A Comparison of Propagation Over Rough Sea Surfaces Using MOM and PWE Methods

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Microwave propagation over rough seas plays an important role in maritime communication and surveillance applications. For propagation between low altitude antennas, the prediction of the electromagnetic fields is complicated by a number of effects including: 1) non-flat rough sea surfaces caused by wind waves and swell, 2) shadowing or blockage of direct-path due to wave crests, 3) finite conductivity surface boundary conditions, 4) surface waves (for vertical polarization), and 5) boundary effects which lead to non-planar wave fields near the air-sea interface. Traditional methods for modeling RF path loss or propagation factor using simple 2-ray geometrical optics models, or even spherical wave models, fail to correctly predict the near surface EM fields. More exact propagation techniques such as integral equation or parabolic wave equation (PWE) methods could be employed to predict the fields, but the veracity of PWE for near surface predictions has often been questioned.

This paper compares and contrasts the electric and magnetic fields predicted by method-of-moments (MOM) and parabolic wave equation codes for X-band vertically and horizontally polarized signals propagated over realistic rough sea surfaces. Random realizations of 2-D rough sea surfaces are generated using wind-wave and swell surface power spectra for young and old seas. Finite dielectric boundary conditions are used for nominal sea surface temperature, salinity, and surface tension. Both ideal (i.e. point) and finite aperture antennas are considered. The propagated electric and magnetic fields are examined in both the spatial domain (i.e. position) and in the conjugate angle-of-arrival (i.e. spectral) domain.

The method-of-moments code employs a numerically exact method based on the Forward-Backward Novel Spectral Acceleration solution of the discretized MOM, which enables the efficient solution of large scale (in wavelengths) problems. The MOM code includes the finite conductivity surface currents and the non-planar boundary. Because of the nature of the MOM integral equations, both small and large surface grazing angles are treated.

The PWE code is based upon a rotated split-step Green's function (SSGF) algorithm which employs a Fresnel-type surface boundary condition and propagates the electric and magnetic fields in conformal sea surface coordinates. This SSGF PWE method is not limited to narrow angles.