Scilab Textbook Companion for Optical Fiber Communication by R. R. Dudeja[1]

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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

Contents

List of Scilab Codes

Chapter 2

OPTICAL FIBER

Scilab code Exa 2.1 critical angle

```
// Example 2.1:Critical angle
clc;
clear;
close;
n2=1.402;//Waveguide Refractive Index
n1=1.495;//Cladding Refractive Index
no=1;// for air
Oc=asind(n2/n1);// Critical Angle
disp(Oc,"Critical angle in degree")
```

Scilab code Exa 2.2.a critical angle

```
// Example 2.2.a: Critical Angle
clc;
clear;
close;
n1=1.50;//Waveguide Refractive Index
n2=1.47;//Cladding Refractive Index
```

```
Oc=asind(n2/n1);//Critical Angle
oc=floor(Oc);//
x=Oc-oc;//
disp("CRITICAL ANGLE IS "+string(oc)+" DEGREE AND "+
   string(round((60*(x))))+" MINUTES ")
//answer is wrong in the textbook
```

Scilab code Exa 2.2.b NA

```
// Example 2.2.b:Numerical Aperture
clc;
clear;
close;
n1=1.50;//Waveguide Refractive Index
n2=1.47;//Cladding Refractive Index
NA=sqrt(n1^2-n2^2);// Numerical Aperture
disp(NA,"Numerical Aperture is")
```

Scilab code Exa 2.2.c acceptance angle

```
// Example 2.2.c: Acceptance Angle
clc;
clear;
close;
n1=1.50;//Waveguide Refractive Index
n2=1.47;//Cladding Refractive Index
h= 1.3;// Wavelenght in micrometers
NA=sqrt(n1^2-n2^2);// Numerical Aperture
Oa=asind(NA);//ACCEPTANCE ANGLE
oa=floor(Oa);//
x=Oa-oa;//
disp("ACCEPTANCE ANGLE IS "+string(oa)+" DEGREE AND
   "+string(round((60*(x))))+" MINUTES ")
```

```
//answer is wrong in the textbook
```

Scilab code Exa 2.3 NA solid acceptance angle and critical angle

```
// Example 2.3:Numerical Aperture ,Acceptance Angle
   and criticle angke
clc;
clear;
close;
n1=1.46;//core Refractive Index
d=1;// refractive index differnce in percentage
NA=n1*(sqrt(2*(d/100)));// Numerical Aperture
Sa= %pi*(NA)^2;//solid accepance angle in strad
r=1-(d/100);//ratio of refractive index
Oc=asind(r);//criticle angle in degree
oc=floor(Oc);//
x=Oc-oc;//
disp(NA,"numerical aperture is")
disp(Sa,"solid acceptance angle in air in stard is")
disp("CRITICAL ANGLE IS "+string(oc)+" DEGREE AND "+
   string(round((60*(x))))+" MINUTES ")
```

Scilab code Exa 2.4 critical angle

```
// Example 2.4; Critical Angle
clc;
clear;
close;
n1=1.48;//Waveguide Refractive Index
n2=1.46;//Cladding Refractive Index
Oc=asind(sqrt((1-(n2/n1)^2)));//Critical Angle
disp(Oc,"critical angle in degree is")
```

Scilab code Exa 2.5 refrative index

```
// Example 2.5: Core and Cladding Index
clc;
clear;
close;
NA=0.3;// numerical aperture
d= 0.01;// Cange in core-cladding refractive index
r=(1-d);//ratio
n1=sqrt(((NA)^2)/(1-r^2));//core refrative index
n2= n1-(d*n1);
disp(n1,"refrative index of core is")
disp(n2,"Refradctive index of cladding is")
```

Scilab code Exa 2.6 compare acceptance angle

```
// Example 2.6: compare acceptance angle
clc;
clear;
close;
NA=0.4;// numerical aperture
r2=100;//angle at which rays change dirction
r=r2/2;//in degree
Oa=asind(NA);//ACCEPTANCE ANGLE
oa=floor(Oa);//
x=Oa-oa;//
Oas=asind(NA/cosd(r));//ACCEPTANCE ANGLE for skew
    rays in degree
oas=floor(Oas);//
xs=Oas-oas;//
disp("ACCEPTANCE ANGLE IS "+string(oa)+" DEGREE AND
    "+string(round((60*(x))))+" MINUTES ")
```

```
disp("ACCEPTANCE ANGLE FOR MEIDONAL RAYS IS "+string
    (oas)+" DEGREE AND "+string(round((60*(xs))))+"
    MINUTES ")
```

Scilab code Exa 2.7 number of modes

```
// Example 2.7:Number of the modes
clc;
clear;
close;
a=50;;// Radius in meter
NA=0.29;// Numerical Aperture
h=0.85;// Wavelength in meter
M=round((2*%pi^2*a^2*NA^2)/(h)^2);//
disp(M,"Number of modes")
//answer is wrong in the textbook
```

Scilab code Exa 2.8 normalised frequency and number of modes

```
// Example 2.8:Number of modes
clc;
clear;
close;
n1=1.5;//Waveguide Refractive Index
d= 0.015;// Cange in core-cladding refractive index
a=40;// core radius in micro meters
h=0.85;//wavelngth in micro meters
v=(2*%pi*a*n1*sqrt(2*d))/h;//Normalised wavelngth
m= round (v^2/2);// number of modes
disp(m,"number of modes")
//answer is wrong in the textbook
```

Scilab code Exa 2.9 radius

```
// Example 2.9:Maximum Core Readius
clc;
clear;
close;
n1=1.55;//Waveguide Refractive Index
n2=1.52;//
d= n1-n2;// Cange in core-cladding refractive index
h=1550;//wavelngth in nano meters
a=((2.405*h*10^-9)/(2*%pi*sqrt(n1^2-n2^2)));//Core
    Radius
disp(a*10^6,"maximum core radius in micro meters")
```

Scilab code Exa 2.10 number of modes

```
// Example 2.10:Number of modes
clc;
clear;
close;
NA=0.2
a=40;// core radius in micro meters
h=1;//wavelngth in micro meters
v=(2*%pi*(a/2)*NA)/h;//Normalised wavelngth
m= round (v^2/4);// number of modes
disp(m,"number of modes")
```

Scilab code Exa 2.11 core diameter

```
// Example 2.11:diameter
clc;
clear;
close;
v1=1.2;//
v2=2.4;//
h=0.85;//in micro meter
n1=1.5;//refrative index
d1=0.015;//
a1=((v1*h)/(2*%pi*n1*sqrt(2*d1)));//in micro meter
d2=0.0015;//
a2=((v2*h)/(2*%pi*n1*sqrt(2*d2)));//in micro meter
disp(2*a1,"diameter (case 1) in micro meters is")
disp(2*a2,"diameter (case 2) in micro meters is")
//answer is wrong in the textbook
```

Scilab code Exa 2.12 core diameter

```
// Example 2.12:diameter
clc;
clear;
close;
v=2.4*sqrt(2);//
h=1.3;//in micro meter
n1=1.5;//refrative index
d1=0.01;//
a1=((v*h)/(2*%pi*n1*sqrt(2*d1)));//in micro meter
disp(a1,"radius in micro meters is")
```

Scilab code Exa 2.13 cut off wavelength

```
// Example 2.13:Cutoff Wavelength
clc;
```

```
clear;
close;
n1=1.48;//Waveguide Refractive Index
a=4.8;// core radius in micro meters
d= 0.0025;// Cange in core-cladding refractive index
Hc= (2*%pi*a*sqrt(2*d)*n1)/2.4;
disp(round(Hc*10^3),"Cutoff wavelength in nano meters")
//answer is wrong in the textbook
```

Scilab code Exa 2.15 core diameter

```
// Example 2.15:diameter
clc;
clear;
close;
mfd=11.6;//in micro meter
a=mfd/2;//in micro meters
v=2.2;//
alpha=((a*10^-6)/(0.65+1.619*sqrt(v)+2.879*((v)^-6)));//
disp(2*alpha*10^6,"core diameter in micro meter ")
//answer is wrong in the textbook
```

Scilab code Exa 2.16 ESI refractive index difference

```
// Example 2.16:ESI relative refractive index
clc;
clear;
close;
h=1.190;//micro meter
sp=5.2;//in micro meter
n=1.5;//refractive index
```

```
alpha2=1.820*sp;//in micro meter
desi1=(0.293/(n)^2);//
desi2=desi1*(1.19/alpha2)^2;//
disp(desi2*100,"ESI relative refrative index
    difference in percentage is")
//answer is wrong in the textbook
```

Chapter 3

OPTICAL FIBER FABRICATION

Scilab code Exa 3.1.a fracture stress

```
// Example 3.1.a:fracture stress
clc;
clear;
close;
la=0.16;//bond length in nm
st=2.6*10^6;//psi
psi=6894.76;//Nm^-2
e=9*10^10;//NM^-2
yp=((4*la*10^-9*(st*psi)^2)/(e));//in joules
c=10^-8;//
sf=sqrt((2*e*yp)/(%pi*c));//N/m^2
sf1=sf/(psi);//psi
disp(sf1,"fracture stress in psi is")
```

Scilab code Exa 3.1.b percentage strain

```
// Example 3.1.b:percentage strain
clc;
clear;
close;
la=0.16;//bond length in nm
st=2.6*10^6;//psi
psi=6894.76;//Nm^-2
e=9*10^10;//NM^-2
yp=((4*la*10^-9*(st*psi)^2)/(e));//in joules
c=10^-8;//
sf=sqrt((2*e*yp)/(%pi*c));//N/m^2
sf1=sf/(psi);//psi
e=(sf/e)*100;//
disp(round(e),"percentage strain (%) is")
```

Scilab code Exa 3.2 loss

```
//Example 3.2 // The loss
clc;
clear;
close;
//given data :
format('v',5)
n1=1.5;
n2=1;
r=((n1-n2)/(n1+n2))^2;
L_f= (-10*log10(1-r));
disp(L_f,"The optical loss at one end,(dB) = ")
Lt=2*L_f;
disp(Lt,"Total loss at both joints,(dB) = ")
```

Scilab code Exa 3.3.a insertion loss and lateral misalignment

```
// Example 3.3.a:insertion loss
clc;
clear;
close;
n12=1.5;//refractive index
y=5;//lateral misalignment in micro meter
a2=50;//dia in micro meter
nlat=((16*n12^2)/(%pi*(1+n12)^4))*((2*acos(y/a2))-(y
   /a2)*sqrt(1-(y/a2)^2));//
loss=-10*log10(nlat);//loss in dB
disp(loss,"insertion loss in dB is")
//answer is wrong in the textbook
```

Scilab code Exa 3.3.b insertion loss and lateral misalignment

```
// Example 3.3.b:insertion loss
clc;
clear;
close;
n12=1.5;//refractive index
y=5;//lateral misalignment in micro meter
a2=50;//dia in micro meter
nlat=(1/(%pi))*((2*acos(y/a2))-(y/a2)*sqrt(1-(y/a2)
   ^2));//
loss=-10*log10(nlat);//loss in dB
disp(loss,"insertion loss in dB is")
//answer is wrong in the textbook
```

Scilab code Exa 3.4.a insertion loss

```
//Example 3.4.a // insertion loss
clc;
clear;
```

```
close;
//given data :
y=3;// in micro-m
alfa=2;
d=50;// in micro-m
a=d/alfa;
Lt=0.85*(y/a);
eta_lat=1-Lt;
L_lat=-10*log10(eta_lat);
disp(L_lat,"The insertion loss,(dB) = ")
```

Scilab code Exa 3.4.b insertion loss

```
//Example 3.4.b // insertion loss
clc;
clear;
close;
//given data :
y=3;// in micro-m
alfa=2;
d=50;// in micro-m
a=d/alfa;
Lt=0.75*(y/a);
eta_lat=1-Lt;
L_lat=-10*log10(eta_lat);
disp(L_lat,"The insertion loss,(dB) = ")
```

Scilab code Exa 3.5 insertion loss

```
//Example 3.5 // insertion loss
clc;
clear;
close;
```

```
//given data :
n1BYn2=1.48;
NA1=0.2;
n2theta=(5*%pi)/180;
NA2=0.4;
eta1=((16*(n1BYn2)^2)/(1+n1BYn2)^4)*(1-((n2theta/(
    %pi*NA1))));
L_ang1=-10*log10(eta1);
eta2=((16*(n1BYn2)^2)/(1+n1BYn2)^4)*(1-((n2theta/(
    %pi*NA2))));
L_ang2=-10*log10(eta2)
disp(L_ang1,"the insertion loss,(dB) = ")
disp(L_ang2,"the insertion loss,(dB) = ")
```

Scilab code Exa 3.6 total insertion loss

```
//Example 3.6 //total insertion loss
clc;
clear;
close;
//given data :
a=8/2;// in micro-m
V=2.4;
w=a*((0.65+(1.62*V^(-3/2))+(2.88*V^-6))/sqrt(2));
y=1;
NA=0.1;
theta=%pi/180;
n1=1.46;
T_lat=2.17*(y/w)^2;
T_ang=2.17*((theta*w*n1*V)/(a*NA))^2;
T=T_lat+T_ang;
disp(T,"Total insertion loss,(dB) = ")
```

Scilab code Exa 3.7 loss

```
//Example 3.7 //The loss
clc;
clear;
close;
//given data :
a=9.2;// in micro-m
b=8.4;// in micro-m
wo2=b/2;
wo1=a/2;
L=-10*log10(4*((wo2/wo1)+(wo1/wo2))^-2);
disp(L,"The loss ,L(dB) = ")
// answer is wrong in textbook
```

Scilab code Exa 3.8 excess loss insertion loss cross talk and split ratio

```
//Example 3.8.a // Excess loss
clc;
clear;
close;
//given data :
P1=60;// in micro-W
P3=26;// in micro-W
P4=27.5;// in micro-W
P2=0.004;// in micro-W
E_loss=10*log10((P1/(P3+P4)));
disp(E_loss,"(a). The excess loss ,(dB) = ")
I_loss=10*log10(P1/P4);
disp(I_loss,"(b).i. insertion loss port 1 to port
    4,(dB) = ")
I_loss1=10*log10(P1/P3);
disp(I_loss1,"(b).ii. insertion loss port 1 to port
    3,(dB) = ")
C_talk=10*log10(P2/P1);
```

```
disp(C_talk,"Cross talk,(db) = ")
sr=(P3/(P3+P4))*100;
disp(sr,"Split ratio,(%) = ")
```

Scilab code Exa 3.9 total loss and average insertion loss

```
//Example 3.9 // Total loss and Average insertion loss
clc;
clear;
close;
//given data :
N=32;
Pin=10^3;
a=14;// in micro-W
pf=a*N;
s_loss=10*log10(N);
e_loss=10*log10(Pin/pf);
T_loss=s_loss+e_loss;
disp(T_loss,"Total loss,(dB) = ")
I_loss=10*log10(Pin/a);
disp(I_loss,"The insertion loss,(dB) = " )
```

Chapter 4

TRANSMISSION CHARACTERSTICS OF OPTICAL FIBERS

Scilab code Exa 4.1.a overall signal attenuation

```
// Example 4.1.a:signal attenuation
clc;
clear;
close;
L=8;// Length of fiber in km
Pi=120*10^-6;// input power in Watt
Po=4*10^-6;//Output power in Watt
alpha=(10*(log10(Pi/Po)));//Loss in dB
disp(alpha,"signal attenuation in dB")
```

Scilab code Exa 4.1.b signal attenuation per km

```
// Example 4.1.b:signal attenuation per km
clc;
```

```
clear;
close;
L=8;// Length of fiber in km
Pi=120*10^-6;// input power in Watt
Po=4*10^-6;//Output power in Watt
alpha=(10*(log10(Pi/Po)));//Loss in dB
alphal=alpha/L
disp(alphal,"signal attenuation per km in dB/km is")
```

Scilab code Exa 4.1.c overall signal attenuation

```
// Example 4.2.c:Loss for 10Km
clc;
clear;
close;
L=8;// Length of fiber in km
Pi=120*10^-6;// input power in Watt
Po=4*10^-6;//Output power in Watt
alpha= round(10*(log10(Pi/Po)));//Loss in dB
alphadb= alpha/L;//Loss in dB/Km
alphadb2=alphadb*10;// Loss along 10Km fiber length
    in dB
Ds=alphadb2+9;// Due to splices at 1km Interval
disp(Ds,"Atenuation Due to splices at 1km Interval
    in dB")
```

Scilab code Exa 4.1.d ratio of input power to output power

```
// Example 4.1.d:Ratio of powers
clc;
clear;
close;
L=8;// Length of fiber in km
```

```
Pi=120*10^-6;// input power in Watt
Po=4*10^-6;//Output power in Watt
alpha= round(10*(log10(Pi/Po)));//Loss in dB
alphadb= alpha/L;//Loss in dB/Km
alphadb2=alphadb*10;// Loss along 10Km fiber length
    in dB
Ds=alphadb2+9;// Due to splices at 1km Interval
rt= 10^(Ds/10);// Ratio of input to output power
disp(rt,"Ratio of input to output power")
//answer is wrong in the textbook
```

Scilab code Exa 4.2 attenuation

```
// Example 4.2:Attenuation
clc;
clear;
close;
L=1;//in km
h1=0.63;//in micro meter
h2=1;//in micro meter
h3=1.3;//in micro meter
Tf=1400;//Temperature in Kelvin
p=0.286;//photoelastic coefficient of silica
n=1.46;//Refractive index of silica
Bc=7*10^-11;//isothermal compersebility in in Metere
     square per N
K=1.38*10^-23;// boltzman constt. in julian per
    Kelvin
x1= (h1*10^-6);
x2= (h2*10^-6);
x3= (h3*10^-6);
Yr1=(8*%pi^3*n^8*p^2*Bc*K*Tf)/(3*(x1)^4);//ray leigh
     scattering coefficient
Ekm1= exp(-Yr1*L*10^3)
alpha1=10*(log10(1/Ekm1));//Attenuation in dB/km
```

```
Yr2=(8*%pi^3*n^8*p^2*Bc*K*Tf)/(3*(x2)^4);//ray leigh
     scattering coefficient
Ekm2= exp(-Yr2*L*10^3)
alpha2=10*(log10(1/Ekm2));//Attenuation in dB/km
Yr3=(8*%pi^3*n^8*p^2*Bc*K*Tf)/(3*(x3)^4);//ray leigh
     scattering coefficient
Ekm3= exp(-Yr3*L*10^3)
alpha3=10*(log10(1/Ekm3));//Attenuation in dB/km
disp(alpha1,"Attenuation in dB/km for (h=0.63 micro
    meter)")
disp(alpha2,"Attenuation in dB/km for (h=1 micro
    meter)")
disp(alpha3,"Attenuation in dB/km for (h=1.30 micro
    meter)")
```

Scilab code Exa 4.3 threshold stimulated Brillouin and Raman scattering powers

```
// Example 4.3:Optical Powers
clc;
clear;
close;
h=1.5;//Wavelength in micro meter
d=6;//Core diameter in micro meter
v=600;//frequency in Mega Hertz
alpha=0.4;//Attenuation in dB/km
Pb=(4.4*10^-3*d^2*h^2*alpha*v*10^-3)*10^3;//
    Threshold optical power for brillouin scattering
    in milli Watt
Pr=(5.9*10^-2*d^2*alpha*h);//Threshold optical power
     for Raman scattering in Watt
disp(Pb,"Threshold optical power for Brillouin
    scattering in milli Watt")
disp(Pr,"Threshold optical power for Raman
    scattering in Watt")
```

```
//Pb is calculated wrong in the text book
```

Scilab code Exa 4.4.a critical radius

```
// Example 4.4.a:Critical Radius
clc;
clear;
close;
d=0.03;//Refractive index difference
n1=1.5;//Core refractive index
h= 0.85*10^-6;//Wavelength in meters
x=2*n1^2*d;//
Rc=(3*n1^2*h)/(4*%pi*sqrt(x))*10^6;// Critical
    Radius in micro meters
disp(Rc,"Critical Radius in micro meters")
//answer is calculated wrong in the textbook
```

Scilab code Exa 4.4.b critical radius

```
// Example 4.4.b:Critical Radius of curvature
clc;
clear;
close;
a=4;// core radius in micro meters
d=0.003;//Refractive index difference
n1=1.5;//Core refractive index
h= 1.55*10^-6;//Wavelength in meters
x=2*n1^2*d;//
hc= ((2*%pi*a*10^-6*sqrt(2*d)*n1)/2.405)*10^6;//cut
    off wavelength in micro meters;
x1=(20*h)/(sqrt(x));
y=((2.748-0.996*((h*10^6)/hc)))^-3;
Rcs=x1*y*10^6;
```

```
disp(Rcs,"Critical Radius of curvature in micro
   meters")
//answer is calculated wrong in the textbook
```

Scilab code Exa 4.5.a bandwidth

```
// Example 4.5.a:Maximum possible optical bandwidth
clc;
clear;
close;
t=0.1*10^-6;//Time in second
L=15;//Distance in km
Bt=(1/(2*t))*10^-6;//Maximum possible optical
   bandwidth in Mega Hertz
disp(Bt,"Maximum possible optical bandwidth in Mega
   Hertz")
```

Scilab code Exa 4.5.b pulse dispersion

```
// Example 4.5.b:Despersion per unit length
clc;
clear;
close;
t=0.1*10^-6;//Time in second
L=15;//Distance in km
dp=(t/L)*10^6;//Despersion per unit length in micro
   second per Km
disp(dp*10^3,"Despersion per unit length in nano
   second per km")
```

Scilab code Exa 4.5.c bandwidth length product

```
// Example 4.5.c:Bandwidth legth product
clc;
clear;
close;
t=0.1*10^-6;//Time in second
L=15;//Distance in km
Bt=(1/(2*t))*10^-6;//Maximum possible optical
   bandwidth in Mega Hertz
BL=Bt*L;// bandwidth length product in km
disp(BL,"bandwidth length product in MHz km")
```

Scilab code Exa 4.6 material dispersion parameter and pulse broadning

```
// Example 4.6;/Pulse broadning due to material
   dispersion
clc;
clear;
close;
c=3*10^5;// speed of light in km/s
Dh=0.025;//Material dispersion
L=1;//distance in km
h=0.85;//Wavelength micro meters
Sh=20;// Spectral width in nano meter
M=Dh/(c*h*10^3);//
Sm=M*L*Sh//Pulse broadning due to material
   dispersion in nano second per kilometer
disp(Sm*10^9,"Pulse broadning due to material
   dispersion in nano second per kilometer")
```

Scilab code Exa 4.7 rms pulse broadning

```
// Example 4.7//Pulse broadning due to material
    dispersion
clc;
clear;
close;
c=3*10^5;// speed of light in km/s
Dh=0.03;//Material dispersion
L=1;//distance in km
h=0.85;//Wavelength in micro meters
Sh=0.0012*h;// Spectral width in nano meter
M=Dh/(c*h*10^3);//
Sm=M*L*Sh//Pulse broadning due to material
    dispersion in nano second per kilometer
disp(Sm*10^12,"Pulse broadning due to material
    dispersion in nano second per kilometer")
```

Scilab code Exa 4.8 pulse spreading

```
// Example 4.8//Pulse broadning due to material
    dispersion
clc;
clear;
close;
ho=1343;//nm
h=850;//in nm
so=0.097;//in ps/nm^2
m(h)=((so*(h/4))*(1-(h/ho))^4);// in ps/nm-km
tgmat=m(h)*70;//in ns/km
dt=tgmat*100;//in ns
disp(dt,"total pulse spread in ns is")
//answer is wrong in the textbook
```

Scilab code Exa 4.9.a delay difference

```
// Example 4.9.a //delay
clc;
clear;
close;
d=0.01;// Change in refractive index
n1=1.5;//Core refrctive index
L=6*10^3;//Length in meter
C=2.998*10^8;//Speed of light in m/s
dts=round(((L*n1*d)/C)*10^9);//delay in ns
disp(dts,"delay in ns")
```

Scilab code Exa 4.9.b rms pulse broadning

```
// Example 4.9.b;//Pulse broadning due to intermodal
    dispersion
clc;
clear;
close;
d=0.01;// Change in refractive index
n1=1.5;//Core refrctive index
L=6*10^3;//Length in meter
C=2.998*10^8;//Speed of light in m/s
Ss=(L*n1*d)/(2*sqrt(3)*C)*10^9;//Pulse broadning due
    to intermodal dispersion in ns
disp(Ss,"Pulse broadning due to intermodal
    dispersion in ns")
```

Scilab code Exa 4.9.c bit rate

```
// Example 4.9.c//Bit Rate
clc;
clear;
close;
```

```
d=0.01;// Change in refractive index
n1=1.5;//Core refrctive index
L=6*10^3;//Length in meter
C=2.998*10^8;//Speed of light in m/s
dts=round(((L*n1*d)/C)*10^9);//Delay in ns
Bt=(1/(2*dts*10^9))*10^12;//Bit rate in Mbits/sec
Ss=(L*n1*d)/(2*sqrt(3)*C);//Pulse broadning due to
   intermodal dispersion in ns
Btimp=0.2/Ss;//
disp(Bt,"Bit rate in M bit per seconds")
disp(Btimp*10^-6,"improved estimate of bit rate in M
    bit per seconds")
```

Scilab code Exa 4.9.d bandwidth length product

```
// Example 4.9.d//BANDWIDTH LENGTH PRODUCT
clc;
clear;
close;
d=0.01;// Change in refractive index
n1=1.5;//Core refrctive index
L=6*10^3;//Length in meter
C=2.998*10^8;//Speed of light in m/s
dts=round(((L*n1*d)/C)*10^9);//Delay in ns
Bt=(1/(2*dts*10^9))*10^12;//Bit rate in Mbits/sec
Ss=(L*n1*d)/(2*sqrt(3)*C);//Pulse broadning due to
   intermodal dispersion in ns
Btimp=0.2/Ss;//
BL=Btimp*L*10^-9;// bandwidth length product in km
disp(BL,"bandwidth length product MHz km")
```

Scilab code Exa 4.10.a rms pulse broadning

```
// Example 4.10.a;//TOTAL RMS Pulse broadning
clc;
clear;
close;
M=250;//dispersion parametr picosecond per nano
    meter per kilometer
Sa=50;//spectral width in nm
NA=0.3;//numerical aperture
n1=1.45;// Core refractibve index
C=2.998*10^8;//Speed of light in m/s
L=1;//length in Km
Sm=M*L*Sa*10^-3;//rms pulse broadning due to
    material dispersion
Ss=(L*10^3*NA^2)/(4*sqrt(3)*C*n1)*10^9;//Pulse
    broadning due to intermodal dispersion in ns/km
St=sqrt(Sm^2+Ss^2);// Total broadning
disp(St,"Total broadning ns per km is")
```

Scilab code Exa 4.10.b bandwidth length product

```
// Example 4.10.b;//bandwidth length product
clc;
clear;
close;
M=250;//dispersion parameter picosecond per nano
    meter per kilometer
Sa=50;//spectral width in nm
NA=0.3;//numerical aperture
n1=1.45;// Core refractibve index
C=2.998*10^8;//Speed of light in m/s
L=1;//length in km
Sm=M*L*Sa*10^-3;//rms pulse broadning due to
    material dispersion
Ss=(L*10^3*NA^2)/(4*sqrt(3)*C*n1)*10^9;//Pulse
    broadning due to intermodal dispersion in ns/km
```

```
St=sqrt(Sm^2+Ss^2);// Total broadning
BL= (0.2/(St*10^-9))*10^-6;// Bandwidth length
   product in Mega hertz km
disp(BL,"Bandwidth length product is,(MHz-km)")
```

Scilab code Exa 4.11 compare first order dispersion

```
// Example 4.11 //compare the total first order
   dispersion
clc;
clear;
close;
so=0.095;//ps nm^-2 km^-1
h=1270;//in nm
ho=1320;//in nm
dt1=((h*so)/4)*((1-(ho/h)^4));// in ps nm^-1 km^-1
h1=1520;//in nm
dt21=((h1*so)/4)*((1-(ho/h1)^4));// in ps nm^-1 km
   ^-1
dt2=dt21-(13.5+4.1);// in ps nm^-1 km^-1
disp(dt1,"first order dispersion at wavelength 1270
   nm in ps nm^-1 km^-1")
disp(dt2,"first order dispersion at wavelength 1320
   nm in ps nm^-1 km^-1")
//answer is wrong in the textbook
```

Scilab code Exa 4.12 bit rate

```
// Example 4.12;//bit rate
clc;
clear;
close;
dx=2;//in ps/nm-km
```

```
L=100;//in km
h1=1310;// in nm
h2=1300;//in nm
dh=h1-h2;//in nm
brl=(1/(4*dx*(dh/10)));//in Gbps-km
br=brl/L;//in Gbps
disp(br*10^3,"bit rate in Gbps")
```

Scilab code Exa 4.13 bit rate

```
// Example 4.13;//Maximum bit rate
clc;
clear;
close;
L=20;//Length in km
Dt2=300*10^-12;//Birefringent in second per
    kilometer
B=(0.9)/(Dt2*L*10^3);//
Btm= round((B/0.55)*10^-3);// maximum bit rate in
    kilo bit per second
disp(Btm,"maximum bit rate in kilo bit per second")
```

Scilab code Exa 4.14 modal birefringence

```
// Example 4.14 //birefringence
clc;
clear;
close;
Lbc1=0.7;//beat length micro meter
h=1.3;//wavelength in micro meter
Bf1=((h*10^-6)/(Lbc1*10^-3));// birefringence when
    beat length = 0.5mm
Lbc2=80;//beat length meter
```

```
Bf2=((h*10^-6)/(Lbc2));// birefringence when beat
    length = 60 meter
disp(Bf1,"birefringence (high birefringent fiber)
    when beat length = 0.7micro meter")
disp(Bf2,"birefringence (lower birefringent fiber)
    when beat length = 80 meter")
```

Scilab code Exa 4.15 modal birefringence cohrence length and propogation difference

```
// Example 4.15//Bifringence and differnce between
    the propogation constt.
clc;
clear;
close;
Lb=0.09;//Birefringent Coherence over length in
    meter
h=0.9;//wavelength in micro meter
df=1;//spectral width in nano meter
Bf=((h*10^-6)/(Lb));//modal bifringence
Lbc= (((h*10^-6)^2)/(Bf*df*10^-9));//Coherance
    length in meter
Bxy=(2*%pi)/(Lb);//Diff in the propogation constant
disp(Bf,"modal bifringence  is")
disp(Bxy,"Difference in the propgation constants. is
    ")
```

Scilab code Exa 4.16 bit rate

```
// Example 4.16//bit rate
clc;
clear;
close;
```

```
pmc=0.5;//ps/sqrt(km)
l=100;//km
br=(1/(4*pmc*sqrt(l)));//
disp(br*10^3,"bit rate is ,(Gbps)=")
```

Chapter 5

OPTICAL SOURCES LASER

Scilab code Exa 5.1 number of longitudinal modes and their frequency separation

```
// Example 5.1 //number of longitudinal modes and
   frequency spacing
clc;
clear;
close;
h=0.55*10^-6;//Wavelength in meter
n=1.78;//refractive index
L=4*10^-2;//Length in meter
C=3*10^8;//Speed of light in m/s
q=(2*n*L)/(h);//Number of logitudinal modes
df=((C)/(2*n*L))*10^-9;//frequency sepration in Gega
    Hertz
disp(q,"Number of longitudinal modes are ")
disp(df,"frequency spacing in Gega Hertz is ")
```

Scilab code Exa 5.2 radiative minority carrier lifetimes

```
// Example 5.2;//wavelength spacing and frequency
   spacing
clc;
clear;
close;
Br1=7.21*10^-10;//Bit rate
n=10^18;//hole concentration
Trg=((Br1*n)^-1)*10^9;//radiative minority carrier
   lifetime in GaAs in ns
Br2=1.79*10^-15;//Bit rate
Trs=((Br2*n)^-1)*10^3;//radiative minority carrier
   lifetime in Si in ms
disp(Trg,"radiative minority carrier lifetime in
   GaAs in ns")
disp(Trs,"radiative minority carrier lifetime in Si
   in ms")
```

Scilab code Exa 5.3 threshold current density

```

// Example 5.3 //threshold density and threshold
   current
clc;
clear;
close;
B=21*10^-3;//Gain factor in ampere per centimeter
   cube
alpha=10;// in per cm
L=250*10^-4;//length in meter
w=100;//in micro meter
r=0.32;
Jth=(1/B)*(alpha+(1/L)*log(1/r));//Threshold current
    in ampere per centimeter cube
ith=Jth*L*w*10^-4;//
disp(Jth,"threshold density in Ampere per centimeter
```

```
     square")
disp(ith*10^3,"threshold current in mA is")
```

Scilab code Exa 5.4 slope efficiency

```
// Example 5.4 //slope efficiency
clc;
clear;
close;
eg=1242;//
e=1300;//in nm
n=0.1;//efficiency
s=((eg/e)*n);//
disp(s,"slope efficiency is")
```

Scilab code Exa 5.5 external power efficiency

```
// Example 5.5//external power efficiency
clc;
clear;
close;
eg=1.44;//
v=2.8;//in volts
an=0.20;;//efficiency
nep=((an*(eg/v))*100);//external power efficiency
disp(nep,"external power efficiency in percentage is
   ")
```

Scilab code Exa 5.6 compare ratio of threshold current densities

```
// Example 5.6;//ratio of threshold current at
   differnt temperatures
clc;
close;
clear;
To1=160;//Absolute temperature in Kelvin
To=55;//in Kelvin
T1=293;//T=20 in Kelvin
T2=353;//T=80 in Kelvin
J1=exp((T2-T1)/To1);//threshold current ration for
   AlGaAs laser
J2=exp((T2-T1)/To);//threshold current RATIO FOR
   InGaAs laser
disp(J1,"ratio of the threshold current densities
   for AlGaAs laser")
disp(J2,"ratio of current densities for InGaAs laser
   ")
```

Scilab code Exa 5.7.a rms value of power fluctuation

```
// Example 5.7.a;//rms value of power fluctuation
clc;
close;
clear;
op=10^-15;//outputin dB Hz^-1
bw=100;//in MHz
h=1.55;//in micro meter
ef=0.6;//quantum efficiency
pi=2;//in mW
rrmf=op*bw*10^6;//
rmf=sqrt(rrmf);//
disp(rmf,"rms value of power fluctuation is")
```

Scilab code Exa 5.7.b rms noise current

```
// Example 5.7.b;//rms noise current
clc;
close;
clear;
op=10^-15;//outputin dB Hz^-1
bw=100;//in MHz
h=1.55;//in micro meter
ef=0.6;//quantum efficiency
pi=2;//in mW
rrmf=op*bw*10^6;//
rmf=sqrt(rrmf);//
e=1.6*10^-19;//
hc=6.63*10^-34;//
c=3*10^8;//in m/s
x=((e*ef*h*10^-6*pi*10^-3*10^4*3.16*10^-8)/(hc*c));
    //
disp(x,"rms noise current in A is")
```

Chapter 6

OPTICAL SOURCES LEDs

Scilab code Exa 6.1 internal quantum efficiency

```
// Example 6.1 //inernal quantum efficiency
clc;
clear;
close;
tr=2.5;//radiative recombination time in milli
   second
tnr=50;//non radiative recombination time in milli
   second
t=(tr*tnr)/(tr+tnr);//Bulk recombination life time
   in millisecond
nint= (t/tr)
disp(nint*100,"inernal quantum efficiency is(%) ")
```

Scilab code Exa 6.2 total carrier recombination lifetime and power

```
// Example 6.2//internal power level
clc;
clear;
```

```
close;
e=1.6*10^-19;//Electronic charge
ht=6.62*10^-34;//Constt
C=3*10^8;//speed light in m/s
h=0.87*10^-6;//wavelength in meter
tr=80;//radiative recombination time in nano second
tnr=120;//non radiative recombination time in nano
    second
t=(tr*tnr)/(tr+tnr);//Bulk recombination life time
    in nano second
nint= (t/tr)
i=40;//injected current in milli ampere
Pint= (nint*((ht*C*i*10^-3)/(e*h)))*10^3;//internal
    power level in milli Watt
disp(Pint,"internal power level in milli Watt")
```

Scilab code Exa 6.3.a optical power

```
// Example 6.3.a//optical power emitted
clc;
clear;
close;
F=0.62;//transmission factore
nx=3.6;//refractive index
n=1;//refractive index of air
Px=((F*n^2)/(4*nx^2));//optical power emitter
disp("emiiter power in terms of power generated
    internally is "+string(Px)+" Pint")
```

Scilab code Exa 6.3.b external efficiency

```
// Example 6.3.b //external power efficiency
clc;
```

```
clear;
close;
F=0.62;//transmission factore
nx=3.6;//refractive index
n=1;//refractive index of air
Px=((F*n^2)/(4*nx^2));//optical power emitter
Pint=0.5;//
NEP=(Px*Pint)*100;//
disp(NEP,"external power efficiency in (%) is")
```

Scilab code Exa 6.4.a coupling efficiency

```
// Example 6.4.a //coupling efficiency
clc;
clear;
close;
NA=0.2;//numerical aperture
n=1.4;//refractive index
nc=(NA)^2;//coupling efficiency
disp(nc,"coupling efficiency is")
```

Scilab code Exa 6.4.b optical loss

```
// Example 6.4.b //optical power loss
clc;
clear;
close;
NA=0.2;//numerical aperture
n=1.4;//refractive index
nc=(NA)^2;//coupling efficiency
Loss=round(-(10*log10(nc)));//optical loss in dB
disp(Loss,"optical loss in dB is")
```

Scilab code Exa 6.4.c loss

```
// Example 6.4.c //optical  loss
clc;
clear;
close;
NA=0.2;//numerical aperture
n=1.4;//refractive index
nc=(NA)^2;//coupling efficiency
pe=0.012;//
pc1=pe*nc;//
Loss=round(-(10*log10(pc1)));//optical loss in dB
disp(Loss,"optical loss in dB is")
//answer is wrong in the text book
```

Scilab code Exa 6.5 optical power

```
// Example 6.5 //optical power
clc;
clear;
close;
r=0.01;//fresenel reflection coefficient
NA=0.15;//numeical apertrure
Rd=30;//radiance in W sr-1 cm-2
R=30*10^-4;//radis in centi meter
A=(%pi*R^2);//area
Pc=(%pi*(1-r)*A*Rd*NA^2)*10^6;//optical power
    coupled in mincro watt
disp(Pc,"optical power coupled in micro Watt is")
// answer is wrong in the textbook
```

Scilab code Exa 6.6 overall power conversion efficiency

```

// Example 6.6 //overall power conversion efficiency
clc;
clear;
close;
Pc=200*10^-6;//Optical power in Watt
If=25;//forward current in milli Ampere
Vf=1.5;//forward voltage in Volts
P=If*10^-3*Vf;//power in Watt
npc=((Pc/P));//overall power conversion efficiency
disp(npc*100,"overall power conversion efficiency in
    percentage")
//answer is wrong in the textbook
```

Scilab code Exa 6.7 compare electrical and optical bandwidth

```
// Example 6.7:compare
clc;
clear;
close;
ioi=1/sqrt(2);//given
ioi1=1/(2);//given/
disp(ioi,"-3 dB electrical bandwidth point occur
    when Iout/Iin,=")
disp(ioi1,"-3 dB optical bandwidth point occur when
    Iout/Iin,=")
```

Scilab code Exa 6.8 optical power and optical bandwidth

```
// Example 6.8 //find output power and bandwidth
clc;
clear;
close;
Pdc=320*10^-6;//d.c. power in Watt
f1=20*10^6;//frequency in hertz
Ti=5*10^-9;//recombination life time in nano second
Pe1=(Pdc/sqrt(1+(2*%pi*f1*Ti)^2))*10^6;
f2=100*10^6;//frequency in hertz
Pe2=(Pdc/sqrt(1+(2*%pi*f2*Ti)^2))*10^6;
f=((sqrt(3))/(2*%pi*Ti));//in MHz
fele=f*0.707;//
disp(Pe1,"overall power in micro Watt when frequecy
    is 20 MHz")
disp(Pe2,"overall power in micro Watt when frequecy
    is 80 MHz")
disp(f*10^-6,"optical bandwidth in MHz is")
disp(round(fele*10^-6),"electrical bandwidth in MHz
    is")
```

Scilab code Exa 6.9 operating lifetime

```
// Example 6.9;//CW operating lifetime
clc;
clear;
close;
d=0.67;//
bo=1.86*10^7;//in h^-1
ea=1.67*10^-19;//
k=1.38*10^-23;//
t=290;//Kelvin
x=((-ea)/(k*t));//
be=((bo)*exp(-40));//in h^-1
```

```
t=((-log(d))/be);//in hours
disp(t,"CW operating lifetime in hours is")
```

Scilab code Exa 6.10 power coupled

```
// Example 6.10 //power coupled
clc;
clear;
close;
tha=15;//in degree
po=1;//in micro watt
nc=(sind(tha))^2;//
pf=nc*po*10^-6;//in watts
disp(pf*10^9,"power coupled in nW is")
```

Scilab code Exa 6.11 power coupled

```
// Example 6.11 //power coupled
clc;
clear;
close;
If=1.5;//in mA
Vf=20;//in volts
pin=If*Vf;//in Watts
nint=2;//efficiency
tha=20;//in degree
po=((nint/100)*pin);//in Watt
nc=(sind(tha))^2;//
pf=nc*po;//in Watts
disp(pf*10^3,"power coupled in micro watts is")
```

Scilab code Exa 6.12 bandwidth

```
// Example 6.12;//bandwidth
clc;
clear;
close;
tr=10;//in ns
bw=(0.35/tr);//in MHz
disp(bw*10^3,"bandwidth in MHz is")
```

Scilab code Exa 6.13 coupling efficiency

```
// Example 6.13 //coupling efficiency
clc;
clear;
close;
t=1;//
no=1;//
na=0.3;//
x=1;//assume
y=1;//
nc1=(t*(na/no)^2*(x/y)^2)*100;//
alpha=2;//
nc2=((t*(na/no)^2*(x/y)^2*(alpha/(alpha+2))))*100;//
disp(nc1,"coupling efficiency for step index fiber
   in (%)")
disp(nc2,"coupling efficiency for graded index fiber
    in (%)")
```

Scilab code Exa 6.14 coupling efficiency

```
// Example 6.14 //coupling efficiency
clc;
```

```
clear;
close;
t=1;//
no=1;//
na=0.3;//
x=1;//assume
y=3/4;//
alpha=2;//
nc1=((t*(na/no)^2)*(alpha+(1-(y/x)^2)))/(alpha+2)
   *100;//
disp(nc1,"coupling efficiency for graded index fiber
    in (%)")
```

Scilab code Exa 6.15 power coupled

```
// Example 6.15;//power coupled
clc;
clear;
close;
n1=1.48;//
n2=1.46;//
po=100;//in micro watts
pin=((po*((n1^2-n2^2))));//in micro watts
disp(pin,"power coupled in micro watts is")
```

Chapter 7

OPTICAL DETECTORS

Scilab code Exa 7.1 cut off wavelength

```
// Example 7.1 //WAVELENGTH
clc;
clear;
close;
E=1.35//energy gap in electron-volt
e=1.6*10^-19;//elecronic charge
C=3*10^8;//Speed of light in meter per second
ht=6.63*10^-34;//plank constt.
h=((ht*C)/(E*e))*10^6;//Wavelength
disp(h,"wavelength in micro meter")
```

Scilab code Exa 7.2 quantum efficiency and responsivity

```

// Example 7.2 //quantum efficiency and responsivity
clc;
clear;
close;
```

```
e=1.6*10^-19;//elecronic charge
re=1.2*10^12;// Average no. of electron hole pair
    generated
rp=3*10^12;//no. of photons
h=0.85;//wavelength in micro meter
E=0.75;//energy gap in electron volt
C=3*10^8;//SPEED of light in meter per second
n=round((re/rp)*100);//quantum efficiency
ht=6.62*10^-34;//plank constt.
R=((n/100)*e*h*10^-6)/(ht*C);
disp(n,"quantum efficiency (%)")
disp(R,"Responsivity is in Ampere per Watt")
```

Scilab code Exa 7.3 wavelength and optical power

```
// Example 7.3 //Wavelength and Incident optical
    power
clc;
clear;
close;
E=1.5*10^-19;//energy in joule
e=1.6*10^-19;//elecronic charge
If=3*10^-6;//forward current in ampere
C=3*10^8;//Speed of light in meter per second
n=0.6;//quantum efficiency
ht=6.62*10^-34;//plank constt.
h=((ht*C)/E)*10^6;//Wavelength
R=(n*e)/(E);//Responsivity in ampere per watt
Po=(If/R)*10^6;//Output power in micro watt
disp(h,"wavelength in micro meter")
disp(Po,"Output power in micro Watt")
```

Scilab code Exa 7.4 responsivity

```
// Example 7.4 //responsivity
clc;
clear;
close;
n=20;//efficiency
e=1.6*10^-19;//elecronic charge
h=0.80;//wavelength in micro meter
C=3*10^8;//SPEED of light in meter per second
ht=6.62*10^-34;//plank constt.
R=((n/100)*e*h*10^-6)/(ht*C);
disp(R,"Responsivity is in Ampere per Watt")
```

Scilab code Exa 7.5.a photocurrent

```
// Example 7.5.a //photocurrent
clc;
clear;
close;
R=0.85;//in AW^-1
pi=1.5;//in mW
po=1;//in mW
ip=po*R;//in mA
disp(ip,"photocurrent in mA is")
```

Scilab code Exa 7.6 responsivity

```
// Example 7.6 // responsivity
clc;
clear;
close;
e=1.6*10^-19;//elecronic charge
eg=0.75;//eV
```

```
n=0.7;//
R=(n*e)/(eg*e);//
disp(R,"Responsivity is in Ampere per Watt")
```

Scilab code Exa 7.7 width

```
// Example 7.7 //width  of deplition region
clc;
clear;
close;
n=70;//efficinecy
absc=10^5;//cm^-1
W=(2.303*-log10(1-(n/100)))/(absc);//in meter
disp(round(W*10^6),"deplition width in micro meter
    is")
```

Scilab code Exa 7.8 response time

```
//Example 7.8 // Maximum response time
clc;
clear;
close;
//given data :
Vd=3*10^4;// in m/s
W=30*10^-6;// in m
Bm=Vd/(2*%pi*W);
M=(1/Bm)*10^9;
disp(M,"Maximum response time,(ns) = ")
```

Scilab code Exa 7.9 NEP and specific detectivity

```
//Example 7.9 // NEP and specific detectivity
clc;
clear;
close;
//given data :
h=6.63*10^-34;
c=3*10^8;
Id=9*10^-9;// in A
e=1.6*10^-19;
eta=60/100;
lamda=1.3*10^-6;// in m
A=100*50*10^-12;// in m^2
NEP=(h*c*sqrt(2*Id*e))/(eta*e*lamda);
disp(NEP,"NEP,(W) = ")
D=sqrt(A)/NEP;
disp(D,"Specific detectivity ,(MHz^(-1/2) W^-1) = ")
```

Scilab code Exa 7.10 bandwidth

```
//Example 7.10 // Bandwidth
clc;
clear;
close;
//given data :
t_tr=100;// in ps
tau_rc=100;// in ps
BW=(1/(2*%pi*(t_tr+tau_rc)*10^-12))*10^-9;
disp(BW,"Bandwidth ,BW(G bit/s) = ")
```

Scilab code Exa 7.11 multiplication factor

```
//Example 7.11 // Multiplication factor
clc;
```

```
clear;
close;
//given data :
eta=80/100;// quantum efficiency
e=1.6*10^-19;
lamda=.88*10^-6;// in m
h=6.63*10^-34;//
c=3*10^8;
I=12;// in micro-A
R=(eta*e*lamda)/(h*c);
P0=0.6*10^-6;// in W
Ip=P0*R*10^6;
M=I/Ip;
disp(M,"Multiplication factor ,M = ")
```

Scilab code Exa 7.12 optical gain and hfe

```
//Example 7.12 // Optical gain and hFE
clc;
clear;
close;
//given data :
h=6.63*10^-34;
c=3*10^8;
e=1.6*10^-19;
Ic=15*10^-3;// in A
P0=140*10^-6;// in W
lamda=1.3*10^-6;// in m
eta=45/100;// quantum efficiency
G0=(h*c*Ic)/(e*P0*lamda);
disp(G0,"The optical gain ,G0 = ")
h_FE=G0/eta;
disp(h_FE,"hFE = ")
// answer is wrong in the textbook
```

Scilab code Exa 7.13 maximum 3 dB bandwidth

```
//Example 7.13 // Maximum 3dB bandwidth
clc;
clear;
close;
//given data :
tF=5*10^-12;// in sec
G=60;// photoconductive gain
Bm=(1/(2*%pi*tF*G))*10^-6;
disp(Bm,"The maximum 3dB bandwidth,Bm(MHz) = ")
// answer is wrong in textbook
```

Scilab code Exa 7.14 SNR

```
//Example 7.14 // SNR
clc;
clear;
close;
r=1;//responsivity
p=0.1;//micro watt
ins=910;//nA
snr=((r^2*(p*10^3)^2)/(ins^2));//
disp(snr,"SNR is , =")
```

Chapter 8

OPTICAL FIBER COMMUNICATION SYSTEM

Scilab code Exa 8.1 compare shot noise and thermal noise current

```

// Example 8.1 //compare shot noise and thermal
   current
clc;
clear;
close;
T=293;//Temperature in Kelvin
K=1.38*10^-23;//boltzman constt
C=3*10^8;//Speed of light in meter per second
e=1.6*10^-19;//elecronic charge
ht=6.62*10^-34;//plank constt.
Id=3;//dark current in nano ampere
n=0.60;//efficiency
Rl=4;//load resistance in kilo-ohms
h=0.9;//wavelength in micro meter
Po=200;// ouput power in nano Watt
B=5;// bandwidth in mega hertz
Ip= ((n*h*10^-6*Po*10^-9*e)/(ht*C))*10^9;//Photo
   current in Ampere
```

```
its=(2*e*B*10^6*(Id+Ip)*10^-9);//total shot noise
itsr=sqrt(its);//RMS shot noise
disp(itsr,"RMS shot noise current in Ampere is")
T=293;//Temperature in Kelvin
K=1.38*10^-23;//boltzman consttt
C=3*10^8;//Speed of light in meter per second
e=1.6*10^-19;//elecronic charge
ht=6.62*10^-34;//plank consttt.
Id=3;//dark current in nano ampere
n=0.60;//efficiency
Rl=4;//load resistance in killo ohms
h=0.9;//wavelength in micro meter
Po=200;// ouput power in nano wat
B=5;// bandwidth in mega hertz
it=(((4*K*T*B*10^6)/(Rl*10^3)));//thermal noise
itr=sqrt(it);//rms thermal noise
disp(itr,"RMS thermal noise current in Ampere is")
```

Scilab code Exa 8.2.a quantum limit

```
// Example 8.2.a //threshold quantum limit
clc;
clear;
close;
en=10^-9;//
n=-log(en);//
disp(round(n),"quantum limit is (photons per pulse
    required )")
```

Scilab code Exa 8.2.b incident power

```
// Example 8.2.b //minumum incident optical power
clc;
```

```
clear;
close;
en=10^-9;
n=-log(en);//
c=3*10^8;//m/s
ht=6.62*10^-34;//plank constt.
B=10^7;//NO. OF BITS
h=0.85*10^-6;//wavelength in meter
Po=((20.7*ht*B*c)/(2*h));//pulse energy in pico Watt
Podb=10*(log10(Po));//pulse energy in dB when
    refrence level is one Watt
Podb1=10*(log10(Po*10^3));//pulse energy in dB when
    refrence level is one mili Watt
disp(Po, "minimum incident optical power in Watts is
    ")
disp(Podb1 , "pulse energy in dB when refrence level
     is one miiliwatt in dBm")
```

Scilab code Exa 8.3.a bit rate for the system

```
// Example 8.3.a;//bit rate for the system
clc;
clear;
close;
wd=8;//bit wide
ts=32;//time slots
nb=ts*wd;//no. of bits in a frame
nf=8*10^3;//no. of frames
tr=nf*nb;//transmission rate
disp(tr*10^-6,"transmission rate for the system in M
    -bits-s^-1")
```

Scilab code Exa 8.3.b duration of time slot

```
// Example 8.3.b //duration of time slot
clc;
clear;
close;
wd=8;//bit wide
ts=32;//time slots
nb=ts*wd;//no. of bits in a frame
nf=8*10^3;//no. of frames
tr=nf*nb;//transmission rate
bdr1=1/tr;//bit duration
bdr=bdr1*wd;//
disp(bdr*10^6,"duration of time slot in micro
    seconds")
```

Scilab code Exa 8.3.c duration of a frame and multiframe

```
// Example 8.3.c //duration of a frame and
    multiframe
clc;
clear;
close;
wd=8;//bit wide
ts=32;//time slots
nb=ts*wd;//no. of bits in a frame
nf=8*10^3;//no. of frames
tr=nf*nb;//transmission rate
bdr1=1/tr;//bit duration
bdr=bdr1*wd;//
df=bdr*10^6*ts;//duration of frame
dmf=df*(ts/2);//ms
disp(df,"duration of frame in micro seconds")
disp(dmf*10^-3,"duration of multiframe in milli
    seconds")
```

Scilab code Exa 8.4 average number of photons

```
//Example 8.4 // Average nummber of photon
clc;
clear;
close;
//given data :
format('v',5)
M=80;// multiplication factor
K=0.02;// carrier ionization rates
eta=85/100;// quntum efficiency
Bt=0.6;// assuming a raised cosine signal spectrum
SbyN=144;
FM=(K*M)+(2-(1/M))*(1-K);
eta_max=(2*Bt*FM*SbyN)/(eta);
disp(eta_max,"The average number of photon,(photon)
    = ")
// answer is wrong in a textbook
```

Scilab code Exa 8.5 incident optical power

```
// Example 8.5;//minumum incident optical power
clc;
clear;
close;
nmax=732;//
c=3*10^8;//m/s
ht=6.62*10^-34;//plank constt.
B=10^7;//NO. OF BITS
h=1*10^-6;//wavelength in meter
Po=((nmax*ht*B*c)/(2*h))*10^12;//pulse energy in
    pico Watt
```

```
Podb=10*(log10(Po));//pulse energy in dB when refrence level is one Watt
Podb1=10*(log10(Po*10^-9));//pulse energy in dB when refrence level is one mili Watt
disp(Podb1 ,"pulse energy at bit rate of 10 M bit s^-1 in dBm")
B1=14*10^7;//NO. OF BITS
Po1=((nmax*ht*B1*c)/(2*h))*10^12;//pulse energy in pico Watt
Podb1=10*(log10(Po1));//pulse energy in dB when refrence level is one Watt
Podb2=10*(log10(Po1*10^-9));//pulse energy in dB when refrence level is one mili Watt
disp(Podb2 ,"pulse energy at bit rate of 140 M bit s^-1 in dBm")
//at 10 M bit s^-1 power is calc ulated wrong in the book
```

Scilab code Exa 8.6 channel loss

```
// Example 8.6;//total channel loss
clc;
clear;
close;
afc=5;//attenuation in dB/km
aj=2;//splice loss in dB/km
l=5;//length in km
ac=3;//dB
ac1=4.5;//dB
cl=(afc+aj)*l+ac+ac1;//dB
disp(cl,"tota channel loss in dB is")
```

Scilab code Exa 8.7.a dispersion equalization penalty

```
// Example 8.7.a //dispersion equalization penalty
clc;
clear;
close;
sg=0.65;// ns km^-1
l=8;//km
st=sg*l;//ns
bt=20;//M bit s^-1
dlw=2*(2*st*10^-9*bt*10^6*sqrt(2))^4;//dB
st1=sg*sqrt(l);//ns
dlw1=2*(2*st1*10^-9*bt*10^6*sqrt(2))^4;//dB
disp(dlw,"dispersion equalization penalty in dB
    without mode coupling at bit rate of 20 M bit s
    ^-1")
disp(dlw1,"dispersion equalization penalty in dB
    with mode coupling at bit rate of 20 M bit s^-1")
//penalty with mode coupling is calculated wrong in
    the book
```

Scilab code Exa 8.7.b dispersion equalization penalty

```
// Example 8.7.b;// dispersion equalization penalty
clc;
clear;
close;
sg=0.65;// ns km^-1
l=8;//km
st=sg*l;//ns
bt=140;//M bit s^-1
dlw=2*(2*st*10^-9*bt*10^6*sqrt(2))^4;//dB
st1=sg*sqrt(l);//ns
dlw1=2*(2*st1*10^-9*bt*10^6*sqrt(2))^4;//dB
disp(dlw,"dispersion equalization penalty in dB
    without mode coupling at bit rate of 20 M bit s
    ^-1")
```

```
disp(dlw1,"dispersion equalization penalty in dB
   with mode coupling at bit rate of 20 M bit s^−1")
//answer is calculated wrong in the book
```

Scilab code Exa 8.8 bit rate

```

// Example 8.8 //bit rate
clc;
clear;
close;
ts=8;//ns
l=8;//km
tn=4;//ns
tn1=tn*l;//ns
tc=1;//
tc1=tc*l;//ns
td=5;//ns
tsys=1.1*sqrt(ts^2+tn1^2+tc1^2+td^2);//ns
btmax=(0.7/(tsys*10^-9))*10^-6;//M bit/s
bt=btmax/2;//
disp(bt,"maximum bit rate for NRZ format in MHz")
```

Scilab code Exa 8.9.a lonk length

```
// Example 8.9.a //Link length
clc;
clear;
close;
pi=-3;//dBm
po=-56;//dBm
ac=2;//dBm
ma=8;//dBm
```

```
afc=0.4; //dBm
aj=0.1; //dBm
l=((pi-po-ac-ma)/(afc+aj)); //km
disp(l,"link length when operating at 50 M bit/s in
   km is")
```

Scilab code Exa 8.9.b link length

```
// Example 8.9.b;//Link length
clc;
clear;
close;
pi=-3; //dBm
po=-42; //dBm
ac=2; //dBm
ma=8; //dBm
afc=0.4; //dBm
aj=0.1; //dBm
l=((pi-po-ac-ma)/(afc+aj)); //km
disp(l,"link length when operating at 500 M bit/s in
    km is")
```

Scilab code Exa 8.9.c link length

```
// Example 8.9.c;//Link length
clc;
clear;
close;
pi=-3; //dBm
po=-42; //dBm
ac=2; //dBm
ma=8; //dBm
afc=0.4; //dBm
```

```
aj=0.1;//dBm
dl=1.5;//dbm
l=((pi-po-ac-ma-dl)/(afc+aj));//km
disp(l,"link length when dispersion equalisation
   penalty is included in km is")
```

Scilab code Exa 8.10 optical power budget

```
// Example 8.10 //optical power budget
clc;
clear;
close;
mip=-10;//dBm
mop=-41;//dBm
tsm=mip-mop;//dB
disp(tsm,"total system margin in dB is")
l=7;//km
fcl=2.6;//dB
lfc=l*fcl;//fiber cable loss in dB
sl=0.5;//dBm
slc=sl*(l-1);//dB
cl=1.5;//dB
sm=6;//dB
tsm1=lfc+slc+cl+sm;//dB
disp(tsm1,"total system margin in dB is")
epm=tsm-tsm1;//dB
disp(epm,"excess power margin in dB is")
```

Scilab code Exa 8.12 average incident power

```
// Example 8.12 //optical power
clc;
clear;
```

```
close;
e=1.6*10^-19;//electron charge
sndb=55;//signal to noise ration in dB
sn=(10^(sndb/10));//
bw=5;//Mhz
r=0.5;//responsivity
cs=0.7;//signal attenuation
k=1.38*10^-23;//bolzman constant
tc=20;//degree celsius
tk=tc+273;//Kelvin
fdb=1.5;//
f=10^(fdb/10);//
rl=1;//mega ohms
x=((sn*4*k*tk*bw*10^6*f)/(rl*10^6));//
y=((2*sn*e*bw*10^6*r));//
ma=9/8;//
z=(2*ma*r^2*cs^2);//
s=poly(0,"s");//
p=-x-y*s+z*s^2;//
m=roots(p);//
disp(m(1,1)*10^6,"average incident power in micro
    Watts is")
```

Scilab code Exa 8.13 average incident power

```
// Example 8.13 //optical power
clc;
clear;
close;
fdb=6;//
f=10^(fdb/10);//
e=1.6*10^-19;//electron charge
sndb=45;//signal to noise ration in dB
sn=(10^(sndb/10));//
h=6.63*10^-34;//planck constant
```

```
c=3*10^8;//m/s
e=1.6*10^-19;//
n=0.6;//efficneicny
ma=0.5*10^-3;//
k=1.38*10^-23;//boltzman constant
tk=300;//degree celcius
bw=8;//MHz
rl=50;//kilo ohms
po=((h*c)/(e*n*ma^2))*sqrt((8*k*tk*bw*10^6*f)/(rl
    *10^3))*sqrt(sn);//
disp(po*10^6,"average power incident in micro Watts
    is")
```

Scilab code Exa 8.14.a optical power budget

```
// Example 8.14.a //optical power budget
clc;
clear;
close;
mip=-10;//dBm
mop=-25;//dBm
tsm=mip-mop;//dB
disp(tsm,"total system margin in dB is")
l=2;//km
fcl=3.2;//dB
lfc=l*fcl;//fiber cable loss in dB
sl=0.8;//dBm
slc=sl*l;//dB
cl=1.6;//dB
sm=4;//dB
tsm1=lfc+slc+cl+sm;//dB
disp(tsm1,"total system margin in dB is")
epm=tsm-tsm1;//dB
disp(epm,"excess power margin in dB is")
```

Scilab code Exa 8.14.b link length

```
// Example 8.14.b //possible increase in link length
clc;
clear;
close;
mip=-10;//dBm
mop=-25;//dBm
tsm=mip-mop;//dB
disp(tsm,"total system margin in dB is")
l=2;//km
fcl=3.2;//dB
lfc=l*fcl;//fiber cable loss in dB
sl=0.8;//dBm
slc=sl*l;//dB
cl=1.6;//dB
sm=4;//dB
tsm1=lfc+slc+cl+sm;//dB
disp(tsm1,"total system margin in dB is")
epm=tsm-tsm1;//dB
ma=8;//dB
l1=((-mop-cl-ma)/(fcl+sl));//km
eil=l1-l;//
disp(eil,"possible increase in length in km")
```

Scilab code Exa 8.15 time

```
//Example 8.15 //
clc;
clear;
close;
//given data :
```

```
B=5*10^6;// in Hz
Ts=10;// in ns
Td=4;// in ns
a=9;// in ns/km
b=2;// in ns/km
l=6;// in km
Tn=a*l;// in ns
Tc=b*l;// in ns
Ts_max=(0.35/B)*10^9;
disp(Ts_max,"T system_maxmum,(ns) = ")
Tsys=1.1*sqrt(Ts^2+Tn^2+Tc^2+Td^2);
disp(Tsys,"T system,(ns) = ")
//answer is wrong in the textbook
```

Scilab code Exa 8.16.b improvement in SNR and bandwidth

```
// Example 8.16.b //SNR improvement and bandwidth
clc;
clear;
close;
fd=400;//KHz
ba=4;//kHz
df1=fd/ba;//
snri=(1.76+20*log10(df1));//dB
disp(snri,"SNR improvement in dB is")
bm=2*ba*(df1+1);//kHz
disp(bm,"bandwidth in kHz is")
```

Scilab code Exa 8.17 ration of SNR

```
// Example 8.17;//ration of SNR
clc;
clear;
```

```
close;
fa=1;//
pa=1;//
r=1;//
po=1;//
ac=1;//
ba=1;//
no=1;//
snr1=((3*fa^3*po*(r*po)^2*((ac^2)/2))/(2*ba^3*no));
    //SNR output FM
snr2=((fa^3*po*(r*po)^2*((ac^2)/2))/(2*ba^3*no));//
    SNR output FM
rt=snr1/snr2;//
disp(rt,"ratio of output SNR (in dB) in two system
    is")
```

Scilab code Exa 8.18 bandwidth and SNR

```
//Example 8.18 // Optimum receiver bandwidth and
    peak to peak signal power to noise ratio
clc;
clear;
close;
//given data :
Tr=12*10^-9;// in sec
f0=20*10^6;// in Hz
fD=5*10^6;// in Hz
Mr=80;// multiplication factor
Pp=.75*10^-7;
B=5*10^6;// in Hz
i2N=10^-17;// in A^2
fr=(1/Tr)*10^-6;
disp(fr," Optimum receiver bandwidth, fr(MHz) = ")
T0=1/f0;
SbyN=10*log10((3*(T0*fD*Mr*Pp)^2)/((2*%pi*Tr*B)^2*
```

```
i2N));
disp(SbyN,"signal power to noise ratio,(dB) = ")
```

Scilab code Exa 8.19 loss for star and bus distribution system

```
// Example 8.19:compare
clc;
clear;
close;
cl=1;//dB
actr=10;//dB
acl=1;//dB
fcl=4.5;//dB/km
sl=2.5;//dB
cel=2;//dB
dl=100;//m
x=cel*cl-fcl*dl*10^-3+(cel*cl+cl)*-(cel+cl)+(cel*cl+actr)+sl+cl;//
x1=(fcl*dl*10^-3)+(cel*cl+cl);//
disp("total loss for bus distribution system is "+string(x1)+"N + "+string(x)+"")
x3=(cel*2*cl)+cel+(fcl*dl*10^-3);//
disp("total loss for star distribution system is "+string(x3)+"+ 10log10(N)")
```

Scilab code Exa 8.20 length

```
// Example 8.20;//maximum length of the system
clc;
clear;
close;
af=0.20;//dB/km
ac1=0.05;//dB/km
```

```
k=4;//
b=1.2;//G bit/s
c=3*10^8;//m/s
h=1.55;//micro meter
sndb=17
sn=10^(sndb/10);//
l=100;//km
hc=6.63*10^-34;//
lt=((10^-3*h*10^-6*(10^-((af+ac1)*(l/10)))*l*10^3)/(
   k*hc*c*b*10^12*sn));//
disp(lt,"maximum length of the system in km is")
//answer is wrong in the textbook
```

Chapter 9

OPTICAL FIBER SYSTEM II

Scilab code Exa 9.1 temperture

```
// Example 9.1;//maximum termperature change
clc;
clear;
close;
f=0.15;//GHz
fc=18;//GHz/degree celsius
ta=f/fc;//
disp(ta,"maximum temperature change alowed in degree
    celsius is")
```

Scilab code Exa 9.2 bandwidth

```
// Example 9.2;//bandwidth
clc;
clear;
close;
snl=-55.45;//dBm
ps=10^(snl/10);//
```

```
n=0.8;//
h=1.54;//micro meter
hc=6.63*10^-34;//
c=3*10^8;//m/s
sndb=12;//
sn=10^(sndb/10);//
b=((n*ps*10^-3*h*10^-6)/(hc*c*sn));//
disp(b*10^-9,"bandwidth in GHz is")
//answer is wrong in the textbook
```

Scilab code Exa 9.3 number of recieved photons

```
// Example 9.3;//number of received photos
clc;
clear;
close;
ber=10^-9;//
x=-2*log10(ber);//
np1=4*x;//no. of received photons for ASK heterodyne sysnchronous detection
np2=-4*log(2*ber);//no. of received photons for ASK heterodyne non-sysnchronous detection
np3=x/2;//no. of received photons for PSK homodyne detection
disp(round(np1),"no. of received photons for ASK heterodyne sysnchronous detection")
disp(round(np2),"no. of received photons for ASK heterodyne non-sysnchronous detection")
disp(round(np3),"no. of received photons for PSK homodyne detection")
```

Scilab code Exa 9.4 incoming power level

```
// Example 9.4 //minimum incoming power level
clc;
clear;
close;
ber=10^-9;//
x=-2*log10(ber);//
hc=6.63*10^-34;//
c=3*10^8;//m/s
bt=500;//Mbits/s
h=1.55;//micro meter
ps=((x*2*hc*c*bt*10^6)/(h*10^-6));//nW
disp(ps*10^9,"minimum incoming power level in nano
   Watts is")
```

Scilab code Exa 9.5.a repeater spacing

```
// Example 9.5.a;//maximum repeater spacing
clc;
clear;
close;
ber=10^-9;//
x1=-2*log10(ber);//
hc=6.63*10^-34;//
c=3*10^8;//m/s
bt=50;//Mbits/s
h=1.55;//micro meter
ps=((x1*2*hc*c*bt*10^6)/(h*10^-6));//nW
psdb=10*log10(ps*10^3);//
cl=0.25;//dB/km
x=4;//dBm
y=x-psdb;//
mrs1=y/cl;//km
disp(mrs1,"maximum repeater spacing in km at 50 M-
   bit/s  system (ASK) in km is")
bt1=1;//Gbit/s
```

```
ps1=((x1*2*hc*c*bt1*10^9)/(h*10^-6));//nW
psdb1=10*log10(ps1*10^3);//
cl=0.25;//dB/km
x=4;//dBm
y1=x-psdb1;//
mrs2=y1/cl;//km
disp(mrs2,"maximum repeater spacing in km at 1 G-bit
   /s  system (ASK) in km is")
```

Scilab code Exa 9.5.b repeater spacing

```
// Example 9.5.B;//maximum repeater spacing
clc;
clear;
close;
ber=10^-9;//
x1=-2*log10(ber);//
hc=6.63*10^-34;//
c=3*10^8;//m/s
bt=50;//Mbits/s
h=1.55;//micro meter
ps=(((x1/2)*hc*c*bt*10^6)/(h*10^-6));//nW
psdb=10*log10(ps*10^3);//
cl=0.25;//dB/km
x=4;//dBm
y=x-psdb;//
mrs1=y/cl;//km
disp(mrs1,"maximum repeater spacing in km at 50 M-
   bit/s  system (PSK) in km is")
bt1=1;//Gbit/s
ps1=(((x1/2)*2*hc*c*bt1*10^9)/(h*10^-6));//nW
psdb1=10*log10(ps1*10^3);//
cl=0.25;//dB/km
x=4;//dBm
y1=x-psdb1;//
```

```
mrs2=y1/cl;//km
disp(mrs2,"maximum repeater spacing in km at 1 G-bit/s  system (PSK) in km is")
//for 1 Gbit/s systme answer is wrong in the textbook
```

Scilab code Exa 9.6 refractive index and bandwidth

```
//Example 9.6 // refractive index and 3dB spectral bandwidth
clc;
clear;
close;
//given data :
lamda=1.5*10^-6;// in m
L=300*10^-6;// in m
del_lamda=10^-9;// in m
n=lamda^2/(2*del_lamda*L);
disp(n,"refractive index , n = ")
R1=0.3;
R2=R1;
a=4.8;// in dB
Gs=10^(4.8/10);
c=3*10^8;
B=(c/(%pi*n*L)*asin((1-sqrt(R1*R2)*Gs)/(2*sqrt(sqrt(R1*R2)*Gs))))*10^-9;
disp(B," Spectral bandwidth,(GHz) = ")
```

Scilab code Exa 9.7 cavity gain

```
//Example 9.7// cavity gain
clc;
clear;
```

```
close;
x=0.5;//
y=(1-(sqrt(x)))/(1+sqrt(x));//
g=(y/(1-y)^2);//
disp("cavity gain is "+string(g)+"/(sqrt(R1*R2))")
```