

IMITATION MODELING OF ANTENNA OF A HYDROACOUSTIC COMMUNICATION CHANNEL

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Abstract: *The energy calculation of the hydroacoustic communication channel is divided into a number of interrelated stages: the choice of the operating frequency of the communication line; selection of sonar antennas; determination of the acoustic power of the signal. Experimental studies of hydroacoustic systems require significant financial costs. Therefore, recently, in order to reduce these costs, simulation models of individual nodes or even of the entire hydroacoustic system as a whole are resorted to. This work is devoted to the simulation modeling of a hydroacoustic channel antenna. A schematic diagram of the SKOL-2000R hydroacoustic antenna model is given, and the operating parameters of this model are chosen so that the resonant frequency of the model coincides with the resonant frequency of the original 29.6 kHz.*

Keywords – Hydroacoustic communication channel, hydroacoustic channel antenna, hydroacoustic system, modeling, Kotelnikov theorem

I. INTRODUCTION

Energy calculation hydroacoustic channel telemetry (information transfer) is divided into a number of interrelated stages [1]:

- selection of the operating frequency of the communication line. In modern systems for various purposes, working frequencies from units to hundreds of kHz are used;
- the choice of hydroacoustic antennas;
- determination of the acoustic power of the signal.

In the known systems of hydroacoustic communication, power from tenths of watts to hundreds of watts is used.

When choosing the working frequency of hydroacoustic communication systems for various purposes, it is necessary to take into account the frequency dependence of the parameters of the hydroacoustic signal. Changes in the parameters of the received hydroacoustic signal from frequency are considered in many references [2, 3].

Experimental studies of hydroacoustic systems require significant financial costs. Therefore, recently, in order to reduce these costs, simulation models of individual nodes or even of the entire hydroacoustic system as a whole are resorted to. This work is devoted to the simulation modeling of a hydroacoustic channel antenna.

II. FORMULATION OF THE PROBLEM

The developed device is intended to work as part of a hydroacoustic communication system.

The main purpose of this device is to form a discrete relative phase modulation signal (DRPM) at a frequency equal to the resonant frequency of the used type of hydroacoustic antenna. It should be noted that the modulation of the signal can be carried out at the stage of its formation, but it is necessary to ensure the linearity of the power amplifier, and, as you know, the efficiency factor of the linear power amplifier is small and is about 45% [4]. Therefore, the method of nonlinear power amplification with high efficiency factor is used. However, in this case, the modulation of the signal should be carried out after the end of its formation.

III. THEORY

The method proposed in [5] is used, namely: according to the Kotelnikov theorem, the harmonic oscillation is represented by four counts (Fig. 1) spaced $\pi/2$ (90°) from each other. The restoration of the signal takes place in the antenna, since the resonant antenna is a passband filter having its own resonant frequency, and this frequency is lower in range. Therefore, it is possible to directly transmit information at a given frequency without additional transformations. Since the frequency of the generated sinusoid is equal to the resonant frequency of the antenna, in order to represent one period of it with four samples, it is necessary to generate them with a frequency four times higher (Fig. 1).

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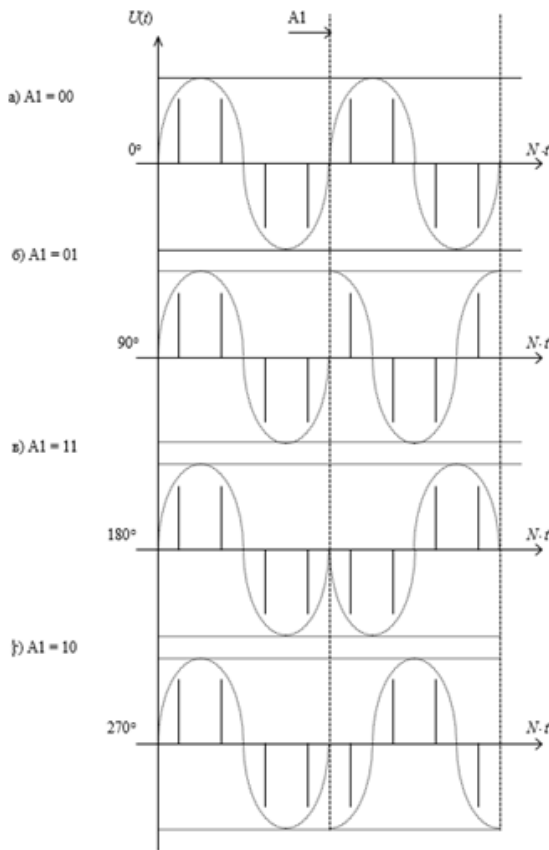


Fig. 1. Presentation of the harmonic oscillation by four samples and an explanation of the modulation implementation, where A1 is the control signal

The DRPM signal formation will consist in alternating the supply of a sequence of pulses to a conditionally positive or a conditionally negative wire (Fig. 2).

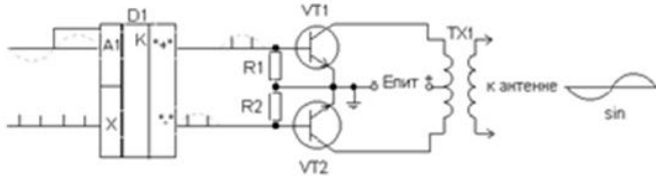


Fig. 2. Switching, amplification of the transmitted signal and restoration of harmonic oscillations in hydroacoustic antenna

From fig. 2 shows how it is necessary to switch the moment of pulse supply (with phase shift - according to the transmitted message).

The double DRPM, in turn, will also include the impulses with phase shift according to the transmitted message. After switching the pulses, they will be amplified, and later, as mentioned earlier, these signals will be filtered in the antenna and, as a result, the harmonic oscillation will recover, the frequency of which is equal to the antenna's resonant frequency, and the phase will change according to the transmitted message.

A change in the power of the transmitted hydroacoustic signal is necessary to ensure the economical mode of using the energy of an autonomous power source onboard the autonomous bottom station, depending on the depth of setting (or immersion) and the signal-to-noise ratio in the communication channel. As a result of the application of the

described embodiment of the formation, modulation and amplification of a signal, it can be seen that to regulate the energy of the transmitted signal, it is necessary to change either the amplitude of the pulses or their duration. However, the option of increasing the amplitude of the signal is impractical, since non-linear amplification of power in this case leads to unacceptable distortion. Therefore, you should dwell on the use of pulse width modulation (PWM).

The task of implementing PWM turned out to be quite simple, since it is necessary to change the signal energy depending on the depth of the bottom station. Since the hydrostatic pressure increases with increasing depth, the task of forming a PWM is reduced to determining the depth, that is, the magnitude of the hydrostatic pressure and a corresponding increase in the energy of the transmitted signal. This condition is realized quite simply, it is only necessary to have a hydrostatic pressure sensor, as well as a ROM that converts the data from this sensor into control signals for the energy regulator.

To determine the required pulse duration depending on the depth of the bottom station, it is necessary to make an energy calculation of the communication line, as a result of which it is necessary to obtain an expression that allows determining the required energy of the transmitting device based on the condition of providing the required signal-to-noise ratio.

The main causes of hydroacoustic signal energy loss with distance are the expansion of the wave front, scattering and absorption [1]. Such losses are most often estimated using a specific spatial attenuation coefficient of β dB/km, which is a function of frequency. At frequencies above 5 kHz, absorption makes the main contribution to attenuation. The engineering methodology of energy calculation of communication lines is given in [1,6]. In general, the equivalent acoustic power can be determined from expression

$$P = P_{tr} \cdot G_{tr} \cdot \eta_{tr} [W]$$

where P_{tr} – the effective electrical power of the signal at the transmitter output, W;

G_{tr} – gain coefficient (radiation) of the transmitting antenna (relative to an isotropic radiator);

η_{tr} – power transfer coefficient of the amplifier-antenna matching path.

The required sound pressure P_s in the plane of the receiving antenna at frequency f is determined from the condition of providing the necessary signal-to-noise ratio at a given level of acoustic noise in accordance with expression [2]

$$P_s = \frac{h \cdot K_{f_0} \cdot \Delta f_{pass}}{\left(\frac{f}{f_0}\right)^2 \cdot K_0}$$

(1)

where: $K_{f_0} = 0,1$ Pa/Hz – the specific acoustic noise pressure, reduced to the frequency $f_0 = 1$ kHz;

Δf_{pass} – the passband of the communication channel;

h – the signal-to-noise ratio at the antenna input;

K_0 – the coefficient of axial concentration of the antenna.

The required signal-to-noise ratio h at the input of the receiving device should be chosen from the condition of ensuring the specified quality of signal transmission. Assuming the use of DRPM signals, the required transmission quality (the error probability is no more than 10^{-5} per symbol) is achieved when $h > 3$.

Taking into account the selected type of antenna "SKOL-2000R", manufactured on the basis of technical conditions NCC3.837.018. let's carry out power calculation of the communication line. The expediency of choosing this antenna is justified in [1]. Some characteristics of this antenna are given in Table 1.

TABLE I
TECHNICAL CHARACTERISTICS OF HYDROACOUSTIC ANTENNA «SKOL-2000R»

Parameter name	SKOL-2000R
1 Resonance frequency f , kHz	29.6
2 Sensitivity in radiation mode β_a , (Pa·m)/V, not less	28
3 The coefficient of axial concentration K_0	25

Substituting the values of specific parameters of the device being developed into formula (2) and making a calculation taking into account the optimal frequency $f_1 = 17.4$ kHz for a communication line 6.7 km long, we get [1]:

$$P_s = 21,9 \cdot 10^3, [Pa]$$

The required radiation power at a distance $r = 1$ meter from the transmitting antenna must be equal to [4]:

$$P_{rad} = \frac{P_s}{\sqrt{10 - 0,1\beta r}}$$

The electrical power that must be supplied to the transmitting antenna is determined from condition

$$P_e = \frac{P_{rad}}{\beta_a^2 \cdot R_a}$$

where: β_a – sensitivity in radiation mode, not less 28 (Pa·m)/V;

R_a – distance between transmitter and receiver;

The average power of the pulses is calculated by the expression:

$$P_{av.} = \frac{C_k}{2}$$

where: C_k – the value of the k^{th} harmonic, in our case $k = 1$.

The value of C_1 is determined by the expression

$$C_1 = \frac{2A \cdot T_p \cdot f_1 \cdot \sin(\pi \cdot T_p \cdot f_1)}{(\pi \cdot T_p \cdot f_1)}$$

where: A – the signal amplitude ($A = U_m$);

T_p – the pulse duration;

f_1 – the frequency of the signal.

Thus, it can be seen that by changing the pulse duration, it is possible to change the energy of the transmitted signals. When calculating the dependence of the pulse duration on the depth of the bottom station, a program written in Turbo Pascal 7.0 was used. Calculation data for two values of

supply voltage ($E_{sup.} = 5$ V и $E_{sup.} = 24$ V) is summarized in Table. 2 and also shown in Fig. 3.

TABLE II
THE DEPENDENCE OF THE PULSE DURATION ON THE DEPTH OF THE BOTTOM STATION SETTING

R, km	0,5	1,0	1,5	2,0	2,5	3,0	3,5	4,0	5,0	6,0
P_e , mW	0,01	0,11	0,46	1,61	4,9	13,8	36,5	93	552	3016
T_p , μs (A=5V)	5,57	15,5	32,5	60,6	106	177,2	288,6	460,4	1122	2624
T_p , μs (A=24V)	1,16	3,24	6,78	12,6	22	36,9	60,11	95,92	233,7	546,7

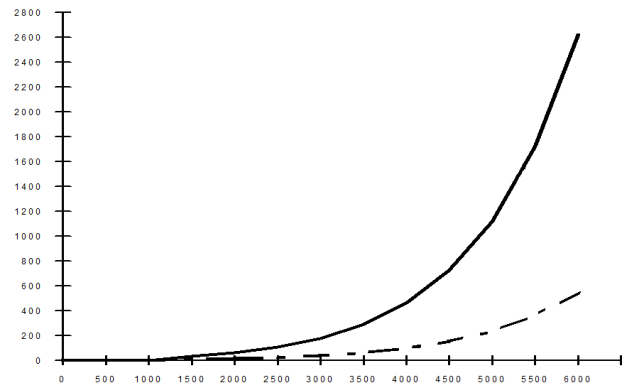


Fig. 3. Dependences of the pulse duration on the depth of the bottom station setting ($E_{sup} = 5$ V – upper line, $E_{sup} = 24$ V – lower line)

To simplify the condition for controlling the energy of the transmitted signal, we consider it necessary to change the pulse duration every 750 meters, which at a descent speed of 2 m/s to a depth of 6000 m is equal to 375 seconds (6 min and 15 s). If this condition is met, it turns out that up to a depth of 6000 m we need only 16 gradations of change in the duration of the pulses, that is, only 4 bits of the ROM ($2^4 = 16$). However, this results in some energy losses, due to the fact that the power at depth at the moments of varying the pulse duration will decrease, but the noise immunity of the entire system as a whole is practically preserved, since the power decreases slightly and for relatively short periods of time.

IV. IMITATION MODELING RESULTS

To simulate a SKOL-2000P hydroacoustic antenna on a computer, it is most expedient to present it in the form of a passband filter - a simple oscillating circuit. In turn, to solve this problem, it is necessary to calculate the inductance parameters (L) and capacitance (C) of such an oscillating circuit.

To calculate these parameters, a program was used that was compiled in the MathCad 7.0 Professional programming environment.

The obtained amplitude-frequency and phase-frequency characteristics of the antenna "SKOL-2000R" are shown in Fig. 4.

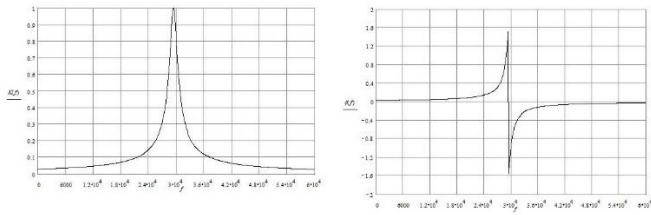


Fig. 4. Amplitude-frequency (upper) and phase-frequency characteristics of the model of hydroacoustic antenna «SKOL-2000R»

The schematic diagram of the model of hydroacoustic antenna «SKOL-2000R» developed using the program *MicroSim Schematics 8.0* software package *DesignLab 8.0* is shown in Fig. 5.

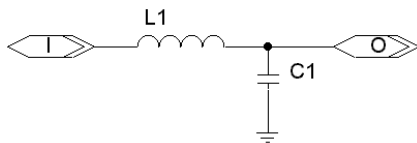


Fig. 5. The schematic diagram of the model of hydroacoustic antenna «SKOL-2000R»

It should be noted that the operating parameters of this model were chosen in such a way that the resonant frequency coincided with the resonance frequency of 29.6 kHz given in Table 1, namely: $L = 581.3 \mu\text{H}$; $C = 49.736 \text{ nF}$.

V. CONCLUSIONS

It is shown that signal recovery occurs in the antenna, so the resonance antenna is a passband filter having its own resonant frequency and this frequency is lower in range. Therefore, it is possible to directly transmit information at a given frequency without additional transformations.

It is shown that after switching the pulses, they will be amplified, and later these signals will be filtered in the antenna and, as a result, the harmonic oscillation will restore, the frequency of which is equal to the resonant frequency of the antenna, and the phase will change according to the transmitted message.

It is shown that the option of increasing the amplitude of the signal when the bottom station is immersed is inexpedient, since non-linear power amplification in this case leads to unacceptable distortions. Therefore, you should dwell on the use of pulse width modulation (PWM).

A schematic diagram of the SKOL-2000R hydroacoustic antenna model is given, and the operating parameters of this model are chosen so that the resonant frequency coincides with the resonant frequency of 29.6 kHz given in Table 1, namely: $L = 581.3 \mu\text{H}$; $C = 49.736 \text{ nF}$.

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