Workshop on Space Technologies & Synergies with Technological Poles

Aveiro, Portugal, 28th November 2011

Microwave & millimeter wave dielectric antennas

Carlos A. Fernandes *

Eduardo B. Lima

Jorge R. Costa

ISCTE IUL Instituto Universitário de Lisboa Lisbon University Institute

Instituto Superior Técnico

Faculdade de Ciências e Tecnologia da Universidade de Coimbra

universidade de aveiro

PT Inovação

SIEMENS Communications

instituto de telecomunicações

creating and sharing knowledge for telecommunications

Outline

- Motivation
- Examples of fabricated and tested prototypes
- ILASH - lens design software tool
- Conclusions

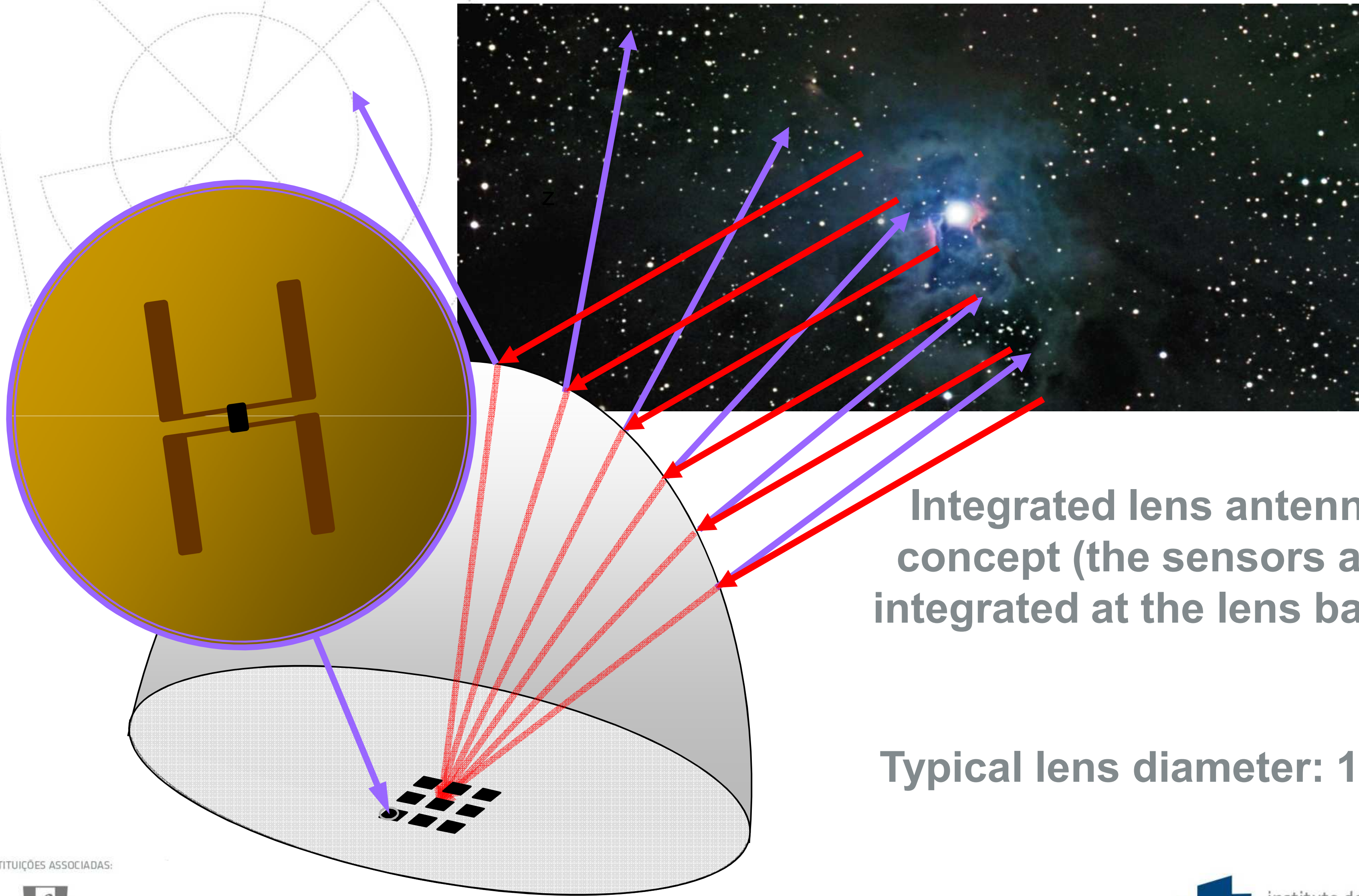
Motivation

Traditional feeds for focal plane arrays: horns

- Physical size of horns limits spot density;

- Not appropriate for sub-mm wave systems and THz.

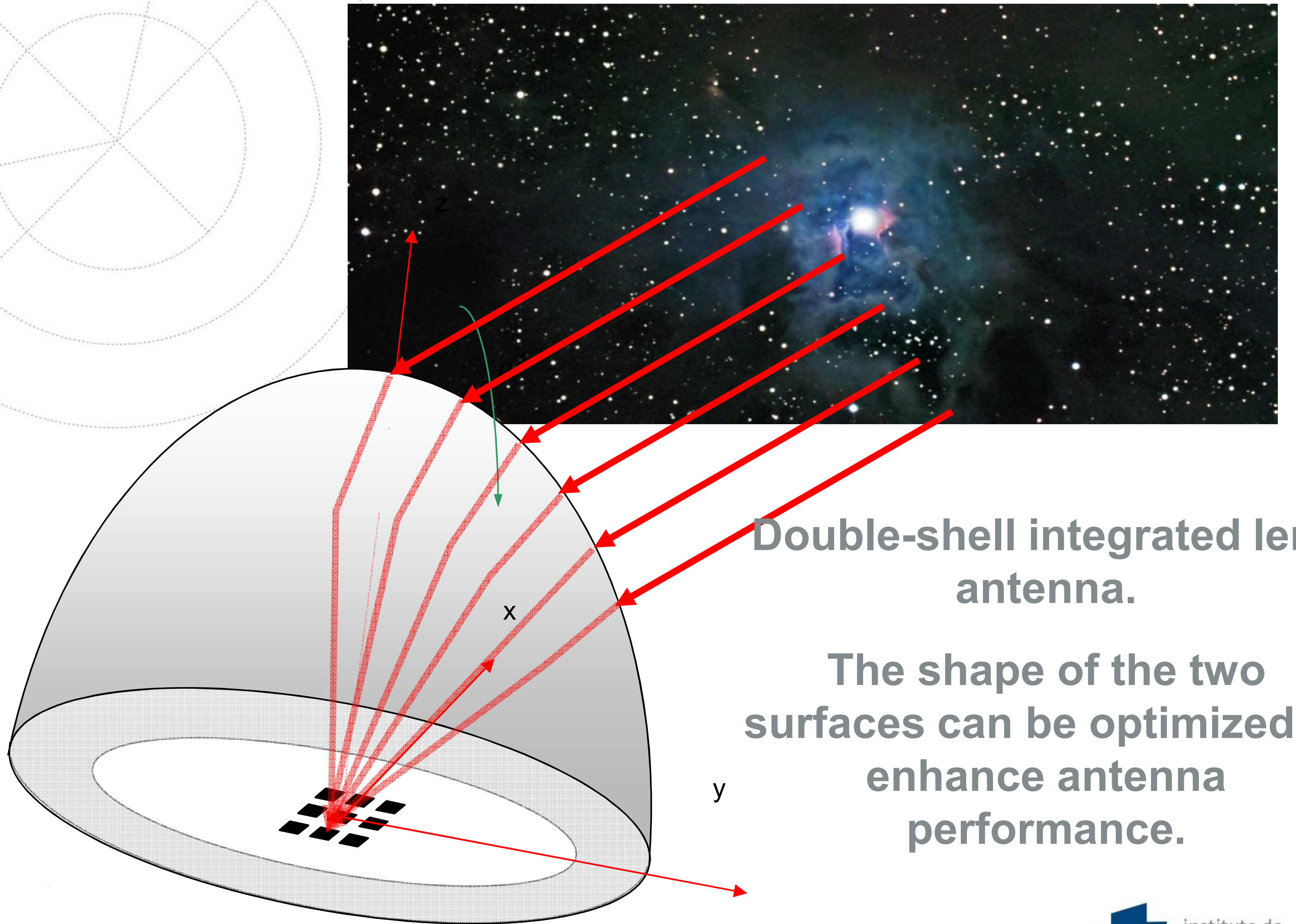
Motivation



Integrated lens antenna concept (the sensors are integrated at the lens base)

Typical lens diameter: 10 λ

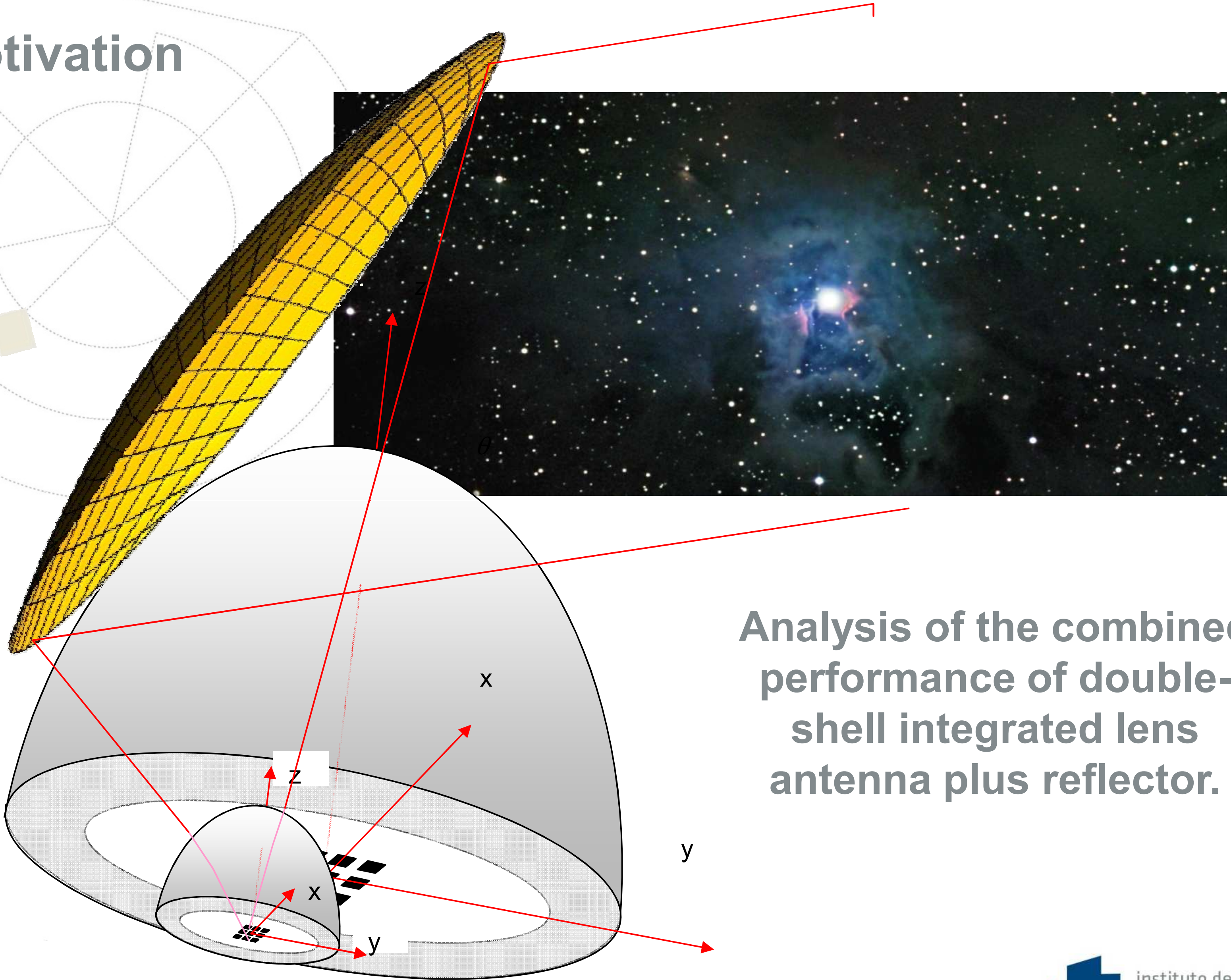
Motivation



Double-shell integrated lens antenna.

The shape of the two surfaces can be optimized to enhance antenna performance.

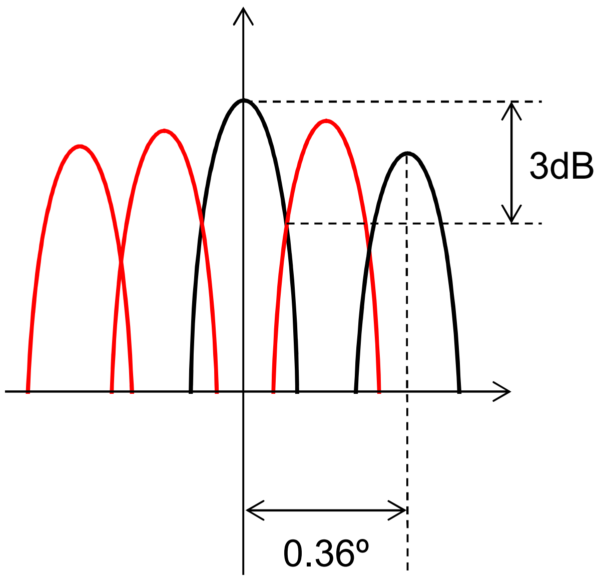
Motivation



Analysis of the combined performance of double-shell integrated lens antenna plus reflector.

Example1 - Quasi-optical imaging reflector system

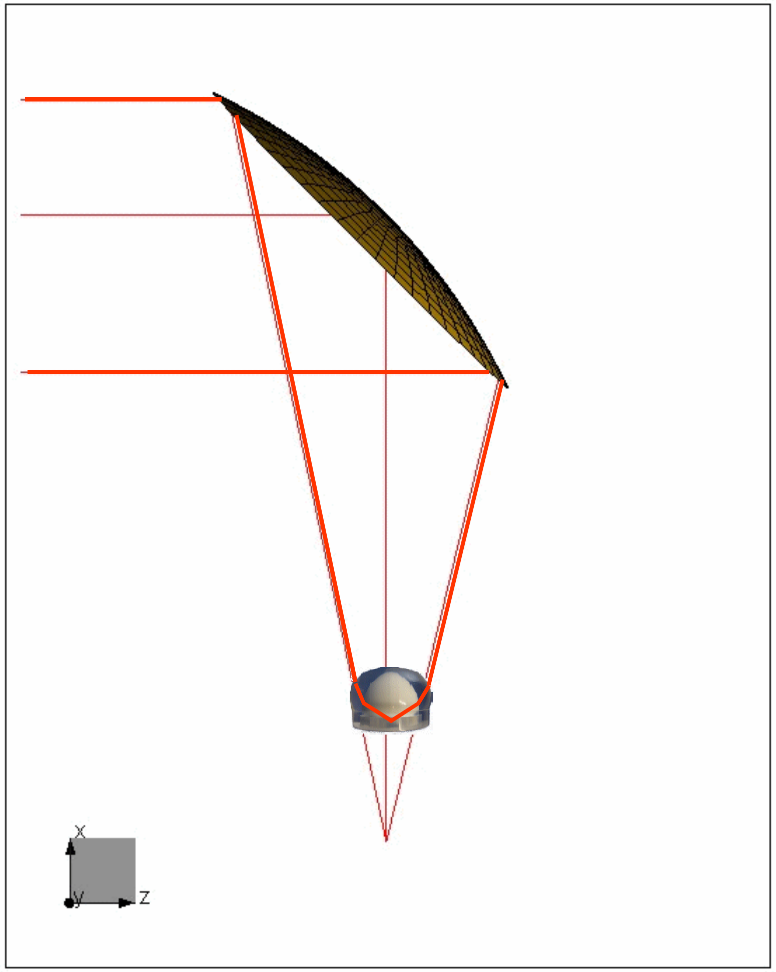
- Frequency = 500 GHz.
- The objective is to obtain a reflector coverage of $\alpha = \pm 0.36°$ in elevation.
- 5 overlapping beams with $Directivity \cong 61dBi$.
- 3dB overlapping beams.



Example 1 - Quasi-optical imaging reflector system

Scaled model for 62.5 GHz

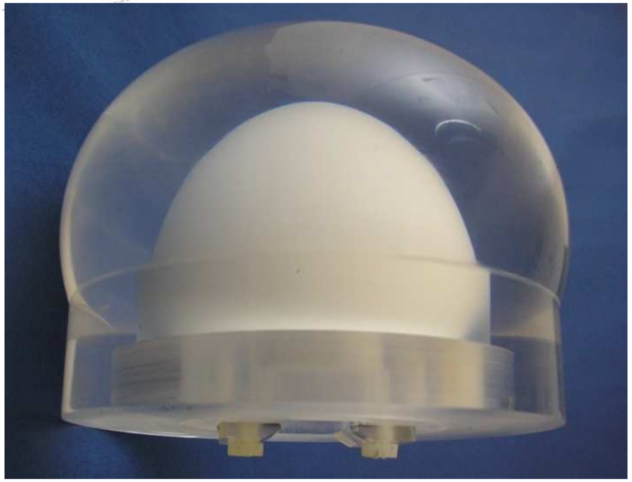
- Off-set parabolic reflector;
- Parabola focal length $f = 1.6m$;
- Parabola diameter $D = 2m$;
- Feed separation ≈ 2λ;
- Feed Gaussian beamwidth: ≈ 13º;
- Azimuth scan: mechanical.

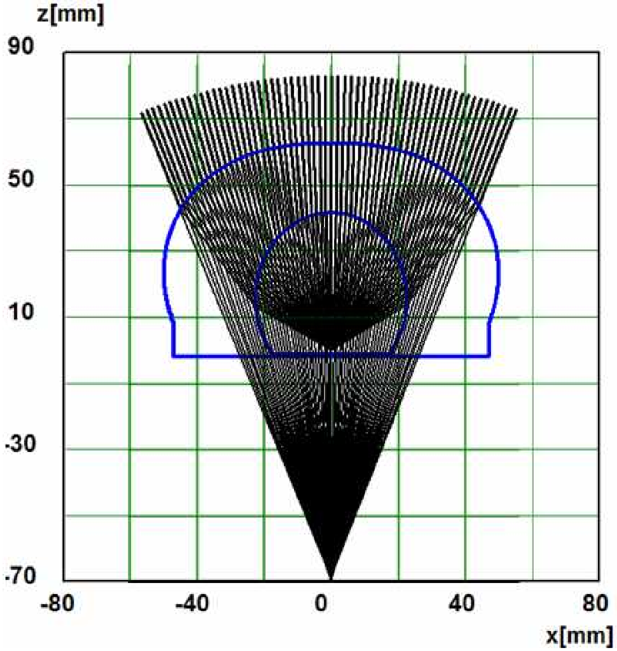


Lens for quasi-optical system

Fabricated lens antenna

- Used materials: MACOR/PLEXIGLAS (ε_r = 5.6/2.53, *tan* δ = 0.012)
- Lens dimensions:
  - F = 41.9 mm;
  - T = 20.9 mm;





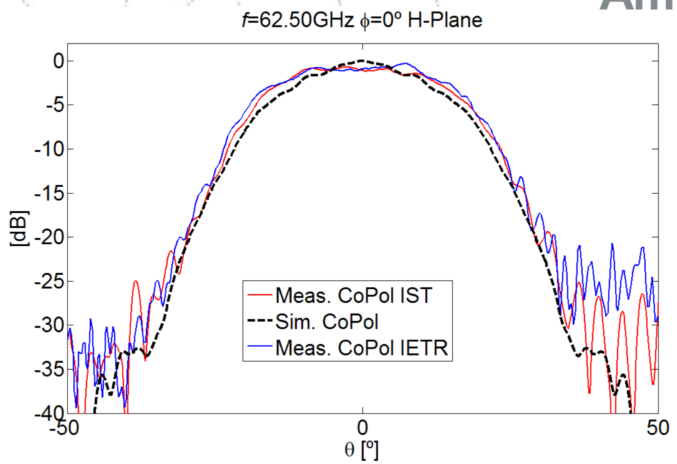
Ray Tracing

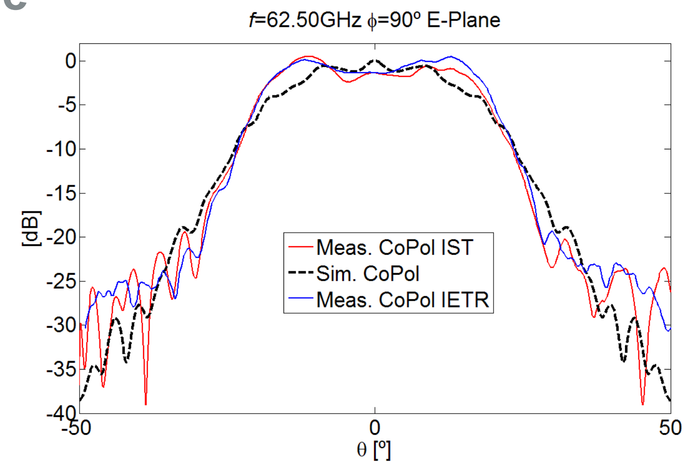
C. A. Fernandes; J. R. Costa; M. van der Vorst; "Design of a Shaped Double-Shell Lens Feed for a Quasi-Optical Reflector System", Proc. IEEE APS/URSI Symposium, Washington, USA, Jun. 2007

Lens for quasi-optical system

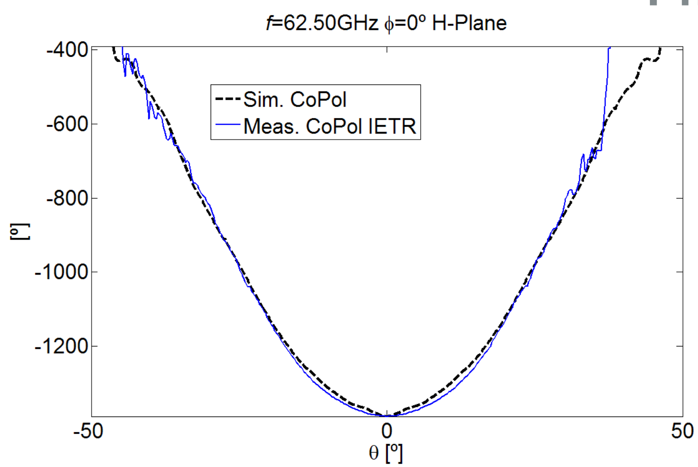
f = 62.5 GHz

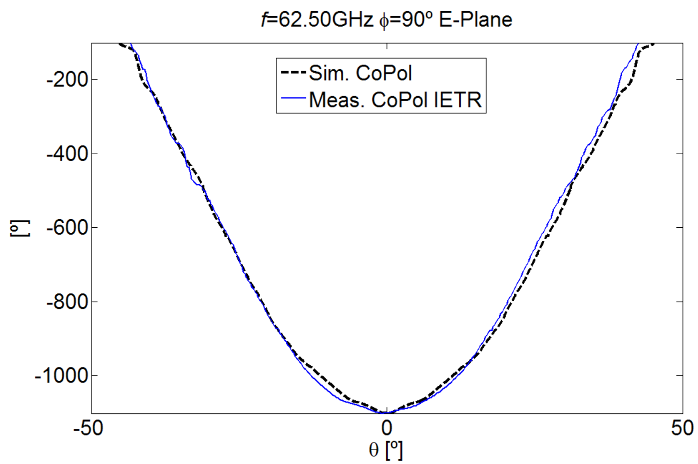
Amplitude





Phase



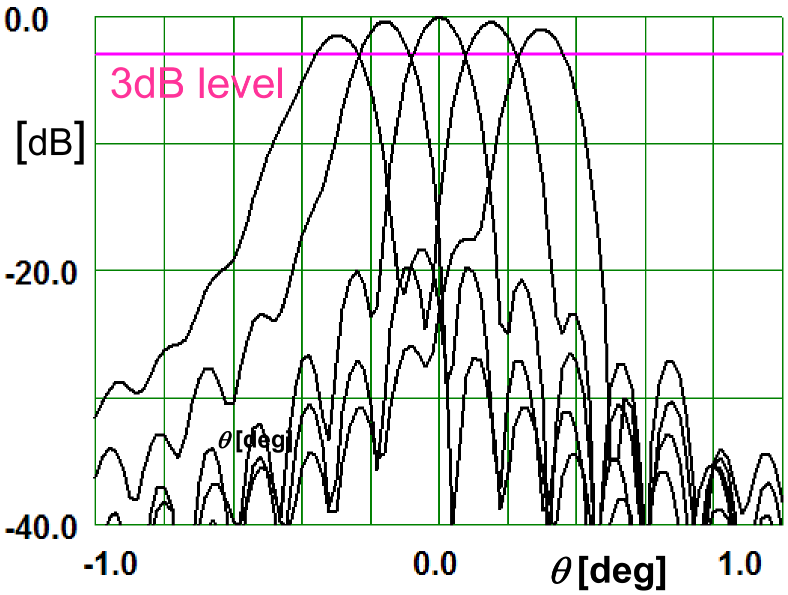


H-plane **E-plane**

Reflector + lens performance

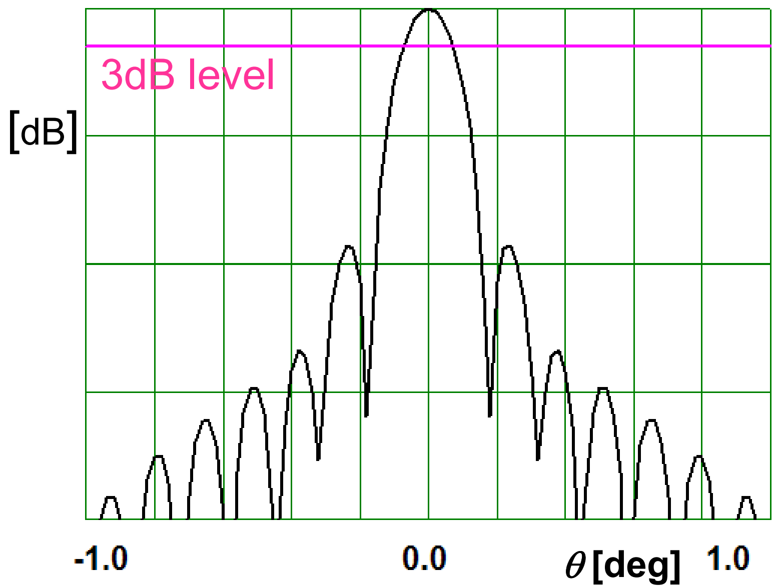
Scaled reflector: F = 1.6 m, D = 2 m

Simulated results @ 62.5 GHz



H-plane

(*x*=–2.75, -1.5, 0, 1.5, 3.0 mm)



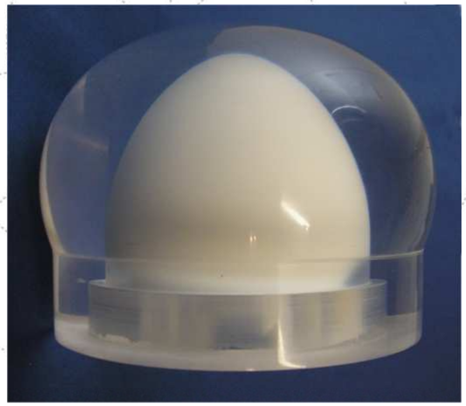
E-plane

Example2 - Broadband Lens Antenna with Frequency Constant Gaussicity

- The objective is to maximize aperture efficiency of the reflector over frequency.
- Illuminate the reflector with a frequency constant beamwidth.
- Design a broadband feed to produce a frequency constant beamwidth.

- Frequency range : 30 to 90 GHz (100% bandwidth).

Fabricated dielectric lens



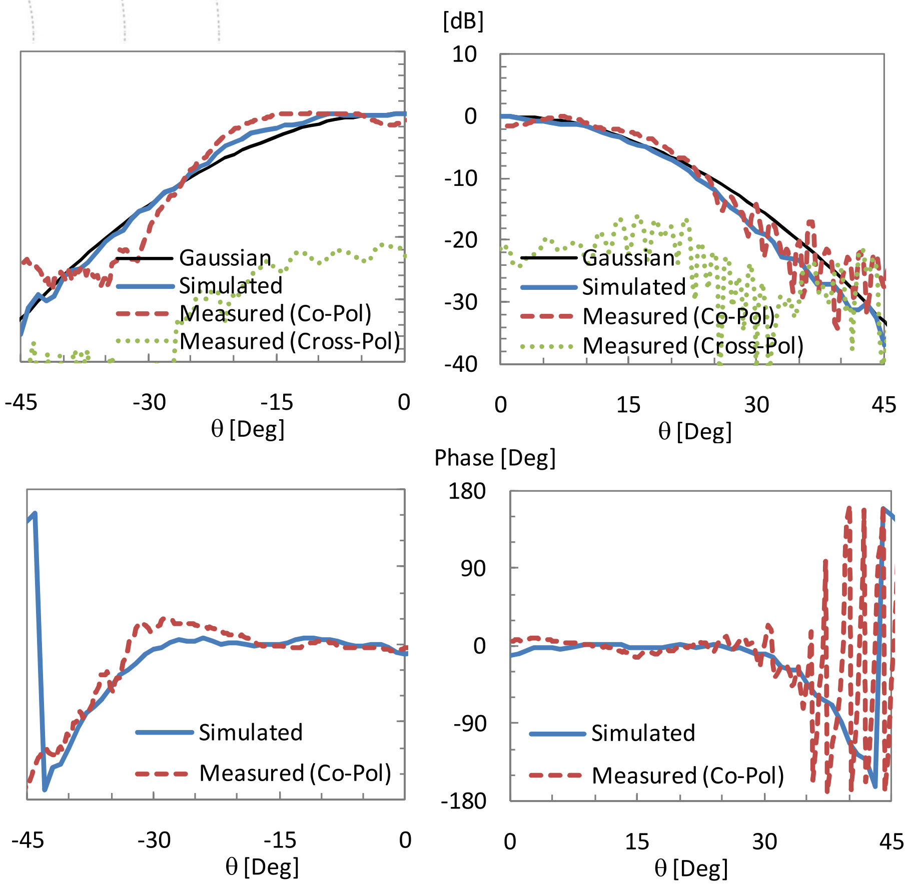
Designation	Variable	Value
Inner shell height	F	41.8 mm
Outer shell height	S	20.9 mm
Inner shell refraction index	n_2	$\sqrt{5.5}$
Outer shell refraction index	n_1	$\sqrt{2.53}$
Feed Gaussian width	φ_0	64º
Maximum feed aperture	φ_{max}	90º
Far-field Gaussian width	α_0	23º
Maximum subtended angle	α_{max}	31º

- Lens material:
  - MACOR
    ε_r = 5.5 (1-j0.0118);
  - Acrylic
    ε_r = 2.53 (1-j0.0118).

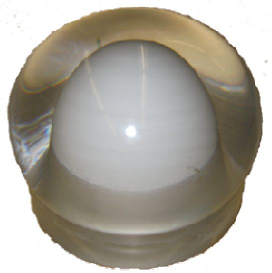
Measured and simulated lens radiation pattern @ 62.5 GHz

Magnitude

Phase



E-plane *H-plane*



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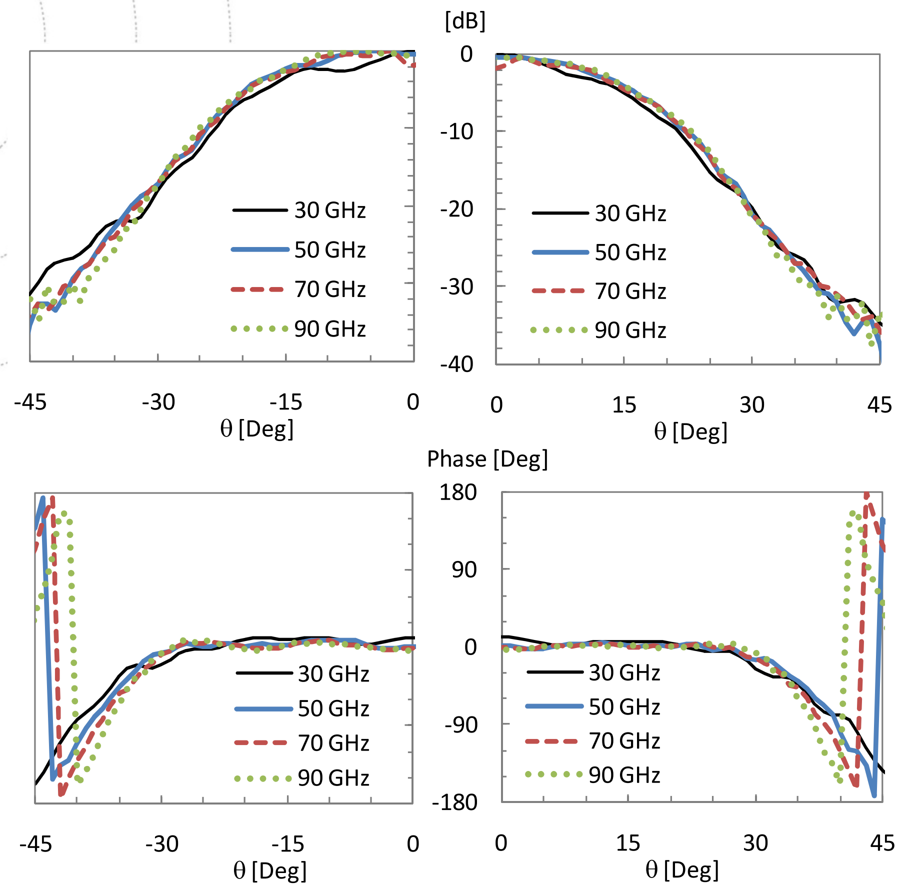
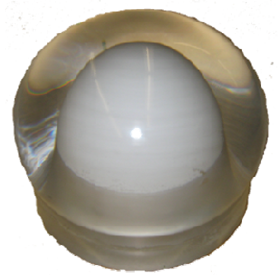
Simulations within the 100% bandwidth

Magnitude

Phase



E-plane *H-plane*



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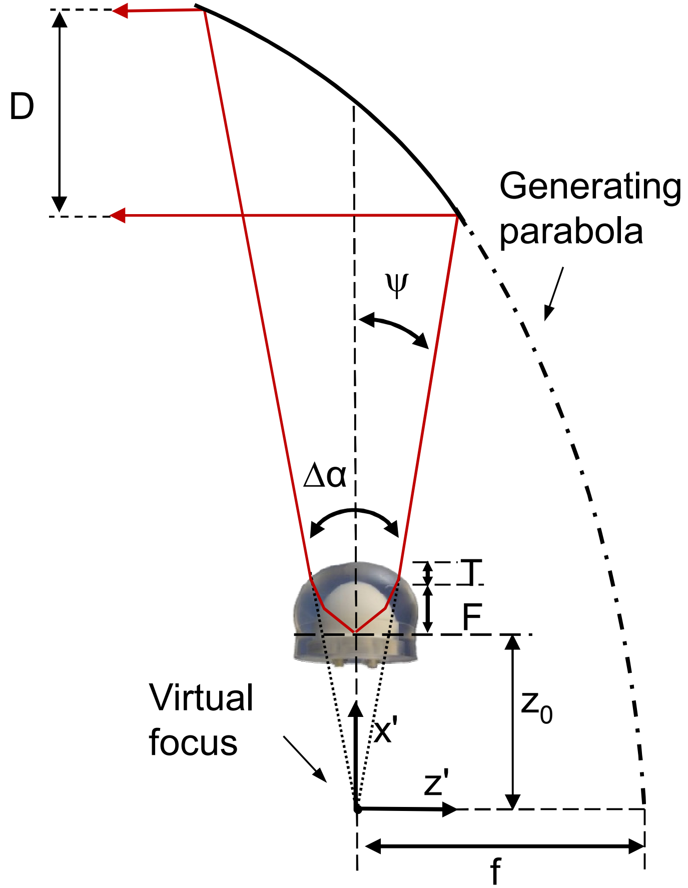
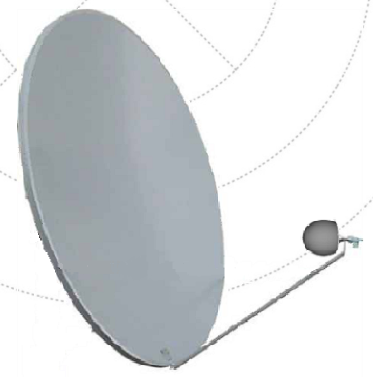
Lens antenna + reflector

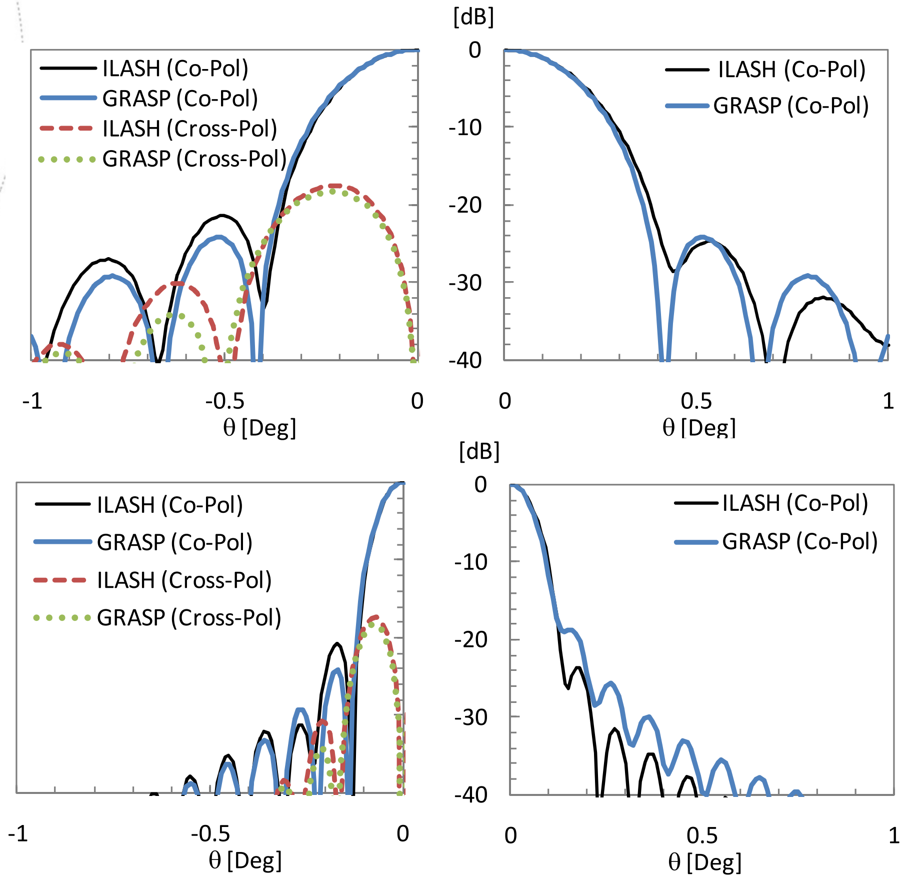
- Off-set parabolic reflector.
- Parabola focal length $f = 1.25m$;
- Parabola diameter $D = 2m$.
- Lens phase center $z_0 = 16.5mm$;
- Feed beam width $\Delta\alpha = 56^0$
  - -16 dB illumination taper at the reflector edge.



Lens antenna + reflector



Reflector illuminated by the lens



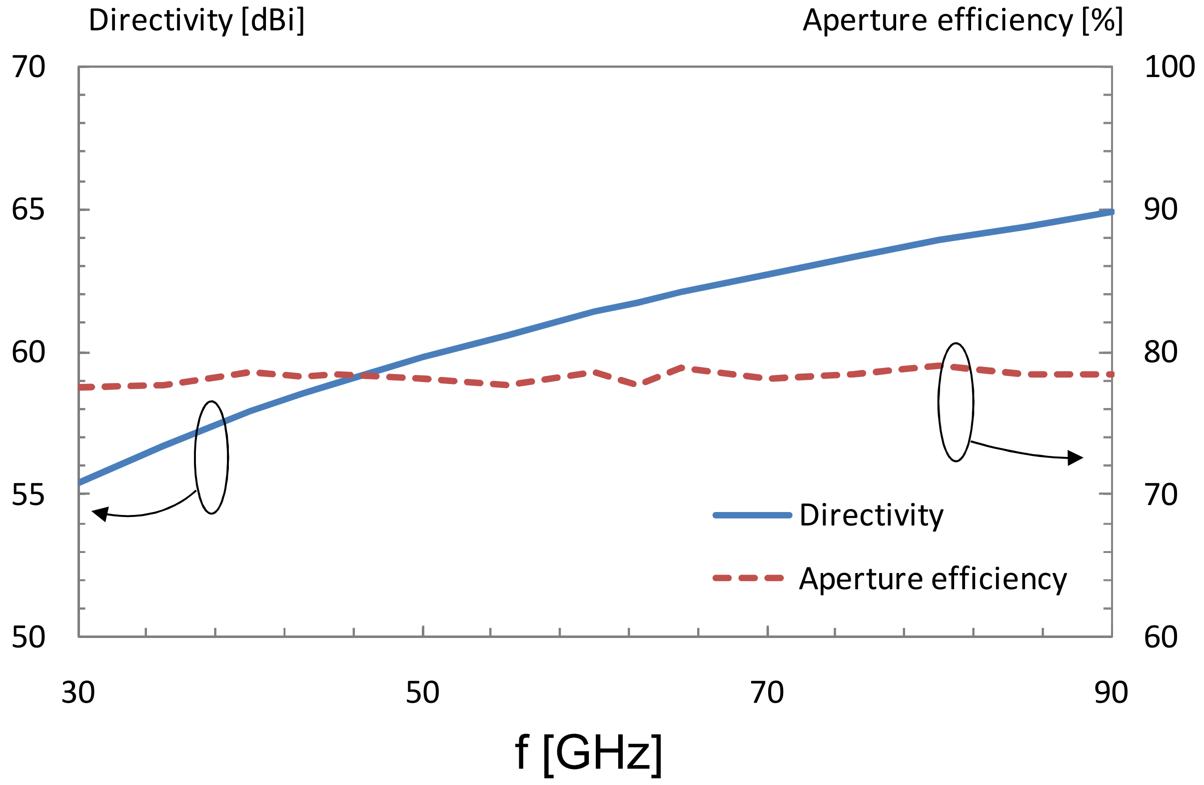
30 GHz

90 GHz

E-plane *H-plane*

Lens antenna + reflector

- Simulations including the off-set parabolic reflector show almost frequency constant aperture efficiency within the 1:3 bandwidth.

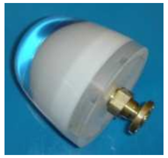


ILASH Overview

- ILASH tool is intended for design, analysis and optimization of shaped single- and double-shell integrated lens antennas (ILA);

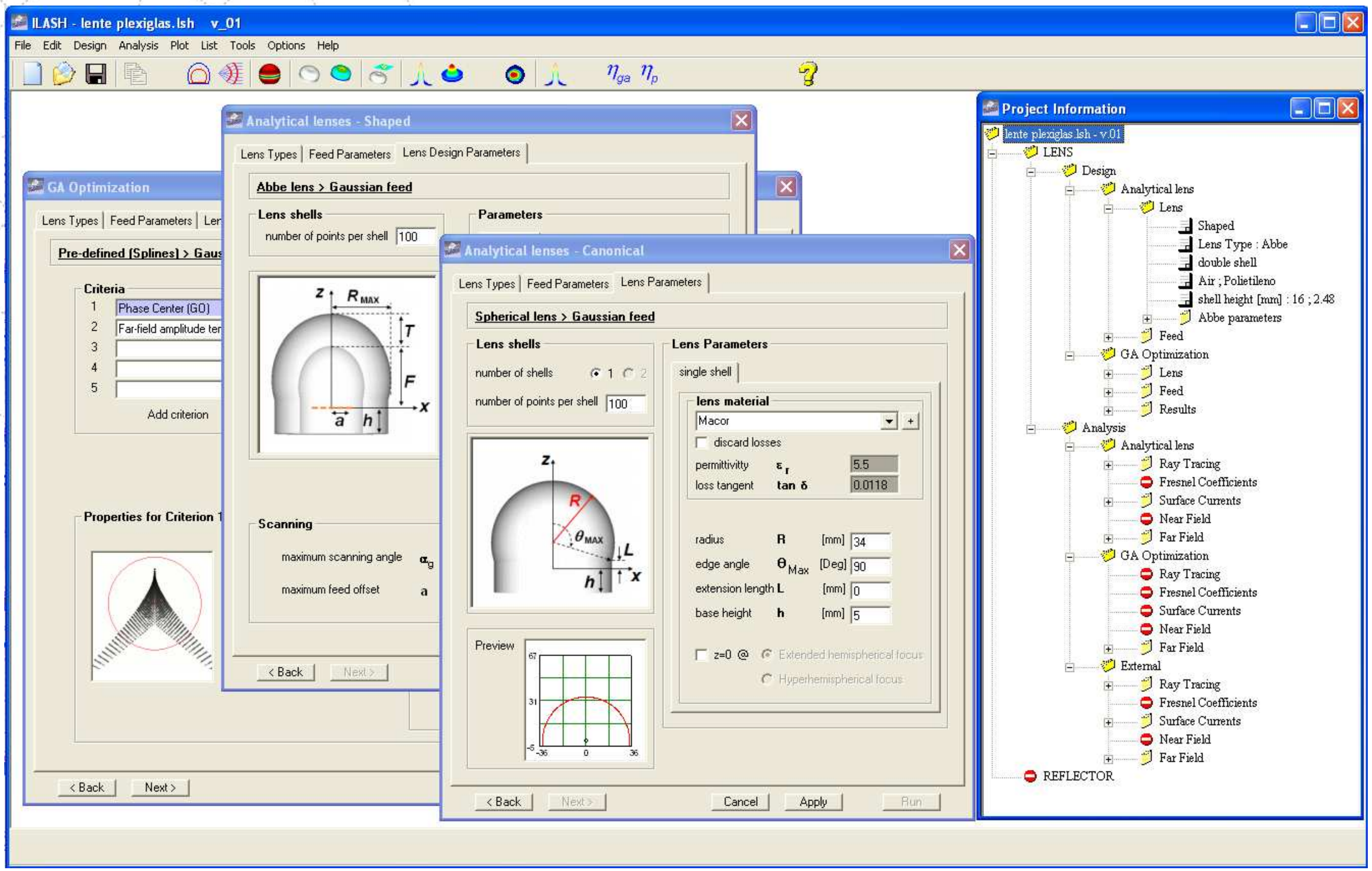




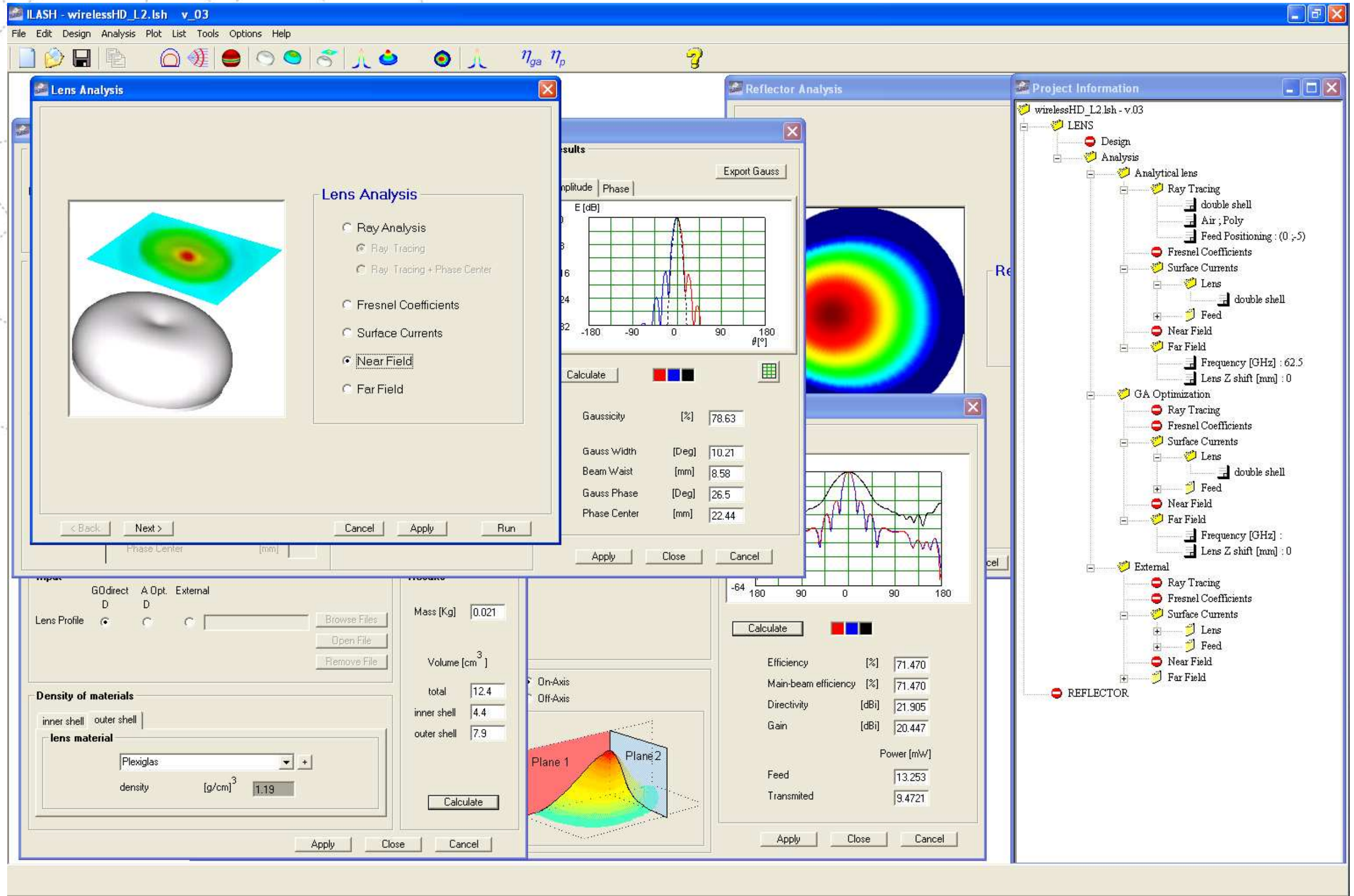


- Lenses can be fed by arbitrary feeds:
  - Internally defined;
  - Defined in data file.
- ILASH combines two lens design modules:
  - Closed-form analytical formulations for several types of shaped double-shell lenses;
  - Genetic Algorithm (GA) optimization.

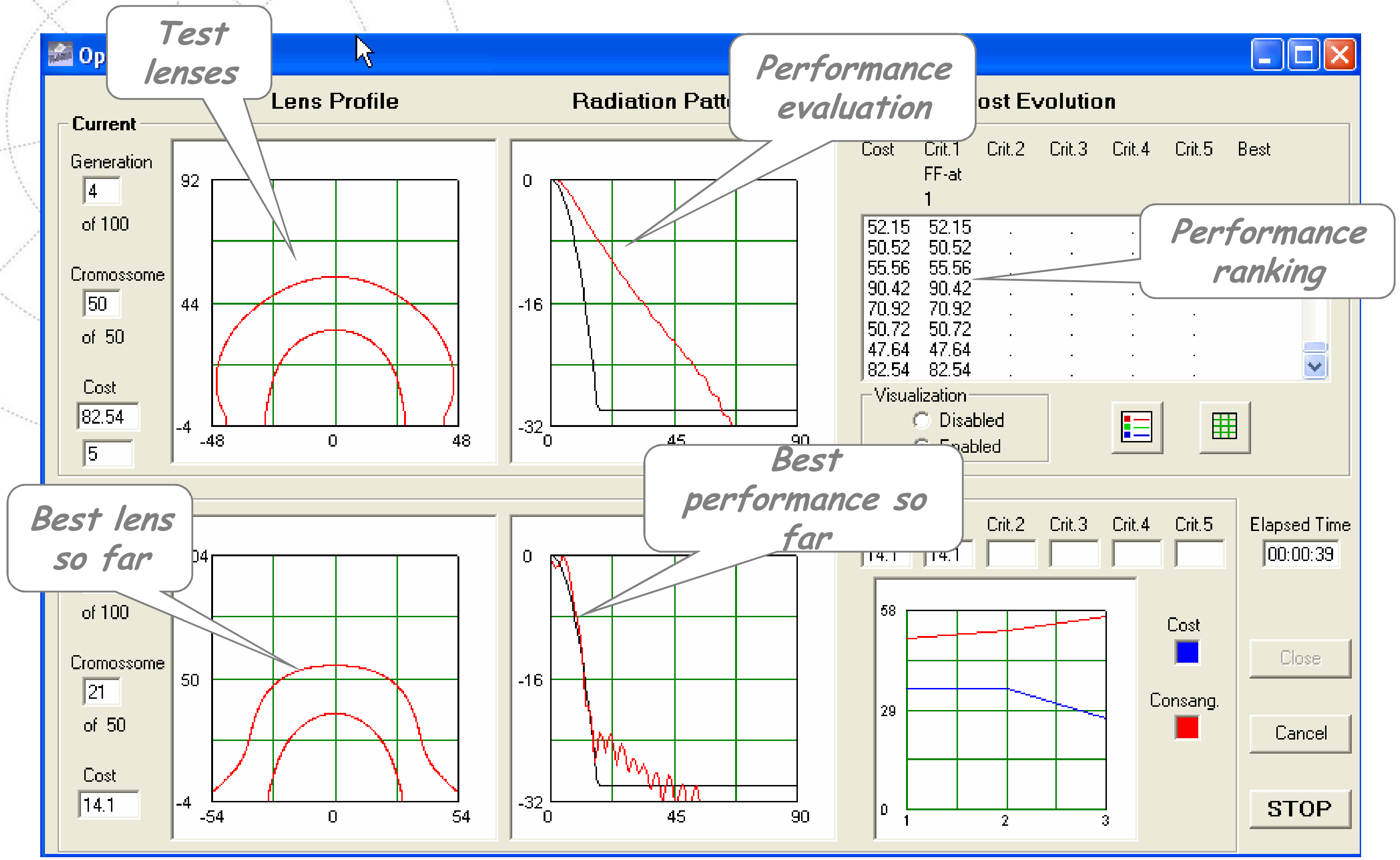
User Interface (Lens Synthesis)



User Interface (Evaluation Tools)



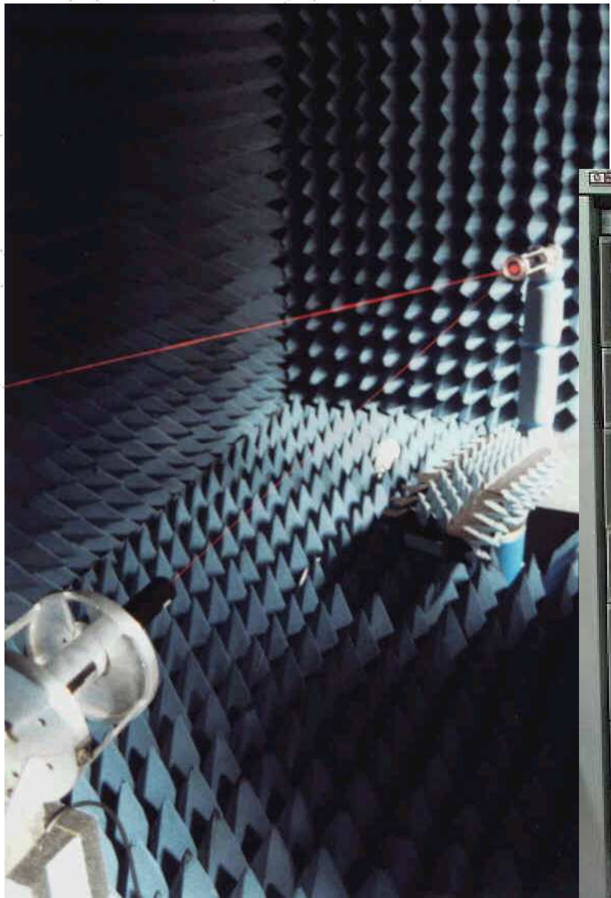
Optimization Module (Genetic Algorithms)

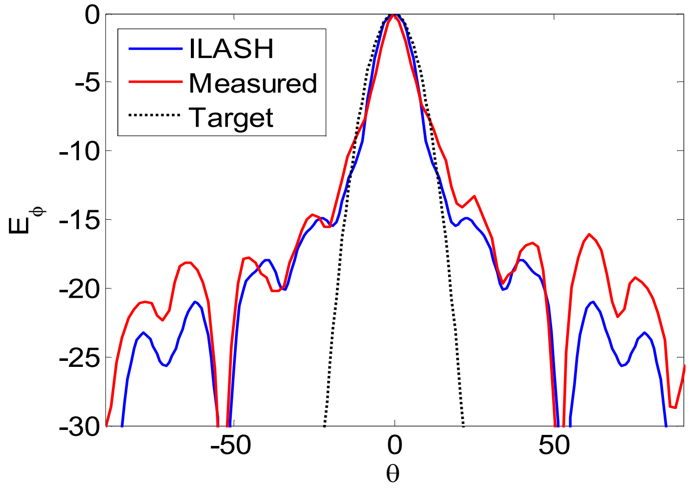


Manufacturing of dielectric lenses by milling or molding

Fabricated lens antenna prototypes

Lens antenna tests





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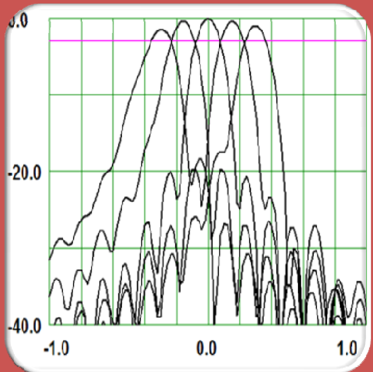
Conclusions

Two different dielectric lens antenna configurations were described, intended to feed a quasi-optical imaging reflector system.



- Good scanning conditions are obtained when combined with an off-set parabolic reflector;
- A single lens antenna can replace multiple individual parabola feeds, not being limited by the available space between feeds in the parabola focal arch.