

Scilab Textbook Companion for
Microwave Engineering
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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

```
1 //Page Number: 12
2 //Example 1.2
3 clc;
4 //Given
5 z0=50; //ohm
6 zg=50; //ohm
7 l=0.25; //m
8 f=4D+9; //hz
9 z1=100; //ohm
10 vg=10; //V
11 w=2*%pi*f; //rad/sec
12 c=3D+8; //m/s
13
14 //(i) Voltage and current at any point
15 tg=(zg-z0)/(zg+z0);
16 t1=(z1-z0)/(z1+z0);
17 vi=z0*vg/(z0+zg); //V
18 disp('V',vi,'Voltage at any point:');
19 ii=vg/(2*z0); //A
```

```
Scilab 5.4.1 Console

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


```

20 disp('A',ii,'Current at any point:');
21
22 //(ii) Voltage at generator end
23 //Taking z=1
24 z=1;
25 bet=w/c;
26 vz=(vg/2)*exp(-%i*bet*(z+1))*(1+(t1*exp(2*%i*bet*z))
    );//V
27 disp('V',vz,'Voltage at generator end:');
28 iz=ii*exp(-%i*bet*(z+1))*(1-(t1*exp(2*%i*bet*z)));//
    A
29 vz1=(vg/2)*exp(-%i*bet*(z+1))*(1+(t1*exp(2*%i*bet*z)
    ));//V
30
31 //Voltage at load end, z=0
32 z11=0;
33 v1=(vg/2)*exp(-%i*bet*1)*(1+(t1*exp(2*%i*bet*z11)));
    //V
34 disp('V',v1,'Voltage at load end:');
35
36 //(iii) Reflection coefficient
37 zx=0.25;
38 tz=t1*exp(%i*2*bet*zx);
39 disp(tz,'Reflection coefficient:');
40
41 //(iv) VSWR
42 p=(1+t1)/(1-t1);
43 disp(p,'VSWR:');
44
45 //(v) Average power delivered to the load
46 v1=20/3;
47 p10=v1^2/(2*z1);//W
48 disp('W',p10,'Average power delivered to the load:')
    ;

```

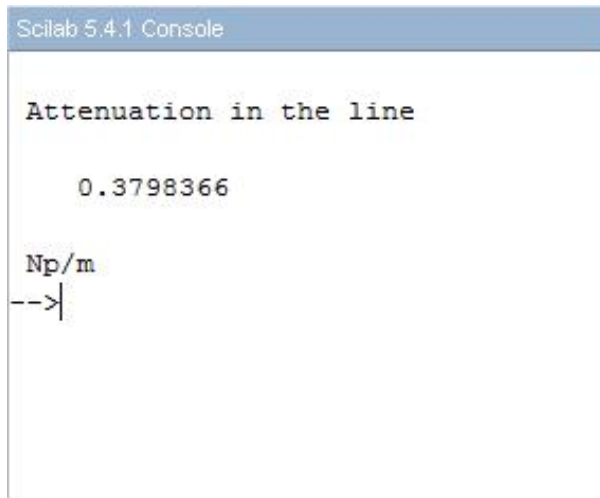


Figure 1.2: Microwave line

Scilab code Exa 1.3 Microwave line

```

1 //Page Number: 14
2 //Example 1.3
3 clc;
4 //Given
5 pm=3;
6 pl=4;
7 l=24; //cm
8 l1=1/100; //m
9
10 //Attenuation
11 tin=(pm-1)/(pm+1);
12 t1=(pl-1)/(pl+1);
13 alp=(1/(2*l1))*log(t1/tin); //Np/m

```

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

Scilab code Exa 1.4 Quater wave transformer

```
1 //Page Number: 14
2 //Example 1.4
3 clc;
4 //Given
5 c=3D+8; //m/s
6 z0=200; //ohm
7 z1=800; //ohm
8 f=30D+6; //hz
9
10 //Characterstic impedance
11 z00=sqrt(z0*z1); //ohm
12 disp('ohm',z00,'Characterstic impedance:');
13
14 //Length of line
15 lam=c/f; //m
16 l=lam/4; //m
17 disp('m',l,'Length of line:');
```

Scilab code Exa 1.5 Parallel resonant circuit

```
1 //Page Number: 15
2 //Example 1.5
3 clc;
4 //Given
5 l=1.2; //mH
```

```
Scilab 5.4.1 Console

Characteristic impedance:

    400.

ohm

Length of line:

    2.5

m

-->
```

Figure 1.3: Quater wave transformer

```
Scilab 5.4.1 Console

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

```

6 r=8; //ohm
7 c=200D-12; //F
8
9 //(i) Resonant frequency
10 f0=(1/(2*pi))*sqrt(1/(l*c)); //hz
11 disp('hz',f0,'Resonant frequency:');
12
13 //(ii) Impedance of circuit
14 disp('ohm',r,'Impedance of circuit:');
15
16 //(iii)Q factor of the circuit
17 q=1/(2*pi*f0*c*r);
18 disp(q,'Q factor of the circuit:');
19
20 //(iv) Bandwidth
21 df=f0/q; //hz
22 disp('hz',df,'Bandwidth:');
23
24 //The value of resonant frequency is calculated
    wrong in book
25 //Hence Q factor and bandwidth, all these answers
    dont match

```

Scilab code Exa 1.6 Lossless line

```

1 //Page Number:
2 //Example 1.6
3 clc;
4 //Given
5 c=3D+8; //m/s
6 le=25; //m
7 z1=40+(%i*30); //ohm
8 f=10D+6; //hz

```

```
Scilab 5.4.1 Console

Input impedance:

    0.5773503 - 0.5773503i

ohm

Reflection coefficient:

- 0.2953651 + 0.3069524i
-->
```

Figure 1.5: Lossless line

```

 9  cap=40D-12; //F
10  l=300D-9; //H/m
11
12  //Input impedance
13  z0=sqrt(1/cap); //ohm
14  z11=z1/z0;
15  lam=c/f; //m
16  bet=(2*%pi*le)/lam; //rad
17  zin=((z11*cos(bet))+(%i*sin(bet)))/(cos(bet)+(%i*z11
    *sin(bet))); //ohm
18  disp('ohm',zin,'Input impedance:');
19
20  //Reflection coefficient
21  t=(z11-1)/(z11+1);
22  disp(t,'Reflection coefficient:');

```

Scilab code Exa 1.7 Lossy cable

```

1  //Page Number: 16
2  //Example 1.7
3  clc;
4  //Given
5  c=3D+8; //m/s
6  R=2.25; //ohm
7  L=1D-9; //H/m
8  C=1D-12; //F/m
9  f=0.5D+9; //hz
10 G=0;
11 w=2*%pi*f; //rad/sec
12
13 //Characteristic impedance
14 z0=sqrt((R+(%i*w*L))/(G+(%i*w*C))); //ohm
15 disp('ohm',z0,'Characteristic impedance:');

```



```
Scilab 5.4.1 Console

Characteristic impedance:

    33.391733 - 10.724171i

ohm

Propagation constant:

    0.0336910 + 0.1049032i
-->
```

Figure 1.6: Lossy cable

```

16
17 //Propagation constant
18 gam=sqrt((R+(%i*w*L))*(G+(%i*w*C)));
19 disp(gam,'Propagation constant:');

```

Scilab code Exa 1.8 Transmission Line

```

1 //Page Number: 20
2 //Example 1.8
3 clc;
4 //Given
5 c=3D+8; //m/s
6 f=3D+9; //Hz
7 ZL=50-(%i*100); //ohms
8 Z0=50; //ohm
9 //Wavelength
10 lam=c/f;
11 disp('cm',lam*100,'Wavelength:');
12
13 //Normalized load impedance
14 z=ZL/Z0;
15 disp(z,'Normalized load impedance:');
16
17 //From chart
18 zin=0.45+(%i*1.2);
19 yin=0.27-(%i*0.73);
20 ZINN=Z0*zin;
21 disp('ohm',ZINN,'Line impedance:');
22 YINN=yin/Z0;
23 disp('mho',YINN,'Line admittance:');

```

```
Scilab 5.4.1 Console

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

```
Scilab 5.4.1 Console

Normalized load impedance:

    1.5 + 2.i

Input impedance at 0.051 lam:

    230.

ohm

Input impedance at 0.102 lam:

    75. - 100.i

ohm

Input impedance at 0.301 lam:

    11.

ohm
-->
```

I

Figure 1.8: Transmission Line

Scilab code Exa 1.9 Transmission Line

```
1 //Page Number: 22
2 //Example 1.9
3 clc;
4 //Given
5 ZL=75+(%i*100); //ohms
6 Z0=50; //ohm
7
8 //Normalized load impedance
9 z=ZL/Z0;
10 disp(z, 'Normalized load impedance:');
11
12 //(i) 0.051*lam
13 //From chart
14 r=4.6;
15 Zi1=r*Z0;
16 disp('ohm',Zi1, 'Input impedance at 0.051 lam:');
17
18 //(ii) 0.102*lam
19 r1=1.5-(%i*2);
20 Zi2=r1*Z0;
21 disp('ohm',Zi2, 'Input impedance at 0.102 lam:');
22
23 //(iii) 0.301*lam
24 r2=0.22;
25 Zi3=r2*Z0;
26 disp('ohm',Zi3, 'Input impedance at 0.301 lam:');
```

Scilab code Exa 1.10 Transmission Line

```
Scilab 5.4.1 Console

Normalized load impedance:

    0.3 + 0.4i

Reflection coefficient:

    0.6

VSWR:

    4.
```

Figure 1.9: Transmission Line

```

1 //Page Number: 23
2 //Example 1.10
3 clc;
4 //Given
5 ZL=15+(%i*20); //ohms
6 Z0=50; //ohm
7
8 //Normalized load impedance
9 z=ZL/Z0;
10 disp(z, 'Normalized load impedance:');
11
12 //From chart
13 T=0.6;
14 disp(T, 'Reflection coefficient:');
15
16 //VSWR
17 p=4;
18 disp(p, 'VSWR:');

```

Scilab code Exa 1.11 Microwave line

```

1 //Page Number: 25
2 //Example 1.11
3 clc;
4 //Given
5 Z0=50; //ohm
6 p=2.4;
7
8 //From chart
9 z1=1.4+%i;
10 L=Z0*z1;
11 disp('ohm',L, 'Load:');

```

```
Scilab 5.4.1 Console

Load:

    70. + 50.i

ohm
-->
```

Figure 1.10: Microwave line

Scilab code Exa 1.12 Active Device

```
1 //Page Number: 26
2 //Example 1.12
3 clc;
4 //Given
5 Z0=50; //ohm
6 T=2.23;
7
8 //From chart
9 z1=2+%i;
10 ZLd=Z0*z1;
11 disp('ohm',ZLd,'Normalized impedance:');
```



```
Scilab 5.4.1 Console

Normalized impedance:

    100. + 50.i

ohm

Impedance of device:

   -100. + 50.i

ohm

-->
```

Figure 1.11: Active Device

```
12
13 //Impedance of device is by negating the real part
14 imp=-real(ZLd)+(imag(ZLd)*%i);
15 disp('ohm',imp,'Impedance of device:');
```

Scilab code Exa 1.13 Transmission line

```
1 //Page Number: 27
2 //Example 1.13
3 clc;
4 //Given
5 p=3;
6 m1=54; //cm
```

```
Scilab 5.4.1 Console

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

```

7 m2=204; //cm
8
9 //Point A
10 disp('Point A');
11 lam=4*(m2-m1);
12 dA=0.083*lam;
13 L=m1-dA;
14 disp('cm',L,'Location of stub:');
15 IA=0.114*lam;
16 disp('cm',IA,'Length:');
17
18 //Point B
19 disp('Point B');
20 dB=0.083*lam;
21 IB=0.386*lam;
22 Lb=dB+m1;
23 disp('cm',Lb,'Location of stub:');

```

Scilab code Exa 1.15 Microwave line

```

1 //Page Number: 30
2 //Example 1.15
3 clc;
4 //Given
5 Z0=50; //ohm
6 ZL=100; //ohms
7 f=10D+9; //Hz
8 c=0.159D-12; //F
9
10 //Normalized load impedance
11 z=ZL/Z0;
12 disp(z,'Normalized load impedance:');
13

```

```
Scilab 5.4.1 Console

Normalized load impedance:

    2.

Normalized impedance:

    20. + 27.5i

ohm

-->
```

Figure 1.13: Microwave line

```
Scilab 5.4.1 Console

Phase velocity:

 33333333.

m/s

Dielectric constant:

 81.

-->
```

Figure 1.14: EM Plane

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

Scilab code Exa 1.16 EM Plane

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

```

3  clc;
4  //From given wave equation we can see
5  w=1D+9; //rad/sec
6  bet=30; //rad/m
7  c=3D+8; //m/s
8  u0=1; //let
9  e0=1/(9D+16);
10
11  vp=w/bet; //m/sec
12  disp('m/s',vp,'Phase velocity:');
13
14  e=1/(vp^2*u0);
15  er=e/(e0*u0);
16  disp(er,'Dielectric constant:');

```

Scilab code Exa 1.17 Polyethylene

```

1  //Page Number: 42
2  //Example 1.17
3  clc;
4  //Given
5  c=3D+8; //m/s
6  f=10D+9; //hz
7  er=6;
8  tandel=2D-4;
9
10  vp=c/er; //m/sec
11  disp('m/sec',vp,'Phase velocity:');
12  al=(%pi*f*tandel)/vp; //Np/m
13  disp('Np/m',al,'Attenuation constant:');
14
15  //Answer for velocity is calculated wrong in book,
    hence answers dont match for both

```

```
Scilab 5.4.1 Console

Phase velocity:

    50000000.

m/sec

Attenuation constant:

    0.1256637

Np/m

-->
```

Figure 1.15: Polyethylene

```
Scilab 5.4.1 Console

Reflection coefficient:

- 0.1946005

VSWR:

1.4832397
-->|
```

Figure 1.16: Electromagnetic wave

Scilab code Exa 1.18 Electromagnetic wave

```
1 //Page Number: 43
2 //Example 1.18
3 clc;
4 //Given
5 er=2.2;
6 n0=377; //ohm
7 n2=n0/sqrt(er); //ohm
8 n1=377; //ohm
9
```



```

10 // Reflection coefficient
11 t=(n2-n1)/(n2+n1);
12 disp(t, 'Reflection coefficient: ');
13
14 //Vswr
15 //Taking mod of reflection coefficient
16 t1=-t;
17 p=(1+t1)/(1-t1);
18 disp(p, 'VSWR: ');

```

Scilab code Exa 1.19 Range in sea water

```

1 //Page Number: 43
2 //Example 1.19
3 clc;
4 //Given
5 sig=5; //mohm/m
6 er=80*8.85D-12;
7 eaz=0.1;
8 u=1.26D-6;
9
10 az=-log(0.1);
11 //(i) Range at 25Khz
12 f=25D+3; //Khz
13 w=2*%pi*f; //rad/sec
14 a=w*(sqrt((u*er/2)*(sqrt(sig^2/(w^2*er^2)+1)-1)));
15 z=az/a; //m
16 disp('m',z, 'Range at 25khz: ');
17
18 //(ii) Range at 25Mhz
19 f1=25D+6; //Mhz
20 w1=2*%pi*f1; //rad/sec
21 a1=w1*(sqrt((u*er/2)*(sqrt(sig^2/(w1^2*er^2)+1)-1)))

```

```
Scilab 5.4.1 Console

Range at 25khz:

    3.2734469

m

Range at 25Mhz:

    0.1046719

m

-->
```

Figure 1.17: Range in sea water

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

Chapter 2

Waveguides

Scilab code Exa 2.1 Dominant mode

```
1 //Page Number:91
2 //Example 2.1
3 clc;
4 //Given ,
5
6 a=6; //cm
7 b=4; //cm
8 d=4.47; //cm
9 c=3D+8; //m/s
10 lamc=2*a;
11 lamg=2*d;
12
13 //Signal wavelength
14 lam=lamg*lamc/(sqrt(lamg^2+lamc^2));
15 lam=lam/100; //m
16 f=c/lam;
17 disp('Ghz',f/1D+9,'Signal frequency of dominant mode
      :');
```

Scilab 5.4.1 Console

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

```
1 //Page Number : 92
2 //Example 2.2
3 clc ;
4 //Given ,
```

```

5 c=3D+8; //m/s
6 a=2.5; //cm
7 b=5; //cm
8 lam=4.5; //cm
9
10 lamc=2*b;
11
12 //Guide wavelength
13 lamg=lam/(sqrt(1-((lam/lamc)^2)));
14 disp('cm',lamg,'Guide wavelength:');
15
16 //Phase constant
17 bet=(2*pi)/lamg;
18 bet=bet*100; //rad/m
19 disp('rad/m',bet,'Phase constant:');
20
21 //Phase velocity
22 w=(2*pi*c)/lam;
23 vp=w/bet;
24 disp('m/s',vp,'Phase velocity:');

```

Scilab code Exa 2.3 Rectangular Waveguide

```

1 //Page Number: 92
2 //Example 2.3
3 clc;
4 //Given ,
5
6 c=3D+8; //m/s
7 a=4; //cm
8 b=2; //cm
9 f=10D+9; //Hz
10 m=1;

```

```
Scilab 5.4.1 Console  
  
Cut-off wavelength:  
    3.5777088  
  
cm  
  
Wave impedance:  
    205.40827  
  
ohm  
-->
```

Figure 2.3: Rectangular Waveguide


```

11 n=1;
12
13
14 // Cutoff wavelength
15 lamc=2/sqrt((m/a)^2+(n/b)^2);
16 disp('cm',lamc,'Cut-off wavelength:');
17
18 //Wave impedance
19 lam=c/f;//m
20 lam=lam*100;//cm
21 eeta=120*%pi;
22 z0=eeta*sqrt(1-(lam/lamc)^2);
23 disp('ohm',z0,'Wave impedance:');

```

Scilab code Exa 2.4 Wider dimension

```

1 //Page Number: 93
2 //Example 2.4
3 clc;
4 //Given ,
5 c=3D+8; //m/s
6 f=10D+9; //Hz
7 zte=410; //ohm
8
9 //Wider dimension
10 lam=c/f;//m
11 lam=lam*100;//cm
12 a=3/(2*(sqrt(1-(120*%pi/zte)^2)));
13 disp('cm',a,'Wider dimension:');

```

```
Scilab 5.4.1 Console  
  
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: 50

2.6832816

cm

Scilab code Exa 2.5 Rectangular waveguide

```
1 //Page Number: 93
2 //Example 2.5
3 clc;
4 //Given ,
5 c=3D+8; //m/s
6 a=3.0; //cm
7 b=1.5; //cm
8 mur=1;
9 er=2.25;
10 x=mur*er;
11
12 //(i) Cutoff wavelength and frequencuy
13 disp('TE10 mode');
14 m1=1;
15 n1=0;
16 lamc10=2/sqrt((m1/a)^2+(n1/b)^2);
17 disp('cm',lamc10,'Cut-off wavelength:');
18 lamc10=lamc10/100;
19 f10=c/(lamc10*sqrt(x));
20 disp('Ghz',f10/1D+9,'Cutoff frequency:');
21
22 disp('TE20 mode');
23 m2=2;
24 n2=0;
25 lamc20=2/sqrt((m2/a)^2+(n2/b)^2);
26 disp('cm',lamc20,'Cut-off wavelength:');
27 lamc20=lamc20/100;
28 f20=c/(lamc20*sqrt(x));
29 disp('Ghz',f20/1D+9,'Cutoff frequency:');
30
31 disp('TE11 mode');
32 m3=1;
```

```

33 n3=1;
34 lamc11=2/sqrt((m3/a)^2+(n3/b)^2);
35 disp('cm',lamc11,'Cut-off wavelength:');
36 lamc11=lamc11/100;
37 f11=c/(lamc11*sqrt(x));
38 disp('Ghz',f11/1D+9,'Cutoff frequency:');
39
40 //(ii) lambg and Z0
41 f=4D+9; //Hz
42 lam=c/f;
43 lamg=lam/(sqrt(x-((lam/lamc10)^2)));
44 disp('cm',lamg*100,'Guide wavelength:');
45
46 fc=3.33D+9; //Hz
47 Z0=(120*%pi*(1/sqrt(x))*(b/a))/sqrt(1-((fc/f)^2));
48 disp('ohm',round(Z0),'Impedance:');

```

Scilab code Exa 2.7 Rectangular waveguide

```

1 //Page Number: 95
2 //Example 2.5
3 clc;
4 //Given ,
5 c=3D+8; //m/s
6 a=4; //cm
7 b=2; //cm
8
9 //(i) Mode
10 lamc=2*a; //cm
11 lamcm=lamc/100; //m
12 fc=c/lamcm;
13 //20% above fc
14 f=1.2*fc; //Hz

```

Scilab 5.4.1 Console

```
Since guide is operating at  
    3.750D+09  
Hz  
Hence mode of operation is TE10  
Guide wavelength:  
    12.060454  
cm  
Phase velocity:  
    5.427D+08  
m/s  
Group velocity:  
    1658312.4  
m/s  
-->
```

Figure 2.6: Rectangular waveguide

```

15
16 //Operating wavelength
17 lam1=c/f; //cm
18
19 //For TE10 mode
20 lamc10=2*b; //cm
21 lamcm10=lamc10/100; //m
22 fc10=c/lamcm10;
23 disp('Hence mode of operation is TE10','Hz',fc,
      'Since guide is operating at');
24
25 //(ii) Guide wavelength
26 lamm1=lam1*100; //cm
27 lamg=lamm1/(sqrt(1-(lamm1/lamc)^2));
28 disp('cm',lamg, 'Guide wavelength:');
29
30 //(iii) Phase velocity
31 vp=f*lamg;
32 disp('m/s',vp/100, 'Phase velocity:');
33
34 //(iii) Group velocity
35 vg=c^2/vp;
36 disp('m/s',vg, 'Group velocity:');

```

Scilab code Exa 2.8 Lossless Rectangular Waveguide

```

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

```

```
Scilab 5.4.1 Console

Average power transmitted:

    32.994372

W

Peak electric field:

    5.3868362

kV/m
-->|
```

Figure 2.7: Lossless Rectangular Waveguide


```

8 f=3D+9; //Hz
9 h0=10; //amp/m
10
11 //Wave impedance
12 lamc=2*a;
13 lam=c/f;//m
14 lam=lam*100;//cm
15 lamg=lam/sqrt(1-(lam/lamc)^2); //cm
16 z0=377*lamg/h0; //ohm
17
18 a1=a/100;//m
19 b1=b/100;//m
20 //Average power transmitted
21 p=(z0*h0*h0*a1*b1)/4;
22 disp('W',p,'Average power transmitted:');
23
24 //Peak electric field
25 e0=z0*h0;
26 disp('kV/m',e0/1000,'Peak electric field:');
27
28 //Answer for p is given as 28.3 W but it should be
    32.99W

```

Scilab code Exa 2.9 Dimensions

```

1 //Page Number: 96
2 //Example 2.9
3 clc;
4 //Given ,
5 c=3D+8; //m/s
6 fc=3D+9; //Hz
7
8 //Cutoff wavelength

```

```
Scilab 5.4.1 Console

Dimensions:

a:
  5.
cm

b:
  2.5
cm
-->
```

Figure 2.8: Dimensions

```

9 lamc=c/fc;
10 a=lamc/2; //m
11 a=a*100; //cm
12 disp('Dimensions:');
13 disp('cm',a,'a:');
14 b=a/2; //cm
15 disp('cm',b,'b:');

```

Scilab code Exa 2.10 Rectangular Waveguide

```

1 //Page Number:
2 //Example 2.10
3 clc;
4 //Given,
5
6 c=3D+8; //m/s
7 a=3; //cm
8 a1=a/100; //m
9 b=2; //cm
10 b1=b/100; //m
11 f=7.5D+9; //HZ
12 p=5D+3; //W
13
14 mu=%pi*4D-7;
15 w=2*%pi*f;
16 bet=sqrt(((w/c)^2)-((%pi/a1)^2));
17 //Charecteristic impedance
18 z0=w*mu*2*b/(bet*a);
19 disp('ohm',z0,'Charecteristic impedance:');
20
21 //Peak electric field
22 e0=4*w*mu*p/(bet*a*b);
23 disp('V/m',e0,'Peak electric field:');

```

```
Scilab 5.4.1 Console

Charecteristic impedance:

    674.38221

ohm

Peak electric field:

    1685955.5

V/m

Maximum voltage:

    33.719111

kV

-->
```

Figure 2.9: Rectangular Waveguide

```

24
25 //Maximum voltage
26 v0=e0*b1;
27 disp('kV',v0/1000,'Maximum voltage:');
28
29 //Answer for v0 is given as 3.172 kV it should be
    33.71 kV

```

Scilab code Exa 2.14 Waveguide

```

1 //Page Number: 99
2 //Example 2.14
3 clc;
4 //Given ,
5 c=3D+8; //m/s
6 a=1.5; //cm
7 a1=a/100; //m
8 b=0.8; //cm
9 b1=b/100; //m
10 mu=1/c*c;
11 e=4;
12 w=%pi*1D+11;
13 n=377;
14
15 //(i) Frequency of operation
16 f=w/(2*%pi);
17 f1=f/1D+9; //ghz
18 disp('Ghz',f1,'Frequency of operation:');
19
20 //(ii) Cutt off frequency
21 fc=(c*sqrt((1/a1)^2+(3/b1)^2))/(2*sqrt(e));
22 fc1=fc/1D+9; //ghz
23 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

```

24
25 //(iii) Phase constant
26 bet=(w*sqrt(e)*sqrt(1-(fc/f)^2))/(c);
27 disp('rad/m',bet,'Phase constant:');
28
29 //(iv) Propagation constant
30 gam=%i*bet;
31 disp('rad/s',gam,'Propagation constant:');
32
33 //(v) Intrinsic wave impedance
34 zte=(n/sqrt(e))/sqrt(1-(fc/f)^2);
35 ztm=(n/sqrt(e))*sqrt(1-(fc/f)^2);
36 disp('Ohm',ztm,'ZTM13','Ohm',zte,'ZTE13','Intrinsic
    wave impedance:');

```

Scilab code Exa 2.17 Air filled Rectangular Waveguide

```

1 //Page Number: 103
2 //Example 2.17
3 clc;
4 //Given
5 a=2; //cm
6 a1=1/100; //m
7 b=1; //cm
8 b1=b/100; //m
9 p=10D-3; //W
10 c=3D+8; //m/s
11 f0=10D+9; //Hz
12
13 //Peak value of electric field
14 fc=c/(2*a);
15 E02=(4*p*377)/(a1*b1*sqrt(1-(fc/f0)^2));
16 E0=sqrt(E02);

```

```
Scilab 5.4.1 Console

Peak value of electric field:

    388.33522

V/m

Maximum power transmitted:

    2340.

kW
-->
```

Figure 2.11: Air filled Rectangular Waveguide


```

17 disp('V/m',E0,'Peak value of electric field:');
18
19 //Maximum power transmitted
20 Ed=3D+6; //V/m
21 Pt=2.6D+13*(Ed/f0)^2;
22 disp('kW',Pt/1000,'Maximum power transmitted:');
23
24 //Answer is given as 2300kW but it is 2340kW

```

Scilab code Exa 2.18 Rectangular Waveguide

```

1 //Page Number: 104
2 //Example 2.18
3 clc;
4 //Given
5 f=5D+9; //Hz
6 c=3D+8; //m/s
7 a=7.5; //cm
8 a1=a/100; //m
9 b=3.5; //cm
10 b1=b/100; //m
11 lam=c/f;
12 lamm=lam*100; //m
13
14 disp('TE10 mode');
15 lamc10=2*a;
16 bet10=(2*%pi*sqrt(((lamc10/lamm)^2)-1))/lamc10;
17 disp('rad/cm',bet10,'Propogation constant:');
18 vp10=(2*%pi*f)/bet10;
19 disp('m/s',vp10/100,'Phase velocity:');
20
21 disp('TE01 mode');
22 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

65

rad/cm

Phase velocity:

0.245D+09

```

23 bet01=(2*%pi*sqrt(((lamc01/lamm)^2)-1))/lamc01;
24 disp('rad/cm',bet01,'Propogation constant:');
25 vp01=(2*%pi*f)/bet01;
26 disp('m/s',vp01/100,'Phase velocity:');
27
28 disp('TE11 mode');
29 lamc11=(2*a*b)/sqrt((a*a)+(b*b));
30 bet11=(2*%pi*sqrt(((lamc11/lamm)^2)-1))/lamc11;
31 disp('rad/cm',bet11,'Propogation constant:');
32 vp11=(2*%pi*f)/bet11;
33 disp('m/s',vp11/100,'Phase velocity:');
34
35 disp('TE02 mode');
36 lamc02=b;
37 bet02=(2*%pi*sqrt(((lamc02/lamm)^2)-1))/lamc02;
38 disp('rad/cm',bet02,'Propogation constant:');
39 disp('As beta is imaginary, mode gets attenuated');
40 alp=(2*%pi*sqrt(1-((lamc02/lamm)^2)))/lamc02;
41 disp('Np/m',alp,'Propogation constant alpha:');

```

Scilab code Exa 2.19 Rectangular Waveguide

```

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

```

```
Scilab 5.4.1 Console  
  
Attenuation constant:  
  
478.04204  
  
dB/m  
-->|
```

Figure 2.13: Rectangular Waveguide

```

12 mu=1/(c^2);
13
14 //Cut off frequency
15 lamc=2*a1;
16 fc=c/lamc;
17 w=2*%pi*fc;
18
19 //Attenuation constant
20 a=(w*sqrt(1-((f/fc)^2)))/c;;
21 adb=-20*log10(exp(-a));
22 disp('dB/m',adb,'Attenuation constant:');

```

Scilab code Exa 2.20 Ratio of cross section

```

1 //Page Number: 105
2 //Example 2.20
3 clc;
4 //Given,
5 a1=1.84;
6 a2=%pi;
7
8 r=2*%pi*(a1/a2)^2;
9 disp(r,'Cross section ratio:');

```

Scilab code Exa 2.21 Rectangular Waveguide

```

1 //Page Number: 106
2 //Example 2.21
3 clc;

```

```
Scilab 5.4.1 Console  
  
Cross section ratio:  
  
    2.1553399  
-->|
```

Figure 2.14: Ratio of cross section

```
Scilab 5.4.1 Console

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

```

4 // Given
5 c=3D+8; //m/s
6 f=15D+9; //hz
7 a=1.07; //cm
8 a1=a/100; //m
9 b=0.43; //cm
10 b1=b/100; //m
11 er=2.08;
12 tandel=0.0004;
13 lam=c/f;
14
15
16 //(i) Cut off frequency
17 m1=1;
18 n1=0;
19 fc10=(c/(2*%pi*sqrt(er))*sqrt((m1*%pi/a1)^2+(n1*%pi/
    b1)^2));
20 disp('GHz',fc10/10^9,'Cut off frequency for mode
    TE10: ');
21
22 m2=2;
23 n2=0;
24 fc20=(c/(2*%pi*sqrt(er))*sqrt((m2*%pi/a1)^2+(n2*%pi/
    b1)^2));
25 disp('Ghz',fc20/10^9,'Cut off frequency at mode TE20
    : ');
26
27 m3=0;
28 n3=1;
29 fc01=(c/(2*%pi*sqrt(er))*sqrt((m3*%pi/a1)^2+(n3*%pi/
    b1)^2));
30 disp('Ghz',fc01/10^9,'Cut off frequency at mode TE01
    : ');
31
32 //Dielectric attenuation constant
33 ad=(%pi*tandel)/(lam*sqrt(1-(fc10/f)^2));
34 adb=-20*log10(exp(-ad));
35 disp('dB/m',adb,'Attenuation constant: ');

```



```
Scilab 5.4.1 Console

Conductor attenuation constant:

    0.1123913

dB/m
-->
```

Figure 2.16: Rectangular Waveguide

Scilab code Exa 2.22 Rectangular Waveguide

```
1 //Page Number: 106
2 //Example 2.22
3 clc;
4 //Given
```

```

5 c=3D+8; //m/s
6 a=2.286; //cm
7 a1=a/100; //m
8 b=1.016; //cm
9 b1=b/100; //m
10 sig=5.8D+7; //s/m
11 f=9.6D+9; //Hz
12
13 w=2*%pi*f;
14 mu=%pi*4D-7;
15 et=377;
16
17 lam=c/f;
18 lamc=2*a1;
19 r=lam/lamc;
20
21 Rs=sqrt((w*mu)/(2*sig));
22 ac=(Rs*(1+(2*(b1/a1)*r*r)))/(et*b1*sqrt(1-(r^2)));
23 adb=-20*log10(exp(-ac));
24 disp('dB/m',adb,'Conductor attenuation constant:');

```

Scilab code Exa 2.23 Circular waveguide

```

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

```

```
Scilab 5.4.1 Console

Maximum power transmitted:

    4.3887952

kW
-->
```

Figure 2.17: Circular waveguide

```

11 p11=1.841;
12
13 fc=(p11*c)/(2*%pi*a1);
14 //Maximum power transmitted
15 pmax=1790*(a1*a1)*sqrt(1-((fc/f)^2));
16 disp('kW',pmax,'Maximum power transmitted:');

```

Scilab code Exa 2.24 Air filled circular waveguide

```

1 //Page Number: 108
2 //Example 2.26
3 clc;
4 //Given
5 c=3D+8; //m/s
6 a=5; //cm
7 a1=a/100; //m
8 f=3D+9; //hz
9 p11=1.841;
10 e=1;
11 w=2*%pi*f;
12
13 //(i) Cut off frequency
14 fc=(p11*c)/(2*%pi*a1);
15 disp('Ghz',fc/10^9,'Cut off frequency:');
16
17 //(ii) Guide wavelength
18 bet=sqrt(((w*w)/(c*c))-((p11/a1)^2));
19 lamg=(2*%pi)/bet;
20 lamg1=lamg*100; //cm
21 disp('cm',lamg1,'Guide wavelength:');
22
23 //(iii) Wave impedance
24 zte=(w*%pi*4D-7)/bet;

```

```
Scilab 5.4.1 Console

Cut off frequency:

    1.7580255

Ghz

Guide wavelength:

    12.341034

cm

Wave impedance:

    465.

ohm
-->
```

Figure 2.18: Air filled circular waveguide

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

Scilab code Exa 2.25 Air filled rectangular waveguide

```
1 //Page Number:108
2 //Example 2.25
3 clc;
4 //Given
5 c=3D+8; //m/s
6 p01=2.405;
7 a=1/100;; //cm
8 p11=1.841;
9
10 fc01=((c*p01)/(2*pi*a));
11 fc11=((c*p11)/(2*pi*a));
12 bw=fc01-fc11;
13 disp('Ghz',bw/10^9,'Bandwidth:');
```

Scilab code Exa 2.26 Rectangular Waveguide

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

```
Scilab 5.4.1 Console

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


```

10 w=2*%pi*f;
11 mu=4D-7;
12 sig=5.8D+7; //s/m
13
14 lamc=2*a;
15 lamm=c/f;//m
16 lam=lamm*100;//cm
17
18 ermax=(lam/a)^2;
19 disp(ermax,'Maximum value of dielectric constant:');
20 ermin=(lam/(2*a))^2;
21 disp(ermin,'Minimum value of dielectric constant:');
22
23 //Guide wavelength
24 lam1=lam/sqrt(er);//cm
25 lamg=lam1/sqrt(1-(lam1/lamc)^2);
26 disp('cm',lamg,'Guide wavelength:');
27
28 lamm1=lam1/100;
29 ad=(%pi/lamm1)*(tandel/sqrt(1-(lam1/lamc)^2));
30 disp('Np/m',ad,'ad:');
31 bet=2*%pi/lamg;
32 disp('rad/cm',bet,'Beta:');
33 vp=w/(bet*100);
34 disp('m/s',vp,'Phase velocity:');

```

Scilab code Exa 2.27 Circular Waveguide

```

1 //Page Number: 110
2 //Example 2.27
3 clc;
4 //Given
5 c=3D+8; //m/s

```

```
Scilab 5.4.1 Console

Cut off frequencies for TE11 mode:

    12.189714

Ghz

Cut off frequencies for TM01 mode:

    15.924096

Ghz

Dielectric attenuation:

    1.4936786

dB/m

Conductor attenuation:

    0.1168103

dB/m

Total attenuation:

    1.6104889

dB/m

Total attenuation in 30 cm line:

    0.4831467

dB
-->
```

Figure 2.21: Circular Waveguide

```

6 a=0.5; //cm
7 a1=a/100; //m
8 f=14D+9; //Hz
9 er=2.08;
10 p11=1.841;
11 p01=2.405;
12 tandel=4D-4;
13 w=2*%pi*f;
14 u=%pi*4D-7;
15 sig=4.1D+7;
16 et=377;
17
18 //(i) Cut off frequencies
19 fcte11=p11*c/(2*%pi*a1*sqrt(er));
20 fctm01=p01*c/(2*%pi*a1*sqrt(er));
21 disp('Ghz',fcte11/10^9,'Cut off frequencies for TE11
mode: ');
22 disp('Ghz',fctm01/10^9,'Cut off frequencies for TM01
mode: ');
23
24 //(ii) Overall noise
25 //Dielectric attenuation
26 ad=(%pi*sqrt(er)*tandel*f)/(c*sqrt(1-((fcte11/f)^2))
);
27 disp('dB/m',ad*8.686,'Dielectric attenuation:');
28
29 //Conductor attenuation
30 k=(2*%pi*f*sqrt(er))/c;
31 bet=sqrt((k*k)-((p11/a1)^2));
32 //Surface resistance
33 rs=sqrt((w*u)/(2*sig));
34 kc2=(p11/a1)^2;
35
36 ac=(rs*(kc2-((k^2)/((p11^2)-1))))/(a1*k*et*bet);
37 disp('dB/m',ac*8.686,'Conductor attenuation:');
38
39 //Total attenuation
40 a=(ac+ad)*8.686;

```

```

41 disp('dB/m',a,'Total attenuation:');
42 ta=a*0.3;
43 disp('dB',ta,'Total attenuation in 30 cm line:');
44
45 //Answer for condcutor attenuation is wrong in book,
    hence answer for total loss is different

```

Scilab code Exa 2.28 Rectangular Waveguide

```

1 //Page Number: 112
2 //Example 2.28
3 clc;
4 //Given
5 c=3D+8; //m/s
6 er=9;
7 a=7; //cm
8 a1=a/100; //m
9 b=3.5; //cm
10 b1=b/100; //m
11 ur=1;
12 f1=2D+9; //Hz
13
14 //(i) Cut off frequency
15 lamc=2*a1;
16 fc=c/(lamc*sqrt(ur*er));
17 disp('Ghz',fc/10^9,'Cut off frequency:');
18
19 //(ii) Phase velocity
20 lam=c/f1; //m
21 lam1=lam*100; //cm
22 lamc1=lamc*100; //cm
23 lamg=lam1/(sqrt((ur*er)-((lamc1/lam1)^2))); //cm
24 lamg1=lamg/100; //m

```

```
Scilab 5.4.1 Console

Cut off frequency:

    0.7142857

Ghz

Phase velocity:

    1.052D+08

m/s

Guide wavelength:

    5.2610892

cm
-->
```

Figure 2.22: Rectangular Waveguide

```

25 vp=f1*lamg1;
26 disp('m/s',vp,'Phase velocity:');
27
28 ///(iii) Guide wavelength
29 disp('cm',lamg,'Guide wavelength:');

```

Scilab code Exa 2.29 Circular waveguide

```

1 //Page Number: 112
2 //Example 2.29
3 clc;
4 //Given
5 c=3D+8; //m/s
6 fc=9D+9; //Hz
7 er=1;
8 er1=4;
9 p11=1.841;
10
11 //(i) air filled
12 a=(p11*c)/(2*%pi*fc*sqrt(er));
13 disp('cm',a*100,'Inside diameter if air filled:');
14 //(ii) dielectric field
15 a1=(p11*c)/(2*%pi*fc*sqrt(er1));
16 disp('cm',a1*100,'Inside diameter if dielectric
    filled:');
17
18 //Answers are calculated wrong in book

```

Scilab code Exa 2.30 Cutoff frequencies

```
Scilab 5.4.1 Console

Inside diameter if air filled:

    0.9766808

cm

Inside diameter if dielectric filled:

    0.4883404

cm

-->
```

Figure 2.23: Circular waveguide

```
Scilab 5.4.1 Console

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


```

1 //Page Number: 113
2 //Example 2.30
3 clc;
4 //Given
5 c=3D+8; //m/s
6 er=2.55;
7 d=1; //mm
8 d1=d/1000; //m
9
10 //Cut off frequencies
11 fctm0=0;
12 disp('Ghz',fctm0,'Cut off frequency for mode TM0:');
13
14 fcte1=c/(4*d1*sqrt(er-1));
15 disp('Ghz',fcte1/10^9,'Cut off frequency at mode TE1
      :');
16
17 fctm1=c/(2*d1*sqrt(er-1));
18 disp('Ghz',fctm1/10^9,'Cut off frequency at mode TM1
      :');
19
20
21 //Answers are calculated wrong in book

```

Scilab code Exa 2.31 Dielectric constant

```

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

```

```
Scilab 5.4.1 Console  
  
Dielectric constant:  
  
    7.25  
-->|
```

Figure 2.25: Dielectric constant

```
8 d1=d/1000; //m
9
10 //Cut off frequency
11 fc=0.8*f;
12 //Dielectric constant
13 er=(c/(2*d1*fc))^2+1;
14 disp(er, 'Dielectric constant:');
```

Chapter 3

Microwave Network Analysis

Scilab code Exa 3.4 Scattering matrix

```
1 //Page Number: 142
2 //Example 3.4
3 clc;
4 //Given
5
6 [z]=[4 2;2 4];
7 [I]=[1 0;0 1];
8
9 //Scattering matrix
10 [s]={[z]-[I]}*inv([z]+[I]);
11 disp([s], 'Scattering Matrix:');
```

Scilab code Exa 3.5 Network

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

```
Scilab 5.4.1 Console

Scattering Matrix:

0.5238095  0.1904762
0.1904762  0.5238095

-->
```

Figure 3.1: Scattering matrix

Scilab 5.4.1 Console

Required Waves:

- 0.0132336 - 0.0585224i

- 0.0352897 - 0.1560597i

-->|

Figure 3.2: Network

```

2 //Example 3.5
3 clc;
4 //Given
5 P=12.8D-3; //W
6 l=3; //cm
7 lamb=4.2; //cm
8 vswr=2.2;
9 jfi=%i*4.49;
10
11 //ap
12 ap=sqrt(2*P);
13
14 //Phase shift
15 bl=(2*%pi*l)/lamb;
16 //bp
17 bp=(ap*(vswr-1))/(vswr+1);
18
19 a=ap*exp(jfi);
20 b=bp*exp(jfi);
21 disp(a,b, 'Required Waves: ');

```

Scilab code Exa 3.6 Microwave network

```

1 //Page Number: 143
2 //Example 3.6
3 clc;
4 //Given
5 S11=0.10;
6 S12=0.90;
7 A12=-45;
8 S21=0.90;
9 A21=45;
10 S22=0.3;

```

```
Scilab 5.4.1 Console

Network is not reciprocal

Network is not lossless

Return Loss:

    5.6286888

dB

-->
```

Figure 3.3: Microwave network


```

11
12 //(i) Network is reciprocal
13 if(A12==A21)
14     disp('Network is reciprocal');
15 else
16
17     disp('Network is not reciprocal');
18 end
19
20 //(ii) Network is lossles
21 x=(S11^2)+(S12^2);
22 if(x==1)
23     disp('Network is lossless');
24 else
25
26     disp('Network is not lossless');
27 end
28
29 //(iii)Return loss
30 T=S11-((S12*S21)/(1+S22));
31 Tm=-T; //mod of T
32 L=-20*log10(Tm);
33 disp('dB',L,'Return Loss:');

```

Scilab code Exa 3.12 Transistor amplifier circuit

```

1 //Page Number: 163
2 //Example 3.12
3 clc;
4 //Given
5 S11=0.6;
6 S12=0.045;
7 S21=2.5;

```

```
Scilab 5.4.1 Console

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

```

8 S22=0.50;
9 TS=0.5;
10 TL=0.4;
11 Z0=50; //ohm
12 Vrms=10; //V
13
14 //(i) Gain Parameters
15 //(i) Reflection coefficients of input and output
16 Tin=S11+((S12*S21*TL)/(1-(S22*TL)));
17 Tout=S22+((S12*S21*TS)/(1-(S22*TS)));
18
19 //Transducer Gain
20 x=(1-(TS)^2)/((1-(S11*TS))^2);
21 y=(S21*S21);
22 z=(1-(TL)^2)/((1-(Tout*TL))^2);
23 GT=x*y*z;
24 disp(GT,'Transducer Gain:');
25
26 //Available Power Gain
27 z1=1-(Tout)^2;
28 GA=(x*y)/z1;
29 disp(GA,'Available power Gain:');
30
31 //Power Gain
32 z2=1-(Tin)^2;
33 GP=(x*y)/z2;
34 disp(GP,'Power Gain:');
35
36 //(ii) Power levels
37 //Power available at source
38 Pavs=(sqrt(2)*Vrms)^2/(8*Z0);
39 disp('W',Pavs,'Power available at source:');
40
41 P1=9.4*Pavs;
42 //Power available at input
43 Pin=P1/13.5;
44 disp('W',Pin,'Power available at input:');
45

```

```
46 //(iii) VSWRs
47 M1=Pin/Pavs;
48 M2=P1/(9.6*Pavs);
49
50 Tin1=sqrt(1-M1);
51 Tout1=sqrt(1-M2);
52
53 vswrin=(1+Tin1)/(1-Tin1);
54 disp(vswrin, 'Input VSWR: ');
55 vswrout=(1+Tout1)/(1-Tout1);
56 disp(vswrout, 'Output VSWR: ');
57
58 //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

```
1 //Page Number: 193
2 //Example 4.1
3 clc;
4 //Given
5 a=5; //cm
6 a1=a/100; //m
7 b=2; //cm
8 b1=b/100; //m
9 c=15; //cm
10 c1=c/100; //m
11
12 //(i) Air filled cavity
13 m=1;
14 n=0;
15 p=1;
16 c=3D+8; //for air
17 fr=(1/2)*c*sqrt((m/a1)^2+(n/b1)^2+(p/c1)^2); //hz
```

```
Scilab 5.4.1 Console

Resonant frequency for an air filled cavity:

    3.1622777

Ghz

Resonant frequency for dielectric cavity:

    1.9764235

Ghz
-->
```

Figure 4.1: Rectangular cavity resonator

```
Scilab 5.4.1 Console

Length c:

    0.6530298

cm
-->
```

Figure 4.2: Rectangulr resonator

```
18 disp('Ghz',fr/10^9,'Resonant frequency for an air
    filled cavity:');
19
20 //(ii) Dielectric filled cavity
21 er=2.56;
22 fr1=(1/2)*(c/sqrt(er))*sqrt((m/a1)^2+(n/b1)^2+(p/c1)
    ^2);//hz
23 disp('Ghz',fr1/10^9,'Resonant frequency for
    dielectric cavity:');
```

Scilab code Exa 4.2 Rectangulr resonator

```

1 //Page Number: 193
2 //Example 4.2
3 clc;
4 //Given
5 a=0.38; //cm
6 a1=a/100; //m
7 b=0.76; //cm
8 b1=b/100; //m
9 f=50D+9;
10 c=3D+8;
11
12 //Length for TE102
13 m=1;
14 n=0;
15 p=2;
16 l=1/sqrt((f/c)^2-(1/(4*b1^2))); //m
17 disp('cm',l*100,'Length c:');

```

Scilab code Exa 4.3 X band resonator

```

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

```



```
Scilab 5.4.1 Console

Shortest cavity length:

  1.987769

cm

Qw of the resonator operating in TE101 mode

  7990.3243

-->
```

Figure 4.3: X band resonator

```

14 eet=377;
15
16 //Shortest cavity length
17 lamc=2*a1; //m
18 fc=c/lamc; //hz
19 lam=c/f; //m
20 lamg=lam/sqrt(1-(fc/f)^2); //m
21 sc=lamg/2; //m
22 disp('cm',sc*100,'Shortest cavity length:');
23
24 //Qw of the resonator operating in TE101 mode
25 rs=sqrt((w*u)/(2*sig)); //ohm
26 lamr=c/f;
27 x=((a1*b1)/(sc^2))+((sc^2+a1^2)/(2*sc*a1))+((b1*sc/
    a1^2));
28 qw=(2*pi*eet*a1*b1*sc)/(rs*(lamr^3)*x);
29 disp(qw,'Qw of the resonator operating in TE101 mode
    ');

```

Scilab code Exa 4.4 Rectangular resonator

```

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

```

```
Scilab 5.4.1 Console

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

```

13 sig=5.813D+7;
14 oneby=3D+8;
15 u=4D-7*%pi;
16 w=2*%pi*f;
17 eet=377;
18
19 //Length at p=1
20 m=1;
21 n=0;
22 p=1;
23 z=(f*2*sqrt(er))/c;
24 cp1=p/sqrt((z^2)-((m/a1)^2)-((n/b1)^2));
25 disp('cm',cp1*100,'Length of resonator at p=1:');
26
27 //At p=2
28 cp2=cp1*2;
29 disp('cm',cp2*100,'Length of resonator at p=2:');
30
31 //Qw
32 rs=sqrt((w*u)/(2*sig)); //ohm
33 lamr=c/(f*sqrt(er));
34 x=((a1*b1)/(cp1^2))+((cp1^2+a1^2)/(2*cp1*a1))+(b1*
    cp1/a1^2));
35 qw=(2*%pi*(eet/sqrt(er))*a1*b1*cp1)/(rs*(lamr^3)*x);
36 qd=1/tandel;
37 q=(qw*qd)/(qw+qd);
38 disp(q,'Q for TE101 mode:');

```

Scilab code Exa 4.5 Cylindrical resonator

```

1 //Page Number: 196
2 //Example 4.5
3 clc;

```

```
Scilab 5.4.1 Console

TE modes

Resonant frequency for mode TE010:

    10.940294

Ghz

Resonant frequency for mode TE111:

    7.437512

Ghz

Resonant frequency for mode TE211:

    9.4423009

Ghz

TM modes:

Resonant frequency for mode TM010

    5.7415146

Ghz

resonant frequency for mode TM011:

    8.3045162

Ghz

Resonant frequency for mode TM111:

    10.940294

Ghz
-->
```

Figure 4.5: Cylindrical resonator

```

4 // Given
5 c=3D+8; //m/s
6 a=2; //cm
7 a1=a/100; //m
8 b=2.5; //cm
9 b1=b/100; //m
10
11 disp('TE modes');
12 h01=3.832;
13 fr=(c/(2*pi))*sqrt((h01/a1)^2+(pi/b1)^2); //hz
14 disp('Ghz',fr/10^9,'Resonant frequency for mode
    TE010:');
15
16 h11=1.841;
17 fr1=(c/(2*pi))*sqrt((h11/a1)^2+(pi/b1)^2); //hz
18 disp('Ghz',fr1/10^9,'Resonant frequency for mode
    TE111:');
19
20 h21=3.054;
21 fr2=(c/(2*pi))*sqrt((h21/a1)^2+(pi/b1)^2); //hz
22 disp('Ghz',fr2/10^9,'Resonant frequency for mode
    TE211:');
23
24 disp('TM modes:');
25 l1=0;
26 h011=2.405;
27 fr3=(c/(2*pi))*sqrt((h011/a1)^2+(pi*l1/b1)^2); //hz
28 disp('Ghz',fr3/10^9,'Resonant frequency for mode
    TM010');
29
30 l2=1;
31 fr4=(c/(2*pi))*sqrt((h011/a1)^2+(pi*l2/b1)^2); //hz
32 disp('Ghz',fr4/10^9,'resonant frequency for mode
    TM011:');
33
34 l3=1;
35 h111=3.832;
36 fr5=(c/(2*pi))*sqrt((h111/a1)^2+(pi*l3/b1)^2); //hz

```

```
Scilab 5.4.1 Console

Ratio of Qs of cylindrical and rectangular resonators:

    1.0828829
-->
```

Figure 4.6: Resonator comparison

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

Scilab code Exa 4.6 Resonator comparison

```
1 //Page Number: 196
2 //Example 4.6
3 clc;
4 //Given
5 QTM010=1.202;
6 QTE101=1.11;
7
8 r=QTM010/QTE101;
9 disp(r,'Ratio of Qs of cylindrical and rectangular  
    resonators:');
```

```
Scilab 5.4.1 Console

Q of resonator:

    1931.8192
-->|
```

Figure 4.7: Cubical Resonator

Scilab code Exa 4.7 Cubical Resonator

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



```

7 a1=a/100; //m
8 sig=5.8D+7;
9 er=2.25;
10 tandel=4D-4;
11 ur=1;
12 n=377;
13 w=2*%pi*f;
14 u=4D-7*%pi;
15
16 //Q of resonantor
17 rs=sqrt(w*u/(2*sig)); //ohm
18 qw=(0.7419*n)/(rs*sqrt(2.25));
19 qd=1/tandel;
20 q=(qw*qd)/(qw+qd);
21 disp(q, 'Q of resonator: ');

```

Scilab code Exa 4.8 Rectangular Resonant Cavity

```

1 //Page Number: 198
2 //Example 4.8
3 clc;
4 //Given
5 a=5; //cm
6 a1=a/100; //m
7 b=4; //cm
8 b1=b/100; //m
9 c=10; //cm
10 c1=c/100; //m
11 sig=5.8D+7;
12 u0=4D-7*%pi;
13 er=3;
14 eet=377;
15

```

```
Scilab 5.4.1 Console

Resonant frequency:

    1.9364917

Ghz

Q for TE101 mode:

    10916.466

Q for lossy dielectric:

    2927.3599

-->
```

Figure 4.8: Rectangular Resonant Cavity

```

16 ur=1;
17 spl=3D+8;
18 tandel=2.5D-4;
19
20 //TE101 mode
21 m=1;
22 n=0;
23 p=1;
24 fr=(spl/(2*sqrt(er*ur)))*sqrt((m/a1)^2+(n/b1)^2+(p/
    c1)^2); //hz
25 disp('Ghz',fr/10^9,'Resonant frequency:');
26
27 w=2*%pi*fr;
28 rs=sqrt((w*u0)/(2*sig)); //ohm
29 lamr=spl/(fr*sqrt(er));
30 x=((a1*b1)/(c1^2))+((c1^2+a1^2)/(2*c1*a1))+((b1*c1)
    /a1^2));
31 qw=(2*%pi*(eet/sqrt(er))*a1*b1*c1)/(rs*(lamr^3)*x);
32 disp(qw,'Q for TE101 mode:');
33
34 qd=1/tandel;
35 q=(qw*qd)/(qw+qd);
36 disp(q,'Q for lossy dielectric:');
37
38 //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

```

1 //Page Number: 198
2 //Example 4.9
3 clc;
4 //Given

```

```
Scilab 5.4.1 Console

Range of piston movement:

    0.7104251

cm
-->|
```

Figure 4.9: Rectangular resonator

```
5 c=3D+8; //m/s
6 a=2.286; //cm
7 a1=a/100; //m
8 b=1.106; //cm
9 b1=b/100; //m
10
11 //For fr1=9.3D+9;
12 fr1=9.3D+9; //hz
13 lamr1=c/fr1; //m
14 c1=(2*a1)/sqrt((((2*a1)/lamr1)^2)-1);
15
16 //For fr2=10.2D+9;
17 fr2=10.2D+9; //hz
18 lamr2=c/fr2; //m
19 c2=(2*a1)/sqrt((((2*a1)/lamr2)^2)-1);
20
21 r=c1-c2;
22 disp('cm',r*100,'Range of piston movement:');
```

Scilab code Exa 4.10 Cylindrical resonator

```
1 //Page Number: 199
2 //Example 4.10
3 clc;
4 //Given
5 a=3; //cm
6 a1=a/100; //m
7 d=10; //cm
8 d1=d/100; //m
9 df=2.5D+6;
10 er=2.25;
11 p11=1.841;
12 c=3D+8; //m/s
13
14 //Resonant frequency
15 fr=(c/2)*(sqrt((p11/a1)^2+(%pi/d1)^2)); //hz
16 disp('Ghz',fr/10^9,'Resonant frequency:');
17
18 //Q without dielectric
19 q0=fr/df;
20 disp(q0,'Q wirhout dielectric constant:');
21
22 // Q with dielectric
23 fr1=fr/sqrt(er);
24 qd=1D+3;
25 q=(q0*qd)/(q0+qd);
26 disp(q,'Q with dielectric constant:');
```

```
Scilab 5.4.1 Console

Resonant frequency:

    10.341114

Ghz

Q wirhout dielectric constant:

    4136.4455

Q with dielectric constant:

    805.31284

-->
```

Figure 4.10: Cylindrical resonator

```
Scilab 5.4.1 Console

Radius of resonantor

    1.221374

cm

Q of the resonator:

    10763.303

-->
```

Figure 4.11: Cylindrical resonantor

Scilab code Exa 4.11 Cylindrical resonantor

```
1 //Page Number: 200
2 //Example 4.11
3 clc;
4 //Given
5 f=9.375D+9; //hz
6 sig=5.8D+7;
7 eet=377;
8 c=3D+8; //m/s
9 w=2*%pi*f;
10 r=1.5;
11 u=4D-7*%pi;
12
13 //Radius
14 a=c/(f*2.62); //m
15 disp('cm',a*100,'Radius of resonantor');
16
17 //O
18 rs=sqrt((w*u)/(2*sig)); //ohm
19 x=1.202*eet;
20 y=rs*(1+(1/r));
21 q=x/y;
22 disp(q,'Q of the resonator:');
23
24 //Answer for Q is calculated as 10875 in book but it
    is 10763.303
```

Scilab code Exa 4.12 Cylindrical Resonator


```
Scilab 5.4.1 Console

Length of resonator:

    5.2730605

cm

Q of resonator:

    2381.0836

-->
```

Figure 4.12: Cylindrical Resonator

```

1 //Page Number: 215
2 //Example 4.12
3 clc;
4 //Given
5 f=5D+9; //hz
6 sig=5.813D+7;
7 er=2.25;
8 tandel=4D-4;
9 c=3D+8; //m/s
10 h01=3.832;
11 u=4D-7*%pi;
12
13 //Length of resonator
14 lamr=c/(f*sqrt(er));
15 d=sqrt([ {( (2*3.832)^2)+( %pi*%pi) }*(lamr*lamr)
        ]/(2*2*%pi*%pi));
16 disp('cm',d*100,'Length of resonator:');
17
18 //Q of resonator
19 n=(120*%pi)/sqrt(er);
20 Rs=sqrt((f*u)/sig);
21 a=d/2;
22 Qw1=n*[[ (h01/a)^2+(%pi/d)^2]^(3/2)];
23 Qw2=2*Rs*[((h01*h01)/(a*a*a))+((2*%pi*%pi)/(d*d*d))
        ];
24 Qw=Qw1/Qw2;
25 Qd=1/tandel;
26 Q=(Qw*Qd)/(Qw+Qd);
27 disp(Q,'Q of resonator:');
28
29 //Value of Qw is calculated wrong in the book, it
        should be 50057.91 instead of 53473.8
30 //Hence the value of Q also differs

```

```
Scilab 5.4.1 Console

Power at port 1:

    75.

mW

Power at port 2:

    25.

mW

Power at port 3:

    50.

mW
-->

I
```

Figure 4.13: Lossless plane H tee

Scilab code Exa 4.13 Lossless plane H tee

```
1 //Page Number: 215
2 //Example 4.13
3 clc;
4 //Given
5 p=100; //mW
6 //As 2 and 3 are matched terminals
7 x=1/2;
8 y=1/sqrt(2);
9 s=[x -x y;-x 0 y;y y 0];
10
11 //Power delivered
12 //Port 1
13 p1=p*(1-s(1,1)^2);
14 disp('mW',p1,'Power at port 1:');
15
16 //Port2
17 p2=p*s(2,1)^2;
18 disp('mW',p2,'Power at port 2:');
19
20 //Port 3
21 p3=p*s(3,1)^2;
22 disp('mW',p3,'Power at port 3:');
```

Scilab code Exa 4.14 E plane tee

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

```
Scilab 5.4.1 Console

Power at port 1:

    19.753086

mW

Power at port 2:

    19.834711

mW

-->

I
```

Figure 4.14: E plane tee

```

7 x=sqrt(2);
8 s=[1 1 x;1 1 -x;x -x 0];
9 r1=40; //ohm
10 r2=60; //ohm
11 w=50; //ohm
12
13 //Reflection coefficients
14 T1=(w-r1)/(w+r1);
15 T2=(r2-w)/(r2+w);
16
17 //As power is fed into 1 and 2 equally
18 pd=p/2;
19
20 //Power delivered
21 //Port 1
22 p1=pd*(1-T1^2);
23 disp('mW',p1,'Power at port 1:');
24
25 //Port2
26 p2=pd*(1-T2^2);
27 disp('mW',p2,'Power at port 2:');

```

Scilab code Exa 4.15 Magic Tee

```

1 //Page Number: 216
2 //Example 4.15
3 clc;
4 //Given
5 T1=1/2;
6 T2=3/5;
7 T3=0;
8 T4=4/5;
9 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

```

10 //S matrix for magic Tee
11 x=1/sqrt(2);
12 s=[0 0 x x;0 0 x -x;x x 0 0;x -x 0 0];
13 //Using the input output relation
14 // [b]=[s]*[a]
15 b=[0.6565;0.7576;0.5536;0.0892];
16
17 //(i) Power transmitted through ports
18 //Port 1
19 p1=(1/2)*b(1,1)^2*(1-T1^2);
20 disp('W',p1,'Power at port 1:');
21
22 //Port2
23 p2=(1/2)*(b(2,1)^2)*(1-(T2^2));
24 disp('W',p2,'Power at port 2:');
25
26 //Port 4
27 p4=(1/2)*b(4,1)^2*(1-T4^2);
28 disp('W',p4,'Power at port 4:');
29
30 //(ii) Power reflected at port 3
31 //Port 3
32 p3=p*b(3,1)^2;
33 disp('W',p3,'Power at port 3:');
34
35 //(iii) Power absorbed
36 pabs=p-(p1+p2+p3+p4);
37 disp('W',pabs,'Power absorbed:');
38
39 //Answer for power absorbed is calculated wrong in
    book

```

Scilab code Exa 4.18 Directional Coupler


```

Scilab 5.4.1 Console

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

```

1 //Page Number: 236
2 //Example 4.18
3 clc;
4 //Given
5 C=10; //dB
6 D=30; //dB
7
8 //Parameters
9 bet=10^(-C/20);
10 x=bet/(10^(D/20));
11 a=sqrt(1-(bet*bet));
12 //Scattering matrix
13 //Assuming symmetry
14 s=[0 a x (bet*%i);a 0 (bet*%i) x;x (bet*%i) 0 a;(bet
    *%i) x a 0];
15 disp(s,'Scattering matrix:');

```

```
Scilab 5.4.1 Console

VSWR:

    2.0075758

Power delivered:

    791.

mW

-->
```

Figure 4.17: Directional coupler

Scilab code Exa 4.20 Directional coupler

```
1 //Page Number: 238
2 //Example 4.20
3 clc;
4 //Given
5 vswr=2;
6 D1=8; //mW
7 D2=2; //mW
8
9 //Reflection coefficient at arm 4
10 T=(vswr-1)/(vswr+1);
11 //Power delivered to D1
12 P=(D1*100)/(1-T^2);
13 P1=0.99*P;
14 //Power reflected at D1
15 W1=(P/100)*T*T;
16 //Power reflected at load
17 W2=D2-W1;
18 Tt=sqrt((W2*100)/(P1));
19 pt=(1+Tt)/(1-Tt);
20 disp(pt, 'VSWR: ');
21 P1=P1*(1-(Tt*Tt));
22 disp('mW', P1, 'Power delivered:');
23
24 //Answer for P1 should be 792 but it is given as 800
```

Scilab code Exa 4.21 Isolator Matrix

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

```
Scilab 5.4.1 Console

Scattering matrix:

    0.          0.0316228
    0.9549926   0.

-->
```

Figure 4.18: Isolator Matrix

```
Scilab 5.4.1 Console

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

```
2 //Example 4.21
3 clc;
4 //Given
5 I=30; //dB
6 I1=0.4; //dB
7
8 S12=10^(I/-20);
9 S21=10^(I1/-20);
10 s=[0 S12;S21 0];
11 disp(s, 'Scattering matrix:');
```

Scilab code Exa 4.22 Circulator Matrix

```
1 //Page Number: 240
2 //Example 4.22
3 clc;
4 //Given
5 I=30; //dB
6 I1=2; //dB
7 p=1.3;
8
9 //Elements
10 T=(p-1)/(p+1);
11 S11=T;
12 S22=T;
13 S33=T;
14 S12=10^(-I1/20);
15 S13=10^(-I/20);
16 S21=S13;
17 S32=S13;
18 S23=S12;
19 S31=S23;
20 s=[S11 S21 S31;S12 S22 S32;S13 S23 S33];
21 disp(s, 'Scattering matrix:');
```

Scilab code Exa 4.23 Rectangular Waveguide

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

```
Scilab 5.4.1 Console

Position:

    0.9925756

cm

-->
```

Figure 4.20: Rectangular Waveguide

```

8 a=2.29; //cm
9 a1=a/100;
10 b=1.02; //cm
11 b1=b/100;
12
13 //E/H
14 w=2*%pi*f;
15 EbyH=(w*u)/sqrt(((w/c)^2)+((%pi/a1)^2));
16 lam=c/f;
17 lamc=2*a1;
18 d=(1/4)*(lam/sqrt(1-((lam/lamc)^2)));
19 disp('cm',d*100,'Position:');
20
21 //Answer for positon is calculated wrong in book

```

Scilab code Exa 4.24 Attenuator matrix

```

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

```

```
Scilab 5.4.1 Console

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

```
1 //Page Number: 288
2 //Example 5.1
3 clc;
4 //Given
5 f=10D+9; //Hz
6 v=9D+3; //V
7 i=40D-3; //A
8 l=3; //cm
9 l1=1/100; //m
10 G=2D-6; //mho
11 bet=0.92;
12 j1x=0.582;
13 x=1.841;
14 ebym=1.7D+11; //J
15
16 //Maximum voltage
17 w=2*%pi*f;
18 v0x=sqrt(2*ebym);
19 thet=(w*l1)/(v0x*sqrt(v));
```

```
Scilab 5.4.1 Console

Maximum voltage:

    20.261554

V

Power gain:

    127.42044

%

-->
```

Figure 5.1: Two Cavity Klystron

```

20
21 av=(bet^2*thet*i*j1x)/(x*v*G);
22 disp('V',av,'Maximum voltage:');
23
24 //Power Gain
25 ic=2*i*j1x;
26 v2=(bet*ic)/G;
27 pout=bet*ic*v2;
28 pin=2*i*v;
29
30 //Efficiency
31 eet=pout/pin;
32 disp('%',eet*100,'Power gain:');
33
34 //Answer for efficiency comes out to be wrong, it is
    calculated wrongly in book

```

Scilab code Exa 5.2 Two cavity Klystron

```

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

```

```
Scilab 5.4.1 Console
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

```

15 x=1.841;
16
17 //(i) Beam Voltage
18 v0=(m*l1*l1*f*f)/(2*e*n*n);
19 disp('V',v0,'Beam voltage:');
20
21 //(ii) Input voltage
22 v1=x*v0/(%pi*bet*n);
23 disp('V',v1,'Input voltage:');
24
25 //(iii) Output voltage
26 v2=0.25*v0;
27 disp('V',v2,'Output voltage');
28
29 //(iv) Power output
30 pmax=i*v0*j1x;
31 disp('W',pmax,'Maximum power output:');
32
33 //(v) Efficiency
34 eet=j1x*bet*v2/v0;
35 disp('%',eet*100,'Efficiency:');

```

Scilab code Exa 5.3 Two cavity Klystron

```

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

```

```
Scilab 5.4.1 Console

Input gap voltage:

    124.87069

Voltage gain:

    9.1858249
-->
```

Figure 5.3: Two cavity Klystron

```

10 d1=d/1000; //m
11 l=3.5; //cm
12 l1=1/100; //m
13 rsh=32D+3; //ohms
14 j1x=0.582;
15 x=1.841;
16
17 //(i) Input gap voltage
18 w=2*%pi*f;
19 v0=(5.93D+5*sqrt(V));
20 thetag=(w*d1)/v0;
21 bet=sin(thetag/2)/(thetag/2);
22 theta0=(w*l1)/v0;
23 v1=(2*V*x)/(bet*theta0);
24 disp(v1,'Input gap voltage:');
25
26 //(ii) Voltage gain
27 av=(bet^2*theta0*j1x*rsh)/(r0*x);
28 disp(av,'Voltage gain:');

```

Scilab code Exa 5.4 Two cavity Klystron

```

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

```



```
Scilab 5.4.1 Console  
  
Input gap voltage:  
  
    95.547121  
  
V  
  
Voltage gain:  
  
    8.757021  
  
Efficiency:  
  
    46.672035  
  
%  
  
Beam loading conductance:  
  
    0.0000010  
-->|
```

Figure 5.4: Two cavity Klystron

```

12 l1=4/100; //m
13 j1x=0.582;
14 x=1.841;
15 rsh=30D+3; //ohm
16
17 //(i) Input gap voltage
18 w=2*%pi*f;
19 v0=(5.93D+5*sqrt(V));
20 thetag=(w*d1)/v0;
21 bet=sin(thetag/2)/(thetag/2);
22 theta0=(w*l1)/v0;
23 vmax=(2*V*x)/(bet*theta0);
24 disp('V',vmax,'Input gap voltage:');
25
26 //(ii) Voltage gain
27 av=(bet*bet*theta0*j1x*rsh)/(r0*x);
28 disp(av,'Voltage gain:');
29
30 //(iii) Efficiency
31 v2=bet*2*i0*j1x*rsh;
32 eet=(bet*2*i0*j1x*v2)/(2*i0*V);
33 disp('%',eet*100,'Efficiency:');
34
35 //(iv) Beam loading conductance
36 gbl=(i0/(2*V))*((bet*bet)-(bet*cos(thetag/2)));
37 disp(gbl,'Beam loading conductance:');
38
39 //Ansewr for beam loading conductance is calculated
   wrong in book

```

Scilab code Exa 5.5 Two cavity Klystron

1 //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

```

2 //Example 5.5
3 clc;
4 //Given
5 f=3D+9; //hz
6 v=900; //V
7 i=30D-3; //A
8 d=4; //cm
9 d1=d/100; //m
10 gap=1; //mm
11 gap1=1/1000; //m
12 rsh=40D+3; //ohm
13 x=1.841;
14 j1x=0.582;
15 r=40D+3; //ohm
16 ebym=1.758D+11; //J
17
18 //(i) Electron velocity
19 v0=sqrt(2*ebym*v);
20 disp('m/s',v0,'Electron velocity:');
21
22 //(ii) Electron transit time
23 t=d1/v0;
24 disp('s',t,'Electron transit time:');
25
26 //(iii) Input voltage gap
27 w=2*%pi*f;
28 theta0=(w*d1)/v0;
29 thetag=(w*gap1)/v0;
30 bet=sin(thetag/2)/(thetag/2);
31 v2=(2*v*x)/(bet*theta0);
32 disp('V',v2,'Input voltage gap:');
33
34 //(iv) Voltage gain
35 av=(bet^2*theta0*j1x*rsh)/(x*r);
36 disp(av,'Voltage gain:');
37
38 //Values of v and f are changed in question and
    answer, hence vaules used in answer are taken.

```

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

Scilab code Exa 5.6 Two cavity Klystron

```
1 //Page Number: 292
2 //Example 5.6
3 clc;
4 //Given
5 f=8D+9; //hz
6 i=2.5; //A
7 v=20D+3; //V
8 bet=1;
9 amp=10*sqrt(2); //V
10 rsh=10D+3; //ohm
11 rsho=30D+3; //ohm
12 dc=1D-6; //c/m^3
13 rf=0.5;
14 e=1.6D-19;
15 ee=8.854D-12;
16 m=9.1D-31; //kg
17
18 //(i) Induced current
19 w=2*%pi*f;
20 wq=rf*sqrt((e*dc)/(m*ee));
21
22 //Amplitude of induced current
23 ic=(i*w*(bet^2)*amp)/(2*v*wq);
24 disp('A',ic,'Induced current:');
25
26 //Induced voltage
27 icrms=ic/sqrt(2);
28 v2rms=icrms*rsho;
29 disp('V',v2rms,'Induced voltage:');
```

```
Scilab 5.4.1 Console

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

```

30
31 //(ii) Power gain
32 pg=((i*w)^2)*(bet^4)*rsh*rsho)/(4*((v*wq)^2));
33 pgdb=10*log10(pg);
34 disp('dB',pgdb,'Power gain:');
35
36 //(iii) Electronic efficiency
37 eeta=((icrms^2)*rsho)/(i*v);
38 disp('%',eeta*100,'Electronic efficiency:');

```

Scilab code Exa 5.7 Two cavity Klystron

```

1 //Page Number: 294
2 //Example 5.7
3 clc;
4 //Given
5 f=3D+9; //hz
6 l=4; //cm
7 l1=4/100; //m
8 d=0.1; //cm
9 d1=d/100; //m
10 V=900; //V
11 i0=30D-3; //A
12 rsh=25D+3; //ohm
13 x=1.841;
14 j1x=0.582;
15
16 //(i) Input voltage for maximum output
17 v0=0.593D+6*sqrt(V);
18 w=2*%pi*f;
19 theta0=w*l1/v0; //rad
20 thetag=w*d1/v0; //rad
21 bet=sin(thetag/2)/(thetag/2);

```

```
Scilab 5.4.1 Console

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


```

22 v1max=2*V*x/(bet*theta0); //v
23 disp('V',v1max,'Input voltage for maximum output:');
24
25 //(ii) Voltage gain
26 r0=V/i0;//ohm
27 av=((bet^2)*theta0*j1x*rsh)/(x*r0);//V
28 disp('V',av,'Voltage gain:');
29
30 //(iii) Efficiency
31 ic=2*i0*j1x; //A
32 v2=bet*ic*rsh; //V
33 eet=bet*ic*v2/(2*i0*V);
34 disp('%',eet*100,'Efficiency:');
35
36 //(iv) Beam loading conductance
37 gb=(i0/(V*2))*(bet^2-(bet*cos(thetag/2)));//ohm
38 disp('ohm',gb,'Beam loading conductance:');

```

Scilab code Exa 5.8 Two cavity Klystron

```

1 //Page Number: 295
2 //Example 5.8
3 clc;
4 //Given
5 f=5D+9; //hz
6 v0=10D+3; //V
7 d=1; //mm
8 d1=d/1000; //m
9 v1=100; //V
10
11 //(i) Gap transit time
12 vv0=0.593D+6*sqrt(v0);//m/sec
13 tau=d1/vv0;//sec

```

```
Scilab 5.4.1 Console

Gap transit time:

    1.686D-11

sec

Gap transit angle:

    0.5297795

rad

Beam coupling coefficient:

    0.9883465

Velocity of electron leaving buncher gap:

    59593045.

m/sec

Depth of modulation:

    0.0098835
-->
```

Figure 5.8: Two cavity Klystron

```

14 disp('sec',tau,'Gap transit time:');
15
16 //Gap transit angle
17 w=2*%pi*f;
18 thetag=w*tau;//rad
19 disp('rad',thetag,'Gap transit angle:');
20
21 //(ii) Beam coupling coefficient
22 betin=sin(thetag/2)/(thetag/2);
23 disp(betin,'Beam coupling coefficient:');
24
25 //(iii) Velocity of electron leaving buncher gap
26 vig=vv0*(1+((betin*v1)/(2*v0)));//m/sec
27 disp('m/sec',vig,'Velocity of electron leaving
    buncher gap:');
28
29 //(iv) Depth of modulation
30 m=betin*v1/v0;
31 disp(m,'Depth of modulation:');

```

Scilab code Exa 5.9 Four cavity Klystron

```

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

```

```
Scilab 5.4.1 Console

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

```

12 p=1D-8; //C/m^3
13 rf=0.6;
14 e=1.6D-19;
15 m=9.1D-31;
16 ee=8.854D-12;
17
18 //(i) DC electron beam phase constant
19 vv0=(0.593D+6*sqrt(v0));
20 w=2*%pi*f;
21 bete=w/vv0; //rad/m
22 disp('rad/m',bete,'DC electron beam phase constant:');
23
24 //(ii) Reduced plasma frequency and reduced plasma
25 //phase constant
26 wq=rf*sqrt(e*p/(m*ee)); //rad/m
27 betq=wq/vv0; //rad/sec
28 disp('rad/sec',betq,'Reduced plasma phase constant:');
29
30 //(iii) Gap transit time
31 tau=d1/vv0; //sec
32 vtg=vv0*(1+(bet*vrms*sin(w*tau)/(2*v0))); //m/sec
33 disp('m/sec',vtg,'Gap transit time:');

```

Scilab code Exa 5.10 Four cavity Klystron

```

1 //Page Number: 296
2 //Example 5.10
3 clc;
4 //Given
5 f=4D+9; //hz

```

```
Scilab 5.4.1 Console

Induced current:

    1.3538475

A

Induced voltage:

    5.41539

kV

Power output:

    13438.135

W
-->
```

Figure 5.10: Four cavity Klystron

```

6 v0=10D+3; //V
7 i0=0.75; //A
8 v1=2; //V
9 bet=1;
10 rsh=10D+3; //ohm
11 p=5D-5; //C/m^3
12 r=0.6;
13 rsht=4D+3; //ohm
14 e=1.6D-19;
15 m=9.1D-31;
16 ee=8.854D-12;
17
18 //(i) Induced current and voltage in output cavity
19 w1=sqrt(e*p/(m*ee)); //rad/sec
20 w=2*%pi*f;
21 wq=0.5*w1; //rad/sec
22 rr=w/wq;
23
24 i4=[(i0^3)*(rr^3)*(bet^6)*v1*(rsh^2)]/(8*(v0^3)); //
    A
25 disp('A',i4,'Induced current:');
26 v4=i4*rsht; //V
27 disp('kV',v4/1000,'Induced voltage:');
28
29 //(ii) Power output
30 pout=(i4^4)*rsht; //W
31 disp('W',pout,'Power output:');
32
33 //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

```
Scilab 5.4.1 Console

Repeller voltage:

    327.23759

V

Required dc current:

    9.5456281

mA
-->
```

Figure 5.11: Reflex Klystron


```

1 //Page Number: 297
2 //Example 5.9
3 clc;
4 //Given
5 f=8D+9; //hz
6 v0=500; //V
7 l=1.2; //mm
8 l1=1/1000; //m
9 rsh=18D+3; //ohm
10 ebym=1.759D+11;
11 ee=8.854D-12;
12
13 //(i) Repeller voltage
14 n=1+(3/4);
15 v11=(ebym*n*n)/(8*(l1^2)*(f^2));
16 vr=sqrt(v0/v11)-v0;
17 disp('V',vr,'Repeller voltage:');
18
19 //(ii) Required dc current
20 v2=200; //V
21 j1x=0.582;
22 i=v2/(2*rsh*j1x); //A
23 disp('mA',i*1000,'Required dc current:');
24
25 //Answer for repeller voltage is calculated wrong in
    book

```

Scilab code Exa 5.12 Reflex Klystron

```

1 //Page Number: 298
2 //Example 5.12
3 clc;
4 //Given

```

```
Scilab 5.4.1 Console

Maximum power output:

    2.760705

W

Operating repeller voltage:

    297.98514

V

-->
```

Figure 5.12: Reflex Klystron

```

5 f=9D+9; //hz
6 v0=361; //V
7 i0=30D-3; //A
8 l=0.1; //cm
9 l1=1/100; //m
10 x=2.408;
11 j1x=0.582;
12 ebym=1.759D+11;
13
14 //Maximum power output
15 n=1;
16 pout=2*i0*v0*x*j1x/(2*pi*(n+(3/4))); //W
17 disp('W',pout,'Maximum power output:');
18
19 //Operating repeller voltage
20 vr=((6.744D-6*sqrt(v0)*l1*f)/(n+(3/4)))-v0; //v
21 disp('V',vr,'Operating repeller voltage:');

```

Scilab code Exa 5.13 Reflex Klystron

```

1 //Page Number: 298
2 //Example 5.13
3 clc;
4 //Given
5 f=9D+9; //hz
6 v0=250; //V
7 l=0.5; //cm
8 l1=1/100; //m
9
10 //Bandwidth
11 n=3;
12 df=(n+(3/4))/(6.774D-6*l1*sqrt(v0)); //hz
13 disp('Mhz',df/10^6,'Bandwidth:');

```

```
Scilab 5.4.1 Console

Bandwidth:

    7.0023863

Mhz
-->
```

Figure 5.13: Reflex Klystron

Scilab code Exa 5.14 Reflex Klystron

```
1 //Page Number: 299
2 //Example 5.14
3 clc;
4 //Given
5 f=10D+9; //hz
6 v0=600; //V
7 vr=250; //V
8 ebym=1.759D+11;
9
10 //Repeller space
11 n=1;
12 l=sqrt((ebym*(n+(3/4))^2*(vr+v0)^2)/(8*f^2*v0)); //m
13 disp('mm',l*1000,'Repeller space:');
```

Scilab code Exa 5.15 Reflex Klystron

```
1 //Page Number: 299
2 //Example 5.15
3 clc;
4 //Given
5 v0=300; //V
6 i0=20D-3; //A
7 v1=40; //V
8 n=2;
9 x=2.408;
```

```
Scilab 5.4.1 Console  
  
Repeller space:  
  
    0.9004701  
  
mm  
-->
```

Figure 5.14: Reflex Klystron

```
Scilab 5.4.1 Console

Input power:

    6.

W

Output power:

    1.3665425

W

Efficiency:

    22.775709

%
-->
```

Figure 5.15: Reflex Klystron

```

10 j1x=0.52;
11
12 //(i) Input power
13 pin=i0*v0;//W
14 disp('W',pin,'Input power:');
15
16 //(ii) Output power
17 pout=(2*v0*i0*x*j1x)/((2*pi*n)-(pi/2));//W
18 disp('W',pout,'Output power:');
19
20 //Efficiency
21 eet=pout/pin;
22 disp('%',eet*100,'Efficiency:');
23
24 //Answer for output power in book is 0.7 which is
    wrong, it should be 1.3W
25 //Hence answer of efficiency also changes

```

Scilab code Exa 5.16 Reflex Klystron

```

1 //Page Number: 300
2 //Example 5.16
3 clc;
4 //Given
5 f=10D+9;//hz
6 v0=600;//V
7 l=0.1;//cm
8 l1=1/100;//m
9 bet=0.9;
10 ebym=1.759D+11;
11 n=2;
12 j1x=0.575;//from standard table
13

```



```
Scilab 5.4.1 Console

Repeller voltage:

    344.

V

Bunching parameter:

    1.6493361

Required DC current:

    8.6956522

mA

Electronic efficiency:

    17.25

%

-->
```

Figure 5.16: Reflex Klystron

```

14
15 // (i) Repeller voltage
16 vr = ((6.744D-6 * sqrt(v0) * l1 * f) / (n - (1/4))) - v0; //V
17 disp('V', round(vr), 'Repeller voltage:');
18
19 // (ii) Bunching parameter
20 v1 = 200; //V
21 x = bet * v1 * 2 * %pi * (n - (1/4)) / (2 * v0);
22 disp(x, 'Bunching parameter:');
23
24 // (iii) Required DC current
25 rsh = 20D+3; //ohm
26 i = v1 / (2 * rsh * j1x); //A
27 disp('mA', i * 1000, 'Required DC current:');
28
29 // (iv) Electronic efficiency
30 eet = 2 * x * j1x / (2 * %pi * (n - (1/4)));
31 disp('%', eet * 100, 'Electronic efficiency:');

```

Scilab code Exa 5.17 Electron Gun

```

1 //Page Number: 301
2 //Example 5.17
3 clc;
4 //Given
5 f = 10D+9; //hz
6 v0 = 300; //V
7 j0 = 0.3; //A/cm
8 i0 = 45D-3; //A
9
10 rb = sqrt(i0 / (%pi * j0)); //mm
11 disp('mm', rb * 10, 'Electron beam radius:');
12 r = rb * (120 / 100); //mm

```

```
Scilab 5.4.1 Console

Electron beam radius:

    2.1850969

mm

Radius of cathode disc:

    2.6221162

mm

Cathode anode spacing:

    2.0110541

mm

Anode hole:

    3.0154337

mm
-->
```

I

Figure 5.17: Electron Gun

```

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

```

Scilab code Exa 5.18 Re entrant Coaxial Cavity

```

1 //Page Number:
2 //Example 5.18
3 clc;
4 //Given
5 f=9D+9;//hz
6 v0=300;//V
7 vr=125;//V
8 bet=0.9;
9 c=3D+8; //m/s
10 w=2*%pi*f;
11 br=2.18;//mm
12 e0=8.854D-12;
13 ebym=1.7D+11;
14
15 //From sin(theta)/theta table, thetag is found out
    to be
16 thetag=0.25*%pi;
17 d=(2*thetag*0.593D+6*sqrt(v0))/w;
18 disp('mm',d*1000,'Distance:');
19
20 //Axial cavity length
21 l=c/(10*f);//m
22 disp('mm',l*1000,'Axial cavity length:');
23

```

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

```

24 //Ratio of outer to inner conductor
25 a=1.5*br;
26 a1=a/1000;
27 x=d/(w*e0*a1*a1*60*tan((w*l)/c));
28 bbya=exp(x);
29 disp(bbya,'Ratio of outer to inner conductor:');
30
31 //radii of outer and inner conductor
32 disp('mm',a,'Radius of outer conductor:');
33
34 b=1.52*a; //mm
35 disp('mm',b,'Radius of inner conductor:');
36
37 //Repeller spacing
38 lopt=sqrt(ebym*(19/4)^2*(v0+vr)^2/(8*f^2*v0)); //m
39 disp('mm',lopt*1000,'Repeller spacing:');
40
41 //Answer for radii of outer and inner conductor have
    wrong calculations in book
42 //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

```
1 //Page Number: 330
2 //Example 6.1
3 clc;
4 //Given
5 clc;
6 //Given
7 I0=30D-3; //A
8 V0=3D+3; //V
9 Z0=10; //ohm
10 l=0.1624; //m
11 f=10D+9; //Hz
12
13 //(i) Gain parameter
14 C=((I0*Z0)/(4*V0))^(1/3);
15 disp(C, 'Gain parameter:');
16
17 N=(1*f)/(0.593D+6*sqrt(V0));
```

```
Scilab 5.4.1 Console

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


```

18
19 // (ii) Power Gain
20 Ap=-9.54+(47.3*C*N);
21 disp('dB',Ap,'Power gain:');
22
23 ve=0.593D+6*sqrt(V0);
24 be=(2*pi*f)/ve;
25
26 // Four propogation constants
27 gam1=(-sqrt(3)*be*C)/2+(%i*be*(2+C))/2;
28 gam2=(sqrt(3)*be*C)/2+(%i*be*(2+C))/2;
29 gam3=%i*be*(1-C);
30 gam4=-%i*be*(1-((C*C*C)/4));
31
32 disp(gam4,gam3,gam2,gam1,'Four propogation constants
    :');
33
34 // Calculations for propogation constants are wrong
    in book for gam 3 and 4, hence answers dont match

```

Scilab code Exa 6.2 Helix TWT

```

1 //Page Number: 332
2 //Example 6.2
3 clc;
4 //Given
5 I0=20D-3; //A
6 V0=4D+3; //V
7 Z0=100; //ohm
8 N=30;
9
10 C=((I0*Z0)/(4*V0))^(1/3);
11 //Gain

```

```
Scilab 5.4.1 Console

Gain:

    61.41

dB

-->
```

Figure 6.2: Helix TWT

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

Scilab code Exa 6.3 Helical TWT

```
1 //Page Number: 332
2 //Example 6.3
3 clc;
4 //Given
5 c=3D+8; //m/s
6 d=2D-3; //m
7 p=50D+2; //turns per m
8 e=1.6D-19; //J
9 m=9.1D-31;
10
11 // Axial phase velocity
12 vp=c/(%pi*p*d);
13 disp('m/s',vp,'Axial phase velocity:');
14
15 //Anode voltage
16 V0=(m*vp*vp)/(2*e);
17 disp('V',V0,'Anode voltage:');
```

Scilab code Exa 6.4 O type TWT

```
1 //Page Number: 332
2 //Example 6.4
3 clc;
4 //Given
```

```
Scilab 5.4.1 Console

Axial phase velocity:

    9549296.6

m/s

Anode voltage:

    259.3189

V

-->
```

Figure 6.3: Helical TWT

Scilab 5.4.1 Console

Propogation constant:

2. + 2183.9642i

-->

Figure 6.4: O type TWT

```

5 a=(4.4*%pi)/180; //radians
6 c=3D+8 //m/s
7 f=8D+9; //Hz
8 al=2; //Np/m
9
10 //Phase velocity
11 vp=c*sin(a);
12
13 //Propogation constant
14 be=(2*%pi*f)/vp;
15
16 gam=al+(%i*be);
17 disp(gam, 'Propogation constant: ');

```

Scilab code Exa 6.5 Cavity coupled

```

1 //Page Number: 333
2 //Example 6.5
3 clc;
4 //Given
5 Vc=11D+3; //V
6 Ir=0.85; //A
7 V0=31D+3; //V
8 Pout=50D+3; //W
9 I=7; //A
10
11 //Electronic efficiency
12 ne=Pout/(V0*I);
13 disp('%',ne*100, 'Electronic efficiency: ');
14
15 //Overall efficiency
16 no=Pout/(Vc*(I-Ir));
17 disp('%',no*100, 'Overall efficiency: ');

```

```
Scilab 5.4.1 Console
Electronic efficiency:
    23.041475
%
Overall efficiency:
    73.90983
%
-->
```

Figure 6.5: Cavity coupled

```
Scilab 5.4.1 Console
```

```
Gain:  
73.589722  
dB  
-->
```

Figure 6.6: O Type Backward Wave amplifier

```
18  
19 //Answer for elecyrtonic efficiency should be 23.04%  
    but it is given as 36.4 in book
```

Scilab code Exa 6.6 O Type Backward Wave amplifier

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



```
Scilab 5.4.1 Console

Electronic efficiency:

    26.666667

%

Overall efficiency:

    66.666667

%

-->
```

Figure 6.7: Multicavity TWT

```
3  clc;
4  // Given
5  I0=0.95; //A
6  V0=7D+3; //V
7  Z0=20; //ohm
8  N=20;
9
10 C=((I0*Z0)/(4*V0))^(1/3);
11 // Gain
12 Ap=-9.54+(47.3*C*N);
13 disp('dB',Ap,'Gain:');
```

Scilab code Exa 6.7 Multicavity TWT

```
1 //Page Number: 334
2 //Example 6.7
3 clc;
4 //Given
5 Vc=12D+3; //V
6 V0=30D+3; //V
7 Pout=60D+3; //W
8 I=7.5; //A
9
10 //Electronic efficiency
11 ne=Pout/(V0*I);
12 disp('%',ne*100,'Electronic efficiency:');
13
14 //Overall efficiency
15 no=Pout/(Vc*I);
16 disp('%',no*100,'Overall efficiency:');
```

Scilab code Exa 6.8 Gridded TWT

```
1 //Page Number: 334
2 //Example 6.8
3 clc;
4 //Given
5 Vc=20D+3; //V
6 V0=32D+3; //V
7 Pout=75D+3; //W
8 I=7; //A
9
10 //Electronic efficiency
11 ne=Pout/(V0*I);
12 disp('%',ne*100,'Electronic efficiency:');
```

```
Scilab 5.4.1 Console

Electronic efficiency:

  33.482143

%

Overall efficiency:

  53.571429

%

-->
```

Figure 6.8: Gridded TWT

```
Scilab 5.4.1 Console
```

```
Gain parameter:
```

```
0.0678604
```

```
Gain of TWT:
```

```
54.655977
```

```
dB
```

```
-->
```

Figure 6.9: Helix TWT

```
13  
14 //Overall efficiency  
15 no=Pout/(Vc*I);  
16 disp('%',no*100,'Overall efficiency:');
```

Scilab code Exa 6.9 Helix TWT

```

1 //Page Number: 335
2 //Example 6.9
3 clc;
4 //Given
5 I0=500D-3; //A
6 V0=10D+3; //V
7 Z0=25; //ohm
8 l=.20; //m
9 f=5.93D+9; //Hz
10
11 //Gain parameter
12 C=((I0*Z0)/(4*V0))^(1/3);
13 disp(C, 'Gain parameter: ');
14
15 N=(1*f)/(0.593D+6*sqrt(V0));
16 //Gain
17 Ap=-9.54+(47.3*C*N);
18 disp('dB', Ap, 'Gain of TWT: ');

```

Scilab code Exa 6.10 Low Power TWT

```

1 //Page Number: 335
2 //Example 6.10
3 clc;
4 //Given
5 Pout=250; //W
6 n=0.15;
7 V0=7.5D+3; //V
8 f=6.15D+9; //Hz
9 c=3D+8; //m/s
10
11 //(i) Input Power
12 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

-->

```

13 disp('W',Pi,'Input Power:');
14
15 //(ii) Beam current
16 I0=Pi/V0;
17 disp('A',I0,'Beam current:');
18
19 //(iii) Beam velocity
20 vb=0.593D+6*sqrt(V0);
21 disp('m/s',vb,'Beam velocity:');
22
23 //(iv) Radius of helix
24 a=(2*vb)/(2*%pi*f);
25 disp('m',a,'Radius of helix:');
26
27 //(v) Electron beam radius
28 r=(3*a)/4;
29 disp('m',r,'Electron beam radius:');
30
31 //(vi) Pitch of helix
32 p=(2*%pi*a*vb)/c;
33 disp('m',p,'Pitch of helix:');
34
35 //(vii) Current density
36 J0=I0/(%pi*r*r);
37 disp('kA/msqr',J0/1000,'Current density:');
38
39 //(viii) Magnetic field for beam confinement
40 B=(4*8.3D-4*sqrt(I0/(r*r*sqrt(V0)))));
41 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

```

1 //Page Number: 336
2 //Example 6.11
3 clc;
4 //Given
5 I0=30D-3; //A
6 V0=3D+3; //V
7 Z0=10; //ohm
8 l=0.1624; //m
9 f=10D+9; //Hz
10 C=((I0*Z0)/(4*V0))^(1/3);
11 N=(1*f)/(0.593D+6*sqrt(V0));
12
13 //Gain
14 Ap=-9.54+(47.3*C*N);
15 disp('dB',Ap,'Gain:');
16
17 ve=0.593D+6*sqrt(V0);
18 be=(2*%pi*f)/ve;
19

```



```

20 //Four propogation constants
21 gam1=((-sqrt(3)*be*C)/2)+(%i*be*(2+C))/2;
22 gam2=((sqrt(3)*be*C)/2)+(%i*be*(2+C))/2;
23 gam3=%i*be*(1-C);
24 gam4=-%i*be*(1-((C*C*C)/4));
25
26 disp(gam4,gam3,gam2,gam1,'Four propogation constants
      :');
27
28 //Calculations for propogation constants are wrong
      for gam 3 and 4 hence answers dont match

```

Scilab code Exa 6.12 TWT

```

1 //Page Number: 337
2 //Example 6.12
3 clc;
4 //Given
5 I0=35D-3; //A
6 V0=4D+3; //V
7 Z0=20; //ohm
8 f=10D+9; //Hz
9
10 //(i) Gain parameter
11 C=((I0*Z0)/(4*V0))^(1/3);
12 disp(C,'Gain parameter:');
13
14 ve=0.593D+6*sqrt(V0);
15 be=(2*pi*f)/ve;
16
17 //Four propogation constants
18 gam1=((-sqrt(3)*be*C)/2)+(%i*be*(2+C))/2;
19 gam2=((sqrt(3)*be*C)/2)+(%i*be*(2+C))/2;

```

Scilab 5.4.1 Console

Gain parameter:

0.0352365

Four propogation constants:

- 51.123255 + 1704.826i

51.123255 + 1704.826i

1616.2779i

- 1675.2917i

-->

Figure 6.12: TWT

```
20 gam3=%i*be*(1-C);
21 gam4=-%i*be*(1-((C*C*C)/4));
22
23 disp(gam4,gam3,gam2,gam1,'Four propogation constants
      : ');
24
25 // 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

```
1 //Page Number: 369
2 //Example 7.1
3 clc;
4 //Given
5 f=10D+9; //Hz
6 C=2.5D-12; //F
7 Gr=2D-4; //mho
8 Ge=0.025D-3; //mho
9 Ploss=18.5D+3; //W
10 V0=5.5D+3; //V
11 I0=4.5; //A
12
13 w=2*%pi*f;
14
15 //(i) Unloaded Q
16 Qun=(w*C)/Gr;
17 disp(Qun, 'Unloaded quality factor:');
```

```
Scilab 5.4.1 Console

Unloaded quality factor:
    785.39816

External quality factor:
    6283.1853

Circuit efficiency:
    11.111111

$

Electronic efficiency:
    25.252525

$

-->
```

Figure 7.1: X band Magnetron

```

18
19 //External Q
20 Qe=(w*C)/Ge;
21 disp(Qe,'External quality factor:');
22
23 //(ii) Circuit efficiency
24 n=1/(1+(Qe/Qun));
25 disp('%',n*100,'Circuit efficiency:');
26
27 //Electronic efficiency
28 ne=1-(Ploss/(V0*I0));
29 disp('%',ne*100,'Electronic efficiency:');
30
31 //Answer for Qe is given as 6285.6 but it should be
    6283.1

```

Scilab code Exa 7.2 Cylindrical Magnetron

```

1 //Page Number: 370
2 //Example 7.2
3 clc;
4 //Given
5 V0=25D+3; //V
6 ebym=1.76D+11;
7 B0=0.0336; //T
8 a=5D-2; //m
9 b=10D-2; //m
10
11 //(i) Cut off voltage
12 x=(b/((b*b)-(a*a)))^2;
13 V=(ebym*B0*B0)/(8*x);
14 disp('KV',V/1000,'Cut off voltage:');
15

```

Scilab 5.4.1 Console

Cut off voltage:

139.7088

KV

Cut off magnetic field:

14.213381

mT

-->

Figure 7.2: Cylindrical Magnetron

```
Scilab 5.4.1 Console

Efficiency:

    40.

%

Cyclotron frequency:

    0.9803944

Ghz

Cut off magnetic field:

    17.766726

mT

Cut off voltage:

    97.

KV

-->
```

Figure 7.3: Cylindrical Magnetron

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

Scilab code Exa 7.3 Cylindrical Magnetron

```
1 //Page Number: 371
2 //Example 7.3
3 clc;
```



```

4 //Given
5 Pout=250D+3; //W
6 V0=25D+3; //V
7 I0=25; //A
8 ebym=1.76D+11;
9 B0=0.035; //T
10 a=4D-2; //m
11 b=8D-2; //m
12
13
14 //(i) Efficiency
15 n=Pout/(V0*I0);
16 disp('%',n*100,'Efficiency:');
17
18 //(ii) Cyclotron frequency
19 f=(ebym*B0)/(2*%pi);
20 disp('Ghz',f/10^9,'Cyclotron frequency:');
21
22 //(iii) Cut off magnetic field
23 x=(b/((b*b)-(a*a)))^2;
24 y=((8*V0*x)/ebym);
25 B=sqrt(y);
26 disp('mT',B*1000,'Cut off magnetic field:');
27
28 //(iv) Cut off voltage
29 V=(ebym*B0*B0)/(8*x);
30 disp('KV',round(V/1000),'Cut off voltage:');
31
32 //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

```
Scilab 5.4.1 Console

Circuit efficiency:

    9.0909091

%

Electronic efficiency:

    67.532468

%

-->
```

Figure 7.4: Conventional Magnetron

```

1 //Page Number: 372
2 //Example 7.4
3 clc;
4 //Given
5 Gr=3D-4; //mho
6 Ge=3D-5; //mho
7 Ploss=200D+3; //W
8 V0=22D+3; //V
9 I0=28; //A
10
11 //(i) Circuit efficiency
12 n=1/(1+(Gr/Ge));
13 disp('%',n*100,'Circuit efficiency:');
14
15 //(ii) Electronic efficiency
16 ne=1-(Ploss/(V0*I0));
17 disp('%',ne*100,'Electronic efficiency:');

```

Scilab code Exa 7.5 Conventional Magnetron

```

1 //Page Number: 372
2 //Example 7.5
3 clc;
4 //Given
5 f=9D+9; //Hz
6 C=2.5D-12; //F
7 Gr=2D-4; //mho
8 Ge=2.5D-5; //mho
9 Ploss=18.5D+3; //W
10 V0=5.5D+3; //V
11 I0=4.5; //A
12
13 //(i) Angular resonant frequency

```

Scilab 5.4.1 Console

Angular resonant frequency:

5.655D+10

rad/s

Unloaded quality factor:

707.

Loaded quality factor:

628.

External quality factor:

5654.8668

Circuit efficiency:

11.11309

%

Electronic efficiency:

25.252525

%

-->

Figure 7.5: Conventional Magnetron

```

14 w=2*%pi*f;
15 disp('rad/s',w,'Angular resonant frequency:');
16
17 //(ii) Unloaded Q
18 Qun=round((w*C)/Gr);
19 disp(Qun,'Unloaded quality factor:');
20
21 //(iii) Loaded Q
22 Ql=round((w*C)/(Gr+Ge));
23 disp(Ql,'Loaded quality factor:');
24
25 //(iv) External Q
26 Qe=(w*C)/Ge;
27 disp(Qe,'External quality factor:');
28
29 //(v) Circuit efficiency
30 n=1/(1+(Qe/Qun));
31 disp('%',n*100,'Circuit efficiency:');
32
33 //(vi) Electronic efficiency
34 ne=1-(Ploss/(V0*I0));
35 disp('%',ne*100,'Electronic efficiency:');
36
37 //Answer for external Q is given as 56.57 but it
   should be 5654.8

```

Scilab code Exa 7.6 Carcinotron

```

1 //Page Number: 373
2 //Example 7.6
3 clc;
4 //Given
5 f=4D+9; //Hz

```

```
Scilab 5.4.1 Console

Electron beam phase constant:

    267.91592

rad/s

Gain Parameter:

    0.1144714

Length for oscillation condition:

    0.0366439

m
-->
```

Figure 7.6: Carcinotron

```

6 V0=25D+3; //V
7 I0=3; //A
8 B0=0.3; //T
9 D=0.8;
10 Z0=50; //ohm
11 ebym=1.76D+11;
12
13 //(i) Electron beam phase constant
14 be=(2*%pi*f)/sqrt(2*ebym*V0);
15 disp('rad/s',be,'Electron beam phase constant:');
16
17 //(ii) Gain Parameter
18 C=((I0*Z0)/(4*V0))^(1/3);
19 disp(C,'Gain Parameter:');
20
21 //(iii) Length for oscillation condition
22 N=1.25/D;
23 l=(2*%pi*N)/be;
24 disp('m',l,'Length for oscillation condition:');

```

Scilab code Exa 7.7 Frequency Agile Magnetron

```

1 //Page Number: 374
2 //Example 7.7
3 clc;
4 //Given
5 N=20;
6 t=0.2D-6; //s
7 DC=0.001; //Duty cycle
8
9 //(i) Agile excursion
10 A=N/t;
11 disp('MHz',A/10^6,'Agile excursion:');

```

Scilab 5.4.1 Console

Agile excursion:

100.

MHz

Signal frequency:

5.

Khz

Agile Rate:

125.

Hz

-->

Figure 7.7: Frequency Agile Magnetron


```

12
13 //(ii) Signal frequency
14 f=DC/t;
15 disp('Khz',f/1000,'Signal frequency:');
16
17 //(iii) Agile rate
18 R=f/(2*N);
19 disp('Hz',R,'Agile Rate:');

```

Scilab code Exa 7.8 Cross field amplifier

```

1 //Page Number: 375
2 //Example 7.8
3 clc;
4 //Given
5 V0=1.8D+3; //V
6 I0=1.3; //A
7 Pin=70; //W
8 n=0.22;
9
10 //(i) Power generated
11 Pgen=n*I0*V0;
12 disp('W',Pgen,'Power generated:');
13
14 //(ii) Total RF power generated
15 Pt=Pin+Pgen;
16 disp('W',Pt,'Total RF power generated:');
17
18 //(iii) Power gain
19 G=Pt/Pin;
20 Gdb=10*log10(G);
21 disp('dB',Gdb,'Power Gain:');

```

```
Scilab 5.4.1 Console

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

```
1 //Page Number: 375
2 //Example 7.9
3 clc;
```

```

4 //Given
5 V0=10D+3; //V
6 I0=2; //A
7 b=4D-2; //m
8 a=3D-2; //m
9 B0=0.01; //Wb/m2
10 ebym=1.759D+11;
11
12 //Cut off voltage
13 x=1-((b*b)/(a*a));
14 V=(ebym*(B0^2)*(a^2)*(x^2))/8;
15 KV=V/1000; //Kilovolts
16 disp('KV',KV,'Cut off voltage:');
17
18 //Magnetic flux density
19 y=-sqrt((8*V0)/ebym);
20 B=y/(a*x);
21 disp('T',B,'Magnetic flux density:');

```

Scilab code Exa 7.10 Inverted coaxial Magnetron

```

1 //Page Number: 376
2 //Example 7.10
3 clc;
4 //Given
5 V0=10D+3; //V
6 I0=2; //A
7 b=4D-2; //m
8 a=3D-2; //m
9 B0=0.01; //Wb/m2
10 ebym=1.759D+11;
11
12 //Cut off voltage

```

Scilab 5.4.1 Console

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

```
13 x=1-((b*b)/(a*a));
14 V=(ebym*(B0^2)*(a^2)*(x^2))/8;
15 disp('KV',V/1000,'Cut off voltage:');
16
17 //Magnetic flux density
18 y=-sqrt((8*V0)/ebym);
19 B=y/(a*x);
20 disp('T',B,'Magnetic flux density:');
```

Scilab code Exa 7.11 Linear Magnetron

```

1 //Page Number: 376
2 //Example 7.11
3 clc;
4 //Given
5 e=1.6D-19; //J
6 B0=0.01; //Wb/m2
7 d=6D-2; //m
8 V0=20D+3; //V
9 ebym=1.759D+11;
10
11 //(i) Hull cut off voltage
12 Voc=(B0*B0*d*d*ebym)/2;
13 disp('KV',Voc/1000,'Hull cut off voltage:');
14
15 //(ii) Hull magnetic field
16 Boc=sqrt((2*V0)/ebym)/d;
17 disp('mT',Boc*1000,'Hull magnetic field:');

```

Scilab code Exa 7.12 Inverted Coaxial Magnetron

```

1 //Page Number: 377
2 //Example 7.12
3 clc;
4 //Given
5 V0=10D+3; //V
6 V01=5D+3; //V
7 I0=2; //A
8 b=3D-2; //m
9 a=2D-2; //m
10 B0=0.01; //Wb/m2
11 ebym=1.759D+11;
12
13 //Cut off voltage

```

Scilab 5.4.1 Console

Cut off voltage:

1.3742188

KV

Magnetic flux density:

0.0190747

Wb/m²

-->

Figure 7.12: Inverted Coaxial Magnetron


```

14 x=1-((b*b)/(a*a));
15 V=(ebym*(B0^2)*(a^2)*(x^2))/8;
16 KV=V/1000; // Kilovolts
17 disp('KV',KV,'Cut off voltage:');
18
19 //Magnetic flux density
20 y=-sqrt((8*V01)/ebym);
21 B=y/(a*x);
22 disp('Wb/m2',B,'Magnetic flux density:');
23
24 //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

```

1 //Page Number: 377
2 //Example 7.13
3 clc;
4 //Given
5 N=15;
6 t=0.3D-6; //s
7 DC=0.0011; //Duty cycle
8
9 //(i) Agile excursion
10 A=N/t;
11 disp('MHz',A/10^6,'Agile excursion:');
12
13 //(ii) Pulse to pulse frequency seperation
14 fp=1/t;
15 disp('Mhz',fp/10^6,'Pulse to pulse frequency
    seperation:');
16

```

```
Scilab 5.4.1 Console
Agile excursion:
    50.
MHz
Pulse to pulse frequency separation:
    3.3333333
Mhz
Signal frequency:
    3.6666667
Khz
Agile Rate:
    122.22222
ps
-->
```

Figure 7.13: Agile coaxial Magnetron

```
17 //(iii) Signal frequency
18 f=DC/t;
19 disp('Khz',f/1000,'Signal frequency:');
20
21 //(iv) Agile rate
22 Tp=N/f;
23 R=1/(2*Tp);
24 disp('ps',R,'Agile Rate:');
```

Chapter 8

Microwave Solid State Control Devices

Scilab code Exa 8.1 Single pole Switch

```
1 //Page Number: 389
2 //Example 8.1
3 clc;
4 //Given
5 Rf=0.5; //ohm
6 Rr=1; //ohm
7 Ls=0.3D-9; //H
8 Cj=0.1D-12; //F
9 f=3.18D+9; //Hz
10 Z0=50; //ohm
11
12 Zf=Rf+(%i*round(2*%pi*f*Ls));
13 Zr=Rr+(%i*(round(2*%pi*f*Ls)-(1/(2*%pi*f*Cj))));
14
15 //Series Configuration
16 disp('Series Configuration');
17
```

```
Scilab 5.4.1 Console

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

```

18 //Insertion Loss
19 x=(2*Z0)/((2*Z0)+Zf);
20 x1=sqrt((real(x))^2+(imag(x))^2);
21 IN=-20*log10(x1);
22 disp('dB',IN,'Insertion Loss:');
23
24 //Isolation Loss
25 y=(2*Z0)/((2*Z0)+Zr);
26 y1=sqrt((real(y))^2+(imag(y))^2);
27 IS=-20*log10(y1);
28 disp('dB',IS,'Isolation Loss:');
29
30 //Shunt Configuration
31 disp('Shunt Configuration');
32
33 //Insertion Loss
34 a=(2*Zr)/((2*Zr)+Z0);
35 a1=sqrt((real(a))^2+(imag(a))^2);
36 INs=-20*log10(a1);
37 disp('dB',INs,'Insertion Loss:');
38
39 //Isolation Loss
40 b=(2*Zf)/((2*Zf)+Z0);
41 b1=sqrt((real(b))^2+(imag(b))^2);
42 ISs=-20*log10(b1);
43 disp('dB',ISs,'Isolation Loss:');
44
45 //Answer for Series configuration insertion loss is
    0.058 but is given as 0.58db

```

Scilab code Exa 8.2 Pin diode switches

1 //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

```

2 //Example 8.2
3 clc;
4 //Given
5 Rf=1; //ohm
6 Rr=4; //ohm
7 Ls=0.3D-9; //H
8 Cj=0.1D-12; //F
9 f=3.18D+9; //Hz
10 Z0=50; //ohm
11
12 Zf=Rf+(%i*round(2*%pi*f*Ls));
13 Zr=Rr+(%i*(round(2*%pi*f*Ls)-(1/(2*%pi*f*Cj))));
14
15 //Series Configuration
16 disp('Series Configuration');
17
18 //Insertion Loss
19 x=(2*Z0)/((2*Z0)+Zf);
20 x1=sqrt((real(x))^2+(imag(x))^2);
21 IN=-20*log10(x1);
22 disp('dB',IN,'Insertion Loss:');
23
24 //Isolation Loss
25 y=(2*Z0)/((2*Z0)+Zr);
26 y1=sqrt((real(y))^2+(imag(y))^2);
27 IS=-20*log10(y1);
28 disp('dB',IS,'Isolation Loss:');
29
30 //Shunt Configuration
31 disp('Shunt Configuration');
32
33 //Insertion Loss
34 a=(2*Zr)/((2*Zr)+Z0);
35 a1=sqrt((real(a))^2+(imag(a))^2);
36 INs=-20*log10(a1);
37 disp('dB',INs,'Insertion Loss:');
38
39 //Isolation Loss

```



```
Scilab 5.4.1 Console

Total series resistance:

    17.683883

ohms

Junction Area:

    0.0009571

cm2

-->
```

Figure 8.3: Silicon switching diode

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

Scilab code Exa 8.3 Silicon switching diode

1 //Page Number: 392

```

2 //Example 8.3
3 clc;
4 //Given
5 Vbd=1000; //V
6 f=30D+9; //Hz
7 E=3D+5; //V/cm
8 Cj=0.3D-12; //F
9 er=11.8;
10 e0=8.854D-12;
11
12 W=Vbd/E;
13 Wpi=W/100; //mu
14
15 //Total series resistance
16 R=1/(2*%pi*f*Cj);
17 disp('ohms',R,'Total series resistance:');
18
19 //Junction Area
20 A=(Cj*Wpi)/(e0*er);
21 disp('cm2',A*10000,'Junction Area:');

```

Scilab code Exa 8.6 Parametric upconverter

```

1 //Page Number: 428
2 //Example 8.6
3 clc;
4 //Given
5 MQ=10;
6 M=0.4;
7 r=20;
8 Td=300; //K
9 T=290; //K
10

```

```
Scilab 5.4.1 Console  
  
Power gain:  
    9.2449028  
  
dB  
  
Noise figure:  
    1.4223258  
  
dB  
  
Bandwidth:  
    3.5777088  
  
-->
```

Figure 8.4: Parametric upconverter

```

11 x=(MQ*MQ)/r;
12 //Power Gain
13 Ap=(r*x)/((1+sqrt(1+x))^2);
14 Apdb=10*log10(Ap);
15 disp('dB',Apdb,'Power gain:');
16
17 //Noise figure
18 z=(Td/T)/sqrt(1+((MQ*MQ)/r));
19 F=1+z;
20 Fdb=10*log10(F);
21 disp('dB',F,'Nosie figure:');
22
23 //Bandwidth
24 BW=2*M*sqrt(r);
25 disp(BW,'Bandwidth:');

```

Scilab code Exa 8.7 Parametric amplifier

```

1 //Page Number: 428
2 //Example 8.7
3 clc;
4 //Given
5 MQ=10;
6 r=10;
7
8 x=(MQ*MQ)/r;
9
10 //Gain
11 Ap=(r*x)/((1+sqrt(1+x))^2);
12 Apdb=10*log10(Ap);
13 disp('dB',Apdb,'Gain:');

```

Scilab 5.4.1 Console

Gain:

7.297114

dB

-->

Figure 8.5: Parametric amplifier

```
Scilab 5.4.1 Console

Effective Q:

    106.66667

-->
```

Figure 8.6: Negative resistance parametric amplifier

Scilab code Exa 8.8 Negative resistance parametric amplifier

```
1 //Page Number: 429
2 //Example 8.8
3 clc;
4 //Given
```

Final charge pulse:

0.967

-->

Figure 8.7: 330 stage CCD

```
5 Rs=1; //ohm
6 ws=5D+9; //Hz
7 M=0.25;
8 C0=2D-12; //F
9
10 //(i) Effective Q
11 Q=1/(Rs*ws*C0*(1-(M*M)));
12 disp(Q, 'Effective Q: ');
```

Scilab code Exa 8.9 330 stage CCD

```
1 //Page Number: 434
2 //Example 8.9
3 clc;
4 //Given
5 e=0.0001;
6 s=330;
7
8 //Charge transfer efficiency
9 n=1-e;
10
11 //Final charge pulse
12 //x=P/P0
13 x=(1-(e*s));
14 disp(x, 'Final charge pulse:');
```

Scilab code Exa 8.10 3 phase CCD

```
1 //Page Number: 434
2 //Example 8.10
3 clc;
4 //Given
5 Qmax=0.05D-12; //C
6 f=10D+6; //Hz
7 V=10; //V
8 n=3;
9
10 //Power dissipated per bit
11 P=n*f*V*Qmax;
```


Scilab 5.4.1 Console

```
Power dissipated 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

```
12 disp('mW',P*10^6,'Power dissipated per bit:');
```

Scilab code Exa 8.11 Surface channel CCD

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

```

3  clc;
4  //Given
5  e0=8.854D-12;
6  er=3.9;
7  d=0.15D-6; //m
8  e=1.6D-19; //J
9  Nmax=2.2D+16; //m-2
10 A=0.6D-8; //m
11 P=0.67D-3; //W
12 n=3;
13
14 // (i) Junction capacitance
15 Ci=(e0*er)/d;
16
17 //Gate voltage
18 V=(Nmax*e)/Ci;
19 disp('V',V,'Gate voltage:');
20
21 // (ii) Charge stored
22 Qmax=Nmax*e*A;
23
24 //Clock frequency
25 f=P/(n*V*Qmax);
26 disp('MHz',f/10^6,'Clock frequency:');

```

Scilab code Exa 8.12 3 phase CCD

```

1 //Page Number: 435
2 //Example 8.12
3 clc;
4 //Given
5 Qmax=0.06D-12; //C
6 f=20D+6; //Hz

```

Scilab 5.4.1 Console

```
Power dissipated per bit:
```

```
36.
```

```
muW
```

```
-->
```

Figure 8.10: 3 phase CCD

```

7 V=10; //V
8 n=3;
9
10 //Power dissipated per bit
11 P=n*f*V*Qmax;
12 disp('µW',P*10^6,'Power dissipated per bit:');

```

Scilab code Exa 8.13 Surface channel CCD

```

1 //Page Number: 435
2 //Example 8.13
3 clc;
4 //Given
5 e0=8.854D-12;
6 er=4;
7 d=0.1D-6; //m
8 si=0.85;
9 e=1.6D-19; //J
10 Na=1D+20;
11
12 Ci=(e0*er)/d;
13 disp('F/m',Ci,'Junction capacitance:');
14
15 W=sqrt((2*e0*er*si)/(e*Na));
16 disp('m',W,'Depletion layer width:');

```

Scilab 5.4.1 Console

Junction capacitance:

0.0003542

F/m

Depletion layer width:

0.0000019

m

-->

Figure 8.11: Surface channel CCD

Chapter 9

Microwave Solid State Generators and Amplifiers

Scilab code Exa 9.2 Bipolar transistor

```
1 //Page Number: 448
2 //Example 9.2
3 clc;
4 //Given
5 fc=5D+9; //Hz
6 Em=2D+7; //V/m
7 vs=4D+3; //ms/s
8 Xc=1; //ohm
9
10 //Maximum allowable power
11 Pm=((Em*vs)^2)/(((2*%pi*fc)^2)*Xc);
12 disp('W',Pm,'Maximum allowable power:');
```

Scilab 5.4.1 Console

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

```
1 //Page Number: 451
2 //Example 9.3
3 clc;
4 //Given
5 XeGe=4.0; //eV
6 XeGaAs=4.1; //eV
7 delEgGe=0.78; //eV
8 delEgGaAs=1.42; //eV
9
10 //Conduction band differential
11 delEc=XeGe-XeGaAs;
12 disp('eV',delEc,'Conduction band differential:');
13
14 //Valence band differential
15 delEv=delEgGaAs-delEgGe-delEc;
16 disp('eV',delEv,'Valence band differential:');
```

Scilab code Exa 9.4 GaAs FET

```
1 //Page Number: 454
2 //Example 9.4
3 clc;
4 //Given
5 S11=0.89;
6 S12=0.02;
7 S21=3.1;
8 S22=0.78;
9
10 del=(S11*S22)-(S12*S21);
11 K=[1-(S11)^2-(S22)^2+(del)^2;]/(2*S12*S21);
12 if(K<1)
```

Scilab 5.4.1 Console

```
Amplifier is potentially unstable
```

```
-->|
```

Figure 9.3: GaAs FET

```

13     disp('Amplifier is potentially unstable');
14 else
15     disp('Amplifier is potentially stable');
16     end

```

Scilab code Exa 9.5 Microwave transistor

```

1 //Page Number: 454
2 //Example 9.5
3 clc;
4 //Given
5 S11=0.40;
6 S12=0.01;
7 S21=2.00;
8 S22=0.35;
9
10 ZL=20; //ohm
11 ZS=30; //ohm
12 Z0=ZL+ZS; //ohm
13
14 //Reflection coefficients of source and load
15 TL=(ZL-Z0)/(ZL+Z0);
16 TLm=-TL;
17 TS=(ZS-Z0)/(ZS+Z0);
18 TSm=-TS;
19
20 //Reflection coefficients of input and output
21 Tin=S11+((S12*S21*TL)/(1-(S22*TL)));
22 Tout=S22+((S12*S21*TS)/(1-(S22*TS)));
23
24 //Transducer Gain
25 x=(1-(TSm)^2)/((1-(S11*TSm))^2); //Value of should
    be 1.145

```

Scilab 5.4.1 Console

Transducer Gain:

5.2066826

Available power Gain:

5.2567776

Power Gain:

5.4729759

-->

Figure 9.4: Microwave transistor

```

26 y=(S21*S21);
27 z=(1-(TLm)^2)/((1-(Tout*TLm))^2);
28 GT=x*y*z;
29 disp(GT,'Transducer Gain:');
30
31 // Available Power Gain
32 z1=1-(Tout)^2;
33 GA=(x*y)/z1;
34 disp(GA,'Available power Gain:');
35
36 // Power Gain
37 z2=1-(Tin)^2;
38 GP=(x*y)/z2;
39 disp(GP,'Power Gain:');
40
41 // 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

```

1 //Page Number: 455
2 //Example 9.6
3 clc;
4 //Given
5 S11=0.60;
6 S12=0.045;
7 S21=2.50;
8 S22=0.50
9 TS=0.5;
10 TL=0.4;
11 Vrms=10; //V
12 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

```

13
14 // (i) Reflection coefficients of input and output
15 Tin=S11+((S12*S21*TL)/(1-(S22*TL)));
16 Tout=S22+((S12*S21*TS)/(1-(S22*TS)));
17 disp(Tin,'Reflection coefficients of input:');
18 disp(Tout,'Reflection coefficients of output:');
19
20 // (ii) Gains
21 // Transducer Gain
22 x=(1-(TS)^2)/((1-(S11*TS))^2);
23 y=(S21*S21);
24 z=(1-(TL)^2)/((1-(Tout*TL))^2);
25 GT=x*y*z;
26 disp(GT,'Transducer Gain:');
27
28 // Available Power Gain
29 z1=1-(Tout)^2;
30 GA=(x*y)/z1;
31 disp(GA,'Available power Gain:');
32
33 // Power Gain
34 z2=1-(Tin)^2;
35 GP=(x*y)/z2;
36 disp(GP,'Power Gain:');
37
38 // Calculation for Tout and Gains are wrong in the
    book, hence the answers dont match
39
40 // (iii) Power available
41 Gt=9.4;
42 Pas=(sqrt(2)*Vrms)^2/(8*Z0);
43 Pal=Gt*Pas;
44 disp('W',Pas,'Power available at source:');
45 disp('W',Pal,'Power available at load:');

```

Scilab 5.4.1 Console

Maximum gain:

19.253664

-->

Scilab code Exa 9.7 Microwave transistor

```
1 //Page Number: 457
2 //Example 9.7
3 clc;
4 //Given
5 S11=0.90;
6 S12=0;
7 S21=2.40;
8 S22=0.80;
9
10 Gmax=(S21*S21)/((1-(S11)^2)*(1-(S22)^2));
11 Gdb=10*log10(Gmax);
12 disp(Gdb, 'Maximum gain:');
```

Scilab code Exa 9.8 JEFT

```
1 //Page Number: 468
2 //Example 9.8
3 clc;
4 //Given
5 e=1.6D-19;
6 Nd=1.1D+23; //m-3
7 a=0.2D-6; //m
8 er=11.8;
9 e0=8.854D-12;
10 mue=800D-4; //m2/Vs
11 Z=50D-6;
12 L=8.5D-6; //m
13 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 frequency:  
    4.7498883  
GHz  
-->
```

Figure 9.7: JEFT

```

14 Vd=12; //V
15 Vg=1.5; //V
16
17 //(i) Pinch off voltage and pinch off current
18 Vp=(e*Nd*a*a)/(2*er*e0);
19 disp('V',Vp,'Pinch off voltage:');
20
21 Ip=(mue*e*e*Nd*Nd*Z*a*a)/(e0*er*L);
22 disp('A',Ip,'Pinch off current:');
23 //Answer for Ip is 55809 A but it is given as
    0.00558 A
24
25 //(ii) Drain and maximum drain current
26 //Taking Ip=5.58mA as given in book
27 Ip1=0.00558; //A
28 x=(2/3)*(((Vd+Vg+W0)/Vp)^(3/2));
29 y=(2/3)*(((Vg+W0)/Vp)^(3/2));
30 Id=Ip1*[(Vd/Vp)-x+y];
31 disp('A',-Id,'Drain current:');
32
33 //Saturation Current
34 Is=Ip1*[(1/3)-((Vg+W0)/Vp)+((2/3)*(((Vg+W0)/Vp)
    ^((3/2))))];
35 disp('A',Is,'Drain saturation current:');
36
37 //(iii) Cut off frequency
38 f=(2*mue*e*Nd*a*a)/(%pi*er*e0*L*L);
39 disp('GHz',f/10^9,'Cutt off frequency:');

```

Scilab code Exa 9.9 MESFET

```

1 //Page Number: 469
2 //Example 9.9

```

Scilab 5.4.1 Console

Pinch off voltage:

7.885496

v

-->

Figure 9.8: MESFET

```

3  clc;
4  //Given
5  e=1.6D-19;
6  Nd=8D+23; //m-3
7  a=0.12D-6; //m
8  er=13.2;
9  e0=8.854D-12;
10
11 //Pinch off voltage
12 Vp=(e*Nd*a*a)/(2*er*e0);
13 disp('V',Vp,'Pinch off voltage:');

```

Scilab code Exa 9.10 Gunn device

```

1  //Page Number: 486
2  //Example 9.10
3  clc;
4  //Given
5  vd=2D+5; //m/s
6  L=10D-6; //m
7  Ec=3.2D+5; //V/m
8
9  //Natural frequency
10 f=vd/L;
11 disp('GHz',f/10^9,'Natural frequency:');
12
13 //Critical voltage
14 Vc=Ec*L;
15 disp('V',Vc,'Critical voltage:');

```

Natural frequency:

20.

GHz

Critical voltage:

3.2

V

-->

Figure 9.9: Gunn device

```
Scilab 5.4.1 Console

Power output:

    774.144

mW

-->
```

Figure 9.10: Gunn oscillator

Scilab code Exa 9.11 Gunn oscillator

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



```

13
14 //Power output
15 Pout=n*A*n0*e*vd*M*L*E;
16 disp('mW',Pout*1000,'Power output:');

```

Scilab code Exa 9.12 Tunnel diode

```

1 //Page Number: 487
2 //Example 9.12
3 clc;
4 //Given
5 G=15.85;
6 Rn=75; //ohm
7
8 Rl=Rn-(Rn/G);
9 C=Rl+(10*i);
10 disp('ohms',C,'Cavity impedance:');

```

Scilab code Exa 9.13 Gunn diode

```

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

```

```
Scilab 5.4.1 Console

Cavity impedance:

    70.268139 + 10.i

ohms

-->
```

Figure 9.11: Tunnel diode

```
Scilab 5.4.1 Console  
  
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

```
10  
11 /// Conductivity  
12 C=e*((n1*mu1)+(nu*muu));  
13 disp('m mho',C*1000,'Conductivity:');
```

Scilab code Exa 9.14 Gunn diode

```
1 //Page Number: 488  
2 //Example 9.14  
3 clc;  
4 //Given  
5 e0=8.854D-12;
```

```
Scilab 5.4.1 Console

Current density:

  3200000.

A/m sqr

Negative electron mobility:

  - 3125.

cm sqr/Vs

-->
```

Figure 9.14: Gunn diode

```
6 er=13.1;
7 vd=2.5D+5; //m/s
8 e=1.6D-19;
9 mu=0.015; //m2/Vs
10
11 // Criteria
12 n0L=(e0*er*vd)/(e*mu);
13 disp('m^-3',n0L,'n0L should be greater than');
```

Scilab code Exa 9.15 Gunn diode

```
1 //Page Number: 488
2 //Example 9.15
3 clc;
4 //Given
```

```

5 L=10D-6; //m
6 f=10D+9; //Hz
7 e=1.6D-19;
8 n0=2D+20; //m3
9 E=3200D+2; //V/m
10
11 //Current density
12 vd=L*f;
13 J=n0*e*vd;
14 disp('A/m sqr',J,'Current density:');
15
16 //Negative electron mobility
17 mu=-vd/E;
18 disp('cm sqr/Vs',mu*10000,'Negative electron
    mobility:');
19
20 //Answer for Negative electron mobility is 3125 but
    it is given as 3100

```

Scilab code Exa 9.17 IMPATT diode

```

1 //Page Number: 497
2 //Example 9.17
3 clc;
4 //Given
5 n=0.15;
6 Vdc=100; //V
7 Idc=200D-3; //A
8 vd=2D+5; //m/s
9 L=6D-6; //m
10
11 //(i) Maximum CW output power
12 Pdc=Vdc*Idc;

```

Scilab 5.4.1 Console

Maximum CW power output:

3.

W

Resonant frequency:

16.666667

GHz

-->

Figure 9.15: IMPATT diode

```

13 Pout=n*Pdc;
14 disp('W',Pout,'Maximum CW power output:');
15
16 //(ii) Resonant frequency
17 f=vd/(2*L);
18 disp('GHz',f/10^9,'Resonant frequency:');

```

Scilab code Exa 9.18 IMPATT diode

```

1 //Page Number: 497
2 //Example 9.18
3 clc;
4 //Given
5 n=0.1;
6 Vdc=100; //V
7 Idc=100D-3; //A
8 vd=2D+5; //m/s
9 L=5D-6; //m
10 V0=90; //V
11 k=3;
12
13 //(i) Maximum CW output power
14 Pdc=Vdc*Idc;
15 Pout=n*Pdc;
16 disp('W',Pout,'Maximum CW power output:');
17
18 //(ii) Resonant frequency
19 f=vd/(2*L);
20 disp('Hz',f,'Resonant frequency:');
21
22 //(iii) Transit time
23 T=L/vd;
24 disp('s',T,'Transit time:');

```


Scilab 5.4.1 Console

Maximum CW power output:

1.

W

Resonant frequency:

2.000D+10

Hz

Transit time:

2.500D-11

s

Avalanche multiplication factor:

2.6900369

-->

Figure 9.16: IMPATT diode

Scilab 5.4.1 Console

Power output:

9.

W

Duty cycle:

3.625D-11

s

-->

Figure 9.17: IMPATT diode

```
25
26 // (iv) Avalanche multiplication factor
27 M=1/(1-((Vdc/V0)^k));
28 disp(-M, 'Avalanche multiplication factor:');
```

Scilab code Exa 9.19 IMPATT diode

```
1 //Page Number: 498
2 //Example 9.19
3 clc;
4 //Given
5 n=0.1;
6 Vdc=100; //V
```

```

7 Idc=0.9; //A
8 t=0.01D-9; //s
9 f=16D+9; //Hz
10
11 //(i)Power output
12 Pdc=Vdc*Idc;
13 Pout=n*Pdc;
14 disp('W',Pout,'Power output:');
15
16 //(ii)Duty cycle
17 D=(t/2)+(1/(2*f));
18 disp('s',D,'Duty cycle:');

```

Scilab code Exa 9.20 IMPATT diode

```

1 //Page Number: 498
2 //Example 9.20
3 clc;
4 //Given
5 Cj=0.5D-12; //F
6 Lp=0.5D-9; //H
7 Irf=0.65; //A
8 Rl=2; //ohms
9 Vbd=80; //V
10 Idc=0.08; //A
11
12 //Resonant frequency
13 f=1/(2*pi*sqrt(Cj*Lp));
14 disp('Hz',f,'Resonant frequency:');
15
16 //Efficiency
17 Pout=(Irf*Irf*Rl)/2;
18 Pin=Vbd*Idc;

```

Scilab 5.4.1 Console

Resonant frequency:

1.007D+10

Hz

Efficiency:

6.6015625

%

-->

Figure 9.18: IMPATT diode

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

Scilab code Exa 9.21 TRAPATT diode

```
1 //Page Number: 501
2 //Example 9.21
3 clc;
4 //Given
5 J=25D+7; //A/m;
6 Na=2.5D+21; //m3
7 e=1.6D-19;
8
9 //Avlance zone velocity
10 vz=J/(Na*e);
11 disp('m/s',vz,'Avlanche zone velocity:');
```

Scilab code Exa 9.22 BARITT diode

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

Scilab 5.4.1 Console

```
Avlanche zone velocity:
```

```
625000.
```

```
m/s
```

```
-->
```

Figure 9.19: TRAPATT diode

Scilab 5.4.1 Console

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

```
11 //Breakdown voltage  
12 Vbd=(e*N*L*L)/(e0*er);  
13 disp('V',round(Vbd),'Breakdown voltage:');  
14  
15 //Breakdown electric field  
16 E=Vbd/L;  
17 disp('V/m',E,'Breakdown electric field:');
```

Scilab code Exa 9.23 Laser


```

1 //Page Number: 515
2 //Example 9.23
3 clc;
4 //Given
5 lam=8000D-10; //m
6 a=0.5D-2; //m
7 D=4D+8; //m
8
9 //Angular Spread
10 t=(1.22*lam)/a;
11 disp('rad',t,'Angular spread:');
12
13 //Aerial spread
14 A=%pi*((D*t)^2);
15 disp('m sqr',A,'Aerial spread:');
16
17
18 //Answer for A is given as 193 m sqr but it is 1.915
    D+10 m sqr

```

Scilab code Exa 9.24 Laser

```

1 //Page Number: 515
2 //Example 9.24
3 clc;
4 //Given
5 E=10; //W
6 T=1D-9; //s
7 c=3D+8; //m/s
8 lam=650D-9; //m
9
10 //Pulse Power
11 P=E/T;

```

Scilab 5.4.1 Console

```
Pulse Power:  
  
1.000D+10  
  
W  
  
Q value:  
  
461538.46  
-->|
```

Figure 9.22: Laser

```
12 disp('W',P,'Pulse Power:');  
13  
14 //Q value  
15 Q=(c*T)/lam;  
16 disp(Q,'Q value:');
```

Scilab code Exa 9.25 Heterojunction laser

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

```
Scilab 5.4.1 Console
Wavelength emitted:
  6716.
A
-->
```

Figure 9.23: Heterojunction laser

```
7 e=1.6D-19;
8 Eg=1.85; //eV
9
10 //Wavelength emitted
11 lam=(h*c)/(Eg*e);
12 lamarm=lam*1D+10;
13 disp('A',round(lamarm),'Wavelength emitted:');
```

Chapter 10

Striplines and Microstrip Lines

Scilab code Exa 10.1 Copper stripline

```
1 //Page Number: 554
2 //Example 10.1
3 clc;
4 //Given ,
5
6 z0=50; //ohm
7 t=0.001; //mm
8 b=0.32; //cm
9 er=2.20;
10 tandel= 0.0005;
11 rs=0.026; //ohm
12 f=10D+9; //Hz
13 c=3D+8; //m/sec
14
15 p=sqrt(er)*z0;
16 //As p<120
17 w=b*[((30*%pi)/p)-0.441];
18 disp('cm',w,'Width');
19
```

```
Scilab 5.4.1 Console
Width
    0.2655478
cm
Total attenuation in db/lambda:
    0.8556728
db/lambda
-->
```

Figure 10.1: Copper stripline

```

20 //Attenuation
21 k={(2*%pi*f*sqrt(er))/c};
22 ad=(k*tandel)/2;
23
24 //and
25 A=1+{(2*w)/(b-t)}+[{(b+t)/((b-t)*%pi)}*log(((2*b)-t)
    /t)];
26 //Hence
27 ac=(2.7D-3*rs*er*z0*A)/{30*%pi*(b-t)*1D-2};
28 //Total attenuation
29 a=ad+ac;
30
31 //Total attenuation in db
32 x=exp(a);
33 alp=20*log10(x); //db/m
34
35 //Total attenuation in db/lambda:
36 lam=c/(sqrt(er)*f);
37 lamm=lam*1D+2;
38 alph=alp/lamm;
39 disp('db/lambda',alph,'Total attenuation in db/lambda
    :');
40
41
42 //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

```

1 //Page Number: 555
2 //Example 10.2
3 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  
  
Characteristic impedance:  
    49.447285  
  
ohm  
  
-->
```

Figure 10.2: Microstrip line

```

4 //Given ,
5 er=9.7;
6 h=0.25; //mm
7 w=0.25; //mm
8 f=5D+9; //Hz
9 c=3D+8; //m/s
10
11 //(i) Dielectric constant
12 dc=((er+1)/2)+(((er-1)/2)*(1/sqrt(1+12*h/w)));
13 disp(dc,'Dielectric constant:');
14
15 //(ii) Phase constant
16 lam0=c/f;
17 pc=sqrt(dc)*(2*pi/lam0);
18 disp('rad/m',pc/100,'Phase constant:');
19
20 //(iii) Microstrip wavelength
21 lams=lam0/sqrt(dc);
22 disp('cm',lams*100,'Microstrip wavelength:');
23
24 //(iv) Capacitance per unit length
25 e0=8.854D-12;
26 cap=(2*pi*e0)/log((8*h/w)-(w/(4*h)));
27 disp('F/cm',cap,'Capacitance per unit length:');
28
29 //(v) Characterstic Impedance
30 ci=(60/sqrt(dc))*log((8*h/w)+(w/(4*h)));
31 disp('ohm',ci,'Characterstic impedance:');

```

Scilab code Exa 10.3 Microstrip

```

1 //Page Number: 556
2 //Example 10.3

```



```
Scilab 5.4.1 Console

Dielectric constant:

  3.8048369

Characteristic impedance:

  54.822056

ohm
-->
```

Figure 10.3: Microstrip

```
Scilab 5.4.1 Console

Strip supports TEM mode only
-->
```

Figure 10.4: Stripline

```
3 clc;
4 //Given ,
5 er=5.23;
6 w=10; //mils
7 t=2.8; //mils
8 h=7; //mils
9
10 dc=((er+1)/2)+(((er-1)/2)*(1/sqrt(1+12*h/w)));
11 disp(dc,'Dielectric constant:');
12
13 //As w/h>1
14 ci=(120*%pi)/(sqrt(dc)*((w/h)+1.393+0.667*log((w/h)
15   +1.444)));
15 disp('ohm',ci,'Characterstic impedance:');
```

Scilab code Exa 10.4 Stripline

```
1 //Page Number: 556
2 //Example 10.4
3 clc;
4 //Given ,
5
6 q=2.5;
7 dh=1.58;
8 er=9;
9 f=10;
10 c=3D+8;
11
12 erff=((er+1)/2)+(((er-1)/2)*((1+(12/q))(-1/2)));
13 vp=(c/sqrt(erff))*erff;
14 fe1=c/(sqrt(vp)*2*dh*q);
15 if f<fe1 then
16     disp('Strip supports TEM mode only');
17 else
18     disp('Strip does not support TEM mode only');
19 end
```

Scilab code Exa 10.5 Microstrip line

```
1 //Page Number: 557
2 //Example 10.5
3 clc;
4 //Given ,
5
6 er=9.7;
```

```
Scilab 5.4.1 Console
Dielectric constant:
    6.5564729
Characteristic 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

```

7 h=0.5; //mm
8 w=0.5; //mm
9 lt=2D-4;
10 t=0.02; //mm
11 f=5D+9; //Hz
12 fg=5; //HZ
13 c=3D+8;
14 rs=8.22D-3*sqrt(fg);
15
16 //(i) Dielectric constant
17 dc=((er+1)/2)+(((er-1)/2)*(1/sqrt(1+12*h/w)));
18 disp(dc,'Dielectric constant:');
19
20 //(ii) Characterstic Impedance
21 ci=(60/sqrt(dc))*log((8*h/w)+(w/(4*h)));
22 disp('ohm',ci,'Characterstic impedance:');
23
24 //(iii) Dielectric attenuation
25 lam0=c/f;
26 alphd=(%pi/lam0)*(er/sqrt(dc))*((dc-1)/(er-1))*lt;
27 disp('Np/m',alphd,'Dielectric attenuation:');
28
29 //Conductor attenuation
30 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));
31 r1m=r1*1D-2;
32 r2=(w/h)/[((w/h)+5.8+(0.03*(h/w)))]*(rs/(w*1D-3));
33 r2m=r2*1D-2;
34 alphc=(r1+r2)/(2*ci);
35 disp('Np/m',alphc,'Conductor attenuation:');
36
37 //(iv) Total attenuation
38 A=alphc+alphd;
39 Adb=A*8.686*1D-2;
40 disp('db/cm',Adb,'Total attenuation:');

```

```
conductor Q of the stripline:  
  
    1815.  
-->
```

Figure 10.6: Microstrip line

Scilab code Exa 10.6 Microstrip line

```
1 //Page Number: 558  
2 //Example 10.6  
3 clc;  
4 //Given  
5  
6 sig=5.8D+7;  
7 f=10; //GHz  
8 h=0.12D-2; //m  
9  
10 q=62.8*h*sqrt(f*sig);  
11 disp(round(q), 'conductor Q of the stripline:');
```

Scilab 5.4.1 Console

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

```
1 //Page Number: 558
2 //Example 10.7
3 clc;
4 //Given
5 Er=6;
6 h=4D-3; //m
7
8 //(i) W for Z0=50W
9 Z0=50; //W
10 W=(120*%pi*h)/(sqrt(Er)*Z0);
11 disp('mm',W*1000,'Required Width:');
12
13 //(ii) Stripline capacitance
14 E0=8.854D-12;
15 C=(E0*Er*W)/h;
16 disp('pF/m',C*10^12,'Stripline capacitance:');
17
18 //(iii) Stripline inductance
19 Mu0=4*%pi*10D-7;
20 L=(Mu0*h)/W;
21 disp('muH/m',L*10^5,'Stripline inductance:');
22
23 //(iv) Phase velocity
24 c=3D+8;
25 vp=c/sqrt(Er);
26 disp('m/s',vp,'Phase velocity');
```

Scilab code Exa 10.8 Stripline coupler


```
Scilab 5.4.1 Console

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

```

1 //Page Number: 559
2 //Example 10.8
3 clc;
4 //Given
5 c1=3D+8; //m/s
6 f=5D+9; //Hz
7 Er=9;
8 C=-10; //db
9 Z0=50; //ohm
10 //Length
11 L=(c1/f)/(4*sqrt(Er));
12 disp('cm',L*100,'Length:');
13
14 //Coupling coefficient
15 C0=10^(C/20);
16 disp(C0,'Coupling coefficient:');
17
18 //Even and odd mode impedance
19 Z0e=(Z0*sqrt(1+C0))/sqrt(1-C0);
20 disp('ohm',Z0e,'Even mode impedance:');
21
22
23 Z0o=(Z0*sqrt(1-C0))/sqrt(1+C0);
24 disp('ohm',Z0o,'Odd mode impedance:');

```

Scilab code Exa 10.9 Branch coupler

```

1 //Page Number: 560
2 //Example 10.9
3 clc;
4 //Given
5 Z0=50; //ohm
6 C=3; //db

```

```
Scilab 5.4.1 Console

Z01:

    35.313339

ohm

Z02:

    50.

ohm
-->|
```

Figure 10.9: Branch coupler

```

7
8 //Line impedance
9 Z01sqr=(1-(10^(C/-10)));
10 Z01=sqrt(Z0*Z0*Z01sqr);
11 disp('ohm',Z01,'Z01:');
12
13 Z02=Z01/(sqrt(1-(1/sqrt(2))^2));
14 disp('ohm',round(Z02),'Z02:');

```

Scilab code Exa 10.10 Broadside stripline

```

1 //Page Number: 560
2 //Example 10.10
3 clc;
4 //Given
5 W=6; //m
6 s=2.2; //m
7 b=4.8; //m
8 Er=2.2;
9
10 //Even and odd mode impedance
11 Z0e=((120*%pi)*(b-s))/(2*sqrt(Er)*W);
12 disp('ohm',Z0e,'Even mode impedance:');
13
14
15 Z0o=(Z0e*s)/b;
16 disp('ohm',Z0o,'Odd mode impedance:');
17
18 //Mid band coupling
19 x=(Z0e-Z0o)/(Z0e+Z0o);
20 C=-20*log10(x);
21 disp('db',C,'Mid band coupling:');
22

```

```
Scilab 5.4.1 Console

Even mode impedance:

    55.069595

ohm

Odd mode impedance:

    25.240231

ohm

Mid band coupling:

    8.6024938

db
-->
```

Figure 10.10: Broadside stripline

```
Scilab 5.4.1 Console

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

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

Scilab code Exa 10.11 Paralle stripline

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

```

8 E0=8.854D-12; //F/m
9 Mu0=4*%pi*10D-7; //H/m
10
11 //(i) W
12 W=(377*d)/(sqrt(Er)*Z0);
13 disp('mm',W*1000,'Required Width:');
14
15 //(ii) Stripline capacitance
16 C=(E0*Er*W)/d;
17 disp('pF/m',C*10^12,'Stripline capacitance:');
18
19 //(iii) Stripline inductance
20 L=(Mu0*d)/W;
21 disp('muH/m',L*10^6,'Stripline inductance:');
22
23 //(iv) Phase velocity
24 c=3D+8;
25 vp=c/sqrt(Er);
26 disp('m/s',vp,'Phase velocity');

```

Scilab code Exa 10.12 Shielded stripline

```

1 //Page Number: 562
2 //Example 10.12
3 clc;
4 //Given
5 Er=2.56;
6 w=25; //mils
7 t=14; //mils
8 d=70; //mils
9 E0=8.854D-12; //F/m
10
11 //(i) K factor

```

```

Scilab 5.4.1 Console

K factor:

    1.25

Fringe capacitance:

    15.664724

pF/m

Charecteristic Impedance:

    51.729298

ohm

-->

```

Figure 10.12: Shielded stripline

```

12 K=1/(1-(t/d));
13 disp(K, 'K factor:');
14
15 //(ii) Fringe capacitance
16 C=[(E0*Er)*[2*K*log(K+1)-(K-1)*log(K^2-1)]]/%pi;
17 disp('pF/m',C*10^12,'Fringe capacitance:');
18
19 //(iii) Charecteristic Impedance
20 X=1/[(w*K)/d+(C/(E0*Er))];
21 Z0=(94.15*X)/sqrt(Er);
22 disp('ohm',Z0,'Charecteristic Impedance:');
23
24
25 //Answer in book for Z0 is given as 50.29 but it
    should be 51.7

```

Scilab 5.4.1 Console

Output Impedance 1:

125.

ohm

Output Impedance 2:

83.333333

ohm

Reflection Coefficients:

- 0.6

- 0.4

-->

Figure 10.13: Lossless stripline

Scilab code Exa 10.13 Lossless stripline

```
1 //Page Number: 563
2 //Example 10.13
3 clc;
4 //Given
5 Z0=50; //ohm
6 //Sincr ratio of power is 2:3
7 x1=5/2;
8 y1=5/3;
9 //Output Impedance
10 Z1=x1*Z0;
11 Z2=y1*Z0;
12 disp('ohm',Z1,'Output Impedance 1:');
13 disp('ohm',Z2,'Output Impedance 2:');
14
15 //Input Impedance
16 Zin=[((Z2*2*Z2)/3)/((Z2+(2*Z2)/3))];
17
18 //Looking into Z1, Z2 is || to Z0
19 A1=(Z2*Z0)/(Z2+Z0);
20
21 //Looking into Z, Z2 is || to Z0
22 A2=(Z1*Z0)/(Z1+Z0);
23
24 //Reflection Coefficients
25 R1=(A1-Z1)/(A1+Z1);
26 R2=(A2-Z2)/(A2+Z2);
27
28 disp(R2,R1,'Reflection Coefficients:');
```

Chapter 11

Microwave Integrated Circuits

Scilab code Exa 11.1 Costs

```
1 //Page Number: 595
2 //Example 11.1
3 clc;
4 //Given
5 fabc=10000; //Rs/waffer
6 c=100;
7 y=40/100;
8 coc=fabc/(y*c);
9 //Cost of one chip
10 disp('Rs',coc, 'Cost of one chip:');
11
12 //Market Cost
13 mc=2*coc;
14 disp('Rs',mc, 'Market costof one chip:');
```

Scilab 5.4.1 Console

```
Cost of one chip:
```

```
    250.
```

```
Rs
```

```
Market cost of one chip:
```

```
    500.
```

```
Rs
```

```
-->|
```

Figure 11.1: Costs

```
Scilab 5.4.1 Console  
  
Yield:  
    62.5  
  
sp  
-->
```

Figure 11.2: Yield

Scilab code Exa 11.2 Yield

```
1 //Page Number: 595
2 //Example 11.2
3 clc;
4 //Given
5 c=5000; //Rs
6 S=0.6; //cm
7 //Sides
8 x=3; //cm
9 y=2.54; //cm
10 //break even cost
11 bec=250;
12 //hence , chips/waffers needed
13 cpw=c/bec;
14 D=x*y;
15 //For given Area, atleast 40 chips are required
16 n=2*cpw;
17
18 //Diameter
19 N=D/(sqrt(2)*S);
20 //Lower round off
21 NN=floor(N);
22 //Chips possible
23 cp=NN^2;
24
25 //Yield
26 Y=(n/cp)*100; //Percent
27 disp('%',Y,'Yield:');
```

Chapter 12

Microwave Measurements

Scilab code Exa 12.1 Microwave diode

```
1 //Page Number: 649
2 //Example 12.1
3 clc;
4 //Given
5 Is=0.1*(10^-6); //A
6 Pi=0; //dBm
7 Cs=0.1*(10^-12); //F
8 Ls=2*(10^-9);
9 Cj=0.15*(10^-12); //F
10 Rs=10; //ohm
11 T=293; //K
12 nktbye=25*(10^-3); //V
13
14 //Rj
15 Rj=(nktbye/Is);
16 disp('Kohm',Rj/1000,'Rj: ');
17
18 //Bi
19 Bi=nktbye/2;
```

Scilab 5.4.1 Console

Rj:

250.

Kohm

Bi:

12.5

A/W

Bv:

3125000.

V/W

-->|

Figure 12.1: Microwave diode


```

Scilab 5.4.1 Console

Mismatch Loss

    1.9382003

dB

Voltage sensitivity reduces by:

    64.

dB
-->|

```

Figure 12.2: Detector mismatch

```

20 Bii=Bi*1000;
21 disp('A/W',Bii,'Bi: ');
22
23 //Bv
24 Bv=Rj*Bii;
25 disp('V/W',Bv,'Bv: ');

```

Scilab code Exa 12.2 Detector mismatch

```

1 //Page Number: 650
2 //Example 12.2
3 clc;
4 //Given
5 vswr=4;

```

```

VSWR:
      10.301015
-->

```

Figure 12.3: Transmission waveguide

```

6
7 modT=(vswr-1)/(vswr+1);
8 Lm=-10*log10(1-(modT*modT)); //dB
9 disp('dB',Lm,'Mismatch Loss:');
10
11 //Sensitivity reduces by a factor
12 Bvd=(1-(modT*modT));
13 Bvdp=Bvd*100;
14 disp('%',Bvdp,'Voltage sensitivity reduces by:');

```

Scilab code Exa 12.3 Transmission waveguide

```

1 //Page Number: 650
2 //Example 12.3
3 clc;
4 //Given
5 f=10D+9; //Hz
6 c=3D+10; //cm/s

```

```
Scilab 5.4.1 Console
```

```
VSWR:  
  
      8.9126768  
-->|
```

Figure 12.4: VSWR of waveguide

```
7 a=4; //cm  
8 s=0.1; //cm  
9 lmb=c/f; //cm  
10 lmbg=lmb/(sqrt(1-((lmb/(2*a))^2)));  
11 vswr=lmbg/(%pi*s);  
12 disp(vswr, 'VSWR: ');  
13  
14 //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

```
1 //Page Number: 651  
2 //Example 12.4  
3 clc;  
4 //Given
```

```
Reflected Power:
```

```
0.5
```

```
W  
-->|
```

Figure 12.5: Directional couplers

```
5 delx=3.5; //cm
6 s=0.25; //cm
7
8 lmbg=2*delx;
9 vswr=lmbg/(%pi*s);
10 disp(vswr, 'VSWR: ');
```

Scilab code Exa 12.5 Directional couplers

```
1 //Page Number: 651
2 //Example 12.5
3 clc;
4 //Given
5 vswr=2;
6 Pin=4.5D-3; //W
7
8 modT=(vswr-1)/(vswr+1);
```

```
Reflection coefficient:  
  
    0.4117647  
-->|
```

Figure 12.6: Microwave line

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

Scilab code Exa 12.6 Microwave line

```
1 //Page Number: 652  
2 //Example 12.6  
3 clc;  
4 //Given  
5 Z0=50; //ohm  
6 p=2.4;  
7 L=0.313;  
8 x=2*%pi*L;  
9 y=tan(x);
```

```
Scilab 5.4.1 Console

Reflection coefficient:

    0.4472136

VSWR:

    2.618034

Fraction of power delivered:

    80.

#
--y|
```

Figure 12.7: Microwave line

```
10
11 Z1=(Z0*(1+(p*p*%i)))/(p+(p*%i));
12 T=(Z1-Z0)/(Z1+Z0);
13 p=sqrt((real(T))^2+(imag(T))^2);
14 disp(p, 'Reflection coefficient:');
```

Scilab code Exa 12.7 Microwave line

1 //Page Number: 652

```

2 //Example 12.7
3 clc;
4 //Given
5 Z1=25+25*i; //ohm
6 Z0=50; //ohm
7
8 T=(Z1-Z0)/(Z1+Z0);
9 p=sqrt((real(T))^2+(imag(T))^2);
10 disp(p,'Reflection coefficient:');
11
12 vswrr=(1+p)/(1-p);
13 disp(vswrr,'VSWR:');
14
15 //Fraction of power delivered
16 Pd=1-(p^2);
17 Pdp=Pd*100;
18 disp('%',Pdp,'Fraction of power delivered:');

```

Scilab code Exa 12.8 Rectangular waveguide

```

1 //Page Number: 653
2 //Example 12.8
3 clc;
4 //Given
5 d=2.4; //cm
6 lmbc=1.8;
7 c=3*10^10; //cm/s
8
9 lmbg=2*d;
10 lmb=(lmbg*lmbc)/(sqrt(lmbg^2+lmbc^2));
11 //Operating frequency
12 f=c/lmb;
13 disp('GHz',f/10^9,'Operating frequency:');

```

```
Scilab 5.4.1 Console

Operating frequency:

    17.800008

GHz

-->
```

Figure 12.8: Rectangular waveguide


```
Scilab 5.4.1 Console

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

```
1 //Page Number: 653
2 //Example 12.9
3 clc;
4 //Given
5 p=1.5;
6 IsL=1; //dB
7 InL=30; //dB
8
9 S21=10^(-IsL/20);
10
11 //Assuming tgree ports to be identical
12 S32=S21;
```

```
Dielectric constant  
1.631006  
Loss tangent of dielectric  
0.0010016  
-->
```

Figure 12.10: Air filled cavity

```
13 S13=S21;  
14  
15 //Isolations are also the same  
16 S31=10^(-InL/20);  
17 S23=S31;  
18 S12=S31;  
19  
20 //Refelction coefficients are also the same  
21 T=(p-1)/(p+1);  
22 S11=T;  
23 S22=T;  
24 S33=T;  
25  
26 S=[S11 S12 S13;S21 S22 S23;S31 S32 S33];  
27 disp(S, 'Matrix is:');
```

Scilab code Exa 12.10 Air filled cavity

```
1 //Page Number: 654
2 //Example 12.10
3 clc;
4 //Given
5 R1=10.6; //GHz
6 R2=8.30; //GHz
7 Q0=8200;
8 Q0d=890;
9
10 Er=(R1/R2)^2;
11 disp(Er, 'Dielectric constant');
12
13 Qd=(Q0-Q0d)/(Q0*Q0d);
14 disp(Qd, 'Loss tangent of dielectric');
```

Scilab code Exa 12.11 Rectangular Waveguide

```
1 //Page Number: 654
2 //Example 12.11
3 clc;
4 //Given
5 l0=0.15; //cm
6 lmbg=2*2.24; //cm
7 le=1.14; //cm
8 a=2.286; //cm
9 d=2;
10
11 B0=(2*%pi)/lmbg;
```

```
Scilab 5.4.1 Console

Er:

    2.0388585
-->
```

Figure 12.11: Rectangular Waveguide

```
12 x=tan(B0*10)/(B0*10);
13 // Also
14 x1=(10*x)/le;
15 // Correct value seems to be
16 Bele=2.786;
17 e1((((a/%pi)^2)*(Bele/le)^2)+1);
18 e2(((2*a)/lmbg)^2)+1;
19 Er=e1/e2;
20 disp(Er, 'Er: ');
21
22
23 // Answer in book for Er is given as 2.062 but it
    should be 2.038
```
