TECHNICAL REPORT

IEC 61000-4-32

First edition
2002-10

BASIC EMC PUBLICATION

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, 3, rue de Varembé, PO Box 131, CH-1211 Geneva 20, Switzerland
Telephone: +41 22 919 02 11 Telefax: +41 22 919 03 00 E-mail: inmail@iec.ch Web: www.iec.ch

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FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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Technical reports do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful by the maintenance team.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.

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 worldand 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[1] covers many categories of nuclear EMPs including those produced by surface bursts (SREMP)[2] or created on space systems (SGEMP)[3] .

[1] Nuclear Electromagnetic Pulse

[2] Source Region EMP

[3] 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 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 Ω). For dipole and hybrid simulators, specify the cone or bicone impedance of the early-time radiating element (for example, 150 Ω).
Wave impedance:	Specify the impedance of the field in the test volume (for example, 377 Ω – 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 ±10 %

Good – between ±20 % and ±10 %

Fair – between ±50 % and ±20 %

Poor – worse than ±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 ≤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 ≤ 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”[4] 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.

[4] 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 restive 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°), 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[5]

Simulator / Characteristic	ALECS	ARES	Trestle	DREMPS	EMIS-III-TL	DM-1200	GIN-1,6-5	GINT-12-30	IEMI-M5M	IEMP-10	SEMP-6M-2M	SEMP-12-3	Pulse-M	SEMP-1,5
Location	Albuq. USA	Albuq. USA	Albuq. USA	Ottawa Canada	The Hague NL	Beijing China	Kharkov Ukraine	Kharkov Ukraine	Kharkov Ukraine	Kharkov Ukraine	Sergiev Posad Russia	St. Pete. Russia	St. Pete. Russia	Istra Russia
Peak output voltage (MV)	1	4	6-8	0,6	0,5	1,2	1,6	4,5	0,7	2,5	6	2,4	0,6	1,5
Rise time (ns)	10	<10	~20	5	10	10	5-10	5-10	5-10	20-40	9	Air ≥ 15 Earth ≥ 20	5	5-12
Duration (ns)	250	250	500	400	?	200	200-2500	200-280	200-250	350-400	580	Air < 400 Earth < 100	150	35-850
Peak electric field (kV/m)	100	>100	50	55	~50	120	150	120	330	140	100	Air < 200 Earth < 30	100	20-100
Length (m)	100	189	~400	100	50	54	48	254	23	110	80	170	15	100
Plate spacing (m)	13	40	105	10	~10	8,4	5	30	3	12	15	10	3-6	~15
Wave-guide impedance (Ohms)	100	125	300	110	100	180	100	100	100	100	120	110	150	100
Initial operational capability (IOC)	mid-60s	1970	early 80s	Mid-90s	1992	1985	1976	1992	1992	1970	1982	1992	Early 90s	1998
Status[6]	2	2	3	2	2	2	2	2	2	2	2	2	2	2
Availability														
Government	?	?	?	Yes	Yes	?	Yes	Yes	Yes	Yes	Yes	MOD	MOD	Yes
Industry	?	?	?	Yes	Yes	?	No	No	No	No	No	?	?	?
IEC type simulator[7]	II	II	II	II	II	II	II	II	II	II	II	II	II	Cand. for Type I
Sub-clause	7.17.1	7.17.2	7.17.4	7.1.1	7.10.2	7.2.1	7.15.1	7.15.2	7.15.3	7.15.4	7.12.2	7.12.4	7.12.3	7.12.5
Compendium page	92	94	98		56	26	82	84	86	88	62	66	64	68

5 This listing is preliminary and subject to verification by the simulator owner/operator.

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

7 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 2 – Guided-wave EMP simulators with distributed termination[8]

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	2	0,8	0,6	0,1	2	0,8	1
Rise time (ns)	10	1-7	5	4	<5	8	1	<10	1-5	2,5	2,5-25
Duration (ns)	250	80-1000	150	?	?	~300	24-36	200	25-200	23-200	25-750
Peak electric field (kV/m)	>100	>100	>50	>100	>200	>100	100	62	>100	75	100
Length (m)	180	120	90	120	130	55	20	10	106	50	30
Maximum height (m)	33	22	18	22	20	~10	~4	~1,5	15	6	~8
Waveguide impedance (Ohms)	90	90	100	100	90	90	100	100	90	140	120
Initial operational capability (IOC)	1979	1981	1990	early 90s	1989	1989	1999	1991	1986	1996	1982
Status[9]	4	2	2	2	2	2	2	2	2	2	2
Availability											
Government	--	Yes	Yes	Yes	?	Yes	Yes	Yes	Yes	Yes	Yes
Industry	--	Yes	Yes	Yes	?	Yes	Yes	?	Yes	Yes	?
IEC type simulator[10]	II	Candidate for Type I	II	II	II	II	Candidate for Type I	II	Candidate for Type I	II	Candidate for Type I
Sub-clause	--	7.6.1	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	70	52	48	76	78	80	32	28	60

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

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

10 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[11]

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[12]	3	2	2	2	3	4
Availability						
Government	?	?	?	Yes	?	?
Industry	?	?	?	Yes	?	?
IEC type simulator[13]	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	--	--

[11] This listing is preliminary and subject to verification by the simulator owner/operator.

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

[13] 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[14]

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[15]	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[16]	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

[14] This listing is preliminary and subject to verification by the simulator owner/operator.

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

[16] 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-Ω 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-Ω 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.

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	

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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)

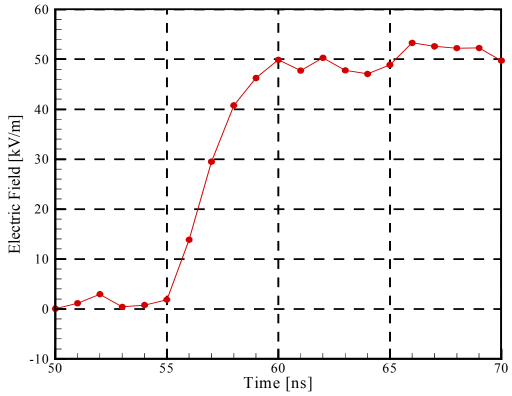
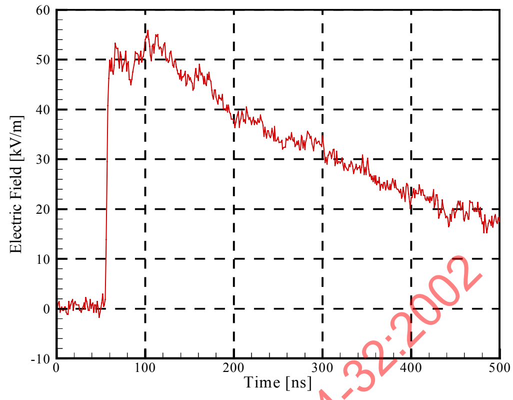
Line Impedance:	110 Ohms (input to terminator)
Electric Field Polarization:	Vertical
Wave Impedance:	377 Ohms (HEMP spherical wave)
Peak Electric Field:	20-55 kV/m
Peak Magnetic Field:	53-146 A/m
Pulse Rise Time:	5 ns (10 %-90 %)
Prepulse:	< 5 %
Pulse Width:	approx. 400 ns (1/e)
Field Uniformity:	• 10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

Typical rise time	Typical time-domain waveform
	

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 Ω (input to terminator)
Wave impedance: 377 Ω
(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)
Point of contact: 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

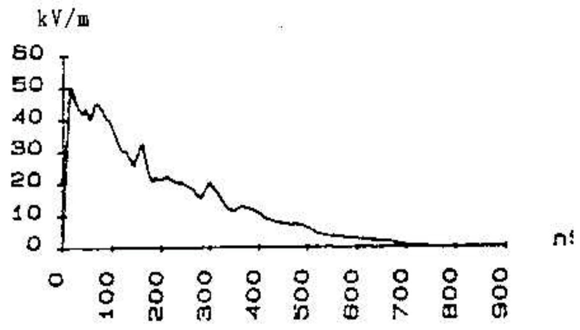
Initial operation date: 1985
Status: Operational

Availability

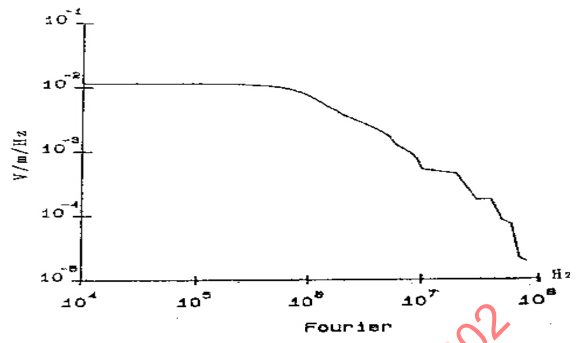
Other government: Check with point of contact

Industry: Check with point of contact

Typical time-domain waveform



Typical frequency spectrum



Other technical information

General description

Information not provided

Available instrumentation

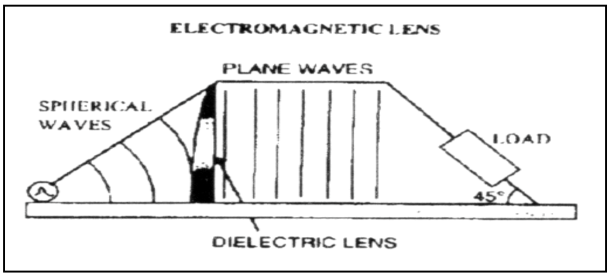
The simulator has an underground instrumentation room and optical fibre measuring system. Digital storage oscilloscopes (500 MHz, 5 GHz/s) are available.

Auxiliary test equipment

Information not provided

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)
5 m maximum height
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 (±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

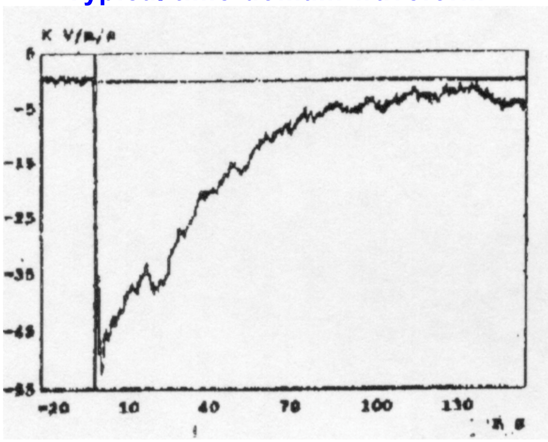
Location: Lannion, France
Owner: France Telecom R&D
Point of contact: Alain Cario
France Telecom FTR&D
2, Avenue P. Marzin
22307 Lannion
Telephone: 33-2 96 05 38 83
Fax: 33-2 96 05 21 11
E-mail: alain.cario@Francetelecom.com
Initial operation date: 1996
Status: Operational

Availability

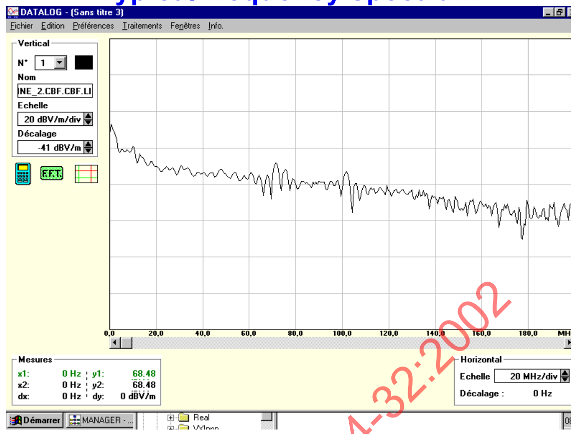
Government: Yes

Industry: Yes

Typical time-domain waveform



Typical frequency spectrum



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

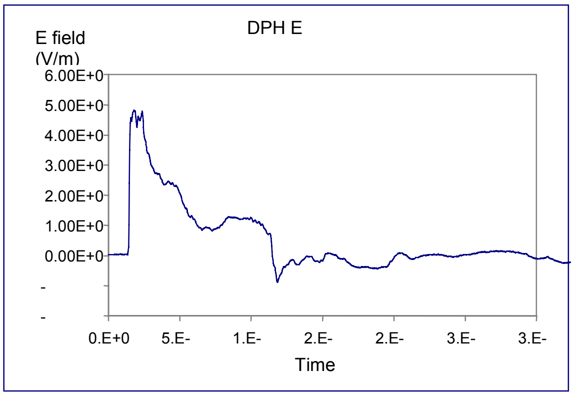
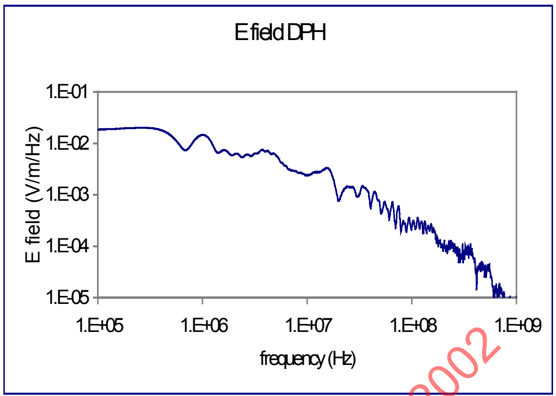
Location: Gramat, France
Owner: Centre d'Etudes de Gramat (CEG), Ministère de la Défense
Point of contact: Pierre Bruguiere, Centre d'Etudes de Gramat (CEG), 46500 Gramat, Tel: 33 5 65 10 54 28; Fax: 33 5 65 10 54 33

Initial operation date: 1980
Status: Operational

Availability

Other government: Yes

Industry: Yes

Typical time-domain waveform	Typical frequency spectrum
	

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)
Wavei 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

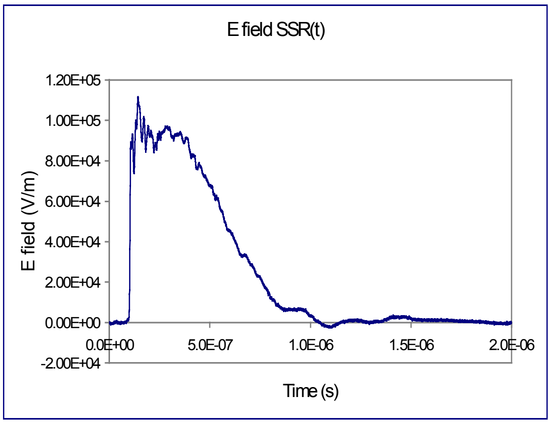
Location: Gramat, France
Owner: Centre d'Etudes de Gramat (CEG), Ministere de la Defence
Point of contact: Pierre Bruguiere, Centre d'Etudes de Gramat (CEG), 46500 Gramat,
Tel: 33 5 65 10 54 28;
Fax: 33 5 65 10 54 33
Initial operation date: 1986
Status: Operational

Availability

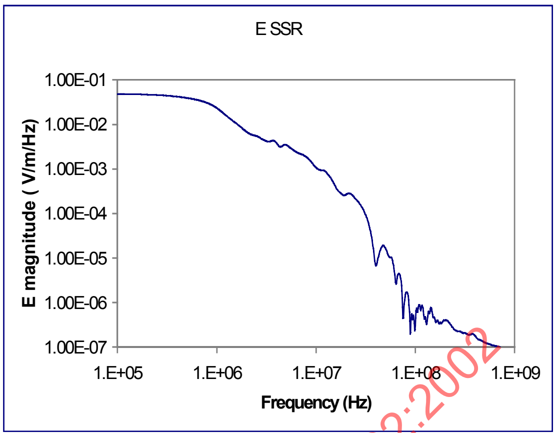
Other government: Yes

Industry: Yes

Typical time-domain waveform



Typical frequency spectrum



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 Ω (input to terminator)
Wave impedance: 377 Ω
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

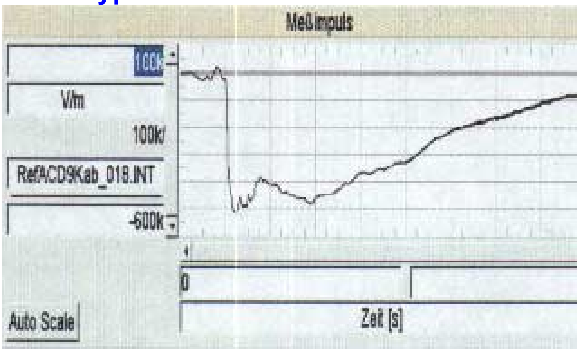
Location: Munster, Germany
Owner: Wehrwissenschaftliches Institut für Schutztechnologien ABC-Schutz (WIS)
Point of contact: Daniel Nitsch, Wehrwissenschaftliches Institut fur Schutztechnologien ABC-Schutz (WIS), D-29633 Munster, Tel: 49-5192-136338; Fax: 49-5192-136355 E-mail: DanielNitsch@bwb.org
Initial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

Availability

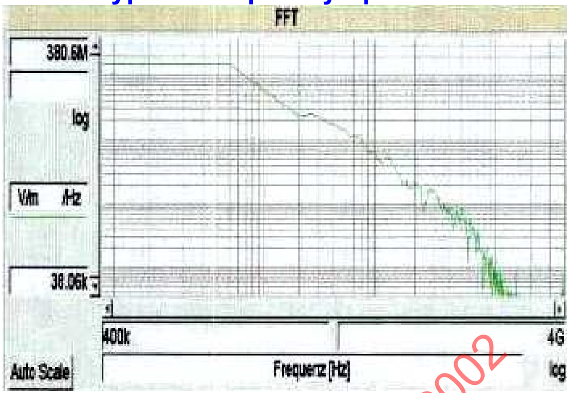
Other government: Yes

Industry: Yes

Typical time-domain waveform



Typical frequency spectrum



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

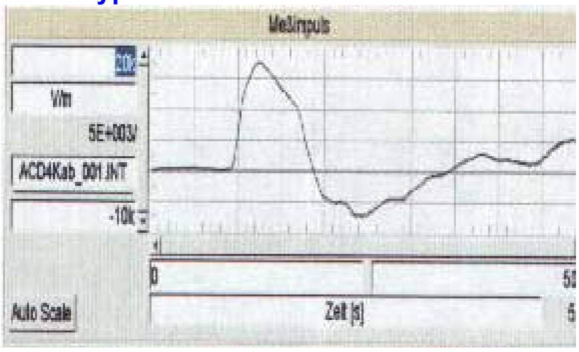
Other information

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@bwb.org
Initial operation date:	1999
Status:	Operational

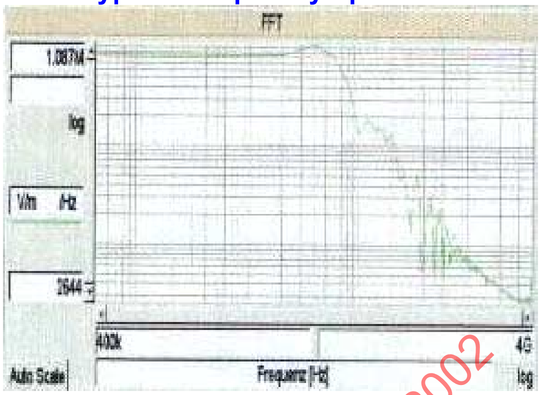
Availability

Other government:	Yes
Industry:	Yes

Typical time-domain waveform



Typical frequency spectrum



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 Ω (input to terminator)
Wave impedance:	377 Ω
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

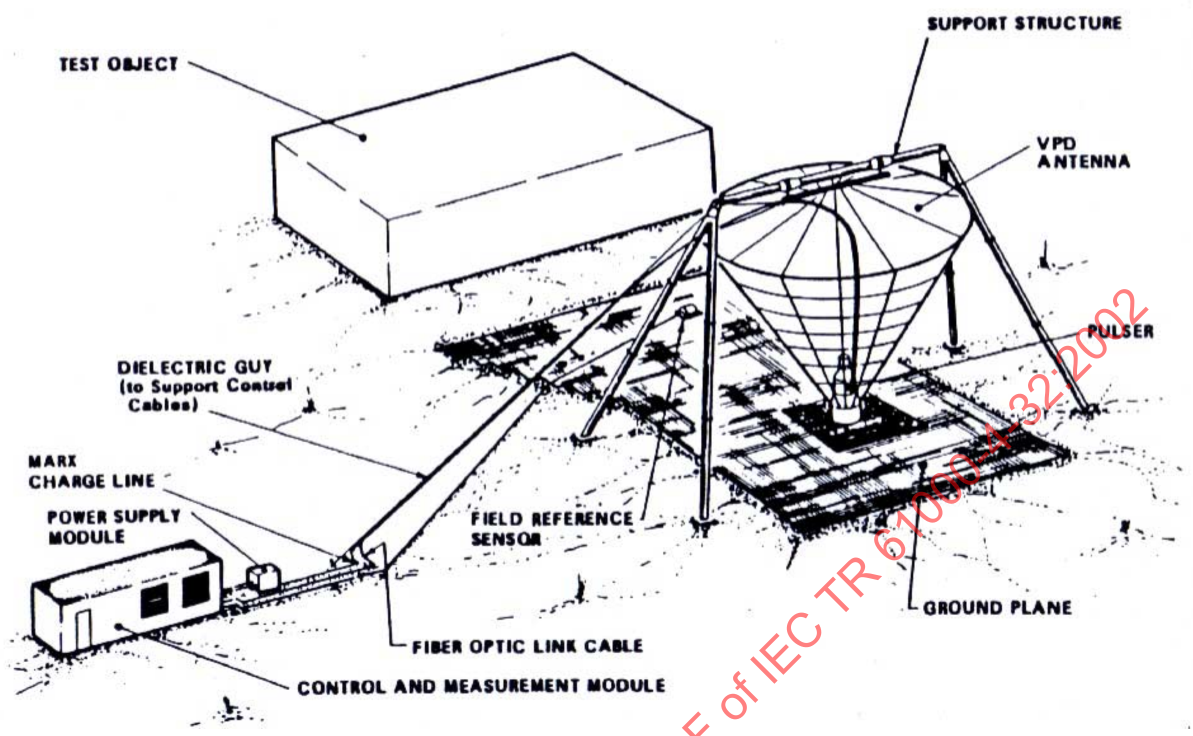
- Electric and magnetic field probes (ground-plane and free-field) up to 12 GHz bandwidth
- Current probes up to 500 MHz bandwidth
- Several fibre optical lines up to 5 GHz bandwidth
- Several semi-rigid cables: bandwidth up to 18 GHz
- Transient recorders and fast analogue scopes up to 5 GHz single-shot 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 Ω (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

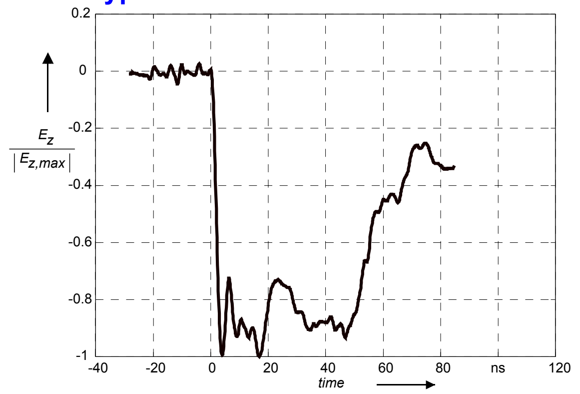
Initial operation date: 1986

Status: Operational

Availability

Government: Yes

Industry: Yes

Typical time-domain waveform	Typical frequency spectrum
	Information not available

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

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

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

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 Ω (input to terminator)
Wave impedance: 377 Ω
Peak electric field: Information not provided
Peak magnetic field: Information not provided
Pulse rise time: <5 ns (10 %-90 %)
Prepulse: ≤10 %
Pulse width: Information not provided
Field uniformity:
- Good (±15 %) uniformity of vertical component
- Fall-off of peak field from front to back of test volume – Information not provided

Horizontal components ≤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

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 Ω

Wave impedance: 377 Ω (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

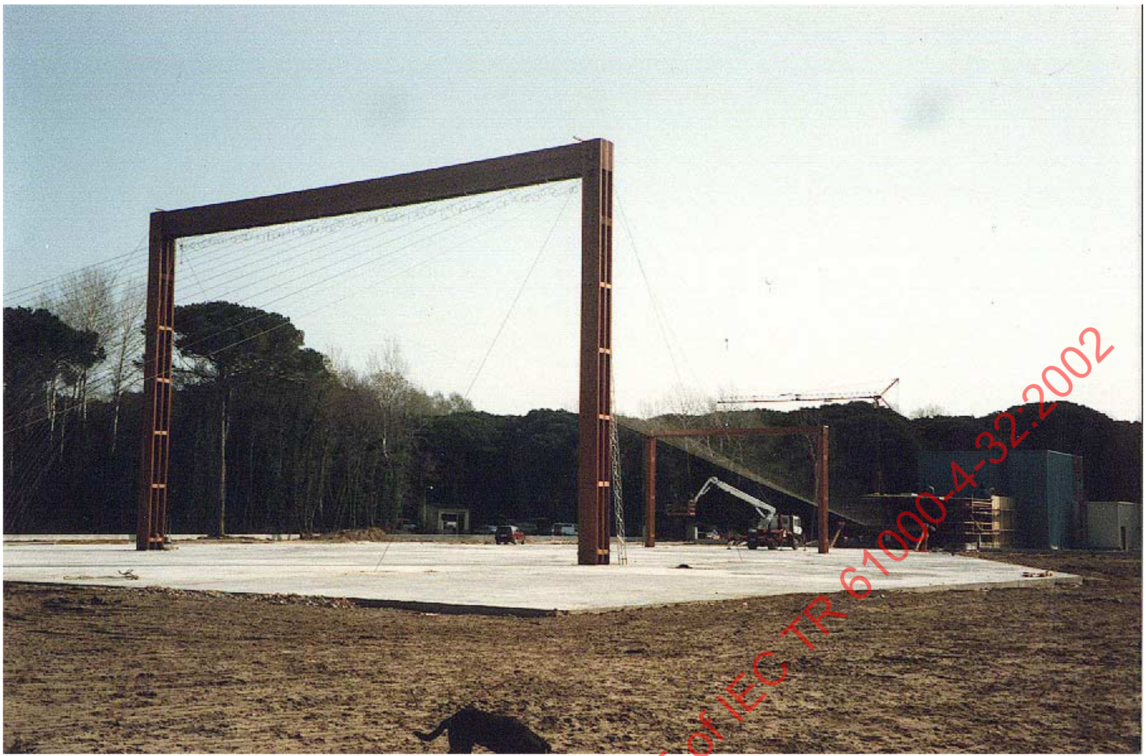
Available instrumentation

Information not provided

Auxiliary test equipment

Information not provided

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

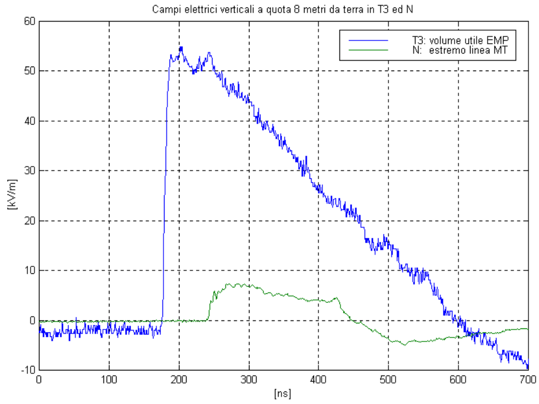
Other information

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

Typical time-domain waveform



Typical frequency spectrum

Information not provided

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" 13th 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

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

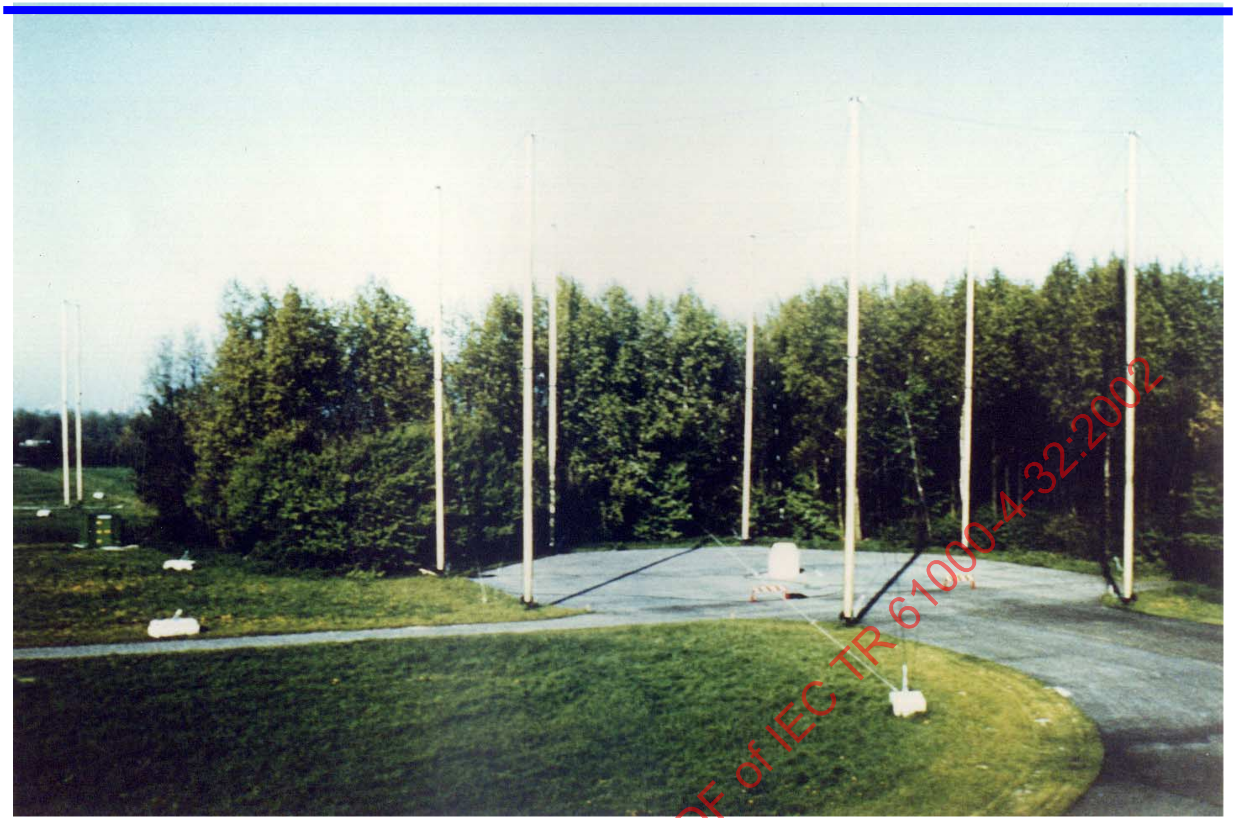
Available instrumentation

Information not provided

Auxiliary test equipment

Information not provided

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 Ω
Electric field polarization:	Vertical (positive or negative)
Wave impedance:	377 Ω (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

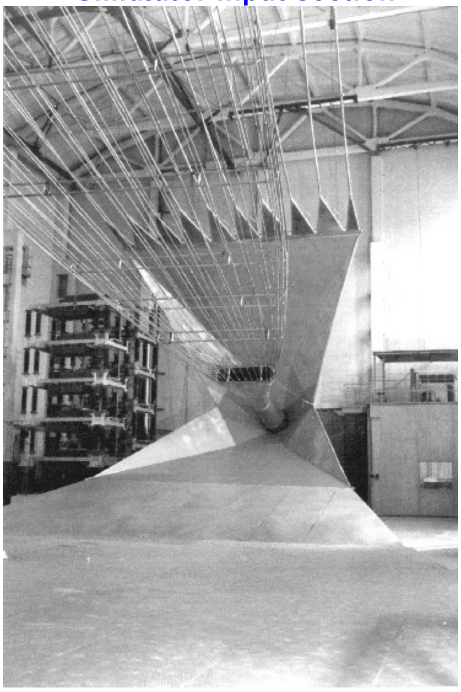
Information not provided

Auxiliary test equipment

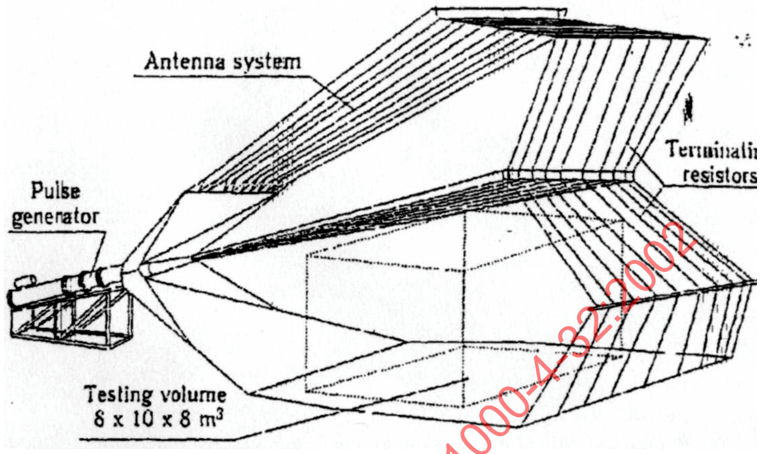
Information not provided

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

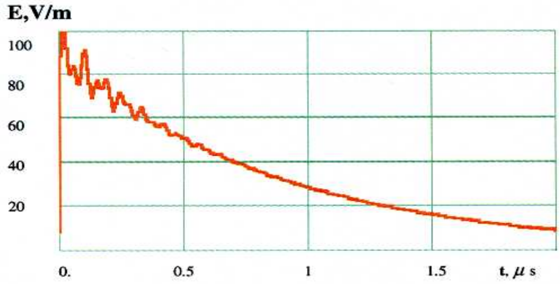
Location: Sergiev Posad-7, Moscow Region, Russia
Owner: Central Institute of Physics and Technology
Point of contact: Information not provided
Initial operation date: 1982
Status: Operational

Availability

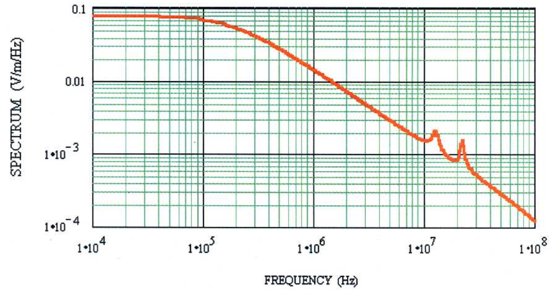
Other government: Yes

Industry: No

Typical time-domain waveform



Typical frequency spectrum



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.

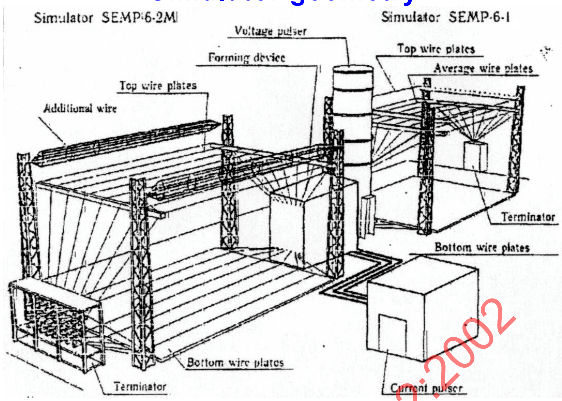
Auxiliary Test Equipment

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

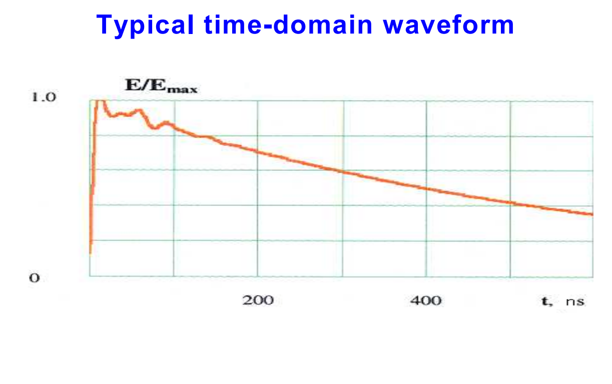
Other information

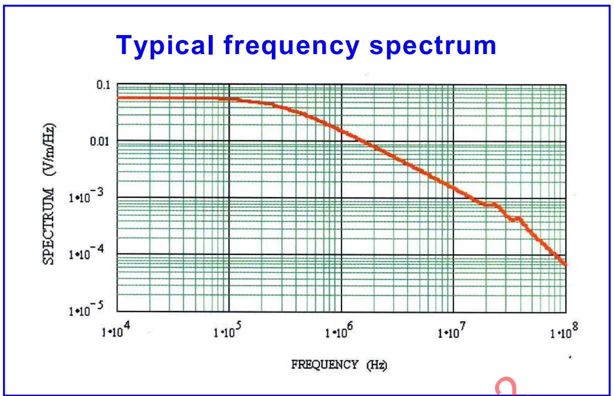
Location: Sergiev Posad-7, Moscow Region, Russia
Owner: Central Institute of Physics and Technology
Point of contact: Information not provided
Initial operation date: 1982
Status: Operational

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.

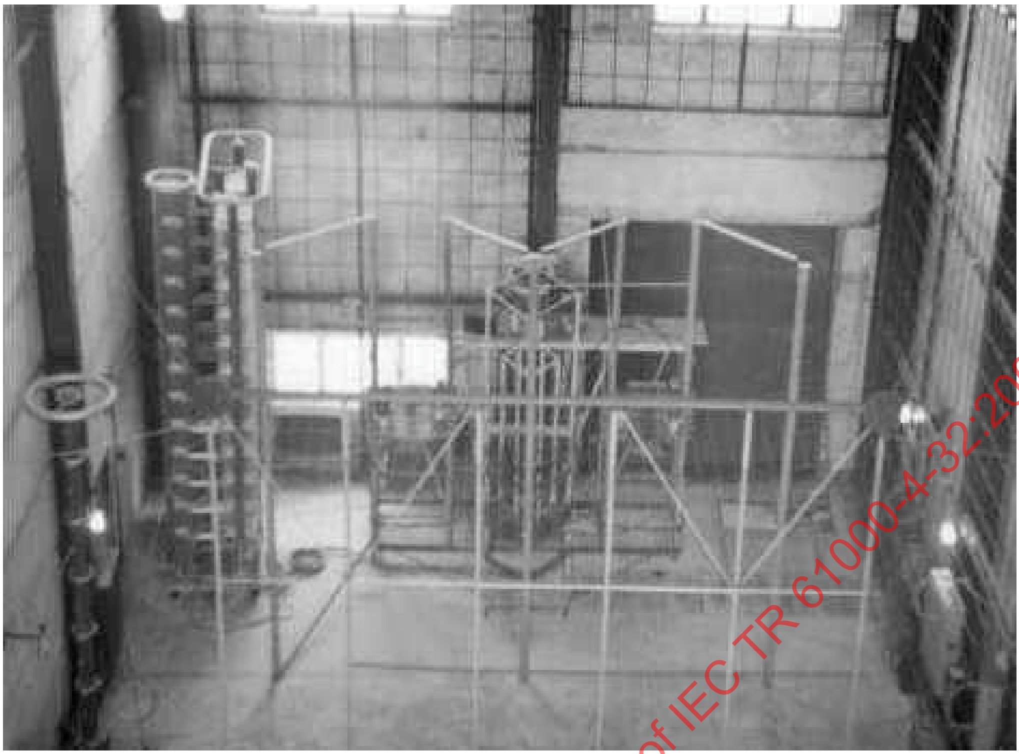
The measuring system includes a variety of different electric field and magnetic field sensors. These sensors provide the measuring of electromagnetic pulse with the following characteristics:

- 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)
3-6 m plate spacing (variable)
Major simulator dimension(s): 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

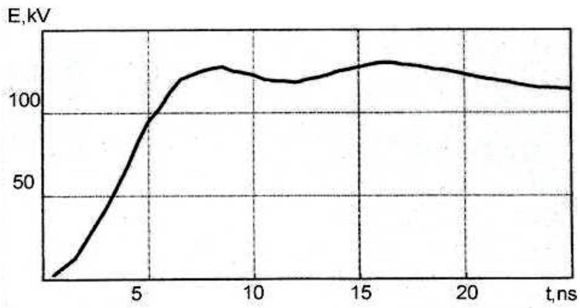
Location: St. Petersburg, Russia
Owner: Central Scientific Research Institute
Point of contact: Dr. Vassili M. Kouprienko, Science Research Centre of 26 Central Scientific Research Institute (SRC 26 CSRI), Russian Federation Ministry of Defence, Gangutskaya, 1, 191187 St. Petersburg
Fax: 7-812-279-7530
Initial operation date: 1993
Status: Operational

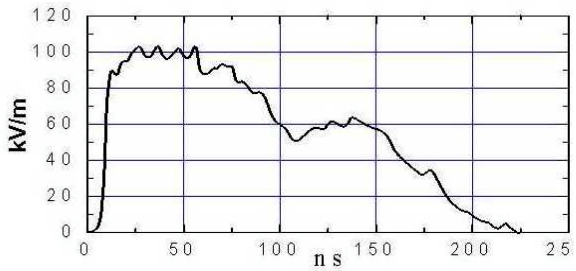
Availability

Other government: Ministry of Defence

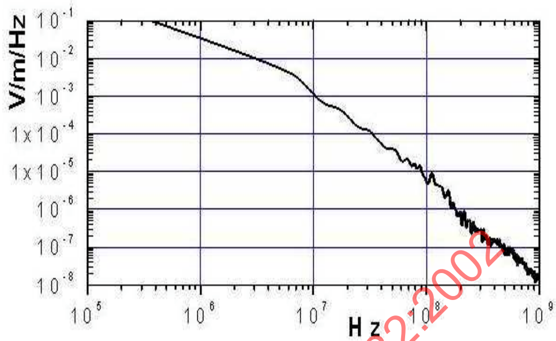
Industry: Information not provided

Typical time-domain waveform





Typical frequency spectrum



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).

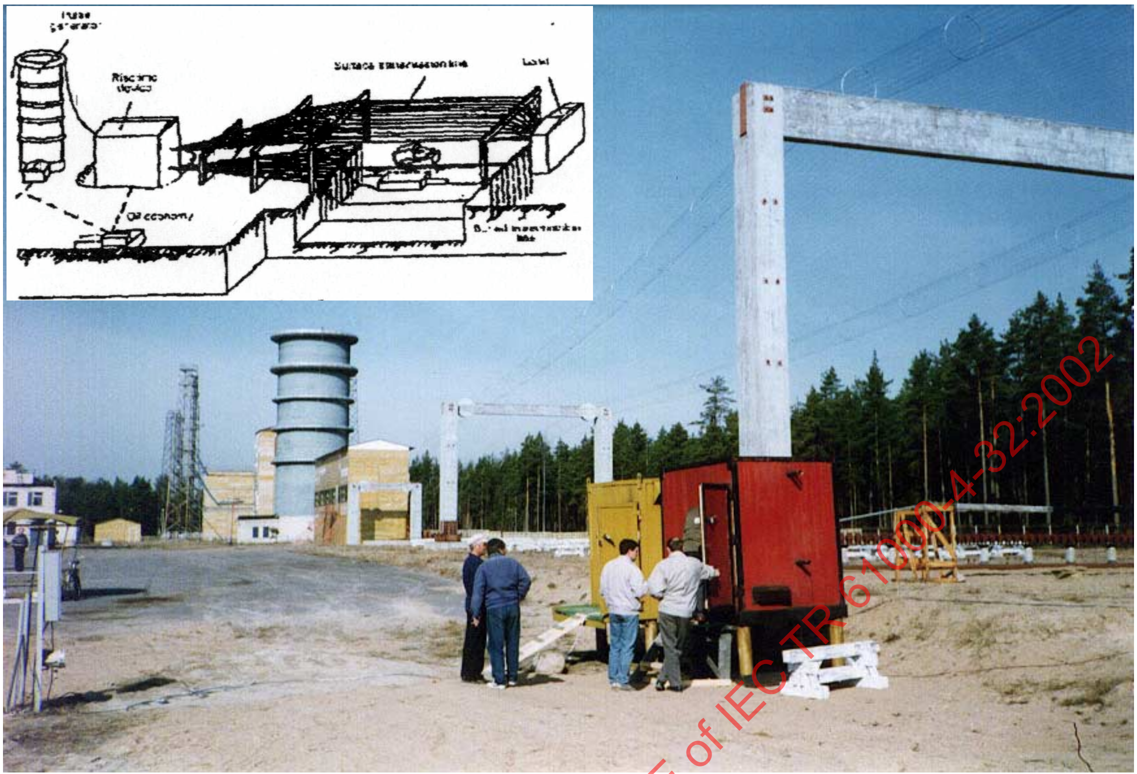
Available instrumentation

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 (±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

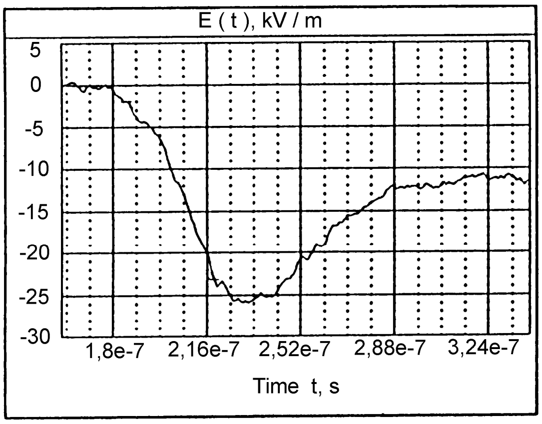
Status: Operational

Availability

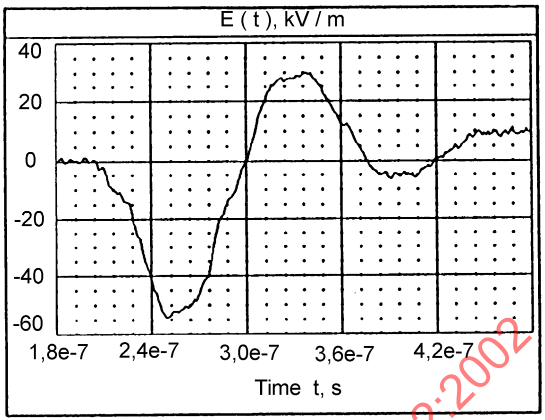
Other government: Ministry of Defence

Industry: Information not provided

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



Vertical electric field
near the Earth surface



Horizontal electric field
near the Earth surface

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.

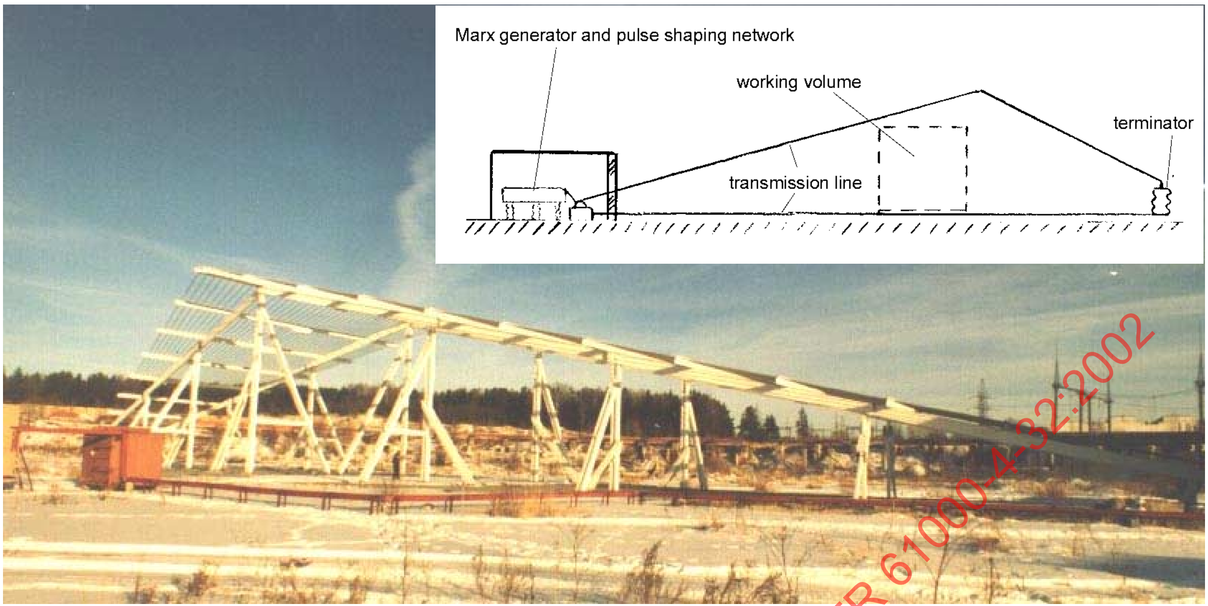
Available instrumentation

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 Ω (input to terminator)
Wave impedance: 377 Ω (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: ±20 % in test volume
Other: Information not provided

Other information

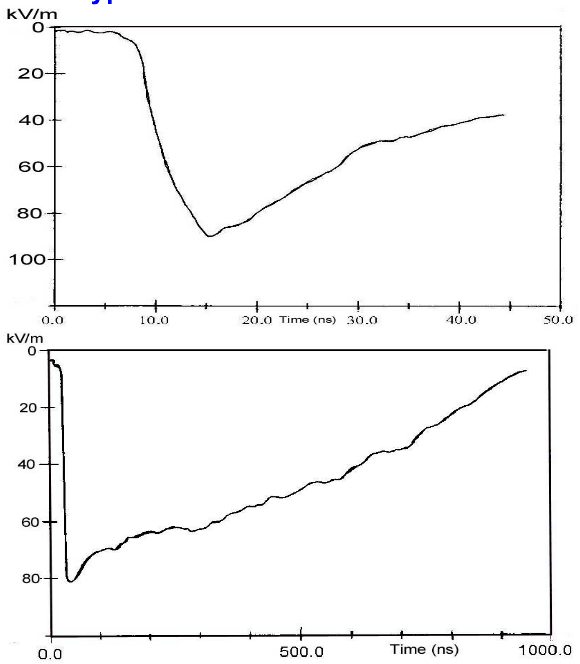
Location: Istra, Moscow region, 143500, Russia
Owner: High-voltage Scientific – Research Centre of V.I. Lenin All-Russian Electrotecnical Institute (VNITs VEI)
Point of contact: Dr. Alexander F. Kharchenko, VNITs VEI, 143500, Istra, Moscow region, Fax: 7-095-994-5107
Initial operation date: 1998
Status: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

Availability

Other government: Yes

Industry: Information not provided

Typical time-domain waveforms



Typical frequency spectrum

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 µs

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)

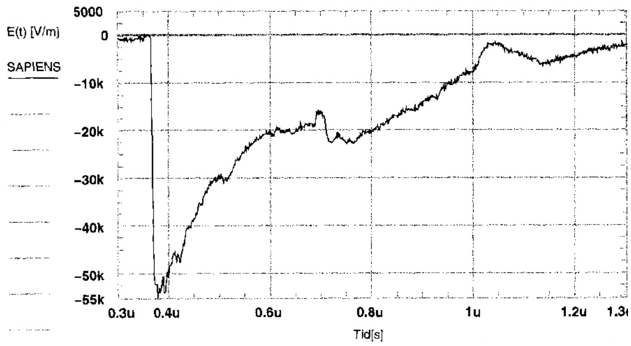
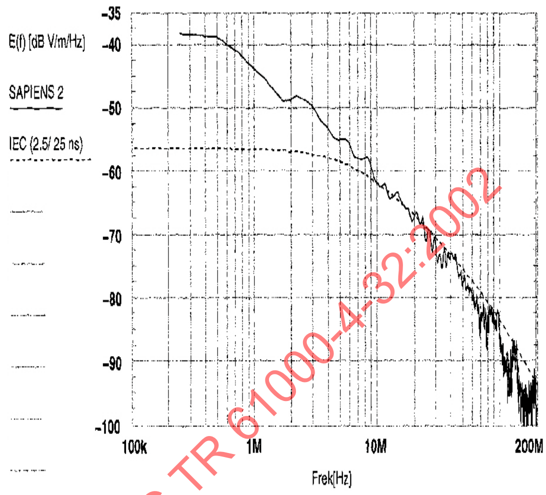
Line impedance:	100 Ω (input to terminator)
Electric field polarization:	Vertical
Wave impedance:	377 Ω (HEMP spherical wave)
Peak electric field:	>50 kV/m
Peak magnetic field:	>132 A/m
Pulse rise time:	5 ±1 ns (10-90 %)
Prepulse:	<10 %
Pulse width:	150 ns (FWHM)
Field uniformity:	• <10 % uniformity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

Typical time-domain waveforms	Typical frequency spectrum
	

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 Ω).

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
20 m pulser centre-line height
Test volume dimensions: 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 Ω
Wave impedance: 377 Ω (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 ± 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

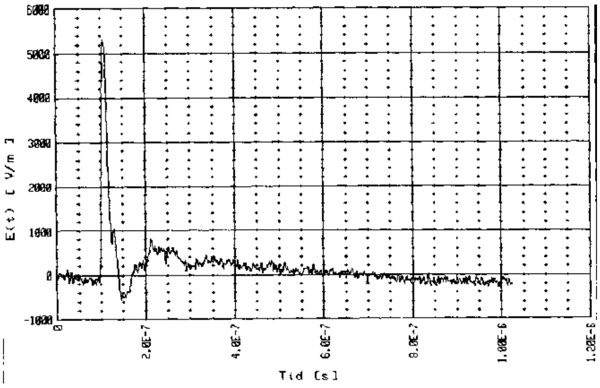
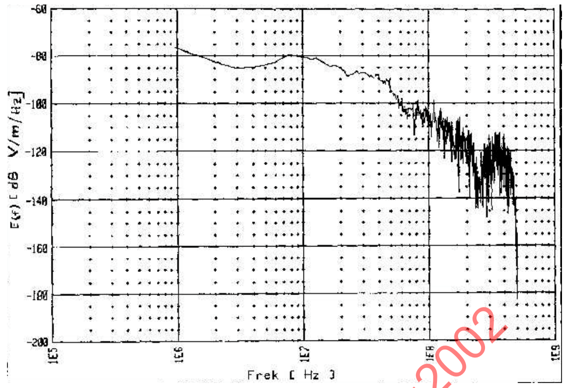
Other information

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

Typical time-domain waveform	Typical frequency-domain spectrum
	

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

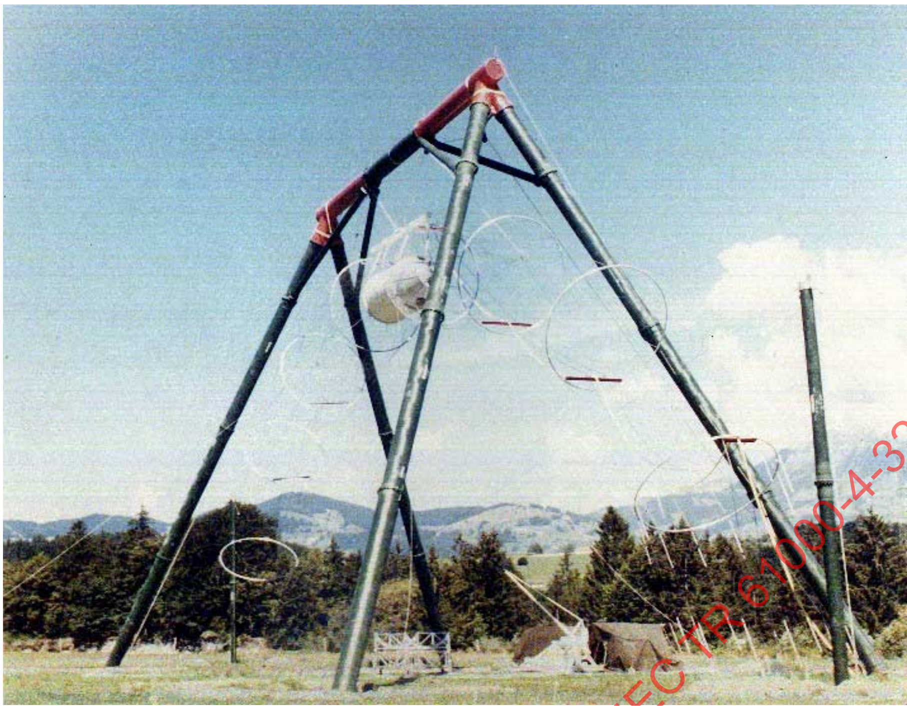
Auxiliary test equipment

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

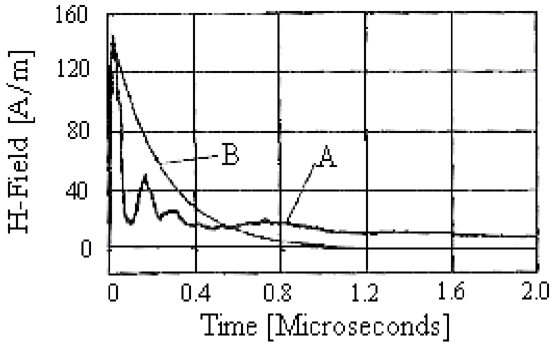
Initial operation date: 1985
Status: Stand-by

Availability

Other government: Yes

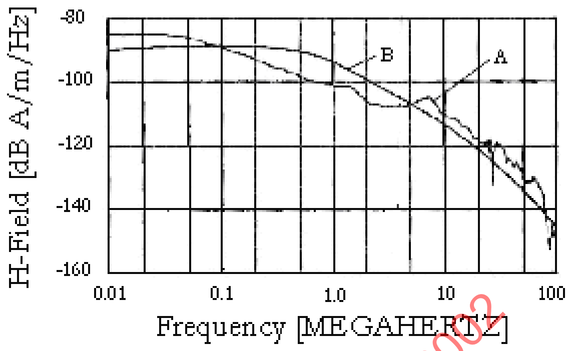
Industry: Yes

Typical time-domain waveform



A – MEMPS Waveform
B – Bell Laboratories standard

Typical frequency spectrum



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

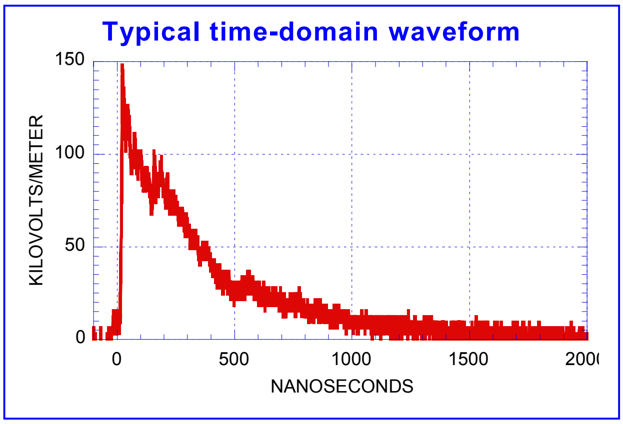
Location: Spiez, Switzerland
Owner: Defence Procurement Agency, NEMP-Laboratory, AC-Zentrum
Point of contact: Markus Nyffeler, Defence Procurement Agency, NEMP-Laboratory, AC-Zentrum, CH-3700, Spiez
Telephone: +41-33-228-1839
Fax: +41-33-228-1833
E-mail: markus.nyffeler@gr.admin.ch

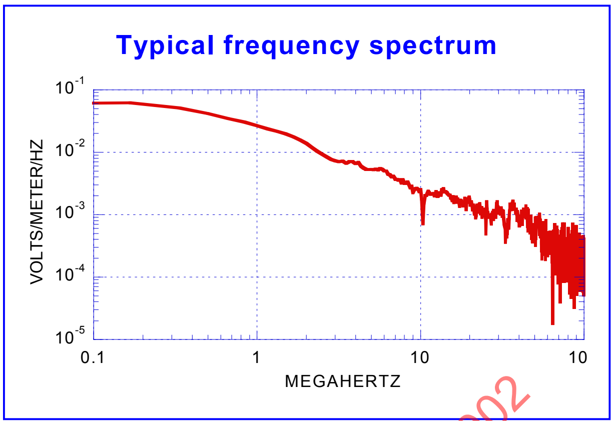
Initial operation date: 1989
Status: Operational

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 Ω (input to terminator)

Electric Field Polarization: Vertical

Wave Impedance: 377 Ω (HEMP spherical wave)

Peak Electric Field: 100 kV/m

Peak Magnetic Field: 260 A/m

Pulse Rise Time: <1 ns (10-90 %)

Prepulse: ≤8 %

Pulse Width: 24-36 ns FWHM

Field Uniformity:

- Excellent (better ±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

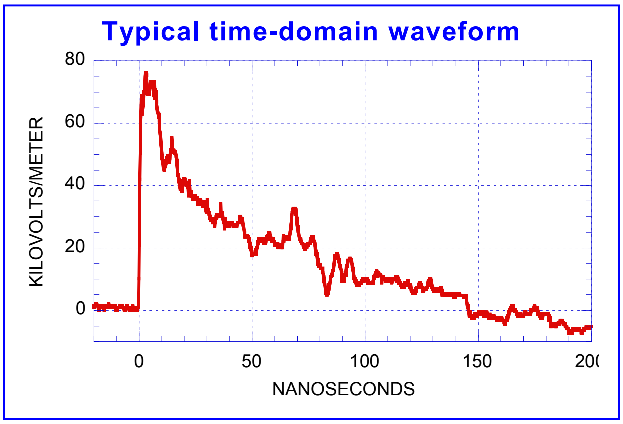
Initial operation date: 1999

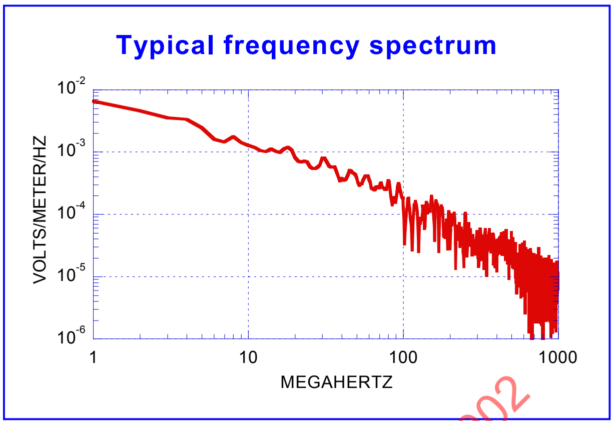
Status: Operational

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

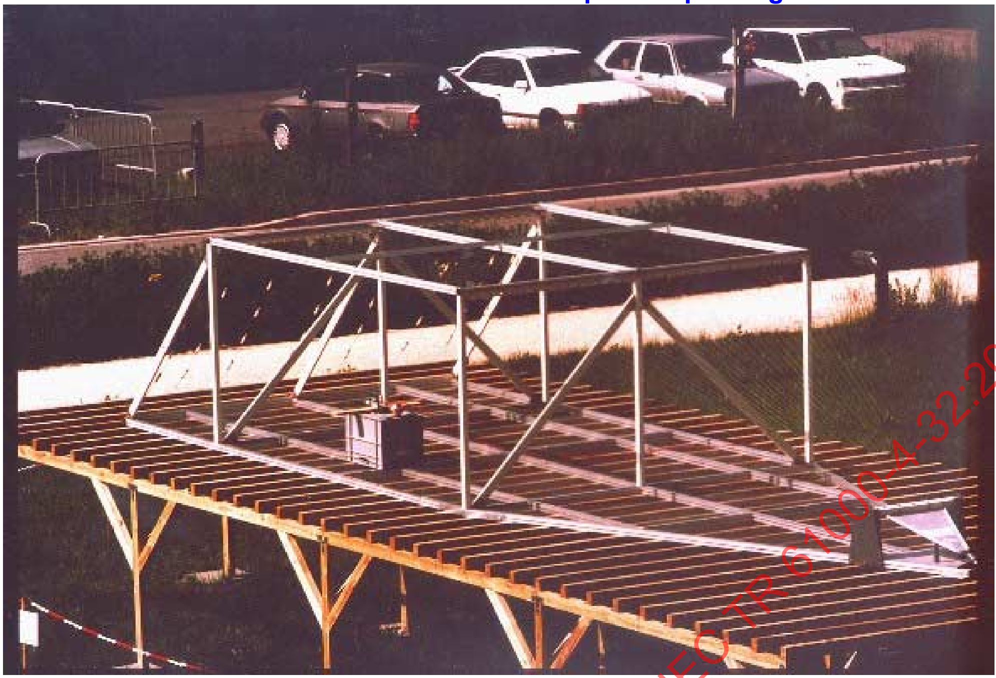
The following measurement instrumentation is available:
E-field-sensors (D-dot-sensors)
    Free-field sensors: < 0,01 mV/m to 1 MV/m
    Ground reference field sensors: < 0,1 mV/m to 1 MV/m
H-field-sensors
    Free-field sensors: < 0,1 mA/m to 2,5 kA/m
    Ground reference field sensors: < 1 mA/m to 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 Ω (input to terminator)
Electric field polarization: Vertical
Wave impedance: 377 Ω (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:
- ± 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

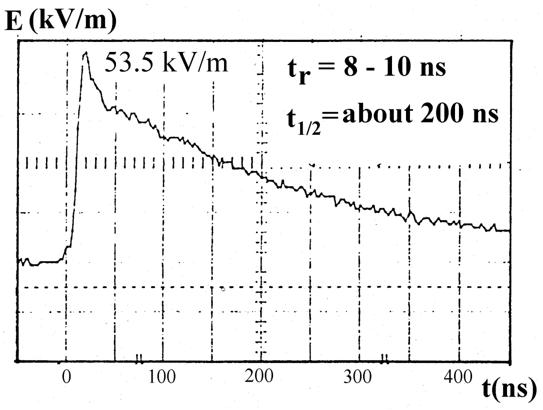
Location: Lausanne, Switzerland
Owner: Swiss Federal Institute of Technology
Point of contact: Prof. M. Ianoz/Dr. F. Rachidi, Power System Laboratory, Swiss Federal Institute of Technology, CH-1015 Lausanne, Switzerland
Phone: 41-21-693-2664/2620
Fax: 41-21-693-4662
E-mail: michel.ianoz@epfl.ch/ farhad.rachidi@epfl.ch
Initial operation date: 1991
Status: Operational

Availability

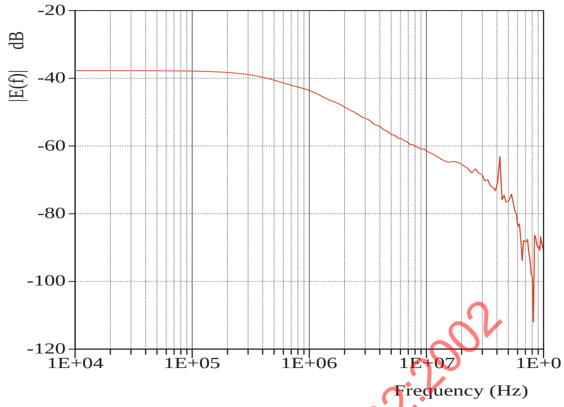
Other government: Yes

Industry: Information not provided

Typical time-domain waveform



Typical frequency spectrum



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: 377Ω
(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

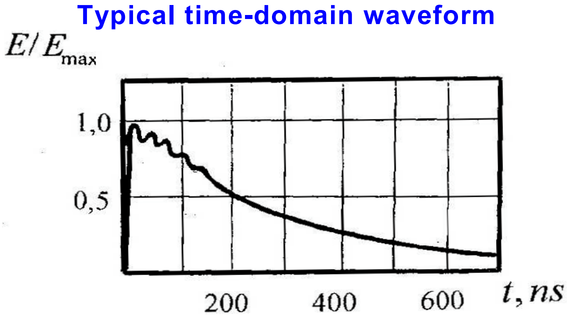
Owner: Research and Engineering Institute "Molniya"
Point of contact: Dr. Vladimir Ivanovich Kravchenko, Director
Research and Engineering Institute "Molniya," Kharkov State Polytechnical University,
Shevchenko St., 47,
61013 Kharkov
Fax: 380-572-400133
Initial operation date: 1976
Status: Operational

Availability

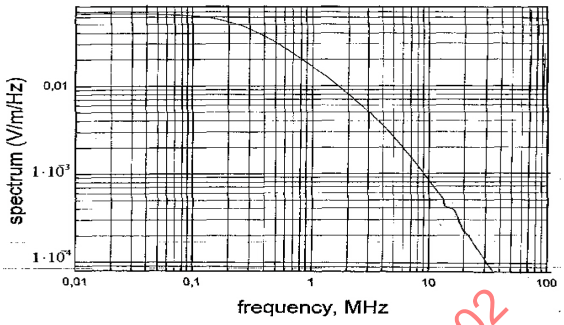
Other government: Yes

Industry: No

Typical time-domain waveform



Typical frequency spectrum



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)
30 m (maximum height)
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 (±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

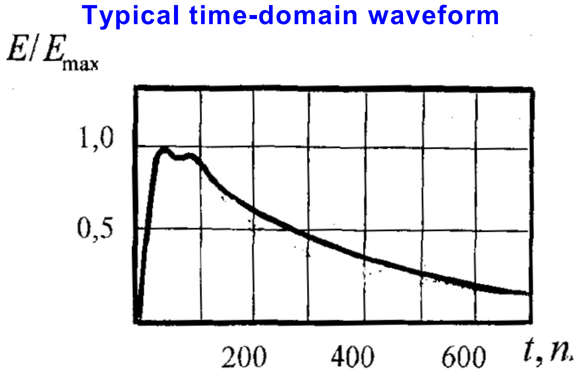
Location: Kharkov, Ukraine
Owner: Research and Engineering Institute "Molniya"
Point of contact: Dr. Vladimir Ivanovich Kravchenko, Director
Research and Engineering Institute "Molniya," Kharkov State Polytechnical University,
Shevchenko St., 47,
61013 Kharkov
Fax: 380-572-400133
Initial operation date: 1992
Status: Operational

Availability

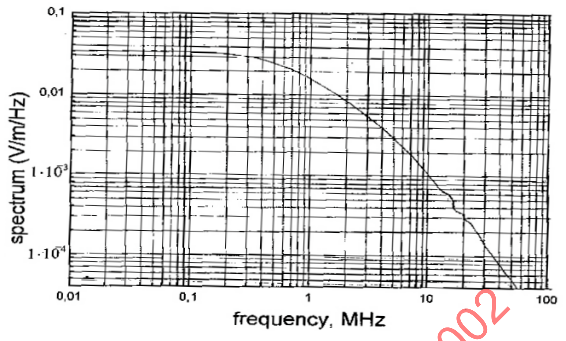
Other government: Yes

Industry: No

Typical time-domain waveform



Typical frequency spectrum



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:

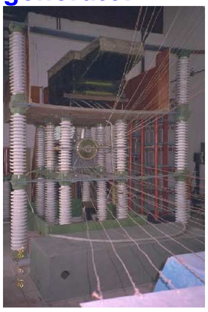
- Amplitude range: 1-500 kV/m
- Rise time: 2-500 ns
- Pulse duration: 10-1 000 ns

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) 3 m (maximum plate spacing)
Test volume dimensions:	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 (±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.

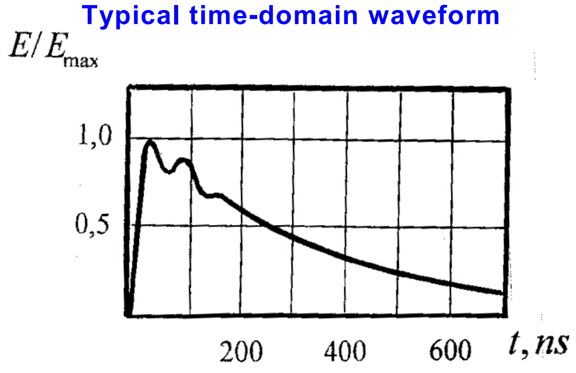
Other information

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

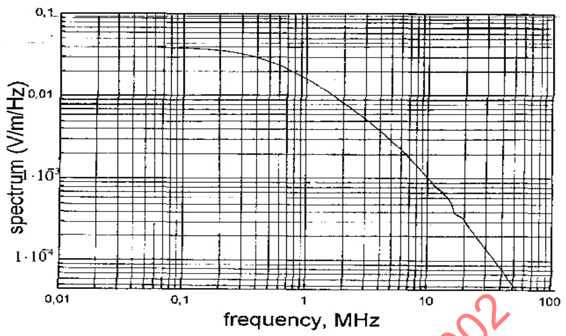
Availability

Other government:	Yes
Industry:	No

Typical time-domain waveform



Typical frequency spectrum



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