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ANTENNA OF RADIO CONTROL

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Abstract. The article is devoted to current issues in the field of radio monitoring. In this article was considered the antenna of radio control, which represents a grid from three vibrators. Three-element antenna array provides simultaneous control of two radio electronic devices that radiates at frequencies that are close to each other. Antenna system using simple technical means provides noise suppression, even if noise will have the same frequency as useful signal. This makes it possible to use the antenna system in conditions of multibeam wave propagation under the adjustment on the most intense by the power beam. Antenna system makes it possible to measure the electromagnetic field intensity, congestion of the frequency spectrum, direction of noise electromagnetic waves incidence, noise electric field intensity.

Keywords: antenna array; noise suppression; radiation; radio control.

1. Introduction

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 [1,2]. 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.

2. Problem definition

Considering the modern receiving antennas, that are used in radio monitoring systems, we can mention, that the majority of the recommended antennas are the ordinary electromagnetic devices with the classical characteristics [3]. But, in some cases it is necessary to use the antennas with the special radiation patterns, which are formed by means of antenna systems, which consists of a few simple radiators. In this case the reception of radio emission that is coming in signifi-

cantly smaller spatial sector than to the non-directional antennas can be ensured. It is obvious, that under such directional characteristic, inherent to the antenna systems, the signal to noise ratio incase. In addition, such antenna system can perform some specific functions, such as noise suppression function. The problem is to use small element antenna array, to create an antenna system with noise suppression and with a sector of space reviewing in the horizontal plane less than 180° ($2\varphi_{0,5} < 90^\circ$). Using the principle of amplitude noise suppression it is necessary to apply such minimum quantity of elements in the lattice to narrow the radiation pattern, and also to simplify a little the block diagram of signal processing. For that purpose, we consider the three-element antenna array.

3. Theoretical basis

The line of vibrators location (antenna aperture) sets in such way that rays from the radiation source of controlled signals was falling at certain angles (Fig. 1).

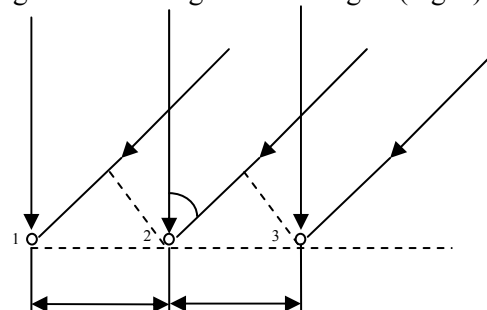


Fig. 1. Three-element antenna array

The rays from the source of noise fall at a right angle to the perpendicular conducted to the grating

aperture. Antenna system places in a horizontal plane, so we will use the azimuthal angle φ of spherical coordinate system, assuming, that $\theta=90^\circ$. Vibrators of the antenna array are identical in design and have the same value of the active length l_θ .

After the frequency conversion and amplification we obtain next voltages [4]

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

where $\dot{U}_s = \alpha \dot{E}_s l_\theta$ - voltage of useful signal;

$\dot{U}_n = \alpha \dot{E}_n l_\theta$ - voltage of noise;

α - transfer factor of frequency conversion channels and voltages amplification. Transfer factor of the second channel is twice as much as transfer factor of vibrator 1 and vibrator 2, that is $\alpha_2 = 2\alpha$. Let's introduce exponential multipliers of the system (1) as trigonometric functions

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

where the designation for spatial phase shift accepts as

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

Theoretically, three variables of changeable voltages on the output of three vibrators give a chance to calculate all the necessary parameters. But, 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 .

Let's consider some simple math operation that is easily realized by instrumental means. The sum of all three voltages is

$$\dot{U}_4 = \sum_{i=1}^3 \dot{U}_i = 4\dot{U}_s + 4\dot{U}_n \cos^2 u. \quad (4)$$

The difference of outside vibrators voltages

$$\dot{U}_5' = \dot{U}_3 - \dot{U}_1 = i2\dot{U}_n \sin 2u = i4\dot{U}_n \sin u \cos u. \quad (5)$$

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

$$\dot{U}_6 = \dot{U}_2 - \dot{U}_1 - \dot{U}_3 = 4\dot{U}_n \sin^2 u. \quad (6)$$

Let's find also such combination of voltages

$$\dot{U}_7 = \dot{U}_2 - 2\dot{U}_1 = i4e^{-iu} \dot{U}_n \sin u.$$

and

$$\dot{U}_8 = \dot{U}_2 - 2\dot{U}_3 = -i4e^{iu} \dot{U}_n \sin u.$$

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

$$\begin{aligned}\sin u &= \frac{\left| \begin{array}{c} \dot{U}_n \\ \dot{U}_7 \end{array} \right|}{\left| \begin{array}{c} \dot{U}_6 \\ \dot{U}_8 \end{array} \right|}; \\ \cos u &= \frac{\left| \begin{array}{c} \dot{U}_5' \\ \dot{U}_7 \end{array} \right|}{\left| \begin{array}{c} \dot{U}_5' \\ \dot{U}_8 \end{array} \right|}; \\ \text{ctg} u &= \frac{\left| \begin{array}{c} \dot{U}_5 \\ \dot{U}_6 \end{array} \right|}{}.\end{aligned}$$

Complex noise voltage is define through the voltage \dot{U}_5 (5) or voltage \dot{U}_6

$$\dot{U}_n = -i\frac{1}{2}\dot{U}_5' \text{cosec} 2u.$$

and

$$\dot{U}_n = i\frac{1}{4}\dot{U}_6 \text{cosec}^2 u.$$

To find the signal voltage without noise can be used such correlation

$$\dot{U}_s = \frac{1}{2}(\dot{U}_2 + i\dot{U}_5' \text{cosec} u), \quad (7, a)$$

or

$$\dot{U}_s = \frac{1}{4}(\dot{U}_4 + i\dot{U}_5' \text{ctg} u). \quad (7, b)$$

In some cases (under the small values of the angle) it is appropriate to use next option. Let's create a voltage sum of the output vibrators 1 and 3 voltage

$$\dot{U}_9 = \dot{U}_1 + \dot{U}_3 = 2\dot{U}_s + 2\dot{U}_n \cos 2u. \quad (8)$$

From the expression (5) we can see, that

$$\dot{U}_{10} = -i\dot{U}_5' = i2\dot{U}_n \text{ctg} 2u = 2\dot{U}_n \cos 2u.$$

Subtracting the voltage \dot{U}_{10} from the voltage \dot{U}_9 , we obtain

$$\dot{U}_9 - \dot{U}_{10} = 2\dot{U}_5.$$

To choose the variant of useful signal voltage calculation, let's consider the dependence of the coefficients on which it is necessary to multiply the voltage \dot{U}_5 , during determination of the useful signal, from the angle u . To do this, we plot a graph (Fig. 2)

$$\begin{aligned} b_1 &= \operatorname{cosec}2u; \\ b_2 &= \operatorname{cosec}^2u; \\ b_3 &= \operatorname{ctg}u; \\ b_4 &= \operatorname{ctg}2u; \end{aligned} \quad (9)$$

From this graphs it follows that for a given interval of angles, the smallest dynamic range will be for the multiplier b_2 at $6^\circ < u < 90^\circ$. To determine in which cases there is better one or another multiplier, consider the generalized array pattern associated with one of (9) multiplier b . The family of these diagrams

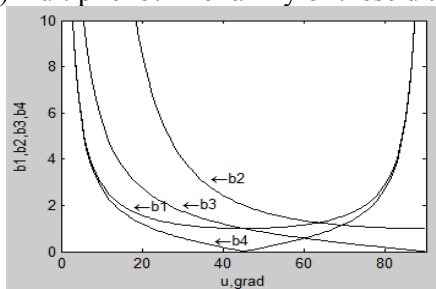


Fig. 2. The dependence of the multipliers from the intensity noise vector phase shift

is shown on the fig. 3. Number 1 determine the directional diagram of separate vibrator $F(u)=const$. According to this pattern the voltage \dot{U}_2 forms. Number 2 determine the directional diagram $F(u)=\cos^2u$, according to which the voltage \dot{U}_4 (4) forms. Number 3 determine the directional diagram $F(u)=\sin2u$, that forms by vibrators 1 and 3 and according to which the voltage \dot{U}_5 (5) forms. Number 4 determine the directional diagram $F(u)=\sin^2u$, i.e. it forms by all three vibrators and with this diagram links the emergence of voltage \dot{U}_6 (6). Finally, directional diagram 5 – is $F(u)=\cos2u$. Antenna with this directional diagram excites the voltage \dot{U}_9 (8).

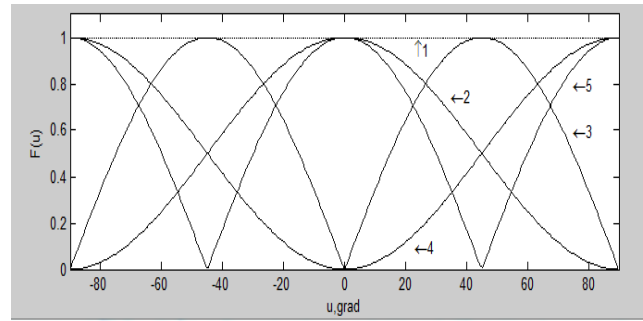


Fig. 3. Generalized directional diagrams

Based on the possibility of receiving an electromagnetic wave, that falls in directions that do not coincides with the diagrams maximum, determine the level $F_{\min}(u)$. Under noise selection according to the formulas (11) the minimum value of the directional characteristic $F_{\min}(u)$ makes it possible to identify that spatial sector from which will comes the noise electromagnetic waves with dangerous levels. As we can see from the graphs (fig. 3) diagram 3 has two areas of uncertainty that are placed around $u = 0$ and $u = 90^\circ$. Diagram 4 has only one area of uncertainty around $u = 0$, but this zone is wider than the area of the diagram 3. Obviously, it is necessary to provide a transition from one to another diagram, depending on the angle of interference wave incidence in the real antenna.

4. Block diagram of the antenna system

Viewed functional connections between separate electrical quantities realize by device, constructed according to synthesized block diagram (Fig. 4).

Three vibrators of the antenna array through switches $S1$, $S2$ and $S3$ connects with frequency translation channels and voltage amplification channels. Each of the three channels contracted under the same scheme. Individual elements are marked with indices (numbers) that coincide with the vibrator number. The first stage of the channel is a converter (C_{A1} , C_{A2} i C_{A3}), 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 frequency amplifier (FA_1 , FA_2 i FA_3) on the one input of which comes oscillation from the heterodyne (Het). The main element of the voltage amplification and frequency selectivity is a frequency amplifier (IFA). Channels of the 1st and 3rd vibrators are ends by amplitude-phase correctors (APC). Channel of the 2nd vibrator is considered as

a reference, so its transfer coefficient is not corrected. The final channel element of the 2nd vibrator is amplifier A_2 , with a transfer coefficient 2. Actually amplifier A_2 can be removed, but it is necessary to take into account the double increase of the channel output voltage in the transferring of the appropriate adder, that practically does not cause any dif-

ficulties. On the scheme, shown in Fig. 4, on the channels outputs we obtain voltages \dot{U}_1, \dot{U}_2 and \dot{U}_3 (2).

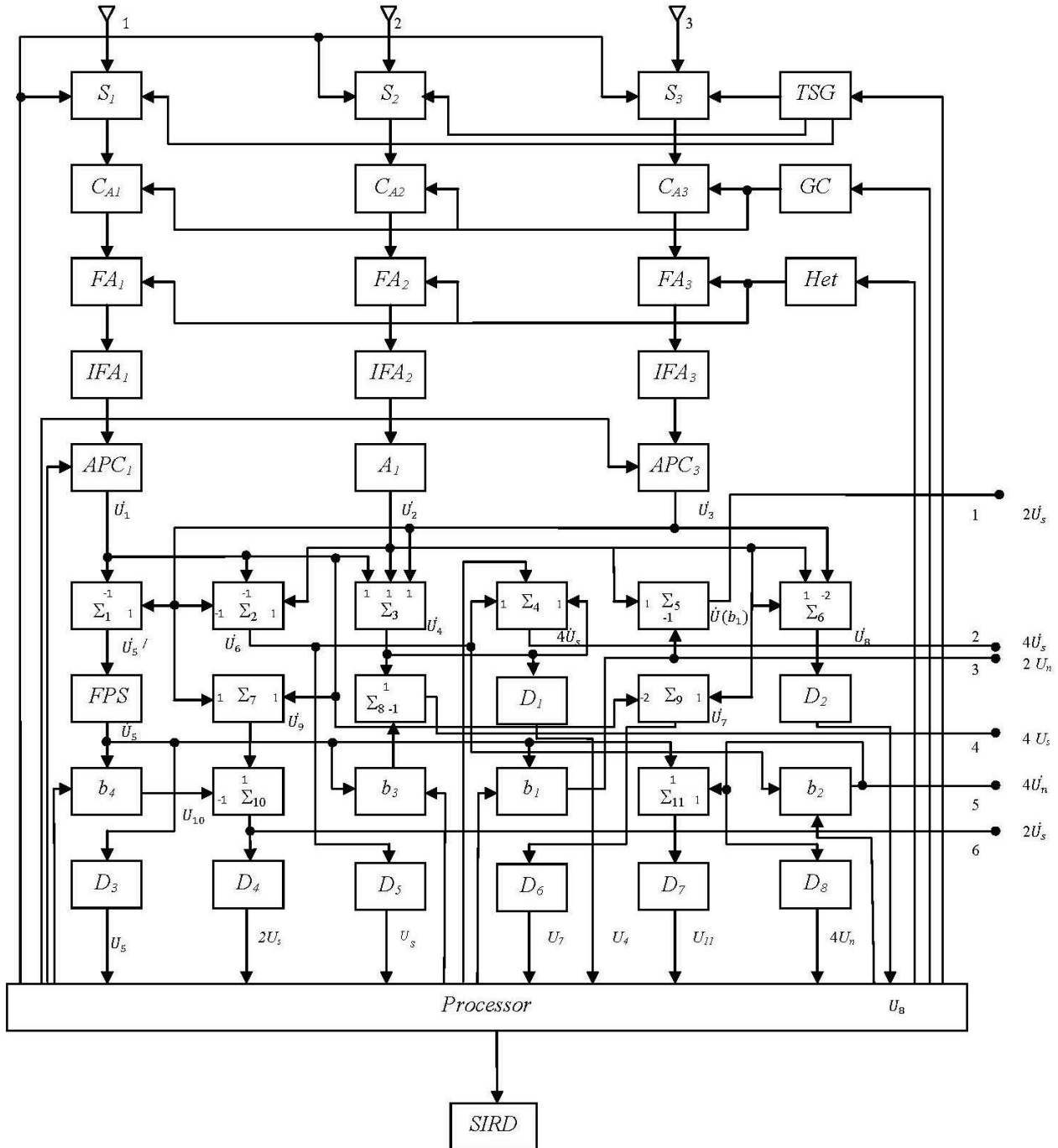


Fig. 4. Block diagram of the antenna array

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

$$E_s = \frac{U_s}{\alpha l_0}$$

The interference electric field intensity is

$$E_n = \frac{U_7^2}{4\alpha l_0 U_6}$$

All results of calculations, such as data about radiation parameters, displays on the signals indicating and recording device (SIRD).

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 U_4 , the processor operates with voltages \dot{U}_4 , \dot{U}_5 , \dot{U}_6 and \dot{U}_{11} .

In the second mode, under the presence of noise, that cannot be suppress by frequency selectivity circles, the adder Σ_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_3 , U_6 , U_7 , and U_8 . 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 S_1 , S_2 and S_3 . To the channels input joined test signal generator (TSG), functioning of which is set by the processor.

5. 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 S_1 , S_2 and S_3 , 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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Статтю присвячено актуальним питанням у сфері радіомоніторингу. Розглянуто антену радіоконтролю, що являє собою решітку з трьох вібраторів. Трьохелементна антенна решітка забезпечує одночасний контроль двох радіоелектронних засобів, які випромінюють на частотах, котрі близькі одна до одної. Антенна система, використовуючи прості технічні засоби, забезпечує придушення завади, навіть якщо завада матиме таку ж частоту, як і корисний сигнал. Це дає можливість використовувати антенну систему в умовах багатопроменевого поширення радіохвиль, при настроюванні на найбільш інтенсивний за потужністю промінь. Антенна система дає можливість вимірювати напруженість електромагнітного поля, завантаженість частотного спектра, напрям падіння електромагнітних хвиль завади, напруженість електричного поля завади.

Ключові слова: антенна решітка; випромінювання; придушення завади; радіоконтроль.

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Статья посвящена актуальным вопросам в сфере радиомониторинга. Рассматривается антенна радиоконтроля, которая представляет собой решетку из трех вибраторов. Трёхэлементная антенная решетка обеспечивает одновременный контроль двух радиоэлектронных средств, излучающих на частотах, которые близки друг к другу. Антенная система, используя простые технические средства, обеспечивает подавление помехи, даже если помеха будет иметь такую же частоту, как и полезный сигнал. Это дает возможность использовать антенную систему в условиях многолучевого распространения радиоволн, при настройке на наиболее интенсивный по мощности луч. Антенная система дает возможность измерять напряженность электромагнитного поля, загруженность частотного спектра, направление падения электромагнитных волн помехи, напряженность электрического поля помехи.

Ключевые слова: антенная решетка; излучение; подавление помехи; радиоконтроль.

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