Additive Manufacturing of Leaky-Wave Antennas

Aurélie Dorlé, Raphaël Gillard, Esteban Menargues, Maarten Van Der Vorst, Emile De Rijk, Petronilo Martín-Iglesias and María García-Vigueras

Outline

1. **Context**
2. **Additive Manufacturing**
3. **Additive Manufacturing of Leaky-Wave Antennas**
4. **Conclusion and Perspectives**

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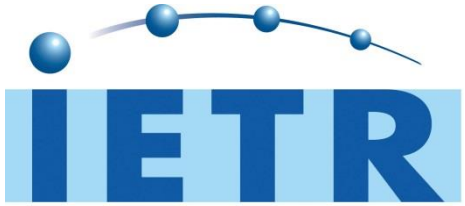
Context

Additive Manufacturing of Leaky-Wave Antennas

- IETR laboratoty



- European Space Agency

- SWISSto12

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2. **Additive Manufacturing**
   - Definition and Properties
   - Stereolithography
   - Selective Laser Melting
   - Comparison of the Processes
   - Examples of Antennas

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Definition of Additive Manufacturing

- Additive Manufacturing groups the technics enabling to fabricate objects with a layer-by-layer process

- Advantages

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- Advantages
  - Free-Form Manufacturing

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  - Monolithic Fabrication

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  - Free-Form Manufacturing
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  - Cost Saving

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  - Free-Form Manufacturing
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  - Cost Saving
  - Wide Choice of Materials

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- Advantages
  - Free-Form Manufacturing
  - Monolithic Fabrication
  - Cost Saving
  - Wide Choice of Materials
  - Precision and Tolerances?

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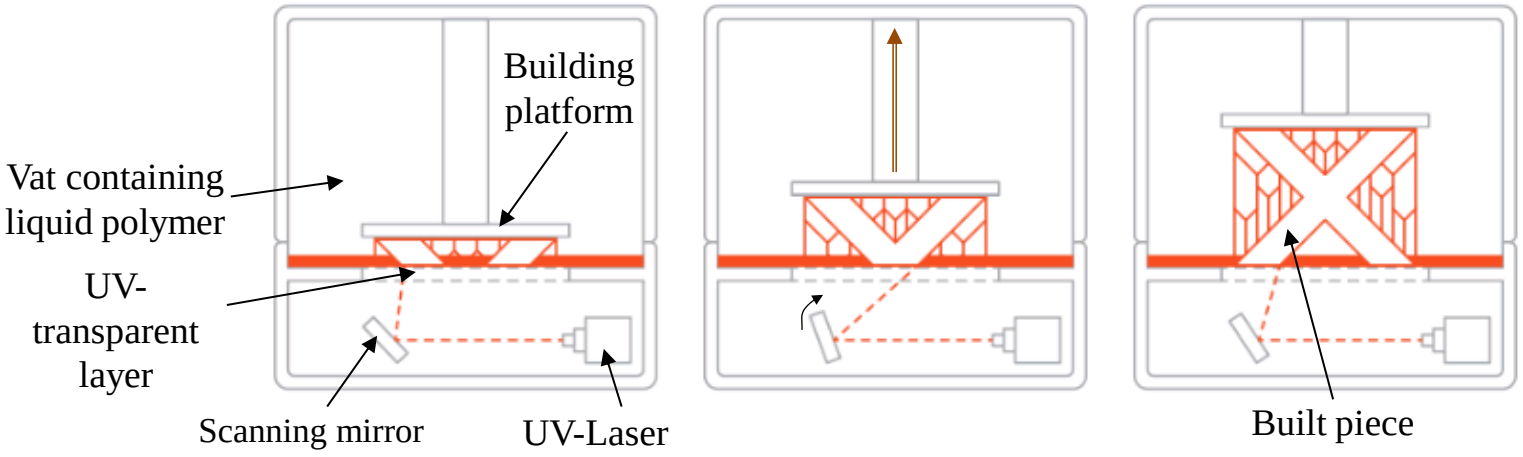
Stereolithography (SLA)



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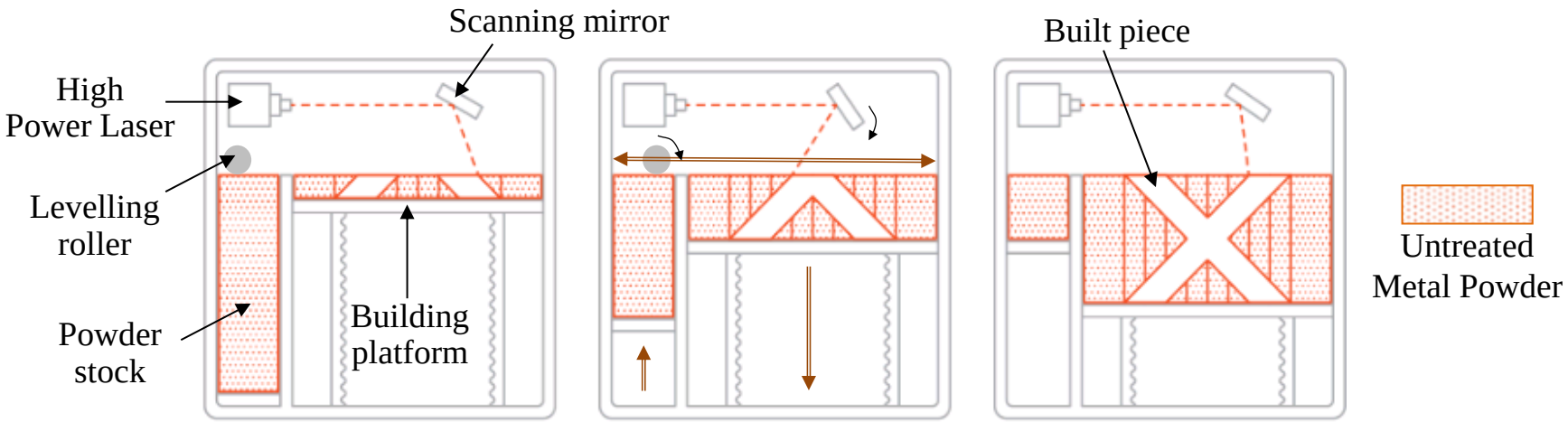
Selective Laser Melting (SLM)

Similar to DMLS



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Comparison of SLA and SLM

Property of the Device	SLA	SLM
Size	Limited by the Machine	
Weight	Light	Metal Parts
Robustness	Low	High
Thermal Handling	No	Yes
Precision of the Process	0.02 – 0.05 mm	0.05 – 0.15 mm
Roughness	Low < 10 µm	High Corrected with Post-Processing Porous Structure = Bad Conductivity
Limitations	Metallization Complexity	No Closed Structure

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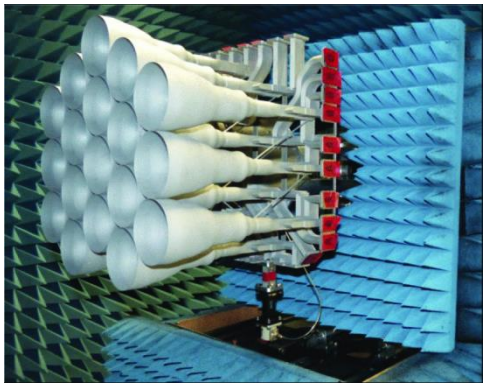
SLA and SLM Antennas

- Slotted array, SLA / DMLS, [G. P. Le Sage, 2016, IEEE Access]

- Bull's-eye, Stereolithography (SLA), [U. Beaskoetxea, 2017, IEEE TAP]



- Horn Cluster, DMLS, [M. Kilian, 2019, EuCAP]

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   - What is a Leaky-Wave Antenna?
   - Single-Polarized Structure
   - Dual-Polarized Structure
   - Single-Polarized Array
   - Circularly-Polarized Antenna

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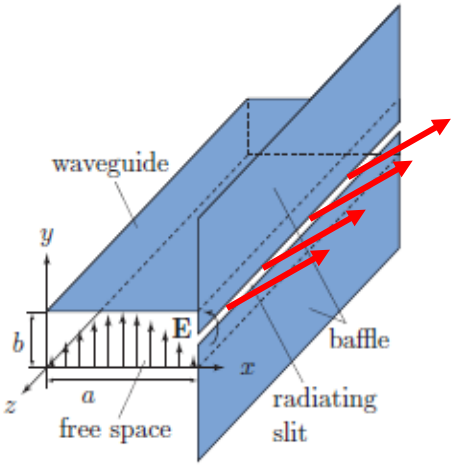
What is a Leaky-Wave Antenna?

- Guided structure which lets energy leak in a controlled way to get a desired radiation pattern

- Complex propagation component: $k_{z/\rho}(\omega) = \beta(\omega) - j\alpha(\omega)$
  - $\alpha(\omega)$ leakage rate : controls pattern shape, radiation efficiency
  - $\beta(\omega)$ phase constant : controls pointing angle



- Waveguide slit, single polarization, [C. Caloz, 2010, Leaky-Wave Antennas]

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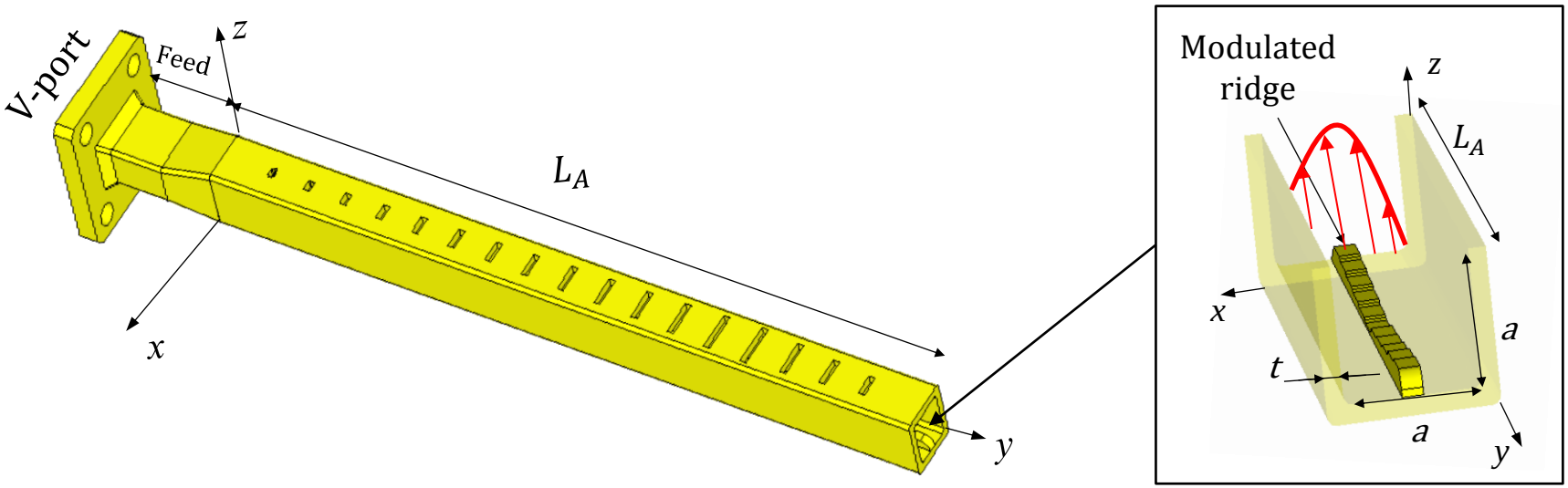
Single-Polarized Antenna

Structure

- Single V-polarization

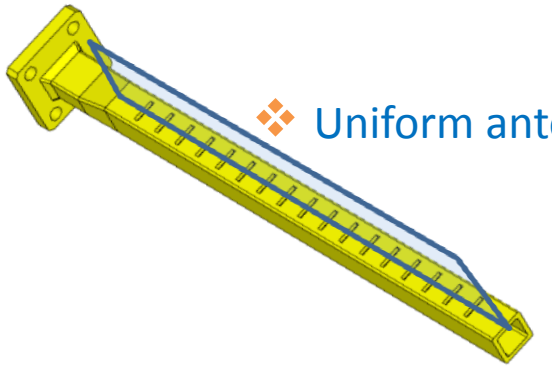


- Full control of α^V, β^V
- Tuning parameters: slot length and ridge height

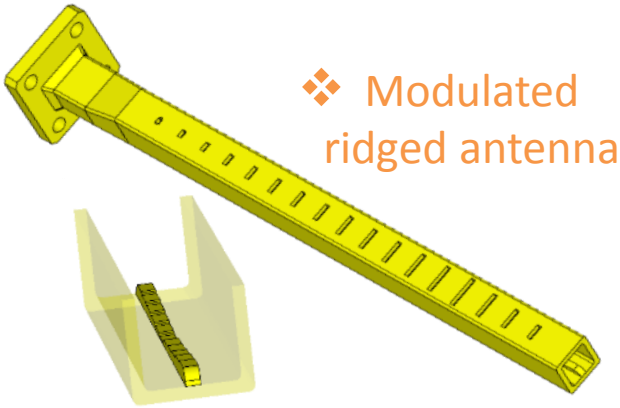
- [Sidelobe Level Reduction in Ridged Leaky Waveguide Through Stereolithography, A. Dorlé, 2019, EuCAP]

Single-Polarized Antenna

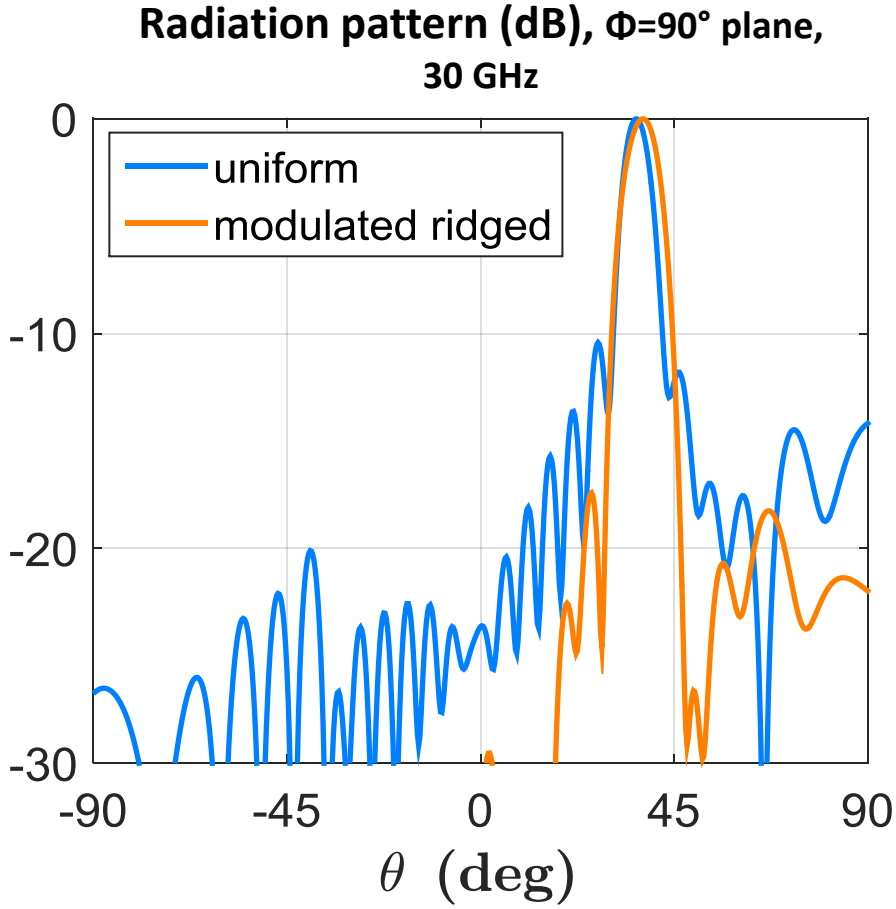
Performance



❖ Uniform antenna



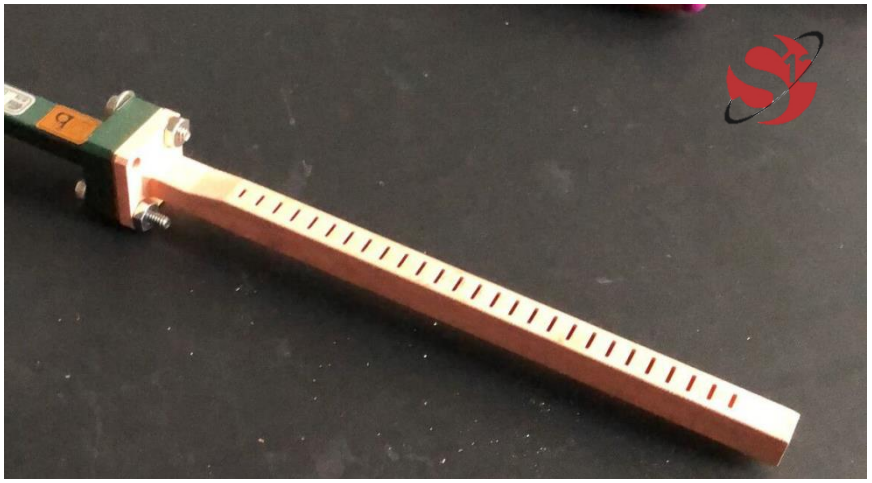
❖ Modulated ridged antenna



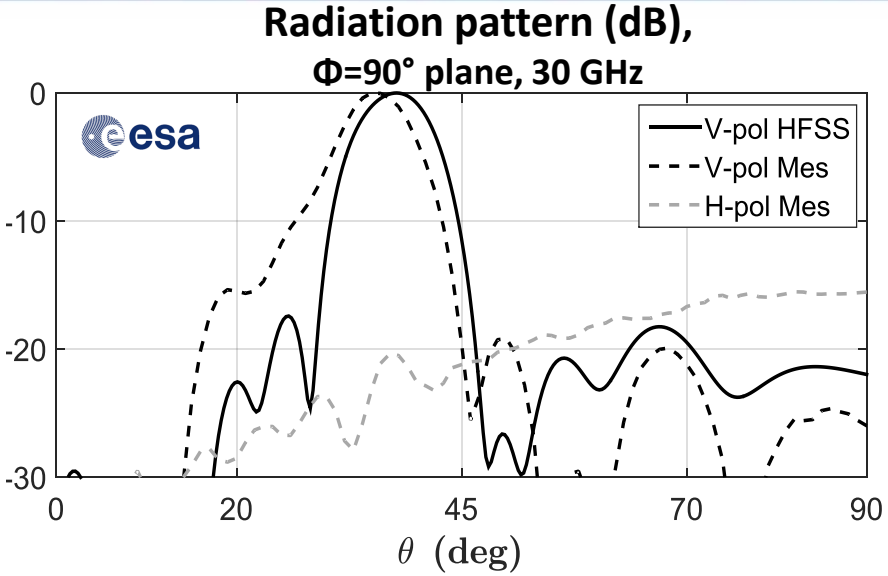
❖ SLL reduction of 7 dB

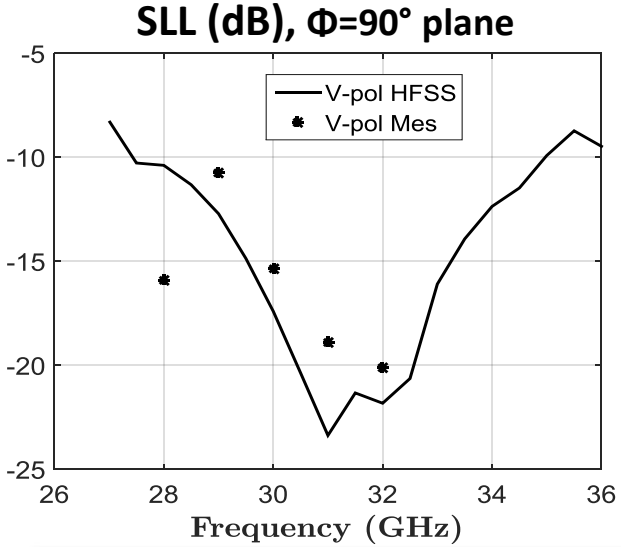
Single-Polarized Antenna

Measurement



- 30 GHz
- $L_A = 10.8\lambda$
- Matched below – 10 dB between 26.5 and 40 GHz





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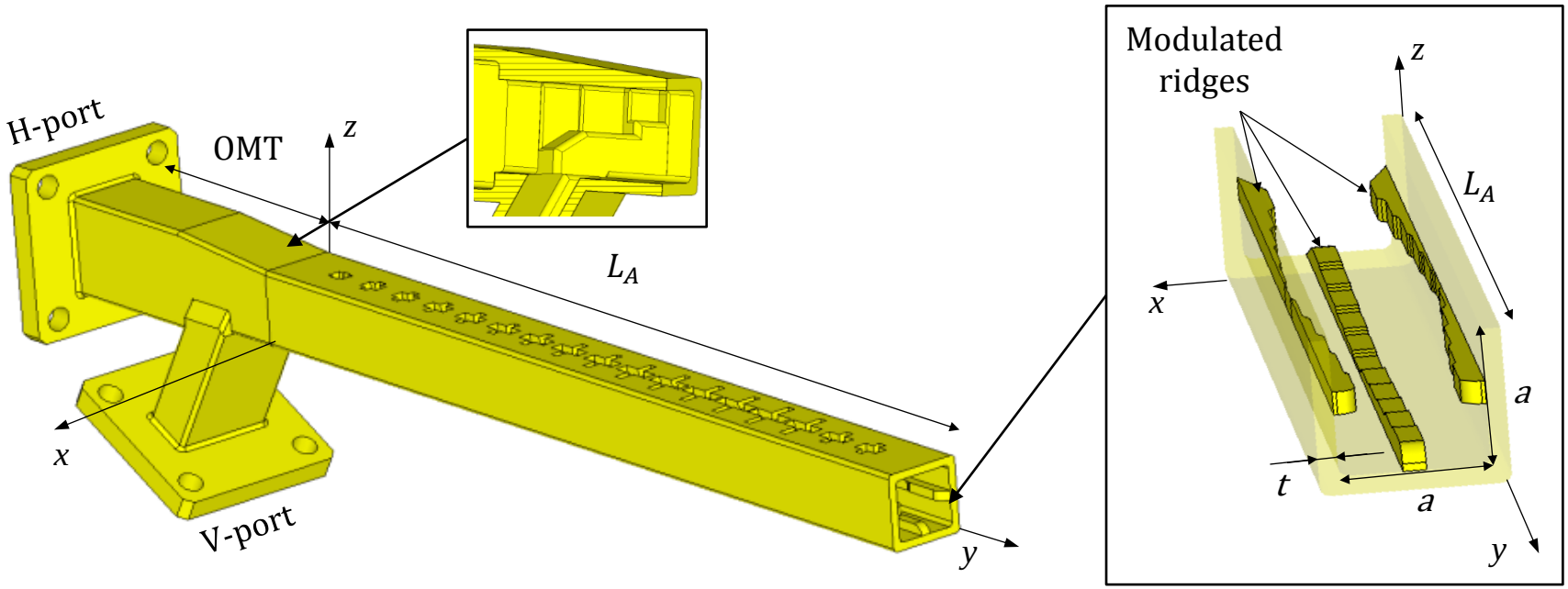
Dual-Polarized Antenna

Structure

- Dual-linear polarization

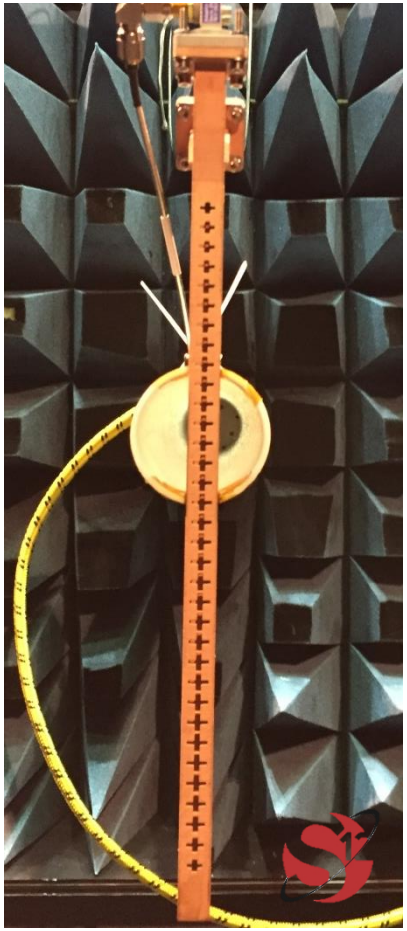


- Full control of $\alpha^V, \beta^V, \alpha^H, \beta^H$
- Tuning parameters: slots lengths and ridges heights

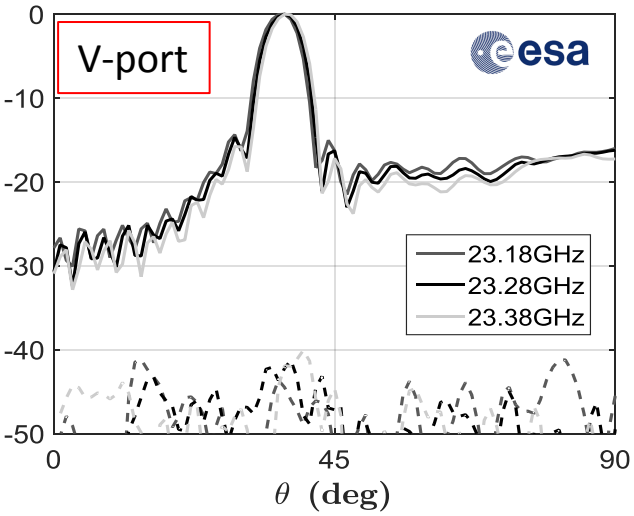
- [Additive Manufacturing of Modulated Triple-Ridge Leaky-Wave Antenna, A. Dorlé, 2018, IEEE AWPL]

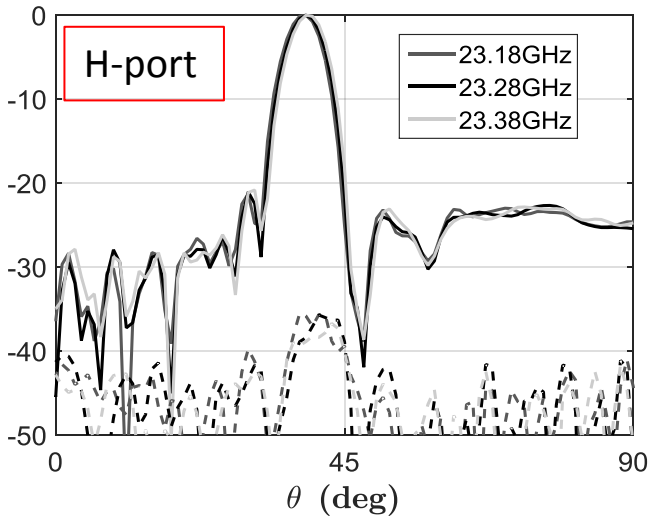
Dual-Polarized Antenna

Measurement



Radiation pattern (dB),
Φ=90° plane





Dual-Polarized Antenna

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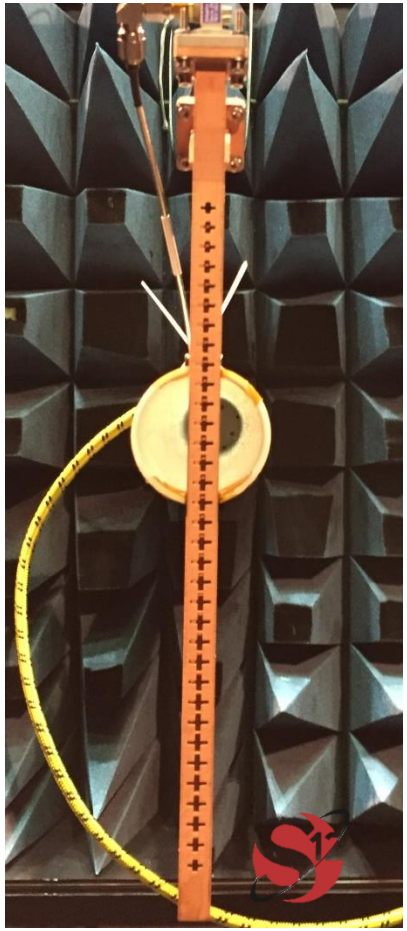
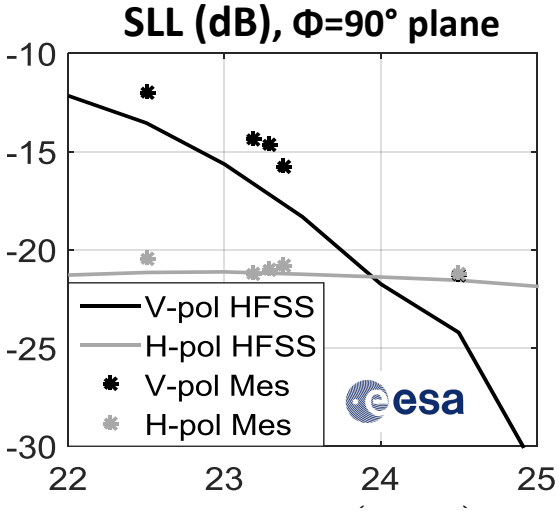


- 23.28 GHz
  - Iridium ISL band
- $L_A = 15.83\lambda$
- Matched below – 10 dB from 22.3 to 25.2 GHz
- Isolation better than – 40 dB
- $D_{max}^{H} = 18.22$ dB
  - 0.17 < simulation
- $D_{max}^{V} = 17.84$ dB
  - 0.31 < simulation



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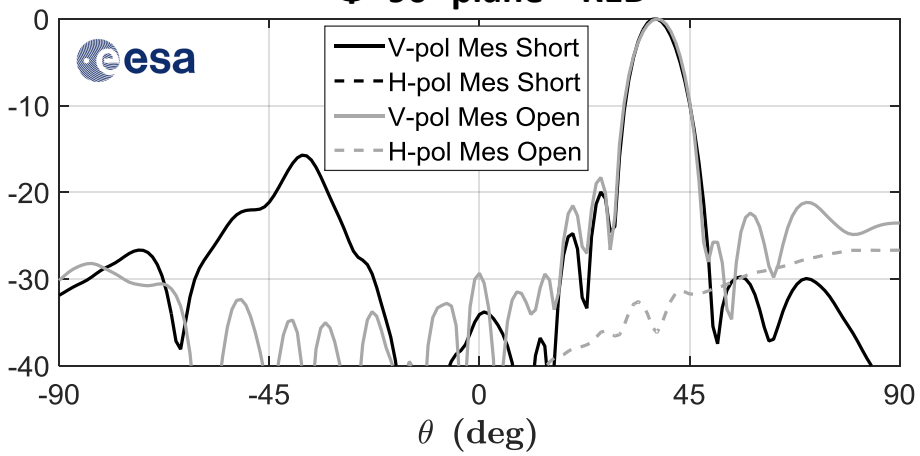
Single-Polarized Array

Structure

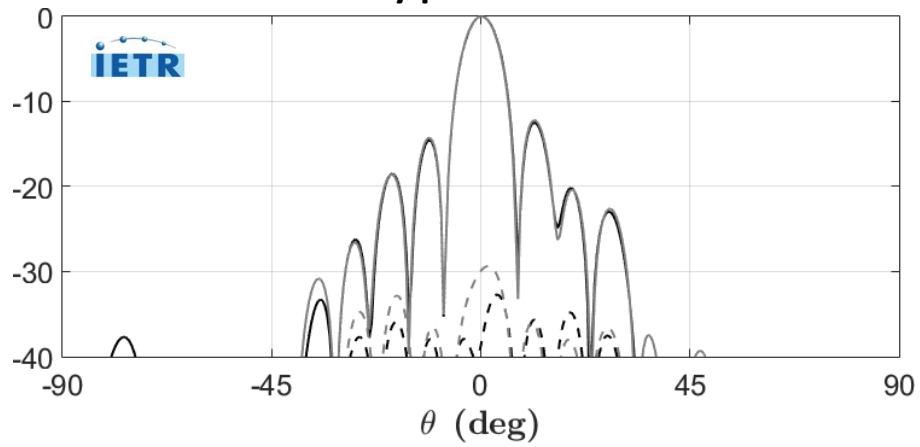
Single-Polarized Array

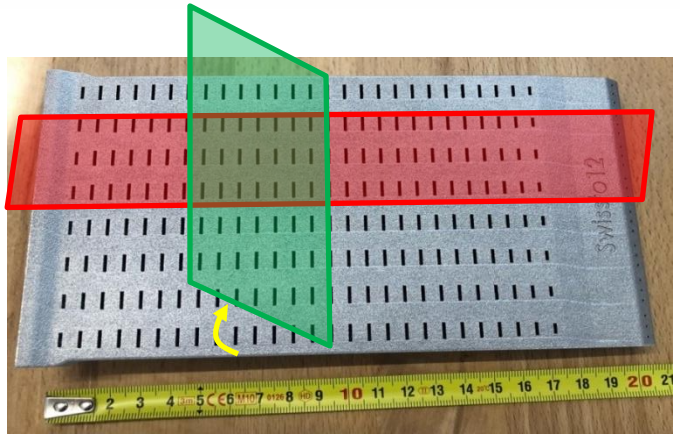
Measurement

Radiation pattern (dB), Φ=90° plane – RED



Radiation pattern(dB), Array plane – GREEN





- 20 GHz
- $L_A = 10.8\lambda$
- Additional adaptive metal short circuit plate
- Matched below – 10 dB
  - From 19 to 22 GHz with CC plate
  - From 18.5 to 22 GHz with open end
- $D^V_{max} = 27.6$ dB with CC plate
  - 0.2 > simulation

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Conclusions and Perspectives

- SLA and SLM enable to print 3-D complex structures in monolithic pieces, avoiding bulky assemblies and their drawbacks. Measured antenna prototypes confirm the enhanced performances at microwave frequencies thanks to AM.

- The proposed topology allows for polarization versatility with independant control of the two leaky waves.

- To go further: dual-band, compact radiators, low coupling arrays.

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