RADIO-SIGNAL PROCESSING IN REAL TIME BY MAGNETIC MEDIA

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ABSTRACT

The domain - acoustic processor (DAP) on the base of ferrite elements of the garnet and spinel compounds has the following characteristics: the sizes are 15×15×70 mm^3, the range of the operating frequencies is 1÷20 MHz, dynamic range is 100 dB, the time of the signal storing is practically unlimited. The DAP provides the realization of the correlation processing of such classes of complicated signals as pulse sequences with binary Barker code, m-sequences, polyphase sequences and linear-frequency-modulated signals as well as separating such signals from noises.
The designed DAP can be widely used in ultrasonic defectoscopy of the construction materials, medical intrascopy and modern communication techniques as well as in other electronic systems using correlation processing of the complicated signals

INTRODUCTION

One of the most important problems in the development of modern information systems is correlation processing of the signals with complicated spectrum [1]. Particularly, in medical diagnostics (ultrasonic investigations and NMR tomography) as well as in defectoscopy of construction materials (nondestructive control) computer correlation processing of such signals is already used[2]. This equipment is highly complicated and can not provide the real time processing of the information signals. Despite the physical phenomenon of domain-acoustic echo (DAE) has not been enough studied it can potentially become the basis of a new functional correlation processor. Functional principle of processing the signals is known to provide the real time operating of information system. Besides that the DAE phenomenon can provide long-time memorizing the signals. In this work the domain-acoustic processor was developed on the base of DAE. The following main features are realized in the processor:
- power independent and long-time memory of information signals;
- practically unlimited number of acts of signal reproduction;
- the real time correlation processing of complicated signals.

The developed domain-acoustic processor is to be attributed to the class of devices with functional principle of construction instead of the circuit engineering. The main constructive elements of this processor are polycrystalline ferrite specimen, electroacoustic transformers (piezotransformers) and magneto-inductive elements (electromagnetic transformers).
Process of excitation-recording-reproduction of signals is provided through the interaction of these elements with ferrite specimen as well as more complex process of the information signals correlation processing.
The investigations of wide class of the polycrystalline ferrite samples for the purpose of the domain-acoustic echo (DAE) effectiveness in them have been carried out to make a choice of the most perspective samples concerning repeatability of the DAE characteristics desirable for the DAP. The DAP was investigated and its functional characteristics have been optimized [3].

THE DOMAIN - ACOUSTIC PROCESSOR DESCRIPTION

The structural scheme of the DAP is shown in Fig.1. The main part of the processor is the element of domain-acoustic memory (polycrystalline ferrite sample 1). For the signal input the piezo-transducer 2 is used and the output is realized by the coil 3. The technology of cold diffusion welding of piezo-transducer and ferrite sound-guide has been developed. The technology provides high safety of the contact and the increased efficiency of the transformation of electrical signal into sonic one (and wise verse). When recording the signal into the ferrite sample the last one has to be preliminarily demagnetized. Besides that the process of recording is the most effective in the decayed magnetic field. To provide the according magnetic field the solenoid 4 is used.

The DAP is controlled by programmable device 5 for generating complicated phase- and frequency manipulated signals. It is designed in the form of add-in cards placed into standard PC ISA-slots and consists of three blocks. The first one is the block of synthesis 5-A which provides the pulse sequences with the following parameters: the frequency range is 1÷16 MHz, the range of the pulse initial phases is 0÷360°, the duration of a single pulse is 0.32-5.12 μsec, the nonuniformity of the frequency characteristics is not greater than 3 dB. The channel of the signal detection 5-B for the domain-acoustic processor allows us to avoid the use of additional registering devices. The block 5-C forms the signals for the solenoid control during recording. The device has convenient program interface and realizes complete automation of the processes of recording and reproducing the signals. The separate block for amplifying and commutation of the signals is also used in addition to the described blocks.

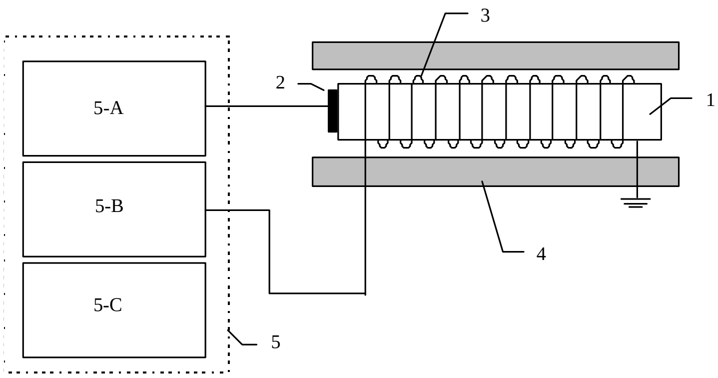


Fig.1

The main part of the processor is the element of domain-acoustic memory (polycrystalline ferrite specimen). Physical basis of the memory is the phenomenon of domain-acoustic echo. This phenomenon is not sufficiently studied yet. The analysis of the obtained experimental results has allowed us to create the according physical model of the DAE.

The theory of work of the memorizing magneto-acoustic processor (MMAP) was considered in two aspects such as recording the acoustic signals into polycrystalline materials and reproducing the recorded signals by acoustic wave or variable magnetic field of the coil.

The following three possible mechanisms were taken into account for the recording in the case of simultaneous action of the acoustic and magnetic fields on the grain:

- shift of the domain walls in the grains;
- the magnetization rotation in the grain which does not contain domain walls;
- formation of sub-domain structures such as Bloch lines and points in the grain domain wall.

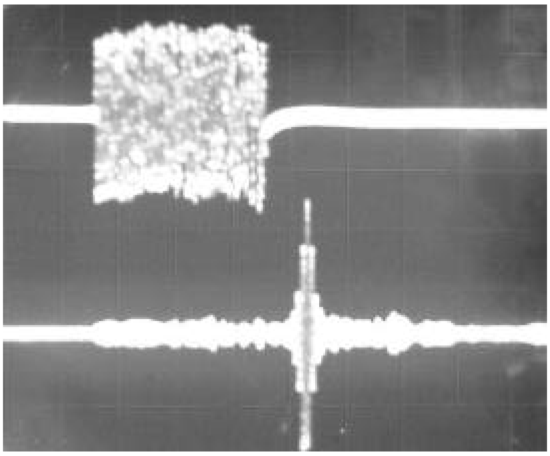
The theory of recording the acoustic signals was created on the base of rotation mechanism. It is based on the model of uniaxial anisotropy of the grain with two equilibrium states relative to the vector of magnetization in the grain. The computer simulation of the recording process confirmed the possibility of formation of the static magnetization $M(x)$ spatial distribution with modulation coefficient of several percents in ferrite sample. This distribution is the image of the acoustic signal and can be stored during long time. The analysis formalism not depending on the way of formation of the signal image $M(x)$ is proposed for the reproducing process. The signal reproducing by acoustic wave and magnetic field is considered. The mechanism of reproducing the recorded signal by variable magnetic field was shown to be effective at low frequencies. In this case the reproduced signal is proportional to the modulation coefficient for static magnetization during recording, the recording field amplitude, acoustic quality factor and the value of magneto-elastic constant. When reproducing the signal by acoustic wave the proportionality of the output signal to the same parameters is kept, however it depends on frequency and is more effective that is different from the previous case. Therefore electromoving force on the reproducing coil can reach 0.5-0.7 V per loop in the case of the modulation coefficient of 50%.

The realized comparative analysis of the effectiveness of different recording mechanisms relative to the MMAP experimental characteristics allows to make the following conclusions. The main mechanisms of the signal recording are those one connected with the domain wall existence in the grain, i.e. the mechanisms of the domain wall shift or sub-domain structures formation in the wall. The signals reproducing should be realized by acoustic wave. In this case the amplitude of the reproduced signal can reach several volts that is confirmed in the experiment.

FUNCTIONAL CHARACTERISTICS OF THE DAP WITH RESPECT TO THE PROCESSING OF COMPLICATED PULSE SEQUENCES.

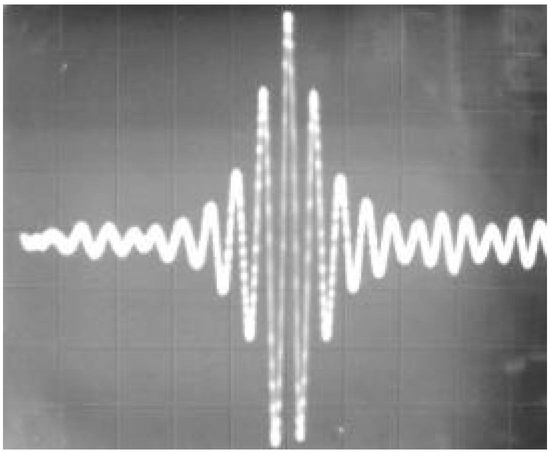
The DAP functional possibilities concerning the processing of the complicated pulse sequences were investigated. The experiments have shown good possibilities of the DAP concerning the processing of such pulse sequences as LFM-signals, the sequences with binary Barker code, polyphase and m- sequences. The photos of the autocorrelation signals was made from oscilloscope. The above mentioned photos are presented in Fig. 2 - 3.

The duration of the elementary pulse in the first two cases is 0.32 μs as well as 0.64 μs in the third case. The carrier frequency for 29-pulse polyphase and 7-pulse binary sequences is 4.195 MHz, in the case of LFM the frequency is changed from 3.8 to 4.6 MHz (Fig. 3 a) as well as from 3.8 to 4.6 MHz (Fig. 3 b,c).



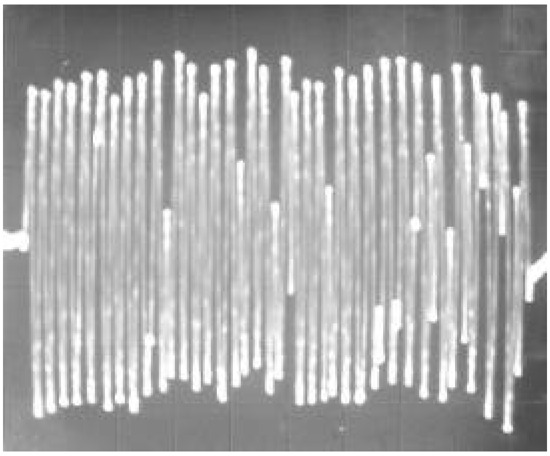
a

Polyphase 29-pulse sequence and its ACF. Time scanning is 2 μsec/point.



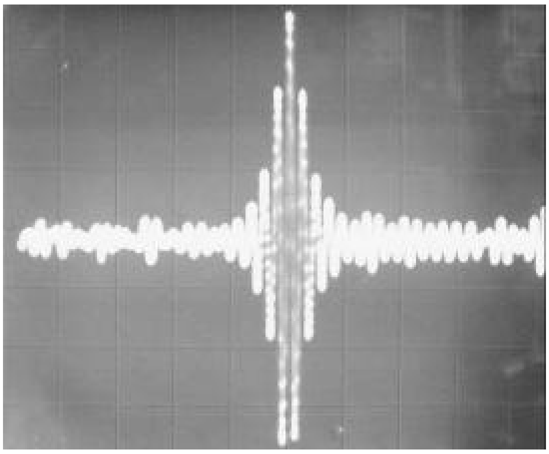
b

ACF of the polyphase 29-pulse sequence. Time scanning is 0.5 μsec/point.



c

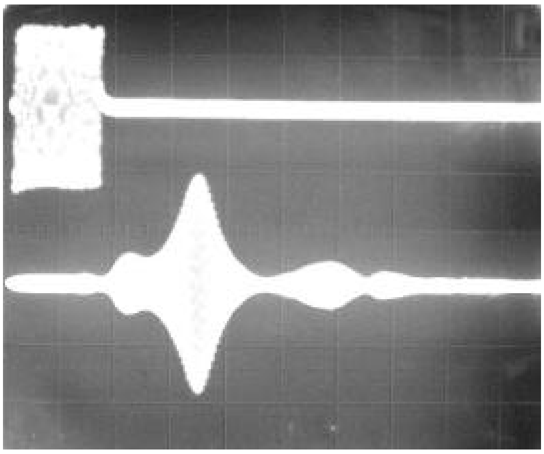
Polyphase 29-pulse sequence. Time scanning is 1 μsec/point.



d

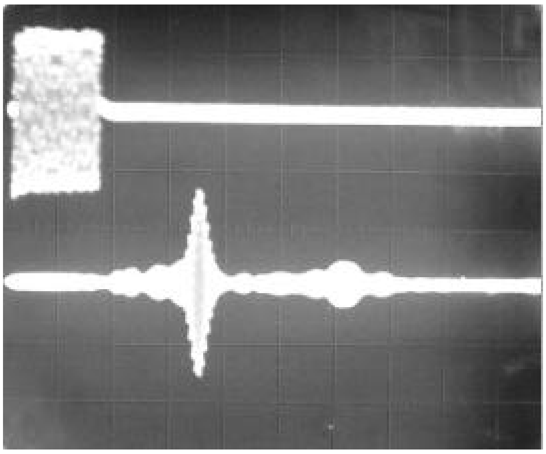
ACF of the polyphase 29-pulse sequence. Time scanning is 1 μsec/point.

Fig. 2. Oscillograms of the signal and its autocorrelation function (ACF) for the polyphase 29-pulse sequence.



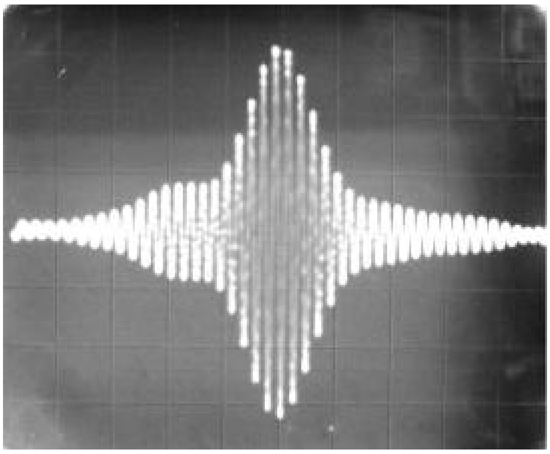
a

LFM-signal with the frequency changing from 3.8 to 4.6 MHz and its ACF. Time scanning is 5 μsec/point.



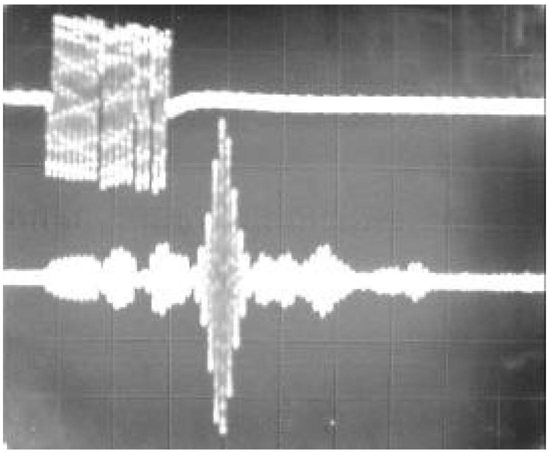
b

LFM-signal with the frequency changing from 3.7 to 4.7 MHz and its ACF. Time scanning is 5 μsec/point.



c

ACF of the LFM-signal with the frequency changing from 3.7 to 4.7 MHz. Time scanning is 1 μsec/point.



d

7-pulse sequence with binary Barker code (1110010) and its ACF. Time scanning is 2 μsec/point.

Fig. 3. Oscillograms of the autocorrelation function (ACF) for the LFM-signals and 7-pulse sequence with binary Barker code.

ACKNOWLEDGEMENT

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