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L.Y. Ilnitskyi (National Aviation University, Kyiv, Ukraine)
L.V. Sibruk(National Aviation University, Kyiv, Ukraine)
I.I. Mykhalchuk(National Aviation University, Kyiv, Ukraine)

Antenna of mobile radio monitoring system

The theoretical bases of the development of an antennas for monitoring system are presented. Antennas combine the functions of measuring the emissions parameters, directional finding and suppression of the interference waves, close by the frequency to the main radiation. Antenna system includes array 3x2, flat screen and mechanical rotator.

Radio monitoring stations use a considerable number of antennas, each of which performs only one of its inherent function [1]. For example, the antenna system measures the field characteristics or determines the angular position of the radiation source of radiation. In the case of mobile radio monitoring systems, it is necessary to limit the number of antennas, since such systems are located on cars and therefore there is a need to use multifunction antennas. Broadband non-directional antennas in modern cities often receive electromagnetic radiation in conditions of significant interference, which in some cases makes impossible measurements with given accuracy.

The essence of the problem is to synthesize the antenna system, which would combine the possibility of reception the required radiation in an unfavorable electromagnetic environment, creating an electrical signal with the intensity necessary to detect the source of radiation; suppress interference, which operates at a frequency close to the frequency required for radiation monitoring; measurement of the angular position of the radiation source and the value of electric field strength. Such antenna system can be a system consisting of several elements. It should be noted that the most common case of the radiation sources location is at angles near zero, that is, in a horizontal plane. Taking this into account, it is possible to limit the directional finding only to the azimuthal angle and to measure the meridional and azimuthal angles with simplified methods using a turnstile antenna system. In order to reduce the antenna dimensions it is desirable to apply the linear array of three active dipoles. If necessary accurate measurements of field parameters the flat antenna array 3x2 should be considered.

Let's consider the antenna array, the elements of which are three turnstiles antennas (Fig. 1). The phase of EMF induced in radiator 2 is assumed zero.

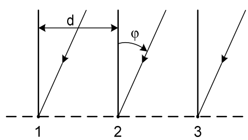


Figure 1. Three element array

The waves fall on the antenna system at an angle to the direction perpendicular to the array's axis. The EMF at antenna terminals:

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

where a is a constant factor; $\dot{A} = \dot{E} l_{\partial} F_1(\varphi)$, $\dot{E}$ - is field intensity of incident wave; l_{∂} - is effective length of radiator; $F_1(\varphi)$ is the pattern of array element; $k = 2\pi/\lambda$ is the wave number; λ is the wavelength; d is a distance adjacent radiators.

Let`s create voltages:

$$\left.\begin{aligned} \dot{U}_{12} &= \dot{U}_1 + 0.5\dot{U}_2 = 2a\dot{A}e^{-i0.5kd\sin(\varphi)}\cos(0.5kd\sin(\varphi)); \\ \dot{U}_{23} &= 0.5\dot{U}_2 + \dot{U}_3 = 2a\dot{A}e^{i0.5kd\sin(\varphi)}\cos(0.5kd\sin(\varphi)), \end{aligned}\right\} \qquad (2)$$

Their sum and difference are:

$$\dot{U}_{\Sigma} = \dot{U}_{12} + \dot{U}_{23} = 4a\dot{A}\cos^2(0.5kd\sin(\varphi)) \qquad (3)$$

$$\dot{U}_{\Delta} = \dot{U}_{23} - \dot{U}_{12} = i2a\dot{A}\sin(kd\sin(\varphi)) \qquad (4)$$

Obviously, the voltage (3) is the output voltage of the antenna array with a binomial distribution of excitation currents. Consequently, the pattern (Fig. 2):

$$F_{\Sigma}(\varphi) = \cos^2(0.5kd\sin(\varphi)) \qquad (5)$$

For the same condition ($kd = \pi$) the difference pattern (Fig. 3), which from expression (4) is defined as:

$$F_{\Delta}(\varphi) = \sin(kd\sin(\varphi)) \qquad (6)$$

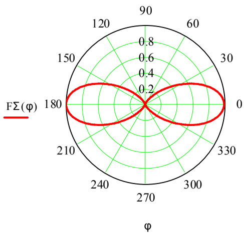


Figure 2. The pattern in the sum mode.

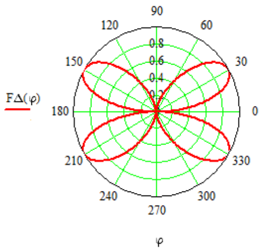


Figure 3. The pattern in the difference mode.

It is clear that these two patterns with the use of appropriate technical means will exist simultaneously. Consequently, the antenna array will have two output channels: the total, in which the voltage (3) and the voltage difference (4) can be processed. Positive property of difference pattern is high slope near the angles $\varphi = 0^{\circ}$ and $\varphi = 180^{\circ}$. As beamwidth of $F_{\Sigma}(\varphi)$ at $kd = \pi$ is equal to 42,7є. But at pattern level 0,2 from maximum, that is enough for reception, the beamwidth $2\varphi_{0.2} = 90^{\circ}$.

For detecting emission in horizontal plane the pattern lobe must have an opportunity to shift. In the case of electrical scanning, two phase shifters can be used in the channels of the array elements 1 and 3. In this case, the voltage in channel 1 will shift to an angle Ψ and in channel 3 to $-\Psi$,

$$\Psi = kd \sin \varphi_q , \quad (7)$$

where φ_q is azimuthal angle on emission source number q.

At phase shifts the patterns in channels 1 and 3 become

$$F_\Sigma(\varphi) = \cos^2(0.5kd(\sin(\varphi) - \sin(\varphi_q)) \quad (8)$$

$$F_\Delta(\varphi) = \sin(kd(\sin(\varphi) - \sin(\varphi_q)) \quad (9)$$

From (8) and (9) follows that at phase shift (7), which satisfies the equation $\sin(\varphi) = \sin(\varphi_q)$ the sum pattern obtain maximal value and the difference pattern approaching zero.

Response factors of channels to change angles φ, φ_q are also different:

$$K_\Sigma(\varphi) = 0.5kd \cos(\varphi_q) \sin(kd(\sin(\varphi) - \sin(\varphi_q)) \quad (10)$$

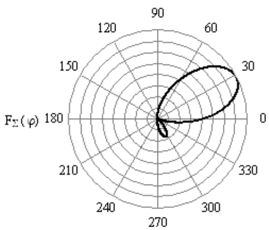
$$K_\Delta(\varphi) = kd \cos(\varphi_q) \cos(kd(\sin(\varphi) - \sin(\varphi_q)) \quad (11)$$

From these relationships follows that the direction of radiation sources should be found using a difference pattern (9), whereas detecting the source of radiation, the mode of the sum pattern should be used (8). The survey sector in space is limited by directions in which the value of the patterns decreases to the admissible level. For example, it can be taken $F_\Sigma(\varphi) = 0.5$. For $\varphi_q = 0$ and $kd = \pi$ the survey sector lies in borders $\varphi = \pm 30^\circ$. At phase shifts $\psi = \pm 45^\circ$, that correspond to angles $\varphi = \pm 30^\circ$ the patterns $F_\Sigma(\varphi) = \cos^2(90^\circ(\sin(\varphi) \pm 0.5))$ have four lobes with maximums at angles $\psi = \pm 30^\circ; \pm 210^\circ$. For unambiguous determination of the position of radiation sources, it is necessary to use antenna array with a reflector - a flat screen. In this case, the patterns (8) and (9) are supplemented by the screen multiplier [2]

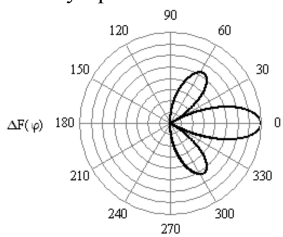
$$F_\Sigma(\varphi) = \cos^2(0.5kd(\sin(\varphi) - \sin(\varphi_q)) \sin(kh \cos(\varphi))$$

$$F_\Delta(\varphi) = \sin(kd(\sin(\varphi) - \sin(\varphi_q)) \sin(kh \cos(\varphi))$$

where *h* is a distance between the screen and array's plane.



a



b

Figure 4. The patterns of array with flat screen: a is a sum pattern, b is a difference pattern. (Fig. 4 at $kd = 180^\circ$, $\sin \varphi_q = 0.5$ and $kh = 90^\circ$).

When using the antenna's mechanical rotation, space review in the azimuth plane can be made from six fixed positions: $0^{\circ}; 60^{\circ}; 120^{\circ}; 180^{\circ}; 240^{\circ}; 300^{\circ}$; The patterns will intersect at the level of 0.49, which allows the identification of the radiation source. The advantage of mechanical rotation in comparison with the electric changing of lobe position lies in the fact that in all six antenna positions, its pattern is not distorted and remains unchanged, while in the case of electric scanning the pattern beamwidth increases and its form becomes asymmetric. Besides when adjusting the minimum of the pattern to the direction $\varphi \approx 90^{\circ}$ using electric scanning the sensitivity to the change of angle φ approaches zero, which will lead to significant errors in the direction finding.

Let us consider the case when two sources of radiation in the survey sector operate at such close frequencies that frequency selective circles do not allow them to be separated.

An important characteristic of such antennas is the minimum angular spacing between the two sources, which ensures the correct reception of electromagnetic waves with suppression of interference. Obviously, in order to suppress the interference signal, a difference pattern is used, the zero value of which must coincide with the direction of interference wave arrival. In this case, the arises the question about the voltage on antenna terminals, sufficient for the further processing at separation angle $\Delta\varphi = \varphi_1 - \varphi_2$.

Angular separation $\Delta\varphi$ at a given level of useful voltage δ can be found using equations (7) and (5). Expression (7) is transformed into the following form:

$$\Delta\varphi = arc\left(\frac{\arcsin(\delta)}{kd}\right) \qquad (12)$$

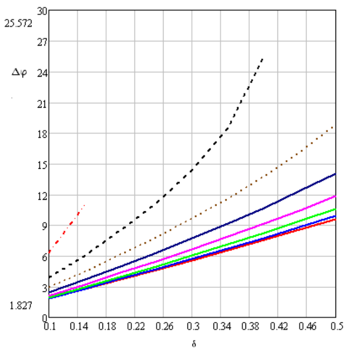


Figure 5. Dependences of the minimum angular separation of the 1st and 2nd radiation sources from the angular position of the 2nd source at electric shift of antenna pattern.

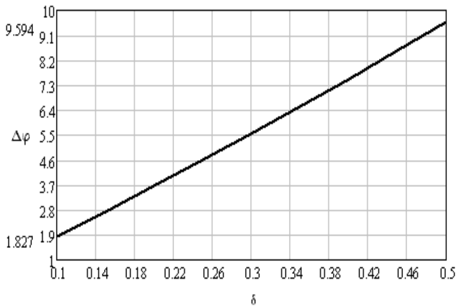


Figure 6. Dependences of the minimum angular separation of the 1st and 2nd radiation sources from the angular position of the 2nd source at mechanical turn of antenna.

Using formulas (18) and (19) the graps of dependence $\Delta\varphi = f(\delta)$ were built. Fig. 5 shows the dependences of the minimum angular separation of the 1st and 2nd radiation sources from the angular position of the 2nd source at the minimum value of the relative voltage induced by the first source using the electric displacement of the pattern zero. Fig. 6 depicts the same dependence as Fig. 5 but using the mechanical antenna turn.

Based on the theoretical considerations, the mechanical method for the antenna turn is chosen. Consequently, the antenna array can with the help of rotary device change the position of the major lobe in the azimuthal plane discretely through 60° and continuously within ± 45°.

The antenna array 3x2 consists of three turn style radiator in the upper row and three vertical dipoles in the lower row.

Conclusions

When the antenna pattern is electrically scanning in order to prevent interference, the minimum angular separation of signal source and interference source increases with increasing azimuthal angle of the interference source position. This is due to the deformation main lobes of pattern at deviation of the pattern zero direction from the perpendicular to the antenna aperture of the antenna system.

At mechanical turn of antenna the pattern does not change, that provides a steady separation capability for all positions of the interference source.

Next work will describe the antenna and processing blocks, which constructing on the presented theoretical basis.

References

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