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A. Derzjavin, A. Semenov. Ocean ambient low frequency acoustic noise structure in shallow and deep water regions. Journal de Physique IV Proceedings, 1994, 04 (C5), pp.C5-1269-C5-1272. 10.1051/jp4:19945281 . jpa-00252993

HAL Id: jpa-00252993

<https://hal.science/jpa-00252993>

Submitted on 1 Jan 1994

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Ocean ambient low frequency acoustic noise structure in shallow and deep water regions

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Abstract: Physical analysis of processes responsible for left hand side spectrum part of ocean ambient low frequency (LF) pressure field formation in ocean is fulfilled, estimate of natural background ULF pressure spectrum levels observed by bottom installed transducer in frequency band 0.03-10.0 Hz are obtained. This interval is laying in fact on the boundary between ultra low (ULF) and low frequency (LF) ocean pressure fields. To derive such estimate two types of results are used - results of direct pressure measurements in the frequency range (30-10000) mHz obtained by authors in sea coastal regions of former USSR (the Black sea, the Japanese sea, the Barentz sea) during multiyear observation cycles, results of pressure measurements fulfilled by other authors, as well as materials of indirect long period gravity waves parameters measurements fulfilled on the sea surface. The latter results were obtained by oceanologists in the form of surface wave oscillations spectra and were transformed by authors in bottom pressure variations by recalculation. On the basis of pressure measurement statistical treatment important conclusion is obtained, that pressure fields observed on ocean bottom in frequency range below 1000 mHz are formed presumably by pressure pulsations produced by long period and wind ocean gravity waves.

1. INTRODUCTION

Presented measurements results are obtained in sea coastal regions of former USSR (Black, Japanese, Barentz and Baltic seas) and different deep water regions of Ocean for bottom pressure transducer installed in the depth range between 30-400 meters for shallow regions and up to 250 meters for deep regions (depths more than 3000 meters). Spectrum characteristics were studied in frequency range from 0.03 to 10 Hz. Spectra presented are averaged on the basis of signal signatures duration from 1 to 12 hours obtained in approximately ten year observation periods. Sea weather in that periods differs tremendously in the limits from quiet conditions to beginning of storm as well as shipment density changes from weak to intensive. Conventional bottom measuring system includes pressure transducer connected to first stage electronic amplifier. Measuring systems were protected from flow fluctuations caused by ocean currents, and special measures were taken

to ensure ship cable connected transducer (omitting vibrations) low noise operation. Most probable and recognized noise source nature in the band from 0.1 to 5 Hz important both for deep and shallow sea regions is multiple surface gravity wave interaction mechanisms. What is new in proposed generalization procedure for that band and quite different with respect to widely used Wenz diagram - intensity spectral levels are laying very close for different regions of deep ocean and weather conditions. If measuring point is staying far from the shore then this frequency band with shown above noise mechanisms could be even wider, up to 10 Hz. For deep sea regions in the band from 5 to 30 Hz ocean noise is well investigated, presumably artificial in nature and caused by far shipment noises. Spectrum character there is discrete and most probable discrete frequency here corresponds to civil ship propeller main frequency and its harmonics. If we come from deep to shallow sea regions then far shipment noises influence decreases due to high propagation losses. So here main noise sources are near shipment, if it is present, and mentioned above wind surface wave interaction mechanism, and our observations showed that coastal noise differ from deep water noise because the former is greatly dependent on local weather conditions in region. Thus the main aim of the paper is to investigate most contradictory part of acoustic noise spectrum comprising range between 30 and 1000 mHz

2. MEASUREMENTS AND RECALCULATIONS RESULTS

Our measurements in ULF and LF range, described below, are conducted by means of measuring utility including piezoceramic pressure transducer with parameters comparable to 8100 or 8104 B & K type hydrophones loaded by charge preamplifier with parameters comparable to 2651 B & K type charge preamplifier. Special control of meteoconditions, wind velocity, atmospheric pressure fluctuations and shipment was provided. After measuring equipment being immersed reached bottom or after ship passed in the vicinity of measuring point, special pause was provided to exclude corresponding transient processes generated in preamplifier. Let us draw attention to physical principles of sea surface displacements to pressures recalculation. Free ocean surface contains a row of wave motions which could be responsible for wide band energy bearing maxima in ULF background pressure frequency range. In simplest case, pressure fluctuations for surface gravity waves could be recalculated taking into account that 1 mm water column displacement corresponds to 10 Pa of pressure. It is true, however, only for very long waves or for very small depths. For finite depths water layer will act as hydrodynamical filter of low frequencies for surface waves. Examples of experimental results obtained in coastal region of the Black sea nearby Pitsunda cape are shown on Fig.1 in the form of averaged LF and ULF pressure spectra corresponding to frequency analysis band $\Delta f = 0.4$ mHz, in frequency range 2-100 mHz, for realization length $T = 43$ min - curve 1. Averaging here corresponds to wide range of experiments from calm condition with mirror sea surface, absent wind and slight swell, nearby shipment is absent too to corresponds to mighty 7-balls storm, where 20 dB pressure levels increase, in comparison with case where wind waves are absent, was observed in fact. Simultaneously mighty swell waves could be seen from spectrograms with maximum frequency approximately 16 mHz. Thus, excluding two former ocure 1 corresponds to the spectrum obtained by 16 spectrum averaging procedure with total averaging time approximately 11,5 h. It is an example of intermediate conditions with wind of force 2 with slight tide. While stormy conditions here are not present, ULF spectra are practically the same as on curve 1, while LF spectra differs. It means,

that while background ULF pressure are determined not by wind waves, but by long surface gravity waves related to other sources, LF - are determined by wind surface short gravity waves. It is useful to notice, that sometimes temporal pressure level increase on the left boundary of ULF range, related to shipment, was observed too. For the sake of comparison, data of other authors are depicted on Fig.1 as well - curve 2 is ULF pressure background spectra obtained in shallow water Pacific Ocean region near La Jolla, described in paper [1], with $\Delta f=2$ mHz, $T=90$ min for frequency range 30-130 mHz, and $\Delta f=0.5$ mHz, $T=640$ min for frequency range 1-30 mHz. Curves 3-6 here correspond to bottom pressure fluctuations obtained indirectly by recalculation from surface gravity waves displacement spectra. Curve 3 shows tsunamis background observed near Maui island (Hawaii) in Pacific Ocean [1] with $\Delta f=0.027$ mHz, dashed region here corresponds to spectra divergence obtained during 8 months experiments for $T=7$ days in March, 9.5 days in May and 2 days in October. Spectra family 4a, 4b, 4c corresponds to practically pure influence of atmospheric pressure pulsations observed in conditions of absolute calm over all the Black sea [3]. One could see here the direct action of "inverse barometer law" when pressure fluctuations observed on sea bottom are increased when atmospheric pressure is decreased. It is evident, that atmospheric pressure fluctuations should be taken into account only in this part of ULF pressure spectra and could be practically neglected in LF part. In other parts different phenomena are responsible for ULF pressure field formation. Curve 5 shows the action of surf beats during storm observed by means of resistance wave recorder installed on depth 15 m at distance 300 m from the shore near Katzively in the Black sea [3]. Spectral maximum corresponds here to 3.8 mHz. Curve 6 shows ULF sea level fluctuations obtained in the Black sea near Sebastopol at distance 40 km from the shore at mean depth 30 m by string resistance wave recorder installed on stationary bottom basement [4]. Wind wave spectra maximum could not be observed here due to special filtration undertaken. Curves 7, 8, 9 are related to direct measurements of ULF and LF bottom pressure fluctuation fields obtained by differential pressure gauge [2] in deep water ocean regions. Dashed regions in the vicinity of curves 7, 8 are obtained here by averaging of 8 and 10 realizations with duration 68.2 min each correspondingly. The influence of environment currents on ULF pressure spectra amplitudes could be derived from analysis of curve 9, where current velocity was independently controlled on the distance approximately 5 m from the bottom. For instance, curve 9 corresponds to mean subbottom current velocity not more than 5 cm/s, and observation during 83 days with 6 one hour sampling per day. Thus, deep water region experiments analysis shows qualitative equivalence of pressure spectra observed within 3 subranges between 0.004 and 1 Hz where pressure fields are formed by sources of quite different physical nature.

3. CONCLUSIONS

Demonstrated results of measurements, recalculations and comparison of pressure spectra lead to following conclusions:

- background noise ULF and LF pressure spectra levels could vary strongly in dependence of measuring point depth, region of measurement, surface gravity wave length and amplitude, distance of measuring point from the shore line. In frequency range 0.1-1000 mHz background ocean noise is directly connected with pressure fluctuations produced by long period surface and short gravity waves. Experimental background pressure spectra values observed in different regions for definite frequencies lay in the intervals: $(200-6000) \text{ Pa/Hz}^{1/2}$ for frequency 0.1 mHz; $(60-600) \text{ Pa/Hz}^{1/2}$ for frequency 2 mHz; $(0.1-3000) \text{ Pa/Hz}^{1/2}$ for

frequency 30 mHz. It is evident, that spectra level divergence observed in different regions for right boundary of ULF (left boundary of LF) range - frequency 30 mHz, is much wider, than for left, due to influences of low frequency tails of wind waves spectra increasing levels in that part of spectra and factor of bottom pressure spectra hydrodynamic filtration by water layer acting in opposite direction. For instance, in deep water regions ocean background spectra levels for frequency 30 mHz could be 50-90 dB lower, than for shallow water regions, due to hydrodynamical filtration mentioned;

- for frequency range 0.1-1 Hz in deep water regions substantial increase of pressure spectra levels (50-60 dB) near frequency 0.1 Hz is conventionally observed, second spectra maximum could be observed for frequencies of an order 0.2 Hz corresponding to microseism Longuet-Higgins effect spectra maximum obliged to nonlinearity of surface gravity waves interaction near the shore line transmitted to measuring point through sea bottom. For frequencies lower than 30 mHz background spectra pressure levels are practically not dependent on microseisms.

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