Vojnotehnicki glasnik/Military Technical Courier
ISSN: 0042-8469
ISSN: 2217-4753
vojnotehnicki.glasnik@mod.gov.rs
University of Defence
Serbia

High energy microwave weapon: Electromagnetic bomb

Banjac, Goran M.; #or#evi#, Vladimir D.; #ivkovi#, Miladin Z.; Ferdjali, Abdellah
High energy microwave weapon: Electromagnetic bomb
Vojnotehnicki glasnik/Military Technical Courier, vol. 69, no. 2, 2021
University of Defence, Serbia
Available in: https://www.redalyc.org/articulo.oa?id=661771134009

Professional papers

High energy microwave weapon: Electromagnetic bomb

Высокоэнергетическое СВЧ-оружие – электромагнитная бомба

Високоенергетско микроталасно оружје – електромагнетна бомба

Goran M. Banjac a
University of Defence in Belgrade, Serbia
gbbanjac@yahoo.com
https://orcid.org/0000-0002-3547-9723

Vladimir D. Đorđević b
University of Defence in Belgrade, Serbia
ketidjole@ptt.rs
https://orcid.org/0000-0003-0669-0770

Miladin Z. Živković c
University of Defence in Belgrade, Serbia
miladin32dus@yahoo.com
https://orcid.org/0000-0002-3060-4011

Abdellah Ferdjali d
Polytechnic Military School, Algeria
ferdjali.abdellah@gmail.com
https://orcid.org/0000-0002-1748-1715

Redalyc: https://www.redalyc.org/articulo.oa?id=661771134009

Received: 24 October 2020
Revised document received: 16 March 2021
Accepted: 18 March 2021

Abstract:

Introduction/purpose: Technological progress has led to the actualization of the problem of construction and use of high-energy microwave weapons, especially electromagnetic bombs. However, in the recent military-professional literature, this issue is little represented.
Methods: The available existing literature on the subject was analyzed.
Results: It has been established that the general principles of functioning and theoretical bases have been widely available and known for many years. Numerous experiments in specialized institutions have confirmed the electromagnetic pulse effectiveness. This is especially true of sensitivity of devices based on semiconductor technology. Also, it is assumed that, at the current technological level, technical solutions are widely available to a large number of entities. The most common model of electromagnetic bomb dealt with in the literature is the realization of the use of a compression flux generator and an oscillator with a virtual cathode. According to the authors, this variant would ensure that the final product has realistic physical dimensions and sufficient strength to be useful. Another problem identified in the literature is the massive absence of adequate protection measures

Author notes

a University of Defence in Belgrade, Military Academy, Department of Air Defence, Belgrade, Republic of Serbia

b University of Defence in Belgrade, Military Academy, Department of Air Defence, Belgrade, Republic of Serbia

c University of Defence in Belgrade, Military Academy, Department of Air Defence, Belgrade, Republic of Serbia

d Polytechnic Military School, Algiers, People's Democratic Republic of Algeria

gbbanjac@yahoo.com

against the effects of electromagnetic pulses. This applies not only to the civilian but also to the military sector and imposes the need to invest significant resources in order to subsequently increase resilience.
Conclusion: The available literature indicates that it is possible to make an electromagnetic bomb of acceptable physical dimensions and power. It is assumed that it would generate an electromagnetic pulse with a power of about 10 GW and a frequency of 5 GHz. In combination with high-precision weapons, even protected devices would be successfully disabled. The wide presence of semiconductor technology in all spheres of life makes this weapon extremely effective and it is realistic to expect its much wider application in the coming period.

Keywords: high energy microwave weapon, electromagnetic bomb, electromagnetic pulse, explosively pumped flux compression generators, vircator.

Резюме:

Введение/цель: Технический прогресс привел к актуализации вопроса о создании и применении высокоэнергетического СВЧ-оружия, в частности электромагнитных бомб. Однако в новейшей военно-профессиональной литературе этот вопрос недостаточно освещен.
Методы: В данной статье представлен анализ имеющейся литературы по данной теме.
Результаты: Выявлено, что общие принципы функционирования и теоретические основы широко доступны и известны на протяжении многих лет. Многочисленные эксперименты в специализированных учреждениях подтвердили эффективность электромагнитного импульса. Особенно касательно чувствительности устройств на основе полупроводниковой техники. Также предполагается, что на текущем технологическом уровне технические решения широко доступны большому количеству организаций. В изученной литературе наиболее распространенной моделью электромагнитной бомбы является использование генератора сжатия потока и генератора с виртуальным катодом. По мнению авторов, этот вариант гарантирует, что конечный продукт будет обладать достаточной мощностью и реалистичными физическими размерами для того чтобы иметь ценность использования. Еще одна проблема, обозначенная в литературе, касается вопроса об отсутствии соответствующих мер защиты от воздействия электромагнитных импульсов. Это относится не только к гражданскому, но и к военному сектору и требует инвестирования значительных ресурсов для последующего повышения сопротивления.
Выводы: В доступной литературе указывается, что можно разработать электромагнитную бомбу приемлемых физических размеров и мощности. Предполагается, что она будет генерировать электромагнитный импульс мощностью около 10 ГВт и частотой 5 ГГц. В сочетании с высокоточным оружием даже защищенные устройства можно будет успешно вывести из строя. Широкое присутствие полупроводниковых технологий во всех сферах жизни делает это оружие чрезвычайно эффективным, следовательно, можно ожидать его широкого применения в ближайшем периоде.

Ключевые слова: СВЧ-оружие высокой энергии, электромагнитная бомба, электромагнитный импульс, генераторы сжатия потока с взрывной накачкой, виркатор.

Abstract:

Увод/циљ:Технолшки напредак довео је до актуелизације питања конструкције и коришћења високоенергетског микроталасног оружја, а посебно електромагнетене бомбе. Међутим, у новијој војностручној литератури ова проблематика је ретко заступљена.
Методе: Извршена је анализа постојеће доступне литературе из предметне проблематике.
Резултати: Установљено је да су општа начела функционисања и теоријске основе доступни и познати већ дужи низ година. Бројни експерименти у специјализованим установама потврдили су ефикасност утицаја електромагнетног импулса, што се превасходно односи на осетљивост уређаја базираних на полупроводничкој технологији. Такође, претпоставља се да су, на садашњем технолошком нивоу, техничка решења доступна великом броју субјеката. Као најчешћи модел електромагнетне бомбе, у литератури се истиче реализација коришћењем компресионог флукс-генератора и осцилатора са виртуелном катодом. Ова варијанта могла би да обезбеди да коначни производ има реалне физичке димензије и довољну снагу, као и употребну вредност. Још један од проблема који је идентификован у обрађеној литератури јесте масовније одсуство адекватних мера заштите од дејства електромагнетног импулса. То се не односи само на цивилни, него и на војни сектор и намеће потребу улагања знатних средстава ради накнадног повећања отпорности.
Закључак: Доступна литература указује на могућност израде електромагнетне бомбе прихватљивих физичких димензија и снаге. Претпоставља се да би њом био генерисан електромагнетни импулс снаге око 10 GW и фреквенције 5 GHz. У комбинацији са високопрецизним оружјем могли би се успешно ометати чак и заштићени уређаји. Широка заступљеност полупроводничке технологије чини овакво оружје изузетно ефикасним, паје реално очекивати његову значајнију примену у наредном периоду.

Keywords: високоенергетско микроталасно оружје, електромагнетна бомба, електромагнетни импулс, компресиони флукс-генератор, виркатор.

Introduction

The harmful effects of electromagnetic pulses have been known for a long time. The most famous example is the activation of a warhead with a power of 1.45 megatons, at an altitude of 250 miles above the Pacific Ocean. The consequences of this experiment were much more serious than expected. The impact of electromagnetic pulses was felt in Hawaii, 1445 km from the explosion center. The consequences were the destruction of street lighting, alarm systems and telecommunication systems. Six satellites at such a distance for which the possibility of affecting them had not even been considered were completely destroyed. After this event, the effect of the electromagnetic pulse becomes extremely relevant from the aspect of military use. Further research has yielded more accurate knowledge about the consequences of using such weapons. Thus, a nuclear warhead, with a power of 1-2 megatons, activated at an altitude of 250 miles, would release an electric field of 10-50 kV / m, which would cause damage to a larger continental part of the United States (Miller, 2005, p.390).

Numerous laboratory research studies have significantly contributed to understanding the mechanisms of influence of electromagnetic impulses. In them, the electromagnetic pulse is not generated as a product of a nuclear explosion, but is created by certain high-frequency high-power devices. Although they can be used more than once, these technical solutions, due to their dimensional limitations, have not found wider application outside specialized scientific research institutions.

Technical solutions called high-energy microwave weapons stand out today as very important for military use. These are devices capable of emitting directed high-frequency electromagnetic energy. Their pulse power is 100 MW-100 GW, and the operating frequency is 1-300 GHz (Ni et al, 2005, p.2). Progress in their development in recent decades has been most pronounced in the domain of reducing physical dimensions, while maintaining and increasing power. Currently, such systems have a spatially limited scope, but create an electric field strong enough to disable integrated electrical circuits (Miller, 2005, p.391). There are different types of their construction and use, and a special focus is on a solution realized in the form of an electromagnetic bomb. It is made as a disposable device, whose main functional units are realized using a compression coaxial flux generator, a high-frequency generator with a virtual cathode oscillator, and an antenna system based on a helix antenna.

Explosively Pumped Flux Compression Generators

The main problem in the construction of such weapons is the provision of an adequate power source. It is easily overcome if the concept of a disposable weapon, i.e. electromagnetic bomb (e-bomb) is adopted. A popular approach to the problem is the choice of an Explosively Pumped Flux Compression Generator. Its advantage is the well-known working principle, technical simplicity and high efficiency. In addition, estimates indicate that it can be made by any country with a developed information technology sector (Miller, 2005, p.392).

The idea its construction is based on is to use the power of explosion to quickly compress the magnetic field, thus ensuring the conversion of explosion energy into electromagnetic field energy. An explanation of this can be easily found in the available literature, and is illustrated by a simplified cross-section in Figure 1 (Kopp, 1996, p.3).

The basis of the construction is an electric coil wound on a copper pipe, in which there is a shaped explosive charge. The coil represents the generator stator. On the outside, there is an additional sheath made of dielectric material so that the electromagnetic field is better directed. The central explosive charge extends along the entire length of the copper pipe.

On the side of the charge, from which the detonation path begins, there is an explosive lens which should provide a certain law of formation and propagation of the explosive wave. This deforms the copper tube into a regular conical shape. The aim of this is to spread the copper tube evenly over the entire diameter of the stator, thus causing a short circuit between the stator windings. This deformation will move with the explosive wave towards the stator output contacts, Figure 2 (Kopp, 1996, p.3).

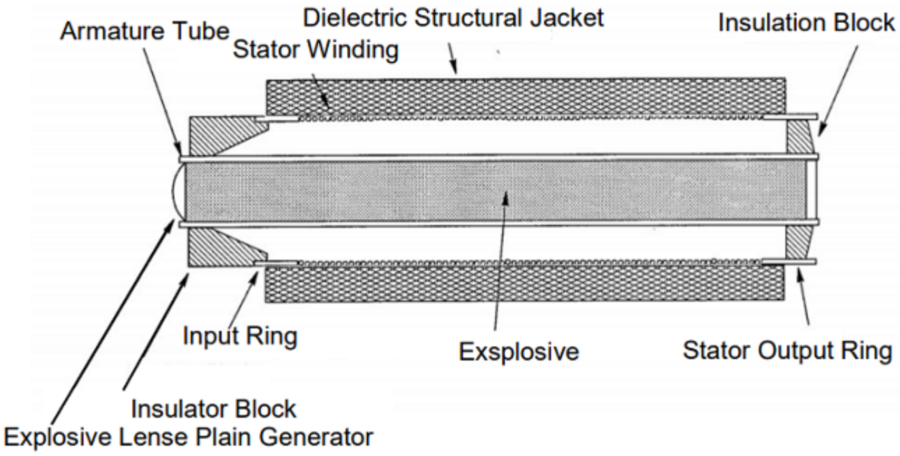

FIGURE 1
Construction of Explosively Pumped Flux Compression Generators
(Kopp, 1996)

Immediately before the activation of the explosive charge, the coil is supplied with high-power current, of the order of mega amperes (for which another, smaller flux generator can be used). Due to the flow of current, a large, rapidly decreasing electromagnetic field is created. The activation of the explosive charge is timed to correspond to the moment of reaching the current peak in the stator windings.

The explosive generator with the lens is activated and forms an explosive wave that deforms the copper tube into a conical shape, which spreads over the inner diameter of the stator windings, short circuits them and "traps" the current in the device.

The short circuit moving along the generator body has the effect of compressing the magnetic field while reducing the inductance of the stator winding. The result is the formation of a rapidly growing impulse, the maximum of which is reached immediately before the physical destruction of the generator itself.

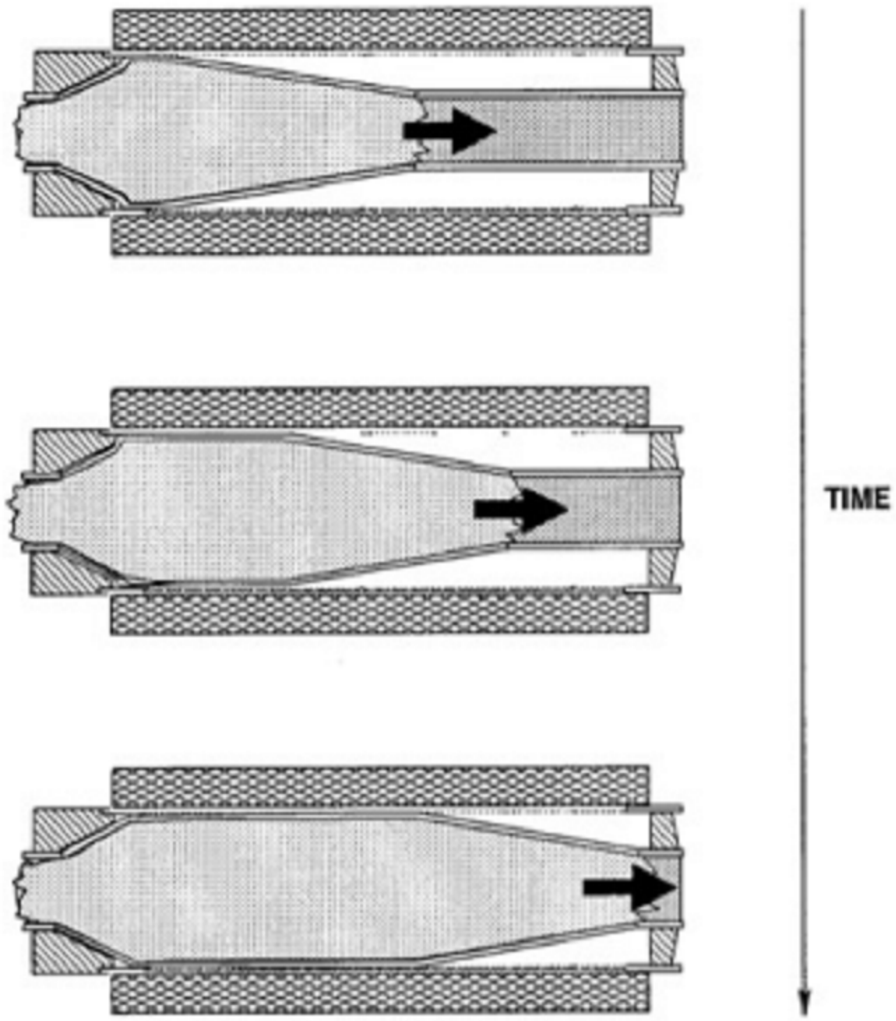

FIGURE 2
Deformations of a copper pipe under the action of an explosive wave
(Kopp, 1996)

According to the available results, the maximum is reached in a few milli or micro seconds. Also, for a current peak of 10 MA, an output power of several tens of MJ is provided (Kopp, 1996, p.5). In this way, an electromagnetic field of 1 kV / m is created at a distance of approximately 2 km, or 10 kV / m at a distance of 175 meters. A field of this strength would ensure the safe destruction of all electrical systems (Miller, 2005, p.392). However, the main problem is the low frequency of this pulse, usually below 1 MHz, which does not provide sufficient efficiency on targets of smaller dimensions (such as integrated circuits).

Oscillator with a virtual cathode

There are several possible solutions how to provide a high frequency pulse of sufficient power from the output pulse of the flux generator. The available literature offers several different HF sources, the characteristics of which can be seen in Table 1 (Ni et al, 2005, p.3).

It is interesting that the most common choice from the aspect of making an e-bomb is a variant of a device with a virtual cathode oscillator (vircator). Although it does not provide the highest output power, nor can it cover higher frequencies of the microwave spectrum and has low efficiency, it is a popular solution for making e-bombs. The main reason is a simple construction and small dimensions, which is why it has a great possibility of practical use. It should be noted that the realization in the variant of the axial vircator stands out in terms of efficiency (Kopp, 1996, p.5).

TABLE 1
Different sources of HF energy

Device name	P (GW)	F (GHz)	τ (ns)	η (%)
Virtual cathode oscillator	1.2	5.9	-	-
Freedom electronic laser	>1	40	-	30
Axial driven cathode oscillator	7.5	1.17	-	-
Plasma auxiliary slow wave oscillator	4-8	-	-	15-25
Single pulse looping-wave oscillator	1.5	8. -12.5	60	30
Looping-wave oscillator	1	10	2	30
Field radiation oscillator	0.06	7	-	25
Looping-wave oscillator	1.5	X band	60	50
Repeating pulse looping-wave oscillator	1	10	2	30
Relativity magnetron	0.1	-	1000	-
Improved cyclotron tube	2	12.5	50	-
Polarized radiation microwave tube	0.06	7	700	25

(Ni et al, 2005)

Kop offers a simple explanation of the principles on which the operation of the vircator is based, Figure 3. The basic idea is to accelerate a strong jet of electrons to the mesh anode which is grounded to the device body. Most electrons will pass through the anode and form a charged space behind it. This charged area represents the virtual cathode.

The virtual cathode will oscillate at the appropriate frequency, which can be adjusted by manipulating its position in the cavity. The output power ranges from 170 kW to 40 GW, and the frequency range covers the decimeter and centimeter wavelength range.

Although it has a very low efficiency, which is only 1%, the simplicity of design, small dimensions, and the absence of external magnetic field makes this a popular solution (Dražan & Vrána, 2009, p.622).

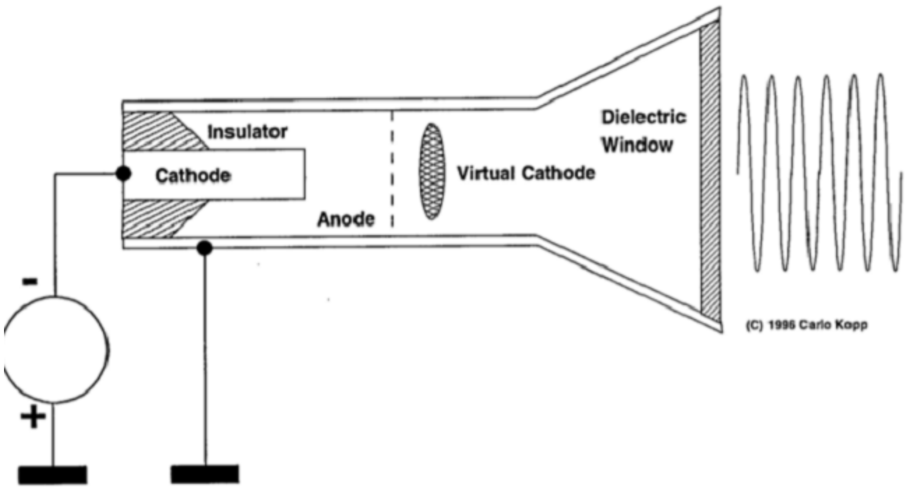

FIGURE 3
Simplified presentation of the construction and principle of operation of the vircator

Kopp cites pulse duration as the biggest limitation in using a vircator. It is usually of the order of microseconds and is limited by the melting time of the anode and the stability of the oscillation frequency which are conditioned by the emitted power.

Antenna system

The next step in the construction of the e-bomb is the selection of an appropriate antenna system. The main problem here is the high output power of the vircator and ensuring the maximum utilization of the transmitting antenna.

Practical problems as an optimal choice impose the choice of a circularly polarized antenna. This brings the following advantages in relation to solutions with linear polarization:

- reflection - the signal strength is not reduced because it is emitted in all planes, so its reflection is not mostly expressed on one plane;
- absorption - due to broadcasting in all planes, the probability of coupling with the target device is higher;
- phase - since these are signals of higher frequencies, this type of polarization provides a higher probability of coupling regardless of the position and shape of the target object as well as obstacles;
- multi-path problem - the problem arises when the basic and reflected signals reach the receiver almost at the same time. This can have the problem of creating dead spots and reducing the total power at the reception. Circularly polarized antennas are less susceptible to this problem;
- visibility line - when the line of sight is disturbed by obstacles such as vegetation and smaller buildings, circular polarization has a better ability to establish a coupling with the target object; and
- influence of atmospheric conditions - thanks to the characteristics described above, there is greater resistance to the influence of rain, snow and other microconditions on signal absorption.

As an optimal solution, Krop states the use of a narrowing helix or a conical spiral antenna. According to the shown solution, Figure 4 (Kopp, 1996, p.10), the connection is by means of probes in the resonant cavity of the vircator, which are directly connected to the antenna.

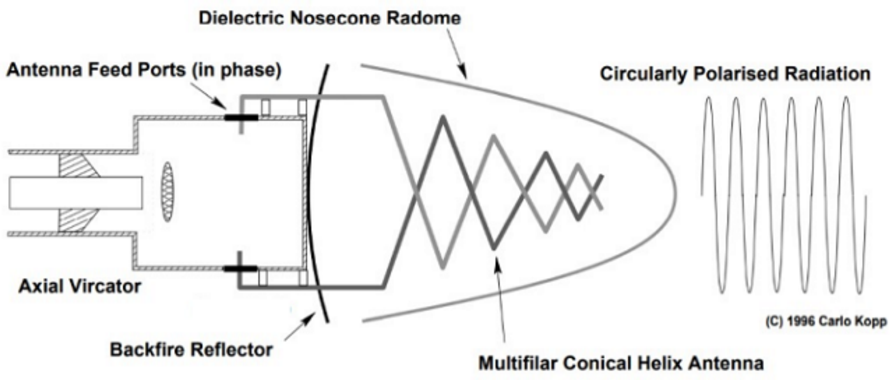

FIGURE 4
An example of a link between a vircator and an antena
(Kopp, 1996)

Effect of electromagnetic pulse on electric circuits

The importance of the problem of the influence of EMP on the operation of electrical circuits is shown by the fact that it is the subject of work of specialized institutions. For example, in Sweden, there is The Microwave Test Facility, whose task was originally to test the impact of high-frequency signals on aircraft, and later to start testing with commercial electrical devices.

The influence of EMP is considered through: impulse characteristics, coupling mode, and mechanism of influence. The quantities through which EMP is defined and through which its influence on electric circuits is estimated are: pulse growth time (v/s), electric field strength (V/m), and frequency (Hz), (Miller, 2005, p.387). Growth time is a basic factor in terms of "bypassing" overload protection. The strength of the electric field directly indicates the amount of energy that can be transmitted, and the frequency indicates transmission efficiency. Tests have shown that integrated circuits are more sensitive to higher frequency EMP, while physically larger electrical systems (such as power grids) are more sensitive to lower frequency EMPs. EMPs at frequencies from 200 MHz to 5 GHz [1] are considered the most dangerous for electrical systems.

Coupling is the way EMP is introduced into an electrical system, and can be accomplished in two ways (Vasilevich & Pershenkov, 2016, pp.621-629). The first is through the front door, i.e. the points that are intended to be the inputs / outputs of electrical circuits. The simplest example of this is the transceiver antennas of various devices. The second way is through the back door or through the points whose purpose is to connect parts of the system into a functional whole (signal transmission, power supply elements, etc.). In this case, the correlation with the frequency spectrum of the pulse is very important. Because EMP covers a wide range of frequencies, it easily penetrates parasitic antennas and connects to electrical systems.

Regardless of the type of coupling, these two authors further list four basic levels of influence on electrical systems. As such, they single out: upset, lock-up, latch-up, and burnout.

The first two ways are interfering with the operation of electrical devices and as such are found in foreign literature under the name soft kill. Uupset is the temporary interference with one or more electrical nodes in a device. Due to the appearance of parasitic voltages, the device does not function normally. The malfunction is rectified when the source of interference is switched off. The lock-up is similar to the previous case, except that now, in addition to stopping the interference, it is also necessary to turn off or reset the device.

With greater power, permanent damage and destruction of electrical devices is achieved. This influence is found in the literature under the name hard-kill. The only way to eliminate the consequences of such actions is to repair or replace certain parts of the circuit. A latch-up is an extreme variant of locking in which, due to the level of induced voltage, certain nodes in circuits either self-destruct or turn off. Burnout is the most extreme form of impact on electric circuits. It takes place physically through the form of a short circuit or even the physical burning of certain nodes, the melting of capacitors, resistors or conductive paths. Incineration is most often localized at points where more conductors intersect, more bases, collectors or emitters are connected. Damage occurs because, due to the described phenomenon, the components of the circuit are heated to a temperature exceeding 300 °C.

The main factors, important for the damage of semiconductor elements, are the following:

- occurrence of voltages and overload currents in electric circuits,
- breakdown of dielectrics and air insulation between and near conductive roads,
- formation of short circuits in parasitic thyristor structures, and
- the induced EMP recombination currents.

Which of the mechanisms will exert a key effect depends mostly on the distance of the target from the EMP source, its frequency, the vulnerability of the target itself, the degree of EMP connection, as well as the entry points.

These authors give a tabular overview, Table 2, of the voltage quantities required for the physical destruction of certain elements realized in semiconductor technology. What can be seen is that semiconductor elements are extremely sensitive and that it is necessary to achieve voltage induction of the order of several tens of volts in order to ensure the safe destruction of such elements. Computers and integrated circuits are especially sensitive, for which a voltage of only 10V is sufficient. In contrast, "older technology" based on pipe technology is much more resistant.

TABLE 2
Voltage levels required to damage various semiconductor components

Types of semiconductor devices	Breakdown voltage
Silicon high frequency bipolar transistors	15V-65V
Gallium Arsenide Field Effect Transistors	10V
High density Dynamic Random Access Memories (DRAM)	7V
Generic CMOS logic	7V-15V
Microprocessors running off 3.3 V or 5 V power suppliesV	3.3V-5V

Numerous experiments are being conducted to better understand the impact of EMP. The importance of this question shows that there have been specialized institutes in the world for decades that deal with research in this field. One example is the Swedish microwave test facility. They are capable of producing electromagnetic pulse frequency up to 15GHz and pulse power up to 10GV (Bäckström et al, 2002).

An interesting resistance test of the computer network resistance to the influence of EMP was conducted in this institution (Arnesen et al, 2005). The subject of the test were LAN and WLAN networks, implemented on three desktops and five laptops. A field of maximum strength of 29 kV/m at a frequency of 1.3GHz and 17.5 kV/m at a frequency of 2.86 GHz was used as a source of interference. The tested equipment was distributed in three different radiation areas (according to intensity).

The results of this study were as follows. Parts of the equipment tested showed varying degrees of failure, from interference to failure (which could have been instantaneous or manifested with a delay of 5 minutes). Wireless networks are extremely sensitive because AP [2] were damaged by a field of strength in 175 V/m. The operation of LAN networks was already disrupted with a field of 2 kV/m, while interference of higher intensity [3] occurred with a field of over 4 kV/m. The physical damage of the electrical components started at 8 kV/m, and the power field of 12 kV/m had the effect of certain destruction. Computers have shown varying degrees of sensitivity. Laptops are up to ten times more resistant than desktops, but there were also differences depending on the specific type and manufacturer.

It is interesting to note that parts of the network equipment are significantly more resistant than computers themselves. Although the LAN was already disrupted at 500 V/m, its operation was interrupted for fields of 8 V/m, there was no physical damage to the parts of this equipment. [4]

These and similar experiments indicate that it is possible to make EMP of sufficient power to affect electrical devices. This data, in addition to the possibility of making an e-bomb, also indicates the problem of designing a successful protection against this type of threat.

Electromagnetic pulse protection

Protection measures and their efficiency depend on several factors, and armor protection and grounding have proven to be the most effective. The best example of armor protection is the use of a Faraday cage. This type of protection is realized by complete shielding, protected device, conductive material.

This ensures the distribution of electricity on the surface of the armor, which cancels the electric field inside it. Although efficient, this system has disadvantages that arise from the need to provide power and signal flow to the protected device. This causes the need to make holes in the armor, which will represent imperfections in the electrostatic armor. These openings will be "open doors", for all EMP wavelengths smaller than their dimensions and thus reduce the effectiveness of this type of protection. In addition, the use of conductors represents additional points for coupling with EMP.The problem with signal flow is successfully solved by using optical cables, while the issue of power supply still remains one of the main problems.

Although there are standard protection solutions, they must be adapted to the specific mode of threat, i.e. the type of electromagnetic pulse. The best example of this is a graphical representation of different types of electromagnetic pulses, Figure 5 (Kopp, 1996, p.3). What can be seen, as the most obvious difference, is the time of growth and duration.

Thus, the EMP caused by a nuclear explosion almost immediately reaches its maximum value and lasts extremely short, which dictates the specific conditions for the design of protection systems. In contrast, the EMP created by the flux generator gradually reaches its maximum value and lasts longer. The fact that these diffences are significant is indicated by the results of the research conducted in the USA, to which Kopp refers.

According to them, the protection measures developed for the purpose of preventing the impact of EMP caused by a nuclear strike are not sufficiently effective in preventing the effects of pulses generated by the use of high-energy microwave weapons.

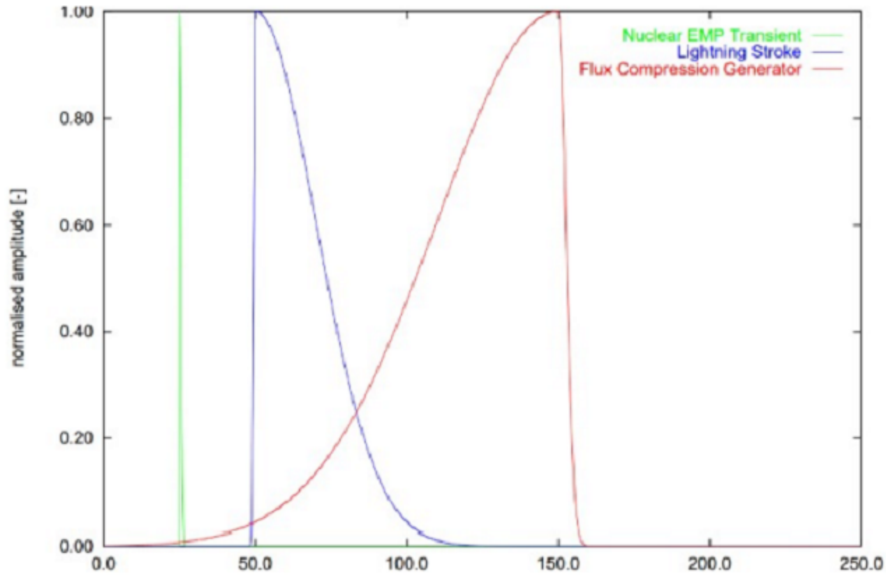

FIGURE 5
Forms of electromagnetic pulses
(Kopp, 1996)

The most economically viable is the design and installation of protection during the construction of devices themselves, while the costs of subsequent protection are significantly higher. As an example, various studies on the sensitivity to the use of EMP conducted in the United States can be cited (Foster et al, 2008, p.23). According to them, the estimated costs of installing protection in the existing elements of the high-energy electric, gas and telecommunication network range between 20 and 30 billion US $. Between $ 800 million and $ 1.5 billion need to be set aside to protect the most basic parts of the power system (such as high-voltage transformers). Strengthening most military systems would amount to an additional 10% of the cost, and strengthening only the military energy network an additional 10% of the cost. What everyone agrees on is that there are a very large number of systems without any protection, not only in the civilian but also in the military sphere. The problem is still extremely current because recent estimates suggest that the achieved level of resistance to electromagnetic pulse is still low and requires a more vigorous approach in eliminating this danger (Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack, 2017)

Example of an electromagnetic bomb model

Back in 1996, Kopp presented an assessment of the dimensions and manner of realization of the applicable e-bomb. According to him, this can be realized in the housing of the dimensions of an air bomb type Mk.84, Figure 6 (Kopp, 1996, p.10).

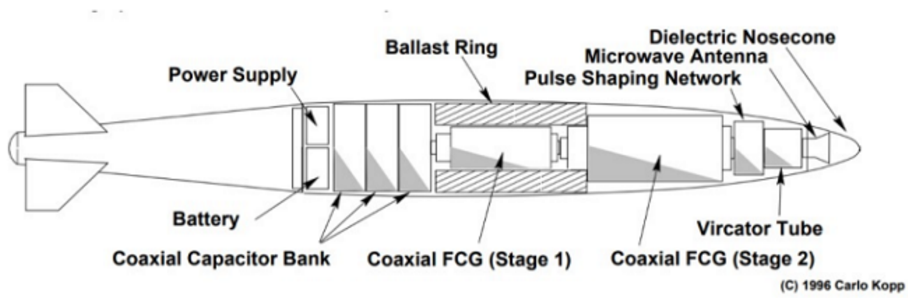

FIGURE 6
An e-bomb placed in Mk.84 air bomb
(Kopp, 1996)

The air bomb body, 3.8 m long and 0.46 m in diameter, would successfully accommodate an e-bomb realized on a two-stage compression flux generator, with a virtual cathode generator. This would provide a usable model whose biggest problem would be a limited field of action, which can be overcome by high probability of kill. Also, by reducing the activation height, the lethal area is reduced, but the strength of the electric field is increased. In this way, targets of greater resistance can be destroyed.

Michael Abrams gave an estimate of how much EMP power could be achieved (Abrams, 2003). With the application of technical solutions stated by Kop, such a bomb would have a power of 10 GW, a frequency of 5 GHz and would have a deadly footprint with a diameter of 400-500 m. In this area, it would create a field of several kilowatts per meter. This would have an extremely distructive effect, even if the electrical devices in the targeted area had a certain degree of protection.

Conclusion

The trend of digitalization of all spheres of society has brought a wide presence of semiconductor technology. Besides numerous advantages, however, this undoubtedly brings certain weaknesses. The biggest one, extremely interesting from the aspect of both attack and protection, is the sensitivity to electromagnetic pulse effects. This area is important because the mechanisms of affecting electrical devices are well known and confirmed by numerous experiments.

The theoretical basis and technology of making an applicable model of an e-bomb are known and available to a wider number of subjects. The optimal choice of technical solutions, such as a flux generator for a power source and a vircator for an HF generator, would ensure the production of an e- bomb with real physical dimensions, a power of about 10 GW and a frequency of 5 GHz. In combination with high-precision weapons, satisfactory delivery accuracy would be achieved and thus limited power would be compensated. A large number of lucrative targets, ranging from radar and missile systems, through communication systems, to modern battle tanks, would justify the development and use of such weapons.

The high efficiency of e-bombs indicates the importance of this problem not only in the civilian but also in the military sphere. The main reason is the declining awareness of the importance of installing protection measures; and if they exist, they are not fully effective in protection against EMP produced by the e-bomb. A certain problem is a dominant trend of commercialization of the military sector, which leads to the growing presence of electrical components, which are not sufficiently protected. This is important because it is realistic to expect wider application of such weapons systems in the coming period. Also, timely protection, installed in the design phase, is significantly less financially burdensome compared to the cost of the entire project.

References

Abrams, M. 2003. Dawn of the E-Bomb. *IEEE Spectrum*, 40(11), pp.24-30. Avalable at: https://doi.org/10.1109/MSPEC.2003.1242953.

Arnesen, O.H., Krogager, E., Backstrom, M., Bo-Sande, S., Godo, J., & Harkonen, S. 2005. High power microwave effects on civilian equipment. In: *Proceedings of 28th General Assembly of the URSI*, India, New Delhi, October 23-29.

Bäckström, M., Lövstrand, K.G. & Nordström, B. 2002. The swedish microwave test facility: technical features and experience from system testing. In: *Proceedings of 27th General Assembly of the URSI*, The Netherlands, Maastricht, August 17-24 [online]. Available at: https://www.ursi.org/proceedings/procGA02/papers/p0451.pdf [Accessed: 28 September 2020].

-Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack. 2017. *Assessing the Threat from Electromagnetic Pulse (EMP): Executive Report* [online]. Available at: http://www.firstempcommission.org/uploads/1/1/9/5/119571849/executive_report_on_assessing_the_threat_from_emp_-_final_april2018.pdf [Accessed: 28 September 2020].

Dražan, L. & Vrána, R. 2009. Axial Vircator for Electronic Warfare Applications. *Radioengineering*, 18(4), pp.618-626 [online]. Available at: https://www.radioeng.cz/fulltexts/2009/09_04_618_626.pdf [Accessed: 28 September 2020].

Foster, J.S., Gjelde, E., Graham, W.R., Hermann, R.J., Kluepfel, H.M., Lawson, R.L., Soper, G.K., Wood, L.L. & Woodard, J.B. 2008. *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack: Critical National Infrastructures*. Fort Belvoir, Virginia: Defense Technical Information Center [online]. Available at: https://apps.dtic.mil/sti/citations/ADA484672 [Accessed: 28 September 2020].

Kopp, C. 1996. *The electromagnetic Bomb – a Weapon of Electric mass destruction*. Fort Belvoir, Virginia: Defense Technical Information Center [online]. Available at: https://apps.dtic.mil/sti/citations/ADA332511 [Accessed: 28 September 2020].

Miller, C.R. 2005. *Electromagnetic Pulse Threats in 2010*. Fort Belvoir, Virginia: Defense Technical Information Center [online]. Available at: https://apps.dtic.mil/sti/citations/ADA463475 [Accessed: 28 September 2020].

Ni, G., Gao, B. & Lu, J. 2005. Research on High Power Microwave Weapons. In: *Asia-Pacific Microwave Conference Proceedings*, Suzhou, China, p.4, December 4-7. Available at: https://doi.org/10.1109/APMC.2005.1606492.

Vasilevich, S.V. & Pershenkov, V.S. 2016. Electromagnetic pulse effects and damage mechanism on the semiconductor electronics. *Facta universitatis - series: Electronics and Energetics*, 29(4), pp.621-62. Available at: https://doi.org/10.2298/FUEE1604621S.

Notes

1 This is the frequency area with the largest number of radars, TV systems, mobile telephony systems, etc.
2 Acces point
3 Interference was performed at frequencies of 1.3 and 2.86 GHz
4 For a frequency signal of 2.857 GHz

Additional information

FIELD: Electromagnetics

ARTICLE TYPE: Professional paper

Alternative link

https://scindeks.ceon.rs/article.aspx?artid=0042-84692102499B (html)
https://scindeks-clanci.ceon.rs/data/pdf/0042-8469/2021/0042-84692102499B.pdf (pdf)
https://www.elibrary.ru/item.asp?id=44887828 (pdf)
http://www.vtg.mod.gov.rs/archive/2021/military-technical-courier-2-2021.pdf (pdf)