

Statistical Characterization of Fish School Clutter

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LONG-TERM GOALS

To significantly reduce the probability of false alarm in Navy active sonar systems. This goal will be achieved through developing signal processing algorithms for active sonar systems which can account for the non-Rayleigh nature of clutter from fish schools. Part of this goal will involve characterizing the performance of the algorithm.

OBJECTIVES

To investigate the statistical properties of echoes recorded from a unique broadband active acoustic system which we recently used to survey schools of fish. Both the matched-filter output and spectral components of the echoes in the 2-4 kHz band are analyzed and statistical tests performed to quantify the degree to which the echoes are non-Rayleigh.

APPROACH

This brief pilot study takes advantage of broadband acoustic data recently collected in another program (N00014-1-04-0440; Ocean Optics/Biology). The active sonar was towed over schools of fish and echoes were recorded from 1000's of transmissions. The system transmitted chirps over the frequency range 2-14 kHz, with most of the energy in the 2-4 kHz range. This range also coincided with the resonance frequency of the swimbladder of the fish, giving rise to strong echoes. The echoes were observed to be strongly non-Rayleigh. In order to systematically study the statistical behavior of the echoes, the echoes are grouped according to whether or not they were all from within a patch of fish, spanned multiple patches of fish, or involved only resolved individual fish. Candidate analytical probability density functions (PDF's) are identified and compared with the data.

WORK COMPLETED

All tasks were completed and a conference proceedings describing the work was published.

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1. Echoes from one area were grouped into three categories: echoes occurring within a patch of fish, echoes spanning across multiple patches of fish, and echoes spanning a distribution of resolved fish (Figs. 1, 2).
2. The distributions of echoes were compared with the Rayleigh PDF as well as two candidate distributions-- the K-distribution and a power law distribution that explicitly accounts for the beampattern of the sonar. Part of the comparison involved use of the Kullback-Leibler distance to make quantitative comparisons between data and distribution.

RESULTS

The echoes were observed to be Rayleigh distributed from echoes contained within a patch of fish. Once the beam spans multiple patches and/or single resolved fish, the echoes are strongly non-Rayleigh. The K-distribution was observed to satisfactorily predict across-patch echoes (Fig. 3). However, once the echoes involved resolved fish, the power law distribution was required to describe the fluctuations of the echoes, especially in the tail of the distribution (Fig. 4).

IMPACT/APPLICATIONS

The fact that the fish echoes were strongly non-Rayleigh is significant to the performance of ASW active sonar systems. It has already been demonstrated that under important conditions, schools of fish can dominate reverberation (i.e., at shallow grazing angles and near the resonance frequency of the swimbladder of the fish). The fish echoes are strongly non-Rayleigh distributed as a result of a combination of their inherent patchiness and sonar beampattern effects. If this non-Rayleigh property is not incorporated into a classification algorithm, then system performance will be compromised, increasing the probability of false alarm. The good comparison between the power law distribution and the data shows great promise for a predictable sonar model. The power law distribution is physics-based, as it was derived based on the sonar beampattern.

RELATED PROJECTS

This research draws from the data collected in another project (N00014-1-04-0440, Ocean Optics/Biology). In that project, a broadband active acoustics system was towed over schools of fish to study the distributions of fish. The focus of the project is to study the fish through resonance classification. High quality acoustic data were collected in combination with net samples to ground truth the data.

PUBLICATION

- 2006 Stanton, T.K., D. Chu, J.M. Jech, and J. D. Irish. "Statistical behavior of echoes from swimbladder-bearing fish at 2-4 kHz," Proceedings of the MTS/IEEE Oceans '06 Conference, Boston.

Fish Schools: Unresolved echoes (uncorrected depth)

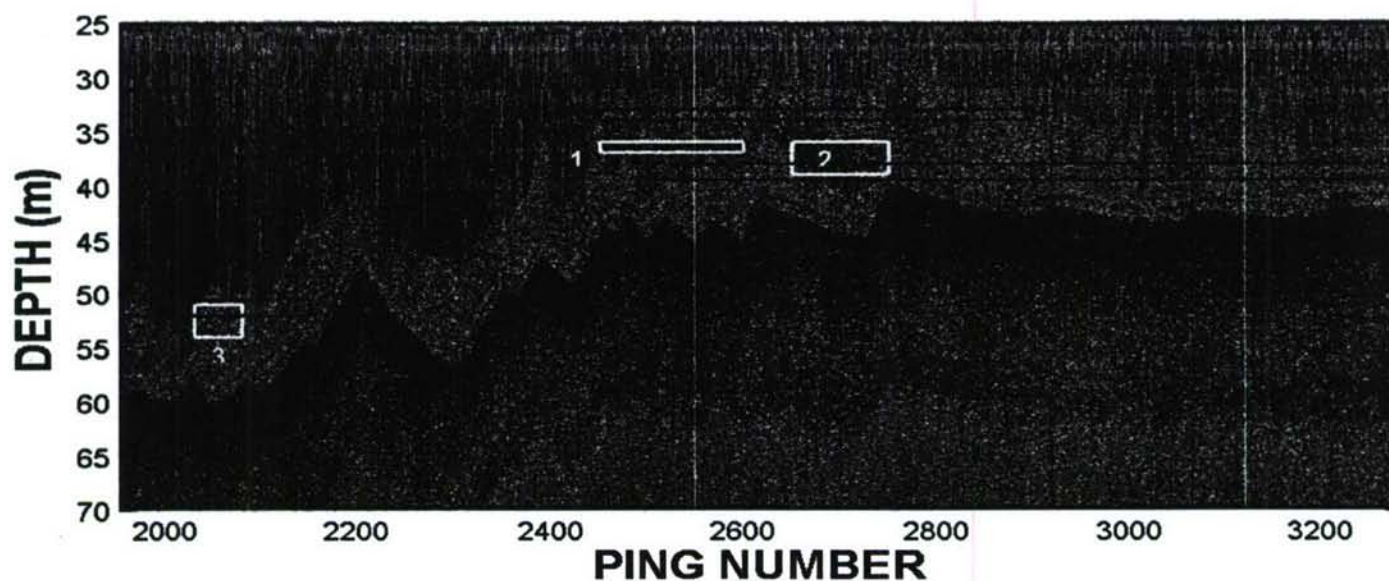


Figure 1. Grouping of 2-5 kHz echoes from fish. White boxes-- within patch. Red boxes-- across patches. The apparent jaggedness of the seafloor is an artifact and due to the fact that this raw data has not been corrected for the undulating trajectory of the towbody.

Resolved Echoes (uncorrected depth)

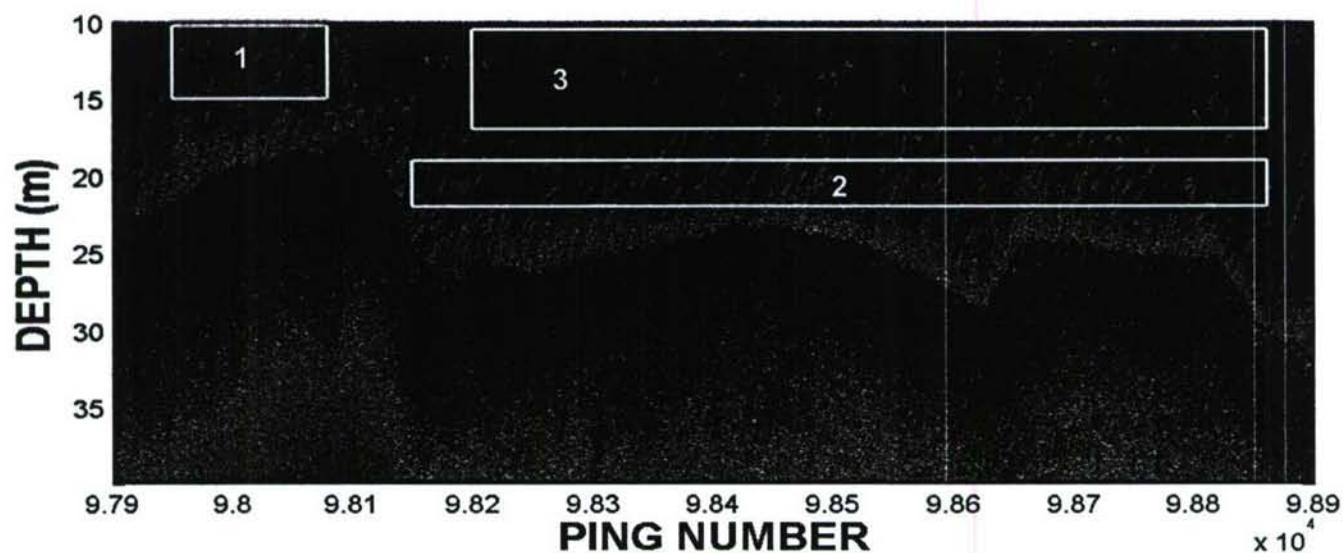


Figure 2. Grouping of 2-5 kHz echoes from fish. Each white box contains multiple resolved echoes from the fish. The apparent jaggedness of the seafloor is an artifact and due to the fact that this raw data has not been corrected for the undulating trajectory of the towbody.

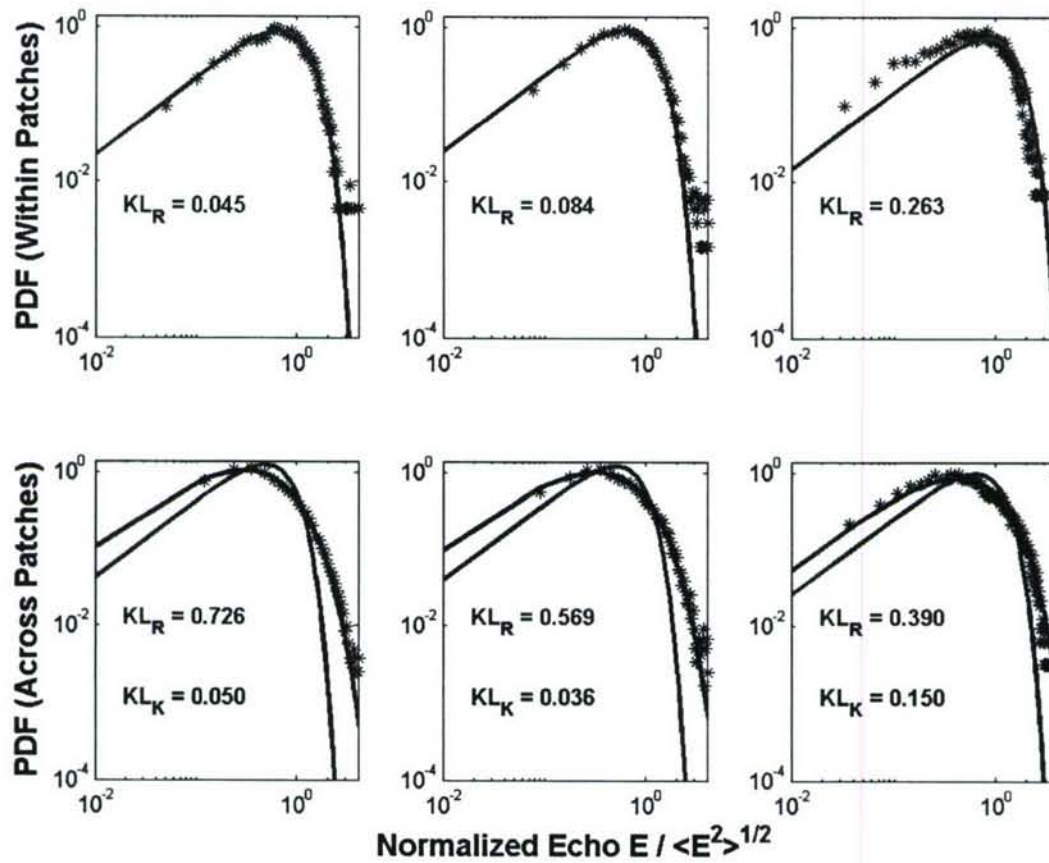


Figure 3. Comparison between observed distributions of echoes (after matched filter) and theoretical distributions for two types of groupings of echoes-- within patches and across patches corresponding to Fig. 1. Green curves are the Rayleigh distribution; red is the K-distribution. Three examples (columns) are given for each type of grouping. The Kullback-Leibler (KL) distance between the observed and theoretical distributions is given.

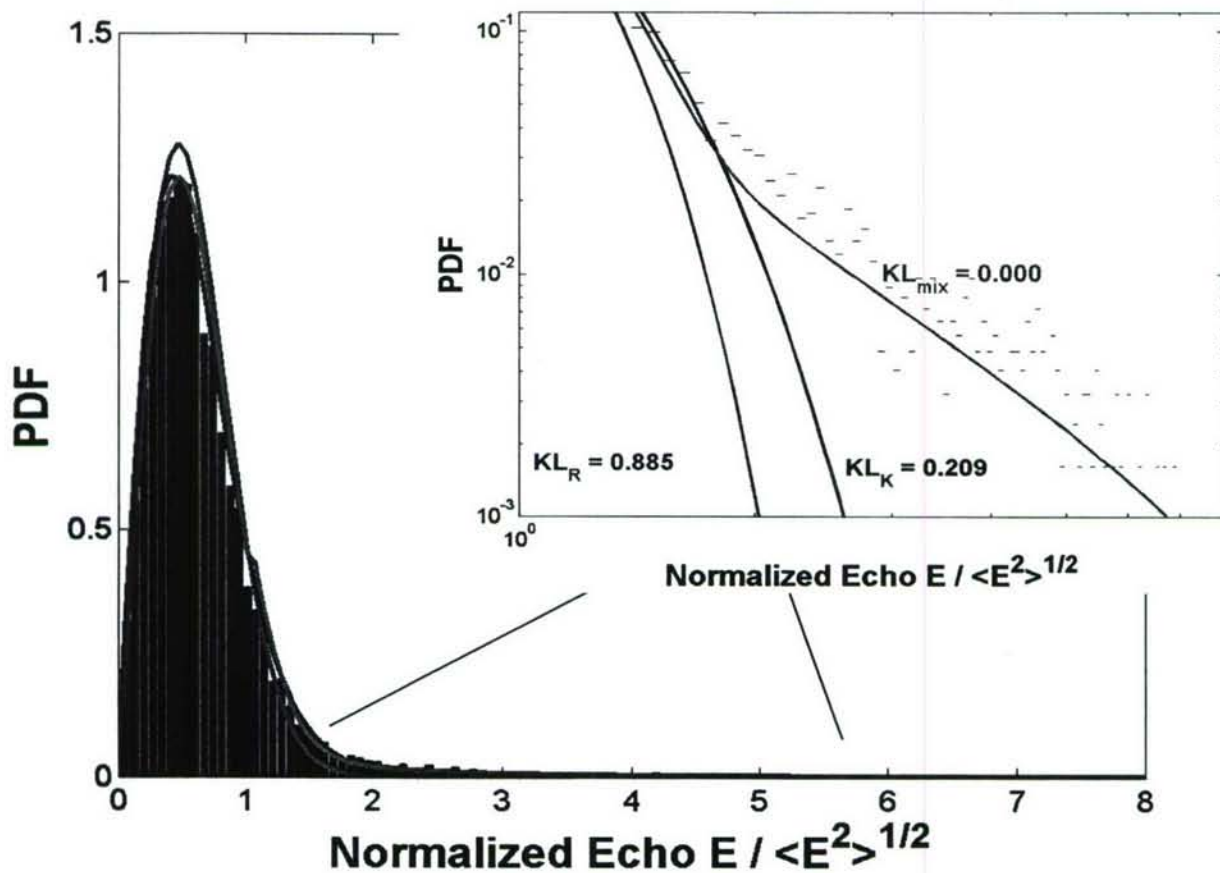


Figure 4. Detailed examination of tail of one PDF for case of resolved echoes corresponding to region 1 of Fig. 2. Both K-distribution (red) and Rayleigh distribution (green) fail to describe the elevated tail. A mix distribution (blue) is required, which involves a combination of a power-law distribution (based on beampattern effects) and Rayleigh distribution (to describe between-echo noise).

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