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Uppsala University
Department of Astronomy and Space Physics
Laboration report

Laboratory Work

Antenna engineering 5p

Laboratory Assignment No.1

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Contents

Chapter 1

The Electric Dipole Antenna

1.1 Theory

When the length of a dipole gets larger than the wavelenght, the lobes of the antenna gets thinner and the number of sidelobes increases. In *Constantine A. Balanis* book *Antenna Theory*, Figure 4.6 we can see how the lobes gets thinner as we increase the lenghth towards λ. $\Rightarrow$ The directivity increases when you increase the length of the antenna. The formula for the directivity D_0 is

$$D_0 = 4\pi \frac{U_{max}}{P_{rad}} \tag{1.1}$$

where $U_{max} = \frac{\eta}{2} \left(\frac{kI_0 l}{4\pi}\right)^2$ and $P_{rad} = \eta \left(\frac{\pi}{3}\right) \left|\frac{I_0 l}{\lambda}\right|^2$

1.2 Matlab Plots

In the first plot we see how the directivity increases as the length of the dipole increases, and in the second plot we can see the input and radiation resistanse as a function of dipole lenght. When the lenght is equal to 0.5λ both the radiation and input resistanse are 73 Ω, which matches the characteristic impedance (75 Ω) of some transmission lines . This is one reason why $\lambda/2$ dipoles are so common.

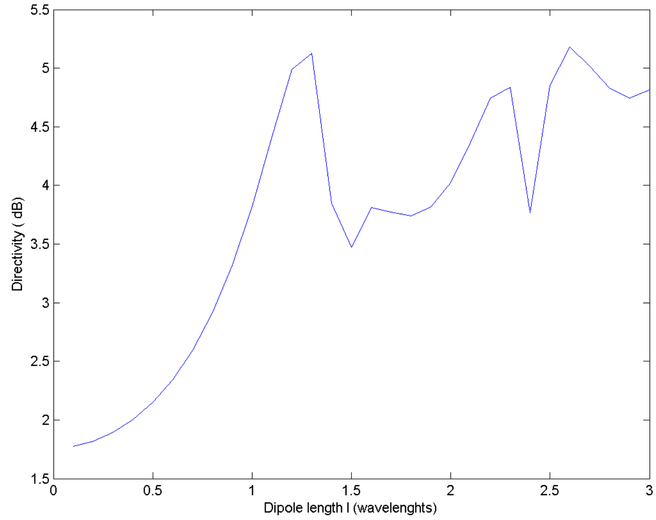


Figure 1.1: In this figure you see how the directivity vary with the length of the dipole

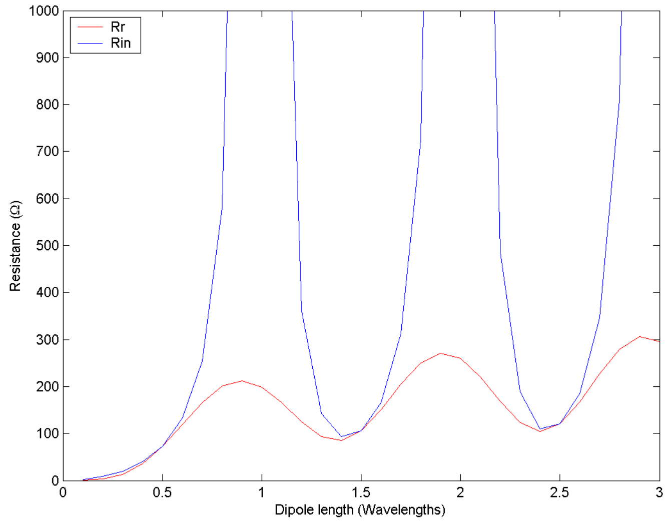


Figure 1.2: In this figure you see how the radiation and input resistance, Rr and Rin, vary with the length of the dipole

Chapter 2

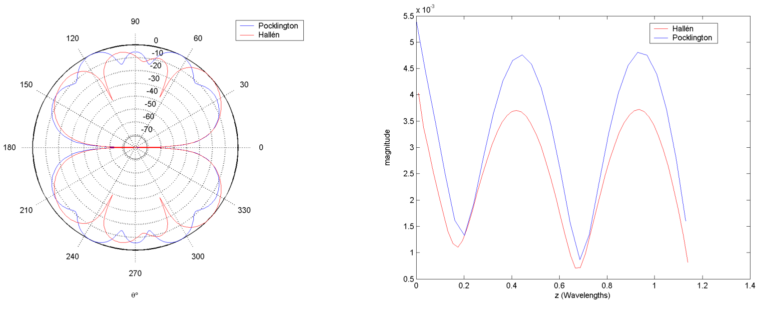
Moment methods

2.1 Theory

The purpose of Hallén's integral equation and Pocklington's integrodifferential equation is to find the current distrubution on conducting wires in a convenient way. Hallén's equation is only usable for the delta-gap voltage source model, but Pocklington's equation is more general(works for both delta-gap and magnetic frill voltage source). Also Hallén's equation requires the inversion af a N + 1 order matrix while Pocklington's equation only requires the inversion of an N order matrix.

2.2 Plots

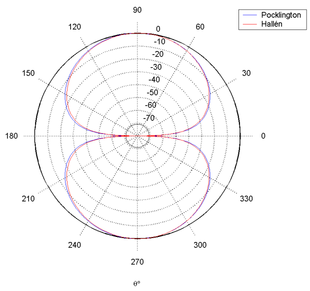
In the following figures we can see that when the length of the dipole is shorter than λ we only have one lobe, but when the dipole is longer than λ more lobes appear. The plots of the current distrubution is only for half of the dipole, but the other half looks the same. We obtain the other side by flipping the plot around z = 0.



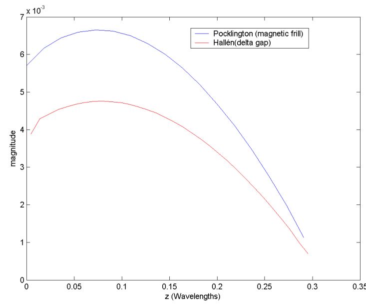
(a) radiation pattern

(b) Current

Figure 2.1: The radiation pattern and current distrubution of a 2.3λ dipole of radius 0.005λ calculated using Hallén's (red) and Pocklington's (blue) moment methods with 57 segments))

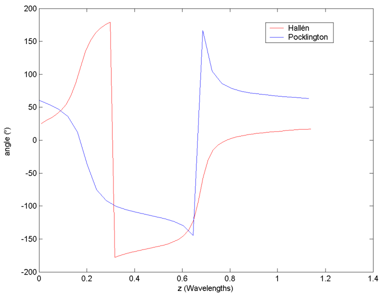


(a) radiation pattern

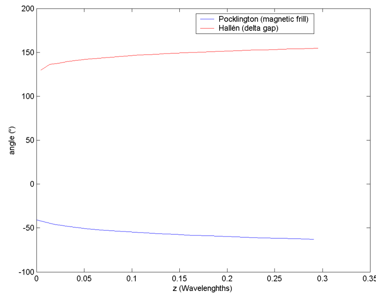


(b) Current

Figure 2.2: The radiation pattern and current distrubution of a 0.6λ dipole of radius 0.005λ calculated using Hallén's (red) and Pocklington's (blue) moment methods with 33 segments)) Hallén's is calculated whith the delta gap model, and Pocklington's whith the magnetic frill generator model.



(a) 2.3λ dipole



(b) 0.6λ dipole

Figure 2.3: Phases for the two dipoles. The antenna is symmetrically fed in the center.

Chapter 3

Antenna Arrays

3.1 Theory

Array Factor (AF))

The array factor is important for array characterization. The formula for the array factor is given by:

$$AF = \left[\frac{e^{jN\psi} - 1}{e^{j\psi} - 1}\right] = e^{j[(N-1)/2]\psi}\left[\frac{e^{j(N/2)\psi} - e^{-j(N/2)\psi}}{e^{j(1/2)\psi} - e^{-j(1/2)\psi}}\right] = e^{j[(N-1)/2]\psi}\left[\frac{sin(\frac{N}{2}\psi)}{sin(\frac{1}{2}\psi)}\right] \tag{3.1}$$

where $\psi = kd\cos\theta + \beta$, N is the number of elements , θ is the angle between the array and the radius vector and β is the phase differnce between the elemets

Broadside and End-Fire arrays

In a Broadside array we want to have have the maximum radiation of the array directed normal to the axis of the array ($\theta = 90°$).

$$\psi = kd\cos\theta + \beta|_{\theta=90°} = \beta = 0 \tag{3.2}$$

In a Ordinary End-Fire array we want to have have the maximum radiation along the axis of the array (end-fire), either $\theta = 0° or 180°$.
To direct the maximum toward $\theta = 0°$,

$$\psi = kdcos\theta + \beta|_{\theta=0°} = kd + \beta \Rightarrow \beta = -kd \tag{3.3}$$

To direct the maximum toward $\theta = 180°$,

$$\psi = kd\cos\theta + \beta|_{\theta=180°} = -kd + \beta \Rightarrow \beta = kd \tag{3.4}$$

Hansen-Woodyard End-Fire Array

Another type of End-Fire Array is the Hansen-Woodyard type. In 1938 they proposed that the phase shift β should be

$$\beta = -\left(kd + \frac{2.92}{N}\right) \simeq -\left(kd + \frac{\pi}{N}\right) \tag{3.5}$$

for maximum in $\theta = 0°$ and

$$\beta = +\left(kd + \frac{2.92}{N}\right) \simeq +\left(kd + \frac{\pi}{N}\right) \tag{3.6}$$

for maximum in $\theta = 180°$

Scanning Arrays or Phased array

In a Phased array we can shoose in which direction we want to direct the beam by controll the phase difference of the elements.

Binomial and Dolph-Tschebycheff non-uniform broadside arrays

In both types of arrays the spacing between the elements should be at most $\lambda/2$. In the Binomial array the excitation coefficients are determined from the binomial series axpansion i.e the Pascal's triangle. This leads to big differnce between the elements and becouse of this we get low efficiency, therefore this type of array not so practical.
In the Dolph-Tscebycheff array the amplitude coefficients are determined by use of the Tschebycheff polnomials. This type of array is of array is more often used. It's a compromise between the uniform and the biomial array.
The binomial has smallest sidelobes, but largest beamwidth (not so good directivity).
The Dolph-Tscebycheff has small beamwidth and small sidelobes.

array factor of a uniform planar array

If we have one linear planar array along the x-axis whith M elements and one along the y-axis whith N elemnts, we can then form a grid of M*N elements. The (AF) of the linear arrays are

$$\sum_{m=1}^{M} I_m e^{j(m-1)(kd_x sin\theta \cos\phi + \beta_x)} \tag{3.7}$$

and

$$\sum_{n=1}^{N} I_n e^{j(n-1)(kd_y \sin\theta \sin\phi + \beta_y)} \tag{3.8}$$

By assuming $I_{mn} = I_m I_n = I_0$, we can write the (AF) of the total planar array as

$$I_0 \sum_{i=1}^{M} e^{j(m-1)(kd_x \sin\theta \cos\phi + \beta_x)} \sum_{n=1}^{N} e^{j(n-1)(kd_y \sin\theta \sin\phi + \beta_y)} \tag{3.9}$$

or

$$AF_n(\theta, \phi) = \left[\frac{1}{M} \frac{\sin(\frac{M}{2}\psi_x)}{\sin(\frac{\psi_x}{2})} \right] \left[\frac{1}{N} \frac{\sin(\frac{N}{2}\psi_y)}{\sin(\frac{\psi_y}{2})} \right] \tag{3.10}$$

where
$\psi_x = kd_x \sin\theta \cos\phi + \beta_x$
$\psi_y = kd_y \sin\theta \sin\phi + \beta_y$

Spacing between the elements

The spacing between the elements must be less than $\lambda/2$ to avoid multiple maxima, grating lobes. This occur when the phase difference is zero and the waves interfear constructively.

3.2 Plots

I the following plot we can see that when the distanse between the elements is $\lambda/2$, the lobes is thinner and the sidelobes is thinner compared with we had the distance $\lambda/4$

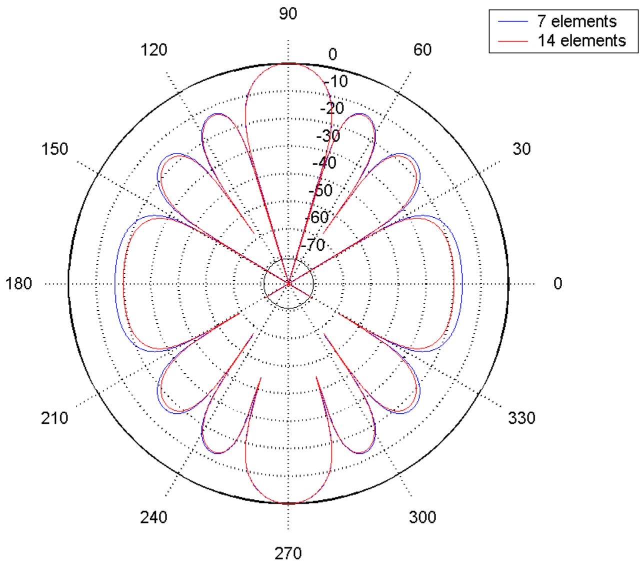


Figure 3.1: This is the radiation pattern of a linear, uniform, Broadside array, the spacing between the elements is $\lambda/4$. The maximum directivity is in the $\theta = 90°$ direction, $\theta = 270°$ is the same as $\theta = 90°$. We also get maxima directed toward $\theta = 0°$, $180°$