Designer Emissivities

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The emissivity of an object is defined as the ratio of the brightness temperature $T_{B\nu}$ emitted by the object to its actual physical temperature T_{phys}, under the assumption that the object is at a constant physical temperature [1], $T_{B\nu} = e_\nu\,(\theta,\,\phi)T_{phys}$. In this equation the subscript ν refers to the polarization of the brightness temperature, while $(\theta,\,\phi)$ are the polar and azimuthal angles of observation. Kirchhoffs law [2] relates the emissivity $e_\nu(\theta,\,\phi)$ to the reflectivity of the surface, $e_\nu(\theta,\,\phi) = 1 - r_\nu(\theta,\,\phi)$, where the reflectivity $r_\nu(\theta,\,\phi)$ is the fraction of the power scattered from the surface when $a\,\nu = p$, s wave is incident on it from the direction $(\theta,\,\phi)$. Since the reflectivity of a surface is affected by its roughness [3], it follows that its emissivity is affected by the roughness. The question then arises, can one design a random surface that produces an emissivity with a specified wavelength dependence at a fixed angle of emission?

We investigate this question for a one-dimensional random surface defined by $x_3 = \zeta(x_1)$. The region $x_3 > \zeta(x_1)$ is vacuum, while the region $x_3 < \zeta(x_1)$ is a perfect conductor. This surface is illuminated by an s-polarized plane wave of frequency ω, whose plane of incidence is the x_1x_3 plane. We represent the surface profile function in the form $\zeta(x_1) = nb < x_1 < (n+1)b$, with $n = 0, \pm1, \pm2, \ldots$ Here b is a characteristic length, and the $\{d_n\}$ are independent, identically distributed random deviates. The probability density function (pdf) of d_n, $\langle\delta(\gamma - d_n)\rangle = f(\gamma)$, where the angle brackets denote an average over the ensemble of realizations of $\zeta(x_1)$, is therefore independent of n. In the Kirchhoff approximation, which we use due to its simplicity, the reflectivity is given by $r_s(\theta_0, \omega) =\mid F((2\omega b/c)\cos\theta_0)\mid^2$, where θ_0 is the polar angle of incidence, and $F(\nu) = \int_{-\infty}^{\infty} d\gamma f(\gamma)\exp(-i\nu\gamma)$. Thus, if we wish to have a particular frequency dependence of the emissivity $e_s(\theta_0, \omega)$ at an angle of emission θ_0, we have to solve the equation $\mid F((2\omega b/c)\cos\theta_0 \mid= [1 - e_s(\theta_0,\,\omega)]^{1/2}$ to obtain $f(\gamma)$. This is done iteratively by the use of a modified Gerchberg-Saxton algorithm [4]. From the result a long sequence of $\{d_n\}$ is generated by the rejection method [5], from which a realization of the surface profile function is generated. To validate the approach described, the emissivity produced by the resulting surface is calculated by solving the scattering problem numerically for a particular example.

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