Ducted Millimeter Wave Propagation Over Rough Seas Using PWE

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Microwave and millimeter wave propagation over rough sea surfaces is dominated by the effects of coherent multipath interference between direct and surface reflected paths. In addition, the omnipresent near surface atmospheric refractivity ducting creates additional multipath phenomena. The prediction of the propagated 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 and presence of foam, 4) surface waves (for vertical polarization), and 5) boundary effects which lead to non-planar wave fields near the air-sea interface. One technique that is capable of handling both the refractivity ducting and rough sea surface phenomena is the parabolic wave equation (PWE) method. This presentation will describe a PWE code based upon a rotated, split-step Green's function (SSGF) algorithm used to model maritime RF propagation over rough seas.

In contrast to other PWE methods which employ a Miller-Brown type rough surface reflection coefficient, the SSGF technique directly propagates the EM fields over a stochastic realization of a rough sea surface generated from convolution of a surface wave spectrum with a 2-D Gaussian random field. Nonlinear corrections are then applied to produce an oceanographically correct sea surface having non-zero kurtosis and skewness. The surface wave spectrum used includes both wind waves (gravity and capillary) as well as swell. The surface wave spectrum utilizes a wave action method allowing for synthesis of both fully developed (i.e. open ocean) and young seas. The 2-D sea surface is time varying and the local vertical acceleration is used to synthesize breaking wave white water foam patches having different dielectric constant than the sea water. The rotated coordinate system used by the SSGF PWE method is conformal to the rough sea surface.

Coverage diagram examples will be shown of millimeter wave (Ka,Ku-band) propagation under ducting conditions over varying types of seas including wind waves and swell for varying wind speeds. Both the spatial and the spectral (angle-of-arrival) EM fields for within and cross-duct geometries will be shown.