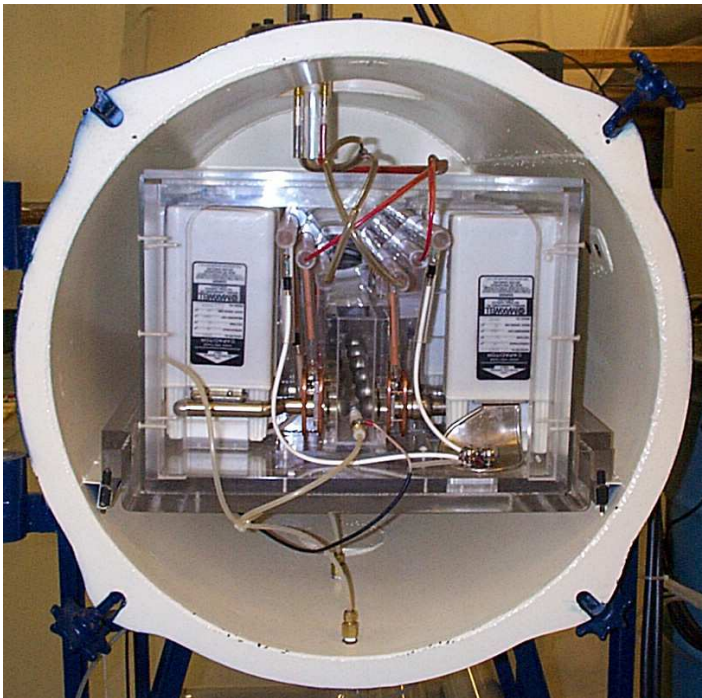


## Specifications

- 6-stage Marx generator has two capacitors per stage for the total of twelve capacitors
- Each capacitor has 90 nF with the rating of 75 kV
- Charging voltage used is from 12 to 33 kV
- Maximum energy of the system is 300 J
- Dual polarity DC power supply is incorporated in the system
- With crowbar switch and with high (700  $\Omega$ ) impedance load, the pulse width can be made to vary from 200 to 1000 ns
- With 100  $\Omega$  load, the pulse becomes double exponential waveform with the width of 380 ns
- Meets QSTAG 244 (NATO) - EMP criteria for military equipment

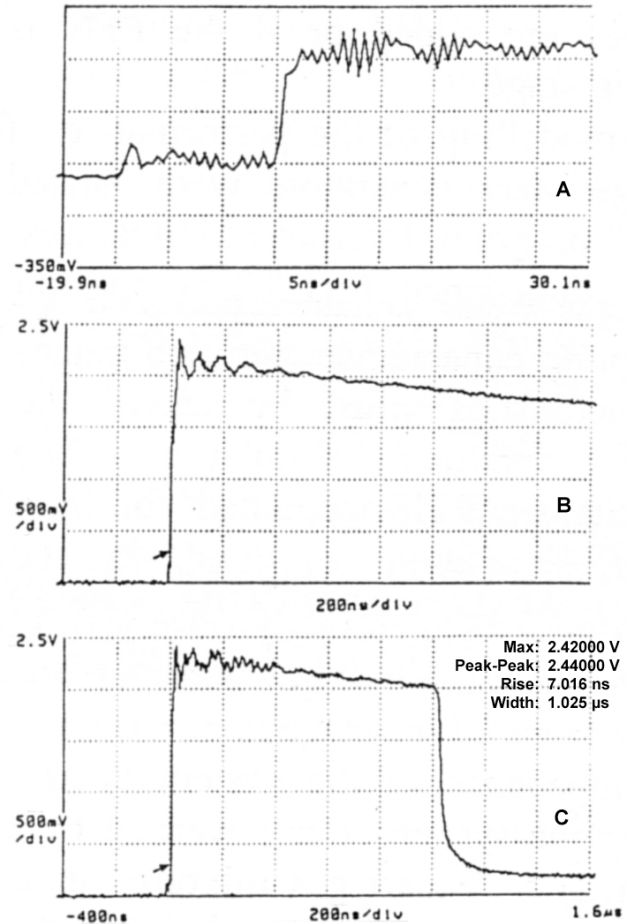
## Applications

- To drive EMP antenna and to energize the RF/HPM sources.



**Figure 1.** Photograph of the classical six-stage 12 capacitors (0.09  $\mu$ F, 75 kV) Marx generator

## EMP experiments



**Figure 2.** **Frame A** shows that the rise time of the EMP pulse is 1 ns. The record is made with the capacitive probe. If the load is placed in a coaxial enclosure, the rise-time falls to 0.4 ns.

**Frame B** is the waveform obtained with the load consisting of two resistors of 400 and 300  $\Omega$  connected in series. With the resistive probe, the rise-time of the voltage measured across 300  $\Omega$  "rises" from 1ns to 7-12 ns.

**Frame C** is obtained as in frame B, except that the crowbar switch is activated at 1.025  $\mu$ s. The crowbar action can be added to yield square shaped pulses from 200 ns to 1  $\mu$ s in a programmable manner.

**Dr. M. M. Kekez**

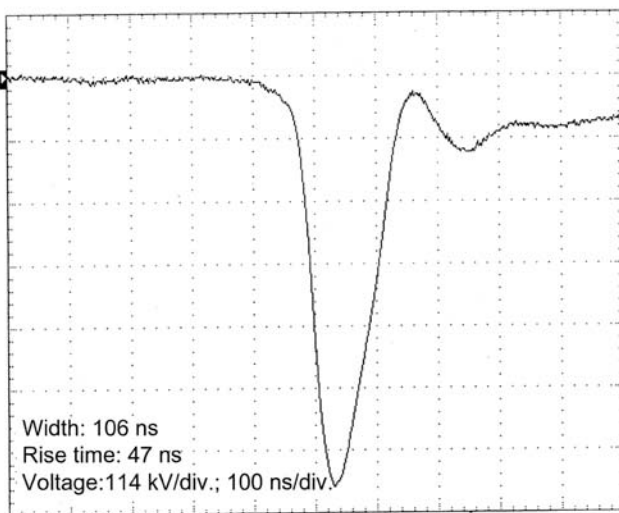
**HEFTI – High-Energy Frequency Tesla Inc.**

1200 Montreal Road, Building M-51, Ottawa, Ontario, Canada, K1A 0R6  
Tel.: 613-993-0427 / Fax: 613-941-6982 / E-mail: mkekez@magma.ca

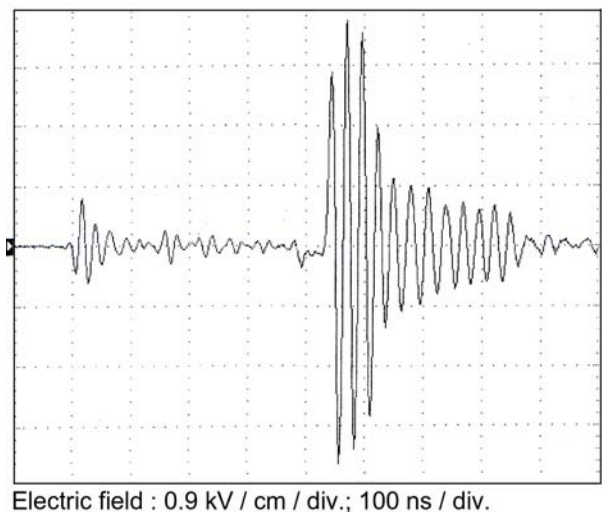
The results of these experiments are given in the paper entitled: “Energy compression experiments: Simulate a small-size MCG to obtain a RF source”. The paper was presented at the Megagauss Conference in 2006. Some highlights from the paper are herewith reproduced in Figs 3 to 5.

In the experiments 6-stage Marx generator is charging 12 capacitors of 90 nF to the voltage of 13.1 kV. The energy stored in the generator is 92.6 J. The energy from the generator is transferred into the coil (into the magnetic energy) via a thin wire attached to the ground. When the current through the coil reaches the maximum value, the wire explodes and the voltage waveform of Fig. 3 is obtained. This voltage drives the oscillatory circuit. The circuit is tuned to radiate mainly at 40 MHz. Note that the system emits also higher frequencies components that are superimposed on the frequency of 40 MHz. See Fig 5.

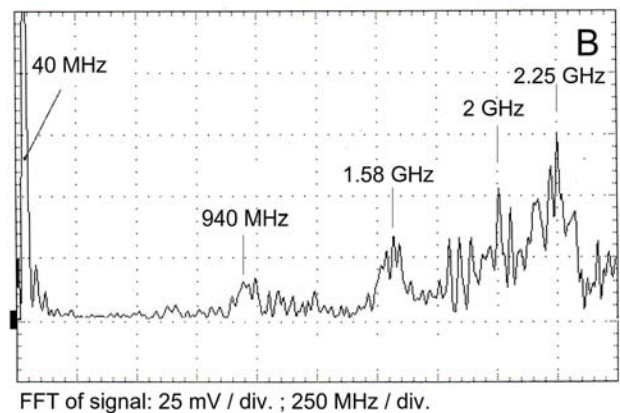
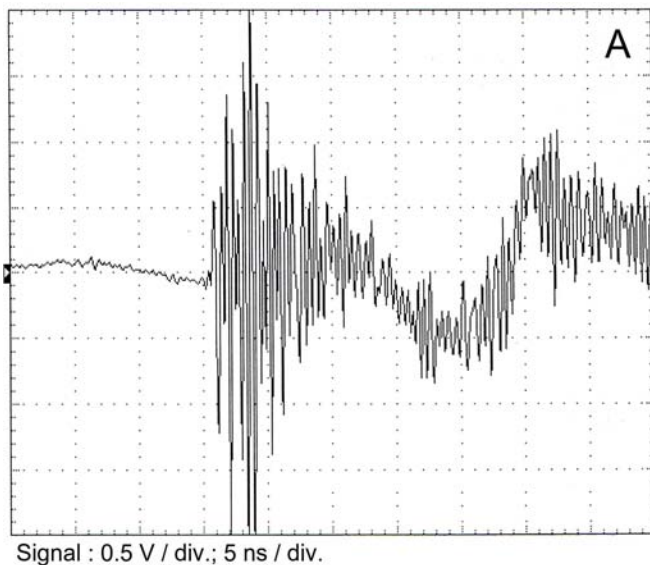
The radiating power at 40 MHz is estimated to be 648 MW. Over the width of 70 ns, the radiated energy is 45 J. The efficiency of the system is calculated to 45 J over 92.6 J= 49%



**Figure 3.** Voltage waveform across the exploding wire/fuse.

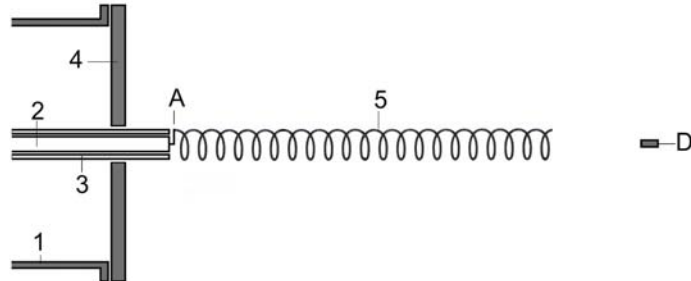


**Figure 4.** RF signal recorded by D-dot probe. Low 70 MHz pass filter is also used. The probe is placed at the distance of 1.25 m.



**Figure 5** Signal in Frame A is recorded by 50  $\Omega$  BNC female (jack to jack) adapter placed 1.1 m away from the oscillatory circuit. Frame B is FFT of the signal

Experimental set up is given in Fig. 6



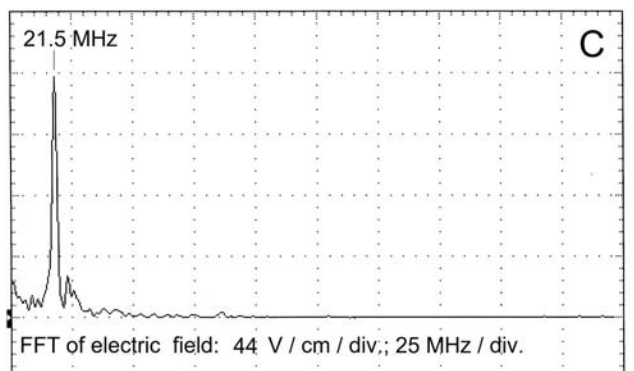
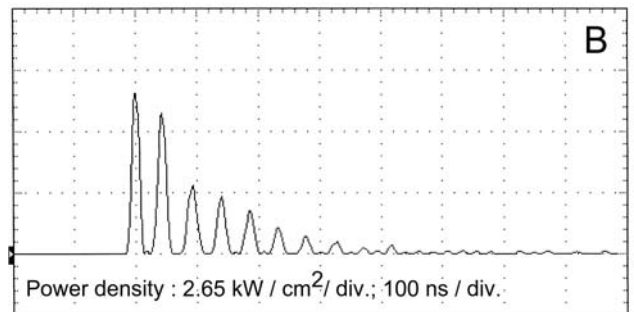
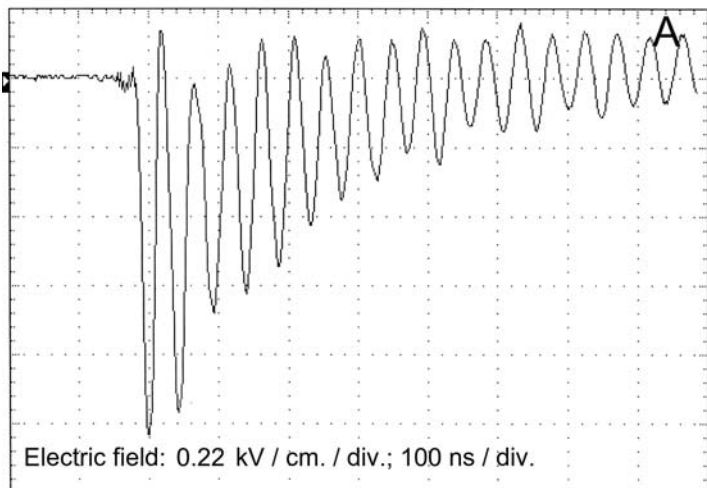
**Figure 6;** In the schematic 1 is the metallic enclosure of the 6-stage Marx generator, 2 the hot electrode of the generator, 3 the plexiglass tube, 4 the metallic flange, 5 the helix and D is the detector.

To avoid unnecessary stressing of the charging resistive network of the Marx generator during the discharge cycle, the resistor of  $300 \Omega$  is connected at the output of the generator between point A and the metallic enclosure of the generator.

For the antenna, the flange, 4 is the ground reflector/plane. This flange is of  $15 \frac{3}{4}$ " (40 cm) diameter. Copper tubing of 20 feet (= 6 m) long, of  $\frac{1}{4}$  inch (=0.635 cm) diameter is used to form the helix of 2.5 inches (=6.35cm) inner diameter, D. In the design of the antenna, the wavelength of the antenna,  $\lambda$  is equal to the circumference ( $= \pi D$ ), and the pitch between the turns is made to be  $\lambda/4$ .

### Experimental conditions:

- 6-stage Marx generator is charged to 26 kV / stage (= 13 kV / capacitor).
- The electric field probe is used to measure the field.
- The results are shown in Fig.6

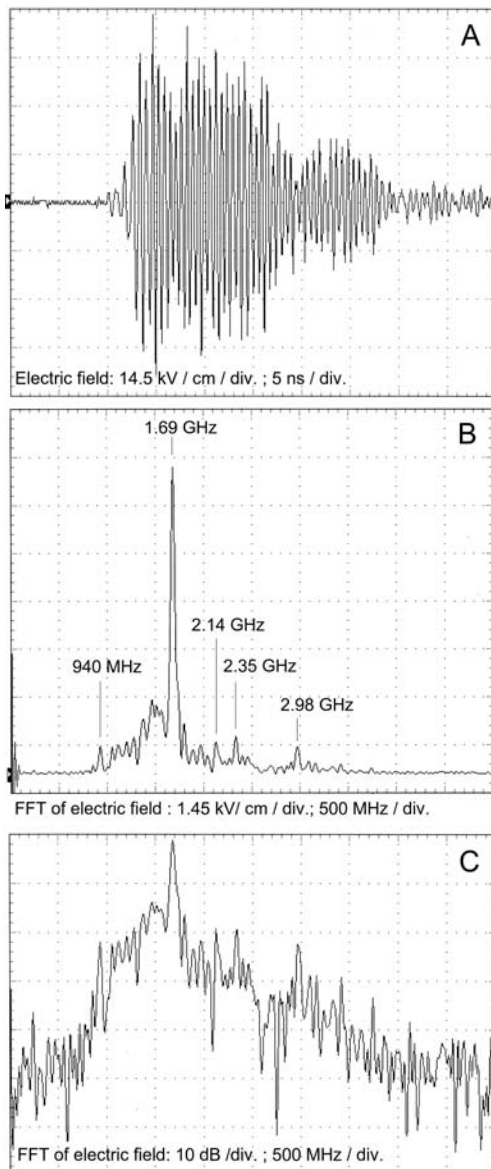


**Figure 6.** The system radiates mainly RF radiation at 21 MHz. Frame A shows the electric field, E recorded at the distance of 1.12 m. Frame B is the calculated value of the power density, ( $=E^2/(120\pi)$ ). Frame C is FFT of the field.

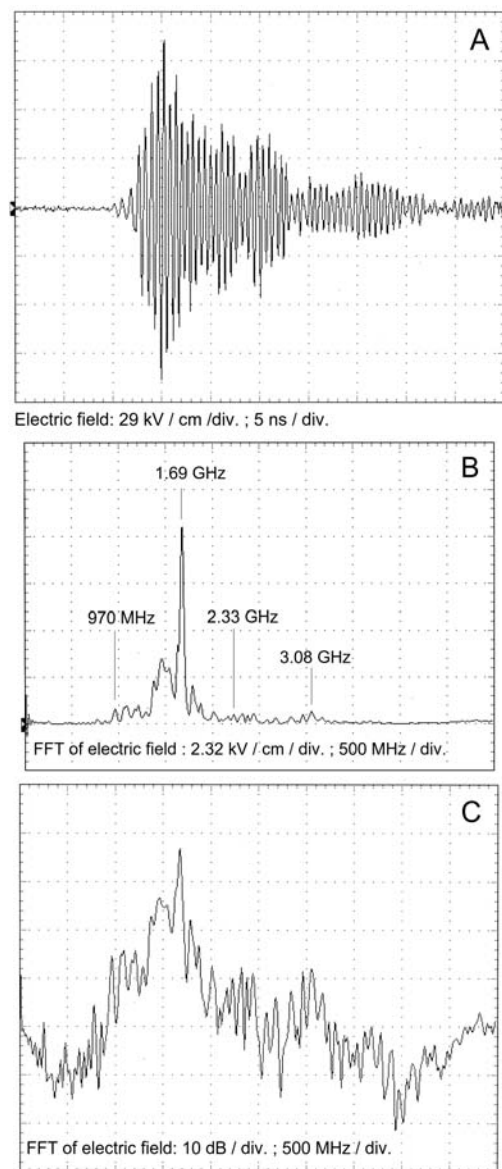


## Experimental conditions:

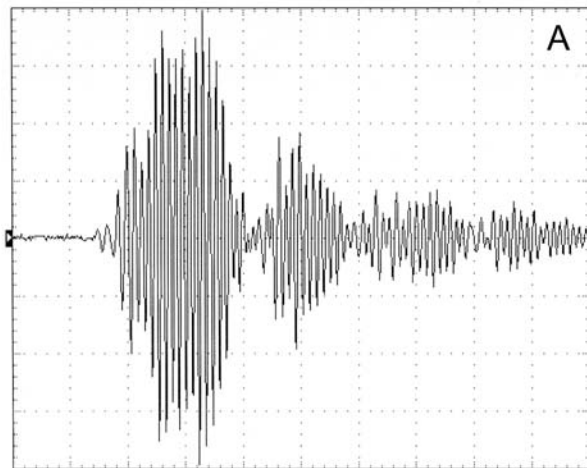
- 6-stage Marx generator charged at 26 kV / stage energizes the MCG-like structure and produces the corona/ spark discharges across the turns of the helix. The evolution of the discharge between the turns of the helix is given in Fig. 7 of the paper: “ A direct approach to RF/ HPM generation with regards to MCG” by M. M. Kekez, IEEE Pulsed Power and Plasma Science Conference, Albuquerque, N.M., June 17-22, 2007.
- To suppress the RF radiation, the metallic cylinder is used to enclose the MCG-like structure.
- Dielectrics tubes are inserted between the cylinder and the helix to prevent the electrical spark breakdown between the cylinder and the helix.
- The E-field probe is placed in the longitudinal direction 70 cm away from the MCG helix. 3 GHz oscilloscope is used.
- Results shown in Figs. 7 and 8 are obtained when the dielectrics tubes of different diameters are use.



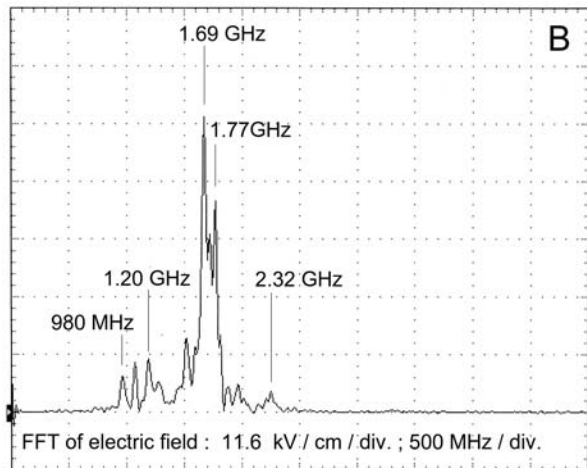
**Figure 7.** Frame A is the electric field. Frames B and C are FFT's given on the linear and logarithmic scale respectively.



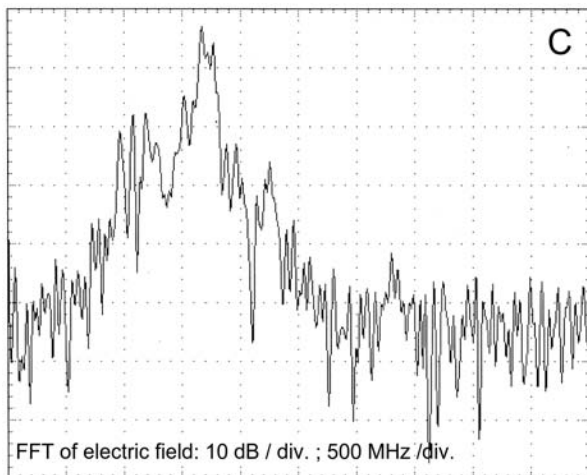
**Figure 8** As in Fig. 7 except that the diameter of dielectrics tube is now larger in comparison to that used in Fig. 7



Electric field: 116 kV / cm / div.; 5 ns / div.



FFT of electric field : 11.6 kV / cm / div. ; 500 MHz / div.



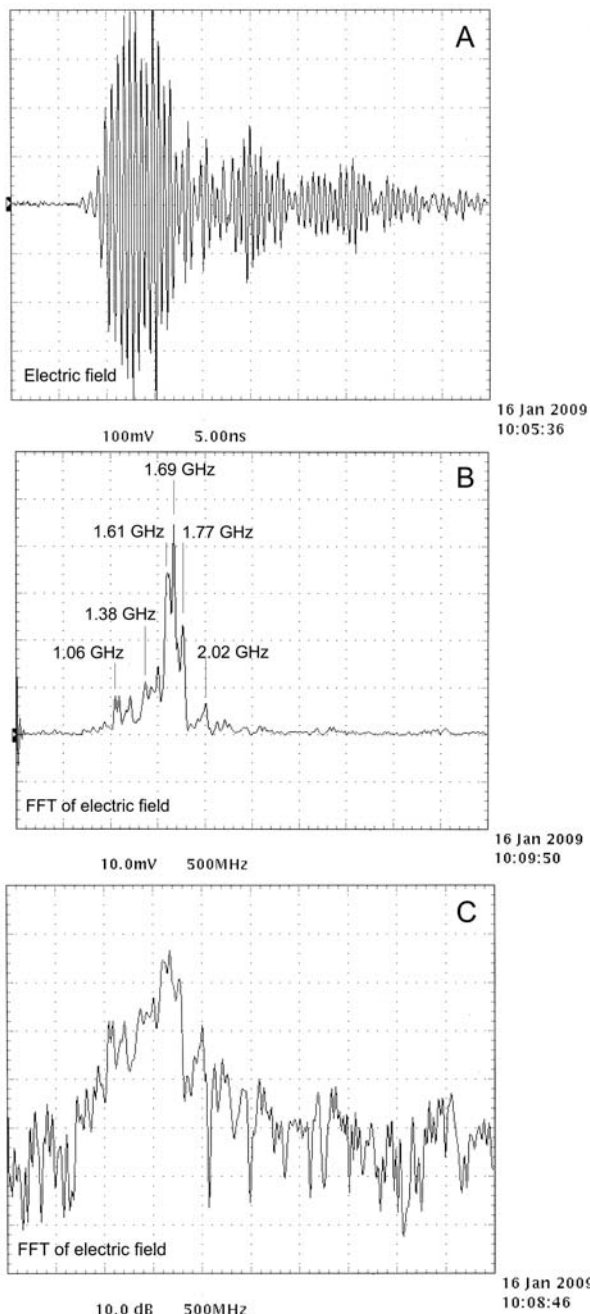
FFT of electric field: 10 dB / div. ; 500 MHz /div.

## Notes and discussion:

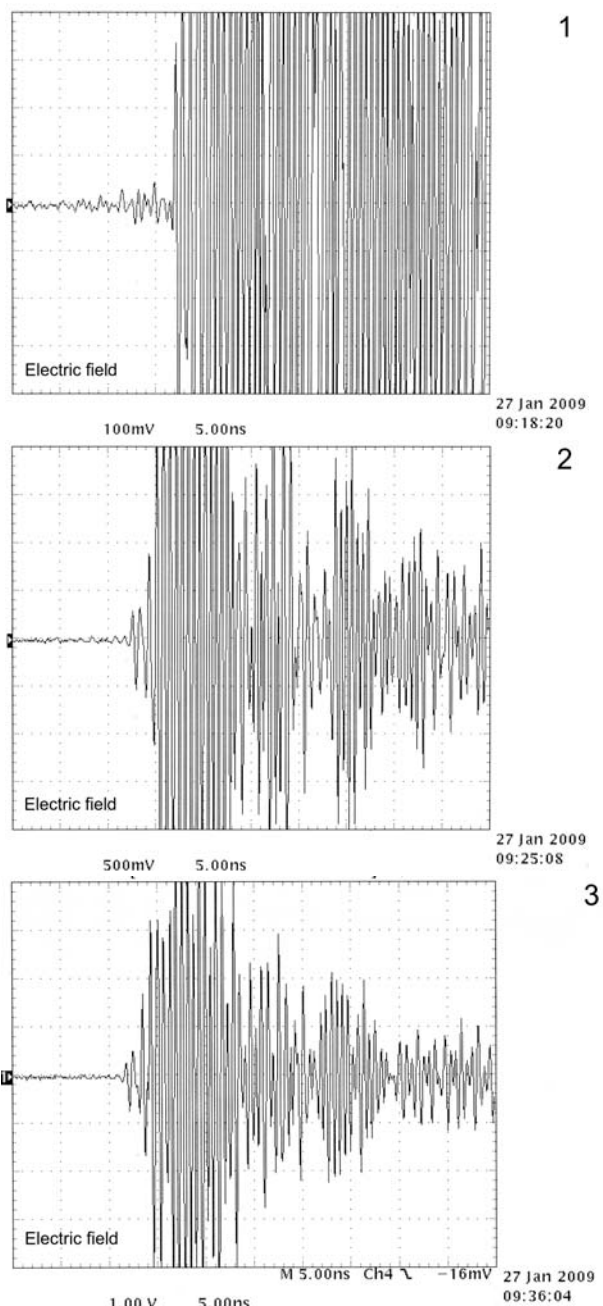
- The diameter of the helix of the MCG-like structure is 3” (= 7.62 cm) and the diameter of the inner tube is 2.25” (=5.72 cm).
- Flat plate of 3” (= 7.62 cm) diameter joins the helix of MCG with the inner tube of MCG-like structure.
- E-field probe is mounted inside the Varian 2 ¾ “ (~7 cm) conflate flange. The probe is positioned to be parallel to the flat plate of MCG-like structure at the distance, d.
- The radiation at mainly single frequency of 1.69 GHz (as indicated in Figs 7 to 9 and in Figs. 1 to 2 of Appendix) occurs when the electric field probe is placed at the specific distance, d away from the MCG-like structure.
- By measuring this distance, d and by relating the distance to the frequency of 1.69 GHz, it is found that we are dealing with the resonance. The signal at 1.69 GHz being launched from the flat plate of the MCG-like structure is bouncing back and forth from the E-field probe between two sides of this (unexpected) resonator.
- The condition for resonance in the resonator is that the round trip distance 2d is equal to an integer number of wavelengths,  $\lambda$ . This can be expressed as:
- $2 d = N \lambda$  where  $N \in \{1, 2, 3, \dots\}$
- In Figs 11 to 14 of the main text and Figs. 1 to 3 of the appendix, it was found that N is 7. Exactly.
- If N is increased, the shape of the pulse remains the same, but the amplitude of the pulse decreases. This is because smaller amount of the radiation emitted by the MCG-like structure participates in the resonance.
- Fig. 9 shows that there is a sudden increase in the value of the electric field in the resonator in comparison to the data given in Fig. 7. In some shots this increase is more than factor of 10, implying that the HPM has risen by factor of 100.
- In attempt to understand the data of Fig. 8, the experimental set-up was changed. The new results obtained are presented in the paper: “HPM generation in atmospheric air” by M. M. Kekez at the 13<sup>th</sup> Megagauss Conference, 2010. Further details of the mechanism involved is summarized in the paper: “HPM amplification in atmospheric air” (to be published)

**Figure 9.** Experimental conditions are as in Fig. 8 except that different combinations of dielectrics are inserted between the metallic cylinder and the helix of MCG-like structure.

- Fig 9 was posted on the website January 25, 2009. Fig. 2 of the Appendix was obtained on January 27, 2009.
- The Appendix is presented to demonstrate that the sudden increase of the radiated field is recorded periodically. Three consequent shots are presented in Fig. 2.



**Figure 1 of Appendix.** The data were obtained Jan. 16, 2009. Experimental conditions are as in Fig. 7. The measurement were done with 20 dB attenuator and the oscilloscope set to read 100mV/div. and 5 ns/div. Note, 100 mV/div. corresponds to 5.8 kV/cm/div.



**Figure 2 of Appendix.** As in Fig. 1 of Appendix, except that the 20 dB attenuator is not used. 100 mV / div. scale is used in the frame No. 1. To get a meaningful trace it is necessary to decrease sensitivity in the next consequent shot. The data were obtained Jan. 27, 2009