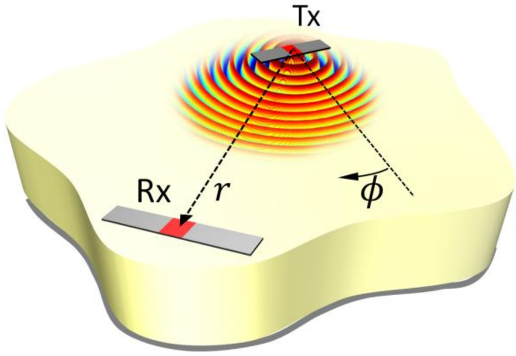
EE4620 Spectral Domain Methods in EM: Final Projects

Project 1



Imagine that you would like to use surface waves propagating in a grounded dielectric slab to create integrated communication networks. You want to maximize the excitation of the surface wave with a transmitting dipole antenna (Tx) on top of the substrate to connect through a wireless link to a receiving dipole antenna (Rx). Both dipoles have width $w = 1\mathrm{mm}$ and length $l = 3\mathrm{mm}$, while the frequency is $10\mathrm{GHz}$. The transmitting dipole is fed by 1 ampere of current.)

1. What substrate height and dielectric constant would you use?

2. How would the orientation of the receiving antenna be to maximize the received power?

3. How would the received power change as a function of the radial distance? And as a function of the azimuthal angle?

Justify your answers with figures and try to give a physical insight into the problem.

Project 2

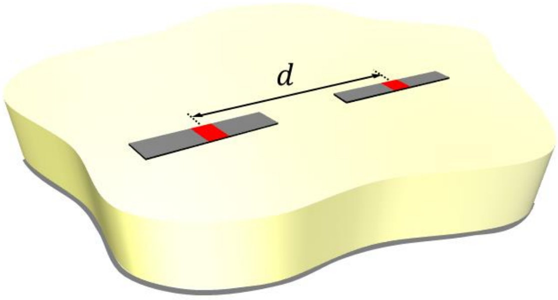
Imagine that you have to design a planar antenna composed of two in-phase resonant dipoles printed on a grounded substrate.

1. What height and relative permittivity of the substrate would you choose and why?

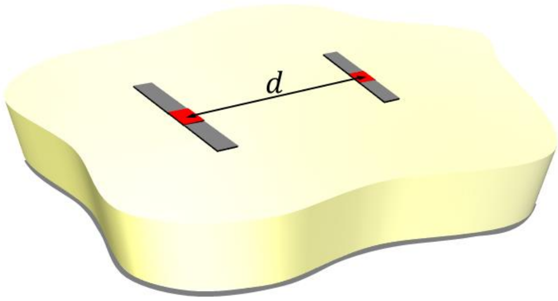
2. What is the optimum distance d and relative orientation of the dipoles ((a) or (b) in the figure) to minimize the power lost in surface waves?

3. Is it more convenient to use two dipoles or two slots?

Justify your answers with figures and try to give a physical insight into the problem.

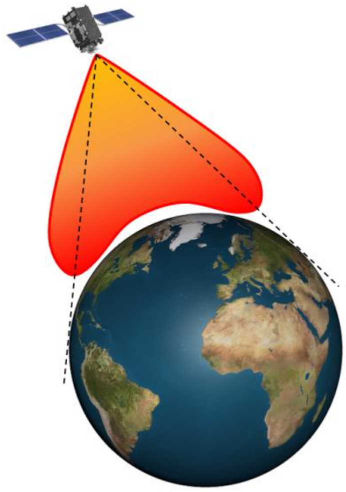


(a)



(b)

Project 3



Imagine that you would like to design an isoflux antenna for space applications. The requirement is that the antenna far field has larger amplitude at $\pm 30°$ than at broadside in order compensate for a longer propagation path until the Earth. Since a low cost solution is required, it is not possible to use a phased array to shape the radiation pattern. Instead the antenna should be designed using a slot on a ground plane with one or more dielectric super-layers at a certain distance from the slot.

1. How many dBs could you compensate with respect to broadside with a single dielectric layer of $\varepsilon_r = 5$? What are the dimensions and position of the super-layer that maximize this directivity?
2. Describe how you could further increase this compensation.
3. Up to which angles could one achieve a significant compensation? What happens at large angles?
4. Study the bandwidth of the antenna (variation of the pattern with frequency) for different angular distances between the maxima of the pattern and different directivities.

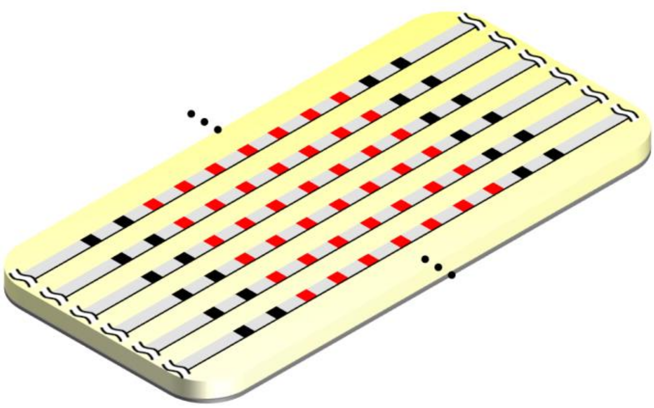
Justify your answers with figures and try to give a physical insight into the problem.

Project 4

Analyze the edge effects of a connected dipole array on a grounded slab. For the analysis, derive numerically the active input impedance of a finite-by-infinite array of connected dipoles. The relative permittivity of the slab is $\varepsilon_r = 2.2$ and the height is $1/4$ of the wavelength at the highest frequency.

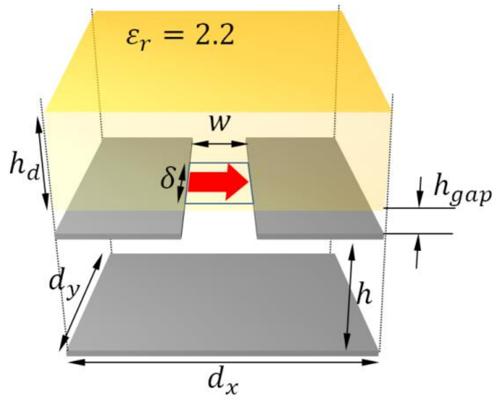
1) Study edge effects by quantifying how the active impedances and matching change for broadside compared to the infinite array approximation.
2) How do the edge effects change when scanning?
3) Plot the patterns of the finite array using stationary phase point method, for different scanning angles. At what angle do you find scan blindness? How the scan blindness changes with the number of elements?

Justify your answers with figures and try to give a physical insight into the problem.



Project 5

Imagine that you have to design a connected array of slots with a superstrate to be matched over a 2:1 bandwidth. The unit cell geometry is described in the figure. The space between the slots and the backing reflector and between the slots and the superstrate is air, while the superstrate is characterized by $\varepsilon_r = 2.2$.



1) Make a parametric analysis of the impedance matching as a function of $w, \delta, h, h_d, h_{gap}$

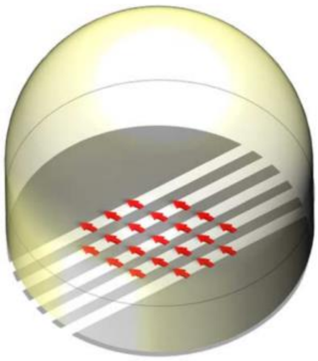
2) Find a suitable set of geometrical parameters that maximize bandwidth when scanning broadside.

3) Study how the matching changes when scanning. What is the maximum scan angle in each main plane?

Justify your answers with figures and try to give a physical insight into the problem.

Project 6

Consider a connected array of slots radiating inside a lens. For the analysis of the feed array consider a semi-infinite medium above the antenna with the same permittivity of the lens ($\varepsilon_r = 12$).



1) Dimension the slot width w and gap size δ to obtain stable active impedance over frequency.

2) Calculate the patterns inside the lens (windowing approximation).

3) How many element you need in the array to illuminate the lens with a -10dB beamwidth of 20 degrees?

Justify your answers with figures and try to give a physical insight into the problem.

Project 7

Consider a plane wave incident normally at the interface between air and a semi-infinite material with relative permittivity $\varepsilon_r = 20$.

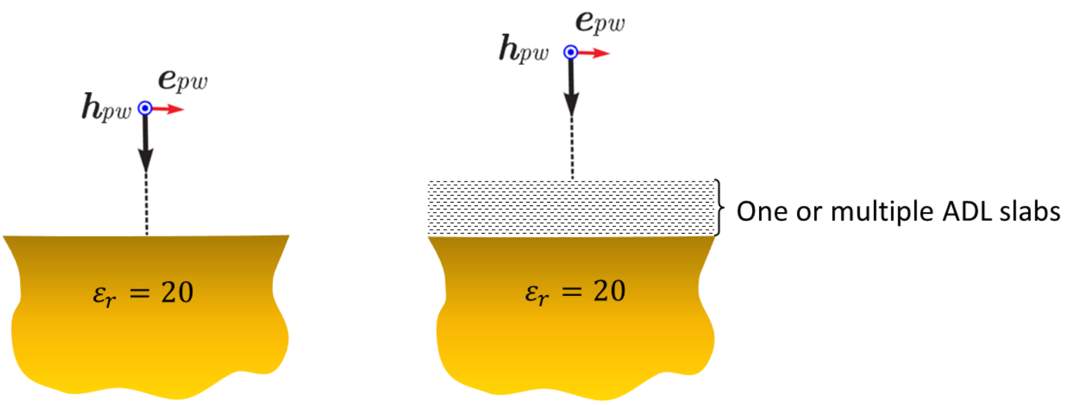
1) Determine the reflection and transmission for normal incidence using the spectral GF transmission lines model.

2) Using the same transmission line models, design an artificial dielectric slab matching layer to maximize the transmission of the plane wave in the medium.

3) Design multiple ADL slabs to achieve a wideband transmission and study the bandwidth performance as a function of number of matching layers.

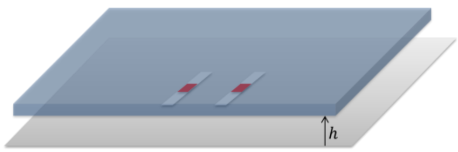
Note: represents the ADLs with the shunt susceptance formulas given in the lecture.

Justify your answers with figures and try to give a physical insight into the problem.



Project 8

Imagine that you are designing a parabolic reflector antenna with a diameter of $D = 50\lambda_0$ fed by two in-phase slots. It is possible to place a dielectric substrate on top of the slots, as shown in the figure, to improve the performance.



1) Determine the optimum parameters of the feed and reflector antenna (slot length, inter-slot distance, height h, substrate thickness, reflector focal length, phase center) for maximum aperture efficiency as a function of the substrate permittivity.

2) Select the substrate permittivity that will have the optimum trade-off between bandwidth and aperture efficiency. Plot the different efficiency terms versus frequency (spill over, taper and front to back efficiencies) as well as the achieved gain.

3) Only a material with $\varepsilon_r = 2.5$ is available. Synthesize the selected permittivity using a multi-layer configuration.

Explain the used analysis methodology, justify your answers with figures and try to give a physical insight into the problem.