Multifunctional fiber optic system for microwave signals transmitting in frequency range from 0.135 to 40 GHz

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Abstract. In article of the developed design of a fiber-optic system for transmitting microwave signals in radar is presented. The using the developed design of a fiber optic transmission system of microwave signal allows to increase the range of operating frequencies of the radar at least twice as well as its functional capabilities. The new method of realization design of a fiber optic transmission system of microwave signal is proposed. Its use allowed to reduce in the fiber optic system, the number of functional blocks in this frequency range of the radar work on the compared to previously used designs. The experimental research results are presented.

1. Introduction
Currently, the radar stations are actively used for the various tasks solution, for example, for investigation of the surface and the atmosphere of the Earth [1-5], for the determination of the moving objects position [6-9], for the information transmission [10-12], etc. In most cases, the switching connections (cables, feeder paths, etc.) are placed in the radar of the overactive interference zones of the various kind [7, 8, 9, 13-16]. Especially, in the case of restrictions with the space for the placing in the radar of the receiving and transmitting elements, for example, the mobile unit [10, 17, 18]. The using of the fiber optic communication lines (FOCL) is one solution to the problem [19-22]. In the past two decades, the FOCL is indispensable and most important elements in the various system information transmitting [19-26]. Depending on the location and method of the radar operating of structure and specifications FOCL are differed. The despite this, the basic principles for the FOCL implementation are remained the same [19-22, 27]. The main elements in the design of FOCLs are the transmitting laser module, the electro-optical modulator, the receiving module and the optical isolators [13-17]. The optical amplifiers may be used in the depending from the distance at which information are transmitting. The radar during the considering of the microwave and control signals transmission are the features number [14, 16, 17, 19-22]. Therefore, in the radar design during a transmission of the signals at the different frequencies are using the various optical elements and the additional assembly [28-34]. In case, the using them it is necessary take into consideration the radar operating conditions [16, 17, 19-22, 27].
As a result of the radar operation, we founded that the best characteristics for the microwave signal transmitting has a single mode fiber. Its used in various signal transmission systems with the FOCL has advantages and disadvantages [16, 17, 19-22]. These flaws are clearly manifested in new transmitting and receiving antennas operating in a wide range of microwave frequencies. These antennas have been developed in recent years based on new technologies and research. For modern radar is arisen a need in developed of the universal system for the microwave signals transmitting in the frequency range from 0.135 GHz to 40 with the using the FOCL.

The modular system design is consisting at 8 separate channels is presented on fig 1. Unlike FOCL is developed for the X-band [17, 21, 22], are changed only the frequency ranges. This makes it possible to use this circuit as a multi-function

The completed investigations by us shown that the system design for the microwave signals transmission is inefficient for the several reasons:

- The expensive optical elements while ensuring the operation of the system in a narrow frequency range, for example, 1-2 GHz.
- For each optical element or the block (there are several optical elements) need to ensure temperature stabilization in various operation areas.
- In the case of the using this design in the APAA, moving objects (where there are restrictions on the volume and weight of the blocks and temperature stabilization is necessary), problems arise.

![Figure 1](image.png)

**Figure 1.** The diagram of a fiber optic microwave signal transmission line in a radar frequency range from 0.135 to 40 GHz.

2. The multifunctional design of the fiber-optic system for transmitting microwave signals and the features of its operation

The completed investigations by us shown that the used of direct and external modulation does not influence the amplitude-frequency characteristic (AFC) of FOCL frequency range from 0.135 to 2.0 GHz during a transmission of the microwave signal. Moreover, the lack in the FOCL channel of the electrooptical modulator reduces to 20 – 25 % of the optical signal loss (attenuation). Therefore, in new design of FOST should be used the transmitter module with direct modulation and merge two channels into one (from 0.135 to 2.0 GHz). The new design of FOTS for the microwave signals transmitting is presented on fig.2.

It is also possible taking into account features of the electrooptical modulators into a single channel with a frequency range from 2 GHz to 8 and from 8 - 18 GHz to convert other channels. By using the optical divider 5 (fig. 2) was reduced number of laser transmitter modules to two. The new design FOST of the number electrooptic modulator (EOM) decreased from eight to 5.
The reducing of the EOM number is decreased the size and weight of the thermal stabilization system, as well as its cost. The operating point of each modulator is different. Therefore, each EOM needs its thermal stabilization system with the working point adjusting, and each needs its own EOM. The reducing the number of EON allows to decrease the number of photodetectors to 5. For stable operation of the photodetectors is also needed the thermal stabilization system [36, 37].

![Figure 2](image_url) A new diagram of a fiber-optic signal transmission line in the frequency range from 0.135 to 40 GHz: 1 and 2 microwave channel switches; 3 - transmitting laser modules; 4 - optical isolator; 5 - transmitting laser module; 6 - electro-optical modulator; 7 – photo detector module; 8 - amplifier.

Since the transmission distance is not more than 300 m of the signal, such a construction design FOST is justified. The losses in the optical fiber at such distances are insignificant. The different types of dispersions do not have time to form on bending the optical fiber due to the small propagation time. The important characteristics in this case are the spectral purity of the transmitted signal and the value of the temperature maintenance phase modulation optical signal during propagation in the fiber.

3. The results of experimental studies and discussion

The operating experience of the radar with the FOCL showed that distortions in the spectrum, in some cases [7, 8, 9, 13-16, 20, 21], the transmitted signal can lead to loss of control or to errors in determining the position coordinates of the object. As an example, one of the investigation results of the microwave signal transmission of the optical channel in the frequency range from 0.135 to 2.0 GHz is presented on fig. 3.

A comparison of the spectra (fig. 3), we can note the high efficiency of the transmission oscillator signal at the carrier frequency. The distortions in the spectrum are present only on the sides of components which do not affect the determination of the distance accuracy.

The developed of FOST is designed for a radar that will operate in various temperature conditions. As a result of the change in ambient temperature changes the refractive index of the fiber (fiber elongation due to thermal expansion or contraction when cold). This leads a change of the modulation phase of the radiation is transmitted through the fiber. Therefore, we performed an experimental assessment of the temperature change in the modulation phase of the optical signal during its propagation to optical fiber. The experimental dependence of the phase shift modulation $\Delta \phi_m$ laser radiation to the ambient temperature $T$ is presented on fig 4.

The obtained results showed that the change of phase modulation in the fiber G.657 of no more than 3.0 degrees in a selected temperature range from 213.1 to 323.3 K for different signal transmission frequencies. A less than 120 m of the optical fiber the influence of the change $\Delta \phi_m$ on the amplitude and frequency characteristics of the transmission signal will be negligible.
4. Conclusion
The results obtained showed that the design of the FOST developed by us can be successfully operated as part of the radar in the various climatic conditions. On the basis of the conducted investigations was obtained the confirmation of the proposed design solutions proposed and implemented by us in the manufactured FOST.

Also, it was found that the newly developed design of FOST of the technical characteristics (dynamic range, transmission ratio, etc.) are not deteriorated. In some cases, we get them improved. This allows to expand the tasks number which can be solved during the of the developed FOST in the radar.

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