ACOUSTO-OPTIC METHODS AND DEVICES OF SIGNALS HANDLING IN TEMPORAL AREA

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The results of the authors investigations directed on the use of peculiarities of photoelastic effect for electronically controllable signals delay, for separation of channel signals by a temporal indication and for a pulse-width modulation of a sequence of rectangular impulses are generalized.

1. GENERAL INFORMATION

Interaction of light and acoustic waves in photoelastic media (the photoelastic effect) has a number of peculiarities representing a certain interest in the context of applicability for the solution of series of the radioelectronic problems. They include: significant regulated delay of an output response, modification of a distribution direction, intensity and frequency of diffraction order in accordance with coordinates of acousto-optic interaction, frequency and amplitude of an elastic wave being spatial analog of an input electrical signal.

The purpose of the present work is a generalization of outcomes of the authors theoretical and experimental investigations directed on handling of signals in temporal area based on the use of peculiarities of acousto-optic interaction effect in photoelastic media.

For facilitation of perception of the accepted decisions, at first we shall consider some properties of photoelastic effect.

A major unit of any acousto-optic device is an acousto-optic modulator representing a photoelastic medium, to one edge of which an electroacoustic converter is attached, it transforms a radio-frequency signal into an elastic wave spreading in a photoelastic medium with a velocity, approximately, 10^5 times less than a velocity of propogation of an electromagnetic wave. During an excitation of an elastic wave in a photoelastic medium dynamic modifications of an index of refraction (density of a medium) occur. These modifications lead to the formation of a phase lattice, with a step equal to the length of an elastic wave, and the amplitude proportional to the amplitude of an acoustic wave, as well as photoelastic constant medium. With realization of definite conditions, optical waves incident on this phase lattice deviate.

Diffractions of Raman-Nath and Bragg are distinguished. The diffraction of Raman-Nath is widely applied in acousto-optic devices of signal handling working on frequencies up to 100 MHz. Acousto-optic devices using Bragg diffraction are applied in data reduction systems working in the field of frequencies from several tens MHz up to units of GHz. The basic exterior difference of Bragg from a Raman-Nath diffractions consists of a nonsymmetric emerging of diffractional orders, with modification of the incidence angle a light stream in the aperture of acousto-optic modulator. The maximum of light intensity in a diffractional order takes place if the Bragg [1] conditions are fulfilled, i.e. if light falls on the aperture of acousto-optic modulator at the Bragg angle θ_B, defined from the relation

$$Sin\theta_B = 0,5\lambda/\Lambda \,, \qquad (1)$$

where λ is a wavelength of incident light; Λ- is an elastic wavelength in a photoelastic medium of acousto-optic modulator. Thus all deviating light will be concentrated in one order spreaded at the angle,

$$sin\theta_d = \lambda/\Lambda = 0,5f\lambda/\vartheta, \qquad (2)$$

where f and ϑ are frequency and velocity of elastic wave distribution, respectively.

From (2) it follows, that the modification of an elastic wave frequency is accompanied by the modification of deviating light distribution direction.

The intensity of a deviating bundle is determined by an expression [2]:

$$I_1 = BU^2 \qquad (3)$$

where U is the amplitude of the voltage on an electrical input of acousto-optic modulator; B is a constant factor.

In correspondence with (3), the intensity of deviating light is proportional to a square of input voltage.

2. VARIABLE SIGNALS DELAY

The indicated peculiarities of acousto-optic interaction can be applied to a signal delay, by extraction of a useful signal by means of elastic-optical connection on a defined distance from the electro-acoustic converter. A significant signal delay accessed by this method is determined by the run time of an elastic wave from the electro -acoustic converter up to the point of acousto-optic interaction. The device which operation is based on the indicated principle is named an acousto-optic delay line. Thus, the controlled delay of signals is got by a modification of a distance (span) from an electro-acoustic converter up to the point of acousto-optic interaction, by transition of acousto-optic modulator relative to a laser beam. However, the mechanical installation of the position of acousto-optic modulator eliminates the possibility to use the acousto-optic delay line in systems of information processing, in which fast regulation by hold time of signals is required.

In this context electronically controlled acousto-optic delay line (fig.1) with small time of installation of a required delay [3,4], has high potential abilities. Here the beam of the laser 1 is splitted on n bundles by the forming cascade 2. The spectrum of a treated signal is transferred in the area of working frequencies of acousto-optic modulator 3 by amplitude modulator 7, modulating on amplitude made by a generator 6, high-frequency oscillations, which face values frequencies are selected by governing voltage U and can accept one of n discrete values thus remaining, in a band of acousto-optic modulator 3. The modulated high-frequency oscillations act on an input of acousto-optic modulator 3 and raise in it elastic waves of an appropriate frequency. Light bundles intersecting the aperture of acousto-optic modulator 3 deviate on elastic waves and form signal bundles hitting on a photosensitive surface of a photoreception device 5, on exit of which an entering signal with a constant multiplicand corresponds to delayed on time $\tau=h/\vartheta$, where h is a distance from electro-acoustic converter 8 of acousto-optic modulator 3 up to a signal bundle, which passes through an appropriate hole of a screen 4. The modification of controlling voltage given on a high-frequency generator 6 results in a modification of frequency of an elastic wave and angle of diffraction of deviating orders in a focal plane of acousto-optic modulator 3. As a results, through the hole other signal bundle will passes, i.e. the distance h and hold time τ vary.

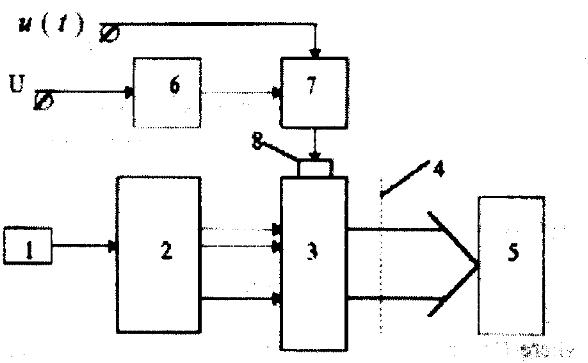

Fig.1.

In the offered device the improvement of parameters of formed time intervals is ensured by transition of acousto-optic modulator relative to a beam of the laser.

Experimentally the possibility of construction of discrete acousto-optic delay line with the possibility of choice of three values of hold time, 1; 1,7; and 2,5 μs., accordingly was checked. As a photoelastic medium the mesh from TF-7 was used, and the electro-acoustic converter was made from $LiNbO_3$. The central frequency of acousto-optic modulator was 80 MHz.

3. SEPARATION OF CHANNEL SIGNALS ON A TEMPORAL BASIC

The method of temporal division of channels consists of translational means (communication circuit, the instrument tract etc.) are represented by various sourses in turn; each elementary signal (signal possessing necessary and sufficient properties for its selection from the aggregate of all transferred signals of a multichannel system) exists during a strictly defined time interval. In general case it can be premises of a binary code, reference of a signal, sine wave oscillation of definite frequency etc.

For a separation of channel signals in modern selectors the presence of controlling impulses for each channel is necessary. These controlling impulses are broadcasted on appropriate communication circuits, resulting in complication of the system in whole.

The offered acousto-optic method allows to replace n controlling impulses for n of channels by one clock pulse for all channels. As a results the number of communication circuits is reduced by n-1.

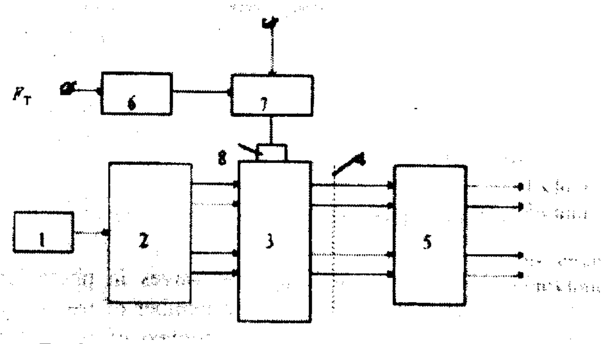

Fig.2.

The structural electrical scheme of acousto-optic selector of channel signals is represented on figure 2. A ray of the laser 1 is splitted into n bundles by the forming cascade 2, and any k- th light bundle falls in the aperture of acousto - optic modulator 3 under an angle Bragg θ_{Bk}, defined from the relation

$$\sin\theta_{Bk}=0,5\lambda/\Lambda_k \quad , \qquad (4)$$

where Λ_k is the length of an elastic wave appropriate to any k-th channel n-th channel signal in photoelastic medium of acousto-optic modulator 3.

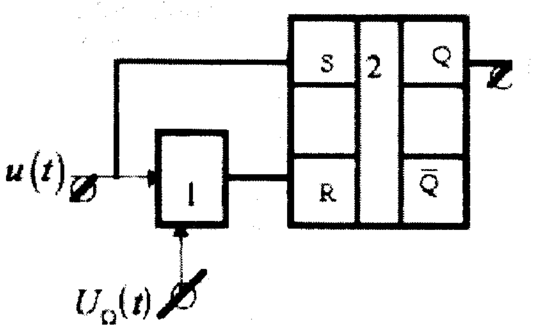

Fig.3.

The group signal modulates in the modulator 7 high-frequency line frequency-modulated oscillations of a generator 6, started by clock pulses with frequency F_T. The radioimpulses will be transformed by an electro-acoustic converter 8 into an elastic wave spreading in photoelastic medium of acousto-optic modulator 3.

The incident light bundles diffract on elastic wave packets. Diffracting orders, spreading at angles

$$\theta_{dk} = 0,5 f_k\, \lambda/\vartheta \quad , \qquad (5)$$

where $f_k = \vartheta/\Lambda_k$ is the frequency of an elastic wave packet appropriate to any k-th channel of a n-th channel signal, are selected with the help of appropriate diaphragms with orifices 4 and fall on a photosensitive surface of a multichannel photoreception device 5, on which exits the channel signals turn out. The diaphragms are placed in such a manner that any k diaphragm selects only bundle diffracted at the angle θ_{dk}.

The virtue of the offered device is, also, a possibility of operating regulation of time intervals of reception.

The possibility of construction of acousto-optic selector of channel signals was checked experimentally. As a photoelastic medium of acousto-optic modulator 3 the monocrystalline quartz was used, and the electro-acoustic converter 8 was made from ZnO, which was put on a surface of crystal by a method of vacuum dispersion. The central frequency of acousto-optic modulator 3 was 157 MHz. The device ensured a separation of channels of a 4 channel signal.

4. PULSE-WIDTH MODULATION OF A SEQUENCE OF RECTANQULAR IMPULSES

A basic unit of pulse-width modulators is the temporal modulator of a continuous operation, sensitive to amplitude of modulating low-frequency voltage. In this context smoothly controlled acousto-optic delay line has high [5] potential possibilities, which can ensure a large index of modulation in comparison with existing analogs, and these devices differ by high linearity of temporal modulation.

Because of explained above the acousto-optic method of pulse-width modulation is synthesized. The method [6] is explained by the block diagram given on fig. 3. Here modulated impulse sequence $u(t)$ acts on an input smoothly controlled acousto-optic delay line 1 and on an input «S» of the trigger 2. Under an operation of a modulating (primary) signal $U_\Omega(t)$ the hold time of an impulse sequence $u(t)$ in acousto-optic delay line varies. Thus, the delaying impulse sequence acts on an input «R» of the trigger 2. As a results on the exit of the trigger impulses are formed, which duration [6] is defined as:

$$\tau \approx \tau_0 \pm cU_\Omega, \tag{6}$$

where τ_0 is the duration of an impulse on the exit of the trigger in a case $U_\Omega(t)=0$; c is a dimensionality factor, s/V.

From (6) it follows, that the increment of duration of an impulse on the exit of the trigger is directly proportional to the amplitude of modulating voltage $U_\Omega(t)$ on the input. In other words, the offered modulator is ensured with a linear pulse-width modulation.

The author checked experimentally the principle of a construction of acousto-optic breadth-impulse modulator ensuring linear modification of duration of impulse τ on the exit Q of the trigger 2 from 4 up to 5,8 μs., with modification of voltage on the input $U_\Omega(t)$ from 0 up to 3 V.

CONCLUSION

The proposed methods and devices of handling of signals in temporal area allow to expand the boundaries of application of peculiarities of photoelastic effect for transformation, transmission and reception of information. These devices are distinguished by simplicity and do not require special set-up. Besides, the visualization of basic processes in acousto-optic modulator (a laser radiates in visible range) considerably simplifies a specification of separate parameters of the device in whole. During last years acousto-optic modulator with satisfactory maintenance and engineering by indices (low power of an elastic wave excitations, high effectiveness of a diffraction etc.) and semiconductor lasers with a sufficient coherence of a radiation have been developed. Taking into account all this it is possible to state, that in the nearest future some compact acousto-optic device of handling of signals considerably exceeding their electronic analogs in characteristics will be created.

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SİQNALLARIN ZAMAN OBLASTINDA İŞLƏNMƏSİ ÜÇÜN AKUSTOOPTİK ÜSULLAR VƏ QURĞULAR

Siqnalların electron-tənzimləməli ləngiməsi, kanal siqnallarının paylanması və düzbucaqlı impulslar ardıcıllığının eninə-impuls modulyasiyası üçün fotoelastik effektdən istifadə olunması istiqamətində müəllifin apardığı elmi-tədqiqat işlərinin nəticələri ümumiləşdirilir.

А.Р. Гасанов

АКУСТООПТИЧЕСКИЕ МЕТОДЫ И УСТРОЙСТВА ОБРАБОТКИ СИГНАЛОВ ВО ВРЕМЕННОЙ ОБЛАСТИ

Обобщаются результаты научных исследований автора, направленных на использование особенностей фотоупругого эффекта для электронно-управляемой задержки сигналов, для разделения канальных сигналов по временному признаку и для широтно-импульсной модуляции последовательности прямоугольных импульсов.

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