Study of Relationship between Multiple Scatter and Backscatter Enhancement from Rough Surfaces

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Abstract — The backscattering enhancement from rough surfaces is predicted due to the constructive interference of multiple surfaces scattering. For specialized surfaces involving roughness large compared with the incident wavelength, the multiple scatter and backscattering enhancement takes place. The phenomenon of backscatter enhancement becomes evident for both larger normalized surface height and surface rms slope. In this paper we take further study to predict the backscattering enhancement mainly comes from upward multiple scattering. On the contrary the downward multiple scattering has no contributions to the scatter strength of backscattering enhancement. The existing integral equations model is modified to be able to predict the phenomena of multiple scattering and backscattering enhancement. The total multiple scattering strength is the summation of upward and downward multiple scattering strength. The depolarized multiple scattering makes much contribution to the strength of backscatter enhancement in the backward direction along the plane of incidence from random rough surfaces, but depolarized single scattering makes little. In comparison of model prediction of total multiple scattering strength with measured data along the specular plane, excellent agreement is obtained.

Introduction: The experimental study of backscattering enhancement from characterized random surfaces was studied by L. Ailes-Sengers in 1995. The comparisons of Monte Carlo numerical studies and experimental measurement of backscattering enhancement from 2-D perfectly conducting random rough surfaces was made by Joel T. Johnson in 1996. Up to date a theoretical model for studying the backscattering enhancement and the relationship among the backscattering enhancement and the multiple scattering is still lacking. Further the study of upward or downward multiple scattering making major contributions to backscattering enhancement is also lacking.

In this paper we develop the scattering model to predict the multiple scattering and backscattering enhancement and the relationship between them. Due that the phase terms of Green’s function and its derivative in the integral equation pairs is a possible candidate for the multiple scatter and backscattering enhancement from very rough surfaces, the model developed in this paper is based upon the integral equation pairs with tangential electric and magnetic surface fields.

Model Description: The modified integral equations for tangential surface fields on a dielectric interface are applied to predict the contributions of multiple scattering from rough surfaces. In the model development the estimates of the tangential surface electrical and magnetic fields in the dielectric medium are more general than Kirchhoff, perturbation surface fields and the existing integral equation model [Fung, 1994].

The spectral representation for the Green’s function is stated below

\[
G = \left( -\frac{1}{2\pi} \right) \int \frac{j}{q} \exp \left[ ju(x - x') + jv(y - y') - jq|z - z'| \right] du dv
\] (1)

The absolute value term in the Green’s function represents the downward and upward scattering pattern and strength. When the phase term of the Green’s function with an absolute value sign is included, the major impact is on the evaluation of the ensemble averages for finding the ensemble average scattered power.

The bistatic scattering coefficients related to the ensemble average scatter power can be obtained with the given Kirchhoff and complementary scattered field by

\[
\sigma^0_{qp} = \left( 4\pi R^2 P_{qp} \right) / E_0^2 A_0
\] (2)

The scatter strength of multiple scattering with the correction of shadowing function is therefore expressed as

\[
\sigma^s_{qp} = s(\theta_{in}) \cdot s(\phi_s) \cdot \frac{(kL)^2}{4} e^{-(k\sigma)^2(\cos^2 \phi_s + \cos^2 \phi)} \sum_{n=1}^{\infty} \frac{(k\sigma)^{2n} |I_{qp}|^2}{n!} \exp \left\{ -\frac{(kL)^2}{4n} \left[ (\sin \theta_s \cos \phi_s \sin \theta \cos \phi)^2 + (\sin \theta_s \sin \phi_s - \sin \theta \sin \phi)^2 \right] \right\}
\] (3)
Model Prediction and Comparisons: To evaluate the validity of model prediction for the depolarized multiple scattering for rough surfaces we compare the level and trend of depolarized scattering coefficient of model prediction with the measured data. The measurements were made by Hauck et al. [1]. Due to the scatter energy transmitting into the second medium, the specular peak and the backscatter peak decreases with smaller surface dielectric constant. The normalized surface correlation length is 13.2 and surface standard deviation is 4.4. The incident angle is chosen to be 20 degrees. For further evaluating the model developed in this paper, we show the comparisons of model prediction with the measured data from rough surface [Hauck, 1998]. The excellent prediction is shown in Figure 1. The difference is less than a dB.

![Comparison of prediction with measurement](image)

Figure 1: Comparison of prediction with measurement (\(d\) = downward multiple, \(u\) = upward multiple, \(t\) = total multiple).

REFERENCES