

L.K. Rimskaya-Korsakova, N.A. Dubrovskiy

**A ROLE OF TWO WAYS OF SOUND CONDUCTION TO THE COCHLEAE IN  
FORMATION OF CLICKS INTERAURAL DIFFERENCES IN THE DOLPHIN**

Andreyev Acoustics Institute  
117036, Moscow, Shvernika Ul, 4  
Phone: (095) 126-9968; Fax:(095) 126-8411  
E-mail: [lkrk@akin.ru](mailto:lkrk@akin.ru), [dubrov@akin.ru](mailto:dubrov@akin.ru)

*The modeling experiment allows reproducing qualitatively features of interaural time delay and intensity differences (IAD) gained in electrophysiological experiment at stimulation of Amazon River dolphin by short acoustic pulses. Thus we have admitted that the dolphin has two acoustic channels of signals transmission from the water to each cochleae (two acoustical inputs). The superposition of signals arriving to a cochleae through two acoustical inputs provides dolphins with enhancement of clicks interaural differences in a direction close to frontal one. It is supposed that through one of acoustical inputs (the external acoustical meatus) omni directional reception of sounds is carried out, while the second acoustical input (through " the acoustic window " of the lower jaw of the dolphin) provides directional reception of sounds in a frontal direction or close to it. The lower jaw can be considered as the traveling-wave antenna. KEY WORDS: interaural time and intensity differences of sounds in dolphins, auditory brain - stem evoked response, modeling of periphery of the high-frequency part of the auditory system.*

Dolphins use sonar for detection and identification of vitally important targets. Integral part of this sonar is the auditory system. One of the sonar adaptations to water environment is development besides auditory meatus, of an additional acoustical path to the cochleae through so called "an acoustic window " located on the lower jaw [3,5,6,11,13]. We believe [16,17] there are experimental data indicating influence of the two acoustical inputs [20,21].

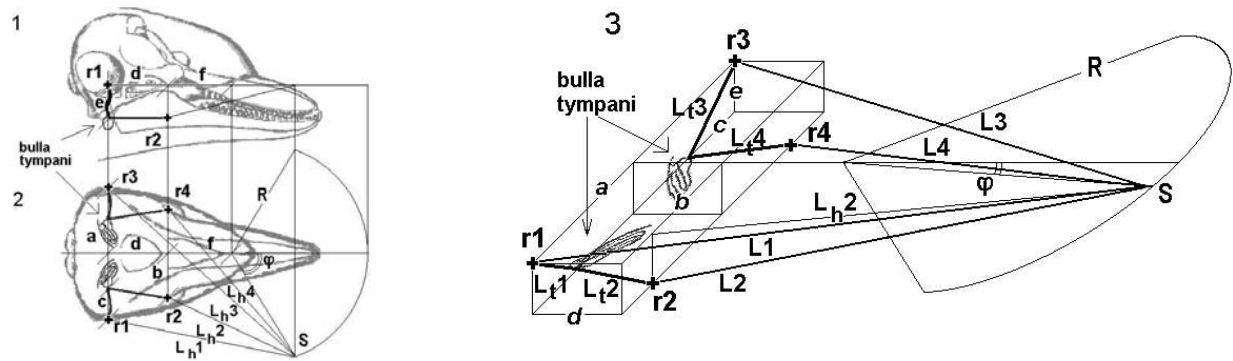
At terrestrial mammals the spatial localization of the sound sources is based on interaural time delay and intensity differences (IAD) [2]. IAD were gained in electrophysiological experiment on Amazon River dolphin that was stimulated by clicks similar to ongoing echolocation clicks [20]. A source of clicks was moved around a dolphin head. The earliest wave of the auditory brain - stem evoked response (ABR) was recorded. The authors consider this wave as a summed response of the auditory nerve fibers (SRANF). Amplitudes of the SRANF were determined for various positions of the click source. The signal intensity necessary evoking reaction of certain amplitude of the SRANF was determined by the method of linear extrapolation. It turned out that IAD on intensity (IAID) and latency (IALD) in dolphins strongly differ from the same of terrestrial mammals. At the Amazon River dolphin IAID grows quickly up to 20 dB with increase of the azimuth of the source from 0 to 15 - 20 degrees, and varies slightly near 15 dB at the further growth of the azimuth. IALD also grows up to 250  $\mu$ s with increase of the azimuth from 10 to 15 degrees; IALD slightly goes down at the azimuth from 30 to 45 degree, and grows up again at further increase of the azimuth.

The purpose of the modeling experiment was in general reproduction of the IAD received in electrophysiological experiment [20]; determination of conditions, at which simultaneous simulation of the IAD on intensity and latency is possible; the revealing of the reasons for occurring at dolphins significantly larger IAD in a frontal direction in comparison with other animals.

For modeling IAD, we applied the simulation method that allows reproducing the basic properties of ABR of porpoise *Phocoena Phocoena* to pulse [4] and tonal [15] sounds. ABR is formed due to practically synchronous excitation of high-frequency fibers of the auditory nerve. It reflects consecutive inclusion in reaction the neuron nucleuses of a direct auditory path. Proceeding from this, modeling ABR (MABR) can be computed as convolution of two functions. One describes development in time the firing in set of the fiber models. The second function describes a temporal structure of elementary ABR determined by generation of a single spike and past through a chain of neurons of different levels of the direct auditory path. As audiogram of Amazon River dolphin exhibits a maximum of sensitivity near 70 kHz [19], so far as MABR should form channels of the model with characteristic frequencies in the narrow frequency band near 70 кГц. We have assumed the temporal structure of elementary ABR equals to the temporal structure of ABR caused by a short sound click [4,15].

A simulation model of the dolphin auditory periphery was developed on the basis of generally known physiological data about functioning of the mammal hearing [7,14,15,18]. An output of the model of one fiber of the auditory nerve is sequence of spikes. There can be only one spike in each fiber in reply to sound click owing to inertia of fibers. The single reaction of set of high-frequency fibers of the auditory nerve with different characteristic frequencies, different thresholds of reaction and dynamic properties [14,15,18] is capable transferring the complete information on fine time, frequency and intensity structure of echo within broad range of the echo level.

We performed two modelling experiments. The first one was carried out under the assumption that the sound arrives to the cochleae only through auditory meatus. The second one was carried out under the assumption that the sound arrives to the cochleae through both auditory meatus and acoustic window. It is necessary to determine azimuth-depending values of amplitudes and time delays of the pulse responses of the Basilar membrane model at moving the source around a head of the dolphin at 1 m range in a plane of acoustical inputs for each of modelling experiments.



**Fig. 1.** A position of the sound source and acoustical inputs (marked by crosses) in vertical (1) and horizontal (2) planes and their spatial configuration (3). The source moves in a plane of the arrangement of auditory meatuses on a circle of radius  $R$  with the center located at the center of dolphin's melon,  $\varphi$  is an angle between a medium sagittal plane and a straight line connecting the source and the center of the melon.  $L1, L3$  and  $L2, L4$  are distance from the source  $S$  to auditory meatuses  $r1$  and  $r3$ , and to "acoustic windows" of the lower jaw  $r2$  and  $r4$ ;  $L_h1, L_h3$  and  $L_h2, L_h4$  are horizontal projections of lengths  $L1, L3$  and  $L2, L4$ .  $L_t1, L_t2, L_t3, L_t4$  are distances traveled by a sound through tissues of the dolphin's head from the appropriate acoustical inputs up to the bulla tympani.  $2a$  - distance between two auditory meatuses  $r1, r3$ ;  $2b$  - distance between two "acoustic windows"  $r2, r4$ ;  $c$  is a horizontal projection  $L_t1$ ;  $d$  - distance between lengths of straight lines connecting the auditory meatuses  $r1, r3$  and the "acoustic windows"  $r2, r4$ ;  $e$  is a vertical projection of  $L_t1$ ;  $f$  is a distance between a length of a straight line connecting the "acoustic windows"  $r2, r4$  with a center dolphins melon.

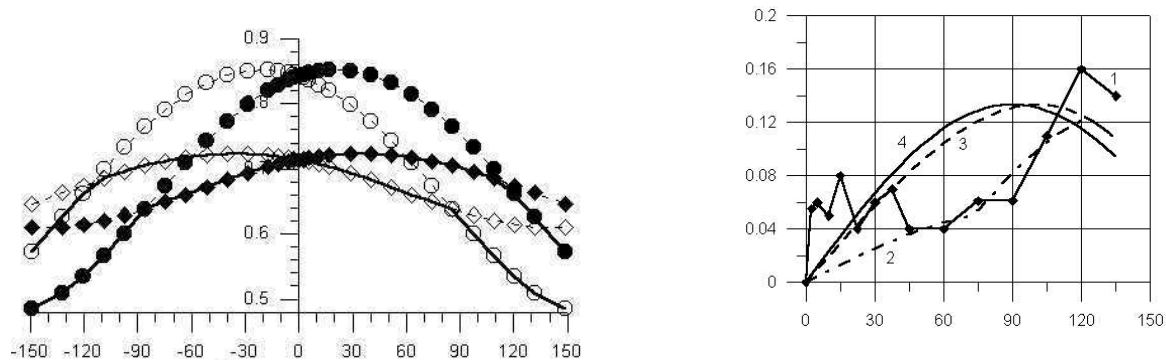
Let's estimate paths of sound propagation  $L1, L2, L3, L4$  from the sound source up to both the cochleae through different acoustical inputs (Fig. 1) [16]. It follows from the figure (see designations in the caption to the figure), that

$$\begin{aligned}
 L_h1^2 &= [d+f+R(\cos\varphi)]^2 + [R(\sin\varphi)-a]^2, & L_h2^2 &= [f+R(\cos\varphi)]^2 + [R(\sin\varphi)-b]^2, \\
 L_h3^2 &= [d+f+R(\cos\varphi)]^2 + [R(\sin\varphi)+a]^2, & L_h4^2 &= [f+R(\cos\varphi)]^2 + [R(\sin\varphi)+b]^2, & (1); \\
 L1 &= L_h1, & L2^2 &= L_h2^2 + e^2, & L3 &= L_h3, & L4^2 &= L_h4^2 + e^2, & (2); \\
 L_t1^2 &= L_t3^2 = e^2 + c^2, & & & L_t2^2 &= L_t4^2 = d^2 + (c-a+b)^2, & (3).
 \end{aligned}$$

The times of sound propagation from different acoustical inputs up to cochleae were assumed equal. Using the formulas (1-3) it is possible to determine dependencies on the azimuth of the sound of the times of sounds propagation  $T1, T2$ , and  $T3, T4$ , for the sounds going to cochleae through different acoustical inputs (fig. 2). As dolphin head is extended in a frontal direction, therefore these delays change asymmetrically in regard to a frontal position of the source. By subtraction values of respective curves (fig.2), it is possible to get modeling IALD (MIALD) of the sound arriving to cochleae through the one of two acoustical inputs, which nearest to the source (Fig. 3, curve 2), and MIALD of the sound arriving to cochleae through auditory meatus (Fig. 3, curve 3).

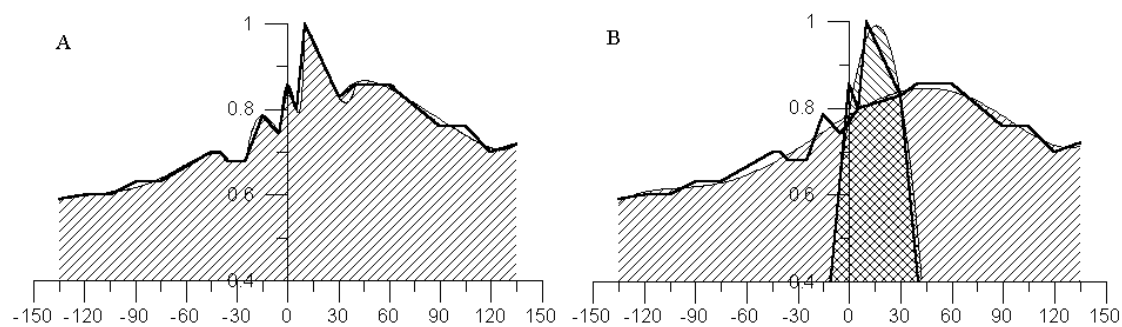
IALD vs. source azimuth for the Amazon River dolphin is also shown in Fig. 3 (curve 1) [20]. In the range of source azimuths of 45-135 degree MIALD of the sound arriving to cochleae through

the acoustical input, which nearest to the source, (curve 2) reproduce experimental ones quite well. The profile of a theoretical curve 3 (MIALD of the sound arriving to cochleae through auditory meatus vs. source azimuth) almost coincides with a structure of the other theoretical curve 4. The latter was computed according to the wave theory of sound diffraction around a head that was approximated by a solid sphere [10]. This approximation is widely used by the researchers of binaural hearing for computation of interaural time delay for terrestrial mammals. The satisfactory concurrence of profiles of curves 1 and 2, on the one hand, and profiles of curves 3 and 4, on the other hand, allows us application the formulas (1-3) for assessments time delays of the pulse responses of the Basilar membrane model in reply to the sounds arriving at different azimuth and through different acoustical inputs.



**Fig. 2.** The calculated dependences of the propagation times of acoustic signals from the source  $S$  up to the cochlea located at the left, through acoustical inputs  $r1$  and  $r2$  (curves are marked with filled symbols) and up to a cochlea located on the right, through acoustical inputs  $r3$  and  $r4$  (the curves are marked with hollow symbols) on the azimuth of the source  $\varphi$ . The curves marked with rhombuses, show propagation times of acoustic signal to a cochlea through the "acoustic windows", with circles - through auditory meatus. The thick lines show the minimal propagation times of acoustic signal up to a cochlea through the acoustical inputs nearest to the source located on each side of a dolphin's head. An axis of abscissa is the azimuth  $\varphi$  in degrees; an axis of ordinates is the time in milliseconds.

**Fig. 3.** Curve 1 is an interaural difference SRANF on the latency (IALD) in case of equal response amplitude received in experiment on Amazon River dolphin [20] as a function of the azimuth of the source. Curves 2-4 are theoretical IALD. The curves 2 and 3 were calculated, proceeding from the assumption, that either sound arrives to a cochlea through nearest of two acoustical inputs, or it comes to a cochlea only through auditory meatus. The curve 4 was computed according to the wave theory of sound propagation around a solid sphere, which simulated the form of a human head [10]. A horizontal axis is the azimuth in degrees, a vertical axis represents time in milliseconds.



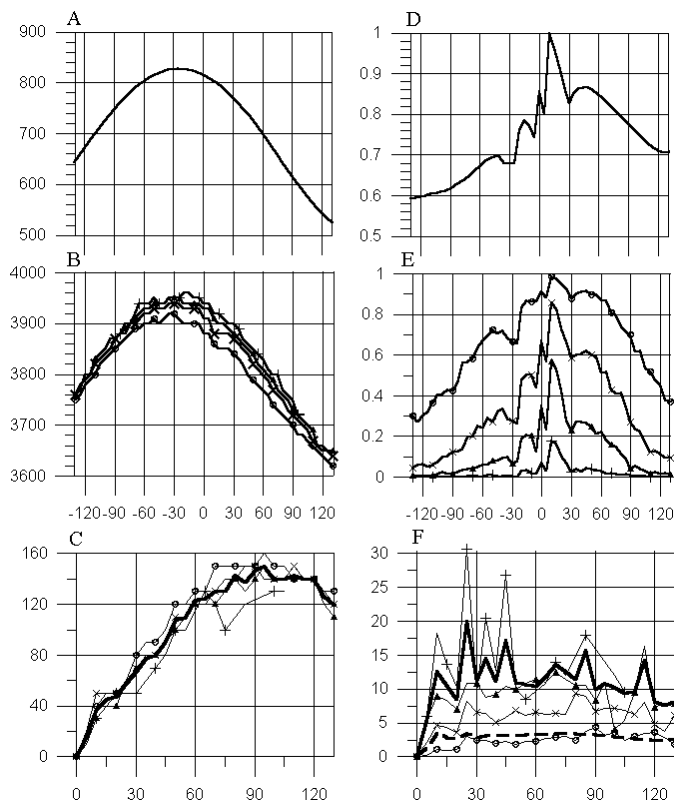
**Fig. 4.** The normalized experimental dependence of the SRANF amplitudes of Amazon River dolphin on the azimuth of the source (thick continuous line) [20], and its approximation (thin continuous lines above the shaded areas). A - the experimental dependence is exactly in a wide range of the azimuths. B - experimental dependence approximated by two functions, one of them in a wide range of the azimuths (curve above area shaded with the right inclination), and another one is in the limited range of the azimuths (curve above area shaded with the left inclination). On an axis of abscises is the azimuth of the source in degrees, the negative values correspond to the

position of the source on contralateral side of the dolphin's head. On an axis of abscises is the normalized amplitude of the response.

The amplitudes of the SRANF of Amazon river dolphin, received by a method of extrapolation, was used [20] for determination of amplitudes of the pulse responses of the Basilar membrane model vs. source azimuth (Fig. 4, a thick curve).

For the first modeling experiment, when arrival of a sound to a cochlea through auditory meatus is assumed, this curve was reproduced exactly (Fig. 4A, thin continuous curve over the shaded area). This reproduction function corresponds to pulse responses of BM model as a function of the azimuth of the source. A single pulse is arrived to the model input in this experiment. The delay for this pulse calculated, on the basis of the formulas (1-3), taking into account a position of a source of a sound, a cochlea and an auditory meatus.

For the second modeling experiment, it is assumed that sound arrives to a cochlea through different acoustical inputs. A curve in a Fig. 4B is approximated by two functions. One of them determines azimuth - dependent amplitude of the pulse response of BM model for sounds arriving to cochleae through auditory meatus. The second one determines similar dependence for sounds passing through an acoustic window. A pair of pulses is delivered to the model input in the second modeling experiment. Their amplitudes also were set within the limits of a dynamic range of the model and were multiplied by appropriate weight factor proportional to the corresponding function of approximation. At calculation of delays of the pulses, the formulas (1-3), taking into account a position of a sound source, a cochlea and two acoustical inputs were used.

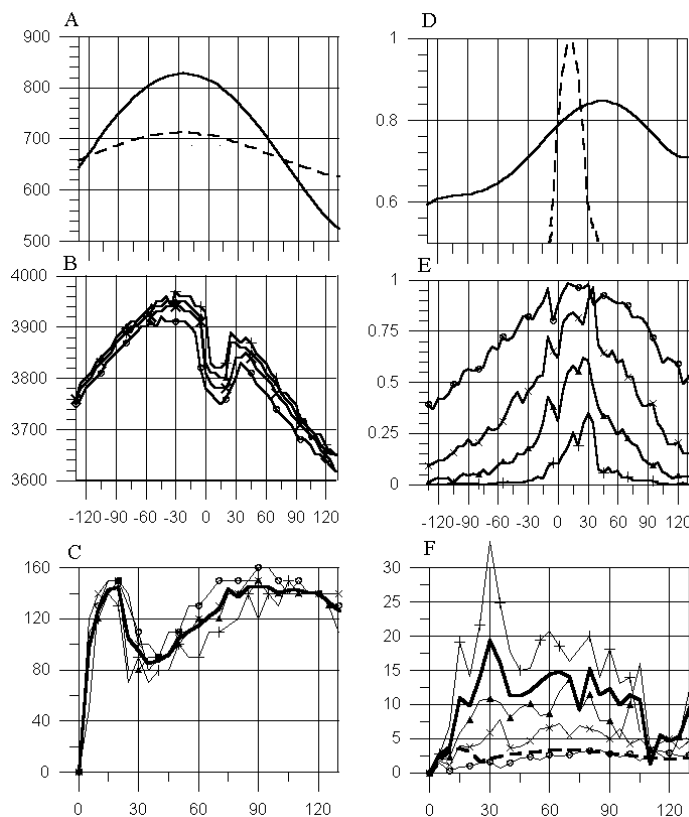


**Fig. 5.** Results of the first modeling experiment by determination IAD on the latent period and amplitudes MABR. A and D are weight factors, which are taking into account dependencies of time delays and amplitudes of the pulse response of the Basilar membrane model on the azimuth of the source provided that the sound comes to cochlea only through an auditory meatus. B and E are dependences of the latencies and amplitudes of MABR on the azimuth of the source. C and F are dependences on the azimuth of the source of IAD on the latencies (MIALD) and amplitudes (MIAAD) of reactions gained from data, submitted on figures with indexes B and E. The curves are received at the different levels of acoustic pulses: triangles - 3 dB above a threshold of model reaction; by a direct cross - 5 dB; by a slanting cross - 7 dB; by a circle - 10 dB. The thick curves in figures with indexes C and F are averaged MIALD and MIAAD. A thick dotted curve in figure with an index F is input MIAAD, received from the data presented in the figure with an index D. On an axis of abscissas is the azimuth of the source in degrees. On an axis of ordinates: in figures with indexes A, B and C is time in  $\mu\text{s}$ ; in figures with indexes D, E are normalized amplitudes of reactions; in figure with an index F is MIAAD in dB.

MABR were calculated in the range of source azimuths from  $-130$  grad. to  $+130$  grad. in each modeling experiment. Amplitude and latency were determined by the largest peak of MABR [4,15]. Using these peaks, modeling IAD on amplitudes (MIAAD) and MIALD were estimated and then compared to experimental data [20].

Let's consider the results of the first modeling experiment. The original data of experiment were weight factors determining time delays (Fig. 5A) and amplitude (Fig. 5D) of the pulse responses of the Basilar membrane model in reply to a single pulse (input signal), which arrived to a cochlea through the auditory meatus. Fig. 5B and Fig. 5E show dependences of the latencies and amplitudes of MABR on the azimuth of the source. The latency and amplitude vary according to weight function and level of the input signal above a threshold of model reaction. MIALD (fig. 5C), received for different levels of the input signal, and their average, smoothly accrue at increase of the azimuth of the source, reaching the maximum at the azimuth  $90^0$ .

The level of the input signal strongly influenced the amplitude of the MABR (fig. 5E) and the MIAAD (Fig. 5F) received from the data of Fig. 5E. Let's compare among themselves MIAAD at the input and the output of the model. Input MIAAD or MIAAD on values of weight function (Fig. 5F, the thick dashed line) was gained using data of Fig. 5D. In all range of source azimuths its values do not exceed 3 dB and correspond to output MIAAD, received from the data of Fig. 5E, at the large input signal levels. But, it appears that output MIAAD the more, the less level of the input signal. Output MIAAD reaches 30 dB at the threshold level of the input signal. The wide variation of output MIAAD values at different levels of the input signal is determined by properties of transformation of receptor potential of the auditory nerve fibers in a sequence of spikes. Such transformation is carried out by neurons of the spiral ganglion by comparison of the input signal with a threshold. Change of the input signal level was emphasised better by those model of the auditory nerve fibers which had the threshold closer to the signal level [14]. Dynamics of average values of the output MIAAD (thick black curve in the Fig. 5F) is similar to dynamics of the MIAAD at small levels of the input signal. The average values grow up to 20 dB in the range of azimuths from  $0^0$  up to  $25^0$ . With growth of the azimuth, these values fluctuate at first, then fall down a little.



**Fig. 6.** Results of the second modeling experiment by definition IAD on the latent period and amplitudes of MABR. A and D are the weight factors, which are taking into account dependencies of time delays and amplitudes of the pulse response of the Basilar membrane model on the azimuth of the source. It was accepted that the sound comes to a cochlea through an auditory meatus (continuous curve) and the acoustic window (dashed line). Other explanations are the same, as in Figure 5.

In the second modeling experiment, pairs of pulses (input signal) were presented to the input of the model. Its time delays and amplitudes of the pulse responses of the Basilar membrane model were formed with use of weight factors, which are taking into account the azimuth of the source (Fig. 6A and 6D). The dependences of the latencies and normalized amplitudes of the MABR on the azimuth of the source are shown in a Fig. 6B and Fig. 6E. They are gained for the pulses of different

level. These characteristics find out strong interaction of the pulse cochlea responses to each pulse in pair.

At change of the azimuth of the source from  $-130^{\circ}$  up to  $0^{\circ}$ , latencies of MABR (Fig. 6B) on contralateral side of a dolphin head are equal to time of occurrence of summed excitation on a cochlea from the signal, which has come through auditory meatus, as it was supposed that the acoustic window is completely shielded by a dolphin head. In a direction, frontal or close to it, there is a response to the sound, which passed through an acoustic window (fig. 6A and 6D) earlier. Such situation is kept up to the azimuth of the source  $25^{\circ}$ - $35^{\circ}$ , which already is situated on the ipsilateral side of the head. At the further growth of the azimuth from  $35^{\circ}$  up to  $130^{\circ}$ , signal which reaches an acoustic window, is absorbed by a head tissue, and the cochlea is excited by the sound, which arrives through the auditory meatus.

MIALD (Fig. 6C), received for pulses of different levels, and their average values behave practically identically. MIALD sharply grow up to  $150 \mu\text{s}$  at increase of the azimuth of the source up to  $15^{\circ}$ - $20^{\circ}$ . This jump arises due to cochlea, which is situated on contralateral side of a head is raised by the signal, which goes through the auditory meatus by longer way, and on ipsilateral side of the head by the signal, which goes through an acoustic window by shorter way. At the azimuth of the source more than  $35^{\circ}$ - $40^{\circ}$ , signals get on a cochlea only through auditory meatus and MIALD in the second experiment behave precisely the same way as in first one.

The change of the MABR amplitude as a function of the azimuth of the source (Fig. 6E) is rather curious. In a direction, frontal or close to it, such function manifests a number of distinct peaks. The central peak occurs at the azimuth of the source approximately  $15^{\circ}$ . It corresponds to a case, when the signal comes to a cochlea through an acoustic window, as according to weight function the BM reaction has thus the greatest value. Two lateral peaks are formed as results of addition on BM of the pulse responses, which have arisen on a sound come by two different ways. These two lateral peaks are distinctly expressed, as in formation of summed reaction of the model, on the basis of which MABR was calculated, the channels participated with best frequencies within a range 68 -74 kHz.

MIAAD for different levels of the input signal (Fig. 6F) were also received. The comparison with data presented by a Fig. 5F specifies similarity of MIAAD dynamics in two modeling experiments. MIAAD also can reach 30 dB and more at small levels of the input signal. They hardly exceed 3 dB, and coincide with MIAAD of weight factors (Fig. 6F, thick dotted curves) at the large levels of pulses.

Let's compare results of two modeling experiments to results of electrophysiological experiments and state a number of hypotheses following from this comparison. At Amazon River dolphin at a small deviation of the azimuth of the source from frontal one, IALD received in case of constant intensity of stimulus, change sharply. IALD reach  $250 \mu\text{s}$  [20] at change of the azimuth of the source from  $0^{\circ}$  up to  $10^{\circ}$ - $15^{\circ}$ . They occurred less and amount to  $50$ - $70 \mu\text{s}$  in case of identical amplitude of SABR. Only the second modeling experiment which is taking into account presence of two acoustical inputs to a cochlea reproduces such a course of the experimental curves. The first modeling experiment rather reproduces dynamics of IALD, characteristic for hearing of terrestrial animals, at which the sound on a cochlea arrives only through the auditory meatus.

Let's compare behavior of the latencies of the MABR (fig. 5B and 6B) and the latencies of the dolphins ABR at change of the azimuth of the source. Such behavior was studied in the range of azimuths  $0^{\circ}$ - $150^{\circ}$  in experiment on *Tursiops truncatus* [21]. The authors compared experimental data with theoretically calculated times of propagation of a signal from a source to the auditory meatus. It turned out that experimental and theoretical latencies coincide at the azimuth of  $75^{\circ}$  to  $150^{\circ}$ . But, at a frontal position of a source, experimental latency occurred less than calculated almost on  $100 \mu\text{s}$  and varied a little in the range of azimuths  $0^{\circ}$ - $75^{\circ}$ . If our first modeling experiment (Fig. 5B) reproduces well the specified theoretical latency, our second modeling experiment (fig. 6B) reproduce latency gained in the dolphin. It means that at a frontal position of a source, the sound comes to a cochlea through the acoustic window almost  $100 \mu\text{s}$  earlier, than through the auditory meatus.

As we already specified earlier, IAID for Amazon River dolphin amounted 15-20 dB [20]. These IAID were received by using amplitudes of the SRANF and a method of extrapolation with the subsequent averaging. In the same work, the influence of the signal level on dependence on the

azimuth of the source of the amplitudes ratio of the SRANF received on ipsilateral and contralateral sides of the dolphin's head is investigated. This ratio amounted to 1,5 and 2 at levels of the input signal 105 and 85 dB, and grew up to 10 at a level of 45 dB. It implies that in assessment of the IAID the data participate that reproduce variously the ratio of amplitudes of the input signal on two sides of a dolphin's head depending on level of the input signal.

It is known that the basic universal operation at coding of signals in nervous system is the analysis of changes of its amplitude by a set of nonlinear threshold elements - neurons [9]. Owing to nonlinearity any acoustical neurons emphasise changes of signals amplitudes the more, the less level of the input signals [12]. This property of the nervous system is well reproduced by our model of auditory periphery that includes neurons of the spiral ganglion [7,14,15]. This property is manifested itself in behavior of MIAAD under variation of the azimuth of the source (Fig. 5F and 6F). If MIAAD on weight functions (input MIAAD) hardly exceed 3 dB, average MIAAD grew up to 12 -20 dB in each of our modeling experiments.

We estimated MIAAD, but did not perform extrapolation for calculation modeling IAD on intensity of the input signal (MIAID). Nevertheless, on the basis of above stated, we believe that IAID reaching 15 - 20 dB at the Amazon river dolphin [20] can be overestimated due to properties of spiral ganglion neurons, ensuring emphasis of amplitudes changes of input signals at its small levels.

It is necessary to identify as characteristic feature of spatial hearing and vital for dolphins the sharp increase of the IAID at small changes of the azimuth of the source next to the frontal direction [20]. This increase can be explained either presence of the complex spatial transfer function determined by extended shape of a dolphin's head and the auditory meatus (the first modeling experiment) or presence of the complex spatial transfer function caused by presence of two ways of a sound conduction to the cochlea (the second modeling experiment). At Amazon River dolphin, IALD (which are reproduced only in the second modeling experiment) change abruptly in the same range of azimuths. This fact gives us the bases to believe that there are two simultaneously functioning paths of sound conduction to the cochlea at Amazon River dolphin.

Let's consider experimental data, which could justify a choice of amplitude weight factors in the second modeling experiment. We shall specify in the beginning that the amplitude weight functions were determined by a trial and error method, proceeding from the best conformity modeling and experimental data. Their shape, as we believe, can be competent for sounds with frequencies close to 70 kHz.

We have assumed that the auditory meatus at dolphins has not lost its function [8,19-21]. Therefore we utilized the generalized dependence of sound pressure in the auditory meatus of terrestrial mammals or human on the azimuth of the source as a basis of formation of amplitude weight function for the auditory meatus (fig. 4B).

The profile of amplitude weight function for the acoustic window was chosen in view of the data which exhibit high sensitivity to sounds, arrived to the cochlea through the lower jaw [3,5,6,11,13]. It is emphasised in a number of the referred works that there are frequency-dependent point areas of high acoustical sensitivity [3,11,13]. They are explained by focusing properties of a thinnest area on the bones of the lower jaw near to an acoustic window [3,13]. In a number of other works [7,8], frequency-dependent extended areas of high acoustical sensitivity situated on a forward part of the lower jaw was discovered. Such areas are found out both in electrophysiological [6] and behavioral [5] experiments. The presence of such areas allows us to consider the lower jaw, for example, as the array of a traveling wave. Such an array creates highly directional reception because the phases of oscillations of the linearly distributed elements are proportional to distance between them. As is known, the lower jaw of the dolphin represents thin-walled and rectilinear bone consisting of two halves [1]. Three to four genial apertures are situated on both sides of an external surface of the lower jaw. The whole internal mandibular channel is filled with fat body and passing here the vascular nervous fascicle. The length of a sound wave makes 3-1,5 cm within a band of frequencies near maximum of auditory sensitivity, i.e. in the band of 50-100 kHz. The extent of a forward part of the lower jaw makes 10-15 cm. It means that the genial apertures of the rectilinear bone of the lower jaw quite possible can be by elements of the reception array. The downturn of sound frequency will

increase the wavelength and the lower jaw will lose inherent to the array of a traveling wave property to be highly directional.

The presence of two acoustical inputs to the cochlea is expanded the acoustical abilities of dolphins. The authors of the article [22] investigated dolphin's ability to distinguish targets at the presence of interfering cylinders at different angular separation of targets and cylinders. The authors analyzed behavior of an animal, fixed position of targets and a dolphin head on a starting position at the moment of decision making. They came to a conclusion that dolphin used monaural reception of signals, i.e. a dolphin was able to localize the objects by using only one cochlea. It is easily to imagine if to assume that the cochlea has two acoustical inputs.

So, our modeling experiments show that for achievement of conformity of model IAD on time and amplitude with appropriate IAD gained at registration of ABR in the Amazon River dolphin, it is necessary to admit existence of two acoustical inputs on each side of a dolphin's head. The interaction of two acoustical inputs provides dolphins an important information due to abrupt increase of IAD on time and amplitude in the frontal direction or close to it.

We believe that IAID gained on a Amazon River dolphin by registration ABR in reply to short sound click, and reaching 15 - 20 dB, are determined not only spatial distribution of a sound field formed by a dolphin head and two acoustical inputs, but also by nonlinear properties of the nervous system. These properties provide appreciable highlighting of changes of the input signal level at small values of latter. We believe also that the auditory meatus carries out the rather omni directional reception of sounds in the wide range of frequencies similar to terrestrial animals. The lower jaw of the dolphins can be considered as a traveling wave array that carries out effective highly directional reception high-frequency (more than 40-50 kHz) sounds in the frontal direction or close to it.

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