In free space, a PEC folded dipole has length $\ell = 0.454\lambda$, wire spacing $s = 0.04\lambda$, and wire diameter $2a = 0.003\lambda$ operating at wavelength $\lambda = 150$ cm ($f_c \approx 200$ MHz). Assume $c = 2.998\times10^8$ m/s. Compute the characteristic impedance of the transmission line mode and effective radius (cm) of the equivalent dipole. Given a 300 Ω feeding twin-lead transmission line made with the same wire, find its spacing s_{300} (cm). Make scale drawing of the folded dipole (all dimensions in cm). Then, find and **tabulate** the transmission line mode input impedance Z_t, antenna mode input impedance Z_a, and overall input impedance Z_{in} at frequencies f_c, f_c - 5%, and f_c + 5%. [**EE 583 only:** Also, find and **tabulate** the input reflection coefficient (polar form w/ angle in degrees) and VSWR on the 300 Ω feeding twin-lead transmission line at frequencies f_c, f_c - 5%, and f_c + 5%.] Show all work including NEC-2 input file(s) and relevant excerpts of output file(s).

MathCad

$\lambda c := 1.5$ m $\qquad \varepsilon 0 := 8.8541878\cdot 10^{-12}$ F/m $\qquad \mu 0 := 4\cdot\pi\cdot 10^{-7}$ H/m

$c := 2.998\cdot 10^{8}$ m/s $\qquad Zfd := 300$ Ω $\qquad l := 0.454\cdot\lambda c \qquad l\cdot 100 = 68.1$ cm

$\eta := \sqrt{\dfrac{\mu 0}{\varepsilon 0}} \qquad \eta = 376.7303$ Ω $\qquad s := 0.04\cdot\lambda c \qquad s\cdot 100 = 6$ cm

$a := 0.0015\cdot\lambda c \qquad a = 0.00225$ m $\qquad 2\cdot a\cdot 100 = 0.45$ cm

Characteristic impedance Z_0 of a transmission line mode

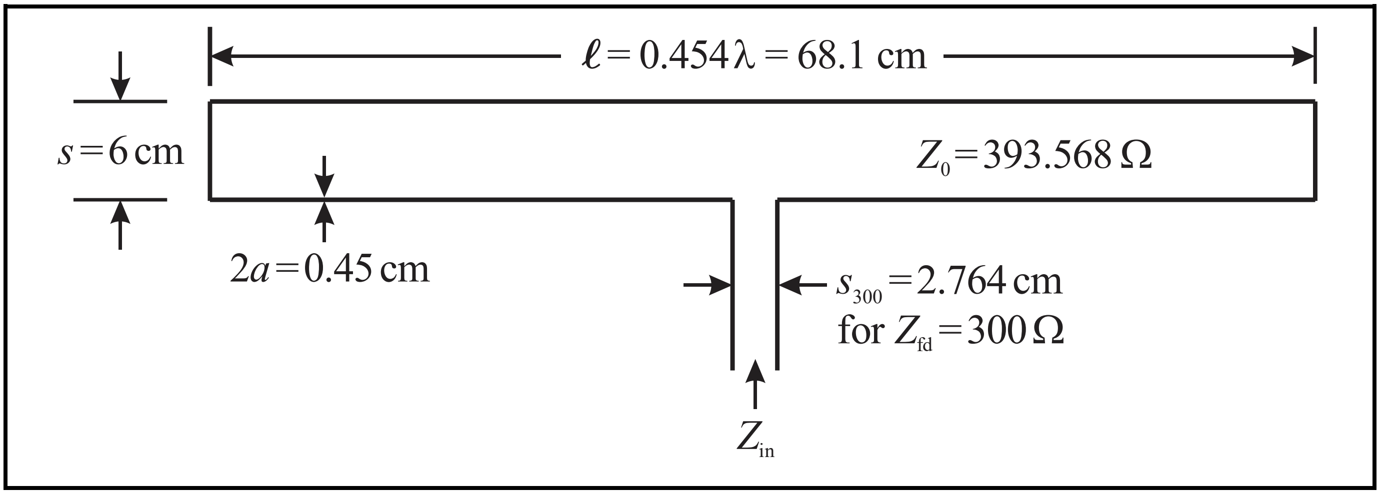
$$Z0 := \frac{\eta}{\pi}\cdot \operatorname{acosh}\left(\frac{s}{2\cdot a}\right) \qquad \boxed{Z0 = 393.5682} \ \Omega$$

Effective radius a_e of folded dipole.

$$ae := \sqrt{a\cdot s} \qquad ae = 0.011619 \text{ m} \qquad \boxed{ae\cdot 100 = 1.1619} \text{ cm}$$

Find spacing s_{300} for a 300 Ω feeding transmission line.

$$s300 := 2\cdot a\cdot \cosh\left(\frac{Zfd\cdot\pi}{\eta}\right) \qquad \boxed{s300\cdot 100 = 2.7642} \text{ cm}$$



<u>Compute transmission line mode input impedances Z_t at f_c - 5%, f_c, and</u>

$fc := \frac{c}{\lambda c}$ $\quad fl := 0.95 \cdot fc$ $\quad fh := 1.05 \cdot fc$

$fc = 1.99867 \times 10^{8}$ Hz $\quad fl = 1.89873 \times 10^{8}$ Hz $\quad fh = 2.0986 \times 10^{8}$ Hz

$\lambda l := \frac{c}{fl}$ $\quad \lambda h := \frac{c}{fh}$ $\quad kc := \frac{2 \cdot \pi}{\lambda c}$ $\quad kl := \frac{2 \cdot \pi}{\lambda l}$ $\quad kh := \frac{2 \cdot \pi}{\lambda h}$

$Ztl := j \cdot Z0 \cdot \tan\left(\frac{kl \cdot l}{2}\right)$ $\quad Ztc := j \cdot Z0 \cdot \tan\left(\frac{kc \cdot l}{2}\right)$ $\quad Zth := j \cdot Z0 \cdot \tan\left(\frac{kh \cdot l}{2}\right)$

$Ztl = 1795.1i$ Ω $\quad Ztc = 2704.42i$ Ω $\quad Zth = 5367.1i$ Ω

<u>NEC-2 Input file to determine antenna mode input impedances</u>

```
CM  EE 483 Folded Dipole Problem (folded_dipole_454_lambda_200MHz.txt)
CM  This file is used to determine input impedance of folded dipole
CM  w/ effective radius = 0.011619 m & length = 0.454 lambda = 0.681 m
CM  driven at lambda = 1.5 m (f+/-5% = 199.8666 MHz +/-5%).
CM  Used 11 segments (del/ae ~ 5.3).  DRIVEN SEGMENT IS #6.
CE
GW 1 11 0.0 0.0 -0.3405 0.0 0.0 0.3405 0.011619
GE 0            ! no ground plane
EK 0            ! Use extended kernel command
FR 0 3 0 0 189.8733333 9.9933333   ! 3 frequencies
EX 0 1 6 00 1.0 0.0   ! drive w/ 1V source at center
PT -1   ! suppress current outputs
XQ 0
EN
```

NEC-2 Output file (folded_dipole_454_lambda_200MHz_dat.txt) excerpts

```
<snip>   NUMERICAL ELECTROMAGNETICS CODE (NEC-2D)
<snip>
                         FREQUENCY= 1.8987E+02 MHZ
<snip>
                        - - - ANTENNA INPUT PARAMETERS - - -
TAG SEG.    VOLTAGE (V)        CURRENT (A)         IMPEDANCE (OHMS)       ADMITTANCE (MHOS)      POWER
 NO. NO.    REAL         IMAG.        REAL         IMAG.          REAL         IMAG.              REAL         IMAG.     (WATTS)
 1     6   1.00E+00 0.00E+00 1.39518E-02 5.74365E-03 6.12883E+01 -2.52311E+01 1.395E-02 5.744E-03 6.976E-03
<snip>
                          FREQUENCY= 1.9987E+02 MHZ
<snip>
                         - - - ANTENNA INPUT PARAMETERS - - -
TAG SEG.    VOLTAGE (V)        CURRENT (A)        IMPEDANCE (OHMS)       ADMITTANCE (MHOS)      POWER
 NO. NO.    REAL         IMAG.        REAL         IMAG.        REAL         IMAG.             REAL         IMAG.     (WATTS)
 1     6 1.00E+00 0.00E+00 1.38621E-02 7.77579E-05 7.21370E+01 -4.04645E-01 1.3862E-02 7.776E-05 6.931E-03
<snip>
                         FREQUENCY= 2.0986E+02 MHZ
<snip>
                      - - - ANTENNA INPUT PARAMETERS - - -
TAG SEG.    VOLTAGE (V)        CURRENT (A)        IMPEDANCE (OHMS)       ADMITTANCE (MHOS)      POWER
 NO. NO.    REAL         IMAG.        REAL         IMAG.        REAL         IMAG.             REAL         IMAG.     (WATTS)
1    6 1.00E+00 0.00E+00 1.09354E-02-3.06035E-03 8.48041E+01 2.37330E+01 1.0935E-02-3.060E-03 5.4677E-03
```

Used NEC-2 to find antenna mode input impedance Z_a of dipole (length ℓ & radius a_e.

$Zal := 61.2883 - j\cdot 25.2311 \quad \Omega \qquad Zac := 72.137 - j\cdot 0.404645 \quad \Omega$

$Zah := 84.8041 + j\cdot 23.733 \quad \Omega$

At f_c - 5% $\qquad Zinl\_apprx := 4\cdot Zal \qquad Zin\_l := \dfrac{4\cdot Zal\cdot Ztl}{2\cdot Zal + Ztl}$

$Zinl\_apprx = 245.153 - 100.924i \quad \Omega \qquad \boxed{Zin\_l = 258.265 - 85.698i} \quad \Omega$

At f_c $\qquad Zinc\_apprx := 4\cdot Zac \qquad Zin\_c := \dfrac{4\cdot Zac\cdot Ztc}{2\cdot Zac + Ztc}$

$Zinc\_apprx = 288.548 - 1.619i \quad \Omega \qquad \boxed{Zin\_c = 287.901 + 13.744i} \quad \Omega$

At f_c + 5% $\qquad Zinh\_apprx := 4\cdot Zah \qquad Zin\_h := \dfrac{4\cdot Zah\cdot Zth}{2\cdot Zah + Zth}$

$Zinh\_apprx = 339.216 + 94.932i \quad \Omega \qquad \boxed{Zin\_h = 332.968 + 104.53i} \quad \Omega$

Frequency (MHz)	Z_t (Ω)	Z_a (Ω)	Z_{in} (Ω)
f_c - 5% = 189.873	j1795.1	61.2883 - j25.2311	258.265 - j85.698
f_c =199.867	j2704.42	72.137 - j0.404645	287.901 + j13.744
f_c + 5% = 209.86	j5367.1	84.8041 + j23.733	332.968 + j104.53

EE 583

Find input reflection coefficient & VSWR for a 300 Ω feeding transmission line.

$$\Gamma inl := \frac{Zin\_l - Zfd}{Zin\_l + Zfd} \qquad |\Gamma inl| = 0.1688 \qquad \arg(\Gamma inl)\cdot\frac{180}{\pi} = -107.2 \text{ deg}$$

$$VSWR\_low := \frac{1 + |\Gamma inl|}{1 - |\Gamma inl|} \qquad VSWR\_low = 1.4061$$

$$\Gamma inc := \frac{Zin\_c - Zfd}{Zin\_c + Zfd} \qquad |\Gamma inc| = 0.0311 \qquad \arg(\Gamma inc)\cdot\frac{180}{\pi} = 130 \text{ deg}$$

$$VSWR\_ctr := \frac{1 + |\Gamma inc|}{1 - |\Gamma inc|} \qquad VSWR\_ctr = 1.0643$$

$$\Gamma inh := \frac{Zin\_h - Zfd}{Zin\_h + Zfd} \qquad |\Gamma inh| = 0.1708 \qquad \arg(\Gamma inh)\cdot\frac{180}{\pi} = 63.1 \text{ deg}$$

$$VSWR\_high := \frac{1 + |\Gamma inh|}{1 - |\Gamma inh|} \qquad VSWR\_high = 1.4121$$

Frequency (MHz)	Γ_{in}	VSWR
f_c - 5% = 189.873	0.1688∠-107.2°	1.4061
f_c =199.867	0.0311∠130°	1.0643
f_c + 5% = 209.86	0.1708∠63.1°	1.4121