Scilab Textbook Companion for Antenna and Wave Propagation by S. Wali[1]

Created by
Rajkumar
B.Tech
Electrical Engineering
Uttarakhand Technical University
College Teacher
Vinesh Saini
Cross-Checked by
Prathan Mehta

June 16, 2014

[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: Antenna and Wave Propagation

Author: S. Wali

Publisher: Tech-max Publications, Pune

Edition: 1

Year: 2012

ISBN: 978-93-5077-069-6

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 1

Review of Electromagnetics and Transmission Lines

Scilab code Exa 1.1.1 Find the wavelengths

```
//Example No. 1.1.1
clc;
clear;
close;
format('v',7);

f1=100;//kHz
f2=1;//MHz
f3=10;//MHz
c=3*10^8;//m/s
lambda1=c/(f1*10^3);//m
lambda2=c/(f2*10^6);//m
lambda3=c/(f3*10^6);//m
disp(lambda1/1000,"At 100kHz, wavelength(km) : ");
disp(lambda2,"At 1MHz, wavelength(m) : ");
disp(lambda3,"At 10MHz, wavelength(m) : ");
```

Chapter 3

Fundamental parameters of Antenna

Scilab code Exa 3.3.1 Half Power Beam Width

```
//Example No. 3.3.1
clc;
clear;
close;
format('v',7);
E_theta=1/sqrt(2);//Electric Field at half power
//theta=thetaHP/2;//E(thetaHP/2)=cosd(thetaHP/2)
thetaHP=2*acosd(E_theta);//degree(Half power beam
    width)
disp(thetaHP,"Half power beam width(degree) : ");
```

Scilab code Exa 3.3.2 HPBW and FNBW

```
//Example No. 3.3.2
clc;
clear;
```

```
close;
format('v',7);
E_theta=1/sqrt(2);//Electric field at theta=90-thetaHP/2
//E(90-thetaHP/2)=sind(90-thetaHP/2)
thetaHP=2*(90-asind(E_theta));//degree(HPBW)
disp(thetaHP,"HPBW(degree) : ");
theta1=0;theta2=180;//degree(Pattern angles)
FNBW=theta2-theta1;//degree(FNBW)//as E is zero at these points
disp(FNBW,"FNBW(degree) : ");
```

Scilab code Exa 3.3.3 Half Power Beam width

```
//Example No. 3.3.3
clc;
clear;
close;
format('v',7);
E_theta=1/sqrt(2);//Elecric field at half power point
//E(thetaHP/2)=(cosd(thetaHP/2))^2
thetaHP=2*(acosd(sqrt(E_theta)));//degree(HPBW)
disp(thetaHP,"Half Power Beam Width(degree) : ");
```

Scilab code Exa 3.8.1 Exact and Approximate Directivity

```
//Example No. 3.8.1
clc;
clear;
close;
format('v',6);
theta1=0;theta2=%pi/2;//radian(Angles)
```

```
fi1=0;fi2=2*%pi;//radian(Angles)
//Prad=integrate('integrate(’U','thheta',theta1,
   theta2)','fi',fi1,fi2);
Prad_BY_Um=%pi*(1/2)*(cos(2*theta1)-cos(2*theta2));
   //(Power radiated/Max intensity)
Do=4*%pi/Prad_BY_Um;//Exact Directivity
disp(Do,"Exact Directivity : ");
//Um*Cosd(thetaHP/2)=0.5*Um
thetaHP=2*acosd(0.5);//degree(HPBW)
fiHP=thetaHP;//degree(HPBW)
Do=41253/(thetaHP*fiHP);//Approximate Directivity
disp(Do,"Approximate Directivity : ");
```

Scilab code Exa 3.10.1 Power radiated

```
//Example No. 3.10.1
clc;
clear;
close;
format('v',6);

K=90;//%//radiation efficiency
Pin=10;//W
Prad=(K/100)*Pin;//W
disp(Prad,"Radiated power in Watts : ");
```

Scilab code Exa 3.11.1 Gain in dB

```
//Example No. 3.11.1
clc;
clear;
close;
format('v',6);
```

```
D=20;//Directivity
K=90;//%//radiation efficiency
G=(K/100)*D;//Gain
GdB=10*log10(G);//dB
disp(GdB,"Gain in dB : ");
//Answer is not calculated in the book.
```

Scilab code Exa 3.11.2 Directivity in dB

```
//Example No. 3.11.2
clc;
clear;
close;
format('v',7);
Rr=72;//
RL=8;//
G=16;//Gain
K=Rr/(Rr+RL)*100;//%//radiation efficiency
D=G/(K/100);//Directivity
DdB=10*log10(D);//dB
disp(DdB,"Directivity in dB : ");
```

Scilab code Exa 3.13.1 Radiation Resistance

```
//Example No. 3.13.1
clc;
clear;
close;
format('v',6);
Irms=15;//A(Current Drawn)
Prad=5;//kW(Radiated Power)
Rr=Prad*10^3/Irms^2;//  (Radiation Resistance)
```

```
disp(Rr,"Radiation resistance in   : ");
```

Scilab code Exa 3.13.2 Current Drawn

```
//Example No. 3.13.2
clc;
clear;
close;
format('v',4);
Prad=1000;//W(Radiated Power)
Rr=300;//  (Radiation Resistance)
Irms=sqrt(Prad/Rr);//A(Current Drawn)
disp(Irms,"Current drawn in A : ");
```

Scilab code Exa 3.13.3 Maximum Effective Aperture

```
//Example No. 3.13.3
clc;
clear;
close;
format('v',5);
Rr=73;//  (Radiation Resistance)
Z=120*%pi;//  (For free space)
//le=lambda/%pi
AemBYlambda_sqr=(1/%pi)^2*Z/(4*Rr);
disp("Maximum effective aperture in m  is "+string(
   AemBYlambda_sqr)+"*lambda ");
```

Scilab code Exa 3.13.4 Effective length

```
//Example No. 3.13.4
clc;
clear;
close;
format('v',7);

Rr=73;//
Z=120*%pi;//  (For free space)
//Aem=0.13*lambda
AemBylambda_sqr=0.13;
leBYlambda=2*sqrt(AemBylambda_sqr*Rr)/sqrt(Z);
disp("Effective length in meter is "+string(
    leBYlambda)+"*lambda");
```

Scilab code Exa 3.15.1 Polarization Loss factor

```
//Example No. 3.15.1
clc;
clear;
close;
format('v',4);

cos_si_p=1/sqrt(2);
PLF=cos_si_p^2;//Polarization Loss factor
PLFdB=10*log10(PLF);//dB
disp(PLFdB,"Power loss factor in dB : ");
```

Scilab code Exa 3.16.1 Maximum effective aperture and power

```
//Example No. 3.16.1
clc;
clear;
close;
```

```
format('v',9);

Do_dB=20;//dB
f=10;//GHz
Wi=2*10^-3;//W/ m
c=3*10^8;//m/s
lambda=c/(f*10^9);//m
Do=10^(Do_dB/10);//unitless
Aem=lambda^2/(4*%pi)*Do;// m
disp(Aem,"Maximum effective aperture in m  : ");
Pr=Aem*Wi;//W
disp(Pr*10^6,"Maximum received power in  W : ");
```

Scilab code Exa 3.16.2 Directivity of Antenna

```
//Example No. 3.16.2
clc;
clear;
close;
format('v',6);
ecd=1;//for lossless antenna
Aem=2.147;// m  (Maximum Effective aperture)
Zin=75;//  (Input impedence)
Zo=50;//  (Output impedence)
f=100;//MHz(Operating frequency)
c=3*10^8;//m/s(speed f light)
aw_aa=1;//For no polarization loss
lambda=c/(f*10^6);//m(Wavelength)
Tau=(Zin-Zo)/(Zin+Zo);//(Reflection Coefficient)
Do=Aem/(ecd*(1-Tau^2)*lambda^2/(4*%pi)/aw_aa^2);//unitless(Directivity)
disp(Do,"Directivity of antenna : ");
```

Scilab code Exa 3.17.1 Find the power delivered

```
//Example No. 3.17.1
clc;
clear;
close;
format('v',11);
PT=15;//W(Transmitted Power)
AeT=0.2;// m (Effective aperture)
AeR=0.5;// m (Effective aperture)
f=5;//GHz(frequency)
r=15;//km(line of sight distance)
c=3*10^8;//m/s(Speed of light)
lambda=c/(f*10^9);//m(Wavelength)
PR=PT*AeT*AeR/((r*1000)^2*lambda^2);//Watts(Power delivered to reciever)
disp(PR,"Power delivered to receiver in Watts : ");
//Answer is wrong in the book. lambda is 0.6 instead of 0.06 and lambda^2 is 0.06 instead of 0.0036
```

Scilab code Exa 3.17.2 Calculate the power

```
//Example No. 3.17.2
clc;
clear;
close;
format('v',6);
DT=20;//dB(Transmitter Directivity)
DR=20;//dB(Reciever Directivity)
PT=10;//W(Transmitted Power)
ecdT=1;ecdR=1;//(For lossless antenna)
aT_aR=1;//(For polarization match)
DT=10^(DT/10);//unitless(Transmitter Directivity)
DR=10^(DR/10);//unitless(Reciever Directivity)
Tau_T=0;Tau_R=0;//(Reflection coefficient)
```

```
rBYlambda=50; //m
PR=PT*ecdT*ecdR*(1-Tau_T^2)*(1-Tau_R^2)/(4*%pi*
   rBYlambda)^2*DT*DR*aT_aR^2; //Watts(Power
   delivered to reciever)
disp(PR,"Power at receiving antenna in Watts : ");
```

Scilab code Exa 3.17.3 Power delivered to load

```
//Example No. 3.17.3
clc;
clear;
close;
format('v',9);
f=3; //GHz
c=3*10^8; //m/s(Speed of light)
lambda=c/(f*10^9); //m(wavelength)
r=500; //m(distance)
PT=100; //W(Transmitted Power)
GT=25; //dB(Transmitter Gain)
GR=20; //dB(Reciever Gain)
GT=10^(GT/10); //unitless(Transmitter Gain)
GR=10^(GR/10); //unitless(Reciever Gain)
PLF=1; aT_aR=1; //(For polarization match)
PR=PT*(lambda/4/%pi/r)^2*GT*GR*aT_aR^2; //Watts(Power
    delivered to reciever)
disp(PR,"Power delivered to load  in Watts : ");
```

Chapter 4

Linear Wire Antennas

Scilab code Exa 4.2.1 Er Etheta and Hfi

```
//Example No. 4.2.1
clc;
clear;
close;
format('v',7);
l=5;//cm(length of antenna)
f=100;//MHz(operating frequency)
Io=120;//mA(Terminal current)
t=1;//s(time)
theta=45;//degree(Angle)
r=3;//m(radius)
c=3*10^8;//m/s////Speed of light
omega=2*%pi*f*10^6;//rad/sec(rotation)
k=omega/c;//rad/m(Phase constant)
kr=2*%pi*r/3;//degree(Phase constant)
Er=Io*10^-3*l*10^-2/(2*%pi*r^2)*cosd(theta)*120*%pi
    *[1+1/(%i*kr)]*exp(-%i*kr+%i*omega*t);//V/m(
    Electric field)
Er=Er*1000;//mV/m(Electric field)
Er_mag=abs(Er);//mV/m(magnitude of Er)
Er_angle=atand(imag(Er),real(Er));//degree(angle of
```

```
Er)
disp(Er_angle,Er_mag,"Value of Er : magnitude(mV/m)
    and angle in degree : ");
Etheta=Io*10^-3*l*10^-2/(4*%pi*r)*sind(theta)*120*
    %pi*%i*k*[1+1/(%i*kr)+1/(%i*kr)^2]*exp(-%i*kr+%i*
    omega*t);//V/m(Electric field)
Etheta_mag=abs(Etheta);//V/m(magnitude of Etheta)
Etheta_angle=atand(imag(Etheta),real(Etheta));//
    degree(angle of Etheta)
disp(Etheta_angle,Etheta_mag,"Value of Etheta :
    magnitude(V/m) and angle in degree : ");
Hfi=Io*10^-3*l*10^-2/(4*%pi*r)*sind(theta)*%i*k
    *[1+1/(%i*kr)]*exp(-%i*kr+%i*omega*t);//A/m(
    Magnetic field)
Hfi_mag=abs(Hfi);//A/m(magnitude of Hfi)
Hfi_angle=atand(imag(Hfi),real(Hfi));//degree(angle
    of Hfi)
disp(Hfi_angle,Hfi_mag,"Value of H  : magnitude(A/m
    ) and angle in degree : ");
//Answer is not accurate in the book.
```

Scilab code Exa 4.5.1 Effective area

```
//Example No. 4.5.1
clc;
clear;
close;
format('v',6);
f=500;//MHz(Operating Frequency)
Do=1.643;//for half wave dipole
c=3*10^8;//m/s////Speed of light
lambda=c/(f*10^6);//m(Wavelength)
Aem=lambda^2/(4*%pi)*Do;// m (Effective area)
disp(Aem,"Effective area in m  : ");
```

Scilab code Exa 4.6.1 Current required

```
//Example No. 4.6.1
clc;
clear;
close;
format('v',6);

l=1;//m
Prad=4;//W
f=1.5;//MHz
c=3*10^8;//m/s////Speed of light
lambda=c/(f*10^6);//m
//here l/lambda<1/50 tells us it is a Hertzian
    monopole antenna
h=1;//m
Rr=40*%pi^2*(h/lambda)^2;// m
Io=sqrt(2*Prad/Rr);//A
disp(Io,"Current required in A : ");
```

Scilab code Exa 4.9.1 Power radiated

```
//Example No. 4.9.1
clc;
clear;
close;
format('v',6);

le=100;//m
Irms=450;//A
f=40000;//Hz
c=3*10^8;//m/s////Speed of light
```

```
lambda=c/f;//m
P=160*%pi^2*(le/lambda)^2*Irms^2;//mW
Rr=160*%pi^2*(le/lambda)^2;//
disp(P*10^-3,"Power radiated in W : ");
disp(Rr,"Radiation resistance in   : ");
//Answer wrong for radiation resistance in the book.
```

Scilab code Exa 4.9.2 Radiation resistance and power

```
//Example No. 4.9.2
clc;
clear;
close;
format('v',6);

le=61.4;//m
Irms=50;//A
lambda=625;//m
P=160*%pi^2*(le/lambda)^2*Irms^2;//kW
Rr=160*%pi^2*(le/lambda)^2;//
disp(P*10^-3,"Power radiated in kW : ");
disp(Rr,"Radiation resistance in   : ");
```

Scilab code Exa 4.9.3 Power radiated and efficiency

```
//Example No. 4.9.3
clc;
clear;
close;
format('v',5);
le=10;//m(effective length)
Irms=450;//A(rms current)
Rl=1.5;//  (resistance)
```

```
f=50;//kHz(Operating frequency)
c=3*10^8;//m/s////Speed of light
lambda=c/(f*10^3);//m(Wavelength)
P=160*%pi^2*(le/lambda)^2*Irms^2;//kW(Power)
P=P*1000;//W(Power)
Rr=160*%pi^2*(le/lambda)^2;//  (Radiation resistance)
Eta=Rr/(Rr+Rl)*100;//%(Efficiency)
disp(Eta,"Efficiency of antenna in % : ");
```

Scilab code Exa 4.9.4 Radiation Resistance

```
//Example No. 4.9.4
clc;
clear;
close;
format('v',6);
//l=lambda/8
lBYlambda=1/8;//(length/Wavelength)
Rr=80*%pi^2*(lBYlambda)^2;//  (Radiation resistance)
disp(Rr,"Radiation resistance in   : ");
```

Scilab code Exa 4.9.5 Radiation Resistance

```
//Example No. 4.9.5
clc;
clear;
close;
format('v',6);
L=1;//m(Length of element)
f=10;//MHz(Operating frequency)
c=3*10^8;//m/s////Speed of light
lambda=c/(f*10^6);//m(Wavelength)
```

```
Rr=80*%pi^2*(L/lambda)^2;//   (Radiation  resistance)
disp(Rr,"Radiation  resistance  in     : ");
```

Chapter 6

Antenna Arrays

Scilab code Exa 6.2.1 Relative field pattern

```
//Example No. 6.2.1
clc;
clear;
close;
format('v',5);
n=2;//(No. of point source)
//E=E0*{exp(%i*%pi/2)-exp(-%i*si/2)} where exp(-%i*si)=-1
//si=Beta*d*cosd(fi)=2*%pi*cosd(fi)
//E=2*%i*E0*sind(%pi*cosd(fi)); But 2*%i*E0=1
fi=[0 30 60 90 120 150 180 210 240 270 300 330];//degree(angle)
En=sin(%pi*cosd(fi));//Normalized field
disp("Different values of fi : ");
disp(string(fi));
disp("Corresponding normalized field is : ");
disp(string(abs(En)));
```

Scilab code Exa 6.2.2 Radiation patern

```
//Example No. 6.2.2
clc;
clear;
close;
format('v',5);
n=2;//(No. of point source)
//E=E0*{exp(%i*(%pi/4+si/2))-exp(-%i*(%pi/4+si/2))}
    as exp(%i*theta)+exp(-%i*theta)=2*cos(theta)
//E=2*E0*cos(%pi/4+si/2);
//si=Beta*d*cosd(fi)=2*%pi*cosd(fi)
//En=cos(%pi/4+Beta*d*cosd(%pi/4)); But 2*E0=1
fi=[0 30 60 90 120 150 180 210 240 270 300 330];//
    degree(angle)
En=cos(%pi/4+%pi/4*cosd(fi));//Normalized field
disp("Different values of fi : ");
disp(string(fi));
disp("Corresponding normalized field is : ");
disp(string(abs(En)));
```

Scilab code Exa 6.2.3 Field pattern

```
//Example No. 6.2.3
clc;
clear;
close;
format('v',5);
//E=cos(fi)+sin(fi)<si;
//En=cos(%pi/4+%pi*cosd(fi)) as 2*E0=1
fi=[0 30 60 90 120 150 180 210 240 270 300 330];//
    degree(Angle)
si=%pi/2*(cosd(fi)+1);//(Phase)
En=cos(%pi/4+%pi*cosd(fi));//Normalized field
disp("Different values of fi : ");
disp(string(fi));
disp("Corresponding normalized field is : ");
```

```
disp(string(abs(En)));
//Answer in the book is wrong.
```

Scilab code Exa 6.6.1 Location of first null

```
//Example No. 6.6.1
clc;
clear;
close;
format('v',5);
n=80;//(no. of elements)
N=1;//for first null
//d=lambda/2;(spacing)
dBYlambda=1/2;//(spacing/wavelength)
fi01=acosd(N/n/dBYlambda);//degree(Angle)
Null_1st=(%pi/2*180/%pi)-fi01;//degree(First Null)
disp(Null_1st,"Location of 1st null from maxima in
   degree : ");
```

Scilab code Exa 6.6.2 Various parameters of isotropic array

```
//Example 6.6.2
clc;
clear;
close;
n=4;//(No. of elements)
//d=lambda/2;(Spacing)
dBYlambda=1/2;//(Spacing/wavelength)
alfa=0;//degree(angle)
N=1;//(For first null)
disp("Part (i)");
theta01=[acosd(+N/2) acosd(-N/2)];//degree(Angle)
N=2;//(For second null)
```

```
theta02=[acosd(+N/2) acosd(-N/2)];//degree(angle)
//N=3;//not possible as N/2 is greater than 1
disp(theta01,"Null directions for N=1 : theta01(
    degree) ");
disp(theta02,"Null directions for N=2 : theta02(
    degree) ");
disp("Part (ii)");
m=0;//for maxima
theta_m=acosd(m/dBYlambda);//degree(angle)
disp(theta_m,"Direction of maxima : theta_m(degree)
    ");
disp("Part (iii)");
S=1;//for side lobe maxima
//S=2 & onwards not possible
theta_S=[acosd((2*S+1)/2/n/dBYlambda) acosd(-(2*S+1)
    /2/n/dBYlambda)];//degree(angle for side lobe)
disp(theta_S,"Side lobe maxima : theta_S(degree) ");
disp("Part (iv)");
HPBW=2*[90-acosd(1.391/%pi/n/dBYlambda)];//degree(
    HPBW)
disp(HPBW,"HPBW(degree) ");
disp("Part (v)");
FNBW=2*[90-acosd(1/n/dBYlambda)];//degree(FNBW)
disp(FNBW,"FNBW(degree) ");
disp("Part (vi)");
SLL=-13.46;//dB////for isotropic sources array(Side
    lobe level)
disp(SLL,"Side lobe level(dB) ");
```

Scilab code Exa 6.8.1 Ordinary endfire array

```
//Example No. 6.8.1
clc;
clear;
close;
```

```
format('v',5);
n=4;//(No. of elements)
//d=lambda/2;(spacing)
dBYlambda=1/2;//(spacing/wavelength)
theta=0;//degree(angle)
//Beta=2*%pi/lambda
disp("Part (i)");
Beta_into_lambda=2*%pi;//(Coefficient)
//alfa=-Beta*d
alfa=-Beta_into_lambda*dBYlambda;//radian(Progressive phase shift)
alfa=alfa*180/%pi;//degree(Progressive phase shift)
disp(alfa,"Progressive phase shift(degree) ");
disp("Part (ii)");
N=1:3;//as N=4 is not allowed
theta01=acosd(1-N(1)/n/dBYlambda);//degree(angle)
theta02=acosd(1-N(2)/n/dBYlambda);//degree(angle)
theta03=acosd(1-N(3)/n/dBYlambda);//degree(angle)
disp(theta03,theta02,theta01,"Null directions, theta01, theta02 & theta03 in degree are : ");
disp("Part (iii)");
m=0:1;//as m=2 & onwards is not allowed
theta0=acosd(1-m(1)/dBYlambda);//degree(angle)
theta1=acosd(1-m(2)/dBYlambda);//degree(angle)
disp(theta1,theta0,"Maxima directions, theta0, theta1 in degree are : ");
disp("Part (iv)");
FNBW=2*acosd(1-1/n/dBYlambda);//degree(FNBW)
disp(FNBW,"FNBW in degree : ");
disp("Part (v)");
HPBW=2*acosd(1-1.391/n/%pi/dBYlambda);//degree(HPBW)
disp(HPBW,"HPBW in degree : ");
```

Scilab code Exa 6.8.2 Half Power Beam Width

```
//Example No. 6.8.2
clc;
clear;
close;
format('v',6);
n=16;//no. of point source
//d=lambda/4;(spacing)
dBYlambda=1/4;//(Spacing/wavelength)
HPBW=2*acosd(1-1.391/n/%pi/dBYlambda);//degree(HPBW)
disp(HPBW,"HPBW in degree :  ");
```

Scilab code Exa 6.10.1 Find the Directivity

```
//Example No. 6.10.1
clc;
clear;
close;
format('v',6);
n=10;//no. of elements
//d=lambda/4;(spacing)
dBYlambda=1/4;///(Spacing/wavelength)
//Broadside array
D=2*n*dBYlambda;//unitless(Directivity)
D=10*log10(D);//dB(Directivity)
disp(D,"Directivity for broadside array in dB : ");
//Endfire array
D=4*n*dBYlambda;//unitless(Directivity)
D=10*log10(D);//dB(Directivity)
disp(D,"Directivity for Ordinary endfire array in dB
    : ");
```

Scilab code Exa 6.10.2 Design ordinary endfire array

```
//Example No. 6.10.2
clc;
clear;
close;
format('v',6);
D=20;//dB(Directivity)
//d=lambda/4;(spacing)
dBYlambda=1/4;//(spacing/wavelength)
D=10^(D/10);//unitless(Directivity)
n=D/4/dBYlambda;//no. of elements
disp(n,"(i) No. of elements : ");
LBYlambda=(n-1)*dBYlambda;//(length/wavelength)
disp("(ii) Length of the array is "+string(LBYlambda
    )+"*lambda");
HPBW=2*acosd(1-1.391/%pi/n/dBYlambda);//degree(HPBW)
disp(HPBW,"(iii) HPBW in degree : ");
SLL=-13.46;//dB(Side lobe level)
disp(SLL,"(iv) SLL in dB : ");
Beta_into_lambda=2*%pi;//(temorary calculatuion)
//alfa=-Beta*d;//for theta=0
//alfa=Beta*d;//for theta=180
alfa1=-Beta_into_lambda*dBYlambda;//radian////for
    theta=0
alfa1=alfa1*180/%pi;//degree(angle)
alfa2=Beta_into_lambda*dBYlambda;//radian////for
    theta=180
alfa2=alfa2*180/%pi;//degree(angle)
disp(alfa2,alfa1,"(v) Progressive phase shift,
    for theta equals to 0  & 180  are : ");
```

Scilab code Exa 6.14.1 Four Element broadside array

```
//Example No. 6.14.1
clc;
clear;
```

```
close;
format('v',6);
SLL=19.1;//dB(Side Lobe Level)
//d=lambda/2;(spacing)
dBYlambda=1/2;//(Spacing/wavelength)
n=4;//(no. of elements)
r=round(10^(SLL/20));//(ratio of main lobe to side
    lobe)
m=n-1;//(degree )
//T3(x0)=r=4*x0^3-3*x0;
x0=roots([4 0 -3 -r]);//(Coefficient)
x0=x0(1);//taking real value(Coefficient)
//E4(z)=T3(x)=4*x^3-3*x=4*a1*z^3-3*a1*z+a0*z
//4*a1*z^3=4*x^3 where z^3=(x/x0)^3
a1=4*x0^3/4;//(Coefficient)
//a0*z-3*z*a1=-3*x
a0=(3/x0*a1-3)*x0;//(Coefficient)
disp(a0,a1,"Coefficients of array polynomial a1 & a0
     are : ");
disp(a0/a1,a1/a1,"Relative current amplitudes are :"
    );
```

Chapter 7

Loop Antenna

Scilab code Exa 7.10.1 Input Voltage

```
//Example No. 7.10.1
clc;
clear;
close;
format('v',6);
A=1;// m (Area of loop)
N=400;//no. of turns
Q=100;//Quality factor
theta=60;//degree(angle)
Erms=10;// V /m(field strength)
f=1;//MHz(tuned frequency)
c=3*10^8;//m/s////Speed of light
lambda=c/(f*10^6);//m(Wavelength)
Vr=Q*2*%pi*A*N*cosd(theta)*Erms*10^-6/lambda;//V(
   reciever input voltage)
disp(Vr*1000,"Input voltage to the receiver in mV :
   ");
```

Scilab code Exa 7.10.2 Voltage induced in lop

```
//Example No. 7.10.2
clc;
clear;
close;
format('v',7);
N=12;//no. of turns
A=1;// m (Area of loop)
Erms=100;// V /m(field strength)
f=10;//MHz(tuned frequency)
theta=0;//degree(angle)
c=3*10^8;//m/s////Speed of light
lambda=c/(f*10^6);//m(Wavelength)
Vr=2*%pi*A*N*cosd(theta)*Erms*10^-6/lambda;//V(
    reciever input voltage)
disp(Vr*10^6,"Voltage induced in loop in  V /m : ");
```

Scilab code Exa 7.10.3 Find the field strength

```
//Example No. 7.10.3
clc;
clear;
close;
format('v',6);
N=25;//no. of turns
Vrms=150;// V (emf induced)
f=500;//kHz(tuned frequency)
A=0.5^2;// m (Area of loop)
theta=0;//degree(angle)
c=3*10^8;//m/s////Speed of light
lambda=c/(f*10^3);//m(Wavelength)
Erms=lambda/(2*%pi*A*N*cosd(theta))*Vrms*10^-6;//V/m
    (maximum emf induced)
disp(Erms*10^3,"Field strength in mV/m : ");
```

Scilab code Exa 7.10.4 Radiation Resistance

```
//Example No. 7.10.4
clc;
clear;
close;
format('v',7);
N1=1;//no. of turns in primary
N2=8;//no. of turns in secondary
//a=lambda/25;
aBYlambda=1/25;//(temporary calculation)
//A=%pi*a^2
A_BY_lambda_sqr=%pi*aBYlambda^2;//(temporary
    calculation)
Rr1=31200*(N1*A_BY_lambda_sqr)^2;//  (Radiation
    resistance for single turn)
disp(Rr1,"Radiation resistance for single turn loop
    in     : ");
Rr2=31200*(N2*A_BY_lambda_sqr)^2;//  (Radiation
    resistance for 8 turn)
disp(Rr2,"Radiation resistance for 8 turn loop in
      : ");
```

Scilab code Exa 7.10.5 Radiation Efficiency

```
//Example No. 7.10.5
clc;
clear;
close;
format('v',6);
f=100;//MHz(Operating frequency)
c=3*10^8;//m/s////Speed of light
```

```
lambda=c/(f*10^6);//m(Wavelength)
a=lambda/25;//m(radius)
C=2*%pi*a;//m(Circumference)
d=2*10^-4*lambda;//m(Spacing)
disp("For single turn : ");
N=1;//n. of turns
RL_BY_Rr=3430/(C^3*f^(3.5)*N*d);//(temporary
    calculation)
K=1/(1+RL_BY_Rr)*100;//%(Radiation efficiency)
disp(K,"Radiation efficiency of single turn in % : "
    );
disp("For Eight turn : ");
N=8;//no. of turns
RL_BY_Rr=3430/(C^3*f^(3.5)*N*d);//(temporary
    calculation)
K=1/(1+RL_BY_Rr)*100;//%(Radiation efficiency)
disp(K,"Radiation efficiency of eight turn in % : ")
    ;
```

Scilab code Exa 7.10.6 Directivity

```
//Example No. 7.10.6
clc;
clear;
close;
format('v',6);
a=0.5;//m(radius)
f=0.9;//MHz(OPerating frequency)
c=3*10^8;//m/s////Speed of light
lambda=c/(f*10^6);//m(wavelength)
C=2*%pi*a;//m(Circumference)
if C/lambda<1/3 then
    D=3/2;//Directivity
elseif C/lambda>1/3 then
    D=0.682*C/lambda;//Directivity
```

```
end
disp(D,"Directivity : ");
```

Chapter 8

Slot Antenna

Scilab code Exa 8.3.1 Input Impedence

```
//Example No. 8.3.1
clc;
clear;
close;
format('v',7);
Zcs=73+%i*42.5;//  (Impedence of complementry structure)
Eta=120*%pi;//(Constant for free space)
ZS=Eta^2/4/Zcs;//  (Input Impedence)
disp(ZS,"Input impedence in    : ");
//At resonance
Zcs=73;//  (Impedence of complementry structure)
Eta=120*%pi;//(Constant for free space)
ZS=Eta^2/4/Zcs;//  (Input Impedence)
disp(ZS,"At resonance, Input impedence in     : ");
disp("ZS can be rounded to 500   ");
```

Chapter 9

Horn Antenna

Scilab code Exa 9.6.1 Capture Area

```
//Example No. 9.6.1
clc;
clear;
close;
format('v',7);
f=2;//GHz(Frequency)
G=12;//dBi(Gain)
D=12;//dBi(Gain)
D=10^(D/10);//unitless(Directivity)
c=3*10^8;//m/s(speed of light)
lambda=c/(f*10^9);//m(wavelength)
Ap=D*lambda^2/7.5;// m (capture area)
disp(Ap,"Required capture area in m   : ");
```

Scilab code Exa 9.6.2 Various parameters of horn

```
//Example No. 9.6.2
clc;
```

```
clear;
close;
format('v',7);
aEBYlambda=10;//(Aperture/wavelength)
del_EBYlambda=0.2;//in E-plane
del_HBYlambda=0.375;//in H-plane
LBYlambda=aEBYlambda^2/8/del_EBYlambda;//(Length/wavelength)
disp("Length of the horn is "+string(LBYlambda)+"*lambda");
aHBYlambda=sqrt(LBYlambda*8*del_HBYlambda);//(Aperture/wavelength)
disp("H-plane aperture, aH is "+string(aHBYlambda)+"*lambda");
theta_E=2*atand(aEBYlambda/2/LBYlambda);//degree(Angle)
theta_H=2*atand(aHBYlambda/2/LBYlambda);//degree(Angle)
disp(theta_H,theta_E,"Flare angles theta_E & theta_H (in degree) are : ");
HPBW_E=56/aEBYlambda;//degree(HPBW for E-plane)
disp(HPBW_E,"HPBW(E-plane) in degree : ");
HPBW_H=67/aHBYlambda;//degree(HPBW for H-plane)
disp(HPBW_H,"HPBW(H-plane) in degree : ");
FNBW_E=102/aEBYlambda;//degree(FNBW for E-plane)
disp(FNBW_E,"FNBW(E-plane) in degree : ");
FNBW_H=172/aHBYlambda;//degree(FNBW for F-plane)
disp(FNBW_H,"FNBW(H-plane) in degree : ");
D=10*log10(7.5*aEBYlambda*aHBYlambda);//(Directivity)
disp(D,"Directivity in dB : ");
```

Chapter 10

Broadband and frequency independent antenna

Scilab code Exa 10.5.1 Five turn helical antenna

```
//Example No. 10.5.1
clc;
clear;
close;
format('v',6);
N=5;//no. of turns
f=400;//MHz(Frequency)
c=3*10^8;//m/s(Speed of light)
lambda=c/(f*10^6);//m(Wavelength)
disp("Part (i)");
S=lambda/50;//m(Spacing between turns)
S_BY_lambda=1/50;//(Spacing/wavelength)
C_BY_lambda=sqrt(2*S_BY_lambda);//(Circumference/
    wavelength)
disp("Circumference is "+string(C_BY_lambda)+"*
    lambda");
C=sqrt(2*lambda*S);//m(Circumference)
disp(C,"Circumference in meter : ");
disp("Part (ii)");
```

```
Lo_BY_lambda=sqrt(S_BY_lambda^2+C_BY_lambda^2);//(Length/wavelength)
disp("Length of single turn is "+string(Lo_BY_lambda)+"*lambda");
Lo=sqrt(S^2+C^2);//m(Length of single turn)
disp(Lo,"Length of single turn in meter : ");
disp("Part (iii)");
Ln_BY_lambda=N*Lo_BY_lambda;//(Overall length/wavelength)
disp("Overall Length is "+string(Ln_BY_lambda)+"*lambda");
Ln=N*Lo;//m(Overall length)
disp(Ln,"Overall Length in meter : ");
disp("Part (iv)");
alfa=atand(S/C);//degree(Pitch angle)
disp(alfa,"Pitch angle,    in degree : ");
```

Scilab code Exa 10.5.2 Five turn helical antenna

```
//Example No. 10.5.2
clc;
clear;
close;
format('v',6);
N=5;//no. of turns
f=300;//MHz(Frequency)
c=3*10^8;//m/s(speed of light)
disp("Part (i)");
lambda=c/(f*10^6);//m(Wavelength)
C_BY_lambda=1;//(Circumference/wavelength)
disp("Near optimum circumference is "+string(C_BY_lambda)+"*lambda");
C=lambda;//m(Circumference)
disp(C,"Near optimum circumference in meter : ");
disp("Part (ii)");
```

```
alfa=14;//degree//(Pitch angle)//for near optimum
S_BY_lambda=C_BY_lambda*tand(alfa);
disp("Spacing is "+string(S_BY_lambda)+"*lambda");
S=C*tand(alfa);//m(Spacing)
disp(S,"Spacing in meter : ");
disp("Part (iii)");
Rin=140*C/lambda;//  (Input impedence)
disp(Rin,"Input impedence in    : ");
disp("Part (iv)");
HPBW=52/(C/lambda*sqrt(N*S/lambda));//degree(HPBW)
disp(HPBW,"HPBW in degree : ");
disp("Part (v)");
FNBW=115/(C/lambda*sqrt(N*S/lambda));//degree(FNBW)
disp(FNBW,"FNBW in degree : ");
disp("Part (vi)");
Do=15*(C/lambda)^2*N*(S/lambda);//unitless////Directivity
disp(Do,"Directivity(unitless) : ");
Do_dB=10*log10(Do);//dB(Directivity)
disp(Do_dB,"Directivity in dB : ");
disp("Part (vii)");
AR=(2*N+1)/2/N;//axial ratio
disp(AR,"Axial ratio : ");
disp("Part (viii)");
Rin=140*(C/lambda);//  (Input impedence)
//50    line
Zo=50;//  (Output impedence)
Tau=(Rin-Zo)/(Rin+Zo);//Scaling factor
VSWR=(1+Tau)/(1-Tau);//(VSWR)
disp(VSWR,"VSWR for 50   line : ");
//75    line
Zo=75;//  (Output impedence)
Tau=(Rin-Zo)/(Rin+Zo);//Scaling factor
VSWR=(1+Tau)/(1-Tau);//(VSWR)
disp(VSWR,"VSWR for 75   line : ");
```

Scilab code Exa 10.5.3 Various parameters of helix array

```
//Example No. 10.5.3
clc;
clear;
close;
format('v',6);
HPBW=39;//degree(HPBW)
alfa=12.5;//degree(Pitch angle)
f=475;//MHz(Frequency)
c=3*10^8;//m/s(Speed of light)
lambda=c/(f*10^6);//m(Wavelength)
C=lambda;//m(Circumference)
disp("Part (i)");
//it is in axial mode as 3/4*lambda<C<4/3*lambda
S=C*tand(alfa);//meter(Spacing)
N=52^2/HPBW^2/(S/lambda)/(C/lambda)^2;//turns
disp(round(N),"Number of turns : ");
disp("Part (ii)");
N=round(N);//turns
Do=15*(C/lambda)^2*N*(S/lambda);//unitless(Directivity)
Do_dB=10*log10(Do);//dB(Directivity)
disp(Do_dB,"Directivity in decibels : ");
disp("Part (iii)");
AR=(2*N+1)/2/N;//axial ratio
disp(AR,"Axial ratio : ");
disp("Part (iv)");
//3/4*lambda<C<4/3*lambda
lambda1=C/(3/4);//meter(Wavelength)
lambda2=C/(4/3);//meter(Wavelength)
f1=c/lambda1;//Hz(Frequency)
f2=c/lambda2;//Hz(Frequency)
disp("Frequency range is "+string(f1/10^6)+" MHz to
```

```
    "+string(f2/10^6)+" MHz.")
disp("Part (v)");
//At  design frequency
Rin=140*C/lambda;//  (Input impedence)
disp(Rin,"At design frequency , Input impedence in
     is : ");
//3/4*lambda<C<4/3*lambda
//At high frequency end
Rin=140*C/lambda2;//  (Input impedence)
disp(Rin,"At high frequency end, Input impedence in
      is : ");
//At low frequency end
Rin=140*C/lambda1;//  (Input impedence)
disp(Rin,"At low frequency end, Input impedence in
      is : ");
```

Scilab code Exa 10.5.4 Input Impedence HPBW and Axial ratio

```
//Example No. 10.5.4
clc;
clear;
close;
format('v',6);
Do_dB=14;//dB(Directivity)
f=2.4;//GHz(Frequency)
c=3*10^8;//m/s(Speed of light)
lambda=c/(f*10^6);//m(Wavelength)
Do=10^(Do_dB/10);//unitless(Directivity)
C=lambda;//m////for optimum result(Circumference)
alfa=14;//degree;////for optimum result(Pitch angle)
S=C*tand(alfa);//m(Spacing)
N=Do/15/(C/lambda)^2/(S/lambda);//turns
N=round(N);//turns
Rin=140*C/lambda;//  (Input impedence)
disp(Rin,"Input impedence in    is : ");
```

```
HPBW=52/(C/lambda*sqrt(N*S/lambda));//degree
disp(HPBW,"HPBW in degree : ");
format('v',4);
FNBW=115/(C/lambda*sqrt(N*S/lambda));//degree
disp(FNBW,"FNBW in degree : ");
AR=(2*N+1)/2/N;//(Axial ratio)
disp(AR,"Axial ratio : ");
```

Scilab code Exa 10.8.1 Symmetrical two wire spiral

```
//Example No. 10.8.1
clc;
clear;
close;
format('v',8);
f=10;//MHz(Frequency)
c=3*10^8;//m/s(Speed of light)
lambda=c/(f*10^6);//m(Wavelength)
d0=10^-3*lambda;//m(spacing)
Lo=1*lambda;//m(Length)
fi=%pi;fi0=0;//radian
r0=d0/2;//m
disp("Part (i)");
//R=r0*exp(a*fi-a*fi0);//m
//a=sqrt(1/Lo^2/(R-r0)^2-1);//per adian
a=1.166;//rad^-1(by above equation)
disp(a,"Rate of spiral in rad^-1 : ");
R_BY_lambda=r0/lambda*exp(a*2*%pi);//m(Radius/
    wavelength)
disp("Radius of terminal point is "+string(
    R_BY_lambda)+"*lambda");
disp("Part (ii)");
R=r0*exp(a*2*%pi);//m(Radius)
disp(R,"Radius at terminal point in meter : ");
```

Scilab code Exa 10.8.2 Design Equiangular spiral Antena

```
//Example No. 10.8.2
clc;
clear;
close;
format('v',5);
fU=900;//MHz(Upper frequency)
fL=450;//MHz(Lower frequency)
c=3*10^8;//m/s(Speed of light)
lambdaU=c/(fU*10^6);//m(Upper wavelength)
lambdaL=c/(fL*10^6);//m(Lower wavelength)
Exp_ratio=4;//expansion ratio
a=log(Exp_ratio)/(2*%pi);//rad^-1////rate of spiral
Beta=atand(1/a);//degree
r0=lambdaU/4;//meter////minimum radius
disp(r0*100,"Minimum radius in cm : ");
R=lambdaL/4;//meter////minimum radius
disp(R*100,"Maximum radius in cm : ");
fi_m=log(R/r0)/a;//radian
fi_m=fi_m*180/%pi;//degree
disp(fi_m," m in degree is ");
N=1/2;//for  m =180;//degree
disp(N,"Number of turns, N is  ");
```

Scilab code Exa 10.10.1 Elements length and spacing

```
//Example No. 10.10.1
clc;
clear;
close;
format('v',7);
```

```
Gain=8.5;//dB(Gain)
tau=0.822;sigma=0.149;//for given gain
alfa=2*atand((1-tau)/4/sigma);//degree
fL=54;//MHz(Lower frequency)
fU=216;//MHz(Upper frequency)
c=3*10^8;//m/s(Speed of light)
lambdaU=c/(fU*10^6);//m(Upper wavelength)
lambdaL=c/(fL*10^6);//m(Lower wavelength)
l1=lambdaU/2;//m(Length of element1)
lN=lambdaL/2;//m(Length of longest element)
l2=l1/tau;l3=l2/tau;l4=l3/tau;l5=l4/tau;l6=l5/tau;l7=l6/tau;l8=l7/tau;l9=l8/tau;//m(Length of elements)
d1=2*sigma*l1;d2=2*sigma*l2;d3=2*sigma*l3;d4=2*sigma*l4;d5=2*sigma*l5;d6=2*sigma*l6;d7=2*sigma*l7;d8=2*sigma*l8;d9=2*sigma*l9;//meter(Spacing between elements)
d=d1+d2+d3+d4+d5+d6+d7+d8+d9;//meter(total spacing)
disp(lN,"Length(m) of longest element : ");
disp(l1,"Length(m) of element1 : ");
disp(l2,"Length(m) of element2 : ");
disp(l3,"Length(m) of element3 : ");
disp(l4,"Length(m) of element4 : ");
disp(l5,"Length(m) of element5 : ");
disp(l6,"Length(m) of element6 : ");
disp(l7,"Length(m) of element7 : ");
disp(l8,"Length(m) of element8 : ");
disp(l9,"Length(m) of element9 : ");
disp(d1,"Spacing(m) of element1 : ");
disp(d2,"Spacing(m) of element2 : ");
disp(d3,"Spacing(m) of element3 : ");
disp(d4,"Spacing(m) of element4 : ");
disp(d5,"Spacing(m) of element5 : ");
disp(d6,"Spacing(m) of element6 : ");
disp(d7,"Spacing(m) of element7 : ");
disp(d8,"Spacing(m) of element8 : ");
disp(d9,"Spacing(m) of element9 : ");
disp(d,"Total Spacing length(m) : ");
```

```
//Answer is not accurate in the book.
```

Scilab code Exa 10.10.2 Design a log periodic dipole

```
//Example No. 10.10.2
clc;
clear;
close;
format('v',7);
tau=0.895;//scale factor
sigma=0.166;//(spacing factor)
fU=30;//MHz(Upper frequency)
fL=10;//MHz(Lower frequency)
c=3*10^8;//m/s(Speed of light)
lambdaU=c/(fU*10^6);//m(Upper wavelength)
lambdaL=c/(fL*10^6);//m(Lower wavelength)
l1=lambdaU/2;//m(Length of shortest element)
disp(l1,"Length of shortest element, l1 in meter is
    : ");
l2=l1/tau;l3=l2/tau;l4=l3/tau;l4=l3/tau;l5=l4/tau;l6
   =l5/tau;l7=l6/tau;l8=l7/tau;l9=l8/tau;l10=l9/tau;
   l11=l10/tau;//m(Length of element)
disp(l11,l10,l9,l8,l7,l6,l5,l4,l3,l2,"Other elements
    length(m) l2, l3, l4, l5, l6, l7, l8, l9, l10,
   l11 are : ");
alfa=17.97;//degree(angle)
R1=(l1/2)/tand(alfa/2);//m(Spacing between elements)
R2=R1/tau;R3=R2/tau;R4=R3/tau;R4=R3/tau;R5=R4/tau;R6
   =R5/tau;R7=R6/tau;R8=R7/tau;R9=R8/tau;R10=R9/tau;
   R11=R10/tau;//m
disp(R11,R10,R9,R8,R7,R6,R5,R4,R3,R2,R1,"Spacing
   between elements in meter R1, R2, R3, R4, R5, R6,
    R7, R8,R9, R10, R11 are : ");
//Answer is not accurate in the book.
```

Chapter 11

Microstrip Antennas

Scilab code Exa 11.9.1 Determine physical dimensions

```
//Example No. 11.9.1
clc;
clear;
close;
format('v',7);
fr=10;//GHz(center frequency)
fr=fr*10^9;//Hz(center frequency)
epsilon_r=10.2;//(constant)
h=0.127;//cm(height of sustrate)
c=3*10^10;//cm/s(Speed of light)
W=c/2/fr*sqrt(2/(epsilon_r+1));//cm(Physical
    dimension)
epsilon_reff=(epsilon_r+1)/2+(epsilon_r-1)/2*[1+12*h
    /W]^(-1/2);//(effective constant)
delta_L=h*0.412*(epsilon_reff+0.3)*(W/h+0.264)/[(
    epsilon_reff-0.258)*(W/h+0.8)];//cm(distance)
L=c/2/fr/sqrt(epsilon_reff)-2*delta_L;//cm(distance)
disp(L,W,"Design values of W & L(in cm) are :  ");
```

Chapter 12

Reflector Antennas

Scilab code Exa 12.9.1 First null beam width and power gain

```
//Example No. 12.9.1
clc;
clear;
close;
format('v',6);
D=2;//m(Diameter)
f=6000;//MHz(Frequency)
c=3*10^8;//m/s////speed of light
lambda=c/(f*10^6);//m(Wavelength)
FNBW=140*lambda/D;//degree
disp(FNBW,"First null beam width(FNBW in degree) : "
  );
GP=6*(D/lambda)^2;//unitless(Power gain)
GP_dB=10*log10(GP);//dB(Power gain)
disp(GP_dB,"Power Gain in dB : ");
//Ans in the book is not accurate.
```

Scilab code Exa 12.9.2 Diameter of mouth and HPBW

```
//Example No. 12.9.2
clc;
clear;
close;
format('v',5);
GP=1000;//unitless(Power gain)
lambda=10;//cm(Wavelength)
D=sqrt(GP/6)*(lambda/100);//m(Diameter)
disp(D,"Diameter of mouth in meter : ");
HPBW=58*(lambda/100)/D;//degree(HPBW)
disp(HPBW,"Half power beam width(HPBW in degree) : "
  );
```

Scilab code Exa 12.9.3 Gain Beamwidth and capture area

```
//Example No. 12.9.3
clc;
clear;
close;
format('v',6);
D=6;//meter(Diameter)
f=10;//GHz(Frequency)
c=3*10^8;//m/s////speed of light
lambda=c/(f*10^9);//m(Wavelength)
GP=6*(D/lambda)^2;//unitless(Power gain)
GP_dB=10*log10(GP);//dB(Power gain)
disp(GP_dB,"Gain in dB : ");
FNBW=140*lambda/D;//degree(FNBW)
disp(FNBW,"FNBW in degree : ");
HPBW=58*lambda/D;//degree(HPBW)
disp(HPBW,"HPBW in degree : ");
K=0.65;//constant
Ao=K*%pi/4*D^2;// m (Capture area)
disp(Ao,"Capture area in m  : ");
```

Chapter 13

Antenna Measurement

Scilab code Exa 13.4.1 Gains of Antennas

```
//Example No. 13.4.1
clc;
clear;
close;
format('v',7);
Pr1=0.0297/1000;//W(Recieved power)
Pr2=0.0471/1000;//W(Recieved power)
Pr3=0.0374/1000;//W(Recieved power)
Pt=1;//W(Transmitted power)
R=10;//m(Radius)
f=980;//MHz(Frequency)
f=f*10^6;//Hz(Frequency)
c=3*10^8;//m/s(Speed of light)
lambda=c/f;//m(Wavelength)
A=20*log10(4*%pi*R/lambda)+10*log10(Pr1/Pt);//(A=G1dB+G2dB)
B=20*log10(4*%pi*R/lambda)+10*log10(Pr2/Pt);//(B=G1dB+G3dB)
C=20*log10(4*%pi*R/lambda)+10*log10(Pr3/Pt);//(C=G2dB+G3dB)
G1dB=(A+B-C)/2;
```

```
G2dB=(A-B+C)/2;
G3dB=(-A+B+C)/2;
disp(round(G3dB),round(G2dB),round(G1dB),"Gain of antennas, G1db, G2dB & G3dB(in dB) are : ");
```

Chapter 14

Ground Wave Propagation

Scilab code Exa 14.6.1 Loss and power received

```
//Example No. 14.6.1
clc;
clear;
close;
format('v',7);
d=36000;//km(height of satellite)
f=4000;//MHz(frequency)
GT=20;//dB(Transmitter gain)
GR=40;//dB(Reciever gain)
PT=200;//W(Transmitted power)
PT=10*log10(PT);//dB(Transmitted power)
disp("Part (i)");
Ls=32.44+20*log10(f)+20*log10(d);//dB(Free space
    transmission loss)
disp(Ls,"Free space transmission loss in dB : ");
disp("Part (ii)");
PT=200;//W(Transmitted power)
PT_dB=10*log10(PT);//dB(Transmitted power)
PR_dB=PT_dB+GT+GR-Ls;//dB(Recieved power)
PR=10^(PR_dB/10);//W(Recieved power)
disp(PR*10^12,"Received power in pW : ");
```

Scilab code Exa 14.6.2 Open circuit voltage

```
//Example No. 14.6.2
clc;
clear;
close;
format('v',7);
f=150;//MHz(frequency)
c=3*10^8;//m/s(speed of light)
GT=1.64;//dB(Transmitter gain)
PT=20;//W(Transmitted power)
d=50;//km(distance)
lambda=c/(f*10^6);//m(Wavelength)
E=sqrt(30*GT*PT)/(d*1000);//V/m(emf induced)
le=lambda/%pi;//m(Effective length)
Voc=E*le;//V/m(Open circuit voltage)
disp(Voc*10^6,"Open circuit voltage in micro Volt :
   ");
```

Scilab code Exa 14.10.1 Calculate the range

```
//Example No. 14.10.1
clc;
clear;
close;
format('v',7);
ht=100;//m(transmitter height)
hr=100;//m(receiver height)
d=3.57*[sqrt(ht)+sqrt(hr)];//km(Range)
disp(d,"Range of space wave propagation in km : ");
```

Scilab code Exa 14.10.2 Radio horizon

```
//Example No. 14.10.2
clc;
clear;
close;
format('v',6);
ht=100;//feet(transmitter height)
hr=50;//feet(receiver height)
d=1.4142*[sqrt(ht)+sqrt(hr)];//miles(Range)
disp(d,"Radio horizon in miles : ");
```

Scilab code Exa 14.10.3 Maximum covered distance

```
//Example No. 14.10.3
clc;
clear;
close;
format('v',6);
ht=80;//m(transmitter height)
hr=50;//m(receiver height)
d=4.12*[sqrt(ht)+sqrt(hr)];//km(Range)
disp(d,"Maximum distance in km : ");
```

Scilab code Exa 14.10.4 Required height of antenna

```
//Example No. 14.10.4
clc;
clear;
```

```
close;
format('v',6);
ht=100;//m(transmitter height)
d=80;//km(receiver height)
hr=(d/4.12-sqrt(ht))^2;//m(range)
disp(hr,"Required height of receiving antenna in
   meter : ");
```

Scilab code Exa 14.10.5 Radio horizon distance

```
//Example No. 14.10.5
clc;
clear;
close;
format('v',6);
ht=100;//m(transmitter height)
d=4.12*sqrt(ht);//km(Horizon distance)
disp(d,"Horizon distance in km : ");
```

Scilab code Exa 14.10.6 Find Distance and field strength

```
//Example No. 14.10.6
clc;
clear;
close;
format('v',6);
P=35;//W(Transmitter power
ht=45;//m(transmitter height)
hr=25;//m(receiver height)
f=90;//MHz(frequency)
c=3*10^8;//m/s(Speed of light)
d=4.12*[sqrt(ht)+sqrt(hr)];//km(line of sight
   distance)
```

```
disp(d,"Distance of line of sight communication in
  km : ");
lambda=c/(f*10^6);//m(Wavelength)
ER=88*sqrt(P)*ht*hr/(lambda*(d*1000)^2);//V/m(Field
  strength)
disp(ER*10^6,"Field strength in micro Volt/meter : "
  );
//Answer is wrong in the textbook.
```

Chapter 15

Ionospheric Propagation

Scilab code Exa 15.8.1 Maximum electron density

```
//Example No. 15.8.1
clc;
clear;
close;
format('v',11);
fc_E=2.5;//MHz(critical frequency of E-layer)
fc_F=8.4;//MHz(critical frequency of F-layer)
disp("For E-layer : ");
Nm=(fc_E*10^6)^2/81;//per m^3(Maximum electron
    density)
disp(Nm,"Maximum electron density  in per m^3 : ");
disp("For F-layer : ");
Nm=(fc_F*10^6)^2/81;//per m^3(Maximum electron
    density)
disp(Nm,"Maximum electron density  in per m^3 : ");
```

Scilab code Exa 15.8.2 Critical Frequency

```
//Example No. 15.8.2
clc;
clear;
close;
format('v',6);
Nm_D=400;//electron/cm^3(Maximum electron density)
Nm_E=5*10^5;//electron/cm^3(Maximum electron density)
Nm_F=2*10^6;//electron/cm^3(Maximum electron density)
fc_D=9*sqrt(Nm_D);//kHz(critical frequency of D-layer)
disp(fc_D,"Critical frequency for D-layer in kHz : ");
fc_E=9*sqrt(Nm_E);//kHz(critical frequency of E-layer)
disp(fc_E/1000,"Critical frequency for E-layer in MHz : ");
fc_F=9*sqrt(Nm_F);//kHz(critical frequency of F-layer)
disp(fc_F/1000,"Critical frequency for F-layer in MHz : ");
```

Scilab code Exa 15.8.3 Calculate frequency

```
//Example No. 15.8.3
clc;
clear;
close;
format('v',7);
Eta=0.5;//(refractive index)
N=400;//electron/cm^3(Electron density)
f=sqrt(81*N/(1-Eta^2));//kHz(frequency)
disp(f,"Frequency in kHz : ");
```

Scilab code Exa 15.9.1 Find the virtual height

```
//Example No. 15.9.1
clc;
clear;
close;
format('v',7);
T=5;//milli-seconds(time period)
c=3*10^8;//m/s///speed of light
H=1/2*c*T*10^-3;//m(Virtual height)
disp(H/1000,"Virtual height in km : ");
```

Scilab code Exa 15.12.1 Calculate MUF

```
//Example No. 15.12.1
clc;
clear;
close;
format('v',7);

d=2000;//km
H=200;//km
fc=6;//MHz
f_MUF=fc*sqrt(1+(d/2/H)^2);//MHz
disp(f_MUF,"MUF in MHz : ");
```

Scilab code Exa 15.13.1 Calculate the range

```
//Example No. 15.13.1
```

```
clc;
clear;
close;
format('v',8);

Eta=0.9;//refractive index
f_MUF=10;//MHz
H=400;//km
Nm=(1-Eta^2)*(f_MUF*10^6)^2/81;//per m^3
fc=9*sqrt(Nm);//Hz
Dskip=2*H*sqrt((f_MUF*10^6/fc)^2-1);//km
disp(Dskip,"Skip distance or range in km : ");
```