Çankaya University
Electrical & Electronics Engineering Department
Solutions to EE 322 Energy Distribution Homework 1 and 2

HW1-1

$$\text{(a)}\quad GMR=\sqrt[9]{\left[\left(e^{-\frac{1}{4}}r\right)(2r)(2r)\right]^{3}}=r\sqrt[3]{4e^{-\frac{1}{4}}}$$

$$=\underline{\underline{1.4605\,r}}$$

$$\text{(b)}\quad GMR=\sqrt[16]{\left[\underbrace{\left(e^{-\frac{1}{4}}r\right)(2r)(4r)(6r)}_{\text{Distances for each outer conductor}}\right]^{2}\left[\underbrace{\left(e^{-\frac{1}{4}}r\right)(2r)(2r)(4r)}_{\text{Distances for each inner conductor}}\right]^{2}}$$

$$GMR=\sqrt[16]{\left(e^{-\frac{1}{4}}\right)^{4}(2)^{6}(4)^{4}(6)^{2}}\,(r)=\underline{\underline{2.1554r}}$$

(c) $$GMR = r\sqrt[81]{\left[\underbrace{\left(e^{-\frac{1}{4}}\right)(2)^2(4)^2\left(\sqrt{20}\right)^2\left(\sqrt{8}\right)\left(\sqrt{32}\right)}_{\text{Distances for each corner conductor}}\right]^4 \times \left[\underbrace{\left(e^{-\frac{1}{4}}\right)(2)^3\left(\sqrt{8}\right)^2\left(\sqrt{20}\right)^2(4)}_{\text{Distances for each outside non-corner conductor}}\right]^4 \times \left[\underbrace{\left(e^{-\frac{1}{4}}\right)(2)^4\left(\sqrt{8}\right)^4}_{\text{Distances for the center conductor}}\right]}$$

$$GMR = r\sqrt[81]{\left(e^{-\frac{1}{4}}\right)^9 (2)^{24}\left(\sqrt{8}\right)^{16}\left(\sqrt{20}\right)^{16}(4)^{12}\left(\sqrt{32}\right)^4}$$

$$GMR = \underline{\underline{2.6374\,r}}$$

HW1-2

$$D_{AB} = \sqrt[9]{(6.1)^2(6.2)^2(6.3)6(6.05)(6.15)(6.25)} = 6.15\text{m}$$

The geometric mean radius of the equilateral arrangement of line A is

$$R_A = \sqrt[9]{(0.015576)^3(0.1)^6} = 0.0538\text{m}$$

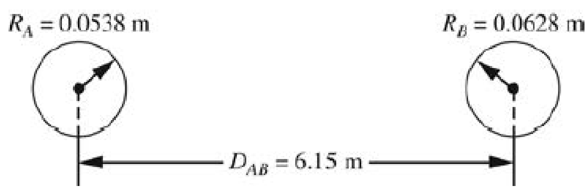
In which the first term beneath the radical is obtained from

$$r' = 0.7788 \quad r = 0.7788(0.02) = 0.015576\text{m}$$

The geometric mean radius of the line B is calculated below as per its configuration:

$$R_B = \sqrt[9]{(0.015576)^3(0.1)^4(0.2)^2} = 0.0628\text{m}$$

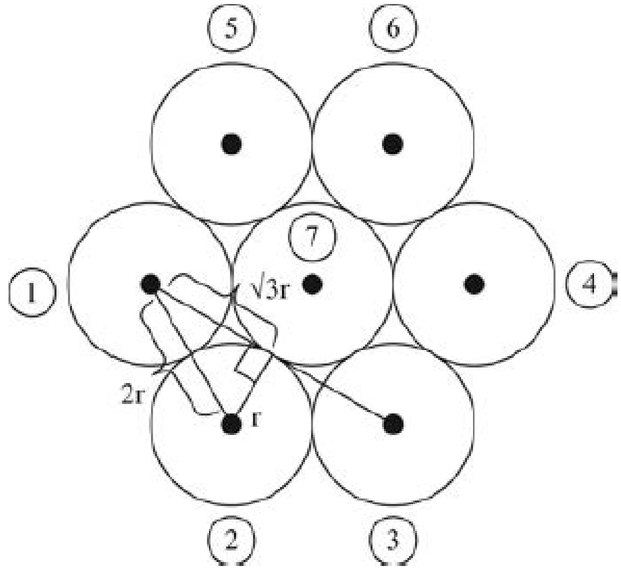
The actual configuration can now be replaced by the two equivalent hollow conductors each with its own geometric mean radius and separated by the geometric mean distance as shown below:



HW1-3

For each of six outer conductors:

$$D_{11} = r' = e^{-\frac{1}{7}} r$$
$$D_{12} = D_{16} = D_{17} = 2r$$
$$D_{13} = D_{15} = 2\sqrt{3}r$$
$$D_{14} = 4r$$



HW2-1

(a) The total line inductance is given by

$$L_T = \left[4\times10^{-4} \ln\frac{D}{r'} \right] \text{mH/m}$$

$$= 4\times10^{-4} \ln\frac{3.6}{(0.7788)(0.023)} = 0.0021 \text{mH/m}$$

(b) The total line reactance is given by

$$X_T = 2\pi(60)4\times10^{-4} \ln\frac{D}{r'}$$

$$= 0.1508 \ln\frac{D}{r'} \Omega/\text{km}$$

$$\text{or} \quad 0.2426 \ln\frac{D}{r'} \Omega/\text{mi}$$

$$\therefore X_T = 0.787\,\Omega/\text{km} \text{ or } 1.266\,\Omega/\text{mi}$$

(c) $L_T = 4\times10^{-4} \ln\dfrac{7.2}{0.7788(0.025)} = 0.002365 \text{ mH/m}$

Doubling the separation between the conductors causes only about a 13% rise in inductance.

Çankaya University
Electrical & Electronics Engineering Department
Solutions to EE 322 Energy Distribution Homework 1 and 2

HW2-2

$$D_{eq} = \sqrt[3]{10\times 10\times 20} = 12.6\,\text{m}$$

$$D_S = (0.0435\,\text{ft})\frac{1\,\text{m}}{3.28\,\text{ft}} = 0.0133\,\text{m}$$

$$X_1 = \omega L_1 = 2\pi(60)2\times 10^{-7}\ln\left(\frac{12.6}{0.149}\right)\frac{\Omega}{\text{m}}\times\frac{1000\,\text{m}}{1\,\text{km}}$$

$$= 0.335\,\Omega/\text{km}$$

HW2-3

$$D_{eq} = \sqrt[3]{10\times 10\times 20} = 12.6\,\text{m}$$

$$r = \frac{1.293}{2}\,\text{in}\left(\frac{0.0254\,\text{m}}{1\,\text{in}}\right) = 0.01642\,\text{m}$$

$$D_{SC} = \sqrt[3]{rd^2} = \sqrt[3]{0.01642(0.5)^2} = 0.16\,\text{m}$$

$$C_1 = \frac{2\pi\varepsilon_0}{\ln\frac{D_{eq}}{D_{Sc}}} = \frac{2\pi\left(8.854\times 10^{-12}\right)}{\ln\left(\frac{12.6}{0.16}\right)} = 1.275\times 10^{-11}\,\text{F/m}$$

$$\overline{Y}_1 = j\omega C_1 = j2\pi(60)1.275\times 10^{-11}(1000) = j4.807\times 10^{-6}\,\text{S/km}$$

$$Q_1 = V_{LL}{}^2 Y_1 = (500)^2\,4.807\times 10^{-6} = 1.2\,\text{MVAR/km}$$