DESIGN OF 800PICO-SECOND RISE-TIME ULTRAFAST CO-AXIAL MARX GENERATOR AND APPLICATIONS

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Abstract**:** A Marx generator delivers high power electrical pulse in very short duration and can be configured to be compact. This ultrafast coaxial Marx generator has also been developed without pulse shaping/peaking circuit. The results of 5-stage ultrafast coaxial Marx generator has a rise time of 800ps, maximum output voltage 75kv, pulsewidth(FWHM) of 1.5ns, and source impedance 63Ω is experimented. The coaxial geometry is used throughout the system to achieve low value of inductance leading to fast rise time of the output pulse. The fast Marx generator, load impedance and Current Viewing Resistor (CVR) are connected in series and the 50mΩ CVR is used as a diagnostics to measure the output current. This compact fast Marx generator is fit into a stainless steel (metallic) cylinder. The fast Marx generator is tested for the charging voltages of 10kv with 50Ω and 100Ω ceramic resistive loads. The design and experimental results of coaxial fast Marx generator are presented. This Marx generator can be used as a source for applications like electronics vulnerability test study, Ultra Wideband (UWB) and radar experiments, water microbial inactivation, for killing the breast cancer cells, using pulsed electric field. The few of the applications are discussed.

Keywords*: Ultrafast Marx generator, Impulse voltage generator, 800pico second rise time.*

I. INTRODUCTION

Conventionally fast rise time pulse can be achieved by pressurizing the sparkgap switch with high pressure[1]. But this fast Marx generator has been developed without pressurized gas inside the chamber. This fast rise time pulse Marx generator can be used as Ultra Wide band (UWB) source.

In recent years progress has been made in the development of ultra-wideband (UWB) technology[2]. UWB is defined as a signal whose bandwidth is at least wider than 25% of its center frequency. The modern electronic systems are very susceptible to EMP attacks because the electronic systems operate at low voltage, low power, very large number/densely populated of transistor integration, and high clock frequency. Electronic systems are susceptible to electromagnetic wave interaction. These waves generate undesired currents and voltages in electronic circuits. Ultra-wideband (UWB) radio is an emerging and promising technology with uniquely attractive features inviting major advances in wireless communications, networking, and radar, imaging, and positioning systems[3]. In either conventional communication systems or UWB communication systems, an antenna plays a very crucial role. Nevertheless, there are more challenges in designing an UWB antenna than a narrow band one.

2.TOPOLOGY

The topology used in this experiment is Goodlet Marx scheme. It's charging N-number of capacitor in parallel with charging voltage-V and discharging them in series to achieve N-times inverse voltage multiplication (i.e. Output voltage is equal to $\eta_{Marx} \cdot N \cdot V$)[4]. Unlike simple Marx generator, if we charge the Goodlet Marx generator by positive polarity and we will get the negative polarity output voltage with multiplication of N-times charging voltage and for negative polarity voltage charging is vice versa [5].

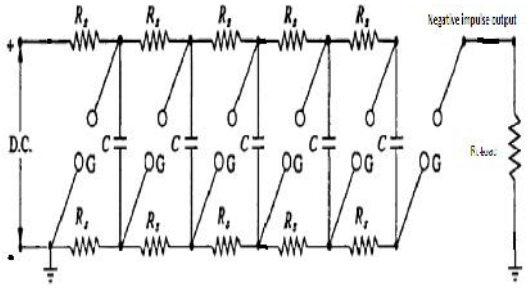

Fig-1: Schematic of Goodlet Marx generator

The Goodlet Marx generator schematic diagram is shown in Fig-1. In Schematic of Goodlet Marx generator, R_S is charging resistor 10KΩ, G is sparkgap switch, C is 50pF capacitance of capacitor of each stage and R_L is the load impedance 100Ω. The Goodlet Marx generator is stacking one stage upon another stage and fit in to a co-axial stainless steel (SS) cylinder acting as a discharge current return path. All the sparkgap electrodes dimension and the gap of the each spark gap is identical, which is leading to good erection of Marx generator.

3. EXPERIMENTAL ASSEMBLY

The Marx generator is constructed in the form of completely coaxial geometry to minimize the circuit inductance. The each stage design experimental view of Marx generator consists of one capacitor, one sparkgaps; two charging resistors all mounted in Perspex disc that is enclosed by stainless steel cylinder (return conductor). Marx generator is designed in a way that the distance between the high voltage charging resistor and the ground electrode has sufficient clearance avoiding occurrence of breakdown. or ground plate have been made for enough clearance. The sparkgap assembly at one stage is shown in Fig-2. Aluminium 12mm diameter flat top and length of 8mm sparkgap electrodes are connected at both ends of the each capacitor and the two spark gap electrodes are separated by 3.5 mm between them.

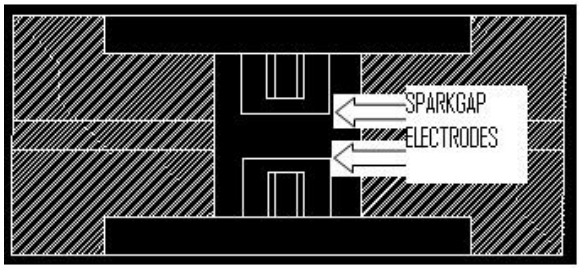

Fig-2: Spark-gap assembly setup in every stage with electrodes

Aluminium disc of 5mm thickness is used between the capacitor and sparkgap electrode, which gives electrical connection and mechanical support to capacitor, charging resistor and spark gap electrode. The capacitor, aluminium disc and sparkgap of the each module are mounted on the slotted Perspex disc. Every stage Perspex disc is well connected vertically with four limbs of nylon stick in the periphery, which are tightened at both ends by nuts. The experimental arrangement of fast Marx generator Enclosed in the stainless steel cylinder is shown in Fig-3. The entire stack is then enclosed by a stainless steel cylindrical structure, which acts as current return conductor while erection.

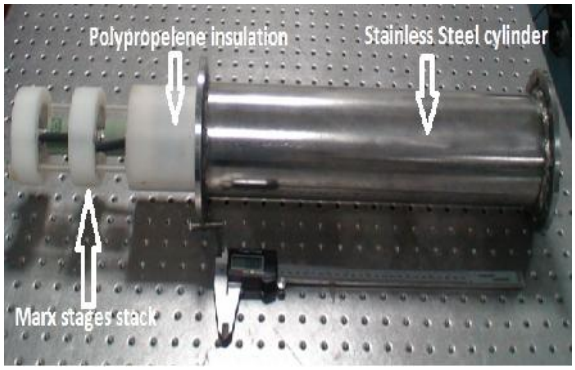

Fig-3: Ultrafast Marx generator experimental assembly view

The first stage has a trigatron type sparkgap [6]. The trigger electrode is mounted inside the ground electrode, but trigger electrode height is 2mm less than the ground electrode height so that current pass through the ground electrode while erection and it prevents the current passing to the trigger electrode at the time of erection. The sparkplug is used as a trigger electrode, so the trigger pulse is applied from the pulse transformer to spark plug. The output switch is placed between the last stage of the Marx generator and the load, which is used to isolate the load while charging and also to transfer the full energy to load while erection.

The disc type ceramic resistor is used as a load for this experiment. This will dump the full Marx energy at rated voltages. The current viewing resistor (CVR) 50mΩ, maximum energy rating of 75J and rise time of 300ps is connected in series with the load [7]. The signal output from the CVR is given to the high bandwidth 10GHz and high sampling rate 40Gs/s oscilloscope and the waveforms are recorded on the

same. The CVR and the load impedance assembly view is shown in fig-4.

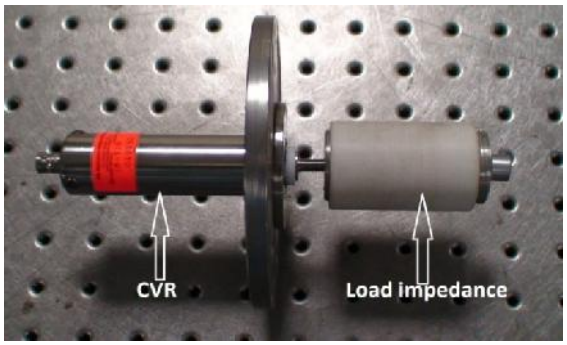

Fig-4: Current Viewing Resistor and Load impedance assembly view

4. TEST & RESULTS

The Marx generator is charged by the by 12V DC battery powered high voltage DC power supply. The first stage trigatron type switch is closed by the external trigger pulse given to the third electrode and leads to close of first stage switch, which increases the voltage across the second switch and causes the chain reaction of self-breakdown of the consecutive stage switches. All the stage capacitors are switched in to a series configuration delivering voltage pulse to the load ie. $\eta_{Marx} \cdot N \cdot V$ (efficiency of Marx generator X number of stages X charging voltage) [8]. In order to find the source impedance of the Marx generator, we conducted the short circuit test. The generator is shorted between the center conductor and the return conductor (metallic enclosure) [9,10]. The rise time demonstration of output voltage waveform is shown in Fig-5.

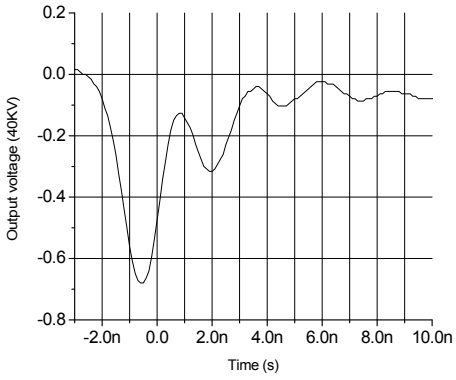

Fig-5: Rise time demonstration of output voltage waveform

5. APPLICATIONS

The susceptibility of electronics can be found applying of high voltage radiated electric field strength by this ultrafast Marx pulse generator. The susceptibility test diagram is given in figure-6. The pulse generator is act as a source for test. The output of the pulse generator is given to the Transmitting antenna. The impedance of the source and Transmitting antenna should match to produce the effective radiation[11,12,13]. The receiving antenna is placed opposite to the transmitting antenna. The device under test should be kept at between the transmitting antenna and the receiving antenna.

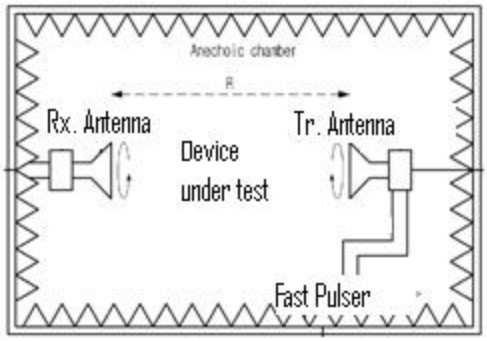

Figure-6: Susceptibility test diagram

The fast pulser generated output pulse risetime of 800ps in this experiment. The frequency for the corresponding risetime is 438MHz. The minimum size of the antenna required for the transmitting the 800ps rise time pulse is equal to the wavelength of the pulse. The antenna and the device under test should be enclosed in the anechoic chamber.

Nanosecond pulsed electric fields (nsPEFs) extend conventional electroporation by using electric pulses with shorter durations, in the nanosecond range, and even higher electric fields in the tens of kilovolts per centimeter (kV/cm) range. The pulse electric field acts on cells of microorganisms. Main effect of PEF treatment is electroporation. PEF can influence the permeability of cell membranes and may induce the structural changes and local membrane breakdown[14,15]. This is called electroporation. Electroporation causes significant increase in the permeability of the cell membrane and finally electroporation affecting the viability of the cells. That means it causes irreversible disruption of the cell membrane. The disruption of a cell is a threshold effect. The strength of the electric field must be higher than a certain

critical value to inflict microorganisms. Also there is minimum threshold pulse duration required to inflict cell membrane disruption. The critical value of the field and pulse duration depends on the type of microorganism[16,17]. It is preferable to use the pulse of rectangular shape rather than of exponential decay or sawtooth shape. In the case of exponential decay shape of pulse, only a narrow part of the pulse exceeds the critical value (Ec) and residual tail of the pulse only causes heating of the solution. The detailed cell membrane ruptures with electric field shown in figure-7. The water microbial inactivation can be done by this theory.

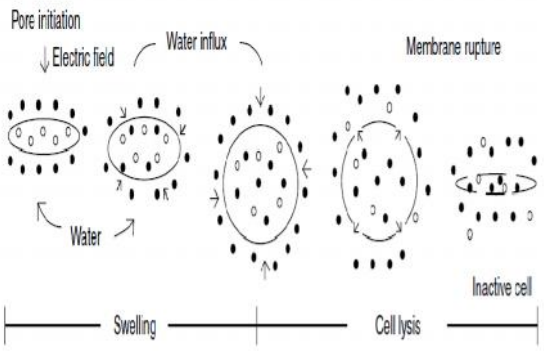

Figure-7: Electroporation cell membrane rupture

. The same principle is applicable to breast cancer cell killing experiments. The cell plasma membrane consists of a lipid bi-layer with a thickness of approximately 5 nm. An even newer field of research opens up when pulse duration is decreased even further, into the subnanosecond range. By reducing the duration of electrical pulses into the sub-nanosecond range, the electric field-cell interactions shift increasingly from the plasma membrane to sub-cellular structures. In this case, the electric field distribution is determined by the dielectric permittivity rather than the resistivity of cell components. At present, electric fields are invasively delivered to the tumor using implanted electrodes.

6. CONCLUSIONS

This fast coaxial Marx generator has also been developed without pulse shaping/peaking circuit and without pressurized insulation gas inside the chamber. The 5-stage, 75kv, 800ps rise time, 1.5ns (FWHM) pulse duration and 63Ω source impedance ultrafast Marx generator is developed in our laboratory, which can deliver an output voltage pulse of 75kV for the charge voltage of 15kV. The erected voltage efficiency of 60% is achieved at 100Ω load impedance. By increasing the load resistance value the output load voltage can be increased. The applications are discussed like vulnerability study, UWB and water microbial inactivation, Breast cancer cell killing study. The future work to be achieved is 10 of pico-second rise time pulse with higher voltage and energy.

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