D.B.Ostrovsky, S.A.Smirnov, V.B.Zhelezny

CAPABILITIES OF ACOUSTIC PARAMETRIC PROFILOGRAPHS AT RESEARCH OF MARINE SEDIMENTARY FORMATIONS

Research Institute Morphyspribor
Russia, 197376, St.-Petersburg, Chkalovsky pr., 46
Ph.: (812) 320-80-40 Fax: (812) 320-80-52
E-mail: mfp@mail.wplus.net

The problems of selection of base models for the description of parametric profilographs and ways of an estimation of their capabilities are esteemed. On the base of experiments with a number of parametric transmitting arrays and employment of known theoretical approaches the simple system for definition of capabilities of parametric profilographs is constructed. The examples of experimental characteristics of parametric radiators and calculations of depths of profiling of sedimentary layers are presented.

In the yearly 70 years the parametric transmitting antennas (PTA) that were used for the solution of practical problems, have appeared. For the first time PTA have used the principle of formation of directional low frequency radiation at the expense of non-linear interaction in medium of propagation of a high frequency signal - biharmonic or polyharmonic [1]. Practically at once designers of PTA have confronted with a set of problems, that have not allowed to apply widely PTA in oceanological and hydroacoustic devices. To these problems it is possible to relate: an inaccurance of the idealized description of the PTA characteristics and experimental outcomes; unefficient performance of number of parametric radiators because of unsuccessful selection of the generating device (GD) and principles of formation of pumping signals, application for the PTA control and measurements of the conventional measuring equipment disregarding specificities of non-linear acoustic phenomena; absence of a comprehensive approach on definition of field of PTA application. And though from middle 80 years become to come up parametric profilographs for exploring marine sediments - Atlas Parasound, TOPAS, X-STAR, Datasonics CAP-6000, SASS etc. [2,3], the marked problems have not lost their urgency.

The relevant problem of usage of profilographs with PTA is the absence of the base approach similar for hydroacoustic means of a conventional type [4]. At construction of the base approach for the description of a parametric profilograph it is necessary to establish:

- the working conditions of a profilograph;
- model of PTA field with allowance of physical limitations, imposed on it;
- form of an equation of operating range for profilographs.

We shall limit the working conditions by a case of profiling of marine sedimentary layers from a ship or towed vehicle for the depths from several meters up to several kilometers. Thus the primary frequencies in range from 5 up to 200 kHz will be used. Such versions of application of parametric profilographs are most widespread at research of sea bottom.

It is the most difficult to establish reasonable model for the description of the PTA characteristics. In published work [1] the model of PTA on the basis of solution of an equation Khokhlov-Zabolotskaya-Kuznetsov (KZK) is offered. However at derivation of an equation KZK the condition ”slowly of varying transverse profile” of primary waves is selected [1]. This condition practically leads PTA model on the basis of the solutions of an equation KZK to the versions of PTA models with plane or quasiplane primary waves (models of Westervelt, Zverev-Kalachjov [5]). The experimental results on [1] are also insufficient for definition of parameters of parametric profilographs, as these data are obtained basically for PTA with pumping frequencies above 200 kHz.

With the purpose of selection or refinement of engineering model for low and midfrequency PTA on divergent waves. The wide experimental testing arrays for parametric profilographs deigned in *Morphyspribor* was conducted. PTA’s were conducted to different types of generating devices (GD). Thus, the breadboards of profilographs were esteemed as unified parametric systems, their characteristics are listed in table.

Number of a system	Parameters of a system				
	f_0, kHz	Dimensions of a source, m	W, kW	Type of GD	Ä F, kHz
1	120	0,21	0,7	K	0,2-30
2	115	0,43	1,7	T	0,1÷25
3	105	0,36	2,5	T	0,1÷25
4	100	0,31	0,3	T, L	0,3÷25
5	41	0,2 õ 1,6	8	L	0,3÷5
6	19	0,9	12	K, L	0,3÷6
7	15	0,9 õ 1,3	5÷20	K, T, L	0,3÷4
8	11	0,4 õ 1,6	12	L	0,1÷2
9	8	2 õ 2	100	L	0,1÷2

In the table is indicated: f_0- medium frequency of pumping, $f_0 = (f_1 + f_2)/2$; f_1, f_2- partial primary frequencies; *W* - maximum effective acoustic power on primary frequencies; *ÄF*-range of intercarrier frequencies $F=|f_1- f_2|$; K - key power amplifiers (D class), L - lamp linear amplifiers (A class), T - transistor linear amplifiers (A, B classes); surface of radiators are flat, on radiators 1-4,6 diameter is indicated. The signals of parametric radiation were received by different receiving arrays depending on a solved task or investigated properties.

Series of experiments on definition of character of PTA fields were conducted in test basin of *Morphyspribor* with base up to 40 m and in range conditions with base from 30 up to 800 m at maintenance of stabilization of receivers and radiators in space. Some experiments were conducted in marine conditions with base up to 10 km. The considerable bases of measurements in basin and in range conditions provided comparing with [1] more full experimental description of the PTA characteristics. All measurements were conducted in a far field of primary signals (area of a spherical divergence of primary waves), and in a number of cases at distances more or comparable to length of attenuation area on primary waves.

At organization of the works besides general requirements to acoustic measurements [6] the requirements specific to PTA measurements were taken in consideration [7]. According to [7] in experiments the control of the characteristics of spectra of radiated audio signals was and levels of nonlinear distortions in receiving channels (in laboratory measuring channels the level of a biharmonic volume range up to 140 dB) was provided.

As a result of series of experiments with indicated in tab. PTA and with allowance of methods [4,8] the system (1-5) for estimation of capabilities of parametric profilographs in a mode up to a saturation of primary waves was constructed:

$$P_F = \frac{\sqrt{2}pe \cdot F \cdot P_{f1} \cdot P_{f2}}{r c^3} \ln\left(R/R_0\right), \qquad (1)$$

$$D_F(j, y) = D_{f1}(j, y) \cdot D_{f2}(j, y), \qquad (2)$$

$$\begin{aligned} &40 \lg(h + L) + 2\sum_i b_i(F) l_i + \sum_i K_{i-1,i} + \sum_i K_{i,i-1} = \\ &= (20 \lg P_F + 120) + g(F) + T - M - N(F) - 10 \lg dF \end{aligned} \qquad (3)$$

$$s = \frac{2\sqrt{2} \cdot pe \cdot f \cdot (P_{f1} + P_{f2})}{r c^3}\left(1{,}4 + \ln\left(R/R_0\right)\right) \qquad (4)$$

$R>1{,}5R_0$, $R<1/(2á_f)$, $R<h$, $2pR_0> c/F$, $DD_F<(7^{Î}\ldots10^{Î})$, $ó(R)<2$, (5)

where P_F, P_{f1}, P_{f2}- reduced to 1 m effective pressures on frequencies *F*; f_1, f_2, accordingly; *å* - parameter of nonlinearity, *ñ* – density, *c*- speed of sound in water; *R*- the effective size of a zone of signal forming of frequency *F*; $R_0=f_0S/c$; *S* - the area of a source; $á_f$ – an attenuation coefficient in water on frequency f_0; *h*- depth of a place; D_F, D_{f1}, D_{f2} - directivity patterns (DP) on frequencies *F*, f_1, f_2, accordingly; *ÄD*- width of DP; *ö* and *ø* - angular coordinates; *L*- depth of profiling; l_i – thickness of i-th layer; $â_i(F)$ – an absorption coefficient on frequency *F* in an i-layer, (dB/m); $K_{i-1,i}$, $K_{i,i-1}$ - losses at transit on borders of layers (layer i-1=0 - water); *ã*(*F*) – directivity factor in a reception; *T*- target strenth (layer) on depth *L*; *M*- a recognition coefficient; *N*(*F*) - level of noise (0 dB re 1 ìPa) in a point of a reception on frequency *F*; *äF*- an optimum band of a receiving channel; *ó* - parameter for estimation of saturation mode of a source of primary waves; all items in (3) are calculated in dB.

In a system (1-5) formulas (1,2) correspond to the description of the PTA characteristics on a method of wavefront sets [8] in a mode up to a saturation of primary waves (4,5), and equation of range (3) is obtained by analogy with methods of [4] with parameters of the DP (2,5). The conditions (5) limit the parameters, for which one the PTA field in a far-field region (1) is calculated in an approximated analytic form as a matter of convenience of fast estimation of capabilities of parametric profilographs. The computational model of an axial field of a difference frequency of the parametric radiator (1) differs from one, introduced in [1] on a method KZK and gives higher outcomes, specially for large ratios f/F. However, as experiments with PTA demonstrate, at measurements on distances $r > 3Sc/f_0$ and with maintenance high quality of given spectrum of pumping signal in a broad band of frequencies, the good coincidence of experimental outcomes with (1) for parametric radiators with pumping frequencies below 130-150 kHz is observed.

The obtained system (1-5) despite of approximated nature allows to forecast capabilities of parametric profilographs for different situations. In particular, the estimations for a profilograph PGI-120 (item 1 of tab.), intended for functioning on small vessels in shallow sea or in a shelf zone were obtained. The calculations were conducted for following parameters: *W*=140 W; f_0=115 kHz; 0,1 kHz < *F* < 10 kHz; diameter of the radiator ~0,21 m; the area of a receiving array ~1 m^2; in water *å*=4, *c*=1450 m/s, *ñ*=1000 kg / m^3; duration of a signal - 20 ms; total losses on transit through borders of layers 12 dB; distance to the bottom *h*=100 m; a level of a noise *N*(*F*) = (100 - 20lg (*F*/1000)) dB; absorption in sedimentary stratas *â*=0,1 dB/(m·kHz); force of the targets: T_1 = (20lg(*h*+*L*) - 16) dB and T_2 = (10lg(*h*+*L*) - 10) dB accordingly for coherent and partly-coherent dissipations losses from a deep layer of a seabed; *M*=6 dB; band of the optimum filter *äF*=100 Hz. For control of parameters of a PTA field measurements in acoustic basin at distance of 35 m (signals of pumping were of key GD, class D) were conducted.

The experimental relations $P_F(F)$ and $D_F(F)$ of PTA are submitted on fig.1, standard DP on *F*=4 kHz and f_0=115 kHz - on fig.2. The calculation of depth of profiling according to (1-5) is shown on fig. 3. It is visible, that the depth of profiling of layers by a profilograph PGI-120 can reach 20 ÷ 40 m.

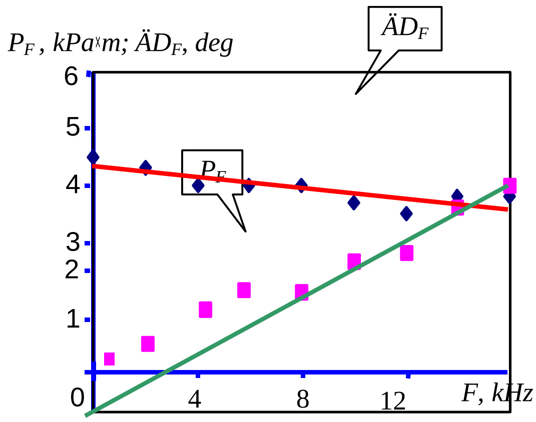

Fig.1

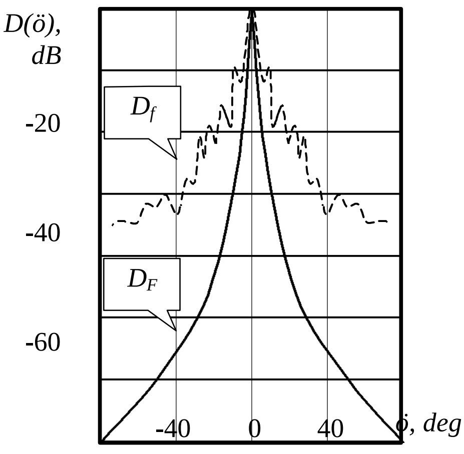

Fig.2

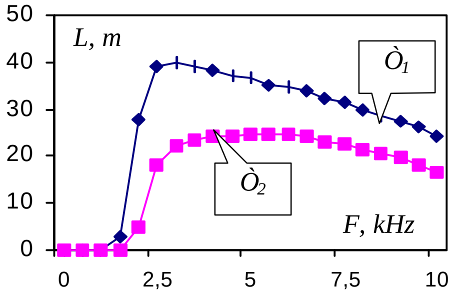

Fig.3

R E F E R E N C E S

1. B.K.Novikov, O.V.Rudenko and V.I.Timoshenko. Non-linear Hydroacoustics. (Leningrad, Sudostroenie, 1981).
2. B.K.Novikov and V.I.,Timoshenko. Parametric Antennas in a Hydrolocation.. (Leningrad, Sudostroenie, 1990).
3. A.Marino, Multibeam, "Wide-Swath, Parametric, Sub-Bottom Profiler", Sea Technology, N 6, 39-44 (1996)
4. R.J.Urick. Principles of Underwater Sound. (Leningrad, Sudostroenie, 1978).
5. K.A.Naugol'nykh, L.A.Ostrovsky and A.M.Sutin, "Parametric radiators of sound." in *Nonlinear Acoustics. Theoretical and Experimental Researches*. (Gorkiy, 1980, pp.9-30)
6. A.E.Kolesnikov. Acoustic Measurements. (Leningrad, Sudostroenie, 1983).
7. V.B.Zhelezny and D.B.Ostrovsky, "About perfecting the schemes of measurement of the characteristics of the parametric radiator", Sudostroitel'naja promyshlennost. General questions of shipbuilding. Ser. Standardizing and metrology, N 13, 59-64 (1992)
8. V.B.Zhelezny, "Parametric interaction on spherical and cylindrical waves", Prikladnaja akustika (Taganrog), N11, 23-26 (1985)