

I. I. 1000 *

$(\leq \lambda_0)$ \parallel $\rho \neq 1$ \parallel $[1, 4]$ \parallel $[1]$ \parallel $\rho = 0$ \parallel 1 \parallel

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$I = \frac{1}{2} \int_{-1}^1 \sqrt{1-x^2} dx = \frac{1}{2} \left[\frac{x}{2} \sqrt{1-x^2} + \frac{1}{2} \arcsin x \right]_{-1}^1 = \frac{1}{2} \left(\frac{1}{2} \sqrt{1-1} + \frac{1}{2} \arcsin 1 \right) - \frac{1}{2} \left(\frac{-1}{2} \sqrt{1-1} + \frac{1}{2} \arcsin(-1) \right) = \frac{1}{2} \left(\frac{1}{2} \cdot 0 + \frac{1}{2} \cdot \frac{\pi}{2} \right) - \frac{1}{2} \left(\frac{-1}{2} \cdot 0 + \frac{1}{2} \cdot \left(-\frac{\pi}{2}\right) \right) = \frac{1}{2} \left(\frac{\pi}{4} + \frac{\pi}{4} \right) = \frac{1}{2} \cdot \frac{\pi}{2} = \frac{\pi}{4}$

$[4, \dots]$

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 $\rho < \rho$
 $\rho > \rho$
 $\rho > \rho$
0
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$$\mathcal{F}[\theta] = \frac{1}{\theta} \int_0^{\theta} \left[(K_{\parallel} + \theta + K) \left(\frac{4K}{K} \rho + \frac{\Delta\varepsilon}{K} \frac{1}{\pi} \right) + \frac{K}{\theta} \left(\frac{4\pi}{\theta} \right) \right] \frac{1}{\left[\int_0^{\theta} \frac{1}{\varepsilon_{\perp} + \theta + \varepsilon_{\parallel}} \right]} d\theta \quad (9)$$

where $\rho = \frac{K_{\perp}}{K}$ is the ratio of the perpendicular to the parallel conductivity, ε_{\perp} and ε_{\parallel} are the perpendicular and parallel permittivities, respectively. The integral in (9) is taken over the range $\theta \in [0, \theta^*]$, where θ^* is the value of θ for which the denominator in (9) becomes zero.

$$\mathcal{F}[\theta] = \frac{1}{\theta} \left[\frac{4\pi K}{\theta} + \frac{\varepsilon_{\parallel}}{\theta} \right] + \frac{1}{\theta} \int_0^{\theta} \left[K + \theta \left(\frac{\Delta\varepsilon}{K} + \frac{4\pi K}{\theta} \right) \right] \frac{1}{\left[\int_0^{\theta} \frac{1}{\varepsilon_{\perp} + \theta + \varepsilon_{\parallel}} \right]} d\theta + O(\theta^4). \quad (10)$$

The integral in (10) can be evaluated using the method of residues. The integrand has a simple pole at $\theta = -\varepsilon_{\perp}$ and a branch cut along the real axis for $\theta > -\varepsilon_{\perp}$. The integral is then given by the residue at the pole and the integral along the branch cut.

$$\frac{1}{\theta} \int_0^{\theta} \frac{1}{\varepsilon_{\perp} + \theta + \varepsilon_{\parallel}} d\theta = \frac{1}{\theta} \left[\ln \left(\frac{\varepsilon_{\perp} + \theta + \varepsilon_{\parallel}}{\varepsilon_{\perp} + \varepsilon_{\parallel}} \right) \right] = \frac{1}{\theta} \ln \left(1 + \frac{\theta}{\varepsilon_{\perp} + \varepsilon_{\parallel}} \right) \approx \frac{\theta}{\varepsilon_{\perp} + \varepsilon_{\parallel}} - \frac{\theta^2}{2(\varepsilon_{\perp} + \varepsilon_{\parallel})^2} + \dots \quad (10)$$

where the expansion is valid for $\theta \ll \varepsilon_{\perp} + \varepsilon_{\parallel}$. The integral in (10) is then given by the residue at the pole and the integral along the branch cut. The residue at the pole is $\frac{1}{\theta} \frac{1}{\varepsilon_{\perp} + \varepsilon_{\parallel}}$. The integral along the branch cut is $\frac{1}{\theta} \int_0^{\theta} \frac{1}{\varepsilon_{\perp} + \theta + \varepsilon_{\parallel}} d\theta$. The integral in (10) is then given by the residue at the pole and the integral along the branch cut.

$$\Delta\phi = \frac{\pi}{\rho} \int_0^{\rho} \frac{K}{K - \theta + K} \theta \quad (11)$$

ρ $\Delta\phi$ $K/K \approx 0.4$
 $0.4 * \pi\rho < \Delta\phi < \pi\rho,$ (1)

$\Delta\phi$ $\theta \approx 0$
 $\theta \approx \pi/2$
 ρ $\Delta\phi$ ρ

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