X-band Scatter from Directional Targets Over Rough Sea Surfaces Using PO-PTD and PWE Methods

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Radar detection of a near surface target in a maritime environment is strongly affected by multipath due to atmospheric ducting and forward scatter from the rough sea surface. The resulting target radar cross section (RCS) $\sigma(\theta, \phi)$, as observed by the radar, varies with elevation θ and azimuthal ϕ direction. For rough sea surfaces, the RCS can vary significantly depending upon whether or not the target is a directional scatterer and thus invalidate standard 2-way power based radar equation methodology.

This paper will discuss the computation of bistatic scattering from electrically large objects on or near rough sea surfaces using a hybrid approach which combines a physical optics (PO) and physical theory of diffraction(PTD) scattering model with a parabolic wave equation (PWE) propagation model. This hybrid approach includes in the target RCS the effects of coherent multipath propagation between the radar and target arising from rough sea surface forward scatter and anomalous propagation due to ducting and non-neutral atmospheric stability.

The PO-PTD target scatter model is based on rigorous, high-frequency EM scattering methods which decomposes a large object into many smaller scattering objects (scatterers) such as plates, cones, dihedrals, etc. Assuming an incident generalized plane wave field, the complex bistatic scattered E/H fields from each scatterer are then coherently combined to yield the total target reflectivity $\chi(\theta, \phi) = \sum_i \chi_i(\theta, \phi)$. (The target RCS is $\sigma = |\chi|^2$.) In the hybrid model, a generalized set of incident plane wave fields (and, by reciprocity, receive directions) are obtained by projecting the PWE EM fields onto a continuous plane wave (Weyl) basis. The PWE model rigorously incorporates environmental propagation effects between the radar and target including ducting and stochastic rough sea surface forward scatter.

Examples of X-band directional (e.g. large plates, dihedrals) and non-directional (e.g. small plate, spheres) scatterer RCS will be shown for a variety of sea states, including wind waves and swell, and for ducting and non-ducting atmospheres. Monte Carlo averages of target RCS over rough seas using the hybrid PO-PTD/PWE scattering method will be compared with conventional scattering using a coherent 2-ray (direct + sea surface reflected) propagation model with a Miller-Brown rough surface reflection coefficient. For a directional scatterer, this 2-ray model often under predicts target RCS.