ELECTROMAGNETIC IMPULSE RADIATOR

Prokhorenko V.P., Ivashchuk V.E. and Korsun S.V.

VIY, Transient Technologies, P.O. Box 28, Kyiv 02147, Ukraine
E-mail: office@viy.com.ua

Abstract

A novel method of short electromagnetic pulse producing by electrical dipole antenna is a topic of this paper. This method assumes the antenna current interruption instead of voltage pulse excitation. In this case antenna-generator matching requirements are considerable simplified and antenna radiation efficiency is increased.

In according to proposed method the electromagnetic impulse radiator prototype was developed. Antenna current is interrupted by a drift step recovery diode (DSRD), and antenna is a part of the DSRD generator itself. More than 800 watts peak power was achieved on the antenna terminal with 3 ns monocycle pulse duration and up to 250 kHz pulse repetition frequency (PRF). The radiator power consumption didn't exceed 3 watts at 100 kHz PRF condition.

The proposed method allows producing of nanosecond electromagnetic pulses with hundred kilowatts peak power and PRF up to hundreds kHz. Only switch parameters and power supply limit potential possibilities of such kind of radiator.

Keywords: Drift step recovery diode, DSRD, transient radiation, electromagnetic pulse, TEM horn.

1. INTRODUCTION

In general an electromagnetic energy radiating system consists of such basic components as generator, feeder, RF balun and antenna. Conventional design procedure assumes the system is divided into separate parts and they are developed under condition of neighboring unit's impedance matching. To determine efficiency of energy transmission along the system a standing wave ratio (SWR) is used. This approach is ideally suited for narrow band system development.

However this algorithm isn't acceptable for design of ultra-wide-band (UWB) or impulse systems because of transient operation mode that is the system parameters are time-dependent. It brings to unexpected results when correctly operated units are connected together.

We propose to develop impulse-radiating system entirely without it's splitting to separate parts. Following the design concept the system efficiency the higher and the smaller power loss and signal disturbance the shorter way between generator and antenna. Feeder limits impulse power transfer and can be omitted by direct connection of generator and antenna. The powerful UWB RF balun is considerably bulky. It can also be removed by utilizing of pulse generator with balanced output. Consequently powerful impulse radiating system consists of integrated on single unit pulse generator and UWB antenna.

Design principles of high effective antenna for powerful nanosecond pulse radiating is discussed at this paper. Results of the antenna-generator prototype examination are also presented.

2. ENERGY ANTENNA CLASSIFICATION

It is known a lot of different antenna classifications. Antennas are differed by excitation mode (voltage or current), conductivity (perfectly or imperfectly conducted, resistively or capacitive loaded, etc.), bandwidth (resonant, wideband, UWB, etc.), shape (cylindrical, cone, V-dipole, bow-tie, spiral, log-periodic, slot, Vivaldi, TEM horn, etc.), manufacture process (bulky or printed), and so on.

We propose to classify antennas by energy behavior in antenna systems. There is energy transfer from generator to antenna, and energy transformation into the antenna. Energy transfer and transformation can take place simultaneously or sequentially. And potential (voltage) or kinetic (current) energy can be transferred into the antenna system. In spite of numerous antenna types are known anyone refers to structure with simultaneous energy transfer and transformation, or with separation of these processes.

Simultaneous energy transfer and transformation can be observed in antennas with voltage or current excitation. Voltage excited antennas (Fig. 1a) are most frequently used. They are realized by impulse voltage applying to the antenna terminal. Radiation intensity is only depended on energy accepted by the antenna energy. Therefore impedance matching between generator and antenna should certainly be maintained. Such antennas have about some hundreds Ohms input impedance and high voltage impulse generator is required to get powerful radiation. Current excited antenna or, so-called, large current radiator (LCR) (Fig. 1b), has low impedance and is easily matched with impulse generators [1]. However because of small dimensions and low efficiency to reach powerful radiation is impossible in practice.

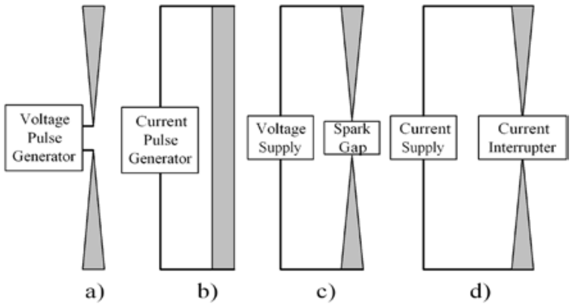

Fig. 1. Voltage (a) and current (b) excitation, potential (c) and kinetic (d) energy accumulation

Sequential energy transfer and transformation can be observed in antennas with potential or kinetic energy accumulation. Separation of theses processes eliminates necessity of generator to antenna matching. Potential energy accumulated antennas are looked very promising for powerful radiation (Fig. 1c) [2]. Such antenna can accumulate a lot of energy for a long time and radiates it during short time interval. Extremely powerful radiation can be reached [3], however pulse repetition frequency and impulse shape stability are strongly dependent on the spark gap parameters. Kinetic energy accumulated antenna (Fig. 1d) is even seemed more attractive then previous one. In this case energy is accumulated by the antenna's inductance and it can operates with comparatively low voltage powering. Electromagnetic radiation appears during breaking of the antenna current. Impulse shape doesn't depend on the switcher parameter and is exclusively determined by passive components of the antenna system. Therefore nonvolatile impulse shape stability can be achieved. However the switch should interrupt large current at nanosecond time and keeps high over voltage because of self-induction effect.

3. ANTENNA WITH KINETIC ENERGY ACCUMULATION

Design of the kinetic energy accumulated antenna meets certain difficulties. Firstly, the antenna configuration should eliminate the power supply line influences on the radiation; secondly, special methods of current ringing suppression should be applied; thirdly, fast current interrupter with voltage breakdown resistance is required.

Current process of the electromagnetic impulse generation includes two stages. At first the switch is closed and current through the antenna is growing. This is energy accumulation stage. A slope of the antenna current depends on antenna inductance and switch resistance. During the second stage the switch is opening and interrupting antenna current. Accumulated kinetic energy is transferred to potential energy on the switch terminals. The transfer time is determined be the switch capacitance and the antenna inductance. During the transfer process electric and magnetic fields are observed simultaneously and electromagnetic radiation is observed. Since electromagnetic radiation is a part of transferred energy only, the rest one should be putted out or recuperated into the power supply.

The proposed principle has been utilized by novel antenna design. We modified the TEM horn configuration to provide all necessary conditions for the antenna with kinetic energy accumulation (Fig. 2).

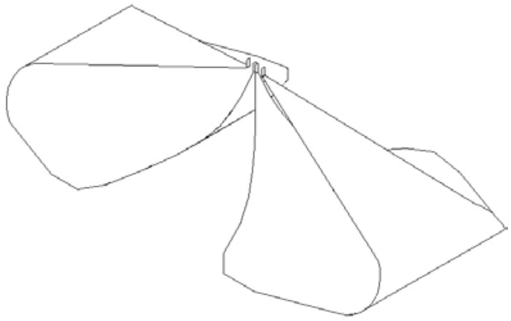

Fig. 2. The TEM horn configuration that operates in kinetic energy accumulated mode

To reduce back lobe and modify side lobes we fixed metal plate behind of the TEM horn. As a result five TEM horns were formed. A symmetrical TEM horn is formed by inner plates and has constant impedance along main axis. Outer plates with inner plates and ground plate form two pairs of asymmetrical TEM horns (Fig. 3).

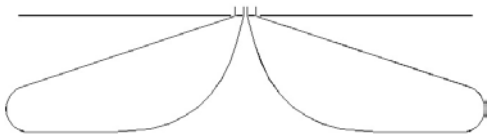

Fig. 3. Modified TEM horn configuration

To improve radiation capability the symmetrical TEM horn is transformed to electric dipole with aperture commensurable to impulse rise time. In order to suppress current ringing and short pulse response each TEM horn are terminated with matched load (Fig. 4). Such solution allows getting effective radiation capability and short pulse response simultaneously.

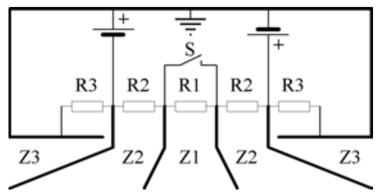

Fig. 4. Antenna "ringing" suppression schematics

4. EXPERIMENTAL RESULTS

To examine proposed concept we developed antenna-generator prototype in according with described configuration (Fig. 5).

The drift step-recovery diode (DSRD) was used for the antenna current interruption. Since the DSRD can interrupt hundreds amperes current and keep impulse voltage up to dozens kilovolts, it is nature choice for such kind of antenna's switch. We developed novel current driver to provide the DSRD specific operation conditions [4]. The DSRD was inserted into the antenna that was a part of the current driver itself.

Fig. 5. Antenna-generator prototype

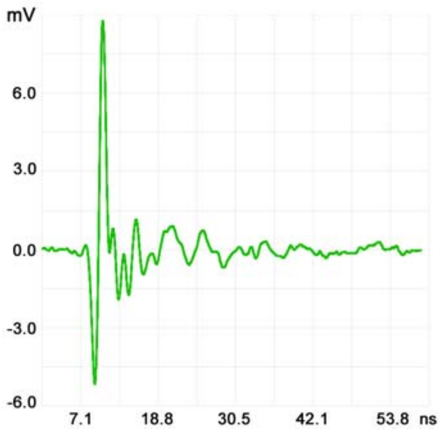

Fig. 6. Receiver output (transmitter-to-receiver distance is about 5 meters)

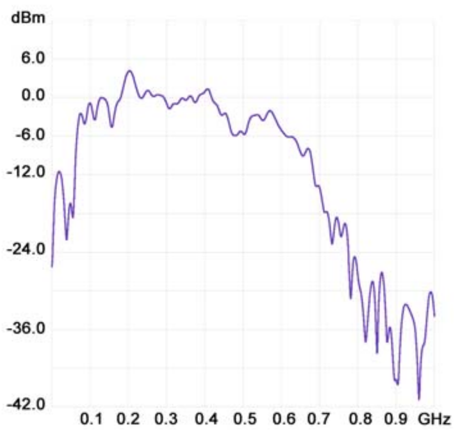

Fig. 7. Power spectrum of the received signal

The DSRD current driver and power supply are mounted on the rear of the metal plate. The antenna plates are fixed by closed-cell foam plastic. Its outer dimensions are 200x160x80 mm^3. On the antenna terminal as voltage as $350V_{p\text{-}p}$ has been obtained with 250 kHz PRF under air-cooling condition. Power consumption didn't exceed 3 Watts at 100 kHz PRF with 12VDC powering. Prototype weight was about 1 kg.

Received signal waveform and power spectrum are shown on Fig. 6 and Fig. 7, respectively. Note that antenna with 150 mm aperture radiates impulse with spectrum from near 50 MHz up to 700 MHz (-20dB level). A relative bandwidth of the received impulse exceeds 85%.

5. Conclusions

A novel method of powerful short electromagnetic pulse generation is proposed and discussed. It assumes antenna current interruption instead of voltage pulse excitation. In this case antenna-generator wideband balance and matching are automatically provided during the current interruption on the antenna terminal due to self-induction effect. Because the antenna current is growing slowly, large current and impulse peak power are achieved with low voltage supply utilizing. Maximum impulse power is only limited by current interrupter parameters.

In according to proposed concept antenna-generator prototype was developed and examined. The DSRD was used for antenna current interruption. A peak power more than 800 watt was achieved on the antenna terminal with 3 ns pulse duration (monocycle) and up to 250 kHz PRF. The prototype power consumption didn't exceed 3 watts at 100 kHz PRF.

The proposed method allows producing of nanosecond electromagnetic impulses with hundred kilowatts peak power and up to hundreds kHz PRF. Potential capabilities of the radiator are only limited by present switch parameters and power supply.

References

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