Insights into Evaporation Duct Modelling for RF System Analysis

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The vertical gradient of humidity in air just above the ocean surface can strongly refract radio waves. When the gradients are strong enough, this layer is called a "duct" because it can trap horizontally-propagating radio waves, channelling them well beyond the normal radio horizon. More specifically, they are called "evaporation ducts" because the humidity gradients arise from evaporation off the ocean surface.

The evaporation duct layer is usually turbulent. Radio waves travelling through this turbulent air experience an overall refraction that can be represented by a smooth, roughly logarithmic refractivity profile versus height. The shape of this bulk-average refractivity profile is computed using Monin-Obukhov similarity theory (MOST). These MOST-based "evaporation duct models" have become central to our understanding of radio wave propagation in the marine atmospheric boundary layer (MABL). They are a key piece in the modeling, simulation, and analysis (MS&A) of marine radar and radio-frequency (RF) communication systems.

MS&A of evaporation ducting impacts has evolved over time. Initial system-level studies of radar- and RF-communication-system performance in the MABL were based on assumptions of spatial homogeneity and neutral stability. Under these assumptions the impact of evaporation ducting becomes dependent on a single parameter, the evaporation duct height (EDH). This is in contrast to modern analyses, which are increasingly being done using numerical weather prediction (NWP) data. In this type of analysis, NWP output are fed into a MOST-based evaporation duct model, and the resultant refractivity profiles are then input to RF propagation models as part of system-level performance analyses. These NWP-generated MABL scenarios restrict neither the stability nor the range/azimuth variability of evaporation ducting, enabling inclusion of these effects in RF system MS&A.

When considering this evolution in MS&A an important question arises: when do variations in range/azimuth and stability matter to system-level analyses? This is a deep technical question that is difficult to answer. Recent analysis has provided some insights that will be presented here.