ζetamix ε

Dielectric filaments for FFF 3D printing

Whitepaper

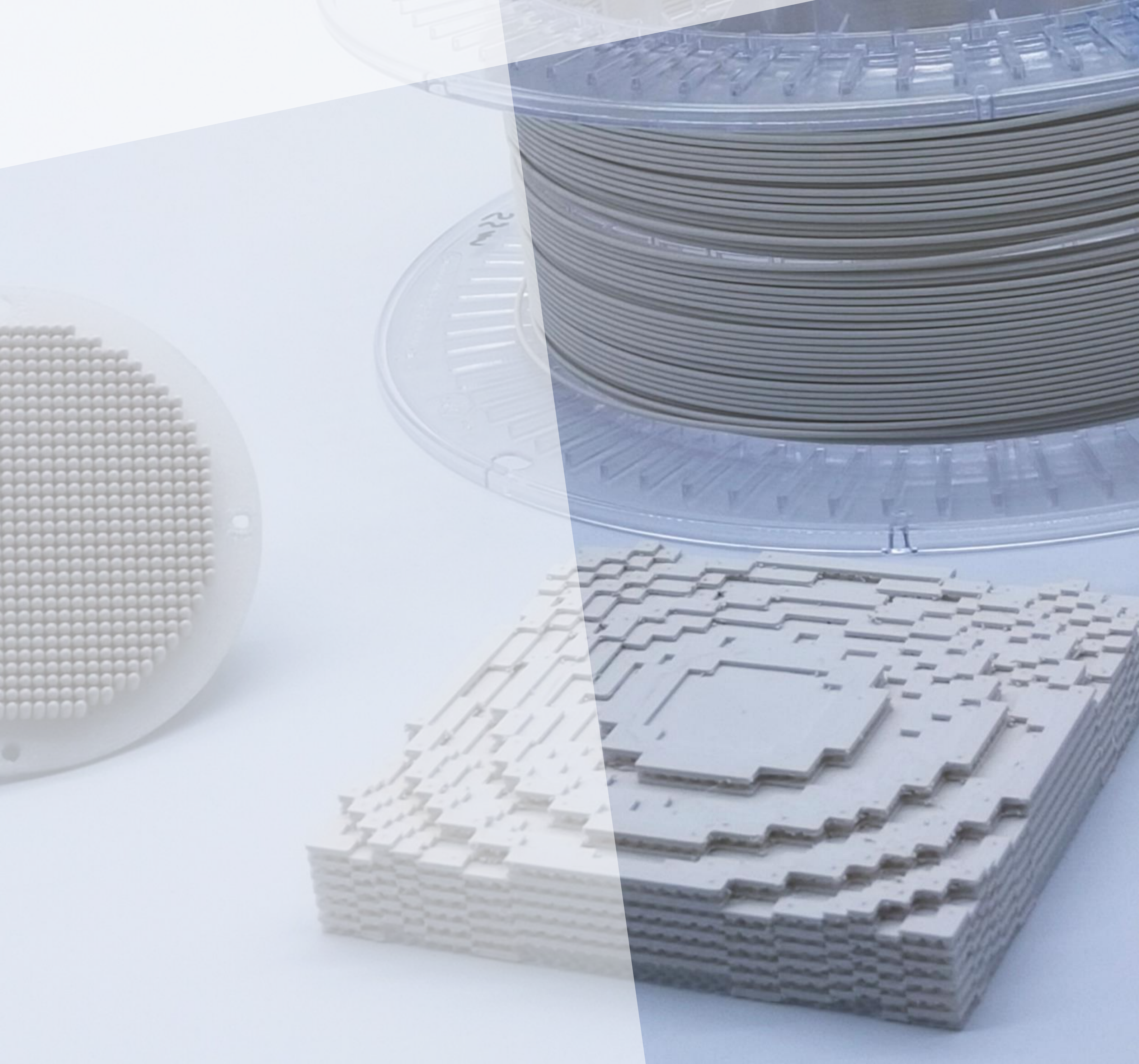


Table of content

01 Introduction

02 Zetamix Epsilon properties

03 Why using FFF 3D printing for Radiofrequency?

04 Uses Cases

a) Disruptive antennas concepts brought to life through 3D-printing of Zetamix Epsilon filaments

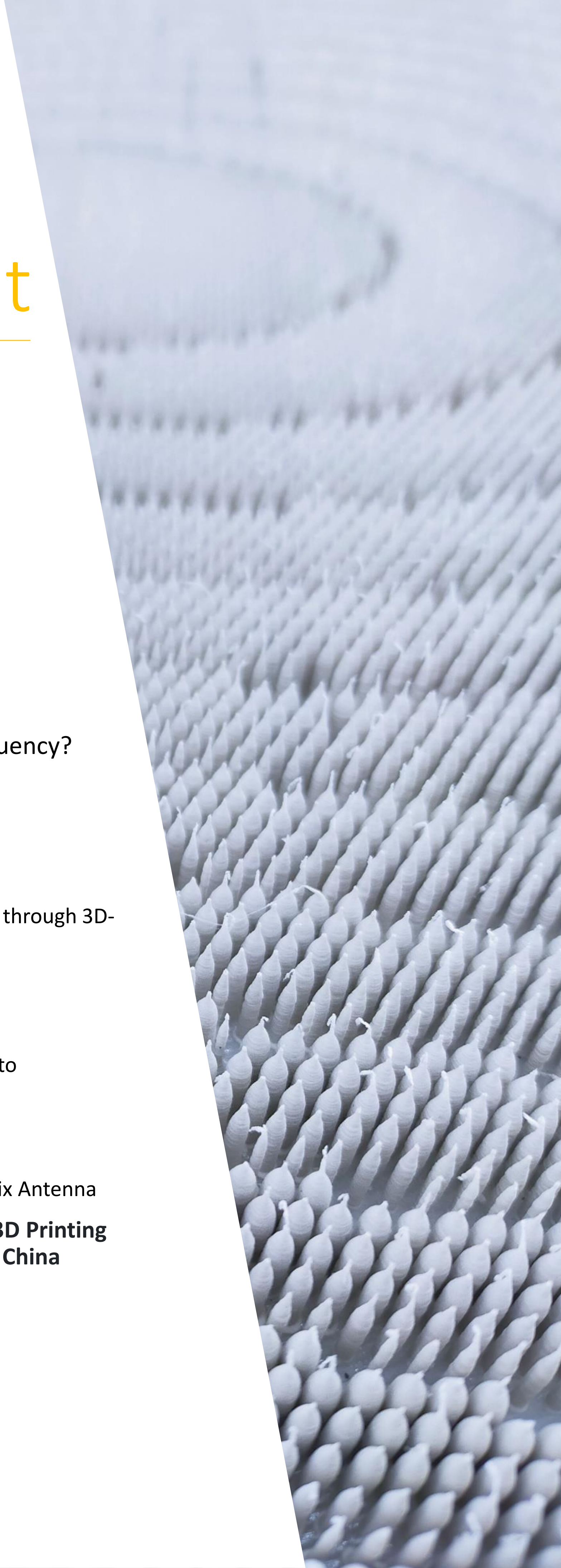
Example of Thales

b) The futuristic 3D printed RF Dielectric Reflecto

Example of the LEAT

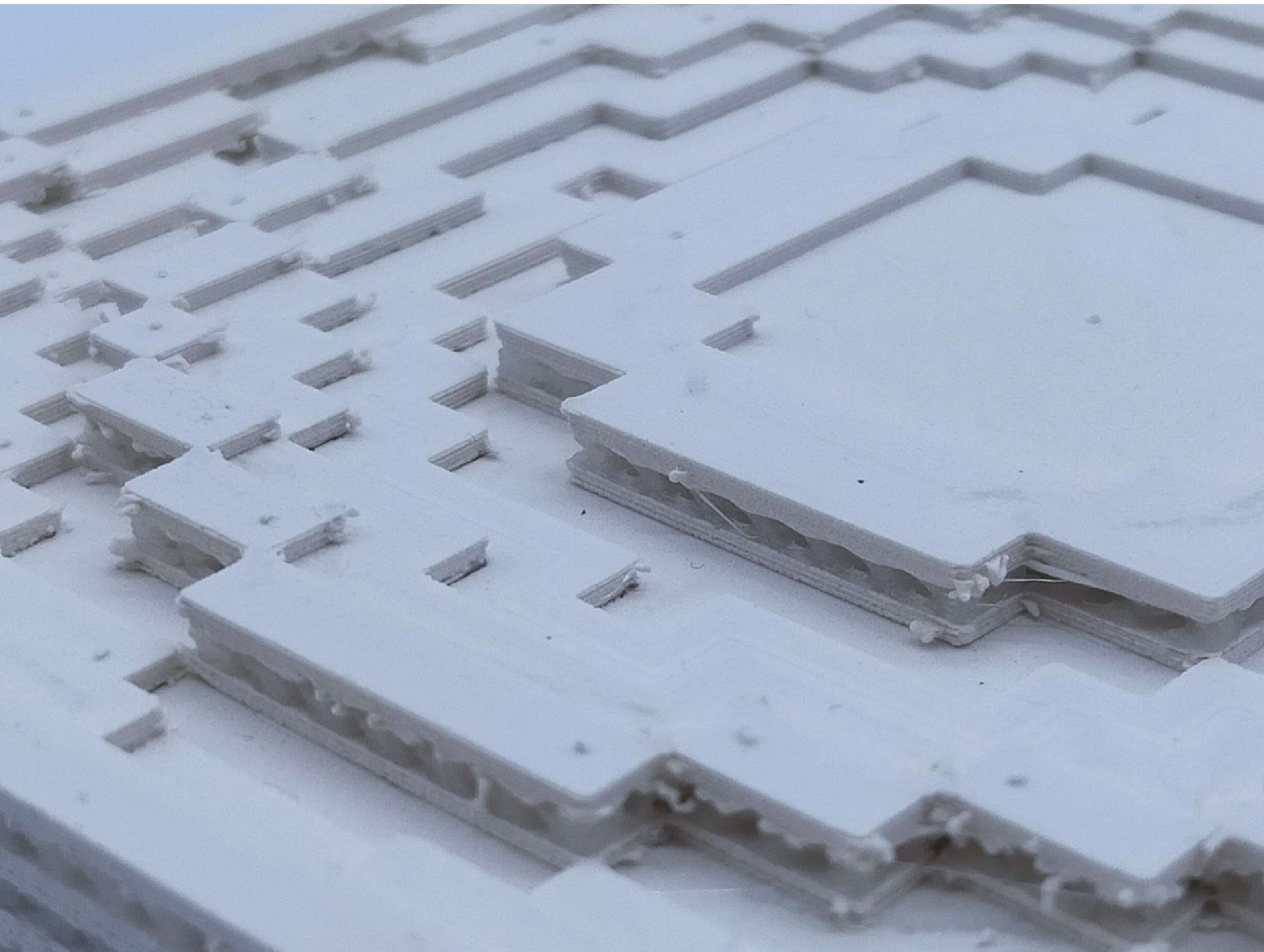
C) 3D Printed Circularly Polarized Dielectric Helix Antenna

Example of the Jiangsu Key Laboratory of 3D Printing Equipment and Manufacturing in Nanjing, China



Introduction

The Zetamix Epsilon range of products contains 3 filaments, each with different permittivity going from 2.2 for the lowest to 7.5 for the highest. These products are also characterized by their low dielectric losses and their high heat resistance for enduring up to 110 degrees Celsius HDT in continuous operation.



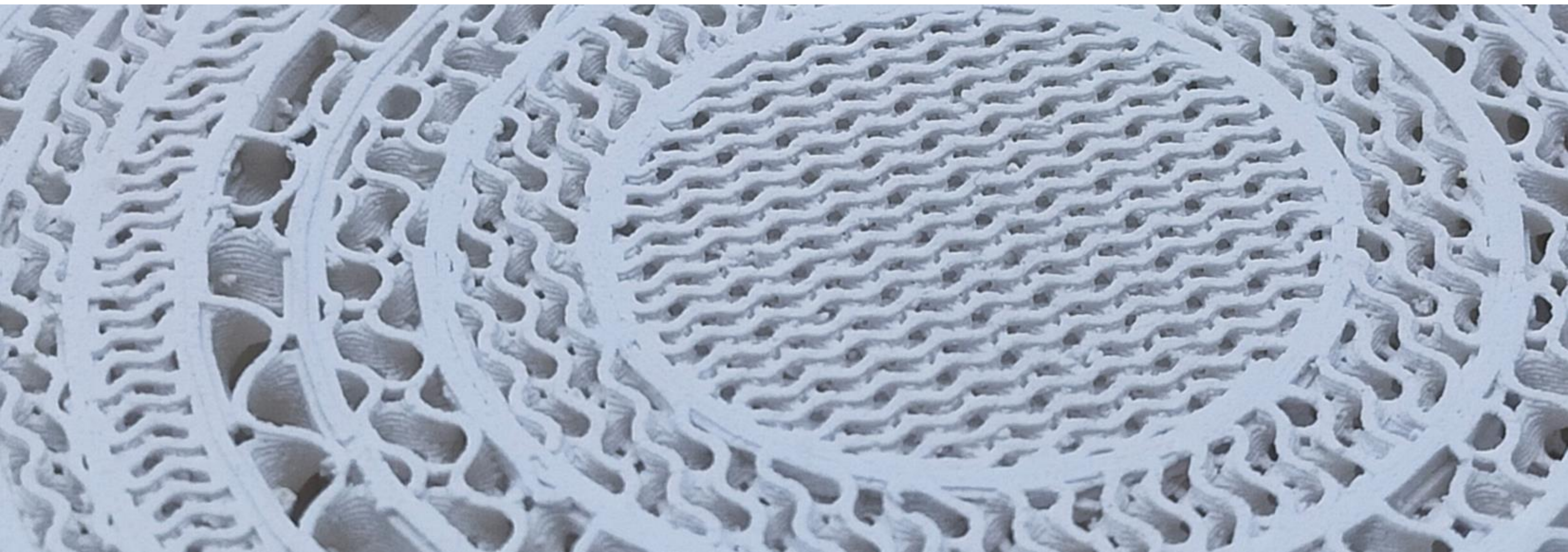
Material properties

PRODUCT DESCRIPTION

Zetamix Epsilon filaments are used for 3D printing. They are made of a proprietary polymer formulation, plus a ceramic filler to increase the permittivity. They are 3 different filaments available, with three different filler loadings.
Diameter available: 1.75 mm and 2.85 mm

IDENTIFICATION

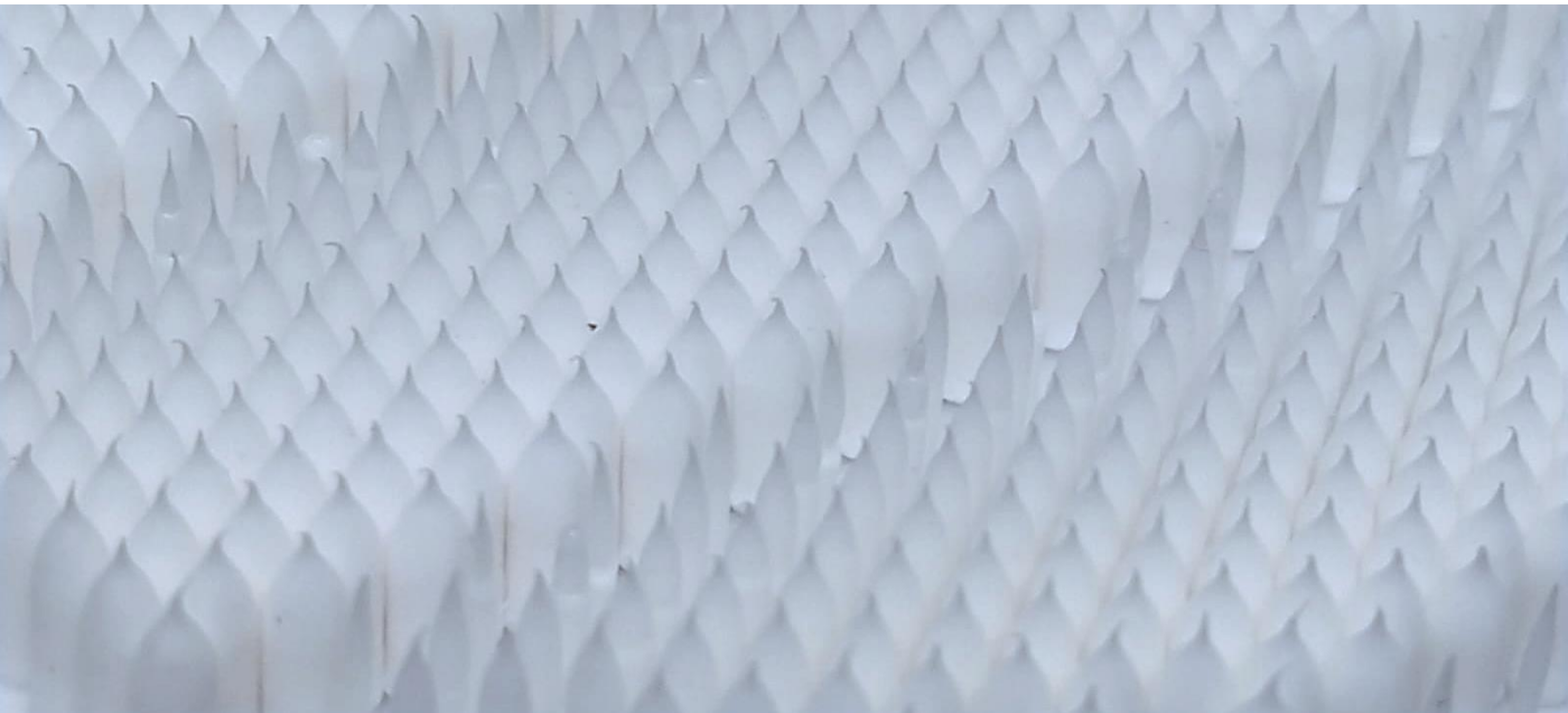
Trade name	Zetamix Epsilon **Ɛ = 2.2**	Zetamix Epsilon **Ɛ = 4.5**	Zetamix Epsilon **Ɛ = 7.5**
Chemical name of raw material	Polyoleofine	Polyoleofine	Polyoleofine
Binding proportion (vol) %	100	70	60
Binding proportion (mass) %	100	35	26
TiO_2 proportion (vol) %	0	30	40
TiO_2 proportion (mass) %	0	65	74



Material properties

TYPICAL PROPERTIES OF THE FILAMENT

	ε = 2.2	**ε = 4.5**	**ε = 7.5**
Mass fluidity index [g/10 min]	16	16	16
Volumetric fluidity index [cm^3/10 min]	5	5	5
Moisture Absorption 24 hours [%]	<0.1%	<0.1%	<0.1%
Moisture Absorption , 7 days [%]	<0.3%	<0.3%	<0.3%
Shor D	56	56	56



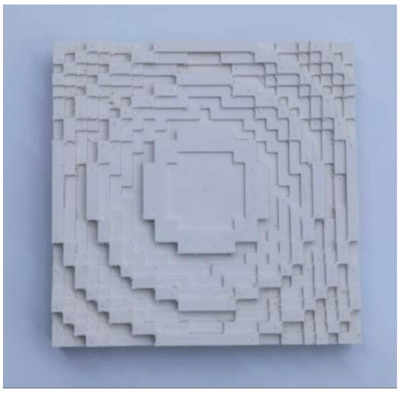
Material properties

PROPERTIES

Zetamix	**Ɛ = 2.2**	**Ɛ= 4.5**	**Ɛ= 7.5**
Dielectric properties			
Dielectric constant *	2.2 (± 0.2)	4 (± 0.5)	7.5 (± 0.5)
Loss tangent	$< 1.10^{-3}$ (± 5.10^{-4})	$\approx 1.10^{-3}$ (± 5.10^{-4})	$\approx 1.10^{-3}$ (± 5.10^{-4})
Physical properties			
Specific gravity	1.00	2.00	2.30
Water absorption, max.	<0.3%	<0.3%	<0.3%
Mechanical properties			
Tensile strength	23 MPa	23 MPa	23 MPa
Flexural strenght	25 MPa	25 MPa	25 MPa
Flexion at break	3.2%	3.2%	3.2%
Elongation at break	3.1%	3.1%	3.1
Impact properties			
Charpy impact test (KJ/m²)	11.86	11.86	11.86
Thermal properties			
Heat deflection temperature	110°C	110°C	110°C

* Dielectric constant at 9.4 GHz. The permittivity value depends on the printing parameters and can decrease if the part is not fully dense

Why use 3D printing for RF?

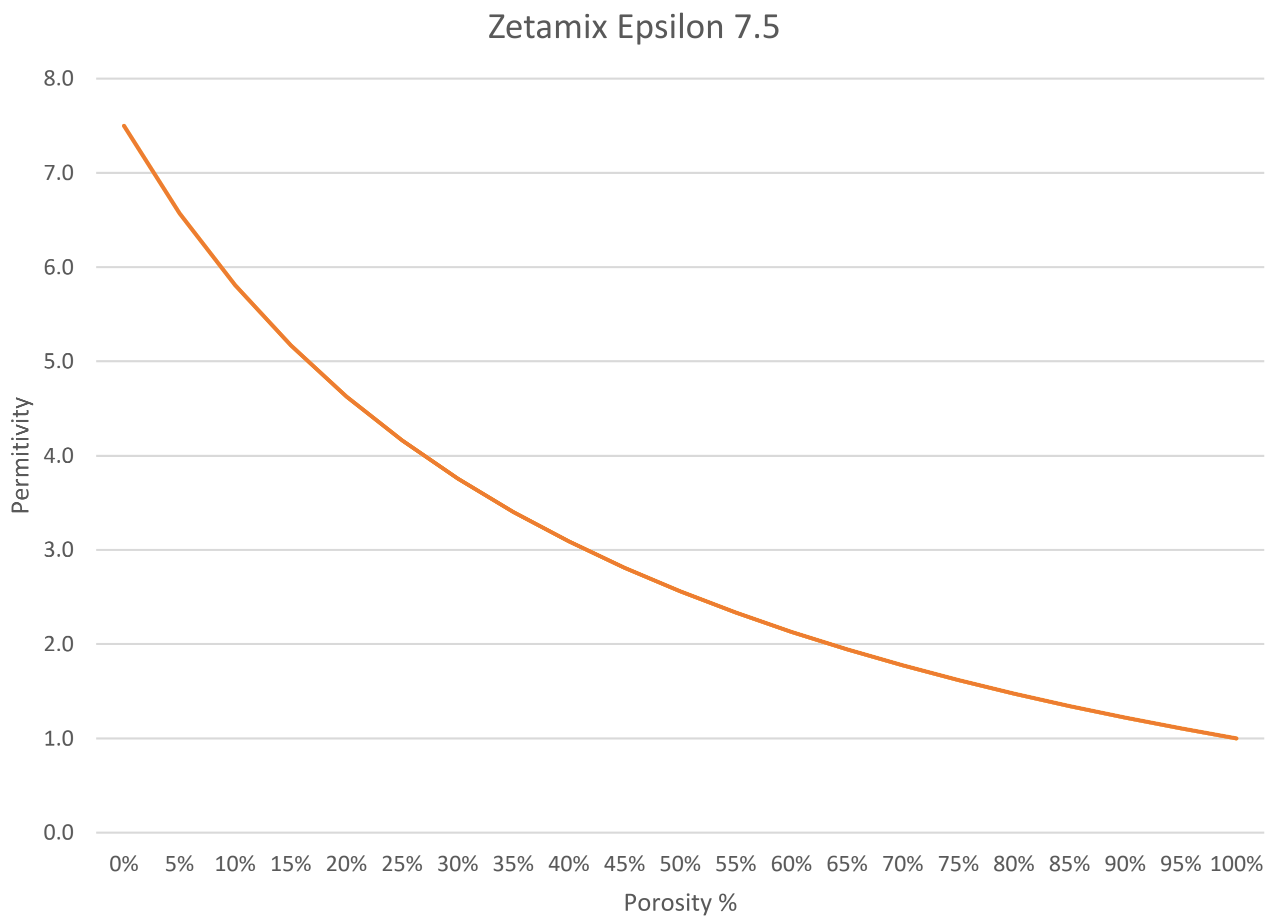


1

To produce complex shapes difficult to machine, small volume production, prototypes, fixtures, radomes…

Why use 3D printing for RF?

2 To tune permittivity through variations on infill



Permittivity adjustment

By printing porous structure with a cell size below the wavelength (typically 5 to 10 times smaller), the material will behave as an isotropic material with a lower permittivity than the bulk material. This can allow to adapt precisely permittivity to the application, or to have parts with different zones exhibiting different permittivities, the gradient of permittivity…

Why use 3D printing for RF?

3

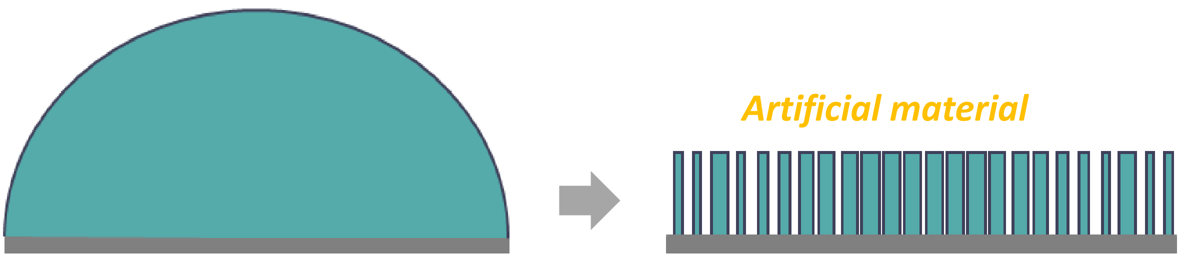
To produce metamaterial and metasurfaces, structured below the operating wavelength

Example of an RF component

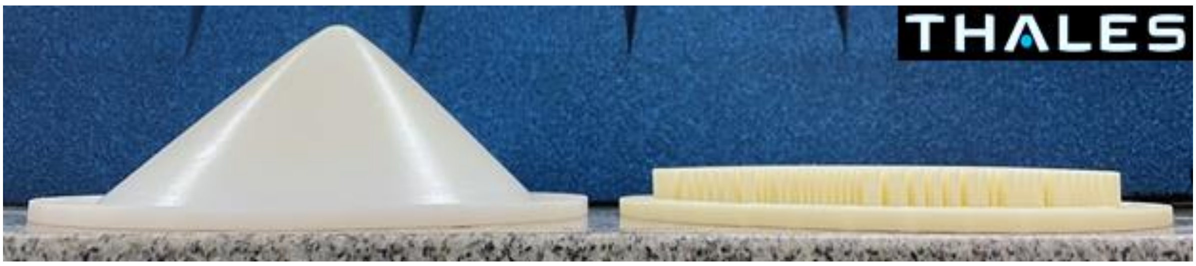
Bulk dielectric lens

Structured dielectric lens

Low profile and efficient



Thousands of pillars from hundreds µm to several mm



Material : Rexolite
Process : Machining

Material : ABS
Process : **FDM 3D-printing**

Metamaterials

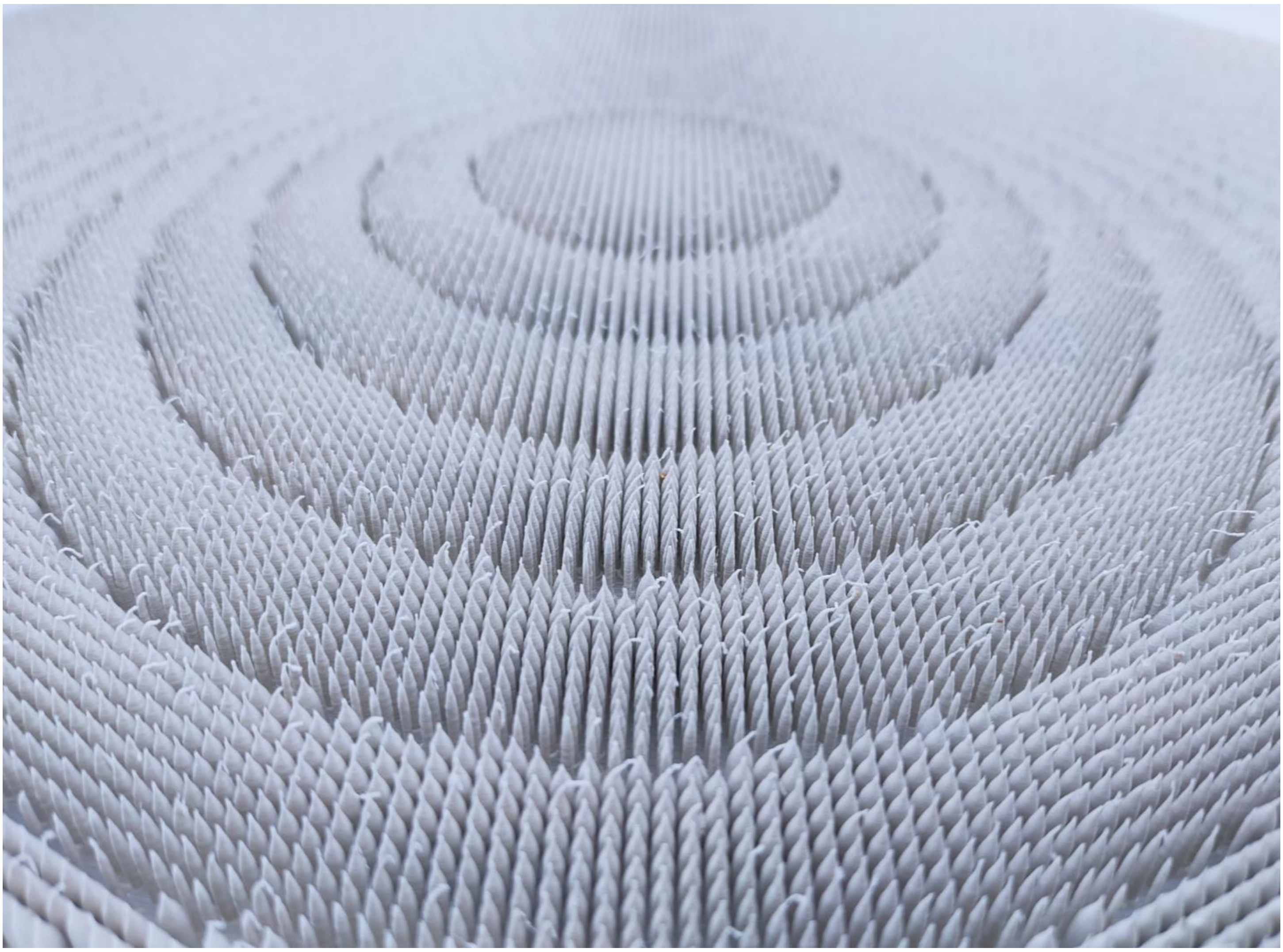
Structured surfaces of volumes can have complex behaviours, such as this meta – lens, which has the same function as the bulk lens, with much less material and a lower profile.

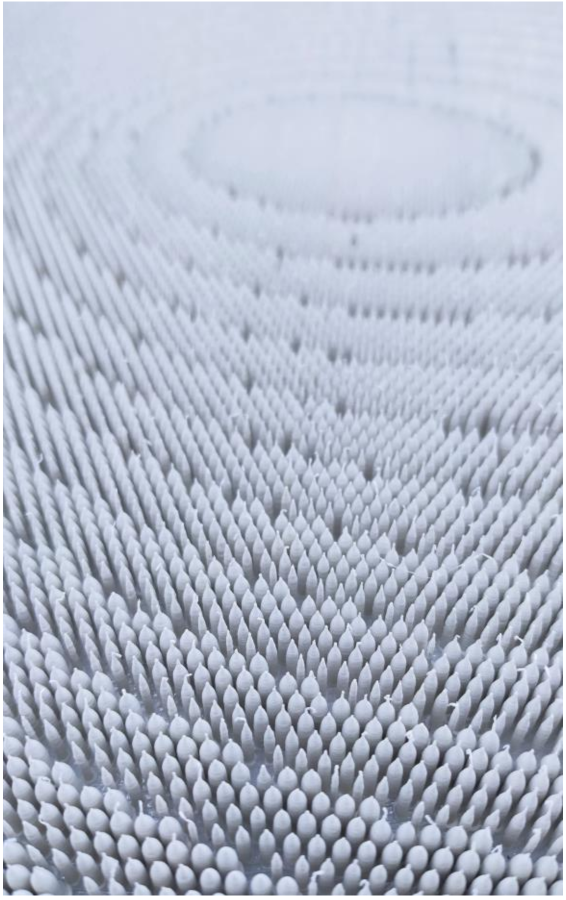
USE CASE 1

Example of Thales

Disruptive antennas concepts brought to life through 3D-printing of Zetamix Epsilon filaments

In recent years, several 3D-printed microwave components have been successfully demonstrated, which makes 3D printing a promising technology for the next generation of antennas and radiofrequency (RF) devices. To take full advantage of 3D printing for RF applications, new materials with specific dielectric properties need to be developed and mastered.





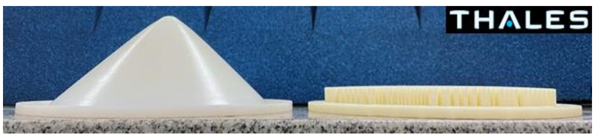
STORY

In the framework of a collaborative project, MACOY-3D, partly funded by the French Agency of Innovation for Defense, the consortium, with ICMCB, CANOE, Thales Research & Technology, and Nanoe, has developed a material with specific properties such as high permittivity and low dielectric losses. From this result, Nanoe has commercially launched the Zetamix Epsilon filaments, dedicated to radiofrequency applications. These filaments feature a high permittivity of 7.5 and a low loss tangent of 0.001. In addition, the Zetamix Epsilon filaments offer a good resistance in temperature with a Heat Deflection Temperature (HDT) of 115°C, which allows for operation in environments such as aerospace applications.

BENEFITS

One benefit of using 3D-printing technology is to end up with low-profile RF components as illustrated in the pictures below. The compactness is obtained with a 3D-structuration approach: on the left, a conventional RF lens fabricated by machining, and on the right, the same function obtained by 3D-printing

Adding to that, the filament can be used to create parts with large dimensions as illustrated below on the 46cm-diameter metasurface printed from Zetamix Epsilon filament, by the traditional single-step FDM process without any post-processing;



Picture above : bulk lens (machining) versus sub-λ lens (3D printing)

“Adding to that, the filament can be used to create parts with large dimensions as illustrated below on the 46cm-diameter metasurface printed from Zetamix Epsilon filament”

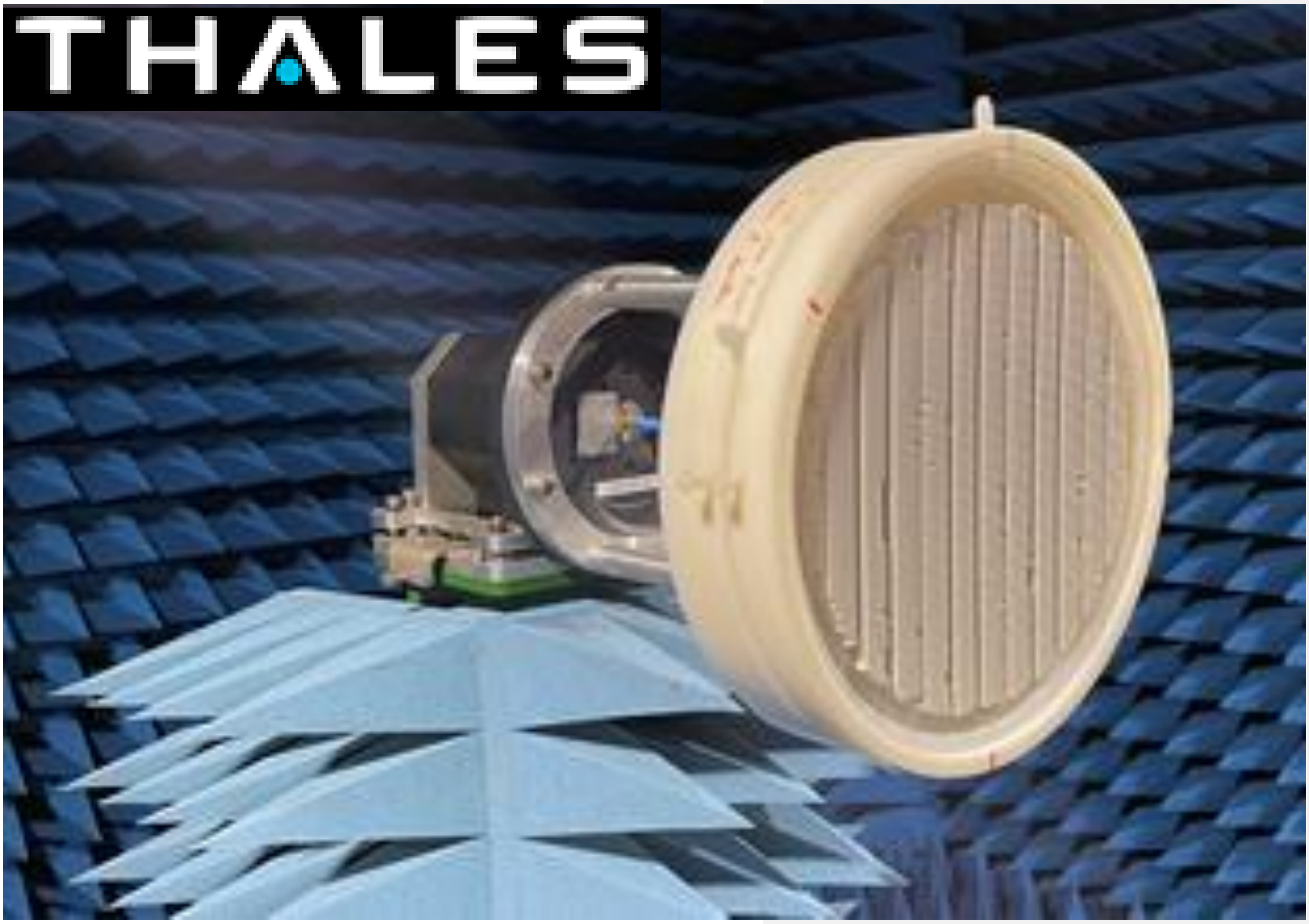
Based on 3D-printing of Zetamix Epsion filaments, Thales was able to demonstrate a novel efficient and low-profile steerable antenna architecture, which consists of a fixed feeder and two rotatable 28cm-diameter flat dielectric metasurfaces, printed by using Zetamix Epsilon filaments.

Such results of the printed metasurfaces with Zetamix Epsilon pave the way for the development of low-cost low-profile components for various radiofrequency applications

Want to learn more?

Read the complete paper from Thales here

The picture below: Low-profile 2D-beam-steering antenna, 30GHz



USE CASE 2

Example of LEAT

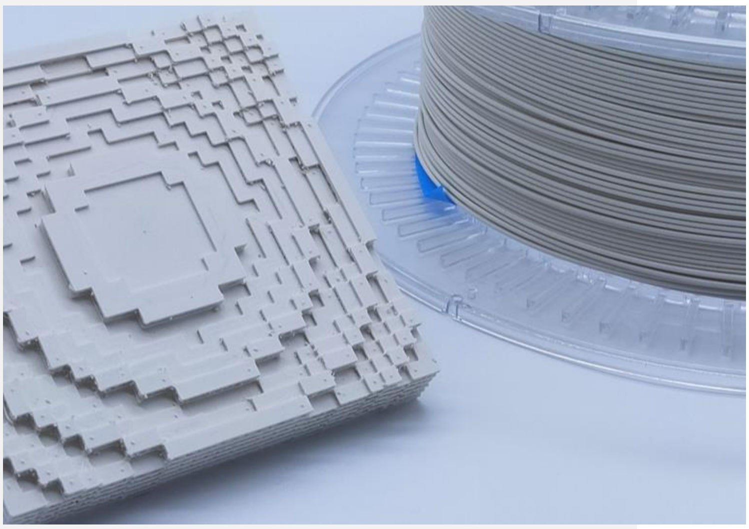
The futuristic 3D printed RF Dielectric Reflector

LEAT(Laboratoire d'Electronique, Antennes et Télécommunications) is a French laboratory dedicated to Information and Communication Technologies (ICT).

When talking about satellite and backhaul antenna, the better ones were usually determined by being the larger and heavier to produce the higher peak power. However, this makes them very expensive, hard to handle, and time-consuming to develop.

The Regular Dielectric Reflector

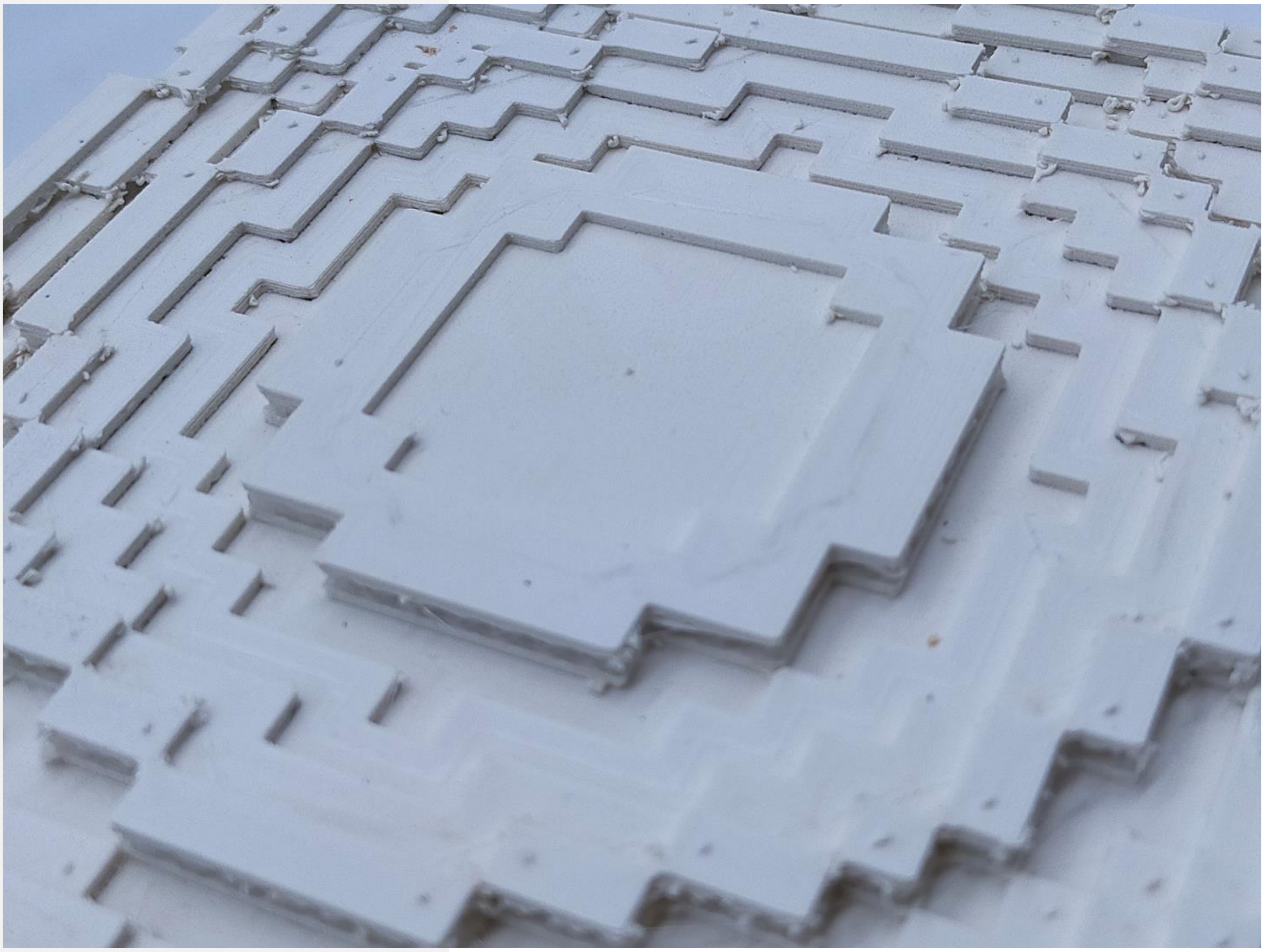
The classical Rf Deflectors are generally heavy weighted, voluminous, and design limited, not to forget that they are extremely expensive to fabricate.



Therefore, the requirement for an alternative RF Reflector with less complexity was suggested to be highly needed. In addition, the RF Dielectric reflector can reflect waves at certain frequencies and be transparent at other frequencies. The innovative feature can enable multi-functional parameters depending on the band.

Zetamix Epsilon Dielectric Reflector

Zetamix, in a collaboration with The LEAT and thanks to the new Epsilon Filament, managed to 3D print a brand-new innovative RF Deflector. It was created using 2 different materials, the epsilon 2.2 and the epsilon 7.5, this combination was made possible by using the Raise 3D. The 3D printing technique enables to print metasurface structures allowing the creation of flat parts with complex and lightweight discreet shapes. It is also characterized by its low losses and low cost.



This new innovative RF Reflector has an adjustable design and composition, making it interactable with a different range of frequencies. Since the Epsilon Filament comes in different permittivity, this characteristic allows interference with different Frequencies (the 7.5 permittivity filament reaches out to 100 GHz) The ratio of the filament used can also take part in this unique mission, the adjustment of it can allow the interaction with complicated frequency rates usually almost impossible to reach.

USE CASE 3

Example of, the Jiangsu Key Laboratory of 3D Printing Equipment and Manufacturing in Nanjing

3D Printed Circularly Polarized Dielectric Helix Antenna

By virtue of the new Epsilon Filament of Zetamix and low-cost FDM/FFF craft, the Jiangsu Key Laboratory of 3D Printing Equipment and Manufacturing in Nanjing, China, developed a new circularly polarized dielectric helix antenna.

Before use, the dielectric properties of the new Epsilon Filament including the permittivity and loss tangent were put to test. The results proved that the new parts relative permittivity can be adjusted from about 2 to 6 by changing the infill density and flow rate..

Fig. 1 Printed samples with different infill densities and flow rates.

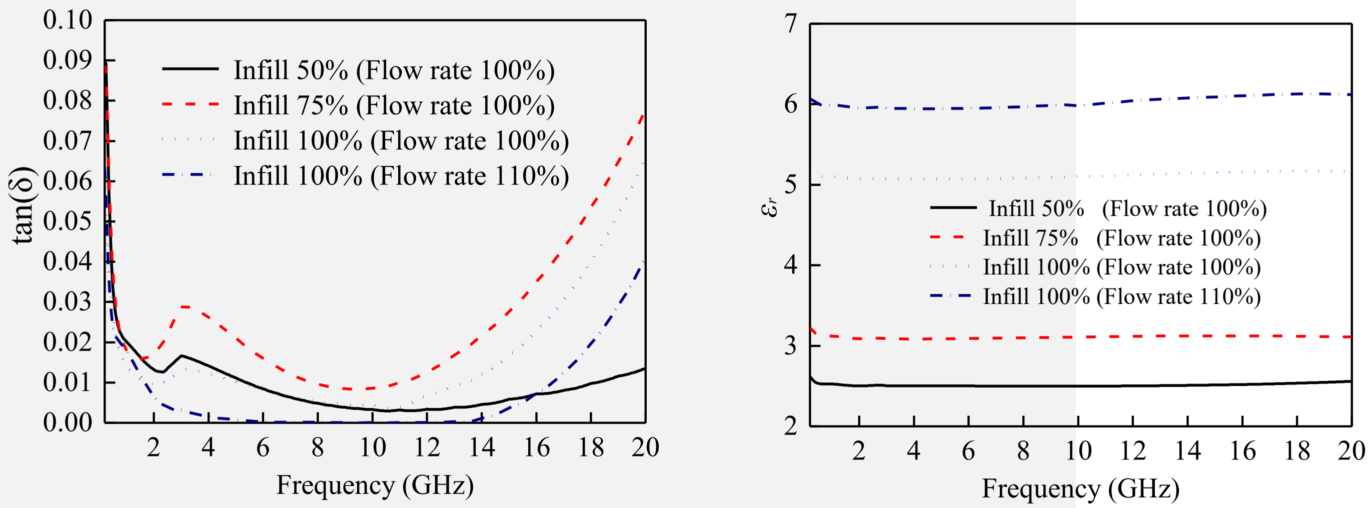
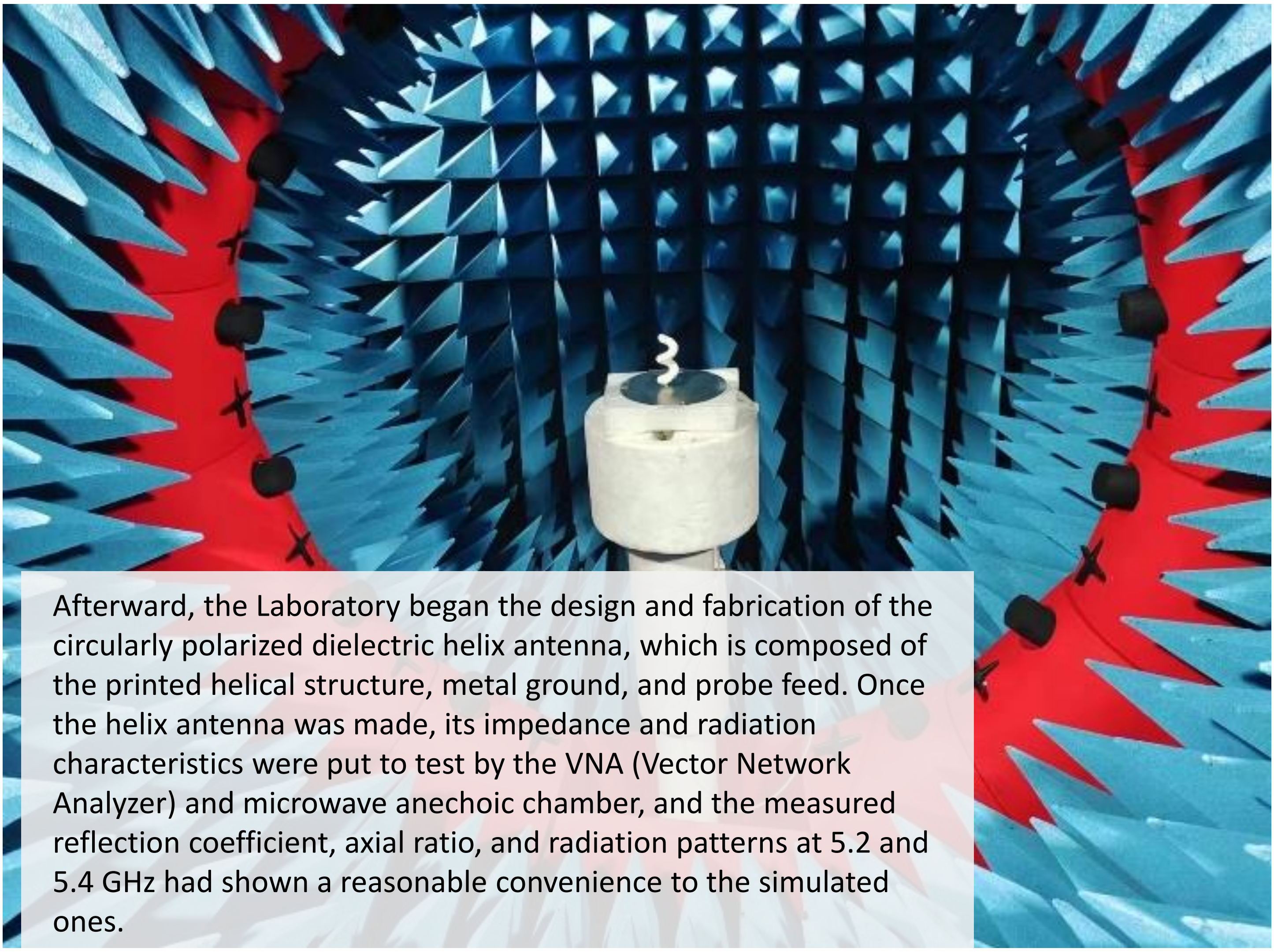


Fig. 2 Measured relative permittivities and loss tangents of printed samples.

Adding to that, the results has also proven the new Epsilon Filament to be a low-loss material that is indeed very suitable for RF applications



Afterward, the Laboratory began the design and fabrication of the circularly polarized dielectric helix antenna, which is composed of the printed helical structure, metal ground, and probe feed. Once the helix antenna was made, its impedance and radiation characteristics were put to test by the VNA (Vector Network Analyzer) and microwave anechoic chamber, and the measured reflection coefficient, axial ratio, and radiation patterns at 5.2 and 5.4 GHz had shown a reasonable convenience to the simulated ones.

Fig. 3 The measured process of fabricated antenna.

Fig. 4 The simulated and measured reflection coefficients of the antenna.

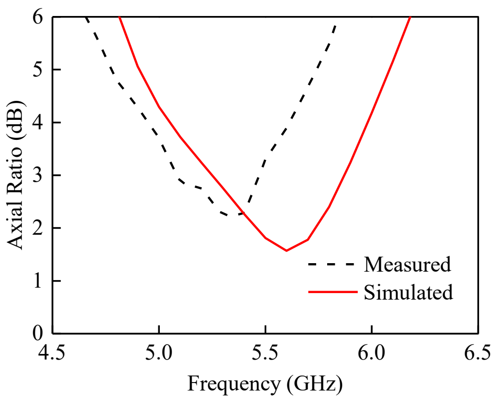
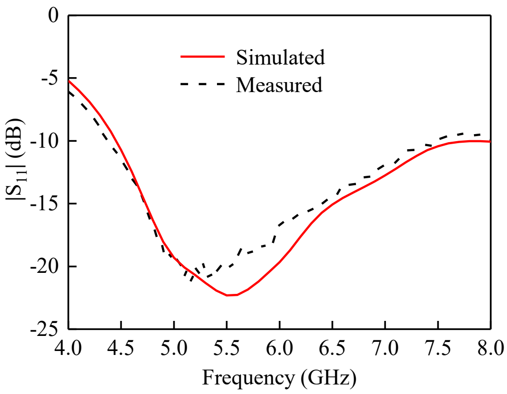


Fig. 5 The simulated and measured axial ratios of the antenna.



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