Simulations of dipole and array antennas in MATLAB

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Overview

Task 1: Theory

If the dipole is considered to be short

$$\mathbf{G}(\theta, \phi) = G_\theta \hat{\theta} + G_\phi \hat{\phi}, \tag{1}$$

with

$$\begin{cases} G_\theta = G_\theta(\theta, \phi) = C_k \eta I_0 l/2 cos(\theta) sin(\phi) 2 j sin(khcos(\theta))) \\ G_\phi = G_\phi(\theta, \phi) = C_k \eta I_0 l/2 cos(\phi) 2 j sin(khcos(\theta))). \end{cases} \tag{2}$$

with

$$\begin{cases} C_k = -jk/4\pi \\ \eta \approx 120\pi[\Omega] \\ k = \frac{2*pi}{\lambda} \\ h = \frac{\lambda}{4} \\ I_0 = \text{incident current} \end{cases} \tag{3}$$

Task 1: Results

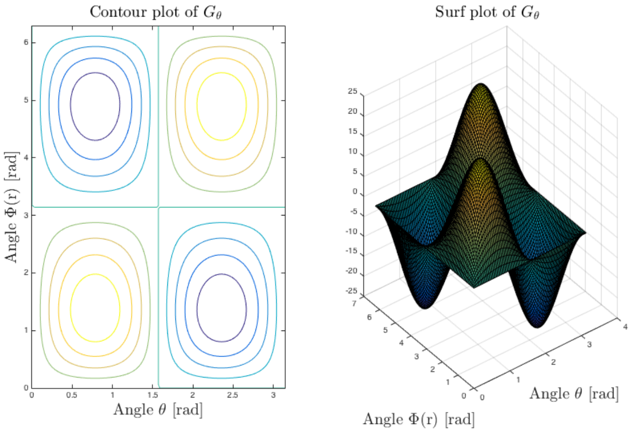

Figure: This figure shows G_θ as a function of θ and ϕ

Task 1: Results

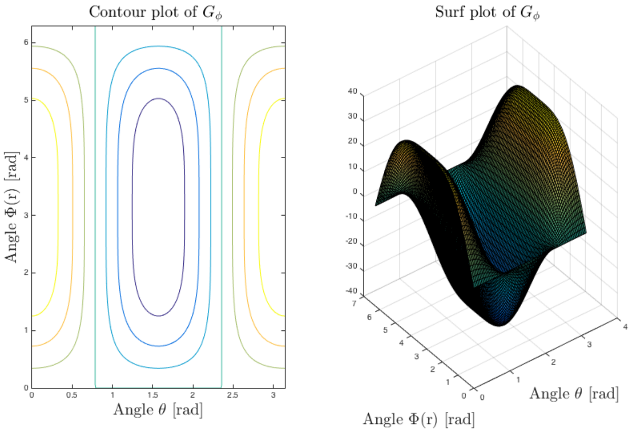

Figure: This figure shows G_ϕ as a function of θ and ϕ

Task 2: Theory

Co- and cross-polarizations

$$\hat{co} = cos(\phi - \epsilon)\hat{\theta} - sin(\phi - \epsilon)\hat{\phi} \tag{4}$$

and

$$\hat{xp} = -sin(\phi - \epsilon)\hat{\theta} - cos(\phi - \epsilon)\hat{\phi} \tag{5}$$

Co- and Cross- polarized parts of the far field function

$$G_{co} = \mathbf{G} \cdot \hat{co}^* \tag{6}$$

$$G_{xp} = \mathbf{G} \cdot \hat{xp}^*. \tag{7}$$

The total radiated power

$$P_{rad} = \frac{1}{2\eta} \int_0^{\pi} d\phi \int_0^{2*\pi} d\theta sin(\theta)(|G_{co}|^2 + |G_{xp}|^2). \tag{8}$$

Task 2: Results

- Numerical integration with the midpoint method
- The numerical result of the total radiated power was 9.5984 W, with y, x, LHC and RHC polarization.
- The excitation current was chosen to be unity A for this task.

Task 3: Theory

The radiation pattern for the co polarization according to the function

$$Pattern = 10 \cdot \ {}^{10}log\left(\frac{4\pi|G_{co}(\theta,\phi_0)|^2}{P_{rad}2\eta}\right). \tag{9}$$

Here the co polar radiation pattern is only considered, and is has also been normalized with respect to the radiated power. By taking the logarithm of the pattern the results will be given in [dBi] which is commonly used in antenna.
The far field patterns for the E and H plane of the far field function are defined as $|G_{co}(\theta, 0)|$ and $|G_{co}(\theta, pi/2)|$ in the H- and E- planes respectively. These patterns can be plotted in dBi as

$$Pattern = 10 \cdot \ {}^{10}log\left(\frac{4\pi|G_{co}(\theta,\phi_0)|}{\sqrt{P_{rad}2\eta}}\right). \tag{10}$$

Task 3: Results

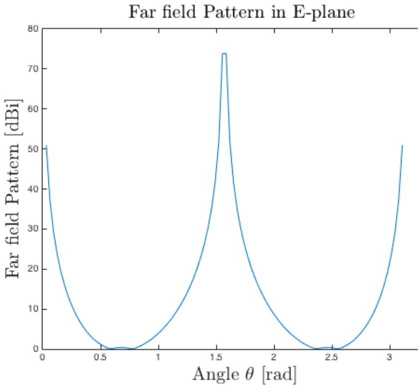

Figure: This figure shows the radiation pattern in the E-plane

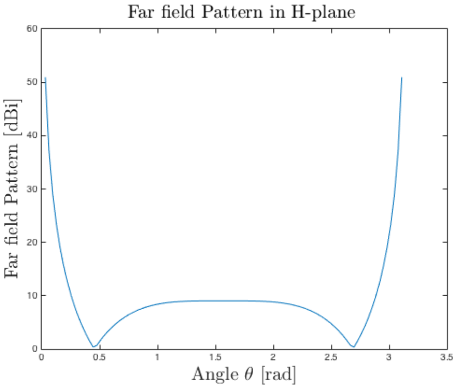

Figure: This figure shows the radiation pattern in the H-plane

Task 3: Results

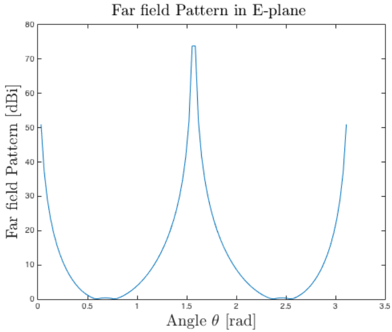

Figure: This figure shows the radiation pattern in the E-plane

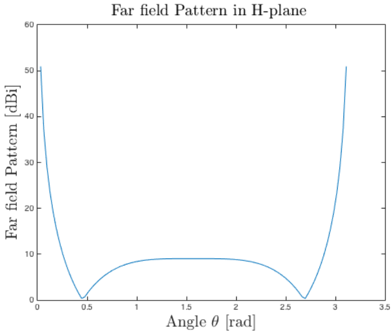

Figure: This figure shows the radiation pattern in the H-plane

Task 4: Theory

The excitation current

$$\mathbf{I} = [A_1 e^{j\Phi_1} A_2 e^{j\Phi_2} \ldots A_{N-1} e^{j\Phi_{N-1}}], \tag{11}$$

element positions $\{\mathbf{r}_i\}_{i=1}^{N}$
Far field function of the array (assuming identical elements)

$$\mathbf{G}_A(\theta, \phi) = \sum_{n=1}^{N} A_n e^{j\phi_n} (G_\theta \hat{\theta} + G_\phi \hat{\phi}) e^{jk\mathbf{r}_n \dot{\hat{r}}}. \tag{12}$$

Which can be written as

$$\mathbf{G}_A(\theta, \phi) = \mathbf{G}(\theta, \phi) \cdot AF \tag{13}$$

Task 4: Results

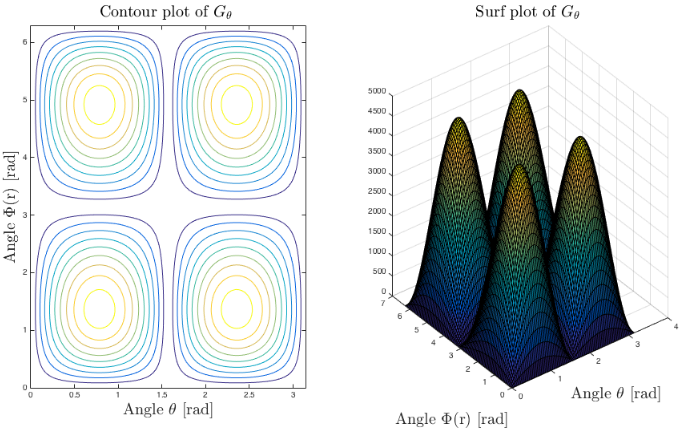

Figure: This figure shows G_θ as a function of θ and ϕ

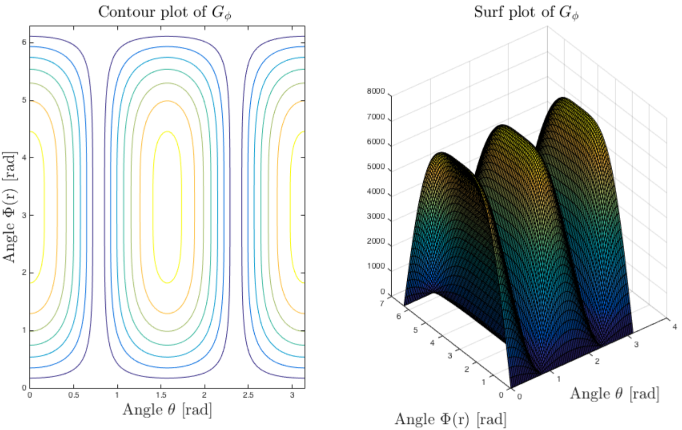

Figure: This figure shows G_ϕ as a function of θ and ϕ

Task 5: Theory

Consider now the spherical coordinates

$$\hat{r} = sin\theta cos\phi \hat{x} + sin\theta sin\phi \hat{y} + cos\theta \hat{z}, \tag{14}$$

$$d_n = \mathbf{r}_n \cdot \hat{r} = (x_n\hat{x} + y_n\hat{y} + z_n\hat{z})(sin\theta cos\phi \hat{x} + sin\theta sin\phi \hat{y} + cos\theta \hat{z}) = \tag{15}$$
$$sin\theta_0 cos\phi_0 x_n + sin\theta_0 sin\phi_0 y_n + cos\theta_0 z_n. \tag{16}$$

$$\Psi_{n,0} = kd_{n,0} = \frac{2\pi}{\lambda}|sin\theta_0 cos\phi_0(x_n) + sin\theta_0 sin\phi_0(y_n) + cos\theta_0(z_n)|. \tag{17}$$

Amplitude of current was set to 1 A

Task 5: Results

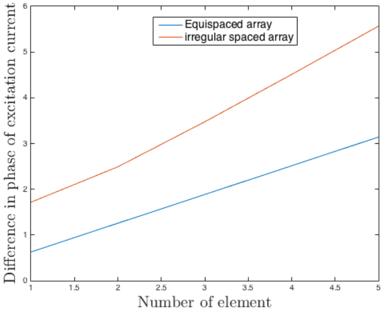

Figure: This figure shows the phase of the excitation current as a function of element positions and steering direction $\theta_0 = \pi/3$rad and $\phi_0 = \pi/2$rad

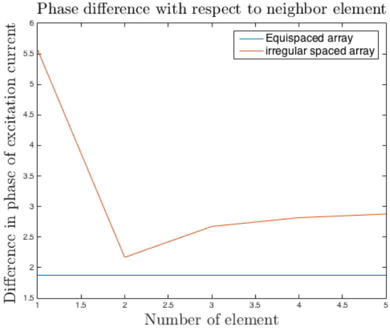

Figure: This figure shows the phase of the excitation current with respect to the neighbor as a function of element positions and steering direction $\theta_0 = \pi/3$rad and $\phi_0 = \pi/2$rad

Task 6: Theory

$$Pattern^{tot}_{radiation} = (\text{element radiation pattern}) \times (AF) \quad (18)$$

$$AF = 1 + e^{j(kd \cdot 1 cos(\theta) + \alpha)} + ... + e^{j \cdot (N-1)(kdcos(\theta)+\alpha)} = \quad (19)$$

$$e^{j(N-1)\Psi/2} sin(N\Psi/2)/sin(\Psi/2) \Rightarrow |AF| = sin(N\Psi/2)/(Nsin(\Psi/2)) \quad (20)$$

with $\Psi = \alpha + kdcos\theta$. Element Pattern of horizontal dipole

$$f = \sqrt{1 - sin(\theta)cos(\phi)} \quad (21)$$

$$|AF|_{max} = AF(\Psi = 0) \Rightarrow \alpha = kdcos(\theta_0) \quad (22)$$

θ_0 is called the steering angle.
H-plane: $\alpha = kdcos(\theta_0) = kd$, Broadside : $\alpha = 0$

Task 6a: Results

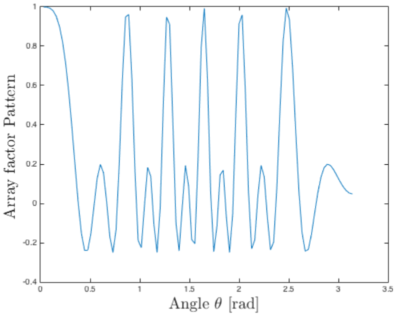

Figure: This figure shows $|AF|$ as a function of θ and ϕ for y polarized dipoles

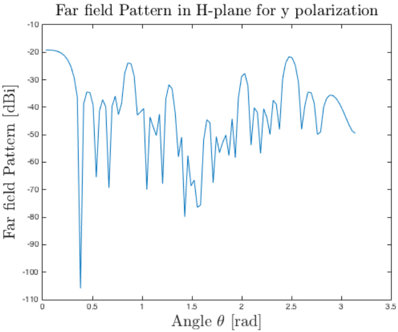

Figure: This figure shows the far field pattern as a function of θin the H-plane

Task 6b: Results

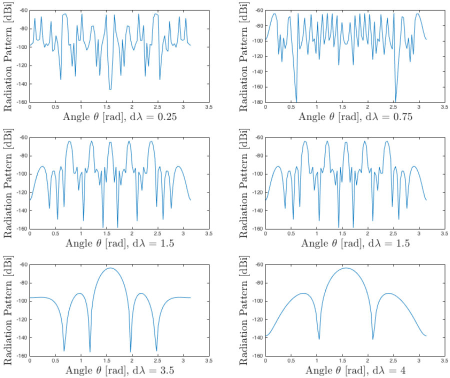

Figure: This figure shows the far field pattern as a function of θ for y polarized dipoles in arrays

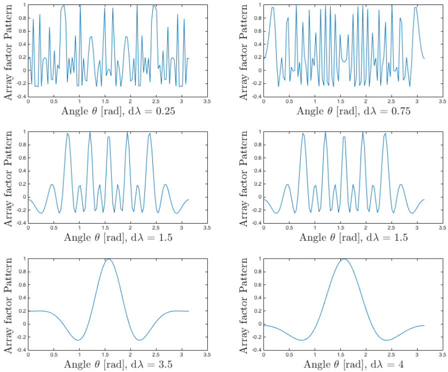

Figure: This figure shows $|AF|$ as a function of θ for y polarized dipoles

Discussion and Conclusion

- simulated results appear to recreate the theoretical expected results
- have not found conclusive expected results for radiation patterns

Thank you for listening