

Radio Frequencies Explosive Magnetic Flux Compression Generator and Its Military Applications

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Abstract. Radio frequencies explosive magnetic flux compression generator, an alternative to the use of capacitors as the load for helical magnetic flux compression generator, can provide a larger energy-to-volume ratio given than other conventional systems. As a kind of maneuverable device for generating and radiating electromagnetic pulse, radio frequencies explosive magnetic flux compression generator which bases on the theory magnetic field frozen effect is driven by explosive go off. Although this kind of device only adds a small capacitor to helical magnetic flux compression generator, but its characteristic has changed dramatically. The most important is that it has higher high-frequency component compared with helical magnetic flux compression generator means that it is easier to generate impulse radiation. Radio frequencies explosive magnetic flux compression generator has been found widespread uses as pulsed power sources for many fields. Also, due to their nature as a true one-time-use device with superior energy density, a large portion of applications is defense related. In this paper, the development of magnetic flux compression generator in recent decades is introduced. According to equivalent circuit model, we discussed the working principle of radio frequencies explosive magnetic flux compression generator. Its applications as pulsed weapons in military filed are shown. One of them is electromagnetic bomb, which is a mature technology as an electromagnetic weapon, uses an intense electromagnetic field to create a brief pulse of energy that affects electronic circuitry without harming humans or buildings. This kind of technology is discussed. Of course, the development of pulse weapon is introduced too.

Keywords: Radio frequencies explosive magnetic flux compression generator; radiation frequency; working principle; military applications; electromagnetic bomb;

1. Introduction

1.1. Brief History of Magnetic Flux Compression Generator

The magnetic flux compression generator (MFCG) was demonstrated in the early 1950s by Andrey D. Sacharov, who proposed transforming the energy of explosives into the energy of a magnetic field in January 1952 in Russia. MFCG which bases on the theory magnetic field frozen effect that no matter how the shape of good conductor circuit changes the magnetic flux conservation is built upon the idea of using high explosive explode to rapidly transfer a large amount of mechanical energy into a magnetic field, thereby significantly increasing the strength of the field[1-3].

The theory of MFCG was followed with the start of experiments at Russian Federal Nuclear Center in Russian and LANL (Los Alamos) in the United States in the spring of 1952.

Much effort and staffing has been expended both by Russian and the United States in the intervening period, as a result of which a wide range of generator configurations has been developed. A great many of original works on MFCG was conducted in the 1960s with many of reports in the Proceedings of the International IEEE Pulsed Power Conferences and the Mega gauss Conferences. Now among the countries

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that are persistently conducting or using research on MFCGs are Russia, Ukraine the United States, China, France, United Kingdom, Sweden, Italy, Romania, Germany and Poland, In these countries, Russia, Ukraine, the United Kingdom, China, Australia and France are well ahead in this field [4].

1.2. Radio Frequencies Explosive Magnetic Flux Compression Generator

Radio Frequencies Explosive Magnetic Flux Compression Generator (RF MFCG) as a kind of maneuverable and compacted device for generating and radiating electromagnetic pulse is composed of a helical magnetic flux compression generator and a small capacitor[5-7]. First reported of such kind of devices is a paper by Prishchepenko and Shchelkachev published in 1993[8]. Although this device only added a small capacitor to helical magnetic flux compression generator, but its characteristics have dramatically changed, that it has higher high-frequency component compared with helical magnetic flux compression generator means that it is easier to generate impulse radiation. For this characteristic, RF MFCG could be utilized in many fields including exploration for oil well and minerals detection, high power lasers, drivers for high current and high magnetic field experiments, and variety of military applications.

One of RE MFCG applications in military fields is electromagnetic bomb. It uses an intense electromagnetic field to create a brief energy pulse that destroy electronic circuitry, thus disabling any type of machine that uses electricity, including fundamental computing and communications infrastructure. The key technology which could be applied to electromagnetic bomb design in the near term is RF MFCG. We introduced the working principle of RF MFCG and analyzed that the high-frequency component of RF MFCG can reach up to 20MHz. The use of RF MFCG as electromagnetic bomb in military applications was introduced. The development of pulse weapon is discussed.

2. structure and working principle of RF MFCG

RF MFCG has a similar construction with helical MFCG, The structure sketch is shown in Fig.1. It has six key components, armature, explosive, plane wave generator, stator coils, detonator and a small capacitor. The armature is typically a precisely machined and seamless tube of Copper, which is strict concentricity filled with fast explosive. Any fast high energy explosive with stable detonation or burn properties may be used. Armature must be well-made to ensure the strict concentricity. Detonator is initiated with a plane wave generator such as this ensures that an asymmetrical or heterogeneous burn front does not distort the armature shape and compromise RF MFCG performance giving rise to flux loss. The stator coil which is typically made from a copper wire and wound on a mandrel could be split into segments, to optimize the current carrying capability. During the priming and the operation of the RF MFCG, to prevent the possibility that stator could be ruptured, some non-conductive material is placed around the stator, such as fibre and so on.

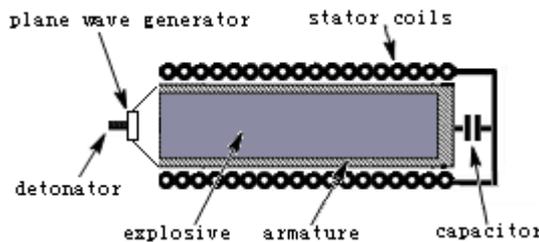


Fig.1 Structure sketch of RF MFCG

The circuit model of RF MFCG is shown in Fig.2

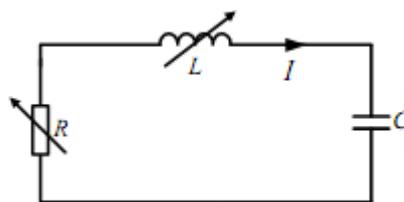


Fig.2 Circuit model of RF MFCG

Before the operation of RF MFCG, system need initial or seed flux. It can be established by a permanent or pulsed magnetic field utilizing either permanent magnets or a current-pulsed seed inductance fed, for instance, by a capacitor bank.

In operation the explosive is initiated when the seed current peaked. As is shown in Fig 2, the detonation wave will distort the armature, expanding the armature, short-circuiting the armature and the stator coils and compressing the magnetic field forward. Armature will form a conical shape as the explosion progress, which propagates along the length of the axis. The propagating short compresses the magnetic field and reduces the stator coils inductance, which causes the circuit current to rapidly ramp up until the RF MFCG disintegrates. We can estimate the performance of an ideal RF MFCG which is less flux loss relatively by simply equation:

$$\Phi_i = L_i I_i = \Phi_f = L_f I_f \quad (1)$$

In(1), Φ_i is initial flux; L_i is initial inductance; I_i is initial current; Φ_f is final flux; L_f is final inductance; I_f is final current. Then we obtain that

$$GAIN_1 = L_f / L_i \quad (2)$$

On the other hand, magnetic energy

$$W_f = \frac{1}{2} L_f I_f^2 = W_i \frac{L_f}{L_i} = W_i \frac{I_f}{I_i} \quad (3)$$

In (3), W_i is initial magnetic energy; W_f is final magnetic energy. From (3) we know that the explosion chemical energy translate into magnetic energy.

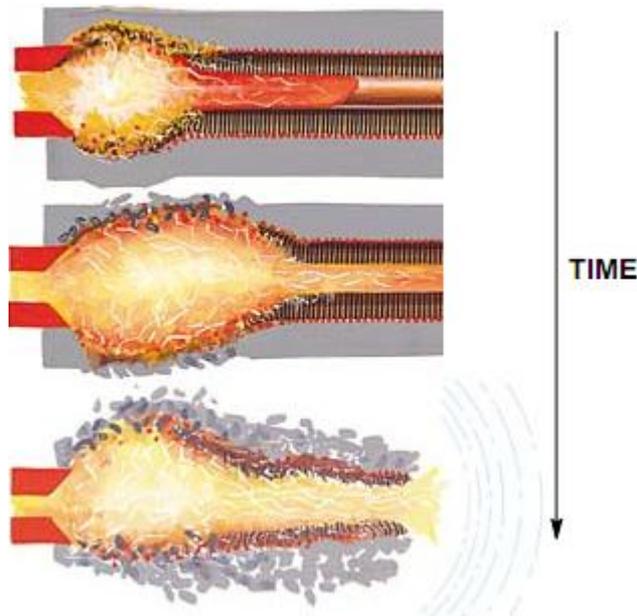


Fig.3 The operational process of RF MFCG[8]

In consequence of capacitor, the circuit has oscillating characteristic, current strength will keep increasing and emitting electromagnetic pulses finally in a short time. In the operation we assume that carrier frequency

$$f \approx \frac{1}{2\pi\sqrt{LC}} \quad (4)$$

Then the carrier frequency of RF MFCG is shown in Fig.3.

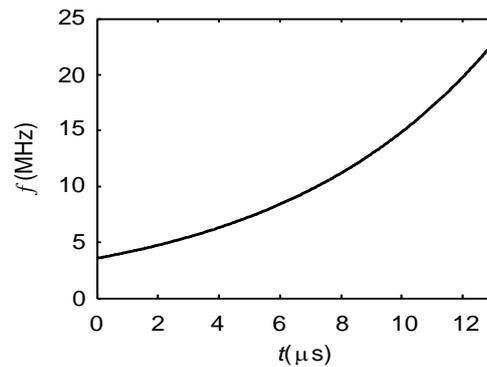


Fig.3 Carrier frequency

In order to make the energy scattering in frequency clear, the energy spectrum is shown in Fig.4. We obtain that RF MFCG has a higher energy-frequency scattering. The high-frequency component could reach to 20MHz. That means more easy to radio energy. For this characteristic, RF MFCG is valuable for many military applications.

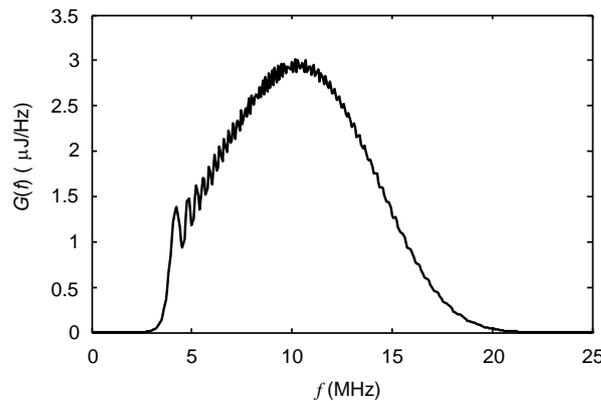


Fig.4 Energy spectrum of RF MFCG

3. MILITARY APPLICATIONS

One of the most important military applications of RF MFCG is pulse weapon, that is electromagnetic bomb. The concept of electromagnetic bomb arose from nuclear weaponry research in the 1950s. This type of electromagnetic pulse weapon, which RF MFCG is the key component, is a warhead that, when exploded, emits a high-energy pulse that will fuse electrical equipment within range. An electromagnetic bomb attack would leave buildings standing and spare lives, but it could destroy a sizeable military. It could destroy communication systems and stop civilian infrastructures such as power plants, manufacturing, hospitals and transportation which comprise the technological foundation of this infrastructure shares a common attribute, in that it is built with modern integrating circuit(IC), from working. It can scramble phones and computers and knock out various facilities. For its potentially non-lethal, but still highly destructive characteristic, electromagnetic bomb is extremely valuable for military application in modern warfare.

3.1. Development of Electromagnetic Pulse Weapons

Since 1949, former Soviet Union show intense interest in developing pulse weapons. Then the United States expended great efforts and staffing .So far a great many of countries are researching pulse weapons. Reported from unclassified literatures, the United States, Russia, Ukraine, the United Kingdom, China, Australia and France are well ahead in this field, while Germany, Sweden, South Korea, India and Israel are emerging and have ample details of the Russian work and of the proceedings of more than 20 years of international conferences. Up to now, lots of international conferences beginning in 1940s have been a principal source of technology transfer. The related conferences as follows:

- Mega gauss Conference

- EUROEM Conference
- The BEAMS conference
- The EUROEM Conference
- International Pulse Power Conference
- The International Particle Accelerator Conference

1) *U.S. development state of electromagnetic pulse*

The United States sectors engaged in the development of electromagnetic pulse weapons is mainly the Department of Energy, Department of Defense, research institutions and other universities. In 1983, Sandia National Laboratories successfully created an explosive magnetic flux compression generator which can produce 18 MegaJoules magnetic energy pulses. Los Alamos National Laboratory has developed a kind of weapon driven by high explosive, it could generate 16 MegaJoules electromagnetic pulse in 400 Nanoseconds. U.S. Department of Energy institute of nuclear weapon has developed a new type air-dropped high explosive magnetic flux compression microwave generator device. This device could produce high power wide-band microwave radiation. Boeing has developed a high-power microwave device weapon used to destroy enemy electronics.

The United States carried out a project known as the Balboa, the aim of the project is to develop a device using explosive magnetic flux compression generator to drive virtual cathode oscillator to generate high power microwave. This project which has tested in a small size warhead at a frequency of 1 GHz can produce thousands of joules of energy. Since 2004, the United States began a new project of extensive testing of electromagnetic pulse weapons. Plan to significantly reduce the cost of electromagnetic pulse weapons [10].

2) *Russia recent progresses in the research on electromagnetic pulse*

Russia is roughly in the same level of electromagnetic pulse technology with the United States. In some technical aspects of microwave radiation is better than the United States. It is reported that Russia has developed a series of electromagnetic pulse weapons. With its moving target test on goat, 1km away from the goat die immediately, 2km away from the goat fell to the ground paralytically. For air defense of Russia's land-based high-power microwave weapon system has 1Gigawatt emitting peak power in the valid range of 1~10 km.

Recently, Rainbow Manufacturing Design Bureau disclosed an electromagnetic pulse bomb which could be used to against aircraft carrier battle groups. This electromagnetic pulse bomb can be used as a trump to destroy defense system of aircraft firstly, then launching air strike.

3) *Other countries development statuses.*

Now, the United Kingdom, Australia, France, India and other countries also carried out electromagnetic pulse bomb research but lower than the U.S. and Russia. There are several research institutions engaged in the research of electromagnetic pulse weapons in China. Such as CAEP, Harbin Institute of Technology (HIT), National University of Defense Technology. However, a pronounced gap still exists as compared with the advanced countries.

4) *The trend of development*

Overall, electromagnetic pulse weapon is a mature technology now. U.S. and Russian electromagnetic pulse weapon researches will reach partial application stage. According to the present world electromagnetic pulse weapon R&D situation, its trend of development in the future is :

a) *Smaller*

Electromagnetic pulse weapon needs Pulsed Power Supply to charge or to energize, RF MFCG needs a current pulsed seed to establish initial or seed flux for instance, by a capacitor bank. Due to the capacitor itself is bulky and weighty owing to the low energy density, the maneuver performance of electromagnetic pulse weapon does not produce the desired result. Especially, it's not very convenient to mount in small massive transportations. The future research trend is how to ensure the combat effectiveness of electromagnetic pulse weapons, under the premise of a small size, light weight and good maneuverability.

b) *Bigger energy density*

The combat effectiveness of electromagnetic pulse weapon system is determined by energy concentrate after radiated from the antenna. In order to satisfy the battle requests, it is very important to increase the radiation power and pulse energy.

3.2. Structure of Electromagnetic bomb with RF MFCG

As is shown in Fig.4 is a kind of electromagnetic bomb structure with key component RF MFCG [9]. The bomb is consist of two parts. The first part includes a GPS guidance system and a capacitor bank which is used as a priming source for establishing initial magnetic flux for RF MFCG [11]. The second part is RF MFCG system which would begin to work in consequence of detonator fired when electromagnetic bomb arrives on target. Stator coils are employed as an antenna to emit electromagnetic pulse to destroy the target. The target mainly like:

- The military infrastructures
- The communication systems
- The power grids
- The transportation systems
- Finance and banking systems
- Manufacturing industries

All of those targets of electromagnetic bombs are vital important for the smooth operating of political systems, finance sectors, government bureaucracies, manufacturing industries and so on.

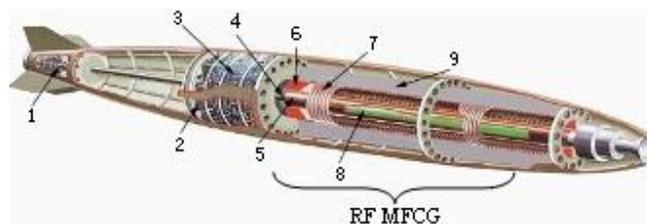


Fig.5 The structure of electromagnetic bomb with RF MFCG[9]

1: GPS guidance system. 2: batteries. 3: capacitor bank. 4: detonator.

5: armature. 6: insulator. 7: stator coils. 8: explosive. 9: protective material.

Electromagnetic superior are the important precondition and the key factor to win the modern high-tech battle and as well for the information battle in the future war. Electromagnetic pulse weapons could play a key role in this.

4. Conclusion

The artical has introduced the working principle and development of MFCG and RF MFCG, presented the development of pulsed weapon with the key element of RF MFCG. RF MFCG as key component of pulse weapon is a mature technology now. One problem of RF MFCG that has been pointed out by researchers is the low conversion efficiency of electromagnetic energy [12]. Next work is study approaches for achieving higher conversion efficiency of electromagnetic energy.

5. Acknowledgement

Yingchao Han, master student, major in Electromagnetic Field and Microwave Technology in Harbin Institute of Technology. His current research interests are high-power electromagnetic pulse, antenna miniaturization and RF Circuit.

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