LAB EXERCISE: Effective medium theories

Step 1:

Plot, as a function of the inclusion's fill factor, the relative effective permittivity of a mixture of spherical inclusions with dielectric constant $\varepsilon_i = 10$, immersed in air ($\varepsilon_h = 1$).

Use the Maxwell-Garnett approximation to model your material.

$$\varepsilon_{\mathrm{MG}} = \varepsilon_{\mathrm{h}} \left[1 + 3f \frac{\varepsilon_{\mathrm{i}} - \varepsilon_{\mathrm{h}}}{\varepsilon_{\mathrm{i}} + 2\varepsilon_{\mathrm{h}} - f(\varepsilon_{\mathrm{i}} - \varepsilon_{\mathrm{h}})}\right].$$

Step 2:

Consider a metal-dielectric, planar multilayer in the electrostatic approximation with fill factor *f*=0.5. Assume for metal a complex, frequency-dependent dielectric constant:

$$\varepsilon(\omega) = 1 - \frac{\omega_p^2}{\omega^2 - j\omega\gamma},$$

with $\omega_p = 2\pi\, 2.18 \times 10^{15}\mathrm{Hz}$ and $\gamma = 2\pi\, 4.35 \times 10^{12}\mathrm{Hz}$, and for the dielectric a dispersion-free relative permittivity of 2.25.

1) Determine the wavelength ranges in which the dispersion of the mixture for TM polarized fields is *hyperbolic*, i.e., when Real[$\varepsilon_{\parallel}$] ×Real[$\varepsilon_{\perp}$]<0.
2) How the metal fill factor moves the hyperbolic ranges in the wavelength domain?

The effective permittivity formulas for anisotropic mixtures are:

$$\varepsilon_{\parallel} = f\varepsilon_{\mathrm{i}} + (1-f)\varepsilon_{\mathrm{h}}$$

$$\varepsilon_{\perp} = \frac{\varepsilon_{\mathrm{i}}\varepsilon_{\mathrm{h}}}{f\varepsilon_{\mathrm{h}} + (1-f)\varepsilon_{\mathrm{i}}}$$