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EXPLORING RESULTS OF THE POSSIBILITY ON DETECTING COSMIC RAY PARTICLES BY ACOUSTIC WAY

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1 Introduction

The idea of detecting ultrahigh energy cosmic ray particles by acoustic way has been suggested for years. To date many theoretical and experimental researches have been completed(1-9). In order to pursue this possibility the acoustic background noise in ocean and large lake have been examined. Stenger et al first explored the ultrasonic signals in the sea off the Barking Sand coast of the Hawiian island Kauai in May 1977(10). Some waveforms of transient and ultrasonic signals were recorded. But there is no conclution on the sources and the properties of these signals.In the recent years Kaneko et al have examined the possibility on observation of super giant air showers above 10^{20}eV by aid of detecting the acoustic signals generated by the shower cores in a lake at mountain level(11). In the past we reported that there are some transient and puzzling ultrasonic signals in large reservoirs(12). In order to clarify the sources and the properties of these signals and to examine whether some signals among them are produced by ultrahigh energy cosmic ray particles a new experiment was carried out during the period from June to August in 1984 at Reservoir Miyuin.

2 Experimental status and apparatus

The experiment was carried out on a ship floating on Reservoir Miyuin(altitude:134m). The distance from the ship to the major dam is about 150m. Observation was conducted at night. The new apparatus consists of a hydrophone array, a small EAS array and electronic instruments. A schematic diagram of the experimental setup is shown in Fig. 1.

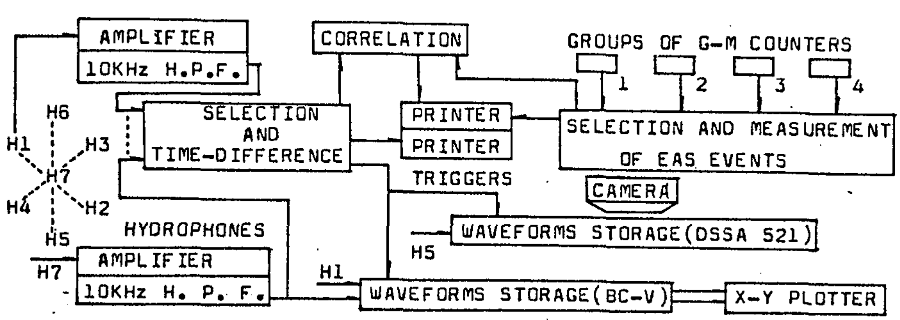

Fig. 1: Aschematic diagram of the experimental setup.

The construction of acoustic array is a rectangular coordinate system. Radial distance from central hydrophone to external one is 1m. The depth of the center of the array is 2.85m under water. The hydrophones with pre-amplifiers(gain: 20db) subject to three types. Frequency response is uniform in the range from 4KHz to 100KHz($\pm$3db). The sensitivity is from 150μv/μbar to 350μv/μbar. Self noise of all acoustic system is approximate to (0.2-0.5)μbar. Sevenfold coincidence with discrimination threshold of 2μbar was used for selecting transient ultrasonic signals. It provides a counting rate of 30 hour^{-1}. The occurence time, three waveforms recieved by three different hydrophones(H1,H5 and H7) and time-differences between central hydrophone signal and external ones were recorded for each selection event. The accuracy of positioning based on hypothesis of the point source is better than 20% within 10m.

The small EAS array consists of four groups of G-M counters(J109-γ). The efficient area of each group having two layers of G-M counters is 0.32m^2. They were placed on the top of the ship(area:~14x4m^2). A threefold coincidence between four groups provides a counting rate of 40 hour^{-1}.The threshold energy of EAS array is equal to 10^{14}eV in such a case. The occurence time and local particle densities were measured.

There is a correlation circuit between acoustic event and EAS one. If an acoustic event take places after the occurence of an EAS event within 1 s the delay time ΔT can be measured by the correlation circuit. If an equation, $C \times \Delta T = R$, is satisfied(where C is the velocity of sound in water, R the distance from the sound source to the center of acoustic array) the position of this signal source may be coincident with EAS core.

3 Results and analysis

The aim of this experimental was directed at trying to investigate the question whether the ultrasonic signals in water were relevant to high energy cosmic ray particles.

Correlation events: During an efficient observation term of about 329 hours 116 correlation events were recorded. The distribution of the delay time ΔT of these events consists with uniform distribution.In addition according to the counting rates of acoustic array and EAS array there must be 110 accident coincidence events. Therefore most of them belong to accident coincidences. We could not find any event which shows that the equation $C \times \Delta T = R$ is realized within the sensitive distance of 10m. The results imply that the threshold energy of detecting EAS core with this acoustic array is above 3×10^{16} eV and that the mechanism of sound generated by EAS core in water may be the thermo-acoustic mechanism(6,7). Unfortunately we can not answer an important question whether there were real correlation events at R above 10m. In future it is necessary for detecting acoustic signals created by EAS cores in water to develop new high sensitive and low noise hydrophones and to extend the sensitive distance of acoustic array. If the sensitive distance of an acoustic array with a small EAS array is about 500m perhaps it is possible to detect acoustic signals generated by EAS cores of energies above 10^{18}eV.

Ultrasonic signals under water: It is very important to search for acoustic signal created by high energy nuclear cascade in water. This is one of the possible effects on the basis of which DUMAND project try to observe cosmic ray neutrinos in deep ocean. During our observation many transient ultrasonic signals under water were recorded. In order to explore whether some of them are relevant to the local cascades produced by high energy cosmic ray particles their caracteristics were examined. Two typical waveforms of these signals and basic data are shown in Fig. 2. Obvious properties

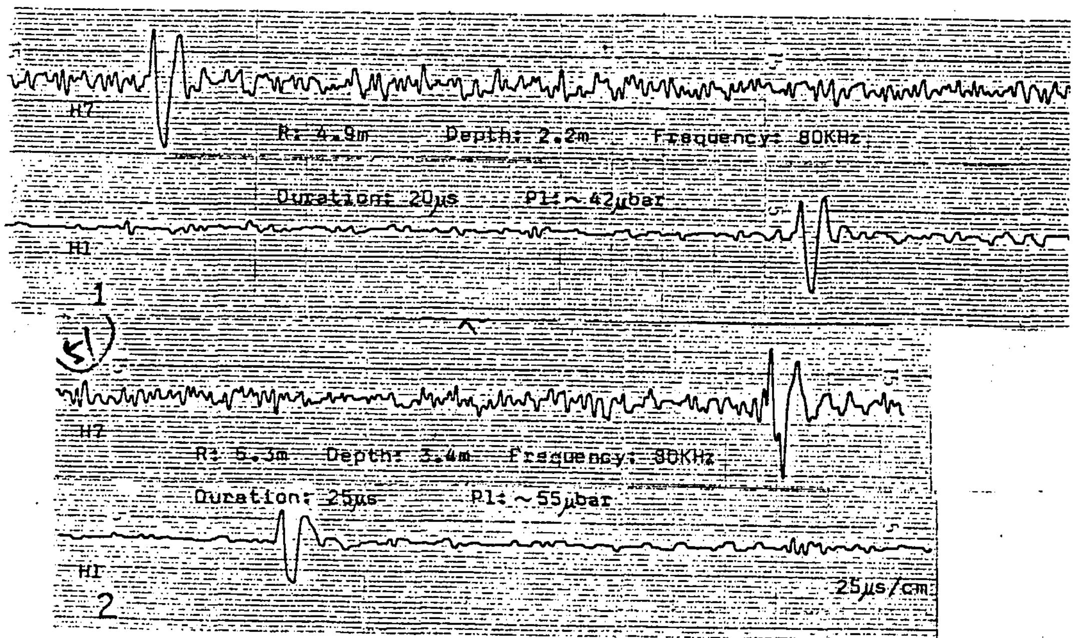

Fig. 2: Two typical waveforms of ultrasonic signals recorded by waveform storage(BC-V) under water.

of signals is as follows:transient and individual, multipole (most of them are tripolar pulses), short duration of from 25µs to 60µs, ultrasonic frequency of from 60KHz to 100KHz. An evaluation based on hypothesis of the point source shows that the peak sound pressure P1(normalization at 1m from the source) is approximate to several tens µbar and that the total energy radiated by a source is about several GeV. These properties are very similar to that of sound signals radiated by microbubbles with radii from 3×10^{-3}cm to 7×10^{-3}cm (13). These microbubbles have the potential energy in the range from 10^{11} eV to 10^{12}eV(14). Taking account of the radiation efficiency of about 1.5% they are capable of releasing the acoustic energy of several GeV(13). In addition it is impossible that the total acoustic energy arises directly from local energy deposition produced by local nuclear cascade. Therefore a primary conclution is that the mechanism of generating there ultrasonic signals under water is sound radiation of microbubbles. It is well known that there are a lot of microbubbles in natural water(15). Many years since it has been investigated that cosmic ray particles can create bubble nuclei in water(16, 17). We suppose the local energy depositions produced by nuclear cascades in water may induce sound radiations of a part of microbubbles.

4 Conclutions

Although it has been demonstrated experimentally and theoretically that high energy particles produce detectable sound in water many years ago. However no one can find an acoustic signal generated by high energy cosmic ray particle in water as yet. Our results show that transient ultrasonic signals in a large lake or reservoir are fairly complex and that transient signals under water may arise mainly from sound radiation of microbubbles. This field is not explored in detail. Maybe the sounds created by cosmic ray particles hide in these ultrasonic signals. Thus in order to develop the technique of acoustic detection it is the most important to make a thorough investigation of these ultrasonic signals in water.

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