# EED4106 ANTENNAS AND PROPAGATION LABORATORY REPORT

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## 1 Horizontal Electric Dipole Over Pec Ground Analysis

Horizontal electric dipole, as its name implies, is placed horizontally relative to the infinite electric ground plane. The image of an antenna assumption based on the image theory is valid. According to the preliminary report, radiation calculations consists of direct component and image component. The addition of them results in *array factor* term in E-field Equation(1).

$$E_\phi = j\eta \frac{kI_0le^{-jkr}}{4\pi r}\sqrt{1-sin^2(\theta)sin^2(\phi)}[2jsin(khcos(\theta))] \tag{1}$$

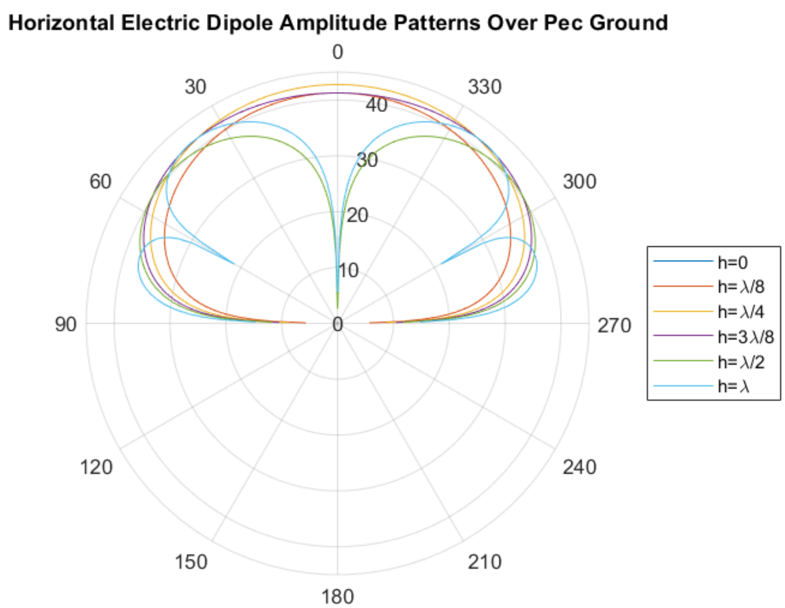


Figure 1: Field Pattern of Horizontal Electric Dipole

By comparing the results in Figure(1) and Figure(2), it is possible to see that side lobes appear at h=$\lambda$. As the $h$ increases, number of side lobes increases, too. In order to estimate quickly, the number of side lobe determined by,

$$\#\, of\ side\ lobes \approx 2(\frac{h}{\lambda}) \tag{2}$$

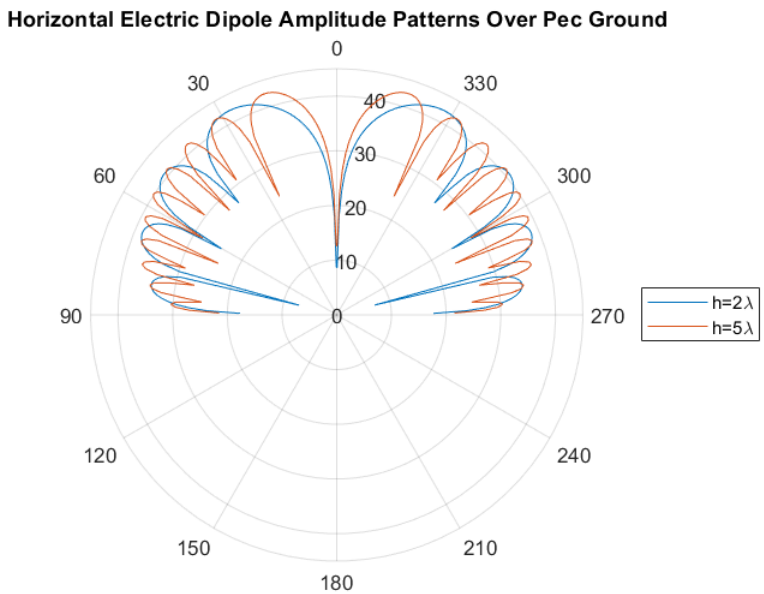


Figure 2: Field Pattern of Horizontal Electric Dipole

Radiated power formula is derived by hand in preliminary report. It is formalized such that

$$P_{rad} = \eta\frac{\pi}{2}|\frac{I_0 l}{\lambda}|^2\left[\frac{2}{3} - \frac{sin(2kh)}{2kh} - \frac{cos(2kh)}{(2kh)^2} + \frac{sin(2kh)}{(2kh)^3}\right] \tag{3}$$

By using the Equation(3, radiation resistance is calculated such that

$$R_{rad} = \frac{2P_{rad}}{|I_0|^2} \tag{4}$$

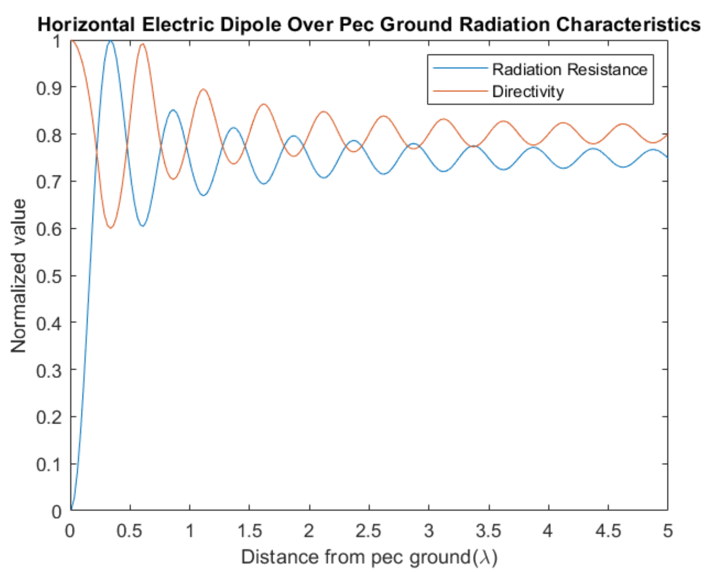


Figure 3: Radiation resistance and directivity relation between antenna height from the PEC ground

Here, there is an important point such that directivity maxima is followed by the minima of the radiation resistance. This means that maximum of the directivity does not mean that radiation is maximum for that $h$ value since the antenna can not radiate its power since its radiation resistance is minimum for that specific $h$ value.

# 2 Appendix

## 2.1 Amplitude Pattern Codes

```
%
%     This function calculates amplitude pattern of the horizontal electrical
%     dipole.
%      The input variables of the function are
%
%      h->the distance between antenna and pec ground in terms of wavelengths
%      theta->the angle which the pattern is calculated.
%
%     The output of the function is
%
%      E->radiated E-field.
%

function [E]=amplitude_pattern(h,theta)
c=3e8;
f=3e8;
lambda=c/f;
I_0=1;
eta=120*pi;
k=2*pi/lambda;
l=0.01;
r=2*l^2/lambda;
phi=pi/2;
E=1j*eta*(k*I_0*l*exp(-1j*k*r)/(4*pi*r)).*sqrt(1-(sin(theta)).^2).*(2*1j*sin(k.*h.*cos(theta)));
end
```

```
m=200; %number of iterations for the calculations
theta=linspace(-pi/2,pi/2,m); %the angle in which the pattern is observed.
c=3e8;  %speed of EM wave in space
f=3e8;  %operation frequency
lambda=c/f; %wavelength in operation frequency

%distance between pec ground and antenna
%h=[0 lambda/8 lambda/4 3*lambda/8 lambda/2 lambda];
h=[2*lambda 5*lambda];

E=[];   %memory allocation
for i=1:length(h)
    E(i,:)=amplitude_pattern(h(i),theta);
end

polarplot(theta,10*log10(abs(E)))
ax=gca;
ax.ThetaZeroLocation='top';
```

```
ax.Title.String='Horizontal Electric Dipole Amplitude Patterns Over Pec Ground';
%legend('h=0','h=\lambda/8','h=\lambda/4','h=3\lambda/8','h=\lambda/2','h=\lambda');
legend('h=2\lambda','h=5\lambda')
```

## 2.2 Radiation Resistance and Directivity Codes

```
%
% This function calculates radiation resistance and directivity of horizontal
% electrical dipol with perfect pec ground.
%
% Input parameters of the function are
%     h->the distance between antenna and pec ground in terms of wavelengths
%     f->operation frequency.
%
% Output parameters of the function are
%     radiation resistance
%     directivity.
%

function [rad_res, D]=radiation_parameters_function(h,f)
c=3e8;  %speed of EM wave in space
lambda=c/f; %wavelength in operation frequency
I0=1;   %current amplitude
eta=120*pi; %intrinsic impedance of free space
l=0.01; %antenna length
k=2*pi/lambda; %wave number
h1=lambda.*h; %antenna and pec ground distance

%radiated power calculation
constant=eta*(pi/2)*(abs(I0*l/lambda))^2;
var1=((2/3)-(sin(2*k.*h)./(2*k.*h)));
var2=-cos(2*k.*h)./(2*k.*h).^2;
var3=sin(2*k.*h)./(2*k.*h).^3;

rad_pow=constant.*(var1+var2+var3);
%radiation resistance calculation
rad_res=(2/I0^2).*rad_pow;
%directivity calculation
D=[];
for i=1:length(h)
if(k*h(i)<=pi/2 && h(i)<=lambda/4)
    D(i)=4*(sin(k.*h(i)))^2/rad_res(i);
end
if(k*h(i)>pi/2 && h(i)>lambda/4)
    D(i)=4/rad_res(i);
end
end

end
```

```
f=3e8;  %operation frequency
h=linspace(0.01,5,200);
[rad_res,D]=radiation_parameters_function(h,f);
plot(h,rad_res/max(rad_res),h,D/max(D));
ax=gca;
ax.Title.String='Horizontal Electric Dipole Over Pec Ground Radiation Characteristics';
ax.XLabel.String='Distance from pec ground(\lambda)';
ax.YLabel.String='Normalized value';
legend('Radiation Resistance','Directivity')
```

## References


[1] BALANIS, C. A., Antenna Theory: Analysis and Design, Wiley-Interscience, 3th edition, 2005.