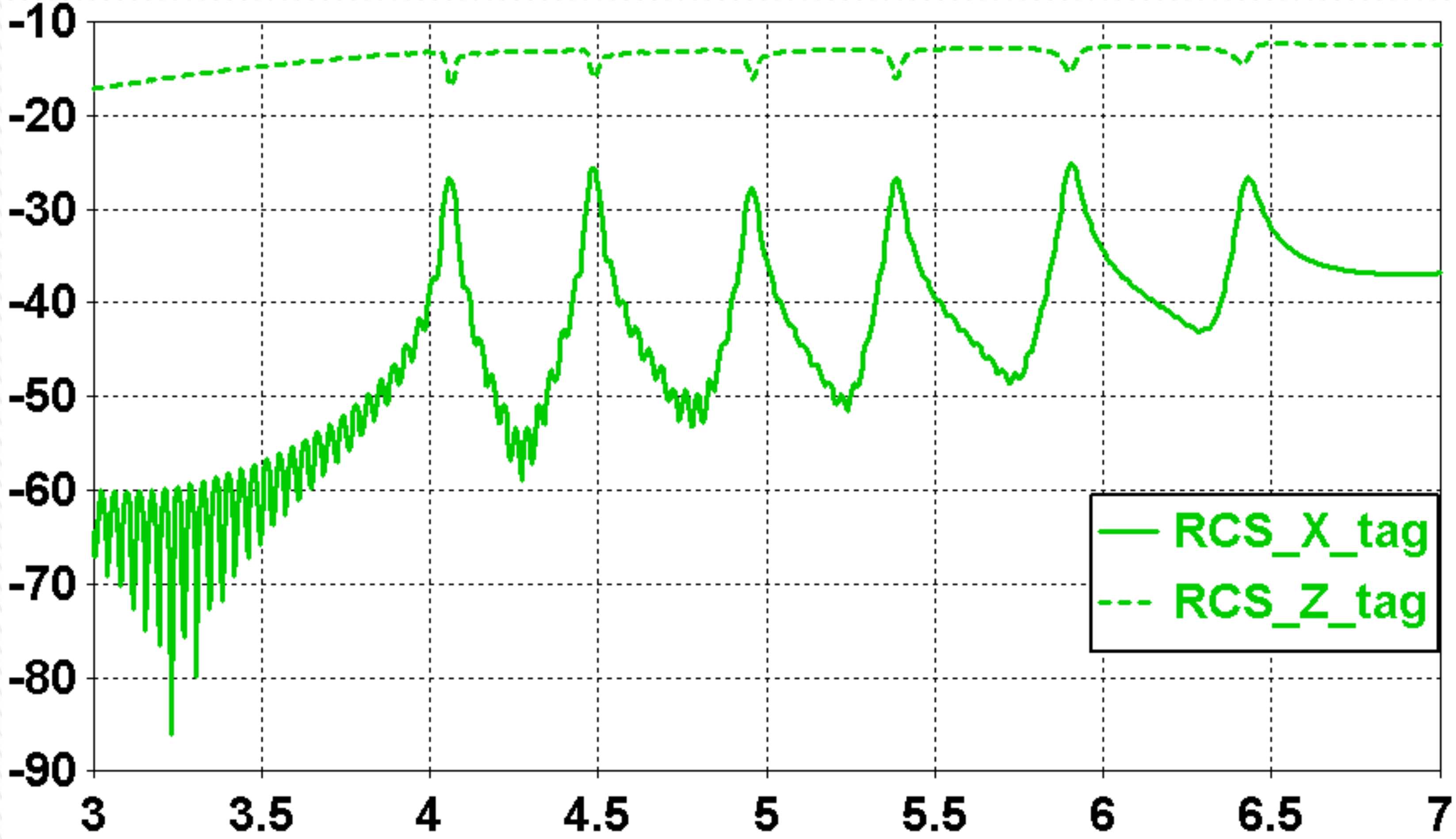


De-polarization of incident signal

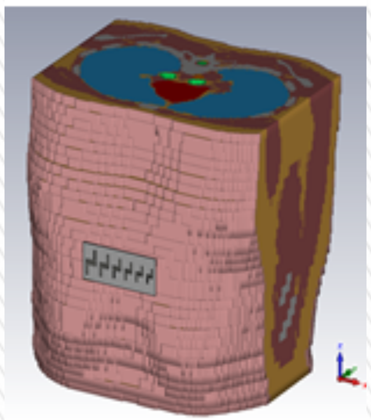
Shape of the the scatter

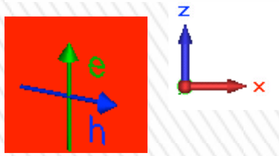
Ground plane

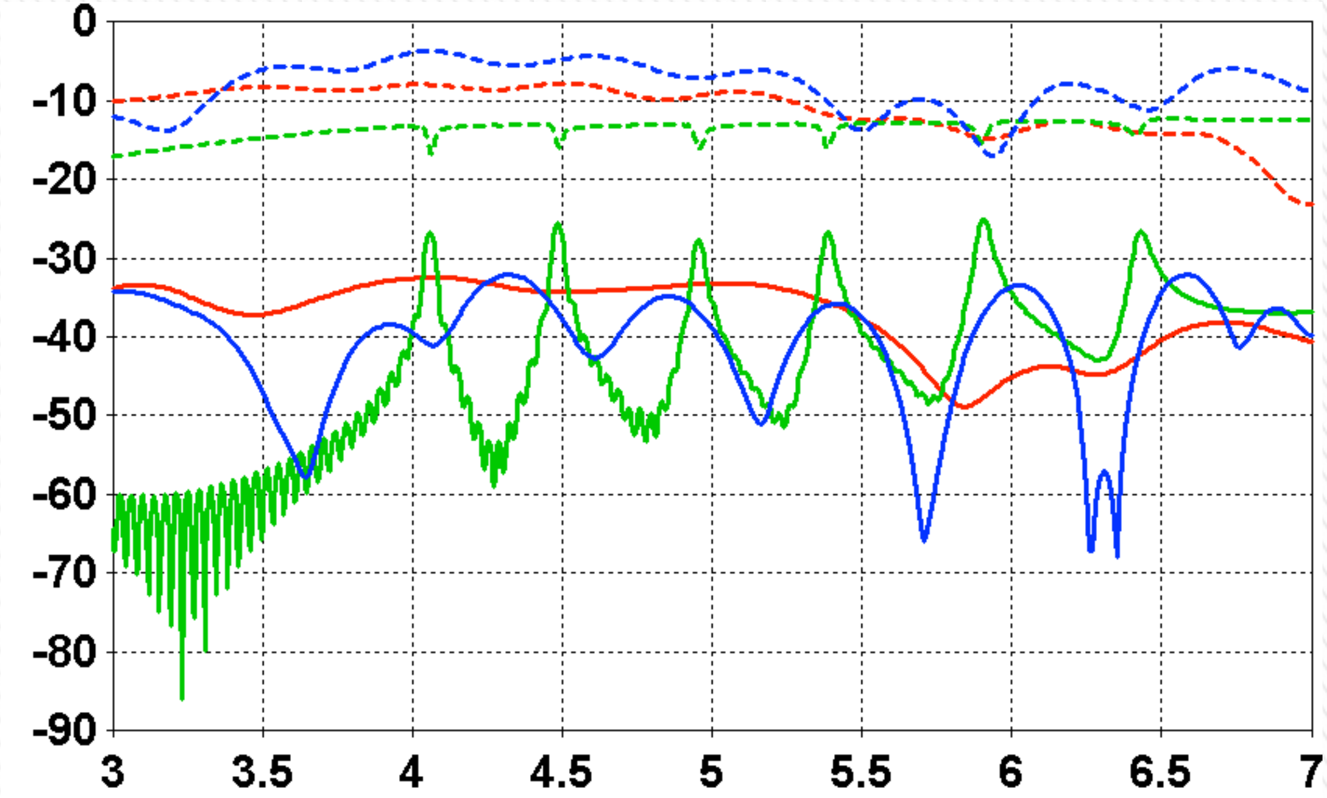
« Cooperative » Depolarizing Tag



Response on Body







Chipless Tags on paper

Flexography printing technique : paper substrate characterization

Paper under test

Freq. (GHz)	Card-board		Gloss paper		Paper (120 µm)		PE	
	εr	**tanδ**	εr	**tanδ**	εr	**Tanδ**	εr	tanδ
0.9	2.55	**0.095**	3.2	**0.09**	3.2	**0.13**	2.3	10^{-3}
2.4	2.3	**0.105**	3	**0.09**	2.87	**0.102**	2.55	10^{-3}
5.8	2.2	**0.09**	2.85	**0.08**	2.7	**0.95**	2.55	10^{-3}

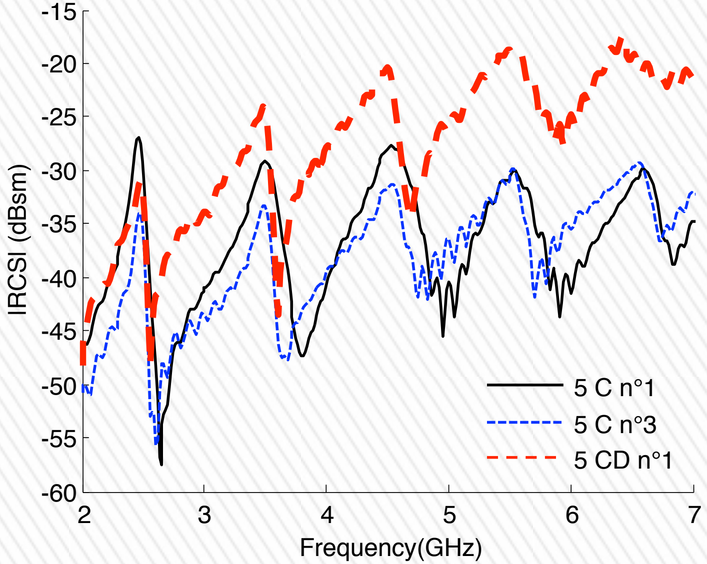
Dielectric characteristics of different printable substrates using the cavity method

A. Vena, E. Perret, S. Tedjini, G. Eymin-Petot-Tourtollet, A: Delattre, F. Garet, Y. Boutant, “Design of Chipless RFID Tags Printed on Paper by Flexography,” IEEE Transactions on Antennas and Prop, vol. 61, no. 12, pp. 5868 - 5877, Dec. 2013.

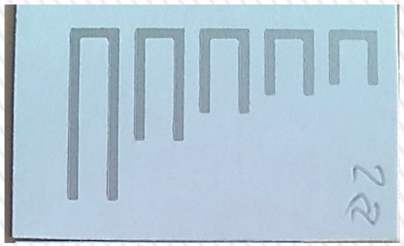
Chipless Tags on paper

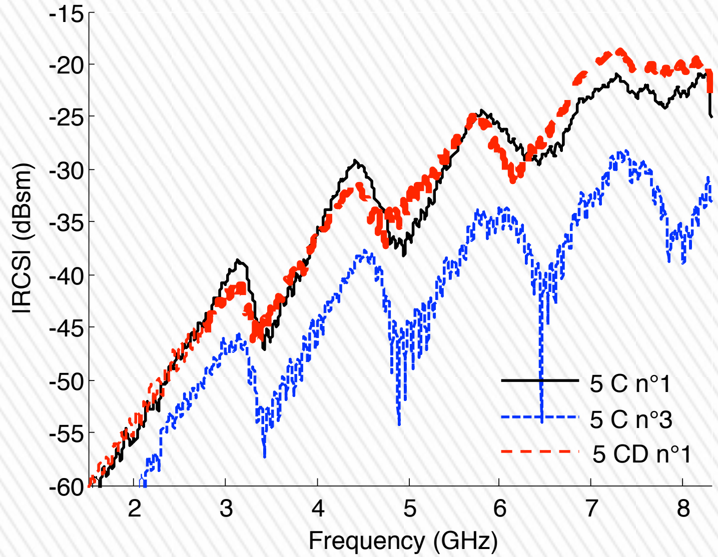
High speed and low cost realization printing process

Flexography printing technique : Non optimized chipless tags

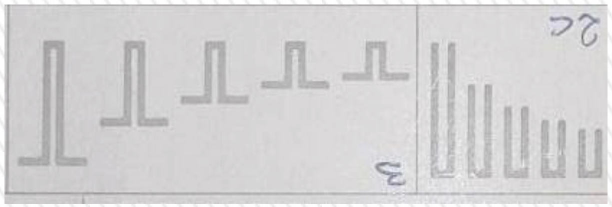


FR-4 substrate / bulk copper

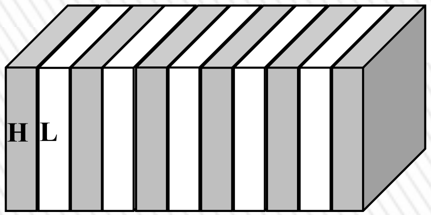




paper substrate / printed silver ink strip

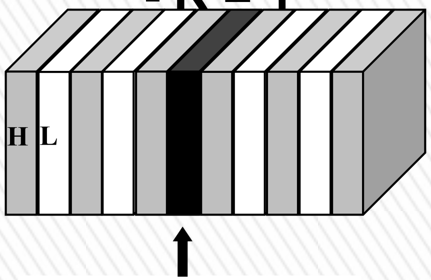


Principles of the THz TAGs



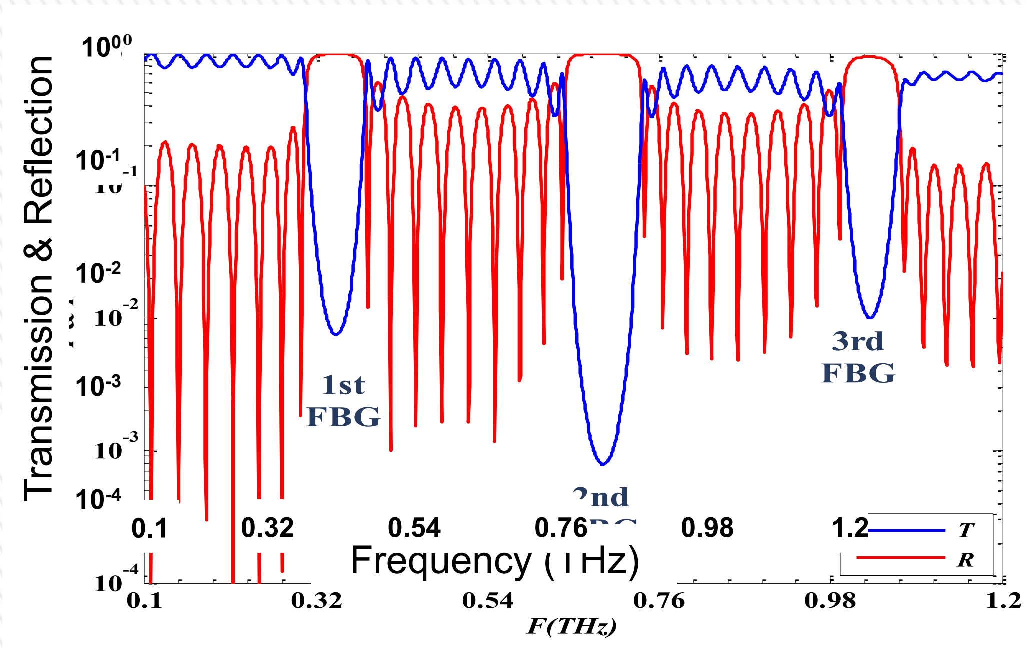
1D periodic structure

1D periodic stack => Forbidden Band Gap - T = 0 - R = 1



Disrupted periodicity

Structural defect



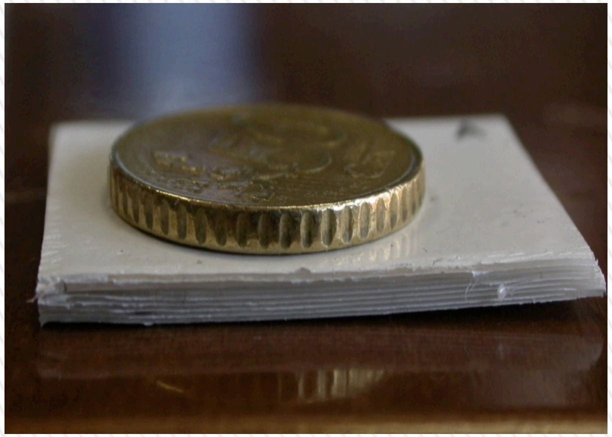
***Number and Position of defect* can be tune!**

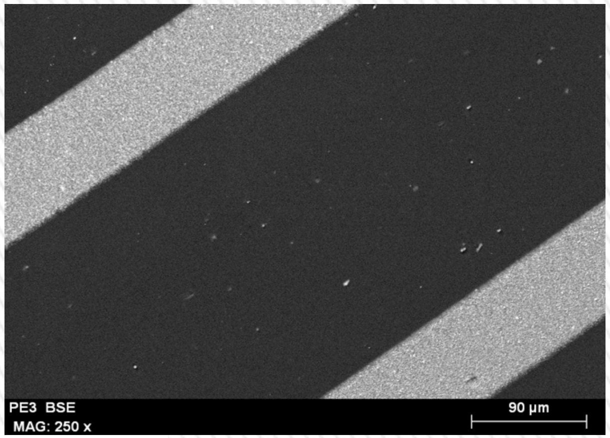
** M. Bernier et.al.," THz encoding approach for secured chipless radio frequency identification", Applied Optics, Vol. 50, Issue 23, pp. 4648-4655 (2011)*

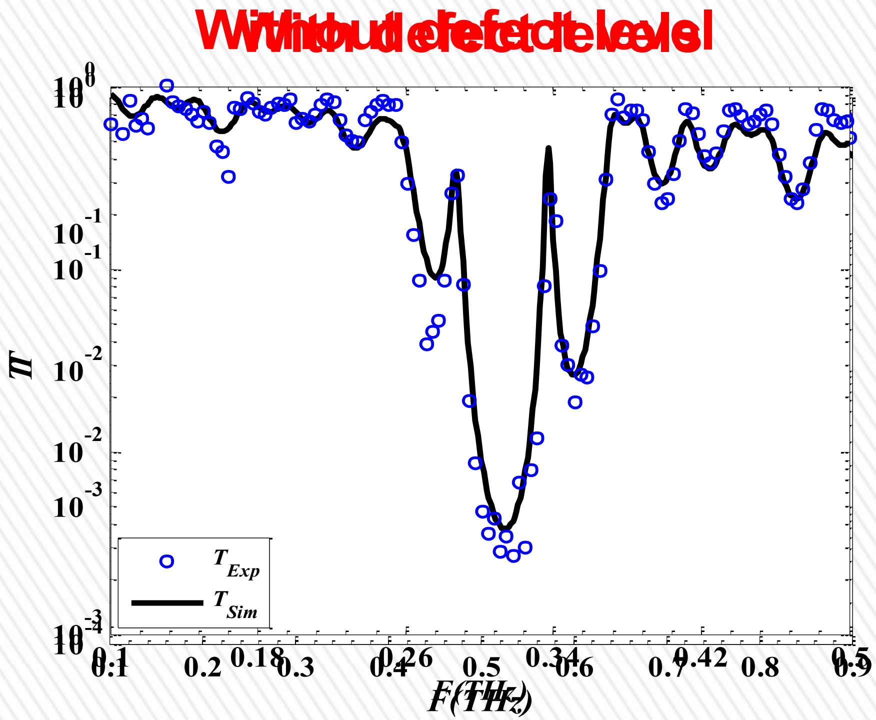
THz Tags Prototypes

19 layers
(high rejection in FBG)

L index (n=1.51): pure PE (214 µm)
H index (n=2.2): TiO_2 60% - PE 40% mixture (50 µm)

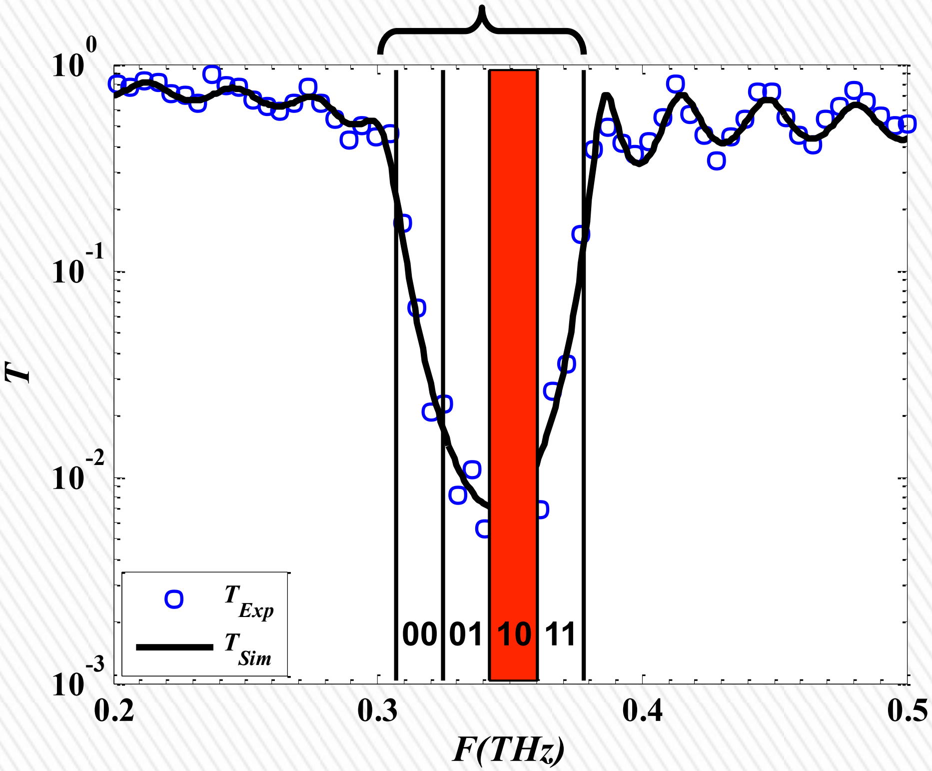






A Simple Encoding Approach

FBG bandwidth (Δf)
Frequency resolution (δfres) → N=2^n channels



Encoding principle:
- Each channel is coded with n bits
- Number of defect : M

=>Capacity < nxM

Encoding Capacity

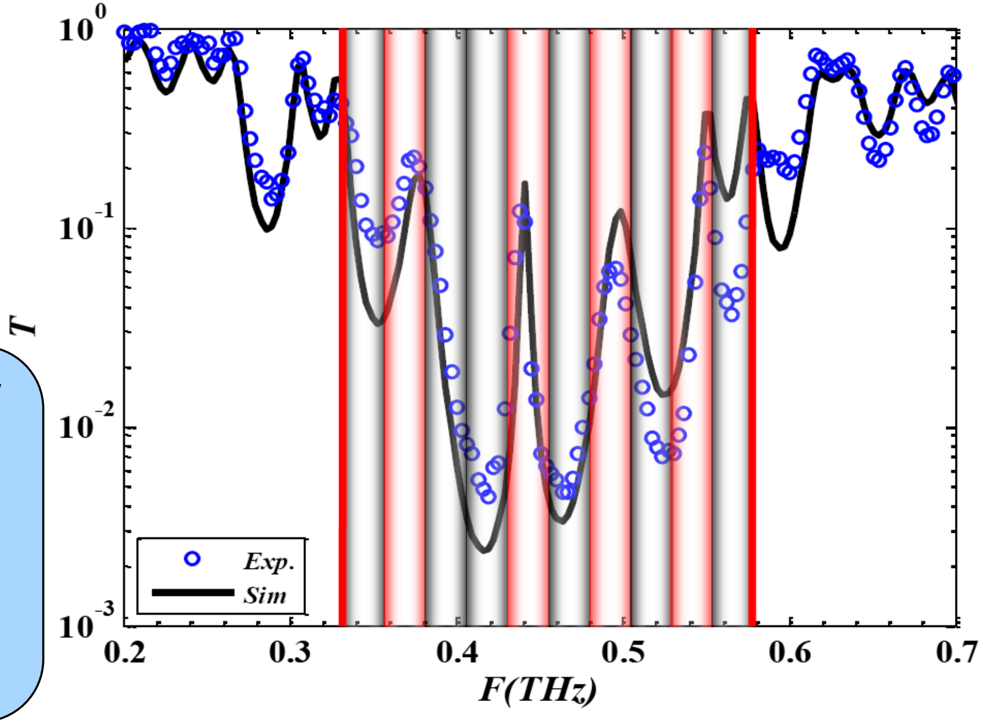
Δf = 254 GHz
δfres = 3.17 GHz
M = 4

$$N = \frac{\Delta f}{2 \times \delta fres \times M} = 10$$

$$C(M) = \log 2\left[\frac{(N+M-1)!}{M!(N-1)!}\right]$$

Effective Coding Capacity
- **M=1, N=10 => 5.32 bits**
- **M=2, N=10 => 7.72 bits**
- **M=3, N=10 => 8.83 bits**
- **M=4, N=10 => 9.48 bits**

0001 0100 0110 1000



RF Surface Encoding: Processes

Choice of the process according:

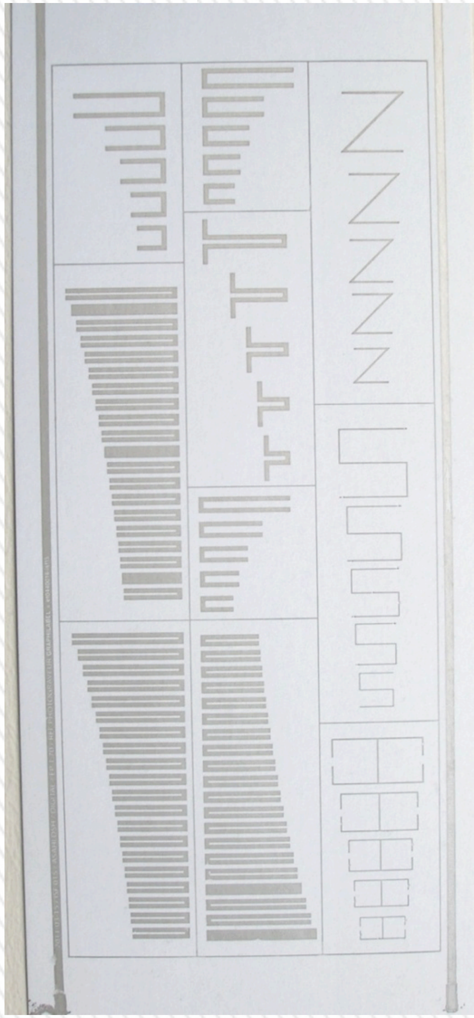
- Quality targeted
- Volume to produce
- Ink availability
- Personalization degree

Printing processes => Ink viscosity

• Ink Jet :	1 - 10 cps
• Gravure:	30 - 200 cps
• Flexography:	50 - 500 cps
• Offset newspapers:	200 - 1 000 cps
• Screen printing:	1 000 - 50 000 cps
• Offset:	10 000 - 80 000 cps

Converting processes

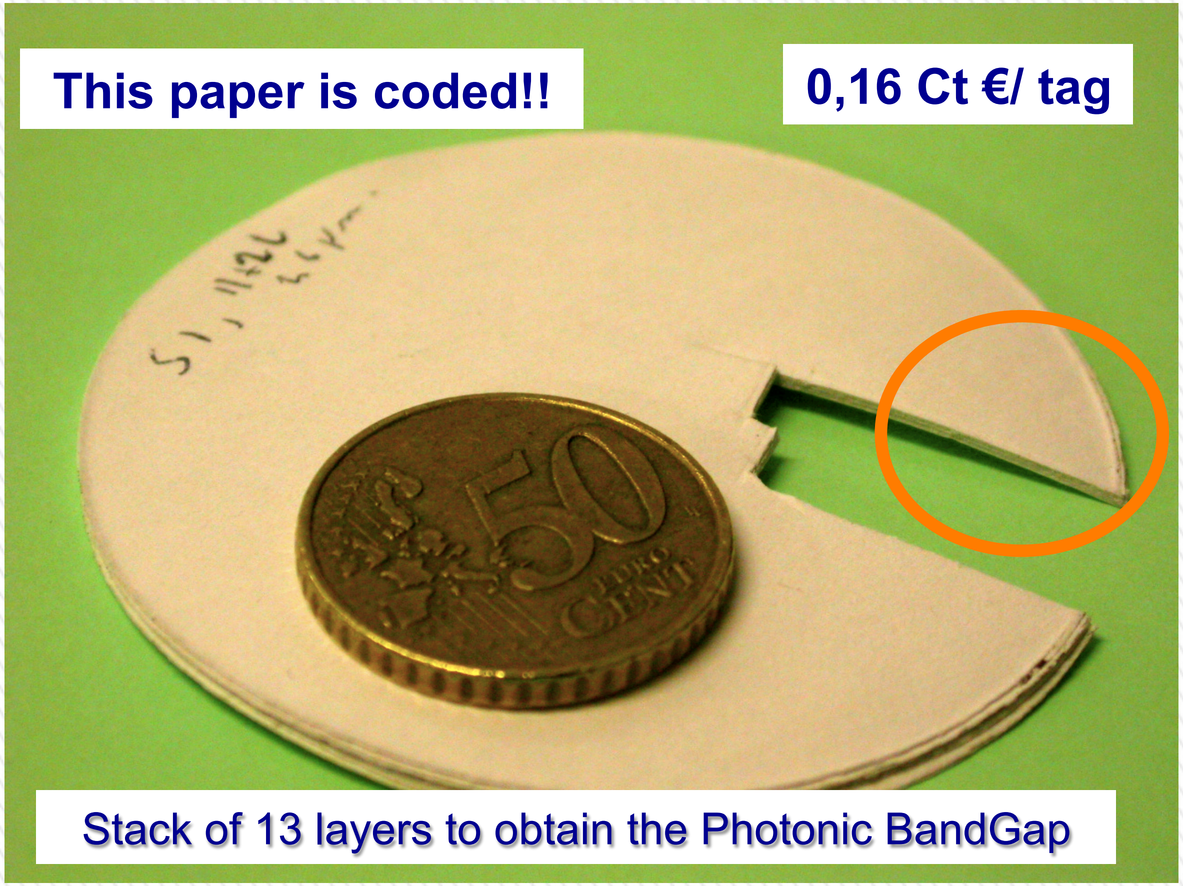
- Laminating / report/ gluing….

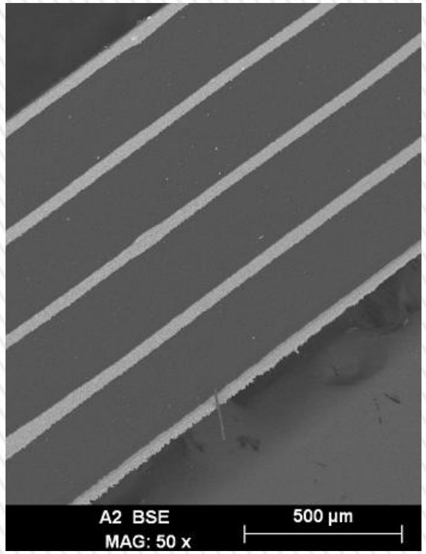


WIPE COST IC 1301

THz Volume Encoding : Demonstrators

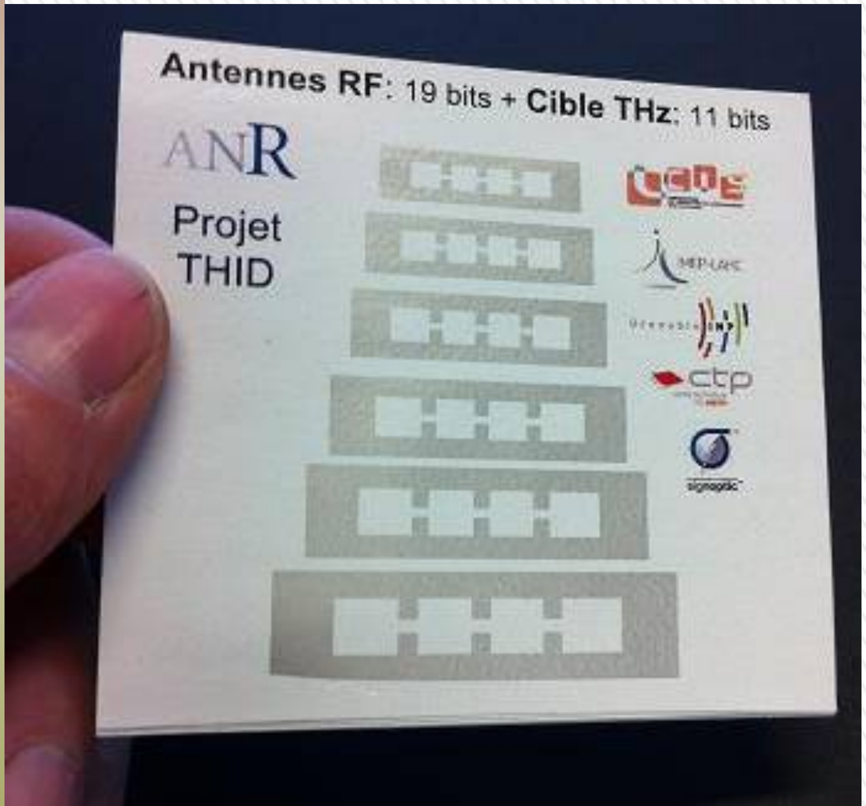
- **Prototypes on paper industry materials: Fibres and fillers**

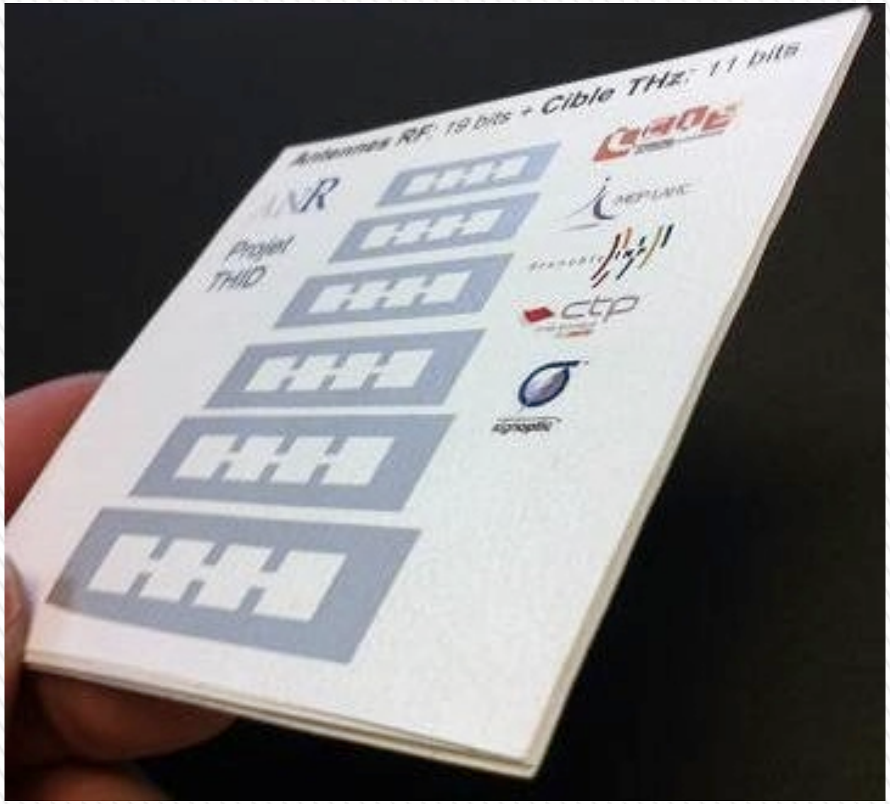




Combining RF & THz in the same tag

Surface Coding : RF -19 bits, Volume Coding : THz, 11bits

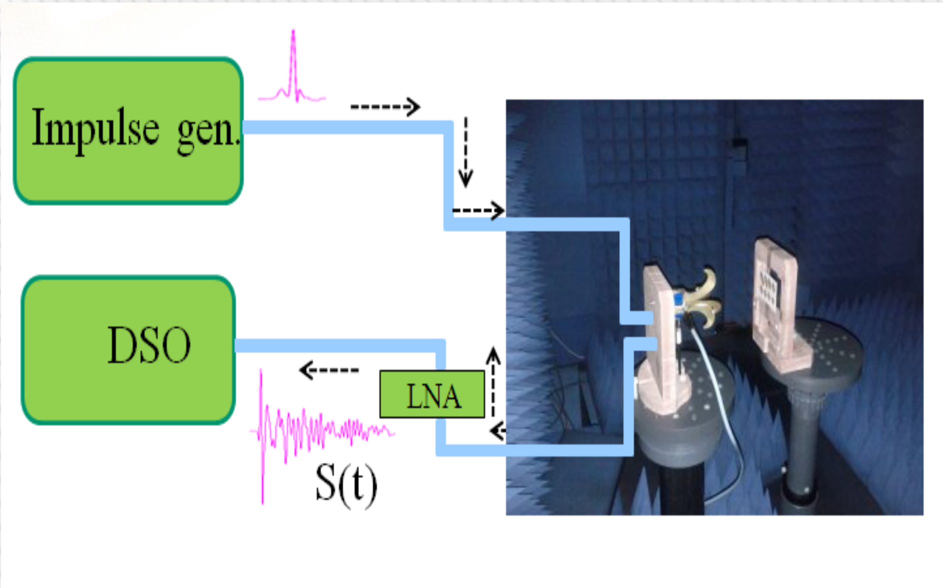


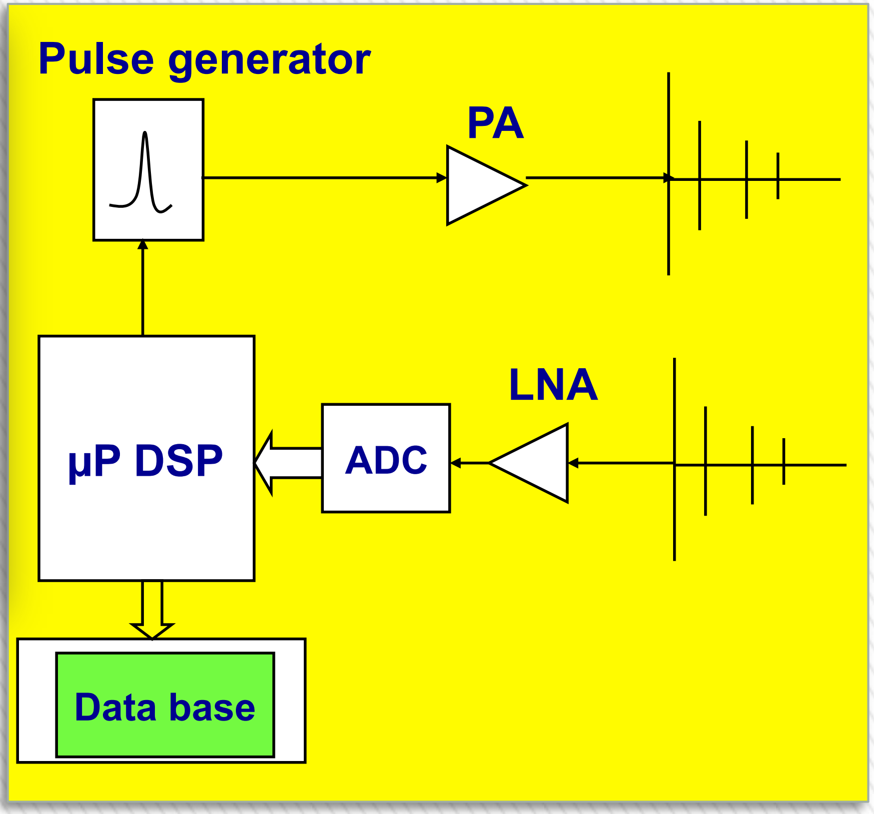


ETSI Regulations : 1-24 GHz
ETSI EN 300 440-1, V1.6.1 (2010-08)

Frequency Bands	Power (e.i.r.p.)	Application
2400-2483,5 MHz	10 mW	Generic use
2400-2483,5 MHz	25 mW	Detection, movement and alert applications
2 446- 2 454 MHz	500 mW (outdoor) 27 dBm	RFID
2 446- 2 454 MHz	4 W (indoor) 36 dBm	RFID
5 725 -5 875 MHz	25 mW	Generic use
9 200 -9 500 MHz	25 mW	Radio determination: radar, detection, movement and alert applications
9 500-9 975 MHz	25 mW	Radio determination: radar, detection, movement and alert applications
10,5 -10,6 GHz	500 mW	Radio determination: radar, detection, movement and alert applications

Measurement Set-Up/ Reader

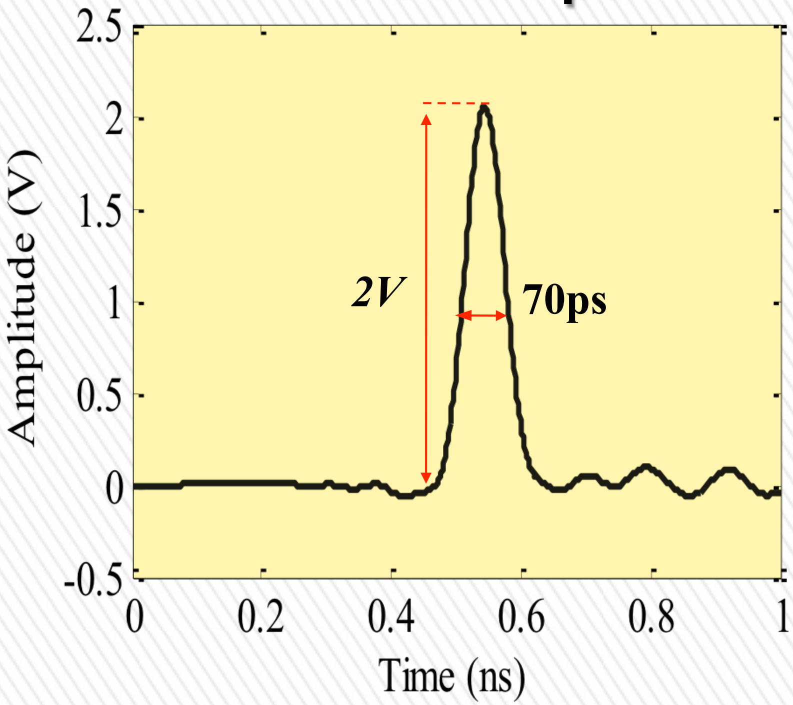




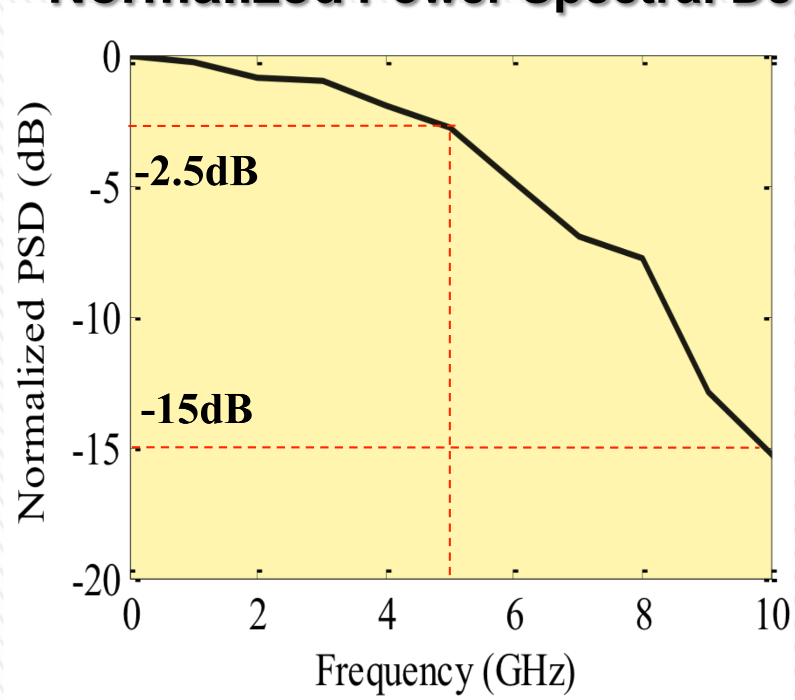
- FCC UWB bandwidth : 3.1GHz to 10.6GHz
- -41.3dBm/MHz => -2.5dBm mean power
- Pulse repetition rate min ➔ 1MHz
- Instantaneous peak power as high as 5W for 100ps pulse duration
- Sampling rate min : 20Gs/s !!➔ Equivalent Time possible

Interrogation Signal : UWB pulse

Pulse shape

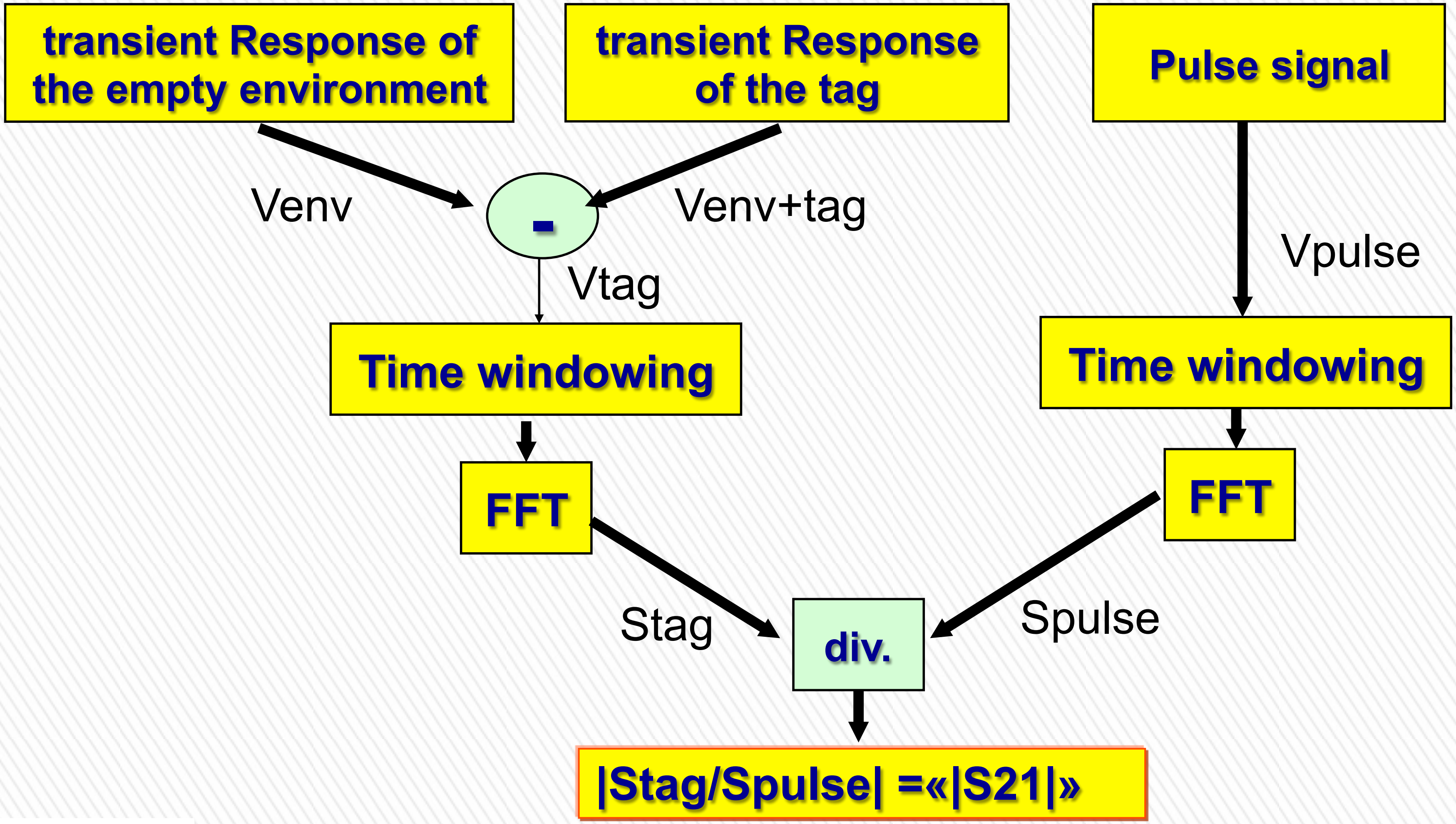


Normalized Power Spectral Density



- Pulse width of 70ps, gives a quasi constant PSD until 5GHz
- Instantaneous peak power is 19dBm

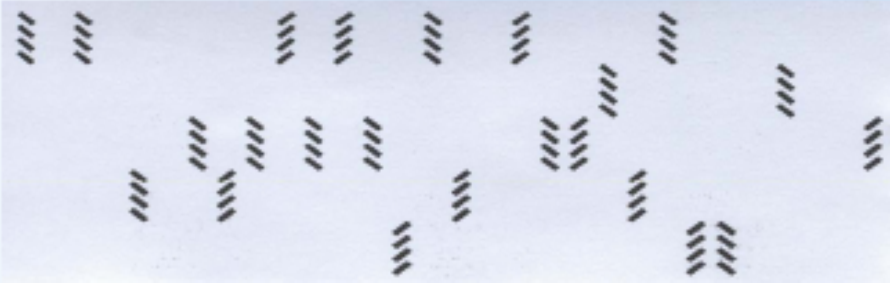
Signal Extraction

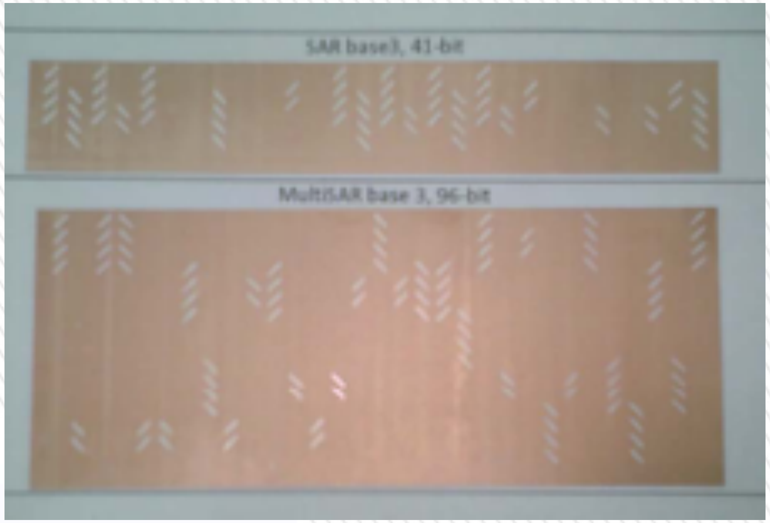


FUTURE DIRECTIONS

RF Barcode

Coming Soon: 2D-SAR Tags





SARcode Summary

2009

- Pilot tests begin
- Read Range =1 foot (conveyor/handheld)
- Read Speed=0.15 second (conveyor), 0.85 second (handheld)
- Information Capacity = up to 96 bits
- Print Sizes = 4.6" x 1.6"
- Non-Line of sight reading = yes
- Orientation Flexibility = yes
- Anti–collision = yes
- Anti-counterfeiting capability = no

2010 and Beyond

- Commercial Availability
- Read Range =3 feet (conveyor), 2 feet (handheld)
- Read Speed = 0.15 sec. (conveyor), 0.85 second (handheld)
- Information Capacity = up to 113 bits
- Print Sizes = 4.6" x 1.6"
- Non-Line of sight reading = yes
- Orientation flexibility = yes
- Anti –collision = yes
- Anti-counterfeiting capability = yes

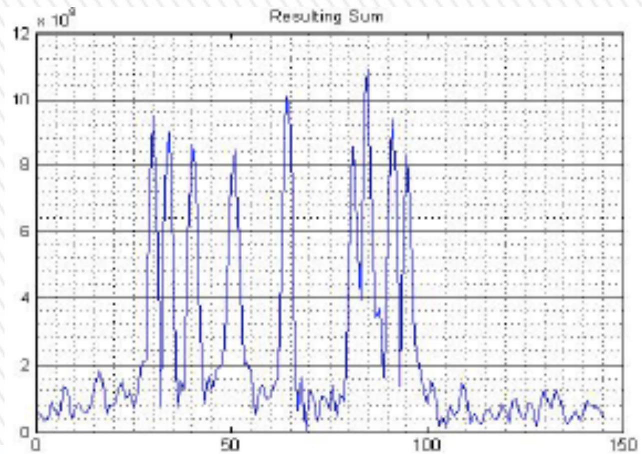
InkSure Technologies

LCIS

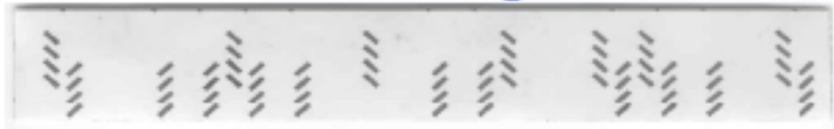
RF Barcode

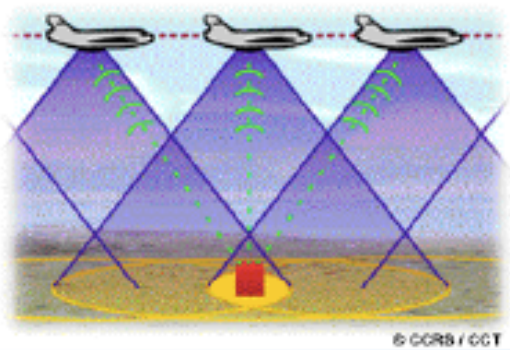
- A "Read-Only" system (no chip, no memory)
- Bits of data based on a new printed symbology
- Potential to produce the lowest cost RFID tag (**less than 1¢**)
- Capabilities for printing directly and covertly on products or packaging
- Frequencies above UHF

InkSure Technologies



Basic 1D 32 bit tag





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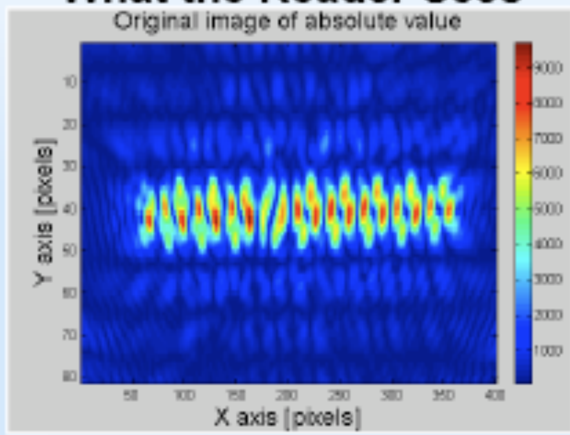
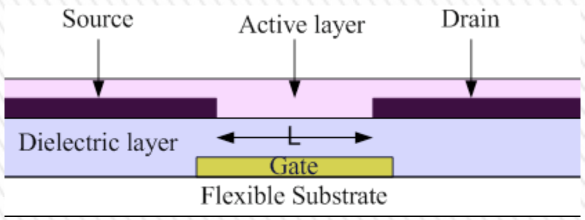
What the Reader Sees



LCIS

Printed Organic Electronics

Silicon Electronics	Printed Organic Electronics
+ High integration	+ Flexible polymeric material
+ Very small devices	+ Flexible substrates
+ High performance	+ Continuous processes
– Batch processes	+ High productivity
– Stiff & brittle material	+ Ambient conditions
– Wet chemistry	– Low integration
– Vacuum processes	– Low performance v/s Silicon



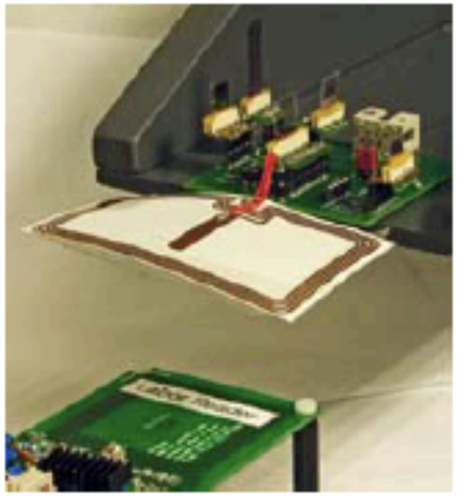
Experimental printed flexible polymer OLED by Dai Nippon Printing

Example from PolyIC

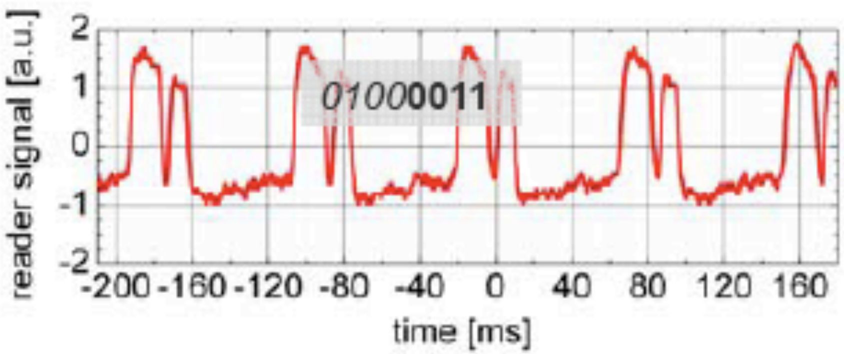
First organic 4bit CMOS RFID realized

- CMOS- transponder chip
  - Lab process
  - p-type P3HT
  - n-type: ActivInk N1200™
  - Source/Drain: Au
- RFID tag with
  - organic rectifier
  - 4 bit organic CMOS chip
  - organic modulation circuit
- 13.56 MHz reader
  - Reader H-field : 1.95 A/m
  - Reading distance: 4.5 cm
  - data rate: ~45b/s

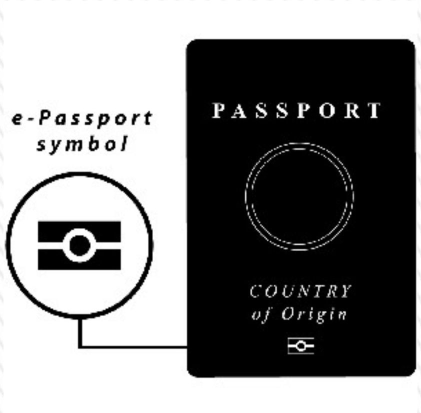
Source: ISSCC dig. Tech. Papers p.208-209, Feb. 2009



RFID – signal at 13.56 MHz



Towards the Last few meters of Internet of things

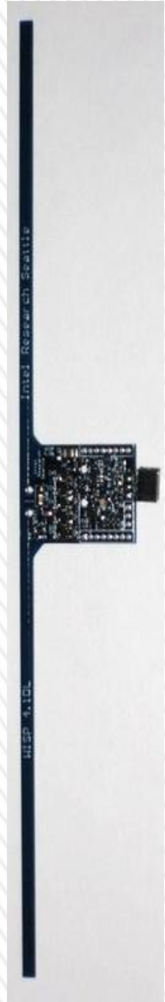


Ways to Evolve RFID Tags

» **ADDING EXTERNAL DEVICES**
  - > WISP PLATFORM http://wisp.wikispaces.com

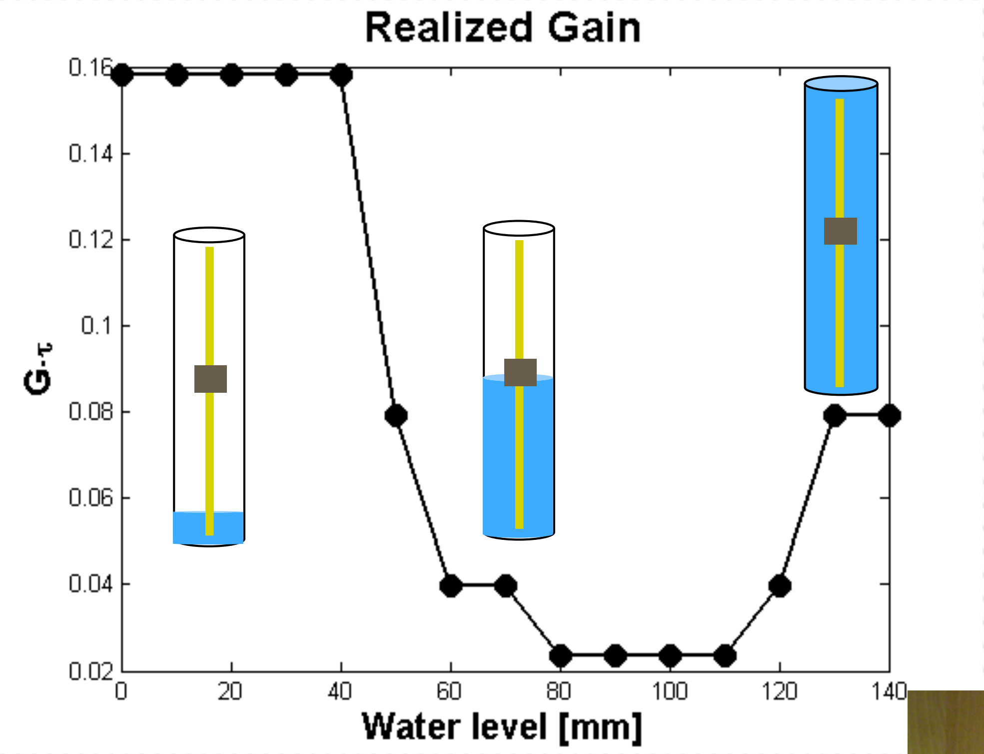
» **EXPLOITING THE ANTENNA SENSITIVITY**
  - > NEAR FIELD PROPERTIES
  - > SENSITIVE MATERIAL

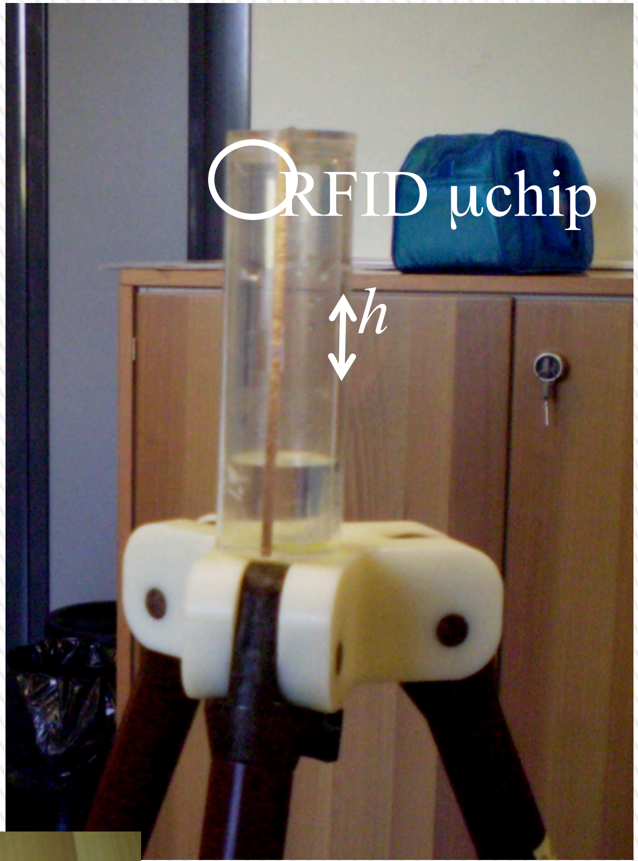
» **EXPLOITING THE CHIP BEHAVIOR**
  - > CHIP SENSITIVITY (ON-OFF)
  - > NON-LINEAR CHARACTERISTICS



A low cost sensor

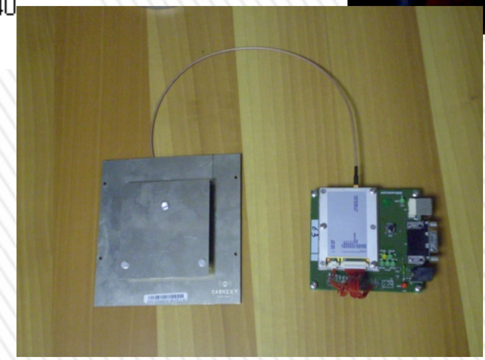
Tag: planar dipole *L*=14 cm, NXP strap
Target: water-filled plexiglass cylinder (H=14cm, r=2.5cm)





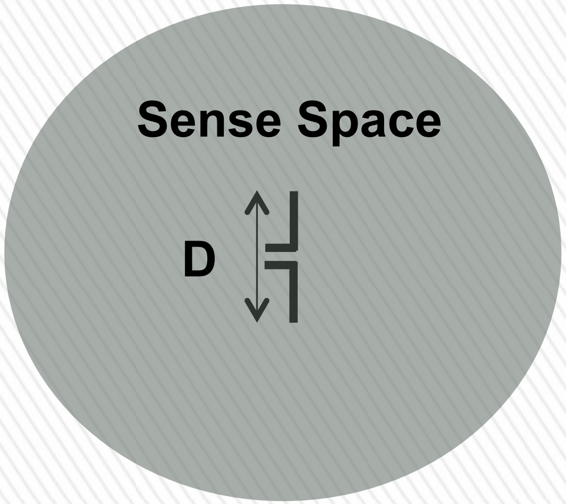
Measured @ 870 MHz

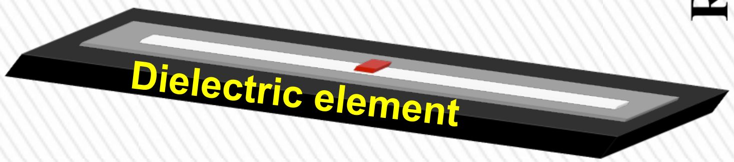
Reader: CAEN A528
(Intel R1000 Transceiver) + PIFA

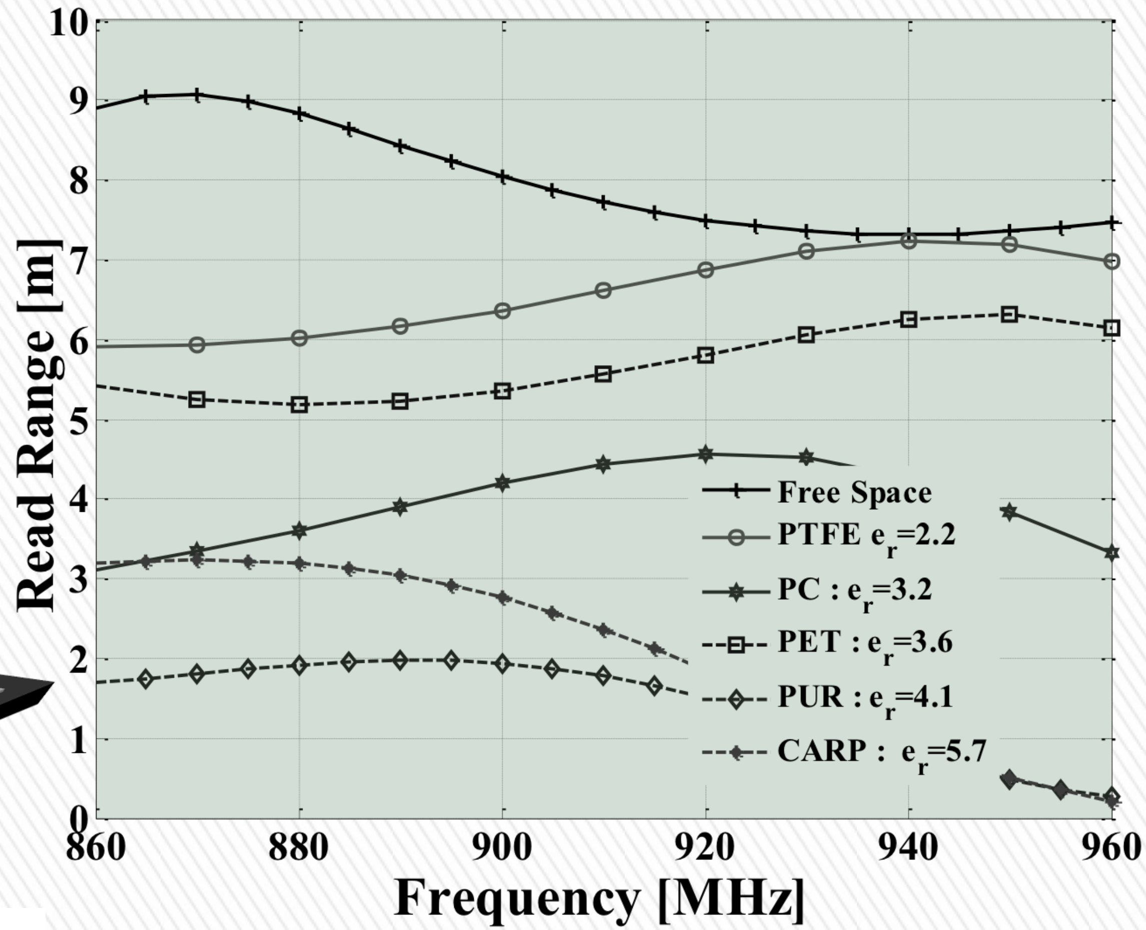


Courtesy : G. Marrocco

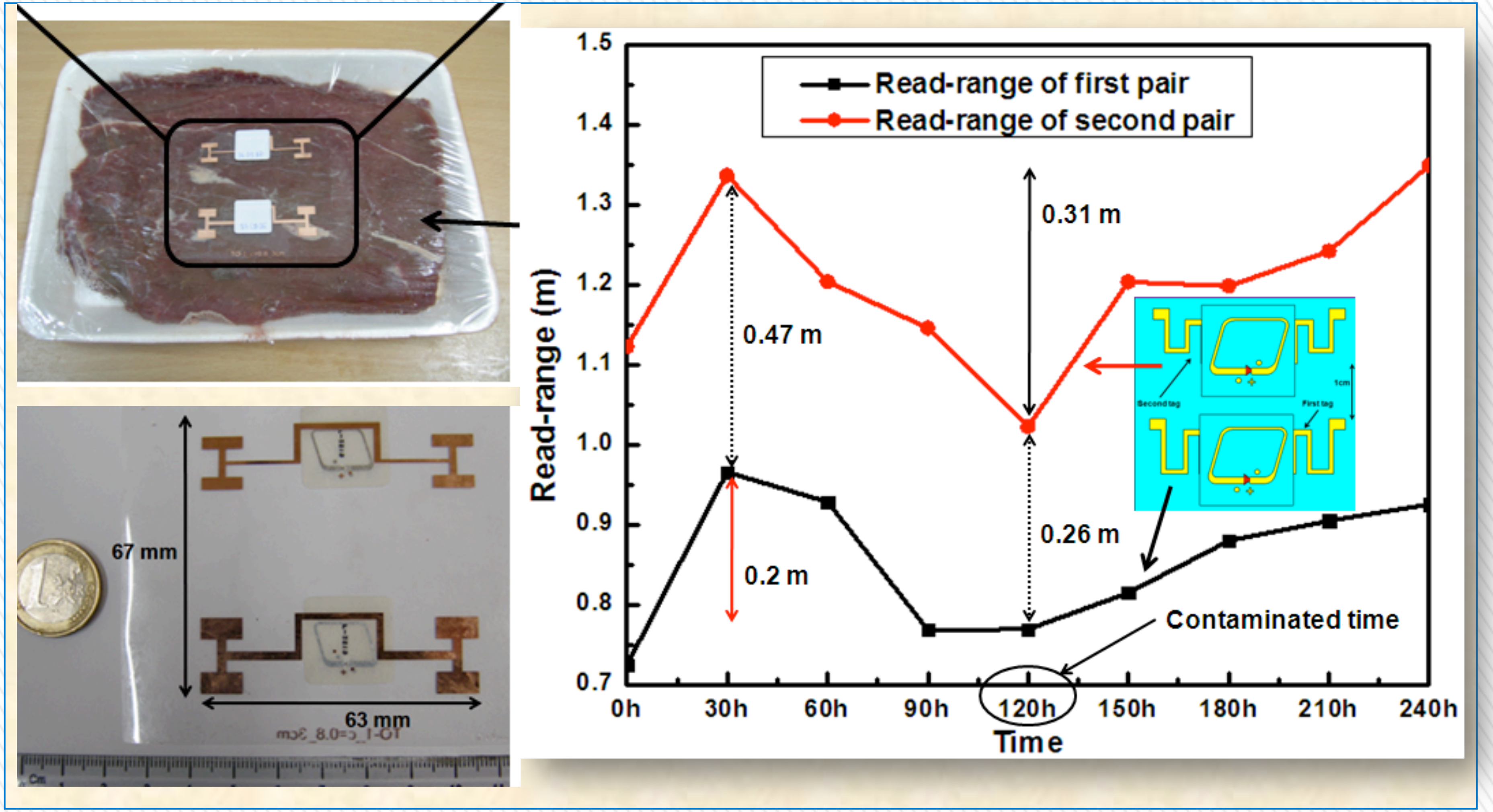
Sensitivity of Antenna to the Near-Field Environment



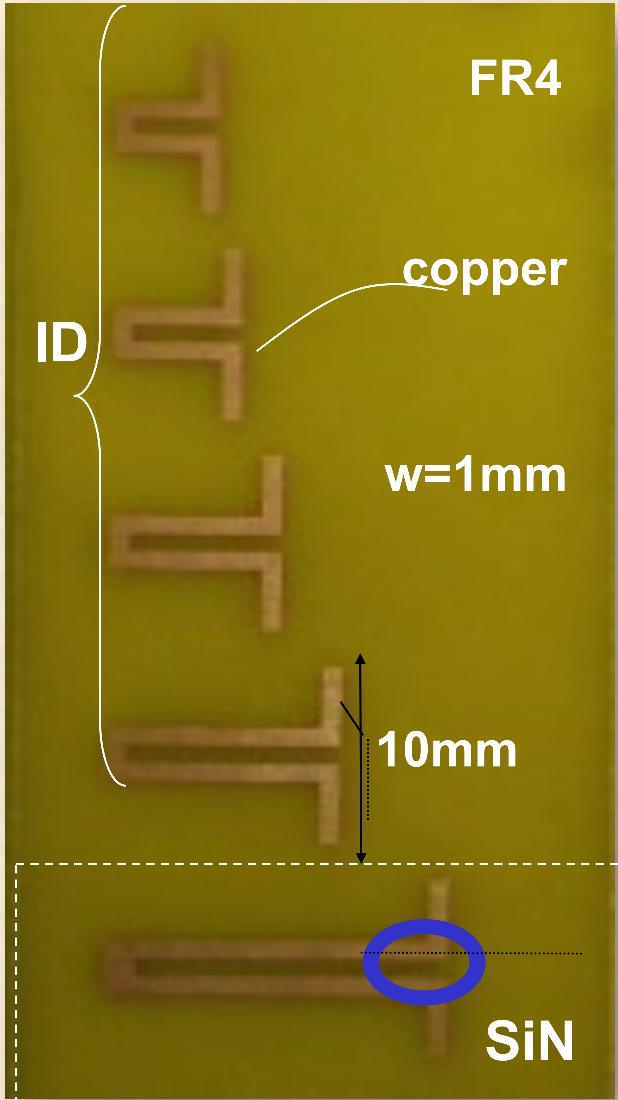




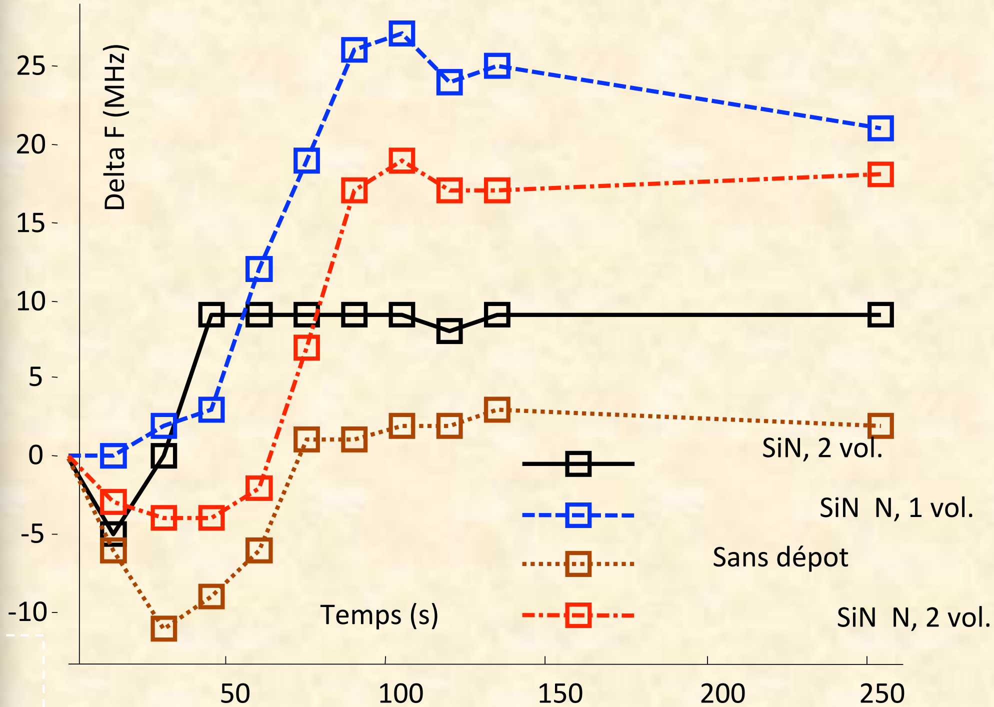
RFID Meat Quality Sensor



Chipless RFID Sensor

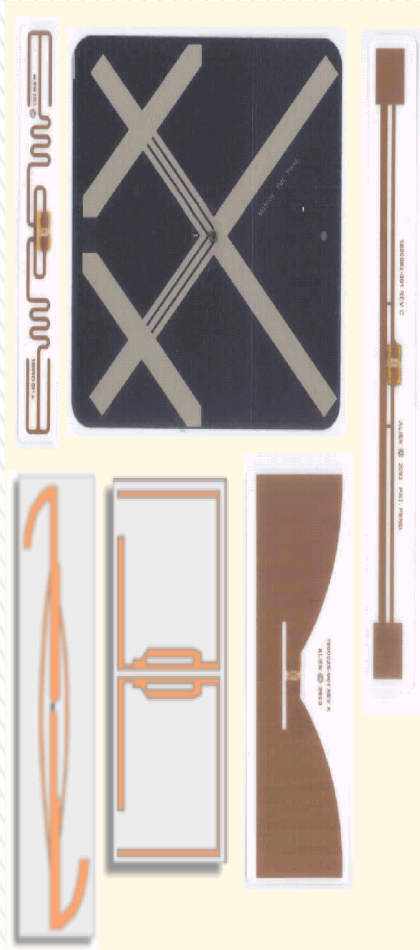


70*25mmm



UHF Tag Read-Range Evolution

Year	IC sensitivity	Read Range*
1997	-8 dBm	5.2 m
1999	-10 dBm	6.5 m
2005	-12 dBm	8.2 m
2007	-13 dBm	9.3 m
2008	-15 dBm	11.7 m
2010	-18 dBm	16.5 m
2011	-20 dBm	20.7 m
2014	-22 dBm	26.1 m



* (FS, 36 dBm EIRP, 2 dBi tag antenna)

$$r_{tag} = \frac{\lambda}{4\pi}\sqrt{\frac{EIRP}{P_{tag}}}$$

$$P_{chip} = P_{tag}\, p\, G\, \tau$$

Concluding Remarks

» Chipless Technology at its Infancy Age
» EMSignature coding
» Coding Capacity : REP has Higher capacity
» 49 Bits Demonstrated
» Cost Issues : Low Cost Substrate as Paper
» Combining Surface & Volume Coding : THID
» Chipless Reader under UWB Regulation
» Evolution : Chipless Sensor with ID
» Read-range limitation
» All printed „Chipless tags“

RFID Contribution to Green World

- » Wireless = Less wires
- » Battery less = Less energy use
- » Required power is roughly 10µW
- » LBT Protocol = Less EM pollution
- » Energy Harvesting
- » Smart Sensor
- » Natural material as substrates

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- Tedjini, S.; Karmakar, N.; Perret, E.; Vena, A.; Koswatta, R.; E-Azim, R., "Hold the Chips: Chipless Technology, an Alternative Technique for RFID," Microwave Magazine, IEEE , vol.14, no.5, pp.56,65, July-Aug. 2013
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- A. Vena, B.Sorli, E. Perret, S. Tedjini “A low cost realization process, and a reliable detection system to make chipless RFID sensor technology ubiquitous”, IEEE RFID 2014, Orlando, April 2014.
- O Boularess, H Rmili, T Aguili, S Tedjini, “Analysis of electromagnetic signature of Arabic alphabet as RF elementary coding particles” Wireless Power Transfer 2 (02), 97-106, 2015