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Wave interaction with active dielectric slab

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Reflection of a plane wave entering with normal incidence from free space against a planar boundary of a dielectric half space is computed—according to electromagnetics textbooks—using the expression

$$R = \frac{\eta - \eta_0}{\eta + \eta_0} = \frac{1-n}{1+n} \tag{1}$$

where R is the (complex) ratio between the reflected and incident electric fields, $\eta = \sqrt{\mu_0/\varepsilon}$ is the intrinsic impedance of the dielectric half space with relative permittivity $\varepsilon_r = \varepsilon/\varepsilon_0$ and refractive index $n = \sqrt{\varepsilon_r}$, and the free-space impedance is $\eta_0 = \sqrt{\mu_0/\varepsilon_0}$. For lossless media, the permittivity and refractive index are real numbers, but for lossy (dissipative) materials, they come with an imaginary part. Using the electrical engineering time-harmonic convention $\exp(\mathrm{j}\omega t)$, for lossy (dissipative) media, the imaginary part of the permittivity is negative, usually coded as $n = n' - \mathrm{j}n''$ where n'' is positive in the dissipative case.

Equation (1) works well for reflection from passive media (passive media include the classes of lossless ($n'' = 0$) and dissipative ($n'' > 0$) materials). However, taking an active (gainy) medium, for example $n = 2 + \mathrm{j}$, we arrive at $R = -0.4 - \mathrm{j}0.2$. But active medium creates power, and hence the reflection coefficient is larger that unity in magnitude. Using an analysis of wave reflection and transmission on an active dielectric slab, the correct form of Equation (1) is derived (leading to $R = -2 + \mathrm{j}$ in the case $n = 2 + \mathrm{j}$), as well as several other interesting phenomena in the context of gainy media.

For example, for active slabs, strong resonances can appear that make the reflection and transmission coefficients singular. This is illustrated in Figure 1 which shows the amplitude of the reflection and transmission coefficients for a slab with free-space optical thickness $kd = 3$ (where $k = \omega\sqrt{\mu_0\varepsilon_0}$). In the part of the complex n-plane of the illustration, three resonances can be seen.

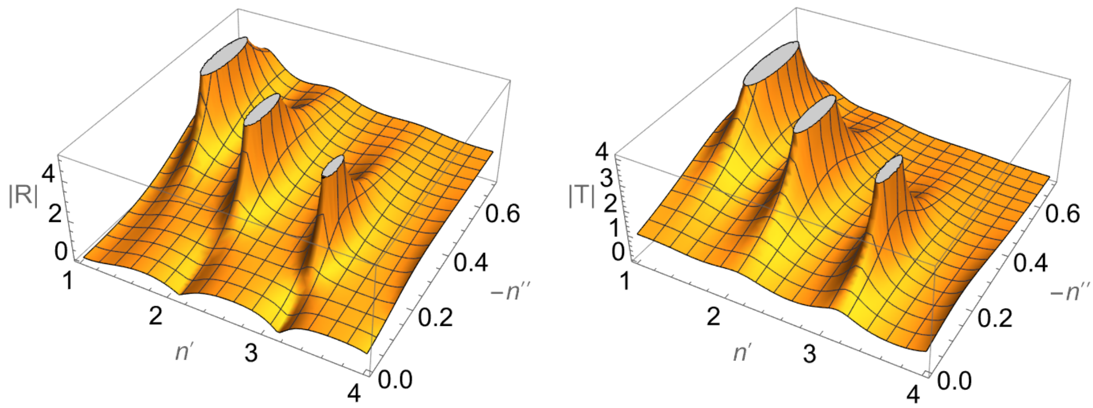

Figure 1. The absolute value of the reflection and transmission coefficients for an active slab with optical thickness $kd = 3$, as function of the complex refractive index $n = n' - \mathrm{j}n''$ of the slab. Normal incidence of the plane wave.