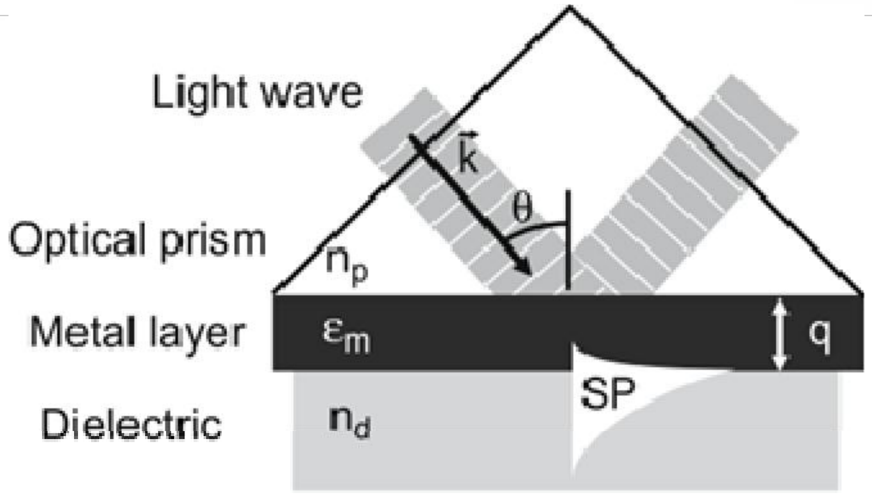
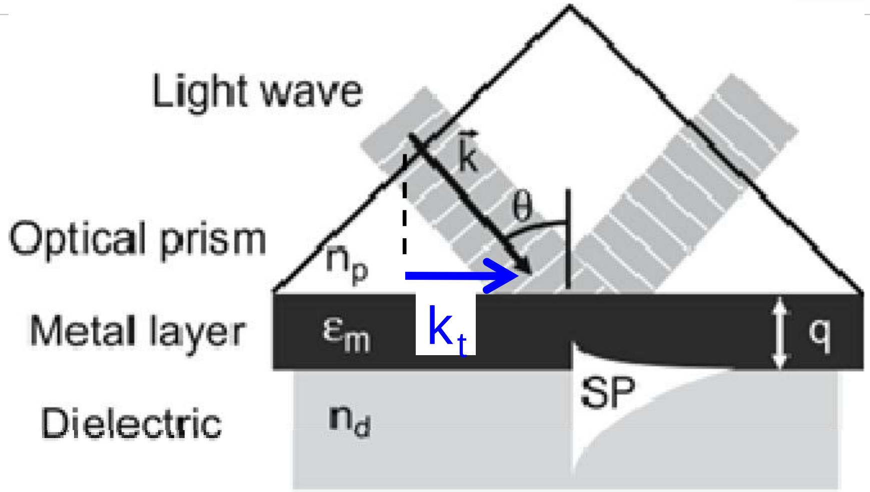
Excitación de SPPs (Surface plasmons polaritons)



Excitation of surface plasmons in the Kretschmann geometry of the attenuated total reflection (ATR) method

The existence of this resonance is based on a unique and simple optical phenomenon. In this phenomenon, the collective coherent oscillations of free electrons in the conduction band of a metal is first excited by the interactive electromagnetic field at a metal/dielectric interface and these created charge density oscillations are called surface plasmon polaritons (SPPs). The SPPs will then form an electric field that exponentially decays into its surrounding medium with a penetration depth in hundreds of nanometers range.

Excitación de SPPs (Surface plasmons polaritons)

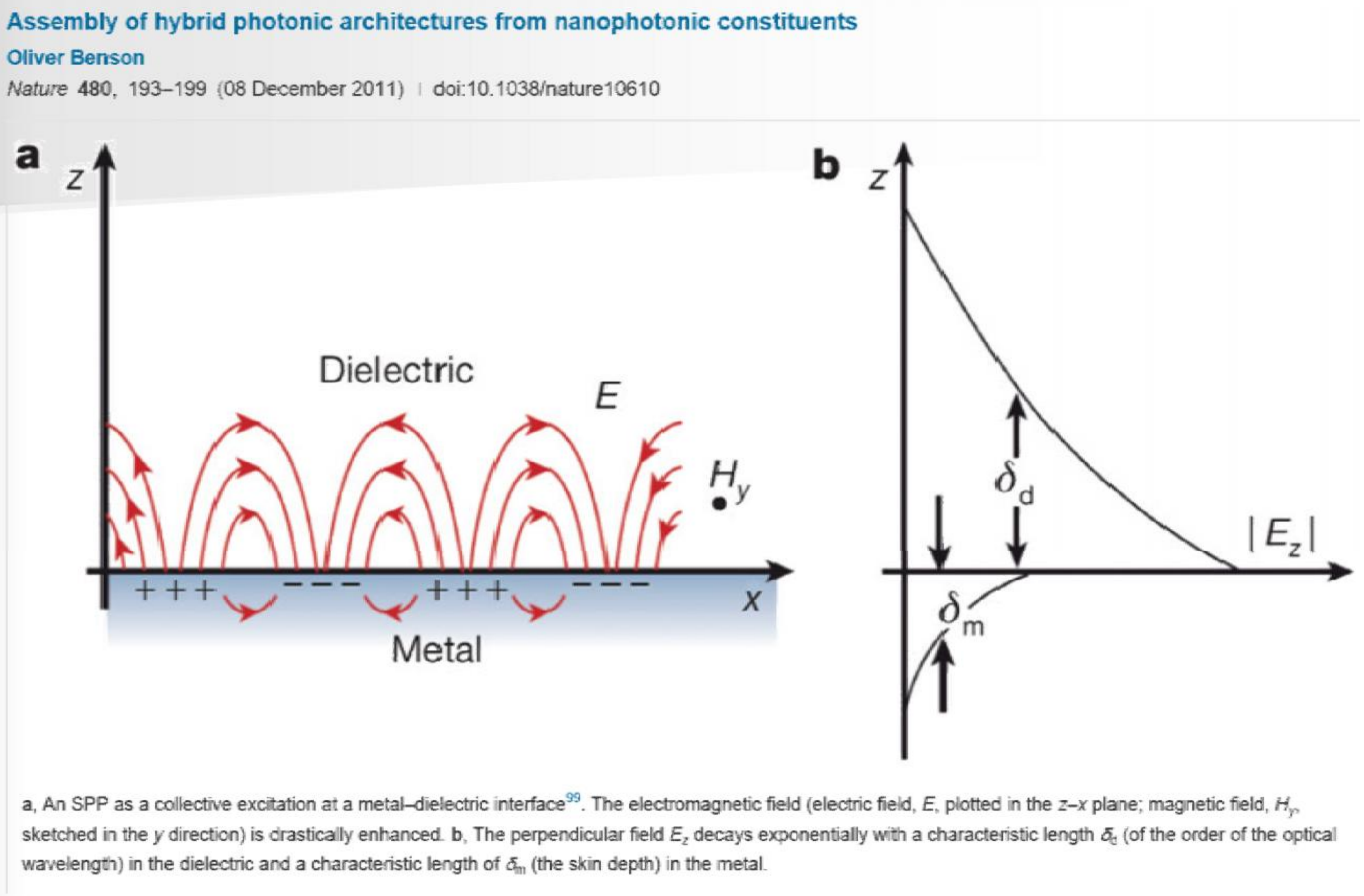


$$k_{spp} = k_0 \sqrt{\frac{\pounds_m \pounds_d}{\pounds_m + \pounds_d}}$$

Excitation of surface plasmons in the Kretschmann geometry of the attenuated total reflection (ATR) method

$$\mathbf{k}_t \cong \mathrm{Re}\left(k_{spp}\right)$$

$$-_{spp} = Arc\sin\left(\sqrt{\frac{\pounds_m \pounds_d}{(\pounds_m + \pounds_d)\pounds_p}}\right)$$



Assembly of hybrid photonic architectures from nanophotonic constituents

Oliver Benson

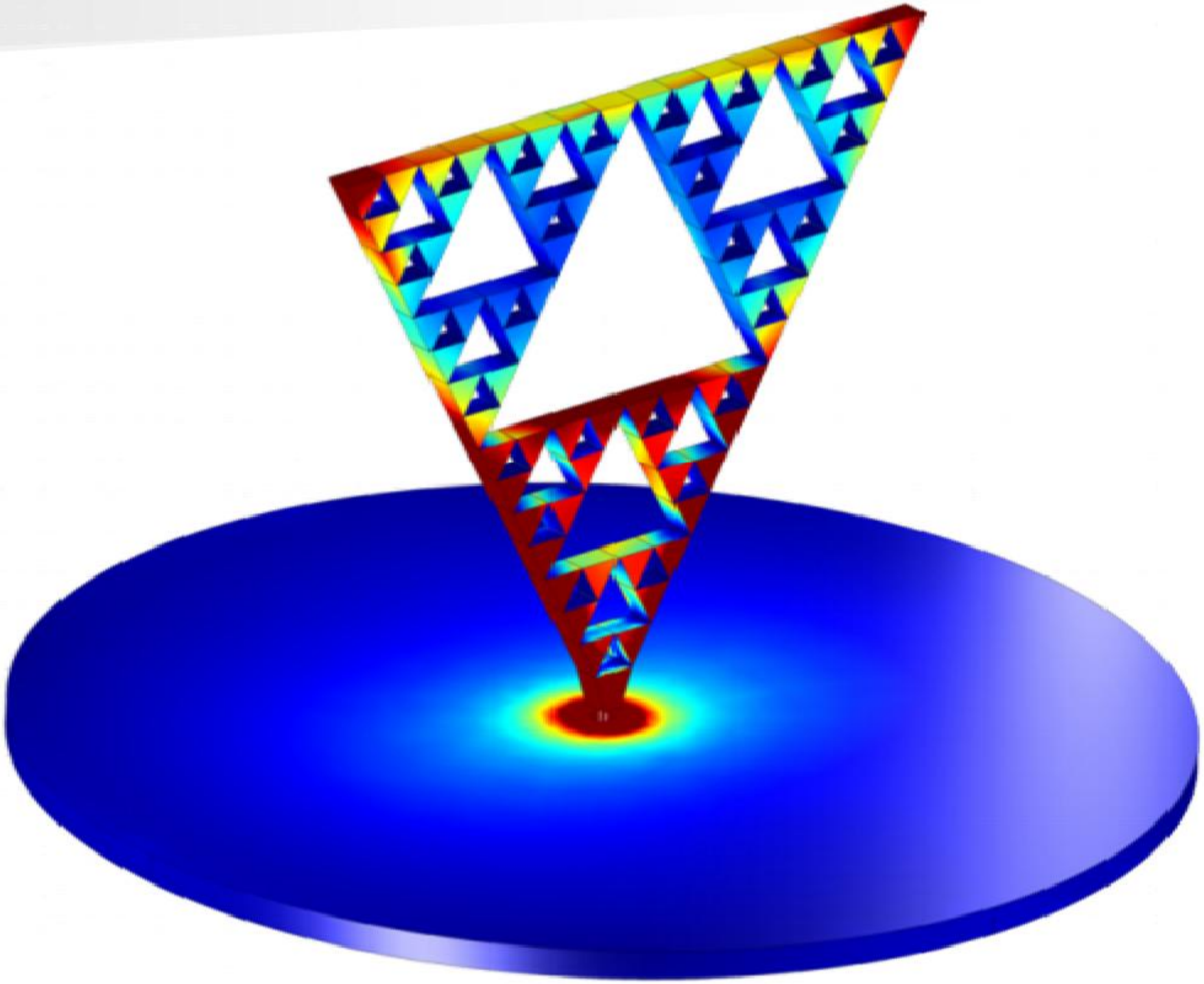
Nature **480**, 193–199 (08 December 2011) | doi:10.1038/nature10610

a, An SPP as a collective excitation at a metal–dielectric interface[99]. The electromagnetic field (electric field, E, plotted in the z–x plane; magnetic field, H_y, sketched in the y direction) is drastically enhanced. **b**, The perpendicular field E_z decays exponentially with a characteristic length δ_d (of the order of the optical wavelength) in the dielectric and a characteristic length of δ_m (the skin depth) in the metal.

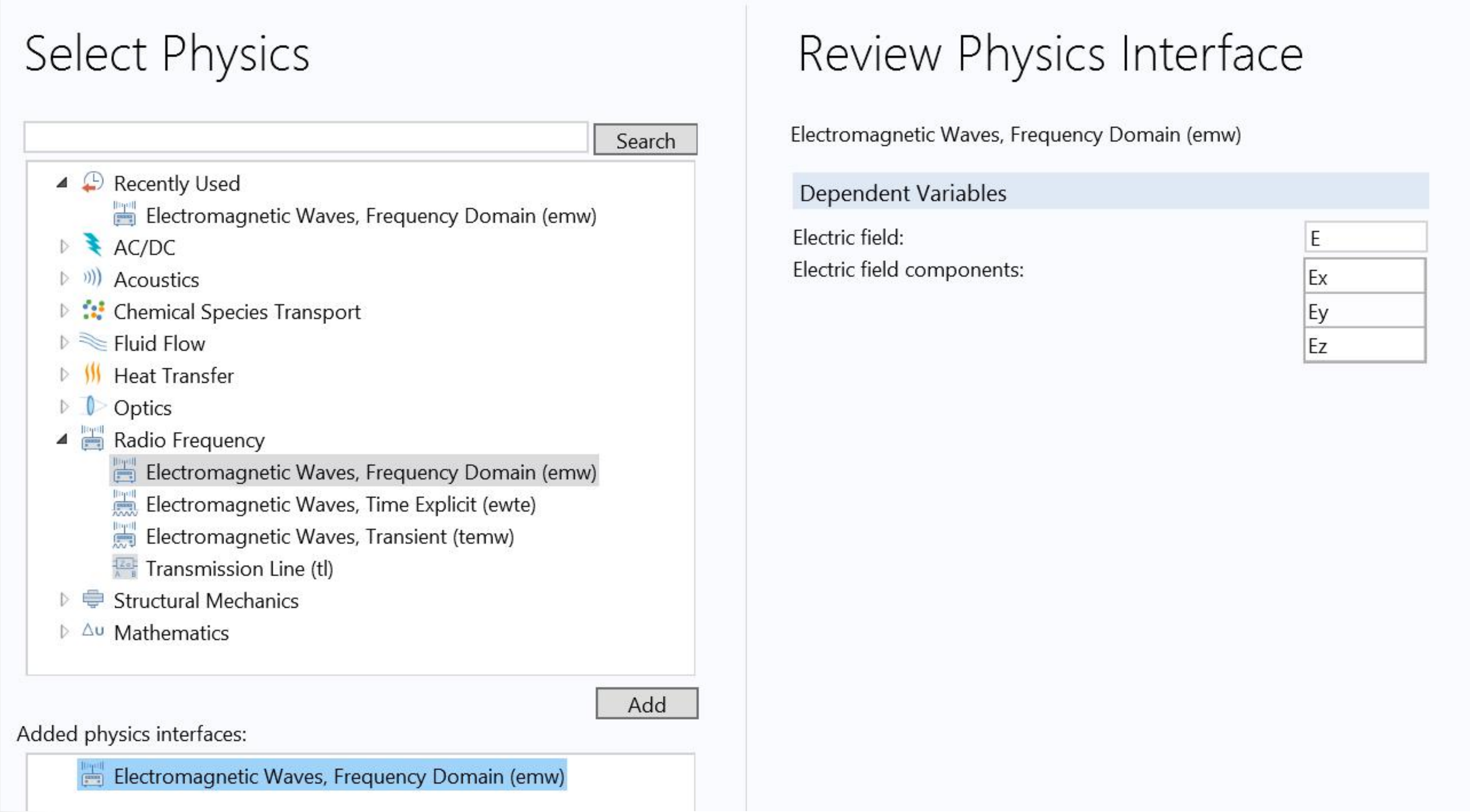
Skin depth

$$\delta_d = \frac{\lambda_0}{2\pi}\sqrt{\frac{\mathrm{Re}(\varepsilon_m)+\varepsilon_d}{\varepsilon_d^2}} \qquad \delta_m = \frac{\lambda_0}{2\pi}\sqrt{\frac{\mathrm{Re}(\varepsilon_m)+\varepsilon_d}{\mathrm{Re}(\varepsilon_m)^2}}$$

Introduction to the RF Module



Radio-Frequency module:
Problemas 2D



Select Physics

Added physics interfaces:

Electromagnetic Waves, Frequency Domain (emw)

Review Physics Interface

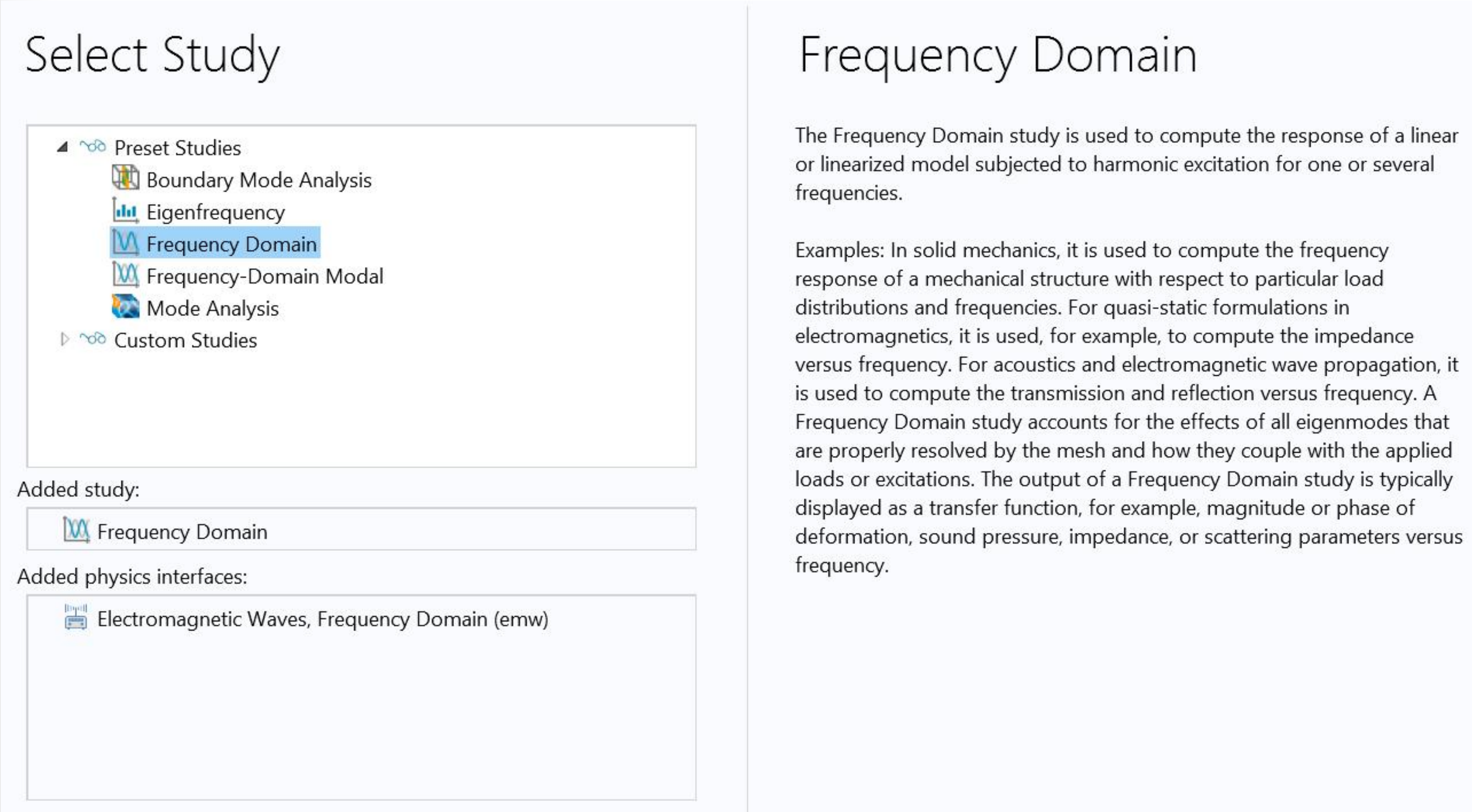
Electromagnetic Waves, Frequency Domain (emw)

Dependent Variables

Electric field: E

Electric field components: Ex, Ey, Ez

Radio-Frequency module: Problemas 2D



Select Study

- Preset Studies
  - Boundary Mode Analysis
  - Eigenfrequency
  - Frequency Domain
  - Frequency-Domain Modal
  - Mode Analysis
- Custom Studies

Added study:

Frequency Domain

Added physics interfaces:

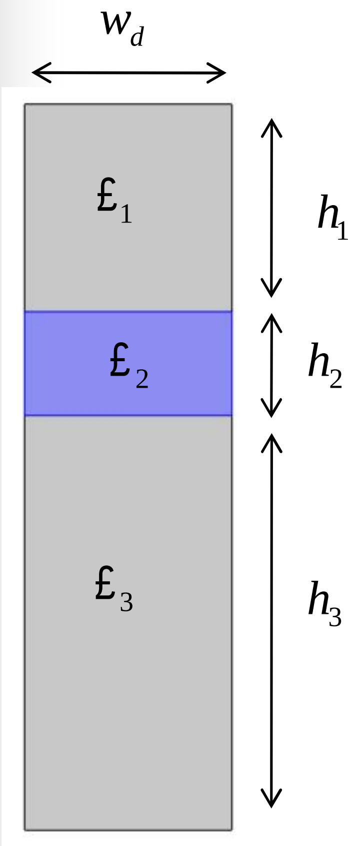
Electromagnetic Waves, Frequency Domain (emw)

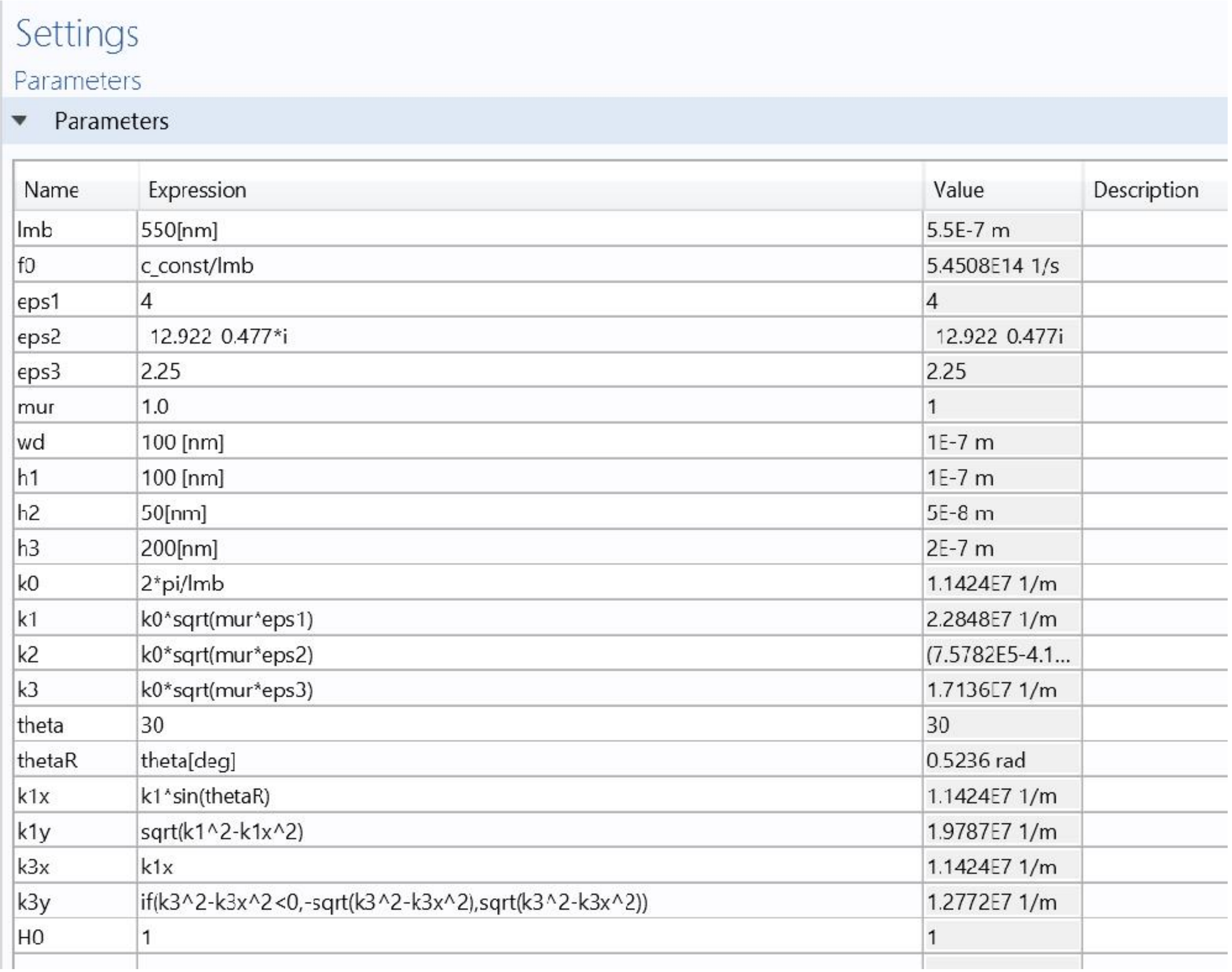
Frequency Domain

The Frequency Domain study is used to compute the response of a linear or linearized model subjected to harmonic excitation for one or several frequencies.

Examples: In solid mechanics, it is used to compute the frequency response of a mechanical structure with respect to particular load distributions and frequencies. For quasi-static formulations in electromagnetics, it is used, for example, to compute the impedance versus frequency. For acoustics and electromagnetic wave propagation, it is used to compute the transmission and reflection versus frequency. A Frequency Domain study accounts for the effects of all eigenmodes that are properly resolved by the mesh and how they couple with the applied loads or excitations. The output of a Frequency Domain study is typically displayed as a transfer function, for example, magnitude or phase of deformation, sound pressure, impedance, or scattering parameters versus frequency.

Radio-Frequency module: Problemas 2D





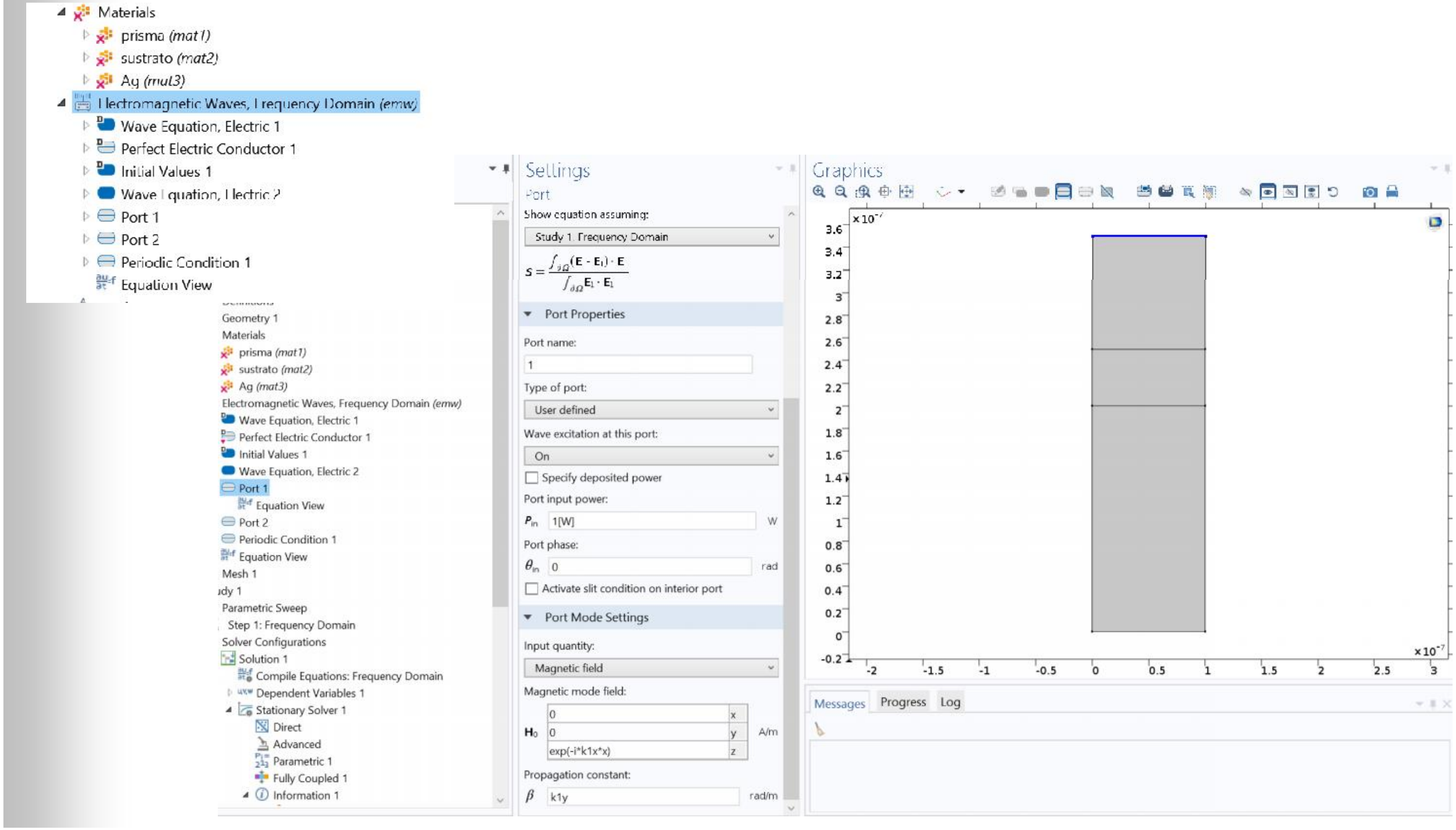
Settings

Parameters

▼ Parameters

Name	Expression	Value	Description
lmb	550[nm]	5.5E-7 m	
f0	c_const/lmb	5.4508E14 1/s	
eps1	4	4	
eps2	12.922 0.477*i	12.922 0.477i	
eps3	2.25	2.25	
mur	1.0	1	
wd	100 [nm]	1E-7 m	
h1	100 [nm]	1E-7 m	
h2	50[nm]	5E-8 m	
h3	200[nm]	2E-7 m	
k0	2*pi/lmb	1.1424E7 1/m	
k1	k0*sqrt(mur*eps1)	2.2848E7 1/m	
k2	k0*sqrt(mur*eps2)	(7.5782E5-4.1...	
k3	k0*sqrt(mur*eps3)	1.7136E7 1/m	
theta	30	30	
thetaR	theta[deg]	0.5236 rad	
k1x	k1*sin(thetaR)	1.1424E7 1/m	
k1y	sqrt(k1^2-k1x^2)	1.9787E7 1/m	
k3x	k1x	1.1424E7 1/m	
k3y	if(k3^2-k3x^2<0,-sqrt(k3^2-k3x^2),sqrt(k3^2-k3x^2))	1.2772E7 1/m	
H0	1	1	

Radio-Frequency module: Problemas 2D



- Materials
  - prisma (mat1)
  - sustrato (mat2)
  - Ag (mat3)
- Electromagnetic Waves, Frequency Domain (emw)
  - Wave Equation, Electric 1
  - Perfect Electric Conductor 1
  - Initial Values 1
  - Wave Equation, Electric 2
  - Port 1
  - Port 2
  - Periodic Condition 1
  - Equation View

Geometry 1
Materials
prisma (mat1)
sustrato (mat2)
Ag (mat3)
Electromagnetic Waves, Frequency Domain (emw)
Wave Equation, Electric 1
Perfect Electric Conductor 1
Initial Values 1
Wave Equation, Electric 2
Port 1
Equation View
Port 2
Periodic Condition 1
Equation View
Mesh 1
udy 1
Parametric Sweep
Step 1: Frequency Domain
Solver Configurations
Solution 1
Compile Equations: Frequency Domain
Dependent Variables 1
Stationary Solver 1
Direct
Advanced
Parametric 1
Fully Coupled 1
Information 1

Settings
Port

Show equation assuming: Study 1, Frequency Domain

$$S = \frac{\int_{\partial\Omega}(\mathbf{E}-\mathbf{E}_1)\cdot\mathbf{E}}{\int_{\partial\Omega}\mathbf{E}_1\cdot\mathbf{E}_1}$$

Port Properties

Port name: 1

Type of port: User defined

Wave excitation at this port: On

☐ Specify deposited power

Port input power: P_{in} 1[W] W

Port phase: θ_{in} 0 rad

☐ Activate slit condition on interior port

Port Mode Settings

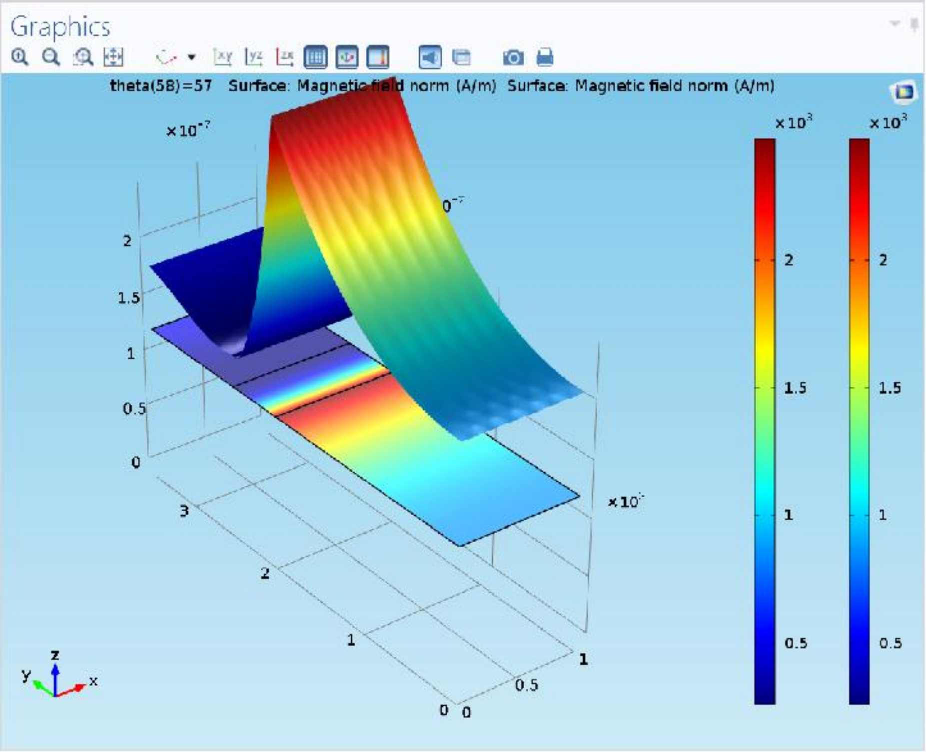
Input quantity: Magnetic field

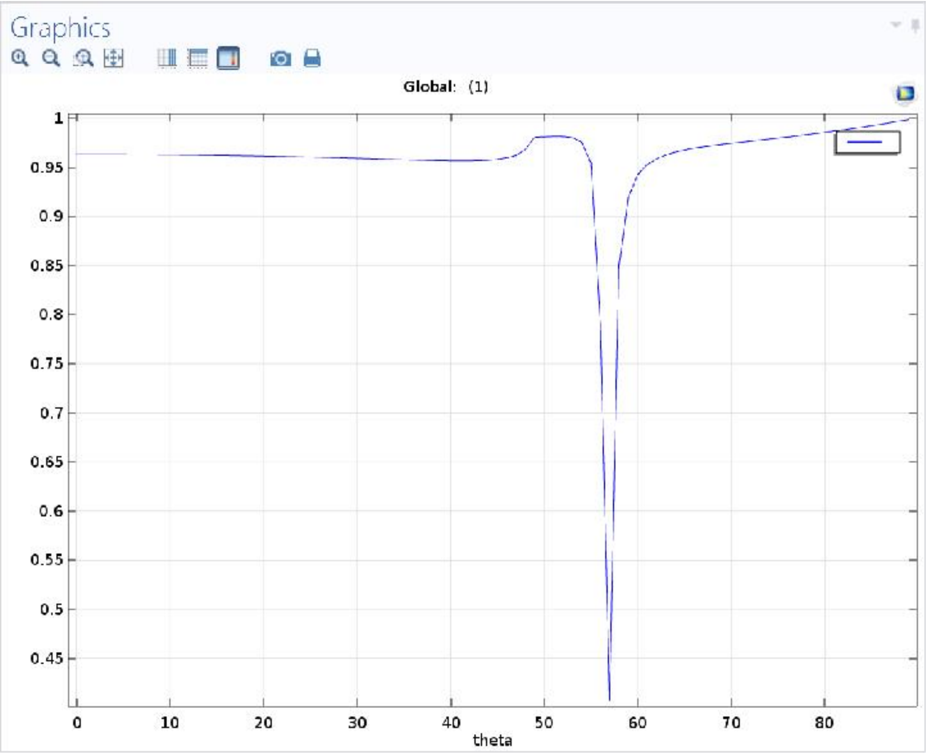
Magnetic mode field: $\mathbf{H}_0$

0	x	A/m
0	y	
exp(-i*k1x*x)	z	

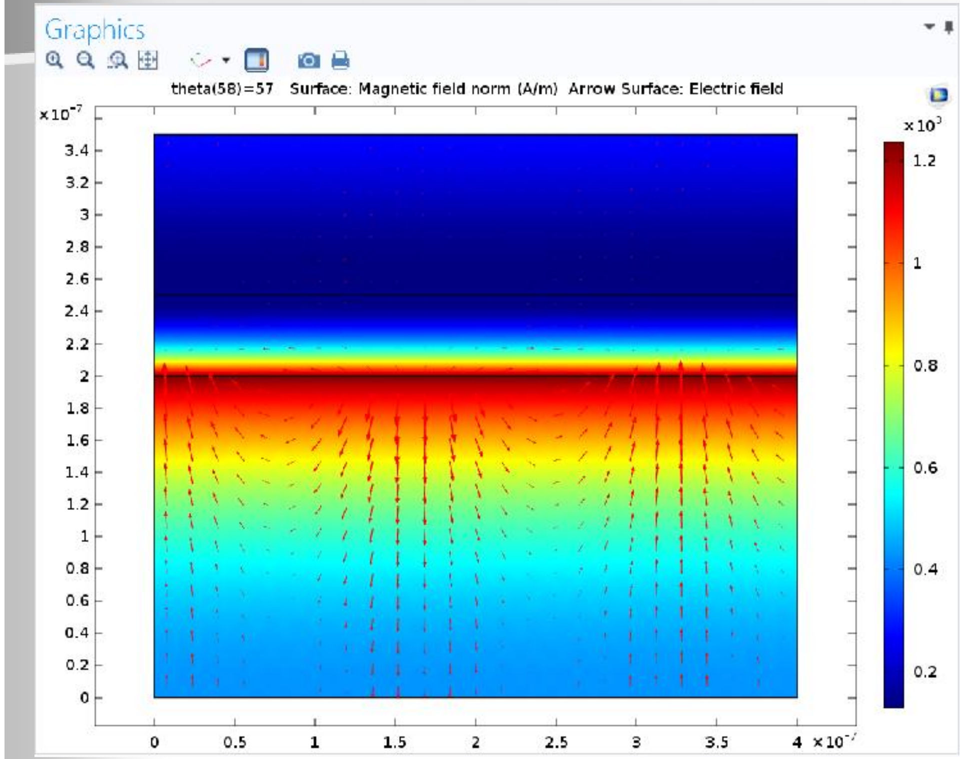
Propagation constant: β k1y rad/m

Radio-Frequency module: Problemas 2D

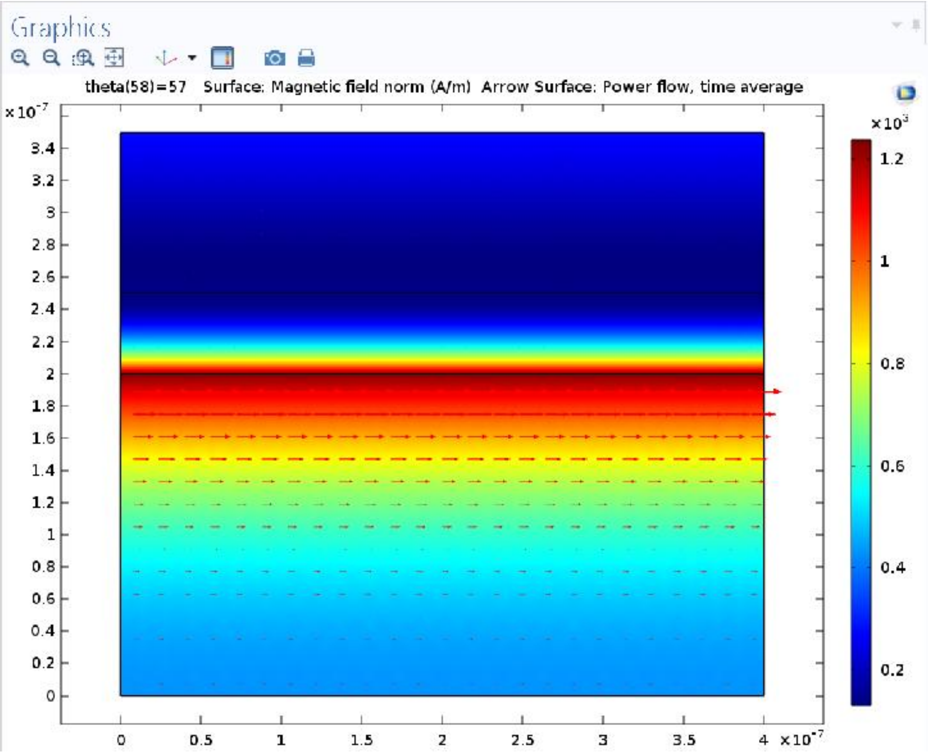




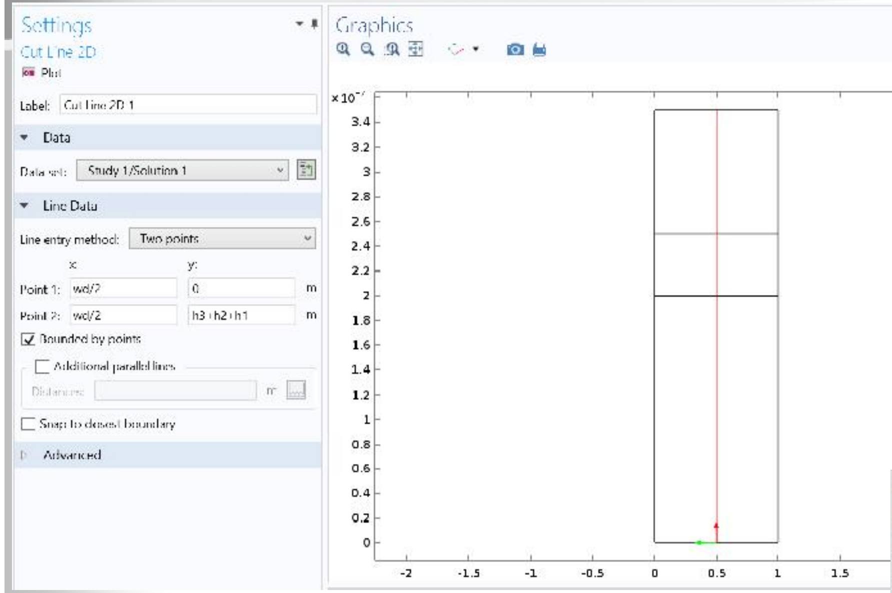
Radio-Frequency module: Problemas 2D



$w_d = 400$ [nm]



Radio-Frequency module: Problemas 2D



Settings

Cut Line 2D

Label: Cut Line 2D 1

Data

Data set: Study 1/Solution 1

Line Data

Line entry method: Two points

	x:	y:	
Point 1:	wd/2	0	m
Point 2:	wd/2	h3+h2+h1	m

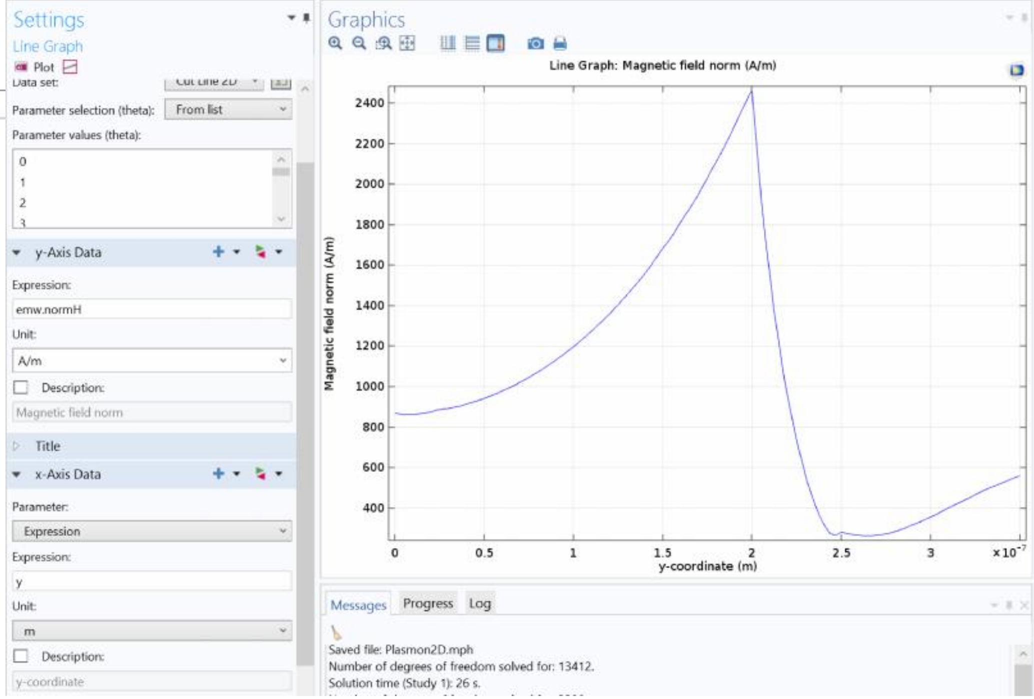
☑ Bounded by points

☐ Additional parallel lines

Distances: m

☐ Snap to closest boundary

Advanced



Settings

Line Graph

Data set: Cut Line 2D

Parameter selection (theta): From list

Parameter values (theta):
0
1
2
3

y-Axis Data

Expression: emw.normH

Unit: A/m

☐ Description: Magnetic field norm

Title

x-Axis Data

Parameter: Expression

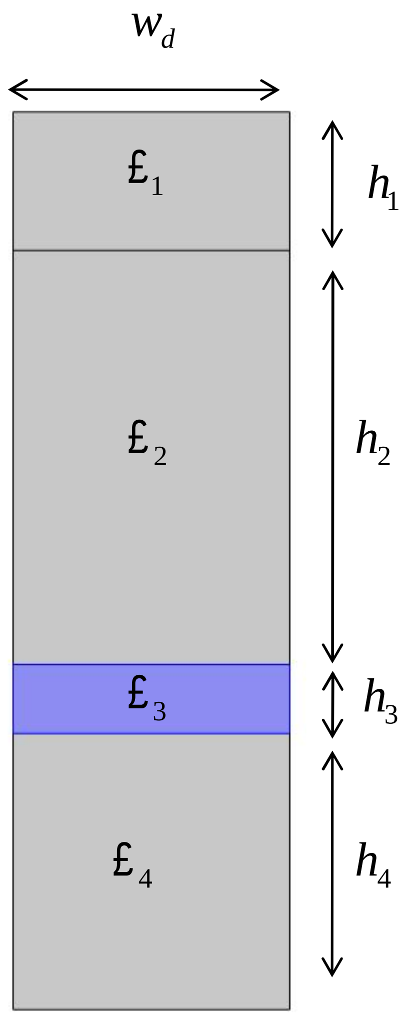
Expression: y

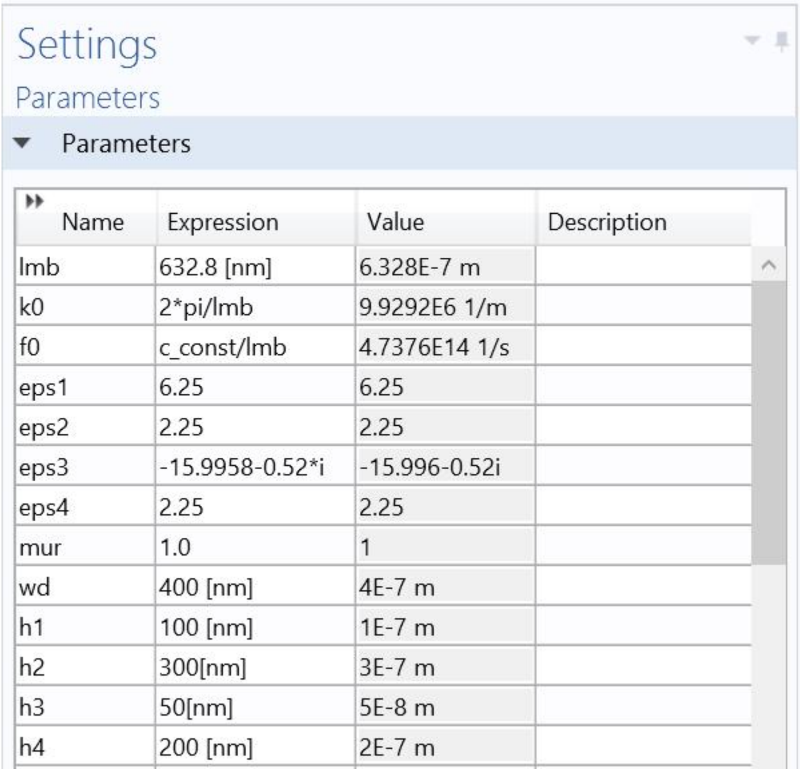
Unit: m

☐ Description: y-coordinate

```
Saved file: Plasmon2D.mph
Number of degrees of freedom solved for: 13412.
Solution time (Study 1): 26 s.
```

Radio-Frequency module: Problemas 2D

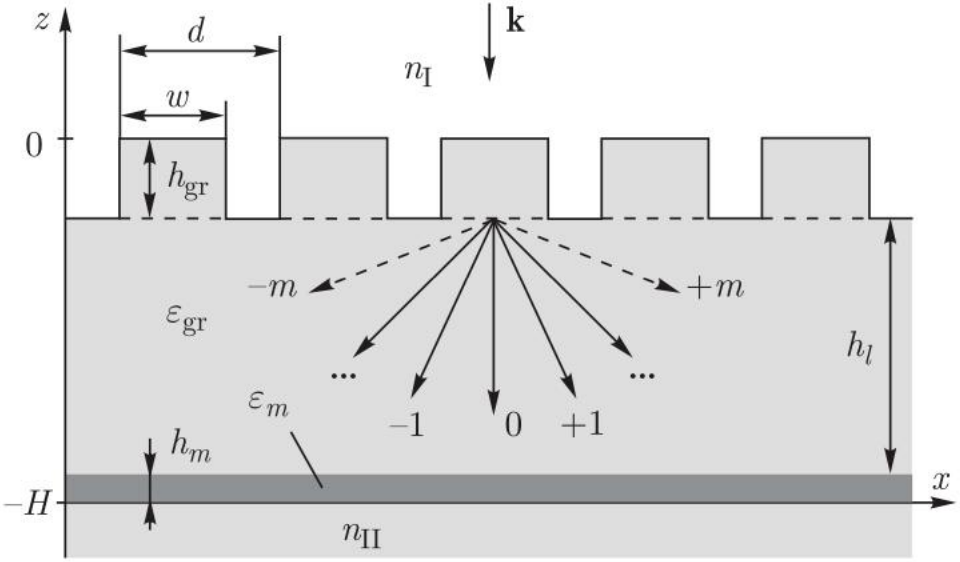




Name	Expression	Value	Description
lmb	632.8 [nm]	6.328E-7 m	
k0	2*pi/lmb	9.9292E6 1/m	
f0	c_const/lmb	4.7376E14 1/s	
eps1	6.25	6.25	
eps2	2.25	2.25	
eps3	-15.9958-0.52*i	-15.996-0.52i	
eps4	2.25	2.25	
mur	1.0	1	
wd	400 [nm]	4E-7 m	
h1	100 [nm]	1E-7 m	
h2	300[nm]	3E-7 m	
h3	50[nm]	5E-8 m	
h4	200 [nm]	2E-7 m	

Radio-Frequency module: Problemas 2D

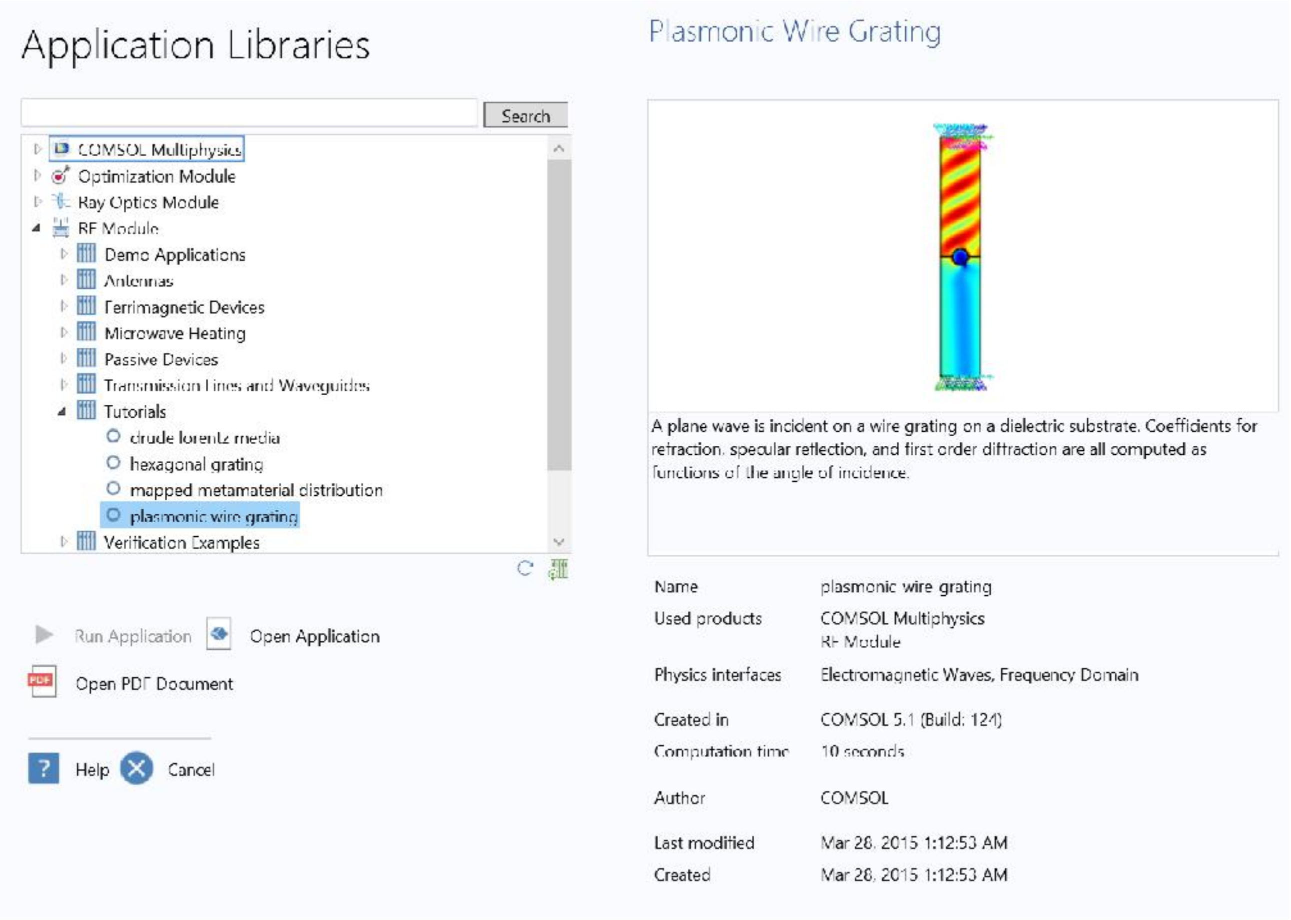
Otra posibilidad para excitar SPPs es mediante el uso de redes de difracción



El número de onda transversal de los ordenes superiores viene dado por:

$$k_{t,m} = k_{x,m} = \frac{2\pi}{d} m + k_{x,incidente}$$

Radio-Frequency module: Problemas 2D

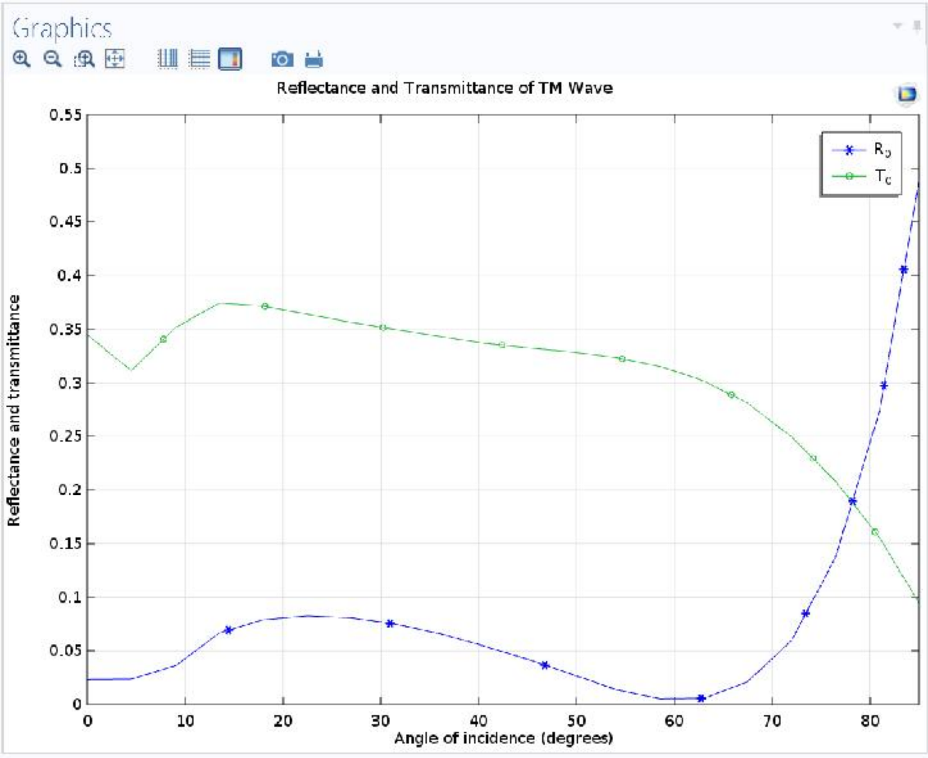


Plasmonic Wire Grating

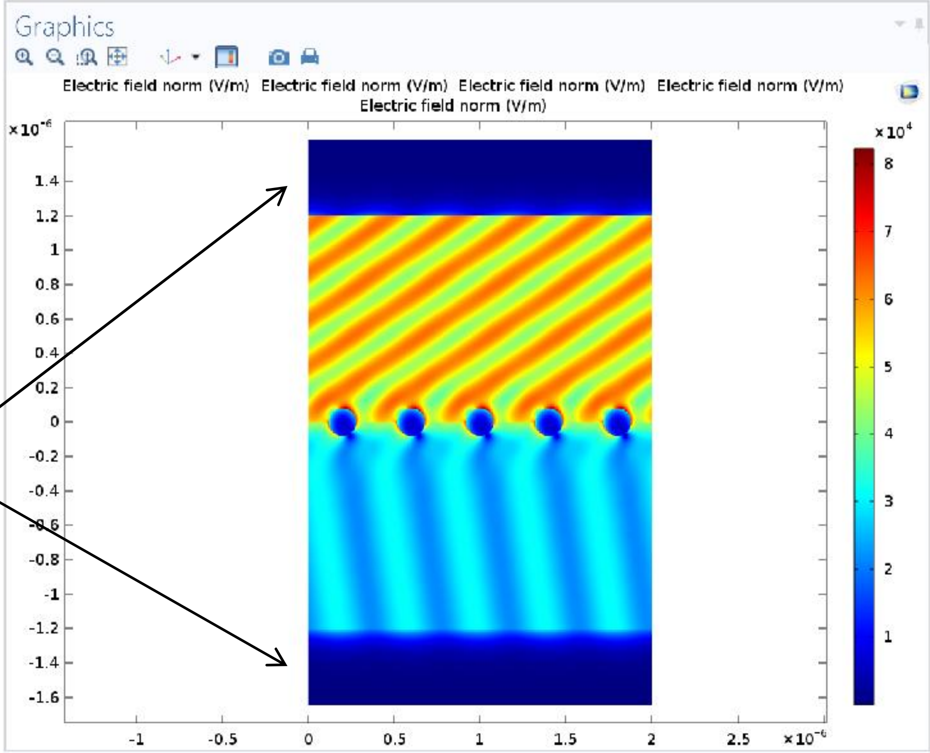
A plane wave is incident on a wire grating on a dielectric substrate. Coefficients for refraction, specular reflection, and first order diffraction are all computed as functions of the angle of incidence.

Name	plasmonic wire grating
Used products	COMSOL Multiphysics RF Module
Physics interfaces	Electromagnetic Waves, Frequency Domain
Created in	COMSOL 5.1 (Build: 124)
Computation time	10 seconds
Author	COMSOL
Last modified	Mar 28, 2015 1:12:53 AM
Created	Mar 28, 2015 1:12:53 AM

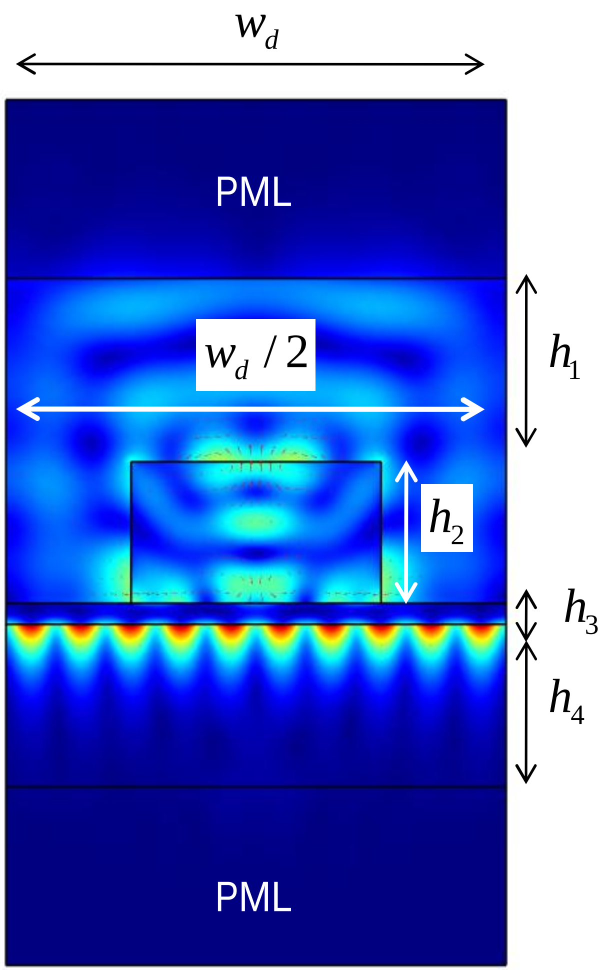
Radio-Frequency module:
Problemas 2D

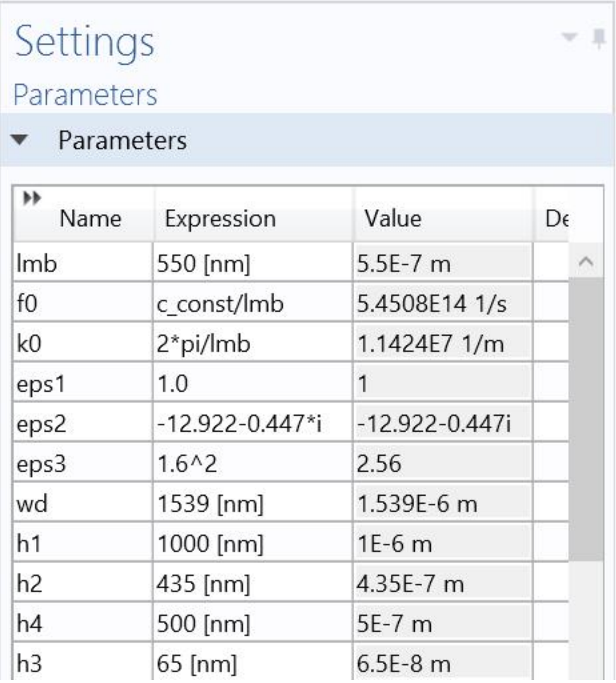


Incorporaremos PMLs



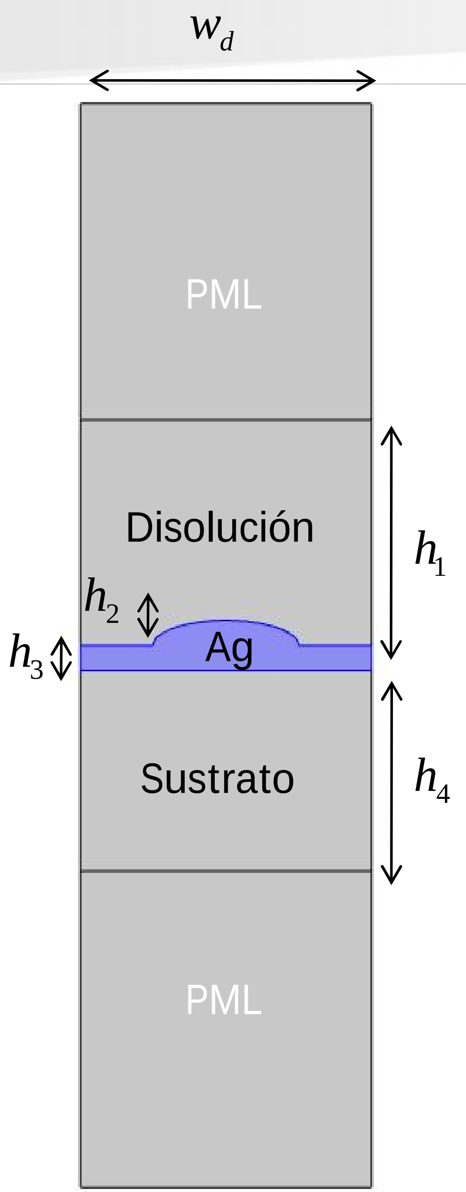
Radio-Frequency module: Problemas 2D

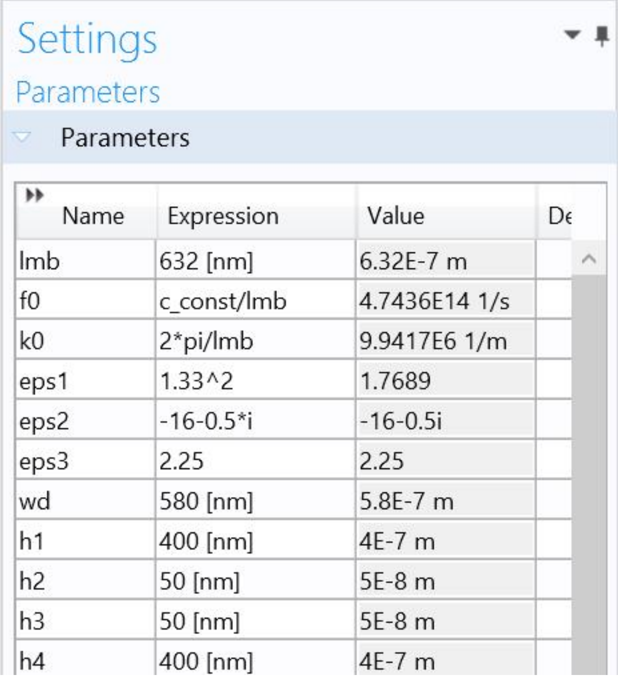




Name	Expression	Value	De
lmb	550 [nm]	5.5E-7 m	
f0	c_const/lmb	5.4508E14 1/s	
k0	2*pi/lmb	1.1424E7 1/m	
eps1	1.0	1	
eps2	-12.922-0.447*i	-12.922-0.447i	
eps3	1.6^2	2.56	
wd	1539 [nm]	1.539E-6 m	
h1	1000 [nm]	1E-6 m	
h2	435 [nm]	4.35E-7 m	
h4	500 [nm]	5E-7 m	
h3	65 [nm]	6.5E-8 m	

Radio-Frequency module:
Problemas 2D





Name	Expression	Value	De
lmb	632 [nm]	6.32E-7 m	
f0	c_const/lmb	4.7436E14 1/s	
k0	2*pi/lmb	9.9417E6 1/m	
eps1	1.33^2	1.7689	
eps2	-16-0.5*i	-16-0.5i	
eps3	2.25	2.25	
wd	580 [nm]	5.8E-7 m	
h1	400 [nm]	4E-7 m	
h2	50 [nm]	5E-8 m	
h3	50 [nm]	5E-8 m	
h4	400 [nm]	4E-7 m	