Interaction of Ultrawideband Radiators in Linear Array with Wave Beam Steering

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Results of investigations of ultrawideband linear four-element arrays of combined antennas are presented. Space-time and energetic radiation characteristics of the arrays excited with a 1-ns length bipolar pulse and a 0.5-ns monopolar pulse in the wave beam steering mode were obtained.

1. Introduction

Application of short (~10^{-9} s) ultrawideband (UWB) electromagnetic pulses is promising for solving series of tasks. Short pulse length provides good space resolution and wide frequency band allows increasing the information concerning sounding objects and media. In order to localize the sounding region it is necessary to use array antennas. Linear arrays allow decreasing the pattern width in one plane and realizing the aperture synthesizing mode in another plane. Besides, in some applications it is necessary to shift the pattern maximum relative to the array normal (steering mode). The latter is achieved owing to the time delay change of the array element excitation. Results of the linear array investigations in the wave beam steering mode are presented below.

2. Array element

A ~0.5-ns length monopolar voltage pulse and a ~1-ns length bipolar voltage pulse were used to excite a four-element linear array. Voltage pulses enter the input of a 4-channel power divider and then pass to the antennas by the cables. Change of the pulse delay time at the antenna input (steering mode) was realized owing to the change of the cable lengths.

A combined antenna intended to radiate high-power UWB pulses and described in detail in Ref [1] was used as elements in the arrays under investigation. Voltage standing-wave ratio (VSWR) of the antenna doesn't exceed 3 in the frequency band from 350 to 2000 MHz. Energy reflected from the antenna input equals approximately to 11% and 45% of the generator pulse energy at the excitation by a bipolar and a monopolar pulses, respectively. The pattern width by the half level of the peak power is ~90° for the H-plane and ~100° for the E-plane.

3. Array parameters

Fig. 1 presents schematically horizontal and vertical arrays. The arrows indicate a polarization plane of the radiated pulse. Here, h is the element dimension equal to 15 cm and d is the distance between the centers of the elements. The elements are fastened at a dielectric plate. In case when d = h, the array elements are coupled with each other galvanically.

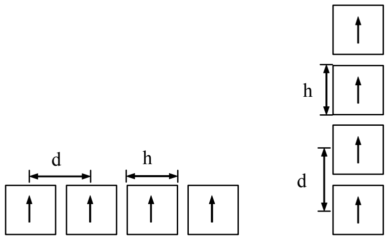

FIg.1. Configuration of the arrays under investigation

Measurements of the energy reflected from the inputs of the elements and VSWR versus the distance between the elements of the arrays were made.

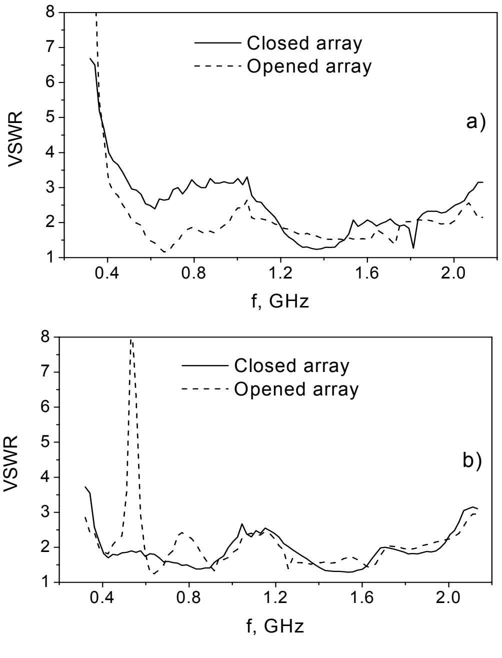

Fig.2. VSWR of internal elements of horizontal (a) and vertical (b) arrays

Fig. 2 presents VSWR of internal elements of the horizontal (a) and vertical (b) four-element arrays. A closed array denotes that the array elements are closed with each other galvanically and the distance between the centers of the elements is d = h. An opened array has d = 1.2h in this case. A vertical opened array has a resonance in the frequency band of f = 0.49÷0.58 GHz.

According to the results of measurements of reflected energy and VSWR, an optimum variant for a horizontal and vertical plane is d = 1.2h and d = h, respectively. Investigations on the wave beam steering were carried out with such arrays.

Measurements of the peak field strength E_p versus the distance R between a four-element array and a receiving antenna were carried out in order to determine the far-field zone boundary. As it is seen from Fig.3, at the distance *R* >2 m the curve of the efficient potential E_pR weakly depends on *R*, i.e., the field changes proportionally to *1/R* that is the factor of the far-field zone. All measurements with arrays were made at the distance exceeding 2 m.

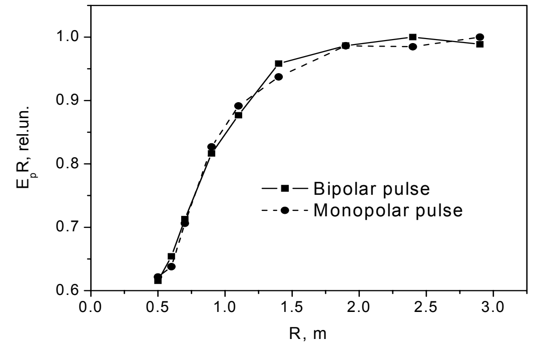

Fig.3. Efficient potential versus the distance

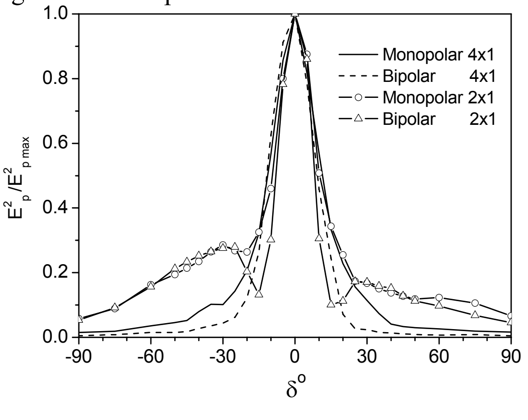

Fig.4. Patterns of vertical arrays in E-plane

4. Wave beam steering

The array pattern depends both on the number of elements and on the distance between them. Fig.4 presents the patterns by power in the E-plane for two- and four-element vertical arrays with equal aperture of 0.6 m. As it was shown previously in numerical calculations [2], the pattern width for the arrays excited by bipolar and monopolar voltage pulses is determined by the array aperture and the level of the background radiation is determined by the number of the array elements and the distance between them. The obtained experimental data agree with calculation results. The pattern width in the E-plane for the four-element array by the half-power level is not higher than 25°. Analogous results were obtained for a horizontal array in the H-plane.

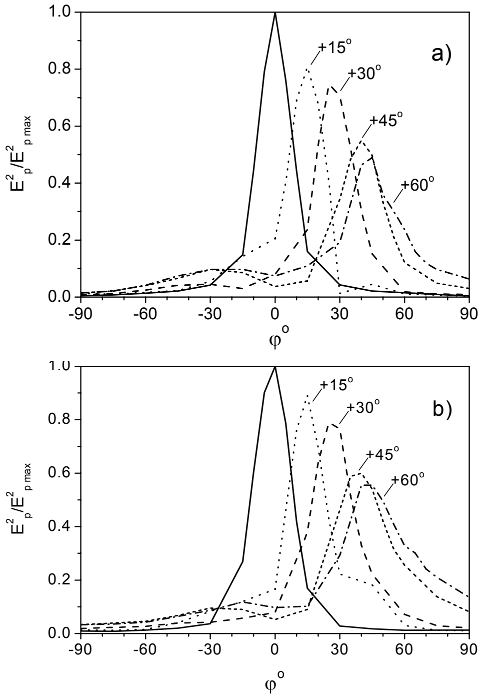

Fig.5. Horizontal array patterns for different steering angles at excitation by bipolar (a) and monopolar (b) pulses

A steering mode was realized by choosing the length of the cables exciting the array elements so that they should provide the necessary pulse delay. When the array operated in the steering mode, changes of the pulse waveform in the main direction of the pattern and position of the pattern maximum were investigated. Figs.5 and 6 present the patterns of four-element arrays for different steering angles at excitation by bipolar and monopolar pulses, respectively. The patterns were normalized to the pattern maximum without steering, i.e., in the mode of synchronous excitation of the array elements. Alongside with the diagrams measured experimentally, the values of the estimated angles of the pattern main direction are presented without taking into account interaction of the array elements. As it follows from the obtained results, the difference between the given (estimated) angle of the pattern main direction and the measured one appears with the steering angle increase. This difference is not higher than 5° at the steering angles of

±45°. Note that the diagram measurements were made with the step of 5°. It is seen from the diagrams that the electromagnetic field strength in the pattern maximum decreases and the pattern width increases at the steering by the wave beam. In contrast to Ref. [1] where an electric dipole was used for signal receiving, a receiving TEM-antenna was used in the given work that allowed increasing the accuracy of measurement of the waveform of radiated UWB pulses.

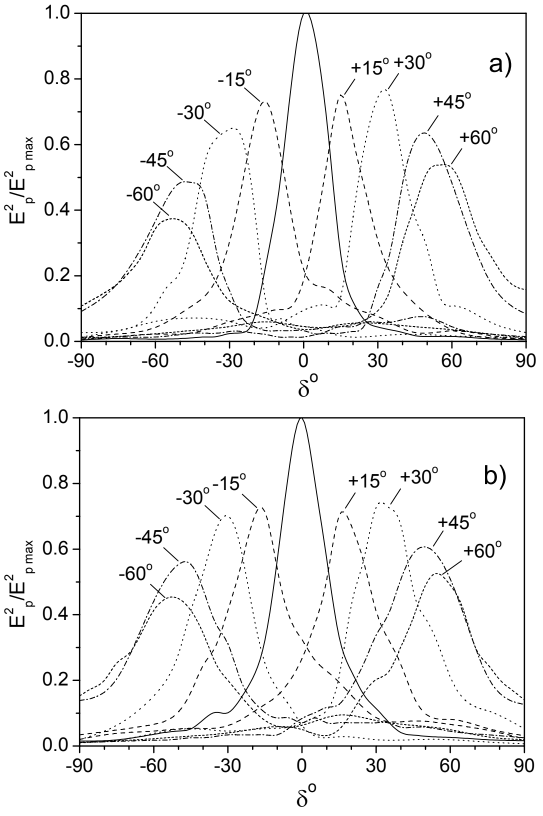

Fig.6. Vertical array patterns for different steering angles at excitation by bipolar (a) and monopolar (b) pulses

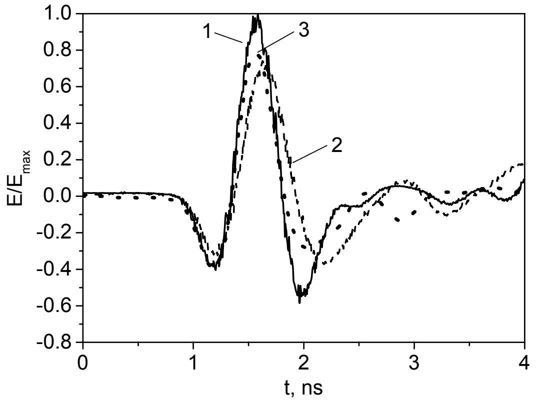

Fig.7. Pulse waveforms in the pattern maxima for horizontal array without steering (1) and for steering angle of +45° for horizontal (2) and vertical (3) arrays

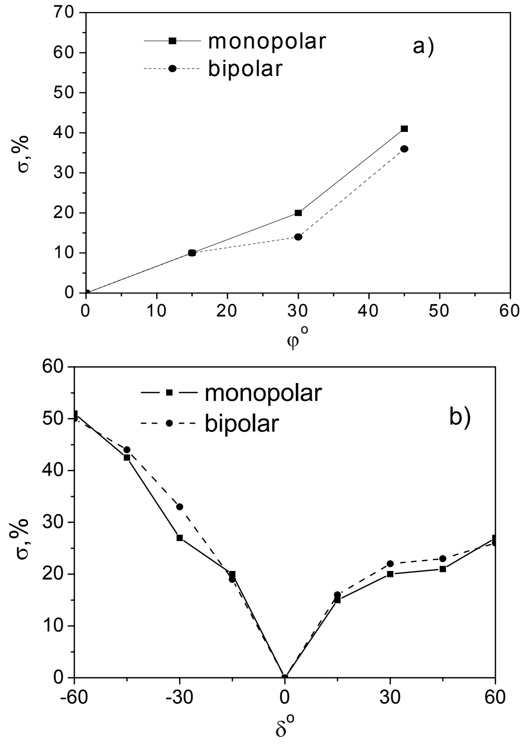

Fig.8. Root-mean-square deviation of the pulse waveform for different steering angles at excitation of horizontal (a) and vertical (b) arrays

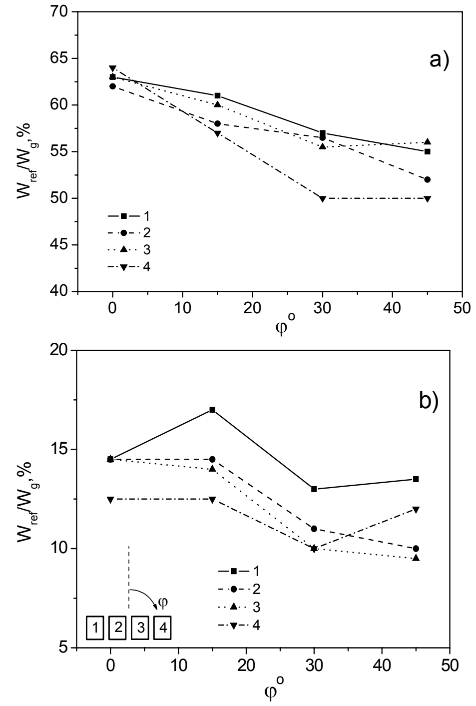

Fig.9. Reflected energy versus the steering angle for horizontal array excited by monopolar (a) and bipolar (b) pulses

Fig.7 presents pulse waveforms in the pattern maxima for the horizontal array without steering and for the steering angle of +45° for the horizontal and vertical arrays.

Fig.8 presents deviations of the measured pulse waveform in the pattern maximum at different estimated steering angles versus the pulse in the pattern maximum without steering. Increase of the root-mean-square deviation with the steering angle increase is conditioned mainly by the radiation pulse broadening. Pulse waveforms of the single antenna and array at the given steering angle are close.

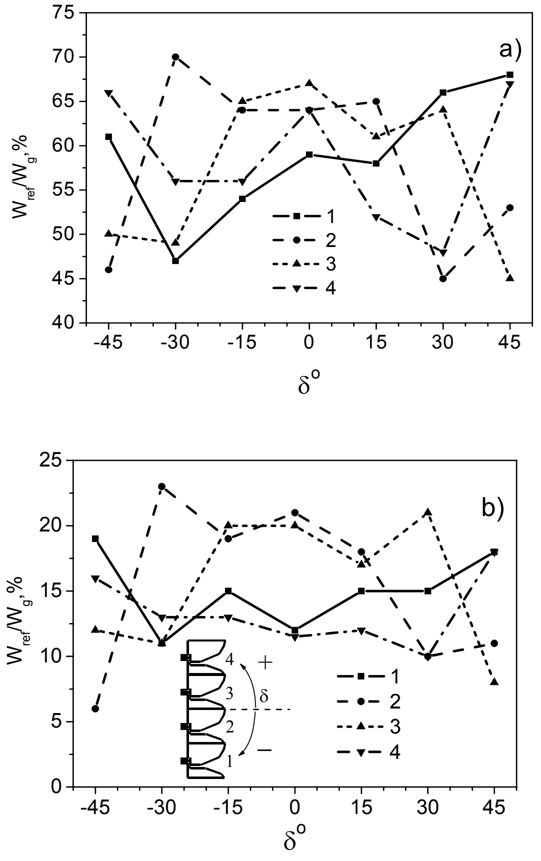

Fig.10. Reflected energy versus steering angle for vertical array excited by monopolar (a) and bipolar (b) pulses

Fig.9 presents reflected energy versus the estimated steering angle for a monopolar (a) and bipolar (b) pulses for a horizontal four-element array. It is seen that in the average the reflected energy decreases with the steering angle increase for the horizontal array. Dependence of reflected energy on the steering angle for the vertical array is expressed more significantly and differs for the elements in the array (Fig.10).

5. Conclusion

Arrays based on combined antennas allow providing steering by the wave beam of high-power UWB radiation in the limits of ±45°. The steering angle can be increased up to ±60° without changing the dimensions of the array elements owing to increase of the pattern width at the increase of the combined antenna magnetic dipole perimeter up to $S/S_0 = 0.8$ [1] instead of the one used in the given work, and namely $S/S_0 = 0.6$. Note, that UWB arrays based on TEM-antennas provide less steering angles equal to ±7° [3] and ±20° [4] owing to a narrower pattern.

References

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