Resistive–Wall Impedance for Arbitrary Beam Energies

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OUTLINE

- **Theoretical Model**
- **Longitudinal Coupling Impedance**
  Arbitrary wall thickness
  Beam Shielding via a thin conducting wall
- **Transverse Coupling Impedance**
  Thick beam pipe wall
- **Transverse Coupling Impedance**
  Arbitrary wall thickness
  Beam Shielding via a thin conducting wall
- **Conclusions**

Wave Equations

- **Maxwell's Equations**

$$\nabla^2\vec{B} - \mu\epsilon\frac{\partial^2\vec{B}}{\partial t^2} - \mu S\,\frac{\partial\vec{B}}{\partial t} = -\mu\vec{\nabla}\times\vec{j}_i$$

$$\nabla^2\vec{E} - \mu\epsilon\frac{\partial^2\vec{E}}{\partial t^2} - \mu S\,\frac{\partial\vec{E}}{\partial t} = \mu\frac{\partial\vec{j}_i}{\partial t} + \frac{\vec{\nabla}\rho_i}{\epsilon}$$

- **Boundary Conditions**

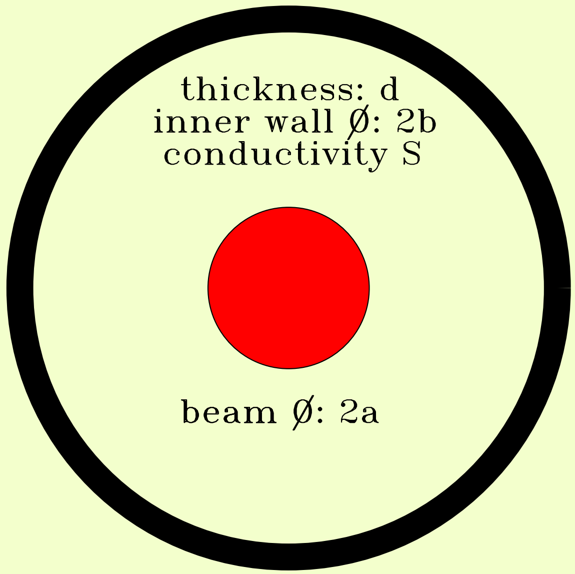
  1. **Thick Wall such that $d \gg \delta_s$: Impedance B. C.**

$$\vec{E}_t = Z_m\vec{j}_s = Z_m\hat{n}\times\vec{H}_t \quad Z_m = \frac{1-i}{S\delta_s}\,, \quad \delta_s = \sqrt{\frac{2}{\mu\omega S}}$$

     Impedance or Leontovich B. C. is not valid down to zero frequency

  2. **Arbitrary Wall Thickness: ($d \leq \delta_s$)**: **Max. field eqns.**

Beam–Pipe Structures



$$\rho(\mathbf{r},\mathbf{t}) = \sigma(\mathbf{r},\theta)\delta(\mathbf{z}-\beta\mathbf{ct}) = \frac{\mathbf{Q^2}}{\pi\mathbf{a^2}}\,\mathbf{H}\left(\mathbf{a}-|\vec{\mathbf{r}}-\vec{\mathbf{d}}|\right)\delta\left(\mathbf{z}-\mathbf{vt}\right)$$

$$\sigma_{\mathbf{0}}(\mathbf{r},\theta) = \frac{\mathbf{Q^2}}{\pi\mathbf{a^2}} \qquad \sigma_{\mathbf{1}}(\mathbf{r},\theta) = \frac{\mathbf{P}}{\pi\mathbf{a^2}}\,\cos(\theta-\theta_{\mathbf{0}})\delta(\mathbf{a}-\mathbf{r})$$

Machine Parameters

	SIS18	SIS100	HESR
Circumference $\mathbf{C}$	216 m	1080 m	570 m
Conductivity $\mathbf{S}$ in $(\Omega\ \mathrm{m})^{-1}$	10^6	10^6	10^6
Pipe Radius $\mathbf{b}$	10 cm	1 cm	5 cm
Wall Width in the Dipoles d_w	0.3 mm	0.3 mm	1 cm
Reference Energy $\gamma_\mathbf{0}$	1.0122	1.098	2
Reference Energy $\beta_\mathbf{0}$	0.155	0.413	0.866
Rev. Frequency $\mathbf{f_0}$ in kHz	214	113	453

Longitudinal Impedance: Arbitrary d

$$\mathbf{Z}_{\|,\mathbf{0}}^{(\mathrm{rw})}(\omega) = (1-i)\ \frac{nZ_0\beta\delta_s^*}{2\sqrt{n}\ b}\ \frac{4I_1^2(\sigma_0 a)}{\sigma_0^2 a^2 I_0^2(\sigma_0 b)}\ \times$$

$$\times \frac{\mathbf{1} + \eta\frac{\mathbf{K_1}(\sigma_\mathbf{0}\mathbf{h})}{\mathbf{K_0}(\sigma_\mathbf{0}\mathbf{h})}\ \tanh \underline{\sigma}\mathbf{d}}{\tanh \underline{\sigma}\mathbf{d} + \eta\mathbf{V_1} + \eta^\mathbf{2}\mathbf{V_2}\tanh \underline{\sigma}\mathbf{d}}$$

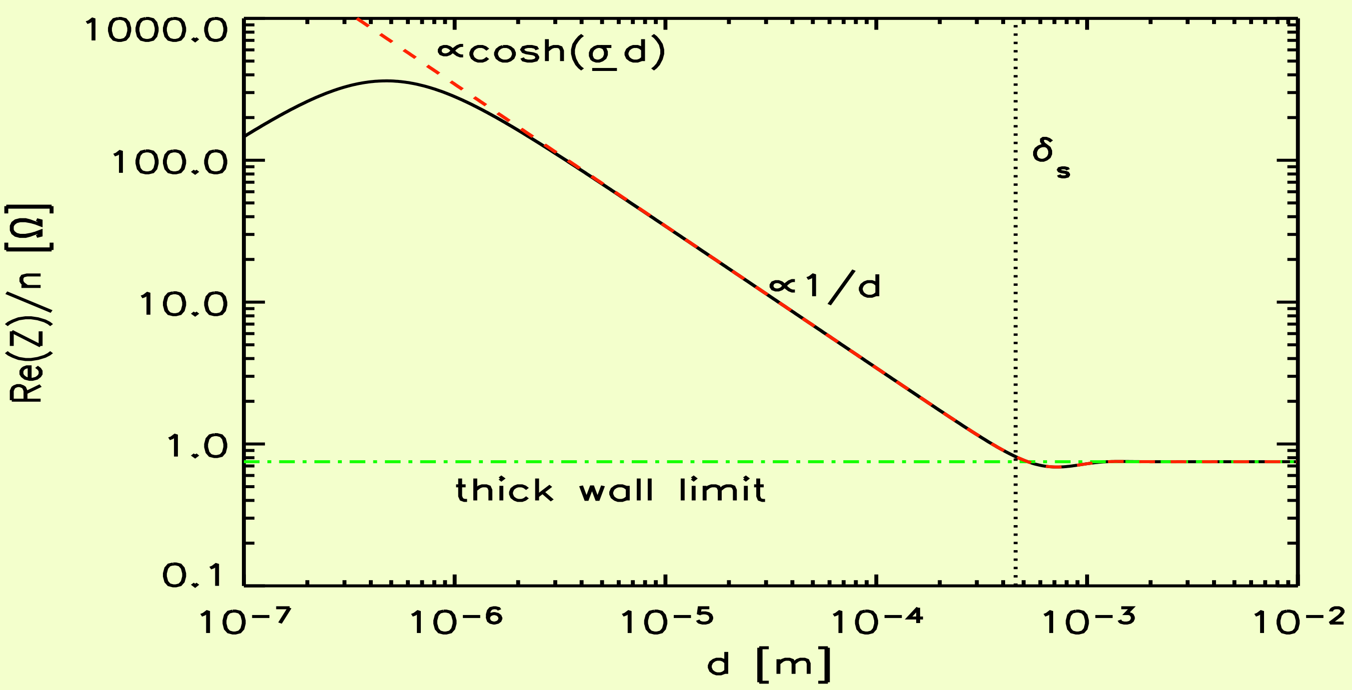
$$\mathbf{V_1} = \frac{K_1(\sigma_0 h)}{K_0(\sigma_0 h)} + \frac{I_1(\sigma_0 b)}{I_0(\sigma_0 b)}\ ,\ \mathbf{V_2} = \frac{K_1(\sigma_0 h)}{K_0(\sigma_0 h)}\frac{I_1(\sigma_0 b)}{I_0(\sigma_0 b)}$$

$$\sigma_\mathbf{0} = \frac{\mathbf{k_z}}{\gamma_\mathbf{0}}\ , \underline{\sigma} = \frac{\mathbf{k_z}}{\underline{\gamma}}\ , \underline{\gamma}^{-\mathbf{2}} = \gamma_\mathbf{0}^{-\mathbf{2}} - \mathbf{i}\frac{\mu_\mathbf{0}\mathbf{S}\omega}{\mathbf{k_z^2}}\ , \eta = \frac{\omega\epsilon_\mathbf{0}\gamma_\mathbf{0}}{\mathbf{i}\underline{\gamma}(\mathbf{S} - \mathbf{i}\omega\epsilon_\mathbf{0})}$$

Ahmed Al-Khateeb et al, Phys. Rev. E (2005)

Longitudinal Resistive Wall Impedance $\mathbf{Z}^{(\mathrm{rw})}(\omega)$

SIS18 for $\mathbf{n = 1}$, $\gamma_0 = \mathbf{2}$: $\mathbf{C = 216}$ m, $\mathbf{a = 1}$ cm, $\mathbf{b = 10}$ cm, $d_{\mathrm{w}} = 0.3$ mm:
$\mathbf{Z}^{(\mathrm{rw})}/\mathbf{n}$ remains below $\mathbf{10\Omega}$



$$\mathbf{Z}^{(\mathrm{rw})\parallel,0}(\omega) \approx (\mathbf{1} - \mathbf{i})\frac{\mathbf{nZ_0}\beta\delta_{\mathbf{s}}^*}{\mathbf{2}\sqrt{\mathbf{n}}\mathbf{b}}\frac{\mathbf{4I_1^2}(\sigma_\mathbf{0}\mathbf{a})}{\sigma_\mathbf{0}^\mathbf{2}\mathbf{a^2I_0^2}(\sigma_\mathbf{0}\mathbf{b})}\coth\underline{\sigma}\mathbf{d} \quad [\mathbf{Any\ d}\ ,\ \delta_\mathbf{s}\mathbf{k_z} \ll \mathbf{1}]$$

Transmission coefficient

Beam shielding via metallic walls: : **Transmission coefficient** τ

- Ahmed Al-Khateeb et al, Phys. Rev. E (2005)

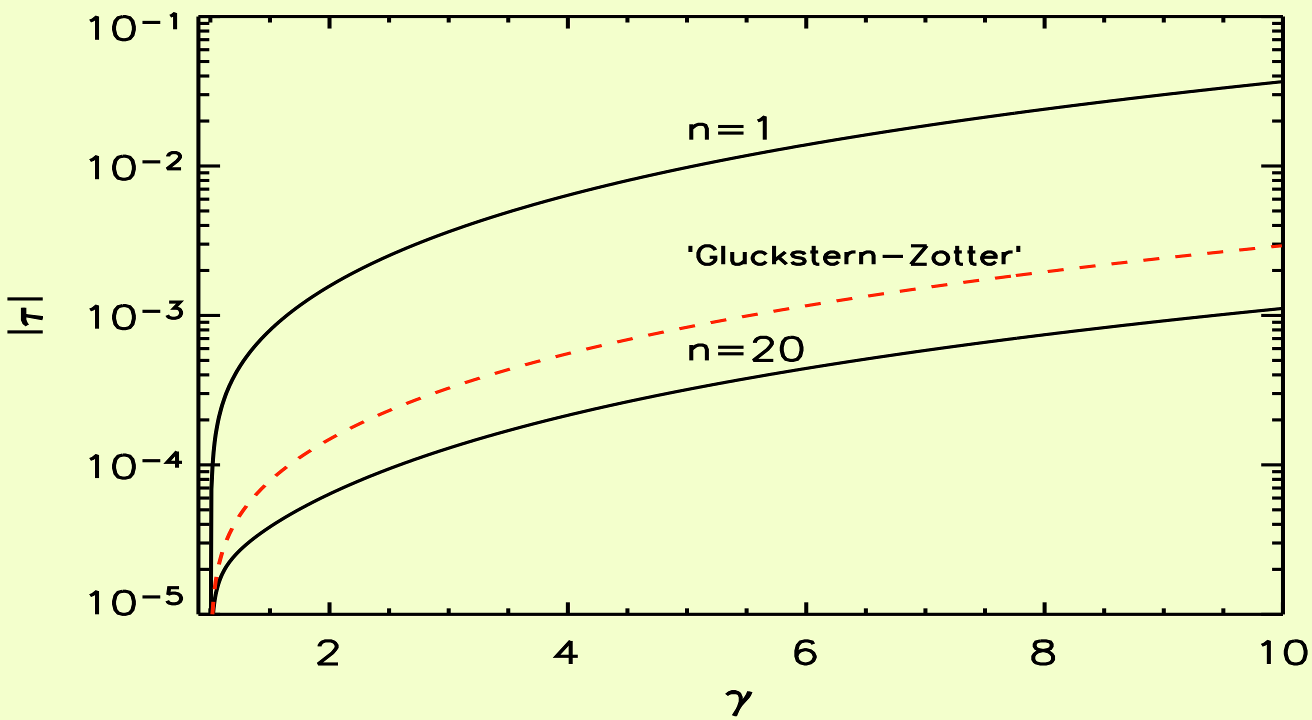
$$\tau^{-1} = \sqrt{\frac{\mathbf{h}}{\mathbf{b}}}\sigma_0 \mathbf{b} \mathbf{K_1}(\sigma_0 \mathbf{h}) \mathbf{I_0}(\sigma_0 \mathbf{b}) \sinh \underline{\sigma} \mathbf{d} \left[\coth \underline{\sigma} \mathbf{d} + \frac{\mathbf{K_0}(\sigma_0 \mathbf{h})}{\eta \mathbf{K_1}(\sigma_0 \mathbf{h})} + \frac{\mathbf{I_1}(\sigma_0 \mathbf{b})}{\mathbf{I_0}(\sigma_0 \mathbf{b})} \left(\eta + \frac{\mathbf{K_0}(\sigma_0 \mathbf{h})}{\mathbf{K_1}(\sigma_0 \mathbf{h})} \coth \underline{\sigma} \mathbf{d} \right) \right]$$

- Gluckstern and Zotter, Phys. Rev. STAB (2001)

$$\tau^{-1} \approx \mathbf{1} + \frac{\beta^2 \mathbf{k_z^2 b}}{\mathbf{2}}\, \mathbf{d} + \mathbf{i}\, \frac{\mathbf{2bd}}{\beta^2 \gamma_0^2 \delta_s^2}\, \ln \frac{\mathbf{k_z b}}{\gamma_0}$$

Transmission coefficient: SIS18

$\mathbf{C} = \mathbf{216}$ m, $\mathbf{a} = \mathbf{1}$ cm, $\mathbf{b} = \mathbf{10}$ cm, $d_{\mathrm{w}} = 0.3$ mm



n=1 or $\omega = \omega_0$: Up to $\gamma_0 = 6$, τ reaches 1%

Thick Wall Transverse Impedance

$$\mathbf{Z_{1,\perp}^{(sc+rw)}} = \frac{\mathbf{iZ_0LI_1^2}(\sigma_0\mathbf{a})}{\pi\mathbf{a^2}\gamma_0^2\beta}\left[\frac{\mathbf{K_1}(\sigma_0\mathbf{a})}{\mathbf{I_1}(\sigma_0\mathbf{a})} - \frac{\mathbf{K_1}(\sigma_0\mathbf{b}) + \frac{\mathbf{i}\gamma_0\beta\mathbf{Z_m}}{\mathbf{Z_0}}\mathbf{K_1'}(\sigma_0\mathbf{b})}{\mathbf{F}}\right.$$

$$\left.\frac{\mathbf{iZ_m}\gamma_0^3}{\mathbf{F}\ \mathbf{Z_0}\beta\mathbf{k_z^2b^2}}\frac{\mathbf{I_1}(\sigma_0\mathbf{b})\ \mathbf{G}}{\mathbf{I_1'}(\sigma_0\mathbf{b}) - \frac{\mathbf{iZ_m}}{\mathbf{Z_0}\beta\gamma_0}\mathbf{I_1}(\sigma_0\mathbf{b})}\right].$$

$$\mathbf{F} = \mathbf{I_1}(\sigma_0\mathbf{b}) + \mathbf{i}\frac{\gamma_0\beta\mathbf{Z_m}}{\mathbf{Z_0}}\mathbf{I_1'}(\sigma_0\mathbf{b}) - \mathbf{i}\frac{\mathbf{Z_m}\gamma_0^3}{\mathbf{Z_0}\beta\mathbf{k_z^2b^2}}\frac{\mathbf{I_1^2}(\sigma_0\mathbf{b})}{\mathbf{I_1'}(\sigma_0\mathbf{b}) - \mathbf{i}\frac{\mathbf{Z_m}}{\mathbf{Z_0}\beta\gamma_0}\mathbf{I_1}(\sigma_0\mathbf{b})}$$

$$\mathbf{G} = \mathbf{K_1}(\sigma_0\mathbf{b}) + \frac{\beta^2\mathbf{k_z^2ab}}{\gamma_0^2\mathbf{I_1}(\sigma_0\mathbf{a})}\left[\mathbf{I_1'}(\sigma_0\mathbf{a})\left(\mathbf{K_1'}(\sigma_0\mathbf{b}) - \mathbf{i}\frac{\mathbf{Z_mK_1}(\sigma_0\mathbf{b})}{\mathbf{Z_0}\beta\gamma_0}\right) - \right.$$

$$\left.\frac{\mathbf{K_1}(\sigma_0\mathbf{b})}{\mathbf{I_1}(\sigma_0\mathbf{b})}\left(\mathbf{I_1'}(\sigma_0\mathbf{b}) - \mathbf{i}\frac{\mathbf{Z_mI_1}(\sigma_0\mathbf{b})}{\mathbf{Z_0}\beta\gamma_0}\right)\right].$$

TM $\mathbf{Z}^{(\mathrm{rw})}_{\perp,\mathbf{1}}(\omega)$ for Thick Wall

$Z_m = 0$, TM + TE → TM

$$\mathbf{Z}^{(\mathrm{sc})}_{\mathbf{1},\perp,\mathbf{TM+TE}} \to \mathbf{Z}^{(\mathrm{sc})}_{\mathbf{1},\perp,\mathbf{TM}} = \mathbf{i}\,\frac{\mathbf{Z_0 L I_1^2}(\sigma_\mathbf{0}\mathbf{a})}{\pi\mathbf{a^2}\gamma_\mathbf{0}^\mathbf{2}\beta}\left[\frac{\mathbf{K_1}(\sigma_\mathbf{0}\mathbf{a})}{\mathbf{I_1}(\sigma_\mathbf{0}\mathbf{a})} - \frac{\mathbf{K_1}(\sigma_\mathbf{0}\mathbf{b})}{\mathbf{I_1}(\sigma_\mathbf{0}\mathbf{b})}\right]$$

$$\mathbf{Z}^{(\mathrm{sc})}_{\mathbf{1},\perp,\mathbf{TM+TE}}(\omega) = \mathbf{Z}^{(\mathrm{sc})}_{\mathbf{1},\perp,\mathrm{TM}}(\omega) = \mathbf{i}\,\frac{\mathbf{Z_0 L}}{\mathbf{2}\pi\beta\gamma_\mathbf{0}^\mathbf{2}}\left[\frac{\mathbf{1}}{\mathbf{a^2}} - \frac{\mathbf{1}}{\mathbf{b^2}}\right]$$

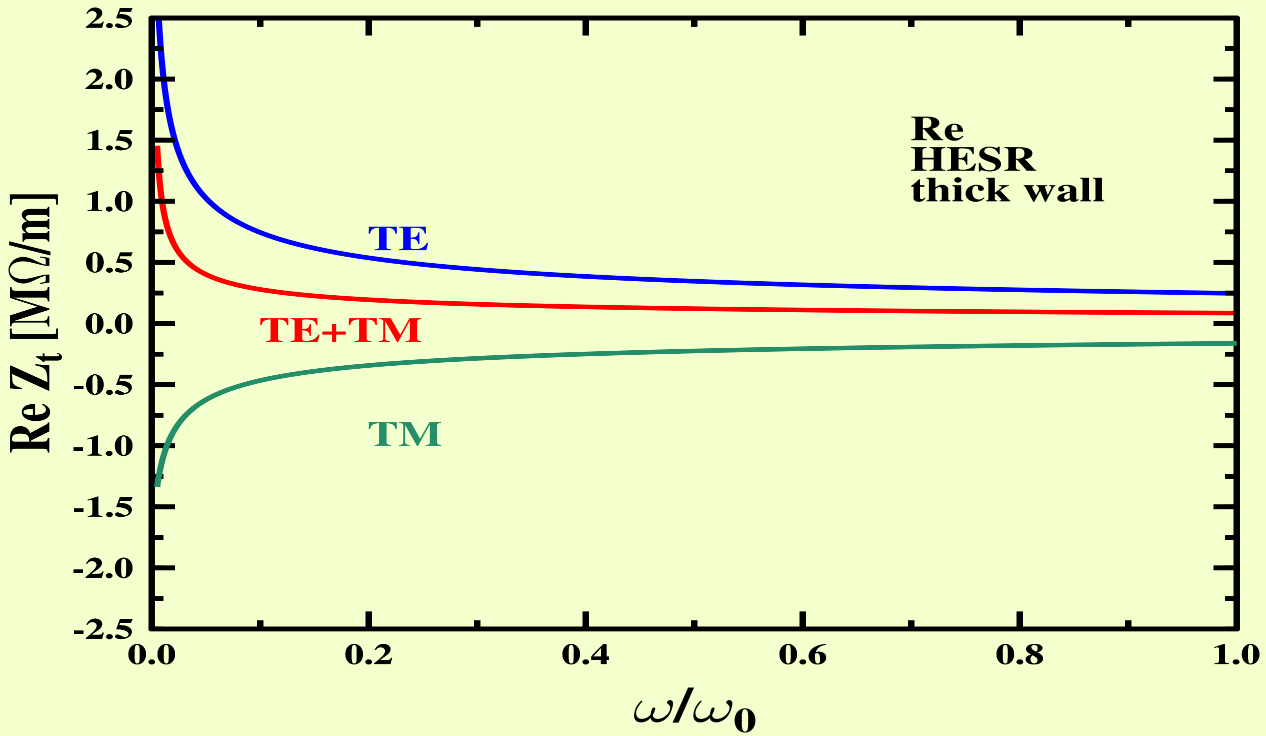
$Z_m \neq 0$, TM only

$$\mathbf{Z}^{(\mathrm{rw})}_{\mathbf{1},\perp,\mathrm{TM}}(\omega) = \mathbf{i}\,\frac{\mathbf{Z_0 L I_1^2}(\sigma_\mathbf{0}\mathbf{a})}{\pi\mathbf{a^2}\gamma^\mathbf{2}\beta}\left[\frac{\mathbf{K_1}(\sigma_\mathbf{0}\mathbf{b})}{\mathbf{I_1}(\sigma_\mathbf{0}\mathbf{b})} - \frac{\mathbf{K_1}(\sigma_\mathbf{0}\mathbf{b}) + \mathbf{i}\frac{\gamma\beta\mathbf{Z_m}}{\mathbf{Z_0}}\,\mathbf{K}'_\mathbf{1}(\sigma_\mathbf{0}\mathbf{b})}{\mathbf{I_1}(\sigma_\mathbf{0}\mathbf{b}) + \mathbf{i}\frac{\gamma\beta\mathbf{Z_m}}{\mathbf{Z_0}}\,\mathbf{I}'_\mathbf{1}(\sigma_\mathbf{0}\mathbf{b})}.\right]$$

$$\mathrm{Re}\left(\mathbf{Z}^{(\mathrm{rw})}_{\mathbf{1},\perp,\mathrm{TM}}(\omega)\right) \approx -\frac{\mathbf{2}}{\mathbf{b^2 k}}\,\frac{\mathbf{L Z_0}\omega\delta_\mathbf{s}}{\mathbf{4}\pi\mathbf{bc}} = -\frac{\mathbf{2}}{\mathbf{b^2 k}}\,\mathrm{Re}\left(\mathbf{Z}^{\mathrm{rw}}_{\mathbf{0},\parallel,\mathrm{TM}}(\omega,\gamma_\mathbf{0}\longrightarrow\infty)\right)$$

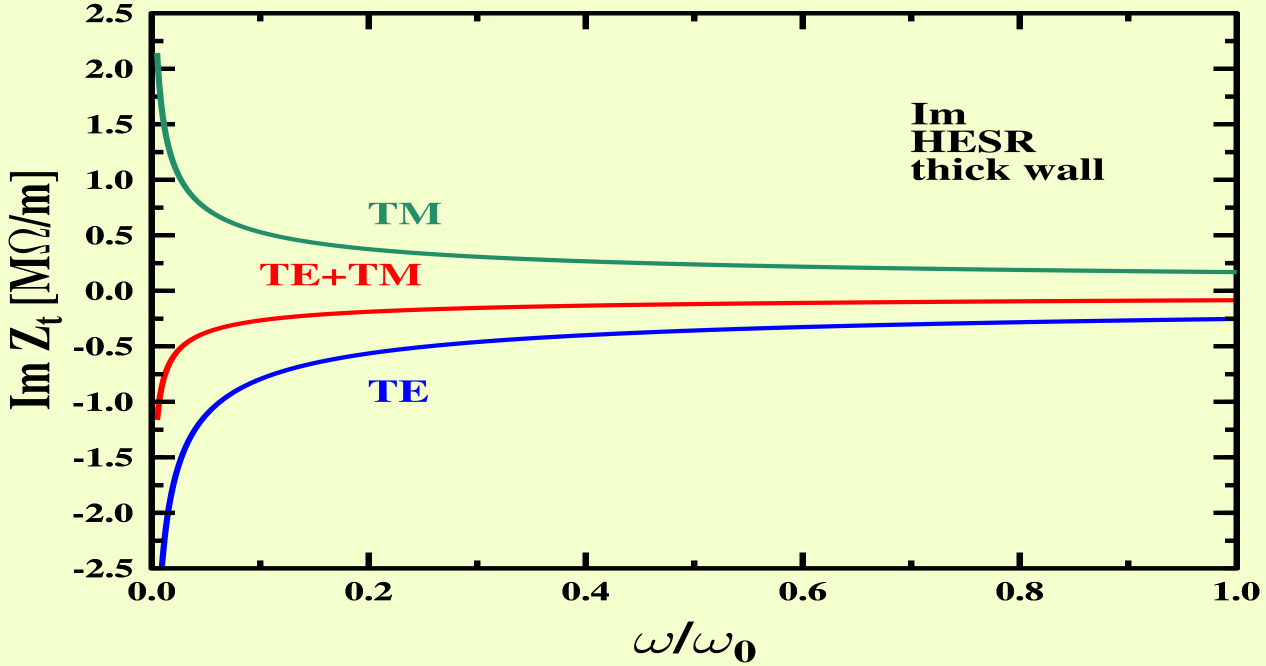
Thick Wall: Real Part of $\mathbf{Z}_{\perp,1}^{(\mathrm{rw})}(\omega)$ for HESR

$\mathbf{C} = \mathbf{570}$ m, $\mathbf{b} = \mathbf{5}$ cm, $\mathbf{a} = \mathbf{1}$ cm, $\gamma_0 = \mathbf{2}$



Thick Wall: Imaginary Part of $\mathbf{Z}_{\perp,\mathbf{1}}^{(\mathrm{rw})}(\omega)$ for HESR

$\mathbf{C} = \mathbf{570}$ m, $\mathbf{b} = \mathbf{5}$ cm, $\mathbf{a} = \mathbf{1}$ cm, $\gamma_\mathbf{0} = \mathbf{2}$



Note: $-\mathbf{i} \rightarrow \mathbf{j}$

Transverse Impedance: Arbitrary Wall Thickness

$$\mathbf{Z_{1,\parallel}}(\omega) = \mathbf{i}\frac{\mathbf{nZ_0}}{\mathbf{2}\beta\gamma_\mathbf{0}^\mathbf{2}}\ \frac{\mathbf{4I_1^2}(\sigma_\mathbf{0}\mathbf{a})}{\mathbf{a^2}}\ \mathbf{F}\ , \quad \mathbf{Z_{1,\perp}}(\omega) = \frac{\mathbf{Z_{1,\parallel}}(\omega)}{\mathbf{k_z}}$$

$$\mathbf{f_0} = \frac{P\sigma_0 a\ K_1(\sigma_0 a)}{\epsilon_0\gamma_0\beta c\pi a^2}\ , \quad \mathbf{a_{00}} = \frac{\omega}{k_z\underline{\sigma}h}\left(1 - \frac{\eta_3\underline{\sigma}}{\sigma_0}\right)\ , \quad \mathbf{h = b + d}$$

$$\mathbf{f_3} = \left(1 - \frac{\underline{\gamma}^2}{\gamma_0^2}\right)\left(\frac{K_1(\underline{\sigma}h)}{I_1(\underline{\sigma}h)} - \frac{K_1(\underline{\sigma}b)}{I_1(\underline{\sigma}b)}\right)\ , \quad \eta_\mathbf{3} = \frac{\omega\epsilon_0\gamma_0}{i\underline{\gamma}(S_w - i\omega\epsilon_w)}$$

$$\mathbf{F} = \frac{I_1(\underline{\sigma}b)}{I_1(\sigma_0 b)}\ \frac{\alpha_{22}\beta_{11} - \alpha_{12}\beta_{22}}{\alpha_{11}\alpha_{22} - \alpha_{12}\alpha_{21}} + \frac{K_1(\underline{\sigma}b)}{I_1(\sigma_0 b)}\frac{\alpha_{11}\beta_{22} - \alpha_{21}\beta_{11}}{\alpha_{11}\alpha_{22} - \alpha_{12}\alpha_{21}} + \frac{K_1(\sigma_0 a)}{I_1(\sigma_0 a)} - \frac{K_1(\sigma_0 b)}{I_1(\sigma_0 b)}$$

Transverse Impedance: Arbitrary Wall Thickness

$$\alpha_{11} = c_{11} \frac{I_1(\underline{\sigma} b)}{I_1(\sigma_0 b)} + c_{21} - \eta_3 \frac{K_1'(\sigma_0 h)}{K_1(\sigma_0 h)} \; \frac{a_{11}}{a_{00}} \; \frac{I_1(\underline{\sigma} h)}{K_1(\sigma_0 h)}$$

$$\alpha_{12} = c_{11} \frac{K_1(\underline{\sigma} b)}{I_1(\sigma_0 b)} + c_{22} - \eta_3 \frac{K_1'(\sigma_0 h)}{K_1(\sigma_0 h)} \; \frac{a_{11}}{a_{00}} \; \frac{K_1(\underline{\sigma} h)}{K_1(\sigma_0 h)}$$

$$\beta_{11} = c_{11} \; \frac{K_1(\sigma_0 b)}{I_1(\sigma_0 b)} - c_{12} \; , \quad \beta_{22} = e_{11} \; \frac{K_1(\sigma_0 b)}{I_1(\sigma_0 b)} - e_{33}$$

$$\alpha_{21} = e_{11} \; \frac{I_1(\underline{\sigma} b)}{I_1(\sigma_0 b)} - d_{11} - d_{21} \; \frac{I_1(\underline{\sigma} h)}{K_1(\sigma_0 h)} \; ,$$

$$\alpha_{22} = e_{11} \; \frac{K_1(\underline{\sigma} b)}{I_1(\sigma_0 b)} - d_{12} - d_{21} \; \frac{K_1(\underline{\sigma} h)}{K_1(\sigma_0 h)}$$

$$\mathbf{c_{11}} = f_3 \; I_1(\sigma_0 b) - \eta_3 \; \frac{b}{h} \; \frac{I_1'(\sigma_0 b)}{I_1(\sigma_0 b)} \; \frac{a_{12}}{a_{00}} \; , \mathbf{c_{12}} = f_3 \; K_1(\sigma_0 b) - \eta_3 \; \frac{b}{h} \; \frac{K_1'(\sigma_0 b)}{I_1(\sigma_0 b)} \; \frac{a_{12}}{a_{00}}$$

$$\mathbf{c_{21}} = \frac{a_{11}}{a_{00}} \; \frac{I_1'(\underline{\sigma} h)}{K_1(\sigma_0 h)} + \frac{a_{12}}{a_{00}} \; \frac{b}{h} \; \frac{I_1'(\underline{\sigma} b)}{I_1(\sigma_0 b)} \; , \mathbf{c_{22}} = \frac{a_{11}}{a_{00}} \; \frac{K_1'(\underline{\sigma} h)}{K_1(\sigma_0 h)} + \frac{a_{12}}{a_{00}} \; \frac{b}{h} \; \frac{K_1'(\underline{\sigma} b)}{I_1(\sigma_0 b)}$$

Transverse Impedance: Arbitrary Wall Thickness

$$\mathbf{d_{11}} = \frac{a_{21}}{a_{00}}\ \frac{I_1'(\underline{\sigma}h)}{K_1(\sigma_0 h)} + \frac{a_{22}}{a_{00}}\ \frac{b}{h}\ \frac{I_1'(\underline{\sigma}b)}{I_1(\sigma_0 b)}$$

$$\mathbf{d_{12}} = \frac{a_{21}}{a_{00}}\ \frac{K_1'(\underline{\sigma}h)}{K_1(\sigma_0 h)} + \frac{a_{22}}{a_{00}}\ \frac{b}{h}\ \frac{K_1'(\underline{\sigma}b)}{I_1(\sigma_0 b)}$$

$$\mathbf{e_{11}} = \frac{\eta_3 a_{22}}{a_{00}}\frac{b}{h}\frac{I_1'(\sigma_0 b)}{I_1(\sigma_0 b)}\ , \quad \mathbf{e_{33}} = \frac{\eta_3 a_{22}}{a_{00}}\frac{b}{h}\frac{K_1'(\sigma_0 b)}{I_1(\sigma_0 b)}$$

$$\mathbf{d_{21}} = f_3 K_1(\sigma_0 b) - \frac{\eta_3 K_1'(\sigma_0 h)}{K_1(\sigma_0 h)}\frac{a_{21}}{a_{00}}$$

$$\mathbf{a_{11}} = \frac{\underline{\gamma} b\omega}{\gamma_0^2}\ K_1'(\underline{\sigma}b)\ \frac{K_1(\sigma_0 h)}{I_1(\underline{\sigma}h)} - \frac{\underline{\gamma} b\omega}{\gamma_0^2}\ I_1'(\underline{\sigma}b)\ \frac{K_1(\underline{\sigma}b)}{I_1(\underline{\sigma}b)}\ \frac{K_1(\sigma_0 h)}{I_1(\underline{\sigma}h)}$$

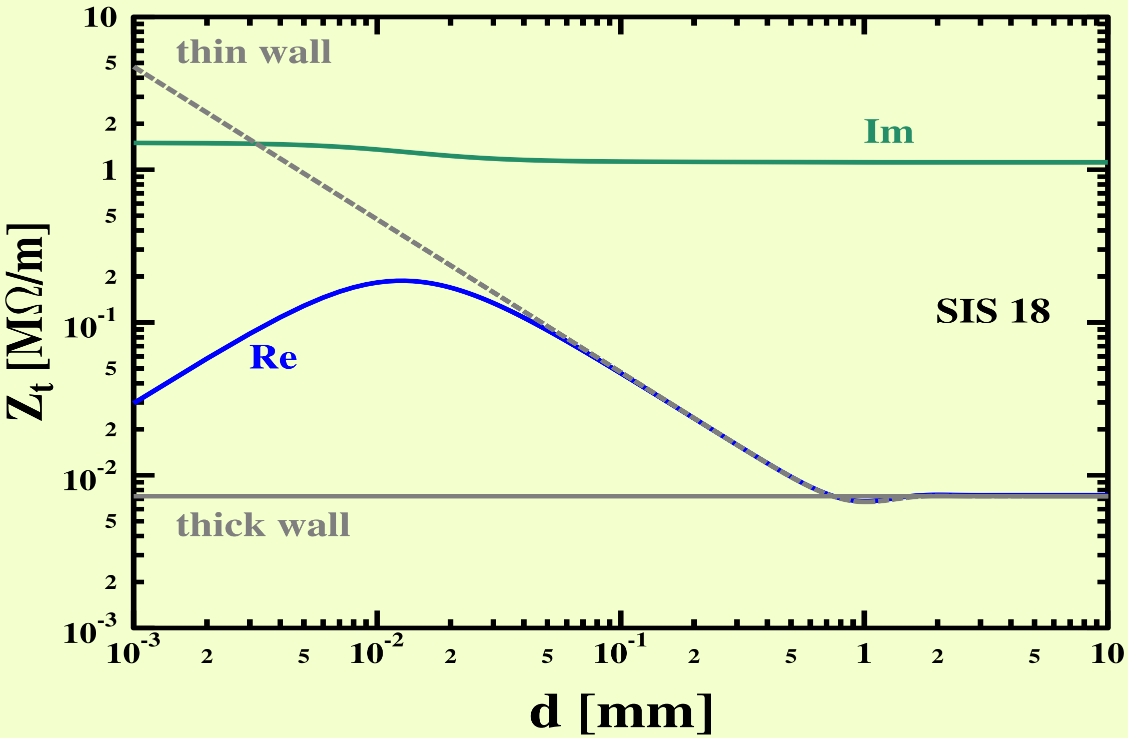
$$\mathbf{a_{12}} = \frac{\underline{\gamma} b\omega}{\gamma_0^2}\ I_1'(\underline{\sigma}b)\ \frac{K_1(\underline{\sigma}h)}{I_1(\underline{\sigma}h)}\ \frac{I_1(\sigma_0 b)}{I_1(\underline{\sigma}b)} - \frac{\underline{\gamma} b\omega}{\gamma_0^2}\ K_1'(\underline{\sigma}b)\ \frac{I_1(\sigma_0 b)}{I_1(\underline{\sigma}b)} - \frac{b\omega}{\gamma_0}\ I_1'(\sigma_0 b)$$

$$\mathbf{a_{21}} = \frac{\underline{\gamma} h\omega}{\gamma_0^2}\ K_1'(\underline{\sigma}h)\ \frac{K_1(\sigma_0 h)}{I_1(\underline{\sigma}h)} - \frac{\underline{\gamma} h\omega}{\gamma_0^2}\ I_1'(\underline{\sigma}h)\ \frac{K_1(\underline{\sigma}b)}{I_1(\underline{\sigma}b)}\ \frac{K_1(\sigma_0 h)}{I_1(\underline{\sigma}h)} - \frac{h\omega}{\gamma_0}\ K_1'(\sigma_0 h)$$

$$\mathbf{a_{22}} = \frac{\underline{\gamma} h\omega}{\gamma_0^2}\ I_1'(\underline{\sigma}h)\ \frac{K_1(\underline{\sigma}h)}{I_1(\underline{\sigma}h)}\ \frac{I_1(\sigma_0 b)}{I_1(\underline{\sigma}b)} - \frac{\underline{\gamma} h\omega}{\gamma_0^2}\ K_1'(\underline{\sigma}h)\ \frac{I_1(\sigma_0 b)}{I_1(\underline{\sigma}b)}$$

Transverse Impedance: SIS18

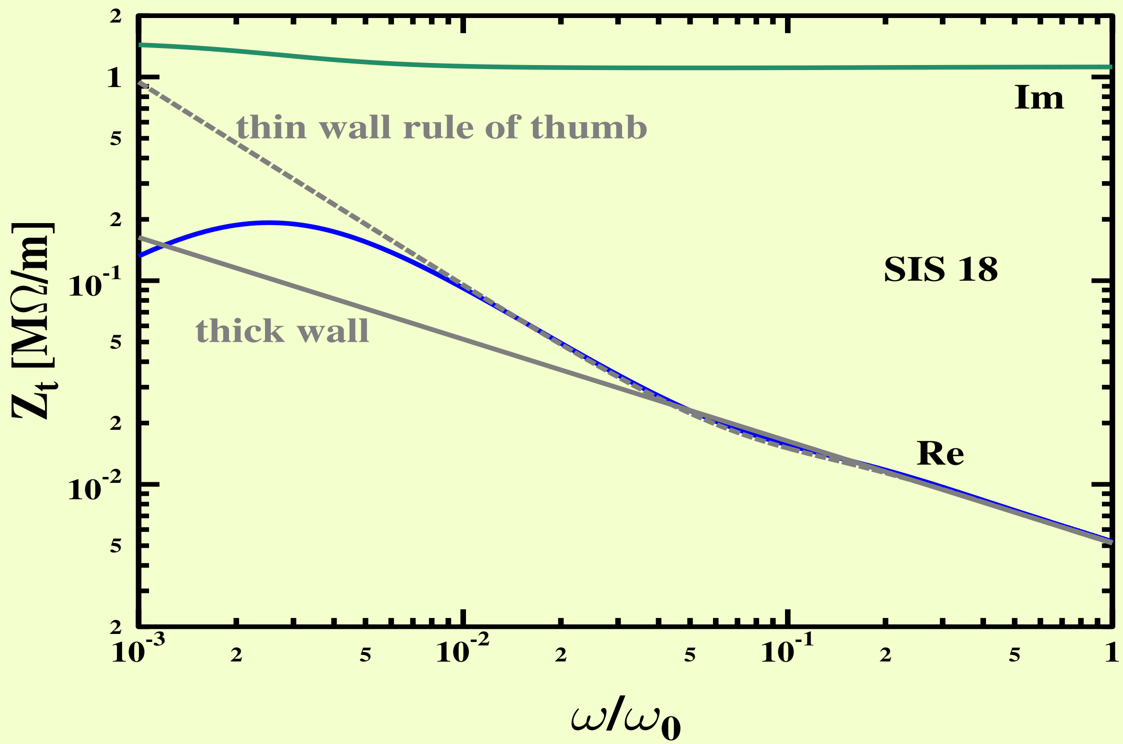
$\mathbf{C = 216}$ m, $\mathbf{b = 10}$ cm, $\mathbf{a = 0.5b}$, $\mathbf{d_w = 0.3}$ mm, $\gamma = \mathbf{2}$, $\omega = \mathbf{0.5}\omega_0$



Thin wall rule of thumb: $\mathbf{Z_{\perp,1} = \frac{2}{b^2 k_z} Z_{\parallel,0}}$!!

Transverse Impedance: SIS18

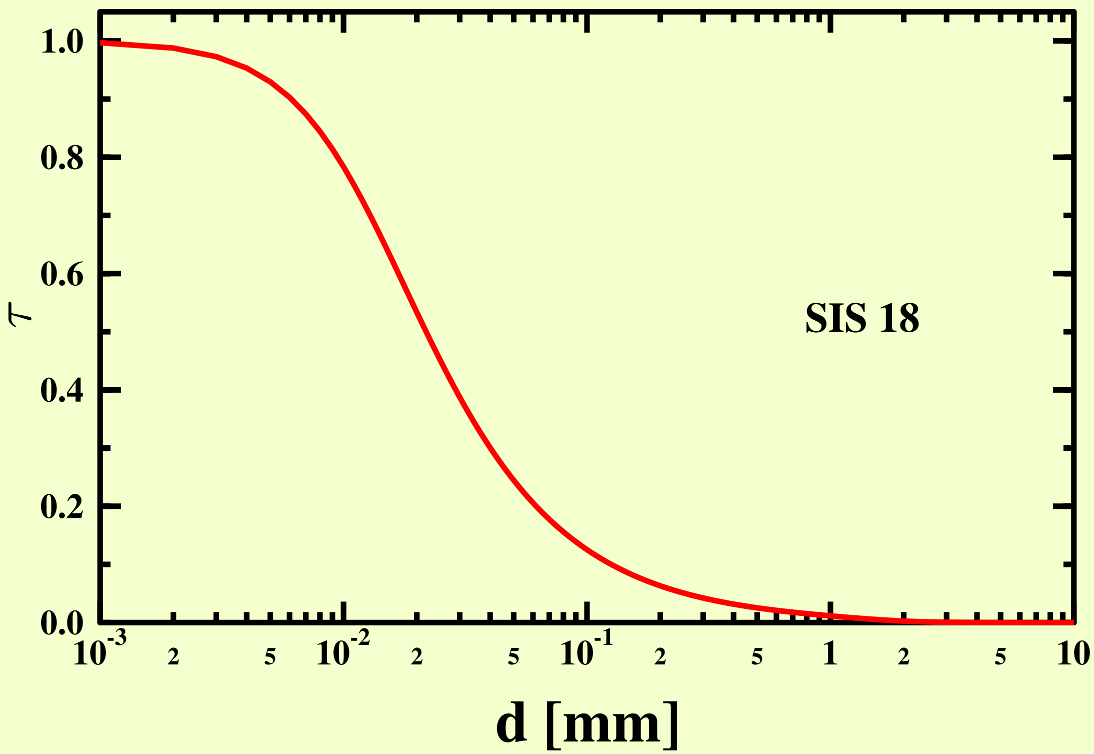
$\mathbf{C = 216\ \mathrm{m},\ b = 10\ \mathrm{cm},\ a = 0.5b\ ,\ d_w = 0.3\ \mathrm{mm},\ \gamma = 2,\ d = 2.5\ mm}$



Thin wall rule of thumb: $\mathbf{Z_{\perp,1} = \frac{2}{b^2 k_z} Z_{\parallel,0}}$ **!!**

Transmission Coefficient: SIS18

$\mathbf{C = 216}$ m, $\mathbf{b = 10}$ cm, $\mathbf{a = 0.5b}$, $\mathbf{d_w = 0.3}$ mm, $\omega = \mathbf{0.5}\omega_\mathbf{0}$, $\gamma = \mathbf{2}$



Summary

- **Derivation of analytical expressions for $Z_{\parallel}$ and $Z_{\perp}$ for arbitrary frequency ω, energy γ and wall thickness d**
- **Beam shielding is of relevance for high–current SIS18 upgrade and new SIS100**

  Compromise: **to reduce return currents to 1% of peak value d of few 0.1mm of St. Steel provides good return current shielding**
- **Both TM and TE modes contribute to the transverse resistive–wall impedance**:
  Positive total real part and Positive total imaginary part (Inductive)
- **Apply Panofski–Wenzel theorem at the same azimuthal number**
- **Needed**: **Comparison between existing expressions (arbitrary d) from different authors for the transverse coupling impedance**

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