THE NEW UNDERWATER ACOUSTIC COMMUNICATION ALGORITHM BASED ON AN APPROXIMATION METHOD

TOMASZ WIECZOREK

Koszalin University of Technology
Racławicka 15-17, Koszalin, Poland
tomasz.wieczorek@tu.koszalin .pl

In the paper has been presented the new algorithm for the underwater acoustic transmission. The algorithm based on the approximation method. The transmitter and receiver block diagrams has been described. At the end of the paper the future research areas has been presented. The aim of the paper is the algorithm description and the receiver and transmitter structure consideration.

INTRODUCTION

Human activity in coastal regions includes offshore industries, underwater minerals exploration, telecommunication networks, wreck exploration and many other areas. These regions are also interested for the military. Human activity required using of wireless communication systems. Underwater wireless communications systems usually use acoustic waves to transmit signals. Acoustics underwater communications systems in coastal regions use shallow underwater channel. The shallow underwater channel is very difficult from transmission point of view.

Signals in shallow underwater acoustic channel are strongly attenuated and distorted. Distortions of signal come from:

- signal multipath propagation;
- signal reverberation at sea bottom and surface (signal attenuation and phase shifting);
- ambient noise, etc.

The most important disadvantageous factor is multipath propagation. The effect of multipath propagation and different signal propagation time at different rays and large intersymbol interference (ISI). Effective underwater acoustic communication system should reduce influence of the multipath propagation.

1. FUNDAMENTALS OF AN ADAPTIVE TRANSMISSION

The previous research proved that the optimal transmission system for shallow underwater channel should work with adaptive receiver [4]. The idea of adaptive transmission is well described in literature [4] and won't be described in this paper in details. The fundamental of adaptive transmission is determination of underwater channel properties based on probe signal. That operation requires special signal frame. The signal frame for adaptive underwater transmission is presented in figure 1.

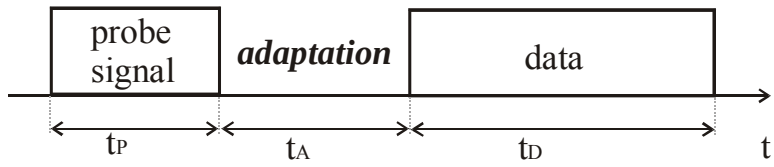

Fig.1 Signal frame for adaptive underwater acoustic transmission

2. CALCULATION OF THE CHANNEL CHARACTERISTIC IN AN ADAPTIVE RECEIVER

The underwater acoustic channel can be presented as two-terminal box in the signal block diagram (fig. 2). In the case of block diagram representation the physical properties of underwater acoustic channel are not considered. The transfer function $H(\omega)$ of the underwater channel calculation is based only on signal, which were transmitted in the channel, analysis.

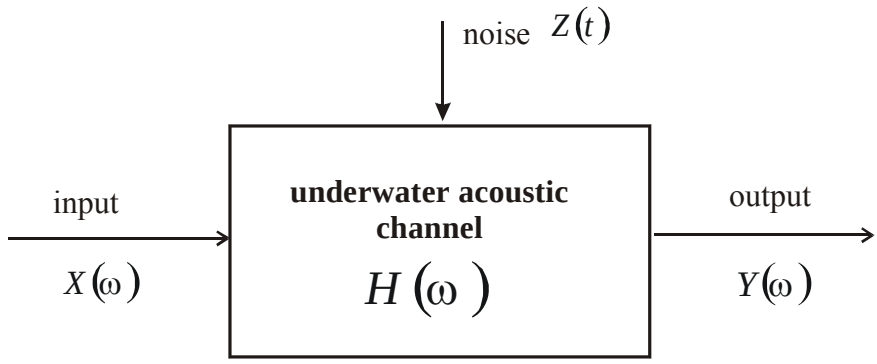

Fig.2 Underwater acoustic channel in a block diagram

The transfer function $H(\omega)$ is calculated based on formula:

$$H(\omega) = \frac{Y(\omega)}{X(\omega)} \tag{1}$$

In that case the input probe signal $X(\omega)$ should be stored in the receiver. That is required for proper channel characteristics calculation.

After channel characteristics calculation the input filters weights are examined. If the weights are not accommodated to the channel characteristics, they should be changed. The

input filters weights modification should be made with specified method. That research method is one of aims in realized and presented in this paper.

3. THE TRANSMISSION ALGORITHM

The generally transmission algorithm is presented in figure 3. In figure 4 the adaptation algorithm is presented.

The first step of transmission algorithm is system set up. During this step the system parameters are set up to start position. That means, that the input filters weights in receiver, modulation and demodulation parameters and transmission power are set up to values stored in the system memory as the staring values. Values of that parameters can be chosen based on typical channel characteristics in underwater regions. After first adaptation, that parameters will be changed to values appropriates to current underwater transmission channel. This step is executed only at the system startup.

There is also another possibility to set parameters of the receiver. Receiver's parameters like input filter weights can be set up after first adaptation. But probably better way is to make an assumption that channel is typical and set up input filters weights for typical underwater shallow water channel.

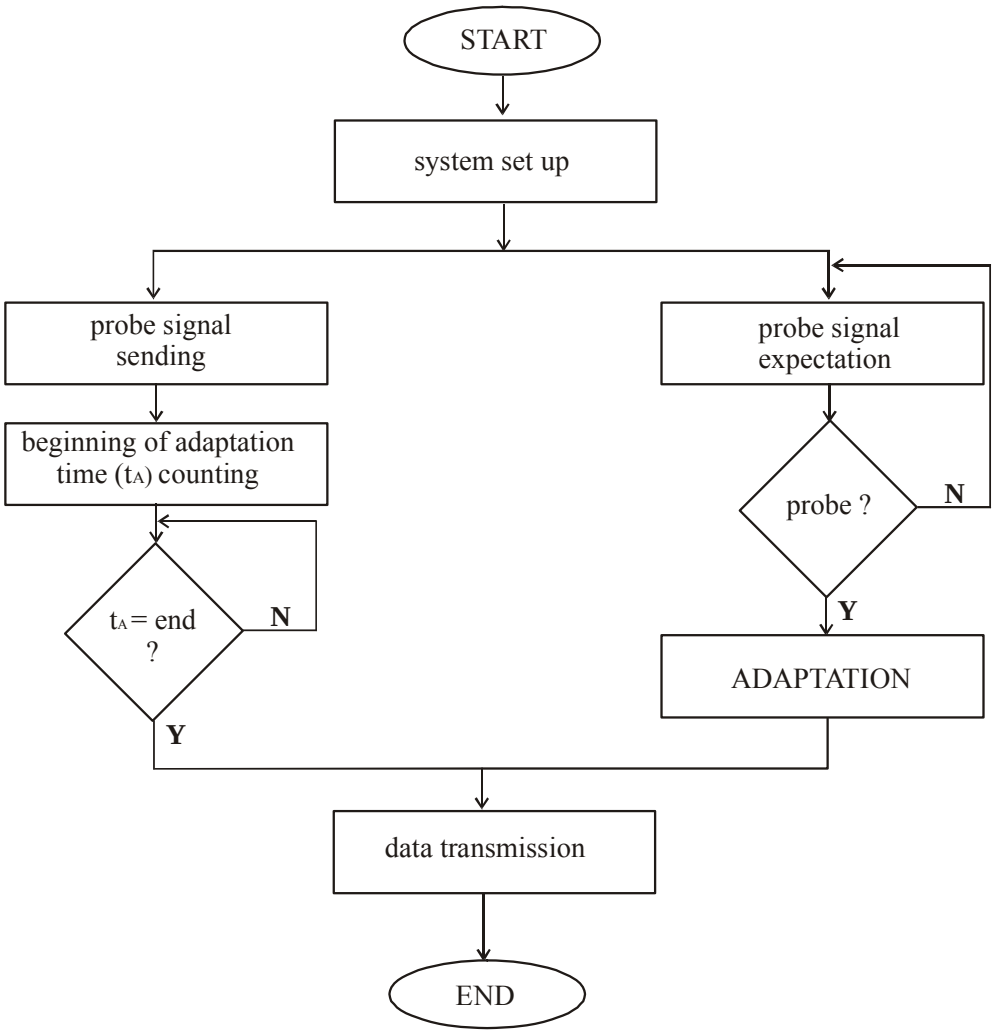

Fig.3 General transmission algoritm

Next steps of the transmission algorithm are typical for adaptive transmission, so they are not described in details.

Next step of the transmission algorithm is transmitting the probe signal. The probe signal properties are known in the receiver. After receive the probe signal, the adaptation of the receiver is made. The adaptation algorithm is described in part 4. After the adaptation the data are transmitted.

It is important to consider few questions:

- probe signal properties;
- adaptation time and method;
- adaptation interval;

4. ADAPTATION ALGORITHM

The adaptation algorithm is presented in figure 4. Presented adaptation algorithm is based on the approximation method. This is the new proposal for acoustic underwater transmission systems. The goal of that method is to calculate the channel characteristics with approximation of the channel response for the probe signal.

The first step of the algorithm is the transmitted probe signal samples acquisition. The sampling frequency should be adequate to probe signal properties. In the case of use different probe signals in different areas, the system should contained information about different sampling frequency for each probe. It is also necessary to design algorithm for probe signal selection.

After receiving of the probe signal the channel response is calculated. That calculation is based on the approximation method. For each probe signal the approximation functions are specified. Those functions are stored in receiver approximation unit. The specified approximation function (and method) is chosen at the system startup. There should be considered the possibility of the probe signal and approximation method modification if the chosen function failed.

In the case of approximation function selection the following problems should be consider:

The channel response simplification degree. It is important because typical channel response is very complex. For this reason the simplification should be made. Degree of this simplification has big influence for transmission error. In the case of too big simplification, the transmission error will be to high. When the simplification is too less, the calculation time will be too big.

The approximation function selection is important for adaptation time and accuracy. During examinations of presented system assumptions different approximation functions should be used. The first results of approximation functions examinations are presented in part 6.

The second step of the algorithm is the Fourier transform calculation of the obtained channel response for probe signal. Until now only the FFT method were considered. It is possible to consider other method of the Fourier transform calculation.

Next step of the algorithm is calculation of the receiver's input filters parameters $K_T(s)$. After that calculations the input filters weights are known. Methods for that calculation are still under examination.

After calculations made in the third step, the obtained filters parameters $K_T(s)$ are compared with existed input filters $K_F(s)$ under the formula:

$$\delta(s) = K_F(s) - K_T(s) \tag{2}$$

If δ is grater than δ_0 which were made as an assumption the receiver adaptation is made. The value of δ_0 will be determine during the examination. During the receiver adaptation, the input filters weights are change with specified values. After the adaptation the δ factor is calculated once again. That step verifies adaptation ratio. If δ is still grater than δ_0, the adaptation is made once again. In δ is less than δ_0 the adaptation is finished.

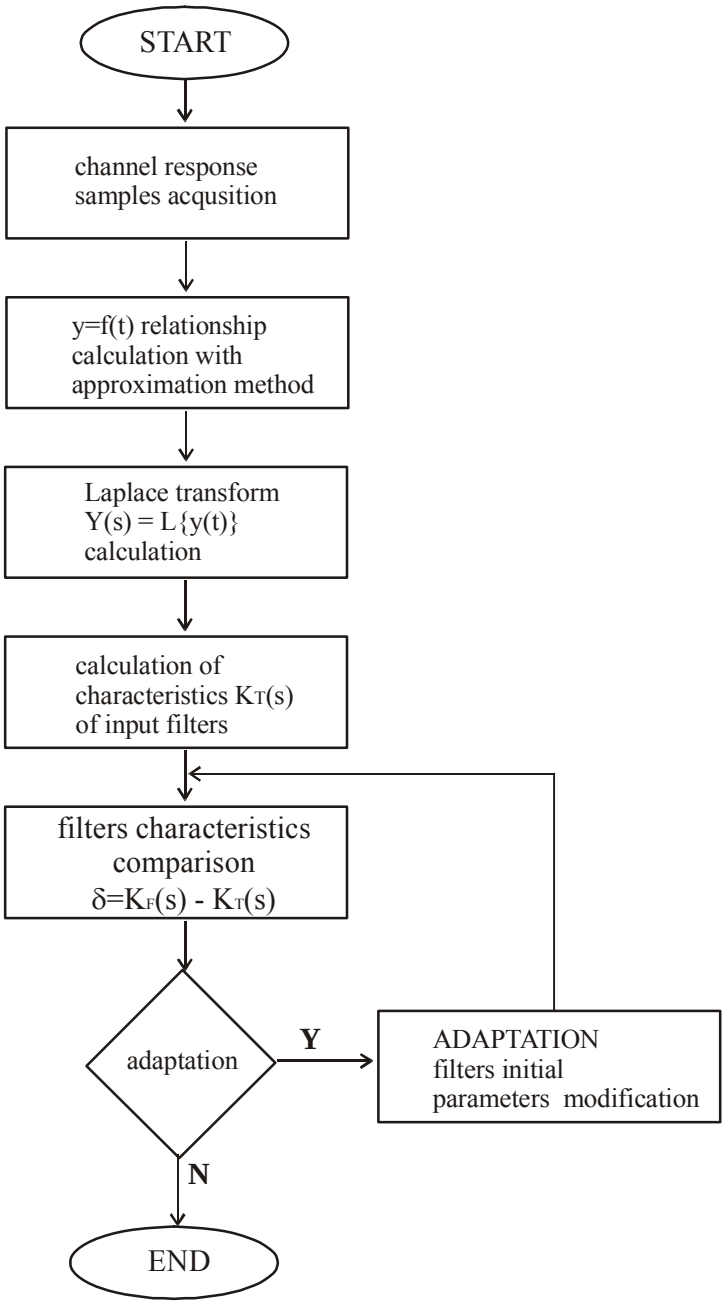

Fig.4 Adaptation algorithm

The adaptation algorithm is still under the examination. Presented in this paper results are only preliminary examinations.

5. TRANSMITER AND RECEIVER STRUCTURE

The transmitter block diagram is presented in figure 5a. That is typical transmitter structure extended with transmission control unit and probe signal generator.

When the transmission is started the transmission control unit connects the probe signal generator with output and probe signal is transmitted. After probe signal sending, the adaptation time is counted. After adaptation time end transmission control unit connect the signal source/modulator with output and the data are transmitted through the underwater channel.

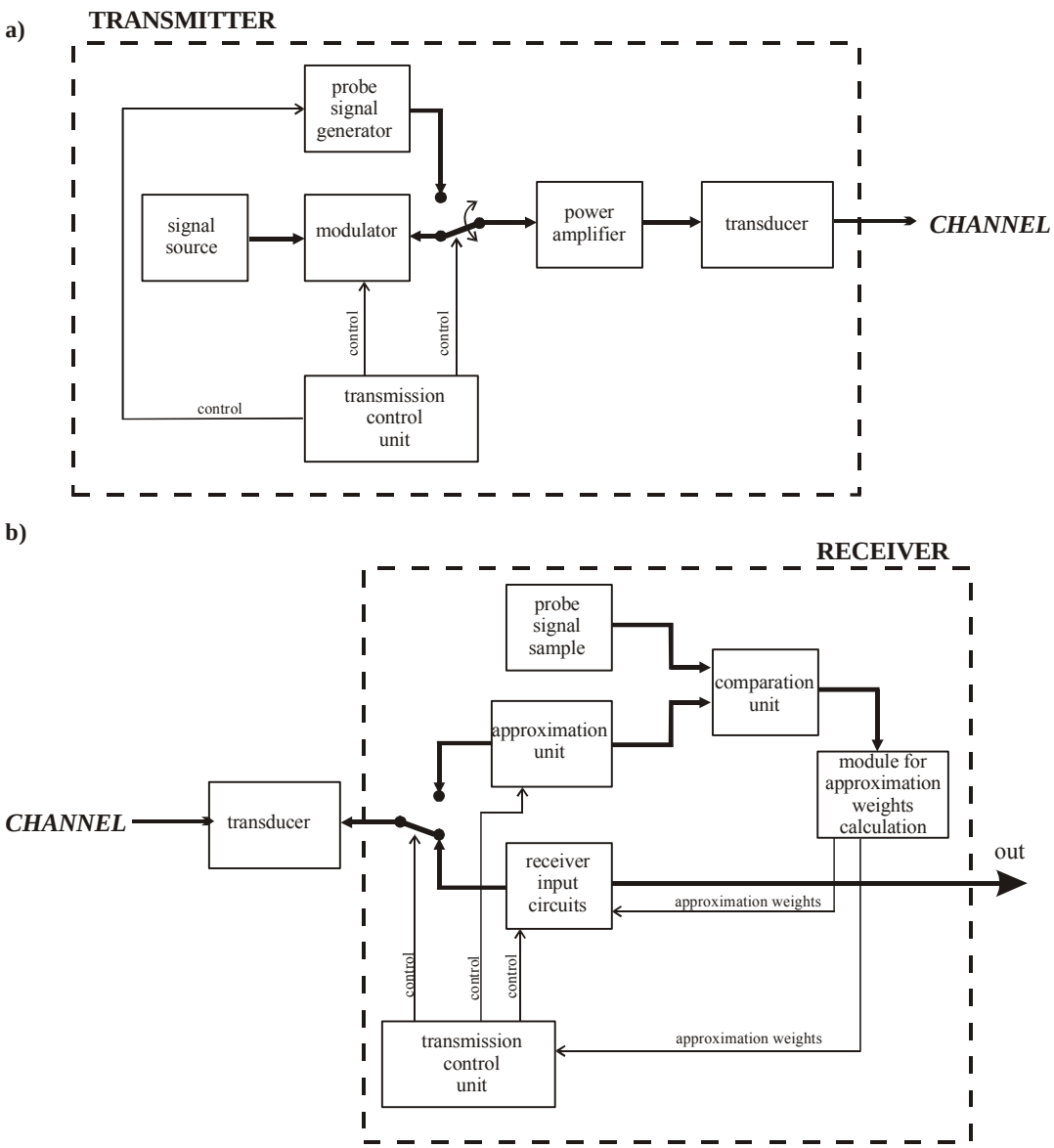

Fig.5 The block diagram of: a) transmitter, b) receiver

The receiver structure is presented in figure 5b. Signals from transducer array can be send to the approximation unit and the receiver input circuits. The input signal connection is controlled by the *transmission control unit*. During the probe signal transmission the transducer array is connected to approximation block. In this block the channel response for probe signal is calculated. After the calculation, the δ factor is examined. If it is necessary the new input filters weights are calculated. Than the transmission control unit change the input filters properties and connect the transducer array with receiver block. After that the adaptation of the receiver is made.

6. THE FIRST STEP OF CALCULATION

The first assumption was to use the orthogonal functions to calculate the channel transient function with approximation method. The Laguerre and Chebyshev functions were choosen. The results of these calculations were presented in [2].

Results presented in [2] was obtained under assumption about channel impulse response simplification. Results are presented in figure 6 and formula 3. Channel impulse response (formula 3) is too complex. In the case without simplification the function is more complex.

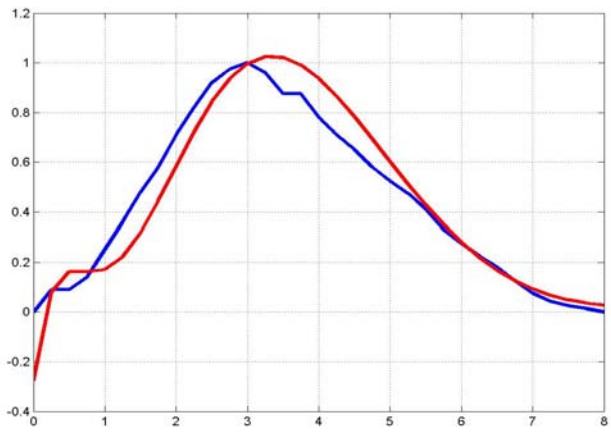

Fig.6 The channel response for the probe signal calculated with Laguerre functions. (blue line – simplified channel response, red line – calculated response)

$$
\begin{aligned}
k(t)_{apr} &= -0{,}27559 \cdot e^{-0{,}5 \cdot t} + 2{,}22985 \cdot e^{-0{,}5 \cdot t} \cdot t - 3{,}66185 \cdot e^{-0{,}5 \cdot t} \cdot t^2 + 2{,}61935 \cdot e^{-0{,}5 \cdot t} \cdot t^3 + \\
&- 0{,}71219 \cdot e^{-0{,}5 \cdot t} \cdot t^4 + 0{,}08499 \cdot e^{-0{,}5 \cdot t} \cdot t^5 - 0{,}00282 \cdot e^{-0{,}5 \cdot t} \cdot t^6 - 0{,}00046 \cdot e^{-0{,}5 \cdot t} \cdot t^7 + \\
&+ 0{,}00074 \cdot e^{-0{,}5 \cdot t} \cdot t^8 - 0{,}0000055 \cdot e^{-0{,}5 \cdot t} \cdot t^9 + 2{,}47 \cdot 10^{-7} \cdot e^{-0{,}5 \cdot t} \cdot t^{10} - 6{,}63 \cdot 10^{-9} \cdot e^{-0{,}5 \cdot t} \cdot t^{11} + \\
&+ 9{,}8 \cdot 10^{-11} \cdot e^{-0{,}5 \cdot t} \cdot t^{12} - 6{,}1 \cdot 10^{-13} \cdot e^{-0{,}5 \cdot t} \cdot t^{13}
\end{aligned}
\tag{3}
$$

Results presented in [2] was obtained under assumption about channel impulse response simplification. Results are presented in figure 6 and formula 3. Channel impulse response (formula 3) is too complex. In the case without simplification the function is more complex.

Those research show that selection of approximation function and probe signal properties are very important. The results with orthogonal functions are unsatisfactorily. Obtained channel response has too many components. It is inadmissible for considered simplification of the channel response..

The next step is Fourier transform calculation and channel model calculation. Based on (3) the channel transfer function is very complex. The complexity of transfer function excludes using that function in practical realization. There is a need to find another approximation functions.

The next step of calculation is using nonorthogonal approximation functions.

7. CONCLUSIONS

The paper presents the new adaptive transmission algorithm based on the approximation method. Presented method seems to be good solution to overcome difficulties with transmission in shallow underwater acoustic channel.

The block diagram presents simple construction of transmitter and receiver. The calculation unit in receiver can be realized as a microprocessor unit. Other solution for receiver realization is reprogramable ICs. All calculations presented in paper can be executed with microprocessor system or reprogramable ICs in sufficient time of calculations.

Presented method required future examinations in different areas. That areas are presented in section 8.

8. THE FUTURE RESEARCH AREAS

The future research areas are:

Examination of the different probe signal properties. That properties are: probe signal shape, duration and amplitude.

Approximation functions and method examinations. Results obtained with orthogonal functions show that it is necessary to use non orthogonal functions even if it required the calculations complexity increase.

Hardware realization of presented system with microprocessor systems and reprogramable circuits (for example in VHDL language).

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