Microwave Pulse Generator

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Abstract—The article is aimed at analyzing and describing feasible effects of electromagnetic high-power weapons, their potentialities and ways of penetrating and affecting a part or the entire system. Furthermore, it deals with increasing efficiency of electromagnetic weapons and protection against their effects. The paper describes the device based on a dual microwave pulse generator that can be used for verifying and setting the standards suitable for measuring and mapping a high-frequency electromagnetic field at great power.

Keywords—microwave generator, EMP, high-power pulse, HIRF, controlled generator, pulse generator.

I. INTRODUCTION

Electromagnetic pulse (EMP) is characterized as a very short pulse of approximately hundreds of nanoseconds with a high-level intensity of electromagnetic field. In other words, the principle lies in generating a high-energy pulse in a very short time interval. The need to accurately map and measure a high-frequency electromagnetic field at great power has arisen during the EMP research. For this reason a microwave pulse generator with variable parameters for verifying and setting parameters suitable for this type of measurement had to be assembled.

II. EFFECTS OF ELECTROMAGNETIC WEAPONS

Electromagnetic weapons have similar effects as electromagnetic fields in nonobservance of the principles of electromagnetic compatibility; thus they can be described by similar characteristics and procedures.

First, we are going to describe how an electromagnetic field can affect an arbitrary system, then how these systems can be distinguished in terms of their resistance, and how to design a system that would be resistible to this electromagnetic field.

Affecting a system by an electromagnetic weapon:

temporary faults—faults which the system can by itself evaluate, correct or replace;

reduced operation (efficiency) of the system—faults that have more disruptive effects on the system leading to its so-called “employment” in order to correct the failures about which the operator is informed, but his intervention is not required;

putting a part of the system temporarily out of operation—requires the operator’s intervention (reset, restart);

permanent functional failure—the system cannot be reactivated after a simple intervention by the operator (reset, restart), more complex intervention from the operator is necessary (update);

permanent damage to the system—usually destructive; components, parts or blocks must be replaced.

Immunity Degrees.

Degrees of a system immunization (protection), or its parts, are often selected by a level of its financial demands, importance or safety:

unprotected—no protection is used, very low financial costs;

partly protected—a part of the system is protected, low financial costs;

protected—as a whole, the entire system is protected, very high financial costs.

Protection procedures:

protection applied on parts or the entire system;

designing hardware and software fault-tolerance;

monitoring electromagnetic energy;

system’s physical security;

overdesigning the system’s functions.

There are two ways how electromagnetic energy can penetrate into the system:

A. “Front Door”—electromagnetic energy penetrates via the antenna system, the system’s input parts, etc. Based on the principle of functioning such receiving devices and sensors, it is obvious that power electromagnetic signals cannot be, in real conditions, prevented from penetrating into the device or system. It is only possible to limit their destructive effects.

“Back Door”—is the case when interfering and destructive electromagnetic signals penetrate into the electronic device or system through cables, electric contacts, bus-bars, supply conductors, connectors, various openings, grids, gaps, etc. In contrast to the “front door” penetration, the interfering and destructive effects can be significantly reduced directly by their design in the stage of drafting the electronic device/system, or by additional modifications. The ways and methods of such reductions are now well-known and rest primarily in a perfect compact electric screening effect on both the electronic circuits and all contacts together with wires, and also in limiting the metallic inputs and outputs (replaced by
optical cables), placing the critical blocks in suitable locations inside buildings, etc.

A low-frequency weapon can develop a strong effect upon telephone lines, net cables and distribution of electric energy. In most cases, this cabling is long enough and differently twisted, so the relative orientation of electromagnetic field in the weapon is not an important factor, as the segment of the conductive system will nearly always find suitable orientation to the travelling electromagnetic wave. Manufacturers display different breakdown voltage values for some typical semiconductor devices, such as high-frequency bipolar transistors (amply used, for example, in communication equipment). Elements controlled by the GaAs pole are rated at approximately 10V. DRAM memories used in computers are rated at 7V, basic CMOS technology at 7-15V and, for instance, a processor supply voltage moves around 3.3V or 5V. Many modern circuits, in spite of being equipped with extra circuits for protecting each pin against electrostatic discharge, are often destroyed by constant or repeated high voltage effects.

Communication interfaces and supply lines must meet typical requirements for electrical safety; therefore, these components are usually protected by insulation transformers that are rated at approx. 2-3kV. Thus it is obvious that even such a low voltage as 50V has destructive effects on these components if the insulation transformer or screening fails. Many items of equipment (PC, consumer electronics, etc.) are known, even from our own experience, that were destroyed or necessitated a complicated technical intervention after being exposed to low-frequency high-voltage peak levels (e.g. near a place hit by lightning, etc.).

Electromagnetic weapons operating in the centimeter and millimeter-wave band have the capability of enlarging the “back door” structure by another possibility of penetrating into the equipment through vent holes, gaps between individual constructional parts, and unshielded places. In this band any gap behaves as a slot in a microwave cavity permitting the microwave electromagnetic energy to enter this equipment. Thanks to its properties, the penetrating microwave energy generates standing waves inside this space. Individual components found in the places of a high-value electromagnetic field will be destroyed by the effects of this field. From these facts we can obviously conclude that microwave weapons are more used because of their enlarged structures and potentiality of penetrating through barriers at low frequencies, in contrast to low frequency weapons.

As inferred from previous paragraphs, an unambiguous and accurate specification when and what will be destroyed is impossible, since geometric arrangements, cable systems and variety of components are always different and depend on even the smallest constructional details.

What can be generalized are only structures across the cable systems that are determined by known destructive levels, then their usage for finding the demanded intensity of electromagnetic field for the specific construction, and potentialities of the electromagnetic weapon.

III. ENHANCING EFFICIENCY OF ELECTROMAGNETIC BOMBS

To enhance efficiency of electromagnetic bombs, the coupled power for penetrating into the system must be maximized.

First, it is necessary to maximize peak power of the electromagnetic weapon and duration of the pulse, and then maximally increase the efficiency of binding into the system, especially using every binding opportunity that is available in the weapon’s frequency band.

In order to achieve a good binding energy into the surrounding, low-frequency weapons will use “a big” antenna. These weapons mostly use, for the purpose of adapting a low impedance of the output generator to much higher antenna impedance, a high-power coupling transformer. As these are broadband weapons and most of radiated power is found in the band up to 1 MHz, use of a compact antenna is impossible here.
Another option rests in transporting an electromagnetic bomb to a close vicinity of the target and relying on the nearby field generated by the output winding which, in comparison with an operating wavelength, takes the role of a very “small” loop antenna. In this case, binding efficiency of the electromagnetic weapon is very low; however, this drawback can be alleviated by guiding the weapon to a vicinity of the target with an accuracy of few meters.

Microwave weapons have larger binding capabilities and, in contrast to their size, generate signals of a “small” wavelength that can be easily aimed at systems using compact antennas. If an area is covered by a radiation characteristic, the weapon’s efficiency can be increased by activating a frequency sweep, alias generator warbling, which improves, comparing with a weapon working on one frequency, its binding efficiency. Bindings are enabled through various openings, and resonances via the weapon’s frequency band. This method is based on using a high quantity of bindings into the system. Furthermore, in order to improve bindings of the emitted electromagnetic filed, polarization of the weapon can be taken into consideration. For example linear polarization to binding gaps, if properly selected, results in 50% binding efficiency, as compared to a circularly polarized wave that uses more binding gaps and develops resonance. For its complicated design, practical limitations of a circularly polarized antenna can cover the entire bandwidth in maintaining a high efficiency. A narrowing helical antenna may be an example of a suitable type.

Detonation distance is another aspect having an influence on efficiency of an electromagnetic bomb. It is based on the proper rate of the affected area and degree of electromagnetic field intensity in this area.

As concluded from the facts stated above, microwave weapons appear to be more suitable for enhancing efficiency of electromagnetic bombs for the reason of aiming energy of larger binding capabilities and more efficient transfer of energy between the generator and environment.

**IV. PROTECTION AGAINST ELECTROMAGNETIC WEAPONS**

The most effective protection against electromagnetic weapons rests in preventing electromagnetic energy from being emitted (e.g. destroying or disabling them). As this is not always possible, the systems call for an efficient protection against electromagnetic weapons, which is implemented in a similar manner as protection against electromagnetic incompatibility. The most effective method is the so-called Faraday cage, the principle of which lies in placing the system into an electrically conductive space which prevents electromagnetic field from penetrating into the protected space. A problem associated with these devices can be seen in the fact that they must communicate with the surroundings and be supplied from an external network. These factors may contribute to creating passage gaps in this area that an electromagnetic weapon may use as bindings, and thus damage the system. There are many protective measures to safeguard supplying and communication conductors. In choosing these devices, it is necessary to select thoroughly their parameters, so as to suppress or prevent undesired signals from entering and, at the same time, be permeable enough for the signal that we need. Furthermore, it is important to see the process of consolidating at the system level, since any disruption of a single element by an electromagnetic weapon can result in malfunctions or even disability of the entire system. Similarly, this problem may appear in the process of modernizing equipment when a new device meets all the protection criteria, but the old parts do not, or are insufficient. Therefore, such an intervention, if carried out in the phase of implementing a system protection, necessitates higher financial costs, so consolidation in the stage of drafting is much simpler solution than interventions into the already existing system.

**V. MICROWAVE GENERATOR**

To assemble the generators, two channels (S and X) have been selected. Within these bands we can find the channel S generator which is amply used as a source of microwave energy in microwave ovens. The channel X generator represents the other range that is used, for example, as a source for ship radars. Such a configuration has been chosen on purpose, since its acquisition is easy and cheap, but on the other hand these easily accessible parts can fall into hands of terrorist groups. In both channels of the generator, the pulse width and pulse duty factor can be adjusted as shown in Table I and II.

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<th>TABLE I. CHANNEL S ELECTRICAL CHARACTERISTICS</th>
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<td>Channel</td>
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<td>Frequency</td>
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<td>Pulse width</td>
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<td>Pulse duty factor</td>
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<td>Peak power of pulses</td>
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<td>Waveguide</td>
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<th>TABLE II. CHANNEL X ELECTRICAL CHARACTERISTICS</th>
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<td>Channel</td>
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Each channel is ended with a horn antenna, which is also found on the side of checking reception, but here equipped with a directional coupler that enables connecting a power meter, see Fig 3.
VI. TESTS

After solving the design problems, the first experiments on the generator could be conducted. The tests focused on the functionality of the generator. One of the tests is shown in Fig. 6. The effect HF energy transmitted from the generator to the tube light is clearly visible. The tube light stayed on the stand without any physical connections. Fig. 6 also shows the focusing effect of the directivity horn antenna.

In another part of the tests was carried out measuring signal, as shown in next Fig.

Fig. 7 shows that the generator does not operate continuously and to vary the signal amplitude and frequency. Frequency change is clearly seen in the following Fig. 8 which shows the frequency range.
The generator does not operate continuously and frequency is two peaks because the voltage rectifier is not sufficiently smooth. Fig. 9 shows the frequency envelope signal X channel generator.

Fig. 9. The signal range X band

VII. DESIGNING PROBLEMS

In the process of its designing, it was necessary to solve not only controlling and regulating the generator with the PC that was placed outside the measuring point, but also protection of individual components while being retroactively affected by the generated high-frequency energy.

VIII. EXPECTED RESULTS

This generator will be used for developing, verifying and setting standards that are appropriate for measuring and mapping high-frequency electromagnetic field of great power, such as calorimeter. It can also be used as a source of high-frequency electromagnetic field of great power imitating interferences in the channels S and X. At the same time it may be applied for running EMP resistance and EMC (electromagnetic compatibility) tests.

REFERENCES