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ACOUSTO-OPTICAL RECEIVER OF AN OBSTRUCTION PASSIVE RADAR SYSTEM

Abstract. **The subject** of research in the article is the passive radar system of a warship. **The purpose** of the work was to review the characteristics use of the acousto-optical receiver in the new passive radar system of the warship, to investigate the peculiarities of acoustooptic effect and the relevant synthesis of methods and tools for measuring the photodetector photoelectric characteristics and, in addition, to investigate the energy-and-geometric parameters of laser radiation **Justification.** It is shown that the transition, impulse and frequency characteristics are taken as the main means to determine the operating and technical parameters of the acousto-optical delay line. It is not possible to unambiguously extrapolate these characteristics to the known models of the characteristics of the acousto-optic radar receiver created on AODL. **Research results.** In the context of this postulate, mathematical models of the main characteristics of AODL were developed. On the basis of the synchronous compensation pulse obstacles applied to the passive radar acousto-optic receiver on military ships, the full compensation of the obstacles is determined for the effective reception of signals from the acousto-optic receiver. In radar stations (radar), the main attention is focused on the statistical properties of the useful signal and passive obstacles, the speed (frequency) of the signal passing through the passive obstacle and the space-time differences. **The recommendations.** These features are recommended to be used only in special cases where the target is outside the reflectors for informational duration, amplitude and differences between passive obstacles, obstacle silencing and signal separation. **Conclusion.** Applying the full attenuation of the band filter and synphase barrier organizers, whose frequency characteristics do not depend on the tuning frequency, it is possible to provide full compensation of obstacles during the effective reception of signals by the acousto-optic receiver in the passive radar system of warships based on the proposed method for high resistance to obstacles, pulse obstacle compensation.

Keywords: radar stations; acousto-optical receiver; passive barrier; radio-reflective systems; impulse barriers; band-pass acousto-optical filter; amplitude modulator.

Introduction

The need to increase the communication channel capacity stipulates the widespread development of optical range that predetermines the necessity to develop new optoelectronic devices that are used in different spheres of science and technology for solving most diverse radio engineering tasks.

Photodetector (PD) and laser are the main components of any optoelectronic product. Therefore, the continuous search is underway for new photosensitive materials and generation facilities of coherent light that are used for developing more advanced optoelectronic devices.

All this predetermines a high scientific and technical significance of creating new methods and instrumentation for measuring the parameters of both photosensitive materials and lasers.

Inertia is the key PD parameter. It is estimated by the constant of rise time of transient response PD or rise time of transient response τ_{PD}^{r} In case of the analog signal processing, the PD inertia is characterized by cutoff frequency, f_{PD}^{cut}at which the amplitude of PD signal is reduced to level $2^{-0.5}$ with respect to the stationary value. The cutoff frequency is determined by formula:

$$f_{PD}^{cut} = \ln(9)/(2\pi\tau_{PD}^{r}). \qquad (1)$$

Methods and instrumentation for measuring the parameters of photodetector inertia are well-known [1–3]. Paper deals with the discussion of the method for measuring the speed-of-response parameters of PD, where laser. The self-regulating electric method for measuring the frequency characteristics of high-speed PD using the segmental frequency up-conversion based on low-speed photon sampling is proposed in [4]. The modulation method for measuring parameters of PD operating in the heterodyne regime with wavelength 10.6 m is described in [5–7].

It is obvious that in all cases the possibility of adaptation of test signal parameters to expected values of parameters of PD under investigation is excluded. Therefore, each of the above methods alone cannot be used for investigating the photoelectric characteristics of a wide spectrum of semiconductors, including PD. Thus, the creation of measuring system that can be easily adapted for the investigation of photoelectric characteristics of various semiconductor materials, in particular PD, is an important scientific and technical task

The configuration of cross-section of light beam and the distribution law of power flux density therein are the main energy-and-geometric parameters of laser radiation. The generation of laser beam with uniform distribution of power flux density is not practically possible. The theoretical methods for determination of the distribution law of power flux density are not very accurate. Therefore, various experimental measurement methods and devices for their implementation are developed for solving this task. For solving this task, paper [8–12] proposes a matrix of piezoelectric resonators that can be preferably applied for measuring the distribution of power flux density of relatively low-power lasers. The measurement method described in [5, 13–17] is suitable for solving the specified task (problem) as applied for high-power lasers. A brief review of methods and tools for solving this problem provides evidence of its high topicality.

The purpose of this study is to investigate the peculiarities of acoustooptic effect and the relevant synthesis of methods and tools for measuring the photodetector photoelectric characteristics and, in addition, to investigate the energy-and-geometric parameters of laser radiation.

1. Acoustooptic processor

Let us consider the main assemblies and operation algorithm of acoustooptic processor (AOP). The signal uin(t) processed in AOP modulates in amplitude the signal of high frequency generator (HFG) using an amplitude modulator (AM). The amplitude modulation, balanced amplitude modulation or amplitude manipulation (shift keying) can be applied depending on the nature of solved problem (Fig. 1).

Numerical analysis 4. Let us consider the interaction of laser beam with normal (Gaussian) distribution with acoustic wave packet at H = 1.6 mm, P_0= 3 mW, ϑ= 3.63 km/s, τ_p= 0.2 s, x_0= 0.4 mm, and ŋ= 0.3. The Gaussian distribution can be adapted to the current situation as follows:

$$f(x) = exp\left[\frac{-(x - x_0 - 0.5H')^2}{2(0.5H')^2}\right], \qquad (2)$$

$at\ x_0 \le x;\ x \ge x_0 + H'$.

Fig. 2 is uniquely corresponds to formula (2).

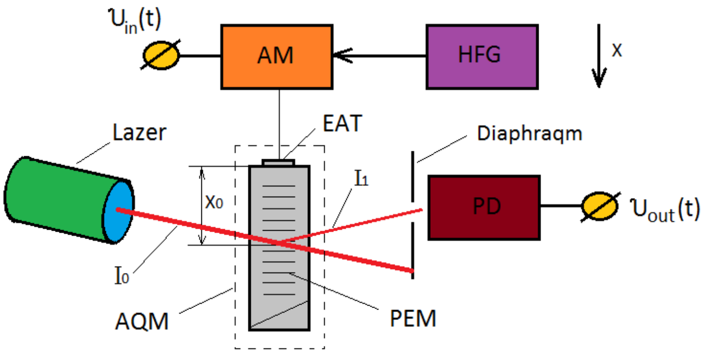

Fig. 1. Schematic diagram of acoustooptic processor

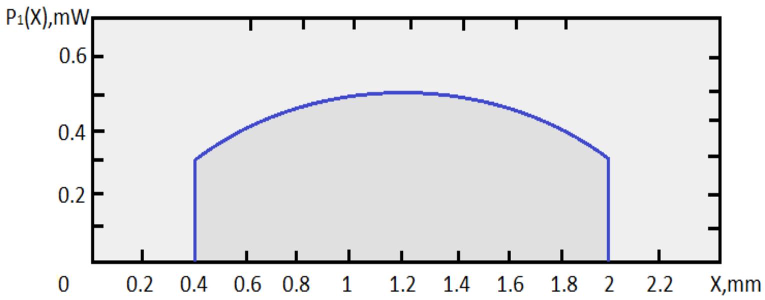

Fig. 2. Power distribution graph in square cross-section of laser radiation

2. Experimental investigations

The schematic diagram of experimental setup is presented in Fig. 3. Here AOP is implemented on the basis of AOM with center frequency of 80 MHz that is built using the glass-like photo-elastic TF-7 material, in which the elastic waves propagate with velocity $\vartheta = 3.63 km/s$. The frequency of G4-107 generator is selected to be equal to the AOM center frequency that amounts to 80 MHz.

A rectangular pulse with relevant parameters generated in the G5-54 pulse generator synchronizes the oscillograph RIGOL MSO 4052 and modulates the oscillation of G4-107 generator that operates in the mode of external pulse modulation. A semiconductor laser is used as a light source. In other words, the requirements to coherence are low. The photo of zero I_0 and first I_1 diffraction orders was made in the mode of signal without modulation. The light in the first diffraction order passing through the aperture in screen falls on the light-sensitive surface of PD.

Measurement of AOP parameters while neglecting PD influence. For solving this task in the above schematic diagram (Fig. 3), FEU-114 photoelectric multiplier is used as a PD. According to the nameplate data of the above multiplier, the rise time of transient response of FEU-114 amounts to ≤9 ns that is much less than the time of optical beam crossing by elastic wave packet. Therefore, the rise time of AOP transient response actually is determined by the time of optical beam crossing by elastic wave packet, while an insignificant contribution of PD is neglected (see, numerical analysis 1). The rectangular pulse having duration $\tau_P = 1\mu s$ from G5-54 generator and the pulse from the PD output are simultaneously displayed on the screen of oscillograph RIGOL MSO 4052 (Fig. 4)

The pulse at the PD output (Fig. 4, line 2) lags behind the pulse at the processor input (Fig. 4, line 1) by about 3 μs. The rise time of output pulse determined from the oscillogram (Fig. 4, line 2) is approximately equal to 0.3μs that is fully coincides with the results of numerical analysis 1.

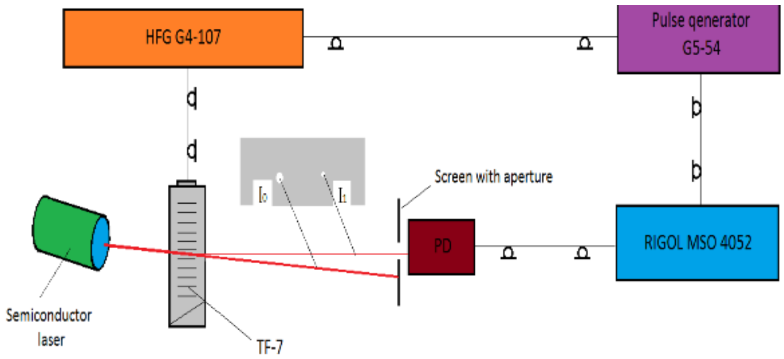

Fig. 3. Schematic diagram of experimental setup

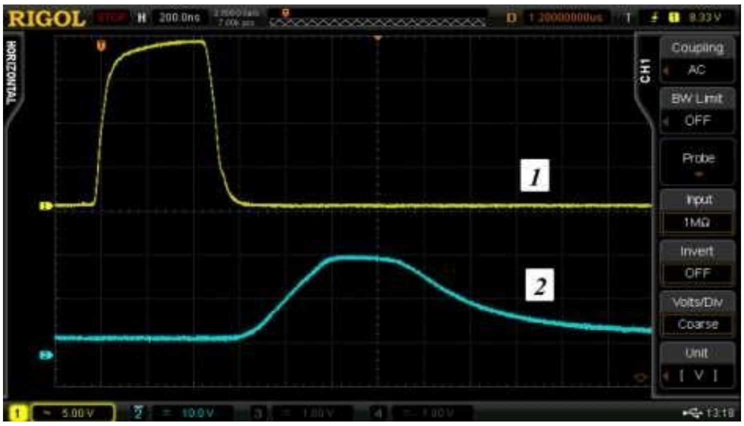

Fig. 4. Oscillograms of voltages at processor input (1) and FEU-114 output (2)

The complexity of separating signals against the background of passive obstacles in the receiving system of radar instruments of warships is due to the fact that the obstacle, like the useful signal, is also reflected in the bandpass filter. Therefore, the main problem in the design of effective protection systems is the choice of the parameter with the greatest differences between the signal and the passive barrier. Angular velocity, speed, polarization, differences in trajectories and amplitudes, etc. when choosing parameters. should be taken into account [1, 4, 6].

It is advisable to have an acousto-optic receiver as the main component of a passive radar system for radar obstacles on warships. At the same time, the effectiveness of radar barrage stations and dipole reflectors in detecting and neutralizing a radiation source directly depends on the characteristics of the receiver. In this case, the receiver itself must have high noise immunity in the operating conditions of radio transmission systems. All this testifies to the need to use special methods and means that provide high noise immunity in acousto-optical receivers of a passive radar system on warships [3].

The high intensity of radio-reflective barriers requires the use of special methods and means aimed at weakening them. The use of a bandpass filter whose frequency response is independent of the tuning frequency and a method that provides complete attenuation of common-mode barrier elements ensures high noise immunity. Research aimed at eliminating defects found in the application of impulse barrier suppression methods created the conditions for the application of a new method called synchronous impulse barrier compensation . In more detail, the way to compensate for impulse barriers can be explained by the block diagram shown in Fig. 5. Two band-pass filters (BF) were used in the circuit. The mixture of the signal and the obstacle $u_s(t) + u_{n1}(t)$ is selected with the help of BF1, and a part of the spectrum of the impulse barrier $u_{n2}(t)$ in frequency domain is selected with the help of BF2, which is hushed up, but has components [11, 12, 16].

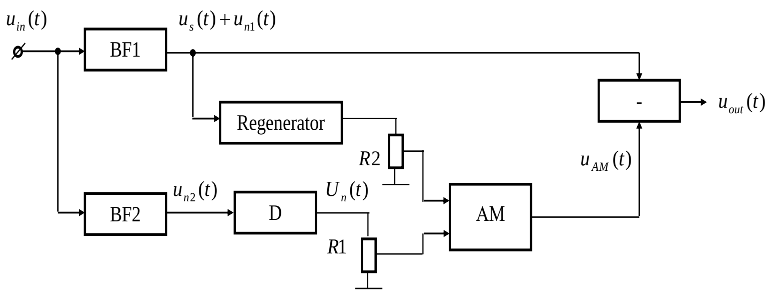

Fig. 5. Device for studying the method of synchronous compensation

The circuit also used an amplitude modulator (AM). An isolated voltage Un(t) is applied to its input. Zero-phase reference oscillations recovered from the output signal of (BF1) are fed to the second input of the AM. As a result, oscillations with amplitude modulation $U_{AM}(t)$ are formed in the AM. These generated oscillations act as an obstacle with a carrier frequency equal to the frequency of the desired signal. Such formation of a compensating signal can be expressed by the expression $u_{AM}(t) = u_{n1}(t)$. The compensating signal $U_{AM}(t)$ is subtracted from the mixture of the signal $u_s(t) + u_{n1}(t)$ and the impedance in the corresponding device. Complete damping of the impulse barrier occurs:

$$u_{out}(t) = u_s(t) + u_{n1}(t) - u_{AM}(t) = u_s(t).$$

The selection of the modulating voltage by the potentiometer R1 and the amplitude of the carrier oscillations by the potentiometer R2 leads to complete compensation of the impulse barriers. Fig. 6 shows the doubling of the impedance amplitude and waveform at the output of the output device after a phase shift. On the basis of a resonant amplifier with the help of a limiter, it is possible to form zero reference oscillations of the initial phase [2, 6, 7]. In this device, the phase of the voltage at the input of the limiter coincides with the phase of the first harmonic of the current and, accordingly, the output voltage.

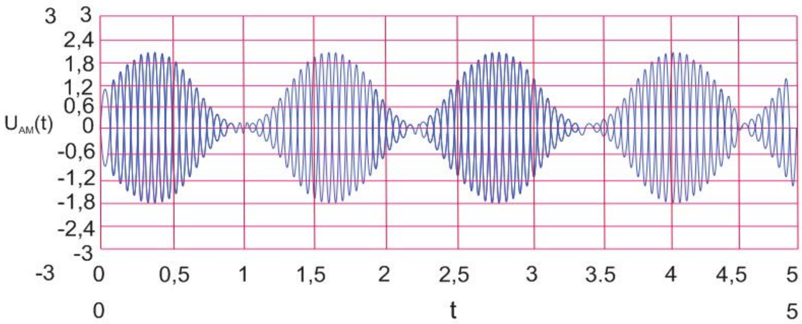

Fig. 6. Waveform at the output of the output device

Conclusions

By determining the influencing factors during the reception of some parameters in unobstructed and obstructed conditions, the difficulty of separating signals from the background of passive obstacles as a result of the application of the acousto-optical receiver of the passive radar system of surface ships, the reflection of the obstacle as a useful signal in the band filter, the selection of an additional reception channel necessary for the weakening of blocking and targeting obstacles makes it easier. Applying the full attenuation of the band filter and synphase barrier organizers, whose frequency characteristics do not depend on the tuning frequency, it is possible to provide full compensation of obstacles during the effective reception of signals by the acousto-optic receiver in the passive radar system of warships based on the proposed method for high resistance to obstacles, pulse obstacle compensation.

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Акустооптичний приймач загороджувальної пасивної радіолокаційної системи

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Abstract. Предметом дослідження в статті є пасивна радіолокаційна система бойового корабля. **Метою роботи** був огляд характеристик використання акустооптичного приймача в новій пасивній радіолокаційній системі бойового корабля, дослідження особливостей акустооптичного ефекту та відповідний синтез методів і засобів вимірювання фотоелектричних характеристик фотодетектора, а також дослідження енергетично-геометричних параметрів лазерного випромінювання. **Обґрунтування.** Показано, що основними засобами визначення робочих і технічних параметрів акустооптичної лінії затримки є перехідна, імпульсна та частотна характеристики. Однозначно екстраполювати ці характеристики на відомі моделі характеристик акустооптичного радіолокаційного приймача, створеного на AODL, неможливо. **Результати дослідження.** У контексті цього постулату були розроблені математичні моделі основних характеристик AODL. На основі синхронної компенсації імпульсних перешкод, застосованих до пасивного радіолокаційного акустооптичного приймача на військових кораблях, визначено повну компенсацію перешкод для ефективного прийому сигналів від акустооптичного приймача. У радіолокаційних станціях основна увага зосереджена на статистичних властивостях корисного сигналу і пасивних перешкод, швидкості (частоті) проходження сигналу через пасивну перешкоду і просторово-часових різницях. **Рекомендації.** Ці функції рекомендовано використовувати лише в особливих випадках, коли ціль знаходиться за межами відбивачів для тривалості інформації, амплітуди та різниці між пасивними перешкодами, глушінням перешкод і розділенням сигналу. **Висновок.** Застосовуючи повне ослаблення смугового фільтра та синфазних бар'єрних організаторів, частотні характеристики яких не залежать від частоти налаштування, можна забезпечити повну компенсацію перешкод під час ефективного прийому сигналів акустооптичним приймачем у системі пасивної радіолокації бойових кораблів на основі запропонованого способу високої стійкості до перешкод, імпульсної компенсації перешкод.

Ключові слова: радіолокаційні станції; акустооптичний приймач; пасивний бар'єр; радіовідбивні системи; імпульсні бар'єри; смуговий акустооптичний фільтр; амплітудний модулятор.