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ANTENNA ARRAY FOR RADIOMONITORING

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Abstract*—*The radio control system based on the three elements antenna array with noise suppression function is considered. Using of three elements allow to narrow the sector of space reviewing and to simplify the block diagram. The proposed system provides suppression of the noise by means of simple technical means including situation, when frequencies of the noise and useful signal coincide.

Index Terms—Antenna array; noise suppression; directional diagram; sources of radiation, radiocontrol.

I. INTRODUCTION

The main task of radio control is to measure the parameters of radiation, to find the direction of the source of radiation, to conduct surveillance for a certain period of time and perform post-controlled measurements [1]. Under radio control it is necessary to examine the implementation of established rules of radio frequency resource usage by radio electronic means users (REM), to estimate the electromagnetic environment in the area of REM action to ensure the electromagnetic compatibility and to measure REM radiation parameters [2]. As radio control performs in a real electromagnetic environment, the spatial selectivity acquires the paramount importance. Under a large territory saturation by radio-electronic means there is a high probability that some other source will radiate on the frequency, closely to the frequency of controlled REM, that creates a significant obstacle for monitoring and control of radio emission. Sometimes, in this case, it is difficult to distinguish the signal voltage from a mixture of signal plus noise by some hardware. It is obvious, that the antenna with the properties to suppress the interference will better ensure the radio control performance. To the antennas with such properties belong adaptive antennas, antennas with amplitude and phase methods of noise suppression.

The majority of the modern receiving antennas used in radio monitoring systems represents ordinary electromagnetic devices with classical characteristics. But there is the possibility to maintain the reception of radio emission in the significantly smaller spatial sector than in the classical non-directional antennas [3].

The main aim if this work is to create an antenna system with noise suppression and space coverage area in the horizontal plane less than 180° $(2\varphi_{0.5}<90^\circ)$ using small element antenna. Based on the principle of amplitude noise suppression it is necessary to apply such minimum quantity of elements in the array to either narrow the radiation pattern and to simplify a little the block diagram of signal processing. It was decided to create the antenna system on the basis on 3 dipoles.

II. SOLUTION OF THE PROBLEM

Antenna array for radiomonitoring is a measuring instrument, the structure of which is based on the principles of direct conversion of electromagnetic field parameters into electrical signals. Generalized block diagram consists of antenna unit, frequency conversion and amplification unit, linear transformation unit, functional transformation unit and processor.

Antenna unit consists of three elements. The line of vibrators location (antenna aperture) is set in such way that rays from the radiation source of controlled signals fall at right angles (Fig. 1).

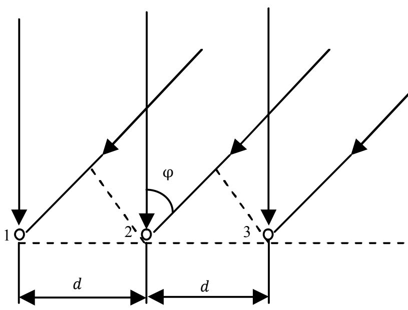

Fig. 1. Three element antenna array

The rays from the source of noise fall at a right angle to the perpendicular conducted to the grating aperture. Antenna system is placed in a horizontal plane, so the azimuthal angle φ of spherical coordinate system is used, assuming, that θ = 90°. Vibrators of the antenna array are identical in design and have the same value of the active length l_∂ .

In the frequency conversion and amplification unit signals is transferred to suitable for further processing range and amplified by narrowband amplifiers. These amplifiers provides increasing of signal to noise ratio and sufficient to minimize measurement errors voltage level.

We will assume that the voltages, generated after frequency transformation and amplification in signal processing channels are proportional to the amplitude of EMF on the dipoles terminals and they keep the phase relations. After the frequency conversion and amplification we obtain next voltages on the output of dipoles [4]:

$$\left.\begin{aligned} \dot{U}_1 &= \dot{U}_s + \dot{U}_n e^{-ikd\sin\varphi};\\ \dot{U}_2 &= 2(\dot{U}_s + \dot{U}_n);\\ \dot{U}_3 &= \dot{U}_s + \dot{U}_n e^{ikd\sin\varphi}, \end{aligned}\right\} \qquad (1)$$

where $\dot{U}_s = \alpha \dot{E}_s l_\partial$ is the voltage of useful signal; $\dot{U}_n = \alpha \dot{E}_n l_\partial$ is the voltage of noise; α is the transfer factor of frequency transformation and voltages amplification channels.

Transfer factor of the second channel is twice as much as transfer factor of dipole 1 and dipole 2, that is $\alpha_2 = 2\alpha$. Let's introduce exponential multipliers of the system (1) in a form of trigonometric functions

$$\left.\begin{aligned} \dot{U}_1 &= \dot{U}_s + \dot{U}_n \cos 2u - i\dot{U}_n \sin 2u;\\ \dot{U}_2 &= 2(\dot{U}_s + \dot{U}_n);\\ \dot{U}_3 &= \dot{U}_s + \dot{U}_n \cos 2u - i\dot{U}_n \sin 2u, \end{aligned}\right\} \qquad (2)$$

where

$$u = \frac{kd}{2}\sin\varphi. \qquad (3)$$

Taking into account that the transfer factor of the second channel is twice as much as transfer factor of dipole 1 and dipole 2, the directional diagram of indicated antenna can be found from the equation

$$\dot{E} = E_{\max 1} F(\theta, \varphi) e^{-ikr}\left(1 + 2e^{ikd\cos\varphi} + e^{2ikd\cos\varphi}\right). \qquad (4)$$

Directional diagram of three element antenna array that locates at a distance $d = \lambda/2$ is shown on the Fig. 2.

From the expression (2) we can see that three variables of changeable voltages on the output of three dipoles give a chance to calculate all the necessary parameters. However, it is theoretical solution and we need to take into account the phase shifts between signals of noise and voltages. This is due to the fact that the radiation of interfering source and the useful signal source is incoherent, even if their frequencies are matching.

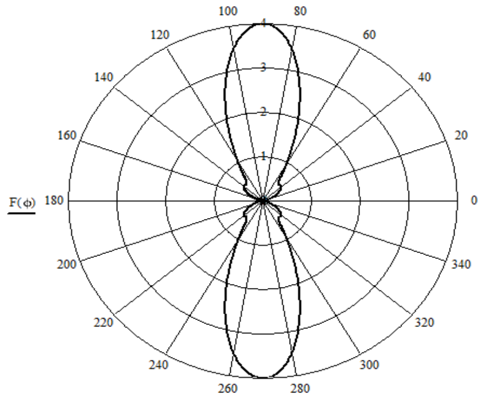

Fig. 2. Directional diagram of three element antenna array

The phase shift between the voltage $\dot{U}_s$ and $\dot{U}_n$ is random and changes over time. Therefore, the solution of equations (2) has no practical value. Another way to solve the set of equations (2) is to renounce the determination of voltages phase shift between $\dot{U}_s$ and $\dot{U}_n$ [4].

Linear transformation unit consists of adders and a fixed phase shifter that shifts the phase of the sum of two voltages to –90°.

Let's consider some simple math operation that is easily realized by instrumental means.

The difference of outside dipoles voltages

$$\dot{U}_4 = \dot{U}_3 - \dot{U}_1 = i2\dot{U}_n \sin 2u = i4\dot{U}_n \sin u \cos u. \qquad (5)$$

The difference of voltage $\dot{U}_2$ and the sum of outside dipoles

$$\dot{U}_5 = \dot{U}_2 - \dot{U}_1 - \dot{U}_3 = 4\dot{U}_n \sin^2 u. \qquad (6)$$

Let's find also such combination of voltages

$$\dot{U}_6 = \dot{U}_2 - 2\dot{U}_1 = i4e^{-iu}\dot{U}_n \sin u. \qquad (7)$$

and

$$\dot{U}_7 = \dot{U}_2 - 2\dot{U}_3 = -i4e^{iu}\dot{U}_n \sin u. \qquad (8)$$

Amplitude values of obtained voltages make it possible to calculate the trigonometric functions of the angle u

$$\left.\begin{aligned} \sin u &= \frac{|\dot{U}_5|}{|\dot{U}_7|};\\ \cos u &= \frac{|\dot{U}_4|}{|\dot{U}_7|};\\ \operatorname{ctg} u &= \frac{|\dot{U}_4|}{|\dot{U}_5|}. \end{aligned}\right\} \qquad (9)$$

In some cases (under the small values of the angle) it is appropriate to use next option

$$\dot{U}_8 = \dot{U}_1 + \dot{U}_3 = 2\dot{U}_s + 2\dot{U}_n \cos 2u. \quad (10)$$

From the expression (5) we can see that

$$\dot{U}_9 = 2\dot{U}_n \sin 2u. \quad (11)$$

While subtracting the voltage $\dot{U}_9$ from the voltage $\dot{U}_8$ we receive

$$\dot{U}_8 - \dot{U}_9 = 2\dot{U}_s. \quad (12)$$

Viewed functional connections between separate electrical quantities realized by device, constructed according to synthesized block diagram (Fig. 3).

Three dipoles of the antenna array through switches connect to three channel preselector with discrete variable of occupied bandwidth. Each of three channels is constructed under the same scheme. The first stage of the channel is a converter through which the antenna system can be used in different frequency bands. Each converter is powered by the voltage of the same quantities, identical frequency and identical phase as this voltage is creating by electrical for all converters convertors generator (CG). The next channel element is the three element frequency convertor on the one input of which come oscillation from the heterodyne (Het). The main element of the voltage amplification and frequency selectivity is a frequency amplifier (IFA). On the scheme we obtain voltages $\dot{U}_1$, $\dot{U}_2$ and $\dot{U}_3$ (3) on the channels output.

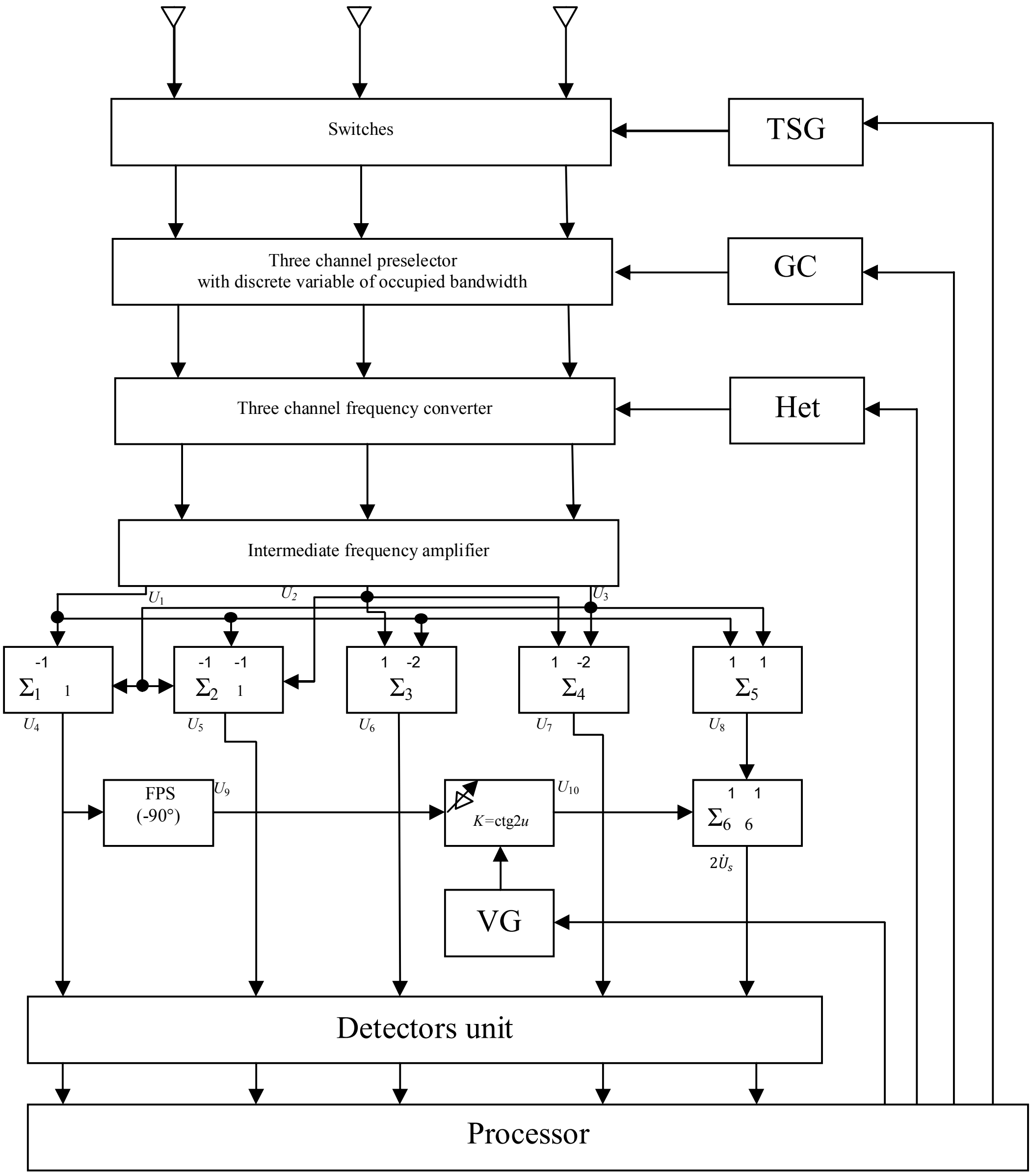

Fig. 3. Block diagram of three element antenna array

Adder $\sum_1$ has two inputs, on which voltages $\dot{U}_1$ and $\dot{U}_3$ came and transfer factor of adder inputs equal to one. On the output of $\sum_1$ we obtain voltage $\dot{U}_4$ (5). Adder $\sum_2$ has three inputs with three transfer coefficients that equals to one. To its inputs applied voltages of all three channels, but voltages $\dot{U}_1$ and $\dot{U}_3$ summarize in opposite phase to the voltage $\dot{U}_2$ and due to this we obtain voltage $\dot{U}_5$ (6). Adder $\sum_3$ has 2 inputs with the transfer factor (+1) and (-2). On its output terminals form voltage $\dot{U}_6$ (7). As we can see from the scheme that is shown of Fig. 3, on the outputs of adders $\sum_4$ and $\sum_2$ form voltages $\dot{U}_7$ (8) and $\dot{U}_8$ (9) correspondingly.

Voltage $\dot{U}_4$ is shifted in fixed phase shifter and as a result we obtain voltage $\dot{U}_9$. The operation amplifier with the coefficient K = ctg2u is used to calculate the voltage of signal and this amplifier is controlled by voltage generator. As a result of indicated amplification we obtain voltage $\dot{U}_{10}$.

A useful signal $\dot{U}_s$ is formed on the adder $\sum_6$ output. We can see that after the subtraction of voltages $\dot{U}_9$ and $\dot{U}_8$ we receive $2\dot{U}_s$.

Using the expression (3), the processor calculates the direction of electromagnetic wave interference coming

$$\varphi = \arcsin\frac{2u}{kd},$$

due to the known value of the argument u.

The field intensity of the useful signal is calculated by the formula

$$E_s = \frac{U_s}{\alpha l_\partial}$$

The interference electric field intensity is

$$E_n = \frac{U_7^2}{4\alpha l_\partial U_6}$$

All results of calculations, such as data about radiation parameters.

The device can operate in three modes. The simplest process of operation relates to the case, when the signal can be selected from the mixture of the received signals by means of frequency selectivity In this mode, that selects by the nature of voltage $\dot{U}_4$, the processor operates with voltages $\dot{U}_4$, $\dot{U}_5$, $\dot{U}_6$.

In the second mode, under the presence of noise, that cannot be suppress by frequency selectivity circles, the adder $\sum_4$ blocks by a processor, and on the output 2 the voltage drops to zero. The necessity to move to this mode of operation determines by the voltage U_4. Under the presence of interference will occurs the beat of harmonics that will inform that mixture of incoherent oscillations is receiving. In addition, the indicators of received oscillations mixture are voltages U_4, U_5, U_6, and U_7. Under two sources of radiation these voltages at any orientation of antenna system are not dropping to zero.

In this antenna system mode of operation, the vibrators panel should target so that one source of radiation was at a perpendicular to the aperture ($\varphi = 0$). Then, the signal and noise voltage selection is occurring in accordance with the formulas given in the theoretical part of this work.

The third mode of operation is control and configuration of voltages channel processing. The processor transfers the device in this mode using the switches. To the channels input joined test signal generator (TSG), functioning of which is set by the processor.

III. CONCLUSIONS

From the antenna principle of action and the block diagram analysis follows next conclusions.

1) The antenna array of three dipoles make it possible by using of simple technical means to provide noise suppression, even if the interference will have the same frequency as the useful signal. Thus, such antenna can be used in conditions of multibeam wave propagation under the adjustment on the most intense by the power beam.

2) Antenna system provides simultaneous control of two radiation sources whose frequencies are close to each other. However, thanks to the computer technology, the system can work automatically on different work programs.

3) The antenna system with frequency meter can be used as electromagnetic fields tester. It makes it possible to measure the electromagnetic field intensity, congestion of the frequency spectrum, direction of noise electromagnetic waves incidence, noise electric field intensity. Under the presence in the grid the three mutually perpendicular vibrators, the outputs of which will switch with switches, the antenna will measure the meridional and azimuthal components of the electric field vector and the coefficient of electromagnetic waves ellipticity.

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Л. Я. Ільницький, Л. В. Сібрук, Д. В. Поліщук. Антенна решітка для радіомоніторингу

Розглянуто систему радіоконтролю, що засновується на триелементній антенній решітці з функцією придушення завади. Використання трьох елементів дозволяє звузити сектор огляду простору та спростити блок-схему оброблення сигналу. Запропонована система забезпечує придушення завади, у тому числі співпадаючої за частотою з корисним сигналом, за допомогою простих технічних засобів.

Ключові слова: антенна решітка; придушення завади; діаграма спрямованості; джерело випромінювання; радіоконтроль.

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Л. Я. Ильницкий, Л. В. Сибрук, Д. В. Полищук. Антенная решетка для радиомониторинга
Рассмотрена система радиоконтроля, в основу которой положена трехэлементная антенная решетка с функцией подавления помехи. Использование трех элементов позволяет сузить сектор обзора пространства и упростить блок-схему обработки сигнала. Предложенная система обеспечивает подавление помехи, в том числе совпадающей по частоте с полезным сигналом, при помощи простых технических средств.
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