1. TEM mode is a 2D static field problem. By cylindrical symmetry, the magnetic field goes along the $\hat{\boldsymbol{\phi}}$ direction. In the space between the two conductors, $\boldsymbol{\nabla} \times \mathbf{H} = 0$ implies

$$\mathbf{H}(\rho) = \hat{\boldsymbol{\phi}} H_0 \frac{a}{\rho} \tag{1}$$

and by (8.28)

$$\mathbf{E}(\rho) = \pm\hat{\boldsymbol{\rho}} \sqrt{\frac{\mu}{\epsilon}} H_0 \frac{a}{\rho} \tag{2}$$

So the time-averaged power is

$$P = 2\pi \int_a^b \left| \frac{1}{2} \mathbf{E}(\rho) \times \mathbf{H}^*(\rho) \right| \rho \, d\rho = \pi a^2 |H_0|^2 \sqrt{\frac{\mu}{\epsilon}} \ln\left(\frac{b}{a}\right) \tag{3}$$

2. When we consider energy loss to the conductor, by (8.12), we have

$$\left.\frac{dP_{\text{loss}}(z)}{da}\right|_{\rho=a} = \frac{\mu\omega\delta}{4} |H_0(z)|^2 \qquad \left.\frac{dP_{\text{loss}}(z)}{da}\right|_{\rho=b} = \frac{\mu\omega\delta}{4} |H_0(z)|^2 \left(\frac{a}{b}\right)^2 \tag{4}$$

Thus from $z \to z + dz$, the total energy loss is

$$dP_{\text{loss}}(z) = \frac{\mu\omega\delta}{4} |H_0(z)|^2 \cdot 2\pi \left(a + \frac{a^2}{b}\right) dz \tag{5}$$

From (3), we know

$$|H_0(z)|^2 = \frac{\dfrac{P(z)}{\pi a^2} \sqrt{\dfrac{\epsilon}{\mu}}}{\ln\left(\dfrac{b}{a}\right)} \tag{6}$$

hence (5) becomes

$$\frac{dP_{\text{loss}}(z)}{dz} = \frac{\mu\omega\delta}{4} \cdot 2P(z) \sqrt{\frac{\epsilon}{\mu}} \left[\frac{\dfrac{1}{a} + \dfrac{1}{b}}{\ln\left(\dfrac{b}{a}\right)} \right] = \frac{1}{2\sigma\delta} \cdot 2P(z) \sqrt{\frac{\epsilon}{\mu}} \left[\frac{\dfrac{1}{a} + \dfrac{1}{b}}{\ln\left(\dfrac{b}{a}\right)} \right] \tag{7}$$

Clearly, this describes a differential equation

$$\frac{dP(z)}{dz} = -2\gamma P(z) \qquad \text{where} \qquad \gamma = \frac{1}{2\sigma\delta} \sqrt{\frac{\epsilon}{\mu}} \left[\frac{\dfrac{1}{a} + \dfrac{1}{b}}{\ln\left(\dfrac{b}{a}\right)} \right] \tag{8}$$

3. For TEM mode, the voltage difference V and the current I can be calculated as the following

$$V = \int_a^b E(\rho) \, d\rho = \sqrt{\frac{\mu}{\epsilon}} H_0 a \ln\left(\frac{b}{a}\right) \qquad I = 2\pi a H_0 \tag{9}$$

giving the impedance

$$Z_0 = \frac{V}{I} = \frac{1}{2\pi} \sqrt{\frac{\mu}{\epsilon}} \ln\left(\frac{b}{a}\right) \tag{10}$$

4. We treat the waveguide as a series circuit with per unit length resistance R, which can be deduced by the the energy loss per unit length

$$\frac{dP_{\text{loss}}}{dz} = \frac{1}{2} I_{\text{peak}}^2 R \qquad \Longrightarrow \qquad R = \frac{2dP_{\text{loss}}/dz}{I_{\text{peak}}^2} = \frac{2 \cdot \dfrac{1}{2\sigma\delta} |H_0(z)|^2 \cdot 2\pi \left(a + \dfrac{a^2}{b}\right)}{4\pi^2 a^2 |H_0(z)|^2} = \frac{1}{2\pi\sigma\delta} \left(\frac{1}{a} + \frac{1}{b}\right) \tag{11}$$

The equivalent inductance per unit length, L, can be computed from the total magnetic energy stored per length

$$\frac{dW_{\text{mag}}}{dz} = \frac{1}{4} I_{\text{peak}}^2 L \qquad \Longrightarrow \qquad L = \frac{4dW_{\text{mag}}/dz}{I_{\text{peak}}^2} \tag{12}$$

Magnetic field exists in all of the three regions,

$$\frac{dW_{\text{mag}}}{dz} = 2\pi \left[\overbrace{\int_0^a \frac{\mu_c}{4} H_{\rho<a}^2(\rho)\rho d\rho}^{W_1} + \overbrace{\int_a^b \frac{\mu}{4} H_{a<\rho<b}^2(\rho)\rho d\rho}^{W_2} + \overbrace{\int_b^\infty \frac{\mu_c}{4} H_{\rho>b}^2(\rho)\rho d\rho}^{W_3} \right] \tag{13}$$

Assuming $\delta \ll a < b$, we can ignore the curvature and use (8.9) to approximate $H_{\rho<a}, H_{\rho>b}$, which gives

$$\begin{aligned}
W_1 &= \frac{\mu_c}{4} \int_0^a H_0^2 e^{-2(a-\rho)/\delta} \rho d\rho \\
&= \frac{\mu_c H_0^2}{4} e^{-2a/\delta} \int_0^a e^{2\rho/\delta} \rho d\rho \\
&= \frac{\mu_c H_0^2}{4} \left[\frac{\delta a}{2} - \frac{\delta^2}{4} \left(1 - e^{-2a/\delta}\right) \right] &(14) \\
W_3 &= \frac{\mu_c}{4} \int_b^\infty H_0^2 \left(\frac{a}{b}\right)^2 e^{-2(\rho-b)/\delta} \rho d\rho \\
&= \frac{\mu_c H_0^2}{4} \left(\frac{a}{b}\right)^2 e^{2b/\delta} \int_b^\infty e^{-2\rho/\delta} \rho d\rho \\
&= \frac{\mu_c H_0^2}{4} \left(\frac{a}{b}\right)^2 \left(\frac{\delta b}{2} + \frac{\delta^2}{4}\right) &(15)
\end{aligned}$$

Also,

$$W_2 = \frac{\mu}{4} \int_a^b H_0^2 \left(\frac{a}{\rho}\right)^2 \rho d\rho = \frac{\mu H_0^2 a^2}{4} \ln\left(\frac{b}{a}\right) \tag{16}$$

Ignoring $O\left(\delta^2\right)$ in (14) and (15), and putting everything back to (12), we eventually get

$$\begin{aligned}
L &\approx \frac{2\pi \left[\mu_c H_0^2 \left(\frac{\delta a}{2}\right) + \mu_c H_0^2 \left(\frac{\delta a^2}{2b}\right) + \mu H_0^2 a^2 \ln\left(\frac{b}{a}\right) \right]}{4\pi^2 a^2 H_0^2} \\
&= \frac{\mu}{2\pi} \ln\left(\frac{b}{a}\right) + \frac{\mu_c \delta}{4\pi} \left(\frac{1}{a} + \frac{1}{b}\right) &(17)
\end{aligned}$$