# Corona Charged Subnanosecond Impulse Generator

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***Abstract*—An impulse generation system based on the floating electrodes corona charging mechanism is presented. Measurement results demonstrate that it is possible to obtain subnanosecond impulses with this novel charging technique. The low cost and simplicity makes this system very suitable for developing sources for intentional EMI studies.**

## I. Introduction

Since 1960s, significant efforts have been deployed by the engineers worldwide to develop modern short pulse power technology. These include theoretical studies, but also development of prototypes that have formed the basis of the high technological advances on pulsed power systems (e.g. [1-3]).

One of the most important development areas of pulse power is the production of intense radiation sources such as electron beams, ion beams, radars and non lethal weapons [1,4].

In general, high voltage pulsed power systems may be either DC charged, or their high speed section can be pulse charged [3]. A novel charging mechanism for pulsed power systems based on the corona charging of a floating electrode was introduced by Roman in the late 1990s [5]. This is a DC based charging mechanism in which a floating electrode with a protrusion is charged by corona ionic currents. Corona currents are produced in the protrusion when the background electric field is amplified until the onset of corona currents is reached. The accumulated charge on the floating electrode can be discharged resulting in a current impulse with a rise time in the order of nanoseconds or some fractions of nanoseconds, depending on the discharge gap characteristics. Such current impulses generated using the floating electrode technique have been named Roman Generator RG [7, 8].

The low cost and high pulse repetition frequency of the corona charging mechanism makes it a very suitable pulsed power source for high power radiators. In the present work, an impulse generation system based on the floating electrode charging principle is presented.

## II. General Background

### A. *Corona from floating electrodes*

In Figure 1, a complex electrode gap arrangement is presented. A floating electrode with a geometrical protrusion is placed at a distance *D* from a high voltage plate electrode and at a distance *d* from a grounded plate electrode. The gap distance *d* represents a gas discharge switch.

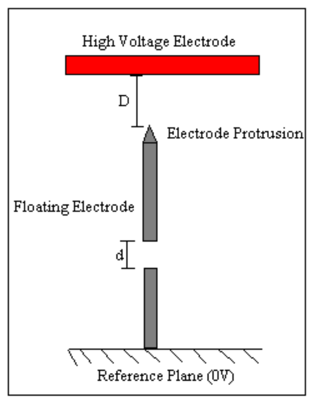


Fig. 1. Complex gap arrangement. A floating electrode is placed at a distance *D* from the high voltage electrode and at a distance *d* from the grounded electrode.

When a floating electrode is inserted between the high voltage plate and the ground electrode, it modifies the electrostatic field distribution inside the complex gap arrangement [6]. The electric field is enhanced at the protrusion's surface and the whole metallic body acquires a certain electric potential. The net charge in the floating electrode will remain zero.

If the enhanced electric field over the protrusion is high enough to reach the critical electric field for the onset of corona currents, corona ionic currents of opposite polarity of the high voltage electrode start to flow up from the floating electrode to the gap region of length *D*. When this occurs, the floating electrode becomes charged with the same polarity of the high voltage electrode, acquiring a net charge different from zero.

Therefore, during the corona charging process, the floating electrode increases its electrical potential. If the floating electrode potential exceeds the breakdown voltage of the gas discharge switch of length *d*, a breakdown will occur. During the breakdown process of the gas discharge switch, the charge excess in the floating electrode will be neutralized. If the corona discharge mechanism is sustained, breakdown will occur again and a continuous charge-discharge process can be established.

### *B. The Roman Generator (RG)*

A special type of RG impulse generator was designed and built based on the above-mentioned mechanism, with the aim of producing pulses characterized by subnanosecond risetimes and durations (full width at half maximum). A floating electrode gas discharge switch is charged through corona mechanism. The anode of the gas discharge switch is terminated on a test load. When the potential on the floating electrode reaches the breakdown voltage of the gas discharge switch, a current impulse flows through the test load.

In the next Section, the experimental setup aiming at verifying the performance of the generator will be described.

## III. EXPERIMENTAL SETUP

A schematic diagram of the experimental setup used for measuring the current output of the impulse generator is shown in Figure 2.

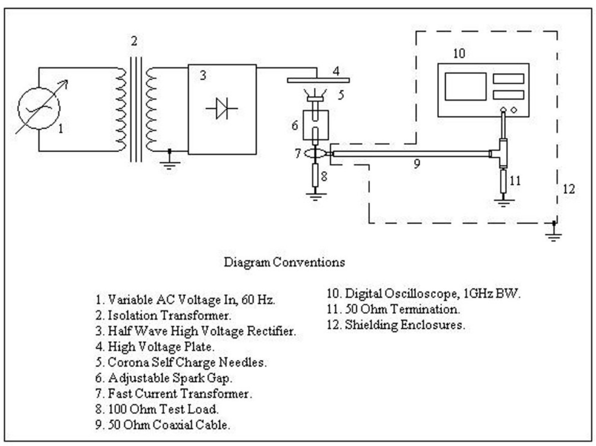


Fig. 2. Schematic diagram of the experimental setup to measure the current impulses produced in the floating electrode arrangement.

### *A. High- Voltage Source*

A 0-70 kV/60Hz variable HV source consisting of a 60 Hz variac connected to an isolation transformer was used as primary source of the system (1 and 2 in the above diagram). A half-wave, 5mA HV rectifier (3) was connected to the primary source to feed the HV plate electrode (4). Due to the fact that the HV source was only used to initiate corona discharges on a floating electrode, the over current failure of the system was not considered. The variac was adjusted to apply 10 kV DC on the HV plate electrode. The HV plate electrode was a 20-cm brass disc, connected with a copper rod to the output of the HV rectifier.

### *B. Corona Charged Impulse Generator*

The corona charging mechanism for this system was a small cylindrical plate with five embedded steel needles (5). To assure that each needle contributes with the same amount of current to the charging process, they were positioned in a geometrical configuration in which all the needle tips were at the same height from the HV plate electrode.

Several simulations were performed using the finite elements method (FEM), in order to obtain the best geometrical distribution of the five needles. The obtained distribution assures the enhancement of the electric field on the tips. Figure 3 shows the final distribution. Four needles were located on the sides of a circular brass plate and one was located on its center. Each outer needle was equidistant from the center needle. The external needles had an elevation angle of 30° from the horizontal edge of the circular plate.

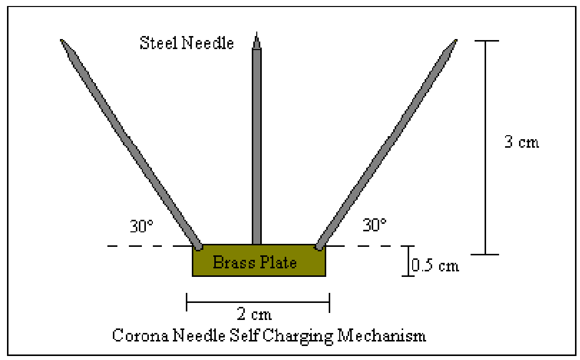


Fig. 3. Geometrical distribution of the Corona Needles. Notice that the needles are located at the same distance from the HV plate electrode.

The corona charging mechanism of the generator was located below the disc at a separation distance of 100 mm. It was calculated [5] that for this distance, 10 kV DC would be enough to initiate corona in the needles. The anode of the spark gap switch was connected to the corona needles, forming the floating electrode section of the generator.

The gas discharge switch (6) is composed of two round shape end brass cylinders. The cylinder diameter is 10 mm terminated on a 5-mm radius semi-sphere. Figure 4 shows a picture of the spark gap switch before connecting it to the entire system.

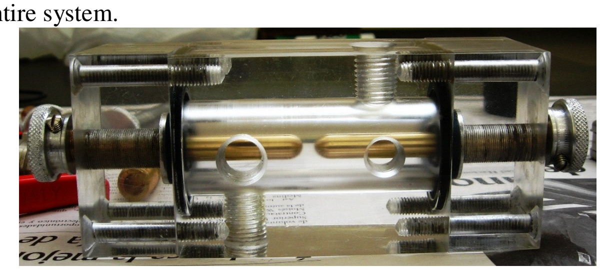

Fig. 4. Spark gap switch of the impulse generator

The spark gap switch has two adjusting knobs that enable the separation distance to be varied between 0 to 5 mm. The electrode enclosure is made of acrylic, and is designed for being pressurized up to 8 Atm. Figure 4 shows the gas inlets that were drilled in the enclosure for this purpose. The experiment was carried out with air at atmospheric pressure and with an electrode distance of 320 µm. The test load used (8) in the experiment was a parallel array of ten 1-kΩ/2-W thin carbon resistors. This provides a 10-W low inductance 100Ω load, for testing the generator. Figure 5 shows a picture of the overall system before being tested.

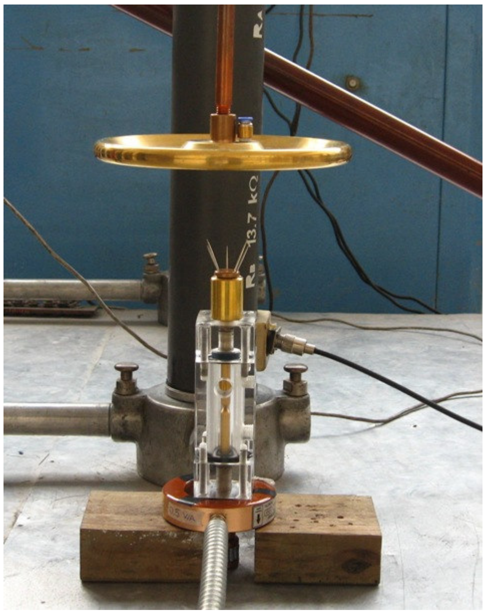

Fig. 5. Picture of the impulse generator

## C. Current Measurement

A Bergoz FCT-055 fast current transformer (7) was used to measure the current entering to the test load. This was a 300 ps risetime transformer, with 1.1 GHz bandwidth and, 0.5 V/A sensitivity. The signal was transmitted to a digital oscilloscope via a terminated 50-Ohm coaxial cable (9). An AgilentDSO6104A digital oscilloscope (10) was used for recording the current. This oscilloscope has a bandwitdth of 1 GHz with a sampling rate of 4GSa/s.

As it is shown in the experimental setup diagram, the coaxial cable and the oscilloscope were shielded against interferences (12). For the coaxial cable, a cylindrical metal shield was used to screen crosstalk. The cable enters a shielded cabin in which the oscilloscope was housed with a UPS to provide power. This was done to ensure that the recorded signal was free of interferences.

# IV. RESULTS AND ANALYSIS

The experiment consisted of turning on the HV source and recording a single-shot current waveform entering the test load. Waveforms were captured on time spans of 20 ns and 100 ns.

## A. Current Waveform

Figure 6 shows one of the waveforms that were captured with a 100-ns span. In this figure a typical output curve of the generator test is presented. The resulting waveform is nearly a monopulse, with a rise time ($t_r$) of 600 ps and a full width at half maximum delay (FWHM) of 900 ps. The peak current for this test was 10.9 A ($I_{peak}$), and the zero-to-peak time was 800 ps.

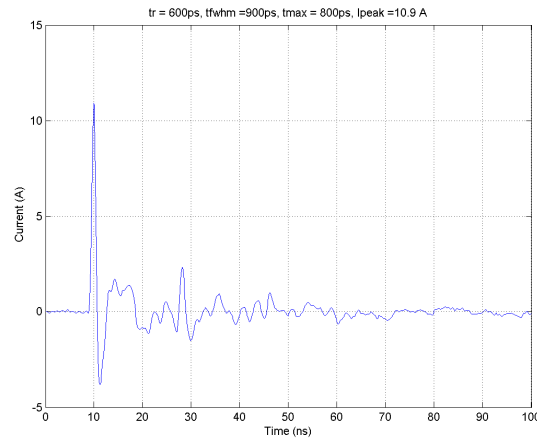


Fig. 6. Current output of the Impulse Generator for a 100 ns span.

The FFT response of the waveform in Figure 6 is shown in Figure 7. As it can be seen, the signal spectrum extends to some hundreds of MHz. The signal exhibits also some resonances that maybe due to the subsequent oscillations in the waveform after the main pulse.

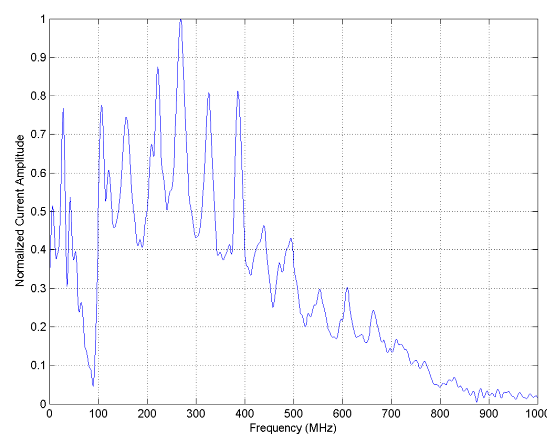


Fig. 7. Normalized FFT of the current waveform

To verify this, a comparison was made between the FFT of the main pulse (and the FFT of the complete pulse, considering the first 20 ns only. The results are shown in Figure 8. In the first column of Figure 8, the main pulse is considered in time and frequency domain. In the second column, the complete pulse is considered.

Figure 8 implies that it is the main first pulse that widely contributes to the frequency spectrum in the hundreds of Megahertz range. As shown in the second column of Fig. 8, the subsequent oscillations in the waveform are producing the observed resonances.

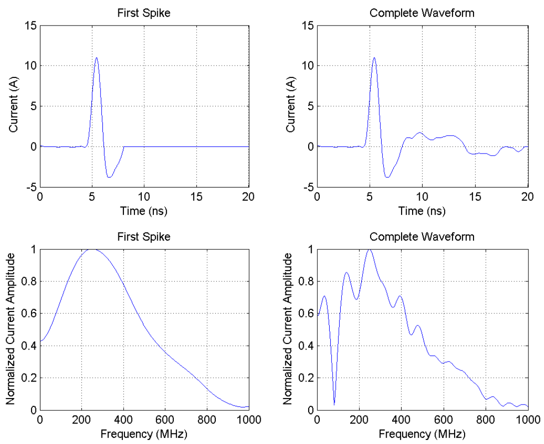


Fig. 8. Normalized FFT comparison between a single spike and the complete waveform

The subsequent oscillations observed in the measured current waveform could be due to additional space charge injection that is typically observed after the gap closure on corona charging process [5].

## B. *Repetition Frequency*

During the tests, the existence of jitter was evidenced on the waveforms. This suggests that the charging rate of the system is not stable. One explanation for this problem is the fact that there are not much corona space charge sources connected to the floating electrode. If one could increase the corona sources, the space charge availability would increase and the charging rate could be stable.

Some of the waveforms captured exhibited two pulses per shot. The time delay between the pulses varied between 1 µs and 1.5 µs. This suggests that bursts with repetition frequencies between 600 kHz and 1 MHz could be accomplished if the pulse delay is stable.

# V. Concluding Remarks

An impulse generation system with corona charging mechanism was developed and tested. This is a modified version of the so called Roman Generator. The performed analysis suggests the following conclusions:

- Roman Generator represents a low-cost solution to generate fast subnanosecond impulses.
- The obtained impulse waveforms are suitable for constructing an EMI radiation source if correctly delivered to an appropriate antenna.
- High pulse repetition frequency might be achieved with the generator if a stable corona charge source is connected to the floating electrode.
- There is no galvanic connection between the high voltage source and the overall system. This considerably simplifies the electrical design of the system since no considerations have to be made for over current failures in the source.

Work is in progress to obtain better performances in terms of increasing pulse repetition rate, and decreasing pulse risetimes. It is also possible to obtain higher peak currents if the breakdown voltage of the gap is increased. A pressurized spark gap switch generator can be used for this purpose.


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