# Scilab Textbook Companion for Microwave Engineering by G. S. Raghuvanshi[1]

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June 6, 2016

[1]Funded by a grant from the National Mission on Education through ICT, http://spoken-tutorial.org/NMEICT-Intro. This Textbook Companion and Scilab codes written in it can be downloaded from the "Textbook Companion Project" section at the website http://scilab.in

# Book Description

**Title:** Microwave Engineering

**Author:** G. S. Raghuvanshi

**Publisher:** Cengage Learning, New Delhi

**Edition:** 1

**Year:** 2012

**ISBN:** 978-81-315-1721-5

Scilab numbering policy used in this document and the relation to the above book.

**Exa** Example (Solved example)

**Eqn** Equation (Particular equation of the above book)

**AP** Appendix to Example(Scilab Code that is an Appednix to a particular Example of the above book)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means a scilab code whose theory is explained in Section 2.3 of the book.

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# Chapter 1

# Microwaves

**Scilab code Exa 1.2** Lossless line

```
//Page Number: 12
//Example 1.2
clc;
//Given
z0=50;//ohm
zg=50;//ohm
l=0.25;//m
f=4D+9;//hz
zl=100;//ohm
vg=10;//V
w=2*%pi*f;//rad/sec
c=3D+8; //m/s

//(i) Voltage and current at any point
tg=(zg-z0)/(zg+z0);
tl=(zl-z0)/(zl+z0);
vi=z0*vg/(z0+zg);//V
disp('V',vi,'Voltage at any point:');
ii=vg/(2*z0);//A
```

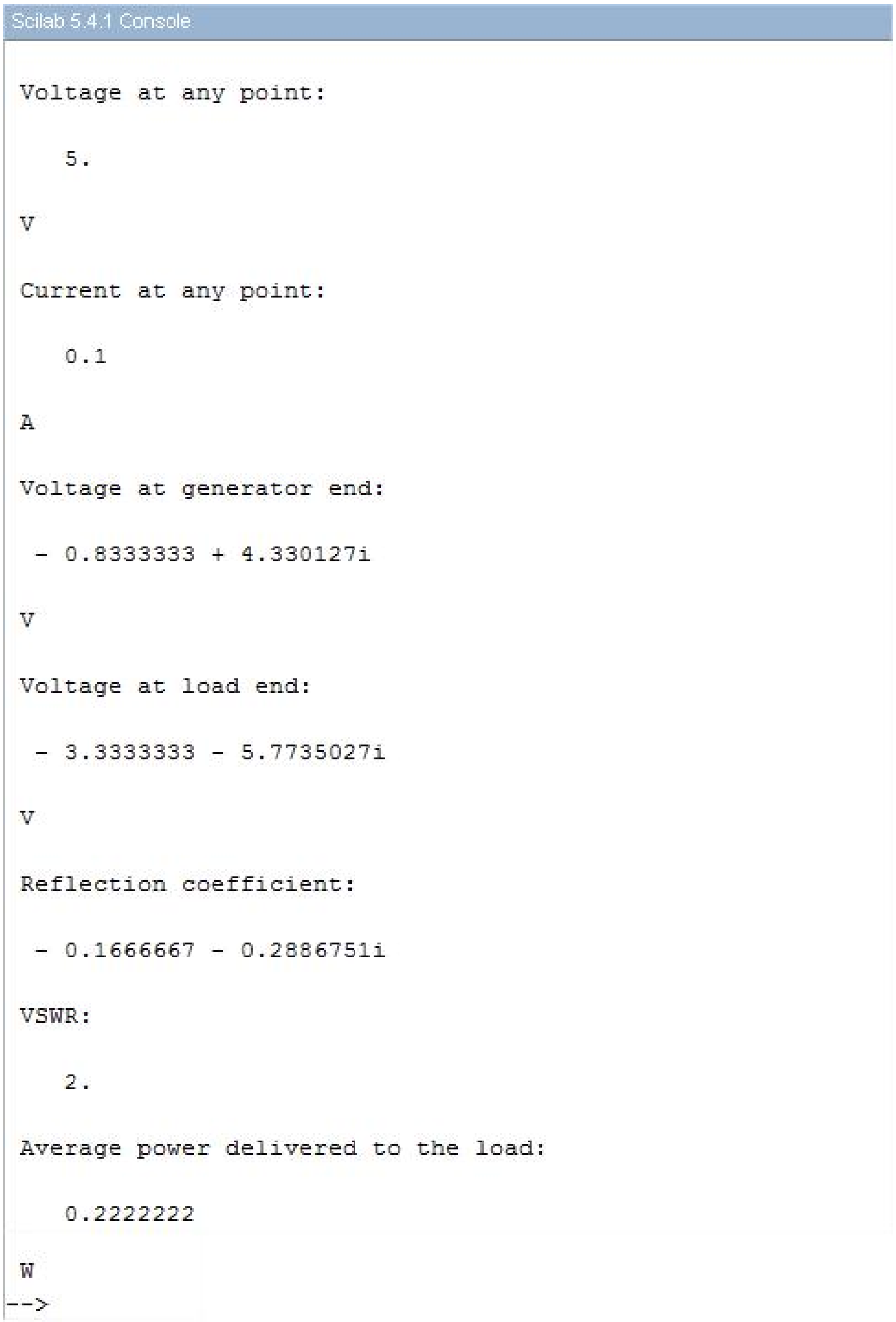





Figure 1.1: Lossless line

```
disp('A',ii,'Current at any point:');

//(ii) Voltage at generator end
//Taking z=1
z=1;
bet=w/c;
vz=(vg/2)*exp(-%i*bet*(z+l))*(1+(tl*exp(2*%i*bet*z)));//V
disp('V',vz,'Voltage at generator end:');
iz=ii*exp(-%i*bet*(z+l))*(1-(tl*exp(2*%i*bet*z)));//A
vz1=(vg/2)*exp(-%i*bet*(z+l))*(1+(tl*exp(2*%i*bet*z)));//V

//Voltage at load end, z=0
z11=0;
vl=(vg/2)*exp(-%i*bet*l)*(1+(tl*exp(2*%i*bet*z11)));//V
disp('V',vl,'Voltage at load end:');

//(iii) Reflection coefficient
zx=0.25;
tz=tl*exp(%i*2*bet*zx);
disp(tz,'Reflection coefficient:');

//(iv) VSWR
p=(1+tl)/(1-tl);
disp(p,'VSWR:');

//(v) Average power delivered to the load
vl=20/3;
pl0=vl^2/(2*zl);//W
disp('W',pl0,'Average power delivered to the load:');
```

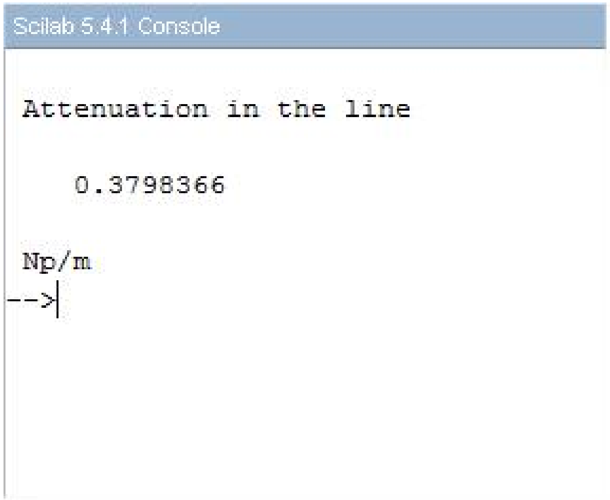



Figure 1.2: Microwave line

**Scilab code Exa 1.3** Microwave line

```
//Page Number: 14
//Example 1.3
clc;
//Given
pm=3;
pl=4;
l=24;//cm
l1=l/100;//m

//Attenuation
tin=(pm-1)/(pm+1);
tl=(pl-1)/(pl+1);
alp=(1/(2*l1))*log(tl/tin);//Np/m
```

```
disp('Np/m',alp,'Attenuation in the line');
```

**Scilab code Exa 1.4** Quater wave transformer

```
//Page Number: 14
//Example 1.4
clc;
//Given
c=3D+8; //m/s
z0=200;//ohm
zl=800;//ohm
f=30D+6;//hz

//Characterstic impedance
z00=sqrt(z0*zl);//ohm
disp('ohm',z00,'Characterstic impedance:');

//Length of line
lam=c/f;//m
l=lam/4;//m
disp('m',l,'Length of line:');
```

**Scilab code Exa 1.5** Parallel resonant circuit

```
//Page Number: 15
//Example 1.5
clc;
//Given
l=1.2;//mH
```

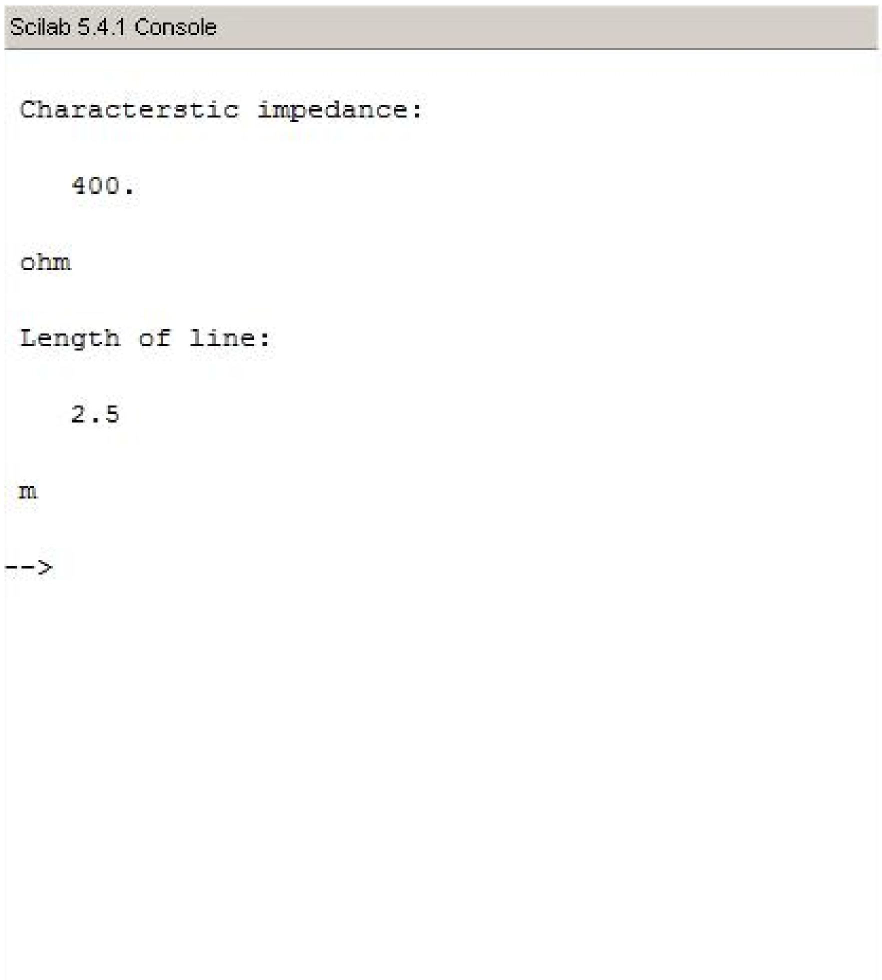



Figure 1.3: Quater wave transformer

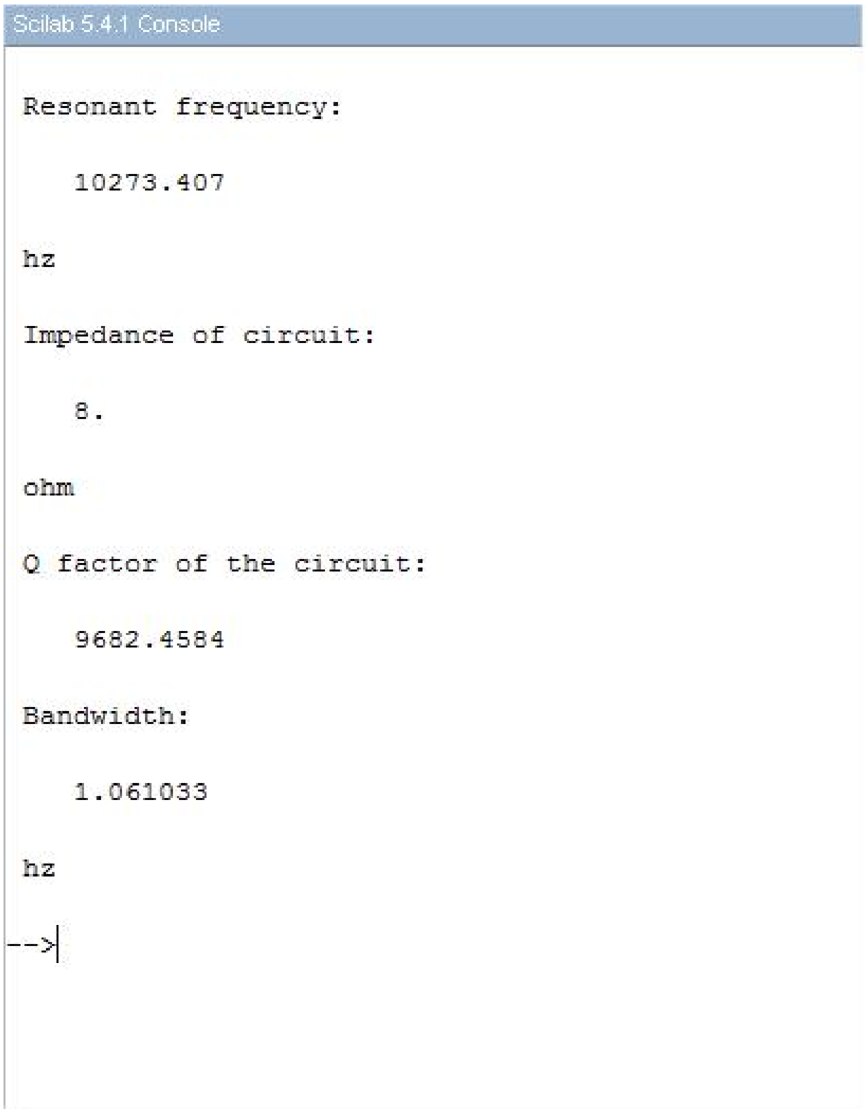



Figure 1.4: Parallel resonant circuit

```
r=8;//ohm
c=200D-12;//F

//(i) Resonant frequency
f0=(1/(2*%pi))*sqrt(1/(l*c));//hz
disp('hz',f0,'Resonant frequency:');

//(ii) Impedance of circuit
disp('ohm',r,'Impedance of circuit:');

//(iii)Q factor of the circuit
q=1/(2*%pi*f0*c*r);
disp(q,'Q factor of the circuit:');

//(iv) Bandwidth
df=f0/q;//hz
disp('hz',df,'Bandwidth:');

//The value of resonant frequency is calculated
    wrong in book
//Hence Q factor and bandwidth, all these answers
    dont match
```

**Scilab code Exa 1.6** Lossless line

```
//Page Number:
//Example 1.6
clc;
//Given
c=3D+8; //m/s
le=25;//m
zl=40+(%i*30);//ohm
f=10D+6;//hz
```

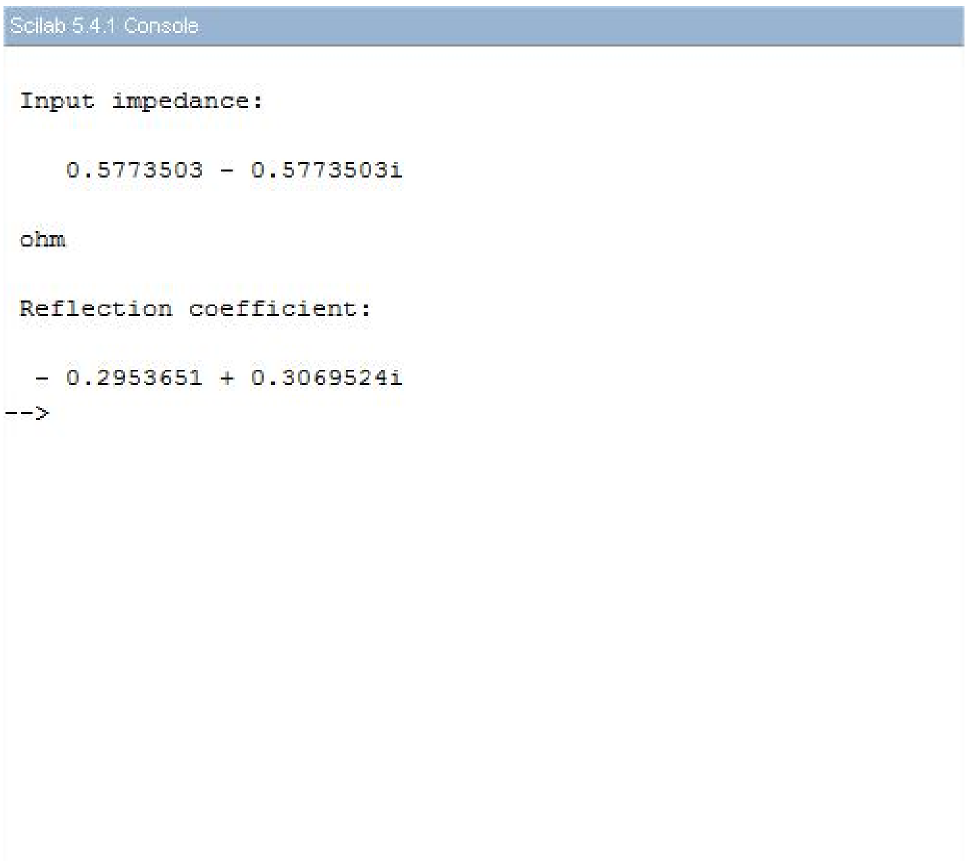



Figure 1.5: Lossless line

```
cap=40D-12;//F
l=300D-9;//H/m

//Input impedance
z0=sqrt(l/cap);//ohm
zl1=zl/z0;
lam=c/f;//m
bet=(2*%pi*le)/lam;//rad
zin=((zl1*cos(bet))+(%i*sin(bet)))/(cos(bet)+(%i*zl1
    *sin(bet)));//ohm
disp('ohm',zin,'Input impedance:');

//Reflection coefficient
t=(zl1-1)/(zl1+1);
disp(t,'Reflection coefficient:');
```

**Scilab code Exa 1.7** Lossy cable

```
//Page Number: 16
//Example 1.7
clc;
//Given
c=3D+8; //m/s
R=2.25;//ohm
L=1D-9;//H/m
C=1D-12;//F/m
f=0.5D+9;//hz
G=0;
w=2*%pi*f;//rad/sec

//Characterstic impedance
z0=sqrt((R+(%i*w*L))/(G+(%i*w*C))); //ohm
disp('ohm',z0,'Characterstic impedance:');
```

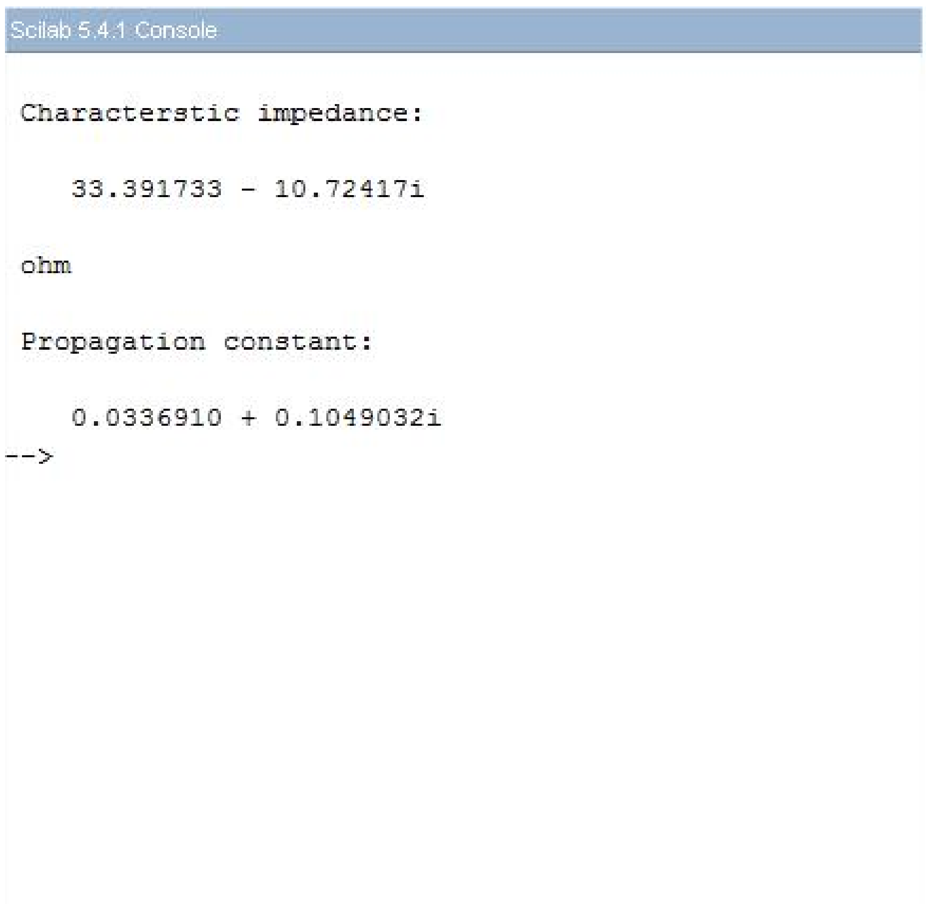



Figure 1.6: Lossy cable

```

//Propagation constant
gam=sqrt((R+(%i*w*L))*(G+(%i*w*C)));
disp(gam,'Propagation constant:');
```

**Scilab code Exa 1.8** Transmission Line

```
//Page Number: 20
//Example 1.8
clc;
//Given
c=3D+8; //m/s
f=3D+9; //Hz
ZL=50-(%i*100); //ohms
Z0=50; //ohm
//Wavelength
lam=c/f;
disp('cm',lam*100,'Wavelength:');

//Normalized load impedance
z=ZL/Z0;
disp(z,'Normalized load impedance:');

//From chart
zin=0.45+(%i*1.2);
yin=0.27-(%i*0.73);
ZINN=Z0*zin;
disp('ohm',ZINN,'Line impedance:');
YINN=yin/Z0;
disp('mho',YINN,'Line admittance:');
```

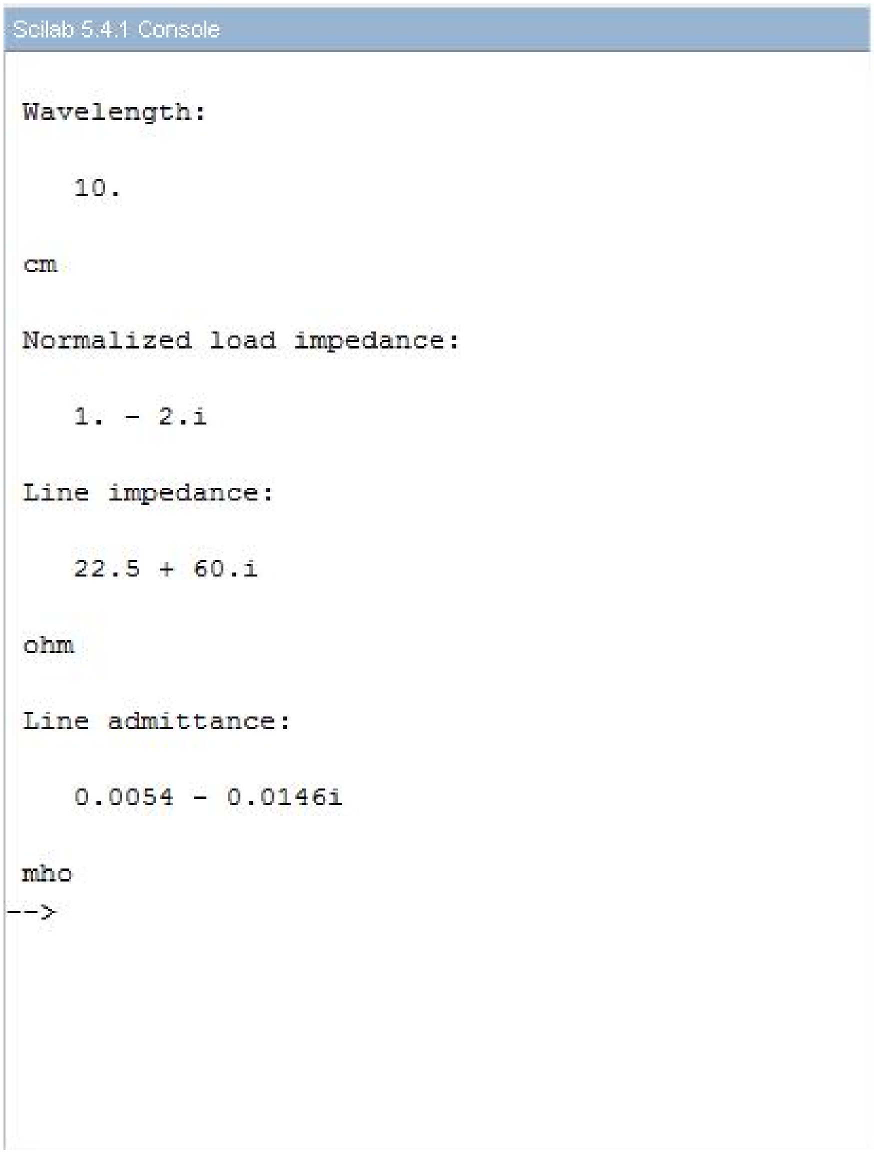



Figure 1.7: Transmission Line

```
Scilab 5.4.1 Console

 Normalized load impedance:

    1.5 + 2.i

 Input impedance at 0.051 lam:

    230.

 ohm

 Input impedance at 0.102 lam:

    75. - 100.i

 ohm

 Input impedance at 0.301 lam:

    11.

 ohm
-->
```

Figure 1.8: Transmission Line

**Scilab code Exa 1.9** Transmission Line

```
//Page Number: 22
//Example 1.9
clc;
//Given
ZL=75+(%i*100); //ohms
Z0=50; //ohm

//Normalized load impedance
z=ZL/Z0;
disp(z,'Normalized load impedance:');

//(i) 0.051*lam
//From chart
r=4.6;
Zi1=r*Z0;
disp('ohm',Zi1,'Input impedance at 0.051 lam:');

//(ii) 0.102*lam
r1=1.5-(%i*2);
Zi2=r1*Z0;
disp('ohm',Zi2,'Input impedance at 0.102 lam:');

//(iii) 0.301*lam
r2=0.22;
Zi3=r2*Z0;
disp('ohm',Zi3,'Input impedance at 0.301 lam:');
```

**Scilab code Exa 1.10** Transmission Line

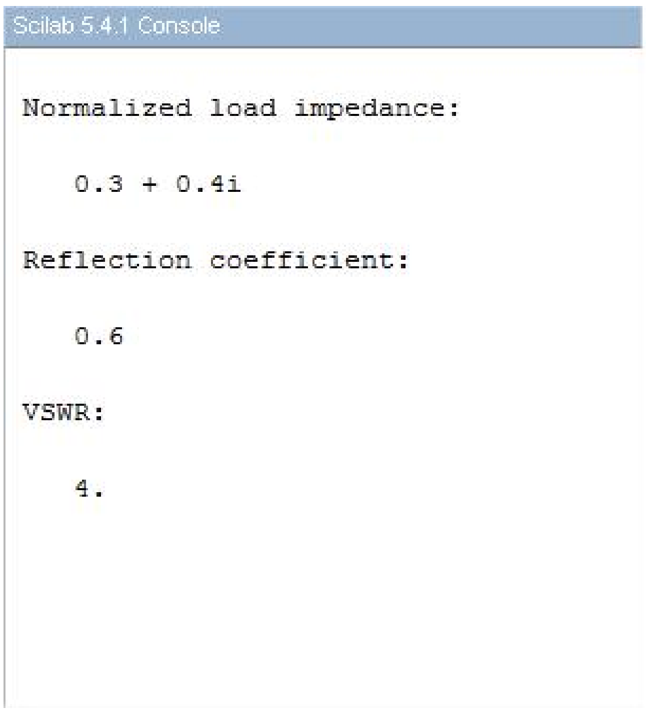



Figure 1.9: Transmission Line

```
//Page Number: 23
//Example 1.10
clc;
//Given
ZL=15+(%i*20); //ohms
Z0=50; //ohm

//Normalized load impedance
z=ZL/Z0;
disp(z,'Normalized load impedance:');

//From chart
T=0.6;
disp(T,'Reflection coefficient:');

//VSWR
p=4;
disp(p,'VSWR:');
```

**Scilab code Exa 1.11** Microwave line

```
//Page Number: 25
//Example 1.11
clc;
//Given
Z0=50; //ohm
p=2.4;

//From chart
zl=1.4+%i;
L=Z0*zl;
disp('ohm',L,'Load:');
```

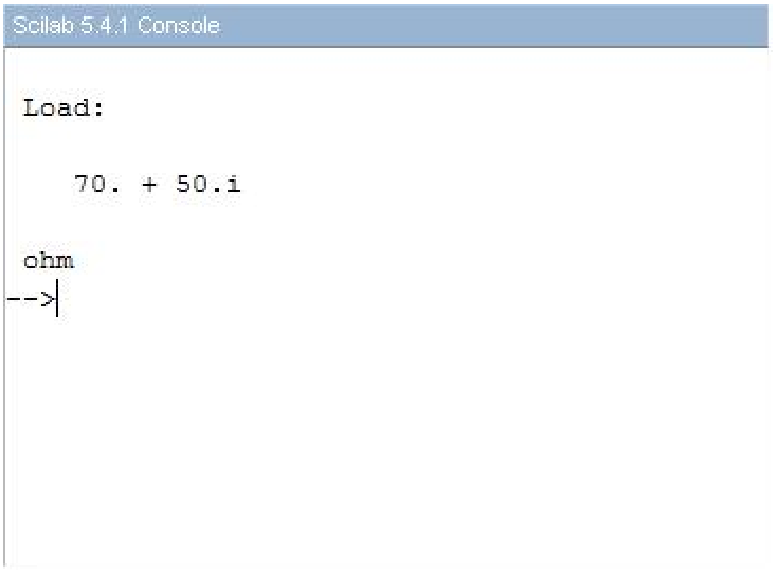



Figure 1.10: Microwave line

**Scilab code Exa 1.12** Active Device

```
//Page Number: 26
//Example 1.12
clc;
//Given
Z0=50; //ohm
T=2.23;

//From chart
zl=2+%i;
ZLd=Z0*zl;
disp('ohm',ZLd,'Normalized impedance:');
```

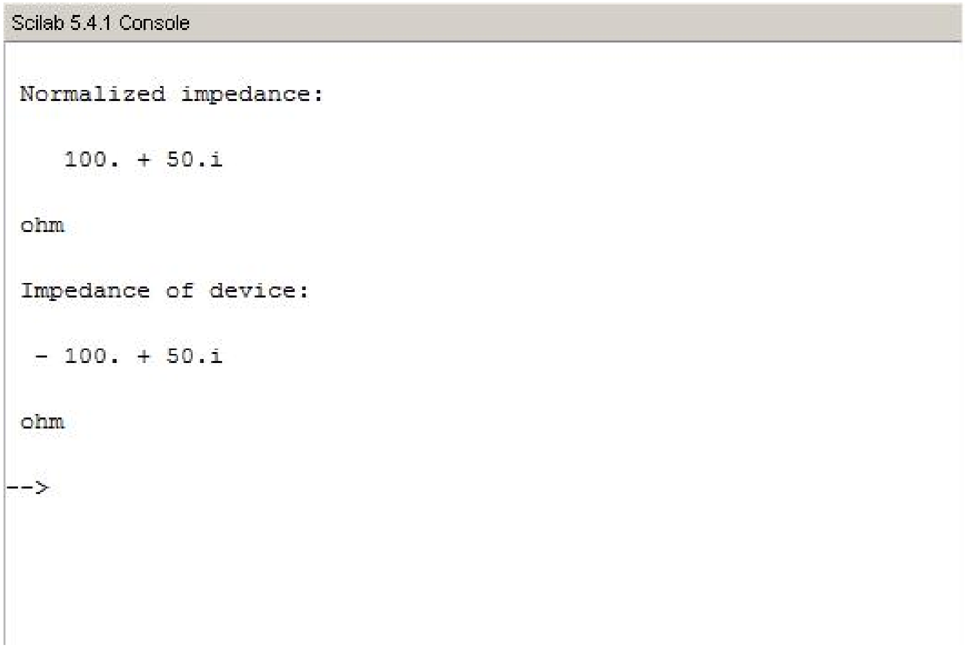



Figure 1.11: Active Device

```

//Impedance of device is by negating the real part
imp=-real(ZLd)+(imag(ZLd)*%i);
disp('ohm',imp,'Impedance of device:');
```

**Scilab code Exa 1.13** Transmission line

```
//Page Number: 27
//Example 1.13
clc;
//Given
p=3;
m1=54; //cm
```

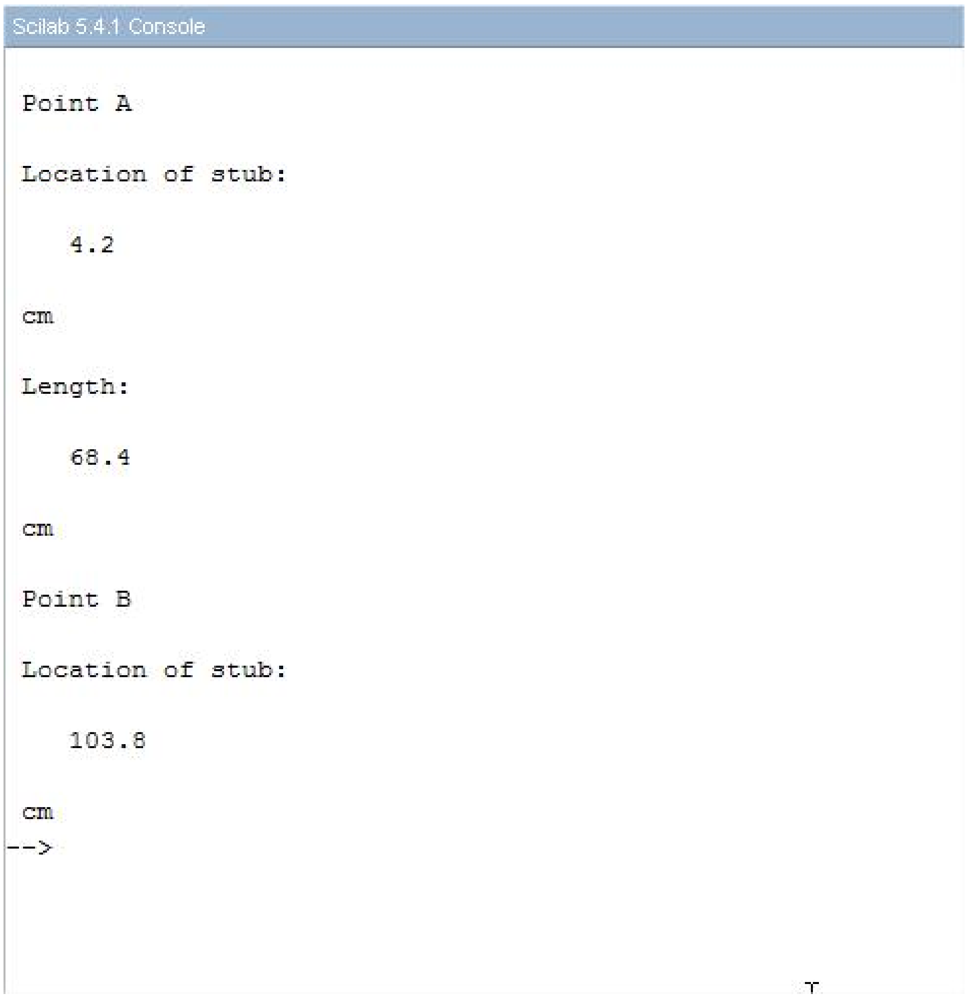



Figure 1.12: Transmission line

```
m2=204; //cm

//Point A
disp('Point A');
lam=4*(m2-m1);
dA=0.083*lam;
L=m1-dA;
disp('cm',L,'Location of stub:');
IA=0.114*lam;
disp('cm',IA,'Length:');

//Point B
disp('Point B');
dB=0.083*lam;
IB=0.386*lam;
Lb=dB+m1;
disp('cm',Lb,'Location of stub:');
```

---

**Scilab code Exa 1.15** Microwave line

```
//Page Number: 30
//Example 1.15
clc;
//Given
Z0=50; //ohm
ZL=100; //ohms
f=10D+9; //Hz
c=0.159D-12; //F

//Normalized load impedance
z=ZL/Z0;
disp(z,'Normalized load impedance:');

```

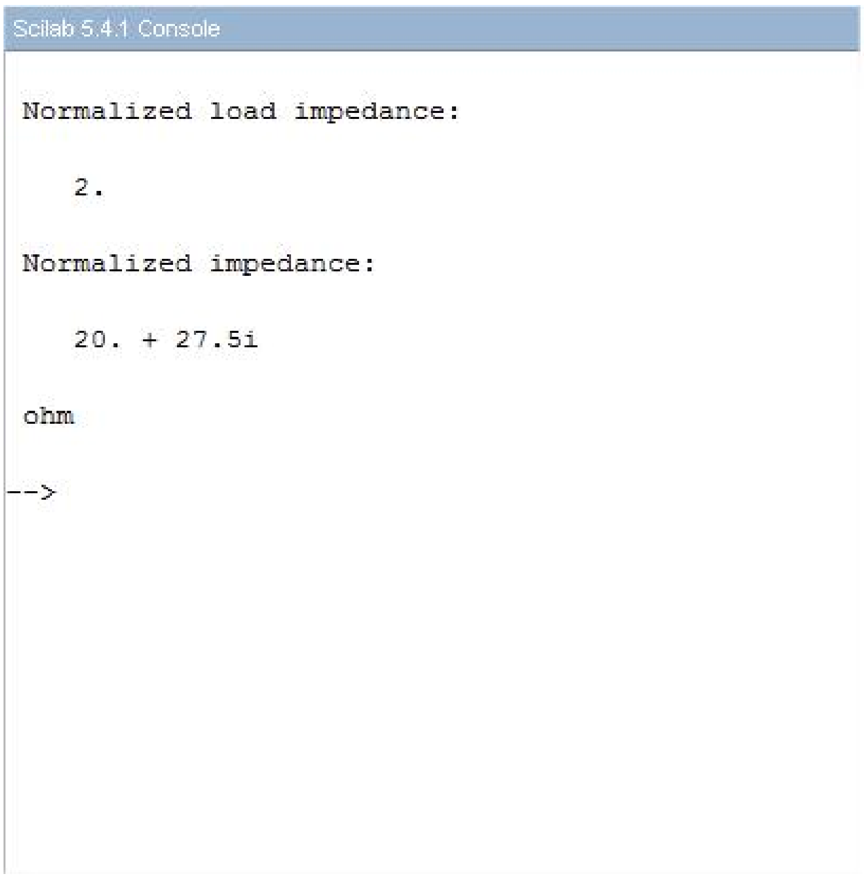



Figure 1.13: Microwave line

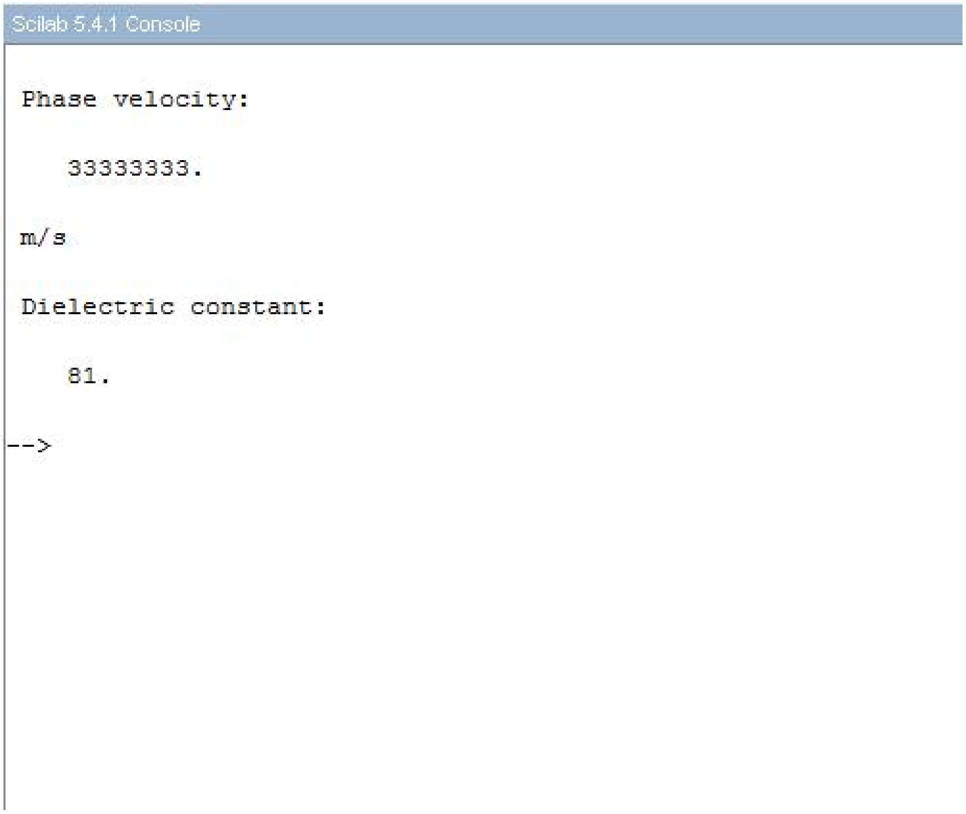



Figure 1.14: EM Plane

```
//From chart
zin=0.4+(%i*0.55);
ZINN=Z0*zin;
disp('ohm',ZINN,'Normalized impedance:');
```

**Scilab code Exa 1.16** EM Plane

```
//Page Number: 42
//Example 1.16
```

```
clc;
//From given wave equation we can see
w=1D+9;//rad/sec
bet=30;//rad/m
c=3D+8; //m/s
u0=1; //let
e0=1/(9D+16);

vp=w/bet;//m/sec
disp('m/s',vp,'Phase velocity:');

e=1/(vp^2*u0);
er=e/(e0*u0);
disp(er,'Dielectric constant:');
```

---

**Scilab code Exa 1.17** Polyethylene

```
//Page Number: 42
//Example 1.17
clc;
//Given
c=3D+8; //m/s
f=10D+9;//hz
er=6;
tandel=2D-4;

vp=c/er;//m/sec
disp('m/sec',vp,'Phase velocity:');
al=(%pi*f*tandel)/vp;//Np/m
disp('Np/m',al,'Attenuation constant:');

//Answer for velocity is calculated wrong in book,
    hence answers dont match for both
```

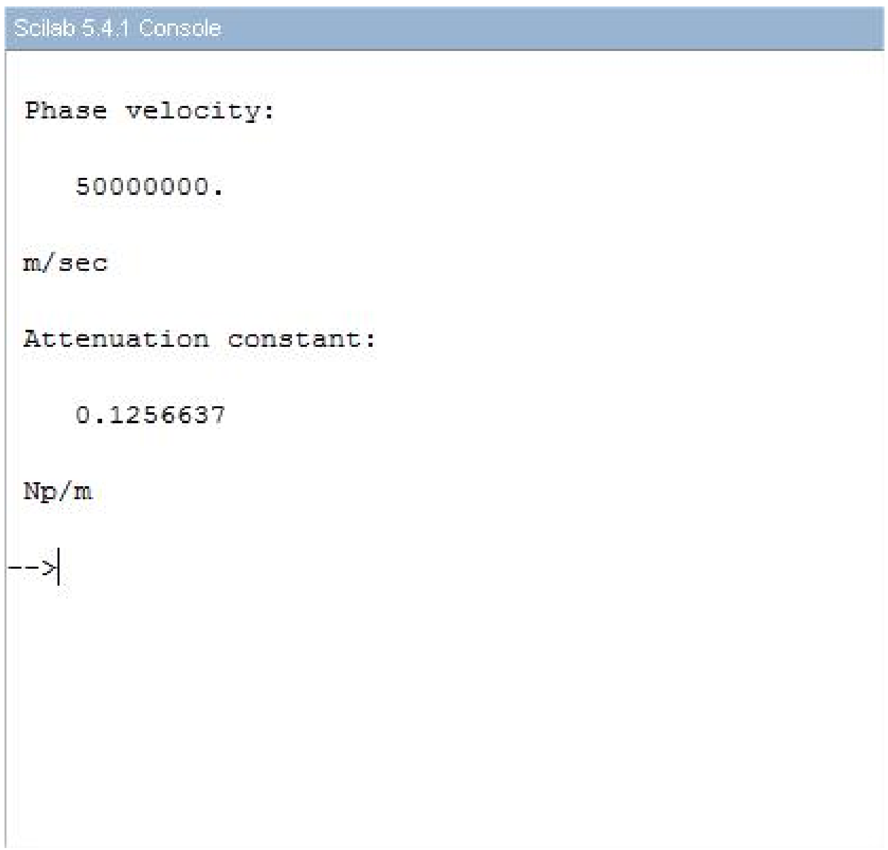



Figure 1.15: Polyethylene

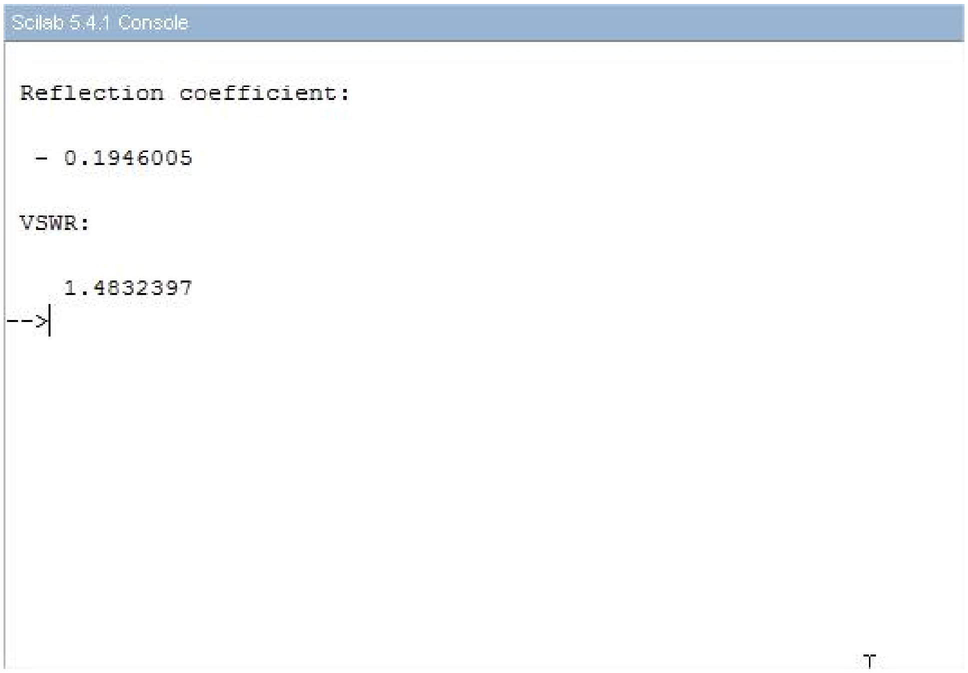



Figure 1.16: Electromagnetic wave

**Scilab code Exa 1.18** Electromagnetic wave

```
//Page Number: 43
//Example 1.18
clc;
//Given
er=2.2;
n0=377;//ohm
n2=n0/sqrt(er);//ohm
n1=377;//ohm

```

```
//Reflection coefficient
t=(n2-n1)/(n2+n1);
disp(t,'Reflection coefficient:');

//Vswr
//Taking mod of reflection coefficient
t1=-t;
p=(1+t1)/(1-t1);
disp(p,'VSWR:');
```

**Scilab code Exa 1.19** Range in sea water

```
//Page Number: 43
//Example 1.19
clc;
//Given
sig=5;//mohm/m
er=80*8.85D-12;
eaz=0.1;
u=1.26D-6;

az=-log(0.1);
//(i) Range at 25Khz
f=25D+3;//Khz
w=2*%pi*f;//rad/sec
a=w*(sqrt((u*er/2)*(sqrt(sig^2/(w^2*er^2)+1)-1)));
z=az/a;//m
disp('m',z,'Range at 25khz:');

//(ii) Range at 25Mhz
f1=25D+6;//Mhz
w1=2*%pi*f1;//rad/sec
a1=w1*(sqrt((u*er/2)*(sqrt(sig^2/(w1^2*er^2)+1)-1)))
```

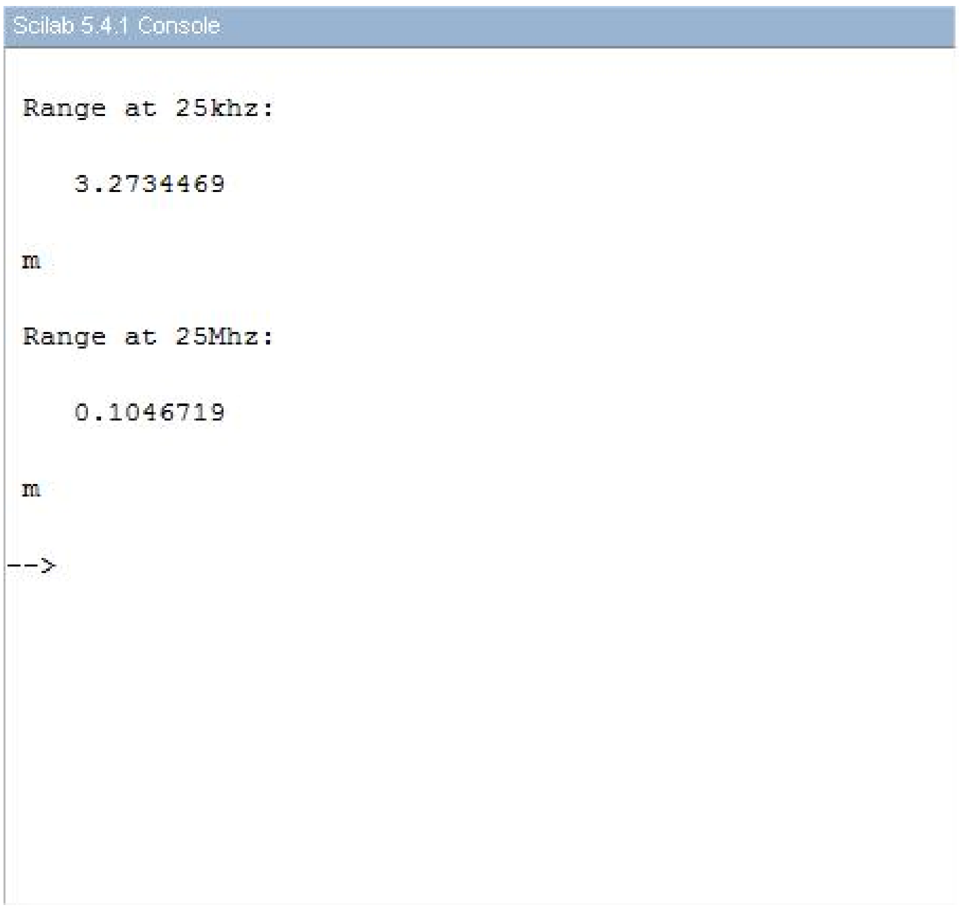



Figure 1.17: Range in sea water

```
    ;
z1=az/a1;//m
disp('m',z1,'Range at 25Mhz:');
```

# Chapter 2

# Waveguides

**Scilab code Exa 2.1** Dominant mode

```
//Page Number:91
//Example 2.1
clc;
//Given,

a=6;//cm
b=4;//cm
d=4.47;//cm
c=3D+8; //m/s
lamc=2*a;
lamg=2*d;

//Signal wavelength
lam=lamg*lamc/(sqrt(lamg^2+lamc^2));
lam=lam/100; //m
f=c/lam;
disp('Ghz',f/1D+9,'Signal frequency of dominant mode
    :');
```

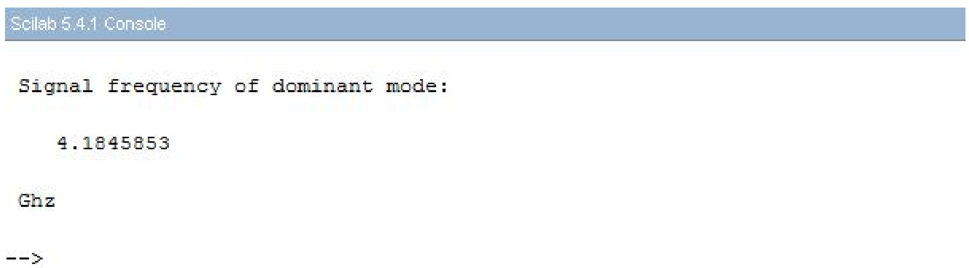



Figure 2.1: Dominant mode


Figure 2.2: Rectangular Waveguide

**Scilab code Exa 2.2** Rectangular Waveguide

```
//Page Number: 92
//Example 2.2
clc;
//Given,
```

```
c=3D+8; //m/s
a=2.5; //cm
b=5; //cm
lam=4.5; //cm

lamc=2*b;

//Guide wavelength
lamg=lam/(sqrt(1-((lam/lamc)^2)));
disp('cm',lamg,'Guide wavelength:');

//Phase constant
bet=(2*%pi)/lamg;
bet=bet*100; //rad/m
disp('rad/m',bet,'Phase constant:');

//Phase velocity
w=(2*%pi*c)/lam;
vp=w/bet;
disp('m/s',vp,'Phase velocity:');
```

**Scilab code Exa 2.3** Rectangular Waveguide

```
//Page Number: 92
//Example 2.3
clc;
//Given,

c=3D+8; //m/s
a=4; //cm
b=2; //cm
f=10D+9; //Hz
m=1;
```


Figure 2.3: Rectangular Waveguide

```
n=1;


//Cutoff wavelength
lamc=2/sqrt((m/a)^2+(n/b)^2);
disp('cm',lamc,'Cut-off wavelength:');

//Wave impedance
lam=c/f;//m
lam=lam*100;//cm
eeta=120*%pi;
z0=eeta*sqrt(1-(lam/lamc)^2);
disp('ohm',z0,'Wave impedance:');
```

**Scilab code Exa 2.4** Wider dimension

```
//Page Number: 93
//Example 2.4
clc;
//Given,
c=3D+8; //m/s
f=10D+9; //Hz
zte=410; //ohm

//Wider dimension
lam=c/f;//m
lam=lam*100;//cm
a=3/(2*(sqrt(1-(120*%pi/zte)^2)));
disp('cm',a,'Wider dimension:');
```

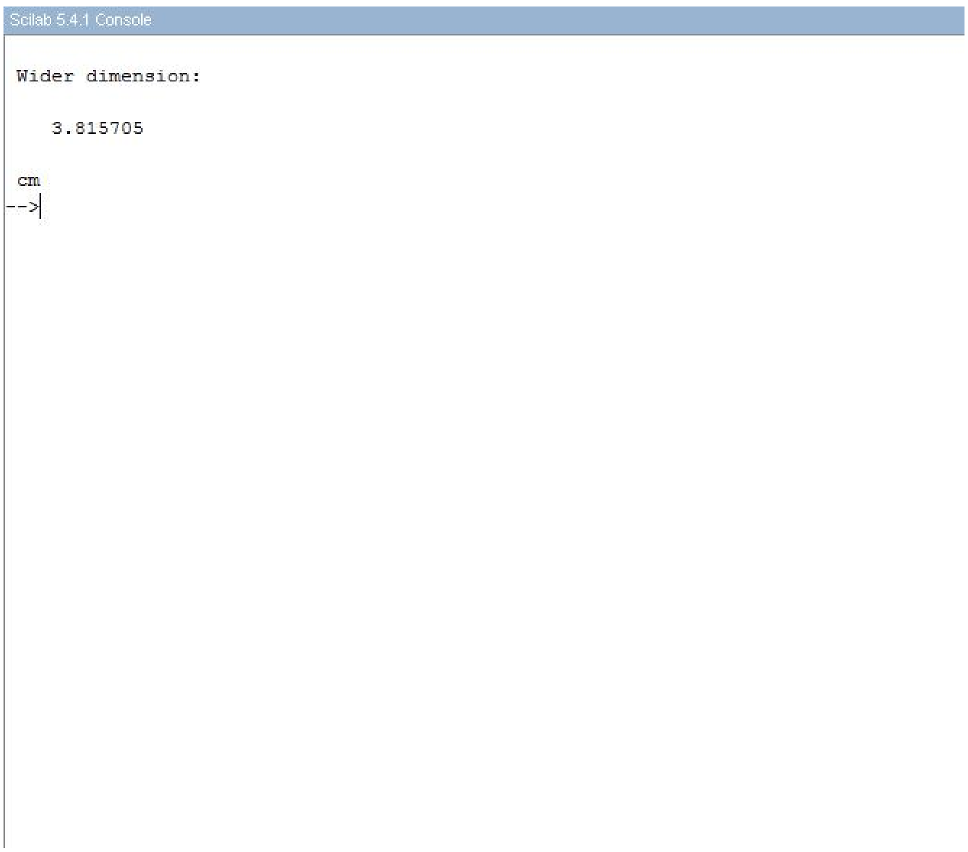



Figure 2.4: Wider dimension

Scilab 5.4.1 Console

```
TE10 mode

Cut-off wavelength:

   6.

cm

Cutoff frequency:

   3.3333333

Ghz

TE20 mode

Cut-off wavelength:

   3.

cm

Cutoff frequency:

   6.6666667

Ghz

TE11 mode

Cut-off wavelength:

   2.6832816

cm
```

**Scilab code Exa 2.5** Rectangular waveguide

```
//Page Number: 93
//Example 2.5
clc;
//Given,
c=3D+8; //m/s
a=3.0; //cm
b=1.5; //cm
mur=1;
er=2.25;
x=mur*er;

//(i) Cutoff wavelength and frequencuy
disp('TE10 mode');
m1=1;
n1=0;
lamc10=2/sqrt((m1/a)^2+(n1/b)^2);
disp('cm',lamc10,'Cut-off wavelength:');
lamc10=lamc10/100;
f10=c/(lamc10*sqrt(x));
disp('Ghz',f10/1D+9,'Cutoff frequency:');

disp('TE20 mode');
m2=2;
n2=0;
lamc20=2/sqrt((m2/a)^2+(n2/b)^2);
disp('cm',lamc20,'Cut-off wavelength:');
lamc20=lamc20/100;
f20=c/(lamc20*sqrt(x));
disp('Ghz',f20/1D+9,'Cutoff frequency:');

disp('TE11 mode');
m3=1;
```

```
n3=1;
lamc11=2/sqrt((m3/a)^2+(n3/b)^2);
disp('cm',lamc11,'Cut-off wavelength:');
lamc11=lamc11/100;
f11=c/(lamc11*sqrt(x));
disp('Ghz',f11/1D+9,'Cutoff frequency:');

//(ii) lambg and Z0
f=4D+9; //Hz
lam=c/f;
lamg=lam/(sqrt(x-((lam/lamc10)^2)));
disp('cm',lamg*100,'Guide wavelength:');

fc=3.33D+9; //Hz
Z0=(120*%pi*(1/sqrt(x))*(b/a))/sqrt(1-((fc/f)^2));
disp('ohm',round(Z0),'Impedance:');
```

**Scilab code Exa 2.7** Rectangular waveguide

```
//Page Number: 95
//Example 2.5
clc;
//Given,
c=3D+8; //m/s
a=4; //cm
b=2; //cm

//(i) Mode
lamc=2*a; //cm
lamcm=lamc/100; //m
fc=c/lamcm;
//20% above fc
f=1.2*fc; //Hz
```

```
Scilab 5.4.1 Console

 Since guide is operating at

    3.750D+09

 Hz

 Hence mode of operation is TE10

 Guide wavelength:

    12.060454

 cm

 Phase velocity:

    5.427D+08

 m/s

 Group velocity:

    1658312.4

 m/s

-->
```

Figure 2.6: Rectangular waveguide

```
//Operating wavelength
lam1=c/f; //cm

//For TE10 mode
lamc10=2*b;//cm
lamcm10=lamc10/100;//m
fc10=c/lamcm10;
disp('Hence mode of operation is TE10','Hz',fc,'
   Since guide is operating at');

//(ii)Guide wavelength
lamm1=lam1*100;//cm
lamg=lamm1/(sqrt(1-(lamm1/lamc)^2));
disp('cm',lamg,'Guide wavelength:');

//(iii) Phase velocity
vp=f*lamg;
disp('m/s',vp/100,'Phase velocity:');

//(iii) Group velocity
vg=c^2/vp;
disp('m/s',vg,'Group velocity:');
```

**Scilab code Exa 2.8** Lossless Rectangular Waveguide

```
//Page Number: 96
//Example 2.8
clc;
//Given,
c=3D+8; //m/s
a=7; //cm
b=3.5; //cm
```


Figure 2.7: Lossless Rectangular Waveguide

```
f=3D+9; //Hz
h0=10; //amp/m

//Wave impedance
lamc=2*a;
lam=c/f;//m
lam=lam*100;//cm
lamg=lam/sqrt(1-(lam/lamc)^2); //cm
z0=377*lamg/h0; //ohm

a1=a/100;//m
b1=b/100;//m
//Average power transmitted
p=(z0*h0*h0*a1*b1)/4;
disp('W',p,'Average power transmitted:');

//Peak electric field
e0=z0*h0;
disp('kV/m',e0/1000,'Peak electric field:');

//Answer for p is given as 28.3 W but it should be
    32.99W
```

**Scilab code Exa 2.9** Dimensions

```
//Page Number: 96
//Example 2.9
clc;
//Given,
c=3D+8; //m/s
fc=3D+9; //Hz

//Cutoff wavelength
```

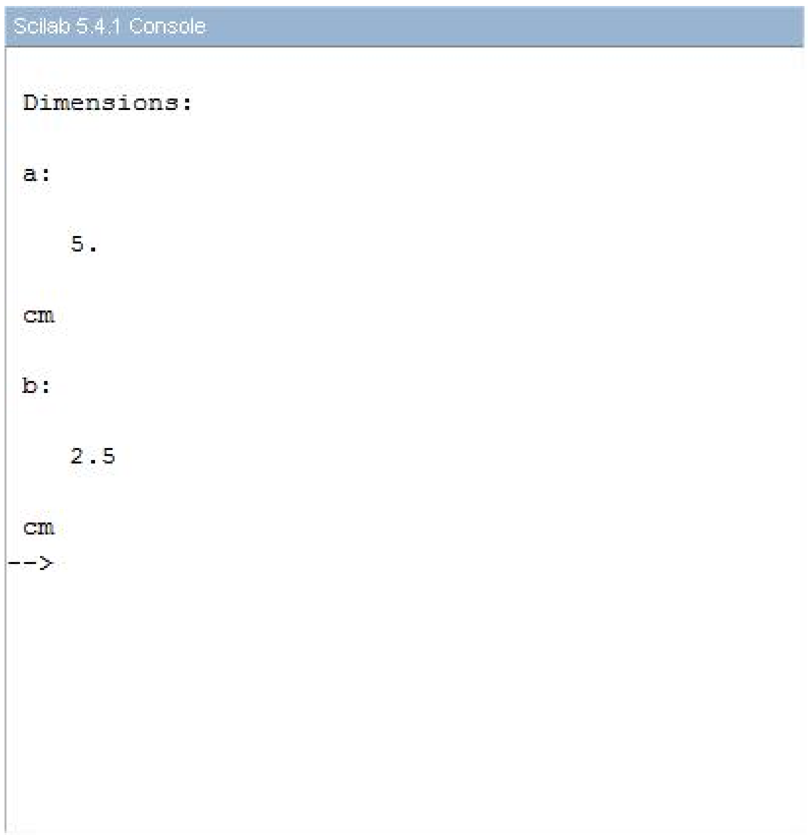



Figure 2.8: Dimensions

```
lamc=c/fc;
a=lamc/2;//m
a=a*100;//cm
disp('Dimensions:');
disp('cm',a,'a:');
b=a/2; //cm
disp('cm',b,'b:');
```

**Scilab code Exa 2.10** Rectangular Waveguide

```
//Page Number:
//Example 2.10
clc;
//Given,

c=3D+8; //m/s
a=3; //cm
a1=a/100; //m
b=2; //cm
b1=b/100; //m
f=7.5D+9; //HZ
p=5D+3; //W

mu=%pi*4D-7;
w=2*%pi*f;
bet=sqrt(((w/c)^2)-((%pi/a1)^2));
//Charecteristic impedance
z0=w*mu*2*b/(bet*a);
disp('ohm',z0,'Charecteristic impedance:');

//Peak electric field
e0=4*w*mu*p/(bet*a*b);
disp('V/m',e0,'Peak electric field:');
```

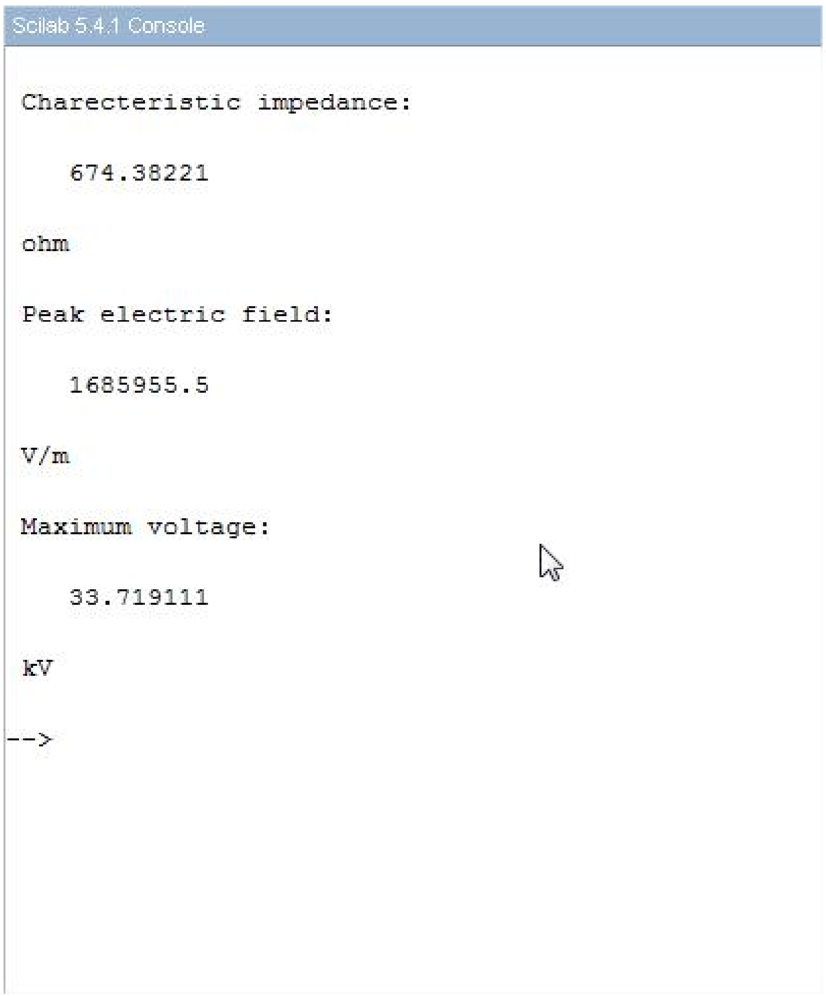



Figure 2.9: Rectangular Waveguide

```
//Maximum voltage
v0=e0*b1;
disp('kV',v0/1000,'Maximum voltage:');

//Answer for v0 is given as 3.172 kV it should be
   33.71 kV
```

---

**Scilab code Exa 2.14** Waveguide

```
//Page Number: 99
//Example 2.14
clc;
//Given,
c=3D+8; //m/s
a=1.5;//cm
a1=a/100;//m
b=0.8;//cm
b1=b/100;//m
mu=1/c*c;
e=4;
w=%pi*1D+11;
n=377;

//(i) Frequency of operation
f=w/(2*%pi);
f1=f/1D+9;//ghz
disp('Ghz',f1,'Frequency of operation:');

//(ii) Cutt off frequency
fc=(c*sqrt((1/a1)^2+(3/b1)^2))/(2*sqrt(e));
fc1=fc/1D+9;//ghz
disp('Ghz',fc1,'Cut off frequency:');
```

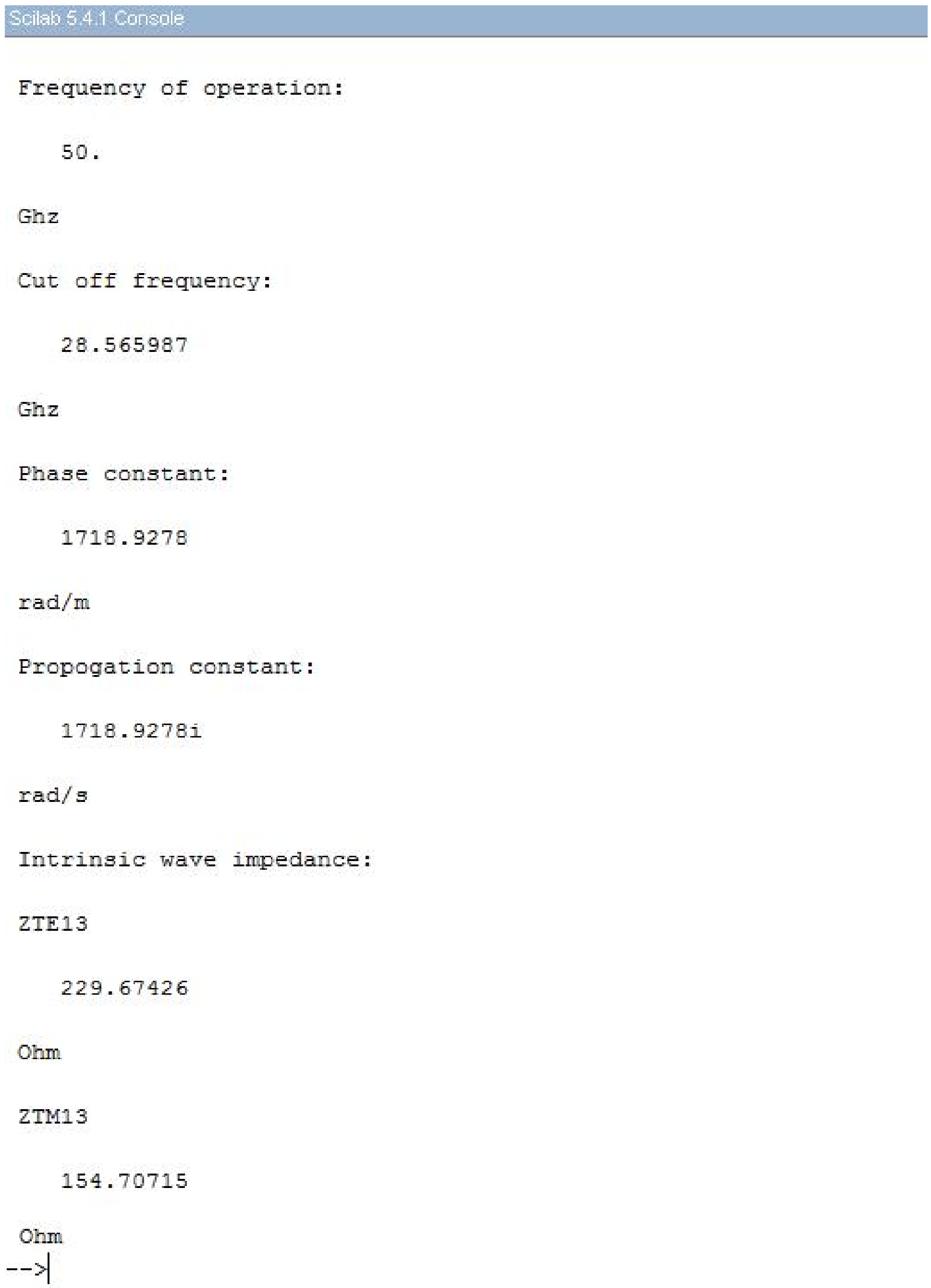



Figure 2.10: Waveguide

```
//(iii) Phase constant
bet=(w*sqrt(e)*sqrt(1-(fc/f)^2))/(c);
disp('rad/m',bet,'Phase constant:');

//(iv) Propogation constant
gam=%i*bet;
disp('rad/s',gam,'Propogation constant:');

//(v) Intrensic wave impedance
zte=(n/sqrt(e))/sqrt(1-(fc/f)^2);
ztm=(n/sqrt(e))*sqrt(1-(fc/f)^2);
disp('Ohm',ztm,'ZTM13','Ohm',zte,'ZTE13','Intrinsic
    wave impedance:');
```

**Scilab code Exa 2.17** Air filled Rectangular Waveguide

```
//Page Number: 103
//Example 2.17
clc;
//Given
a=2; //cm
a1=1/100; //m
b=1; //cm
b1=b/100; //m
p=10D-3; //W
c=3D+8; //m/s
f0=10D+9; //Hz

//Peak value of electric field
fc=c/(2*a);
E02=(4*p*377)/(a1*b1*sqrt(1-(fc/f0)^2));
E0=sqrt(E02);
```

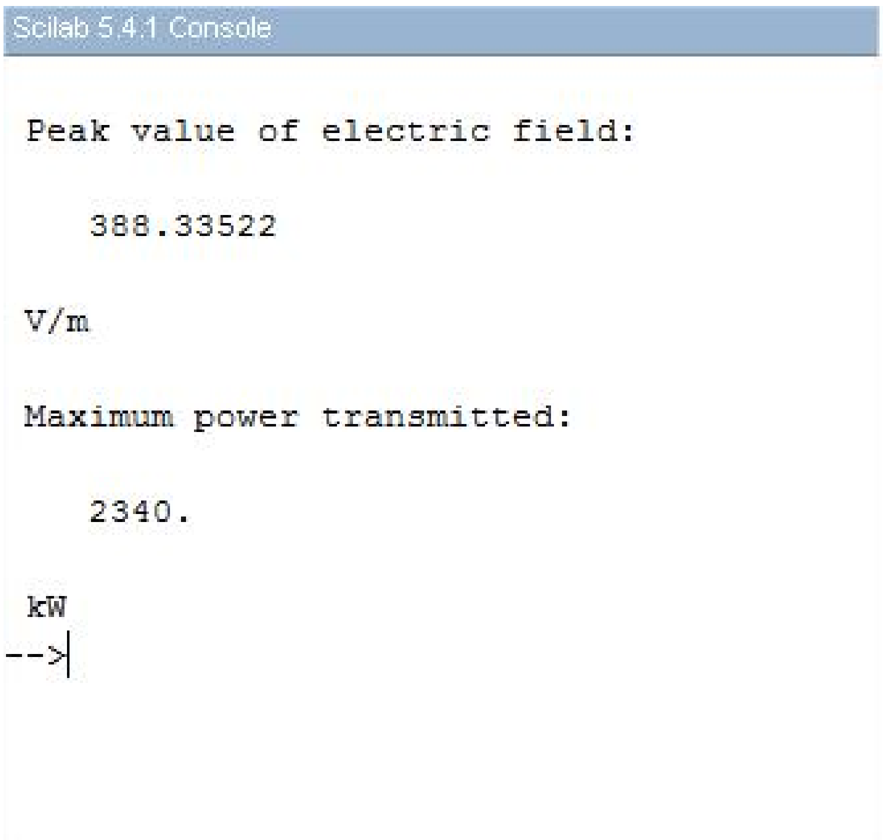



Figure 2.11: Air filled Rectangular Waveguide

```
disp('V/m',E0,'Peak value of electric field:');

//Maximum power transmitted
Ed=3D+6; //V/m
Pt=2.6D+13*(Ed/f0)^2;
disp('kW',Pt/1000,'Maximum power transmitted:');

//Answer is given as 2300kW but it is 2340kW
```

**Scilab code Exa 2.18** Rectangular Waveguide

```
//Page Number: 104
//Example 2.18
clc;
//Given
f=5D+9; //Hz
c=3D+8; //m/s
a=7.5; //cm
a1=a/100; //m
b=3.5; //cm
b1=b/100; //m
lam=c/f;
lamm=lam*100; //m

disp('TE10 mode');
lamc10=2*a;
bet10=(2*%pi*sqrt(((lamc10/lamm)^2)-1))/lamc10;
disp('rad/cm',bet10,'Propogation constant:');
vp10=(2*%pi*f)/bet10;
disp('m/s',vp10/100,'Phase velocity:');

disp('TE01 mode');
lamc01=2*b;
```

```
Scilab 5.4.1 Console

TE10 mode

Propogation constant:

   0.9597724

rad/cm

Phase velocity:

   3.273D+08

m/s

TE01 mode

Propogation constant:

   0.5393892

rad/cm

Phase velocity:

   5.824D+08

m/s

TE11 mode

Propogation constant:

   0.3398251

rad/cm

Phase velocity:
```

```
bet01=(2*%pi*sqrt(((lamc01/lamm)^2)-1))/lamc01;
disp('rad/cm',bet01,'Propogation constant:');
vp01=(2*%pi*f)/bet01;
disp('m/s',vp01/100,'Phase velocity:');

disp('TE11 mode');
lamc11=(2*a*b)/sqrt((a*a)+(b*b));
bet11=(2*%pi*sqrt(((lamc11/lamm)^2)-1))/lamc11;
disp('rad/cm',bet11,'Propogation constant:');
vp11=(2*%pi*f)/bet11;
disp('m/s',vp11/100,'Phase velocity:');

disp('TE02 mode');
lamc02=b;
bet02=(2*%pi*sqrt(((lamc02/lamm)^2)-1))/lamc02;
disp('rad/cm',bet02,'Propogation constant:');
disp('As beta is imaginary, mode gets attenuated');
alp=(2*%pi*sqrt(1-((lamc02/lamm)^2)))/lamc02;
disp('Np/m',alp,'Propogation constant alpha:');
```

**Scilab code Exa 2.19** Rectangular Waveguide

```
//Page Number: 105
//Example 2.19
clc;
//Given
c=3D+8; //m/s
a=2.29; //cm
b=1.02; //cm
a1=a/100 ;//m
b1=b/100; //m
f=6D+9; //Hz
e=1;
```

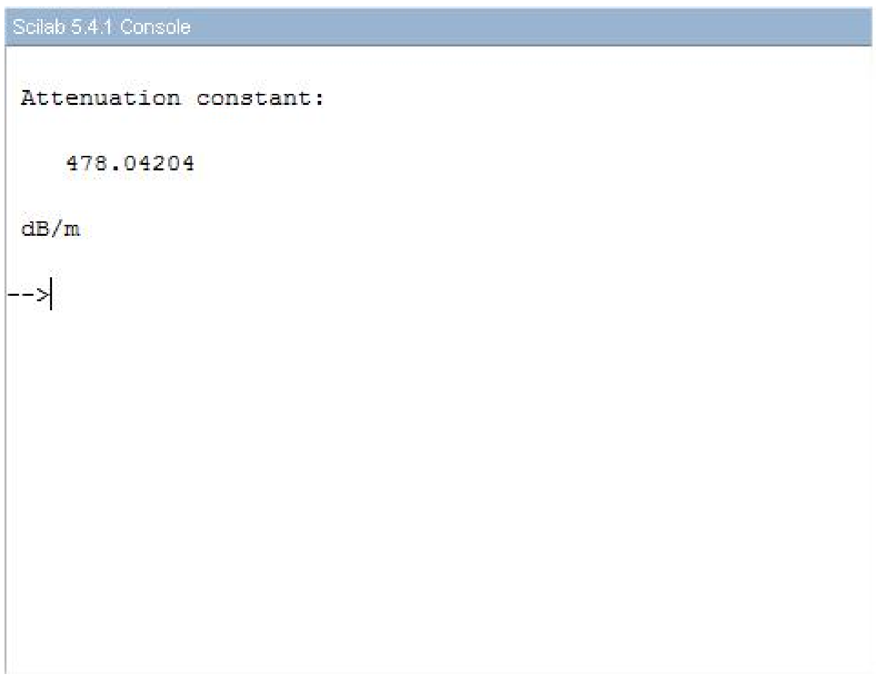



Figure 2.13: Rectangular Waveguide

```
mu=1/(c^2);

//Cut off frequency
lamc=2*a1;
fc=c/lamc;
w=2*%pi*fc;

//Attenuation constant
a=(w*sqrt(1-((f/fc)^2)))/c;;
adb=-20*log10(exp(-a));
disp('dB/m',adb,'Attenuation constant:');
```

**Scilab code Exa 2.20** Ratio of cross section

```
//Page Number: 105
//Example 2.20
clc;
//Given,
a1=1.84;
a2=%pi;

r=2*%pi*(a1/a2)^2;
disp(r,'Cross section ratio:');
```

**Scilab code Exa 2.21** Rectangular Waveguide

```
//Page Number: 106
//Example 2.21
clc;
```

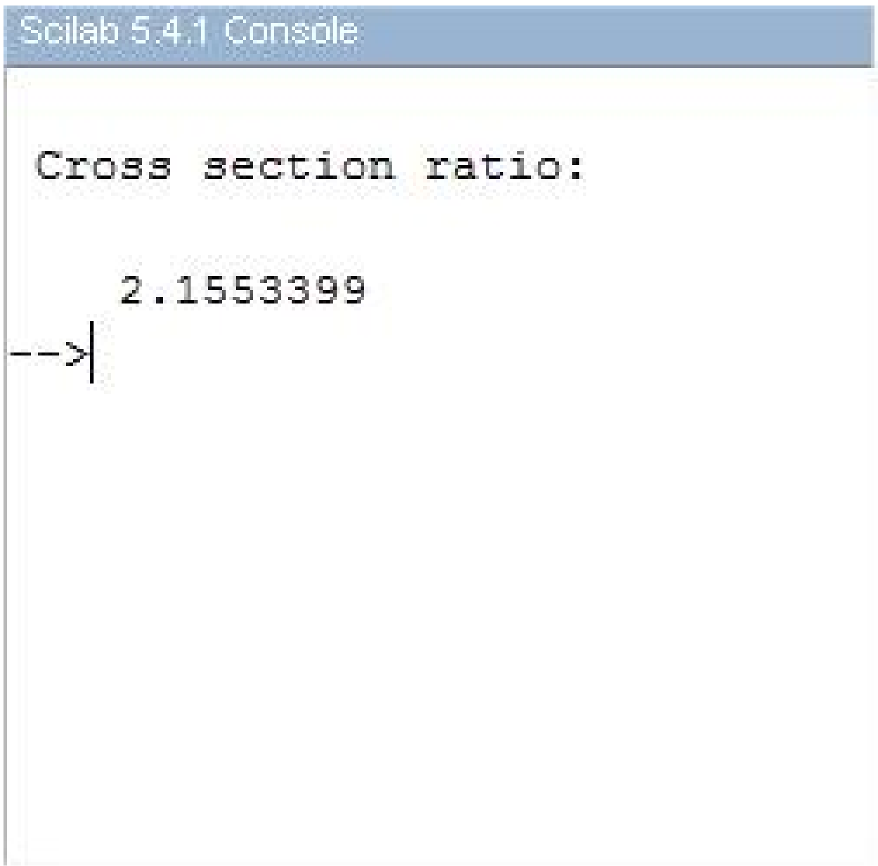



Figure 2.14: Ratio of cross section

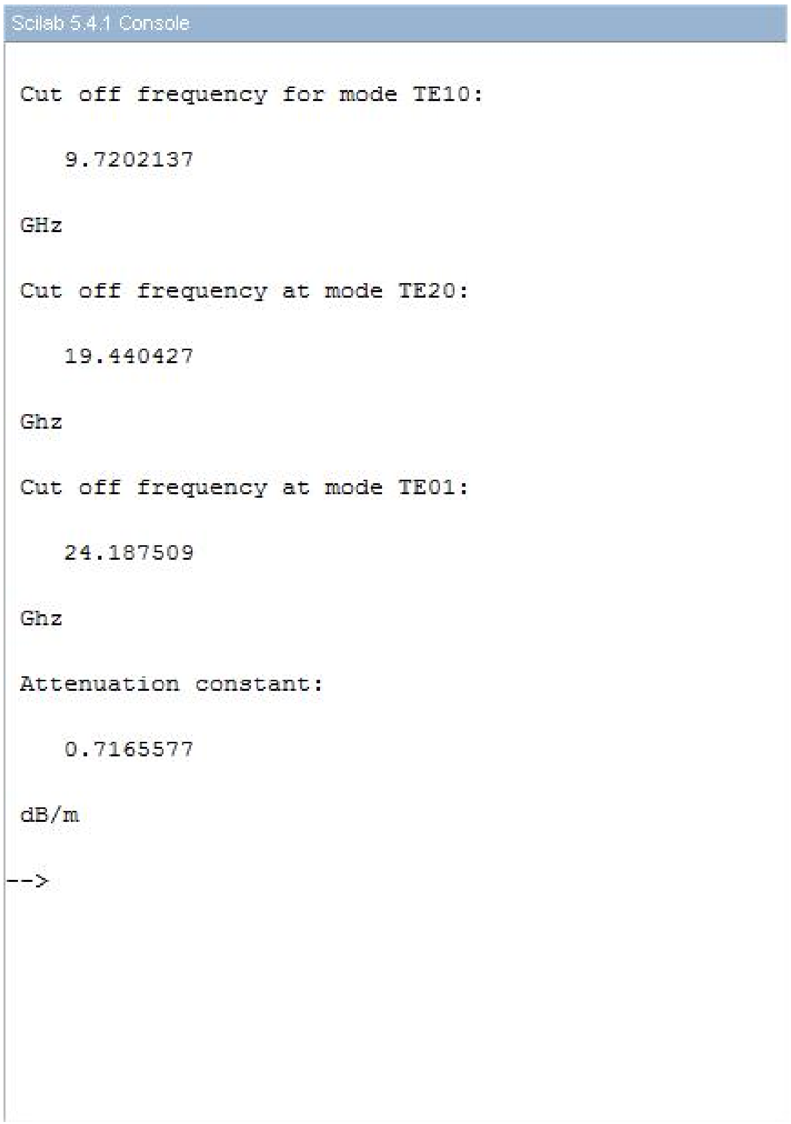



Figure 2.15: Rectangular Waveguide

```
//Given
c=3D+8; //m/s
f=15D+9; //hz
a=1.07; //cm
a1=a/100; //m
b=0.43; //cm
b1=b/100; //m
er=2.08;
tandel=0.0004;
lam=c/f;


//(i) Cut off frequency
m1=1;
n1=0;
fc10=(c/(2*%pi*sqrt(er))*sqrt((m1*%pi/a1)^2+(n1*%pi/
    b1)^2));
disp('GHz',fc10/10^9,'Cut off frequency for mode
    TE10:');

m2=2;
n2=0;
fc20=(c/(2*%pi*sqrt(er))*sqrt((m2*%pi/a1)^2+(n2*%pi/
    b1)^2));
disp('Ghz',fc20/10^9,'Cut off frequency at mode TE20
    :');

m3=0;
n3=1;
fc01=(c/(2*%pi*sqrt(er))*sqrt((m3*%pi/a1)^2+(n3*%pi/
    b1)^2));
disp('Ghz',fc01/10^9,'Cut off frequency at mode TE01
    :');

//Dielectric attenuation constant
ad=(%pi*tandel)/(lam*sqrt(1-(fc10/f)^2));
adb=-20*log10(exp(-ad));
disp('dB/m',adb,'Attenuation constant:');
```

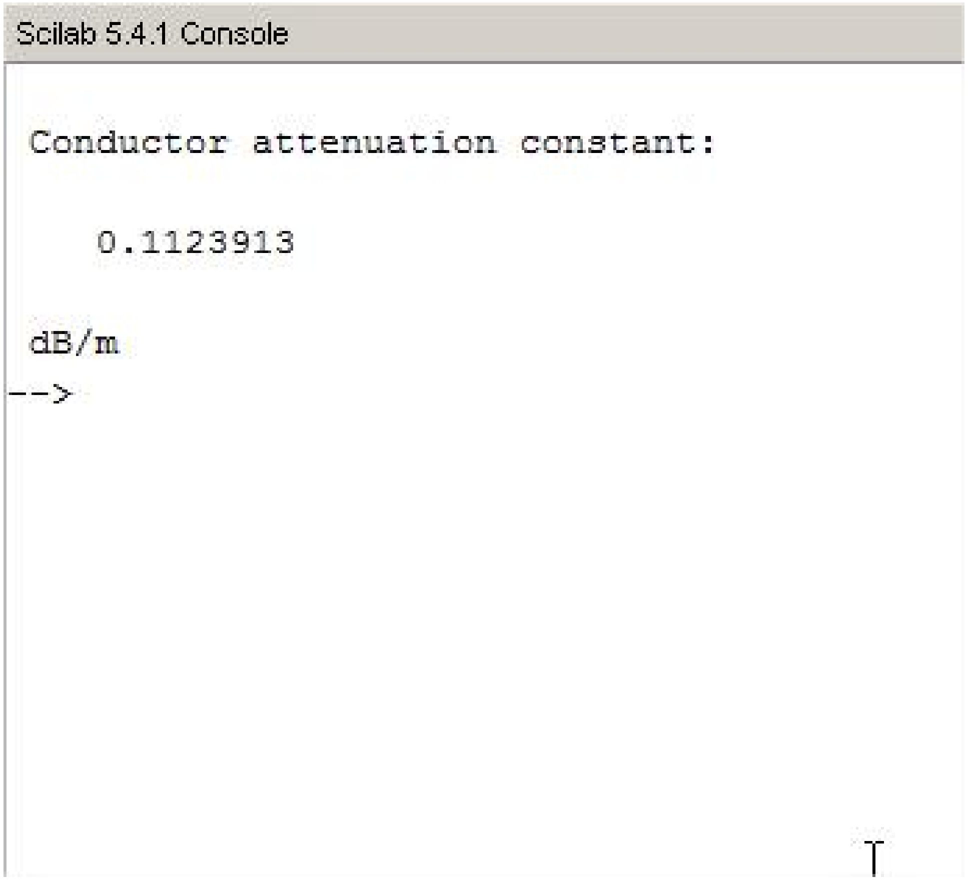



Figure 2.16: Rectangular Waveguide

---

**Scilab code Exa 2.22** Rectangular Waveguide

```
//Page Number: 106
//Example 2.22
clc;
//Given
```

```
c=3D+8; //m/s
a=2.286; //cm
a1=a/100; //m
b=1.016; //cm
b1=b/100; //m
sig=5.8D+7; //s/m
f=9.6D+9; //Hz

w=2*%pi*f;
mu=%pi*4D-7;
et=377;

lam=c/f;
lamc=2*a1;
r=lam/lamc;

Rs=sqrt((w*mu)/(2*sig));
ac=(Rs*(1+(2*(b1/a1)*r*r)))/(et*b1*sqrt(1-(r^2)));
adb=-20*log10(exp(-ac));
disp('dB/m',adb,'Conductor attenuation constant:');
```

**Scilab code Exa 2.23** Circular waveguide

```
//Page Number: 107
//Example 2.23
clc;
//Given
c=3D+8; //m/s
f=9D+9; //hz
a=5; //cm
a1=a/100; //m
e=1;
mu=1/(c*c);
```

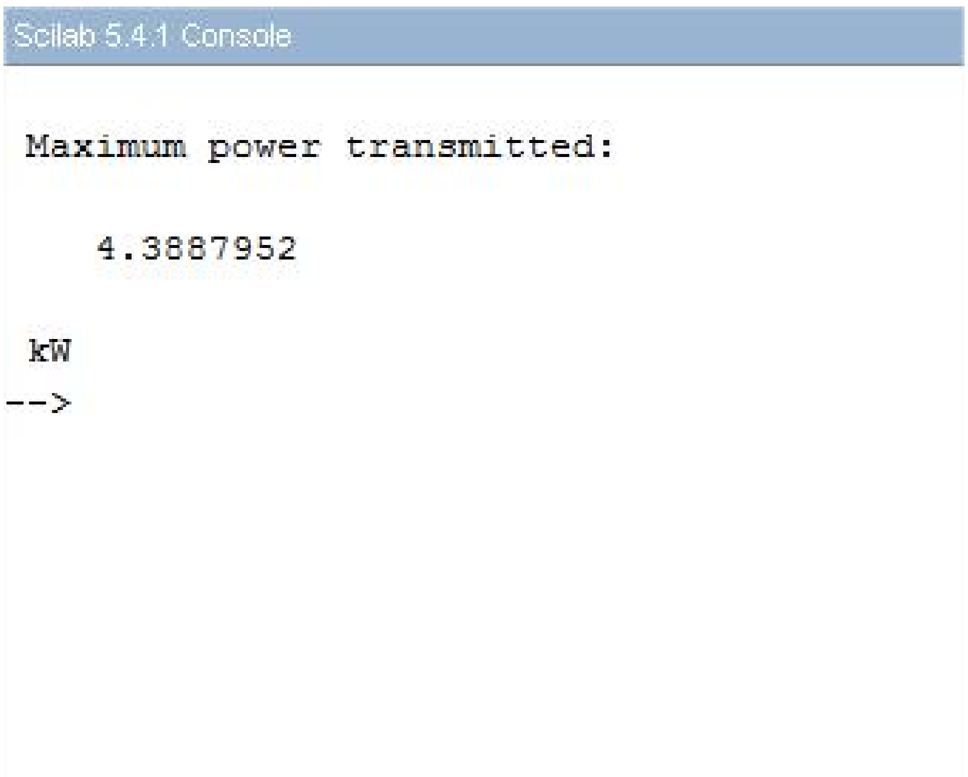



Figure 2.17: Circular waveguide

```
p11=1.841;

fc=(p11*c)/(2*%pi*a1);
//Maximum power transmitted
pmax=1790*(a1*a1)*sqrt(1-((fc/f)^2));
disp('kW',pmax,'Maximum power transmitted:');
```

**Scilab code Exa 2.24** Air filled circular waveguide

```
//Page Number: 108
//Example 2.26
clc;
//Given
c=3D+8; //m/s
a=5; //cm
a1=a/100; //m
f=3D+9; //hz
p11=1.841;
e=1;
w=2*%pi*f;

//(i) Cut off frequency
fc=(p11*c)/(2*%pi*a1);
disp('Ghz',fc/10^9,'Cut off frequency:');

//(ii) Guide wavelength
bet=sqrt(((w*w)/(c*c))-((p11/a1)^2));
lamg=(2*%pi)/bet;
lamg1=lamg*100; //cm
disp('cm',lamg1,'Guide wavelength:');

//(iii) Wave impedance
zte=(w*%pi*4D-7)/bet;
```

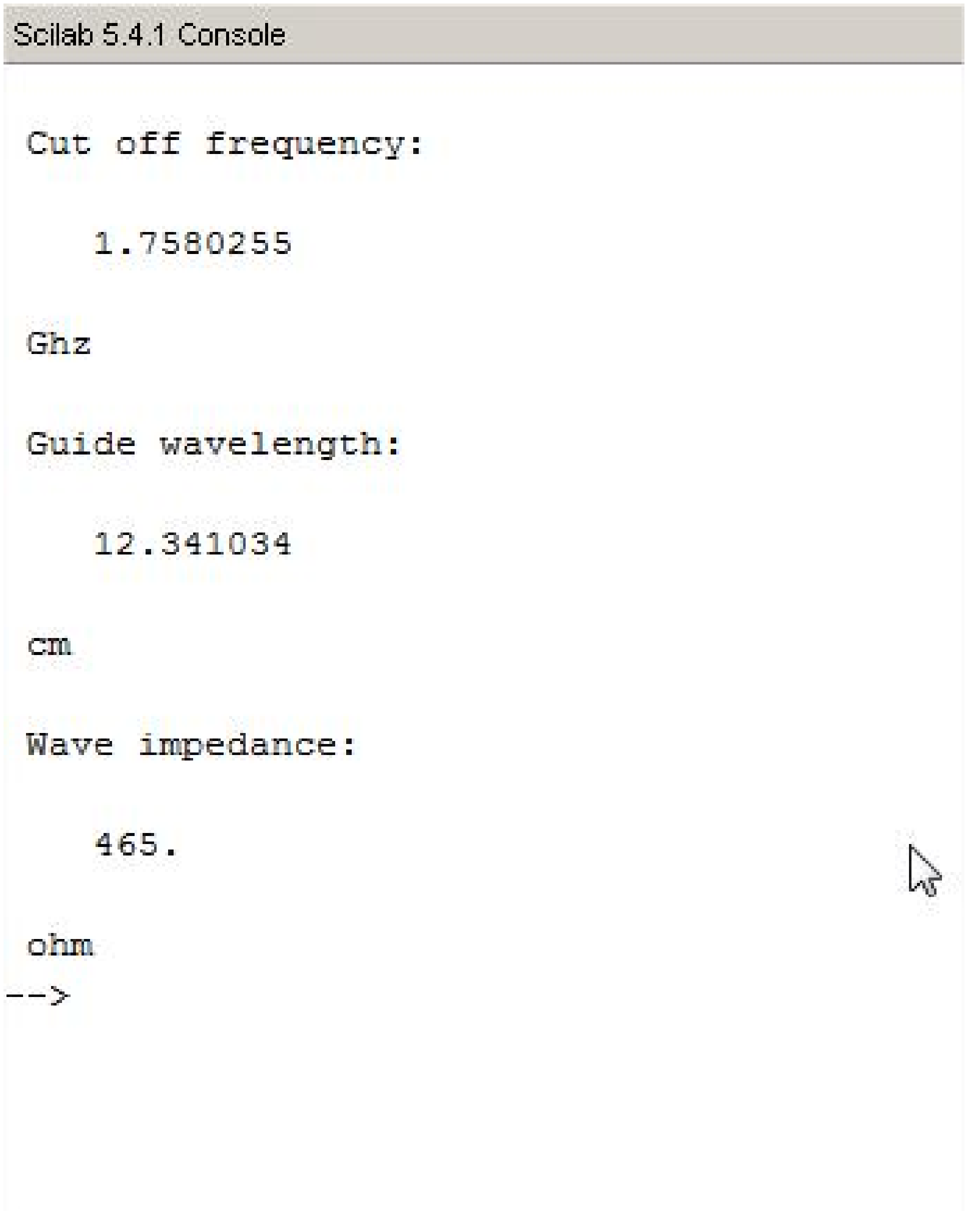



Figure 2.18: Air filled circular waveguide

```
disp('ohm',round(zte),'Wave impedance:');
```

**Scilab code Exa 2.25** Air filled rectangular waveguide

```
//Page Number:108
//Example 2.25
clc;
//Given
c=3D+8; //m/s
p01=2.405;
a=1/100;; //cm
p11=1.841;

fc01=((c*p01)/(2*%pi*a));
fc11=((c*p11)/(2*%pi*a));
bw=fc01-fc11;
disp('Ghz',bw/10^9,'Bandwidth:');
```

**Scilab code Exa 2.26** Rectangular Waveguide

```
//Page Number: 109
//Example 2.26
clc;
//Given
c=3D+8; //m/s
a=2.286; //cm
f=5D+9; //Hz
er=2.25;
tandel=1D-3;
```

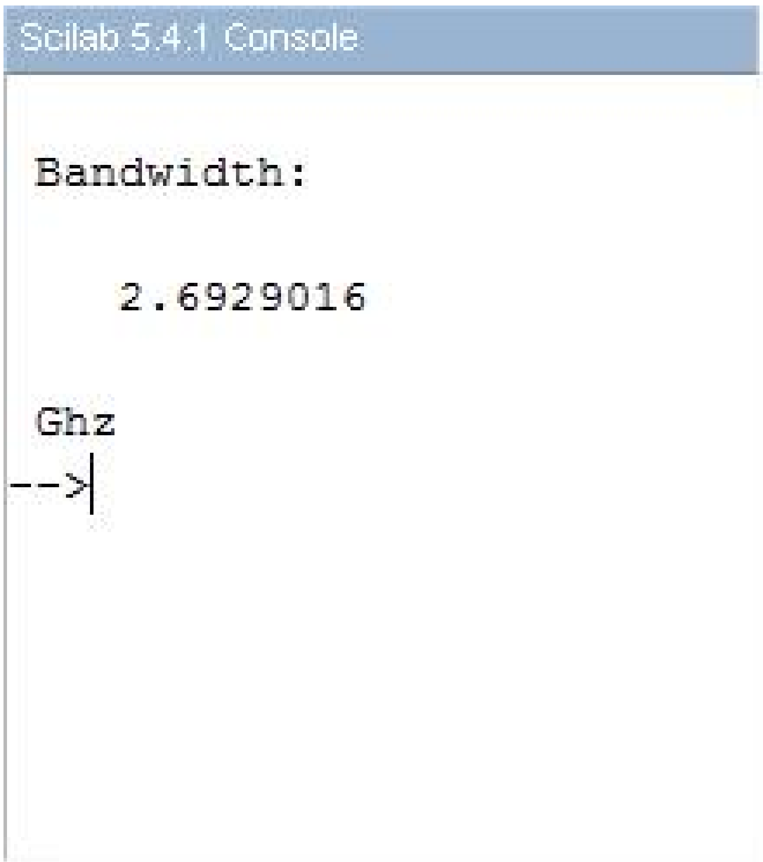



Figure 2.19: Air filled rectangular waveguide

Scilab 5.4.1 Console

```
Maximum value of dielectric constant:

   6.8889027

Minimum value of dielectric constant:

   1.7222257

Guide wavelength:

   8.2589934

cm

ad:

   0.1621650

Np/m

Beta:

   0.7607689

rad/cm

Phase velocity:

   4.129D+08

m/s
-->
```



Figure 2.20: Rectangular Waveguide

```
w=2*%pi*f;
mu=4D-7;
sig=5.8D+7; //s/m

lamc=2*a;
lamm=c/f;//m
lam=lamm*100;//cm

ermax=(lam/a)^2;
disp(ermax,'Maximum value of dielectric constant:');
ermin=(lam/(2*a))^2;
disp(ermin,'Minimum value of dielectric constant:');

//Guide wavelength
lam1=lam/sqrt(er);//cm
lamg=lam1/sqrt(1-(lam1/lamc)^2);
disp('cm',lamg,'Guide wavelength:');

lamm1=lam1/100;
ad=(%pi/lamm1)*(tandel/sqrt(1-(lam1/lamc)^2));
disp('Np/m',ad,'ad:');
bet=2*%pi/lamg;
disp('rad/cm',bet,'Beta:');
vp=w/(bet*100);
disp('m/s',vp,'Phase velocity:');
```

**Scilab code Exa 2.27** Circular Waveguide

```
//Page Number: 110
//Example 2.27
clc;
//Given
c=3D+8; //m/s
```

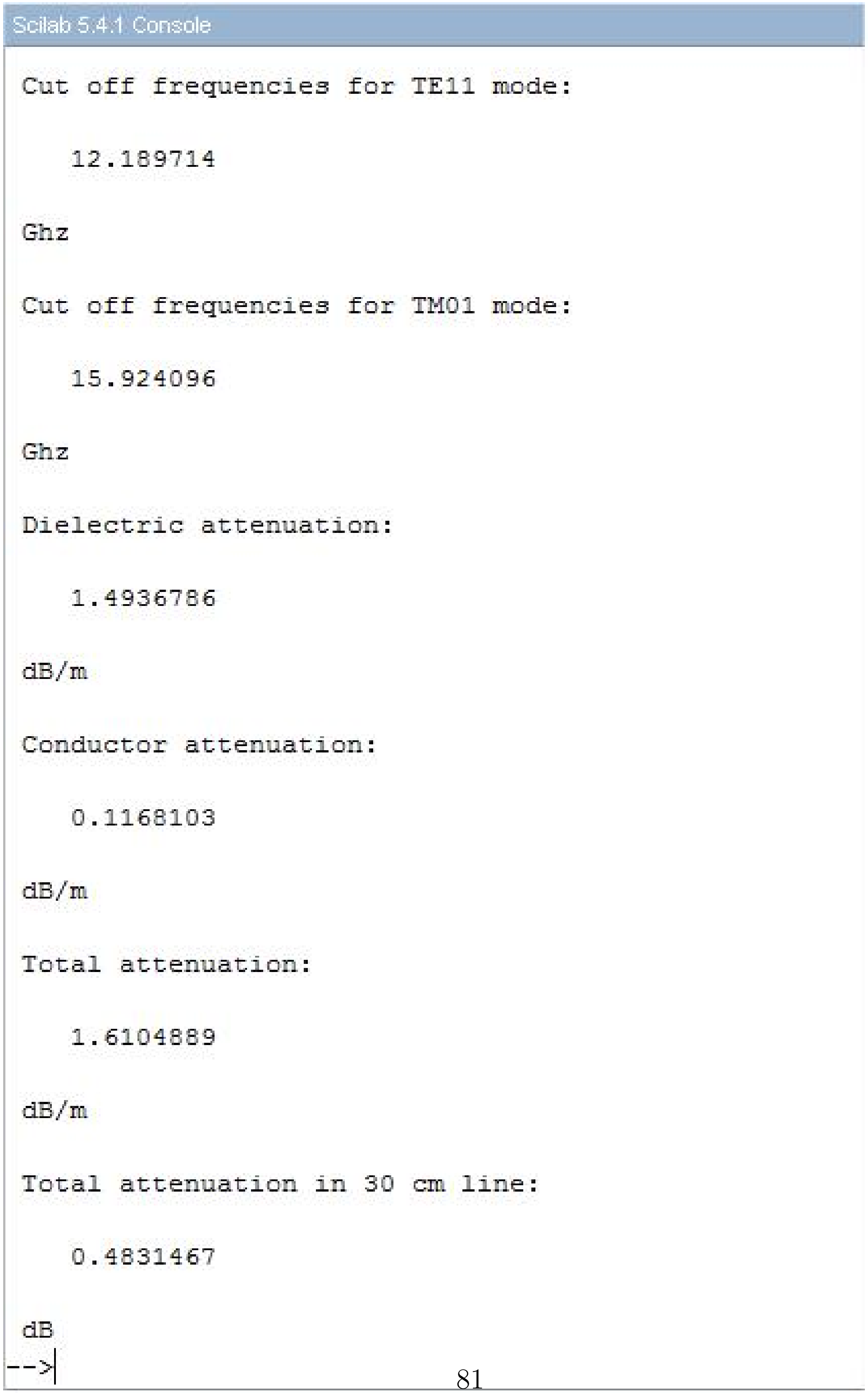

```
Scilab 5.4.1 Console

Cut off frequencies for TE11 mode:

   12.189714

Ghz

Cut off frequencies for TM01 mode:

   15.924096

Ghz

Dielectric attenuation:

   1.4936786

dB/m

Conductor attenuation:

   0.1168103

dB/m

Total attenuation:

   1.6104889

dB/m

Total attenuation in 30 cm line:

   0.4831467

dB
-->
```



Figure 2.21: Circular Waveguide

```
a=0.5; //cm
a1=a/100; //m
f=14D+9; //Hz
er=2.08;
p11=1.841;
p01=2.405;
tandel=4D-4;
w=2*%pi*f;
u=%pi*4D-7;
sig=4.1D+7;
et=377;

//(i) Cut off frequencies
fcte11=p11*c/(2*%pi*a1*sqrt(er));
fctm01=p01*c/(2*%pi*a1*sqrt(er));
disp('Ghz',fcte11/10^9,'Cut off frequencies for TE11 mode:');
disp('Ghz',fctm01/10^9,'Cut off frequencies for TM01 mode:');

//(ii) Overall noise
//Dielectric attenuation
ad=(%pi*sqrt(er)*tandel*f)/(c*sqrt(1-((fcte11/f)^2)));
disp('dB/m',ad*8.686,'Dielectric attenuation:');

//Conductor attenuation
k=(2*%pi*f*sqrt(er))/c;
bet=sqrt((k*k)-((p11/a1)^2));
//Surface resistance
rs=sqrt((w*u)/(2*sig));
kc2=(p11/a1)^2;

ac=(rs*(kc2-((k^2)/((p11^2)-1))))/(a1*k*et*bet);
disp('dB/m',ac*8.686,'Conductor attenuation:');

//Total attenuation
a=(ac+ad)*8.686;
```

```
disp('dB/m',a,'Total attenuation:');
ta=a*0.3;
disp('dB',ta,'Total attenuation in 30 cm line:');

//Answer for condcutor attenuation is wrong in book,
    hence answer for total loss is different
```

**Scilab code Exa 2.28** Rectangular Waveguide

```
//Page Number: 112
//Example 2.28
clc;
//Given
c=3D+8; //m/s
er=9;
a=7; //cm
a1=a/100; //m
b=3.5; //cm
b1=b/100; //m
ur=1;
f1=2D+9; //Hz

//(i) Cut off frequency
lamc=2*a1;
fc=c/(lamc*sqrt(ur*er));
disp('Ghz',fc/10^9,'Cut off frequency:');

//(ii) Phase velocity
lam=c/f1;//m
lam1=lam*100;//cm
lamc1=lamc*100;//cm
lamg=lam1/(sqrt((ur*er)-((lamc1/lam1)^2))); //cm
lamg1=lamg/100;//m
```

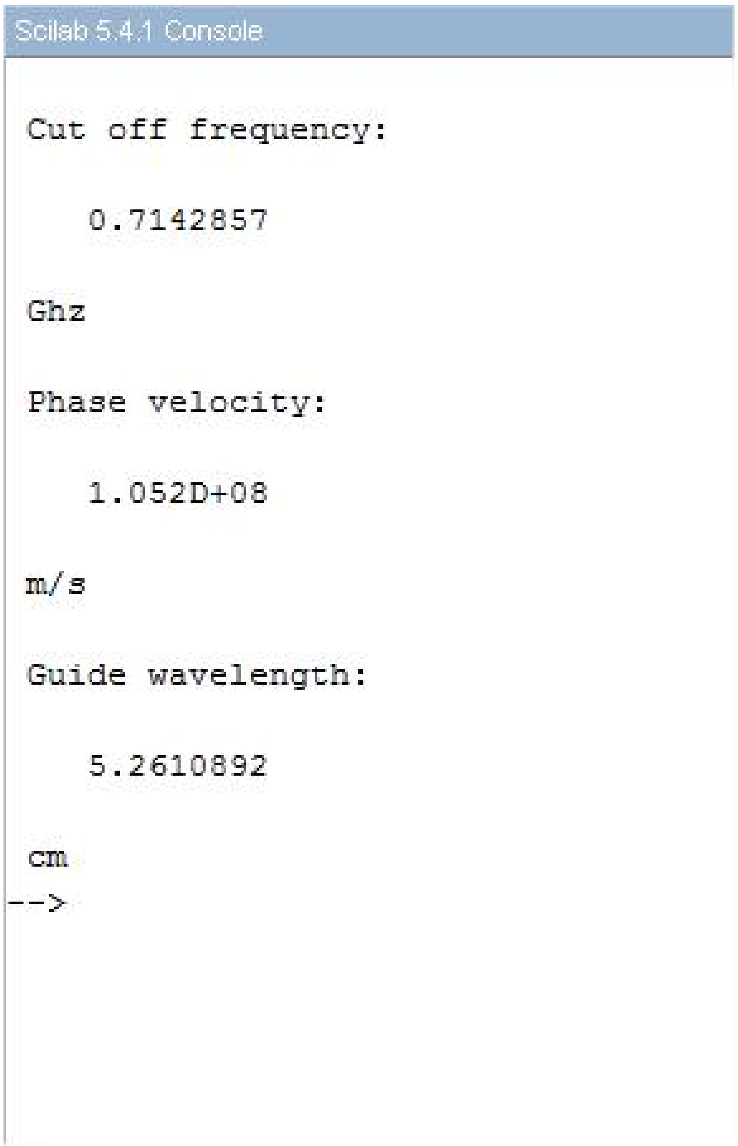



Figure 2.22: Rectangular Waveguide

```
vp=f1*lamg1;
disp('m/s',vp,'Phase velocity:');

///(iii)Guide wavelength
disp('cm',lamg,'Guide wavelength:');
```

**Scilab code Exa 2.29** Circular waveguide

```
//Page Number: 112
//Example 2.29
clc;
//Given
c=3D+8; //m/s
fc=9D+9; //Hz
er=1;
er1=4;
p11=1.841;

//(i) air filled
a=(p11*c)/(2*%pi*fc*sqrt(er));
disp('cm',a*100,'Inside diameter if air filled:');
//(ii) dielectric field
a1=(p11*c)/(2*%pi*fc*sqrt(er1));
disp('cm',a1*100,'Inside diameter if dielectric
   filled:');

//Answers are calculated wrong in book
```

**Scilab code Exa 2.30** Cutoff frequencies

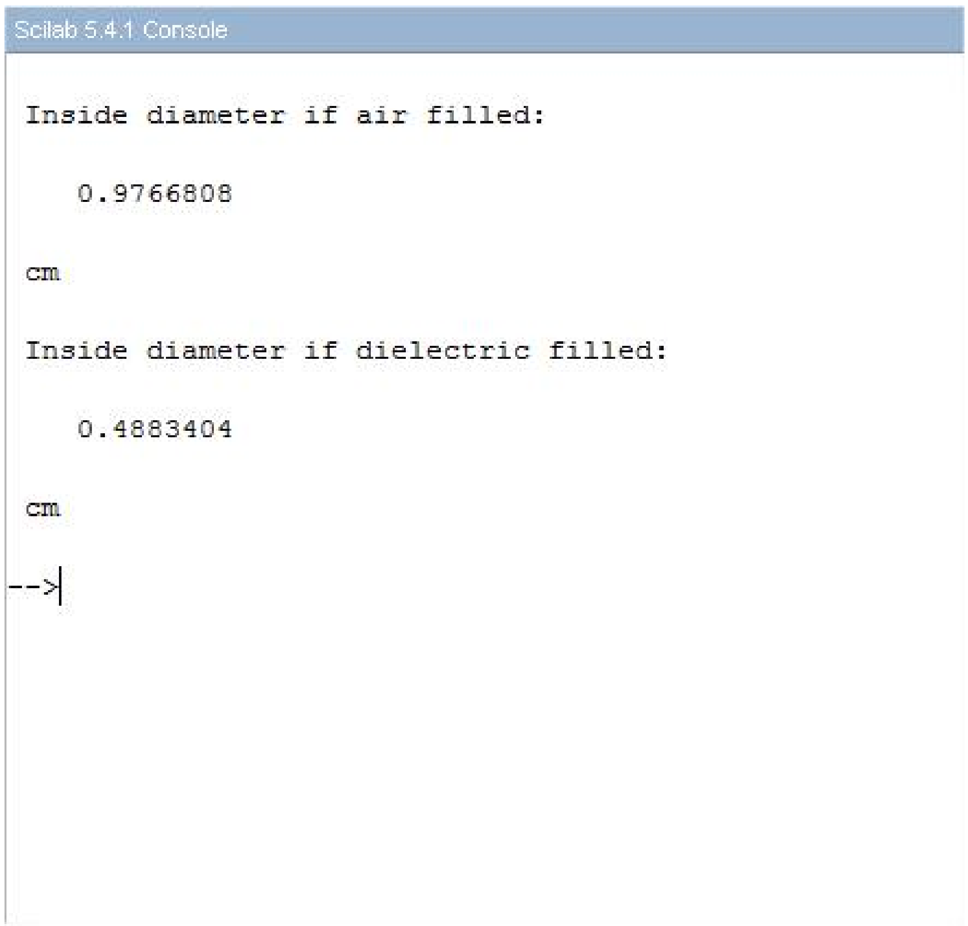



Figure 2.23: Circular waveguide

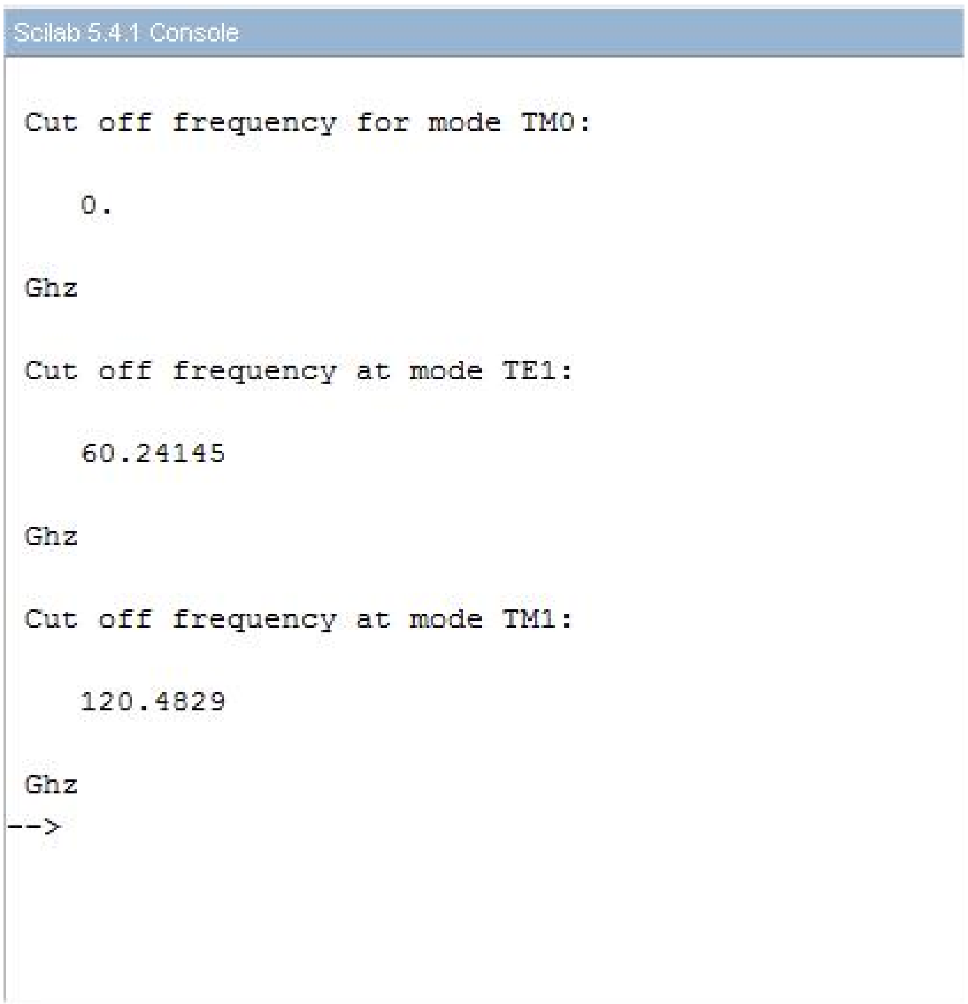



Figure 2.24: Cutoff frequencies

```
//Page Number: 113
//Example 2.30
clc;
//Given
c=3D+8; //m/s
er=2.55;
d=1; //mm
d1=d/1000;//m

//Cut off frequencies
fctm0=0;
disp('Ghz',fctm0,'Cut off frequency for mode TM0:');

fcte1=c/(4*d1*sqrt(er-1));
disp('Ghz',fcte1/10^9,'Cut off frequency at mode TE1
    :');

fctm1=c/(2*d1*sqrt(er-1));
disp('Ghz',fctm1/10^9,'Cut off frequency at mode TM1
    :');


//Answers are calculated wrong in book
```

**Scilab code Exa 2.31** Dielectric constant

```
//Page Number: 113
//Example 2.31
clc;
//Given,
c=3D+8; //m/s
f=15D+9; //hz
d=5; //mm
```

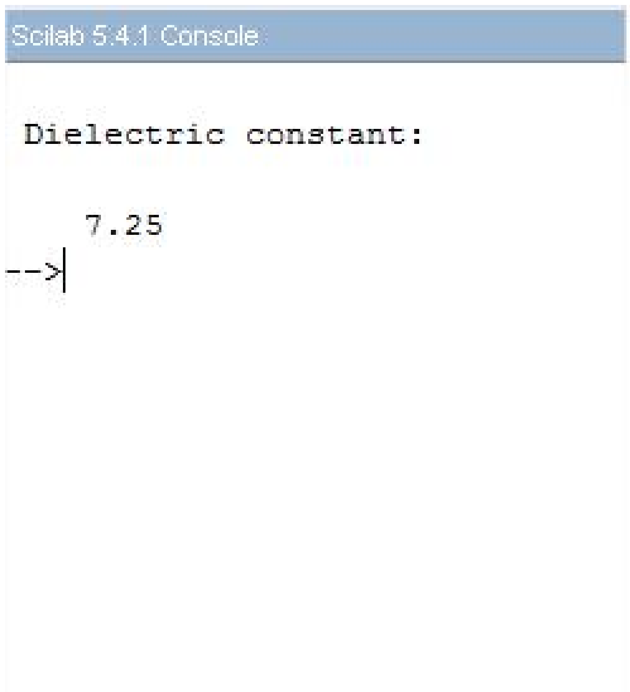



Figure 2.25: Dielectric constant

```
d1=d/1000; //m

//Cut off frequency
fc=0.8*f;
//Dielctric constant
er=(c/(2*d1*fc))^2+1;
disp(er,'Dielectric constant:');
```

# Chapter 3

# Microwave Network Analysis

**Scilab code Exa 3.4** Scattering matrix

```
//Page Number: 142
//Example 3.4
clc;
//Given

[z]=[4 2;2 4];
[I]=[1 0;0 1];

//Scattering matrix
[s]={[z]-[I]}*inv({[z]+[I]});
disp([s],'Scattering Matrix:');
```

**Scilab code Exa 3.5** Network

```
//Page Number: 142
```

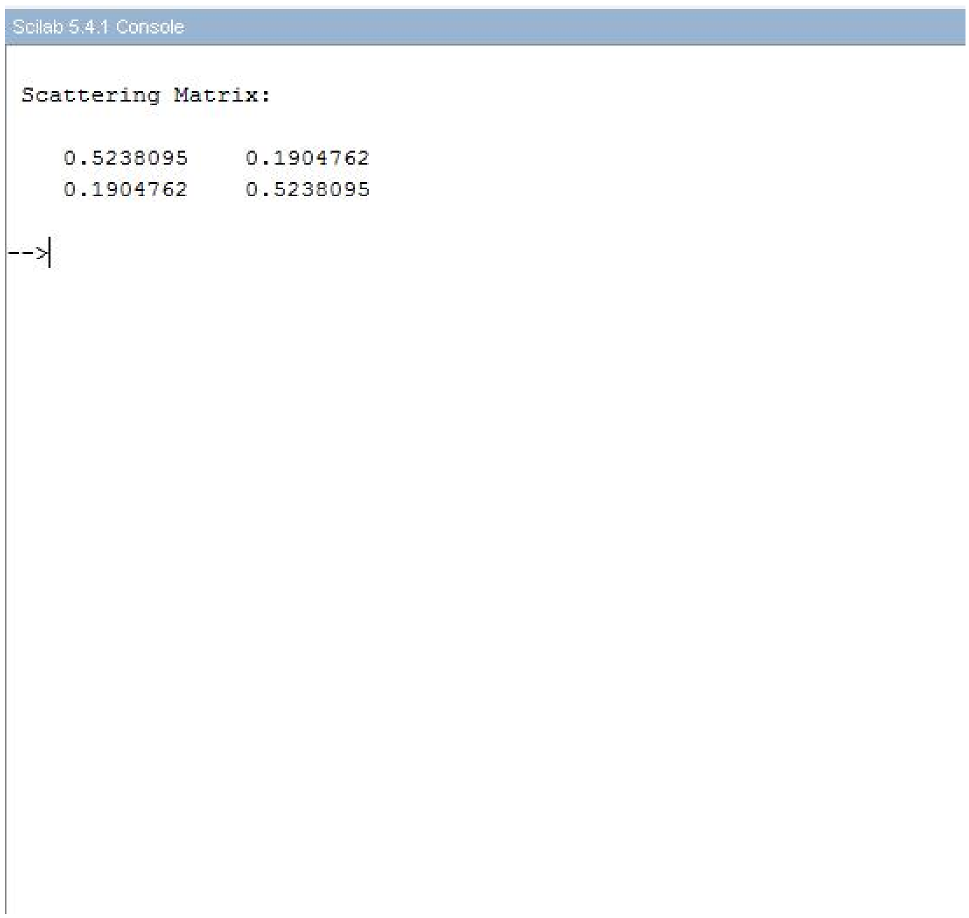



Figure 3.1: Scattering matrix

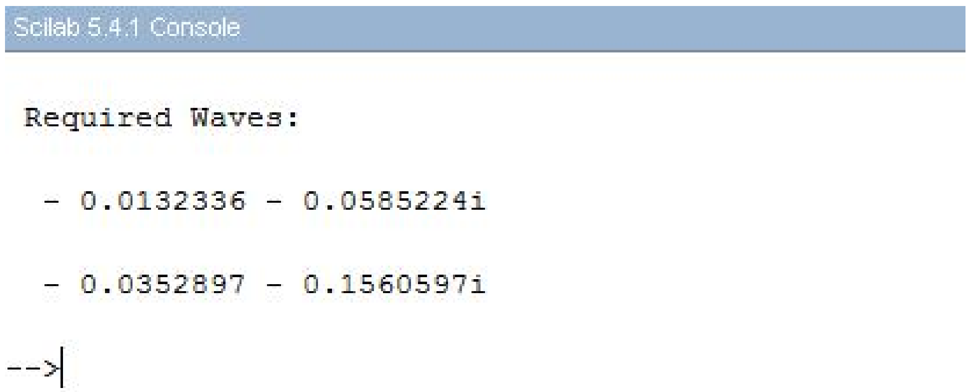



Figure 3.2: Network

```
//Example 3.5
clc;
//Given
P=12.8D-3; //W
l=3; //cm
lamb=4.2; //cm
vswr=2.2;
jfi=%i*4.49;

//ap
ap=sqrt(2*P);

//Phase shift
bl=(2*%pi*l)/lamb;
//bp
bp=(ap*(vswr-1))/(vswr+1);

a=ap*exp(jfi);
b=bp*exp(jfi);
disp(a,b,'Required Waves:');
```

**Scilab code Exa 3.6** Microwave network

```
//Page Number: 143
//Example 3.6
clc;
//Given
S11=0.10;
S12=0.90;
A12=-45;
S21=0.90;
A21=45;
S22=0.3;
```

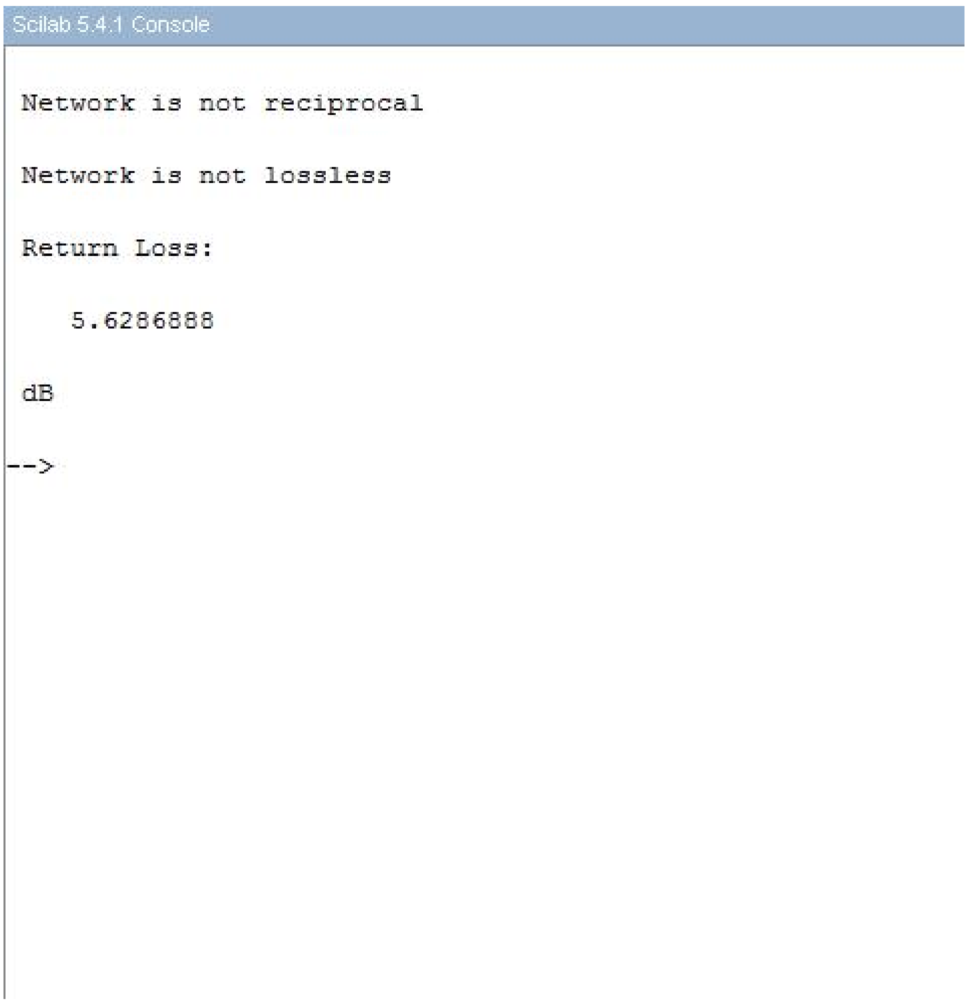



Figure 3.3: Microwave network

```
//(i) Network is reciprocal
if(A12==A21)
    disp('Network is reciprocal');
else

    disp('Network is not reciprocal');
end

//(ii) Network is lossles
x=(S11^2)+(S12^2);
if(x==1)
    disp('Network is lossless');
else

    disp('Network is not lossless');
end

//(iii)Return loss
T=S11-((S12*S21)/(1+S22));
Tm=-T; //mod of T
L=-20*log10(Tm);
disp('dB',L,'Return Loss:');
```

**Scilab code Exa 3.12** Transistor amplifier circuit

```
//Page Number: 163
//Example 3.12
clc;
//Given
S11=0.6;
S12=0.045;
S21=2.5;
```

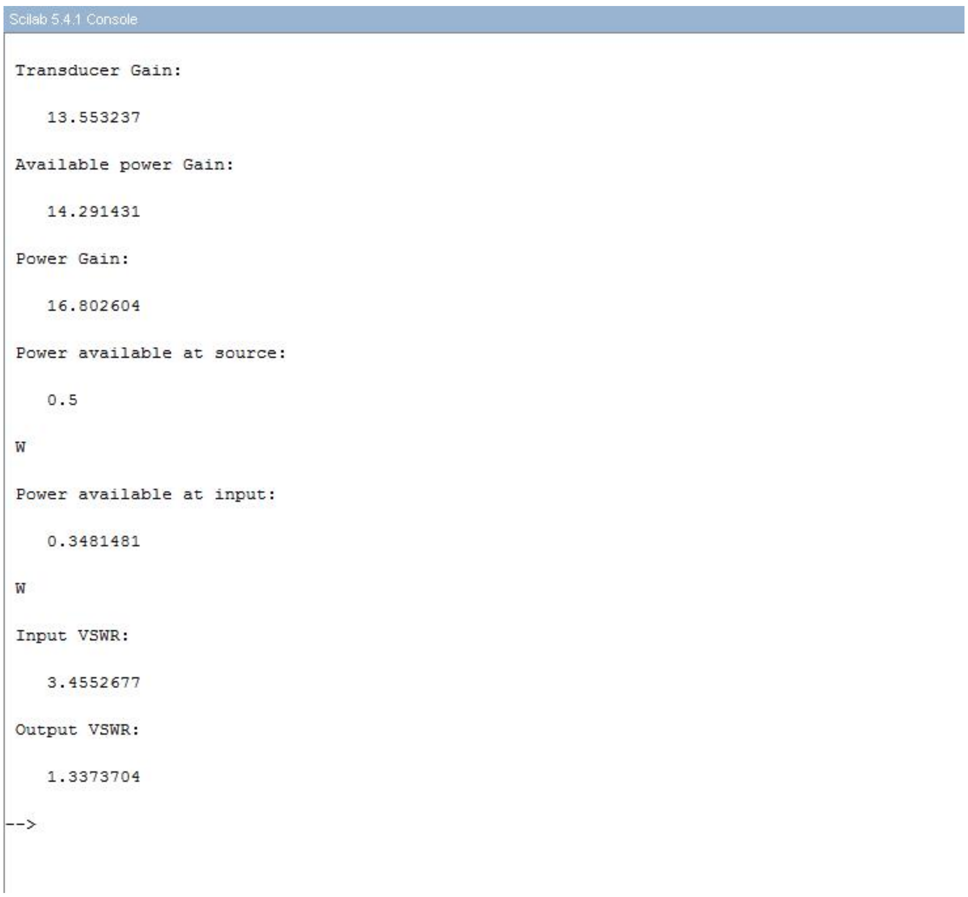



Figure 3.4: Transistor amplifier circuit

```
S22=0.50;
TS=0.5;
TL=0.4;
Z0=50; //ohm
Vrms=10; //V

//(i) Gain Parameters
//(i)Reflection coefficients of input and output
Tin=S11+((S12*S21*TL)/(1-(S22*TL)));
Tout=S22+((S12*S21*TS)/(1-(S22*TS)));

//Transducer Gain
x=(1-(TS)^2)/((1-(S11*TS))^2);
y=(S21*S21);
z=(1-(TL)^2)/((1-(Tout*TL))^2);
GT=x*y*z;
disp(GT,'Transducer Gain:');

//Available Power Gain
z1=1-(Tout)^2;
GA=(x*y)/z1;
disp(GA,'Available power Gain:');

//Power Gain
z2=1-(Tin)^2;
GP=(x*y)/z2;
disp(GP,'Power Gain:');

//(ii) Power levels
//Power available at source
Pavs=(sqrt(2)*Vrms)^2/(8*Z0);
disp('W',Pavs,'Power available at source:');

Pl=9.4*Pavs;
//Power available at input
Pin=Pl/13.5;
disp('W',Pin,'Power available at input:');

```

```
//(iii) VSWRs
M1=Pin/Pavs;
M2=Pl/(9.6*Pavs);

Tin1=sqrt(1-M1);
Tout1=sqrt(1-M2);

vswrin=(1+Tin1)/(1-Tin1);
disp(vswrin,'Input VSWR:');
vswrout=(1+Tout1)/(1-Tout1);
disp(vswrout,'Output VSWR:');

//Calculations for gain are done wrong in book,
    hence answers dont match
```

# Chapter 4

# Microwave Resonators and Waveguide Components

**Scilab code Exa 4.1** Rectangular cavity resonator

```
//Page Number: 193
//Example 4.1
clc;
//Given
a=5;//cm
a1=a/100;//m
b=2;//cm
b1=b/100;//m
c=15;//cm
c1=c/100;//m

//(i) Air filled cavity
m=1;
n=0;
p=1;
c=3D+8; //for air
fr=(1/2)*c*sqrt((m/a1)^2+(n/b1)^2+(p/c1)^2); //hz
```

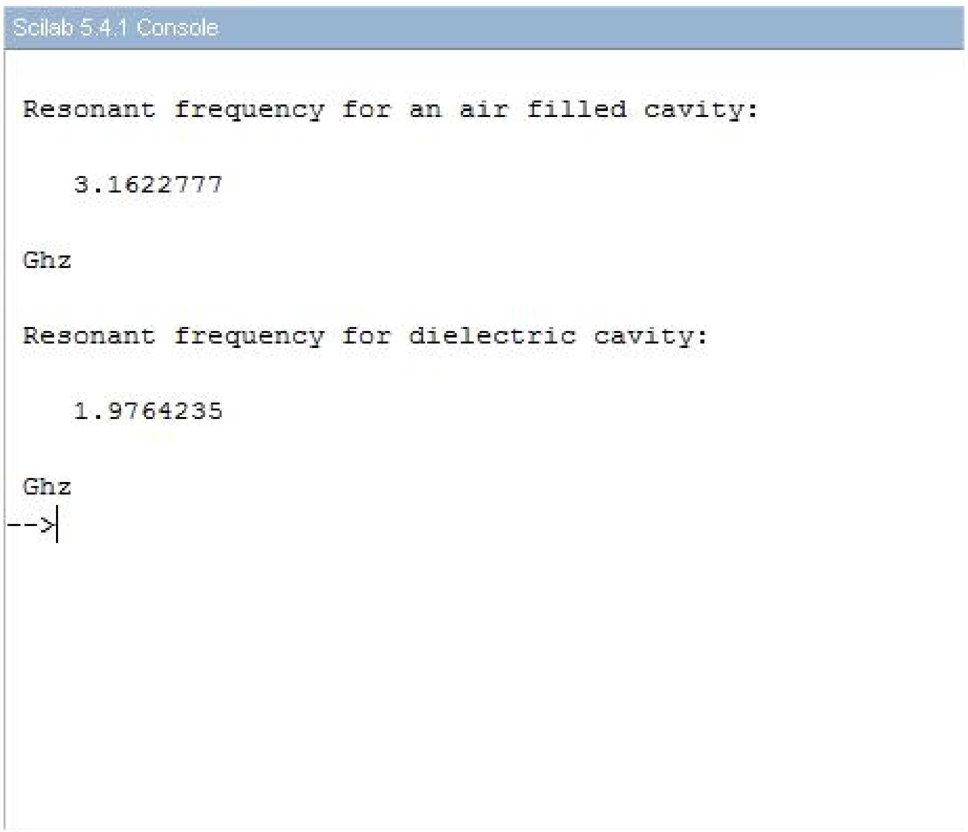



Figure 4.1: Rectangular cavity resonator


Figure 4.2: Rectangulr resonator

```
disp('Ghz',fr/10^9,'Resonant frequency for an air filled cavity:');

//(ii) Dielctric filled cavity
er=2.56;
fr1=(1/2)*(c/sqrt(er))*sqrt((m/a1)^2+(n/b1)^2+(p/c1)^2);//hz
disp('Ghz',fr1/10^9,'Resonant frequency for dielectric cavity:');
```

**Scilab code Exa 4.2** Rectangulr resonator

```
//Page Number: 193
//Example 4.2
clc;
//Given
a=0.38;//cm
a1=a/100;//m
b=0.76;//cm
b1=b/100;//m
f=50D+9;
c=3D+8;

//Length for TE102
m=1;
n=0;
p=2;
l=1/sqrt((f/c)^2-(1/(4*b1^2)));//m
disp('cm',l*100,'Length c:');
```

**Scilab code Exa 4.3** X band resonator

```
//Page Number: 194
//Example 4.3
clc;
//Given
c=3D+8; //m/s
a=2.286;//cm
a1=a/100;//m
b=1.024;//cm
b1=b/100;//m
f=10D+9;//hz
sig=6D+7;
u=4D-7*%pi;
w=2*%pi*f;
```

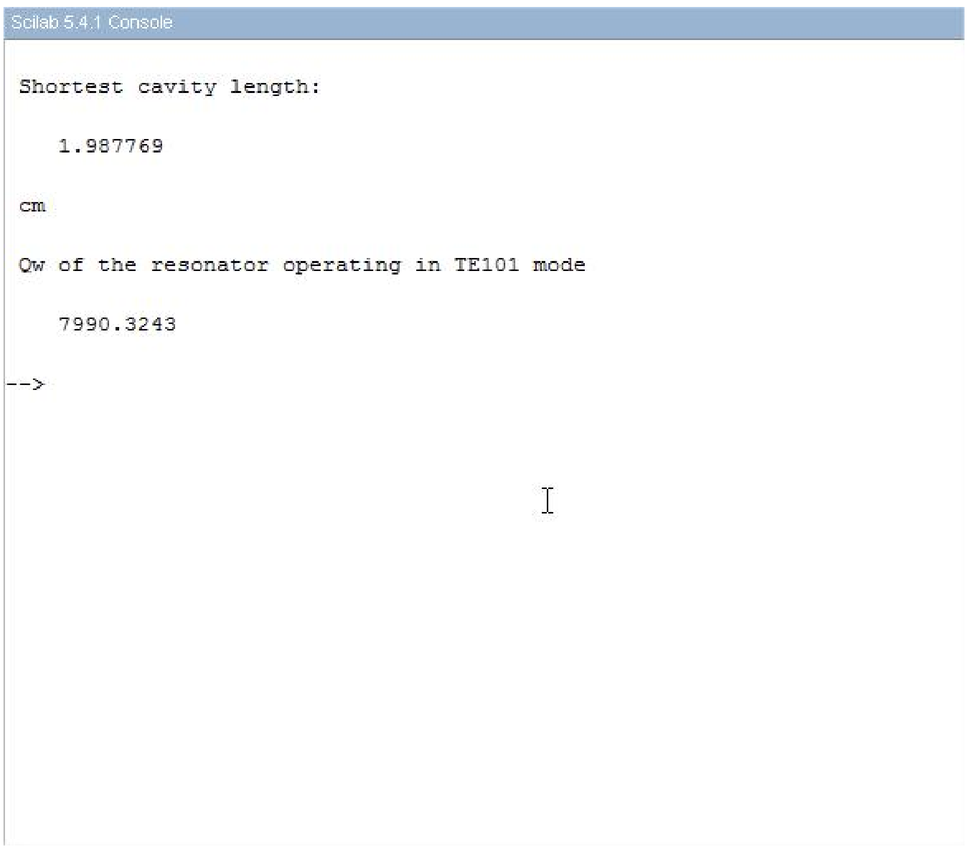



Figure 4.3: X band resonator

```
eet=377;

//Shortest cavity length
lamc=2*a1;//m
fc=c/lamc;//hz
lam=c/f;//m
lamg=lam/sqrt(1-(fc/f)^2);//m
sc=lamg/2;//m
disp('cm',sc*100,'Shortest cavity length:');

//Qw of the resonator operating in TE101 mode
rs=sqrt((w*u)/(2*sig));//ohm
lamr=c/f;
x=(((a1*b1)/(sc^2))+((sc^2+a1^2)/(2*sc*a1))+(b1*sc/
    a1^2));
qw=(2*%pi*eet*a1*b1*sc)/(rs*(lamr^3)*x);
disp(qw,'Qw of the resonator operating in TE101 mode
    ');
```

**Scilab code Exa 4.4** Rectangular resonator

```
//Page Number: 195
//Example 4.4
clc;
//Given
c=3D+8; //m/s
a=4.8;//cm
a1=a/100;//m
b=2.2;//cm
b1=b/100;//m
f=5D+9;//hz
er=2.25;
tandel=4D-4;
```

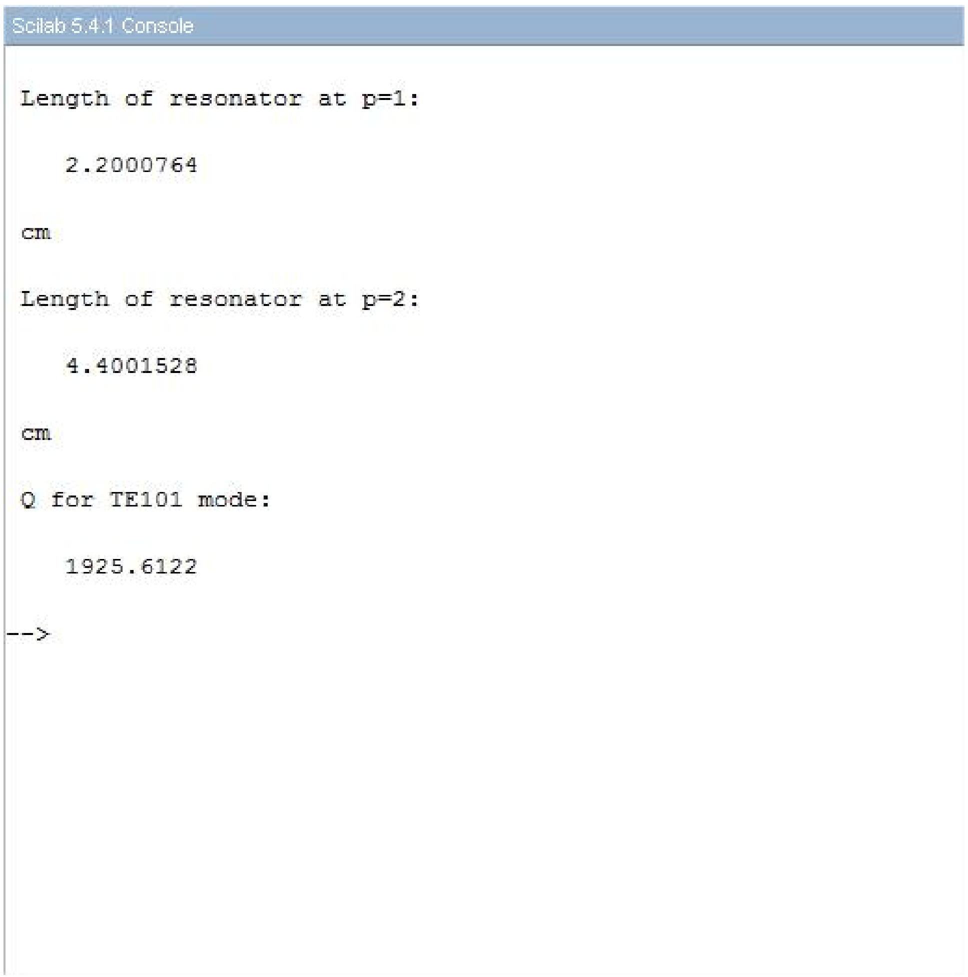



Figure 4.4: Rectangular resonator

```
sig=5.813D+7;
oneby=3D+8;
u=4D-7*%pi;
w=2*%pi*f;
eet=377;

//Length at p=1
m=1;
n=0;
p=1;
z=(f*2*sqrt(er))/c;
cp1=p/sqrt((z^2)-((m/a1)^2)-((n/b1)^2));
disp('cm',cp1*100,'Length of resonator at p=1:');

//At p=2
cp2=cp1*2;
disp('cm',cp2*100,'Length of resonator at p=2:');

//Qw
rs=sqrt((w*u)/(2*sig));//ohm
lamr=c/(f*sqrt(er));
x=(((a1*b1)/(cp1^2))+((cp1^2+a1^2)/(2*cp1*a1))+(b1*
    cp1/a1^2));
qw=(2*%pi*(eet/sqrt(er))*a1*b1*cp1)/(rs*(lamr^3)*x);
qd=1/tandel;
q=(qw*qd)/(qw+qd);
disp(q,'Q for TE101 mode:');
```

**Scilab code Exa 4.5** Cylindrical resonator

```
//Page Number: 196
//Example 4.5
clc;
```

Scilab 5.4.1 Console

```
TE modes

Resonant frequency for mode TE010:

   10.940294

Ghz

Resonant frequency for mode TE111:

   7.437512

Ghz

Resonant frequency for mode TE211:

   9.4423009

Ghz

TM modes:

Resonant frequency for mode TM010

   5.7415146

Ghz

resonant frequency for mode TM011:

   8.3045162

Ghz

Resonant frequency for mode TM111:

   10.940294

Ghz
-->
```

Figure 4.5: Cylindrical resonator

```
//Given
c=3D+8; //m/s
a=2;//cm
a1=a/100;//m
b=2.5;//cm
b1=b/100;//m

disp('TE modes');
h01=3.832;
fr=(c/(2*%pi))*sqrt((h01/a1)^2+(%pi/b1)^2);//hz
disp('Ghz',fr/10^9,'Resonant frequency for mode TE010:');

h11=1.841;
fr1=(c/(2*%pi))*sqrt((h11/a1)^2+(%pi/b1)^2);//hz
disp('Ghz',fr1/10^9,'Resonant frequency for mode TE111:');

h21=3.054;
fr2=(c/(2*%pi))*sqrt((h21/a1)^2+(%pi/b1)^2);//hz
disp('Ghz',fr2/10^9,'Resonant frequency for mode TE211:');

disp('TM modes:');
l1=0;
h011=2.405;
fr3=(c/(2*%pi))*sqrt((h011/a1)^2+(%pi*l1/b1)^2);//hz
disp('Ghz',fr3/10^9,'Resonant frequency for mode TM010');

l2=1;
fr4=(c/(2*%pi))*sqrt((h011/a1)^2+(%pi*l2/b1)^2);//hz
disp('Ghz',fr4/10^9,'resonant frequency for mode TM011:');

l3=1;
h111=3.832;
fr5=(c/(2*%pi))*sqrt((h111/a1)^2+(%pi*l3/b1)^2);//hz
```

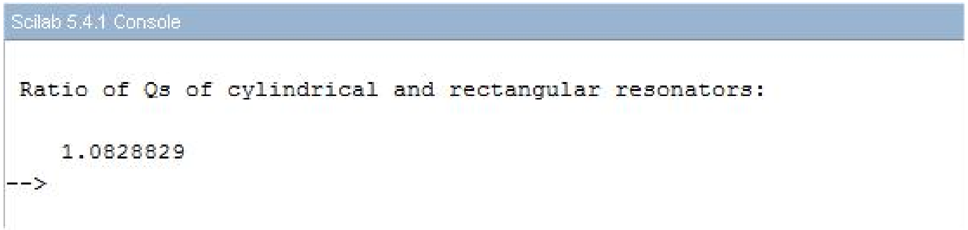



Figure 4.6: Resonator comparison

```
disp('Ghz',fr5/10^9,'Resonant frequency for mode
   TM111:');
```

---

**Scilab code Exa 4.6** Resonator comparison

```
//Page Number: 196
//Example 4.6
clc;
//Given
QTM010=1.202;
QTE101=1.11;

r=QTM010/QTE101;
disp(r,'Ratio of Qs of cylindrical and rectangular
   resonators:');
```

---

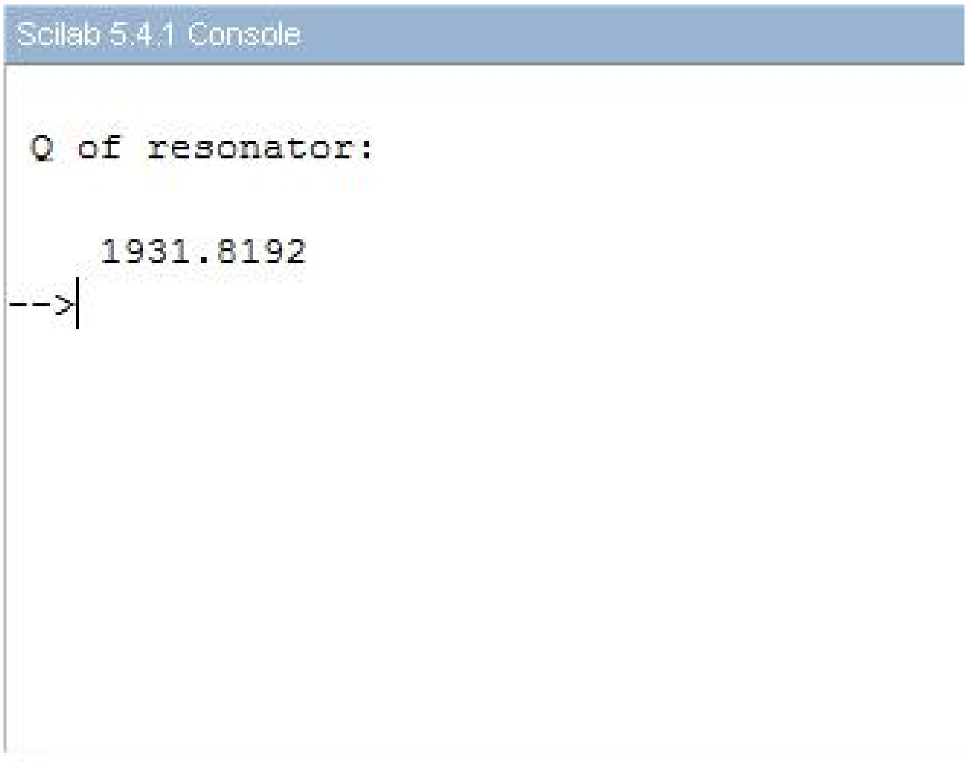



Figure 4.7: Cubical Resonator

**Scilab code Exa 4.7** Cubical Resonator

```
//Page Number: 197
//Example 4.7
clc;
//Given
f=7.07D+9;//hz
a=3;//cm
```

```
a1=a/100; //m
sig=5.8D+7;
er=2.25;
tandel=4D-4;
ur=1;
n=377;
w=2*%pi*f;
u=4D-7*%pi;

//Q of resonantor
rs=sqrt(w*u/(2*sig)); //ohm
qw=(0.7419*n)/(rs*sqrt(2.25));
qd=1/tandel;
q=(qw*qd)/(qw+qd);
disp(q,'Q of resonator:');
```

**Scilab code Exa 4.8** Rectangular Resonant Cavity

```
//Page Number: 198
//Example 4.8
clc;
//Given
a=5; //cm
a1=a/100; //m
b=4; //cm
b1=b/100; //m
c=10; //cm
c1=c/100; //m
sig=5.8D+7;
u0=4D-7*%pi;
er=3;
eet=377;

```

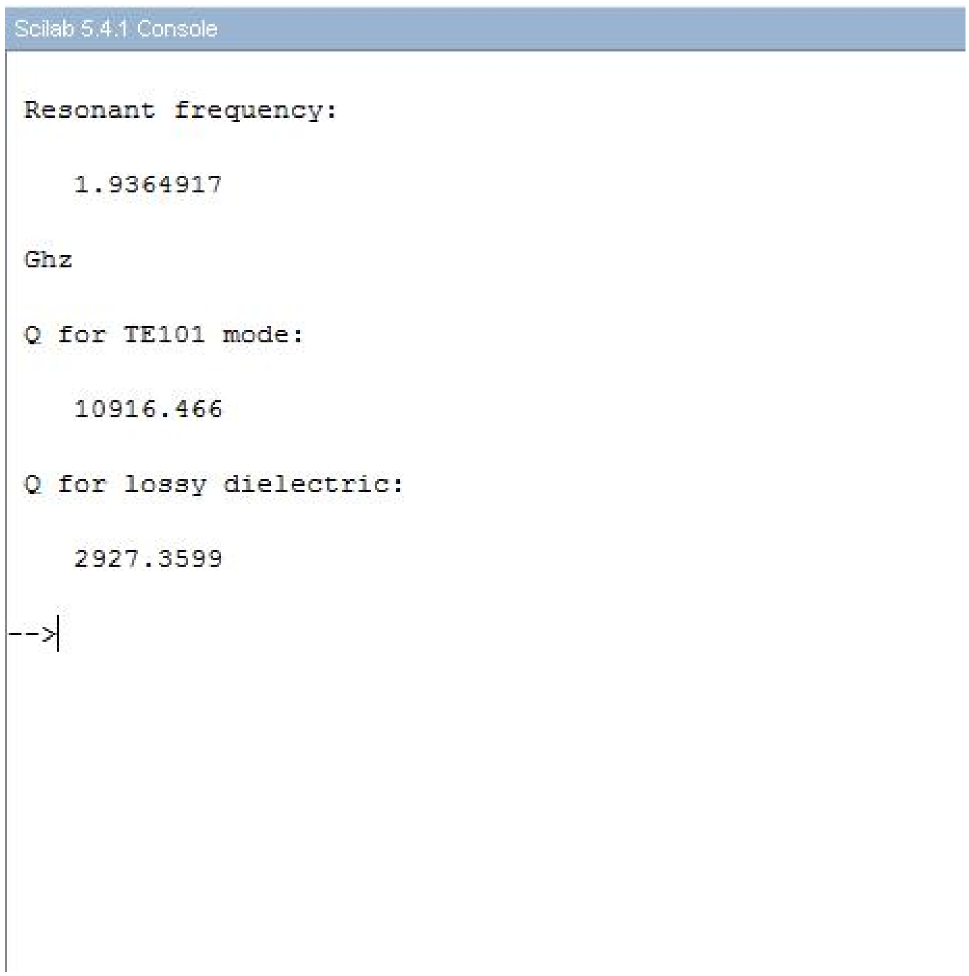



Figure 4.8: Rectangular Resonant Cavity

```
ur=1;
spl=3D+8;
tandel=2.5D-4;

//TE101 mode
m=1;
n=0;
p=1;
fr=(spl/(2*sqrt(er*ur)))*sqrt((m/a1)^2+(n/b1)^2+(p/
    c1)^2);//hz
disp('Ghz',fr/10^9,'Resonant frequency:');

w=2*%pi*fr;
rs=sqrt((w*u0)/(2*sig));//ohm
lamr=spl/(fr*sqrt(er));
x=(((a1*b1)/(c1^2))+((c1^2+a1^2)/(2*c1*a1))+((b1*c1)
    /a1^2));
qw=(2*%pi*(eet/sqrt(er))*a1*b1*c1)/(rs*(lamr^3)*x);
disp(qw,'Q for TE101 mode:');

qd=1/tandel;
q=(qw*qd)/(qw+qd);
disp(q,'Q for lossy dielectric:');

//Value of qw is calculated wrong in book as lamr
    comes to be 0.08 not 0.89 m
```

**Scilab code Exa 4.9** Rectangular resonator

```
//Page Number: 198
//Example 4.9
clc;
//Given
```

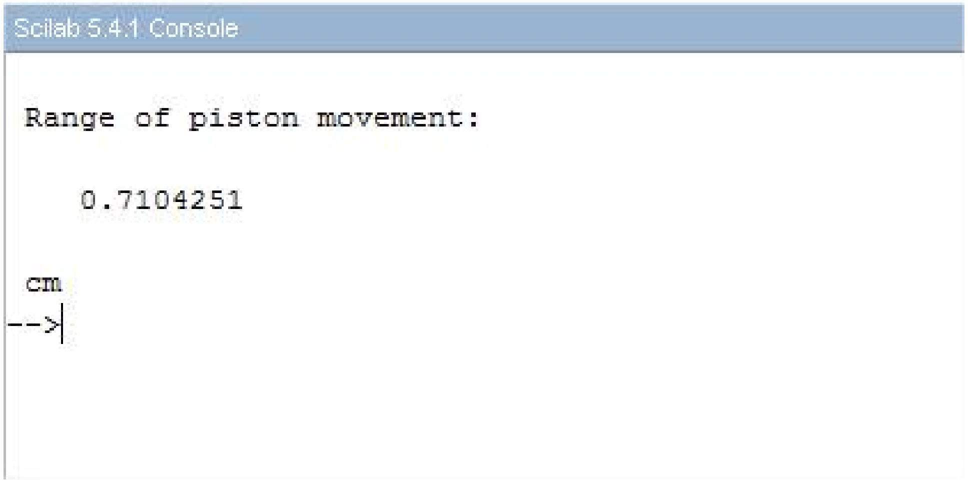



Figure 4.9: Rectangular resonator

```
c=3D+8; //m/s
a=2.286;//cm
a1=a/100;//m
b=1.106;//cm
b1=b/100;//m

//For fr1=9.3D+9;
fr1=9.3D+9;//hz
lamr1=c/fr1;//m
c1=(2*a1)/sqrt((((2*a1)/lamr1)^2)-1);

//For fr2=10.2D+9;
fr2=10.2D+9;//hz
lamr2=c/fr2;//m
c2=(2*a1)/sqrt((((2*a1)/lamr2)^2)-1);

r=c1-c2;
disp('cm',r*100,'Range of piston movement:');
```

**Scilab code Exa 4.10** Cylindrical resonator

```
//Page Number: 199
//Example 4.10
clc;
//Given
a=3;//cm
a1=a/100;//m
d=10;//cm
d1=d/100;//m
df=2.5D+6;
er=2.25;
p11=1.841;
c=3D+8; //m/s

//Resonant frequency
fr=(c/2)*(sqrt((p11/a1)^2+(%pi/d1)^2));//hz
disp('Ghz',fr/10^9,'Resonant frequency:');

//Q without dielectric
q0=fr/df;
disp(q0,'Q wirhout dielectric constant:');

// Q with dielectric
fr1=fr/sqrt(er);
qd=1D+3;
q=(q0*qd)/(q0+qd);
disp(q,'Q with dielectric constant:');
```

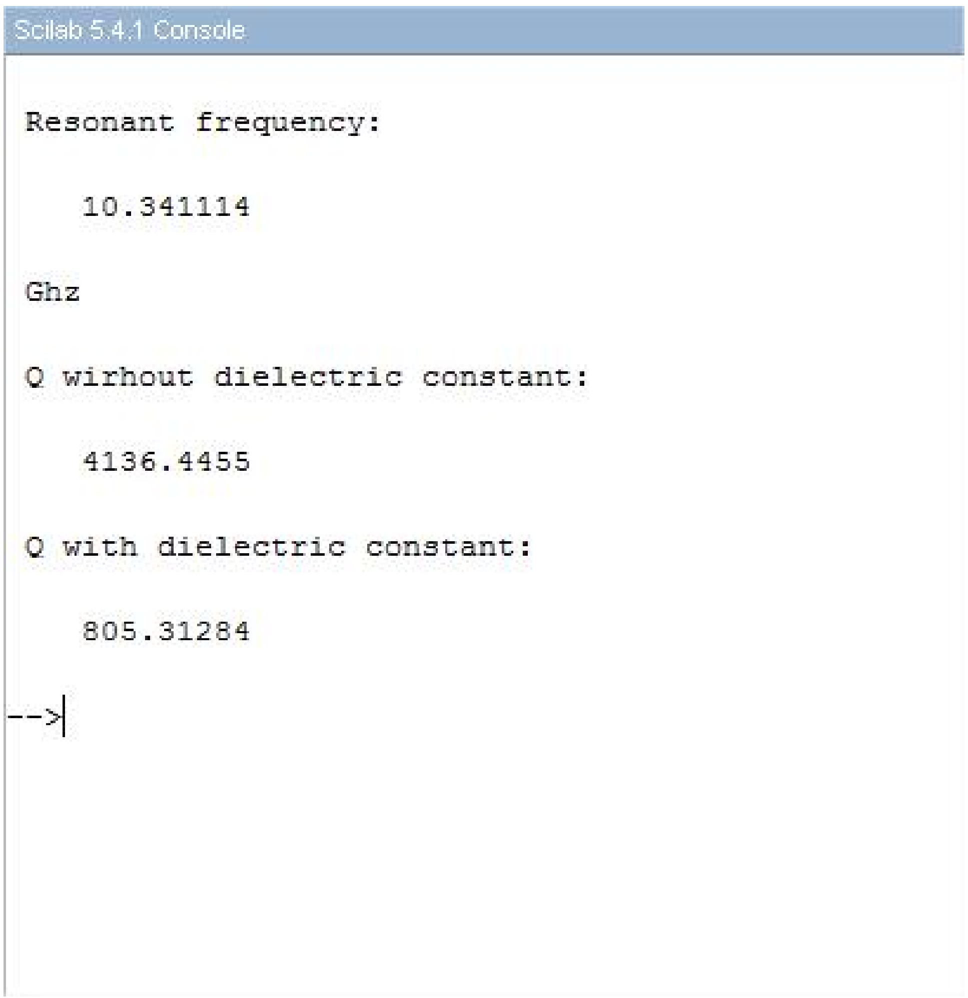



Figure 4.10: Cylindrical resonator

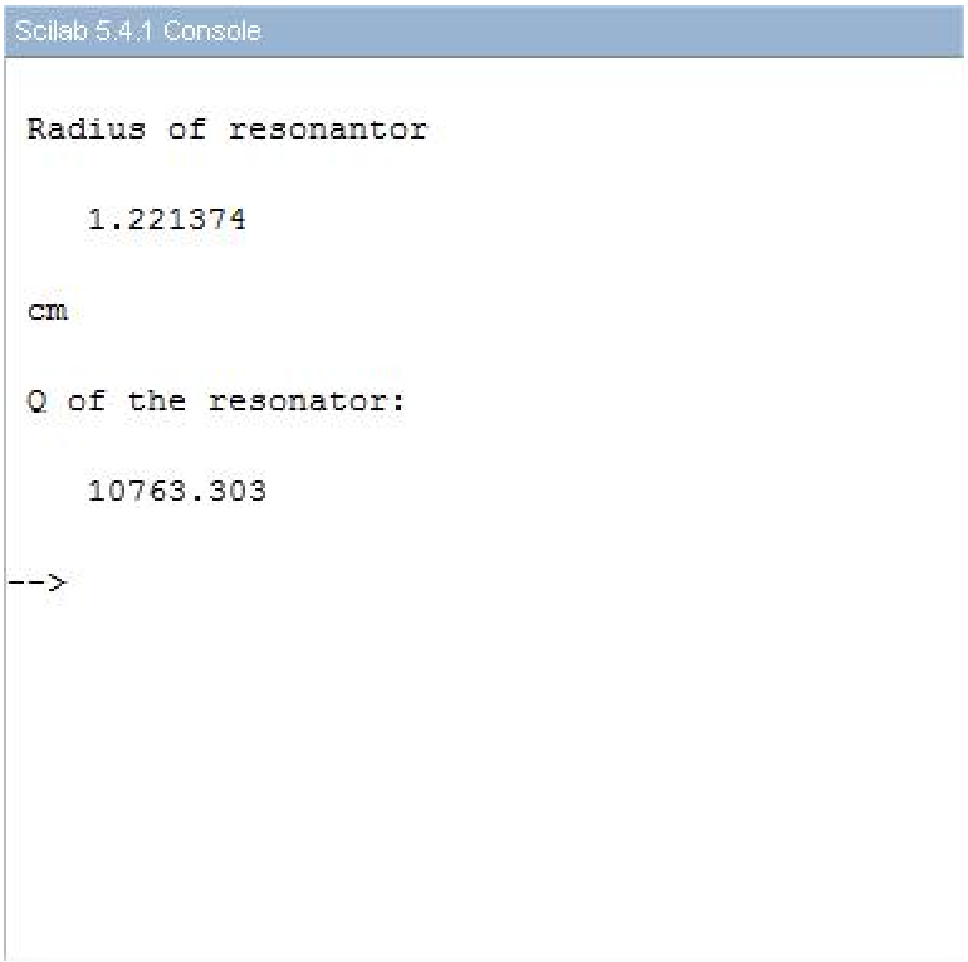



Figure 4.11: Cylindrical resonantor

**Scilab code Exa 4.11** Cylindrical resonantor

```
//Page Number: 200
//Example 4.11
clc;
//Given
f=9.375D+9;//hz
sig=5.8D+7;
eet=377;
c=3D+8; //m/s
w=2*%pi*f;
r=1.5;
u=4D-7*%pi;

//Radius
a=c/(f*2.62);//m
disp('cm',a*100,'Radius of resonantor');

//O
rs=sqrt((w*u)/(2*sig));//ohm
x=1.202*eet;
y=rs*(1+(1/r));
q=x/y;
disp(q,'Q of the resonator:');

//Answer for Q is calculated as 10875 in book but it
    is 10763.303
```

**Scilab code Exa 4.12** Cylindrical Resonator

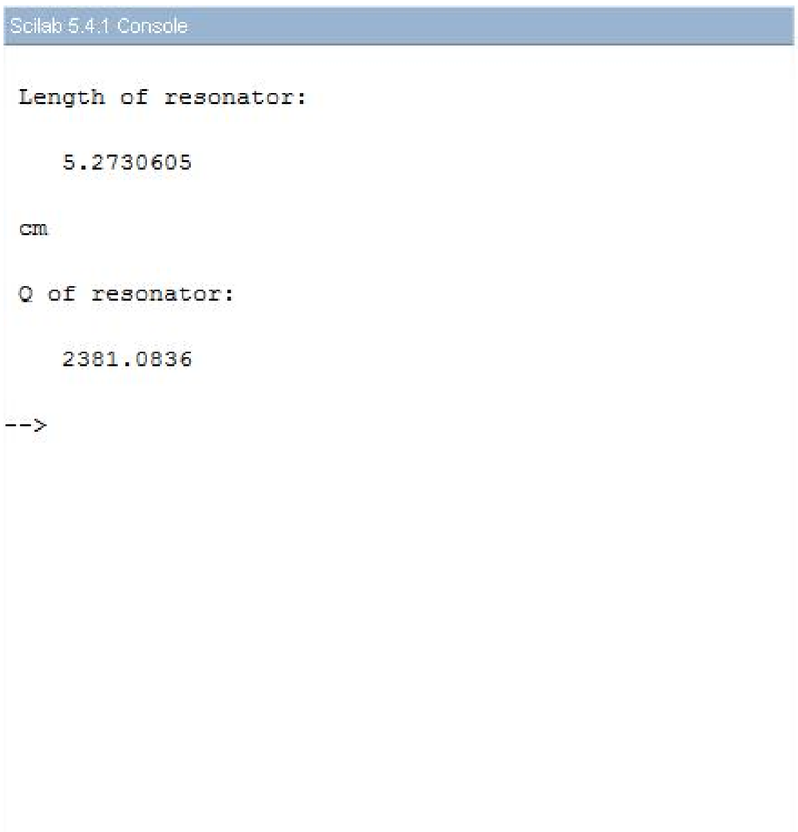



Figure 4.12: Cylindrical Resonator

```
//Page Number: 215
//Example 4.12
clc;
//Given
f=5D+9;//hz
sig=5.813D+7;
er=2.25;
tandel=4D-4;
c=3D+8; //m/s
h01=3.832;
u=4D-7*%pi;

//Length of resonator
lamr=c/(f*sqrt(er));
d=sqrt([{(((2*3.832)^2)+(%pi*%pi))*(lamr*lamr)
    }/(2*2*%pi*%pi)]);
disp('cm',d*100,'Length of resonator:');

//Q of resonator
n=(120*%pi)/sqrt(er);
Rs=sqrt((f*u)/sig);
a=d/2;
Qw1=n*[[(h01/a)^2+(%pi/d)^2]^(3/2)];
Qw2=2*Rs*[((h01*h01)/(a*a*a))+((2*%pi*%pi)/(d*d*d))
    ];
Qw=Qw1/Qw2;
Qd=1/tandel;
Q=(Qw*Qd)/(Qw+Qd);
disp(Q,'Q of resonator:');

//Value of Qw is calculated wrong in the book, it
    should be 50057.91 instead of 53473.8
//Hence the value of Q also differs
```

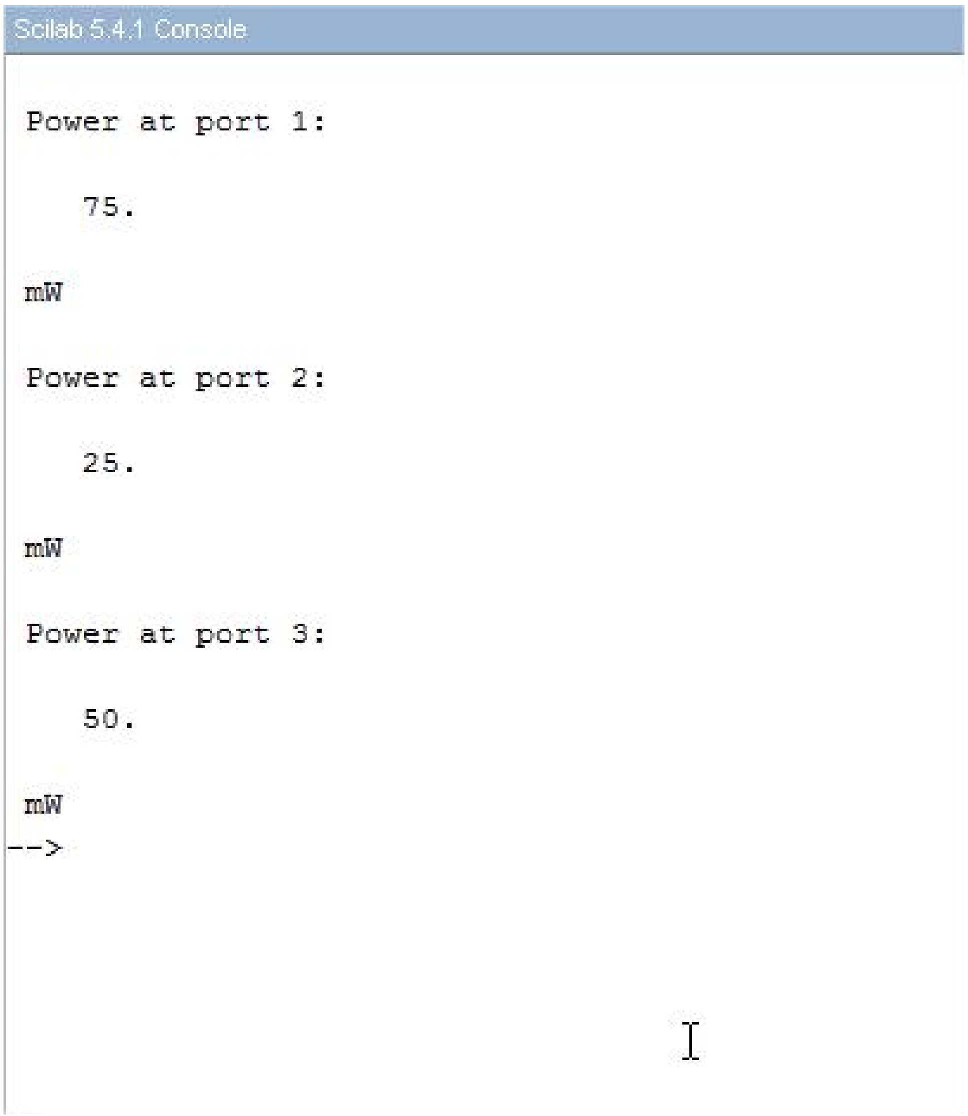



Figure 4.13: Lossless plane H tee

**Scilab code Exa 4.13** Lossless plane H tee

```
//Page Number: 215
//Example 4.13
clc;
//Given
p=100; //mW
//As 2 and 3 are matched terminals
x=1/2;
y=1/sqrt(2);
s=[x -x y;-x 0 y;y y 0];

//Power delivered
//Port 1
p1=p*(1-s(1,1)^2);
disp('mW',p1,'Power at port 1:');

//Port2
p2=p*s(2,1)^2;
disp('mW',p2,'Power at port 2:');

//Port 3
p3=p*s(3,1)^2;
disp('mW',p3,'Power at port 3:');
```

**Scilab code Exa 4.14** E plane tee

```
//Page Number: 216
//Example 4.14
clc;
//Given
p=40; //mW
//Since port 3 is matched
```

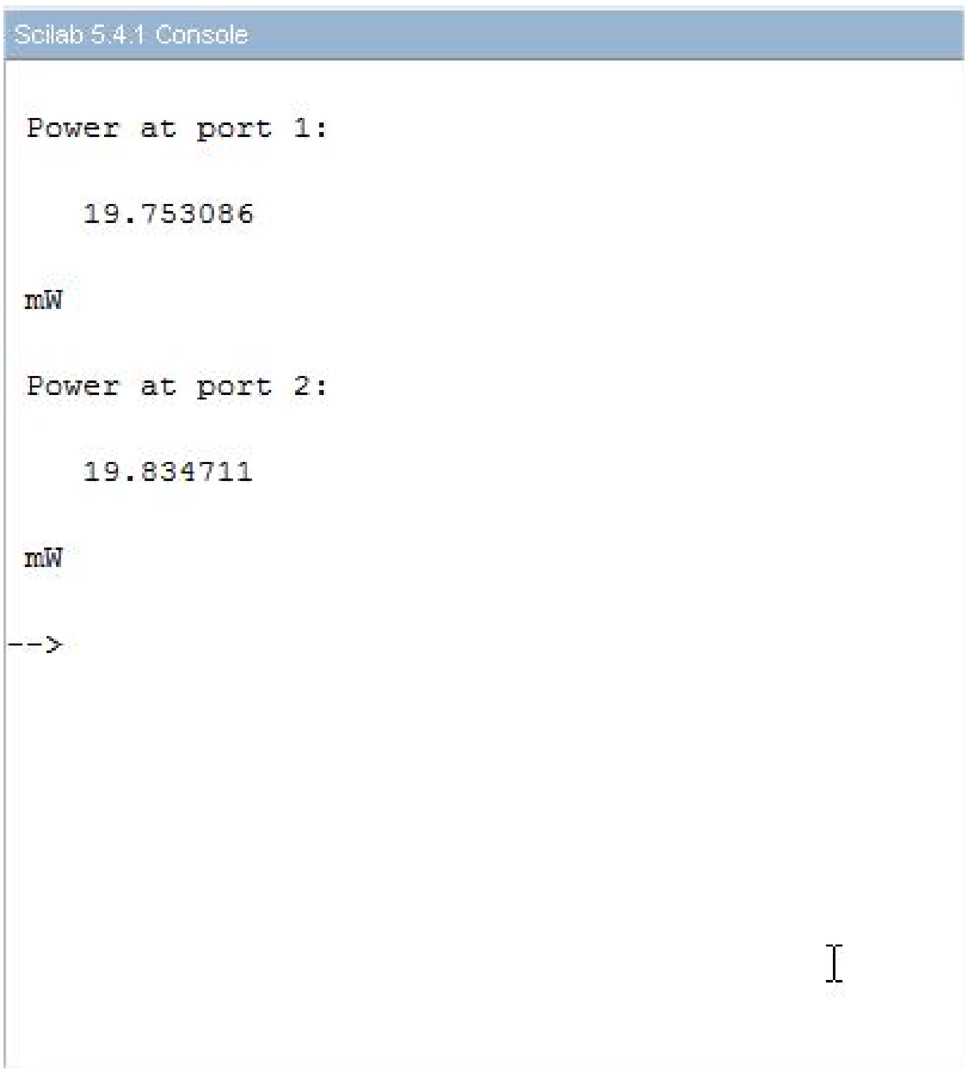



Figure 4.14: E plane tee

```
x=sqrt(2);
s=[1 1 x;1 1 -x;x -x 0];
r1=40; //ohm
r2=60; //ohm
w=50; //ohm

//Reflection coefficients
T1=(w-r1)/(w+r1);
T2=(r2-w)/(r2+w);

//As power is fed into 1 and 2 equally
pd=p/2;

//Power delivered
//Port 1
p1=pd*(1-T1^2);
disp('mW',p1,'Power at port 1:');

//Port2
p2=pd*(1-T2^2);
disp('mW',p2,'Power at port 2:');
```

**Scilab code Exa 4.15** Magic Tee

```
//Page Number: 216
//Example 4.15
clc;
//Given
T1=1/2;
T2=3/5;
T3=0;
T4=4/5;
p=500D-3; //W
```

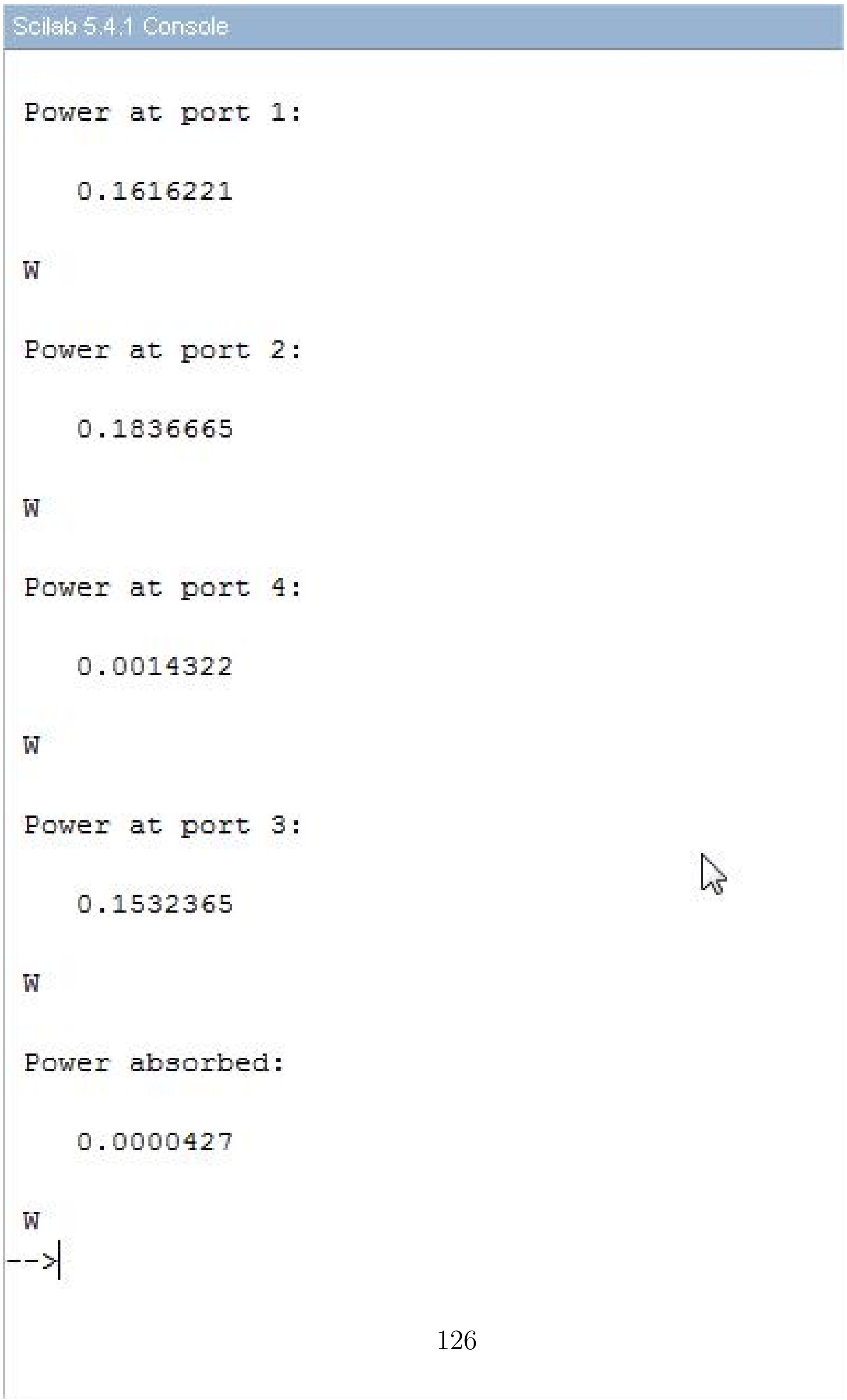



Figure 4.15: Magic Tee

```
//S matrix for magic Tee
x=1/sqrt(2);
s=[0 0 x x;0 0 x -x;x x 0 0;x -x 0 0];
//Using the input output relation
//[b]=[s]*[a]
b=[0.6565;0.7576;0.5536;0.0892];

//(i) Power transmitted through ports
//Port 1
p1=(1/2)*b(1,1)^2*(1-T1^2);
disp('W',p1,'Power at port 1:');

//Port2
p2=(1/2)*(b(2,1)^2)*(1-(T2^2));
disp('W',p2,'Power at port 2:');

//Port 4
p4=(1/2)*b(4,1)^2*(1-T4^2);
disp('W',p4,'Power at port 4:');

//(ii) Power reflected at port 3
//Port 3
p3=p*b(3,1)^2;
disp('W',p3,'Power at port 3:');

//(iii) Power absorbed
pabs=p-(p1+p2+p3+p4);
disp('W',pabs,'Power absorbed:');

//Answer for power absorbed is calculated wrong in
   book
```

**Scilab code Exa 4.18** Directional Coupler

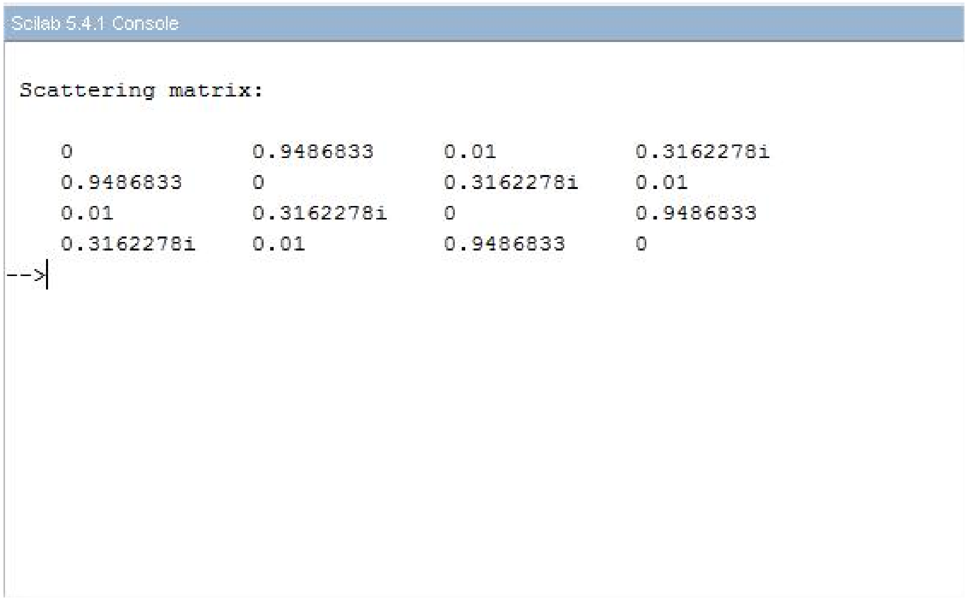



Figure 4.16: Directional Coupler

```
//Page Number: 236
//Example 4.18
clc;
//Given
C=10; //dB
D=30; //dB

//Parameters
bet=10^(-C/20);
x=bet/(10^(D/20));
a=sqrt(1-(bet*bet));
//Scattering matrix
//Assuming symmetery
s=[0 a x (bet*%i);a 0 (bet*%i) x;x (bet*%i) 0 a;(bet
    *%i) x a 0];
disp(s,'Scattering matrix:');
```

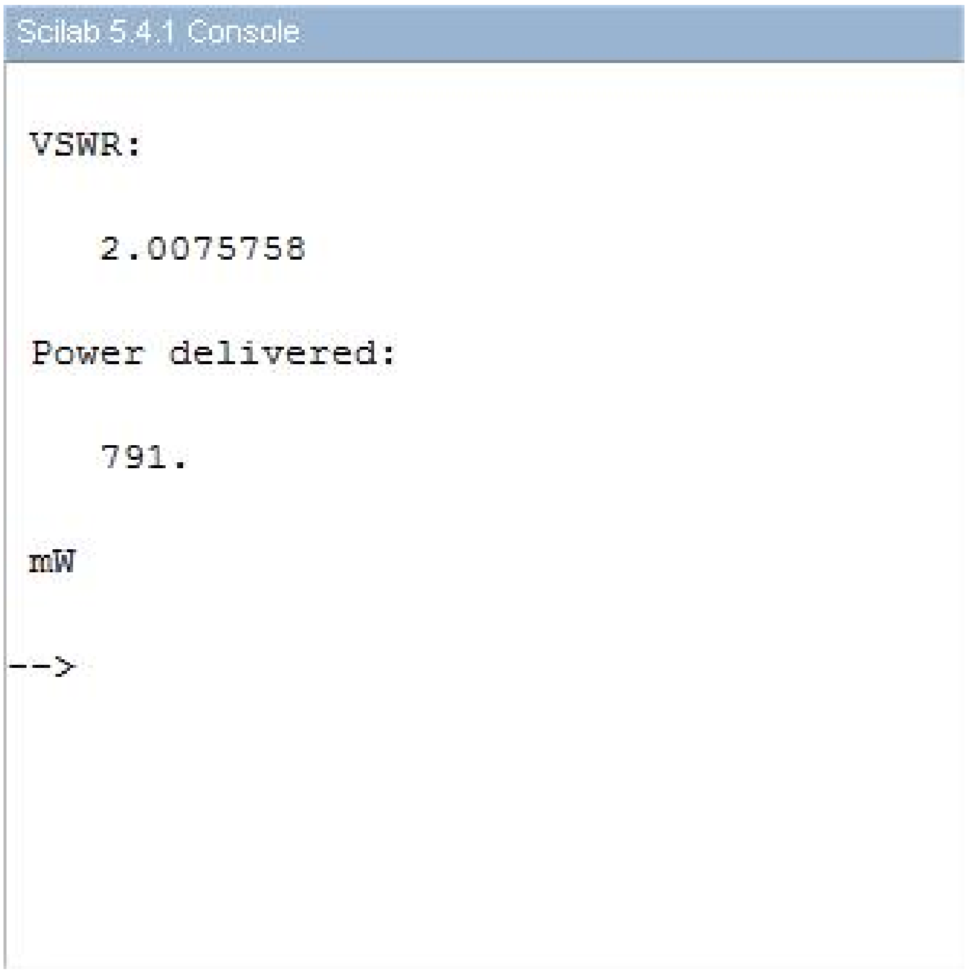



Figure 4.17: Directional coupler

**Scilab code Exa 4.20** Directional coupler

```
//Page Number: 238
//Example 4.20
clc;
//Given
vswr=2;
D1=8; //mW
D2=2; //mW

//Reflection coefficient at arm 4
T=(vswr-1)/(vswr+1);
//Powwe delivered to D1
P=(D1*100)/(1-T^2);
P1=0.99*P;
//Power reflected at D1
W1=(P/100)*T*T;
//Power reflected at load
W2=D2-W1;
Tt=sqrt((W2*100)/(P1));
pt=(1+Tt)/(1-Tt);
disp(pt,'VSWR:');
Pl=P1*(1-(Tt*Tt));
disp('mW',Pl,'Power delivered:');

//Answer for P1 should be 792 but it is given as 800
```

**Scilab code Exa 4.21** Isolator Matrix

```
//Page Number: 239
```

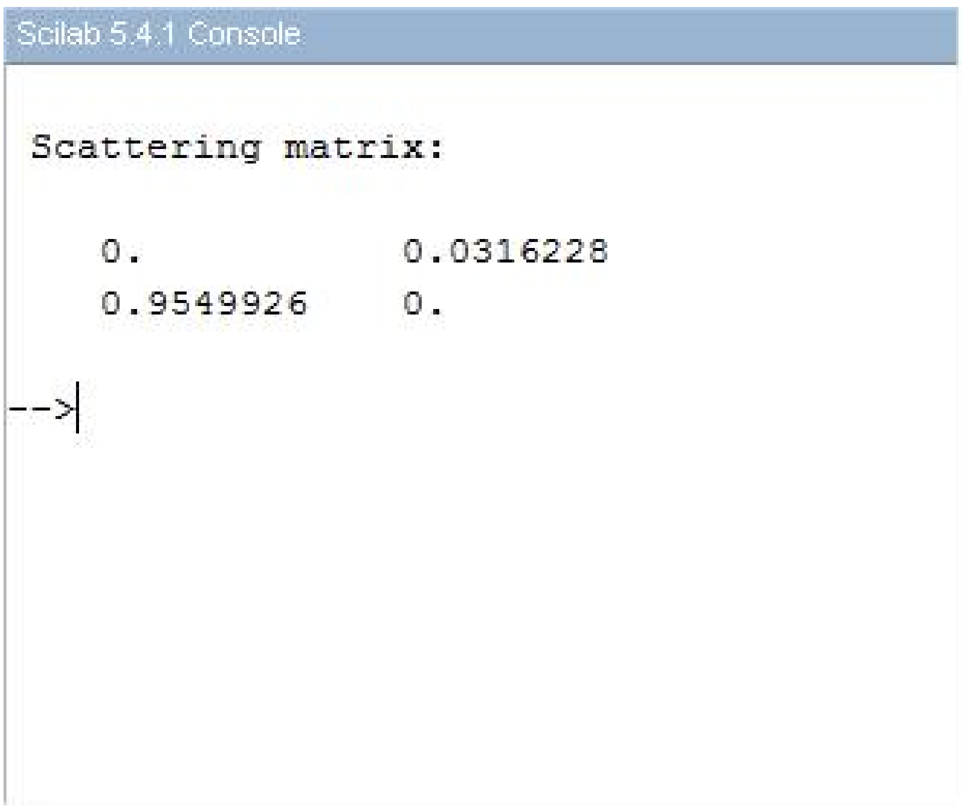



Figure 4.18: Isolator Matrix

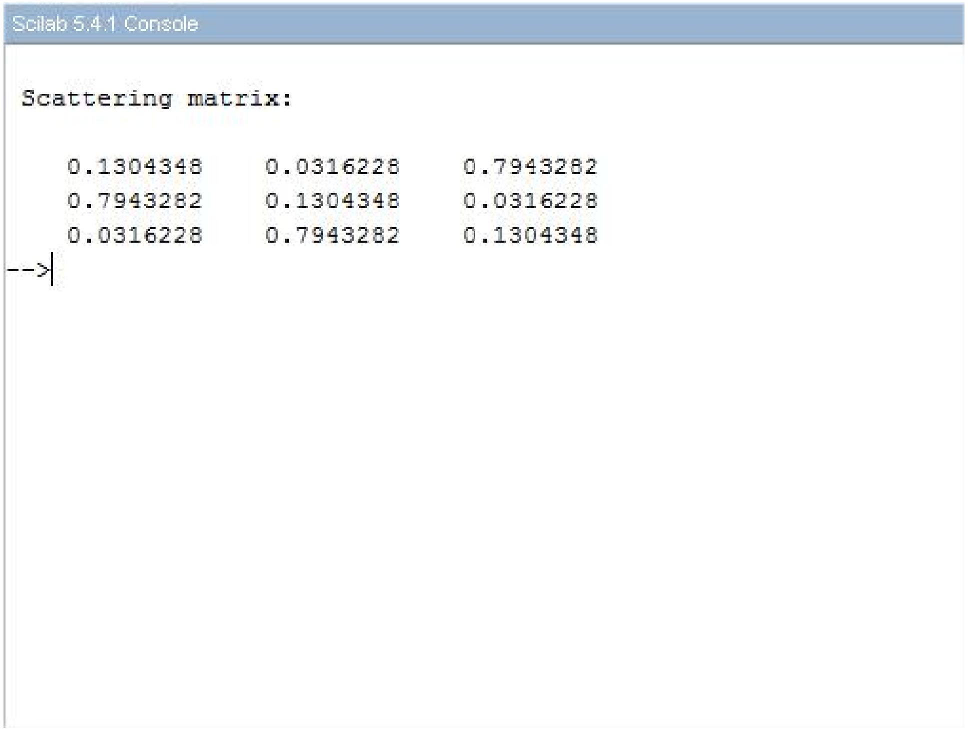



Figure 4.19: Circulator Matrix

```
//Example 4.21
clc;
//Given
I=30; //dB
Il=0.4; //dB

S12=10^(I/-20);
S21=10^(Il/-20);
s=[0 S12;S21 0];
disp(s,'Scattering matrix:');
```

**Scilab code Exa 4.22** Circulator Matrix

```
//Page Number: 240
//Example 4.22
clc;
//Given
I=30; //dB
Il=2; //dB
p=1.3;

//Elelments
T=(p-1)/(p+1);
S11=T;
S22=T;
S33=T;
S12=10^(-Il/20);
S13=10^(-I/20);
S21=S13;
S32=S13;
S23=S12;
S31=S23;
s=[S11 S21 S31;S12 S22 S32;S13 S23 S33];
disp(s,'Scattering matrix:');
```

**Scilab code Exa 4.23** Rectangular Waveguide

```
//Page Number: 249
//Example 4.23
clc;
//Given
f=10D+9; //Hz
u=4D-7*%pi;
c=3D+8; //m/s
```

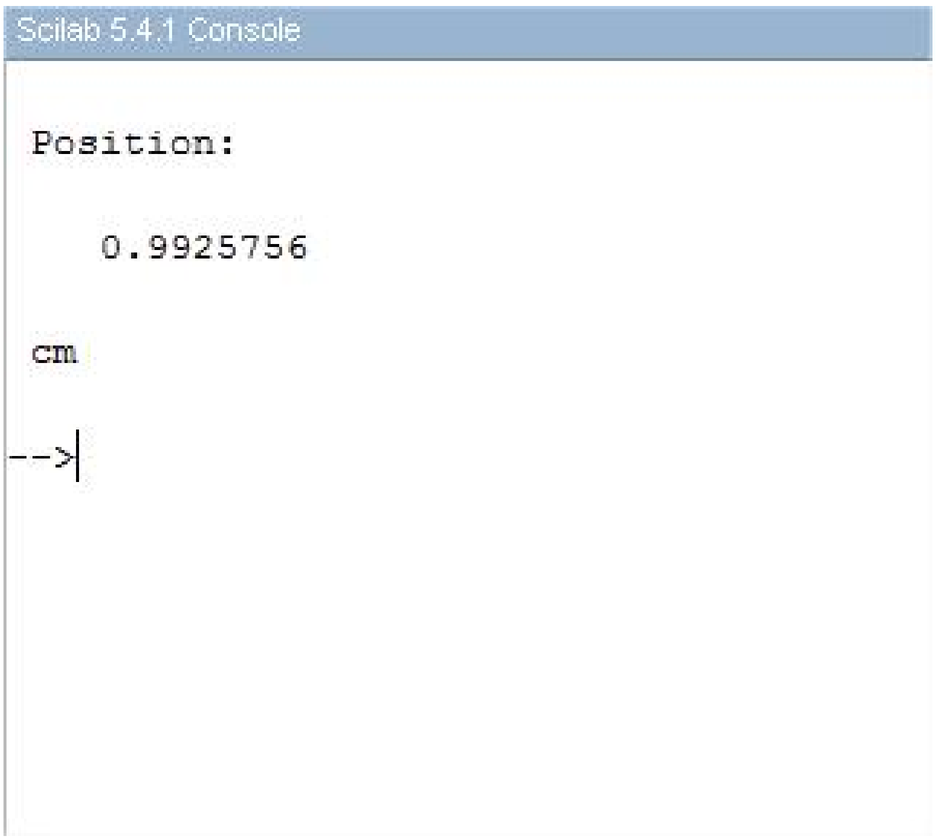



Figure 4.20: Rectangular Waveguide

```
a=2.29; //cm
a1=a/100;
b=1.02; //cm
b1=b/100;

//E/H
w=2*%pi*f;
EbyH=(w*u)/sqrt(((w/c)^2)+((%pi/a1)^2));
lam=c/f;
lamc=2*a1;
d=(1/4)*(lam/sqrt(1-((lam/lamc)^2)));
disp('cm',d*100,'Position:');

//Answer for positon is calculated wrong in book
```

**Scilab code Exa 4.24** Attenuator matrix

```
//Page Number: 250
//Example 4.24
clc;
//Given
//As it is perfectly matched
S12=1/sqrt(2);
S21=S12;
s=[0 S12;S21 0];
disp(s,'Scattering matrix:');
```

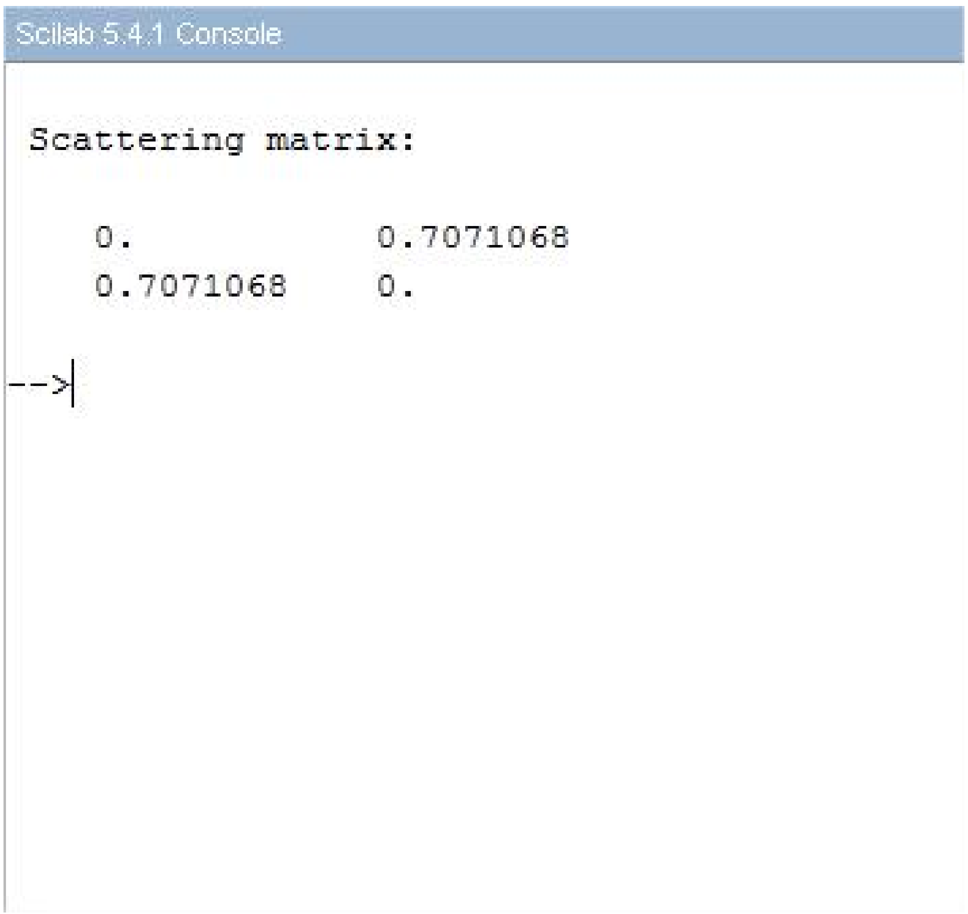



Figure 4.21: Attenuator matrix

# Chapter 5

# Microwave Tubes Klystrons

**Scilab code Exa 5.1** Two Cavity Klystron

```
//Page Number: 288
//Example 5.1
clc;
//Given
f=10D+9; //Hz
v=9D+3; //V
i=40D-3; //A
l=3; //cm
l1=l/100; //m
G=2D-6; //mho
bet=0.92;
j1x=0.582;
x=1.841;
ebym=1.7D+11; //J

//Maximum voltage
w=2*%pi*f;
v0x=sqrt(2*ebym);
thet=(w*l1)/(v0x*sqrt(v));
```

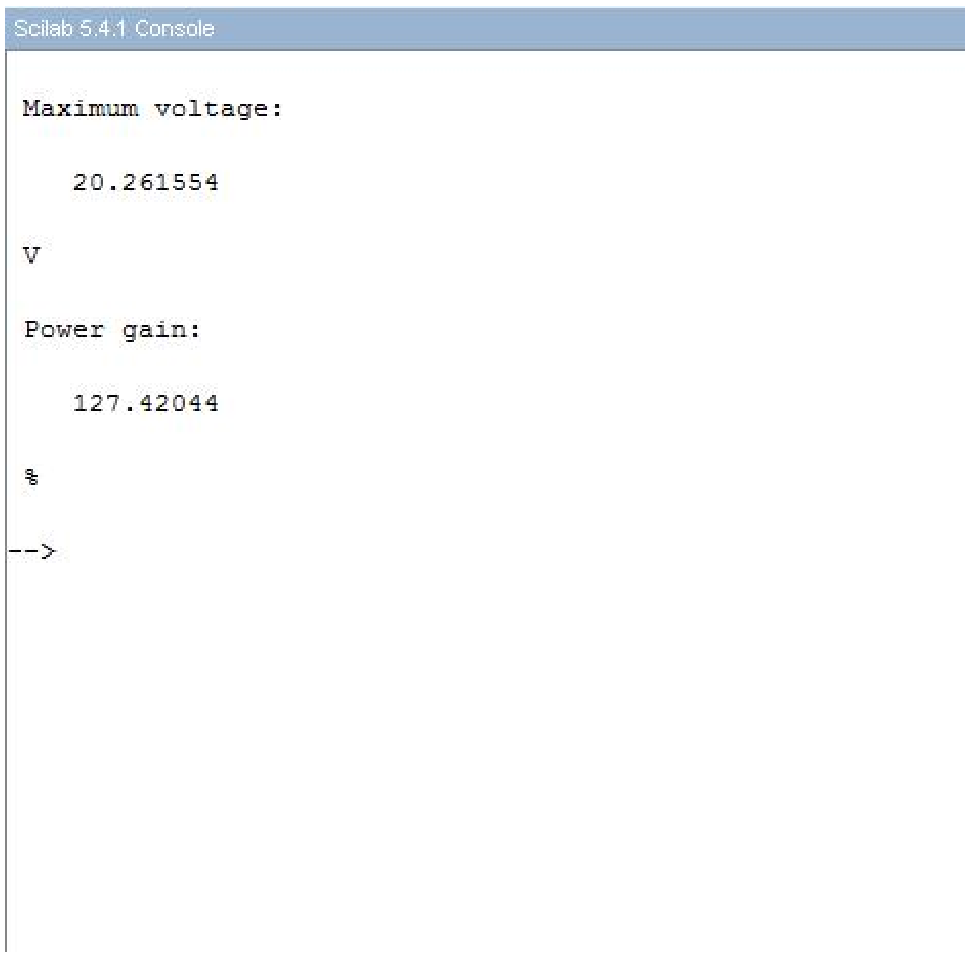



Figure 5.1: Two Cavity Klystron

```
av=(bet^2*thet*i*j1x)/(x*v*G);
disp('V',av,'Maximum voltage:');

//Power Gain
ic=2*i*j1x;
v2=(bet*ic)/G;
pout=bet*ic*v2;
pin=2*i*v;

//Efficiency
eet=pout/pin;
disp('%',eet*100,'Power gain:');

//Answer for effciency comes out to be wrong, it is
    calculted wrongly in book
```

**Scilab code Exa 5.2** Two cavity Klystron

```
//Page Number: 288
//Example 5.2
clc;
//Given
l=2; //cm
l1=l/100;//m
f=5D+9; //Hz
i=25D-3; //A
n=21/4;
e=1.6D-19;
m=9.1D-31;
thetag=0;
bet=1;
j1x=0.582;
```

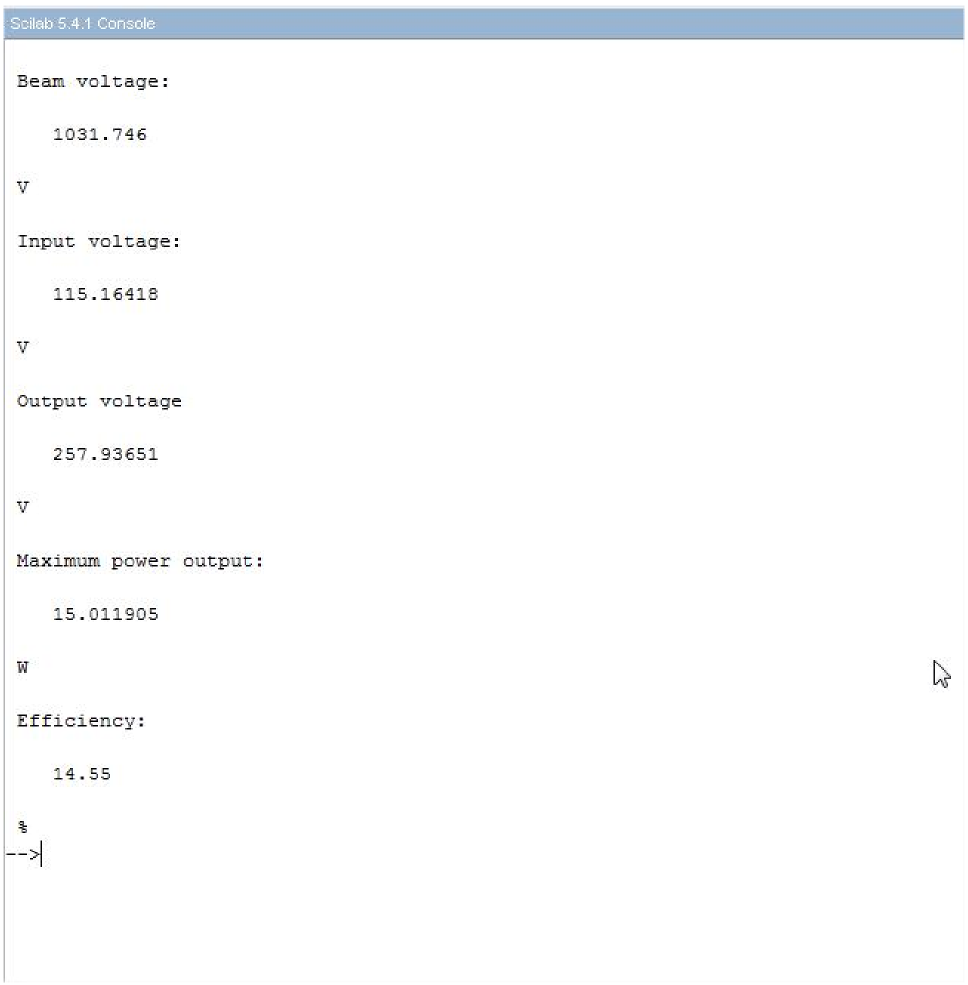



Figure 5.2: Two cavity Klystron

```
x=1.841;

//(i) Beam Voltage
v0=(m*l1*l1*f*f)/(2*e*n*n);
disp('V',v0,'Beam voltage:');

//(ii) Input voltage
v1=x*v0/(%pi*bet*n);
disp('V',v1,'Input voltage:');

//(iii) Output voltage
v2=0.25*v0;
disp('V',v2,'Output voltage');

//(iv) Power output
pmax=i*v0*j1x;
disp('W',pmax,'Maximum power output:');

//(v) Efficiency
eet=j1x*bet*v2/v0;
disp('%',eet*100,'Efficiency:');
```

**Scilab code Exa 5.3** Two cavity Klystron

```
//Page Number: 289
//Example 5.3
clc;
//Given
r0=45D+3; //W
j0=25D-3; //A
V=1500; //V
f=5D+9; //hz
d=1; //mm
```

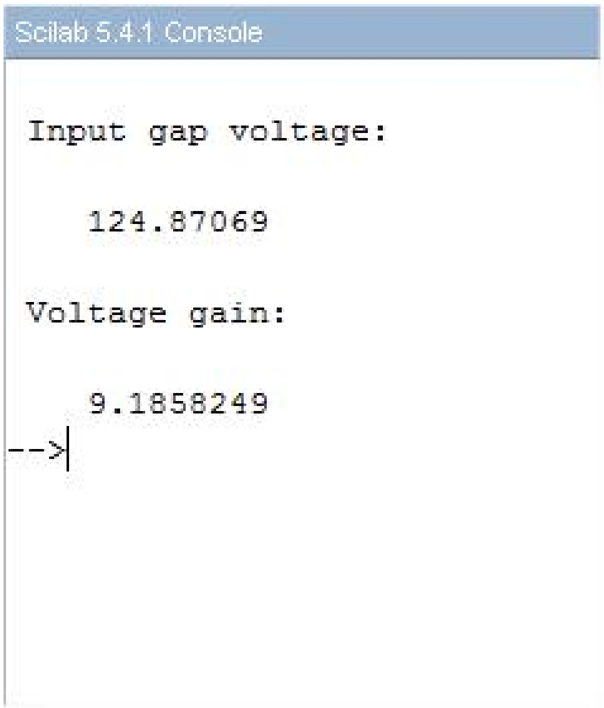



Figure 5.3: Two cavity Klystron

```
d1=d/1000; //m
l=3.5; //cm
l1=l/100; //m
rsh=32D+3; //ohms
j1x=0.582;
x=1.841;

//(i) Input gap voltage
w=2*%pi*f;
v0=(5.93D+5*sqrt(V));
thetag=(w*d1)/v0;
bet=sin(thetag/2)/(thetag/2);
theta0=(w*l1)/v0;
v1=(2*V*x)/(bet*theta0);
disp(v1,'Input gap voltage:');

//(ii) Voltage gain
av=(bet^2*theta0*j1x*rsh)/(r0*x);
disp(av,'Voltage gain:');
```

**Scilab code Exa 5.4** Two cavity Klystron

```
//Page Number: 290
//Example 5.4
clc;
//Given
V=1000;  //V
r0=40D+3; //ohm
i0=25D-3; //A
f=3D+9; //Hz
d=1; //mm
d1=d/1000; //m
l=4; //cm
```


Figure 5.4: Two cavity Klystron

```
l1=4/100; //m
j1x=0.582;
x=1.841;
rsh=30D+3; //ohm

//(i) Input gap voltage
w=2*%pi*f;
v0=(5.93D+5*sqrt(V));
thetag=(w*d1)/v0;
bet=sin(thetag/2)/(thetag/2);
theta0=(w*l1)/v0;
vmax=(2*V*x)/(bet*theta0);
disp('V',vmax,'Input gap voltage:');

//(ii) Voltage gain
av=(bet*bet*theta0*j1x*rsh)/(r0*x);
disp(av,'Voltage gain:');

//(iii) Efficiency
v2=bet*2*i0*j1x*rsh;
eet=(bet*2*i0*j1x*v2)/(2*i0*V);
disp('%',eet*100,'Efficiency:');

//(iv) Beam loading conductance
gbl=(i0/(2*V))*((bet*bet)-(bet*cos(thetag/2)));
disp(gbl,'Beam loading conductance:');

//Ansewr for beam loading conductance is calculated wrong in book
```

**Scilab code Exa 5.5** Two cavity Klystron

```
//Page Number: 291
```

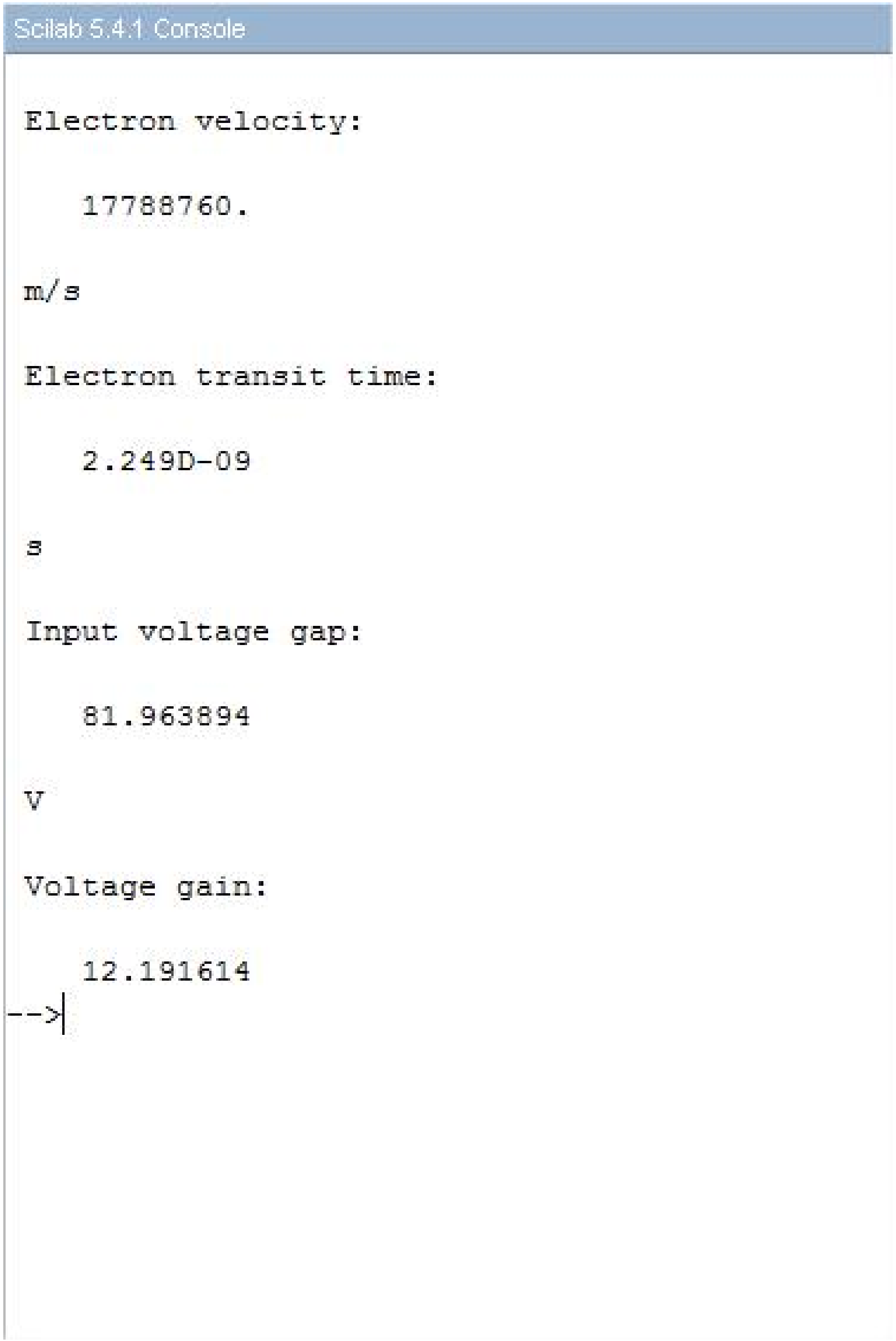



Figure 5.5: Two cavity Klystron

```
//Example 5.5
clc;
//Given
f=3D+9; //hz
v=900; //V
i=30D-3; //A
d=4; //cm
d1=d/100; //m
gap=1; //mm
gap1=1/1000; //m
rsh=40D+3; //ohm
x=1.841;
j1x=0.582;
r=40D+3; //ohm
ebym=1.758D+11; //J

//(i) Electron velocity
v0=sqrt(2*ebym*v);
disp('m/s',v0,'Electron velocity:');

//(ii) Electron transit time
t=d1/v0;
disp('s',t,'Electron transit time:');

//(iii) Input voltage gap
w=2*%pi*f;
theta0=(w*d1)/v0;
thetag=(w*gap1)/v0;
bet=sin(thetag/2)/(thetag/2);
v2=(2*v*x)/(bet*theta0);
disp('V',v2,'Input voltage gap:');

//(iv) Voltage gain
av=(bet^2*theta0*j1x*rsh)/(x*r);
disp(av,'Voltage gain:');

//Values of v and f are changed in question and
   answer, hence vaules used in answer are taken.
```

```
//Also second part has not been done in book
```

**Scilab code Exa 5.6** Two cavity Klystron

```
//Page Number: 292
//Example 5.6
clc;
//Given
f=8D+9; //hz
i=2.5; //A
v=20D+3; //V
bet=1;
amp=10*sqrt(2); //V
rsh=10D+3; //ohm
rsho=30D+3; //ohm
dc=1D-6; //c/m^3
rf=0.5;
e=1.6D-19;
ee=8.854D-12;
m=9.1D-31; //kg

//(i) Induced current
w=2*%pi*f;
wq=rf*sqrt((e*dc)/(m*ee));

//Amplitude of induced current
ic=(i*w*(bet^2)*amp)/(2*v*wq);
disp('A',ic,'Induced current:');

//Induced voltage
icrms=ic/sqrt(2);
v2rms=icrms*rsho;
disp('V',v2rms,'Induced voltage:');
```

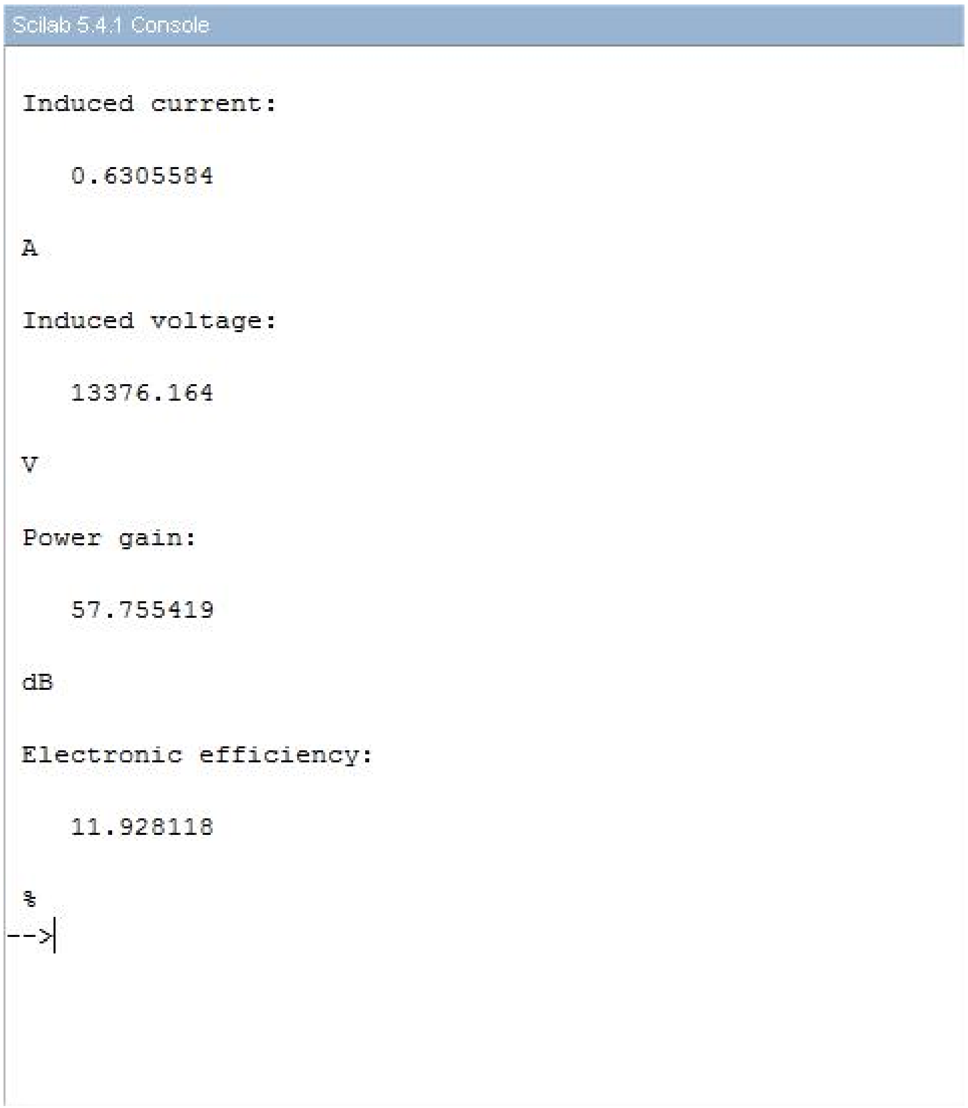



Figure 5.6: Two cavity Klystron

```
//(ii) Power gain
pg=(((i*w)^2)*(bet^4)*rsh*rsho)/(4*((v*wq)^2));
pgdb=10*log10(pg);
disp('dB',pgdb,'Power gain:');

//(iii) Electronic efficiency
eeta=((icrms^2)*rsho)/(i*v);
disp('%',eeta*100,'Electronic efficiency:');
```

**Scilab code Exa 5.7** Two cavity Klystron

```
//Page Number: 294
//Example 5.7
clc;
//Given
f=3D+9; //hz
l=4; //cm
l1=4/100; //m
d=0.1; //cm
d1=d/100; //m
V=900; //V
i0=30D-3; //A
rsh=25D+3;//ohm
x=1.841;
j1x=0.582;

//(i) Input voltage for maximum output
v0=0.593D+6*sqrt(V);
w=2*%pi*f;
theta0=w*l1/v0; //rad
thetag=w*d1/v0; //rad
bet=sin(thetag/2)/(thetag/2);
```

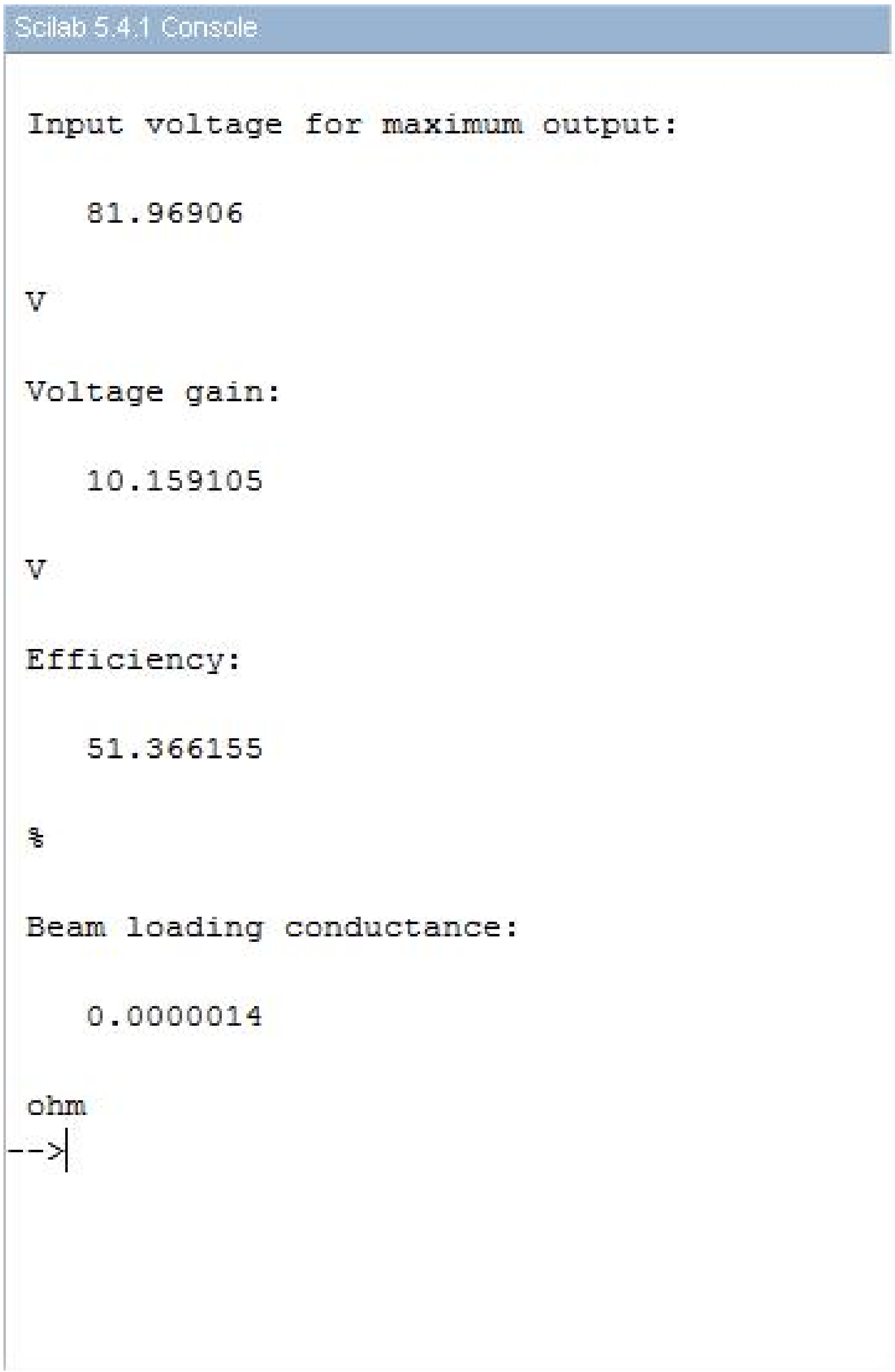
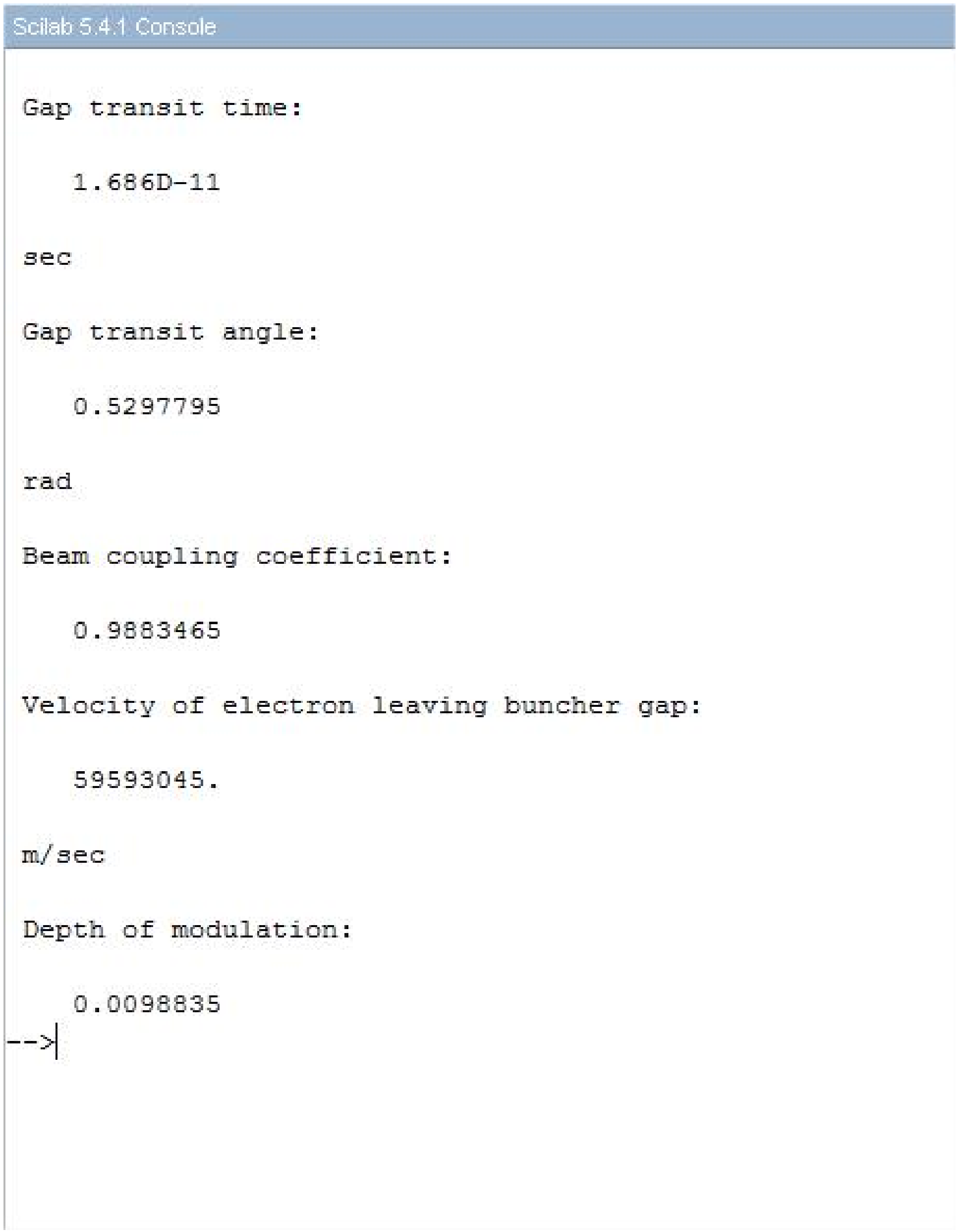



Figure 5.7: Two cavity Klystron

```
v1max=2*V*x/(bet*theta0); //v
disp('V',v1max,'Input voltage for maximum output:');

//(ii) Voltage gain
r0=V/i0;//ohm
av=((bet^2)*theta0*j1x*rsh)/(x*r0);//V
disp('V',av,'Voltage gain:');

//(iii) Efficiency
ic=2*i0*j1x; //A
v2=bet*ic*rsh; //V
eet=bet*ic*v2/(2*i0*V);
disp('%',eet*100,'Efficiency:');

//(iv) Beam loading conductance
gb=(i0/(V*2))*(bet^2-(bet*cos(thetag/2)));//ohm
disp('ohm',gb,'Beam loading conductance:');
```

**Scilab code Exa 5.8** Two cavity Klystron

```
//Page Number: 295
//Example 5.8
clc;
//Given
f=5D+9; //hz
v0=10D+3; //V
d=1; //mm
d1=d/1000; //m
v1=100; //V

//(i) Gap transit time
vv0=0.593D+6*sqrt(v0);//m/sec
tau=d1/vv0;//sec
```



```
Scilab 5.4.1 Console

Gap transit time:

   1.686D-11

sec

Gap transit angle:

   0.5297795

rad

Beam coupling coefficient:

   0.9883465

Velocity of electron leaving buncher gap:

   59593045.

m/sec

Depth of modulation:

   0.0098835
-->
```

Figure 5.8: Two cavity Klystron

```
disp('sec',tau,'Gap transit time:');

//Gap transit angle
w=2*%pi*f;
thetag=w*tau;//rad
disp('rad',thetag,'Gap transit angle:');

//(ii) Beam coupling coefficient
betin=sin(thetag/2)/(thetag/2);
disp(betin,'Beam coupling coefficient:');

//(iii) Velocity of electron leaving buncher gap
vig=vv0*(1+((betin*v1)/(2*v0)));//m/sec
disp('m/sec',vig,'Velocity of electron leaving
    buncher gap:');

//(iv) Depth of modulation
m=betin*v1/v0;
disp(m,'Depth of modulation:');
```

**Scilab code Exa 5.9** Four cavity Klystron

```
//Page Number: 296
//Example 5.9
clc;
//Given
f=10D+9; //hz
v0=15D+3; //V
i0=2.5D-3; //A
d=1; //cm
d1=d/100; //m
vrms=10; //V
bet=1;
```

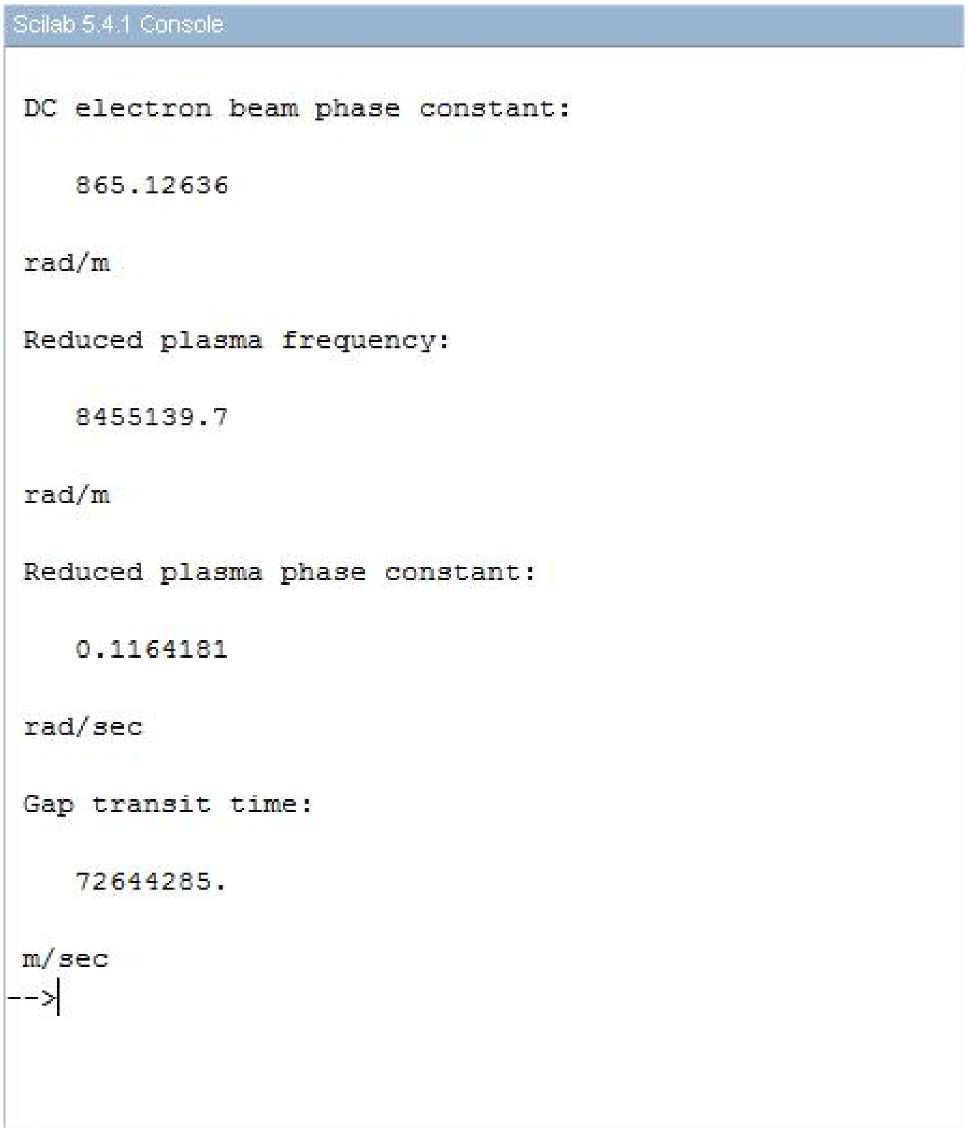



Figure 5.9: Four cavity Klystron

```
p=1D-8; //C/m^3
rf=0.6;
e=1.6D-19;
m=9.1D-31;
ee=8.854D-12;

//(i) DC electron beam phase cobstant
vv0=(0.593D+6*sqrt(v0));
w=2*%pi*f;
bete=w/vv0; //rad/m
disp('rad/m',bete,'DC electron beam phase constant:'
    );

//(ii) Reduced plasma frequency and reduced plasma
    phase constant
wq=rf*sqrt(e*p/(m*ee));//rad/m
disp('rad/m',wq,'Reduced plasma frequency:');
betq=wq/vv0;//rad/sec
disp('rad/sec',betq,'Reduced plasma phase constant:'
    );

//(iii) Gap transit time
tau=d1/vv0;//sec
vtg=vv0*(1+(bet*vrms*sin(w*tau)/(2*v0)));//m/sec
disp('m/sec',vtg,'Gap transit time:');
```

**Scilab code Exa 5.10** Four cavity Klystron

```
//Page Number: 296
//Example 5.10
clc;
//Given
f=4D+9;//hz
```

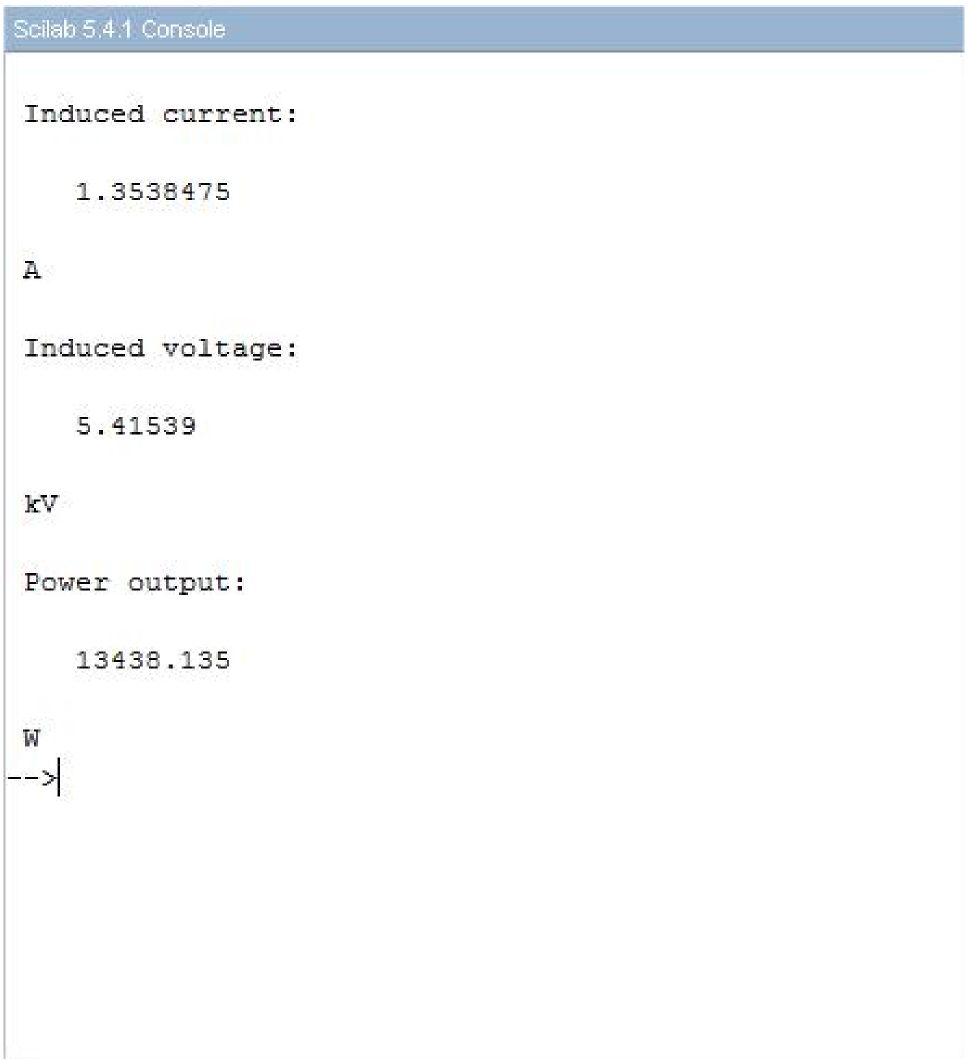



Figure 5.10: Four cavity Klystron

```
v0=10D+3;//V
i0=0.75;//A
v1=2; //V
bet=1;
rsh=10D+3;//ohm
p=5D-5;//C/m^3
r=0.6;
rsht=4D+3;//ohm
e=1.6D-19;
m=9.1D-31;
ee=8.854D-12;

//(i) Induced current and voltage in output cavity
w1=sqrt(e*p/(m*ee));//rad/sec
w=2*%pi*f;
wq=0.5*w1;//rad/sec
rr=w/wq;

i4=[(i0^3)*(rr^3)*(bet^6)*v1*(rsh^2)]/(8*(v0^3)); //A
disp('A',i4,'Induced current:');
v4=i4*rsht;//V
disp('kV',v4/1000,'Induced voltage:');

//(ii) Power output
pout=(i4^4)*rsht;//W
disp('W',pout,'Power output:');

//Answer for Pout should be 13.43 kW but it is given as 10.89kW as value of I4 is calculated as 1.289 but it comes out to be 1.35
```

**Scilab code Exa 5.11** Reflex Klystron

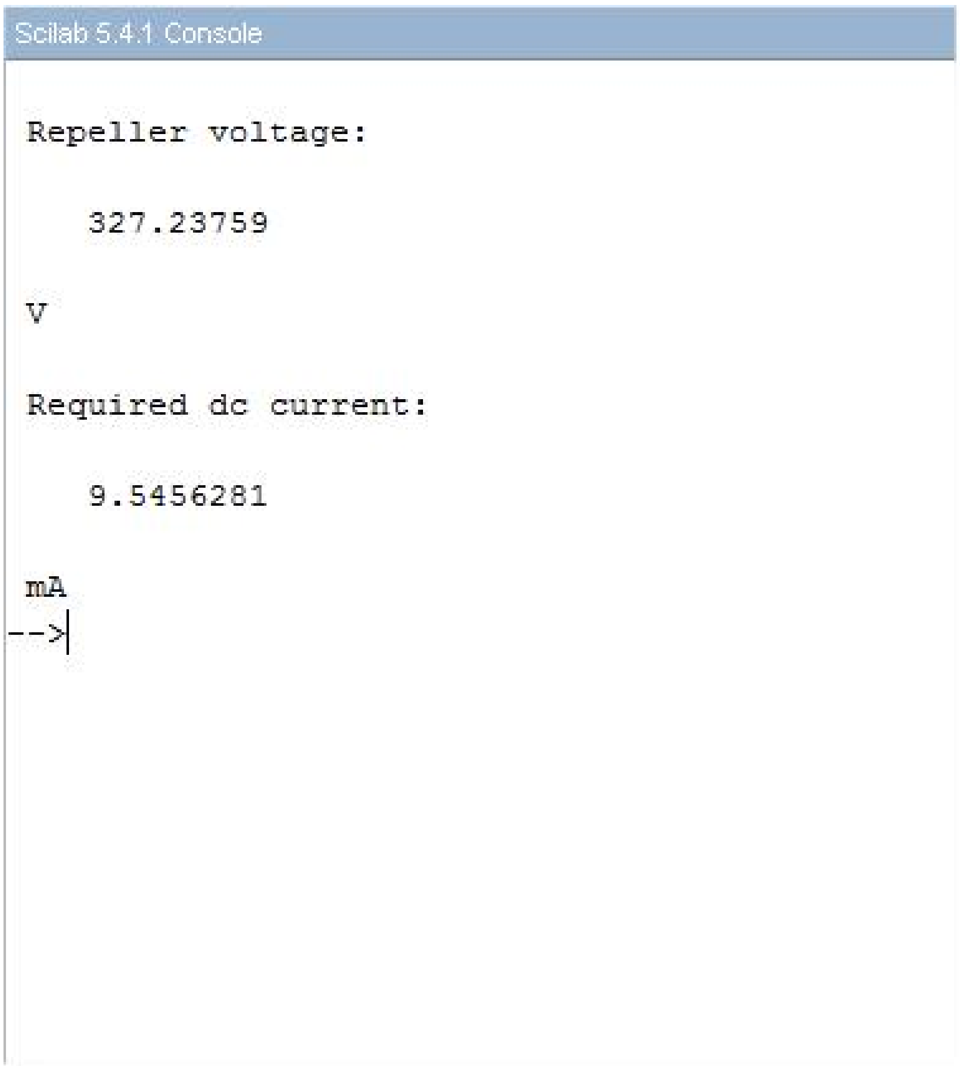



Figure 5.11: Reflex Klystron

```
//Page Number: 297
//Example 5.9
clc;
//Given
f=8D+9;//hz
v0=500;//V
l=1.2;//mm
l1=l/1000;//m
rsh=18D+3;//ohm
ebym=1.759D+11;
ee=8.854D-12;

//(i) Repeller voltage
n=1+(3/4);
v11=(ebym*n*n)/(8*(l1^2)*(f^2));
vr=sqrt(v0/v11)-v0;
disp('V',vr,'Repeller voltage:');

//(ii) Required dc current
v2=200;//V
j1x=0.582;
i=v2/(2*rsh*j1x);//A
disp('mA',i*1000,'Required dc current:');

//Answer for repeller voltage is calculated wrong in
    book
```

**Scilab code Exa 5.12** Reflex Klystron

```
//Page Number: 298
//Example 5.12
clc;
//Given
```

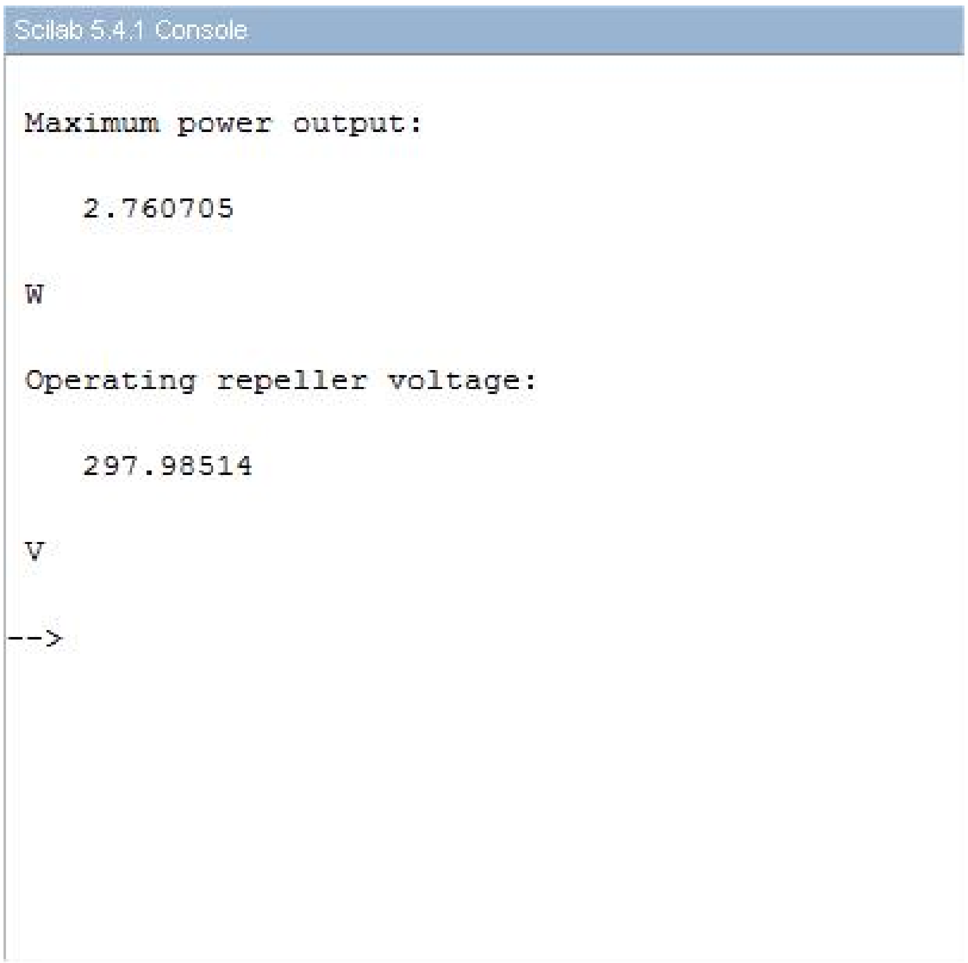



Figure 5.12: Reflex Klystron

```
f=9D+9;//hz
v0=361;//V
i0=30D-3;//A
l=0.1;//cm
l1=l/100;//m
x=2.408;
j1x=0.582;
ebym=1.759D+11;

//Maximum power output
n=1;
pout=2*i0*v0*x*j1x/(2*%pi*(n+(3/4)));//W
disp('W',pout,'Maximum power output:');

//Operating repeller voltage
vr=((6.744D-6*sqrt(v0)*l1*f)/(n+(3/4)))-v0;//v
disp('V',vr,'Operating repeller voltage:');
```

**Scilab code Exa 5.13** Reflex Klystron

```
//Page Number: 298
//Example 5.13
clc;
//Given
f=9D+9;//hz
v0=250;//V
l=0.5;//cm
l1=l/100;//m

//Bandwidth
n=3;
df=(n+(3/4))/(6.774D-6*l1*sqrt(v0));//hz
disp('Mhz',df/10^6,'Bandwidth:');
```

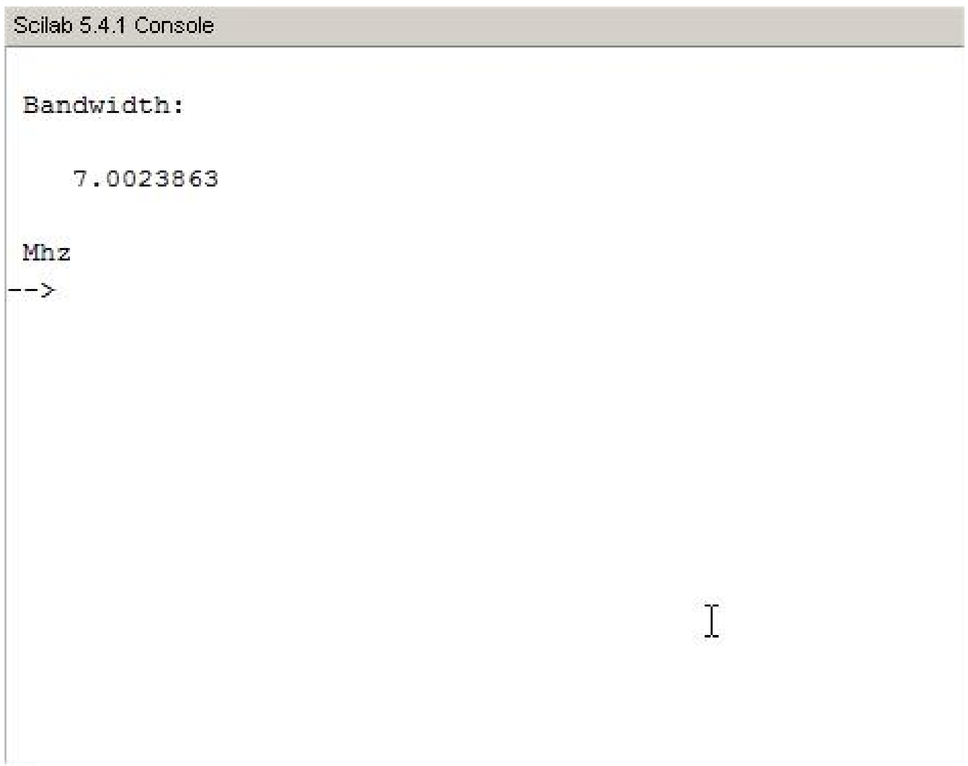



Figure 5.13: Reflex Klystron

**Scilab code Exa 5.14** Reflex Klystron

```
//Page Number: 299
//Example 5.14
clc;
//Given
f=10D+9;//hz
v0=600;//V
vr=250;//V
ebym=1.759D+11;

//Repeller space
n=1;
l=sqrt((ebym*(n+(3/4))^2*(vr+v0)^2)/(8*f^2*v0));//m
disp('mm',l*1000,'Repeller space:');
```

**Scilab code Exa 5.15** Reflex Klystron

```
//Page Number: 299
//Example 5.15
clc;
//Given
v0=300;//V
i0=20D-3;//A
v1=40;//V
n=2;
x=2.408;
```

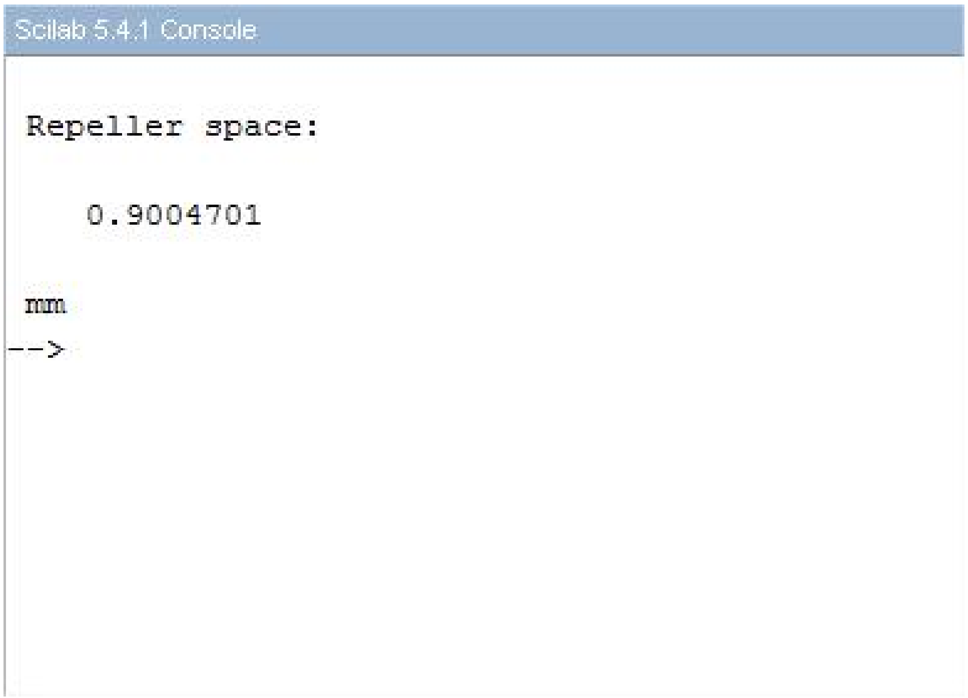



Figure 5.14: Reflex Klystron

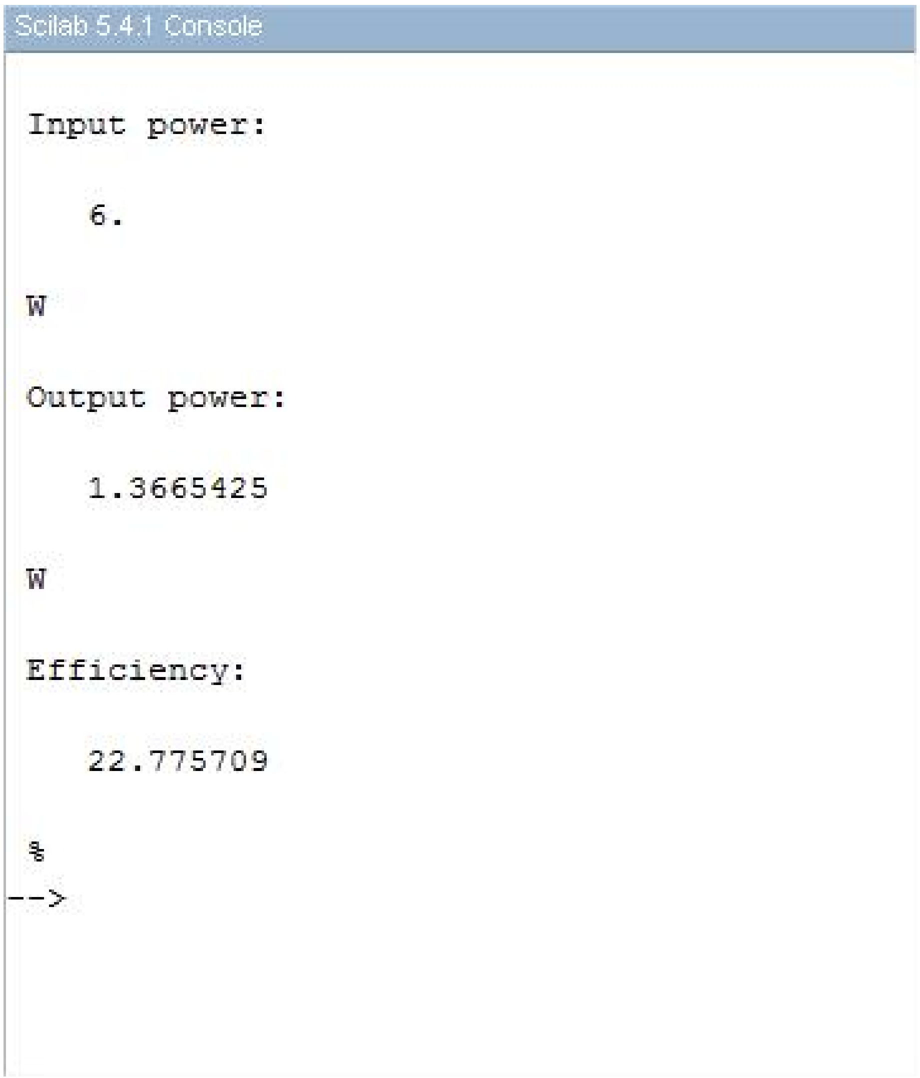



Figure 5.15: Reflex Klystron

```
j1x=0.52;

//(i) Input power
pin=i0*v0;//W
disp('W',pin,'Input power:');

//(ii) Output power
pout=(2*v0*i0*x*j1x)/((2*%pi*n)-(%pi/2));//W
disp('W',pout,'Output power:');

//Efficiency
eet=pout/pin;
disp('%',eet*100,'Efficiency:');

//Answer for output power in book is 0.7 which is wrong, it should be 1.3W
//Hence answer of efficiency also changes
```

**Scilab code Exa 5.16** Reflex Klystron

```
//Page Number: 300
//Example 5.16
clc;
//Given
f=10D+9;//hz
v0=600;//V
l=0.1;//cm
l1=l/100;//m
bet=0.9;
ebym=1.759D+11;
n=2;
j1x=0.575;//from standard table

```

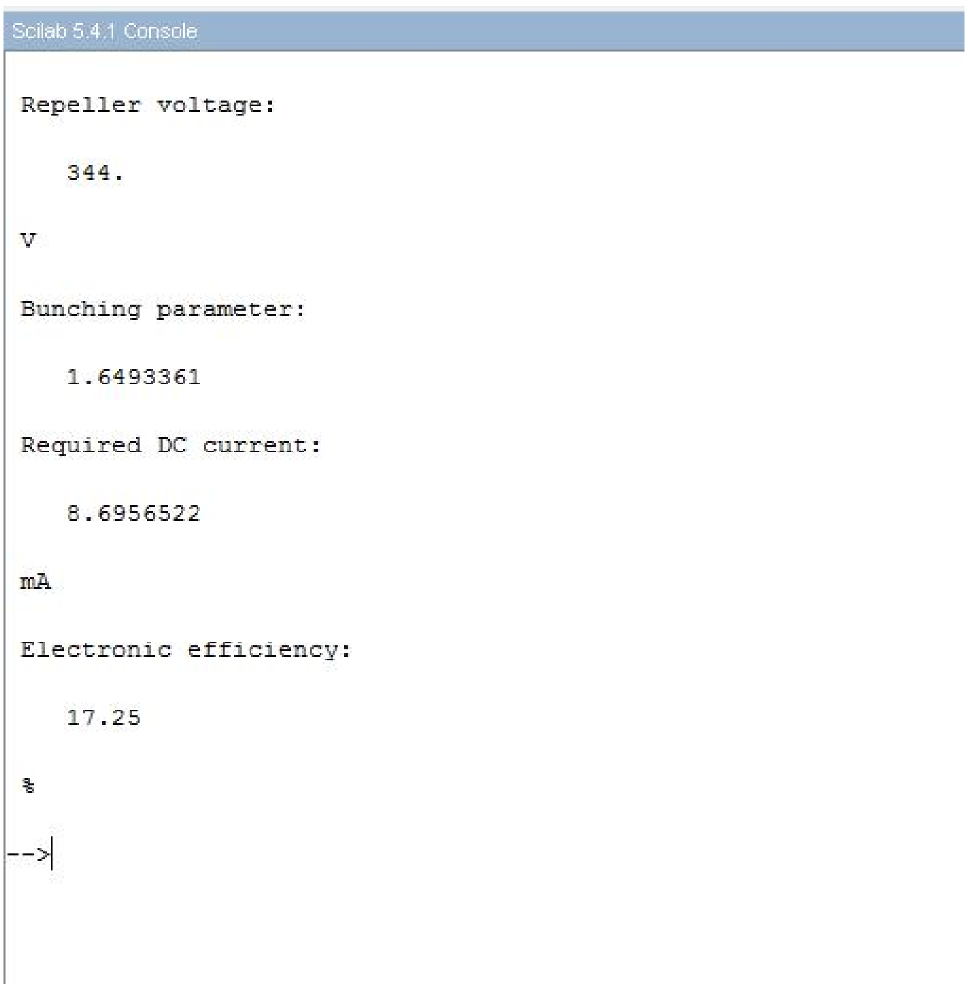



Figure 5.16: Reflex Klystron

```

//(i) Repeller voltage
vr=((6.744D-6*sqrt(v0)*l1*f)/(n-(1/4)))-v0;//V
disp('V',round(vr),'Repeller voltage:');

//(ii) Bunching parameter
v1=200;//V
x=bet*v1*2*%pi*(n-(1/4))/(2*v0);
disp(x,'Bunching parameter:');

//(iii) Required DC current
rsh=20D+3;//ohm
i=v1/(2*rsh*j1x);//A
disp('mA',i*1000,'Required DC current:');

//(iv) Electronic efficiency
eet=2*x*j1x/(2*%pi*(n-(1/4)));
disp('%',eet*100,'Electronic efficiency:');
```

**Scilab code Exa 5.17** Electron Gun

```
//Page Number: 301
//Example 5.17
clc;
//Given
f=10D+9;//hz
v0=300;//V
j0=0.3;//A/cm
i0=45D-3;//A

rb=sqrt(i0/(%pi*j0));//mm
disp('mm',rb*10,'Electron beam radius:');
r=rb*(120/100);//mm
```

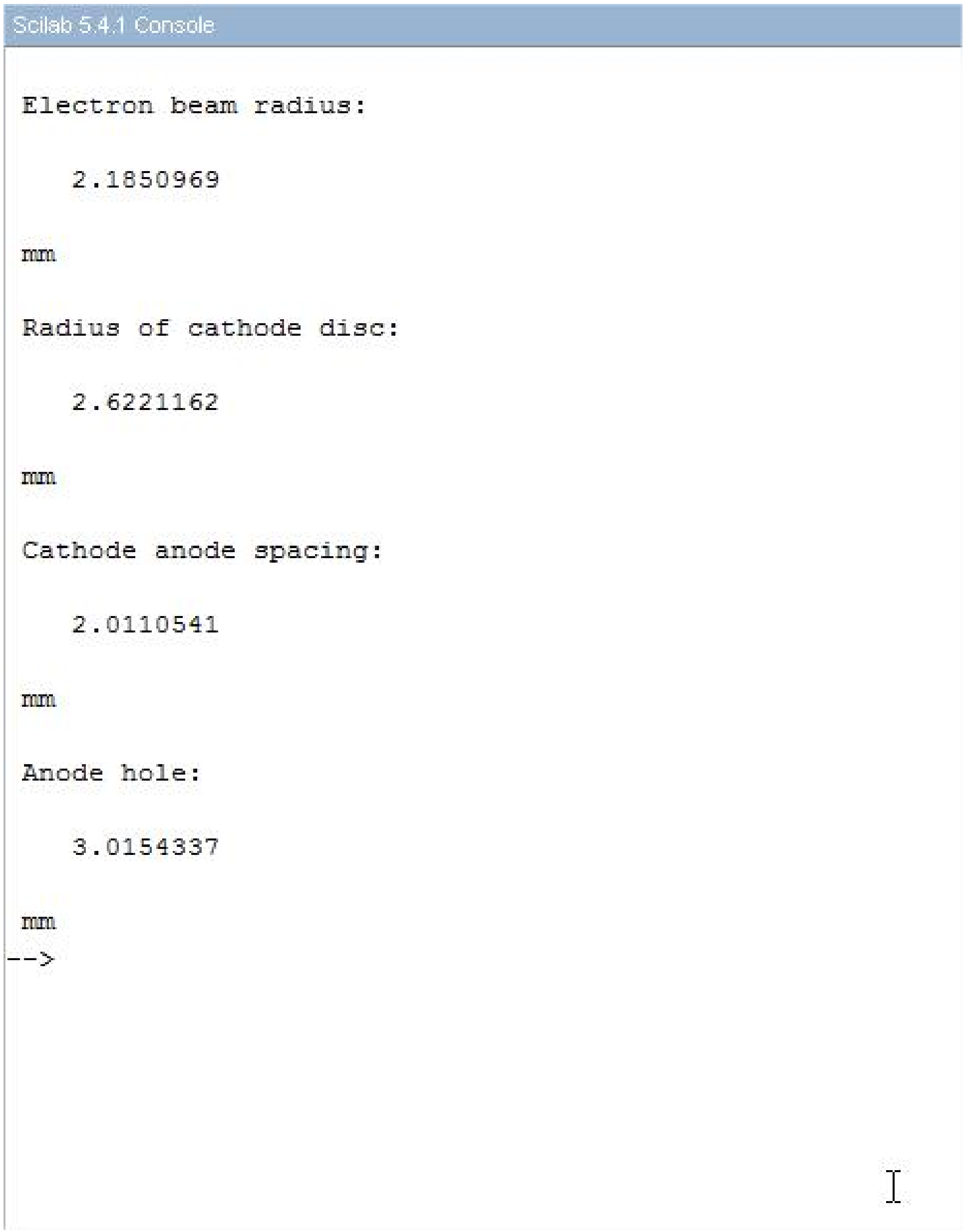



Figure 5.17: Electron Gun

```
disp('mm',r*10,'Radius of cathode disc:');
d=sqrt(2.335D-6*(300)^(3/2)/j0);//mm
disp('mm',d*10,'Cathode anode spacing:');
//Anode hole has to be 15% larger than cathode disc
ra=r*1.15;//mm
disp('mm',ra*10,'Anode hole:');
```

**Scilab code Exa 5.18** Re entrant Coaxial Cavity

```
//Page Number:
//Example 5.18
clc;
//Given
f=9D+9;//hz
v0=300;//V
vr=125;//V
bet=0.9;
c=3D+8; //m/s
w=2*%pi*f;
br=2.18;//mm
e0=8.854D-12;
ebym=1.7D+11;

//From sin(theta)/theta table, thetag is found out
   to be
thetag=0.25*%pi;
d=(2*thetag*0.593D+6*sqrt(v0))/w;
disp('mm',d*1000,'Distance:');

//Axial cavity length
l=c/(10*f);//m
disp('mm',l*1000,'Axial cavity length:');

```

```
Scilab 5.4.1 Console

 Distance:

    0.2853073

 mm

 Axial cavity length:

    3.3333333

 mm

 Ratio of outer to inner conductor:

    3.3956114

 Radius of outer conductor:

    3.27

 mm

 Radius of inner conductor:

    4.9704

 mm

 Repeller spacing:

    1.8878126

 mm

-->
```

Figure 5.18: Re entrant Coaxial Cavity

```
//Ratio of outer to inner conductor
a=1.5*br;
a1=a/1000;
x=d/(w*e0*a1*a1*60*tan((w*l)/c));
bbya=exp(x);
disp(bbya,'Ratio of outer to inner conductor:');

//radii of outer and inner conductor
disp('mm',a,'Radius of outer conductor:');

b=1.52*a;//mm
disp('mm',b,'Radius of inner conductor:');

//Repeller spacing
lopt=sqrt(ebym*(19/4)^2*(v0+vr)^2/(8*f^2*v0));//m
disp('mm',lopt*1000,'Repeller spacing:');

//Answer for radii of outer and inner conductor have
    wrong calculations in book
//Also ratio of outer to inner conductor is also
    calculated wrong
```

# Chapter 6

# Microwave Travelling Wave Tubes O type

**Scilab code Exa 6.1** TWT

```
//Page Number: 330
//Example 6.1
clc;
//Given
clc;
//Given
I0=30D-3; //A
V0=3D+3; //V
Z0=10; //ohm
l=0.1624; //m
f=10D+9; //Hz

//(i) Gain parameter
C=((I0*Z0)/(4*V0))^(1/3);
disp(C,'Gain parameter:');

N=(l*f)/(0.593D+6*sqrt(V0));
```

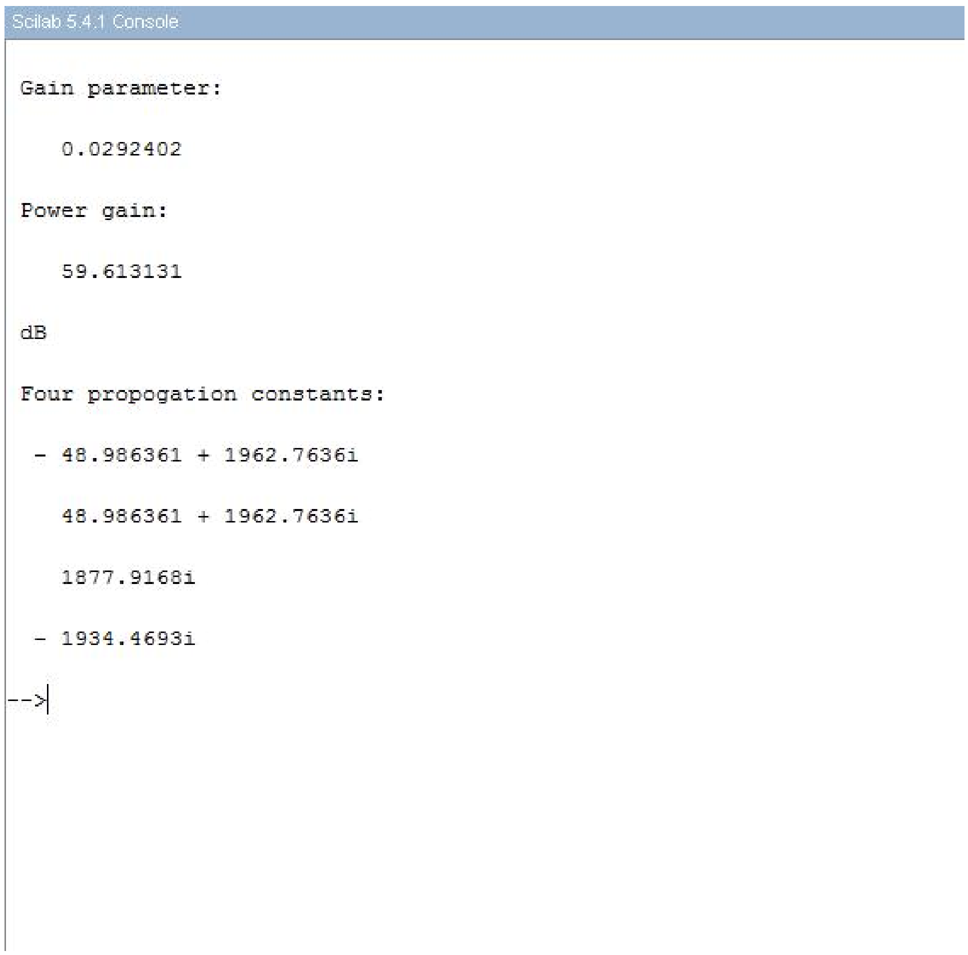



Figure 6.1: TWT

```

//(ii) Power Gain
Ap=-9.54+(47.3*C*N);
disp('dB',Ap,'Power gain:');

ve=0.593D+6*sqrt(V0);
be=(2*%pi*f)/ve;

//Four propogation constants
gam1=((-sqrt(3)*be*C)/2)+(%i*be*(2+C))/2;
gam2=((sqrt(3)*be*C)/2)+(%i*be*(2+C))/2;
gam3=%i*be*(1-C);
gam4=-%i*be*(1-((C*C*C)/4));

disp(gam4,gam3,gam2,gam1,'Four propogation constants
    :');

//Calculations for propogation constants are wrong
    in book for gam 3 and 4, hence answers dont match
```

**Scilab code Exa 6.2** Helix TWT

```
//Page Number: 332
//Example 6.2
clc;
//Given
I0=20D-3; //A
V0=4D+3; //V
Z0=100; //ohm
N=30;

C=((I0*Z0)/(4*V0))^(1/3);
//Gain
```

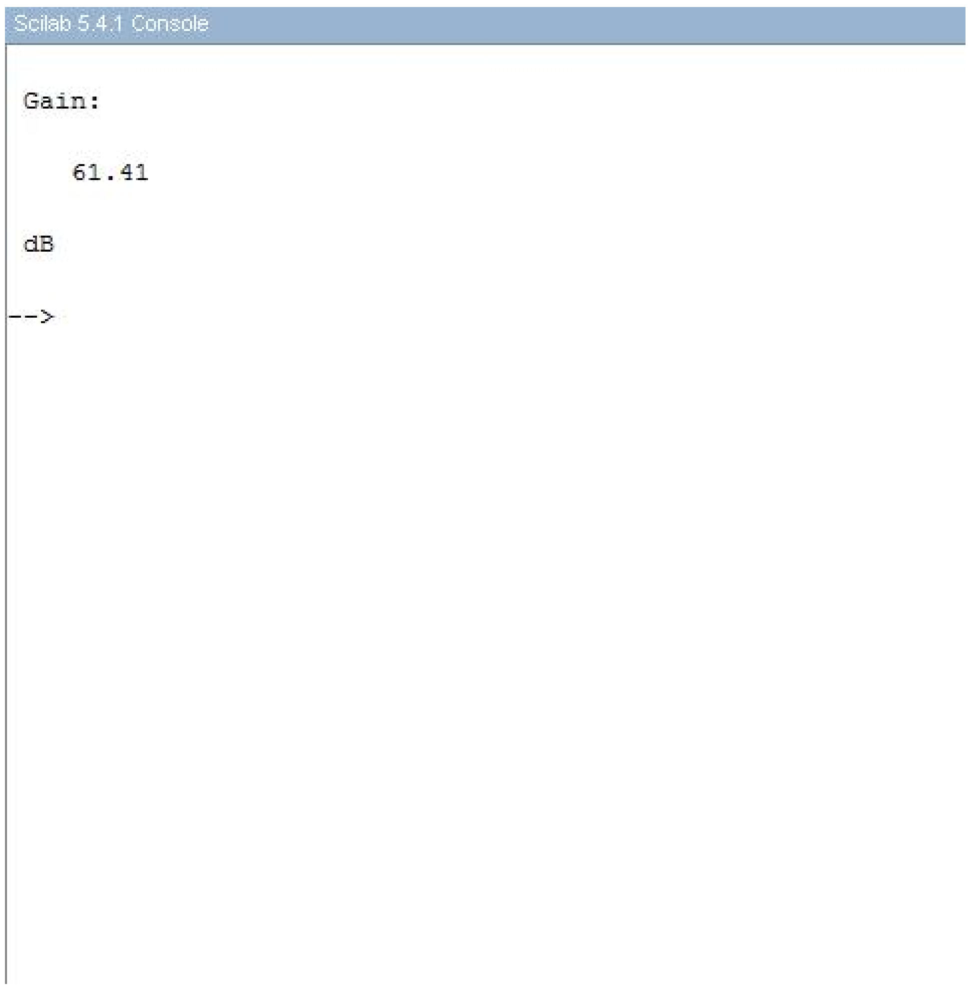



Figure 6.2: Helix TWT

```
Ap=-9.54+(47.3*C*N);
disp('dB',Ap,'Gain:');
```

**Scilab code Exa 6.3** Helical TWT

```
//Page Number: 332
//Example 6.3
clc;
//Given
c=3D+8; //m/s
d=2D-3; //m
p=50D+2; //turns per m
e=1.6D-19; //J
m=9.1D-31;

// Axial phase velocity
vp=c/(%pi*p*d);
disp('m/s',vp,'Axial phase velocity:');

//Anode voltage
V0=(m*vp*vp)/(2*e);
disp('V',V0,'Anode voltage:');
```

**Scilab code Exa 6.4** O type TWT

```
//Page Number: 332
//Example 6.4
clc;
//Given
```

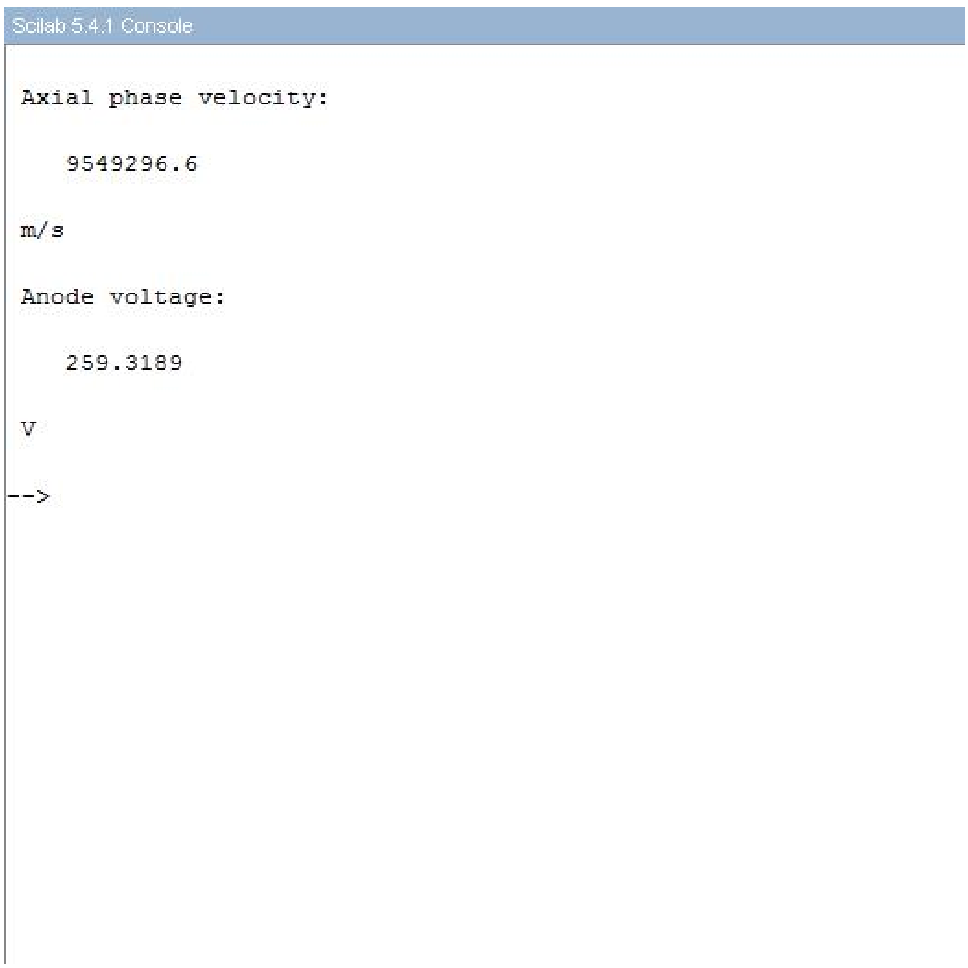



Figure 6.3: Helical TWT


Scilab 5.4.1 Console

```
 Propogation constant:

    2. + 2183.9642i

-->
```

Figure 6.4: O type TWT

```
a=(4.4*%pi)/180; //radians
c=3D+8 //m/s
f=8D+9; //Hz
al=2; //Np/m

//Phase velocity
vp=c*sin(a);

//Propogation constant
be=(2*%pi*f)/vp;

gam=al+(%i*be);
disp(gam,'Propogation constant:');
```

**Scilab code Exa 6.5** Cavity coupled

```
//Page Number: 333
//Example 6.5
clc;
//Given
Vc=11D+3; //V
Ir=0.85; //A
V0=31D+3; //V
Pout=50D+3; //W
I=7; //A

//Electronic efficiency
ne=Pout/(V0*I);
disp('%',ne*100,'Electronic efficiency:');

//Overall efficiency
no=Pout/(Vc*(I-Ir));
disp('%',no*100,'Overall efficiency:');
```


Figure 6.5: Cavity coupled


Figure 6.6: O Type Backward Wave amplifier

```

//Answer for elecytronic efficiency should be 23.04%
    but it is given as 36.4 in book
```

**Scilab code Exa 6.6** O Type Backward Wave amplifier

```
//Page Number: 333
//Example 6.6
```


Figure 6.7: Multicavity TWT

```
clc;
//Given
I0=0.95; //A
V0=7D+3; //V
Z0=20; //ohm
N=20;

C=((I0*Z0)/(4*V0))^(1/3);
//Gain
Ap=-9.54+(47.3*C*N);
disp('dB',Ap,'Gain:');
```

**Scilab code Exa 6.7** Multicavity TWT

```
//Page Number: 334
//Example 6.7
clc;
//Given
Vc=12D+3; //V
V0=30D+3; //V
Pout=60D+3; //W
I=7.5; //A

//Electronic efficiency
ne=Pout/(V0*I);
disp('%',ne*100,'Electronic efficiency:');

//Overall efficiency
no=Pout/(Vc*I);
disp('%',no*100,'Overall efficiency:');
```

**Scilab code Exa 6.8** Gridded TWT

```
//Page Number: 334
//Example 6.8
clc;
//Given
Vc=20D+3; //V
V0=32D+3; //V
Pout=75D+3; //W
I=7; //A

//Electronic efficiency
ne=Pout/(V0*I);
disp('%',ne*100,'Electronic efficiency:');
```


Figure 6.8: Gridded TWT


Figure 6.9: Helix TWT

```

//Overall efficiency
no=Pout/(Vc*I);
disp('%',no*100,'Overall efficiency:');
```

**Scilab code Exa 6.9** Helix TWT

```
//Page Number: 335
//Example 6.9
clc;
//Given
I0=500D-3; //A
V0=10D+3; //V
Z0=25; //ohm
l=.20; //m
f=5.93D+9; //Hz

//Gain parameter
C=((I0*Z0)/(4*V0))^(1/3);
disp(C,'Gain parameter:');

N=(l*f)/(0.593D+6*sqrt(V0));
//Gain
Ap=-9.54+(47.3*C*N);
disp('dB',Ap,'Gain of TWT:');
```

**Scilab code Exa 6.10** Low Power TWT

```
//Page Number: 335
//Example 6.10
clc;
//Given
Pout=250; //W
n=0.15;
V0=7.5D+3; //V
f=6.15D+9; //Hz
c=3D+8; //m/s

//(i) Input Power
Pi=Pout/n;
```

```
Scilab 5.4.1 Console

 Input Power:

    1666.6667

 W

 Beam current:

    0.2222222

 A

 Beam velocity:

    51355306.

 m/s

 Radius of helix:

    0.0026580

 m

 Electron beam radius:

    0.0019935

 m

 Pitch of helix:

    0.0028589

 m


 Current density:

    17.798951

 kA/msqr

 Magnetic field for beam confinement:

    84.

 mT

-->
```

Figure 6.10: Low Power TWT

```
disp('W',Pi,'Input Power:');

//(ii) Beam current
I0=Pi/V0;
disp('A',I0,'Beam current:');

//(iii) Beam velocity
vb=0.593D+6*sqrt(V0);
disp('m/s',vb,'Beam velocity:');

//(iv) Radius of helix
a=(2*vb)/(2*%pi*f);
disp('m',a,'Radius of helix:');

//(v) Electron beam radius
r=(3*a)/4;
disp('m',r,'Electron beam radius:');

//(vi) Pitch of helix
p=(2*%pi*a*vb)/c;
disp('m',p,'Pitch of helix:');

//(vii) Current density
J0=I0/(%pi*r*r);
disp('kA/msqr',J0/1000,'Current density:');

//(viii) Magnetic field for beam confinement
B=(4*8.3D-4*sqrt(I0/(r*r*sqrt(V0))));
disp('mT',round(B*1000),'Magnetic field for beam
    confinement:');
```

**Scilab code Exa 6.11** TWT


Figure 6.11: TWT

```
//Page Number: 336
//Example 6.11
clc;
//Given
I0=30D-3; //A
V0=3D+3; //V
Z0=10; //ohm
l=0.1624; //m
f=10D+9; //Hz
C=((I0*Z0)/(4*V0))^(1/3);
N=(l*f)/(0.593D+6*sqrt(V0));

//Gain
Ap=-9.54+(47.3*C*N);
disp('dB',Ap,'Gain:');

ve=0.593D+6*sqrt(V0);
be=(2*%pi*f)/ve;

```

```
//Four propogation constants
gam1=((-sqrt(3)*be*C)/2)+(%i*be*(2+C))/2;
gam2=((sqrt(3)*be*C)/2)+(%i*be*(2+C))/2;
gam3=%i*be*(1-C);
gam4=-%i*be*(1-((C*C*C)/4));

disp(gam4,gam3,gam2,gam1,'Four propogation constants
    :');

//Calculations for propogation constants are wrong
    for gam 3 and 4 hence answers dont match
```

**Scilab code Exa 6.12** TWT

```
//Page Number: 337
//Example 6.12
clc;
//Given
I0=35D-3; //A
V0=4D+3; //V
Z0=20; //ohm
f=10D+9; //Hz

//(i) Gain parameter
C=((I0*Z0)/(4*V0))^(1/3);
disp(C,'Gain parameter:');

ve=0.593D+6*sqrt(V0);
be=(2*%pi*f)/ve;

//Four propogation constants
gam1=((-sqrt(3)*be*C)/2)+(%i*be*(2+C))/2;
gam2=((sqrt(3)*be*C)/2)+(%i*be*(2+C))/2;
```

```
Scilab 5.4.1 Console

 Gain parameter:

    0.0352365

 Four propogation constants:

  - 51.123255 + 1704.826i

    51.123255 + 1704.826i

    1616.2779i

  - 1675.2917i

-->
```

Figure 6.12: TWT

```
gam3=%i*be*(1-C);
gam4=-%i*be*(1-((C*C*C)/4));

disp(gam4,gam3,gam2,gam1,'Four propogation constants
    :');

//Calculations for propogation constants are wrong
    hence answers dont match
```

# Chapter 7

# Cross Field Microwave Tubes M Type

**Scilab code Exa 7.1** X band Magnetron

```
//Page Number: 369
//Example 7.1
clc;
//Given
f=10D+9; //Hz
C=2.5D-12; //F
Gr=2D-4; //mho
Ge=0.025D-3; //mho
Ploss=18.5D+3; //W
V0=5.5D+3; //V
I0=4.5; //A

w=2*%pi*f;

//(i) Unloaded Q
Qun=(w*C)/Gr;
disp(Qun,'Unloaded quality factor:');
```


Figure 7.1: X band Magnetron

```
//External Q
Qe=(w*C)/Ge;
disp(Qe,'External quality factor:');

//(ii) Circuit effciency
n=1/(1+(Qe/Qun));
disp('%',n*100,'Circuit effciency:');

//Electronic effciency
ne=1-(Ploss/(V0*I0));
disp('%',ne*100,'Electronic effciency:');

//Answer for Qe is given as 6285.6 but it should be 6283.1
```

**Scilab code Exa 7.2** Cylindrical Magnetron

```
//Page Number: 370
//Example 7.2
clc;
//Given
V0=25D+3; //V
ebym=1.76D+11;
B0=0.0336; //T
a=5D-2; //m
b=10D-2; //m

//(i) Cut off voltage
x=(b/((b*b)-(a*a)))^2;
V=(ebym*B0*B0)/(8*x);
disp('KV',V/1000,'Cut off voltage:');

```

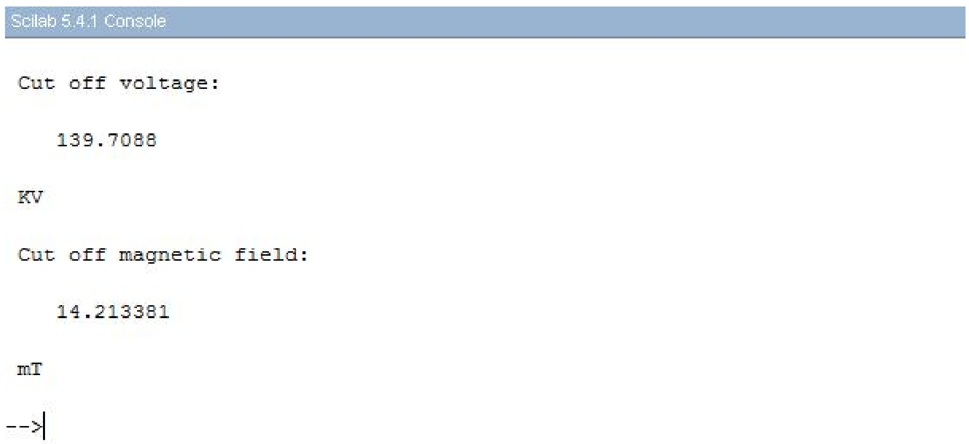



Figure 7.2: Cylindrical Magnetron


Figure 7.3: Cylindrical Magnetron

```
//(ii) Cut off magnetic field
y=((8*V0*x)/ebym);
B=sqrt(y);
disp('mT',B*1000,'Cut off magnetic field:');
```

**Scilab code Exa 7.3** Cylindrical Magnetron

```
//Page Number: 371
//Example 7.3
clc;
```

```
//Given
Pout=250D+3; //W
V0=25D+3; //V
I0=25; //A
ebym=1.76D+11;
B0=0.035; //T
a=4D-2; //m
b=8D-2; //m


//(i) Efficiency
n=Pout/(V0*I0);
disp('%',n*100,'Efficiency:');

//(ii) Cyclotron frequency
f=(ebym*B0)/(2*%pi);
disp('Ghz',f/10^9,'Cyclotron frequency:');

//(iii) Cut off magnetic field
x=(b/((b*b)-(a*a)))^2;
y=((8*V0*x)/ebym);
B=sqrt(y);
disp('mT',B*1000,'Cut off magnetic field:');

//(iv) Cut off voltage
V=(ebym*B0*B0)/(8*x);
disp('KV',round(V/1000),'Cut off voltage:');

//Answer for Cyclotron frequency is is given as 9.8
   GHz but it should be 0.98 GHz as value of B0
   =0.035 not 0.35 as taken in part 2
```

**Scilab code Exa 7.4** Conventional Magnetron


Figure 7.4: Conventional Magnetron

```
//Page Number: 372
//Example 7.4
clc;
//Given
Gr=3D-4; //mho
Ge=3D-5; //mho
Ploss=200D+3; //W
V0=22D+3; //V
I0=28; //A

//(i) Circuit effciency
n=1/(1+(Gr/Ge));
disp('%',n*100,'Circuit effciency:');

//(ii) Electronic effciency
ne=1-(Ploss/(V0*I0));
disp('%',ne*100,'Electronic effciency:');
```

**Scilab code Exa 7.5** Conventional Magnetron

```
//Page Number: 372
//Example 7.5
clc;
//Given
f=9D+9; //Hz
C=2.5D-12; //F
Gr=2D-4; //mho
Ge=2.5D-5; //mho
Ploss=18.5D+3; //W
V0=5.5D+3; //V
I0=4.5; //A

//(i) Angular resonant frequency
```

```
Scilab 5.4.1 Console

 Angular resonant frequency:

    5.655D+10

 rad/s

 Unloaded quality factor:

    707.

 Loaded quality factor:

    628.

 External quality factor:

    5654.8668

 Circuit effciency:

    11.11309

 %

 Electronic effciency:

    25.252525

 %

-->
```

Figure 7.5: Conventional Magnetron

```
w=2*%pi*f;
disp('rad/s',w,'Angular resonant frequency:');

//(ii) Unloaded Q
Qun=round((w*C)/Gr);
disp(Qun,'Unloaded quality factor:');

//(iii) Loaded Q
Ql=round((w*C)/(Gr+Ge));
disp(Ql,'Loaded quality factor:');

//(iv) External Q
Qe=(w*C)/Ge;
disp(Qe,'External quality factor:');

//(v) Circuit effciency
n=1/(1+(Qe/Qun));
disp('%',n*100,'Circuit effciency:');

//(vi) Electronic effciency
ne=1-(Ploss/(V0*I0));
disp('%',ne*100,'Electronic effciency:');

//Answer for external Q is given as 56.57 but it
    should be 5654.8
```

**Scilab code Exa 7.6** Carcinotron

```
//Page Number: 373
//Example 7.6
clc;
//Given
f=4D+9; //Hz
```

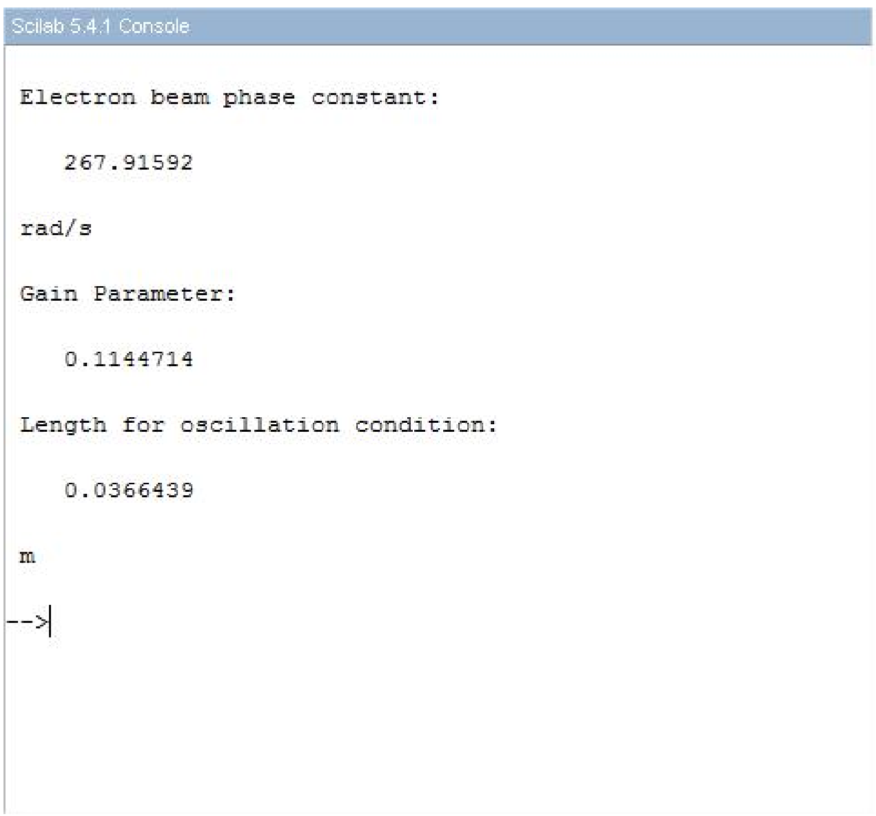



Figure 7.6: Carcinotron

```
V0=25D+3; //V
I0=3; //A
B0=0.3; //T
D=0.8;
Z0=50; //ohm
ebym=1.76D+11;

//(i) Electron beam phase constant
be=(2*%pi*f)/sqrt(2*ebym*V0);
disp('rad/s',be,'Electron beam phase constant:');

//(ii) Gain Parameter
C=((I0*Z0)/(4*V0))^(1/3);
disp(C,'Gain Parameter:');

//(iii) Length for oscillation condition
N=1.25/D;
l=(2*%pi*N)/be;
disp('m',l,'Length for oscillation condition:');
```

**Scilab code Exa 7.7** Frequency Aglile Magnetron

```
//Page Number: 374
//Example 7.7
clc;
//Given
N=20;
t=0.2D-6; //s
DC=0.001; //Duty cycle

//(i) Agile excursion
A=N/t;
disp('MHz',A/10^6,'Agile excursion:');
```

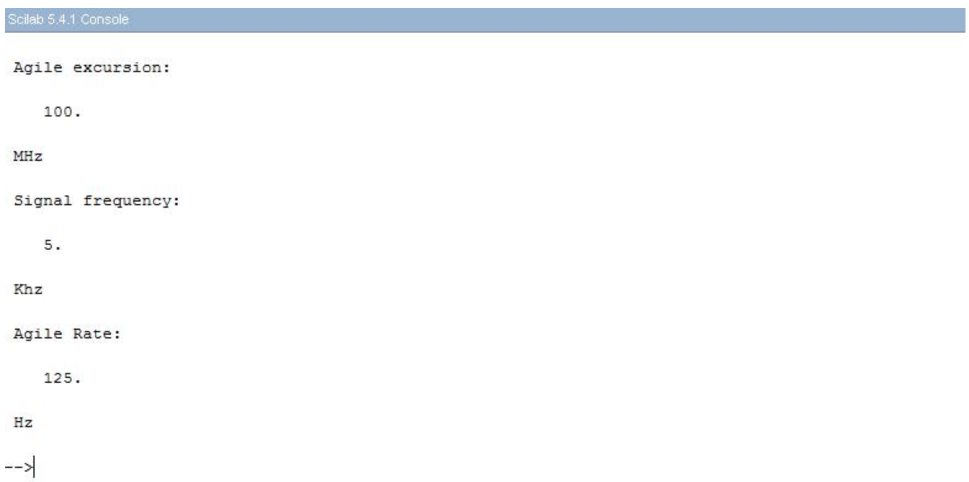



Figure 7.7: Frequency Aglile Magnetron

```
//(ii) Signal frequency
f=DC/t;
disp('Khz',f/1000,'Signal frequency:');

//(iii) Agile rate
R=f/(2*N);
disp('Hz',R,'Agile Rate:');
```

**Scilab code Exa 7.8** Cross field amplifier

```
//Page Number: 375
//Example 7.8
clc;
//Given
V0=1.8D+3; //V
I0=1.3; //A
Pin=70; //W
n=0.22;

//(i) Power generated
Pgen=n*I0*V0;
disp('W',Pgen,'Power generated:');

//(ii) Total RF power generated
Pt=Pin+Pgen;
disp('W',Pt,'Total RF power generated:');

//(iii) Power gain
G=Pt/Pin;
Gdb=10*log10(G);
disp('dB',Gdb,'Power Gain:');
```

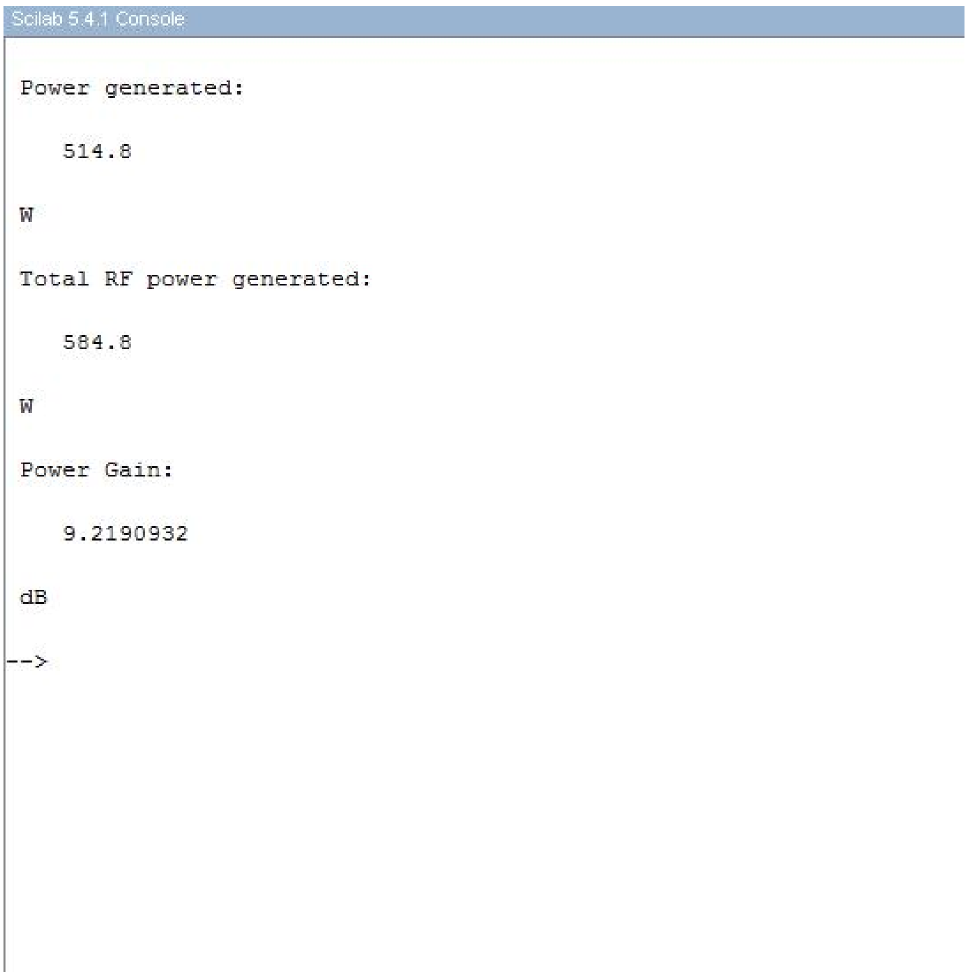



Figure 7.8: Cross field amplifier

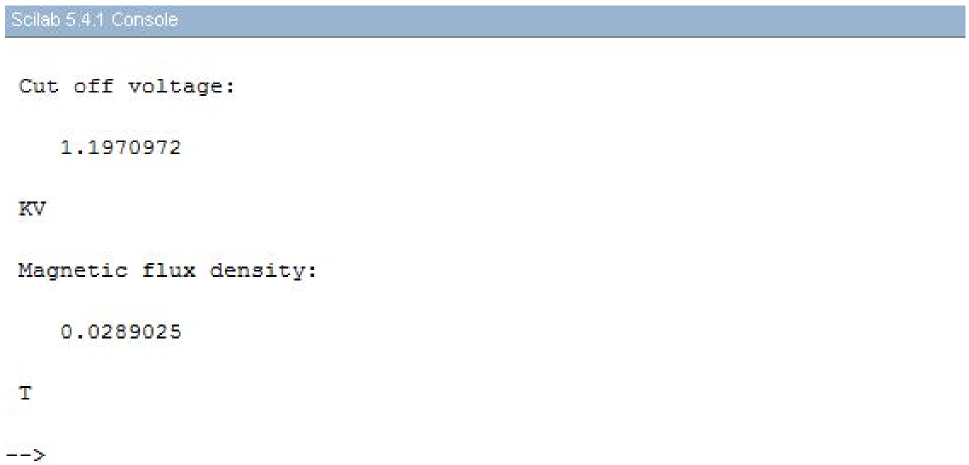



Figure 7.9: Inverted coaxial Magnetron

**Scilab code Exa 7.9** Inverted coaxial Magnetron

```
//Page Number: 375
//Example 7.9
clc;
```

```
//Given
V0=10D+3; //V
I0=2; //A
b=4D-2; //m
a=3D-2; //m
B0=0.01; //Wb/m2
ebym=1.759D+11;

//Cut off voltage
x=1-((b*b)/(a*a));
V=(ebym*(B0^2)*(a^2)*(x^2))/8;
KV=V/1000; //Kilovolts
disp('KV',KV,'Cut off voltage:');

//Magnetic flux density
y=-sqrt((8*V0)/ebym);
B=y/(a*x);
disp('T',B,'Magnetic flux density:');
```

**Scilab code Exa 7.10** Inverted coaxial Magnetron

```
//Page Number: 376
//Example 7.10
clc;
//Given
V0=10D+3; //V
I0=2; //A
b=4D-2; //m
a=3D-2; //m
B0=0.01; //Wb/m2
ebym=1.759D+11;

//Cut off voltage
```


Figure 7.10: Inverted coaxial Magnetron

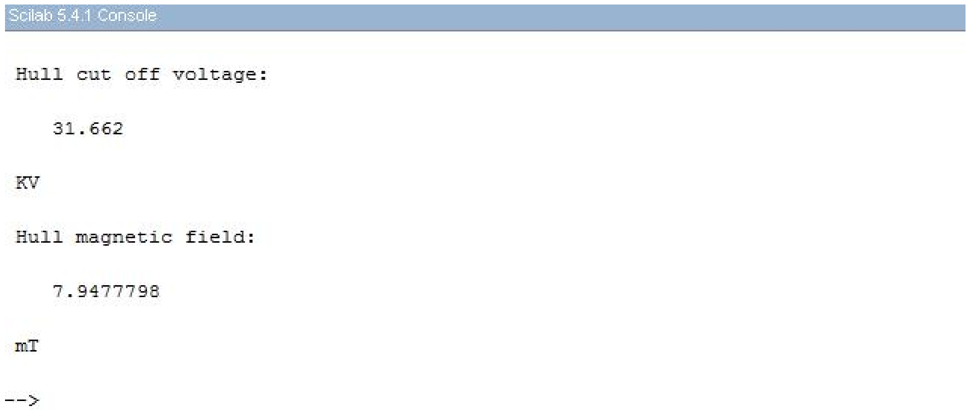



Figure 7.11: Linear Magnetron

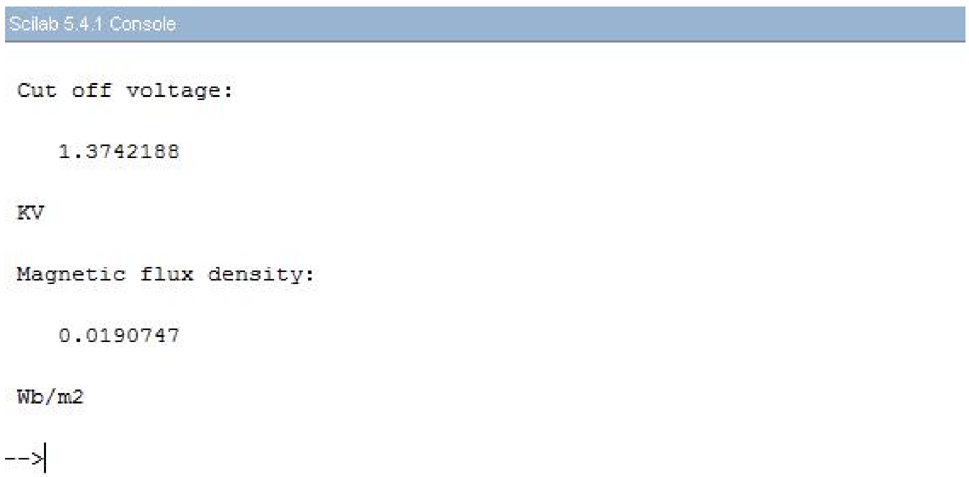
```
x=1-((b*b)/(a*a));
V=(ebym*(B0^2)*(a^2)*(x^2))/8;
disp('KV',V/1000,'Cut off voltage:');

//Magnetic flux density
y=-sqrt((8*V0)/ebym);
B=y/(a*x);
disp('T',B,'Magnetic flux density:');
```

**Scilab code Exa 7.11** Linear Magnetron

```
//Page Number: 376
//Example 7.11
clc;
//Given
e=1.6D-19; //J
B0=0.01; //Wb/m2
d=6D-2; //m
V0=20D+3; //V
ebym=1.759D+11;

//(i) Hull cut off voltage
Voc=(B0*B0*d*d*ebym)/2;
disp('KV',Voc/1000,'Hull cut off voltage:');

//(ii) Hull magnetic field
Boc=sqrt((2*V0)/ebym)/d;
disp('mT',Boc*1000,'Hull magnetic field:');
```

**Scilab code Exa 7.12** Inverted Coaxial Magnetron

```
//Page Number: 377
//Example 7.12
clc;
//Given
V0=10D+3; //V
V01=5D+3; //V
I0=2; //A
b=3D-2; //m
a=2D-2; //m
B0=0.01; //Wb/m2
ebym=1.759D+11;

//Cut off voltage
```



```
Scilab 5.4.1 Console

 Cut off voltage:

    1.3742188

 KV

 Magnetic flux density:

    0.0190747

 Wb/m2

-->
```

Figure 7.12: Inverted Coaxial Magnetron

```
x=1-((b*b)/(a*a));
V=(ebym*(B0^2)*(a^2)*(x^2))/8;
KV=V/1000; //Kilovolts
disp('KV',KV,'Cut off voltage:');

//Magnetic flux density
y=-sqrt((8*V01)/ebym);
B=y/(a*x);
disp('Wb/m2',B,'Magnetic flux density:');

//Answer in book is wrong for Magnetic flux density
    as a*a ,where a=2, is taken as 5, which should be
    4
```

**Scilab code Exa 7.13** Agile coaxial Magnetron

```
//Page Number: 377
//Example 7.13
clc;
//Given
N=15;
t=0.3D-6; //s
DC=0.0011; //Duty cycle

//(i) Agile excursion
A=N/t;
disp('MHz',A/10^6,'Agile excursion:');

//(ii) Pulse to pulse frequency seperation
fp=1/t;
disp('Mhz',fp/10^6,'Pulse to pulse frequency
    seperation:');

```

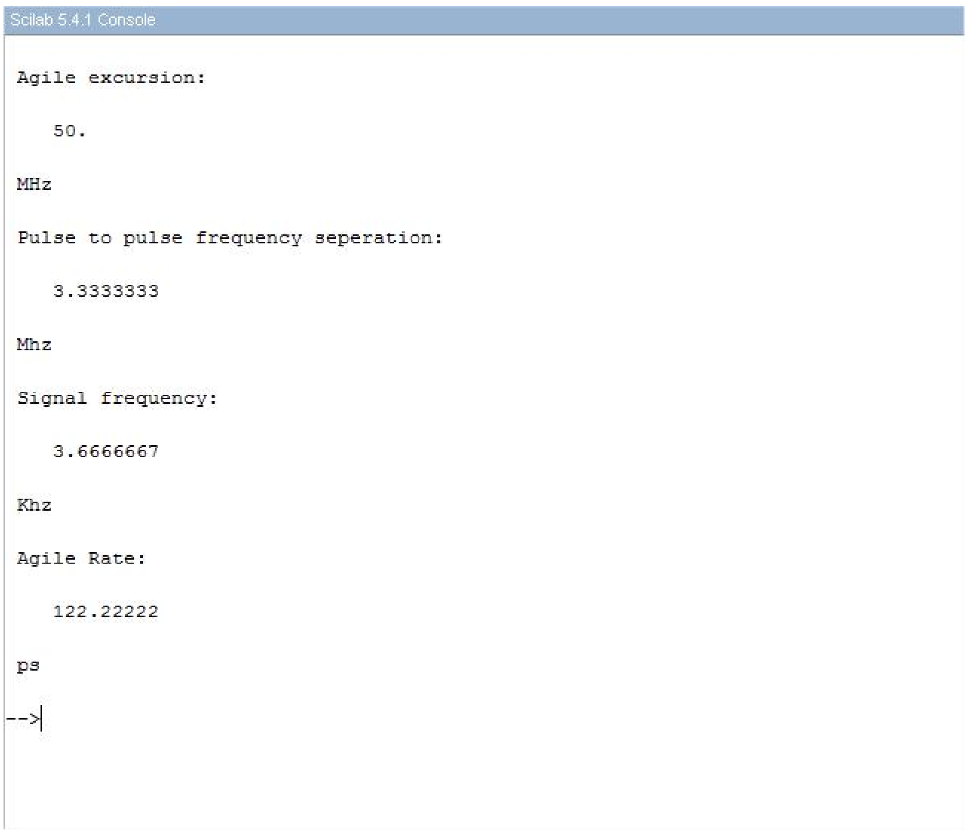



Figure 7.13: Agile coaxial Magnetron

```
//(iii) Signal frequency
f=DC/t;
disp('Khz',f/1000,'Signal frequency:');

//(iv) Agile rate
Tp=N/f;
R=1/(2*Tp);
disp('ps',R,'Agile Rate:');
```

# Chapter 8

# Microwave Solid State Control Devices

**Scilab code Exa 8.1** Single pole Switch

```
//Page Number: 389
//Example 8.1
clc;
//Given
Rf=0.5; //ohm
Rr=1; //ohm
Ls=0.3D-9; //H
Cj=0.1D-12; //F
f=3.18D+9; //Hz
Z0=50; //ohm

Zf=Rf+(%i*round(2*%pi*f*Ls));
Zr=Rr+(%i*(round(2*%pi*f*Ls)-(1/(2*%pi*f*Cj))));

//Series Configuration
disp('Series Configuration');

```

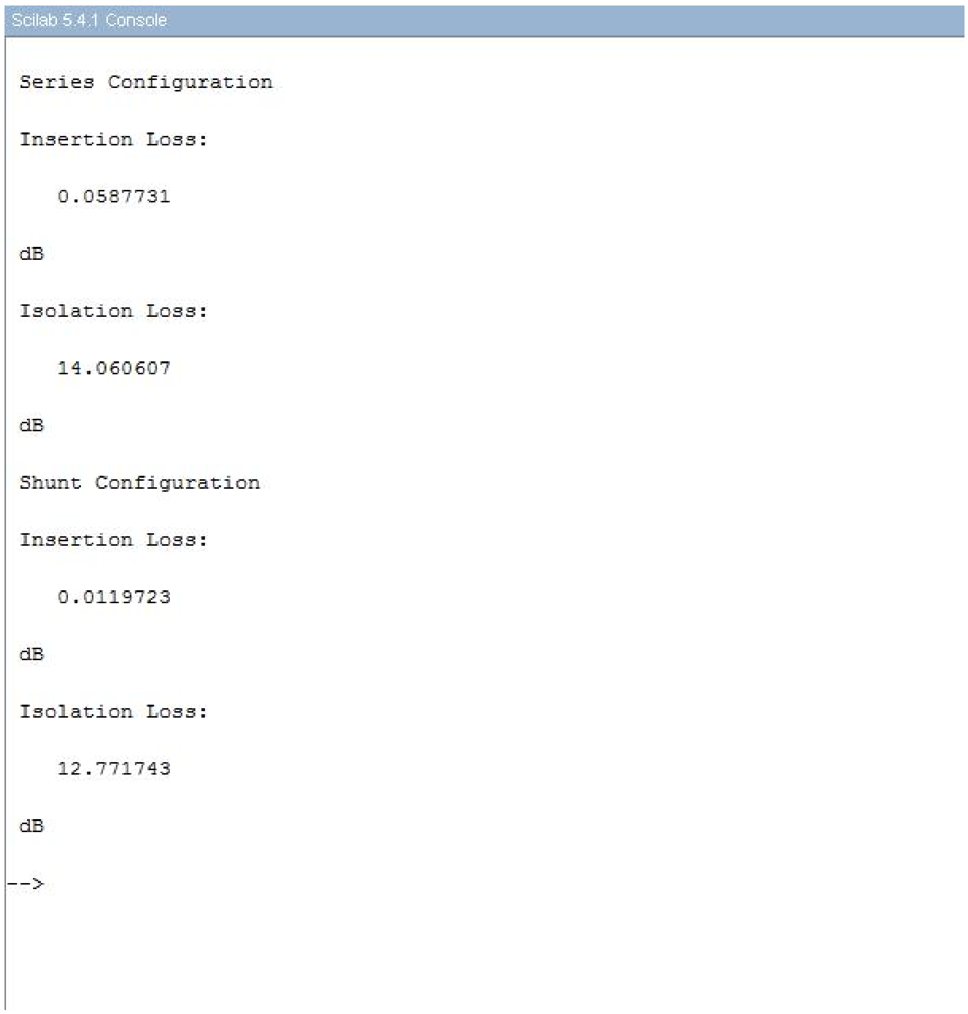



Figure 8.1: Single pole Switch

```
//Insertion Loss
x=(2*Z0)/((2*Z0)+Zf);
x1=sqrt((real(x))^2+(imag(x))^2);
IN=-20*log10(x1);
disp('dB',IN,'Insertion Loss:');

//Isolation Loss
y=(2*Z0)/((2*Z0)+Zr);
y1=sqrt((real(y))^2+(imag(y))^2);
IS=-20*log10(y1);
disp('dB',IS,'Isolation Loss:');

//Shunt Configuration
disp('Shunt Configuration');

//Insertion Loss
a=(2*Zr)/((2*Zr)+Z0);
a1=sqrt((real(a))^2+(imag(a))^2);
INs=-20*log10(a1);
disp('dB',INs,'Insertion Loss:');

//Isolation Loss
b=(2*Zf)/((2*Zf)+Z0);
b1=sqrt((real(b))^2+(imag(b))^2);
ISs=-20*log10(b1);
disp('dB',ISs,'Isolation Loss:');

//Answer for Series configuration insertion loss is 0.058 but is given as 0.58db
```

**Scilab code Exa 8.2** Pin diode switches

```
//Page Number: 390
```


Figure 8.2: Pin diode switches

```
//Example 8.2
clc;
//Given
Rf=1; //ohm
Rr=4; //ohm
Ls=0.3D-9; //H
Cj=0.1D-12; //F
f=3.18D+9; //Hz
Z0=50; //ohm

Zf=Rf+(%i*round(2*%pi*f*Ls));
Zr=Rr+(%i*(round(2*%pi*f*Ls)-(1/(2*%pi*f*Cj))));

//Series Configuration
disp('Series Configuration');

//Insertion Loss
x=(2*Z0)/((2*Z0)+Zf);
x1=sqrt((real(x))^2+(imag(x))^2);
IN=-20*log10(x1);
disp('dB',IN,'Insertion Loss:');

//Isolation Loss
y=(2*Z0)/((2*Z0)+Zr);
y1=sqrt((real(y))^2+(imag(y))^2);
IS=-20*log10(y1);
disp('dB',IS,'Isolation Loss:');

//Shunt Configuration
disp('Shunt Configuration');

//Insertion Loss
a=(2*Zr)/((2*Zr)+Z0);
a1=sqrt((real(a))^2+(imag(a))^2);
INs=-20*log10(a1);
disp('dB',INs,'Insertion Loss:');

//Isolation Loss
```


Figure 8.3: Silicon switching diode

```
b=(2*Zf)/((2*Zf)+Z0);
b1=sqrt((real(b))^2+(imag(b))^2);
ISs=-20*log10(b1);
disp('dB',ISs,'Isolation Loss:');
```

**Scilab code Exa 8.3** Silicon switching diode

```
//Page Number: 392
```

```
//Example 8.3
clc;
//Given
Vbd=1000; //V
f=30D+9; //Hz
E=3D+5; //V/cm
Cj=0.3D-12; //F
er=11.8;
e0=8.854D-12;

W=Vbd/E;
Wpi=W/100; //mu

//Total series resistance
R=1/(2*%pi*f*Cj);
disp('ohms',R,'Total series resistance:');

//Junction Area
A=(Cj*Wpi)/(e0*er);
disp('cm2',A*10000,'Junction Area:');
```

**Scilab code Exa 8.6** Parametric upconverter

```
//Page Number: 428
//Example 8.6
clc;
//Given
MQ=10;
M=0.4;
r=20;
Td=300; //K
T=290; //K

```


Figure 8.4: Parametric upconverter

```
x=(MQ*MQ)/r;
//Power Gain
Ap=(r*x)/((1+sqrt(1+x))^2);
Apdb=10*log10(Ap);
disp('dB',Apdb,'Power gain:');

//Noise figure
z=(Td/T)/sqrt(1+((MQ*MQ)/r));
F=1+z;
Fdb=10*log10(F);
disp('dB',F,'Nosie figure:');

//Bandwidth
BW=2*M*sqrt(r);
disp(BW,'Bandwidth:');
```

**Scilab code Exa 8.7** Parametric amplifier

```
//Page Number: 428
//Example 8.7
clc;
//Given
MQ=10;
r=10;

x=(MQ*MQ)/r;

//Gain
Ap=(r*x)/((1+sqrt(1+x))^2);
Apdb=10*log10(Ap);
disp('dB',Apdb,'Gain:');
```


Figure 8.5: Parametric amplifier


Figure 8.6: Negative resistance parametric amplifier

**Scilab code Exa 8.8** Negative resistance parametric amplifier

```
//Page Number: 429
//Example 8.8
clc;
//Given
```


Figure 8.7: 330 stage CCD

```
Rs=1; //ohm
ws=5D+9; //Hz
M=0.25;
C0=2D-12; //F

//(i) Effective Q
Q=1/(Rs*ws*C0*(1-(M*M)));
disp(Q,'Effective Q:');
```

**Scilab code Exa 8.9** 330 stage CCD

```
//Page Number: 434
//Example 8.9
clc;
//Given
e=0.0001;
s=330;

//Charge transfer effciency
n=1-e;

//Final charge pulse
//x=P/P0
x=(1-(e*s));
disp(x,'Final charge pulse:');
```

---

**Scilab code Exa 8.10** 3 phase CCD

```
//Page Number: 434
//Example 8.10
clc;
//Given
Qmax=0.05D-12; //C
f=10D+6; //Hz
V=10; //V
n=3;

//Power disspated per bit
P=n*f*V*Qmax;
```


Figure 8.8: 3 phase CCD

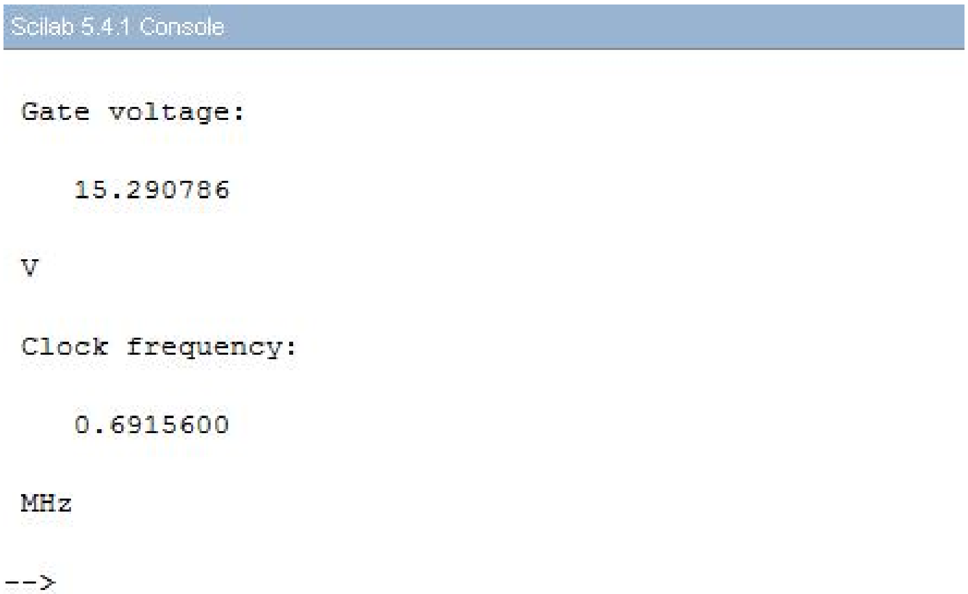



Figure 8.9: Surface channel CCD

```
disp('muW',P*10^6,'Power disspated per bit:');
```

**Scilab code Exa 8.11** Surface channel CCD

```
//Page Number: 434
//Example 8.11
```

```
clc;
//Given
e0=8.854D-12;
er=3.9;
d=0.15D-6; //m
e=1.6D-19; //J
Nmax=2.2D+16; //m-2
A=0.6D-8; //m
P=0.67D-3; //W
n=3;

//(i) Junction capacitance
Ci=(e0*er)/d;

//Gate voltage
V=(Nmax*e)/Ci;
disp('V',V,'Gate voltage:');

//(ii) Charge stored
Qmax=Nmax*e*A;

//Clock frequency
f=P/(n*V*Qmax);
disp('MHz',f/10^6,'Clock frequency:');
```

**Scilab code Exa 8.12** 3 phase CCD

```
//Page Number: 435
//Example 8.12
clc;
//Given
Qmax=0.06D-12; //C
f=20D+6; //Hz
```

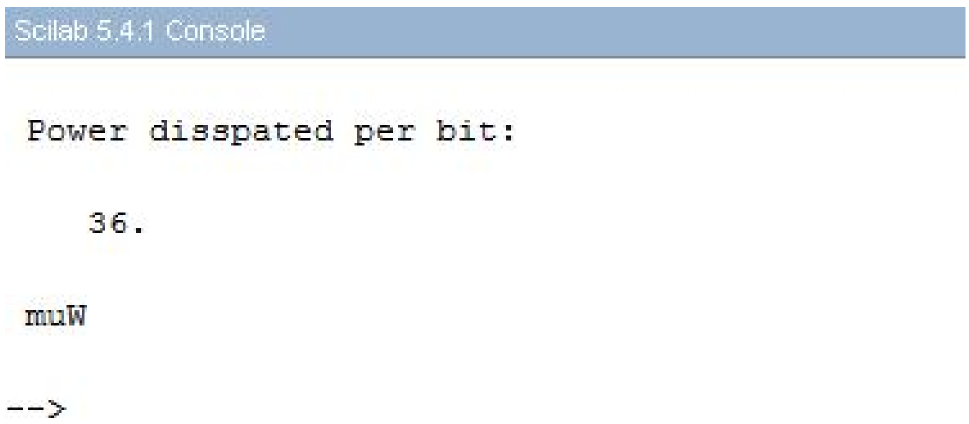



Figure 8.10: 3 phase CCD

```
V=10; //V
n=3;

//Power disspated per bit
P=n*f*V*Qmax;
disp('muW',P*10^6,'Power disspated per bit:');
```

**Scilab code Exa 8.13** Surface channel CCD

```
//Page Number: 435
//Example 8.13
clc;
//Given
e0=8.854D-12;
er=4;
d=0.1D-6; //m
si=0.85;
e=1.6D-19; //J
Na=1D+20;

Ci=(e0*er)/d;
disp('F/m',Ci,'Junction capacitance:');

W=sqrt((2*e0*er*si)/(e*Na));
disp('m',W,'Depletion layer width:');
```

```
Scilab 5.4.1 Console

 Junction capacitance:

    0.0003542

 F/m

 Depletion layer width:

    0.0000019

 m

-->
```

Figure 8.11: Surface channel CCD

# Chapter 9

# Microwave Solid State Generators and Amplifiers

**Scilab code Exa 9.2** Bipolar transistor

```
//Page Number: 448
//Example 9.2
clc;
//Given
fc=5D+9; //Hz
Em=2D+7; //V/m
vs=4D+3; //ms/s
Xc=1; //ohm

//Maximum allowable power
Pm=((Em*vs)^2)/(((2*%pi*fc)^2)*Xc);
disp('W',Pm,'Maximum allowable power:');
```

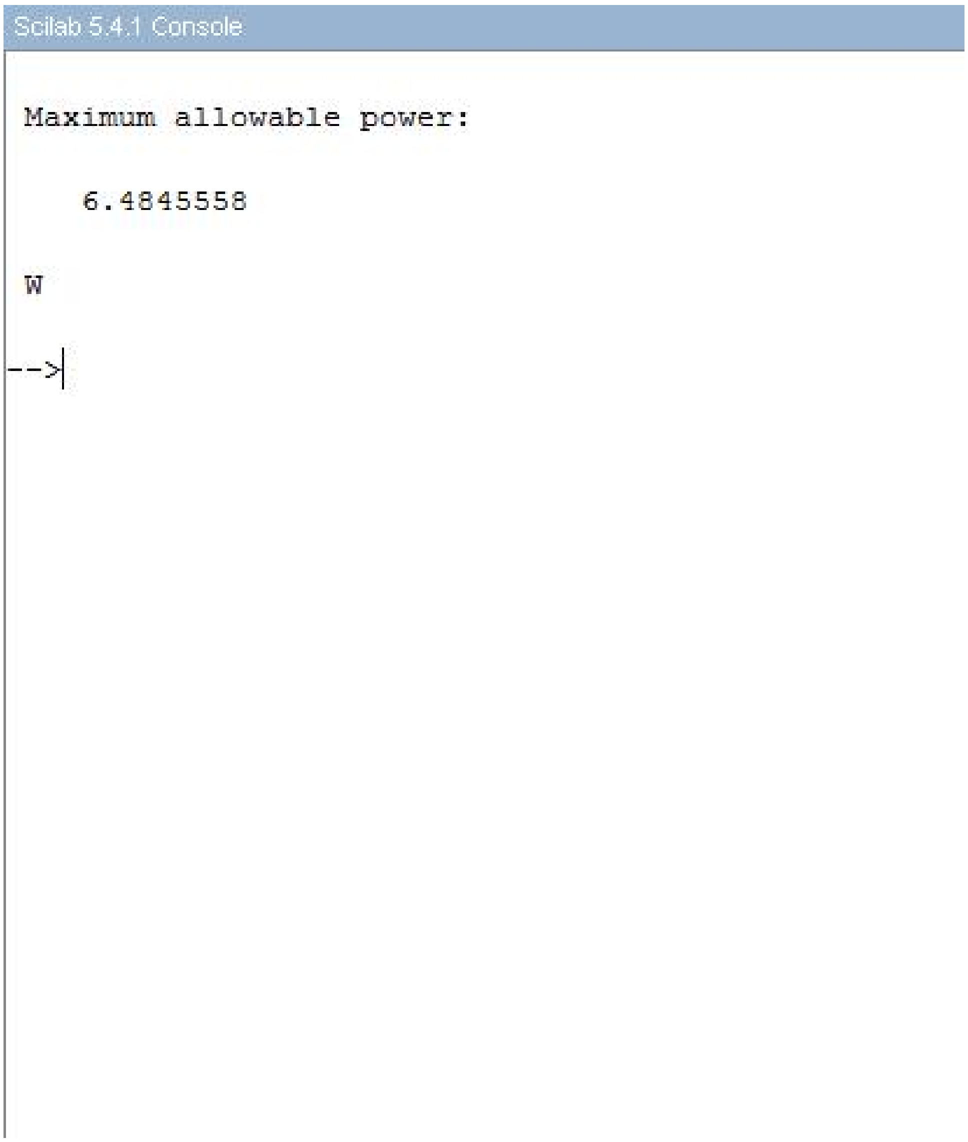



Figure 9.1: Bipolar transistor

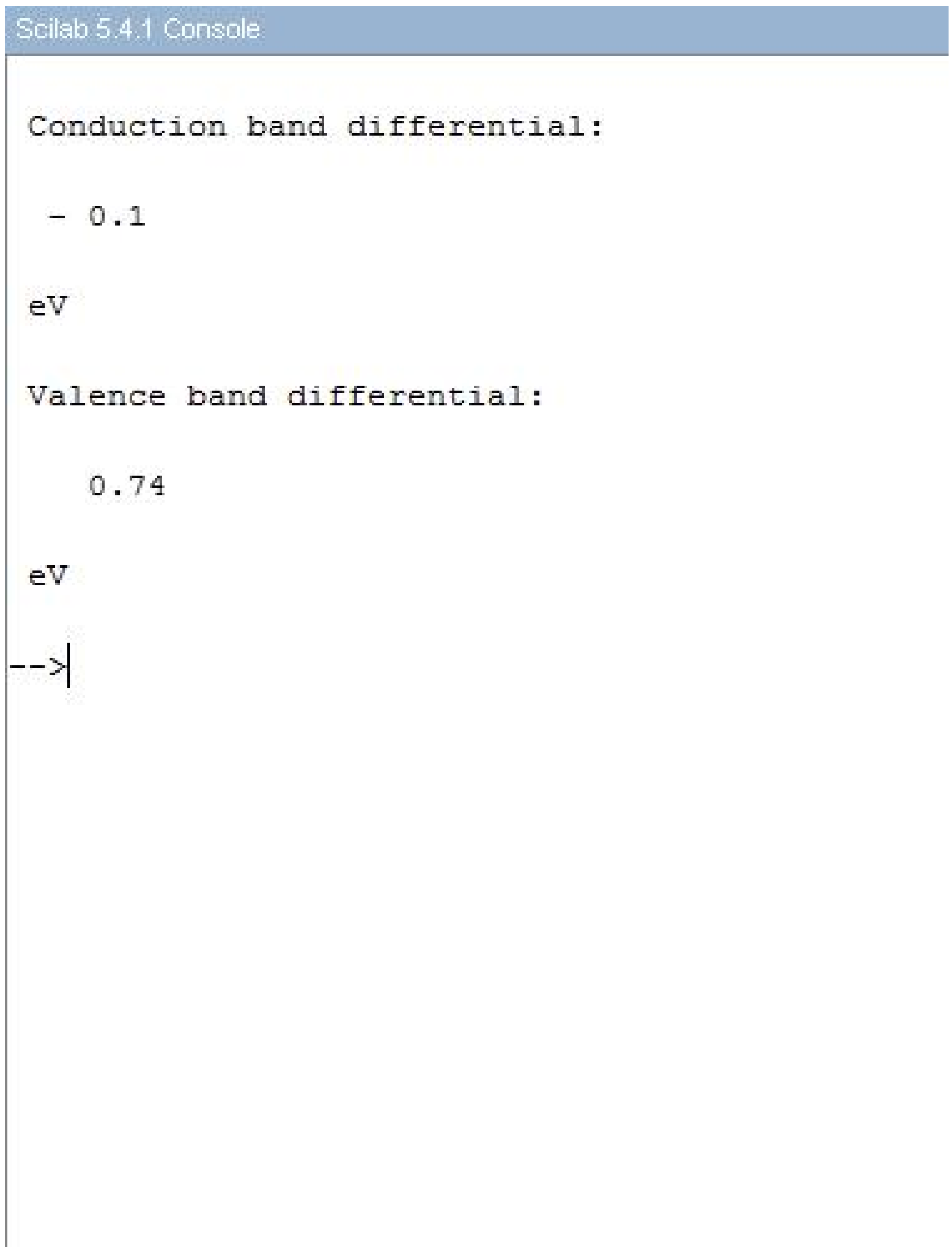



Figure 9.2: Heterojunction transistor

**Scilab code Exa 9.3** Heterojunction transistor

```
//Page Number: 451
//Example 9.3
clc;
//Given
XeGe=4.0; //eV
XeGaAs=4.1; //eV
delEgGe=0.78; //eV
delEgGaAs=1.42; //eV

//Conduction band differential
delEc=XeGe-XeGaAs;
disp('eV',delEc,'Conduction band differential:');

//Valence band differential
delEv=delEgGaAs-delEgGe-delEc;
disp('eV',delEv,'Valence band differential:');
```

**Scilab code Exa 9.4** GaAs FET

```
//Page Number: 454
//Example 9.4
clc;
//Given
S11=0.89;
S12=0.02;
S21=3.1;
S22=0.78;

del=(S11*S22)-(S12*S21);
K=[1-(S11)^2-(S22)^2+(del)^2;]/(2*S12*S21);
if(K<1)
```

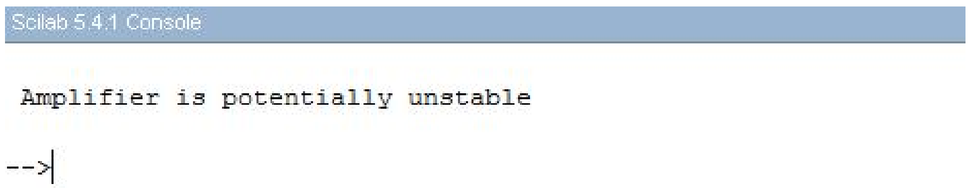



Figure 9.3: GaAs FET

```
    disp('Amplifier is potentially unstable');
else
     disp('Amplifier is potentially stable');
     end
```

**Scilab code Exa 9.5** Microwave transistor

```
//Page Number: 454
//Example 9.5
clc;
//Given
S11=0.40;
S12=0.01;
S21=2.00;
S22=0.35;

ZL=20; //ohm
ZS=30; //ohm
Z0=ZL+ZS; //ohm

//Reflection coefficients of source and load
TL=(ZL-Z0)/(ZL+Z0);
TLm=-TL;
TS=(ZS-Z0)/(ZS+Z0);
TSm=-TS;

//Reflection coefficients of input and output
Tin=S11+((S12*S21*TL)/(1-(S22*TL)));
Tout=S22+((S12*S21*TS)/(1-(S22*TS)));

//Transducer Gain
x=(1-(TSm)^2)/((1-(S11*TSm))^2); //Value of should be 1.145
```

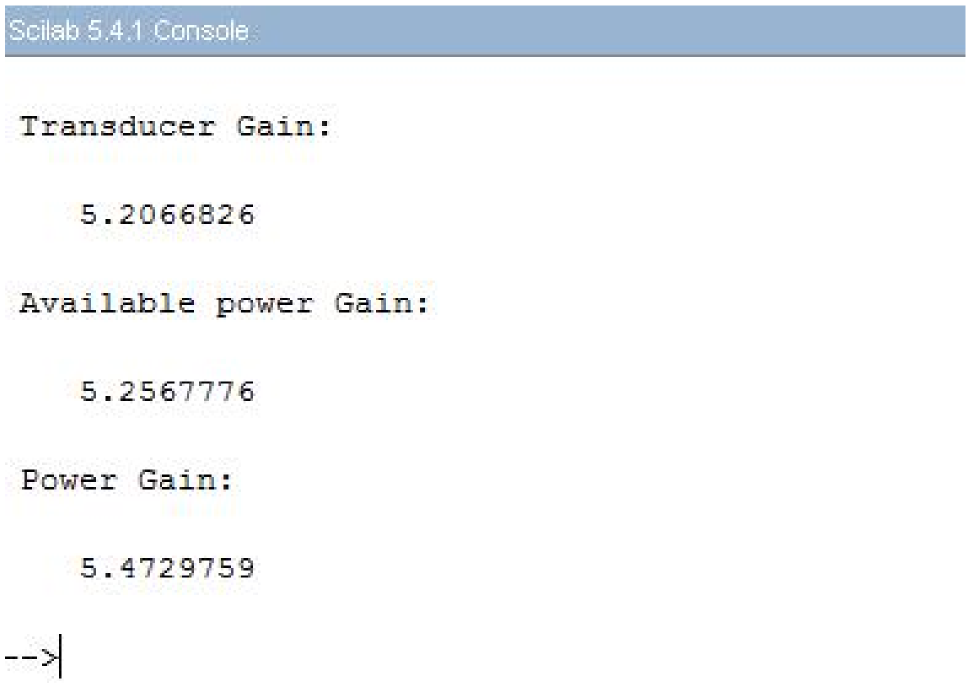



Figure 9.4: Microwave transistor

```
y=(S21*S21);
z=(1-(TLm)^2)/((1-(Tout*TLm))^2);
GT=x*y*z;
disp(GT,'Transducer Gain:');

//Available Power Gain
z1=1-(Tout)^2;
GA=(x*y)/z1;
disp(GA,'Available power Gain:');

//Power Gain
z2=1-(Tin)^2;
GP=(x*y)/z2;
disp(GP,'Power Gain:');

//All the end calculations of finding gain are not accurate in the book, hence the answers dont match
```

**Scilab code Exa 9.6** Transistor Amplifier

```
//Page Number: 455
//Example 9.6
clc;
//Given
S11=0.60;
S12=0.045;
S21=2.50;
S22=0.50
TS=0.5;
TL=0.4;
Vrms=10; //V
Z0=50; //ohm
```

```
Scilab 5.4.1 Console

 Reflection coefficients of input:

    0.65625

 Reflection coefficients of output:

    0.575

 Transducer Gain:

    13.553237

 Available power Gain:

    14.291431

 Power Gain:

    16.802604

 Power available at source:

    0.5

 W

 Power available at load:

    4.7

 W

-->
```



Figure 9.5: Transistor Amplifier

```
//(i)Reflection coefficients of input and output
Tin=S11+((S12*S21*TL)/(1-(S22*TL)));
Tout=S22+((S12*S21*TS)/(1-(S22*TS)));
disp(Tin,'Reflection coefficients of input:');
disp(Tout,'Reflection coefficients of output:');

//(ii) Gains
//Transducer Gain
x=(1-(TS)^2)/((1-(S11*TS))^2);
y=(S21*S21);
z=(1-(TL)^2)/((1-(Tout*TL))^2);
GT=x*y*z;
disp(GT,'Transducer Gain:');

//Available Power Gain
z1=1-(Tout)^2;
GA=(x*y)/z1;
disp(GA,'Available power Gain:');

//Power Gain
z2=1-(Tin)^2;
GP=(x*y)/z2;
disp(GP,'Power Gain:');

//Calculation for Tout and Gains are wrong in the
   book, hence the answers dont match

//(iii) Power available
Gt=9.4;
Pas=(sqrt(2)*Vrms)^2/(8*Z0);
Pal=Gt*Pas;
disp('W',Pas,'Power available at source:');
disp('W',Pal,'Power available at load:');
```

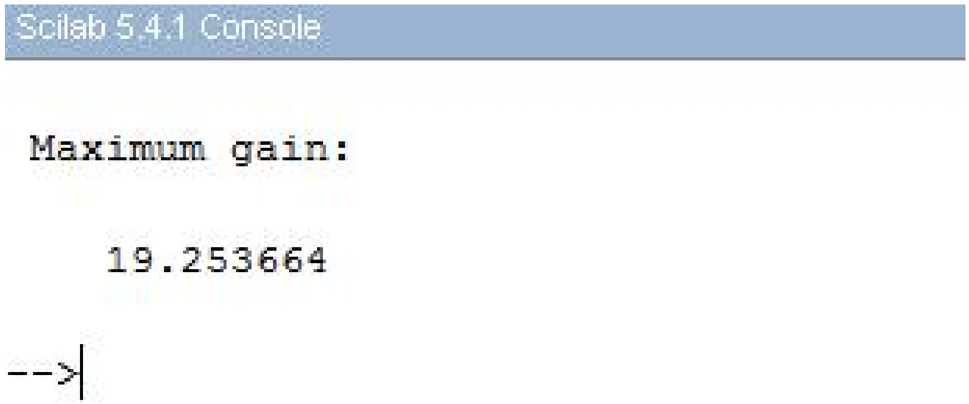





Figure 9.6: Microwave transistor

**Scilab code Exa 9.7** Microwave transistor

```
//Page Number: 457
//Example 9.7
clc;
//Given
S11=0.90;
S12=0;
S21=2.40;
S22=0.80;

Gmax=(S21*S21)/((1-(S11)^2)*(1-(S22)^2));
Gdb=10*log10(Gmax);
disp(Gdb,'Maximum gain:');
```

**Scilab code Exa 9.8** JEFT

```
//Page Number: 468
//Example 9.8
clc;
//Given
e=1.6D-19;
Nd=1.1D+23; //m-3
a=0.2D-6; //m
er=11.8;
e0=8.854D-12;
mue=800D-4; //m2/Vs
Z=50D-6;
L=8.5D-6; //m
W0=1; //V
```

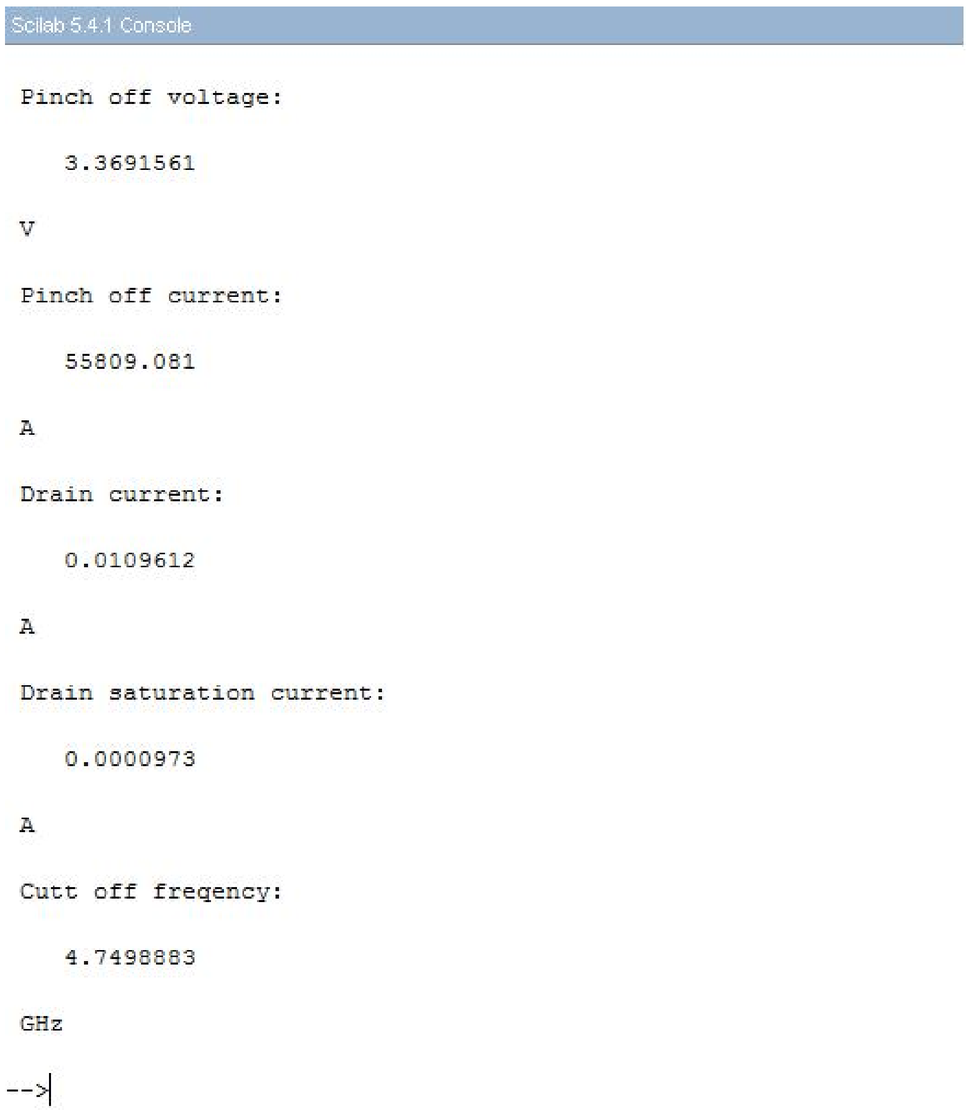



Figure 9.7: JEFT

```
Vd=12; //V
Vg=1.5; //V

//(i) Pinch off voltage and pinch off current
Vp=(e*Nd*a*a)/(2*er*e0);
disp('V',Vp,'Pinch off voltage:');

Ip=(mue*e*e*Nd*Nd*Z*a*a)/(e0*er*L);
disp('A',Ip,'Pinch off current:');
//Answer for Ip is 55809 A but it is given as 0.00558 A

//(ii) Drain and maximum drain current
//Taking Ip=5.58mA as given in book
Ip1=0.00558; //A
x=(2/3)*(((Vd+Vg+W0)/Vp)^(3/2));
y=(2/3)*(((Vg+W0)/Vp)^(3/2));
Id=Ip1*[(Vd/Vp)-x+y];
disp('A',-Id,'Drain current:');

//Saturation Current
Is=Ip1*[(1/3)-((Vg+W0)/Vp)+((2/3)*(((Vg+W0)/Vp)^(3/2)))];
disp('A',Is,'Drain saturation current:');

//(iii) Cut off frequency
f=(2*mue*e*Nd*a*a)/(%pi*er*e0*L*L);
disp('GHz',f/10^9,'Cutt off freqency:');
```

**Scilab code Exa 9.9** MESFET

```
//Page Number: 469
//Example 9.9
```

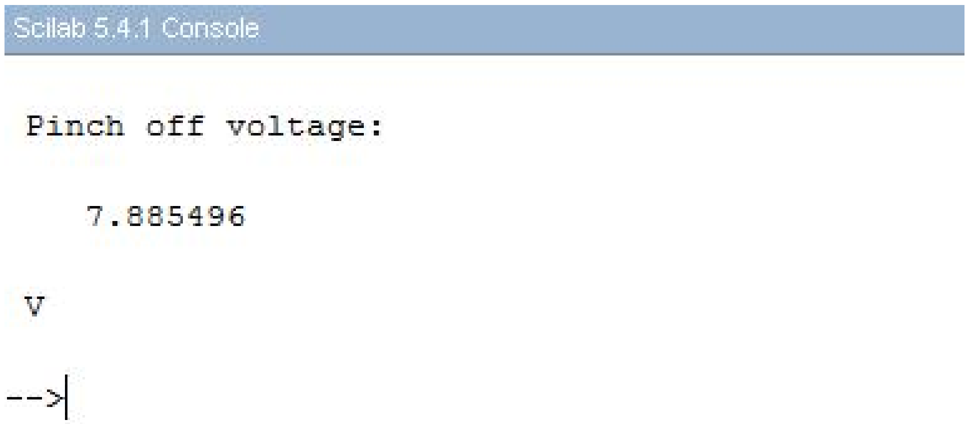



Figure 9.8: MESFET

```
clc;
//Given
e=1.6D-19;
Nd=8D+23; //m-3
a=0.12D-6; //m
er=13.2;
e0=8.854D-12;

//Pinch off voltage
Vp=(e*Nd*a*a)/(2*er*e0);
disp('V',Vp,'Pinch off voltage:');
```

**Scilab code Exa 9.10** Gunn device

```
//Page Number: 486
//Example 9.10
clc;
//Given
vd=2D+5; //m/s
L=10D-6; //m
Ec=3.2D+5; //V/m

//Natural frequency
f=vd/L;
disp('GHz',f/10^9,'Natural frequency:');

//Critical voltage
Vc=Ec*L;
disp('V',Vc,'Critical voltage:');
```


Figure 9.9: Gunn device

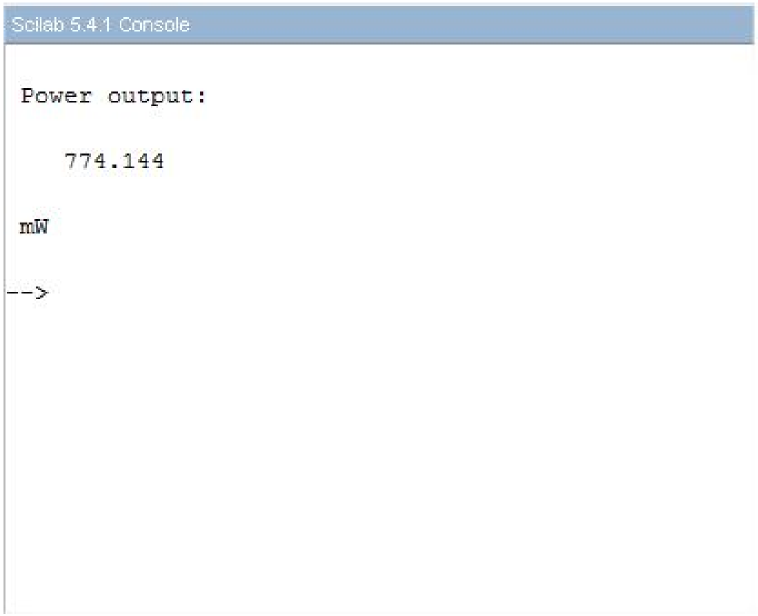



Figure 9.10: Gunn oscillator

**Scilab code Exa 9.11** Gunn oscillator

```
//Page Number: 487
//Example 9.11
clc;
//Given
n=0.08;
A=3D-8; //m2
n0=1D+21; //m-3
e=1.6D-19;
vd=1.5D+5; //m/s
M=3.2
E=350D+3; //V
L=12D-6; //m
```

```
//Power output
Pout=n*A*n0*e*vd*M*L*E;
disp('mW',Pout*1000,'Power output:');
```

**Scilab code Exa 9.12** Tunnel diode

```
//Page Number: 487
//Example 9.12
clc;
//Given
G=15.85;
Rn=75; //ohm

Rl=Rn-(Rn/G);
C=Rl+(10*%i);
disp('ohms',C,'Cavity impedance:');
```

**Scilab code Exa 9.13** Gunn diode

```
//Page Number: 487
//Example 9.13
clc;
//Given
e=1.6D-19;
n1=1D+16; //m-3
mu1=8000D-4; //m2/Vs
nu=1D+14; //m-3
muu=180D-4; //m2/Vs
```


Figure 9.11: Tunnel diode


Figure 9.12: Gunn diode

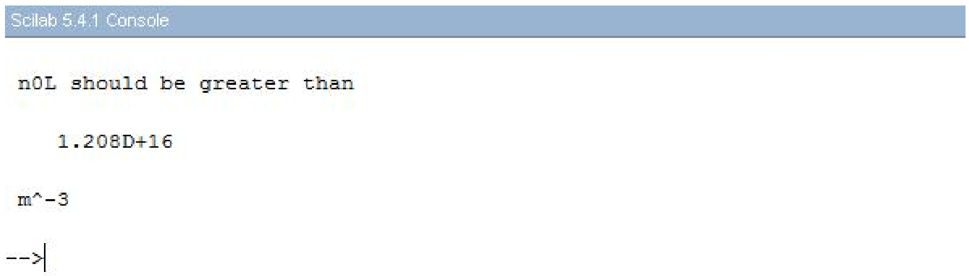



Figure 9.13: Gunn diode

```

///Conductivity
C=e*((n1*mu1)+(nu*muu));
disp('m mho',C*1000,'Conductivity:');
```

**Scilab code Exa 9.14** Gunn diode

```
//Page Number: 488
//Example 9.14
clc;
//Given
e0=8.854D-12;
```

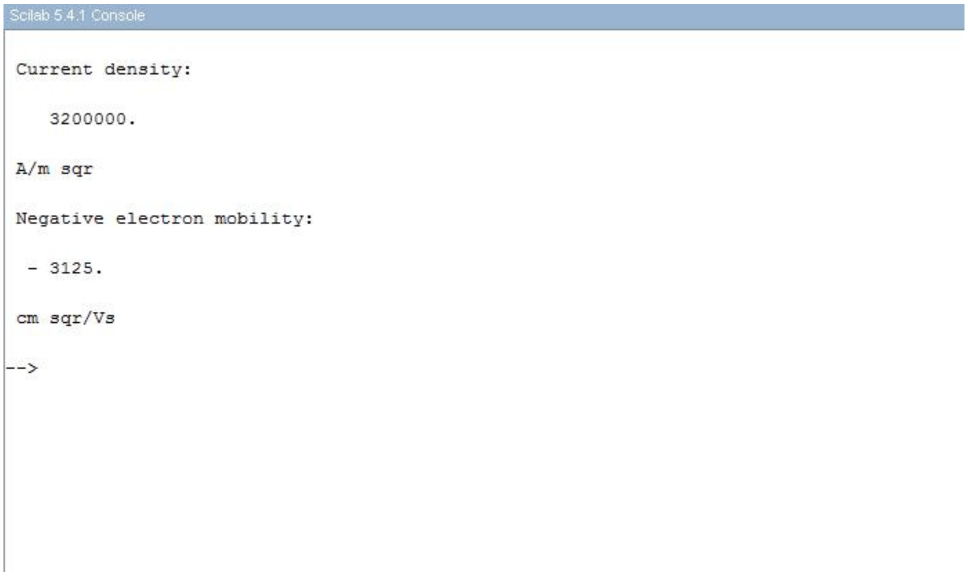



Figure 9.14: Gunn diode

```
er=13.1;
vd=2.5D+5; //m/s
e=1.6D-19;
mu=0.015; //m2/Vs

//Criteria
n0L=(e0*er*vd)/(e*mu);
disp('m^-3',n0L,'n0L should be greater than');
```

**Scilab code Exa 9.15** Gunn diode

```
//Page Number: 488
//Example 9.15
clc;
//Given
```

```
L=10D-6; //m
f=10D+9; //Hz
e=1.6D-19;
n0=2D+20; //m3
E=3200D+2; //V/m

//Current density
vd=L*f;
J=n0*e*vd;
disp('A/m sqr',J,'Current density:');

//Negative electron mobility
mu=-vd/E;
disp('cm sqr/Vs',mu*10000,'Negative electron
    mobility:');

//Answer for Negative electron mobility is 3125 but
    it is given as 3100
```

**Scilab code Exa 9.17** IMPATT diode

```
//Page Number: 497
//Example 9.17
clc;
//Given
n=0.15;
Vdc=100; //V
Idc=200D-3; //A
vd=2D+5; //m/s
L=6D-6; //m

//(i) Maximum CW output power
Pdc=Vdc*Idc;
```

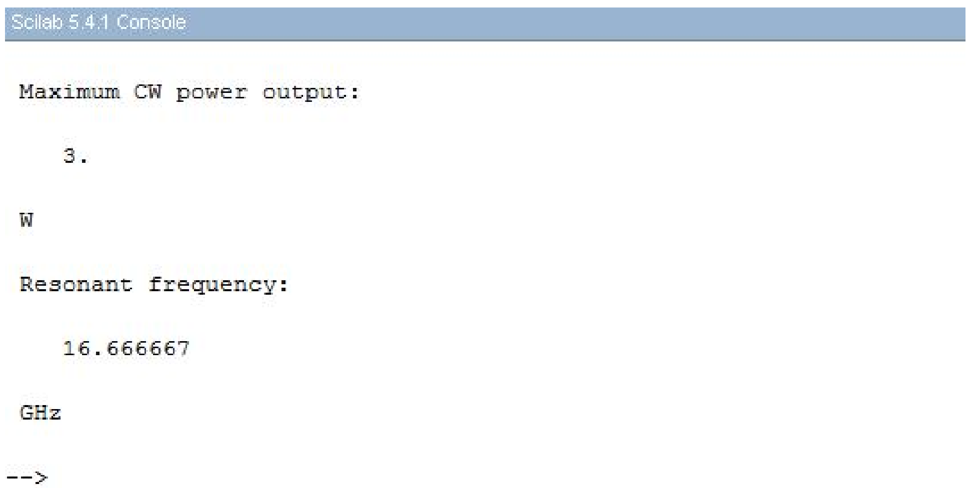



Figure 9.15: IMPATT diode

```
Pout=n*Pdc;
disp('W',Pout,'Maximum CW power output:');

//(ii) Resonant frequency
f=vd/(2*L);
disp('GHz',f/10^9,'Resonant frequency:');
```

**Scilab code Exa 9.18** IMPATT diode

```
//Page Number: 497
//Example 9.18
clc;
//Given
n=0.1;
Vdc=100; //V
Idc=100D-3; //A
vd=2D+5; //m/s
L=5D-6; //m
V0=90; //V
k=3;

//(i) Maximum CW output power
Pdc=Vdc*Idc;
Pout=n*Pdc;
disp('W',Pout,'Maximum CW power output:');

//(ii) Resonant frequency
f=vd/(2*L);
disp('Hz',f,'Resonant frequency:');

//(iii)Transit time
T=L/vd;
disp('s',T,'Transit time:');
```

```
Scilab 5.4.1 Console

 Maximum CW power output:

    1.

 W

 Resonant frequency:

    2.000D+10

 Hz

 Transit time:

    2.500D-11

 s

 Avalanche multiplication factor:

    2.6900369

-->
```

Figure 9.16: IMPATT diode


Figure 9.17: IMPATT diode

```

//(iv) Avalanche multiplication factor
M=1/(1-((Vdc/V0)^k));
disp(-M,'Avalanche multiplication factor:');
```

**Scilab code Exa 9.19** IMPATT diode

```
//Page Number: 498
//Example 9.19
clc;
//Given
n=0.1;
Vdc=100; //V
```

```
Idc=0.9; //A
t=0.01D-9; //s
f=16D+9; //Hz

//(i)Power output
Pdc=Vdc*Idc;
Pout=n*Pdc;
disp('W',Pout,'Power output:');

//(ii)Duty cycle
D=(t/2)+(1/(2*f));
disp('s',D,'Duty cycle:');
```

**Scilab code Exa 9.20** IMPATT diode

```
//Page Number: 498
//Example 9.20
clc;
//Given
Cj=0.5D-12; //F
Lp=0.5D-9; //H
Irf=0.65; //A
Rl=2; //ohms
Vbd=80; //V
Idc=0.08; //A

//Resonant frequency
f=1/(2*%pi*sqrt(Cj*Lp));
disp('Hz',f,'Resonant frequency:');

//Efficiency
Pout=(Irf*Irf*Rl)/2;
Pin=Vbd*Idc;
```


Figure 9.18: IMPATT diode

```
n=(Pout*100)/Pin;
disp('%',n,'Efficiency:');
```

**Scilab code Exa 9.21** TRAPATT diode

```
//Page Number: 501
//Example 9.21
clc;
//Given
J=25D+7; //A/m;
Na=2.5D+21; //m3
e=1.6D-19;

//Avlance zone velocity
vz=J/(Na*e);
disp('m/s',vz,'Avlanche zone velocity:');
```

**Scilab code Exa 9.22** BARITT diode

```
//Page Number: 503
//Example 9.22
clc;
//Given
e=1.6D-19;
N=4D+21; //m
L=10D-6; //m
e0=8.854D-12;
er=11;

```

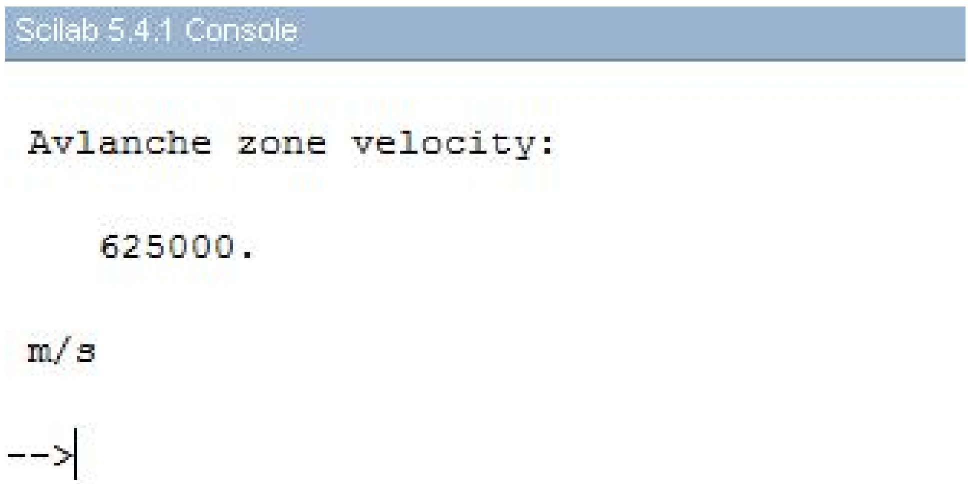



Figure 9.19: TRAPATT diode

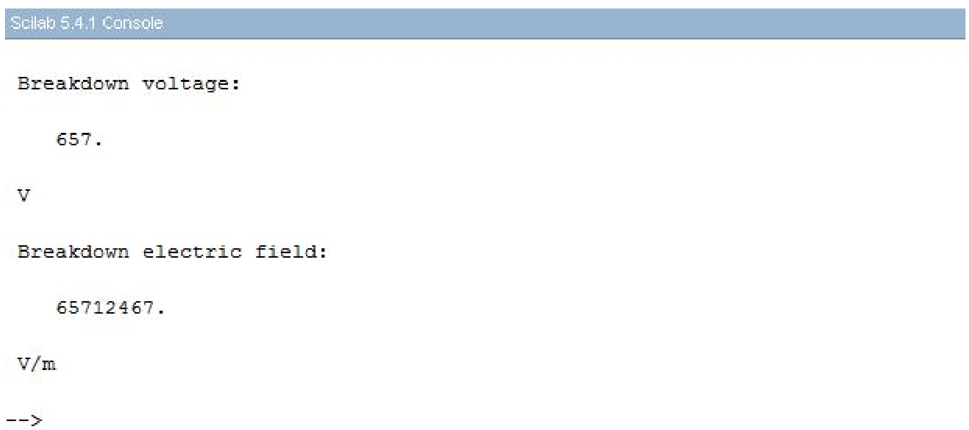



Figure 9.20: BARITT diode

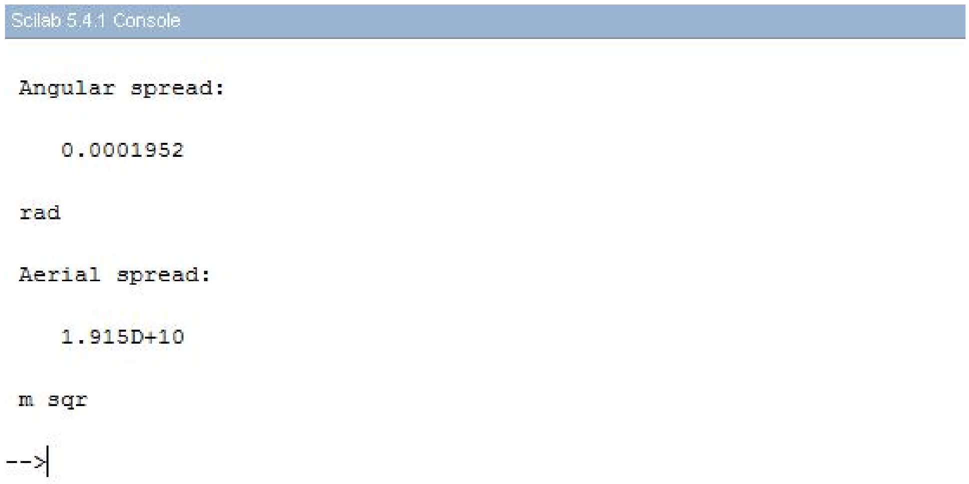



Figure 9.21: Laser

```
//Breakdown voltage
Vbd=(e*N*L*L)/(e0*er);
disp('V',round(Vbd),'Breakdown voltage:');

//Breakdown electric field
E=Vbd/L;
disp('V/m',E,'Breakdown electric field:');
```

**Scilab code Exa 9.23** Laser

```
//Page Number: 515
//Example 9.23
clc;
//Given
lam=8000D-10; //m
a=0.5D-2; //m
D=4D+8; //m

//Angular Spread
t=(1.22*lam)/a;
disp('rad',t,'Angular spread:');

//Aerial spread
A=%pi*((D*t)^2);
disp('m sqr',A,'Aerial spread:');


//Answer for A is given as 193 m sqr but it is 1.915
   D+10 m sqr
```

**Scilab code Exa 9.24** Laser

```
//Page Number: 515
//Example 9.24
clc;
//Given
E=10; //W
T=1D-9; //s
c=3D+8; //m/s
lam=650D-9; //m

//Pulse Power
P=E/T;
```


Figure 9.22: Laser

```
disp('W',P,'Pulse Power:');

//Q value
Q=(c*T)/lam;
disp(Q,'Q value:');
```

**Scilab code Exa 9.25** Heterojunction laser

```
//Page Number: 515
//Example 9.25
clc;
//Given
h=6.626D-34;
c=3D+8; //m/s
```


Figure 9.23: Heterojunction laser

```
e=1.6D-19;
Eg=1.85; //eV

//Wavelenght emitted
lam=(h*c)/(Eg*e);
lamarm=lam*1D+10;
disp('A',round(lamarm),'Wavelenght emitted:');
```

# Chapter 10

# Striplines and Microstrip Lines

**Scilab code Exa 10.1** Copper stripline

```
//Page Number: 554
//Example 10.1
clc;
//Given,

z0=50; //ohm
t=0.001; //mm
b=0.32; //cm
er=2.20;
tandel= 0.0005;
rs=0.026; //ohm
f=10D+9; //Hz
c=3D+8;//m/sec

p=sqrt(er)*z0;
//As p<120
w=b*[((30*%pi)/p)-0.441];
disp('cm',w,'Width');

```


Figure 10.1: Copper stripline

```
//Attenuation
k={(2*%pi*f*sqrt(er))/c};
ad=(k*tandel)/2;

//and
A=1+{(2*w)/(b-t)}+[{(b+t)/((b-t)*%pi)}*log(((2*b)-t)
   /t)];
//Hence
ac=(2.7D-3*rs*er*z0*A)/{30*%pi*(b-t)*1D-2};
//Total attenution
a=ad+ac;

//Total attenution in db
x=exp(a);
alp=20*log10(x); //db/m

//Total attenution in db/lambda:
lam=c/(sqrt(er)*f);
lamm=lam*1D+2;
alph=alp/lamm;
disp('db/lambda',alph,'Total attenution in db/lambda
   :');


//Answer in book for alph is given as 0.856 but it
   should be 0.0856 as value of f is taken as 10D+10
    but it should be 10D+9
```

**Scilab code Exa 10.2** Microstrip line

```
//Page Number: 555
//Example 10.2
clc;
```


```
 Dielectric constant:

    6.5564729

 Phase constant:

    2.6814133

 rad/m

 Microstrip wavelength:

    2.3432364

 cm

 Capacitance per unit length:

    2.717D-11

 F/cm

 Characterstic impedance:

    49.447285

 ohm

-->
```

Figure 10.2: Microstrip line

```
//Given,
er=9.7;
h=0.25; //mm
w=0.25; //mm
f=5D+9; //Hz
c=3D+8; //m/s

//(i) Dielectric constant
dc=((er+1)/2)+(((er-1)/2)*(1/sqrt(1+12*h/w)));
disp(dc,'Dielectric constant:');

//(ii) Phase constant
lam0=c/f;
pc=sqrt(dc)*(2*%pi/lam0);
disp('rad/m',pc/100,'Phase constant:');

//(iii) Microstrip wavelength
lams=lam0/sqrt(dc);
disp('cm',lams*100,'Microstrip wavelength:');

//(iv) Capacitance per unit length
e0=8.854D-12;
cap=(2*%pi*e0)/log((8*h/w)-(w/(4*h)));
disp('F/cm',cap,'Capacitance per unit length:');

//(v) Characterstic Impedance
ci=(60/sqrt(dc))*log((8*h/w)+(w/(4*h)));
disp('ohm',ci,'Characterstic impedance:');
```

**Scilab code Exa 10.3** Microstrip

```
//Page Number: 556
//Example 10.3
```

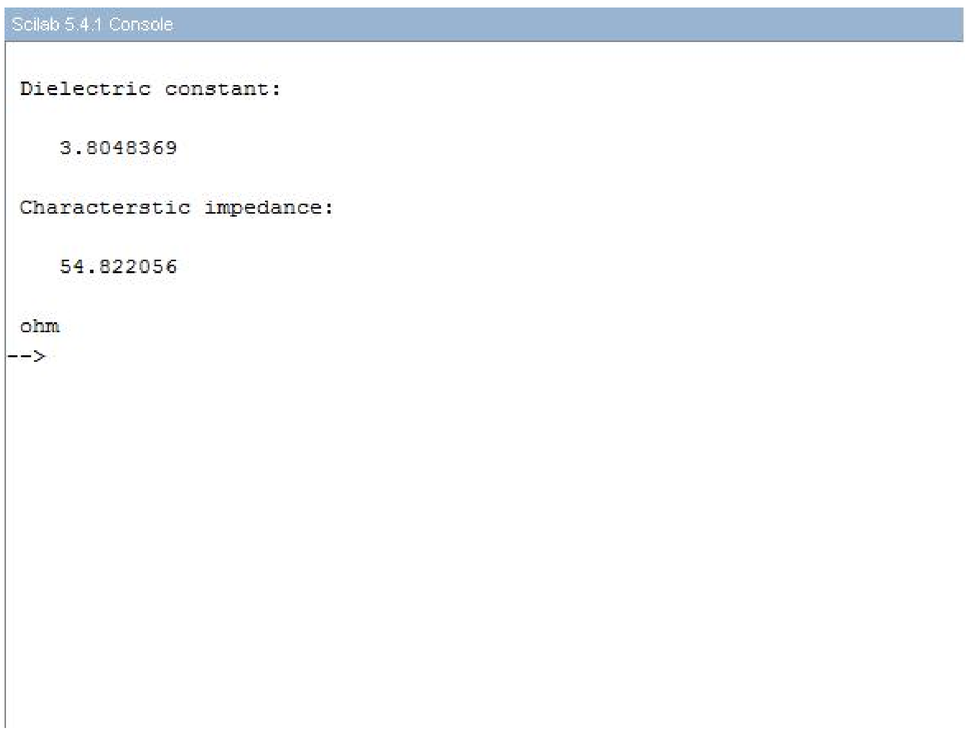



Figure 10.3: Microstrip

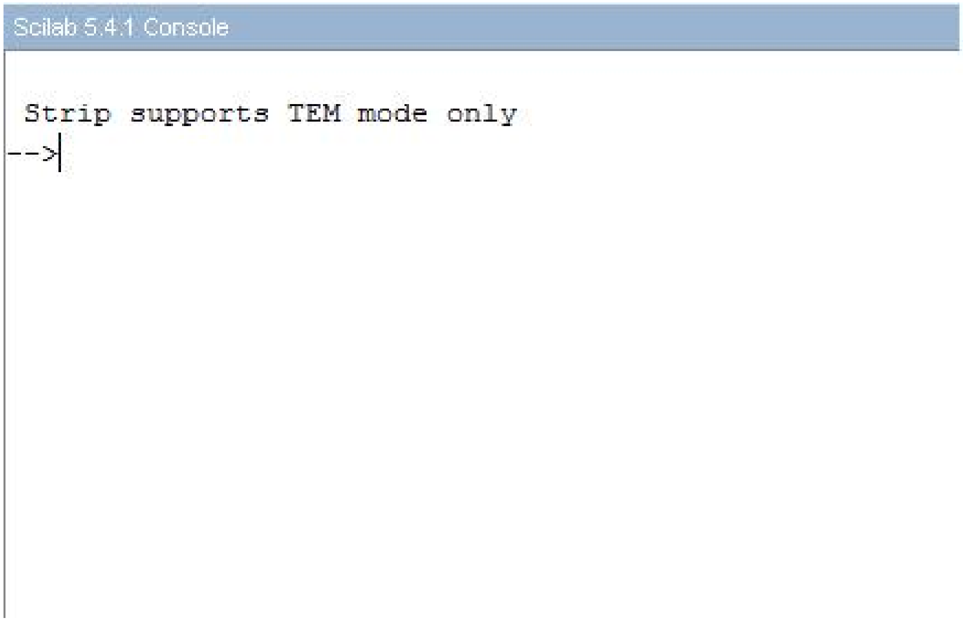



Figure 10.4: Stripline

```
clc;
//Given ,
er=5.23;
w=10; //mils
t=2.8; //mils
h=7; //mils

dc=((er+1)/2)+(((er-1)/2)*(1/sqrt(1+12*h/w)));
disp(dc,'Dielectric constant:');

//As w/h>1
ci=(120*%pi)/(sqrt(dc)*((w/h)+1.393+0.667*log((w/h)
    +1.444)));
disp('ohm',ci,'Characterstic impedance:');
```

**Scilab code Exa 10.4** Stripline

```
//Page Number: 556
//Example 10.4
clc;
//Given,

q=2.5;
dh=1.58;
er=9;
f=10;
c=3D+8;

erff=((er+1)/2)+(((er-1)/2)*((1+(12/q))^(-1/2)));
vp=(c/sqrt(erff))*erff;
fe1=c/(sqrt(vp)*2*dh*q);
if f<fe1 then
    disp('Strip supports TEM mode only');
else
    disp('Strip does not support TEM mode only');
end
```

**Scilab code Exa 10.5** Microstrip line

```
//Page Number: 557
//Example 10.5
clc;
//Given,

er=9.7;
```


Figure 10.5: Microstrip line

```
h=0.5; //mm
w=0.5; //mm
lt=2D-4;
t=0.02; //mm
f=5D+9; //Hz
fg=5; //HZ
c=3D+8;
rs=8.22D-3*sqrt(fg);

//(i) Dielectric constant
dc=((er+1)/2)+(((er-1)/2)*(1/sqrt(1+12*h/w)));
disp(dc,'Dielectric constant:');

//(ii) Characterstic Impedance
ci=(60/sqrt(dc))*log((8*h/w)+(w/(4*h)));
disp('ohm',ci,'Characterstic impedance:');

//(iii) Dielectric attenuation
lam0=c/f;
alphd=(%pi/lam0)*(er/sqrt(dc))*((dc-1)/(er-1))*lt;
disp('Np/m',alphd,'Dielectric attenuation:');

//Conductor attenuation
r1=[0.94+(0.132*(w/h))-(0.0062*((w/h)^2))]*[(1/%pi)
   +(1/(%pi^2))*log((4*%pi*w)/t)]*(rs/(w*1D-3));
r1m=r1*1D-2;
r2=(w/h)/[((w/h)+5.8+(0.03*(h/w)))]*(rs/(w*1D-3));
r2m=r2*1D-2;
alphc=(r1+r2)/(2*ci);
disp('Np/m',alphc,'Conductor attenuation:');

//(iv) Total attenuation
A=alphc+alphd;
Adb=A*8.686*1D-2;
disp('db/cm',Adb,'Total attenuation:');
```


Figure 10.6: Microstrip line

**Scilab code Exa 10.6** Microstrip line

```
//Page Number: 558
//Example 10.6
clc;
//Given

sig=5.8D+7;
f=10; //GHz
h=0.12D-2; //m

q=62.8*h*sqrt(f*sig);
disp(round(q),'conductor Q of the stripline:');
```


Figure 10.7: Parallel stripline

**Scilab code Exa 10.7** Parallel stripline

```
//Page Number: 558
//Example 10.7
clc;
//Given
Er=6;
h=4D-3; //m

//(i) W for Z0=50W
Z0=50; //W
W=(120*%pi*h)/(sqrt(Er)*Z0);
disp('mm',W*1000,'Required Width:');

//(ii)Stripline capacitance
E0=8.854D-12;
C=(E0*Er*W)/h;
disp('pF/m',C*10^12,'Stripline capacitance:');

//(iii)Stripline inductance
Mu0=4*%pi*10D-7;
L=(Mu0*h)/W;
disp('muH/m',L*10^5,'Stripline inductance:');

//(iv)Phase velocity
c=3D+8;
vp=c/sqrt(Er);
disp('m/s',vp,'Phase velocity');
```

**Scilab code Exa 10.8** Stripline coupler

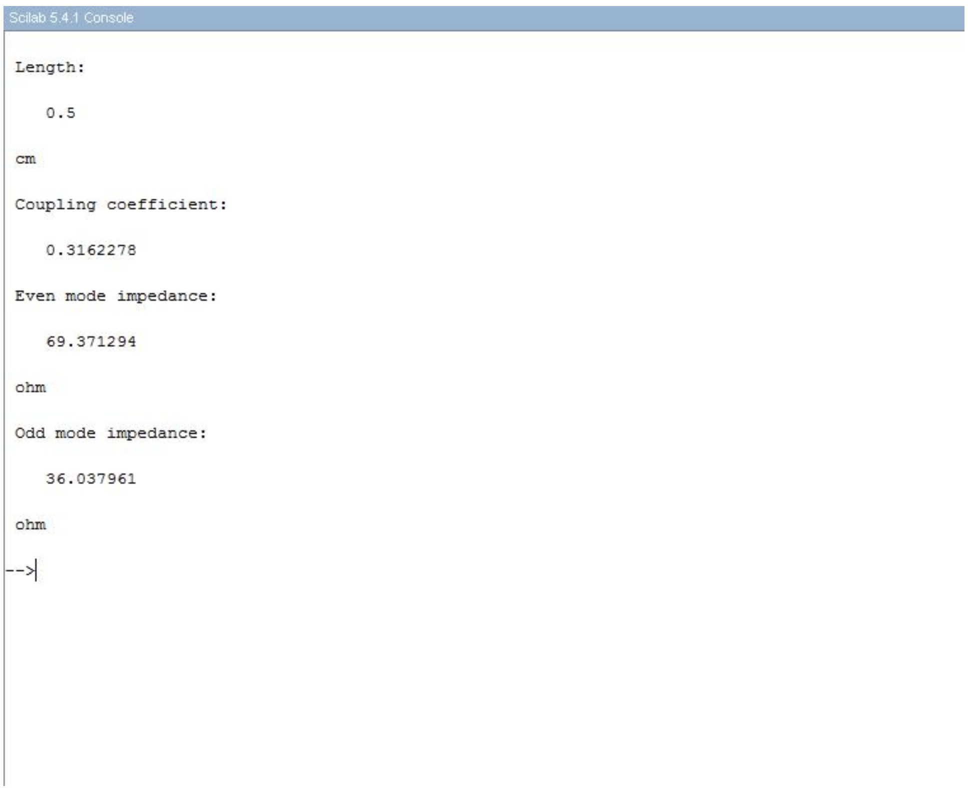



Figure 10.8: Stripline coupler

```
//Page Number: 559
//Example 10.8
clc;
//Given
cl=3D+8; //m/s
f=5D+9; //Hz
Er=9;
C=-10; //db
Z0=50; //ohm
//Length
L=(cl/f)/(4*sqrt(Er));
disp('cm',L*100,'Length:');

//Coupling coefficient
C0=10^(C/20);
disp(C0,'Coupling coefficient:');

//Even and odd mode impedance
Z0e=(Z0*sqrt(1+C0))/sqrt(1-C0);
disp('ohm',Z0e,'Even mode impedance:');


Z0o=(Z0*sqrt(1-C0))/sqrt(1+C0);
disp('ohm',Z0o,'Odd mode impedance:');
```

**Scilab code Exa 10.9** Branch coupler

```
//Page Number: 560
//Example 10.9
clc;
//Given
Z0=50; //ohm
C=3; //db
```

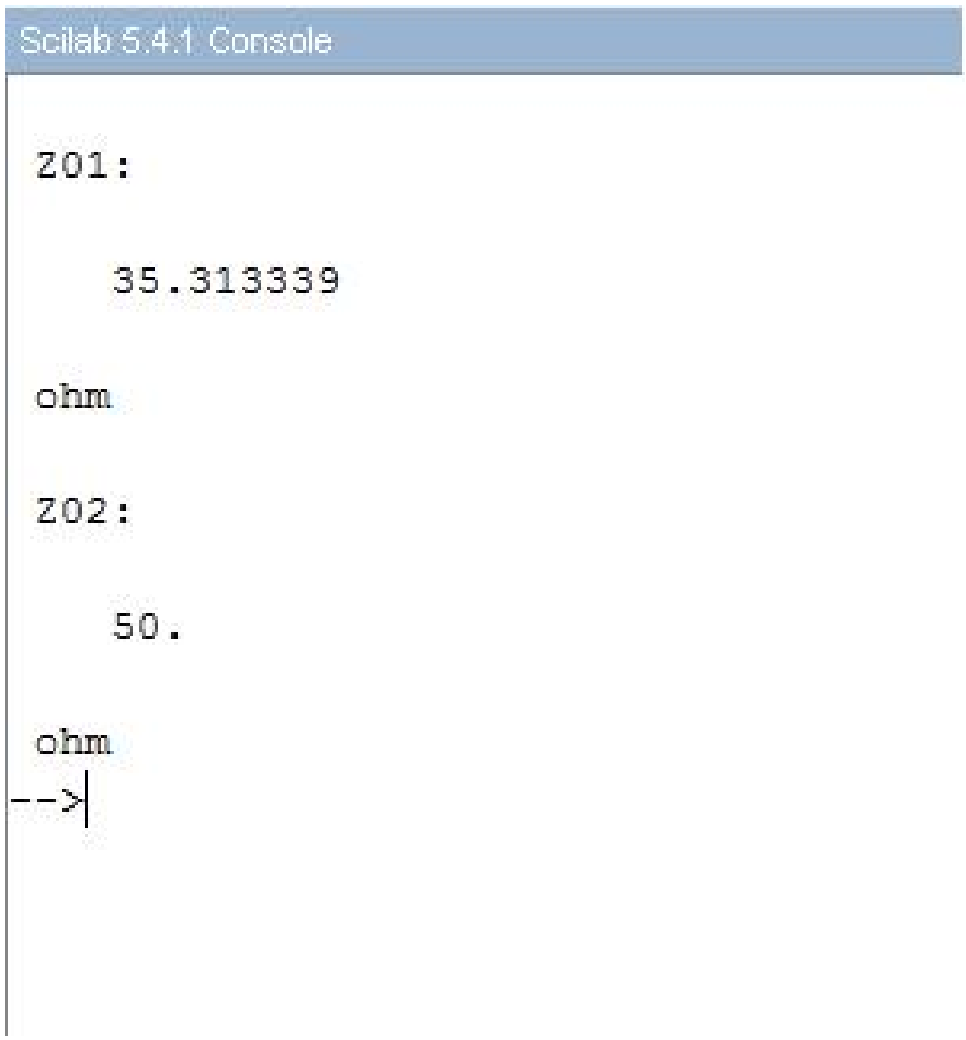



Figure 10.9: Branch coupler

```

//Line impedance
Z01sqr=(1-(10^(C/-10)));
Z01=sqrt(Z0*Z0*Z01sqr);
disp('ohm',Z01,'Z01:');

Z02=Z01/(sqrt(1-(1/sqrt(2))^2));
disp('ohm',round(Z02),'Z02:');
```

**Scilab code Exa 10.10** Broadside stripline

```
//Page Number: 560
//Example 10.10
clc;
//Given
W=6; //m
s=2.2; //m
b=4.8; //m
Er=2.2;

//Even and odd mode impedance
Z0e=((120*%pi)*(b-s))/(2*sqrt(Er)*W);
disp('ohm',Z0e,'Even mode impedance:');


Z0o=(Z0e*s)/b;
disp('ohm',Z0o,'Odd mode impedance:');

//Mid band coupling
x=(Z0e-Z0o)/(Z0e+Z0o);
C=-20*log10(x);
disp('db',C,'Mid band coupling:');

```

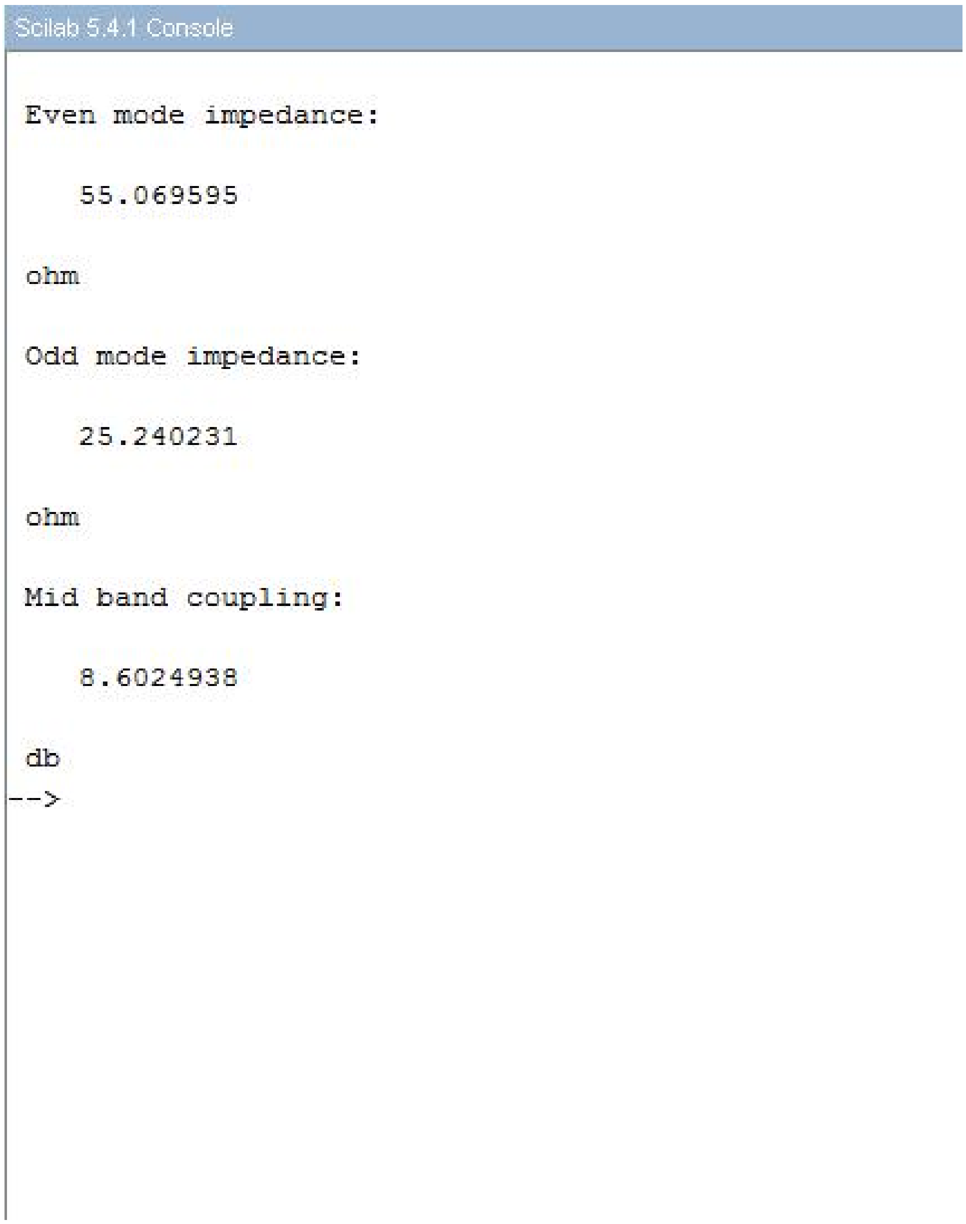



Figure 10.10: Broadside stripline

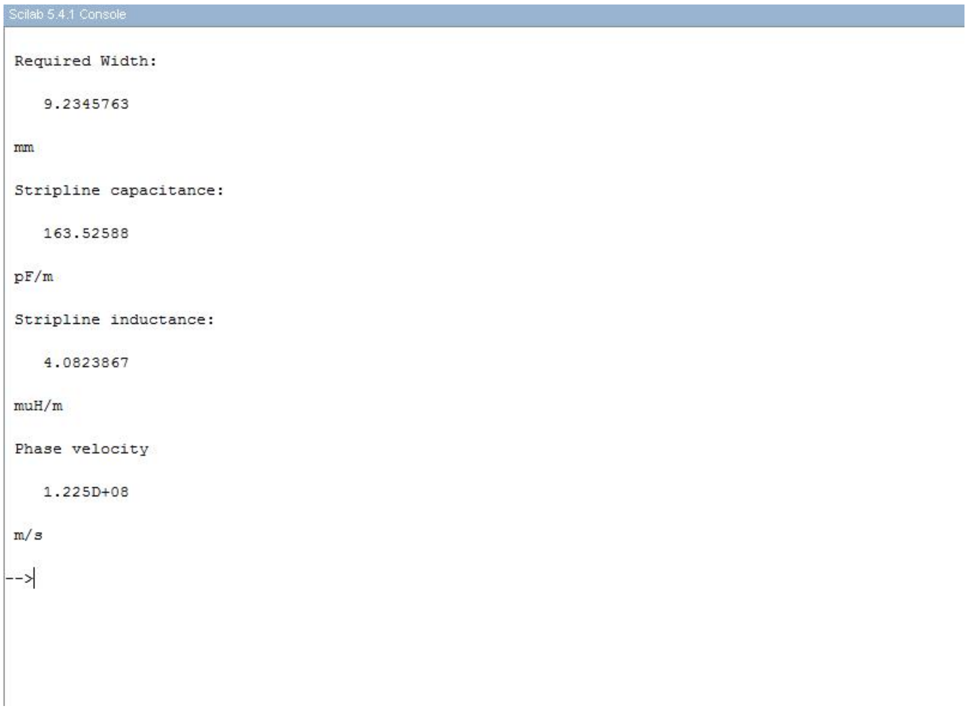



Figure 10.11: Paralle stripline

```
//Answer in book for C is given as 54.2 but it
    should be 8.60
```

---

**Scilab code Exa 10.11** Paralle stripline

```
//Page Number: 562
//Example 10.11
clc;
//Given
Er=6;
d=3D-3; //m
Z0=50; //ohm
```

```
E0=8.854D-12; //F/m
Mu0=4*%pi*10D-7; //H/m

//(i) W
W=(377*d)/(sqrt(Er)*Z0);
disp('mm',W*1000,'Required Width:');

//(ii)Stripline capacitance
C=(E0*Er*W)/d;
disp('pF/m',C*10^12,'Stripline capacitance:');

//(iii)Stripline inductance
L=(Mu0*d)/W;
disp('muH/m',L*10^6,'Stripline inductance:');

//(iv)Phase velocity
c=3D+8;
vp=c/sqrt(Er);
disp('m/s',vp,'Phase velocity');
```

**Scilab code Exa 10.12** Shielded stripline

```
//Page Number: 562
//Example 10.12
clc;
//Given
Er=2.56;
w=25; //mils
t=14; //mils
d=70; //mils
E0=8.854D-12; //F/m

//(i) K factor
```

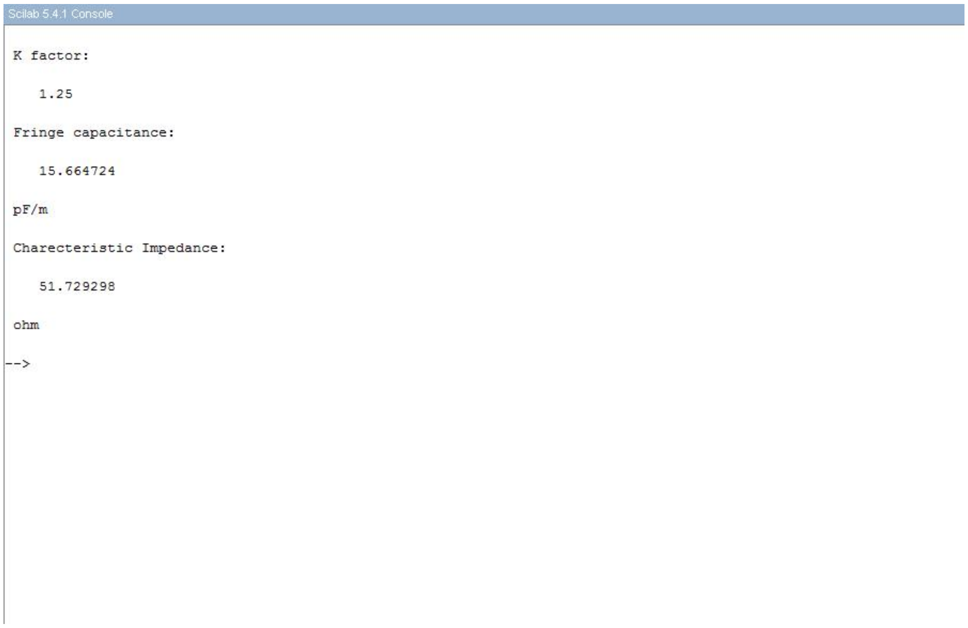



Figure 10.12: Shielded stripline

```
K=1/(1-(t/d));
disp(K,'K factor:');

//(ii) Fringe capacitance
C=[(E0*Er)*[2*K*log(K+1)-(K-1)*log(K^2-1)]]/%pi;
disp('pF/m',C*10^12,'Fringe capacitance:');

//(iii) Charecteristic Impedance
X=1/[((w*K)/d)+(C/(E0*Er))];
Z0=(94.15*X)/sqrt(Er);
disp('ohm',Z0,'Charecteristic Impedance:');


//Answer in book for Z0 is given as 50.29 but it
    should be 51.7
```

```
Scilab 5.4.1 Console

 Output Impedance 1:

    125.

 ohm

 Output Impedance 2:

    83.333333

 ohm

 Reflection Coeffcients:

  - 0.6

  - 0.4
-->
```

Figure 10.13: Lossless stripline

**Scilab code Exa 10.13** Lossless stripline

```
//Page Number: 563
//Example 10.13
clc;
//Given
Z0=50; //ohm
//Sincr ratio of power is 2:3
x1=5/2;
y1=5/3;
//Output Impedance
Z1=x1*Z0;
Z2=y1*Z0;
disp('ohm',Z1,'Output Impedance 1:')
disp('ohm',Z2,'Output Impedance 2:')

//Input Impedance
Zin=[((Z2*2*Z2)/3)/((Z2+(2*Z2)/3))];

//Looking into Z1, Z2 is || to Z0
A1=(Z2*Z0)/(Z2+Z0);

//Looking into Z, Z2 is || to Z0
A2=(Z1*Z0)/(Z1+Z0);

//Reflection Coeffcients
R1=(A1-Z1)/(A1+Z1);
R2=(A2-Z2)/(A2+Z2);

disp(R2,R1,'Reflection Coeffcients:');
```

# Chapter 11

# Microwave Integrated Circuits

**Scilab code Exa 11.1** Costs

```
//Page Number: 595
//Example 11.1
clc;
//Given
fabc=10000; //Rs/waffer
c=100;
y=40/100;
coc=fabc/(y*c);
//Cost of one chip
disp('Rs',coc,'Cost of one chip:');

//Market Cost
mc=2*coc;
disp('Rs',mc,'Market costof one chip:');
```

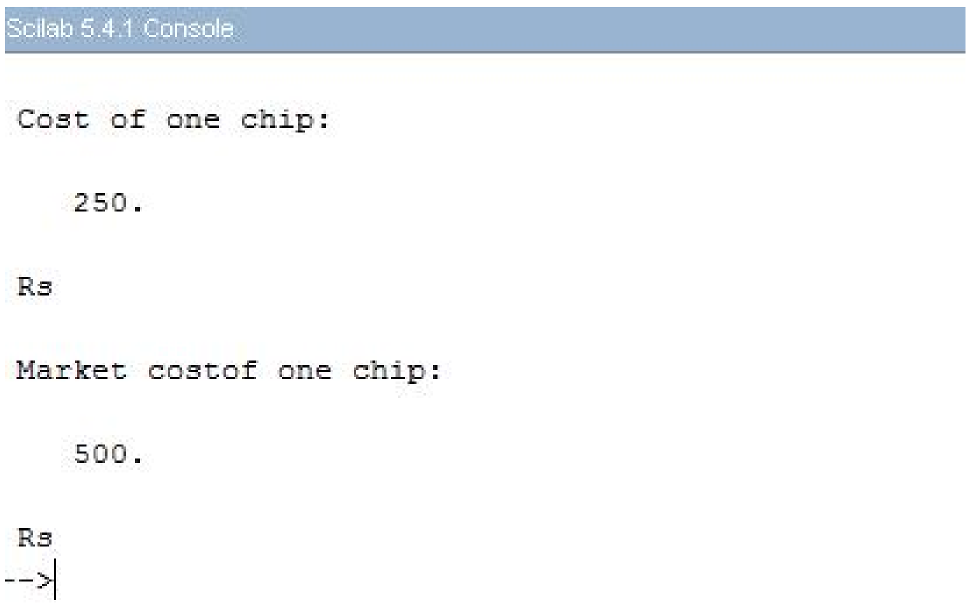



Figure 11.1: Costs

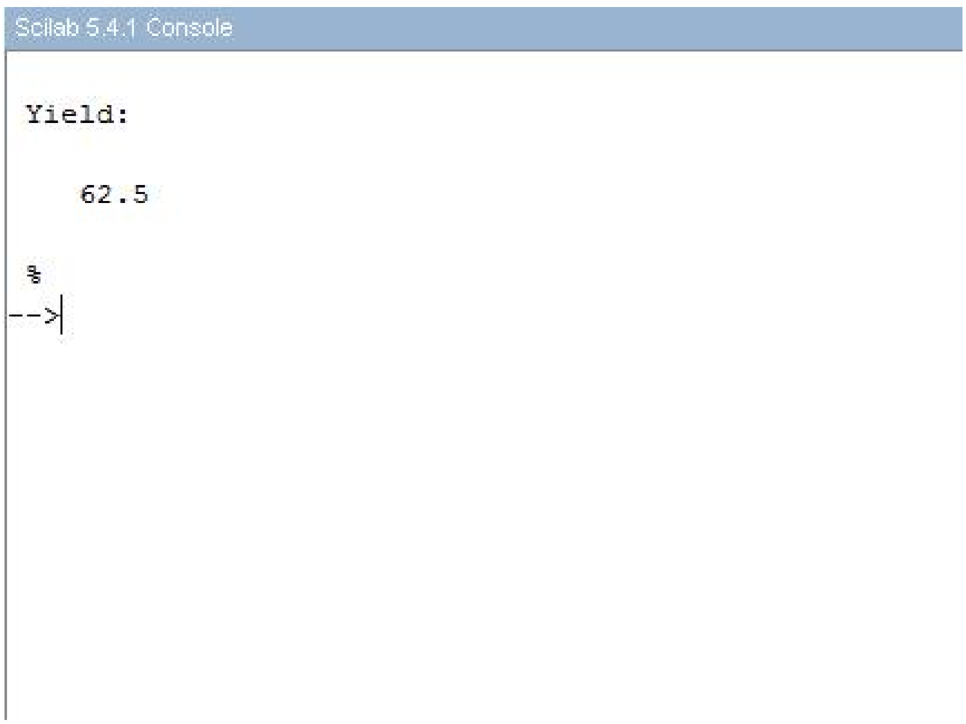



Figure 11.2: Yield

**Scilab code Exa 11.2** Yield

```
//Page Number: 595
//Example 11.2
clc;
//Given
c=5000; //Rs
S=0.6; //cm
//Sides
x=3; //cm
y=2.54; //cm
//break even cost
bec=250;
//hence, chips/waffers needed
cpw=c/bec;
D=x*y;
//For given Area, atleast 40 chips are required
n=2*cpw;

//Diameter
N=D/(sqrt(2)*S);
//Lower round off
NN=floor(N);
//Chips possible
cp=NN^2;

//Yield
Y=(n/cp)*100; //Percent
disp('%',Y,'Yield:');
```

# Chapter 12

# Microwave Measurements

**Scilab code Exa 12.1** Microwave diode

```
//Page Number: 649
//Example 12.1
clc;
//Given
Is=0.1*(10^-6); //A
Pi=0; //dBm
Cs=0.1*(10^-12); //F
Ls=2*(10^-9);
Cj=0.15*(10^-12); //F
Rs=10; //ohm
T=293; //K
nktbye=25*(10^-3); //V

//Rj
Rj=(nktbye/Is);
disp('Kohm',Rj/1000,'Rj:');

//Bi
Bi=nktbye/2;
```

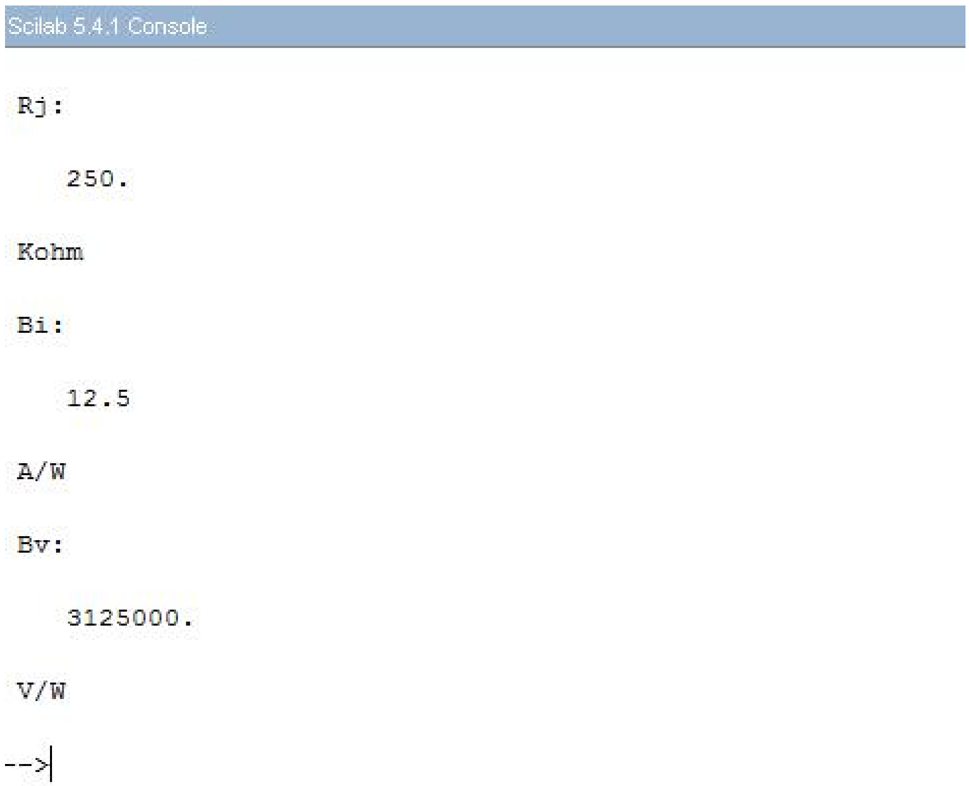



Figure 12.1: Microwave diode

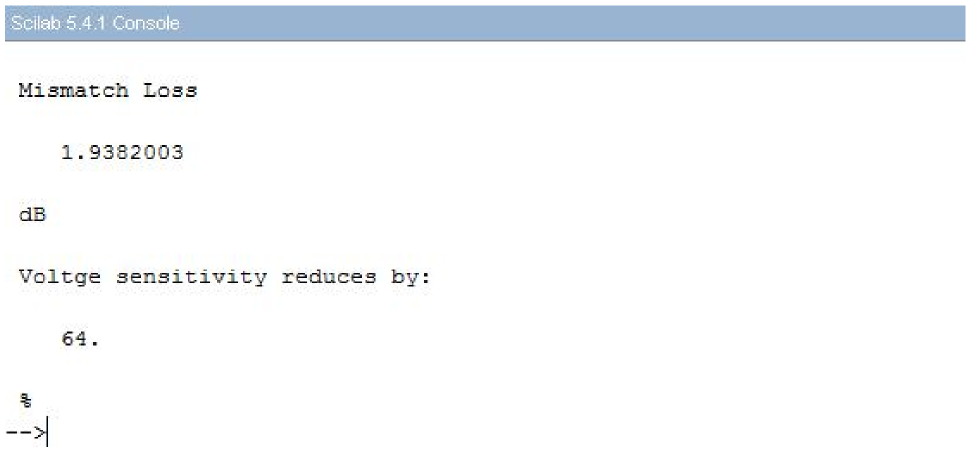



Figure 12.2: Detector mismatch

```
Bii=Bi*1000;
disp('A/W',Bii,'Bi:');

//Bv
Bv=Rj*Bii;
disp('V/W',Bv,'Bv:');
```

**Scilab code Exa 12.2** Detector mismatch

```
//Page Number: 650
//Example 12.2
clc;
//Given
vswr=4;
```


Figure 12.3: Transmission waveguide

```

modT=(vswr-1)/(vswr+1);
Lm=-10*log10(1-(modT*modT)); //dB
disp('dB',Lm,'Mismatch Loss:');

//Sensitivity reduces by a factor
Bvd=(1-(modT*modT));
Bvdp=Bvd*100;
disp('%',Bvdp,'Voltge sensitivity reduces by:');
```

**Scilab code Exa 12.3** Transmission waveguide

```
//Page Number: 650
//Example 12.3
clc;
//Given
f=10D+9; //Hz
c=3D+10; //cm/s
```


Figure 12.4: VSWR of waveguide

```
a=4; //cm
s=0.1; //cm
lmb=c/f; //cm
lmbg=lmb/(sqrt(1-((lmb/(2*a))^2)));
vswr=lmbg/(%pi*s);
disp(vswr,'VSWR: ');

//Answer in book for lmbg is given as 3.49 but it
   should be 3.23 and hence the answer will be 10.3
```

**Scilab code Exa 12.4** VSWR of waveguide

```
//Page Number: 651
//Example 12.4
clc;
//Given
```


Figure 12.5: Directional couplers

```
delx=3.5; //cm
s=0.25; //cm

lmbg=2*delx;
vswr=lmbg/(%pi*s);
disp(vswr,'VSWR:');
```

---

**Scilab code Exa 12.5** Directional couplers

```
//Page Number: 651
//Example 12.5
clc;
//Given
vswr=2;
Pin=4.5D-3; //W

modT=(vswr-1)/(vswr+1);
```


Figure 12.6: Microwave line

```
//Power reflected ,
Pr=(modT^2)*Pin;
//As coupler samples only 1/1000th power
Prr=Pr*1000;
disp('W',Prr,'Reflected Power:');
```

**Scilab code Exa 12.6** Microwave line

```
//Page Number: 652
//Example 12.6
clc;
//Given
Z0=50; //ohm
p=2.4;
L=0.313;
x=2*%pi*L;
y=tan(x);
```

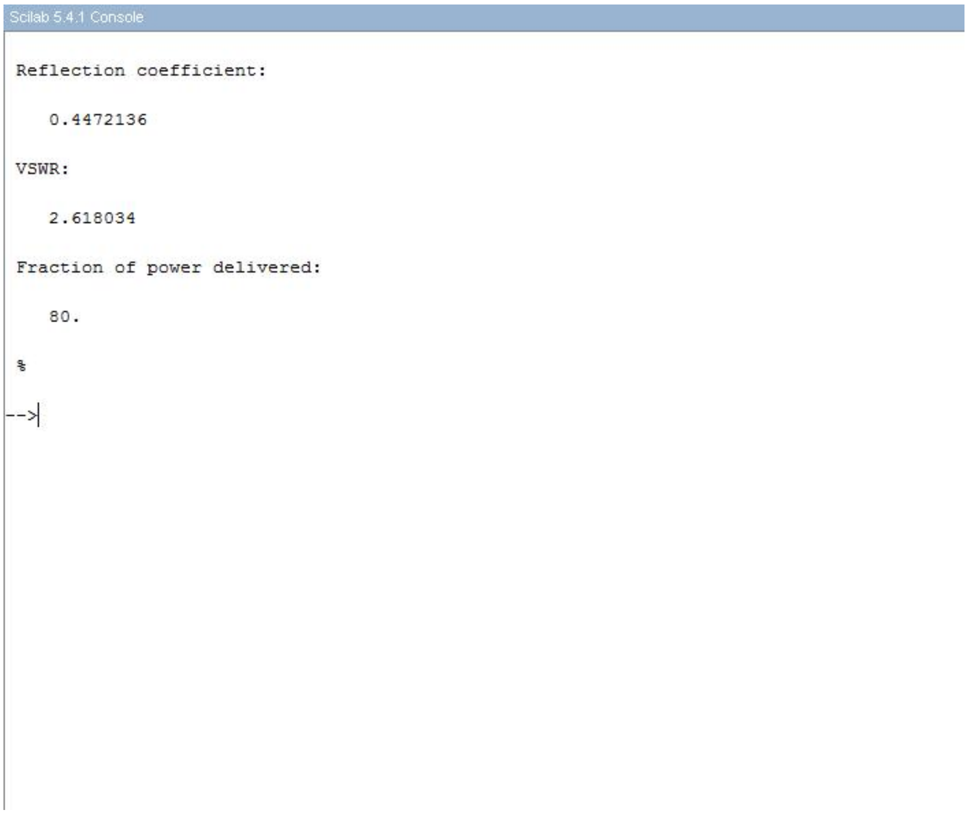



Figure 12.7: Microwave line

```

Zl=(Z0*(1+(p*p*%i)))/(p+(p*%i));
T=(Zl-Z0)/(Zl+Z0);
p=sqrt((real(T))^2+(imag(T))^2);
disp(p,'Reflection coefficient:');
```

**Scilab code Exa 12.7** Microwave line

```
//Page Number: 652
```

```
//Example 12.7
clc;
//Given
Zl=25+25*%i; //ohm
Z0=50; //ohm

T=(Zl-Z0)/(Zl+Z0);
p=sqrt((real(T))^2+(imag(T))^2);
disp(p,'Reflection coefficient:');

vswrr=(1+p)/(1-p);
disp(vswrr,'VSWR:');

//Fraction of power delivered
Pd=1-(p^2);
Pdp=Pd*100;
disp('%',Pdp,'Fraction of power delivered:');
```

**Scilab code Exa 12.8** Rectangular waveguide

```
//Page Number: 653
//Example 12.8
clc;
//Given
d=2.4;//cm
lmbc=1.8;
c=3*10^10; //cm/s

lmbg=2*d;
lmb=(lmbg*lmbc)/(sqrt(lmbg^2+lmbc^2));
//Operating frequency
f=c/lmb;
disp('GHz',f/10^9,'Operating frequency:');
```


Figure 12.8: Rectangular waveguide

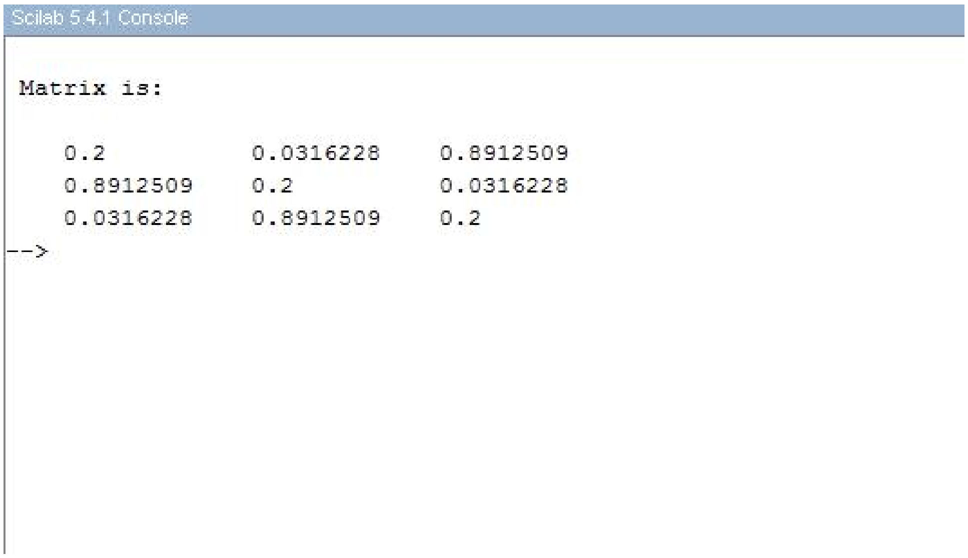



Figure 12.9: Three port circulator

---

**Scilab code Exa 12.9** Three port circulator

```
//Page Number: 653
//Example 12.9
clc;
//Given
p=1.5;
IsL=1; //dB
InL=30; //dB

S21=10^(-IsL/20);

//Assuming tgree ports to be identical
S32=S21;
```

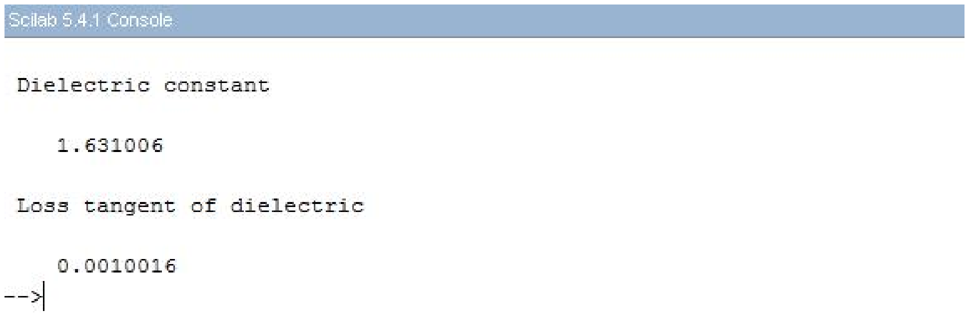



Figure 12.10: Air filled cavity

```
S13=S21;

//Isolations are also the same
S31=10^(-InL/20);
S23=S31;
S12=S31;

//Refelction coefficients are also the same
T=(p-1)/(p+1);
S11=T;
S22=T;
S33=T;

S=[S11 S12 S13;S21 S22 S23;S31 S32 S33];
disp(S,'Matrix is:');
```

**Scilab code Exa 12.10** Air filled cavity

```
//Page Number: 654
//Example 12.10
clc;
//Given
R1=10.6; //GHz
R2=8.30; //GHz
Q0=8200;
Q0d=890;

Er=(R1/R2)^2;
disp(Er,'Dielectric constant');

Qd=(Q0-Q0d)/(Q0*Q0d);
disp(Qd,'Loss tangent of dielectric');
```

**Scilab code Exa 12.11** Rectangular Waveguide

```
//Page Number: 654
//Example 12.11
clc;
//Given
l0=0.15; //cm
lmbg=2*2.24; //cm
le=1.14; //cm
a=2.286; //cm
d=2;

B0=(2*%pi)/lmbg;
```


Figure 12.11: Rectangular Waveguide

```
x=tan(B0*l0)/(B0*l0);
//Also
x1=(l0*x)/le;
//Correct value seems to be
Bele=2.786;
e1=((((a/%pi)^2)*(Bele/le)^2)+1);
e2=(((2*a)/lmbg)^2)+1;
Er=e1/e2;
disp(Er,'Er:');


//Answer in book for Er is given as 2.062 but it should be 2.038
```