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Fiber-optic system development for the output frequency setting of a voltage-controlled oscillator at the radar station antenna complex

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Abstract. The necessity of introducing fiber-optic communication lines for the frequency tuning codes transmission and frequency regulation is substantiated. A new scheme is presented for constructing the radar station radiation path in the range from 1 to 18 GHz. A functional expansion of the radar station capabilities is presented through the introduction of a modernized radiation path and the study of radiation formations. Fiber-optic lines investigations have been carried out in terms of launching frequency codes and a control channel. The corresponding characteristics have been given.

Keywords: Fiber optic communication line, microwave signal, radar station, radiation monitoring, voltage controlled oscillator

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Материалы конференции
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Разработка волоконно-оптической системы для управления и контроля частоты генератора, управляемого напряжением в антенном комплексе радиолокационной станции

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Аннотация. Обоснована необходимость внедрения волоконно-оптических линий связи для передачи частотных кодов настройки и частотного регулирования. Представлена новая схема построения тракта излучения радиолокационной станции в диапазоне от 1 до 18 ГГц. Представлено функциональное расширение возможностей радиолокационной станции за счет внедрения модернизированного тракта излучения и исследования радиационных образований. Проведены исследования волоконно-оптических линий в части запуска кодов частоты и канала контроля, приведены соответствующие характеристики.

Ключевые слова: волоконно-оптическая линия связи, СВЧ сигнал, радиолокационная станция, радиационный контроль, генератор управляемый напряжением

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Introduction

Much attention is paid to monitoring the airspace and environment state in the modern world [1–3]. A large number of different instruments and devices have been developed to solve these problems [3–6]. Most of these devices have a number of disadvantages that are associated with weather factors, detection range, and others, especially for the airspace state monitoring [6–9]. The radar station usage eliminates many of these shortcomings. Therefore, increased attention is paid to the radar station development and modernization [6, 7, 9–13]. One of the radar development areas is the expansion of its functionality to the airspace state control [6, 10, 11, 13–15].

The operation of any nuclear power plant results in the release of radioactive isotopes through ventilation systems into the air [3, 6, 8]. The reflected microwave signal is associated with the natural radionuclide isotopes resonant frequencies (for example, ^{131}I, ^{16}N, ^{133}Xe, ^{88}Kr and others). It is required to ensure a change in the microwave frequency f_{SHF} of the radar microwave signal radiation in the range of all radionuclide natural frequencies. The microwave radiation frequency f_{SHF} varies in the range from 1 to 18 GHz, providing the same power level over the entire frequency range for plasmoid research. Therefore, the article goal is new fiber-optic communication line (FOCL) design development for controlling and monitoring voltage-controlled oscillator (VCO) frequency changes in the range from 1 to 18 GHz.

Materials and Methods

The stationary post includes equipment for processing and generating commands. A microwave signal is transmitted from it to the antenna. The distance between them is from 50 to 2000 meters. The FOCL can be placed in various temperature conditions, areas of increased electromagnetic activity, areas with γ-radiation, etc. Fig. 1 shows a block diagram of the two-channel FOCL developed by us for solving problems of controlling f_{SHF} in the VCO and controlling its nominal value.

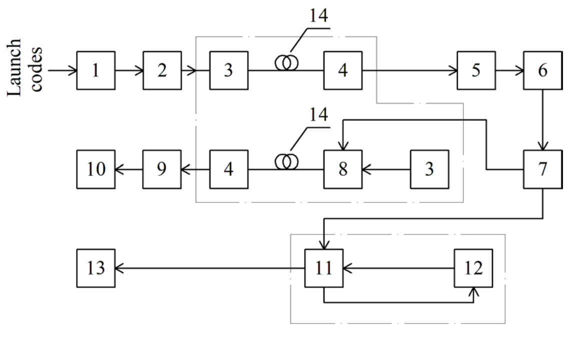

Fig. 1. Block diagram of the two-channel FOCL for VCO frequency monitoring and control:
Read Only Memory (ROM) 1; digital-to-analog converter (DAC) 2; laser module with direct modulation 3; photodetector module 4; low-noise amplifier 5 based on an operational amplifier (LNA); voltage controlled analog oscillator 6; 1:4 power divider 7; electro-optical modulator 8; analog-to-digital converter (ADC) 9; indication and control device 10; amplifier 11; bandpass filter 12 in the feedback circuit of the amplifier; short emitter-dipole 13 of a parabolic antenna; single-mode optical fiber *14*

The designer loads special codes into the memory device (1) during the development and manufacture of the radar transmitting path in this work. The launch codes are applied to VCO to generate a signal of a certain frequency f_{SHF} in the range from 1 to 18 GHz with a given step. These frequency codes are unique for the developed FOCL, are loaded on a permanent basis and remain unchanged during the FOCL operation. The frequency codes usage makes it possible to set a master signal stable frequency. The launch codes are sent in turn to the DAC (2). An analog signal is formed for a given frequency at the output (2). It is necessary to transmit the signal to the antenna complex. This construction is located at a distance of 50 to 2000 meters from the premises with the installed equipment. The trajectory of the line and the features of its laying are taken into account on development stage. It is possible to increase the distance. Typical construction length of solid fiber is 2, 3, 4 and 10 km. There is no big problem to have such path length. A single-mode fiber of the G.652 standard is used with a core doped with 2% germanium oxide GeO_2 to microwave signal transmit. The power loss is 0.32 dB/km at λ = 1310 nm. Therefore, the margin is more than sufficient to signal transmit. The analog signal is fed to the laser module 3 with direct modulation of the pump current. The optical signal is fed through the fiber 14 to the antenna complex (to the input of the photodetector module 4).

Results and Discussion

The studies were carried out for two channels of the developed FOCL under laboratory conditions with different characteristics. Fig. 2 shows the FOCL frequency response.

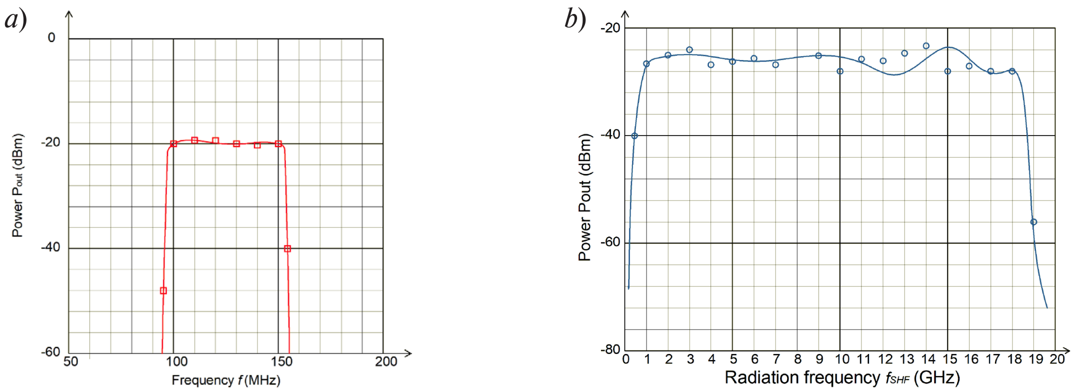

Fig. 2. Frequency response of the FOCL for the frequency code transmission channel (*a*) and the radiation frequency f_{SHF} control channel (*b*)

Analysis of the obtained results shows that the frequency code transmission channel characteristic unevenness is 3–6 dB at a radiation frequency f_{SHF} up to 18 GHz (Fig. 2,*b*). This fact confirms the high degree of the reliability of signal transmission over FOCL. The uneven characteristics of the code transmission channel is less than 1 dB, which ensures high information transmission stability (Fig. 2,*a*).

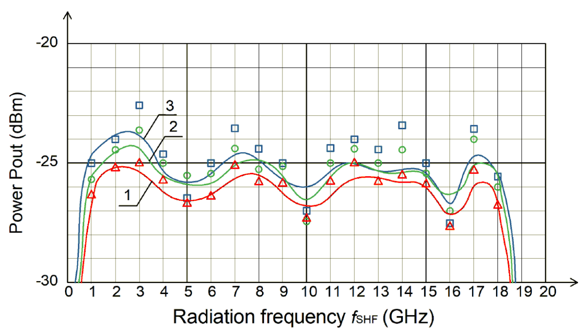

Fig. 3. Frequency response of the FOCL frequency control channel f_{SHF} for various temperatures *T*. Graphs *1, 2* and *3* correspond to the following temperature values *T* in °C: −23; −5; 27

An analysis was made of the temperature factor influence on the channel for controlling the radiation frequency f_{SHF} in the research course. Fig. 3 shows the amplitude-frequency characteristics of the FOCL at three temperatures.

The obtained data analysis showed that the temperature factor has practically no effect on signal transmission over FOCL. Temperature shift is about 0.5 dB. Stable operation of the frequency control channel is maintained in the operating range of the FOCL. A similar situation applies to the code transmission channel.

Conclusion

The obtained results show the reliability of the developed two-channel FOCL to provide the necessary operating mode of the radiating antenna in each frequency range and to conduct research on radioactive formations.

The introduction of an additional control channel on the FOCL makes it possible to control the radar transmitting path operability, serviceability of the frequency generation system by means of the VCO, and to determine the exact value of the steady-state radiation frequency f_{SHF} for atmospheric research. It becomes possible to localize weak reflected signals from supposed ionization radiations formed as a result of the ingress of radioactive elements into the atmosphere, and to establish a possible type of particles, since the microwave signal reflected at different frequencies f_{SHF} is closely related to the natural frequencies of radionuclide isotopes that have entered the atmosphere.

The obtained results show that the FOCL developed design allows to control the operation of the antenna complex radiator at distances of the order of 100 km. It is especially important for work in the areas of the far north.

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