For single, 18.5 cm diameter, circular loop of wire (16 AWG, $\sigma = 5 \times 10^7$ S/m) in free space, centered on the x-y plane and fed where it crosses the positive x-axis, use NEC-2 to:

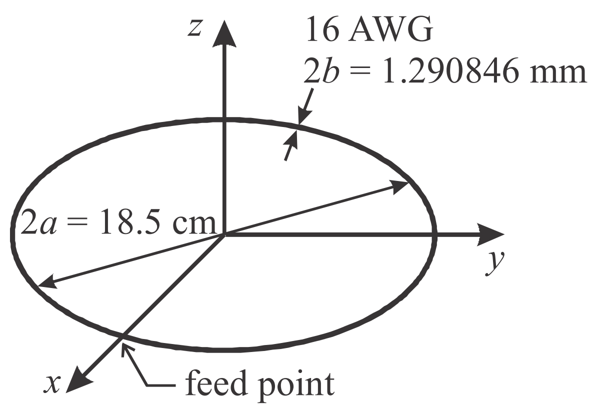
a) Determine the input impedance over normalized frequency range $0.1 \le ka \le 2$. On a single graph, plot R_A and X_A versus ka. Use vertical scale of -1000 Ω to 1500 Ω for both R_A and X_A.

b) **EE 483 only**: In a table, list ka equal to 0.1 as well as for the anti-resonant & resonant frequencies w/in the range $0.1 \le ka \le 2$, frequency f (MHz), R_A, X_A, and antenna efficiency η. Format: col. 1 ka, col. 2 f (MHz), col. 3 R_A, col. 4 X_A, col. 5 η, and col. 6 description (e.g., small loop, resonance #1 …) **EE 583 only**: In a table, list ka equal to 0.1 as well as for the anti-resonant & resonant frequencies within the range $0.1 \le ka \le 2$, frequency f (MHz), R_A, X_A, R_r, R_l, and η. Format: Col. 1 ka, col. 2 f (MHz), col. 3 R_A, col. 4 X_A, col. 5 R_{rad}, , col. 6 R_{loss}, col. 7 η, and col. 8 description (e.g., small loop, resonance #1 …)

c) Determine the current distributions at $ka = 0.1$ and the first resonant frequency. On a single graph, plot the normalized current **magnitudes** versus the fractional circumference (e.g., $0 \le$ distance/circumference < 1). Normalize each current magnitude independently so that its maximum is 1.

d) **Extra credit:** At $ka = 0.1$ and the first resonant frequency, determine the far-zone E-plane (x-y plane) and H-plane (x-z plane) power gain radiation patterns (in dBi). On two polar graphs, plot the relative power radiation patterns for the E-plane and H-plane scaled so that the center of each plot is at –30 dB and the outer ring is at 0 dB. Tabulate the maximum and minimum gain in each plane at each frequency.

****



a) Find diameter of 16 AWG wire (mm) using $d_{16} = 0.127 \text{ mm} \times 92^{(36-16)/39} = 2b = 1.290846$ mm

$\Rightarrow$ **wire radius = b = 0.645423 mm**

Loop circumference $C = 2\pi a = \pi$ (18.5 cm) $\Rightarrow$ **C = 58.119464 cm**

Determine the lower and upper frequencies.

$$ka = C/\lambda_{\text{low}} = 0.1 \rightarrow \lambda_{\text{low}} = 58.119464 \text{ cm}/0.1 = 5.8119464 \text{ m}$$

$$f_{\text{low}} = c/\lambda_{\text{low}} = 2.998\times10^8/5.8119464 \Rightarrow \mathbf{f_{\text{low}} = 51.5834 \text{ MHz}}$$

$ka = C/\lambda_{high} = 2 \;\rightarrow\; \lambda_{high} = 58.119464\text{ cm}/2 = 0.29059732\text{ m}$

$f_{high} = c/\lambda_{high} = 2.998\times10^{8}/0.29059732 \;\Rightarrow\;$ $\underline{\mathbf{f_{high} = 1031.66815\ MHz}}$

Try a segment for every 5° of arc, # of segments will be $N = 360°/5° \;\Rightarrow\;$ $\underline{\mathbf{N = 72}}$

Segment length $\Delta = C/N = 58.119464\text{ cm}/72 \;\Rightarrow\;$ $\underline{\mathbf{\Delta = 0.8072\ cm}}$

Check to see if the resulting segment length Δ is acceptable.

$\Delta / b = 0.8072\times10^{-2} / 0.645423\times10^{-3} = 12.5065$ (OK, but use EK 0 command)

$2\pi b/ \lambda_{high} = 2\pi(0.645423\times10^{-3}) / 0.29059732 = 0.01396 << 1/10$ (~OK)

$2\pi b/ \lambda_{low} = 2\pi(0.645423\times10^{-3}) / 5.8119464 = 0.0006978 << 1/10$ (OK)

$\Delta / \lambda_{high} = 0.8072\times10^{-2} / 0.29059732 = 0.02778 = 1/36 < 1/10$ (OK)

$\Delta / \lambda_{low} = 0.8072\times10^{-2} / 5.8119464 = 0.0013889 = 1/720 < 1/10$ (OK)

NEC-2 input file

```
CM 18_5cm_16awg_loop_zin.txt
CM
CM This file is used to determine the input impedance
CM for ka = 0.1 (51.5834 MHz) to ka = 2 (1031.66815 MHz)
CM for a 16 AWG loop antenna with a diameter of 18.5 cm,
CM wire radius = 0.645423 mm,& wire conductivity = 5*10^7 S/m,
CM
CM Place the loop on the x-y plane with the drive point
CM where it crosses the positive x-axis.  DRIVEN SEGMENT IS #1.
CM Used 72 segments. segment length = 0.8072 cm
CE
GA 1 72 9.25e-2 -2.5 357.5 0.645423e-3 ! Make 9.25cm radius loop
GM 0 0 90.0 0 0 0 0 0 ! Rotate loop onto x-y plane
GE 0 ! No ground plane
EK 0 ! Extended kernel
FR 0 20 0 0 51.5834 10.0 ! Go in 10MHz steps using multiple runs
EX 0 1 1 01 1.0 0.0 ! voltage excitation on segment 1
LD 5 0 0 0 5.0e7    ! conductivity loading
PT -1  ! suppress currents
XQ 0   ! execute
EN
```

The data generated was imported into MS-Excel and plotted. Plots of R_{ant} and X_{ant} versus ka are on the next page.

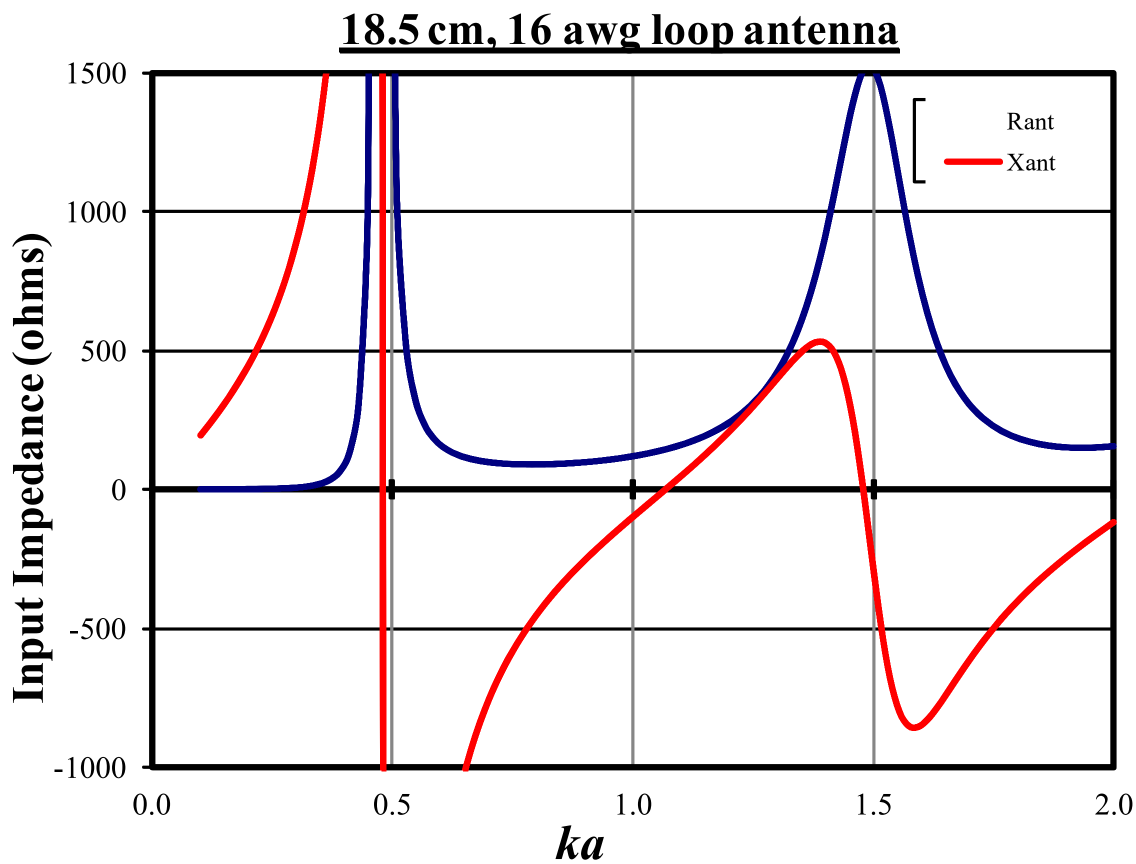


Figure 1 Close-up of input impedance versus *ka*

b) Calculations and table follow with the anti-resonant and resonant frequencies (*ka* and in MHz) in this range. Then, the R_{ant}, R_{rad}, R_{loss}, and the antenna efficiency at *ka* = 0.1 and the resonant frequencies are determined.

At ***ka* = 0.1 (small loop)**, calculate R_{rad} and R_{loss}. From the NEC-2 output file:

<snip>

```
         FREQUENCY= 5.1583E+01 MHZ
         WAVELENGTH= 5.8119E+00 METERS
```

<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.              (W)
1  1 1.0 0.0 8.59517E-06-5.05235E-03 3.36718E-01 1.97927E+02 8.59517E-06-5.05235E-03 4.29758E-06

      - - - POWER BUDGET - - -
      INPUT POWER    = 4.2976E-06 WATTS
      RADIATED POWER= 2.8156E-07 WATTS
      STRUCTURE LOSS= 4.0160E-06 WATTS
      EFFICIENCY     =    6.55 PERCENT
```

So, |I| = 0.005052357 A, and

$R_r = 2\,P_{rad} / |I|^2 = 2(2.8156E\text{-}07)/\ 0.005052357^2 \quad \Rightarrow \quad R_r = 0.02206\ \Omega$

$R_L = 2\,P_{loss} / |I|^2 = 2(4.0160E\text{-}06)/\ 0.005052357^2 \quad \Rightarrow \quad R_L = 0.314656\ \Omega$

****

At ***ka* = 0.468 (anti-resonant)**, calculate R_{rad} and R_{loss}. From the NEC-2 output file:

<snip>

```
        FREQUENCY= 2.4158E+02 MHZ
        WAVELENGTH= 1.2410E+00 METERS
```

<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.             (W)
1  1 1.00 0.0 2.72530E-05-3.59604E-05 1.33864E+04 1.76633E+04 2.72530E-05-3.59604E-05 1.36265E-05

     - - - POWER BUDGET - - -
     INPUT POWER   = 1.3627E-05 WATTS
     RADIATED POWER= 1.3186E-05 WATTS
     STRUCTURE LOSS= 4.4079E-07 WATTS
     NETWORK LOSS  = 0.0000E+00 WATTS
     EFFICIENCY    =  96.77 PERCENT
```

So, |I| = 0.000045121 A, and

$R_r = 2\,P_{\mathrm{rad}} / |I|^2 = 2(1.3186\text{E-}05)/\,0.000045121^2$ $\Rightarrow$ $R_r = 12953.455\ \Omega$

$R_L = 2\,P_{\mathrm{loss}} / |I|^2 = 2(4.4079\text{E-}07)/\,0.000045121^2$ $\Rightarrow$ $R_L = 433.016\ \Omega$

****

At ***ka* = 1.065 (resonant #1)**, calculate R_{rad} and R_{loss}. From the NEC-2 output file:

<snip>

```
     FREQUENCY= 5.494E+02 MHZ
     WAVELENGTH= 5.4569E-01 METERS
```

<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.             (W)
1   1 1.00 0.00 6.97382E-03-1.93857E-06 1.43393E+02 3.98602E-02 6.97382E-03-1.93857E-06 3.48691E-03

    - - - POWER BUDGET - - -
INPUT POWER   = 3.4869E-03 WATTS
RADIATED POWER= 3.4753E-03 WATTS
STRUCTURE LOSS= 1.1581E-05 WATTS
EFFICIENCY    =  99.67 PERCENT
```

So, |I| = 0.00697382 A, and

$R_{\mathrm{rad}} = 2\,P_{\mathrm{rad}} / |I|^2 = 2(3.4753\text{E-}03)/\,0.00697382^2$ $\Rightarrow$ $R_r = 142.916\ \Omega$

$R_{\mathrm{loss}} = 2\,P_{\mathrm{loss}} / |I|^2 = 2(1.1581\text{E-}05)/\,0.00697382^2$ $\Rightarrow$ $R_L = 0.476\ \Omega$

****

At ***ka* = 1.479 (resonant #2)**, calculate R_{rad} and R_{loss}. From the NEC-2 output file:

<snip>

```
      - - - - - - FREQUENCY - - - - - -
    FREQUENCY= 7.6304E+02 MHZ
    WAVELENGTH= 3.9290E-01 METERS

      - - - ANTENNA INPUT PARAMETERS - - -
TAG SEG VOLTAGE (V) CURRENT (A)        IMPEDANCE (OHMS)    ADMITTANCE (MHOS)      POWER
NO. NO. REAL IMAG.  REAL  IMAG.        REAL         IMAG.  REAL   IMAG.             (W)
1  1 1.00 0.00 6.62672E-04 1.31405E-09 1.50904E+03-2.99237E-03 6.62672E-04 1.31405E-09 3.31336E-04

       - - - POWER BUDGET - - -
       INPUT POWER    = 3.3134E-04 WATTS
       RADIATED POWER= 3.3022E-04 WATTS
       STRUCTURE LOSS= 1.1141E-06 WATTS
       EFFICIENCY     =  99.66 PERCENT
```

So, |I| = 0.000662672 A, and

$R_{\text{rad}} = 2\,P_{\text{rad}} / |I|^2 = 2(3.3022\text{E-}04)/\ 0.000662672^2 \quad \Rightarrow \quad R_r = 1503.959\ \Omega$

$R_{\text{loss}} = 2\,P_{\text{loss}} / |I|^2 = 2(1.1141\text{E-}06)/\ 0.000662672^2 \quad \Rightarrow \quad R_L = 5.074\ \Omega$

****

EE 483 only:

ka	***f* (MHz)**	**R_{ant} (ohms)**	**X_{ant} (ohms)**	**η (%)**	**Description**
0.1	51.5834	0.337	197.927	6.55	small loop
0.468	241.583	13386.4	17663.3	96.77	anti-resonant
1.065	549.4	143.393	0.03986	99.67	resonant #1
1.479	763.045	1509.04	-0.00299	99.66	resonant #2

EE 583 only:

ka	***f* (MHz)**	**R_{ant} (ohms)**	**X_{ant} (ohms)**	**R_{rad} (ohms)**	**R_{loss} (ohms)**	**η (%)**	**Description**
0.1	51.5834	0.337	197.927	0.02206	0.31466	6.55	small loop
0.468	241.583	13386.4	17663.3	12953.455	433.016	96.77	anti-resonant
1.065	549.4	143.393	0.03986	142.916	0.476	99.67	resonant #1
1.479	763.045	1509.04	-0.00299	1503.959	5.074	99.66	resonant #2

****

c) Determine the current distribution at $ka = 0.1$ and the first resonant frequency. On a single graph, plot the <u>normalized</u> current magnitudes (normalize each trace independently so its maximum is 1) versus the fractional circumference (e.g., $0 \le$ distance/circumference < 1).

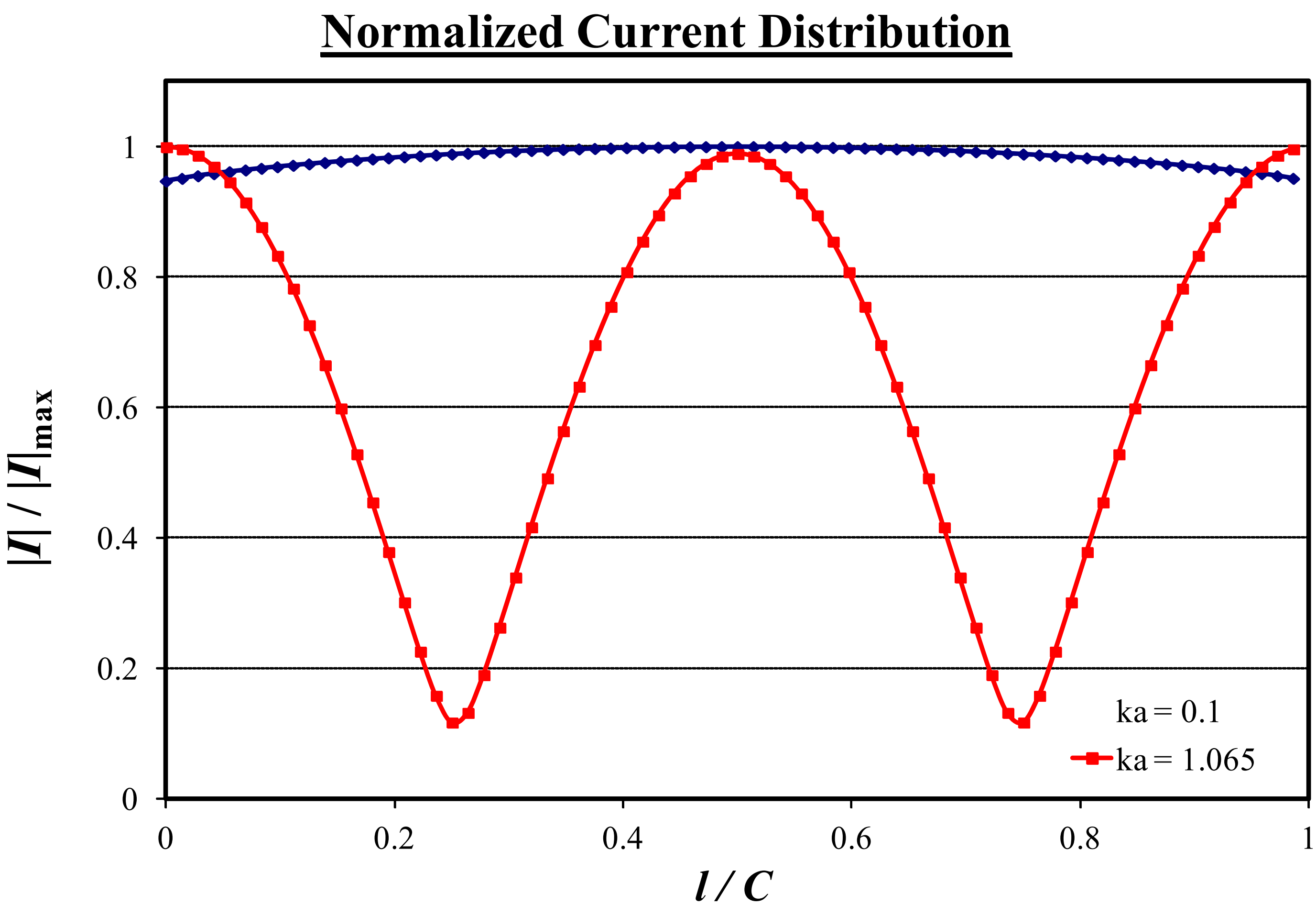
NEC-2 input file

```
CM 18_5cm_16awg_loop_Imag.txt
CM
CM This file is used to determine the input impedance
CM for ka = 0.1 (51.5834 MHz) & ka = 1.065 (549.4 MHz)
CM for a 16 AWG loop antenna with a diameter of 18.5 cm,
CM wire radius = 0.645423 mm,& wire conductivity = 5*10^7 S/m,
CM
CM Place the loop on the x-y plane with the drive point
CM where it crosses the positive x-axis.  DRIVEN SEGMENT IS #1.
CM Used 72 segments. segment length = 0.8072 cm
CE
GA 1 72 9.25e-2 -2.5 357.5 0.645423e-3 ! Make 9.25cm radius loop
GM 0 0 90.0 0 0 0 0 0 ! Rotate loop onto x-y plane
GE 0 ! No ground plane
EK 0 ! Extended kernel
FR 0 2 0 0 51.5834 497.8166 ! two freqs
EX 0 1 1 01 1.0 0.0 ! voltage excitation on segment 1
LD 5 0 0 0 5.0e7    ! conductivity loading
XQ 0   ! execute
EN
```

The current data generated was imported into MS-Excel and plotted as shown.

SEG. NO.	fractional circumference	ka = 0.1, f = 51.5834 MHz |I| (A)	|I| / |I|max	ka = 1.065, f = 549.4 MHz |I| (A)	|I| / |I|max
1	0	0.0050524	0.947189	0.0069738	1.000000
2	0.013888889	0.0050745	0.951332	0.0069514	0.996788
3	0.027777778	0.0050956	0.955288	0.0068829	0.986965
4	0.041666667	0.005113	0.958550	0.0067652	0.970088
5	0.055555556	0.0051287	0.961493	0.0065983	0.946156
6	0.069444444	0.0051431	0.964193	0.0063829	0.915269
7	0.083333333	0.0051567	0.966742	0.0061203	0.877613
8	0.097222222	0.0051694	0.969123	0.0058123	0.833448
9	0.111111111	0.0051815	0.971392	0.0054612	0.783102
10	0.125	0.0051929	0.973529	0.0050698	0.726978
11	0.138888889	0.0052038	0.975572	0.0046413	0.665534
12	0.152777778	0.0052141	0.977503	0.0041795	0.599315
13	0.166666667	0.0052239	0.979340	0.0036886	0.528923
14	0.180555556	0.0052332	0.981084	0.0031741	0.455146
15	0.194444444	0.0052421	0.982752	0.0026427	0.378947
16	0.208333333	0.0052505	0.984327	0.0021043	0.301744
17	0.222222222	0.0052584	0.985808	0.0015771	0.226146
18	0.236111111	0.005266	0.987233	0.0011052	0.158479
19	0.25	0.0052731	0.988564	0.00081877	0.117407
20	0.263888889	0.0052798	0.989820	0.00092268	0.132307

21	0.277777778	0.0052861	0.991001	0.0013263	0.190183
22	0.291666667	0.0052919	0.992089	0.0018345	0.263056
23	0.305555556	0.0052974	0.993120	0.0023707	0.339944
24	0.319444444	0.0053025	0.994076	0.0029075	0.416918
25	0.333333333	0.0053072	0.994957	0.0034318	0.492099
26	0.347222222	0.0053115	0.995763	0.0039355	0.564326
27	0.361111111	0.0053155	0.996513	0.0044124	0.632711
28	0.375	0.005319	0.997169	0.0048576	0.696550
29	0.388888889	0.0053222	0.997769	0.005267	0.755255
30	0.402777778	0.005325	0.998294	0.0056368	0.808282
31	0.416666667	0.0053274	0.998744	0.0059638	0.855172
32	0.430555556	0.0053295	0.999138	0.0062453	0.895538
33	0.444444444	0.0053311	0.999438	0.0064788	0.929020
34	0.458333333	0.0053325	0.999700	0.0066625	0.955361
35	0.472222222	0.0053334	0.999869	0.0067948	0.974333
36	0.486111111	0.0053339	0.999963	0.0068746	0.985775
37	0.5	0.0053341	**1.000000**	0.0069013	0.989604
38	0.513888889	0.0053339	0.999963	0.0068746	0.985775
39	0.527777778	0.0053334	0.999869	0.0067948	0.974333
40	0.541666667	0.0053325	0.999700	0.0066625	0.955361
41	0.555555556	0.0053311	0.999438	0.0064788	0.929020
42	0.569444444	0.0053295	0.999138	0.0062453	0.895538
43	0.583333333	0.0053274	0.998744	0.0059638	0.855172
44	0.597222222	0.005325	0.998294	0.0056368	0.808282
45	0.611111111	0.0053222	0.997769	0.005267	0.755255
46	0.625	0.005319	0.997169	0.0048576	0.696550
47	0.638888889	0.0053155	0.996513	0.0044124	0.632711
48	0.652777778	0.0053115	0.995763	0.0039355	0.564326
49	0.666666667	0.0053072	0.994957	0.0034318	0.492099
50	0.680555556	0.0053025	0.994076	0.0029075	0.416918
51	0.694444444	0.0052974	0.993120	0.0023707	0.339944
52	0.708333333	0.0052919	0.992089	0.0018345	0.263056
53	0.722222222	0.0052861	0.991001	0.0013263	0.190183
54	0.736111111	0.0052798	0.989820	0.00092268	0.132307
55	0.75	0.0052731	0.988564	0.00081877	0.117407
56	0.763888889	0.005266	0.987233	0.0011052	0.158479
57	0.777777778	0.0052584	0.985808	0.0015771	0.226146
58	0.791666667	0.0052505	0.984327	0.0021043	0.301744
59	0.805555556	0.0052421	0.982752	0.0026427	0.378947
60	0.819444444	0.0052332	0.981084	0.0031741	0.455146
61	0.833333333	0.0052239	0.979340	0.0036886	0.528923
62	0.847222222	0.0052141	0.977503	0.0041795	0.599315
63	0.861111111	0.0052038	0.975572	0.0046413	0.665534
64	0.875	0.0051929	0.973529	0.0050698	0.726978
65	0.888888889	0.0051815	0.971392	0.0054612	0.783102
66	0.902777778	0.0051694	0.969123	0.0058123	0.833448
67	0.916666667	0.0051567	0.966742	0.0061203	0.877613
68	0.930555556	0.0051431	0.964193	0.0063829	0.915269
69	0.944444444	0.0051287	0.961493	0.0065983	0.946156
70	0.958333333	0.005113	0.958550	0.0067652	0.970088
71	0.972222222	0.0050956	0.955288	0.0068829	0.986965
72	0.986111111	0.0050745	0.951332	0.0069514	0.996788
	Imax =	**0.0053341**	**Imax =**	**0.0069738**	



****

d) Extra credit: At *ka* = 0.1 and the first resonant frequency, determine the far-zone E-plane (*x-y* plane) and H-plane (*x-z* plane) power gain radiation patterns (in dBi). On two polar graphs, plot the relative power radiation patterns for the E-plane and H-plane scaled so that the center of each plot is at –30 dB and the outer ring is at 0 dB. Tabulate the maximum and minimum gain in each plane at each frequency.

```
CM 18_5cm_16awg_loop_rad_small.txt
CM
CM This file is used to determine the E-plane (x-y) and
CM H-plane (x-z) radiation patterns for ka = 0.1 (51.5834 MHz)
CM for a 16 AWG loop antenna with diameter of 18.5 cm
CM (loop radius= a = 9.25 cm), wire radius = 0.645423 mm, and
CM wire conductivity = 5*10^7 S/m.
CM
CM Place the loop on the x-y plane with drive point where it
CM crosses the positive x-axis.  DRIVEN SEGMENT IS #1.
CM Used 72 segments. segment length = 0.8072 cm
CE
GA 1 72 9.25e-2 -2.5 357.5 0.645423e-3 ! Make 9.25cm radius loop
```

```
GM 0 0 90.0 0 0 0 0 0 ! Rotate loop onto x-y plane
GE 0 ! No ground plane
EK 0 ! Extended kernel
FR 0 1 0 0 51.5834 0.0 ! ka=0.1 freq
EX 0 1 1 01 1.0 0.0 ! voltage excitation on segment 1
LD 5 0 0 0 5.0e7    ! conductivity loading
PT -1 !suppress currents
RP 0 1 360 0000   90.0  0.0 0.0 1.0 ! x-y plane vs phi
RP 0 360 1 0000 -179.0  0.0 1.0 0.0 ! x-z plane vs theta
EN

CM 18_5cm_16awg_loop_rad_resonant.txt
CM
CM This file is used to determine the E-plane (x-y) and
CM H-plane (x-z) radiation patterns for ka = 1.065 (549.4 MHz)
CM for a 16 AWG loop antenna with diameter of 18.5 cm
CM (loop radius= a = 9.25 cm), wire radius = 0.645423 mm, and
CM wire conductivity = 5*10^7 S/m.
CM
CM Place the loop on the x-y plane with drive point where it
CM crosses the positive x-axis.  DRIVEN SEGMENT IS #1.
CM Used 72 segments. segment length = 0.8072 cm
CE
GA 1 72 9.25e-2 -2.5 357.5 0.645423e-3 ! Make 9.25cm radius loop
GM 0 0 90.0 0 0 0 0 0 ! Rotate loop onto x-y plane
GE 0 ! No ground plane
EK 0 ! Extended kernel
FR 0 1 0 0 549.4 0.0 ! resonant freq
EX 0 1 1 01 1.0 0.0 ! voltage excitation on segment 1
LD 5 0 0 0 5.0e7    ! conductivity loading
PT -1 !suppress currents
RP 0 1 360 0000   90.0  0.0 0.0 1.0 ! x-y plane vs phi
RP 0 360 1 0000 -179.0  0.0 1.0 0.0 ! x-z plane vs theta
EN
```

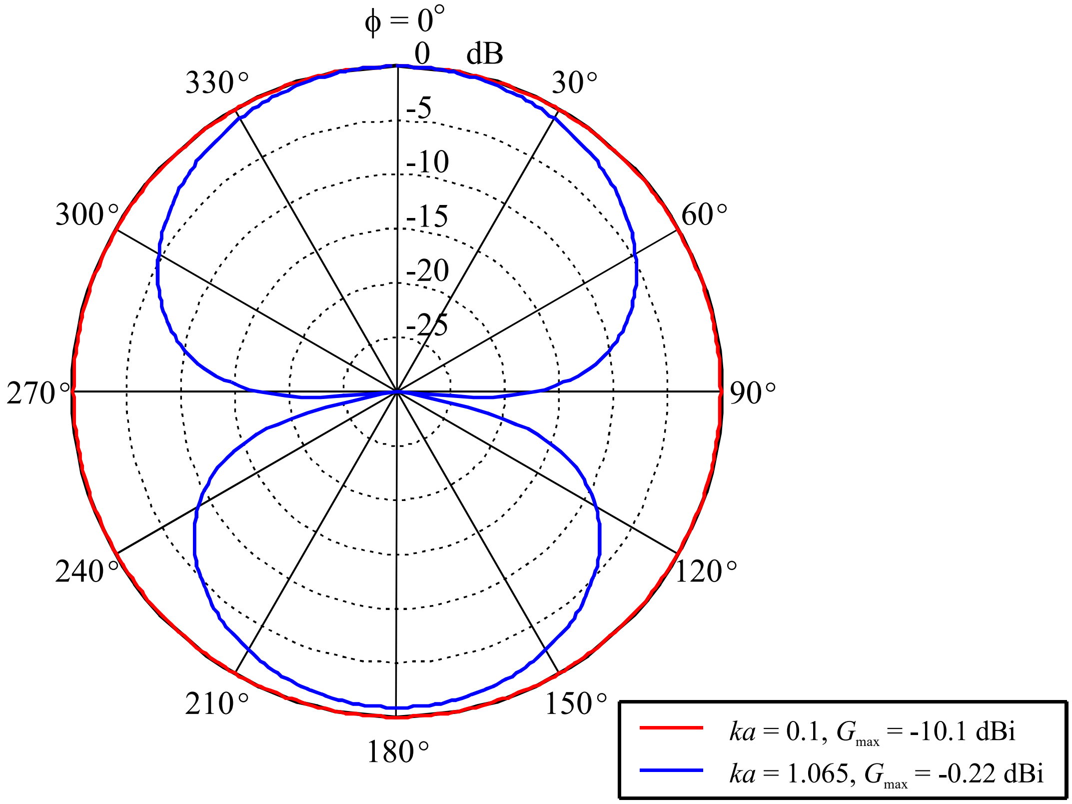
			E-Plane (*x-y* plane wrt ϕ at $\theta = 90°$		H-Plane (*y-z* plane wrt θ at $\phi = 90°$	
Description	*ka*	*f* (MHz)	G_{max} (dBi)	G_{min} (dBi)	G_{max} (dBi)	G_{min} (dBi)
small loop	0.1	51.5834	-10.10	-10.23	-10.11	-24.12
resonant #1	1.065	549.4	-0.22	-34.73	3.67	-1.12

- Put radiation pattern data into MS-Excel spreadsheet, pre-normalized and saved stripped down data to 5-column MS-DOS *.txt files with angle (deg), ka = 0.1 gain (dBi), ka = 1.065 (dBi) gain, ka = 0.1 normalized gain (dB), & ka = 1.065 normalized gain (dB).

```
% H_plane_18_5cm_16AWG_loop.m
% Plot H-plane radiation pattern (wrt theta at phi = 0) for
% 18.5 cm 16 AWG loop at small ka=0.1 (f=51.5834 MHz) and
% resonant ka=1.065 (f=549.4 MHz) frequencies.
clear; clc; close all;
M = dlmread('18_5cm_16AWG_loop_H_plane_rad_patt_data.txt');
for i =1:360
  theta(i) = M(i,1);
  Gsmall(i) = M(i,4);
  Gres(i) = M(i,5);
end
% ******* Plot Radiation Patterns in dB format *******
radpat(theta,Gsmall,'r-',theta,Gres,'b-')
%
set(findobj('type','line'),'linewidth',1.5)
set(findobj('type','axes'),'linewidth',2)
```

```
% E_plane_18_5cm_16AWG_loop.m
% Plot E-plane radiation pattern
% (wrt phi at theta = 90 deg) for
% 18.5 cm 16 AWG loop at small ka=0.1 (f=51.5834 MHz) and
% resonant ka=1.065 (f=549.4 MHz) frequencies.
clear; clc; close all;
M = dlmread('18_5cm_16AWG_loop_E_plane_rad_patt_data.txt');
for i =1:360
  phi(i) = M(i,1);
  Gsmall(i) = M(i,4);
  Gres(i) = M(i,5);
end
% ******* Plot Radiation Patterns in dB format *******
radpat(phi,Gsmall,'r-',phi,Gres,'b-')
%
set(findobj('type','line'),'linewidth',1.5)
set(findobj('type','axes'),'linewidth',2)
```

E-plane (*x*-*y* plane)



H-plane (*x*-*z* plane)