Optimization of Combined Radiators of High-Power Ultrawideband Electromagnetic Pulses

Yu.A. Andreev and S. Liu*

Institute of High Current Electronics SB RAS, 2/3, Akademichesky ave., Tomsk, 634055, Russia, Phone: 8(3822) 49-19-00, 8(3822) 49-24-10, E-mail: andreev@lhfe.hcei.tsc.ru
**Tomsk Polytechnic University, 30, Lenin ave., Tomsk, 634050, Russia*

Abstract – The paper presents the results of the combined UWB antenna geometry optimization. This optimization was done for increasing the electric field strength in the boreside direction of the antenna.

1. Introduction

One of the main problems of high-power ultrawideband (UWB) radiation sources is to obtain pulsed electromagnetic fields with maximum possible peak amplitudes. This requires optimization of all parts of the sources: pulse generators, feeder lines, and radiators. Optimization of a transmitting UWB antenna geometry for the purpose of increasing the peak amplitude of the electric field strength Ep in the boresight direction of antenna radiation is considered in the present paper.

Several approaches can be used in order to achieve the problem.

The first consists in improvement of the antenna matching with feeder in a possibly broader passband (absorbing materials are not used) and, hence, increasing of a part of radiated energy. Maximum effect will be observed at the antenna matching improvement in the range of frequencies corresponding to the spectrum maximum of the pulse exciting the antenna.

The second method consists in the antenna pattern narrowing. This approach usually requires increasing the transmitting antenna aperture.

The third method is stabilization of position of the antenna pattern maximum in a possibly broader frequency band. This method can be also interpreted as the antenna passband broadening.

The subject of investigation is a combined UWB antenna. This type of antennas has been actively used during more than ten years as radiators in high-power sources of UWB radiation built by the “one generator – one transmitting antenna” scheme [1] as well as when radiator is an array antenna [2].

2. Antenna and model antenna geometries

Figure 1, *a* presents the combined antenna geometry. This antenna can be considered as a combination of an electric type radiator made as a TEM-horn with one active and two passive magnetic dipoles. The antenna input is a transition from a coaxial line to two strip lines. The lower strip line (Fig. 1, *a*) feeds the TEM-horn and the upper line of the length $\cong h$ feeds an active magnetic dipole.

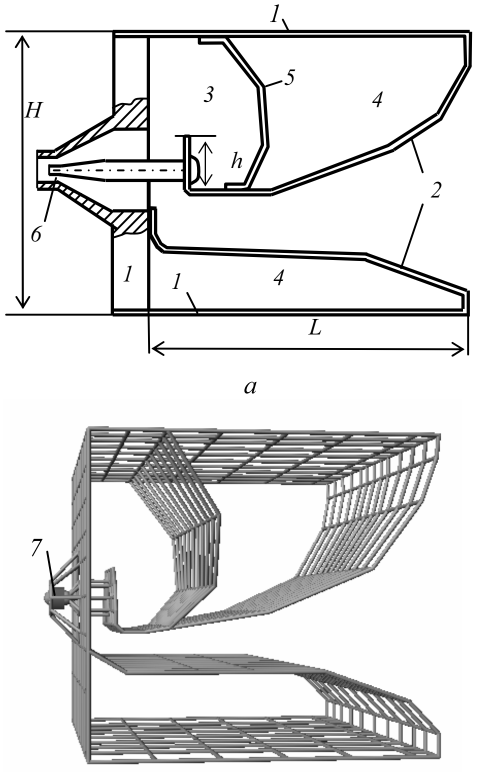

Fig. 1. Antenna (*a*) and wire model (*b*) design: *1* – case; *2* – TEM-horn; *3* – active magnetic dipole; *4* – passive magnetic dipole; *5* – additional electrode; *6* – N-connector; *7* – voltage source

The antenna chosen as a subject of investigations had the following sizes: longitudinal L = 16 cm, height H = 15 cm (Fig. 1, *a*), and antenna width of 15 cm [3]. The thickness of aluminum plates of which the antenna is made (except the rear wall) is 1.7 mm. This antenna is optimized to radiate a bipolar voltage pulse of the length 1 ns.

Characteristics of the present antenna were investigated in the frequency and time domains. To carry out numerical simulations, there was used a 4NEC2 program that is a free version of a NEC2 code allowing carrying out investigations of models in a frequency domain. A wire numerical model of the antenna (Fig. 1, *b*) had the same dimensions and was made of 900 aluminum cylindrical wires (1500 segments) of a 2-mm diameter. The voltage source with the internal impedance of 50 Ω was placed at a central conductor of the input coaxial line. The external conductor of the coaxial line is formed by eight wires, each of them being connected to the voltage source through a conductor with a lumped resistance of 400 Ω. This design simulates a 50-Ω coaxial feeder.

3. Combined antenna characteristics in frequency domain

Comparative investigations of the combined antenna characteristics and the wire model were made to test the latter.

Figure 2 presents VSWR of the combined antenna and wire model versus frequency. The diagrams show that numerical simulation and experiment results are in good agreement.

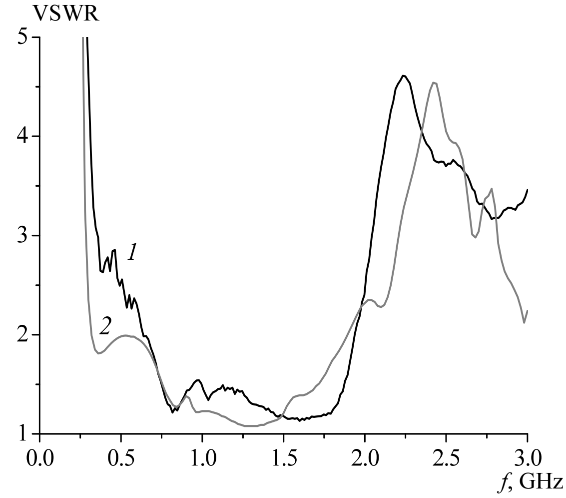

Fig. 2. VSWR of combined antenna (*1*) and the wire model antenna (*2*)

Investigations of spatial distribution of radiation were fulfilled as well. The investigations were made at the frequencies ranging from 0.3 to 1.8 GHz. The lower boundary frequency (300 MHz) in these investigations was determined by the lower boundary frequency of the antenna matching (f_1 = 310 MHz by the level of VSWR = 4), and the upper one (1.8 GHz) – by the measurement capability. Fig. 3 presents the normalized power patterns of the combined antenna and wire model in E- and H-planes for the frequencies equal to 0.3, 0.5, 1, 1.5, and 1.8 GHz, respectively. The diagrams show that the antenna and model patterns are in good agreement in the given frequency range and some noticeable differences are available only at the edges.

Further, comparative investigations of the antenna and model amplitude-frequency responses were made in the frequency band ranging from 0.3 to 2 GHz. Investigation of the amplitude-frequency responses of a combined antenna were carried out by two identical

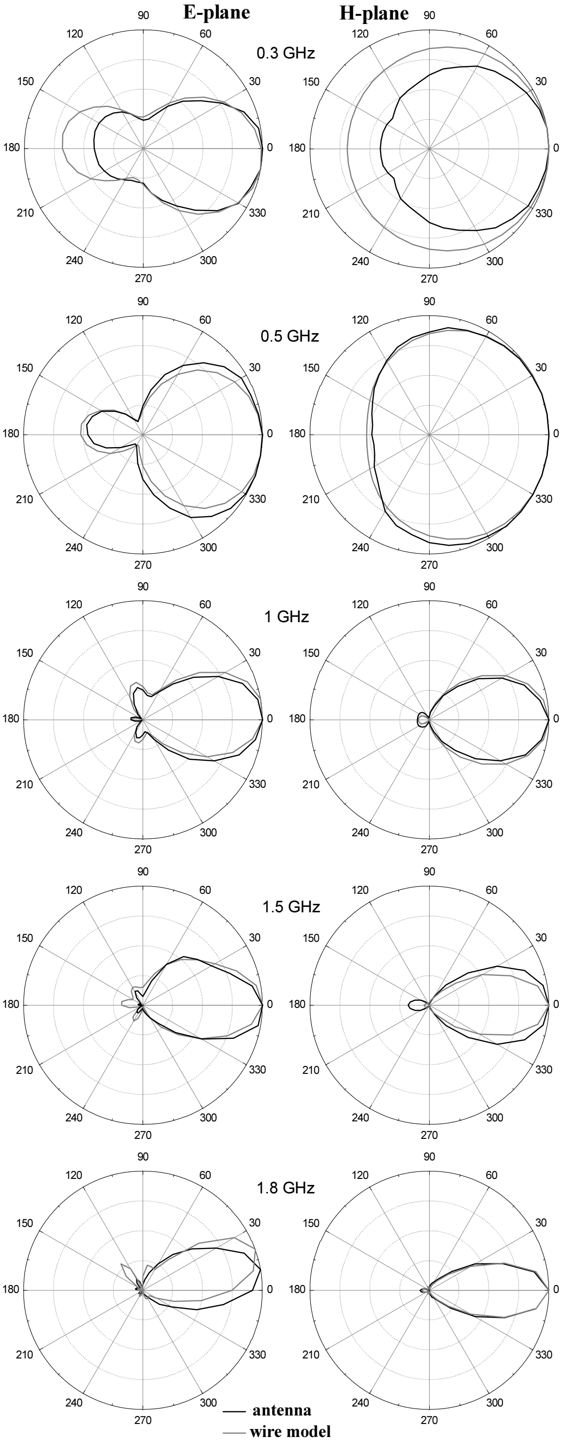

Fig. 3. Combined antenna and wire model normalized power patterns for E- and H-planes

antennas setup at an Agilent 87619ET network analyzer. To find out the wire-model amplitude-frequency responses at fixed frequencies, the model patterns were calculated and the electric field strengths were found out in the boresight direction (φ = 0° and δ = 0°, where φ is the azimuth angle, δ is the elevation). The input power was chosen taking into account VSWR of the model at this frequency.

As it is obvious from the above-presented diagrams, the antenna and model amplitude-frequency responses practically coincide for the frequencies ranging from 0.6 to 2 GHz. In the low-frequency region (0.3–0.6 GHz), the model amplitude-frequency responses are essentially lower than those of the antenna. For the frequencies close to 300 MHz this mismatch can be related to the essentially higher level of the wire model radiation power compared to the antenna in the rear half-plane. This is especially noticeable for H-plane (Fig. 3). Hence, at the equal input power, the power radiated by the antenna in the boresight direction should be higher than that of the wire model that is confirmed by Fig. 4.

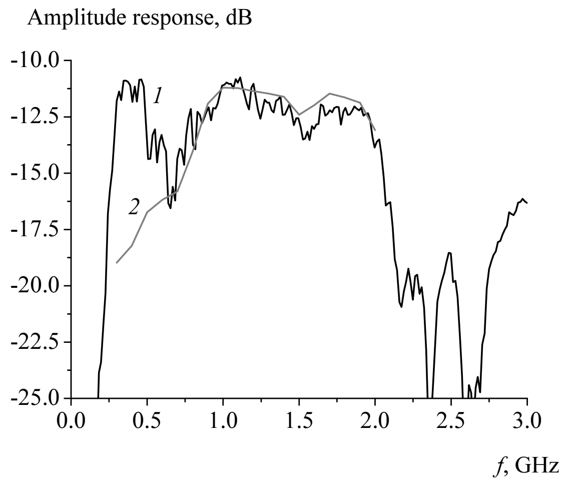

Fig. 4. Combined antenna (*1*) and wire model (*2*) amplitude response for a boresight direction

4. Possible approaches to a combined antenna optimization

Here, we consider optimization possibilities of the combined antenna under investigation. As it is seen from the diagram (Fig. 2), VSWR is < 1.5 for the combined antenna in the frequency band ranging from 750 to 1800 MHz. I.e., the antenna has got a good matching in the given frequency band and it will be very difficult to decrease VSWR in this band.

Figures 5, *a* and *b* present, respectively, the pulse exciting the antenna and the power spectra of this pulse. It is seen from the diagrams (Fig. 2 and Fig. 5, *b*) that the power spectral density maximum corresponds to the frequency range where the antenna has a good matching. Capabilities of the antenna matching improvement are related to the region of low and high frequencies that is less effective owing to a small part of energy of the generator pulse corresponding to these frequencies.

Optimization of the combined antenna geometry in our investigation implies conservation dimensional sizes of the antenna. Hence, it is impossible to increase E_p in the boresight direction owing to the antenna aperture broadening and, as a result, the pattern narrowing. Besides, in the previous investigations it was shown that the location of additional electrode *5* (Fig. 1) in the antenna volume influences the value of E_p in the boresight direction [4]. The location of this electrode in the combined antenna is close to optimum for obtaining maximum E_p.

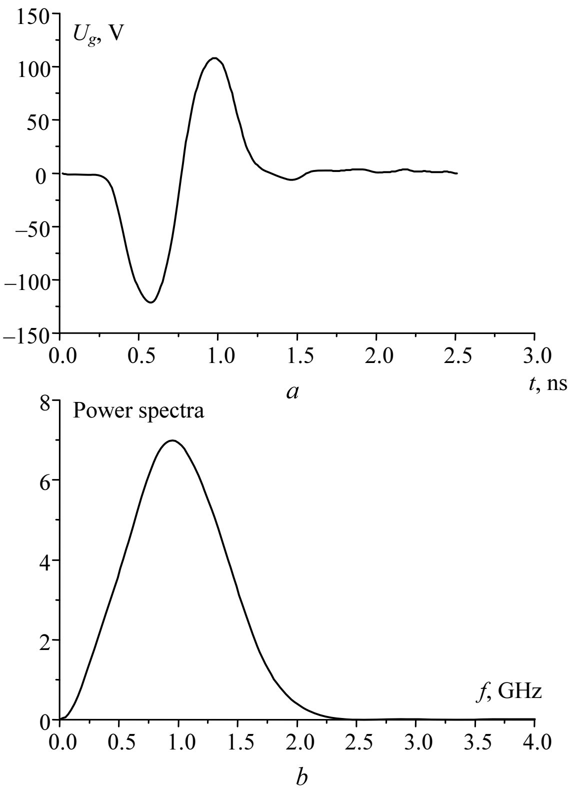

Fig. 5. Generator pulse (*a*) and its spectrum (*b*)

5. Results of combined antenna optimization

As it was suggested in [5] it is possible to improve the antenna matching in the region of high frequencies decreasing the height of a coaxial-to-strip transition *h*. This modification (first) of the antenna geometry was investigated at a wire model in the frequency domain and at the antenna at its excitation with a bipolar pulse.

The ratio of the field strength change (ΔE) in the boresight direction for the fixed frequencies in the range of 0.3–2 GHz to the initial model field strength (E_{norma}) will be used as a criterion of the wire model optimization efficiency. One can expect the increase of the E_p amplitude in a pulsed mode if the antenna phase-frequency response is linear, if there is the field strength rise at the fixed frequencies.

Figurev 6 (curve *1*) presents the field strength change dependence in the frequency band for a wire model with a length *h* shortened by 3 mm (initial length $h = 28$ mm). It is obvious from the diagram that the electric field strength for the first wire antenna modification exceeds the norm at the frequencies of 1–2 GHz, however, noticeable field strength increments (> 4%) are available for too high frequencies

(> 1.7 GHz) and one should not expect any noticeable increase of E_p value.

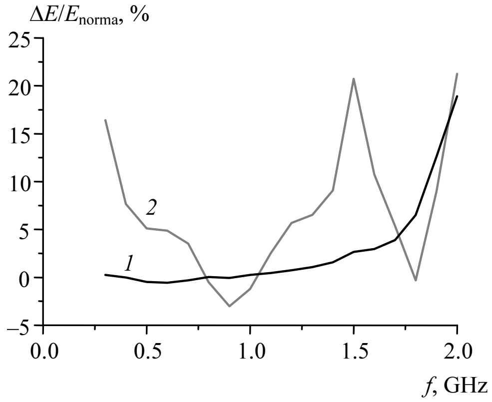

Fig. 6. Electric field strength change in the frequency band for two wire-model modifications

This assumption was confirmed in the pulsed investigations of the antenna. A receiving TEM-antenna was located at a 2-m distance from a combined one. A TDS 6604 oscilloscope with a 6-GHz passband recorded radiated pulse. Measurement results show a 2% increase of the E_p amplitude of the modified antenna.

Perhaps, second antenna modification will be more promising. Here, there was made an attempt to improve the antenna matching in the low-frequency region. As it was shown in [6], we increase the wire-model TEM-horn opening angle (Fig. 7). In addition, the geometry of additional electrode *5* (Fig. 1) was changed insignificantly in this model. Calculation of the field strength change in the frequency band for this wire model is shown in curve *2*, Fig. 6.

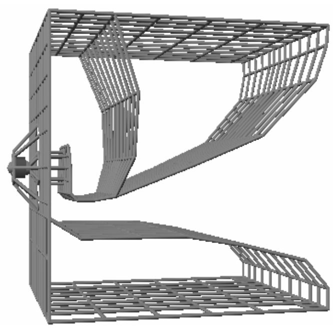

Fig. 7. Wire model secondary modification

Pulse measurements of the given modification of a combined antenna are the subject for future investigations.

6. Conclusion

A wire model of a combined UWB antenna was created. Measured combined antenna VSWR, radiation pattern and amplitude amplitude-frequency response agree with calculated values. Possibilities to optimize the antenna for the purpose of increasing the peak amplitude of the radiated electric field in the mode of antenna excitation with a bipolar voltage pulse were considered.

References

[1] Yu.A. Andreev, V.P. Gubanov, A.M. Efremov, V.I. Koshelev, S.D. Korovin, B.M. Kovalchuk, V.V. Kremnev, V.V. Plisko, A.S. Stepchenko, and K.N. Sukhushin, Laser and Particle Beams **21**, 211 (2003).

[2] V.P. Gubanov, A.M. Efremov, V.I. Koshelev, B.M. Kovalchuk, S.D. Korovin, V.V. Plisko, A.S. Stepchenko, and K.N. Sukhushin, Prib. Tekh. Eksp. **3**, 312 (2005).

[3] V.I. Koshelev, V.V. Plisko, and K.N. Sukhushin, *in Proc. 4th Conf. Electronnye Sredstva i Sistemy Upravleniy*, 2007, pp. 202–205.

[4] Yu.A. Andreev, Yu.I. Buyanov, and V.I. Koshelev, Radiotekhn. Elektron. **50**, 585 (2005).

[5] Yu.A. Andreev and S. Liu, *in Proc. 4th Conf. Electronnye Sredstva i Sistemy Upravleniy*, 2007, pp. 150–152.

[6] W. Simon, A. Lauer, D. Manteuffel, A. Wien, and I. Wolff, *in Proc. Ultra-Wideband, Short-Pulse Electromagnetics*, 2007, pp. 131–141.