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mm-Wave Chipless RFID Tag for Healthcare Applications

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Outline

- Introduction
- State of the art
- System development
- Design of the tag
- Numerical results

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RFID Tag in HEALTHCARE

Radio Frequency Identification (RFID) technology offers a practical opportunity

for management applications, e.g.

- reducing errors in patient care
- facilitating tracing and tracking of patients and equipment
- allowing better management of healthcare assets

for monitoring vital signs extending its functionality to sensing, e.g.

- heart rate
- breathing
- blood pressure
- sleep disorders like sleep apnea

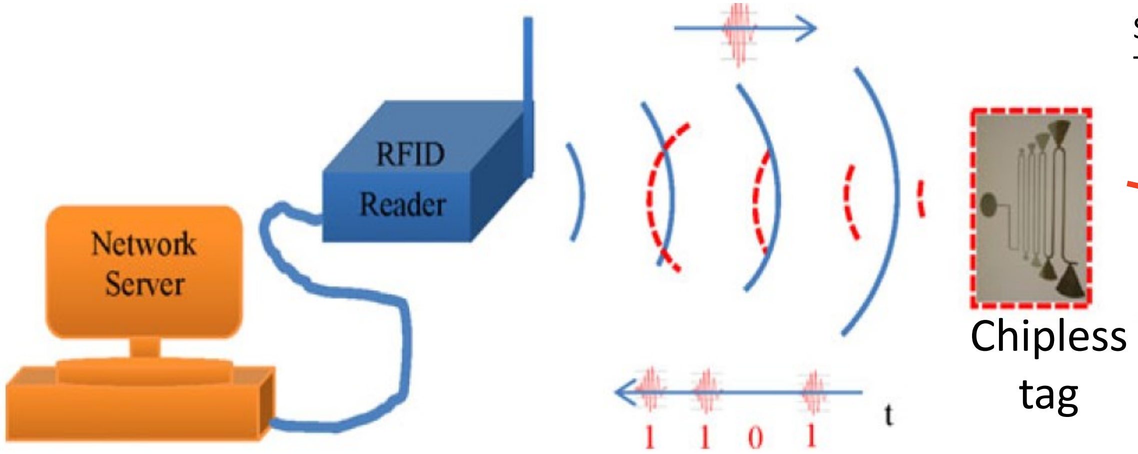
RFID CHIPLESS TAG

Chipless → cheap; disposable biodegradable

Includes a passive network for → storing the ID; performing sensing

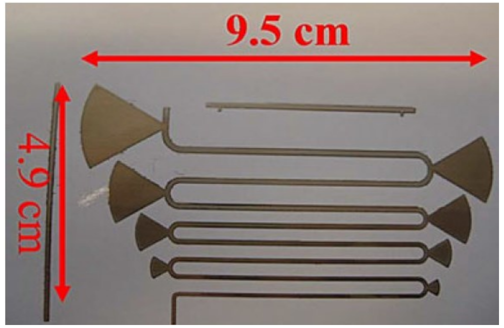
Data encoding → Time domain; Frequency domain signature

TIME DOMAIN DATA ENCODING



Chipless tag

Shao, B. et al.: Chipless RFID tags fabricated by fully printing of metallic inks. Annals of Telecommunications-Annales des télécommunications, 68 (7–8) (2013), 401–413.



Information is encoded by connecting the antenna to a passive network with discontinuities that generate delayed echoes of the incoming signal.

CONSTRAINT:
Very short pulse or a long structure is necessary to distinguish adjacent echos.

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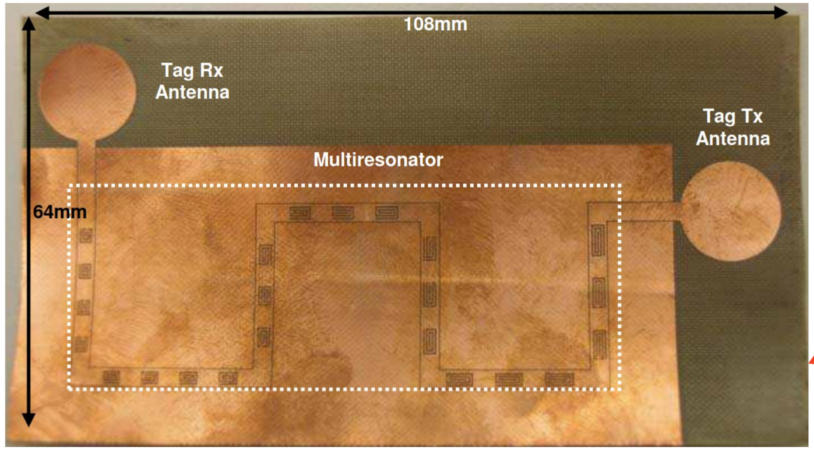
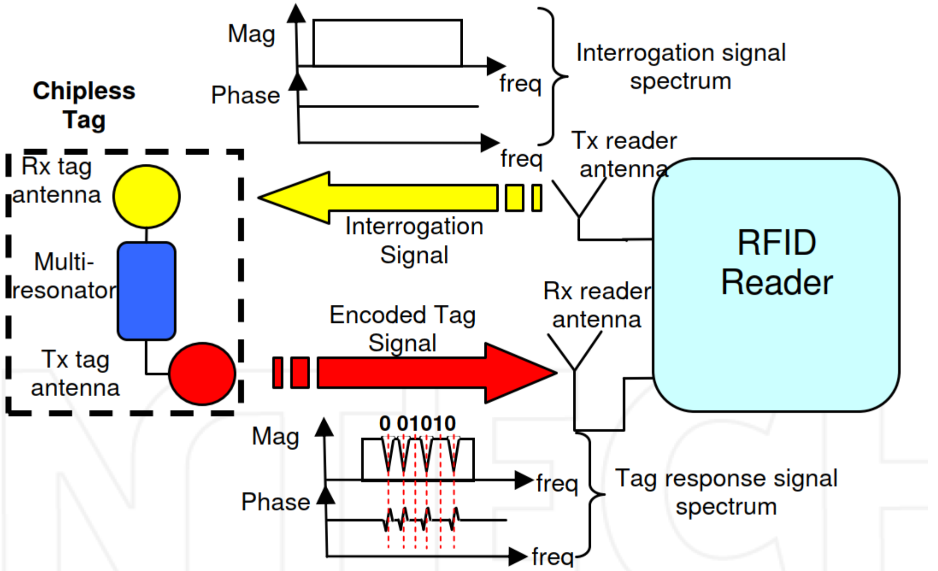
FREQUENCY DOMAIN DATA ENCODING

Stevan Preradovic, Nemai Chandra Karmakar, "Multiresonator-Based Chipless RFID», Spinger, ISBN 978-1-4614-2094-1

Retransmission based tags





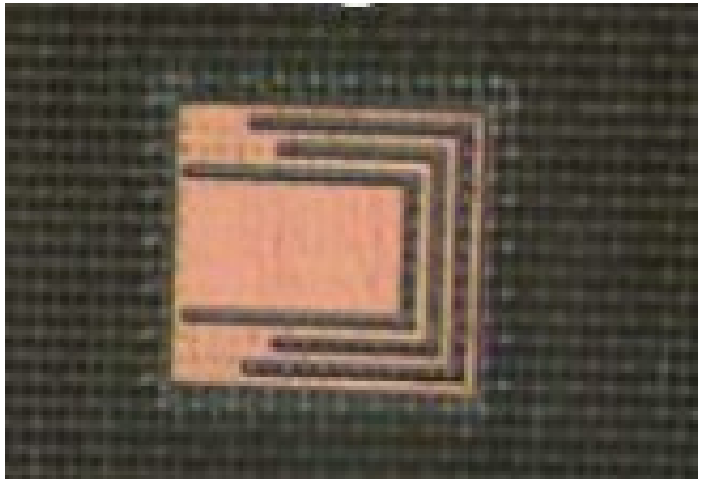
Information is encoded by connecting the antenna to a set of resonators that produces singularities in the amplitude and/or phase of the frequency response of the tag

CONSTRAINT

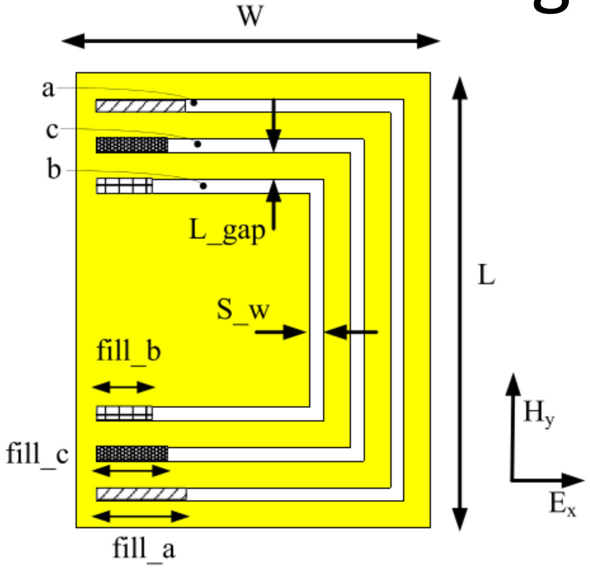
the interrogating signal must have a bandwidth that covers all the resonators frequencies

FREQUENCY DOMAIN DATA ENCODING

Emran Md. Amin et al., “Development of a Low Cost Printable Chipless RFID Humidity Sensor”, IEEE SENSORS JOURNAL, VOL. 14, NO. 1, JANUARY 2014



Backscatter based tag



Information is encoded by means of resonant elements (e.g. U-shaped slots) that provide singularities in the amplitude and/or phase in the response of the Radar Cross Section.

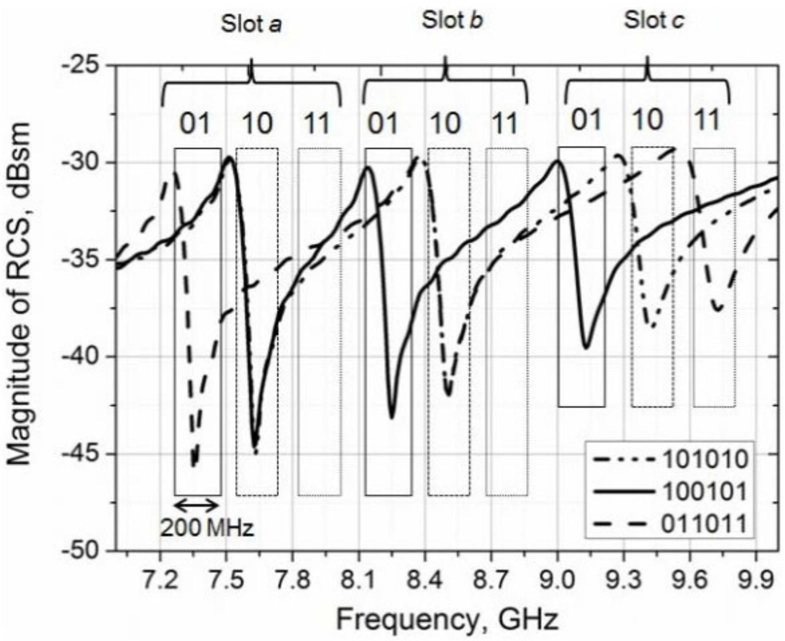
CONSTRAINT

the interrogating signal must have a bandwidth that covers all the resonators frequencies

SPECTRAL SIGNATURE DATA ENCODING

Emran Md. Amin et al., “Development of a Low Cost Printable Chipless RFID Humidity Sensor”, IEEE SENSORS JOURNAL, VOL. 14, NO. 1, JANUARY 2014

TAG ID



The ID of the tag is encoded by a spectral signature. The presence or the lack of a resonance corresponds to a 1 or 0 bit. Typically, the ID cannot be re-writeable because it is included in the structure of the tag, nevertheless there are example in the literature showing investigations to make chipless tag re-writable.

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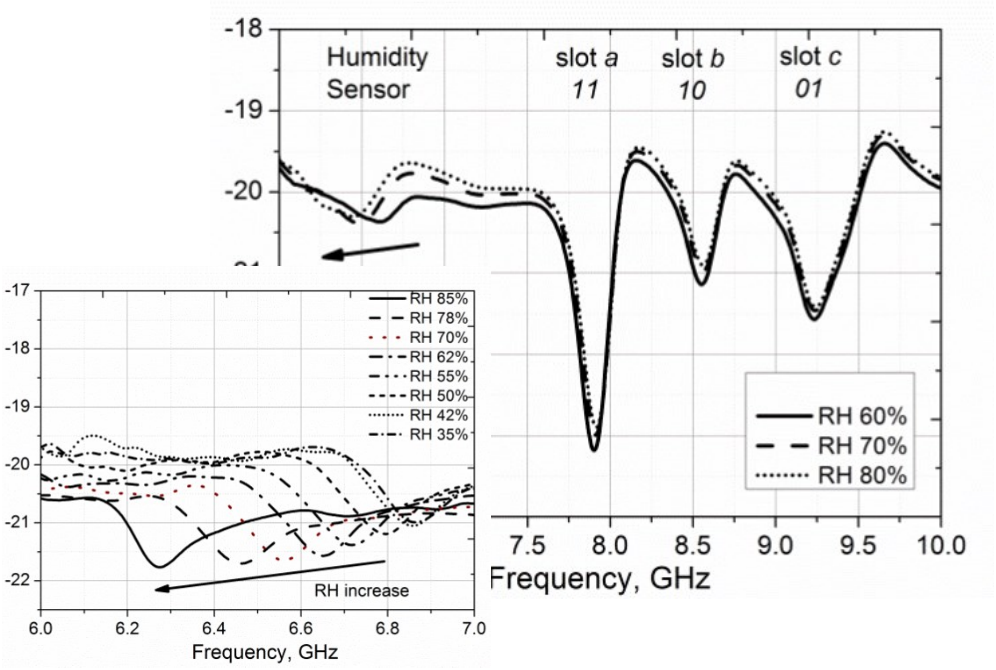
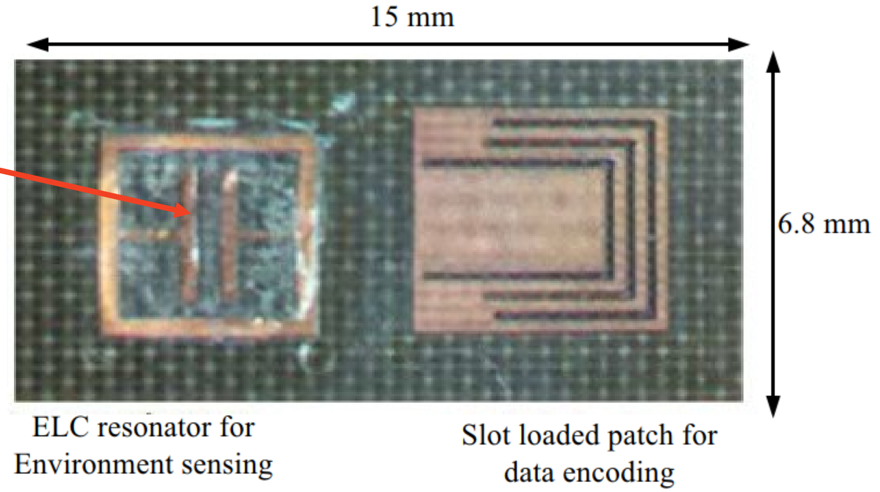
ANALOGIC SENSING DATA ENCODING

Emran Md. Amin et al., "Development of a Low Cost Printable Chipless RFID Humidity Sensor", IEEE SENSORS JOURNAL, VOL. 14, NO. 1, JANUARY 2014



Resonator coated with a humidity sensitive material



The mechanism for sensing is based on frequency shifts.

LIMITS of CHIPLESS TAG

Weakness of backscattered signal:

- It permits short reading range because of small RCS
- RCS decreases for non-orthogonal angles of incidence

Clutter from the environment:

- It camouflages the backscattered signal

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IMPROVEMENTS of CHIPLESS TAG

Polarization diversity (the tag receives and retransmits the signal using two orthogonal polarizations)

It improves the useful signal with respect to the clutter

Increasing of RCS (it makes the backscattered signal stronger)

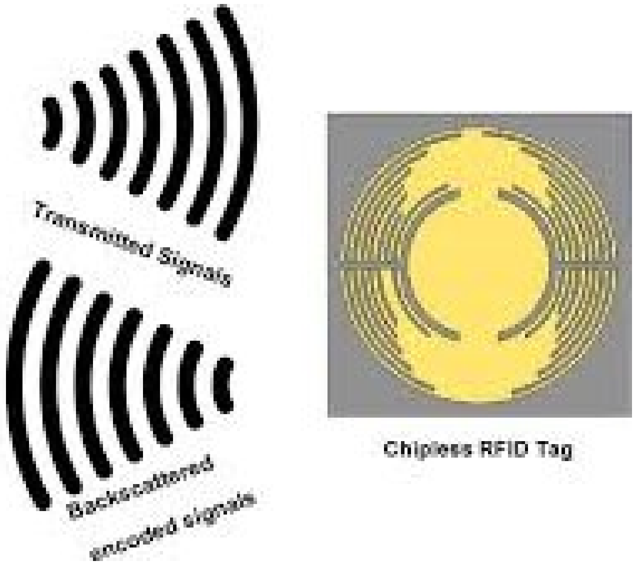
Electrically large tag

electrically large antenna can be physical small at **mm-wave band**

retrodirective arrays (e.g. Van Atta) have RCS independent from the direction for a wide angular extension

System Developments

Re-using of automotive radar

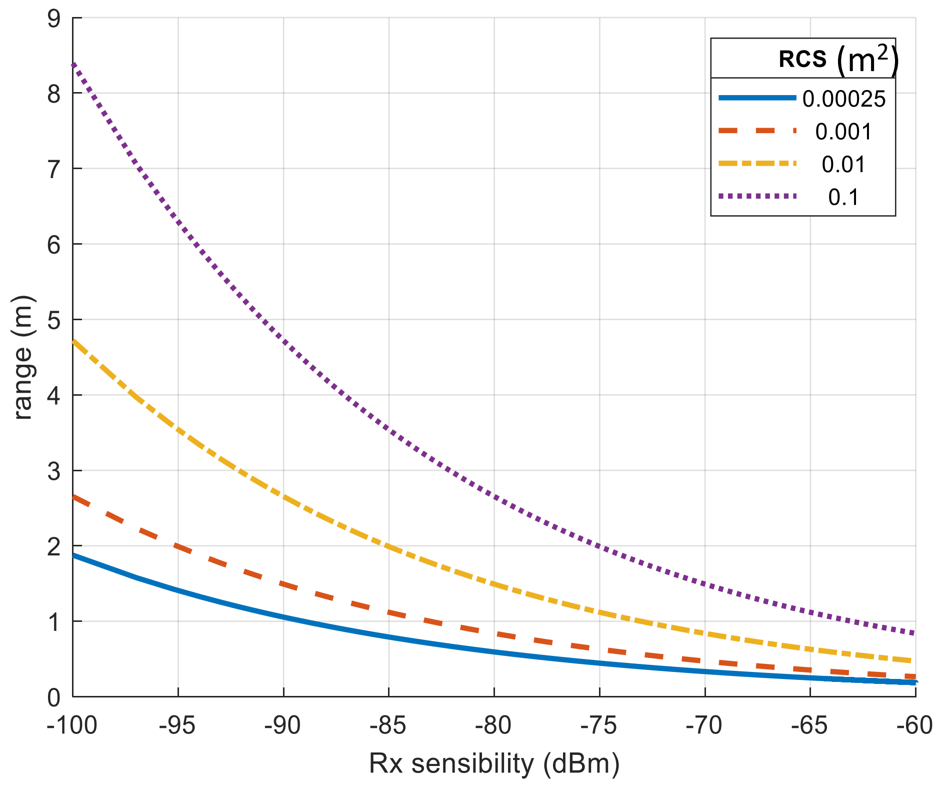


- Automotive radar at 25 GHz;
- Bandwidth 2 GHz (encoding many bits)

Theoretical reading range @ 24GHz

$$R_{max} = \sqrt[4]{\frac{P_t G^2 \lambda^2 \sigma}{P_{r\,min}\,(4\pi)^3 L_{loss}}}$$

- P_t is the transmitted power;
- G is the radar's antenna gain;
- λ is the wavelength;
- σ is the tag's RCS;
- $P_{r\,min}$ is the smallest received power that can be detect by the radar;
- L_{loss} is a factor accounting for all possible losses.



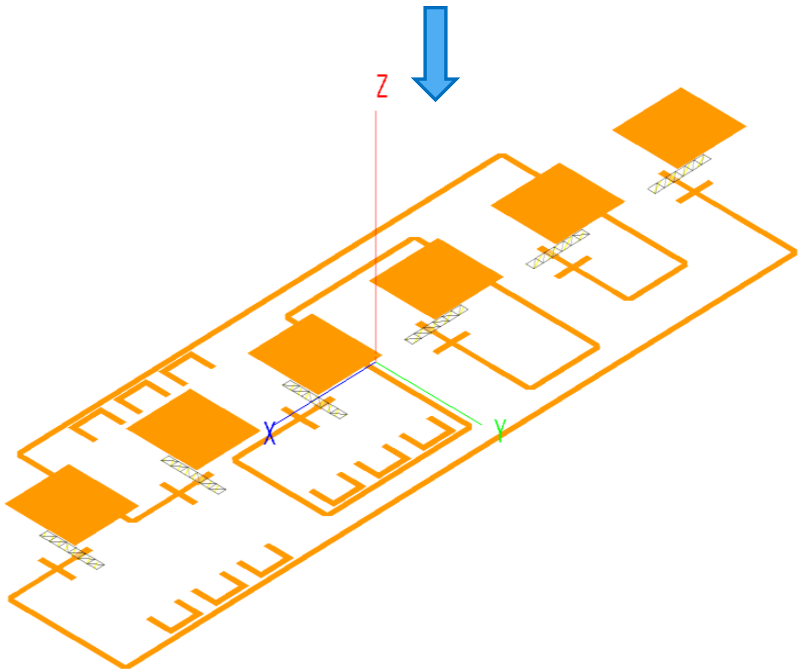
Description of Proposed Tag

The tag realizes a retro-directive Van Atta array that retro-reflects the imping signal in the orthogonal polarization:

- Two sets of 3 rectangular patches;
- The two sets are distinguished by different (orthogonal) polarization.
- The patches are fed by slots made on the ground plane (not shown) of a stripline.
- three U-shaped resonators encode data.

$$(60 \times 20 \times 2)\ mm^3$$

dielectric layers and ground plane are hidden



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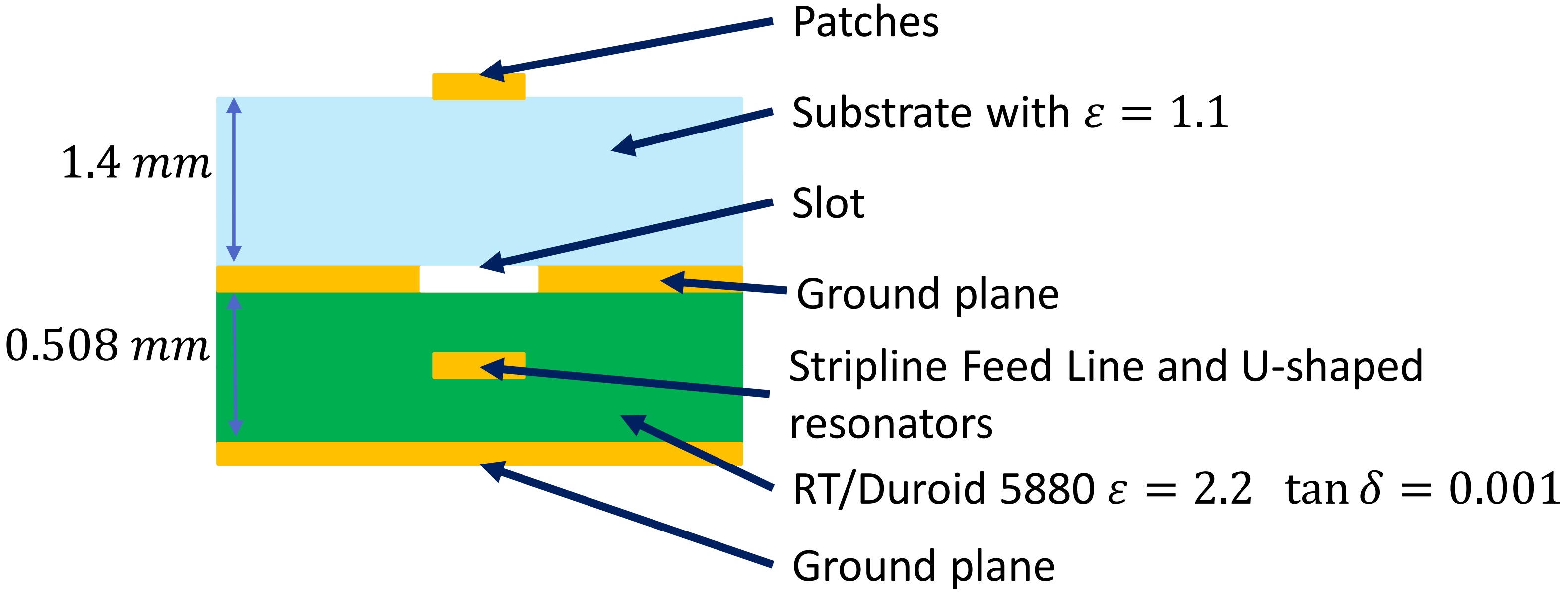
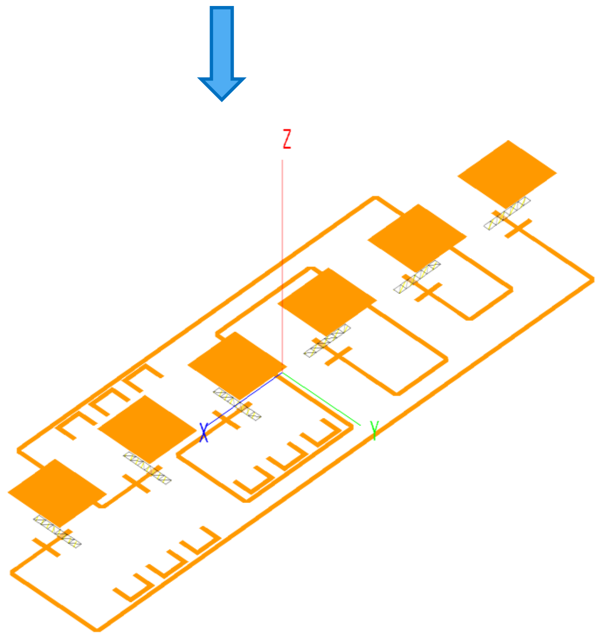
Tag description



$(60 \times 20 \times 2)\ mm^3$

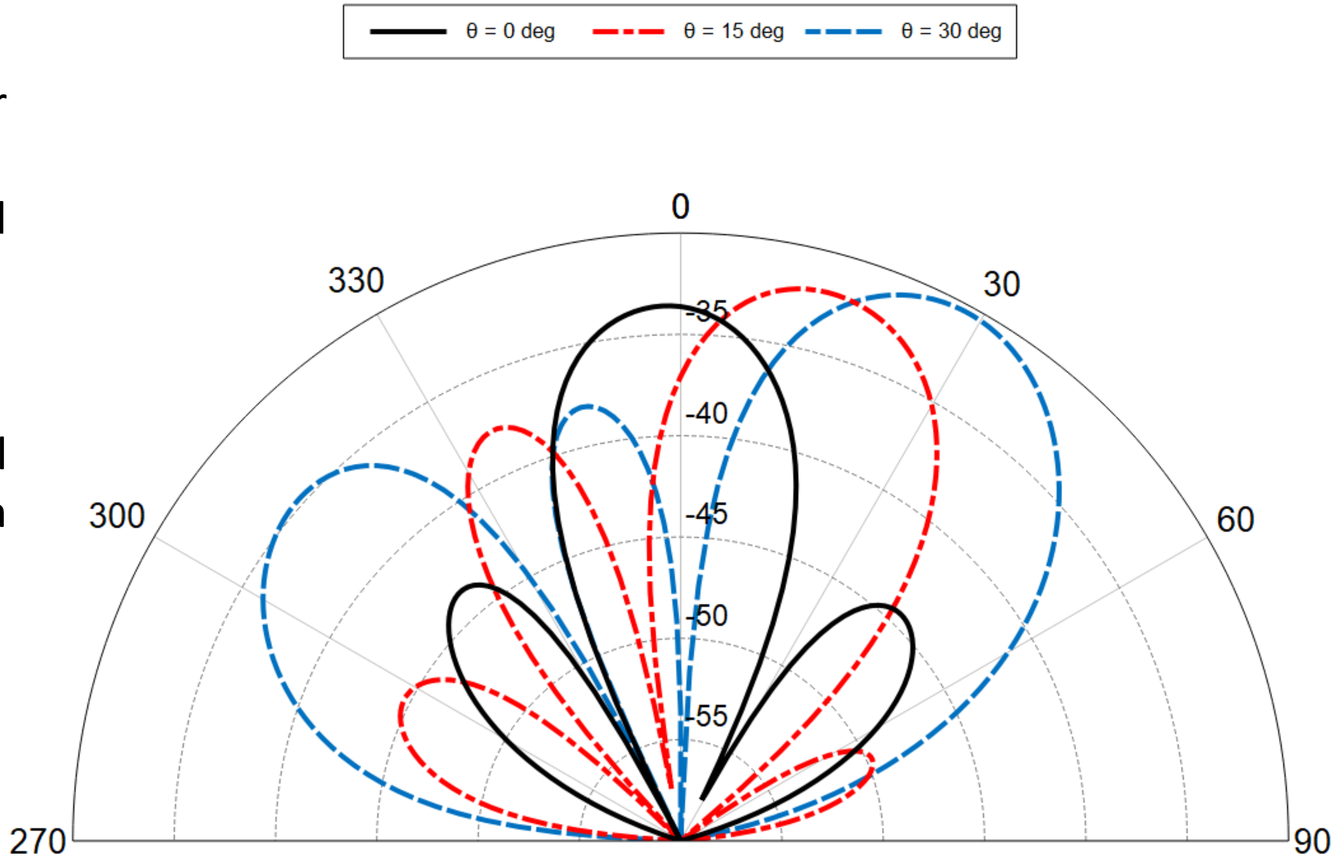
dielectric layers and ground plane are hidden



Numerical results

Cross-polar RCS diagrams of the tag @ 25 GHz and for plane waves impinging from three different angles: 0° (continuous black), 15° (dash-dotted red), 30° (dashed blue).

The retrodirective lobes are clearly obtained with a level greater than -35dBsm. That RCS level permits a detection distance of about 2 m.



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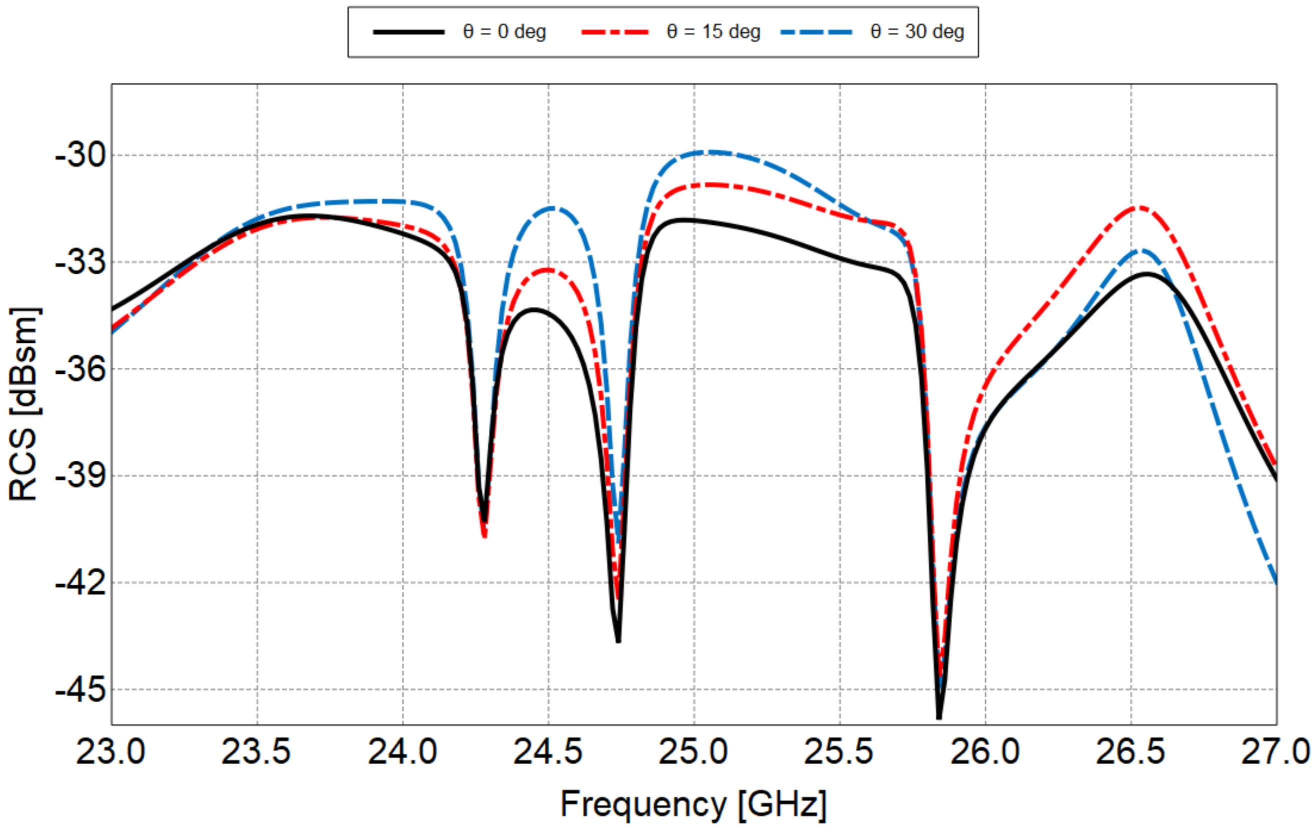
Numerical results

Monostatic cross-polar RCS of the tag vs. frequency for plane waves impinging from three different angles: 0° (continuous black), 15° (dash-dotted red), 30° (dashed blue). The spectral signature is clearly shown by three notches within the 24-26 GHz band.

The position of the notches does not change with the impinging angle while their depth remains sufficiently long to be easily distinguished.



Conclusions

- We have shown the possibility to develop small chipless tag at mm-wave frequency band.
- It exploits a cross-polarized Van Atta retrodirective array.
- The physical dimensions are comparable with that of an off-the-shelf UHF RFID tag.
- The obtained RCS level is sufficiently high to detect the tag from few meters.
- The designed tag encodes only three bits but more bits are possible with an optimization of the use of the bandwidth.
- It can be used in healthcare applications for both the identification of people and objects and the remote monitoring of the health status of patients.