Ultra-Wideband Sub-Nanosecond High Power Radiators[1]

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Abstract – The high power ultra-wideband (UWB) radiators for the electromagnetic video-pulses were built as assemblies of the radiating modules. Each module contained the UWB radiating antenna which constructed with few TEM-horns and the sub-nanosecond pulse power semiconductor generator with high repetition of the 3–100 kV pulsed voltage of the 50–200 ps rise time as well as a synchronizing unit. For achievement of electromagnetic compatibility of the high power radiating modules with the triggering and controlled systems we applied following methods: matching loads, ferrite rings, series shielding, optical network lines. We have used experimental and computer modeling methods to investigate some singularities at propagation of the electromagnetic video-pulses.

1. Introduction

The 0.2–200 MW pulsed generators with high repeated sub-nanosecond pulses are developed last years successfully using semiconductor technology [1–3]. We have successfully used these pulsed power sources at creation of the devices for a radiation of electromagnetic sub-nanosecond pulses with ultra-wideband frequency spectrum (UWB radiation). The giga-watt range power UWB radiators with controlled parameters were constructed as multi-source system using the UWB radiators with semiconductor generators [4, 5]. They have compared with the giga-watt range power radiators using spark switches [6] an advantage as longer life-time as create the Radiators with a controlled direction of the radiation pattern and high repetition of pulses.

2. Problem statement

The Radiator with a controlled direction of the radiation pattern is usually constructed by using few units of the pulsed radiators with a control system for a time-delay of output pulses. Each radiator-unit is composed by the radiating antenna-unit connected with the high power generator-unit by triggering off from the multi-channel master generator (MMG) with controlled time-delay into the channels ("TRIM Ltd" [7]). Few problems are needed to solve then. At first, to provide a stabilization of time delay with accuracy of better 30 ps (between a trigger pulse and the output sub-nanosecond pulse from the high power generator). Secondly, to provide electromagnetic compatibility of the giga-watt range power UWB radiator (operating with high voltage pulses) and the triggering and controlled systems (using low voltage pulses). The Radiator about 300 MW pulsed power was made and successfully employed at IHED RAS in 2005 [4, 5]. In this article, we present results on creation and investigations of the UWB radiators with the pulses of the 50–150 ps range duration and investigations on some singularities at propagation of the electromagnetic video-pulses.

3. 300 MW multi modules radiator

The high power ultra wide-band (UWB) radiator (Radiator) with total aperture of 56 × 56 cm in size was built as an assembly with the eight radiating modules. Each module is made of the UWB radiating antenna unit (into an insulator box of 28 × 14 × 50 cm in size) and a synchronizing pulsed power source placed into a metallic screened box of 28 × 14 × 45 cm in size (Fig. 1).

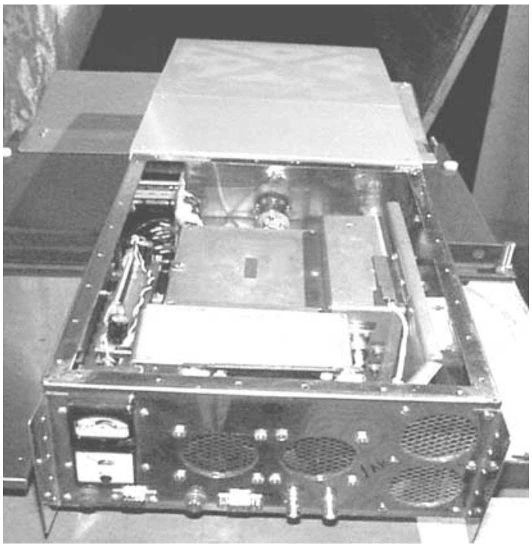

Fig. 1. One radiating module with the 35 MW pulse power

The screened box contains the 35 MW pulsed generator GIN35 ("FID Technology" [2]) and the auto synchronizing device ASU1 [4, 7], and block to buffering the primary power supply and systems to inter-

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nal ventilation (see Fig. 1). ASU1 stabilizes time-delay of radiating pulses. The electric field $E(t)$ from one switched-on module in assembly by 8 modules is shown in Fig. 2.

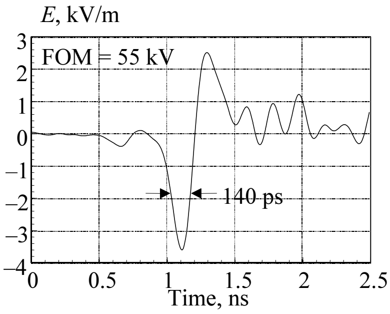

Fig. 2. $E(t)$ – in electromagnetic wave was radiated by one module in assembly of the multi module radiator

The assembly of these modules is shown in Fig. 3.

Fig. 3. High power ultra-wideband Radiator (the Radiator created FOM = $E_{max}(R) \times R$ = 455 kV – the “radiated voltage”), view on site to connectors for power supply and triggering cables

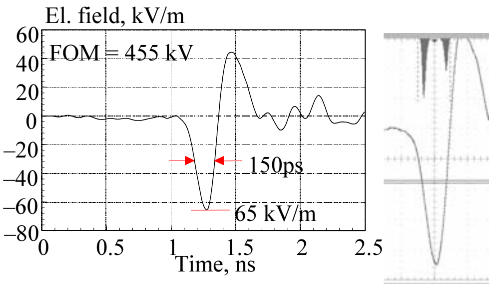

Fig. 4. $E(t)$ – electric field strength of electromagnetic wave of the video-pulse was measured at 7 m distance from the Radiator. On right-hand, traces of the 40 ps – jitter of time-delay between the video-pulses ($3 \cdot 10^3$) and trigger pulses was registered on the TDS 6604B digital scope

For achievement of electromagnetic compatibility of the giga-watt-range power radiator (generating high strength of electromagnetic fields) with the triggering and controlled systems (with low voltage pulses) we applied traditional methods. For instance, they are matched loads on cable terminals, and ferrite damping rings on cables, and series shielding by means of metallic screen boxes, and optical network cables. One can see some elements of the protected shielding in Figs. 1 and 3. The Radiator is being triggered off from the multi-channel master generator (MMG10 [7]) that was mounted into metallic shielded box with the noise filters (Fig. 5). The MMG10 has the digital controlled time-delay at 10 ns range into all channels. It is controlled by personal computer with an optical network cable of 30 m length.

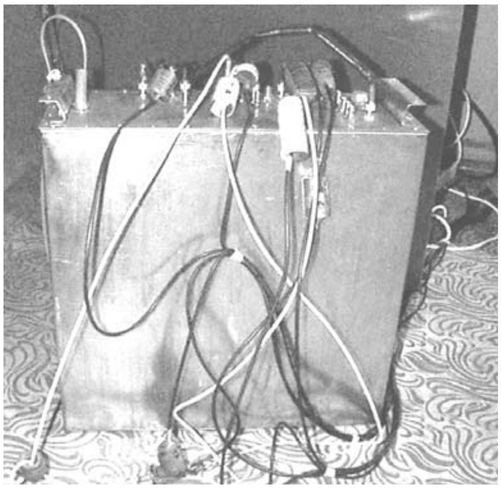

Fig. 5. TheMMG10 – multi-channel master generator is placed into metallic shielded box. Lead-in of the fiber network cable is placed on left side of top plate of box

4. Two-modules radiator with the high repetition pulses up to 100 kHz

The problem to increase intensity of the UWB radiations can be solved by use the large number of the radiating modules and very high pulsed voltage as well as high repetition pulses. High intensity is needed in radar applications and at checking on electromagnetic compatibility of electronics devices. We created the compact UWB radiator with the high repetition pulses up to 100 kHz (Fig. 6).

Fig. 6. Two-modules compact radiator with the high repetition video-pulses

This radiator uses the antenna unit like in the radiating module with the 35 MW pulse power (Fig. 1). Excited power sources use two the Gin 10–100 with repetition pulses up to 100 kHz [2] (Fig. 7).

This radiator produces the UWB radiation with $E(r = 7\text{ m}) = 3.3$ kV/m (FOM = 22 kV) and the FWHM = $T_{0.5}$ = 130 ps – on half level of amplitude maximum on front wave (Fig. 8).

Fig. 7. Gin 10–100 generated pulses of the 10–kV (rapid leap about 8 kV with rise time of 100 ps) with repetition pulses up to 100 kHz. Output feeder is HN-connector type, it can transport pulses with rise time more 30 ps

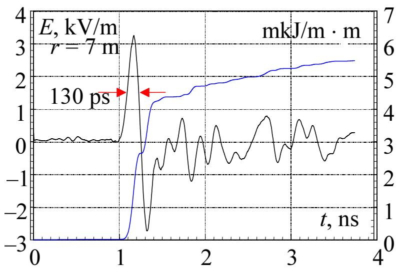

Fig. 8. $E(t)$ – from the compact radiator, on axis to the right is shown $\varepsilon(t) = \int E^2(t)dt/120\pi$ – energy density flux for this single video-pulse radiation

Our analysis of this video-pulse radiation show a limit of upper frequency in the radiation spectrum is owing to the antenna unit.

5. Ultra fast measuring devices and new 50 ps antenna unit

Investigation and creation of new high power radiators for video-pulses with rise time less 100 ps is required measuring devices with upper frequency limit at 18GHz and more. For this task we use the TMR7118 [7] – digital sampling registrar for electrical signals with DC-18 GHz bandwidth. The registrar was controlled by removed computer with optical network cable. It was placed into metallic full electrical shielding box (TMR18). A checking of diagnostic feeders and voltage dividers was made in addition with sampling oscilloscope of the DSA8200 with 30 GHz bandwidth as well as low voltage pulse test generators (TMG35V; TMG40S [7] for pulses with rise time about 20 ps).

The $E(t)$ fields in electromagnetic wave traveling in a free space were measured by few sensors: few types of linear strip transducer (made at NIIOFI [8] and others made at our laboratory), test antenna of TMA18 [7] with bandwidth of 0.1–18 GHz. Measurement module is shown in Fig. 9.

Antenna of TMA18 has big effective receiving aperture with around 17 × 17 cm sizes. It is provided high receiving sensitivity of $V_{\text{TMA}}(t) = K_{\text{TMA}} \cdot E(t)$, $K_{\text{TMA}} = 63$ V/(kV/m). This allows to measure the UWB waves at distances about 10 m when were used the low voltage test sources to excite antennas.

Fig. 9. The measurement module is composed with TMR18 connected by short cable with TMA18

We have created new the 50 ps antenna unit (FN2) for high power "fast radiators"(Fig10).

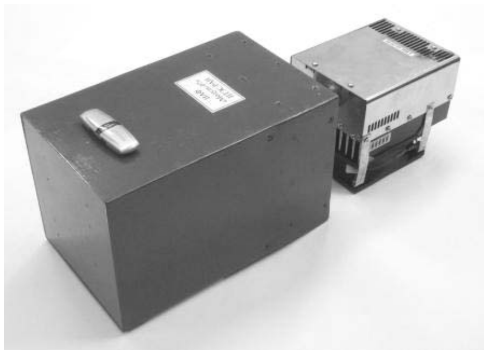

Fig. 10.The fast radiator on base the FN2 antenna connected with GIN10A-100 (8 kV with rise time τ_f= 75 ps [2])

The FN2 has an aperture size of 16 × 16 cm. It is constructed on base four TEM-horns with dielectric insets for best phasing of waves at radiating aperture.

The FN2 was checked by use of the TMG35V(bell pulse with $T_{0.5}$ = 35 ps, $V_{\max}$ = 25 V) (Fig. 11).

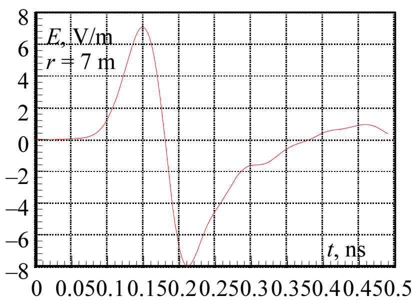

Fig. 11. $E(t)$ – pulse radiation from FN2+TMG35V

Shown signal of the $E(t)$ (in Fig. 11) has rise time of 45 ps and $T_{0.5}$ = 50 ps. The FN2 has an input high voltage connector of the HN type. This results show possibility to use the FN2 antenna to produce the 50 ps pulse radiation.

First version of fast generator of the GIN10A-100 (8 kV with rise time around τ_f = 75 ps [2]) was loaded on the FN2 (Fig. 11) and result is sown in Fig. 12.

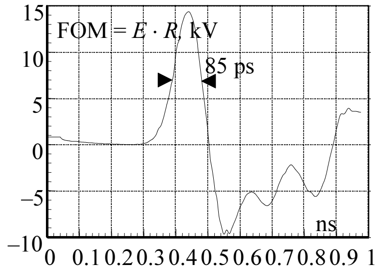

Fig. 12. FOM(t)-radiated voltage was produced on the FN2 antenna, it was excited by the GIN10A-100. First oscillation has rise time of 80 ps and $T_{0.5}$ = 85 ps

6. Non-stationary processes at propagation of the electromagnetic video-pulses

Non-stationary processes are main source for singularities at propagation of electromagnetic waves of the video-pulses (against harmonic waves) in an object space with sharp boundaries. One example is shown in Fig. 13.

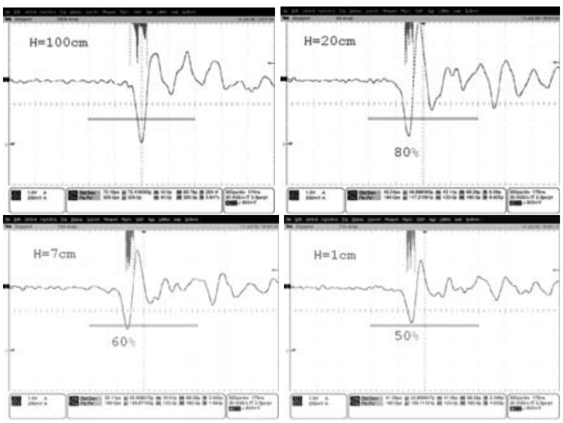

Fig. 13. $E(t)$ waveforms for propagation of the video-pulses electromagnetic waves near the Earth surface (H is the height of sensor above the Earth surface). The Radiator (Fig. 3) placed at the H = 3.5 m height at R = 13 m distance, axis of the Radiator has taken aim at theEarth surface on R = 20 m

We have done computer simulation of these processes using numerical 3D full-electromagnetic PIC code KARAT [5, 9]. As result, the surface electromagnetic (SEM) wave is generated near the boundary surface. Composition of two waves (SEM and primary EM) creates various weakening and distortion of a wave shape for the EM video-pulses in depending on heights.

Very interesting phenomenon happens when electromagnetic wave of the video-pulse comes to metallic plate with small hole. This plate with hole plays the role of the open resonator which is excited by the UWB pulse like shock pulse. One picture of computer simulation by code of KARAT is shown in Fig. 14.

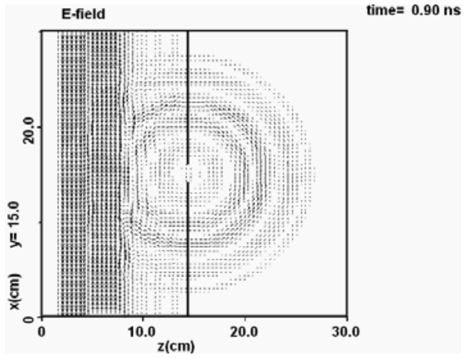

Fig. 14. Picture of electric vectors for t = 0.9 ns from beginning process. The EM plane wave (vertical polarization) of the video-pulse (single period of the sine by length Δz = 6 cm) comes from left boundary. Metallic plate (z = 15 cm) has a hole with 2 cm diameter

7. Conclusion

The Radiators for high power video-pulses with FWHM = 80–150 ps was constructed and successfully employed with the FOM up to 450 kV and repetition pulses up to 100 kHz. The non-stationary processes are main source for singularities at propagation of the EM video-pulses in object space with sharp boundaries.

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