CRESITT INDUSTRIE
Centre de Ressources
Technologiques en Électronique

Séminaire : Électronique imprimée, flexible et 3D

Design et fabrication d'antenne flexible,

C.Alayrac CRESITT Industrie & S. Parlati Arc-en-Ciel – 28 Juin 2022 – version 1.0

Réf du document : DT_PPT_CA_Séminaire_ElectroniqueImprimée_flexible_3D_v1.0_20220628

Le CRT CRESITT est soutenu par :

L'action de diffusion technologique est cofinancée par l'Union européenne.
L'Europe s'engage en région Centre-Val de Loire avec le Fonds européen de développement régional.

Sommaire

- les applications antennes flexibles
- La technologie
- Le démonstrateur réalisé
- La problématique du DAS
- Conclusion et temps pour les questions

Les antennes flexibles

FLEX Antennas

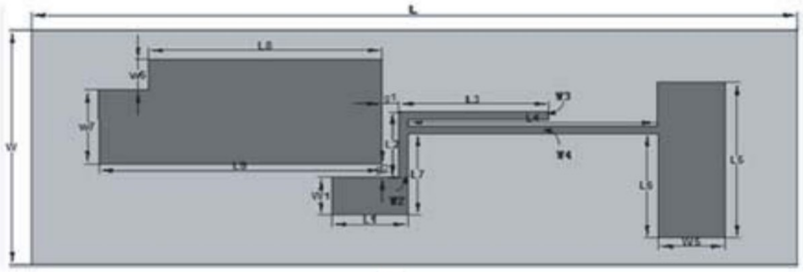
	Image	Référence fabricant	Description	Fréquence (centre/bande)	Pertes par réflexion	Gain	Quantité disponible	Afficher les détails
		W3906B0100	RF ANT 2.15GHZ FLAT PATCH CAB	2,15GHz	-10dB	4dBi	2724 - Immédiatement	Afficher les détails
		W3907B0100	RF ANT 2.15GHZ FLAT PATCH CAB	2,15GHz	-7,5dB	4,2dBi	11611 - Immédiatement	Afficher les détails
		W3908B0100	RF ANT 1.585GHZ FLAT PATCH ADH	1,585GHz	-10dB	0,3dBi	7196 - Immédiatement	Afficher les détails
		W3917B0100	RF ANT 2.4GHZ/5.4GHZ FLAT PATCH	2,4GHz, 5,4GHz	-	4dBi	7608 - Immédiatement	Afficher les détails
		W3918B0100	RF ANT 2.4GHZ/5.4GHZ FLAT PATCH	2,4GHz, 5,4GHz	-	4dBi	0	Afficher les détails
		W3919B0100	RF ANT 5.4GHZ FLAT PATCH CAB ADH	5,4GHz	-	3dBi	0	Afficher les détails
		W3920B0100	RF ANT 5.4GHZ FLAT PATCH CAB ADH	5,4GHz	-	3dBi	1430 - Immédiatement	Afficher les détails
		W3921B0100	RF ANT 2.4GHZ FLAT PATCH CAB ADH	2,4GHz	-	1dBi	2625 - Immédiatement	Afficher les détails
		W6102B0100	RF ANT 2.4GHZ/5.4GHZ FLAT PATCH	2,4GHz, 5,4GHz	-	6dBi	544 - Immédiatement	Afficher les détails
		W6113B0100	RF ANT 829MHZ/1.47GHZ FLAT CAB	829MHz, 1,47GHz, 1,58GHz, 1,94GHz, 2,5GHz, 3,5GHz	-10dB	4,2dBi	1080 - Immédiatement	Afficher les détails
		W3312B0100	RF ANT 892MHZ PCB TRACE U.FL ADH	892MHz	-8dB	0,8dBi	11392 - Immédiatement	Afficher les détails
		W3334B0150	RF ANT 2.4GHZ/5.4GHZ FLAT PATCH	2,4GHz, 5,4GHz	-	5,5dBi	2490 - Immédiatement	Afficher les détails
	Photo Non Disponible	W3915	RF ANT 920MHZ/1.59GHZ CAB 100MM	920MHz, 1,59GHz, 1,94GHz	8dB	2dBi	195 - Immédiatement	Afficher les détails

On en trouve à pléthore chez les cataloguistes

- Dédiée à une bande de fréquence
- Dédiée à certains substrats
- Rayon de courbure
- … vérifiez la datasheet !

Abracon
Advantech
Anaren
Antenova
Ethertronics
Johanson
LAIRD
LANTRONIX
LINX Technologies
LPRS
LS Research
MOLEX
Murata
ProANT
Radiall
RF solutions
Siretta
TAOGLAS
TE connectivity
TDK
Vishay
Walsin
Wurth
Yageo

Antenne double bande



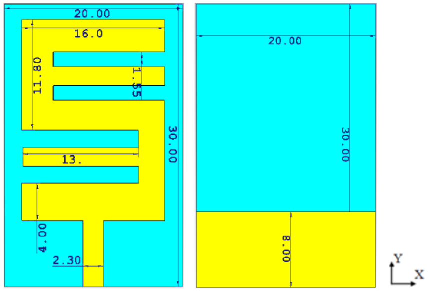
(a)

(b)

- bande ISM @2.45GHz & @5.8GHz
- Substrat : Denim (ε_r = 1.54)

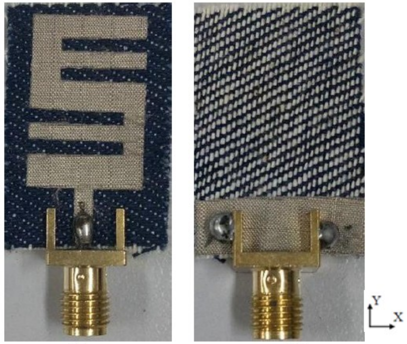
-Gain: 6.34 dBi @ 2.45 GHz
& 4.7 dBi @ 5.8 GHz

- Shift en fréquence et varation BW sur corps humain



(a) (b)

FIGURE 3. (a) Proposed antenna (Ant.5) (a) Front view (b) Back view [2].



(a) (b)

FIGURE 8. Prototype of the antenna (a) Front view (b) Back view.

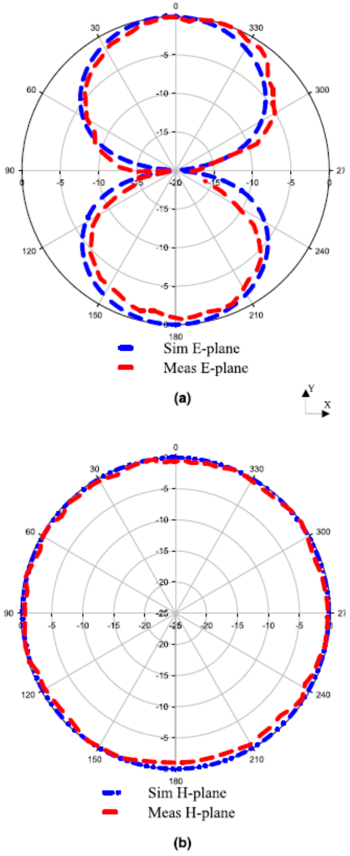


FIGURE 9. Simulated and measured radiation patterns of the antenna (Ant. 5): (a) E plane (b) H plane.

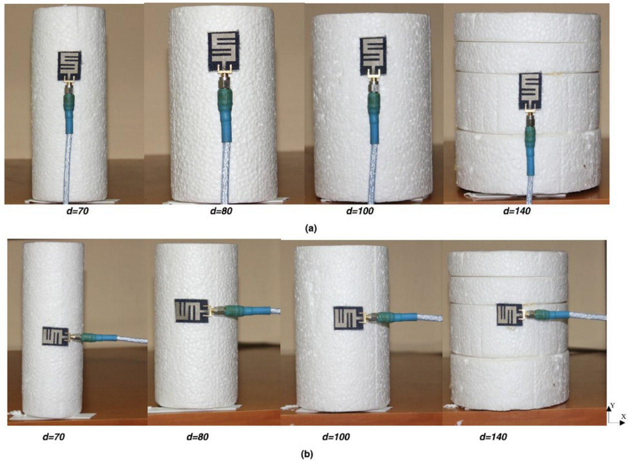


FIGURE 10. Photographs showing the antenna deformed by different curvatures (a) y-axis, (b) x-axis.

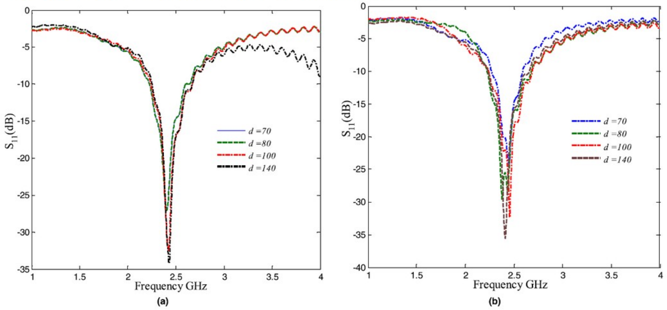
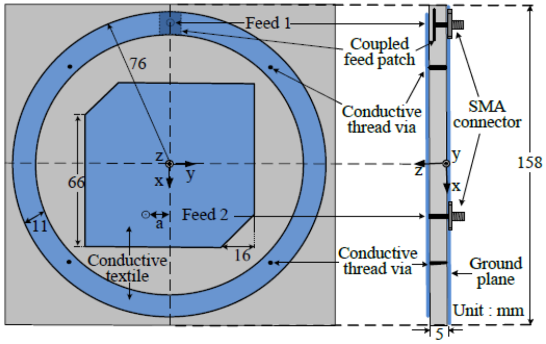
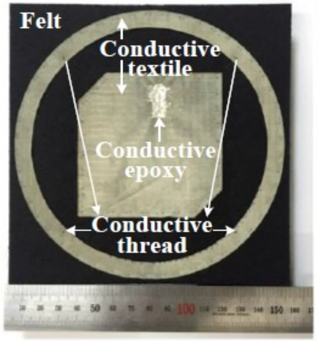


FIGURE 11. Measured reflection coefficient, S_{11}, on the (a) y-axis and (b) x-axis respectively, for different bending diameters (in mm).

Antenne Patch





- Patch tronqué : bande gps
- patch anneau circulair bande ISM

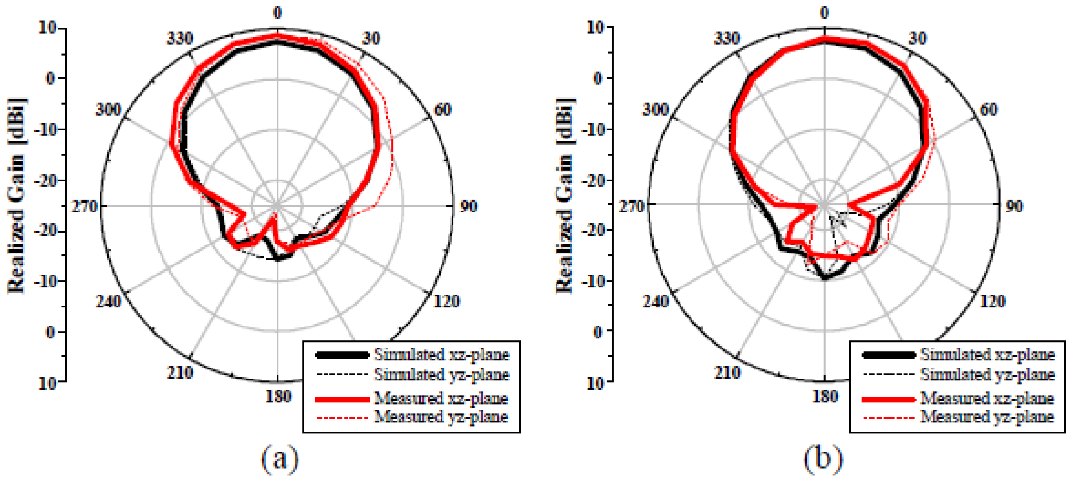
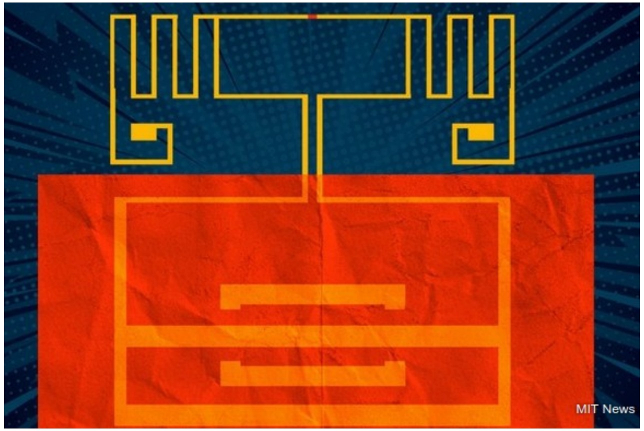


Fig. 13. Simulated and measured radiation patterns of the proposed antenna at 1.575 GHz (a) in free space, (b) on the head phantom.

Récupération d'énergie



Antenne patch flexible (*MIT*)

Redresseur Semi conducteur ultra fin (upto 10GHz)
(couche de disulfure de molybdène épaisseur trois atomes)

Efficacité : 40 %
(contre 50 à 60 % sur circuit intégré rigide)

Puissance 40µW *(150µW puissance RF Wifi)*

https://www.clubic.com/energie-renouvelable/actualite-850285-chercheurs-mit-reussi-transformer-ondes-wifi-electricite.html

Antenne mais pas seulement !

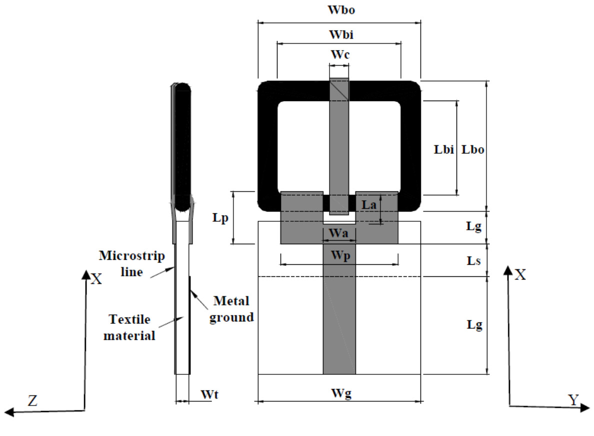


Fig.,2. Belt antenna dimensions

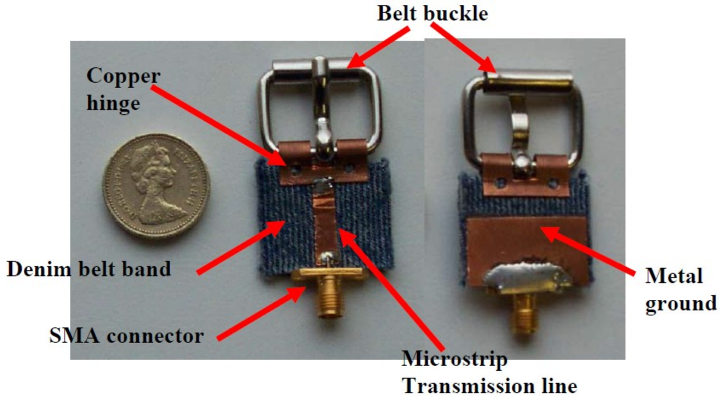


Fig.1. Photos of the belt antenna. Left: Front view; right: back view.

@2.4 GHz @ 5 GHz

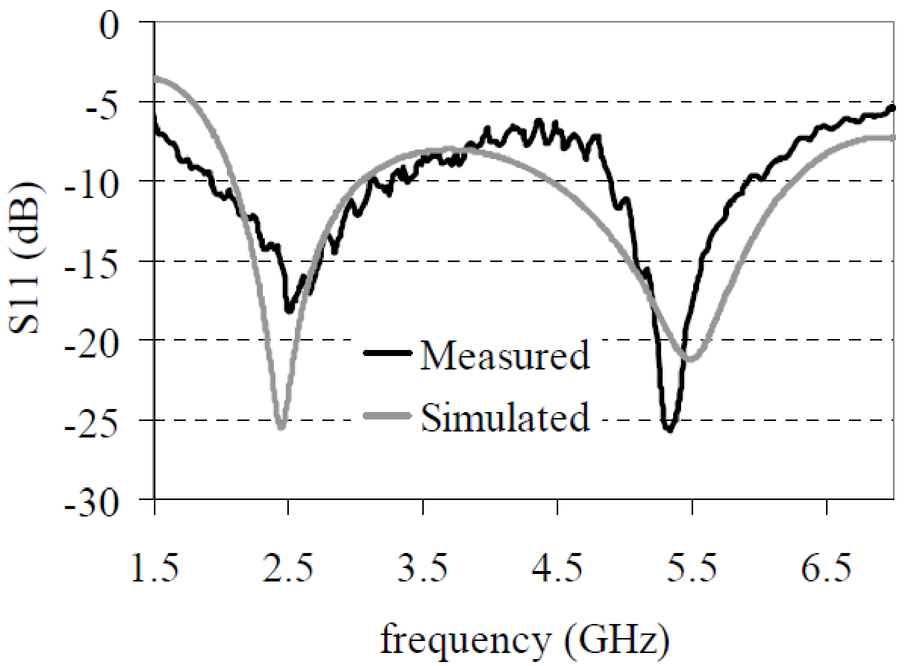
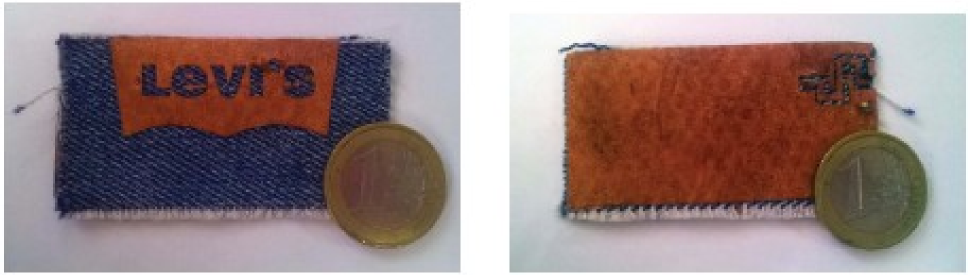
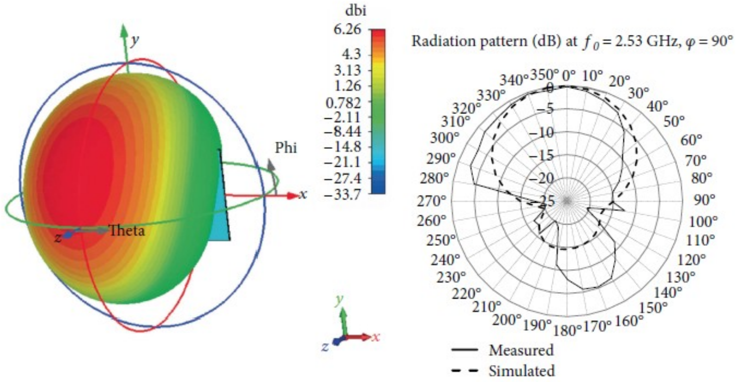


Fig.3. Reflection coefficient for the belt antenna

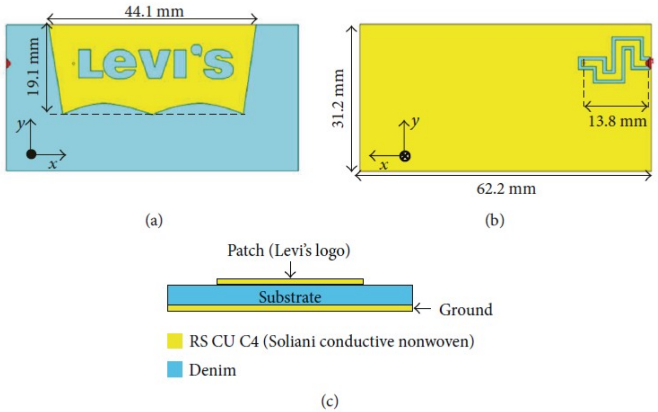
Antenne mais pas seulement !

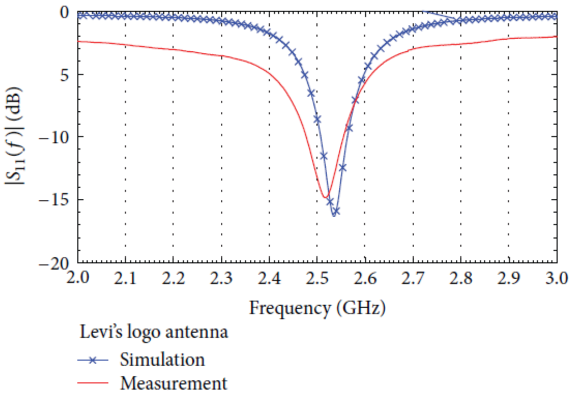


(a) (b)

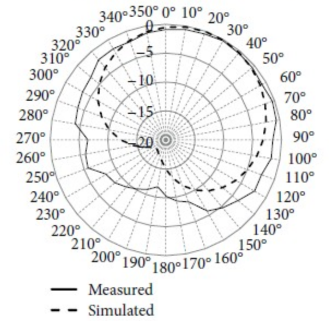


(a) (b)



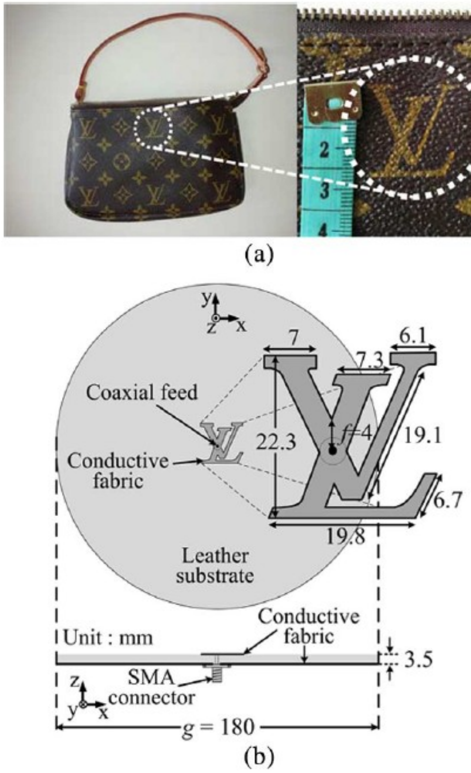


Radiation pattern (dB) at f_0 = 2.53 GHz, φ = 90°



(c)

Antenne mais pas seulement !



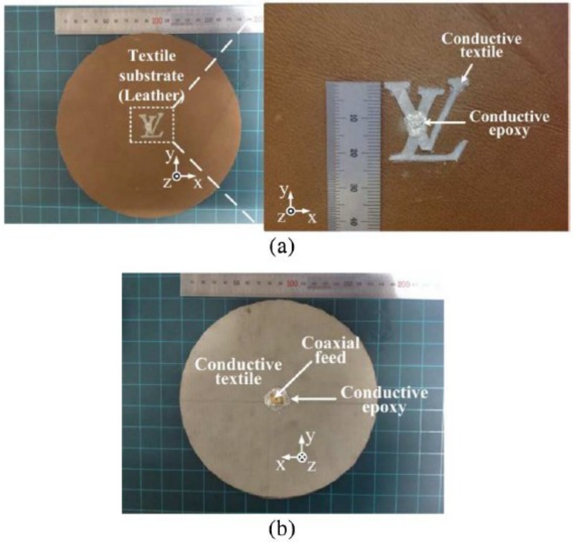


Fig. 5. Photographs of a fabricated antenna: (a) top view; (b) bottom view

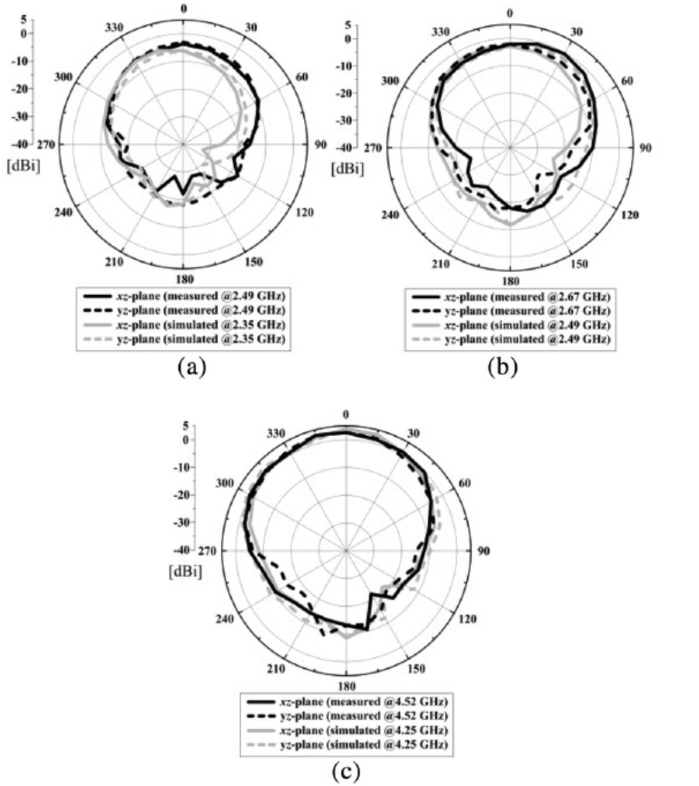


Fig. 8. Simulated and measured far field radiation patterns on the xz-plane and yz-plane (E-total) at: (a) 2.49 GHz; (b) 2.67 GHz; (c) 4.52 GHz.

La technologie

Arc en Ciel Sérigraphie

PME innovante de la Loire depuis 1984

Impression écrans capacitifs et résistifs avec rétroéclairage

Capteurs imprimés

Plastronique, Textronics
Impression tous capteurs sur tous substrats (métal, verre, tissu, céramique polymères…)

1984 — **Création**
Impressions textiles

1990 — **Spécialisation**
Interfaces Hommes Machines

2005

2013

2015 — **Participation**
à des projets collaboratifs

2018 — **Développement**
d'un bureau d'études en électronique imprimée

2020 — **Labellisation CIR**
et
certification ISO

- 18 salariés
- 1 bureau d'études interne labellisé CIR
- De nombreux partenaires universitaires
- Membre des associations et pôles de compétitivité

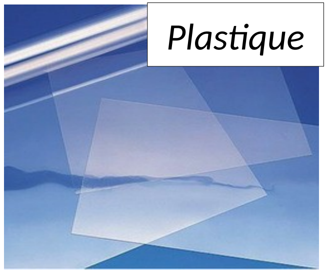
La technologie

Matière premières utilisées

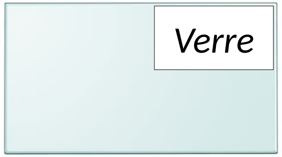
Les substrats

Métal

Plastique

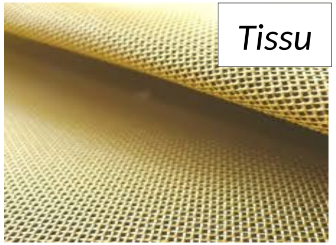


Verre

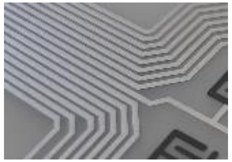


Céramique

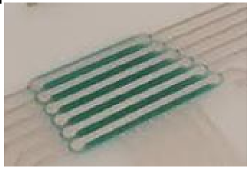
Tissu



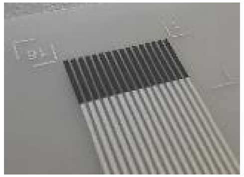
Les encres techniques



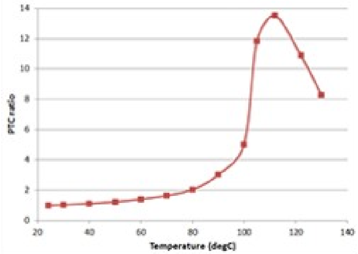
Conductrice
(ex: argent)



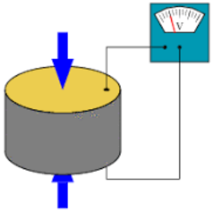
Diélectrique
(ex: vernis pont)



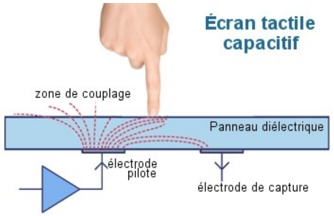
Protectrice
(ex: graphite)



Sensible à la température,
à la pression, à l'élongation, etc



Piézoélectrique



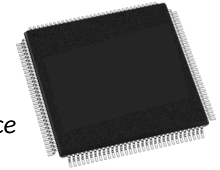
Capacitive

Les composants CMS

Pose de CMS 0603 à 2220
par machine automatisée Pick&Place

LED

Puce



Micro

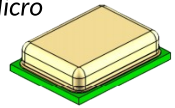


Photo-dio

La technologie

Phases projet

1) BE +prototypage

2) Production sérigraphie

Matières premières
Encre / Substrat / Composants

Design, BAT, film, clichage

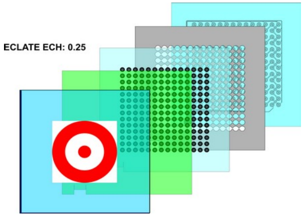
Impression, séchage, cuisson

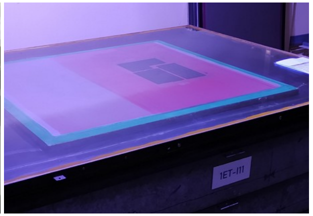
Découpe sur table, laser, usinage

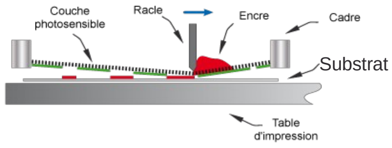
Pick&place, montage, adhésivage

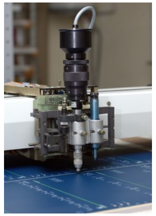
Produits finis ou semi-finis

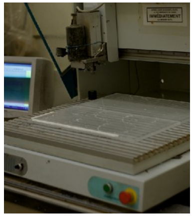
Intégration verticale sérigraphie

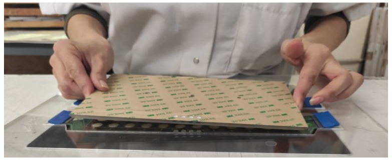












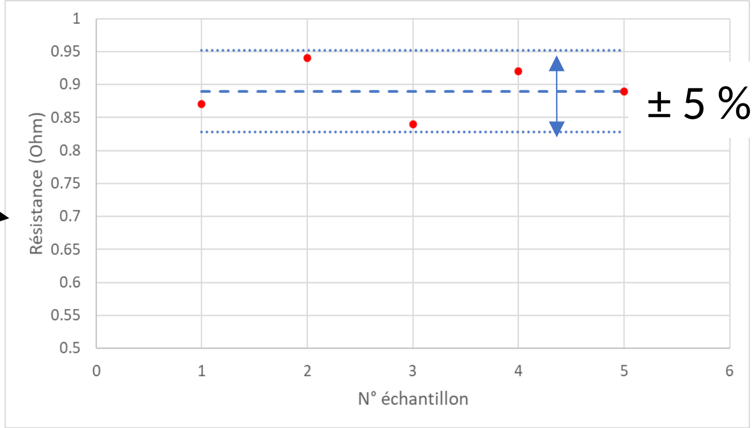
La technologie

Adéquation encre - substrat

SUBSTRAT / ENCRE	PET	PI	PC	PU	Sheet resistivity (mOhm/□/mil)	Propriété
A					7	Circuit imprimée
B					15	Circuit imprimée
C					10	Thermoformable
D					12	Circuit imprimée
E					15	Thermoformable
F					50	Stretchable

<u>Paramètres clés:</u>

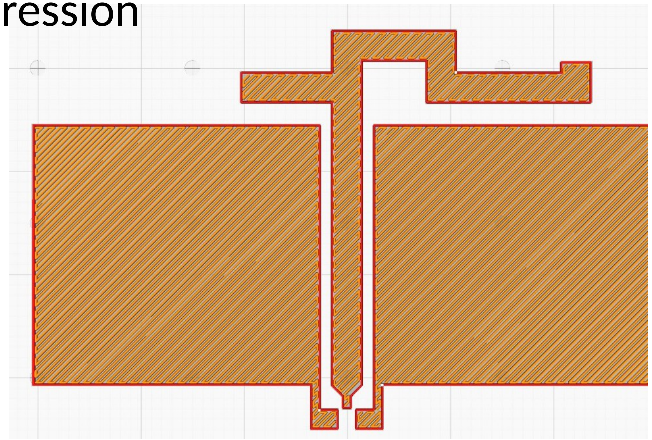
- Dimensionnement précis
 résolution d'impression
- Conductivité
- Homogénéité dépôt

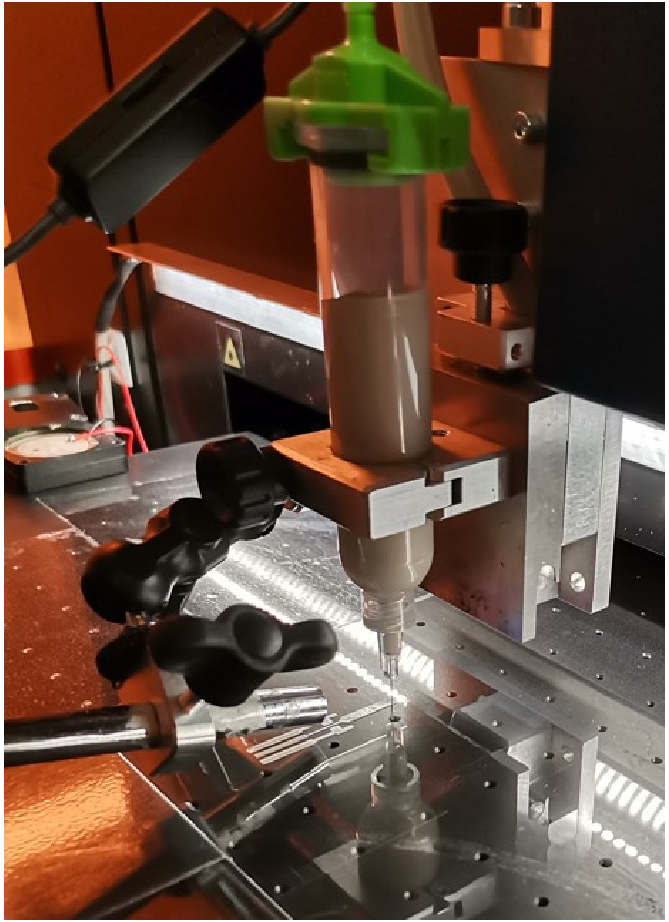


Prototypage par dispensing

<u>Paramètres clés:</u>

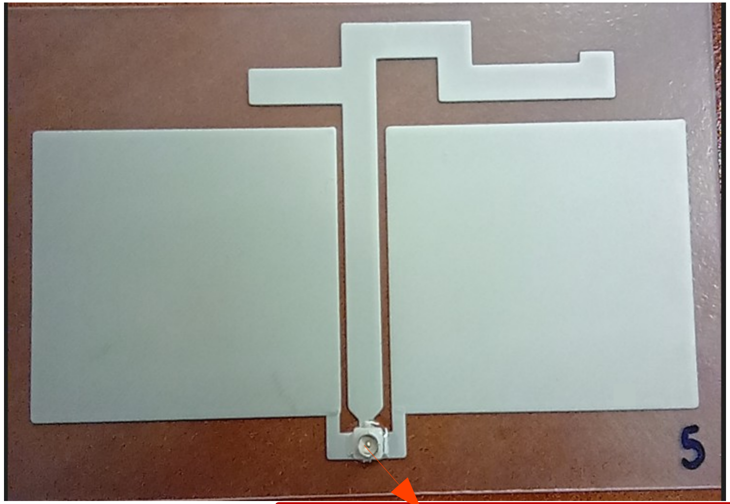
- Type et pas du remplissage
- Taille gauge
- Pression d'impression
- Vitesse d'impression

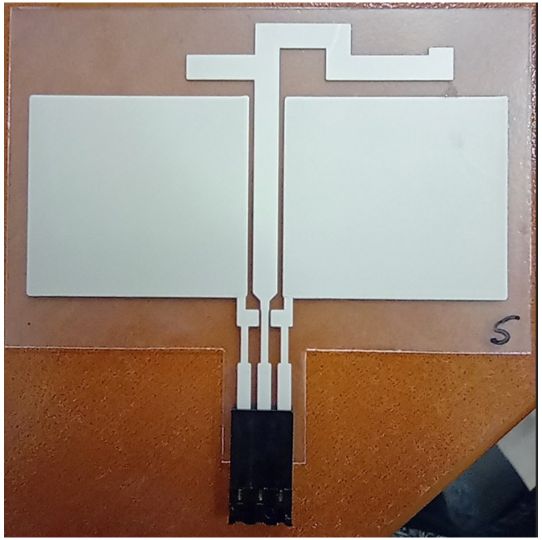


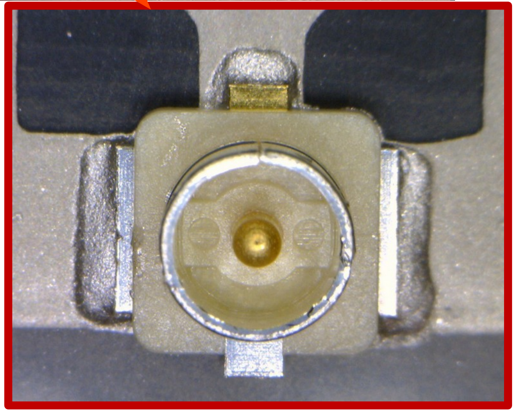


La technologie

Prototypes PET

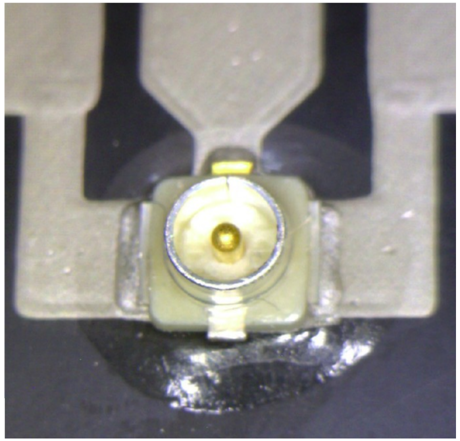






Report de composant

- Pose de colle conductrice
- Report du composant
- Encapsulation résine



La technologie

Table 2. Commonly used flexible substrates with their dielectric constant, loss tangent, and thickness.

	Substrates	Dielectric Constant (ε_r)	Dielectric Loss ($\tan\delta$)	Thickness (mm)
	PET [63]	3	0.008	0.140
	PEN [70]	2.9	0.025	0.125
	Polyimide [61]	2.91	0.005	0.2
	PDMS-MCT [84]	3.8	0.015	-
	PDMS [73]	2.65	0.02	-
	PDMS with glass microsphere [73]	1.85	0.014	-
	PDMS with phenolic microsphere [73]	2.24	0.022	-
	PDMS with silicate microsphere [73]	2.45	0.02	-
	Paper (Kodak Photo paper) [79]	2.85	0.05	0.254
	Liquid Crystal Polymer (ULTRALIM 3850) [62]	2.9	0.0025	0.1
Wearable antenna substrates	Fleece Fabric [85]	1.25	-	2.56
	Cordura [86]	1.1–1.7	0.0098	0.5
	Woolen felt [87]	1.16	0.02	3.5
	Felt [88]	1.3	0.02	1.1
	Cotton/Polyester [89]	1.6	0.02	2.808

Table 1 Electrical Properties (2.48 GHz) of Human Body Tissue at Pectoral Region

	Tissue Type	Relative Dielectric Constant	Conductivity (S/m)
1	Air	1.00	0.00
2	**Human Muscle (parallel fiber, i.e. worst case conductivity)**	**54.38**	**1.90**
3	Human Rib	18.51	0.82
4	Human Lung (inflated)	20.46	0.81
5	Human Lung (deflated)	48.34	1.70
6	Human Fat	5.28	0.11
7	Human Skin (wet)	37.97	1.48
8	Human Skin (dry)	42.81	1.61

Matériau	Permittivité relative ε_r
vide	1
Air sec	1,0006
isolant de câble de téléphone	1,5
Téflon (PTFE)	2,1
huile de transformateur, paraffine, pétrole	2,2
papier	2,3
polystyrène (PS)	2,4
caoutchouc vulcanisé	2,7
Plexiglas (PMMA)	3,5
Papier Kraft (imprégné d'huile)	3,5[2]
Bakélite (PF)	3,6
marbre	4
isolant de câble pour courant fort	4,5
quartz	4,5
verre standard	5
mica	3–6[3]
eau	78,5

FR4 constante diélectrique 3,3 à 4,8 en fonction de l'empilement

CRESITT INDUSTRIE

La technologie

CRT centre de ressources technologiques

afaq ISO 9001 Qualité AFNOR CERTIFICATION

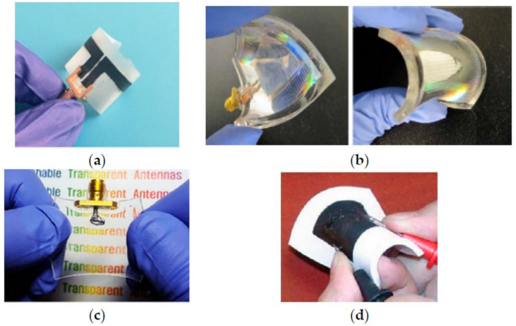


Figure 2. (**a**) Lycra fabric on porous film [153], (**b**) flexible antenna composed of liquid metal encased in the elastomer [154], (**c**) Ag/NW embedded PDMS [155], and (**d**) fabric-embedded PDMS [144].

Table 1. Conductive materials and their electrical conductivity values.

Materials Types	Conductive Materials	Conductivity, σ (S/m)
Metal nanoparticles	Ag nanoparticle [43]	2.173×10^7
	Cu nanoparticle [44]	1×10^6
Conductive Polymers	PEDOT:PSS [45]	100–1500
	Polyaniline (Pani) [45]	5
	Polypyrrole (PPy) [45]	40–200
Conductive Polymers with additives	C nanotube [46]	4000–7000
	PANI/CCo Composite [47]	7.3×10^3
	AgNW/PDMS [23]	8130
	Ag flakes + Fluorine Rubber [24]	8.5×10^4
Graphene Based materials	Nanoflakes [48]	6×10^5
	Paper [31]	4.2×10^5
	Meshed Fabric [49]	2×10^5
Liquid Metal	Eutectic GaIn [40]	3.4×10^6

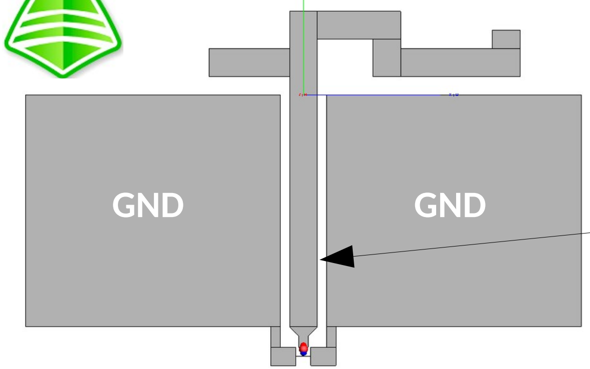
Table 2. Flexible conductors [96].

Conductive Materials	Thickness (t: mm)	Conductivity (σ: s/m)
Egaln Liquid	0.08	2.5×10^5
Polyleurethene Nanoparticle Composite	0.0065	1.1×10^6
Zoflex + Copper	0.175	1.93×10^5
Silver Flakes Fluorine Rubber	NA	8.5×10^4
AgNW/PDMS	0.5	8.1×10^5
PANI/CCo Composite	0.075	7.3×10^3
Copper Coated Taffeta	0.15	3.4×10^6
Graphene	100 µm	33×10^3

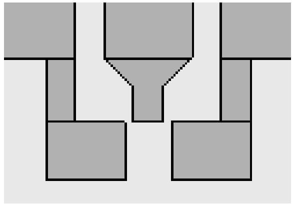
Le démonstrateur

Antenne monopole

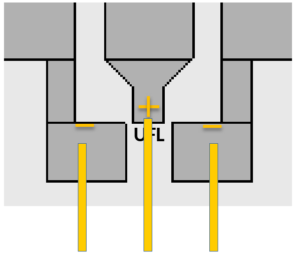
Geometrie



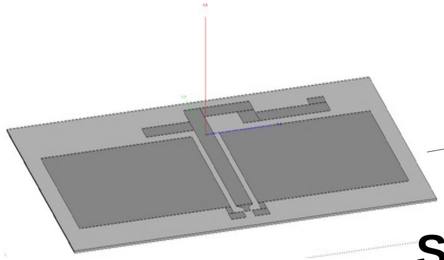
Gap 1mm contrainte fabrication



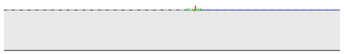
UFL



Nappe

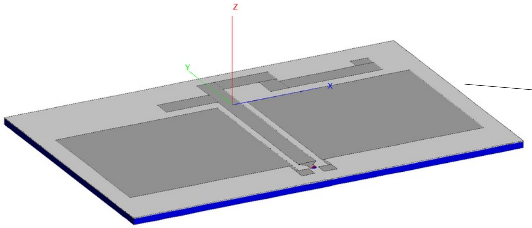


PET

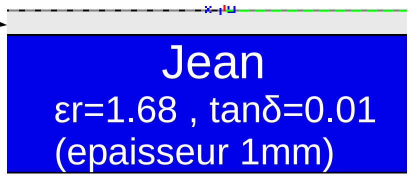


Substrat

PET: εr=3 , tanδ=0.008, Ep=175µm
PC: εr=2.64 , tanδ=0.0018, Ep=250µm
PU: εr=3.2 , tanδ=0.002, Ep=300µm

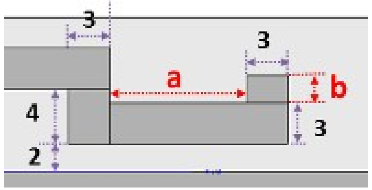


PET sur Jean



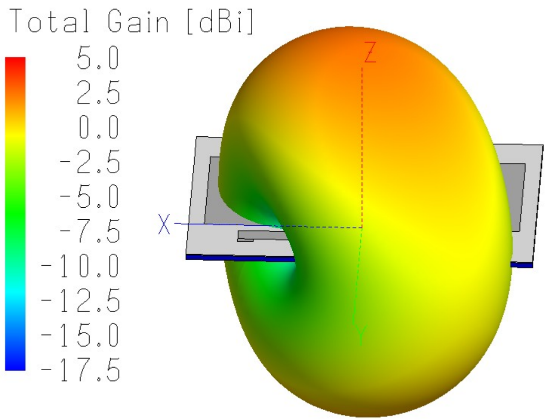
Le démonstrateur

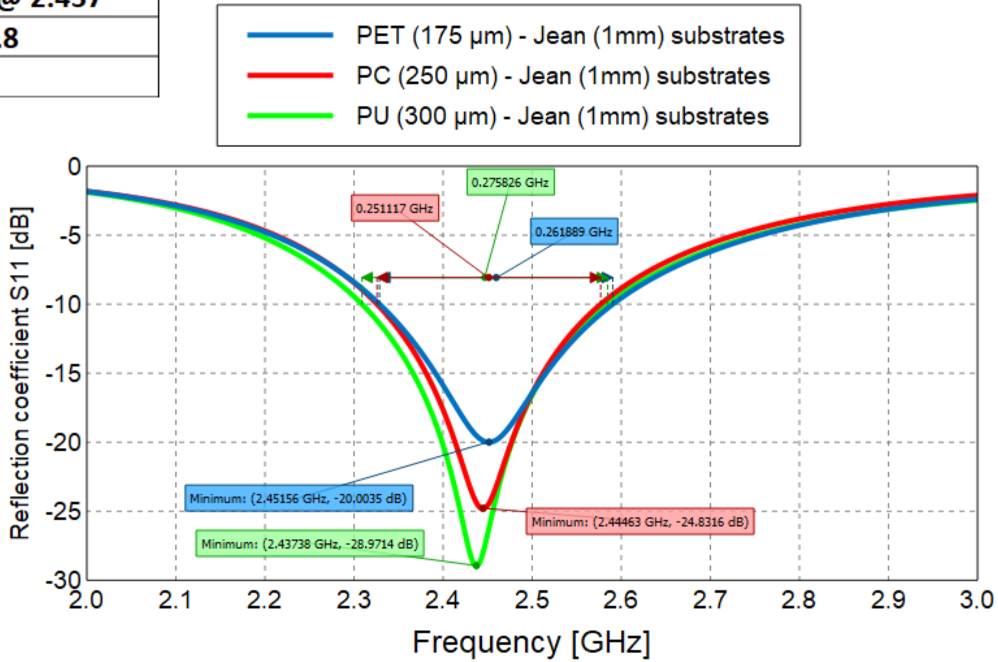
Substrats	PET	PC	PU
Permittivité (Er)	3	2.64	3.2
Tangent loss	0.008	0.0018	0.002
Epaisseur substrat (µm)	175	250	300
a (mm)	9.9	10.25	9
b (mm)	1	1	1
S11 (dB) @ F_{res} (GHz)	-20 @ 2.45	-24.8 @ 2.444	-29 @ 2.437
BP (MHz)	261.9	251.1	275.8
Gain max de l'antenne (dBi)	2.57	2.7	2.6



Excitation

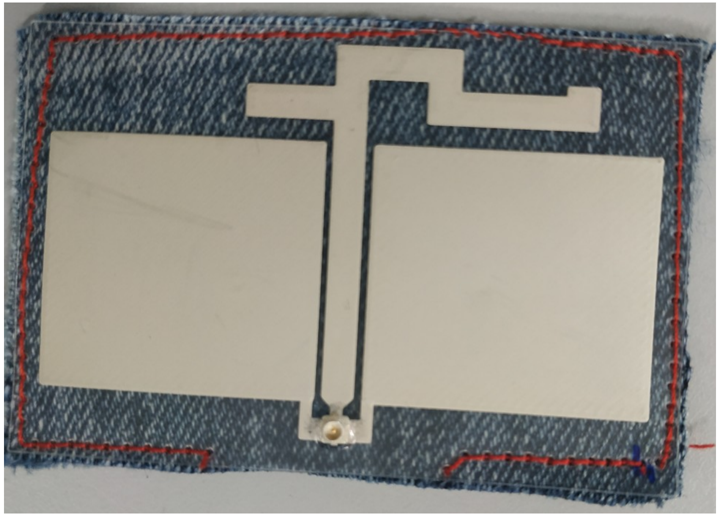
Substrat sur Jean 1mm



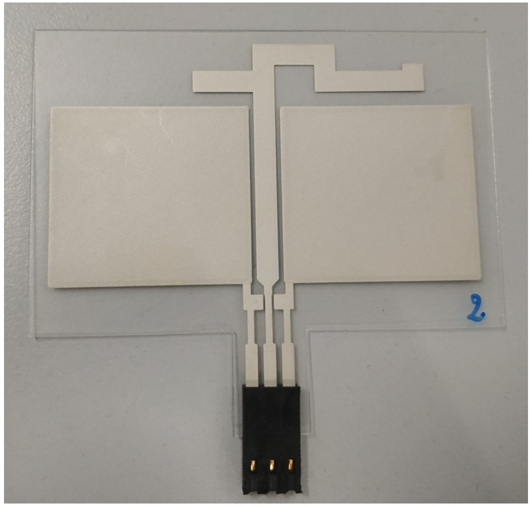


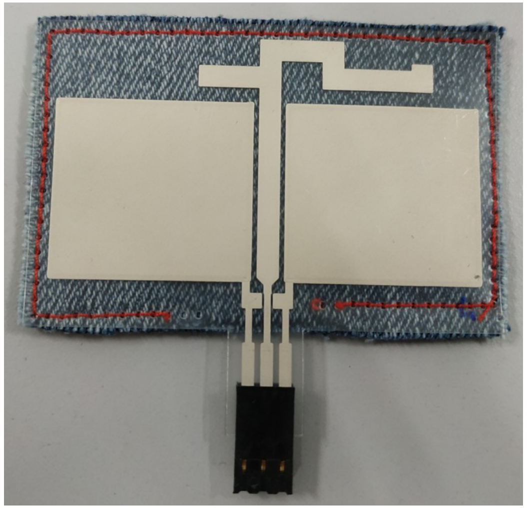
Les échantillons

UFL

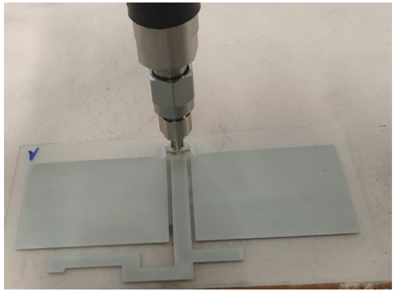


Nappe

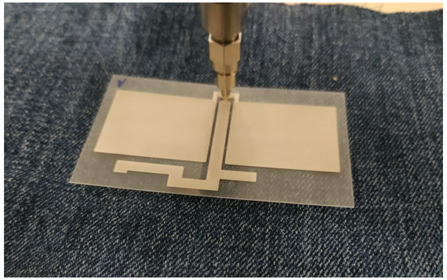




Les premières mesures

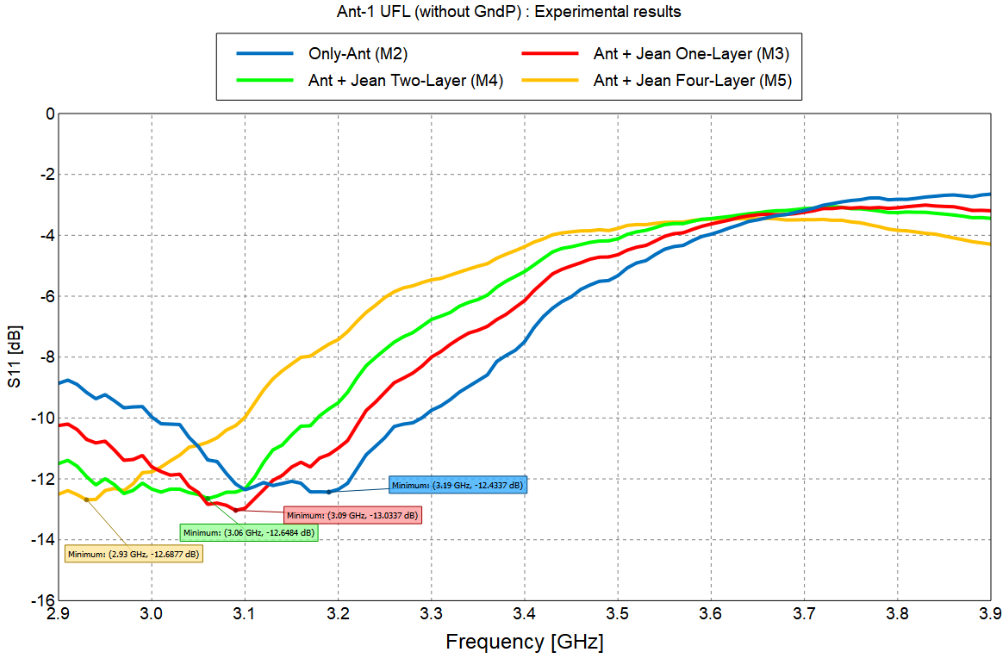


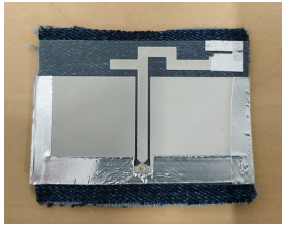
Antenne seule

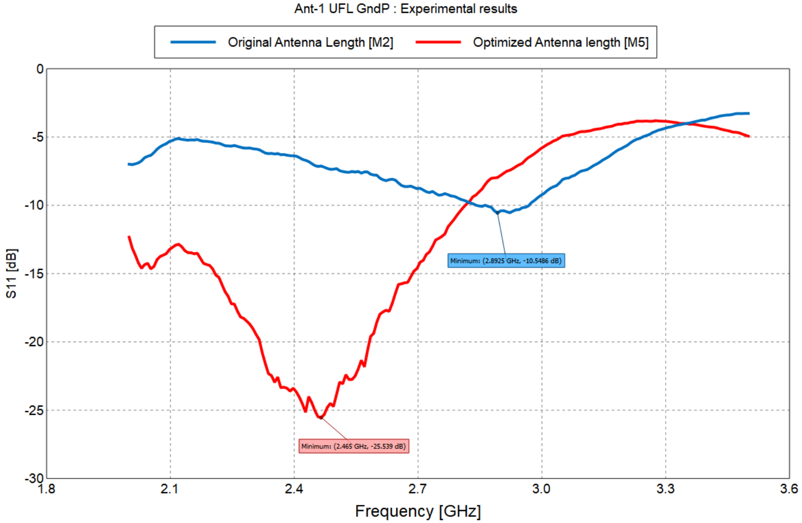


Antenne sur Jean
- 1 couche
- 2 couches
- 4 couches

Premières mesures



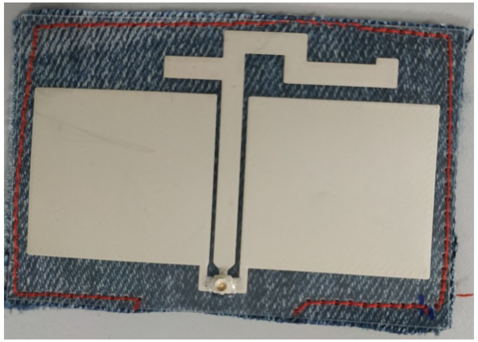


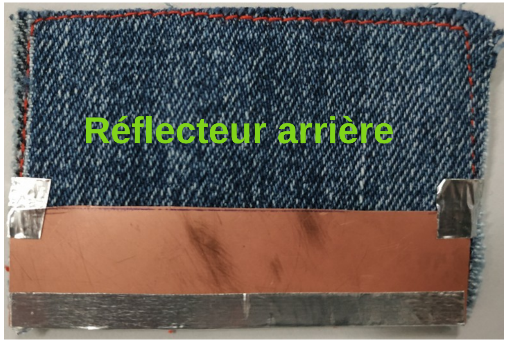


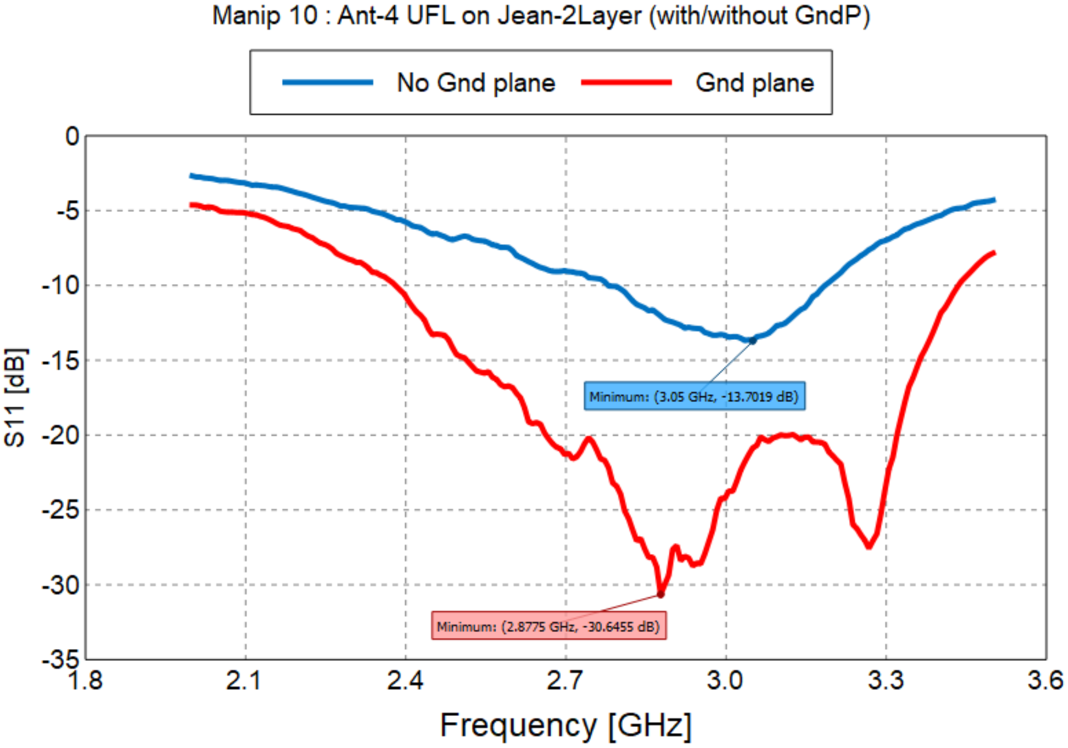
Only-Ant: S11 = -12.4dB @ 3.19GHz
Ant-Jean One-Layer: S11 = -13dB @ 3.09GHz
Ant-Jean Two-Layer: S11 = -12.6dB @ 3.06GHz
Ant-Jean Four-Layer: S11 = -12.7dB @ 2.93GHz

100 à 260MHz de shift versus antenne seule

Premières mesures

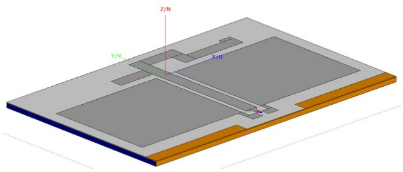


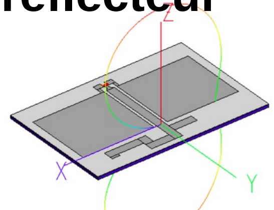


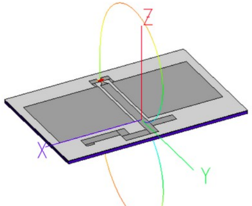


Optimisation

Optimisation avec réflecteur







Gain_Max = 2.32 dBi

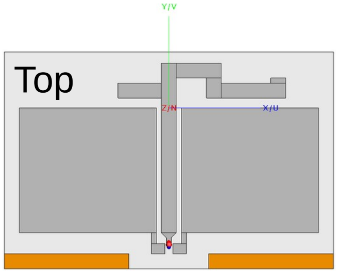
Gain_Max = 2.48 dBi

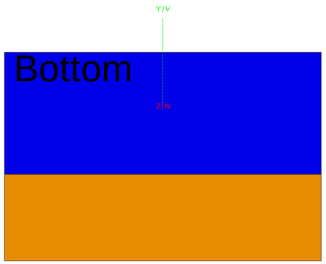
UN (xy) Far-Field (ɵ, ϕ=0)

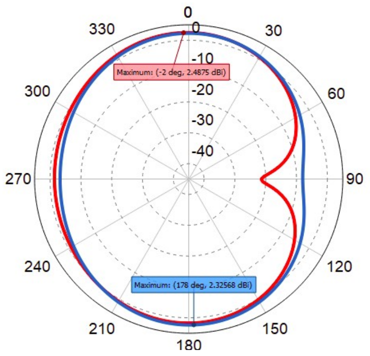
Gain_Max = 2.49 dBi

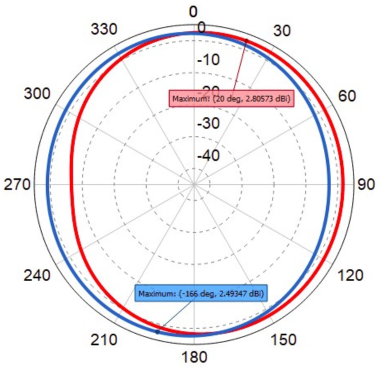
Gain_Max = 2.8 dBi

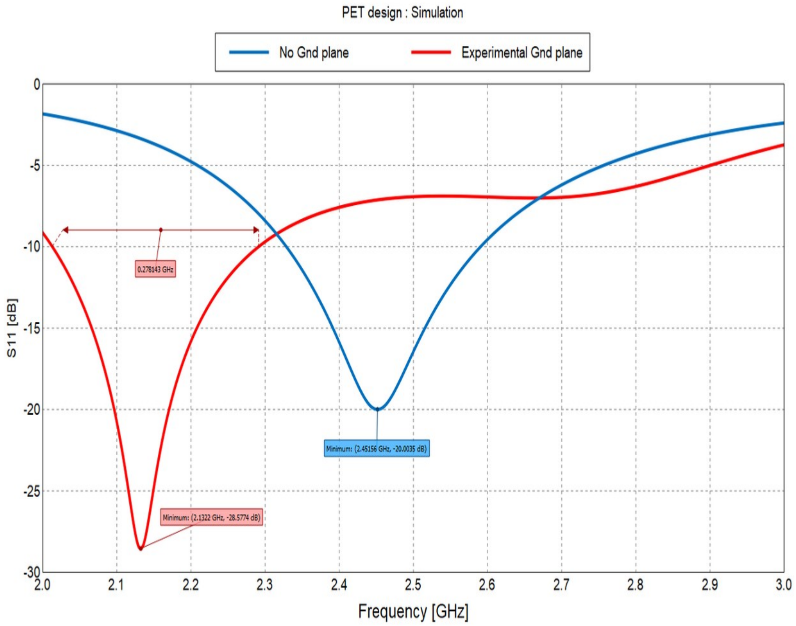
VN (yz) Far-Field (ɵ, ϕ=90)



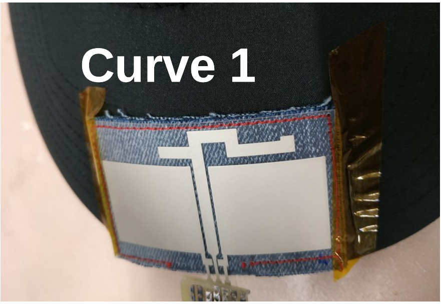


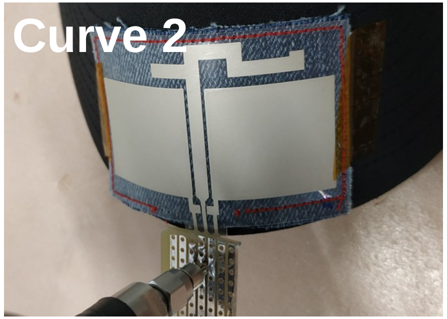


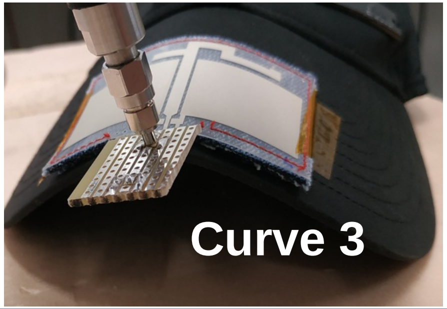


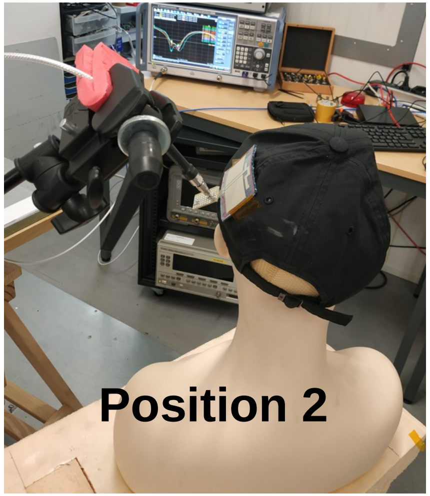


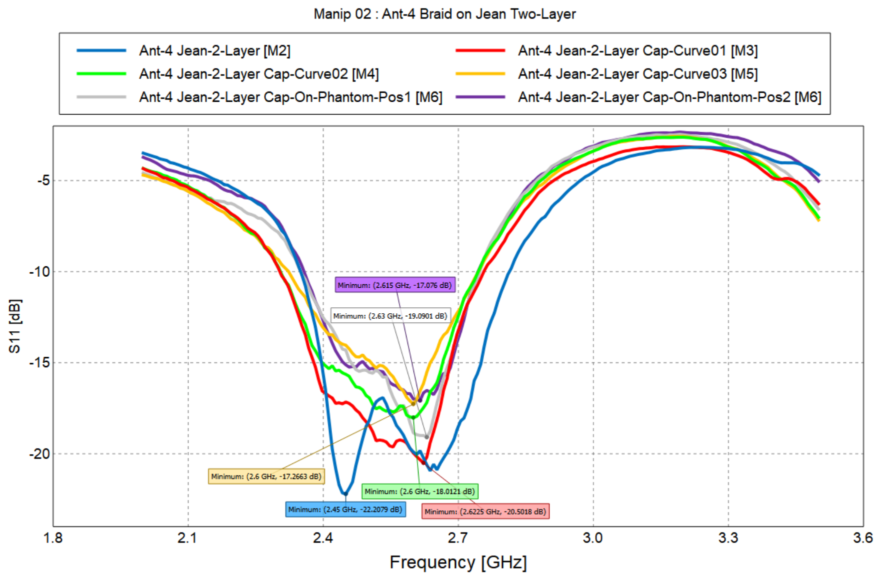
Influence rayon de courbure



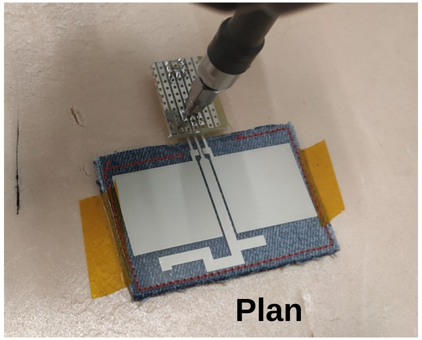


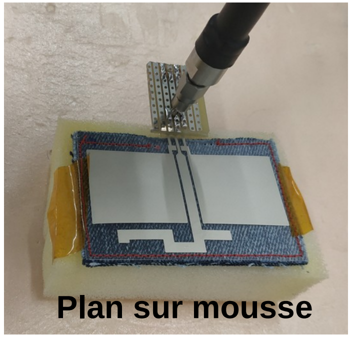


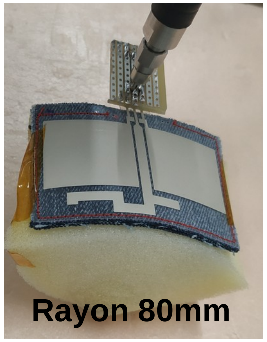


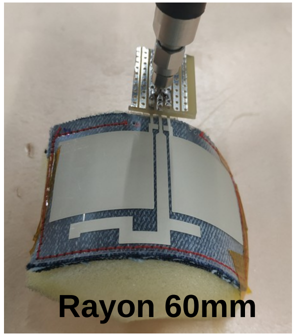


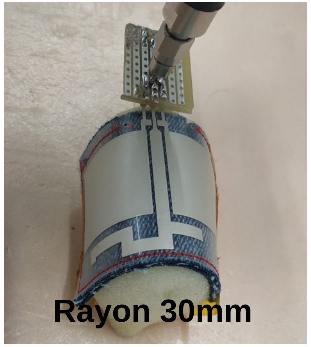
Influence rayon de courbure

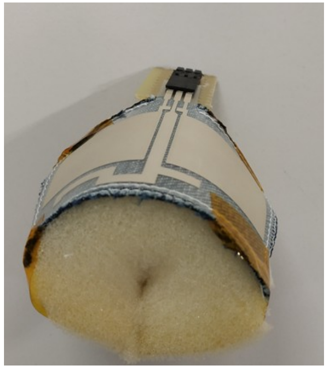

Plan

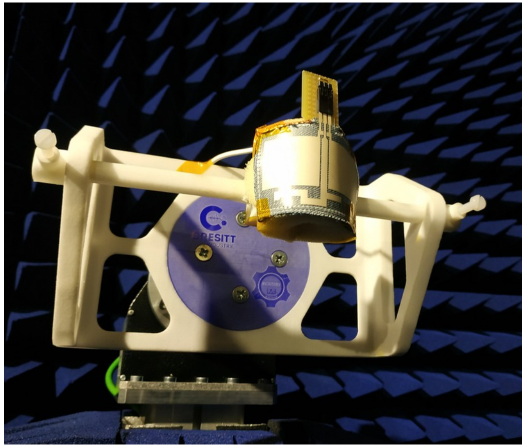

Plan sur mousse


Rayon 80mm

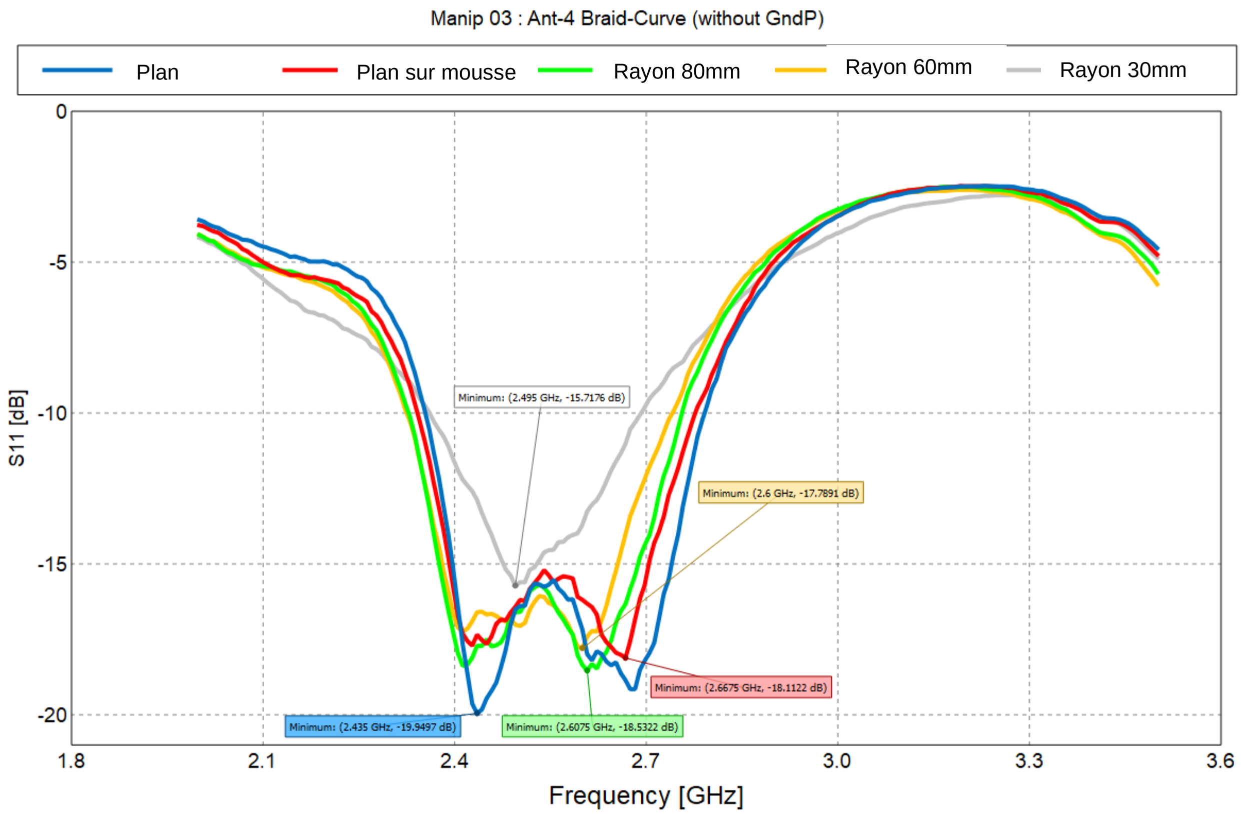

Rayon 60mm


Rayon 30mm



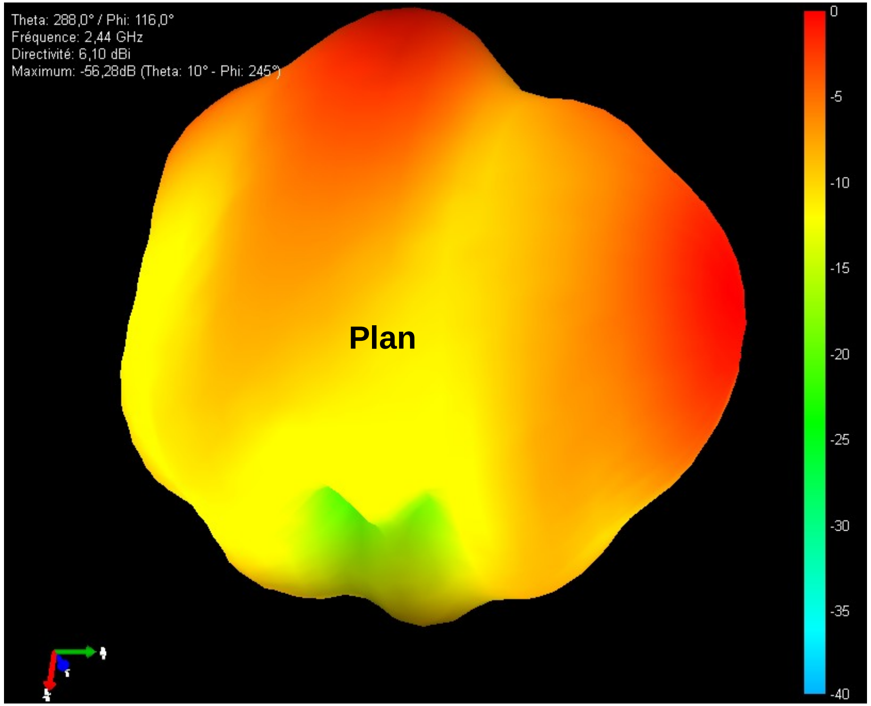


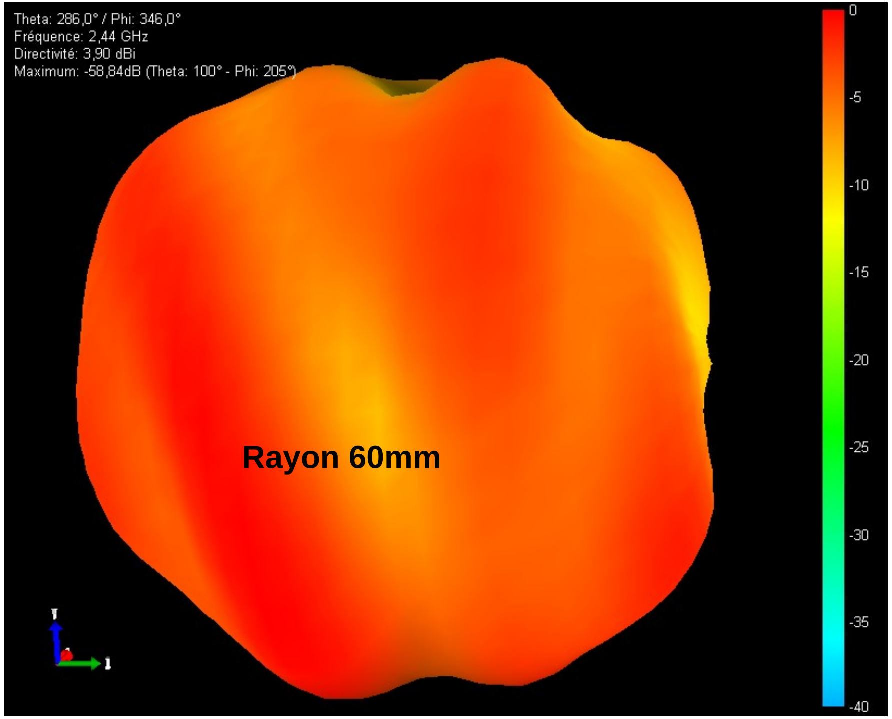
Influance rayon courbure



Influence rayon de courbure

3D E_tot @ 2.44 GHz

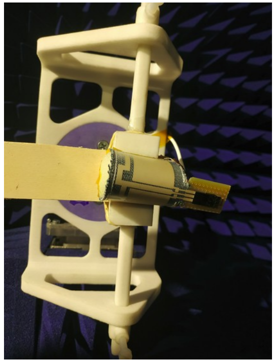




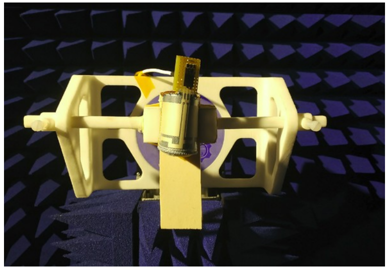
Directivité : 6.1 dBi
E_Max : - 56.28 dB (Theta : 10° - Phi : 245°)

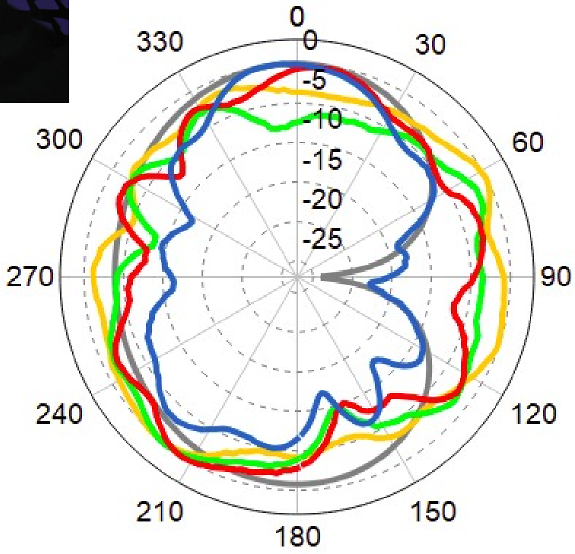
Directivité : 3,9 dBi
E_Max : - -58,48 dB (Theta : 100° - Phi : 205°)

Influence rayon de courbure

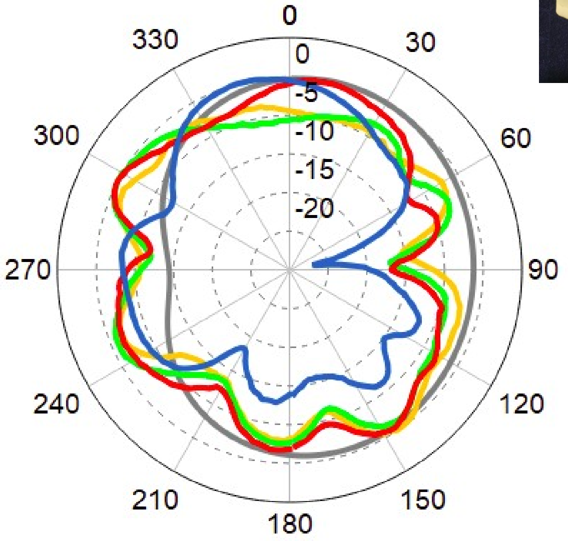


Plan
Rayon 80mm
Rayon 60mm
Rayon 30mm
Simulation





Azimith

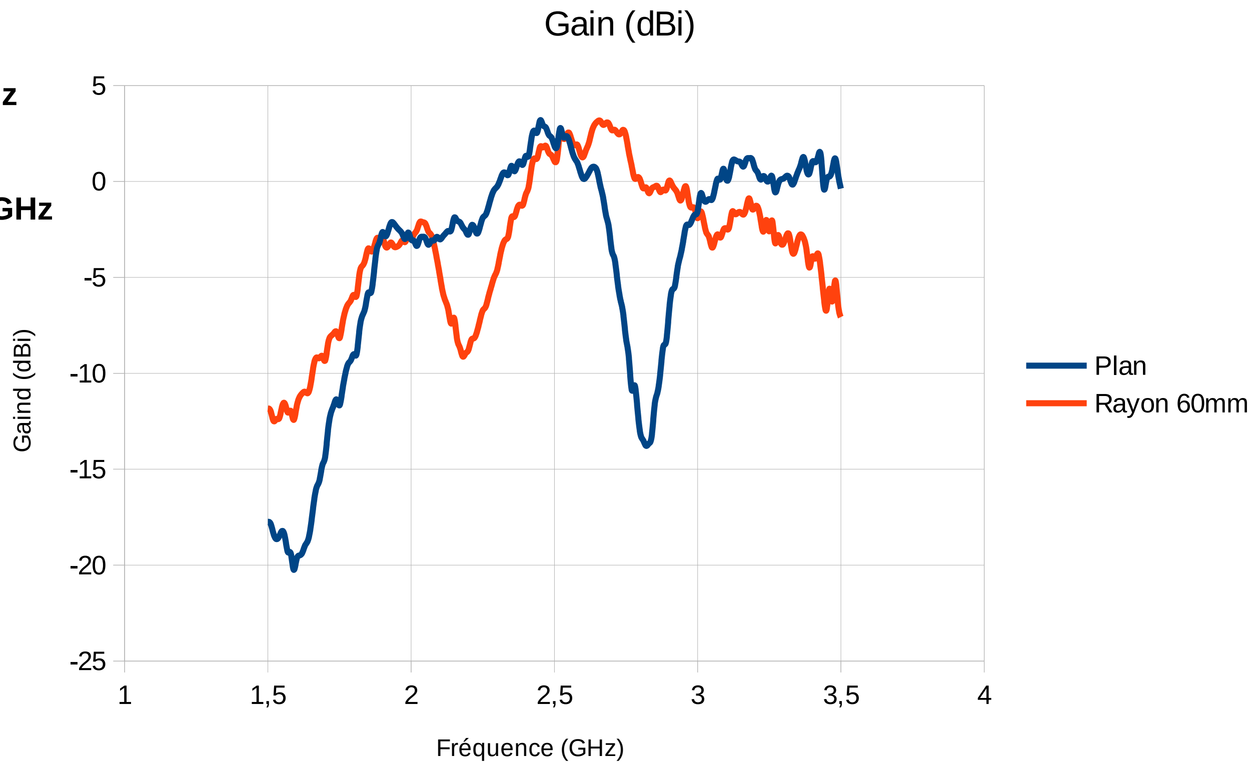


Elevation

Influence rayon de courbure

Plan
Theta 5°, Phi 330°, Gain 2,56dBi@2,44GHz

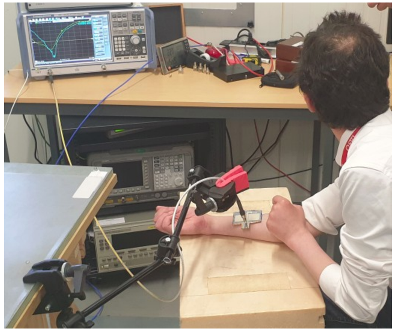
Rayon 60mm
Theta 100°, Phi 205°, Gain 1,22dBi@2,44GHz

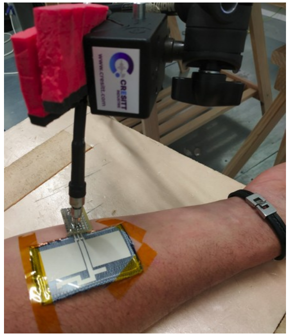


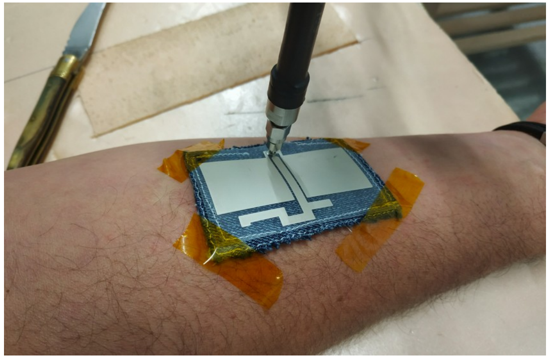
CRESITT INDUSTRIE

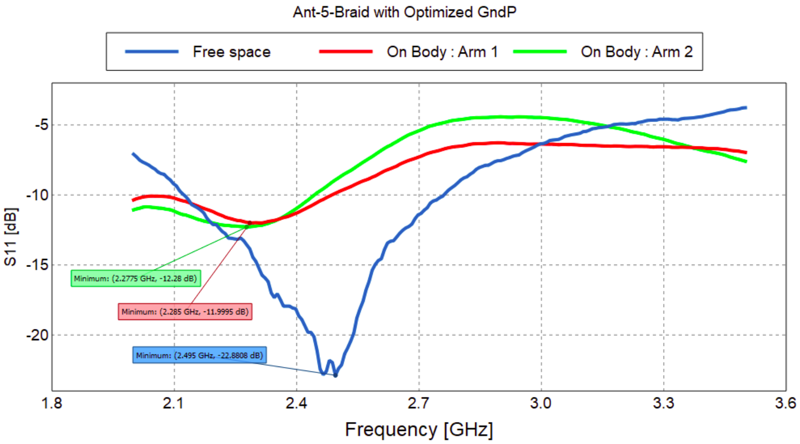
Influence corps humain

centre de ressources technologiques

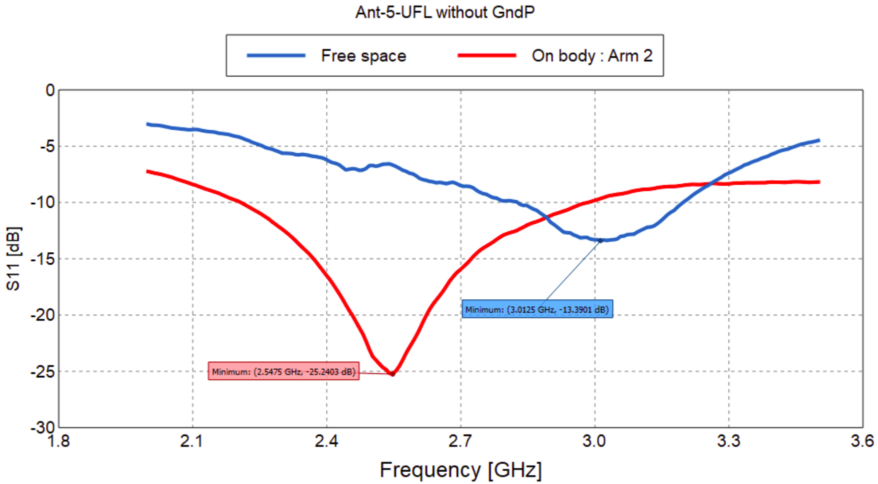








Shift 220MHz, avec relecteur arrière

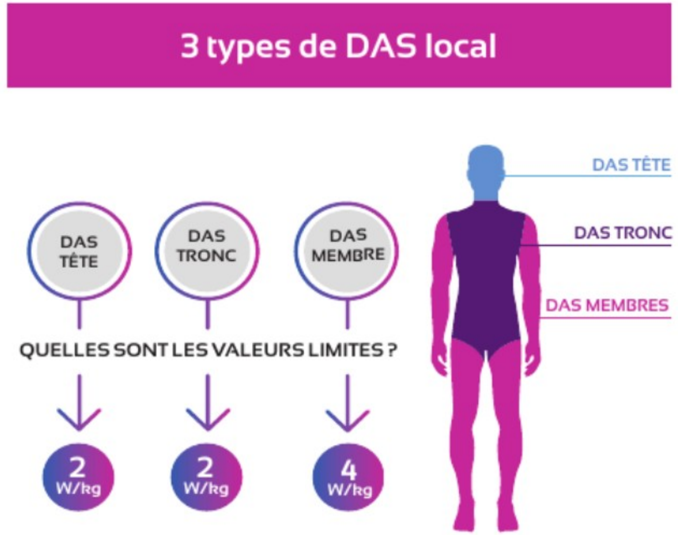


Shift 460MHz, sans réflecteur arrière

Quid du DAS !

DAS : **Obligatoire** depuis 1er juillet 2020 pour tous les équipements radioélectriques

Sécurisation : Publication de la Commission Européenne le 29/10/2021



- Bande Fréquence 100kHz-10GHz
- puissance d'émission > 20 mW (BLE, WiFi 100mW)
- si utilisés à une distance < 20 cm du corps humain

Baisse Puissance → 20mW→ 13dBm portée ≈/2

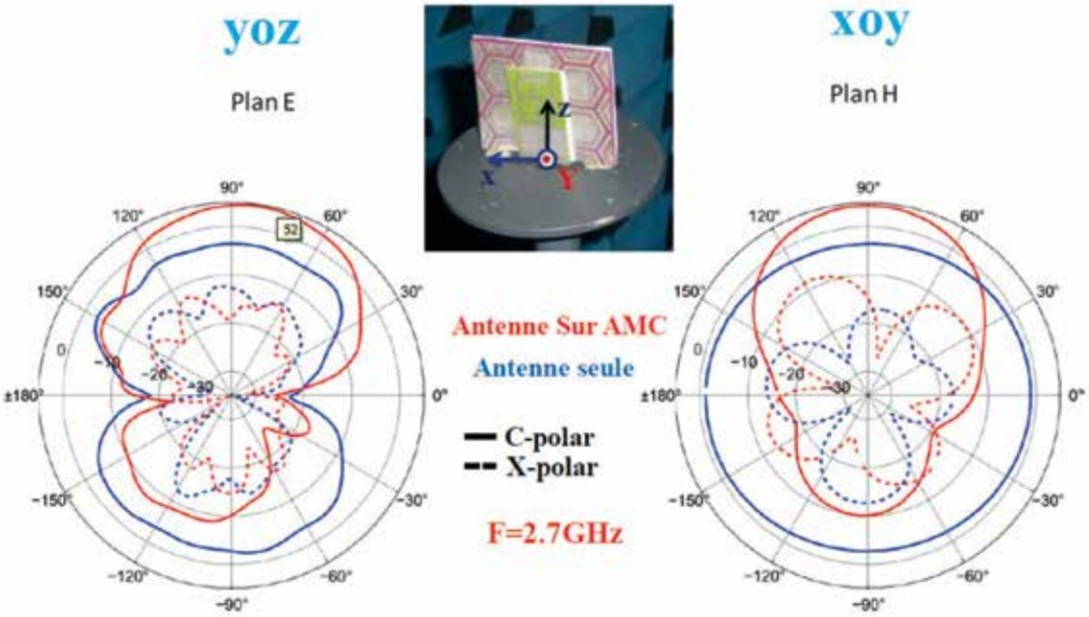
Rayonnement arrière

- Couplage antenne avec le corps
  → shift en fréquence
  → pertes
- Problématique du DAS
  → réglementation

→ **Ajout d'un réfleteur**
CEP : Conducteur électrique parfait
CMP : Conducteur magnétique parfait
(*CMA : conducteur magnétique artificiel, à base de métamatériaux)*

Onde incidente normale
CEP : S11 = -1 → distance λ/4
CMP : S11 = +1

Rayonnement arrière



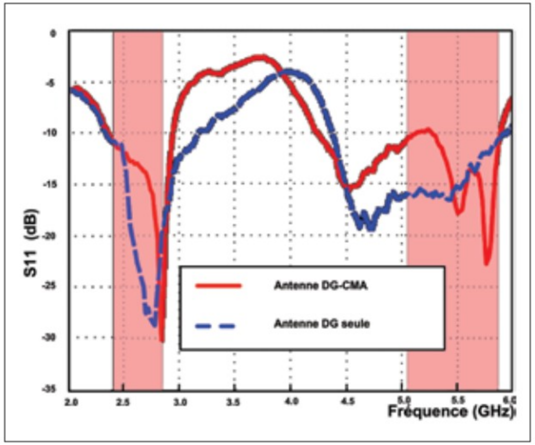


Figure 4 : S11 mesuré de l'antenne textile double G avec et sans CMA.

S11

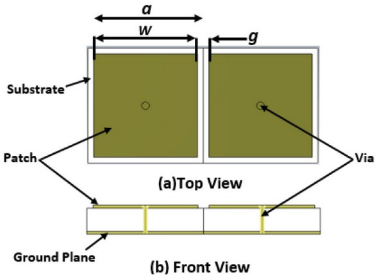
2.5 GHz (600 MHz BW)
5.5 GHz (1.66 GHz BW)

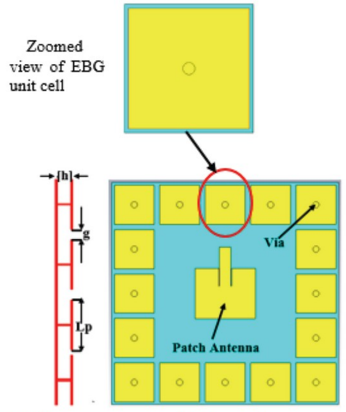
DAS

Puissance émise = 1 W	DAS 10 g W/Kg
Ant double G seule	30,82
Ant double G + CMA	5,58

Rayonnement arrière

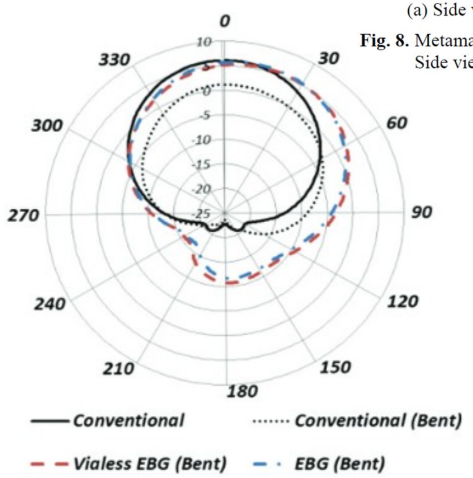
Substarte Integrated Waveguide

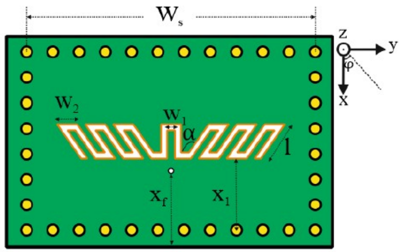


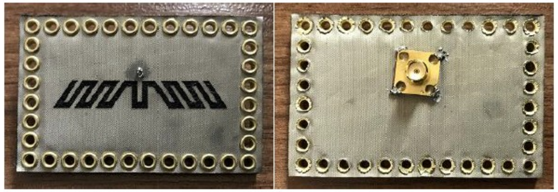


(a) Side view (b) Front view

Fig. 8. Metamaterial based microstrip patch antenna: (a) Side view; (b) Front view

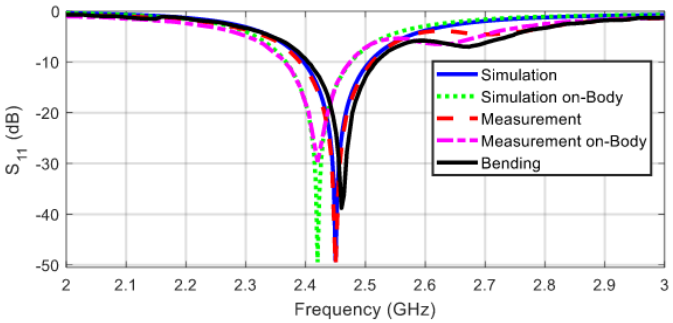


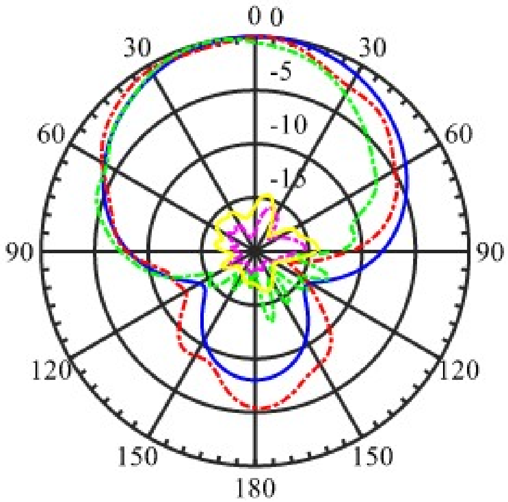




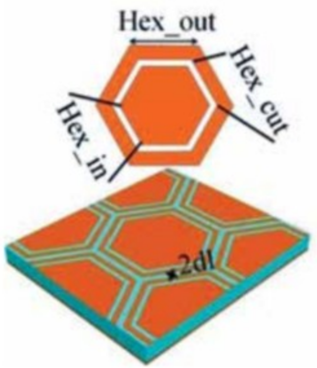
(a) (b)

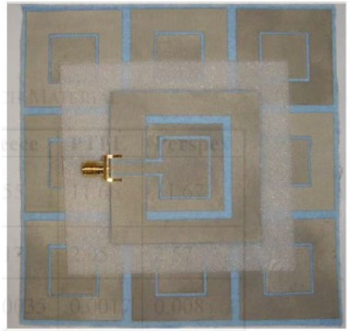
Fig. 2. Prototype of the antenna, (a) top. (b) bottom views.

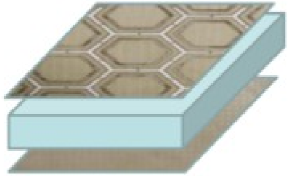




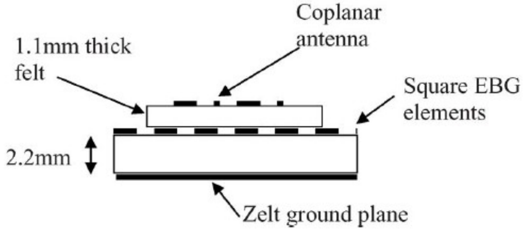
Exemple matériaux





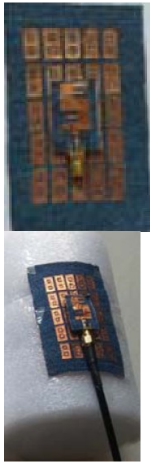


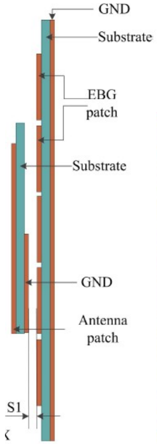
- **Substrat:**
  Feutrine (Er=1.22, h=2mm)
- Matériaux Conducteurs**:**
  Electro-textile de type Shieldit



- **Substrate:** Feutre
- Matériaux conducteur**:** Zelt

- **Space-substrat:** Mousse
- **Conducting material**:
  Metallic sheet (Cuivre)





- **Substrate:** Denim (Er=1.7)
- **Conducting material: Cuivre**

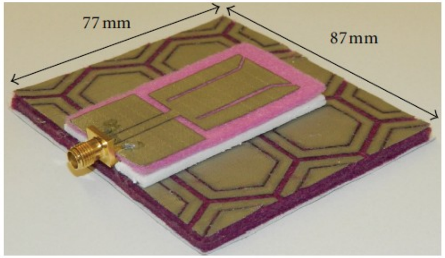
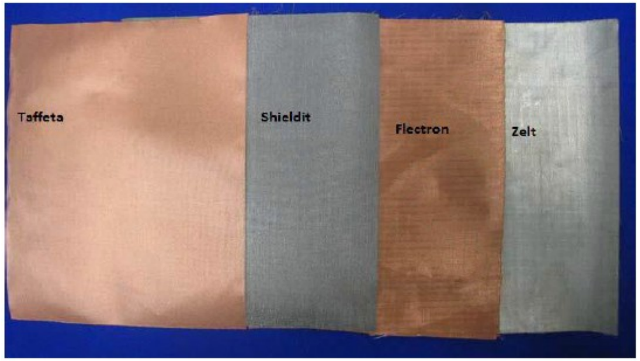


FIGURE 16: CPW-fed antenna on AMC prototype using felt and electrotextile.

- **Space-substrat:** Feutre
- **Conducting material**:Electrotextile



Samples of Taffeta, Shieldit, Flectron, Zelt electro-textile material.

Des questions ?

?

Contacts

Christophe Alayrac

Directeur technique

christophe.alayrac@cresitt.com

Sophie Parlati
Ingénieur développement & innovation
sophie.parlati@arcenciel-serigraphie.fr

Christian Dreesen
Gérant
christian.dreesen@ arcenciel-serigraphie.fr