香港研发中心成员

# RFID Tagging for Food Products

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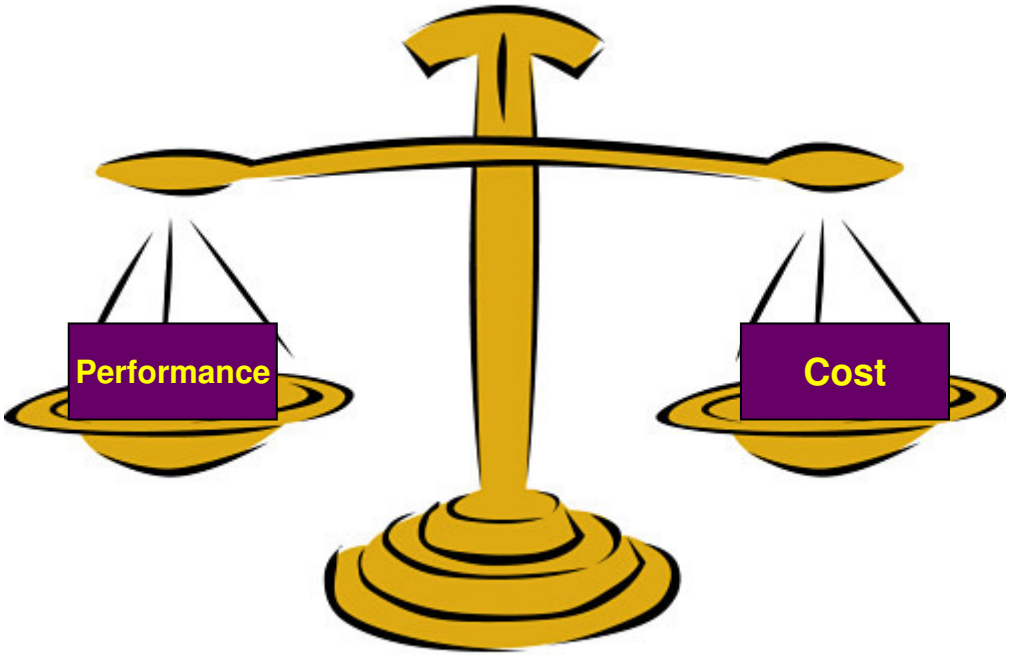
Hong Kong R&D Centre for Logistics and Supply Chain Management Enabling Technologies

# RFID Market Penetration


RFID Market

# Cost and Performance Trade-Offs

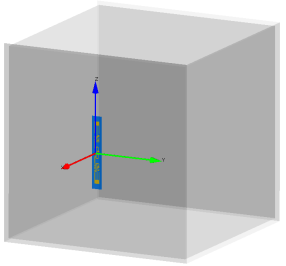


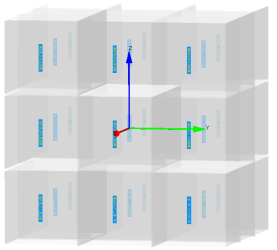
# Cost Challenges for Tags

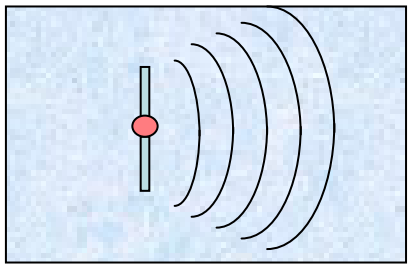
- 20 cents
  - Pallet level
- 10 cents
  - High end products
  - Anti-counterfeiting medicine, luggage
- 5 cents
  - Books, garments
- 1 cent
  - Most consumer products

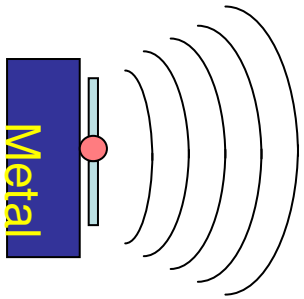
# Performance Challenges for tags

- Detuning effects
  - Free space properties altered when sticking to specific objects
- Stacking effects
  - Stand-alone tag's characteristics different from stacking tags
- Water and moisture contents
  - Liquid is bad to EM, but cannot be avoided
- Metallic surface
  - Reflecting, obstruction, and shielding









# Cost Challenges for Readers

- ~$1000 USD
  - Docking doors and warehouses for Walmart and Metro
- ~$500 USD
  - Conveyor belt
  - Luggage sorting, WIP for manufacture
- ~$100 USD
  - Smart shelf, retailers POS
- ~$10 USD
  - Every consumer can have a reader embedded into their cellular phones

$2000

$500

$100

$10

# Performance Challenges for Readers

**Warehouse applications have strict requirements**

- Reading range
- Dense reader mode
- Reading rate and speed
- Interference rejection
- Noise rejection
- Embedded OS
- Network connections





**Embedded applications have special requirements**

- Mostly near field
- Reading speed optimized for specific scenarios
- Data rate optimized for specific scenarios
- Interference and dense reader mode determined by application setup
- Sharing with hosting infrastructure
- **But power consumption and form-factor really matters**

# Tag and Antenna Research Topics

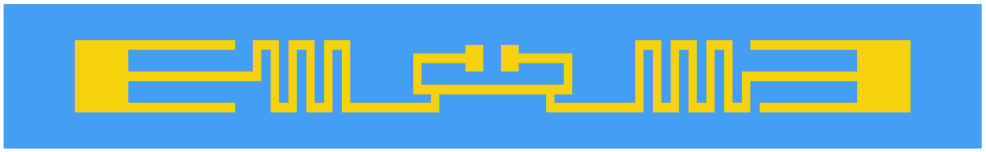
- Application-Specific Antennas
  - Detuning effects
  - Stacking effects
  - Package-specific antennas
  - 3D and package conformal antennas

- Antenna Printing Using Conductive Inks
  - Cost saving and environmentally friendly
  - Strap bonding

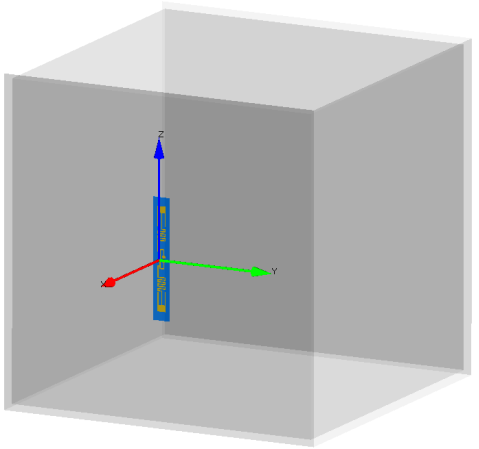
# Tags Are Not Used in Free-Space

- Most antenna designs and analysis are based on the free-space assumption
  - Simulation and 3D radiation measurement
  - Link budget
  - Sensitivity and interference rejection, etc
- But tags have to be attached to something

# Detuning Effect – An Empty Carton Box



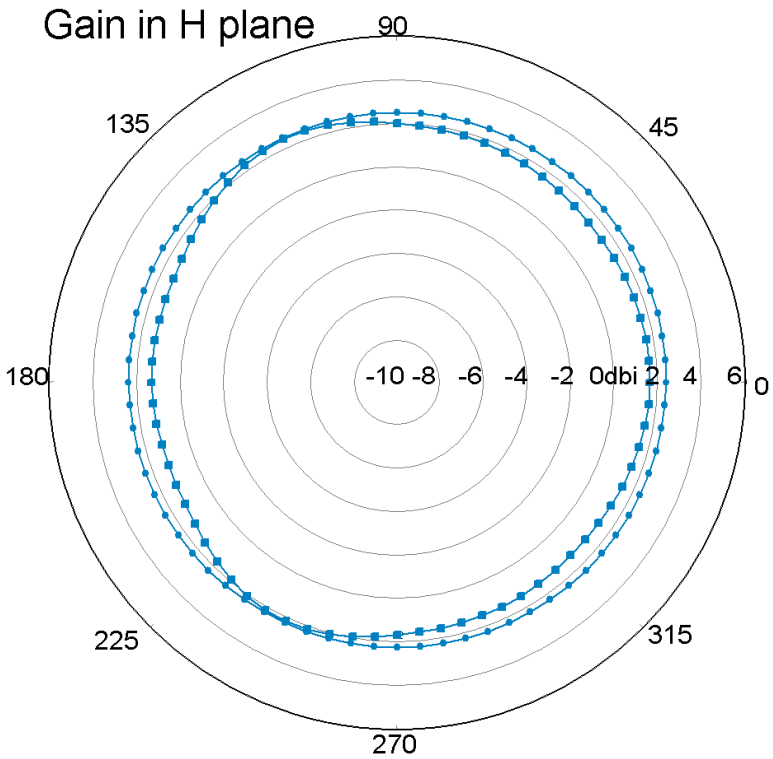
ALN-9540 antenna

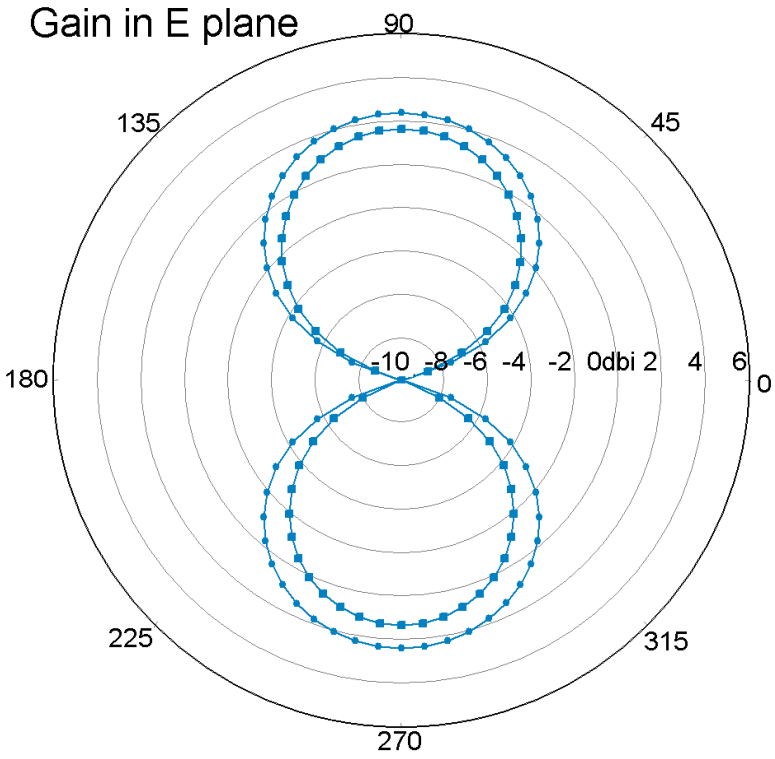


Empty Carton Box

| | Radiation Efficiency | Impedance | Gain |
|---|---|---|---|
| **Free space** | **97.24%** | **15.8+108.1j** | **2.47dBi** |
| **Attached on package** | **91.4%** | **27.9+85.4j** | **2.41dBi** |

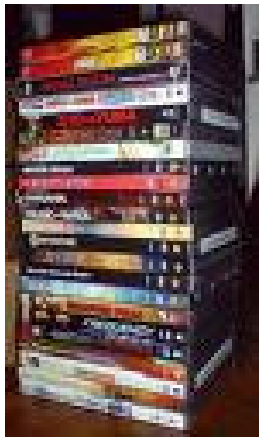
# Detuned Antenna Radiation



# Stacked Tags v.s. Stand-alone Tags

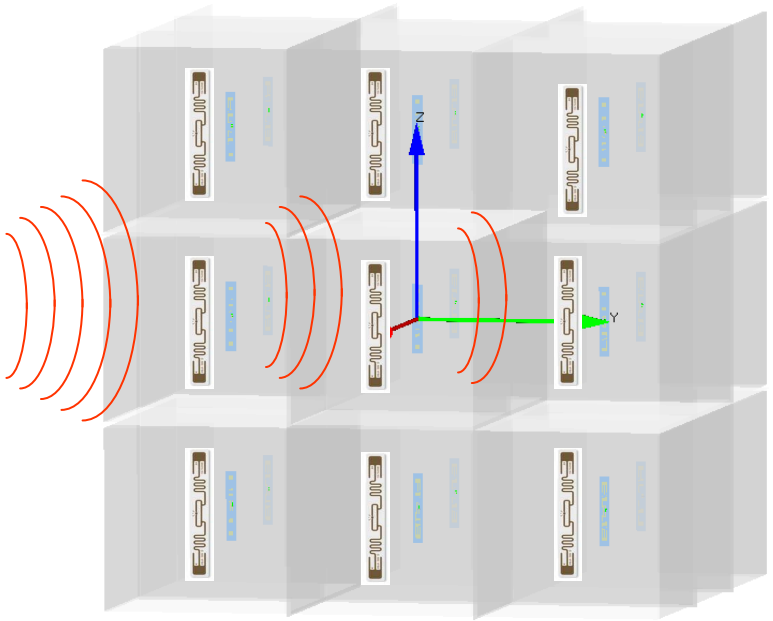
- Tags are seldom used stand-alone in real-world
  - Stacked cartons on pallet
  - Packed DVDs
  - Shelved books
  - Etc.



# Stacking Effects

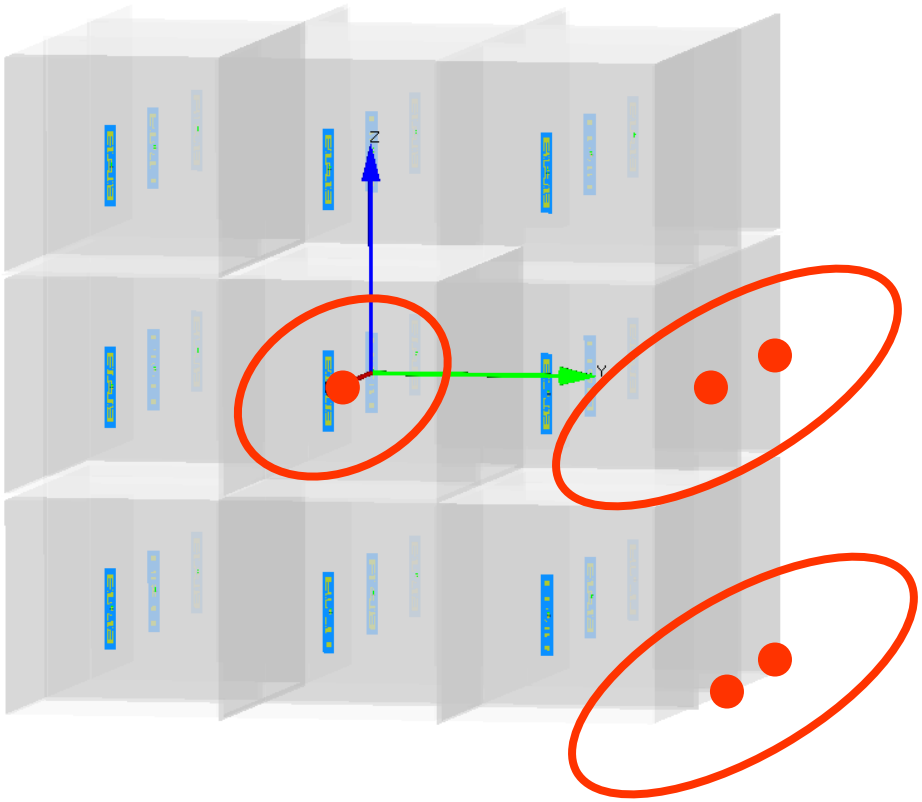
- Stacked RFID Tags
  - Shielding
  - Reflecting
  - Absorbing

- Analysis from stand-alone tags are no longer reliable
  - Performance degradation
  - Weak spot and dead spot



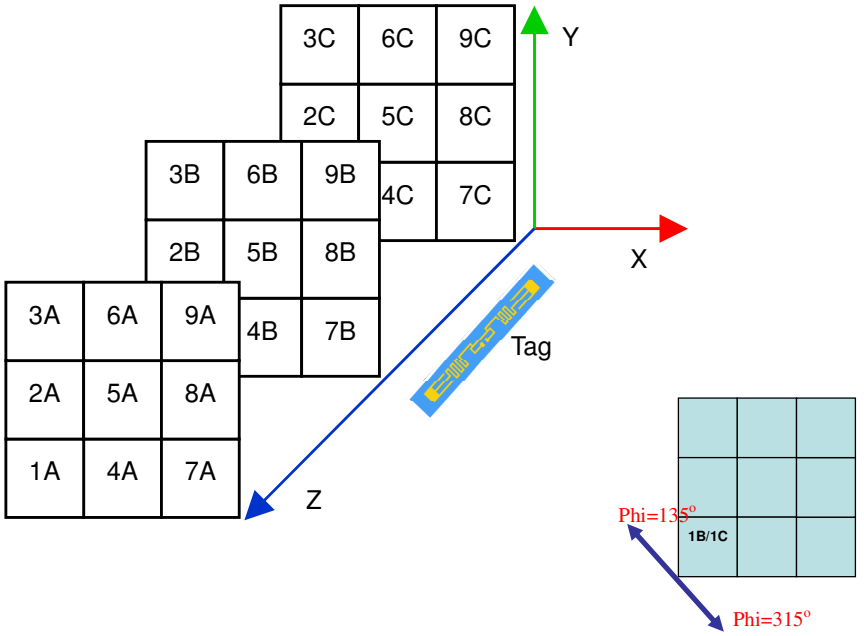
# Radiation Pattern is More Interesting

- Three general patterns among six positions



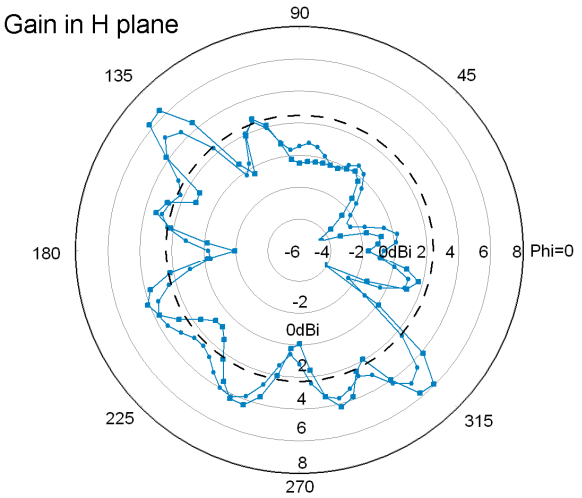
# Radiation Analysis

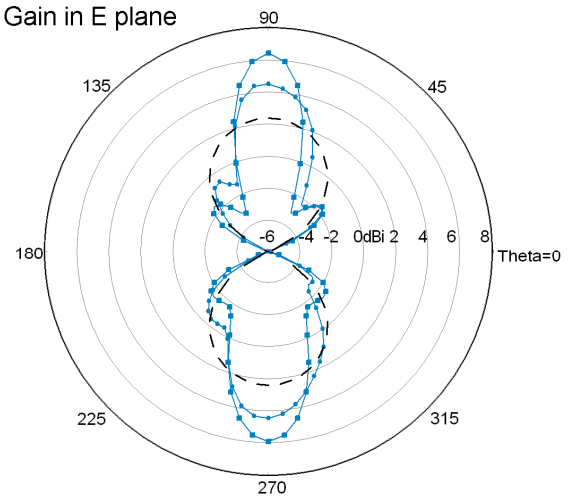
- Edge and Corner (1B and 1C)
  - Less shielding and scattering
  - Enhanced at certain directions
    - +6dBi for direction away from stack





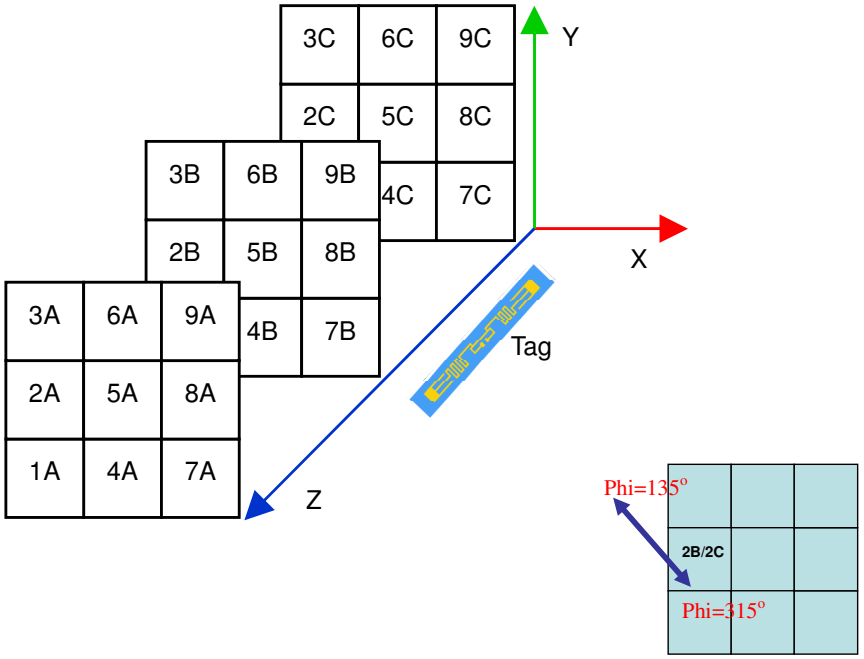




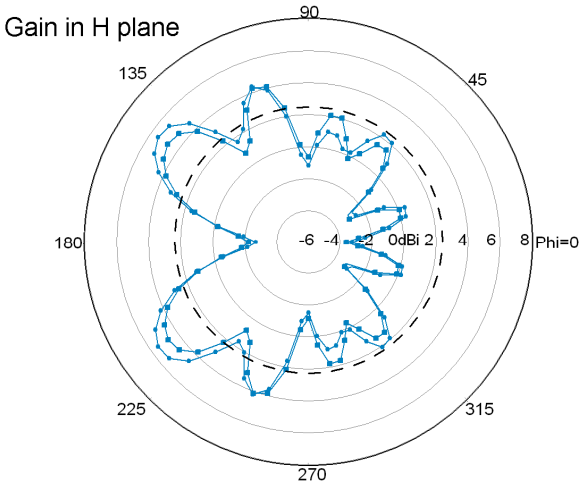
# Radiation Analysis

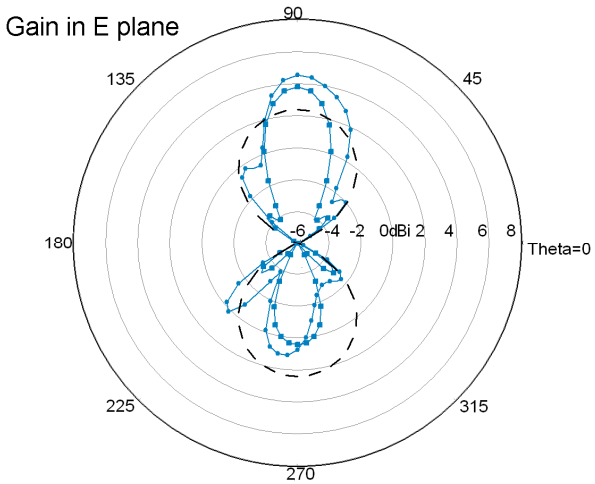
- Surface center (2B and 2C)
  - Surroundings on the sides
    - -4dBi towards the stacks
    - +4dBi on diagonal away from sta





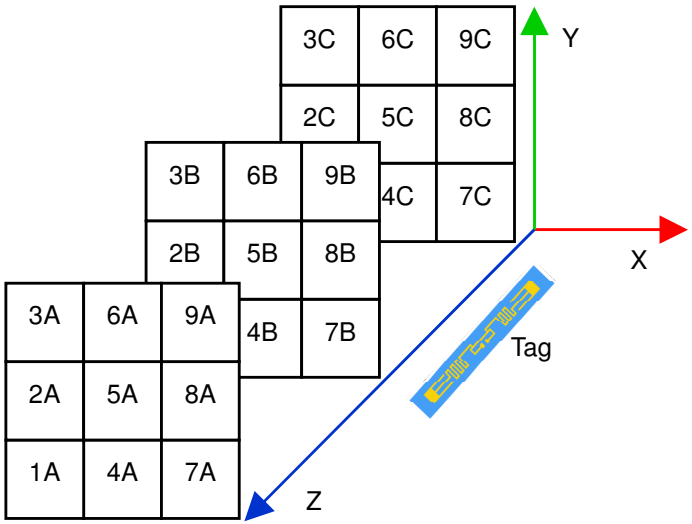


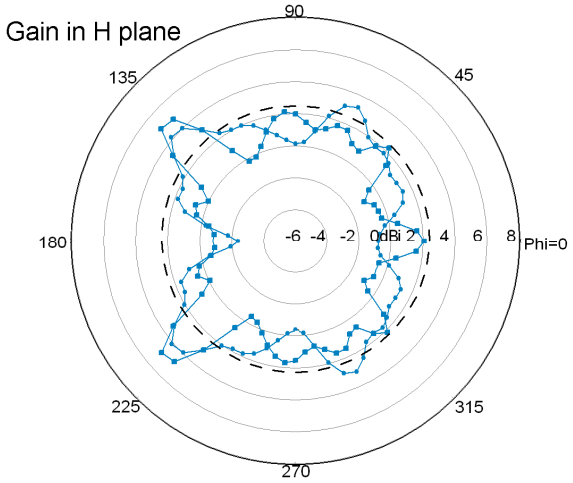


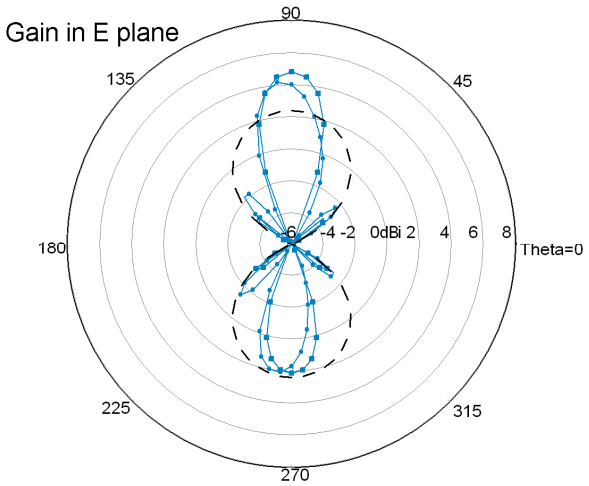



# Radiation Analysis

- Mass center (5B 5C)
  - Suffered the most degradation
    - Most directions to -4dBi

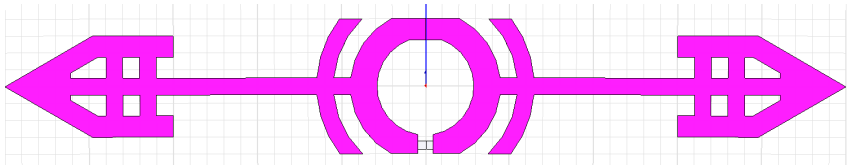


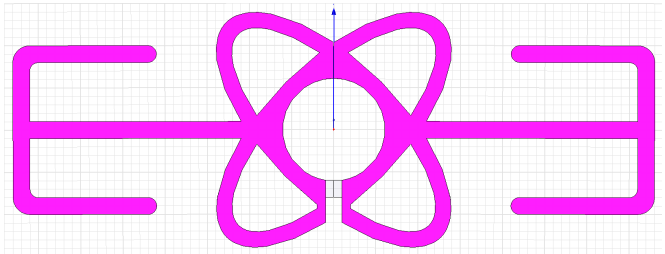



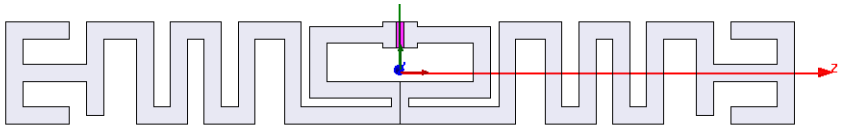



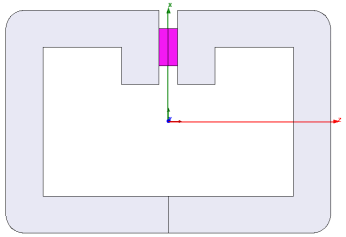
# Pre-tuned Antennas

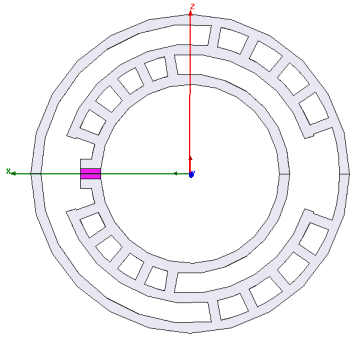
- Factor in the detuning effects from hosting materials
- Fit into the size of special form factors

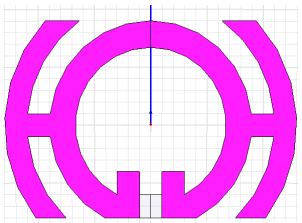


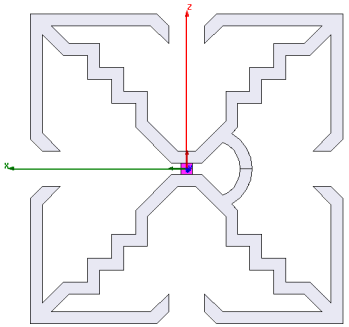






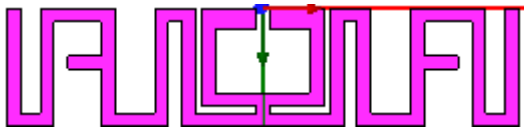


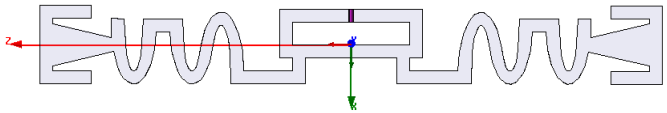


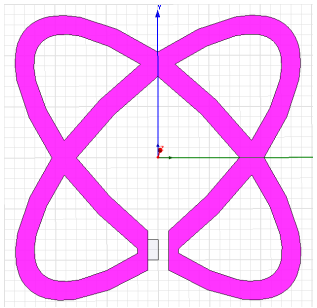


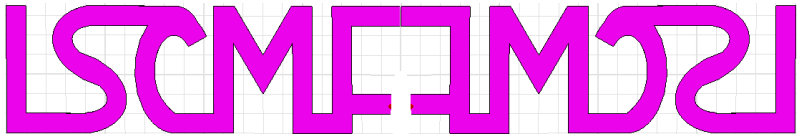
# Logo Antennas

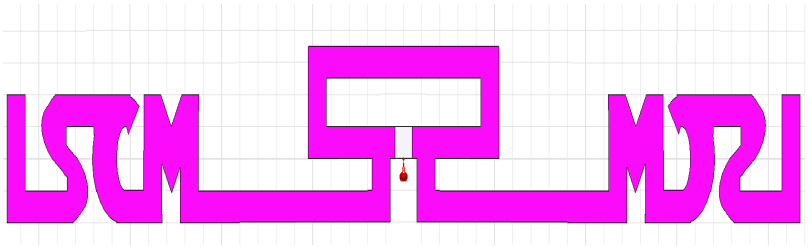
- Logo and brands
- Letters and words





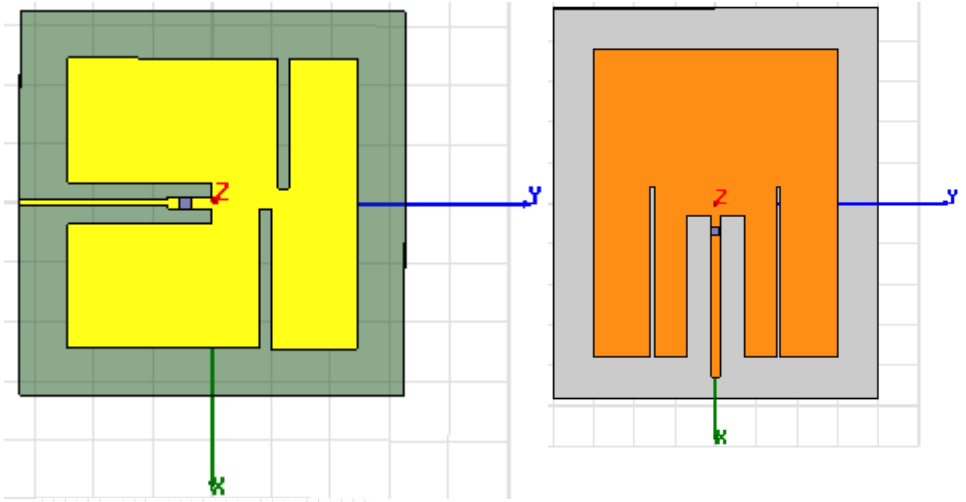


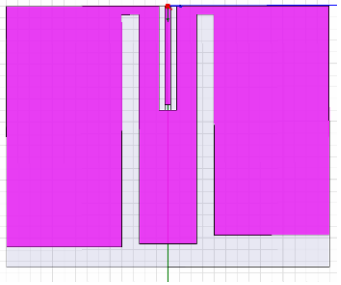


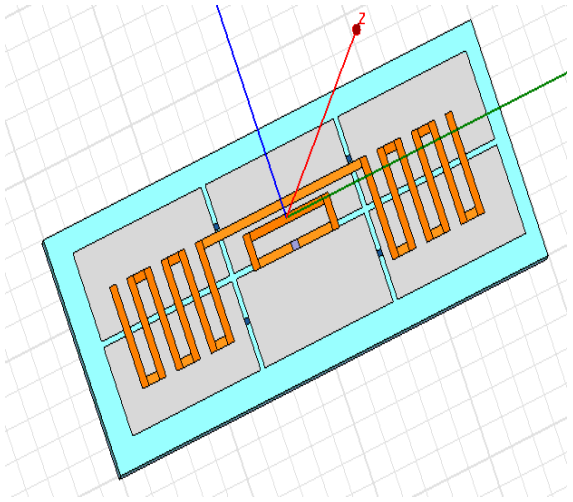


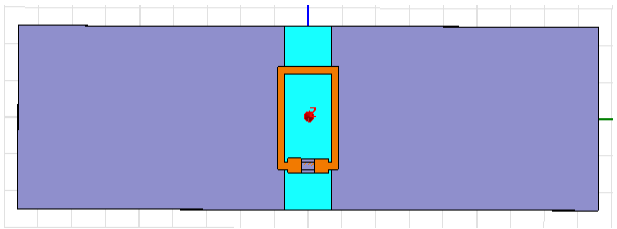
# Water and Metal Antennas

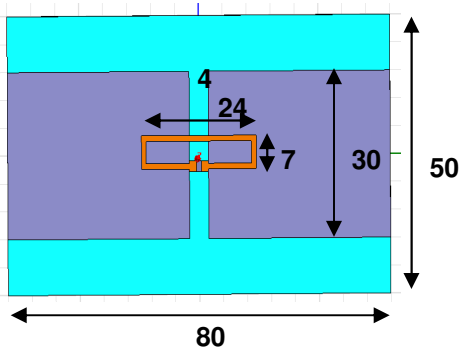
- Inductive coupling antenna
- Patch antenna
- Micro strip antenna
- EBG antenna







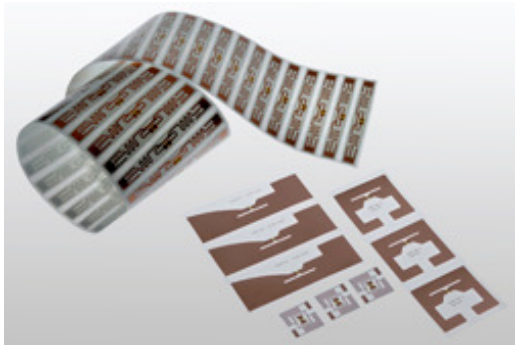
# Tag and Antenna Research Projects

- Application-Specific Antennas
  - Detuning effects
  - Stacking effects
  - Package-specific antennas
  - 3D and package conformal antennas

- Antenna Printing Using Conductive Inks
  - Cost saving and environmentally friendly
  - Strap bonding

# Antenna Printing Techniques

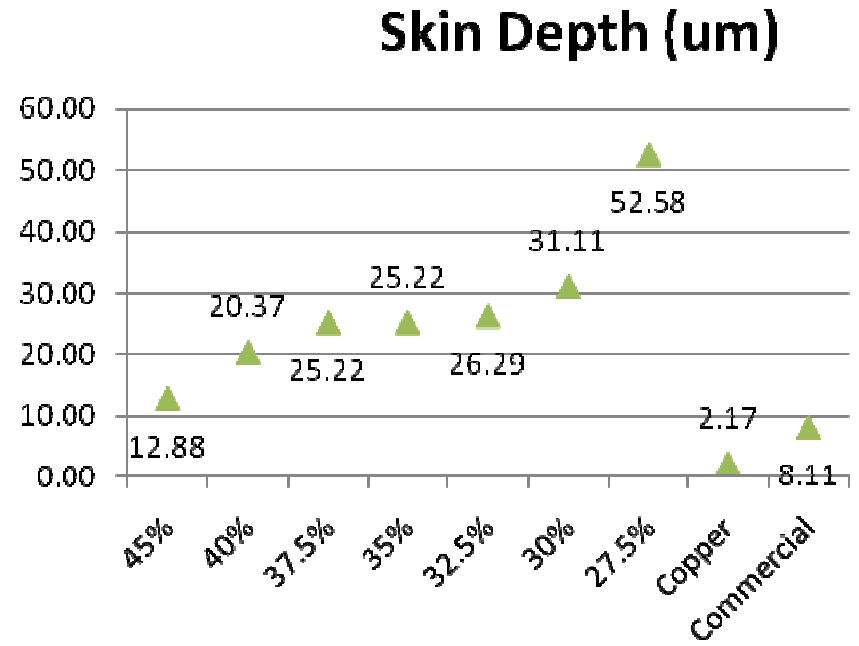
- Copper and aluminum RFID antenna
  - Copper/aluminum plating
    - Complicated and expensive process,
  - Copper/aluminum etching
    - Waste of materials, causing pollution
  - Not decomposable in recycling process
    - Another potential environmental hazard

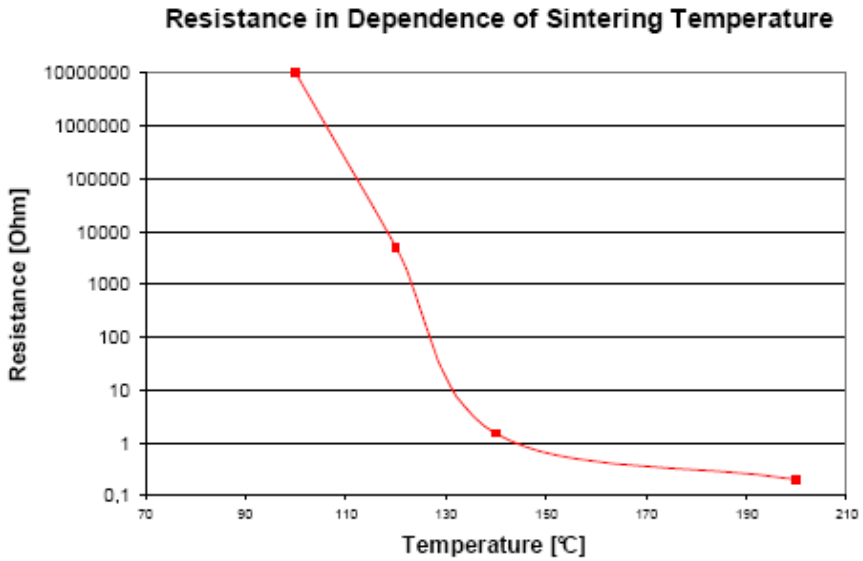


- RFID antenna printing using conductive ink
  - Integrating with the package printing process
    - Significant cost reduction
  - Environment friendly
    - Made of silver and carbon powder
    - Recyclable and decomposable

# Printed Antenna Designs

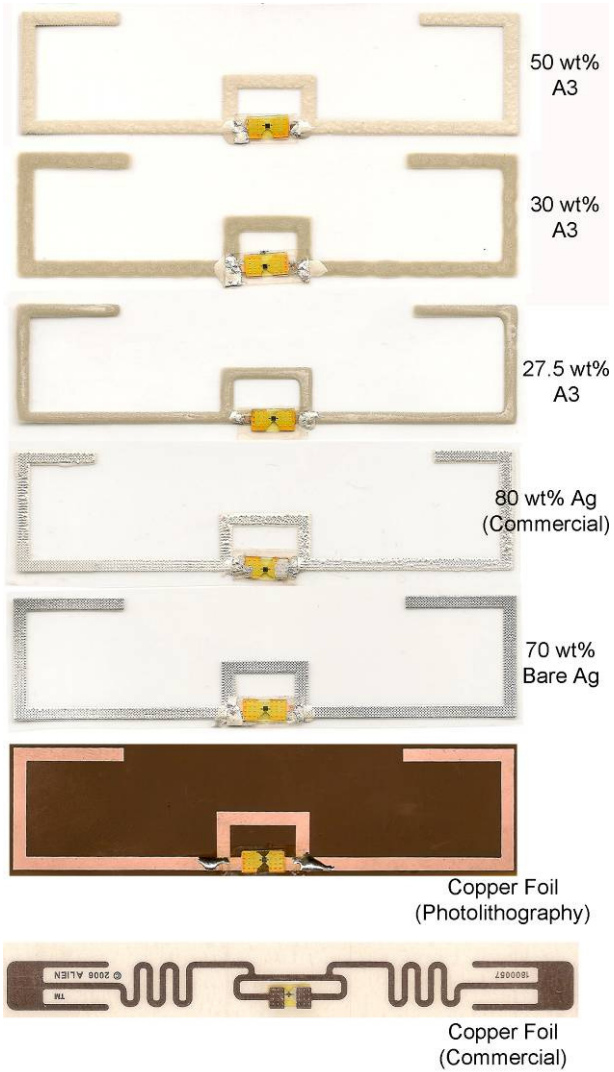
- Conductive ink thickness
  - Achieving enough conductivity
  - Considering skin effect under 900MHz
- Curing temperature
  - Working on formula with lower curing temperature
  - UV curing
- Curing time
  - Traditional curing time around 10 mins
  - Not suitable for roll-to-roll mass production



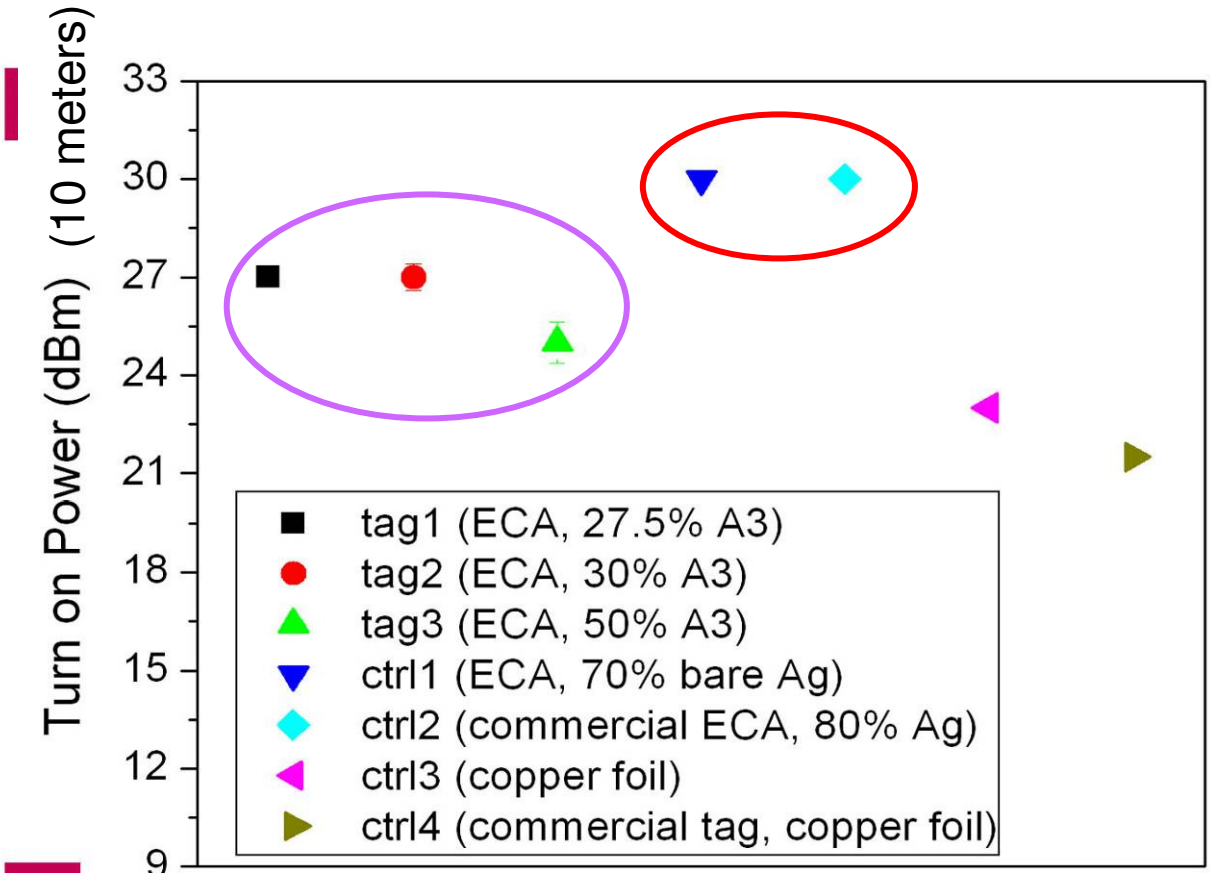



# Use Less Sliver ?

- Conductive ink is still not really cheap
  - Commercial ink contains 70~80 % of silver (silver loading)
  - Price dependent highly on silver price in the market
- Improved conductive ink formula
  - 30~40% of silver loading still shows comparable results



# Less Silver, More Conductivity



# RFID Market Penetration


RFID Market

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