A DEVICE FOR DETECTION OF ACOUSTIC SIGNALS FROM SUPER HIGH ENERGY NEUTRINOS *

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We present the design of a device for detection of acoustic signals from high energy particle showers. The module will be stationary installed above the Baikal Neutrino Telescope NT-200+.

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1. Introduction

The investigation of very high energy neutrinos is one of the most interesting task for astrophysics. It requires huge arrays with effective volumes much beyond a cubic kilometre. One of the possible ways to study high energy neutrinos is to detect acoustic pulses from cascade showers ¹. The absorption length for acoustic waves in water is at least an order of magnitude larger than that of Cherenkov light, so acoustic pulses can be detected from very large distance.

However, as it was shown in ^{2,3}, the acoustic noise in natural basins consists of pulses with a large variety in amplitude, shape and duration, including bipolar pulses. The last provide an essential background for acoustic neutrino detection. The actual energy threshold of the acoustic method depends on possibilities to increase the signal-to-noise ratio by means of both hardware and software methods. The small value of the speed of sound prevents a direct application of the proven signal-to-noise discrimination techniques known from nuclear physics. In this work we present a deep-water 4-channel digital device, intended for the search of small-pulse signals from distant, quasi-local acoustic sources. We also present the results of test measurements performed at Lake Baikal in April, 2005.

2. A device for detection of acoustic signals from high energy neutrinos

Supposing the thermo-elastic mechanism, an acoustic signal from neutrino-induced cascades is expected to peak at frequencies of 20 kHz, with calculated amplitudes for a 10 PeV cascade at 400 m distance ranging from a few μPa ⁴ to a few tens of μPa ^{1,5}. Although such a signal is close to the sensitivity of the human ear, its detection is far from being trivial since it has to be separated from various sources of noise. For this purpose a digital hydro-acoustic device with four input channels has been developed. The principal scheme of the device is shown in Fig1. Acoustic signals are recorded by four cylindrical hydrophones (Hf-1,2,3,4) with a sensitivity of about 1 mV/Pa, made from a tangentially polarized piezoceramic. The signals are further processed by preamplifiers (Preamp-1,2,3,4) with 40 dB amplification and frequency correction. In the range down from 1 kHz, the relative amplification is lowered by 20 dB per octave in order to suppress low frequency noise. High frequency noise is suppressed by discrete low-pass filters following the preamplifiers. The further processing is performed by an IC (ADM416x200), which is mounted on the base

Figure 1. Block scheme of an autonomous hydro-acoustic device

board (AMBPCI v2.0) of a computer (NOVA-C400 Series) and includes four software programmable amplifiers (PGA-1,2,3,4) and the 16-bit over sampling ADC-AD7722 (ADC-1,2,3,4) with a maximum conversion rate of 0.2 Msamples/sec. A single board computer pre-processes the data and communicates with a shore computer via DSL modem. The electronics is housed by a cylindrical metallic container with 22 cm outer diameter and 40 cm height. Four hermetic connectors penetrate the upper cap of the container (1 - power connection 300 v; 2,3 - network twisted-pair cable, 4 - coaxial cable for trigger signal from NT200+) and two pairs of hydrophone connectors penetrate the left and right sides of the container.

The module is designed for operation together with the Baikal Neutrino Telescope NT200+. There are three regimes of operation of the instrument:

- (1) Transmitting of a one-second sample of data from all hydrophones to the shore computer centre, after a trigger signals from NT200 or the NT200+ outer strings.
- (2) Online search for short acoustic pulses of definite shape, which can be interpreted as signals from distant quasi-local sources.
- (3) An autonomous analysis of acoustic background statistics.

The joined operation with NT200+ could give us an opportunity to identify the properties of acoustic emission from cascades and provide energy calibration (assuming that signal strength and flux are high enough and the energy threshold low enough to collect a usable number of true coincidences). To suppress the amount of raw information which should be transferred to the shore station the pre-processing of data will be done in situ using the algorithm described in ⁶. The analysis software is able to detect an acoustic signal which exceeds the threshold and to extract the

Figure 2. Left (a): The distribution of arrival of all impulses. Right (b): The distribution of bipolar impulses versus zenith angle.

parameters of the signal, such as maximum amplitude, number of periods, duration of each period and etc. Several years of study of acoustic noise in Lake Baikal ² have shown, that most of short bipolar impulses are the result of an interference of acoustic waves from numerous distributed sources of sound. Extraction of small pulse signals from such a background requires an antenna consisting of several hydrophones. The optimum distance between the hydrophones is defined by the condition that it should clearly exceed several wave-lengths of the expected signal, but on the other hand should be not too long in order to minimize the number of background impulses captured by the 'time window'. So, we arranged the hydrophones in a pyramid-like geometry with the distance between the hydrophones of 1.5 m. Eventually we will install the device on one of mooring of underwater complex of Baikal Neutrino Telescope NT200+ and perform a long-term study of the background as well as a search for short acoustic impulses, including the regime of coincidences with NT200+.

3. Results

The combined data were taken during the test measurements in April 2005. The acoustic antenna allows us to estimate the vertical and horizontal angles of incidence of acoustic signals. The position of antenna's hydrophones in water is fixed by acoustic transponders located around NT200+. The results of a preliminary analysis show, as it was expected, that most of all impulses come from the upper hemisphere. This means that their sources are on the surface of the lake (Fig.2a). Therefore, for the next measurements we assume to place the device at small depth and to search for

acoustic signals from the lower hemisphere. In Fig.2b the distribution of bipolar impulses is presented. One sees an insignificant number of bipolar impulses coming from the lower hemisphere, but with the angles not more than 20° to the horizon. These signals also could arise on the surface of the lake, but changed their direction due to refraction. The bipolar signals entering Fig.2b have been requested to have a length smaller than $50 \mu\text{s}$ and an amplitude larger than four standard deviations. These criteria have been chosen in order to select only signals which may simulate signals due to high energy particle cascades.

4. Summary and Outlook

A device for registration and preliminary analysis of acoustic signals has been constructed and tested in-situ in April, 2005. Apparently, for the search of acoustic signals from high energy cascades it is preferable to listen to water volume from top to down, that is to place the acoustic antennas at depths of the order of 100 - 200 m. One also has to reduce the sensitivity with respect to signals from above, for example, by means of caps made from a sound-absorbing material. The results of the measurement of acoustic noise in Lake Baikal show its complicated structure and its strong dependence on different factors. To study it more systematically in 2006, we intend to deploy the device for one year operation, together with the Baikal Neutrino Telescope. At the next stage we plan to use this antenna as an elementary unit of a future hydrophone array.

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