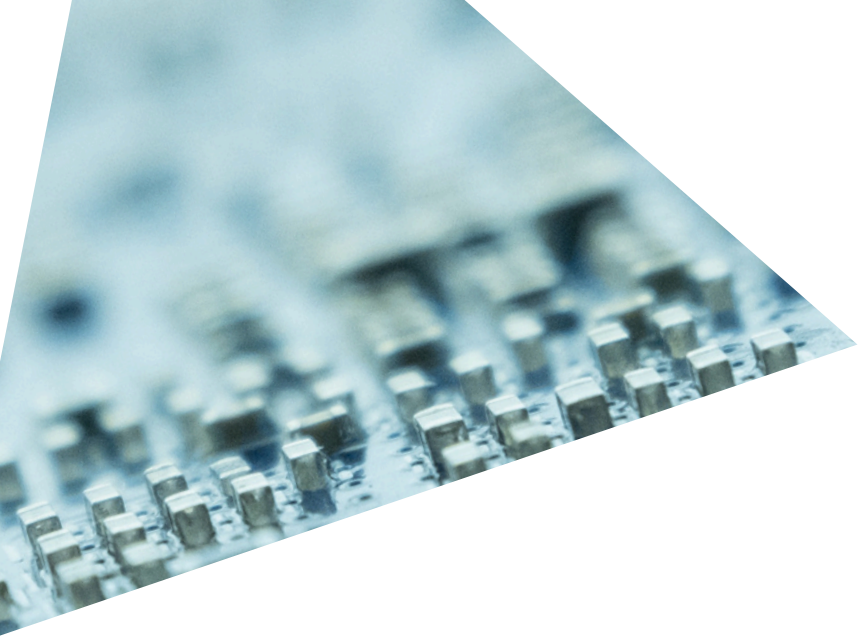
HYMAG'IN

Product catalogue

Magnetic filaments and ferrite powders

March 2025



Discover HYMAG'IN

HYMAG'IN produces and sells several ranges of **innovative ferrite-based magnetic materials**. **The products are ultra-fine powders and semi-finished products for additive manufacturing**, such as magnetic filaments. HYMAG'IN products are aimed at aerospace, spatial, defense, telecom, industry and automotive markets.

Ferrites are widely used in electronic systems. They are essential magnetic materials for passive components and solutions for electromagnetic compatibility (EMC). However, the use of ferrites, comes with many challenges:

- **Miniaturize to reduce weight and volume**
- **Reduce their environmental impact and energy consumption**
- **Secure their supply chains**

HYMAG'IN provides a solution to these needs by producing ferrites 100 times smaller, **using a unique, sustainable and low-energy technology based in Europe**.

NANOMAG is a range of powders designed for the manufacture of radiofrequency absorbers for EMC. It can also be used to produce passive components for inductors, transformers and filters in the kHz - MHz range.

FILAMAG™ is a range of filaments designed for the additive manufacturing of microwave absorbers.

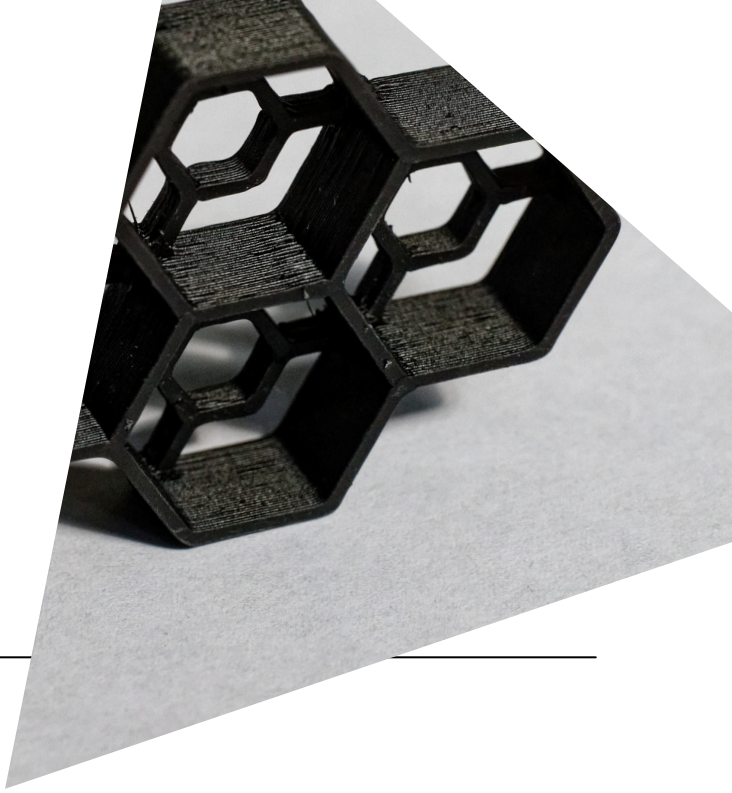


Table of contents

NANOMAG

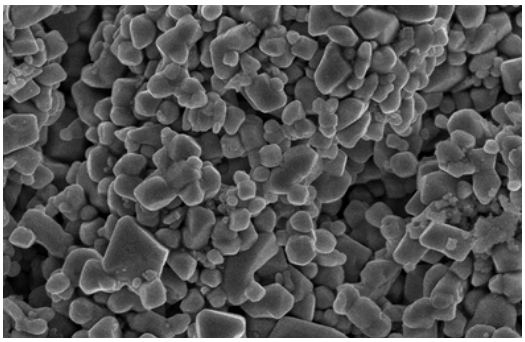
FILAMAG™

3D Designs

Use Cases

NANOMAG | Features

1 NANOMAG-MnZn



SEM Picture

NANOMAG-MnZn is a **Manganese-Zinc (Mn,Zn)Fe_2O_4 ferrite powder**.

The quality of NANOMAG products is characterised by electron microscopy (SEM-EDS) and X-ray diffraction (XRD).

Density		3.5 g/cm³
Purity		85 %
Laser granulometry		2 µm (avg)
Crystal size (SEM)	D10	150 nm
	D50	300 nm
	D90	520 nm
Curie temperature		330 °C
Saturation magnetisation		55-70 emu/g

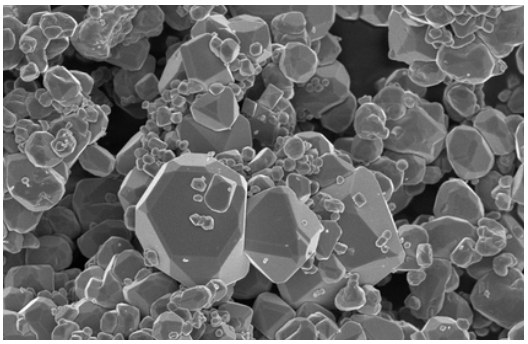
NANOMAG-MnZn powder is **easily incorporated into all types of polymers and silicones thanks to its ultrafine size**. Therefore, sheets and coatings made from NANOMAG-MnZn-filled composites are excellent EMC absorbers at frequencies ranging from 100 MHz to 5 GHz.

NANOMAG-MnZn can also be sintered to produce dense, low-loss ferrite products for energy conversion or signal filtering in the kHz - MHz range.

NANOMAG | Features

2

NANOMAG-Fe



SEM Picture

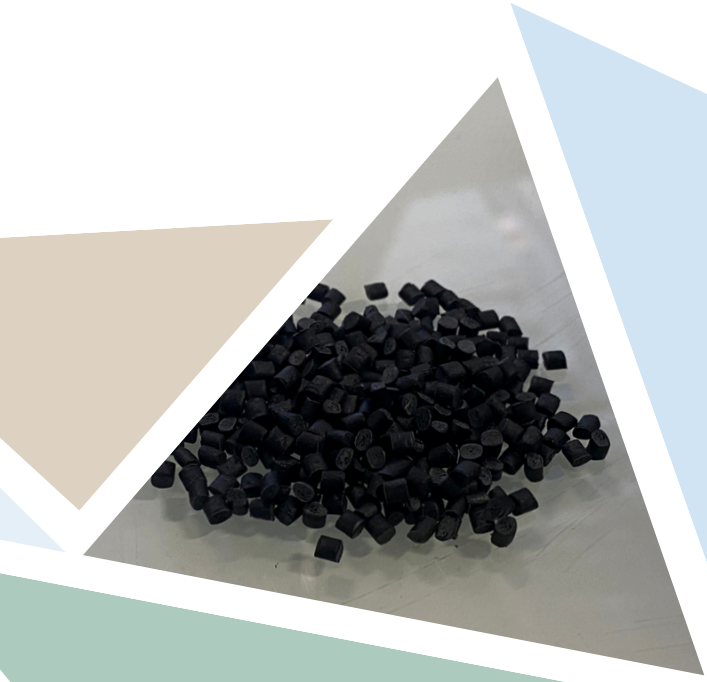
NANOMAG-Fe is a powder of iron oxide Fe_3O_4.
The quality of NANOMAG products is characterised by electron microscopy (SEM-EDS) and X-ray diffraction (XRD).

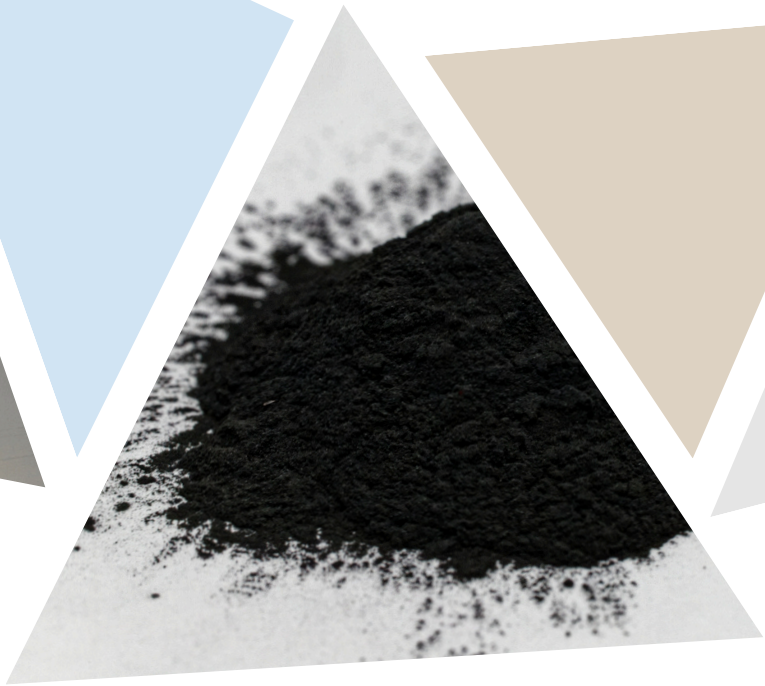
NANOMAG-Fe is **easily incorporated into all types of polymers and silicones** to produce electromagnetic absorbing composite materials, such as thin, flexible, machinable sheets.

Density		4.2 g/cm³
Purity		>99%
Laser granulometry		4.6 µm (avg)
Crystal size (SEM)	D10	250 nm
	D50	1 300 nm
	D90	2 500 nm
Curie temperature		580 °C
Saturation magnetisation		86 emu/g

From pellets,

a mix of NANOMAG and polymer,





to FILAMAG,™

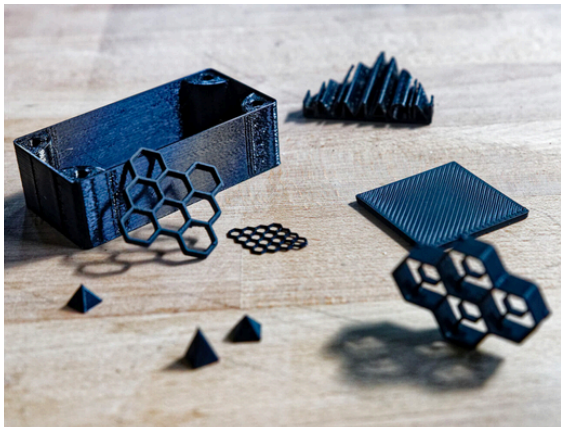
an innovative 3D filament for RF absorption.

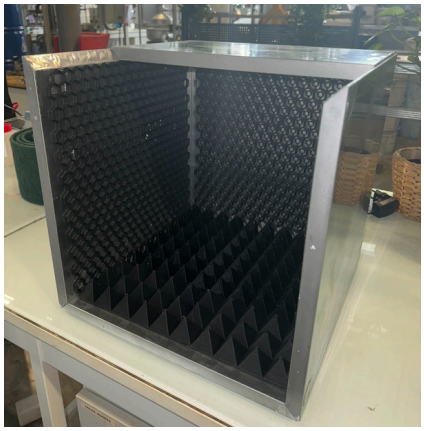
FILAMAG™ | 3D-printed filament

FILAMAG™ is a range of **magnetic filaments made from polymer filled with magnetic nanoferrite powders NANOMAG**. These powders can be integrated into different types of rigid or flexible polymer matrices.
FILAMAG™ can be used with Fused Deposition Modeling (FDM) 3D-printing technology.

GEOMETRY CONCEPTION

FILAMAG™ filaments enable to print absorbing parts as precisely as required **to match the geometry and the space complexity of your electronic systems.** The structure of the printed materials, micro-pyramids or honeycombs for example, and their dimensionsare accurately calibrated during the set up of the 3D printing process to suit your specific application (see photo below of an anechoic chamber filled with our absorbers).





PERFORMANCE OPTIMIZATION AND WEIGHT REDUCTION

Through a relationship linking the geometry of the absorber and its interaction with electromagnetic waves, designing 3D-printed absorbers with FILAMAG™ considerably **improves their performance while lightening their structure**.

DELIVERY TIME

By choosing to print on your own premises, you have the freedom **to produce whenever you want, whatever you want, and wherever you want**, ensuring on-demand manufacturing perfectly tailored to your needs.

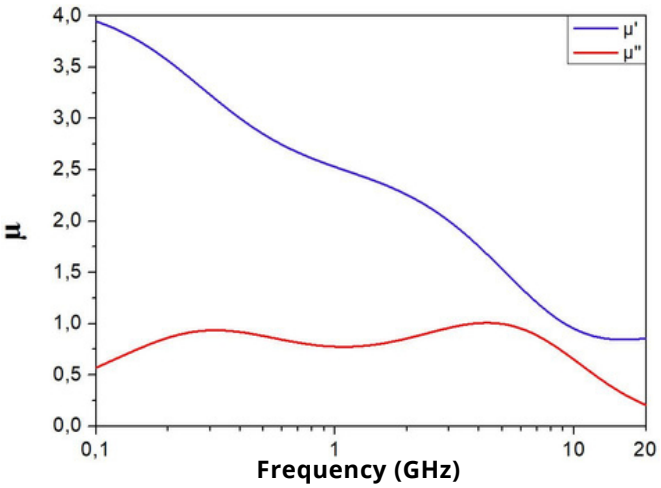
Should you prefer to rely on our in-house expertise, our streamlined process offers a **delivery lead time of 1 to 4 weeks**.

FILAMAG™-F
| Flexible filament

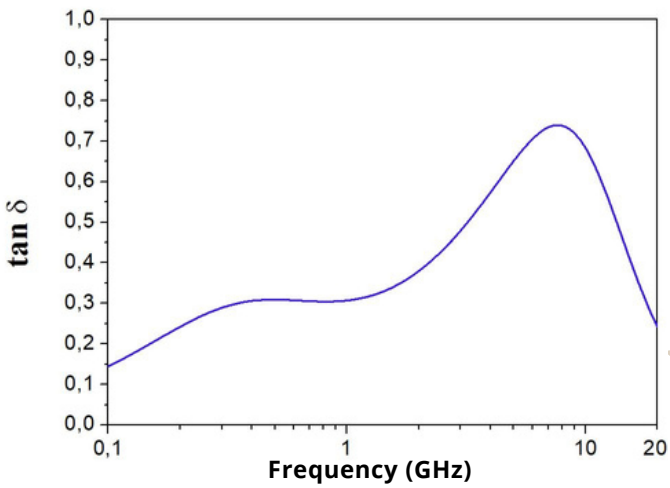
FILAMAG™-F is a **flexible magnetic filament** created by blending our NANOMAG powder with a copolyester.
This flexibility enables his integration into different types of systems, as well as potential applications **under mechanical stress.**

Printing parameters for FILAMAG™-F	
Composition	NANOMAG Flexible polymer
Loading rate	70% by mass
Extrusion temperature	230 °C
Printer bed temperature	45 °C
Type of printer bed	Textured
Nozzle (recommended)	0.6 - 1 mm
Diameter	1.75 mm

Electromagnetic properties	
Permittivity at 1 GHz	ε' = 19.00 ; ε'' = 3.86



Permeability (measured)



Magnetic loss tangent (measured)

FILAMAG-F™
| Features

Mechanical properties (measured at 23°C = 73°F)		
Physics	Density	2.8 g/cm
	Hardness **ISO868**	98 Shore A
Traction *Tests performed at 1mm/min* **ISO527-2**	Tensile modulus (Young)	559 MPa
	Maximum tensile stress at break	11 MPa
	Deformation at maximum stress	9.2 %
Bending (3 points) *Tests performed at 2mm/min* **ISO178**	Bending modulus	467 MPa
	Maximum bending elasticity stress	14.9 MPa
	Deformation at maximum stress	8.6 %
Shearing *Tests realised at 2mm/min* **ISO14129**	Modulus of planar shear G^{12}	294 MPa
	Shear stress at break	4.4 MPa

Thermal properties		
ISO75	HDT-B (0,45 MPa)	44°C

Properties of test samples printed with FILAMAG-F™, successively at -45 and +45° per layer.

FILAMAG™-F | 3D Designs

3D-printed parts are made using the FILAMAG™-F magnetic filament, specifically designed to absorb electromagnetic waves. Thanks to this technology, it is possible to create customized structures, adaptable to the specific needs of GHz applications.

1

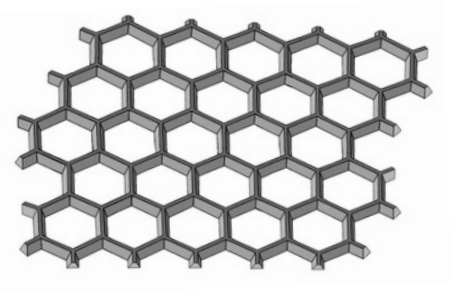
GHZ NARROWBAND: SHEET

Selecting a ferrite filler with appropriate electromagnetic characteristics and matching the thickness to the required frequency are essential factors **for optimum absorption**.

Page 11

2

GHZ NARROWBAND: HONEYCOMB STRUCTURE



In the quest for effective absorption of electromagnetic waves, custom-designed shapes play a crucial role. **By customizing the design** of your 3D parts, **HYMAG'IN targets absorption at the specific frequencies** of your EMC requirements.

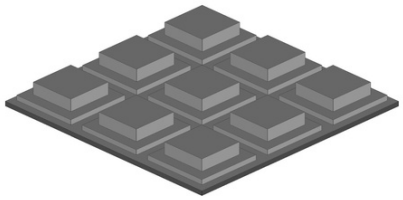
Page 13

3

GHZ BROADBAND: MULTI-SCALE SQUARE

HYMAG'IN has developed a shape that extends the targeted frequency range. With FILAMAG™-F, **this multiscale square structure absorbs broadband electromagnetic waves in the GHz range.**

Page 15



3D DESIGNS
| GHz Narrowband

1

SHEET

The sheet is a simple but effective design for applications requiring absorption of electromagnetic waves on a **specific frequency between 1 and 20 GHz.** The flexibility and adjustable dimensions of the sheet make it an optimal solution for targeting a given frequency according to its thickness, and for easy integration on the surface or inside the system. This product is used in the **telecommunications, electronics and Defense applications.**

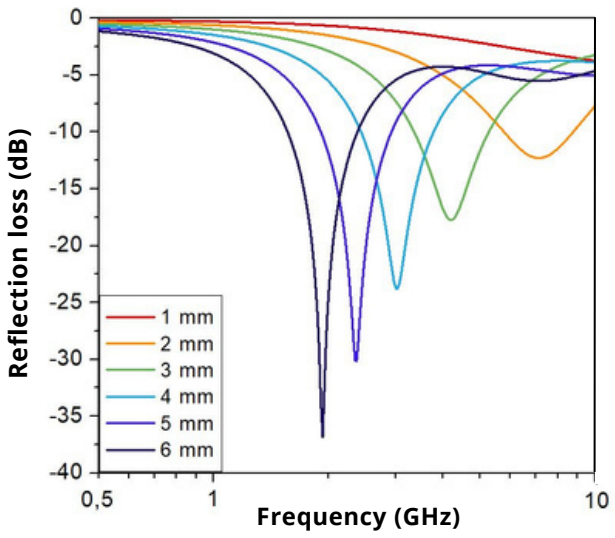
Shape: Depending on your needs, our sheets can take any form.

Dimensions: **Thickness adjusted** to target frequency.
Length and width adjustable according to specifications.

Use frequencies: Adjustable depending on the thickness, **between 1 and 20 GHz.**

Specifics: **Flexible** material, adaptable to your space constraints.

The graph below illustrates how varying thickness affects the reflection loss of the sheet. Simulations are required to **select the optimum thickness according to the required frequency, performances and system dimensions.**



Reflection loss of FILAMAG-F™ sheet structure of different thicknesses (simulated)

When thickness is equal to a quarter of the wavelength, a resonance phenomenon occurs, allowing absorption (reflection losses) thanks to the **appearance of destructive interferences.**

Why choose FILAMAG-F™ sheet structure?

- **Flexible: easy to integrate and place on any surface**
- **Adaptable dimensions**
- **No need for machining or cutting**

Example of use: Metal casing shielding is commonly used for home energy meters. However, the conductivity of the metal can cause waves to reflect on the surface of the case, interfering with the electronic components inside and disrupting the device's operation.
To mitigate these effects, an absorbing sheet can be placed within the casing to **prevent wave reflections** and at the joints to **reduce energy leakage.**

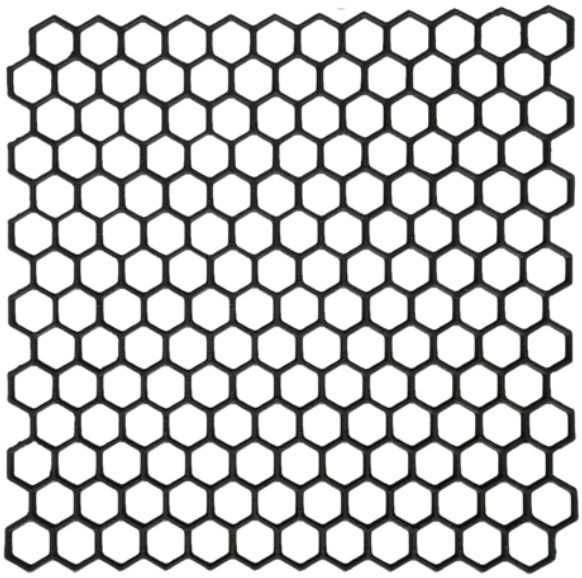
***of the filament used: here refer to FILAMAG-F™**

3D DESIGNS
| GHz Narrowband

2

HONEYCOMB

The honeycomb structure is optimized for the absorption of electromagnetic waves **on a targeted frequency.** This honeycomb design maximizes absorption efficiency while maintaining a **light weight and robust** mechanical structure. By adjusting the dimensions (cell diameter, wall thickness, angle of inclination), absorption can be calibrated to a specific frequency in the GHz range.

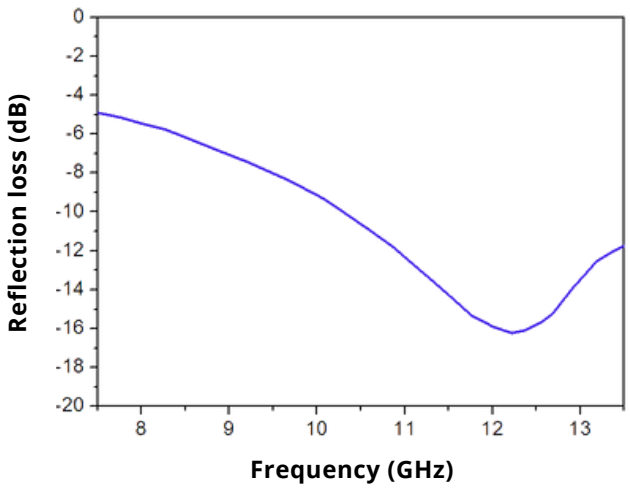


Shape: Honeycomb structure.

Dimensions: **Adjustable dimensions** to target other frequencies.

Use frequencies: **Adjustable** on request and according to the constraints of your systems.

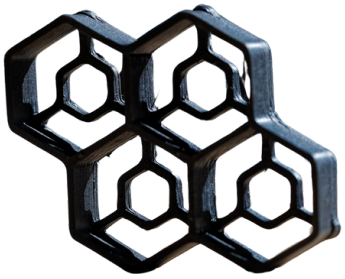
Below the results of a 3D honeycomb pattern designed to absorb in the dozen of GHz: significant reflection losses of **-16 dB around 12 GHz** and **a weight three times lighter** than a 3D sheet of the same thickness.



-16 dB around 12 GHz

Reflection loss of FILAMAG-F™ honeycomb structure (measured)

This architecture shows resonance when the cell dimensions correspond to a quarter of the targeted wavelength. This wave will be reflected many times in the cells, generating a **progressive absorption of the wave.**



More elaborate architectures can be developed on request, in particular to enable multiple resonances.
New architecture breaks down into multi-scale cells. With this shaping, **several resonances will appear to allow absorption peaks at different frequencies.**

Why choose FILAMAG-F™ honeycomb structure?

- **Lightweight: performance/weight ratio**
- **Flexible material**
- **Customized, adaptable**

Example of use: This honeycomb is used by device manufacturers and/or users whose aim is to reduce the reflection of electromagnetic waves on the surface of these systems. This is particularly the case for equipment that needs to **be made undetectable by reducing its radar cross section (RCS).**

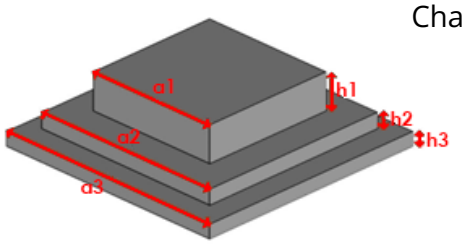
***of the filament used: here refer to FILAMAG-F™**

3D DESIGNS
| GHz Broadband

3

MULTI-SCALE SQUARE

The square patterned structure is designed to **extend the frequency range of electromagnetic wave absorption.** Thanks to its modular design, it is particularly suited to environments where GHz broadband performance is required, while allowing **functional integration into devices.**

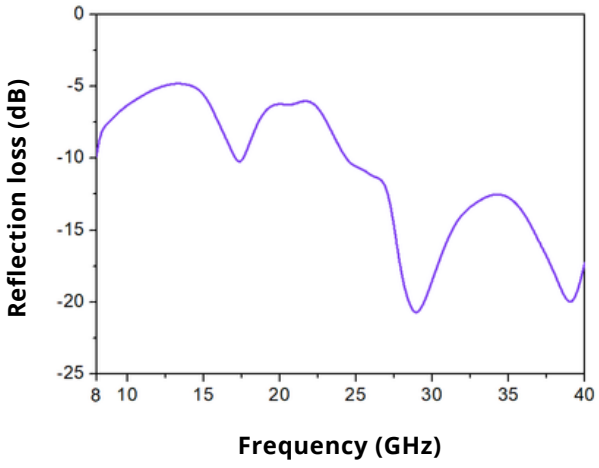


Shape: Square structure with repeating square geometric patterns.

Dimensions:
Ex: 200x200x3,7 mm³ and patterns
h1 = 2,4 mm; h2 = 0,8 mm; h3 = 0,5 mm;
a1 = 12 mm; a2 = 18mm; a3 = 20 mm

Use frequencies:
Characterized from 8 to 40 GHz.

This GHz broadband absorption is important in a variety of fields, such as **anechoic chambers, radar cross section (RCS) reduction, wireless communications and antennas.**



Reflection loss of 200x200x3,7 mm³ FILAMAG-F™ multiscale square structure (measured)

Absorption phenomena are induced here by the dimensioning of the patterns. In the lower part of the absorbed frequency range, resonance occurs when the dimensions of the square patterns correspond to a quarter of the wavelength. At higher frequencies, diffraction phenomena allow the wave to penetrate the material.

The dimensioning of this multi-scale square structure is just one example. Absorption performance varies according to size and geometry.
HYMAG'IN is able to adapt and vary the geometry of the design according **to your needs, use cases, constraints**, but also **to your specific requirements**: performance optimization, frequency band extension...

Why choose FILAMAG-F™ multi-scale square structure?

- **Broadband absorption with reduced thickness**
- **Mechanical robustness**
- **Volume gain**

Example of use: These repeated square-pattern structures can be used in **anechoic chambers** to replace GHz pyramidal absorbers. These designs are more compact than pyramids, saving space.

***of the filament used: here refer to FILAMAG-F™**

Use Cases
| When to choose HYMAG'IN?

1

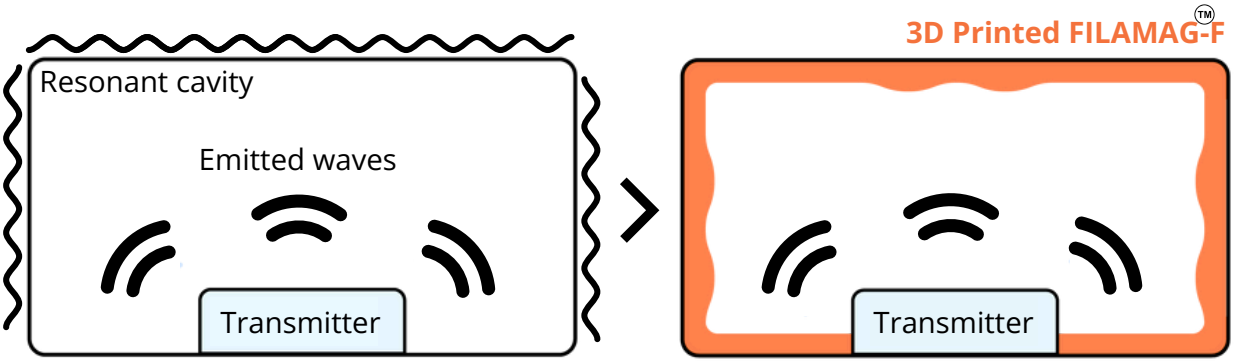
RESONANT CAVITY

How it works?

In resonant cavity, **electronic components and antennas emit waves** that are reflected on the metal walls of the cavity. These reflected waves disturb the circuit **by generating interference**.

- **Internal reflections:** The metal structure amplifies certain frequencies and increases residual EM fields.
- **Stray radiation:** Reflected waves cause interference and measurement or signal disruptions.

The applicable solution is to add our absorber FILAMAG-F™ within the case, in order **to limit internal reflections** and **reduce radiated emissions**.



What's the HYMAG'IN's point?

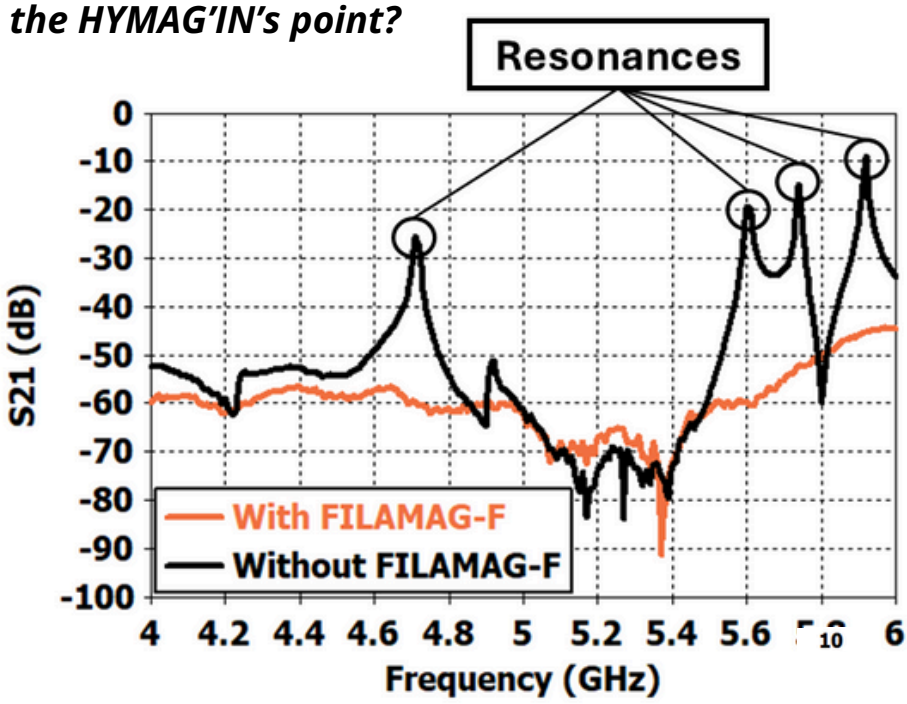


Fig. Transmission coefficient between two SMA connectors in a resonant cavity

Our 3D-printed FILAMAG-F™ absorber **eliminates resonant cavities**.

We offer 3D-printed absorbers, FILAMAG-F™, providing:

- **Compatibility with confined spaces**: Compact solutions adapted to restricted environments.
- **Ease of implementation**: Quick installation and easy integration into existing systems.
- **Custom optimization**: Adjustable geometries to maximize absorption in specific configurations.

For instance, our honeycomb structure showcases **advanced adaptability**, with thicknesses precisely **tailored to specific frequencies**, ensuring **optimal absorption performance**:

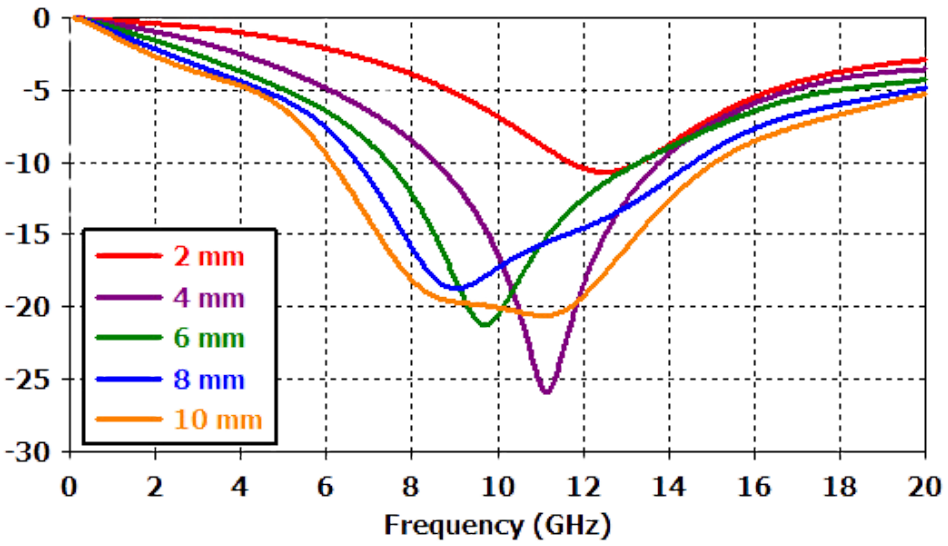


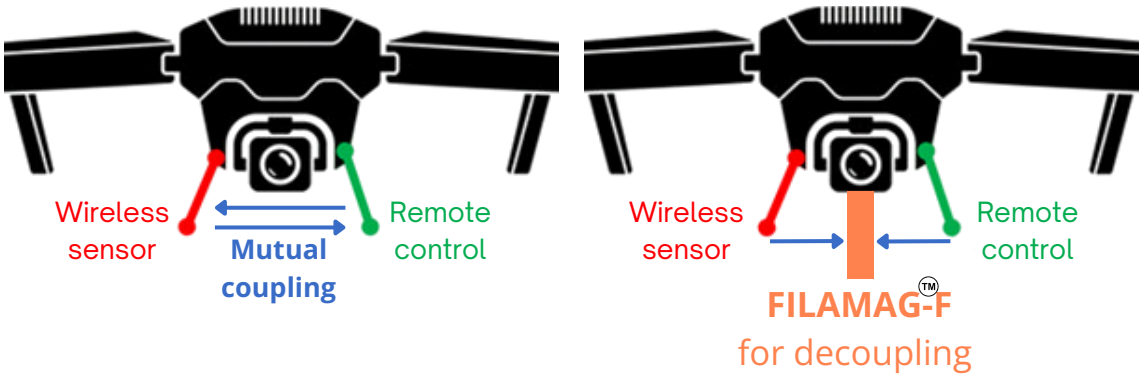
Fig. Reflection loss in dB: Parametric study of honeycomb geometry thickness

Use Cases
| When to choose HYMAG'IN?

2 ANTENNA DECOUPLING

How it works?

Antenna decoupling is a set of techniques, based on physical and technical mechanisms, used **to minimize interference between multiple antennas** in an RF system. It ensures optimal performance in terms of radiation and reception while preserving signal integrity. In modern environments, **effective decoupling is essential to maximize the performance** of communication systems.



Coupling between antennas can significantly affect their resonant frequency, potentially **shifting it outside the originally intended band** and **distorting the radiation pattern.**

What's the HYMAG'IN's point?

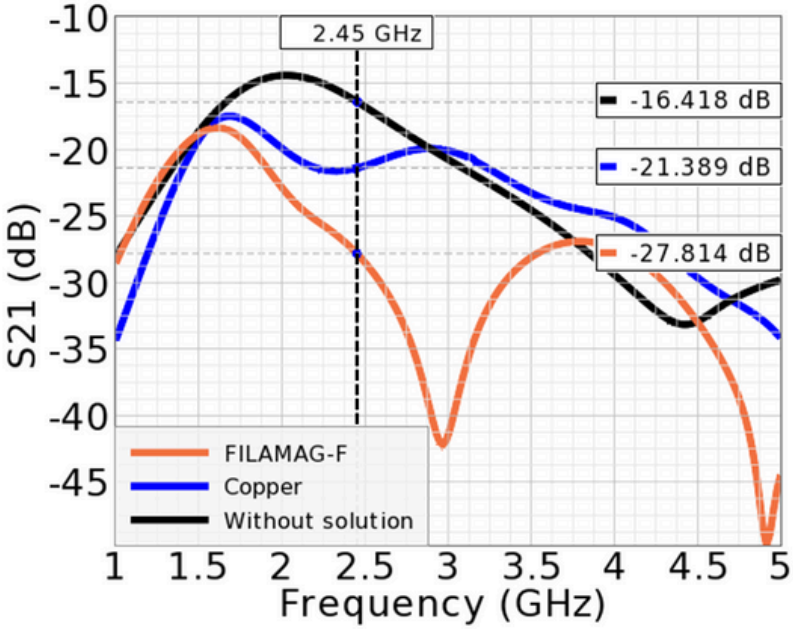


Fig. Mutual coupling (transmission coefficient) between two antennas with FILAMAG-F and copper

With FILAMAG-F™, the transmission coefficient improves **from -16.4 dB to -27.8 dB**, at the Wi-Fi frequency, corresponding to a **69.4% reduction in coupling.**

Our decoupling methods **can be adapted to the space available** and to your systems.

Use Cases
| When to choose HYMAG'IN?

3

ANECHOIC CHAMBERS

How it works?

Anechoic chambers are controlled environments that act as Faraday cages, with pyramid-shaped absorbing materials covering their conductive walls. These materials **absorb electromagnetic waves, eliminating interference,** reflections, and echoes while preventing refractions. By simulating an infinite free-space environment around the RF system, anechoic chambers enable **precise, reproducible measurements** for electronic and RF systems.

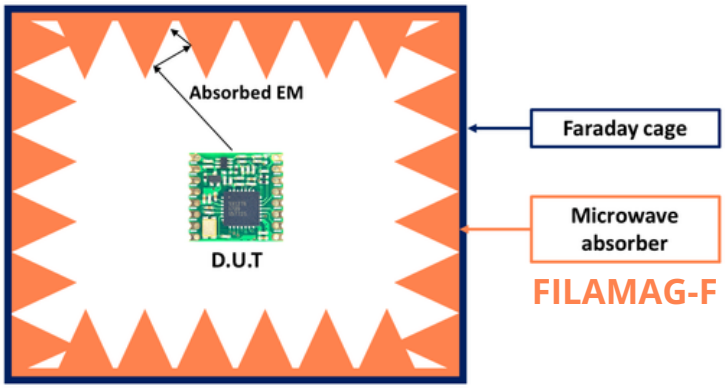


Fig. Diagram of an achenoic chamber

What's the HYMAG'IN's point?

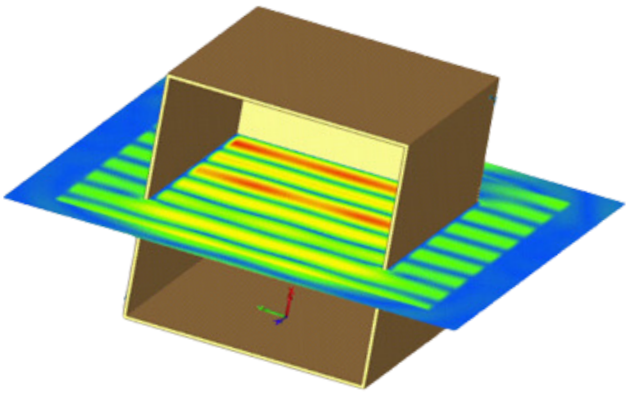


Fig. EM field in a housing without absorber in response to a 6 GHz plane wave, amplitude 1 V (calculated)

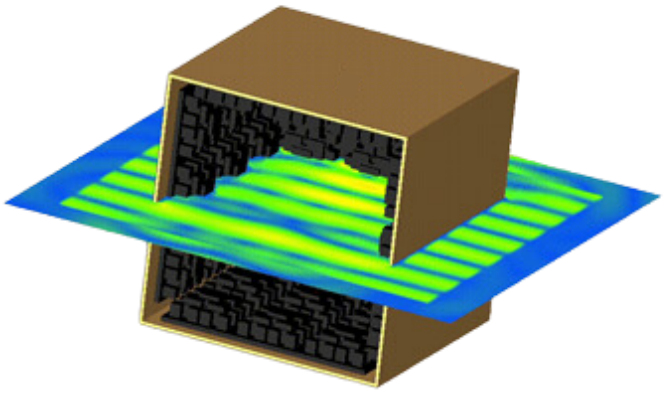


Fig. EM field in an anechoic chamber with absorbers in response to a 6 GHz plane wave, amplitude 1 V (calculated)

HYMAG'IN offers 3D-printed absorbers, FILAMAG™-F, providing:

- **Compact surfaces**: Offer a space-saving solution suitable for measurement enclosures.
- **Wide frequency coverage**: Ensure effective EM wave absorption across a broad range of frequencies, allowing various RF devices to be tested.
- **Adaptable geometry**: Maximize absorption performance through customizable plate shapes.

PA6,

soon.

CONTACT US

FERRITES AND TAILOR-MADE PRODUCTS

Do you want to explore new applications and uses of ferrites?
Are you looking for new formulations of ferrite materials?
Do you have specifications on filament properties?

Our experts look forward to hearing from you about:

- **Exploring new formulations of ferrites;**
- **Developing composite materials with higher flexibility and higher performance;**
- **Designing specific 3D geometries to adapt to your use case;**
- **3D printing precise absorbent parts, calibrated to absorb the desired frequency or frequency band;**
- **Providing 3D printing support throughout the entire process;**
- **Characterizing your products in terms of chemical, magnetic, and electromagnetic properties;**
- **Investigating new and trendy applications for magnetic materials.**

NEED MORE INFORMATION?

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