Partially Saturated Transmission Scintillation and the Bias of the Sonar Equation

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Abstract: The statistical properties of partially saturated ocean-acoustic intensity measurements are analyzed. This extends previous analysis of completely saturated measurements [J. Acoust. Soc. Am. 100, 769-783, 1996]. For example, general expressions are derived for the standard deviation of sound pressure level and the statistical bias of the sonar equation as a function of the partially saturated measurement’s time-bandwidth product. The information content of partially saturated measurements is quantified.

INTRODUCTION

Natural disturbances such as passing surface and internal gravity waves often place ocean-acoustic waveguides in such a state of flux that a signal, deterministic when transmitted from a source, becomes fully randomized after propagating only several channel depths away in range to a receiver, where circular complex Gaussian random (CCGR) field fluctuations are observed. Such fluctuations also commonly occur in active sonar imaging due to relative motion between the source, surface to be imaged, and receiver. Here, wavelength-scale roughness on the surface causes a random interference pattern in the sound field scattered from it by the active system. This random interference pattern is analogous to that generated by acoustic multipath propagation in a waveguide. Motion of the source or receiver through the interference pattern, or variation in the interference pattern itself by waveguide fluctuations lead to temporal stochasticity in the acoustic field. Intensity measurements derived from CCGR fields are corrupted with signal-dependent noise that leads to speckle in any subsequently formed image or time series. In a previous paper [1], the statistics of such intensity measurements and their log-transforms are given in terms of the time-bandwidth product of the received field.

While the random component of the instantaneous field is a CCGR process in both saturated and partially saturated cases, a purely deterministic component is added in the latter but not the former. In both cases, the random component may contain a fluctuating signal as well as noise. The present analysis of partially saturated processes, therefore, is relevant not only to the analysis of fluctuating signals but also to the general analysis of deterministic signals in additive noise.

APPROACH AND CONCLUSIONS

For a partially saturated process, analytic expressions are derived for the probability distributions and moments of finite-time averaged intensity and log-transformed intensity as a function of the time-bandwidth product of the measurement. From these, general formulas are obtained for the bias of the sonar equation and the standard deviation of the logarithmic measures commonly used in ocean acoustics. Asymptotic expressions are also derived for the various distributions examined and their moments. Finally, a quantitative measure is given for the amount of information contained in a partially saturated measurement.

REFERENCES