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CONTROL OF DIRECTIONAL DIAGRAM OF THE INPHASE ARRAY FOR RADIATORS OF SUPERSHORT RADIO IMPULSES

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Abstract

The method simultaneous excitation is considered of microwave oscillations in linear arrays of spark radiators. It is based on the voltage multiplication circuit's usage. The influence is studied of the growing voltage along of antenna array and the switching time of dischargers in the array on performances of the directional diagram.

The method of control directional diagram array is based on short-duration pulse shape properties. The beam direction depends on pulse radiators excitation parameters. The parameters experimental probing results are given for linear antenna array of spark radiators.

Keywords: antenna array, directional diagram, ultra-short impulses (USI).

1. INTRODUCTION

It is necessary to have simple, compact, directed the sources of radiation of ultra-short radio impulses, for solution of some applied problems. The different designs are considered of ultra-wide-band (UWB) strip radiators with spark excitation [1, 2]. Their lacks: the directional diagram (DD) is wide; the power is limited of radiation. For elimination of these lacks, it is necessary to unite spark radiators in array. The chosen design represents of antenna array (AA) integrated connection of radiating elements and generator Arkadeva-Marksa. The offered scheme provides more simple way of synchronous excitation of modules. The power DD AA is characterized by a narrow main beam and absence of lateral petals. The control DD method is based on properties of the pulse form of wave. The beam direction depends on parameters of impulses of excitation radiators.

The work purpose working out of compact in-phase array sparks radiators with control DD.

2. ANTENNA ARRAY

Principle of action of spark radiator:
- the plates strip spark radiator (Fig. 1) [1] form capacity, which is charged to size of voltage of breakdown;
- the spark short-circuit of plates strip spark radiator;
- the oscillatory process arises at a recharge of these plates. Fluctuations fade quickly, because of low Q-factor. It provides reception of short radio impulses. The length of a wave set by the sizes of plates.

The electric scheme offered for excitation of spark radiators in array. It is based on application of schemes of multiplication of voltage (Fig. 2) [3]. This scheme provides excitation of radiators by linearly accruing voltage, which results from an over voltage in the subsequent cascades of multiplication of voltage.

In process of series connection of spark discharge device, there is a gradual additional charge of parasitic capacities in all next capacitor stages.

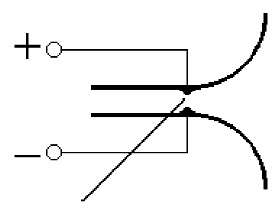

Fig. 1. Strip spark radiator.

The input signal amplitude $X(t)$ increases almost on $(i-1)U_0$ for (i) of spark discharge device. Linear increase of amplitude of an exciting impulse along a linear array takes place. The switching time changes simultaneously with voltage growth of spark discharge device. It leads to delay reduction on a phase of generated fluctuations in each subsequent radiator. Influence of increasing voltage and of time delay on DD array is

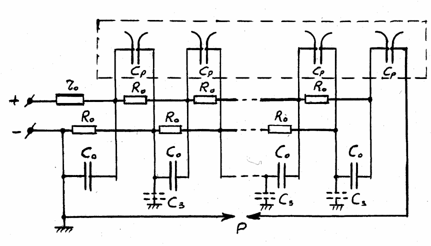

Fig. 2. Synchronous excitation of spark radiators.

defined by expression for a normalized multiplying factor of linear array [3]:

$$F(\eta)=\frac{\left|\dot{f}(\eta)\right|}{\left|\dot{f}_{\max}\right|}=$$

$$=\left\{\left[\frac{\sin(\eta-\beta)}{(\eta-\beta)}\right]^2+\frac{\alpha^2}{(\eta-\beta)^2}\left[\cos(\eta-\beta)-\frac{\sin(\eta-\beta)}{(\eta-\beta)}\right]^2\right\}^{-1/2}, \tag{1}$$

where $f(\eta)$ - nonnormalized multiplying factor of array,

$$\dot{f}(\eta)=\frac{L}{2}\int_{-1}^{1}A(\xi)e^{i\varphi(\xi)}e^{j\eta\xi}d\xi\,; \tag{2}$$

$A(\xi)$ - the factor characterizing change of amplitude lengthways ξ of array, $A(\xi)=1+\alpha\xi$; $\xi=2z/L$; L - size of array; z – coordinate of linear array; α - factor of change of amplitude, $|\alpha|\le 1$; $\varphi(\xi)$ - phase distribution lengthways ξ, $\varphi(\xi)=\beta\xi$; β - phase lag of fluctuations on the brink of array in relation to its middle; $\eta=\frac{\pi L}{\lambda}\sin(\theta)$; λ - wavelength; θ - viewing angle.

The dependences are resulted on Fig. 3 for a normalized multiplying factor linear array with 5 element spark radiators which are placed with interval $d=\lambda/2$, at values $\alpha=1$ and $\beta=0,\pi/2,\pi$.

The radiation maximum is displaced on the size defined by expression

$$\sin(\theta_m)=\frac{\lambda\beta}{\pi L}, \tag{3}$$

where θ_m - angular coordinate of maximum of radiation.

Thus, direction DD depends from size β. It is defined by a difference of phases of fluctuations on the brink of array in relation to its middle. This process can be operated if to change parameters of signal $X(t)$ or to influence signal passage through a generator Arkadeva-Marksa. That as a result will change sizes field strength E in backlashes of spark discharge device.

3. CONTROL SIGNAL

Signal reflected from accompanied object will return to the transceiving AA. With arrival account m the rereflected signals ($1\le m\le M$):

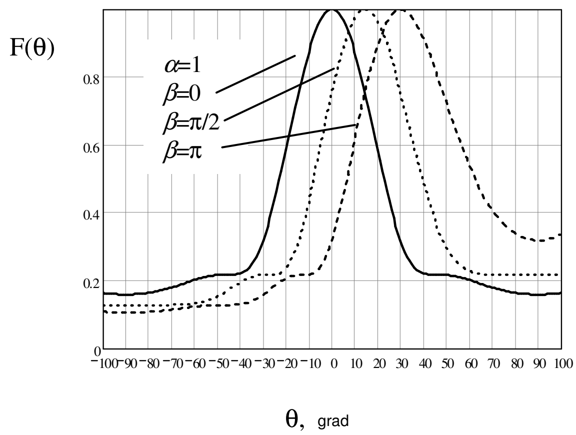

Fig. 3. Normalized multiplying factor of array with spark radiators under following conditions a = 2λ.

$$S_r(t)\equiv\sum_{m=1}^{M}\sum_{n=-N}^{N}\frac{dS(t-\tau_n(\theta)-\tau_m)}{dt}, \tag{4}$$

where the normalized distribution delay of wave is equal:

$$\frac{\tau_n(\theta)}{\tau_u}=\frac{n}{2N}\rho Sin\theta\,,\ -N\le n\le N\,,\ \rho=\frac{L}{c\tau_u}.$$

ρ - space width of a frequency band,

$L=2Nd$ is the length of AA.

Received impulse:

$$Z(t)=S_r(t)\otimes h(t)\equiv$$

$$\sum_{m=1}^{M}\sum_{n=-N}^{N}\int_{-\infty}^{\infty}\frac{dS(t-\tau_n(\theta)-\tau_m)}{dt}h(t-\tau_m-\tau)d\tau, \tag{5}$$

where $h(t)$ is the pulse characteristic of receive antenna.

Let's consider a case, when *m=1*. If on transmission and reception works one AA with *2N>> 1* it is possible to pass in (5) from summation on *n* to integration by means of following replacements:

$$\eta=\frac{n}{2\mathrm{N}},\qquad d\eta=d\left(\frac{n}{2N}\right)\qquad \text{and for}$$

$$n=\pm N\rightarrow -\tfrac{1}{2}\le\eta\le\tfrac{1}{2}$$

The integrated waveform $S_r(t,\theta)$ is expressed as follows

$$S_r(t,\theta) \approx 2N \int_{-\frac{1}{2}}^{\frac{1}{2}} S\left(t - \eta \frac{\rho}{\Delta F} Sin\theta\right) d\eta \qquad (6)$$

At signal reception

$S_r(t - \tau_n(\theta))$, where $n = 0, \pm 1, \pm 2, ...; \pm N$,

falling on array, the impulse front will be transformed by elements of AA to voltage signals. On an exit of each element AA, the signal is compared with the radiated impulse. Correlation process maximizes the relation a signal-noise for a case of the additive white normally distributed noise. After correlation, the signal will be transformed to frequency area. Fourier transformation of signal (6) is resulted for model generalized a Gaussian pulse:

$$\Lambda_r(f,\theta) = 2N\Lambda(f) Sinc\left[\pi\rho \frac{f}{\Delta F} Sin\theta\right], \qquad (7)$$

where $\Lambda(f)$ - Fourier transformation of signal which it is radiated.

This transformation is convenient for the spatially-frequency analysis of the waveform, on an exit of the system formation beam. Each correlator can be regarded as the matched filter having in a complex integrated transfer function $\Lambda_r^*(f)$. All signals arrive on adder SUM after transformations. Function of spectral density of energy on exit SUM can be expressed as follows,

$$W_r(f,\theta) = W(f)\left[H_a(f,\theta)\right]^2 =$$
$$= \Lambda_r(f)\Lambda_r^*(f)\left[2NSinc\left[\pi\rho \frac{f}{\Delta F} Sin\,\theta\right]\right]^2 \qquad (8)$$

In (8) $W(f)$ - the spectrum of density of energy, for USI, which is radiated, and $H_a(f,\theta)$ it is transfer function of the system of formation of a beam AA.

At reception on an axis (on a normal to AA $\theta = 0^\circ$), power spectrum $W_r(f,\theta) = W(f)$. Under other by an angle, power spectrum $W_r(f,\theta)$ on exit (SUM) is modulated of radiated power spectrum $W(f)$. Modulation of the received signal, depending on a direction, is the helpful information for definition of an angular direction.

The oscillation frequency increases in spectrum $W_r(f,\theta)$ - with a deviation from the normal to AA. Hence, the oscillation frequency can be used for estimation of an angle of incidence - θ. This estimation can be used for β correction.

Functional test of real possibilities of formation DD were spent on a breadboard model 5 element linear arrays of strip spark radiators. Array external appearance is represented on Fig. 4.

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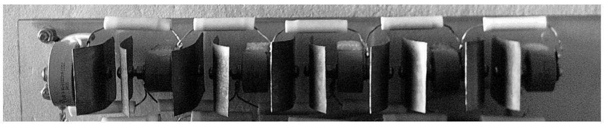

Fig. 4. External appearance of linear array spark radiators under following conditions λ = 12 sm.

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