Nonlocal Contributions to 1-D Rough Surface Scattering

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Rough surface scattering theory has been guided by high and low frequency approximate asymptotic solutions based upon the Kirchhoff term in the Magnetic Field Integral Equation (MFIE) and boundary perturbation theory, respectively. Both of these approximate solutions are mathematically local in so far as the forms of the currents. That is, the currents produced by these simplifications at the point x on the surface depend only on the surface and incident field at the point x. This behavior is also called single scattering for obvious reasons, e.g., it does not depend on the current at any other point on the surface. In the case of the Kirchhoff or high frequency approximation, it is frequently found that the integral equation for the current which uses this as its "source term" fails to converge when higher order terms in the Neumann series are summed. This problem has been hypothesized as being due in part to a failure of the Kirchhoff term to account for all the local or single scattering part of the total current and a method for extracting this part of the current from the integral term was developed. The complete local or single scatter part of the surface current was found to be given by $J_{ss}(x) = J_o(x)/[1 - \bar{\Gamma}(x)]$ where $J_o(x)$ is the Kirchhoff current and $\bar{\Gamma}(x)$ is the integral of the integral equation kernel, $\Gamma(x, x')$, for a one-dimensional rough surface. More recently, computations have shown that for a sinusoidal surface of the form $\zeta(x) = bcos(k_s x)$, where b is its peak amplitude and k_s is the wavenumber of the surface, $\bar{\Gamma}(x)$ could be related to the surface height in a rather simple manner. This resulted in the following for the local or single scatter part of the surface current; $J_{ss}(x) \approx J_o(x)[1 \pm j\left(\frac{10}{\pi}\right)\left(\frac{\lambda_o}{\lambda_s}\right)\left(\frac{\zeta(x)}{\lambda_s}\right)]$ provided $2b \leq \lambda_o \leq 0.2\lambda_s$. The plus sign is for TM or vertical polarization while the negative sign is for TE or horizontal polarization. It should be noted that the "2b" side of the range of validity of this result is the high frequency ($\lambda_o \to 0$) limit while the "$0.2\lambda_s$" comprises the low frequency ($\lambda_o \to \infty$) side. This rather odd appearing range of validity of the solution is a result of fitting numerical computations with simple analytic representations.

This single scatter or local result clearly shows that the Kirchhoff term does indeed require augmentation. The augmenting term has a phase that is polarization dependent and a scaling factor equal to the ratio of the electromagnetic wavelength to the surface wavelength, $\left(\frac{\lambda_o}{\lambda_s}\right)$. While the term is functionally dependent upon the surface height, $\zeta(x)$, its amplitude, b/λ_s, is equal to the surface slope apart from a factor of 2π!

The range of validity of the single scatter or local current result is due to the manner in which it was computed. The total current requires the contribution from the multiple scatter or nonlocal current. This contribution will be presented and compared to the single scatter or local result given above. The range for which the single scatter current dominates the total current will be developed and discussed in this presentation.