New design of fiber-optic communication line for the transmission of microwave signals in the X-band

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Abstract. In the article a new design of a fiber-optic communication line for microwave transmission between devices in a radar station is considered. New designing solutions for the developed fiber-optic communication line are proposed. The results of experimental research are represented.

1. Introduction

In the modern world, there is a constant improvement and development of the various technical vehicles for movement (aircraft, helicopters, ships, etc.). For them determination and identification it is necessary constantly to improve different systems and devices. Radar stations occupy the leading positions in the detection of various objects [1-3]. Always, the development of technology creates the during a various devices exploitation at new problems and complicates the existing. The transmission without distortion of microwave signals between different devices, which are included in the complete set of station, is one of the actual tasks [1-6]. This task is necessary to solve at exploitation of radar stations (RS) in conditions of high level of electromagnetic interference. The greatest number of problems in the transmission of microwave signals occur in the case of placing a radar on a maritime facility (for example, a warship). In this case, the connecting cables through which the signals are transmitted pass through various zones saturated with both interference and sharp turns. Therefore, at transmitting signals in the radar design it is necessary to take into account the specificity of the object on which it is located. In the radar for transmission of signals of different frequencies are used coaxial cables, waveguides and fiber-optic communication lines (FOCL). The using is determined the solved tasks and operating conditions RS. Recently, for carrying out research activities and solving other tasks, the radars on ships are equipped with a large number of radio electronic equipment. It should be noted that the receiving and transmitting modules of the radar should be located compactly on the upper decks of the ship mast racks. In addition, the platforms on which the antennas and locators are placed must be able to perform rotations and scanning movements at various angles at a certain speed. These platforms are located on the upper decks of the ship. Such stringent requirements forced to review the system of signal transmission from the receiving and transmitting devices to the hull of the ship and back. In the ship hull are located the devices for signal processing and work control of radar.
One of the most promising directions for solving this problem is using fiber-optic communication lines for signal transmission. The FOLC have indisputable advantages compared to unlike coaxial cables and waveguides [5-10]. Such advantages are the wide bandwidth (for singlemode fiber it is up to 50 GHz); independence of the magnitude of optical fiber losses from the frequency of transmitted microwave signals; etc. [7-12].

The special attention during the development of new and modernization of existing radars is paid to increase the reliability of the station work while increasing the speed of information transfer between various devices which are included in station structure [5, 12, 13]. The performed experiments showed that at present time at high speeds and volumes of information transmission this task solved extremely difficult without the use of FOLC. Experience in the operation of the radar has shown that a certain design of the station requires the development of a new FOLC. In the structure of this FOLC should take into peculiarities of radar exploitation. And also the frequency diapason in which the radar operates. The presented work for a sea-based radar with separated antennas for radiation and reception is considering the development of a new design a FOCL for the transmission of microwave signals in X-band.

2. Construction of fiber-optic communication line and features of its operation

A feature of exploitation of sea-based radar (for which a FOLC is being developed) that in this station is used a high-power parabolic antenna with a wide directional pattern for microwave signal emission. Reflected signals from various objects are received in a non-periodic sequence by the receiving antenna. It should be noted that receiving device receives in addition to the reflected main signal from the object there are also different mirror signals. The mirror signals are formed a result of reflections, for example, from the sea surface. In addition, a radiation pattern of a parabolic antenna simultaneously irradiates several objects. Often a signal is reflected from one object to another. Then this signal goes to the receiving antenna. If in communication channels during transmitting such signals there will be additional interference, then processing the information will be extremely difficult.

Another feature of the FOCL data design is that the microwave signal must transmitted for distances not exceeding 100 m. Losses in the amplitude of the signal with its attenuation can be considered not essential. Because of low propagation time of the signal through the optical fiber, different types of dispersion introduce slight distortions into its form [13]. The phase shift in the transmitted optical signal can be only due to fluctuations in the temperature $T$ of the fiber $[4, 7]$.

The figure 1 shows the structural diagram, developed FOLC design by us (based on the conducted researches) for the solution of approved task (transmission of microwave signals in the frequency range 8-12 GHz).

![Figure 1](image-url)  
**Figure 1.** Structural diagram of the fiber optic transmission line layout: 1, 7 - low noise amplifiers, 2 - power supply unit, 3 - transmitting optical module, 4 - power driver of the transmitting optical module, 5 - optical isolator, 6 - receiving optical module, 8, 9 - power supplies

The main components of FOCL are 3 and 6. The optical transmission module 3 consists of: a laser diode based on InGaAsP / InP nanoheterostructures and a wavelength of 1550 nm generation with fiber-optic emission; electro-optical Mach-Zehnder modulator based on LiNbO$_3$; matching microwave device; control board and stabilization of the operating points of the laser diode and electro-optical modulator. It also includes an input coaxial microwave connector and an output optical connector. The receiving optical module 6 consists of: an InGaAsP / InP photodiode with fiber-optic radiation input;
buffer GaAs power amplifier; matching microwave device; a power amplifier that provides the required transmission factor; output coaxial microwave connector and input optical connector. Since the optical fiber has bends, when it is laid along the ship, an optical isolator 5 is installed. It prevents the optical signal reflected on the fiber bends from entering the transmitting module 3. The optical isolator and receiver module were connected to each other by an 80 m long fiber-optic FC / APC-FC / APC cable. The figure 2 shows the appearance of our FOCL.

![Figure 2. The Fiber-optic communication line for microwave signal transmission in X-band](image_url)

The during designing FOCL the advantage was given to the domestic element base, if the following condition is satisfied: domestic components are not inferior in performance to imported analogues. All elements of FOLC, including power supplies, will placed in shielded corps, as they have to work in a complex electromagnetic environment.

### 3. Results of experimental studies and their discussion.

One of the most important parameters of any developed FOCL design for microwave signals transmission is its amplitude-frequency characteristic (AFC). The figure 3 the AFC of developed FOCL by us at a temperature $T = 291.2$ K is presented.
The analysis of the obtained results showed that the unevenness of the amplitude-frequency characteristic is of the order of 8 dB in the entire X-band. It allows transmitting over a FOCL of received reflected signals from various objects with a high degree of reliability. Another important characteristic in microwave signals transmission over a FOCL is the tangential sensitivity of the receiving device antenna $G_t$ from the microwave signal frequency. In figure 4, as an example, this dependence at $T = 292.3 \, \text{K}$ is represented.
The received result shows that the sensitivity of the receiving device has not changed significantly when connected to it for transmission of the signal developed by us FOCL. This allows in some cases, when transmitting the microwave signal, to exclude the low-noise amplifier 1 (figure 1) from the design of the receiving antenna part into which includes the FOCL. The receiving antenna part is placing on the upper deck of the mast pillar. The experiments showed that in conditions of an increased level of electromagnetic interference the low-noise amplifier could carry the additional distortions in the transmitted signal.

Since the fiber-optic communication line is designed for operation at sea-based stations, possibility of operation in different temperature ranges must be envisaged. Changes in temperature of the environment cause variations in the index of refraction of the fiber and an increase in the fiber length due to thermal expansion. This leads to a change in the light phase and, hence, a change in the modulation phase of the radiation transmitted through the fiber. For this reason, the experimental estimation of the temperature-induced shift of the modulation phase in the fiber was carried out.

The figure 5 shows the experimental dependence of the phase shift of light modulation $\Delta\varphi_m$ on the ambient temperature $T$.

![Figure 5. The shift of the phase of modulation $\Delta\varphi_m$ from the temperature T](image)

The results of research showed that the temperature dependence of the modulation phase change for the Corning SMF-28e fiber was about 6 degrees in the selected temperature range from $-50$ to $+60$ °C. The influence of this phase shift on the frequency and amplitude characteristics of the transmitted optical signal will be insignificant for the distance of the optical fiber is less than 100 m.

4. Conclusion

The obtained results show that the developed new FOCL design for sea-based radar is efficient and can reliably transmit microwave signals. The design solutions proposed on the basis the make research which using in its manufacture are justified.

In addition, we found that in the developed new FOCL design the dependence of signal power on the output of the system from the signal power at its input is linear from level $-140$ dBm to level $-16$ dBm. It allows drawing a conclusion that the dynamic range (DR) of developed FOCL exceeds 110 dB.

The obtained DR value for FOCL is comparable to the DR of the coaxial cable. The value DR for FOCL differs from the coaxial cable in that is non-dispersivity (no increase in losses with increasing frequency of the transmitted microwave signal). The FOCL noise factor is $10–12$ dB. Compensation of the noise factor by amplification on the microwave, which used in various devices, is not required for this design.
5. References

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