

# TECHNICAL REPORT

**IEC**  
**61000-4-32**

First edition  
2002-10

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BASIC EMC PUBLICATION

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## **Electromagnetic compatibility (EMC) –**

### **Part 4-32:**

### **Testing and measurement techniques – High-altitude electromagnetic pulse (HEMP) simulator compendium**

### *Compatibilité électromagnétique (CEM) –*

#### *Partie 4-32:*

#### *Techniques d'essai et de mesure – Compendium des simulateurs d'impulsions électromagnétiques à haute altitude (IEMN-HA)*



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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

**ELECTROMAGNETIC COMPATIBILITY (EMC) –****Part 4-32: Testing and measurement techniques –  
High-altitude electromagnetic pulse (HEMP) simulator compendium**

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Technical reports do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful by the maintenance team.

IEC 61000-4-32, which is a technical report, has been prepared by subcommittee 77C: High power transient phenomena, of IEC technical committee 77: Electromagnetic compatibility (EMC). It has the status of a basic EMC publication in accordance with IEC Guide 107.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
77C/116/CDV	77C/126/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until 2005. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

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## ELECTROMAGNETIC COMPATIBILITY (EMC) –

### Part 4-32: Testing and measurement techniques – High-altitude electromagnetic pulse (HEMP) simulator compendium

#### 1 Scope

This Technical Report provides information about extant system-level high-altitude EMP (HEMP) simulators and their applicability as test facilities and validation tools for immunity test requirements. This report provides the first detailed listing of HEMP simulators throughout the world and is the preliminary summary of this effort. It should be updated on a regular basis as the status of test facilities change.

The main body of the report is a collection of datasheets describing 42 EMP simulators in 14 countries that are still operational or could be made available for use by the international community.

The owners of the simulators have provided the information contained in this report. The IEC shall not be held responsible for the accuracy of the information.

#### 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61000-2-9: *Electromagnetic compatibility (EMC) – Part 2: Environment – Section 9: Description of HEMP environment – Radiated disturbance*. Basic EMC publication

IEC 61000-2-10: *Electromagnetic compatibility (EMC) – Part 2-10: Environment Description of HEMP environment – Conducted disturbance*

#### 3 General

A high-altitude (above 30 km) nuclear burst produces 3 types of electromagnetic pulses that are observed on the earth's surface:

- early-time HEMP (fast);
- intermediate-time HEMP (medium);
- late-time HEMP (slow).

Historically most interest has been focused on the early-time HEMP that was previously referred to as simply "HEMP". Here we will use the term high-altitude EMP or HEMP to include all 3 types of waveforms. The term NEMP<sup>1</sup> covers many categories of nuclear EMPs including those produced by surface bursts (SREMP)<sup>2</sup> or created on space systems (SGEMP)<sup>3</sup>.

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<sup>1</sup> Nuclear Electromagnetic Pulse

<sup>2</sup> Source Region EMP

<sup>3</sup> System Generated EMP



The classification of the HEMP environment used in this report is the radiated electromagnetic environment (incident plus ground reflection, if any) that would be experienced by the external surfaces of a system thereby producing voltages and currents prevailing at typical locations within a system or installation through external and internal coupling processes. This approach is appropriate because the HEMP environment is generated in the upper atmosphere and is initially described as an external electromagnetic environment (both radiated and conducted; see IEC 61000-2-9 and IEC 61000-2-10). For components, devices, equipment, subsystems or systems located within an installation, the conducted and radiated environments incident at their locations are determined by the amount of protection provided by EM shields and/or conductive point of entry (PoE) elements present in the installation or enclosure. System-level EMP simulators are the most effective means of assessing the effectiveness of these protection measures.

## 4 Terms and definitions

### 4.1

#### **conductive point-of-entry**

penetrating conductor, electrical wire, cable or other conductive object, such as a metal rod, which passes through an electromagnetic barrier

### 4.2

#### **electromagnetic barrier**

topologically closed surface made to limit EM fields and conducted transients from entering the enclosed space. The barrier consists of the shield surface and points-of-entry treatments, and encloses the protected volume

### 4.3

#### **electromagnetic pulse (EMP)**

#### **nuclear electromagnetic pulse (NEMP)**

all types of electromagnetic fields produced by a nuclear explosion. Also referred to as nuclear electromagnetic pulse (NEMP)

### 4.4

#### **electromagnetic shield**

electrically continuous housing for a facility, area, or component used to attenuate incident electric and magnetic fields by both absorption and reflection

### 4.5

#### **HEMP**

high-altitude nuclear EMP

### 4.6

#### **high-altitude (nuclear explosion)**

height of burst above 30 km altitude

### 4.7

#### **point-of-entry (PoE)**

physical location (point) on an electromagnetic barrier, where EM energy may enter or exit a topological volume, unless an adequate PoE protective device is provided. A PoE is not limited to a geometrical point. PoEs are classified as aperture PoEs or conductive PoEs according to the type of penetration. They are also classified as architectural, mechanical, structural or electrical PoEs according to the functions they serve

### 4.8

#### **shielding effectiveness**

measure of the reduction or attenuation in the electromagnetic field strength at a point in space caused by the insertion of a shield between the source and that point; usually expressed in decibels (dB)

## 5 Datasheet definitions and instructions

The request for information that was sent to owners of worldwide EMP simulators included the following definitions and instructions for supplying the requested information.

### 5.1 General information

Simulator type:	Specify the type simulator using one of Baum's 3 categories: guided-wave, dipole, or hybrid.
Termination or resistive loading:	For guided-wave simulators, specify the type termination used (for example, output conic section with approximate point resistive load, output conic section with distributed resistive load, no output conic section with sparse, distributed resistive load). For dipole simulators, specify whether the antenna is resistively loaded. For hybrid simulators, specify whether the antenna is uniformly resistively loaded or end-terminated.
Major simulator dimension(s):	Specify the longest dimension of the simulator in meters (for example, 80 m long).
Test volume dimensions:	Specify the dimensions in meters of the usable test volume (for example, 15 m (high) by 20 m (wide) by 50 m (long)). Specify each if more than one test volume is available.

### 5.2 Simulator input options

Primary pulse power:	Describe the type generator and peak output voltage of the primary high-voltage pulse generator used (for example, 6-MV Marx generator with peaking capacitor).
Repetition rate:	Specify the usable pulse repetition rate and any limits on how long the simulator can be operated at this rate (for example, 12 pulses per hour) for the primary pulse power source.
Low-voltage or CW test capability:	Specify any lower-voltage input sources available (for example, 50-kV, 2-ns rise time, 50-pps pulse generator) and any continuous wave (CW) sources available (for example, 10-kHz to 1-GHz CW generator).

### 5.3 Electromagnetic field characteristics (in test volume unless otherwise noted)

Electric field polarization:	Specify the electric field orientation with respect to the earth (for example, vertical).
Line impedance:	For guided-wave simulator, specify the transmission line impedance (for example, 120 $\Omega$ ). For dipole and hybrid simulators, specify the cone or bicone impedance of the early-time radiating element (for example, 150 $\Omega$ ).
Wave impedance:	Specify the impedance of the field in the test volume (for example, 377 $\Omega$ – HEMP spherical wave).
Peak electric field:	Specify the range of peak electric fields available in the test volume (for example, 20 kV/m to 100 kV/m).
Peak magnetic field:	Specify the range of peak magnetic fields available in the test volume (for example, 50 A/m to 250 A/m).

- Pulse rise time: Specify the 10 % to 90 % pulse rise time (for example, 9 ns).
- Prepulse: Specify the maximum value of the prepulse as a percentage of the peak output of the simulator (for example, 10 %).
- Pulse width: Specify the 1/e or full-width, half-maximum pulse width (e.g., 580 ns (1/e) or 400 ns FWHM).
- Field uniformity: Guided-wave simulators – Use the following qualitative ratings to specify the worst-case uniformity of the peak value of the principal field component in the test volume:
- Excellent – better than  $\pm 10$  %
  - Good – between  $\pm 20$  % and  $\pm 10$  %
  - Fair – between  $\pm 50$  % and  $\pm 20$  %
  - Poor – worse than  $\pm 50$  %
- Use the plane in the test volume closest to the simulator input and normal to the direction of propagation of the wave. Specify the fall-off (1/r) of the peak field in per cent from the front to the back of the test volume. Specify the maximum value of any non-principal component in per cent of the peak value of the principal component. Example:
- Excellent uniformity of peak value of vertical field component.
- 20 % fall-off of peak field from front to back of test volume.
- Horizontal field components  $\leq 15$  % of vertical component everywhere in test volume.
- Other simulators – Specify the maximum and minimum values of the peak of the principal field component anywhere in the test volume (for example, horizontal E-field parallel to simulator axis 65 kV/m maximum and 10 kV/m minimum). Specify the maximum value in per cent of the peak value of the principal component of any non-principal component (for example, vertical and other horizontal components  $\leq 25$  % of principal horizontal component).
- Other: Describe any other pertinent technical features of the simulator not covered above.

#### 5.4 Administrative information

- Location: Specify the location of the simulator (nearest city or military base and country).
- Owner: Specify the name of the company or agency that owns the simulator.
- Point of contact: Specify the name and full address of the person to contact for more information about the simulator.
- Initial operation date: Specify the year in which the simulator first became operational.
- Status: Specify the current status of the simulator (for example, under development, operational, stand-by, inoperative).

## 5.5 Availability

- Government users: State availability of simulator for use by government agencies and any restrictions on this availability (for example, available to government agencies of any EU country).
- Industry users: State availability of simulator for use by private companies and any restrictions on this availability (for example, available to any private company with endorsement of government agency of any EU country).

## 5.6 Other technical information

- Photograph: Provide one or more high-quality colour photographs of the facility that will provide readers of the compendium with a basic understanding of the size and scope of the simulator.
- Typical time-domain waveform: Provide a representative sample of a time-domain E-field or B-field measurement from the simulator test volume.
- Typical frequency-domain spectrum: Provide a Fourier transform of a representative pulse from the simulator test volume.
- General description: Provide whatever general historical and descriptive information about the facility that you would like to present and can fit in the available space.
- Available instrumentation: Describe the sensors and data acquisition equipment available for use with the EMP simulator. Include information about the frequency ranges and/or rise times of the instrumentation.
- Auxiliary test equipment: Describe any auxiliary test equipment, such as direct drive (pulse or CW) equipment, associated with the EMP simulator.

## 6 Project description

### 6.1 Introduction

This report reviews worldwide EMP simulators in terms of their characteristics, capabilities, and limitations. This historical section of the report is a summary and update of papers presented at international conferences in 1984, 1995, 1998, and 1999 and describes several EMP simulators that have been built and dismantled as well as those that currently exist [1-4]. The section that follows is organised into 42 datasheets for individual EMP simulators that remain in operation or could be put back into operation for EMP testing. Other simulators exist in China, Poland, and probably elsewhere, but it was not possible to obtain information about them in time for this report.

Dr. Carl Baum (U.S. Air Force, Kirtland AFB, New Mexico) is the father of most of the Western simulator designs through his series of Sensor and Simulation Notes. He also named many of the simulators [5]. Baum has classified non-source-region EMP simulators in 3 categories: guided-wave, dipole, and hybrid [6], [7]. The scope of the report is restricted to those simulators designed to simulate the nuclear EMP outside of the source region and in particular those that simulate the electromagnetic environment caused by a high-altitude nuclear explosion (HEMP).

The end of the Cold War has provided the opportunity to learn of electromagnetic pulse (EMP) simulators developed in the former Soviet Union as well as China and to compare their performance characteristics and test methods employed in them to those of western simulators. While similarities exist with EMP simulators developed in the U.S. and other western countries, in some cases the simulators developed by researchers of the former Soviet Union and other Warsaw Pact nations provide some very interesting differences in approach.

No one perfect EMP simulator exists. This report describes several examples that fall into Baum's 3 categories (guided-wave, dipole, and hybrid) of HEMP simulators. All designs have inherent limitations; hence the large variety of designs that exists. Some analysis and extrapolation of results must always be done. The ideal of a simple "zap" test to prove a system hard to EMP is just that – an unachievable ideal.

### 6.2 Guided-wave simulators

Guided-wave simulators use metal "plates"<sup>4</sup> driven by one or more high-voltage generators to propagate a nominally TEM wave through a region frequently called the "working volume." The test object is located in this working volume. This class of simulator is used primarily to simulate the free-space environment produced by a high-altitude nuclear burst. Most existing guided-wave simulators produce a vertical electric field (and horizontal magnetic field) because in this case the earth can be used as one of the conducting plates.

This most ubiquitous of EMP simulators is highly efficient in its use of pulsed power. For example, a 1-MV Marx generator can provide high-fidelity fields with strengths of >100 kV/m over objects as long as 6 m. These fields usually have the "double-exponential" shape characteristic of a high-altitude EMP. Guided-wave structures can propagate pulses with sub-nanosecond rise times if the generator is capable of producing them. Simulator impedances and field distributions can be calculated readily, and the fields can be made uniform over a large volume of space.

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<sup>4</sup> The term "plates" is commonly used; however, in almost all EMP simulators the conductors for the transmission line are formed of parallel wires or wire mesh.

Guided-wave simulators are the best choice for testing missiles and aircraft in simulated in-flight configurations. For good simulation fidelity, the test object dimensions should not exceed 60 % of the plate spacing. While they often are used to test ground vehicles (for example, jeeps, tanks, trains), this is not a high-fidelity simulation because it does not provide the ground reflection needed for assessing the EMP coupling characteristics of systems situated on the earth's surface. In general, guided-wave simulators are not transportable; the test object usually must be brought to the simulator.

Several guided-wave simulators outside the U.S., particularly those in the former Soviet Union, have generators that produce very long pulses (microseconds to milliseconds) to provide some information on system response to an endo-atmospheric nuclear burst albeit absent the ionizing radiation and associated conductivity that would exist in a true SREMP environment.

Guided-wave simulators come in two basic types: those with symmetrically tapered input and output-feed sections usually attached to a parallel plate section (Table 1) and those with a single-feed section attached to a sparse, distributed, resistive load, usually without an intervening parallel-plate section (Table 2).

The AFWL-Los Alamos EMP Calibration and Simulation (ALECS), located in the U.S., is one of the earliest examples of the symmetric type guided-wave simulator and is typical of this genre. Built in the early 1960s, it has been used for numerous tests including missiles, scale models of aircraft, communications systems, and automobiles. The facility is used in both pulse and continuous wave (CW) modes. In pulse mode a Marx generator provides input voltage of up to 2 MV. Test data is recorded in a RF-shielded room located beneath the transmission line. The Advanced Research EMP Simulator (ARES) was built in the late 1960s to overcome the size restrictions of ALECS. The largest EMP simulator in the world is the Trestle. The structure was built to perform tests of aircraft in the in-flight mode with horizontally polarized waves. The structure can accommodate 747-size aircraft. The wooden platform on which the aircraft sits is 36 m above the earth and with its ramp over 180 m long. More than 6,5 million board feet of lumber were used in the construction, and more than 100,000 special wooden bolts hold it all together.

Two very large guided-wave simulator complexes are operated by the Ministry of Defence in Russia: one at the Central Institute of Physics and Technology (CIPT) at Sergiev Posad near Moscow and one at the Science Research Centre near St. Petersburg [8-11]. Each of the Russian complexes includes two large guided-wave simulators driven by a centrally located pulse generator. The very large cylindrical housing for the multi-megavolt air-insulated Marx generator adjacent to another large dielectric structure housing the pulse shaping circuitry (e.g., "peaking capacitor") are distinguishing characteristics of these facilities.

In the case of the St. Petersburg complex, one of the simulators is used for high-altitude EMP environments and one for source-region EMP environments. This complex specializes in evaluating the effects of EMP on buried structures. These simulators include a capability for testing objects either on, or buried beneath, the earth's surface. In SEMP-12-3 an underground transmission line, which consists of 2 rows of vertical electrodes positioned at a relative distance of 50 m, is connected to the transition sections leading to the pulse generator section and the matched resistive load.

The SEMP-6 facility near Sergiev Posad is very similar in appearance to the one at St. Petersburg, but important differences exist. For example, the lower plate of the transmission line is on, not below, the earth's surface. However, like SEMP-12-1 at St. Petersburg, the SEMP-6 provides some SREMP simulation capability by the use of large-dimension, rectangular coils in the vertical planes outside the working volume driven by pulsed current sources to produce late-time, long-duration magnetic fields in the simulator. Many different types of military systems are tested in this simulator complex. One portion of the simulator is being upgraded for 1 ns-3 ns rise-time performance.



A similar, antecedent complex that exists at the small town of Andreevka near Kharkov in Ukraine was developed and is operated by the Institute "Molniya" (lightning) [12]. As this name implies, both the Russian and Ukrainian complexes are used for studying the effects of lightning as well as EMP on systems.

Although the simulators have an output transition section, the terminations in the Russian and Ukrainian simulators do not really come to a "point". Instead, a rectangular array of resistive elements absorbs the electromagnetic wave after it has passed through the simulator test volume.

China has a small guided-wave EMP simulator, the DM-1200, that is similar in basic geometry to the ARES system located in Albuquerque, New Mexico. However, the lower plate of the transmission line is not connected to the earth in the transition sections as in the case of ARES. The 1,2-MV Marx generator is located in a building at the end of the transmission line. The DM-1200 was developed and is operated by the Beijing Institute of Electronic Systems Engineering (BIESE) of the Ministry of Aerospace.

The "bend" in the top plate at the transition from conical to parallel geometry in traditional guided-wave EMP simulators produces reflections that limit the unperturbed fields to the forward portion of the parallel plate section in this type simulator [13]. This bend and its twin at the output transition also produce higher-order mode effects particularly limiting the usefulness of these simulators in continuous-wave (CW) mode.

SIEM-2, built in France in the late 1970s for testing strategic missiles, was the first of a class of simpler geometry guided-wave simulators with improved high-frequency performance over the more traditional symmetrical geometry (Table 2) [14]. These simulators basically use just the input conic section in the traditional-geometry simulators. This configuration sometimes is referred to as a "horn" simulator. The large, but sparse, distributed resistive termination used in these simulators allows the high-frequency components of the pulse to radiate out the end of the simulator rather than being trapped as standing waves in the transmission line. Simulators with this basic geometry exist in Germany, Sweden, Switzerland, Italy, Israel, and reportedly Poland (so far, it has not been possible to obtain any information on the Polish simulator).

The conical geometry of the input section that transitions from the relatively small dimensions where the wave is launched to the large dimensions of the working volume produces a spherical wave rather than the desired plane wave. This causes different parts of the test object to experience the arrival of the wave at somewhat different times and introduces non-vertical components to the electric field. In traditional simulator designs, designers controlled this problem by keeping the transition angle small (typically  $15^\circ$ ), which makes the simulator dimensions large.

A different approach has been taken in a new simulator built by France Telecom/CNET in Lannion, France [15-17]. In this simulator, the electromagnetic wave passes through a large lens made from plywood. The effect of the lens is to refract and slow down the electromagnetic waves while traversing the dielectric material. In this way, the spherical wave is transformed into a planar one, because the shape of the lens slows down waves travelling along the direction of the simulator axis more than waves diverging from the simulator axis. The developers claim very good field characteristics (for example, homogeneity, rise time, planarity) in the simulator working volume beyond the lens.

The indoor ERU-2M simulator at Sergiev Posad, Russia is significantly different from those described above because it employs a 3-plate transmission line. The 1-MV pulse generator is much more compact than those typically found in the simulators of the former Soviet Union and produces a 2 ns rise-time field in the simulator working volume.

In addition to those listed in Tables 1 and 2, guided-wave simulators exist or formerly existed in Poland and the former East Germany. Egypt reportedly is developing a small guided-wave simulator.

### 6.3 Dipole simulators

Ideally, the test object is far away from the source of a freely propagating TEM wave for this class of EMP simulator; practically this is seldom quite the case. These simulators can be mobile or fixed. They can radiate very fast rise time pulses, and the fields produced are analytically tractable. One helicopter-borne version (RES I) was capable of varying both incidence angle and field polarization. Aircraft have flown nearby these simulators to perform actual in-flight tests, but these tests usually simulate the incident wave with its associated ground reflection. When used properly, the unwanted simulator-object interaction can be kept very small, and the area covered by a uniform field can be large. These simulators can radiate very fast rise-time pulses, and the fields produced are analytically tractable.

One true dipole simulator was the Radiating EMP Simulator (RES) used by the U.S. Air Force and Army in the early 1970s to test large ground-based facilities. Because the pulser/antenna system was suspended beneath a helicopter, it was highly mobile. Two versions were built: a horizontal antenna and a vertical antenna. A 1,5-MV, 150-ohm biconic generator drove each. The resistively loaded antennas shaped the radiated pulse and prevented a large notch in the frequency spectrum. However, the RES I simulator produced a field strength at reasonable distances of only a few kV/m, and due to the short antenna length the low-frequency content was particularly deficient. Longer, more powerful versions were planned but never built. Operating costs were high because of the helicopter. After sufficient testing was done to correlate the high-quality (except at low frequencies) RES data with other simulators, the antennas were salvaged and the generators used for other simulators.

Most examples of this class of simulator are equivalent dipoles over a conducting surface. In this configuration they produce vertically polarized fields and a single angle of incidence. Since these are radiating antennas, they are not as efficient at converting pulse-power energy into fields as are guided-wave simulators. Dipoles also suffer from a deficiency in low-frequency energy because they cannot radiate at d.c. and their physical size must be held to practical limits.

Most of these antennas are resistively loaded to prevent reflection of the currents when they reach the top of the cone [18]. Some information about coupling to an in-flight aircraft can be extracted from the test data, but the effects of the conducting ground must be considered in the analysis. Employing a large antenna, large pulser capacitance, and very large shunt resistance to ground enhanced low frequencies. The fields can be predicted accurately by analytical methods. The agreement of the predicted and measured peak field strengths is excellent, and the correlation in the frequency domain is also quite good. Baum's model also predicts the spatial distribution of the fields very well.



### Table 1 – Guided-wave EMP simulators with conventional termination

Table 2 – Guided-wave EMP simulators with distributed termination<sup>8</sup>

Characteristic	Simulator	SIEM-2	DIESES	SAPIENS 2	INSIEME	Rafael	VEPES	VERIFY	SEMIRAMIS	SSR	France Telecom	ERU-2M
Location		Mimizan France	Munster Germany	Linköping Sweden	Pisa Italy	Haifa Israel	Spiez Switzerland	Spiez Switzerland	Lausanne Switzerland	Gramat France	Lannion France	Sergiev Posad Russia
Peak output voltage (MV)	2,8	1	1	1	1	2	0,8	0,6	0,1	2	0,8	1
Rise time (ns)	10	1-7	1-7	5	4	<5	8	1	<10	1-5	2,5	2,5-25
Duration (ns)	250	80-1000	80-1000	150	?	?	~300	24-36	200	25-200	23-200	25-750
Peak electric field (kV/m)	>100	>100	>100	>50	>100	>200	>100	100	62	>100	75	100
Length (m)	180	120	120	90	120	130	55	20	10	106	50	30
Maximum height (m)	33	22	22	18	22	20	~10	~4	~1,5	15	6	~8
Waveguide impedance (Ohms)	90	90	90	100	100	90	90	100	100	90	140	120
Initial operational capability (IOC)	1979	1981	1981	1990	early 90s	1989	1989	1999	1991	1986	1996	1982
Status <sup>9</sup>	4	2	2	2	2	2	2	2	2	2	2	2
Availability												
Government	--	Yes	Yes	Yes	Yes	?	Yes	Yes	Yes	Yes	Yes	Yes
Industry	--	Yes	Yes	Yes	Yes	?	Yes	Yes	?	Yes	Yes	?
IEC type simulator <sup>10</sup>	II	Candidate e for Type I	II	II	II	II	II	Candidate for Type I	II	Candidate e for Type I	II	Candidate e for Type I
Sub-clause	--	7.6.1	7.9.1	7.13.1	7.9.1	7.8.1	7.14.2	7.14.3	7.14.4	7.5.3	7.5.1	7.12.1
Compendium page	--	34	52	70	52	48	76	78	80	32	28	60

<sup>8</sup> This listing is preliminary and subject to verification by the simulator owner/operator.

<sup>9</sup> Status Codes: 1 – Under development; 2 – Operational; 3 – Stand-by; 4 – Dismantled or no longer in use; ? – Unknown.

<sup>10</sup> Type I and Type II EMP simulators are defined in IEC 61000-4-25:2001, Electromagnetic compatibility (EMC) – Part 4-25: Testing and measurement techniques – HEMP immunity test methods for equipment and systems.

Table 3 – Vertical dipole EMP simulators<sup>11</sup>

Characteristic	Simulator	VPD-I	VPD-II	USN NAWCAD VPD	EMIS-III-VPD	EMPRESS I	EMPRESS II
Location		Albuquerque USA	Albuquerque USA	Patuxent River USA	The Hague Netherlands	Virginia USA	Norfolk USA
Peak output voltage (MV)		1.6	4	?	0.5	1.5	7
Rise time (ns)		<5	10	<5	<5	8-15	<10
Peak electric field (kV/m @ stated meters)		10 @100	36 @100	?	2 @100	3 @375	25 @200
Height (m)		30	40	25	?	?	40
Cone impedance (Ohms)		75	60	75	75	75	70
Initial operational capability (IOC)		early 70s	late 70s	early 80s	early 80s	early 70s	late 80s
Status <sup>12</sup>		3	2	2	2	3	4
Availability	Government	?	?	?	Yes	?	?
	Industry	?	?	?	Yes	?	?
IEC type simulator <sup>13</sup>		Candidate for Type I	II	II	II	II	II
Sub-clause		7.17.5	7.17.6	7.17.8	7.10.3	--	--
Compendium page		100	102	106	58	--	--

<sup>11</sup> This listing is preliminary and subject to verification by the simulator owner/operator.

<sup>12</sup> Status Codes: 1 – Under development; 2 – Operational; 3 – Stand-by; 4 – Dismantled or no longer in use; ? – Unknown.

<sup>13</sup> Type I and Type II EMP simulators are defined in IEC 61000-4-25:2001, Electromagnetic compatibility (EMC) – Part 4-25: Testing and measurement techniques – HEMP immunity test methods for equipment and systems.

Table 4 – Hybrid EMP simulators<sup>14</sup>

Simulator Characteristic	TEMPS & AESOP	HPD	USN NAWCAD HPD	EMIS-III- HPD	WIS	DPH	MEMPS	SPERANS	Rafael
Location	USA	Albuquerque USA	Patuxent River USA	The Hague NL	Munster Germany	Gramat France	Spiez Switzerland	Linköping Sweden	Haifa Israel
Peak output voltage (MV)	7	4	4	0,5	0,36	4	4	0,2	0,6
Rise time (ns)	4-12	8-12	8-12	<5	1,2	1-5	10	2,5	<5
Peak electric field (kV/m @ stated meters)	52 @50	33 @30	33 @30	2 @100	~10 @8	~50 @30	60 @20	4 @20	?
Height (m)	20	30	30	20	8	30	20	20	10
Length (m)	300	150	150	100	30	150	60	150	30
Bicone impedance (Ohms)	120	150	150	75	150	150	150	150	150
Initial operational capability (IOC)	early-70s	mid-70s	mid-70s	early 80s	1999	1980	1985	1984	1991
Status <sup>15</sup>	4	2	2	3	2	2	3	3	2
Availability									
Government	--	?	?	Yes	Yes	Yes	Yes	Yes	?
Industry	--	?	?	Yes	Yes	Yes	Yes	Yes	?
IEC type simulator <sup>16</sup>	II	II	II	II	Candidate for Type I	Candidate for Type I	II	Candidate for Type I	II
Sub-clause	--	7.17.3	7.17.7	7.10.1	4.6.2	7.5.2	7.14.1	7.13.2	7.8.2
Compendium page	--	96	104	54	38	30	74	72	50

<sup>14</sup> This listing is preliminary and subject to verification by the simulator owner/operator.

<sup>15</sup> Status Codes: 1 – Under development; 2 – Operational; 3 – Stand-by; 4 – Dismantled or no longer in use; ? – Unknown.

<sup>16</sup> Type I and Type II EMP simulators are defined in IEC 61000-4-25:2001, Electromagnetic compatibility (EMC) – Part 4-25: Testing and measurement techniques – HEMP immunity test methods for equipment and systems.

The U.S. built the Vertically Polarized Dipole I (VPD-I) in the early 1970s for testing aircraft in the ground-alert mode. It is an equivalent dipole over a ground plane. The 30-m tall antenna is resistively loaded, using Dr. Baum's method to prevent reflection of the currents when they reach the top of the cone. One of the 1,5-MV pulsers built for RES-I was used to drive the 75- $\Omega$  antenna. The aircraft under test is parked on a pad centred 100 m from the apex of the antennas. Peak field strengths of 10 kV/m with rise times of about 5 ns were available at the centre of the pad. Some information about coupling to an in-flight aircraft can be extracted from the test data, but the effects of the image aircraft created by the conducting ground must be considered in the analysis. One aircraft was tested in an actual in-flight configuration by pulsing it as it flew by the simulator. VPD-I has been used little since its larger and more powerful successor, VPD-II, became operational. The 60- $\Omega$  antenna is 40 m high and driven by a 4 MV pulser. The peak field strength at the centre of the parking pad 100 m away exceeds 36 kV/m with a rise time of 10 ns. The low-frequency content of the fields far exceeds that for VPD-I because of the large antenna, larger pulser capacitance and very large shunt resistance to ground. The simulator has been used to test several aircraft, helicopters, and other systems. The most unique of this class of simulator was the U.S. EMPRESS II, a pulser/antenna system similar to VPD-II that floated on a barge in water deep enough to test the largest of naval vessels. Unfortunately, EMPRESS II has been dismantled and is no longer available for use.

Only a few examples of this class of simulator exist outside the United States, and all are vertical dipoles.

#### 6.4 Hybrid simulators

This class of EMP simulators simulates the plane wave and its ground reflection by combining properties of both radiating and static simulators [19]. Hybrid simulators provide the best available approximation to the environment that would be experienced by a ground-based system exposed to an EMP from a high-altitude nuclear detonation.

A small source region, usually a bicone radiator, produces early-time (high-frequency) fields. Currents and charges distributed over a large structure that surrounds or is near the test object produce the later-time (lower-frequency) fields. Usually, the antenna is sparse and resistively loaded to reduce interactions with the test object and to minimize resonances.

Some hybrid simulators are transportable so that they can be taken to fixed installations such as missile silos and C3 facilities. Conceptually, the position of the pulser could be varied in the antenna to change the angle of incidence and the polarisation; however, this capability has not been incorporated in an actual system.

Because the early-time portion of the wave is radiated by a biconic antenna (an isotropic radiator), the field strengths achievable for a given generator voltage do not match those of a guided-wave system. The limit on pulser output becomes a mechanical design consideration because the generator must be suspended high above the earth. The early-time bicone is matched to a cylindrical cross-section antenna. This interface is an abrupt impedance discontinuity that has an appreciable effect on the pulse waveform. This transition is made as smooth as possible using tapered wire mesh sections to minimize the abruptness of the unavoidable impedance discontinuity. The fields produced by these simulators are more complex functions of both space and time than for the other classes of simulators, so a detailed experimental mapping of them is necessary for understanding of the test data [20].

Several simulators exist that employ the elliptically shaped HPD antenna design first developed in the U.S. in the mid-70s. The standard HPD antenna has a diameter of 5 m and contains discrete resistors uniformly distributed throughout its length to provide the desired ratio of electric and magnetic field amplitudes at low frequencies. The resistors also damp resonances within the structure. France has two simulators identical to U.S. versions of the HPD, and one of the French systems is transportable. Switzerland developed the MEMPS, a

smaller pulser/antenna system suspended beneath a fibreglass structure that can be disassembled into modules for transport by truck or helicopter. Germany, Sweden, and Israel have non-transportable systems very similar to the MEMPS. When used to test very large facilities, particularly those with overhead and buried conductors entering them, the field simulators cannot adequately excite the complete facility and the attached conductors, so a form of direct drive for these points of entry (POEs) usually is used to supplement the field testing.

## **7 EMP simulator datasheets**

This section provides individual datasheets for 42 simulators identified in this study. The datasheets are organized by country as shown in Table 5 below. Sections have been reserved for future datasheets for simulators believed to exist in the Czech Republic, Egypt, and Poland.

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**Table 5 – EMP simulator datasheets**

Country/simulators	Subclause	Page
Canada simulators	7.1	
DREMPs	7.1.1	24
China simulators	7.2	
DM-1200	7.2.1	26
Czech Republic simulators	7.3	
Reserved	7.3.1	To be determined
Egypt simulators	7.4	
Reserved	7.4.1	To be determined
France simulators	7.5	
CNET guided-wave	7.5.1	28
DPH	7.5.2	30
SSR	7.5.3	32
Germany simulators	7.6	
DIESES	7.6.1	34
HPD	7.6.2	36
WIS indoor guided-wave	7.6.3	38
VPD	7.6.4	40
MIGUS	7.6.5	42
India simulators	7.7	
IBWEMPS	7.7.1	44
RBWEMPS	7.7.2	46
Israel simulators	7.8	
Rafael guided-wave	7.8.1	48
Rafael hybrid	7.8.2	50
Italy simulators	7.9	
INSIEME	7.9.1	52
Netherlands simulators	7.10	
EMIS-III-HPD	7.10.1	54
EMIS-III-TL	7.10.2	56
EMIS-III-VPD	7.10.3	58
Poland simulators	7.11	

Country/simulators	Subclause	Page
Reserved	7.11.1	To be determined
Russia simulators	7.12	
ERU-2M	7.12.1	60
SEMP-6-2M	7.12.2	62
PULSE-M	7.12.3	64
SEMP-12-3	7.12.4	66
SEMP-1,5	7.12.5	68
Sweden simulators	7.13	
SAPIENS 2	7.13.1	70
SPERANS	7.13.2	72
Switzerland simulators	7.14	
MEMPS	7.14.1	74
VEPES	7.14.2	76
VERIFY	7.14.3	78
SEMIRAMIS	7.14.4	80
Ukraine simulators	7.15	
GIN-1.6-5	7.15.1	82
GINT-12-30	7.15.2	84
IEMI-M5M	7.15.3	86
IEMP-10	7.15.4	88
United Kingdom simulators	7.16	
DERA guided-wave	7.16.1	90
United States simulators	7.17	
ALECS	7.17.1	92
ARES	7.17.2	94
HPD	7.17.3	96
Trestle	7.17.4	98
VPD-I	7.17.5	100
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USN NAWCAD HPD	7.17.7	104
USN NAWCAD VPD	7.17.8	106



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## 7.1.1 Canada – DREMPs



**Terminator-Transmission Line-Pulse Generator**

### General Information

**Simulator Type:** Guided-wave  
**Termination or Resistive Loading:** Output conic section with resistive load  
**Major Simulator Dimension(s):** 10 m (high) by 20 m (wide) by 100 m (long)  
**Test Volume Dimensions:** 5 m (high) by 10 m (wide) by 10m (long) [the first 10m beyond the input taper]

### Simulator Input Options

**Primary Pulse Power:** 0,6-MV Marx generator with peaking capacitor  
**Repetition Rate:** 2 shots per min.  
**Low-voltage or CW Test Capability:** Operational in both polarities and as low as 0,2-MV

### Electromagnetic Characteristics

(in test volume unless otherwise noted)

**Line Impedance:** 110 Ohms (input to terminator)  
**Electric Field Polarization:** Vertical  
**Wave Impedance:** 377 Ohms (HEMP spherical wave)  
**Peak Electric Field:** 20-55 kV/m  
**Peak Magnetic Field:** 53-146 A/m  
**Pulse Rise Time:** 5 ns (10 %-90 %)  
**Prepulse:** < 5 %  
**Pulse Width:** approx. 400 ns (1/e)  
**Field Uniformity:**

- 10 % uniformity of vertical component from side to side
- approx. 10 % fall-off of peak field from front to back of test volume

**Other:** Information not provided

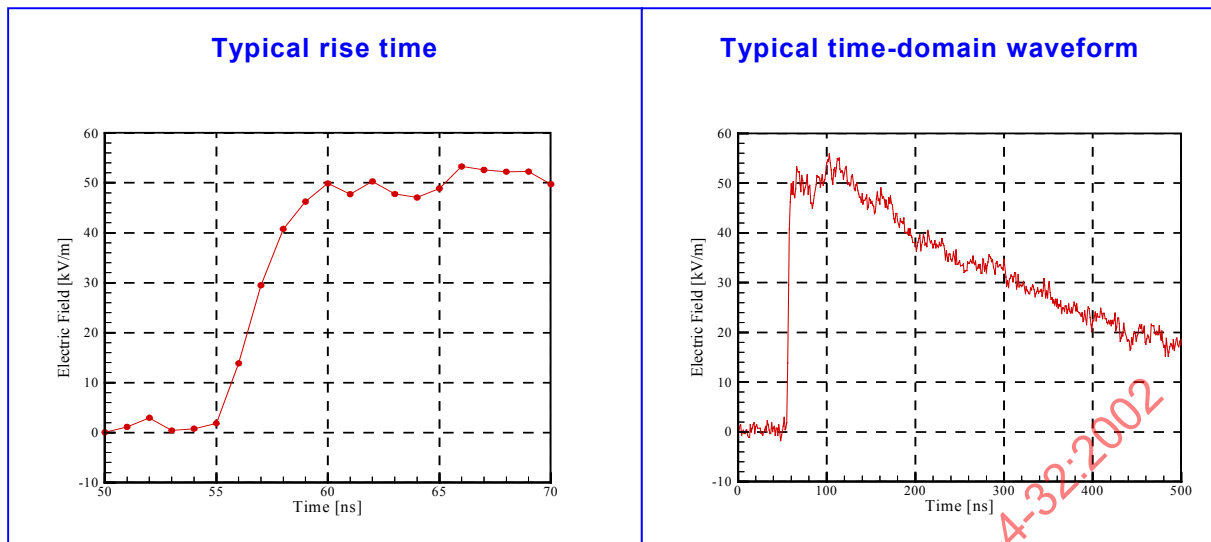
### Other Information

**Location:** Ottawa, Ontario  
**Owner:** Defence Research Establishment Ottawa (DREO)  
**Point of Contact:** Joe Seregelyi, Microwave Analysis and Countermeasures Group, 3701 Carling Ave. Ottawa Ontario, Canada. K1A 0Z4.  
 Telephone: (613) 998-5576  
 Fax: (613) 998-9087  
 E-mail: joe.seregelyi@dreo.dnd.ca  
**Initial Operation Date:** ~1994  
**Status:** Operational

### Availability

**Other Government:** Yes

**Industry:** Yes



### Other technical information

#### Available instrumentation

A variety of digitizers in the range of 400 MHz to 1 000 MHz single-shot bandwidth are available. Fibre optic links with 300 MHz to 1 000 MHz bandwidth are the primary means of extracting signals from the test pad. A dedicated data-acquisition software package efficiently processes and stores the waveforms obtained from a variety of commercial and custom-design electric-field, magnetic-field and current sensors.

#### General description

The system is designed to test to MIL-STD-461C. Easy access by road or helicopter facilitates equipment handling. On-site machine shop and calibration facilities allow fabrication of custom sensors, support jigs etc.

A description of the experimental field mapping and numerical analysis (NEC) both inside and around the simulator is available in:

J.S. Seregelyi, S. Kashyap and A. Louie '**Field Dynamics in a Parallel-Plate Simulator**', IEEE EMC, Vol 37, No 3, Aug. 1995. (Keep in mind that the field mapping was performed with a preliminary pulse generator. A full threat-level pulse generator has replaced this unit.)

#### Auxiliary test equipment

Current injection testing (CS) is available upon request.

An extended length TEM cell with resistive load is available. The cell is 2 m (high) by 2 m (wide) by 6 m (long) with a working volume of 30 cm (high) by 60 cm (wide) by 60 cm (long). The cell can be driven with a 60-kV pulse generator (with a repetition rate of 10 shots per minute) or in CW mode. The electric field is vertically polarized, and the cell is operational in both polarities.

## 7.2.1 China – DM-1200

### Terminator-Transmission line – Pulse generator building



#### General information

**Simulator type:** Guided-wave  
**Termination or resistive loading:** Output conic section with approximately point resistive load  
**Major simulator dimension(s):** 54 m (overall length)  
 8,4 m (plate spacing)  
**Test volume dimensions:** Information not provided

#### Simulator input options

**Primary pulse power:** 1,2-MV Marx generator with pulse-shaping network  
**Repetition rate:** 12 pulses per hour  
**Low-voltage or CW test capability:** Not available

#### Electromagnetic characteristics

(in test volume unless otherwise noted)

**Electric field polarization:** Vertical  
**Line impedance:** 180  $\Omega$  (input to terminator)  
**Wave impedance:** 377  $\Omega$  (HEMP spherical wave)  
**Peak electric field:** 120 kV/m  
**Peak magnetic field:** 318 A/m  
**Pulse rise time:** ~10 ns (10-90 %)  
**Prepulse:** Information not provided  
**Pulse width:** 200 ns (1/e)  
**Field uniformity:** Uniformity of vertical component – Not available  
 Fall-off of peak field from front to back of test volume – Not available  
 Horizontal components as per cent of vertical component – Not available

**Other:** Information not provided

#### Other information

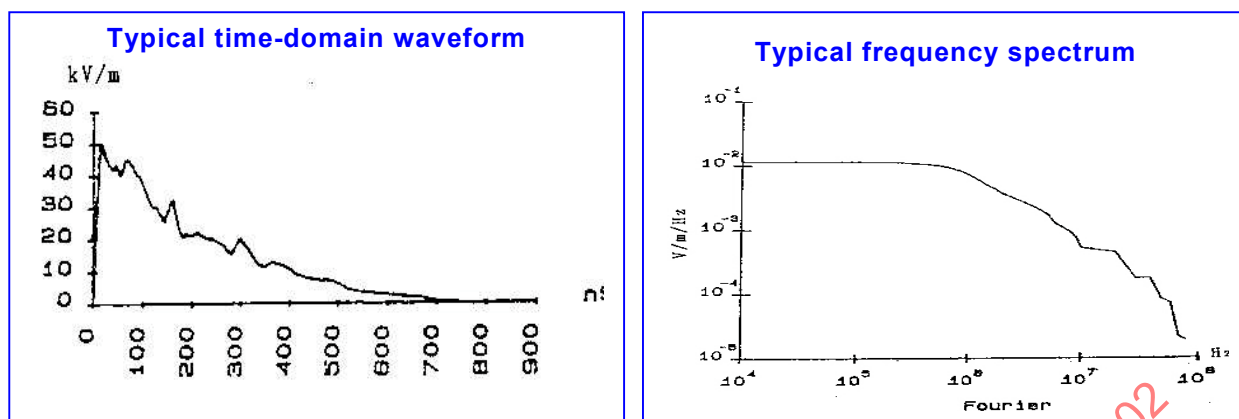
**Location:** Beijing, China  
**Owner:** Beijing Institute of Electronic System Engineering (BIESE)  
 Mr. Pan Hu, China Aerospace Corporation, Second Research Academy, Beijing Institute of Electronic System Engineering, No. 52 Yong Ding Road, P.O. Box 3922, Beijing 100039  
 Telephone: 86-1-6838-6534  
 Fax: 86-1-6821-2656

**Initial operation date:** 1985  
**Status:** Operational

#### Availability

**Other government:** Check with point of contact

**Industry:** Check with point of contact



### Other technical information

#### General description

Information not provided

#### Available instrumentation

The simulator has an underground instrumentation room and optical fibre measuring system. Digital storage oscilloscopes (500 MHz, 5 GHz/s) are available.

#### Auxiliary test equipment

Information not provided

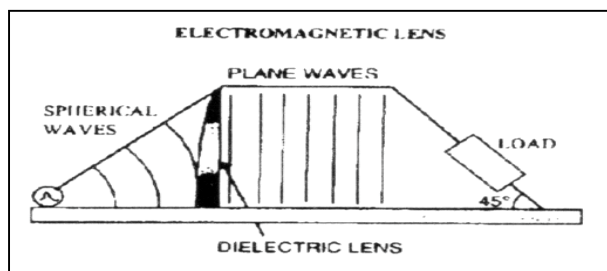
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## 7.5.1 France – France Telecom R&D guided-wave



**Pulser and dielectric lens**



**Terminator – Test volume**

### General information

**Simulator type:** Guided-wave  
**Termination or resistive loading:** No output conic section with sparse, distributed resistive load  
**Major simulator dimension(s):** 50 m (overall length)  
**Test volume dimensions:** 2,5 m (high) × 2,5 m (wide) × 10 m (long)

### Simulator input options

**Primary pulse power:** 800-kV Marx generator with pulse-shaping network  
**Repetition rate:** 5 pulses per minute  
**Low-voltage or CW test capability:** Not available

### Electromagnetic characteristics (in test volume unless otherwise noted)

**Electric field polarization:** Vertical  
**Line impedance:** 140 Ω (input to terminator)  
**Wave impedance:** 377 Ω  
**Peak electric field:** 15-110 kV/m  
**Peak magnetic field:** 40-200 A/m  
**Pulse rise time:** 2,5-4,2 ns (10-90 %)  
**Prepulse:** <1 %  
**Pulse width:** 23-200 ns (1/e)  
**Field uniformity:**

- Excellent ( $\pm 10$  %) uniformity of vertical component
- Fall-off of peak field from front to back of test volume – not available
- Horizontal components as percent of vertical component – not available

**Other:** Indoor EMP simulator.

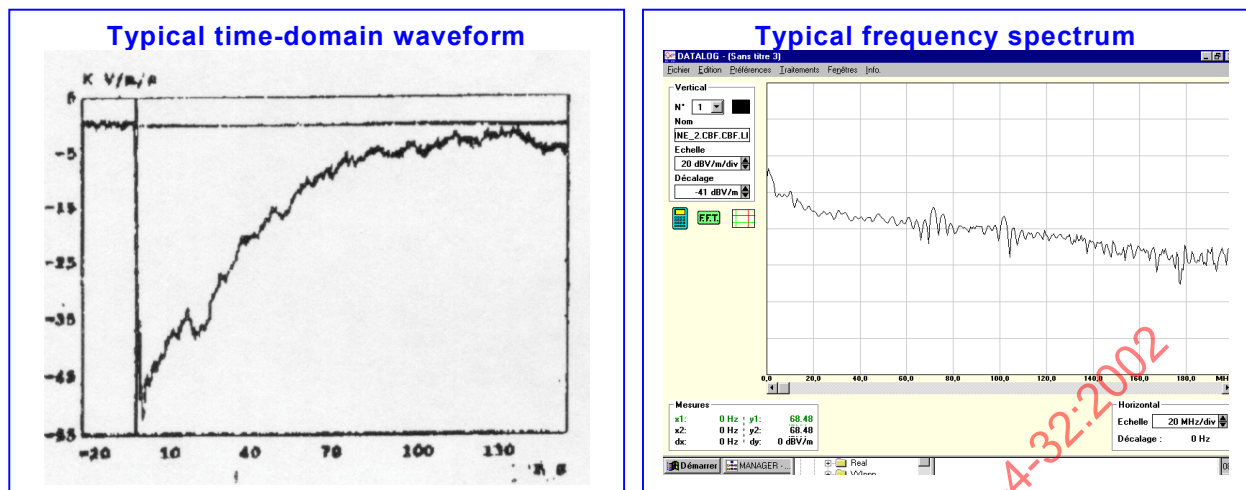
### Other information

**Location:** Lannion, France  
**Owner:** France Telecom R&D  
**Point of contact:** Alain Cario  
 France Telecom FTR&D  
 2, Avenue P. Marzin  
 22307 Lannion  
 Telephone: 33-2 96 05 38 83  
 Fax: 33-2 96 05 21 11  
 E-mail: alain.cario@Francetelecom.com  
**Initial operation date:** 1996  
**Status:** Operational

### Availability

**Government:** Yes

**Industry:** Yes



### Other technical information

#### General description

This EMP simulator is used to test large equipment with, at choice, the Bell waveform (rise time = 4,2ns, fall time = 180ns) or the IEC waveform (IEC 61000-2-9, rise time = 2,5 ns, fall time = 23 ns). This system is original by the use of a dielectric lens placed at the geometric discontinuity of the strip line.

#### Available instrumentation

Electric field sensors: Thomson E 1601 and E 1602  
 VCO: V1004 Thomson for derivative signal (BW : 1 kHz – 1 GHz)  
 Optical link: MM1000 Thomson  
 Receiver: R1000 Thomson  
 Processor: P1004 Thomson  
 Digitising oscilloscope: TEKTRONIX TDS 684 A (5 GS/s – 1Ghz)  
 Software: FEMTO V3 Thomson

#### Auxiliary test equipment

Information not provided

## 7.5.2 France – DPH

### Pulse generator in elliptical antenna



#### General information

**Simulator type:** Hybrid  
**Termination or resistive loading:** Uniform, sparse, distributed antenna resistive loading  
**Major simulator dimension(s):** 150 m overall length  
 30 m pulser centreline height  
**Test volume dimensions:** 6 m (high) × 50 m (wide) × 50 m (long)

#### Simulator Input Options

**Primary pulse power:** 1-MV, 2-MV, and 4-MV Marx generators with peaking capacitors  
**Repetition rate:** Information not provided  
**Low-voltage or CW test capability:** Information not provided

#### Electromagnetic characteristics

(in test volume unless otherwise noted)

**Electric field polarization:** Horizontal (early times)  
**Bicone impedance:** 150 Ω  
**Wave impedance:** 377 Ω (early times)  
**Peak electric field:** 50 kV/m @ 30 m from pulser apex  
**Peak magnetic field:** 133 A/m @ 30 m from pulser apex  
**Pulse rise time:** 1-5 ns (10-90 %)  
**Prepulse:** Information not provided  
**Pulse width:** 25-200 ns (FWHM; complicated function of position)  
**Field uniformity:**

- Peak horizontal E-field – Information not provided
- Vertical and other non-principal components – Information not provided

**Other:** Information not provided

#### Other Information

**Location:** Gramat, France  
**Owner:** Centre d'Etudes de Gramat (CEG), Ministère de la Défense  
**Point of contact:** Pierre Bruguier, Centre d'Etudes de Gramat (CEG), 46500 Gramat,  
 Tel: 33 5 65 10 54 28;  
 Fax: 33 5 65 10 54 33

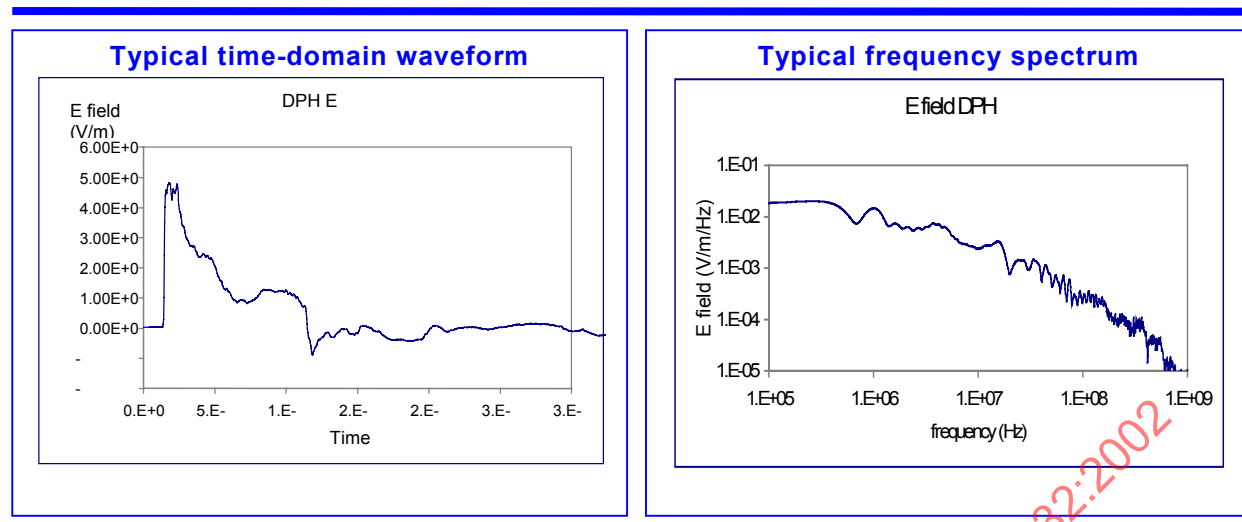
**Initial operation date:** 1980  
**Status:** Operational

#### Availability

**Other government:** Yes

**Industry:** Yes





### Other technical information

#### General description

A transportable version of this simulator provides the same fields in the same test volume.

#### Available instrumentation

- Thomson mélopée 1500-1600 series (100 kHz-1,5 GHz bandwidth) active electric and magnetic field sensors and optical data links
- Ailtech current probes
- EG&G passive electric and magnetic field probes
- Hewlett Packard fast transient analysers

#### Auxiliary test equipment

Information not provided

## 7.5.3 France – SSR

### Pulse generator – Transmission line – Test volume



#### General information

**Simulator type:** Guided-wave  
**Termination or resistive loading:** No output conic section with sparse, distributed resistive load  
**Major simulator dimension(s):** 106 m overall length  
 15 m maximum height  
**Test volume dimensions:** 10 m (high) × 23 m (wide) × 23 m (long)

#### Simulator input options

**Primary pulse power:** 2-MV Marx generator with pulse-shaping network  
**Repetition rate:** Information not provided  
**Low-voltage or CW test capability:** Not available

#### Electromagnetic characteristics

(in test volume unless otherwise noted)

**Electric field polarization:** Vertical  
**Line impedance:** 90 Ω (input to terminator)  
**Wave impedance:** 377 Ω  
**Peak electric field:** >100 kV/m  
**Peak magnetic field:** >265 A/m  
**Pulse rise time:** 1-5 ns (10-90 %)  
**Prepulse:** Information not provided  
**Pulse width:** 25 ns, 200 ns half-time duration  
**Field uniformity:**

- Uniformity of vertical component – Information not provided
- 2 % fall-off of peak field from front to back of test volume
- Horizontal components as per cent of vertical component – Information not provided

**Other:** Information not provided

#### Other information

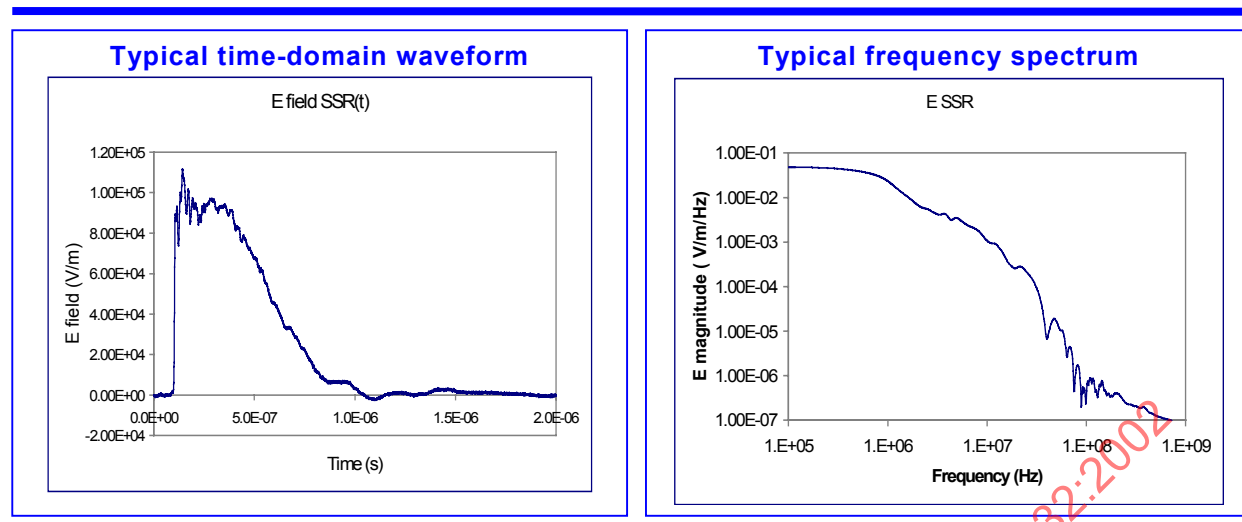
**Location:** Gramat, France  
**Owner:** Centre d'Etudes de Gramat (CEG), Ministère de la Défense  
**Point of contact:** Pierre Bruguère, Centre d'Etudes de Gramat (CEG), 46500 Gramat,  
 Tel: 33 5 65 10 54 28;  
 Fax: 33 5 65 10 54 33

**Initial operation date:** 1986  
**Status:** Operational

#### Availability

**Other government:** Yes

**Industry:** Yes



### Other technical information

#### General description

The transportable version of this simulator (164 m in length and 25 m in height) provides the same fields in a test volume of 15 m (high), 40 m (wide), and 40 m (long).

#### Available instrumentation

- Thomson mélopée 1500-1600 series (100 kHz-1,5 GHz bandwidth) active electric and magnetic field sensors and optical data links
- Ailtech current probes
- EG&G passive electric and magnetic field probes
- Hewlett Packard fast transient analysers

#### Auxiliary test equipment

Information not provided

## 7.6.1 Germany – DIESES

### Pulse generator building – Transmission line – Test volume – Terminator



#### General information

**Simulator type:** Guided-wave  
**Termination or resistive loading:** No output conic section with sparse, distributed resistive load  
**Major simulator dimension(s):** 120 m overall length  
 22 m maximum height  
**Test volume dimensions:** 8 m (high) × 10 m (wide) × 20 m (long)

#### Simulator input options

**Primary pulse power:** 1-MV Marx generator with peaking capacitor;  
**Repetition rate:** 1 pulse per minute  
**Low-voltage or CW test capability:** Both available

#### Electromagnetic characteristics

(in test volume unless otherwise noted)

**Electric field polarization:** Vertical  
**Line impedance:** 90  $\Omega$  (input to terminator)  
**Wave impedance:** 377  $\Omega$   
**Peak electric field:** >100 kV/m  
**Peak magnetic field:** >265 A/m  
**Pulse rise time:** 1 ns or 7 ns (10-90 %)  
**Prepulse:** ≤10 %  
**Pulse width:** 80 - 1 000 ns (1/e)  
**Field uniformity:**

- Good (±15 %) uniformity of vertical component
- 27 % fall-off of peak field from front to back of test volume
- Horizontal components ≤10 % of vertical component

**Other:** Information not provided.

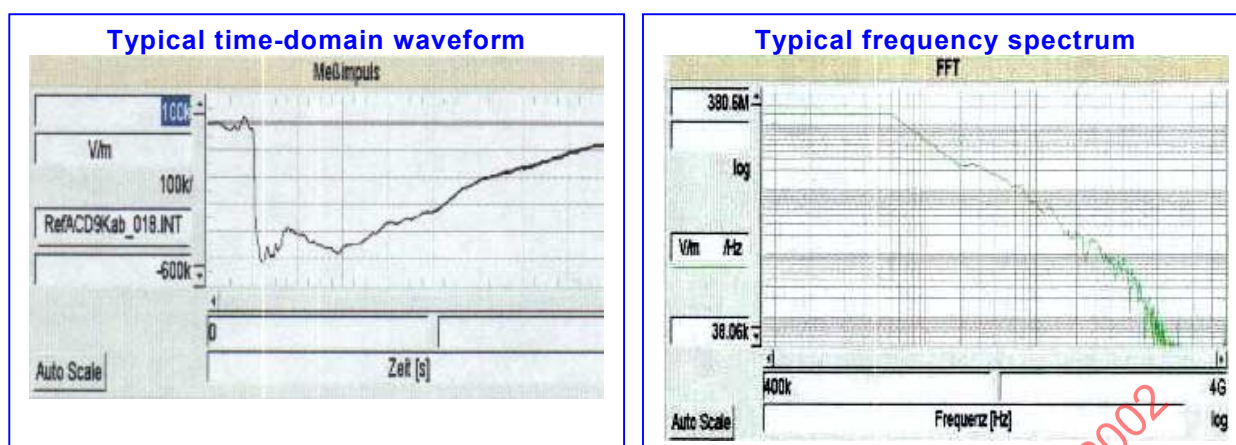
#### Other information

**Location:** Munster, Germany  
**Owner:** Wehrwissenschaftliches Institut für Schutztechnologien ABC-Schutz (WIS)  
**Point of contact:** Daniel Nitsch, Wehrwissenschaftliches Institut für Schutztechnologien ABC-Schutz (WIS), D-29633 Munster, Tel: 49-5192-136338; Fax: 49-5192-136355  
 E-mail: DanielNitsch@bwb.org  
**Initial operation date:** 1981  
**Status:** Operational

#### Availability

**Other government:** Yes

**Industry:** Yes



## Other technical information

### General description

This simulator can also be used in an UWB mode with a rise time of less than 500 ps and a field strength of up to 300 kV/m.

### Available instrumentation

- Electric and magnetic field probes (ground-plane and free-field) up to 12 GHz bandwidth
- Current probes up to 500 MHz bandwidth
- Several fibre optical lines up to 5 GHz bandwidth
- Transient recorders and fast analogue scopes up to 5 GHz single-shot bandwidth
- Modern PC-based data acquisition with mathematical features

### Auxiliary test equipment

Information not provided

## 7.6.2 Germany – HPD

### Pulse generator in hybrid antenna



#### General information

**Simulator type:** Hybrid (Dipole)  
**Termination or resistive loading:** Uniform, sparse, distributed antenna resistive loading  
**Major simulator dimension(s):** 30m overall length  
 8m maximum height  
**Test volume dimensions:** 4m (high) × 10m (wide) × 10m (long)

#### Simulator Input Options

**Primary pulse power:** 360 pV Marx generator with peaking capacitor  
**Repetition rate:** 1 pulse per minute  
**Low-voltage or CW test capability:** Both available

#### Electromagnetic characteristics

(in test volume unless otherwise noted)

**Electric field polarization:** Horizontal  
**Line impedance:** 150 Ω (input to terminator)  
**Wave impedance:** 377 Ω  
**Peak electric field:** ~10 kV/m @ 8 m from pulser apex  
**Peak magnetic field:** ~27 A/m @ 8 m from pulser apex  
**Pulse rise time:** 1,2 ns (10-90 %)  
**Prepulse:** Information not provided  
**Pulse width:** 10 ns (dependant on height of test object in test volume)  
**Field uniformity:** Good (no further information provided)  
**Other:** Information not provided

#### Other information

**Location:** Munster, Germany  
**Owner:** Wehrwissenschaftliches Institut für Schutztechnologien ABC-Schutz (WIS)  
**Point of contact:** Daniel Nitsch  
 Wehrwissenschaftliches Institut für Schutztechnologien ABC-Schutz (WIS),  
 D-29633 Munster,  
 Tel: 49-5192-136338;  
 Fax: 49-5192-136355  
 E-mail: DanielNitsch@bwv.org

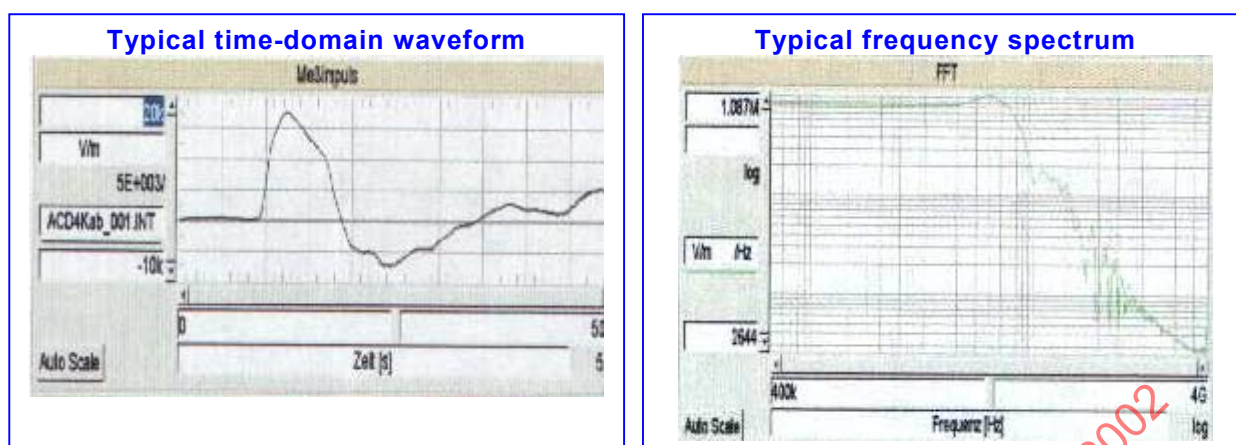
**Initial operation date:** 1999  
**Status:** Operational

#### Availability

**Other government:** Yes

**Industry:** Yes





### Other technical information

#### General description

In 2003 an upgrade will be in operation that uses mainly a new (1-MV) generator and produces a field strength of 50 kV/m in the test volume.

#### Available instrumentation

- Electric and magnetic field probes (ground-plane and free-field) up to 12 GHz bandwidth
- Current probes up to 500 MHz bandwidth
- Several fibre optical lines up to 5 GHz bandwidth
- Transient recorders and fast analogue scopes up to 5 GHz single-shot bandwidth
- Modern PC-based data acquisition with mathematical features

#### Auxiliary test equipment

Information not provided

### 7.6.3 Germany – WIS indoor guided-wave simulator



Transmission line

#### General information

**Simulator type:** Guided-wave  
**Termination or resistive loading:** Distributed resistive load  
**Major simulator dimension(s):** Information not provided  
**Test volume dimensions:** 2,75m (high) × 2,3 m (wide) × 6 m (long)

#### Simulator input options

**Primary pulse power:** Different generators  
**Repetition rate:** Up to 200 pulses per minute  
**Low-voltage or CW test capability:** Yes

#### Electromagnetic characteristics

(in test volume unless otherwise noted)

**Electric field polarization:** Vertical  
**Line impedance:** 50  $\Omega$  (input to terminator)  
**Wave impedance:** 377  $\Omega$   
**Peak electric field:** Up to 50 kV/m  
**Peak magnetic field:** Up to 133 A/m  
**Pulse rise time:** 90 ps 100 ns (10-90 %)  
**Prepulse:** Information not provided  
**Pulse width:** 2 ns or 2 000 ns (1/e)  
**Field uniformity:** Good (no further information provided)

**Other:** NEMP, UWB and arbitrary waveform generators available

#### Other information

**Location:** Munster, Germany  
**Owner:** Wehrwissenschaftliches Institut für Schutztechnologien ABC-Schutz (WIS)  
**Point of contact:** Daniel Nitsch  
 Wehrwissenschaftliches Institut für Schutztechnologien ABC-Schutz (WIS),  
 D-29633 Munster,  
 Tel: 49-5192-136338;  
 Fax: 49-5192-136355  
 E-mail: DanielNitsch@bwb.org  
**Initial operation date:** Information not provided  
**Status:** Operational

#### Availability

**Other government:** Yes  
**Industry:** Yes



Typical time-domain waveform	Typical frequency spectrum
NEMP, UWB and arbitrary waveforms available	Information not provided

### Other technical information

#### General description

Information not provided

#### Available instrumentation

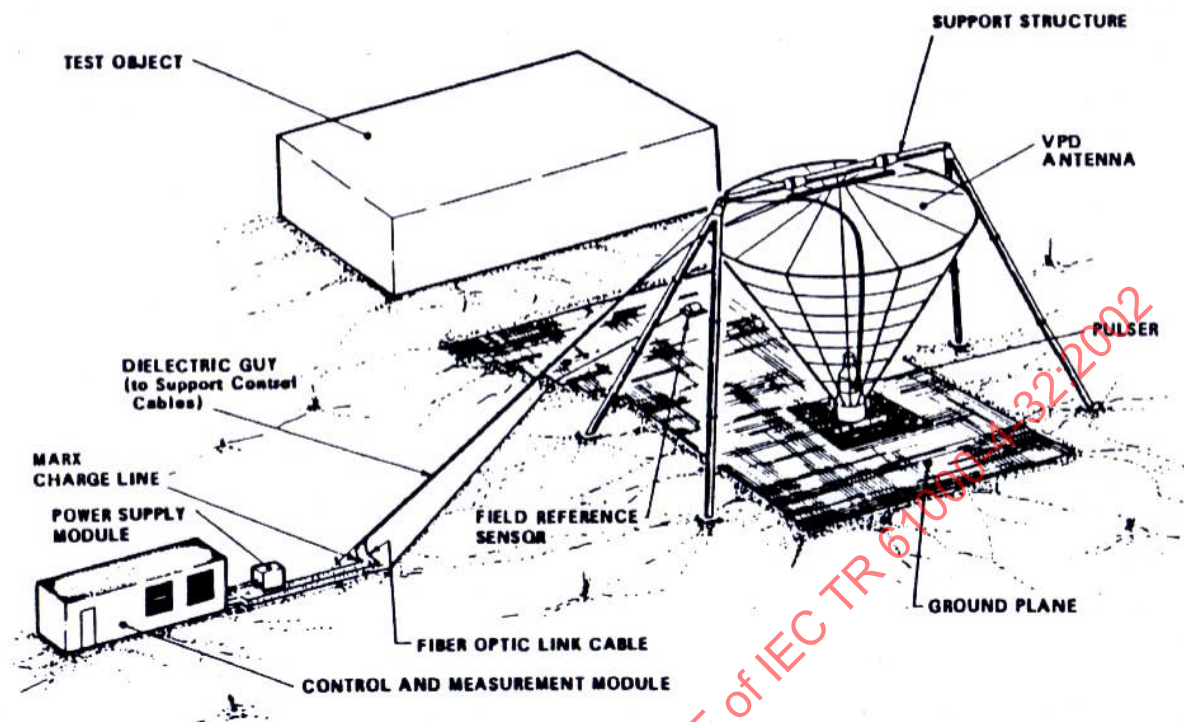
- Electric and magnetic field probes (ground-plane and free-field) up to 12 GHz bandwidth
- Current probes up to 500 MHz bandwidth
- Several fibre optical lines up to 5 GHz bandwidth
- Several semi-rigid cables: bandwidth up to 18 GHz
- Transient recorders and fast analogue scopes up to 5 GHz single-shot bandwidth (20 GHz repetitive pulse bandwidth)
- Modern PC-based data acquisition with mathematical features

#### Auxiliary test equipment

Information not provided

## 7.6.4 Germany – VPD

### Artist's view of future VPD simulator



#### General information

**Simulator type:** Dipole  
**Termination or resistive loading:** Uniform, sparse, distributed antenna resistive loading  
**Major simulator dimension(s):** 17 m diameter  
 12 m maximum height  
**Test volume dimensions:** 8 m (high) × 10 m (wide) × 10 m (long)

#### Simulator input options

**Primary pulse power:** 360 kV Marx generator with peaking capacitor  
**Repetition rate:** 1 pulse per minute  
**Low-voltage or CW test capability:** Information not provided

#### Electromagnetic characteristics

(in test volume unless otherwise noted)

**Electric field polarization:** Vertical  
**Line impedance:** 75 Ω (input to terminator)  
**Wave impedance:** 377 Ω  
**Peak electric field:** ~10 kV/m @ 8 m from pulser apex  
**Peak magnetic field:** ~27 A/m @ 8 m from pulser apex  
**Pulse rise time:** 1,2 ns (10-90 %)  
**Prepulse:** Information not available  
**Pulse width:** 60 ns  
**Field uniformity:** Information not available

**Other:** Information not provided

#### Other information

**Location:** Munster, Germany  
**Owner:** Wehrwissenschaftliches Institut für Schutztechnologien ABC-Schutz (WIS)  
**Point of contact:** Daniel Nitsch  
 Wehrwissenschaftliches Institut für Schutztechnologien ABC-Schutz (WIS),  
 D-29633 Munster,  
 Tel: 49-5192-136338;  
 Fax: 49-5192-136355  
 E-mail: DanielNitsch@bwb.org  
**Initial operation date:** 2001  
**Status:** Conceptual design complete. Components under procurement

#### Availability

**Other government:** Yes  
**Industry:** Yes

Typical time-domain waveform	Typical frequency spectrum
Information not available	Information not available

### Other technical information

#### General description

Information not provided

#### Available instrumentation

- Electric and magnetic field probes (ground-plane and free-field) up to 12 GHz bandwidth
- Current probes up to 500 MHz bandwidth
- Several fibre optical lines up to 5 GHz bandwidth
- Several semi-rigid cables: bandwidth up to 18 GHz
- Transient recorders and fast analogue scopes up to 5 GHz single-shot bandwidth (20 GHz repetitive pulse bandwidth)
- Modern PC-based data acquisition with mathematical features

#### Auxiliary test equipment

Information not provided

## 7.6.5 Germany – MIGUS



### General information

**Simulator type:** Guided-wave  
**Termination or resistive loading:** Output conic section with resistive load  
**Major simulator dimension(s):** 30 m overall length  
**Test volume dimensions:** 6m (high) by 6m (wide) by 10m (long)

### Simulator input options

**Primary pulse power:** 0,6-MV Marx generator with peaking capacitor; 100-kV generator for fast rise times  
**Repetition rate:** 2 shots per minute  
**Low-voltage or CW test capability:** Information not provided

### Electromagnetic characteristics (in test volume unless otherwise noted)

**Electric field polarization:** vertical  
**Line impedance:** 150  $\Omega$  (input to terminator)  
**Wave impedance:** Information not provided  
**Peak Electric Field:** ~90 kV/m  
**Peak Magnetic Field:** Information not provided  
**Pulse Rise Time:** 1,5-5,0 ns (10-90 %)  
**Prepulse:** Information not provided  
**Pulse Width:** 10 ns-250 ns (1/e)  
**Field Uniformity:**

- Uniformity of vertical component – Information not provided
- Fall-off of peak field from front to back of test volume – Information not provided
- Horizontal components as per cent of vertical component – Information not provided

**Other:** Information not provided

### Other information

**Location:** Stuttgart, Germany  
**Owner:** University of Stuttgart

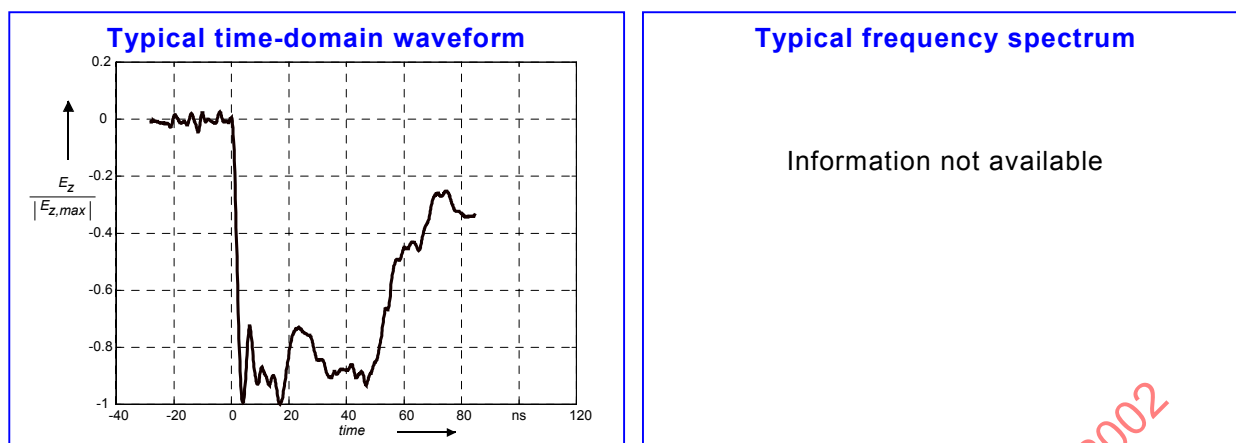
**Point of contact:** Martin Kull, HV-Lab, University of Stuttgart, Nielsenstrasse 18, D-73760 Ostfildern-Nellingen  
 Telephone: 49-711-341-2075  
 Fax: 49-711-348-1669  
 E-mail: mkull@ieh.uni-stuttgart.de

**Initial operation date:** 1986  
**Status:** Operational

### Availability

**Government:** Yes

**Industry:** Yes



### Other technical information

#### General description

Information not provided

#### Available instrumentation

Digital Oscilloscopes with BW up to 1 GHz  
E- and H-field sensors, BW 50 Hz ... 500 MHz, risetime ~1 ns  
Current probes

#### Auxiliary test equipment

Information not provided

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## 7.7.1 India – IBWEMPS (India bounded-wave EMP simulator)

Information not provided

### General information

**Simulator type:** Guided-wave  
**Termination or resistive loading:** Information not provided.  
**Major simulator dimension(s):** 55 m (length)  
**Test volume dimensions:** 5 m (high) × ? m (wide) × ? m (long)

### Simulator input options

**Primary pulse power:** 0,6 MV  
**Repetition rate:** Information not provided.  
**Low-voltage or CW test capability:** Information not provided.

### Electromagnetic characteristics (in test volume unless otherwise noted)

**Line impedance:** 150 Ω (input to terminator)  
**Electric field polarization:** Vertical  
**Wave impedance:** 377 Ω (HEMP spherical wave)  
**Peak electric field:** 80 kV/m  
**Peak magnetic field:** 212 A/m  
**Pulse rise time:** 10 ns (nominal)  
**Prepulse:** Information not provided.  
**Pulse width:** 1000 ns (1/e?)  
**Field uniformity:** Information not provided.  
**Other:** Test object size – 3,5 m by 4,5 m by 4,5 m

### Other information

**Location:** Bangalore, India

**Owner:** LRDE

**Point of contact:** Dr. D. C. Pande, Scientist "F"  
 EMR Division, LRDE, CV Raman Nagar, Bangalore, 560093  
 Fax: 91 080 5242916

**Initial operation date:** Information not provided.  
**Status:** Information not provided.

### Availability

**Other government:** Information not provided.

**Industry:** Information not provided.

Typical time-domain waveform	Typical frequency spectrum
Information not provided	Information not provided

### Other technical information

#### General description

Information not provided

#### Available instrumentation

Information not provided

#### Auxiliary test equipment

Information not provided

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## 7.7.2 India – RBWEMPS (repetitive bounded-wave EMP simulator)

Information not provided

### General Information

**Simulator type:** Guided-wave  
**Termination or resistive loading:** Information not provided.

**Major simulator dimension(s):** 4,5 (length)  
**Test volume dimensions:** 1 m (high) × ? m (wide) × ? m (long)

### Simulator input options

**Primary pulse power:** 0,12 MV  
**Repetition rate:** Information not provided.  
**Low-voltage or CW test capability:** Information not provided.

### Electromagnetic characteristics (in test volume unless otherwise noted)

**Line impedance:** 100 Ω (input to terminator)  
**Electric field polarization:** Vertical  
**Wave impedance:** 377 Ω (HEMP spherical wave)  
**Peak electric field:** 100 kV/m  
**Peak magnetic field:** 265 A/m  
**Pulse rise time:** 10 ns (peak)  
**Prepulse:** Information not provided.  
**Pulse width:** 500 ns (1/e?)  
**Field uniformity:** Information not provided.  
**Other:** Test object size – 0,6 m by 1,5 m by 1,5 m

### Other information

**Location:** Bangalore, India

**Owner:** LRDE

**Point of contact:** Dr. D. C. Pande, Scientist "F"  
 EMR Division, LRDE, CV Raman Nagar, Bangalore, 560093  
 Fax: 91 080 5242916

**Initial operation date:** Information not provided.  
**Status:** Information not provided.

### Availability

**Other government:** Information not provided.

**Industry:** Information not provided.

Typical time-domain waveform	Typical frequency spectrum
Information not provided	Information not provided

### Other technical information

#### General description

Information not provided

#### Available instrumentation

Information not provided

#### Auxiliary test equipment

Information not provided

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## 7.8.1 Israel – Rafael guided-wave EMP simulator

### Pulse generator – Transmission line – Terminator



#### General information

**Simulator type:** Guided-wave  
**Termination or resistive loading:** No output conic section with sparse, distributed resistive load  
**Major simulator dimension(s):** 120 m overall length  
 22 m maximum height  
**Test volume dimensions:** Information not provided

#### Simulator input options

**Primary pulse power:** 2-MV Marx generator with peaking capacitor  
**Repetition rate:** Information not provided  
**Low-voltage or CW test capability:** Information not provided

#### Electromagnetic characteristics

(in test volume unless otherwise noted)

**Electric field polarization:** Vertical  
**Line impedance:** 90  $\Omega$  (input to terminator)  
**Wave impedance:** 377  $\Omega$   
**Peak electric field:** Information not provided  
**Peak magnetic field:** Information not provided  
**Pulse rise time:** <5 ns (10 %-90 %)  
**Prepulse:**  $\leq 10$  %  
**Pulse width:** Information not provided  
**Field uniformity:**

- Good ( $\pm 15$  %) uniformity of vertical component
- Fall-off of peak field from front to back of test volume – Information not provided

 Horizontal components  $\leq 10$  % of vertical component

**Other:** Information not provided

#### Other information

**Location:** Haifa, Israel  
**Owner:** RAFAEL – Israeli Armament and Development Authority  
**Point of contact:** Dr. Joseph Shiloh, Director, EMP and Pulsed Power Department (Department 23), RAFAEL, Derech Ako, P.O. Box 2250, Haifa  
 Telephone: 972-4-879-5016  
 Fax: 972-4-879-5315  
**Initial operation date:** 1989  
**Status:** Operational

#### Availability

**Other government:** Information not provided

**Industry:** Information not provided

Typical time-domain waveform	Typical frequency spectrum
Information not provided	Information not provided

### Other technical information

#### General description

Information not provided

#### Available instrumentation

Information not provided

#### Auxiliary test equipment

Information not provided

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## 7.8.2 Israel – Rafael hybrid



Pulse generator – Elliptical antenna – Fibreglass support stand

### General information

**Simulator type:** Hybrid  
**Termination or resistive loading:** Uniform, sparse, distributed antenna resistive loading  
**Major simulator dimension(s):** 30m overall length  
 10m pulser centre-line height  
**Test volume dimensions:** Information not provided

### Simulator input options

**Primary pulse power:** 0,6-MV. Marx generator with peaking capacitors  
**Repetition rate:** Information not provided  
**Low-voltage or CW test capability:** Information not provided

### Electromagnetic characteristics

(in test volume unless otherwise noted)

**Electric field polarization:** Horizontal (early times)  
**Bicone impedance:** 150  $\Omega$   
**Wave impedance:** 377  $\Omega$  (early times)  
**Peak electric field:** Information not provided  
**Peak magnetic field:** Information not provided  
**Pulse rise time:** <5 ns (10-90 %)  
**Prepulse:** Information not provided  
**Pulse width:** Information not provided  
**Field uniformity:**

- Peak horizontal E-field parallel to simulator axis – Information not provided
- Vertical and other non-principal components - Information not provided

**Other:** Transportable

### Other information

**Location:** Haifa, Israel  
**Owner:** RAFAEL – Israeli Armament and Development Authority  
**Point of contact:** Dr. Joseph Shiloh, Director, EMP and Pulsed Power Department (Department 23), RAFAEL, Derech Ako, P.O. Box 2250, Haifa  
 Telephone: 972-4-879-5016  
 Fax: 972-4-879-5315  
 E-mail: jshiloh@rafael.co.il  
**Initial operation date:** 1991  
**Status:** Operational

### Availability

**Other government:** Information not provided

**Industry:** Information not provided

Typical time-domain waveform	Typical frequency spectrum
Information not provided	Information not provided

### Other technical information

#### General description

Information not provided

#### Available instrumentation

Information not provided

#### Auxiliary test equipment

Information not provided

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## 7.9.1 Italy – INSIEME



**Terminator – Transmission line – Pulse generator building**

### General information

**Simulator type:** Guided-wave  
**Termination or resistive loading:** No output conic section with sparse, distributed resistive load  
**Major simulator dimension(s):** 120 m overall length; 22 m maximum height  
**Test Volume Dimensions:** 6 m (high) × 10 m (wide) × 10 m (long)

### Simulator input options

**Primary pulse power:** 1,3 MV • Marx generator with peaking capacitor; 100-kV generator for fast rise times  
**Repetition rate:** 1 pulse per minute  
**Low-voltage or CW test capability:** Under consideration.

### Electromagnetic characteristics

(in test volume unless otherwise noted)

**Electric field polarization:** Vertical  
**Line impedance:** 100 Ω (input to terminator)  
**Wave impedance:** 377 Ω  
**Peak electric field:** Conforms to AEP-IV ed. 1986  
**Peak magnetic field:** Conforms to AEP-IV ed. 1986  
**Pulse rise time:** < 5 ns (10-90 %)  
**Prepulse:** Conforms to AEP-IV ed. 1986  
**Pulse width:** 200 ns  
**Field uniformity:**

- Good (±15 %) uniformity of vertical component in vertical section
- Fall-off of peak field from front to back of test volume – Information not provided
- Horizontal components – Information not provided

**Other:** Information not provided

### Other information

**Location:** S. Piero a Grado, Pisa, Italy  
**Owner:** CISAM – Italian MOD

**Point of contact:** Col. Elio Bottari – CISAM (Joint Experimental Military Centre)  
 56010 S. Piero a Grado, Pisa  
 Telephone: +39-050-964330  
 Fax: +39-050-964332  
 E-mail: elio.bottari@cisam.it

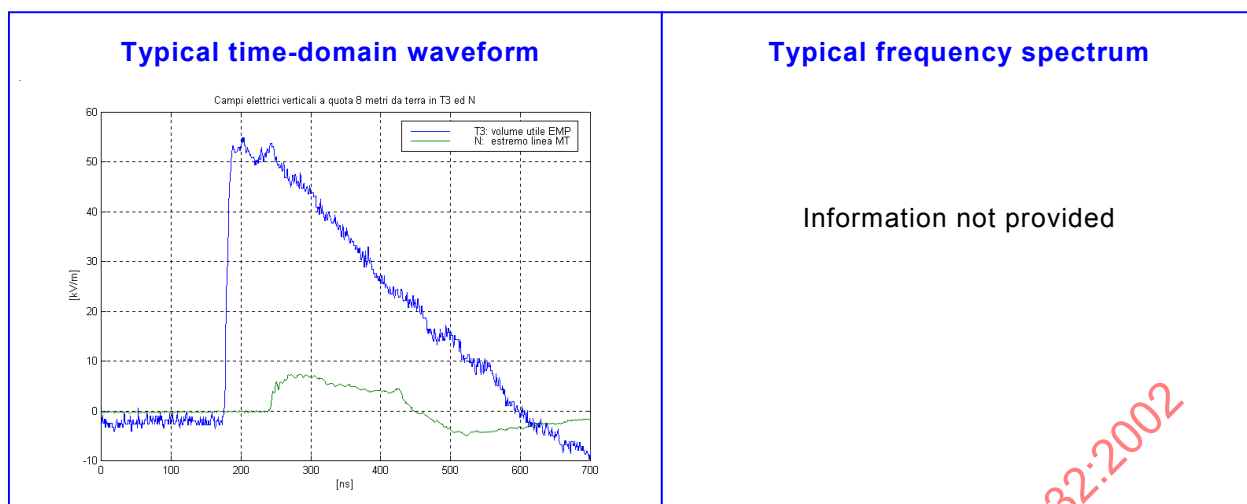
**Initial operation date:** 1993  
**Status:** Operational

### Availability

**Other government:** Yes

**Industry:** Yes





### Other technical information

#### General description

The system is designed to test according to MIL-STD-461C. A description of the experimental field characterization of the CISAM EMP facility and an overall EMP facility simulation based on advanced prediction tools (i.e. EMC 2000 by Matra MMS, France) is available in: C. Imposimato, L. Pandini, E. Bottari, L. Inzoli: "Evaluation of the radiated lightning coupling on real MV power lines by EMP simulator" 13<sup>th</sup> International Symposium & Technical Exhibition on EMC – Zurich (CH), February 16-18 1999. Information about the antenna design is given in: L. Carbonini, "Comparison of Analysis of a WTEM Cell with Standard TEM Cells for Generating EM Fields", IEEE Transactions on Electromagnetic Compatibility, Vol. 35, n. 2, pp. 255-263, Mai 1993.

#### Available instrumentation

The main acquisition system is based on 7 circuits Melope 1000 Thomson connected to 7 optical links whose length is about 300 m.

In addition, 4 T1060 integrators with their related electric and magnetic field sub-miniature sensors, 2 built-in ET 1052 sensors and 1 voltage sensor with 4 1004 inputs for voltage/current measurements are also available.

A variety of oscilloscopes up to 500 MHz is also connected to a PC that includes a dedicated data acquisition software (FEMTO) to process and stores the waveforms automatically acquired by the system during electric/magnetic fields and voltage/current measurements.

#### Auxiliary test equipment

Close to the facility instrumentation is available to performed conducted EMP and LEMP tests according to FINABEL 2C/10 (waveform A, B for EMP; C, D for LEMP) and EFA (LEMP-EFA-1 and -2) specifications.

## 7.10.1 The Netherlands – EMIS-III-HPD

### Simulator photograph

Information not provided

### General information

**Simulator type:** Hybrid (dipole) antenna  
**Termination or resistive loading:** Uniform, sparse, distributed antenna resistive loading  
**Major simulator dimension(s):** 100 m overall length  
 20 m high  
**Test volume dimensions:** 100 m

### Simulator input options

**Primary pulse power:** 0,5-MV Marx generator with peaking capacitors  
**Repetition rate:** 60 pulses per hour  
**Low-voltage or CW test capability:** Information not provided

### Electromagnetic characteristics

(in test volume unless otherwise noted)

**Electric field polarization:** Horizontal (early times); Positive or Negative  
**Bicone impedance:** 150 Ohms  
**Wave impedance:** 377 Ohms (early times)  
**Peak electric field:** 2 kV/m @ 100 meters from pulser apex  
**Peak magnetic field:** Information not provided  
**Pulse rise time:** <5 ns (10 %-90 %)  
**Prepulse:** Information not provided  
**Pulse width:** Conforms to AEP4 3/4  
**Field uniformity:** Information not provided

**Other:** Transportable simulator. Also can be configured in dipole and transmission-line versions.

### Other information

**Location:** The Hague, The Netherlands  
**Owner:** Netherlands Organization for Applied Scientific Research (TNO) Physics and Electronics Laboratory  
**Point of contact:** Eddy L. Intres, Electromagnetics Effects Group, TNO Physics Laboratory, Oude Waalsdorperweg 63, P. O. Box 96864, 2509 JG, The Hague  
 Telephone: 31-70-374-0355  
 Fax: 31-70-374-0653  
 E-mail: Intres@fel.tno.nl  
**Initial operation date:** ~1983  
**Status:** Not operational

### Availability

**Other government:** Yes

**Industry:** Yes

Typical time-domain waveform	Typical frequency spectrum
Information not provided	Information not provided

### Other technical information

#### General description

Information not provided

#### Available instrumentation

Information not provided

#### Auxiliary test equipment

Information not provided

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## 7.10.2 The Netherlands – EMIS-III-TL



Pulse generator - Transmission line - Terminator

### General information

**Simulator type:** Guided-wave transmission line  
**Termination or resistive loading:** No output conic section with sparse, distributed resistive load  
**Major simulator dimension(s):** 50 m (length)  
**Test volume dimensions:** 6 m (high) × 10 m (wide) × 6 m (long)

### Simulator input options

**Primary pulse power:** 0,5-MV Marx generator with peaking capacitor  
**Repetition rate:** 60 shots per hour  
**Low-voltage or CW test capability:** Information not provided

### Electromagnetic characteristics

(in test volume unless otherwise noted)

**Line impedance:** 100 Ω (input to terminator)  
**Electric field polarization:** Vertical (positive or negative)  
**Wave impedance:** 377 Ω (HEMP spherical wave)  
**Peak electric field:** 30-80 kV/m  
**Peak magnetic field:** Information not provided  
**Pulse rise time:** 1-5 ns (10-90 %)  
**Prepulse:** Information not provided  
**Pulse width:** Conforms to AEP4 edition 3/4  
**Field uniformity:** Information not provided  
**Other:** Transportable simulator. Also can be configured in half-dipole version.

### Other information

**Location:** The Hague, The Netherlands  
**Owner:** Netherlands Organization for Applied Scientific Research (TNO) Physics and Electronics Laboratory  
**Point of contact:** Eddy L. Intres, Electromagnetics Effects Group, TNO Physics Laboratory, Oude Waalsdorperweg 63, P. O. Box 96864, 2509 JG, The Hague  
 Telephone: 31-70-374-0355  
 Fax: 31-70-374-0653  
 E-mail: Intres@fel.tno.nl  
**Initial operation date:** ~1992  
**Status:** Operational

### Availability

**Other government:** Yes

**Industry:** Yes

Typical time-domain waveform	Typical frequency spectrum
Information not provided	Information not provided

### Other technical information

#### General description

Information not provided

#### Available instrumentation

Information not provided

#### Auxiliary test equipment

Information not provided

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### 7.10.3 The Netherlands – EMIS-III-VPD



Pulse generator - Conic antenna - Fibreglass support system

#### General information

**Simulator type:** Dipole (cone over ground plane)  
**Termination or resistive loading:** Tapered, distributed resistive loading  
**Major simulator dimension(s):** 20 m (height)  
 35 m (diameter)  
**Test volume dimensions:** 100 m

#### Simulator input options

**Primary pulse power:** 0.5-MV Marx generator with peaking capacitor  
**Repetition rate:** 60 shots per hour  
**Low-voltage or CW test capability:** Not available

#### Electromagnetic characteristics

(in test volume unless otherwise noted)

**Cone impedance:** 75  $\Omega$   
**Electric field polarization:** Vertical (positive or negative)  
**Wave impedance:** 377  $\Omega$  (HEMP spherical wave)  
**Peak electric field:** 2 kV/m @ 100 m (1/r fall-off)  
**Peak magnetic field:** Information not provided  
**Pulse rise time:** <5 ns (10-90 %)  
**Prepulse:** Information not provided  
**Pulse width:** Conforms to AEP4 3/4  
**Field uniformity:** Information not provided  
**Other:** Transportable simulator. Also can be configured in a transmission-line version.

#### Other information

**Location:** The Hague, The Netherlands  
**Owner:** Netherlands Organization for Applied Scientific Research (TNO) Physics and Electronics Laboratory  
**Point of contact:** Eddy L. Intres, Electromagnetics Effects Group, TNO Physics Laboratory, Oude Waalsdorperweg 63, P. O. Box 96864, 2509 JG, The Hague  
 Telephone: 31-70-374-0355  
 Fax: 31-70-374-0653  
 E-mail: Intres@fel.tno.nl  
**Initial operation date:** ~1983  
**Status:** Operational

#### Availability

**Other government:** Yes  
**Industry:** Yes

Typical time-domain waveform	Typical frequency spectrum
Information not provided	Information not provided

### Other technical information

#### General description

Information not provided

#### Available instrumentation

Information not provided

#### Auxiliary test equipment

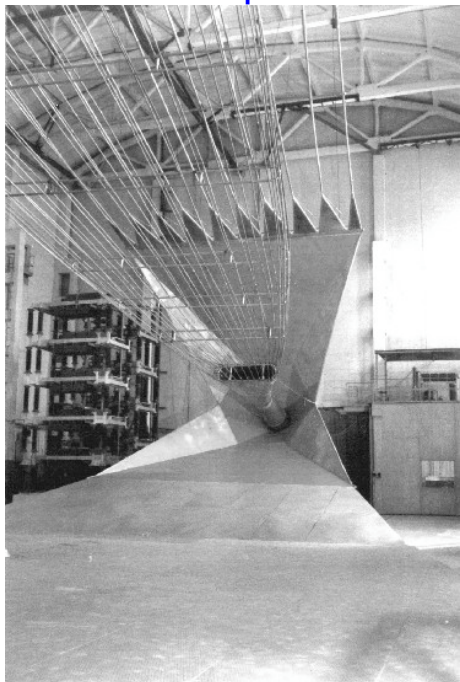
Information not provided

IECNORM.COM : Click to view the full PDF of IEC TR 61000-4-32:2002

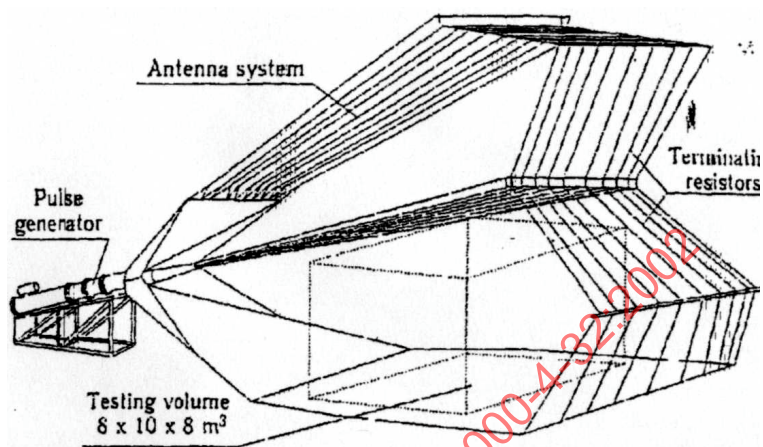


## 7.12.1 Russia – ERU-2M

**Simulator input section**



**Simulator geometry**



### General information

**Simulator type:** Guided-wave (three-plate with distributed termination)  
**Termination or resistive loading:** No output conic section with sparse, distributed resistive load  
**Major simulator dimension(s):** 30 m (overall length)  
**Test volume dimensions:** 8 m (high) × 10 m (wide) × 8 m (long)

### Simulator input options

**Primary pulse power:** 1-MV Marx generator with pulse-shaping network  
**Repetition rate:** 2 pulses per minute  
**Low-voltage or CW test capability:** Not available

### Electromagnetic characteristics

(in test volume unless otherwise noted)

**Electric field polarization:** Vertical  
**Line impedance:** 120 Ω (input to terminator)  
**Wave impedance:** 377 Ω (HEMP spherical wave)  
**Peak electric field:** 35-100 kV/m  
**Peak magnetic field:** 93-265 A/m  
**Pulse rise time:** 2,5-25 ns (10-90 %)  
**Prepulse:** Information not provided  
**Pulse width:** 25-750 ns (1/e)  
**Field uniformity:**

- Good (±20 %) uniformity of vertical component
- Fall-off of peak field from front to back of test volume – Information not provided
- Horizontal components – Information not provided

**Other:** Resistively terminated 3-plate transmission line.

### Other information

**Location:** Sergiev Posad-7, Moscow Region, Russia

**Owner:** Central Institute of Physics and Technology

**Point of contact:** Information not provided

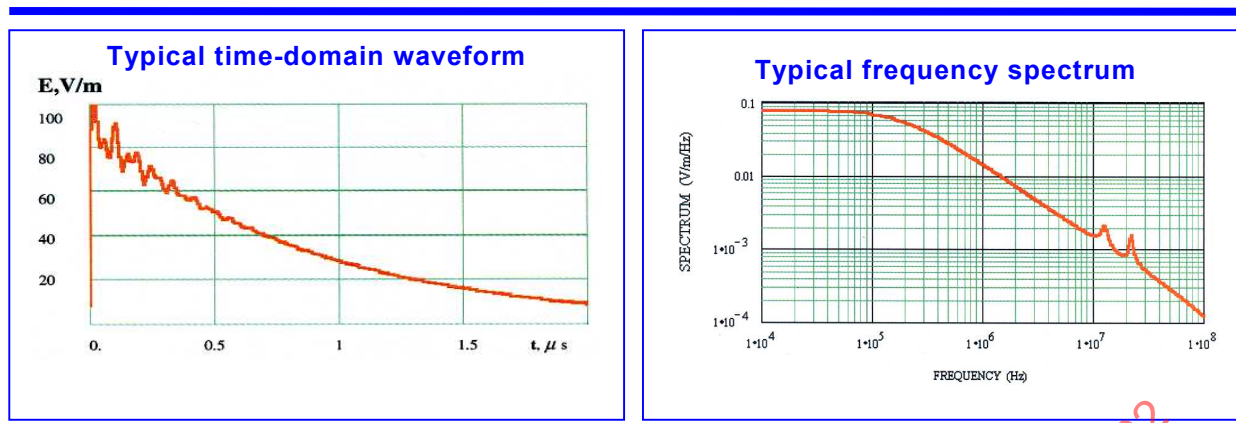
**Initial operation date:** 1982

**Status:** Operational

### Availability

**Other government:** Yes

**Industry:** No



### Other Technical Information

#### General Description

The simulator “ERU-2M” consists of the pulse generator, transition section, three-electrode antenna system, and termination resistors. The transition section adapts the coaxial output of the pulse generator to the balanced transmission line. The top and bottom wire plates are grounded. The terminating resistors are connected between the ends of the wire plates. The simulator is located in a heated hall of dimensions 50mx30mx20m.

#### Available Instrumentation

The simulator has an underground instrumentation room and automated measuring system. The system measures free-space high-amplitude pulsed electric fields with peak amplitudes from 0,5 kV/m to 500 kV/m, 0,5 ns rise time, and pulse durations from 20 ns to 1000 ns.

#### Auxiliary Test Equipment

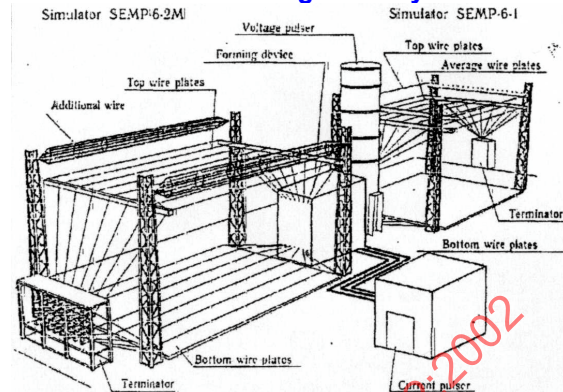
None.

## 7.12.2 Russia – SEMP-6-2M

**SEMP-6 Complex (SEMP-6-2M on left)**



**Simulator geometry**



### General information

**Simulator type:** Guided-wave  
**Termination or resistive loading:** Short output conic section with distributed resistive load  
**Major simulator dimension(s):** 80 m (overall length)  
**Test volume dimensions:** 15 m (high) × 20 m (wide) × 50 m (long)

### Simulator Input Options

**Primary pulse power:** 6-MV Marx generator with pulse-shaping network  
**Repetition rate:** 12 pulses per hour  
**Low-voltage or CW test capability:** Not available

### Electromagnetic characteristics (in test volume unless otherwise noted)

**Electric field polarization:** Vertical  
**Line impedance:** 120 Ω (input to terminator)  
**Wave impedance:** 377 Ω (HEMP spherical wave)  
**Peak electric field:** 20-100 kV/m  
**Peak magnetic field:** 53-265 A/m  
**Pulse rise time:** 9 ns (10-90 %)  
**Prepulse:** Information not provided  
**Pulse width:** 580 ns (1/e)  
**Field uniformity:**

- Excellent (±10 %) uniformity of vertical component
- Fall-off of peak field from front to back of test volume – Information not provided

Horizontal components – Information not provided  
**Other:** Information not provided

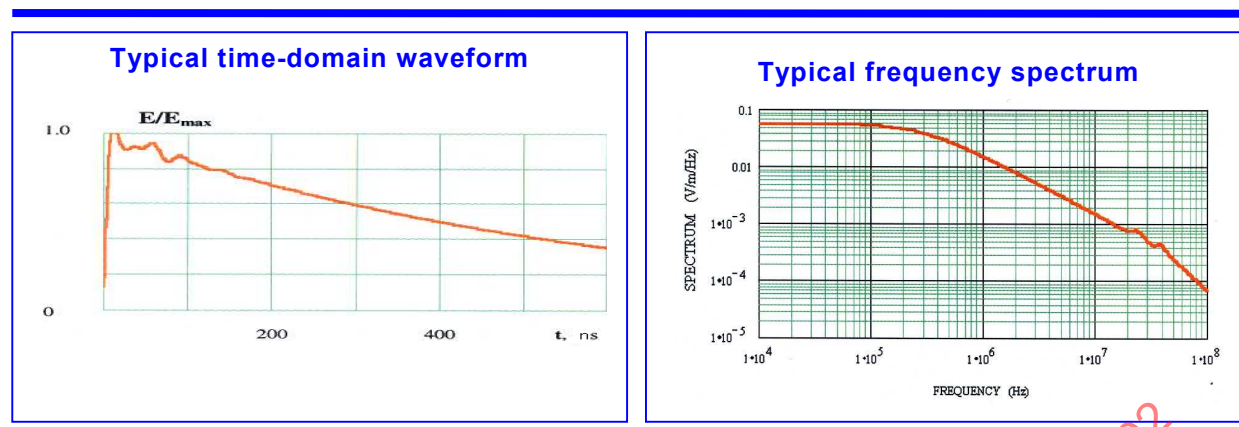
### Other information

**Location:** Sergiev Posad-7, Moscow Region, Russia  
**Owner:** Central Institute of Physics and Technology  
**Point of contact:** Information not provided  
**Initial operation date:** 1982  
**Status:** Operational

### Availability

**Other government:** Yes

**Industry:** No



### Other technical information

#### General description

The SEMP-6-2M simulator consists of 4 Marx-type pulse generators (with maximum voltages up to 6 MV, 250 kV, 50 kV, and 6 kV), a pulse-shaping network, and a 2-plate transmission line with terminator and adjustable capacity. Wires forming the bottom plate of the transmission line are located in the concrete of the test platform. The 6-MV generator produces the fast-rise-time and peak-amplitude portions of the electromagnetic pulse. Auxiliary generators produce the slowly decreasing portion of the electromagnetic pulse.

#### Available instrumentation

The simulator includes an underground instrumentation room and automated measuring system. The measuring system consists of opto-electronic controlled measuring channels, recording devices, control computers with appropriate software, and a protective shielded enclosure. The total number of measuring channels varies from 8 to 80 pieces.

The measuring system includes a variety of different electric field and magnetic field sensors. These sensors provide the measuring of electromagnetic pulse with the following characteristics:

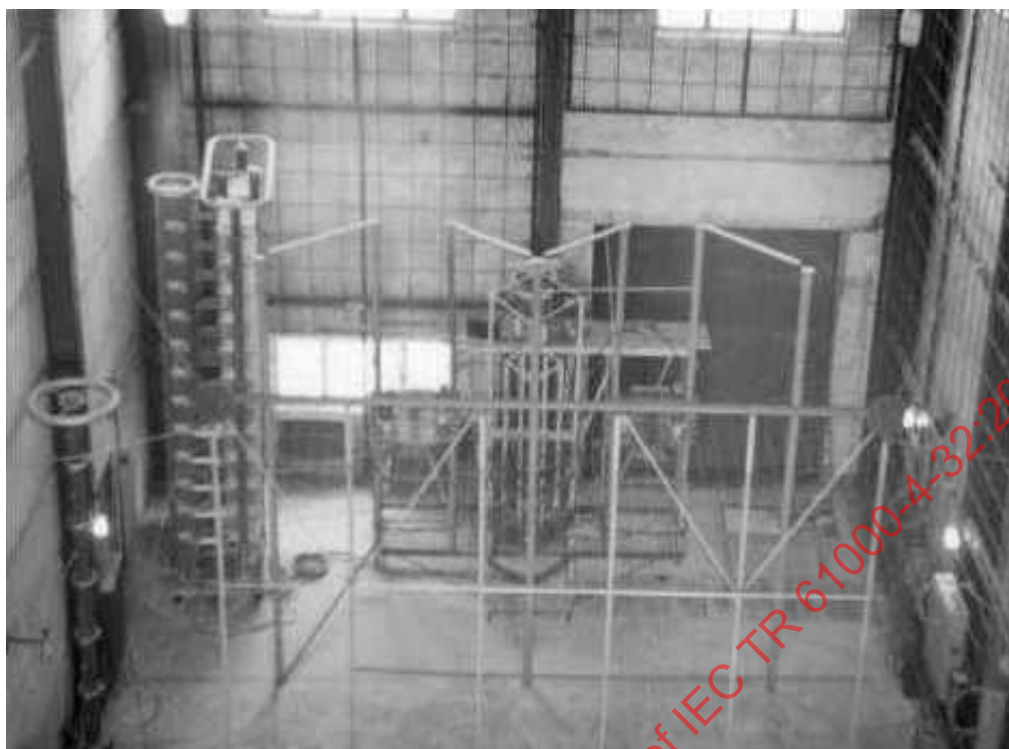
- Amplitude range: 1-500 kV/m;
- Rise time: 5-500 ns;
- Pulse duration: 100 ns -10 ms.

#### Auxiliary test equipment

None



### 7.12.3 Russia – PULSE-M



#### General information

**Simulator type:** Guided-wave (conventional termination)  
**Termination or resistive loading:** 15 m (overall length)  
**Major simulator dimension(s):** 3-6 m plate spacing (variable)  
**Test volume dimensions:** 2,5 m (high) × 5 m (wide) × 10 m (long)  
**Test volume dimensions:** Guided-wave (conventional termination)

#### Simulator input options

**Primary pulse power:** 600-kV Marx generator with pulse-shaping network  
**Repetition rate:** 15 pulses per hour  
**Low-voltage or CW test capability:** Not available

#### Electromagnetic characteristics (in test volume unless otherwise noted)

**Electric field polarization:** Vertical  
**Line impedance:** 150 Ω (input to terminator)  
**Wave impedance:** 377 Ω (HEMP spherical wave)  
**Peak electric field:** 100 kV/m  
**Peak magnetic field:** 265 A/m  
**Pulse rise time:** 5 ns (10-90 %)  
**Prepulse:** Information not provided  
**Pulse width:** 150 ns (1/e)  
**Field uniformity:**

- Fair (±25 %) uniformity of vertical component
- Fall-off of peak field from front to back of test volume – Information not provided
- Horizontal components – Information not provided

**Other:** Indoor EMP simulator.

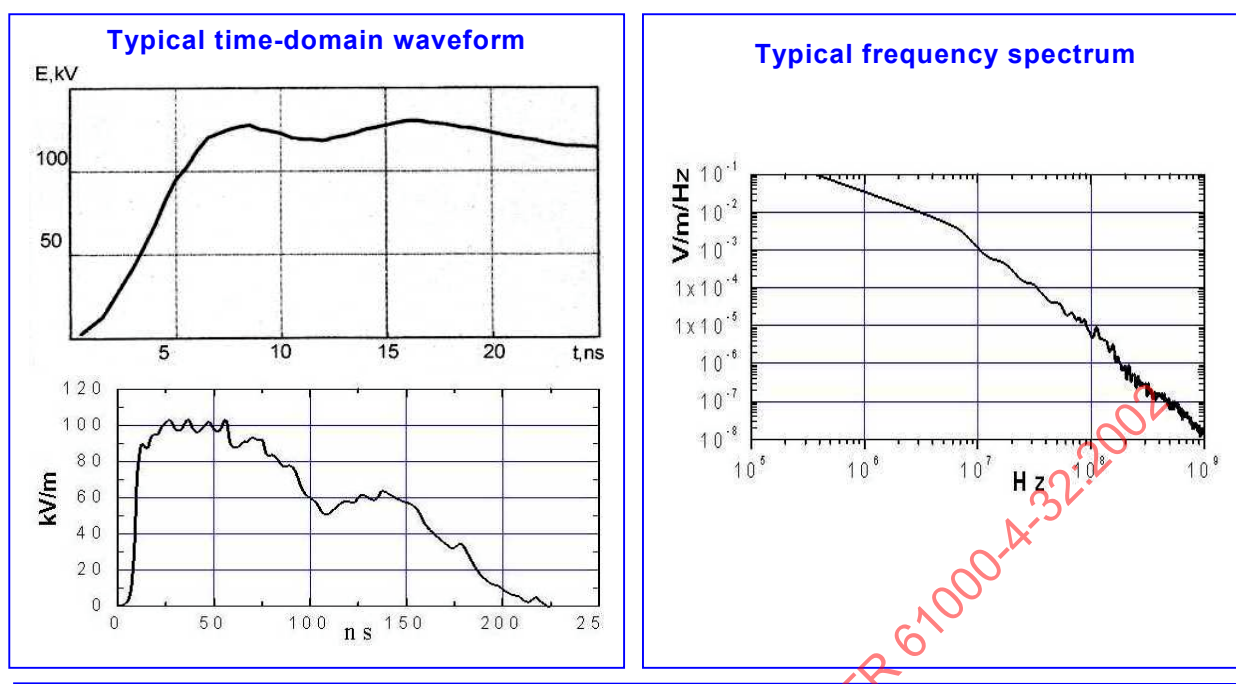
#### Other information

**Location:** St. Petersburg, Russia  
**Owner:** Central Scientific Research Institute  
**Point of contact:** Dr. Vassili M. Kouprienko, Science Research Centre of 26 Central Scientific Research Institute (SRC 26 CSRI), Russian Federation Ministry of Defence, Gangutskaya, 1, 191187 St. Petersburg  
**Initial operation date:** 1993  
**Status:** Operational

#### Availability

**Other government:** Ministry of Defence

**Industry:** Information not provided



### Other technical information

#### General description

This guided-wave EMP simulator is driven at a peak voltage of 600 kV by a 1,5-MV Marx generator. The rise time is 5 ns. The top plate can be at 3 m or 6 m above the ground plane, which is on the floor of the building beneath a wooden floor. The termination assembly is a series-parallel array similar to nearby large outdoor simulators (SEMP-12-1 and SEMP-12-3).

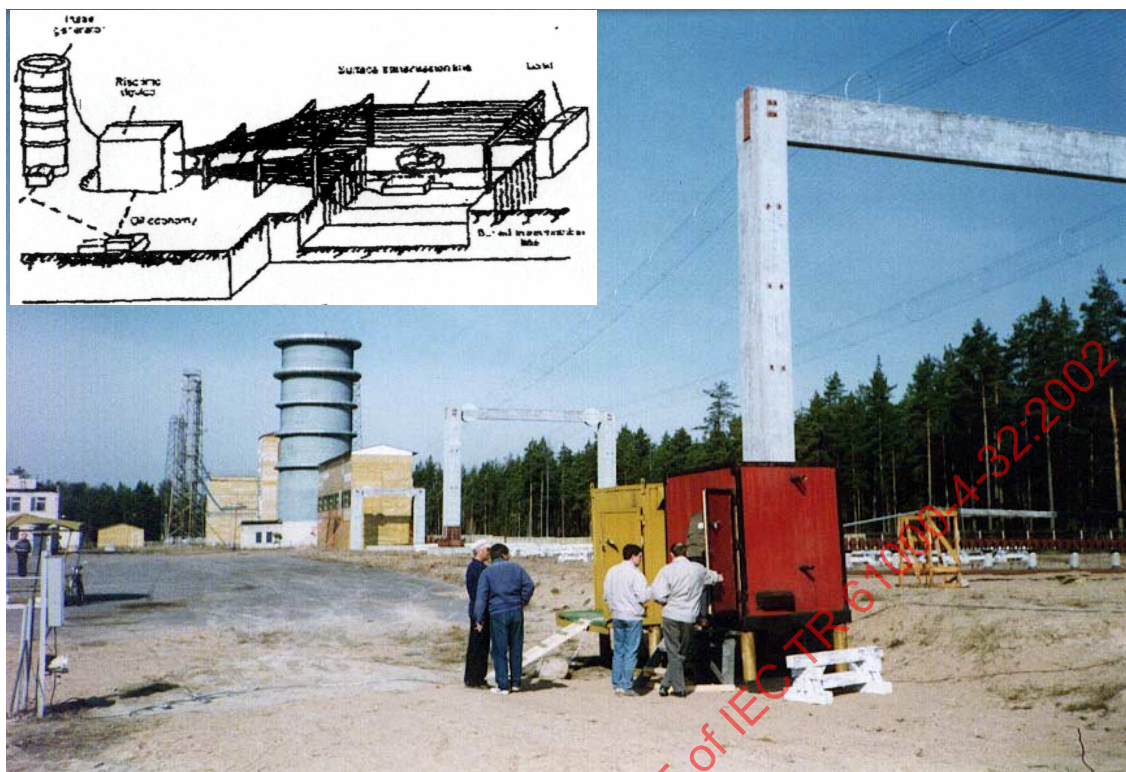
#### Available instrumentation

Information not provided

#### Auxiliary test equipment

Information not provided

### 7.12.4 Russia – SEMP-12-3



#### General information

**Simulator type:** Guided-wave  
**Termination or resistive loading:** Short output conic section with distributed resistive load  
**Major simulator dimension(s):** 170 m (overall length)  
**Test volume dimensions:** 10 m (high) × 15 m (wide) × 100 m (long)

#### Simulator input options

**Primary pulse power:** 2,4-MV Marx generator with pulse-shaping network  
**Repetition rate:** 10 pulses per hour  
**Low-voltage or CW test capability:** Not available

#### Electromagnetic characteristics (in test volume unless otherwise noted)

**Electric field polarization:** Vertical  
**Line impedance:** 110 Ω (input to terminator)  
**Wave impedance:** 377 Ω (HEMP spherical wave)  
**Peak electric field:** 30-200 kV/m  
**Peak magnetic field:** Up to 500 A/m  
**Pulse rise time:** 15-50 ns (10-90 %)  
**Prepulse:** Information not provided  
**Pulse width:** 50-400 ns (1/e)  
**Field uniformity:**

- Fair ( $\pm 25$  %) uniformity of vertical component
- Fall-off of peak field from front to back of test volume – Information not provided
- Horizontal components – Information not provided

**Other:** Conductive ground plane does not extend through test volume allowing test objects to be located either above or below the surface of the ground

#### Other information

**Location:** St. Petersburg, Russia  
**Owner:** Central Scientific Research Institute  
**Point of contact:** Dr. Vassili M. Kouprienko, Science Research Center of 26 Central Scientific Research Institute (SRC 26 CSRI), Russian Federation Ministry of Defense, Gangutskaya, 1, 191187 St. Petersburg  
 Fax: 7-812-279-753  
**Initial operation date:** 1992  
**Status:** Operational

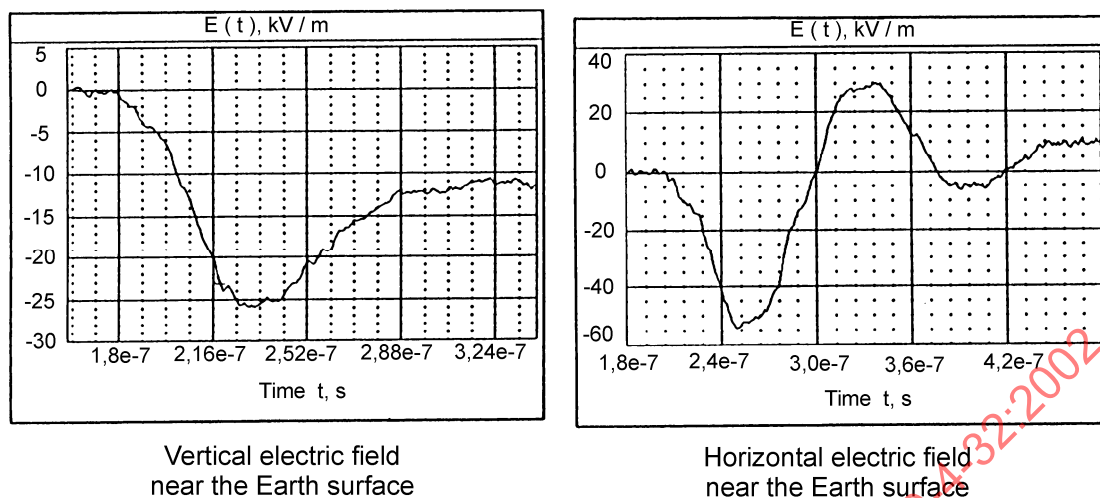
#### Availability

**Other government:** Ministry of Defence

**Industry:** Information not provided



### Typical time-domain waveforms (frequency-domain data not provided)



### Other technical information

#### General description

The SEMP-12-3 simulator consists of a Marx-type pulse generator, a pulse-shaping network, a 2-plate transmission line with conic transition section, and matched resistive load. The discontinuous underground transmission line works with the continuous top plate to guide the electromagnetic wave across the working volume region. In addition to vertical electric field components in the region of the working volume in air, horizontal components of the electric and magnetic fields are formed in the region of the working volume in the ground. This allows test objects to be located either above or below the surface of the ground.

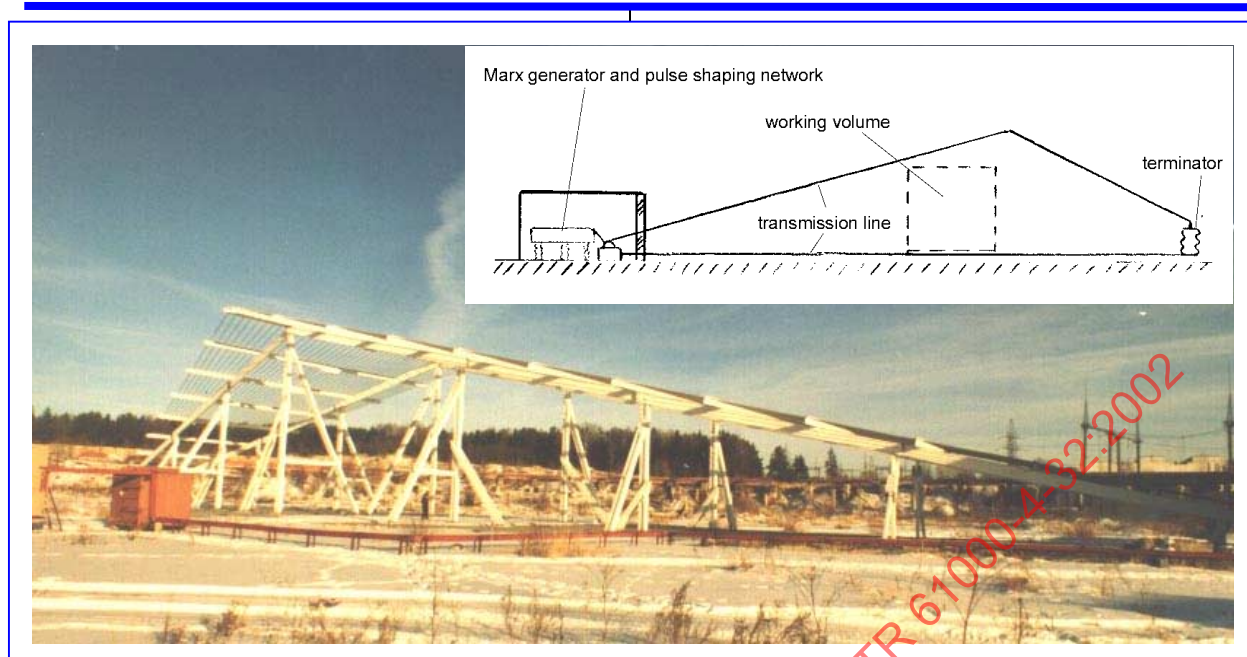
#### Available instrumentation

Information not provided

#### Auxiliary test equipment

Information not provided

## 7.12.5 Russia – SEMP-1,5 (simulator of the electromagnetic pulse)



### General information

**Simulator type:** Guided-wave  
**Termination or resistive loading:** Conventional – Output conic section with approximately point resistive load  
**Major simulator dimension(s):** 100 m (overall length)  
**Test volume Dimensions:** 10 m (high) × 10 m (wide) × 10 m (long)

### Simulator input options

**Primary pulse power:** 1,5-MV Marx generator with pulse-shaping network  
**Repetition rate:** 20 pulses per hour  
**Low-voltage or CW test capability:** Not available

### Electromagnetic characteristics (in test volume unless otherwise noted)

**Electric field polarization:** Vertical  
**Line impedance:** 100  $\Omega$  (input to terminator)  
**Wave impedance:** 377  $\Omega$  (HEMP spherical wave)  
**Peak electric field:** 20-100 kV/m  
**Peak magnetic field:** 50-250 A/m  
**Pulse rise time:** 5-12 ns (10-90 %)  
**Prepulse:** Information not provided  
**Pulse width:** 35 to 850 ns (1/e)  
**Field uniformity:**  $\pm 20$  % in test volume  
**Other:** Information not provided

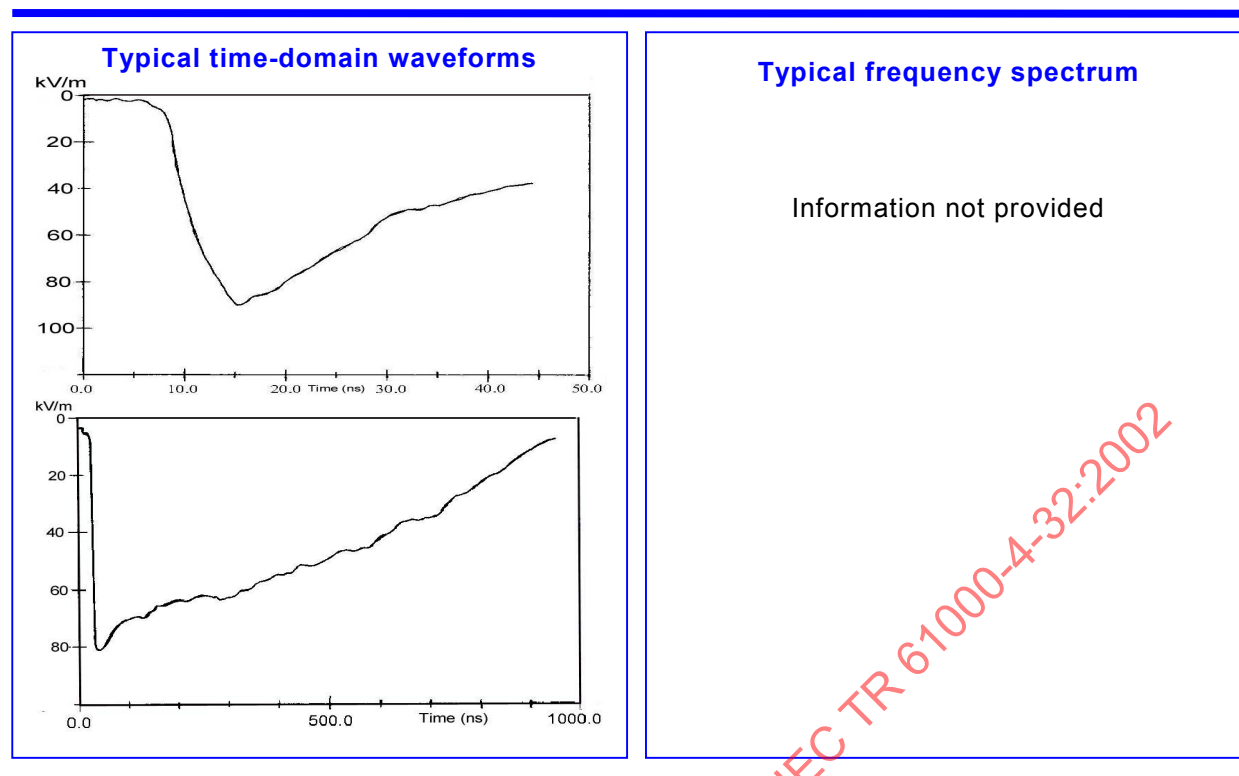
### Other information

**Location:** Istra, Moscow region, 143500, Russia  
**Owner:** High-voltage Scientific – Research Centre of V.I. Lenin All-Russian Electrotechnical Institute (VNITs VEI)  
**Point of contact:** Dr. Alexander F. Kharchenko, VNITs VEI, 143500, Istra, Moscow region, Fax: 7-095-994-5107  
**Initial operation date:** 1998  
**Status:** Operational

### Availability

**Other government:** Yes

**Industry:** Information not provided



### Other technical information

#### General description

Simulator consists of Marx-type pulse generators with the maximum voltage up to 1,5 MV, a pulse-shaping network and transmission line with terminator. Bottom wire plate of transmission line is located in concrete of a test platform. The rise time and amplitude of electromagnetic pulse are reproduced by 1,5 MV generator.

#### Available instrumentation

The simulator has an automatic measuring system. The measuring system consists of opto-electronic controlled measuring channels, recording devices, control computers with appropriate software and a protective shielded enclosure. The total number of measuring channel varies from 2 to 4 pieces.

The measuring system has electric field and magnetic field sensors. These sensors provide the measuring of electromagnetic pulse with the following characteristics:

- Amplitude range: 10-200 kV/m
- Rise time: 2-50 ns
- Pulse duration: 10-1,5  $\mu$ s

#### Auxiliary test equipment

Information not provided

## 7.13.1 Sweden – SAPIENS 2

Terminator-Transmission Line-Pulser Building (SPERANS at right rear)



### General information

**Simulator type:** Guided-wave  
**Termination or resistive loading:** No output conic section with sparse, distributed resistive load  
**Major simulator dimension(s):** 90 m (length) (130 m including termination) × 30 m (wide) × 18 m (high)  
**Test volume dimensions:** 5 m (high) × 10 m (wide) × 10 m (long)

### Simulator input options

**Primary pulse power:** 1-MV Marx generator with pulse-shaping network  
**Repetition rate:** 1 shot per minute  
**Low-voltage or CW test capability:** Not available

### Electromagnetic characteristics (in test volume unless otherwise noted)

**Line impedance:** 100 Ω (input to terminator)  
**Electric field polarization:** Vertical  
**Wave impedance:** 377 Ω (HEMP spherical wave)  
**Peak electric field:** >50 kV/m  
**Peak magnetic field:** >132 A/m  
**Pulse rise time:** 5 ± 1 ns (10-90 %)  
**Prepulse:** <10 %  
**Pulse width:** 150 ns (FWHM)  
**Field uniformity:**

- <10 % uniformity of vertical component
- 15 % fall-off of peak field from front to back of test volume (angle of inclination 11°)

Horizontal components <10 % of vertical component  
**Other:** Tests can be performed in lower conic section for higher peak field values (up to 600 kV/m).

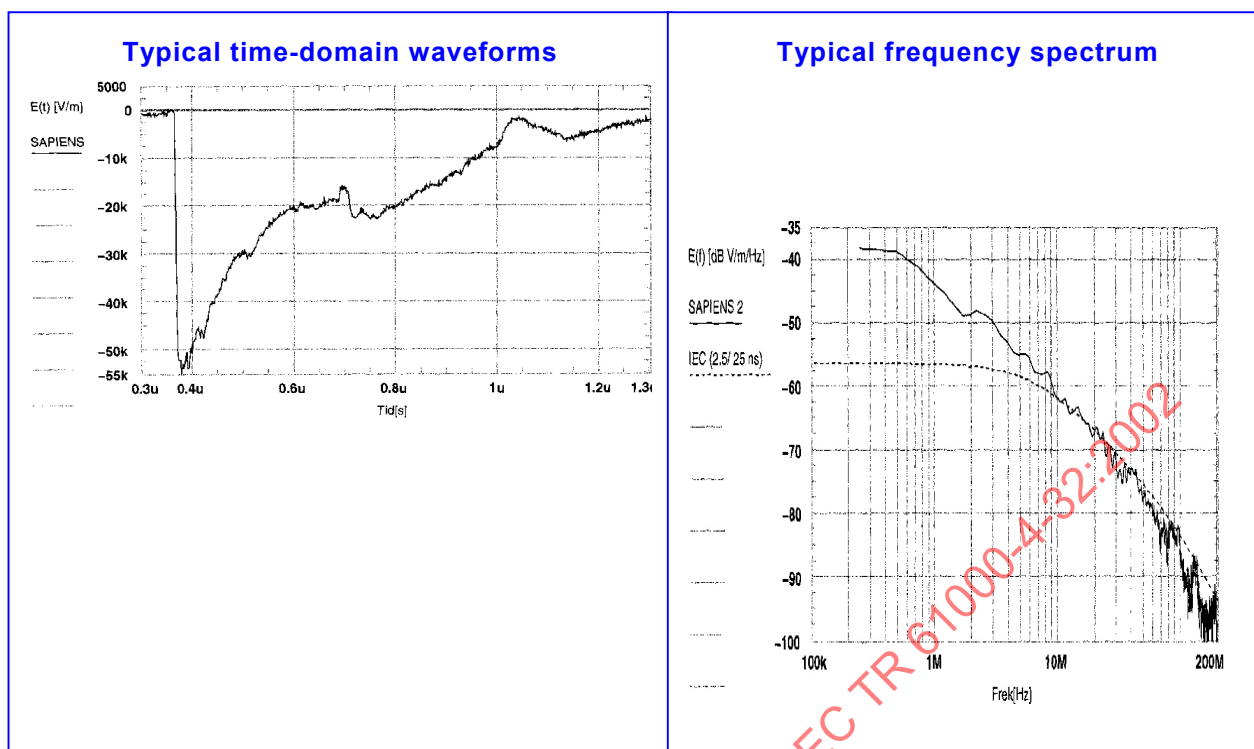
### Other information

**Location:** Linköping, Sweden  
**Owner:** Swedish Defence Material Administration  
**Point of contact:** Per Bohlin, FMV:PROV, P.O. Box 13400, SE-580 13 Linköping, Sweden  
Telephone: 46-13 24 34 31  
Fax: 46-13 24 83 42  
E-mail: peboh@fmv.se  
**Initial operation date:** 1990  
**Status:** Operational

### Availability

**Other government:** Yes

**Industry:** Yes



## Other technical information

### General description

The top-plate of the simulator is a corrugated steel sheet with metallic beams. This is done to withstand snow and ice loads in wintertime. The top-plate can be used to hang up exposed cables to maximize the current. It is also possible to connect a cable direct to the top-plate via a resistor (for example, 400  $\Omega$ ).

### Available instrumentation

Several complete measurement links with 500-MHz and 1 with 1-GHz bandwidth are available.

- Sensors: D-dot (E-field), B-dot (H-field), current probes, voltage probes
- Transformer: Integrator (active and passive)
- Links: Coaxial cables, fibre optical links
- Digitizing oscilloscope: Nominal 2 Gsample/s max. 4 Gsample/s
- Computer programme: Special design for pulse measurements
- Network analyser: To calibrate every part in the measure system

### Auxiliary test equipment

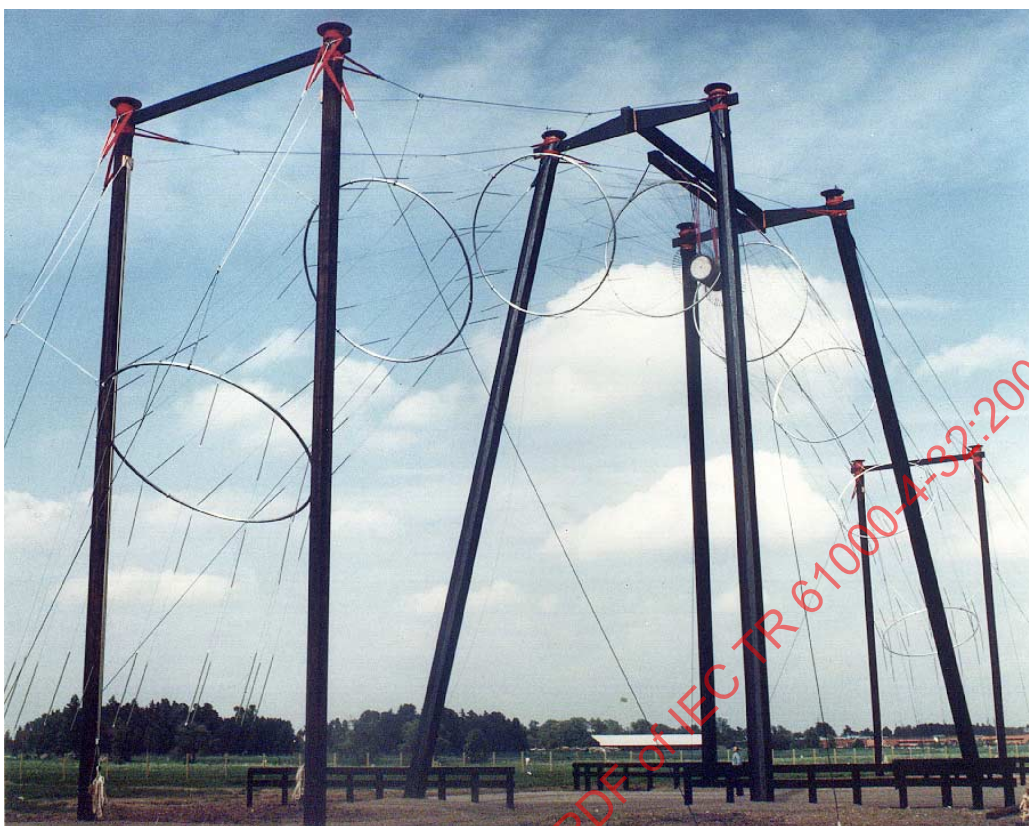
It is possible to make current injection inside the simulator as described in general description.

A mobile current injection system with max. 2 kA is available.

Complete instrumentation to make LLCW-testing (Low levels continuous wave) including computer programme to handle the data in both frequency and time domain.



## 7.13.2 Sweden – SPERANS



### General information

**Simulator type:** Hybrid  
**Termination or resistive loading:** Uniform, sparse, distributed antenna resistive loading  
**Major simulator dimension(s):** 150 m overall length  
**Test volume dimensions:** 20 m pulser centre-line height  
 Information not provided

### Simulator input options

**Primary pulse power:** 200-kV generator  
**Repetition rate:** 5 pulses per minute  
**Low-voltage or CW test capability:** Not available

### Electromagnetic characteristics (in test volume unless otherwise noted)

**Electric field polarization:** Horizontal (early times)  
**Bicone impedance:** 150  $\Omega$   
**Wave impedance:** 377  $\Omega$  (early times)  
**Peak electric field:** 4 kV/m @ 20 m from the pulser apex  
**Peak magnetic field:** 11 A/m @ 20 m from the pulser apex  
**Pulse rise time:** 2,5  $\pm$  0,5 ns (10-90 %)  
**Prepulse:** <10 %  
**Pulse width:** Information not provided  
**Field uniformity:**

- Peak horizontal E-field parallel to simulator axis – Information not provided
- Vertical and other non-principal components – Information not provided

**Other:** Information not provided

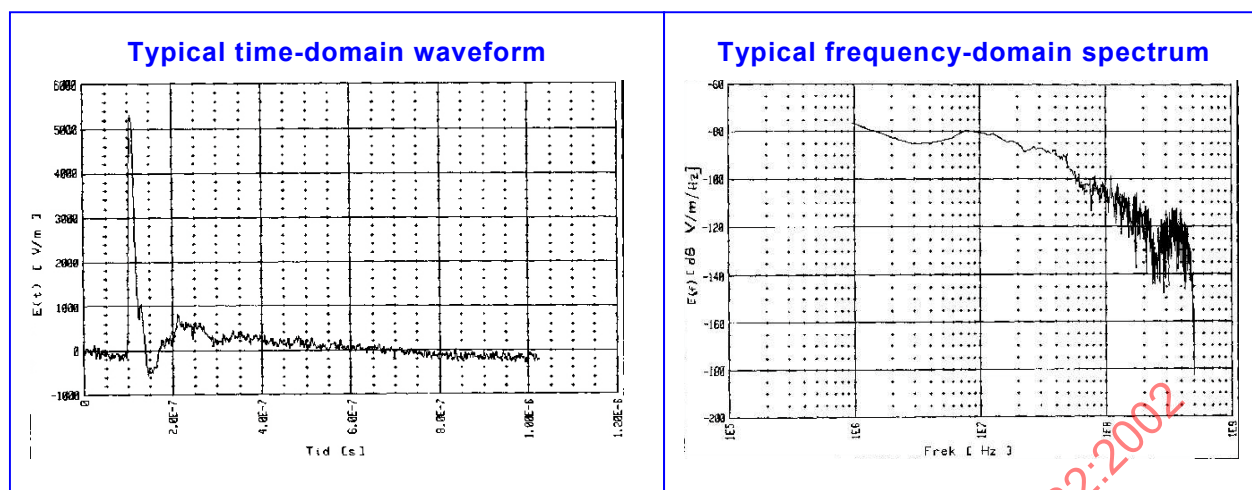
### Other information

**Location:** Linköping, Sweden  
**Owner:** Swedish Defence Material Administration  
**Point of contact:** Per Bohlin, FMV:PROV, P.O. Box 13400, SE-580 13 Linköping, Sweden  
 Telephone: 46-13 24 34 31  
 Fax: 46-13 24 83 42  
 E-mail: peboh@fmv.se  
**Initial operation date:** 1984  
**Status:** Stand-by

### Availability

**Government:** Yes

**Industry:** Yes



### General description

Information not provided

### Available instrumentation

Several complete measurement links with 500-MHz and 1 with 1-GHz bandwidth are available.

- Sensors: D-dot (E-field), B-dot (H-field), current probes, voltage probes
- Transformer: Integrator (active and passive)
- Links: Coaxial cables, fibre optical links
- Digitizing oscilloscope: Nominal 2 Gsample/s max. 4 Gsample/s.
- Computer programme: Special design for pulse measurements
- Network analyser: To calibrate every part in the measure system

### Other technical information

#### Auxiliary test equipment

It is possible to make current injection inside the simulator as described in the general description.

A mobile current injection system with max. 2 kA is available.

Complete instrumentation to make LLCW-testing (low levels continuous wave) including computer programme to handle the data in both frequency and time domain.



### 7.14.1 Switzerland – MEMPS (Mobile EMP simulator)



#### General information

**Simulator type:** Hybrid  
**Termination or resistive loading:** Uniform, sparse, distributed antenna resistive loading  
**Major simulator dimension(s):** 60 m overall length  
 20 m pulser centre-line height  
**Test volume dimensions:** 10 m (high) × 10 m (wide) × 20 m (long)

#### Simulator input options

**Primary pulse power:** 4-MV Marx generator with peaking capacitors  
**Repetition rate:** 20 pulses per hour  
**Low-voltage or CW test capability:** CW available.

#### Electromagnetic characteristics

(in test volume unless otherwise noted)

**Electric field polarization:** Horizontal (early times)  
**Bicone impedance:** 150 Ω  
**Wave Impedance:** 377 Ω (early times)  
**Peak electric field:** 60 kV/m @ 20 m from the pulser apex  
**Peak magnetic field:** 150 A/m @ 30 m from the pulser apex  
**Pulse rise time:** <10 ns (10-90 %)  
**Prepulse:** ≤10 %  
**Pulse width:** ~90 ns (FWHM; complicated function of position)  
**Field uniformity:**

- Peak horizontal E-field parallel to simulator axis 110 kV/m maximum and 30 kV/m minimum in test volume
- Vertical and other non-principal components: complicated function of position

**Other:** Transportable

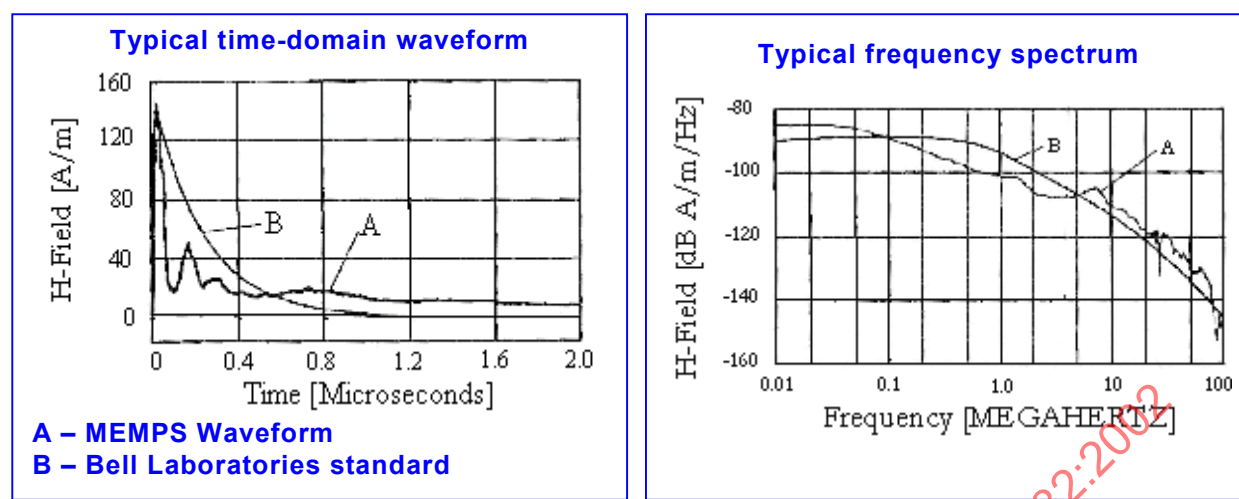
#### Other information

**Location:** Spiez, Switzerland  
**Owner:** Defence Procurement Agency, NEMP-Laboratory, AC-Zentrum  
**Point of contact:** Markus Nyffeler, Defence Procurement Agency, NEMP-Laboratory, AC-Zentrum, CH-3700, Spiez  
 Telephone: +41-33-228-1839  
 Fax: +41-33-228-1833  
 E-mail: markus.nyffeler@gr.admin.ch  
**Initial operation date:** 1985  
**Status:** Stand-by

#### Availability

**Other government:** Yes

**Industry:** Yes



### Other technical information

#### General description

MEMPS (Mobile EMP simulator) is designed as a mobile system for EMP-hardness assessment of fixed facilities. It can be transported by truck or helicopter, but it is presently installed in a fixed facility in Spiez, Switzerland.

#### Available instrumentation

The following measurement instrumentation is available:

E-field-sensors (D-dot-sensors)

Free-field sensors: < 0,01 mV/m to 1 MV/m

Ground reference field sensors: < 0,1 mV/m to 1 MV/m

H-field-sensors

Free field sensors: < 0,1 mA/m to 2,5 kA/m

Ground reference field sensors: < 1 mA/m to 2,5 kA/m

Current probes

Ranges from < 1 A to 6000 A

Bandwidth up to 1 GHz

Fibre-optic links

for disturbance-free measurements, various types in use, bandwidths up to 5 GHz

Digitizer

Various types, bandwidth up to 3 GHz (single-shot) and 10 Gs/s sampling rate

#### Auxiliary test equipment

Personal computers and special software are used to control the EMP simulator and the measurement instrumentation and to analyse, plot, and store the test data.

## 7.14.2 Switzerland – VEPES (Vertical polarized EMP simulator)

### Pulse generator building – Transmission line – Terminator



#### General information

**Simulator type:** Guided-wave  
**Termination or resistive loading:** No load conic section; sparse, distributed resistive load  
**Major simulator dimension(s):** 55 m (length)  
**Test volume dimensions:** 4m (high) × 8m (wide) × 10m (long)

#### Simulator Input Options

**Primary pulse power:** 0,85-MV Marx generator with pulse-shaping network  
**Repetition rate:** 60 shots per hour  
**Low-voltage or CW test capability:** Not available

#### Electromagnetic characteristics (in test volume unless otherwise noted)

**Line impedance:** 90 Ω (input to terminator)  
**Electric field polarization:** Vertical  
**Wave impedance:** 377 Ω (HEMP spherical wave)  
**Peak electric field:** 150 kV/m  
**Peak magnetic field:** 400 A/m  
**Pulse rise time:** <8 ns (10 %-90 %)  
**Prepulse:** ≤10 %  
**Pulse width:** ~300 ns FWHM  
**Field uniformity:**

- Fair (±40 %) uniformity of vertical component
- 40 % fall-off of peak field from front to back of test volume
- Horizontal components ≤30 % of vertical component

**Other:** Tests can be performed in input conic section for higher peak field values (up to 500 kV/m) for smaller test objects

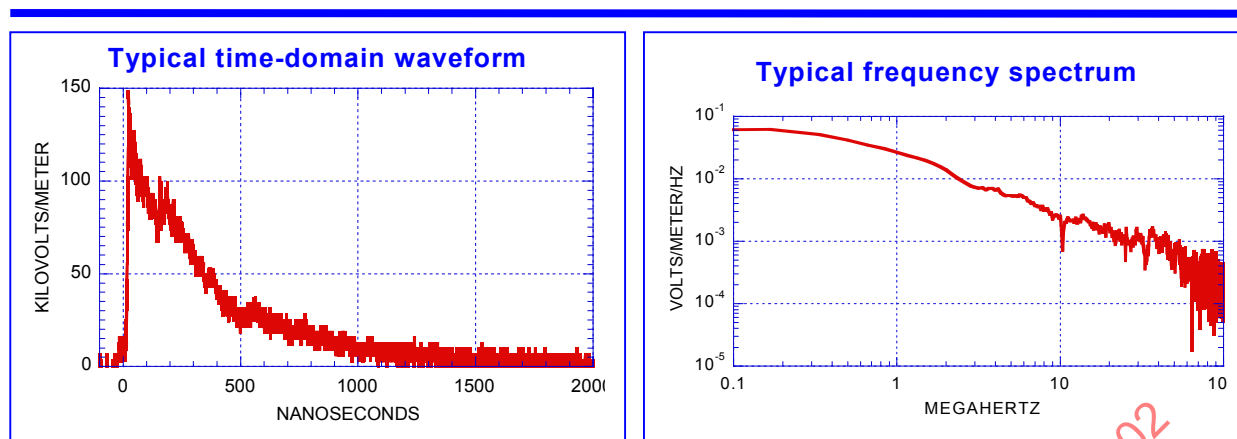
#### Other information

**Location:** Spiez, Switzerland  
**Owner:** Defence Procurement Agency, NEMP-Laboratory, AC-Zentrum  
**Point of contact:** Markus Nyffeler, Defence Procurement Agency, NEMP-Laboratory, AC-Zentrum, CH-3700, Spiez  
 Telephone: +41-33-228-1839  
 Fax: +41-33-228-1833  
 E-mail: markus.nyffeler@gr.admin.ch  
**Initial operation date:** 1989  
**Status:** Operational

#### Availability

**Other government:** Yes

**Industry:** Yes



## Other technical information

### General description

VEPES (Vertical polarized EMP simulator) is Switzerland's largest plan-wave EMP-simulator. It is designed to simulate HEMP environments similar as defined by Bell Laboratories or RS05 in MIL-STD 461C.

VEPES provides test capabilities for large, mobile test objects.

### Available instrumentation

The following measurement instrumentation are available:

E-field-sensors (D-dot-sensors)

Free-field sensors: < 0,01 mV/m to 1 MV/m

Ground reference field sensors: < 0,1 mV/m to 1 MV/m

H-field-sensors

Free-field sensors: < 0,1 mA/m to 2,5 kA/m

Ground reference field sensors: < 1 mA/m to 2,5 kA/m

Current probes

Ranges from < 1 A to 6 000 A

Bandwidth up to 1 GHz

Fibre-optic links

for disturbance-free measurements, various types in use, bandwidths up to 5 GHz

Digitizer

Various types, bandwidth up to 3 GHz (single-shot) and 10 Gs/s sampling rate

### Auxiliary test equipment

Personal computers and special software are used to control the EMP simulator and the measurement instrumentation and to analyse, plot, and store the test data.



### 7.14.3 Switzerland – VERIFY (Vertical EMP radiating indoor facility)

Terminator – Transmission line – Pulse generator



#### General information

**Simulator type:** Guided-wave  
**Termination or resistive loading:** No load conic section, sparse, distributed resistive load  
**Major simulator dimension(s):** 20 m (length)  
**Test volume dimensions:** 2,5 m (high) × 4 m (wide) × 4 m (long)

#### Simulator input options

**Primary pulse power:** 0,6-MV Marx generator with pulse-shaping network  
**Repetition rate:** >60 shots per hour  
**Low-voltage or CW test capability:** Not available

#### Electromagnetic characteristics

(in test volume unless otherwise noted)

**Line Impedance:** 100  $\Omega$  (input to terminator)  
**Electric Field Polarization:** Vertical  
**Wave Impedance:** 377  $\Omega$  (HEMP spherical wave)  
**Peak Electric Field:** 100 kV/m  
**Peak Magnetic Field:** 260 A/m  
**Pulse Rise Time:** <1 ns (10-90 %)  
**Prepulse:**  $\leq 8$  %  
**Pulse Width:** 24-36 ns FWHM  
**Field Uniformity:**

- Excellent (better  $\pm 10$  %) uniformity of vertical component
- <20 % fall-off of peak field from front to back of test volume
- Horizontal components <20 % of vertical component

**Other:** Indoor simulator. Tests can be performed in input conic section for higher peak field values (up to 500 kV/m) for smaller objects.

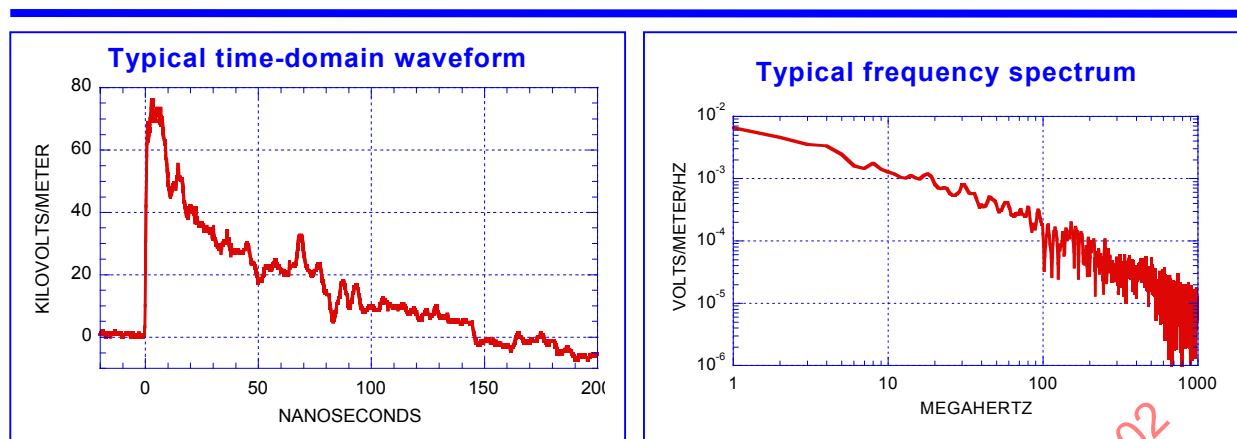
#### Other information

**Location:** Spiez, Switzerland  
**Owner:** Defence Procurement Agency, NEMP-Laboratory, AC-Zentrum  
**Point of contact:** Markus Nyffeler, Defence Procurement Agency, NEMP-Laboratory, AC-Zentrum, CH-3700, Spiez  
 Telephone: +41-33-228-1839  
 Fax: +41-33-228-1833  
 E-mail: markus.nyffeler@gr.admin.ch  
**Initial operation date:** 1999  
**Status:** Operational

#### Availability

**Other government:** Yes

**Industry:** Yes



## Other technical information

### General fescription

VERIFY (Vertical EMP radiating indoor facility) replaces Switzerland's first EMP-simulator HEISS. It is designed to simulate the latest HEMP environments. Positive or negative output pulses can be chosen.

As an indoor facility, it provides all-weather test capabilities for test objects not exceeding the test volume dimensions. The building consist mainly of dielectric material. The wall facing the antenna termination is covered with EM-absorbers.

### Available instrumentation

The following measurement instrumentation is available:

E-field-sensors (D-dot-sensors)

Free-field sensors: < 0,01 mV/m to 1 MV/m

Ground reference field sensors: < 0,1 mV/m to 1 MV/m

H-field-sensors

Free-field sensors: < 0,1 mA/m to 2,5 kA/m

Ground reference field sensors: < 1 mA/m to 2,5 kA/m

Current probes

Ranges from < 1 A to 6000 A

Bandwidth up to 1 GHz

Fibre-optic links

for disturbance-free measurements, various types in use, bandwidths up to 5 GHz

Digitizer

Various types, bandwidth up to 3 GHz (single-shot) and 10 Gs/s sampling rate

### Auxiliary test equipment

Personal computers and special software are used to control the EMP simulator and the measurement instrumentation and to analyse, plot, and store the test data.



## 7.14.4 Switzerland – SEMIRAMIS

### Terminator – Transmission line – Input for pulse generator



#### General information

**Simulator type:** Guided-wave  
**Termination or resistive loading:** Distributed resistive load  
**Major simulator dimension(s):** 10 m (length)  
**Test volume dimensions:** 1 m (high) × 1 m (wide) × 3 m (long)

#### Simulator Input Options

**Primary pulse power:** 100 kV generator with pulse-shaping network  
**Repetition rate:** Information not provided  
**Low-voltage or CW test capability:** Information not provided

#### Electromagnetic characteristics

(in test volume unless otherwise noted)

**Line impedance:** 100  $\Omega$  (input to terminator)  
**Electric field polarization:** Vertical  
**Wave impedance:** 377  $\Omega$  (HEMP spherical wave)  
**Peak electric field:** 62,5 kV/m  
**Peak magnetic field:** 166,67 A/m  
**Pulse rise time:** <10 ns (10-90 %)  
**Prepulse:** Information not provided  
**Pulse width:** About 200 ns (1/e)  
**Field uniformity:**

- $\pm 1,5$  dB uniformity of vertical component in the working volume
- 12 % fall-off of peak field from front to back of test volume
- Horizontal E-field component about 1 % of vertical component

**Other:** Information not provided

#### Other information

**Location:** Lausanne, Switzerland  
**Owner:** Swiss Federal Institute of Technology

**Point of contact:** Prof. M. Ianoz/Dr. F. Rachidi,  
 Power System Laboratory,  
 Swiss Federal Institute of Technology, CH-1015  
 Lausanne, Switzerland  
 Phone: 41-21-693-2664/2620  
 Fax: 41-21-693-4662  
 E-mail: michel.ianoz@epfl.ch/  
 farhad.rachidi@epfl.ch

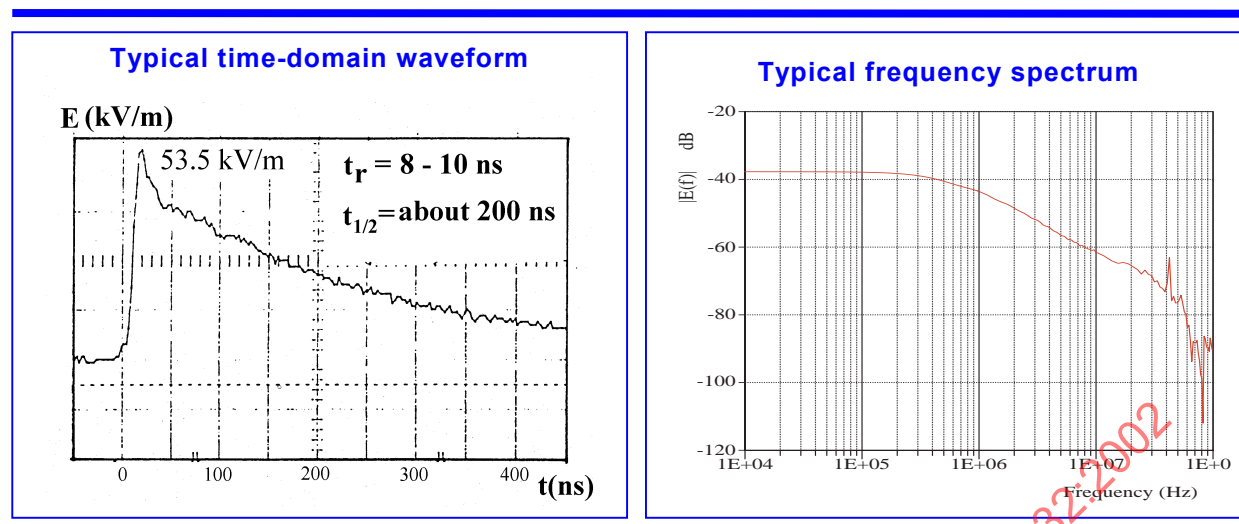
**Initial operation date:** 1991

**Status:** Operational

#### Availability

**Other government:** Yes

**Industry:** Information not provided



### Other technical information

#### General description

The initial ELGAL design of the antenna was improved to reach the present parameters (see F. Arreghini, M. Ianoz, P. Zweiacker, D.V. Giri, A. Tehori, "SEMIRAMIS : an asymmetrical bounded wave EMP simulator with a good confinement inside the transmission line", Proc. 10th Int. Zurich Symp. On EMC, 9-11 March 1993, paper 109P5).

#### Available instrumentation

Thomson CSF "Melopée" chain, E-field and H-field sensors, frequency range : 1 kHz to 200 MHz or 100 kHz to 1 GHz

Various current sensors up to 200 MHz.

#### Auxiliary test equipment

Information not provided

## 7.15.1 Ukraine – GIN-1,6-5

Transmission line, test volume, and termination



Transmission line and pulse generator building



### General information

**Simulator type:** Guided-wave  
**Termination or resistive loading:** Short output conic section with distributed resistive load  
**Major simulator dimension(s):** 48 m (overall length)  
 5 m (plate spacing)  
**Test volume dimensions:** 5 m (high) × 5,6 m (wide) × 15 m (long)

### Simulator input options

**Primary pulse power:** 1,6-MV Marx generator with pulse-shaping network  
**Repetition rate:** 12 pulses per hour  
**Low-voltage or CW test capability:** Not available

### Electromagnetic characteristics (in test volume unless otherwise noted)

**Electric field polarization:** Vertical  
**Line impedance:** 100 Ω (input to terminator)  
**Wave impedance:** 377 Ω (HEMP spherical wave)  
**Peak electric field:** 50-150 kV/m  
**Peak magnetic field:** 150-400 A/m  
**Pulse Rise Time:** 5-10 ns (10-90 %)  
**Prepulse:** None  
**Pulse Width:** 200-2 500 ns (FWHM)  
**Field Uniformity:**

- Good (±10 %) uniformity of vertical component
- Fall-off of peak field from front to back of test volume – Information not provided
- Horizontal components 50 % of vertical component (when test object on isolation platform under 26° section)

**Other:** Simulator has an underground instrumentation room.

### Other information

**Location:** Kharkov, Ukraine

**Owner:** Research and Engineering Institute "Molniya"

**Point of contact:** Dr. Vladimir Ivanovich Kravchenko, Director  
 Research and Engineering Institute "Molniya," Kharkov State Polytechnical University,  
 Shevchenko St., 47,  
 61013 Kharkov  
 Fax: 380-572-400133

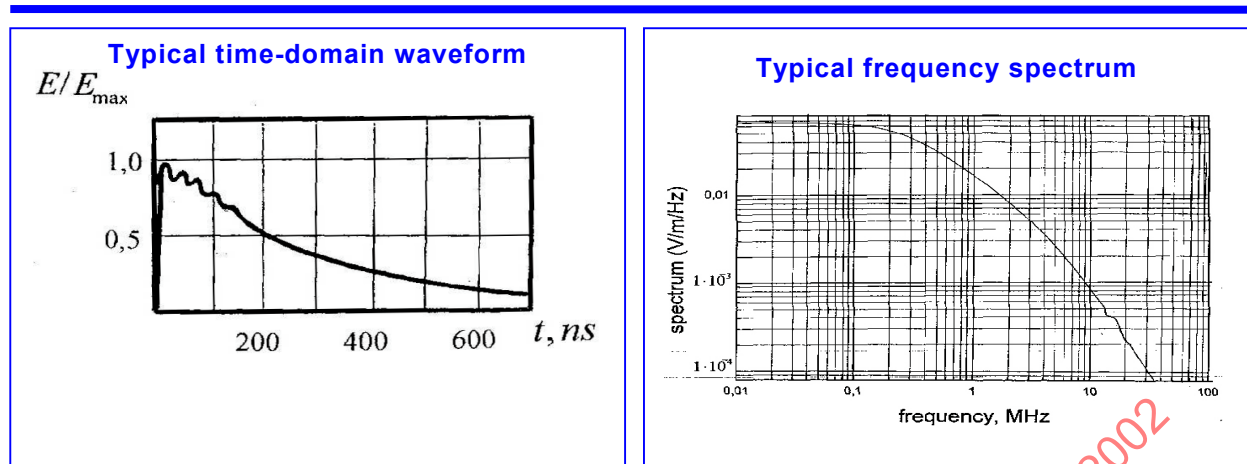
**Initial operation date:** 1976

**Status:** Operational

### Availability

**Other government:** Yes

**Industry:** No



### Other technical information

#### General description

The GIN-1,6-5 simulator consists of 5 Marx-type pulse generators of the special wave construction (with maximum voltages up to 1,8 MV, 1,6 MV, 0,8 MV, 0,4 MV, and 0,2 MV) and a 2-plate transmission line with conic transition sections, and a matched resistive load. Wires forming the bottom-plate of the transmission line are located in the concrete of the test volume platform. The 1,6-MV generator produces portions of the electromagnetic pulse. Auxiliary generators produce the slowly decreasing portion of the electromagnetic pulse.

#### Available instrumentation

The simulator includes an underground instrumentation room and measuring system. The measuring system consists of opto-electronic-controlled measuring channels, recording devices, and a protective shielded enclosure. The total number of measuring channels varies from 2 to 10 pieces.

The measuring system includes a variety of different electric field and magnetic field sensors. These provide the measurement of electromagnetic pulses with the following characteristics:

- Amplitude range: 1-500 kV/m
- Rise time: 2-500 ns
- Pulse duration: 10-1 000 ns

#### Auxiliary test equipment

None

## 7.15.2 Ukraine – GINT-12-30

Pulse generator building



Transmission line and terminator



### General information

**Simulator type:** Guided-wave  
**Termination or resistive loading:** Short output conic section with distributed resistive load  
**Major simulator dimension(s):** 254 m (overall length)  
**Test volume dimensions:** 30 m (high) × 50 m (wide) × 50 m (long)

### Simulator input options

**Primary pulse power:** 4,5-MV Marx generator with pulse-shaping network  
**Repetition rate:** 12 pulses per hour  
**Low-voltage or CW test capability:** Not available

### Electromagnetic characteristics

(in test volume unless otherwise noted)

**Electric field polarization:** Vertical  
**Line impedance:** 100 Ohms (input to terminator)  
**Wave impedance:** 377 Ohms (HEMP spherical wave)  
**Peak electric field:** 100-120 kV/m  
**Peak magnetic field:** 265-318 A/m  
**Pulse rise time:** 5-10 ns (10 %-90 %)  
**Prepulse:** None  
**Pulse width:** 200-280 ns (FWHM)  
**Field uniformity:**

- Good ( $\pm 10$  %) uniformity of vertical component
- Fall-off of peak field from front to back of test volume – Information not provided
- Horizontal components 50 % of vertical component (when test object placed under 26° section)

**Other:** Dielectric stand in working volume for elevating test object. Simulator has an underground instrumentation room

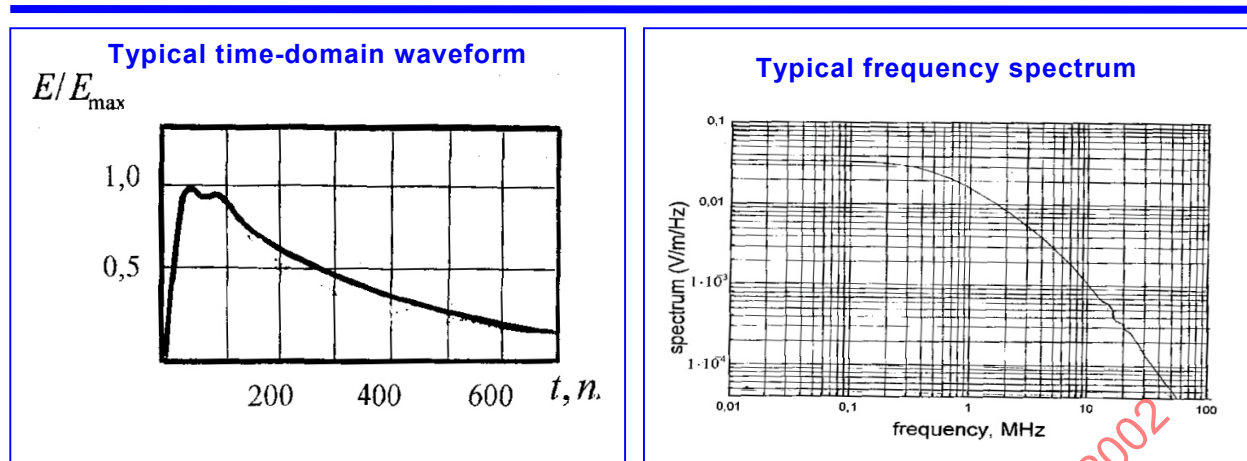
### Other information

**Location:** Kharkov, Ukraine  
**Owner:** Research and Engineering Institute "Molniya"  
**Point of contact:** Dr. Vladimir Ivanovich Kravchenko, Director Research and Engineering Institute "Molniya," Kharkov State Polytechnical University, Shevchenko St., 47, 61013 Kharkov  
**Initial operation date:** 1992  
**Status:** Operational  
**Other government:** Yes

### Availability

**Industry:** No





### Other technical information

#### General description

The GINT-12-30 simulator consists of Marx-type pulse generators (with maximum voltages up to 4,5 MV), a pulse-shaping network, a 2-plate transmission line with conic transition sections, and a matched resistive load. Wires forming the bottom plate of the transmission line are located in the concrete of the test volume platform. GINT-12-30 includes 10 current and voltage pulse generators (2-50 kV; 3,75 kJ).

#### Available instrumentation

The simulator includes an underground instrumentation room and measuring system. The measuring system consists of opto-electronic-controlled measuring channels, recording devices, and a protective shielded enclosure. The total number of measuring channels varies from 2 to 10 pieces.

The measuring system includes a variety of different electric field and magnetic field sensors. These provide the measurement of electromagnetic pulses with the following characteristics:

- Amplitude range: 1-500 kV/m
- Rise time: 2-500 ns
- Pulse duration: 10-1 000 ns

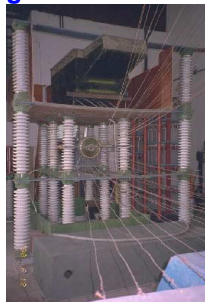
#### Auxiliary test equipment

None



### 7.15.3 Ukraine – IEMI-M5M

**Pulse generator**



**Pulse generator and transmission line**



**Test volume**



#### General information

**Simulator type:** Guided-wave  
**Termination or resistive loading:** Short output conic section with distributed resistive load  
**Major simulator dimension(s):** 23 m (overall length)  
**Test volume dimensions:** 3 m (maximum plate spacing)  
 3 m (high) × 4 m (wide) × 7 m (long)

#### Simulator input options

**Primary pulse power:** 700-kV Marx generator with pulse-shaping network  
**Repetition rate:** 12 pulses per hour  
**Low-voltage or CW test capability:** Not available

#### Electromagnetic characteristics

(in test volume unless otherwise noted)

**Electric field polarization:** Vertical  
**Line impedance:** 100 Ω (input to terminator; variable with plate spacing)  
**Wave impedance:** 377 Ω (HEMP spherical wave)  
**Peak electric field:** 110-330 kV/m  
**Peak magnetic field:** 290-875 A/m  
**Pulse rise time:** 5-10 ns (10-90 %)  
**Prepulse:** None  
**Pulse width:** 200-250 ns (FWHM)  
**Field uniformity:**

- Good ( $\pm 10$  %) uniformity of vertical component
- Fall-off of peak field from front to back of test volume – Information not provided
- Horizontal components 50 % of vertical component (when test object placed in 26° section)

**Other:** Indoor EMP simulator. The simulator has an underground instrumentation room.

#### Other information

**Location:** Kharkov, Ukraine  
**Owner:** Research and Engineering Institute "Molniya"

**Point of contact:** Dr. Vladimir Ivanovich Kravchenko, Director  
 Research and Engineering Institute "Molniya," Kharkov State Polytechnical University, Shevchenko St., 47, 61013 Kharkov  
 Fax: 380-572-400133

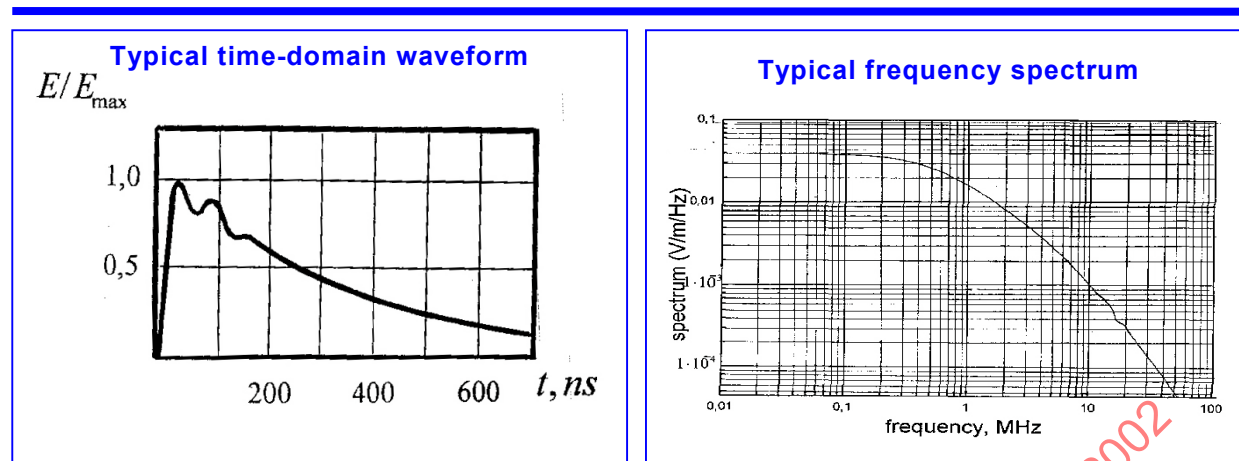
**Initial operation date:** 1992

**Status:** Operational

#### Availability

**Other government:** Yes

**Industry:** No



### Other technical information

#### General description

The IEMP-M5M simulator consists of Marx-type pulse generators (with maximum voltages up to 0,7 MV), a pulse-shaping network, a 2-plate transmission line with conic transition sections, and a matched resistive load. Wires forming the bottom plate of the transmission line are located in the concrete of the test volume platform.

#### Available instrumentation

The simulator includes an underground instrumentation room and measuring system. The measuring system consists of opto-electronic-controlled measuring channels, recording devices, and a protective shielded enclosure. The total number of measuring channels varies from 2 to 10 pieces.

The measuring system includes a variety of different electric field and magnetic field sensors. These provide the measurement of electromagnetic pulses with the following characteristics:

- Amplitude range: 1-500 kV/m
- Rise time: 2-500 ns
- Pulse duration: 10-1 000 ns

#### Auxiliary test equipment

None