Observation of short-wave radio signals reflected and scattered by the ionosphere and the earth's surface, at the test site of the Moscow State University

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Abstract. The problem of remote diagnostics of a "rough" earth surface and dielectric subsurface structures in the shortwave radio wave band is considered. A new incoherent method for estimating the signal-to-noise parameter is proposed. The idea of the method for determining this parameter is that, by having synchronous information about a wave reflected from the ionosphere and about a wave reflected from the earth and the ionosphere (or having passed the ionosphere twice when probing from a satellite), it is possible to extract information about the scattering parameter. The paper presents the results of recording the quadrature components of the signal by means of the ground measuring complex of installation of coherent sounding in the short-wave range of radio waves at the test site of the Moscow State University (Moscow). A comparative analysis is performed and it is shown that according to the analytical (relative) accuracy of the definition of this parameter the new method is an order of magnitude larger than the widely used standard method. Analysis of the analytical errors in the estimation of this parameter allowed us to recommend a new method instead of the standard one. The software for synchronous registration of quadrature components of radio signals of various multiplicities in real time with the formation of a database of experimental data was developed, successfully tested and patented; one of the functions of the software is to protect the computer system from the powerful radiating pulse of the radio transmitter.

1. Introduction

Parameter of returned partially scattered ionospheric signal $\beta_K$ is of interest to an important characteristic of the "perturbation" and "turbidity" of statistically inhomogeneous ionospheric plasma and to the work index of reliability of ionospheric communication channels including diagnostic one [3]. Prompt and reliable estimate of the parameter $\beta_K$ is of interest to radio physics, geophysics, and optics. Specification for ionospheric case is implemented [6].

This range allows us to diagnose subsurface layers of the earth because the scattering parameter is formed by inhomogeneities in the dielectric permittivity of the subsurface structures [11].

The problem of measuring and accounting of the scattering power of the earth's surface in the short-wave range of radio waves is important for solving such challenges as diagnosing properties of the environment using methods that apply this radio band, when in the channel there is an intermediate
reflection (scattering) of the earth's surface, which is of interest for exploration and environmental studies [12].

Selection of the working sensing range and the impact of environment on the passing radiation are an important issues for using space-based tools, for environmental management and environmental monitoring [14].

The most important aspects of using space-based tools for environmental management and environmental monitoring are the choice of the operating range and probing questions about the influence of media on the passing radiation [16]. The problem of this discussion is the "rough" remote diagnostics of the earth's surface and subsurface of the dielectric structures in the SW range [10]. Selection of SW range takes into account the subsurface layer (thickness of the order of the wavelength of the incident signal). Interpretation of the data is based on a statistical multiplicative model of the signal. Testing the method of obtaining a signal/noise ratio in this model was produced by the example of a double reflection of the probe signal from the SW ionosphere in a vertical sounding (remember that when using a satellite, the signal passes twice through the atmosphere and ionosphere) [8]. The work addressed issues of sensitivity of the model parameters that were studied [4].

The measurement, mapping, and computation of the "rough" Earth Surface Scattering Power (ESSP) in the SW range are of interest for a set of problems (communication, geology, etc.) [7]. The ESSP parameter is the signal/noise ratio of the $\beta_K$ waves reflected from the earth's "rough" backing. There is the back of the $\beta_K$ -data and measuring method is in SW range. The paper [20] presents the experimental method of $\beta_K$ determination.

In this paper, this method is tested on the parameter of $\beta_K$ sensitivity. According to the statistical model (SM), a database ("records" for the numerical experiment) adequate to the real conditions was created. The properties of the "rough" earth area were defined by the theoretical $\beta_K$ value. Based on the method of [4], $\beta_K$ (numerical experiment) was determined. Then, the arrays of the $\beta_K$ and $\beta_K^c$ were compared and analyzed. In this paper, the admissible sensitivity and stability of the method were justified. The comparative analysis of the real experimental data and adequate numerical ones were fulfilled. As a result, the plausibility of the ionosphere echo statistical structures used were justified [13].

In this paper, we propose a new method for estimating the parameters of the noncoherent signal/noise ratio $\beta_K$ ionospheric echo. A comparative analysis shows that the analytical (relative) accuracy of the determination of the parameter $\beta_K$ using the new method exceeds the widely-used standard, and the same order of known coherent methodology [9]. The paper presents the results of comparison of the measurement method from the point of view of their admissible relative analytical errors [15]. The new method is suggested.

2. **Calculation methods**

Narrowband random process $E(t)$ in fixed point of reception in the ground in scalar approximation is the superposition of mirror $E_c(t)$ and scattered $E_s(t)$ components distributed by the normal law [1]:

$$E(t) = E_c(t) + E_s(t) = E_{00} e^{i(\omega_0 t - \phi(t))} + E_s(t) = R(t) e^{i(\omega_0 t - \phi(t))} = E_c(t) + i \cdot E_s(t) \cdot e^{i\omega_0 t}, \quad (1)$$

where $\phi(t)$, $\Phi(t)$, $R(t)$, $E_{md}(t)$, $m$=c,s – shown to slow random processes on the period $T = \frac{2\pi}{\omega_0}$; $E_{00}$ = Const.

Scattering parameter is the ratio:

$$\beta_K^2 = \frac{\text{power of mirror components}}{\text{power of scattered components}} = \frac{E_{00}^2}{2 \cdot E_s^2}. \quad (2)$$

Here and below, “—” means statistical averaging. $E_c(t) = R(t) \cos \Phi(t)$ and $E_s(t) = R(t) \sin \Phi(t)$ are the low-frequency quadrature of the ionospheric signal, $R(t)$ is the envelope, $\Phi(t)$ is the total phase.
The subscript \( k \) = E4, R2, R4 means experimentally recorded primary random processes, and the appropriate method of their registration: E4 – coherent; R2, R4 – noncoherent amplitude. Index \( k \) indicates the primary parameter recorded: E – quadrature, R – envelope of the ionospheric signal.

Standard noncoherent R2-method based on the relationship (3) is widely used for estimating \( \beta_k \) (2) [1]:

\[
\frac{R^2}{\langle R \rangle^2} = f(\beta_{k2}) = \frac{4}{\pi} \left[ \frac{1}{(1+\beta_{k2})^2} \cdot \text{exp}\left( \frac{\beta_{k2}}{1+\beta_{k2}} \right) \langle \beta_{k2}^2 \rangle \right], \quad \text{if} \quad 1 < \frac{R^2}{\langle R \rangle^2} \leq 4. \tag{3}
\]

\( I_n(x) \) is the Bessel function of the \( n \)th order of a purely imaginary argument.

Using the coherent E4-method and estimating \( \beta_{E4} \) by \( \gamma_{E4} \) kurtosis of quadrature [9]:

\[
\gamma_{E4}(\beta_{E4}) = \frac{E^4_{m}}{(E^2_{m})^2} - 3 = -\frac{3}{2} \frac{\beta_{E4}^2}{(1+\beta_{E4})^2}, \quad m = e, s, \quad \text{if} \quad 1 < \frac{R^2}{\langle R \rangle^2} \leq 2. \tag{4}
\]

It should be noted that the measured primary parameters are the ratio of moments \( \frac{R^2}{\langle R \rangle^2} \), \( \frac{E^4_{m}}{(E^2_{m})^2} \) respectively. Relations (3), (4) are obtained by taking into account the specific models of structure of the ionospheric signal [17].

Probabilistic properties of the ionospheric signal (1) of the first multiplicity response is well described by the Rice model with a displaced spectrum (RS-model). Expressions (3) and (4) are obtained based on the Rice model with a displaced spectrum [18].

A priori expression (4) of coherent method E4 contributes an order of magnitude higher relative analytical accuracy of the estimation of parameter \( \beta_k \).

In this paper, we propose a new noncoherent R4-method of determination of \( \beta_{R4} \) by \( \gamma_{R4} \) kurtosis of the envelope for the RS-model:

\[
\gamma_{R4}(\beta_{R4}) = \frac{R^4}{\langle R \rangle^4} - 3 = -1 - \frac{\beta_{R4}^2}{(1+\beta_{R4})^2}, \quad \text{if} \quad 1 < \frac{R^2}{\langle R \rangle^2} \leq 2. \tag{5}
\]

For comparison of the given methods in the sense of relative errors permitted in calculating \( \beta_k \), due to their functional dependencies \( f(\beta) \), \( \gamma_{E4}(\beta) \) and \( \gamma_{R4}(\beta) \), we obtain the following expressions (6) [19]:

\[
\varepsilon_k = \frac{\Delta \beta_k}{\beta_k} \geq \frac{1}{\beta_k} \frac{dG_k}{dZ_k} \cdot \Delta(Z_k), \quad Z_k = \frac{R^2}{\langle R \rangle^2}, \quad \frac{E^2_{m}}{(E^2_{m})^2}, \quad \frac{R^2}{\langle R \rangle^2}. \tag{6}
\]

where \( K = R2, E4, R4; G_k = f; \gamma_{E4, R4}; \) and \( \Delta(Z_k) \) – absolute statistical errors of measured values.

Measures of inaccuracy, including statistics for the different techniques of determination of \( \beta_k \), are [22]:

\[
\varepsilon_{R2}(\beta) = \frac{\pi}{8} \frac{\left[ (1+\beta^2) \cdot I_m(\beta^2/2) + \beta^2 \cdot I_1(\beta^2/2) \right]}{\beta^2 \cdot \text{exp}(\beta^2/2) \cdot I_1(\beta^2/2)} \cdot \Delta(Z_{R2});
\]

\[
\varepsilon_{E4}(\beta) = \frac{(1+\beta^2)^3}{6 \cdot \beta^4} \cdot \Delta(Z_{E4});
\]

\[
\varepsilon_{R4}(\beta) = \frac{(1+\beta^2)^3}{4 \cdot \beta^4} \cdot \Delta(Z_{R4}). \tag{7}
\]

Statistical error \( \Delta(Z_k) \) depends on the sample volume \( N \). It may be different for identical sample volume for each of the methods. We normalize (7) on \( \Delta(Z_k) \) for focusing on the errors due to differences in functional dependencies (3)–(5) [25].

Dependency Graphs \( \varepsilon_k^* = \frac{\varepsilon_k}{\Delta(Z_k)} \) for \( \beta_{R2} \), \( \beta_{E4} \) and \( \beta_{R4} \) are shown in figure 1. \( \varepsilon_k^* \) will be called analytic (relative) error method.
Figure 1. Dependency Graphs $\varepsilon_k^*$, $K = R2, R4, E4$ (solid curves) and the experimental distribution $W_3(\beta)$ (dashed curve) (F2-layer, 4.5 – 9.5 MHz, single signal).

Experimental distribution $W_3(\beta)$ determines the range of variation of $\beta$ [9]. From equation (4) and (5), we conclude that $\varepsilon_{R4}^* = \frac{2}{3} \varepsilon_{R4}^*$ have the same order and significantly (by order) exceed the measurement accuracy of the standard $R2$-method [1].

Analysis of analytical error of estimation of the parameter $\beta_K$ allowed us to recommend the $R4$-method instead of the standard $R2$-method [1]. A sufficiently high analytical (relative) accuracy of parameter estimation for $\beta_K$ can be achieved using a noncoherent apparatus applying (5) the $R4$-method. Naturally, the ability to optimize the statistical error by the relevant special digital processing of ionospheric signal is keep on coherent methodology $E4$ [2].

The comparative analysis of the normalized relative analytical errors $\varepsilon_k^*$ of the known methods and the new one was performed. It was shown that errors $\varepsilon_{E}^*$ and $\varepsilon_{R4}^*$ have the same order, and both errors significantly exceed the error $\varepsilon_{R2}^*$ in comparison with the standard $R2$-method by a measurement accuracy of $\beta_K$.

Environmental monitoring of the earth's surface by remote sensing in the short-wave band can provide quick identification of some ecological characteristics for the purposes of control and management in the fields of Environment [23]. This band range allows one to diagnose subsurface aspects of the earth, as the scattering parameter is affected by irregularities in the dielectric permittivity of subsurface structures [24]. This method based on the organization of the monitoring probe may detect changes in these environments, for example, to assess seismic hazard and seismic risk. The problem of measuring and accounting for the scattering power of the earth's surface in the short range of radio waves is important for a number of purposes, such as diagnosing properties of the medium using this radio band when going on the road to interpret the intermediate reflection (scattering) from the earth's surface, which is of interest for geological and environmental studies [21].

As a result, it was found that sufficient $\beta_K$ analytical measurement accuracy can be achieved when using an noncoherent apparatus applying a new $R4$-method. But the coherent $E4$-method reserves the possibility of statistical error optimization with a special processing of the ionospheric signal [2].

Let us consider in more detail the essence of the proposed method. If the equipment is incoherent or there are records only of the envelope of the signal R(t). (Example: an AI – 804 ionosonde produces only R(t)), and non-coherent instrumentation does not, in principle, provide registration of the phase F(t). Then in these cases it is generally impossible to apply the coherent $E4$-method and it is impossible to reconstruct the quadrature $E_c = R(t)\cos \Phi(t)$, since there are no records of the phase $\Phi(t)$. In these cases, it remains to apply only the methods on the envelope: either $R2$ or $R4$. There is an alternative: either the $R2$-method, using cumbersome Bessel functions that are not always convenient for calculations, or the new proposed $R4$-method without such functions, and, moreover, by analytic accuracy by an order of magnitude superior to the standard $R2$-method and one order with the coherent $R4$-method. In addition, there may be situations when the $R2$-method is not applicable: if the conditions for its applicability are violated (3). Also, when using coherent registration of signals, there are cases when the $E4$-method cannot be used due to violation of its applicability conditions (4).
And in this case, the proposed $R_4$-method can also be used to process the recorded signal.

The article discusses three methods: $R_2$, $R_4$ and $E_4$ to determine the characteristics of a scattering (reflective) screen, which are both the ionosphere and the earth's surface, as well as its subsurface layer to a depth of the order of the wavelength, which also participates in the formation of the reflected radio signal, and therefore, it carries information about the characteristics of the subsurface structures of the scattering layer. The three methods listed can equally be used to calculate the parameter of the $\beta_{\text{ionosphere}}$ or $\beta_{\text{зем}}$.

For reflections of multiplicity above the first ($n > 1$), the standard methods in variants (3), (4) and (5) are not applicable, since the statistics of the signal of multiplicity $n > 1$ are not described by the RS-model. For this case, the statistical multiplicative multiple reflection model (SM-model) is used.

According to the provisions of the SM-model, the complex amplitude of the $E_5(t)$ field of a radio signal, twice reflected from the ionosphere and once from the earth screen, at the earth's surface can be represented as a probability multiplicative relationship:

$$
E_5(t) = \frac{E_{11}(t) \cdot E_{\text{зем}}(t) \cdot E_{12}(t)}{A^2}, \quad R_s^2 = \frac{R_{11}^n \cdot R_{12}^n \cdot R_{11m}^n}{A^2}; \quad E_{1m}^n = \frac{E_{11m}^n \cdot E_{12m}^n \cdot E_{12w}^n}{A^2}; \quad m = \text{c,s}; \quad n = 1,2,3,... (8)
$$

where $A$ is the normalization constant (amplitude of a plane wave), and $E_{11}(t)$, $E_{1\text{зем}}(t)$, $E_{12}(t)$ are the complex amplitudes of the one-time reflected random fields on the $j$-th hop ($j=1$, “зем.””, 2; $E_{11}(t) = E_{11}(t)$) when falling on the corresponding screen of the probe wave: $A \cdot \exp[i \cdot k \cdot \mathbf{r} - i \cdot \omega_0 \cdot t]$. These amplitudes in the probabilistic sense are adequate to the modulation functions of the corresponding random diffraction screens. In the notation used, the first index indicates that this value refers to one jump, and the second index indicates the sequence number of the jump at multiple reflection.

With known statistics and independence of the processes $E_{11}(t)$ (and, consequently, the quadrature $E_{1jm}(t)$, $m = \text{c,s}$ and envelopes $R_j(t)$, $j = 1$, “зем.””, 2), the SM-model allows determining the statistical characteristics processes $E_{2m}(t)$; $R_s(t)$; $\Phi(t)$ for doubly reflected signals. It is obvious that the moments of the envelopes $R_{a0}(t)$ and quadrature components $E_{ajm}(t)$ ($n = 1,2,3,..$; $m = \text{c,s}$) obey relations (8).

As a result, registering fluctuations of the fields $E_5(t)$ and $E_5(t)$ and assuming that under conditions of vertical sounding, the regions of formation of reflections of various multiplicity are statistically equivalent ($\beta_{11} = \beta_{12} = \beta_1$), and the “rough” earth screen applies RS-model (there is reason to believe that the structure of a decameter radio signal, once scattered only by the earth's surface, is also of a Gaussian type [11]), it becomes possible to extract the desired parameter of the scattering power of the earth's surface. Based on ratios [20]:

$$
a) \text{on the envelope method } R_2: \quad f(\beta_{1\text{зем},R_2}) = \left( \frac{R_s^2}{R_2^2} \right)^2 \left( \frac{R_1^2}{R_1} \right)^2 ;
$$

$$
b) \text{on the quadratur method } E_4: \quad \gamma(\beta_{1\text{зем},E_4}) + 3 = \left( \frac{E_{2m}^4}{E_{2m}^2} \right)^2 \left( \frac{E_{1m}^4}{E_{1m}^2} \right)^2 ; \quad m = \text{c,s}; \quad (9)
$$

$$
c) \text{on the envelope method } R_4: \quad \gamma_{R_4}(\beta_{1\text{зем},R_4}) + 3 = \left( \frac{R_s^2}{R_4^2} \right)^2 \left( \frac{R_1^2}{R_1} \right)^2 .
$$

We emphasize that the definition of the parameter $\beta_{\text{зем},k}$ from (9) is possible only if the right-hand sides of expressions (9) satisfy inequalities (3) – (5), respectively. In case (9) one can use either $m = \text{c}$ or $m = \text{s}$, i.e. one of the quadrature components, because they are statistically equivalent.

3. Test method
Interpretation of the received data is based on statistical signal multiplicative model.
Testing method for obtaining "scattering parameter" signal/noise ratio in this model is produced by the example of the double reflection of the signal at its vertical distribution. In progress issues of sensitivity pattern of the studied parameter are considered [21].

Scattering parameter is formed also inhomogeneities of the dielectric permeability of the subsurface structures. According to the method of the organization of the monitoring may detect fields of environmental changes [26]. For example, there is estimation of seismic hazard and seismic risk.

Test method in usual ionospheric conditions with varying parameter of scattering “substrate” was carrying out. Analysis of numerical experiment revealed that:

1. Method of remote diagnostics in sort wave diapason is sensitive by studying parameter. If sample volume \( N \geq 240 \) then accuracy of estimation of studying parameter is better than 5%.
2. Sensitivity of this method, its accuracy characteristics are saved even after significant changing of parameters of spreads of environment.
3. A comparison of data of numerical and physical experiments shows that, to provide estimation of scattering parameter in real experiment conditions with precise comparing with equipment error, it can be recommended to increase the duration of the sessions of observation till \( 8 \div 10 \) minutes.

4. The Experimental setup for simultaneous recording of ionospheric signals of different multiplicity
To obtain the necessary experimental data using the pulse method of coherent reception. This method allow to register low-frequency quadrature components of ionospheric signal \( E_c(t), E_s(t) \). To determine signal modulation functions the envelope \( R(t) \) and the phase \( \Phi(t) \) are possible using these components. The equipment of coherent reception allow to register directly the envelope and the phase of the reflected signal from the ionosphere. A number of factors simultaneously determinate field of ionospheric signal and such complex approach to the study of the properties of the radio signal is necessary with studying of multiple ionospheric reflections [5].

It’s necessary to allow separation and simultaneous recording parameters of different multiplicity. All of the above identified ways to modernize the equipment of the coherent reception to ensure that work on the study of the properties of multiple reflections. The installation uses a scheme of registration of low-frequency quadrature component of the ionospheric signal \( E_c(t), E_s(t) \) and envelope \( R(t) \). Modernization of the installation provided the registration with the aid of computer above-mentioned signal parameters simultaneously for signals of different multiplicity. This is achieved using a special multi-channel strobbing (gating) system and registration. Figure 2 is a block diagram of the installation with the scheme of registration and strobbing. Installation allows simultaneous recording of the parameters of multiple ionospheric reflections: https://preview.ibb.co/czVJho/2_1.jpg, https://preview.ibb.co/gd2Lx8/3_2.jpg, https://preview.ibb.co/maiFTT/4_1_2.jpg. Below we consider the work and purpose of the individual blocks.

A brief description of the ground-based measuring complex and its main units (without engineering details) is provided to make it clear where the experimental data came from: not from outside researchers, and not from computer simulations, but from a developed and constructed experimental setup, the development of which was spent more than one year, as well as the development of software to manage the operation of this complex, and then to process the results of experimental data.

5. The principle of basic units
The master oscillator generates a voltage of sine wave with amplitude 1-2 V in frequency diapason 2-15 MHz. This voltage is supplied to the transmitter controlled by synchronizing pulses. As a result, the transmit antenna receives rectangular radio pulses adjustable duration in interval 100 ÷ 500 μs. The period of the pulse repetition is 20 ms, it’s enough for receiving several multiple reflections in the time between sending. The transmitter has a pulse power of about 12-15 kW. Radiation occurs via rhombus type antenna with diagonal 50 m and 25 m horizontally and vertically, respectively.

The reflected from the ionosphere signal is received to the symmetrical dipole with a ray length 14 m and arrives at the receiver input on two-wire cable. There is amplified signals. The amplification factor can be adjusted, its maximum value is 20 db. Further there is a frequency conversion. As local oscillator
(heterodyne) in transform schema uses the generator by inductive scheme with three points. With the mixer of the receiver voltage is applied to the intermediate-frequency amplifier, which provides for adjustment both the gain and the bandwidth. The amplifier has 4 amplification stage with intermediate frequency transformers. The second and third transformers are adjustable, which changes the bandwidth of between 7 to 30 kHz.

The amplified voltage of intermediate frequency is detected and is fed to the amplifier of low-frequency receiver and the ADC. On the “Test indicator” goes low frequency voltage from matching device after the receiver and strobe pulses from the synchronization and strobe scheme. The “Test indicator” allows you to visually select the desired signal multiplicities and determine the order of their registration. Coherent reception method provides, inter alia, the comparison phases of the received signal and emitted. This requires channel reference voltage. Since the comparison in this installation takes place at the intermediate frequency, then to the reference voltage input of channel occurs transformation of the oscillator frequency to the intermediate one in the reference channel mixer block (“Basic channel”). The reference voltage of the intermediate frequency is generated from the reference generator voltage and the local oscillator’ receiver. Further, the reference voltage is supplied to the amplifier of the intermediate frequency channel of the reference voltage. The reference voltage empowered to the required level is applied to the matching device of reference channel, where the pulse sequence is generated from sinusoidal voltage. These pulses are applied to the ADC. As a result, it can be registered the low-frequency quadrature signal components, and even with the use of a computer with not very high speed due to the use of original optimization algorithms. Patent: [2]. Functional diagram registrar is substantially modified for simultaneous recording of parameters of the various multiplicities of the signals. It is established a multi-channel strobe system and a special synchronizer. Earlier the recorder lets you record on film quadrature components of signals of different multiplicity and also the power envelope and the total phase.

Cathode-ray tube (CRT) is a “Test indicator” in the system for visual observation and guidance strobe system. By changing the time position of the strobes, you can select the desired reflection as of different multiplicity corresponds to different delay with respect to the probe pulse. Contact signals of different multiplicity to the appropriate ADC registrar channel is provided by synchronization and strobing scheme and controlled by a visual indicator. Performance management of measurement complex and coordination of its components is carried out synchronizing scheme, on the input of which receives the voltage frequency of 50 Hz, which runs all the basic building blocks of the installation. With this frequency modulating pulse is formed for controlling the operation of the transmitter, the lock impulse of the receiving channel for the duration of the probe pulse, and a number of voltages to control the operation of the control indicator and computer.

6. Methodology of experimental research

Earlier issues of theory of common methodologies and methods of determining the parameters of the signal/noise in the study of the properties of multiple ionospheric reflections have been discussed: a method of determining a parameter $\beta$ for reflection of different multiplicity, a method of determining $\beta_2$ in the new statistical model for multiple reflections; estimation of scattering power of "rough" earth surface in the short-wave-range [11].

Performed comparative analysis of the effectiveness of different methods for determining a parameter $\beta$ on the one hand allowed to justify the selection of the optimal methods of reliable parameter $\beta$ estimation in the conditions of the present experiment. On the other hand the analysis has a more general significance, since the receipt of prompt and reliable information about $\beta$ is of interest in solving reliability problems and improving the communication channel, and gives an indication of the mechanism of the ionosphere and the earth scattering of the signal structure.

Parameter of scattering power of "rough" surface of the earth in the short-wave-range may depend: on the spatial concentration of buildings, on its distribution and combination with open spaces (the degree of polarization with a conditional natural elements); on functional content areas (residential, industrial or recreational) causes the intensity and nature of the activity, as well as the permittivity of the inhomogeneities of the subsurface structures [10].
Figure 2. Functional diagram of the experimental installation.
7. Conclusion
The problem of remote diagnostics of a "rough" earth surface and dielectric subsurface structures in the shortwave radio wave band is considered. A new incoherent method for estimating the signal-to-noise parameter is proposed. Specification was carried out for the ionospheric case. This range makes it possible to diagnose a subsurface layer of the earth, since the scattering parameter is also formed by inhomogeneities in the dielectric permeability of subsurface structures. These techniques can be used to develop a system for monitoring, monitoring and forecasting natural and man-made emergencies.

The idea of the method for determining this parameter is that, by having synchronous information about a wave reflected from the ionosphere and about a wave reflected from the earth and the ionosphere (or having passed the ionosphere twice when probing from a satellite), it is possible to extract information about the scattering parameter.

The paper presents the results of recording the quadrature components of the signal by means of the ground measuring complex of installation of coherent sounding in the short-wave range of radio waves at the test site of the Moscow State University (Moscow). A comparative analysis is performed and it is shown that according to the analytical (relative) accuracy of the definition of this parameter the new method is an order of magnitude larger than the widely used standard method. Analysis of the analytical errors in the estimation of this parameter allowed us to recommend a new method instead of the standard one. The software for synchronous registration of quadrature components of radio signals of various multiplicities in real time with the formation of a database of experimental data was developed, successfully tested and patented; one of the functions of the software is to protect the computer system from the powerful radiating pulse of the radio transmitter.

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