Scilab Textbook Companion for
Microwave Engineering
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Book Description

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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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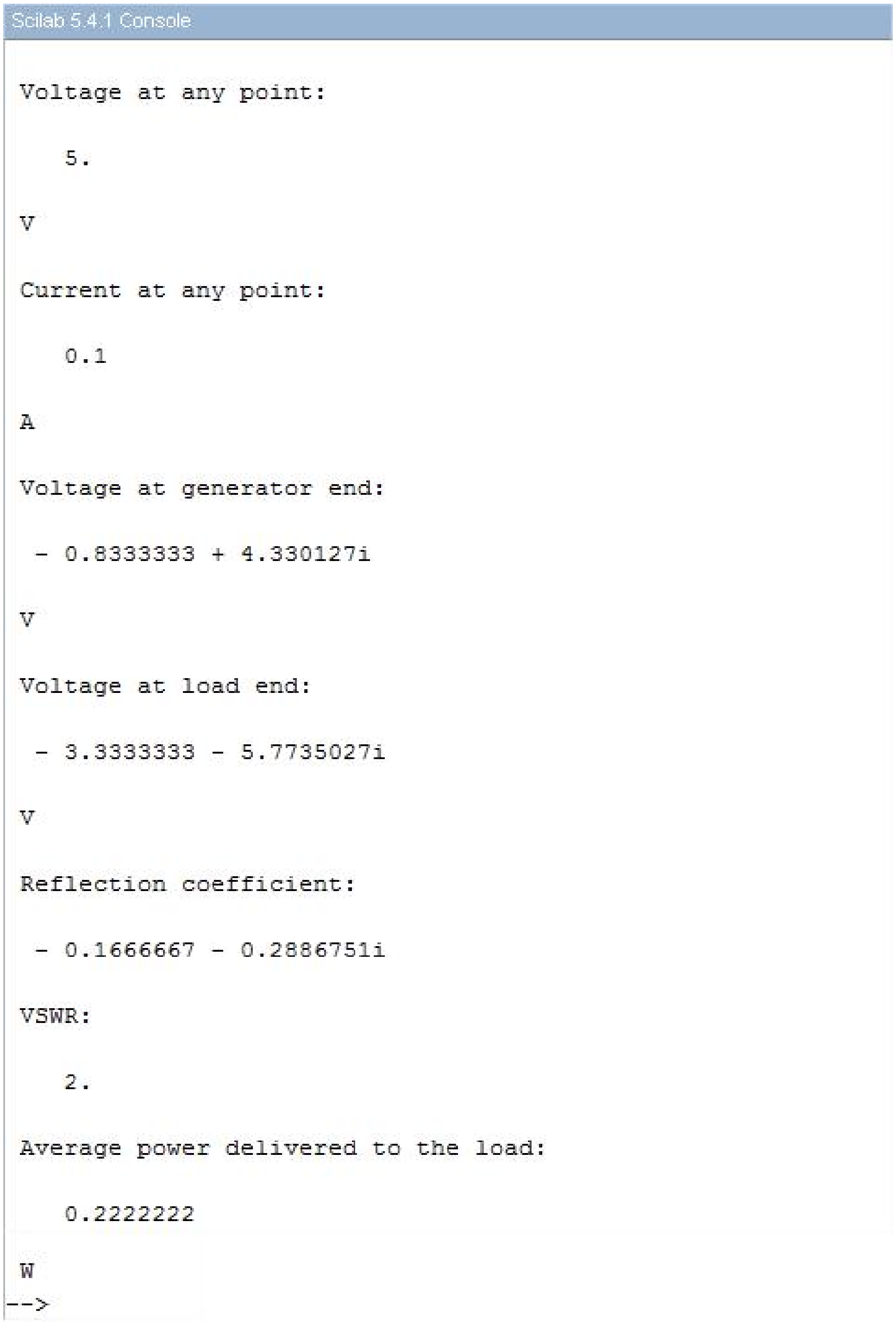
Chapter 1

Microwaves

Scilab code Exa 1.2 `Lossless line`

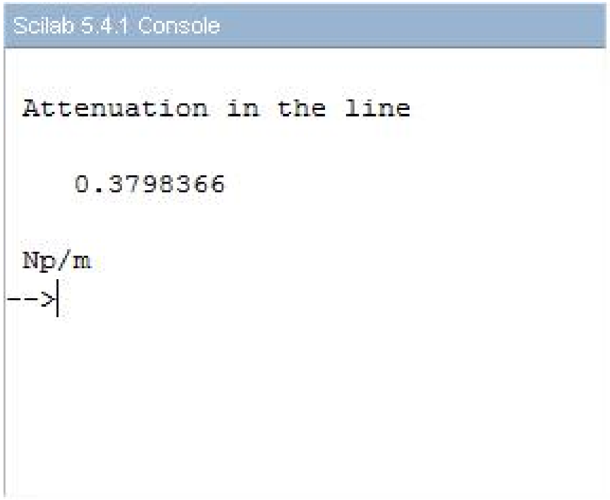
```
//Page Number: 12
//Example 1.2
clc;
//Given
z0=50;//ohm
zg=50;//ohm
l=0.25;//m
f=4D+9;//hz
zl=100;//ohm
vg=10;//V
w=2*%pi*f;//rad/sec
c=3D+8; //m/s

//(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
```



```
Voltage at any point:

   5.

V

Current at any point:

   0.1

A

Voltage at generator end:

 - 0.8333333 + 4.330127i

V

Voltage at load end:

 - 3.3333333 - 5.7735027i

V

Reflection coefficient:

 - 0.1666667 - 0.2886751i

VSWR:

   2.

Average power delivered to the load:

   0.2222222

W
-->
```

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:');
```



```
Attenuation in the line

   0.3798366

Np/m
-->
```

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
```

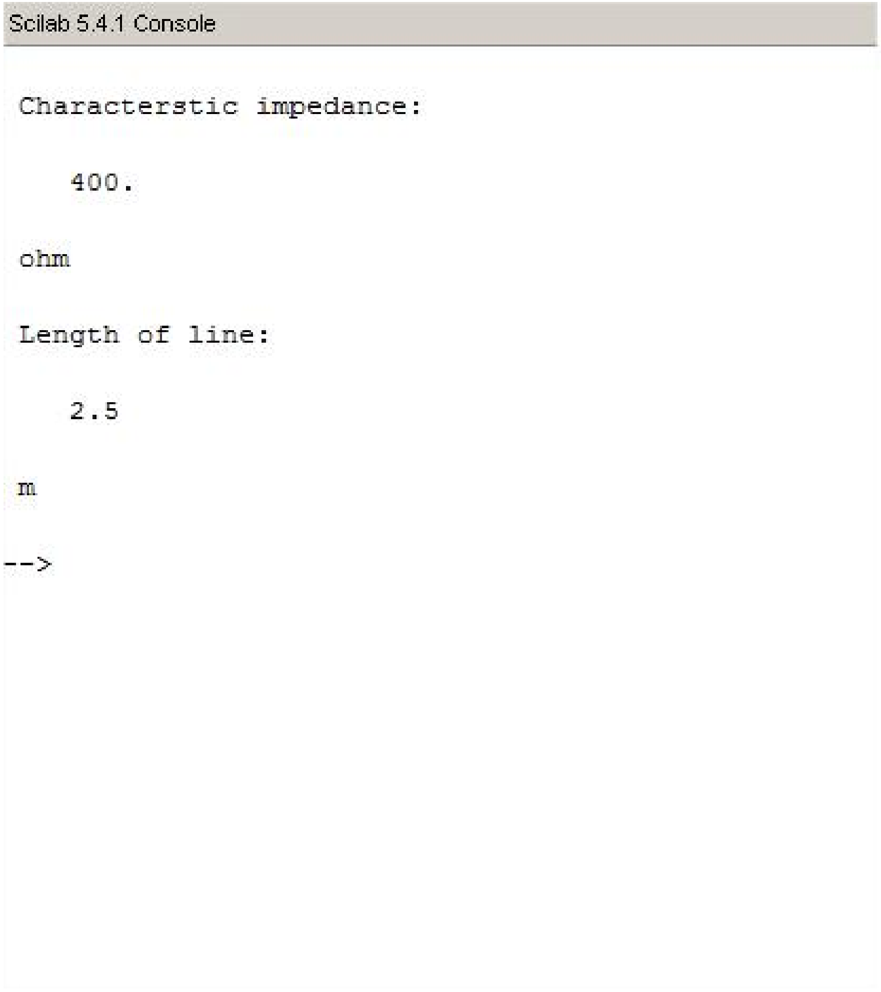
```
disp('Np/m',alp,'Attenuation in the line');
```

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:');
```

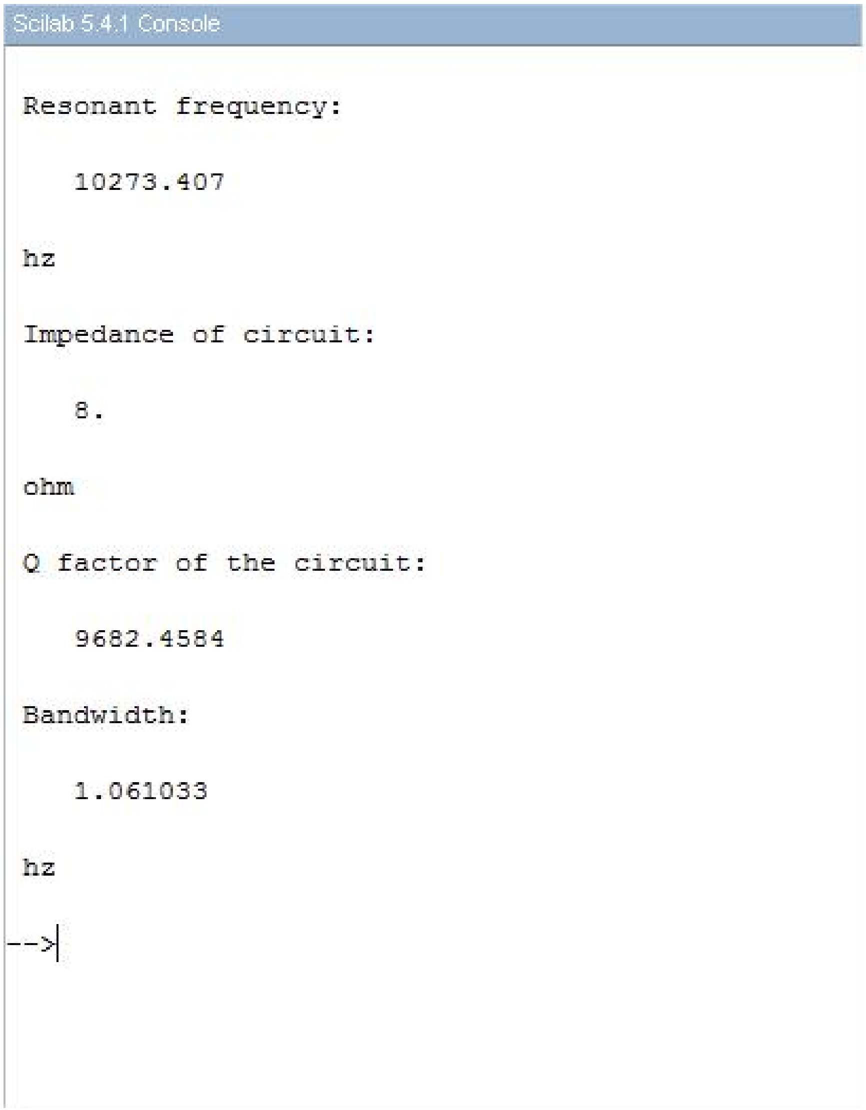
Scilab code Exa 1.5 `Parallel resonant circuit`

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



```
 Characterstic impedance:

    400.

 ohm

 Length of line:

    2.5

 m

-->
```

Figure 1.3: Quater wave transformer



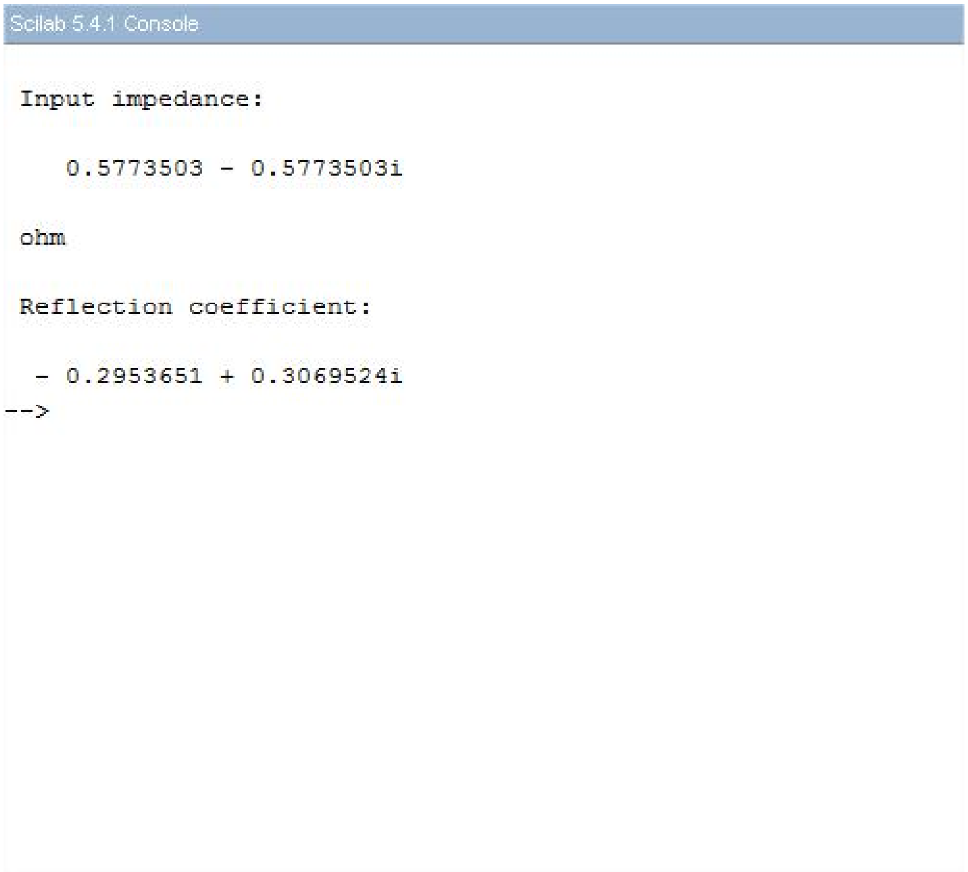
```
Resonant frequency:

   10273.407

hz

Impedance of circuit:

   8.

ohm

Q factor of the circuit:

   9682.4584

Bandwidth:

   1.061033

hz

-->
```

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
```



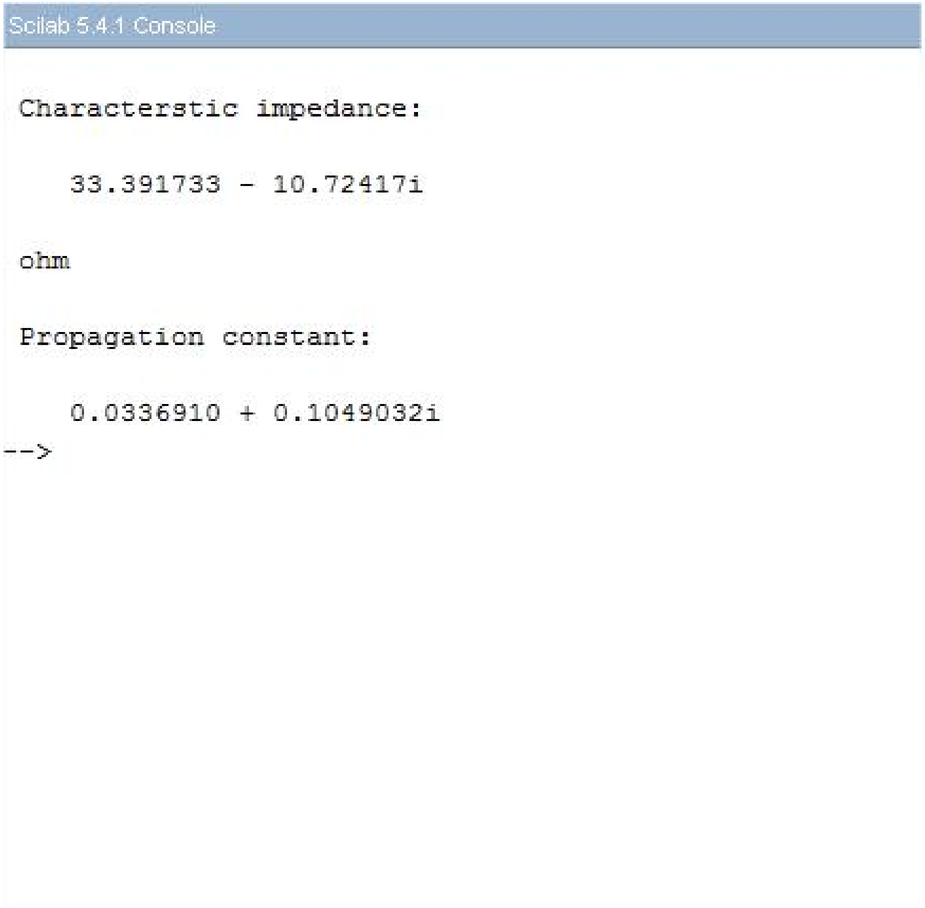
```
 Input impedance:

    0.5773503 - 0.5773503i

 ohm

 Reflection coefficient:

  - 0.2953651 + 0.3069524i
-->
```

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:');
```



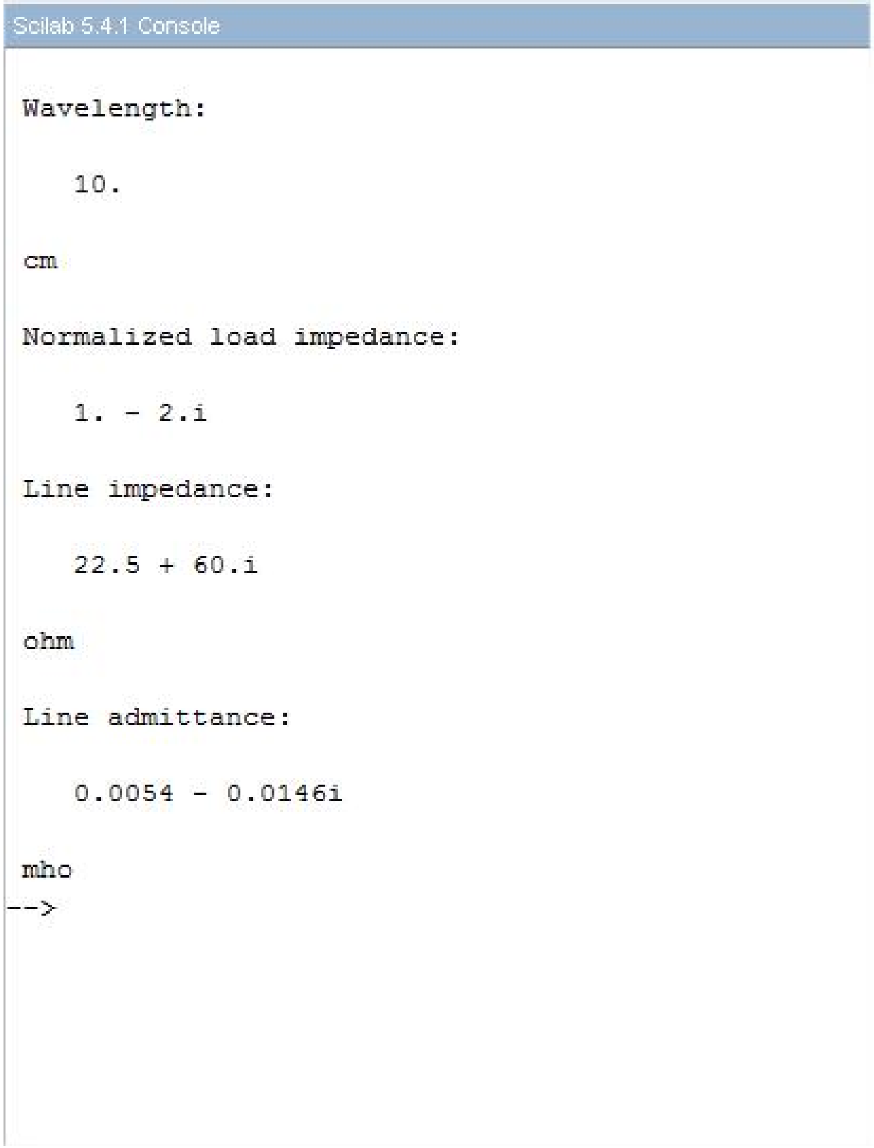
```
 Characterstic impedance:

    33.391733 - 10.72417i

 ohm

 Propagation constant:

    0.0336910 + 0.1049032i
-->
```

Figure 1.6: Lossy cable

```

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

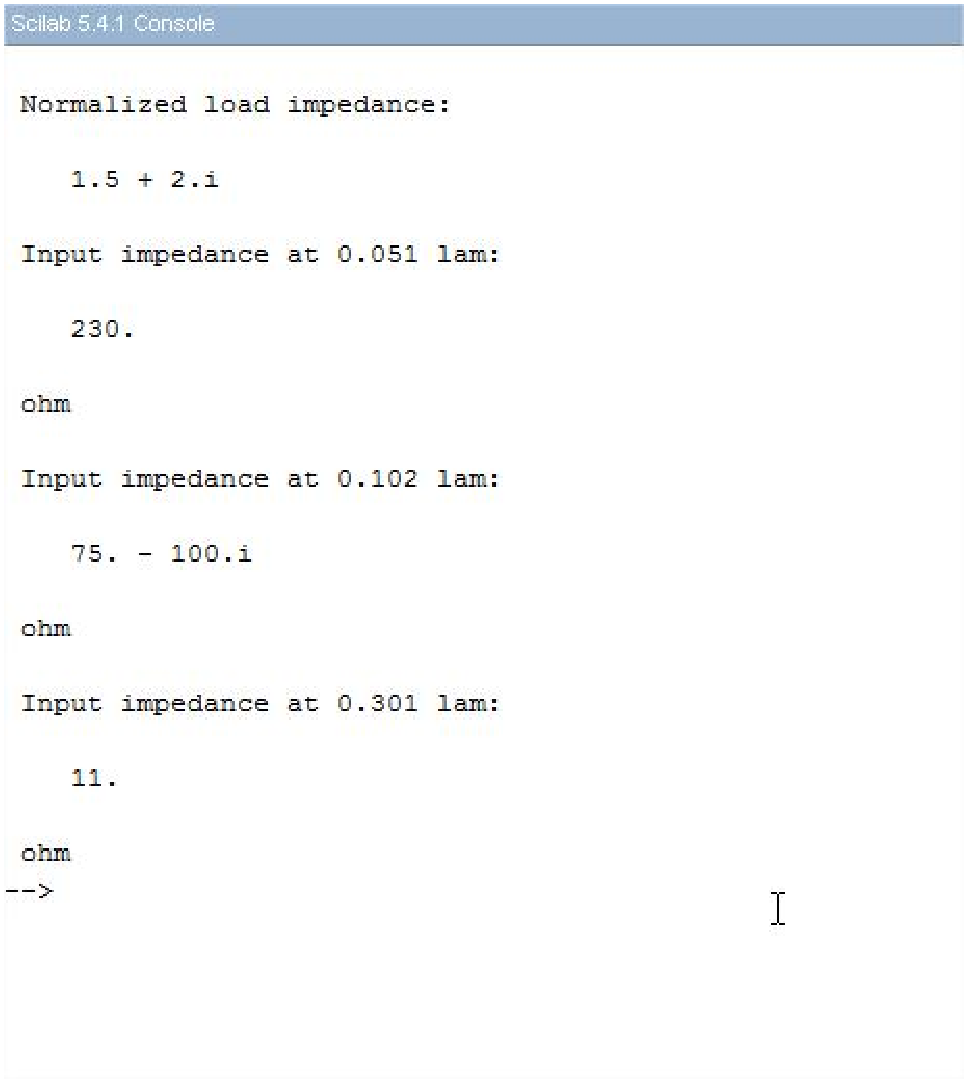
Scilab code Exa 1.8 `Transmission Line`

```
//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:');
```



```
Wavelength:

   10.

cm

Normalized load impedance:

   1. - 2.i

Line impedance:

   22.5 + 60.i

ohm

Line admittance:

   0.0054 - 0.0146i

mho
-->
```

Figure 1.7: Transmission Line



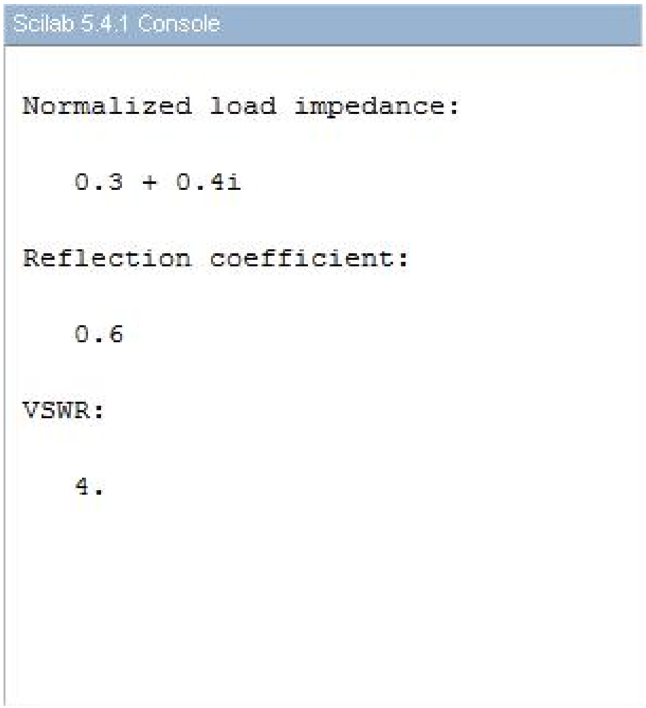
```
 Normalized load impedance:

    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`



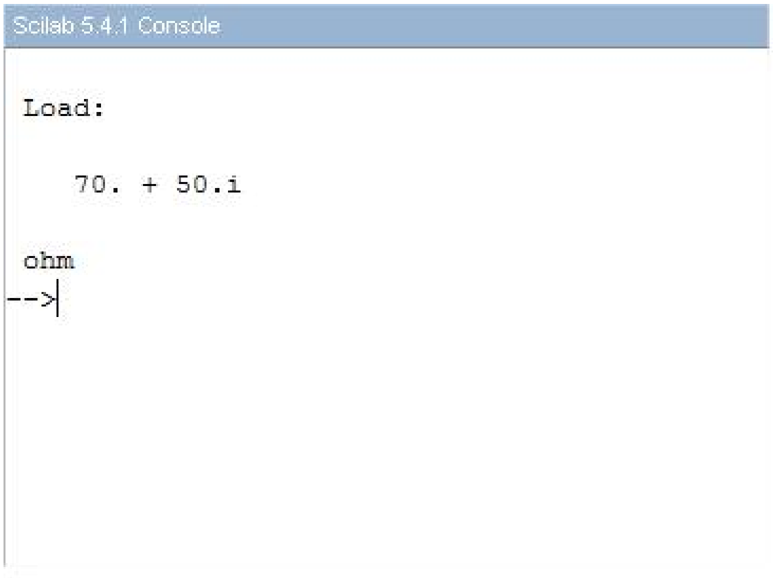
```
Normalized load impedance:

   0.3 + 0.4i

Reflection coefficient:

   0.6

VSWR:

   4.
```

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:');
```

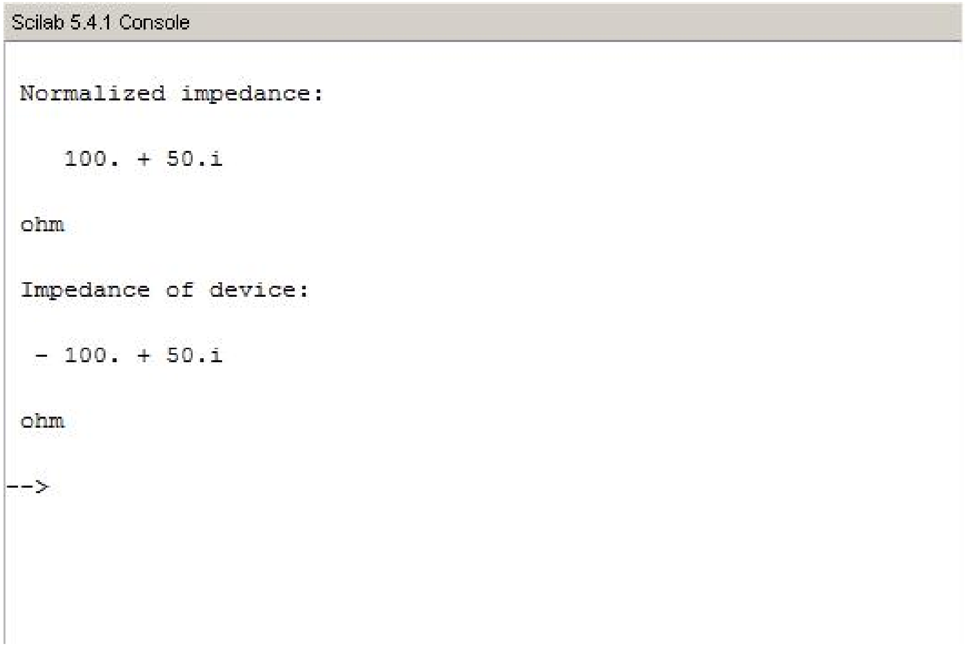


```
Load:

   70. + 50.i

ohm
-->
```

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:');
```



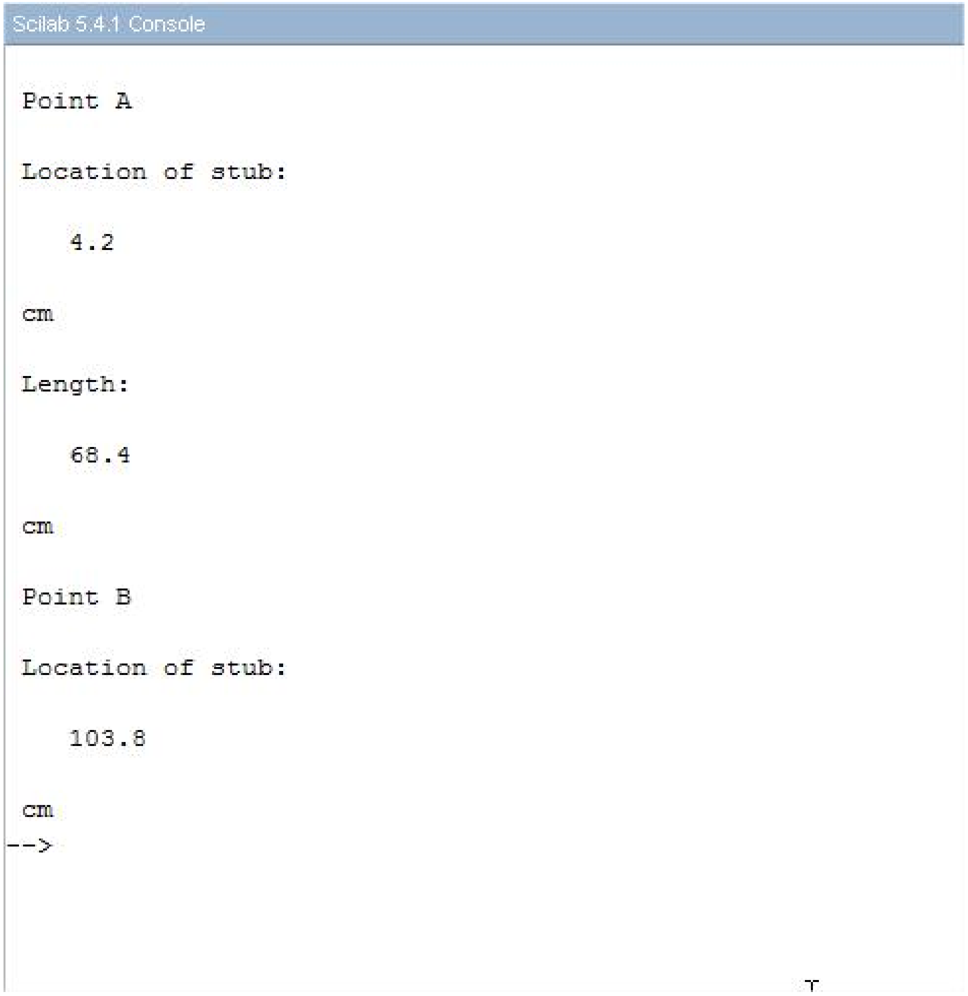
```
Normalized impedance:

   100. + 50.i

ohm

Impedance of device:

 - 100. + 50.i

ohm

-->
```

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
```



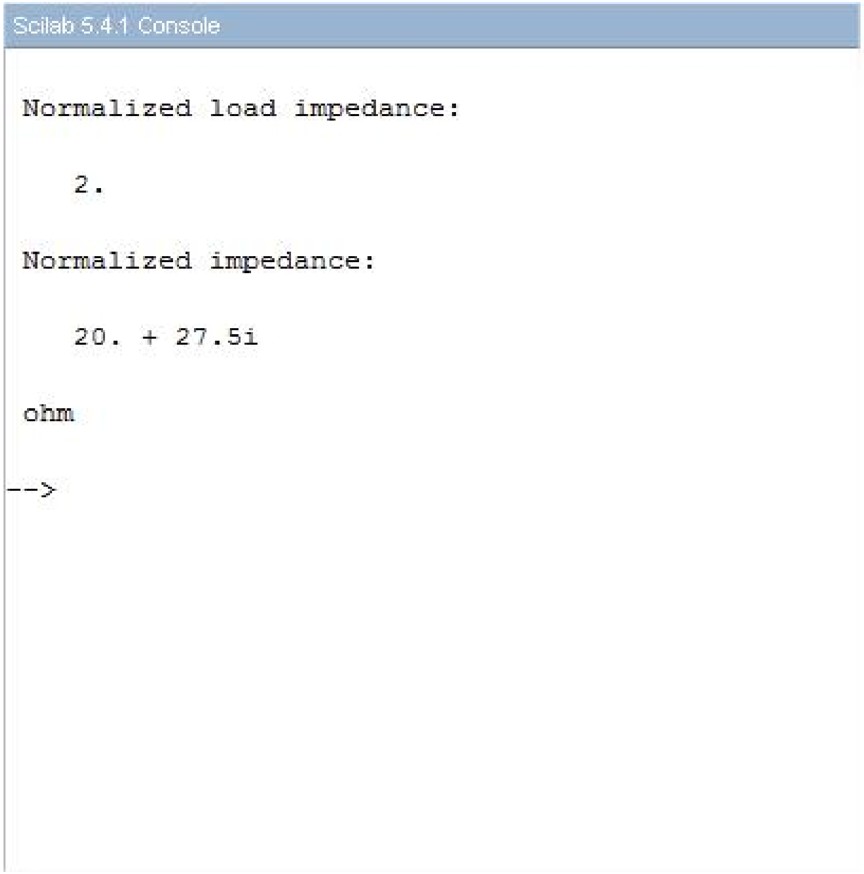
```
 Point A

 Location of stub:

    4.2

 cm

 Length:

    68.4

 cm

 Point B

 Location of stub:

    103.8

 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:');
```

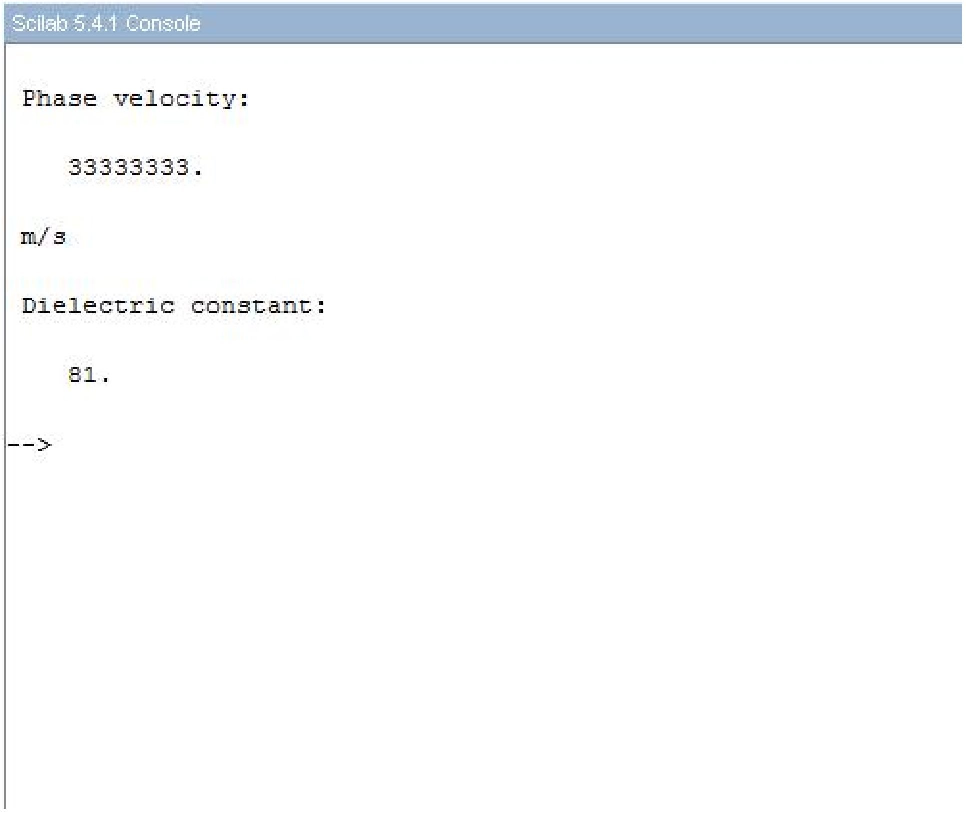
Scilab code Exa 1.15 `Microwave line`

```
//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:');

```



```
 Normalized load impedance:

    2.

 Normalized impedance:

    20. + 27.5i

 ohm

-->
```

Figure 1.13: Microwave line



```
Phase velocity:

   33333333.

m/s

Dielectric constant:

   81.

-->
```

Figure 1.14: EM Plane

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

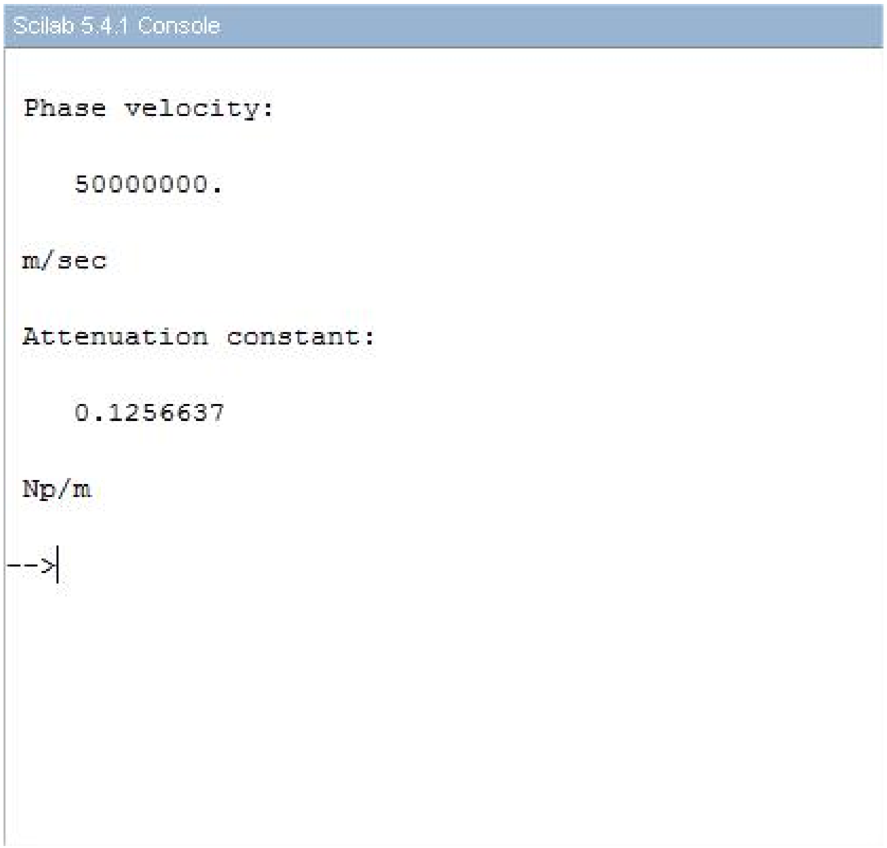
Scilab code Exa 1.16 `EM Plane`

```
//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:');
```

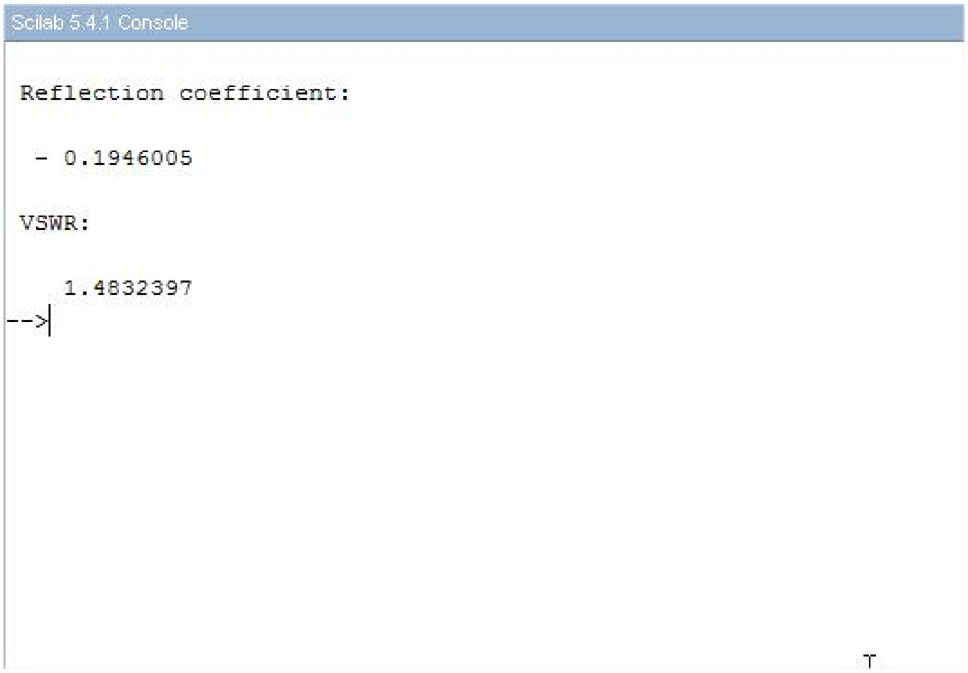
Scilab code Exa 1.17 Polyethylene

```
//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
```



```
 Phase velocity:

    50000000.

 m/sec

 Attenuation constant:

    0.1256637

 Np/m

-->
```

Figure 1.15: Polyethylene



```
Reflection coefficient:

 - 0.1946005

VSWR:

   1.4832397
-->
```

Figure 1.16: Electromagnetic wave

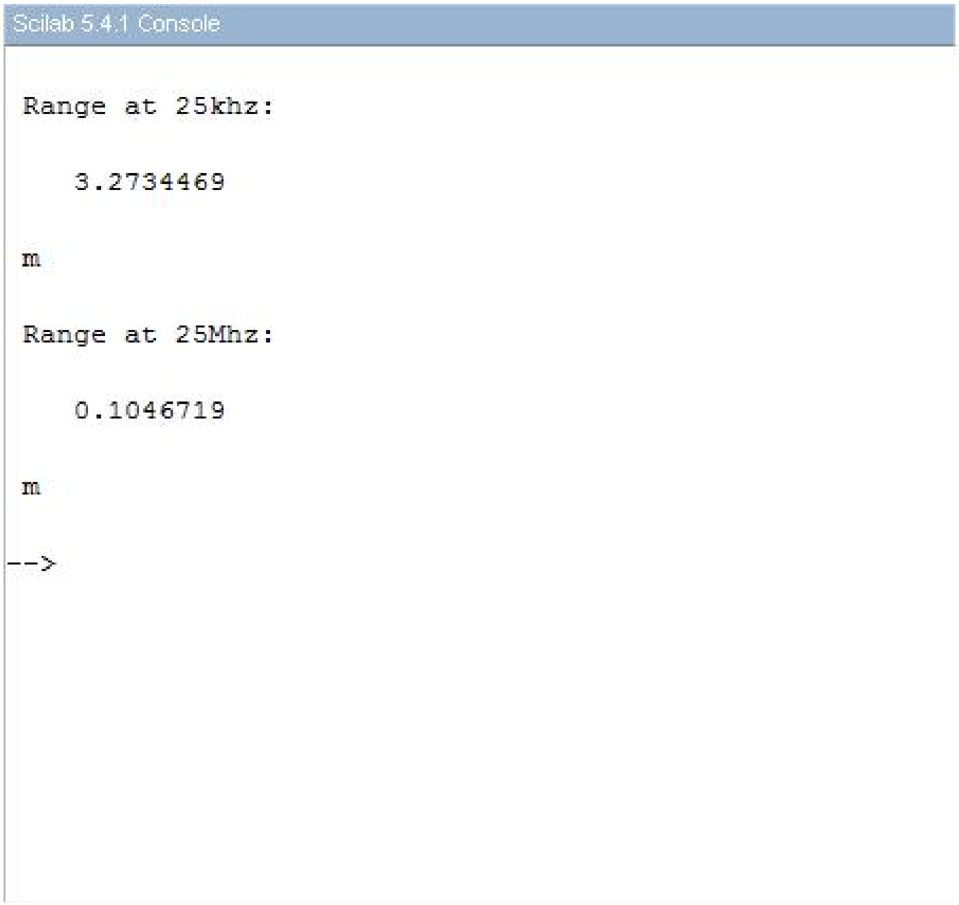
Scilab code Exa 1.18 `Electromagnetic wave`

```
//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)))
```



```
 Range at 25khz:

    3.2734469

 m

 Range at 25Mhz:

    0.1046719

 m

-->
```

Figure 1.17: Range in sea water

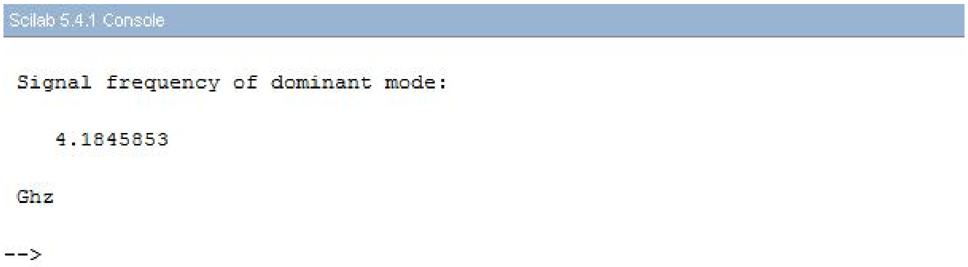
```
    ;
z1=az/a1;//m
disp('m',z1,'Range at 25Mhz:');
```

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 :');
```



```
 Signal frequency of dominant mode:

    4.1845853

 Ghz

-->
```

Figure 2.1: Dominant mode

```
 Guide wavelength:

    5.0390326

 cm

 Phase constant:

    124.69031

 rad/m

 Phase velocity:

    3359355.1

 m/s
-->
```

Figure 2.2: Rectangular Waveguide

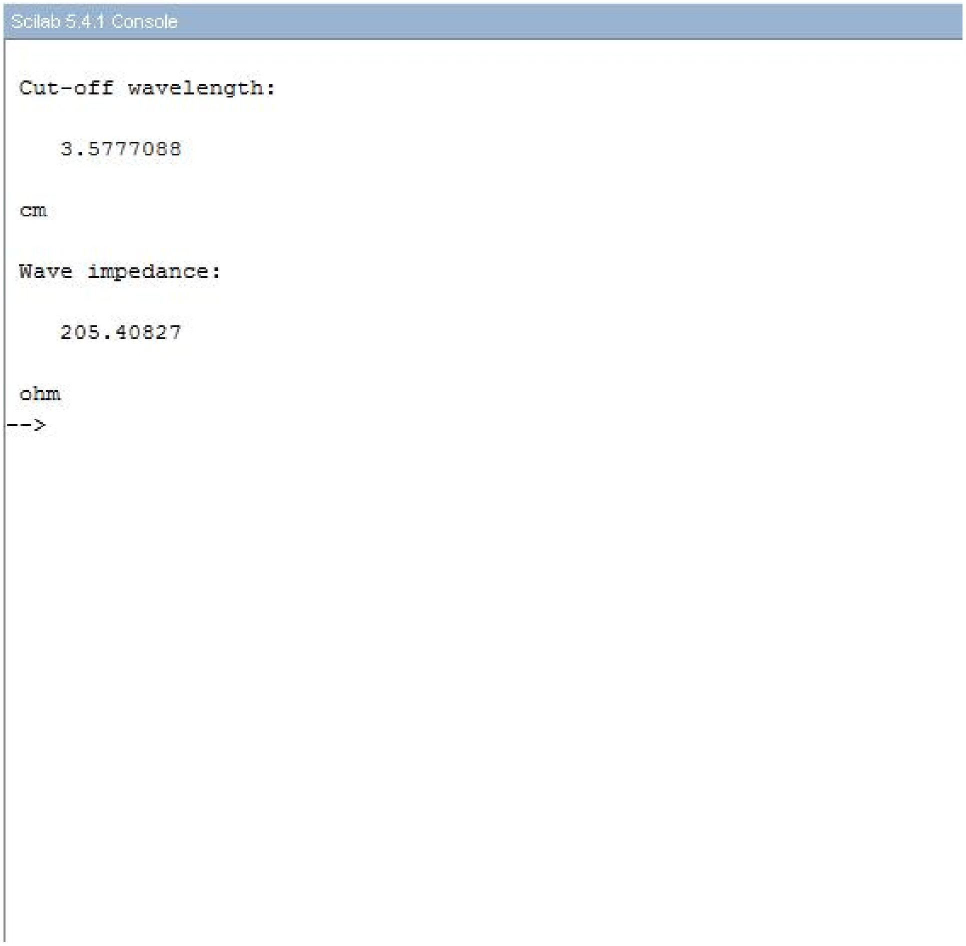
Scilab code Exa 2.2 `Rectangular Waveguide`

```
//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;
```



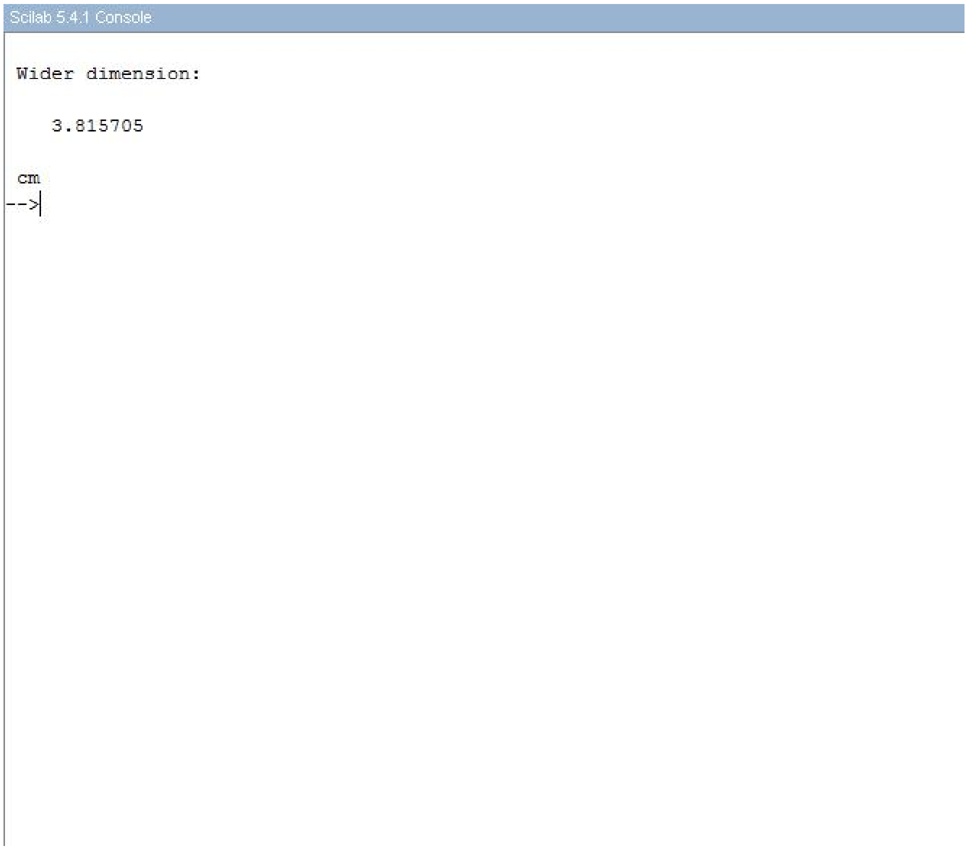
```
 Cut-off wavelength:

    3.5777088

 cm

 Wave impedance:

    205.40827

 ohm
-->
```

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:');
```

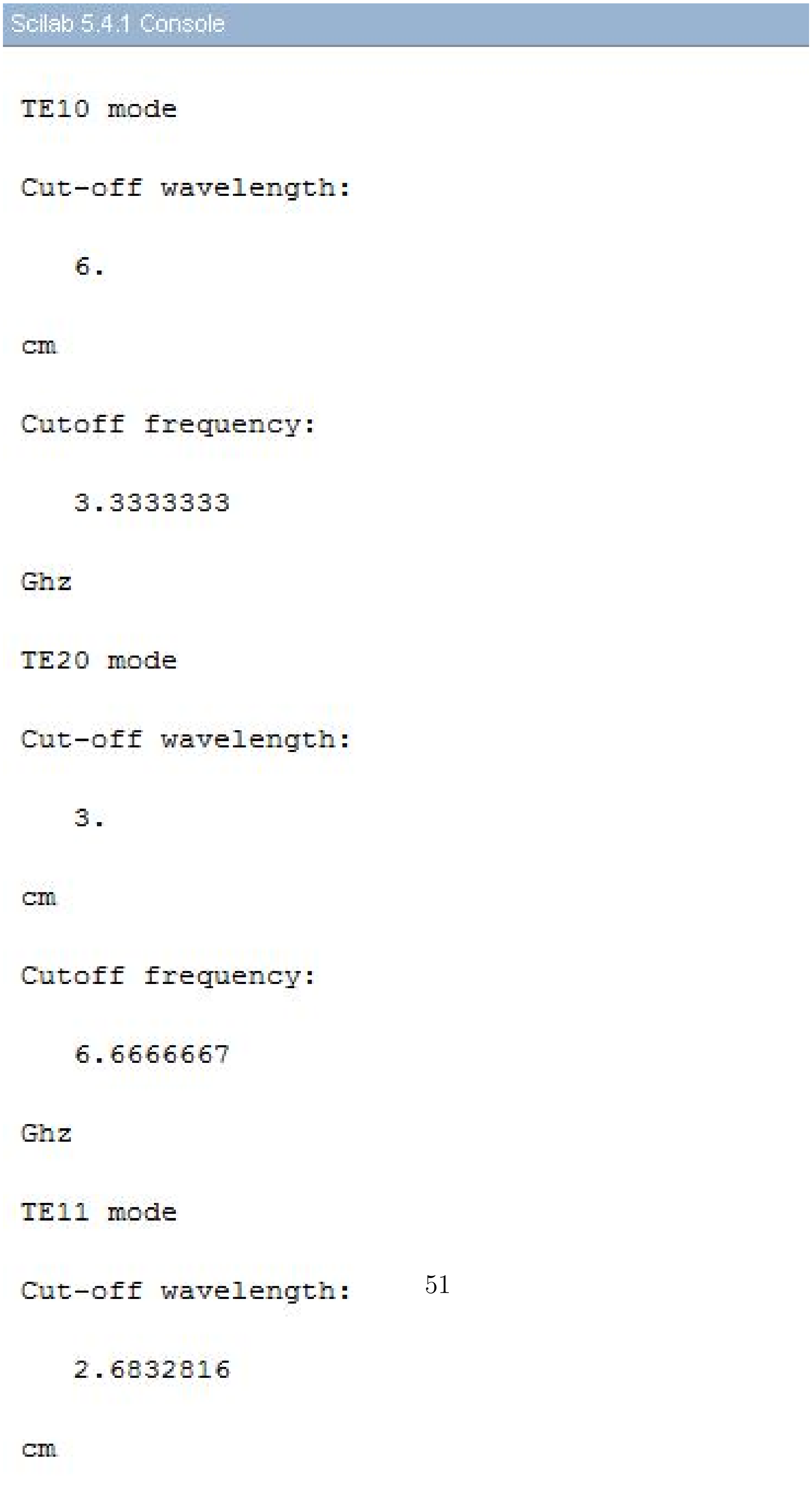
Scilab code Exa 2.4 `Wider dimension`

```
//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:');
```



```
 Wider dimension:

    3.815705

 cm
-->
```

Figure 2.4: Wider dimension



```
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
```

```
 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
```

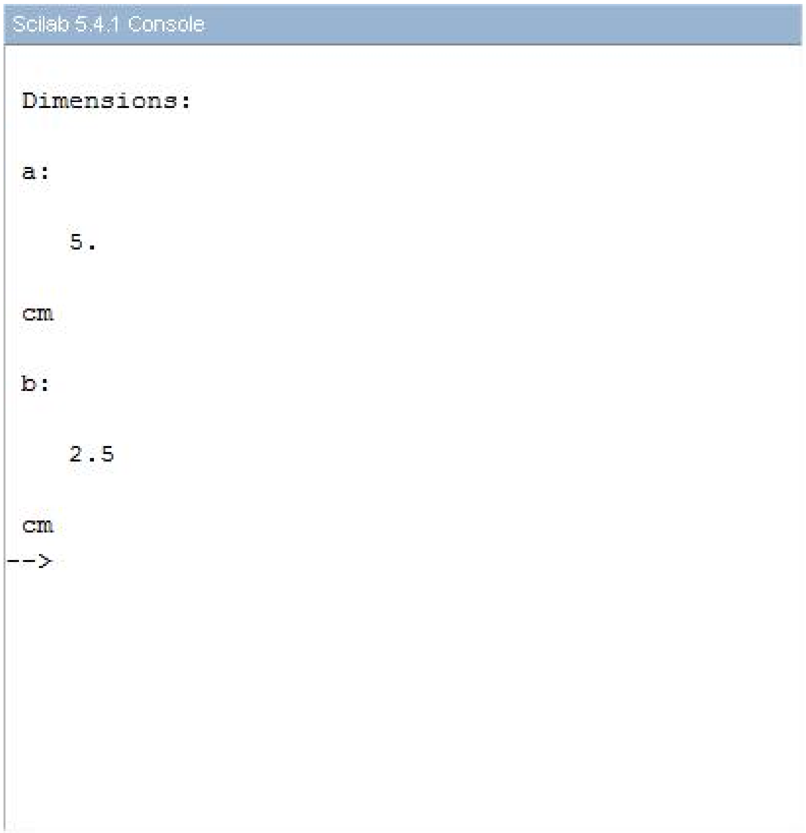
```
Average power transmitted:

   32.994372

W

Peak electric field:

   5.3868362

kV/m
-->
```

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
```



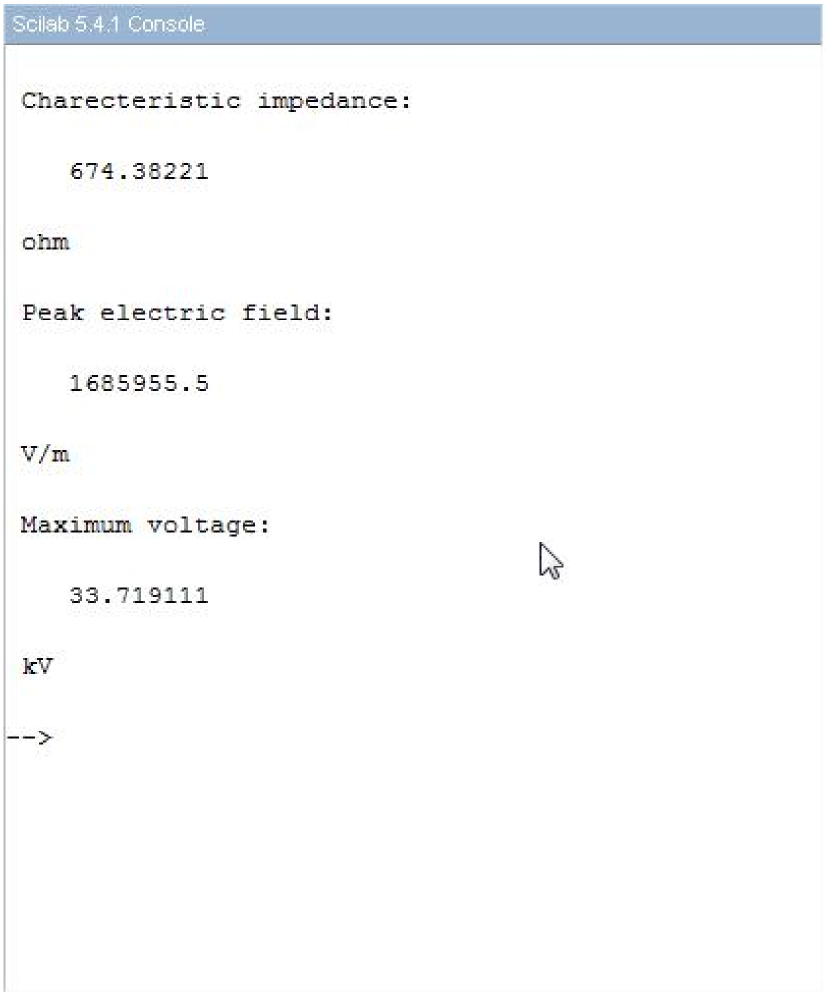
```
 Dimensions:

 a:

    5.

 cm

 b:

    2.5

 cm
-->
```

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:');
```



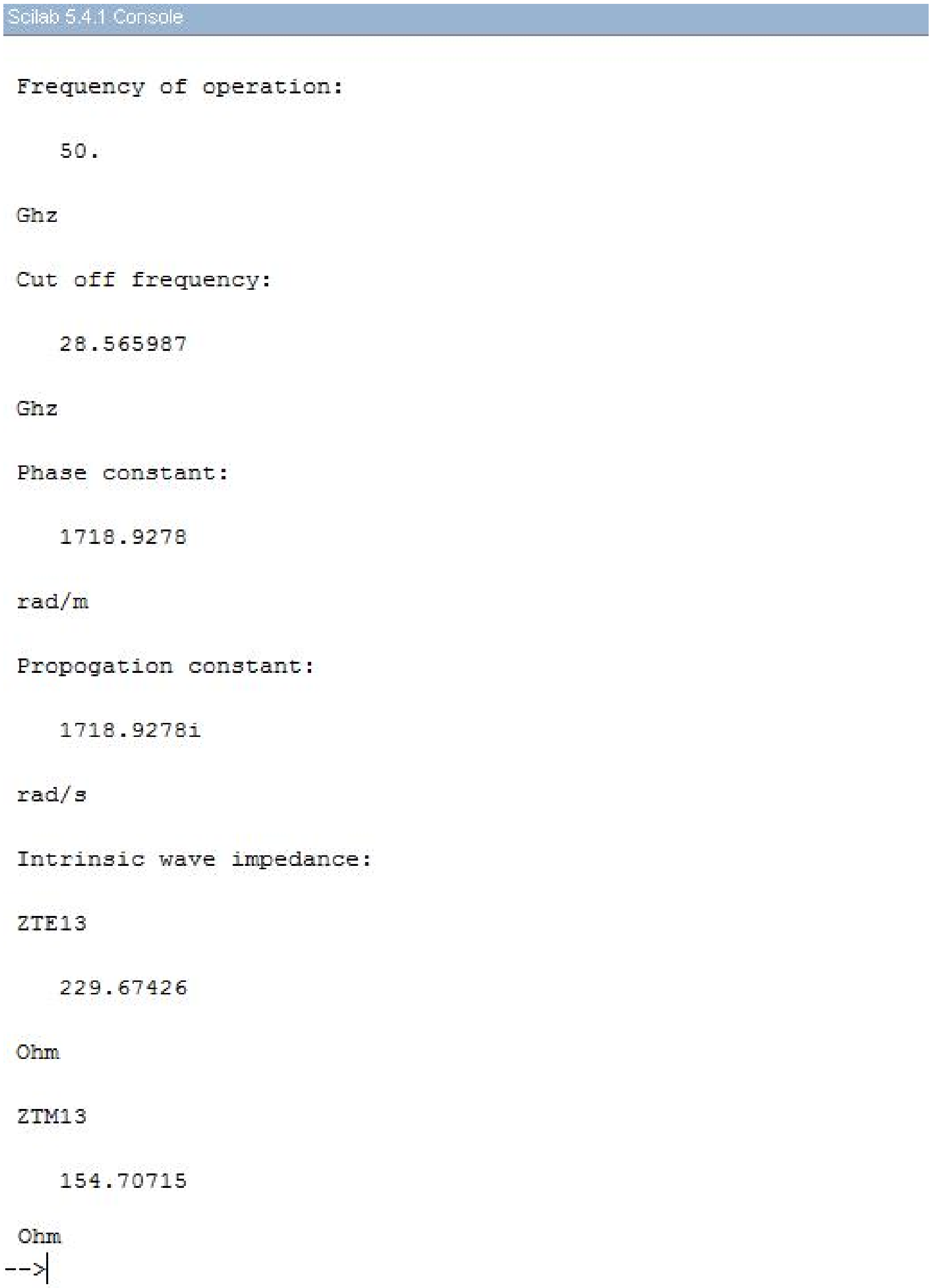
```
 Charecteristic impedance:

    674.38221

 ohm

 Peak electric field:

    1685955.5

 V/m

 Maximum voltage:

    33.719111

 kV

-->
```

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:');
```



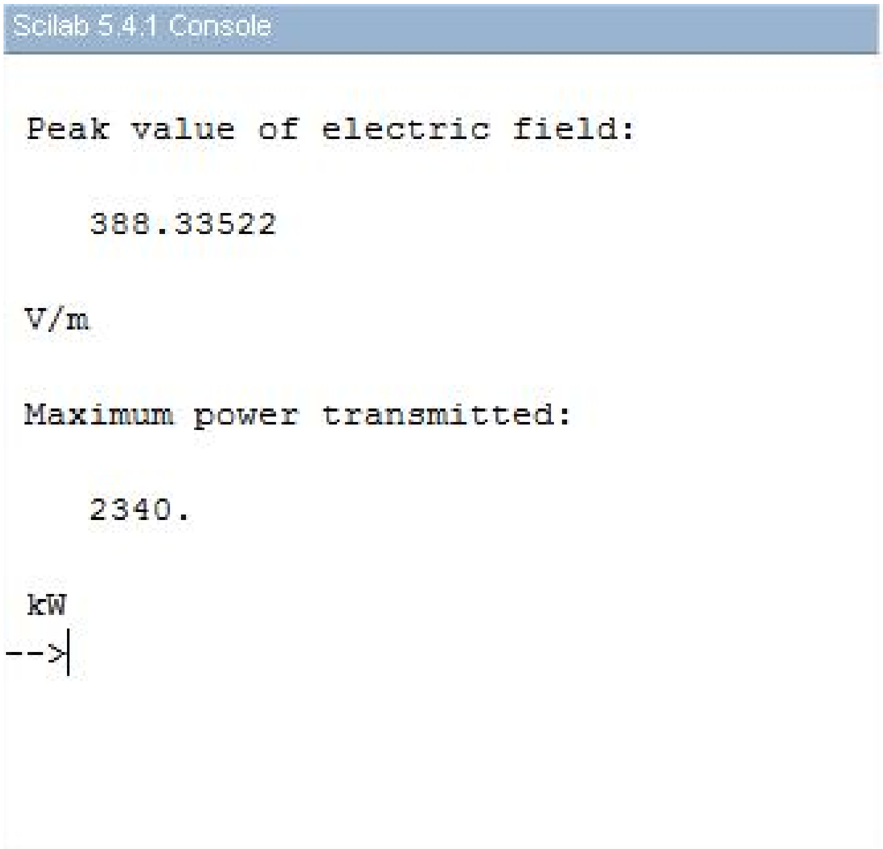
```
 Frequency of operation:

    50.

 Ghz

 Cut off frequency:

    28.565987

 Ghz

 Phase constant:

    1718.9278

 rad/m

 Propogation constant:

    1718.9278i

 rad/s

 Intrinsic wave impedance:

 ZTE13

    229.67426

 Ohm

 ZTM13

    154.70715

 Ohm
-->
```

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);
```



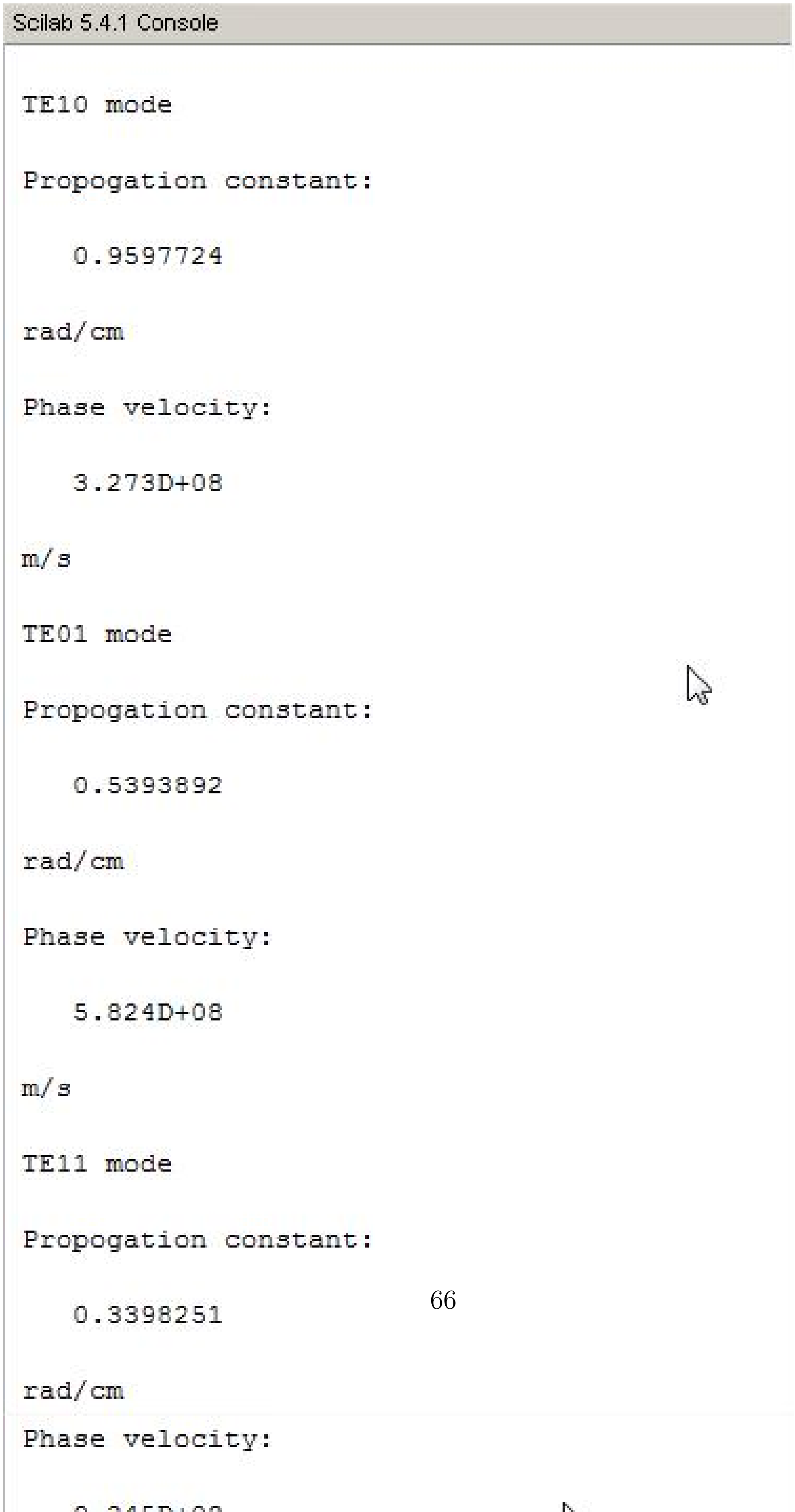
```
 Peak value of electric field:

    388.33522

 V/m

 Maximum power transmitted:

    2340.

 kW
-->
```

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;
```

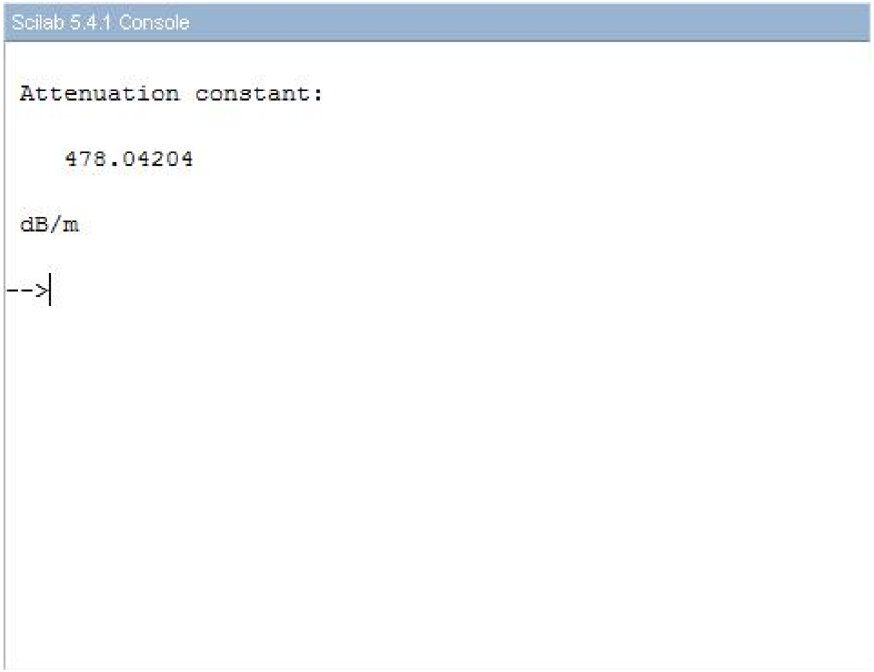


```
TE10 mode

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;
```



```
Attenuation constant:

   478.04204

dB/m

-->
```

Figure 2.13: Rectangular Waveguide

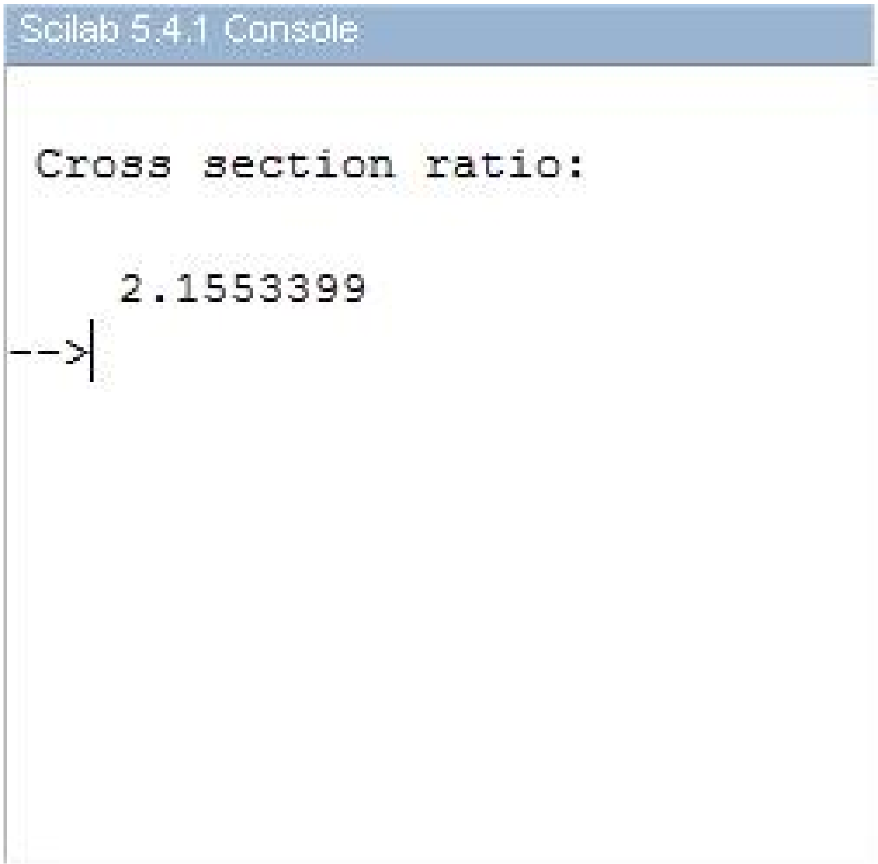
```
mu=1/(c^2);

//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:');
```

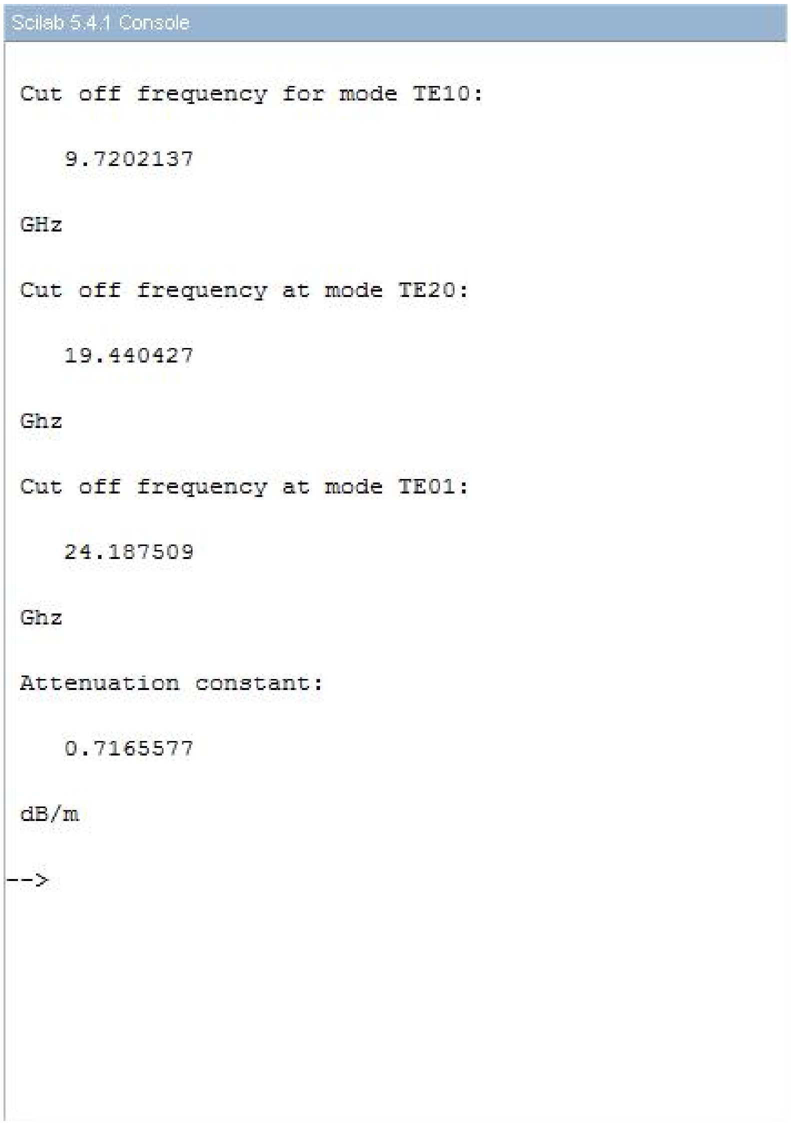
Scilab code Exa 2.21 `Rectangular Waveguide`

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



```
 Cross section ratio:

    2.1553399
-->
```

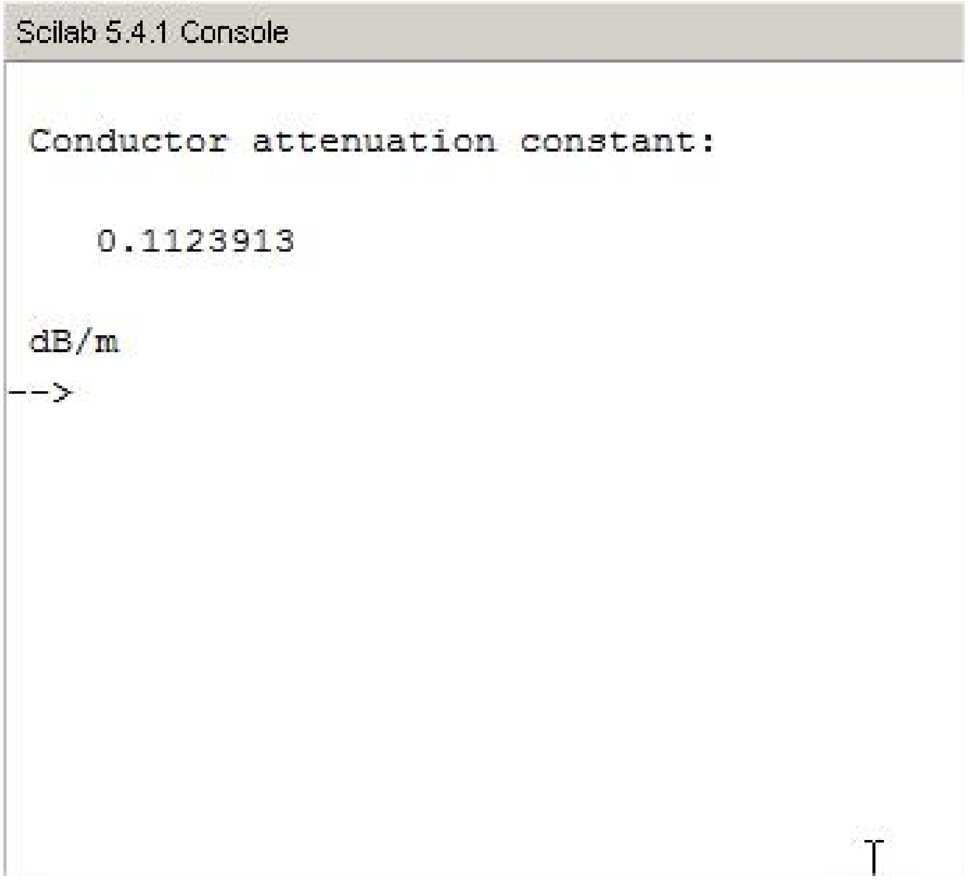
Figure 2.14: Ratio of cross section



```
Cut off frequency for mode TE10:

   9.7202137

GHz

Cut off frequency at mode TE20:

   19.440427

Ghz

Cut off frequency at mode TE01:

   24.187509

Ghz

Attenuation constant:

   0.7165577

dB/m

-->
```

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:');
```



```
 Conductor attenuation constant:

    0.1123913

 dB/m
-->
```

Figure 2.16: Rectangular Waveguide

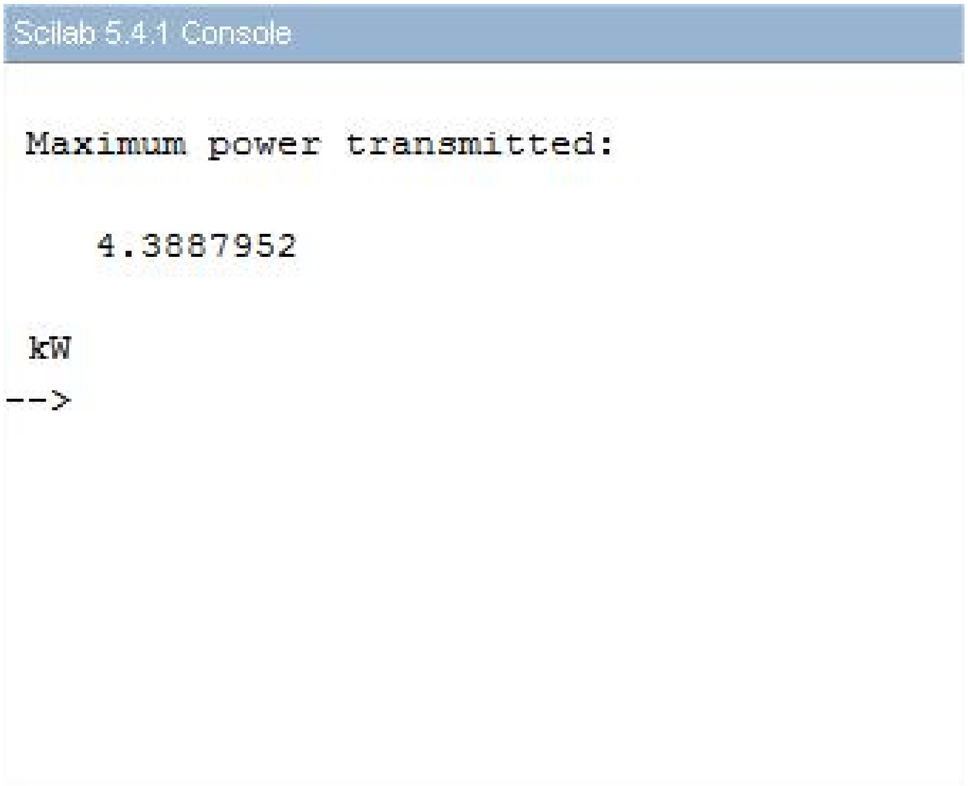
Scilab code Exa 2.22 `Rectangular Waveguide`

```
//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);
```



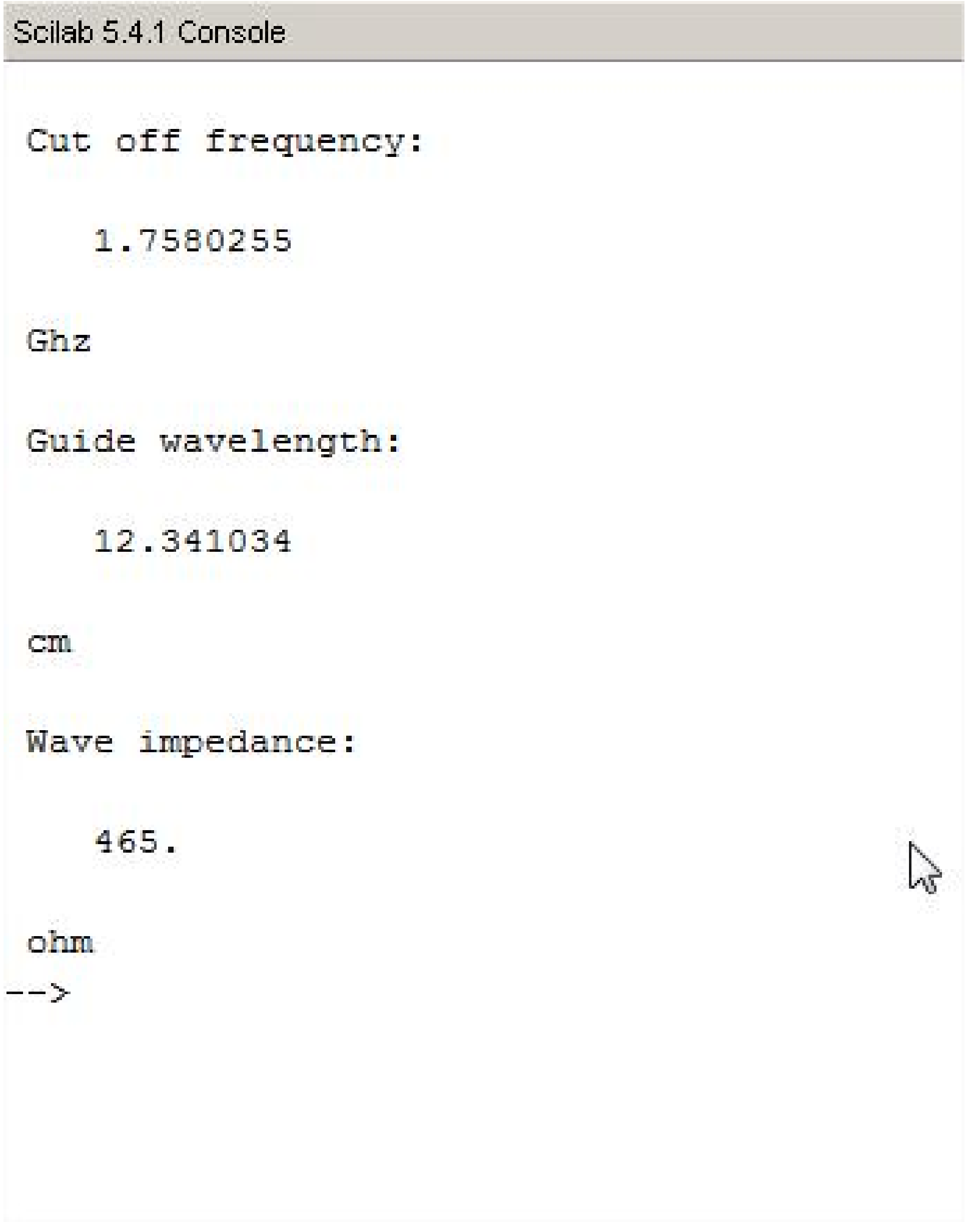
```
 Maximum power transmitted:

    4.3887952

 kW
-->
```

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;
```



```
Cut off frequency:

   1.7580255

Ghz

Guide wavelength:

   12.341034

cm

Wave impedance:

   465.

ohm
-->
```

Figure 2.18: Air filled circular waveguide

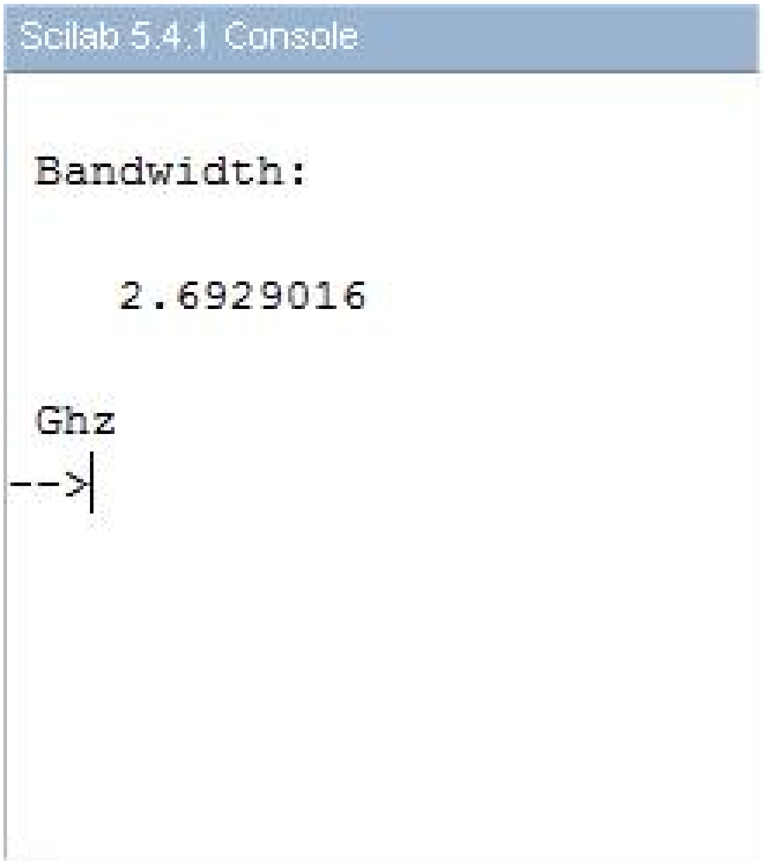
```
disp('ohm',round(zte),'Wave impedance:');
```

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:');
```

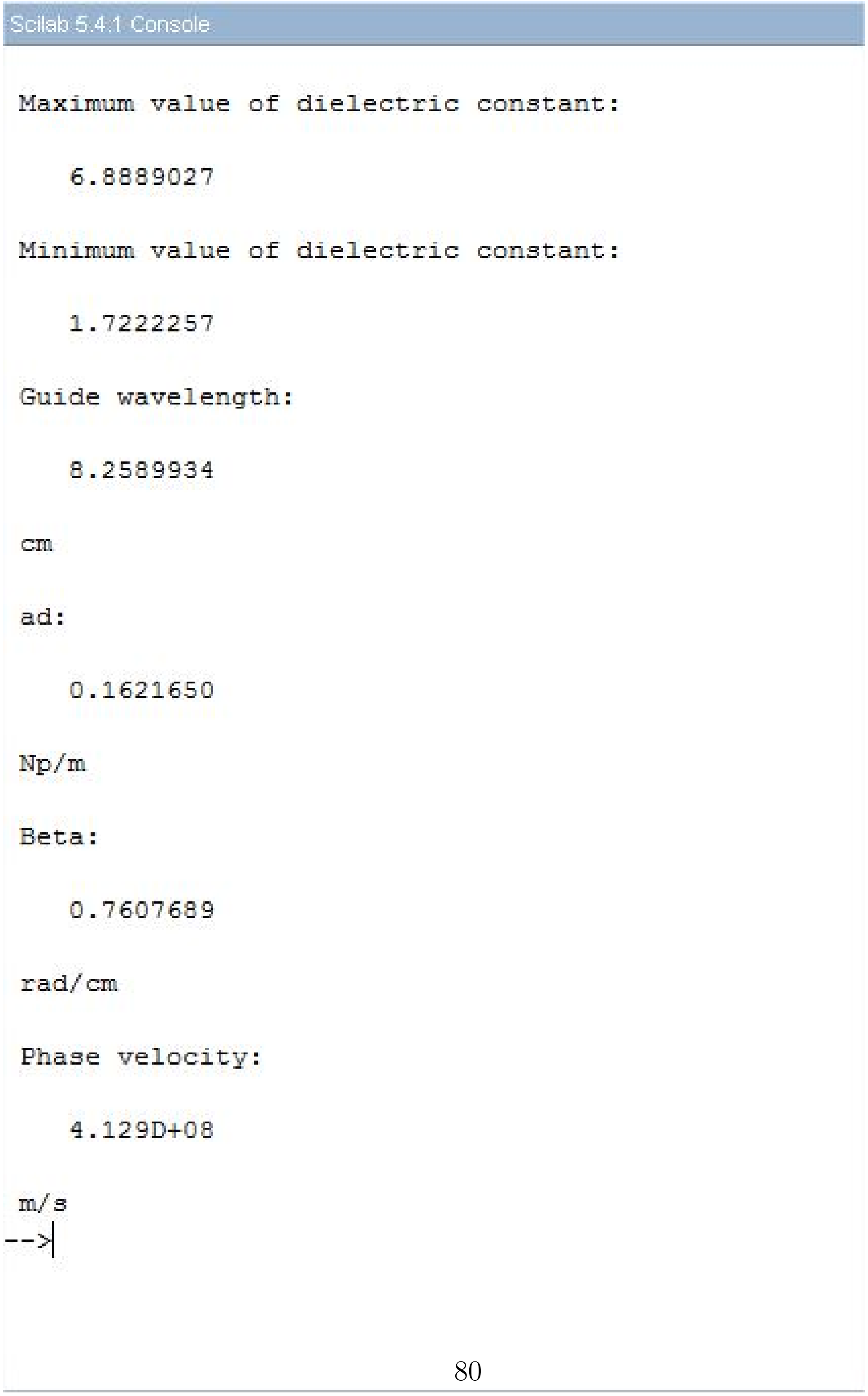
Scilab code Exa 2.26 `Rectangular Waveguide`

```
//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;
```



```
 Bandwidth:

    2.6929016

 Ghz
-->
```

Figure 2.19: Air filled rectangular waveguide



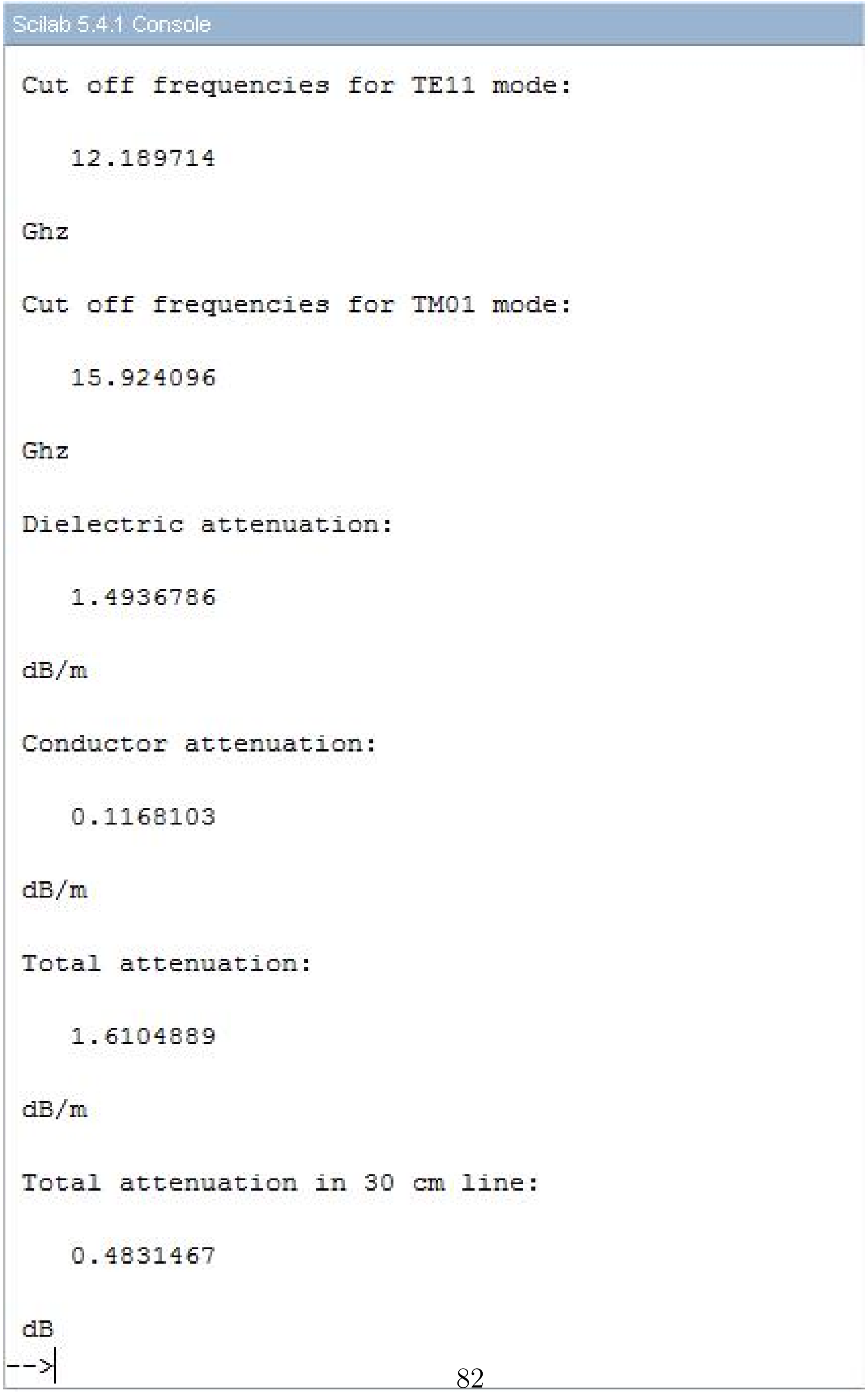
```
Maximum value of dielectric constant:

   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
```



```
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
-->
```

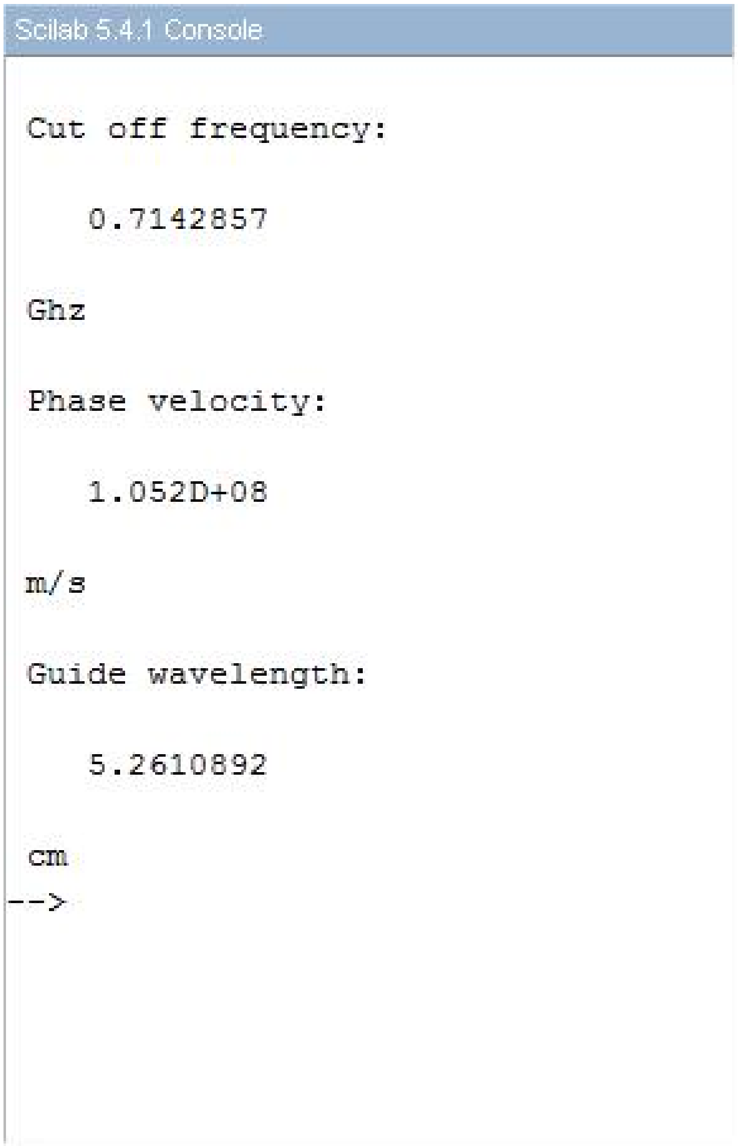
Figure 2.21: Circular Waveguide

```
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
```



```
 Cut off frequency:

    0.7142857

 Ghz

 Phase velocity:

    1.052D+08

 m/s

 Guide wavelength:

    5.2610892

 cm
-->
```

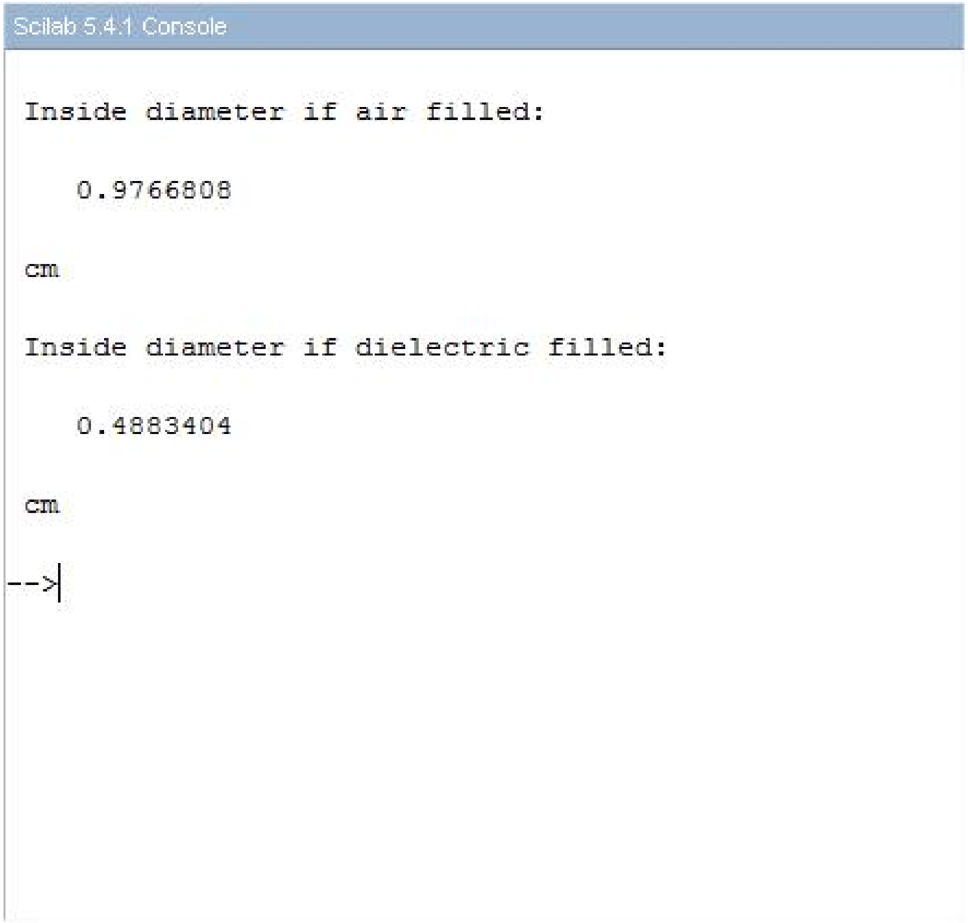
Figure 2.22: Rectangular Waveguide

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

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

Scilab code Exa 2.29 `Circular waveguide`

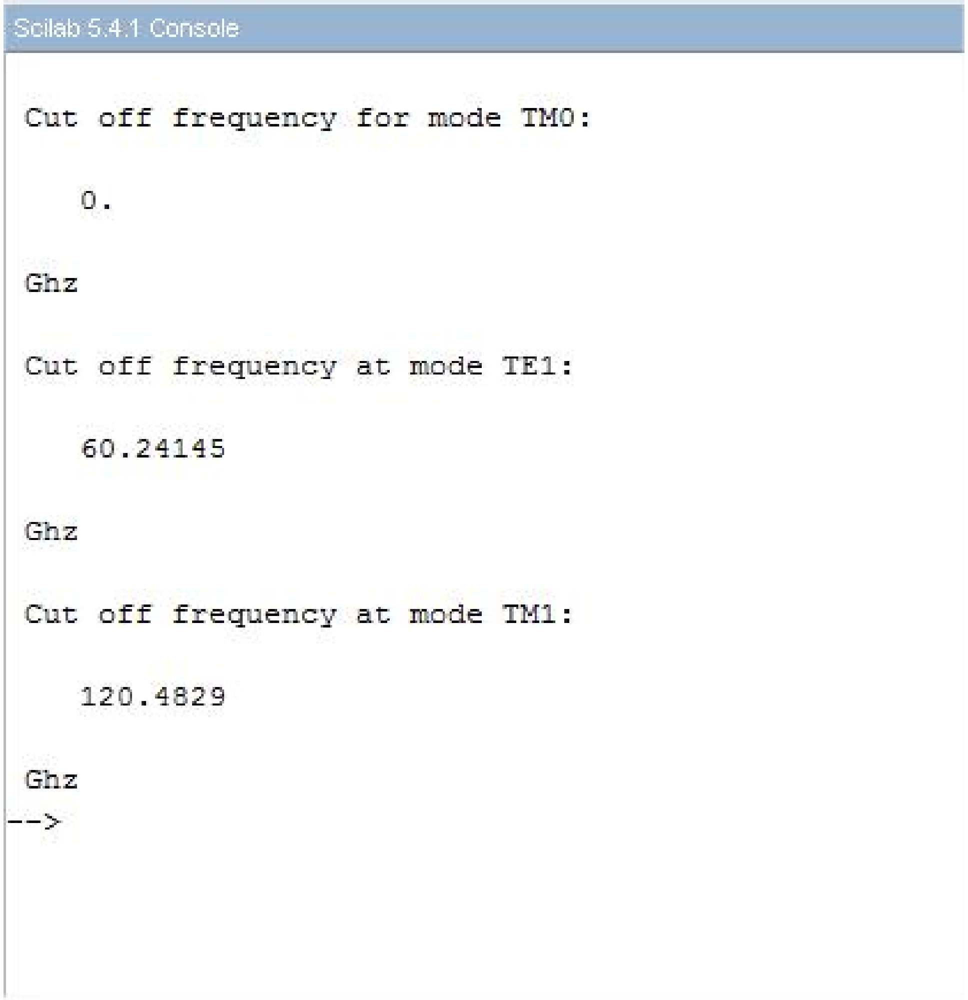
```
//Page Number: 112
//Example 2.29
clc;
//Given
c=3D+8; //m/s
fc=9D+9; //Hz
er=1;
er1=4;
p11=1.841;

//(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`



```
 Inside diameter if air filled:
 
 
    0.9766808
 
 cm
 
 Inside diameter if dielectric filled:
 
 
    0.4883404
 
 cm
 
-->
```

Figure 2.23: Circular waveguide



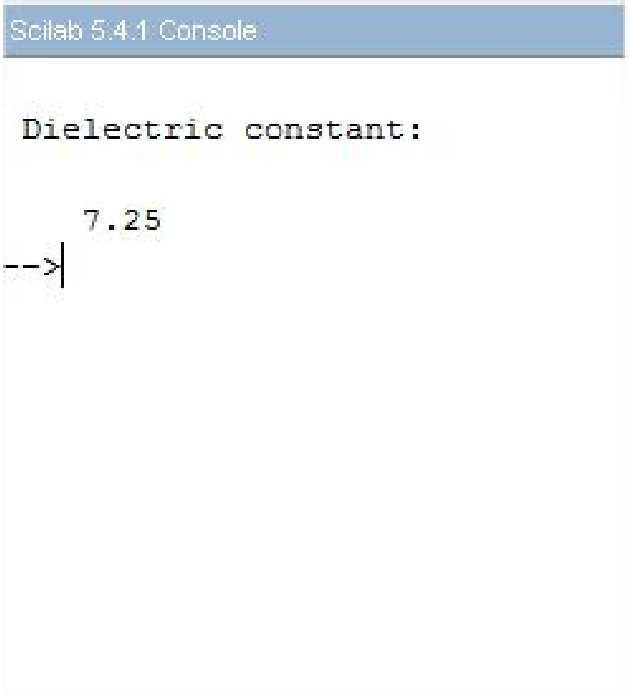
```
 Cut off frequency for mode TM0:

    0.

 Ghz

 Cut off frequency at mode TE1:

    60.24145

 Ghz

 Cut off frequency at mode TM1:

    120.4829

 Ghz
-->
```

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
```



```
 Dielectric constant:   

    7.25   
-->
```

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

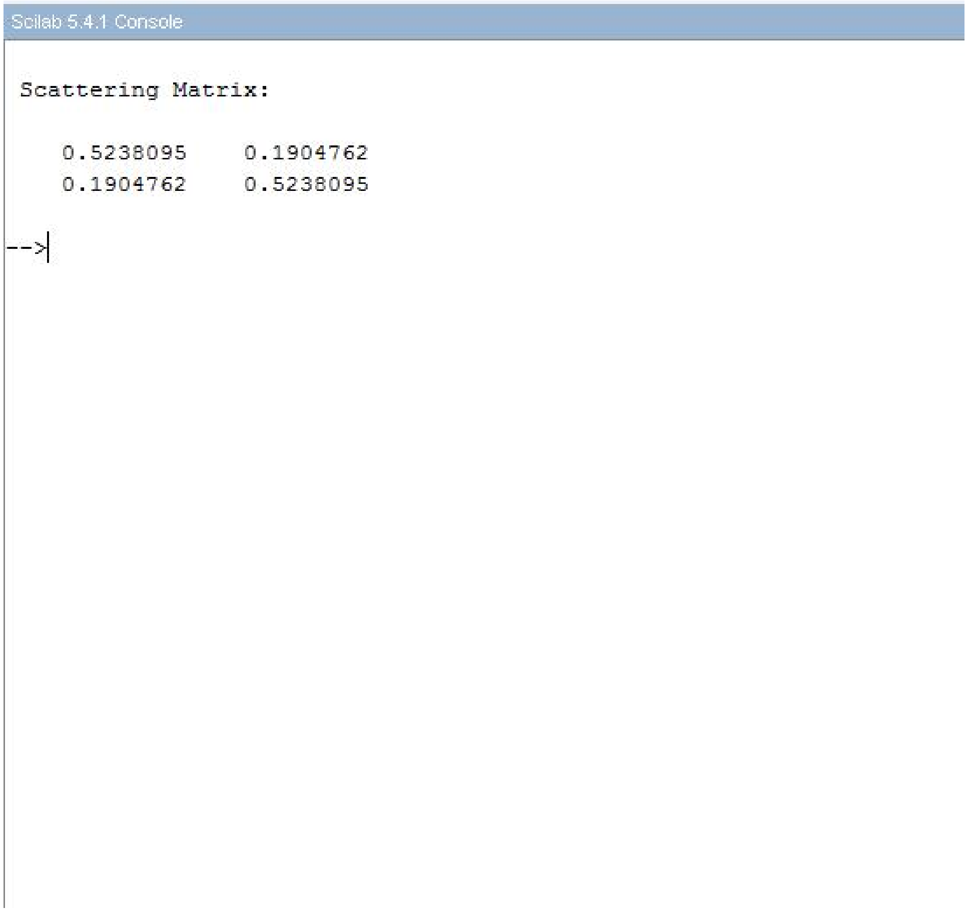
Microwave Network Analysis

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:');
```

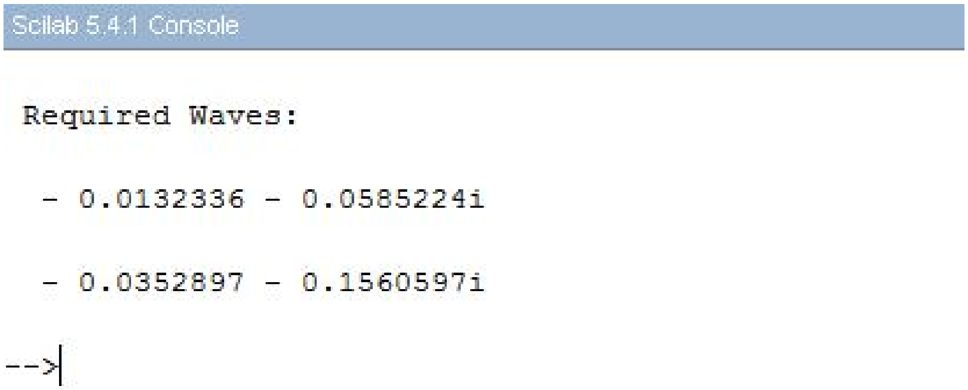
Scilab code Exa 3.5 `Network`

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



```
Scattering Matrix:

    0.5238095    0.1904762
    0.1904762    0.5238095

-->
```

Figure 3.1: Scattering matrix



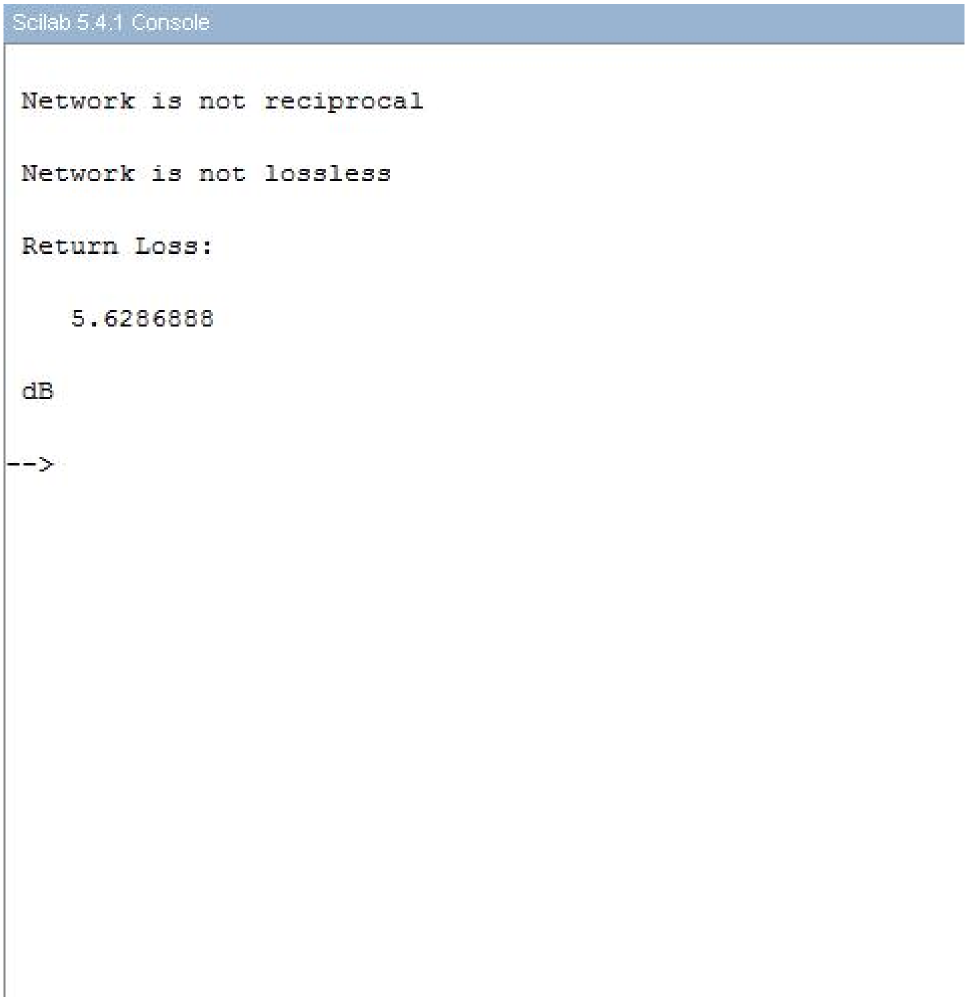
```
 Required Waves:

  - 0.0132336 - 0.0585224i

  - 0.0352897 - 0.1560597i

-->
```

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;
```



```
 Network is not reciprocal

 Network is not lossless

 Return Loss:

    5.6286888

 dB

-->
```

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;
```

```
Transducer Gain:

   13.553237

Available power Gain:

   14.291431

Power Gain:

   16.802604

Power available at source:

   0.5

W

Power available at input:

   0.3481481

W

Input VSWR:

   3.4552677

Output VSWR:

   1.3373704

-->
```

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:');

```

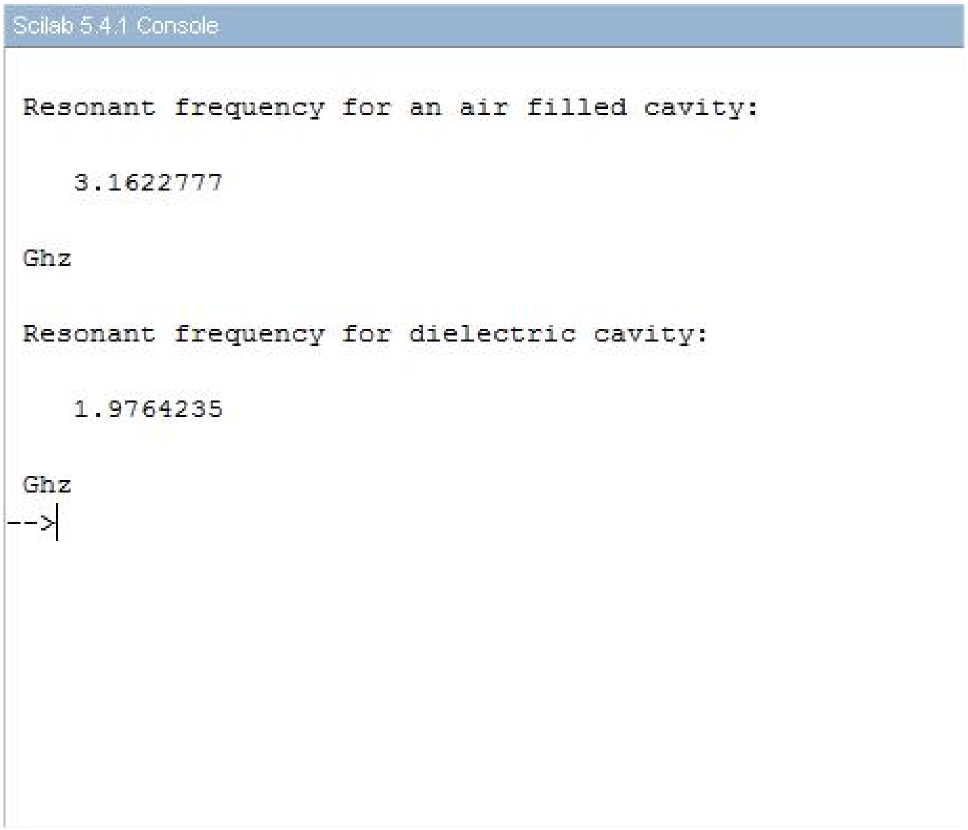
```
//(iii) VSWRs
M1=Pin/Pavs;
M2=Pl/(9.6*Pavs);

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

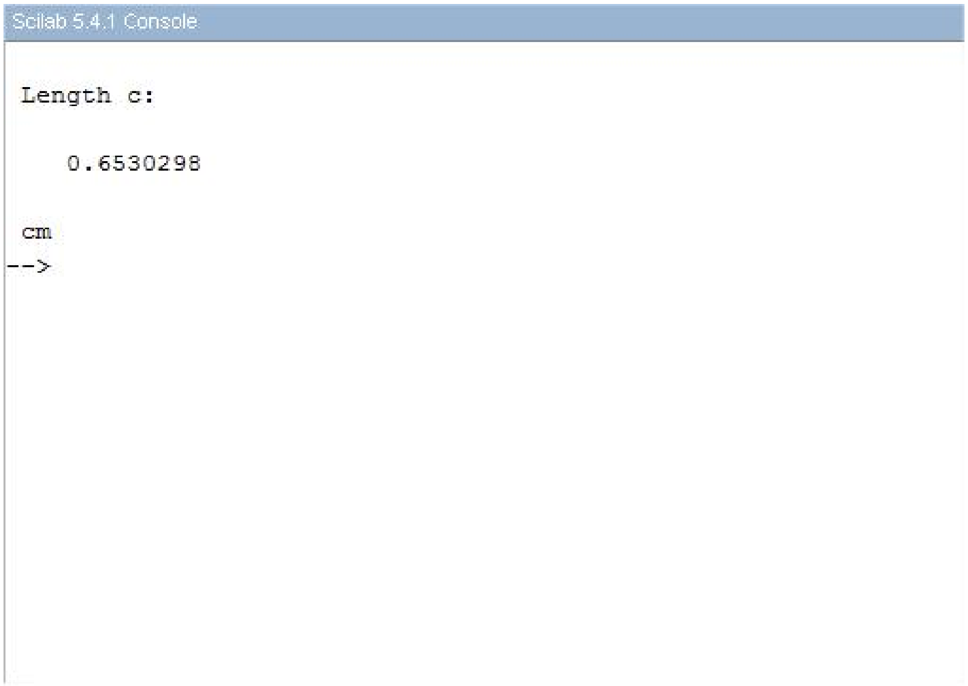
Scilab code Exa 4.1 `Rectangular cavity resonator`

```
//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
```



```
Resonant frequency for an air filled cavity:

    3.1622777

Ghz

Resonant frequency for dielectric cavity:

    1.9764235

Ghz
-->
```

Figure 4.1: Rectangular cavity resonator



```
Length c:

   0.6530298

 cm
-->
```

Figure 4.2: Rectangulr resonator

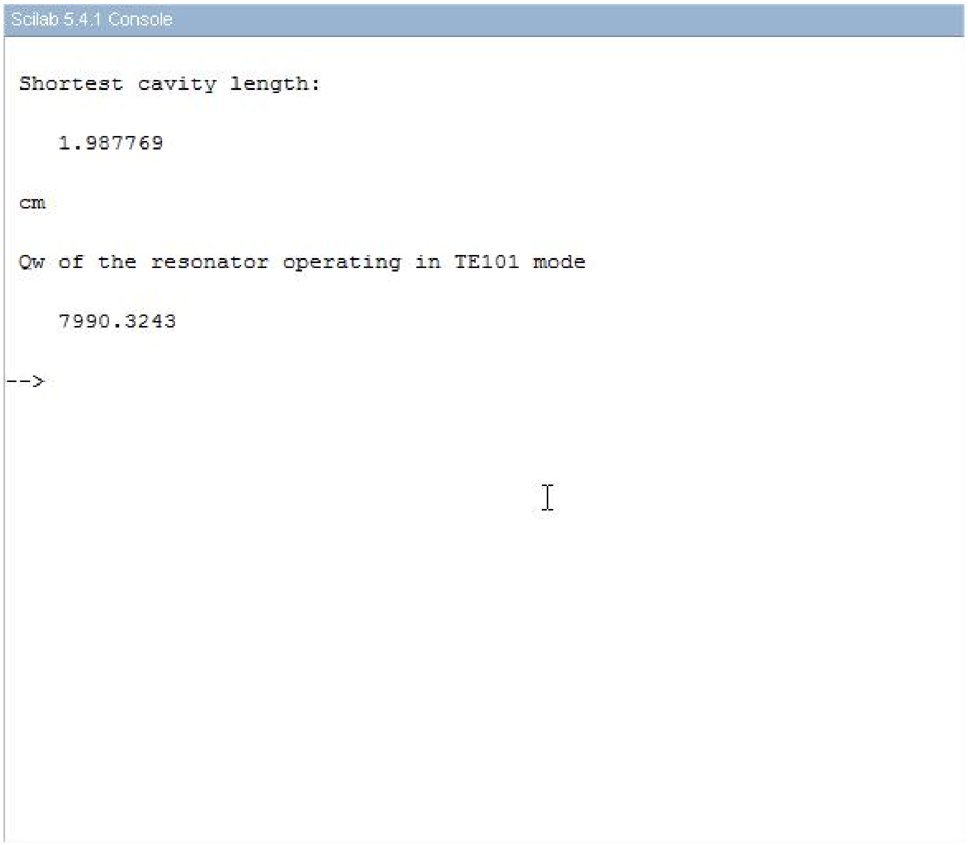
```
disp('Ghz',fr/10^9,'Resonant frequency for an air
    filled cavity:');

//(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;
```



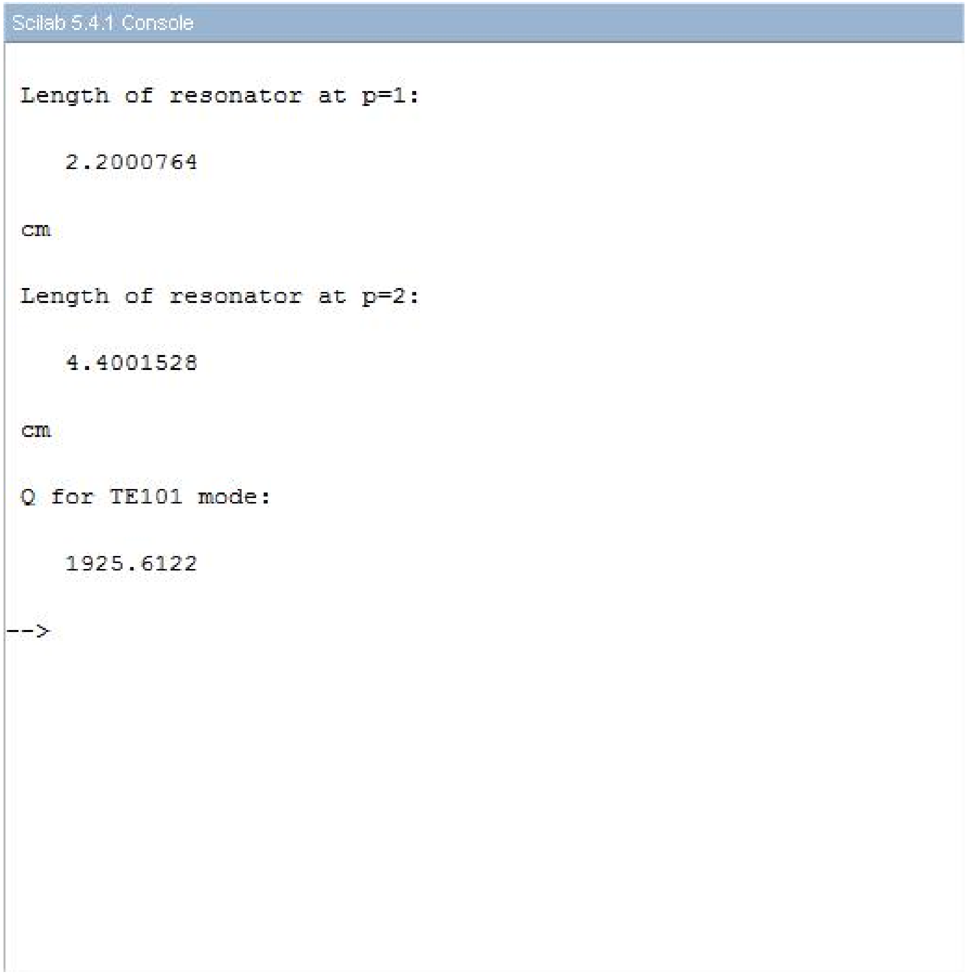
```
 Shortest cavity length:

    1.987769

 cm

 Qw of the resonator operating in TE101 mode

    7990.3243

-->
```

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;
```



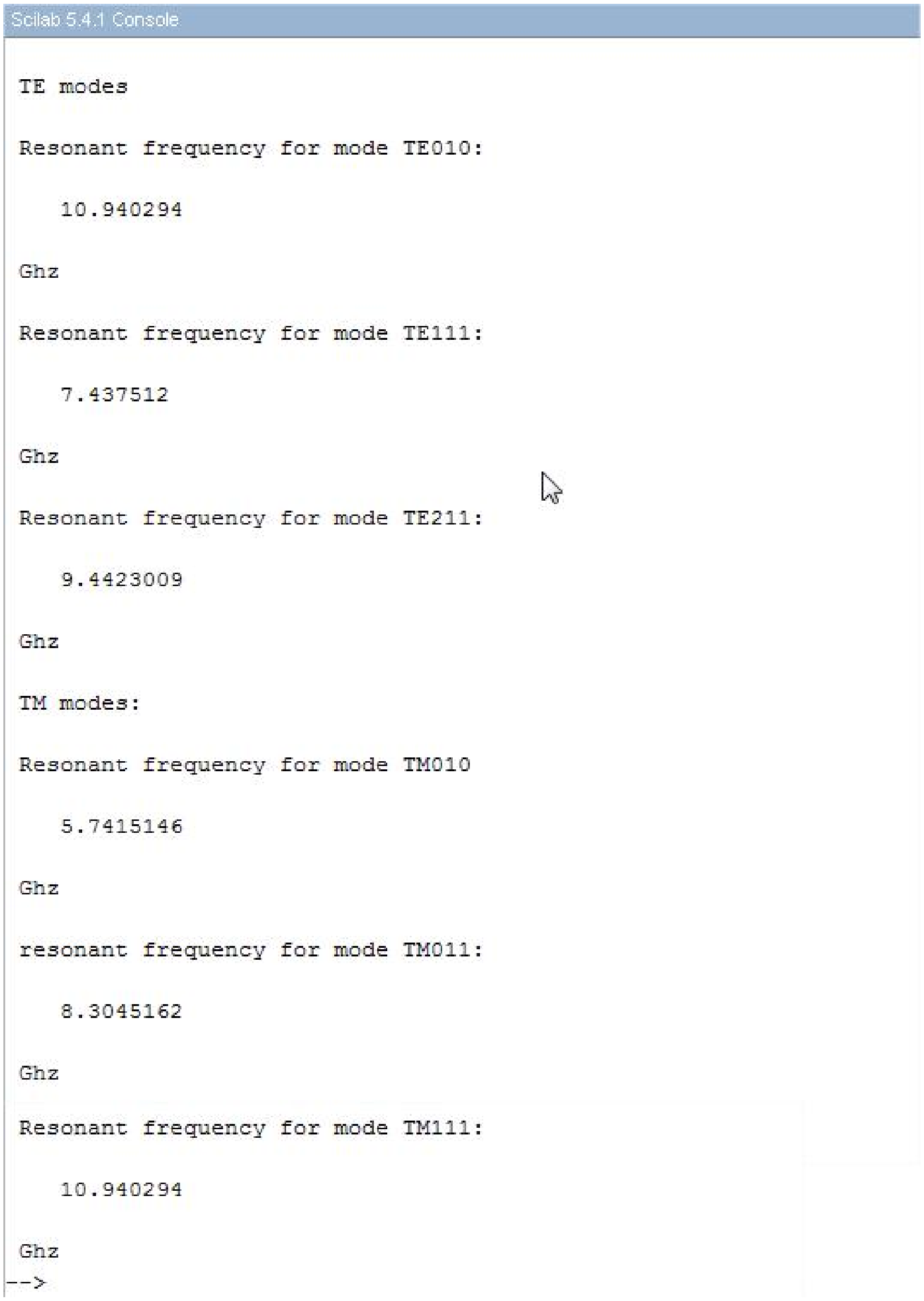
```
Length of resonator at p=1:

   2.2000764

cm

Length of resonator at p=2:

   4.4001528

cm

Q for TE101 mode:

   1925.6122

-->
```

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

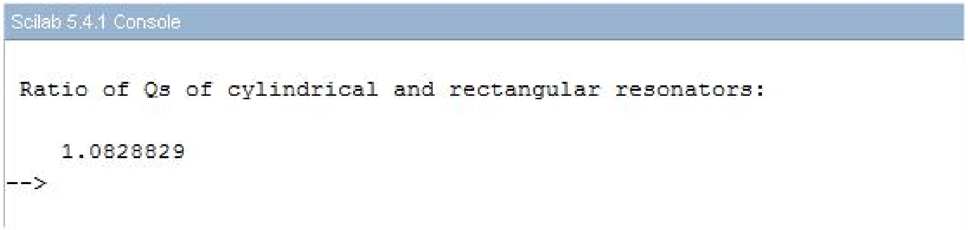
```
//Page Number: 196
//Example 4.5
clc;
```



```
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
```



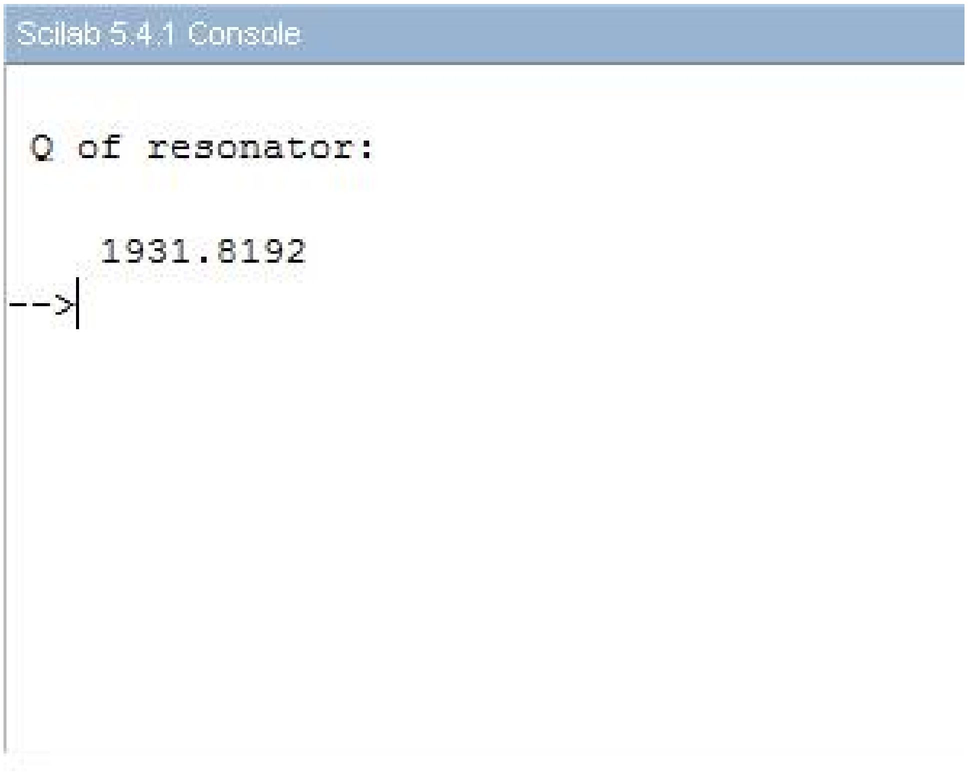
```
 Ratio of Qs of cylindrical and rectangular resonators:

    1.0828829
-->
```

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:');
```



```
Q of resonator:

    1931.8192
-->
```

Figure 4.7: Cubical Resonator

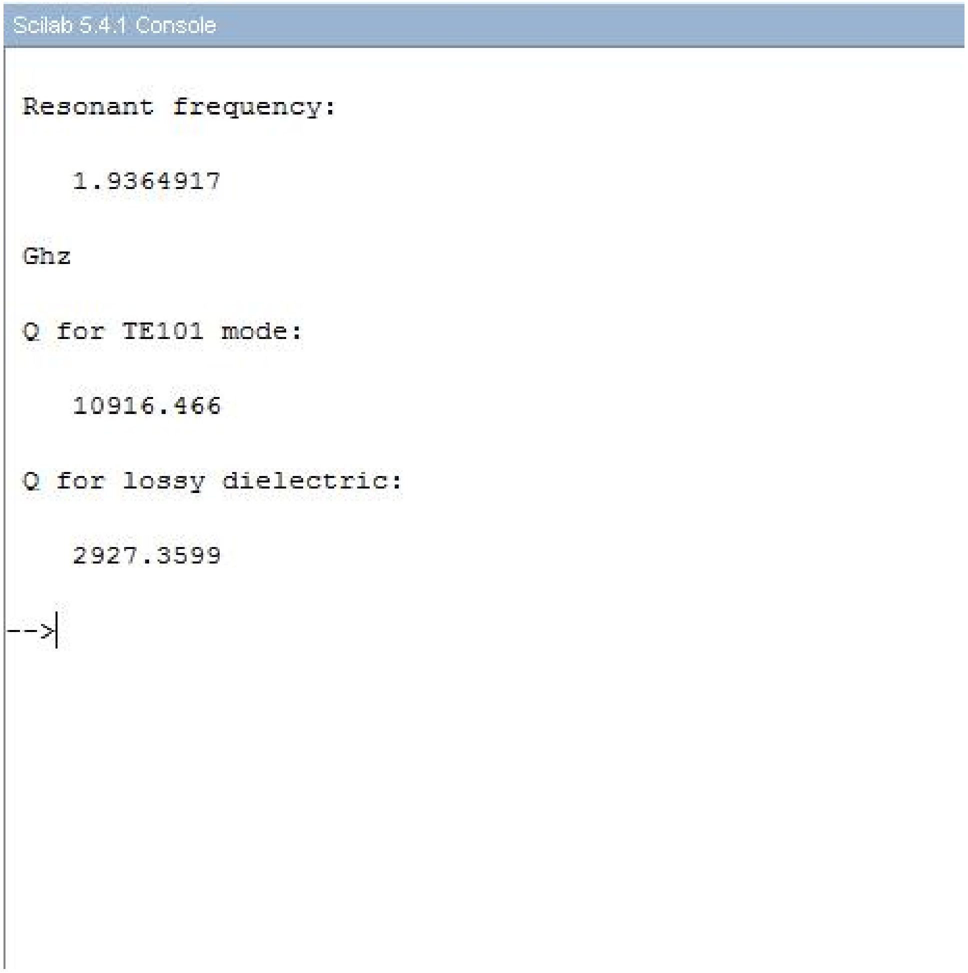
Scilab code Exa 4.7 `Cubical Resonator`

```
//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;

```



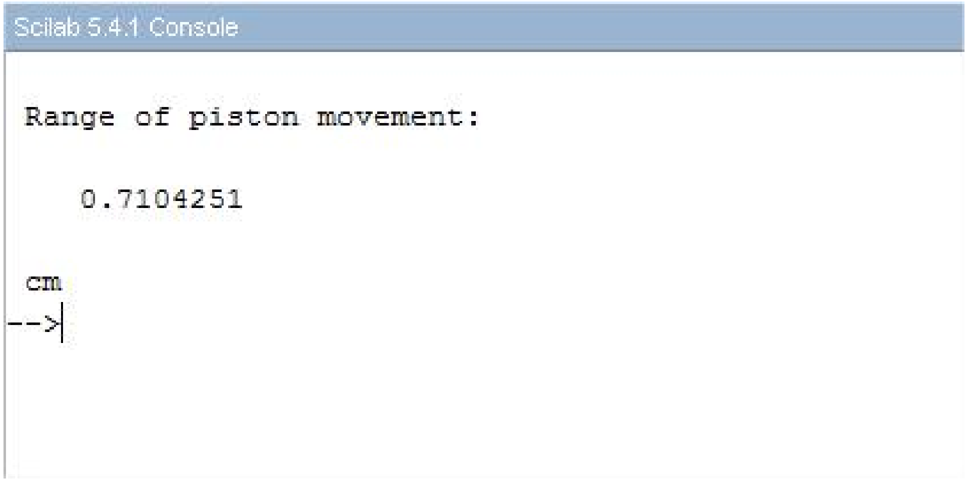
```
Resonant frequency:

   1.9364917

Ghz

Q for TE101 mode:

   10916.466

Q for lossy dielectric:

   2927.3599

-->
```

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
```



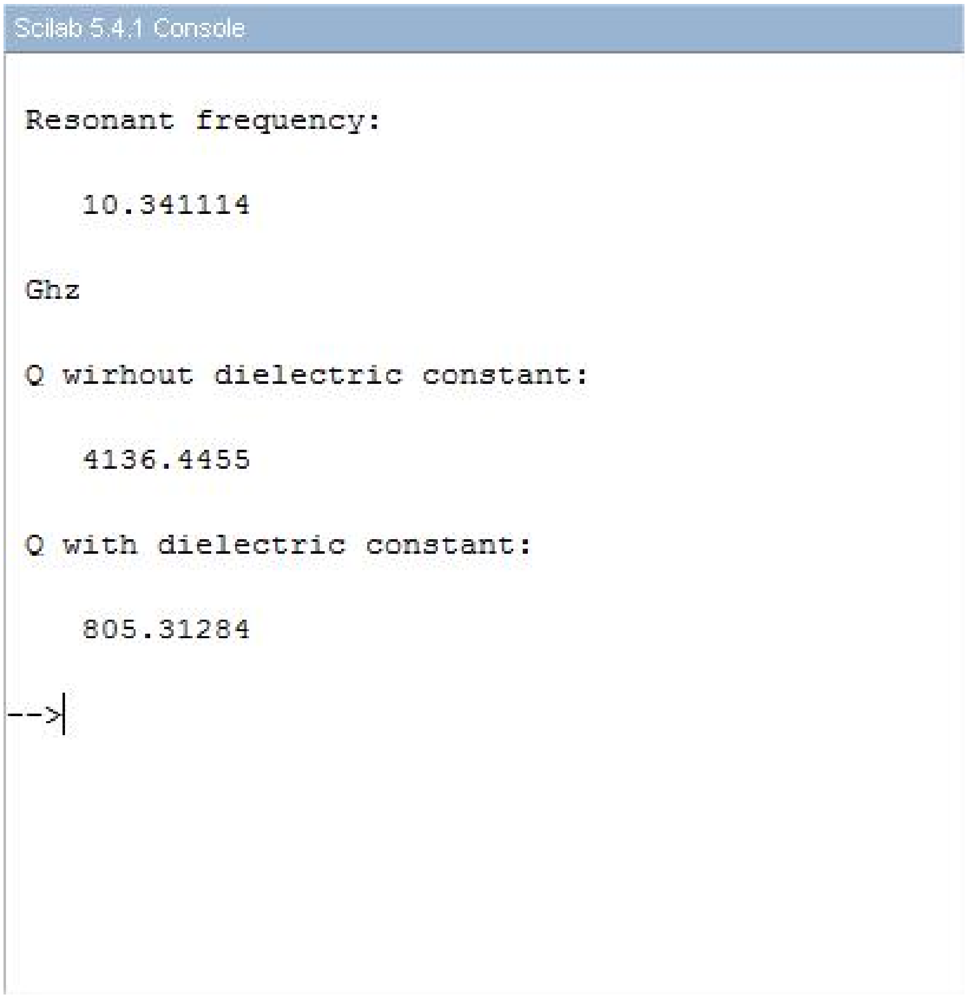
```
Range of piston movement:

   0.7104251

cm
-->
```

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:');
```

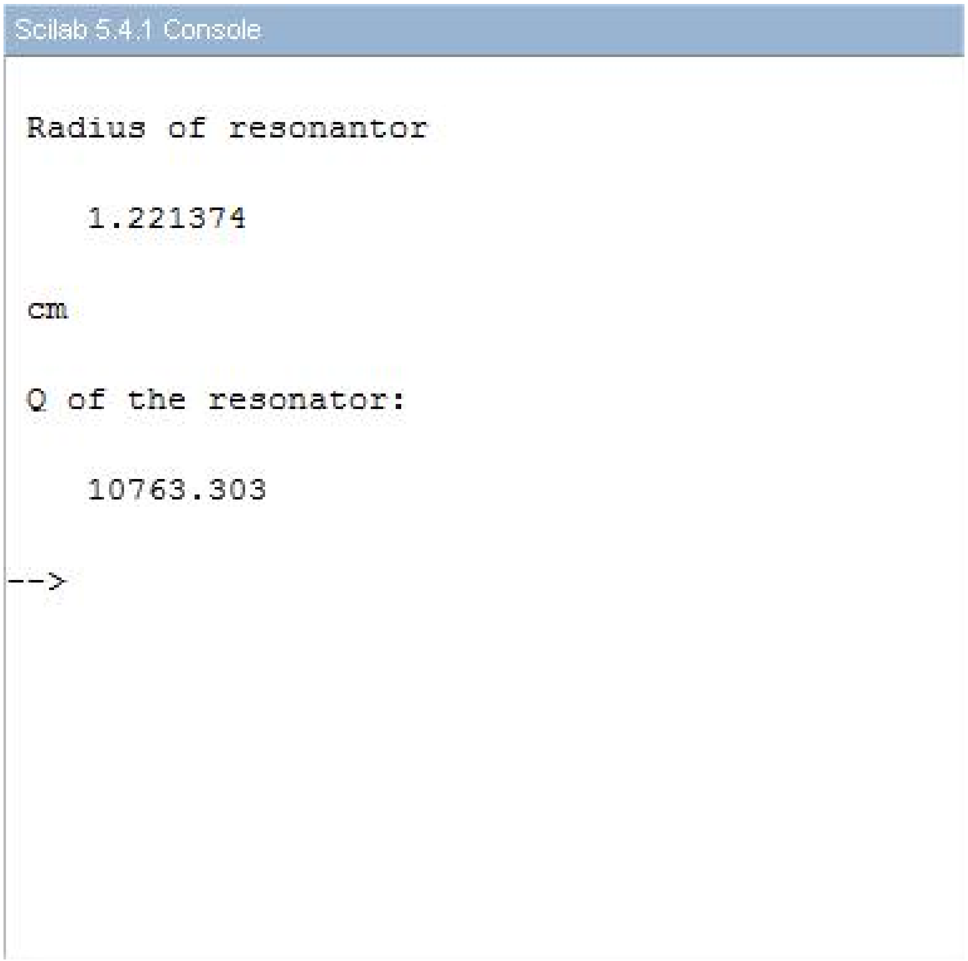
Scilab code Exa 4.10 `Cylindrical resonator`

```
//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:');
```



```
Resonant frequency:

   10.341114

Ghz

Q wirhout dielectric constant:

   4136.4455

Q with dielectric constant:

   805.31284

-->
```

Figure 4.10: Cylindrical resonator



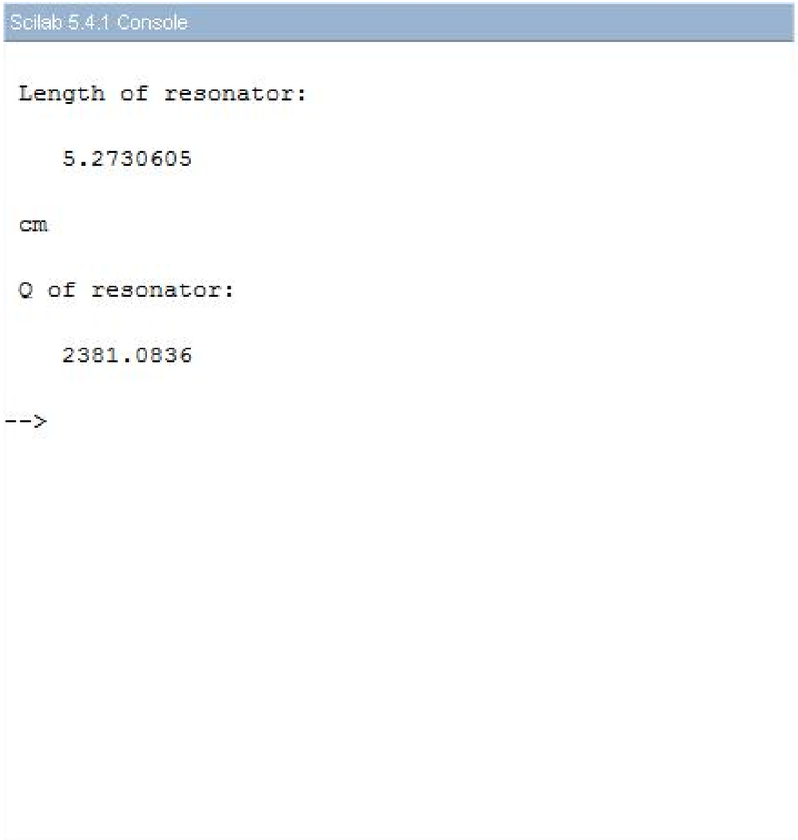
```
Radius of resonantor

   1.221374

cm

Q of the resonator:

   10763.303

-->
```

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
```

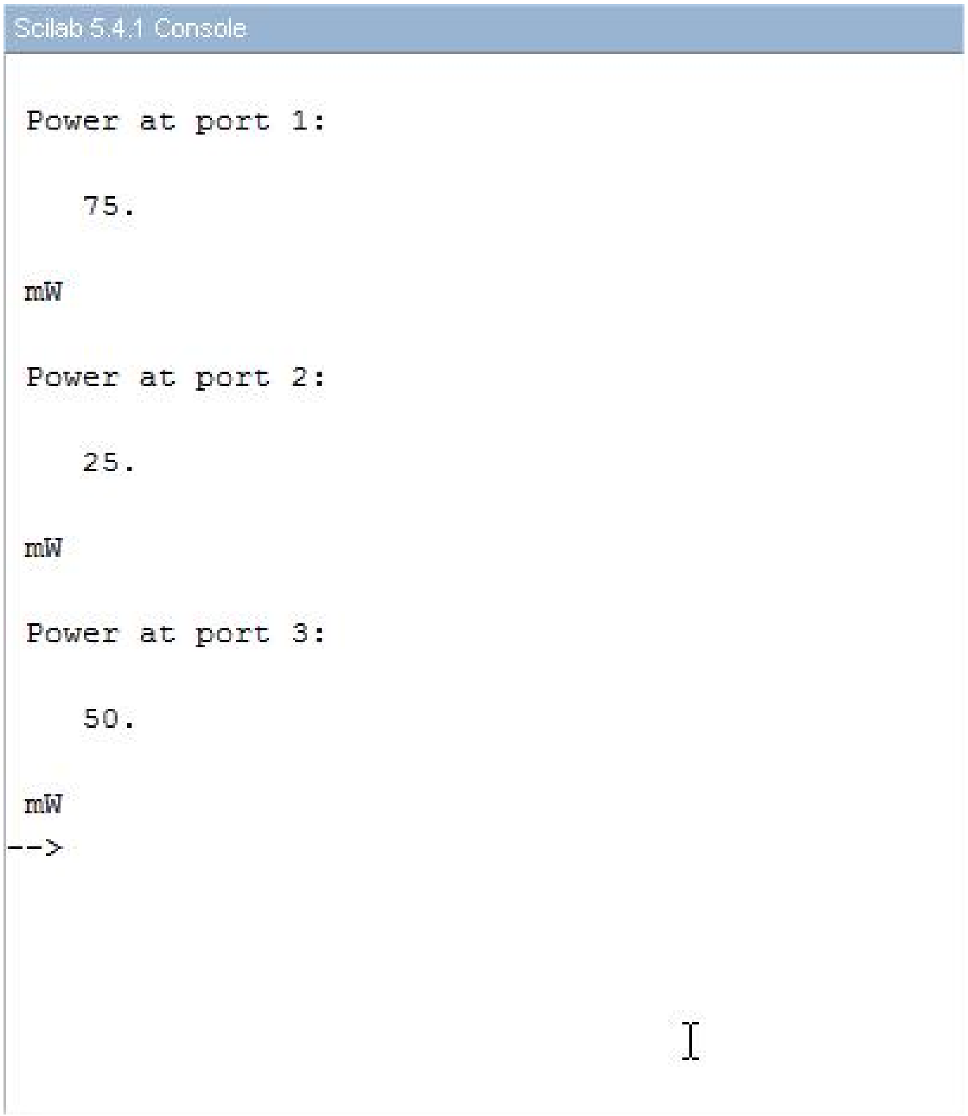
Scilab code Exa 4.12 `Cylindrical Resonator`



```
 Length of resonator:

    5.2730605

 cm

 Q of resonator:

    2381.0836

-->
```

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
```



```
Power at port 1:

   75.

mW

Power at port 2:

   25.

mW

Power at port 3:

   50.

mW
-->
```

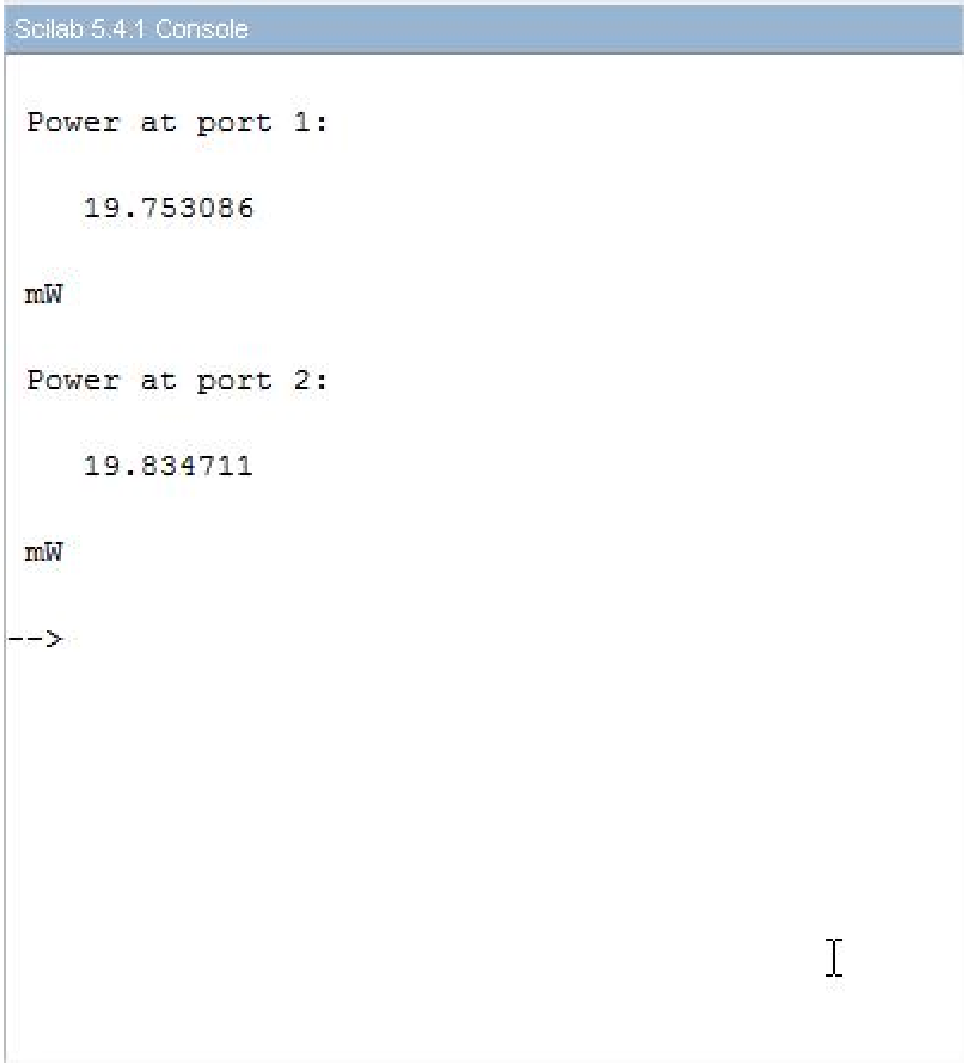
Figure 4.13: Lossless plane H tee

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
```



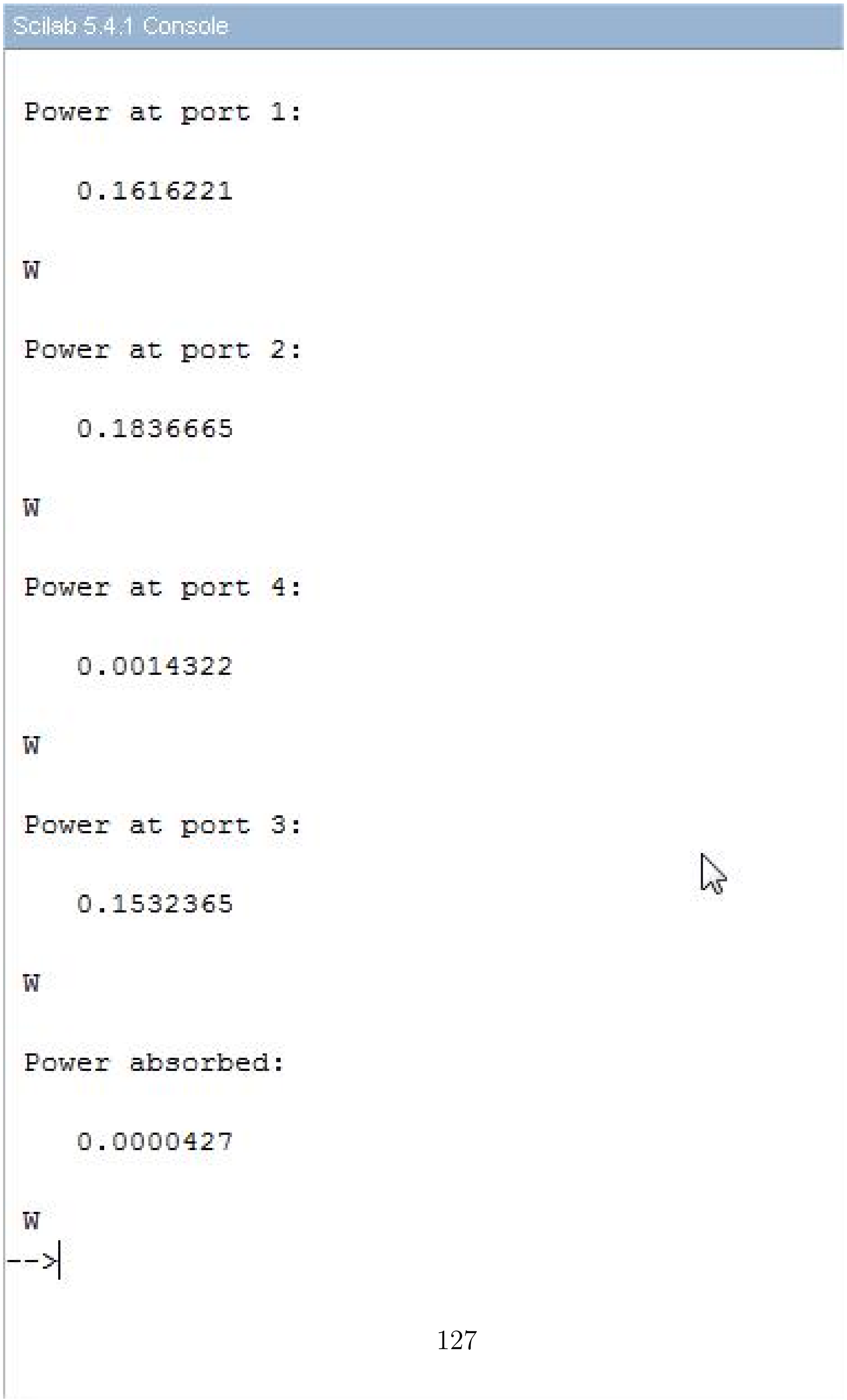
```
 Power at port 1:

    19.753086

 mW

 Power at port 2:

    19.834711

 mW

-->
```

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
```

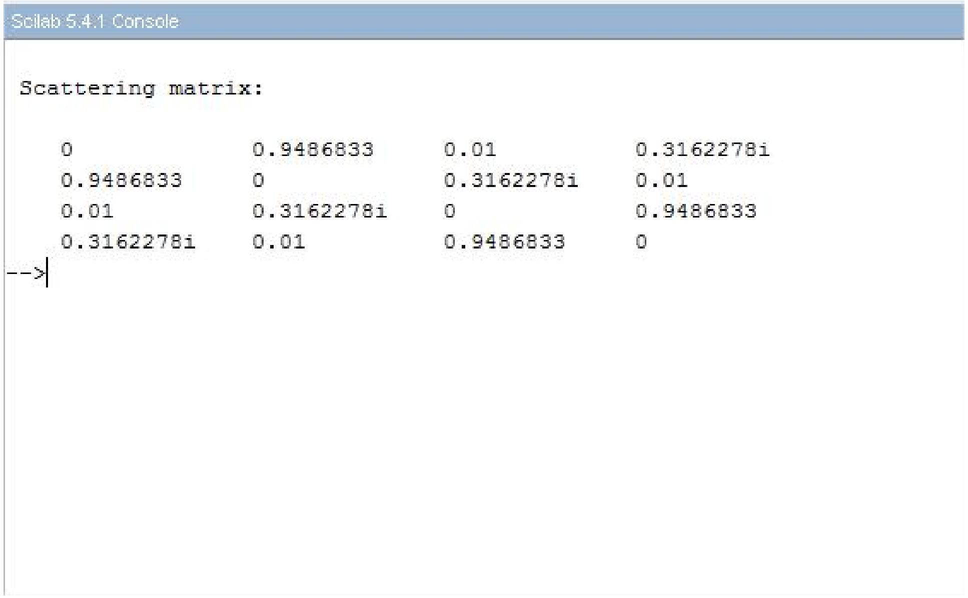


```
Power at port 1:

   0.1616221

W

Power at port 2:

   0.1836665

W

Power at port 4:

   0.0014322

W

Power at port 3:

   0.1532365

W

Power absorbed:

   0.0000427

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
```

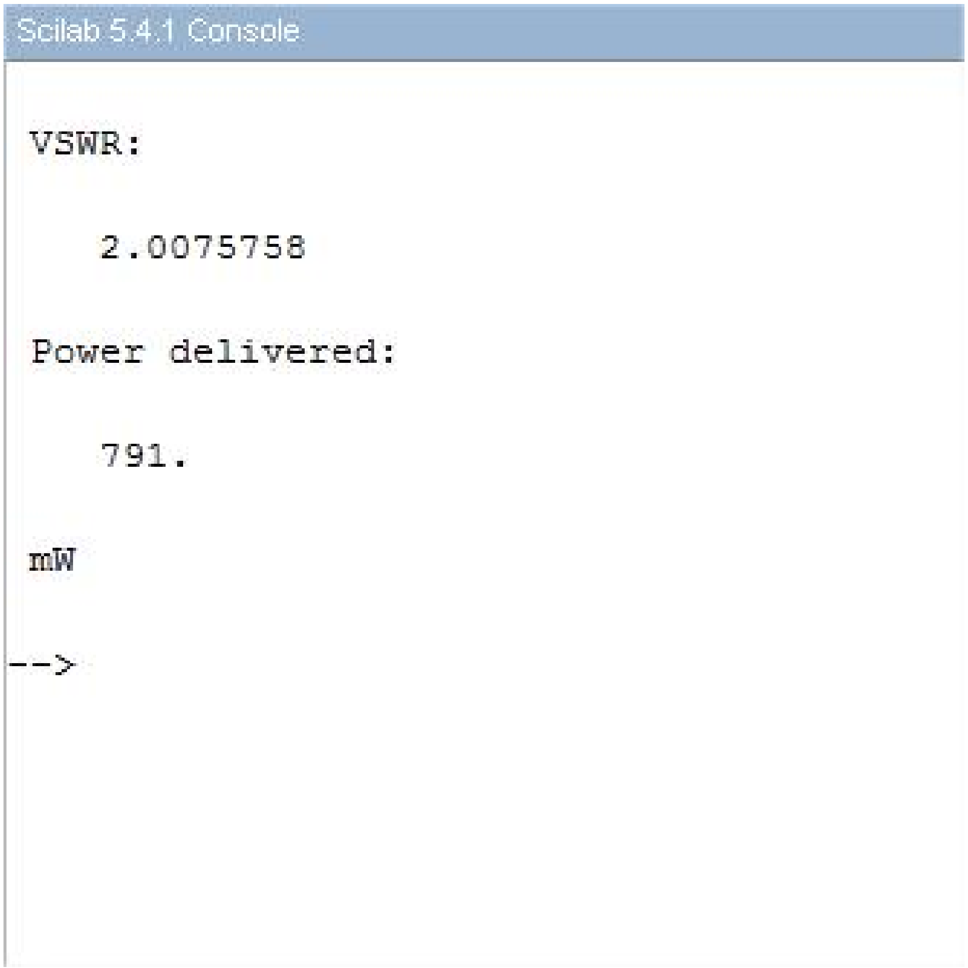
Scilab code Exa 4.18 `Directional Coupler`



```
Scattering matrix:

   0            0.9486833     0.01          0.3162278i
   0.9486833    0             0.3162278i    0.01
   0.01         0.3162278i    0             0.9486833
   0.3162278i   0.01          0.9486833     0
-->
```

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:');
```



```
 VSWR:

    2.0075758

 Power delivered:

    791.

 mW

-->
```

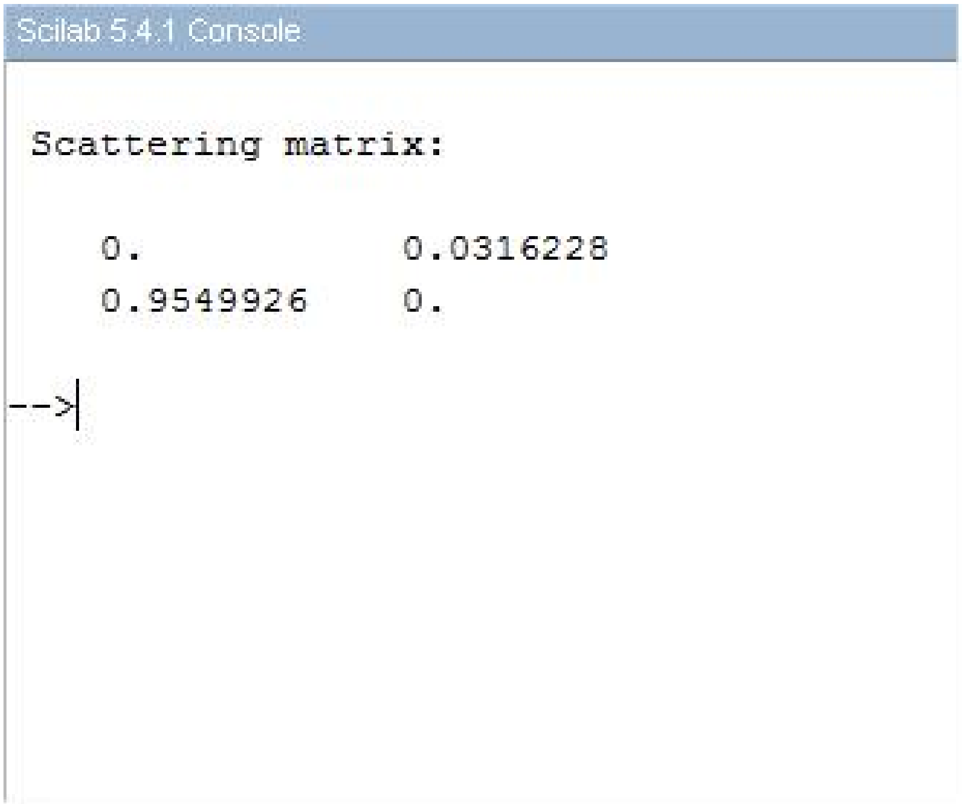
Figure 4.17: Directional coupler

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:');
P1=P1*(1-(Tt*Tt));
disp('mW',P1,'Power delivered:');

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

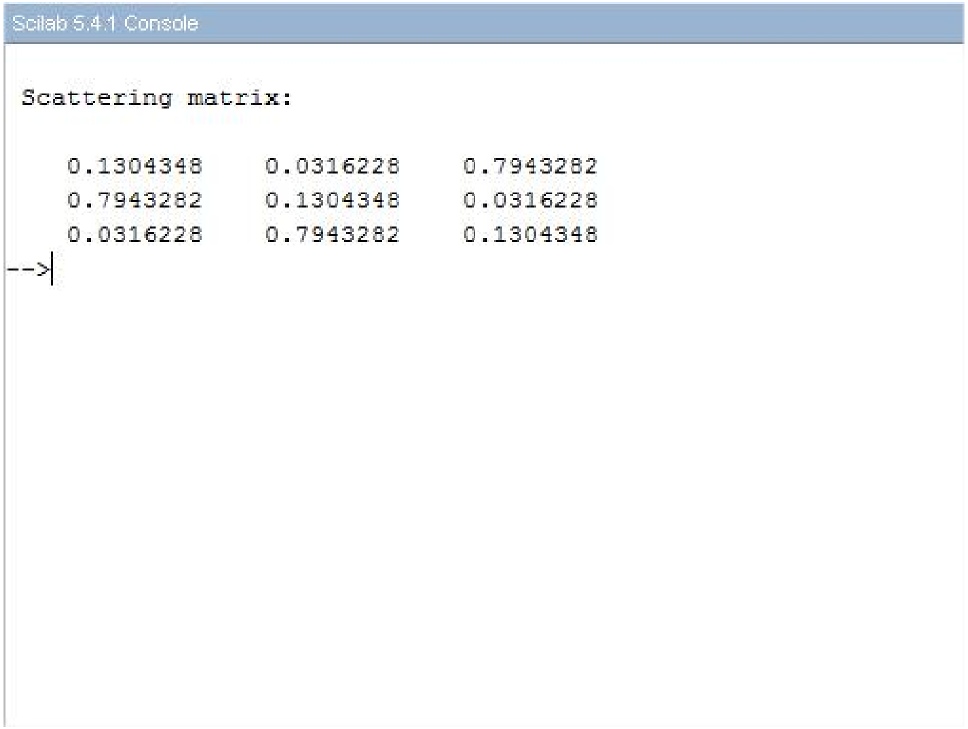
Scilab code Exa 4.21 `Isolator Matrix`

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



```
Scattering matrix:

    0.           0.0316228
    0.9549926    0.

-->
```

Figure 4.18: Isolator Matrix



```
Scattering matrix:

    0.1304348    0.0316228    0.7943282
    0.7943282    0.1304348    0.0316228
    0.0316228    0.7943282    0.1304348
-->
```

Figure 4.19: Circulator Matrix

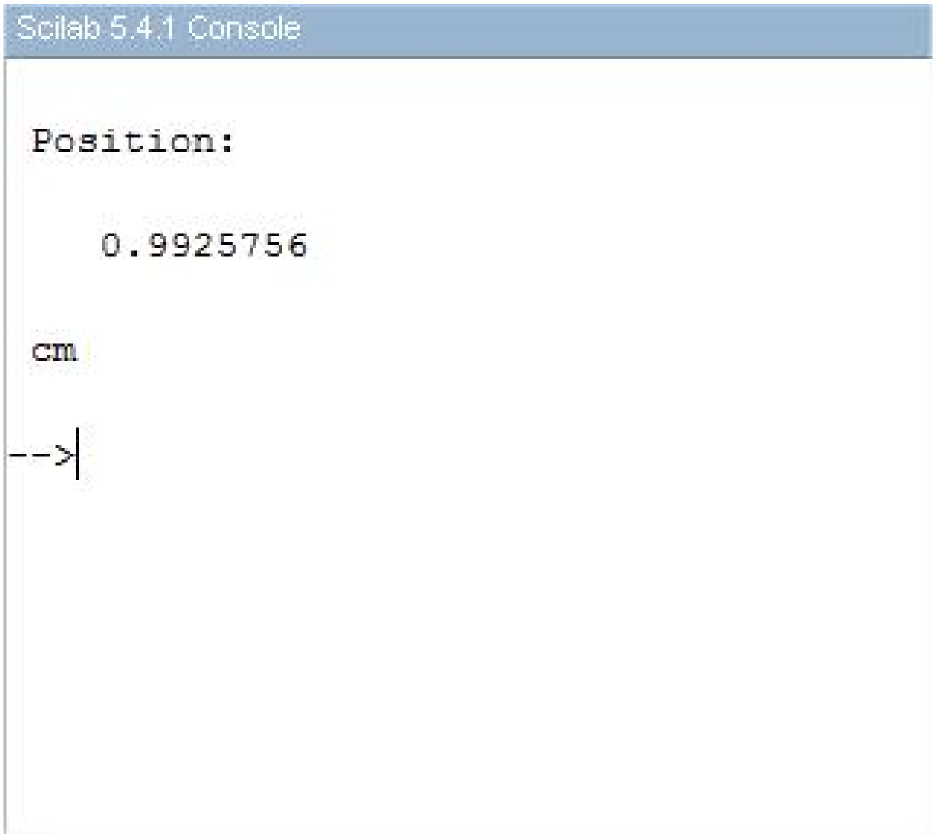
```
//Example 4.21
clc;
//Given
I=30; //dB
Il=0.4; //dB

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
```



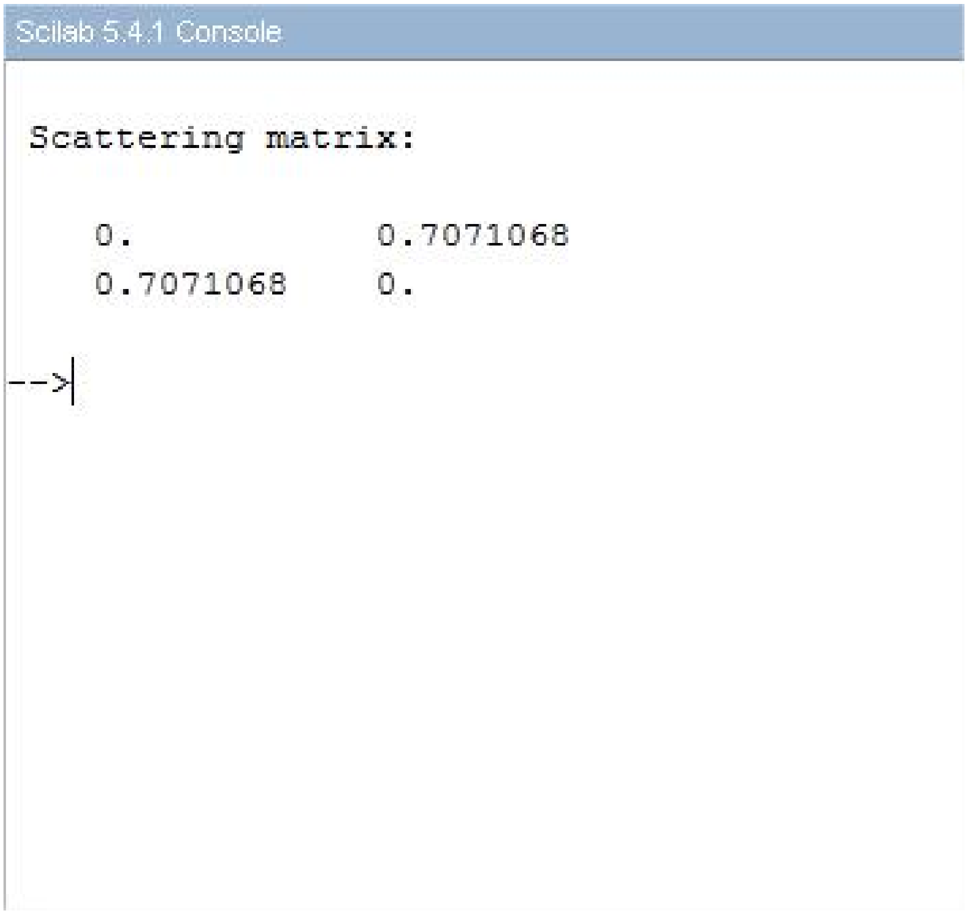
```
 Position:

    0.9925756

 cm

-->
```

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:');
```



```
Scattering matrix:

   0.           0.7071068
   0.7071068    0.

-->
```

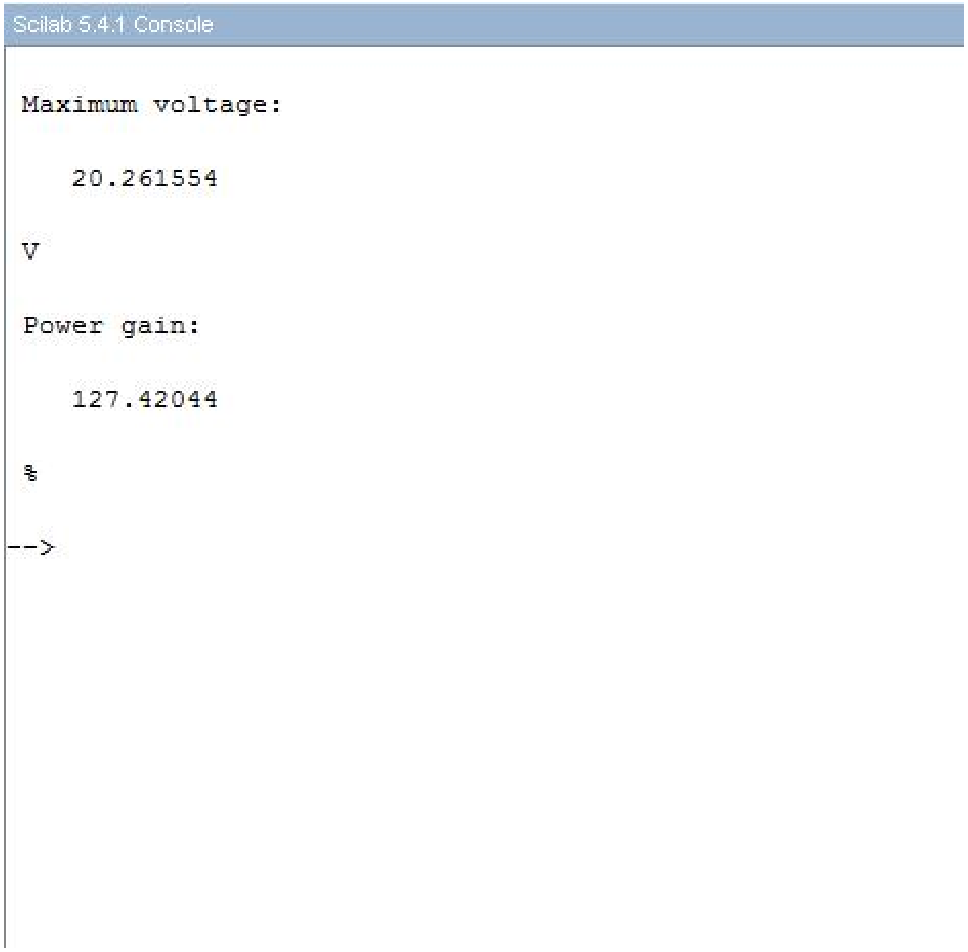
Figure 4.21: Attenuator matrix

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));
```



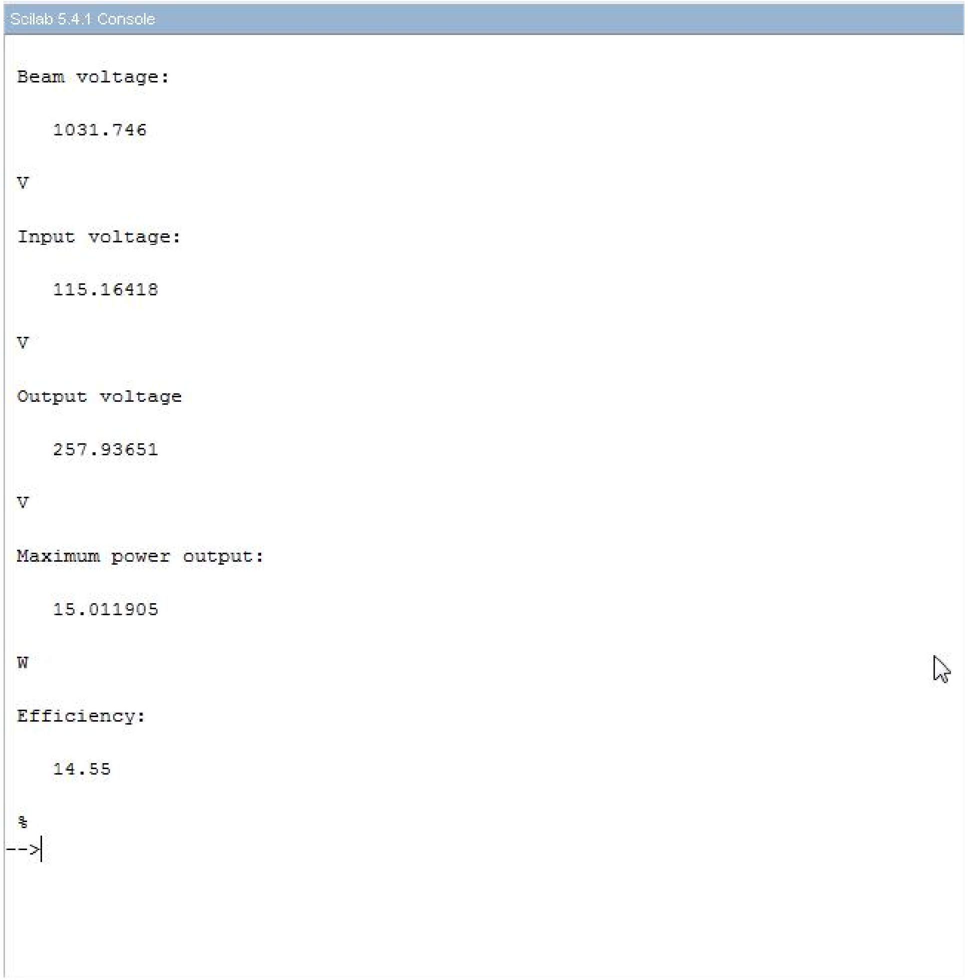
```
 Maximum voltage:

    20.261554

 V

 Power gain:

    127.42044

 %

-->
```

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;
```



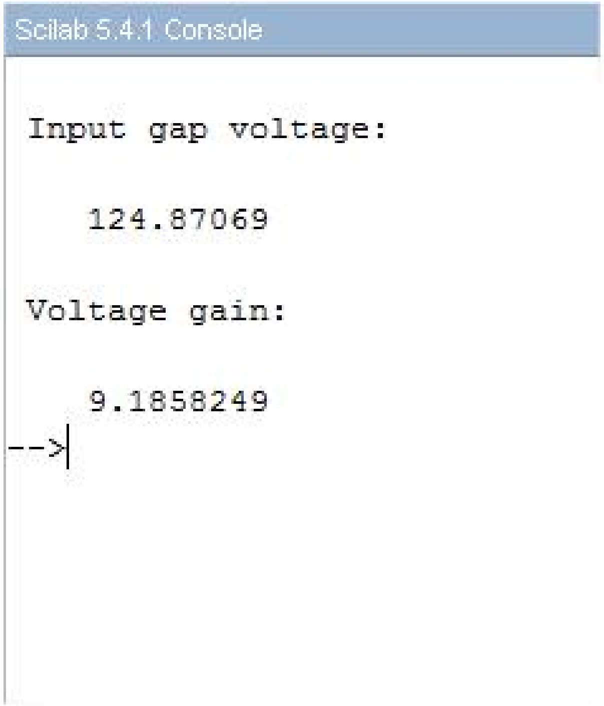
```
Beam voltage:

   1031.746

V

Input voltage:

   115.16418

V

Output voltage

   257.93651

V

Maximum power output:

   15.011905

W

Efficiency:

   14.55

%
-->
```

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
```



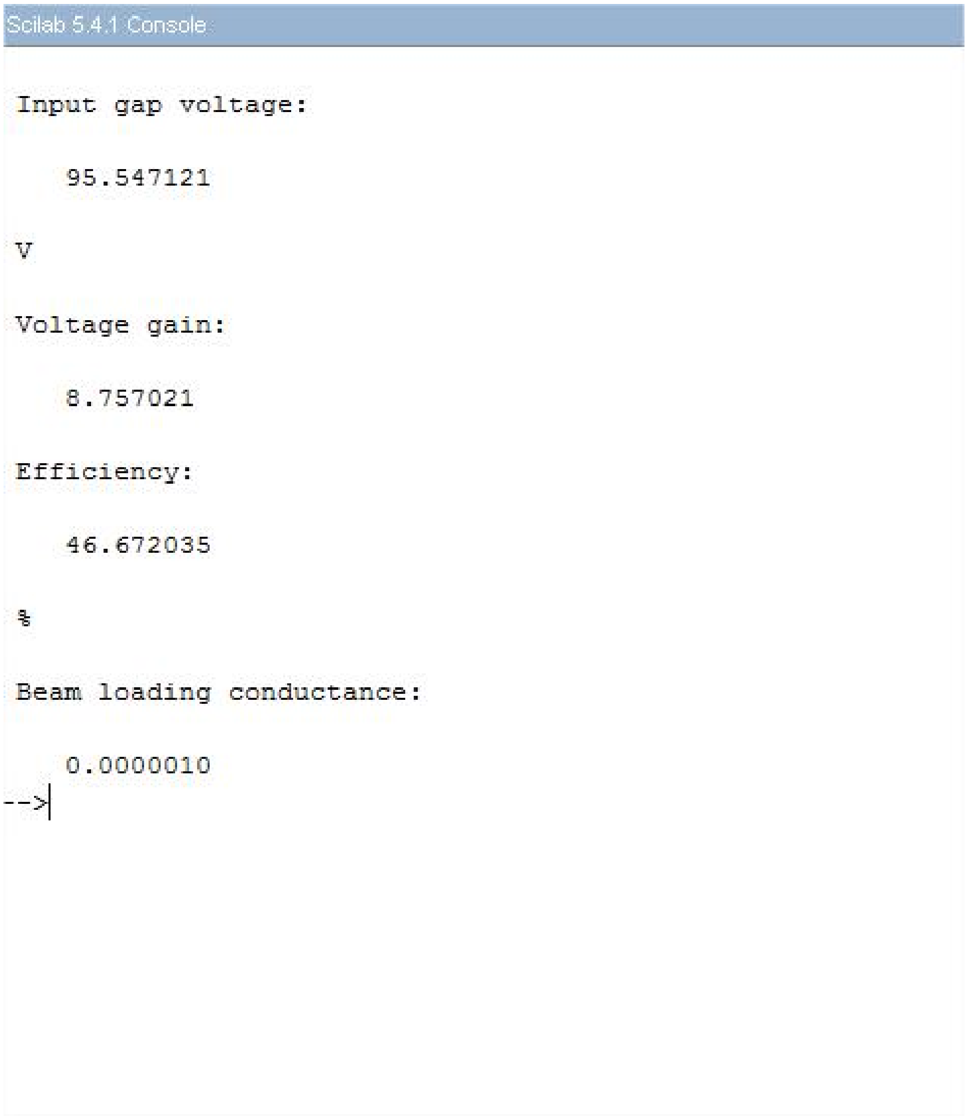
```
 Input gap voltage:

    124.87069

 Voltage gain:

    9.1858249
-->
```

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
```



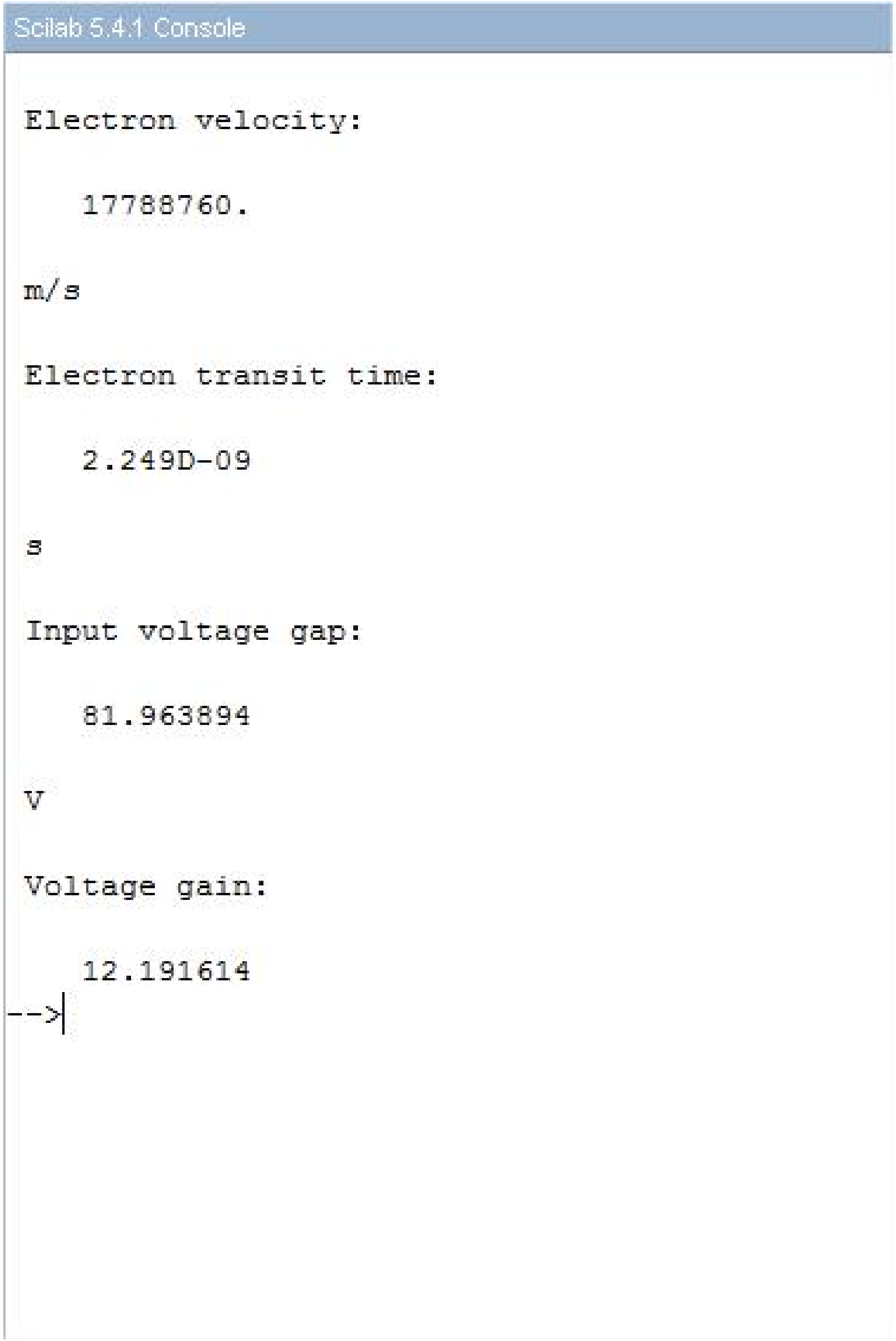
```
Input gap voltage:

   95.547121

V

Voltage gain:

   8.757021

Efficiency:

   46.672035

%

Beam loading conductance:

   0.0000010
-->
```

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:');

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

Scilab code Exa 5.5 `Two cavity Klystron`

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



```
Electron velocity:

   17788760.

m/s

Electron transit time:

   2.249D-09

s

Input voltage gap:

   81.963894

V

Voltage gain:

   12.191614
-->
```

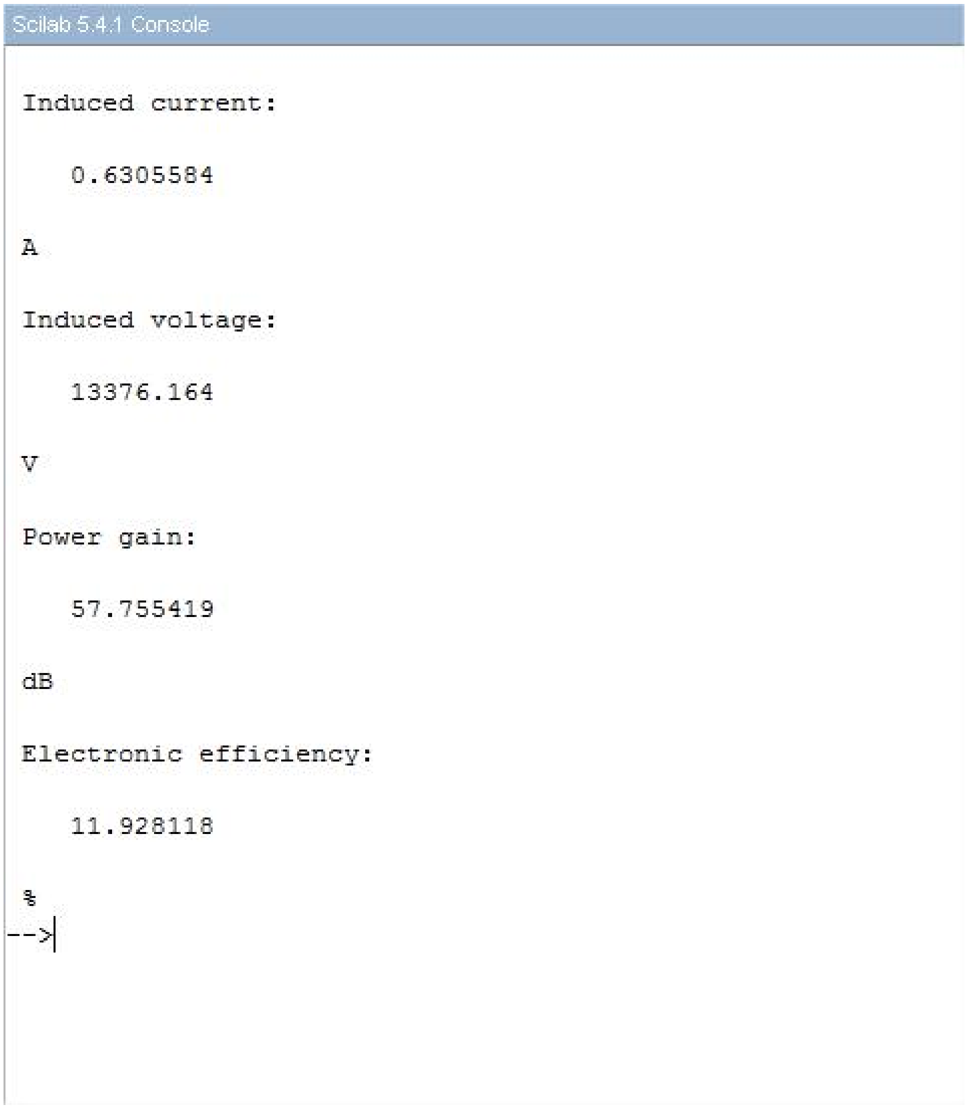
Figure 5.5: Two cavity Klystron

```
//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:');
```



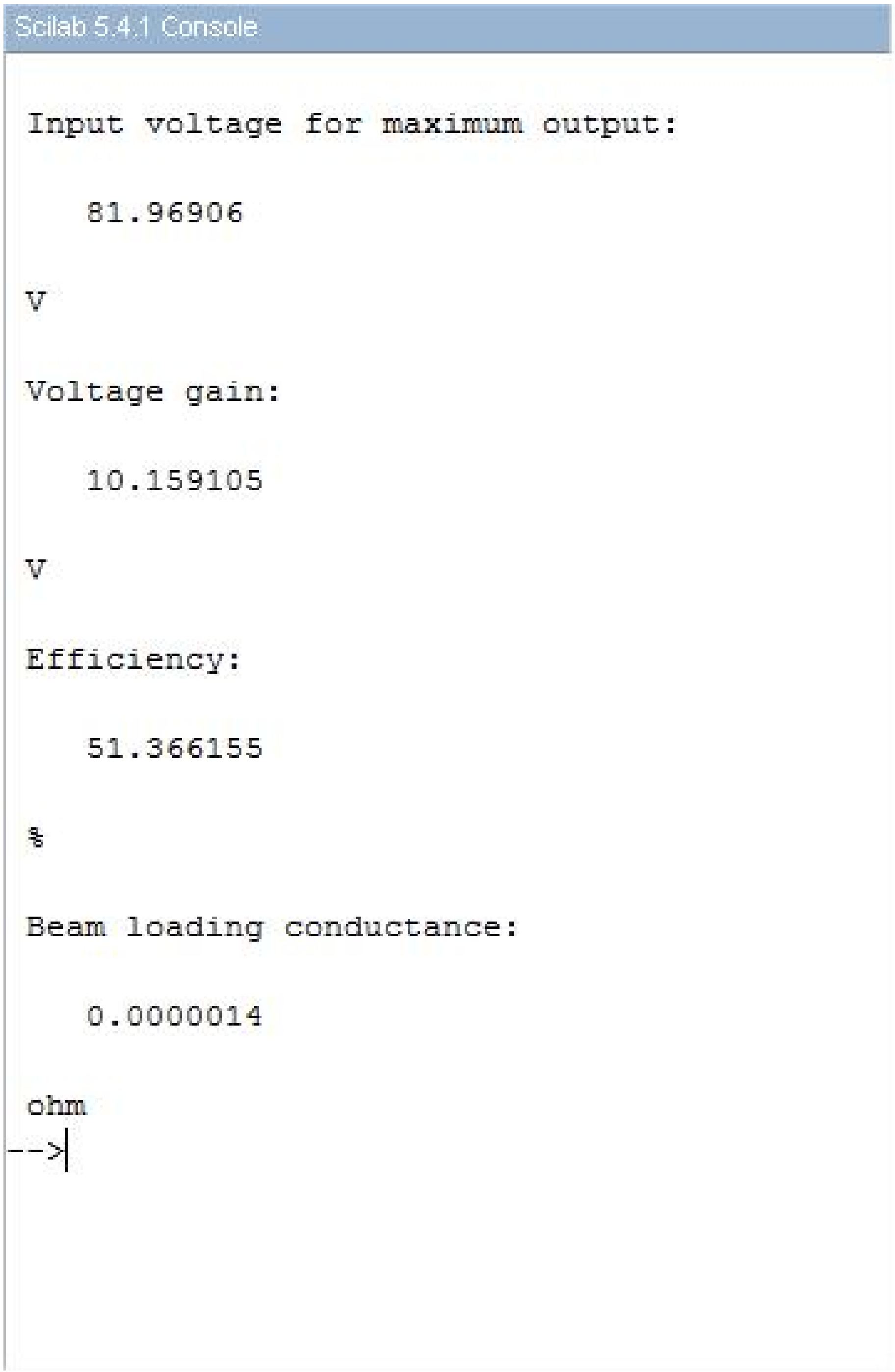
```
Induced current:

   0.6305584

A

Induced voltage:

   13376.164

V

Power gain:

   57.755419

dB

Electronic efficiency:

   11.928118

%
-->
```

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);
```



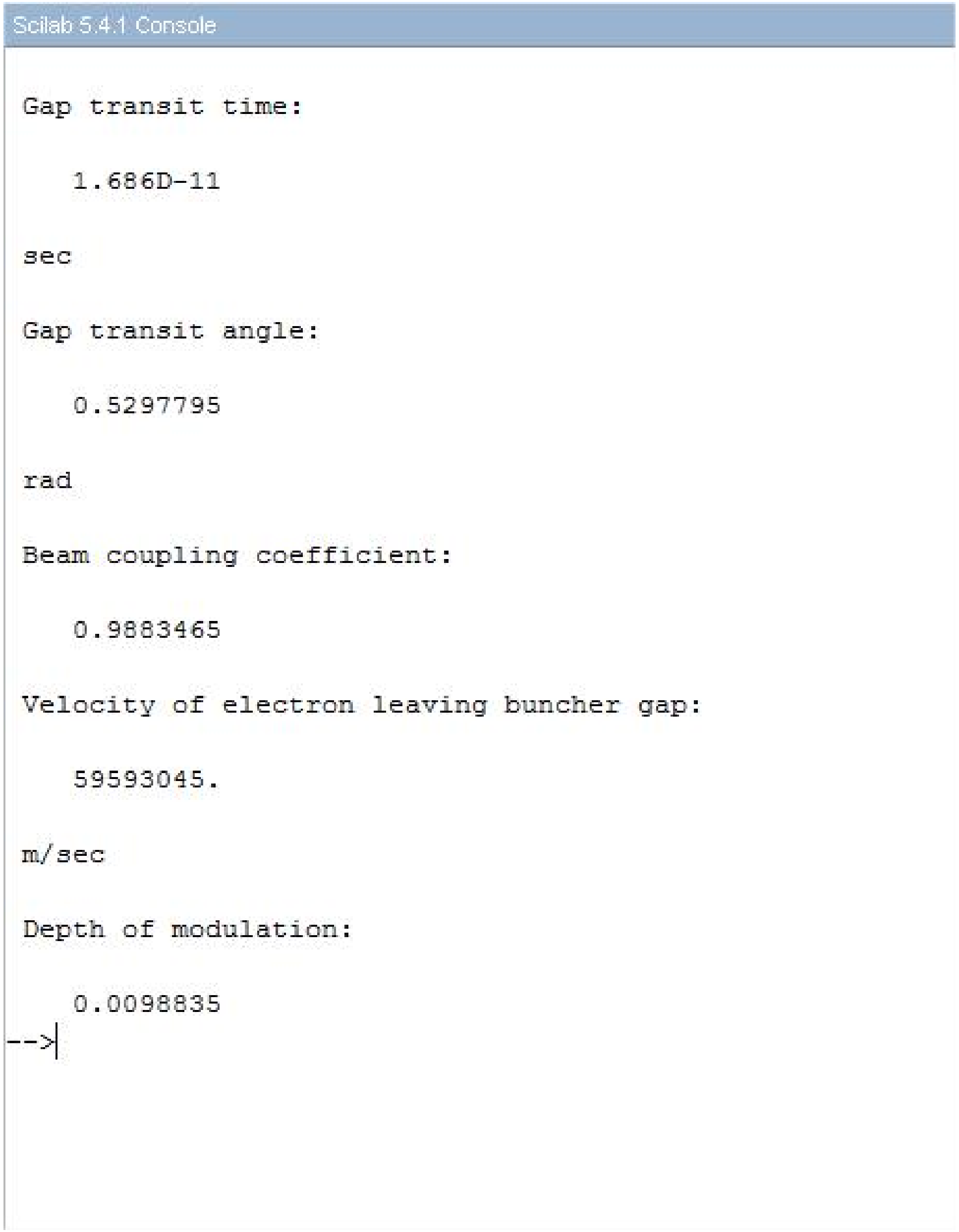
```
Input voltage for maximum output:

   81.96906

V

Voltage gain:

   10.159105

V

Efficiency:

   51.366155

%

Beam loading conductance:

   0.0000014

ohm
-->
```

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
```



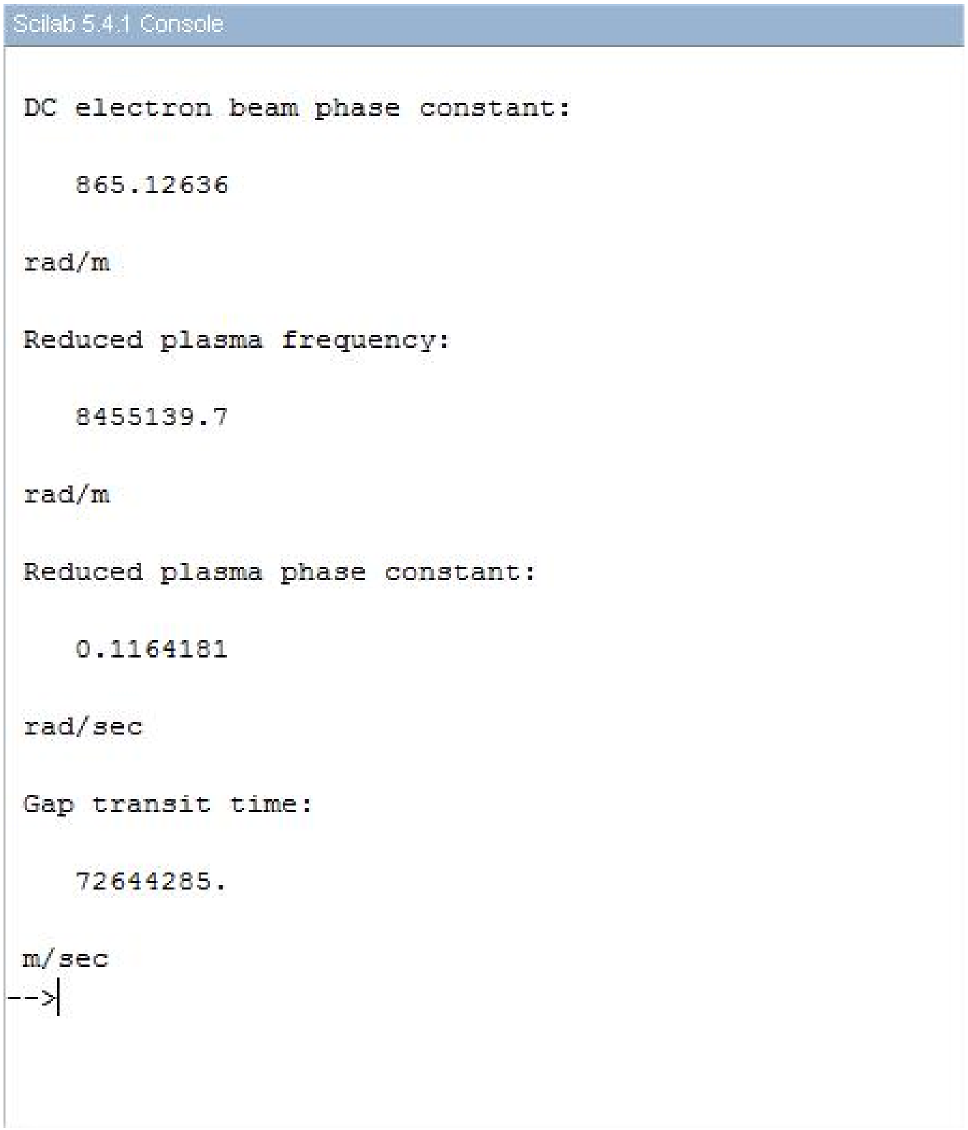
```
Gap transit time:

   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;
```



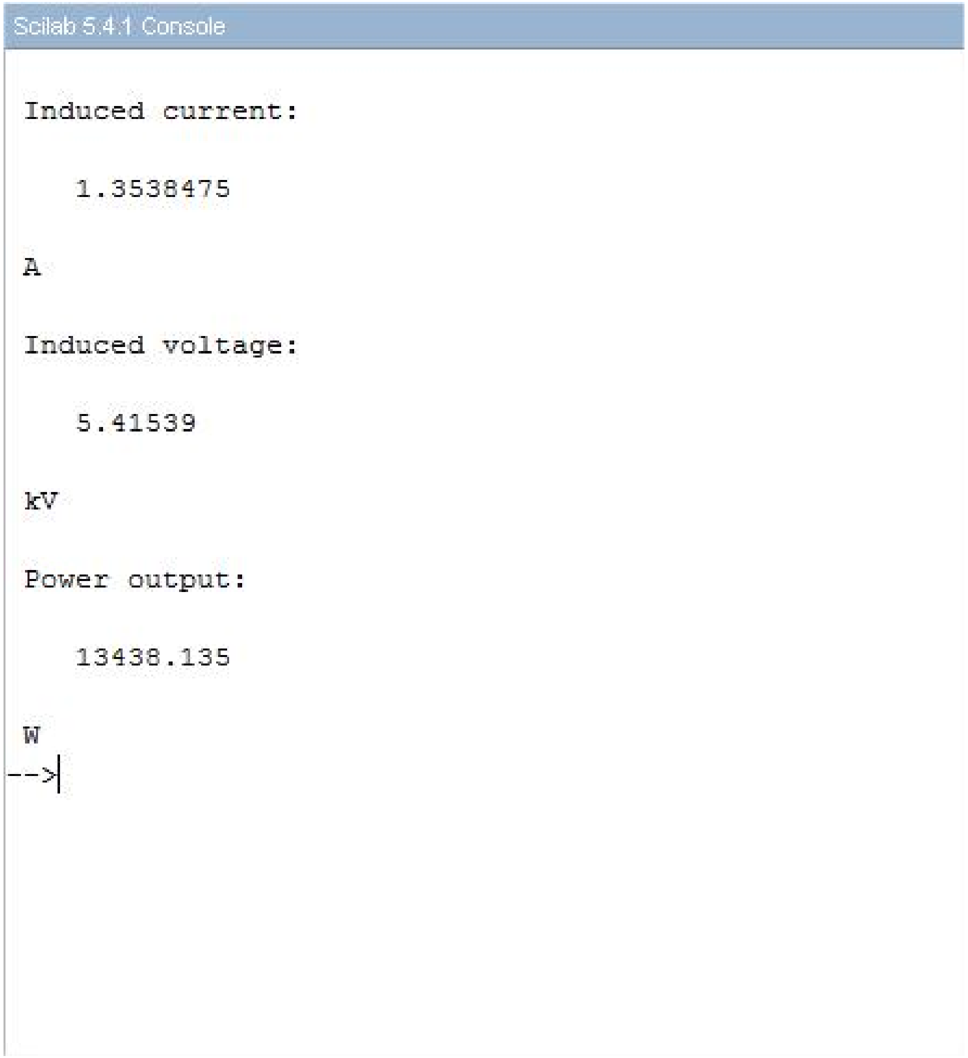
```
 DC electron beam phase constant:

    865.12636

 rad/m

 Reduced plasma frequency:

    8455139.7

 rad/m

 Reduced plasma phase constant:

    0.1164181

 rad/sec

 Gap transit time:

    72644285.

 m/sec
-->
```

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
```

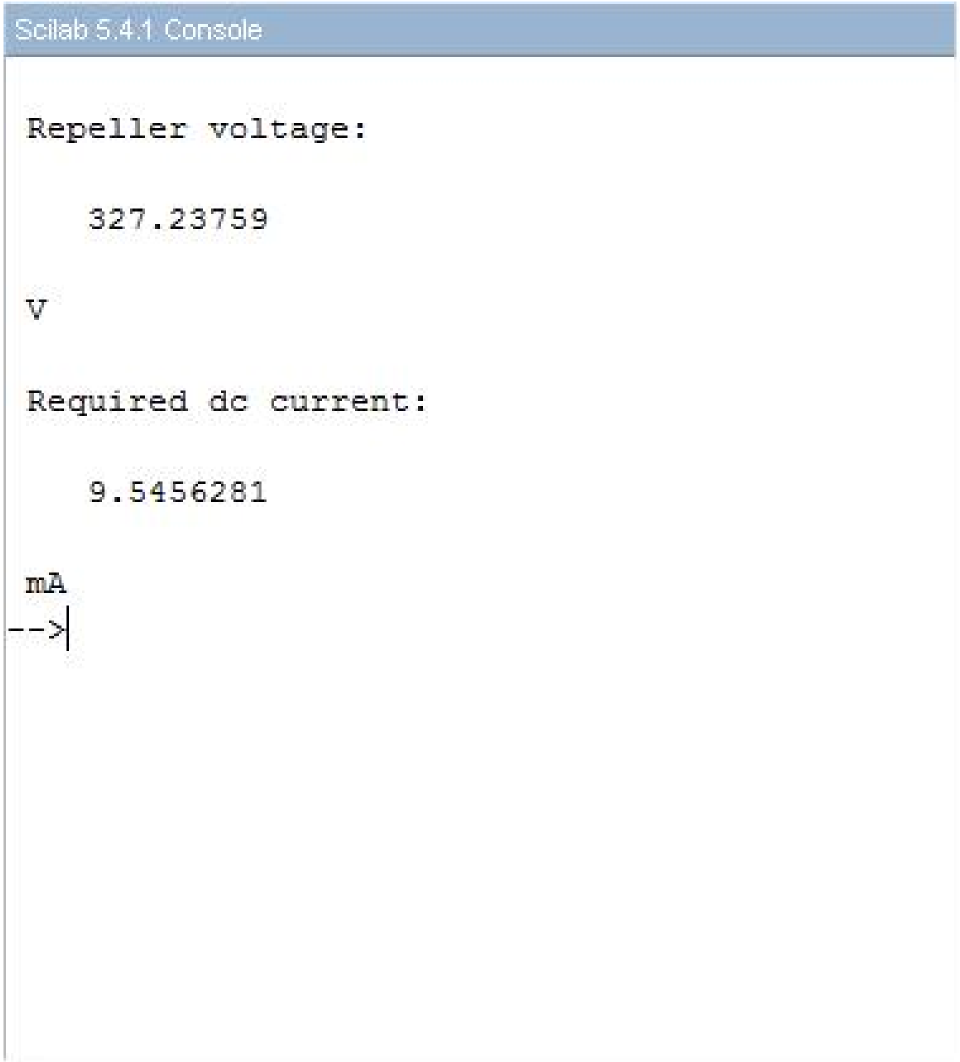


```
Induced current:

   1.3538475

A

Induced voltage:

   5.41539

kV

Power output:

   13438.135

W
-->
```

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`



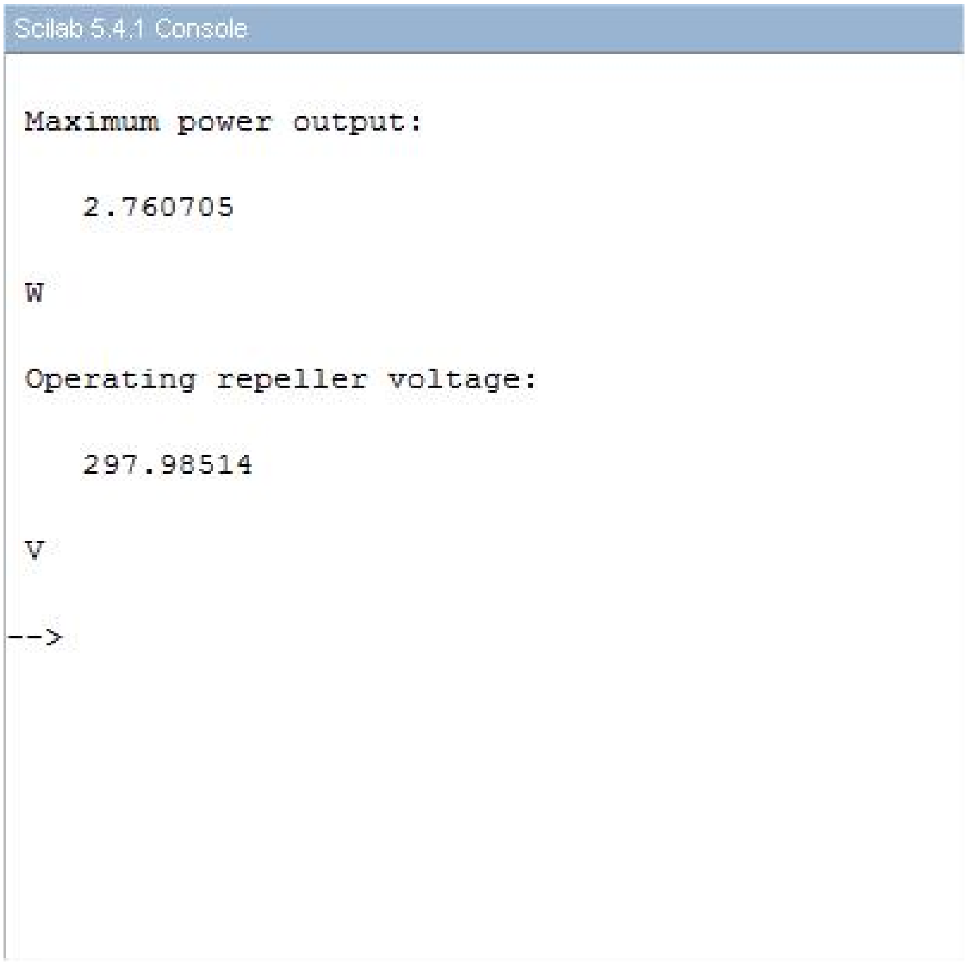
```
Repeller voltage:

   327.23759

V

Required dc current:

   9.5456281

mA
-->
```

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
```



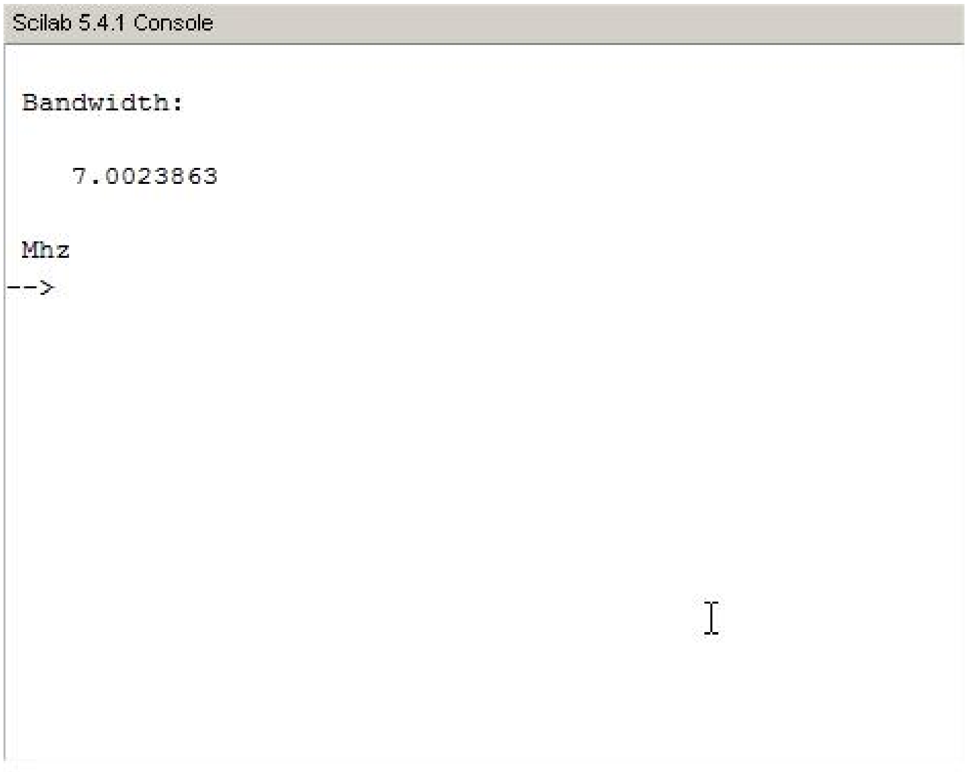
```
 Maximum power output:

    2.760705

 W

 Operating repeller voltage:

    297.98514

 V

-->
```

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:');
```



```
 Bandwidth:   
 
    7.0023863  
 
 Mhz   
-->
```

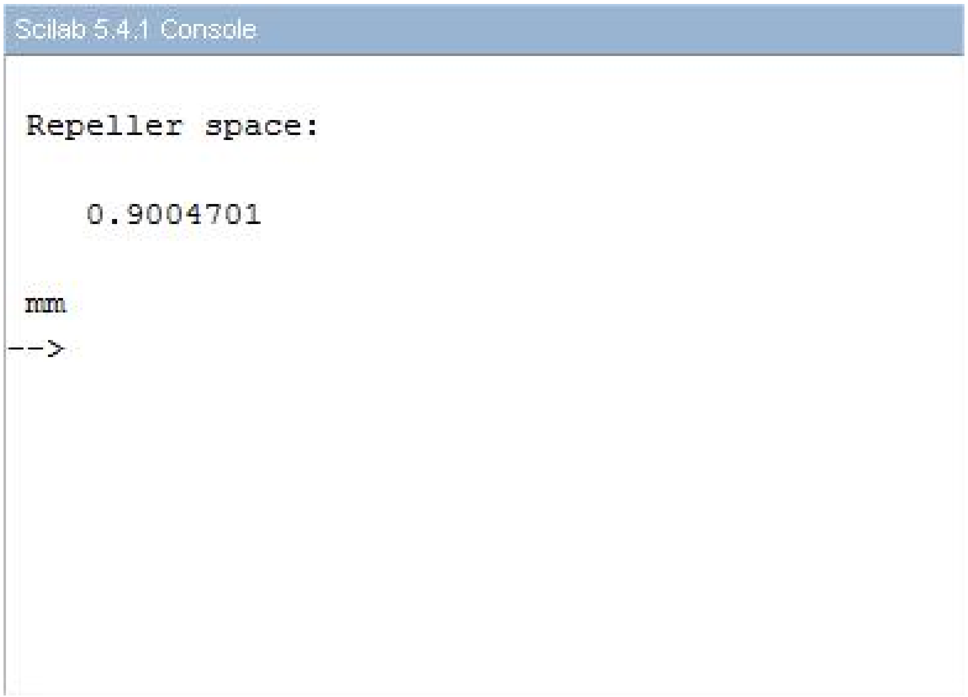
Figure 5.13: Reflex Klystron

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:');
```

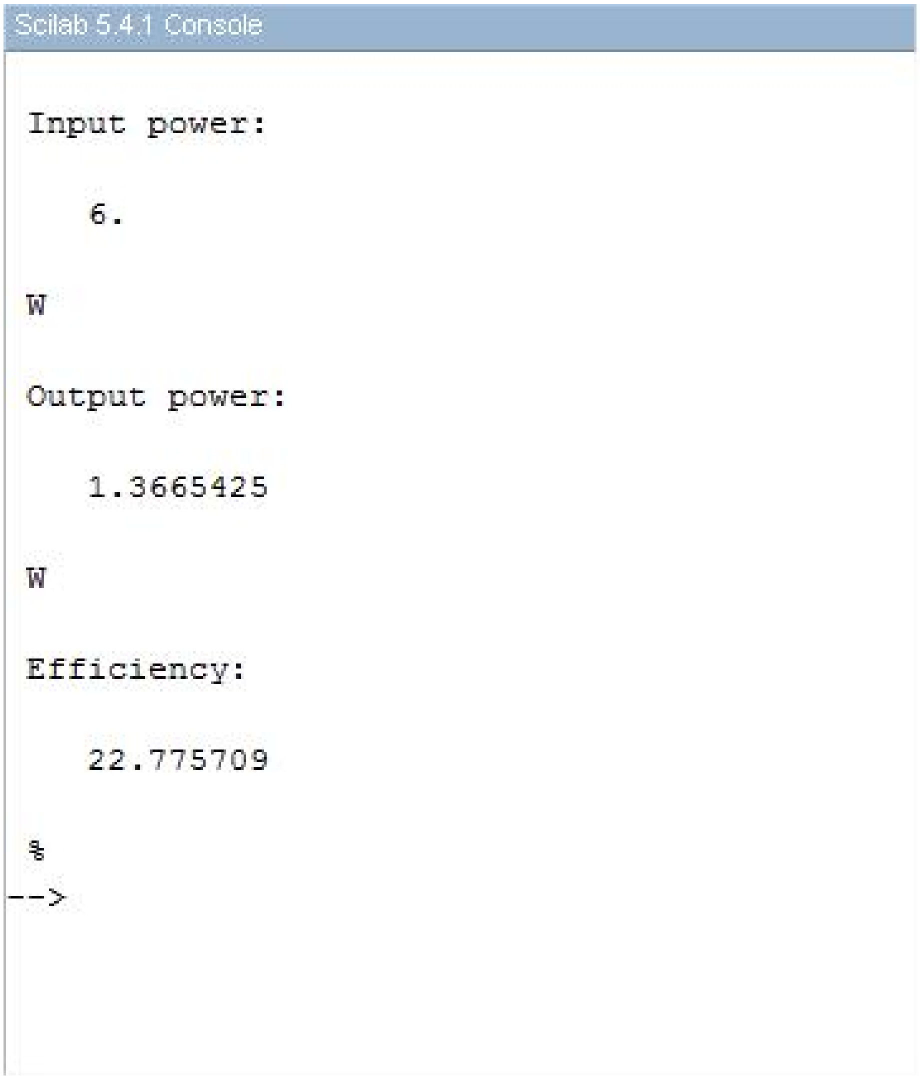
Scilab code Exa 5.15 `Reflex Klystron`

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



```
 Repeller space:

    0.9004701

 mm
-->
```

Figure 5.14: Reflex Klystron



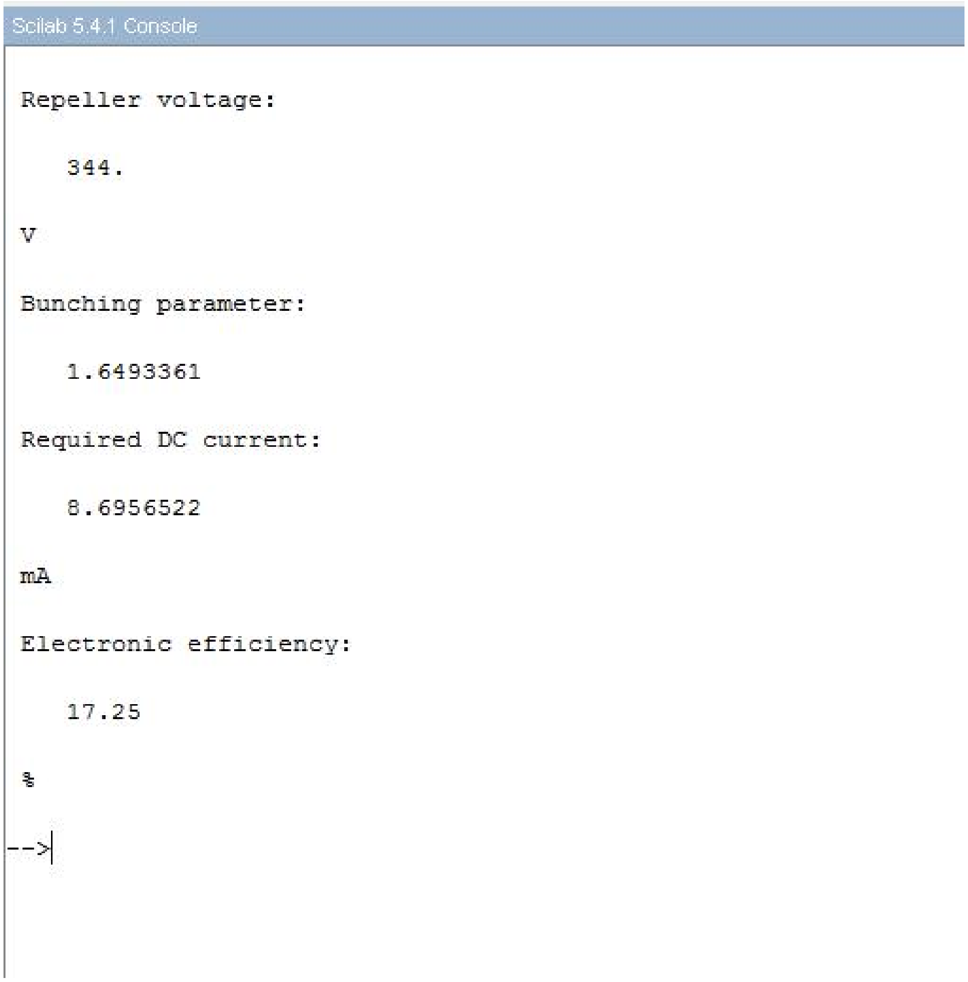
```
 Input power:

    6.

 W

 Output power:

    1.3665425

 W

 Efficiency:

    22.775709

 %
-->
```

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

```



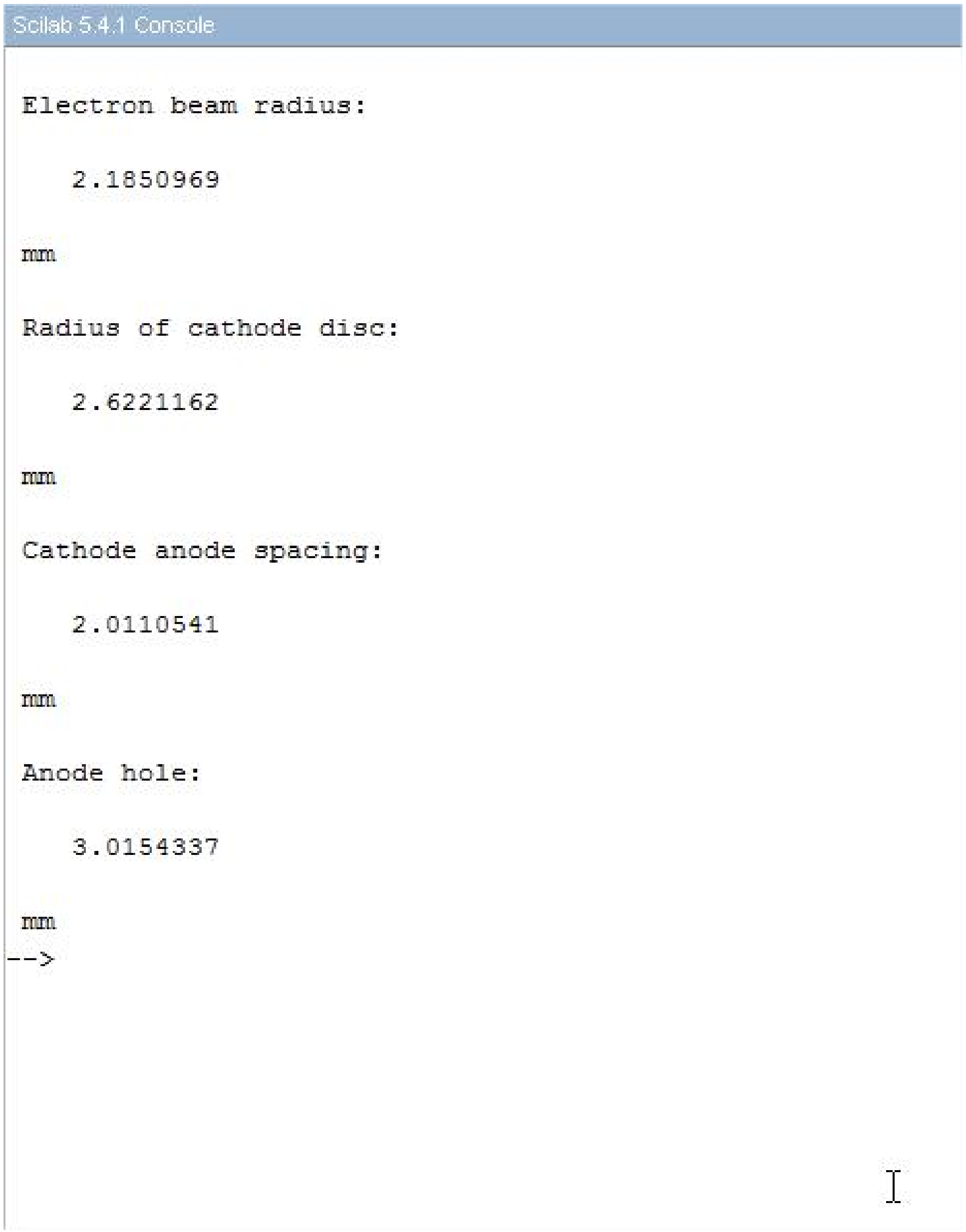
```
Repeller voltage:

   344.

V

Bunching parameter:

   1.6493361

Required DC current:

   8.6956522

mA

Electronic efficiency:

   17.25

%

-->
```

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
```



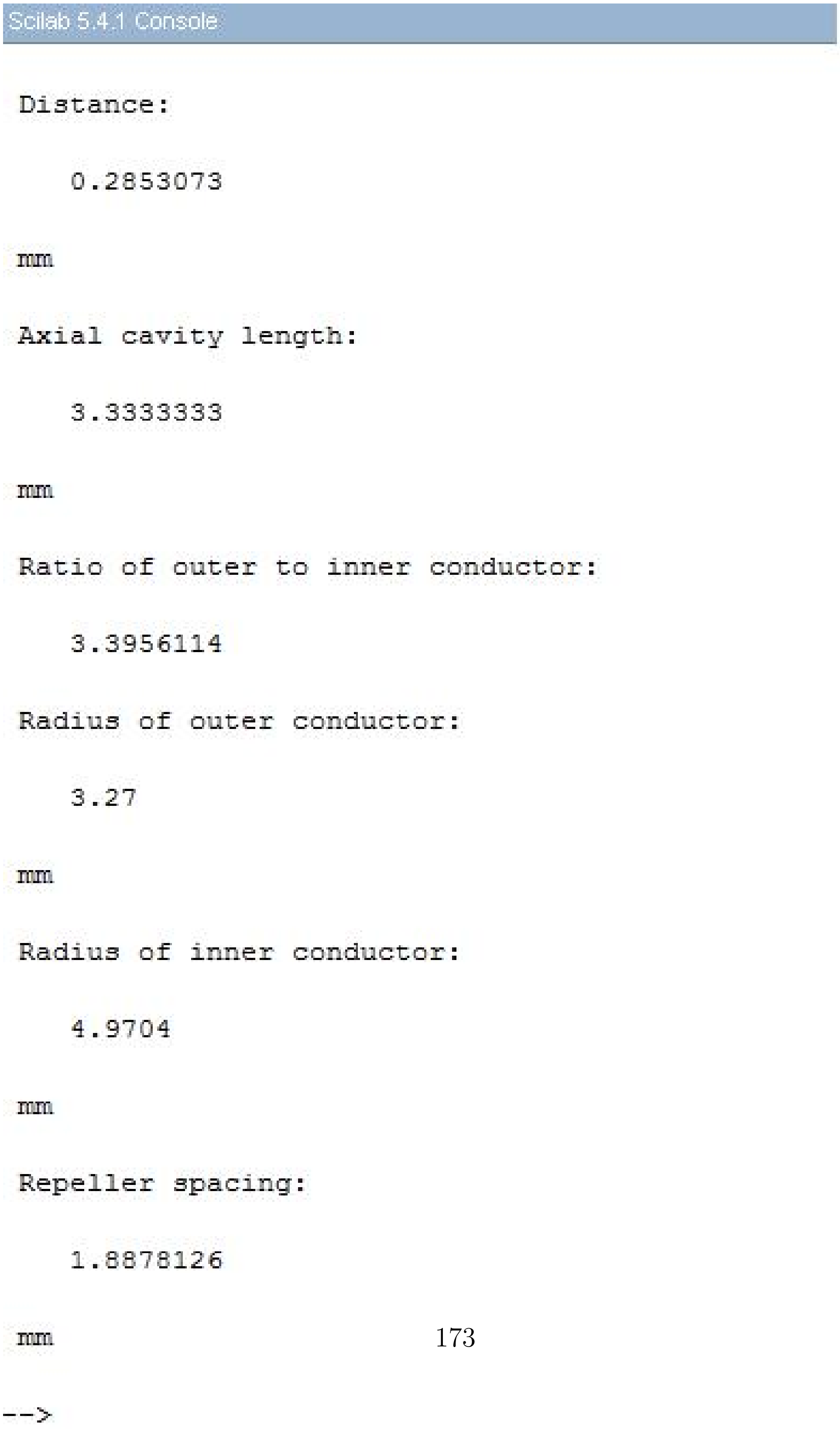
```
 Electron beam radius:
 
 
    2.1850969
 
 
 mm
 
 
 Radius of cathode disc:
 
 
    2.6221162
 
 
 mm
 
 
 Cathode anode spacing:
 
 
    2.0110541
 
 
 mm
 
 
 Anode hole:
 
 
    3.0154337
 
 
 mm
-->
```

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:');

```



```
 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

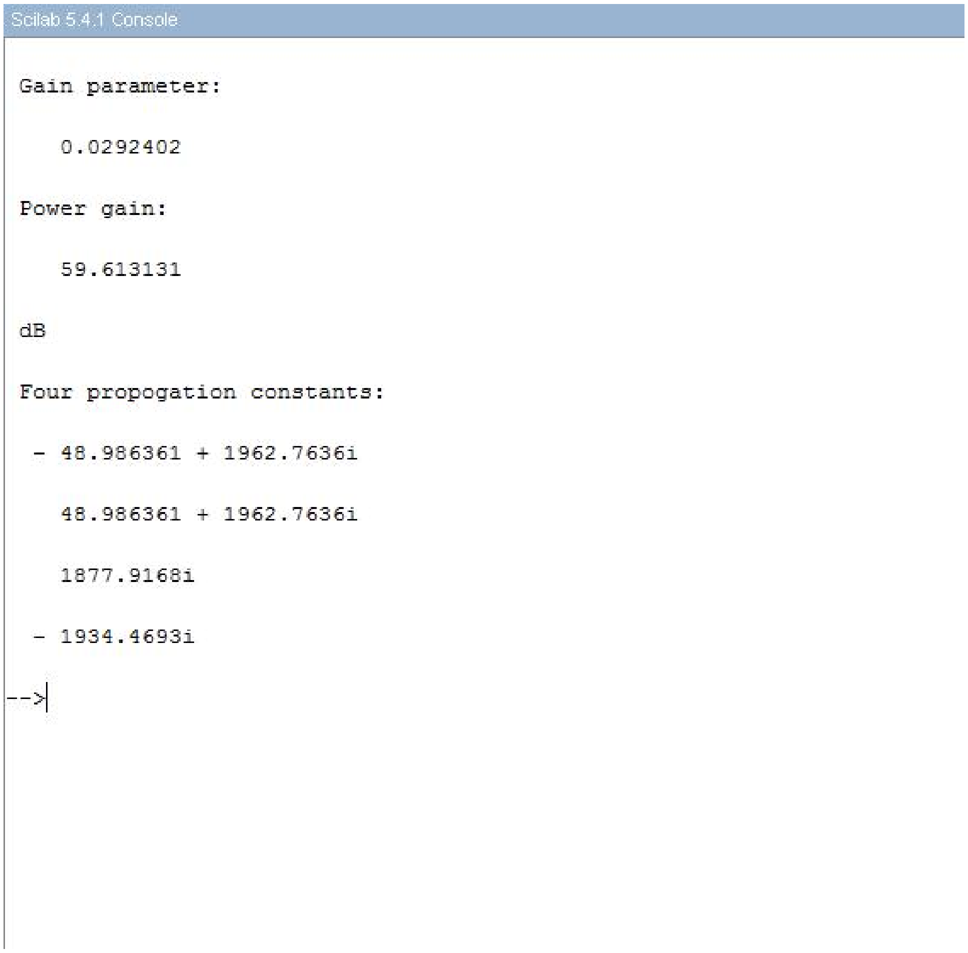
```
//Ratio of outer to inner conductor
a=1.5*br;
a1=a/1000;
x=d/(w*e0*a1*a1*60*tan((w*l)/c));
bbya=exp(x);
disp(bbya,'Ratio of outer to inner conductor:');

//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));
```



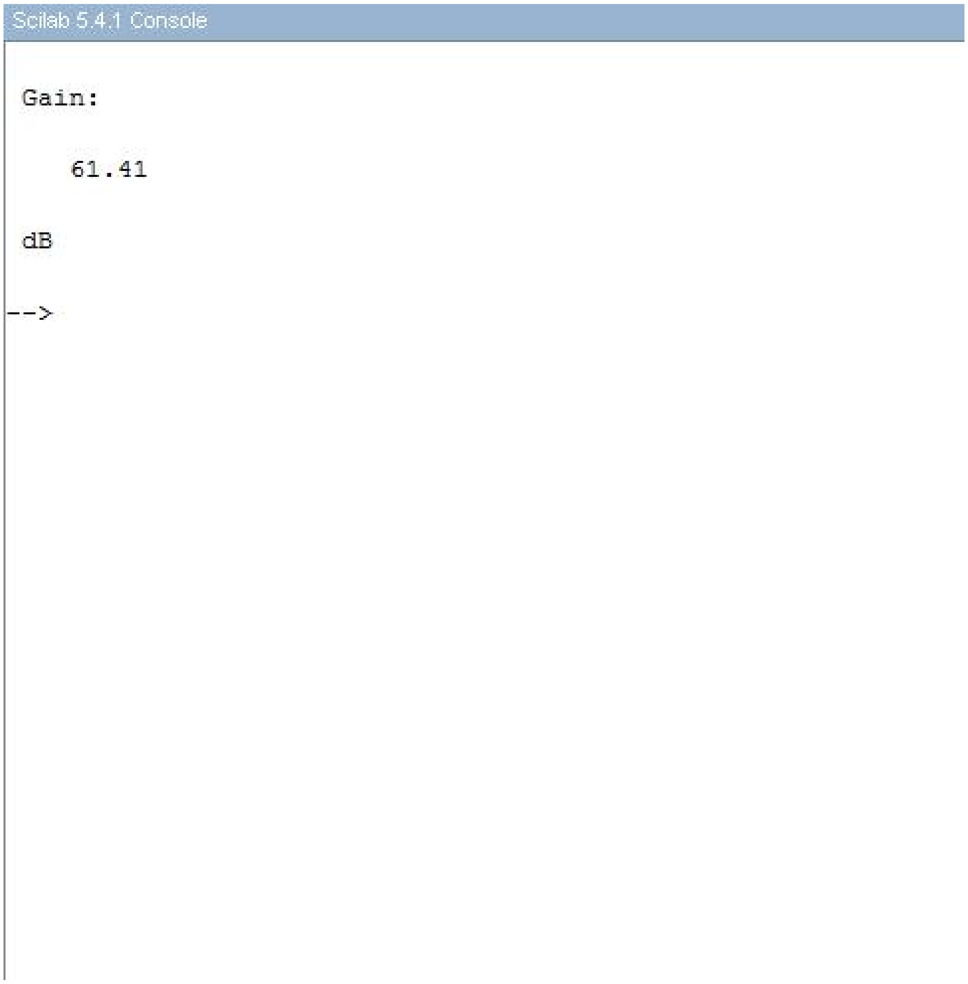
```
Gain parameter:

   0.0292402

Power gain:

   59.613131

dB

Four propogation constants:

 - 48.986361 + 1962.7636i

   48.986361 + 1962.7636i

   1877.9168i

 - 1934.4693i

-->
```

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
```



```
 Gain:

    61.41

 dB

-->
```

Figure 6.2: Helix TWT

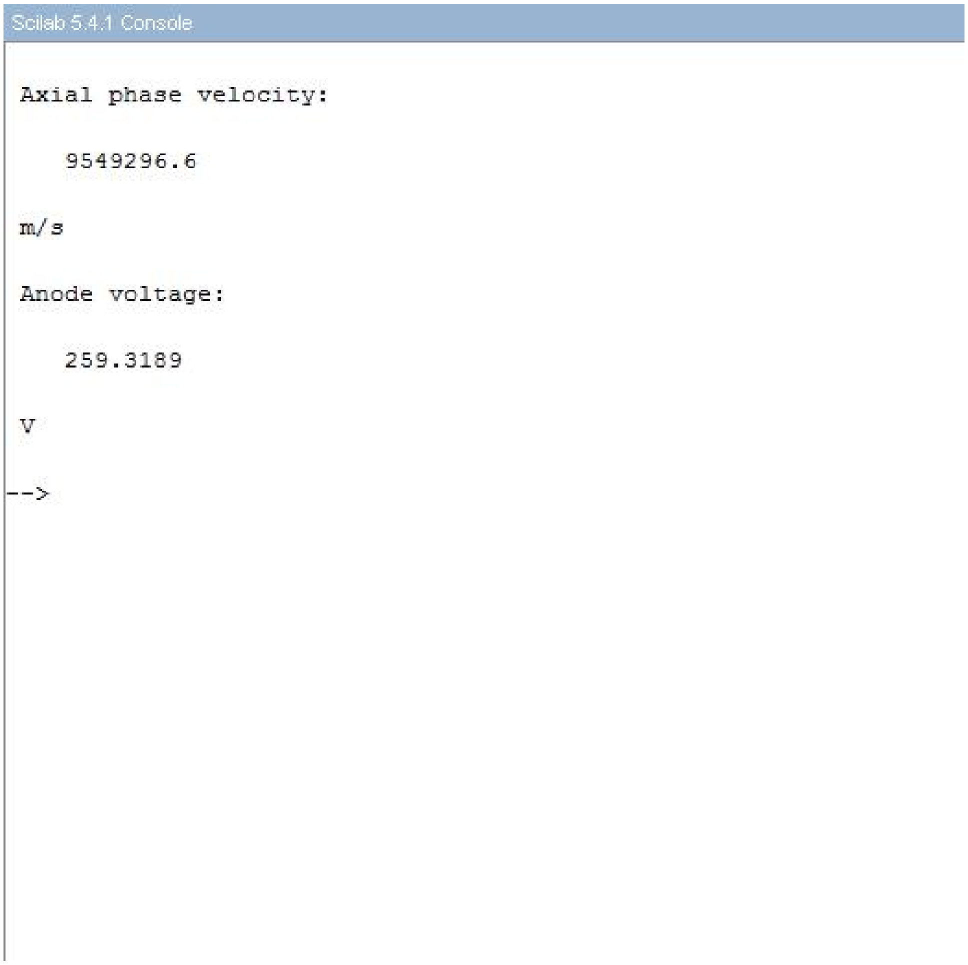
```
Ap=-9.54+(47.3*C*N);
disp('dB',Ap,'Gain:');
```

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
```



```
 Axial phase velocity:

    9549296.6

 m/s

 Anode voltage:

    259.3189

 V

-->
```

Figure 6.3: Helical TWT

```
 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:');
```

```
 Electronic efficiency:

    23.041475

 %

 Overall efficiency:

    73.90983

 %

-->
```

Figure 6.5: Cavity coupled

```
 Gain:

    73.589722

 dB

-->
```

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
```

```
Electronic efficiency:

   26.666667

%

Overall efficiency:

   66.666667

%

-->
```

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:');
```

```
 Electronic efficiency:

    33.482143

 %

 Overall efficiency:

    53.571429

 %

-->
```

Figure 6.8: Gridded TWT

```
 Gain parameter:

    0.0678604

 Gain of TWT:

    54.655977

 dB

-->
```

Figure 6.9: Helix TWT

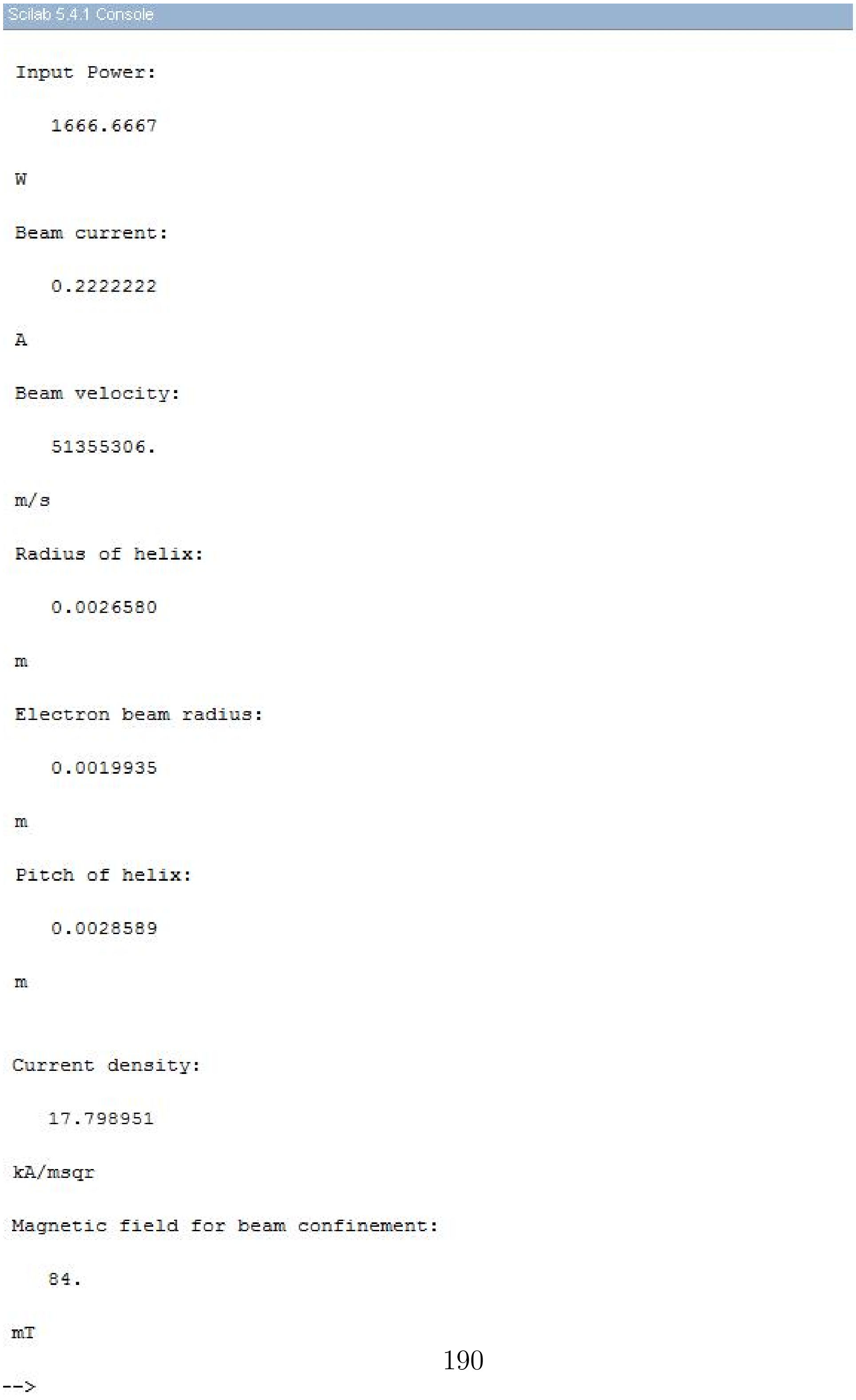
```

//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;
```



```
 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`

```
 Gain:

    59.613131

 dB

 Four propogation constants:

  - 48.986361 + 1962.7636i

    48.986361 + 1962.7636i

    1877.9168i

  - 1934.4693i

-->
```

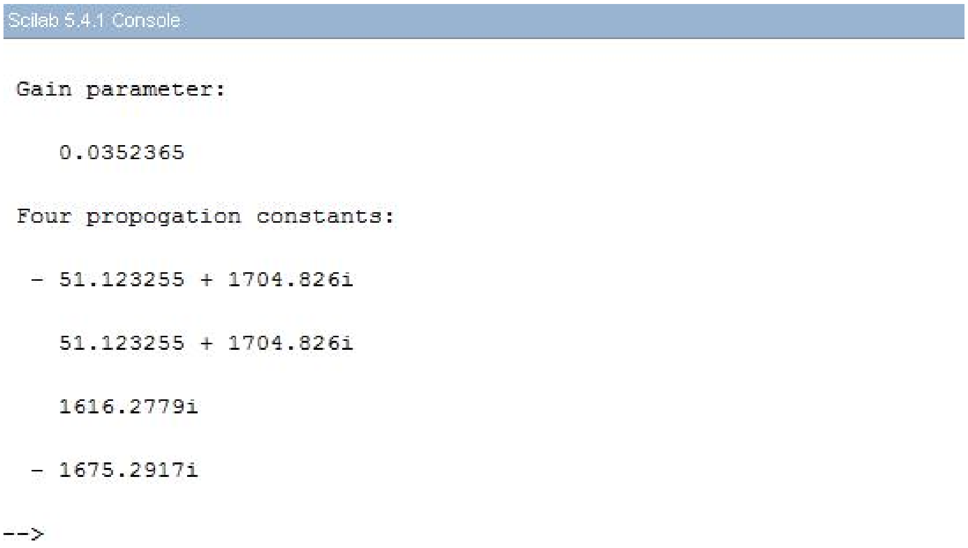
Figure 6.11: TWT

```
//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;
```



```
 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:');
```

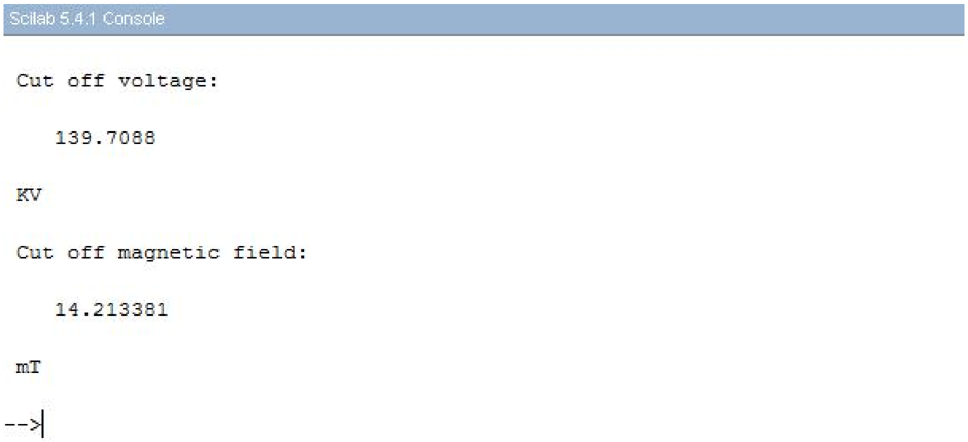
```
 Unloaded quality factor:

    785.39816

 External quality factor:

    6283.1853

 Circuit effciency:

    11.111111

 %

 Electronic effciency:

    25.252525

 %

-->
```

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:');

```



```
 Cut off voltage:

    139.7088

 KV

 Cut off magnetic field:

    14.213381

 mT

-->
```

Figure 7.2: Cylindrical Magnetron

```
 Efficiency:

    40.

 %

 Cyclotron frequency:

    0.9803944

 Ghz

 Cut off magnetic field:

    17.766726

 mT

 Cut off voltage:

    97.

 KV

-->
```

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`

```
 Circuit effciency:

    9.0909091

 %

 Electronic effciency:

    67.532468

 %

-->
```

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
```

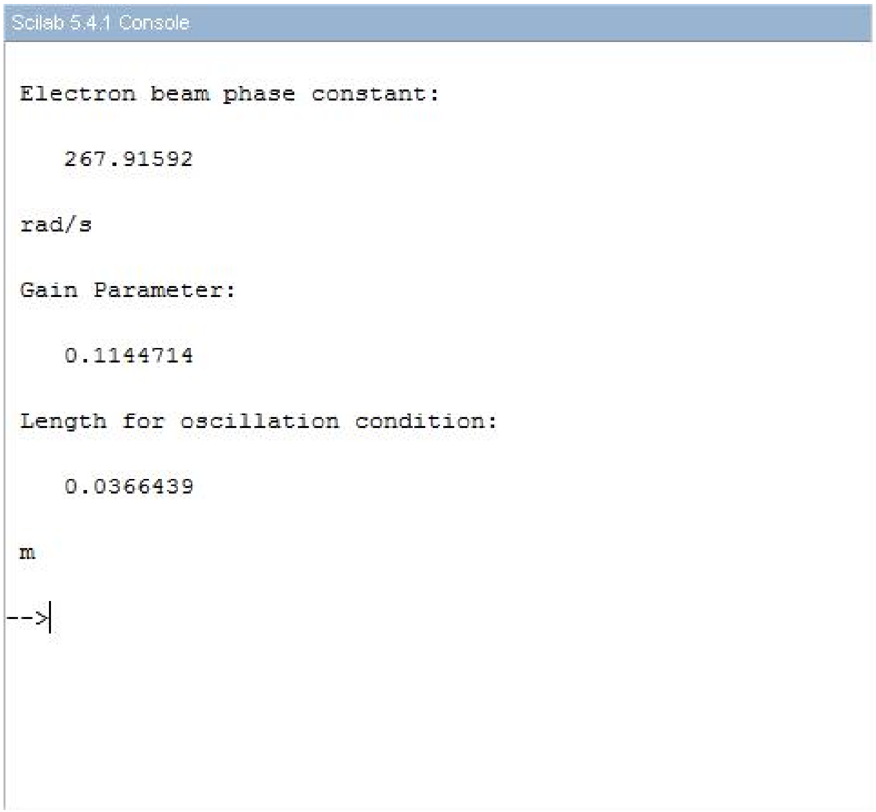
```
 Angular resonant frequency:

    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
```



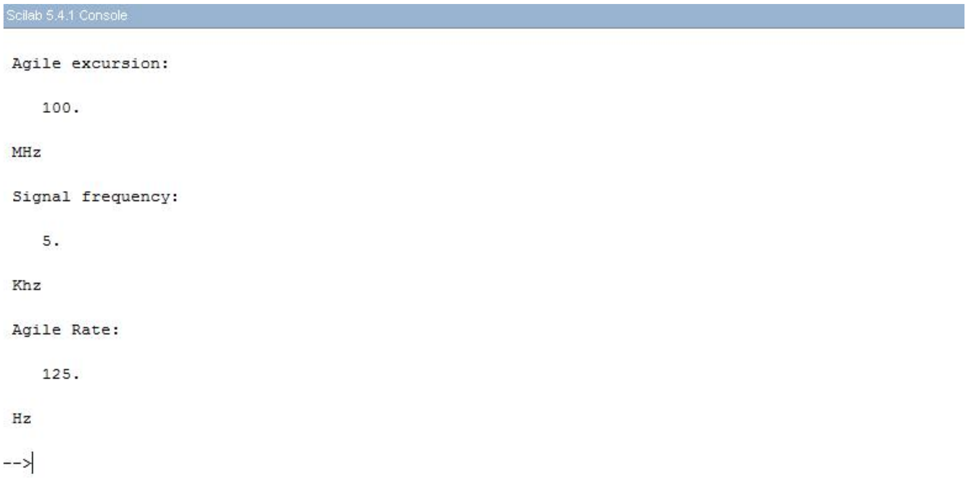
```
Electron beam phase constant:

   267.91592

rad/s

Gain Parameter:

   0.1144714

Length for oscillation condition:

   0.0366439

m

-->
```

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:');
```



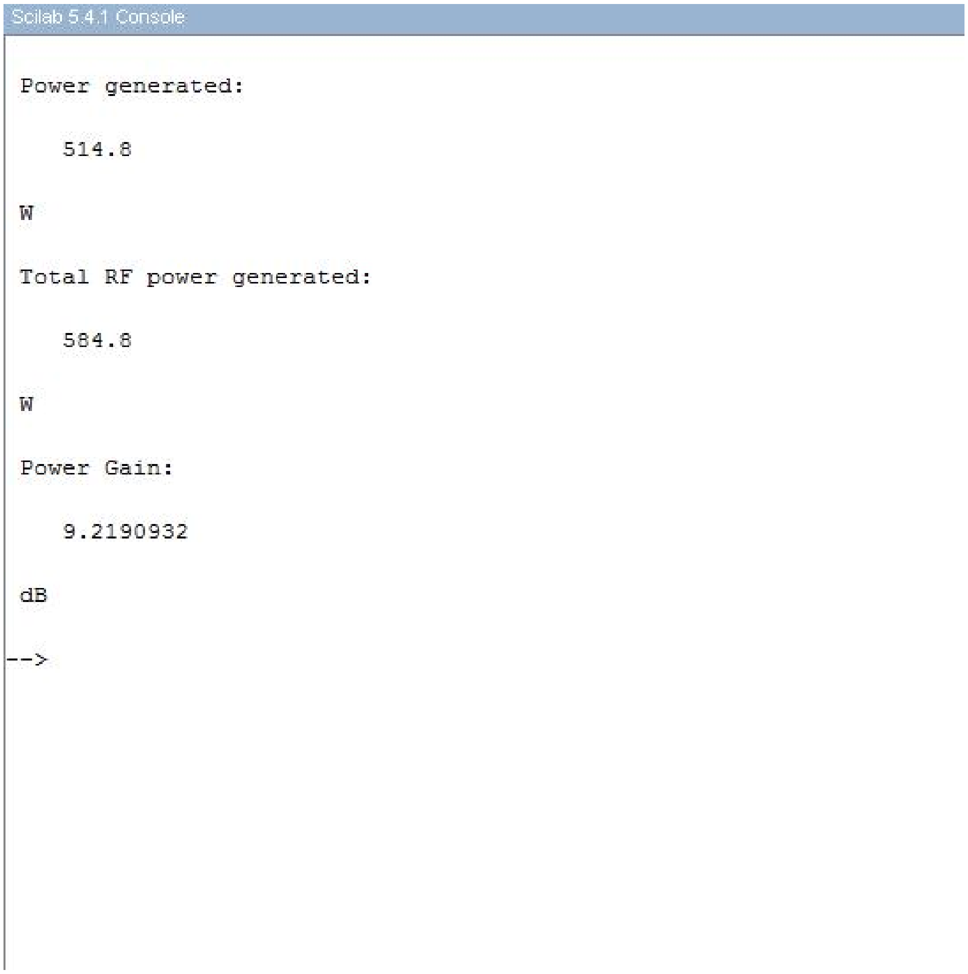
```
Agile excursion:

   100.

MHz

Signal frequency:

   5.

Khz

Agile Rate:

   125.

Hz

-->
```

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:');
```

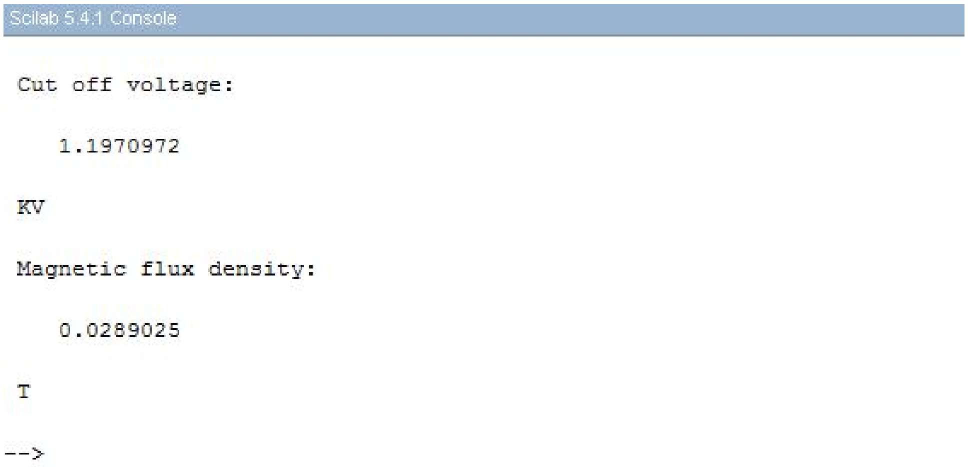
Scilab code Exa 7.8 `Cross field amplifier`

```
//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:');
```



```
 Power generated:

    514.8

 W

 Total RF power generated:

    584.8

 W

 Power Gain:

    9.2190932

 dB

-->
```

Figure 7.8: Cross field amplifier



```
 Cut off voltage:

    1.1970972

 KV

 Magnetic flux density:

    0.0289025

 T

-->
```

Figure 7.9: Inverted coaxial Magnetron

Scilab code Exa 7.9 `Inverted coaxial Magnetron`

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

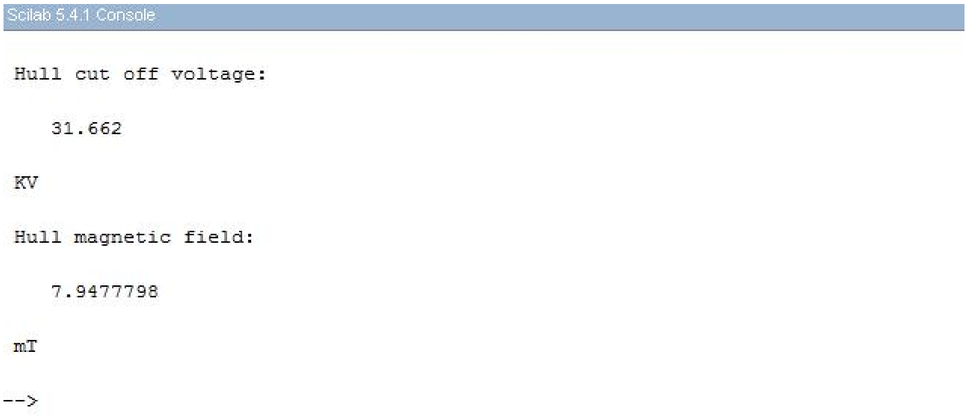
```
//Given
V0=10D+3; //V
I0=2; //A
b=4D-2; //m
a=3D-2; //m
B0=0.01; //Wb/m2
ebym=1.759D+11;

//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
```

```
 Cut off voltage:

    1.1970972

 KV

 Magnetic flux density:

    0.0289025

 T

-->
```

Figure 7.10: Inverted coaxial Magnetron



```
 Hull cut off voltage:

    31.662

 KV

 Hull magnetic field:

    7.9477798

 mT

-->
```

Figure 7.11: Linear Magnetron

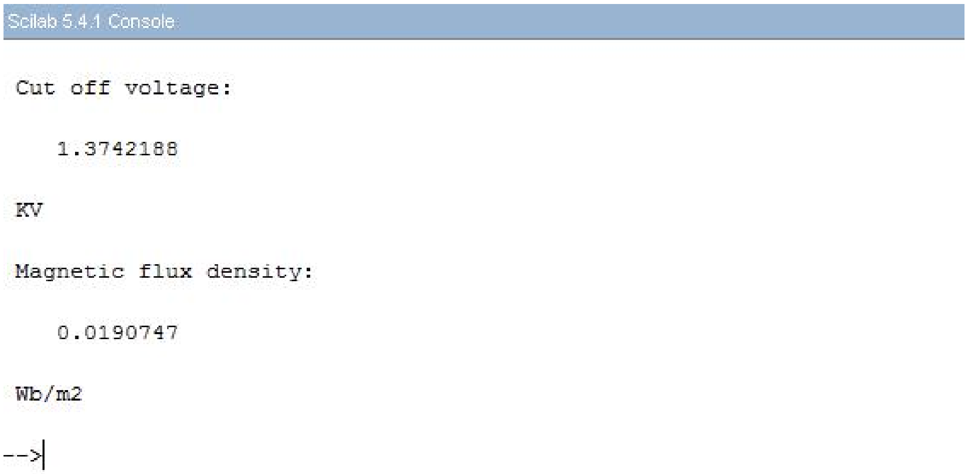
```
x=1-((b*b)/(a*a));
V=(ebym*(B0^2)*(a^2)*(x^2))/8;
disp('KV',V/1000,'Cut off voltage:');

//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
```



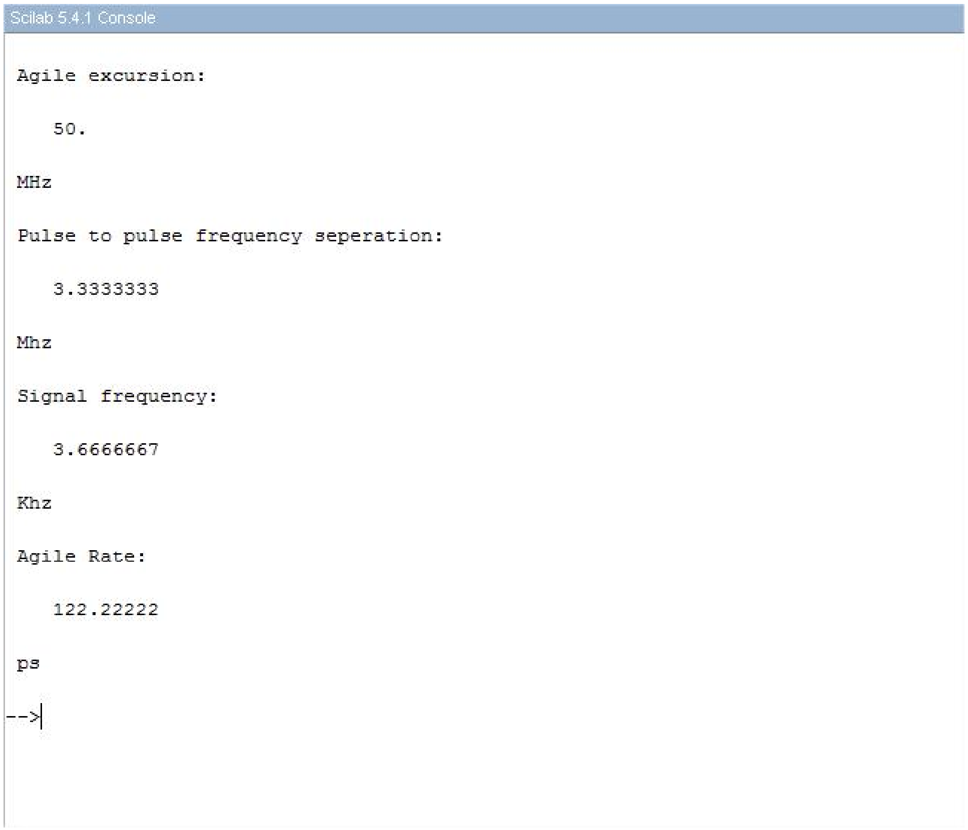
```
 Cut off voltage:

    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:');

```



```
 Agile excursion:

    50.

 MHz

 Pulse to pulse frequency seperation:

    3.3333333

 Mhz

 Signal frequency:

    3.6666667

 Khz

 Agile Rate:

    122.22222

 ps

-->
```

Figure 7.13: Agile coaxial Magnetron

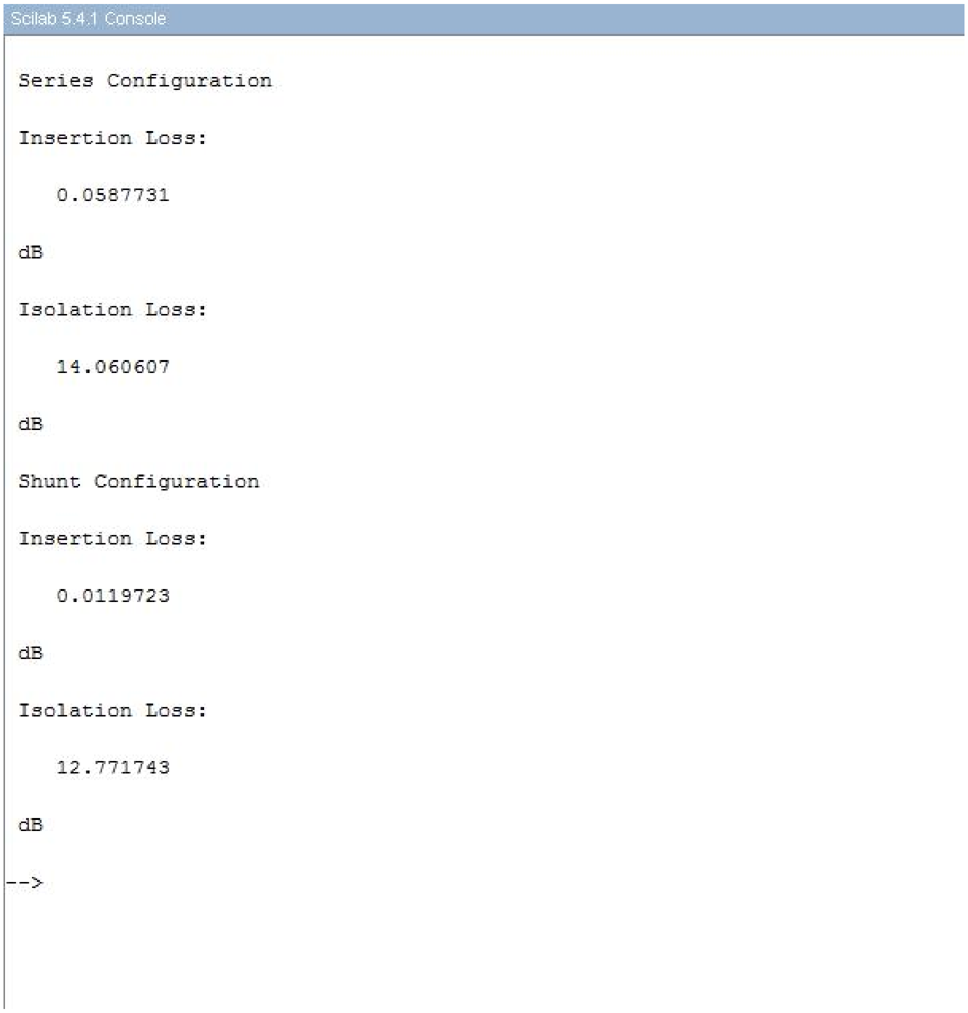
```
//(iii) Signal frequency
f=DC/t;
disp('Khz',f/1000,'Signal frequency:');

//(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');

```



```
 Series Configuration

 Insertion Loss:

    0.0587731

 dB

 Isolation Loss:

    14.060607

 dB

 Shunt Configuration

 Insertion Loss:

    0.0119723

 dB

 Isolation Loss:

    12.771743

 dB

-->
```

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
```

```
 Series Configuration

 Insertion Loss:

    0.1017270

 dB

 Isolation Loss:

    14.07108

 dB

 Shunt Configuration

 Insertion Loss:

    0.0146274

 dB

 Isolation Loss:

    12.842783

 dB

-->
```

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
```

```
 Total series resistance:

    17.683883

 ohms

 Junction Area:

    0.0009571

 cm2

-->
```

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

```

```
 Power gain:

    9.2449028

 dB

 Nosie figure:

    1.4223258

 dB

 Bandwidth:

    3.5777088

-->
```

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:');
```

```
 Gain:
 
    7.297114
 
 dB
 
-->
```

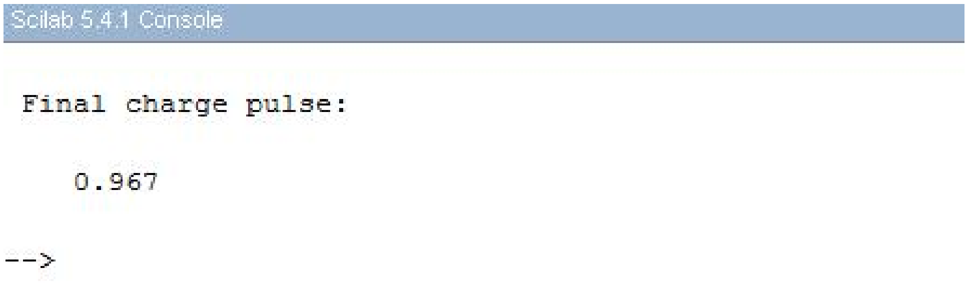
Figure 8.5: Parametric amplifier

```
Effective Q:

   106.66667

-->
```

Figure 8.6: Negative resistance parametric amplifier

Scilab code Exa 8.8 `Negative resistance parametric amplifier`

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



```
 Final charge pulse:

    0.967

-->
```

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`

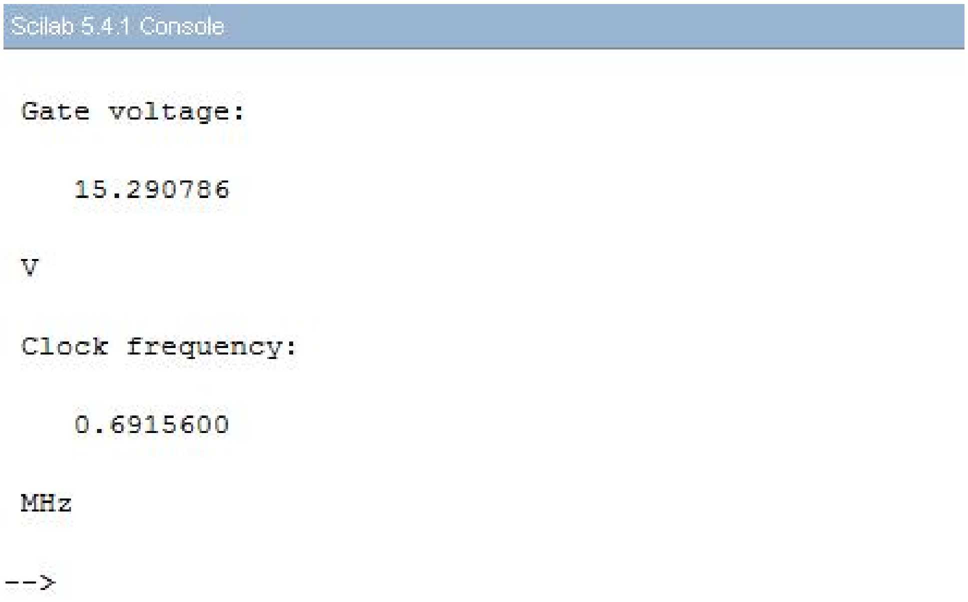
```
//Page Number: 434
//Example 8.9
clc;
//Given
e=0.0001;
s=330;

//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;
```

```
 Power disspated per bit:

    15.

 muW

-->
```

Figure 8.8: 3 phase CCD



```
 Gate voltage:

    15.290786

 V

 Clock frequency:

    0.6915600

 MHz

-->
```

Figure 8.9: Surface channel CCD

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

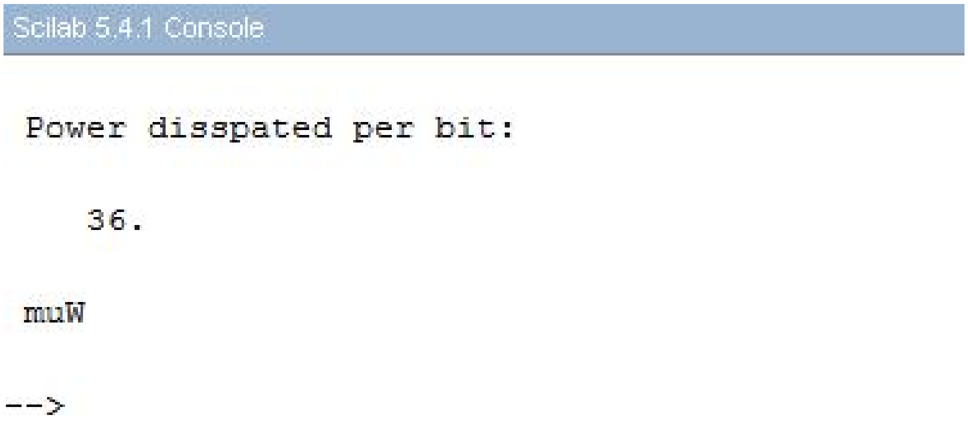
Scilab code Exa 8.11 Surface channel CCD

```
//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
```



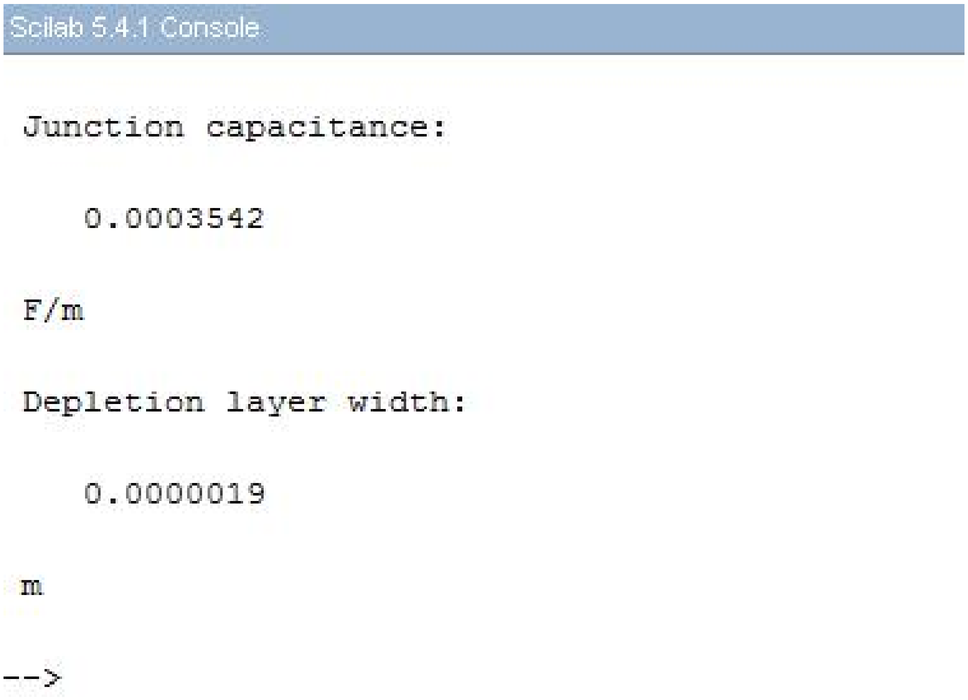
```
 Power disspated per bit:
 
    36.
 
 muW
 
-->
```

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:');
```



```
 Junction capacitance:

    0.0003542

 F/m

 Depletion layer width:

    0.0000019

 m

-->
```

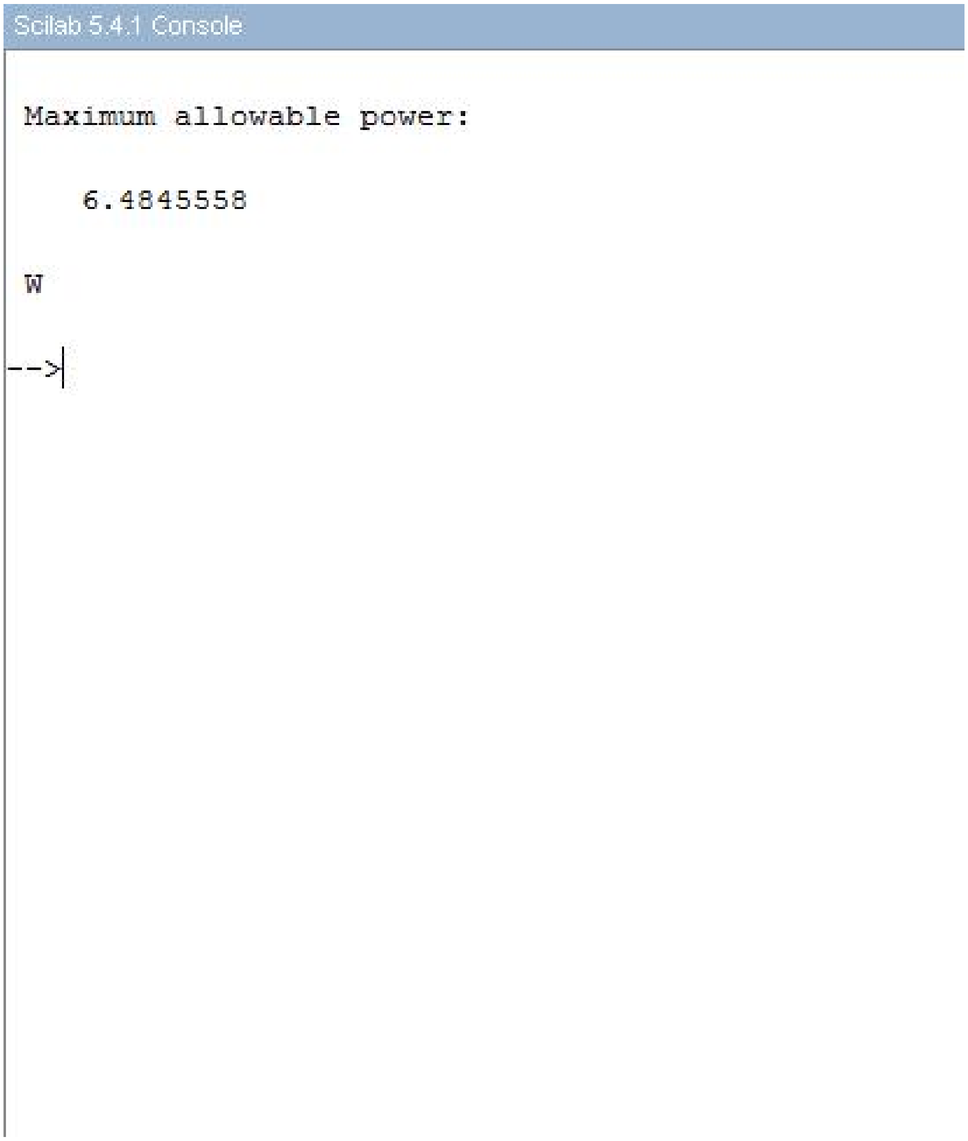
Figure 8.11: Surface channel CCD

Chapter 9

Microwave Solid State Generators and Amplifiers

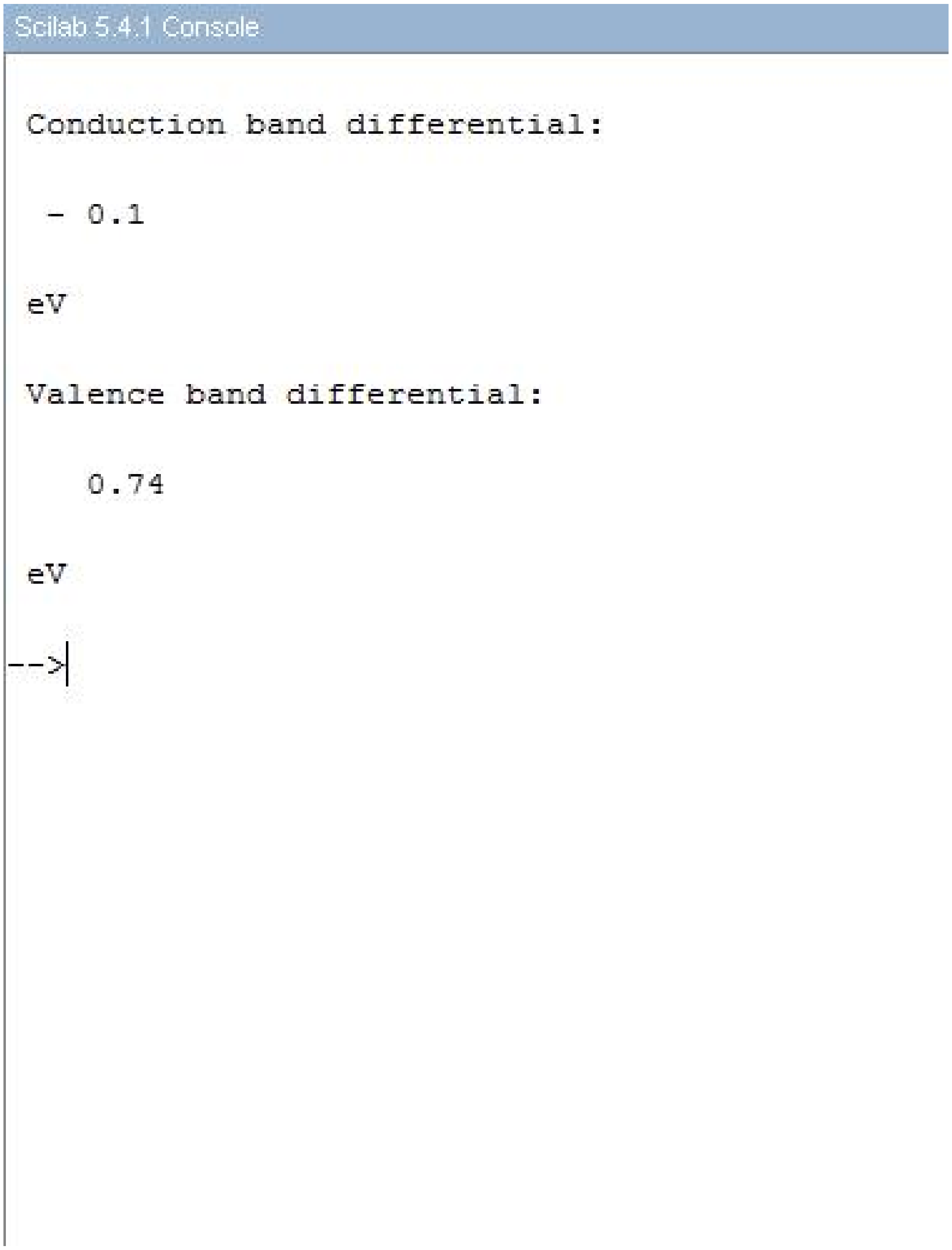
Scilab code Exa 9.2 `Bipolar transistor`

```
//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:');
```



```
Maximum allowable power:

   6.4845558

W

-->
```

Figure 9.1: Bipolar transistor



```
 Conduction band differential:

  - 0.1

 eV

 Valence band differential:

    0.74

 eV

-->
```

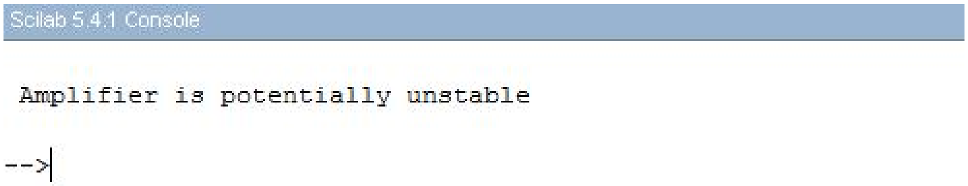
Figure 9.2: Heterojunction transistor

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)
```



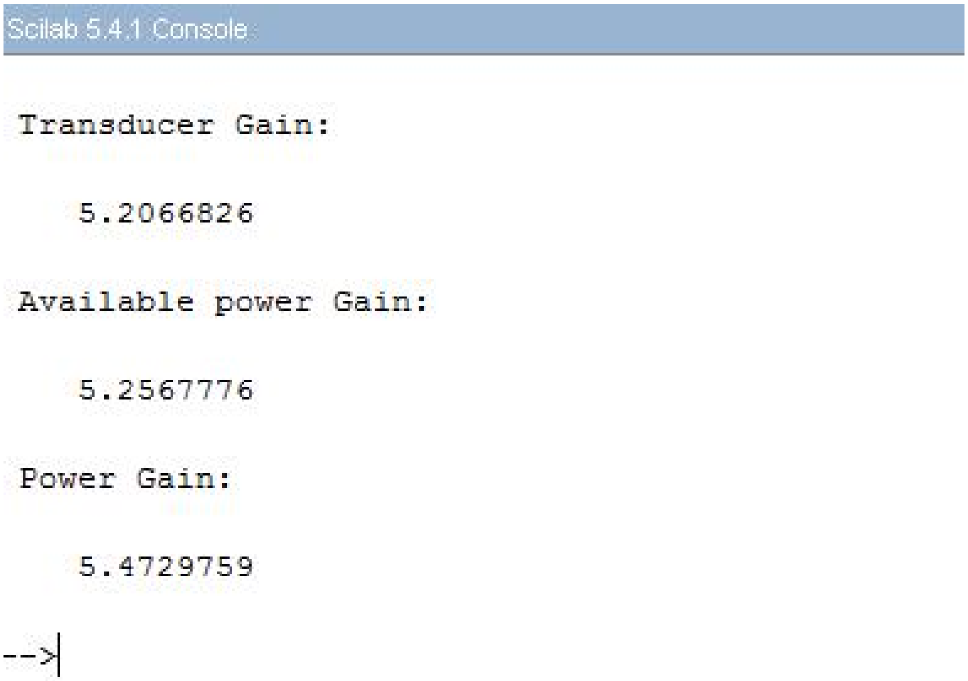
```
 Amplifier is potentially unstable

-->
```

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
```



```
 Transducer Gain:

    5.2066826

 Available power Gain:

    5.2567776

 Power Gain:

    5.4729759

-->
```

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
```

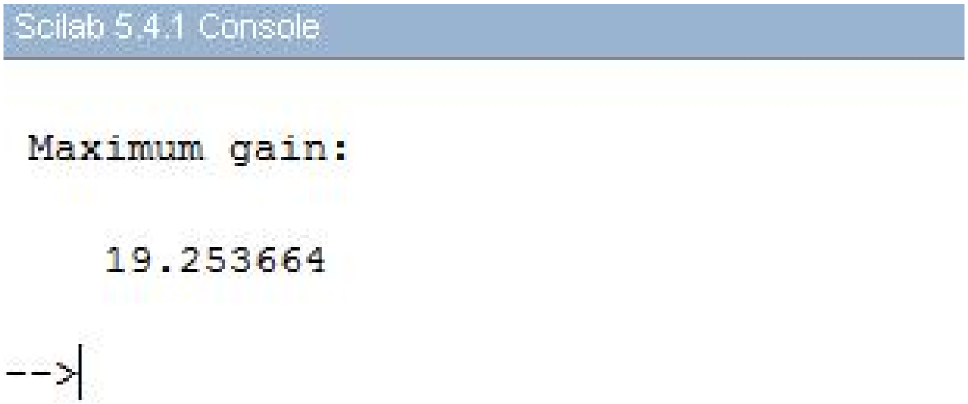
Scilab code Exa 9.6 `Transistor Amplifier`

```
//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
```

```
 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:');
```



```
 Maximum gain:

    19.253664

-->
```

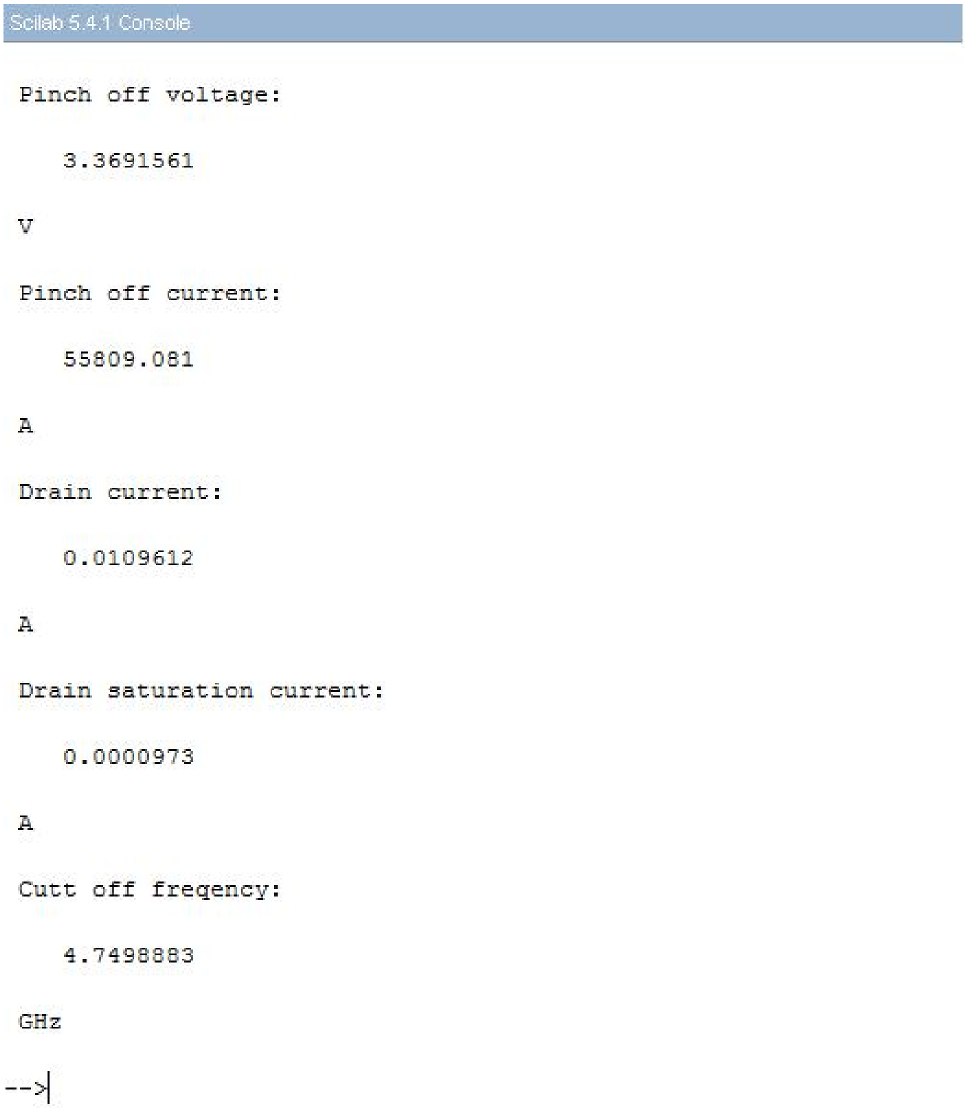
Figure 9.6: Microwave transistor

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
```



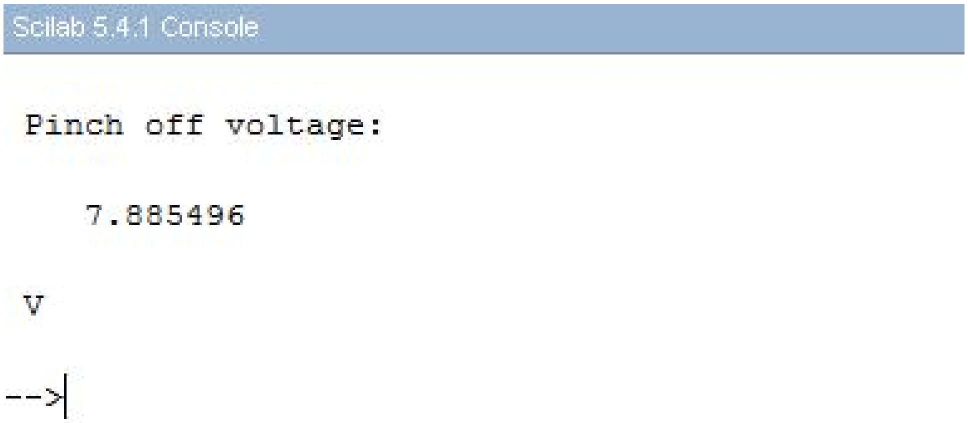
```
 Pinch off voltage:

    3.3691561

 V

 Pinch off current:

    55809.081

 A

 Drain current:

    0.0109612

 A

 Drain saturation current:

    0.0000973

 A

 Cutt off freqency:

    4.7498883

 GHz

-->
```

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
```



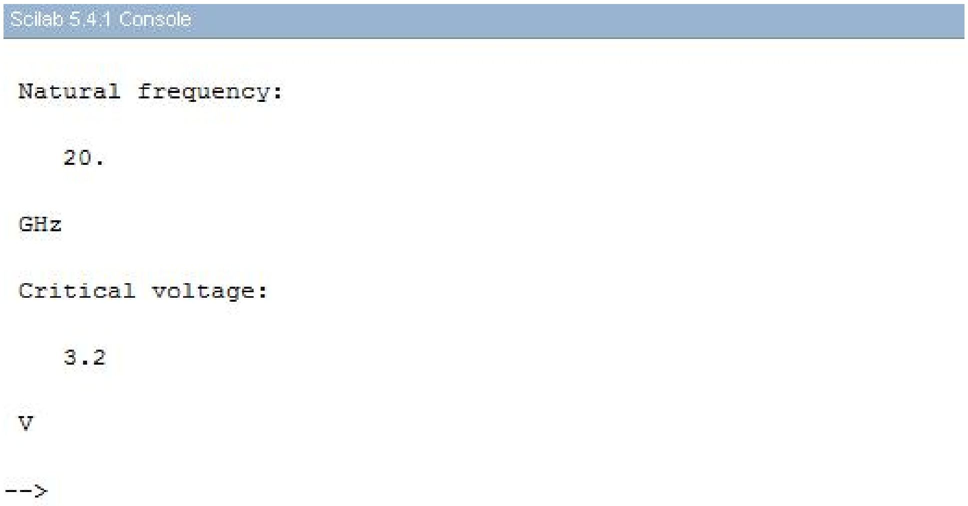
```
 Pinch off voltage:

    7.885496

 V

-->
```

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:');
```

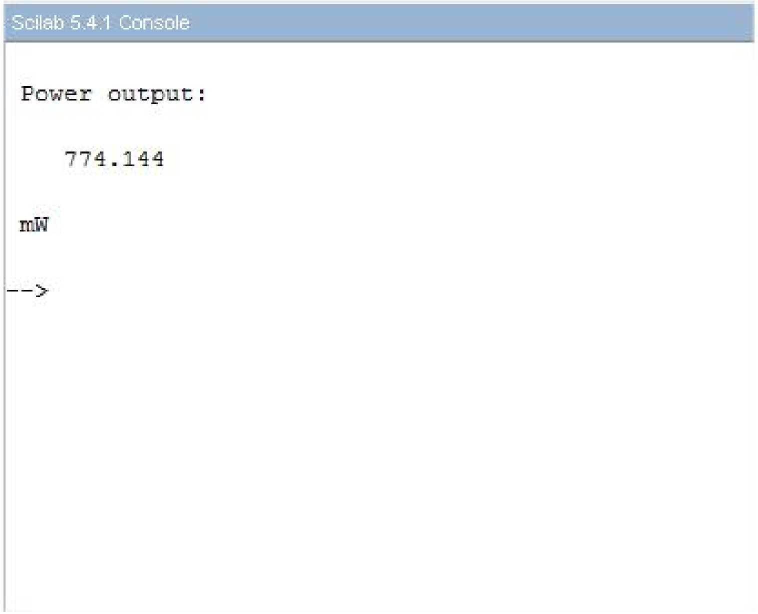
Scilab code Exa 9.10 `Gunn device`

```
//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:');
```



```
 Natural frequency:

    20.

 GHz

 Critical voltage:

    3.2

 V

-->
```

Figure 9.9: Gunn device



```
 Power output:
 
    774.144
 
 mW
 
-->
```

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`

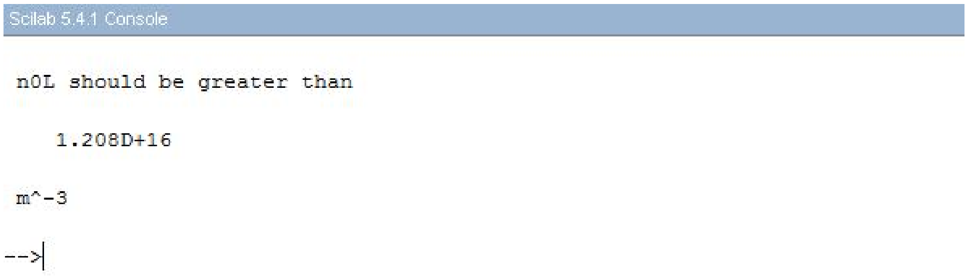
```
//Page Number: 487
//Example 9.13
clc;
//Given
e=1.6D-19;
n1=1D+16; //m-3
mu1=8000D-4; //m2/Vs
nu=1D+14; //m-3
muu=180D-4; //m2/Vs
```

```
 Cavity impedance:

    70.268139 + 10.i

 ohms

-->
```

Figure 9.11: Tunnel diode

```
Conductivity:

   1.280288

m mho

-->
```

Figure 9.12: Gunn diode



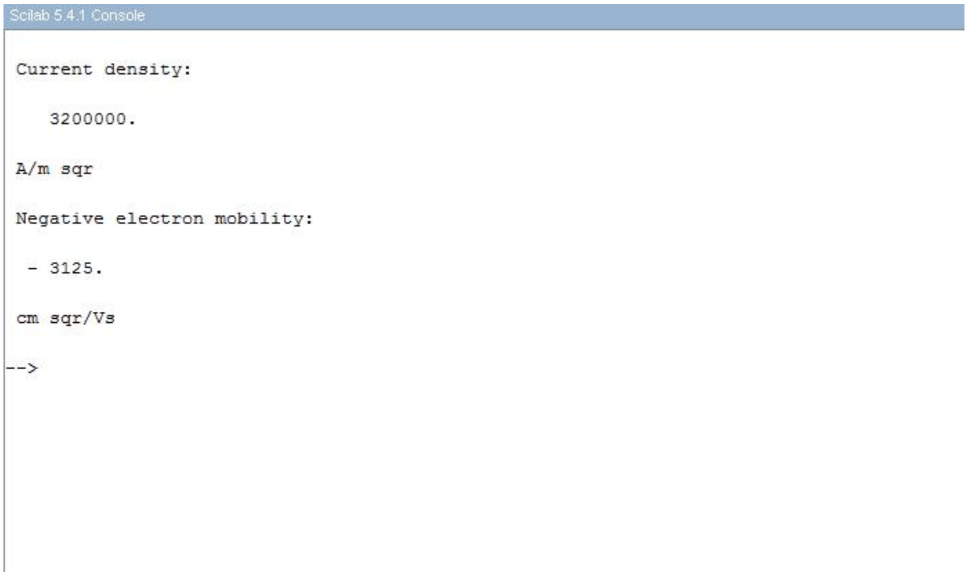
```
 n0L should be greater than

    1.208D+16

 m^-3

-->
```

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;
```



```
 Current density:   
 
    3200000.  
 
 A/m sqr   
 
 Negative electron mobility:   
 
  - 3125.  
 
 cm sqr/Vs   
 
-->
```

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');
```

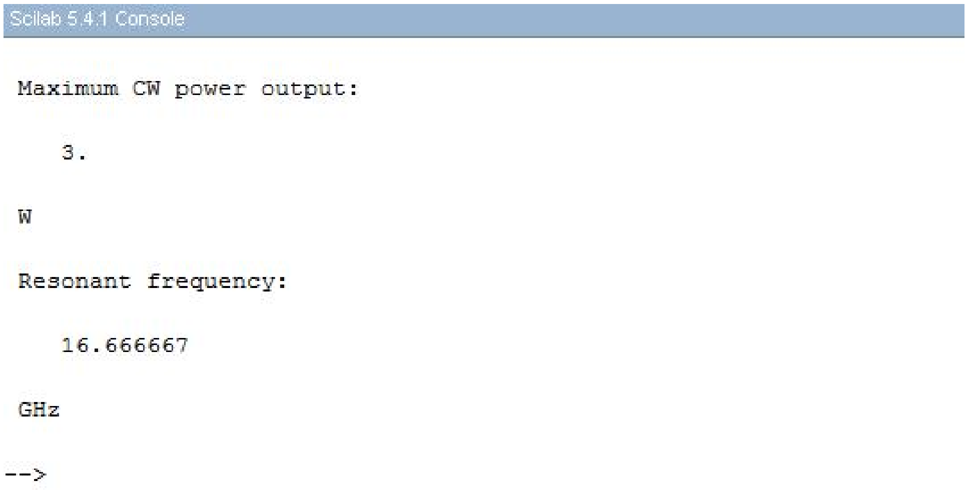
Scilab code Exa 9.15 `Gunn diode`

```
//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;
```



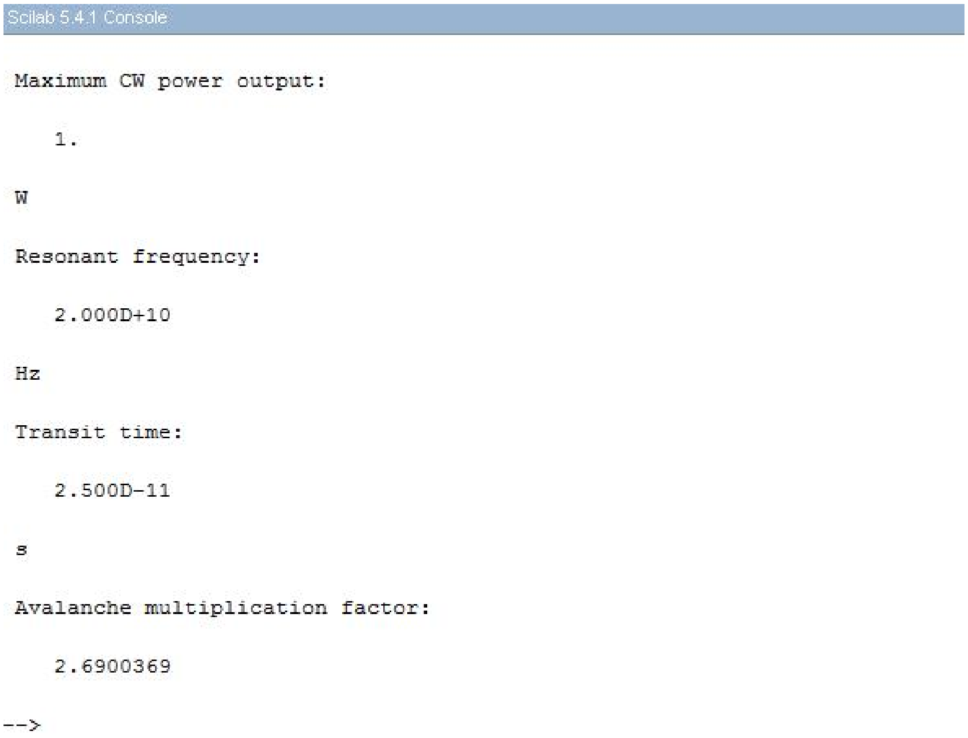
```
 Maximum CW power output:

    3.

 W

 Resonant frequency:

    16.666667

 GHz

-->
```

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:');
```



```
 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

```
 Power output:

    9.

 W

 Duty cycle:

    3.625D-11

 s

-->
```

Figure 9.17: IMPATT diode

```

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

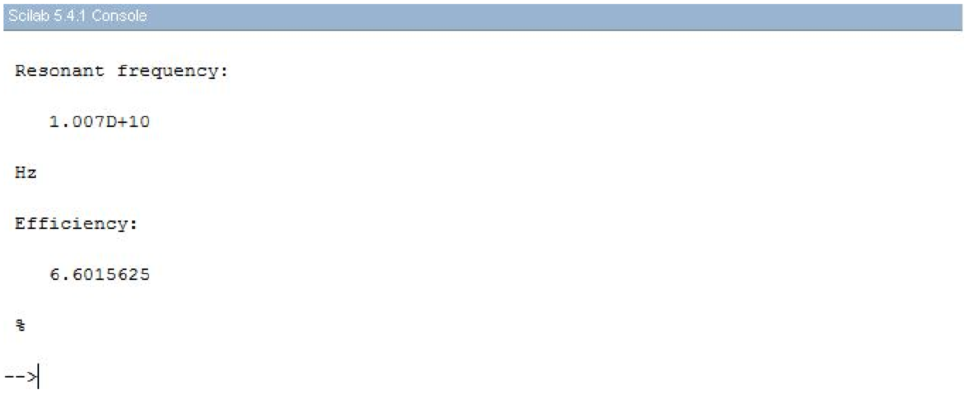
Scilab code Exa 9.19 `IMPATT diode`

```
//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;
```



```
 Resonant frequency:

    1.007D+10

 Hz

 Efficiency:

    6.6015625

 %

-->
```

Figure 9.18: IMPATT diode

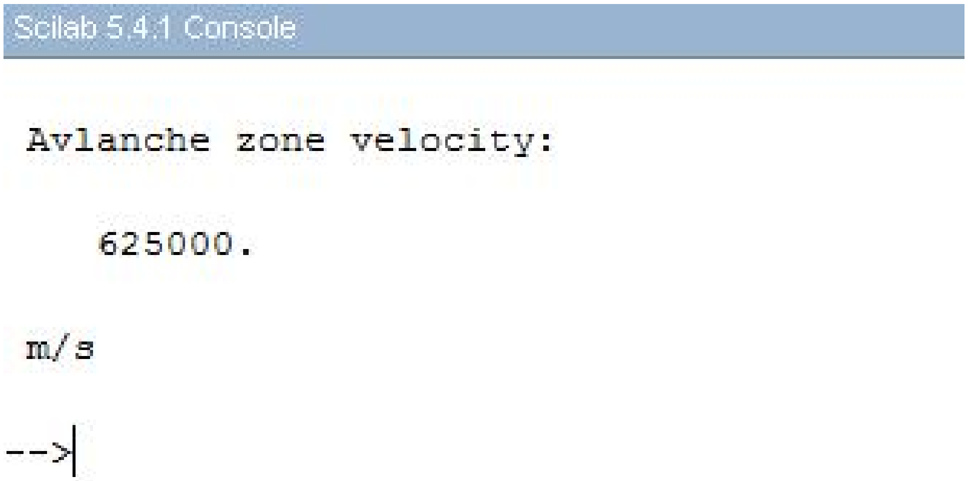
```
n=(Pout*100)/Pin;
disp('%',n,'Efficiency:');
```

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:');
```

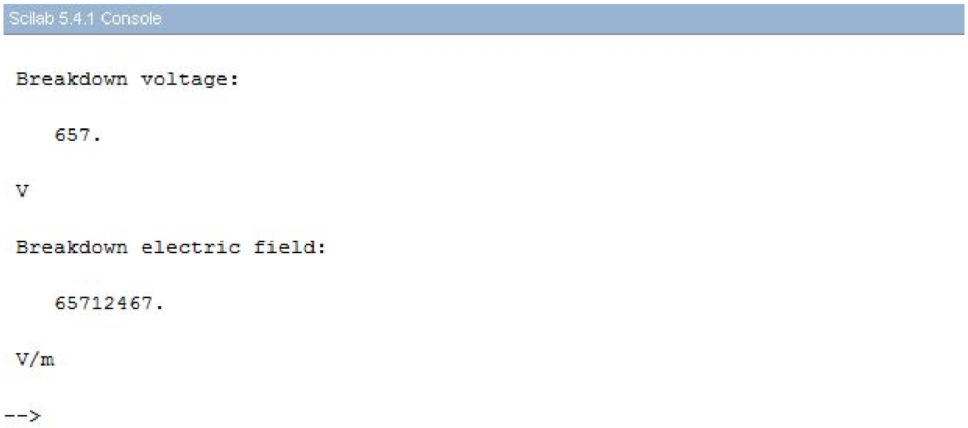
Scilab code Exa 9.22 `BARITT diode`

```
//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;

```



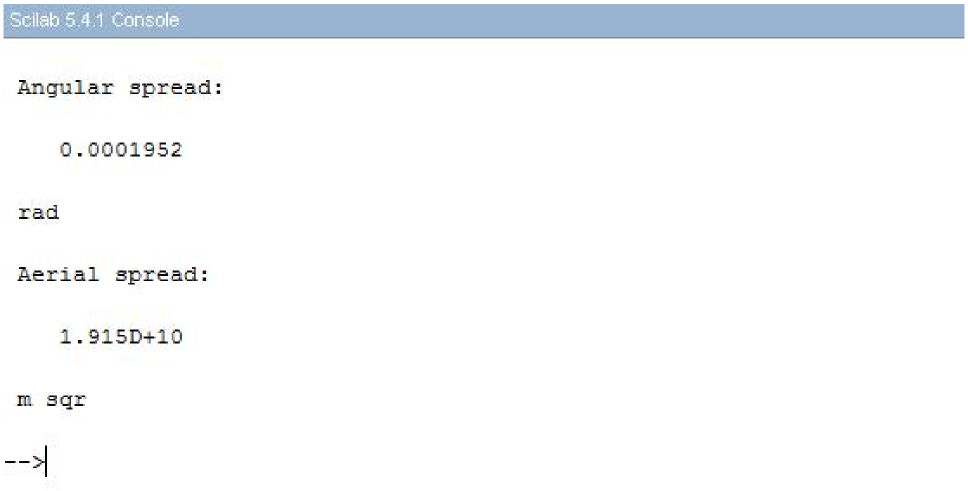
```
 Avlanche zone velocity:

    625000.

 m/s

-->
```

Figure 9.19: TRAPATT diode



```
 Breakdown voltage:   
 
    657.  
 
 V   
 
 Breakdown electric field:   
 
    65712467.  
 
 V/m   
 
-->
```

Figure 9.20: BARITT diode



```
 Angular spread:

    0.0001952

 rad

 Aerial spread:

    1.915D+10

 m sqr

-->
```

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;
```

```
 Pulse Power:

    1.000D+10

 W

 Q value:

    461538.46

-->
```

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
```

```
Wavelenght emitted:

   6716.

A

-->
```

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');

```

```
 Width

    0.2655478

 cm

 Total attenution in db/lambda:

    0.8556728

 db/lambda

-->
```

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;
```

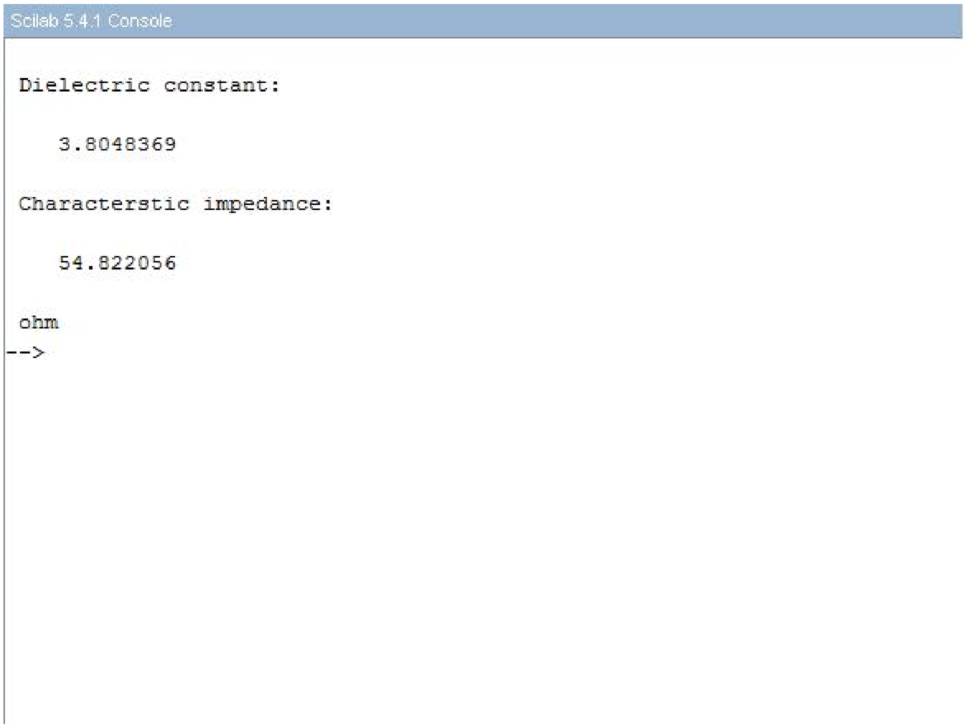
```
Scilab 5.4.1 Console

 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:');
```

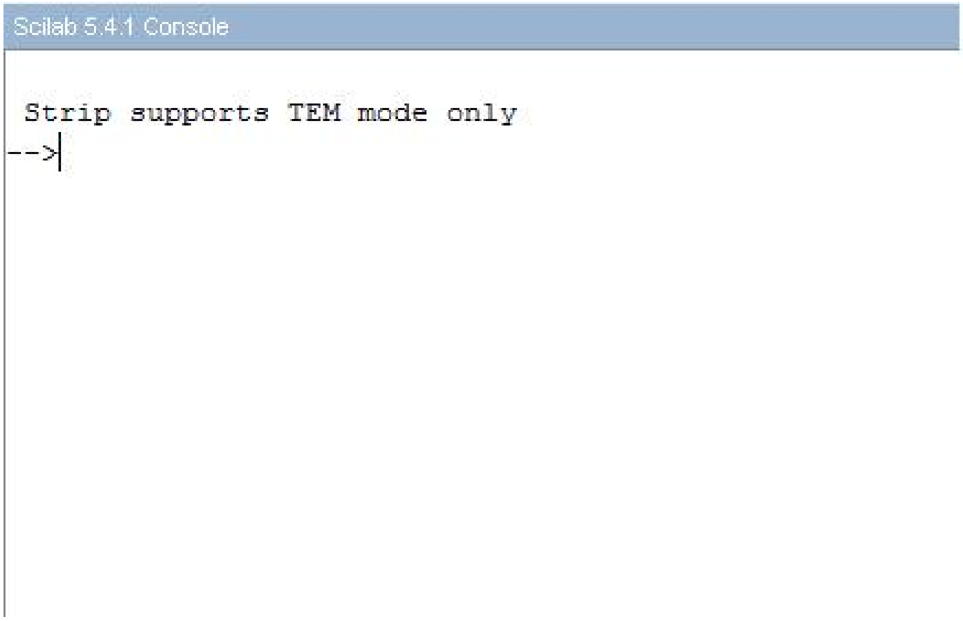
Scilab code Exa 10.3 `Microstrip`

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



```
 Dielectric constant:

    3.8048369

 Characterstic impedance:

    54.822056

 ohm
-->
```

Figure 10.3: Microstrip



```
 Strip supports TEM mode only
-->
```

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;
```

```
Dielectric constant:

   6.5564729

Characterstic impedance:

   49.447285

ohm

Dielectric attenuation:

   0.0253364

Np/m

Conductor attenuation:

   0.4113396

Np/m

Total attenuation:

   0.0379297

db/cm
-->
```

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:');
```

```
 conductor Q of the stripline:

    1815.
-->
```

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:');
```

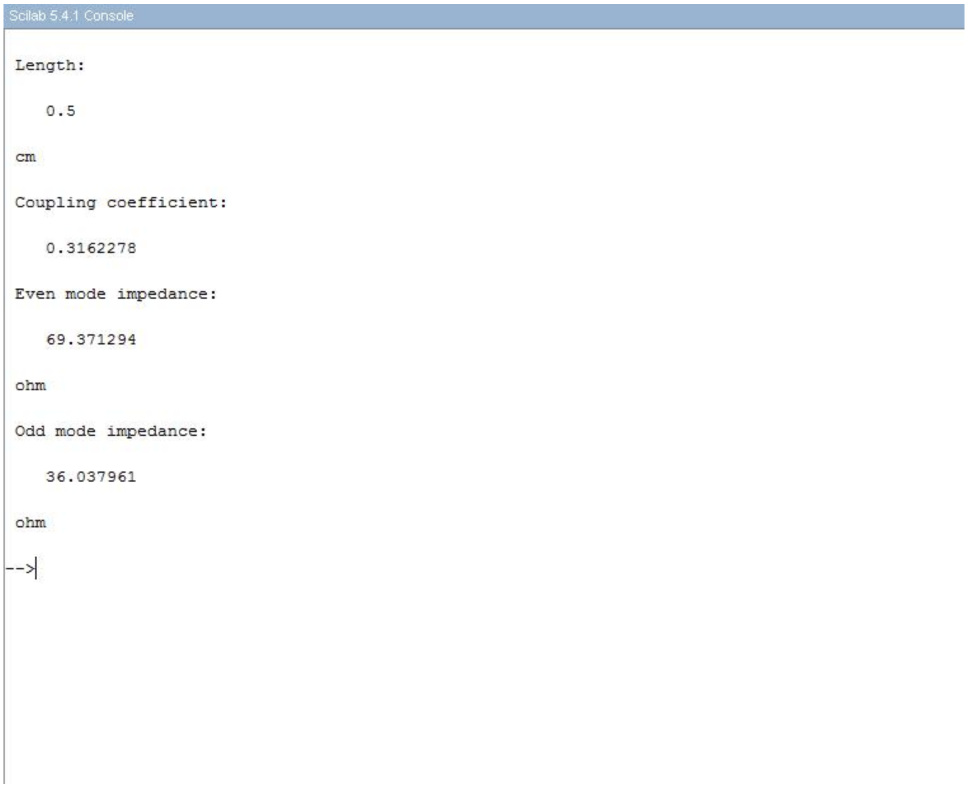
```
 Required Width:

    12.312478

 mm

 Stripline capacitance:

    163.52203

 pF/m

 Stripline inductance:

    0.4082483

 muH/m

 Phase velocity

    1.225D+08

 m/s

-->
```

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`



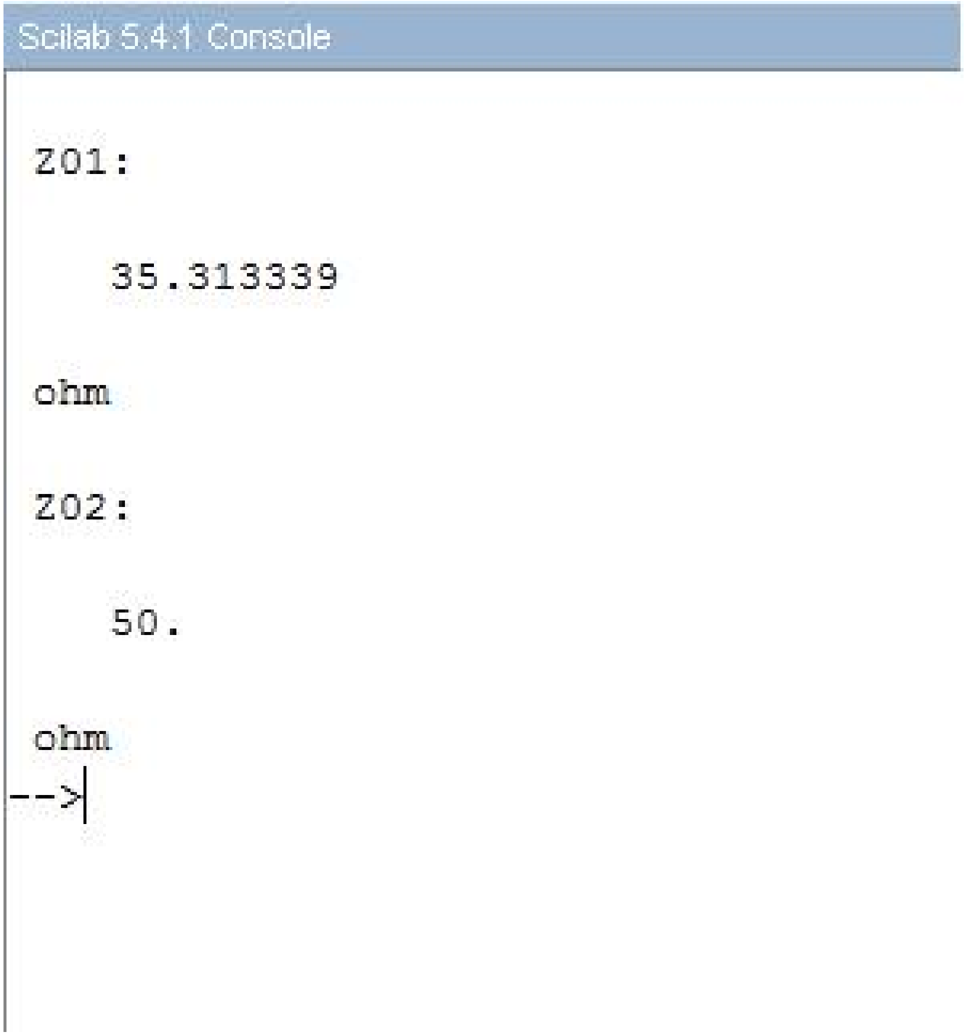
```
 Length:

    0.5

 cm

 Coupling coefficient:

    0.3162278

 Even mode impedance:

    69.371294

 ohm

 Odd mode impedance:

    36.037961

 ohm

-->
```

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
```



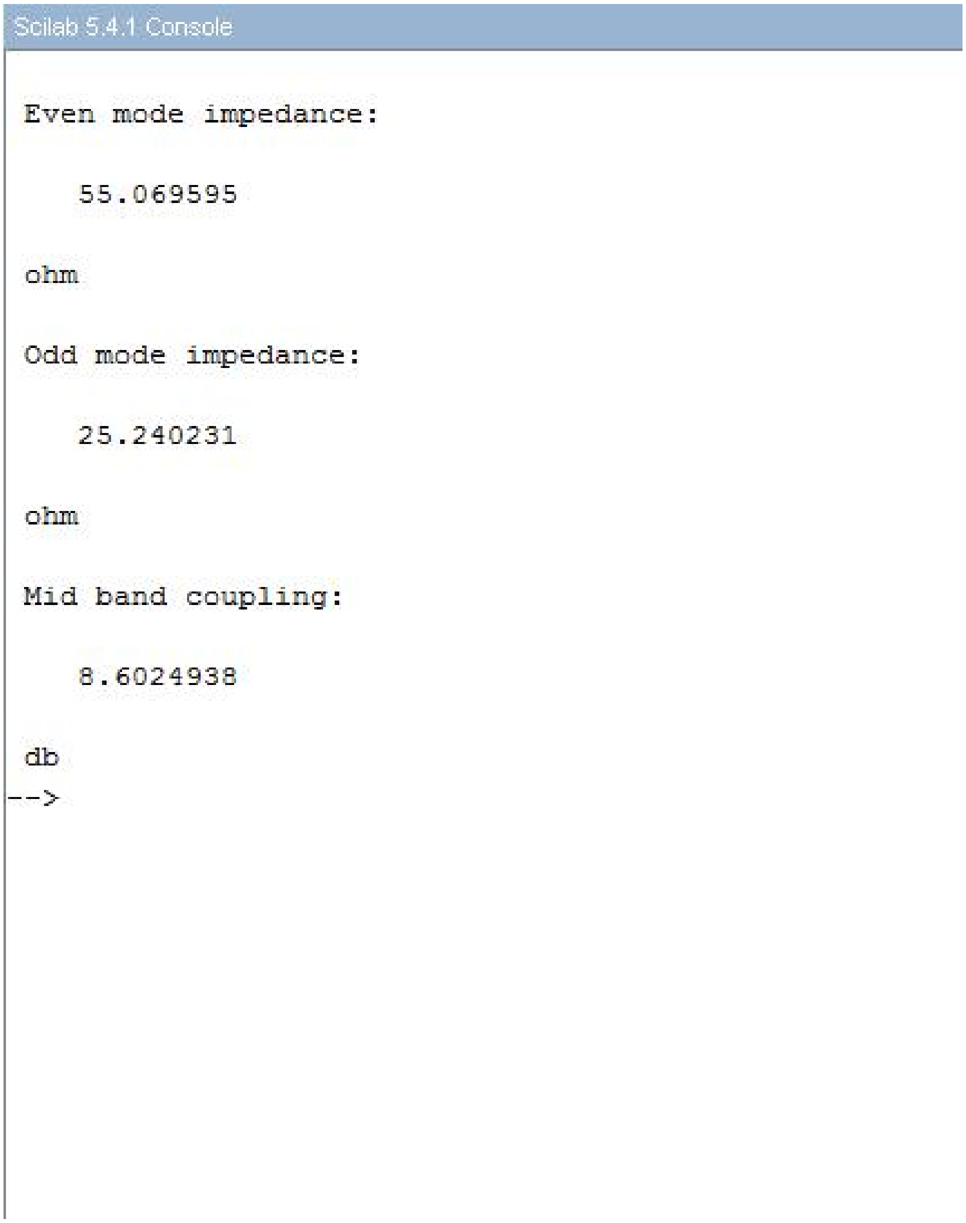
```
Z01:

   35.313339

ohm

Z02:

   50.

ohm
-->
```

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:');
```

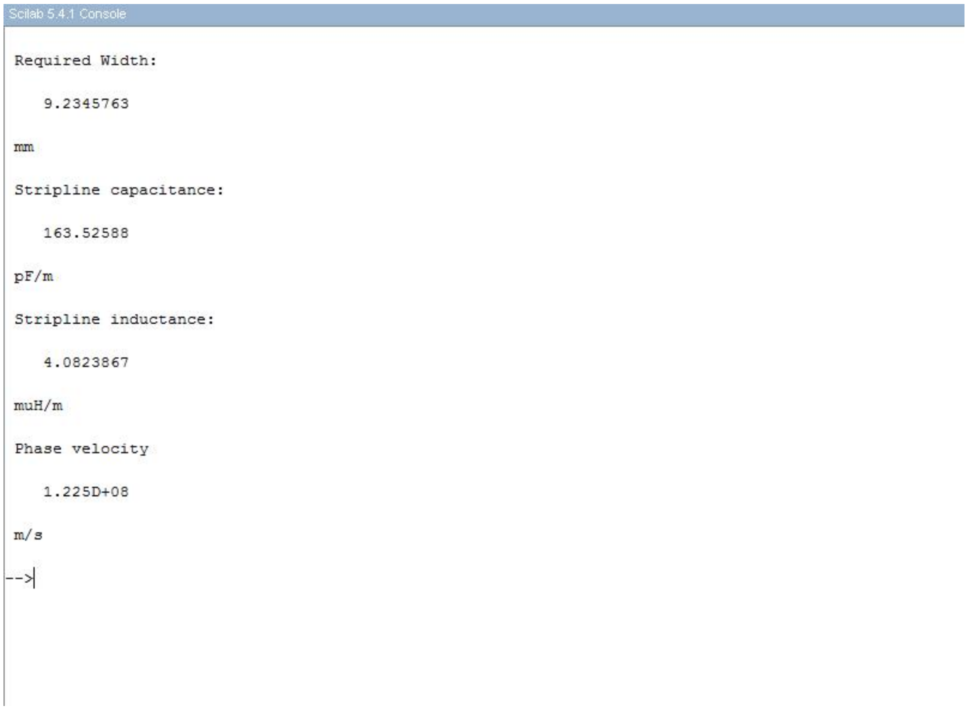
Scilab code Exa 10.10 `Broadside stripline`

```
//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:');

```



```
Even mode impedance:

   55.069595

ohm

Odd mode impedance:

   25.240231

ohm

Mid band coupling:

   8.6024938

db
-->
```

Figure 10.10: Broadside stripline



```
Required Width:

   9.2345763

mm

Stripline capacitance:

   163.52588

pF/m

Stripline inductance:

   4.0823867

muH/m

Phase velocity

   1.225D+08

m/s

-->
```

Figure 10.11: Paralle stripline

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

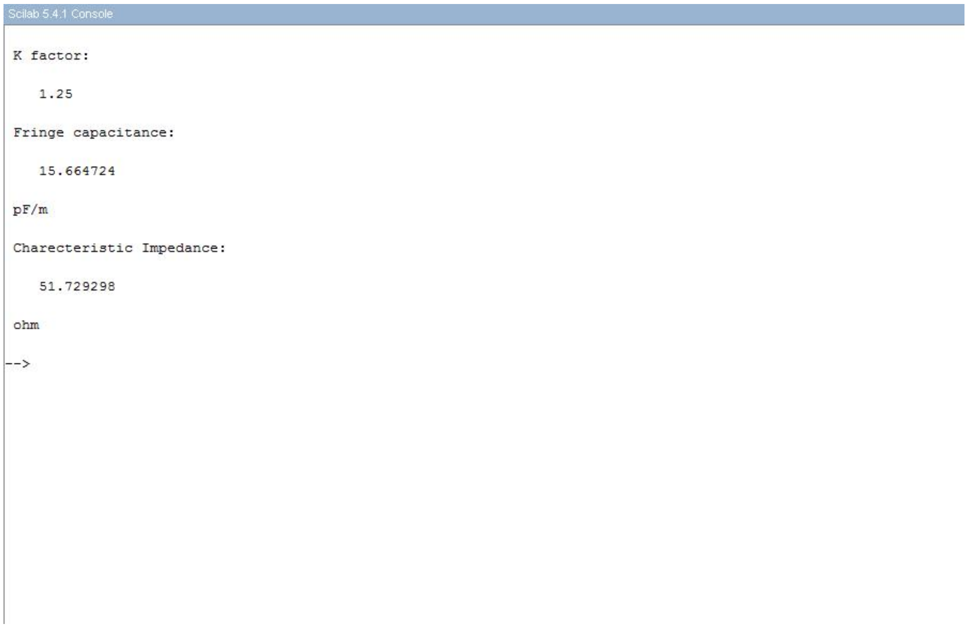
Scilab code Exa 10.11 `Paralle stripline`

```
//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
```



```
 K factor:   
 
    1.25  
 
 Fringe capacitance:   
 
    15.664724  
 
 pF/m   
 
 Charecteristic Impedance:   
 
    51.729298  
 
 ohm   
 
-->
```

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
```

```
 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`

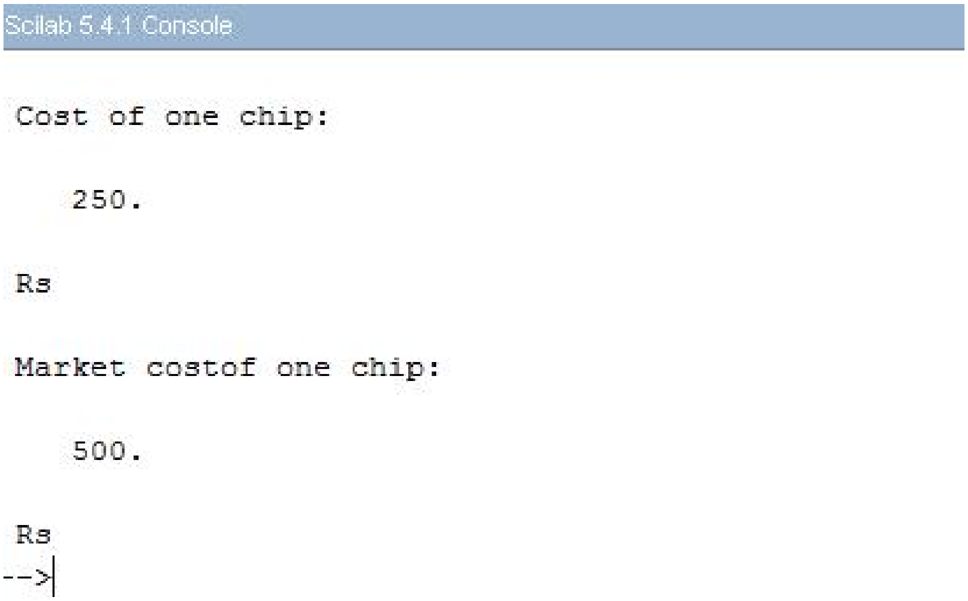
```
//Page Number: 563
//Example 10.13
clc;
//Given
Z0=50; //ohm
//Sincr ratio of power is 2:3
x1=5/2;
y1=5/3;
//Output Impedance
Z1=x1*Z0;
Z2=y1*Z0;
disp('ohm',Z1,'Output Impedance 1:')
disp('ohm',Z2,'Output Impedance 2:')

//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

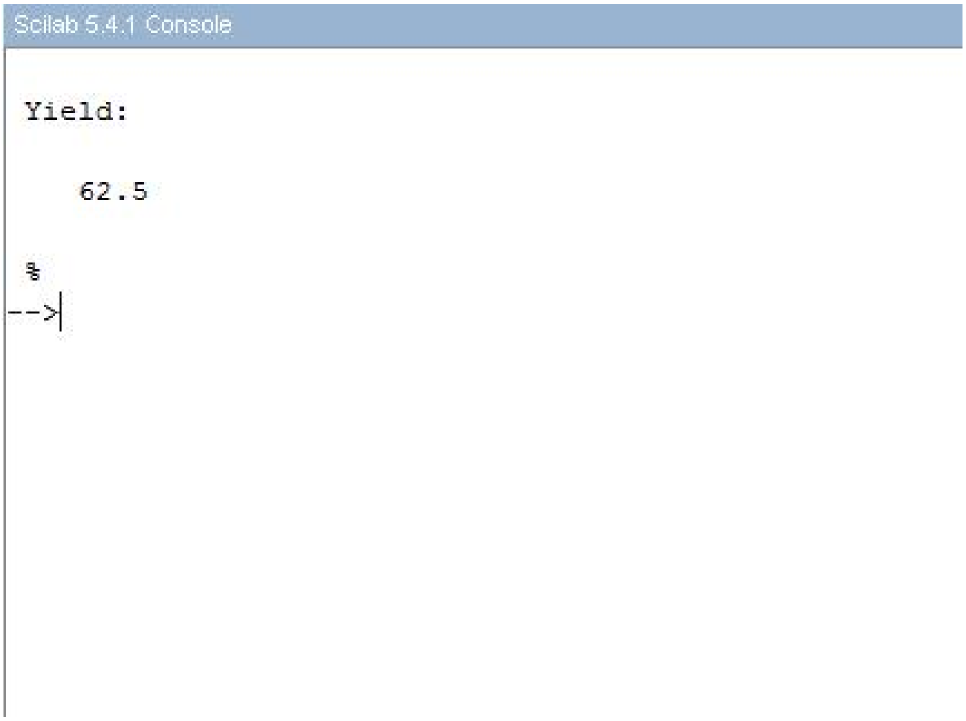
Scilab code Exa 11.1 `Costs`

```
//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:');
```



```
 Cost of one chip:

    250.

 Rs

 Market costof one chip:

    500.

 Rs
-->
```

Figure 11.1: Costs



```
 Yield:

    62.5

 %
-->
```

Figure 11.2: Yield

Scilab code Exa 11.2 `Yield`

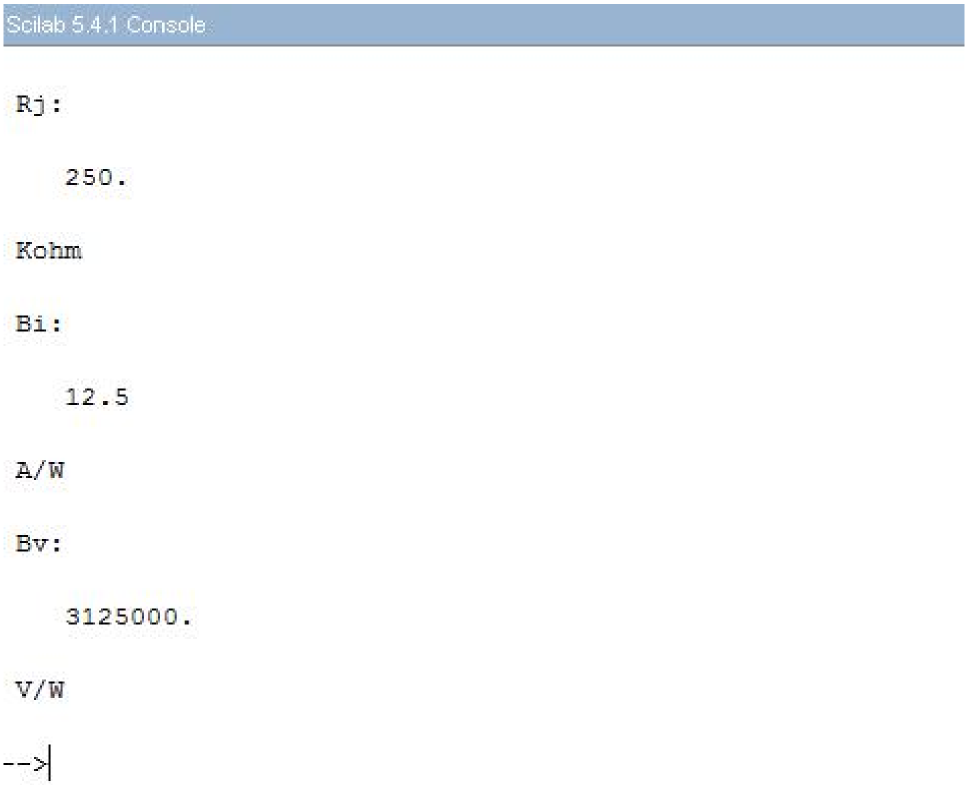
```
//Page Number: 595
//Example 11.2
clc;
//Given
c=5000; //Rs
S=0.6; //cm
//Sides
x=3; //cm
y=2.54; //cm
//break even cost
bec=250;
//hence, chips/waffers needed
cpw=c/bec;
D=x*y;
//For given Area, atleast 40 chips are required
n=2*cpw;

//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

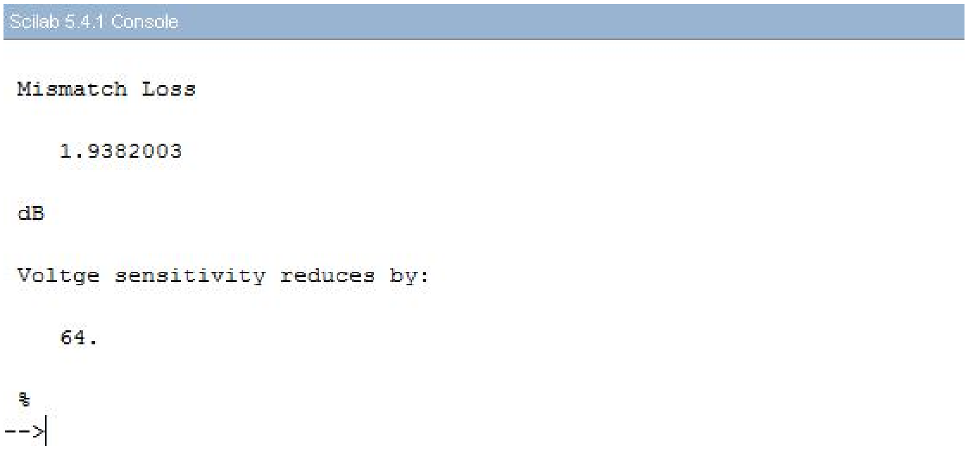
Scilab code Exa 12.1 `Microwave diode`

```
//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;
```



```
 Rj:

    250.

 Kohm

 Bi:

    12.5

 A/W

 Bv:

    3125000.

 V/W

-->
```

Figure 12.1: Microwave diode



```
 Mismatch Loss

    1.9382003

 dB

 Voltge sensitivity reduces by:

    64.

 %
-->
```

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;
```

```
 VSWR:

    10.301015
-->
```

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
```

```
 VSWR:

    8.9126768
-->
```

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
```

```
Reflected Power:

   0.5

W
-->
```

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);
```

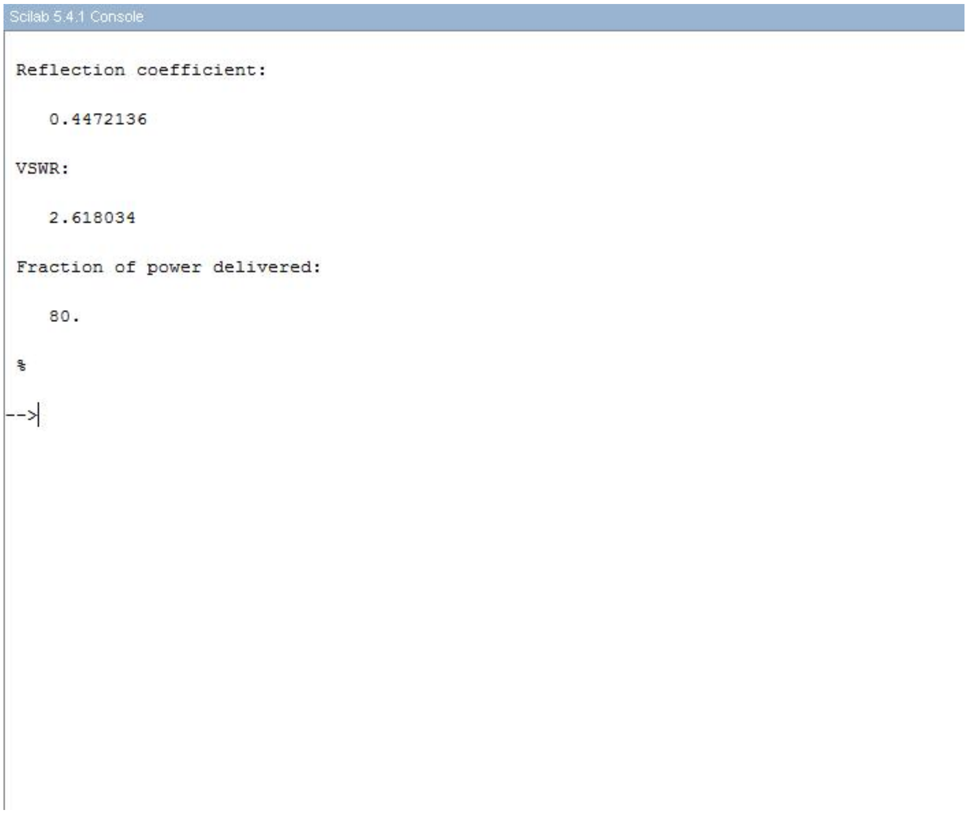
```
 Reflection coefficient:

    0.4117647
-->
```

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);
```



```
Reflection coefficient:

   0.4472136

VSWR:

   2.618034

Fraction of power delivered:

   80.

%

-->
```

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
```

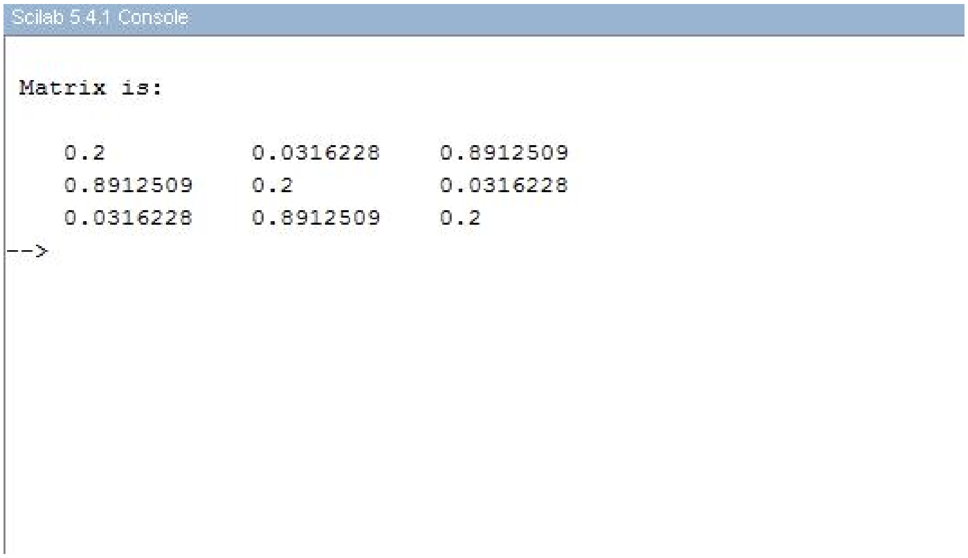
```
//Example 12.7
clc;
//Given
Zl=25+25*%i; //ohm
Z0=50; //ohm

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:');
```

```
 Operating frequency:

    17.800008

 GHz

-->
```

Figure 12.8: Rectangular waveguide

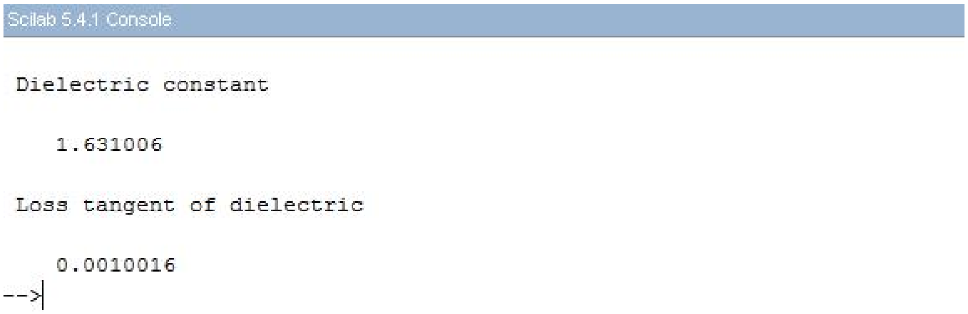


```
 Matrix is:

    0.2          0.0316228    0.8912509
    0.8912509    0.2          0.0316228
    0.0316228    0.8912509    0.2
-->
```

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;
```



```
 Dielectric constant

    1.631006

 Loss tangent of dielectric

    0.0010016
-->
```

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;
```

```
Er:

    2.0388585
-->
```

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
```
