SAVEETHA SCHOOL OF ENGINEERIING,

SAVEETHA INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES

TRANSMISSION LINES & WAVEGUIDES

ECA15

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SAVEETHA SCHOOL OF ENGINEERING
SAVEETHA INSTITUTE OF TECHNICAL AND MEDICAL SCIENCES

Engineer to Excel

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EXNO: 1	**Estimation of Characteristic Impedance (Zo), and Propagation Constant (γ) of aTransmission Line from Primary Constants**
DATE:	

Test Case 1:

Investigating the significance of Characteristic Impedance (Zo), and Propagation Constant (γ) of aTransmission Line using the following parameters

a) **Resistance =10 Ω/Km**
b) **Capacitance = 8 µF/Km**
c) **Inductance =3.5 mH/Km**
d) **Conductance =4 µmho/Km**
e) **Frequency= 2 Khz**

AIM: Investigating the significance of Characteristic Impedance (Zo), and Propagation Constant (γ) of a Transmission Line with Resistance =10 Ω/Km, Capacitance = 8 µF/Km, Inductance =3.5 mH/Km, Conductance =4 µmho/Km, Frequency= 2 Khz

SOFTWARE REQUIRED:

SCILAB Version 6.1.1

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION:

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}} = \sqrt{\frac{Z}{Y}}$$

$$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)} = \sqrt{ZY}$$

PROGRAM:

```
clear; clc;
R=10;L=0.003;f=2*10^3;G=4*(10^-6);C=16*(10^-6);
w=2*%pi*f;
Z=R+(%i*w*L);
Y=G+(%i*w*C);
Zo=sqrt(Z/Y);
C=round(real(Zo));
D=round(imag(Zo));
printf('-Zo = %f + j(%f)ohms\n',C,D);
P=sqrt(Z*Y);
a=real(P);
a1=round(a*10000)/10000;
printf('-Attenuation constant a = %f neper/km\n',a1);
b=imag(P);
b1=round(b*10000)/10000;
printf('-Phase constant b = %f radians/km',b1);
```

OUTPUT:

Constants L=3mH; f=2000; G=.4*(10^-6); C=8*(10^-6).

Simulation Results			Theoretical Results	
Z0(ohms)	**α(neper/km)**	**β(radians/km)**	**α(neper/km)**	**β(radians/km)**

RESULT:

The characteristic impedance and propagation constant of a transmission line is calculated using SCILAB and the impact of primary constants on secondary constants are investigated.

Test Case 2:

Examine the impact of resistance and inductance on the significance of Characteristic Impedance (Zo) and Propagation Constant (γ) of aTransmission Line at a frequency f=2.5 Khz. Vary the resistance value from 10 Ω to 50 Ω at the interval of 10 Ω with L,G and C values constant and calculate the Characteristic Impedance and Propagation Constant . Vary the inductance values from 3.5 mH to 11.5 mH at the interval of 2.5 mH with R,G and C values constant.

AIM: To examine the impact of resistance and inductance on the significance of

Characteristic Impedance (Zo) and Propagation Constant (γ) of a Transmission Line at a frequency f=2.5 Khz. Vary the resistance value from 10 Ω to 50 Ω at the interval of 10 Ω with L,G and C values constant and calculate the Characteristic Impedance and Propagation Constant . Vary the inductance values from 3.5 mH to 11.5 mH at the interval of 2.5 mH with R,G and C values constant.

SOFTWARE REQUIRED:

SCILAB Version 6.1.1

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program
-

CALCULATION:

$$Z_0 = \sqrt{\frac{R+j\omega L}{G+j\omega C}} = \sqrt{\frac{Z}{Y}}$$

$$\gamma = \sqrt{(R+j\omega L)(G+j\omega C)} = \sqrt{ZY}$$

PROGRAM:

```
clear; clc;
R=10;L=0.003;f=2*10^3;G=4*(10^-6);C=16*(10^-6);
w=2*%pi*f;
Z=R+(%i*w*L);
Y=G+(%i*w*C);
Zo=sqrt(Z/Y);
C=round(real(Zo));
D=round(imag(Zo));
printf('-Zo = %f + j(%f)ohms\n',C,D);
P=sqrt(Z*Y);
a=real(P);
a1=round(a*10000)/10000;
printf('-Attenuation constant a = %f neper/km\n',a1);
b=imag(P);
b1=round(b*10000)/10000;
printf('-Phase constant b = %f radians/km',b1);
```

OUTPUT:

Variable R
Constants L=3mH; f=2000; G=.4*(10^-6); C=8*(10^-6).

S. No.	Inputs (R)	Simulation Results			Theoretical Results	
		Z0(ohms)	α(neper/km)	β(radians/km)	α(neper/km)	β(radians/km)
1						
2						
3						
4						
5						

Variable L
Constants R=10Ω; f=2000; G=.4*(10^-6); C=8*(10^-6).

S. No.	Inputs (L)	Simulation Results			Theoretical Results	
		Z0(ohms)	α (neper/km)	β (radians/km)	α (neper/km)	β (radians/km)
1						
2						
3						
4						
5						

RESULT:

The impact of resistance and inductance on the significance of Characteristic Impedance (Zo) and Propagation Constant (γ) of aTransmission Line is examined at a frequency f=2.5 Khz.

Test Case 3:

Explore the impact of frequency and capacitance on the significance of Characteristic Impedance (Zo) and Propagation Constant (γ) of aTransmission Line. Vary the frequency from 2KHz to 10 KHz at the interval of 2 KHz with L,R ,G and C values constant and calculate the Characteristic Impedance and Propagation Constant . Vary the capacitance values from 8 µF to 16 µF at the interval of 2 µF with R,G and L values constant.

AIM: To explore the impact of frequency and capacitance on the significance of Characteristic Impedance (Zo) and Propagation Constant (γ) of aTransmission Line. Vary the frequency from 2KHz to 10 KHz at the interval of 2 KHz with L,R ,G and C values constant and calculate the Characteristic Impedance and Propagation Constant

CALCULATION:

$$Z_0 = \sqrt{\frac{R+j\omega L}{G+j\omega C}} = \sqrt{\frac{Z}{Y}}$$

$$\gamma = \sqrt{(R+j\omega L)(G+j\omega C)} = \sqrt{ZY}$$

PROGRAM:

```
clear; clc;
R=10;L=0.003;f=2*10^3;G=4*(10^-6);C=16*(10^-6);
w=2*%pi*f;
Z=R+(%i*w*L);
Y=G+(%i*w*C);
Zo=sqrt(Z/Y);
C=round(real(Zo));
D=round(imag(Zo));
printf('-Zo = %f + j(%f)ohms\n',C,D);
P=sqrt(Z*Y);
a=real(P);
a1=round(a*10000)/10000;
printf('-Attenuation constant a = %f neper/km\n',a1);
b=imag(P);
b1=round(b*10000)/10000;
printf('-Phase constant b = %f radians/km',b1);
```

OUTPUT:

Variable f
Constants L=3mH; f=2000; G=.4*(10^-6); C=8*(10^-6).
;

S. No.	Inputs (f) Hz	Simulation Results			Theoretical Results	
		Z0(ohms)	α (neper /km)	β (radians/ km)	α (neper/km)	β (radians/k m)
1						
2						
3						
4						
5						

Variable C
Constants R=10; L=.009; f=2500; G=.4*(10^-6);

S. No.	Inputs (C) F	Simulation Results			Theoretical Results	
		Z0(ohms)	α (neper/km)	β (radians/km)	α (neper/km)	β (radians/km)
1						
2						
3						
4						
5						

RESULT:

The impact of frequency and capacitance on the significance of Characteristic Impedance (Zo) and Propagation Constant (γ) of a Transmission Line is investigated for various values of frequencies and capacitance values.

EXNO: 2	**Estimation of Primary Constants (R,L,G &C) from Secondary Constants (Zo & γ)of an open wiretransmission line**
DATE:	

Test Case 1:

Find the primary constants R,L,G and C for the varying values of Characteristic Impedance (Zo) of a Transmission Line at a frequency f=2 Khz. Vary the Characteristic Impedance value from 100 Ω and take five readings at the interval of 20 Ω. Keep the Propagation Constant (γ) constant

AIM: To find the primary constants R,L,G and C for the varying values of Characteristic Impedance (Zo) of a Transmission Line at a frequency f=2 Khz. Vary the Characteristic Impedance value from 100 Ω and take five readings at the interval of 20 Ω. Keep the Propagation Constant (γ) constant

SOFTWARE REQUIRED:

SCILAB

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

$R+j\omega L= Zo .\gamma$
$g+j\omega C= \gamma/Zo$

PROGRAM:

```
clear; clc;
Zo=100.6;f=2000; //value of Zo as taken in solution P=0.054* exp(%i*(%pi/(180/87.9)));
w=2*%pi*f;
Z=Zo*P;
R=real(Z);
```

```
printf('-Resistance R = %f ohms/km\n',R); L=(imag(Z))/w;
printf('-Inductance L = %f mH/km\n',L*(10^3)); Y=P/Zo;
G=real(Y);
printf('-Conductance G = %f micromhos/km\n',G*(10^6));
C=((imag(Y))/w)*(10^6);c=round(C*10000)/10000 printf('-Capacitance C = %f
microfarads/km\n',c);
```

OUTPUT:
Variable Zo; Constant f= 2000 Hz;

S. No	**Input (Zo) ohms**	**Outputs**			
		R(ohms/km)	**L(mH/km)**	**G(microohms/km)**	**C(microfarads/km)**
1					
2					
3					
4					
5					

RESULT:

Primary constants R,L,G and C are calculated by varying values of Characteristic Impedance (Zo) of a Transmission Line at a frequency f=2 Khz keeping the Propagation Constant (γ) constant.

Test Case 2:

Find the primary constants R,L,G and C for the varying values of Propagation constant of a Transmission Line at a frequency f=2 Khz. Vary the Propagation constant value from 200 $\angle 30^o$Ω and take five readings at the interval of 50 Ω. Keep the characteristic impedance Zo=100Ω **constant**

AIM: To find the primary constants R,L,G and C for the varying values of Propagation constant of a Transmission Line at a frequency f=2 Khz. Vary the Propagation constant value from 200 30^oΩ and take five readings at the interval of 50 Ω. Keep the characteristic impedance Zo=100 Ω constant

SOFTWARE REQUIRED:

SCILAB

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

R+jωL= Zo .γ
g+jωC= γ/Zo

PROGRAM:

```
clear; clc;
Zo=100.6;f=2000; //value of Zo as taken in solution P=0.054* exp(%i*(%pi/(180/87.9)));
w=2*%pi*f;
Z=Zo*P;
R=real(Z);
printf('-Resistance R = %f ohms/km\n',R); L=(imag(Z))/w;
printf('-Inductance L = %f mH/km\n',L*(10^3)); Y=P/Zo;
G=real(Y);
printf('-Conductance G = %f micromhos/km\n',G*(10^6));
C=((imag(Y))/w)*(10^6);c=round(C*10000)/10000 printf('-Capacitance C = %f
microfarads/km\n',c);
```

OUTPUT :

Variable γ;
Constant Zo=100Ω;

S. No	Input (γ)	Outputs			
		R(ohms/km)	L(mH/km)	G(microohms/km)	C(microfarads/km)
1					
2					
3					
4					
5					

RESULT:

Primary constants R,L,G and C are calculated by varying values of Propagation Constant at a frequency f=2 Khz keeping the Characteristic Impedance constant.

EXNO: 3	Evaluation of current in short circuited Lossless transmission line at the receiving end
DATE:	

Test Case 1:

Find the current at the receiving end for the varying values of the attenuation constant α from keeping the characteristic impedance Zo and the phase constant β constant

|

AIM: To find current at the receiving end for the varying values of the attenuation constant α from 0.1 to 0.4 N/Km keeping the characteristic impedance Zo and the phase constant β constant. |

SOFTWARE REQUIRED:

SCILAB

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

$$E_{SC} = j I_R \cdot R_0 \cdot \sin\frac{2\pi s}{\lambda}$$

$$I_{SC} = I_R \cos\frac{2\pi s}{\lambda}$$

PROGRAM:

```
clear;
clc;
Zo=600;a=0.1;b=0.05;x=10;Is=20*(10^-3);
```

```
Vr=0;
printf("-Receiving end voltage Vr=0 because the receiving end has been short
ciruited\n");
P=a+(%i*b);
Ir=Is/(cosh(10*P));
A=real(Ir);
B=imag(Ir);
printf("-Received current is Ir = %f /_ %f mA
",round(abs(Ir)*(10^3)*100)/100,fix(atan(B,A)*180*10/%pi)/10);
```

OUTPUT:

Variable = α N/Km   Constant parameters = Zo Ω , β rad/Km

Sl.No	**Simulation Results**		**Theoretical Results**	
	α N/Km)	**I_R(mA)**	**α N/Km)**	**I_R(mA)**
1				
2				
3				
4				

RESULT:

The current at the receiving end for the varying values of the attenuation constant α is found while keeping the characteristic impedance Zo and the phase constant β constant

Test Case 2:

Find the current at the receiving end for the varying values of the phase constant β attenuation constant α from keeping the characteristic impedance Zo and the attenuation constant α constant

AIM: To find current at the receiving end for the varying values of the attenuation constant α from keeping the characteristic impedance Zo and the attenuation constant α constant

SOFTWARE REQUIRED:

SCILAB

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

$$E_{SC} = j I_R \cdot R_0 \cdot \sin\frac{2\pi s}{\lambda}$$

$$I_{SC} = I_R \cos\frac{2\pi s}{\lambda}$$

PROGRAM:

```
clear;
clc;
Zo=600;a=0.1;b=0.05;x=10;Is=20*(10^-3);
Vr=0;
printf("-Receiving end voltage Vr=0 because the receiving end has been short
ciruited\n");
P=a+(%i*b);
Ir=Is/(cosh(10*P));
A=real(Ir);
B=imag(Ir);
printf("-Received current is Ir = %f /_ %f mA
",round(abs(Ir)*(10^3)*100)/100,fix(atan(B,A)*180*10/%pi)/10);
```

OUTPUT:

Variable = β rad/Km Constant parameters = Zo Ω , α N/Km

Sl.No	Simulation Results		Theoretical Results	
	β rad/Km	**I_R(mA)**	**β rad/Km**	**I_R(mA)**
1				
2				
3				
4				

RESULT:

The current at the receiving end for the varying values of the phase constant β is found while keeping the characteristic impedance Zo and the attenuation constant α constant.

EXNO: 4	Analysis of SWR (Standing Wave Ratio)Transmission Lines by varying a)load impedance b) characteristic impedance
DATE:	

Test Case 1:

Analyze the SWR of a transmission line for a fixed characteristic impedance (Z_0) of 50 ohms, as the load impedance (Z_L) is varied across 650 ohms to 850 ohms. Verify how the SWR changes with each value ofZ_L. When Z_L=Z_0, the SWR should equal 1 (indicating no reflection).

AIM: To analyze the SWR of a transmission line for a fixed characteristic impedance (Zo) of 50 ohms, as the load impedance (ZL) is varied across the following values: 25 ohms, 50 ohms, 75 ohms, and 100 ohms. To verify how the SWR changes with each value of Z_L and when Z_L =Zo.

SOFTWAREREQUIRED:

SCILABVersion6.1.1

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Typetheprogram
- Execute the program
- End the program

CALCULATION

$$K = \frac{Z_R - R_0}{Z_R + R_0}$$

$$S = \frac{1 + |K|}{1 - |K|}$$

PROGRAM:

```
clc;clear;close;
Zo=200;ZR=650-(%i*475);
K=(ZR-Zo)/(ZR+Zo);
```

```
ampK=sqrt((real(K)^2)+(imag(K)^2));S=(1+ampK)/(1-ampK);
printf("(c)Standing wave ratio = %f",round(S*1000)/1000);
```

OUTPUT:

Zo=50 ohmsVariable:ZR

ZROhms	Simulation Results	Theoretical Results
	SWR	SWR

ZR=50/_40oohmsVariable:Zo

Zo Ohms	Simulation Results	Theoretical Results
	SWR	SWR

RESULT:

The SWR of a transmission line for a fixed characteristic impedance (Zo) of 50 ohms, is analyzed for various values of load impedance ZL. SWR is also examined for the condition Z_L =Zo.

Test Case 2:

Analyze the SWR for a fixed load impedance (Z_L) of 50 ohms while varying the characteristic impedance (Z_0) of the transmission line to 250 ohms to 400 ohms. Verify how the SWR changes with each value Z_0 including $Z_0=Z_L$.

AIM: To analyze the SWR for a fixed load impedance (Z_L) of 75 ohms while varying the characteristic impedance (Z_0) of the transmission line to 25 ohms, 50 ohms, 75 ohms, and 100 ohms. To Verify how the SWR changes with each value Z_0 including $Z_0=Z_L$

SOFTWAREREQUIRED:

SCILABVersion6.1.1

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Typetheprogram
- Execute the program
- End the program
- End the program

CALCULATION

$$K = \frac{Z_R - R_0}{Z_R + R_0}$$

$$S = \frac{1 + |K|}{1 - |K|}$$

PROGRAM:

```
clc;clear;close;
Zo=200;ZR=650-(%i*475);
K=(ZR-Zo)/(ZR+Zo);
ampK=sqrt((real(K)^2)+(imag(K)^2));S=(1+ampK)/(1-ampK);
printf("(c)Standing wave ratio = %f",round(S*1000)/1000);
```

OUTPUT:

ZR=50/_40° ohms   Variable: Zo

Zo Ohms	Simulation Results	Theoretical Results
	SWR	SWR

RESULT:

SWR for a fixed load impedance (Z_L) of 50 ohms is analyzed while varying the characteristic impedance (Z_0) of the transmission line to 250 ohms to 400 ohms. Impact of the condition Z_0=Z_L on SWR is also examined for various values of Z_0 .

EXNO: 5	**Exploration of the relationship between position of Voltage minima nearest to the load by varying magnitude of reflection coefficient K**
DATE:	

Test Case 1:

For a fixed characteristic impedance (Z_0) of 50 ohms and varying reflection coefficient magnitudes ($K=|\Gamma|=\{0.1,0.3,0.5,0.7,0.9\}$), determine the position of the voltage minima (d_{min}) relative to the load.The position of voltage minima should shift based on K and the corresponding phase of Γ. Compute d_{min} using $d_{min}=\lambda/2\pi\tan^{-1}(Im(\Gamma)/Re(\Gamma))$, where $\Gamma=Ke^{j\theta}$.

AIM: To explore the relationship between position of Voltage minima nearest to the load by varying magnitude of reflection coefficient K for the range of values ($K=|\Gamma|=\{0.1,0.3,0.5,0.7,0.9\}$).

SOFTWAREREQUIRED:

SCILABVersion6.1.1

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Typetheprogram
- Execute the program
- End the program

CALCULATION

$$K = \frac{Z_R - R_0}{Z_R + R_0}$$

$$S = \frac{1+|K|}{1-|K|}$$

PROGRAM:

```
Zo=50;f=300*(10^6);ZR=50+(%i*50);
```

```
lo=300/(f*(10^-6)); //where f is in megahertz
,lo=wavelength of wave in airK=(ZR-Zo)/(ZR+Zo);
ampK=sqrt((real
(K)^2)+(imag(K
)^2));S=(1+amp
K)/(1-ampK);
printf("-VSWR = %f\n",round(S*100)/100);
phi=atan(imag(K)/real(K));
ymax=phi*lo/(2*2*%pi);
ymin=ymax+(lo/4);
printf("-Position of voltage minimum nearest load = %f
metres",round(ymin*10000)/10000);
```

OUTPUT:

Zo=50 ohmsVariable:ZR

Z_ROhms	SWR	Position of Vmin

ZR=50/_40oohmsVariable:Zo

Z_0Ohms	SWR	Position of Vmin

RESULT:

The relationship between position of Voltage minima nearest to the load with Zo and Z_R is evaluated by varying magnitude of reflection coefficient K for the range of values (K=|Γ|={0.1,0.3,0.5,0.7,0.9}).

.**Test Case 2:**

For a fixed reflection coefficient magnitude (K=0.5) and varying load impedances (ZL={25 Ω,50 Ω,100 Ω,150 Ω}), calculate the position of voltage minima nearest to the load. Validate that the position of Vmin changes with the phase angle of Γ, which is influenced by the load impedance.

AIM: To calculate the position of voltage minima nearest to the load For a fixed reflection coefficient magnitude (K=0.5) and varying load impedance values.

SOFTWARE REQUIRED:

SCILABVersion6.1.1

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Typetheprogram

- Execute the program
- End the program

CALCULATION

$$K = \frac{Z_R - R_0}{Z_R + R_0}$$

$$S = \frac{1 + |K|}{1 - |K|}$$

PROGRAM:

```
clear;clc;
Zo=50;f=300*(10^6);ZR=50+(%i*50);
lo=300/(f*(10^-6)); //where f is in megahertz
,lo=wavelength of wave in airK=(ZR-Zo)/(ZR+Zo);
ampK=sqrt((real
(K)^2)+(imag(K
)^2));S=(1+amp
K)/(1-ampK);

printf("-VSWR = %f\n",round(S*100)/100);
phi=atan(imag(K)/real(K));
ymax=phi*lo/(2*2*%pi);
ymin=ymax+(lo/4);
printf("-Position of voltage minimum nearest load = %f
metres",round(ymin*10000)/10000);
```

OUTPUT:

Zo=50 ohms Variable: ZR

Z_ROhms	SWR	Position of Vmin

ZR=50/_40oohmsVariable:Zo

Z_0Ohms	SWR	Position of Vmin

RESULT:

The position of voltage minima nearest to the load for a fixed reflection coefficient magnitude (K=0.5) is estimated for varying load impedance values. Variation of the position of Vmin with the phase angle of Γ influenced by the load impedance is also validated.

EXNO: 6	Designing a Quarter wave transformer by varying following parameters a) frequency b) input impedance c) characteristic impedance
DATE:	

Designing a Quarter wave transformer by varying following parameters

d) frequency
e) input impedance
f) characteristic impedance

Experiment Number:7

Test Case 1:

Design a quarter-wave transformer for an input impedance (Z_{in}) of 50 ohms and a load impedance (Z_L) of 100 ohms. Analyze the transformer's performance as the operating frequency is varied across {100 MHz, 200 MHz, 300 MHz, 500 MHz}.

AIM: To design a quarter-wave transformer for an input impedance (Z_{in}) of 50 ohms and a load impedance (Z_L) of 100 ohms and to analyze the transformer's performance as the operating frequency is varied across {100 MHz, 200 MHz, 300 MHz, 500 MHz }.

SOFTWAREREQUIRED:

SCILAB

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Typetheprogram
- Execute the program
- End the program

CALCULATION:

$$R_0 = \left|\sqrt{Z_R \cdot Z_{in}}\right|$$

PROGRAM:

```
clear;clc;
Zr=100;s=9;d=0.1;
Zs=50;
Ro=sqrt(Zs*Zr);f=500*(10^6);r=d/2;
Zof=276*log10(s/r);
Zoq=sqrt(Zr*Zof);
L=300/(f*(10^-6));
printf("length of lambda/4 transformer = %f meters\n",L);
printf("characteristic impedance of quarter wave line = %f ",fix(Ro*10000)/10000);
```

OUTPUT:

Z_R=100 ohms Zin =50 ohms

Z_S ohms	Z_R ohms	Ro ohms

Z_R=100 ohms Zin =50 ohms

Frequency (MHz)	Length of λ/4 transformer (meters)

RESULT: A quarter-wave transformer for an input impedance (Z_{in}) of 50 ohms and a load impedance (Z_L) of 100 ohms is designed and the transformer's performance is analyzed for the varying operating frequency is varied across {100 MHz, 200 MHz, 300 MHz, 500 MHz }.

Test Case 2:

For a fixed operating frequency of 2 GHz and a load impedance (Z_L) of 100 ohms, design a quarter-wave transformer and evaluate its performance as the input impedance (Z_{in}) varies through {25 ohms, 50 ohms, 75 ohms, 100 ohms}. Validate that the transformer's characteristic impedance ($Z_{transformer}$= Ro= sqrt($Z_{in}\cdot Z_L$) changes with Z_{in}.

AIM: To design a quarter-wave transformer a ftixed operating frequency of 2 GHz and a load impedance (Z_L) of 100 ohms and evaluate its performance as the input impedance (Z_{in}) varied .To validate that the transformer's characteristic impedance ($Z_{transformer}$= Ro= sqrt($Z_{in}\cdot Z_L$) changes with Z_{in}.

SOFTWAREREQUIRED:

SCILAB

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Typetheprogram
- Execute the program
- End the program

CALCULATION

$$R_0 = \left|\sqrt{Z_R \cdot Z_{in}}\right|$$

PROGRAM:

```
clear;clc;
Zr=100;s=9;d=0.1;
Zs=50;
```

```
Ro=sqrt(Zs*Zr);f=100*(10^6);r=d/2;
Zof=276*log10(s/r);
Zoq=sqrt(Zr*Zof);
L=300/(f*(10^-6));
printf("length of lambda/4 transformer = %f lambda\n",L);
printf("characteristic impedance of quarter wave line = %f ",fix(Ro*10000)/10000);
```

OUTPUT:

ZR=100 ohms Variable :Zin

Z_{in}	Ro

RESULT: A quarter-wave transformer is designed at a fixed operating frequency of 2 GHz and load impedance (Z_L) of 100 ohms and its performance is evaluated for various input impedance values. The variation of transformer's characteristic impedance with Zin is also validated..

EXNO: 7	Strategize impedance matching with characteristic impedance and load impedance throughthe measurement of a) Location of the stub b) Length of the stub
DATE:	

Test Case 1:

Optimize impedance matching using single stub matching by finding the location and length of the stub for the values of load impedance of $100\angle 30^o$ to $350\angle 30^o$ keeping the characteristic impedance Zo= 60 Ω constant .

AIM: To optimize impedance matching using single stub matching by finding the location and length of the stub for the values of load impedance of $100\angle 30^o$ to $350\angle 30^o$ keeping the characteristic impedance Zo= 60 Ω constant .

SOFTWAREREQUIRED:

SCILAB

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

$$s_1 = \frac{\phi + \pi - \cos^{-1}(|K|)}{2\beta}$$

Length of the stub,

$$L = \frac{\lambda}{2\pi} \tan^{-1}\left[\frac{\sqrt{1-|K|^2}}{2\,|K|}\right]$$

PROGRAM:

```
clear; clear; clc;
ZR=100;Zo=600;f=100*(10^6);
lo=300/(f*(10^-6)); //lo=wavelength Ls=(lo/(2*%pi))*(atan(sqrt(ZR/Zo)));
printf("-Point of attachment = %f cms\n",round(Ls*(10^2)*10)/10)
Lt=(lo/(2*%pi))*(%pi+(atan((sqrt(ZR*Zo))/(ZR-Zo))));
printf("-Length of the short circuited stub = %f cms",round(Lt*(10^2)));
```

OUTPUT:

Variables Z_R;
Constants Zo = 60Ω; f=100*(10^6);

Input	**Output**	
ZR Ohms. angle 30°	**Point of attachment**	**Length of short-circuited stub (cm)**

RESULT:

f Impedance matching using single stub matching is optimized by calculating the location and length of the stub or varying values of load impedance keeping the characteristic impedance Zo= 60 Ω constant .

Test Case 2:

Optimize impedance matching using single stub matching by finding the location and length of the stub for the values of characteristic impedance ranging from 600Ω to 1800 Ω. Keeping the load impedance Z_R= 100 $\angle 30^o$ constant .

AIM: To optimize impedance matching using single stub matching by finding the location and length of the stub for the values of characteristic impedance ranging from 600Ω to 1800 Ω. Keeping the load impedance Z_R= 100 30^o constant .

SOFTWAREREQUIRED:

SCILAB

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

$$s_1 = \frac{\phi + \pi - \cos^{-1}(|K|)}{2\beta}$$

Length of the stub,

$$L = \frac{\lambda}{2\pi} \tan^{-1}\left[\frac{\sqrt{1-|K|^2}}{2|K|}\right]$$

PROGRAM:

```
clear; clear; clc;

ZR=100;Zo=600;f=100*(10^6);

lo=300/(f*(10^-6)); //lo=wavelength Ls=(lo/(2*%pi))*(atan(sqrt(ZR/Zo)));

printf("-Point of attachment = %f cms\n",round(Ls*(10^2)*10)/10)

Lt=(lo/(2*%pi))*(%pi+(atan((sqrt(ZR*Zo))/(ZR-Zo))));

printf("-Length of the short circuited stub = %f cms",round(Lt*(10^2)));
```

OUTPUT:

Variables Z_0;
Constants $Z_R = 100\angle 30^o\ \Omega$; f=100*(10^6);

Input	Output	
Zo Ohms.	**Point of attachment**	**Length of short-circuited stub (cm)**

RESULT:

Impedance matching using single stub matching is optimized by calculating the location and length of the stub for varying values of characteristic impedance keeping the load impedance constant .

EXNO: 8	**Analysis of Electromagnetic Waves across the two parallel plates estimating the following** **a) Critical Wavelength** **b) Guide Wavelength**
DATE:	

Test Case 1:

Analyze the variation of critical wavelength and guide wavelength of Electromagnetic waves between parallel plates with separation a ranging from 7.62 cm to 13 cm for TE1 mode.

AIM: To analyze the variation of critical wavelength and guide wavelength of Electromagnetic waves between parallel plates with separation a ranging from 7.62 cm to 13 cm for TE1 mode..

SOFTWAREREQUIRED:

SCILAB Version 6.1.1

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

Critical wavelength $\lambda c = V/fc$

$$\text{Guide wavelength } \lambda_g = \frac{\lambda}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$$

PROGRAM:

```
clear; clc;
c=3*(10^8); f=3000*(10^8);
lo=c/f; l=lo*(10^4); m=1;n=0;a=7.62;
lc=2*a;
```

```
printf("-Critical wavelength = %f cm\n",lc); lg=sqrt((l*l*lc*lc)/((lc*lc)-(l*l)));
printf("-Guide wavelength = %f cm",round(lg*10)/10);
```

OUTPUT:

Spacing a(cm)	Critical wavelength (cm)	Guide wavelength (cm)

RESULT:

The variation of critical wavelength and guide wavelength of Electromagnetic waves propagated between parallel plates with separation a ranging from 7.62 cm to 13 cm is analyzed with SCILAB.

Test Case 2:

Analyze the variation of cutoff frequencies of Electromagnetic waves between parallel plates with for TE1, TE2, TE 3 and TE4 modes.

AIM: To analyze the variation of cutoff frequencies of Electromagnetic waves between parallel plates with for TE1, TE2, TE 3 and TE4 modes.

SOFTWAREREQUIRED:

SCILAB Version 6.1.1

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values

- Type the program
- Execute the program
- End the program

CALCULATION

Critical wavelength λc= V/fc

$$\text{Guide wavelength } \lambda_g = \frac{\lambda}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$$

PROGRAM:

```
clc;
clear;
close;
//TE10 Mode
a=7.62*10^-2;
f=4*10^9;
V=3*10^8;
m=input("enter the value of m= ");
fc=(V/(2*3.14))*sqrt(m*3.14/a)^2;
disp("Cut off frquency in GHz=",fc*10^-9);
//let critical wavelength = lc
  lc=(V/fc);
disp("critical wavelength in cm =",lc*10^2);
```

OUTPUT:

Modes	**Cutoff frequency (GHz)**	**Critical wavelength (cm)**

RESULT:

The variation of cutoff frequencies of Electromagnetic waves between parallel plates with for TE1, TE2, TE 3 and TE4 modes is examined using SCILAB.

EXNO: 9	Calculation of Group velocity, Phase velocity and phase constant of EM waves in rectangular waveguides
DATE:	

Test Case 1 :

You are experimenting with a rectangular waveguide to analyze the relationship between its dimensions and wave propagation. The waveguide dimensions are a=4.0 cm, b=2.0 cmand the operating frequency is f=8 GHz.

1. **Calculate the cutoff frequencies for TE_{10}modes.**
2. **Predict the phase and group velocities for the TE_{10}mode at the given frequency.**
3. **If the width of the waveguide is reduced to a=3.0 cm, how does it affect the cutoff frequency and propagation characteristics?**

AIM: To find the group velocity, phase velocity and phase constant of Electromagnetic waves in Rectangular Waveguides whose dimensions are a=4.0 cm, b=2.0 cmand the operating frequency is f=8 GHz.

SOFTWARE REQUIRED:

SCILAB Version 6.1.1

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

$$\beta = \sqrt{\omega^2 \mu \epsilon - \left(\frac{\pi}{a}\right)^2} = \omega\sqrt{\mu\epsilon}\sqrt{1 - \left(\frac{f_c}{f}\right)^2}.$$

PROGRAM:

```
clc;
clear;
close;
//TE10 Mode
a=8.636*10^-2;
b=4.318*10^-2;
f=4*10^9;
V=3*10^8;
m=input("enter the value of m= "); n=input("enter the value of n= ");
fc=(V/(2*3.14))*sqrt((m*3.14/a)^2+(n*3.14/b)^2);
disp("Cut off frquency=",fc*10^-9);
//let phase velocity = A
A=V/sqrt(1-(fc/f)^2);
disp("Phase velocity in Mm/sec=",A*10^-6);
//let group velocity = B
B=V*V/A;
disp("Group velocity in Mm/sec =", B*10^-6);
```

OUTPUT:

Case 1:

Original Dimensions (a=4.0 cm,b=2.0 cm)

Inputs:

- m=1, n=0.
- f=8 GHz.

Outputs:

Parameter	Simulation Results	Theoretical Results
	Value	**Value**
Cutoff Frequency (fc)		
Phase Velocity (vp)		
Group Velocity (vg)		

Test Case 2:

Reduced Width (a=3.0 cm,b=2.0 cm)
Inputs:

- m=1, n=0.
- f=8 GHz.

Outputs:

Parameter	Simulation Results	Theoretical Results
	Value	Value
Cutoff Frequency (fc)		
Phase Velocity (vp)		
Group Velocity (vg)		

Table: Variation of Phase and Group Velocities with a

Waveguide Width (a)	Simulation Results			Theoretical Results		
	Cutoff Frequency (fc)	Phase Velocity (v_p)	Group Velocity (v_g)	Cutoff Frequency (fc)	Phase Velocity (v_p)	Group Velocity (v_g)

RESULT:

The group velocity, phase velocity and phase constant of waves in a rectangular waveguide are estimated using SCILAB.

Test Case 2 :

In a radar system operating at f=15 GHz the waveguide dimensions are a = 2.5 and b = 1.25 cm

1. **Compute the cutoff frequencies for TE_{10} modes.**
2. **Determine the phase and group velocities for the TE_{10} mode.**
3. **If dispersion is critical to radar signal accuracy, what strategies would you recommend maintaining signal fidelity?**

AIM: To find the group velocity, phase velocity and phase constant of Electromagnetic waves in Rectangular Waveguides whose dimensions are a= 2.5 cm, b=1.25 cmand the operating frequency is f=15 GHz.

SOFTWARE REQUIRED:

SCILAB Version 6.1.1

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

PROGRAM:

```
clc;
clear;
close;
//TE10 Mode
a=8.636*10^-2;
b=4.318*10^-2;
f=4*10^9;
V=3*10^8;
m=input("enter the value of m= "); n=input("enter the value of n= ");
fc=(V/(2*3.14))*sqrt((m*3.14/a)^2+(n*3.14/b)^2);
disp("Cut off frquency=",fc*10^-9);
//let phase velocity = A
A=V/sqrt(1-(fc/f)^2);
disp("Phase velocity in Mm/sec=",A*10^-6);
```

```
//let group velocity = B
B=V*V/A;
disp("Group velocity in Mm/sec =", B*10^-6);
```

Program Output for TE_{10} Mode:

Using the program with a=0.025 m b=0.0125 m and f=15 GHz:

Parameter	Simulation Results	Theoretical Results
	Value	Value
Cutoff Frequency (f_c)		
Phase Velocity (v_p)		
Group Velocity (v_g)		

RESULT:

The group velocity, phase velocity and phase constant of waves in a rectangular waveguide are estimated using SCILAB.

Test Case 3 :

A waveguide with dimensions a=5.0 cm and b=2.5 cmis used to carry a signal at f=10 GHz

1. **Determine the number of TE modes that can propagate at this frequency.**
2. **For the TE_{10}mode, calculate the phase velocity and group velocity.**
3. **Discuss how the presence of multiple propagating modes affects the transmission quality and suggest practical solutions to limit multimode effects.**

AIM:

To find the group velocity, phase velocity and phase constant of Electromagnetic waves in Rectangular Waveguides whose dimensions are a= 5.0 cm, b=2.5 cmand the operating frequency is f=10 GHz.

SOFTWARE REQUIRED:

SCILAB Version 6.1.1

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

PROGRAM:

```
clc;
clear;
close;
//TE10 Mode
a=8.636*10^-2;
b=4.318*10^-2;
f=4*10^9;
V=3*10^8;
m=input("enter the value of m= ");
n=input("enter the value of n= ");
fc=(V/(2*3.14))*sqrt((m*3.14/a)^2+(n*3.14/b)^2);
disp("Cut off frquency=",fc*10^-9);
//let phase velocity = A
A=V/sqrt(1-(fc/f)^2);
disp("Phase velocity in Mm/sec=",A*10^-6);
//let group velocity = B
B=V*V/A;
disp("Group velocity in Mm/sec =", B*10^-6);
```

OUTPUT:

Waveguide Parameters:

- Width (a) = 5.0 cm=0.05m

- Height (b) = 2.5 cm=0.025 m
- Operating Frequency (f) = 10 GHz
- Speed of Light (V) = 3×10^8 m/s

1. ***Number of TE Modes that Can Propagate:***

The cutoff frequency for a TE_{mn}_mode is:

$f_c(m,n)=V/2\ (\ \text{sqrt}\ [(m/a)^2+(n/b)^2]\ )$

Modes propagate if f>fc(m,n).The number of modes can be determined by calculating fc for different combinations of m and n.

	Simulation Results		**Theoretical Results**	
Mode (m,n)	**Cutoff Frequency (fc)**	**Propagation (Yes/No)**	**Cutoff Frequency (fc)**	**Propagation (Yes/No)**
TE_{10}				
TE_{01}				
TE_{11}				
TE_{20}				
TE_{21}				
TE_{02}				

- *Result:*

Five TE modes can propagate TE_{10}, TE_{01},TE_{11}, TE_{20}, TE_{21}, TE_{02}

2. **Output for TE_{10} Mode:**

Using the program with a=5 m b=2.5 m and f=10 GHz:

Parameter	**Simulation Results**	**Theoretical Results**
	Value	**Value**
Cutoff Frequency (f_c)		
Phase Velocity (v_p)		
Group Velocity (v_g)		

RESULT:

The group velocity, phase velocity and phase constant of waves in a rectangular waveguide are estimated using SCILAB.

Test Case 4 :

A research lab is experimenting with high-order TE modes (m,n>1) in a waveguide with dimensions a=3.0 cm b=1.5 cm, and an operating frequency of f=12 GHz.

1. **Calculate the cutoff frequencies for TE_{10} mode.**
2. **Compute the phase and group velocities of this mode.**
3. **Discuss how high-order modes can be utilized for advanced applications such as mode multiplexing in communications.**

AIM:

To find the group velocity, phase velocity and phase constant of Electromagnetic waves in Rectangular Waveguides whose dimensions are a=3.0 cm, b=1.5 cmand the operating frequency is f=12 GHz.

SOFTWARE REQUIRED:

SCILAB Version 6.1.1

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

PROGRAM:

```
clc;
clear;
close;
//TE10 Mode
a=8.636*10^-2;
b=4.318*10^-2;
f=4*10^9;
```

```
V=3*10^8;
m=input("enter the value of m= ");
n=input("enter the value of n= ");
fc=(V/(2*3.14))*sqrt((m*3.14/a)^2+(n*3.14/b)^2);
disp("Cut off frquency=",fc*10^-9);
//let phase velocity = A
A=V/sqrt(1-(fc/f)^2);
disp("Phase velocity in Mm/sec=",A*10^-6);
//let group velocity = B
B=V*V/A;
disp("Group velocity in Mm/sec =", B*10^-6);
```

OUTPUT:

Waveguide Parameters:

- Width (a) = 3.0 cm=0.03 m
- Height (b) = 1.5 cm=0.015 m
- Operating Frequency (f) = 12 GHz=12×10^9 Hz
- Speed of Light (V) = 3×10^8 m/s

1. **No. of Modes:**

To analyze all modes, calculate fc for other modes with m,n>1.

OUTPUT:

	Simulation Results		**Theoretical Results**	
Mode (m,n)	**Cutoff Frequency (fc)**	**Propagation (Yes/No)**	**Cutoff Frequency (fc)**	**Propagation (Yes/No)**
TE_{10}				
TE_{20}				
TE_{01}				
TE_{11}				
TE_{21}				
TE_{30}	15.0 GHz	No	15.0 GHz	No

2. Program Output for TE_{10} Mode:

Using the program with a=0.03 m b=0.015 m and f=12 GHz:

Parameter	Simulation Results	Theoretical Results
	Value	**Value**
Cutoff Frequency (f_c)		
Phase Velocity (v_p)		
Group Velocity (v_g)		

RESULT:

The group velocity, phase velocity and phase constant of waves in a rectangular waveguide are estimated using SCILAB.

EXNO: 10	Examining the propagation characteristics of circular waveguide in terms of a)Cutoff wavelength d) Guide wavelength e) Characteristic impedance
DATE:	

Test Case 1:
Design a circular waveguide for the TE_{11} mode to transmit a signal at 10 GHz. The material is air, and the waveguide length is 2 meters.

1. **Determine the minimum radius of the waveguide.**
2. **Calculate the cutoff wavelength, guide wavelength, and characteristic impedance.**

AIM:
To determine the propagation characteristics of circular waveguide in terms of Cutoff wavelength. Guide wavelength and characteristic impedance.

SOFTWAREREQUIRED:
SCILAB Version 6.1.1
PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

TE Mode

$$\beta_{nm} = \sqrt{k^2 - k_c^2} = \sqrt{k^2 - \left(\frac{p'_{nm}}{a}\right)^2},$$

with a cutoff frequency of

$$f_{c_{nm}} = \frac{k_c}{2\pi\sqrt{\mu\epsilon}} = \frac{p'_{nm}}{2\pi a\sqrt{\mu\epsilon}}.$$

The wave impedance is

$$Z_{\mathrm{TE}} = \frac{E_\rho}{H_\phi} = \frac{-E_\phi}{H_\rho} = \frac{\eta k}{\beta}.$$

TM Mode

The propagation constant of the TM_{nm} mode is

$$\beta_{nm} = \sqrt{k^2 - k_c^2} = \sqrt{k^2 - (p_{nm}/a)^2},$$

and the cutoff frequency is

$$f_{c_{nm}} = \frac{k_c}{2\pi\sqrt{\mu\epsilon}} = \frac{p_{nm}}{2\pi a\sqrt{\mu\epsilon}}.$$

The wave impedance is

$$Z_{\mathrm{TM}} = \frac{E_\rho}{H_\phi} = \frac{-E_\phi}{H_\rho} = \frac{\eta\beta}{k}.$$

PROGRAM:

```
// Constants
c = 3e8; // Speed of light in m/s
f = 10e9; // Frequency in Hz
chi_11 = 1.841; // First root for TE11 mode
Z0 = 377; // Impedance of free space in ohms

// Calculations
lambda0 = c / f; // Free-space wavelength
r = (chi_11 * c) / (2 * %pi * f); // Minimum radius
lambda_c = 2 * %pi * r / chi_11; // Cutoff wavelength
lambda_g = lambda0 / sqrt(1 - (lambda0 / lambda_c)^2); // Guide wavelength
Z = Z0 / sqrt(1 - (lambda_c / lambda0)^2); // Characteristic impedance

// Output
disp("Minimum Radius (m): " + string(r));
disp("Cutoff Wavelength (m): " + string(lambda_c));
disp("Guide Wavelength (m): " + string(lambda_g));
disp("Characteristic Impedance (Ohms): " + string(Z));
```

OUTPUT:

Given Data:

- Frequency $f=10$ GHz$=10\times10^9$ Hz
- Speed of light $c=3\times10^8$ m/s
- Material: Air (vacuum)
- Waveguide length = 2 meters
- For TE_{11} mode, the first root $\chi11\approx1.841$

Output Table:

Parameter	Simulation Results	Theoretical Results
	Value	**Value**
Minimum Radius (r)		
Cutoff Wavelength (λc)		
Guide Wavelength (λg)		
Characteristic Impedance (Z)		

RESULT:

The propagation characteristics of circular waveguide in terms of Cutoff wavelength Guide wavelength and characteristic impedance

Test Case 2:

You are designing a circular waveguide to operate in the TE_{11} mode at 12 GHz, and the waveguide is filled with a dielectric material with a relative permittivity of 2.5. The waveguide length is 3 meters.

1. **Determine the minimum radius of the waveguide.**
2. **Calculate the cutoff wavelength and guide wavelength for the TE_{11} mode.**
3. **What would be the impact if the operating frequency is increased to 18 GHz? Would higher-order modes propagate?**

AIM:

To determine the propagation characteristics of circular waveguide in terms of Cutoff wavelength. Guide wavelength and characteristic impedance

SOFTWAREREQUIRED:

SCILAB Version 6.1.1

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

TE Mode

$$\beta_{nm} = \sqrt{k^2 - k_c^2} = \sqrt{k^2 - \left(\frac{p'_{nm}}{a}\right)^2},$$

with a cutoff frequency of

$$f_{c_{nm}} = \frac{k_c}{2\pi\sqrt{\mu\epsilon}} = \frac{p'_{nm}}{2\pi a\sqrt{\mu\epsilon}}.$$

The wave impedance is

$$Z_{\mathrm{TE}} = \frac{E_\rho}{H_\phi} = \frac{-E_\phi}{H_\rho} = \frac{\eta k}{\beta}.$$

TM Mode

The propagation constant of the TM_{nm} mode is

$$\beta_{nm} = \sqrt{k^2 - k_c^2} = \sqrt{k^2 - (p_{nm}/a)^2},$$

and the cutoff frequency is

$$f_{c_{nm}} = \frac{k_c}{2\pi\sqrt{\mu\epsilon}} = \frac{p_{nm}}{2\pi a\sqrt{\mu\epsilon}}.$$

The wave impedance is

$$Z_{\mathrm{TM}} = \frac{E_\rho}{H_\phi} = \frac{-E_\phi}{H_\rho} = \frac{\eta\beta}{k}.$$

PROGRAM:

```
// Constants
c = 3e8; // Speed of light in m/s
f = 10e9; // Frequency in Hz
chi_11 = 1.841; // First root for TE11 mode
Z0 = 377; // Impedance of free space in ohms

// Calculations
lambda0 = c / f; // Free-space wavelength
r = (chi_11 * c) / (2 * %pi * f); // Minimum radius
lambda_c = 2 * %pi * r / chi_11; // Cutoff wavelength
lambda_g = lambda0 / sqrt(1 - (lambda0 / lambda_c)^2); // Guide wavelength
Z = Z0 / sqrt(1 - (lambda_c / lambda0)^2); // Characteristic impedance

// Output
disp("Minimum Radius (m): " + string(r));
disp("Cutoff Wavelength (m): " + string(lambda_c));
disp("Guide Wavelength (m): " + string(lambda_g));
disp("Characteristic Impedance (Ohms): " + string(Z));
```

OUTPUT:

Given Data:

- Operating Frequency f=12 GHz
- Relative permittivity ϵ_r=2.5
- Speed of light in vacuum $c=3\times10^8$ m/s
- Waveguide length L=3 m
- For TE_{11} mode, the first root $\chi 11\approx1.841$

1. **Minimum Radius (r)**:

The cutoff wavelength (λc) for TE_{11} mode is given by:

$\lambda c = (2\pi r / \chi_{11})$
r can be found using the above formula: r= 22.7 mm

2. **Output**

Parameter	**Simulation Results**	**Theoretical Results**
	Value	**Value**
Minimum Radius (r)		
Cutoff Wavelength (λc)		
Guide Wavelength (λg)		

RESULT

The propagation characteristics of circular waveguide in terms of Cutoff wavelength Guide wavelength and characteristic impedance

Test Case 3:
A circular waveguide with a radius of 5 cm is designed to transmit a signal at 8 GHz in the TE_{11} mode. Initially, the waveguide is filled with air, but it is later filled with a dielectric material of relative permittivity 4.

1. **Calculate the cutoff wavelength and guide wavelength before and after the dielectric is added.**
2. **Determine the characteristic impedance in both cases.**
3. **Discuss how the material change affects the waveguide's ability to transmit signals and how to mitigate any undesired effects.**

AIM:
To determine the propagation characteristics of circular waveguide in terms of Cutoff wavelength. Guide wavelength and characteristic impedance

SOFTWAREREQUIRED:

SCILAB Version 6.1.1
PROCEDURE:

- Open SCILAB software

- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

TE Mode

$$\beta_{nm} = \sqrt{k^2 - k_c^2} = \sqrt{k^2 - \left(\frac{p'_{nm}}{a}\right)^2},$$

with a cutoff frequency of

$$f_{c_{nm}} = \frac{k_c}{2\pi\sqrt{\mu\epsilon}} = \frac{p'_{nm}}{2\pi a\sqrt{\mu\epsilon}}.$$

The wave impedance is

$$Z_{TE} = \frac{E_\rho}{H_\phi} = \frac{-E_\phi}{H_\rho} = \frac{\eta k}{\beta}.$$

TM Mode

The propagation constant of the TM_{nm} mode is

$$\beta_{nm} = \sqrt{k^2 - k_c^2} = \sqrt{k^2 - (p_{nm}/a)^2},$$

and the cutoff frequency is

$$f_{c_{nm}} = \frac{k_c}{2\pi\sqrt{\mu\epsilon}} = \frac{p_{nm}}{2\pi a\sqrt{\mu\epsilon}}.$$

The wave impedance is

$$Z_{TM} = \frac{E_\rho}{H_\phi} = \frac{-E_\phi}{H_\rho} = \frac{\eta\beta}{k}.$$

PROGRAM:

```
// Constants
c = 3e8; // Speed of light in m/s
f = 10e9; // Frequency in Hz
chi_11 = 1.841; // First root for TE11 mode
Z0 = 377; // Impedance of free space in ohms

// Calculations
lambda0 = c / f; // Free-space wavelength
r = (chi_11 * c) / (2 * %pi * f); // Minimum radius
lambda_c = 2 * %pi * r / chi_11; // Cutoff wavelength
```

```
lambda_g = lambda0 / sqrt(1 - (lambda0 / lambda_c)^2); // Guide wavelength
Z = Z0 / sqrt(1 - (lambda_c / lambda0)^2); // Characteristic impedance

// Output
disp("Minimum Radius (m): " + string(r));
disp("Cutoff Wavelength (m): " + string(lambda_c));
disp("Guide Wavelength (m): " + string(lambda_g));
disp("Characteristic Impedance (Ohms): " + string(Z));
```

OUTPUT:

Given Data:

- Operating Frequency f=8 GHz
- Waveguide Radius r=5 cm=0.05 m
- Relative Permittivity of Air ϵ_r=1
- Relative Permittivity of Dielectric ϵ_r=4
- For TE_{11} mode, the first root $\chi 11 \approx 1.841$
- Speed of light in vacuum $c=3\times10^8$ m/s
-

Output

Parameter	**Simulation Results**		**Theoretical Results**	
	Before Dielectric (Air)	**After Dielectric (ϵ_r = 4)**	**Before Dielectric (Air)**	**After Dielectric (ϵ_r = 4)**
Cutoff Wavelength (λc)				
Guide Wavelength (λg)				
Characteristic Impedance (Z)				

RESULT:

The propagation characteristics of circular waveguide in terms of Cutoff wavelength Guide wavelength and characteristic impedance

Test Case 4:

A satellite communication system requires a circular waveguide to operate at 14 GHz in the TE_{11} mode. The waveguide's internal radius is 2.5 cm, and it is filled with air.

- **Calculate the cutoff frequency for the TE_{11} mode.**
- **If the operating frequency is reduced to 12 GHz, will the TE_{11} mode still propagate?**
- **Design the waveguide parameters to ensure that only the TE_{11} mode propagates when operating between 10 GHz and 16 GHz.**

AIM:

To determine the propagation characteristics of circular waveguide in terms of Cutoff wavelength. Guide wavelength and characteristic impedance

SOFTWAREREQUIRED:

SCILAB Version 6.1.1

PROCEDURE:
- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

TE Mode

$$\beta_{nm} = \sqrt{k^2 - k_c^2} = \sqrt{k^2 - \left(\frac{p'_{nm}}{a}\right)^2},$$

with a cutoff frequency of

$$f_{c_{nm}} = \frac{k_c}{2\pi\sqrt{\mu\epsilon}} = \frac{p'_{nm}}{2\pi a\sqrt{\mu\epsilon}}.$$

The wave impedance is

$$Z_{\mathrm{TE}} = \frac{E_\rho}{H_\phi} = \frac{-E_\phi}{H_\rho} = \frac{\eta k}{\beta}.$$

TM Mode

The propagation constant of the TM_{nm} mode is

$$\beta_{nm} = \sqrt{k^2 - k_c^2} = \sqrt{k^2 - (p_{nm}/a)^2},$$

and the cutoff frequency is

$$f_{c_{nm}} = \frac{k_c}{2\pi\sqrt{\mu\epsilon}} = \frac{p_{nm}}{2\pi a\sqrt{\mu\epsilon}}.$$

The wave impedance is

$$Z_{\mathrm{TM}} = \frac{E_\rho}{H_\phi} = \frac{-E_\phi}{H_\rho} = \frac{\eta\beta}{k}.$$

PROGRAM:

```
// Constants
c = 3e8; // Speed of light in m/s
f = 10e9; // Frequency in Hz
chi_11 = 1.841; // First root for TE11 mode
Z0 = 377; // Impedance of free space in ohms

// Calculations
lambda0 = c / f; // Free-space wavelength
r = (chi_11 * c) / (2 * %pi * f); // Minimum radius
lambda_c = 2 * %pi * r / chi_11; // Cutoff wavelength
lambda_g = lambda0 / sqrt(1 - (lambda0 / lambda_c)^2); // Guide wavelength
Z = Z0 / sqrt(1 - (lambda_c / lambda0)^2); // Characteristic impedance

// Output
disp("Minimum Radius (m): " + string(r));
disp("Cutoff Wavelength (m): " + string(lambda_c));
disp("Guide Wavelength (m): " + string(lambda_g));
disp("Characteristic Impedance (Ohms): " + string(Z));
```

OUTPUT:

Given Data:

- Operating Frequency f=14 GHz
- Waveguide Radius r= 2.5 cm=0.025 m
- Relative Permittivity of Air ϵ_r=1
- Relative Permittivity of Dielectric ϵ_r =4
- For TE_{11} mode, the first root $\chi 11 \approx 1.841$
- Speed of light in vacuum $c=3\times10^8$ m/s

Output :

Parameter	Simulation Results	Theoretical Results
	Value	**Value**
Cutoff Frequency at 14 GHz		
TE_{11} Mode Propagation at 12 GHz		
Waveguide Radius for 10 GHz (minimum)		
Waveguide Radius for 16 GHz (maximum)		

RESULT:

The propagation characteristics of circular waveguide in terms of Cutoff wavelength Guide wavelength and characteristic impedance

EXNO: 11	**Inference of Q Factor of Rectangular Cavity Resonator for TE101mode with the following inputs** **a) Dimension a in x axis** **b) Dimension b in y axis** **c) Dimension p in z axis**
DATE:	

Test Case 1:

You are tasked with designing a rectangular cavity resonator that operates in the TE101 mode. The dimensions of the resonator are a=5 cm, b=4 cm, and c=10 cm. The cavity is made of copper (C=5.8×10^7 S/m).

1. **If the dimension a is increased to 7 cm while keeping b and c constant, how does the Q-factor change? Explain the relationship between a and the Q-factor.**
   Hint: Use the given formula for Q and compare the resulting values.

AIM:

To determine the Q Factor of Rectangular Cavity Resonator for TE_{101} mode by varying three dimensions

SOFTWAREREQUIRED:

SCILAB

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

$$Q_{101} = \frac{\pi f_{101} \mu_0 abd(a^2 + d^2)}{R_s[2b(a^3 + d^3) + ad(a^2 + d^2)]} \qquad (TE_{101} \text{ mode}),$$

PROGRAM:

```
clear;

clc;

a=5*10^-2,b=4*10^-2,c=10*10^-2,C=5.8*10^7,Uo=4*%pi*10^-7;

f101=3.335*10^9;
```

```
d=sqrt(1/(%pi*f101*Uo*C));
Q=(a*a+c*c)*a*b*c/(d*(2*b*(a^3 + c^3)+a*c*(a*a+c*c)));
disp(Q,'Quality factor of TE101 = ');
```

OUTPUT:

a (cm)	b (cm)	c (cm)	Simulation Results	Theoretical Results
			Q Factor	Q Factor

RESULT: The Q Factor of Rectangular Cavity Resonator for TE101 mod by varying three dimensions is determined using Scilab

Test Case 2 :

You are asked to optimize the rectangular cavity resonator to achieve the highest possible Q-factor using the dimensions provided.

1. **Based on the variation in a, b, and c, which combination of dimensions yields the maximum Q-factor?**
2. **Explain why this combination results in a higher Q-factor.Consider the relationship between a, b, and c and how they affect the Q-factor in the given formula.**

AIM:

To determine the Q Factor of Rectangular Cavity Resonator for TE_{101} mode by varying three dimensions

SOFTWAREREQUIRED:

SCILAB

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

$$Q_{101} = \frac{\pi f_{101}\mu_0 abd(a^2 + d^2)}{R_s[2b(a^3 + d^3) + ad(a^2 + d^2)]} \qquad (\mathrm{TE}_{101}\ \text{mode}),$$

PROGRAM:

```
clear;
clc;
a=5*10^-2, b=4*10^-2, c=10*10^-2,C=5.8*10^7, Uo=4*%pi*10^-7;
f101=3.335*10^9;
d=sqrt(1/(%pi*f101*Uo*C));
Q=(a*a+c*c)*a*b*c/(d*(2*b*(a^3 + c^3)+a*c*(a*a+c*c)));
disp(Q,'Quality factor of TE101 = ');
```

OUTPUT:

The combination of dimensions that yields the highest Q-factor is as follows:

a (cm)	b (cm)	c (cm)	Simulation Results	Theoretical Results
			Q Factor	Q Factor

RESULT:

The Q Factor of Rectangular Cavity Resonator for TE101 mode by varying three dimensions is determined using Scilab.

Test Case 3 :

Your task is to assess how changes in a single dimension affect the resonator's performance.

1. **Fix b=4 cm and c=10 cm and vary a between 4 cmand 6 cm. How does the Q-factor change? What does this tell you about the sensitivity of the Q-factor to the dimension a?**
2. **In practical scenarios, which dimension is most critical to optimize for achieving a high Q-factor, and why?**

AIM:

To determine the Q Factor of Rectangular Cavity Resonator for TE_{101} mode by varying three dimensions

SOFTWAREREQUIRED:

SCILAB

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

$$Q_{101} = \frac{\pi f_{101}\mu_0 abd(a^2 + d^2)}{R_s[2b(a^3 + d^3) + ad(a^2 + d^2)]} \qquad (\mathrm{TE}_{101} \text{ mode}),$$

PROGRAM:

```
clear;
clc;
a=5*10^-2, b=4*10^-2, c=10*10^-2,C=5.8*10^7, Uo=4*%pi*10^-7;
f101=3.335*10^9;
d=sqrt(1/(%pi*f101*Uo*C));
Q=(a*a+c*c)*a*b*c/(d*(2*b*(a^3 + c^3)+a*c*(a*a+c*c)));
disp(Q,'Quality factor of TE101 = ');
```

OUTPUT:

Below is the result of how changes in the dimension of'a' affect the Q-factor, we can calculate the Q-factor for fixed values of b=4 cm and c=10 cm, while varying 'a'between 4 cm and 6 cmin equal steps.

1. **Q-Factor Calculation for Varying a:**

a (cm)	b (cm)	c (cm)	Simulation Results	Theoretical Results
			Q-Factor	Q-Factor

RESULT:

The Q Factor of Rectangular Cavity Resonator for TE101 mode by varying three dimensions is determined using Scilab.

Test Case 4 :

You are tasked with investigating how changes in b(the y-axis dimension) affect the Q-factor of the rectangular cavity resonator. Fix a=5 cm and c=10 cm and vary b between 3 cm and 5 cm. Analyze the Q-factor for these changes.

AIM:

To determine the Q Factor of Rectangular Cavity Resonator for TE_{101} mode by varying three dimensions

SOFTWAREREQUIRED:

SCILAB

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values

- Type the program
- Execute the program
- End the program

CALCULATION

$$Q_{101} = \frac{\pi f_{101}\mu_0 abd(a^2 + d^2)}{R_s[2b(a^3 + d^3) + ad(a^2 + d^2)]} \qquad (\text{TE}_{101} \text{ mode}),$$

PROGRAM:

```
clear;
clc;
a=5*10^-2, b=4*10^-2, c=10*10^-2,C=5.8*10^7, Uo=4*%pi*10^-7;
f101=3.335*10^9;
d=sqrt(1/(%pi*f101*Uo*C));
Q=(a*a+c*c)*a*b*c/(d*(2*b*(a^3 + c^3)+a*c*(a*a+c*c)));
disp(Q,'Quality factor of TE101 = ');
```

OUTPUT:

Calculation of Q-Factor for Varying b

a (cm)	b (cm)	c (cm)	Simulation Results	Theoretical Results
			Q-Factor	Q-Factor

RESULT:

The Q Factor of Rectangular Cavity Resonator for TE101 mode by varying three dimensions is determined using Scilab.

EXNO: 12	**Calculation of Resonant Frequency of Rectangular Cavity Resonator for TE and TM mode**
DATE:	

Test Case 1: Construct a Rectangular Cavity Resonator with dimensions a= 5 cm, b=3 cm and height c= 9 cm. Find the resonant frequencies by varying the dimension a from 5 cm to 9 cm for 5 intervals keeping the other dimensions b and c constant for the modes TM_{110} and TE_{101}.

AIM: To Construct a Rectangular Cavity Resonator with dimensions a= 5 cm, b=3 cm and height c= 9 cm. Find the resonant frequencies by varying the dimension a from 5 cm to 9 cm for 5 intervals keeping the other dimensions b and c constant for the modes TM_{110} and TE_{101}

SOFTWAREREQUIRED:

SCILAB Version 6.1.1

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program
- **CALCULATION**

The resonant frequency of the $TE_{mn\ell}$ or $TM_{mn\ell}$ mode is given by

$$f_{mn\ell} = \frac{ck_{mn\ell}}{2\pi\sqrt{\mu_r\epsilon_r}} = \frac{c}{2\pi\sqrt{\mu_r\epsilon_r}}\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 + \left(\frac{\ell\pi}{d}\right)^2}.$$

-

PROGRAM:

```
clc; clear;
format('e',11); a=0.05; b=0.03; c=0.09;
v=3*10^8;
//for m=1; n=1; p=0;
m=1;n=1; p=0;
```

```
fr110=v/2*sqrt((m/a)^2+(n/b)^2+(p/c)^2); disp(fr110,"fr110(in Hz)=");
//for m=1,n=0. m=1; n=0;
m=1;n=0; p=1;
fr101=v/2*sqrt((m/a)^2+(n/b)^2+(p/c)^2); disp(fr101,"fr101(in Hz)=");
```

OUTPUT:

Variable: dimension a cm

a (cm)	Simulation Results		Theoretical Results	
	fr (TM110) GHz	fr (TE101) GHz	fr (TM110) GHz	fr (TE101) GHz

RESULT:

A Rectangular Cavity Resonator with dimensions a= 5 cm, b=3 cm and height c= 9 cm. is constructed and the resonant frequencies are found by varying the dimension a from 5 cm to 9 cm for 5 intervals keeping the other dimensions b and c constant for the modes TM_{110} and TE_{101}

Test Case 2: Design a Rectangular Cavity Resonator with dimensions a= 5 cm, b=3 cm and height c= 9 cm. Find the resonant frequencies by varying the dimension b from 3 cm to 6 cm for 5 intervals keeping the other dimensions a and c constant for the modes TM_{110} and TE_{101}.

AIM: To design a Rectangular Cavity Resonator with dimensions a= 5 cm, b=3 cm and height c= 9 cm. Find the resonant frequencies by varying the dimension b from 3 cm to 6 cm for 5 intervals keeping the other dimensions a and c constant for the modes TM_{110} and TE_{101}.

SOFTWARE REQUIRED:

SCILAB Version 6.1.1

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

The resonant frequency of the $TE_{mn\ell}$ or $TM_{mn\ell}$ mode is given by

$$f_{mn\ell} = \frac{ck_{mn\ell}}{2\pi\sqrt{\mu_r\epsilon_r}} = \frac{c}{2\pi\sqrt{\mu_r\epsilon_r}}\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 + \left(\frac{\ell\pi}{d}\right)^2}.$$

PROGRAM:

```
clc; clear;
format('e',11); a=0.05; b=0.03; c=0.09;
v=3*10^8;
//for m=1; n=1; p=0;
m=1;n=1; p=0;
fr110=v/2*sqrt((m/a)^2+(n/b)^2+(p/c)^2); disp(fr110,"fr110(in Hz)=");
//for m=1,n=0. m=1; n=0;
m=1;n=0; p=1;
fr101=v/2*sqrt((m/a)^2+(n/b)^2+(p/c)^2); disp(fr101,"fr101(in Hz)=");
```

OUTPUT:

Variable: dimension b cm
constant a=5 cm , c=9 cm

b(cm)	Simulation Results		Theoretical Results	
	fr (TM110) GHz	fr (TE101) GHz	fr (TM110) GHz	fr (TE101) GHz
4.5	4.48	3.43	4.48	3.43
5	4.24	3.43	4.24	3.43
6	3.90	3.43	3.90	3.43

RESULT:

A Rectangular Cavity Resonator with dimensions a= 5 cm, b=3 cm and height c= 9 cm. is constructed and the resonant frequencies are found by varying the dimension b from 3 cm to 6 cm for 5 intervals keeping the other dimensions a and c constant for the modes TM_{110} and TE_{101}. In TE_{101} mode, since n=0, the variations in the dimension b is not affecting the result , therefore the outcome remains the same.

Test Case 3: Design a Rectangular Cavity Resonator with dimensions a= 5 cm, b=3 cm and height c= 9 cm. Find the resonant frequencies by varying the dimension c from 8 cm to 12 cm for 5 intervals keeping the other dimensions a and b constant for the modes TM_{110} and TE_{101}.

AIM: To design a Rectangular Cavity Resonator with dimensions a= 5 cm, b=3 cm and height c= 9 cm. Find the resonant frequencies by varying the dimension c from 8 cm to 12 cm for 5 intervals keeping the other dimensions a and b constant for the modes TM_{110} and TE_{101}.

SOFTWARE REQUIRED:

SCILAB Version 6.1.1

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values

- Type the program
- Execute the program
- End the program

c) CALCULATION

The resonant frequency of the $TE_{mn\ell}$ or $TM_{mn\ell}$ mode is given by

$$f_{mn\ell} = \frac{ck_{mn\ell}}{2\pi\sqrt{\mu_r \epsilon_r}} = \frac{c}{2\pi\sqrt{\mu_r \epsilon_r}}\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 + \left(\frac{\ell\pi}{d}\right)^2}.$$

d)

PROGRAM:

```
clc; clear;
format('e',11); a=0.05; b=0.03; c=0.09;
v=3*10^8;
//for m=1; n=1; p=0;
m=1;n=1; p=0;
fr110=v/2*sqrt((m/a)^2+(n/b)^2+(p/c)^2); disp(fr110,"fr110(in Hz)=");
//for m=1,n=0. m=1; n=0;
m=1;n=0; p=1;
fr101=v/2*sqrt((m/a)^2+(n/b)^2+(p/c)^2); disp(fr101,"fr101(in Hz)=");
```

OUTPUT:

Variable: dimension c cm

c (cm)	**Simulation Results**		**Theoretical Results**	
	fr (TM110) GHz	**fr (TE101) GHz**	**fr (TM110) GHz**	**fr (TE101) GHz**

RESULT:

A Rectangular Cavity Resonator with dimensions a= 5 cm, b=3 cm and height c= 9 cm. is constructed and the resonant frequencies are found by varying the dimension c from 8 cm to 12 cm for 5 intervals keeping the other dimensions a and b constant for the modes TM_{110} and TE_{101}. In TM_{110} mode,p=0, therefore variation in C dimension does not affect the outcome.

Test Case 4: Design a cubic Cavity Resonator with dimension of 5 cm Find the resonant frequency by varying the dimension from 5 cm to 9 cm for 5 intervals for the modes TM_{110} and TE_{101}.Compare the results with that of Rectangular Cavity Resonator with dimension a assuming the same range of 5 cm to 9 cm for 5 intervals.

AIM: To design a cubic Cavity Resonator with dimension of 5 cm Find the resonant frequency by varying the dimension from 5 cm to 9 cm for 5 intervals for the modes TM_{110} and TE_{101}.Compare the results with that of Rectangular Cavity Resonator with dimension a assuming the same range of 5 cm to 9 cm for 5 intervals.

SOFTWARE REQUIRED:

SCILAB Version 6.1.1

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

The resonant frequency of the $TE_{mn\ell}$ or $TM_{mn\ell}$ mode is given by

$$f_{mn\ell} = \frac{ck_{mn\ell}}{2\pi\sqrt{\mu_r\epsilon_r}} = \frac{c}{2\pi\sqrt{\mu_r\epsilon_r}}\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 + \left(\frac{\ell\pi}{d}\right)^2}.$$

PROGRAM:

```
clc; clear;
format('e',11); a=0.05; b=0.04; c=0.03;
v=3*10^8; p=1;
//for m=0,n=1. m=0; n=1;
fr011=v/2*sqrt((m/a)^2+(n/b)^2+(p/c)^2); disp(fr011,"fr011(in Hz)=");
//for m=1,n=0. m=1; n=0;
fr101=v/2*sqrt((m/a)^2+(n/b)^2+(p/c)^2); disp(fr101,"fr101(in Hz)=");
```

OUTPUT:

a (cm)	**fr (TM110) GHz – Rectangular cavity b= 3 cm, c=9 cm**	**fr (TM110) GHz Cubic cavity**	**fr (TE101) GHz Rectangular cavity b= 3 cm, c=9 cm**	**fr (TE101) GHz Cubic cavity**

RESULT:

A cubic Cavity Resonator with dimension of 5 cm is designed and the resonant frequencies are calculated by varying the dimension from 5 cm to 9 cm for 5 intervals for the modes TM_{110} and TE_{101}.Tthe results are compared with that of Rectangular Cavity Resonator with dimension a assuming the same range of 5 cm to 9 cm for 5 intervals. In both modes, cubic cavity takes the dimension of a and since m=1 in these modes, the resonant frequencies remain the same for the two modes.

EXNO: 13	Estimation of Resonant Frequency in a Cylindrical Cavity Resonator for a)Transverse Electric mode b)Transverse Magnetic mode
DATE:	

Test Case 1: Design a Teflon filled Cylindrical Cavity Resonator with dimensions a= 3 cm, and height c= 10 cm. Find the resonant frequencies by varying the dimension a from 3 cm to 8 cm for 5 intervals with c at a constant value of 10 cm for the dominant mode.

AIM: To design a Teflon filled Cylindrical Cavity Resonator with dimensions a= 3 cm, and height c= 10 cm. Find the resonant frequencies by varying the dimension a from 3 cm to 8 cm for 5 intervals with c at a constant value of 10 cm for the dominant mode.

SOFTWAREREQUIRED:

SCILAB Version 6.1.1

PROCEDURE:

- **Open SCILAB software**
- **Open file-new**
- **Put the input values**
- **Type the program**
- **Execute the program**
- **End the program**

CALCULATION

the resonant frequency of the $TM_{nm\ell}$ mode is

$$f_{nm\ell} = \frac{c}{2\pi\sqrt{\mu_r \epsilon_r}} \sqrt{\left(\frac{p_{nm}}{a}\right)^2 + \left(\frac{\ell\pi}{d}\right)^2}.$$

the resonant frequency of the $TE_{nm\ell}$ mode is

$$f_{nm\ell} = \frac{c}{2\pi\sqrt{\mu_r \epsilon_r}} \sqrt{\left(\frac{p'_{nm}}{a}\right)^2 + \left(\frac{\ell\pi}{d}\right)^2},$$

PROGRAM:

TE Mode

```
clc; clear;
a=0.0274;
v=3*10^8;
Xnm=3.832;
d=2*a; TE011=v/2*%pi*sqrt((Xnm/a)^2+(%pi/d)^2)*10^-9; printf("TE011(in Hz)=%f
GHZ",TE011);
```

TM Mode

```
clc; clear;
a=0.0274;
v=3*10^8;
Xnm=2.405;
d=2*a; TM011=v/(2*%pi^1.44)*sqrt((Xnm/a)^2+(%pi/d)^2)*10^-9; printf("TM011(in Hz)=%f
GHZ",TM011);
```

OUTPUT :

Teflon, εr= 2.08, c= 10 cm

a (cm)	Simulation Results	Theoretical Results
	fr (TE111) GHz	fr (TE111) GHz

RESULT:

A Teflon filled Cylindrical Cavity Resonator is designed with dimensions a= 3 cm, and height c= 10 cm. Resonant frequencies are estimated by varying the dimension a from 3 cm to 8 cm for 5 intervals with c at a constant value of 10 cm for the dominant mode.

Test Case 2: Design a hollow Cylindrical Cavity Resonator with dimensions a= 4.2 cm, and height c= 8 cm. Find the resonant frequencies by varying the dimension a from 4.2 cm to 8 cm for 5 intervals with a constant c value of 8 cm for TM_{011} and TE_{101} modes.

AIM: To design a hollow Cylindrical Cavity Resonator with dimensions a= 4.2 cm, and height c= 8 cm. Find the resonant frequencies by varying the dimension a from 4.2 cm to 8 cm for 5 intervals with a constant c value of 8 cm for TM_{011} and TE_{101} modes.

SOFTWARE REQUIRED:

SCILAB Version 6.1.1

PROCEDURE:

- Open SCILAB software
- Open file-new
- Put the input values
- Type the program
- Execute the program
- End the program

CALCULATION

the resonant frequency of the $TM_{nm\ell}$ mode is

$$f_{nm\ell} = \frac{c}{2\pi\sqrt{\mu_r\epsilon_r}}\sqrt{\left(\frac{p_{nm}}{a}\right)^2 + \left(\frac{\ell\pi}{d}\right)^2}.$$

the resonant frequency of the $TE_{nm\ell}$ mode is

$$f_{nm\ell} = \frac{c}{2\pi\sqrt{\mu_r\epsilon_r}}\sqrt{\left(\frac{p'_{nm}}{a}\right)^2 + \left(\frac{\ell\pi}{d}\right)^2},$$

PROGRAM:

TE01 Mode

```
clc; clear;
a=0.042;
```

```
v=3*10^8;
Xnm=3.832;
d=2*a; TE101=v/2*%pi*sqrt((Xnm/a)^2+(%pi/d)^2)*10^-9; printf("TE101(in Hz)=%f GHZ",TE101);
```

TE11 Mode

```
clc; clear;
a=0.0424;
v=3*10^8;
Xnm=1.83;
d=2*a; TE111=v/2*%pi*sqrt((Xnm/a)^2+(%pi/d)^2)*10^-9; printf("TE111(in Hz)=%f GHZ",TM011);
```

OUTPUT:
Constant c= 10 cm

a (cm)	Simulation Results		Theoretical Results	
	fr (TE101) MHz	fr (TE111) MHz	fr (TE101) MHz	fr (TE111) MHz

RESULT:

A hollow Cylindrical Cavity Resonator is constructed with dimensions a= 4.2 cm, and height c= 8 cm. Resonant frequencies are found by varying the dimension a from 4.2 cm to 8 cm for 5 intervals with a constant c value of 8 cm for TM_{011} and TE_{101} modes.

Test Case 3: A hollow Cylindrical Cavity Resonator is constructed such that its length c is equal to its diameter 2a. Find a and c for the resonant frequency of 10 GHz and 12 GHz at the TM_{010} mode.

AIM: To construct a hollow Cylindrical Cavity Resonator such that its length c is equal to its diameter 2a. Find a and c for the resonant frequency of 10 GHz and 12 GHz at the TM_{010} mode.

SOFTWARE REQUIRED:

SCILAB Version 6.1.1

PROCEDURE:

- **Open SCILAB software**
- **Open file-new**
- **Put the input values**
- **Type the program**
- **Execute the program**
- **End the program**

CALCULATION

the resonant frequency of the $TM_{nm\ell}$ mode is

$$f_{nm\ell} = \frac{c}{2\pi\sqrt{\mu_r \epsilon_r}} \sqrt{\left(\frac{p_{nm}}{a}\right)^2 + \left(\frac{\ell\pi}{d}\right)^2}.$$

the resonant frequency of the $TE_{nm\ell}$ mode is

$$f_{nm\ell} = \frac{c}{2\pi\sqrt{\mu_r \epsilon_r}} \sqrt{\left(\frac{p'_{nm}}{a}\right)^2 + \left(\frac{\ell\pi}{d}\right)^2},$$

PROGRAM:

TM Mode

```
clc; clear;
v=3*10^8;
Xnm=2.405;
f= 10*10^9
a=v/2*%pi*((Xnm/f));
c=2*a;
printf("a(in cm)=%f ",a);
printf ("c ( in cm)=%f ",c);
```

OUTPUT :

fr (GHz)	Simulation Results		Theoretical Results	
	a (cm)	**c=2a (cm)**	**a (cm)**	**c=2a (cm)**

RESULT:

A hollow Cylindrical Cavity Resonator is constructed such that its length c is equal to its diameter 2a. The dimensions a and c are calculated for the resonant frequencies of 10 GHz and 12 GHz at the TM_{011} mode.

EXNO: 14	Design a two conductor transmission line and Investigate the impact of Dielectric layer thickness on characteristic Impedance and Propagation Velocity
DATE:	

Test Case 1: Design a Two conductor transmission line with single ground plane and estimate the impact of varying the thickness of the dielectric layer on characteristic Impedance and Propagation Velocity. Thickness to be varied between 5 to 15mm,

AIM: To design a Two conductor transmission line with single ground plane and estimate the impact of varying the thickness of the dielectric layer on characteristic Impedance and Propagation Velocity. Thickness to be varied between 5 to 15mm,

TOOL REQUIRED:

TNT 1.2.2

PROCEDURE:

- **Open TNT 1.2.2 Tool**
- **Open file-new**
- **Create a two conductor transmission line**
- **Select the dielectric layer with specified material and dimensions**
- **Select the ground plane with specified dimensions**
- **Place the dielectric layer on top of the ground plane**
- **Select two rectangular conductors with specified material and dimensions and place on the top of dielectric layer.**

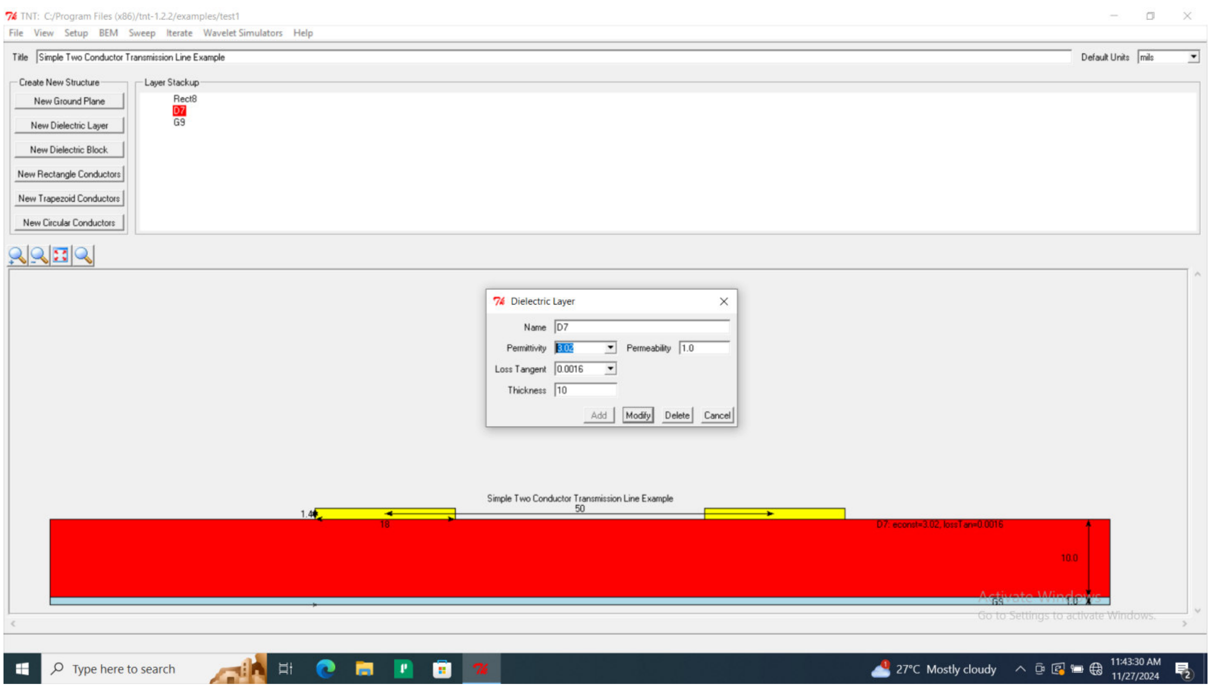
CALCULATION

$$Z_0 = \frac{276}{\sqrt{k}} \log \frac{d}{r}$$

Z_0 = Characteristic impedance of line
d = Distance between conductor centers
r = Conductor radius
k = Relative permittivity of insulation between conductors

$$\text{Velocity factor} = \frac{v}{c} = \frac{1}{\sqrt{k}}$$

v = Velocity of wave propagation
c = Velocity of light in a vacuum
k = Relative permittivity of insulation between conductors



OUTPUT:

Thickness of Dielectric layer (mm)	Simulation Results		Theoretical Results	
	Characteristic Impedance (ohms)	**Propagation Velocity (m/s)**	**Characteristic Impedance (ohms)**	**Propagation Velocity (m/s)**

RESULT:

A Two conductor transmission line is designed with single ground plane and the impact of varying the thickness of the dielectric layer on characteristic Impedance and Propagation Velocity is estimated.

Test Case 2: Design a Two conductor transmission line with single ground plane and investigate the effect of far end cross talk and near end cross talk by varying the thickness of the dielectric layer .Thickness to be varied between 5 to 15mm

AIM: To design a Two conductor transmission line with single ground plane and estimate the impact of varying the thickness of the dielectric layer on characteristic Impedance and Propagation Velocity. Thickness to be varied between 5 to 15mm,

TOOL REQUIRED:

TNT 1.2.2

PROCEDURE:

- Open TNT 1.2.2 Tool
- Open file-new
- Create a two conductor transmission line
- Select the dielectric layer with specified material and dimensions
- Select the ground plane with specified dimensions
- Place the dielectric layer on top of the ground plane
- Select two rectangular conductors with specified material and dimensions and place on the top of dielectric layer.

CALCULATION

$$Z_0 = \frac{276}{\sqrt{k}} \log \frac{d}{r}$$

Z_0 = Characteristic impedance of line
d = Distance between conductor centers
r = Conductor radius
k = Relative permittivity of insulation between conductors

$$\text{Velocity factor} = \frac{v}{c} = \frac{1}{\sqrt{k}}$$

v = Velocity of wave propagation
c = Velocity of light in a vacuum
k = Relative permittivity of insulation between conductors

OUTPUT:

Thickness of Dielectric layer	**Simulation Results**		**Theoretical Results**	
	Far end cross talk (dB)	**Near end cross talk (dB)**	**Far end cross talk (dB)**	**Near end cross talk (dB)**

RESULT:

A Two conductor transmission line is designed with single ground plane and the effect of far end cross talk and near end cross talk is investigated by varying the thickness of the dielectric layer .

EXNO: 15	**Design a two conductor transmission line and examine the impact of conductor dimensions on characteristic Impedance and Propagation Velocity**
DATE:	

Test Case 1: Design a Two conductor transmission line with single ground plane and investigate the impact of the width of the rectangular conductor on Characteristic Impedance and Propagation Velocity .Thickness to be varied between 10 to 20 mm.

AIM: To design a Two conductor transmission line with single ground plane and investigate the impact of the width of the rectangular conductor on Characteristic Impedance and Propagation Velocity .Thickness to be varied between 10 to 20 mm.

TOOL REQUIRED:

TNT 1.2.2

PROCEDURE:

- Open TNT 1.2.2 Tool
- Open file-new
- Create a two conductor transmission line
- Select the dielectric layer with specified material and dimensions
- Select the ground plane with specified dimensions
- Place the dielectric layer on top of the ground plane
- Select two rectangular conductors with specified material and dimensions and place on the top of dielectric layer.

CALCULATION

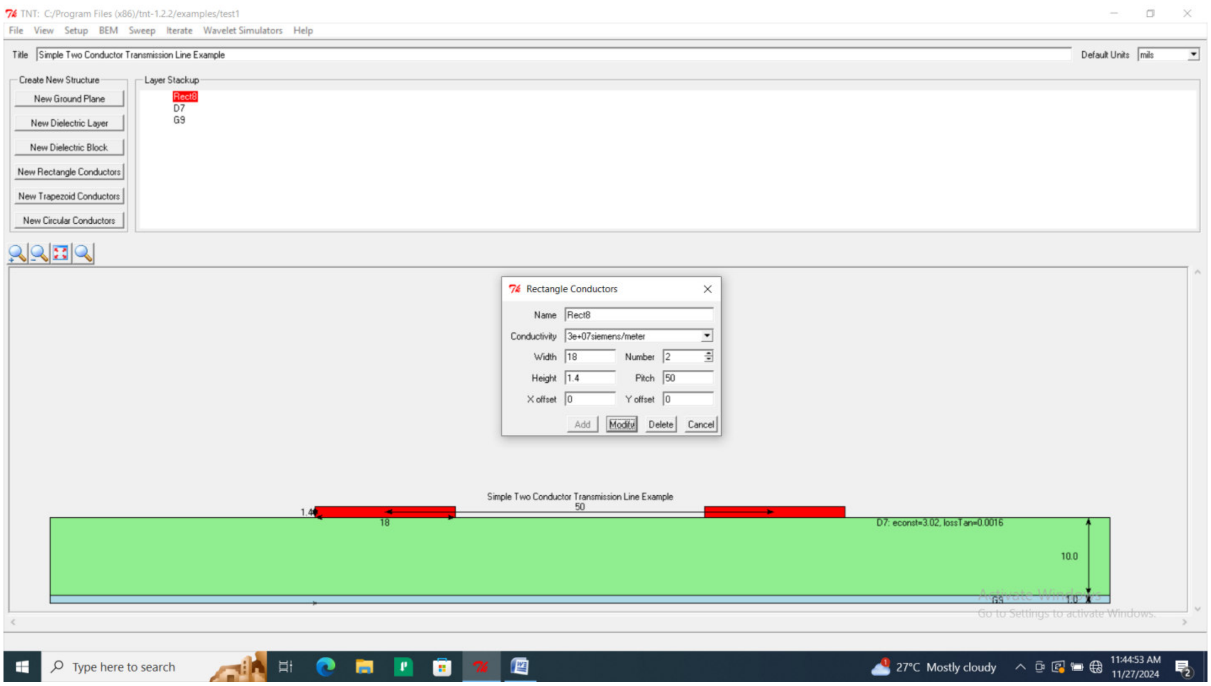
$$Z_0 = \frac{276}{\sqrt{k}} \log \frac{d}{r}$$

Z_0 = Characteristic impedance of line
d = Distance between conductor centers
r = Conductor radius
k = Relative permittivity of insulation between conductors

$$\text{Velocity factor} = \frac{v}{c} = \frac{1}{\sqrt{k}}$$

v = Velocity of wave propagation
c = Velocity of light in a vacuum
k = Relative permittivity of insulation between conductors

OUTPUT:



Width of the Conductor (mm)	Simulation Results		Theoretical Results	
	Characteristic Impedance (ohms)	Propagation Velocity (m/s)	Characteristic Impedance (ohms)	Propagation Velocity (m/s)

RESULT:

A Two conductor transmission line with single ground plane is designed and the impact of the width of the rectangular conductor on Characteristic Impedance and Propagation Velocity is investigated.

Test Case 2: Examine the effect of Characteristic Impedance and Propagation Velocity by varying the height of the rectangular conductor .Height to be varied between 1 to 1.4 mm.

AIM: To examine the effect of Characteristic Impedance and Propagation Velocity by varying the height of the rectangular conductor .Height to be varied between 1 to 1.4 mm.

TOOL REQUIRED:

TNT 1.2.2

PROCEDURE:

- Open TNT 1.2.2 Tool
- Open file-new
- Create a two conductor transmission line
- Select the dielectric layer with specified material and dimensions
- Select the ground plane with specified dimensions
- Place the dielectric layer on top of the ground plane
- Select two rectangular conductors with specified material and dimensions and place on the top of dielectric layer.

CALCULATION

$$Z_0 = \frac{276}{\sqrt{k}} \log \frac{d}{r}$$

Z_0 = Characteristic impedance of line
d = Distance between conductor centers
r = Conductor radius
k = Relative permittivity of insulation between conductors

$$\text{Velocity factor} = \frac{v}{c} = \frac{1}{\sqrt{k}}$$

v = Velocity of wave propagation
c = Velocity of light in a vacuum
k = Relative permittivity of insulation between conductors

OUTPUT:

Height of the Conductor (mm)	Simulation Results		Theoretical Results	
	Characteristic Impedance (ohms)	Propagation Velocity (m/s)	Characteristic Impedance (ohms)	Propagation Velocity (m/s)

RESULT:

The effect of Characteristic Impedance and Propagation Velocity is examined by varying the height of the rectangular conductor between 1 to 1.4 mm.

EXNO: 16	Design a two conductor transmission line and examine the impact of Dielectric layer material on characteristic Impedance and Propagation Velocity
DATE:	

Test Case 1: Design a Two conductor transmission line with single ground plane and investigate the impact of the Dielectric layer material on characteristic Impedance and Propagation Velocity. Materials to be tested - GETEK ,FR 404, ADS995 and RO3203 .

AIM: To design a Two conductor transmission line with single ground plane and investigate the impact of the Dielectric layer material on characteristic Impedance and Propagation Velocity. Materials to be tested - GETEK ,FR 404, ADS995 and RO3203 .

TOOL REQUIRED:

TNT 1.2.2

PROCEDURE:

- Open TNT 1.2.2 Tool
- Open file-new
- Create a two conductor transmission line
- Select the dielectric layer with specified material and dimensions
- Select the ground plane with specified dimensions
- Place the dielectric layer on top of the ground plane
- Select two rectangular conductors with specified material and dimensions and place on the top of dielectric layer.

CALCULATION

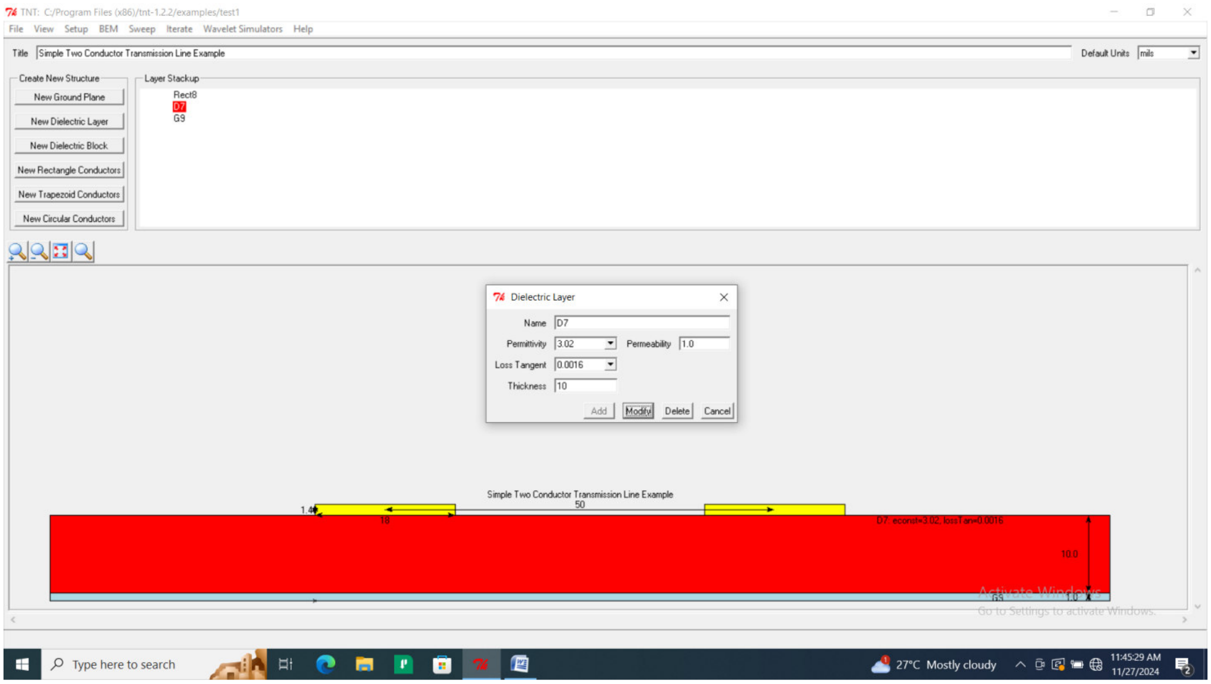
$$Z_0 = \frac{276}{\sqrt{k}} \log \frac{d}{r}$$

Z_0 = Characteristic impedance of line
d = Distance between conductor centers
r = Conductor radius
k = Relative permittivity of insulation between conductors

$$\text{Velocity factor} = \frac{v}{c} = \frac{1}{\sqrt{k}}$$

v = Velocity of wave propagation
c = Velocity of light in a vacuum
k = Relative permittivity of insulation between conductors

OUTPUT:



Dielectric layer material	Permittivity	Loss tangent	Simulation Results		Theoretical Results	
			Characteristic Impedance (ohms)	Propagation Velocity (m/s)	Characteristic Impedance (ohms)	Propagation Velocity (m/s)

RESULT:

A Two conductor transmission line with single ground plane is constructed and the impact of the Dielectric layer material like GETEK, FR 404, ADS995 and RO3203 on characteristic

Impedance and Propagation Velocity is examined. Materials to be tested -

Test Case 2: Design a Two conductor transmission line with single ground plane and investigate the impact of the conductor material on Rdc parameters. Width of the conductor is 18 mm and the height is 1.4 mm.Conductor is placed on a 10 mm thickness dielectric layer.

AIM: To design a Two conductor transmission line with single ground plane and investigate the impact of the conductor material on Rdc parameters. Width of the conductor is 18 mm and the height is 1.4 mm. Conductor is placed on a 10 mm thickness dielectric layer.

TOOL REQUIRED:

TNT 1.2.2

PROCEDURE:

- Open TNT 1.2.2 Tool
- Open file-new
- Create a two conductor transmission line
- Select the dielectric layer with specified material and dimensions
- Select the ground plane with specified dimensions
- Place the dielectric layer on top of the ground plane
- Select two rectangular conductors with specified material and dimensions and place on the top of dielectric layer.

CALCULATION

$$Z_0 = \frac{276}{\sqrt{k}} \log \frac{d}{r}$$

Z_0 = Characteristic impedance of line
d = Distance between conductor centers
r = Conductor radius
k = Relative permittivity of insulation between conductors

$$\text{Velocity factor} = \frac{v}{c} = \frac{1}{\sqrt{k}}$$

v = Velocity of wave propagation
c = Velocity of light in a vacuum
k = Relative permittivity of insulation between conductors

OUTPUT:

Condutor material	**Conductivity S/m**	**Rdc R1 R1**	**Rdc R1 R0**	**Rdc R0 R1**	**Rdc R0 R0**
Tungston	**$1x10^7$**				
Aluminium	**$3x10^7$**				
Copper	**$5x10^7$**				
Silver	**$6x10^7$**				

RESULT:

A Two conductor transmission line with single ground plane is designed and the impact of the conductor material on Rdc parameters is evaluated.