DIPARTIMENTO DI
INGEGNERIA INFORMATICA,
MODELLISTICA, ELETTRONICA
E SISTEMISTICA

Master’s Degree in Telecommunication Engineering: Smart Sensing, Computing and Networking

Antennas and propagation

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index

PLOT SIN AND COS FUNCTION

Exercises1

1. Graph the Sine function in [rad] and [deg], with : 0<θ<2pi 2.
2. Graph the Cosine function in [rad] and [deg], with : 0<θ<2pi
3. Graph the cos(ωt), with a frequency of 1GHz.
4. Graph the sin(ωt), with a frequency of 1GHz.

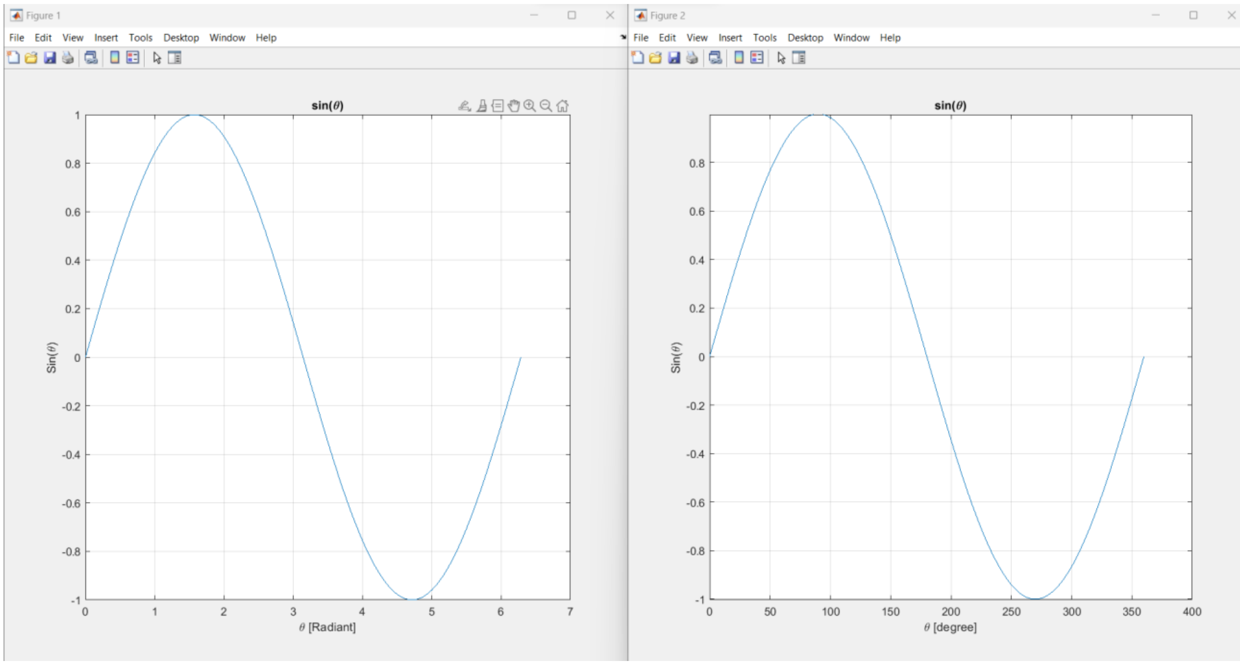
5. Graph the cos(ωt + ϕ), with a frequency of 1GHz and phase: ϕ=pi/4 and ϕ=-pi/4
6. Graph the sin(ωt + ϕ), with a frequency of 1GHz and phase: ϕ=pi/4 and ϕ=-pi/4
7. Graph the sin (ω t + ϕ), with a frequency of 1GHz and different phases using for loop: ϕ1=0 ϕ2=pi/4 ϕ3=pi/2

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

Code MATLAB:

```
x=0:pi/100:2*pi;
x1=x*180/pi;
y=sin(x);
figure
plot(x,y);
xlabel('\theta [Radiant]');
ylabel('Sin(\theta)');
title('sin(\theta)');
grid on;
y1=sind(x1);
figure
plot(x1,y1);
xlabel('\theta [degree]');
ylabel('Sin(\theta)');
title('sin(\theta)');
grid on;
```

Screenshot of the Results

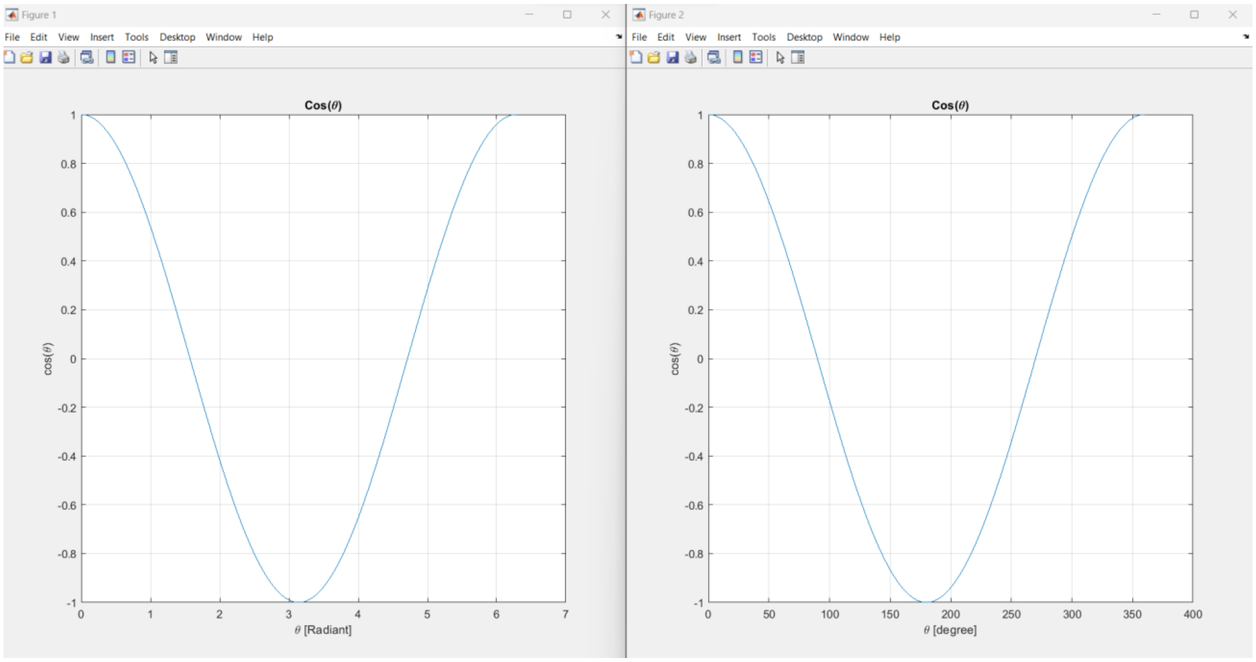


Graph the Cosine function in [rad] and [deg], with: 0<θ<2pi

Code MATLAB:

```
x=0:pi/100:2*pi;
x1=x*180/pi;
y2=cos(x);
figure
plot(x,y2);
xlabel('\theta [Radiant]');
ylabel('cos(\theta)');
title('cos(\theta)');
grid on;
y3=cosd(x1);
figure
plot(x1,y3);
xlabel('\theta [degree]');
ylabel('cos(\theta)');
title('cos(\theta)');
grid on;
```

Screenshot of the Results

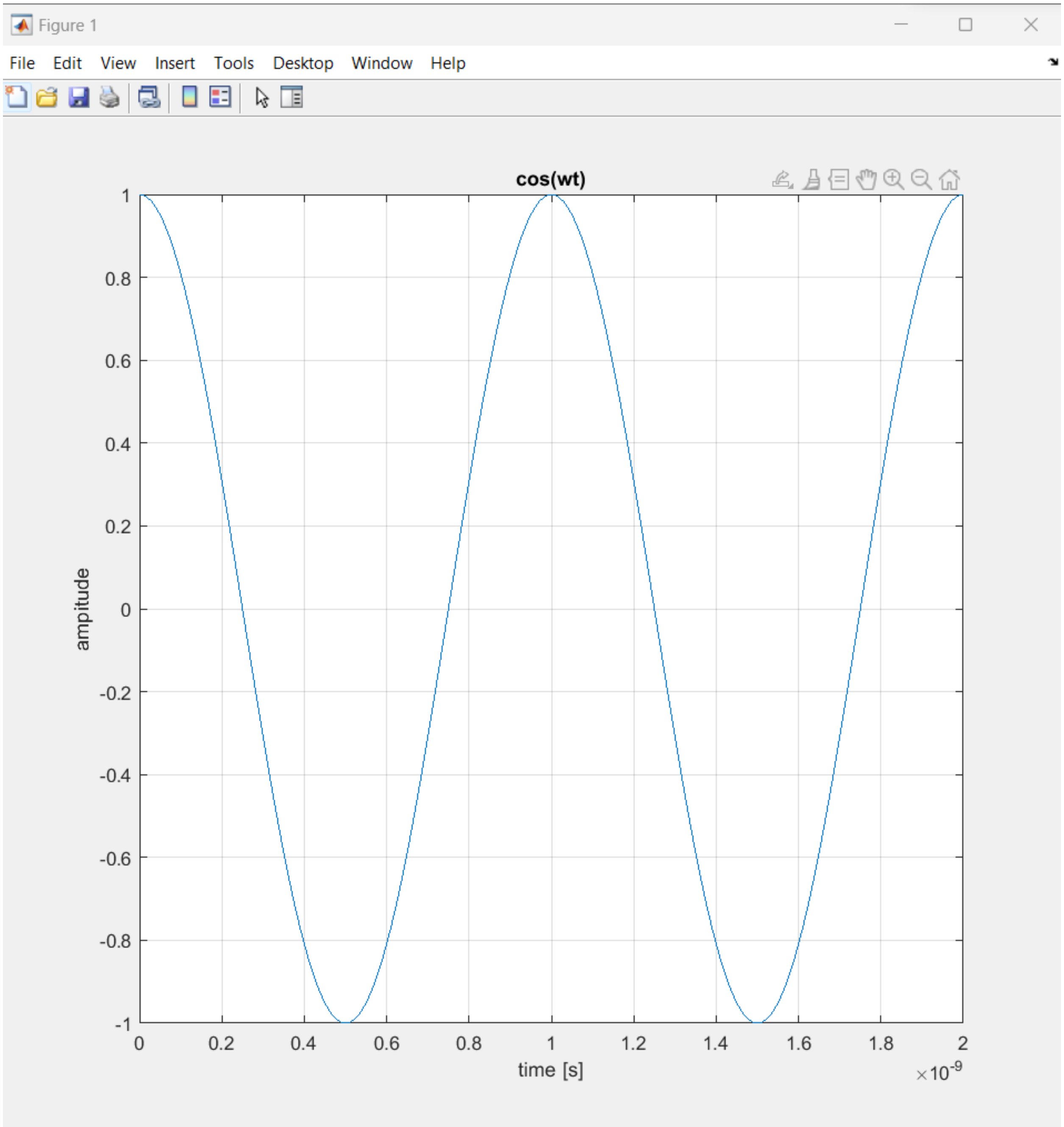


Graph the cos(ωt), with a frequency of 1GHz.

Code MATLAB:

```
f=1e9;
w=2*pi*f;
T=1/f;
t=0:T/100:2*T;
y=cos(w*t);
figure
plot(t,y);
xlabel('time [s]');
ylabel('ampitude');
title('cos(wt)');
grid on;
```

Screenshot of the Results



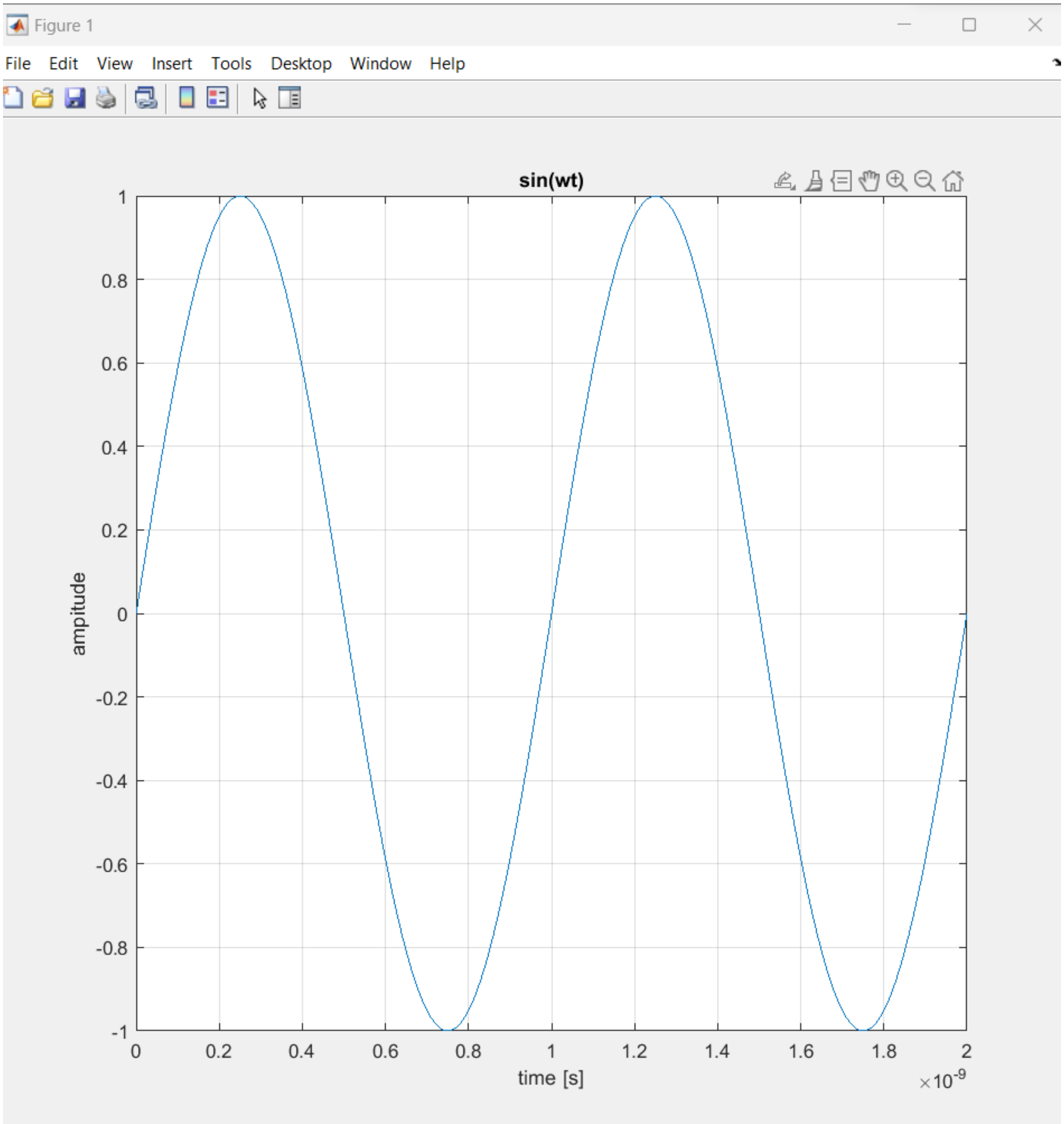
Graph the sin(ωt), with a frequency of 1GHz.

Code MATLAB:

```
f=1e9;
w=2*pi*f;
T=1/f;
y1=sin(w*t);
plot(t,y1);
xlabel('time [s]');
```

```
ylabel('ampitude');
title('sin(wt)');
grid on;
```

Screenshot of the Results

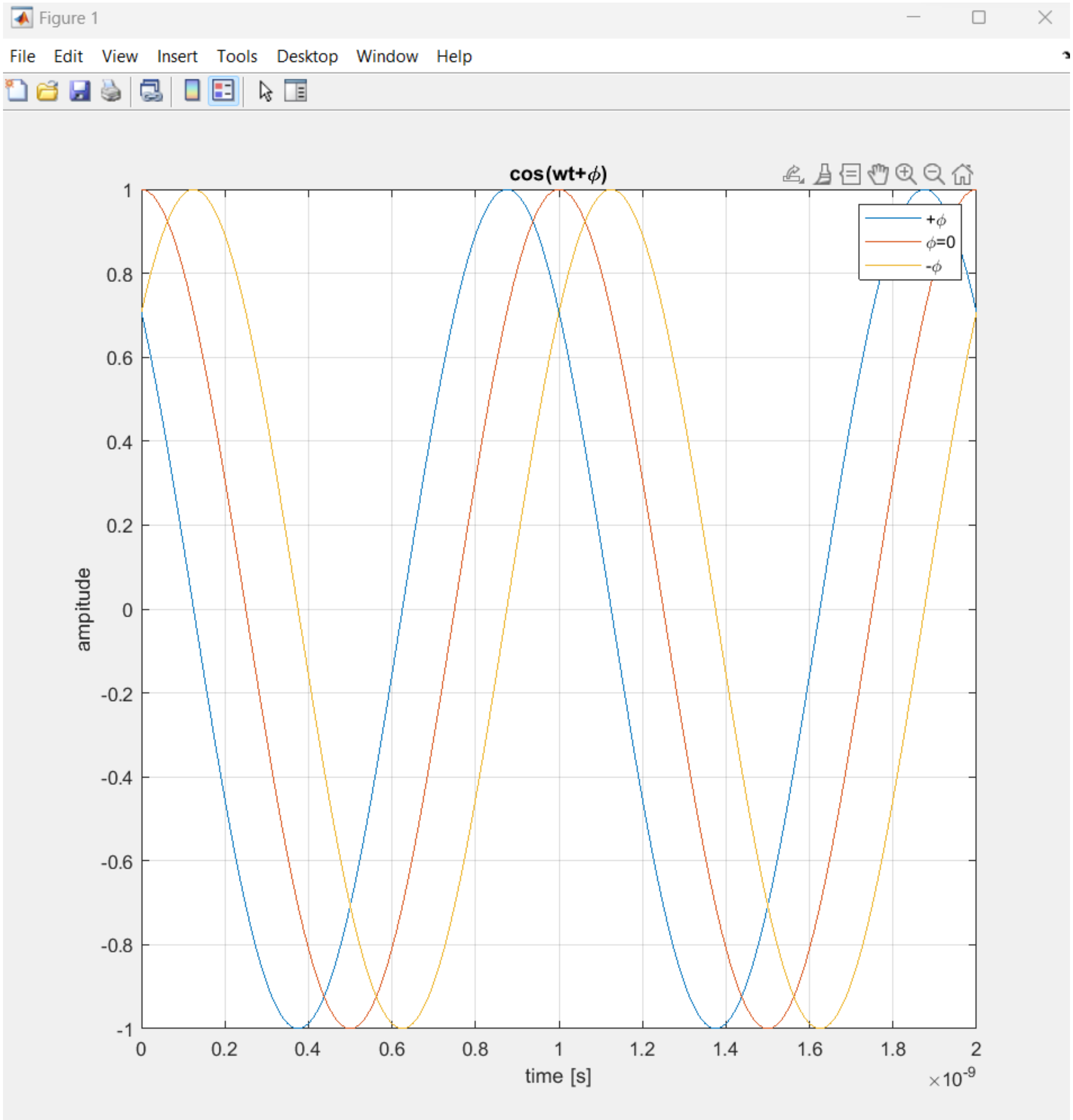


Graph the cos(ωt + ϕ), with a frequency of 1GHz and phase: ϕ=pi/4 and ϕ=-pi/4

Code MATLAB:

```
f=1e9;
w=2*pi*f;
T=1/f;
y=cos(w*t);
phi1=pi/4;
phi2=-pi/4;
y3=cos(w*t+phi1);
plot(t,y3);
xlabel('time [s]');
ylabel('ampitude');
title('cos(wt+\phi)');
grid on;
hold on;
plot(t,y);
y4=cos(w*t+phi2);
plot(t,y4);
legend('+\phi ','\phi=0','-\phi');
hold off;
```

Screenshot of the Results



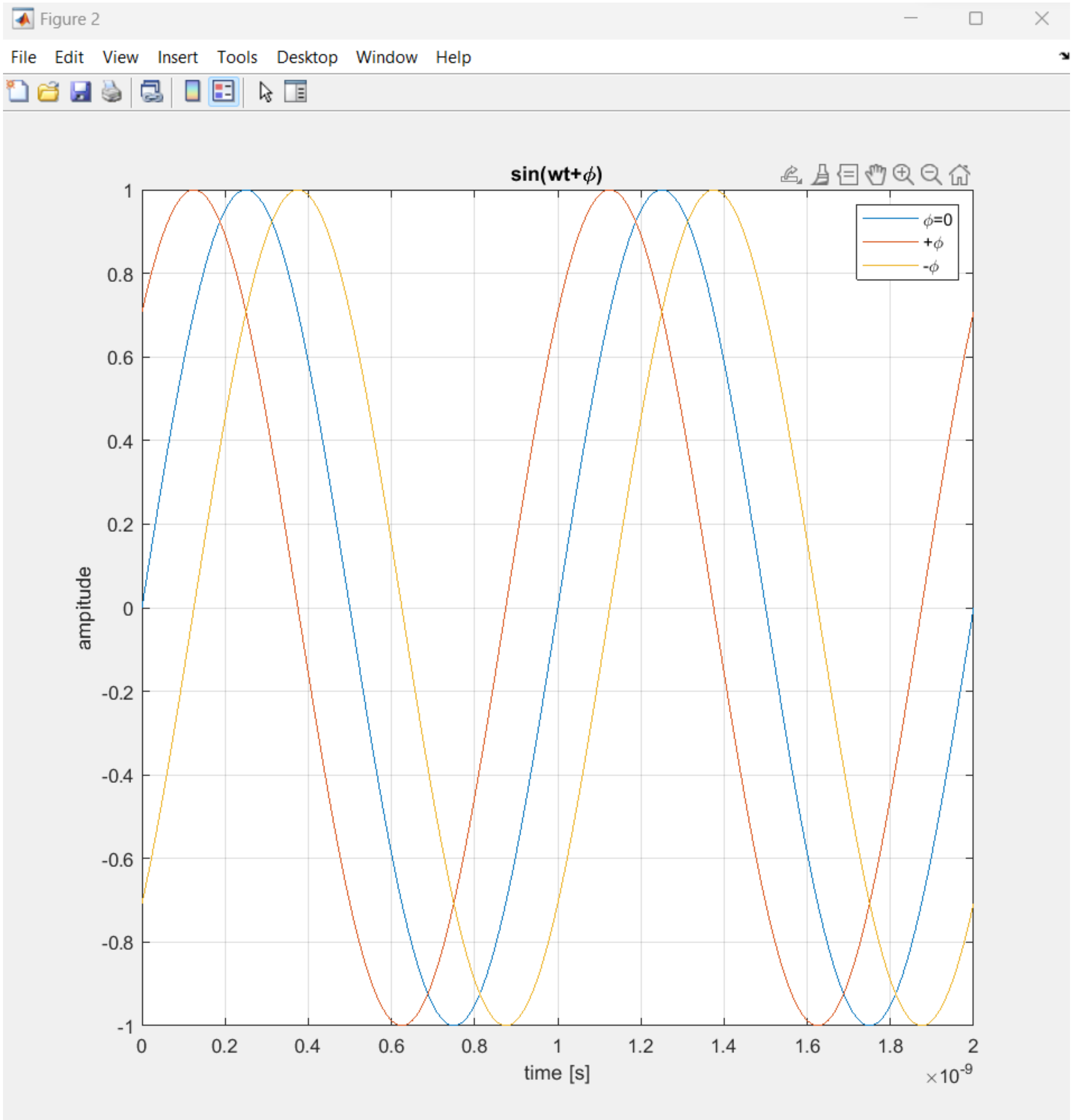
Graph the sin(ωt + ϕ), with a frequency of 1GHz and phase: ϕ=pi/4 and ϕ=-pi/4

Code MATLAB:

```
f=1e9;
w=2*pi*f;
T=1/f;
y1=sin(w*t);
phi1=pi/4;
```

```
phi2=-pi/4;
figure;
plot(t,y1);
xlabel('time [s]');
ylabel('ampitude');
title('sin(wt+\phi)');
grid on;
hold on;
y5=sin(w*t+phi1);
y6=sin(w*t+phi2);
plot(t,y5);
plot(t,y6);
legend('\phi=0','+\phi','-\phi');
```

Screenshot of the Results



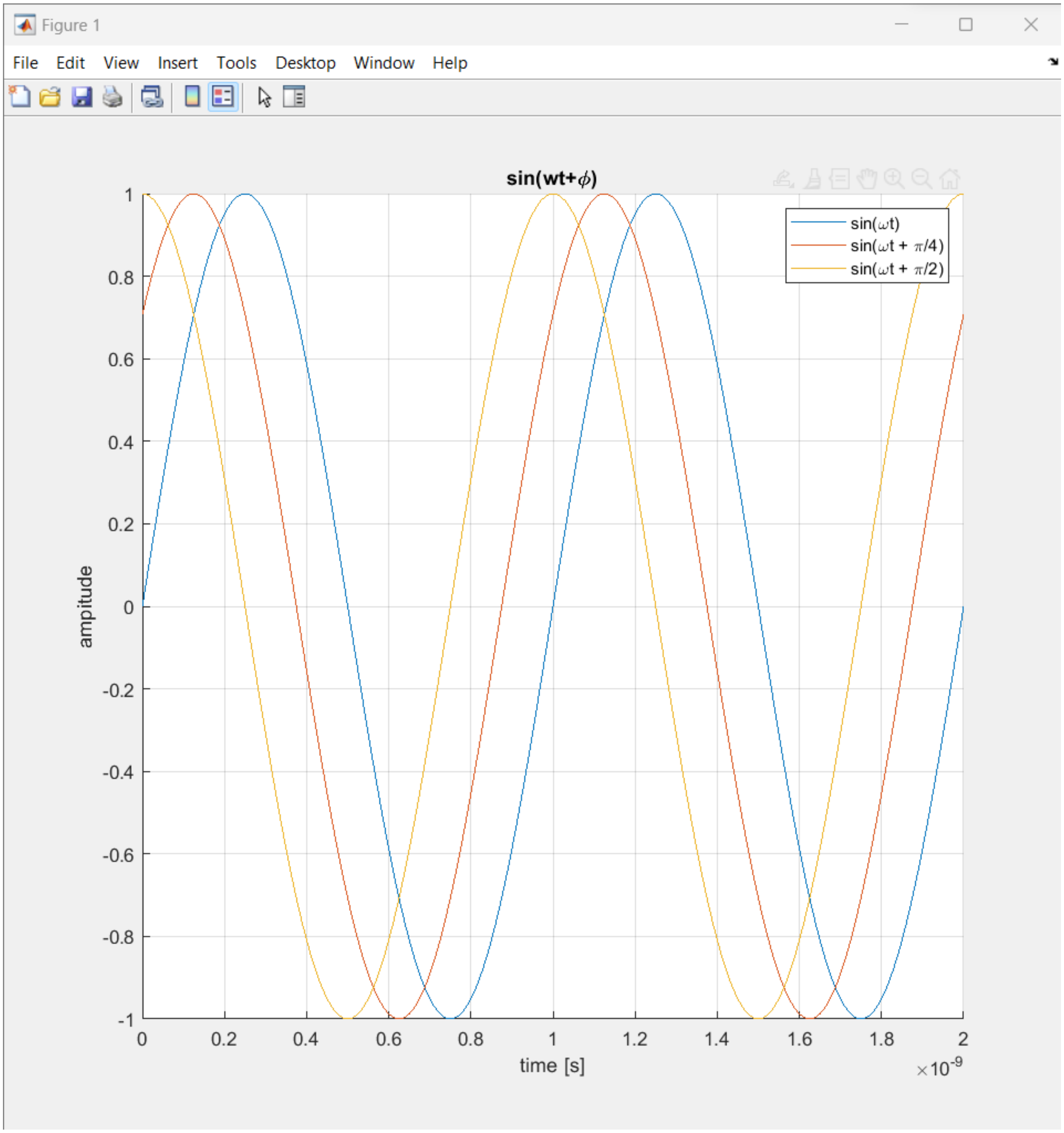
Graph the sin(ωt + ϕ), with a frequency of 1GHz and different phases using for loop: ϕ1=0 ϕ2=pi/4 ϕ3=pi/2.

Code MATLAB:

```
f=1e9;
w=2*pi*f;
T=1/f;
```

```
t=0:T/100:2*T;
phases=[0,pi/4,pi/2];
y=zeros(length(t),length(phases));
figure;
hold on;
for i=1 : length(phases)
    y(:,i)=sin(w*t+phases(i));
    plot(t,y(:,i));
end
xlabel('time [s]');
ylabel('ampitude');
title('sin(wt+\phi)');
grid on;
legend('sin(\omegat)','sin(\omegat + \pi/4)','sin(\omegat + \pi/2)');
```

Screenshot of the Results



Wave Equation

Exercise 1

8. Graph the function: $u(z,t) = A\cos(wt - kz)$; For fixed $z=z_0=0$.

all variables:

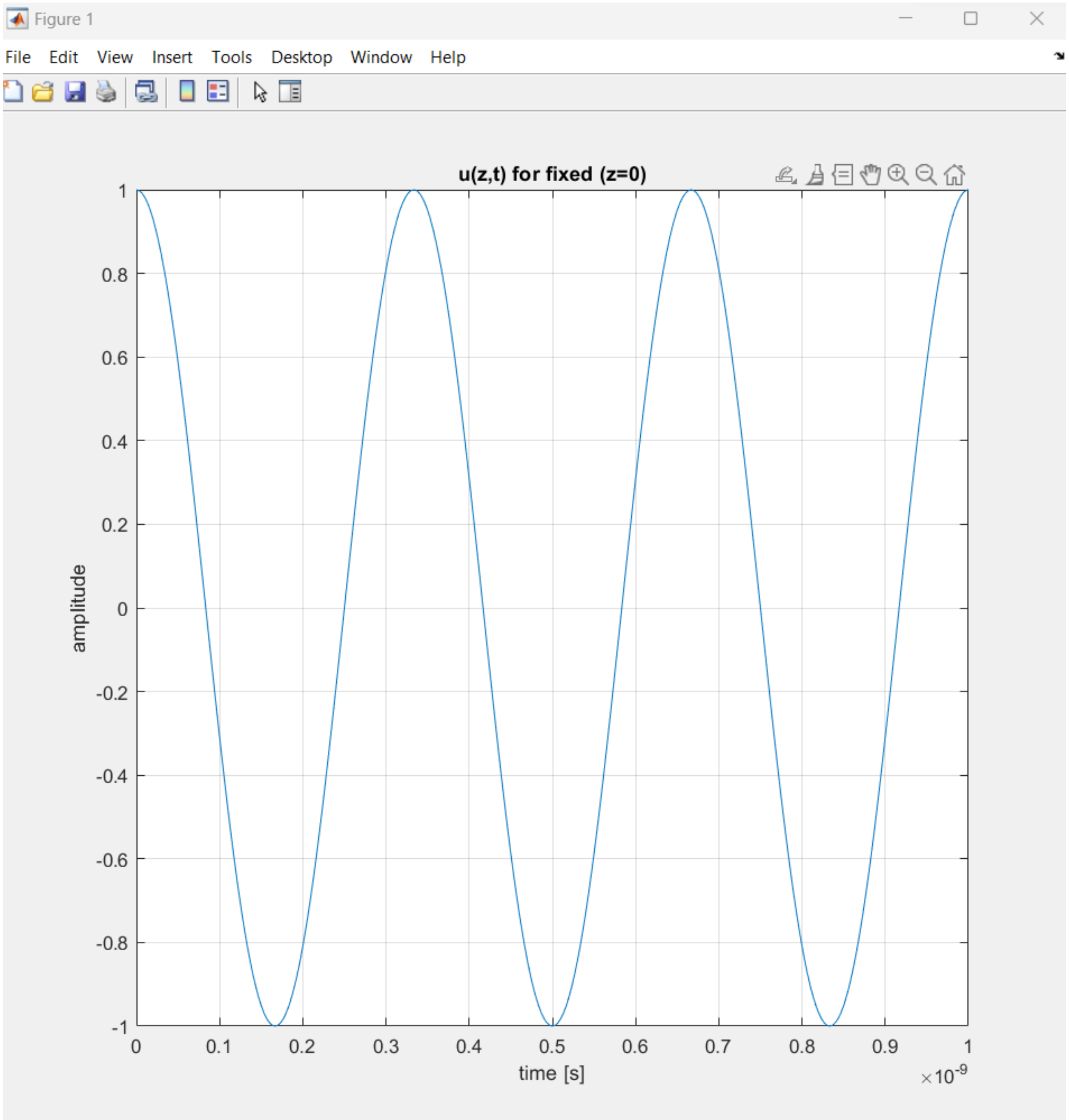
- frequency=3 [GHz]
- A=1 amplitude [m]
- ε0=8.85e-12 ->electrical permittivity free space
- μ0=pi*4e-7 ->magnetic permeability free space
- ω -> Angular frequency [rad/s]
- T -> time period [s]
- t -> time [s]
- k ->propagation constant
- C - >speed of light [m/s]
- λ ->spatial period - wavelength [m]

Graph the function: $u(z,t) = A\cos(wt - kz)$; For fixed $z=z_0=0$.

Code MATLAB:

```
f=3e9;
A=1;
e0=8.85e-12;
mu0=pi*4e-7;
w=2*pi*f;
T=1/f;
vp=1/sqrt(e0*mu0);
lamda=vp/f;
k=2*pi/lamda;
z=0;
t=0:T/100:3*T;
u=A*cos(w*t-k*z);
plot(t,u);
xlabel('time [s]');
ylabel('amplitude');
title('u(z,t) for fixed (z=0)');
grid on;
```

Screenshot of the Results



Exercise 2

9. Graph the function: $u(z,t) = A\cos(wt - kz)$; For fixed $t=t_0=0$.

all variables:

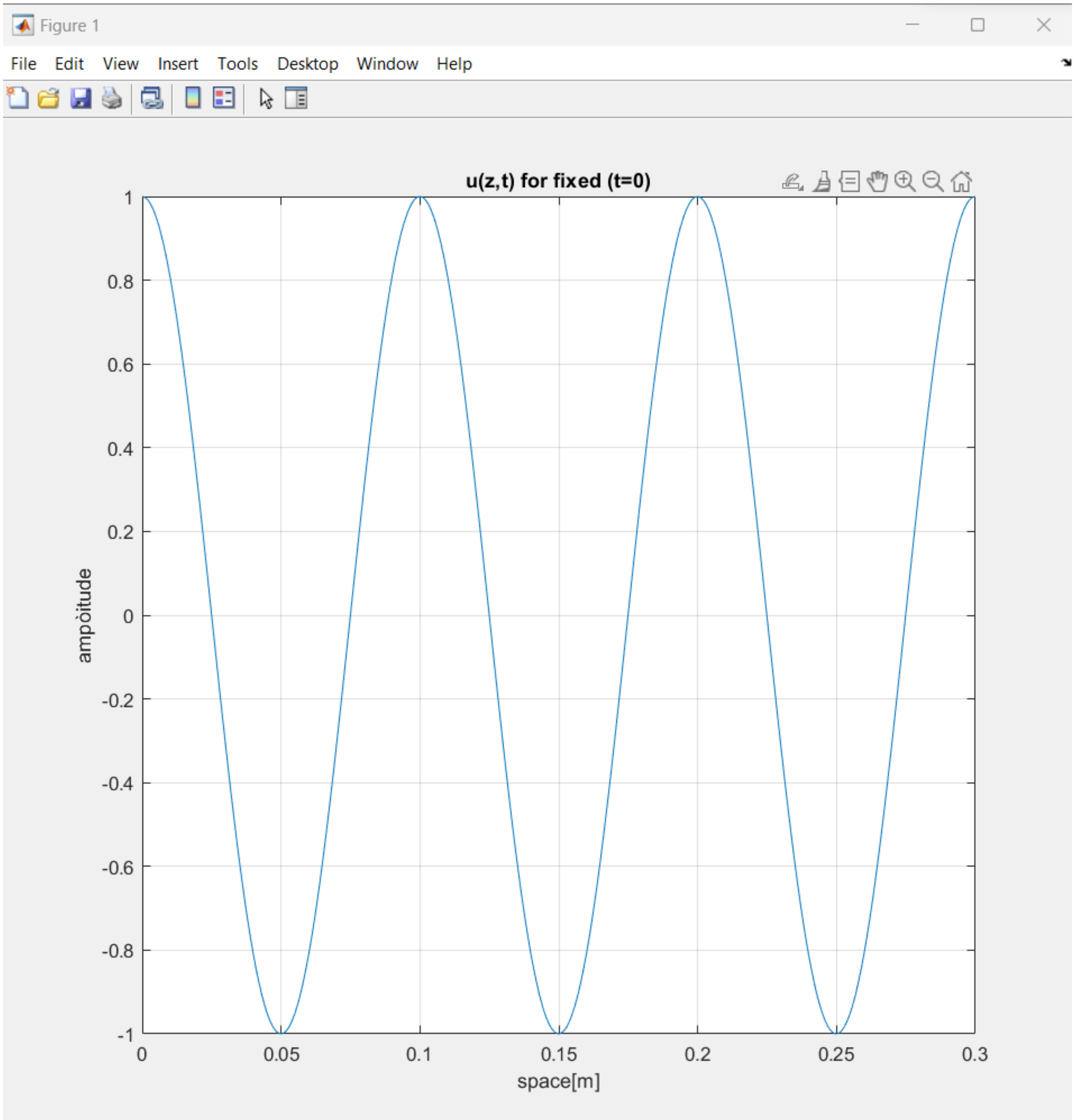
- frequency=3 [GHz]
- A=1 amplitude [m]
- ε0=8.85e-12 ->electrical permittivity free space
- μ0=pi*4e-7 ->magnetic permeability free space
- ω -> Angular frequency [rad/s]
- T -> time period [s]
- z-> space[m]
- k ->propagation constant
- C - >speed of light [m/s]
- λ ->spatial period - wavelength [m]

Graph the function: $u(z{,}t) = A\cos(wt - kz)$; For fixed t=t0=0.

Code MATLAB:

```
f=3e9;
A=1;
e0=8.85e-12;
mu0=pi*4e-7;
w=2*pi*f;
T=1/f;
vp=1/sqrt(e0*mu0);
lamda=vp/f;
k=2*pi/lamda;
t=0;
z=0:lamda/100:3*lamda;
u=A*cos(w*t-k*z);
plot(z,u);
xlabel('space[m]');
ylabel('ampòitude');
title('u(z,t) for fixed (t=0)');
grid on;
```

Screenshot of the Results



Exercise 3

10. Graph the function in 3-D: $u(z,t) = A\cos(wt - kz)$;

all variables:

- frequency=3 [GHz]
- A=1 amplitude [m]

- ε0=8.85e-12 ->electrical permittivity free space
- μ0=pi*4e-7 ->magnetic permeability free space
- ω -> Angular frequency [rad/s]
- T -> time period [s]
- z-> space[m]
- t-> time[s]
- k ->propagation constant
- C - >speed of light [m/s]
- λ ->spatial period - wavelength [m]

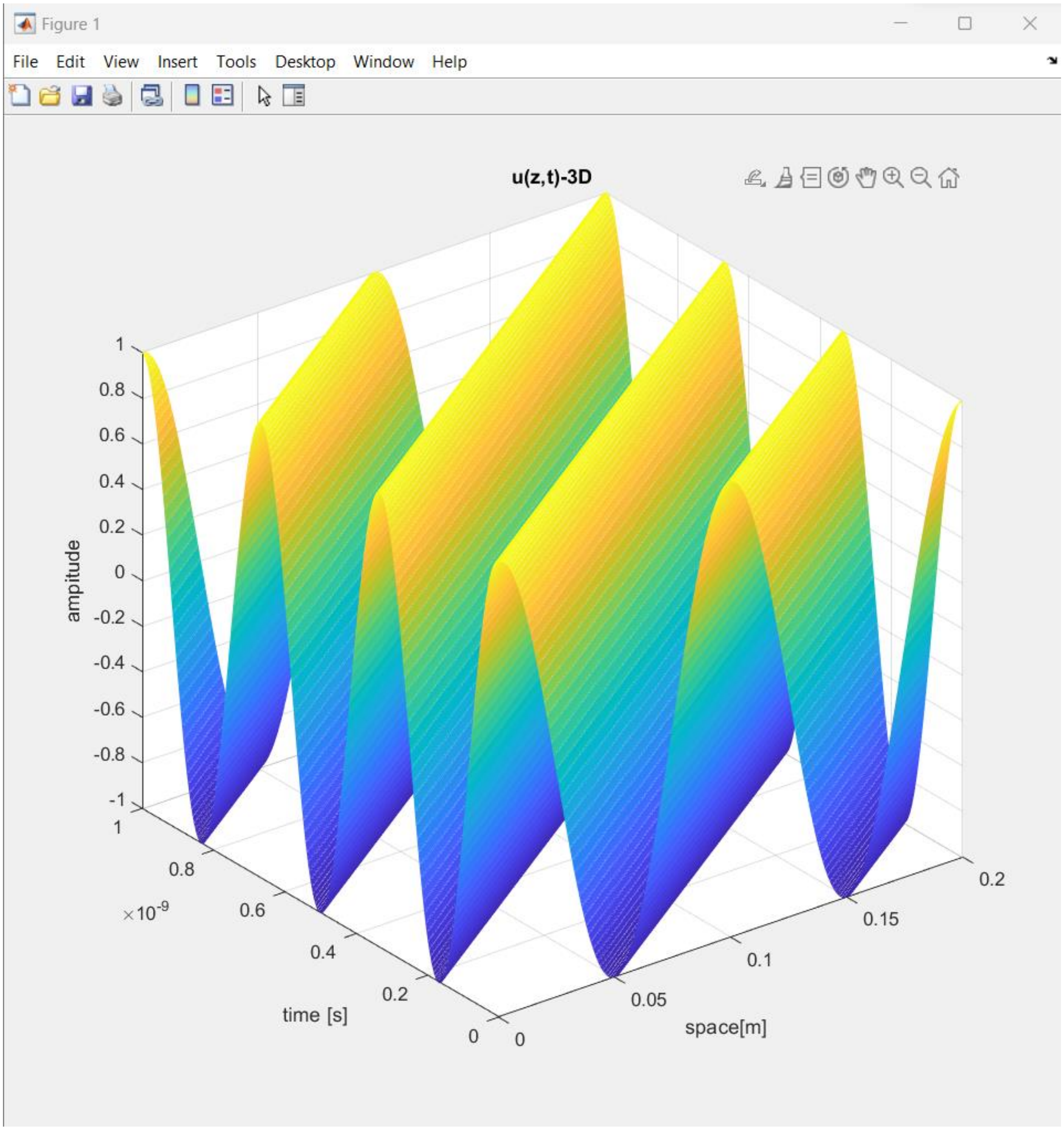
Graph the function in 3-D:

$u(z,t) = A\cos(wt\text{-}kz)$;

Code MATLAB:

```
f=3e9;
A=1;
e0=8.85e-12;
mu0=pi*4e-7;
w=2*pi*f;
T=1/f;
vp=1/sqrt(e0*mu0);
lamda=vp/f;
k=2*pi/lamda;
z=0:lamda/100:2*lamda;
t=0:T/100:3*T;
u=zeros(length(t),length(z));
for i=1 : length(z)
    u(:,i)=A*cos(w*t-k*z(i));
end
figure;
mesh(z,t,u);
xlabel('space[m]')
ylabel('time [s]');
zlabel('ampitude');
title('u(z,t)-3D');
grid on;
```

Screenshot of the Results



Exercise 4

11. Graph the function in 3-D: $u(z,t) = A\cos(wt - kz)$;

Using Meshgrid

all variables:

- frequency=3 [GHz]
- A=1 amplitude [m]
- ε0=8.85e-12 ->electrical permittivity free space
- μ0=pi*4e-7 ->magnetic permeability free space
- ω -> Angular frequency [rad/s]
- T -> time period [s]
- z-> space[m]
- t-> time[s]
- k ->propagation constant
- C - >speed of light [m/s]
- λ ->spatial period - wavelength [m]

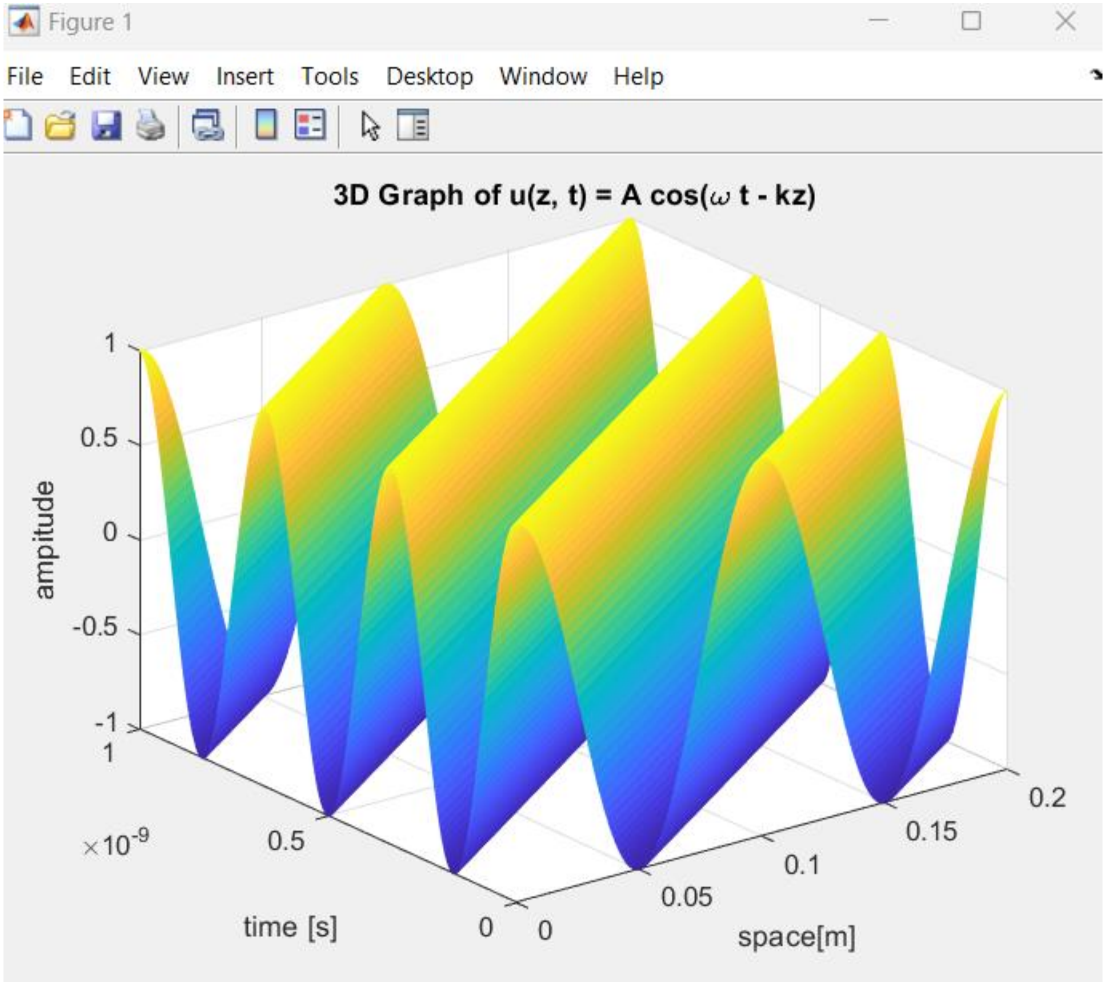
Graph the function in 3-D:

$u(z,t) = A\cos(wt\text{-}kz)$; using Mashgrid.

Code MATLAB:

```
clear all;
clc;
f=3e9;
A=1;
e0=8.85e-12;
mu0=pi*4e-7;
w=2*pi*f;
Period=1/f;
vp=1/sqrt(e0*mu0);
lamda=vp/f;
k = 2*pi/lamda;
z = 0:lamda/100:2*lamda;
t = 0:Period/100:3*Period;
u=zeros(length(t),length(z));
% Create a meshgrid
[Z, T] =meshgrid(z, t);
% Calculate the function u(z, t)
u = A*cos(w*T-k*Z);
figure;
mesh(z,t,u);
mesh(z,t,u);
xlabel('space[m]')
ylabel('time [s]');
zlabel('ampitude');
title('3D Graph of u(z, t) = A cos(\omega t - kz)');
grid on;
```

Screenshot of the Results



Exercise 5

12. Graph the function: $u(z,t)$ = A cos($wt - kz$); For fixed t=t_0=0.

Frequencies = [3e9, 10e9,30e9] using for loop

all variables:

- Frequencies=[3e9, 10e9,30e9]][Hz]
- A=1 amplitude [m]
- ε0=8.85e-12 ->electrical permittivity free space
- μ0=pi*4e-7 ->magnetic permeability free space
- ω -> Angular frequency [rad/s]
- T -> time period [s]
- z-> space[m]

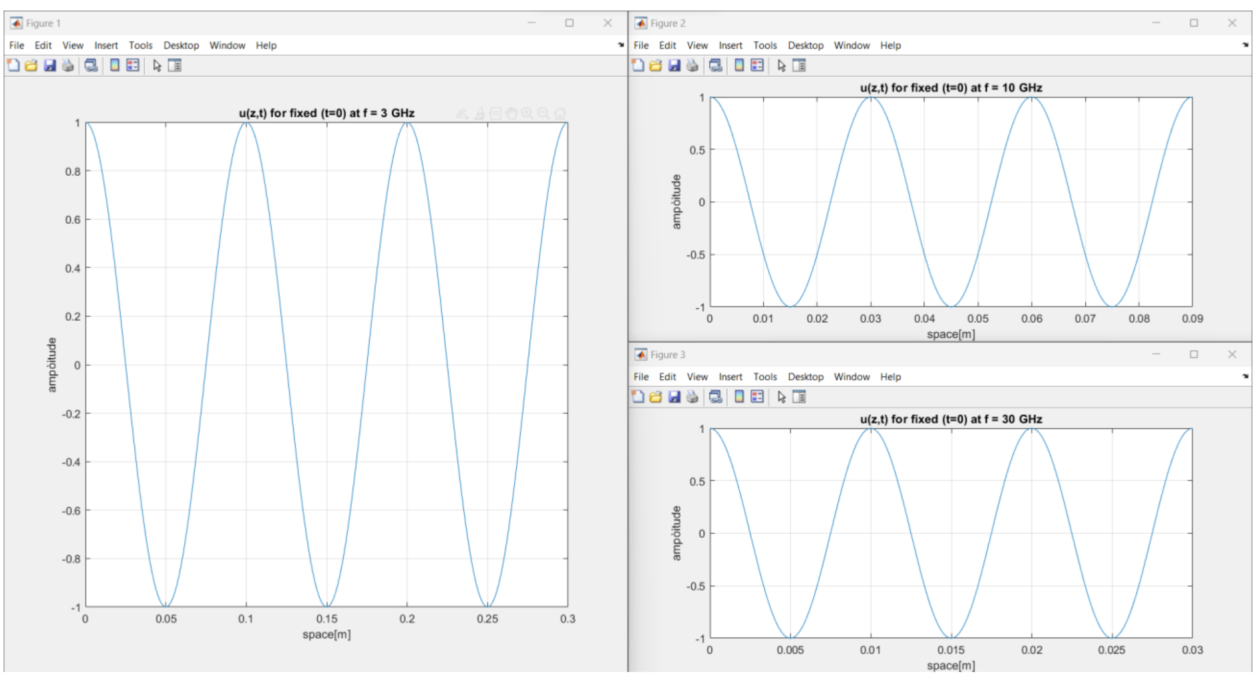
- k ->propagation constant
- C - >speed of light [m/s]
- λ ->spatial period - wavelength [m]

Graph the function: $u(z,t) = A\cos(wt - kz)$; For fixed t=t0=0. Frequencies=[3e9,10e9,30e9] using for loop

Code MATLAB:

```
A=1;
e0=8.85e-12;
mu0=pi*4e-7;
vp=1/sqrt(e0*mu0);
t=0;
f=[3e9,10e9,30e9];
for i=1 :length(f)
    figure;
    w=2*pi*f(i);
    T=1/f(i);
    lamda=vp/f(i);
    k=2*pi/lamda;
    z=0:lamda/100:3*lamda;
    u=A*cos(w*t-k*z);
    plot(z,u);
    xlabel('space[m]');
    ylabel('ampòitude');
    title(['u(z,t) for fixed (t=0) at f = ' num2str(f(i)/1e9) ' GHz']);
    grid on;
end;
```

Screenshot of the Results



Exercise 6

13. Graph the function in 3-D: $u(z,t) = A\cos(wt - kz)$; For: Frequencies = [3e9, 10e9,30e9] using for loop

all variables:

- Frequencies=[3e9, 10e9,30e9][Hz]
- A=1 amplitude [m]
- ε0=8.85e-12 ->electrical permittivity free space
- μ0=pi*4e-7 ->magnetic permeability free space
- ω -> Angular frequency [rad/s]
- T -> time period [s]
- z-> space[m]
- t-> time[s]
- k ->propagation constant
- C - >speed of light [m/s]
- λ ->spatial period - wavelength [m]

Graph the function in 3-D:

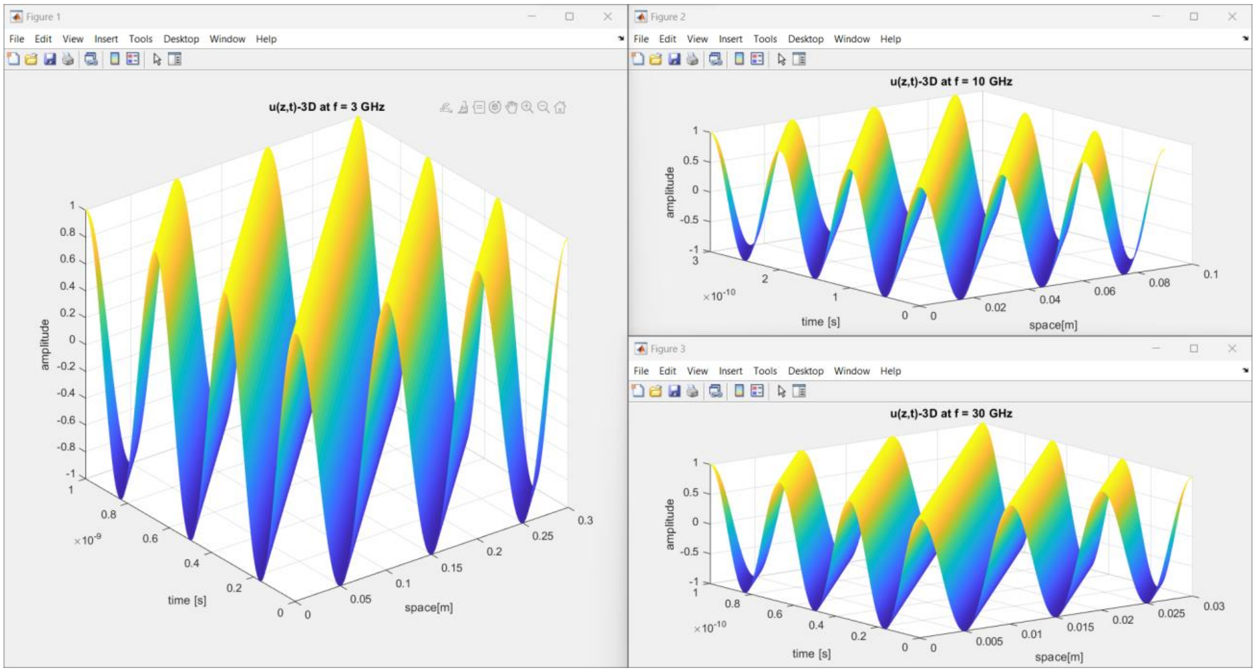
$u(z,t) = A\cos(wt\text{-}kz)$; For:

Frequencies=[3e9,10e9,30e9] using for loop

Code MATLAB:

```
A=1;
e0=8.85e-12;
mu0=pi*4e-7;
vp=1/sqrt(e0*mu0);
f=[3e9,10e9,30e9];
for i=1 :length(f)
    w=2*pi*f(i);
    T=1/f(i);
    lamda=vp/f(i);
    k=2*pi/lamda;
    z=0:lamda/100:3*lamda;
    t=0:T/100:3*T;
    u=zeros(length(t),length(z));
    for mo=1 : length(z)
        u(:,mo)=A*cos(w*t-k*z(mo));
    end
    figure;
    mesh(z,t,u);
    xlabel('space[m]')
    ylabel('time [s]');
    zlabel('amplitude');
    title(['u(z,t)-3D at f = ' num2str(f(i)/1e9) ' GHz']);
    grid on;
end;
```

Screenshot of the Results



PHASOR AND INSTANTANEOUS EXPRESSION

Time domain function to Phasor

If we have a time domain function of this type:

$$u(t)=\underbrace{A}_{\text{magnitude}}\cos(wt+\underbrace{\varphi}_{\text{phase}})$$

The phasor associated with the time domain function is given by:

$$U=\underbrace{A}_{\text{Magnitude}}e^{j\underbrace{\varphi}_{\text{phase}}}$$

Phasor to time domain

$U = Ae^{j\varphi}$

$$u\ (t) = Re(\ U\ e^{j\omega t})$$

$$u\ (t) = Re(\ Ae^{j\varphi}\ e^{j\omega t}\ )$$

$$u\ (t) = A\ Re(\ e^{j(\omega t+\varphi)})$$

$$u\ (t) = A\ cos(wt + \varphi)$$

Exercise 1

14. Converting this phasor to time domain:

$$U = Ae^{j\varphi} \rightarrow u\ (t) = Re(U\ e^{j\omega t})\ .$$

all variables:

Considering two cases:

1) A_1=2, φ_1=45 degrees

2) A_2=1, φ_2=90 degrees

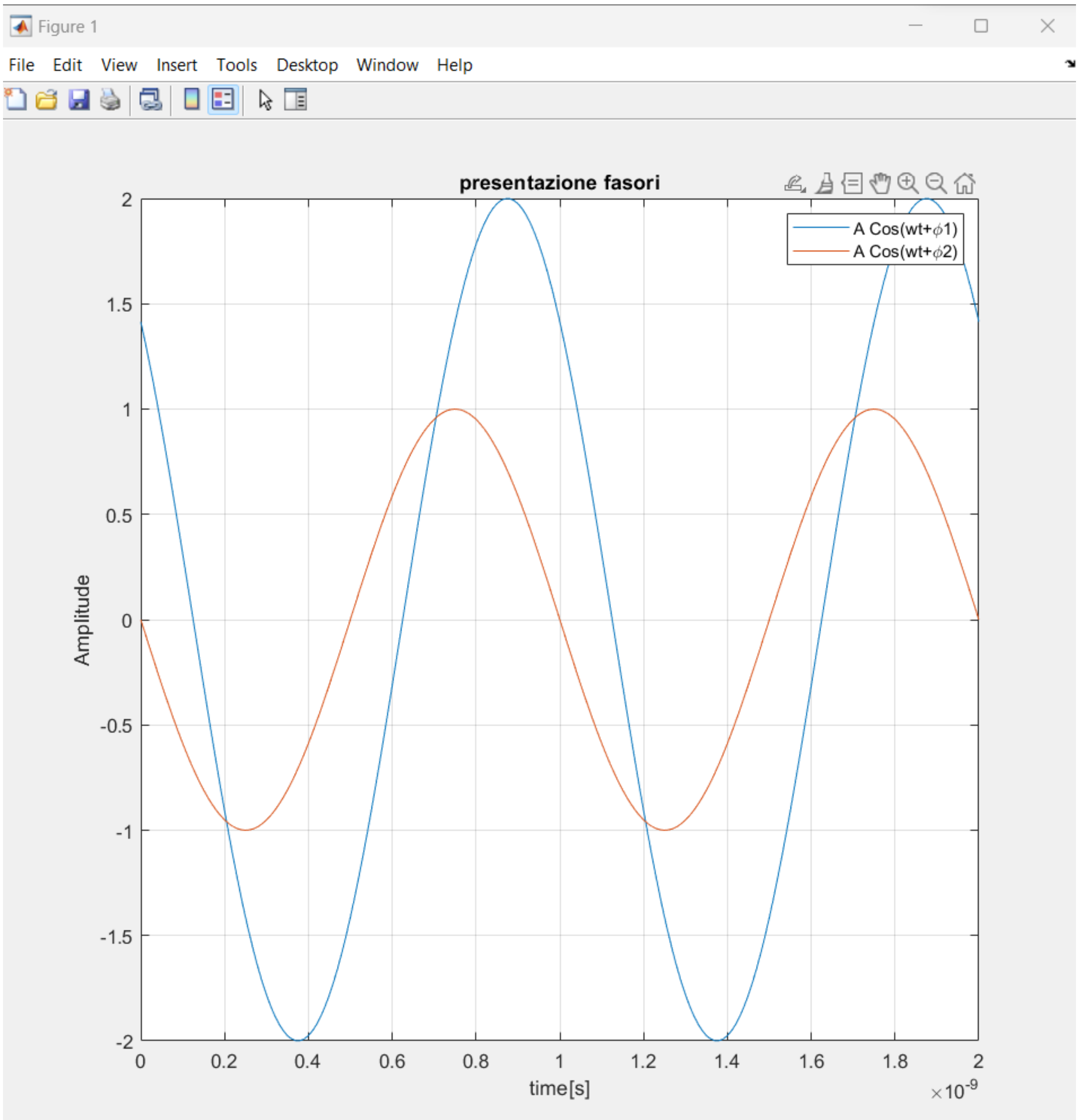
Converting this phasor to time domain.

Code MATLAB:

```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
A1=input('enter amplitude of the first phasor:');
phi1=input('enter the first phase in grad:');
A2=input('enter amplitude of the second phasor:');
phi2=input('enter the second phase in grad:');
f=f*10^9;
phi1=phi1*pi/180;
phi2=phi2*pi/180;
T=1/f;
t=0:T/100:2*T;
w=2*pi*f;
U1=A1*exp(i*phi1);
U2=A2*exp(i*phi2);
u1=real(U1*exp(i*w*t));
u2=real(U2*exp(i*w*t));
figure;
plot(t,u1);
hold on;
plot(t,u2);
xlabel('time[s]');
ylabel('Amplitude');
legend('A Cos(wt+\phi1)','A Cos(wt+\phi2)');
title('presentazione fasori');
grid on;
```

Screenshot of the Results

```
enter the frequenz [Ghz]:1
enter amplitude of the first phasor:2
enter the first phase in grad:45
enter amplitude of the second phasor:1
enter the second phase in grad:90
```



Converting the phasor of Electric Field to its instantaneous expression:

$\underline{E} = \hat{x}E_0 e^{-jkz}$

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

$\underline{e}(z,t) = Re(\hat{x}E_0 e^{-jkz}\, e^{j\omega t})$

$\underline{e}(z,t) = \hat{x}E_0 Re(e^{j(\omega t - kz)})$

$\underline{e}(z,t) = \hat{x}E_0 \cos(wt - kz)$

Exercise 2

15. Converting the phasor of Electric Field to its instantaneous expression:

    $\underline{E} = \hat{x}E_0 e^{-jkz} \rightarrow \underline{e}(z,t) = \hat{x}E_0 \cos(wt - kz)$

    - For z=0
    - 3D plot

all variables:

Set input parameters:

- Frequency
- E_0 Amplitude

f=input('Please enter the Frequency Ghz:');

E0=input('Please enter the Amplitude:');

- Electrical permittivity free space: eps0=8.854e^{-12}
- Magnetic permeability free space: u0=pi*4e^{-7}.

Converting the phasor of Electric Field to its instantaneous expression.

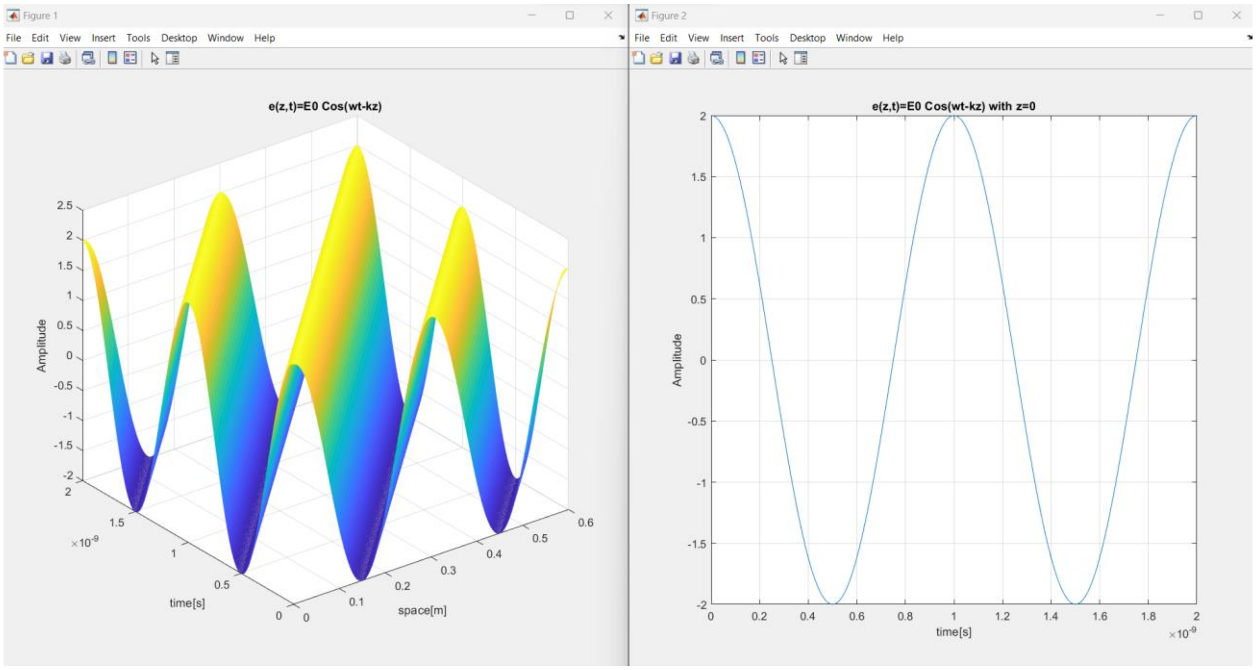
Code MATLAB:

```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter amplitude:');
f=f*10^9;
T=1/f;
```

```
w=2*pi*f;
e0=8.85e-12;
mu0=pi*4e-7;
vp=1/sqrt(e0*mu0);
lamda=vp/f;
k=2*pi/lamda;
z=0:lamda/100:2*lamda;
t=0:T/100:2*T;
E=E0*exp(-i*k*z);
e=zeros(length(t),length(z));
for n=1:length(t)
    e(n,:)=real(E*exp(i*w*t(n)));
end;
figure;
mesh(z,t,e)
xlabel('space[m]')
ylabel('time[s]');
zlabel('Amplitude');
title('e(z,t)=E0 Cos(wt-kz)');
grid on;
figure;
plot(t,e(:,1));
xlabel('time[s]');
ylabel('Amplitude');
title('e(z,t)=E0 Cos(wt-kz) with z=0');
grid on;
```

Screenshot of the Results

```
enter the frequenz [Ghz]:1
enter amplitude:2
```



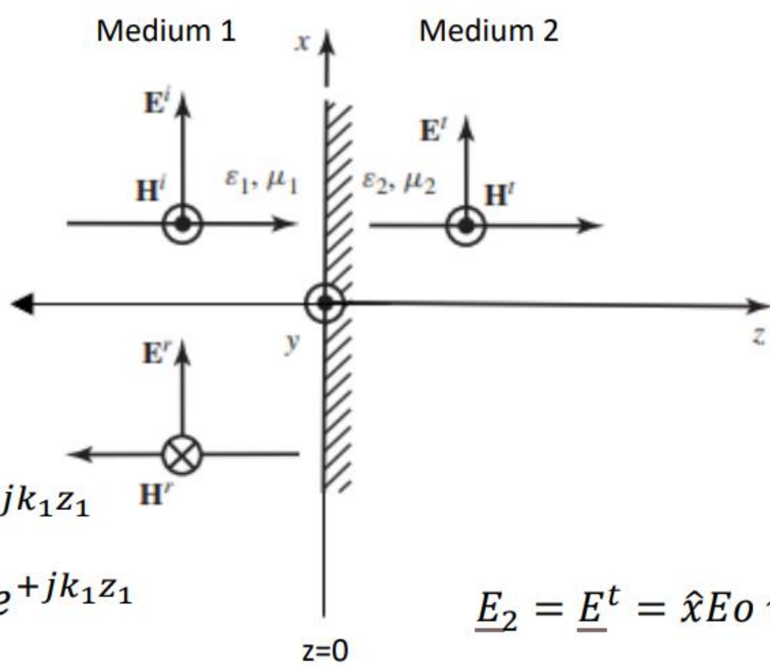
NORMAL INCIDENCE_ LOSSLESS MEDIA

Exercise 1

Normal Incidence – Lossless Media

If consider a plane wave with an incident electric field directed along the x axis propagates in a medium with parameters $\varepsilon 1$, $u1$ in the positive z direction. At the abscissa z=0 there is an interface that separates the first medium from a second of parameters $\varepsilon 2$, $u2$. Graphically represent the two media with:

1. Incident field in medium 1
2. Reflected field in medium 1
3. Total field in medium 1
4. Total or Transmitted field in medium 2
5. Check boundary conditions: $E_1(z = 0) = E_2(z = 0)$



$$\underline{E}^i = \hat{x}Eo\, e^{-jk_1 z_1}$$

$$\underline{E}^r = \hat{x}Eo\, \Gamma\, e^{+jk_1 z_1}$$

$$\underline{E}_1 = \underline{E}^i + \underline{E}^r$$

$$\underline{E}_2 = \underline{E}^t = \hat{x}Eo\, \tau\, e^{-jk_2 z_2}$$

Figure 1 Normal Incidence – Lossless Media

all variables:

- Frequency=1GHz
- Electric Field Amplitude =2
- Relative Permittivity of medium 1= εr_1=1
- Relative Permeability of medium 1= μr_1 =1
- Relative Permittivity of medium 2 = εr_2=3
- Relative Permeability of medium 2 = μr_2 =1

all Formulation:

1. Electrical permittivity
   - $\varepsilon_1 = \varepsilon_0\, \varepsilon r_1$
   - $\varepsilon_2 = \varepsilon_0\, \varepsilon r_2$
2. Magnetic permeability
   - $\mu_1 = \mu_0\, \mu r_1$
   - $\mu_2 = \mu_0\, \mu r_2$
3. Propagation constant
   - $k_1 = w\sqrt{\varepsilon 1 \mu 1}$
   - $k_2 = w\sqrt{\varepsilon 2 \mu 2}$
4. Intrinsic impedance
   - $n_1 = \sqrt{\frac{\mu 1}{\varepsilon 1}}$

- $n_2 = \sqrt{\frac{\mu 2}{\varepsilon 2}}$

5. Propagation velocity
   - $v_{p1} = \frac{1}{\sqrt{\varepsilon 1 \mu 1}}$
   - $v_{p2} = \frac{1}{\sqrt{\varepsilon 2 \mu 2}}$
6. Wavelength
   - $\lambda_1 = \frac{vp1}{f}$
   - $\lambda_2 = \frac{vp2}{f}$
7. Reflection coefficient
   - $\Gamma = \frac{n2-n1}{n2+n1}$
8. Transmition coefficient
   - $\tau = \frac{2*n2}{n2+n1}$
9. Electrical permittivity free space:
   - $\varepsilon_0 = 8.854e^{-12}$
10. Magnetic permeability free space:
    - $\mu_0 = pi*4e^{-7}$

Expressions for fields in their phasor form:

- Incident field phasor - Medium 1
  - $\underline{E}^i = \hat{x} E_0 e^{-jk1z1}$
- Reflected field phasor - Medium 1
  - $\underline{E}^r = \hat{x}\, \Gamma\, E_0 e^{+jk1z1}$
- Total field phasor -Medium 1
  - $\underline{E}_1 = \underline{E}^i + \underline{E}^r$
- Total or transmitted field phasor - Medium 2
  - $\underline{E}_2 = \underline{E}^t = \hat{x} E_0\, \tau\, e^{-jk2z2}$

Transform the phasor form of the Fields to their instantaneous expression:

- Incident field - Medium 1
  - $\underline{E}^i = \hat{x} E_0 e^{-jk1z1}$
  - $\underline{e}^i(t, z) = Re(\underline{E}^i e^{j\omega t})$
- Reflected field - Medium 1
  - $\underline{E}^r = \hat{x}\, \Gamma\, E_0 e^{+jk1z1}$
  - $\underline{e}^r(t, z) = Re(\underline{E}^r e^{j\omega t})$
- Total field -Medium 1

- $\underline{E}_1=\underline{E}^i+\underline{E}^i$
- $\underline{e}_1$(t, z) =Re($\underline{E}_1 e^{j\omega t}$)

- Total or transmitted field - Medium 2
  - $\underline{E}_2=\underline{E}^t=\hat{x}E_0\,\tau\, e^{-jk2z2}$
  - $\underline{e}_2$(t, z) =Re($\underline{E}_2 e^{j\omega t}$)
- Verify the Boundary Conditions:
  - $\underline{E}_1(z=0) = \underline{E}_2(z=0)$

$$\underline{E} = \hat{x}E_0 e^{-jkz}$$

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

$$\underline{e}\,(z, t)= Re(\,\hat{x}E_0 e^{-jkz}\, e^{j\omega t})$$

$$\underline{e}\,(z, t)= \hat{x}E_0 Re(\,e^{j(\omega t-kz)})$$

$$\underline{e}\,(z, t)= \hat{x}E_0 \cos(wt - kz)$$

Normal Incidence – Lossless Media

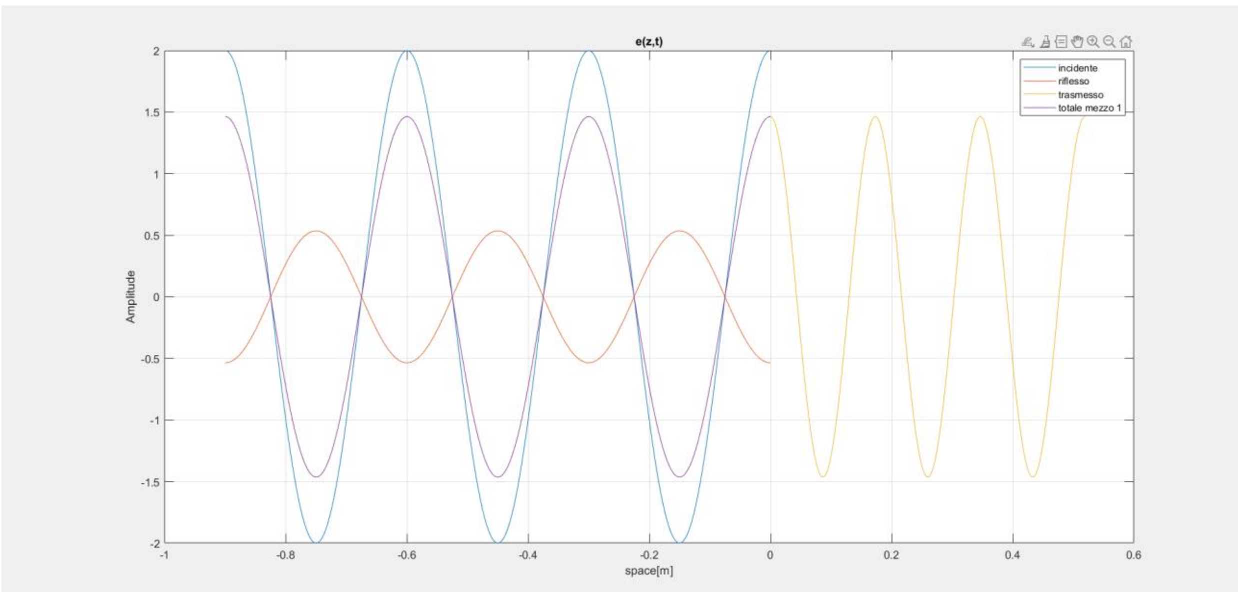
Code MATLAB:

```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
epsr1=input('enter the relative permittivity of medium 1:');
mur1=input('enter the relative magnetic permeability of medium 1:');
epsr2=input('enter the relative permittivity of medium 2:');
mur2=input('enter the relative magnetic permeability of medium 2:');
f=f*10^9;
T=1/f;
w=2*pi*f;
e0=8.85e-12;
mu0=pi*4e-7;
eps1=e0*epsr1;
eps2=e0*epsr2;
mu1=mu0*mur1;
mu2=mu0*mur2;
k1=w*sqrt(eps1*mu1);
k2=w*sqrt(eps2*mu2);
```

```matlab
vp1=1/(sqrt(eps1*mu1));
vp2=1/(sqrt(eps2*mu2));
n1=sqrt(mu1/eps1);
n2=sqrt(mu2/eps2);
ref=(n2-n1)/(n2+n1);
tras=(2*n2)/(n2+n1);
lamda1=vp1/f;
lamda2=vp2/f;
z1=-3*lamda1:lamda1/100:0;
z2=0:lamda2/100:3*lamda2;
t=0:T/100:3*T;
EiF=E0*exp(-i*k1*z1);
EtF=E0*tras*exp(-i*k2*z2);
ErF=E0*ref*exp(i*k1*z1);
E1F=EiF+ErF;
Ei=zeros(length(t),length(z1));
Et=zeros(length(t),length(z2));
Er=zeros(length(t),length(z1));
E1=zeros(length(t),length(z1));
for n=1:length(t)
    Ei(n,:)=real(EiF*exp(i*w*t(n)));
    Et(n,:)=real(EtF*exp(i*w*t(n)));
    Er(n,:)=real(ErF*exp(i*w*t(n)));
    E1(n,:)=real(E1F*exp(i*w*t(n)));
end;
figure;
plot(z1,Ei(1,:));%incidente
hold on;
plot(z1,Er(1,:));%riflesso
plot(z2,Et(1,:));%trasmesso
plot(z1,E1(1,:));%totale
xlabel('space[m]');
ylabel('Amplitude');
legend('incidente','riflesso','trasmesso','totale mezzo 1')
title('e(z,t)');
grid on;
```

Screenshot of the Results

```
enter the frequenz [Ghz]:1
enter the Amplitude:2
enter the relative permittivity of medium 1:1
enter the relative magnetic permeability of medium 1:1
enter the relative permittivity of medium 2:3
enter the relative magnetic permeability of medium 2:1
>>
```



Exercise 2

Modify to Exercise 1 update the plot for different time instances. You can use a for loop and pause to simulate an animation.

Exercise 1 with animation

Code MATLAB:

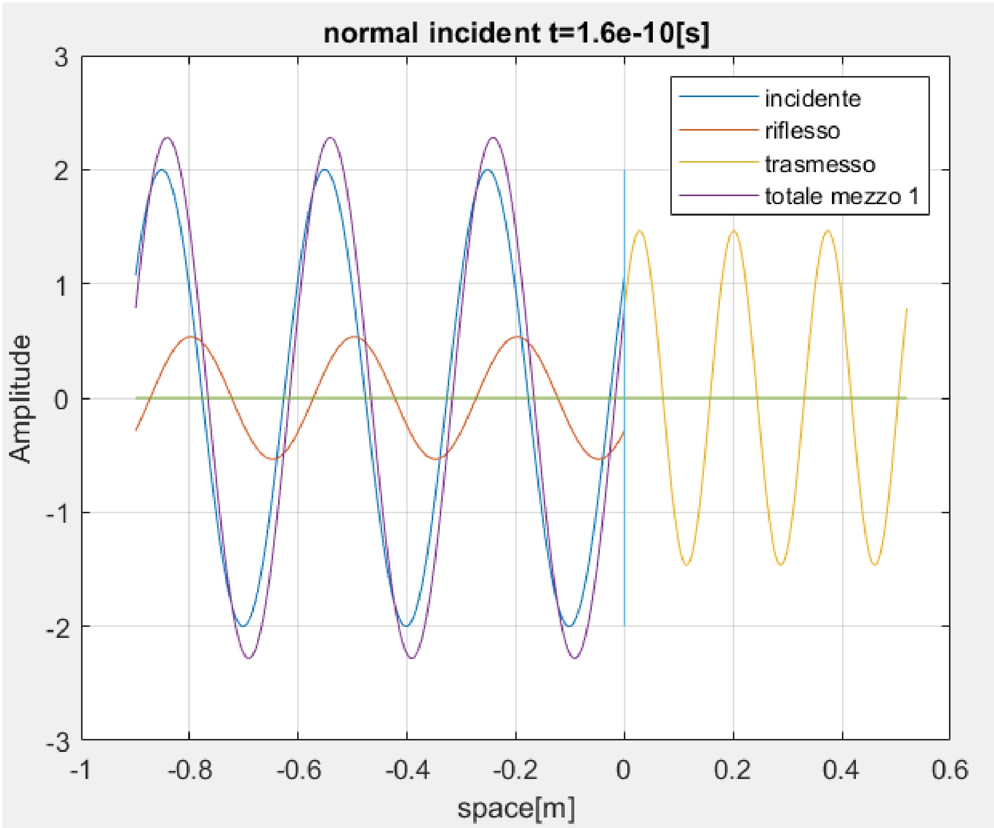
```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
epsr1=input('enter the relative permittivity of medium 1:');
mur1=input('enter the relative magnetic permeability of medium 1:');
epsr2=input('enter the relative permittivity of medium 2:');
mur2=input('enter the relative magnetic permeability of medium 2:');
f=f*10^9;
```

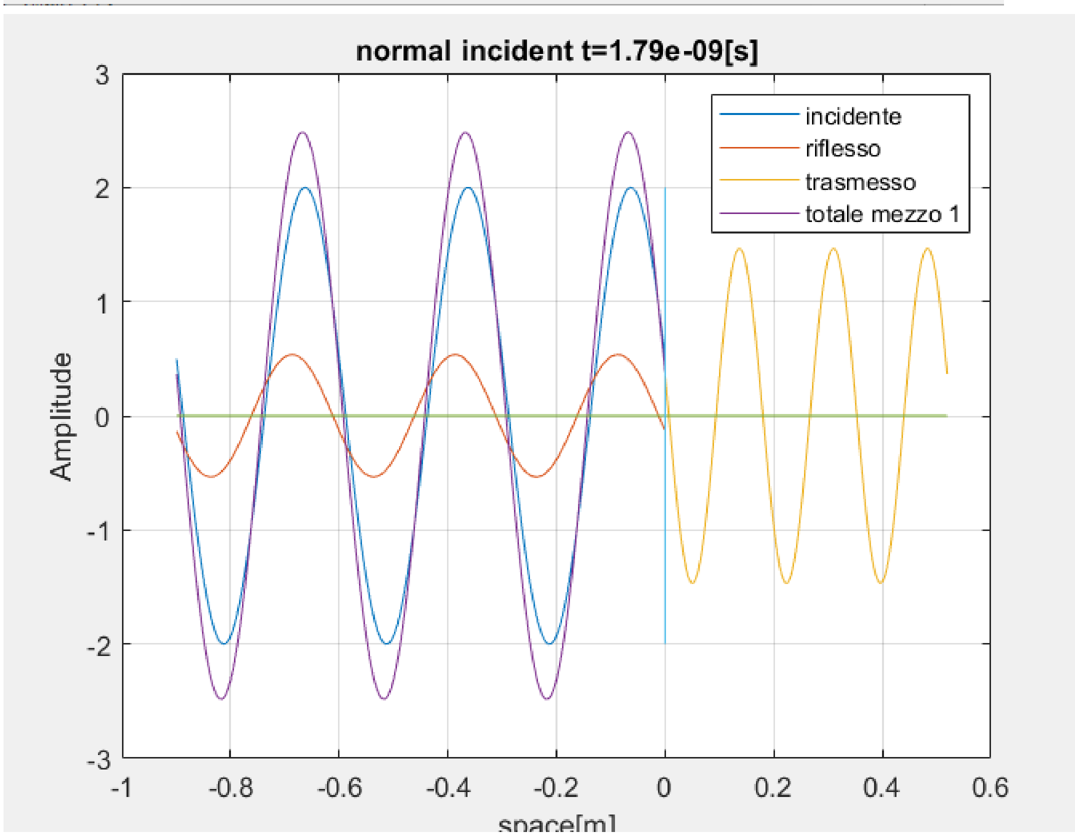
```
T=1/f;
w=2*pi*f;
e0=8.85e-12;
mu0=pi*4e-7;
eps1=e0*epsr1;
eps2=e0*epsr2;
mu1=mu0*mur1;
mu2=mu0*mur2;
k1=w*sqrt(eps1*mu1);
k2=w*sqrt(eps2*mu2);
vp1=1/(sqrt(eps1*mu1));
vp2=1/(sqrt(eps2*mu2));
n1=sqrt(mu1/eps1);
n2=sqrt(mu2/eps2);
ref=(n2-n1)/(n2+n1);
tras=(2*n2)/(n2+n1);
lamda1=vp1/f;
lamda2=vp2/f;
z1=-3*lamda1:lamda1/100:0;
z2=0:lamda2/100:3*lamda2;
t=0:T/100:3*T;
EiF=E0*exp(-i*k1*z1);
EtF=E0*tras*exp(-i*k2*z2);
ErF=E0*ref*exp(i*k1*z1);
E1F=EiF+ErF;
Ei=zeros(length(t),length(z1));
Et=zeros(length(t),length(z2));
Er=zeros(length(t),length(z1));
E1=zeros(length(t),length(z1));
for n=1:length(t)
    Ei(n,:)=real(EiF*exp(i*w*t(n)));
    Et(n,:)=real(EtF*exp(i*w*t(n)));
    Er(n,:)=real(ErF*exp(i*w*t(n)));
    E1(n,:)=real(E1F*exp(i*w*t(n)));
end
a=[-3*lamda1,3*lamda2];
b=[0,0];
c=[0,0];
d=[-E0,E0];
figure;
for m=1:length(t)
clf;
plot(z1,Ei(m,:));%incidente
hold on;
plot(z1,Er(m,:));%riflesso
plot(z2,Et(m,:));%trasmesso
plot(z1,E1(m,:));%totale
plot(a,b);
plot(c,d);
xlabel('space[m]');
ylabel('Amplitude');
legend('incidente','riflesso','trasmesso','totale mezzo 1')
title(['normal incident t=',num2str(t(m)),'[s]']);
```

```
grid on;
ylim([-3,3]);
pause(0.1);
end;
```

Screenshot of the Results

```
enter the frequenz [Ghz]:1
enter the Amplitude:2
enter the relative permittivity of medium 1:1
enter the relative magnetic permeability of medium 1:1
enter the relative permittivity of medium 2:3
enter the relative magnetic permeability of medium 2:1
>>
```


normal incident t=1.6e-10[s]
Amplitude
space[m]
incidente
riflesso
trasmesso
totale mezzo 1


normal incident t=1.79e-09[s]
Amplitude
incidente
riflesso
trasmesso
totale mezzo 1

NORMAL INCIDENCE_ LOSSY MEDIA

Exercise 1

Normal Incidence – Lossy Media

If consider a plane wave with an incident electric field directed along the $\hat{x}$ axis propagates in a medium with parameters ε_1, u_1 in the positive z direction. At the abscissa z=0 there is an interface that separates the first medium from a second of parameters ε_2, u_2.

- Let us now examine the reflection and transmission of waves under normal incidence when the first medium is lossless, and the second medium is lossy.

Represent:

6. Incident field in medium 1
7. Reflected field in medium 1
8. Total field in medium 1
9. Total or Transmitted field in medium 2
10. Attenuation medium 2
11. Check boundary conditions: $E_1(z = 0) = E_2(z = 0)$ Total or Transmitted field in medium 2

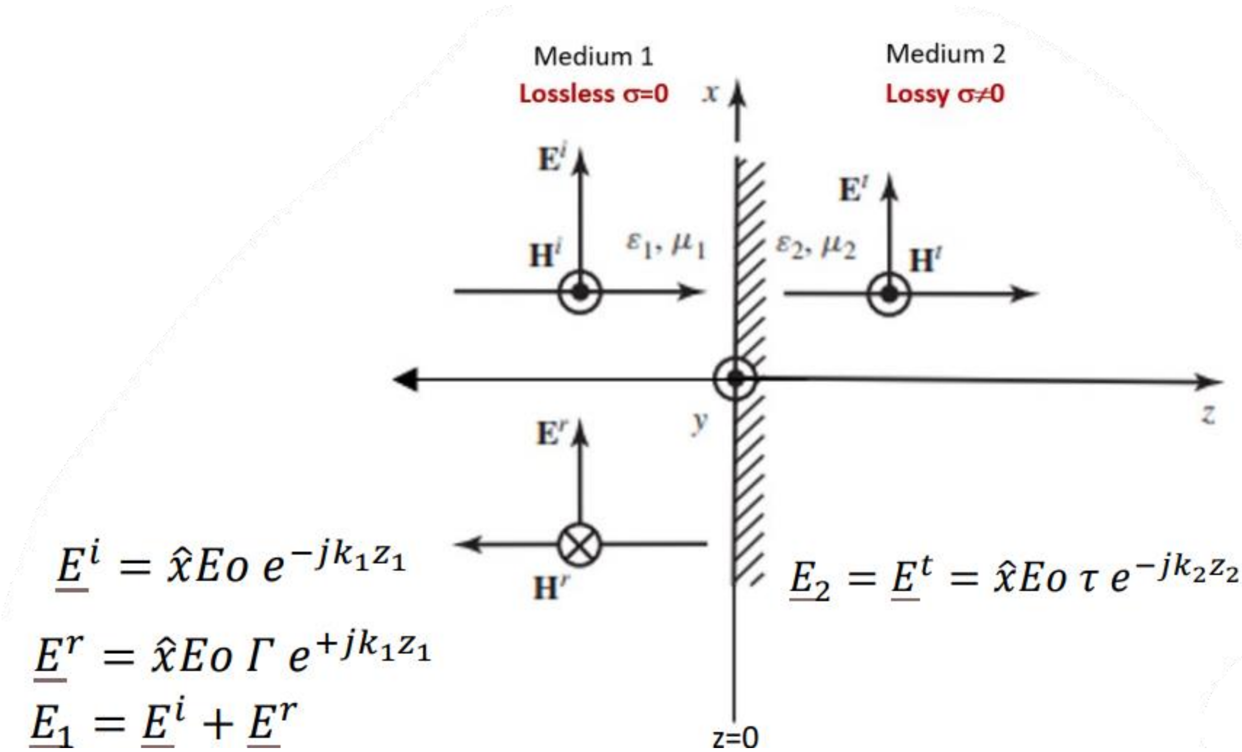


Figure 2 Normal Incidence – Lossy Media

all variables:

- Frequency=1GHz
- Electric Field Amplitude =2
- Relative Permittivity of medium 1= εr_1=1
- Relative Permeability of medium 1= μr_1 =1
- Conductivity medium 1 -> σ=0
- Relative Permittivity of medium 2 = εr_2=3
- Relative Permeability of medium 2 = μr_2 =1
- Conductivity medium 2 -> σ=0.03

all Formulation:

11. Electrical permittivity
    - $\varepsilon_1 = \varepsilon_0\, \varepsilon r_1$
    - $\varepsilon_2 = \varepsilon_0\, \varepsilon r_2$
12. Magnetic permeability
    - $\mu_1 = \mu_0\, \mu r_1$
    - $\mu_2 = \mu_0\, \mu r_2$
13. Propagation constant
    - $k_1 = w\sqrt{\varepsilon 1 \mu 1} = \beta_1 - j\alpha_1$
    - $k_2 = w\sqrt{\widetilde{\varepsilon 2}\mu 2} = w\sqrt{\left(\varepsilon 2 - \mathrm{j}\frac{\sigma 2}{w}\right) * \mu 2} = \beta_1 - j\alpha_1$

14. Intrinsic impedance

- $n_1 = \sqrt{\frac{\mu 1}{\varepsilon 1}}$
- $n_2 = \sqrt{\frac{\mu 2}{\widetilde{\varepsilon 2}}} = \sqrt{\frac{\mu 2}{\left(\varepsilon 2 - j\frac{\sigma 2}{w}\right)}} = \sqrt{\frac{jw\mu 2}{\sigma 2 + jw\varepsilon 2}}$

15. Propagation velocity

- $v_{p1} = \frac{1}{\sqrt{\varepsilon 1 \mu 1}}$
- $v_{p2} = \frac{1}{\sqrt{\varepsilon 2 \mu 2}}$

16. Wavelength

- $\lambda_1 = \frac{2\pi}{\beta 1}$
- $\lambda_2 = \frac{2\pi}{\beta 2}$

17. Reflection coefficient

- $\Gamma = \frac{n2 - n1}{n2 + n1}$

18. Transmition coefficient

- $\tau = \frac{2 * n2}{n2 + n1}$

19. Transmition coefficient

- $\delta = \frac{1}{\alpha 2}$

20. Electrical permittivity free space:

- $\varepsilon_0 = 8.854e^{-12}$

21. Magnetic permeability free space:

- $\mu_0 = pi*4e^{-7}$

Expressions for fields in their phasor form:

- Incident field phasor - Medium 1
  - $\underline{E}^i = \hat{x} E_0 e^{-jk1z1}$
- Reflected field phasor - Medium 1
  - $\underline{E}^r = \hat{x}\, \Gamma\, E_0 e^{+jk1z1}$
- Total field phasor -Medium 1
  - $\underline{E_1} = \underline{E}^i + \underline{E}^r$
- Total or transmitted field phasor - Medium 2
  - $\underline{E_2} = \underline{E}^t = \hat{x} E_0\, \tau\, e^{-jk2z2}$

Transform the phasor form of the Fields to their instantaneous expression:

- Incident field - Medium 1

- $\underline{E}^i = \hat{x} E_0 e^{-jk1z1}$
- $\underline{e}^i(t, z) = Re(\underline{E}^i e^{j\omega t})$

- Reflected field - Medium 1
  - $\underline{E}^r = \hat{x}\ \Gamma\ E_0 e^{+jk1z1}$
  - $\underline{e}^r(t, z) = Re(\underline{E}^r e^{j\omega t})$
- Total field -Medium 1
  - $\underline{E}_1 = \underline{E}^i + \underline{E}^i$
  - $\underline{e}_1(t, z) = Re(\underline{E}_1 e^{j\omega t})$
- Total or transmitted field - Medium 2
  - $\underline{E}_2 = \underline{E}^t = \hat{x} E_0\ \tau\ e^{-jk2z2}$
  - $\underline{e}_2(t, z) = Re(\underline{E}_2 e^{j\omega t})$
- Verify the Boundary Conditions:
  - $\underline{E}_1(z=0) = \underline{E}_2(z=0)$
- Attenuation in medium 2:
  - $Ae^{-\alpha 2z2}$

    where: A is $\underline{E}_2$ amplitude.

Normal Incidence – Lossy Media

Code MATLAB:

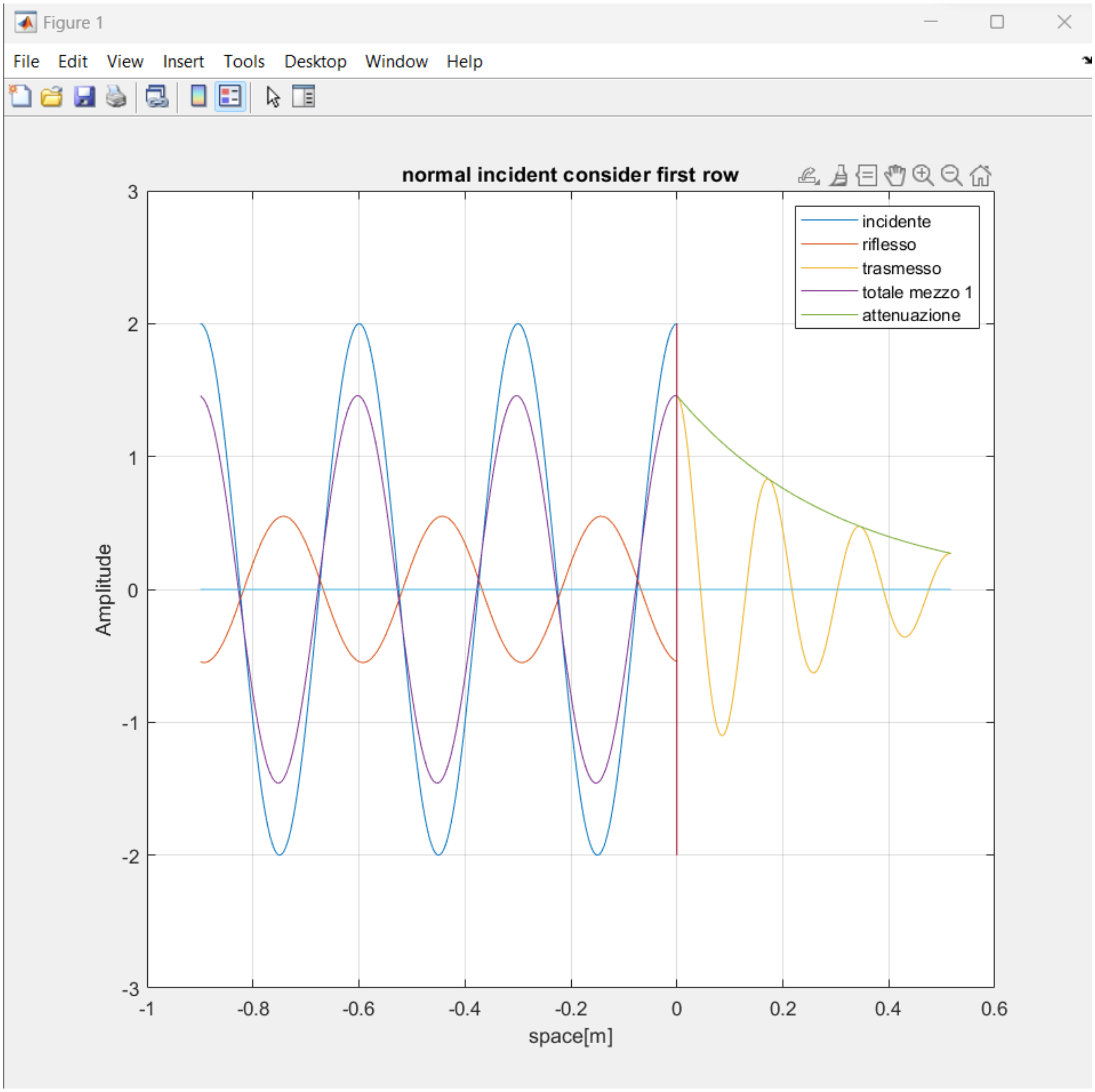
```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
epsr1=input('enter the relative electric permittivity of medium 1:');
mur1=input('enter the relative magnetic permeability of medium 1:');
sigma1=input('enter the conductivity of medium 1:');
epsr2=input('enter the relative electric permittivity of medium 2:');
mur2=input('enter the relative magnetic permeability of medium 2:');
sigma2=input('enter the relative conductivity of medium 2:');
f=f*10^9;
T=1/f;
w=2*pi*f;
e0=8.85e-12;
mu0=pi*4e-7;
eps1=e0*epsr1;
eps2=e0*epsr2;
mu1=mu0*mur1;
mu2=mu0*mur2;
k1=w*sqrt(eps1*mu1);
k2=w*sqrt((eps2-(i*(sigma2/w)))*mu2);
n1=sqrt(mu1/eps1);
n2=sqrt((i*w*mu2)/(sigma2+(i*w*eps2)));
%primo medio
beta1=real(k1);
alfa1=-imag(k1);
%secondo medio
beta2=real(k2);
```

```
alfa2=-imag(k2);
%penetration depth
delta=1/alfa2;
ref=(n2-n1)/(n2+n1);
tras=(2*n2)/(n2+n1);
lamda1=(2*pi)/beta1;
lamda2=(2*pi)/beta2;
z1=-3*lamda1:lamda1/100:0;
z2=0:lamda2/100:3*lamda2;
t=0:T/100:3*T;
EiF=E0*exp(-i*k1*z1);
EtF=E0*tras*exp(-i*k2*z2);
ErF=E0*ref*exp(i*k1*z1);
E1F=EiF+ErF;
Ei=zeros(length(t),length(z1));
Et=zeros(length(t),length(z2));
Er=zeros(length(t),length(z1));
E1=zeros(length(t),length(z1));
for n=1:length(t)
    Ei(n,:)=real(EiF*exp(i*w*t(n)));
    Et(n,:)=real(EtF*exp(i*w*t(n)));
    Er(n,:)=real(ErF*exp(i*w*t(n)));
    E1(n,:)=real(E1F*exp(i*w*t(n)));
end;
a=[-3*lamda1,3*lamda2];
b=[0,0];
c=[0,0];
d=[-E0,E0];
figure;

plot(z1,Ei(1,:));%incidente
hold on;
plot(z1,Er(1,:));%riflesso
plot(z2,Et(1,:));%trasmesso
plot(z1,E1(1,:));%totale
A=max(E1(1,:));
attenuation=A*exp(-1*alfa2*z2);
plot(z2,attenuation);%attenuazione
plot(a,b);
plot(c,d);
xlabel('space[m]');
ylabel('Amplitude');
legend('incidente','riflesso','trasmesso','totale mezzo 1','attenuazione');
title('normal incident consider first row');
grid on;
ylim([-3,3]);
```

Screenshot of the Results

```
enter the frequenz [Ghz]:1
enter the Amplitude:2
enter the relative electric permittivity of medium 1:1
enter the relative magnetic permeability of medium 1:1
enter the conductivity of medium 1:0
enter the relative electric permittivity of medium 2:3
enter the relative magnetic permeability of medium 2:1
enter the relative conductivity of medium 2:0.03
```



Exercise 2

Modify Exercise 1 to update the plot for different time instances. You can use a for loop and pause to simulate an animation.

Exercise 1 with animation

Code MATLAB:

```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
```

```
epsr1=input('enter the relative electric permittivity of medium 1:');
mur1=input('enter the relative magnetic permeability of medium 1:');
sigma1=input('enter the conductivity of medium 1:');
epsr2=input('enter the relative electric permittivity of medium 2:');
mur2=input('enter the relative magnetic permeability of medium 2:');
sigma2=input('enter the relative conductivity of medium 2:');
f=f*10^9;
T=1/f;
w=2*pi*f;
e0=8.85e-12;
mu0=pi*4e-7;
eps1=e0*epsr1;
eps2=e0*epsr2;
mu1=mu0*mur1;
mu2=mu0*mur2;
k1=w*sqrt(eps1*mu1);
k2=w*sqrt((eps2-(i*(sigma2/w)))*mu2);
n1=sqrt(mu1/eps1);
n2=sqrt((i*w*mu2)/(sigma2+(i*w*eps2)));
%primo medio
beta1=real(k1);
alfa1=-imag(k1);
%secondo medio
beta2=real(k2);
alfa2=-imag(k2);
%penetration depth
delta=1/alfa2;
ref=(n2-n1)/(n2+n1);
tras=(2*n2)/(n2+n1);
lamda1=(2*pi)/beta1;
lamda2=(2*pi)/beta2;
z1=-3*lamda1:lamda1/100:0;
z2=0:lamda2/100:3*lamda2;
t=0:T/100:3*T;
EiF=E0*exp(-i*k1*z1);
EtF=E0*tras*exp(-i*k2*z2);
ErF=E0*ref*exp(i*k1*z1);
E1F=EiF+ErF;
Ei=zeros(length(t),length(z1));
Et=zeros(length(t),length(z2));
Er=zeros(length(t),length(z1));
E1=zeros(length(t),length(z1));
for n=1:length(t)
    Ei(n,:)=real(EiF*exp(i*w*t(n)));
    Et(n,:)=real(EtF*exp(i*w*t(n)));
    Er(n,:)=real(ErF*exp(i*w*t(n)));
    E1(n,:)=real(E1F*exp(i*w*t(n)));
end;
a=[-3*lamda1,3*lamda2];
b=[0,0];
c=[0,0];
d=[-E0,E0];
figure;
```

```
for m=1:length(t)
clf;
plot(z1,Ei(m,:));%incidente
hold on;
plot(z1,Er(m,:));%riflesso
plot(z2,Et(m,:));%trasmesso
plot(z1,E1(m,:));%totale
A=max(abs(tras*Ei(m,:)));
attenuation=A*exp(-1*alfa2*z2);
plot(z2,attenuation);%attenuazione
plot(a,b,'k--');
plot(c,d,'k--');
xlabel('space[m]');
ylabel('Amplitude');
legend('incidente','riflesso','trasmesso','totale mezzo 1','attenuazione');
title(['normal incident t=',num2str(t(m)),'[s]']);
grid on;
ylim([-3,3]);
pause(0.1);
end;
```

Screenshot of the Results

```
enter the frequenz [Ghz]:1
enter the Amplitude:2
enter the relative electric permittivity of medium 1:1
enter the relative magnetic permeability of medium 1:1
enter the conductivity of medium 1:0
enter the relative electric permittivity of medium 2:3
enter the relative magnetic permeability of medium 2:1
enter the relative conductivity of medium 2:0.03
```

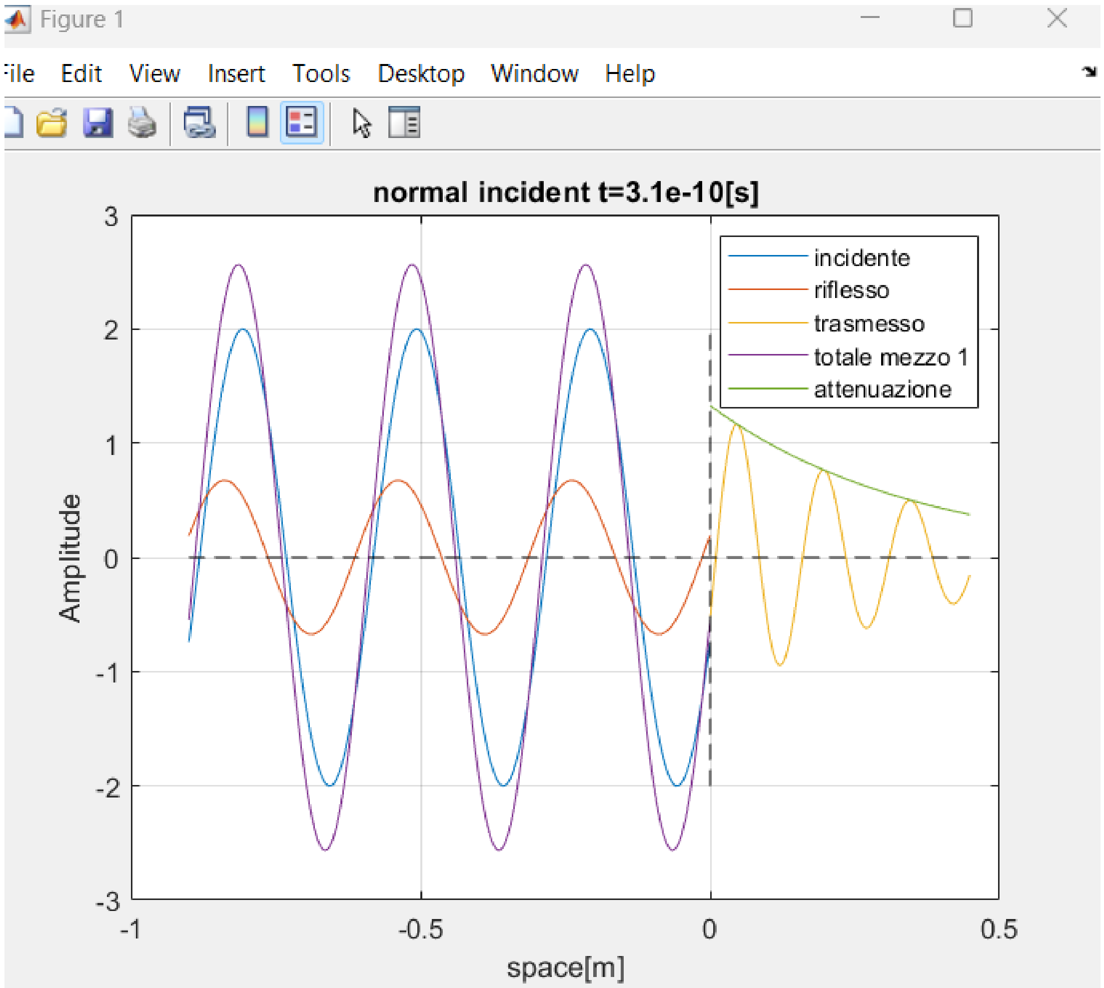
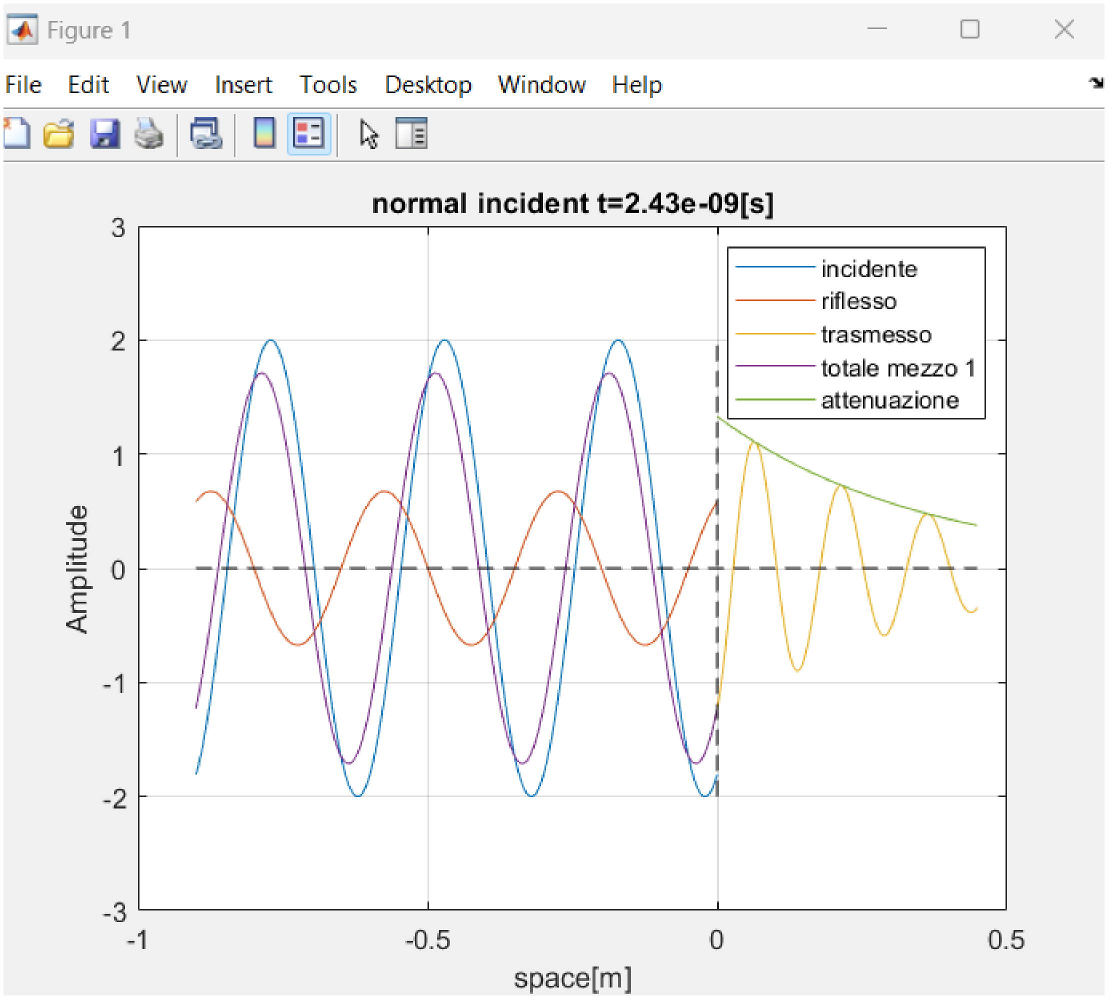


Figure 1
File Edit View Insert Tools Desktop Window Help
normal incident t=3.1e-10[s]
incidente
riflesso
trasmesso
totale mezzo 1
attenuazione
Amplitude
space[m]
3
2
1
0
-1
-2
-3
-1
-0.5
0
0.5



Exercise 3

Represent the Transmitted Electric Field in medium 2 ($\underline{E}_2$), with its attenuation and Penetration Depth.

Penetration Depth

Code MATLAB:

```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
epsr1=input('enter the relative electric permittivity of medium 1:');
mur1=input('enter the relative magnetic permeability of medium 1:');
sigma1=input('enter the conductivity of medium 1:');
epsr2=input('enter the relative electric permittivity of medium 2:');
mur2=input('enter the relative magnetic permeability of medium 2:');
sigma2=input('enter the relative conductivity of medium 2:');
e=2.7183;
f=f*10^9;
```

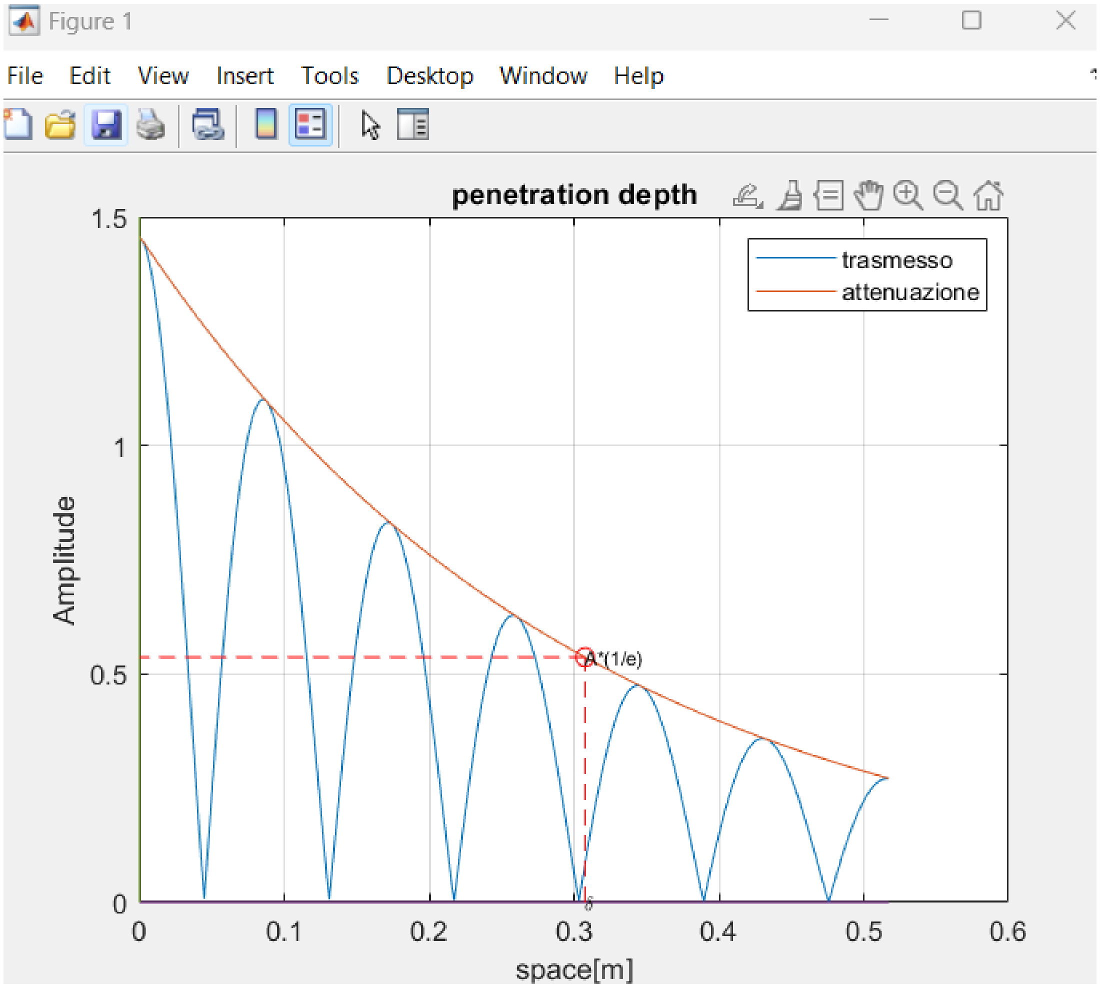
```
T=1/f;
w=2*pi*f;
e0=8.85e-12;
mu0=pi*4e-7;
eps1=e0*epsr1;
eps2=e0*epsr2;
mu1=mu0*mur1;
mu2=mu0*mur2;
k1=w*sqrt(eps1*mu1);
k2=w*sqrt((eps2-(i*(sigma2/w)))*mu2);
n1=sqrt(mu1/eps1);
n2=sqrt((i*w*mu2)/(sigma2+(i*w*eps2)));
%primo medio
beta1=real(k1);
alfa1=-imag(k1);
%secondo medio
beta2=real(k2);
alfa2=-imag(k2);
%penetration depth
delta=1/alfa2;
ref=(n2-n1)/(n2+n1);
tras=(2*n2)/(n2+n1);
lamda1=(2*pi)/beta1;
lamda2=(2*pi)/beta2;
z1=-3*lamda1:lamda1/100:0;
z2=0:lamda2/100:3*lamda2;
t=0:T/100:3*T;
EiF=E0*exp(-i*k1*z1);
EtF=E0*tras*exp(-i*k2*z2);
ErF=E0*ref*exp(i*k1*z1);
E1F=EiF+ErF;
Ei=zeros(length(t),length(z1));
Et=zeros(length(t),length(z2));
Er=zeros(length(t),length(z1));
E1=zeros(length(t),length(z1));
for n=1:length(t)
    Ei(n,:)=real(EiF*exp(i*w*t(n)));
    Et(n,:)=real(EtF*exp(i*w*t(n)));
    Er(n,:)=real(ErF*exp(i*w*t(n)));
    E1(n,:)=real(E1F*exp(i*w*t(n)));
end;
h=[0,3*lamda2];
b=[0,0];
c=[0,0];
d=[0,E0];
figure;

plot(z2,abs(Et(1,:)));%trasmesso
hold on;
A=max(abs(tras*Ei(1,:)));
attenuation=A*exp(-1*alfa2*z2);
plot(z2,attenuation);%attenuazione
plot(delta,A*(1/e),'ro','MarkerSize',7);
```

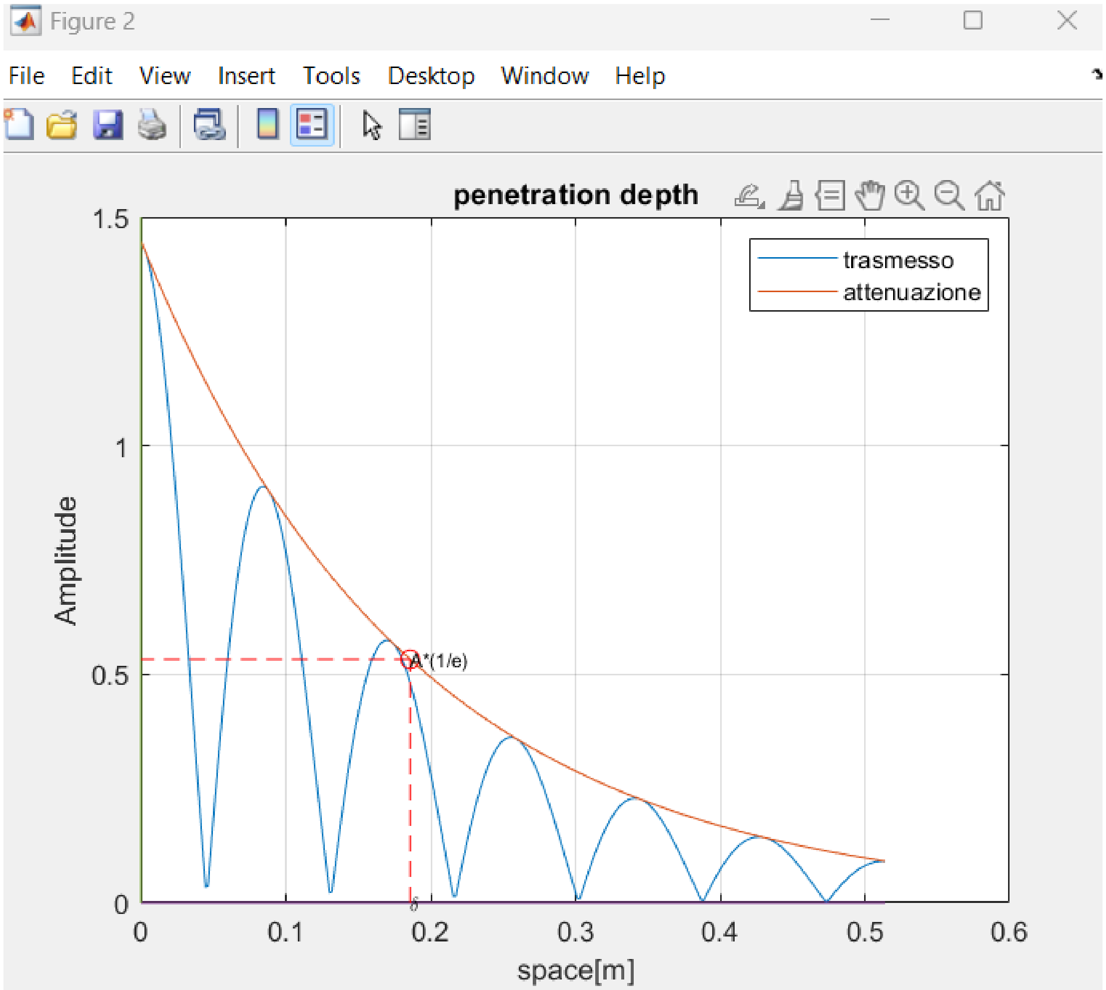
```
plot(h,b);
plot(c,d);
r=[delta,delta];
m=[0,A*(1/e)];
plot(r,m,'r--');
o=[delta,0];
l=[A*(1/e),A*(1/e)];
plot(o,l,'r--');
text(delta,A*(1/e),'A*(1/e)','Fontsize',7);
text(delta,0,'\delta','FontSize',7);
xlabel('space[m]');
ylabel('Amplitude');
legend('trasmesso','attenuazione');
title('penetration depth');
grid on;
ylim([0,1.5]);
```

Screenshot of the Results

```
enter the frequenz [Ghz]:1
enter the Amplitude:2
enter the relative electric permittivity of medium 1:1
enter the relative magnetic permeability of medium 1:1
enter the conductivity of medium 1:0
enter the relative electric permittivity of medium 2:3
enter the relative magnetic permeability of medium 2:1
enter the relative conductivity of medium 2:0.03
```




```
enter the frequenz [Ghz]:1
enter the Amplitude:2
enter the relative electric permittivity of medium 1:1
enter the relative magnetic permeability of medium 1:1
enter the conductivity of medium 1:0
enter the relative electric permittivity of medium 2:3
enter the relative magnetic permeability of medium 2:1
enter the relative conductivity of medium 2:0.05
```



Exercise 4

Represent the Transmitted Electric Field in medium 2 (E_2), considering different sigma values.

values

- Consider the following vector for the sigma values:
  - sigma2=0:0.1/5:0.1;
- C Set a single time value:
  - t=1e-9; %1ns

considering different sigma values

Code MATLAB:

```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
```

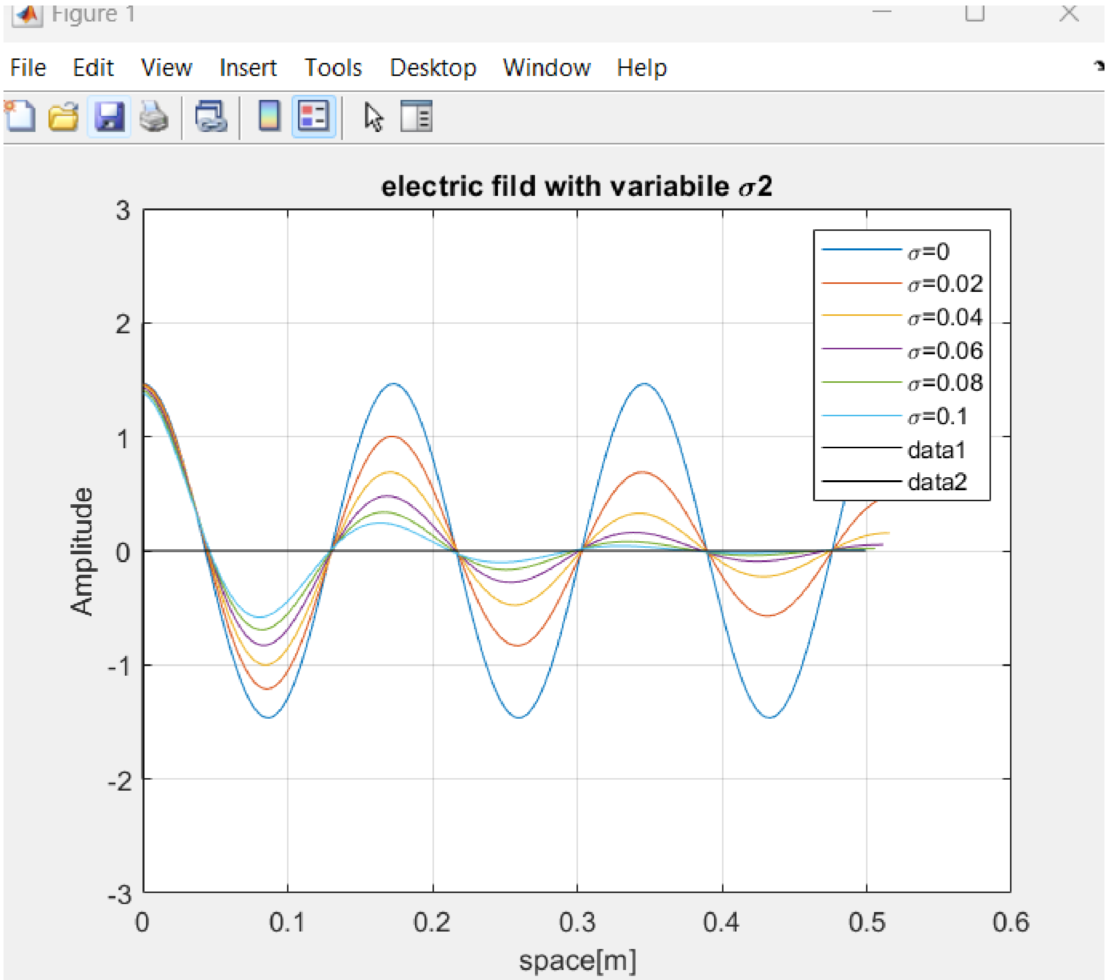
```
E0=input('enter the Amplitude:');
epsr1=input('enter the relative electric permittivity of medium 1:');
mur1=input('enter the relative magnetic permeability of medium 1:');
sigma1=input('enter the conductivity of medium 1:');
epsr2=input('enter the relative electric permittivity of medium 2:');
mur2=input('enter the relative magnetic permeability of medium 2:');
%sigma2=input('enter the relative conductivity of medium 2:');
sigma2=0:0.1/5:0.1;
f=f*10^9;
T=1/f;
w=2*pi*f;
e0=8.85e-12;
mu0=pi*4e-7;
eps1=e0*epsr1;
eps2=e0*epsr2;
mu1=mu0*mur1;
mu2=mu0*mur2;
k1=w*sqrt(eps1*mu1);
n1=sqrt(mu1/eps1);
%primo medio
beta1=real(k1);
alfa1=-imag(k1);
lamda1=(2*pi)/beta1;
z1=-3*lamda1:lamda1/100:0;
t=T;
EiF=E0*exp(-i*k1*z1);
Ei=zeros(length(t),length(z1));
figure;
for n=1:length(sigma2)
    n2=sqrt((i*w*mu2)/(sigma2(n)+(i*w*eps2)));
    k2=w*sqrt((eps2-(i*(sigma2(n)/w)))*mu2);
    %secondo medio
    beta2=real(k2);
    alfa2=-imag(k2);
    ref=(n2-n1)/(n2+n1);
    tras=(2*n2)/(n2+n1);
    lamda2=(2*pi)/beta2;
    z2=0:lamda2/100:3*lamda2;
    Et=zeros(length(t),length(z2));
    EtF=E0*tras*exp(-i*k2*z2);
    ErF=E0*ref*exp(i*k1*z1);
    E1F=EiF+ErF;
    Et(n,:)=real(EtF*exp(i*w*t));
plot(z2, Et(n, :), 'DisplayName', ['\sigma=' num2str(sigma2(n))]);
%trasmesso

    hold on;
end;
legend('show');
a=[0,3*lamda2];
b=[0,0];
c=[0,0];
d=[-E0,E0];
```

```
plot(a,b,'k');
plot(c,d,'k');
xlabel('space[m]');
ylabel('Amplitude');
title('electric fild with variabile \sigma2');
grid on;
ylim([-3,3]);
```

Screenshot of the Results

```
enter the frequenz [Ghz]:1
enter the Amplitude:2
enter the relative electric permittivity of medium 1:1
enter the relative magnetic permeability of medium 1:1
enter the conductivity of medium 1:0
enter the relative electric permittivity of medium 2:3
enter the relative magnetic permeability of medium 2:1
fx >>
```



Aperture Antenna– Uniform illumination.

Exercise 1

Aperture Antenna– Uniform illumination.

Implement the expression of the Incident Electric Field of an aperture antenna, with:

$$\underline{E^i} = -\hat{y} E_0 e^{-jkz}$$

$$dE_y = -E_0 e^{-jkr}\, e^{jkx\sin(\theta)}$$

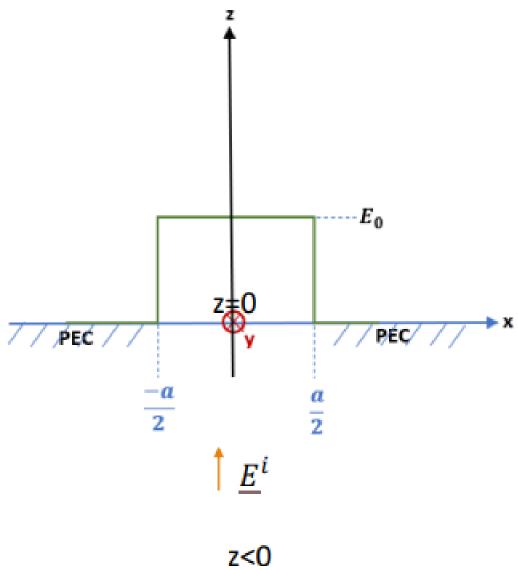
$$E_y = \int_{-\frac{a}{2}}^{\frac{a}{2}} dE_y dx$$

$$E_y = -\hat{y}\, a E_0 e^{-jkr} * \frac{\sin\left(\frac{ka}{2} * \sin(\theta)\right)}{\frac{ka}{2} * \sin(\theta)}$$

$E_y = aE_0e^{-jkr}\text{sinc}(\frac{ka}{2}\sin(\theta))$

$F(\theta) = \text{sinc}(\frac{ka}{2}\sin(\theta))$

✓ Uniform illumination



Conditions for the x-axis:

- [-a -a/2[→PEC (the field is null)
- [-a/2 a/2] → $E0$
-]a/2 a] →PEC (the field is null)

all variables:

- Eo=2
- z=0
- F=10 GHz
- a=5 λ --> (a> **λ**)

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

Code MATLAB:

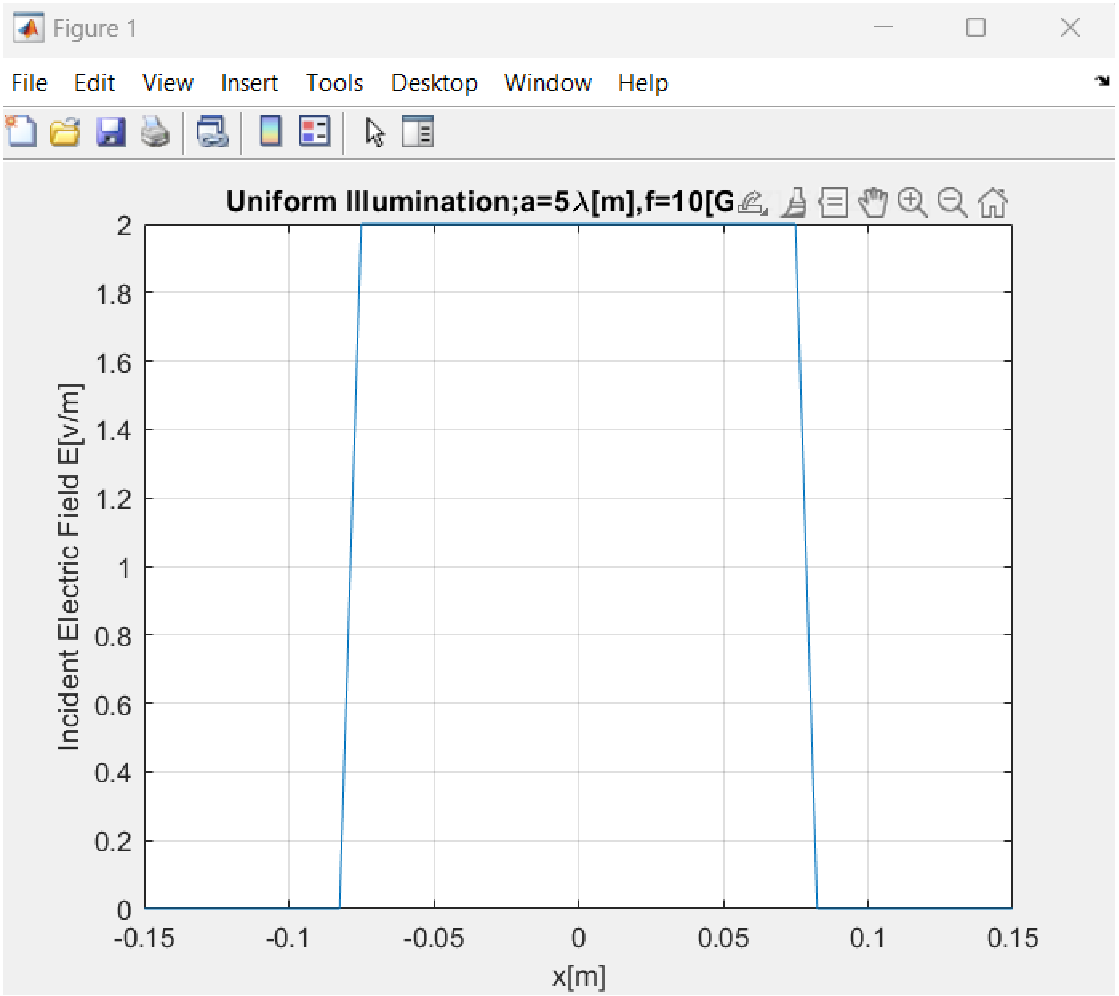
```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
f=f*10^9;
z=0;
T=1/f;
w=2*pi*f;
eps0=8.85e-12;
mu0=pi*4e-7;
k=w*sqrt(eps0*mu0);
```

```
lamda=(2*pi)/k;
a=5*lamda;
x1=-a:a/20:(-a/2)-(a/20);
x2=-a/2:a/20:a/2;
x3=(a/2)+(a/20):a/20:a;
Einc=E0*exp(-i*k*z);
Ei=[(zeros(1,length(x1))),(ones(1,length(x2)))*Einc,(zeros(1,length(x3)))];
X=[x1,x2,x3];


figure;
plot(X,abs(Ei));%incidente
xlabel('x[m]');
ylabel('Incident Electric Field E[v/m]');
title('Uniform Illumination;a=5\lambda[m],f=10[GHZ],E0=2[v/m]');
grid on;
ylim([0,2]);
```

Screenshot of the Results

```
enter the frequenz [Ghz]:10
enter the Amplitude:2
fx >>
```



Exercise 2

Aperture Antenna– Uniform illumination.

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

- $E_{y} = aE_0 e^{-jkr} \mathrm{sinc}(\frac{ka}{2}\sin(\theta))$
- $F(\theta) = \mathrm{sinc}(\frac{ka}{2}\sin(\theta))$

Conditions for θ:

- ➢ θ = $-\frac{\pi}{2} \rightarrow \frac{\pi}{2}$

all variables:

- Eo=2
- z=0
- F=10 GHz
- a=5 λ --> (a> λ)
- r=100m

Far Field Condition:

- ➢ r$\geq\frac{2a^2}{\lambda}$

Note:

$$\operatorname{sinc}(x) = \frac{\sin(x)}{x}$$

In Matlab:

$$\operatorname{sinc}(x) = \frac{\sin(\pi x)}{\pi x}$$

- *So divide* the argument for π $\operatorname{sinc}(x/\pi)$

First Null:

- ➢ First Null=$sin^{-1}\left(\frac{\lambda}{a}\right)$
- ➢ Beam width $\Delta\theta$ = 2 $*$First Null

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

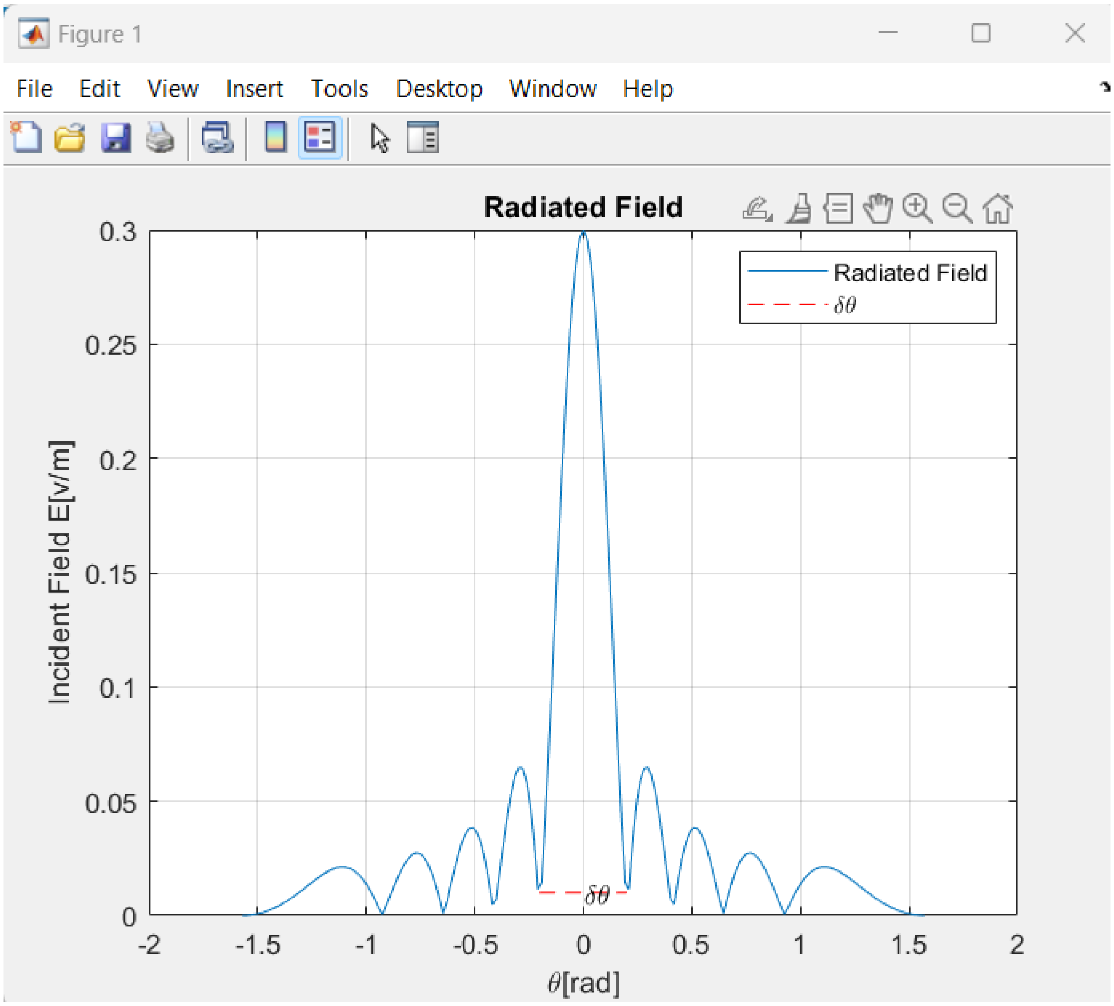
Code MATLAB:

```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
f=f*10^9;
z=0;
r=100;%in meter
T=1/f;
w=2*pi*f;
eps0=8.85e-12;
mu0=pi*4e-7;
k=w*sqrt(eps0*mu0);
```

```
lamda=(2*pi)/k;
a=5*lamda;
theta=-pi/2:pi/180:pi/2;
X=((k*a)/2)*sin(theta);
Ei=a*E0*exp(-i*k*r)*sinc(X/pi);
first_null=asin(lamda/a);
delta_theta=2*first_null;
to_plot=[-1*first_null,first_null];
figure;
plot(theta,abs(Ei));%incidente
hold on;
plot(to_plot,[0.01,0.01],'--R');
xlabel('\theta[rad]');
ylabel('Incident Field E[v/m]');
legend('Radiated Field','\delta\theta');
title('Radiated Field');
text(0,0.01,'\delta\theta');
grid on;
```

Screenshot of the Results

```
enter the frequenz [Ghz]:10
enter the Amplitude:2
fx >>
```



Exercise 3

Aperture Antenna– Uniform illumination.

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

- $E_{y=}$ $-\hat{y}\ aE_0 e^{-jkr}$ *sinc$(\frac{ka}{2}\sin(\theta))$ $[\frac{v}{m}]$
- $E_{y[dB]}$ =20*$\log_{10}(\frac{abs(Ey)}{max(abs(Ey))})$

Conditions for θ:

- $\theta = -\frac{\pi}{2} \rightarrow \frac{\pi}{2}$

all variables:

- Eo=2
- z=0
- F=10 GHz

- a=5 λ --> (a> **λ**)
- r=100m

Far Field Condition:

- ➢ $r \geq \frac{2a^2}{\lambda}$

Note:

$$\text{sinc}(x) = \frac{\sin(x)}{x}$$

In Matlab:

$$\text{sinc}(x) = \frac{\sin(\pi x)}{\pi x}$$

- *So divide* the argument for π $\text{sinc}(x/\pi)$

First Null:

- ➢ First Null=$sin^{-1}(\frac{\lambda}{a})$
- ➢ Beam width $\Delta\theta = 2 *$First Null

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

Code MATLAB:

```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
f=f*10^9;
z=0;
r=100;%in meter
T=1/f;
w=2*pi*f;
eps0=8.85e-12;
mu0=pi*4e-7;
k=w*sqrt(eps0*mu0);
lamda=(2*pi)/k;
a=5*lamda;
theta=-pi/2:pi/180:pi/2;
X=((k*a)/2)*sin(theta);
Ei=a*E0*exp(-i*k*z)*sinc(X/pi);
EiDB=20*log10(abs(Ei)/max(abs(Ei)));
first_null=asin(lamda/a);
fist_null_DB=20*log10(first_null);
delta_theta=2*first_null;
```

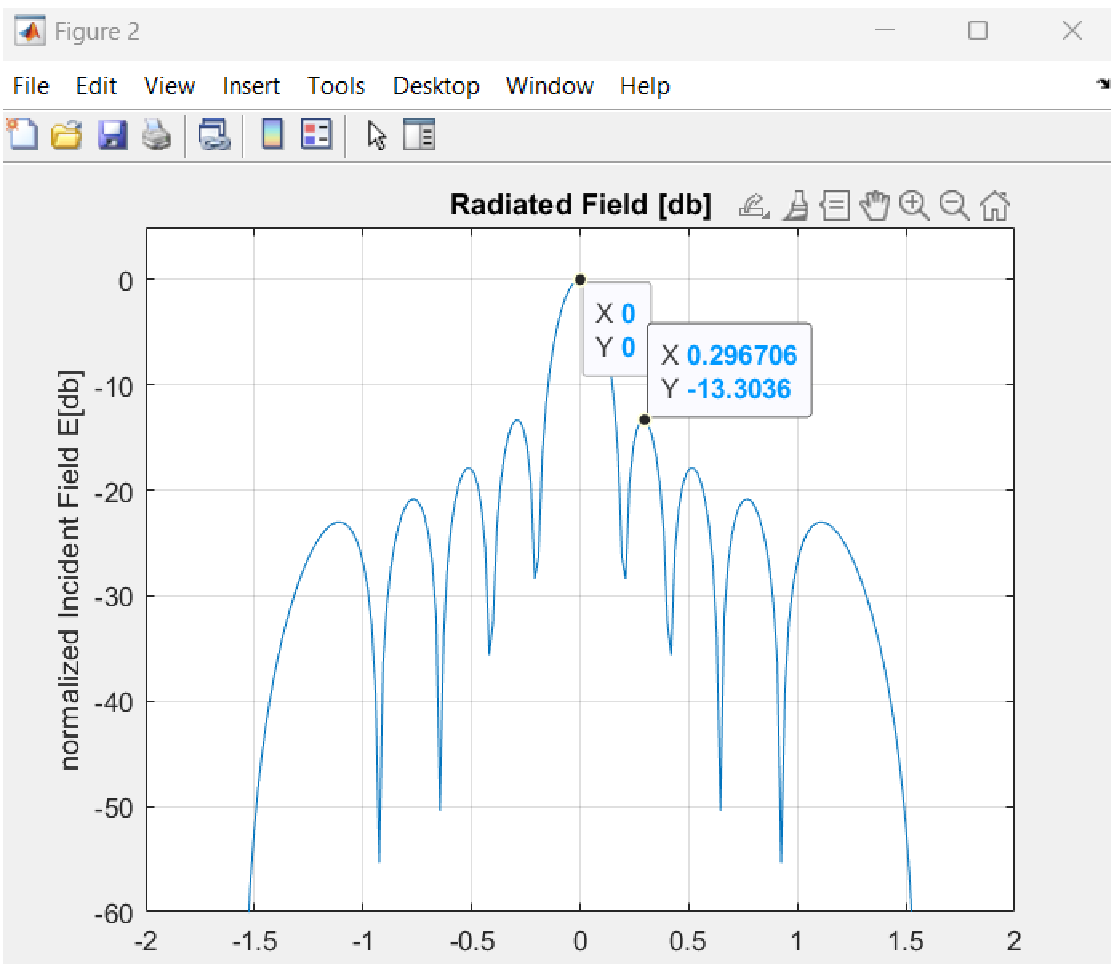
```
to_plot=[-1*first_null,first_null];

figure;
plot(theta,EiDB);%incidente
axis([-2,2,-60,5])
hold on;
xlabel('\theta[rad]');
ylabel('normalized Incident Field E[db]');

title('Radiated Field [db]');
grid on;
```

Screenshot of the Results

```
enter the frequenz [Ghz]:10
enter the Amplitude:2
fx >>
```



Exercise 4

Aperture Antenna– Uniform illumination.

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

- $E_y = -\hat{y}\ aE_0 e^{-jkr} * \frac{\sin\left(\frac{ka}{2} * \sin(\theta)\right)}{\frac{ka}{2} * \sin(\theta)}$
- $E_y = aE_0 e^{-jkr} \mathrm{sinc}\left(\frac{ka}{2}\sin(\theta)\right)$
- ✓ $F(\theta) = \mathrm{sinc}\left(\frac{ka}{2}\sin(\theta)\right)$

Conditions for θ:

- $\theta = -\frac{\pi}{2} \to \frac{\pi}{2}$

all variables:

- Eo=2
- z=0
- F=10 GHz
- a=5 λ --> (a> **λ**)

Note:

$$\mathrm{sinc}(x) = \frac{\sin(x)}{x}$$

In Matlab:

$$\mathrm{sinc}(x) = \frac{\sin(\pi x)}{\pi x}$$

- *So divide* the argument for π $\mathrm{sinc}(x/\pi)$

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

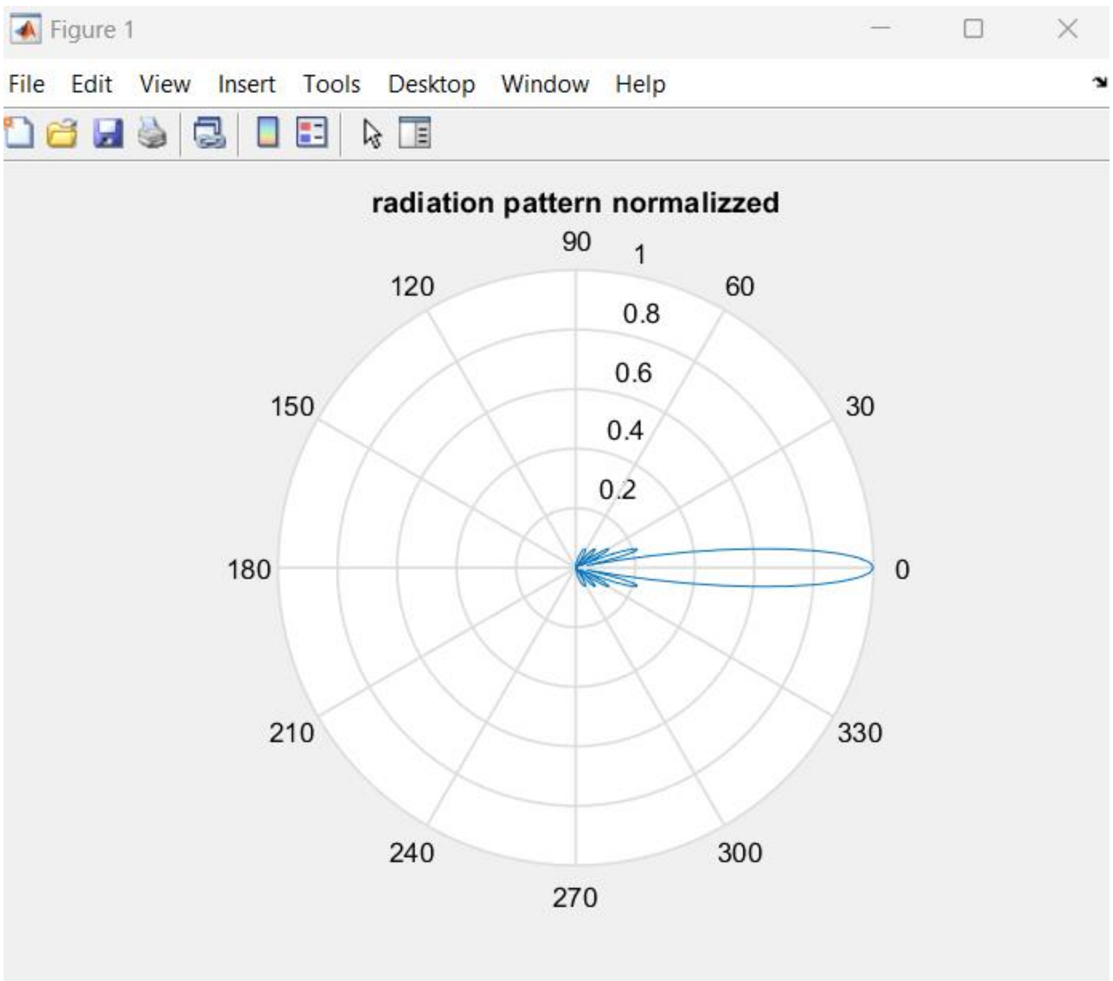
Code MATLAB:

```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
f=f*10^9;
z=0;
T=1/f;
w=2*pi*f;
eps0=8.85e-12;
mu0=pi*4e-7;
k=w*sqrt(eps0*mu0);
lamda=(2*pi)/k;
```

```
a=5*lamda;
theta=-pi/2:pi/180:pi/2;
X=((k*a)/2)*sin(theta);
Ei=a*E0*exp(-i*k*z)*sinc(X/pi);
radiation_pattern_normalized=sinc(X/pi);
figure;
polar(theta,abs(radiation_pattern_normalized)/max(radiation_pattern_normalized))
title('radiation pattern normalizzed');
grid on
```

Screenshot of the Results

```
enter the frequenz [Ghz]:10
enter the Amplitude:2
fx >>
```



Aperture Antenna_ Uniform illumination

Exercise 1

Aperture Antenna– Uniform illumination.

Implement the expression of the Incident Electric Field of an aperture antenna, with:

$\underline{E}^i = -\hat{y}E_0 e^{-jkz}$

$dE_y = -E_0 e^{-jkr} e^{jkx\sin(\theta)}$

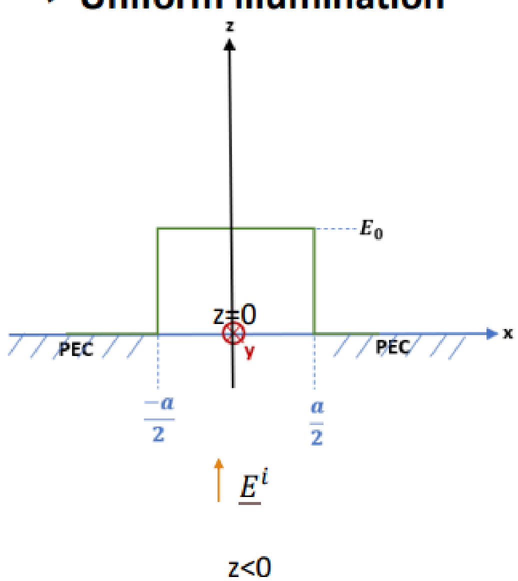
$E_y = \int_{-\frac{a}{2}}^{\frac{a}{2}} dE_y dx$

$E_y = -\hat{y}\, a E_0 e^{-jkr} * \frac{\sin\left(\frac{ka}{2} * \sin(\theta)\right)}{\frac{ka}{2} * \sin(\theta)}$

$E_y = a E_0 e^{-jkr} \mathrm{sinc}\left(\frac{ka}{2}\sin(\theta)\right)$

$F(\theta) = \mathrm{sinc}\left(\frac{ka}{2}\sin(\theta)\right)$

✓ **Uniform illumination**



Conditions for the x-axis:

- [-a -a/2[→PEC (the field is null)
- [-a/2 a/2] → $E0$
-]a/2 a] →PEC (the field is null)

all variables:

- Eo=2
- z=0
- F=10 GHz
- a=5 λ --> (a> **λ**)

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

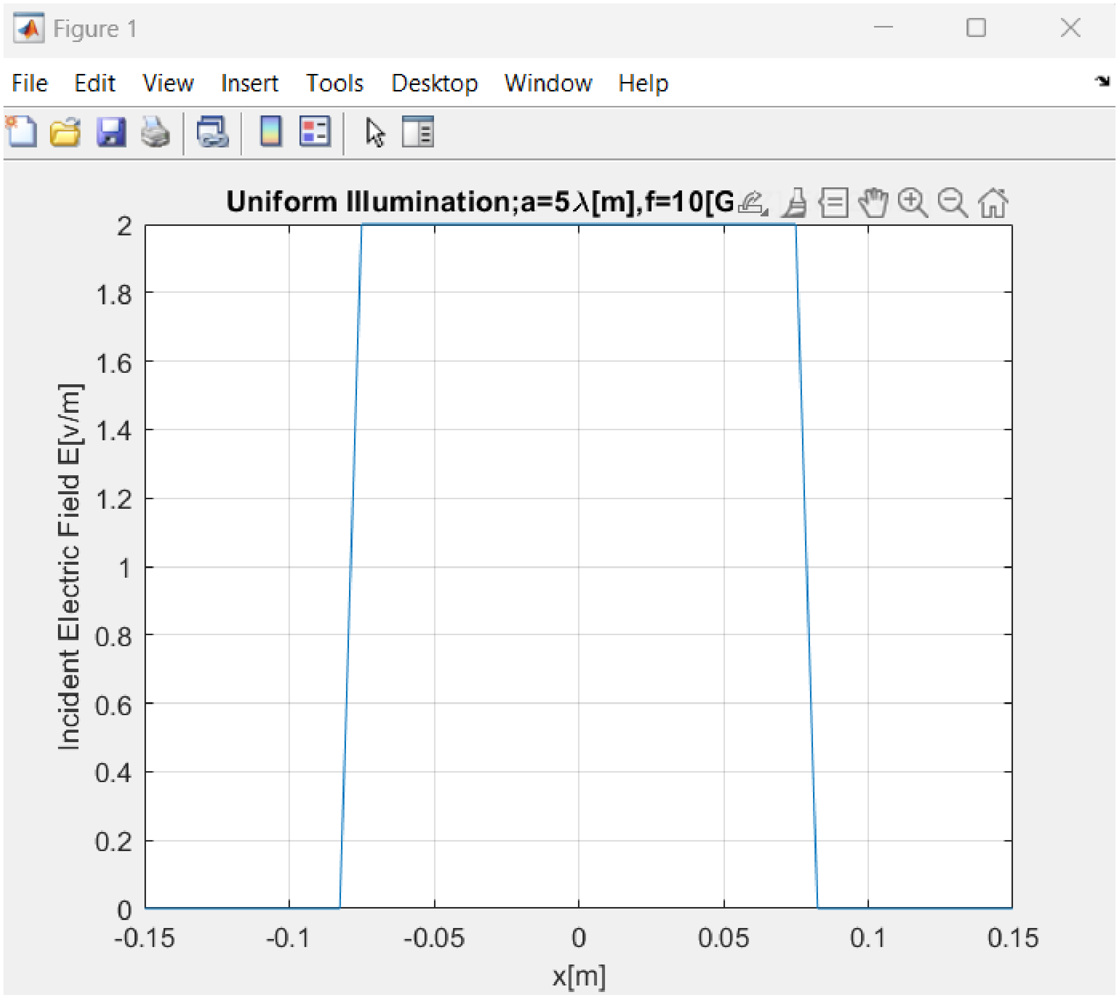
Code MATLAB:

```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
f=f*10^9;
z=0;
T=1/f;
w=2*pi*f;
eps0=8.85e-12;
mu0=pi*4e-7;
k=w*sqrt(eps0*mu0);
lamda=(2*pi)/k;
a=5*lamda;
x1=-a:a/20:(-a/2)-(a/20);
x2=-a/2:a/20:a/2;
x3=(a/2)+(a/20):a/20:a;
Einc=E0*exp(-i*k*z);
Ei=[(zeros(1,length(x1))),(ones(1,length(x2))*Einc,(zeros(1,length(x3)))];
X=[x1,x2,x3];


figure;
plot(X,abs(Ei));%incidente
xlabel('x[m]');
ylabel('Incident Electric Field E[v/m]');
title('Uniform Illumination;a=5\lambda[m],f=10[GHZ],E0=2[v/m]');
grid on;
ylim([0,2]);
```

Screenshot of the Results

```
enter the frequenz [Ghz]:10
enter the Amplitude:2
fx >>
```



Exercise 2

Aperture Antenna– Uniform illumination.

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

- $E_{y} = a E_0 e^{-jkr} \text{sinc}(\frac{ka}{2}\sin(\theta))$
- $F(\theta) = \text{sinc}(\frac{ka}{2}\sin(\theta))$

Conditions for θ:

- ➢ θ = -$\frac{\pi}{2} \to \frac{\pi}{2}$

all variables:

- Eo=2
- z=0
- F=10 GHz
- a=5 λ --> (a> **λ**)
- r=100m

Far Field Condition:

- ➢ r≥$\frac{2a^2}{\lambda}$

Note:

$$\operatorname{sinc}(x) = \frac{\sin(x)}{x}$$

In Matlab:

$$\operatorname{sinc}(x) = \frac{\sin(\pi x)}{\pi x}$$

- $So\ divide$ the argument for π $\operatorname{sinc}(x/\pi)$

First Null:

- ➢ First Null=sin^{-1} ($\frac{\lambda}{a}$)
- ➢ Beam width $\Delta\theta$ = 2 $*$First Null

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

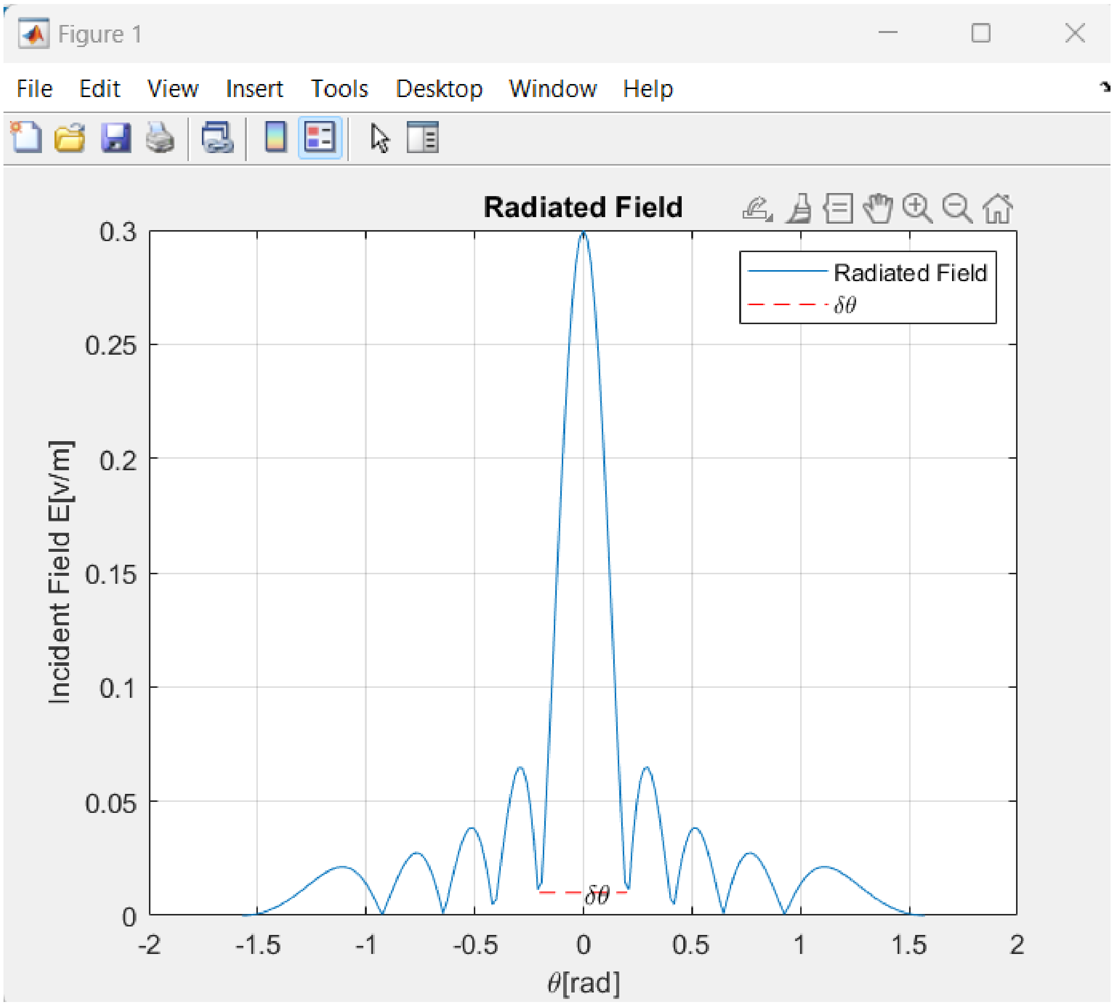
Code MATLAB:

```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
f=f*10^9;
z=0;
r=100;%in meter
T=1/f;
w=2*pi*f;
eps0=8.85e-12;
mu0=pi*4e-7;
k=w*sqrt(eps0*mu0);
```

```
lamda=(2*pi)/k;
a=5*lamda;
theta=-pi/2:pi/180:pi/2;
X=((k*a)/2)*sin(theta);
Ei=a*E0*exp(-i*k*r)*sinc(X/pi);
first_null=asin(lamda/a);
delta_theta=2*first_null;
to_plot=[-1*first_null,first_null];
figure;
plot(theta,abs(Ei));%incidente
hold on;
plot(to_plot,[0.01,0.01],'--R');
xlabel('\theta[rad]');
ylabel('Incident Field E[v/m]');
legend('Radiated Field','\delta\theta');
title('Radiated Field');
text(0,0.01,'\delta\theta');
grid on;
```

Screenshot of the Results

```
enter the frequenz [Ghz]:10
enter the Amplitude:2
fx >>
```



Exercise 3

Aperture Antenna– Uniform illumination.

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

- $E_{y=}$ -$\hat{y}$ $a E_0 e^{-jkr}$ *sinc($\frac{ka}{2}\sin(\theta)$) [$\frac{v}{m}$]
- $E_{y[dB]}$ =20*$\log_{10}$($\frac{abs(Ey)}{max(abs(Ey))}$)

Conditions for θ:

- θ = -$\frac{\pi}{2} \rightarrow \frac{\pi}{2}$

all variables:

- Eo=2
- z=0
- F=10 GHz

- a=5 λ --> (a> **λ**)
- r=100m

Far Field Condition:

- $r \geq \frac{2a^2}{\lambda}$

Note:

$$\text{sinc}(x) = \frac{\sin(x)}{x}$$

In Matlab:

$$\text{sinc}(x) = \frac{\sin(\pi x)}{\pi x}$$

- *So divide* the argument for π $\text{sinc}(x/\pi)$

First Null:

- First Null=$sin^{-1}\left(\frac{\lambda}{a}\right)$
- Beam width $\Delta\theta = 2 *$First Null

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

Code MATLAB:

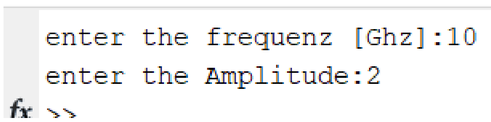
```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
f=f*10^9;
z=0;
r=100;%in meter
T=1/f;
w=2*pi*f;
eps0=8.85e-12;
mu0=pi*4e-7;
k=w*sqrt(eps0*mu0);
lamda=(2*pi)/k;
a=5*lamda;
theta=-pi/2:pi/180:pi/2;
X=((k*a)/2)*sin(theta);
Ei=a*E0*exp(-i*k*z)*sinc(X/pi);
EiDB=20*log10(abs(Ei)/max(abs(Ei)));
first_null=asin(lamda/a);
fist_null_DB=20*log10(first_null);
delta_theta=2*first_null;
```

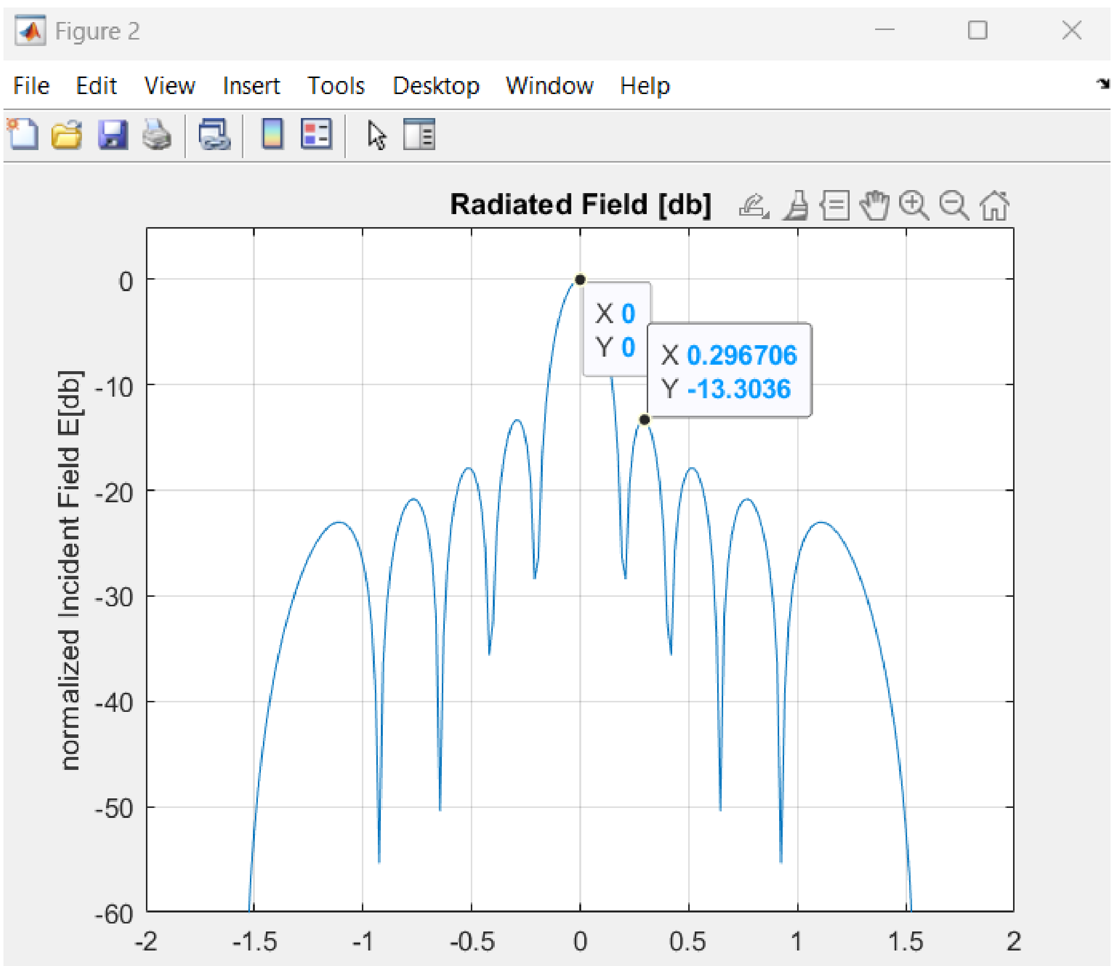
```
to_plot=[-1*first_null,first_null];

figure;
plot(theta,EiDB);%incidente
axis([-2,2,-60,5])
hold on;
xlabel('\theta[rad]');
ylabel('normalized Incident Field E[db]');

title('Radiated Field [db]');
grid on;
```

Screenshot of the Results





Exercise 4

Aperture Antenna– Uniform illumination.

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

- $E_y = -\hat{y}\, a E_0 e^{-jkr} * \frac{\sin\left(\frac{ka}{2} * \sin(\theta)\right)}{\frac{ka}{2} * \sin(\theta)}$
- $E_{y=}\ a E_0 e^{-jkr} \mathrm{sinc}\left(\frac{ka}{2}\sin(\theta)\right)$
- ✓ $F(\theta) = \mathrm{sinc}\left(\frac{ka}{2}\sin(\theta)\right)$

Conditions for θ:

- $\theta = -\frac{\pi}{2} \rightarrow \frac{\pi}{2}$

all variables:

- Eo=2
- z=0
- F=10 GHz
- a=5 λ --> (a> **λ**)

Note:

$$\mathrm{sinc}(x) = \frac{\sin(x)}{x}$$

In Matlab:

$$\mathrm{sinc}(x) = \frac{\sin(\pi x)}{\pi x}$$

- *So divide* the argument for π $\mathrm{sinc}(x/\pi)$

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

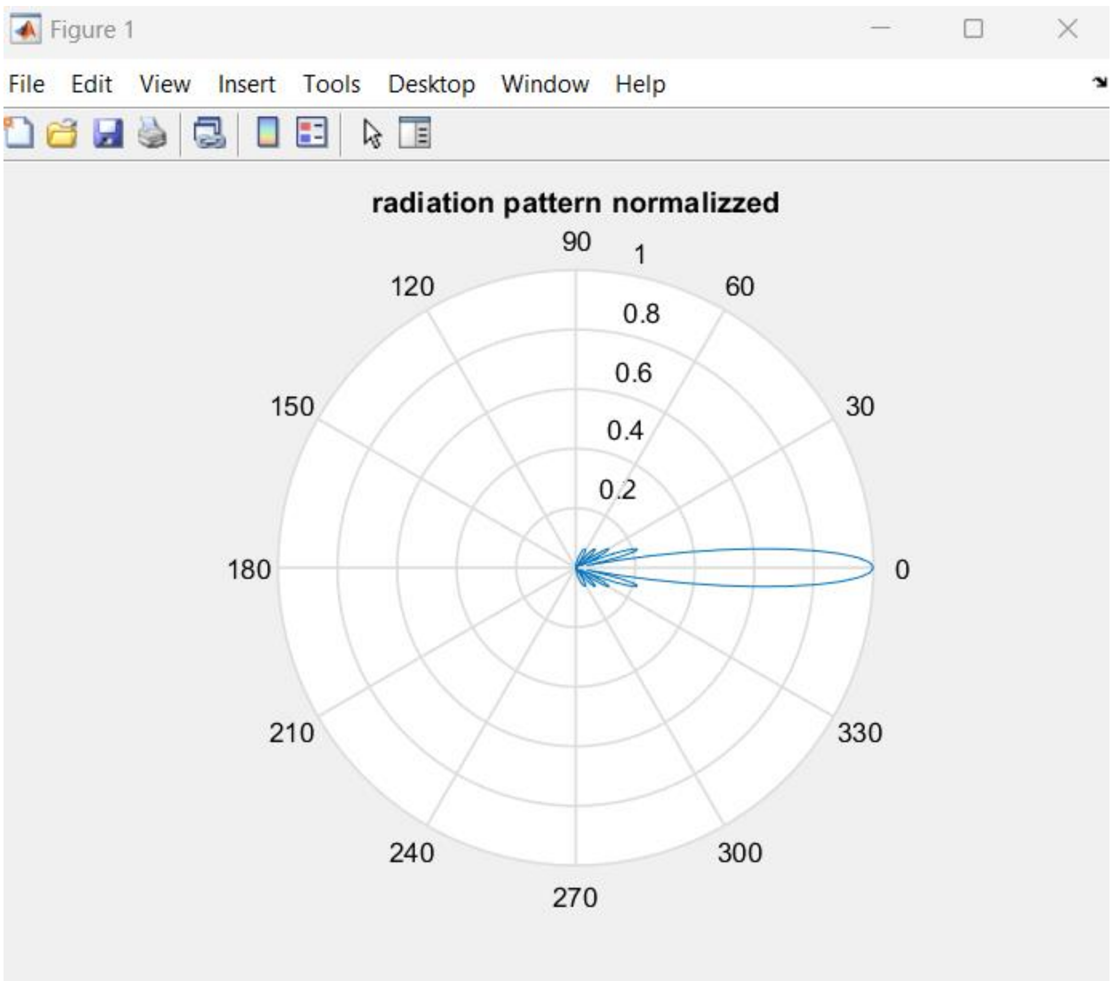
Code MATLAB:

```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
f=f*10^9;
z=0;
T=1/f;
w=2*pi*f;
eps0=8.85e-12;
mu0=pi*4e-7;
k=w*sqrt(eps0*mu0);
lamda=(2*pi)/k;
```

```
a=5*lamda;
theta=-pi/2:pi/180:pi/2;
X=((k*a)/2)*sin(theta);
Ei=a*E0*exp(-i*k*z)*sinc(X/pi);
radiation_pattern_normalized=sinc(X/pi);
figure;
polar(theta,abs(radiation_pattern_normalized)/max(radiation_pattern_normalized))
title('radiation pattern normalizzed');
grid on
```

Screenshot of the Results

```
enter the frequenz [Ghz]:10
enter the Amplitude:2
fx >>
```



Aperture Antenna_ Triangular illumination

Exercise 1

Aperture Antenna– Triangular illumination.

Implement the expression of the Incident Electric Field of an aperture antenna, with:

$\underline{E}^i = -\hat{y}\,(1-\frac{|x|}{\frac{a}{2}})E_0 e^{-jkz}$

$dE_y = -E_0\,(1-\frac{|x|}{\frac{a}{2}})e^{-jkr}\, e^{jkx\sin(\theta)}$

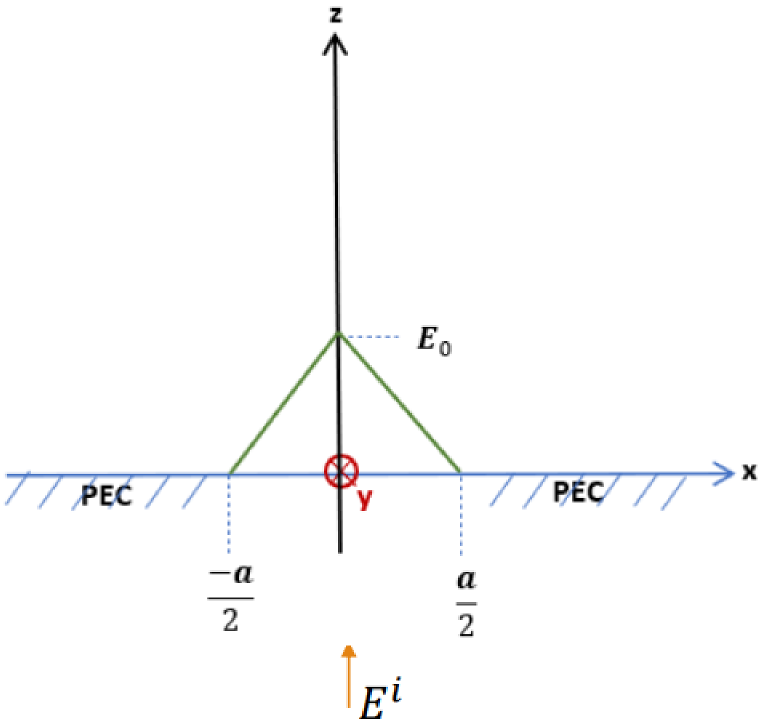
$dE_y = -(1-\frac{2|x|}{a})\, E_0 e^{-jkr}\, e^{jkx\sin(\theta)}$

$E_y = \int_{-\frac{a}{2}}^{\frac{a}{2}} dE_y dx$

$E_y = \frac{a}{2} E_0 e^{-jkr}\mathrm{sinc}^2(\frac{ka}{4}\sin(\theta))$

$F(\theta) = \mathrm{sinc}^2(\frac{ka}{4}\sin(\theta))$

✓ Triangular illumination



Conditions for the x-axis:

- [-a -a/2[→PEC (the field is null)
- [-a/2 a/2] → $E0$
-]a/2 a] →PEC (the field is null)

all variables:

- Eo=2
- z=0
- F=10 GHz
- a=5 λ --> (a> λ)

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

Code MATLAB:

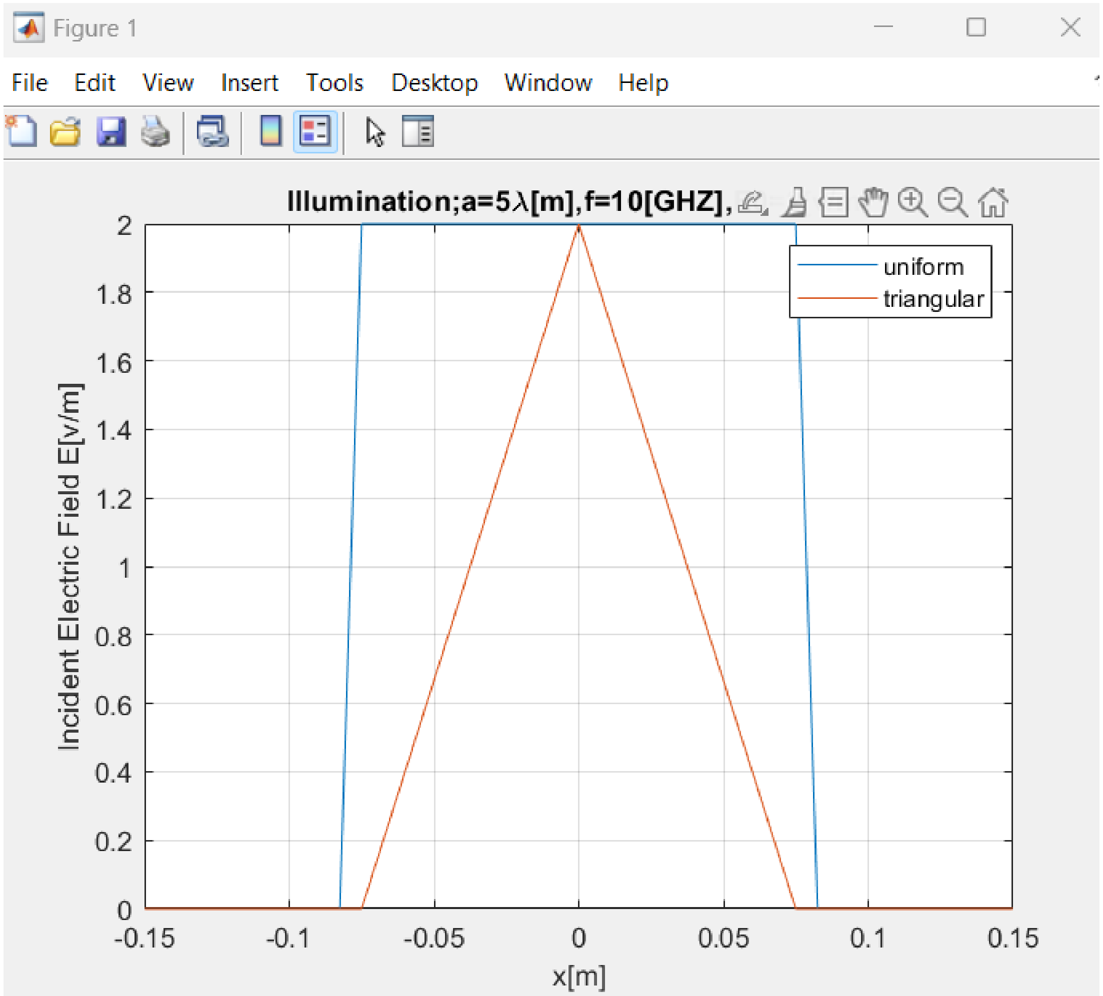
```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
f=f*10^9;
```

```
z=0;
T=1/f;
w=2*pi*f;
eps0=8.85e-12;
mu0=pi*4e-7;
k=w*sqrt(eps0*mu0);
lamda=(2*pi)/k;
a=5*lamda;
x1=-a:a/20:(-a/2)-(a/20);
x2=-a/2:a/20:a/2;
x3=(a/2)+(a/20):a/20:a;
y=[x1,x2,x3];
Einc=E0*exp(-i*k*z);
Einct=-1*(1-(abs(x2))/(a/2))*E0*exp(-i*k*z);
Ei=[(zeros(1,length(x1))),(ones(1,length(x2))).*Einc,(zeros(1,length(x3)))];
Eit=[(zeros(1,length(x1))),(ones(1,length(x2))).*Einct,(zeros(1,length(x3)))];


figure;
plot(y,abs(Ei));%incidente
hold on;
plot(y,abs(Eit));%incidente
xlabel('x[m]');
legend('uniform','triangular');
ylabel('Incident Electric Field E[v/m]');
title('Illumination;a=5\lambda[m],f=10[GHZ],E0=2[v/m]');
grid on;
ylim([0,2]);
```

Screenshot of the Results

```
enter the frequenz [Ghz]:10
enter the Amplitude:2
fx >>
```



Exercise 2

Aperture Antenna– Triangular illumination.

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

- $E_{y}= \frac{a}{2}E_0 e^{-jkr}\text{sinc}^2(\frac{ka}{4}\sin(\theta))$

Conditions for θ:

- $\theta = -\frac{\pi}{2} \rightarrow \frac{\pi}{2}$

all variables:

- Eo=2

- z=0
- F=10 GHz
- a=5 λ --> (a> **λ**)
- r=100m

Far Field Condition:

- $r \geq \frac{2a^2}{\lambda}$

Note:

$$\mathrm{sinc}(x) = \frac{\sin(x)}{x}$$

In Matlab:

$$\mathrm{sinc}(x) = \frac{\sin(\pi x)}{\pi x}$$

- *So divide* the argument for π $\mathrm{sinc}(x/\pi)$

First Null:

- First Null_uni=$sin^{-1}\left(\frac{\lambda}{a}\right)$
- First Null_tri=$sin^{-1}\left(\frac{2*\lambda}{a}\right)$

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

Code MATLAB:

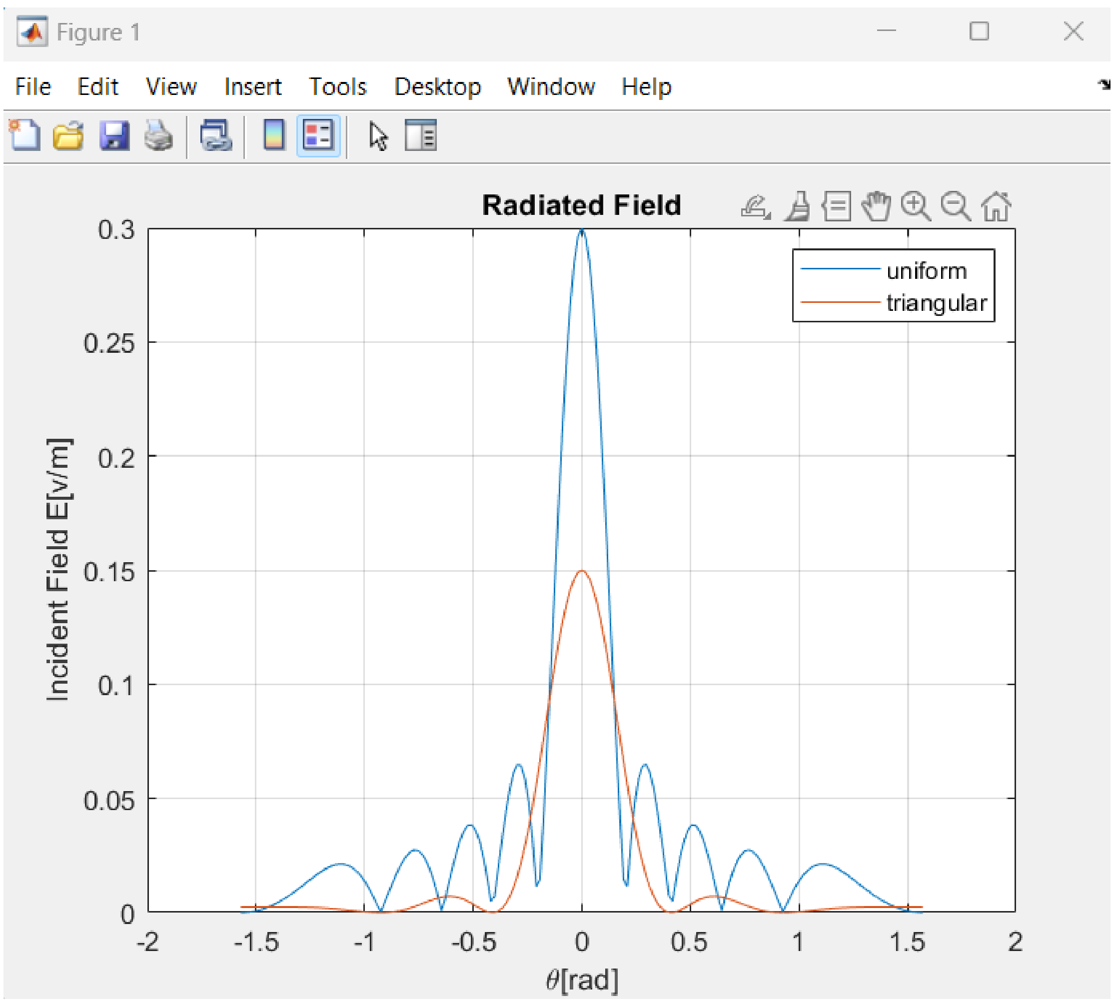
```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
f=f*10^9;
z=0;
r=100;%in meter
T=1/f;
w=2*pi*f;
eps0=8.85e-12;
mu0=pi*4e-7;
k=w*sqrt(eps0*mu0);
lamda=(2*pi)/k;
a=5*lamda;
theta=-pi/2:pi/180:pi/2;
X=((k*a)/2)*sin(theta);
Ei=a*E0*exp(-i*k*r)*sinc(X/pi);
Einct=(a/2)*E0*exp(-i*k*r)*(sinc(X/(2*pi))).^2;
```

```
first_null_uni=asin(lamda/a);
first_null_tri=asin((2*lamda)/a);

figure;
plot(theta,abs(Ei));%incidente
hold on;
plot(theta,abs(Einct));%incidente
xlabel('\theta[rad]');
ylabel('Incident Field E[v/m]');
legend('uniform','triangular');
title('Radiated Field');
grid on;
```

Screenshot of the Results

```
enter the frequenz [Ghz]:10
enter the Amplitude:2
fx >>
```



Exercise 3

Aperture Antenna– Triangular illumination.

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

- $E_{y=}\frac{a}{2}E_0e^{-jkr}\text{sinc}^2(\frac{ka}{4}\sin(\theta))[\frac{v}{m}]$
- $E_{y[dB]}=20*\log_{10}(\frac{abs(Ey)}{max(abs(Ey))})$

Conditions for θ:

- $\theta = -\frac{\pi}{2} \rightarrow \frac{\pi}{2}$

all variables:

- Eo=2
- z=0
- F=10 GHz
- a=5 λ --> (a> λ)
- r=100m

Far Field Condition:

- $r \geq \frac{2a^2}{\lambda}$

Note:

$$\text{sinc}(x) = \frac{\sin(x)}{x}$$

In Matlab:

$$\text{sinc}(x) = \frac{\sin(\pi x)}{\pi x}$$

- $So\ divide$ the argument for π $\text{sinc}(x/\pi)$

First Null:

- First Null Uni=$sin^{-1}(\frac{\lambda}{a})$
- First Null Tri=$sin^{-1}(\frac{2\lambda}{a})$

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

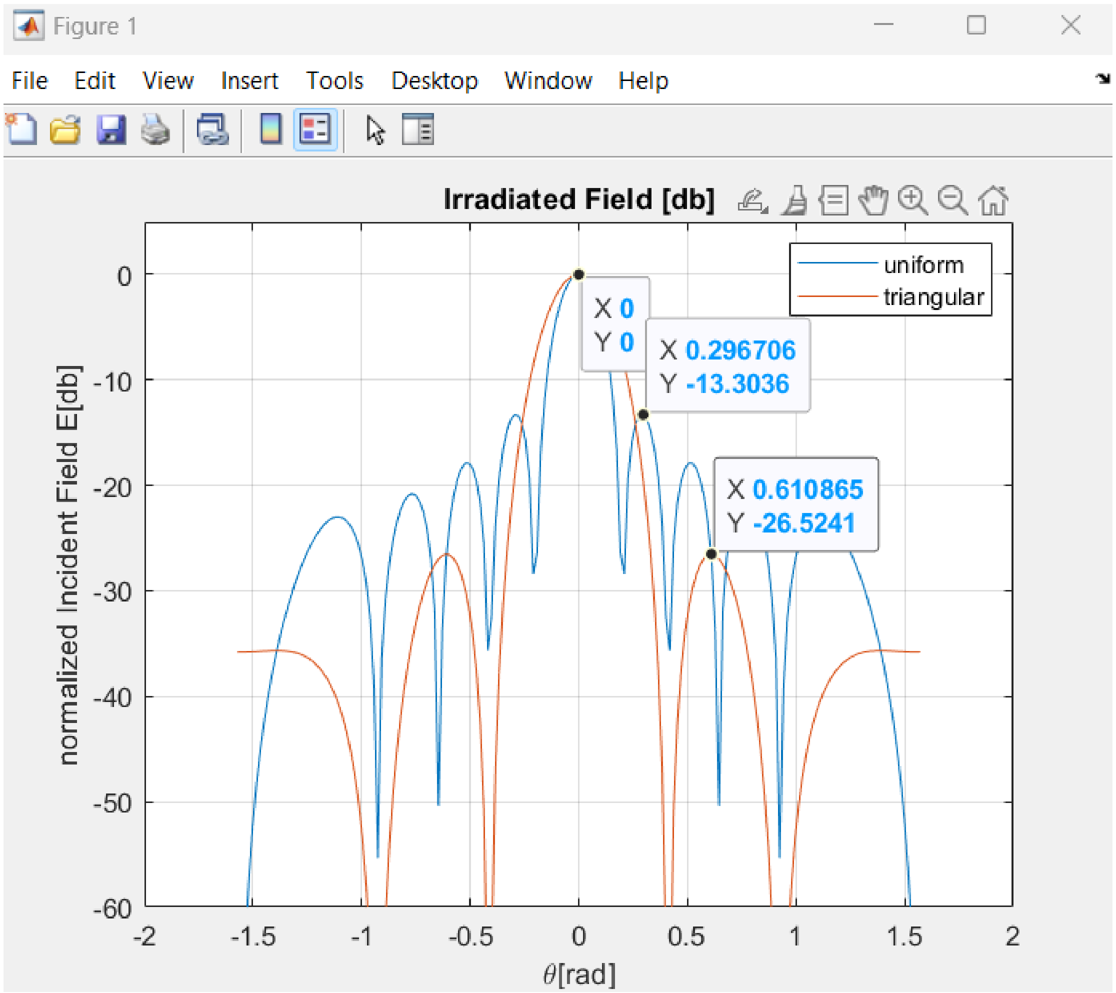
Code MATLAB:

```
clear all;
```

```
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
f=f*10^9;
z=0;
r=100;%in meter
T=1/f;
w=2*pi*f;
eps0=8.85e-12;
mu0=pi*4e-7;
k=w*sqrt(eps0*mu0);
lamda=(2*pi)/k;
a=5*lamda;
theta=-pi/2:pi/180:pi/2;
X=((k*a)/2)*sin(theta);
Ei=a*E0*exp(-i*k*z)*sinc(X/pi);
EiDB=20*log10(abs(Ei)/max(abs(Ei)));
Einct=(a/2)*E0*exp(-i*k*r)*(sinc(X/(2*pi))).^2;
EinctDB=20*log10(abs(Einct)/max(abs(Einct)));
first_null_uni=asin(lamda/a);
first_null_tri=asin((2*lamda)/a);
fist_null_Uni_DB=20*log10(first_null_uni);
fist_null_tri_DB=20*log10(first_null_tri);
figure;
plot(theta,EiDB);%incidente
axis([-2,2,-60,5]);
hold on;
plot(theta,EinctDB);%incidente
xlabel('\theta[rad]');
ylabel('normalized Incident Field E[db]');
legend('uniform','triangular');
title('Irradiated Field [db]');
grid on;
```

Screenshot of the Results

```
enter the frequenz [Ghz]:10
enter the Amplitude:2
fx >>
```



Exercise 4

Aperture Antenna– Triangular illumination.

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

- ✓ $E_{y=}\frac{a}{2}E_0 e^{-jkr}\text{sinc}^2(\frac{ka}{4}\sin(\theta))$
- ✓ $F(\theta)=\text{sinc}^2(\frac{ka}{4}\sin(\theta))$

Conditions for θ:

- ➢ $\theta = -\frac{\pi}{2} \rightarrow \frac{\pi}{2}$

all variables:

- Eo=2
- z=0
- F=10 GHz

- a=5 λ --> (a> **λ**)

Note:

$$\mathrm{sinc}(x) = \frac{\sin(x)}{x}$$

In Matlab:

$$\mathrm{sinc}(x) = \frac{\sin(\pi x)}{\pi x}$$

- *So divide* the argument for π $\mathrm{sinc}(x/\pi)$

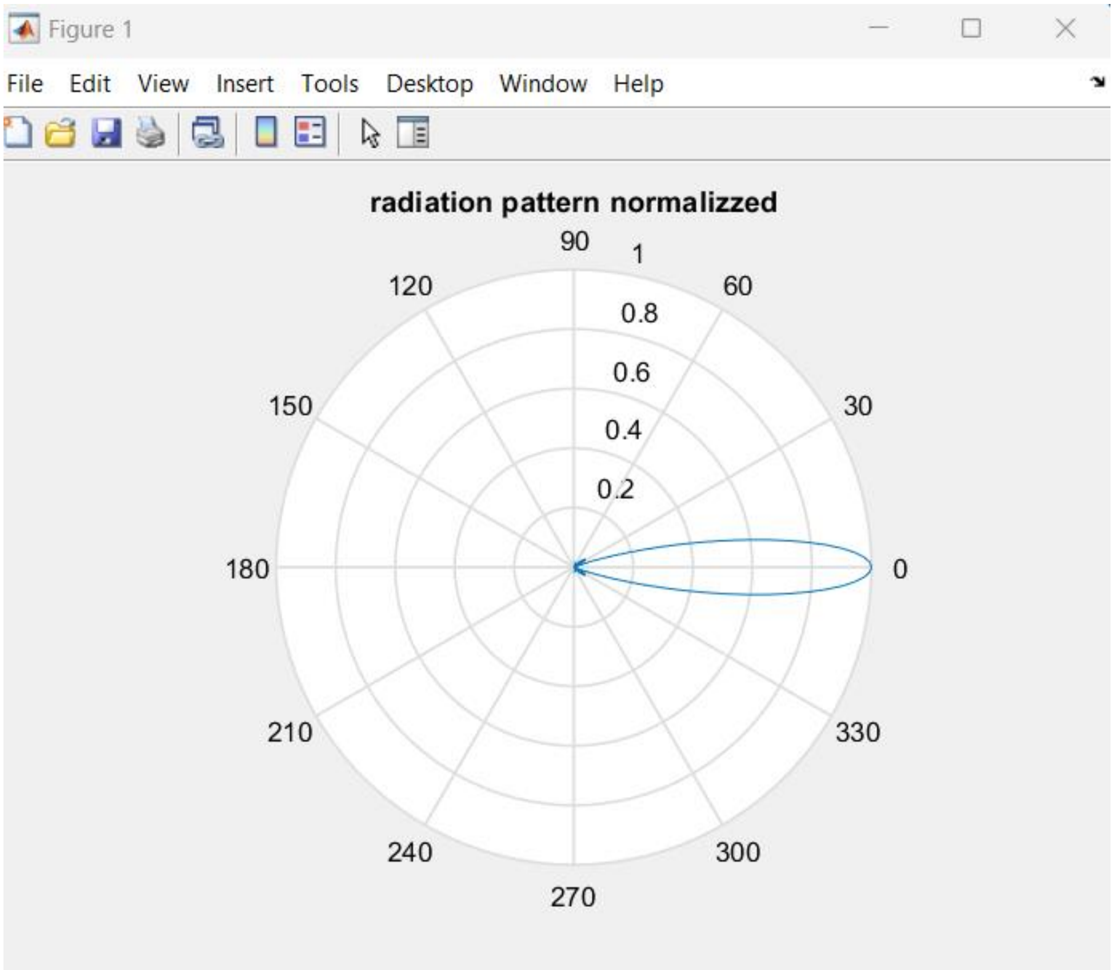
Implement the expression of the Radiation pattern of an aperture antenna with Triangular Illumination.

Code MATLAB:

```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
f=f*10^9;
z=0;
r=100;%in meter
T=1/f;
w=2*pi*f;
eps0=8.85e-12;
mu0=pi*4e-7;
k=w*sqrt(eps0*mu0);
lamda=(2*pi)/k;
a=5*lamda;
theta=-pi/2:pi/180:pi/2;
X=((k*a)/2)*sin(theta);
radiation_pattern_normalized=(sinc(X/(2*pi))).^2;
figure;
polar(theta,abs(radiation_pattern_normalized)/max(radiation_pattern_normalized))
title('radiation pattern normalizzed');
grid on;
```

Screenshot of the Results

```
enter the frequenz [Ghz]:10
enter the Amplitude:2
fx >>
```



Aperture Antenna_ Cosine illumination

Exercise 1

Aperture Antenna– Cosine illumination.

Implement the expression of the Incident Electric Field of an aperture antenna, with:

$$\underline{E}^i = -\hat{y}\cos\left(\frac{\pi x}{a}\right)E_0 e^{-jkz}$$

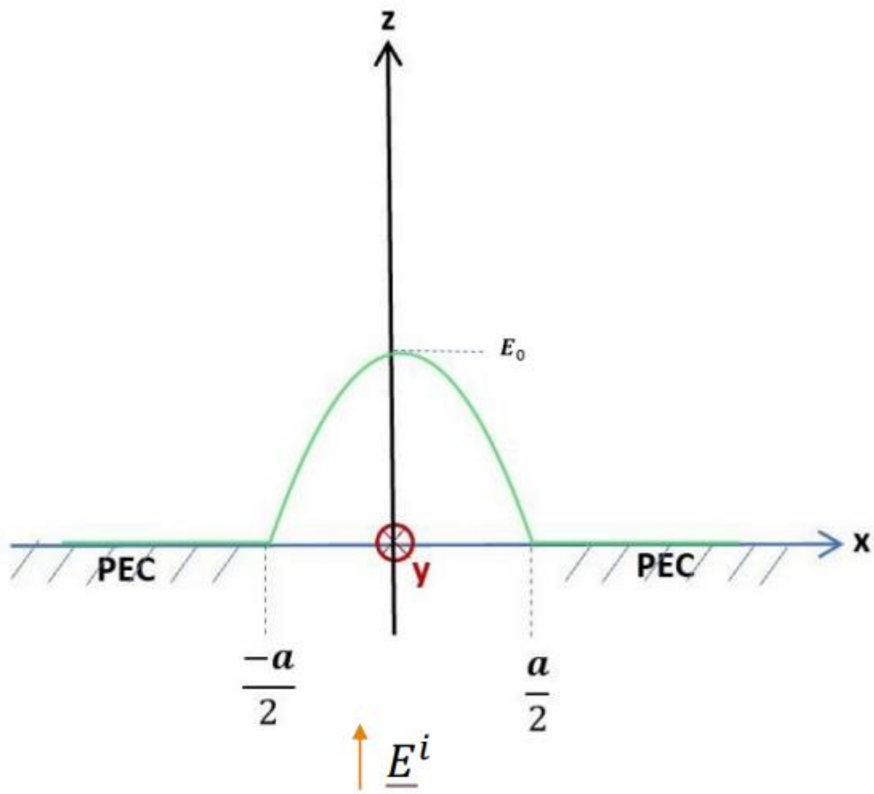
$$dE_y = -\cos\left(\frac{\pi x}{a}\right)E_0\, e^{-jkr}\, e^{jkx\sin(\theta)}$$

$$E_y = \int_{-\frac{a}{2}}^{\frac{a}{2}} dE_y\, dx$$

$$E_y = \frac{a}{2}E_0 e^{-jkr}\left\{\mathrm{sinc}\left(\frac{\pi}{2}+\frac{ka}{2}\sin(\theta)\right)+\mathrm{sinc}\left(\frac{\pi}{2}-\frac{ka}{2}\sin(\theta)\right)\right\}$$

$F(\theta) = \text{sinc}(\frac{\pi}{2} + \frac{ka}{2}\sin(\theta)) + \text{sinc}(\frac{\pi}{2} - \frac{ka}{2}\sin(\theta))$

✓ Cosine illumination



Conditions for the x-axis:

- [-a -a/2[→PEC (the field is null)
- [-a/2 a/2] → $E0$
-]a/2 a] →PEC (the field is null)

all variables:

- Eo=2
- z=0
- F=10 GHz
- a=5 λ --> (a> λ)

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

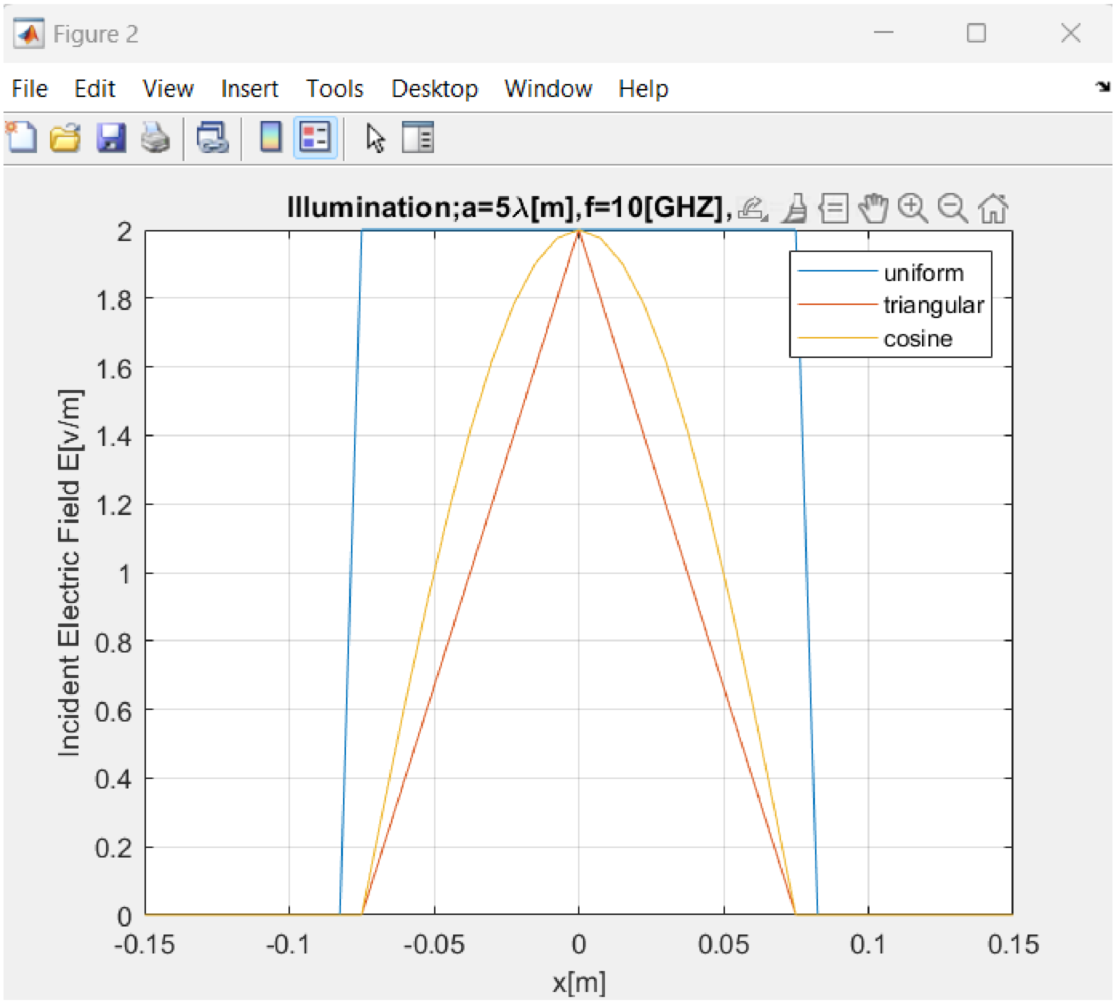
Code MATLAB:

```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
```

```
E0=input('enter the Amplitude:');
f=f*10^9;
z=0;
T=1/f;
w=2*pi*f;
eps0=8.85e-12;
mu0=pi*4e-7;
k=w*sqrt(eps0*mu0);
lamda=(2*pi)/k;
a=5*lamda;
x1=-a:a/20:(-a/2)-(a/20);
x2=-a/2:a/20:a/2;
x3=(a/2)+(a/20):a/20:a;
y=[x1,x2,x3];
Einc=E0*exp(-i*k*z);
Einct=-1*(1-(abs(x2))/(a/2))*E0*exp(-i*k*z);
Eincc=-1*cos((pi*x2)/a)*E0*exp(-i*k*z);
Ei=[(zeros(1,length(x1))),(ones(1,length(x2))).*Einc,(zeros(1,length(x3)))];
Eit=[(zeros(1,length(x1))),(ones(1,length(x2))).*Einct,(zeros(1,length(x3)))];
Eic=[(zeros(1,length(x1))),(ones(1,length(x2))).*Eincc,(zeros(1,length(x3)))];
figure;
plot(y,abs(Ei));%incidente
hold on;
plot(y,abs(Eit));%incidente
plot(y,abs(Eic));%incidente
xlabel('x[m]');
legend('uniform','triangular','cosine');
ylabel('Incident Electric Field E[v/m]');
title('Illumination;a=5\lambda[m],f=10[GHZ],E0=2[v/m]');
grid on;
ylim([0,2]);
```

Screenshot of the Results

```
enter the frequenz [Ghz]:10
enter the Amplitude:2
fx >>
```



Exercise 2

Aperture Antenna– Cosine illumination.

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

- $E_y = \frac{a}{2} E_0 e^{-jkr} \{\mathrm{sinc}(\frac{\pi}{2} + \frac{ka}{2}\sin(\theta)) + \mathrm{sinc}(\frac{\pi}{2} - \frac{ka}{2}\sin(\theta))\}$

Conditions for θ:

- $\theta = -\frac{\pi}{2} \rightarrow \frac{\pi}{2}$

all variables:

- Eo=2

- z=0
- F=10 GHz
- a=5 λ --> (a> λ)
- r=100m

Far Field Condition:

- r≥$\frac{2a^2}{\lambda}$

Note:

$$\mathrm{sinc}(x) = \frac{\sin(x)}{x}$$

In Matlab:

$$\mathrm{sinc}(x) = \frac{\sin(\pi x)}{\pi x}$$

- *So divide* the argument for π $\mathrm{sinc}(x/\pi)$

First Null:

- First Null Uni=$sin^{-1}\left(\frac{\lambda}{a}\right)$
- First Null Tri=$sin^{-1}\left(\frac{2\lambda}{a}\right)$
- First Null Cos =$sin^{-1}\left(\frac{3\lambda}{2a}\right)$

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

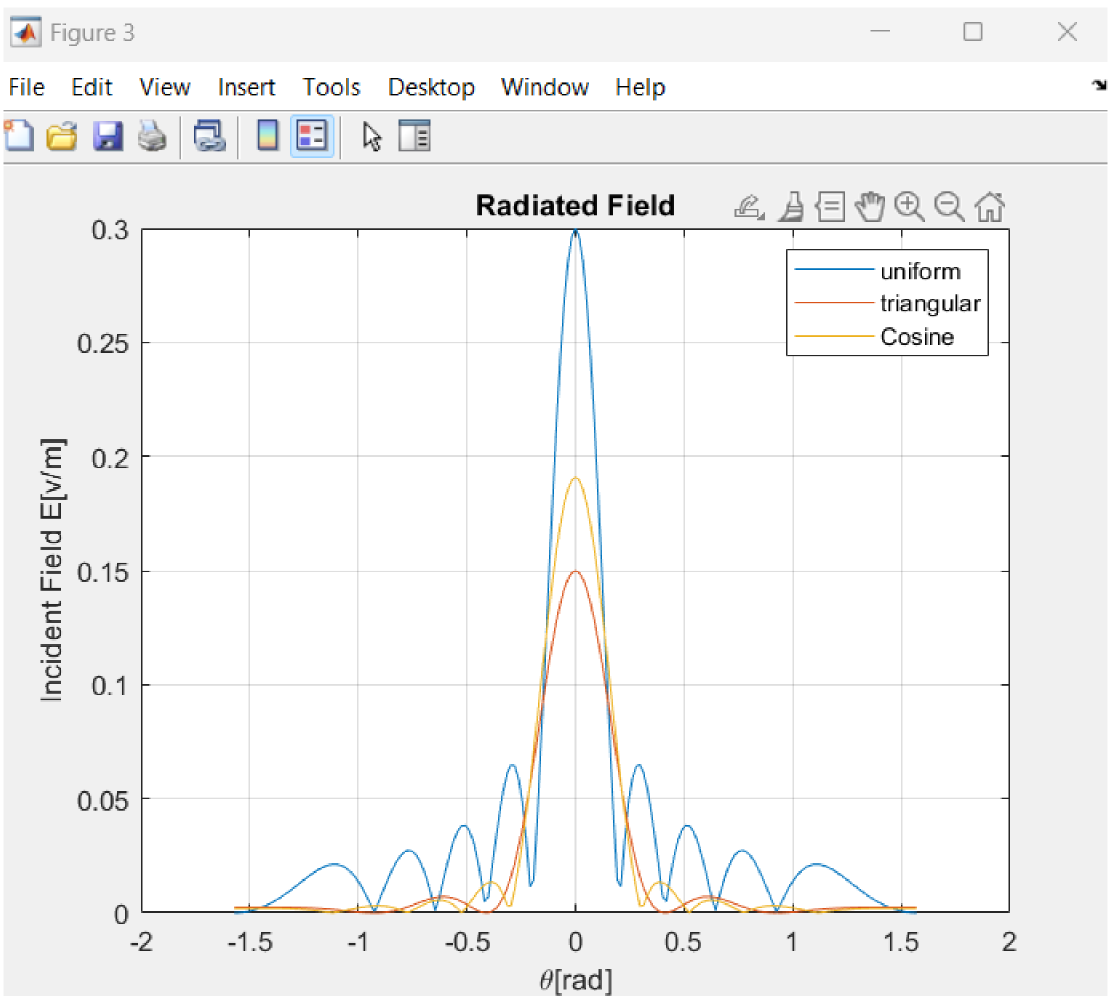
Code MATLAB:

```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
f=f*10^9;
z=0;
r=100;%in meter
T=1/f;
w=2*pi*f;
eps0=8.85e-12;
mu0=pi*4e-7;
k=w*sqrt(eps0*mu0);
lamda=(2*pi)/k;
a=5*lamda;
theta=-pi/2:pi/180:pi/2;
X=((k*a)/2)*sin(theta);
Ei=a*E0*exp(-i*k*r)*sinc(X/pi);
Einct=(a/2)*E0*exp(-i*k*r)*(sinc(X/(2*pi))).^2;
Eincc=(a/2)*E0*exp(-i*k*r)*((sinc(((pi/2)+X)/pi))+(sinc(((pi/2)-X)/pi)));
first_null_uni=asin(lamda/a);
```

```
first_null_tri=asin((2*lamda)/a);
first_null_cos=asin((3*lamda)/(2*a));
figure;
plot(theta,abs(Ei));%incidente
hold on;
plot(theta,abs(Einct));%incidente
plot(theta,abs(Eincc));%incidente
xlabel('\theta[rad]');
ylabel('Incident Field E[v/m]');
legend('uniform','triangular','Cosine');
title('Radiated Field');
grid on;
```

Screenshot of the Results

```
enter the frequenz [Ghz]:10
enter the Amplitude:2
fx >>
```



Exercise 3

Aperture Antenna–Cosine illumination.

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

- $E_y = \frac{a}{2} E_0 e^{-jkr} \{\mathrm{sinc}(\frac{\pi}{2} + \frac{ka}{2}\sin(\theta)) + \mathrm{sinc}(\frac{\pi}{2} - \frac{ka}{2}\sin(\theta))\}$ $[\frac{v}{m}]$
- $E_{y[dB]} = 20 * \log_{10}(\frac{abs(Ey)}{max(abs(Ey))})$

Conditions for θ:

- $\theta = -\frac{\pi}{2} \to \frac{\pi}{2}$

all variables:

- Eo=2
- z=0
- F=10 GHz
- a=5 λ --> (a> **λ**)
- r=100m

Far Field Condition:

- $r \geq \frac{2a^2}{\lambda}$

Note:

$$\mathrm{sinc}(x) = \frac{\sin(x)}{x}$$

In Matlab:

$$\mathrm{sinc}(x) = \frac{\sin(\pi x)}{\pi x}$$

- *So divide* the argument for π $\mathrm{sinc}(x/\pi)$

First Null:

- First Null Uni=$sin^{-1}(\frac{\lambda}{a})$
- First Null Tri=$sin^{-1}(\frac{2\lambda}{a})$
- First Null Cos =$sin^{-1}(\frac{3\lambda}{2a})$

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

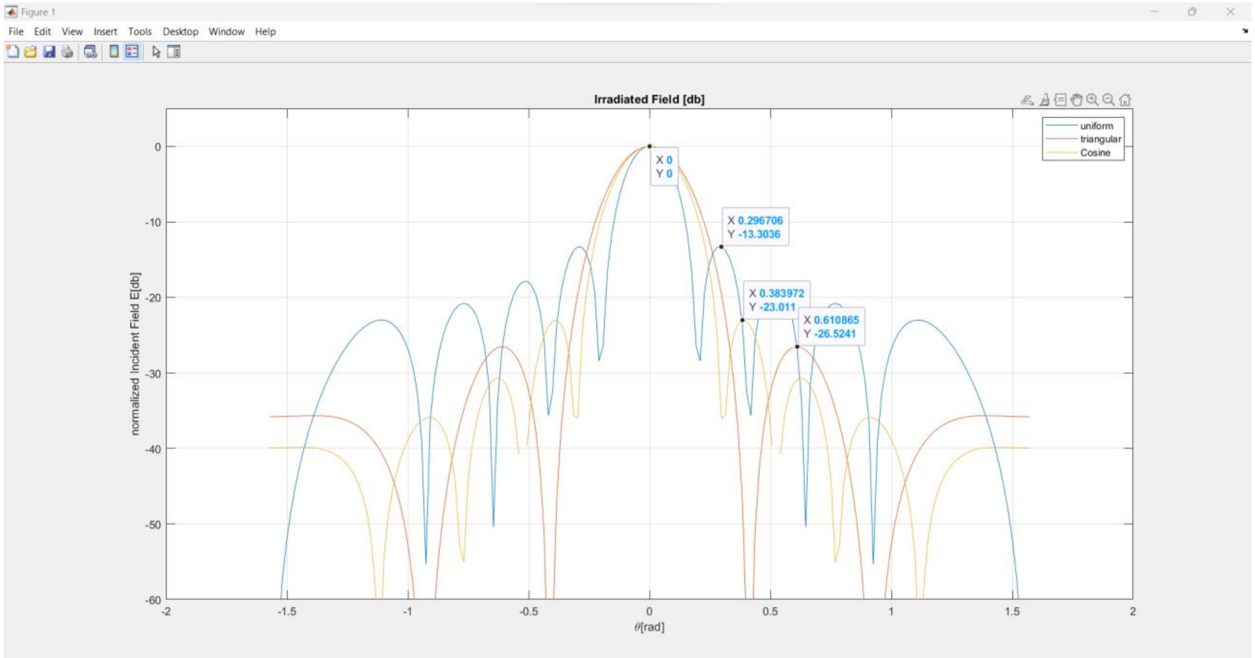
Code MATLAB:

```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
```

```
E0=input('enter the Amplitude:');
f=f*10^9;
z=0;
r=100;%in meter
T=1/f;
w=2*pi*f;
eps0=8.85e-12;
mu0=pi*4e-7;
k=w*sqrt(eps0*mu0);
lamda=(2*pi)/k;
a=5*lamda;
theta=-pi/2:pi/180:pi/2;
X=((k*a)/2)*sin(theta);
Ei=a*E0*exp(-i*k*z)*sinc(X/pi);
EiDB=20*log10(abs(Ei)/max(abs(Ei)));
Einct=(a/2)*E0*exp(-i*k*r)*(sinc(X/(2*pi))).^2;
EinctDB=20*log10(abs(Einct)/max(abs(Einct)));
Eincc=(a/2)*E0*exp(-i*k*r)*((sinc(((pi/2)+X)/pi))+(sinc(((pi/2)-X)/pi)));
EinccDB=20*log10(abs(Eincc)/max(abs(Eincc)));
first_null_uni=asin(lamda/a);
first_null_tri=asin((2*lamda)/a);
first_null_cos=asin((3*lamda)/(2*a));
fist_null_Uni_DB=20*log10(first_null_uni);
fist_null_tri_DB=20*log10(first_null_tri);
fist_null_cos_DB=20*log10(first_null_cos);
figure;
plot(theta,EiDB);%incidente
axis([-2,2,-60,5]);
hold on;
plot(theta,EinctDB);%incidente
plot(theta,EinccDB);%incidente
xlabel('\theta[rad]');
ylabel('normalized Incident Field E[db]');
legend('uniform','triangular','Cosine');
title('Irradiated Field [db]');
grid on;
```

Screenshot of the Results

```
enter the frequenz [Ghz]:10
enter the Amplitude:2
fx >>
```



Exercise 4

Aperture Antenna–Cosine illumination.

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

- $E_{y}= \frac{a}{2} E_0 e^{-jkr} \{\text{sinc}(\frac{\pi}{2} + \frac{ka}{2}\sin(\theta)) + \text{sinc}(\frac{\pi}{2} - \frac{ka}{2}\sin(\theta))\}$
- ✓ $F(\theta) = \text{sinc}(\frac{\pi}{2} + \frac{ka}{2}\sin(\theta)) + \text{sinc}(\frac{\pi}{2} - \frac{ka}{2}\sin(\theta))$

Conditions for $\boldsymbol{\theta}$:

- $\theta = -\frac{\pi}{2} \to \frac{\pi}{2}$

all variables:

- Eo=2
- z=0
- F=10 GHz
- a=5 λ --> (a> **λ**)

Note:

$$\mathrm{sinc}(x) = \frac{\sin(x)}{x}$$

In Matlab:

$$\mathrm{sinc}(x) = \frac{\sin(\pi x)}{\pi x}$$

- *So divide* the argument for π $\mathrm{sinc}(x/\pi)$

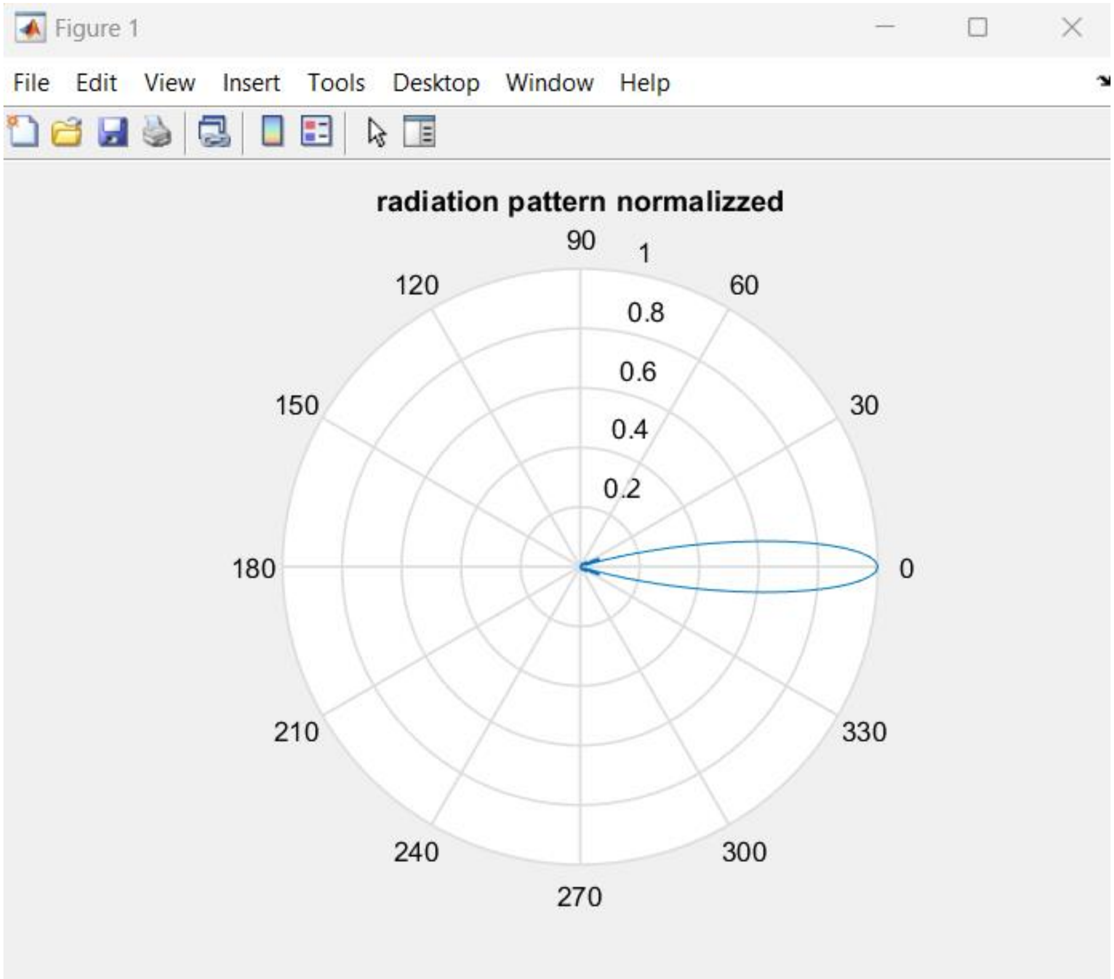
Implement the expression of the Radiation pattern of an aperture antenna with Cosine Illumination.

Code MATLAB:

```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
f=f*10^9;
z=0;
r=100;%in meter
T=1/f;
w=2*pi*f;
eps0=8.85e-12;
mu0=pi*4e-7;
k=w*sqrt(eps0*mu0);
lamda=(2*pi)/k;
a=5*lamda;
theta=-pi/2:pi/180:pi/2;
X=((k*a)/2)*sin(theta);
Eincc=(a/2)*E0*exp(-i*k*r)*((sinc(((pi/2)+X)/pi))+(sinc(((pi/2)-X)/pi)));
EinccDB=20*log10(abs(Eincc)/max(abs(Eincc)));
radiation_pattern_normalized=sinc(((pi/2)+X)/pi)+sinc(((pi/2)-X)/pi);
figure;
polar(theta,abs(radiation_pattern_normalized)/max(radiation_pattern_normalized))
title('radiation pattern normalizzed');
grid on;
```

Screenshot of the Results

```
enter the frequenz [Ghz]:10
enter the Amplitude:2
fx >>
```



Aperture Antenna_ With Different a

Exercise 1

Aperture Antenna–With Different a.

Implement the expression of the Radiated Field of an aperture antenna with different a.

Conditions for θ:

- θ = -$\frac{\pi}{2} \rightarrow \frac{\pi}{2}$

all variables:

- Eo=2
- z=0
- F=10 GHz
- a=2 λ , 3 λ , 5 λ --> (a> **λ**)

- r=100m

Far Field Condition:

- r≥$\frac{2a^2}{\lambda}$

Note:

$$\text{sinc}(x) = \frac{\sin(x)}{x}$$

In Matlab:

$$\text{sinc}(x) = \frac{\sin(\pi x)}{\pi x}$$

- *So divide* the argument for π $\text{sinc}(x/\pi)$

First Null:

- First Null Uni=$sin^{-1}\left(\frac{\lambda}{a}\right)$
- First Null Tri=$sin^{-1}\left(\frac{2\lambda}{a}\right)$
- First Null Cos =$sin^{-1}\left(\frac{3\lambda}{2a}\right)$

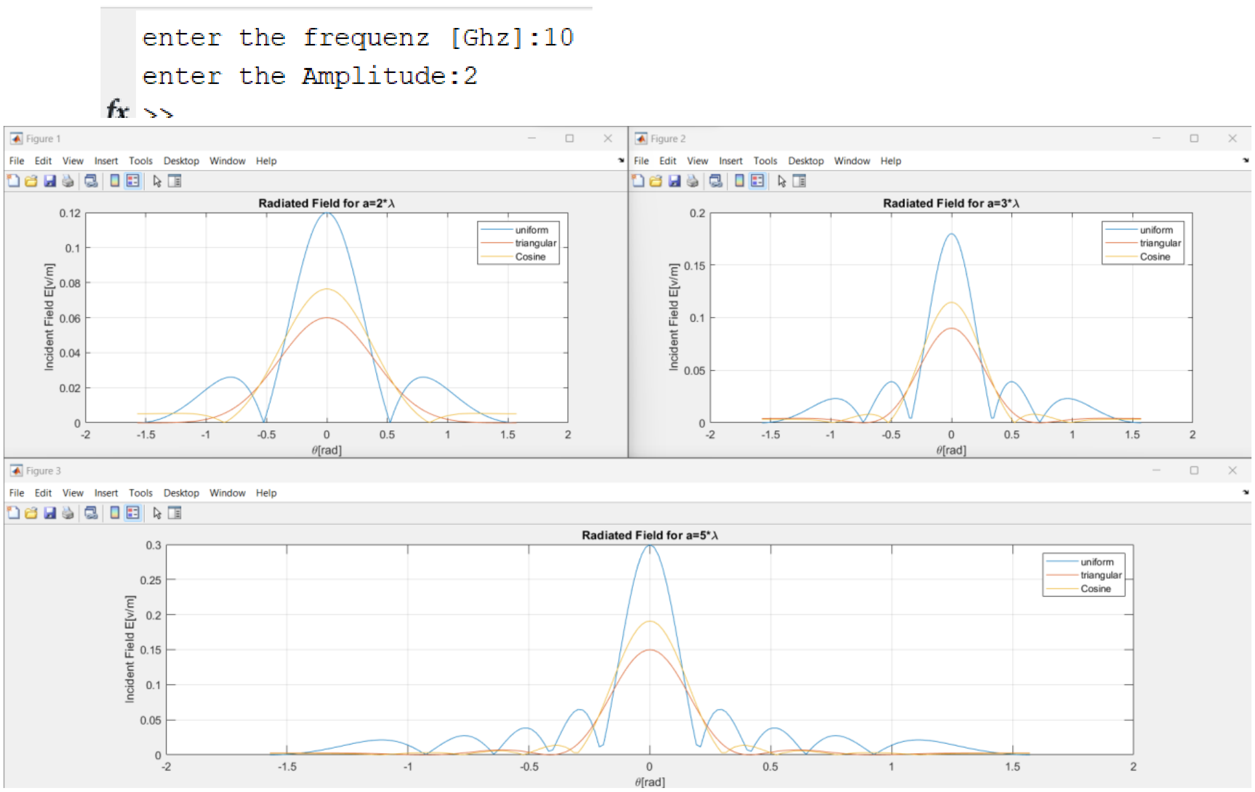
Implement the expression of the Radiated Field of an aperture antenna with different "a".

Code MATLAB:

```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
f=f*10^9;
z=0;
r=100;%in meter
T=1/f;
w=2*pi*f;
eps0=8.85e-12;
mu0=pi*4e-7;
k=w*sqrt(eps0*mu0);
lamda=(2*pi)/k;
a=5*lamda;
theta=-pi/2:pi/180:pi/2;
X=((k*a)/2)*sin(theta);
Ei=a*E0*exp(-i*k*r)*sinc(X/pi);
Einct=(a/2)*E0*exp(-i*k*r)*(sinc(X/(2*pi))).^2;
Eincc=(a/2)*E0*exp(-i*k*r)*((sinc(((pi/2)+X)/pi))+(sinc(((pi/2)-X)/pi)));
first_null_uni=asin(lamda/a);
first_null_tri=asin((2*lamda)/a);
first_null_cos=asin((3*lamda)/(2*a));
figure;
```

```
plot(theta,abs(Ei));%incidente
hold on;
plot(theta,abs(Einct));%incidente
plot(theta,abs(Eincc));%incidente
xlabel('\theta[rad]');
ylabel('Incident Field E[v/m]');
legend('uniform','triangular','Cosine');
grid on;
title('Radiated Field for a=5*\lambda');
```

Screenshot of the Results



Comment

- As the aperture size increases, the directivity of the antenna usually improves.
- Directivity is a measure of how well an antenna focuses its radiation in a particular direction.

Uniform Illumination:

- Illumination Pattern: The entire aperture is uniformly illuminated.

✓ Advantages: Simple to implement, provides symmetric patterns.

☒ Disadvantages: May result in higher sidelobe levels compared to other illumination functions

Triangular Illumination:

- Illumination Pattern: The aperture is illuminated with higher intensity toward the center.

✓ Advantages: Tends to reduce sidelobe levels compared to uniform illumination.

☒ Disadvantages: More complex than uniform illumination.

Cosine Illumination:

- Illumination Pattern: The aperture is illuminated peaking at the center and tapering towardsthe edges.

✓ Advantages: Improved sidelobe performance, better control over the radiation pattern.

☒ Disadvantages: More complex than uniform illumination.

Exercise 2

Aperture Antenna–With Different a.

Implement the expression of the Radiated Field in dB of an aperture antenna with different a.

Conditions for θ:

➢ $\theta = -\frac{\pi}{2} \rightarrow \frac{\pi}{2}$

all variables:

- Eo=2
- z=0
- F=10 GHz
- a=2 λ , 3 λ , 5 λ --> (a> **λ**)
- r=100m

Far Field Condition:

- $r \geq \frac{2a^2}{\lambda}$

Note:

$$sinc(x) = \frac{\sin(x)}{x}$$

In Matlab:

$$\text{sinc}(x) = \frac{\sin(\pi x)}{\pi x}$$

- *So divide* the argument for π $\text{sinc}(x/\pi)$

First Null:

- First Null Uni=$sin^{-1}\left(\frac{\lambda}{a}\right)$
- First Null Tri=$sin^{-1}\left(\frac{2\lambda}{a}\right)$
- First Null Cos =$sin^{-1}\left(\frac{3\lambda}{2a}\right)$

Implement the expression of the Radiated Field in dB of an aperture antenna with different a.

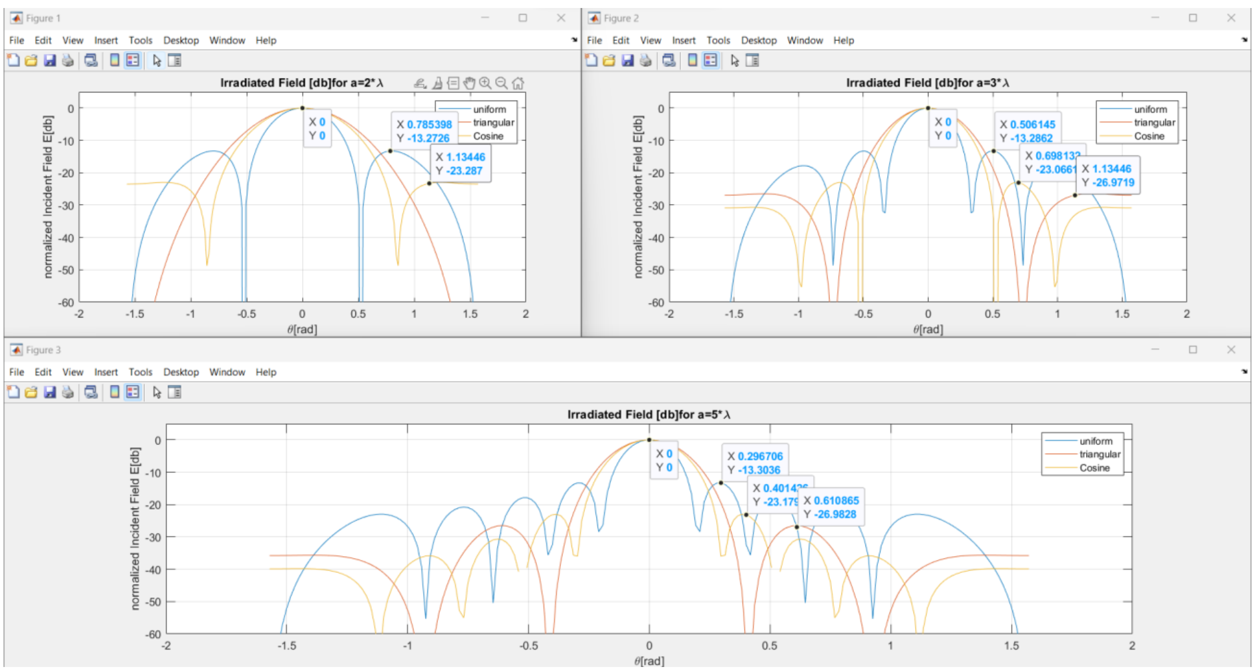
Code MATLAB:

```
clear all;
clc;
f=input('enter the frequenz [Ghz]:');
E0=input('enter the Amplitude:');
f=f*10^9;
z=0;
r=100;%in meter
T=1/f;
w=2*pi*f;
eps0=8.85e-12;
mu0=pi*4e-7;
k=w*sqrt(eps0*mu0);
lamda=(2*pi)/k;
a=5*lamda;
theta=-pi/2:pi/180:pi/2;
X=((k*a)/2)*sin(theta);
Ei=a*E0*exp(-i*k*z)*sinc(X/pi);
EiDB=20*log10(abs(Ei)/max(abs(Ei)));
Einct=(a/2)*E0*exp(-i*k*r)*(sinc(X/(2*pi))).^2;
EinctDB=20*log10(abs(Einct)/max(abs(Einct)));
Eincc=(a/2)*E0*exp(-i*k*r)*((sinc(((pi/2)+X)/pi))+(sinc(((pi/2)-X)/pi)));
EinccDB=20*log10(abs(Eincc)/max(abs(Eincc)));
first_null_uni=asin(lamda/a);
first_null_tri=asin((2*lamda)/a);
first_null_cos=asin((3*lamda)/(2*a));
```

```
fist_null_Uni_DB=20*log10(first_null_uni);
fist_null_tri_DB=20*log10(first_null_tri);
fist_null_cos_DB=20*log10(first_null_cos);
figure;
plot(theta,EiDB);%incidente
axis([-2,2,-60,5]);
hold on;
plot(theta,EinctDB);%incidente
plot(theta,EinccDB);%incidente
xlabel('\theta[rad]');
ylabel('normalized Incident Field E[db]');
legend('uniform','triangular','Cosine');
title('Irradiated Field [db]for a=5*\lambda');
grid on;
```

Screenshot of the Results

```
enter the frequenz [Ghz]:10
enter the Amplitude:2
fx >>
```



Comment

- Minor lobes usually represent radiation in undesired directions and should be minimized.

ELEMENTARY ELECTRIC DIPOLE ANTENNA

Exercise 1

Graph the function: $F(\theta) = j\eta \, \frac{l\Delta z}{2\lambda} \, \mathrm{Sin}(\theta)$.

all variables:

- Θ=0:pi/100:2pi
- l=1 amplitude [m]
- ε0=8.85e-12 ->electrical permittivity free space
- μ0=pi*4e-7 ->magnetic permeability free space
- I -> 1 [A]
- η ->intrinsic impedance
- C - >speed of light [m/s]
- λ ->1 - wavelength [m]

Radiation Pattern of the Elementary Dipole.

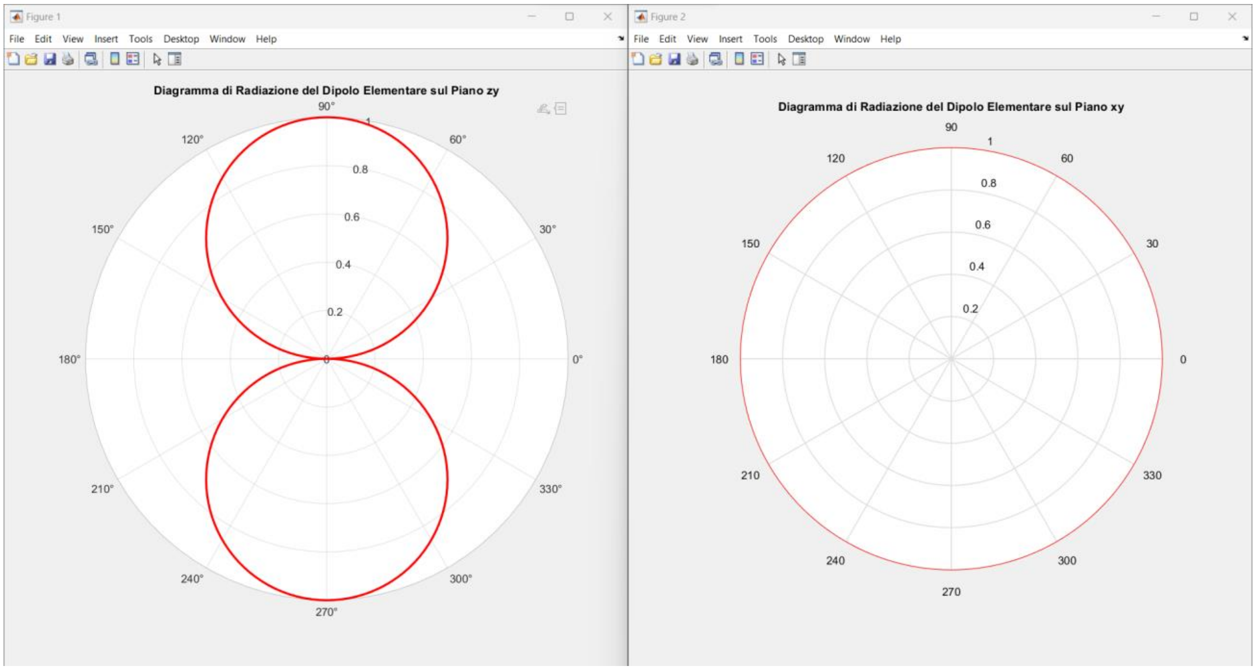
Code MATLAB:

```
% Parametri del dipolo
L = 1;          % Lunghezza del dipolo
lambda = 1;     % Lunghezza d'onda
theta =0:pi/100:2*pi; % Angoli theta da 0 a 2*pi
I=1;%corrente
e0=8.85e-12;
mu0=pi*4e-7;
n0=sqrt(mu0/e0);%impedenza intrinsitca nel vuoto
% Calcola il diagramma di radiazione del dipolo
%diagramma_radiazione=i*n0*((I*L)/(2*lambda))*sin(theta);%diagramma di radiazione
diagramma_radiazione=sin(theta);%diagramma di radiazione_normalizato
% Traccia il diagramma
polarplot(theta, abs(diagramma_radiazione), '-r', 'LineWidth', 2);
title('Diagramma di Radiazione del Dipolo Elementare sul Piano zy');
```

```
% Parametri del dipolo
L = 1;          % Lunghezza del dipolo
lambda = 1;     % Lunghezza d'onda
theta =pi/2; % Angolo theta fissato a 90 gradi
phi=0:pi/100:2*pi; %vettore phi
I=1;%corrente
e0=8.85e-12;
mu0=pi*4e-7;
n0=sqrt(mu0/e0);%impedenza intrinsitca nel vuoto
vector=ones(1,length(phi));
% Calcola il diagramma di radiazione del dipolo
```

```
%diagramma_radiazione=vector.*(i*n0*((I*L)/(2*lambda))*sin(theta));%diagramma di
radiazione
diagramma_radiazione=vector.*sin(theta);%diagramma di radiazione_normalizato
% Traccia il diagramma
figure
polar(phi, abs(diagramma_radiazione),'-r');
title('Diagramma di Radiazione del Dipolo Elementare sul Piano xy');
```

Screenshot of the Results



Wire Antenna

Exercise 1

Graph the function: $F(\theta)=\dfrac{\cos(\frac{\pi}{2}*cos(\theta))}{\text{sen}(\theta)}$.

all variables:

- Θ=-pi/2:pi/100:pi/2

Radiation Pattern of Wire antenna.

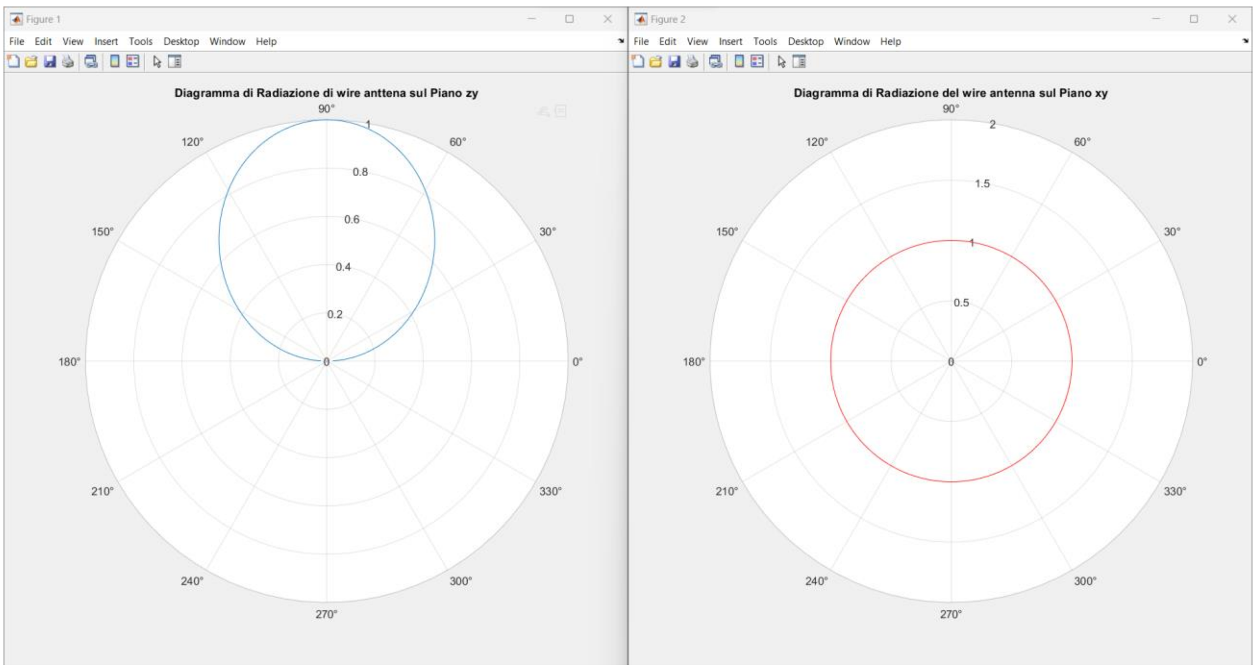
Code MATLAB:

```
clear all;
clc;
theta =-pi/2:pi/100:pi/2; % Angoli theta da 0 a 2*pi
% Calcola il diagramma di radiazione
diagramma_radiazione=cos((pi/2)*cos(theta))./sin(theta);%diagramma di
radiazione_normalizato
```

```
% Traccia il diagramma
polarplot(theta, diagramma_radiazione);
title('Diagramma di Radiazione di wire anttena sul Piano zy');
```

```
theta =pi/2; % Angolo theta fissato a 90 gradi
phi=0:pi/100:2*pi; %vettore phi
vector=ones(1,length(phi));
% Calcola il diagramma di radiazione
diagramma_radiazione=vector.*(cos((pi/2)*cos(theta))/sin(theta));%diagramma di
radiazione_normalizato
% Traccia il diagramma
figure
polarplot(phi, abs(diagramma_radiazione),'-r');
title('Diagramma di Radiazione del wire antenna sul Piano xy');
```

Screenshot of the Results



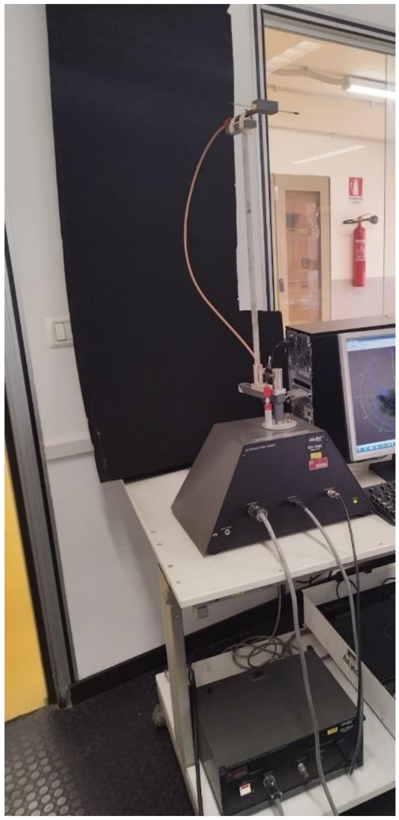
Lab

Exercise 1

The radiation pattern of a dipole antenna represents the spatial distribution of the energy radiated by the antenna as a function of angle. In other words, it shows how the transmitted power varies in different directions relative to the antenna..

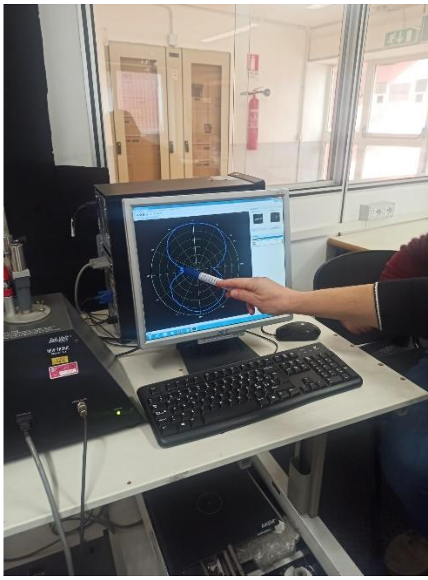
Experimental Setup:

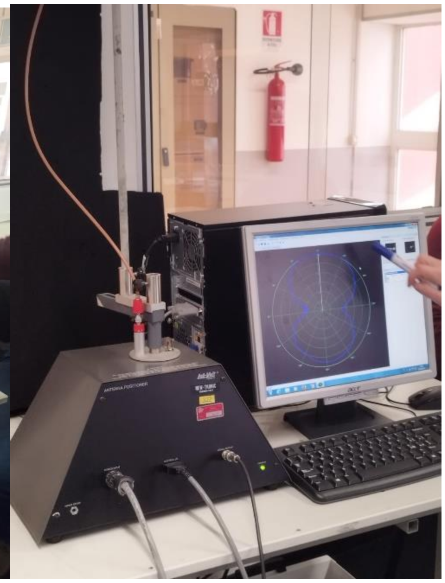
- Set up a dipole antenna in a controlled environment.
- Use a signal generator to power the antenna with a signal at a specific frequency.
- Place a receiver or a test antenna at a certain distance from the antenna under examination.

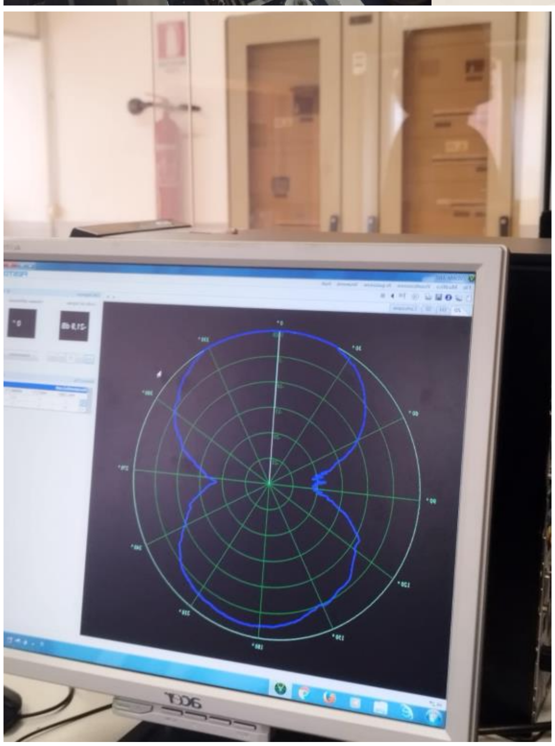


Data Acquisition:

- Measure the power of the received signal in different directions, varying the angle relative to the main axis of the dipole antenna.
- Record the data in relation to the measurement angle.







Data Processing with MATLAB:

- Transfer the acquired data to MATLAB.
- Use MATLAB to process the data and create a radiation pattern diagram.
- Plot the radiation pattern using MATLAB's graphical functions.

all variables:

- f=1 [GHz]
- D=40 [cm] =0.4 [m]

- $\varepsilon 0$=8.85e-12 ->electrical permittivity free space
- $\mu 0$=pi*4e-7 ->magnetic permeability free space
- C - >speed of light [m/s]
- V_p = C
- λ ->$\frac{\mathrm{Vp}}{f} = \frac{C}{f} = 0.3\ [m]$ - wavelength [m]
- R=$\frac{2*D^2}{\lambda}$=1 [m] -> Far_Field Region

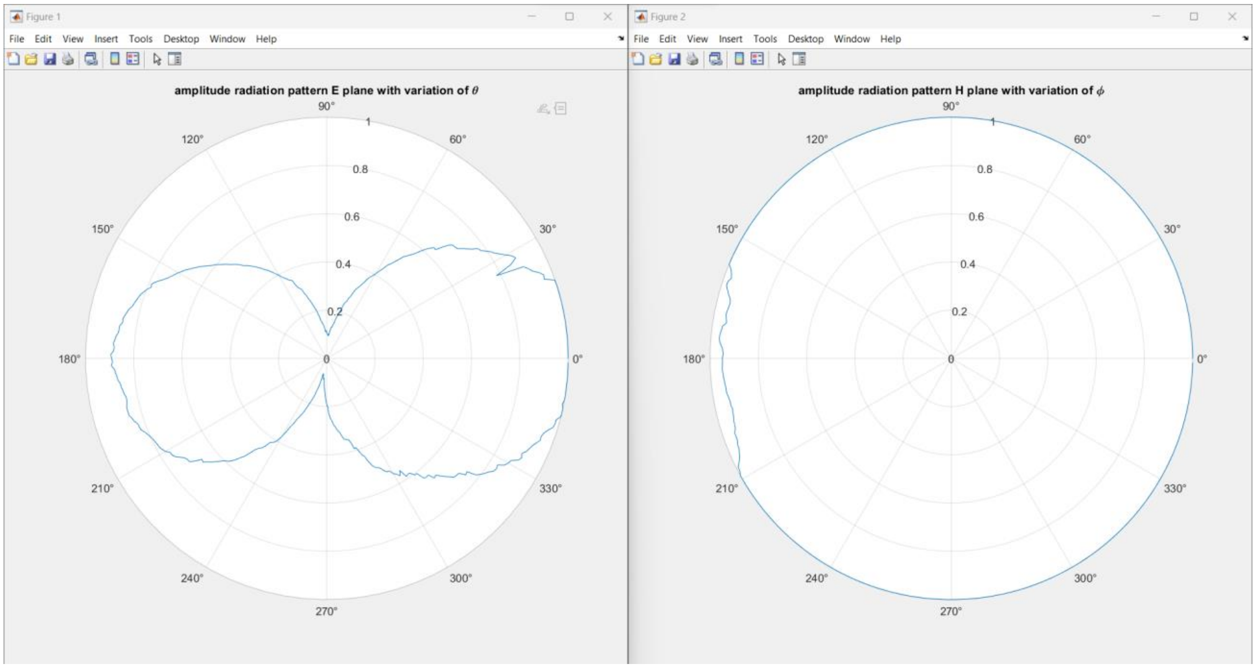
Radiation Pattern of the Elementary Dipole $\frac{\lambda}{2}$.

Code MATLAB:

```
clc
clear all

load("Lambda_mezzi.txt")
matrix=zeros(360,3);
for i=1 : 360
    matrix(i,1)=Lambda_mezzi(i,1).*pi/180;
    matrix(i,2)=10^(Lambda_mezzi(i,2)./20);
    matrix(i,3)=10^(Lambda_mezzi(i,3)./20);
end ;
figure
polarplot(matrix(:,1),matrix(:,2));
title('amplitude radiation pattern E plane with variation of \theta');
figure
polarplot(matrix(:,1),matrix(:,3));
title('amplitude radiation pattern H plane with variation of \phi');
```

Screenshot of the Results

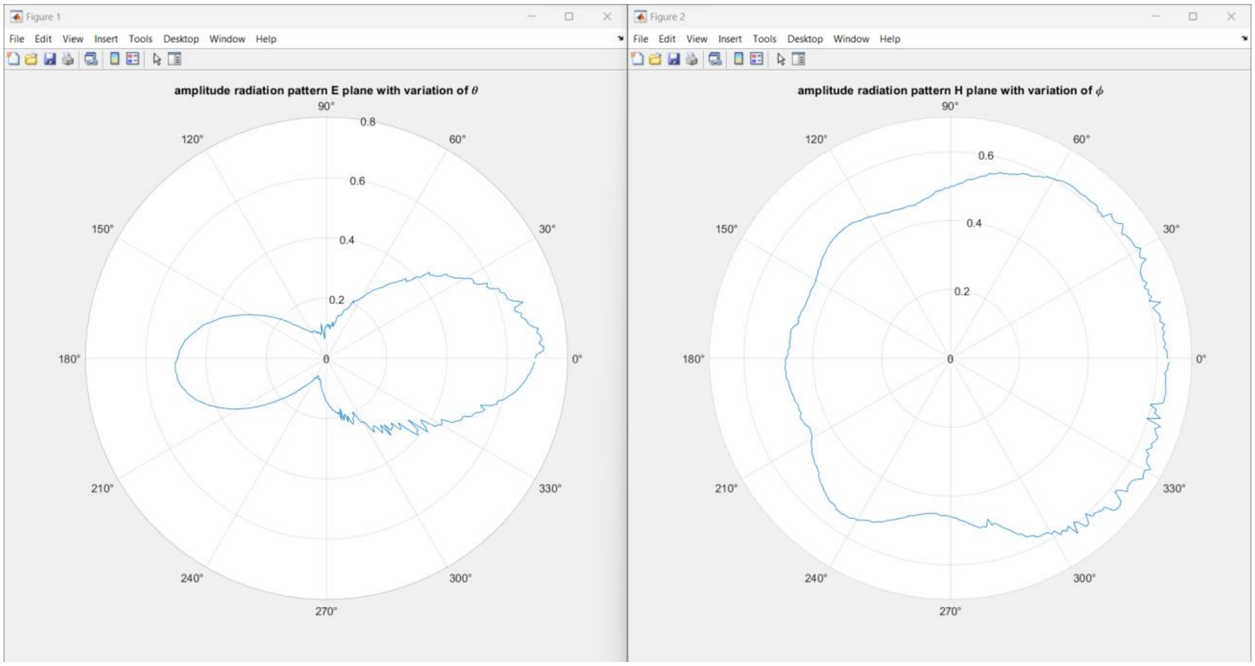


Radiation Pattern of the Elementary Dipole λ.

Code MATLAB:

```
clc
clear all
load("Lambda.txt")
matrix=zeros(360,3);
for i=1 : 360
    matrix(i,1)=Lambda(i,1).*pi/180;
    matrix(i,2)=10^(Lambda(i,2)./20);
    matrix(i,3)=10^(Lambda(i,3)./20);
end ;
figure
polarplot(matrix(:,1),matrix(:,2));
title('amplitude radiation pattern E plane with variation of \theta');
figure
polarplot(matrix(:,1),matrix(:,3));
title('amplitude radiation pattern H plane with variation of \phi');
```

Screenshot of the Results



Radiation Pattern of the Elementary Dipole $\frac{3}{2}\lambda$.

Code MATLAB:

```
clc
clear all
load("3_2Lambda.txt")
matrix=zeros(360,3);
for i=1 : 360
    matrix(i,1)=X3_2Lambda(i,1).*pi/180;
    matrix(i,2)=10^(X3_2Lambda(i,2)./20);
    matrix(i,3)=10^(X3_2Lambda(i,3)./20);
end ;
figure
polarplot(matrix(:,1),matrix(:,2));
title('amplitude radiation pattern E plane with variation of \theta');
figure
polarplot(matrix(:,1),matrix(:,3));
title('amplitude radiation pattern H plane with variation of \phi');
```

Screenshot of the Results