Compact ceramic resonators for RFID applications

Dmitry Dobrykh[1,2], Ildar Yusupov[1], Sergey Krasikov[1], Anna Mikhailovskaya[1,2], Diana Shakirova[1], Andrey Bogdanov[1], Alexey Slobozhanyuk[1], Dmitry Filonov[3] and Pavel Ginzburg[2,3]

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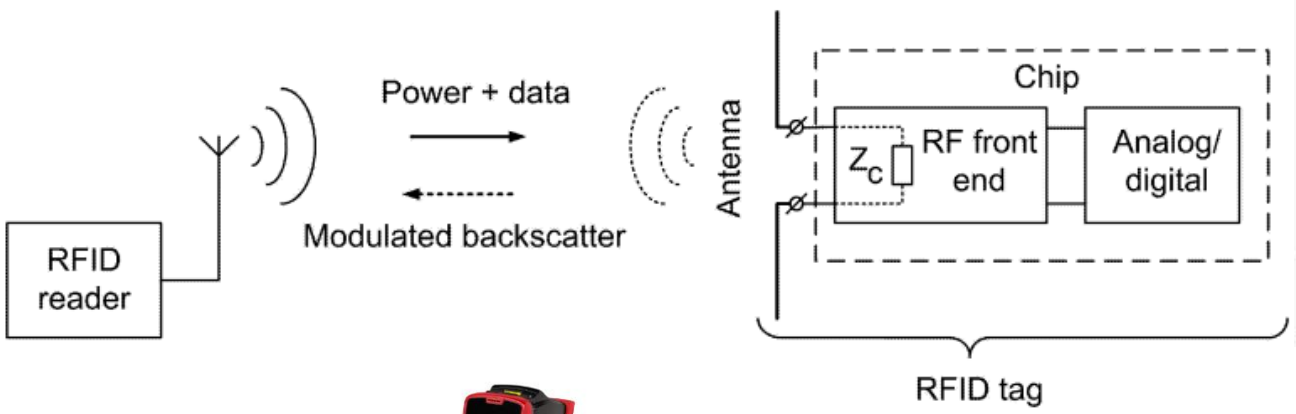
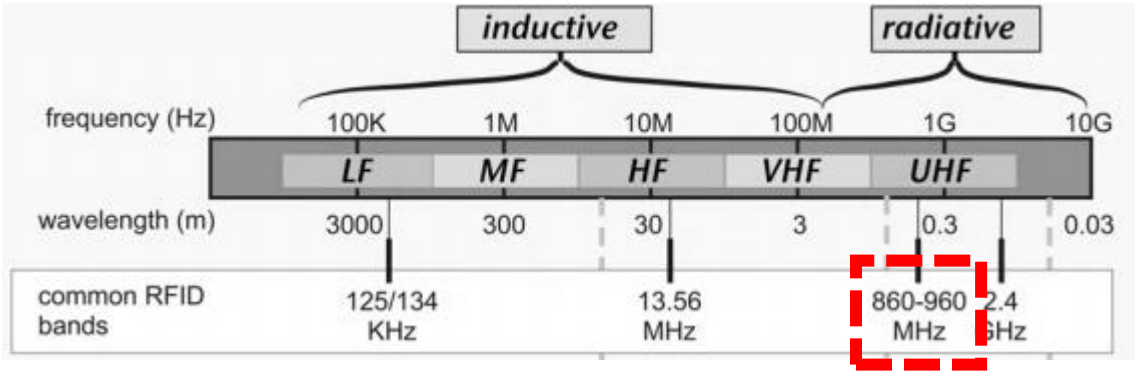
RADIO FREQUENCY IDENTIFICATION – method of using electromagnetic waves to automatically identify and track specific tags attached to objects.





References

[1] Rao, K. V. S et al. IEEE Transactions on Antennas and Propagation, 53(12), 3870–3876 (2005)
[2] www.alientechnology.com
[3] Daniel M. Dobkin «The RF in RFID» 2013

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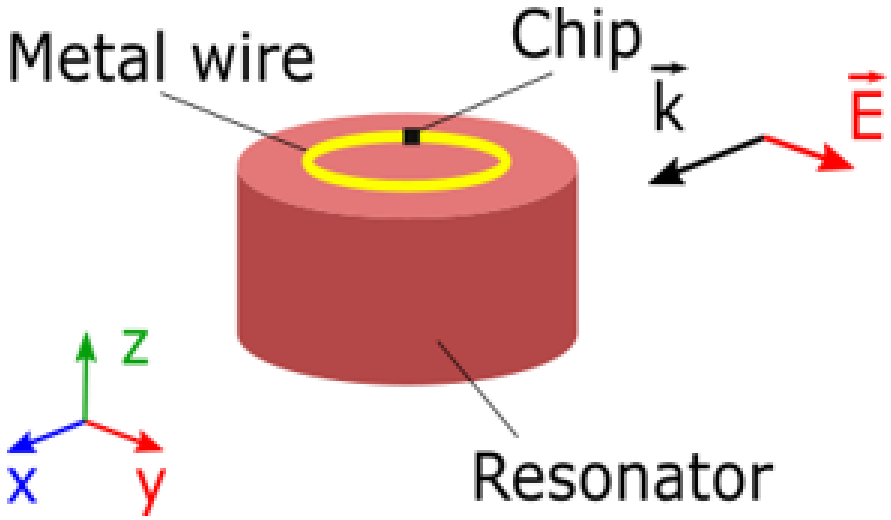
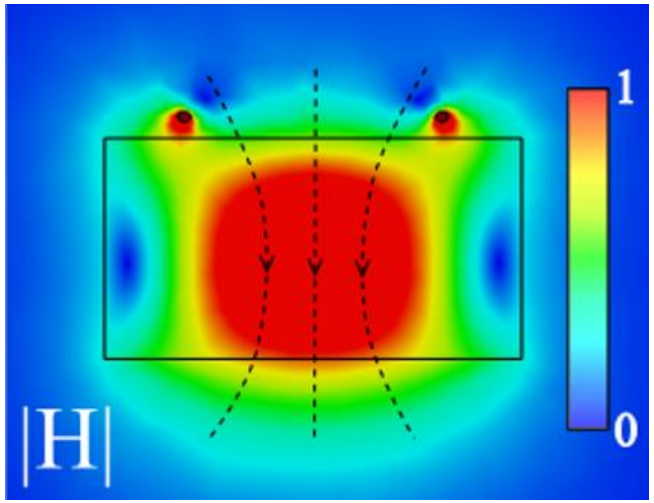
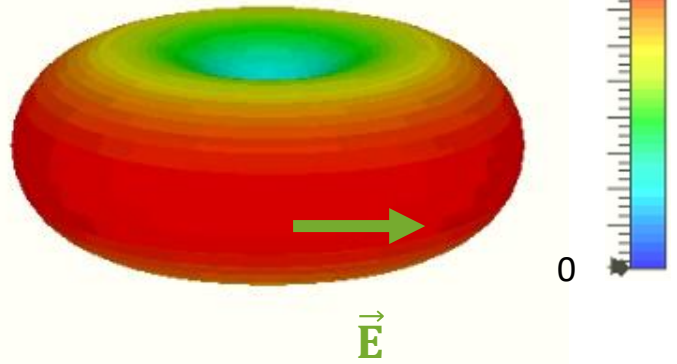
Operational scheme of a miniature ceramic-based RFID tag



Fundamental magnetic TE_{010} mode



Radiation pattern:



f = 900 MHz

Displacement currents within high-Q resonator are inductively coupled to a metal split ring, functionalized with an RFID chip.

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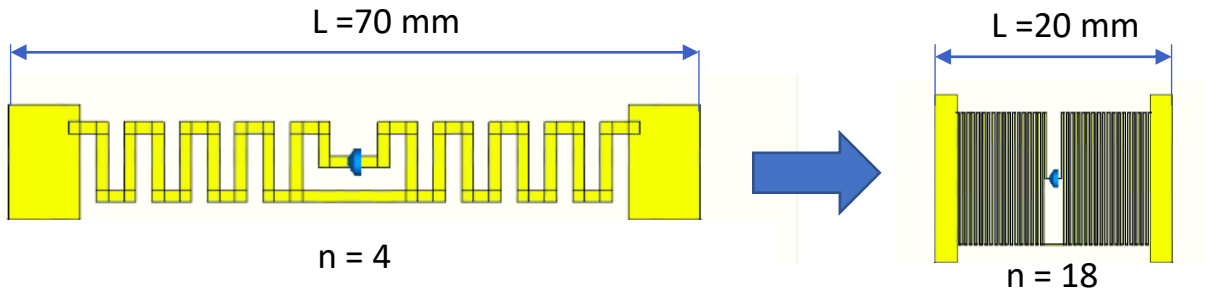
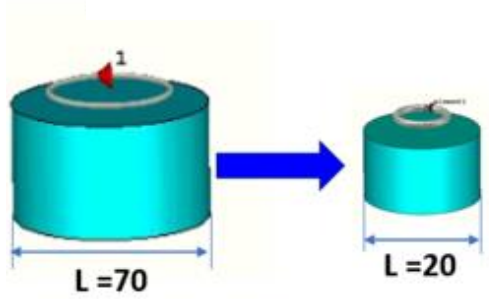
Comparison of miniaturization between metal tag and ceramic tag

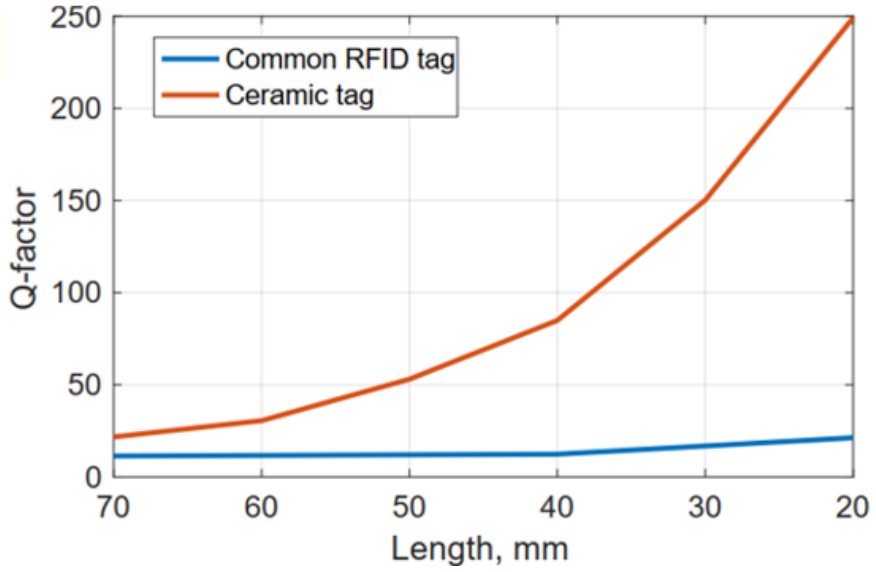
Metal dipole tag miniaturization by increasing the number of meandric elements (n):



Ceramic tag miniaturization by increasing the dielectric permittivity:



Result:



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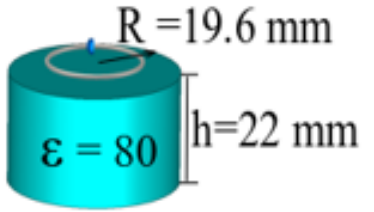
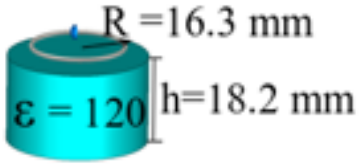
Impact of miniaturization of ceramic tags

The resonant frequency of the fundamental magnetic TE_{010} (dipolar) mode in an open cylindrical resonator:

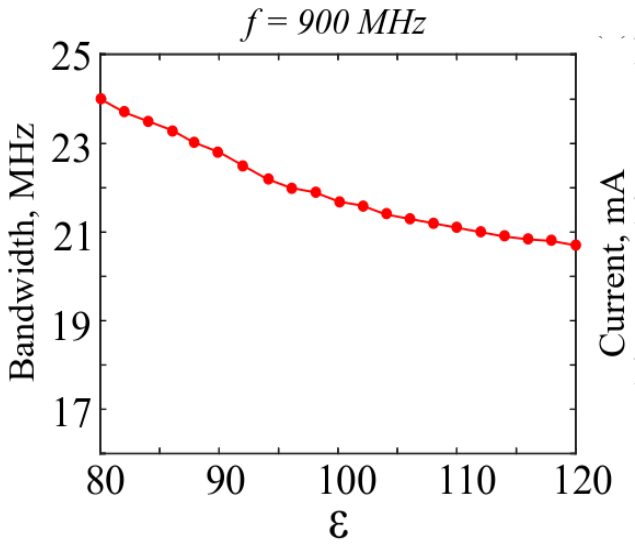
$$f_{TE_{010}} = 2.921 \frac{c\varepsilon^{-0.465}}{2\pi R}\left(0.691 + 0.319\frac{R}{h} - 0.035\left(\frac{R}{h}\right)^2\right)$$

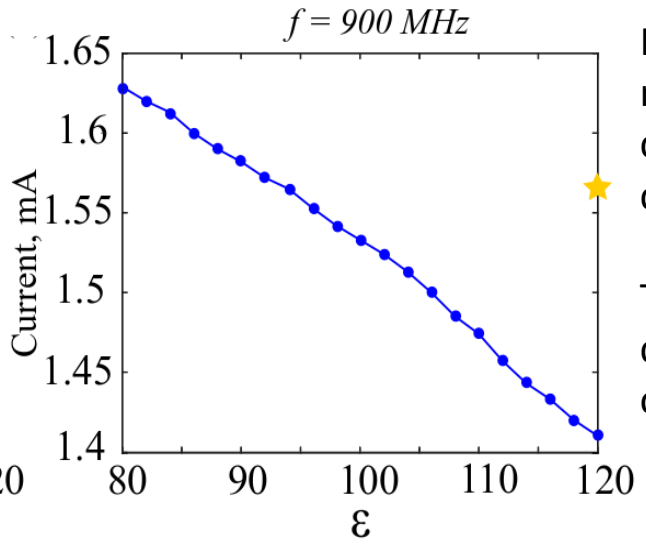




R_{chip}=1650 Ohm

C_{chip} =1.12 pF





In all numerical simulations the same metal ring's radius was used. Thus the matching conditions are not maintained and the current drops.

The yellow star shows the value of the current, where the metal ring is also optimized.

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Electromagnetic properties of ceramic RFID tags

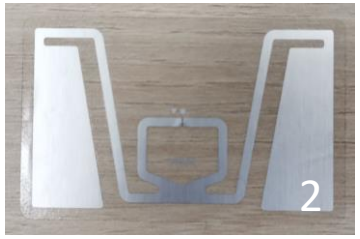
Ceramic tags

Resonator	R	h	ε
1	19 mm	22 mm	80
2	17 mm	20 mm	100

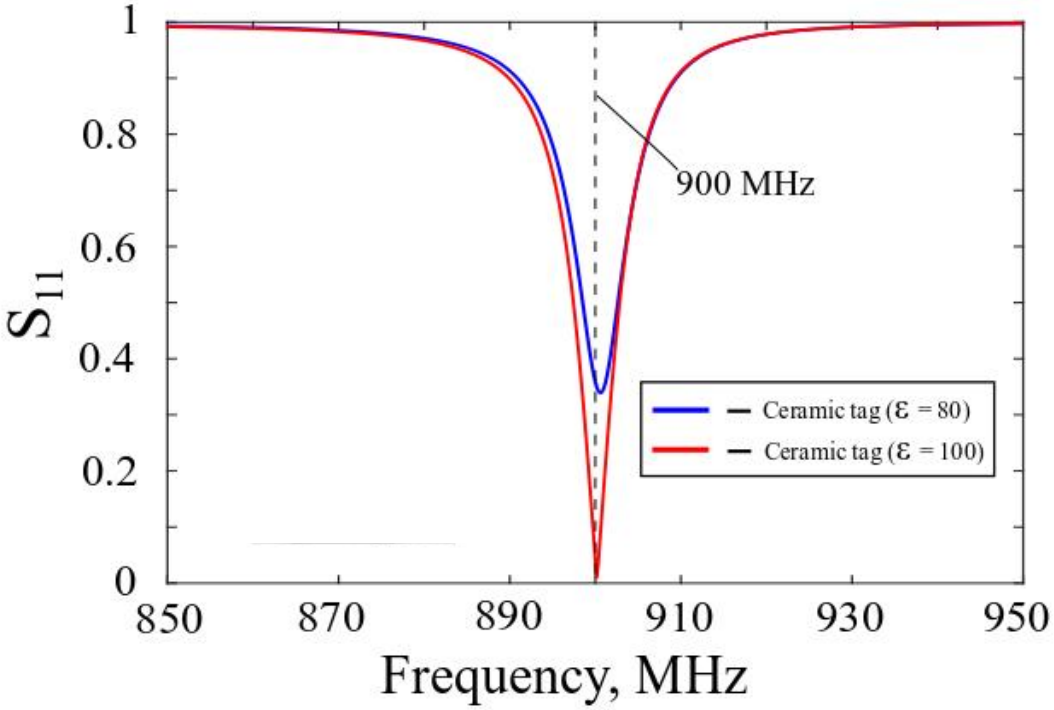
Commercial tags

Tag	L	h
1	73 mm	21 mm
2	54 mm	34 mm
3	73 mm	23 mm

Proposed ceramic tags were experimentally compared with commercial RFID tags.



The numerically calculated S11 spectra of ceramic tags



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Evaluation of link budget of the system

Two main limitations on reading distance:

Chip sensitivity: $$L = \frac{\lambda}{4\pi}\sqrt{\frac{P_t G_{TR} G_t \tau}{P_{ch}}} \quad (1)$$

Reader sensitivity: $$L' = \frac{\lambda}{4\pi}\sqrt[4]{\frac{P_t G_t^2 G_{TR}^2 ME}{P_r}} \quad (2)$$

Parameter	Physical meaning	Value
P_t	Power transmitted by the reader	0.1 W (20 dBm)
G_{TR}	Gain of the reader transmitter/receiver antenna	8.5 dB
G_t	Gain of the ceramic tag	1.22 dB (ε =80) 1.61 dB (ε =100)
P_{ch}	Chip sensitivity	$1.8 \cdot 10^{-5}$ W
P_r	Reader sensitivity	10^{-8} W
λ	Wavelength	0.33 m
τ	Power transmission coefficient (CST)	0.65 (ε =80) 0.98 (ε =100)
ME	Modulation efficiency	1.82 (ε =80) 0.99 (ε =100)
L	Reading distance for equation (1)	5.19 m (ε =80) 6.74 m (ε =100)
L'	Reading distance for equation (2)	6.42 m (ε =80) 5.75 m (ε =100)

References

[4] IEEE Transactions on Antennas and Propagation 53, 3870 (2005)
[5] J.C. Bolomey et al. Proc. IEEE 98, 1555 (2010)):

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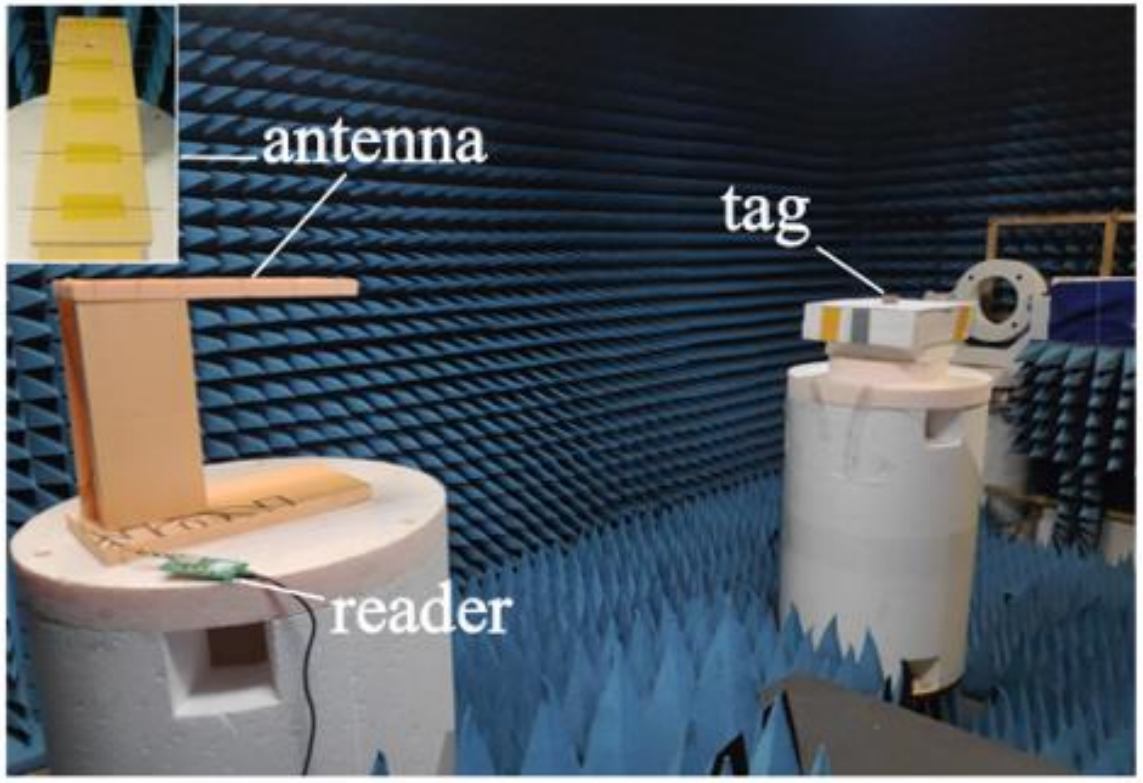
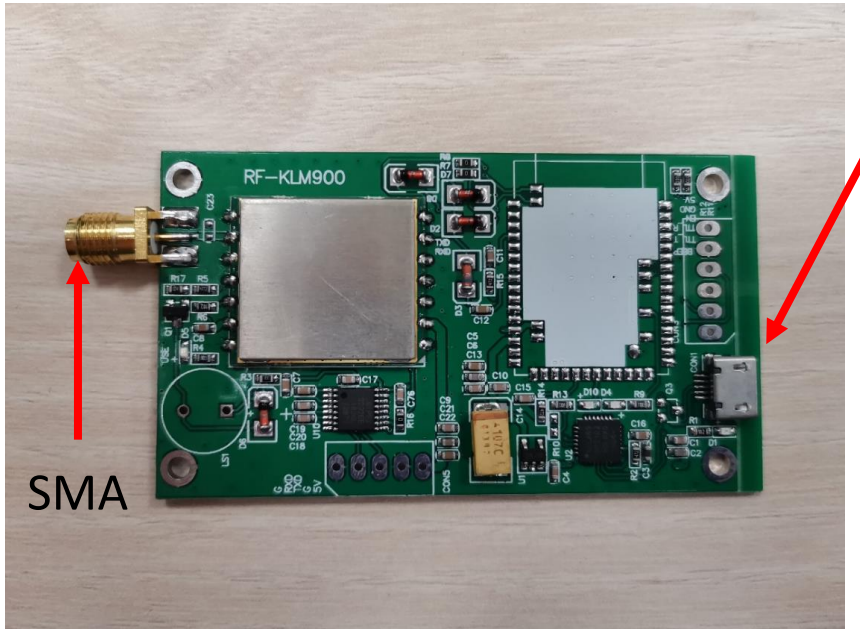
Experimental demonstration of the reading range

Yagi-Uda antenna (4 directors), with -15 dB matching in 880-960 MHz



RFID reader KLM900



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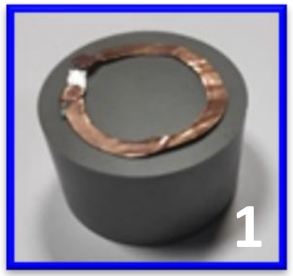
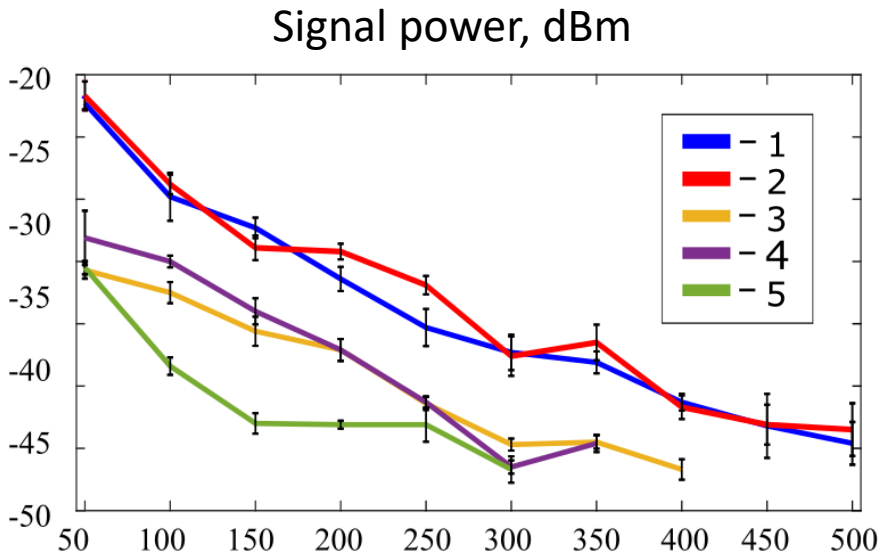
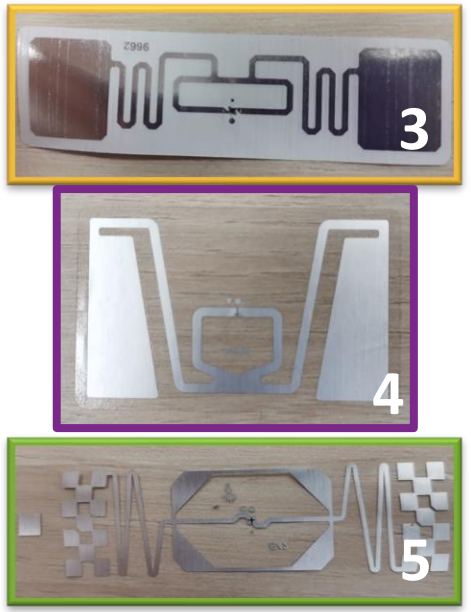
Readout distance of ceramic tags and commercial tags



Ceramic tags





Commercial tags

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1. The new type of RFID tags, based on ceramic resonators, has been investigated.

2. High permittivity ceramic (ε ~ 100) cylinder-based tags were shown to be detected from 25% larger distance in comparison to commercial tags.

3. The new architecture provides new routes for creating small-footprint RFID tags that support long reading range, which is valuable in numerous applications such as retail, security, IoT, and many others.

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