Broadband RF/HPM source

Specifications:

- Resistive charging
- Ten stages with single spark gap per stage
- Capacitance per stage is 2 nF
- Charging voltage varies from 12 to 35 kV per stage
- Charging voltage must not exceed 40 kV per stage
- Output voltage rises from 96 kV to 300 kV (into high impedance load)
- Current peak supplied exceeds 1 kA, when charging voltage of 25 kV per stage and 100 Ohms load are used
- Energy stored in the capacitors varies from 1.15-12.3 J

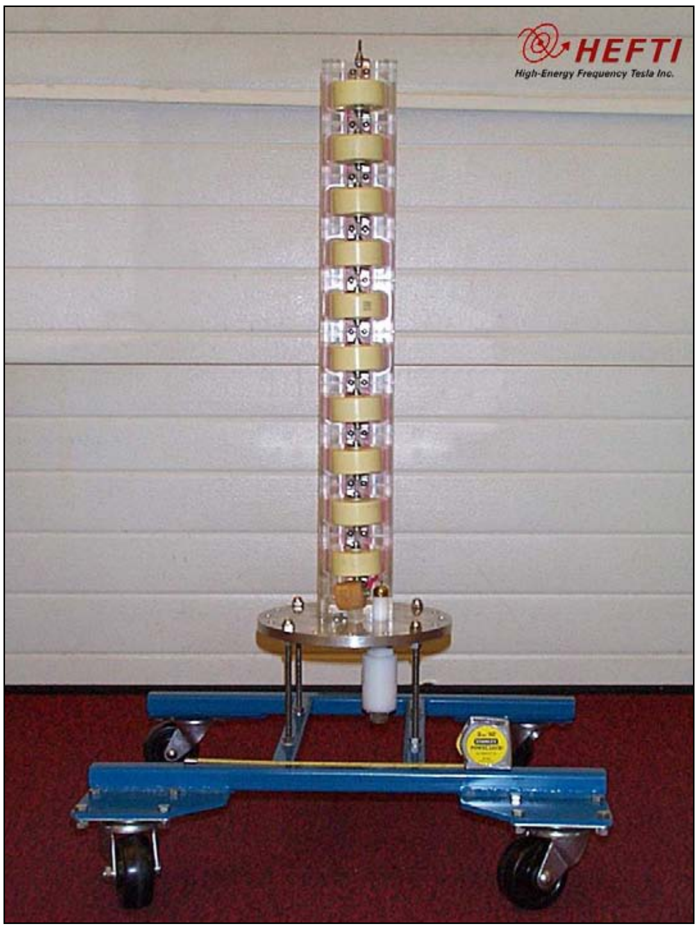

Figure 1 Interior of 10-stage Mini Marx Generator
Measuring tape is set to read 12 inches

Applications:

- To act as the trigger generator to activate high current banks.
- To drive X-ray diode and get hard X-rays
- To study ultra fast electrical breakdown phenomena
- For research in biophysics, the Mini Marx Generator with the X-ray tube was used to inactivate infectious bio-weapons i.e., the surrogate of anthrax. Reduction of 100% (from $9x10^7$ UFC/mg to zero) was achieved. The surrogates were placed between two pieces of paper and inserted in an envelope. In these experiments 20 shots were used making the total exposure time to be 200 ns.
- This generator was used in the fields of the EMP studies, because it has the sub-nanosecond rise-time. Note that the scientific paper on the Mini-Marx: entitled " Simple sub-50-ps rise-time high voltage generator" was published in Rev. Sci. Instrum. 62, pages 2923-2930; 1991
- This generator can also be used in the fields of the RF / HPM / MCG-simulation studies. Some data of the RF and HPM studies are herewith presented.
- To develop appropriate diagnostic devices that are deemed necessary for the studies of the fields above mentioned.
- Towards the understanding of how to mitigate potential RF/HPM attacks.
- To develop the measures for the protection and the hardening of electronic infrastructure.
- To assist in further development of explosively driven MCG's devices.
- To further improve the theoretical model for the HPM generation and amplification in atmospheric air.
- To better understand coherence effect (i.e. how the electro-magnetic waves can cancel each other due to destructive interference).

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Broadband RF/HPM source

HPM studies with the waveguide:

The standing-wave is produced in the waveguide by the oscillatory circuit that is driven by the Mini-Marx generator. The data of the HPM radiation at 1.19 GHz are shown in Fig 2.

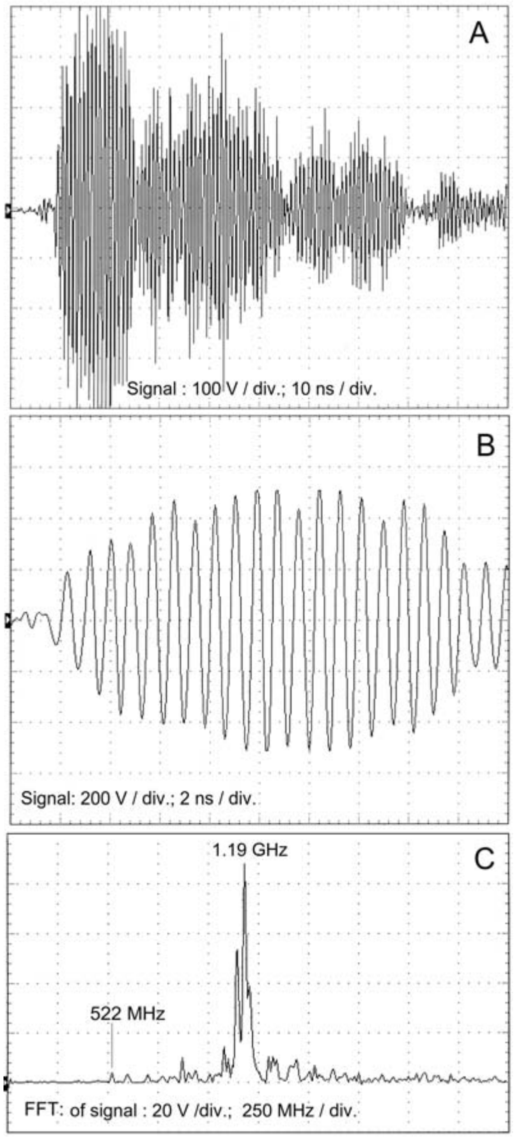

Figure 2. HPM pulse is recorded with the single turn loop probe of 1.89 cm in diameter. The probe is placed in the waveguide. The oscillatory circuit is tuned to produce the standing wave at 1.19 GHz. Frame B is the expanded waveform of frame A. FFT of signal is shown in frame C. Charging voltage is 33 kV/stage.

RF studies with the waveguide:

The basic set-up to get RF radiation is as in Fig. 2. The data of the RF radiation is shown in Fig 3.

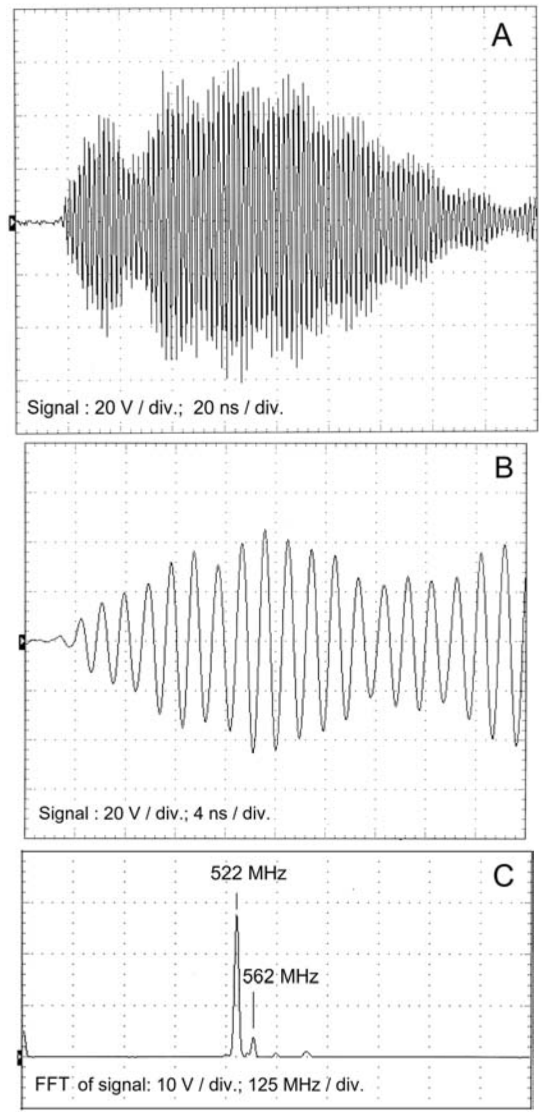

Figure 3. Experimental conditions are as in Figure 2, except that the oscillatory circuit is tuned to produce the frequency of 522 MHz. The waveguide is used as in Fig. 2. The data in Figure 3 are recorded with low-pass filter of 560 MHz.

Large-scale printed circuit board (e.g. 12” by 12”) can be placed in the waveguide to examine the effect of HPM on the electronic circuit

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Broadband radiation study with the helical antenna:

The study is conducted by attaching the helical antenna to the 10-stage Mini Marx generator. The radiation pattern at the exit of the helical antenna is shown in Fig. 4

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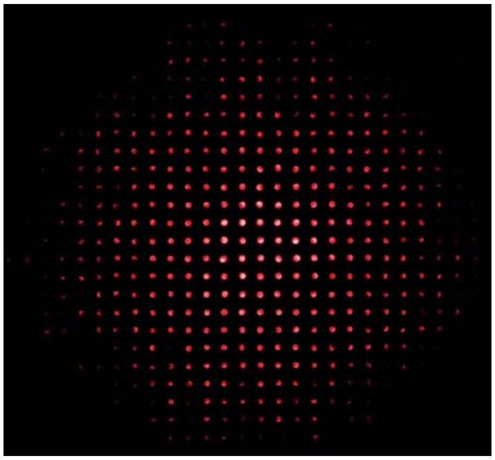

Figure 4. Ignition of the neon bulbs by the RF/HPM radiation

The bulbs are placed on plywood. The separation between the neon bulbs is 1 inch (=2.54 cm). The board is placed at a short distance away from the helical antenna. The generator is charged at 27.5 kV per stage and stores 7.6 J.

RF/HPM waveforms

Using the B-dot probe the data obtained are given in Fig. 5.

The magnetic field measurement of the radiation pulse recorded on the fast time scale close to the helical antenna is shown in Fig. 5, Frame C. The first part of the pulse has fast (<1ns) rise-time. The rise-time of the initial portion of the pulse is of similar shape as the output voltage pulse when the generator is terminated with the matching resistive load.

The second portion of the pulse has a long (15 ns) rise-time. This is due to the fact that, the helical line is an open-circuit enabling the voltage to double its value at the output.

The electric field measurements show that, the electric field is of equal strength within the radius of 10.5±1 cm (and within the area of 346 cm^2) where the center of this radius can be placed in the centre of Fig. 4. At the distance of 12 cm, the electric field, E measured is 20 kV/cm. See Fig. 6, Frame A. The power density is $E^2/(120\pi) = (20 \text{ kV/cm})^2/(120\pi) = 1.06 \text{ MW/cm}^2$.

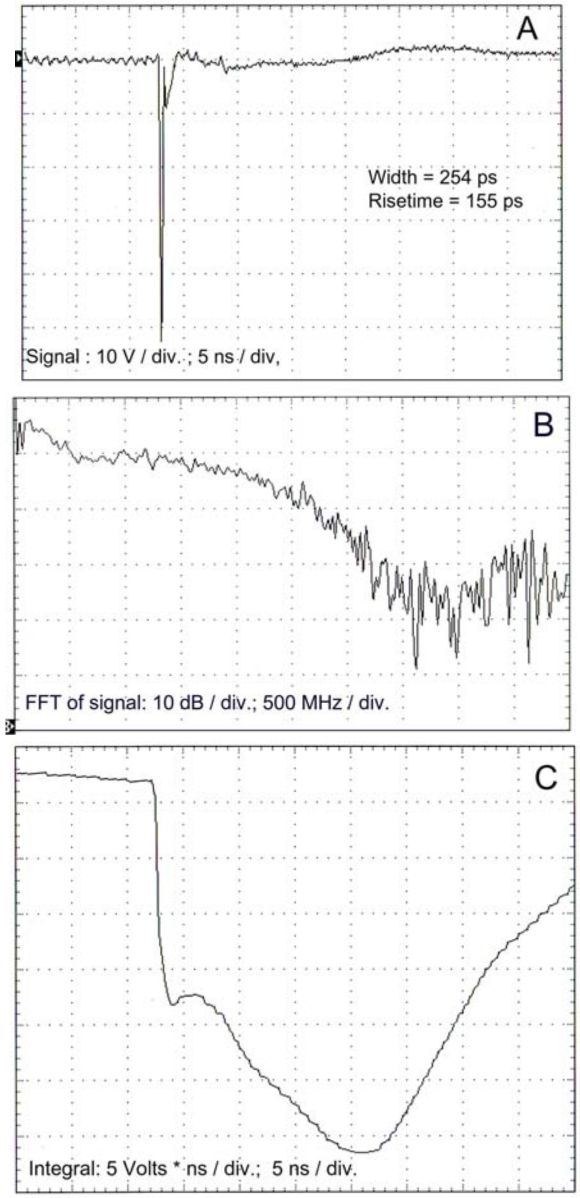

Figure 5; Data at 17 cm. Frame A is the B-dot signal. Frame B is the FFT of A. Frame C is the integral of the B-dot signal to get the magnetic field. B-dot probe is calibrated in the TEM-cell to obtain the electric field (=the integral of B-dot)

These numbers suggest that the generation of RF/HPM power of radiation at the exit of the helical antenna can approach 1GW range if a small 10-stage Mini-Marx generator is charged to the voltage higher than 25 kV per stage.

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Coherence effect occurring in broadband system

There is one major limitation in getting the large powers from the broadband (helical antenna-Mini Marx generator) system on to the target at large distance. This is the coherence effect. To show this, the measurements of the electric field are made as a function of the distance in the longitudinal direction from the helical antenna.

It was observed that the shape of radiation waveform became distorted as the distance was increased. At larger (>30 cm) distance, FFT starts to have many "valleys" in comparison to the smooth FFT shown in Fig. 5, Frame B. This implies that high frequency bands are somehow being "lost" and the first pulse shown in Fig. 5 assumes to be of triangular shape. See Fig. 6

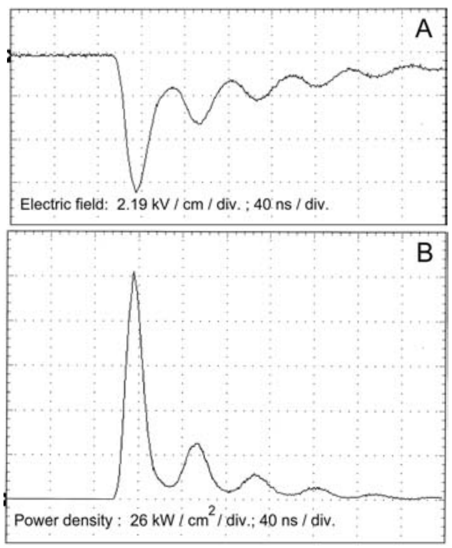

Figure 6. Frame A is the electric field, E recorded by E-field probe and frame B is the power density, $E^2/(120\pi)$. Distance from the antenna to the probe, d is 40 cm.

Fig. 7 also shows that the electrical field decreases faster than 1/distance. From Frame B we see that the product: (r*E) of the broadband is constant (=300kV) up to the distance of 40 cm. However, the internal (single) frequency at 1.19 GHz produced inside the generator obeys the law: r*E=constant over the large distance range. See. Fig.8.

The sharp decrease of the electrical field with distance is due to the coherence effect The theory tells us that from the Heisenberg uncertainty principle, the coherence effects are not pronounced if $\Delta t\, \Delta f \approx 1$. Here, Δf is the spectral bandwidth of the transmitted signal and Δt is the pulse width produced by the generator.

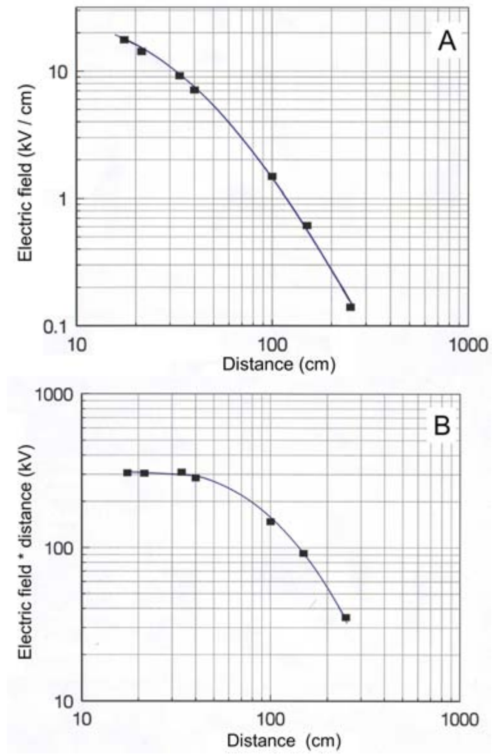

Figure 7; Frame A is the plot of the electric field, E in kV/ cm *vs* distance in cm. Frame B is the graph of the product of the electric field and distance *vs* distance. Here, E is recorded by E field probe.

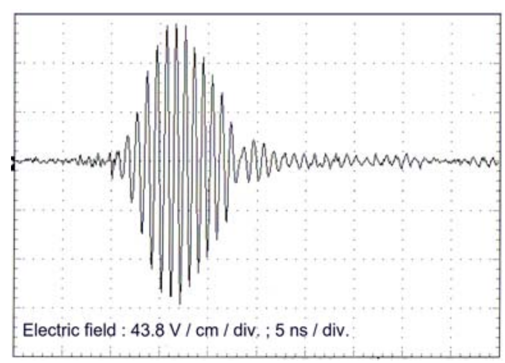

Figure 8. Electric field, E recorded with the electric field probe and 1 GHz high-pass filter at d=35 cm. The product: E times d is constant from 35 cm to 2.5 m.

The current broadband system containing the helical antenna and the Mini Marx generator is an excellent tool to develop the protection for some electronic infrastructure against the HPM.

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