Scilab Textbook Companion for Microwave Engineering by M. Kulkarni[1]

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May 24, 2016

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

Book Description

Title: Microwave Engineering

Author: M. Kulkarni

Publisher: Umesh Publications, New Delhi

Edition: 1

Year: 2011

ISBN: 81-88114-26-X

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.

Contents

List of Scilab Codes

Chapter 3

Transmission Lines

Scilab code Exa 3.1 Program to find value of terminating impedance of lossless transmission line

```
//Caption:Program to find value of terminating
   impedance of lossless transmission line.
//Exa:3.1
clc;
clear;
close;
//Given:
Z_ch=100;//in ohms
S=5;//VSWR (unitless)
Z=Z_ch*S;
printf("\n\n\t The terminating impedence = %d ohms "
   ,Z);
```

Scilab code Exa 3.2 Calculate the charcteristic impedance and attenuation constant and phase constant of transmission line and Calculate power delivered to load if line length is 500 km

```
//Caption:Calculate the charcteristic impedance, attenuation constant, phase constant of transmission line Calculate power delivered to load , if line length=500 km.
//Exa:3.2
clc;
clear;
close;
e=2.718;
//Given:
R=8;//in ohm/kilometer
L=2*10^-3;//in henry/kilometer
C=0.002*10^-6;//in farad/kilometer
G=0.07*10^-6;//second/kilometer
f=2000;//in hertz
//Since [w=2*(pi)*f] & [Zch={(R+jwL)/(G+jwC)}^0.5]
w=2*%pi*f;//in radians
Z_ch={(R+%i*w*L)/(G+%i*w*C)}^0.5;//computing characteristic impedance
disp(Z_ch,"Characteristic impedance (in ohms) =");
y={(R+%i*w*L)*(G+%i*w*C)}^0.5;
a=real(y);//atteneuation constant
b=imag(y);//phase constant
disp(a,"Atteneuation constant (in NP/km) =");
disp(b,"Phase constant (in radian/km) =");
V_in=2;//in volts
l=500;//in kilometers
Z_in=Z_ch;//Since line terminated at its char. imped. so, Z_in=Z_ch=Z(load)
I_s=V_in/Z_in;
Imag=[[{{real(I_s)}^2}+{{imag(I_s)}^2}]^0.5]*10^3;//in milliampere
Iang=atan(imag(I_s)/real(I_s))*(180/%pi);//in degrees
```

```
I=Imag*e^-1.99;//I=Is*e^-yl
//P(power delivered)=I*I*REAL(Z_ch)
P=I*I*real(Z_ch);
disp(P,"Power delivered to load (in microwatt =)");
```

Scilab code Exa 3.3 Calculate phase velocity of the wave that propogates on line

```
//Caption:Calculate phase velocity of the wave that
   propogates on line as given in example 3.2
//Exa:3.3
clc;
clear;
close;
w=4*%pi*10^3;//in rad/sec
b=0.02543;//in rad/km
V_p=w/b;// phase velocity
disp(V_p,"Phase velocity (in km/sec) =");
```

Scilab code Exa 3.4 Calculate Current drawn from generator and Magnitune and phase of load current and Power delivered to load

```
//Caption:Calculate (a)-Current drawn from generator
   . (b)-Magnitune & phase of load current. (c)-
   Power delivered to load.
```

```
//Exa: 3.4
clc;
clear;
close;
f=37.5*10^6;//frequency(in hertz)
wl=(3*10^8)/f;//wavelength (in meters)
Z_l=100;//in ohms
Z_o=200;//in ohms
l=5*wl/4;//length of line (in meters)
b=2*%pi/wl;
//At generator end,
Z_i=Z_o*(Z_l+%i*Z_o*tan(b*l))/(Z_o+%i*Z_l*tan(b*l));
V_s=200*Z_i/(200+Z_i);
I_s=200/(200+Z_i);
disp(real(I_s),"Current drawn from generator(in amps
    ) =");
//for a lossless line , P(avg)*I_input=P(avg)*I_load
P_avg=V_s*I_s;//in watts
disp(real(P_avg),"Power delivered to load (in watts)
    =)");
//Real(Vs*Is)=Real(Vs*I_load)
I_load=(P_avg/Z_l)^0.5;//in amps
disp(real(I_load),"Current flowing in load (in amps)
    =)");
```

Scilab code Exa 3.5 Calculate VSWR and reflection coefficient

```
//Caption:Calculate VSWR & reflection coefficient.
//Exa: 3.5
clc;
clear;
```

```
close;
Z_o=50;//in ohms
f=300*10^6;//in Hz
Z_l=50+%i*50;//in ohms
wl=(3*10^8)/f;//wavelength(in meters)
P=[(Z_l-Z_o)/(Z_l+Z_o)];
P_mag={(real(P)^2)+(imag(P)^2)}^0.5;
P_ang=atan(imag(P)/real(P))*180/%pi;//in degrees
S={1+P_mag}/{1-P_mag};
disp(P,"Reflection coefficient =");
disp(P_mag,"Magnitude of reflection coeffcient =");
disp(P_ang,"Angle (in degree) =");
disp(S,"VSWR =");
```

Scilab code Exa 3.6 Determine point of attachment and length of stub

```
//Caption:Determine point of attachment & length of
    stub.
//Exa 3.6
clc;
clear;
close;
Z_l=100;//in ohms
Z_o=600;//in ohms
f=100*10^6;//in Hz
wl=(3*10^8)/f;
//Position of stub is :
m=((Z_l*Z_o)/(Z_l-Z_o))^0.5;
pos={wl/(2*%pi)}*atan((Z_l/Z_o)^0.5);//in meters
l={wl/(2*%pi)}*{atan(m)};//in meters
disp(pos,"Position of stub (in meters) =");
```

```
disp(abs(l),"Length of stub (in meters) =");
```

Scilab code Exa 3.7 Calculate terminating impedance

```
//Caption:Calculate terminating impedance.
//Exa: 3.7
clc;
clear;
close;
Z_o=50;
S=3.2;
X_min=0.23;//in terms of wavelength(wl))
//So :
Z_l=Z_o*[[1-%i*S*tan(2*%pi*X_min)]/[S-%i*tan(2*%pi*
    X_min)]];//in ohms
Z_lmag=[(real(Z_l)^2)+(imag(Z_l)^2)]^0.5;
Z_lang=atan(imag(Z_l)/real(Z_l));
disp("The load impedance");
disp(Z_lmag,"magnitude (in ohms) =");
disp(Z_lang*180/%pi,"angle (in degrees) =");
```

Scilab code Exa 3.8 Determine the VSWR and Position of 1st Vmin to Vmax and Vmin and Vmax and Impedance at Vmin and Vmax

```
//Caption:Determine:(a)VSWR; (b)Position of 1st Vmin & Vmax; (c)Vmin & Vmax; (d)Impedance at Vmin & Vmax.
//Exa: 3.8
clc;
clear;
close;
Z_o=50;//in ohms
Z_l=100;//in ohms
f=300*10^3;//in Hz
P_l=50*10^-3;//in watts
wl=(3*10^8)/f;
p=(Z_l-Z_o)/(Z_l+Z_o);
S=(1+abs(p))/(1-abs(p));
disp(S,"VSWR =");
//Since real Zl > Zo ,
pos=wl/4;
disp("First Vmax is located --->at the load ");
disp("First Vmin is located at --->(wavelength/4)= ");
disp(pos,"(in meters)");
V_max=(P_l*Z_l)^0.5;
V_min=V_max/S;
disp(V_max,"Vmax (in volts) =");
disp(V_min,"Vmin (in volts) =");
disp(Z_o/S,"Zin at Vmin (in ohms) =:");
disp(Z_o*S,"Zin at Vmax (in ohms) =");
```

Scilab code Exa 3.9 Determine in dB the reflection loss and transmission line and return loss

```
//Caption:Determine in dB: (a)-reflection loss, (b)-
   transmission line (c)-return loss.
//Exa: 3.9
clc;
clear;
close;
Z_o=600;//in ohm
Z_s=50;//in ohm
l=200;//in meter
Z_l=500;//in ohm
p=(Z_l-Z_o)/(Z_l+Z_o);
ref_los=10*(log(1/(1-(abs(p))^2)))/(log(10));//in dB
disp(ref_los,"Reflection loss (in dB) =");
//attenuation loss= 0 dB
//Transmisson loss = (attenuation loss)+(reflection
   loss) = (reflection loss)
tran_los=ref_los;
disp(tran_los,"Transmisson loss (in dB) =");
ret_los=10*((log(abs(p)))/(log(10)));
disp(ret_los,"Return loss(in dB) =");
```

Scilab code Exa 3.10 Calculate the charcterstic impedance and phase velocity

```
//Caption:Calculate the charcterstic impedance &
   phase velocity
//Exa:3.10
clc;
clear;
close;
e=2.718;
```

```
f=1000;//in Hz
l=10000;//in meters
Z_sc=(2631+%i*1289);//in ohms
Z_oc=(221-%i*137);//in ohms
Z_o=[Z_sc*Z_oc]^0.5;
Z_mag=[real(Z_o)^2+imag(Z_o)^2]^0.5;
Z_ang=[atan((imag(Z_o))/real(Z_o))]*180/%pi;
disp(Z_mag,"Characteristic impedance (in ohms) =");
disp(Z_ang,"Angle (in degrees) =");
x=[(Z_oc/Z_sc)^0.5];
//x=tanh(v*l)
//As, tanh(t)=[e^t-e^-t]/[e^t+e^-t]
v=(261+%i*2988)/l;
a=real(v);
b=imag(v);
disp(2*%pi*f/b,"Phase velocity (in meter per sec.) =
    ");
```

Chapter 4

Microwaves Transmission Lines

Scilab code Exa 4.1 Calculate the inductance per unit length and capacitance per unit length and charcteristic impedance and velocity of propagation

```
//Caption:Calculate (i)-inductance per unit length,(ii)-capacitance per unit length,(iii)-charcteristic impedance,(iv)-velocity of propagation
//Exa:4.1
clc;
clear;
close;
//Given:
d=0.49;//in cm
D=1.1;//in cm
e_r=2.3;
c=3*10^8;//in meter/second
L=2*(10^-7)*log(D/d);//in Henry/meter
C=55.56*(10^-12)*(e_r)/log(D/d);//in farad/meter
R_o=(60/sqrt(e_r)) *log(D/d);//in ohms
v=c/sqrt(e_r);//in meter/second
disp(L,'Inductance per unit length(in H/m) =');
disp(C,'Capacitance per unit length(in F/m) =');
disp(R_o,'Characteristic Impedance (in ohms) =');
```

```
disp(v,'Velocity of propagation (in m/s)=');
```

Scilab code Exa 4.2 Calculate the attenuation and phase constants and phase velocity and relative permittivity and power loss

```
//Caption:Calculate the attenuation, phase constants ,phase velocity,relative permittivity,power loss.
//Exa:4.2
clc;
clear;
close;
R=0.05;//in ohms
G=0;
l=50;//in meter
e=2.3;//dielectric constant
c=3*10^8;//in m/s
L=2*(10^-7);//from Exa:4.1
C=1.58*(10^-10);//from Exa:4.1
P_in=480;//in watts
f=3*10^9;//in hertz
Z_o=sqrt(L/C);
a=R/Z_o;//in Np/m
b=2*%pi*f*sqrt(L*C);//in rad/m
V_p=1/sqrt(L*C);
e_r=(c/V_p)^2;
P_loss=P_in*2*l;
disp(a,'Atteneuation (in Np/m) =');
disp(b,'Phase constant (in rad/m) =');
disp(V_p,'Phase velocity (in m/s) =');
disp(e_r,'Relative permittivity =');
disp(P_loss,'Power loss (in watts) =');
```

Scilab code Exa 4.3 Calculate the breakdown power of air filled coaxial cable

```
//Caption:Calculate the breakdown power of air
    filled coaxial cable at 9.375 GHz.
//Exa:4.3
clc;
clear;
close;
//Given:
a=2.42;//in cm
x=2.3;//x=(b/a)
P_bd=3600*a^2*log(x);//in kilowatts
disp(P_bd,'Breakdown Power (in kW) =');

//answer in book is wrongly written as 398 kW.
```

Scilab code Exa 4.4 Calculate charcteristic impedance and velocity of propagation

```
//Caption:Calculate charcteristic impedance &
    velocity of propagation.
//Exa:4.4
clc;
```

```
clear;
close;
b=0.3175;//in cm
d=0.0539;//in cm
c=3*10^8;//in m/s
e_r=2.32;
Z_o=60*log(4*b/(%pi*d))/sqrt(e_r);//in ohms
V_p=c/sqrt(e_r);//in m/s
disp(Z_o,'Charcteristic impedance (in ohms) =');
disp(V_p,'Velocity of propagation (in m/s) =');
```

Scilab code Exa 4.5 Calculate charcteristic impedance and effective dielectric constant and velocity of propagation

```
//Caption:Calculate charcteristic impedance &
    effective dielectric constant & velocity of
    propagation
//Exa:4.5
clc;
clear;
close;
e_r=9.7;
c=3*10^8;//in m/s
r_1=0.5;//when ratio: (W/h)=0.5
r_2=5;//when ratio: (W/h)=5
//For W/h ratio=0.5
e_eff_1=(e_r+1)/2+((e_r-1)/2)*[1/{sqrt(1+12*(1/r_1))
    +0.04*(1-r_1)}];
Z_o_1=60*log(8/r_1+r_1/4)/sqrt(e_eff_1);
v_1=c/sqrt(e_eff_1);
disp("For W/h=0.5 ,");
```

```
disp(e_eff_1,'Effective dielectric constant =');
disp(Z_o_1,'Charcteristic impedance (in ohms) =');
disp(v_1,'Velocity of propagation (in m/s) =');
//For W/h ratio=5
e_eff_2=(e_r+1)/2+((e_r-1)/2)*[1/{sqrt(1+12*(1/r_2))
    }];
Z_o_2=120*%pi*[1/{r_2+1.393+0.667*log(1.444+r_2)}]/
    sqrt(e_eff_2);
v_2=c/sqrt(e_eff_2);
disp("For W/h=5,");
disp(e_eff_2,'Effective dielectric constant =');
disp(Z_o_2,'Charcteristic impedance (in ohms) =');
disp(v_2,'Velocity of propagation (in m/s) =');
```

Scilab code Exa 4.6 Calculate ratio of circular waveguide crosssectional area to rectangular waveguide crosssection

```
//Caption:Calculate ratio of circular waveguide
    cross-sectional area to rectangular waveguide
    cross-section
//Exa:4.6
clc;
clear;
close;
//For TE Wave propagated:
//for Rectangular , taking (a=2b)
r=100;//assume
//for TE11, wavelength=2*pi*r/1.841
//for TE10, wavelength=2a
a=(2*%pi*r/1.841)/2;
ar_rec_TE=(a)*(a/2);
```

```
ar_cir_TE=%pi*r^2;
ratio_TE=(ar_cir_TE)/(ar_rec_TE);
disp(ratio_TE,'Ratio of Circular & Rectangular coss-
    section area (in TE) =');
//For TM Wave propagated:
//for Rectangular , taking (a=2b)
//for TE01, wavelength=2.6155*r
//for TE11, wavelength=4b/sqrt(5)
b=(2.6155*r)/1.78885;
ar_rec_TM=(b)*(b);
ar_cir_TM=%pi*r^2;
ratio_TM=(ar_cir_TM)/(ar_rec_TM);
disp(ratio_TM,'Ratio of Circular & Rectangular coss-
    section area (in TM) =');
```

Scilab code Exa 4.7 Calculate breadth of rectangular waveguide

```
//Caption:Calculate breadth of rectangular waveguide
//Exa:4.7
clc;
clear;
close;
f=9*10^9;//in Hz
c=3*10^10;//in cm/s
wl_g=4;//in m
wl_o=c/f;
wl_c=[sqrt(1-((wl_o/wl_g)^2))/wl_o]^-1;
b=wl_c/4;
disp(b,'Breadth of rectangular waveguide (in cm) =')
    ;
```

Scilab code Exa 4.8 Calculate the cutoff wavelength and guide wavelength and group and phase velocities

```
//Caption:Calculate the cutoff wavelength, guide
   wavelength, group & phase velocities
//Exa:4.8
clc;
clear;
close;
a=10;//in cm
c=3*10^10;//in cm/s
wl_c=2*a;//in cm
f=2.5*10^9;//in Hz
wl_o=c/f;
wl_g=wl_o/(sqrt(1-(wl_o/wl_c)^2));//in cm
V_p=c/(sqrt(1-(wl_o/wl_c)^2));
V_g=c^2/V_p;
disp(wl_c,'Cut-off wavelength (in cm) =');
disp(wl_g,'Guide wavelength (in cm) =');
disp(V_p,'Phase velocity (in cm/s) =');
disp(V_g,'Group velocity (in cm/s) =');
```

Scilab code Exa 4.9 Calculate the possible modes and cutoff frequencies and guide wavelength

```
//Caption:Calculate (i)-possible modes,(ii)-cut-off
    frequencies,(iii)-guide wavelength
//Exa:4.9
clc;
clear;
close;
//For TE mode:
a=2.5;//in cm
b=1;//in cm
f=8.6*10^9;//in Hz
c=3*10^10;//in cm/s
wl_o=c/f;
wl_c_1=2*b;//for TE01
wl_c_2=2*a;//for TE10
disp( 'Only TE10 mode is possible');
f_c=c/wl_c_2;
wl_c_3=2*a*b/sqrt(a^2+b^2);//for TE11 & TM11
wl_g_TE10=wl_o/(sqrt(1-(wl_o/wl_c_2)^2));//for TE10
disp(f_c,'Cut-off frequency(in Hz) =');
disp(wl_g_TE10,'Guide wavelength for TE10 (in cm) ='
    );
//For TM mode:
disp('TM11 also propagates');
wl_c_TM11=wl_c_3;
wl_g_TM11=wl_o/(sqrt(1-(wl_o/wl_c_2)^2));//for TM11
disp(wl_g_TM11,'Guide wavelength for TM11 (in cm) ='
    );
```

Scilab code Exa 4.10 Calculate the required size of guide and frequencies that can be used for this mode of propagation

```
//Caption:Calculate (i)-required size of guide,(ii)-frequencies that can be used for this mode of propagation
//Exa:4.10
clc;
clear;
close;
wl_c=10;//in cm
c=3*10^10;//in cm/s
r=wl_c/(2*%pi/1.841);//in cm
area=%pi*r^2;//in sq. cm
f_c=c/wl_c;
disp(r,'Radius of circular waveguide(in cm) =');
disp(area,'Area of cross-section of circular waveguide(in cm) =');
disp('Frequency above');
disp(f_c);
disp('can be propagated');
```

Scilab code Exa 4.11 Find all modes that can propagate at 5000MHz

```
//Caption:Find all modes that can propagate at 5000 MHz.
//Exa:4_11
clc;
clear;
close;
a=4;//in cm
b=3;//in cm
f=5*10^9;//in Hz
c=3*10^10;//in cm/s
```

```
wl_o=c/f;
//For TE waves:
wl_c_TE01=2*b;//for TE01
wl_c_TE10=2*a;//for TE10
wl_c_TE11=2*a*b/sqrt(a^2+b^2);//for TE11
if(wl_c_TE01>wl_o)
    disp('TE01 can propagate');
else
    disp('TE01 cannot propagate');
end
if(wl_c_TE10>wl_o)
    disp('TE10 can propagate');
else
    disp('TE10 cannot propagate');
end
if(wl_c_TE11>wl_o)
    disp('TE11 can propagate');
else
    disp('TE11 cannot propagate');
end
```

Scilab code Exa 4.12 Calculate the cutoff wavelength and cutoff frequency and wavelength in guide

```
//Caption:Find all modes that can propagate at 5000
   MHz.
//Exa:4_11
clc;
clear;
close;
a=4;//in cm
```

```
b=3;//in cm
f=5*10^9;//in Hz
c=3*10^10;//in cm/s
wl_o=c/f;
//For TE waves:
wl_c_TE01=2*b;//for TE01
wl_c_TE10=2*a;//for TE10
wl_c_TE11=2*a*b/sqrt(a^2+b^2);//for TE11
if(wl_c_TE01>wl_o)
    disp('TE01 can propagate');
else
    disp('TE01 cannot propagate');
end
if(wl_c_TE10>wl_o)
    disp('TE10 can propagate');
else
    disp('TE10 cannot propagate');
end
if(wl_c_TE11>wl_o)
    disp('TE11 can propagate');
else
    disp('TE11 cannot propagate');
end
```

Scilab code Exa 4.13 Calculate the frequency of the wave

```
//Caption:Calculate (i)-cutoff wavelength,(ii)-
    cutoff frequency,(iii)-wavelength in guide
//Exa:4.12
clc;
clear;
```

```
close;
c=3*10^10;//in cm/s
d=4;//in cm
r=d/2;//in cm
wl_c=2*%pi*r/1.841;//in cm
f_c=c/wl_c;
f_signal=5*10^9;//in Hz
wl_o=c/f_signal;
wl_g=wl_o/sqrt(1-(wl_o/wl_c)^2);
disp(wl_c,'Cut-off wavelength (in cm) =');
disp(f_c,'Cut-off frequency (in Hz) =');
disp(wl_g,'Guide wavelength (in cm) =');
```

Scilab code Exa 4.14 Calculate the guide wavelength and phase constant and phase velocity for dominant mode

```
//Caption:Calculate (i)-guide wavelength,(ii)-phase
   constant,(iii)-phase velocity for dominant mode
//Exa:4.14
clc;
clear;
close;
c=3*10^10;//in cm/s
a=5;//in cm
b=2.5;//in cm
wl_o=4.5;//in cm
//For TE10 mode:
wl_c=2*a;
wl_g=wl_o/sqrt(1-(wl_o/wl_c)^2);
V_p=c/sqrt(1-(wl_o/wl_c)^2);
w=2*%pi*c/wl_o;
```

```
w_c=2*%pi*c/wl_c;
b=sqrt(w^2-w_c^2)/c;
disp(wl_g,'Guide wavelength (in cm) =');
disp(b,'Phase constant =');
disp(V_p,'Phase velocity (in cm/s) =');

//answer in book is wrongly written as guide
    wavelength =7.803 cm
//answer in book is wrongly written as Phase
    velocity = 5.22*10^10 cm/s
```

Scilab code Exa 4.15 Calculate what modes propagate at free space wavelength of 10 cm and 5 cm

```
//Caption:Calculate what modes propagate at free
    space wavelength of (i)10 cm,(ii)5 cm
//Exa:4.15
clc;
clear;
close;
c=3*10^10;//in cm/s
wl_c_TE10=16;//Critical wavelength of TE10
wl_c_TM11=7.16;//Critical wavelength of TM11
wl_c_TM21=5.6;//Critical wavelength of TM21
//For (i): 10 cm
wl_o=10;//in cm
disp(wl_o,'For free space wavelength (in cm) =');
if(wl_c_TE10>wl_o)
    disp('    TE10 can propagate');
else
    disp('    TE10 cannot propagate');
```

```
end
if(wl_c_TM11>wl_o)
    disp('    TM11 can propagate');
else
    disp('    TM11 cannot propagate');
end
if(wl_c_TM21>wl_o)
    disp('    TM21 can propagate');
else
    disp('    TM21 cannot propagate');
end
//For (ii): 5 cm
wl_o=5;//in cm
disp(wl_o,'For free space wavelength (in cm) =');
if(wl_c_TE10>wl_o)
    disp('    TE10 can propagate');
else
    disp('    TE10 cannot propagate');
end
if(wl_c_TM11>wl_o)
    disp('    TM11 can propagate');
else
    disp('    TM11 cannot propagate');
end
if(wl_c_TM21>wl_o)
    disp('    TM21 can propagate');
else
    disp('    TM21 cannot propagate');
end
```

Scilab code Exa 4.16 Determine the charcteristic wave impedance

```
//Caption:Determine the charcteristic wave impedance
//Exa:4.16
clc;
clear;
close;
c=3*10^10;//in cm/s
f=10*10^9;//in Hz
a=3;//in cm
b=2;//in cm
n=120*%pi;
wl_o=c/f;
wl_c=2*a*b/sqrt(a^2+b^2);
Z_TM=n*sqrt(1-(wl_o/wl_c)^2);
disp(Z_TM,'Characteristic impedance (in ohms) =');

//answer in book is wrongly written as 61.618 ohms
```

Scilab code Exa 4.17 Determine the diameter of waveguide and guide wavelength

```
//Caption:Determine the diameter of waveguide &
   guide wavelength
//Exa:4.17
clc;
clear;
close;
c=3*10^10;//in cm/s
f=6*10^9;//in Hz
f_c=0.8*f;
```

```
wl_c=c/f_c;
D=1.841*wl_c/%pi;
wl_o=c/f;
wl_g=wl_o/sqrt(1-(wl_o/wl_c)^2);
disp(D,'Diameter of waveguide (in cm) =');
disp(wl_g,'Guide wavelength (in cm) =');
```

Scilab code Exa 4.18 Show TE01 mode propagates under given conditions

```
//Caption:Show TE01 mode propagates under given
    conditions
//Exa:4.18
clc;
clear;
close;
a=1.5;//in cm
b=1;//in cm
e_r=4;//dielectric
c=3*10^10;//in cm/s
wl_c=2*b;
f_c=c/wl_c;
f_imp=6*10^9;//impressed frequency (in Hz)
wl_air=c/f_imp;
//Inserting dielectric:
wl_dielec=wl_air/sqrt(e_r);
if(wl_dielec>wl_c)
    disp('    TE01 can propagate');
else
    disp('    TE01 cannot propagate');
end
```

Scilab code Exa 4.19 Calculate the amount of attenuation if signal of frequency is 6GHz

```
//Caption:Calculate the amount of attenuation if
   signal of frequency is 6GHz
//Exa:4.19
clc;
clear;
close;
u=4*%pi*10^-7;
e=8.85*10^-12;
c=3*10^10;//in cm/s
f=6*10^9;//in Hz
a=1.5;//in cm
b=1;//in cm
//For TE10 mode:
m=1;
n=0;
wl_c=2*a;
f_c=c/wl_c;
t_1=(m*%pi/a)^2;
t_2=(n*%pi/b)^2;
t_3=(((2*%pi*f)^2)*u*e);
a=sqrt(t_1+t_2-t_3);//in neper/m
disp(a*20/log(10),'Attenuation (in dB/m) =');
```

Scilab code Exa 4.20 Calculate the maximum power handling capacity

```
//Caption:Calculate the maximum power handling
   capacity
//Exa:4.21
clc;
clear;
close;
c=3*10^10;//in cm/s
f=9*10^9;//inHz
a=3;//in cm
b=1;//in cm
E_max=3000;//in V/cm
wl_o=c/f;
wl_c=2*a;//in TE10
wl_g=ceil (wl_o/sqrt(1-(wl_o/wl_c)^2));
P_max=(6.63*10^-4)*E_max^2*a*b*(wl_o/wl_g);
disp(P_max/1000,'Maximum power for rectangular
   waveguide (in kilowatts)=');
```

Scilab code Exa 4.21 Calculate the maximum power

```
//Caption:Calculate the maximum power
//Exa:4.21
```

```
clc;
clear;
close;
c=3*10^10;//in cm/s
f=9*10^9;//inHz
E_max=300;//in V/cm
d=5;
wl_o=c/f;
//For TE11
wl_c=d*%pi/1.841;
wl_g=wl_o/sqrt(1-(wl_o/wl_c)^2);
P_max=0.498*E_max^2*d^2*(wl_o/wl_g);
disp(P_max,'Maximum power (in watts) =');
```

Scilab code Exa 4.22 Calculate the peak value of electric feild occuring in the waveguide

```
//Caption:Calculate the peak value of electric feild
    occuring in the waveguide
//Exa:4.22
clc;
clear;
close;
c=3*10^10;//in cm/s
f=30*10^9;//inHz
a=1;//in cm
b=1;
P_max=746;//in watts
wl_o=c/f;
wl_c=2*a;
Z=120*%pi/sqrt(1-(wl_o/wl_c)^2);
```

```
E_max=sqrt(P_max*4*Z/(a*b/10000));
disp(E_max/1000,'Peak value of electric field (in kV
    /m) =');
```

Scilab code Exa 4.23 Calculate the breakdown power of air filled rectangular waveguide for dominant mode

```
//Caption:Calculate the breakdown power of air
    filled rectangular waveguide for dominant mode at
     9.375 GHz.
//Exa:4.23
clc;
clear;
close;
//Given:
c=3*10^10;//in cm/s
a=2.3;//in cm
b=1;//in cm
f=9.375*10^9;//in Hz
wl_o=c/f;
P_bd_TE11=597*2.3*1*{1-{wl_o/(2*a)}^2}^0.5;
disp(P_bd_TE11,'Breakdown power for dominant mode (
    in kW) =');
```

Scilab code Exa 4.24 Calculate the breakdown power of circular waveguide

```
//Caption:Calculate the breakdown power of circular
    waveguide
//Exa:4.24
clc;
clear;
close;
//Given:
d=5;//in cm
c=3*10^10;//in cm/s
f=9*10^9;//inHz
//Dominant mode is TE11:
wl_o=c/f;
wl_c=%pi*d/1.841;
f_c=c/wl_c;
P_bd_TE11=1790*(d/2)^2*[1-{f_c/f}^2]^0.5;
disp(P_bd_TE11/1000,'Breakdown power (in kW) =');
```

Chapter 5

Cavity Resonators

Scilab code Exa 5.1 Determine the minimum distance between two end plates

```
//Caption:Determine the minimum distance between two
    end plates
//Exa:5.1
clc;
clear;
close;
//Given:
a=3;//in cm
c=3*10^10;//in cm/s
f=10*10^9;//in Hz
P_01=2.405;
d=%pi/sqrt(f^2*4*%pi^2/c^2-(P_01/a)^2);
disp(d,'Minimum distance (in cm) =');
```

Scilab code Exa 5.2 Calculate the lowest frequency of a rectangular cavity resonator

```
//Caption:Calculate the lowest frequency of a
   rectangular cavity resonator
//Exa:5.2
clc;
clear;
close;
//Given:
c=3*10^10;//in cm/s
a=2;//in cm
b=1;//in cm
d=3; //in cm
disp('Dominant mode is TE101');
m=1;
n=0;
p=1;
f=(c/2)*[(m/a)^2+(n/b)^2+(p/d)^2]^0.5;
disp(f/10^9,'Lowest resonant frequency(in GHz) =');
```

Scilab code Exa 5.3 Calculate the resonant frequency of a circular cavity resonator

```
//Caption:Calculate the resonant frequency of a
   circular cavity resonator
//Exa:5.3
clc;
clear;
close;
//Given:
```

```
d=12.5;//diameter(in cm)
c=3*10^10;//in cm/s
l=5;//length(in cm)
a=d/2;
//For TM012 mode:
n=0;
m=1;
p=2;
P=2.405;
f=(c/(2*%pi))*[(P/a)^2+(p*%pi/d)^2]^0.5;
disp(f/10^9,'Resonant frequency (in GHz) =');

//Answer in book in wrongly given as 6.27GHz
```

Scilab code Exa 5.4 Calculate the resonant frequency of a circular cavity resonator

```
//Caption:Calculate the resonant frequency of a
    circular cavity resonator
//Exa:5.4
clc;
clear;
close;
//Given:
c=3*10^10;//in cm/s
a=3;//in cm
b=2;//in cm
d=4;//in cm
//For TE101:
m=1;
n=0;
```

```
p=1;
f=(c/2)*[(m/a)^2+(n/b)^2+(p/d)^2]^0.5;
disp(f/10^9,'Resonant frequency(in GHz) =');
```

Chapter 6

Microwave Components

Scilab code Exa 6.2 Find the distance that the position of port 1 should be shifted

```
//Caption:Find the distance that the position of
   port 1 should be shifted .
//Exa:6.2
clc;
clear;
close;
Beeta=34.3;//in rad/m
// S=[0,0.5*%e^(%i*53.13);0.5*%e^(%i*53.13) ,0];
// S'=[0,0.5*%e^(%i*53.13-x);0.5*%e^(%i*53.13-x) ,0];
//For S12& S21 to be real ,
x=53.5;//in degrees
x_rad=53.5*%pi/180;
l=x_rad/Beeta;
disp(l*100,'Distance (in cm)=');
```

Scilab code Exa 6.3 Determine the scattering parameters for 10 dB direction coupler

```
//Caption:Determine the scattering parameters for 10
    dB direction coupler
//Exa:6.3
clc;
clear;
close;
D=30;//in dB
VSWR=1;
C=10;
//p1_p4 = p1/p4
p1_p4=10^(C/-10);
S_41=sqrt(p1_p4);
S_14=S_41;//As matched & lossless
S_31=S_41^2/10^(D/10);
S_11=(VSWR-1)/(VSWR+1);
S_22=S_11;
S_44=S_11;
S_33=S_11;
S_21=sqrt(1-0.1-10^-4);
S_12=S_21;
S_34=sqrt(1-0.1-10^-4);
S_43=S_34;
S_24=sqrt(1-0.1-S_34^2);
S_42=S_24;
S_23=S_41;
S_32=S_23;
S_13=S_31;
```

```
S=[S_11,S_12,S_13,S_14;S_21,S_22,S_23,S_24;S_31,S_32
    ,S_33,S_34;S_41,S_42,S_43,S_44];
disp(S,'Required Scattering Parameters are');
```

Scilab code Exa 6.4 Determine the powers in the remaining ports

```
//Caption:Determine the powers in the remaining
    ports
//Exa:6.4
clc;
clear;
close;
a_2=0;
a_3=0;
a_1=32;//in mW
b_1=(a_1/2^2)+(a_2/-2)+(a_3/sqrt(2));
b_2=(a_1/(-2)^2)+(a_2/-2)+(a_3/sqrt(2));
b_3=(a_1/2)+(a_2/sqrt(2))+(a_3/-sqrt(2));
disp(b_1,'Power at port1(in mW)=');
disp(b_2,'Power at port2(in mW) =');
disp(b_3,'Power at port3(in mW) =');
```

Scilab code Exa 6.5 Determine the powers in the remaining ports

```
//Caption:Determine the powers in the remaining
    ports
//Exa:6.5
clc;
clear;
close;
b_1=20;
b_2=20;
p_1=abs((60-50)/(60+50));
p_2=abs((75-50)/(75+50));
P_1=b_1*(1-p_1^2)/2;
P_2=b_2*(1-p_2^2)/2;
disp(P_1,'Power in port1 (in mW) =');
disp(P_2,'Power in port2 (in mW) =');
```

Scilab code Exa 6.6 Determine the powers reflected at port 3 and power divisions at other ports

```
//Caption:Determine the powers reflected at port 3 &
     power divisions at other ports.
//Exa:6.6
clc;
clear;
close;
p_1=0.5;
p_2=0.6;
p_4=0.8;
b_1=0.6566;
b_2=0.7576;
b_3=0.6536;
b_4=0.00797;
```

```
a_1=p_1*b_1;
a_2=p_2*b_2;
a_3=1;//in Watts
a_4=p_4*b_4;
disp(b_1^2,'Power at port 1(in W)=');
disp(b_2^2,'Power at port 2(in W)=');
disp(b_3^2,'Power at port 3(in W)=');
disp(b_4^2,'Power at port 4(in W)=');
```

Scilab code Exa 6.7 Calculate the scattering matrix

```
//Caption:Calculate the scattering matrix.
//Exa:6.7
clc;
clear;
close;
In_loss=0.5;//in dB
S_21=10^(-In_loss/20);
Isolation=30;//in dB
S_12=10^(-Isolation/20);
S_11=0;
S_22=0;
S=[S_11,S_12;S_21,S_22];
disp(S,'Scattering matrix =');
```

Scilab code Exa 6.9 Calculate the scattering matrix

```
//Caption:Calculate the scattering matrix.
//Exa:6.9
clc;
clear;
close;
VSWR=1;
In_loss=0.5;//in dB
S_21=10^(-In_loss/20);
Isolation=20;//in dB
S_12=10^(-Isolation/20);
S_23=S_12;
S_31=S_12;
S_32=S_21;
S_13=S_21;
p=(VSWR-1)/(VSWR+1);
S_11=p;
S_22=p;
S_33=p;
S=[S_11,S_12,S_13;S_21,S_22,S_23;S_31,S_32,S_33];
disp(S,'Scattering matrix =');
```

Scilab code Exa 6.10 Calculate the scattering matrix

```
//Caption:Calculate the scattering matrix.
//Exa:6.10
clc;
clear;
close;
In_loss=0.5;//insertion loss(in dB)
```

```
C=20;//in dB
D=35;//in dB
Pi_Pf=10^(C/10);
Pi=90;//in Watts
Pf=Pi/Pi_Pf;
Pf_Pb=10^(D/10);
Pb=Pf/Pf_Pb;
P_rec=(Pi-Pf-Pb);//Power received (in Watts)
P_rec_dB=10*log(Pi/P_rec)/log(10);
P_rec_eff=P_rec_dB-In_loss;//Effective power
    received (in dB)
disp(P_rec_eff,'Effective power received (in dB)=');
```

Scilab code Exa 6.11 Calculate the directivity and coupling and isolation

```
 //Caption:Calculate (i)-directivity ,(ii)-coupling,
    (iii)-isolation
//Exa:6.11
clc;
clear;
close;
S_13=0.1;
S_14=0.05;
C=-20*log(S_13)/log(10);
D=20*log(S_13/S_14)/log(10);
I=C+D;
disp(C,'Coupling (in dB) =');
disp(D,'Directivity (in dB)) =');
disp(I,'Isolation (in dB) =');
```

Scilab code Exa 6.12 Calculate the value of VSWR

```
//Caption:Calculate the value of VSWR
//Exa:6.12
clc;
clear;
close;
D=3.5;//distance of seperation(in cm)
w_l=2*D;//wavelength
d2_d1=2.5;//d2-d1(in m)
S=w_l/(%pi*d2_d1*10^-1);
disp(S,'VSWR =');
```

Scilab code Exa 6.13 Calculate the phase shift of the component

```
//Caption:Calculate the phase shift of the component
//Exa:6.13
clc;
clear;
close;
w_l=7.2;//wavelength (in cm)
x=10.5-9.3;
Phase_shift=(2*%pi*x)/(w_l);
```

```
disp(Phase_shift*180/%pi,'Phase Shift (in degree) ='
   );
```

Chapter 7

Microwave Measurements

Scilab code Exa 7.1 Calculate the SWR of the transmission line

```
//Caption:Calculate the SWR of the transmission line
//Exa:7.1
clc;
clear;
close;
//Given:
c=3*10^10;//in cm/s
a=4;//in cm
b=2.5;//in cm
f=10*10^9;//in Hz
d=0.1;//distance between 2 minimum power points(in
   cm)
//For TE10 mode:
wl_c=2*a;
wl_o=c/f;
wl_g=wl_o/sqrt(1-(wl_o/wl_c)^2);
S=wl_g/(%pi*d);
disp(S,'Voltage standing wave ratio =');
```

Scilab code Exa 7.2 Calculate the SWR of the main waveguide

```
//Caption:Calculate the SWR of the main waveguide
//Exa:7.2
clc;
clear;
close;
//Given:
P_i=300;//in mW
P_r=10;//in mW
p=sqrt(P_r/P_i);
S=(1+p)/(1-p);
disp(S,'Voltage standing wave ratio =');
```

Scilab code Exa 7.3 Calculate the SWR of the waveguide

```
//Caption:Calculate the SWR of the waveguide
//Exa:7.3
clc;
clear;
close;
//Given:
P_i=2.5;//in mW
P_r=0.15;//in mW
```

```
p=sqrt(P_r/P_i);
S=(1+p)/(1-p);
disp(S,'Voltage standing wave ratio =');
```

Scilab code Exa 7.4 Calculate the value of reflected power

```
//Caption:Calculate the value of reflected power
//Exa:7.4
clc;
clear;
close;
//Given:
P_i=4.5;//in mW
S=2;//VSWR
C=30;//in dB
p=(S-1)/(S+1);
P_f=P_i/(10^(C/10));
P_r=p^2*P_i;
disp(P_r,'Reflected power (in watts) =');
```

Chapter 8

Microwave Tubes and Circuits

Scilab code Exa 8.1 Calculate the dc electron velocity and dc phase constant and plasma frequency and reduced plasma frequency and dc beam current beam density and instantaneous beam current density

```
//Caption:Calculate (i)-dc electron velocity,(ii)-dc
    phase constant, (iii)-plasma frequency, (iv)-
   reduced plasma frequency for R=0.4, (v)-dc beam
   current beam density, (vi)-instantaneous beam
   current density
//Exa:8.1
clc;
clear;
close;
V_o=14.5*10^3;//in volts
I_o=1.4;//in A
f=10*10^9;//in Hz
p_o=10^-6;//in c/m^3
p=10^-8;//in c/m^3
v=10^5;//in m/s
R=0.4;
v_o=0.593*10^6*sqrt(V_o);
k=2*%pi*f/v_o;
w_p=[1.759*10^11*(10^-6/(8.854*10^-12))]^0.5;
```

```
w_q=R*w_p;
J_o=p_o*v_o;
J=p*v_o+p_o*v;
disp(v_o,'Dc electron velocity (in m/s) =');
disp(k,'Dc phase constant (in rad/s) =');
disp(w_p,'Plasma frequency (in rad/s) =');
disp(w_q,'Reduced plasma frequency (in rad/s) =');
disp(J_o,'Dc beam current density (in A/sq. m) =');
disp(J,'Instantaneous beam current density(in A/sq. m) =');

//Answer in book are wrongly written as: (Dc phase constant =1.41* 10^8 rad/sec)
```

Scilab code Exa 8.2 Calculate the input rms voltage and output rms voltage and power delivered to load

```
//Caption:Calculate (i)-input rms voltage,(ii)-output rms voltage, (iii)-power delivered to load
//Exa:8.2
clc;
clear;
close;
A_v=15;//in dB
P_i=5*10^-3;//in W
R_sh_i=30000;//in ohms
R_sh_o=40000;//in ohms
R_l=20000;//in ohms
V_i=sqrt(P_i*R_sh_i);
V_o=10^((A_v/20))*12.25;
P_out=V_o^2/R_l;
```

```
disp(V_i,'Input rms voltage (in volts) =');
disp(V_o,'Output rms voltage (in volts) =');
disp(P_out,'Power delivered to load (in watts) =');
```

Scilab code Exa 8.3 Calculate the input power in watts and output power in watts and efficiency

```
//Caption:Calculate (i)-input power in watts,(ii)-
   output power in watts, (iii)-efficiency
//Exa:8.3
clc;
clear;
close;
n=2;
V_o=300;//in volts
I_o=20*10^-3;//in A
V_i=40;//in volts
J=1.25;//J(X')
P_dc=V_o*I_o;
P_ac=2*V_o*I_o*J/(2*n*%pi-%pi/2);
eff=(P_ac/P_dc)*100;
disp(P_dc,'Input power (in watts) =');
disp(P_ac,'Output power (in watts) =');
disp(eff,'Efficiency (in percent) =');
```

Scilab code Exa 8.4 Calculate the electron velocity and dc transit time and input voltage for maximum output voltage and voltage gain in dB

```
//Caption:Calculate (i)-electron velocity,(ii)-dc transit time, (iii)-input voltage for maximum output voltage,(iv)-voltage gain in dB
//Exa:8.4
clc;
clear;
close;
V_o=900;//in volts
I_o=30*10^-3;//in A
f=8*10^9;//in Hz
d=0.001;//in m
l=0.04;//in m
R_sh=40*10^3;//in ohm
v_o=0.593*10^6*sqrt(V_o);
T_o=l/v_o;
Theeta_o=(2*%pi*f)*T_o;//Transit angles between cavities(in radian)
Theeta_g=(2*%pi*f)*d/v_o;//Average gap transit angle (in radian)
b=sin(Theeta_g/2)/(Theeta_g/2);
V_in_max=V_o*3.68/(b*Theeta_o);
//As, {J(X)/X=0.582}
A_r=b^2*Theeta_o*0.582*R_sh/(30*10^3*1.841);
disp(v_o,'Electron velocity (in m/s) =');
disp(T_o,'Dc Transit Time (in sec)=');
disp(V_in_max,'Maximum input voltage (in volts) =');
disp(A_r,'Voltage gain (in dB) =');
```

Scilab code Exa 8.5 Calculate the input microwave voltage and voltage gain and efficiency of amplifier and beam loading conductance

```
//Caption:Calculate (i)-i/p microwave voltage,(ii)-voltage gain, (iii)-efficiency of amplifier,(iv)-beam loading conductance
//Exa:8.5
clc;
clear;
close;
V_o=1200;//in volts
I_o=28*10^-3;//in A
f=8*10^9;//inHz
d=0.001;//in m
l=0.04;//in m
R_sh=40*10^3;//in ohms
V_p_max=1200*3.68*0.593*10^6*sqrt(V_o)/(2*%pi*f*l);
Theeta_g=(2*%pi*f)*d/(0.593*10^6*sqrt(V_o));//transit angle (in rad)
beeta=sin(Theeta_g/2)/(Theeta_g/2);
V_i_max=V_p_max/beeta;
Beeta_o=0.768;
J=0.582;//J(X)
A_v=(Beeta_o)^2*97.88*J*R_sh/(1200/(28*10^-3*1.841));//calculating voltage gain
eff=[0.58*[2*28*10^-3*J*Beeta_o*R_sh]/V_o]*100;//calculating efficiency
G_o=23.3*10^-6;
G_b=(G_o/2)*{Beeta_o^2-Beeta_o*cos(Theeta_g)};//beam loading conductance
R_b=1/(G_b*1000);//beam loading resistance(in kilo ohms)
disp(V_i_max,'Input microwave voltage(in volts) =');
disp(A_v,'Voltage gain =');
disp(eff,'Effeciency of amplifier (in percentage) =');
disp(R_b,'Beam loading resistance(in kilo ohms) =');
```

```
//Answer in book is wrongly given as: Voltage gain
    =17.034
```

Scilab code Exa 8.6 Calculate the value of repeller voltage and beam current necessary to give gap voltage of 200V and electronic efficiency

```
//Caption:Calculate (i)-value of repeller voltage
    V_r ,(ii)-beam current necessary to give gap
    voltage of 200V, (iii)-electronic efficiency
//Exa:8.6
clc;
clear;
close;
e_m_ratio=1.759*10^11;//(e/m)
V_o=500;//in volts
R_sh=20*10^3;//in ohms
f=8*10^9;//inHz
w=2*%pi*f;
n=2;//mode
L=0.001;//spacing between repeller & cavity (in m)
x=0.023;
volt_diff=sqrt(V_o*(x));
V_r=volt_diff+V_o;//repeller volatge
Beeta_o=1;//Assuming
J=0.582;
V_1=200;//given (in volts)
I_o=V_1/(R_sh*2*J);
Theeta_o=2*%pi*f*J*10^6*2*10^-3*sqrt(V_o)
    /(1.579*10^11*(V_r+V_o));
X=V_1*Theeta_o/(2*V_o);//X'
j=0.84;//J(X')
```

```
eff=[2*j/(2*%pi*2-%pi/2)]*100;
disp(V_r,'Repeller voltage(in volts) =');
disp(I_o,'Necessary beam current (in Amp.s) =');
disp(eff,'Effeciency  (in percentage) =');
```

Scilab code Exa 8.7 Calculate the efficiency of reflex klystron and total output power in mW and power delivered to load

```
//Caption:Calculate (i)-efficiency of reflex
    klystron ,(ii)-total output power in mW, (iii)-
    power delivered to load
//Exa:8.7
clc;
clear;
close;
P_dc_in=40;//in mW
ratio=0.278;//V_1/V_o;
n=1;
X=ratio*(2*n*%pi-%pi/2);
J=2.35;
eff=ratio*J*100;//in percentage
P_out= 8.91*P_dc_in/100;
P_load=3.564*80/100;
disp(eff,'Effeciency  (in percentage) =');
disp(P_out,'Total power output (in mW) =');
disp(P_load,'Power delivered to load (in mW) =');
```

Scilab code Exa 8.8 Calculate the Hull cutoff voltage and cutoff magnetic flux density if beam voltage is 6000V and cyclotron frequency in GHz

```
//Caption:Calculate (i)-Hull cut-off voltage ,(ii)-cut-off magnetic flux density if beam voltage V_o is 6000V, (iii)-cyclotron frequency in GHz
//Exa:8.8
clc;
clear;
close;
e_m_ratio=1.759*10^11;//(e/m)
R_a=0.15;//in m
R_o=0.45;//in m
B_o=1.2*10^-3;//in weber/m^2
V_o={(e_m_ratio)*B_o^2*R_o^2*[1-(R_a/R_o)^2]^2}/8;
//Given:
V=6000;//in volts
B_c=sqrt(8*V/e_m_ratio)/[[1-(R_a/R_o)^2]*(R_o)];//in weber/m^2
w_c=(e_m_ratio)*B_o;
f_c=w_c/(2*%pi);//in Hz
disp(V_o,'Cut-off voltage (in volts) =');
disp(B_c*10^5,'Cut-off magnetic flux density (in milli weber/sq. m) =');
disp(f_c*10^-9,'Cyclotron frequency (in GHz) =');

//Answer in book is wrongly given as: f_c =0.336Hz & V_o=50.666 kV
```

Scilab code Exa 8.9 Calculate the Axial phase velocity and Anode voltage at which TWT can be operated for useful gain

```
//Caption:Calculate (i)-Axial phase velocity ,(ii)-
    Anode voltage at which TWT can be operated for
    useful gain
//Exa:8.9
clc;
clear;
close;
e_m_ratio=1.759*10^11;//(e/m)
c=3*10^8;//in m/s
d=0.002;//diameter(in m)
pitch=(1/50)/100;//As,50 turns per cm (in m)
circum=%pi*d;
v_p=c*pitch/circum;
V_o=v_p^2/(2*e_m_ratio);
disp(v_p,'Axial phase velocity (in m/s) =');
disp(V_o,'Anode Voltage (in kV) =');

//Answer in book is wrongly given as V_o=25.92 V
```

Scilab code Exa 8.10 Calculate the electron velocity and dc transit time and input voltage for maximum output voltage and voltage gain in dB

```
//Caption:Calculate (i)-electron velocity,(ii)-dc
    transit time, (iii)-input voltage for maximum
    output voltage,(iv)-voltage gain in dB
//Exa:8.10
clc;
clear;
close;
V_o=900;//in volts
I_o=30*10^-3;//in A
f=8*10^9;//in Hz
d=0.001;//in m
l=0.04;//in m
R_sh=40*10^3;//in ohm
v_o=0.593*10^6*sqrt(V_o);
T_o=l/v_o;
Theeta_o=(2*%pi*f)*T_o;//Transit angles between
    cavities(in radian)
Theeta_g=(2*%pi*f)*d/v_o;//Average gap transit angle
     (in radian)
b=sin(Theeta_g/2)/(Theeta_g/2);
V_in_max=V_o*3.68/(b*Theeta_o);
//As, {J(X)/X=0.582}
A_r=b^2*Theeta_o*0.582*R_sh/(30*10^3*1.841);
disp(v_o,'Electron velocity (in m/s) =');
disp(T_o,'Dc Transit Time (in sec)=');
disp(V_in_max,'Maximum input voltage (in volts) =');
disp(A_r,'Voltage gain (in dB) =');
```

Scilab code Exa 8.11 Calculate the dc electron velocity and dc phase constant and plasma frequency and reduced plasma frequency and dc beam current beam density and instantaneous beam current density

```
//Caption:Calculate (i)-dc electron velocity ,(ii)-dc
    phase constant , (iii)-plasma frequency , (iv)-
   reduced plasma frequency for R=0.5, (v)-dc beam
   current beam density , (vi)-instantaneous beam
   current density
//Exa:8.11
clc;
clear;
close;
V_o=20*10^3;//in volts
I_o=2;//in A
f=10*10^9;//in Hz
p_o=10^-6;//in c/m^3
p=10^-8;//in c/m^3
v=10^5;//in m/s
R=0.5;
v_o=0.593*10^6*sqrt(V_o);
k=2*%pi*f/v_o;
w_p=[1.759*10^11*(10^-6/(8.854*10^-12))]^0.5;
w_q=R*w_p;
J_o=p_o*v_o;
J=p*v_o-p_o*v;
disp(v_o,'Dc electron velocity (in m/s) =');
disp(k,'Dc phase constant (in rad/s) =');
disp(w_p,'Plasma frequency (in rad/s) =');
disp(w_q,'Reduced plasma frequency (in rad/s) =');
disp(J_o,'Dc beam current density (in A/sq. m) =');
disp(J,'Instantaneous beam current density(in A/sq.
   m) =');
```

Scilab code Exa 8.12 Calculate the gap transit angle

```
//Caption:Calculate the gap transit angle
//Exa:8.12
clc;
clear;
close;
V_o=1000;//Anode voltage(in volts)
gap=0.002;//in m
f=5*10^9;//in Hz
L=2.463*10^-3;//length of drift region (in m)
u_o=5.93*10^5*sqrt(V_o);//in m/s
Theeta_g=2*%pi*f*2*10^-3/u_o;//radians
disp(Theeta_g,'Transit angle(in radians) =');
```

Scilab code Exa 8.13 Calculate the input rf voltage and voltage gain and efficiency

```
//Caption:Calculate (i)-i/p rf voltage,(ii)-voltage
    gain, (iii)-efficiency
//Exa:8.13
clc;
clear;
close;
V_o=1200;//in volts
I_o=30*10^-3;//in A
f=10*10^9;//inHz
d=0.001;//in m
l=0.04;//in m
R_sh=40*10^3;//in ohms
v_o=0.593*10^6*sqrt(V_o);
Theeta_o=2*%pi*f*l/(20.54*10^6);
X=1.84;//for maximum output power
```

```
V_max=2*X*V_o/122.347;
Theeta_g=122.347*10^-3/(4*10^-2);
Beeta_i=sin(Theeta_g/2)/(Theeta_g/2);
V_1_max=V_max/Beeta_i;
J=0.58;
Beeta_o=Beeta_i;
I_2=2*I_o*J;
V_2=Beeta_o*I_2*R_sh;
A_v=V_2/V_1_max;//in dB
eff=0.58*(V_2/V_o)*100;//in percentage
disp(V_1_max,'Input rf voltage(in volts) =');
disp(A_v,'Voltage gain (in dB) =');
disp(eff,'Maximum efficiency (in percentage) =');

//Answer in book is wrongly given as: A_v=24.33 dB
```

Scilab code Exa 8.14 Calculate the cyclotron angular frequency and cut-off voltage and cutoff magnetic flux

```
//Caption:Calculate (i)-cyclotron angular frequency,
    (ii)-cut-off voltage, (iii)-cut-off magnetic
    flux
//Exa:8.14
clc;
clear;
close;
e_m_ratio=1.759*10^11;//(e/m)
a=0.04;
b=0.08;
V_o=30*10^3;//in volts
I_o=80;//in A
```

```
B_o=0.01;//in weber/sq.m
w=(e_m_ratio)*B_o;
disp(w,'Cyclotron angular frequency( in rad/s) =');
V_c={(e_m_ratio)*B_o^2*b^2*[1-(a/b)^2]^2}/8;
disp(V_c,'Cut-off voltage (in volts) =');
B_c=sqrt(8*V_o/e_m_ratio)/[[1-(a/b)^2]*(b)];//in
    weber/m^2
disp(B_c*10^3,'Cut-off magnetic flux density (in
    milli weber/sq. m) =');
```

Scilab code Exa 8.15 Calculate the input power and output power in watts and efficiency

```
//Caption:Calculate (i)-input power ,(ii)-output
    power in watts, (iii)-efficiency
//Exa:8.15
clc;
clear;
close;
n=2;
V_o=280;//in volts
I_o=22*10^-3;//in A
V_i=30;//in volts
J=1.25;//J(X')
P_dc=V_o*I_o;
P_ac=2*V_o*I_o*J/(2*n*%pi-%pi/2);
eff=(P_ac/P_dc)*100;
disp(P_dc,'Input power (in watts) =');
disp(P_ac,'Output power (in watts) =');
disp(eff,'Efficiency (in percent) =');
```

Scilab code Exa 8.16 Calculate the repeller voltage and beam current necessary to give gap voltage of 200V

```
//Caption:Calculate (i)-repeller voltage V_r ,(ii)-
   beam current necessary to give gap voltage of 200
   V
//Exa:8.16
clc;
clear;
close;
e_m_ratio=1.759*10^11;//(e/m)
V_o=300;//in volts
R_sh=20*10^3;//in ohms
f=8*10^9;//inHz
w=2*%pi*f;
n=2;//mode
L=0.001;//spacing between repeller & cavity (in m)
x=(e_m_ratio)*(2*%pi*n-%pi/2)^2/(8*w^2*L^2);
volt_diff=sqrt(V_o/(x));
V_r=(volt_diff)+V_o;//repeller volatge
J=0.582;
V_1=200;//given (in volts)
I_o=V_1/(R_sh*2*J);
disp(V_r,'Repeller voltage(in volts) =');
disp(I_o*10^3,'Necessary beam current (in milliAmp.s
   ) =');
```

Chapter 9

Solid State Microwave Devices

Scilab code Exa 9.1 Calculate i repeller voltage Vr ii beam current necessary to give gap voltage of 200V

```
//Caption:Calculate operating frequency of IMPATT
   diode
//Exa:9.1
clc;
clear;
close;
v_d=10^7*10^-2;//drift velocity(in m/s)
L=2*10^-6;//drift length(in m)
f=v_d/(2*L);//in Hz
disp(f/10^9,'Operating Frequency (in GHz) =');
```

Scilab code Exa 9.2 Determine threshold electric field

```
//Caption:Determine threshold electric field
```

```
//Exa:9_2
clc;
clear;
close;
f=10*10^9;//in Hz
L=75*10^-6;//Device length (in m)
V=25;//Voltage pulse amplified (in volts)
E_th=V/L;
disp(E_th,'Threshold Electric field (in kV/cm) =');
```

Scilab code Exa 9.3 Calculate the power gain in dB and power gain if it is USB converter

```
//Caption:Calculate (i)-power gain in dB ,(ii)-power
    gain if it is USB converter.
//Exa:9.3
clc;
clear;
close;
f_s=2*10^9;//in Hz
f_p=12*10^9;//in Hz
R_i=16;
R_s=1000;
A_p=10*log((f_p-f_s)/f_s);
A_p_usb=10*log((f_p+f_s)/f_s);
disp(log(10),'Power gain (in dB) =');
disp(A_p_usb,'Power gain as USB converter (in dB) ='
  );
```

Scilab code Exa 9.4 Calculate the critical voltage and breakdown voltage and breakdown electric field

```
//Caption:Calculate (i)-critical voltage ,(ii)-
   breakdown voltage, (iii)-breakdown electric field
//Exa:9.4
clc;
clear;
close;
E_s=12.5;
E_o=8.85*10^-12;
E=E_o*E_s;
N=3.2*10^22;//per cubic meter
L=8*10^-6;//in m
q=1.6*10^-19;//in coulombs
V_c=q*N*L^2/(2*E);
V_bd=2*V_c;
E_bd=V_bd/L;
disp(V_c/10^3,'Critical voltage(in kV) =');
disp(V_bd/10^3,'Breakdown Voltage (in kV) =');
disp(E_bd,'Breakdown Electric field (in V/cm) =');
```

Scilab code Exa 9.5 Calculate the power gain in dB and power gain if it is USB converter

```
//Caption:Calculate (i)-power gain in dB ,(ii)-power
    gain if it is USB converter.
//Exa:9.5
clc;
clear;
close;
N_a=2.5*10^16;//per cubic cm
J=33;//in kA/cm^2
q=1.6*10^-19;
V_z=J/(q*N_a);//Avalanche zone velocity (in cm/s)
disp(V_z,'Avalanche zone velocity (in cm/s) =');
```

Scilab code Exa 9.6 Calculate the power gain in dB

```
//Caption:Calculate the power gain in dB
//Exa:9.6
clc;
clear;
close;
R_neg=25;//in ohm
R_load=50;//in ohm
G={[- abs(R_neg)-R_load]/[- abs(R_neg)+R_load]}^2;
disp(G,'Power gain =');
```

Scilab code Exa 9.7 Calculate the minimum voltage needed to GUNN effect

```
//Caption:Calculate the minimum voltage needed to
   GUNN effect
//Exa:9.7
clc;
clear;
close;
volt_grad=3.3*10^3;//voltage gradient
L=5*10^-4;//in drift length
V_min=volt_grad*L;//in volts
disp(V_min,'Minimum voltage needed (in Volts) =');
```

Scilab code Exa 9.8 Calculate the rational frequency and critical velocity of diode

```
//Caption:Calculate the rational frequency &
    critical velocity of diode.
//Exa:9.8
clc;
clear;
close;
v_d=2*10^7;//in cm/s
L=20*10^-4;//in cm
f=v_d/L;
disp(f*10^-9,'Natural frequency (in GHz) =');
critical_field=3.3*10^3;
V=L*critical_field;
```

```
disp(V,'Critical voltage (in volts) =');
```

Scilab code Exa 9.9 Calculate the resonant frequency and efficiency

```
//Caption:Calculate the resonant frequency &
    efficiency.
//Exa:9.9
clc;
clear;
close;
L_p=0.5*10^-9;//in H
C_j=0.5*10^-12;//in F
V_bd=100;//breakdown voltage (in volts)
I_bias=100*10^-3;//bias current(in A)
I_rf_peak=0.8;
R_l=2;
f=1/(2*%pi*sqrt(L_p*C_j));
eff={(0.5*I_rf_peak^2*R_l)/(V_bd*I_bias)}*100;
disp(f*10^-9,'Resonant frequency (in GHz) =');
disp(eff,'Efficiency (in percentage) =');
```

Scilab code Exa 9.10 Calculate the drift time of carrier and operating frequency of diode

```
//Caption:Calculate (i)-drift time of carrier ,(ii)-
    operating frequency of diode
//Exa:9.10
```

```
clc;
clear;
close;
L=2*10^-6;//drift length (in m)
v_d=10^5;//in cm/s
drift_time=L/v_d;
f=1/(2*drift_time);
disp(drift_time,'Drift time (in sec) =');
disp(f*10^-9,'Operating Frequency (in GHz)=');
```

Scilab code Exa 9.11 Calculate the breakdown voltage and breakdown electric field

```
//Caption:Calculate (i)-breakdown voltage ,(ii)-
    breakdown electric field.
//Exa:9.11
clc;
clear;
close;
E_r=11.8;
E_o=8.85*10^-12;
N=3*10^21;//in per cubic meter
L=6.2*10^-6;//in meter
q=1.6*10^-19;//in coulombs
V_bd=q*N*L^2/(E_o*E_r);
E_bd=V_bd/L;
disp(V_bd,'Breakdown voltage (in volts) =');
disp(E_bd,'Breakdown electric field (in V/m) =');
```

Scilab code Exa 9.12 Calculate the maximum power gain and noise figure and bandwidth

```
//Caption:Calculate (i)-maximum power gain in dBs
    ,(ii)-noise figure F in dBs, (iii)-bandwidth for
     r=0.2
//Exa:9.12
clc;
clear;
close;
ratio=8;
r=0.2;
r_Q=8;
T_d=300;//in Kelvin
T_o=300;//in Kelvin
X=8;
G=(ratio)*X/(1+sqrt(1+X))^2;
G_in_dB=(10*log(G))/log(10);//gain
disp(G_in_dB,'Maximum Gain (in dB)=');
F=[10*log(1+(2*T_d/T_o)*[(1/(r_Q))+(1/(r_Q)^2)])]/
   log(10);//noise figure
disp(F,'Noise figure (in dB) =');
B_W=2*r*sqrt(ratio);//bandwidth
disp(B_W,'bandwidth =');
```

Scilab code Exa 9.13 Calculate the equivalent noise resistance and gain and noise figure and bandwidth

```
//Caption:Calculate (i)−equivalent noise resistance,
    (ii)−gain, (iii)−noise figure, (iv)−bandwidth
//Exa:9.13
clc;
clear;
close;
f_s=2*10^9;//in Hz
f_p=12*10^9;//in Hz
f_i=10*10^9;//in Hz
f_d=5*10^9;//in Hz
R_i=1*10^3;//in ohm
R_g=1*10^3;//in ohm
R_T_s=1*10^3;//in ohm
R_T_i=1*10^3;//in ohm
T_d=300;//in Kelvin
T_o=300;//in Kelvin
w_s=2*%pi*f_s;
w_i=2*%pi*f_i;
r=0.35;
r_Q=10;
r_d=300;//in ohm
C=0.01*10^-12;//in Farad
R=r^2/(w_s*w_i*C^2*R_T_i);
a=R/R_T_s;
g=((4*f_i*R_g*R_i*a)/(f_s*R_T_s*R_T_i*(1-a)^2));//
    gain
Gain=[10*log(g)]/log(10);//gain in dB
```

```
f={1+((2*T_d)/T_o)*[(1/r_Q)+(1/r_Q^2)]};//noise figure
F=[10*log(f)]/log(10);//noise figure in dB
B_W=(r/2)*sqrt(f_d/(f_s*Gain));//bandwidth
disp(a,'Equivalent noise resistance (in ohm) =');
disp(Gain,'Gain (in dB) =');
disp(F,'Noise figure (in dB) =');
disp(B_W,'Bandwidth =');
```