Design of a Stealthy Antenna Using COMSOL Multiphysics®

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Outlines

- introduction
- problem definition
- FSS analysis and design
- COMSOL aided simulations
- Results

Altran Italia provides advanced engineering and Innovation consultancy in different fields of applications.
It is divided in several sectors.

ASD Analysis & Simulation Solution provides high quality services in modeling and simulation.

The solution expertise covers a wide range of disciplines:

✓Radar/SAR signal processing

✓ Low observability Engineering: Radar cross section prediction, Infrared signature analysis, RCS measurements.

✓Electromagnetic engineering applications: antenna coverage studies, EMI analysis.

✓Image processing: surveillance and recognition systems, tracking systems

✓Acoustics: Environmental acoustics prediction, Architectural acoustics studies.

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Electromagnetic Engineering

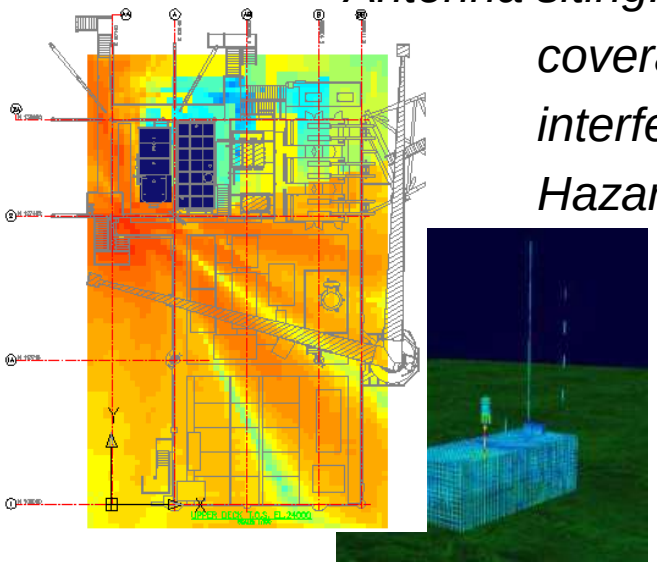
ALTRAN ITALIA

Antenna siting:

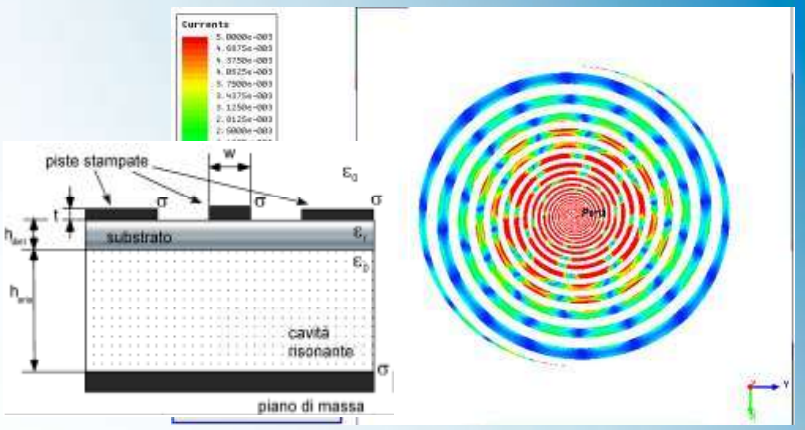
coverage

interferenza (EMI)

Hazard

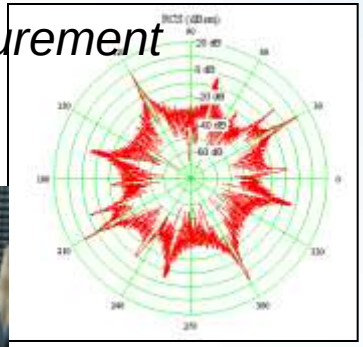


Antenna design

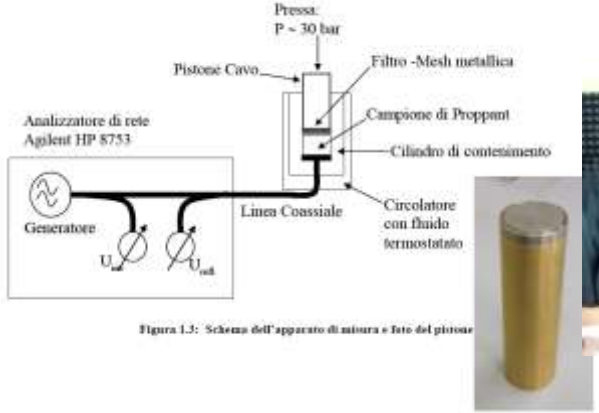


Radar cross section : prediction

And measurement

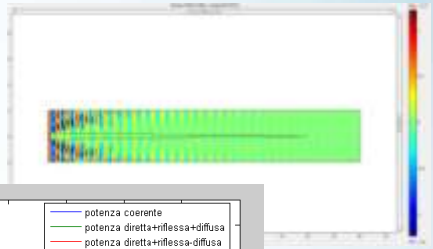


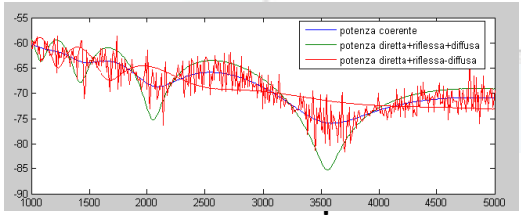
EM material characterization



Propagation model

Development





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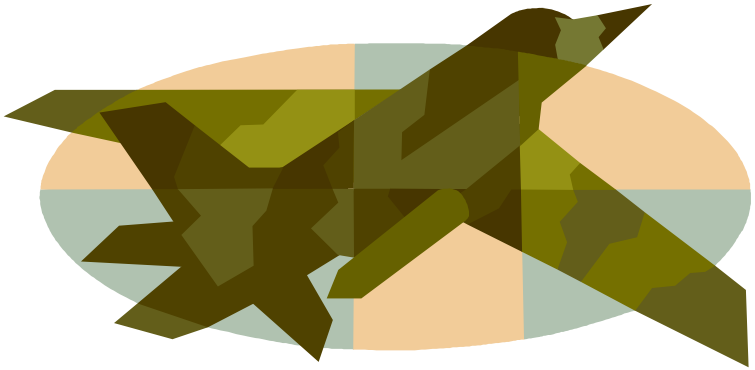
Problem definition

Antenna systems placed on stealthy aircraft or navy ship could destroy their invisibility to radar due to the in-phase sum of reflections from antenna

Stealthy antennas → low RCS

$$\sigma = \lim_{r\to\infty} 4\pi r^2 \frac{\left|E_s^2(r)\right|}{\left|E_i^2(r)\right|}$$



In the direction of the incident wave, the scattered field is reflected straight back to the source of the wave.
This peak reflected wave is related to the standard antenna gain, G, and the radar cross section

$$\sigma = A \cdot G$$

$$\sigma = 4\pi \frac{\mathrm{A}^2}{\lambda^2} = \lambda^2 \frac{\mathrm{G}^2}{4\pi}$$

To lower the RCS, the gain should be reduced. This is opposite to what antenna designers are supposed to do

RCS reduction

Several methods have been investigated to reduce RCS of antennas

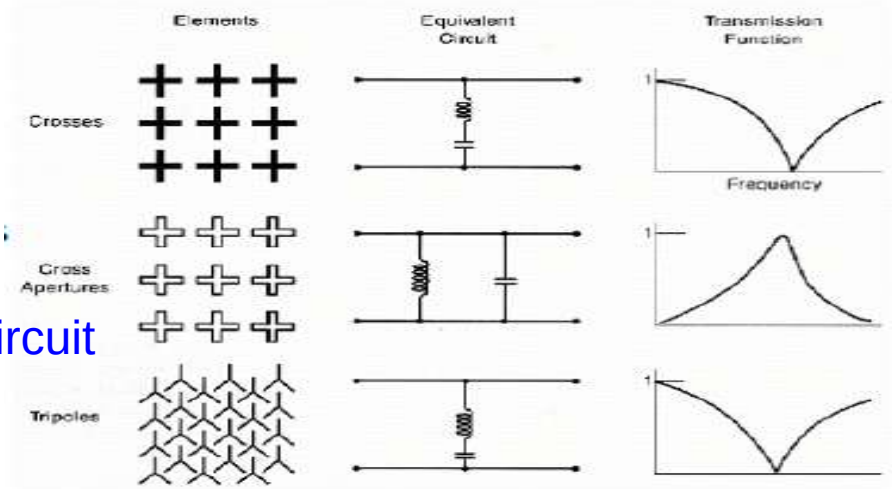
- **Different shape of the structures,**
- **use of active or passive elements,**
- **use of absorbing materials.**

This paper aimed to present a reduction of RCS using FSS structures.

FSS analysis and design

Frequency selective surfaces are usually constructed from periodically arranged metallic patches of arbitrary geometries or their complimentary geometry having aperture elements similar to patches within a metallic screen

A Frequency Selective Surface (FSS) is any surface construction designed as a 'filter' for plane waves



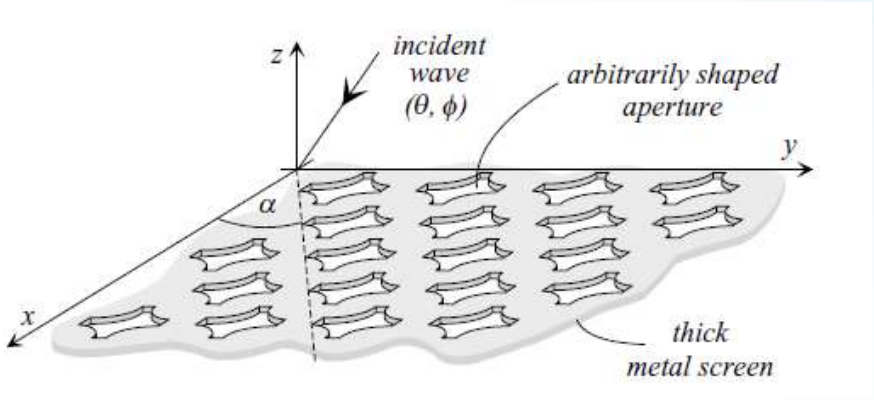
FSS Characteristics

- Typically narrow band
- Periodic, typically in two dimensions

FSS Degrees of Freedom

- Element type: dielectric or metallic/circuit
- Element shape, size, loading
- Element spacing and orientation

FSS analysis and design

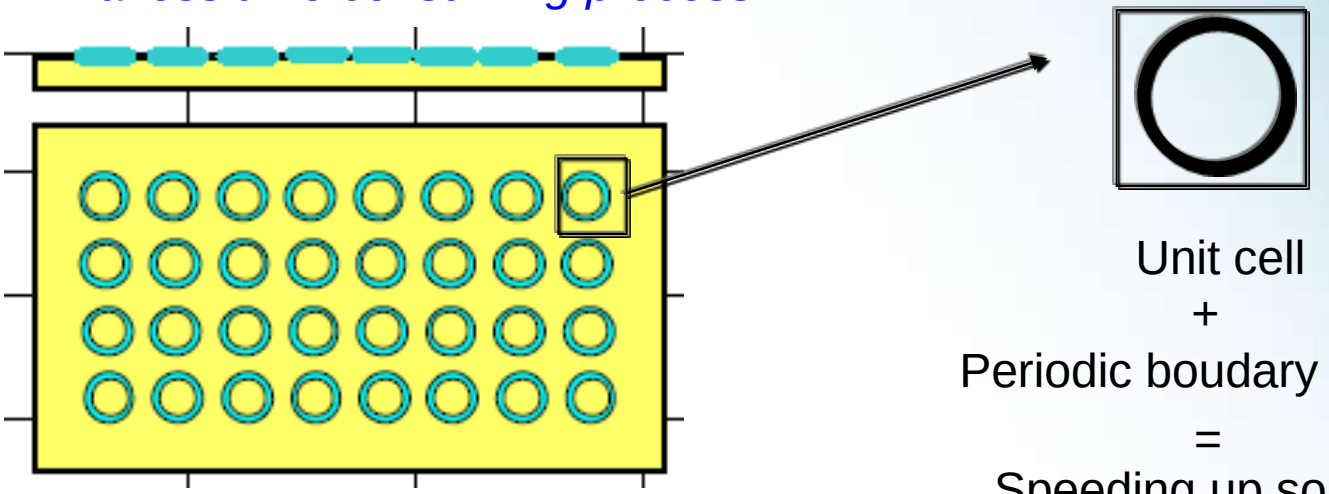


The characteristics of the FSS are that it is transparent at the operating frequency but rejects signals outside a band centered at the operating frequency.

This feature allows the antenna to be low RCS for all frequencies outside the band of frequencies desired.

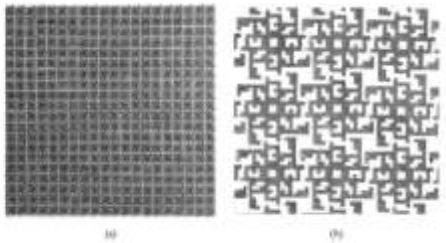
Use of COMSOL Multiphysics

In the case of a FSS constitutes by a periodic array of elements, the availability of Periodic Boundary Condition (PBC) allow the simulation of a single cell unit and therefore a less time consuming process.



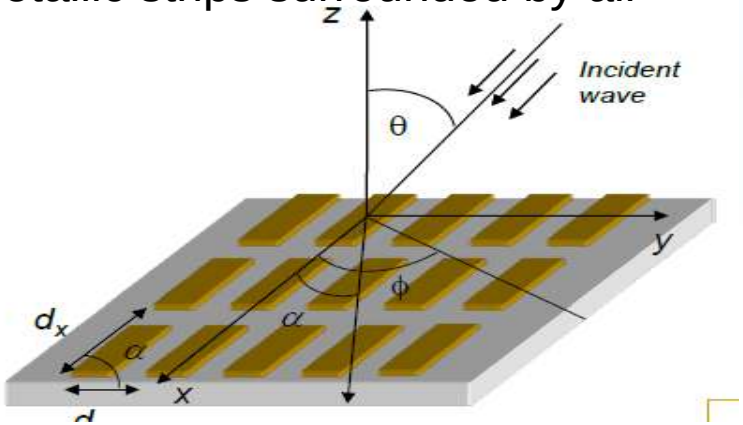
Unit cell
+
Periodic boudary condition
=
Speeding up solution

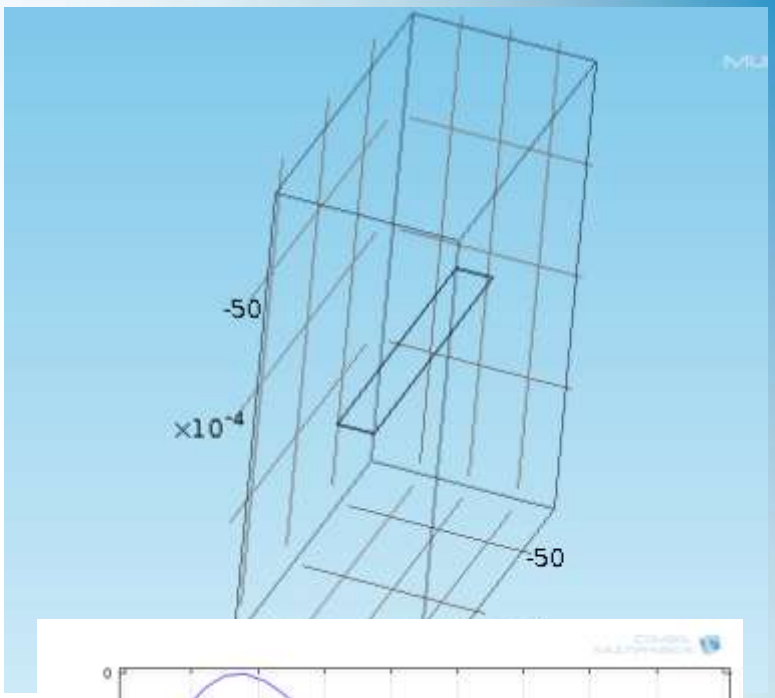
Since the element of FSS could be arbitrarily shaped a synthesis method could be easily set up to optimize the solution



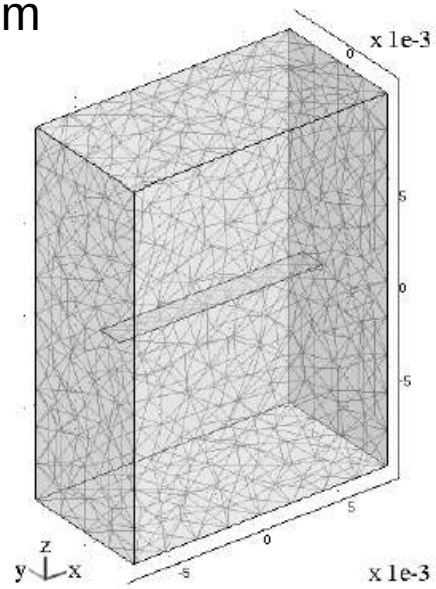
Example – metallic strip array

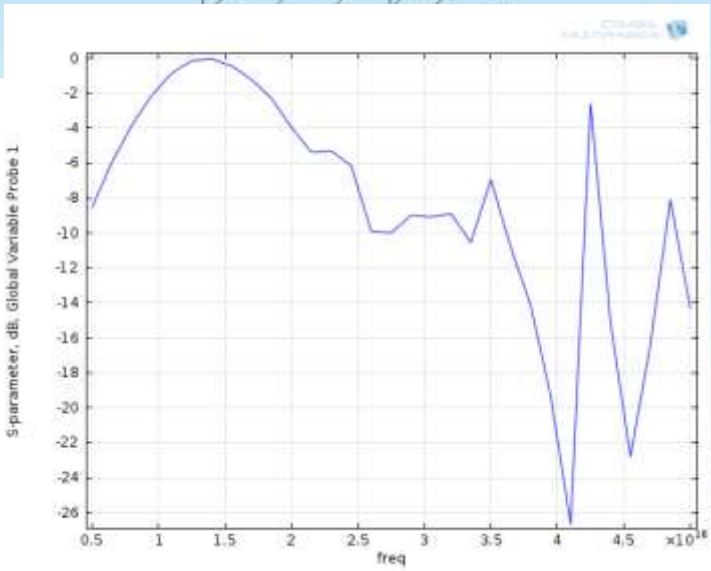
Metallic strips surrounded by air





Width_strip=1.5mm
Length =13mm





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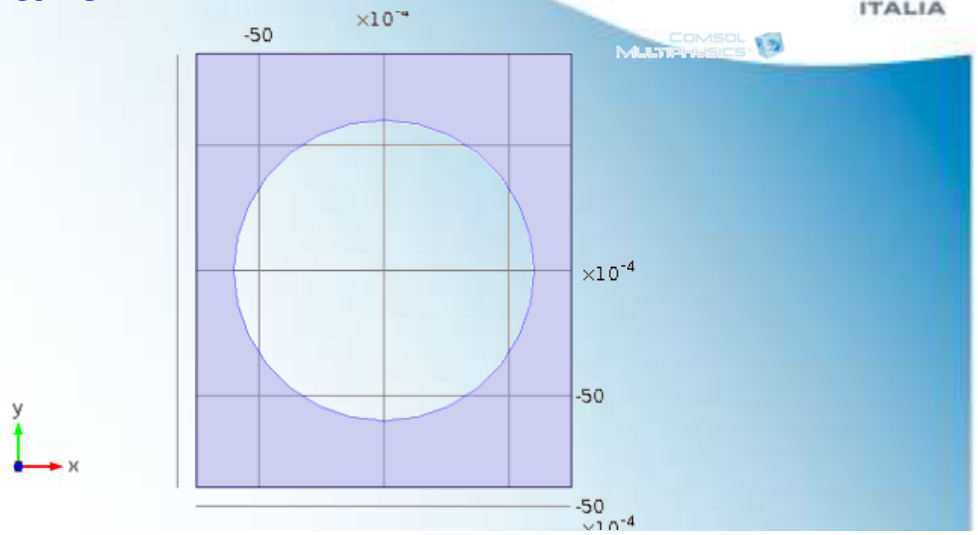
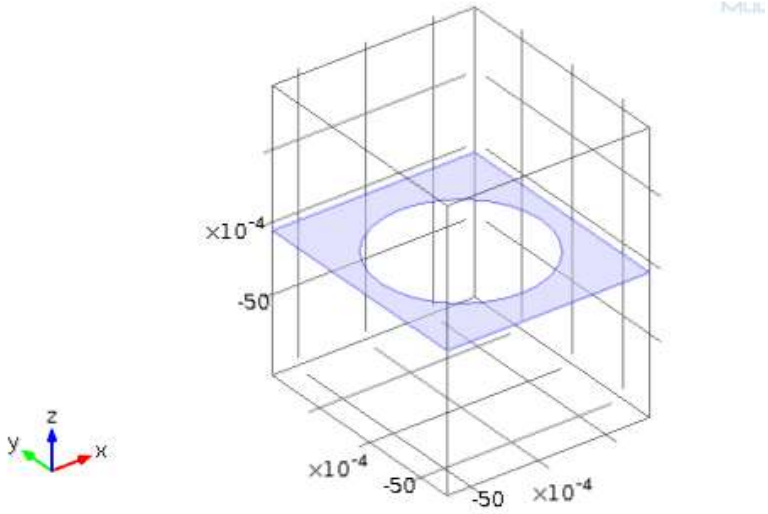
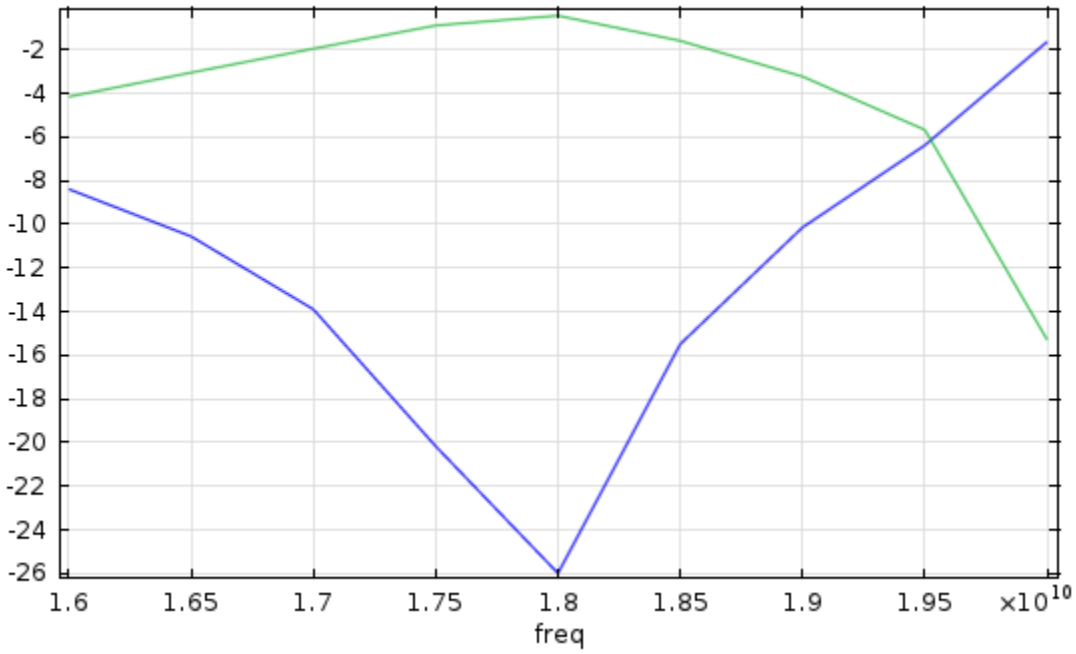
Example- Infinite array of circular aperture

Metallic plane with circular aperture
r=6mm

Plane wave incident on the structure







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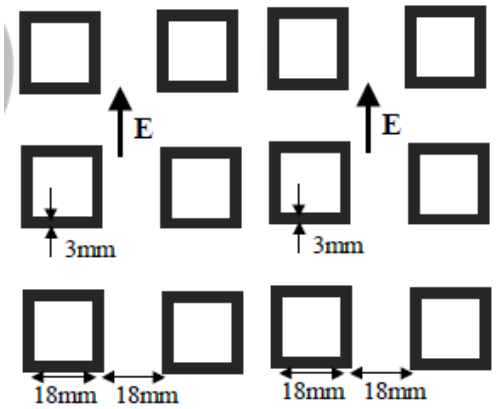
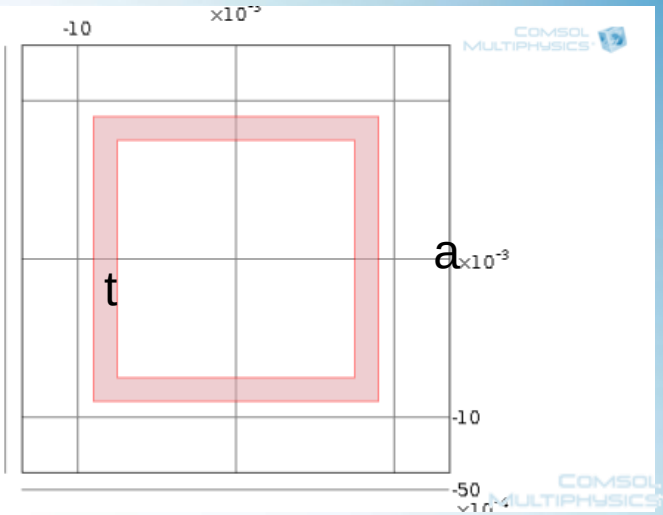
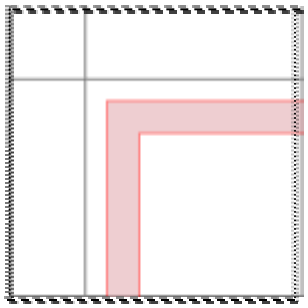
Infintite array of square loop

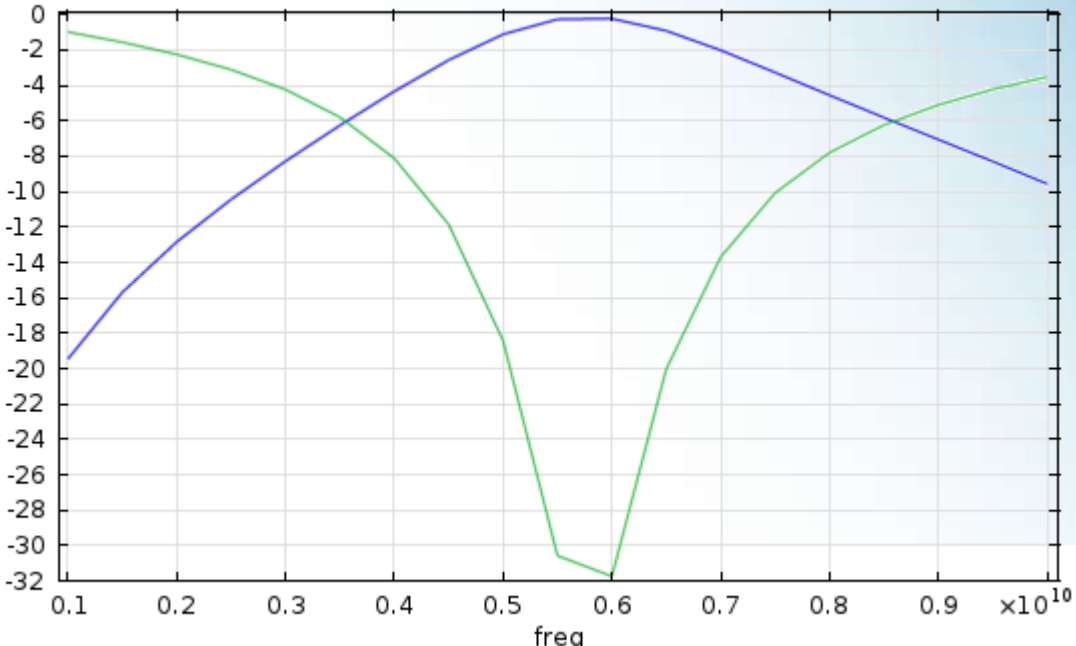


a=18mm
t=3mm

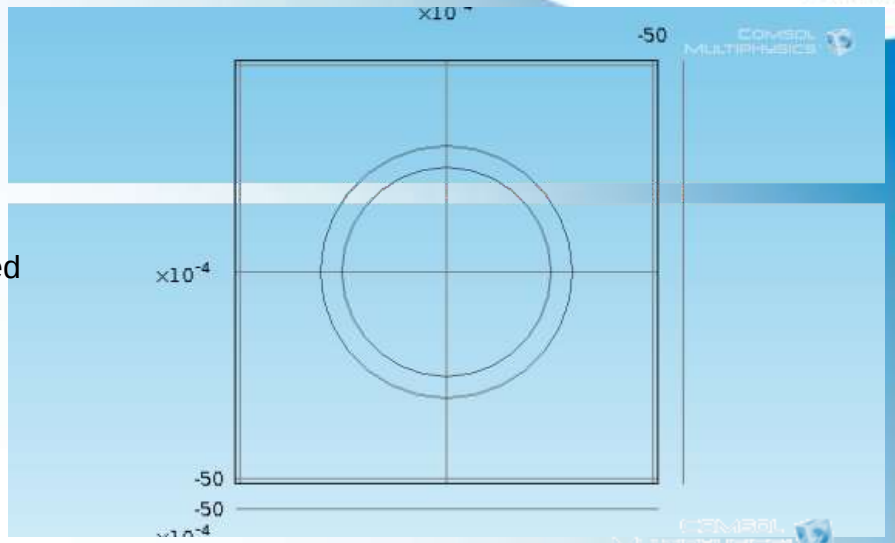




... Magnetic Boundary
--- Electric Boundary

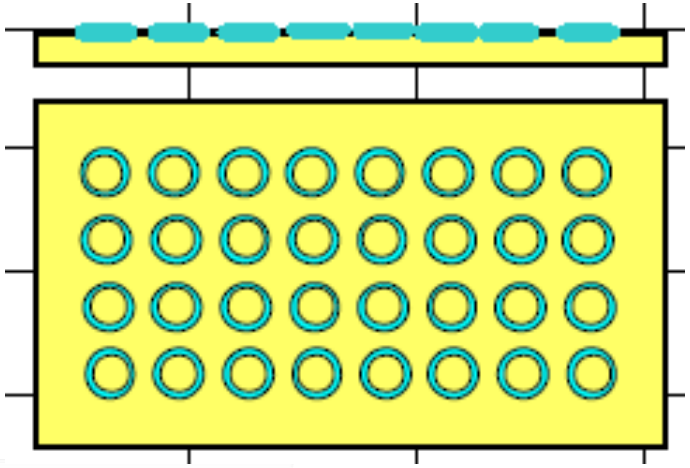


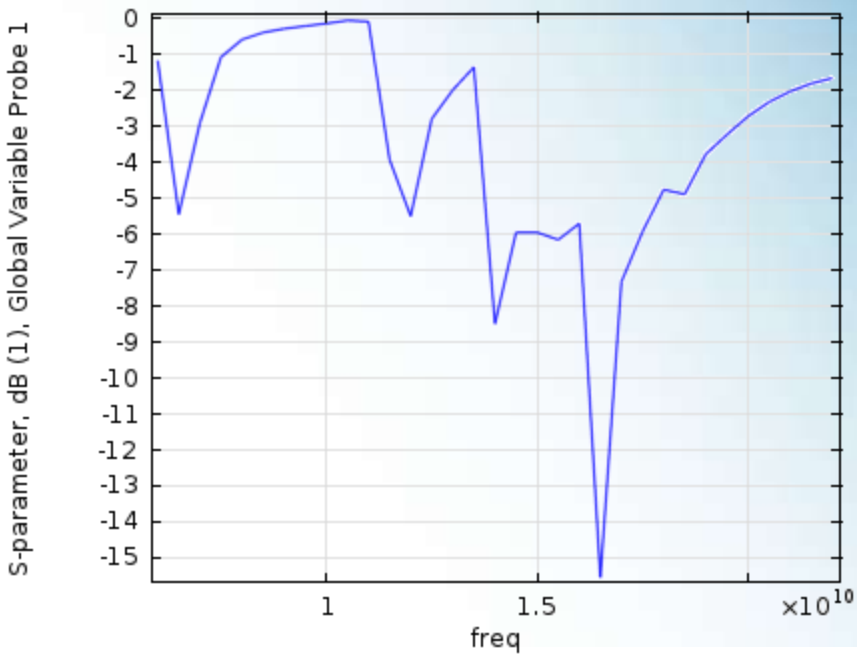
Example- Infinite array of metallic ring



The screen is consists of an infinite array of metallic rings etched on a dielectric substrate.

- The inner/outer diameter of the rings are 6.1/5.06mm
- The dielectric substrate thickness = 0.64mm
- The permittivity of the dielectric substrate = 11





Conclusion

- Stealthy antenna problem
- FSS as cloak of invisibility
- Examples