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APPLICATION OF TECHNOLOGIES BASED ON DISTRIBUTED ACOUSTIC SENSING ON RAILWAY TRACKS

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Currently, a number of developed railways are paying increased attention to monitoring technologies based on distributed virtual acoustic sensors in optical fiber. The use of technical solutions based on fiber bragg grating (FBG) has confirmed the fundamental suitability of fiber optic technologies for detecting the passage of rolling stock wheels [1, 2].

FBG technology involves the formation of a periodic structure in an optical fiber using a laser signal source, which has the properties of a reflector for wave pulses of a certain length [3]. High-frequency light pulses are transmitted into the fiber-optic cable, followed by evaluation of the reflected signal. Sound vibrations and vibrations cause changes in the intensity of the backscatter signal in real time (Fig. 1).

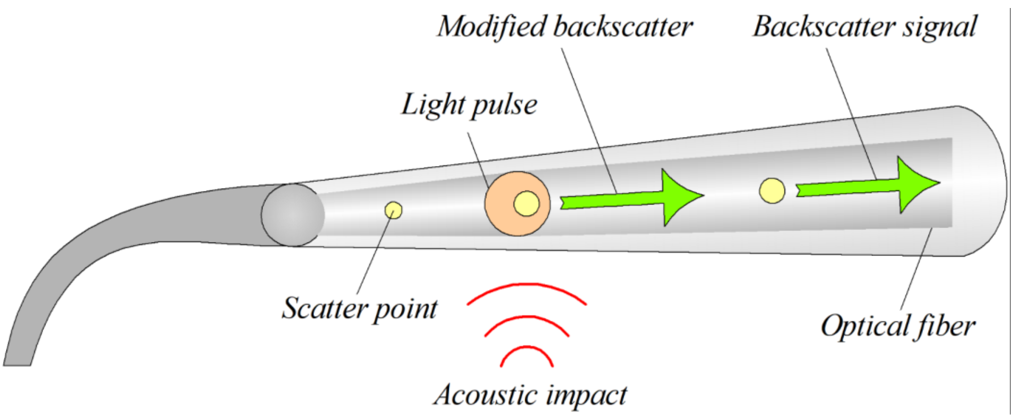

Fig. 1. Operating principle of distributed acoustic sensing

The reflected wavelength λB is affected by any variation in the physical or mechanical parameters of the Bragg grating. The essence of the phenomenon is expressed by an equation in which the first term shows the effect of stretching on λB, and the second – the effect of temperature on λB:

$$\Delta\lambda B = \lambda B \cdot (1 - \rho_\alpha) \cdot \Delta\varepsilon + \lambda B \cdot (\alpha + \xi) \cdot \Delta T, \quad (1)$$

where $\Delta\lambda B$ is the change in Bragg wavelength; ρ_α is the photoelasticity coefficient; α is the coefficient of thermal expansion; ξ is the thermo-optical coefficient of the fiber; $\Delta\varepsilon$ is the change in tension; ΔT is the temperature change.

In addition to temperature and strain, fiber Bragg gratings can be used to measure other physical quantities such as pressure, acceleration, displacement, etc. by integrating them into a sensor. The use of technical solutions based on the FBG fiber Bragg grating has confirmed the fundamental suitability of fiber optic technologies for distributed acoustic sensing (DAS), based on identifying changes in the reflections of light signals sent into a cable by a laser source. These changes are caused by the influence of external low-frequency acoustic signals on the cable. Coherent light pulses of a given frequency are sent by a laser source into a single-mode fiber and are partially reflected under the influence of natural external physical factors.

The intensity of the reflected signal depends on the time that has passed since the pulse was sent, which allows conclusions to be drawn about physical changes in certain sections of the optical fiber. These changes may be caused by structure-borne noise and vibrations near the fiber optic cable. Specially developed algorithms make it possible to classify the causes of changes based on the extraction of backscatter from the reflected signal. Thanks to this, the measured signals can be converted into useful information.

Using DAS technology, any single-mode fiber is converted into a series of virtual microphones arranged in series. By placing fiber optic cables along railway tracks, it becomes possible to continuously monitor the movement of trains. In the mode of monitoring the technical condition of rolling stock, continuous monitoring of the fracture of the wheel pair axle, monitoring of defects in the rolling surface of rolling stock wheels, fixation of breaks in the side frame of the carriage bogie, fixation of cracks in the rails are carried out. Using DAS system, can measure the speed of the train and weigh the cars while the train is moving.

Thus, the study of the processes of physical impact of influencing events on the change in the reflected wavelength in a fiber-optic cable shows the fundamental suitability of fiber-optic technologies for distributed acoustic sensing. The use of this technology on railway tracks will ensure accurate positioning of moving units in the coordinate-time system of disbanding and formation of trains, which will allow the implementation of a full-fledged digital model of the sorting process.

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ANALYSIS OF THE CURRENT STATE OF TELECOMMUNICATION NETWORK TOPOLOGIES

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Rapid growth in telecommunication systems, such as mobile communication, satellite communication, wireless networks like Wi-Fi and Wi-MAX, has created a significant challenge: virtually the entire frequency spectrum is already allocated, while the demand for data transmission continues to rise. Additionally, modern wireless devices interfere with each other, causing disruptions and competing for bandwidth. Unlike static traditional networks, cognitive telecommunications networks have dynamic topologies that can adapt based on spectrum availability, network congestion, user requirements, and environmental conditions. This adaptability helps optimize network performance and resource allocation [1].

Analyzing the topology of cognitive telecommunications networks involves understanding their configurational, operational, and technological aspects. Among the most promising topologies are:

1. Mesh topologies, which are particularly common in cognitive networks as they provide resilience, redundancy, and a high degree of connectivity between nodes, allowing for efficient data routing and rerouting based on changing network conditions. The network can compensate for the failure of one node through alternative connection paths via other nodes. Reducing the load on central nodes is achieved by allowing each node to cooperate directly with others, evenly distributing the workload. Greater flexibility and scalability,