PropCode4 Notes

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1 PropCode4

`PropCode4` is a MATLAB implementation of the algorithm described in Chapter 6 of the author's book *The Theory of Scintillation with Applications in Remote Sensing*

`http://www.wiley.com/WileyCDA/WileyTitle/productCd-047064477X.html.`

Book Chapter 6 develops propagation in weakly inhomogeneous media with embedded discrete scatterers and boundary surfaces. Embedded discrete scatterers in unbounded media are amenable to complete treatment if the scattering functions are known. The theory is developed in book Chapter 6.1. An important result is double passage reciprocity. Interchanging a point source with a point scattering center reproduces the scattered field at the source. It follows that the radar return is the square of the field at the reflecting source times the radar cross section of the scatterer. The reciprocity principle can be used to build models of radar backscatter through turbulence from collections of point non-interacting scattering centers. The examples in Chapter 6.1.3 is left as an exercise for the interested reader. The more challenging problem is the extension forward propagation to accommodate a weakly inhomogeneous medium bounded by an irregular layer, which is treated in book Chapter 6.2. The methodology can be applied to fully three-dimensional problems as with the FPE for unbounded media. However, the implementation is sufficiently complicated that it is prudent to start with bounded two-dimensional media. The reader familiar with parabolic wave equation methods will recognize the similarity of the problems treated, admittedly much more simply. For the extra effort, one does obtain an estimate of the induced surface boundary current that supports the scattered field component. The FPE only uses the forward scatter, but the forward current can be used to calculate the Bragg backscatter from the surface.

2 PropCode4 Examples

The PropCode4 MATLAB scripts reside in the folder

`\PropagationCode4.`

The code structure and operation is similar to `PropCode1,PropCode2`, and `PropCode3`. To accommodate the boundary surface, provisions are made for curved earth or flat earth with a periodic height variation and/or surface roughness. Using a polarization-dependent impedance boundary condition simplifies the computation somewhat, but sub-wavelength sampling is still required. To marry the forward propagation element, which is adequately sampled at many wavelengths per sample, with the sub-wavelength sampling required in computational electromagnetics, the surface is finely sampled within the layer. Thus, within each FPE slab division, computations are preformed at sub-wavelength intervals. However, as with `PropCode1,PropCode2`, and `PropCode3`, a setup utility generates all the inputs required to execute `PropCode4`.

2.1 Multipath

The computation of beam reflected off a conducting surface effectively extends the ray-trace example. In the folder

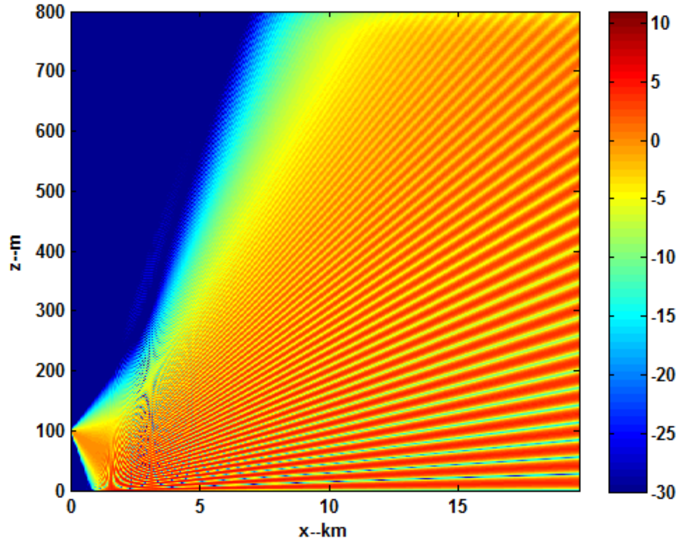
`...\PropCode4_Examples`

run `SetupPropCode4E66` to generate the setup file. Then run `PropCode4` with GUI selection of the setup file. Once the run is complete, running the script `DisplayPropCode4_out2` will generate Figure 2.1 (book Figure 6.6).[1] The well approximated by the interference between the direct ray and the surface-reflected ray. Where each ray intercepts the surface it is reflected at the Snell's law angle. A near 180 degree phase change accompanies the reflection. The interference pattern reproduces the alternating pattern of constructive and destructive interference. Using `PropCode4` for this computation is largely a test of the code. However, the code does accommodate a refracting standard atmosphere model The interfering rays are bent toward the surface. For ease of illustration a flat surface was used here, but an earth-surface model can be used as well.

2.2 Non-Planar Surfaces

Boundary integral methods are most interesting for non-planar surfaces, particularly randomly irregular surfaces. Running the script `SetupPropCode4E67` followed by `PropCode4` and `DisplayPropCode4_out2` will produce Figure 2.2 (book Figure 6.7). Now the pattern is much more complicated with varying strength reflections and shadowing in the valleys of the sinusoidal surface variations. Figure 2.2 shows a comparison of the induced surface currents that support the boundary condition. The surface currents can be used as a source of surface backscatter, which the caveat that the backscatter itself doesn't influence the forward field. The structure on the second surface current peak is from the beam sidelobes.

[1]For the save output option first enter 1 then 1. This will save the output for later comparisons.



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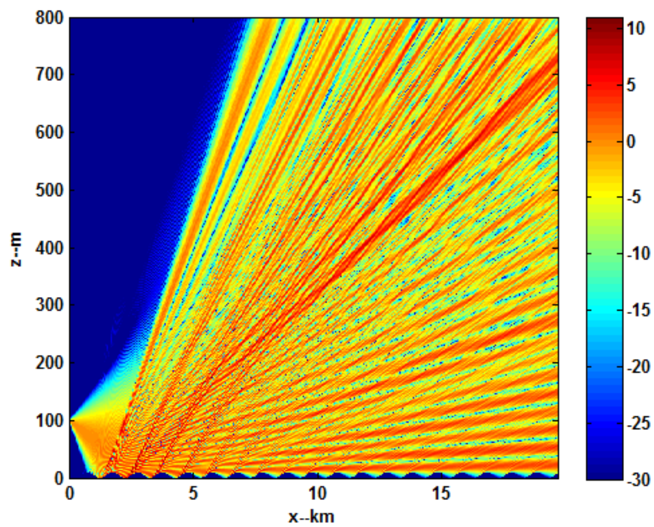

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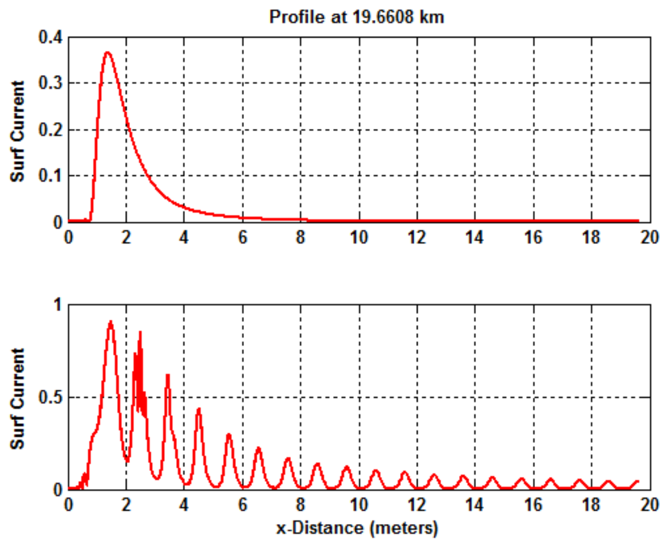
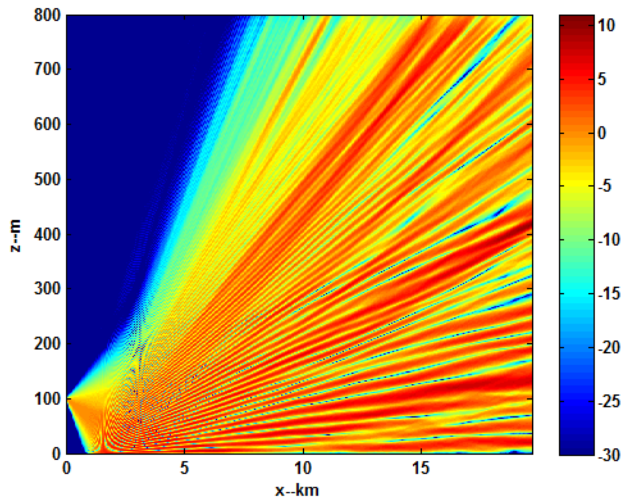


2.3 Multipath and Turbulence

Running the script `SetupPropCode4E67a` followed by `PropCode4` and `DisplayPropCode4_out2` will produce Figure 2.3. This is a rerun of the plan-surface multipath but with uniform turbulence added to the background atmosphere. Here the combined effects of scintillation and multipath are impacting the field as it propagates. Figures 2.3 compares the vertical profiles at 20 km without and with turbulence. It is not uncommon to have both surface roughness and turbulence for over water communications. One should also note that both turbulence and ocean surface waves evolve dynamically.



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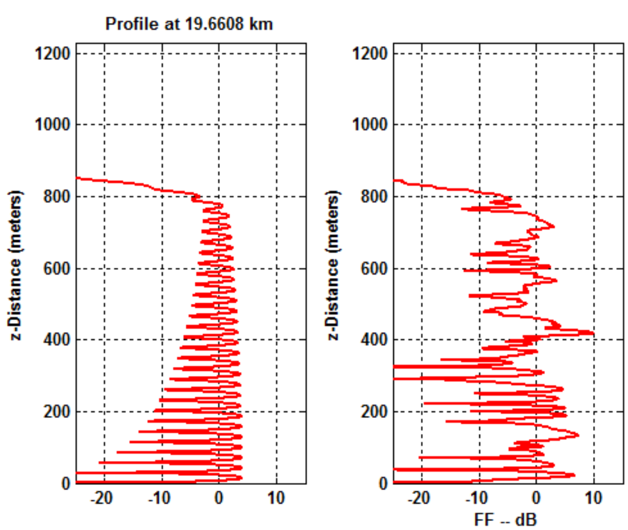

Profile at 19.6608 km
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