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STRUCTURE OF THE CLASSICAL QUARTETS, FORMED IN THE UNDERWATER SOUND CHANNEL OF THE SEA OF JAPAN

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In experiences on long-range propagation of explosive signals in the underwater sound channel it was repeatedly registered obvious and implicit (mask by a background noise) splitting of separate elementary signals, transformation of classical quartets in groups of signals which number exceeded four. Some results of the analysis of quartet's structure in sea of Japan are discussed (on materials of one of experiences).

Registered in experience on long-range propagation of sound the multibeam explosive signal breaks up to three groups of elementary signals. The first - the most powerful basic group of the elementary (one-beam) signals practically not divided in time propagating near axis of the underwater sound channel (USC). The second - group of elementary signals, cleanly water, and also reflecting from a surface which come to the receiver with some advancing concerning the basic group. Elementary signals of this group are formed in the form of divided among themselves classical quartets because of obvious asymmetry USC. At removal from a source the advancing of the quartet concerning the basic group grows, the separate branches, differing by quantity of full cycles (N), described by an middle signal of the quartet concerning axis USC a trajectory are formed. At a contact a signal of a bottom the branch breaks. The third - group of the elementary signals which have tested reflection from a bottom and a surface, coming to a point of reception with some delay concerning the basic. Below it will be a question of the second group of signals.

Analyzing materials of the experience lead in Philippine sea [1], at estimations phase (independent of frequency) shift between the "one-beam" signals of the classical quartets differing by one contact with caustic, we have collided with distinction this shift from multiple 90º. This phenomenon has been explained by splitting of a signal (beam) in a point of turn at its arrangement at border of the water layers, differing a gradient of speed of a sound (at increase of its absolute value in process of removal from axis of USC), occurrence of the additional signal coming to a point of reception practically simultaneously with the main (the time interval between them did not exceed 1 мс), but differing from it on one contact with caustic, their vector summation [2]. The similar phenomenon was observed by us as well in sea of Japan. In sea of Japan [3, 4] transformation of quartets (on distance from a source, exceeding 250-300 km) in groups of difficultly divided signals was marked as well obvious splitting of some signals of quartets.

Experimental materials of the experience lead in the central part of sea of Japan, have been chosen by us for more detailed analysis of process of transformation classical quartets in groups of one-beam signals which number noticeably differed from four, not casually. At carrying out of this experiment the receiver and a source were placed directly with axis of USC (150 and 155 m, accordingly). The time structure of a sound field in this experience has been surveyed in detail enough. On a 440-kilometer path it has been undermined nearby 100 charges - the step on a distance between the next underminings has made 4-5 km. In experience about 12 branches, forming by quartets were well traced. The basic purpose of such analysis - definition of the most probable site of beam turn horizon at which its splitting is registered, and also supervision over development of this process at removal of a source from a point of reception.

On fig.1 the quartets of three branches, the full cycles differing by quantity described by middle signals (N=3, 4 and 5) are presented. It is necessary to remind, that the explosive signal (from small charges), accepted in a strip of frequencies from 40-60 Hz up to 1-2 кГц from a distance of 10-20 km and more in conditions of one-beam propagation, represents in time area two short-term (duration <1мс) impulses, commensurable on size, the same signs (a shock wave and the first pulsation of a gas bubble).

The interval between them (the period of a pulsation) depends on weight of a charge and depth of undermining. In the given experience the period of a pulsation has made ~20 мс.

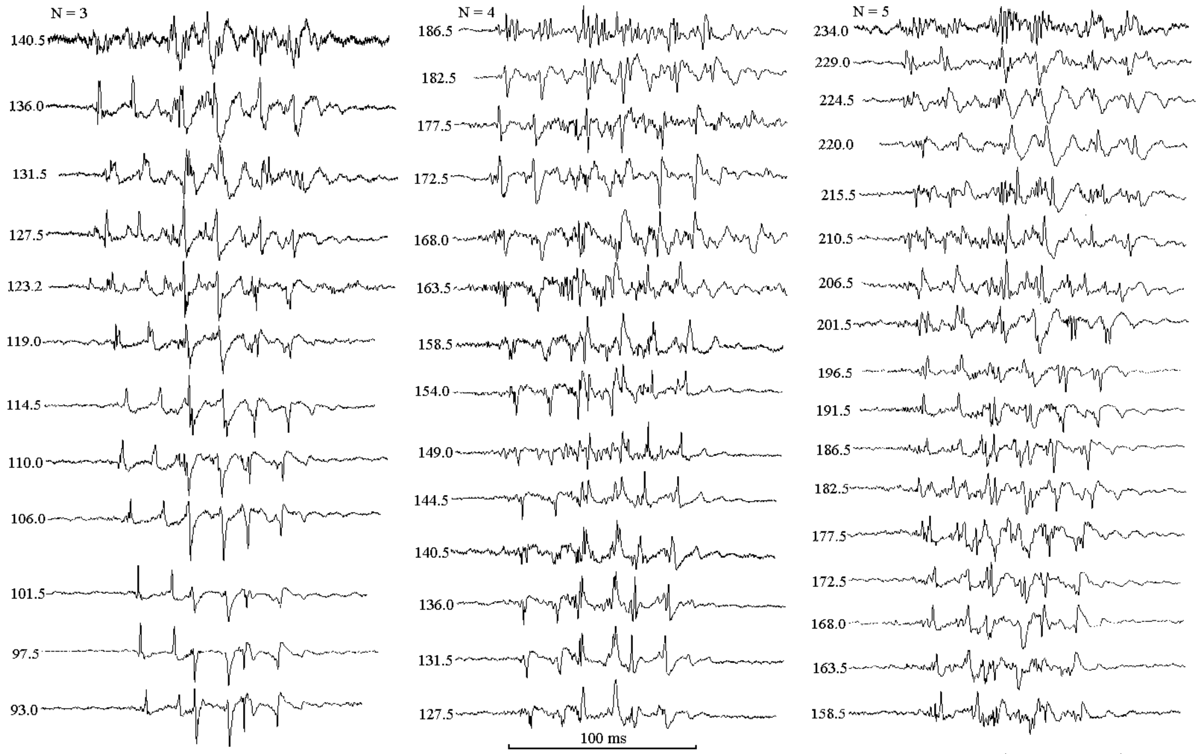

Fig. 1. Japan sea. Evolution of classic quartets at deleting from a source on an example of three branches (N = 3, 4 и 5)

In figure the quartets are built so, that their middle signals are placed one under another, the distance from a source (it is specified to the left of each quartet, km) increases from below upwards. The increase in distance for each branch is unequivocally connected with increase in absolute value of a corner of section of axis USC by middle signals of the quartet, and, hence, and with approach of the top turn-point to a surface.

Distinction in depths of an arrangement of a source and the receiver have affected in distinction of times of propagation of the second and third signals of the quartet reaching 3-7 мс (for small distances from a source). For the majority quartets, resulted on fig.1 their transformation into three of signals (the second and third signals come to the receiver practically simultaneously) is characteristic. Only on occassion (see, for example, R=144.5 km, N=4) the second and third signals of the four come to the receiver not simultaneously, distinction in times of their propagation reaches ~ 4 мс.

Obvious splitting of signals of the quartet is observed on limiting for each of the presented branches distances from a source when the top turn-point as much as possible comes nearer to top border USC.

Splitting of the first and fourth signals of quartet also is well looked through for N=3 on distance from a source of 119-131 km. For N=5 splitting of the first signal of quartet is observed at R = 172-183, 196-202, 210-215, 229 km. We shall note - at R/N ≈ 40 km splitting was observed both in that, and in other case. With increase in distance from a source, with transition to branches with great value N the structure of quartets becomes complicated - the quartets to groups of poorly differing signals which number noticeably exceeds four. In this case for allocation and identification of separate elementary signals we used specially developed program of the analysis classical « quartets» on the computer, considering the basic features of time structure of a probing explosive signal (the form of a signal - two short-term impulses, the period of a pulsation of the gas bubble, phase shift independent of frequency at a contact by caustic and so forth [5]). Thus it was spent as well correlation processing of allocated pairs impulses with pair impulses of a reference one-beam explosive signal, characteristic undermining for the set depth (the bank of the probing signals registered at different depths of undermining of standard small charges used by us - detonators of hydrostatic action has been created). As a result of application of this program at the analysis of the signals accepted on distance from a source, multiple 40 km, for quartets of 8 different branches (at a constancy of value R/N ≈ 40 km) were marked increase in quantity identified (differing among themselves on time of distribution not less, than on 10 мс) one-beam signals in the quartets with 4-5 at N=1,2,3 till 9-13 at N=6,7,8.

Earlier [3] by results of processing materials of this experience it has been constructed truncated τ/N-R/N - the diagram (see fig.2), it is good enough agree with calculation, that has given the basis for rather authentic definition to dependence on the resulted distance (R/N) a corner of section of axis USC by separate beams (θ). Also it has been established, that the difference of absolute values of corners of arrival (that in this case is equivalent to corners of section of axis of USC) lateral signals of the quartets noticeably decreases with increase in distance. If for N=1 this difference makes nearby 1 ° for N=2 it decreases in 2 times, and for N> 4 it does not exceed 0.1°. Thus, at N> 4 horizons of turn average and extreme signals of the quartet practically do not differ. In this case the curve of dependence θ *(R/N)*, resulted on fig.2, can be used at an estimation of turn-horizon any signal of the quartets. It is not necessary to forget thus, that distances from a source up to turn-points different signals of the quartets can differ noticeably enough.

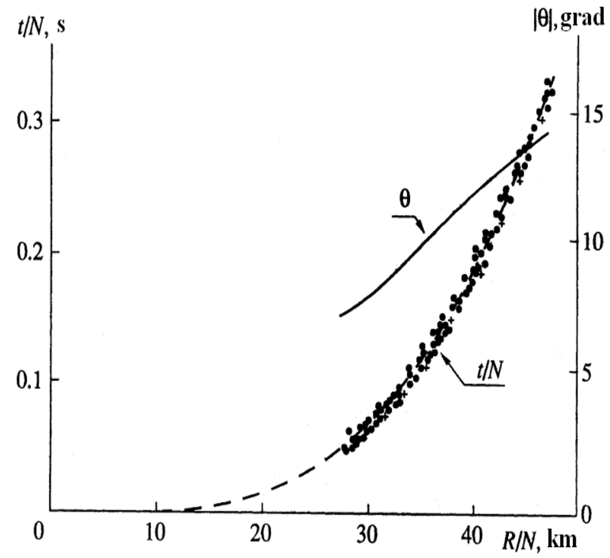

Fig.2. Truncated τ/N-R/N - the diagram constructed on experimental materials, and dependence of a corner of section of axis USC by middle signal of the quartets (θ) from resulted distances R/N (calculation) [3].

Resulted on fig.1 the quartets of three branches there correspond to a range of the resulted distances 31км <R/N <47 km, that as have shown calculations, is equivalent to a range of corners of section of axis USC by middle signals 8 ° <| θ | <14°. On known value of speed of a sound on axis of USC (1452.5 km/s) and to values of a corner of section of an axis it is easy to define limiting values of speed of a sound on turn-horizons for middle signal of the quartets (1466.8 km/s - 1497.0 km/s). On the basis of the experience of a structure registered at carrying out c (z) the range of changes of horizons of the bottom turn has been certain: ~ 1.0 km - 2.85 km. On these depths of appreciable indignations of a structure c (z) it has not been registered. Other picture was observed for the top turn - a turn in a subsurface water layer.

On fig.3 a structure of change with depth of speed of a sound and a gradient of speed of a sound , registered in 100-meter subsurface layer during carrying out of experience are presented (three curves: a, b and c). The structure of change of speed of a sound with depth is resulted smoothed enough. The values of a gradient of speed of a sound resulted in figure were estimated by results of the direct sounding which is carried out by device " Istok-3 " with step on depth ~30-50 m.

Considering limiting values of speed of a sound, on the basis of three resulted structures c (z) it is easy to define limiting values of horizons of an arrangement of points заворота: 21-30 m, 27-38 m and 32-44 m. Signals of quartets were developed in a layer of the temperature jump moving on depth within the limits of 10-15 m.

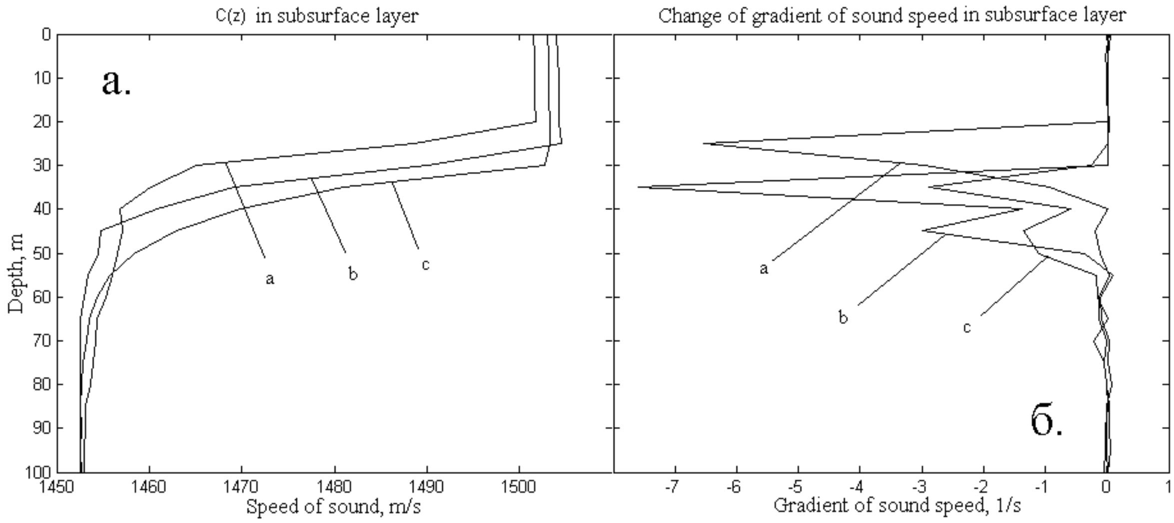

fig.3. Structures of change of speed of a sound (a.) and its gradient (б.) with depth in subsurface water layer on materials of hydrological inspection of an investigated line.

Obvious splitting of the first and fourth signals of the quartet, noted by us at N=3 and N=5, and also increase in number of elementary signals in quartets from 4-5 till 9-13, registered for 8 different branches on distances from a source, multiple 40 km (R≈N·40 km), occurred, as it is easy to show (see fig.2), at section a signal of axis USC under a corner θ ≈ 12 °, that of 1485 km/s. Thus correspond to speed of a sound on horizon of a turn, considering observed at carrying out of experience of change depth of a layer of temperature jump, a turn in subsurface layer occurred on depth 30±7 m where the maximal changes of a gradient of speed of a sound (see fig.3б) have been registered**.**

R E F E R E N C E S

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