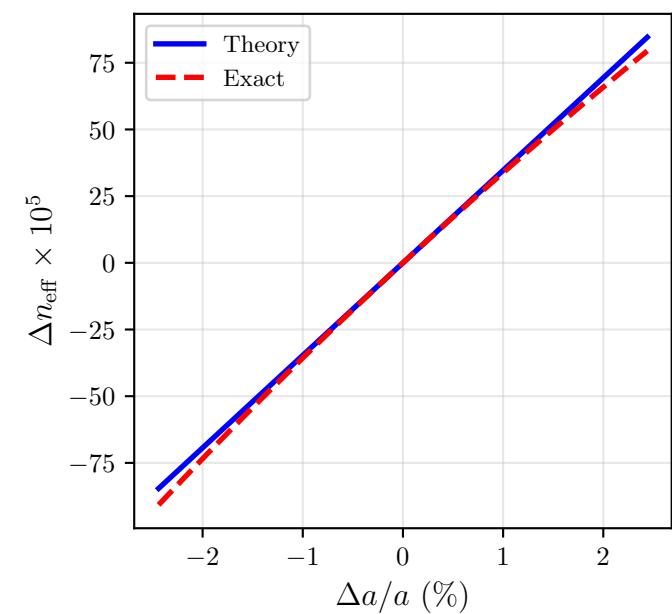
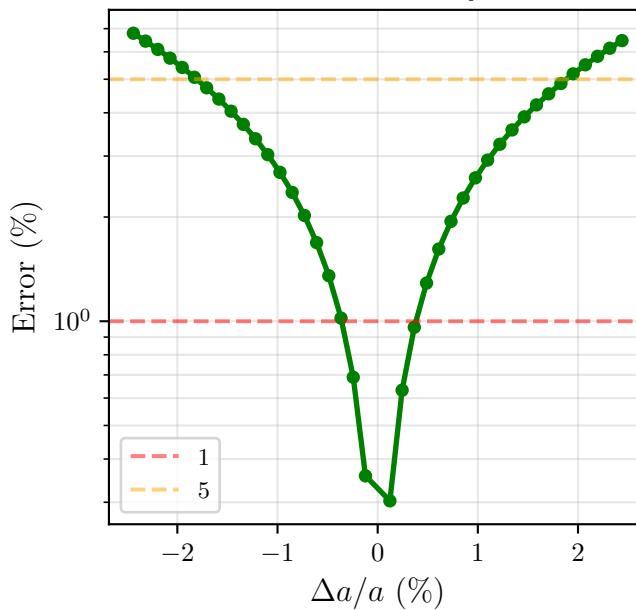


Perturbation Theory: Complete Validation Summary

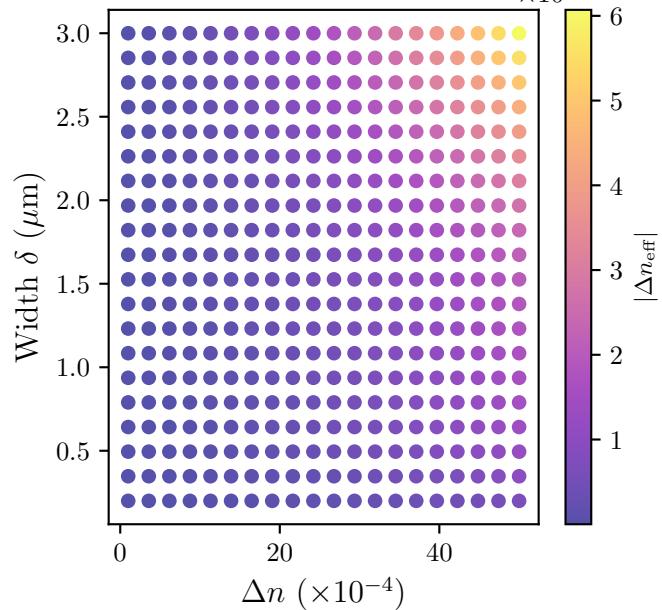
Scenario 1: Radius Variation



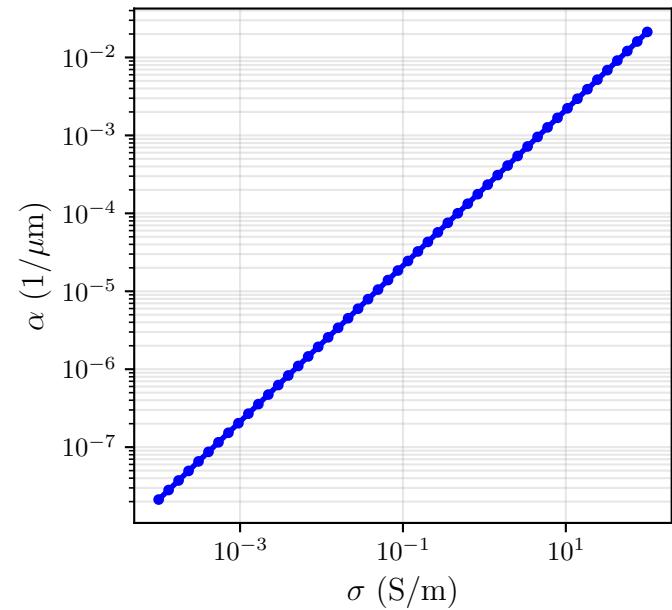
Perturbation Theory Error



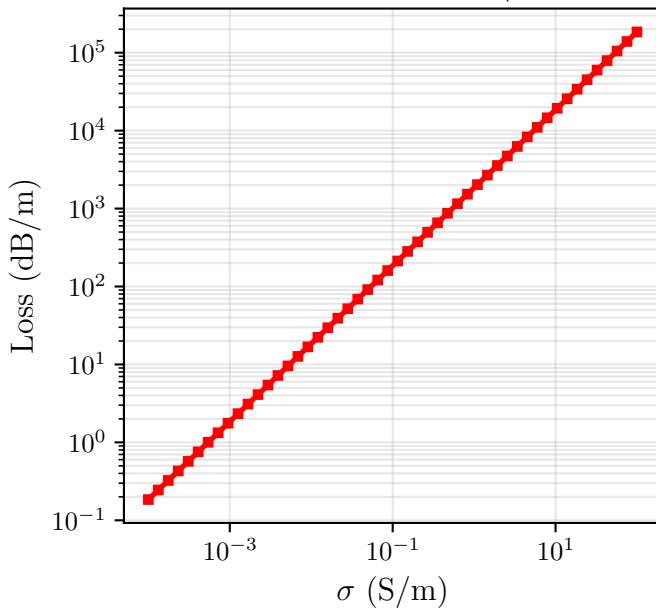
Scenario 2: Index Perturbation



Scenario 3: Weak Absorption



Attenuation in dB/m



Perturbation Theory Validation

Scenario 1: Radius Error

Δa range: -0.1 to $+0.1 \mu\text{m}$
Max error: 6.8%
Mean error: 3.5%

Scenario 2: Index Change

Δn range: 10^{-4} to 5×10^{-3}
Width range: 0.2 to $3 \mu\text{m}$
 $|\Delta n_{\text{eff}}|$ range: 10^{-9} to 10^{-7}

Scenario 3: Absorption

σ range: 10^{-4} to 10^2 S/m
Loss range: 0.002 to 18500 dB/m