Assignment VI Active Element and Total Patterns

EE4725 Quasi Optical Systems

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Abstract

In this assignment, the active element and total patterns in the E and H-planes are analyzed for a frequency selective surface with element spacing $d = 20$ mm. The elements are spaced equally in the x and y-directions and the surface consists of dipoles with width $W = 1$ mm and length $L = 15$ mm. Finally, the frequency of operation is $f = 10$ GHz and the incident wave is from broadside.

I. Simulations

The scripts used to simulate the lens antenna are in the GIT repository Assignment VI; and the library developed and used in the scripts is in quasi-optics-library. To run the simulations either place the script and library repositories in the same parent folder or change the library path in the simulation scripts.

II. Active Element Pattern

The active element pattern (AEP) is

$$E_{AEP} = jk_{z0}\bar{G}^{EJ}(k_{x0}, k_{y0})i_{BF}(k_{x0}, k_{y0})B(k_{x0}, k_{y0})\frac{e^{-jk_0 r}}{2\pi r}, \tag{1}$$

where the bf current $i_{bf}(k_{x0}, k_{y0})$ is

$$i_{bf} = \frac{v}{Z_L + Z_{in}}, \tag{2}$$

where v is the voltage, Z_L is constant load impedance, and Z_{in} is the active input impedance of the frequency selective surface (FSS). The voltage is

$$v = \frac{-\sin\phi V_{TE}^{+} + \cos\phi V_{TM}^{+}}{\sqrt{d_x d_y}} B(-k_{x0}, -k_{y0}), \tag{3}$$

where it is dependent on the TM and TE components of the incident wave and the basis function.

The E and H-planes of the AEP for the frequency selective surface with spacing dipole length $L = 15$ mm and width $W = 1$ mm, and spacing $d_x = d_y = 20$ mm in Fig.1 as a function of the elevation angle θ. At the E-plane, the AEP has a sudden drop in magnitude at the grating lobe at $\theta = 30°$ (the entering floquet mode causes scan blindness). At the H-plane, the AEP is overall constant at the $\theta = 0°$ neighbourhood and has a null at the grating lobe $\theta = 30°$. The sudden drop in the magnitude at the E-plane for the angle of the grating lobe $\theta = 30°$ is caused by the minimum and then sudden increase in the input impedance at the grating lobe. Moreover, the null value at the H-plane is caused by the singularity in the array impedance at the H-plane grating lobe (AEP gives the impedance variation over the scan angles).

The locations of the grating lobes (at which higher order floquet modes enter the visible region) are

$$\theta_{gr,E} = \sin^{-1}(\frac{\lambda}{d_x} - 1), \tag{4a}$$

$$\theta_{gr,H} = \sin^{-1}(\frac{\lambda}{d_y} - 1), \tag{4b}$$

for the E and H-planes respectively. Consequently, the analytical expressions predict the grating lobes enter the visible region at $\theta_{gr,E} = 30°$ and $\theta_{gr,H} = 30°$ for the E and H-planes respectively.

The analytical predictions are confirmed by the plot of the AEP pattern in Fig.1 in which grating lobes are observed at $\theta_{gr,E} = 30°$ and $\theta_{gr,H} = 30°$ for the E and H-planes respectively. Furthermore, the grating lobe diagram for the FSS is plotted in Fig.2. The grating lobe diagram also confirms the expectations of the grating lobes at $\theta = 30°$ for the E and H-planes.

III. Total Pattern

The total far-field pattern of the FSS is

$$E_{AEP} = jk_{z0}\bar{G}^{EJ}(k_{x0}, k_{y0})i_{BF}(k_{x0}, k_{y0})B(k_{x0}, k_{y0})AF_x AF_y \frac{e^{-jk_0 r}}{2\pi r}, \tag{5}$$

where AF_x and AF_y are the array factors in the x and y-directions, and are

$$AF_x = \sum_{n_x=0}^{N_x-1} e^{jn_x d_x(k_x - k_{x0})}, \tag{6a}$$

$$AF_y = \sum_{n_y=0}^{N_y-1} e^{jn_y d_y(k_y - k_{y0})}, \tag{6b}$$

where N_x and N_y are the size of the window's elements in the x and y-directions respectively.

The total far-field pattern of the FSS for incident waves at $\theta = 0°$ and $\theta = 30°$ (grating lobe) at the E-plane are plotted in Fig.3 as a function of the elevation angle θ. When the wave is incident at the angle for which hgiher floquet modes enter the visible region, a grating lobe appears at approximately $\theta = 70^{circ}$ and $\phi = 180°$. Furthermore, the main lobe is approximately at -1.7 dB lower than the main lobe for broadside incidence ($\theta = 0°$ and $\phi = 0°$); the lower magnitude of the main lobe for incidence at the grating lobe is caused by the input impedance variation over the scan angle. Finally, grating lobe is approximately 11.8 dB lower than the main lobe, due to the same impedance variation (causing the lower main lobe).

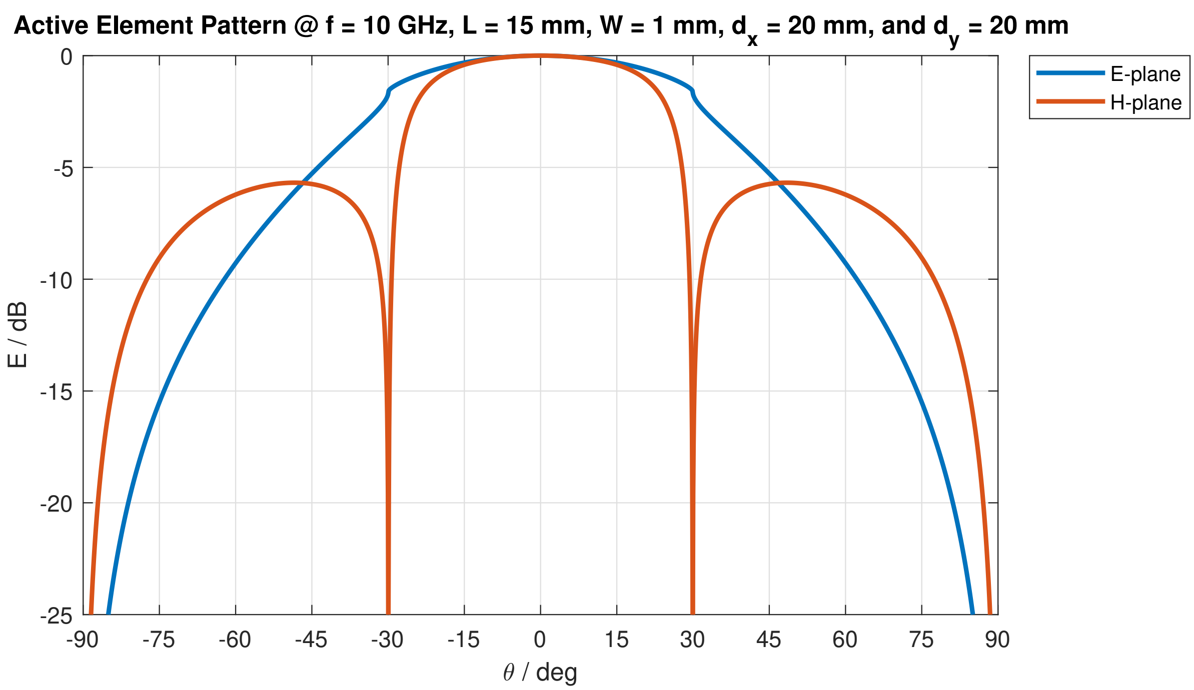

Fig. 1. Active element pattern as a function of the elevation angle θ, for a frequency selective surface with element spacing $d_x = d_y = 20$ mm consisting of dipoles with length $L = 15$ mm and width $W = 1$ mm; the wave has normal incidence and frequency $f = 10$ GHz.

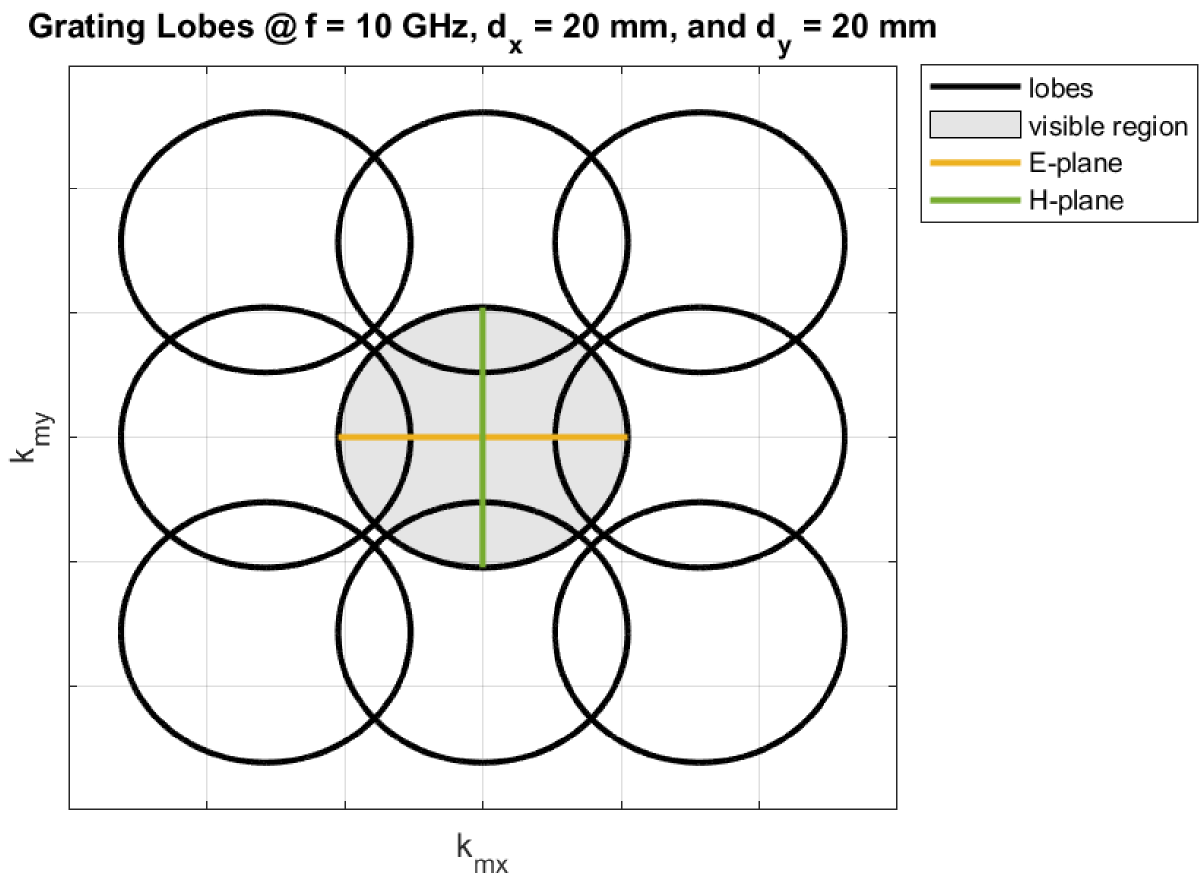

Fig. 2. Grating lobe diagram, for a frequency selective surface with element spacing $d_x = d_y = 20$ mm consisting of dipoles with length $L = 15$ mm and width $W = 1$ mm; the wave has normal incidence and frequency $f = 10$ GHz.

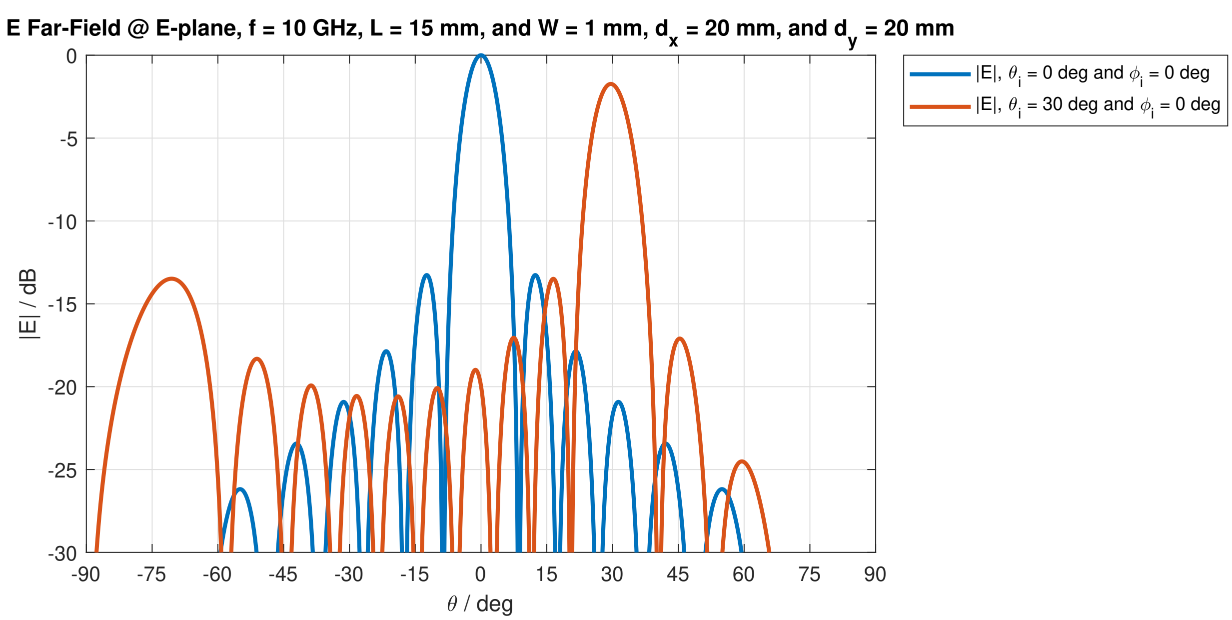

Fig. 3. Total pattern in the E-plane as a function of the elevation angle θ for a frequency selective surface with element spacing $d_x = d_y = 20$ mm consisting of dipole with length $L = 15$ mm and width $W = 1$ mm; the wave has normal incident and frequency $f = 10$ GHz.