4.25 Use the equations in the book or the computer program of this chapter. Find the radiation efficiency of resonant linear electric dipoles of length

(c) $l = \lambda/2$

Assume that each dipole is made out of copper [$\sigma = 5.7 \times 10^7$ S/m], has a radius of $10^{-4}\lambda$, and is operating at $f = 10$ MHz. Use the computer program **Dipole** of this chapter to find the radiation resistances.

- As part of your solution, compute radiation R_r and loss R_L resistances using equations from text and again using NEC-2. [Let $\Delta \sim 8a$. List NEC input file and relevant excerpts of output file.] Tabulate answers and discuss differences. You do not need to use program Dipole.

Using MathCad

$f := 10\cdot 10^6$ Hz $\quad \omega := 2\cdot\pi\cdot f \quad c := 299792458$ m/s $\quad \mu 0 := 4\cdot\pi\cdot 10^{-7}$ H/m

$\sigma := 5.7\cdot 10^7$ S/m $\quad \varepsilon 0 := \dfrac{1}{\mu 0\cdot c^2} \quad \eta := \sqrt{\dfrac{\mu 0}{\varepsilon 0}} \quad \varepsilon 0 = 8.8542\times 10^{-12}$ F/m

For part c), $l = \lambda/2$ $\quad l\lambda := 0.5 \quad rad\lambda := 10^{-4}$ $\quad \eta = 376.73031\ \Omega$

(4-67) & (4-70) $\quad kl2 := \dfrac{2\cdot\pi\cdot l\lambda}{2} \quad kl2 = 1.571$

$$Rr := \frac{\eta}{2\cdot\pi}\cdot\int_0^{\pi}\frac{(\cos(kl2\cdot\cos(\theta)) - \cos(kl2))^2}{\sin(\theta)}\,d\theta \qquad \boxed{Rr = 73.07901}\ \Omega$$

(2-90b) $$Rhf := \frac{l\lambda}{2\cdot\pi\cdot rad\lambda}\cdot\sqrt{\frac{\omega\cdot\mu 0}{2\cdot\sigma}} \qquad Rhf = 0.662266\ \Omega$$

For $l = \lambda/2$, assume current distribution is sinusoidal. Then, per notes or example 2.13/problem 2.52:

$$RL := \frac{Rhf}{2} \qquad \boxed{RL = 0.3311}\ \Omega$$

(2-90) $$ecd := \frac{Rr}{Rr + RL}\cdot 100 \qquad \boxed{ecd = 99.5489}\ \%$$

NEC-2 input file

```
CM EE 483/583 Problem 4.25c (4_25c.txt)
CM This file is used to determine the efficiency of a halfwave copper
CM dipole antenna (sigma = 5.7*10^7 S/m) driven at 10 MHz (lambda = 29.98 m).
CM radius = a = 0.0001(lambda) = 0.002998 m, length = l = 29.98/2 = 14.99 m
CM Used 313 segments (del/a= 16).  DRIVEN SEGMENT IS #157.
CE
GW 1 313 0.0 0.0 -7.495 0.0 0.0 7.495 0.002998
GE 0
EK 0          ! Use extended kernel in simulation
FR 0 1 0 0 10.0 0.0
EX 0 1 157 00 1.0 0.0
LD 5 0 0 0 5.7e7 ! Load all segments w/ conductivity
PT -1 ! Don't print currents
XQ 0
EN
```

NEC-2 output file excerpt

```
 FREQUENCY= 1.0000E+01 MHZ
 WAVELENGTH= 2.9980E+01 METERS
<snip>
              - - - STRUCTURE IMPEDANCE LOADING - - -
LOCATION RESISTANCE INDUCTANCE  CAPACITANCE IMPEDANCE (OHMS)CONDUCTIVITY TYPE
ITAG FROM THRU  OHMS HENRYS FARADS   REAL      IMAGINARY    MHOS/METER
    ALL                                                     5.7000E+07   WIRE
<snip>
- - - ANTENNA INPUT PARAMETERS - - -
TAG SEG. VOLTAGE(VOLTS) CURRENT(AMPS) IMPEDANCE(OHMS) ADMITTANCE(S) POWER
NO. NO.  REAL    IMAG.   REAL  IMAG.  REAL    IMAG.   REAL  IMAG.  (WATTS)
1  157   1.00    0.00  9.30726E-03 -5.34408E-03 8.08032E+01 4.63959E+01
9.30726E-03-5.34408E-03 4.65363E-03

- - - POWER BUDGET - - -
INPUT POWER   = 4.65359E-03 WATTS
RADIATED POWER= 4.6330E-03 WATTS
STRUCTURE LOSS= 2.0590E-05 WATTS
EFFICIENCY    =  99.56 PERCENT
```

From NEC info, $\overline{I}_{in} = 9.30726 - j5.34408$ mA $= 10.73239394\angle\text{-}29.86375°$ mA.

$$\text{(2-76)} \qquad R_r = \frac{P_{\text{rad}}}{0.5\,|\,\overline{I}_{\text{in}}\,|^2} = \frac{4.6330E-03}{0.5(0.01073239)^2} \quad \Rightarrow \quad \underline{R_r = 80.445\ \Omega},$$

$$\text{(2-77)} \qquad R_L = \frac{P_{\text{loss}}}{0.5\,|\,\overline{I}_{\text{in}}\,|^2} = \frac{2.0590E-05}{0.5(0.01073239)^2} \quad \Rightarrow \quad \underline{R_L = 0.3575\ \Omega}.$$

- The NEC radiation resistance R_r of 80.445 Ω is larger than the 73.079 Ω from theory. This because true resonance occurs at a length slightly less than 0.5λ (charge accumulation at antenna tips makes them act longer than physical length).
- The NEC loss resistance R_L of 0.3575 Ω is very close to the 0.3311 Ω from theory.
- The NEC efficiency of 99.56% is very close to the 99.5489% from theory.