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MULTIPLEX DIGITAL CORRELATOR WITH HIGH PRIORITY DEPLOYMENT OF ONE OF THE ACOUSTIC SIGNAL RECEIVERS

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***Summary**. The article deals with theoretical foundations and design solutions for structure synthesis of devices for identification of Hemming spatial parameters of acoustic signals.Acoustic method for optimization of multiplex digital correlator design of acoustic positioning of accumulated information with variable number of acoustic signal receivers with high priority deployment of one of them has been proposed. Advantages for application of multiplex design of digital correlator with high priority deployment of one of the microphones for calculation of module correlation function in comparison with multiplex integral evaluation based on centered function of mutual correlation have been grounded. Peculiarities and effectiveness for application of CAD for designing of correlational back-end processors on the crystals of programmable logical integrated circuits have been determined.*

***Key words**: design, correlation, acoustics.*

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Problem setting. Development of theoretical foundations of the design solutions of software and hardware identification structure synthesis of acoustic signal sources spatial parameters is a topical problem of applied science. The use of process parameters acoustic measuring tools is widely used in contactless identification of acoustic signal sources (ASS) spatial location in relation to spatial location of acoustic signal receivers (ASR). Improving the efficiency of the synthesis of problem-oriented computational tools which perform statistical, correlation and spectral signal processing is an important task of designing detection and identification means of acoustic signal sources spatial parameters.

The research objective is to optimize the structural solution for means of correlation monitoring and identifying acoustic signals (AS) spatial parameters.

Analysis of the known research results and research problem statement

The works [1-2] set forth the principles and theoretical base of the method of location finding, identification of the spatial angle and angular-position measurement of ASS based on two acoustic signal receivers (ASR). The method is characterized by finding the angle β between the perpendicular drawn from middle point of the acoustic base, and the line traced between middle point of the acoustic base and the source point (Figure 1)

$$\sin\beta = \sin(NDO) = \frac{(t_2 - t_1)\times C}{L} = \frac{\Delta t \times C}{L}, \tag{1}$$

where c – the speed of sound in the atmosphere;

t_1 and t_2 – periods of time at which the acoustic waves cover the distance from the source to the first and second acoustic signal receivers respectively;

Δt – time difference in audio signal registration by first and second sound receivers

L – length of acoustic base.

Functional limitations of this method are lack of possibility to determine the ASS spatial location as well as inability to recognize the ASS type.

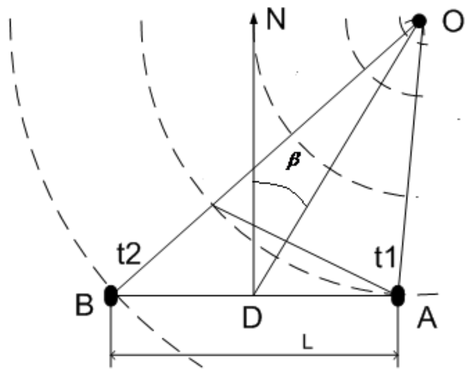

Figure 1. Acoustic base elements arrangement: A, B – microphones; O – sound source

The work [3] shows structural solutions for the acoustic localization accumulated correlation (ALAC) system at random arrangement of ASS and ASR (Figure 2) and theoretical principles of determining multiplicative cross-correlation function based on analytical assessment

$$L(q) = G\left(\int_{\tau(i,q)-\frac{w}{2}}^{\tau(i,q)+\frac{w}{2}} x_i(t) \times x_j(t-\tau_{i,q}+\tau_{j,q})dt\right) + \alpha V_E, \quad (2)$$

where: q – ASS identifier; G – the integrated cross-correlation function; $x_i(t)$ and $x_j(t-\tau_{i,q})$ – current and delayed in the time interval $\pm\tau_{i,q}$ respectively; αV_E – cross-correlation function energy damping coefficient in the interval $\tau_{i,q}$.

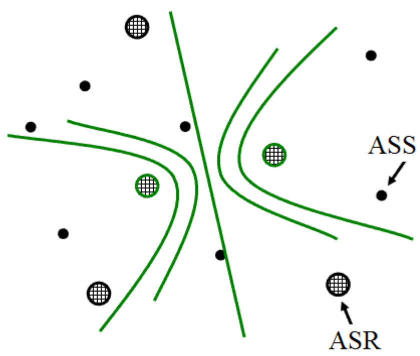

Figure 2. Example of chaotic spatial distribution of ASS and ASR

The authors [3-6] found that correlation method is the most effective as it provides the highest signal/noise ratio.

Fig. 3 shows the structure of the correlation system, which consists of three AS receivers, whose output pairs are connected to respective inputs of three correlators, whose outputs are connected to the inputs of respective accumulative multipliers-adders, the outputs of which are outputs of azimuth and distance to the ASS.

The need for three cross-correlators in the system is caused by correlation matrix symmetry

$$\begin{matrix} 1 & R_{12} & R_{13} \\ - & 1 & R_{23} \\ - & - & 1 \end{matrix} . \quad (3)$$

Thus analysis of existing methods of AS study shows that for a given amount of ASR under the introduced matrix the number of cross-correlators increases almost quadratically.

In chaotic distribution of ASR against ASS the multichannel digital correlator (MDC) structure complies with the principles of ALAC construction.

In a particular case there is a separation of ASS and ASR location, example of which is shown in Figure 4. In the chaotic spatial placement of ASR beyond the line of arrangement the required number of correlators as in the previous case, is equal to three.

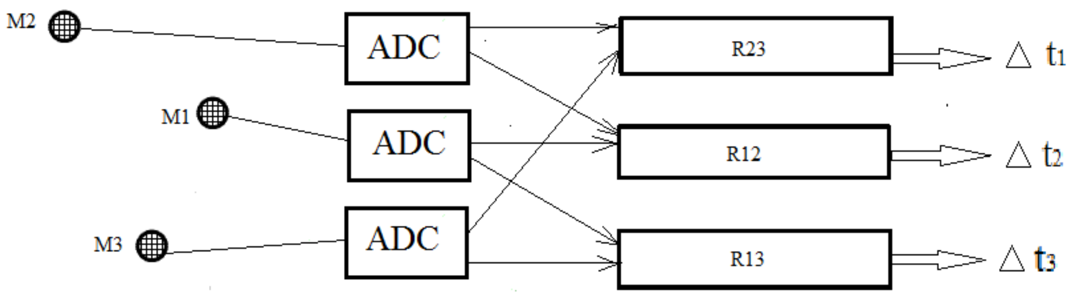

Figure 3. The structure of the acoustic signal correlation processing system with speakers at chaotic spatial arrangement of ASS and ASR

Managed coordinated digital filter (MCDF), which is adapted to the specific ASS should in both cases be placed after ADC for the reliable identification of a particular type ASS. In this case, the correlation structure of the system looks like one shown in Figure 5.

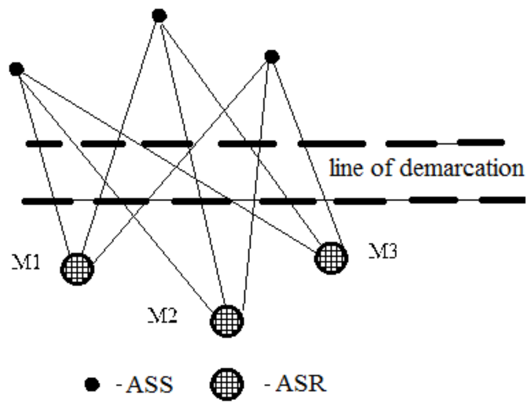

Figure 4. Example of differentiated spatial distribution of ASS and ASR

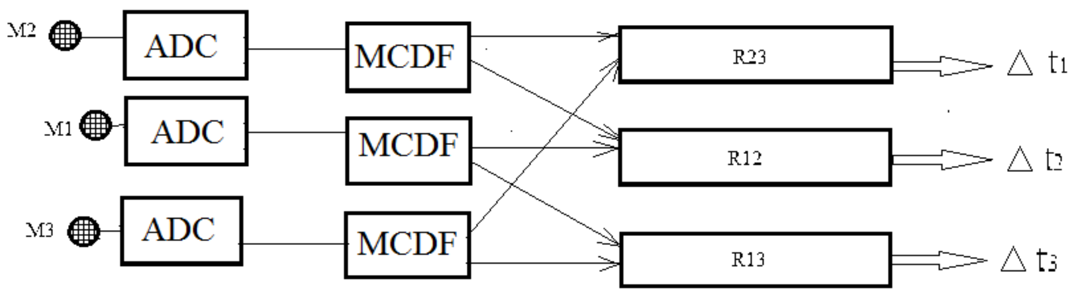

Figure 5. The structure of MDC equipped with MCDF

Thus analysis of existing methods of AS study shows that for a given amount of ASR under the introduced matrix (3), the number of cross-correlators increases almost quadratically.

Formulation of the problem. The main objective is to optimize the monitoring system to simplify hardware correlator.

Optimization of multi-channel digital correlator structure at a particular spatial arrangement of ASS and ASR

MDC structure can be improved by means of a special arrangement of ASR beyond the demarcation line when one of ASR is preferentially placed closer to the demarcation line than other ASR, as shown in Figure 6.

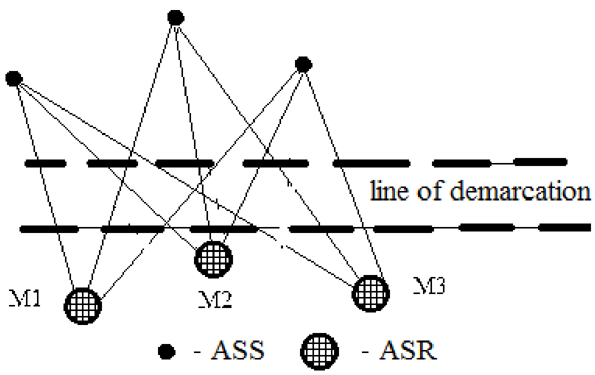

Figure 6. Examples of priority arrangement of one the ASR beyond the ASR and ASS demarcation line

Figure 6 shows that the length of AS distribution from ASS in this case, is the lowest for ASR M2, which makes it possible to reduce the number of necessary correlators in the MDC structure to two. Moreover only priority ASR M2 correlator will include one block of delay register (BDR), and the number of accumulating memory items is reduced to two. The structure of the optimized MDC is shown in Fig. 7.

As shown in Fig. 7, compared with the principles of the correlation processing of ASS signal at random spatial arrangement of ASR in optimized MDC structure due to given priority spatial positioning of one of ASR, the hardware complexity of microelectronic components can be reduced, which results in:

1) the number of BDR is reduced from three to one;

2) the number of integrators (I) is reduced from the three stages to two, plus one;

3) such MDC structure has a high regularity and many similar utilities that significantly simplifies its design and implementation on PLIC chip.

Optimization of calculating analytics of MDC correlation function

When processing software and hardware implementation of analytical expression of definition integrated assessment of correlation by expression (2) it has been found that this method is cumbersome and not effective, as multiplicative correlation algorithm requires alignment of signals $x_i(t)$ and $x_j(t)$ as well as performing their multiplication and accumulation taking into account ± signs.

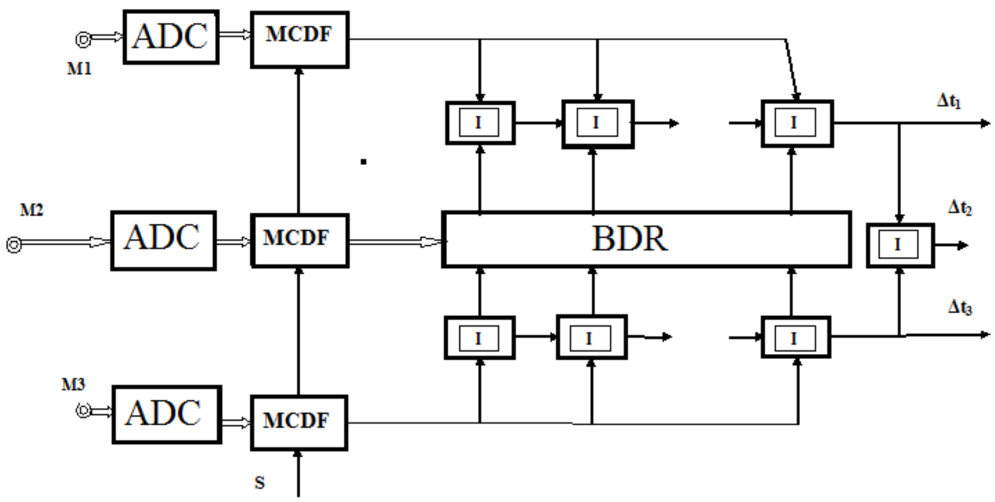

Figure 7. The structure of the optimized MDC

Multiplicative correction of digitized AS values is characterized by low information content as with the existence of zero values in centered codes x_i and x_j out of n – bit sample more than 30 – 40% products are zero, which significantly reduces the information value of multiplicative correlator with respect to, for example, structural and modular ones according to expressions (4) and (5).

$$C_{xx}(j) = \frac{1}{n}\sum_{i=1}^{n}(x_i - x_{i+j})^2 \; ; \tag{4}$$

$$G_{xx}(j) = \frac{1}{n}\sum_{i=1}^{n}| x_i - x_{i+j} | . \tag{5}$$

Analysis of analytical expressions of structural (4) and modular (5) correlation functions shows that the latter is characterized by much simpler algorithm with respect to the expression

(3), which determines the feasibility and effectiveness of the module correlation for MDC implementation.

Fig. 8 shows an example of the correlation interaction of two AC timebase deflections according to the module correlation function $C_{xx}(j)$.

Fig. 9 shows the characteristics of the $C_{xx}(j)$ function at discrepancy and concurrence of signal-wave envelopes x_i and x_{i-j} at a certain time, i.e. cross-correlation modular function verges towards "0" when signal-wave envelopes x_i and x_{i-j}, concur at τ moment of time.

The application of module correlation function in the system of ASS monitoring and spatial parameters identification in the event of priority placement of ASR beyond demarcation line requires an additional introduction into MDC structure certain differentiating units (D) between ASR and ADC inputs, as shown in Fig. 10.

Conclusions. The stated analysis of existing systems of recognition and identification of ASS and ASR spatial distribution allows us to ascertain that the use of multiplicative correlation and chaotic spatial distribution of ASS and ASR is not effective enough in the design of PLIC-based software and hardware special processors.

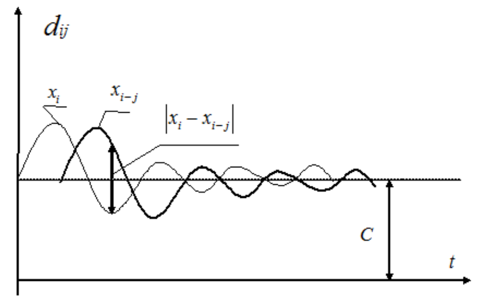

Figure 8. x_i and x_{i-j} signals timing interaction at calculation of module correlation $C_{xx}(j)$:
C – constant of amplitude signal shift

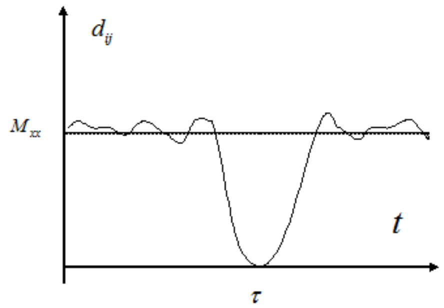

Figure 9. Timing performance of module function of correlation

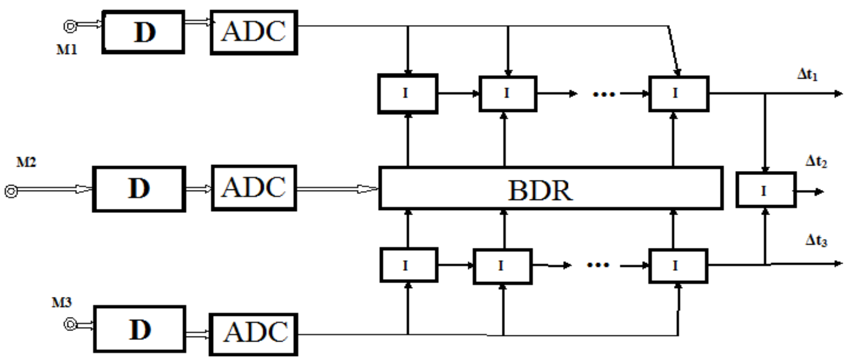

Figure 10. MDC structure based on integrated calculation of module correlation function *I* and differentiator *D*

The proposed optimized structure of multichannel digital correlator with priority spatial placement of one of ASR microphones beyond the line of demarcation with ASS and application of module correlation function for acoustic signal processing can significantly simplify the calculation algorithm, reduce hardware complexity of correlator and enhance its performance, thus justifying feasibility and effectiveness of these solutions at establishing ASS monitoring system and implementation of PLIC-based special microelectronic processors.

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БАГАТОКАНАЛЬНИЙ ЦИФРОВИЙ КОРЕЛЯТОР ПРИ ПРІОРИТЕТНОМУ РОЗМІЩЕННІ ОДНОГО З ПРИЙМАЧІВ АКУСТИЧНИХ СИГНАЛІВ

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Резюме. *Викладено теоретичні засади та проектні рішення синтезу структури апаратних засобів розпізнавання Хеммінгово – просторових параметрів джерел акустичних сигналів. Запропоновано метод оптимізації структури багатоканального цифрового корелятора системи акустичної локалізації накопиченої інформації з різною кількістю приймачів акустичних сигналів при пріоритетному розміщенні одного з них. Обґрунтовано переваги застосування багатоканальної структури цифрового корелятора при пріоритетному розміщенні одного з мікрофонів для обчислення модульної кореляційної функції у порівнянні з мультиплікативною інтегральною оцінкою на основі центрованої функції взаємокореляції. Відзначено особливості та ефективність застосування САПР при проектуванні кореляційних спецпроцесорів на кристалах програмованих логічних інтегральних схем.*

Ключові слова*: структура, кореляція, акустика.*

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