Effects of Fresnel Corrections in the Scattered Field of General Ellipsoids

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Abstract— The study of the scattered field of non-spherical scatterers is becoming an important field, especially in the remote sensing of vegetation. In this study, the scattered field of general ellipsoidal scatterers is formulated based on the generalized Rayleigh-Gans approximation, in which at least one of the dimensions of the ellipsoid is comparably smaller than the wavelength. The scattered field is formulated for the case in which far field approximations are used, as well as for the case in which the Fresnel zone effects are included. Results show that when the Fresnel corrections are considered, the calculated backscattering cross section gives a better match with measurement data compared to when far field approximations are used.

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The generalized Rayleigh-Gans approximation has been widely used in the calculation of scattered fields of non-spherical scatterers such as circular disks, needles and cylinders [1]. In such calculations however, far field approximations are usually used. The importance of including the Fresnel zone effects in the calculation of the scattered fields in a medium with closely spaced scatterers has been studied for the cases of circular disks and needles [2, 3], as well as for cylinders [3].

In this study, the effects of Fresnel corrections in the scattered field of general ellipsoids will be analyzed. The scattered field of the general ellipsoid is formulated based on the generalized Rayleigh-Gans approximation [4], where the scattered field is given by [5]:

$$\hat{p}_{sl} \cdot \vec{E}_{sl} (\vec{r}) = \frac{k^2 (\varepsilon_r - 1)}{4\pi} \int_{V''} \exp \left( -jk |\vec{r} - \vec{r}''| \right) \frac{|\vec{r} - \vec{r}''|}{|\vec{r} - \vec{r}''|} (\hat{p}_{sl} \cdot \vec{E}_{int}) d\vec{r}''$$ (1)

Figure 1: Comparisons between calculated values with and without Fresnel corrections and measured values of the normalized backscattering cross section for four prolate spheroids illuminated by a circularly polarized wave over various incident angles.
where $\vec{E}_{\text{int}}$ is the internal field of the scatterer, $\hat{p}_{\text{sl}}$ the scattered polarization unit vector in the local frame and $V''$ refers to the volume of the scatterer. $\vec{r}$ is the local frame location vector at the observation point. The vector $\vec{r}''$ is the local frame location vector for the volume element in the scatterer. The term $|\vec{r} - \vec{r}''|$ can be approximated by [2,3]:

$$
|\vec{r} - \vec{r}''| \approx r' - \hat{s}'' \cdot \vec{r}'' + \frac{r''^2}{2r} \left[ 1 - (\hat{s}'' \cdot \hat{r}'')^2 \right]
$$

where $\hat{s}'' = \frac{\vec{r}''}{r''}$, and $\hat{r}'' = \frac{\vec{r}''}{r''}$.

In far field approximations, only the first two terms of (2) are considered. To include the Fresnel zone effects, all the terms in (2) are used instead.

Comparisons between results for the normalized backscattering cross section of prolate spheroids calculated using far field approximations (NCT) and with the Fresnel zone effects (AFCT) are shown in Figure 1, together with results obtained through measurements in [6]. It is observed that the backscattering cross section calculated with Fresnel corrections are generally in good agreement with the measured values, and perform better when compared to the theoretical results employing far field approximations.

REFERENCES


