PICO SECOND RISE TIME PULSE GENERATION USING MARX GENERATOR WITH PEAKING CIRCUIT

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Abstract: The work of picoseconds rise time pulse generation using Marx generator with peaking circuit is presented. The measurement of picoseconds rise time pulse using Transmitting antenna and D.dot probe. The received signal from the D.dot probe is measured with High frequency oscilloscope (10GHz). The experiment is conducted with Marx generator and peaking circuit. The 10 stage Marx generator is used to generate high voltage (140KV) 2nanosecond rise time pulse. The characteristics impedance of the Marx generator is 70Ω. The peaking capacitor is developed in our laboratory to achieve the lower capacitance and also withstand higher voltage. The peaking capacitor is made using mixture of barium titanate and neoprene rubber in the ratio of 1:10 respectively. Barium titanate is piezoelectric material so it cracks during high voltages discharges due to stresses developed in it. Barium titanate is mixed with neoprene rubber which absorbs the piezoelectric stresses and prevents damaging of the capacitor. The peaking switch also developed which is used to sharpen the rise time of the pulse. The 50Ω resistor is used as load impedance. Simple 600mm length dipole antenna is used to radiate the picosecond rise time pulse. The radiated pulse is received by the D.dot probe at 5metre distance. The radiated frequency measured is 700MHz in the Fast Fourier Transformation (FFT) spectrum. The rise time of 500picosecond is calculated from the FFT peak frequency.

Keywords

Coaxial peaking capacitor, coaxial peaking switch, Coaxial Marx generator, picosecond rise time pulse, D.dot probe measurement, picosecond transmitting antenna & ultrafast pulsed power

1.INTRODUCTION

Wideband and ultra-wideband (UWB) technologies have achieved notable progress in recent years. The advent of many UWB sources capable of producing output powers in the GW range allows managing real investigations of the susceptibility of electronic systems and of their protection and hardening against such UWB threats. However, in the meantime[1,2], the development of very compact UWB sources remains of real interests. Recent work with compact Marx generators is moving this technology from these applications like electromagnetic weapons, susceptibility and hardening of electronic systems to transient threats, or UWB radars. As the voltage pulse rise time decreasing to a few hundreds of picoseconds and peak power reaching several Giga watts. These compact generators have become of interest for these applications. Particularly for investigations of the susceptibility on UWB threats[3].

The Marx generator with peaking circuit schematic diagram is given in figure-1**.** The Marx generator is assumed as a series combination of lumped capacitance and lumped inductance. The C_m and L_m are the capacitance and inductance of

the Marx generator. R_m is Rp are the resistance of the Marx and peaking circuit. S_1 and S_2 are Marx and peaking switch respectively. C_p and L_p are peaking capacitance and peaking inductance respectively. C_s is stray capacitance of the peaking switch. Z_L is the load impedance. V_{mx} and V_o are the voltage of Marx generator and the peaking circuit.
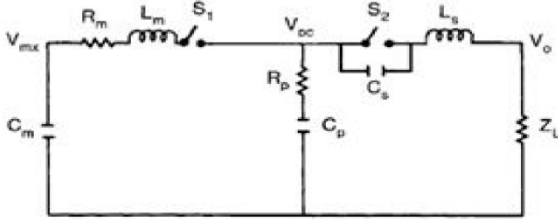

Figure-1: Schematic of Marx generator with peaking circuit

2. BLOCK DIAGRAM OF PULSE RISETIME MEASUREMENT SYSTEM

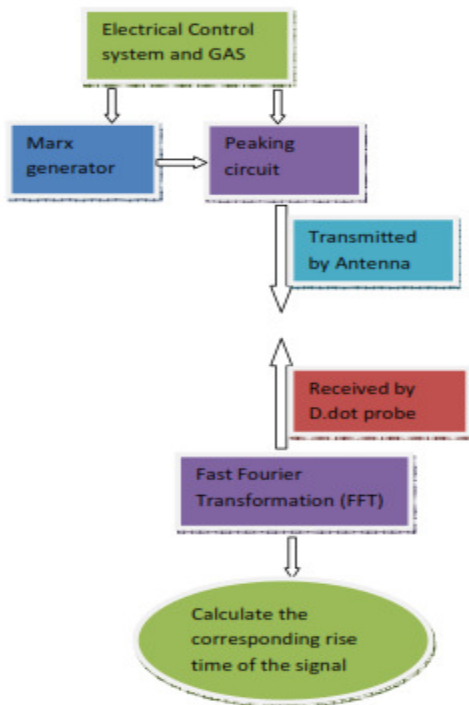The block diagram of the pulse rise time measurement system given below.

Figure-2: block diagram of pulse rise time measurement system

3. MARX GENERATOR

The characteristics of Marx generator used in the experiments are given below. The basic principle of the Marx generator is charging of N number of capacitors is in parallel through the charging resistors and discharges them in series through spark gap switches. The 10 stage coaxial Marx generator with fast rise time of 2.4ns, pulse width 20 ns, energy 4.2J and Impedance 70Ω, which is capable of delivering the peak power of ~500MW with 100Ω load[4]. The coaxial geometry is used throughout the system to achieve high value of capacitance and low value of inductance leading to low impedance and also uses single point triggering for erection. The trigatron type three electrodes switch is used in the first stage to trigger the Marx generator. The generator is designed with consideration of internal inductance and stray capacitance. The strontium titanate (SrTiO3) capacitors are used in this experiment due to very low de-rating capacitance at rated voltage, high dielectric strength and high current capacity. This set up can be pressurized by dry nitrogen air up to 2 atmosphere pressure for the Marx charging voltage of 30KV. This compact Marx is fitted into a stainless steel (metallic) cylinder with 102mm diameter and the total length of 730mm. The Marx generator output of 2ns rise time and 20ns (FWHM) shown in figure-3**.** The present coaxial Marx generator has been operated for the charging voltage of up to 13 KV to charge the peaking capacitor to 140KV.
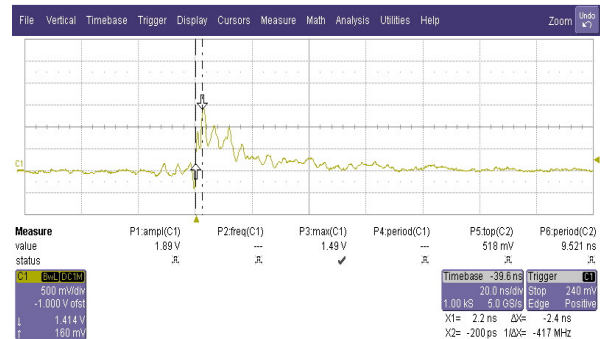

Figure-3: Marx generator output waveform

4. DC CHARGING POWER SUPPLY FOR MARX GENERATOR

The Cockroft Walton (CW) voltage multiplier is used as charging DC power supply for Marx generator. The 7 stage CW voltage multiplier can generate 35KV DC for the input voltage of 5KV 50Hz signal. The primary power is taken from the 230/5KV 50Hz transformer. The input power is given by the 230V 50Hz variable Transformer. The combination of High voltage diode (10KV peak to peak) and the capacitor (0.22 µF) assembly is used in CW voltage multiplier. The maximum current can be delivered by the CW voltage multiplier is 500mA. The picture of the Cockroft Walton DC multiplier circuit is given figure-4
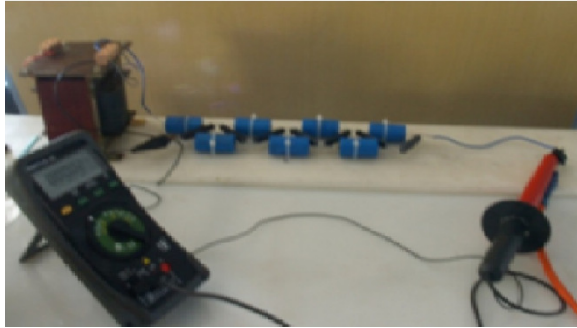

Figure-4: Cockroft Walton voltage multiplier DC charging power supply

5.PEAKING CAPACITOR

The peaking capacitor and the peaking switch combination are used to sharpen the pulse rise time in to the picoseconds region. Basically the relative permittivity of barium titanate is high~1200 and it is a piezoelectric material[5]. We have developed peaking capacitor with the mixture barium titanate and neoprene rubber in the ratio of 1:10 respectively. Barium titanate is piezoelectric material so it cracks during high voltages discharges due to stresses developed in it. Barium titanate is mixed with neoprene rubber which absorbs the piezoelectric stresses and prevents damaging of the capacitor. The relative permittivity of the neoprene rubber is low ~6 which is used to achieve the lower capacitance peaking capacitor. The coaxial geometry peaking capacitor is used in this experiment. The capacitance of the peaking capacitor is 20pF. The

fabricated peaking capacitor is shown in figure-5. The outer radius of the inner conductor and the inner radius of the outer conductor are 10mm and 75mm respectively. The mixture of barium titanate and neoprene rubber is placed between the inner conductor and the outer conductor. This peaking capacitor has tested for the charging voltage of 140KV pulse from the coaxial Marx generator.
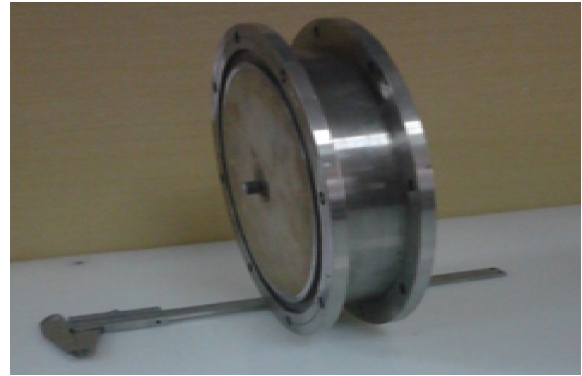

Figure-5: Coaxial peaking capacitor

The charging voltage waveform is given in the figure-6. The charging time required to charge the 20pF peaking capacitor is 10ns for the peak voltage of 140KV. It can be used for higher repetition rate because of very less charging time. The peaking capacitor value is calculated from the Equation (1)

$$C_p = LC_g / (L + R_L{}^2 C_g) \qquad (1)$$

Where C_g is the Marx generator erected capacitance, L Total inductance of the circuit and R_L is the Load impedance.
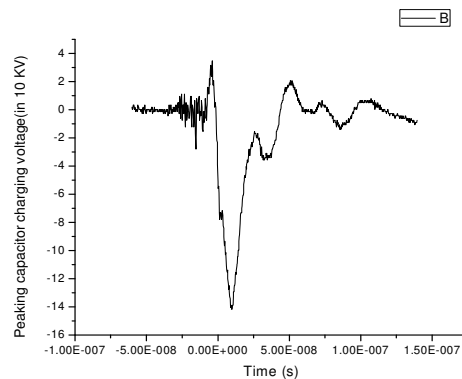

Figure-6: Peaking capacitor charging voltage

6.PEAKING SWITCH

The idea of the peaking switch is to sharpen rise time of the pulse. To achieve the fast rise time the inductance of the system should be as low as possible. In order to make lower inductance and fast rise time pulse the spark gap with two electrodes are as close as possible[6]. We developed the spark gap with the two electrodes are separated with a distance of 2 mm. The one end of the peaking switch is directly mounted with the peaking capacitor and another end is connected with the load. The radius of 30mm circular disc is used as peaking switch electrodes. The coaxial peaking switch return conductor radius is 75mm. The stainless steel is used as a return conductor. The peaking switch is pressurized up to 3atm**.** The Schematic diagram of peaking switch is shown in figure-7
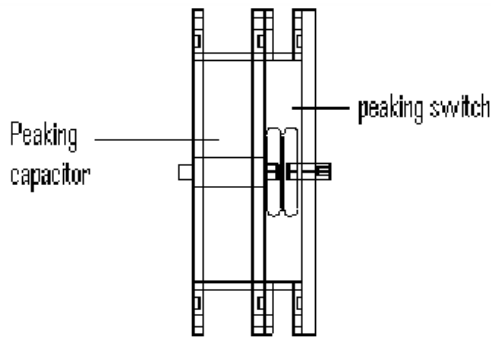

Figure-7: Peaking switch schematic diagram

7.EXPERIMENTAL RESULTS

The output of the Marx generator is multiplication of Number of stages-N and the Charging voltage-V that is (N x V). The Marx generator is operated for the charging voltage of 13KV to charge the peaking capacitor. The charging voltage of peaking capacitor is measured 140KV when the charging voltage of 10 stage Marx generator is 13KV. Due to resonant charging of LC circuit the peaking capacitor is charged to voltage higher than the value of N x V. The equation of resonant charging between the two LC circuits is given in (2) and (3)[7].

$$V_2(t) = V_1(C_1/(C_1 + C_2))(1 - \cos wt) \quad (2)$$

$$V_{2\max} = GV_1 \quad \text{Where ringing}$$

$$\text{Gain } G = 2(C_1/(C_1 + C_2)) \quad (3)$$

Where V_1 and V_2 are Marx generator and peaking capacitor voltage respectively, C_1 and C_2 are the Marx erected capacitance and peaking capacitance.

The charging time of the peaking capacitor for the peak voltage is 10 ns. The experimental view of the Marx generator, peaking capacitor and peaking switch are given figure -8.
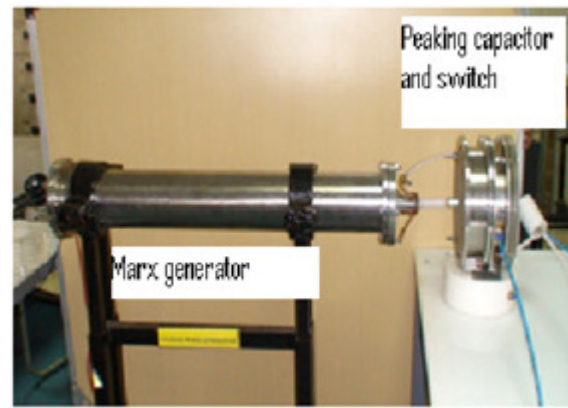

Figure -8: Experimental view of Marx generator, peaking capacitor and peaking switch

The peaking switch and the load resistance are connected in series. The 50 ohm disc resistor used as a load resistance. The 600mm length dipole antenna is connected across the load resistance. This dipole antenna radiates the voltage developed across the load resistance. Prodyn make D dot probe sensor used in this experiment. PRODYN's electric field D-Dot is free-space, high frequency sensors that measure time rate of change of electric displacement. Being differential, they have two asymptotic sensing elements accurately positioned on opposite sides of a common ground plate and have a radial output direction. It has asymptotic design to have less capacitance and higher upper frequency characteristics. The radiated high frequency rise time pulse is measured at distance of 5metre by the D dot probe sensor. The output of the D dot probe signal is given to the high bandwidth and high sampling rate oscilloscope. The measured signal from D dot probe is shown in figure-9**.**
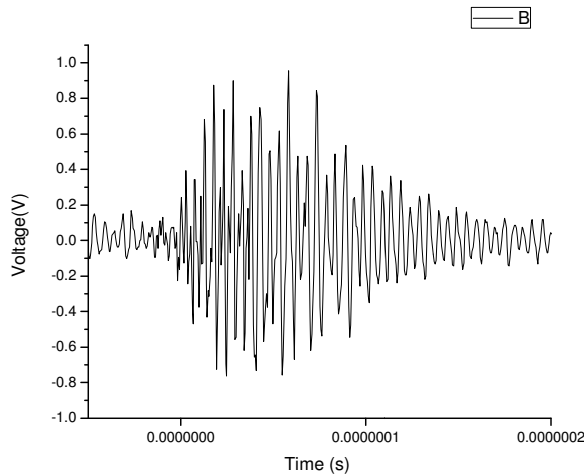
Figure-9: measured signal from D dot probe

Figure-10: FFT frequency spectrum

The received signal is integrated to get the radiated electric field strength. The radiated electric field strength is calculated using the formula given in equation (4).

$$V_o = RA_{eq}dD/dt \qquad (4)$$

Where V_o is sensor output (volts), R is sensor characteristic load impedance (100 ohms), A_{eq} is sensor equivalent area (m2), D is magnitude of electric displacement vector ($D = \varepsilon_0 E$ in Coul/m^2)

The radiated electric field strength is 4.5KV/m. FFT is done with the signal received by the D dot probe sensor to find the highest frequency component. The FFT frequency spectrum is shown in figure-10. From the FFT figure the highest frequency component available is 700 MHz**,** and **t**he corresponding rise time for the highest frequency component is calculated from the equation (5). The Calculated rise time for the corresponding peak frequency is 500 ps.

$$t_r = 0.35/f \qquad (5)$$

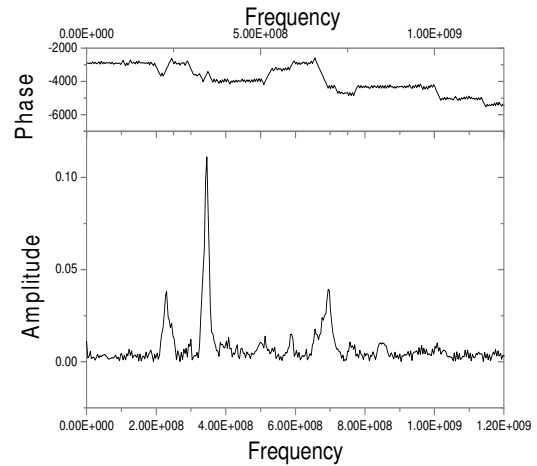Where t_r- Rise time of the pulse and f- Frequency of the pulse signal.

8.CONCLUSION

We have experimented the measurement of picoseconds rise time pulse with transmitting antenna and the D.dot probe. The design and experiment has been conducted an EMP generating system. The system consists of Marx generator, peaking capacitors, and output peaking switch mounted in a tight enclosure. The radiated pulse is received by the D dot probe at distance of 5 metre. The FFT is done with received signal from D dot probe. The rise time of 500picosecond is calculated from the FFT peak frequency. We are working to achieve the 100picosecond rise time with impulse radiating antenna. The future work of this paper is to measure the 10's of picosecond rise time pulse with this concept[8].

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