(16) EQUATION

Given

$j\cdot\omega\cdot L_s\cdot I_{ss} - j\cdot\omega\cdot M\cdot I_{cs} + R_s\cdot I_{ss} + V_{CMs} = 0$ . . . . 1st Loop

$\mathrm{Find}(j\cdot\omega\cdot M\cdot I_{cs}) \rightarrow j\cdot\omega\cdot L_s\cdot I_{ss} + R_s\cdot I_{ss} + V_{CMs}$ . . . . solve for $j\omega M I_{cs}$

Given

$R_d\cdot I_{cs} + R_c\cdot I_{cs} + j\cdot\omega\cdot L_c\cdot I_{cs} + j\cdot\omega\cdot M\cdot I_{ss} + R_L\cdot I_{cs} - V_{CMs} = 0$ . . . . 2nd Loop

$\mathrm{Find}(R_L\cdot I_{cs}) \rightarrow -R_d\cdot I_{cs} - R_c\cdot I_{cs} - j\cdot\omega\cdot L_c\cdot I_{cs} - j\cdot\omega\cdot M\cdot I_{ss} + V_{CMs}$ . . . . . solve for $R_L I_{cs}$

$-R_d\cdot I_{cs} - R_c\cdot I_{cs} - j\cdot\omega\cdot L_s\cdot I_{ss} + R_s\cdot I_{ss} + V_{CMs} - j\cdot\omega\cdot L_s\cdot I_{ss} + V_{CMs}$ . . . . . sub $j\omega M I_{cs}$ from 1st into 2nd & replace all M & Lc w/ Ls

$-R_d\cdot I_{cs} - R_c\cdot I_{cs} - 2\cdot j\cdot\omega\cdot L_s\cdot I_{ss} + R_s\cdot I_{ss} + 2\cdot V_{CMs}$

↖ simplify

$$\frac{\dfrac{R_s\cdot R_L}{R_s\cdot(R_c+R_d+R_L)}\cdot V_{CMs}}{1+\dfrac{j\cdot\omega}{\left[\dfrac{R_s\cdot(R_c+R_d+R_L)}{L_s\cdot(R_s+R_c+R_d+R_L)}\right]}}$$

Now I took equation #16 and simplified it.

$$R_s\cdot V_{CMs}\cdot\frac{R_L}{(R_s\cdot R_c+R_s\cdot R_d+R_s\cdot R_L+j\cdot\omega\cdot L_s\cdot R_s+j\cdot\omega\cdot L_s\cdot R_c+j\cdot\omega\cdot L_s\cdot R_d+j\cdot\omega\cdot L_s\cdot R_L)}$$

Page 11

M = Ls = Lc / Replaced M and Lc w/ Ls

Given

$$\sqrt{-1}\cdot w\cdot Ls\cdot Is - \sqrt{-1}\cdot w\cdot Ls\cdot Ic + Rs\cdot Is + Vcm = 0$$

$$Rd\cdot Ic + Rc\cdot Ic + \sqrt{-1}\cdot w\cdot Ls\cdot Ic - \sqrt{-1}\cdot w\cdot Ls\cdot Is + RL\cdot Ic - Vcm = 0$$

$$\text{Find}(Ic, Is) \rightarrow \begin{bmatrix} i\cdot Rs\cdot\dfrac{Vcm}{(-Rd\cdot Ls\cdot w - Rc\cdot Ls\cdot w - RL\cdot Ls\cdot w + i\cdot Rs\cdot Rd + i\cdot Rs\cdot Rc - Rs\cdot w\cdot Ls + i\cdot Rs\cdot RL)} \\ -i\cdot Vcm\cdot\dfrac{(Rd + Rc + RL)}{(-Rd\cdot Ls\cdot w - Rc\cdot Ls\cdot w - RL\cdot Ls\cdot w + i\cdot Rs\cdot Rd + i\cdot Rs\cdot Rc - Rs\cdot w\cdot Ls + i\cdot Rs\cdot RL)} \end{bmatrix}$$

$V_L = R_L \cdot I_C$

$$Vcm\cdot\frac{Rs}{(i\cdot Rd\cdot w\cdot Ls + i\cdot w\cdot Ls\cdot Rs + i\cdot RL\cdot w\cdot Ls + Rd\cdot Rs + i\cdot Rc\cdot w\cdot Ls + Rc\cdot Rs + RL\cdot Rs)}\cdot RL$$

Instructor's Expression ⇒

$$\frac{\left[\dfrac{Rs\cdot RL}{Rs\cdot(Rc + Rd + RL)}\cdot Vcm\right]}{1 + \dfrac{\sqrt{-1}\cdot w}{\left[\dfrac{Rs\cdot(Rc + Rd + RL)}{Ls\cdot(Rs + Rc + Rd + RL)}\right]}}$$

page (1b)

$$\frac{Vcm \cdot \dfrac{Rs}{(i \cdot Rd \cdot w \cdot Ls + i \cdot w \cdot Ls \cdot Rs + i \cdot RL \cdot w \cdot Ls + Rd \cdot Rs + i \cdot Rc \cdot w \cdot Ls + Rc \cdot Rs + RL \cdot Rs)} \cdot RL}{\dfrac{\left[\dfrac{Rs \cdot RL}{Rs \cdot (Rc+Rd+RL)} \cdot Vcm\right]}{1+\dfrac{\sqrt{-1} \cdot w}{\left[\dfrac{Rs \cdot (Rc+Rd+RL)}{Ls \cdot (Rs+Rc+Rd+RL)}\right]}}}$$

$$1$$

1st check

From Mathcad, (page 1)

$$V_L = R_L I_c = \frac{R_L R_S \cdot V_{cm}}{(jR_d\omega L_S + j\omega L_S R_S + jR_L\omega L_S + R_d R_S + jR_c\omega L_S + R_c R_S + R_L R_S)}$$

$$= \frac{R_L R_S \cdot V_{cm}}{j\left[R_d\omega L_S + \omega L_S R_S + R_L\omega L_S + R_c\omega L_S\right] + \underbrace{R_d R_S + R_c R_S + R_L R_S}_{R_S(R_d + R_c + R_L)}}$$

$$= \frac{V_{cm}(R_L R_S)}{R_S(R_d + R_c + R_L) + j\omega L_S\left[R_d + R_S + R_L + R_c\right]}$$

$$= \frac{V_{cm}(R_L R_S)}{R_S(R_d + R_c + R_L)\left[1 + \frac{j\omega L_S\left[R_d + R_S + R_L + R_c\right)}{R_S(R_d + R_c + R_L}\right]}$$

$$= \frac{\left(\frac{R_L R_S}{R_S(R_c + R_d + R_L)}\right)V_{cm}}{1 + \frac{j\omega}{\left[\frac{R_S(R_c + R_d + R_L)}{L_S(R_d + R_S + R_L + R_c}\right]}}$$

✓ 2nd Check

Ken Kaiser

$\omega = \emptyset$

$$V_L \approx \frac{\left[\frac{R_S R_L}{R_S(R_c+R_d+R_L)}\right] V_{cm}}{1 + \frac{j(0)}{\frac{R_S(R_c+R_d+R_L)}{L_S(R_S+R_c+R_d+R_L)}}} = \boxed{\left[\frac{R_S R_L}{R_S(R_c+R_d+R_L)}\right] V_{cm}}$$

✓

$\omega \gg 1$

$$V_L \approx \frac{\left(\frac{R_S R_L}{R_S(R_c+R_d+R_L)}\right) V_{cm}}{\frac{j\omega}{\frac{R_S(R_c+R_d+R_L)}{L_S(R_S+R_c+R_d+R_L)}}} = \boxed{\frac{R_S R_L \cdot V_{cm}}{j\omega(L_S(R_S+R_c+R_d+R_L))}}$$

✓

Given

$$-V_{Ds} + R_d \cdot I_{cs} + R_c \cdot I_{cs} + \sqrt{-1} \cdot w \cdot L \cdot I_{cs} - \sqrt{-1}\, w \cdot L \cdot I_{ss} + 0 + R_L \cdot I_{cs} = 0$$

$$\sqrt{-1} \cdot w \cdot L \cdot I_{ss} - \sqrt{-1} \cdot w \cdot L \cdot I_{cs} + R_s \cdot I_{ss} = 0$$

$$\mathrm{Find}(I_{cs}, I_{ss}) \rightarrow \begin{bmatrix} \dfrac{V_{Ds}}{\left(-R_d \cdot w \cdot L + i \cdot R_d \cdot R_s - R_c \cdot w \cdot L + i \cdot R_c \cdot R_s - w \cdot L \cdot R_s - R_L \cdot w \cdot L + i \cdot R_L \cdot R_s\right)} \cdot \left(-w \cdot L + i \cdot R_s\right) \\ -V_{Ds} \cdot w \cdot \dfrac{L}{\left(-R_d \cdot w \cdot L + i \cdot R_d \cdot R_s - R_c \cdot w \cdot L + i \cdot R_c \cdot R_s - w \cdot L \cdot R_s - R_L \cdot w \cdot L + i \cdot R_L \cdot R_s\right)} \end{bmatrix}$$

$w := 3.54$ $\quad L := 4.56$ $\quad R_s := 0.45$ $\quad R_c := 8.94$ $\quad R_d := 2.67$ $\quad R_L := 7.98$ $\quad V_{Ds} := 0.45$

$$-V_{Ds} \cdot w \cdot \frac{L}{\left(-R_d \cdot w \cdot L + i \cdot R_d \cdot R_s - R_c \cdot w \cdot L + i \cdot R_c \cdot R_s - w \cdot L \cdot R_s - R_L \cdot w \cdot L + i \cdot R_L \cdot R_s\right)} = 0.022 + 6.115i \times 10^{-4}$$

$$\frac{\sqrt{-1} \cdot \dfrac{w \cdot L}{R_s \cdot (R_d + R_c + R_L)} \cdot V_{Ds}}{1 + \sqrt{-1} \cdot \dfrac{\dfrac{w}{R_s \cdot (R_d + R_c + R_L)}}{L \cdot (R_d + R_c + R_s + R_L)}} = 0.022 + 6.115i \times 10^{-4}$$

$$\underline{I}_{CS}\,(R_d + R_C + j\omega L + R_L) = V_{DS} + j\omega L\,\underline{I}_{SS}$$

$$\underline{I}_{CS} = \frac{V_{DS}}{R_C + R_d + R_L + j\omega L} + \frac{j\omega L\,\underline{I}_{SS}}{R_C + R_d + R_L + j\omega L}$$

~~$j\omega L\,\underline{I}_{SS}$~~ $j\omega L$

$$(j\omega L + R_S)\,\underline{I}_{SS} = j\omega L\left[\frac{V_{DS}}{R_C + R_d + R_L + j\omega L}\right] + j\omega L\left[\frac{j\omega L\,\underline{I}_{SS}}{R_C + R_d + R_L + j\omega L}\right]$$

$$(j\omega L + R_S)\,\underline{I}_{SS} = \frac{V_{DS}\,j\omega L}{R_C + R_d + R_L + j\omega L} - \frac{\omega^2 L^2\,\underline{I}_{SS}}{R_C + R_d + R_L + j\omega L}$$

$$\left(j\omega L + R_S + \frac{\omega^2 L^2}{R_C + R_d + R_L + j\omega L}\right)\underline{I}_{SS} = \frac{V_{DS}\,j\omega L}{R_C + R_d + R_L + j\omega L}$$

$$I_{SS} = \frac{\dfrac{V_{DS}\, j\omega L}{R_C + R_d + R_L + j\omega L}}{j\omega L + R_s + \dfrac{\omega^2 L^2}{R_C + R_d + R_L + j\omega L}}$$

$$= \frac{V_{DS}\, j\omega L}{j\omega L R_C + j\omega L R_d + j\omega L R_L - \omega^2 L^2 + R_s R_d + R_s R_L + j\omega R_s L + \omega^2 L^2 + R_C R_s}$$

$$= \frac{V_{DS}\, j\omega L}{j\omega\left(L R_d + L R_s + L R_L + L R_C\right) + R_s\left(R_d + R_L + R_C\right)}$$

$$= \frac{\dfrac{V_{DS}\, j\omega L}{R_s\left(R_d + R_L + R_C\right)}}{\dfrac{j\omega}{\dfrac{R_s\left(R_d + R_C + R_L\right)}{L\left(R_d + R_s + R_C + R_L\right)}} + 1}$$

Section 22.10 Keeping Noise off the Shield

Loop equations:

Loop 1

$$V_{cm} + R_s \cdot I_s + \left(\sqrt{-1}\right) \cdot \omega \cdot L_s \cdot I_s - \left(\sqrt{-1}\right) \cdot \omega \cdot M \cdot I_c = 0$$

$$V_{cm} + R_s \cdot I_s + i \cdot \omega \cdot L_s \cdot I_s - i \cdot \omega \cdot M \cdot I_c = 0$$

Loop 2

$$R_d \cdot I_c + R_c \cdot I_c + \left(\sqrt{-1}\right) \cdot \omega \cdot L_c \cdot I_c - \left(\sqrt{-1}\right) \cdot \omega \cdot M \cdot I_s + V_L - V_{cm} = 0$$

$$R_d \cdot I_c + R_c \cdot I_c + i \cdot \omega \cdot L_c \cdot I_c - i \cdot \omega \cdot M \cdot I_s + V_L - V_{cm} = 0$$

$I_c = 0$, so this equation simplifies to:

$$-\left(\sqrt{-1}\right) \cdot \omega \cdot M \cdot I_s + V_L - V_{cm} = 0$$

V_L is found from these two equations:

$$Vcm + Rs \cdot Is + i \cdot \omega \cdot Ls \cdot Is = 0$$

$$-Rs \cdot Is - i \cdot \omega \cdot Ls \cdot Is$$

$$-\left(\sqrt{-1}\right) \cdot \omega \cdot M \cdot Is + VL - Vcm = 0$$

$$i \cdot \omega \cdot M \cdot Is + Vcm$$

$$i \cdot \omega \cdot M \cdot Is + (-Rs \cdot Is - i \cdot \omega \cdot Ls \cdot Is)$$

$$-Is \cdot (-i \cdot \omega \cdot M + Rs + i \cdot \omega \cdot Ls)$$

$M = Ls$

$$-Is \cdot (-i \cdot \omega \cdot Ls + Rs + i \cdot \omega \cdot Ls)$$

$V_L =$

$$-Rs \cdot Is$$

For a load resistance of R_L, the loop equations are:

$$V_{cm} + R_s \cdot I_s + i \cdot \omega \cdot L_s \cdot I_s - i \cdot \omega \cdot M \cdot I_c = 0$$

$$R_d \cdot I_c + R_c \cdot I_c + i \cdot \omega \cdot L_c \cdot I_c - i \cdot \omega \cdot M \cdot I_s - V_{cm} + R_L \cdot I_c = 0$$

if $M = L_c = L_s$

$$Vcm + Rs \cdot Is + i \cdot \omega \cdot Ls \cdot Is - i \cdot \omega \cdot Ls \cdot Ic = 0$$

$I_s =$

$$\frac{-(Vcm - i \cdot \omega \cdot Ls \cdot Ic)}{(Rs + i \cdot \omega \cdot Ls)}$$

$$Rd \cdot Ic + Rc \cdot Ic + i \cdot \omega \cdot Ls \cdot Ic - i \cdot \omega \cdot Ls \cdot \left[\frac{-(Vcm - i \cdot \omega \cdot Ls \cdot Ic)}{(Rs + i \cdot \omega \cdot Ls)}\right] - Vcm + RL \cdot Ic = 0$$

$I_c =$

$$\frac{-\left[\omega^2 \cdot \frac{Ls^2}{\left(Rs^2 + \omega^2 \cdot Ls^2\right)} \cdot Vcm - Vcm + i \cdot \omega \cdot Ls \cdot \frac{Rs}{\left(Rs^2 + \omega^2 \cdot Ls^2\right)} \cdot Vcm\right]}{\left[Rd + Rc + \omega^2 \cdot Ls^2 \cdot \frac{Rs}{\left(Rs^2 + \omega^2 \cdot Ls^2\right)} + RL + i \cdot \omega \cdot Ls - i \cdot \omega^3 \cdot \frac{Ls^3}{\left(Rs^2 + \omega^2 \cdot Ls^2\right)}\right]}$$

$$-Vcm \cdot Rs \cdot \frac{(-Rs + i \cdot \omega \cdot Ls)}{\left(Rd \cdot Rs^2 + Rd \cdot \omega^2 \cdot Ls^2 + Rc \cdot Rs^2 + Rc \cdot \omega^2 \cdot Ls^2 + \omega^2 \cdot Ls^2 \cdot Rs + RL \cdot Rs^2 + RL \cdot \omega^2 \cdot Ls^2 + i \cdot \omega \cdot Ls \cdot Rs^2\right)}$$

$R_L I_c =$

$$-Vcm \cdot Rs \cdot \frac{(-Rs + i \cdot \omega \cdot Ls)}{\left(Rd \cdot Rs^2 + Rd \cdot \omega^2 \cdot Ls^2 + Rc \cdot Rs^2 + Rc \cdot \omega^2 \cdot Ls^2 + \omega^2 \cdot Ls^2 \cdot Rs + RL \cdot Rs^2 + RL \cdot \omega^2 \cdot Ls^2 + i \cdot \omega \cdot Ls \cdot Rs^2\right)} \cdot RL$$

– Same as my result!

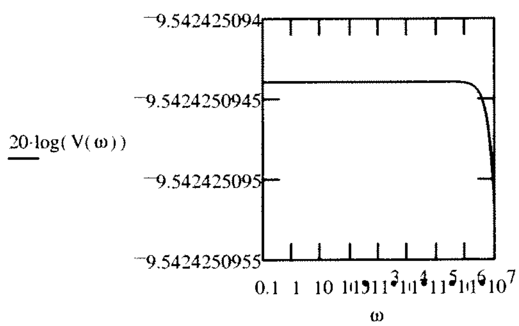
$Rs := 1000$ $\quad Ls := 1 \cdot 10^{-9}$ $\quad Rc := 1000$

$RL := 1000$ $\quad Rd := 1000$

$\omega := .1, 100 .. 1 \cdot 10^{7}$

$Vcm := 1$

$$V(\omega) := \frac{\left[\frac{Rs \cdot RL}{Rs \cdot (Rc + Rd + RL)}\right] \cdot Vcm}{1 + \frac{\left(\sqrt{-1}\right) \cdot \omega}{\left[\frac{Rs \cdot (Rc + Rd + RL)}{Ls \cdot (Rs + Rc + Rd + RL)}\right]}}$$

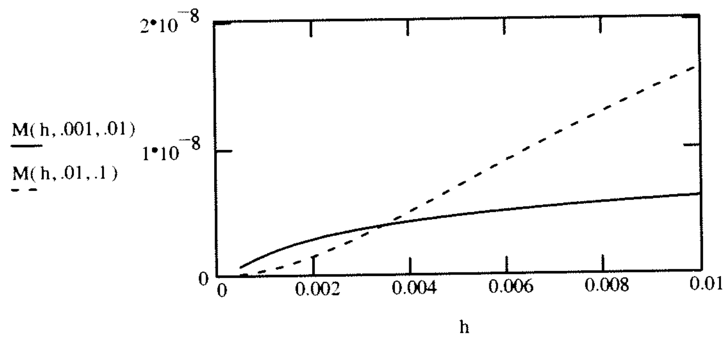

−9.542425094
−9.5424250945
−9.542425095
−9.5424250955
20·log(V(ω))
0.1
1
10
10^7
ω

Section 22.17 Long Lines vs Close Lines

h = Height
d = trace separation
l = length

$h := .0005, .0006 .. .01$

$$M(h,d,l) := 10^{-7} \cdot l \cdot \ln\left[1 + \left(\frac{2 \cdot h}{d}\right)^2\right]$$



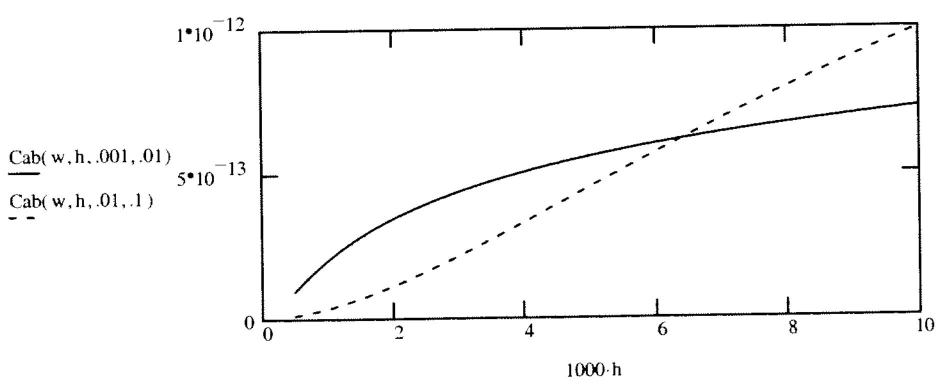
Mistake in my expression!

$\varepsilon o := 8.854 \cdot 10^{-12}$

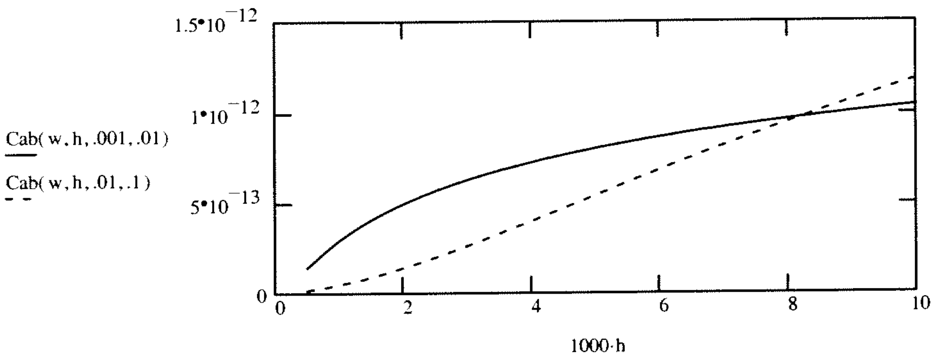
$w := .0004$

$$Cab(w,h,d,l) := 4 \cdot \pi \cdot \varepsilon o \cdot l \cdot \left[\frac{\ln\left[1 + \left(\frac{2 \cdot h}{d}\right)^2\right]}{\ln\left[\left[1 + \frac{32 \cdot h^2}{w^2} \cdot \left[1 + \sqrt{1 + \left(\frac{\pi \cdot w^2}{8 \cdot h^2}\right)}\right]\right]^2\right] - \ln\left[\left[1 + \left(\frac{2 \cdot h}{d}\right)^2\right]^2\right]}\right]$$

2



w := .0008



$w := 15 \cdot 2.54 \cdot 10^{-5} \quad lgt := 0.01 \quad \varepsilon_o := 8.851 \cdot 10^{-12} \quad A := 0.01 \quad R_{bc} := 100$

$x := 1, 2 .. 120$

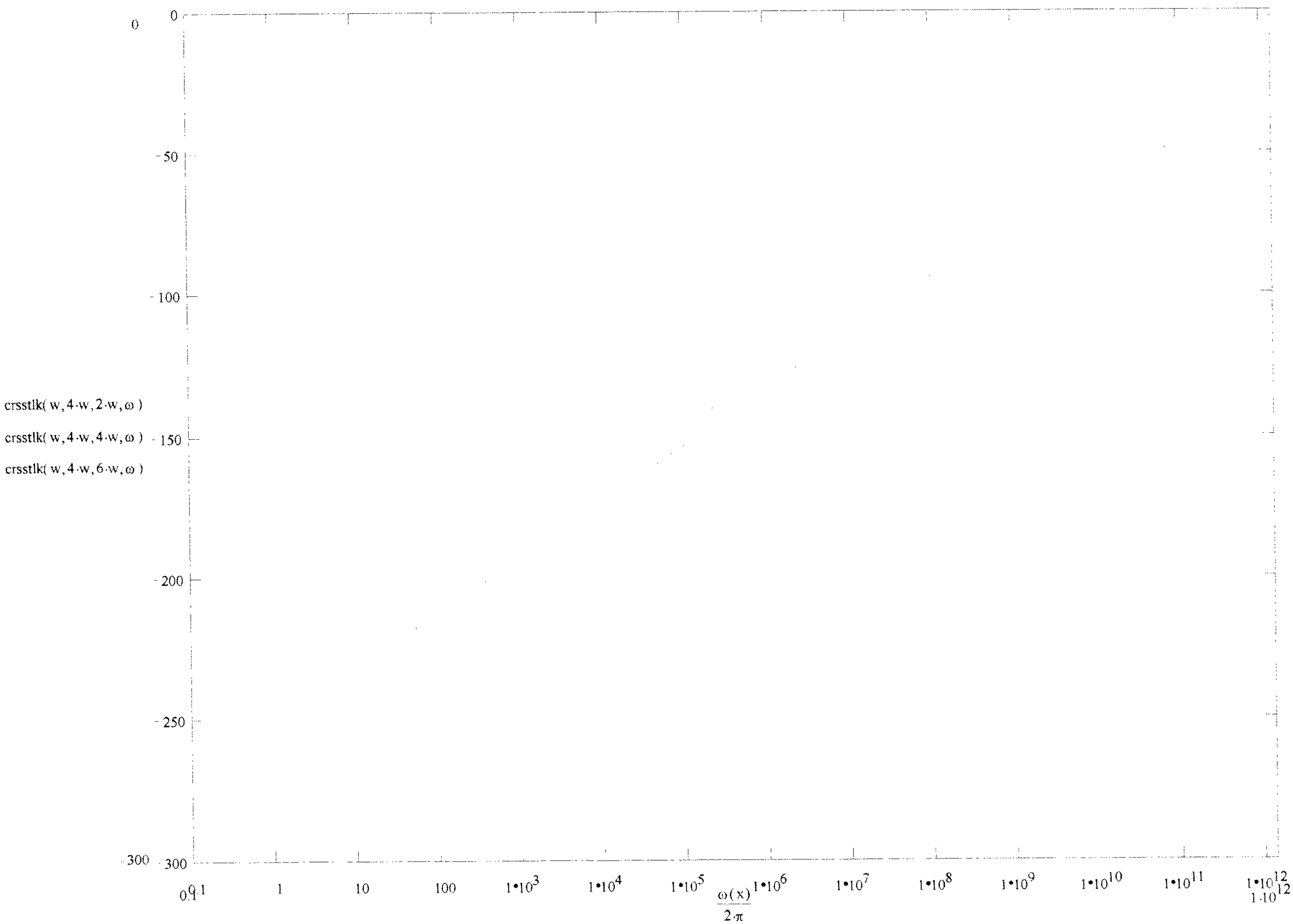
$$\omega(x) := \left(x + 1 - 10 \cdot \text{floor}\left(\frac{x}{10}\right)\right) \cdot 10^{\text{floor}\left(\frac{x}{10}\right)}$$

$$C_{ab}(w,h,d) := 4 \cdot \pi \cdot \varepsilon_o \cdot lgt \cdot \frac{\ln\left[1 + \left(\frac{2 \cdot h}{d}\right)^2\right]}{\ln\left[1 + \frac{32 \cdot h^2}{w^2} \cdot \left[1 + \sqrt{1 + \left(\frac{\pi \cdot w^2}{8 \cdot h^2}\right)}\right]\right]^2 - \ln\left[1 + \left(\frac{2 \cdot h}{d}\right)^2\right]^2}$$

there should be a squared here so that the equation matches with the one on page S88

$$C_{bc}(w,h,d) := 4 \cdot \pi \cdot \varepsilon_o \cdot lgt \cdot \frac{\ln\left[1 + \frac{32 \cdot h^2}{w^2} \cdot \left[1 + \sqrt{1 + \left(\frac{\pi \cdot w^2}{8 \cdot h^2}\right)^2}\right]\right]}{\ln\left[1 + \frac{32 \cdot h^2}{w^2} \cdot \left[1 + \sqrt{1 + \left(\frac{\pi \cdot w^2}{8 \cdot h^2}\right)^2}\right]\right]^2 - \ln\left[1 + \left(\frac{2 \cdot h}{d}\right)^2\right]^2} - C_{ab}(w,h,d)$$

$$\text{crsstlk}(w,h,d,\omega) := 20 \cdot \log\left[\frac{\omega(x) \cdot C_{ab}(w,h,d) \cdot R_{bc} \cdot A}{\sqrt{1 + \left[\omega(x) \cdot R_{bc} \cdot \left(C_{ab}(w,h,d) + C_{bc}(w,h,d)\right)\right]^2}}\right]$$


0
crsstlk(w, 4·w, 2·w, ω)
crsstlk(w, 4·w, 4·w, ω)
crsstlk(w, 4·w, 6·w, ω)
- 300
0
- 50
- 100
- 150
- 200
- 250
- 300
0.1
1
10
100
1•10^3
1•10^4
1•10^5
1•10^6
1•10^7
1•10^8
1•10^9
1•10^10
1•10^11
1•10^12
0.1
1·10^12
ω(x) / 2·π

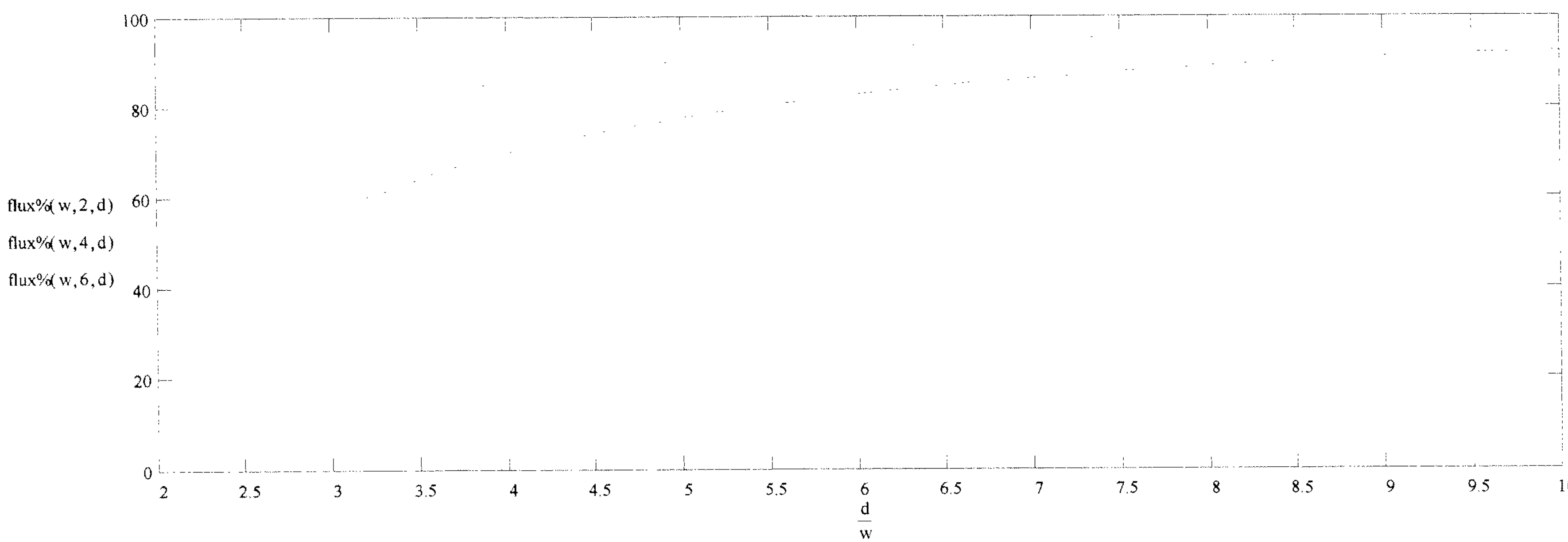
$w := 1 \qquad \varepsilon_o := 8.854 \cdot 10^{-12} \qquad lgt := 1 \qquad d := 2, 2.1 .. 10$

$$C_{ab}(w,h,d) := 4 \cdot \pi \cdot \varepsilon_o \cdot lgt \cdot \frac{\ln\left[1 + \left(\frac{2 \cdot h}{d}\right)^2\right]}{\ln\left[1 + \frac{32 \cdot h^2}{w^2} \cdot \left[1 + \sqrt{1 + \left(\frac{\pi \cdot w^2}{8 \cdot h^2}\right)}\right]\right]^2 - \ln\left[1 + \left(\frac{2 \cdot h}{d}\right)^2\right]^2}$$

There should be a squared term here
So the equations match up with page 588

$$C_{bc}(w,h,d) := 4 \cdot \pi \cdot \varepsilon_o \cdot lgt \cdot \frac{\ln\left[1 + \frac{32 \cdot h^2}{w^2} \cdot \left[1 + \sqrt{1 + \left(\frac{\pi \cdot w^2}{8 \cdot h^2}\right)}\right]\right]}{\ln\left[1 + \frac{32 \cdot h^2}{w^2} \cdot \left[1 + \sqrt{1 + \left(\frac{\pi \cdot w^2}{8 \cdot h^2}\right)}\right]\right]^2 - \ln\left[1 + \left(\frac{2 \cdot h}{d}\right)^2\right]^2} - C_{ab}(w,h,d)$$

$$flux\%(w,h,d) := 100 - \frac{C_{ab}(w,h,d)}{C_{bc}(w,h,d)} \cdot 100$$



$\mathrm{erf}\left(\frac{-1}{0.56}\right)$

$-.98844272033567473730$

$\mathrm{erf}(\infty)$

1

$t \geq 0$

$* \; v(t) = \frac{\Delta V}{2} + \frac{\Delta V}{2} \mathrm{erf}\left(\frac{t-\tau}{k\tau}\right)$

$t = 0,$

$= \frac{\Delta V}{2} + \frac{\Delta V}{2} \mathrm{erf}\left(\frac{-1}{\underbrace{k}_{0.56}}\right) \approx \frac{\Delta V}{2} + \frac{\Delta V}{2} \underbrace{(-0.9884)}_{\text{approx} = 1}$

$\approx \frac{\Delta V}{2} - \frac{\Delta V}{2} = 0$ ✓

$t = \infty,$

$= \frac{\Delta V}{2} + \frac{\Delta V}{2} \mathrm{erf}\left(\frac{\infty-\tau}{k\tau}\right) \approx \frac{\Delta V}{2} + \frac{\Delta V}{2} \underbrace{\mathrm{erf}(\infty)}_{1}$

$\approx \frac{\Delta V}{2} + \frac{\Delta V}{2} = \frac{\cancel{2} \Delta V}{\cancel{2}} = \Delta V$

$x \sim \lambda$

$t \sim \alpha$

$f(\lambda, t) = e^{-\lambda^2} = f(u_1, \alpha)$ $\quad f(u_2, \alpha) = e^{-(0)^2}$

$u_1 = \frac{t-\tau}{k\tau}$

$u_2 = 0$

$\frac{du_1}{dt} = \frac{1}{k\tau}$

$\frac{du_2}{dt} = 0$

$$\frac{dv}{dt} = \underbrace{0}_{\frac{d}{dt}\frac{\Delta V}{2} = 0} + \frac{\Delta V}{2} \cdot \frac{2}{\sqrt{\pi}} \left[\underbrace{e^{-\left(\frac{t-\tau}{k\tau}\right)^2}}_{f(u_1, \alpha)} \underbrace{\frac{1}{k\lambda}}_{\frac{du_1}{dt}} - \underbrace{e^{-(0)^2}}_{f(u_2, \alpha)} \cdot \underbrace{0}_{\frac{du_2}{dt}} + \underbrace{\int_0^{\frac{t-\tau}{k\tau}} 0 \, dx}_{=0} \right]$$

$$\frac{dv}{dt} = \frac{\Delta V}{\sqrt{\pi}} \cdot \frac{1}{k\lambda} e^{-\left(\frac{t-\tau}{k\tau}\right)^2} \checkmark$$

Chain Rule

$$\frac{dv}{dt} = \frac{\Delta V}{k\tau\sqrt{\pi}} e^{-\left(\frac{t-\tau}{k\tau}\right)^2}$$

$\frac{d}{dt}\left(\frac{t}{k\tau}\right)$ $\frac{d}{dt}\left[\frac{\tau}{k\tau}\right]$

$$\frac{dv}{dt} = \frac{\Delta V}{k\tau\sqrt{\pi}} e^{-\left(\frac{t-\tau}{k\tau}\right)^2} \cdot -2\left(\frac{t-\tau}{k\tau}\right) \cdot \left[\frac{1}{k\tau} - 0\right]$$

$$\frac{d}{dt}\left(-\left[\frac{t-\tau}{k\tau}\right]\right)$$

$$\frac{d}{dx} e^x = e^x$$

$$\frac{dv^2}{dt} = \frac{\Delta V}{k\tau\sqrt{\pi}} e^{-\left[\frac{t-\tau}{k\tau}\right]^2} \left[\frac{-2(t-\tau)}{(k\tau)^2}\right]$$

$$\frac{dv^2}{dt} = \frac{-2\Delta V(t-\tau)}{(k\tau)^3\sqrt{\pi}} e^{-\left[\frac{t-\tau}{k\tau}\right]^2}, \quad (t-\tau) = -(\tau-t)$$

$$\therefore \quad \frac{dv^2}{dt^2} = \frac{2\Delta V(\tau-t)}{(k\tau)^3\sqrt{\pi}} e^{-\left(\frac{t-\tau}{k\tau}\right)^2}$$

$$\frac{d}{dt}\frac{2\cdot\Delta V\cdot(\tau-t)}{(k\cdot\tau)^3\cdot\sqrt{\pi}}\cdot e^{-\left(\frac{t-\tau}{k\cdot\tau}\right)^2} = 0$$

solve for t

$$\begin{bmatrix}\left(1+\frac{1}{2}\cdot\sqrt{2}\cdot k\right)\cdot\tau \\ \left(1-\frac{1}{2}\cdot\sqrt{2}\cdot k\right)\cdot\tau\end{bmatrix} = \tau\left(1 \pm \frac{k}{\sqrt{2}}\right)$$

$$\left(1+\frac{1}{2}\cdot\sqrt{2}\cdot k\right)\cdot\tau$$

$$\left.\frac{d^2V}{dt^2}\right|_{t=\tau\left[1+\frac{k}{\sqrt{2}}\right]} = \frac{2\cdot\Delta V\cdot\left[\tau-\left(1+\frac{1}{2}\cdot\sqrt{2}\cdot k\right)\cdot\tau\right]}{(k\cdot\tau)^3\cdot\sqrt{\pi}}\cdot e^{-\left[\frac{\left(1+\frac{1}{2}\cdot\sqrt{2}\cdot k\right)\cdot\tau-\tau}{k\cdot\tau}\right]^2}$$

$$\frac{-\Delta V}{\tau^2}\cdot\frac{\sqrt{2}}{k^2}\cdot\frac{\exp\left(\frac{-1}{2}\right)}{\pi^{\frac{1}{2}}} = \frac{-2\Delta V}{(k\tau)^2\sqrt{2\pi}}e^{-1/2}$$

$$\pi^{\frac{1}{2}} = \sqrt{\pi}$$

$$\left.\frac{d^2V}{dt^2}\right|_{t=\tau\left[1-\frac{k}{\sqrt{2}}\right]} = \frac{2\cdot\Delta V\cdot\left[\tau-\left(1-\frac{1}{2}\cdot\sqrt{2}\cdot k\right)\cdot\tau\right]}{(k\cdot\tau)^3\cdot\sqrt{\pi}}\cdot e^{-\left[\frac{\left(1-\frac{1}{2}\cdot\sqrt{2}\cdot k\right)\cdot\tau-\tau}{k\cdot\tau}\right]^2}$$

$$\frac{\Delta V}{\tau^2}\cdot\frac{\sqrt{2}}{k^2}\cdot\frac{\exp\left(\frac{-1}{2}\right)}{\pi^{\frac{1}{2}}} = \frac{2\Delta V}{(k\tau)^2\sqrt{2\pi}}e^{-1/2}$$

see page 8

$$\left.\frac{di(t)}{dt}\right|_{max} < \frac{1}{R}\frac{dv}{dt} + C\frac{d^2 v}{dt^2}$$

$$< \frac{1}{R}\frac{\Delta V}{K\tau\sqrt{\pi}} e^{-\left(\frac{t-\tau}{K\tau}\right)^2} + C\frac{2\Delta V}{(K\tau)^2\sqrt{2\pi}} e^{-1/2}$$

max value [illegible] max value [illegible]

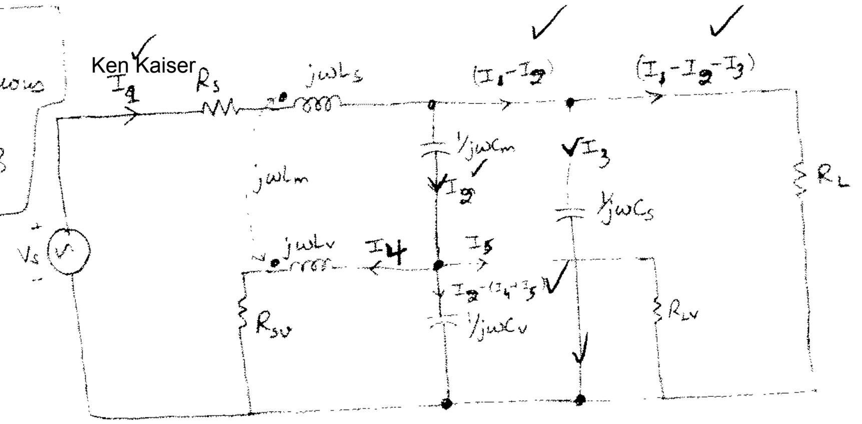
$$< \frac{1}{R}\frac{\Delta V}{K\tau\sqrt{\pi}} + C\frac{2\Delta V}{(K\tau)^2\sqrt{2\pi}} e^{-1/2}$$

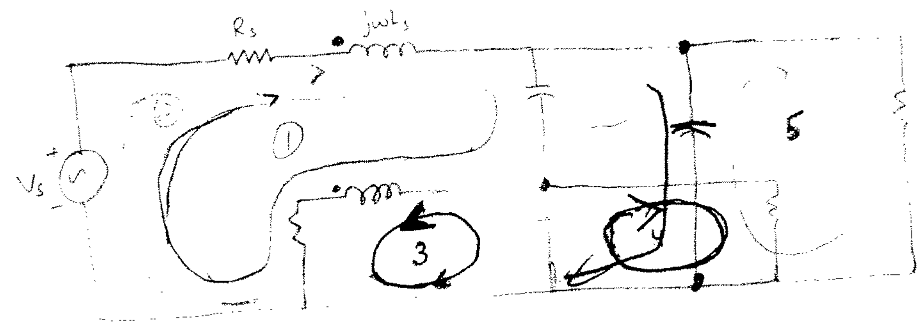
$$< \frac{1}{R}\frac{\Delta V}{\tau}\cdot\frac{1}{K\sqrt{\pi}} + C\cdot\frac{\Delta V}{\tau^2}\left[e^{-1/2}\cdot\frac{2}{K^2\cdot\sqrt{2\pi}}\right]$$

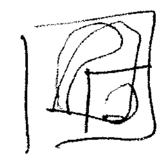
$$\frac{1}{(0.56)\cdot\sqrt{\pi}} \approx 0.9921 \qquad \frac{e^{-1/2}\cdot 2}{(0.56)^2\sqrt{2\pi}} \simeq 1.54 \simeq 1.5$$

$$< \frac{1}{R}\frac{\Delta V}{\tau} + C\frac{\Delta V}{\tau^2}[1.5]$$

C.R. Paul, Solution of transmission line equations for 3-cond^n lines in homogeneous media, IEEE Trans. on Electromag. Compatibility, EMC-20, 216-222 (1978)







Loop 1:

$$-V_s + (R_s + j\omega L_s) I_1 - j\omega L_m I_4 + \frac{1}{j\omega C_m} I_2 + (R_{sv} + j\omega L_v) I_4 - j\omega L_m I_1 = 0$$

$$\Rightarrow (R_s + j\omega L_s - j\omega L_m) I_1 + (R_{sv} + j\omega L_v - j\omega L_m) I_4 + \frac{1}{j\omega C_m} I_2 = V_s \quad \text{— (1)}$$

Loop 2:

$$-V_s + (R_s + j\omega L_s) I_1 - j\omega L_m I_4 + \frac{1}{j\omega C_s} I_3 = 0$$

$$(R_s + j\omega L_s) I_1 + \frac{1}{j\omega C_s} I_3 - j\omega L_m I_4 = V_s \quad \text{— (2)}$$

Loop 3:

$$(R_{sv} + j\omega L_v) I_4 - j\omega L_m I_1 - \frac{1}{j\omega C_v}(I_2 - I_4 - I_5) = 0$$

$$-j\omega L_m I_1 + \left(R_{sv} + j\omega L_v + \frac{1}{j\omega C_v}\right) I_4 - \frac{1}{j\omega C_v} I_2 + \frac{1}{j\omega C_v} I_5 = 0 \quad \text{— (3)}$$

Loop 4:

$$R_{Lv} I_5 - \frac{1}{j\omega C_v}(I_2 - I_4 - I_5) = 0$$

$$-\frac{1}{j\omega C_v} I_2 + \frac{1}{j\omega C_v} I_4 + \left(R_{Lv} + \frac{1}{j\omega C_v}\right) I_5 = 0 \quad \text{— (4)}$$

Loop 5:

$$R_L (I_1 - I_2 - I_3) - \frac{1}{j\omega C_s} I_3 = 0$$

$$\Rightarrow R_L I_1 - R_L I_2 - \left(R_L + \frac{1}{j\omega C_s}\right) I_3 = 0 \quad \text{— (5)}$$

Given

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$$\left(R_s + j\cdot\omega\cdot L_s - j\cdot\omega\cdot L_m\right)\cdot I_1 + \frac{1}{j\cdot\omega\cdot C_m}\cdot I_2 + \left[\left(R_{sv} + j\cdot\omega\cdot L_v\right) - j\cdot\omega\cdot L_m\right]\cdot I_4 = V_s$$

$$\left(R_s + j\cdot\omega\cdot L_s\right)\cdot I_1 + \frac{1}{j\cdot\omega\cdot C_s}\cdot I_3 - j\cdot\omega\cdot L_m\cdot I_4 = V_s$$

$$-j\cdot\omega\cdot L_m\cdot I_1 - \frac{1}{j\cdot\omega\cdot C_v}\cdot I_2 + \left(R_{sv} + j\cdot\omega\cdot L_v + \frac{1}{j\cdot\omega\cdot C_v}\right)\cdot I_4 + \frac{1}{j\cdot\omega\cdot C_v}\cdot I_5 = 0$$

my check

$$-\frac{1}{j\cdot\omega\cdot C_v}\cdot I_2 + \frac{1}{j\cdot\omega\cdot C_v}\cdot I_4 + \left(R_{Lv} + \frac{1}{j\cdot\omega\cdot C_v}\right)\cdot I_5 = 0$$

Maybe one eqn is essentially a repeat ~~set~~ of another

$$R_L\cdot I_1 - R_L\cdot I_2 - \left(R_L + \frac{1}{j\cdot\omega\cdot C_s}\right)\cdot I_3 = 0$$

$\text{Find}\left(I_1, I_2, I_3, I_4, I_5\right) \rightarrow$

No Symbolic result

$C_M << C_v$

$C_M << C_m$

Using $C \cong 1$ for $l << \lambda$

& $C \cong 1$

& $R << 1$

$\therefore$ Den $= 1 - \omega^2 \tau_a \tau_r [1 - 0] + j\omega(\tau_a + \tau_r)$

$= 1 - \omega^2 \tau_a \tau_r + j\omega(\tau_a + \tau_r)$

on factorising

Den $= (1 + j\omega\tau_a)(1 + j\omega\tau_r)$ Hence verified

Cross Check →
$(1 + j\omega\tau_a)(1 + j\omega\tau_r)$
$= 1 + j\omega\tau_r + j\omega\tau_a - \omega^2 \tau_a \tau_r$
$= 1 - \omega^2 \tau_a \tau_r + j\omega(\tau_a + \tau_r)$
Hence verified

& $$\hat{V}_{NE} = \frac{1}{Den}\left[\frac{R_{NE}}{R_{NE}+R_{FE}} j\omega l_m l (1+0)\hat{I}_{GDC} + \frac{R_{NE}R_{FE}}{R_{NE}+R_{FE}} j\omega C_m l [(1+0)\hat{V}_{GDC}]\right]$$

$$= \frac{1}{Den}\left[\frac{R_{NE}}{R_{NE}+R_{FE}} j\omega l_m l \hat{I}_{GDC} + \frac{R_{NE} \cdot R_{FE}}{R_{NE}+R_{FE}} j\omega C_m l \hat{V}_{GDC}\right]$$ Hence verified

IIly $$\hat{V}_{FE} = \frac{1}{Den}\left[-\frac{R_{FE}}{R_{NE}+R_{FE}} j\omega l_m l \hat{I}_{GDC} + \frac{R_{NE} \cdot R_{FE}}{R_{NE}+R_{FE}} j\omega C_m l \hat{V}_{GDC}\right]$$

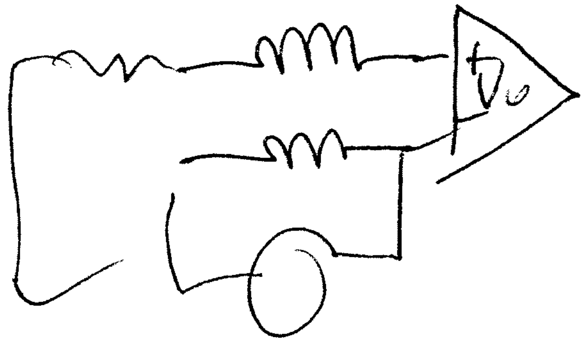
Now if freq of exitation is also small then $\omega << 1$

$\therefore$ Den $= 1$

~~$I_{cs}(R_d + R_c + R_L + j\omega L_c$~~ Crosstalk Chapter 1

$j\omega$

~~$I_{ss}($~~



$$I_{ss}(j\omega L + R_s) = -V_{cms} + j\omega L I_{cs}$$

$$I_{ss} = \frac{-V_{cms}}{j\omega L + R_s} + \frac{j\omega L I_{cs}}{j\omega L + R_s}$$

$$I_{CS} = \frac{V_{CMJ}\left[\dfrac{j\omega L + R_J - j\omega L}{j\omega L + R_J}\right]}{R_d + R_C + R_L + j\omega L + \dfrac{\omega^2 L^2}{j\omega L + R_S}}$$

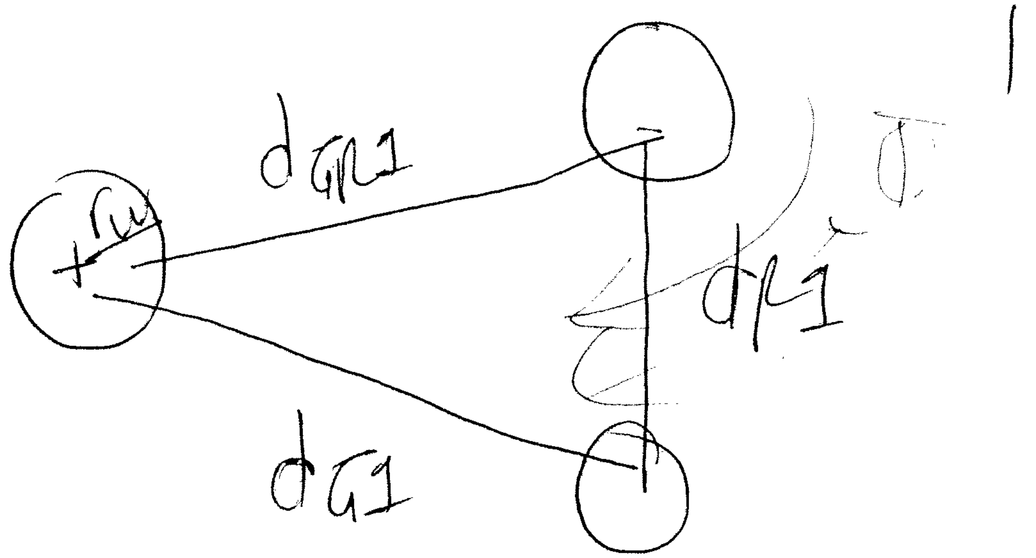
$$= \frac{V_{CMJ} R_J}{(R_d + R_C + R_L + j\omega L)(j\omega L + R_S) + \omega^2 L^2}$$

$$= \frac{V_{CMS} R_S}{j\omega L(R_d + R_C + R_L) - \omega^2 L^2 + R_S(R_d + R_C + R_L) + j\omega L R_S + \omega^2 L^2}$$

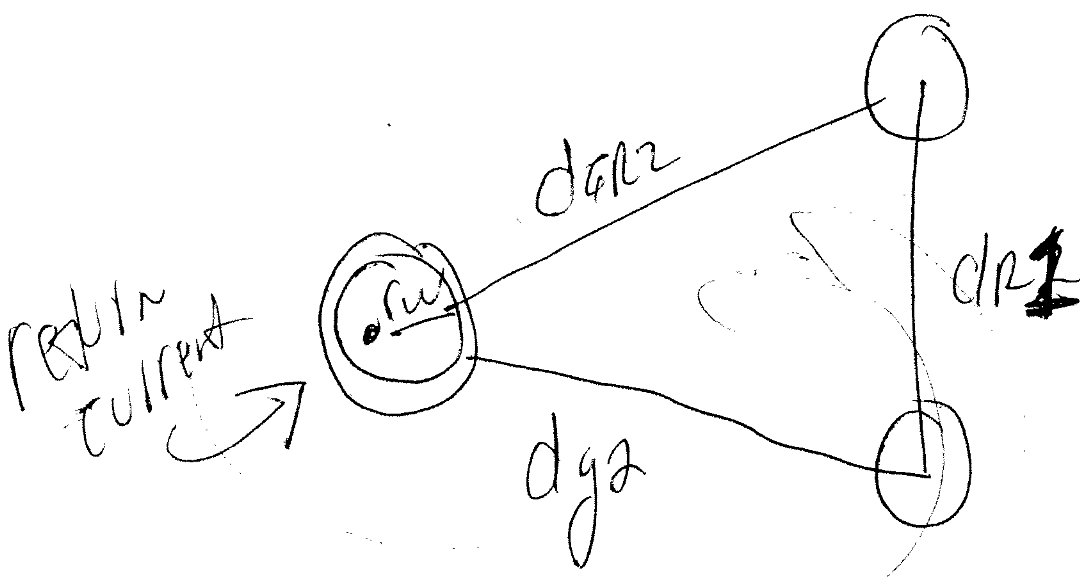
$$= \frac{V_{CMJ} R_J}{j\omega L(R_d + R_C + R_L + R_J) + R_J(R_a + R_C + R_L)}$$

$$I_{CS} = \frac{\dfrac{V_{CM}}{R_d + R_C + R_L}}{\dfrac{j\omega L\,(R_d + R_C + R_L + R_V)}{R_V\,(R_d + R_C + R_L)} + 1}$$

From Paul or



$$l_{m1} = \frac{\mu_0}{2\pi}\left(\frac{d_g d_{R1}}{d_{gR1} r_w}\right)$$



$$l_{M2} = \frac{\mu_0}{2\pi}\ln\left(\frac{d_{g2} d_{r1}}{d_{gr2} r_w}\right)$$

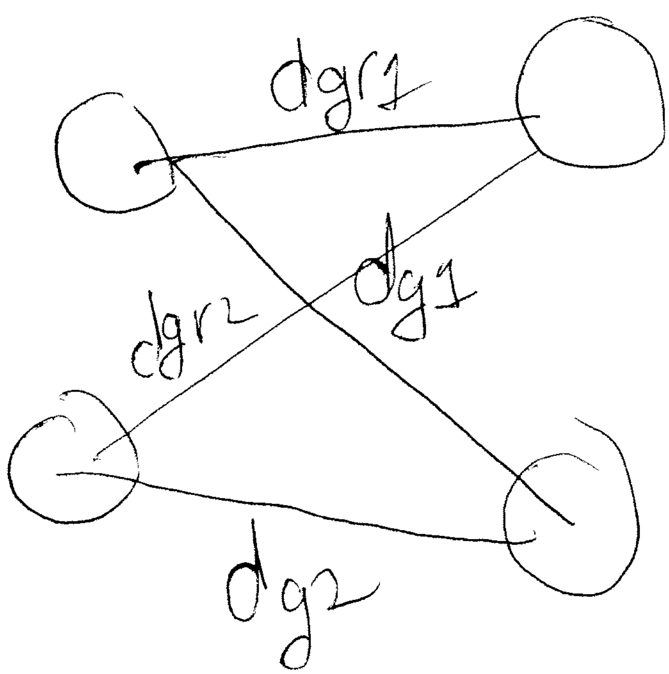
If current flow 2 "rw" in opposite direction the fluxes subtract and

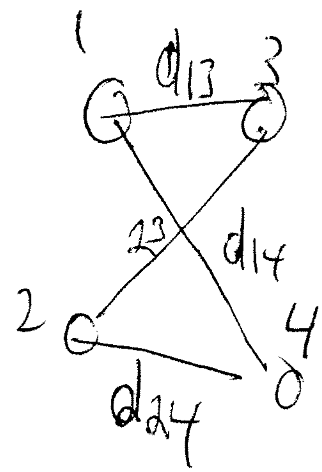
$$l_{mt} \equiv l_{m1} - l_{m2}$$

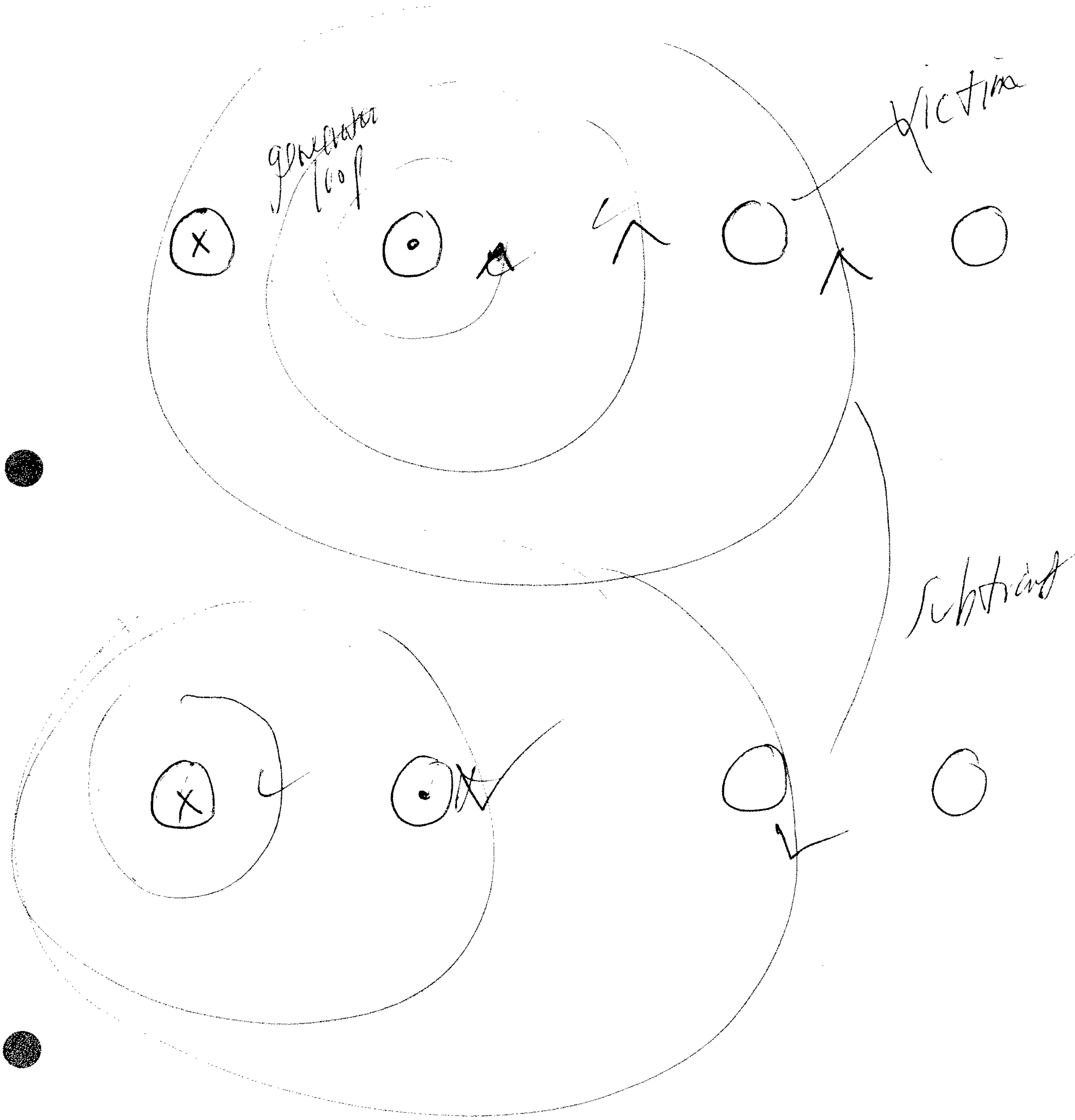
$$= \frac{\mu_0}{2\pi} \ln\left[\frac{d_{g1}\,\cancel{d_{r1}}}{d_{gr1}\,\cancel{r_w}} \times \frac{d_{gr2}\,\cancel{r_w}}{d_{g2}\,\cancel{d_{r1}}}\right]$$

$$= \frac{\mu_0}{2\pi} \ln\left[\frac{d_{g1}\,d_{gr2}}{d_{gr1}\,d_{g2}}\right] = 2\times10^{-7} \ln\left[\frac{d_{14}\,d_{23}}{d_{13}\,d_{24}}\right]$$

agrees with walker ✓






generator loop
victim
subtract

Schelkunoff

$b \equiv$ outer radius
$a =$ inner radius

$$\sigma^2 = 2\pi\sigma\mu f j$$

$$\sigma = \sqrt{2\pi\sigma_c\mu f j} = \frac{1}{\delta} + \frac{j}{\delta}$$

$$Z_t = \frac{1}{2\pi\sigma_c a b D}$$

$$D = I_1(\sigma b)K_1(\sigma a) - I_1(\sigma a)K_1(\sigma b)$$

let $\delta = \sigma$ to avoid confusion
$\sigma_c = \sigma$

$$Z_t = \frac{1}{2\pi\sigma a b D}$$

also from other eqn

$$\eta \equiv \frac{\gamma}{\sigma}$$

$$Z_t \approx \frac{\eta}{2\pi\sqrt{ab}} \operatorname{csch} \sigma t = \frac{\gamma}{2\pi\sqrt{ab}\,\sigma} \frac{1}{\sinh \gamma t}$$

if $\sqrt{ab} \simeq a$ for thin shield

$$= \frac{\gamma}{2\pi a \sigma} \frac{1}{\sinh \gamma t}$$

✓ agrees with commonly used result

$$D = I_1(\gamma b) K_1(\gamma a) - I_1(\gamma a) K_1(\gamma b)$$

large argument approx

$$K_1(x) \approx \frac{e^{-x}}{\sqrt{\frac{2x}{\pi}}}$$

$$I_1(x) \approx \frac{e^{x}}{\sqrt{2\pi x}}$$

$$D \approx \frac{e^{\gamma b}}{\sqrt{2\pi\gamma b}} \frac{e^{-\gamma a}}{\sqrt{\frac{2\gamma a}{\pi}}} - \frac{e^{\gamma a}}{\sqrt{2\pi\gamma a}} \frac{e^{-\gamma b}}{\sqrt{\frac{2\gamma b}{\pi}}}$$

$$= \frac{e^{\gamma(b-a)}}{2\gamma\sqrt{ab}} - \frac{e^{-\gamma(b-a)}}{2\gamma\sqrt{ab}}$$

$$= \frac{1}{\gamma\sqrt{ab}} \frac{e^{\gamma(b-a)} - e^{-\gamma(b-a)}}{2}$$

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2

$$D \doteq \frac{1}{\gamma\sqrt{ab}} \sinh(\gamma(b-a)) \quad \text{let } b-a=t$$

$$D \doteq \frac{1}{\gamma\sqrt{ab}} \sinh \gamma t$$

$$\therefore Z_t = \frac{1}{2\pi\sigma ab \frac{1}{\gamma\sqrt{ab}} \sinh \gamma t}$$

$$= \frac{\gamma}{2\pi\sqrt{ab}\,\sigma \sinh \gamma t}$$

$$= \frac{\gamma}{2\pi\sqrt{ab}\,\sigma} \frac{1}{\sinh \gamma t} \checkmark$$

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3

Let's ≈ Tsalovich's eqn

$$Z_t = \frac{\gamma}{2\pi\sigma\sqrt{ab}\,D}$$

$$D = I_1(\gamma b)K_1(\gamma a) - K_1(\gamma b)I_1(\gamma a)$$

Same D as before

$$\therefore D \approx \frac{1}{\gamma\sqrt{ab}} \sinh \gamma t$$

$$Z_t \approx \frac{\gamma}{2\pi\sigma \frac{\sqrt{ab}}{\gamma\sqrt{ab}} \sinh \gamma t}$$

$$=$$

DELPHI
Energy & Engine
Management Systems

Problem 23.24 ECE-640 [redacted]

SENSIVITY TO 60Hz NOISE —

① Why are low-level analog instrumentation extra sensitive to low freq. noise?

- low frequency noise (e.g. 60Hz) is in the range of operation of those devices, therefore it cannot be filtered.
- low levels can be affected by induced low frequency voltages

② Should shielded Twisted Pair be grounded @ one or both ends?

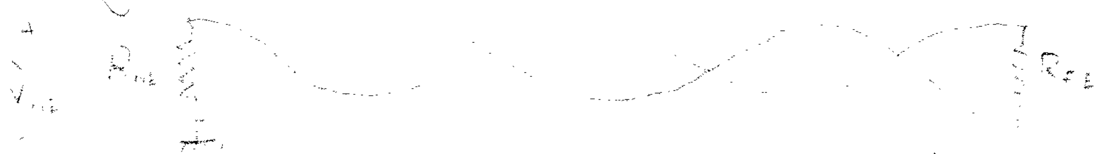
If the source and measurement instrument are both grounded then the shield should be grounded @ both ends.

③ Is the shield acting as an electric or magnetic field shield?

The shield is acting as a magnetic field "shield" by reducing the area of the ground loop.

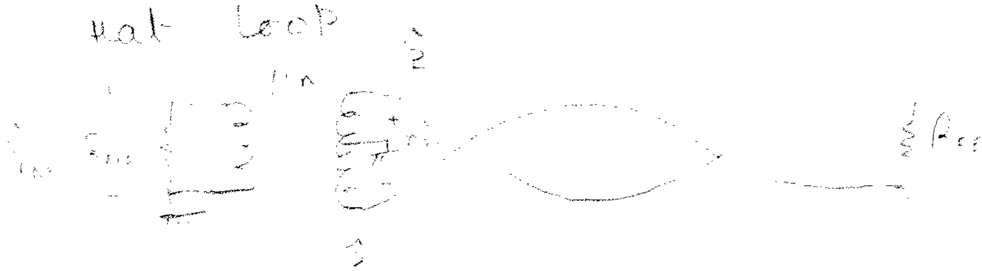
A system or transmission line is balanced when the impedance seen by each line to ground is the same.

Twisted pair is usually balanced but not always. Depending on how it is terminated it can be unbalanced.



Grounded at only one end to avoid groundloops

In this configuration it is unbalanced in the sense that the impedances seen between each wire and ground are not the same. One wire of the twisted pair is connected to the reference conductor at the near end, while the other end is not connected to the reference conductor in order to avoid ground loops between the wire and reference conductor, which will allow flow of circulating currents in that loop.



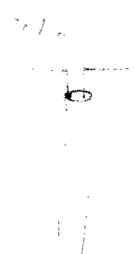
This result is balanced in the sense that impedances seen by each wire and reference conductor are equal which is due to center tapped transformer

Ken Kaiser

Coax [illegible] is usually unbalanced line, but not always. A double [illegible] line, two [illegible] in parallel, is a balanced line.

Center feed dipole antenna is a balanced device, i.e, they are electrically symmetrical with respect to the feed point.

A balanced antenna should be fed by a balanced feeder system to preserve this electrical symmetry with respect to ground, thereby avoiding any difficulties with unbalanced currents on the line and undesirable radiation from the transmission line itself.



[illegible] of dipole antenna is fed at the center through coaxial line then one side of the radiator is connected to the shield while the other is connected to the inner conductor. On the side connected to the shield, current can be diverted from flowing into the antenna and instead can flow through the outside of the coaxial shield. The field thus set up cannot be cancelled by the field from the inner conductor because the fields inside cable cannot escape through the shielding of the outer conductor. Hence outside current flow can cause some radiation

A system is balanced [illegible] by each line to ground is same [illegible] to every other conductor may not be same

O/P of [illegible] is driven in a balanced mode w.r.t ground of [illegible], so that volt of the signal [illegible] and volt of return w.r.t the common ground 180° out of phase. I/P [illegible] is balanced [illegible] between signal [illegible] and common [illegible] signal [illegible] 2 [illegible]

This system eliminates any common mode noise

So [illegible] the impedance [illegible] the 2 lines [illegible]

Double coax   pseudo balanced line

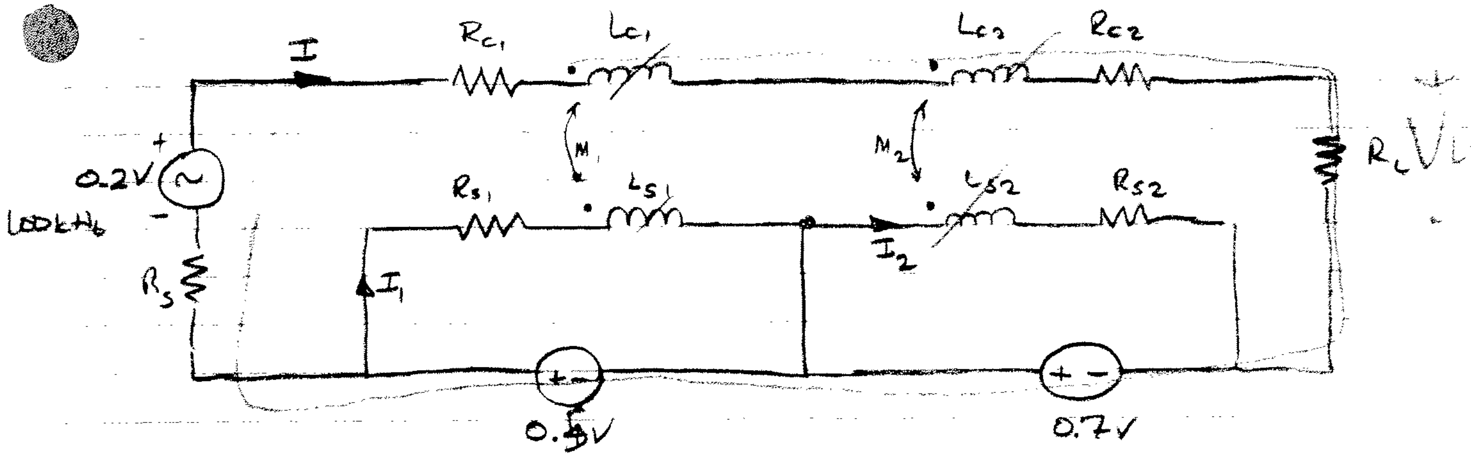
A balanced shielded [illegible] can be [illegible] of a pair of two coaxial cables. Each center conductor becomes one side of a [illegible] with [illegible] are tied to [illegible] ground. In this case the shield of each coax is no longer [illegible] return path.

[illegible] coaxial cable [illegible] characteristic impedance [illegible] higher freq.

Crosstalk

Ken Kaiser

Problem 23.18 ECE-640 [redacted]



0.4 + 0.7 +

1) $0.2 = I(R_s + R_{c1} + j\omega L_{c1} + j\omega L_{c2} + R_{c2} + R_L) + I_1 j\omega M_1 + I_2 j\omega M_2$

2) $0.4 = I_1(R_{s1} + j\omega L_{s1}) + I j\omega M_1$

3) $0.7 = I_2(R_{s2} + j\omega L_{s2}) + I j\omega M_2$

$f = 100kHz$, Let $\omega L_{s1} >> R_{s1}$ and $\omega L_{s2} >> R_{s2}$

Let $M_1 = L_{c1}$ and $M_2 = L_{c2}$

Let $R_s + R_L >> R_{c1} + R_{c2}$

1) $1.3 = I\left[(R_s + R_L) + j\omega(L_{c1} + L_{c2})\right] + j\omega L_{c1} I_1 + j\omega L_{c2} I_2$

2) $0.4 = I j\omega L_{c1} + I_1 j\omega L_{s1} \implies I_1 = \dfrac{0.4 - I j\omega L_{c1}}{j\omega L_{s1}}$

3) $0.7 = I j\omega L_{c2} + I_2 j\omega L_{s2} \implies I_2 = \dfrac{0.7 - I j\omega L_{c2}}{j\omega L_{s2}}$

$$1.3 = I\left[(R_s + R_L) + j\omega(L_{c1} + L_{c2})\right] + j\omega L_{c1}\left(\frac{0.4 - I j\omega L_{c1}}{j\omega L_{s1}}\right) + j\omega L_{c2}\left(\frac{0.7 - I j\omega L_{c2}}{j\omega L_{s2}}\right)$$

$$= I\left[(R_s + R_L) + j\omega\left(L_{c1} + L_{c2} - \frac{L_{c1}^2}{L_{s1}} - \frac{L_{c2}^2}{L_{s2}}\right)\right] + 0.4\frac{L_{c1}}{L_{s1}} + 0.7\frac{L_{c2}}{L_{s2}}$$

Let $L_{c1} = L_{s1} = L_1$ and $L_{c2} = L_{s2} = L_2$

$$1.3 = I\left[(R_s + R_L) + j\omega\left(L_1 + L_2 - \frac{L_1^2}{L_1} - \frac{L_2^2}{L_2}\right)\right] + 0.4\frac{L_1}{L_1} + 0.7\frac{L_2}{L_2}$$

$$I = \frac{0.2}{R_s + R_L}$$

Problem 23.18 cont. ECE 440 [redacted]

$$I = \frac{0.2}{R_S + R_L}$$

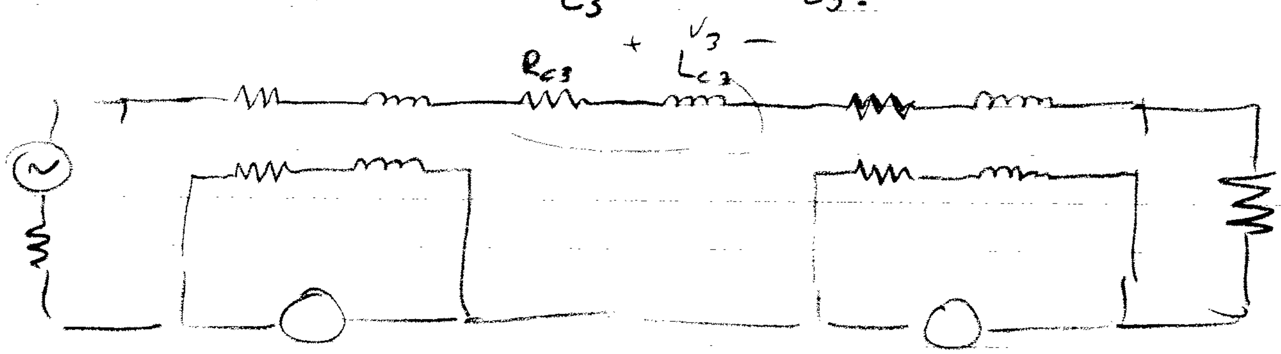
Voltage across load: $V_L = IR_L = R_L \frac{0.2}{R_S + R_L} = \frac{0.2}{1 + R_S/R_L}$

If $R_L \gg R_S \rightarrow V_L = 0.2\,V = V_S$

This result implies that the voltage induced on the center conductor must be equal to the voltage on the shield conductor.

Common mode choke does not effect Dm currents

if part of the center conductor between the 2 shields is exposed w/ R_{C3} and L_{C3}.



D $1.3 = I\left[(R_S + R_L + R_{C3} + R_{C2} + R_{C1}) + j\omega(L_{C1} + L_{C2} + L_{C3})\right] + j\omega L_{C1} I_1 + j\omega L_{C2} I_2$

$\therefore$ If $R_S + R_L \gg R_{C1} + R_{C2} + R_{C3}$

$$1.3 = I\left[(R_S + R_L) + j\omega L_{C3}\right] + 0.4 + 0.7$$

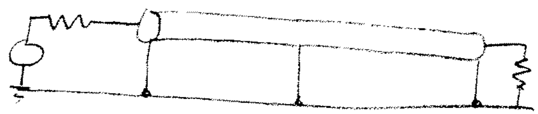
$$I = \frac{0.2}{R_S + R_L + j\omega L_{C3}}$$

$\therefore V_L = R_L \frac{0.2}{R_S + R_L + j\omega L_{C3}}$ or $V_L = V_{in} - V_3$

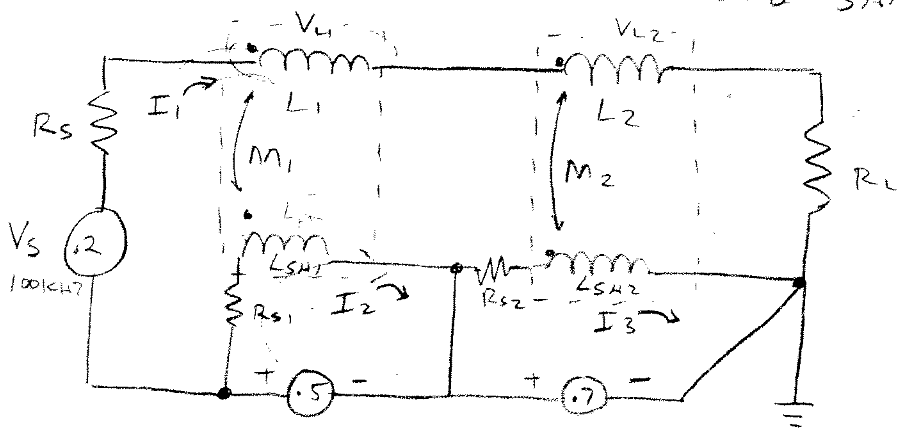
Ken Kaiser

ECE-640 WEEK 9 [redacted]

23-17 COAX W/ SHIELD GROUNDED 3 PLACES & NOISE ON SHLD



TRANSFORMER MODEL FOR COUPLING SHIELD NOISE



AS COAX & SHIELD GROUNDED MIDWAY, CAN ASSUME;

$L_{SH1} = L_1 = M_1$ $\quad\quad$ $L_{SH2} = L_2 = M_2$

A) DETERMINE VOLTAGE INDUCED ACROSS CENTER CONDUCTOR

MATLAB FOR EQUATIONS

$$V_{INDUCED} = \frac{1.2R_S + 1.2R_L + .2Z_{L1} + .2Z_{L2}}{(R_S + R_L)}$$

IF $Z_{L1} = Z_{L2}$,

$$= \frac{1.2(R_S + R_L) + .4Z_L}{(R_S + R_L)}$$

?, MATLAB

B) DETERMINE VOLTAGE AT LOAD (MATLAB)

$$V_{LOAD} = \frac{.2R_L}{(R_S + R_L)}$$

VOLTAGE DIVIDER
SHIELD NOISE CANCELS OUT

ECE-640 Homework 23.17 Coax Cable Modeled with Transformers [redacted]

$j := \sqrt{-1}$ $\omega := 10^5 \cdot 2 \cdot \pi$ $V_s := .2$

$V_{i1} := .5$ $V_{i2} := .7$

Outer Current Loop

$.7 + .5 + .2 = I_1 \cdot R_S + I_1 \cdot Z_{L1} + I_2 \cdot Z_{M1} + I_1 \cdot Z_{L2} + I_3 \cdot Z_{M2} + I_1 \cdot R_L$

$1.4 = I_1 \cdot R_S + I_1 \cdot Z_{L1} + I_2 \cdot Z_{M1} + I_1 \cdot Z_{L2} + I_3 \cdot Z_{M2} + I_1 \cdot R_L$

$1.4 = I_1 \cdot R_S + I_1 \cdot Z_{L1} + I_2 \cdot Z_{L1} + I_1 \cdot Z_{L2} + I_3 \cdot Z_{L2} + I_1 \cdot R_L$

Substitute L1 for M1 & L2 for M2

Current Loop on Shield, Near Source

$.5 = I_2 \cdot R_{s1} + I_2 \cdot Z_{Lsh1} + I_1 \cdot Z_{M1}$

Substitute L1 for M1 & Lsh1 Impedances

$.5 = I_2 \cdot R_{s1} + I_2 \cdot Z_{L1} + I_1 \cdot Z_{L1}$

$$I_2 = -1. \cdot \frac{(.5 - 1. \cdot I_1 \cdot Z_{L1})}{(-1. \cdot R_{s1} - 1. \cdot Z_{L1})}$$

Current Loop on Shield, Near Load

$.7 = I_3 \cdot R_{s2} + I_3 \cdot Z_{Lsh2} + I_1 \cdot Z_{M2}$

Substitute L2 for M2 & Lsh2 Impedances

$.7 = I_3 \cdot R_{s2} + I_3 \cdot Z_{L2} + I_1 \cdot Z_{L2}$

$$I_3 = -1. \cdot \frac{(.7 - 1. \cdot I_1 \cdot Z_{L2})}{(-1. \cdot R_{s2} - 1. \cdot Z_{L2})}$$

Substitute I2 & I3 & Solve for I1

$1.4 = I_1 \cdot R_S + I_1 \cdot Z_{L1} + I_2 \cdot Z_{L1} + I_1 \cdot Z_{L2} + I_3 \cdot Z_{L2} + I_1 \cdot R_L$

$$1.4 = I_1 \cdot R_S + I_1 \cdot Z_{L1} + \left[-1. \cdot \frac{(.5 - 1. \cdot I_1 \cdot Z_{L1})}{(-1. \cdot R_{s1} - 1. \cdot Z_{L1})} \right] \cdot Z_{L1} + I_1 \cdot Z_{L2} + \left[-1. \cdot \frac{(.7 - 1. \cdot I_1 \cdot Z_{L2})}{(-1. \cdot R_{s2} - 1. \cdot Z_{L2})} \right] \cdot Z_{L2} + I_1 \cdot R_L$$

$$I_1 = -1. \cdot \frac{\left[1.4 + \frac{.5}{(-1. \cdot R_{s1} - 1. \cdot Z_{L1})} \cdot Z_{L1} + \frac{.7}{(-1. \cdot R_{s2} - 1. \cdot Z_{L2})} \cdot Z_{L2} \right]}{\left[-1. \cdot R_S - 1. \cdot Z_{L1} - \frac{1.}{(-1. \cdot R_{s1} - 1. \cdot Z_{L1})} \cdot Z_{L1}^2 - 1. \cdot Z_{L2} - \frac{1.}{(-1. \cdot R_{s2} - 1. \cdot Z_{L2})} \cdot Z_{L2}^2 - 1. \cdot R_L \right]}$$

At High Frequencies, Impedance of Shield & Conductor Inductances >> shield resistances

$$I_1 = -1 \cdot \frac{\left[1.4 + \frac{-.5}{(Z_{L1})} \cdot Z_{L1} + \frac{-.7}{(Z_{L2})} \cdot Z_{L2}\right]}{\left[-1 \cdot R_S - 1 \cdot Z_{L1} - \frac{-1.}{(Z_{L1})} \cdot Z_{L1}^2 - 1 \cdot Z_{L2} - \frac{-1.}{(Z_{L2})} \cdot Z_{L2}^2 - 1 \cdot R_L\right]}$$

Ignore R shield at High Frequency

$$I_1 = \frac{.2}{R_S + R_L}$$

High Frequency Simplification

$$I_2 = \frac{\left(.5 + \frac{.2}{R_S + R_L} \cdot Z_{L1}\right)}{(Z_{L1})} \qquad I_3 = \frac{\left(.7 + \frac{.2}{R_S + R_L} \cdot Z_{L2}\right)}{(Z_{L2})}$$

$$I_2 = .1 \cdot \frac{(5 \cdot R_S + 5 \cdot R_L + 2 \cdot Z_{L1})}{[(R_S + R_L) \cdot Z_{L1}]} \qquad I_3 = .1 \cdot \frac{(7 \cdot R_S + 7 \cdot R_L + 2 \cdot Z_{L2})}{[(R_S + R_L) \cdot Z_{L2}]}$$

Voltage Across Center Conductor Inductance L1

$$V_{L1induced} = (I_2) \cdot Z_{M1} \qquad V_{L1induced} = I_2 \cdot Z_{L1}$$

$$V_{L1induced} = \left[.1 \cdot \frac{(5 \cdot R_S + 5 \cdot R_L + 2 \cdot Z_{L1})}{[(R_S + R_L) \cdot Z_{L1}]}\right] \cdot Z_{L1} \qquad V_{L1induced} = .1 \cdot \frac{(5 \cdot R_S + 5 \cdot R_L + 2 \cdot Z_{L1})}{(R_S + R_L)}$$

Voltage Across Center Conductor Inductance L2

$$V_{L2induced} = I_3 \cdot Z_{M2} \qquad V_{L2induced} = I_3 \cdot Z_{L2}$$

$$V_{L2induced} = \left[.1 \cdot \frac{(7 \cdot R_S + 7 \cdot R_L + 2 \cdot Z_{L2})}{[(R_S + R_L) \cdot Z_{L2}]}\right] \cdot Z_{L2} \qquad V_{L2induced} = .1 \cdot \frac{(7 \cdot R_S + 7 \cdot R_L + 2 \cdot Z_{L2})}{(R_S + R_L)}$$

Total Voltage Induced Across Center Conductor

$$V_{induced} = V_{L1induced} + V_{L2induced}$$

$$V_{induced} = \left[.1 \cdot \frac{(5 \cdot R_S + 5 \cdot R_L + 2 \cdot Z_{L1})}{(R_S + R_L)}\right] + .1 \cdot \frac{(7 \cdot R_S + 7 \cdot R_L + 2 \cdot Z_{L2})}{(R_S + R_L)}$$

$$V_{induced} = .2 \cdot \frac{(6 \cdot R_S + 6 \cdot R_L + Z_{L1} + Z_{L2})}{(R_S + R_L)}$$

Total Voltage Across Center Conductor (Induced + Signal)

$$V_{center} = .2 + .5 + .7 - R_s \cdot \left(\frac{.2}{R_S + R_L}\right) - R_L \cdot \left(\frac{.2}{R_S + R_L}\right)$$

$$V_{center} = -.2 \cdot \frac{(-7. \cdot R_S - 6. \cdot R_L + R_s)}{(R_S + R_L)}$$

Voltage at Load

$$V_{Load} = I_1 \cdot R_L$$

$$V_{Load} = \left(\left(\frac{.2}{R_S + R_L}\right)\right) \cdot R_L$$

$$V_{Load} = .2 \cdot \frac{R_L}{(R_S + R_L)}$$