An update of Fresnel reflection coefficient for AIEM model

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\textbf{ABSTRACT}

The Fresnel reflection coefficient is a function of the surface permittivity and surface local incidence angle. In modeling the wave scattering, in order to relief the spatial dependence, it is a common practice to approximate the local angle either by the incident angle for a slightly irregular boundary or otherwise by the specular angle. Such approximation, however, leads to unpredictable error. A transition model was proposed by Wu and Chen et al. (2001, 2003) to fix the deficiency but only at backscattering. As bistatic scattering becoming more important in applications such as estimation of surface emission, it is necessary to generalize the transition function so that the Fresnel reflection coefficients take the local angle variations into account in case of bistatic. To confirm the validation of the new transition function, we compared the scattering coefficients with classical model: small perturbation (SPM) and geometrical optics (GO) models in their valid regions. Small slope approximation (SSA) and moment method (MoM) are also used to verify the AIEM. Except comparing with theoretical simulations, the experimental data [4] with multi-frequency and varying surface roughness by bistatic measurements is applied to contract.

\textbf{1. Update of Fresnel reflection coefficient for AIEM}

It is known that the limitation under the assumption in application is rarely for the real earth ground. However, Wu and Chen [1] in 2001 provided a transition model of Fresnel reflection coefficient for IEM. By applying this model, it already gave good agreement in backscattering behavior. The transition model was developed from original [3] IEM model so that an update of transition model is derived in this study for improving model accuracy. The analysis of validation will focus on the bistatic configurations. The formula of update transition model will be proposed in the following journal completely.

\textbf{2. Validations of update transition model for AIEM}

To illustrate the bistatic scattering behavior of transition model for AIEM, the comparisons between numerical methods, other physical surface scattering models and measurements data are offered in this section. Fig1 shows the comparisons between SSA, MoM and AIEM with transition model. The simulation data of Fig.1 is obtained from [4 & 5]. A Gaussian correlated surface with complex dielectric constant $4+j1$ is used. A moderate rough surface with parameters, $k\sigma=0.5$, $kL=3.0$, is chosen to make the relatively will be encountered inaccurate for SPM and Kirchhoff model here. It can be
observed that AIEM with transition model can get good agreement with SSA and MoM methods except larger scattering (>60 degrees) or near scattering angle =30 degrees. (note that the incidence angle here is 30 degrees). The reason may be the SSA is just first order results.

Fig.1 Comparisons between moment method, SSA and AIEM with rough surface (kσ=0.5, kL=3.0, ε=4+j1.0 and kσ=1.0, kL=6.0, ε=4+j1.0 )
Fig. 2. Gaussian “smooth” ($\sigma=0.4\,\text{cm}, L=6.0\,\text{cm}$). The simulated data and measured bistatic scattering coefficient as a function of scattering angle (a) $f=2$ GHz; $\theta=20^\circ, 40^\circ$, (b) $f=5$ GHz; $\theta=40^\circ$, (c) $f=10$ GHz; $\theta=40^\circ$.

The validations that compare with experimental data are showed as Fig. 2 and Fig. 3. The measured data is obtained from [6]. Fig. 2(a) shows only bistatic behavior of HH polarization due to lack of VV polarization data. We can examine that AIEM is very approach to SPM but can not get good agreement with experimental data while scattering angle greater than 20 degrees. The results of (b) is at frequency=5 GHz with the same surface roughness. The classical GO and SPM can not match experimental data obviously, however the AIEM with update transition model performs well in this match. When the transmitted frequency reaches 10 GHz, seeing (c), the angular trends of AIEM is similar to GO in forward region of larger scattering angle. The comparison also displays that AIEM agrees well when scattering greater than -20 degrees. The AIEM and GO is underestimated below -20 degrees of scattering angle that comparing with experimental data. In Fig. 3, the surface parameter of experimental data is set with $\sigma=2.5\,\text{cm}$ and $L=6.0\,\text{cm}$. In this “rough” surface case, the simulations of AIEM agree well with GO and the trend of AIEM resembles measurement data.
Fig3. Gaussian “rough” (σ=2.5cm, l=6.0cm). The simulated data and measured bistatic scattering coefficient as a function of scattering angle, f=10 GHz; θ=40°

3. Conclusion

In this study, we update the transition model of reflection coefficient for AIEM. By applying the update model, it can provide accurate predictions of bistatic scattering configurations. We also compared it with classical physical model, numerical model and measurement data for more confirmation. The results of AIEM with update transition model show well agreement with most of figures. Further study will focus on field of emissivity.

References