Diffuseur dépolarisant invariant par rotation

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PRESENTATION OUTLINE

Proceedings of the 51st European Microwave Conference

Comparison between Cross-polarization and Circular Polarization Interrogation for Robust Chipless RFID Reading

O. Rance[#1], N. Barbot[#2], E. Perret[#*3]

IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, VOL. 68, NO. 10, OCTOBER 2020 4305

Design of Planar Resonant Scatterer With Roll-Invariant Cross Polarization

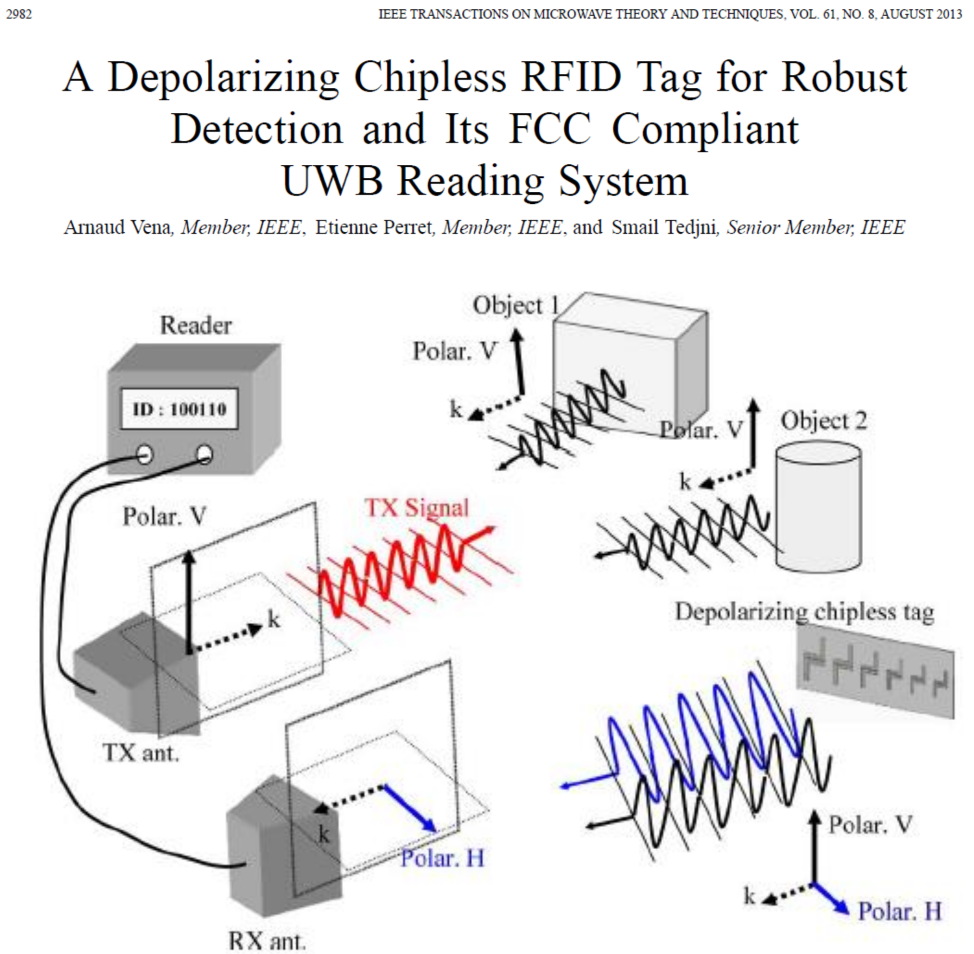
Olivier Rance, *Member, IEEE*, Nicolas Barbot, *Member, IEEE*, and Etienne Perret, *Senior Member, IEEE*

Depolarizing Chipless RFID Tag Made Orientation Insensitive by Using Ground Plane Interaction

Zeshan Ali, Olivier Rance, Nicolas Barbot, and Etienne Perret, *Senior Member, IEEE*

in *IEEE Transactions on Antennas and Propagation*, doi: 10.1109/TAP.2022.3145479.

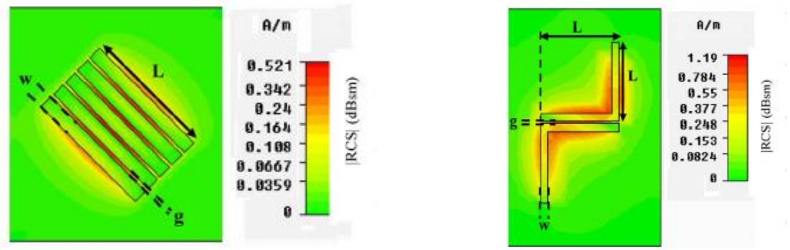
I.Introduction


2982 IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, VOL. 61, NO. 8, AUGUST 2013

A Depolarizing Chipless RFID Tag for Robust Detection and Its FCC Compliant UWB Reading System

Arnaud Vena, *Member, IEEE*, Etienne Perret, *Member, IEEE*, and Smail Tedjni, *Senior Member, IEEE*

Principle of operation of a depolarizing chipless RFID tag

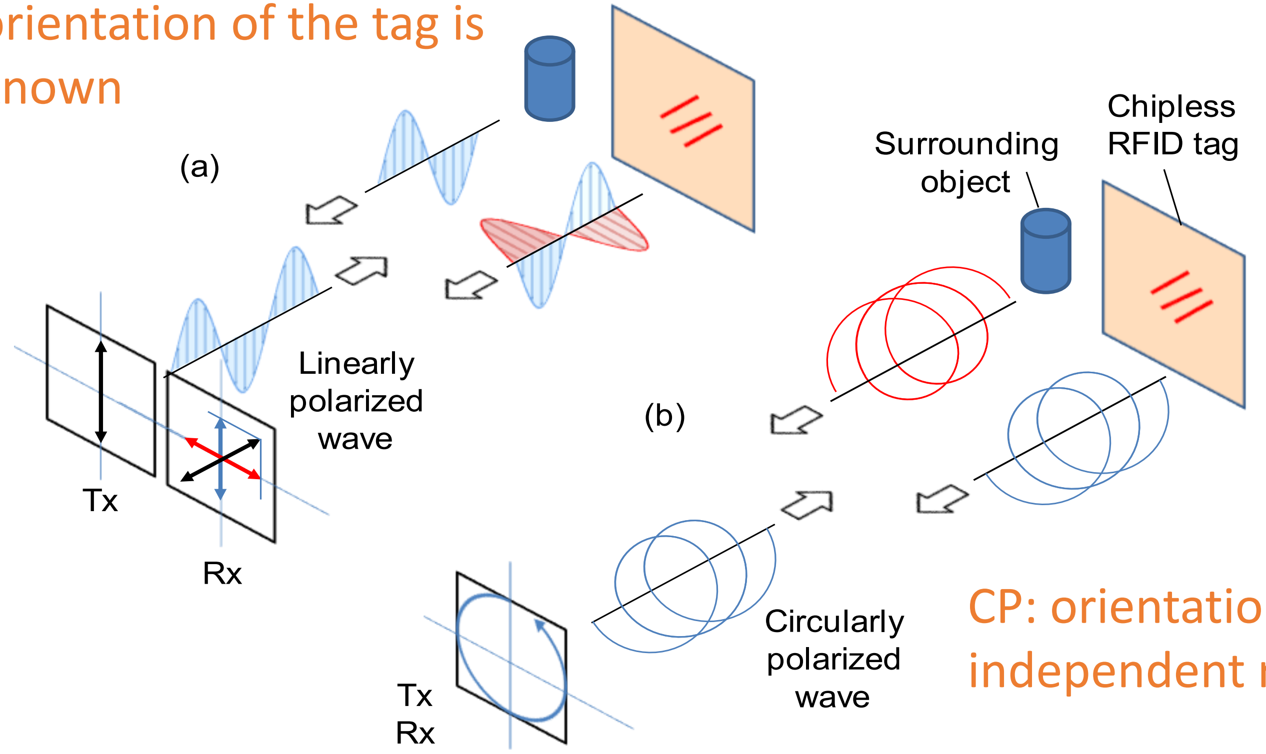


- Tag signature is inferior to its environment
- A depolarizing tag can be separated from its environment using cross-polarization measurement setup

Orientation has to be known …

II. Circular polarization method (CP)

LP: optimal reading when the orientation of the tag is known



CP: orientation-independent reading

Circular Polarization on Depolarizing Chipless RFID Tags

Marcos Martinez, Daniel van der Weide
University of Wisconsin, Madison, Wisconsin, 53706, USA

2016

IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 68, NO. 3, MARCH 2020

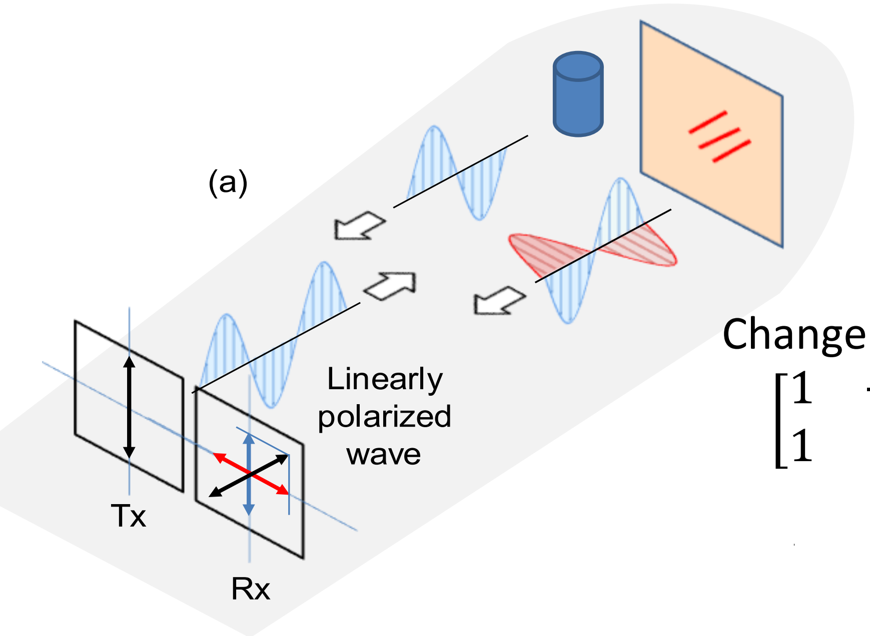
Orientation-Insensitive and Normalization-Free Reading Chipless RFID System Based on Circular Polarization Interrogation

Simone Genovesi, *Member, IEEE*, Filippo Costa, *Senior Member, IEEE*, Francesco Alessio Dicandia, *Student Member, IEEE*, Michele Borgese, and Giuliano Manara, *Fellow, IEEE*

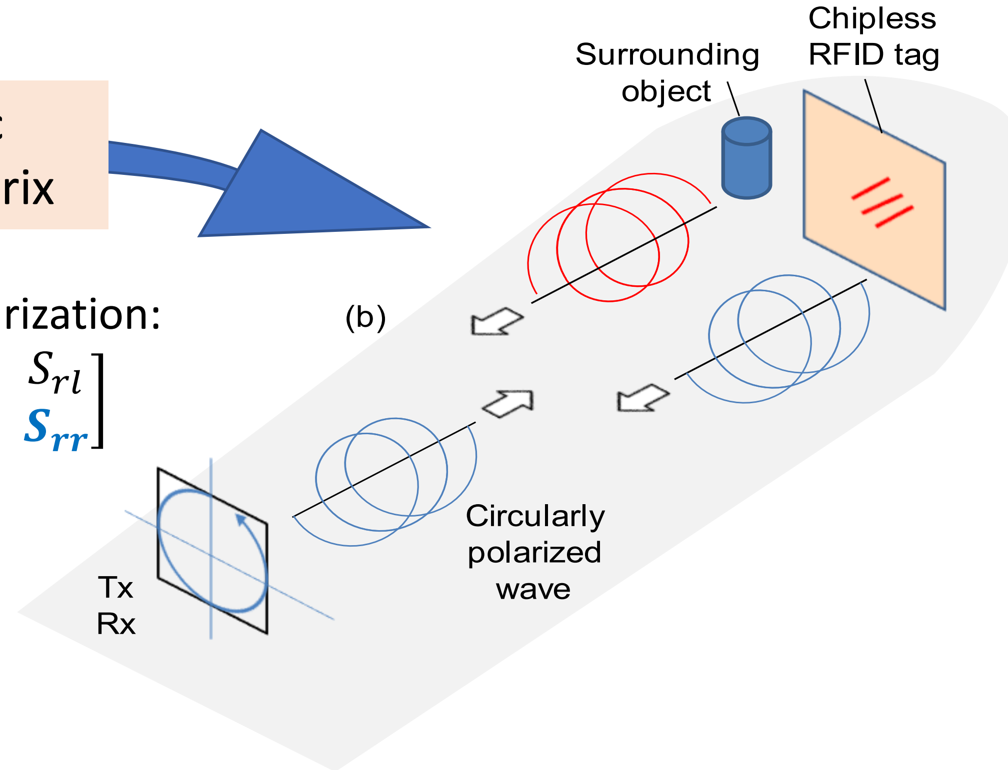
2020

Objective 1:
assess relevance of CP approach

II. Circular polarization method (CP)



Polarimetric scattering matrix

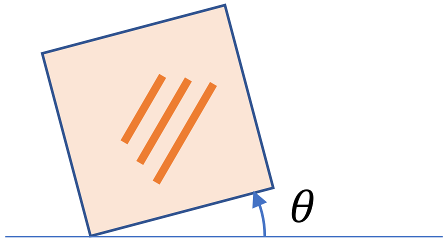


Change of basis from linear to circular polarization:

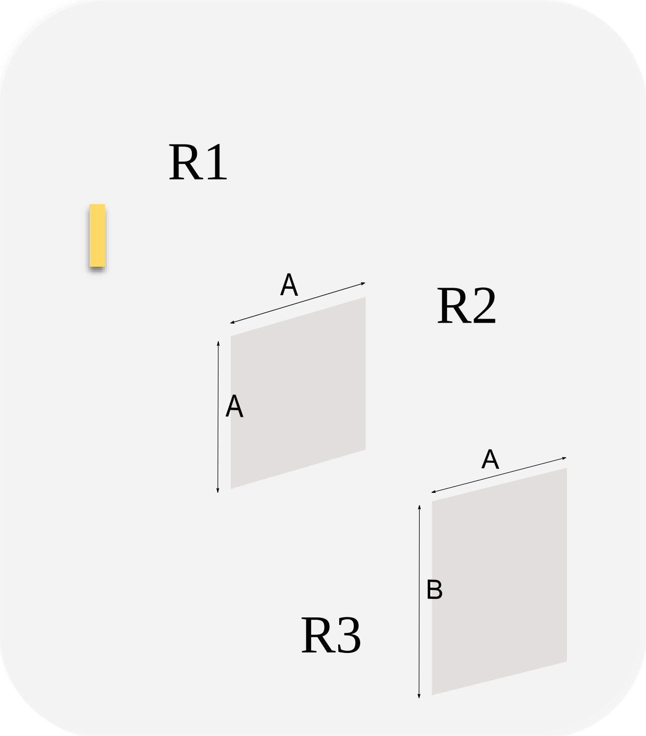
$$\begin{bmatrix} 1 & -j \\ 1 & j \end{bmatrix} \cdot \begin{bmatrix} S_{vv} & \boldsymbol{S_{vh}} \\ S_{hv} & S_{hh} \end{bmatrix} \cdot \begin{bmatrix} 1 & 1 \\ -j & j \end{bmatrix} = \begin{bmatrix} S_{ll} & S_{rl} \\ S_{lr} & \boldsymbol{S_{rr}} \end{bmatrix} \quad (1)$$

Rotation of the tag along the line of sight (roll angle):

$$\boldsymbol{S}(\theta) = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \cdot \begin{bmatrix} S_{vv} & S_{vh} \\ S_{hv} & S_{hh} \end{bmatrix} \cdot \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \quad (2)$$



II. Circular polarization method (CP)



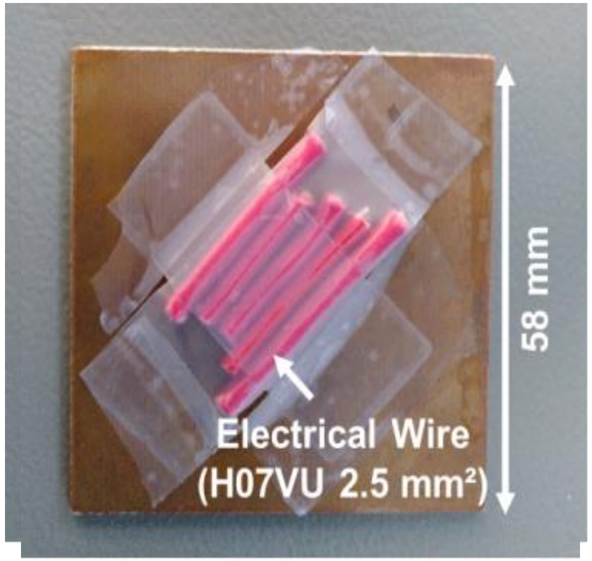
#	Scatterer type	$\boldsymbol{S}(0)$	$\boldsymbol{S}(\theta)$ calculated using (2)	$\boldsymbol{S}_c(\theta)$ calculated using (1) and (2)
R1	Dipole like scatterer	$a\begin{bmatrix}1 & 0\\ 0 & 0\end{bmatrix}$	$a\begin{bmatrix}\cos^2\theta & -\sin\theta\cos\theta\\ -\sin\theta\cos\theta & \sin^2\theta\end{bmatrix}$	$\frac{a}{2}\begin{bmatrix}e^{j2\theta} & 1\\ 1 & e^{-j2\theta}\end{bmatrix}$
R2	Specular reflexion (ideal environment)	$a\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}$	$a\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}$	$a\begin{bmatrix}0 & 1\\ 1 & 0\end{bmatrix}$
R3	Non specular reflexion (realistic environment)	$\begin{bmatrix}a & 0\\ 0 & b\end{bmatrix}$	$\begin{bmatrix}a\cos^2\theta + b\sin^2\theta & (b-a)\sin\theta\cos\theta\\ (b-a)\sin\theta\cos\theta & b\cos^2\theta + a\sin^2\theta\end{bmatrix}$	$\begin{bmatrix}(a-b)e^{j2\theta} & a+b\\ a+b & (a-b)e^{-j2\theta}\end{bmatrix}$

- $\boldsymbol{S_{vh}}$ and $\boldsymbol{S_{rr}}$ are not zero for a realistic environment R3
- The phase of $\boldsymbol{S_{rr}}$ is a function of the angle θ for a realistic environment R3

$$E_S^{tot}(\theta) = \left(S_{rr}^{tag}(\theta) + S_{rr}^{env}(\theta_0)\right) E_r^i$$

- Environment is predominantly vertical or horizontal, so that θ_0=0° or θ_0=90°, which leads to a cancellation of $\boldsymbol{S_{vh}}$ but not $\boldsymbol{S_{rr}}$.
- The magnitude of the total signal E_r^{tot} varies with θ due to the possible recombination of the respective phases. The hypothesis of rotational invariance is therefore not valid for CP in presence of an environment like R3.

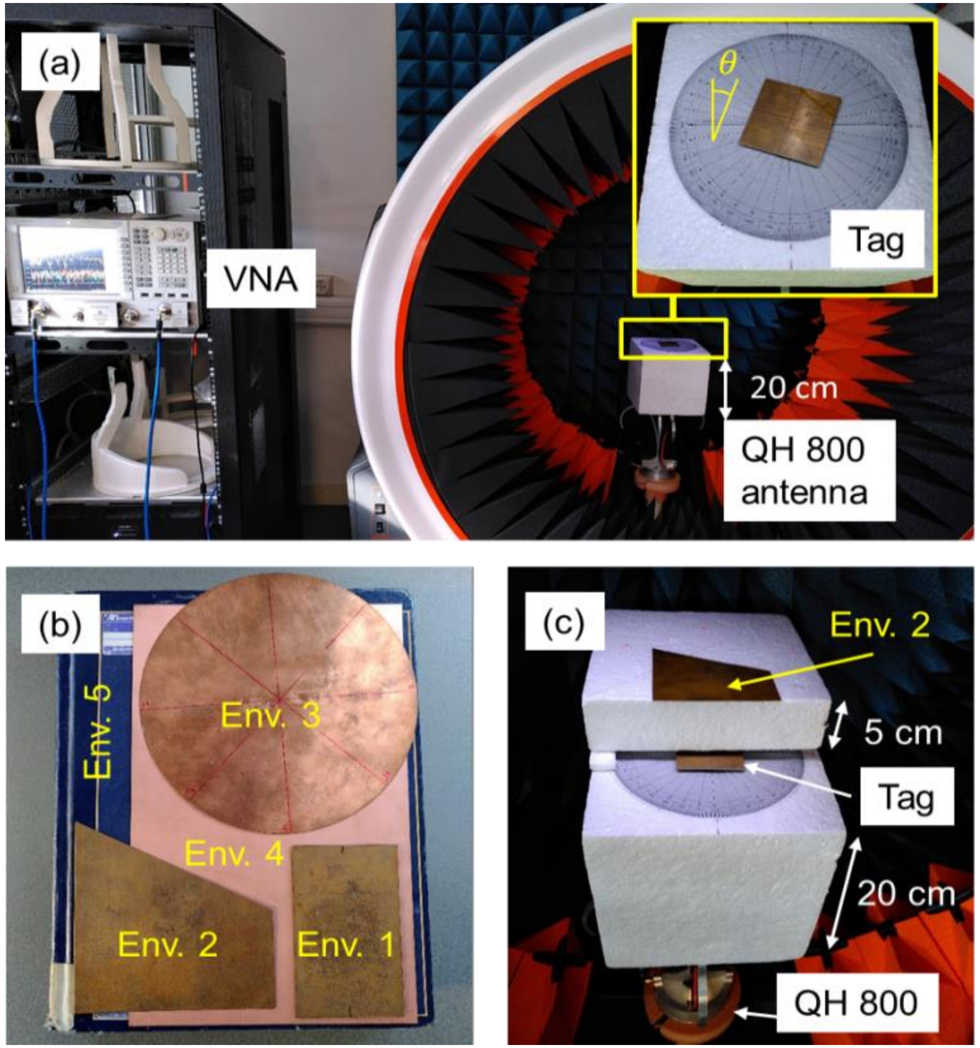
II. CP - Measurments



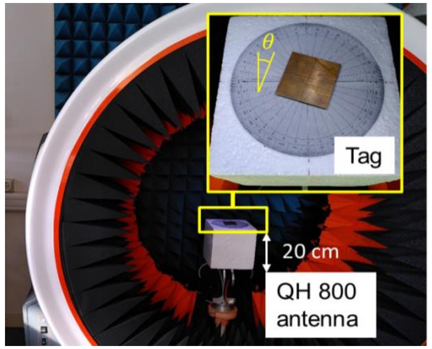
	F(GHz)	Q	$S_{21}(dB)$
Res1	3.06	87	-40.2
Res2	3.59	89	-41.8
Res3	4.1	117	-43.1
Res4	4.50	107	-44.5
Res5	4.96	90	-43.1
[1]	3.58	79	-41.5

Picture of the tag made with electrical wires to a ground plane.

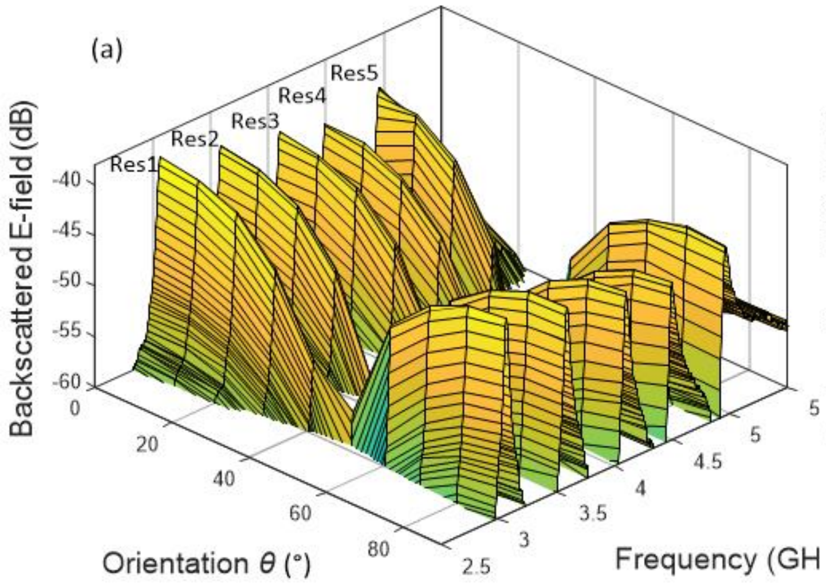
Note: This rapid prototyping method gives comparable performances to optimized tags realized by chemical etching on RF materials



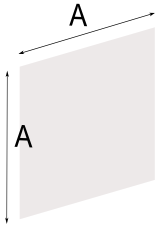
II. CP - Rotational invariance

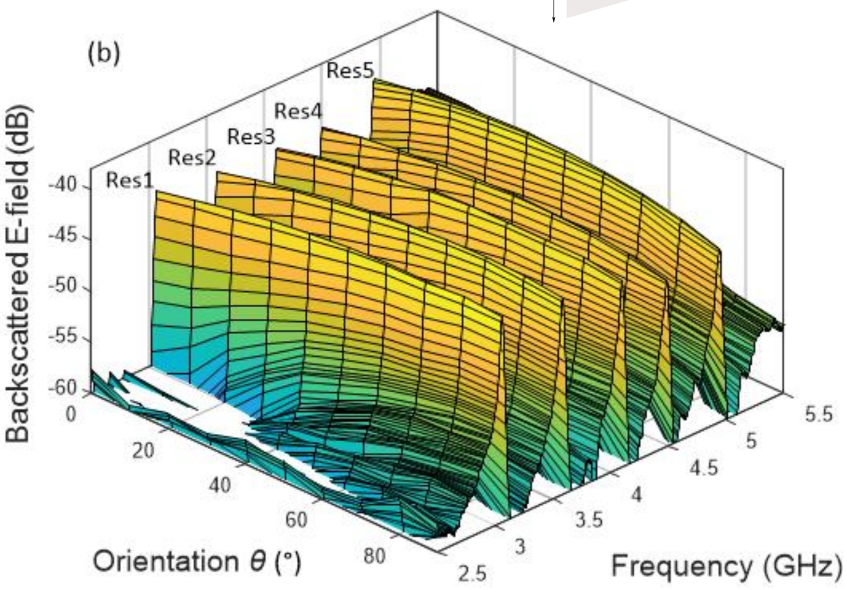


LP method

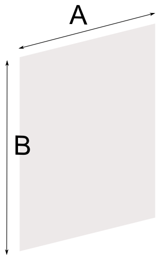


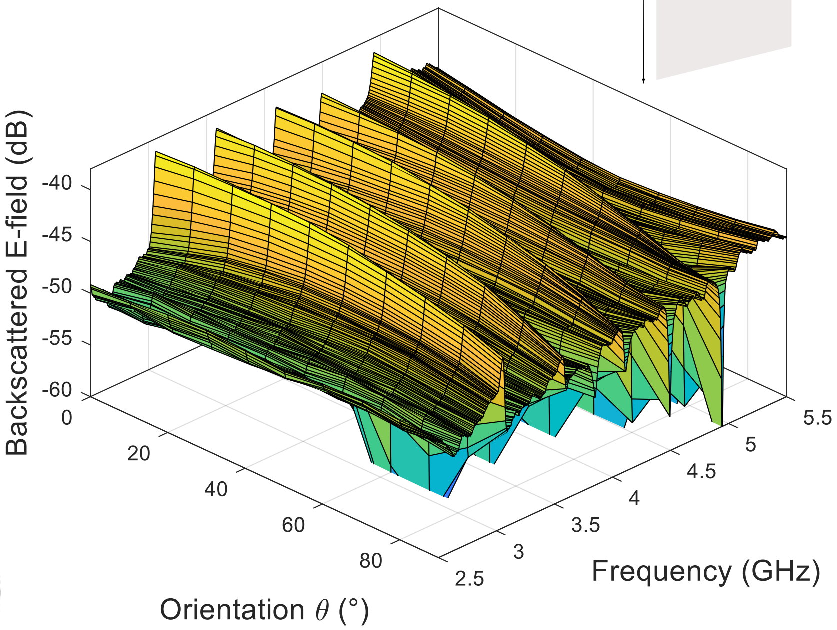
CP method: R2





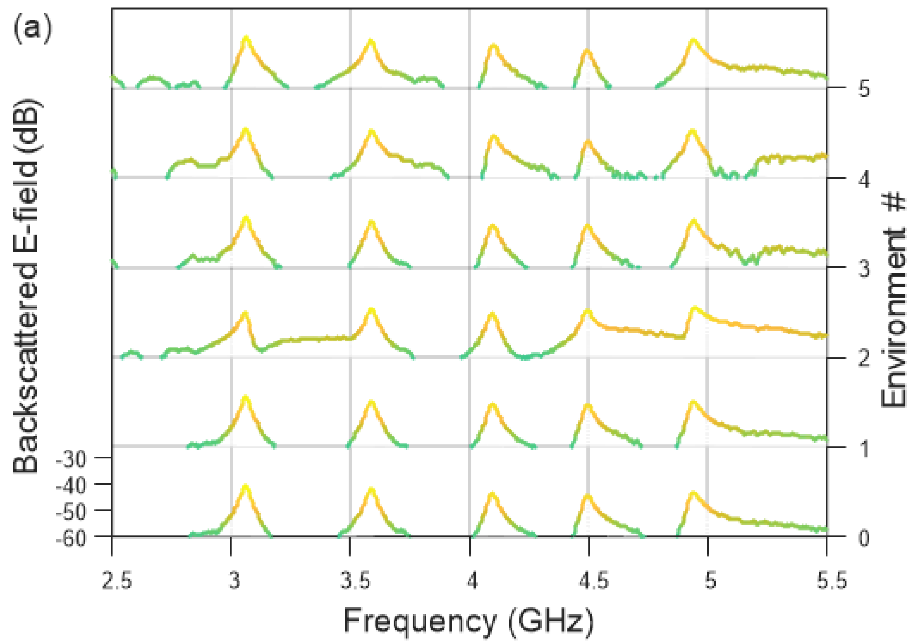
CP method: R3



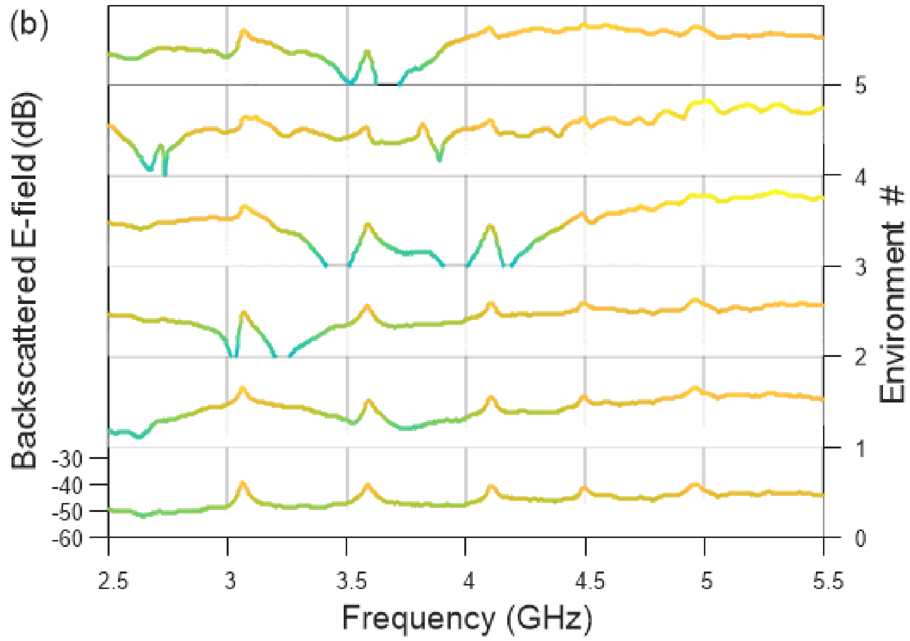


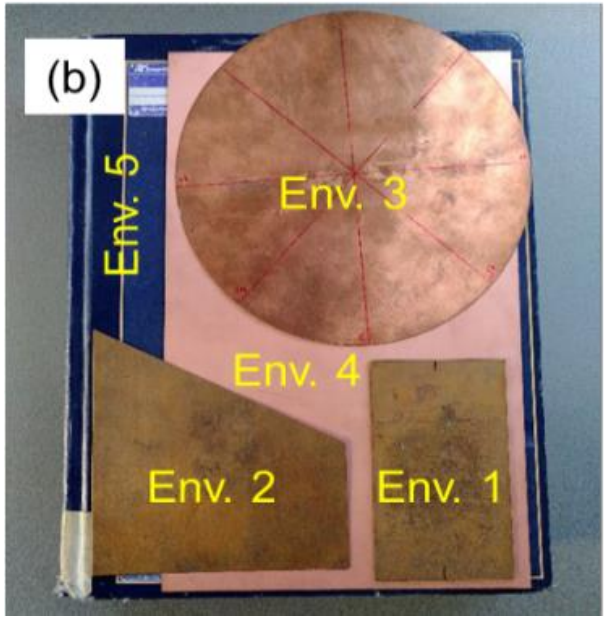
II. CP – Isolation

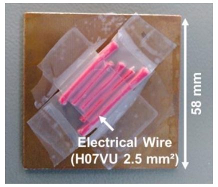
LP methods



CP methods







From both theory and measurements, for the circular polarization approach, the assumptions of orientation independence and isolation are valid only for very specific and non-realistic environments

II. Conclusion for CP

For the circular polarization reading method, we have tested the hypotheses of :

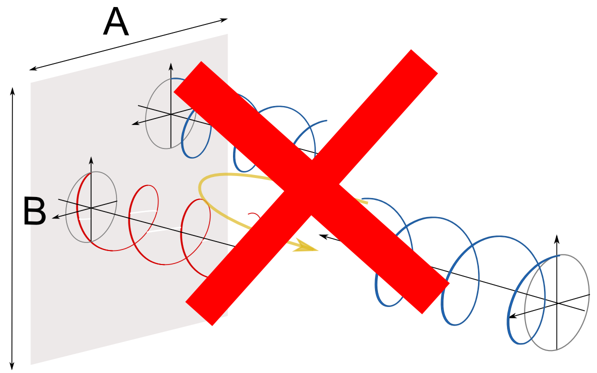
- rotational invariance and
- isolation.

⇒ The method can be considered invariant by rotation for a tag measured in semi-anechoic condition and a well-chosen ground plane shape (R2 of table 1)

⇒ but not for real environment.

It was also found that the method cannot be considered as an improvement of [1] (cross-polarization method) in terms of reading robustness because it is highly impacted by environment.

Other possibilities exist at the reader for invariance by rotation (invariant from the scattering matrix) but are out of the scope of this presentation.



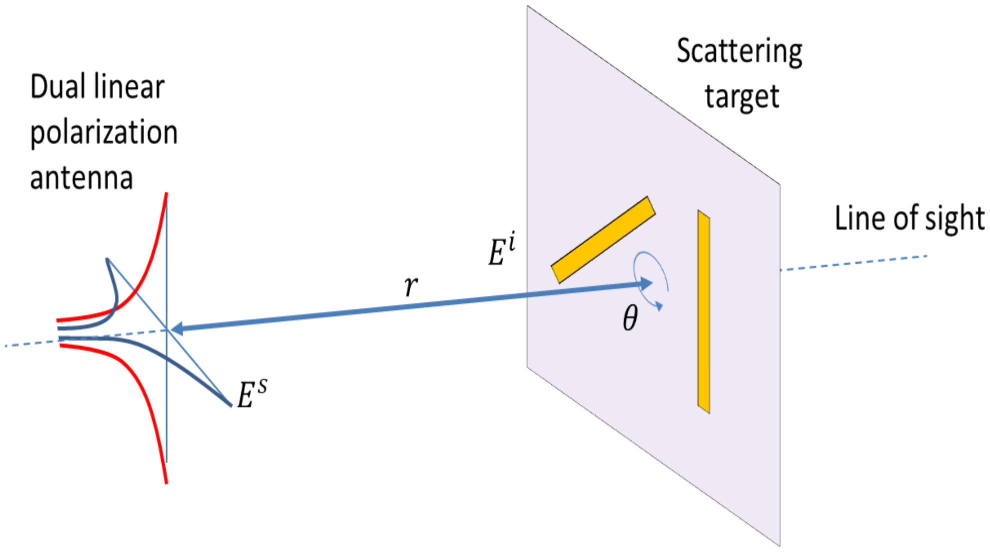
Objective 2:
design cross –roll
invariant scatterers

III. Theory and design of roll invariant scatterer

Polarisation scattering matrix $\boldsymbol{S}$

$$\begin{bmatrix} E_v^s \\ E_h^s \end{bmatrix} = \frac{e^{-jkr}}{\sqrt{4\pi} \cdot r} \cdot \begin{bmatrix} S_{vv} & S_{vh} \\ S_{hv} & S_{hh} \end{bmatrix} \cdot \begin{bmatrix} E_v^i \\ E_h^i \end{bmatrix} \quad (1)$$

with $S_{vh} = S_{hv}$



When the target is rotated from an angle θ with respect to the line of sight:

$$\boldsymbol{S}(\theta) = \boldsymbol{\Omega}^t \cdot \boldsymbol{S}(0) \cdot \boldsymbol{\Omega} \quad (2) \qquad \boldsymbol{\Omega} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix}$$

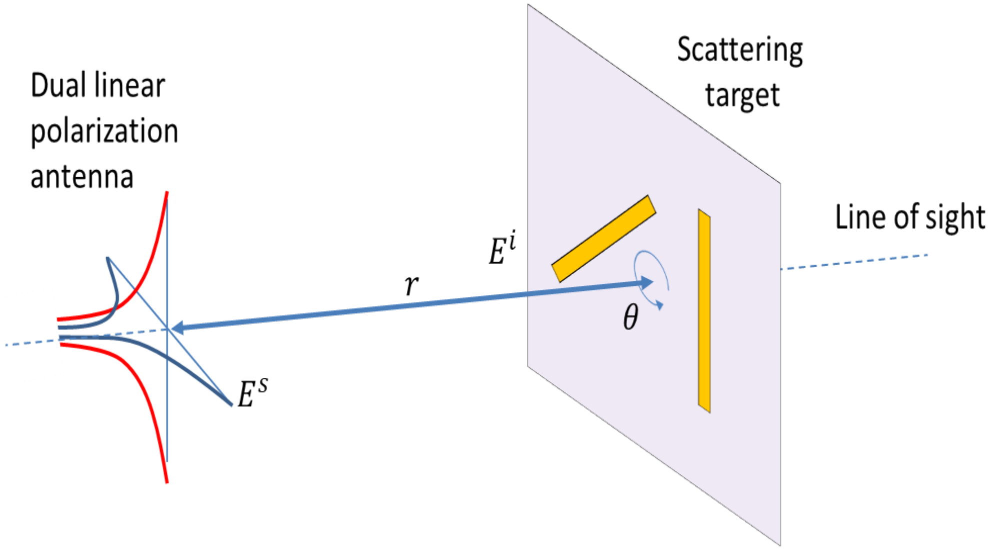
$$S_{vh}(\theta) = \frac{S_{hh} - S_{vv}}{2} \sin 2\theta + S_{vh} \cos 2\theta \quad (3)$$

For any scatterer, the components of the scattering matrix depend on the angle θ

Objective : $|S_{vh}(\theta)| = C$

III. Theory and design of roll invariant scatterer

$$S_{vh}(\theta) = \frac{S_{hh} - S_{vv}}{2} \sin 2\theta + S_{vh} \cos 2\theta \qquad (3)$$



Invariance conditions for cross-polarization :

With (3): $$S_{vh}(\pi/4) = \frac{S_{hh} - S_{vv}}{2}$$

So that (3) can be rewritten:

$$S_{vh}(\theta) = S_{vh}(\pi/4) \cdot \sin 2\theta + S_{vh}(0) \cdot \cos 2\theta \qquad (4)$$

Equation (4) reduces to a circle equation when we satisfy the relation:
which guarantees the invariance of the amplitude of $S_{vh}(\theta)$.

$$S_{vh}(\pi / 4) = j \cdot S_{vh}(0)$$

This condition imposes magnitude equality and phase quadrature for the two orientations $\pi/4$ and 0.

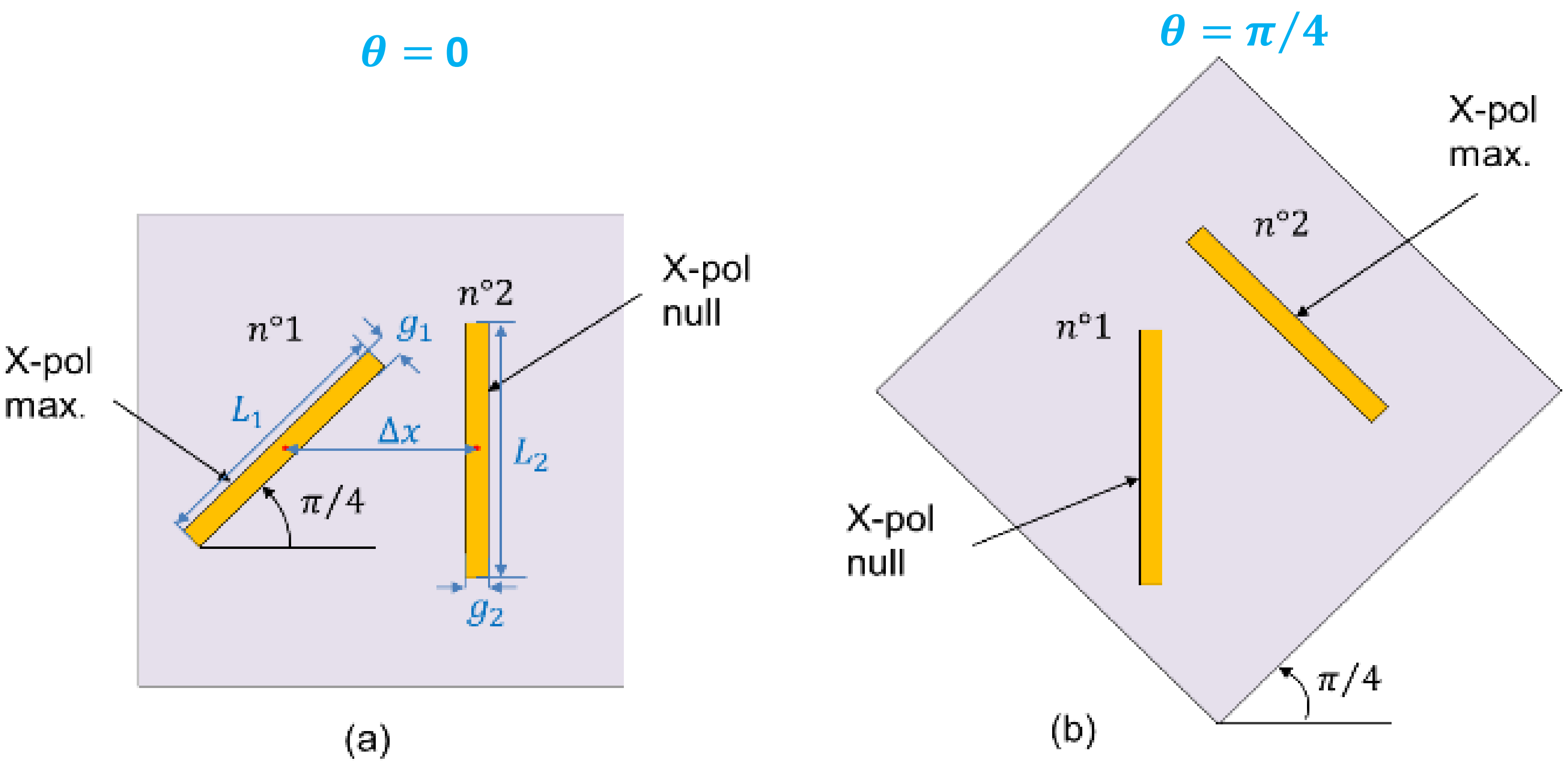
III. Design principle

The scatterer is composed of two microstrip dipoles printed on RO4003 ($\varepsilon_r = 3.55$, $\tan\delta = 2.7 \cdot 10^{-3}$) of thickness 0,8 mm.

The width $g_{1,2}$ of the dipoles is fixed to 2 mm and their length is chosen such that f_0 is approximately 3,19 GHz ($L_{1,2} \simeq 26.9$ mm)

$$L_2 = L_1 + 2\Delta L$$

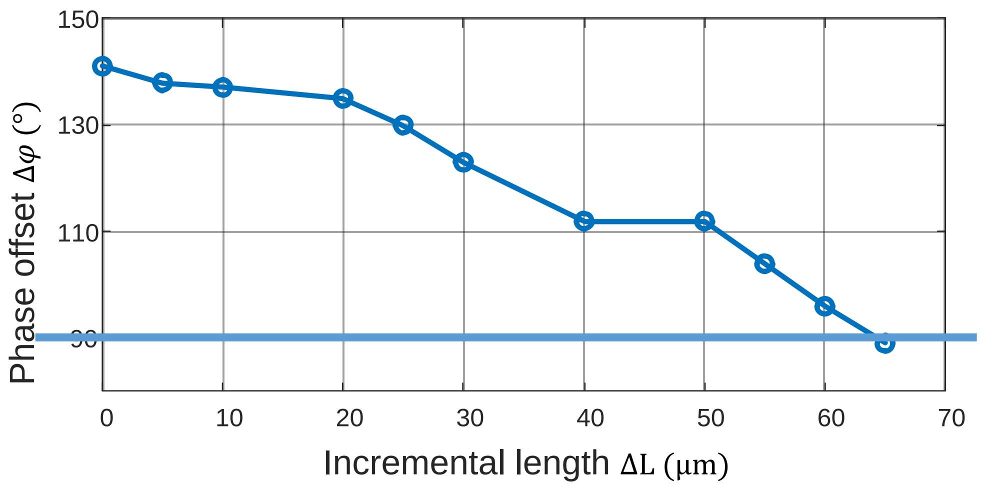
The value ΔL required for a 90° phase shift, calculated is about 50 µm.



Cross-polarization contribution from a target composed of two microstrip dipoles oriented at 0 (a) et $\pi/4$ (b) .

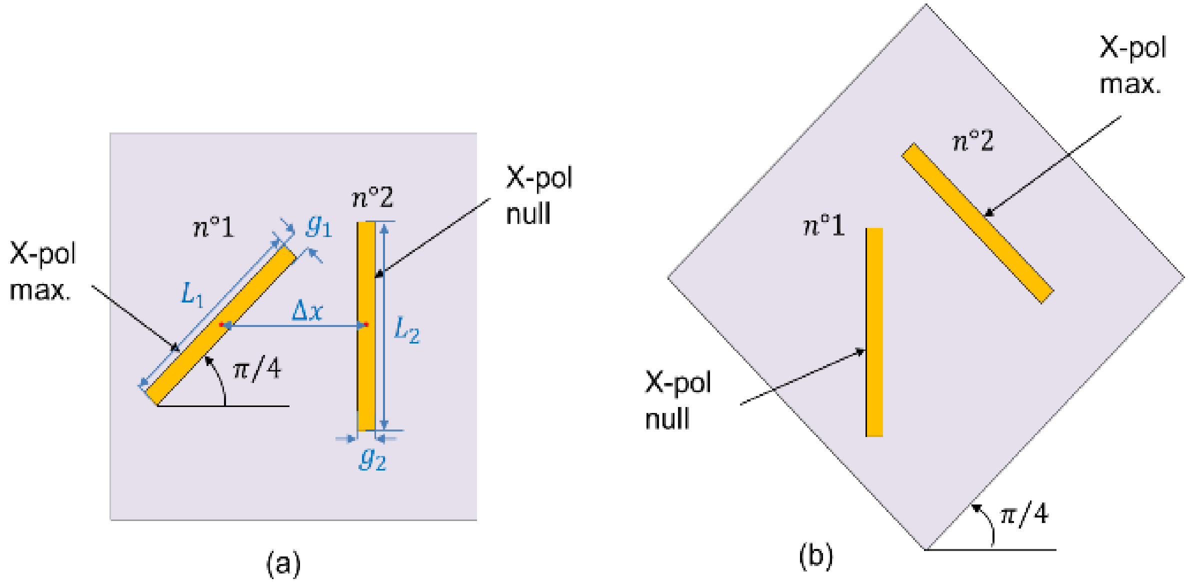
III. Simulation results

Dimension the two dipoles in the presence of coupling :



Phase shift between $S_{vh}(0°)$ and $S_{vh}(45°)$ as a function of incremental length ΔL.

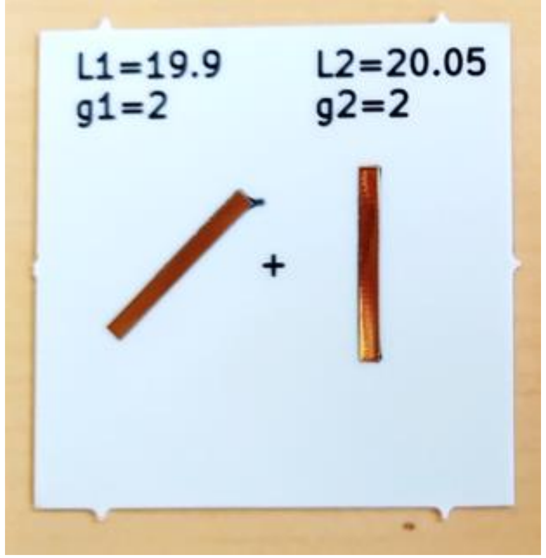
$L_1 = 26.9$ and $L_2 = L_1 + 2\Delta L$, f_0 =3.19 GHz



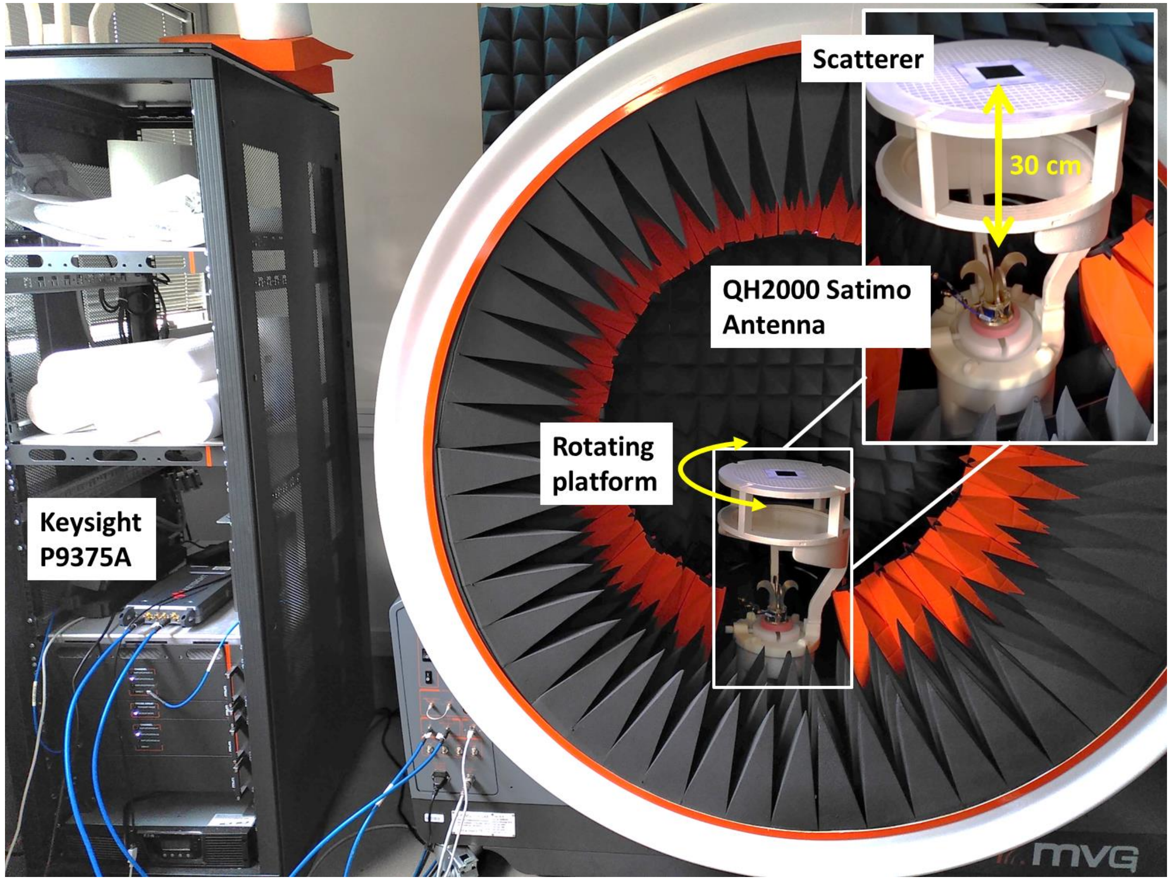
The 90° phase shift is obtained at 3.19 GHz for lengths $L_1 = 26.9$ mm and $L_2 = 27.03$ mm ($\Delta L = 65$ µm).

III. Measurement and results

A scatterer working at 4,26 GHz has been manufactured by chemical etching.
The length of the dipoles are L_1 = 19,9 mm and L_2= 20,05 mm.
Width are g_1= g_2= 2mm.
Square ground plane of dimension 50 mm×50 mm ; realized with RO4003 of thickness h=0,8 mm.

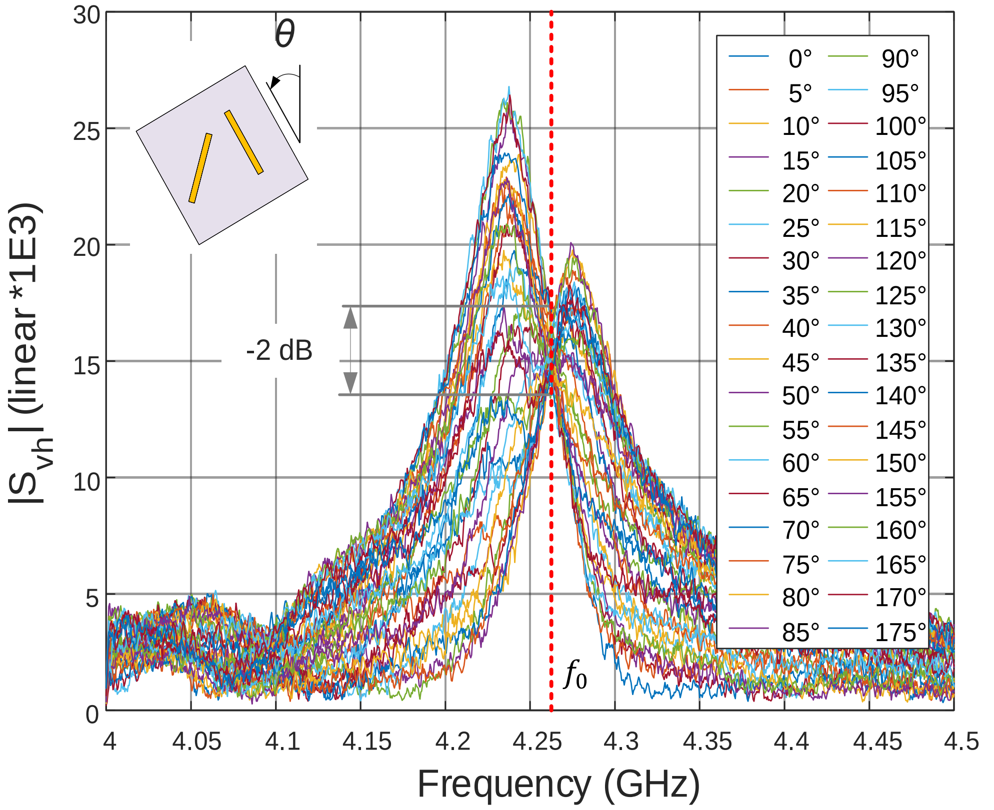


Diffuseur manufacturé

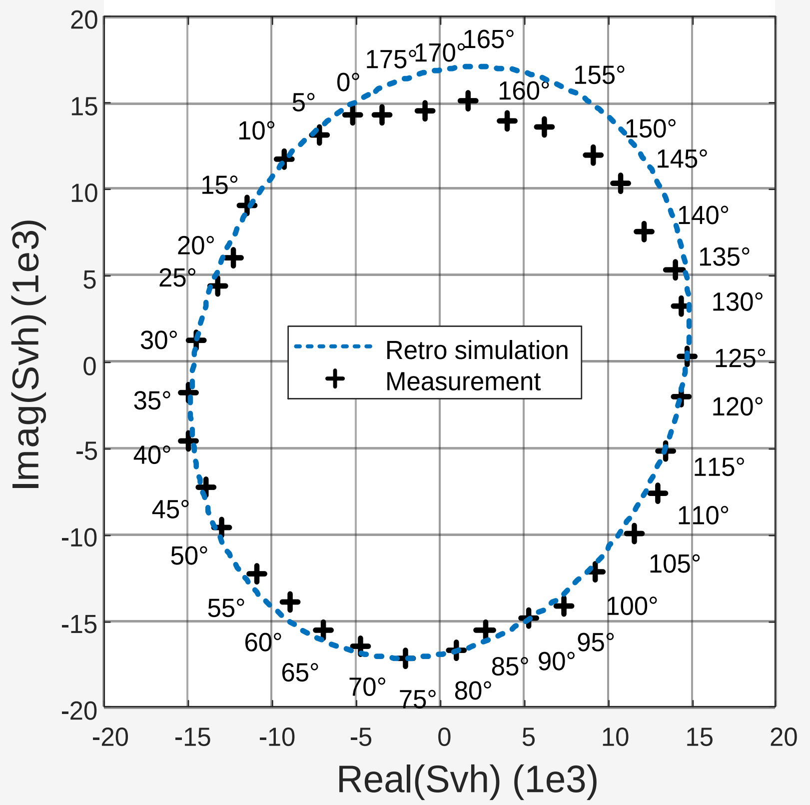


Measurement setup. Monostatic, Cross polar measurement in semi-anechoïc environment (modified starlab).

III. Measurement and results

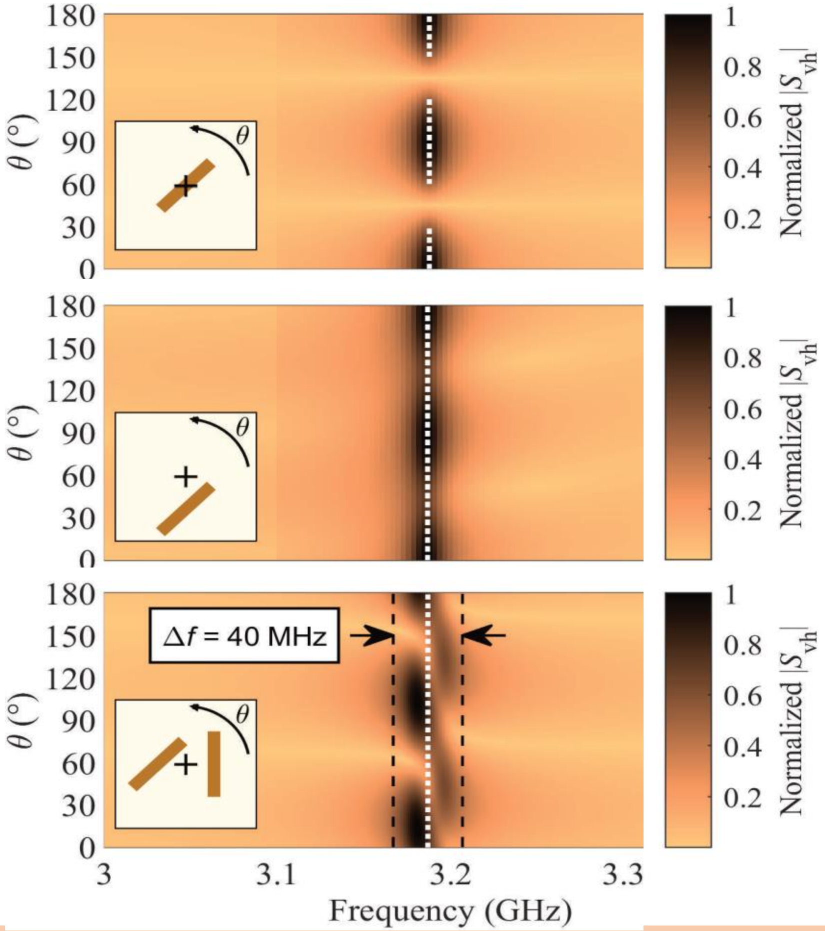


Measurement results of the cross-polarization component of the scattering matrix as a function of frequency for different values of θ.



Evolution of S_{vh} at f0 as a fonction of angle θ in complex plane. f_0= 4,26 GHz, AR=0,79 (-2dB).

IV. Practical implementation



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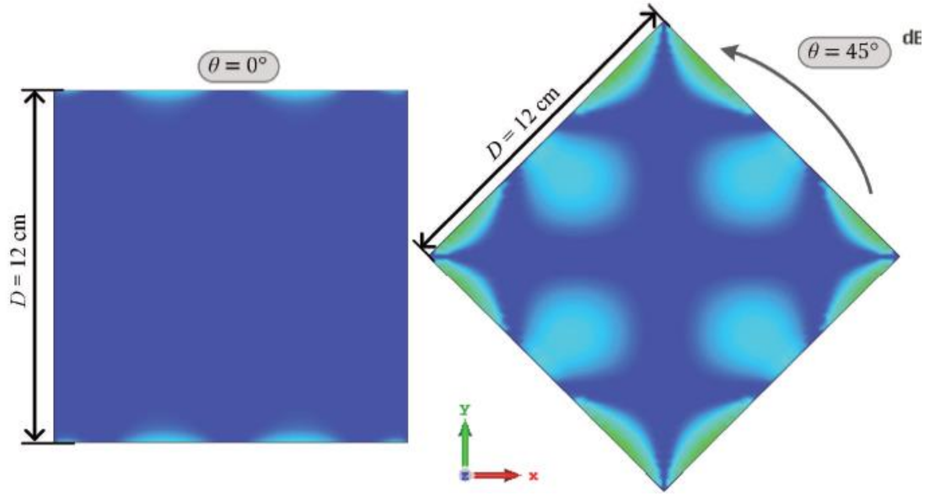

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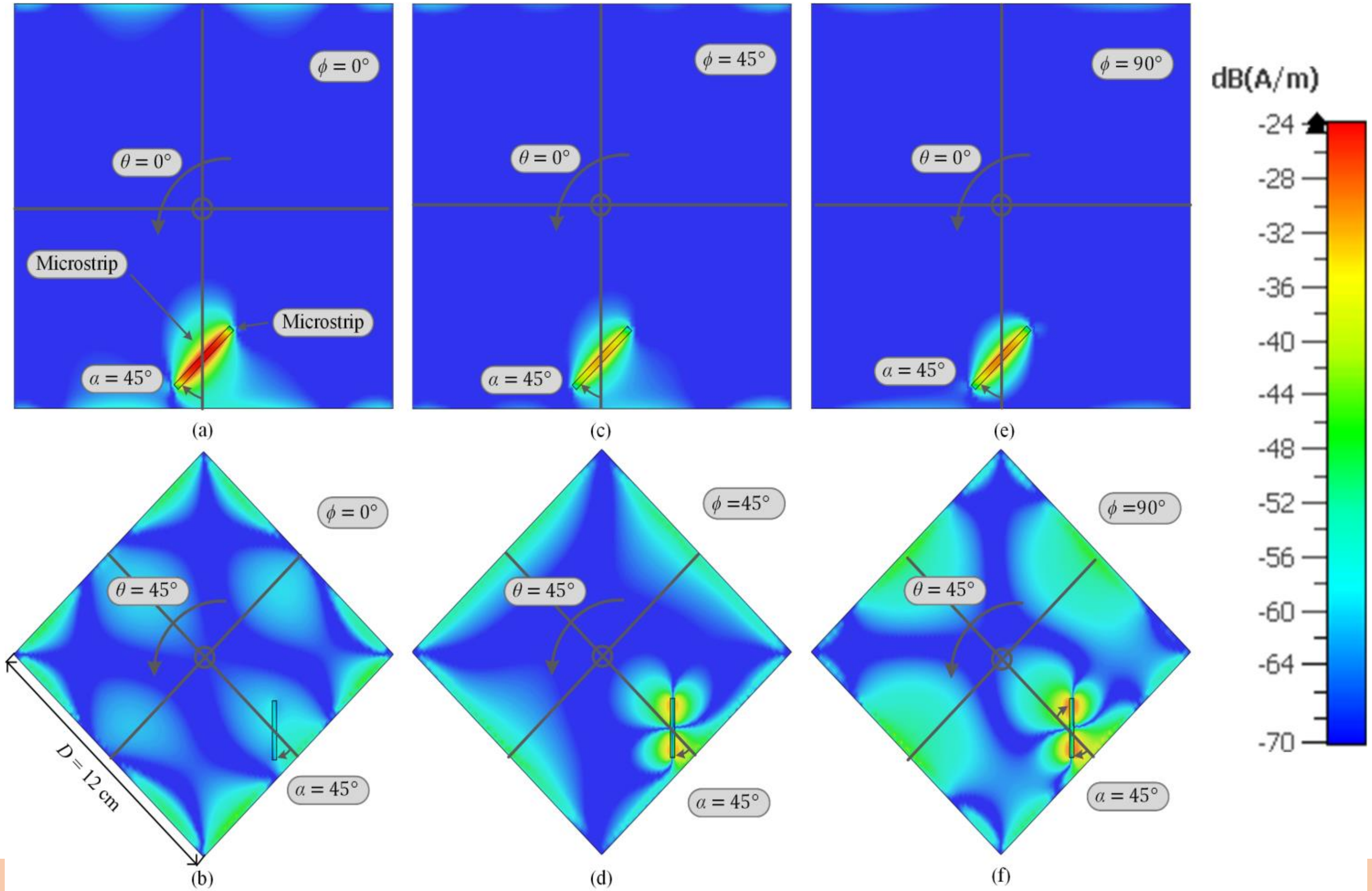
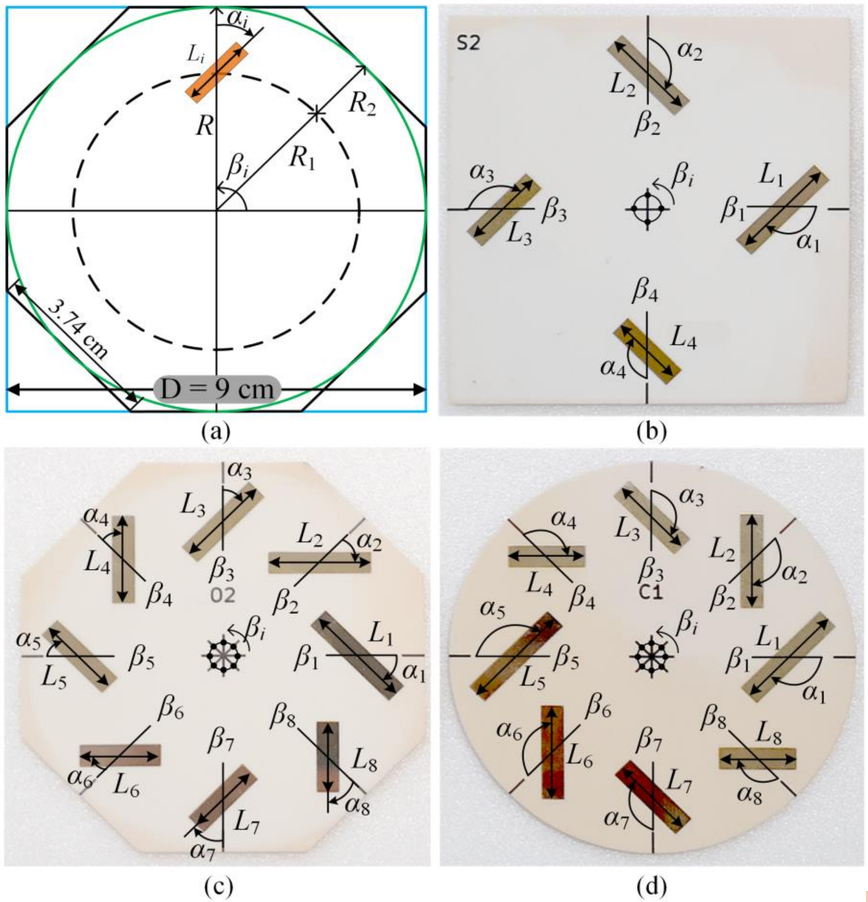
IV. Principle





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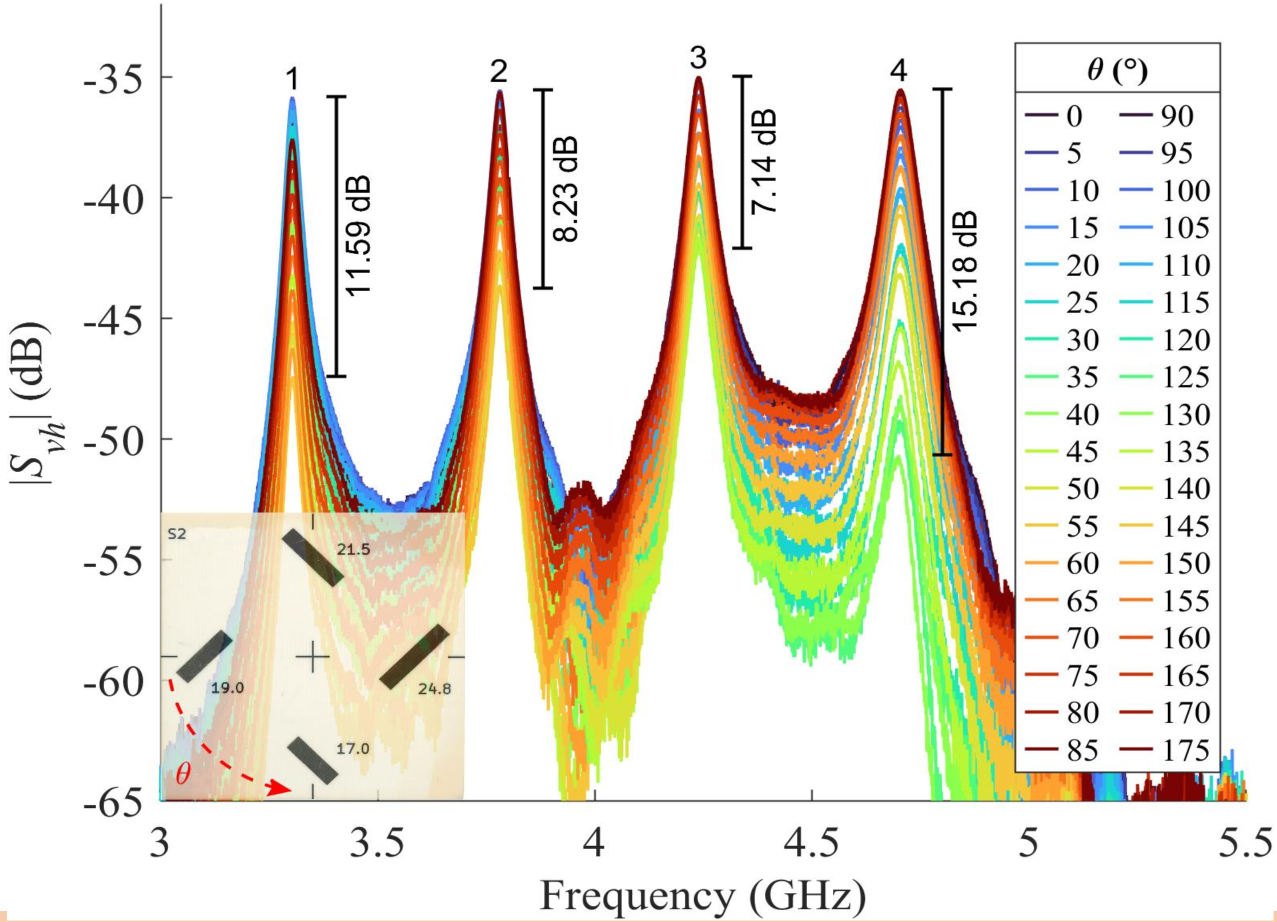
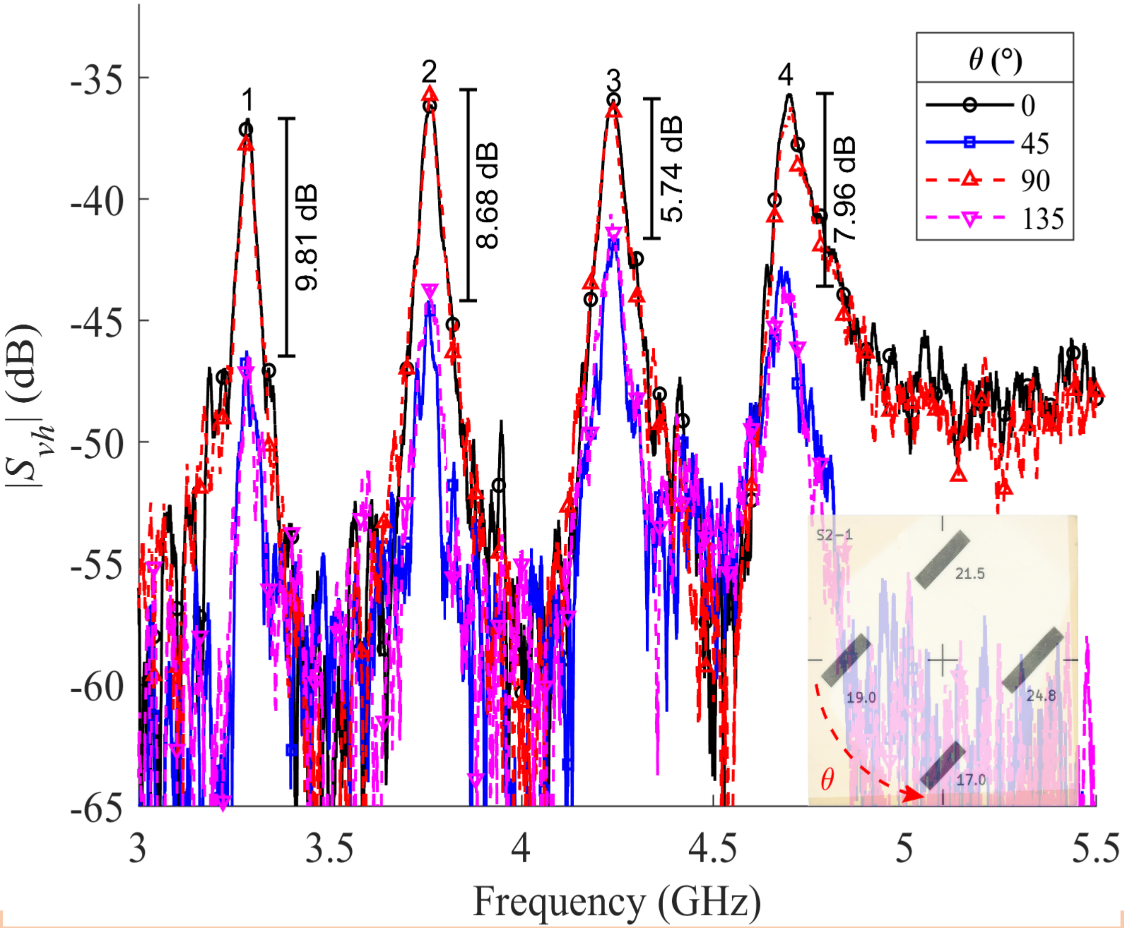
IV. Measurement results





V. Conclusion

- A simple method is proposed to design orientation invariant resonant scatterers composed of two microstrip dipoles slightly shifted in frequency and with a relative orientation of 45.
- A scatterer operating at 4.26 GHz has been fabricated and measured, providing good performance with an axial ratio equal to 2 dB.
- Although simple and illustrative, the current design is sensitive to manufacturing tolerance.

- A robust method that uses coupling between the resonators and the ground plane was used and provided more practical designs (one resonator per frequency, lower spectral occupancy).
- Less uniform amplitude but higher minimal RCS than the previous design.

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Diffuseur dépolarisant invariant par rotation

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