Zetamix and LEAT: Shaping the Future of Antennas Using 3D-Printed Ceramic Material

Founded by three engineers in 2008, Nanoe is a French company specialised in the elaboration and production of highly innovative materials. With its knowledge and know-how in the ceramics field, the company launched in 2018 a new brand, Zetamix: the first ceramic and metal filaments accessible to all. LEAT is a French laboratory dedicated to Information and Communication Technologies (ICT). By bringing together academic actors (UNS, INRIA, EURECOM, CNRS, Polytech Nice Sophia, Mines Paris Tech, etc.), competitiveness clusters, associations and technological platforms. LEAT aims to find technical solution to democratize and generalize IoT (Internet of Things) whether it be for domestic or industrial use.

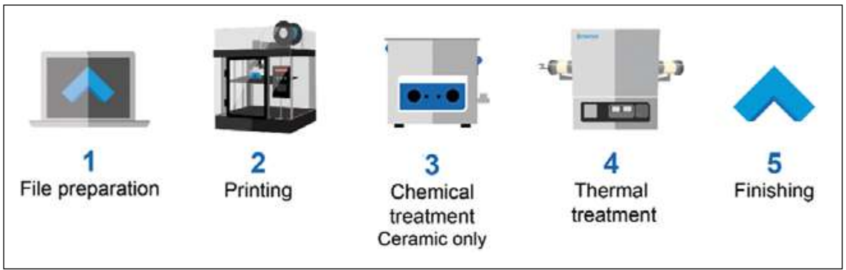

Fig. 1
Zetamix process

Fig. 2
Satellite

To answer the increase demand of connected objects, more communications are required, and therefore more antennas. These devices have to be more affordable, smaller, and as energy efficient as possible, especially for low data rate satellite communications, which are a new target of laboratories and startups such as LEAT.
To reach this goal, LEAT is working on S-Band antennas (frequency from 2 GHz and 4 GHz) and adapted Dielectric Resonator Antenna (DRA).

Keywords
Zetamix, anatennas, satellite, 3D printing ceramic, zirconia, dielectric resonator

The laboratory has identified Zetamix technology as a tool to reach their goal: shaping next generation antennas (Fig. 1). Dielectric resonators have a huge role in such antennas: they broadcast the waves to widen their range. They are made in ceramic, for instance zirconia, which shows both good permittivity and a small loss of signal. For each frequency standards, a specific resonator is required, with both a permittivity given by the choice of material and an adapted design.
However, reaching the right resonance frequency while maintaining a small size device is no easy task. Indeed, to compensate the value of permittivity of a material, engineers usually have to change the size of the object, which triggers design issues.
Moreover, regular antennas are made in two parts: one for supporting downlink satellite communication and the other for uplink satellite communication (Fig. 2). Two dielectric resonators with different resonance frequency are required. Engineers try to find the right material and the right ratio

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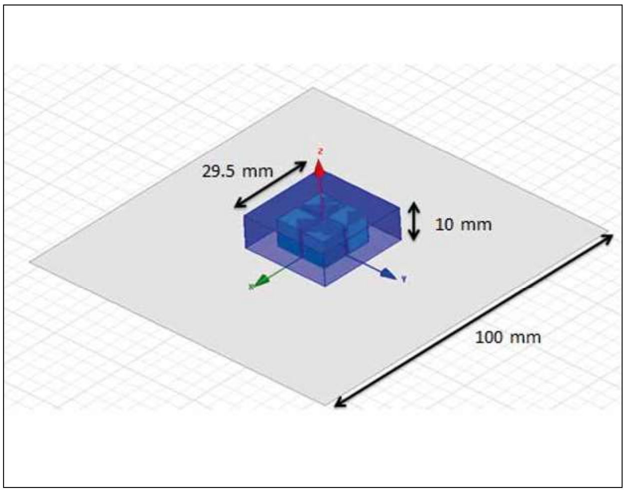

Fig. 3
3D view of the proposed structure

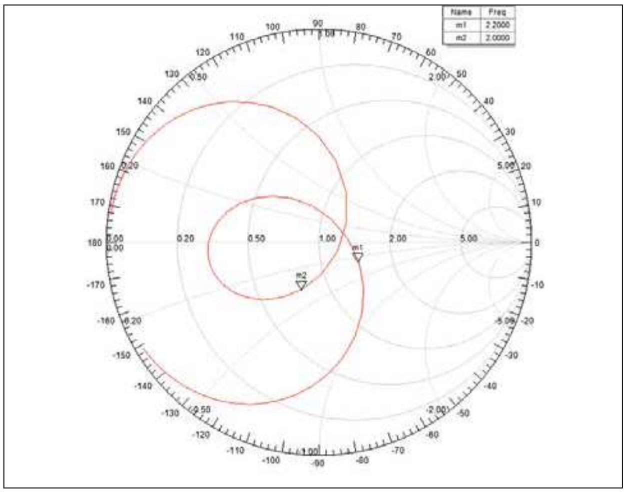

Fig. 4
Simulated Smith chart

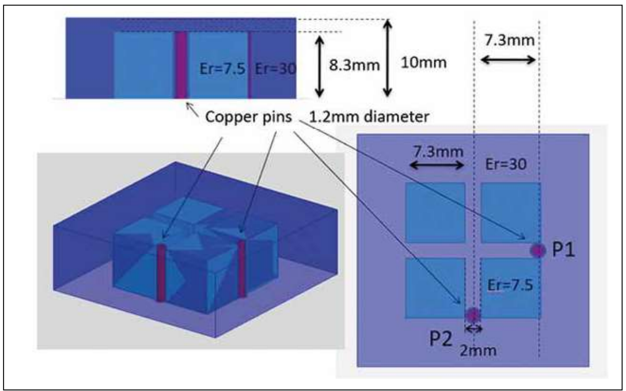

Fig. 5
Side, top and 3D view of the DRA

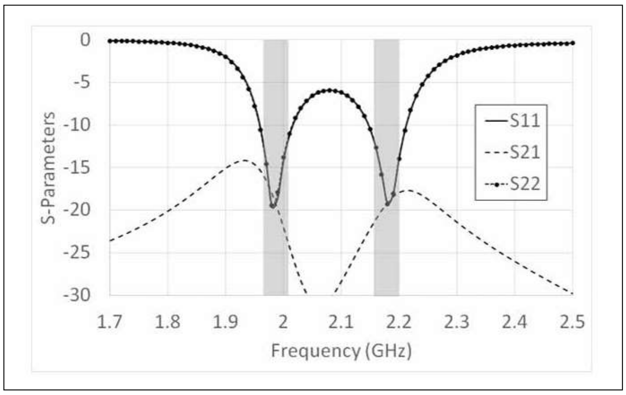

Fig. 6
Simulated S-parameters

between the size of the part and the permittivity for both parts.

That is where Zetamix technology comes in. In addition to provide technical material such as zirconia, Zetamix 3D printing is a very simple and affordable technology. The process of fabrication is simple: the part printed is a mix of binder and ceramic. To reach a density of 99 %, a debinding and sintering post process is required. By combining stunning material properties provided by the brand and the impressive shaping possibilities of 3D printing, the lab succeeded to find a solution for a low investment.

To print their DRA, LEAT used zirconia which shows excellent dielectric properties: permittivity $\varepsilon = 30$ and low loss: $\tan \delta = 10^{-3}$. FFF can make variations of density for the printed part which makes it possible to print a zirconia part with controlled porosity, and therefore a controlled permittivity lower than 30 and thus reach the optimum value. But the revolution of this process does not stop here: 3D printing allows the creation of ceramic parts with different areas having different densities, and therefore different equivalent permittivities.

DRA design

First, the DRA were designed and optimized using the 3D electromagnetic simulator at LEAT. The DRA is placed over a 100 mm × 100 mm ground plane as shown in Fig. 3. The first HEM mode in a rectangular dielectric resonator is excited using vertical pins. As shown in the Smith chart in Fig. 4, the reflection coefficient with a vertical pin excitation result in a loop that can be optimized to match 50 Ω for two close frequency bands. In addition, the size of the loop can be tuned by adding lower permittivity cubes inside the high-permittivity DRA. In this example, the Smith chart was optimized to match 50 Ω for 2 GHz and 2,2 GHz by inserting four small cubes with a permittivity of 7,5 inside the DRA. A detailed view of the proposed structure is proposed in Fig. 5. It can be noted that the overall structure is smaller than $0{,}25 \times 0{,}25 \times 0{,}1\ \lambda$.

Thanks to the 3D printing technologies, such lower permittivity value will be obtained by a partial filling of the structure. The vertical pin will be directly inserted inside the DRA which is also a new feature provided by the 3D printing technique.

The final S-parameters of the dual-port structure are presented in Fig. 6, and show a dual-band matching with –10 dB criteria and an isolation higher than 15 dB.

The simulated realised gain vs. frequency is presented in Fig. 7 and provide a peak gain higher than 5 dB from 1,95 GHz to 2,2 GHz

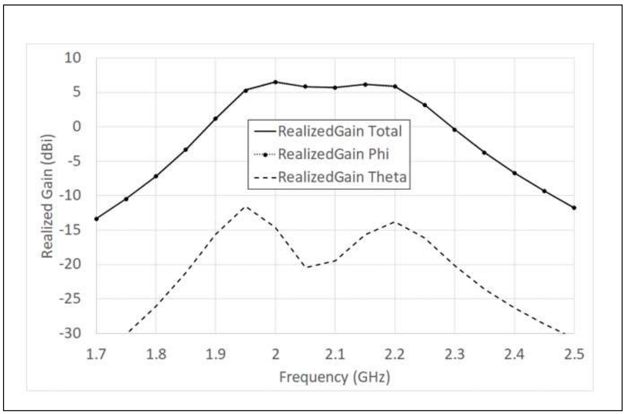

Fig. 7
Simulated gain vs. frequency for port 1

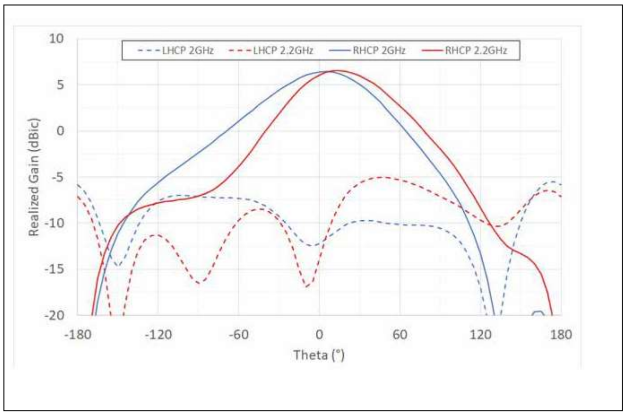

Fig. 8
Simulated realised gain radiation pattern for quadrature feed on P1 and P2

Fig. 9
Sintered part

Fig. 10
Testing apparatus

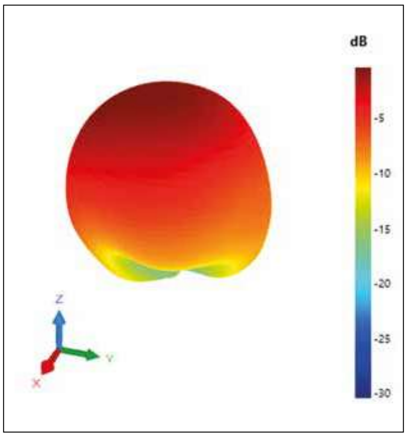

Fig. 11
3D radiation pattern at 2,6 GHz

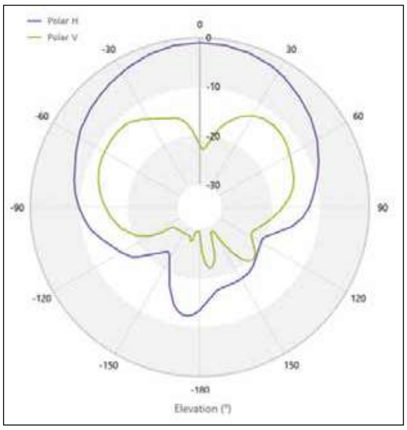

Fig. 12
Normalized measured radiation pattern for the V and H polarization at 2,6 GHz

with a linear polarization. The simulated radiation pattern for a quadrature feeding on P1 and P2 is presented on Fig. 8. A right hand circular polarization is targeted on the two bands. A small asymmetry can be observed in the pattern due to partial excitation of DRA higher modes.

Results

Nanoe printed parts using Zetamix white zirconia filament, with a layer size of 0,1 mm, and 2 giroids infills respectively with 25 % and 95 % density. Parts were then debinded in acetone for 2 h and sintered at 1450 °C in a zetasinter furnace. These parts (Fig. 9) were then tested by LEAT in a small anechoic chamber, on a ground plane by adding 2 RF connectors (Fig. 10).

The resonator was exited in the bandwidth and a full spectrum was acquired by rotating the antenna in the chamber. First results show a very good efficiency of the DRA, and a diagram that matched quite closely the simulated version (Figs. 11–12). Moreover, it also shows a deviation to higher frequency (2600 MHz), which will be adapted by iterations on the DRA design. These results will be fully detailed at the EuCAP Conference (European Conference on Antennas and Propagation) to be held in Madrid/ES, 27 March–1 April 2022.

Conclusion

Zetamix technology enables the production of material with impressive properties for a low investment. Telecommunication is a cutting edge field pushed by an increase of requests from industrials and public, that always needs to provide smaller and cheaper solutions. By exploring the shaping possibilities with 3D printing, LEAT is ready to meet the challenge of next generation antennas.