Scattering of an Electromagnetic Wave from 3-dimensional Rough Layers: Small-amplitude Method and Small-slope Approximation

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The scattering of electromagnetic waves from randomly rough surfaces have been extensively studied in different domains such as radio-physics, geophysical remote sensing, ocean acoustics, surface optics and recently plasmonics where metallic surfaces have a dielectric coating. Our purpose is to show how light can interact with several randomly rough surfaces. In this paper, we consider an electromagnetic polarized plane wave incident on a three-dimensional dielectric film with one or two randomly rough surfaces. We assume that the randomly rough surfaces are Gaussian and statistically independent: a Gaussian probability density function is assumed for the random rough surface heights and the autocorrelation function is a Gaussian function. We study two hypothesis, we consider three-dimensional structures bounded by two-dimensional weakly rough surfaces or by two-dimensional randomly rough surfaces with small-slope.

In the case of weakly randomly rough interfaces, we use the small-amplitude perturbation theory, we have generalized the integral equations called reduced Rayleigh equations in the case of a three-dimensional layer with weakly randomly rough interfaces. The electromagnetic polarized plane wave is incident on a dielectric layer whose mean thickness is constant. The dielectric layer is deposited on a metallic film. Illustrative examples are presented for the bistatic diffuse component of the electromagnetic field.

In the second part of the paper, we discuss the extension of the theory using the small-slope approximation method. We study structures with two-dimensional randomly rough surfaces, including scattering from free-standing films or films on a substrate, one or both of whose surfaces are randomly rough. The fourth order term of the perturbative development is required if we want to take into account the interactions between the two randomly rough surface. Some simulations will be given and compared with the small-amplitude perturbation method.

This analysis is relevant to problems of laser cross-section calculation, remote sensing of irregular layered structures and remote detection of chemical coatings.