Intensity fluctuations of mid-frequency sound signals passing through moving nonlinear internal waves in Shallow Water 2006 experiment.

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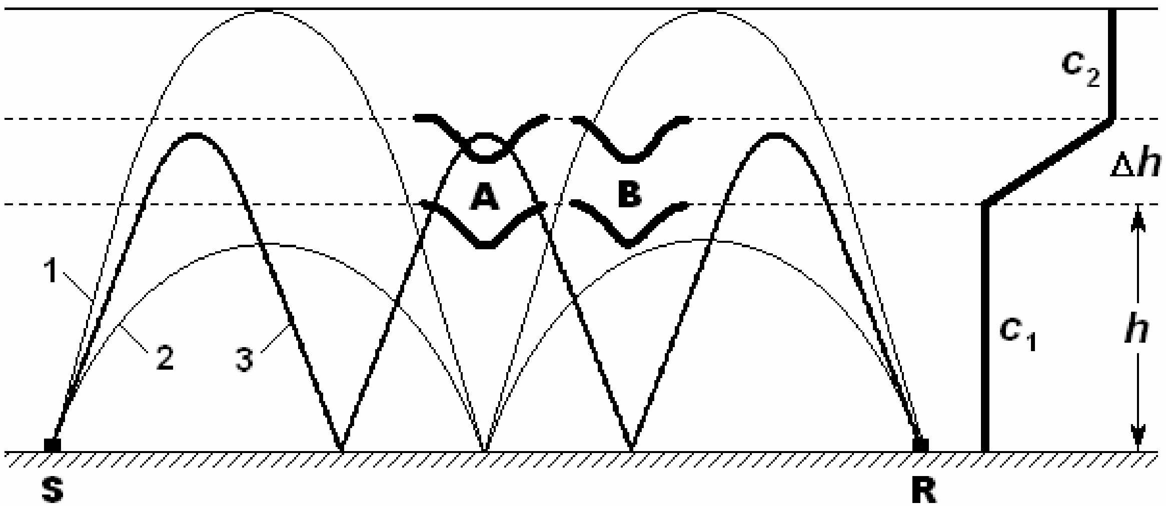
The fluctuations of intensity of broadband pulses in the mid-frequency range (2 – 4.5 kHz) propagating in shallow water in the presence of intense internal waves moving approximately along the acoustic track are considered mode coupling situation). These pulses were received by two separate single hydrophones placed at different distances from the source (~4 km and ~12 km) and in different directions. It is shown that the frequency spectra of the fluctuations for these hydrophones have different predominating frequencies corresponding with the directions of the acoustic track. Comparisons of experimental results with theoretical estimates demonstrate good consistency.

Statement of problem



$h \sim 60$ m

$\Delta h \sim 10$ m

$c_1 \sim 1480$ m/s

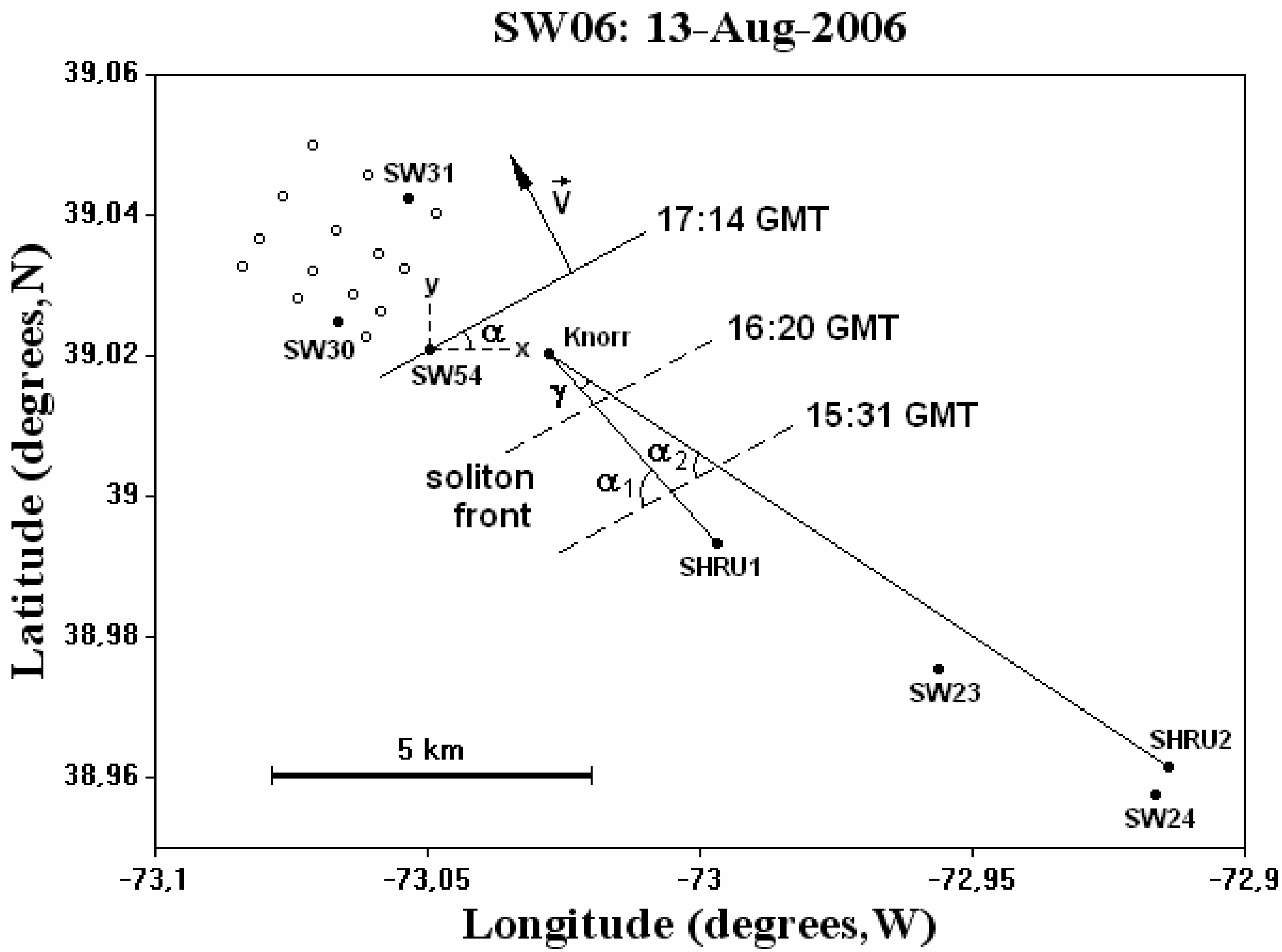
$c_2 \sim 1525$ m/s

Interaction of ray with the moving perturbation at the position A is greater than at the position B. So temporal fluctuations of intensity from the source S at the receiver R take place.

Period of fluctuation $T_c = D_c / v_t$ frequency $\Omega_c \sim v_t / D_c$

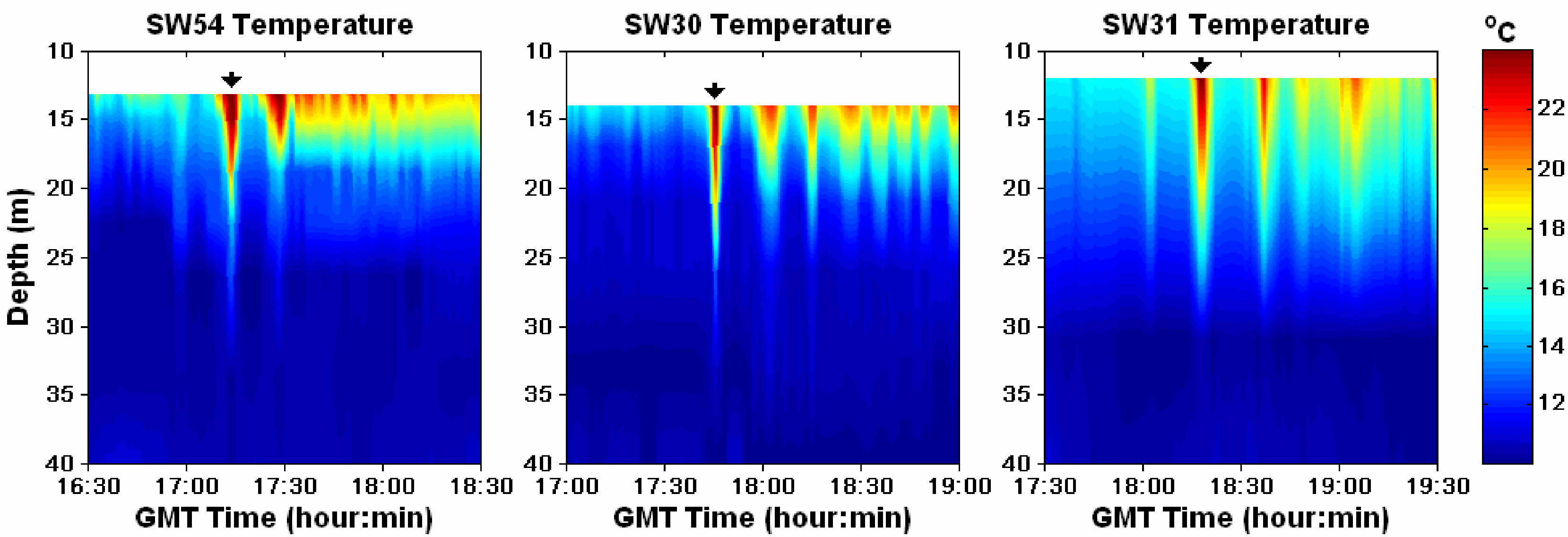
D_c - critical ray cycle v_t - velocity of soliton along acoustic track

$\Omega_c \leq 10$ cph for typical shallow water conditions

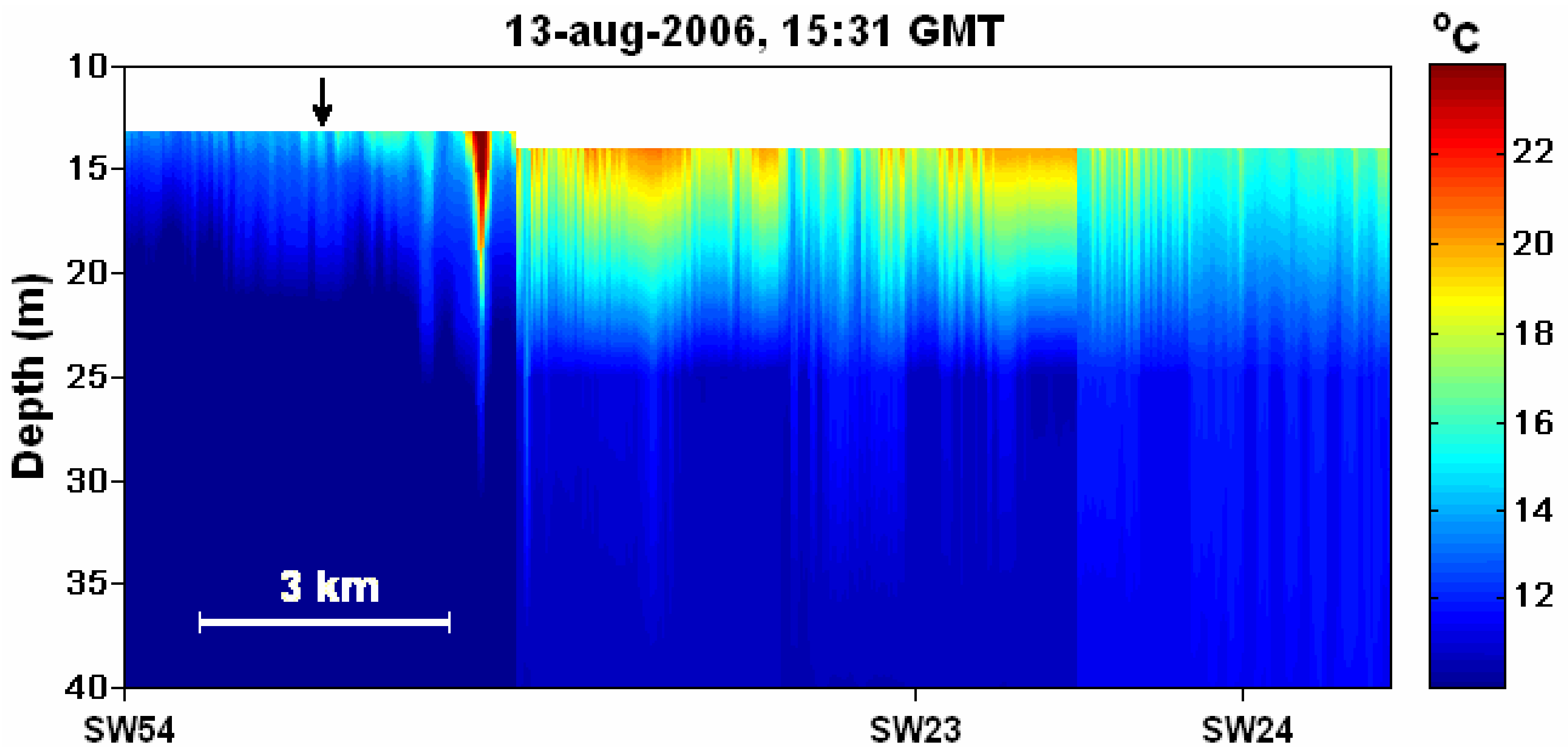


Source is at the R/V Knorr, receivers are SHRU1 and SHRU2, waves fronts of the first peaks in the train are shown for 16:20 and 15;31 GMT $\gamma \sim 15^o$

Temperature records of thermistor strings allows us to construct velocity and direction of propagation of internal waves



In supposition of constant velocity of internal waves it is possible to construct space distribution of temperature, for example for 15:31 GMT along a straight line between thermistor's sensors SW24 – SW23 – SW54. Black arrow denotes position of the soliton at 16:20 GMT



Acoustical data

During period of 15:31-16:20 GMT (13 of August 2006), a sequence of pulses was radiated consisting of 200 separate pulses in the frequency band 2-10 kHz. These pulses were received independently at SHRU1 and SHRU2. The spectrum of radiated signals was in the band 2-10 kHz.

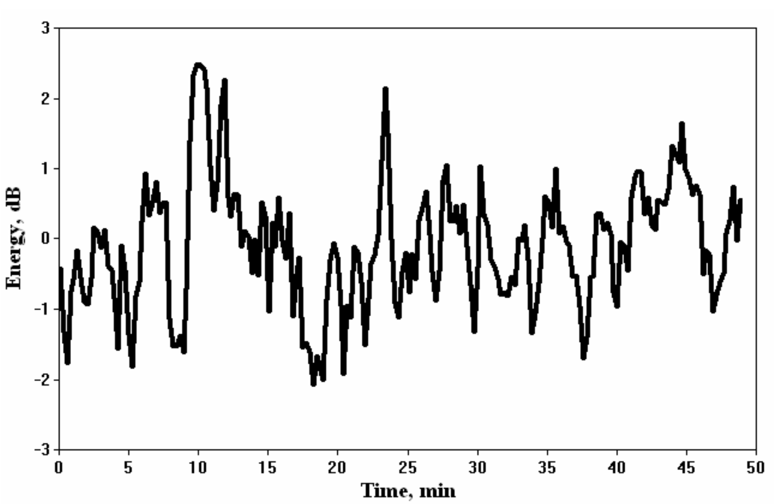
$$S(\omega) = \int_0^{\tau} p(t)\exp(i\omega t)\,dt$$ Spectrum

$$E = \int_{\omega_1}^{\omega_2} \left|S(\omega)\right|^2 d\omega$$ Energy

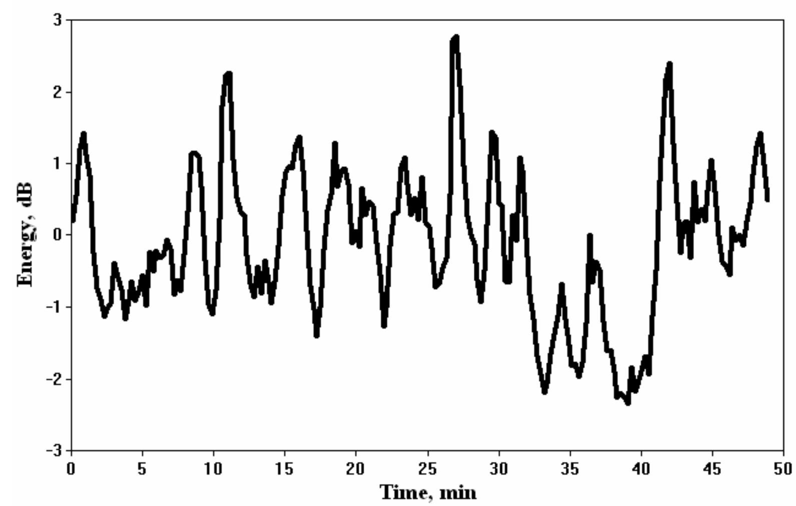
Temporal dependence of the energy (relative units)

$$\overline{E}(T) = \frac{E(T) - \langle E \rangle}{\langle E \rangle}$$

SHRU1

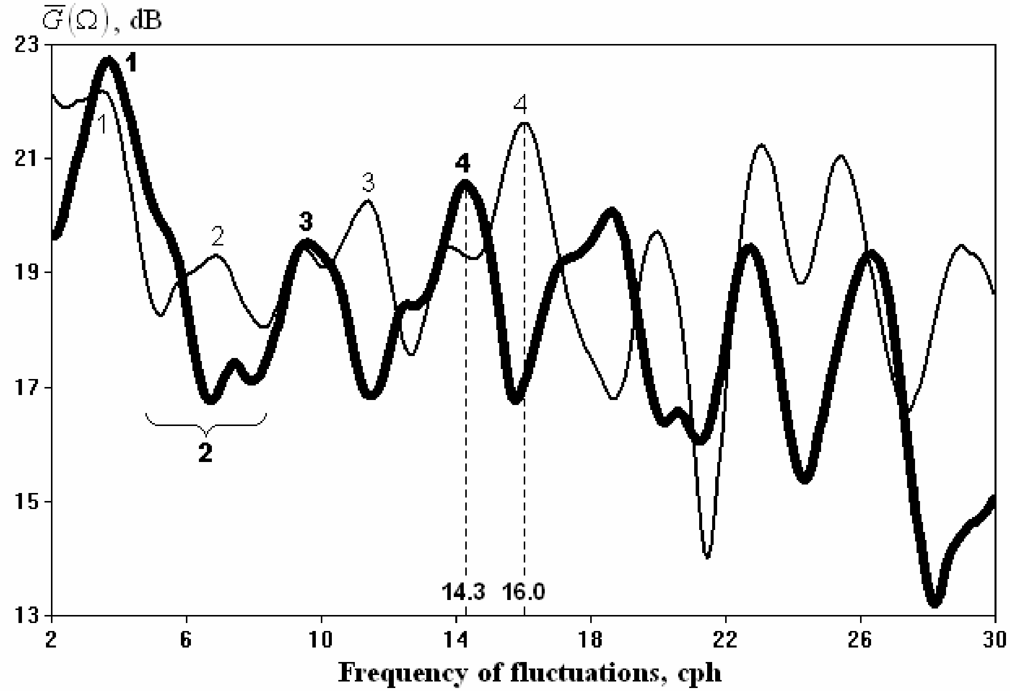


SHRU2



Spectra of fluctuations of pulse energy. $$\overline{G}(\Omega)=\left|\int_0^{\Delta T}\overline{E}(T)\exp(i\Omega T)dT\right|$$

Bold line denotes spectrum for SHRU1, thin line corresponds to SHRU2. Dotted lines denote positions of the 4th harmonics of predominating frequencies



Experiment $\Omega_c^1 \approx 3.58$ cph $\Omega_c^2 \approx 4$ cph

Estimations $D_c \sim 2hc_1/\sqrt{c_2^2-c_1^2}+2\Delta h\sqrt{c_2^2-c_1^2}/\Delta c$ $\alpha_1 \sim 78^o$ $\alpha_2 \sim 63^o$

$v \sim 0.6$ m/s $D_c \sim 640$ m $\Omega_c^1 \approx 3.45$ cph $\Omega_c^2 \approx 3.8$ cph

Summary

- The IS, moving approximately along an acoustic track, interacts with the quasi-periodical spatial interference pattern of the sound field formed by a set of rays radiated from the source in a shallow water. Frequency of temporal fluctuations of the sound intensity at the receiver is proportional to the velocity of the IS along the acoustic track. The difference in spectra of these fluctuations (shift of the predominating frequencies) for two acoustic tracks depends on the angle between them and the observation reported here are in consistent with this hypothesis.
- The value of the predominating frequency does not depend (or depends weakly) upon the shape and amplitude of the IS, and on how many separate peaks there are in the train. It is just this circumstance that allows us to get comparatively good agreement between theory and experiment.