High Angle, X-band Ship RCS Over Rough Sea Surfaces in Ducting Environments Using PO-PTD and PWE Methods

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Radar ship detection can be 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 the directionality of the scatterer and thus invalidate standard 2-way, power based radar range equation methods.

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) ship scattering model coupled to a parabolic wave equation (PWE) propagation model in a rigorous fashion via EM fields. This hybrid approach includes in the target RCS the effects of coherent multi-path propagation between the radar and target arising from rough sea surface forward scatter and anomalous propagation due to ducting and non-neutral atmospheric stability. It does not assume a point scatter target model.

The PWE model propagates the E/H-fields from the radar to the target, and projects them onto a plane wave basis for ingestion into the PO-PTD scatter model. Particular emphasis is placed on computing high angle ($> 30°$) scattering, which imposes stringent requirements on the PWE method to guarantee phase stability between multipath components. This PWE phase stability is validated by comparison with exact GTD solutions for Sommerfeld test cases.

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 the ith scatterer are coherently combined to yield the total target reflectivity: $\chi(\theta, \phi) = \sum_i \chi_i(\theta, \phi)$, with $\sigma = |\chi|^2$. 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 ship 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.