Visual Techniques Laboratory
Department of Physics FM-15
University of Washington
Seattle, WA 98195 U.S.A.

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ACOUSTICAL DETECTION OF CASCADES IN DUMAND

J. G. Learned (University of Hawaii)
and R. J. Wilkes (University of Washington),
for the DUMAND Collaboration*

ABSTRACT

The DUMAND-II array will include a network of 53 hydrophones as part of an acoustical positioning sysetm. We discuss the possibility of employing this network for the acoustical detection of high energy neutrino-induced cascades.

Acoustical detection of astrophysical neutrinos in seawater [1,2] or ice [3] is of great interest because huge detector volumes can be instrumented at very low cost. A number of authors have discussed the nature of signals expected from high energy neutrino-induced cascades [4,5], and experiments using accelerator beams [6] confirm the general validity of these studies. Results indicate that only very high energy cascades could be detected under relatively low-noise conditions using the best underwater acoustical technology available until recently.

The DUMAND experiment will be deployed in several stages, with the first components expected to be in operation by the end of 1993. A network of 53 high-sensitivity, wideband hydrophones will form an integral part of the DUMAND detector, as part of the acoustical locating system used to determine photomultiplier tube positions to the precision required for accurate reconstruction of muon track directions. As described in detail elsewhere [7], each DUMAND string will contain 5 hydrophones, and additional units will be deployed on the central junction box and outlying responder (hardwired transponder) modules. Hydrophone signals will be digitized with 133 kHz sampling, and sent by fiber optic cable to the shore data acquisition system, where the data can be examined for acoustical evidence of neutrino events in addition to routine sonar signal processing. In particular, optically detected neutrino events can be used to trigger enhanced acoustical data processing procedures, providing supplementary estimates of contained cascade energies. The locating system can also be used as a prototype detector in studies directed to the development of enhanced systems for future stages of DUMAND, in which acoustical detection may play a more central role.

Previous work on acoustical detection has focussed on estimates of the expected signal-to-noise ratio as a function of various parameters, assuming simple conventional notch filter and threshold detector techniques. However, realtime Fourier methods, readily implemented using contemporary DSP technology, supply a more powerful technique for isolating signals of known form in the presence of heavy backgrounds. In particular, amplitude S/N ratios on the order of 1 can be tolerated provided the background noise is uncorrelated with the expected signal. The hardware required for implementing matched filter methods will be provided for the DUMAND locating system and can be readily adapted to correlate on signals of the form anticipated for cascades.

As a numerical example, let us consider a cascade depositing energy 10^{16} eV within a core radius of 1.5 cm, values appropriate for typical UHE contained events in DUMAND. Using calculations by Learned [4] we can estimate the sound pressure level expected for the characteristic bipolar pulse produced by the cascade; roughly speaking, the core radius determines the duration of the pulse, while the cascade energy and distance to the receiving hydrophone determine the sound pressure level. At a radius of 40m (the radius of the DUMAND array) this will be approximately 250 μPa for the cascade described, or in the conventional notation of the underwater acoustics community, 48 dB re 1 μPa. Fig. 1 shows the expected signal, and Fig. 2 shows the same signal embedded in white noise of equal amplitude (S/N=1) and sampled at 5 μsec intervals; here the signal center has been delayed by 24 sampling bins or 120 microseconds from the center of the window. Fig. 3 shows the correlogram obtained by correlating the noise-embedded signal with the (window-centered) model signal: a readily identifiable peak occurs in the 24th bin as expected.

Fig. 4 shows the anticipated deep-ocean noise noise spectrum taking into account both surface (wave) and thermal (molecular) noise sources [8]. It is of interest to note that the descending wave noise spectrum and ascending thermal noise spectrum form an acoustical "water hole" in the vicinity of 40 kHz, which is an ideal region for the DUMAND hydrophones (with essentially flat response from 5 to 100 kHz and sensitivity -170 dB re 1V/μPa [9]) and also matches the characteristic frequency for cascades of the type used as an example. Integrating the noise spectrum over the range of frequencies 10--25 kHz where the signal has most of its power, we find the anticipated noise level to be 48 dB for sea state 0 (calm sea conditions), equal to the signal level discussed above. Cascades of energies on the order of 10 PeV may thus be observed, assuming the correlation technique permits detection of cascades with S/N values as low as ~1. The DUMAND shore station hardware and software are being planned to permit offline searches for such signals in acoustical data windows captured following contained event triggers.

REFERENCES

[*] For a full list of authors, see The DUMAND Collaboration, "Status Report on DUMAND-II", this Conference.

1. Proc. 1976 DUMAND Summer Workshop, A. Roberts, ed., Univ. of Hawaii, Honolulu, 1976.
2. G. A. Askarian, et al, Nucl. Instr. and Meth. **164**:267 (1979).
3. P. B. Price, Nucl. Instr. and Meth. **A325**:346 (1993).
4. J. G. Learned, Phys. Rev. **D19**:3293, 1979.
5. T. Bowen, Proc. XVI ICRC 11:184, 1977.
6. L. Sulak, et al, Nucl. Instr. and Meth. **161**:203 (1979).
7. T. Aoki, et al, Proc. XXII ICRC 4:666 (1991).
8. R. J. Urick, Ambient Noise in the Sea, Naval Sea Systems Command, Washington, DC, 1984.
9. R. Catalano, Benthos Corp., (private communication 1992).

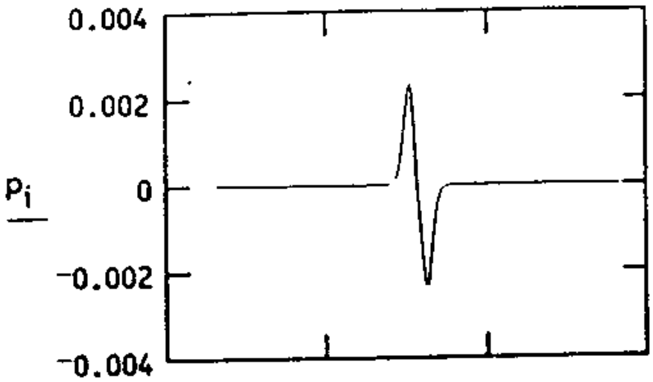

Fig. 1: Expected signal from 10 PeV cascade at 40m. The t axis contains 1024 bins of 5 μsec.

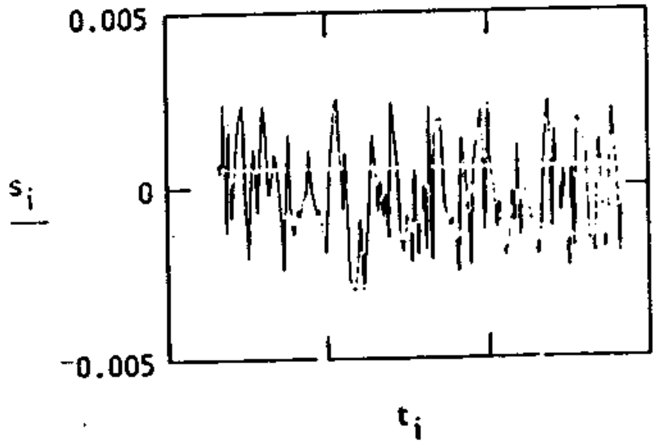

Fig. 2: Signal, delayed 24 time bins, embedded in white noise of equal amplitude, and sampled at 5 μsec intervals.

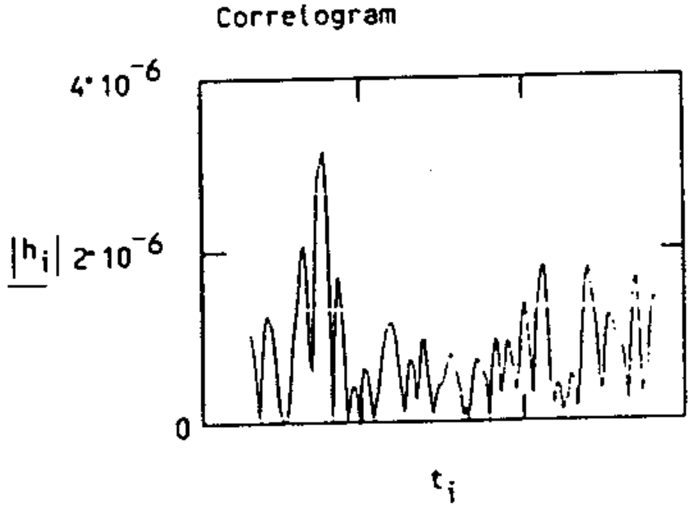

Fig. 3: Correlation of Fig. 1 with Fig. 2 (simulated DSP output). The peak occurs at the 24th bin as expected.

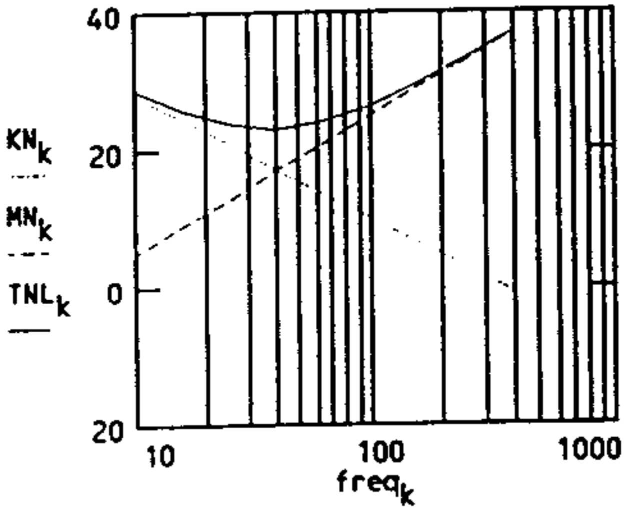

Fig. 4: Ocean noise spectra from ref. 8. The curve labelled KNL represents the Knudsen curve for surface noise in sea state 0 (calm conditions). MNL represents the thermal (molecular) noise spectrum. TNL is the resulting total noise spectrum. Note the minimum around 40 kHz.