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Ultrawideband combined antenna with improved matching

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Abstract. To study the immunity of electronic equipment to ultrawideband irradiation, a combined antenna with improved matching has been created. In contrast to the previously presented, a novel antenna has a modified input node with a flat part instead of a cylindrical one. As a result of optimizing the geometry of the antenna electrodes, a matching band with the feeder of 0.38-2.4 GHz was achieved by the $VSWR = 2$. The results of the investigations of antenna characteristics in the frequency domain, as well as the waveforms of the radiated short ultrawideband pulses are presented.

1. Introduction

To test electronic devices for immunity to high-power pulsed electromagnetic irradiation, compact ultrawideband (UWB) radiation sources are required. The sources should create high intensity of the pulsed electromagnetic field at a short distance from the antenna system. The task of protecting of control circuits and communication equipment from such impacts is equally important.

Commercial devices designed to immobilize modern cars due to the failures in the operation of electronic engine management systems are well known [1, 2]. They can be used to cause a failures in the control, communication and navigation systems of drones and unmanned vehicles. The sources of high-power pulses based on the IRA antenna presenting a high-voltage switch placed in the focus of a parabolic reflector are described in [3]. Relative simplicity is distinguished by the sources having a dipole feed antenna in the focus of a circular parabolic reflector [4]. A feed antenna in the form of a TEM-horn located near the focal point of an offset reflector is noted for relative simplicity too.

To develop the antenna system of a high-power source of nanosecond pulses based on a combined antenna [5] is a subject of interest. A distinctive feature of this type of antennas is their small electrical dimensions allowing to use them as elements of the antenna array [6]. Since the combined antennas have a pattern close to the cardioid, this gives a possibility to use them as an irradiator of the parabolic reflector. For excitation of a high-power UWB source, it is preferable to use a bipolar voltage pulse since it has a mean value close to zero. This means that the spectrum of bipolar pulses has low energy of the low-frequency region, which substantially increases the energy efficiency of the radiator.

Common used communication and control protocols typically use frequencies from 0.4 to 2.5 GHz, which corresponds to the spectrum of 1-ns bipolar voltage pulse exciting the antenna. The maximum energy is concentrated near central frequency that is close to 1 GHz. Previously developed combined antennas for the frequency range indicated above, have been optimized to increase the peak field strength in the direction of the main maximum of the pattern [7]. However, the frequency band in which the antenna was matched to the feeder by the voltage standing wave ratio (VSWR) level of 2 was 0.38-1.8 GHz. The aim of this study is an attempt of further improvement of geometry of the electrodes of combined antenna for improve the antenna matching band without degrading the directional characteristics.



2. Antenna design

The antenna (Figure 1) is a combination of an electric type radiator 1, an active magnetic type radiator 2, and passive elements 3 and 4 of magnetic type. Line 5 feeding an electric type radiator has a variable cross section for creating the necessary amplitude-phase current distribution at the antenna electrodes. The antenna has a 50-ohm coaxial input 6 of increased cross-section for preventing an electrical breakdown by the voltage pulse with increased amplitude. To prevent electrical breakdown of air near the edges of antenna electrodes, the gaps between electrodes are increased too. The input element 8 has a flat part at the top to improve the matching of the antenna with the feeder in a wide frequency band. To measure the antenna characteristics, a conical adapter with an N-type connector is used.

3. Antenna characteristics

The results of measuring the VSWR of the antenna are shown in Figure 2. The VSWR was measured using an Agilent N5227A network analyzer. By the level of $VSWR = 2$, the antenna matching band is equal to 0.38-2.4 GHz. The antenna has the best matching with the feeder at the frequencies about 1 GHz. The maximum energy of the spectrum of bipolar pulses of 1 ns duration is concentrated near this frequency. A full-wave electromagnetic modelling of the combined antenna was made by developed software [8] based on the finite-difference in time domain (FDTD) technique. There is a reasonably good agreement between the simulated (curve 1 in Figure 2) and measured (curve 2) VSWR versus frequency. The difference between the curves 1 and 2 may be caused by the fact that the losses in the dielectric and metal neglected in the model.

In the direction of the main lobe of the pattern, the antenna radiation has a linear polarization. The plane of the polarization coincides with the plane yz . The simulated antenna patterns in the E - and H -planes are shown in Figure 3 and Figure 4 (curves 1). The main lobe of antenna pattern remains the direction along the z axis and the main lobe has no damping exceeding 3 dB in the frequency band equal to 0.3–3 GHz.

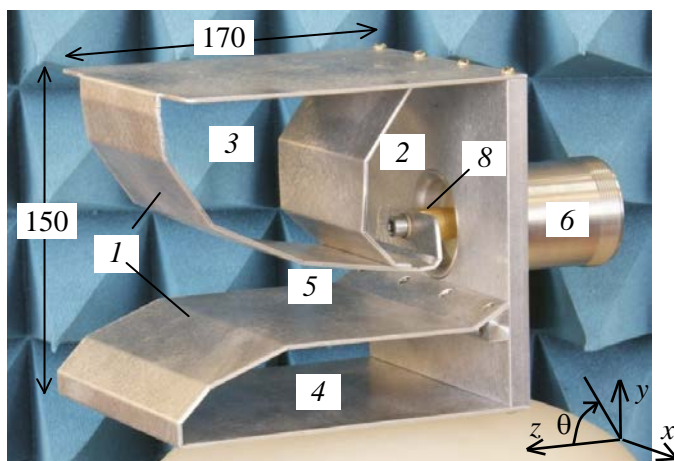


Figure 1. Antenna design.

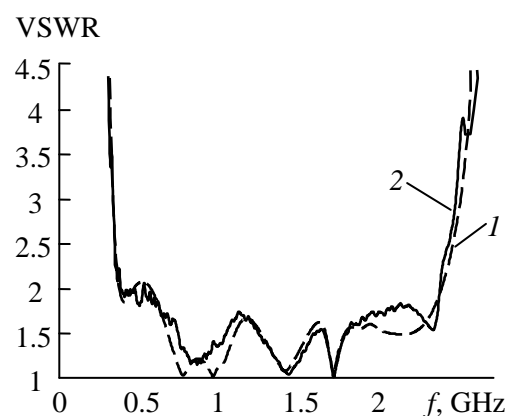


Figure 2. VSWR of the antenna:
1 – simulations, 2 – measurements.

Measurement of radiation patterns was carried out in the time domain. A low-voltage 1-ns bipolar pulse generator was used. The pulses were recorded with a LeCroy Wavemaster 830Zi digital storage oscilloscope. At the output of an auxiliary UWB receiving antenna, the pulse waveform was recorded for each angular position. Using the Fourier transform, we obtained the angular dependences of the spectral components in the 0.3-3 GHz range. Thereby plotted antenna patterns in the E - and H -plane are shown in Figure 3 and Figure 4 (curves 2).

A TEM-antenna with the ground plate dimensions of 120×50 cm and an aperture height of 8 cm was used as a standard receiving antenna for measuring UWB pulse waveforms. The voltage at the

TEM-antenna output is proportional to the incident field strength, and the effective length in a wide range is independent of frequency and equals to half the aperture height. The waveform of the voltage pulses at the output of the TEM-antenna located at a 5-m distance from the transmitting one is shown in Figure 5. The simulated waveform of the electric field strength at the same distance is presented in

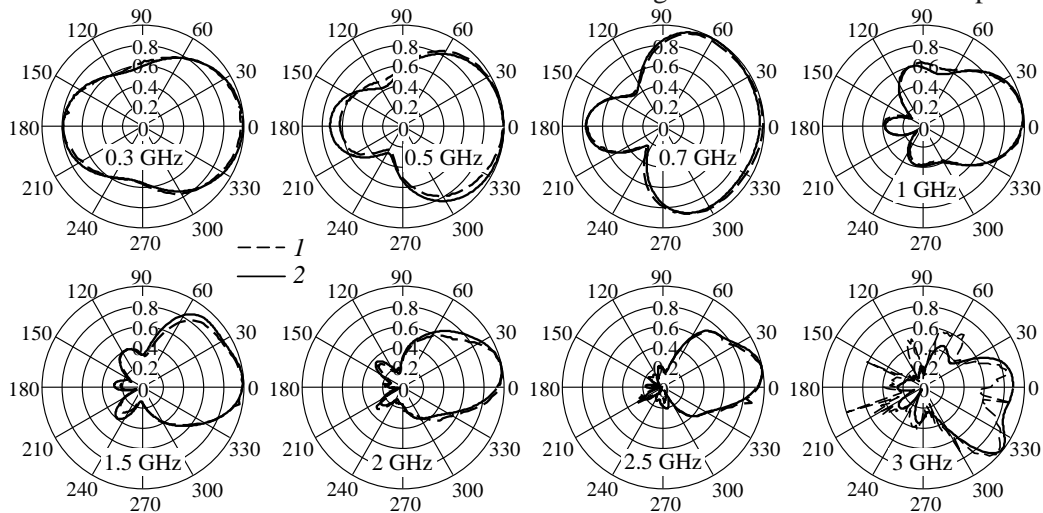


Figure 3. Antenna patterns in the *E*-plane at different frequencies: 1 – simulations, 2 – measurements.

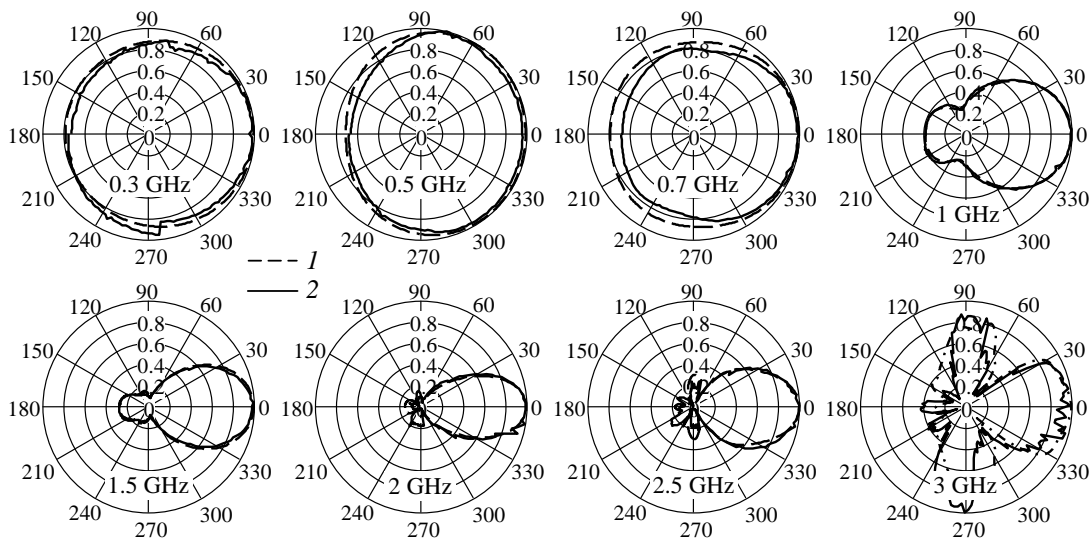


Figure 4. Antenna patterns in the *H*-plane at different frequencies: 1 – simulations, 2 – measurements.

Figure 5 as well. The difference between the curves of simulated and measured patterns in the range of 4-5 ns may be caused by the reflections from the support carrier of the receiving antenna, or from the outside conductor of the coaxial cable behind the receiving antenna.

The waveform of the radiated pulses depends on direction of observation. To quantify the value of distortion of the waveform of the pulses, the root-mean-square (RMS) deviation σ of the pulses $V(t)$ and $U(t)$ was calculated according to the expression: $\sigma = \sqrt{\int_T [v(t) - u(t - t_0)]^2 dt / \int_T u^2(t) dt}$. Here, $V(t)$ is a voltage pulse at the output of the receiving antenna, when the transmitting antenna was rotated to an arbitrary angle θ relative to the axis z . $U(t)$ is the voltage at the output of the receiving antenna in the direction $\theta = 0$. Values $v(t) = V(t) / \sqrt{\int_T V^2(t') dt'}$ and $u(t) = U(t) / \sqrt{\int_T U^2(t') dt'}$ are

the normalized functions, T is the time window, and t_0 is the time shift of $U(t)$ relative to $V(t)$, at which σ drops to the minimum value. The measured RMS deviations of the pulse waveforms at the output of the TEM-antenna at $0 < T < 4$ ns are shown in Figure 6 in the E -plane (curve 1) and in the H -plane (curve 2). When $\sigma < 0.05$, the two functions $V(t)$ and $U(t)$ are practically indistinguishable. The difference of two waveform samples of the same pulse generator registered by the real-time oscilloscope without averaging at different points of time is estimated by the value of $0.05 < \sigma < 0.1$. Appearance of an additional time lobe on the waveform leads to increase of σ to the value of approximately equal to 0.3. For $\sigma > 0.6$, the two waveform samples differ significantly from each other. The angular sector in which σ is no higher than 0.2 has the value of $-35 < \theta < 60$ degrees in the E -plane and $-40 < \theta < 40$ degrees in the H -plane.

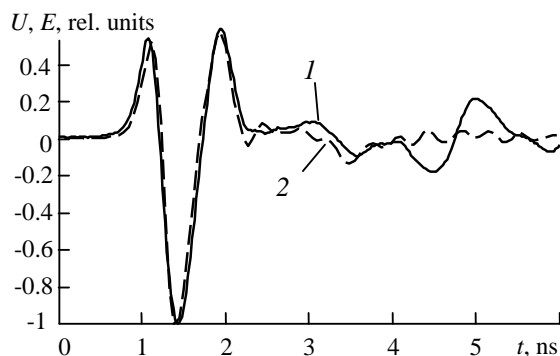


Figure 5. Measured waveform of voltage pulse at the output of receiving TEM-antenna (1); simulated waveform of the electric field strength at a 5-m distance from the antenna (2).

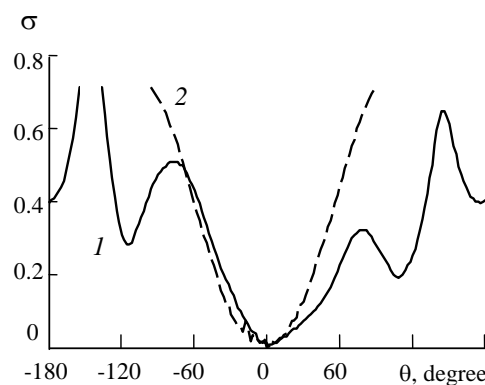


Figure 6. RMS deviation of the pulse waveforms at $\theta = 0$ and arbitrary θ at E - (1) and H -plane (2).

4. Conclusion

A combined antenna with improved matching with a 50-ohm coaxial feeder has been developed. The antenna has a modified input node with a flat part instead of a cylindrical one. Resulting from optimization of geometry of the antenna electrodes, we achieved a 0.38-2.4-GHz band of matching with feeder by the VSWR level of 2. The bandwidth at which the maximum of the antenna pattern retains its position without damping by more than 3 dB is not less than 0.3-3 GHz. The antenna is designed to radiate UWB pulses with a spectrum in the frequency band 0.4-2.4 GHz, or narrowband signals within this frequency band. The increased gaps between the antenna electrodes allow radiating UWB pulses with increased voltage for testing electronic equipment for electromagnetic compatibility.

References

- [1] Urbancokova H, Valouch J, Kovar S 2015 *Przegląd Elektrotechniczny* **91** 101
- [2] Hong K, Braidwood S 2010 *Proc. Int. Conf. Electromagn. Adv. Appl.* 378
- [3] Baum C E, Farr E G 1993 *Ultra-wideband, Short Pulse Electromagnetics* (New York, Plenum Press)
- [4] Ryu J, Lee J, Chin H, Yeom J H, Kim H T, Kwon H O, Han S H, Choi J S 2013 *IEEE Trans. on Plasma Sc.* **41** 2283
- [5] Andreev Yu A, Buyanov Yu I, Koshelev V I 2005 *J. Commun. Technol. Electron.* **50** 535
- [6] Efremov A M, Koshelev V I, Kovalchuk B M, Plisko V V, Sukhushin K N 2014 *Laser and Particle Beams* **32**(3) 413–418 doi: 10.1017/S0263034614000299
- [7] Koshelev V I, Plisko V V 2017 *J. Commun. Technol. Electron.* **62** (6) 565–568 doi: 10.1134/S1064226917050096
- [8] Zorkaltseva M Yu, Koshelev V I, Petkun A A 2017 *Rus Phys. J.* **60** (8) 1291–1297 doi: 10.1007/s11182-017-1210-8