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SEPARATION OF SIGNALS WITH CLOSE PROPAGATION TIMES, WHICH DIFFER BY ONE TOUCH OF A CAUSTIC

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On a technique developed in Acoustic institute, the measurements of phase shift, formed by contact caustic surfaces by a signal are carried out. The pairs of signals in classical "quartets", differing by quantity of contacts with caustics, were analyzed. The noticeable deviations of phase shift from expected (90°) were registered in a number of cases. In this cases curve dependences of correlation factor of pair such signals on phase shift, artificial entered for one of them, differed by the asymmetry and on occasion by two-peaking. For symmetric curve dependence of correlation factor on phase shift K(φ) the monotonous change (proportional to phase shift) of temporary coordinate of a maximum of correlation function (Tm) of pair of signals was observed. For two-peaked curves K(φ) at the phase shift appropriate to a minimum of correlation factor (located between humps), the sharp transition from one monotonous linear dependence Òm (φ) to another (jumping from one maximum of correlation function to another) was observed. This testifies that one of two signals of analyzed pair is not "one-beam". On size of deformation of a curve Òm (φ) it is possible to judge a time interval between the comes "practically simultaneously" elementary signals. Thus, at indemnification of phase shift it is possible reliably to divide signals, which are not divided obviously in time, but differing on one contact of caustics.

At realization of experimental researches of thin structure of a sound field at ocean besides study of the temporary, angular and power characteristics of a field the large interest represents definition phase shifts (independent from frequency) between signals coming on different beams, caused different numbers of its contacts by caustics surfaces. Is theoretically shown, that at a contact the acoustic signal by caustic on sufficient distance from a point of a contact forms change, independent of frequency, of a phase of a signal on 90°. Such change of a phase results in change of the form of a broadband signal. For explosive sources of a sound the change of the form of “one-beam” signals, divided in time, at frequency - independent shift of a phase was marked earlier. However at work with explosive sources of a sound we were repeatedly paid attention to the fact, that signals in classical "quartets", differing on two contact by caustics (that corresponds to shift of a phase on 180°), not always are mutually transformed by change of their polarity.

With the purpose of realization of quantitative ratings of phase shift at a contact the signal by caustic a technique was developed and the program of processing on the computer elementary ("one-beam") explosive signals, accepted on sufficient distance from a source and divided in time, is created.

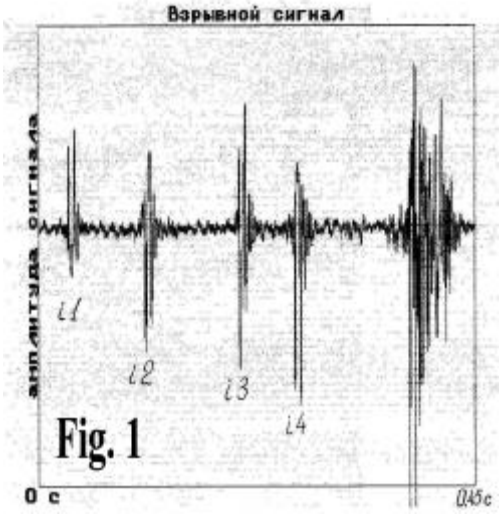


Fig. 1

The program is based on comparison of elementary signals of pair in classical "quartets" at artificial change of a phase of one of them (identical on all frequency components). Thus the degree of similarity of signals is estimated on factor of correlation, as which the maximal value of cross-correlation function is accepted. At smooth artificial change of phase shift of one of signals correlation factor of pair also smoothly changes. The phase shift, at which the maximal value of factor of correlation between two chosen signals is observed, is accepted for relative shift of a phase between them, brought in by environment at sound propagation.

Materials, received in northern part of the Philippine Sea at realization of one of experiences on study of structure of a sound field in the underwater sound channel (USC), its temporary variability in conditions of “one-beam” reception, were used for experimental definition of phase shift at a contact the signal by caustics. The depth of the sea in area of realization of experience exceeded 4500 ì, the axis of USC

settled down on 1000-1200 m. In experience the 400-gramme explosive charges, equipped by electric detonators, were used. The charges were undermined on the large depth (at axis of USC). The period of the first pulsation of a gas bubble was 6.0-6.5 ms, the first (main) maximum in a signal spectrum was on frequency 150-160 Hz. The omnidirectional reception of explosive signals was made on distance of 150 kms from a source on depth little differed (on 250-400 m) from depth of detonation.

In fig. 1 one of nine explosive signals, registered in experience, is submitted. Its temporary structure is well coordinated to results of account executed in beam approximation. By first to the receiver comes four (in figure: i1, i2, i3 and i4) signals, well divided in time, (intervals between them makes 50-100 ms), behind them - the compact group practically not divided near-axes signals. First of elementary signals (i1), most deviating from an axis of USC at its propagation, has turn points on depths 250 and 3500 ì, removed enough from bottom and surface of the sea. Else, the only "water" signals were registered in this experience. For a rating of phase shift, caused by signal contact by caustics, the signals of divided "quartet" were analyzed. On accounts the first signal of this "quartet" has touched by caustics 4 times, second and third 5 times, fourth 6 times.

The accepted explosive signals were filtered with a cut-off frequency of 2.5 kHz, digitized at a 10-kHz sampling rate, and stored in a computer; a 12-digit AD converter was used.

The first results of experimental definition of phase shift at signal contact by caustics have shown, that far from always it is 90°. There were on occasion observed rather essential its deviations from expected 90°. Curves of dependences of correlation factor of pair signals on phase shift, artificial entered for one of them, in a number of cases appreciably differed by its asymmetric and on occasion by its two-peaking. With purpose of finding-out of the reasons of asymmetric and two-peaking of these curves the dependence from artificial entering phase shift (φ) of a situation of a maximum of correlation function on a temporary scale (Tm) was analyzed. For symmetrical curve of dependence of correlation factor on phase shift the change, monotonous, proportional to phase shift, of temporary coordinate of a maximum of correlation function of pair signals was observed. For asymmetrical and two-peaked curve of dependence of correlation factor on phase shift the monotony of change of temporary coordinate Tm (φ) was broken.

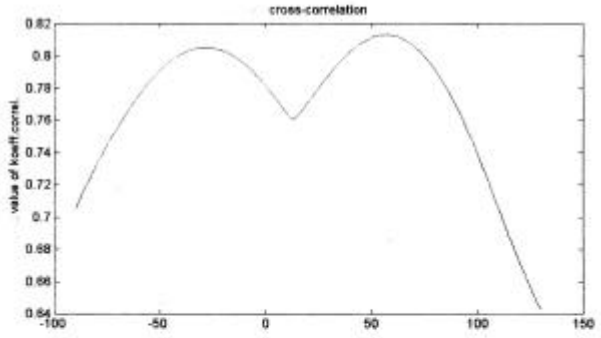
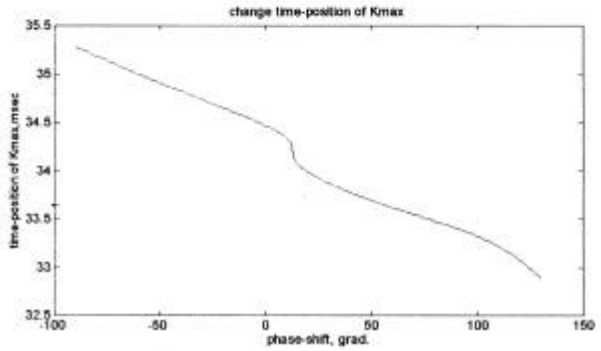


Fig. 2



In a fig. 2 the dependence of correlation factor and temporary coordinate of a maximum of correlation function from phase shift is submitted for pair "i2-i3" of one of the explosive signals, registered in experience. The maxima of factor of correlation for this pair were observed at introduction compensating (for "third" signal) phase shift -29° and 57°. At phase shift 12-13°, appropriate to a minimum of factor of correlation (located between two humps), there is a sharp transition from one monotonous linear dependence Òm(φ) to another (jumping from one maximum of correlation function on another occurs). Such character of change of temporary coordinate of a maximum of correlation function testifies that one of two signals of analyzed pair is not ”one-beam”. On size of deformation of a curve Òm (φ) it is possible to judge a time interval between comes of "practically simultaneously " elementary signals. The size of this interval by our ratings is 1.1 ms.

At indemnification of phase shift the signals, which are not divided obviously in time, were reliably divided.

For this explosive signal has appeared possible to attribute "two-beam" to a signal i3. As a result of the analysis of two pairs signals "i2-i3" and "i3-i4" the curves of dependences of correlation factor and temporary coordinate of a maximum of correlation function from phase shift, were received practically identical to these pairs: two-peaked curves K(φ) with an identical difference of values of phase shift appropriate to the first and second maxima (86° and 87° - not strongly distinguished from 90°!), practically identical time intervals between components of the split signal, determined on deformation of curves Òm (φ), (1.1 and 1.0 ms).

At comparable amplitudes of these signals occurs two-peaked curve of dependence of correlation factor on compensated phase shift, the appreciable distinction in amplitudes results in its asymmetry.

The insignificant distinction of propagation time of these signals (insufficient for their division) results in difference of determined phase shift from multiple 90°. It proves to be true by resultants of additional filtering of an explosive signal, for which one two-peaked curves K(φ) were registered. After additional filtering (the spectrum of a signal was limited to frequency band of 50-650 Hz) two-peaking of a curve K (φ) has disappeared, the phase shift between signals in pairs “i2-i3” and “i3-i4” has appeared equal -13° and 98° instead of earlier determined for first pair -57° and 29°, for second pair 54° and 141°. It is uneasy to notice, that after additional filtering the equal signals in the "third" signal of "quartet" began to be perceived as a single signal with phase shift concerning basic, determined on rules of vector addition: (29°-57°)/2 =-14° and (141° + 54°)/2=97.5°. Before additional filtering the spectrum of a signal was limited to a strip of the low frequencies filter equal 2.5 kHz, after additional filtering the spectrum of a signal was limited to a strip of frequencies only 0.6 kHz. If before filtering this pair was well divided, after filtering it began to be perceived as a single signal. Thus, the results of the analysis of phase parities in classical "quartet" of this explosive signal can be considered as direct confirmation of hypothesis about the reasons of deviations of phase shift between signals of “quartet” from multiple 90°, observable in experiment. In quality of the most probable reason of such deviations splitting a beam on three was considered at its turn at border of water layers differing by gradients of speed of a sound (at increase of absolute size of a gradient in process of removal from an axis of USC). At such splitting the signals, which have come in a point of reception on these beams, a little bit differ on time of propagation, however one of formed “trio” has on one contact by caustics more, than others two.

In summary, it is necessary to note, that the splitting of "one-beam" signals and transformation classical "quartets" (in process of removal of a point of reception from a source) in “groups of signals” (with their number essentially exceeding four) were repeatedly observed by us in various regions of World Ocean. Depending on region such transformation "quartets" in “groups of signals” began to be shown on different distances from a source. The accounts, executed on the computer, give performance about temporary structure of a sound field, but, unfortunately, do not reflect process of splitting of elementary, "one-beam" signals.

Usually at realization of similar accounts there are used the pleased smoothed structures of change of sound speed with depth, which is not taking into account thin structure of a field of sound speed and, especially, its spatial and temporary variability, which, apparently, bear responsibility for splitting of signals, observable in experiment.

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