UNIVERSITÀ
DELLA
CALABRIA

DEPARTMENT OF COMPUTER ENGINEERING, MODELING, ELECTRONICS AND SYSTEM ENGINEERING

Antenna and Propagation

MATLAB Exercises Report

Group Members
1. ASSEFA HAFTU MERESSA
2. GEBERE HALEFOM MERESA
3. MATTHIAS GODEBO JARSO

Submitted to: Prof. SANDRA COSTANZO

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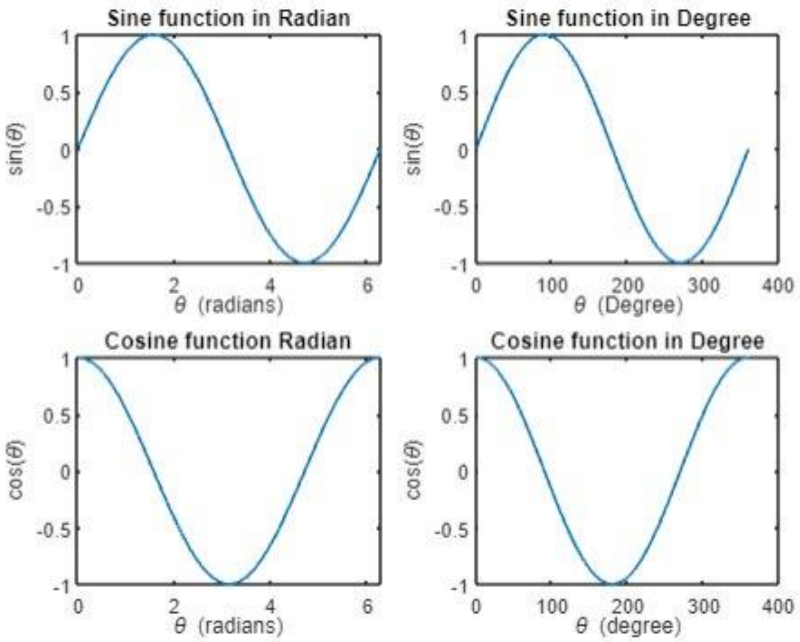
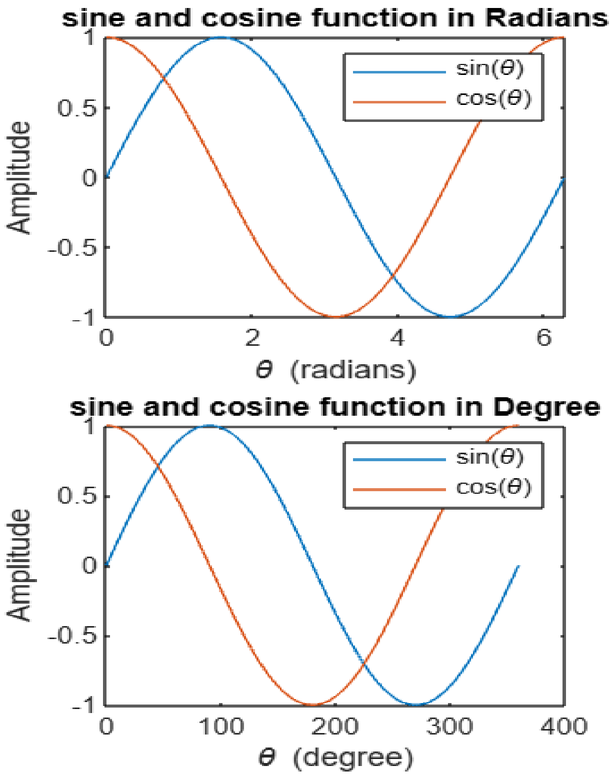
Lab 1

1.Graph the Sine and cosine function in [rad] and [deg], with : 0<θ<2pi

```
% Define the parameters
f = 1*10^9;  % Frequency of the wave in Hz
T = 1/f;  % Period of the wave in seconds
omega = 2 * pi * f;  % Angular frequency in rad/s
theta = 0:0.01:2*pi;
thetaDegree = 0:1:2*pi*180/pi;
x = sin(theta);
x1 = sind(thetaDegree);
y = cos(theta);
y1 = cosd(thetaDegree);

figure;
subplot(2, 2, 1);
plot(theta, x);
title('Sine function in Radian');
xlabel('\theta (radians)');
ylabel('sin(\theta)');

subplot(2, 2, 2);
plot(thetaDegree, x1);
title('Sine function in Degree');
xlabel('\theta (Degree)');
ylabel('sin(\theta)');

subplot(2, 2, 3);

plot(theta, y);
title('Cosine function Radian');
xlabel('\theta (radians)');
ylabel('cos(\theta)');

subplot(2, 2, 4);

plot(thetaDegree, y1);
title('Cosine function in Degree');
xlabel('\theta (degree)');
ylabel('cos(\theta)');
```



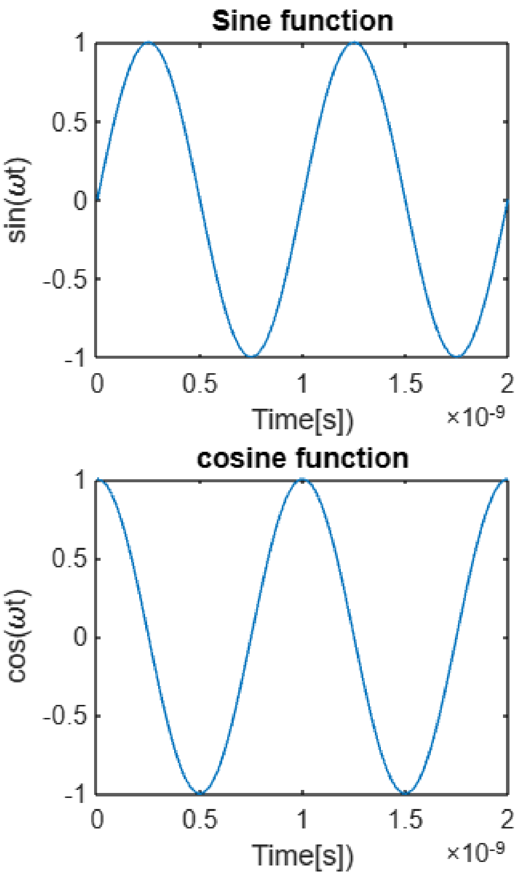

```
% plot sine and cosine in one graph using radian and degree

% define parameters
frequency = 1;  % Frequency of the wave in Hz
period = 1 / frequency;  % Period of the wave in seconds
omega = 2 * pi * frequency;  % Angular frequency in rad/s
theta = 0:0.01:2*pi;  % Radians
thetaDegree = 0:1:2*pi*180/pi;  % Degrees with finer spacing

figure(1);
subplot(2, 2, 1);
plot(theta, sin(theta));
hold on;
plot(theta, cos(theta));
title('sine and cosine function in Radians');
xlabel('\theta (radians)');
ylabel('Amplitude');
legend('sin(\theta)', 'cos(\theta)')

subplot(2, 2, 3);
plot(thetaDegree, sind(thetaDegree));  % Use sind for degrees
hold on;
plot(thetaDegree, cosd(thetaDegree));  % Use sind for degrees
title('sine and cosine function in Degree');
xlabel('\theta (degree)');
ylabel('Amplitude');
legend('sin(\theta)', 'cos(\theta)'
```

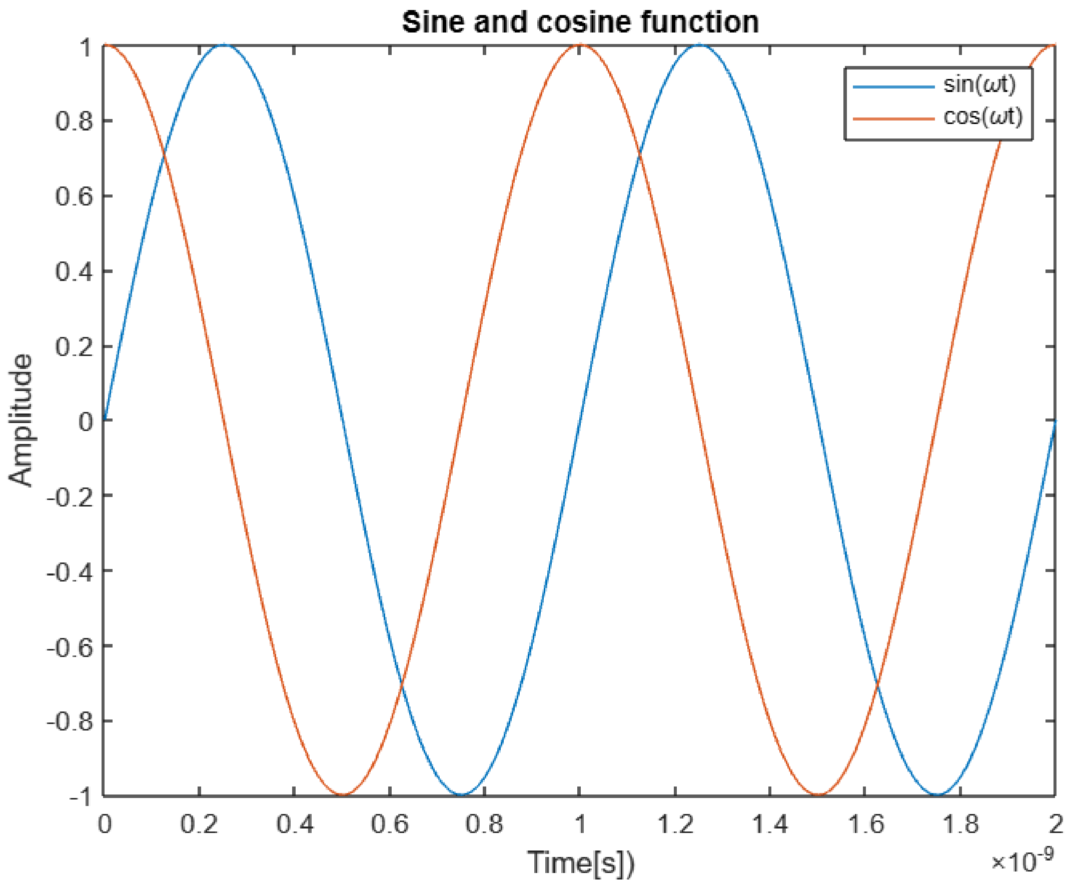


2. Graph the cos(ωt) and sin(ωt), with a frequency of 1GHz.

```
% plot cos( ωt) and sin(ωt) in separate graphs and then both in single graph;
% Define the parameters
f = 1*10^9;  % Frequency of the wave in Hz
T = 1/f;  % Period of the wave in seconds
omega = 2 * pi * f;  % Angular frequency in rad/s
t= 0: T/100: 2*T;
x = sin(omega*t);

figure;
subplot(2, 2, 1);
plot(t, x);
title('Sine function');
xlabel('Time[s])');
ylabel('sin(\omegat)');

subplot(2, 2, 3);
y = cos(omega*t);
plot(t, y);
title('cosine function');
xlabel('Time[s])');
ylabel('cos(\omegat)');

figure(2);

plot(t, x);

hold on;
y = cos(omega*t);
plot(t, y);
```

```
title('Sine and cosine function');
xlabel('Time[s])');
ylabel('Amplitude');
legend('sin(\omegat)','cos(\omegat)')
```

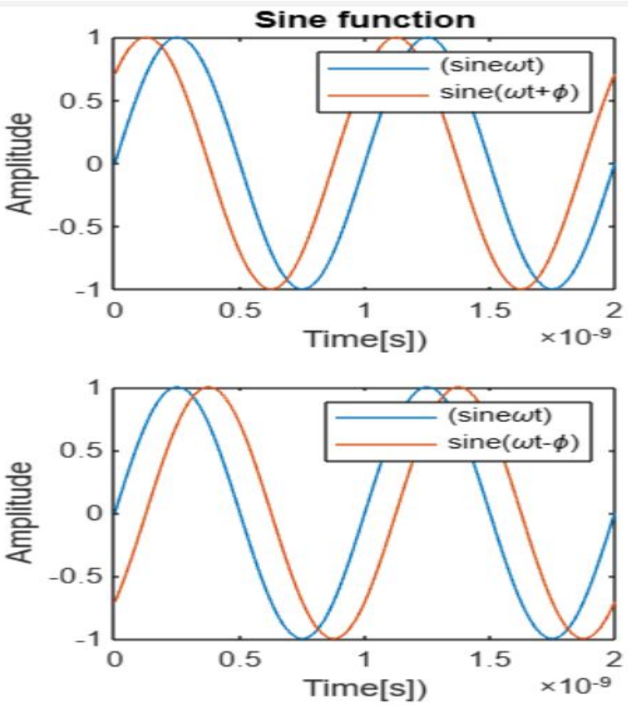




3. Graph the sin(ωt + ϕ), with a frequency of 1GHz and phase: ϕ=pi/4 and ϕ=-pi/4

```
% Define the parameters
f = 1*10^9;  % Frequency of the wave in Hz
T = 1/f;  % Period of the wave in seconds
omega = 2 * pi * f;  % Angular frequency in rad/s
t= 0: T/100: 2*T;
phi=pi/4;

%cosine

u = sin(omega*t);
v=sin(omega*t+phi);
w=sin(omega*t-phi);
figure(2);
subplot(2, 2,1);
plot(t,u);
hold on
plot(t,v);
title('sin function');
xlabel('Time[s])');
ylabel('Amplitude');
legend("(sin\omegat)","sin(\omegat+\phi)");

subplot(2,2,3);
plot(t, u);
hold on
```

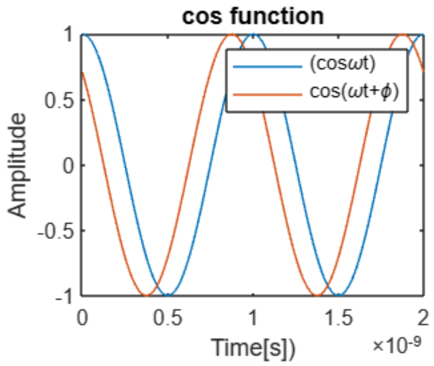
```
plot(t,w);
title('sin function');
xlabel('Time[s])');
ylabel('Amplitude');
legend("(sin\omegat)","sin(\omegat-\phi)");
```

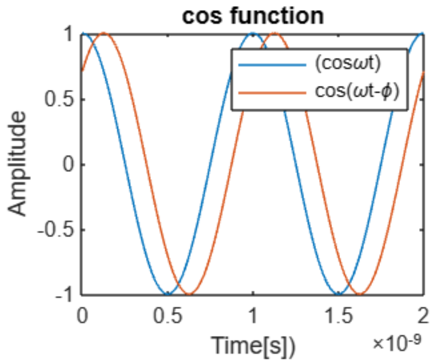


4. Graph the cos(ωt + ϕ), with a frequency of 1GHz and phase: ϕ=pi/4 and ϕ=-pi/4

```
f = 1*10^9;  % Frequency of the wave in Hz
T = 1/f;  % Period of the wave in seconds
omega = 2 * pi * f;  % Angular frequency in rad/s
t= 0: T/100: 2*T;
phi=pi/4;
%cos
u = cos(omega*t);
v=cos(omega*t+phi);
w=cos(omega*t-phi);
figure(2);
subplot(2, 2, 2);
plot(t,u);
hold on
plot(t,v);
title('cos function');
xlabel('Time[s])');
ylabel('Amplitude');
legend("(cos\omegat)","cos(\omegat+\phi)");

subplot(2, 2, 4);
plot(t, u);
hold on
plot(t,w);
```

```
xlabel('Time[s])');
ylabel('Amplitude');
legend("(cos\omegat)","cos(\omegat-\phi)");
```

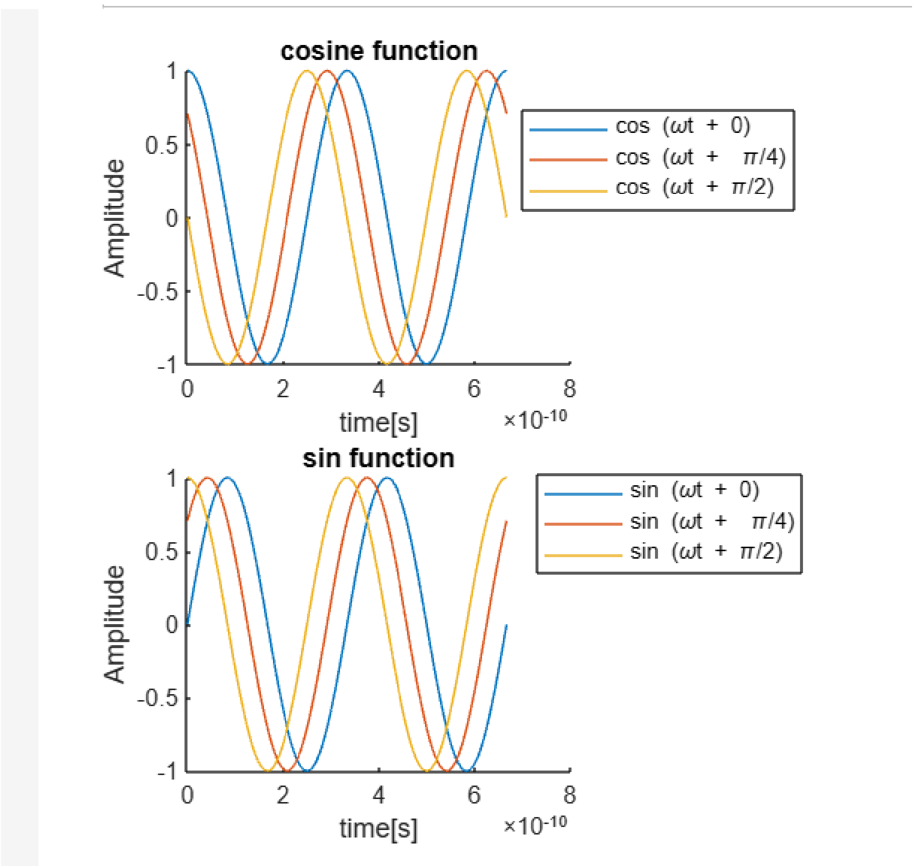




5.Graph the sin (ω t + ϕ) and cos(ω t + ϕ), with a frequency of 1GHz and different phases using for loop: [ϕ1=0, ϕ2=pi/4, ϕ3=pi/2]

```
% Define the parameters
f= 3*10^9;
phases = [0, pi/4, pi/2];
T= 1/f;
t= 0:T/100:2*T;
phase=0;
yPhase  = zeros(length(t),length(phases));

figure;
subplot(2,2,1)
hold on
for i= 1: length(phases)
yPhase = cos(2*pi*f*t + phases(i));
plot(t,yPhase);

end
title("cosine function")
xlabel("time[s]")
ylabel("Amplitude")
legend("cos (\omegat + 0)", "cos (\omegat +  \pi/4)", "cos (\omegat + \pi/2)");

subplot(2,2,3)
hold on
for i= 1: length(phases)
yPhase = sin(2*pi*f*t + phases(i));
```

```
plot(t,yPhase);

end
title("sin function")
xlabel("time[s]")
ylabel("Amplitude")
legend("sin (\omegat + 0)", "sin (\omegat +  \pi/4)", "sin (\omegat + \pi/2)");
```

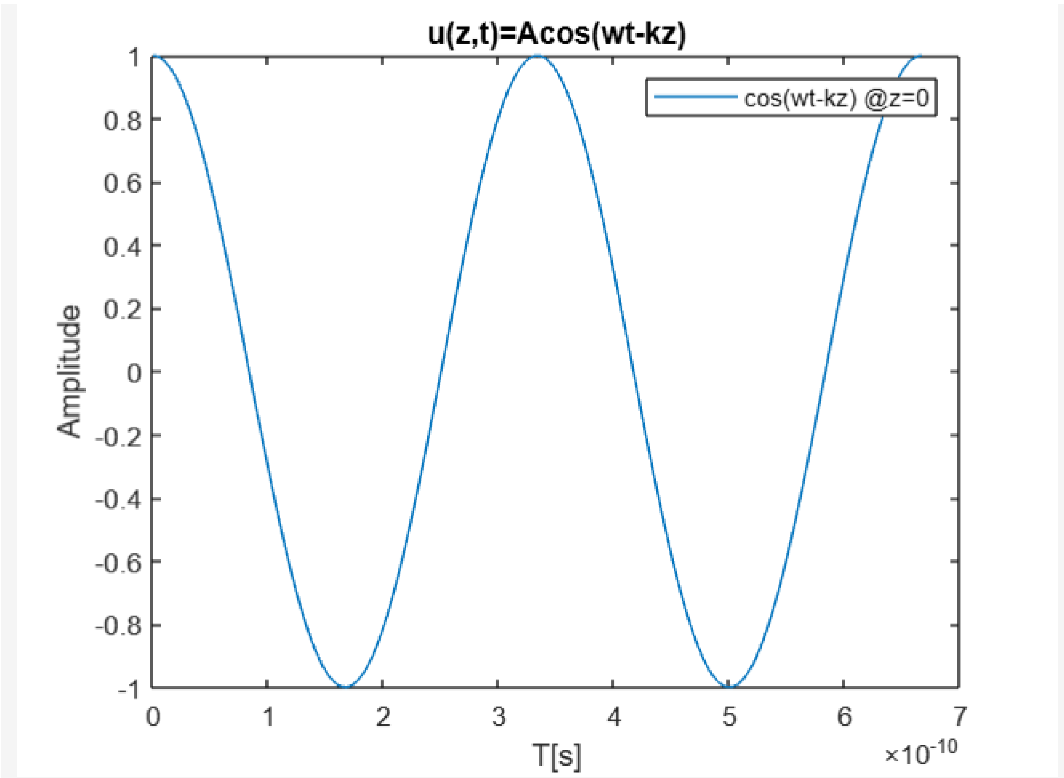


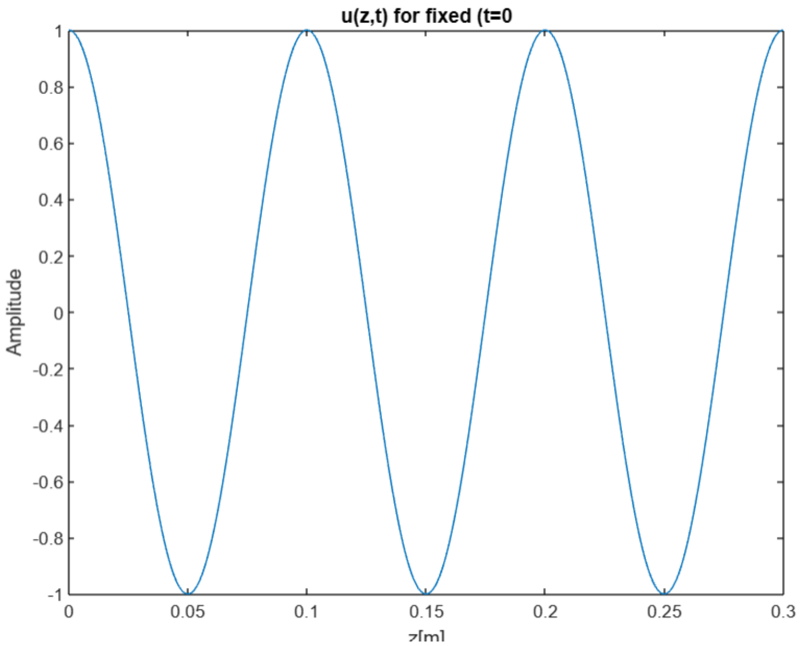
Lab 2

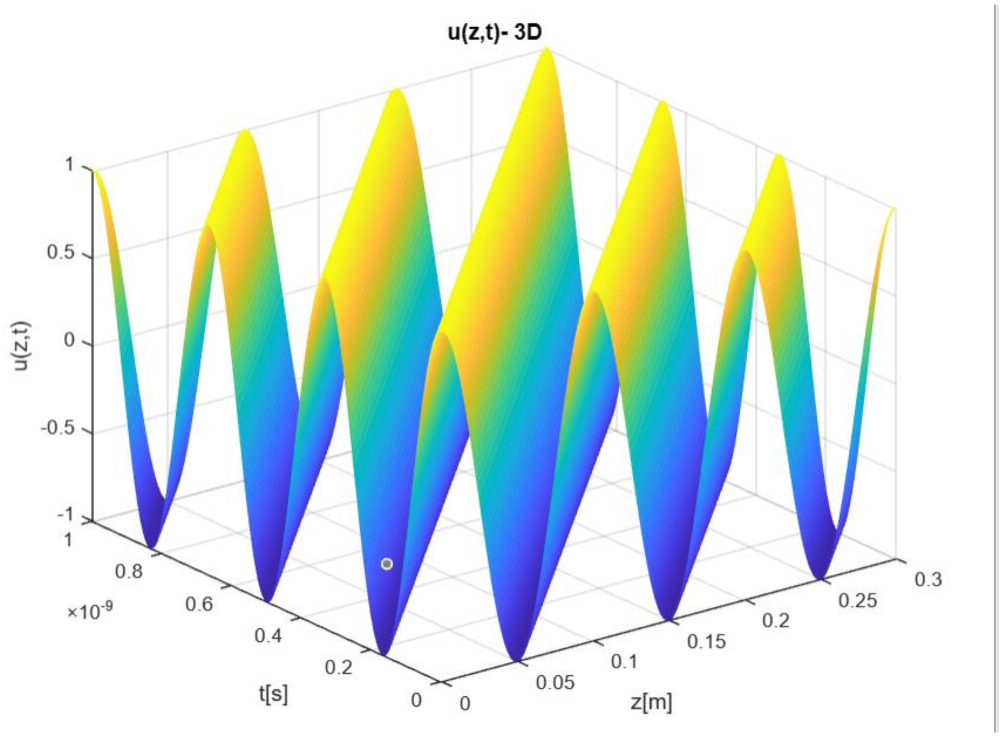
1.Graph of the function: $u\,(z, t) = A\cos(wt - kz)$. For z=0,t=0 and 3-D

```
f = 3*10^9;
T= 1/f;
A = 1;
Eo = 8.85*10^-12;
No=pi*4*10^-7;
c=(Eo*No)^-0.5;
lambda=c/f;
k = 2*pi/lambda;
t= 0:T/100:3*T;
t0=0;
z1=0;
z = 0:lambda/100:3*lambda;
u =  zeros(length(t), length(z));
```

```
figure;
u1 = A*cos(2*pi*f*t- k*z1);
plot(z,u1);
xlabel("T[s]");
ylabel("Amplitude");
title("u(z,t) for fixed (z=0)");

figure(1);
u1 = A*cos(2*pi*f*t0- k*z);
plot(z,u1);
xlabel("z[m]");
ylabel("Amplitude");
title("u(z,t) for fixed (t=0)");

for i = 1: length(z)
    u (:,i) = A*cos(2*pi*f*t- k*z(i));

end
figure(2);
mesh(z,t,u);
xlabel("z[m]");
ylabel("t[s]");
zlabel("u(z,t)");
title("u(z,t)- 3D");
```



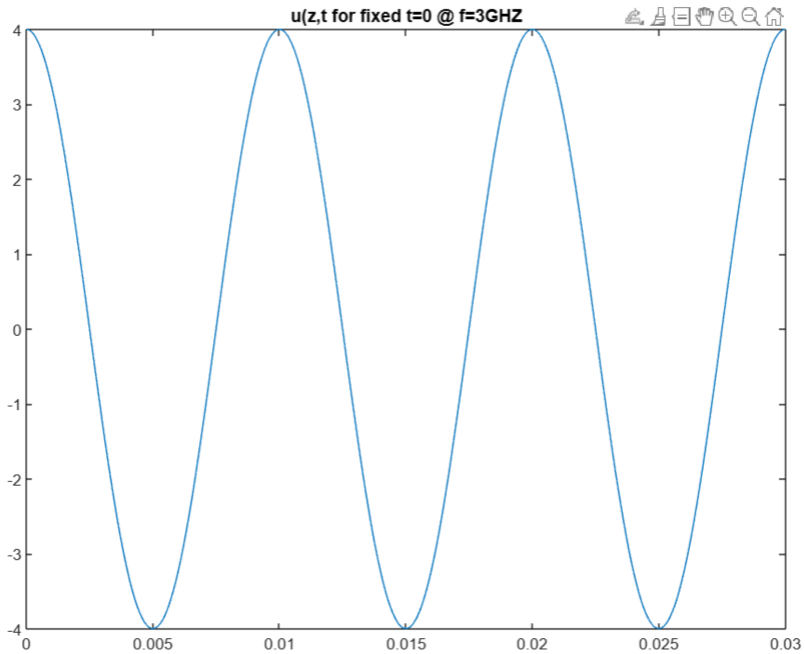

u(z,t) for fixed (t=0
Amplitude
z[m]

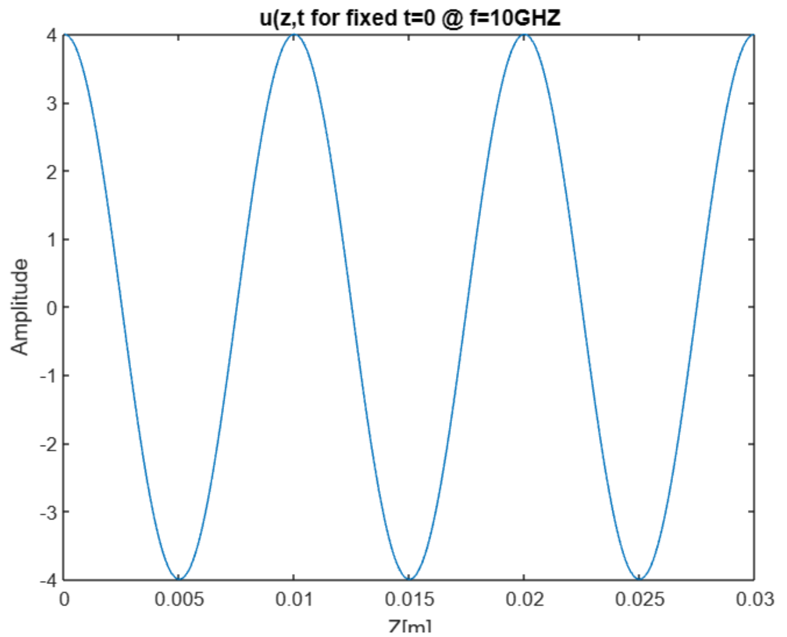

u(z,t)- 3D
u(z,t)
t[s]
×10-9
z[m]

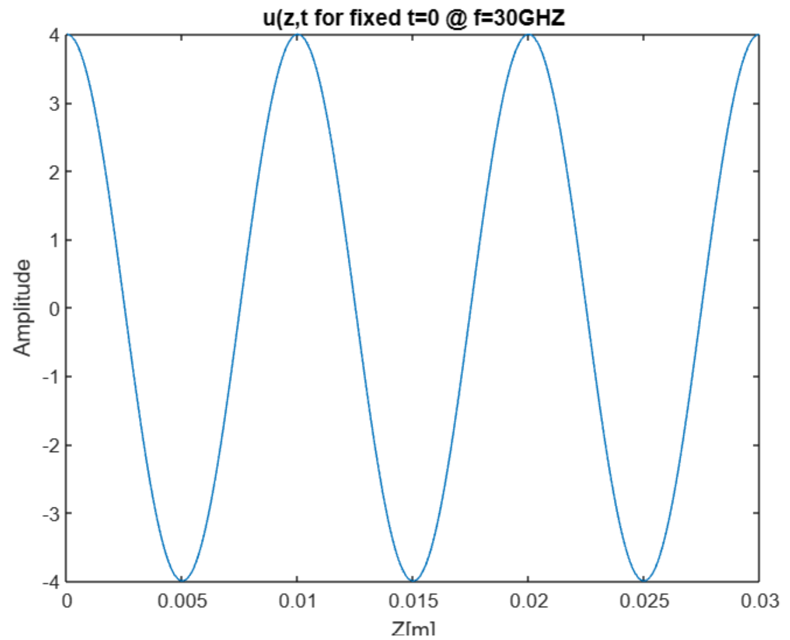
Lab 3

1. **Graph the function: $u\ (z, t\ ) = A\ \cos(wt - kz)$ for fixed t=0 at different frequency using for loop.**

```
f = [3*10^9,10*10^9,30*10^9];
A = 4;
Eo = 8.85*10^-12;
No=pi*4*10^-7;
c=(Eo*No)^-0.5;

t0=0;
for i = 1: length(f)
    lambda=c/f(i);
    k = 2*pi/lambda;
    z = 0:lambda/100:3*lambda;
    u1= A*cos(2*pi*f(i)*t0- k*z);
    figure(1);
    plot(z,u1);

    title("u(z,t for fixed t=0 @ f=3GHZ")
    ylabel("Amplitude");
    xlabel("Z[m]");

    figure(2)
    title("u(z,t for fixed t=0 @ f=10GHZ")
    ylabel("Amplitude");
    xlabel("Z[m]");

    figure(3)
    title("u(z,t for fixed t=0 @ f=30GHZ")
    ylabel("Amplitude");
    xlabel("Z[m]");
end
```



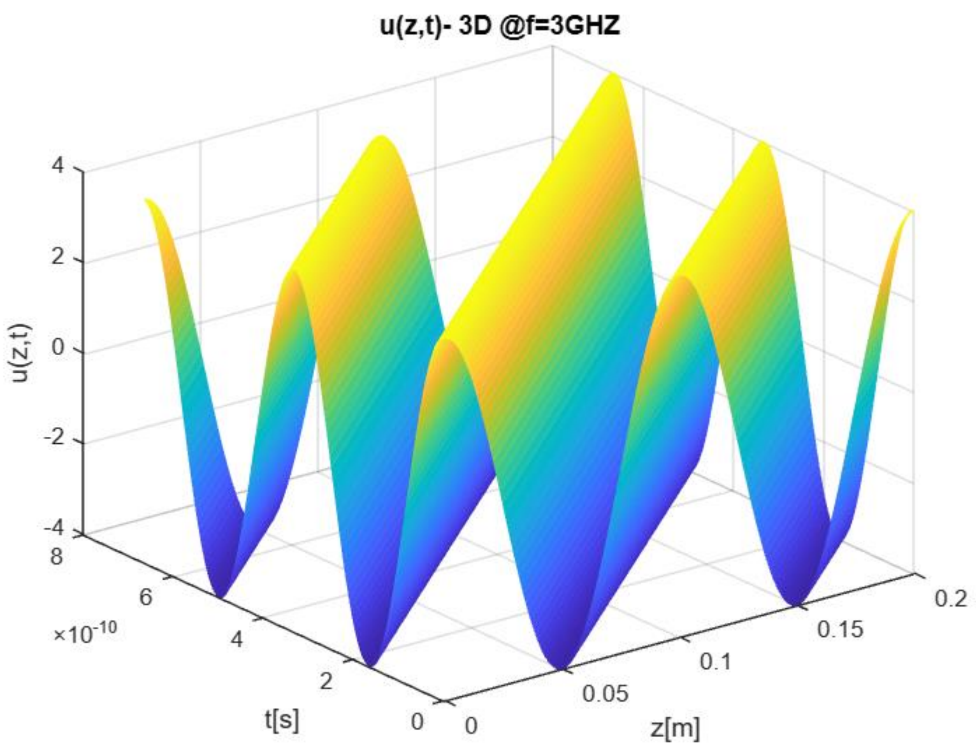


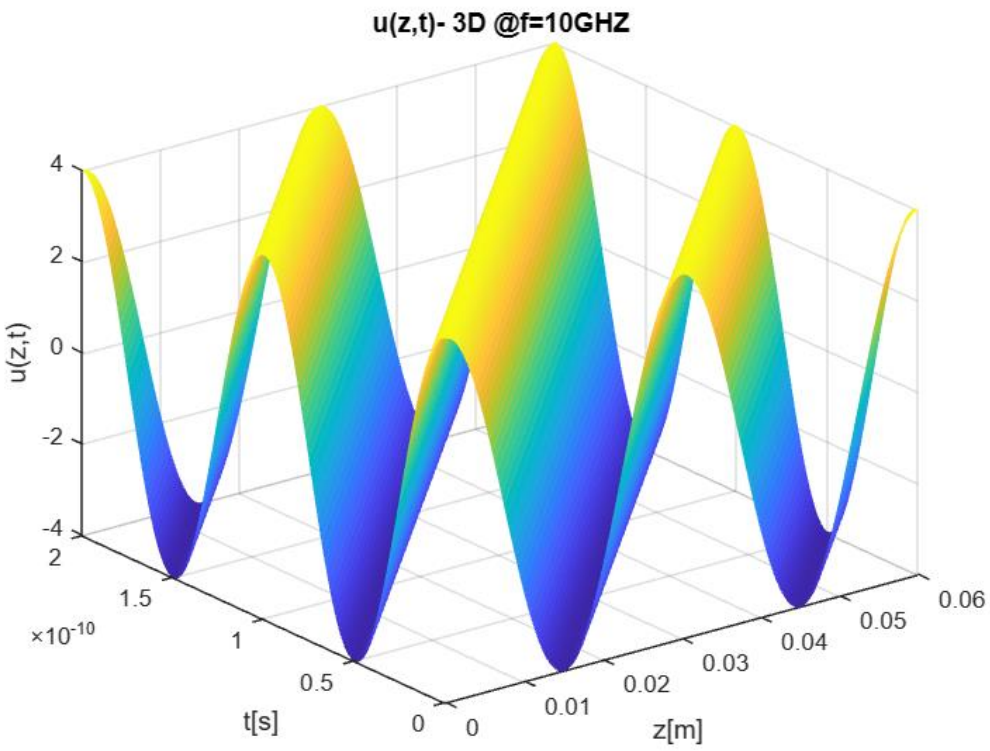


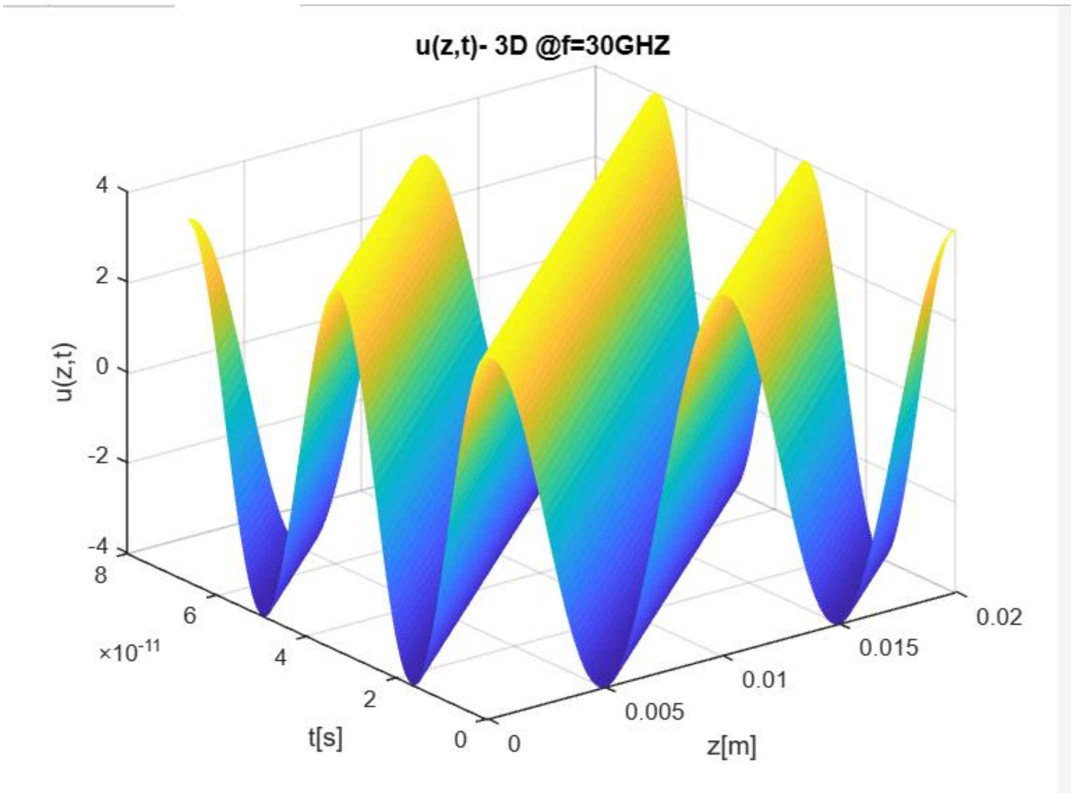
2. **Graph the function in 3D: $u\ (z, t\ )= A\ \cos(wt\ \text{-}\ kz)$ at different frequency using for loop.**

```
f = [3*10^9,10*10^9,30*10^9];
A = 4;
Eo = 8.85*10^-12;
No=pi*4*10^-7;
c=(Eo*No)^-0.5;

for i = 1:length(f)
    T = 1/f(i);
    t = 0:T/100:2*T;  % Moved this line here
    lambda = c/f(i);
    k = 2*pi/lambda;
```

```
    z = 0:lambda/100:2*lambda;
    u =  zeros(length(t), length(z));
    for x = 1: length(z)
    u (:,x) = A*cos(2*pi*f(i).*t- k*z(x));

   end
  figure(1);
  mesh(z,t,u);
  xlabel("z[m]");
 ylabel("t[s]");
 zlabel("u(z,t)");
 title("u(z,t)- 3D @f=3GHZ");

 figure(2);
  mesh(z,t,u);
  xlabel("z[m]");
 ylabel("t[s]");
 zlabel("u(z,t)");
 title("u(z,t)- 3D @f=10GHZ");

 figure(3);
  mesh(z,t,u);
  xlabel("z[m]");
 ylabel("t[s]");
 zlabel("u(z,t)");
 title("u(z,t)- 3D @f=30GHZ");
end
```


u(z,t)- 3D @f=3GHZ
u(z,t)
4
2
0
-2
-4
8
6
×10^-10
4
2
0
t[s]
0
0.05
0.1
0.15
0.2
z[m]

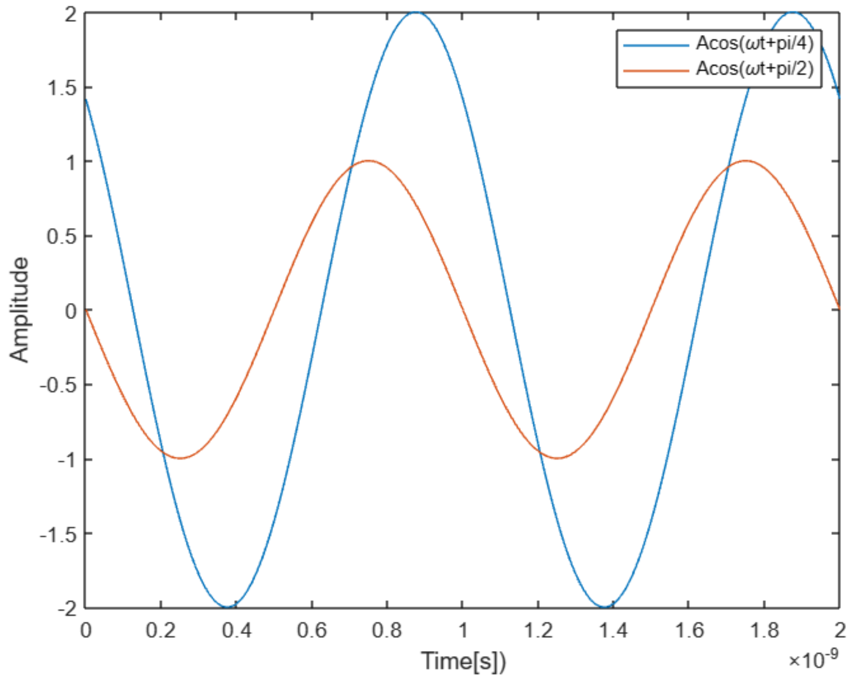

u(z,t)- 3D @f=10GHZ
u(z,t)
4
2
0
-2
-4
2
1.5
×10^-10
1
0.5
0
t[s]
0
0.01
0.02
0.03
0.04
0.05
0.06
z[m]



Lab 4

1. Converting this phasor to time domain: $U = Aej\varphi$. Considering two cases:
1) A1=2 , φ1=45 degrees
2) A2=1, φ2=90 degrees
$u\,(t) = Re(\,U\,ej\omega t)$

```
f = 1*10^9;
w = 2*pi*f;
T = 1/f;
t=0:T/100:2*T;
phi1=pi/4;
phi2=pi/2;
A1=2;
A2=1;
U1=A1*exp(1i*phi1);
U2=A2*exp(1i*phi2);
u1_t=real(U1*exp(1i*w*t));
u2_t=real(U2*exp(1i*w*t));
figure;
plot(t,u1_t);
hold on
plot(t,u2_t);
xlabel('Time[s])');
ylabel('Amplitude');
legend("Acos(\omegat+pi/4)","Acos(\omegat+pi/2)");
```



2.Converting the phasor of Electric Field to its instantaneous expression at z=0 and z different from zero using 3D

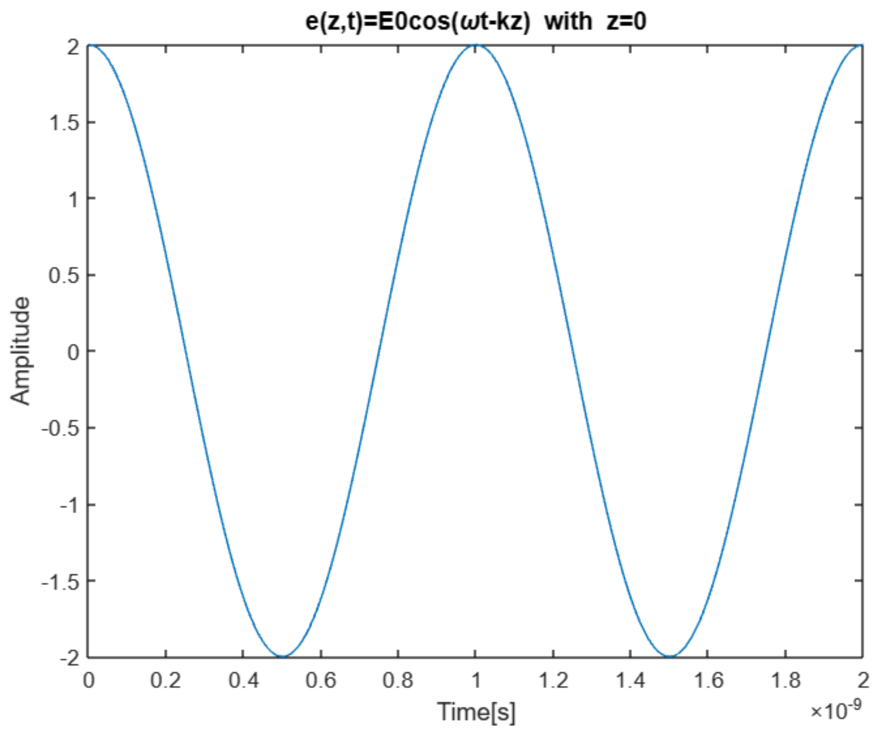
$$\underline{E} = \hat{x}Eo\ e^{-jkz}$$

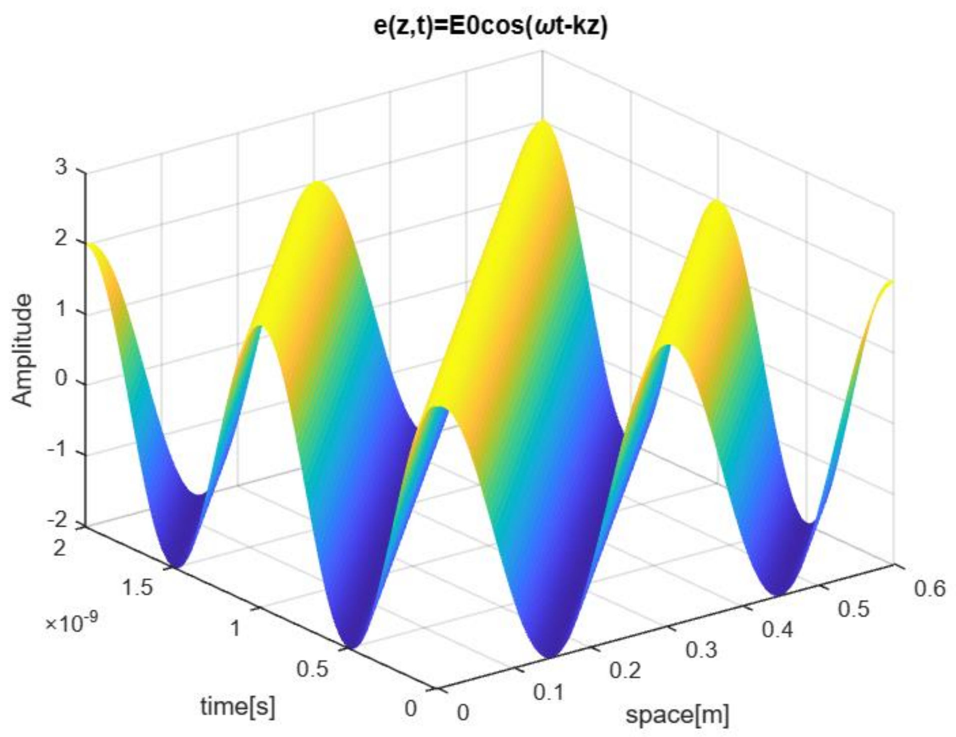
$$\downarrow$$

$$\underline{e}(z,t) = Re(\ \underline{E}\ e^{j\omega t})$$

```
f = 1*10^9;
w = 2*pi*f;
T = 1/f;
t=0:T/100:2*T;
E0=2;
z=0;
c=3*10^8;
lambda=c/f;
z1=0:lambda/100:2*lambda;
k=2*pi/lambda;
E=E0*exp(-1i*k*z);
e=real(E*exp(1i*w*t));

figure;
plot(t,e);
title("e(z,t)=E0cos(\omegat-kz) with z=0")
xlabel('Time[s]');
ylabel('Amplitude');


e1=zeros(length (t),length(z1));
for i=1:length(z1)
    E1=E0*exp(-1i*k*z1);
    e1(:,i)=real(E1*exp(1i*w*t(i)));
end
figure(2);
mesh(z1,t,e1)
```

```
title("e(z,t)=E0cos(\omegat-kz)")
xlabel('space[m]');
ylabel('time[s]');
zlabel("Amplitude")
```



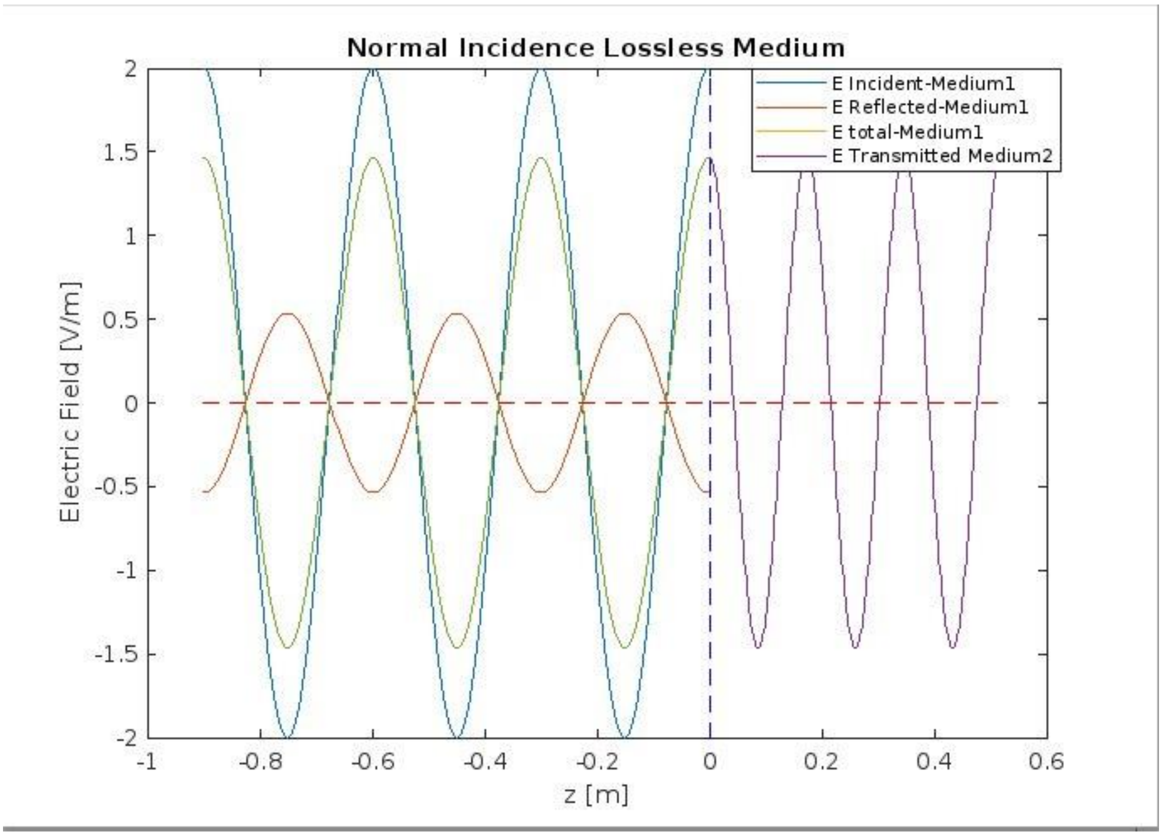


Lab 5

1. Normal Incidence – Lossless Media

```
f = 1*10^9;
w = 2*pi*f;
T = 1/f;
c = 3 * 10^8;
t = 0 : T/100 : 2*T;
lambda = c/f;
E0 = 2;
er1 = 1;
ur1 = 1;
er2 = 3;
ur2 = 1;
e0 = 8.85*10^-12;
u0 = pi*4*10^-7;
e1 = e0*er1;
e2 = e0*er2;
u1 = u0*ur1;
u2 = u0 *ur2;
k1 = w*sqrt(e1*u1);
k2 = w*sqrt(e2*u2);
vp1 = 1/sqrt(e1*u1);
vp2 = 1/sqrt(e2*u2);
n1 = sqrt(u1/e1);
n2 = sqrt(u2/e2);
lambda1 = vp1/f;
lambda2 = vp2/f;
z1 = -3*lambda1 : lambda1/100 : 0;
z2 = 0 : lambda2/100 : 3*lambda2;
%reflection coefficient%
gamma = (n2-n1)/(n1+n2);
%transmission coefficient%
tr = 2*n2/(n1+n2);
Ei = E0*exp(-1i*k1*z1);
Er = E0*gamma*exp(1i*k1*z1);
Et = E0*tr*exp(-1i*k2*z2);
E1 = Ei + Er;
ei = zeros (length(t), length(z1));
er = zeros (length(t), length(z1));
etr = zeros (length(t),length(z2));
e1 = zeros (length(t), length(z1));
for x= 1: length(t)

    ei(x,:) = real(Ei*exp(1i*w*t(x)));
    er(x,:) = real(Er*exp(1i*w*t(x)));
    etr(x,:) = real(Et*exp(1i*w*t(x)));
    e1 (x,:) = real(E1*exp(1i*w*t(x)));

end
figure;
for y =1 : length(t)
    clf;
    plot(z1,ei(y,:))
    hold on;
    plot(z1,er(y,:))
    plot(z1,e1(y,:))
    plot(z2,etr(y,:))
```

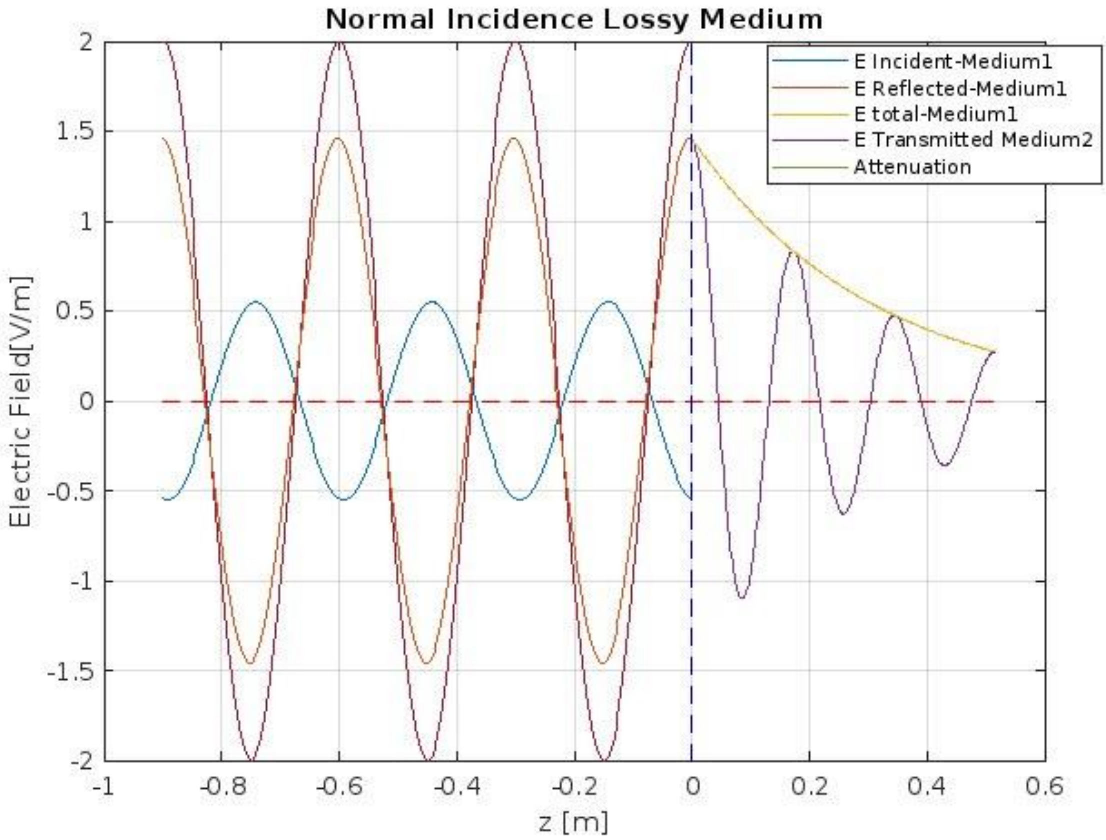
```
    plot(z1,e1(y,:))

  pause(0.1);
end

    a = [-3*lambda1, 3*lambda2]
    b = [0,0];
    c = [-E0,E0];
    d = [0,0];

plot(a,b,'r',LineStyle='--');
plot(d,c,'b',LineStyle='--');

 xlabel('z [m]')
 ylabel('Electric Field [V/m]');
 legend('E Incident-Medium1','E Reflected-Medium1','E total-Medium1','E
Transmitted Medium2','FontSize',8);
 title('Normal Incidence Lossless Medium');
```



2.Normal Incidence – Lossy Media

```
f = 1*10^9;
w = 2*pi*f;
T = 1/f;
c = 3 * 10^8;
t = 0 : T/100 : 2*T;
lambda = c/f;
E0 = 2;
er1 = 1;
ur1 = 1;
er2 = 3;
ur2 = 1;
e0 = 8.85*10^-12;
u0 = pi*4*10^-7;
e1 = e0*er1;
e2 = e0*er2;
u1 = u0*ur1;
u2 = u0 *ur2;
sigma2 = 0.03
e = 2.71828;
A = 1/e;
k1 = w*sqrt(e1*u1);
k2 = w*sqrt((e2-j*sigma2/w)*u2);
%k1 = beta1-jalpha1;
%k2 = beta-jalpha2;
alpha1 = -imag(k1);
beta1 = real(k1);
alpha2 = -imag(k2);
beta2 = real(k2);
A1=1/alpha2
%vp1 = 1/sqrt(e1*u1);
%vp2 = 1/sqrt(e2*u2);
n1 = sqrt(u1/e1);
n2 = sqrt(j*w*u2/(sigma2+j*w*e2));
lambda1 = 2*pi/beta1;
lambda2 = 2*pi/beta2;
z1 = -3*lambda1 : lambda1/100 : 0;
z2 = 0 : lambda2/100 : 3*lambda2;
%reflection coefficient%
gamma = (n2-n1)/(n1+n2);
%transmission coefficient%
tr = 2*n2/(n1+n2);
Ei = E0*exp(-1i*k1*z1);
Er = E0*gamma*exp(1i*k1*z1);
Et = E0*tr*exp(-1i*k2*z2);
E1 = Ei + Er;
ei = zeros (length(t), length(z1));
er = zeros (length(t), length(z1));
etr = zeros (length(t),length(z2));
e1 = zeros (length(t), length(z1));

for x= 1: length(t)

    ei(x,:) = real(Ei*exp(1i*w*t(x)));
    er(x,:) = real(Er*exp(1i*w*t(x)));
    etr(x,:) = real(Et*exp(1i*w*t(x)));
```

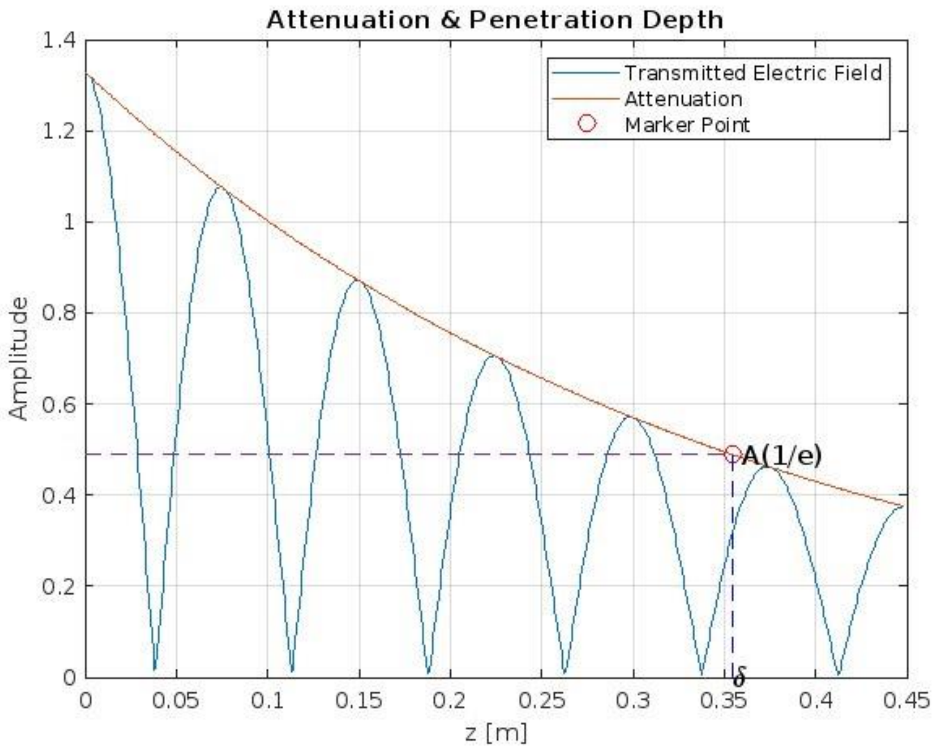
```
    e1 (x,:) = real(E1*exp(1i*w*t(x)));

end
figure;
for y =1 : length(t)
    clf;
    plot(z1,ei(y,:))
    hold on;
    plot(z1,er(y,:))
    plot(z1,e1(y,:))
    plot(z2,etr(y,:))
    plot(z1,e1(y,:))

    amplitude = max(abs(tr*ei(y,:)));
    attenua = amplitude*exp(-alpha2*z2);
    plot(z2,attenua);

   %pause(0.1);
end

    a = [-3*lambda1, 3*lambda2]
    b = [0,0];
    c = [-E0,E0];
    d = [0,0];

    amplitude = max(abs(tr*Ei(1,:)));
    attenua = amplitude*exp(-alpha2*z2);
    plot(z1,Ei (1,:));
    hold on;
    plot(z1,Er (1,:));
    plot(z1,E1 (1,:));
    plot(z2,abs(Et(1,:)));

    plot(a,b,'r',LineStyle='--');
    plot(d,c,'b',LineStyle='--');

 xlabel('z [m]')
 ylabel('Electric Field[V/m]');
 legend('E Incident-Medium1','E Reflected-Medium1','E total-Medium1','E
Transmitted Medium2','Attenuation','FontSize',8);
 title('Normal Incidence Lossy Medium');
 grid on;
```



3.Represent the Transmitted Electric Field in medium 2 ($E2$), with its *attenuation* and *Penetration Depth for sigma =0.03*

```
f = 1*10^9;
w = 2*pi*f;
T = 1/f;
c = 3 * 10^8;
t = 0 : T/100 : 2*T;
lambda = c/f;
%input("please enter Amplitude");
E0 = 2;
%input("please enter relative permittivity er1 of medium");
er1 = 1;
%input("please enter relative permeability ur1 of medium");
ur1 = 1;
%input("please enter relative permittivity er2 of medium");
er2 = 4;
%input("please enter relative permeability ur2 of medium");
ur2 = 1;
e0 = 8.85*10^-12;
u0 = pi*4*10^-7;
e1 = e0*er1;
e2 = e0*er2;
u1 = u0*ur1;
u2 = u0 *ur2;
sigma2 = 0.03;
e = 2.71828;
A = 1/e;
% defining propagation constants k1 and k2
```

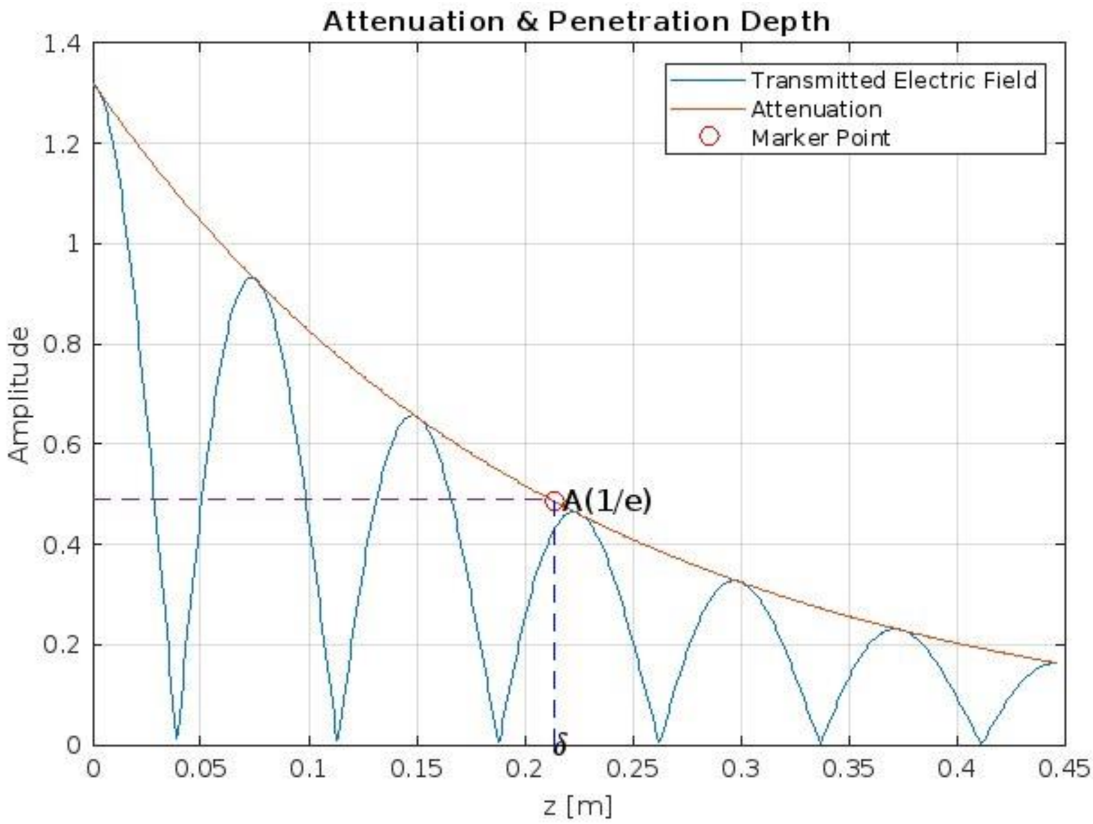
```matlab
k1 = w*sqrt(e1*u1);
k2 = w*sqrt((e2-1i*sigma2/w)*u2);
alpha1 = -imag(k1);
beta1 = real(k1);
alpha2 = -imag(k2);
beta2 = real(k2);
%defining delta
A1=1/alpha2;
%defining intrinsic impedence n1 and n2
n1 = sqrt(u1/e1);
n2 = sqrt(1i*w*u2/(sigma2+1i*w*e2));
%defining lambda1 and lambda2
lambda1 = 2*pi/beta1;
lambda2 = 2*pi/beta2;
z2 = 0 : lambda2/200 : 3*lambda2;
%reflection coefficient(gamma)
gamma = (n2-n1)/(n1+n2);
%transmission coefficient%
tr = 2*n2/(n1+n2);
%transmitted electric field
Et = E0*tr*exp(-1i*k2*z2);
etr = zeros (length(t),length(z2));

for x= 1: length(t)
    etr(x,:) = real(Et*exp(1i*w*t(x)));
end

    a = [0, 0.354639]
    d = [0.354639,0.354639];
    c = [0,0.488787];
    b = [0.488787,0.488787];

figure;
plot(z2,abs(etr(1,:)));
hold on;
%Attenuation
    amplitude = max(Et(1,:));
    attenua = amplitude*exp(-alpha2*z2);

    plot(z2,attenua);
    plot(A1,amplitude*A,'ro','MarkerSize',8);
    text(0.354639,0.4887875,' A(1/e)',FontSize=12)
    text(0.354639,0,'\delta', FontSize=12)

    plot(a,b,'',LineStyle='--');
    plot(d,c,'b',LineStyle='--');


xlabel('z [m]');
ylabel('Amplitude');
title('Attenuation & Penetration Depth');
legend('Transmitted Electric Field', 'Attenuation', 'Marker Point');
grid on;
```



4.Represent the Transmitted Electric Field in medium 2 ($E2$), with its ***attenuation*** **and** ***Penetration Depth for sigma =0.05***

```
c = 3 * 10^8;
t = 0 : T/100 : 2*T;
lambda = c/f;
%input("please enter Amplitude");
E0 = 2;
%input("please enter relative permittivity er1 of medium");
er1 = 1;
%input("please enter relative permeability ur1 of medium");
ur1 = 1;
%input("please enter relative permittivity er2 of medium");
er2 = 4;
%input("please enter relative permeability ur2 of medium");
ur2 = 1;
e0 = 8.85*10^-12;
u0 = pi*4*10^-7;
e1 = e0*er1;
e2 = e0*er2;
u1 = u0*ur1;
u2 = u0 *ur2;
sigma2 = 0.05;
e = 2.71828;
A = 1/e;
% defining propagation constants k1 and k2
k1 = w*sqrt(e1*u1);
k2 = w*sqrt((e2-1i*sigma2/w)*u2);
alpha1 = -imag(k1);
beta1 = real(k1);
alpha2 = -imag(k2);
```

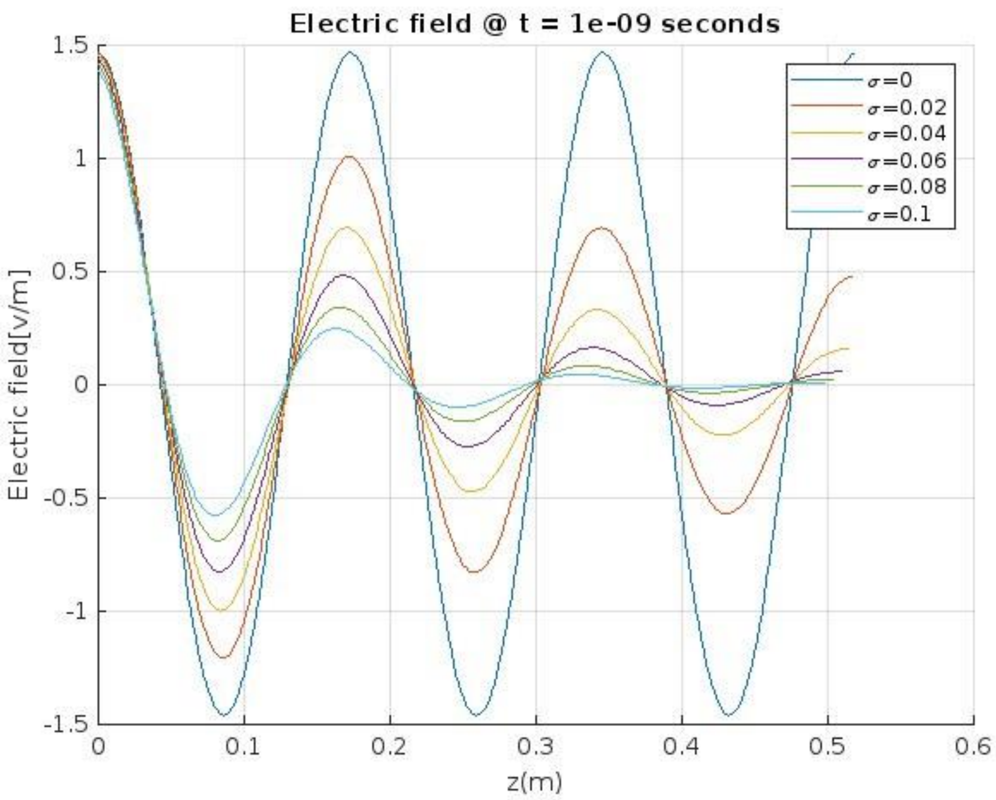
```
beta2 = real(k2);
%defining delta
A1=1/alpha2;
%defining intrinsic impedence n1 and n2
n1 = sqrt(u1/e1);
n2 = sqrt(1i*w*u2/(sigma2+1i*w*e2));
%defining lambda1 and lambda2
lambda1 = 2*pi/beta1;
lambda2 = 2*pi/beta2;
z2 = 0 : lambda2/200 : 3*lambda2;
%reflection coefficient(gamma)
gamma = (n2-n1)/(n1+n2);
%transmission coefficient%
tr = 2*n2/(n1+n2);
%transmitted electric field
Et = E0*tr*exp(-1i*k2*z2);
etr = zeros (length(t),length(z2));

for x= 1: length(t)
    etr(x,:) = real(Et*exp(1i*w*t(x)));
end

    a = [0, 0.2137]
    d = [0.2137,0.2137];
    c = [0,0.488787];
    b = [0.488787,0.488787];

figure;
plot(z2,abs(etr(1,:)));
hold on;
%Attenuation
    amplitude = max(Et(1,:));
    attenua = amplitude*exp(-alpha2*z2);

    plot(z2,attenua);
    plot(A1,amplitude*A,'ro','MarkerSize',8);
    text(0.2137,0.4887875,' A(1/e)',FontSize=12)
    text(0.2137,0,'\sigma', FontSize=12)

    plot(a,b,'',LineStyle='--');
    plot(d,c,'b',LineStyle='--');


xlabel('z [m]');
ylabel('Amplitude');
title('Attenuation & Penetration Depth');
legend('Transmitted Electric Field', 'Attenuation', 'Marker Point');
grid on;
```



5.Represent the Transmitted Electric Field in medium 2 ($E2$), considering different sigma values

```
f = 1*10^9;
w = 2*pi*f;
T = 1/f;
c = 3 * 10^8;
t = T
lambda = c/f;
E0 = 2;
er1 = 1;
ur1 = 1;
er2 = 3;
ur2 = 1;
e0 = 8.85*10^-12;
u0 = pi*4*10^-7;
e1 = e0*er1;
e2 = e0*er2;
u1 = u0*ur1;
u2 = u0 *ur2;
sigma2 = 0:0.1/5:0.1;
etr = zeros (length(sigma2),length(z2));
%k1 = w*sqrt(e1*u1);
n1 = sqrt(u1/e1);
figure;
hold on;
for s=1:length(sigma2)
    k2 = w*sqrt((e2-1i*sigma2(s)/w)*u2);
    alpha2 = -imag(k2);
```

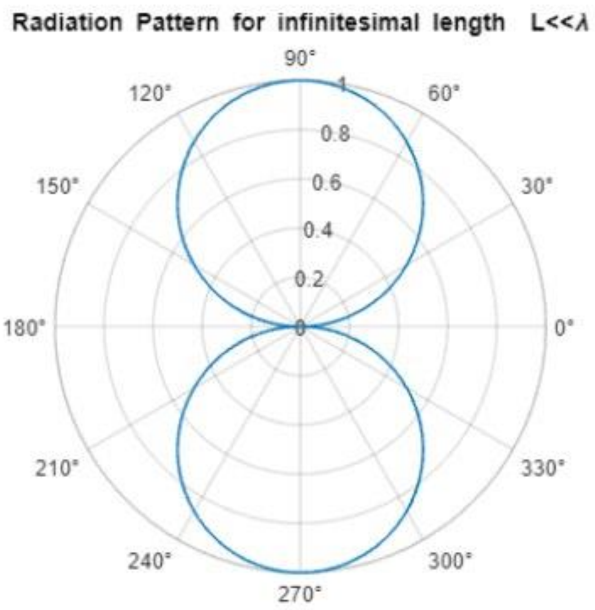
```
    beta2 = real(k2);
    n2 = sqrt(1i*w*u2/(sigma2(s)+1i*w*e2));
    lambda2 = 2*pi/beta2;
    z2 = 0 : lambda2/100 : 3*lambda2;
    %transmission coefficient%
    tr = 2*n2/(n1+n2);
    Et = E0*tr*exp(-1i*k2*z2);
    etr = real(Et*exp(1i*w*t));
    %plot(z2,etr,'Display name',['\sigma =']num2str(sigma2(s)));
    plot(z2,etr);

end
grid on;
xlabel("z(m)");
ylabel("Electric field[v/m]");
title("Electric field @ t = 1e-09 seconds");
grid on;
legend('\sigma=0','\sigma=0.02','\sigma=0.04','\sigma=0.06','\sigma=0.08','\sigma=
0.1')
```



Antenna Lab

1.Radiattion pattern for L<<lambda for 0<theta<2*pi;

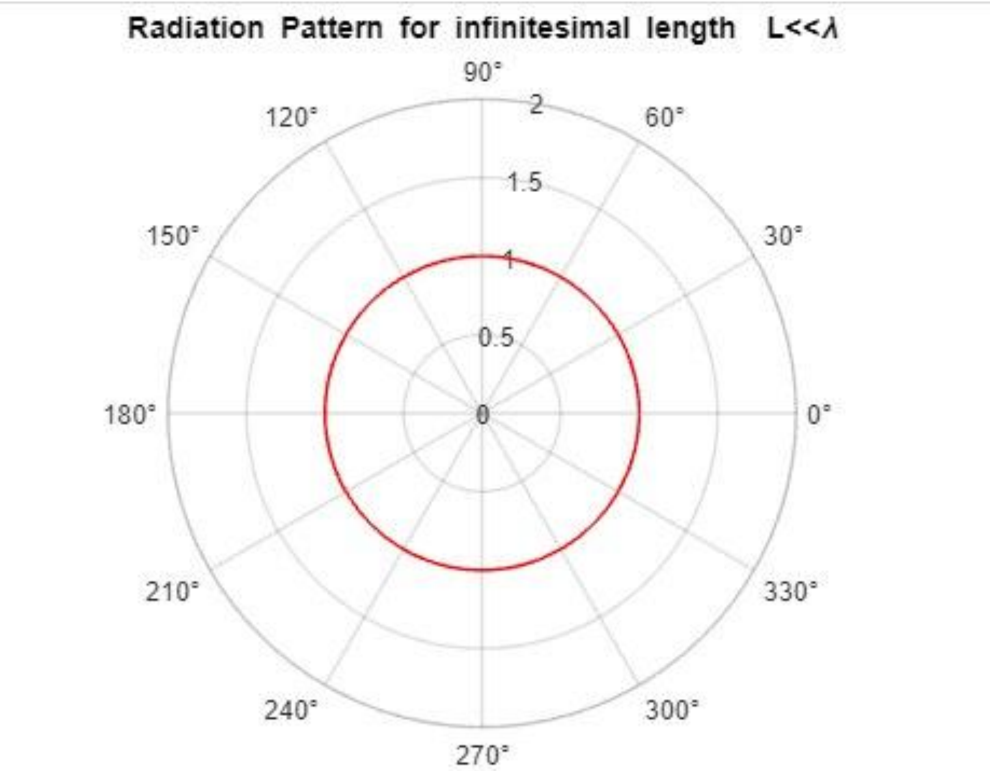
```
n=120*pi;
Io=1;
z=1;
r=10;
lambda=0.3;
k=(2*pi)/lambda;
L=lambda;
theta=0:0.01:2*pi;
%theta=pi/2;
E=1i*n*Io*z*exp(-1i*k*z)*sin(theta)*(1/(2*lambda*r));
F=sin(theta);
H=1i*Io*z*exp(-1i*k*r)*sin(theta)*(1/(2*lambda*r));
polarplot (theta, abs(F))
%plot(theta,abs(F));
%polarplot (theta, abs(H))
title('Radiation Pattern for infinitesimal length  L<<\lambda');
```



2.Radiattion pattern for L<<lambda for 0 <phi<2*pi;

```
n = 120*pi;
Io = 1;
z=1;
r = 10;
lambda = 0.3;
%theta=0:pi/50:2*pi;
theta=pi/2;
phi=0:0.01:2*pi;
phi1=pi;
```

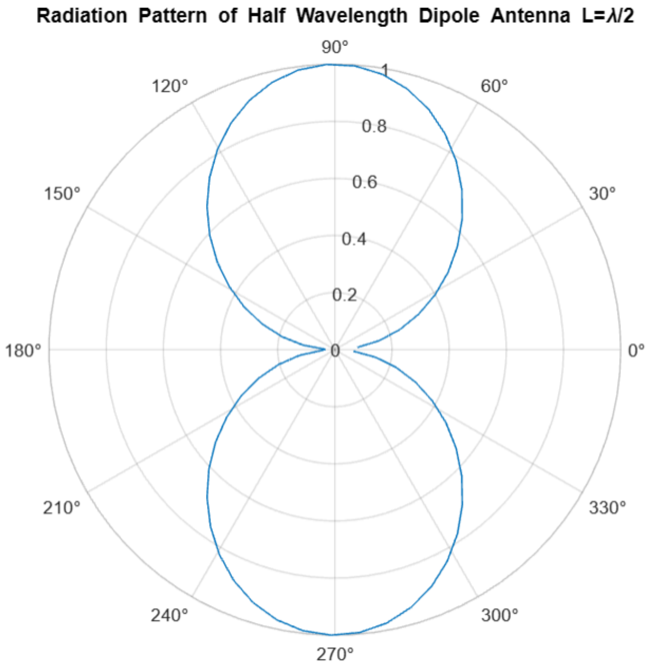
```
theta1=0:0.01:2*pi;
k = (2*pi) / lambda;
%L = lambda / 2;
E=1i*n*Io*z*exp(-1i*k*z)*sin(theta)*(1/(2*lambda*r))*ones(length(phi));
F=sin(theta)*ones(length(phi));
H=1i*Io*z*exp(-1i*k*r)*sin(theta)*(1/(2*lambda*r));

%polarplot(theta, E)
%polarplot(phi, abs(F),'red')
polarplot(theta1, abs(F),'red')
title('Radiation Pattern for infinitesimal length  L<<\lambda');
```

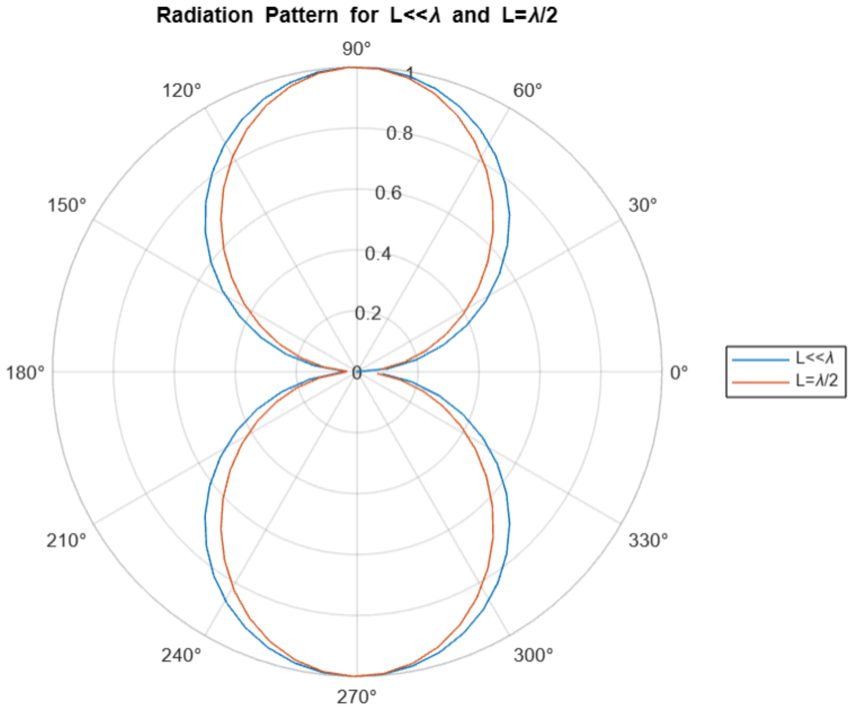


3.Radiattion pattern for L=lambda/2 for 0<theta<2*pi;

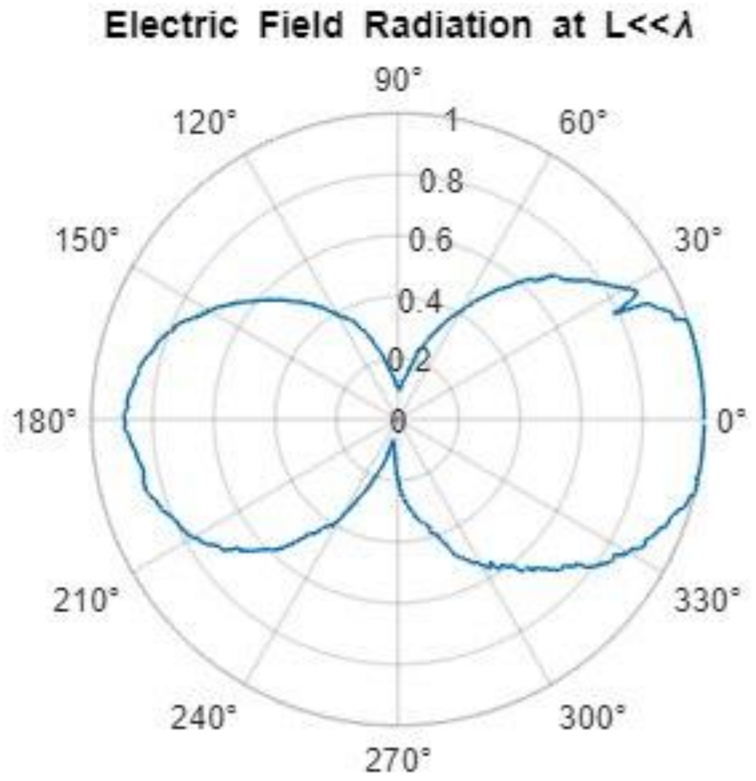
```
% Define parameters
Io = 1; % Adjust the as needed
r = 10; % Adjust the as needed
theta = 0:0.1:2*pi;
lambda = 2;  % Adjust the as needed
k = 2 * pi / lambda;
E_theta = 1i*n*Io*exp(-1i*k*r)*(1/(2*pi*r))*cos((pi/2)*cos(theta))./(sin(theta) );
F_theta = cos((pi/2) * cos(theta)) ./ (sin(theta));

figure;
```

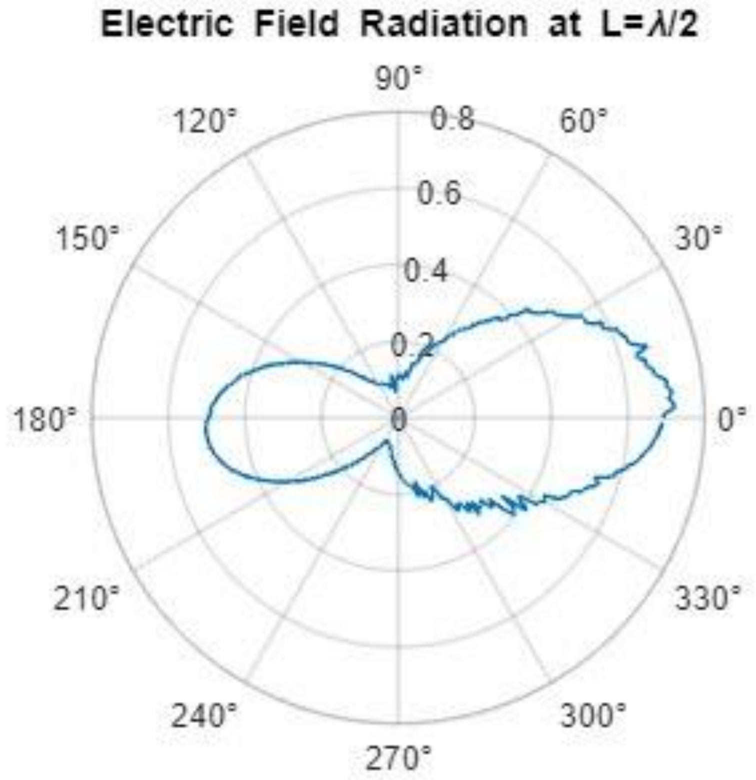
```
%polarplot(theta, abs(E_theta));
polarplot(theta, abs(F_theta));
title('Radiation Pattern of Half Wavelength Dipole Antenna L=\lambda/2');
```

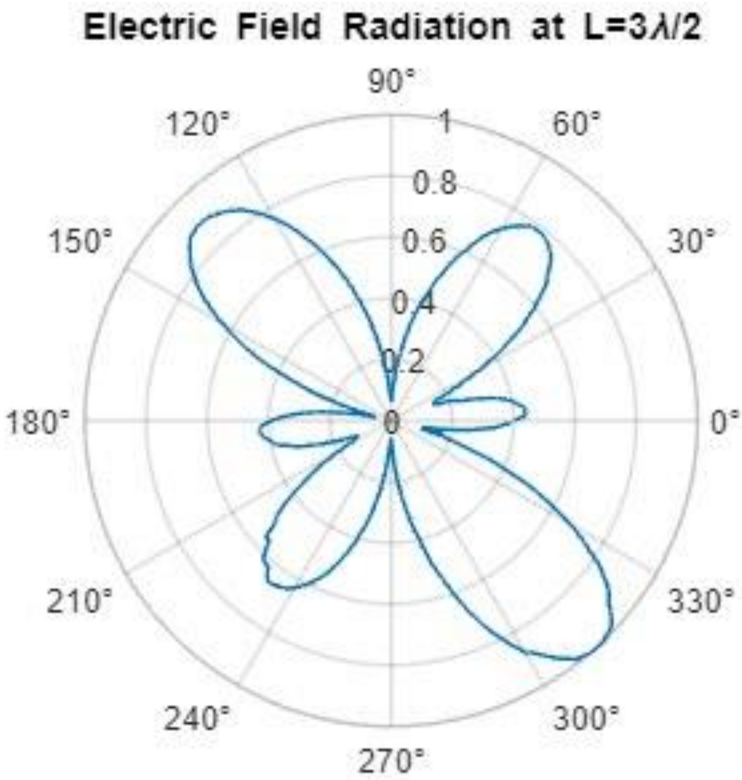




From the practical lab ,we realized the radiation pattern of the three different cases(when L<<λ ,L=λ/2 and L=3λ/2).



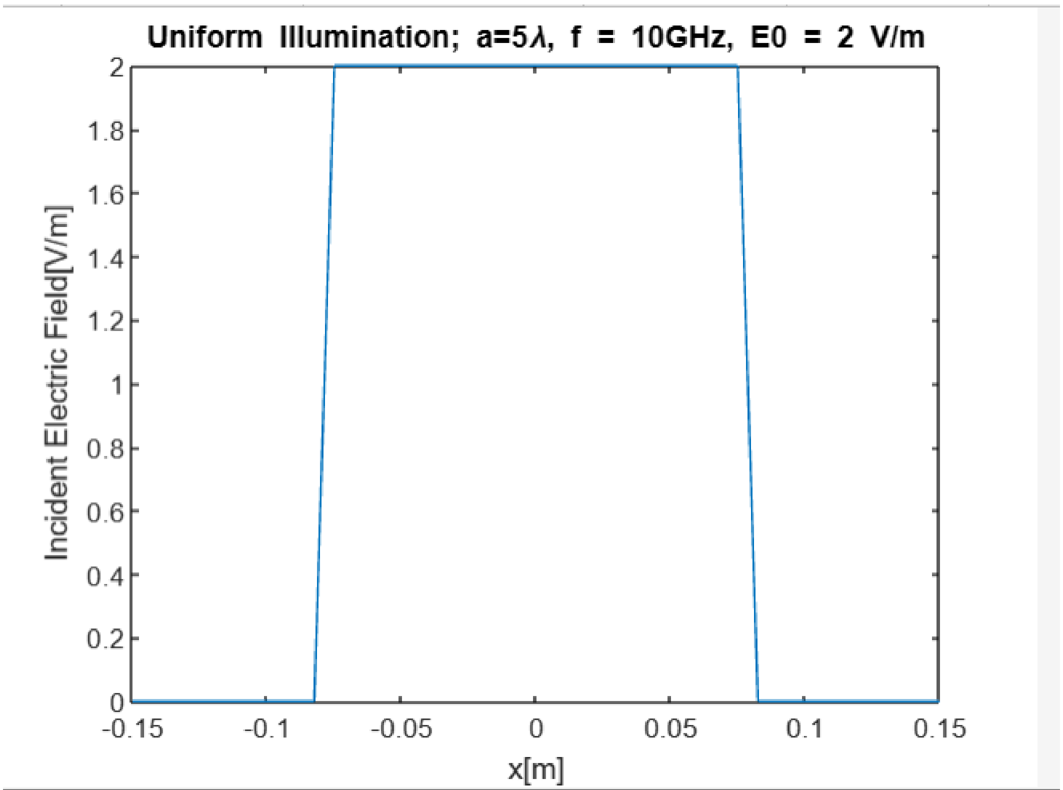




Aperture Antenna Lab

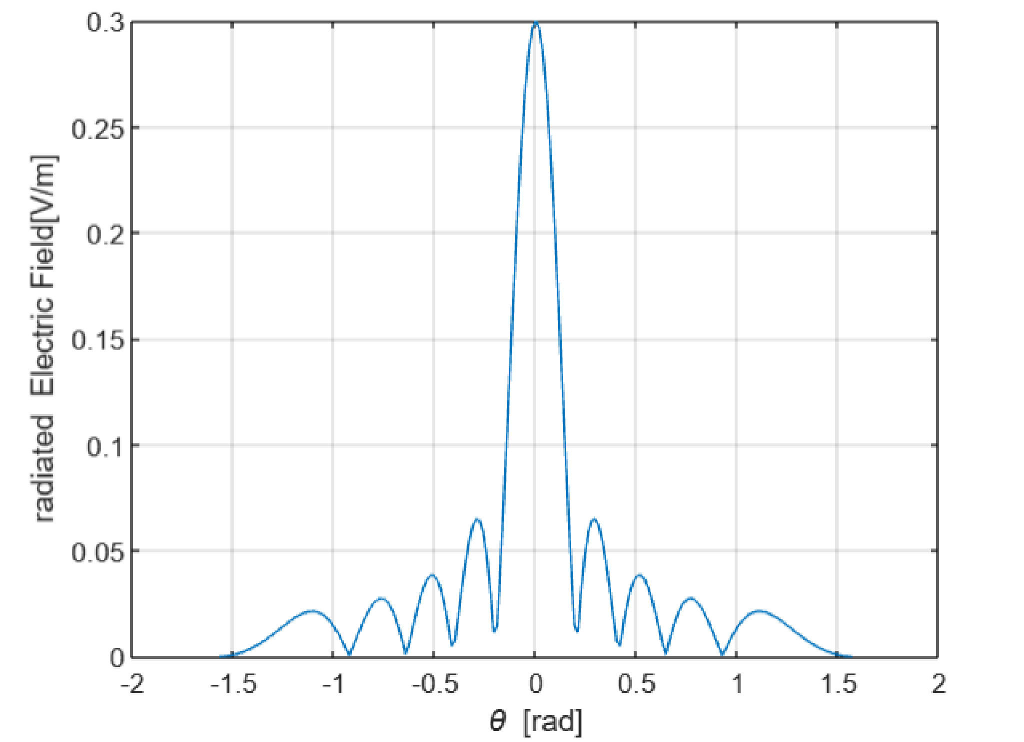
1. Implement the expression of the Incident Electric Field of an aperture antenna, with Uniform illumination:

```
E0=2;
z=0;
F=10*10^9;
c=3*10^8;
lambda=c/F;
a=5*lambda;
x1 = -a: a/20:-a/2-a/20;
x2 = -a/2: a/20:a/2;
x3 = a/2+a/20: a/20:a;
k= (2*pi)/lambda;
Ei = E0*exp(-1i*k*z);
E_inc =[zeros(1, length(x1)) ones(1, length(x2))*Ei zeros(1, length(x3))];

plot([x1 x2 x3], E_inc);

xlabel("x[m]");
ylabel("Incident Electric Field[V/m]");
%legend("uniform","Trigular","Cosine")
title('Uniform Illumination; a=5\lambda, f = 10GHz, E0 = 2 V/m')
```



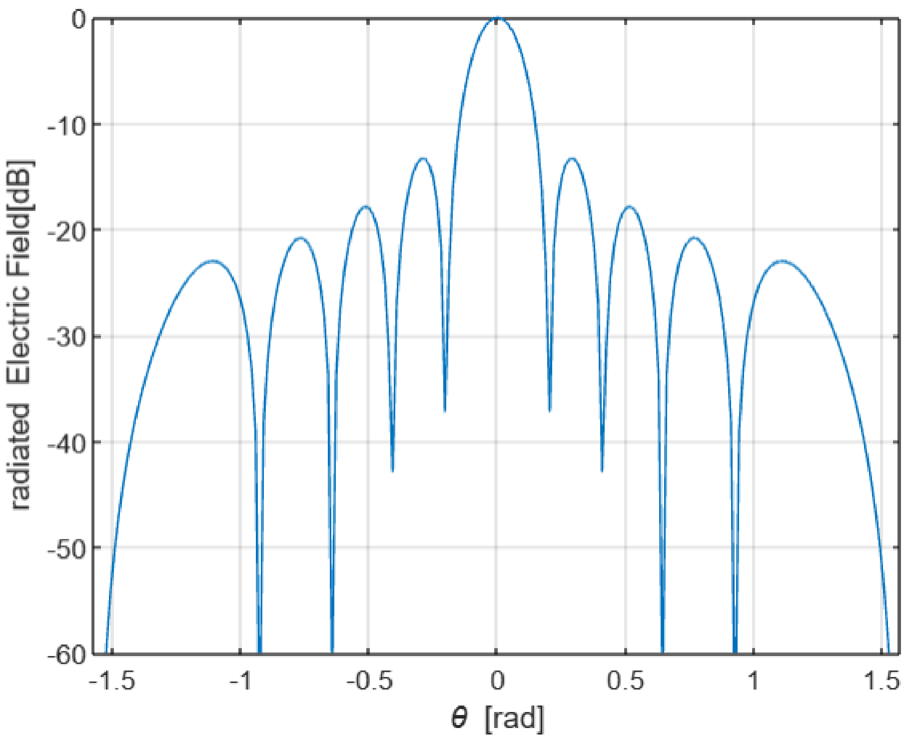
2.Implement the expression of the Radiated Field of an aperture antenna with uniform Illumination:

```
Eo=2;
z=0;
F=10*10^9;
c=3*10^8;
r= 100;
lambda=c/F;
a=5*lambda;
k= (2*pi)/lambda;
theta=-pi/2: pi/180 : pi/2;
Ei = a*Eo*exp(-1i*k*z)*sinc(k*a/2*(sin(theta))/pi);
plot(theta, abs(Ei));

grid on;

xlabel("\theta [rad]");
ylabel("radiated  Electric Field[V/m]");
```



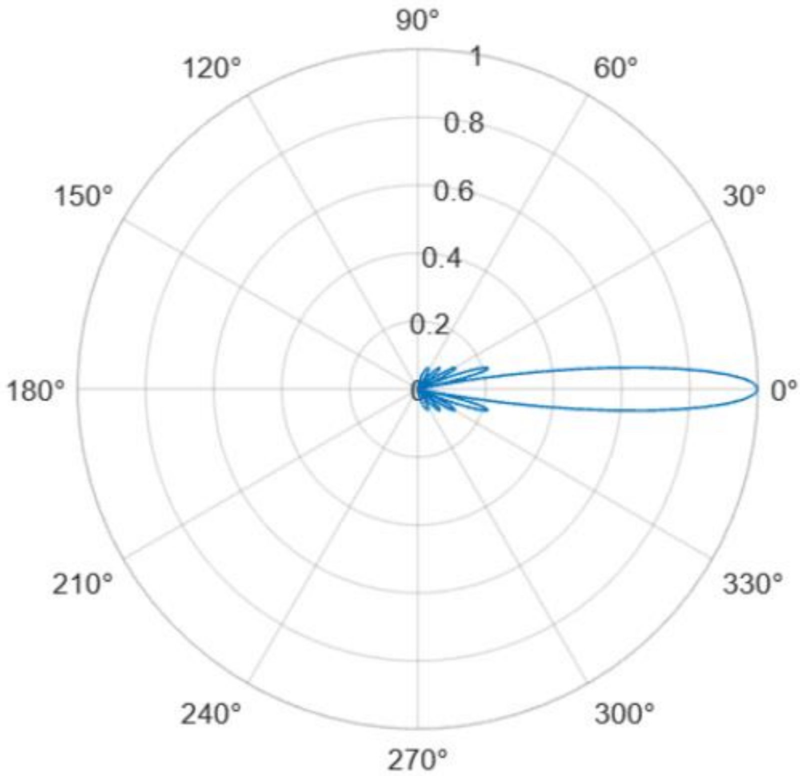
3.Implement the expression of the Radiated Field in dB of an aperture antenna with uniform Illumination:

```
Eo=2;
z=0;
F=10*10^9;
c=3*10^8;
r= 100;
lambda=c/F;
a=5*lambda;
k= (2*pi)/lambda;
theta=-pi/2: pi/200 : pi/2;
Ei = a*Eo*exp(-1i*k*z)*sinc(k*a/2*(sin(theta))/pi);

Ei_dB = 20*log10(abs(Ei)/max(abs(Ei)));
plot(theta,Ei_dB);
axis([-pi/2, pi/2, -60, 0]);

grid on;

xlabel("\theta [rad]");
ylabel("radiated  Electric Field[dB]");
```



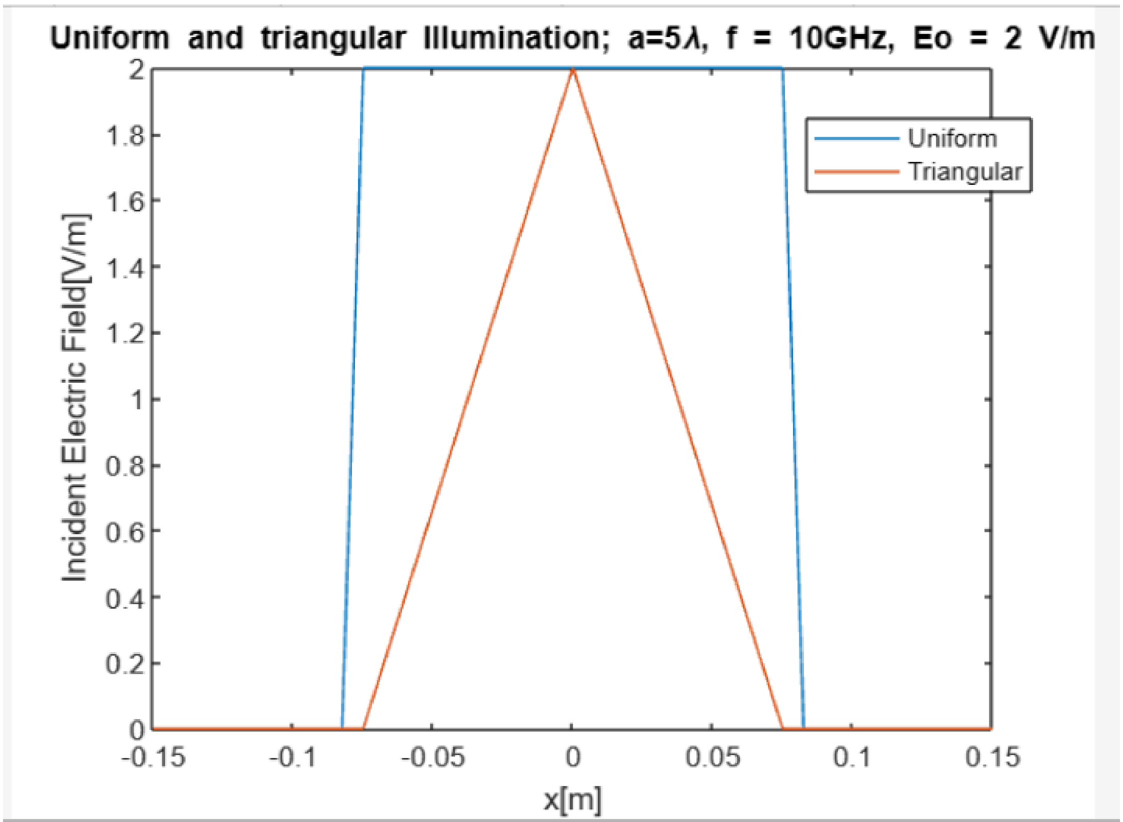
4.Implement the expression of the Radiation pattern of an aperture antenna with uniform Illumination

```
E0=2;
z=0;
F=10*10^9;
c=3*10^8;
r= 100;
lambda=c/F;
a=5*lambda;
k= (2*pi)/lambda;
theta=-pi/2:pi/200 : pi/2;

Ei = a*E0*exp(-1i*k*z)*sinc(k*a/2*(sin(theta))/pi);
Ei_dB = 20*log10(abs(Ei)/max(abs(Ei)));
%F_theta = ((a/2)*E0*exp(-
1i*k*z))*(sinc((pi/2)+(k*a/2)*(sin(theta))/pi)+sinc((pi/2)-
(k*a/2)*(sin(theta))/pi));
F_theta=sinc(((k*a/2)*sin(theta))/pi);
%plot(theta,Ei_dB);
%axis([-pi/2, pi/2, -60, 0]);
polarplot(theta, abs(F_theta));
grid on;
```



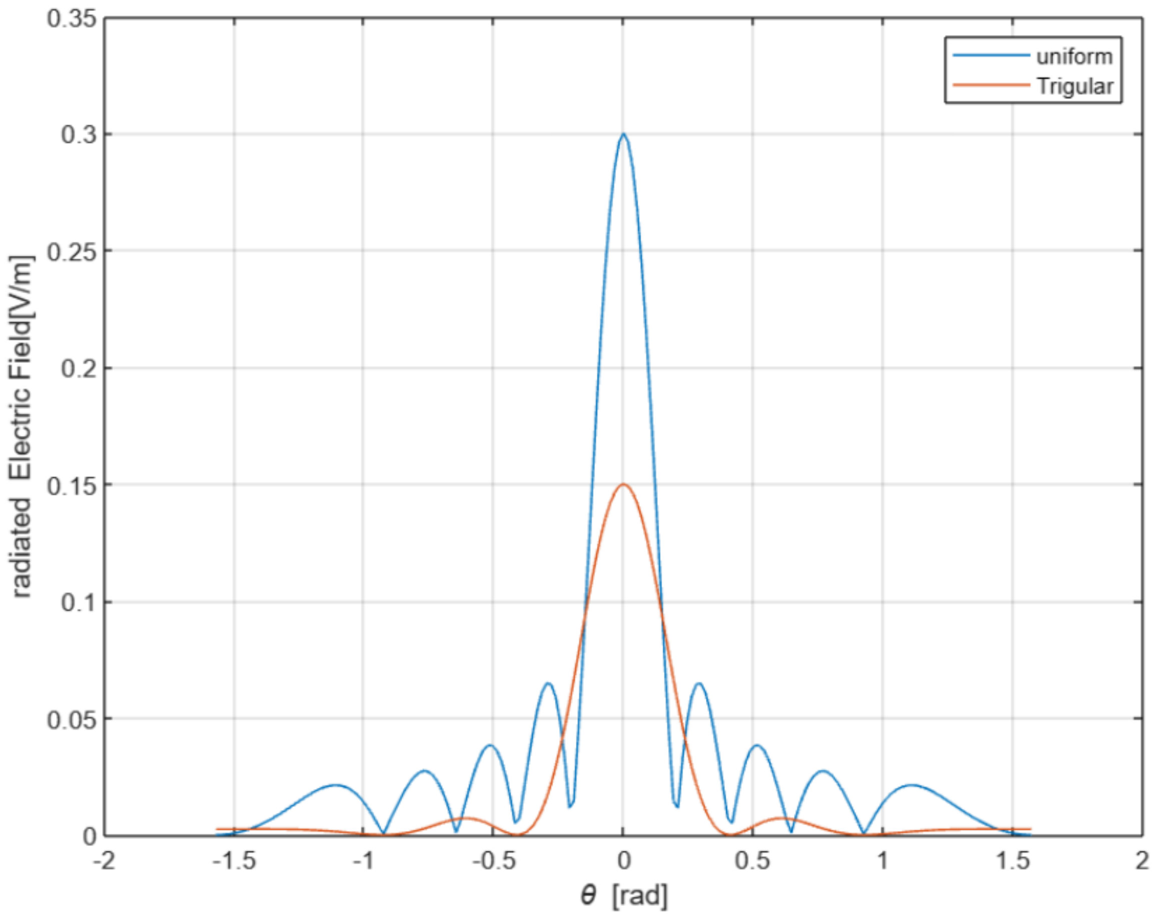
5.Implement the expression of the Incident Electric Field of an aperture antenna, with Triangular illumination

```
E0=2;
z=0;
F=10*10^9;
c=3*10^8;
lambda=c/F;
a=5*lambda;
x1 = -a: a/20:-a/2-a/20;
x2 = -a/2: a/20:a/2;
x3 = a/2+a/20: a/20:a;
k= (2*pi)/lambda;
Ei = E0*exp(-1i*k*z);
Ei_T = (1-abs(x2)/(a/2))*E0*exp(-1i*k*z);

E_inc =[zeros(1,length(x1)) ones(1,length(x2)).*Ei zeros(1, length(x3))];
E_inc_T =[zeros(1,length(x1)) ones(1,length(x2)).*Ei_T zeros(1, length(x3))];

plot([x1 x2 x3], abs(E_inc));
hold on;
plot([x1 x2 x3], abs(E_inc_T));

xlabel("x[m]");
ylabel("Incident Electric Field[V/m]");
title('Uniform and triangular Illumination; a=5\lambda, f = 10GHz, Eo = 2 V/m')
legend("Uniform","Triangular");
```



6. Implement the expression of the Radiated Field of an aperture antenna with Triangular Illumination.

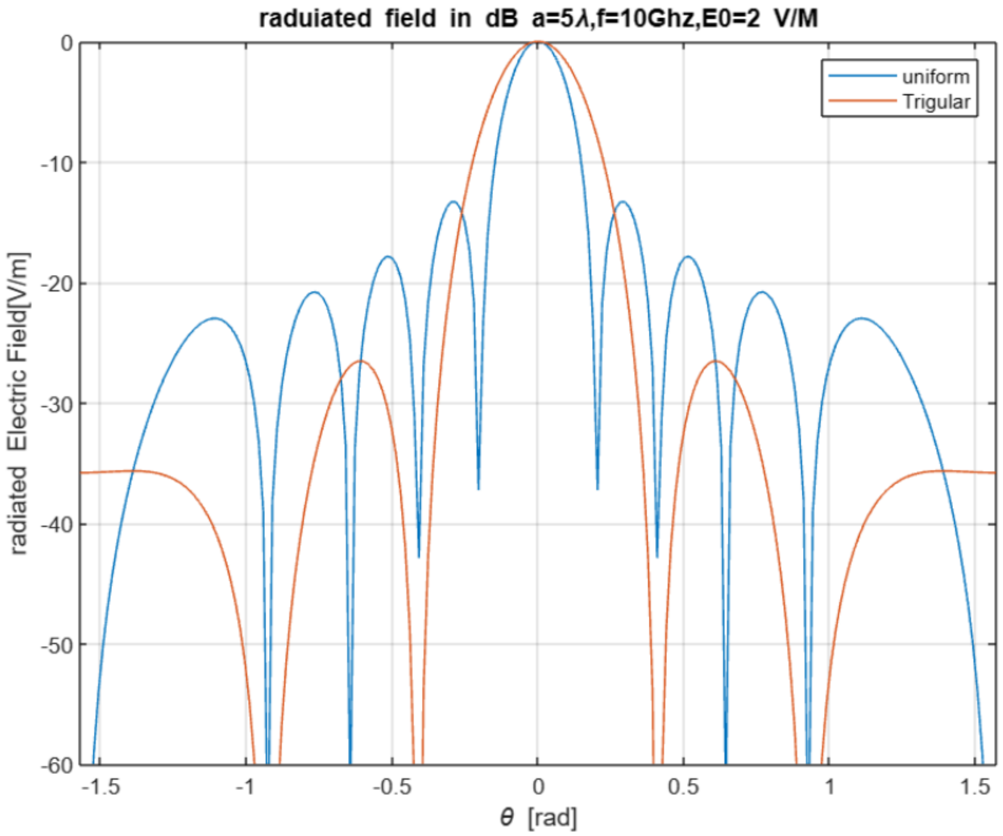
```
E0=2;
z=0;
F=10*10^9;
c=3*10^8;
r= 100;
lambda=c/F;
a=5*lambda;
k= (2*pi)/lambda;
theta=-pi/2: pi/180 : pi/2;

Ei = a*E0*exp(-1i*k*r)*sinc(k*a/2*(sin(theta))/pi);
Ei_T = (a/2)*E0*exp(-1i*k*r)*(sinc(k*a/4*(sin(theta))/pi)).^2;
%Ei_C = (a/2)*E0*exp(-
1i*k*r)*((sinc(((pi/2)+(k*a/2)*(sin(theta)))/pi))+(sinc(((pi/2)-
(k*a/2)*(sin(theta))/pi))));


plot(theta, abs(Ei));
hold on;
plot(theta, abs(Ei_T));
%hold on;
%plot(theta, abs(Ei_C));
grid on;

xlabel("\theta [rad]");
ylabel("radiated  Electric Field[V/m]");
legend("uniform","Trigular",'cosine')
```



7.Implement the expression of the Radiated Field in dB of an aperture antenna with Triangular Illumination.

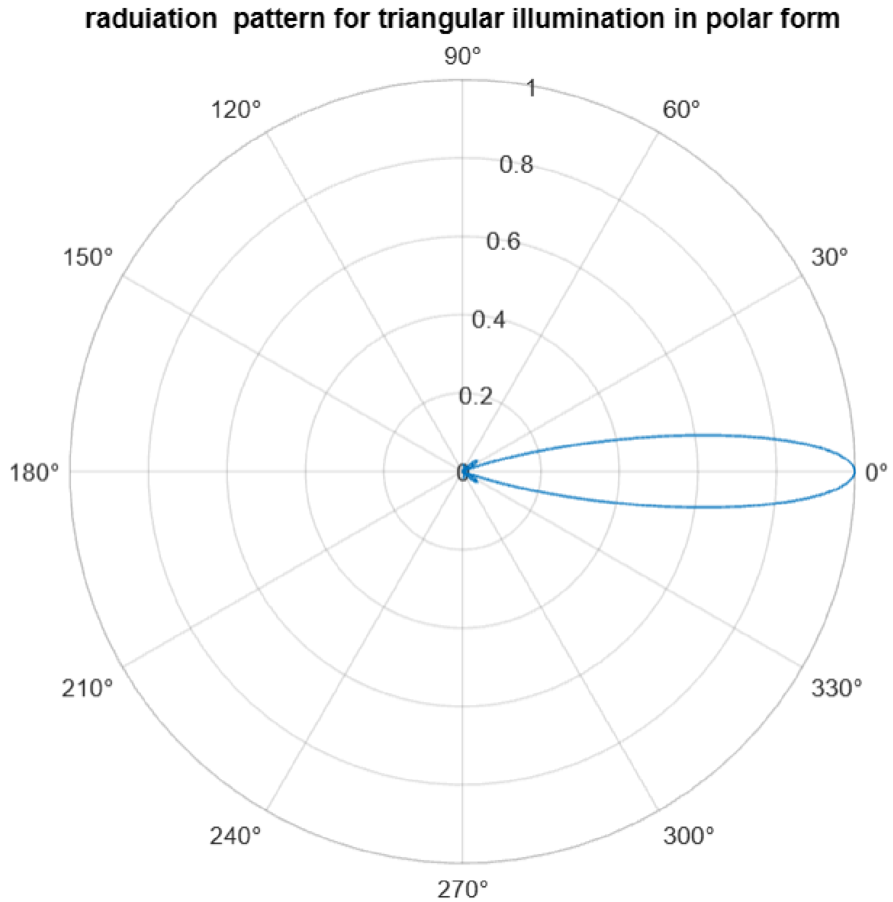
```
E0=2;
z=0;
F=10*10^9;
c=3*10^8;
r= 100;
lambda=c/F;
a=5*lambda;
k= (2*pi)/lambda;
theta=-pi/2: pi/200 : pi/2;

Ei = a*E0*exp(-1i*k*z)*sinc(k*a/2*(sin(theta))/pi);
Ei_T = (a/2)*E0*exp(-1i*k*z)*(sinc(k*a/4*(sin(theta))/pi)).^2;
Ei_T_dB = 20*log10(abs(Ei_T)/max(abs(Ei_T)));
Ei_dB = 20*log10(abs(Ei)/max(abs(Ei)));
F_theta = sinc(k*a/2*(sin(theta))/pi);

plot(theta,Ei_dB);
hold on
plot(theta,Ei_T_dB);

axis([-pi/2, pi/2, -60, 0]);
%polarplot(theta, F_theta);
grid on;
xlabel("\theta [rad]");
```

```
ylabel("radiated  Electric Field[V/m]");
legend("uniform","Trigular")
title("raduiated field in dB a=5\lambda,f=10Ghz,E0=2 V/M")
```



8.Implement the expression of the Radiation pattern of an aperture antenna with Triangular Illumination

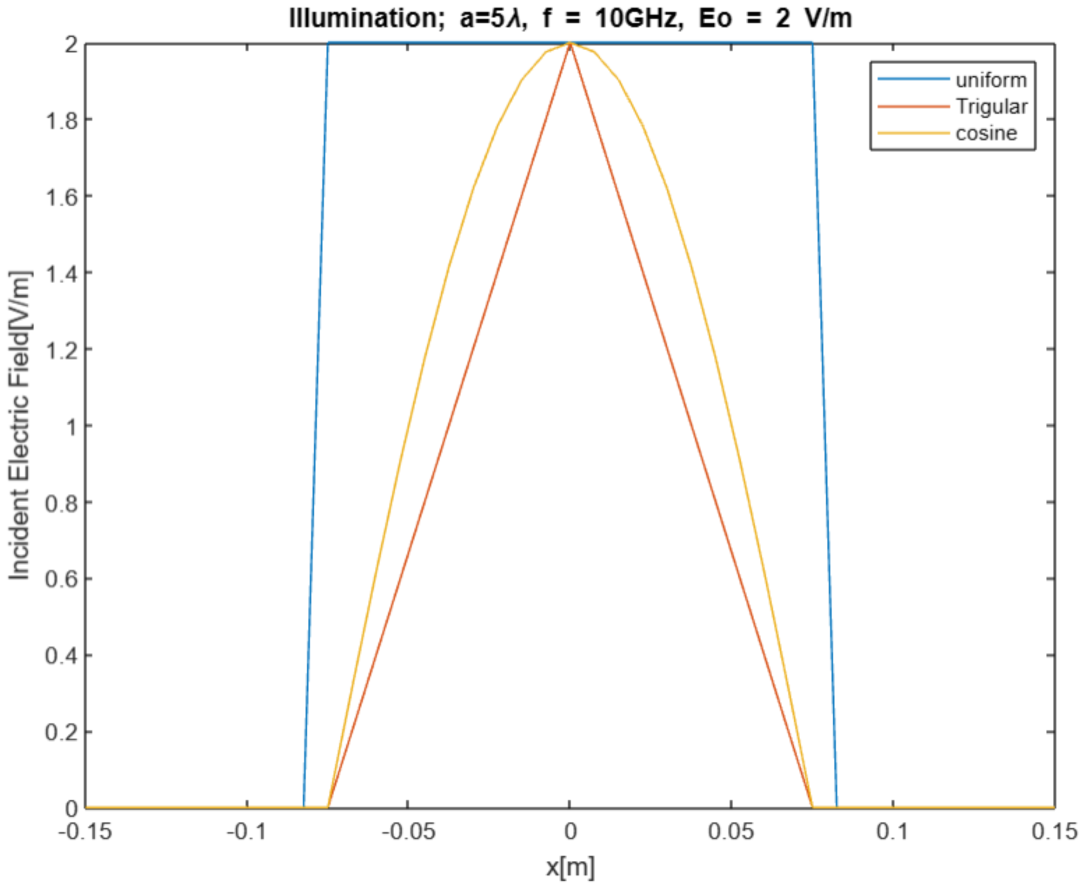
```
E0=2;
z=0;
F=10*10^9;
c=3*10^8;
r= 100;
lambda=c/F;
a=5*lambda;
k= (2*pi)/lambda;
theta=-pi/2: pi/200 : pi/2;
F_theta = (sinc(k*a/4*(sin(theta))/pi)).^2;
polarplot(theta,F_theta);
title("raduiation  pattern for triangular illumination in polar form")
```



9.Implement the expression of the Incident Electric Field of an aperture antenna, with Cosine illumination

```
Eo=2;
z=0;
F=10*10^9;
c=3*10^8;
lambda=c/F;
a=5*lambda;
x1 = -a: a/20:-a/2-a/20;
x2 = -a/2: a/20:a/2;
x3 = a/2+a/20: a/20:a;
k= (2*pi)/lambda;
Ei = Eo*exp(-1i*k*z);
Ei_T = (1-abs(x2)/(a/2))*Eo*exp(-1i*k*z);
Ei_C = cos(pi*x2/a)*Eo*exp(-1i*k*z);

E_inc =[zeros(1,length(x1)) ones(1,length(x2)).*Ei zeros(1, length(x3))];
E_inc_T =[zeros(1,length(x1)) ones(1,length(x2)).*Ei_T zeros(1, length(x3))];
E_inc_C =[zeros(1,length(x1)) ones(1,length(x2)).*Ei_C zeros(1, length(x3))];



plot([x1 x2 x3], abs(E_inc));
hold on;
plot([x1 x2 x3], abs(E_inc_T));
hold on;
plot([x1 x2 x3], abs(E_inc_C));
```

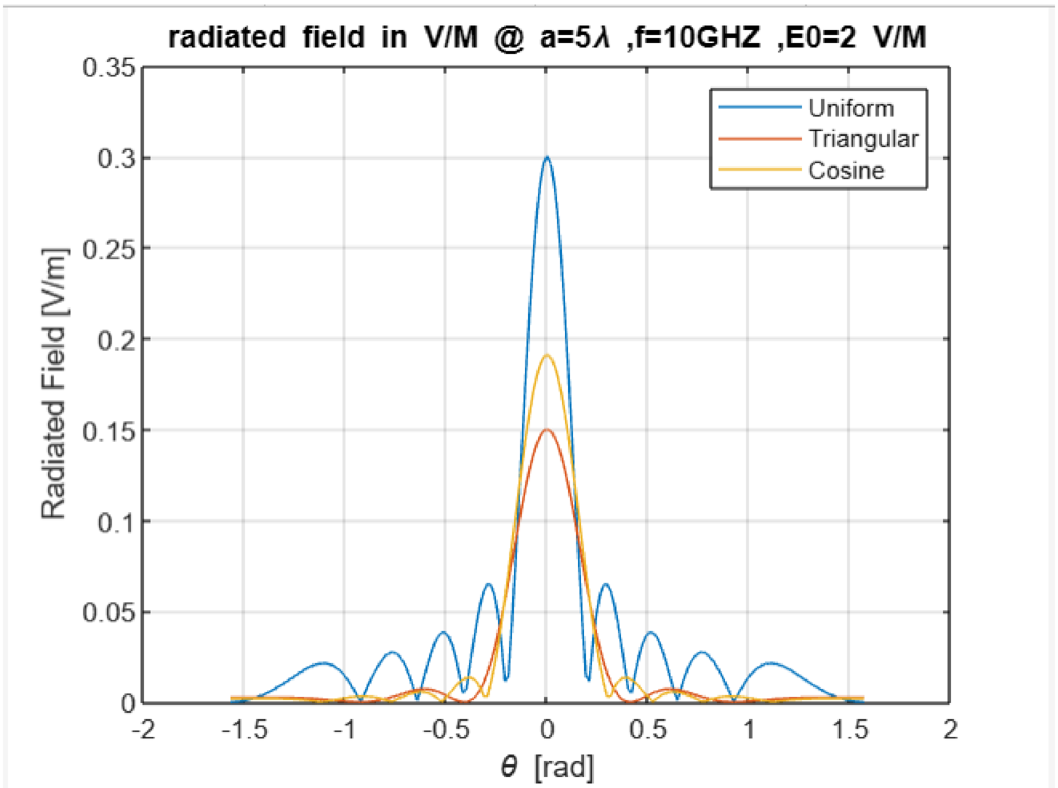
```
xlabel("x[m]");
ylabel("Incident Electric Field[V/m]");
legend("uniform","Trigular","cosine")
title("Illumination; a=5\lambda, f = 10GHz, Eo = 2 V/m")
```



10.Implement the expression of the Radiated Field of an aperture antenna with Cosine Illumination.

```
% Parameters
E0 = 2;
z = 0;
F = 10 * 10^9;
c = 3 * 10^8;
r = 100;
lambda = c / F;
a = 5 * lambda;
k = (2 * pi) / lambda;

% Define theta values
theta = -pi/2 : pi/180 : pi/2;

% Calculate the radiated electric field for different distributions
E_uniform = a * E0 * exp(-1i * k * r) * sinc(k * a / 2 * sin(theta) / pi);
E_triangular = (a / 2) * E0 * exp(-1i * k * r) * (sinc(k * a / 4 * sin(theta) /
pi)).^2;
x=sinc(((pi/2)+k*(a/2)*sin(theta))/pi);
y=sinc(((pi/2)-k*(a/2)*sin(theta))/pi);
%E_cosine = (a / 2) * E0 * exp(-1i * k * r) *((sinc((pi/2) + (k * a / 2) *
sin(theta)) / pi) + (sinc((pi/2) - (k * a / 2) * sin(theta)) / pi));
```

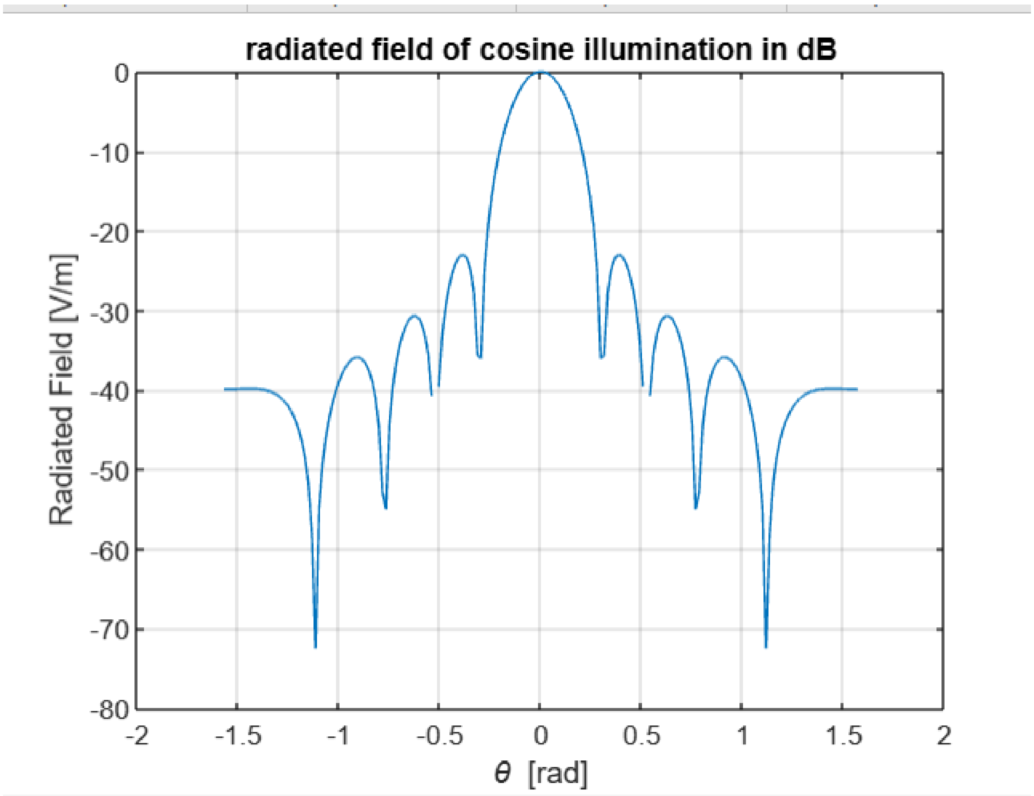
```
E_cosine = (a / 2) * E0 * exp(-1i * k * r)*(x+y);
% Plot the radiated electric field for different distributions
figure;
plot(theta, abs(E_uniform));
hold on;
plot(theta, abs(E_triangular));
hold on;
plot(theta, abs(E_cosine));

grid on;
xlabel('\theta [rad]');
ylabel('Radiated Field [V/m]');
title('radiated field in V/M @ a=5\lambda ,f=10GHZ ,E0=2 V/M');
legend('Uniform', 'Triangular', 'Cosine');
```



11.Implement the expression of the Radiated Field in dB of an aperture antenna with cosine Illumination.

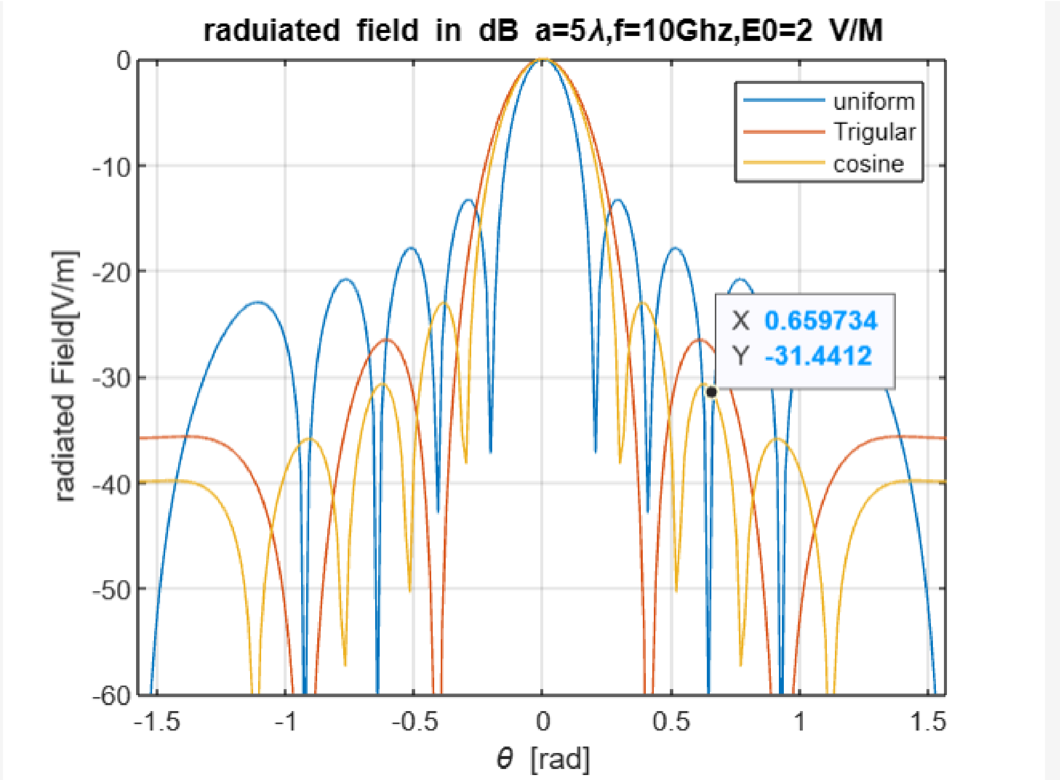
```
% Parameters
E0 = 2;
z = 0;
F = 10 * 10^9;
c = 3 * 10^8;
r = 100;
lambda = c / F;
a = 5 * lambda;
k = (2 * pi) / lambda;

% Define theta values
```

```
theta = -pi/2 : pi/180 : pi/2;

% Calculate the radiated electric field for different distributions
E_uniform = a * E0 * exp(-1i * k * r) * sinc(k * a / 2 * sin(theta) / pi);
E_triangular = (a / 2) * E0 * exp(-1i * k * r) * (sinc(k * a / 4 * sin(theta) /
pi)).^2;
x=sinc(((pi/2)+k*(a/2)*sin(theta))/pi);
y=sinc(((pi/2)-k*(a/2)*sin(theta))/pi);
%E_cosine = (a / 2) * E0 * exp(-1i * k * r) *((sinc((pi/2) + (k * a / 2) *
sin(theta)) / pi) + (sinc((pi/2) - (k * a / 2) * sin(theta)) / pi));
E_cosine = (a / 2) * E0 * exp(-1i * k * r)*(x+y);
E_dB = 20*log10(abs(E_cosine)/max(abs(E_cosine)));
% Plot the radiated electric field for different distributions
figure;
axis([-pi/2, pi/2, -60, 0]);
plot(theta, (E_dB));

grid on;
xlabel('\theta [rad]');
ylabel('Radiated Field [V/m]');
title('radiated field of cosine illumination in dB');
%legend('Uniform', 'Triangular', 'Cosine');
```



12.Implement the expression of the Radiated Field in dB of an aperture antenna with uniform, triangular and cosine Illumination.

```
E0=2;
z=0;
F=10*10^9;
c=3*10^8;
r= 100;
lambda=c/F;
a=5*lambda;
k= (2*pi)/lambda;
theta=-pi/2: pi/200 : pi/2;

Ei = a*E0*exp(-1i*k*z)*sinc(k*a/2*(sin(theta))/pi);
Ei_T = (a/2)*E0*exp(-1i*k*z)*(sinc(k*a/4*(sin(theta))/pi)).^2;
Ei_T_dB = 20*log10(abs(Ei_T)/max(abs(Ei_T)));
Ei_dB = 20*log10(abs(Ei)/max(abs(Ei)));
F_theta = sinc(k*a/2*(sin(theta))/pi);



x=sinc(((pi/2)+k*(a/2)*sin(theta))/pi);
y=sinc(((pi/2)-k*(a/2)*sin(theta))/pi);
%E_cosine = (a / 2) * E0 * exp(-1i * k * r) *((sinc((pi/2) + (k * a / 2) *
sin(theta)) / pi) + (sinc((pi/2) - (k * a / 2) * sin(theta)) / pi));
E_cosine = (a / 2) * E0 * exp(-1i * k * r)*(x+y);
E_dB = 20*log10(abs(E_cosine)/max(abs(E_cosine)));
% Plot the radiated electric field for different distributions
figure;

plot(theta,Ei_dB);
hold on
plot(theta,Ei_T_dB);
hold on
plot(theta, (E_dB));


axis([-pi/2, pi/2, -60, 0]);
%polarplot(theta, F_theta);
grid on;
xlabel("\theta [rad]");
ylabel("radiated Field[V/m]");
legend("uniform","Trigular","cosine")
title("raduiated field in dB a=5\lambda,f=10Ghz,E0=2 V/M")
```



13.Implement the expression of the Radiation pattern of an aperture antenna with Cosine Illumination

```
E0 = 2;
z = 0;
F = 10 * 10^9;
c = 3 * 10^8;
r = 100;
lambda = c / F;
a = 5 * lambda;
k = (2 * pi) / lambda;

% Define theta values
theta = -pi/2 : pi/200 : pi/2;

%E_cosine = (a / 2) * E0 * exp(-1i * k * r) * ((sinc((pi/2) + (k * a / 2) *
sin(theta)) / pi) + (sinc((pi/2) - (k * a / 2) * sin(theta)) / pi));
F_theta = sinc(((pi/2) + k*(a/2)*sin(theta)) / pi) + sinc(((pi/2) -
k*(a/2)*sin(theta)) / pi);
F_theta_normalized = F_theta / max(abs(F_theta));

figure;
polarplot(theta, abs(F_theta_normalized));
title('Radiated Field of Cosine Illumination in Polar Form');
```

Radiated Field of Cosine Illumination in Polar Form