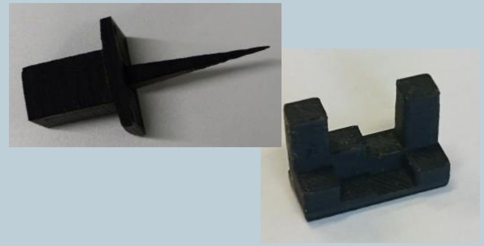
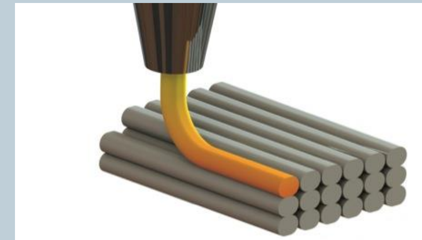
SPCD
SPACE PASSIVE COMPONENT DAYS





Ka-band compact multi-materials rectangular waveguide loads

Lab-STICC / UBO: *L. Martinez-Cano, A. Chevalier, A. Maalouf, J. Benedicto, P. Laurent,* ***V. Laur***

IRDL / UBO: *J. Ville*

CNES: *K. Elis*

Lab-STICC

IRDL
Institut de Recherche Dupuy de Lôme

cnes

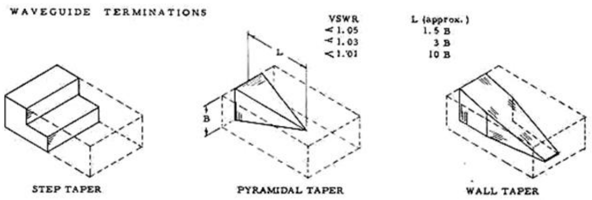
Plan

- ➲ **Technology and materials**
- ➲ **Design, fabrication and measurements**
  - ➲ **Ka-band wedge loads**
  - ➲ **Ka-band compact loads**
- ➲ **Conclusion and prospects**

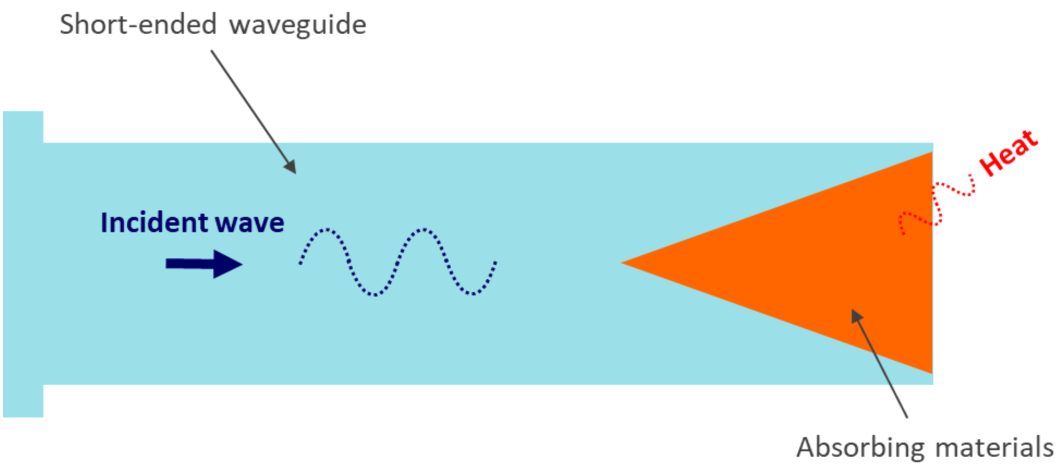
Technology and materials

➲ Microwave loads

- ➲ One port device
- ➲ Applications: isolators, couplers, metrology…
- ➲ Rectangular waveguide: short-ended waveguide + absorbers
- ➲ Characteristics: RL (or VSWR), Power Handling, BW, Size, Cost



Examples of absorber shape



- ➢ **Additive technology: a low-cost way to shape absorbers**
- ➢ **R&T CNES activity: Case study ⇒ Compact WR-28 35.5-36 GHz loads / S_{11} < -15 dB**

Lab-STICC

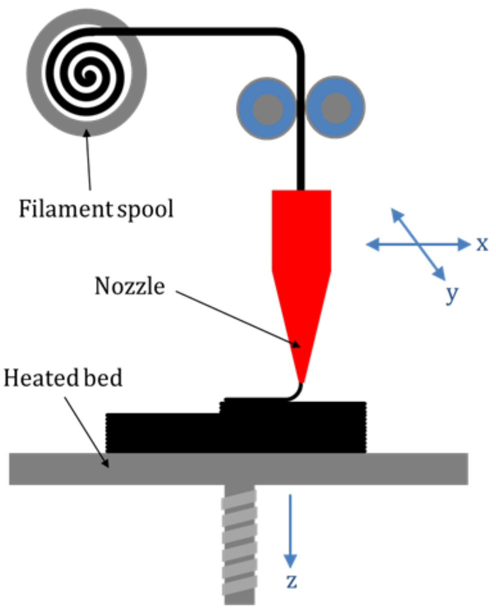
iRDL Institut de Recherche Dupuy de Lôme

cnes

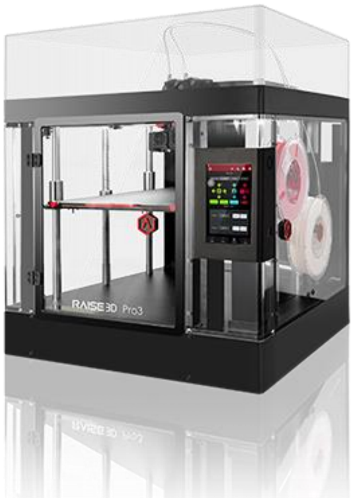
Technology and materials

➲ Fused Deposition Modeling

- ➲ Layer-by-layer deposition of a fused polymer
- ➲ Thickness of layer: 50 to 200 µm



FDM principle



Raise3D Pro3

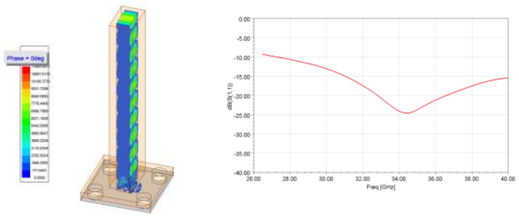
APIUM P155

3NTR A4 & A2

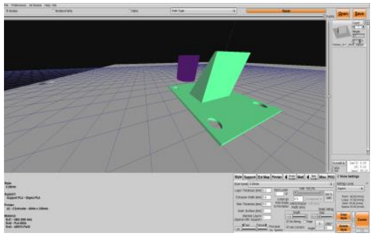
Technology and materials

➲ **From simulation to printed device: a simple and fast process**

Ansys HFSS

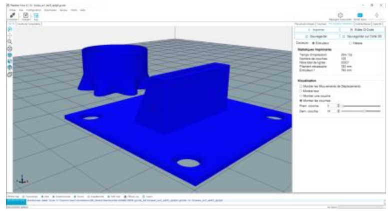


Kisslicer (.gcode generation)



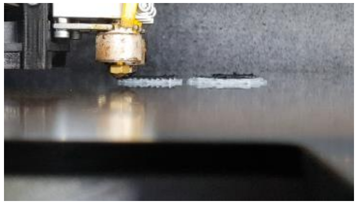
Design → Slicing → .gcode checking → 3D printing → RF meas.

Repetier (.gcode checking)



VNA measurement

Printer server

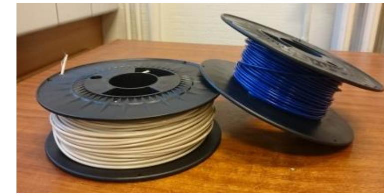


Lab-STICC

iRDL Institut de Recherche Dupuy de Lôme

cnes

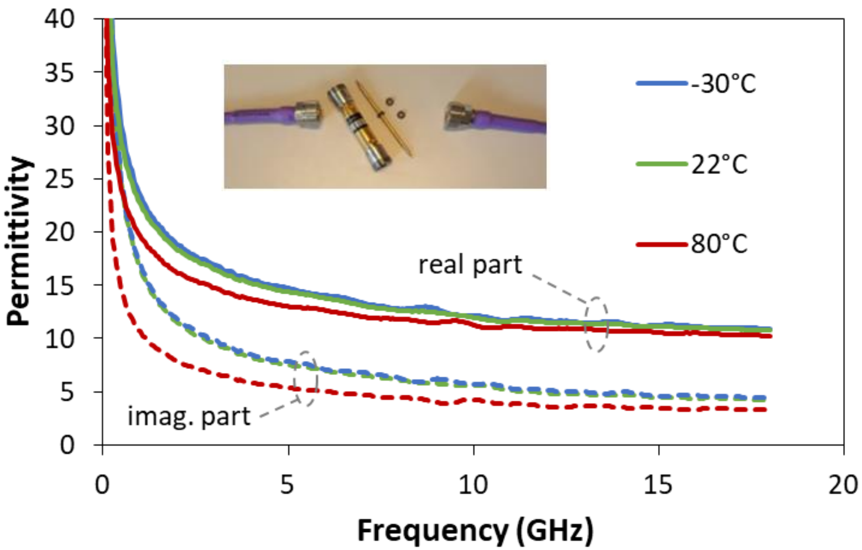
Technology and materials



➲ Printable materials

- ➲ A lot of commercial references (mainly ABS, PLA)
- ➲ Pure polymers not of interest (low to medium losses)
- ➲ Composite materials (carbon, ferromagnetic particles): potential candidates for microwave absorption

- ➢ **Selected material: ABS-ESD (Nanovia)**
- ➢ **3D printers: 3NTR A4 and A2**



EM properties of ABS-ESD

- ➢ **EM properties: standard coaxial line method**
- ➢ **Decrease of permittivity at high temp.**
- ➢ **Ka-band (26-40 GHz):**
  - ➢ $\varepsilon_r = 8$
  - ➢ $\tan\delta = 0.3$

Lab-STICC

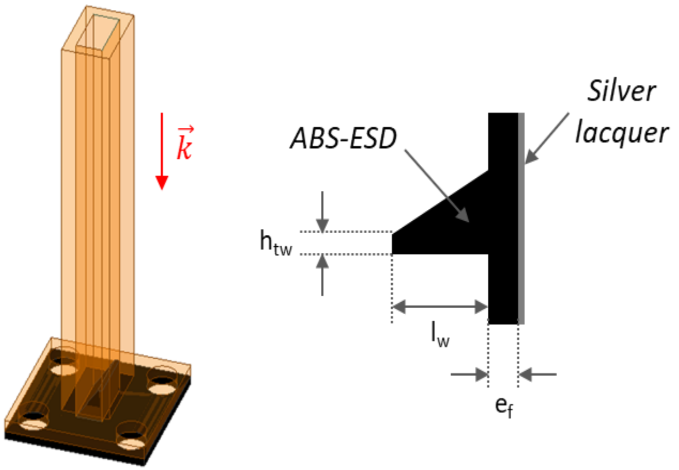
iRDL Institut de Recherche Dupuy de Lôme

cnes

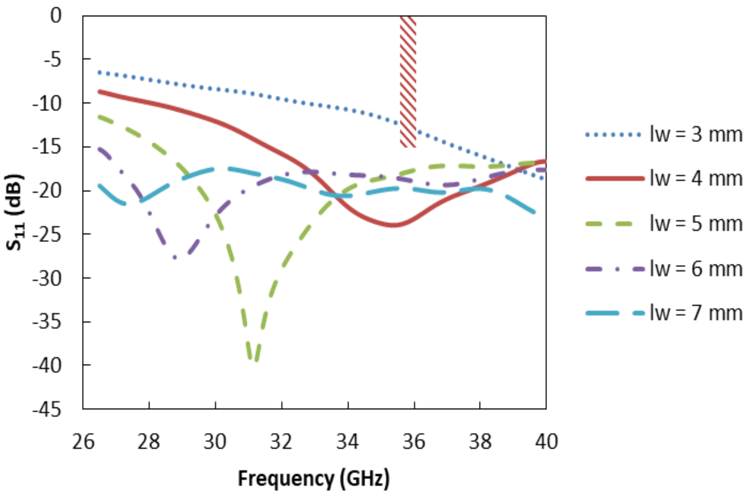
Design, fabrication and measurements

➲ Ka-band wedge loads

- ➲ Compatible with WR-28 RWG
- ➲ With integrated UBR 320 / IEC 60154 flange
- ➲ Metallized back face (silver lacquer $\sigma = 5.10^6$ S/m)



Simulation model

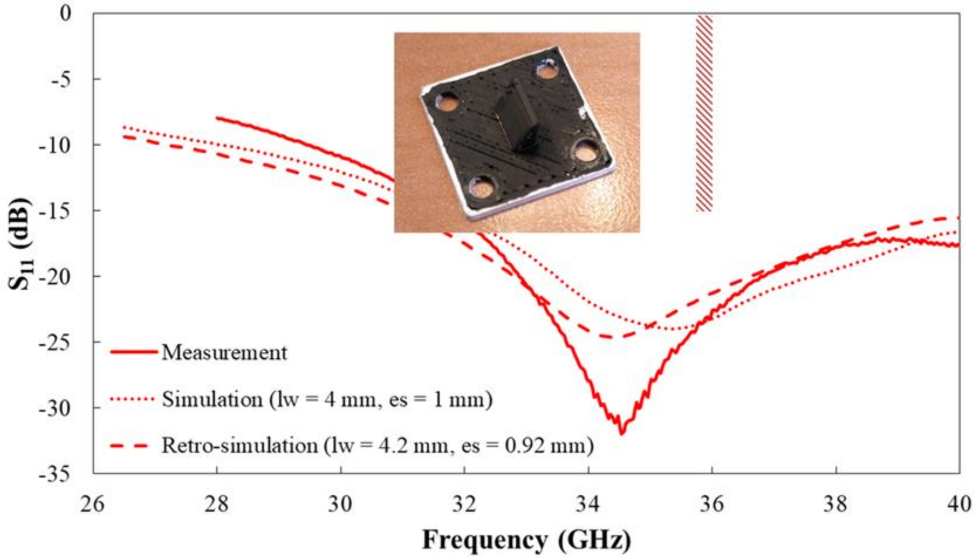


Simulated reflection coefficient for different l_w (h_w = 0.6 mm, e_f = 1 mm)

- **Frequency of maximum absorption decreases when l_w increases**
- **Specifications achieved for l_w = 4 mm (total length 5 mm)**

Design, fabrication and measurements

- **Ka-band wedge loads**
  - 3D printed using a A4V3 printer (5 min.)
  - Silver lacquer on back face (60°C / 1h)
  - VNA measurement of S-parameters

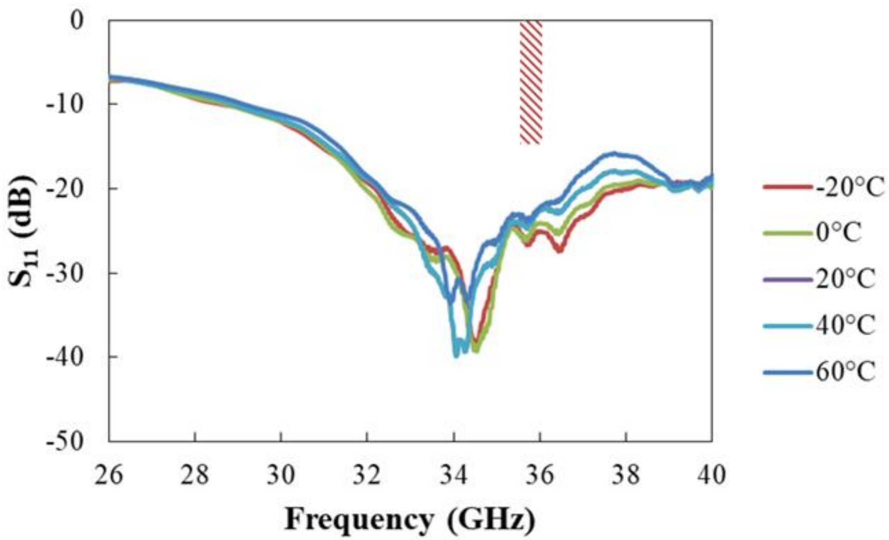


Comparison between simulated, measured and retro-simulated S-parameters

- **Specifications achieved BUT 700 MHz frequency shift between simulated and measured S_{11}**
- **Real dimensions: l_w = 4.2 mm and e_f = 0.92 mm) ⇒ Better agreement**

Design, fabrication and measurements

- **Ka-band wedge loads**
  - Characterization between -20°C and +60°C



Measured S_{11} in Ka-band between -20°C and +60°C

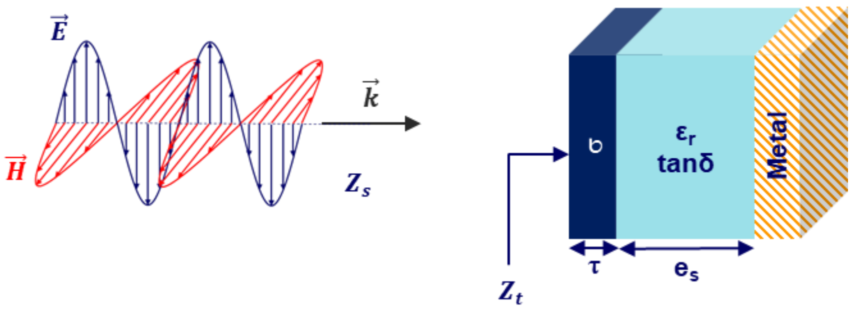
- **Slight increase at high temperature between 37 GHz and 38.5 GHz**
- **Specifications achieved in this temperature range**

Institut de Recherche Dupuy de Lôme

Design, fabrication and measurements

➲ Ka-band compact loads

➲ Multi-materials topology based on a Salisbury screen principle (dielectric spacer + resistive sheet)



Salisbury screen principle in free space

Design equations for RWG

TE_{10} cutoff frequency

$$f_c = \frac{c}{2a}$$

TE_{10} impedance

$$Z_S = \frac{\sqrt{\frac{\mu_0}{\varepsilon_0}}}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$$

TE_{10} guided wavelength

$$\lambda_g = \frac{c}{f\sqrt{\varepsilon_r}\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$$

- **ABS: dielectric spacer ⇒ $\lambda_g/4$ = 1.59 mm at 36 GHz**
- **ABS-ESD: alternative to resistive sheet (τ = 0.1 mm)**

Lab-STICC

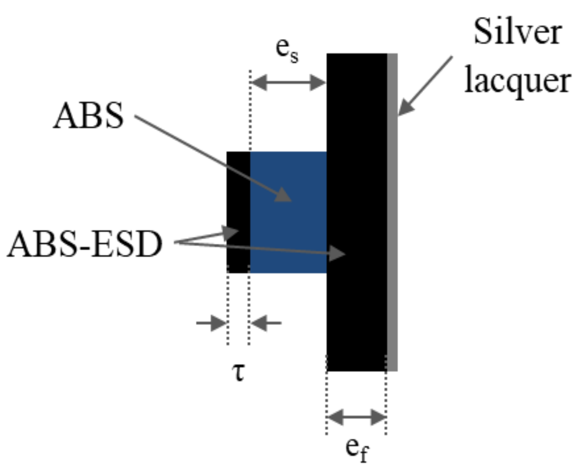
iRDL Institut de Recherche Dupuy de Lôme

cnes

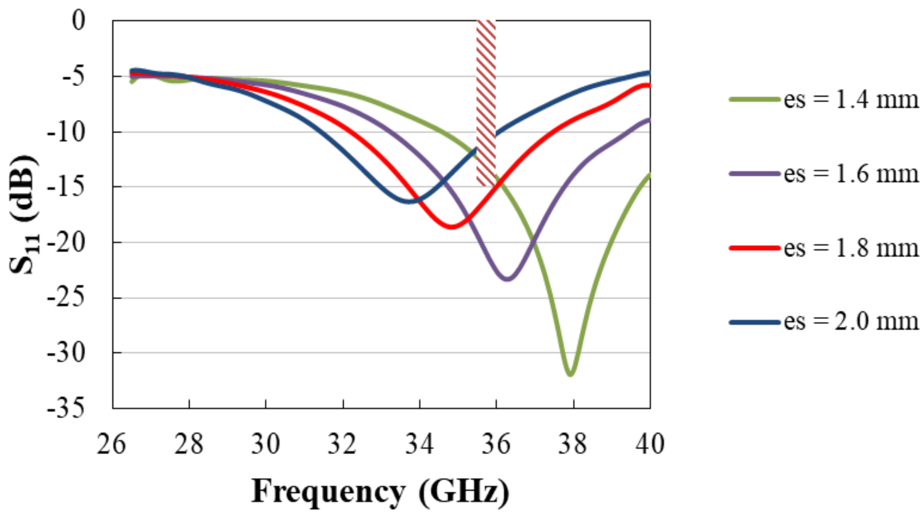
Design, fabrication and measurements

➲ Ka-band compact loads

- ➲ Design of multi-materials compact loads
- ➲ With integrated flange (ABS-ESD)



Side view of the compact load



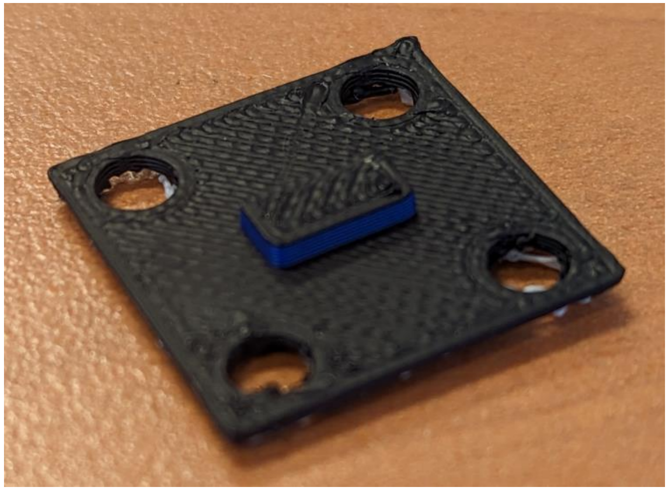
Simulated S_{11} in Ka-band for different spacer thickness

- **Frequency of maximum absorption decreases from 37.9 GHz to 33.7 GHz for 1.4 mm < e_s < 2 mm**
- **Specifications achieved for e_s = 1.6 mm (total length 2.7 mm)**

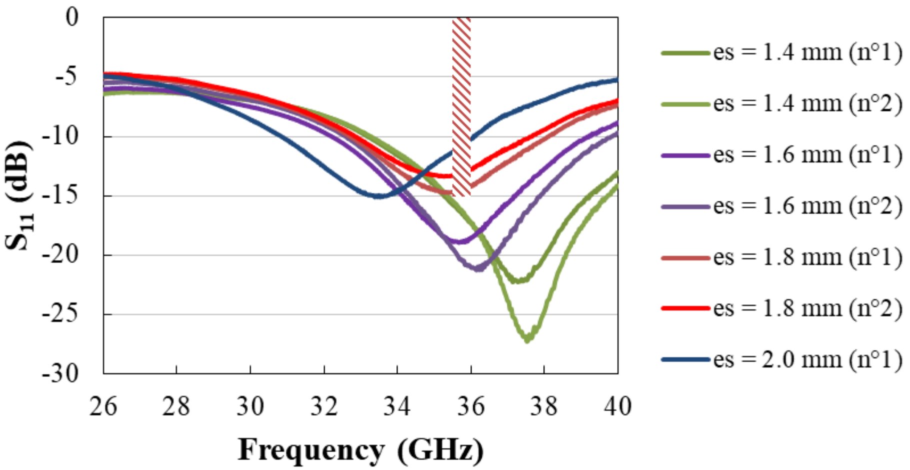
Design, fabrication and measurements

➲ Ka-band compact loads

- ➲ 3D printed using a A4V3 printer (3 min.)
- ➲ Silver lacquer on back face (60°C / 1h)



3D printed multi-materials load



Measured S_{11} in Ka-band for different spacer thickness

- **Good agreement between simulated and measured S_{11}**
- **Quite good reproducibility for two samples**
- **Specifications achieved for a total length of 2.7 mm ⇒ Reduction of 47% / standard topology**

Lab-STICC
iRDL
Institut de Recherche Dupuy de Lôme
cnes

Conclusions and prospects

- FDM technology: promising low-cost, fast and easy-to-use technology for the fabrication of microwave load
- Several commercial printable composite materials with appropriate EM properties
- Useable up to 40 GHz and more…
- Multi-materials topologies: decrease of size and weight

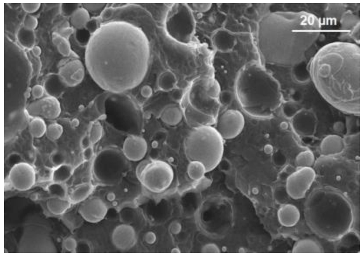
- **Technology limitations:**
  - Is it compatible with space applications ? Not using ABS matrix
  - Spatialization of this technology requires to study/develop new materials $\Rightarrow$ R&T CNES 2

Lab-STICC iRDL Institut de Recherche Dupuy de Lôme cnes

Conclusions and prospects

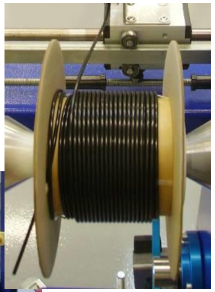
➲ High temperature materials

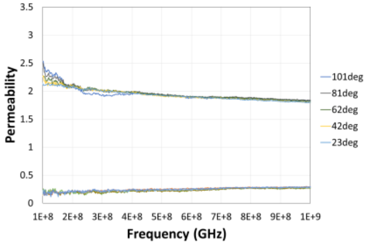
- ➲ Development of PEKK or PPS composites



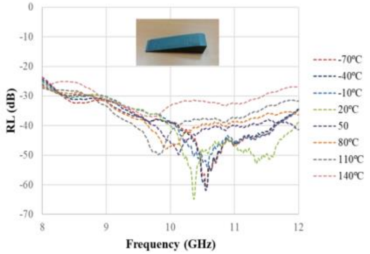
MEB picture of carbonyl iron/PPS composite

Lab-made filament spool





EM properties and S_{11} of a wedge loads



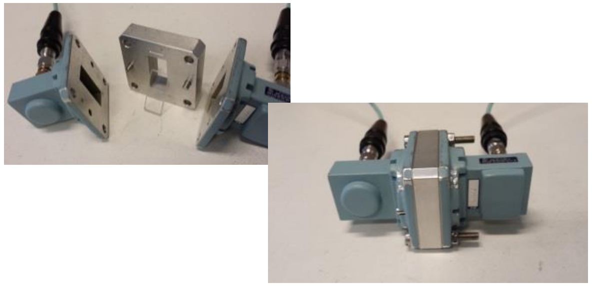
Composites elaboration → Filament extrusion → 3D printing and evaluation

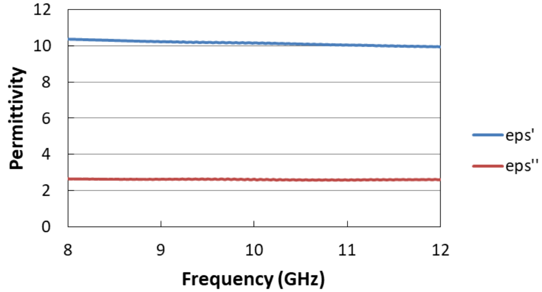
Lab-STICC
iRDL Institut de Recherche Dupuy de Lôme
cnes

Conclusions and prospects

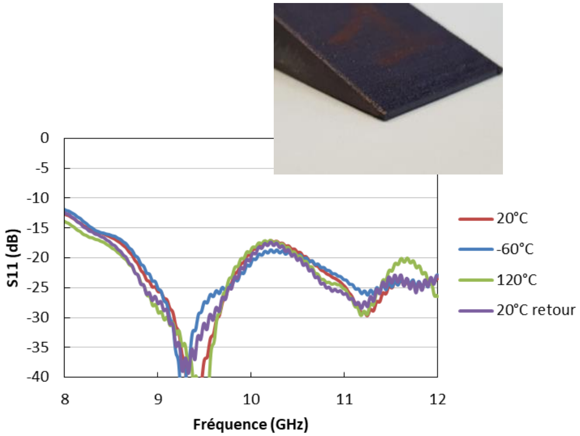
➲ High temperature materials

- ➲ Characterization and evaluation of commercial PPS, PEEK, PEKK composites

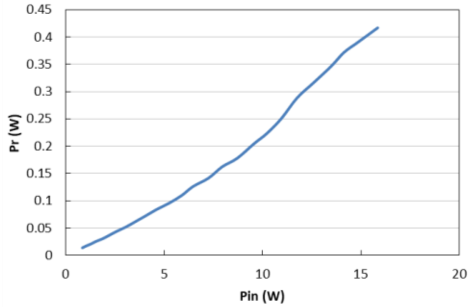




X-band characterization of a carbon-filled PEKK filament



Temperature stability of a carbon-filled PEKK wedge load



PHC evaluation of a carbon-filled PEKK wedge load

Lab-STICC

iRDL
Institut de Recherche Dupuy de Lôme

cnes

Acknowledgements

R&T CNES

« Apport des technologies additives pour la miniaturisation de charges hyperfréquences »

Thank you for your attention