worksheet 5.5 page 1

$\mu_o := 4\cdot\pi\cdot 10^{-7}$ H/m $\qquad \varepsilon_o := 8.854\cdot 10^{-12}$ F/m $\qquad c := 2.998\cdot 10^{8}$ m/s

$\rho := 1.7\cdot 10^{-8}\ \Omega$ m $\qquad l := 15$ m $\qquad h := 10\cdot 10^{-3}$ m

$s := 1.2\cdot 10^{-3}$ m $\qquad r := 0.4\cdot 10^{-3}$ m $\qquad$ see figure 4.3.1

$$Rss_1 := \frac{\rho\cdot l}{\pi\cdot r^2}\ \Omega \qquad Rss_2 := Rss_1 \qquad Rss_3 := 0.005\ \Omega \qquad \text{equation (2.5.11)}$$

$$Fx := \frac{4\cdot\rho}{\mu_o\cdot\pi\cdot r^2} = 1.077\times 10^{5}\ \text{Hz} \qquad \text{equation (2.5.14)}$$

$$Lc_1 := \frac{\mu_o\cdot l}{2\cdot\pi}\cdot\ln\left(\frac{2\cdot h\cdot s}{r\cdot\sqrt{s^2+4\cdot h^2}}\right) \qquad Lc_2 := Lc_1$$

$$Lc_3 := \frac{\mu_o\cdot l}{2\cdot\pi}\cdot\ln\left(\frac{\sqrt{s^2+4\cdot h^2}}{s}\right) \qquad \text{equation (2.11.3)}$$

$$Cc := \frac{1}{Lc}\cdot\left(\frac{l}{c}\right)^2 \qquad \text{equation (2.3.8)}$$

$$Fq := \frac{1}{4\cdot\sqrt{Lc_1\cdot Cc_1}} = 4.997\times 10^{6}\ \text{Hz} \qquad \text{equation (2.3.9)}$$

Component values for three-conductor assembly of figure 5.5.2:-

$$\frac{Rss}{2} = \begin{pmatrix} 0.254 \\ 0.254 \\ 2.5\times 10^{-3} \end{pmatrix} \qquad \frac{Lc}{2} = \begin{pmatrix} 1.645\times 10^{-6} \\ 1.645\times 10^{-6} \\ 4.223\times 10^{-6} \end{pmatrix} \qquad Cc = \begin{pmatrix} 7.608\times 10^{-10} \\ 7.608\times 10^{-10} \\ 2.964\times 10^{-10} \end{pmatrix}$$

$$Zn := \begin{pmatrix} 132 \\ 0 \\ 0 \end{pmatrix}\ \Omega \qquad Zf := \begin{pmatrix} 132 \\ 0 \\ 0 \end{pmatrix}\ \Omega \qquad Gc := \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}\ \text{mho} \qquad Rrad := 50\ \Omega$$

Figure 5.5.3 Calculating parameter values for the three-conductor circuit model worksheet 5.5 page 2

$$
\mathrm{Zbranch}(f) := \left|\begin{array}{l}
\omega \leftarrow 2\cdot\pi\cdot f \\
\text{for } i \in 1..3 \\
\quad \left|\begin{array}{l}
Rc_i \leftarrow Rss_i\cdot\sqrt{1+\dfrac{f}{Fx}} \\
\theta \leftarrow \sqrt{(Rc_i + j\cdot\omega\cdot Lc_i)\cdot(Gc_i + j\cdot\omega\cdot Cc_i)} \\
Zo \leftarrow \sqrt{\dfrac{Rc_i + j\cdot\omega\cdot Lc_i}{Gc_i + j\cdot\omega\cdot Cc_i}} \\
Z_{1,i} \leftarrow Zo\cdot\tanh\left(\dfrac{\theta}{2}\right) \\
Z_{2,i} \leftarrow Zo\cdot\mathrm{csch}(\theta)
\end{array}\right. \\
Z
\end{array}\right.
$$

$$
\mathrm{Zloop}(f) := \left|\begin{array}{l}
Z \leftarrow \mathrm{Zbranch}(f) \\
Z11 \leftarrow Zn_1 + Z_{1,1} + Z_{2,1} + Z_{2,2} + Z_{1,2} + Zn_2 \\
Z12 \leftarrow -(Z_{1,2} + Z_{2,2} + Zn_2) \\
Z13 \leftarrow -(Z_{2,1} + Z_{2,2}) \\
Z14 \leftarrow Z_{2,2} \\
Z22 \leftarrow Zn_2 + Z_{1,2} + Z_{2,2} + Z_{2,3} + Z_{1,3} + Zn_3 + Rrad \\
Z23 \leftarrow Z_{2,2} \\
Z24 \leftarrow -(Z_{2,2} + Z_{2,3}) \\
Z33 \leftarrow Zf_2 + Z_{1,2} + Z_{2,2} + Z_{2,1} + Z_{1,1} + Zf_1 \\
Z34 \leftarrow -(Z_{1,2} + Z_{2,2} + Zf_2) \\
Z44 \leftarrow Zf_3 + Z_{1,3} + Z_{2,3} + Z_{2,2} + Z_{1,2} + Zf_2 \\
\begin{pmatrix} Z11 & Z12 & Z13 & Z14 \\ Z12 & Z22 & Z23 & Z24 \\ Z13 & Z23 & Z33 & Z34 \\ Z14 & Z24 & Z34 & Z44 \end{pmatrix}
\end{array}\right.
$$

Figure 5.5.6 Calculating the values of the branch and loop parameters

$S := 1$

$$\mathrm{Vthreat}(f) := \left| \begin{array}{l} \lambda \leftarrow \dfrac{c}{f} \\ Va \leftarrow \sqrt{S \cdot 377} \cdot \dfrac{\lambda}{\pi} \\ Vb \leftarrow Va \sin\left(2 \cdot \pi \cdot \dfrac{l}{\lambda}\right) \\ Vb \leftarrow Va \quad \text{if } l > \dfrac{\lambda}{4} \end{array} \right.$$

Calculating the threat voltage
for a power density S
at a frequency f.

See figure 5.3.6.

$n := 100 \qquad s := 1 .. 20 \cdot n \qquad F_s := s \cdot \dfrac{Fq}{n}$

defining the frequency range

$$Iout_s := \left| \begin{array}{l} f \leftarrow F_s \\ Z \leftarrow \mathrm{Zloop}(f) \\ V \leftarrow \begin{pmatrix} 0 \\ \mathrm{Vthreat}(f) \\ 0 \\ 0 \end{pmatrix} \\ I \leftarrow \mathrm{lsolve}(Z, V) \\ \left|I_1\right| \end{array} \right.$$

Main program

Figure 5.5.7 Calculating the frequency response of the common-mode current

$\max(Iout) = 0.566$

Calculating I_1/V_2 for figure 5.5.5

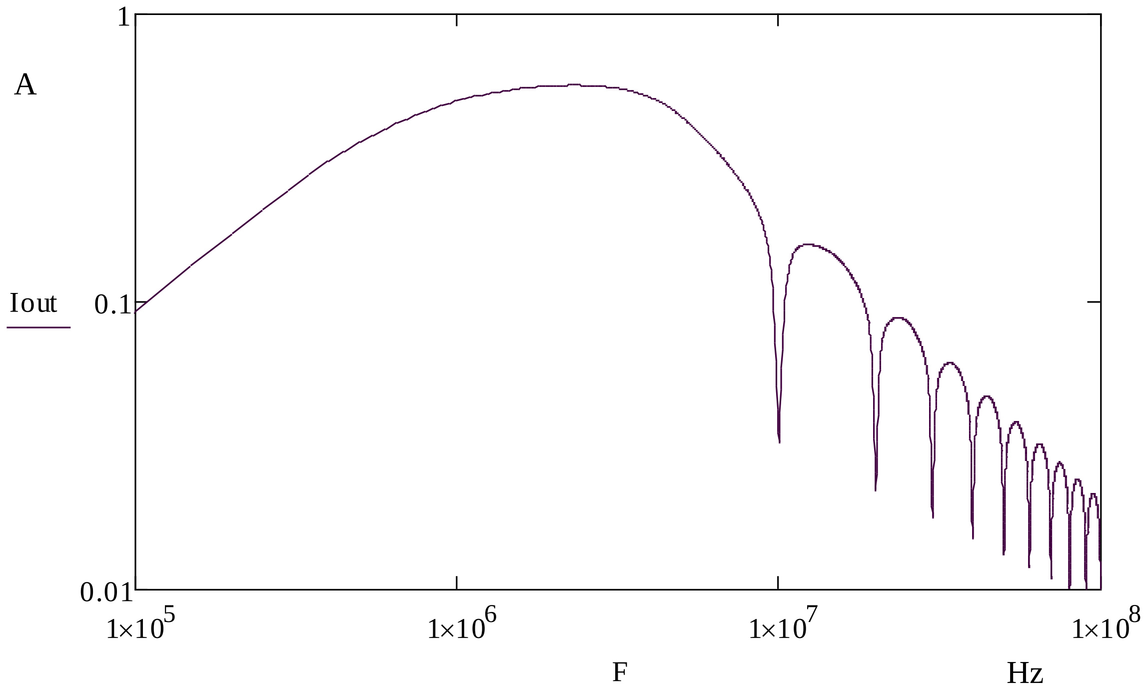

Figure 5.5.9 Frequency response of interference current in differential-mode loop