Scilab Textbook Companion for Microwave Engineering by G. S. N. Raju[1]

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August 13, 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: Microwave Engineering

Author: G. S. N. Raju

Publisher: I.K. International, New Delhi

Edition: 1

Year: 2011

ISBN: 9788189866792

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

INTRODUCTION TO MICROWAVE AND THEIR APPLICATIONS

Scilab code Exa 1.1 electric field its magnitude and direction

```
//calculate the electric field,its magnitude and
   direction.
//given
F=[2 1 1]//force vector in newton
Q=1//charge in columbs
E=F/Q//the electric field
//the magnitude of this field is given by:
e=norm(E)
//THE direction of the electric field is given by:
aE=E/e
e=round(e*1000)/1000//rounding off decimals
aE=round(aE*1000)/1000//rounding off decimals
disp(E,'the electric field is given by:' )//N/C
disp(e,'the magnitude of the electric field E:')//V/
   m
disp(aE,'THE direction of the electric field in x,y,
   z axis respectively :')
```

Scilab code Exa 1.2 electric field at a point

```
//determine the electric field at a point;
//given
clc
Qf=2d-6
Qt=1d-6
rf=[1 0 0]//this can also be written as ax
rt=[0 1 0]//this can also be written as ay
rtf=rt-rf
Rtf=norm(rtf)//this is the magnitude of the vector
atf=rtf/Rtf//the unit vector across the two points p1 and p2
//the electric field at the point p2 is given by:
epsilon0=8.85D-12//value may differ, as i have not used the estimated value
E=((Qf*Qt)/(4*%pi*epsilon0*(Rtf)^2))*atf//electric field calculation
E=round(E*1d+6)/1d+6///rounding off decimals
disp(E*1d+3,'the electric field of p2 is:')//mN/C
```

Scilab code Exa 1.3 TOTAL FIELD AT A POINT P DUE TO ALL THE THREE CHARGES

```
//DETERMINE TOTAL FIELD AT A POINT ,P DUE TO ALL THE THREE CHARGES.
//given
clc
E1=[1 2 -1]//at p due to 1uc
E2=[0 1 3]//due to 2uc
E3=[2 -1 0]//due to 3uc
```

```
//total field at p due to all these three charges is given by:
E=E1+E2+E3//resultant of all the three charges
disp(E,'the fiel at point p due to all the charges')//N/C
```

Scilab code Exa 1.4 charge Q at the point 2 0 0

```
//determine the charge Q at the point (2,0,0).
//given
clc
Q1=-10D-9//coulombs
epsilon0=8.85d-12//permitivity of free space
r1=[3 1 1]-[0 0 0]
r2=[3 1 1]-[2 0 0]
R1=norm(r1)//magnitude of the given vector r1
R2=norm(r2)//magnitude of vector r2
ar1=r1/R1//unit vector
ar2=r2/R2//unit vector
deff("[Qt]=electricfield(E)","Qt=((E-((Q1/(4*%pi*epsilon0*R1^2))*ar1(1,1)))/ar2(1,1))*(4*%pi*epsilon0*R2^2)")
Qt=electricfield(0)//in coulombs
Qt=round(Qt*1d+11)/1d+11///rounding off decimals
disp(Qt/1d-9,'the electrical field at the point [2,0,0] in nC')//nC
```

Scilab code Exa 1.5 electric field at Q1

```
//the electric field at Q1 needed to be determined.
//given
clc
Q1=1d-9//at (-1,1,-3)
```

```
Q2=5d-9//at (3,1,0)
epsilon0=8.85D-12//the values may differ as i have
    used the exact value of permitivity
R=[-1 1 -3]-[3 1 0]//
r=norm(R)//magnitude of the vector r
ar=R/r//unit vector
E=(Q1/(4*%pi*epsilon0*(r^2)))*ar
E=round(E*10000)/10000///rounding off decimals
disp(E,'THE electric field at Q1 is given as:')//
    both vectors are in ax and az directions
    respectively
//ERROR in the book
```

Scilab code Exa 1.6 electric field at location of 3 coulombs

```
//determine the electric field at location of 3
    coulombs
//given
clc
fr=12d-3// N
Qt=3//C
E=fr/Qt//electric field
disp(E*1000,'the electricfield at 3c')//mN/C
```

Scilab code Exa 1.7 magnetic field at distance of 2m in free space

```
//find the magnetic field at distance of 2m in free
    space
//given
clc
fr=3d-3//IN Newtons
mt=2//meters
H=fr/mt//magnetic field
```

```
disp(H*1d+3,'THE magnetic field:')//mN/Wb
```

Scilab code Exa 1.10 direction of power flow of microwave

```
//FIND THE DIRECTION OF POWER FLOW OF MICROWAVE
//given
clc
function w=cross_prod(E,F)//function to determine
    the cross product of two vectors
D=[E(:),F(:)]
w(1)=det([[1;0;0],D])
w(2)=det([[0;1;0],D])
w(3)=det([[0;0;1],D])
endfunction
E=[0 1 0]
F=[1 0 0]
q=cross_prod(E,F)
disp(q','the cross product of the given fields')//
    towards az
//ERROR in book as cross product of two
    perpendicular vector gives the third
```

Scilab code Exa 1.11 pointing vector and direction of power flow of microwave

```
//find pointing vector and direction of power flow
    of microwave
//given
clc
function w=cross_prod(E,H)//function to determine
    the cross product of two vector
D=[E(:),H(:)]
w(1)=det([[1;0;0],D])
```

```
w(2)=det([[0;1;0],D])
w(3)=det([[0;0;1],D])
endfunction
E=1*[1 0 0]//electric field towards ax
H=2*[0 1 0]//magnetic field towards ay
q=cross_prod(E,H)
disp(q','the display is along az axis')//along az
//ERROR in the book as cross product of two
    perpendicular vector is  the third vector
```

Scilab code Exa 1.12 frequency of the wave

```
//find the frequency of the wave
//given
clc
t1=100d-12
t2=500d-12
t3=1d-9
f1=t1^-1
f2=t2^-1
f3=t3^-1
disp(f3*1D-9,f2*1D-9,f1*1D-9,'the frequencies
    respectively')//in GHz
```

Scilab code Exa 1.13 velocity of propogation of microwave

```
//determine the velocity of propogation of microwave
//given
clc
ur=1//permeability in H/m
epsilonr=4//permittivity in F/m
k=3d+8//the speed of light in vaccum
v=k/((ur*epsilonr)^1/2)//velocity of microwave
```

```
disp(v,'the  velocity of propogation of microwave in
    m/s:')//velocity in m/s
```

Scilab code Exa 1.14 wavelength of microwave frequency

```
//find the wavelength of microwave frequency
//given
clc
v0=3d+8//velocity in m/s
function[lem]=wavelength(v0,fr)
lem=v0/fr//calculating wavelength
endfunction
fr=1d+6//frequency in MHz
[lem1]=wavelength(v0,fr)
fr=1d+7//frequency in MHz
[lem2]=wavelength(v0,fr)
fr=1d+8//frequency in MHz
[lem3]=wavelength(v0,fr)
fr=1d+9//frequency in MHz
[lem4]=wavelength(v0,fr)
fr=1d+10//frequency in MHz
[lem5]=wavelength(v0,fr)
disp(lem5,lem4,lem3,lem2,lem1,'the wavelength  for
   given values of frequency in meter')//wavelength
   in meter
```

Scilab code Exa 1.15 phase shift of the wave

```
//find the phase shift of the wave
//given
f=1d+9//Hz
v0=3d+8//m/s
lem=v0/f//calculating wavelength
```

```
b=2*%pi/lem//calculating phase shift
b=round(b*100)/100///rounding off decimals
disp(b,lem,'the wavelength and phase shift respectively')//in rad/m and m
```

Chapter 2

MICROWAVE TUBES FOR MICROWAVE SIGNAL GENERATION

Scilab code Exa 2.1 maximum power for given beam current

```
//maximum power
//GIVEN
I1=20D-3//current in ampere
Va=300//VOLTAGE of the beam in volts
n=1//given mode value
Prf=0.39861*I1*Va/(n+0.75)//the maximum output power
Prf=round(Prf*1000)/1000///rounding off decimals
disp(Prf,'the maximum r−f power when given beam
   current is 20mA in watts:')
```

Scilab code Exa 2.2 gain parameter output power and Be

```
//gain parameter ,output power and Be
//given
```

```
clc
Vdc=2.5d+3//votage  in volts
Idc=25d-3//current in ampere
Z0=10//resistance in ohm
L=40//CIRCUIT LENGTH
f=9.5d+9//in Hz
G=((Idc*Z0)/(4*Vdc))^(1/3)//the gain parameter
Ap=-9.54+47.3*L*G//OUTPUT power in dB
w=2*%pi*f
Ve=0.593d+6*sqrt(Vdc)
Be=w/Ve//in rad/m
Be=round(Be/10)*10///rounding off decimals
Ap=round(Ap*10)/10////rounding off decimals
G=round(G*10000)/10000////rounding off decimals
disp(Be,Ap,G,'the  Be,the output power and the gain
    parameter')//dB,Rad/m
```

Scilab code Exa 2.3 angular frequency and the cutoff voltage

```
//angular frequency and the cutoff voltage
//given
clc
Bm=0.4//magnetic flux in tesla
ebym=1.759d+11//electron to mass ratio
a=0.04//radius of cathode in meter
b=0.1//radius of vane edge from centre in meter
Wc=ebym*Bm//angular frequency in rad
Vc=((ebym/8)*(Bm^2)*((b/10)^2)*((1-((a/b)^2))^2))//
    ERROR cut off voltage in volts
disp(Vc,Wc,'THE  the angular frequency and Cutoff
    voltage in radians and volts is given  by:')//
    rad,volts
//EERROR in cutoff voltage as value of ((1-((a/b)^2)
    )^2)=0.7056 instead  of ((1-((a/b)^2))^2)=0.36
```

Scilab code Exa 2.4 electron velocity transit angle and beam coupling coefficent

```
//electron velocity ,transit angle and beam coupling
   coefficent
//given
Va=900// in volts
Rb=30d+3//in ohm
Ib=20d-3//in ampere
f=3.2d+9//in hertz
d=1d-3//meter
Ve=0.593d+6*sqrt(Va)//m/s
w=2*%pi*f
Qt=w*d/Ve//radians
Bc=(sin(Qt/2))/(Qt/2)
Qt=round(Qt*100)/100///rounding off decimals
Bc=round(Bc*1000)/1000///rounding off decimals
disp(Bc,Qt,Ve,'THE electron eloccity ,transit angle
   and beam coupling coefficient in m/s,radians')//m
   /s,radians.
```

Scilab code Exa 2.5 efficency of kylstron

```
//efficency of kylstron
//given
clc
I2=28d-3//ampere
V2=850//volts
Bc=0.496//beam coupling coefficent
Vd=900//volts
Ib=26d-3//ampere
n=(Bc*I2*V2)/(2*Ib*Vd)
```

```
disp(n*100,'the beam efficiency of kylstron in the
   percentage format')
//ERROR in calcultion of the book the value of Bc is
    different in question
```

Chapter 3

MICROWAVE SEMICONDUCTOR DEVICES

Scilab code Exa 3.1 frequency of IMPATT diode

```
//frequency of IMPATT diode
//given
clc
Vd=2.2d+5//m/s
l=5d-6//meter
f=Vd/(2*l)//hertz
disp(f*1d-9,'THE required frequiency in GHz')//Ghz
```

Scilab code Exa 3.2 frequency of IMPATT diode

```
//frequency of IMPATT diode
//given
clc
Vd=3d+5//m/s
```

```
l=7d-6//meter
f=Vd/(2*l)//hertz
f=round(f*1d-8)/1d-8///rounding off decimals
disp(f*1d-9,'the required frequency of IMPATT diode
    in GHz')//GHz
```

Scilab code Exa 3.3 avalanche zone velocity of TRAPATT diode

```
//avalanche zone velocity of TRAPATT diode
//given
clc
Na=1.8d+15//per cm3//doping concentration
j=25d+3//A/cm2//current density
q=1.6d-19//couloms
Vaz=j/(q*Na)//cms//avalanche zone velocity
Vaz=round(Vaz/1d+5)*1d+5///rounding off decimals
disp(Vaz/100,'the avalanche zone velocity of TRAPATT
     in m/s')//m/s
```

Scilab code Exa 3.4 frequency of gunn diode oscillator

```
//frequency of gunn diode oscillator
//given
clc
Vd=2d+8//m/s
l=12d-6//meter
f=Vd/l//hertz
disp(f*1d-9,'the required frequency in GHz')
//ERROR in the book
```

Scilab code Exa 3.5 minimum voltage to operate

```
//minimum voltage to operate
//given
clc
Vs=3.3d+3//VOLTS//the minimum voltage gradient
   required to start the diode
l=2.5d-6//meter//the drift length
Vmin=Vs*l//the minimum voltage required to operate
disp(Vmin*1000,'the minimum voltage required to
   operate in m/V')//mV//millivolts
```

Chapter 4

SCATTERING MATRIX PARAMETERS

Scilab code Exa 4.3 voltage standing wave ratio

```
//voltage standing wave ratio
//given
clc
LEMg=4.82//cm
d1_d2=0.7//cm
VSWR=LEMg/(%pi*d1_d2)//VSWR
VSWR=round(VSWR*1000)/1000///rounding off decimals
disp(VSWR,'the voltage standing wave ratio:')
```

Scilab code Exa 4.4 scattering matrix of inductor

```
//scattering matrix of inductor
//given
clc
IL=0.3//db//insertion loss
I=40//db//isolation
```

```
s21=(10^(-0.3/20))//-20log|s21|
s12=(10^(-40/20))//-20log|s12|
s11=0//FOR SCATTER MATRIX
s22=0//FOR SCATTER MATRIX
S=[s11,s12;s21,s22]
S=round(S*1000)/1000///rounding off decimals
disp(S,'THE  matrix is  S-matrix:')//all points are
    well matched
```

Scilab code Exa 4.5 wave guide length

```
//wave guide length
//given
clc
d1_d2=0.4//distance measured between twice minima
VSWR=2.5//voltage standing wave ratio
LEMg=VSWR*%pi*d1_d2//wave guide length
LEMg=round(LEMg*100)/100///rounding off decimals
disp(LEMg,'the wave guide length for given VSWR IN
    cm:')//cm
```

Chapter 5

MICROWAVE PASSIVE COMPONENTS

Scilab code Exa 5.1 Zo of a two wire transmission line

```
//Zo of a two wire transmission  line
//given
clc
L=1D-3//H/Km
C=0.25D-6//F/Km
Zo=sqrt(L/C)//ohm
Zo=round(Zo*100)/100///rounding off decimalssc
disp(Zo,'the Zo for two wire transmission line  in
   ohm:')//ohm
```

Scilab code Exa 5.2 Zo of a transmission line

```
//Zo of a transmission line
//given
clc
epsilon_r=1//assume as 1 according to question
```

```
s=0.49//cm
d=0.1//cm
Zo=(276/sqrt(epsilon_r))*log10((2*s)/d)
Zo=round(Zo*100)/100///rounding off decimals
disp(Zo,'the Zo of a transmission line is given in
   ohm  as follows:')//ohm
```

Scilab code Exa 5.3 wavelength in coaxial line

```
//wavelength in coaxial line
//given
clc
V0=3D+8//m/s
f=8D+9//hertz
epsilon_r=2.25
lem=V0/((sqrt(epsilon_r))*f)//meter
disp(lem,'the wave length for the operating
   frequency  of 8GHz in meter:')
//error in the form of miscalculation
```

Scilab code Exa 5.4 frequency of air dielectric and highest frequency

```
//frequency of air dielectric and highest frequency
//given
clc
n=1//lowest mode
d=2.6//mm
D=0.8//mm
V0=3d+11//mm/s//ERROR
lem_c=(%pi/(2*n))*(d+D)
fc=V0/lem_c//hertz//ERROR
disp(fc,'the frequency is as follows:')//Hz
```

```
//ERROR in the calculation  in the book as value of V0=3d+10
```

Scilab code Exa 5.5 Zo of the coaxial cable

```
//Zo of the coaxial cable
//given
clc
epsilon_r=2.25
Dbyd=2.25
Zo=(138/sqrt(epsilon_r))*log10(Dbyd)//ohm
Zo=round(Zo*1000)/1000///rounding off decimals
disp(Zo,'the Zo for the given coaxial cable is :')//ohm
```

Scilab code Exa 5.6 output power of cable

```
//output power of cable
//given
clc
alpha=0.28//db/m//attenuation
alpha_50m=0.28*50//db//attenutaion of 50 m cable
pi=0.4//watt//input power//ERROR
po=pi/(10^((alpha_50m)/10))//watt//output power
disp(po*1000,'the output power of 50m in mW ')//mW
//ERROR in calculation of the book as pi=0.04
```

Scilab code Exa 5.7 percentage of reflected power

```
//percentage of reflected power
```

```
//given
Vi=20//volts//incident voltage
Vr=12.5//volts//reflected voltage
row=Vr/Vi//reflected voltage coefficent
row2=row^2//reflected_power/incident_power
pi=1//watt
pr=0.391*1
%pr=pr*100//percentage power
disp(%pr,'the percentage of reflected power is:')
```

Scilab code Exa 5.8 voltage standing wave ratio

```
//voltage standing wave ratio
//given
clc
Vmax=5//volts
Vmin=3//volts
VSWR=Vmax/Vmin//voltage standing wave ratio
VSWR_S=20*log10(VSWR)//VSWR IN db
VSWR_S=round(VSWR_S*100)/100///rounding off decimals
disp(VSWR_S,'THE voltage standing wave ratio in db:'
    )//decibles
```

Scilab code Exa 5.9 VSWR FOR LOAD impedence

```
//VSWR FOR LOAD impedence
//given
clc
Zo=100
Zl1=50
Zl2=125
VSWR=Zo/Zl1//for Zo>Zl
VSWR_1=Zl2/Zo//for Zo<Zl
```

```
disp(VSWR_1,VSWR,'THE voltage standing wave ratio
   for each case:')
```

Scilab code Exa 5.10 voltage standing wave ratio

```
//voltage standing wave ratio
//given
clc
clear
format
Vr=0.37//volts
Vi=1//volts
row=Vr/Vi
if(row>=0)
VSWR=(1+row)/(1-row)
VSWR=round(VSWR*10)/10///rounding off decimals
disp(VSWR,'THE voltage standing wave ratio is:')
else
disp('not possible')
end
```

Scilab code Exa 5.11 magnitude of the reflection coefficent

```
//magnitude of the reflection coefficent
//given
clc
zl=10*%i//ohm
z0=100//ohm
row=(zl-z0)/(zl+z0)//reflection coefficent
mag_row=norm(row)//magnitude of reflection
   coefficent
disp(mag_row,'the magnitude of the reflection
   coefficent:')
```

Chapter 6

MICROWAVE TRANSMISSION LINE

Scilab code Exa 6.1 determine Z0 for given transmission line

```
//determine Z0 for given transmission line
//given
clc
function[Zo]=zed(L,C)
Zo=sqrt(L/C)//impedence function
endfunction
L=110D-9
C=20D-12
[Zo1]=zed(L,C)
L=110D-9
C=20D-12
[Zo2]=zed(L,C)
Zo2=round(Zo2*100)/100///rounding off decimals
Zo1=round(Zo1*100)/100///rounding off decimals
disp(Zo1,Zo2,'the Zo is determined in ohm:')
```

Scilab code Exa 6.2 characteristic impedence

```
//characteristic impedence
//given
clc
s=300//mm//
r=3/2//mm
Zo=276*log10(s/r)
Zo=round(Zo)///rounding off decimals
disp(Zo,'the characteristic impedence in ohm')
```

Scilab code Exa 6.3 input impedance

```
//input impedance
//given
clc
Zl=0//ohm
Zo=50//ohm
Bl=2*%pi*0.1//((2*pi/lem)*lem)
Zi=Zo*(Zl+%i*Zo*tan(Bl))/(Zo+%i*Zl*tan(Bl))//the
   input impedence in ohm
Zi=round(Zi*100)/100///rounding off decimals
disp(Zi,'the input impedance of 50ohm loss less
   transmission line')
```

Scilab code Exa 6.4 input of lossless transmission line

```
//input of lossless transmission line
//given
clc
Zo=50//ohms
Zl=%inf//defined as infinity
Bl=2*%pi*0.1
```

```
Zi=(Zo*(1+%i*(Zo/Zl)*tan(Bl))/(Zo/Zl+%i*tan(Bl)))//
    taking Zl common from numerrator and denominator
Zi=round(Zi*100)/100///rounding off decimals
disp(Zi,'the input of 50ohm lossless transmission
    line')//ohm
```

Scilab code Exa 6.5 input impedance of a lossless transmission

```
//input impedance of a lossless transmission
//given
clc
Zo=100//ohm
Bl=(2*%pi)/3//ERROR
Zl=150+%i*60
Zi=Zo*(Zl+%i*Zo*tan(Bl))/(Zo+%i*Zl*tan(Bl))//the
    input impedence in ohm
disp(Zi,'the input impedance of lossless
    transmission line in ohm:')
//ERROR in the calculation of the book as value of
    Bl=120*pi
```

Scilab code Exa 6.6 time required for wave to travell

```
//time required for wave to travell
//given
clc
L=1.2d-6//H/m
C=12.5d-12//F/m
leng_line=2//length of the line in meter
t=sqrt(L*C)*leng_line//time required for the wave to
     travell in seconds
t=round(t*1d+12)/1d+12///rounding off decimals
```

```
disp(t*1d+9,'the time required for wave to travell
   in nanoseconds')//nsec
```

Scilab code Exa 6.7 characteristic impedance

```
//characteristic impedance
//given
clc
L=1.5d-6//H/m
C=10d-12//F
Zo=sqrt(L/C)
Zo=round(Zo)///rounding off decimals
disp(Zo,'the characteristic impedence in ohm')//ohm
```

Scilab code Exa 6.8 reflected voltage

```
//reflected voltage
//given
clc
Vi=50//volts
row=0.25//reflection coefficent
Vr=Vi*row//the reflected voltage
disp(Vr,'the reflected voltage for given reflection
   coefficent in volts')
```

Scilab code Exa 6.9 percenage of reflected voltage

```
//percentage of reflected voltage
//given
clc
```

```
Vi=50//volts
Vr=25//volts
row=Vr/Vi//reflection coefficent
per_ref_volt=row*100//percentage of reflected
    voltage
disp(per_ref_volt,'the percentage of reflected
    voltage')
```

Scilab code Exa 6.10 voltage standing wave ratio

```
//voltage standing wave ratio
//given
clc
Vmax=50//volts
Vmin=35//volts
VSWR=Vmax/Vmin
VSWR_db=20*log10(VSWR)//db
VSWR_db=round(VSWR_db*1000)/1000///rounding off
    decimals
disp(VSWR_db,'the voltage standing wave ratio in
    decibles')//db
```

Scilab code Exa 6.11 maximum impedance of the line

```
//maximum impedance of the line
//given
clc
Zo=75//ohm
VSWR=3//voltage standing wave ratio
Zmax=VSWR*Zo//ohm
disp(Zmax,'the maximum impedance of the line for the
     given VSWR IN ohm')//ohm
```

Scilab code Exa 6.12 voltage standing wave ratio

```
//EXAMPLE-6.12;PAGE-201
//voltage standin wave ratio
//given
clc
row=0.4
VSWR=(1+row)/(1-row)//voltage standing wave ratio
VSWR=round(VSWR*100)/100///rounding off decimals
disp(VSWR,'the voltage standing wave ratio')
```

Scilab code Exa 6.13 input impedance

```
//input impedance
//given
clc
Zl=0//ohm
Bl=2*%pi/8//rad
Zo=75//ohm
Zi=Zo*(Zl+%i*Zo*tan(Bl))/(Zo+%i*Zl*tan(Bl))
disp(Zi,'the input impedance at point')//ohm
```

Scilab code Exa 6.14 length and characteristic impedance of transformer

```
//length and characteristic impedance of transformer
//given
Zo=50//ohm
Zl=200//ohm
f=300d+6//MHz
```

```
Vo=3d+8//velocity of wave
lem=Vo/f
leng_trans=lem/4//meter//the length of transformer
   is 1/4 of wavelength
Zt=sqrt(Zo*Zl)//ohm
disp(Zt,leng_trans,'the length and characteristic
   impedance in meter and ohm respectively')
```

Scilab code Exa 6.15 characteristic impedance

```
//characteristic impedance
//given
clc
Zl=300//ohm
Zo=75//ohm//of the line
SWR=1//the source impedence is equal to
   characteristic impedance of the line
Zt=sqrt(Zl*Zo)
disp(Zt,'the  characteristic impedance  in ohm')
```

Scilab code Exa 6.16 reflection coefficent

```
//reflection coefficent
//given
clc
S=2//voltage standing wave ratio(VSWR)
Zo=50//ohm
row=((S-1)/(S+1))
row=round(row*1000)/1000///rounding off decimals
disp(row,'the value of reflection coefficent as
   modulus row')
```

Scilab code Exa 6.17 input impedance of the shorted line

```
//input impedance of the shorted line
//given
clc
Zn=50//ohm
f=500//Mhz
Bl=0.2*%pi//B=2*pi/lemda
Zi=%i*Zn*tan(Bl)//input impedance
Zi=round(Zi*100)/100//rounding off decimals
disp(Zi,'the input impedance of the shorted line in
   ohm')
```

Scilab code Exa 6.18 characteristc impedance of the line for air dielectric

```
//characteristc impedance of the line for air
    dielectric
//given
clc
b=30-2*2//mm//diameter of the outside conductor
a=10-2*1//mm//diameter of the inner conductor
Zo=138*log10(b/a)//characteristic impedance
Zo=round(Zo*100)/100///rounding off decimals
disp(Zo,'the characteristic impedance of the line
    for air  dielectric in ohm')
//error in the value of  b
```

Scilab code Exa 6.19 time delay propogaion velocity propagation delay

```
//time delay ,propogaion velocity,propagation delay
//given
clc
L=500D-9//H/m
C=30D-12//F/m
td=sqrt(L*C)//time delay for 1 m long cable
vp=1/3.87d-9//m/s
C1=C*10//capacitance of 10 m cable
L1=L*10//inductance of 10 m cable
Ld=sqrt(L1*C1)//time delay for 10 m long cable
Ld=round(Ld*1d+10)/1d+10///rounding off decimals
td=round(td*1d+11)/1d+11///rounding off decimals
disp(Ld*1d+9,vp,td*1d+9,'the time delay in
    nanoseconds ,propogaion velocity in meter/second,
    propogation delay over a cable length in
    nanoseconds')
```

Scilab code Exa 6.20 radius of the outer conductor

```
//radius of the outer conductor
//given
clc
C=70D-12//F/m
Zo=75//ohm
L=Zo^2*C//inductance
epsilon_r=2.3
a=0.292//mm//radius of inner conductor
b=a*10^(Zo*sqrt(epsilon_r)/138)//Zo=(138/sqrt(
    epsilon_r))*log(b/a)
b=round(b*1d+4)/1d+4///rounding off decimals
disp(b,'the radius of the outer conductor')
```

Scilab code Exa 6.21 resonant frequency

```
//resonant frequency
//given
clc
a=0.03//m
b=0.01//m
c=0.04//m
v=3d+8//speed of wave
fr=(v/2)*(sqrt((1/a^2)+(1/b^2)+(1/c^2)))//hertz
disp(fr*1d-9,'resonant frequency for TM110 mode in
    Ghz')//Ghz
```

Scilab code Exa 6.22 resonant frequency and quality cycle

```
//resonant frequency and quality cycle
//given
clc
a=0.03//m
b=0.01//m
c=0.04//m
l=0.04//m
v=3d+8//speed of wave in m/s in mho/m
uo=4*%pi*10^-7
con_d=5.8d+7//conductivity of copper
fr=(v/2)*(sqrt((1/a^2)+(1/b^2)))//hertz
fr1=(v/2)*(sqrt((1/a^2)+(1/l^2)))//hertz
del=1/sqrt(%pi*fr1*uo*con_d)
Q=((a^2+c^2)*a*b*c)/(del*(((a^3+c^3)*2*b)+a*c*(a^2+c
    ^2)))
fr=round(fr*1d-8)/1d-8///rounding off decimals
Q=round(Q)///rounding off decimals
disp(Q,fr1*1d-9,fr*1d-9,'resonant frequency of
    dominant mode TM110,dominant mode TE101  in Ghz
    and the quality factor')//GHz
```

Scilab code Exa 6.23 resonant frequency of TE101 and its quality factor

```
//resonant frequency of TE101 and its quality factor
//given
clc
con_d=5.8d+7//mho/m
a=0.05//m
b=0.04//m
c=0.1//m
v=3d+8//m/s
epsilon_r=4//dielectric
uo=4*%pi*10^-7
fr=(v/(2*sqrt(epsilon_r)))*(sqrt((1/a^2)+(1/c^2)))//
    hertz
del=1/sqrt(%pi*fr*uo*con_d)//ERROR
Q=((a^2+c^2)*a*b*c)/(del*(((a^3+c^3)*2*b)+a*c*(a^2+c
    ^2)))//quality factor
disp(Q,fr*1d-9,'resonant frequency in dominant mode
    TE101 in Ghz and the quality factor')//GHz
//ERROR in the calculation of the book as value of
    del=32.275d-7 in the book.
```

Chapter 7

MICROWAVE INTEGRATED CIRCUITS

Scilab code Exa 7.1 resistance of a planar resistor

```
//resistance of a planar resistor
//given
clc
con_d=4.1d+7//mho/m
l=10d-3//m
w=5d-3//m
d=0.2d-6//m
Rp=l/(w*d*con_d)//resistance
Rp=round(Rp*1000)/1000///rounding off decimals
disp(Rp,'resistance of a aluminum planar resistor')
    //ohm
```

Scilab code Exa 7.2 inductance for given dimensions

```
//inductance for given dimensions
//given
```

```
clc
l=100//mils
d=10//mils
Lw=5.08*l*(log(l/d)+0.386)//PH/mil
Lw=round(Lw)///rounding off decimals
disp(Lw*1d-3,'the inductance  in nH/mil')//nH/mil
```

Scilab code Exa 7.3 resistance

```
//resistance
//given
clc
l=11d-3//meter
d=0.2d-6//meter
w=8d-3//meter
delta_s=3.82d+7//mho/m
Rp=l/(w*d*delta_s)//resistance
Rp=round(Rp*100)/100///rounding off decimals
disp(Rp,'the resistance for the given parameter in
   ohm')//ohm
```

Scilab code Exa 7.4 resistance

```
//resistance
//given
clc
l=11d-3
d=0.2d-6
w=8d-3
delta_s=4.10d+7
Rp=l/(w*d*delta_s)//resistance
Rp=round(Rp*1000)/1000///rounding off decimals
```

```
disp(Rp,'the resistance for the given parameter in ohm')//ohm
```

Scilab code Exa 7.5 resistance

```
//resistance
//given
clc
l=11d-3
d=0.2d-6
w=8d-3
delta_s=6.17d+7
Rp=l/(w*d*delta_s)//resistance
Rp=round(Rp*1000)/1000///rounding off decimals
disp(Rp,'the resistance for the given parameter in ohm')//ohm
```

Scilab code Exa 7.6 inductance

```
//inductance
//given
clc
A=0.04//cm^2
N=4//no. of turns
Lss=8.5*(A^(0.5))*(N^(5/3))*1d+3//PH
Lss=round(Lss/10)*10///rounding off decimals
disp(Lss*1d-3,'the inductance for the given parameter in nH')//nH
```

Scilab code Exa 7.7 inductance

```
//inductance
//given
clc
l=10//mils
t=0.2//mils
w=8//mils
Lt=5.08*l*(log(l/(w+t))+0.222*((w+t)/l)+1.19)//PH/
    mil
Lt=round(Lt*10)/10///rounding off decimals
disp(Lt,'the inductance for the given parameters')
```

Scilab code Exa 7.8 resistance of a planer resistor

```
//resistance of a planer resistor
//given
clc
l=8d-3//metre
t=0.1d-6//metre
w=8d-3//metre
delta_s=1/0.262d-7//mho/m
Rp=l/(w*t*delta_s)//resistance in ohm
disp(Rp,'the resistance for the given parameter in
    ohm')//ohm
```

Scilab code Exa 7.9 resistance per square

```
//resistance per square
//given
clc
l=15d-3//metre
t=0.1d-6//metre
w=15d-3//metre
delta_s=6.17d+7//mho/m
```

```
Rp=l/(w*t*delta_s)//resistance in ohm
Rp=round(Rp*1000)/1000///rounding off decimals
disp(Rp,'the resistance for the given parameter in
    ohm/square')//ohm/square
//ERROR IN THE PRINTING OF THE BOOK
```

Scilab code Exa 7.10 resistance per square

```
//resistance per square
//given
clc
l=12d-3//metre
t=0.12d-6//metre
w=10d-3//metre
delta_s=4.10d+7//mho/m
Rp=l/(w*t*delta_s)//resistance in ohm
Rp=round(Rp*10000)/10000///rounding off decimals
disp(Rp,'the resistance for the given parameter in
    ohm')//ohm
```

Scilab code Exa 7.11 resistance per square

```
//resistance per square
//given
clc
l=20d-3//metre
t=15d-6//metre
w=10d-3//metre
delta_s=5.8d+7//mho/m
Rp=l/(w*t*delta_s)//resistance in ohm
disp(Rp,'the resistance for the given parameter in
    ohm/square')//ohm/square
//ERROR IN THE BOOK CALCULATION
```

Scilab code Exa 7.12 resistance per square

```
//resistance per square
//given
clc
l=30d-3//metre
t=0.1d-6//metre
Rp=0.3//ohm
delta_s=4.1d+7//mho/m
w=l/(Rp*t*delta_s)//metre
w=round(w*1000)/1000///rounding off decimals
disp(t*1d+6, w*1000,l*1d+3 ,'the design parameter of
    planer resistor are in mm and um')//millimetre
```

Scilab code Exa 7.13 resistance per square

```
//resistance per square
//given
clc
w=10d-3//metre
t=0.08d-6//metre
Rp=0.15//ohm
delta_s=6.17d+7//mho/m
l=w*(Rp*t*delta_s)//metre
disp(l*1000,'the resistance for the given parameter
   in mm')//millimetre
```

Scilab code Exa 7.14 inductance of circular spiral

```
//inductance of circular spiral
//given
clc
N=10//number of turns
w=50//mils//sepration
s=20//mils//film width
d=2.5*N*(w+s)//
L=31.25*(N^2)*d//PH/mil
L=round(L*1D-3)/1d-3///rounding off decimals
disp(L*1d-3,'the resistance for the given parameter
    in nH/mil')//nH/mil(the value is different on
    book)
```

Chapter 8

MICROWAVE ANTENNAS

Scilab code Exa 8.1 half power beam width

```
//given
clc
Da=2.5//metre
f=5d+9//hertz
v=3d+8
lemda=v/f//metre
NNBW=140*(lemda/Da)//degree//beamwidth between first
    null
HPBW=70*(lemda/Da)//degree//half power beamwidth
disp(HPBW,NNBW,'the beamwidth between first null and
    the value of half power beamwidth in degree')//
   degrees
```

Scilab code Exa 8.2 gain of paraboloid

```
//gain of paraboloid
//given
clc
```

```
Da=2.5//metre
f=5d+9//hertz
v=3d+8//m/s
lemda=v/f
gp=6.4*(Da/lemda)^2
gp_decibles=10*log10(gp)//changing to decibles
gp_decibles=round(gp_decibles*100)/100///rounding off decimals
disp(gp_decibles,'the gain of paraboloid in decibles')//db
```

Scilab code Exa 8.3 half power radiation pattern and beamwidth between first null

```
//half power radiation pattern and beamwidth between first null
//given
clc
Da=0.15//metre
f=9d+9//hertz
v=3d+8//m/s
lemda=v/f//metre
NNBW=140*(lemda/Da)//degree
HPBW=70*(lemda/Da)//degree
gp=6.4*(Da/lemda)^2//gain pattern
gp_decibles=10*log10(gp)//changing to db
gp_decibles=round(gp_decibles*100)/100///rounding off decimals
HPBW=round(HPBW*100)/100///rounding off decimals
NNBW=round(NNBW*100)/100///rounding off decimals
disp(gp_decibles,HPBW,NNBW,'the half power beamwidth and  beamwidth between first null and the gain pattern in degrees and decibles')//degree,db
```

Scilab code Exa 8.4 gain of paraboloid

```
//gain of paraboloid
//given
clc
Da=2//metre
f=2d+9//hertz
v=3d+8//m/s
lemda=v/f
gp=6.4*(Da/lemda)^2
gp_decibles=10*log10(gp)//changing to decibles
disp(gp_decibles,'the gain of paraboloid in decibles')//db
//ERROR in the printing of the book
```

Scilab code Exa 8.5 half power beam width the gain power

```
//half power beam width the gain power
//given
clc
NNBW=5//degree//null to null beamwidth
f=6d+9//hertz
v=3d+8
lemda=v/f//metre
Da=140*(lemda/NNBW)//degree//beamwidth between first null
HPBW=70*(lemda/Da)//degree//half power beamwidth
gp=6.4*(Da/lemda)^2
gp_decibles=10*log10(gp)//changing to decibles
disp(gp_decibles,HPBW,Da,'the beamwidth between first null and the value of half power beamwidth in degree')//degrees
```

```
//ERROR in the printing of the book
```

Scilab code Exa 8.6 beamwidth directivity and capture area

```
//beamwidth , directivity and capture area
//given
clc
Da=5//metre
f=9d+9//hertz
v=3d+8//m/s
lemda=v/f//metre
A=%pi*(Da^2)/4//actual area
Ac=0.65*A//capture area
NNBW=140*(lemda/Da)//degree
HPBW=70*(lemda/Da)//degree
D=6.4*(Da/lemda)^2//directivity
D_decibles=10*log10(D)//changing to db
NNBW=round(NNBW*1D+4)/1D+4///rounding off decimals
HPBW=round(HPBW*1D+3)/1D+3///rounding off decimals
Ac=round(Ac*100)/100///rounding off decimals
D_decibles=round(D_decibles*100)/100///rounding off
   decimals
disp(D_decibles,Ac,HPBW,NNBW,'the half power
   beamwidth and  beamwidth between first null and
   the gain pattern in degrees and decibles')//
   degree ,m^2 ,db
```

Scilab code Exa 8.7 minimum distance between two antennas

```
//minimum distance between two antennas
//given
clc
Da=5//metre
```

```
f=5d+9//hertz
v=3d+8//m/s
lemda=v/f//metre
r=2*(Da^2)/lemda//metre
r=round(r*100)/100///rounding off decimals
disp(r,'the minimum distance required between two
    antennas in metre')//metre
```

Scilab code Exa 8.8 mouth diameter and the beamwidth of antenna

```
//mouth diameter and the beamwidth of antenna
//given
clc
Da=0.15//metre
f=4d+9//hertz
gp=500//
v=3d+8//m/s
lemda=v/f//metre
Da=lemda*sqrt(gp/6.4)//diameter
NNBW=140*(lemda/Da)//degree
HPBW=70*(lemda/Da)//degree
Da=round(Da*1000)/1000///rounding off decimals
HPBW=round(HPBW*100)/100///rounding off decimals
NNBW=round(NNBW*100)/100///rounding off decimals
disp(NNBW,HPBW,Da,'the mouth diameter and the
    beamwidth of antenna in metre and degrees')//
    metre,degree
```

Scilab code Exa 8.9 beamwidth directivity and capture area

```
//beamwidth,directivity and capture area
//given
clc
```

```
f=9d+9//hertz
v=3d+8//m/s
gp_decibles=100//db
lemda=v/f//metre
gp=10^(gp_decibles/10)//
Da=lemda*sqrt(gp/6.4)//metre
A=%pi*(Da^2)/4//actual area
Ac=0.65*A//capture area
NNBW=140*(lemda/Da)//degree
HPBW=70*(lemda/Da)//degree
HPBW=round(HPBW*1D+5)/1D+5///rounding off decimals
NNBW=round(NNBW*1D+4)/1D+4///rounding off decimals
disp(HPBW,NNBW,Ac,'the half power beamwidth and
   beamwidth between first null and the gain pattern
    in degrees and decibles')//degree,m^2,db
```

Scilab code Exa 8.10 half power radiation pattern and beamwidth between first null

```
//half power radiation pattern and beamwidth between
    first null
//given
clc
Da=5//metre
f=10d+9//hertz
v=3d+8//m/s
lemda=v/f//metre
NNBW=140*(lemda/Da)//degree
HPBW=70*(lemda/Da)//degree
gp=6.4*(Da/lemda)^2//gain pattern
gp_decibles=10*log10(gp)//changing to db
gp_decibles=round(gp_decibles*1000)/1000///rounding
   off decimals
disp(NNBW,HPBW,gp_decibles,'the half power beamwidth
    and  beamwidth between first null and the gain
```

```
pattern in degrees and decibles')//degree,db
```

Scilab code Exa 8.11 half power radiation pattern and beamwidth between first null

```
//half power radiation pattern and beamwidth between first null
//given
clc
Da=12//metre
f=10d+9//hertz
v=3d+8//m/s
lemda=v/f//metre
ie=0.6//illumination efficiency
gp=ie*(Da/lemda)^2//gain pattern
gp_decibles=10*log10(gp)//changing to db
gp_decibles=round(gp_decibles*100)/100///rounding off decimals
disp(gp_decibles,'the power gain in decibles')//degree,db
```

Scilab code Exa 8.12 mouth diameter and capture area

```
//mouth diameter and capture area
//given
clc
f=4d+9//hertz
v=3d+8//m/s
NNBW=8//degree
lemda=v/f//metre
Da=140*(lemda/NNBW)//degree
A=%pi*(Da^2)/4//actual area
Ac=0.65*A//capture area
```

```
Ac=round(Ac*1000)/1000///rounding off decimals
disp(Ac,Da,'the mouth diameter and capture area in
   metre and metersquare')//m,m^2
```

Scilab code Exa 8.13 mouth diameter and power gain

```
//mouth diameter and power gain
//given
clc
NNBW=2//degree//null to null beamwidth
f=4d+9//hertz
v=3d+8//m/s
lemda=v/f//metre//
Da=140*(lemda/NNBW)//degree//beamwidth between first
    null
gp=6.4*(Da/lemda)^2
gp_decibles=10*log10(gp)//changing to decibles
gp_decibles=round(gp_decibles*100)/100///rounding
   off decimals
disp(gp_decibles,Da,'the beamwidth between first
   null and the value of half power beamwidth in
   decibles and degree')//decibles,degrees
```

Scilab code Exa 8.14 null to null beamwidth and the gain power

```
//null to null beamwidth and the gain power
//given
clc
HPBW=6//degree//half power beamwidth
f=6d+9//hertz
v=3d+8
NNBW=2*HPBW//degree//null to null beamwidth
lemda=v/f//metre
```

```
Da=70*(lemda/HPBW)//degree//half power beamwidth
gp=6.4*(Da/lemda)^2
gp_decibles=10*log10(gp)//changing to decibles
gp_decibles=round(gp_decibles*100)/100///rounding
   off decimals
disp(gp_decibles,NNBW,'the beamwidth between first
   null and gain power in degree and decibles')//
   degrees,decibles
```

Scilab code Exa 8.15 power gain of paraboloid reflector

```
//power gain of paraboloid reflector
//given
clc
lemda=1//as value of lemda do not effect the
   expression
for(lemda!=0)
Da=6*lemda
gp=6.4*(Da/lemda)^2
gp_decibles=10*log10(gp)//changing to decibles
end
gp_decibles=round(gp_decibles*100)/100///rounding
   off decimals
disp(gp_decibles,'the power gain of paraboloid
   reflector in decibles')//decibles
```

Scilab code Exa 8.16 HPBW NNBW directivity

```
//HPBW NNBW directivity
//given
clc
lemda=1//as value of lemda do not effect the
   expression
```

```
for(lemda!= 0)
Da=7*lemda//aperture diameter
NNBW=140*(lemda/Da)//degree
HPBW=70*(lemda/Da)//degree
D=6.4*(Da/lemda)^2//directivity
end
disp(D,NNBW,HPBW,'the half power beamwidth and
   beamwidth between first null and the directivity
   in degrees and decibles')//degree,db
```

Scilab code Exa 8.17 beamwidth power gain and directivity

```
//beamwidth power gain and directivity
//given
clc
f=8d+9//hertz
v=3d+8//m/s
d=0.09//m//aperture dimentions
W=0.04//m//aperture dimentions
lemda=v/f//metre
QE=56*lemda/d//
QH=67*lemda/W//
gp=4.5*W*d/lemda^2
gp_decibles=10*log10(gp)//changing to decibles
D=7.5*W*d/lemda^2//directivity
gp_decibles=round(gp_decibles*100)/100///rounding
   off decimals
QH=round(QH*100)/100///rounding off decimals
QE=round(QE*100)/100///rounding off decimals
disp(D,gp_decibles,QH,QE,'the beamwidth power gain
   and directivity in degrees,decibles')//degrees,
   decibles
```

Scilab code Exa 8.18 power gain of square horn antenna

```
//power gain of square horn antenna
//given
clc
lemda=1//as value of lemda do not affect the expression
for(lemda!=0)
    d=10*lemda // dimentions
    W=10*lemda//dimentions
gp=4.5*W*d/lemda^2//power gain
gp_decibles=10*log10(gp)//changing to decibles
end
gp_decibles=round(gp_decibles*1000)/1000///rounding off decimals
disp(gp_decibles,'the  power gain  in decibles')//decibles
```

Scilab code Exa 8.19 power gain and directivity of a horn

```
//power gain and directivity of a horn
//given
clc
f=8d+9//hertz
v=3d+8//m/s
d=0.1//m//aperture dimentions
W=0.05//m//aperture dimentions
lemda=v/f//metre
gp=4.5*W*d/lemda^2
gp_decibles=10*log10(gp)//changing to decibles
D=7.5*W*d/lemda^2//directivity
D_decibles=10*log10(D)
gp_decibles=round(gp_decibles*100)/100///rounding off decimals
D_decibles=round(D_decibles*100)/100///rounding off
```

```
    decimals
disp(D_decibles,gp_decibles,'the beamwidth power
    gain and directivity in decibles')//decibles
```

Scilab code Exa 8.20 complementary slot impedence

```
//complementary slot impedence
//given
clc
function[Zs]=slot_imp(Zd)
no=377
Rd=real(Zd)
Xd=imag(Zd)
Zs=(no^2/(4*(Rd^2+Xd^2)))*(Rd-%i*Xd)//slot impedance
Zs=round(Zs*100)/100///rounding off decimals
endfunction
Zd=73+%i*50//ohm
[Zs1]=slot_imp(Zd)
Zd=70//ohm
[Zs2]=slot_imp(Zd)
Zd=800//ohm
[Zs3]=slot_imp(Zd)
Zd=400//ohm
[Zs4]=slot_imp(Zd)
Zd=50+%i*10//ohm
[Zs5]=slot_imp(Zd)
Zd=50-%i*30//ohm
[Zs6]=slot_imp(Zd)
Zd=350//ohm
[Zs7]=slot_imp(Zd)
disp(Zs7,Zs6,Zs5,Zs4,Zs3,Zs2,Zs1,'the complementry
    slot impedence in ohms')//ohm
```

Scilab code Exa 8.21 radiation resistance of hertzian dipole

```
//radiation resistance of hertzian dipole
//given
clc
lemda=1//as the radiation resistance is independent
    of lemda
function[Rr]=rad_resistance(dl)
 for(lemda!=0)
     Rr=80*%pi^2*(dl/lemda)^2
     Rr=round(Rr*1000)/1000///rounding off decimals
     end
 endfunction
dl=lemda/20
[Rr1]=rad_resistance(dl)
dl=lemda/30
[Rr2]=rad_resistance(dl)
dl=lemda/40
[Rr3]=rad_resistance(dl)
disp(Rr3,Rr2,Rr1,'the radiation resistance of
   hertzian dipole')
```

Scilab code Exa 8.22 directivity of half wave dipole

```
//directivity of half wave dipole
//given
clc
Pr=1//watts
r=1//as value of "r" do not effect the expression
n0=120*%pi
for(r!=0)
I=sqrt(Pr/73)
Emax=60*I/r
si=r^2*Emax^2/n0
gdmax=4*%pi*(si)/Pr
```

```
gdmax=round(gdmax*1000)/1000///rounding off decimals
end
disp(gdmax,'the directivity expression for half wave dipole')
```

Scilab code Exa 8.23 radiated power of an antenna

```
//radiated power of an  antenna
//given
clc
I=2//amperes
Rr=300//ohms
Pr=I^2*Rr//radiated power
disp(Pr,'the radiated power  of  anantenna in watts')
```

Scilab code Exa 8.24 effective area of a half wave dipole

```
//effective area of a half wave dipole
//given
clc
f=0.6d+9//hertz
Vo=3d+8//m/s
gd=1.644//directivity of half wave dipole
lemda=Vo/f
Ae=(lemda^2/(4*%pi))*gd//metre^2
Ae=round(Ae*1d+4)/1d+4///rounding off decimals
disp(Ae,'the effective area of a half wave dipole in metre^2')//m^2
```

Scilab code Exa 8.25 effective area of hertzian dipole

```
//effective area of hertzian dipole
//given
clc
f=0.2d+9//hertz
Vo=3d+8//m/s
lemda=Vo/f
Ae=(lemda^2/(4*%pi))//metre^2//ERROR
Ae=round(Ae*1000)/1000///rounding off decimals
disp(Ae,'the effective area of a half wave dipole in
    metre^2')//m^2
//ERROR in the  calculation of the book as effective
    area includes lemda square not cube.
```