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EFFICIENT POLYNOMIAL UNCERTAINTY COMPUTATIONS FOR PHASE IN UNDERWATER ACOUSTIC PROPAGATION

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ABSTRACT

In ocean acoustic propagation modeling from a continuous wave source, the relative phase variation between two phones is important in source localization. The statistics of the variation of relative phase can be estimated from polynomial chaos expansions in several random parameters. In many instances, the full acoustic field at a receiver will appear log-normally distributed when sound speed is normally distributed, so that the relative phase is nearly normally distributed. Thus, the phase distribution and the sound speed distribution are approximately of same type. Under study here are two strategies for computing relative phase within the polynomial chaos framework. Each strategy can be compared with the alternative, both in accuracy and efficiency.

The first approach is based on the computation of the polynomial chaos expansion for the full pressure field using the appropriate differential equations for the chaos coefficients, for example, using a parabolic equation stepping out in range. The chaos coefficients of the logarithmic gradient may then be evaluated from the expansion for the full pressure field. Since phase is the imaginary part of the logarithm, the chaos coefficients for relative phase can be computed by integrating the logarithmic gradient. The accuracy of the computed pressure gradients limits the computations of these chaos coefficients, and requires particular care in near the phase branch cuts corresponding to nulls in the pressure.

The second approach uses a polynomial chaos representation of the phase directly. A differential equation can be derived for the propagation in range for the expansion of the phase. Such equations exist for the vertical normal mode decompositions of the acoustic field. This method carries the burden of computing chaos expansions of exponentials of chaos expansions. This can be done efficiently via numerical integration, albeit with limitations on accuracy for higher values of expansion coefficients.

Finally, Monte Carlo evaluation of statistics using existing propagation codes can be used to validate the results of both approaches. Alternatively, there are also efficient numerical integration methods for evaluating statistics from existing acoustic propagation models, which may also be used for validation. [This research is supported by ONR and has the support of HPC time grants from the DoD HPCMP.]