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TECHNICAL REPORT

Electromagnetic compatibility (EMC) –
Part 4-35: Testing and measurement techniques – HPEM simulator compendium

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CONTENTS

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ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-35: Testing and measurement techniques – HPEM simulator compendium

FOREWORD

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The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC 61000-4-35, which is a technical report, has been prepared by subcommittee 77C: High power transient phenomena, of IEC technical committee 77: Electromagnetic compatibility.

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

Enquiry draft	Report on voting
77C/189/DTR	77C/193/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 the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,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

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

IEC 61000 is published in separate parts according to the following structure:

Part 1: General

General considerations (introduction, fundamental principles)

Definitions, terminology

Part 2: Environment

Description of the environment

Classification of the environment

Compatibility levels

Part 3: Limits

Emission limits

Immunity limits (in so far as they do not fall under responsibility of product committees)

Part 4: Testing and measurement techniques

Measurement techniques

Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines

Mitigation methods and devices

Part 6: Generic standards

Part 9: Miscellaneous

Each part is further subdivided into several parts published either as international standards, technical specifications or technical reports, some of which have already been published as sections. Others will be published with the part number followed by a dash and a second number identifying the subdivision (example: IEC 61000-6-1).

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-35: Testing and measurement techniques – HPEM simulator compendium

1 Scope

This part of IEC 61000 provides information about extant system-level High-Power Electromagnetic (HPEM) simulators and their applicability as test facilities and validation tools for immunity test requirements in accordance with the IEC 61000 series of standards. HPEM simulators with the capability of conducted susceptibility or immunity testing will be included in a further stage of the project. In the sense of this report the group of HPEM simulators consists of narrow band microwave test facilities and wideband simulators for radiated high power electromagnetic fields. IEC 61000-2-13 defines high power electromagnetic (HPEM) radiated environments as those with a peak power density that exceeds 26 W/m^2 (100 V/m or 0,27 A/m). This part of IEC 61000 focuses on a sub-set of HPEM simulators capable of achieving much higher fields. Therefore, the HPEM radiated environments used in this document are characterized by a peak power density exceeding 663 W/m^2 (500 V/m or 1,33 A/m). The intention of this report is to provide the first detailed listing of both narrowband (hypoband) and wideband (mesoband, sub-hyperband and hyperband) simulators throughout the world.

HEMP simulators are the subject of a separate compendium (IEC 61000-4-32) and thus are outside the scope of this Technical Report.

After an introduction, a general description of HPEM simulators, as listed in this Technical Report, is presented. A database has been created by collecting information from simulator owners and operators and this data is presented for the technical characterization of the test facilities. In addition, some important commercial aspects, such as availability and operational status, are also addressed.

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 60050-161, *International Electrotechnical Vocabulary – Chapter 161: Electromagnetic compatibility*

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

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

IEC 61000-2-13, *Electromagnetic compatibility (EMC) – Part 2-13: Environment – High-power electromagnetic (HPEM) environments – Radiated and conducted*

IEC 61000-4-21, *Electromagnetic compatibility (EMC) – Part 4-21: Testing and measurement techniques – Reverberation chamber test methods*

3 Terms and definitions

For the purposes of this document, the following general definitions apply, as well as the terms and definitions given in IEC 60050-161 (IEV) and IEC 61000-2-13.

3.1
bandratio
***b*r**
ratio of the high and low frequencies, which are given by the 90 % energy bandwidth (B_{90EB}); if the signal spectrum has a large d.c. content, the lower limit is nominally defined as 1 Hz.

$$b_r = \frac{f_h}{f_l}$$

3.2
energy bandwidth
***B*90EB**
if $A_{0,9}$ is the collection of non-negative pairs $\{f_l,f_h\}$ of real numbers that satisfy the equation

$$\frac{\int_{f_l}^{f_h} \left|\hat{S}(f)\right|^2 df}{\int_{0}^{\infty} \left|\hat{S}(f)\right|^2 df} = 0,9. \quad (1)$$

where $\hat{S}(f)$ denotes the signal spectrum. The 90 % fractional energy bandwidth (B_{90EB}) is then defined as the infimum of all intervals f_l to f_h that satisfy Equation 1

$$B_{90EB} = \inf\left\{\left(f_h - f_l\right):\ \left\{f_l, f_h\right\} \text{ in } A_{0.9}\right\}. \quad (2)$$

where inf{M} denotes the infimum (or smallest element) of a given set M

NOTE Although more than one pair of $\{f_l, f_h\}$ might satisfy Equation 1, that is $A_{0,9}$ contains more than a single pair of frequencies, B_{90EB} is unique. For example, if the spectral magnitude is a rectangular function, the 90 % fractional bandwidth is a single value, even though $A_{0,9}$ contains an infinite number of distinct pairs $\{f_l, f_h\}$. The 90 % fractional energy bandwidth provides good information on how the signal energy is distributed in the frequency domain. This quality makes B_{90EB} a useful measure for characterizing signals in terms of their spectral occupancy and electromagnetic interference on other sources.

3.3
far field
region, where the angular field distribution and the waveform is essentially independent of the distance from the source [1][1]. In the far field region the power flux density approximately obeys an inverse square law of the distance

NOTE The far field region of an antenna, radiating into free space, is characterized by a transverse electromagnetic field and that the ratio between the electric and magnetic field strength equals the characteristic wave impedance of free space:

$$\frac{E}{H} = \eta_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} = 120 \cdot \pi \approx 377 \ \Omega$$

[1] The number in square brackets refers to the bibliography.

3.4
fractional bandwidth
***b*$_f$**
ratio of the 90 % energy bandwidth (B_{90EB}) and the centre frequency (f_c) of a waveform

$$bf = \frac{B_{90EB}}{f_c} = 2\frac{(f_h - f_\ell)}{(f_h + f_\ell)}$$

3.5
full width at half maximum
T_{FWHM}
duration of a signal; time difference at which the signal (e.g. electrical field strength) is equal to half of its maximum value

3.6
high altitude electromagnetic pulse
HEMP
electromagnetic pulse produced by a nuclear explosion outside the Earth's atmosphere

NOTE Typically above an altitude of 30 km. See IEC 61000-2-9 and IEC 61000-2-10 for details.

3.7
high power electromagnetic
HPEM
general area or technology involved in producing intense electromagnetic radiated fields or conducted voltages and currents with a peak power which has the capability to damage or upset electronic systems

3.8
high power electromagnetic radiated environment
a radiated environment with a peak power density that exceeds 26 W/m^2 (100 V/m or 0,27 A/m)

NOTE In this Technical Report the HPEM radiated environment is used for an environment that is characterized by a peak power density of more than 663 W/m^2 (500 V/m or 1,33 A/m).

3.9
high power microwaves
HPM
narrowband signals, normally with peak power in a pulse, in excess of 100 MW at the source.

NOTE This is a historical definition that depended on the strength of the source. The interest in this Technical Report is mainly on the EM field incident on an electronic system. Therefore in this Technical Report HPM is used for a narrowband microwave field that is characterized by a peak power density of more than 663 W/m^2 (500 V/m or 1,33 A/m).

3.10
hyperband signal
signal with a pbw value between 163,4 % and 200 % or a b_r of >10

3.11
hyperband simulator
simulator that radiates an electromagnetic field with a hyperband waveform

3.12
hypo- or narrowband signal
signal with a pbw of <1 % or a b_r of <1,01

3.13
hypo- or narrowband simulator
simulator that radiates an electromagnetic field with a hypoband waveform

3.14
mesoband signal
signal with a pbw value between 1 % and 100 % or a b_r between 1,01 and 3

3.15
mesoband simulator
simulator that radiates an electromagnetic field with a mesoband waveform

3.16
percentage bandwidth
pbw
bandwidth of a waveform expressed as a percentage of the centre frequency of that waveform

$$pbw = \frac{2\,(f_h - f_\ell)}{(f_h + f_\ell)} \times 100$$

with pbw at a maximum value of 200 %

3.17
short pulse signal
pulse with a rise time in the picoseconds to nanosecond region and a duration (T_{FWHM}) of nanoseconds to tens of nanoseconds

3.18
simulator with spot frequencies
hypoband simulator that operates on dedicated frequencies (spot frequencies) within the specified range

3.19
sub-hyperband signal
signal with a pbw value between 100 % and 163,4 % or a b_r between 3 and 10

3.20
sub-hyperband simulator
simulator that radiates an electromagnetic field with a sub-hyperband waveform

3.21
transient
pertaining to or designating a phenomena or a quantity which varies between two consecutive steady states during a time interval short compared with the time-scale of interest

[IEV 161-02-01]

NOTE A transient can be a unidirectional impulse of either polarity or a damped oscillatory wave with the first peak occurring in either polarity.

3.22
tunable simulator
hypoband simulator that is able to operate at each frequency within the specified frequency range

3.23
ultra wideband signal
UWB
signal with a pbw value of more than 25 %

3.24
ultra wideband simulator
UWB
simulator that radiates a electromagnetic field with a ultra wideband waveform

3.25
wideband signal
WB
signal with a pbw value between 1 % and 25 %

3.26
wideband simulator
WB
simulator that radiates a electromagnetic field with a wideband waveform

4 General

Interest in High-Power Electromagnetics (HPEM), particularly the generation of high-power electromagnetic fields and their effects on electronics appears to have increased in recent times. As components for High-Power Microwave (HPM), wideband (WB) and ultra-wideband (UWB) technologies have achieved notable progress, high-power generator systems difficult or impossible to build ten years ago are now being used for an increasingly wide variety of applications. With the advent of HPEM sources capable of producing output powers in the GW range, there has been interest in using HPEM devices in military defence applications to disrupt or destroy offensive electronic systems.

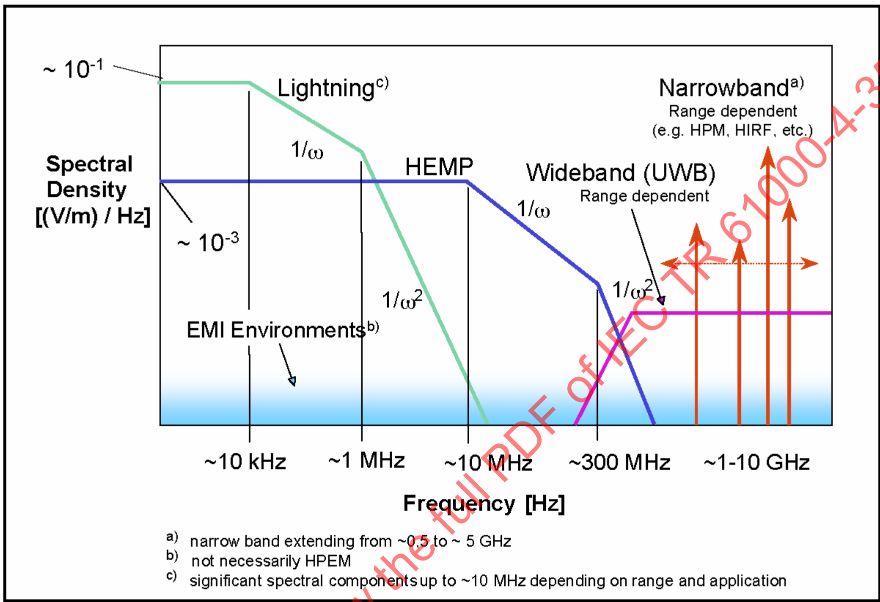
In numerous publications it has been reported that the technical capability to interrupt and/or damage sensitive electronics by generating Intentional Electromagnetic Interference (IEMI) exists and could be used for malicious purposes [2], [3], [4], [5].

The IEC recognises certain major trends in civilian electronic systems as follows:

a) increasing use of automated electronic systems in every aspect of civilized societies – communication, navigation, medical equipment, etc.;
b) increasing susceptibility of electronic systems due to higher package densities, use of monolithic integrated circuits (MIC) (system on a chip), multi-chip modules (MCM) (mixing analogue, digital, microwave, etc.), and
c) increasing use of EM spectrum which include radio, TV, microwave ovens, aircraft electronics, automobile electronics, cell phones, direct broadcast satellites, etc.

Since these electronic components began to control safety critical functions, concern grew over the vulnerability of electronic systems. It is easy to envision a component failure leading to a subsystem and consequently a system-level failure, due to an intense HPEM signal. Therefore the susceptibility of critical systems is of vital interest since a setup or failure in these systems could cause major accidents or economic disasters [6]. The increase of non-metallic materials like carbon-fiber composite as well as the decrease of signal levels result in a decreased susceptibility level of electronic systems. As a consequence, the investigation of the susceptibility of electronic systems as well as their protection and hardening against HPEM threats is of great interest.

Figure 1 compares qualitatively the emerging HPEM environments with classical EMC (EMI, lightning) and HEMP environment. It can clearly be seen that the HPEM environment differs significantly in amplitude and/or frequency from the traditional EMC and HEMP environment.



NOTE The magnitude of the electric field spectrum is plotted on the y-axis.

Figure 1 – Several types of HPEM environments (from IEC 61000-2-13)

Annex A of the IEC 61000-2-13 contains four types of intentional electromagnetic environment, coupling and interference cases that can create system malfunctions. Annex B of IEC 61000-2-13 provides some examples of HPEM generators and their categorization on the basis of the technical sophistication level involved in assembling and deploying them.

The recently developed IEC HPEM environment standard (IEC 61000-2-13) provides both radiated and conducted HPEM environments that are possible and perhaps probable. This report provides a logical support to IEC 61000-2-13 by listing data on facilities that can simulate some of the radiated HPEM environment. These HPEM simulators may be useful for system-level in addition to equipment-level immunity tests.

5 Datasheet definitions and instructions

The request for information that was sent to owners of worldwide High-Power Electromagnetic (HPEM) simulators included the following definitions and general instructions. Owners were asked to make sure that the provided information was cleared for public release and free to be published in an IEC document.

Data sheets are structured as follows:

Clauses 1, 2, 3 and 5 are filled with data for all kinds of simulators. Under Clause 4 only the specific subclause, which is applicable to the reported simulator, is filled with information. For reasons of clarity, unused subclauses are represented by their headlines only.

The antenna and the impulse voltage source are essential (characterizing) components of a wideband (mesoband, sub-hyperband and hyperband) simulator. Generally, changing one of these components will result in a different waveform. In this report such change is treated like the assembly of a different simulator, which is reported by a separate datasheet.

In case a specific parameter, for example carrier frequency, is not applicable to a specific simulator one might check the not applicable (n/a) box. Further information or explanations to the given data can be provided in the comment field at the end of each clause.

For simulators that are radiating narrowband (hypoband) pulses, peak power density and electric field strength are characterized by its peak r.m.s. value (e.g. Maximum r.m.s. peak E-Field).

The following tables provide definitions and background information on the data provided. In data sheets, blue coloured headlines are used. Therefore, clauses are numbered as on the data sheet.

1. General information

Name of the simulator	Specify the name of the simulator.
Country	Specify the country where the simulator is located.
Simulator type	Select the simulator type with regard to the bandwidth classification as provided in IEC 61000-2-13, (hypoband = narrowband, mesoband, sub-hyperband and hyperband) from the drop down menu. For a detailed description, see bandwidth classification in subclause 4.A.
Major simulator dimension(s)	Specify the longest dimension of the simulator in meters (e.g., 80 m long).
Maximum test volume dimensions	Specify the dimensions in meters of the usable test volume (e.g., 15 m (high) by 20 m (wide) by 50 m (long)). The maximum test volume, specified by height × width × length, is the volume that can be occupied by the object under test without undesirable interactions.
Comments	Space to provide extra information or explanations to the data you have provided in the “General Information” clause.

2. Administrative information

Location	Specify the location of the simulator (nearest city and country).
Mobile	Specify if the simulator is mobile (e.g. has the capability to be transported to another location).
Indoor	Specify if the simulator operates indoor, that is the test area is located indoor.
Outdoor	Specify if the simulator operates outdoor, that is the test area is located outdoor.
Owner	Specify the name of the company or agency that owns the simulator.
Type of Organisation	Select the owners type of organization (government, industry, research institute or university) from the drop down menu.
Point of Contact	Specify the name and full address of the person to contact for more information about the simulator.
Status	Select the current status of the simulator (e.g., under development, operational, stand-by, inoperative).
Initial operation date (year)	Specify the year in which the simulator first became operational.

Date of disassembly (year)	In case the simulator is inoperative and has been disassembled, specific parameters of the simulator might still be of interest for the community. In this specific case specify the year in which the simulator was disassembled.

3. Availability

Government users	State availability of simulators for use by government agencies via drop down menu and any restrictions on this availability (e.g., available to government agencies of any EU country).
Industry users	State availability of simulators for use by private companies (via drop down menu) and any restrictions on this availability (e.g., available to any private company with endorsement of government agency).
Comments	Space to provide extra information or explanations to the data you have provided in the "General Information" clause.

4. Electromagnetic field characteristics

If a wideband simulator (e.g. mesoband, sub-hyperband or hyperband simulator) is reported, please fill out subclause 4.A. In case of a narrowband (hypoband) simulator continue with subclause 4.B.

4.A. Wideband simulator and ultra wideband (mesoband, sub-hyperband and hyperband simulator)

Electric field polarisation	Specify the electric field orientation with respect to the earth (e.g., vertical).
Far field range condition met at	Specify the minimal distance to the antennas at which the electromagnetic field met the far field conditions. The far field region of an antenna, radiating into free space, is characterized by a transverse electromagnetic field and that the ration between the electric and magnetic field strength equals the characteristic wave impedance of free space ($Z_0 = 120\pi\ \Omega$).
3 dB beam angle at far field condition	Specify the 3 dB-beam width (e.g. ±5 m) in the a plane horizontal (hor) and vertical (ver) with respect to earth at the minimal distance at which the radiated field complies with the far field condition.
Far field radiated voltage (rE)	Specify the product of range and peak electric fields available in the test volume (e.g., 2 kV to 50 kV).
Maximum peak field level at	Specify the highest peak field level that can be achieved by the simulator and indicate the related distance to the antenna (e.g. 10 kV/m at 15 m).

Exposed area at maximum peak E-field	Specify the area (plane perpendicular to the direction of radiation) which is exposed with the maximum peak E-field. (e.g. 9 m^2).
Minimum peak field level at	Specify the lowest peak field level that can be achieved by the simulator and indicate the related distance to the antenna (e.g. 10 kV/m at 15 m).
Exposed area at minimum peak E-field	Specify the area (plane perpendicular to the direction of radiation) which is exposed with the min peak E-field. (e.g. 9 m^2)
Minimum pulse rise time	Specify the 10 % to 90 % pulse rise time of the transient waveform.
Pulse width	Specify the pulse width T_{FWHM} at half maximum electric field (Full Width at Half Maximum) of the transient waveform.
Centre frequency (resonant frequency)	Specify the center frequency (resonant frequency) of the field signal radiated by the HPEM simulator.
Energy-bandwidth (B_{90EB})	Specify the Energy-Bandwidth as defined in IEC 61000-2-13. The Energy-Bandwidth is the minimal distance between the high (f_h) and low (f_l) edge frequencies, which encompasses 90 % of the signal energy.
Bandwidth classification	Select the bandwidth classification as provided in IEC 61000-2-13. The bandratio (b_r) is the ratio of the high (f_h) and low (f_l) edge frequencies. If the spectrum has a significant dc content, the lower edge frequency is limited as 1 Hz. $b_r = f_h / f_l$ hypoband = narrowband: $b_r \leq 1{,}01$ mesoband: $1{,}01 < b_r \leq 3$ sub-hyperband: $3 < b_r \leq 10$ hyperband: $b_r > 10$
Maximum pulse repetition frequency (per burst)	Specify the maximum pulse repetition frequency that can be achieved within a burst. (e.g. 10 Hz) Indicate if single shot operation is possible.
Length of bursts	Specify the duration of bursts in time (seconds).
Minimum time between bursts	Specify the minimum time interval which is required between two bursts. (e.g. 200 s)

Maximum number of bursts Specify t

he maximum number of burst that can be delivered in a sequence. (e.g. 1 000). In case there is no limit on the number of bursts write in unlimited.

Other Describe any other pertinent technical features of the simulator not covered above.

Comments Space to provide extra info or explanations to the data you have provided in the "Electromagnetic Characteristics" section.

4.B. Narrowband simulator (hypoband simulator)

Frequency range Specify the frequency range (centre frequencies) of the HPEM simulator.

Coverage of frequency range Select how the simulator covers the specified frequency range (tunable source, spot frequencies).

A simulator with a tunable source covers the whole specified frequency range. Gaps or notches shall be noted under comments. If you report data of a tunable simulator continue with subclause 4.B.1 Tunable simulator.

A simulator with spot frequencies operates on a dedicated set of frequencies (spot frequencies) within the specified range. Data of a simulator with spot frequencies should be reported using the table provided in subclause 4.B.2 Spot frequencies. If the simulator operates on more than five spot frequencies additional 4.B.2 data table should be provided separately.

Number of spot frequencies In case of spot frequencies, provide the number of spot frequencies.

4.B.1 Tunable simulator

Maximum pulse power Specify the maximum pulse power of the radiated signal.

Electric field polarisation Specify the electric field orientation with respect to the earth; multiple choices are possible. (e.g., vertical and horizontal).

Far field range condition met at Specify the minimal distance to the antennas at which the electromagnetic field met the far field conditions. The criterion is not applicable (n/a) for reverberation chambers or TEM waveguides.

Nominal test distance Specify the nominal test distance to the antenna. The criterion is not applicable (n/a) for reverberation chambers or TEM waveguides.

3 dB beam angle - at	Specify the 3 dB-beam width (e.g. ±5 m) in a plane horizontal (hor) and vertical (ver) with respect to earth. Select the related distance (*far field condition* or *nominal test distance*).
Maximum r.m.s. peak E-Field - at	Specify the maximum r.m.s. E-field of the simulator. Select the related distance (*far field condition* or *nominal test distance*).
Exposed area - at	Specify the plane perpendicular to the direction of radiation which is exposed by the 3 dB beam (e.g. 9 m^2). Select the related distance (*far field condition* or *nominal test distance*).
Far field radiated voltage (rE)	Specify the product of range and peak electric fields available in the test volume (e.g., 2 kV to 50 kV).
Minimum pulse rise time	Specify the 10 % to 90 % pulse rise time of the transient waveform.
Maximum pulse width	Specify the pulse width T_{FWHM} at half maximum electric field (Full Width Half Maximum) of the radiated field signal.
Max. Pulse repetition frequency (per burst)	Specify the maximum pulse repetition frequency that can be achieved within a burst (e.g. 10 Hz). Indicate if single shot operation is possible.
Length of bursts	Specify the duration of bursts in time (seconds).
Min. time betw. Bursts	Specify the minimum time interval which is required between two bursts (e.g. 200 s).
Max. number of bursts	Specify the maximum number of burst that can be delivered in a sequence. (e.g. 1 000). In case there is no limit on the number of bursts write in unlimited.
Antenna gain	Specify the gain of used antenna (e.g. 30 dB)
Other	Describe any other pertinent technical features of the simulator not covered above.
Comments	Space to provide extra info or explanations to the data you have provided in the “Electromagnetic Characteristics” clause.

4.B.2 Simulator with spot frequencies

The data of a narrowband simulator that operates on a set of spot frequencies should be reported in a table in which the columns providing the required parameter (see subclause 4.b.1) per spot frequency (subclause 4.B.2 of the input data form).

4.B.3 Reverberation Chamber

Lowest Usable Frequency (LUF) in accordance with IEC 61000-4-21	Specify the lowest usable frequency (LUF) of the chamber, as defined in IEC 61000-4-21.
Chamber Q - at	Specify the Q of the reverberation chamber and indicate the related frequency.
Min. Pulse Rise Time	Specify the shortest 10 % to 90 % signal rise time that can be used in the reverberation chamber.
Modes of operation	Specify the modes of operation of the mode stirrer (continuous, stepped/tuning or both).
Other	Describe any other pertinent technical features of the simulator not covered above.
Comments	Space to provide extra info or explanations to the data you have provided in the “Electromagnetic characteristics” clause.

5. Other technical information

Simulators	Provide one or more high-quality color 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. NOTE Not applicable for reverberation chamber.
Typical frequency domain spectrum	Provide a Fourier transform of a representative signal from the simulator test volume. NOTE Not applicable for reverberation chambers.
Available E-field per Watt input power	Provide a graph that shows the normalized (to the square root of the input power) test E-field strength in the empty chamber. The test E-field strength is the positional average of the ensemble maximum (rotation of the tuner) of the magnitude of the rectangular E-field components. [IEC 61000-4-21, Clause 7]. NOTE Only applicable for reverberation chambers.
General description	Provide any 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 HPEM 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 HPEM simulator.

6 Project description

6.1 General

This Technical Report reviews worldwide system-level HPEM simulators in terms of their characteristics, capabilities, and limitations. This clause provides a brief summary and update of papers presented at international conferences and describes several HPEM simulators that currently exist [9], [10].

Clause 7 consists of datasheets for individual HPEM simulators that remain in operation or could be put back into operation for HPEM testing. Other simulators exist in US, Australia, Russia, and probably elsewhere, but the authors were not able to obtain information about them in time for this Technical Report.

6.2 Wideband and ultra wideband simulator

Wideband and ultra wideband (mesoband, sub-mesoband and hyperband) simulators are characterized by a percentage bandwidth (pbw) value of more than 1 %. For this Technical Report only Germany and Ukraine has reported information. In other publications other simulators may be described. The authors hope that the first published edition of IEC 61000-4-35 will motivate owners of those simulators to contribute data to a further edition.

Baum has described certain systems that integrate a switched oscillator into a wideband antenna. The transmission line oscillator consists of a quarter wave section of a transmission line that is charged by a high voltage source and employs a self-breaking switch across the transmission line. When the switch closes, the system generates a damped sinusoidal signal, [11]. The frequency and damping constant are adjustable. An initial working model of this source, called the MATRIX, is due to begin full-scale testing at AFRL this year. It consists of quarter-wave transmission lines charged to 150 kV with the frequency of oscillation adjustable between 180 MHz and 600 MHz. It is predicted to produce a damped sine waveform as shown in Figure 2 with a peak electric field of 30 kV/m and a percent bandwidth of about 10 % (band ratio of 1.1). With the 300 kV charging supply that is planned, this source will radiate energy in the GW range [12], [13].

The Impulse Radiating antenna (IRA) is a good example of a high power hyperband source. The IRA produces a high power electromagnetic (HPEM) signal with a band ratio greater than two decades. It operates from 200 MHz to 2 GHz and has a band ratio of 10. The Original IRA, developed and fielded in 1994, used a high-pressure hydrogen switch, a focusing lens, and a four-arm TEM horn to produce an extremely powerful UWB pulse from a 4 m reflector. With a charge of only ±60 kV, this system generated a transient signal of 4,6 kV/m at 305 m at 200 Hz. This gives a field-range product of and designated the IRA II [19], [20]. The power supply was modified to increase the voltage to ±75 kV and 400 Hz. The radiated spectrum of the 2 m IRA has been measured to be flat from 200 MHz to around 3 GHz.

In 2003 the US Air Force Research Laboratory, Kirtland AFB, NM released a note on the JOLT system. The pulsed power system of JOLT centers around a very compact resonant transformer capable of generating over 1 MV at a pulse repetition frequency (PRF) of 600 Hz. This is switched via an integrated transfer capacitor and an oil peaking switch onto an 85-W Half-IRA (Impulse Radiating Antenna). This unique system delivers a far radiated field with a full-width at half maximum (T_{FWHM}) on the order of 100 ps, and a far radiated voltage (r E) of ~5,3 MV.

FID Technology Corporation of St. Petersburg makes a wide variety of wideband sources featuring much of the solid-state technology developed at the Ioffe Institute. They produce a line of pulse generators designated FPG series that vary in output voltage from 5 V to 50 V with rise times from 100 ps to 200 ps, pulse widths of 1 ns to 2 ns and PRFs ranging from 0,1 kHz to 10 kHz [33].

The High Current Electronics Institute, Russian Academy of Science (RAS) in Tomsk makes a hyperband system that delivers 800 V at 5 kHz into an antenna that is a unique combination of electric and magnetic dipoles. Designated the FGD800, it will deliver a peak electric field of 18 kV/m at 3 m with a rise time of 75 ps and a pulse width of 2 ns [34].

The Ioffe Physico-Technical Institute RAS in St. Petersburg is well known for its research and development in UWB and pulsed power, and the technology developed there is found in many other systems in Russia. Ioffe continues to lead the development of semiconductor opening switches (SOS) and silicon avalanche shapers (SAS) that are used in pulsers around the world [35].

The Ukraine has also shown interest and progress in the development of UWB, short pulse technology. In October of 2002, Karazin Kharkov National University sponsored their First International Workshop on Ultra-Wideband and Ultra-Short Pulses. Papers on UWB signals, propagation, radar, sources, and antennas were presented by participants from the Ukraine, Russia, and the USA, see [33]. Among these, a design for a subnanosecond generator was presented by the Diascarb Research Company in Kiev. It is a high power, sub-nanosecond generator designed for UWB radar. Utilizing both solid state and gas technology, this design produces 400 V pulses with a 2 na to 5 ns pulse widths [34].

One hyperband source from Israel has been presented in recent conferences. Referred to as a sub-nanosecond source, it is a compact, coaxial design driven by a semiconductor opening switch (SOS) pulser. It utilizes cascaded pulse forming network (PFN) stages to produce a 170 kV peak bipolar pulse into a 37 Ω load. The pulse width can be regulated from 2 ns down to 300 ps. The rise and fall times are 200 ps and 150 ps respectively. Either unipolar or bipolar output can be provided. Maximum PRF is 300 Hz [35].

In China, a UWB system design was published recently by researchers from the Northwest Institute of Nuclear Technology in collaboration with Jiaotong University in Xi'an City. The design consists of a wire mesh TEM horn feeding a 2 m parabolic reflector. As one would expect, the radiated far field waveform is bipolar. The antenna is driven by a 200 kV pulse generator with a rise time of 370 ps and a total pulse width of 700 ps. The spectrum has most of its energy between 150 MHz and 580 MHz. The unit is capable of operating at 100 Hz [36], [37], [38].

6.3 Narrowband simulator

HPM sources have been developed for more than 15 years and HPM test capabilities are being used and developed worldwide. Currently, this Technical Report describes five different European HPM test facilities. These HPM test facilities are

- the Czech HPM test facility,
- MTF, the Swedish HPM test facility,
- Orion, the British HPM test facility,
- Hyperion, the French HPM test facility,
- Supra, the German HPM test facility.

The Czech and the Swedish HPM facilities work on dedicated spot frequencies, whereas the other systems are posess the capability to tune their sources in a specified frequency range. Many other HPM test facilities exist, but openly available data is not fully available, as yet. A detailed description of the system capabilities, the design specifications and the operating principles of the HPM facilities described in this document can be found in previous documents [51], [52], [53], [54], [55], [56].

6.4 Reverberation chamber

High-level electromagnetic fields are easily and safely generated using reverberation chambers. The high quality factor or "Q" of most chambers allows fairly high field strengths to be generated with moderate input powers, and the absence of absorber makes generation of high field levels safer as the chance of igniting absorbers is eliminated.

In general, a reverberation chamber is a shielded enclosure with the smallest dimension being large with respect to the wavelength at the lowest useable frequency. The chamber is normally equipped with a mechanical tuning/stirring device whose dimensions are a significant fraction of the chamber dimensions and of the wavelength at the lowest useable frequency. When the chamber is excited with RF energy the resulting multi-mode electromagnetic environment can be "stirred" by the mechanical tuner/stirrer. The resulting environment is statistically uniform and statistically isotropic (i.e. having arrived from all aspect angles and at all polarizations) when averaged over a sufficient number of positions of the mechanical tuner/stirrer.

The chamber mode density and the effectiveness of the mechanical tuner/stirrer determine the lowest useable frequency. The lowest useable frequency is generally accepted to be the frequency at which the chamber meets operational requirements. This frequency generally occurs at a frequency slightly above 3 times the first chamber resonance. In practice, the chamber size, tuner/stirrer effectiveness and the chamber quality factor determine the lowest useable frequency. For the reverberation chamber procedure described in IEC 61000-4-21, it is the lowest frequency at which, the specified field uniformity can be achieved over a volume defined by an 8-location calibration data set.

As stated in Annex A of the IEC 61000-4-21, the frequency range of tests is determined by the size and construction of the chamber and the effectiveness of the mechanical tuner(s). Room sized reverberation chambers (e.g. volumes of between 75 m^2 to 100 m^2) are typically operated from 200 MHz to 18 GHz without limitations. Operations below 200 MHz require chambers that are larger than the typical shielded room.

Details of reverberation chamber tests can be found in IEC 61000-4-21 and are not in the scope of this Technical Report. In the scope of this Technical Report data of reverberation chambers are reported, which are large enough to perform a system level test with peak electric field strength of more than 500 V/m.

NOTE In case of a reverberation chamber IEC 61000-4-21 defines the test field strength as the maximum of a rectangular component of the E-field. Unfortunately, the usual plane wave relation between E and S does not hold in a reverberation chamber. The given level for the electric field corresponds approximately with a maximum scalar power density of 1 989 W/m^2, see [7], [8]. The maximum scalar power density is defined as the ratio between the maximum received power in an antenna and the effective area of the antenna.

7 Datasheets

7.1 Wideband simulator

HIRA II- PBG, Germany

1. General information

Simulator type: hyperband

Major simulator Dimension(s): 2,0 m (high) by 2,0 m (wide) by 2,0 m (long)

Max. test volume dimensions: m (high) by m (wide) by m (long) ☐ n/a

Comments

2. Administrative Information

Location: **Munster. Germany**

mobile ☒ yes ☐ no

outdoor ☒ yes ☐ no

indoor ☒ yes ☐ no

Owner: WIS

Type of Organization Government

Point of Contact: GF 330 EME

Address P.O. Box 1142
29623 Munster, Germany

Phone : +49 5192 136 462

Fax : +49 5192 136 355

E-mail : WIS330ElektromagWirkung en@bwb.org

URL : http://www.bwb.org/

Status: Operational

Initial Operation Date: 2002 ☐ n/a

Date of Disassembly: (in case of unavailable)

3. Availability

	Yes/No	Restrictions
Government users:	Yes	
Industry users:	Yes	

Comments

4. Electromagnetic Characteristics

A. Wideband and ultra wideband simulator (mesoband , sub-hyperband and hyperband)

Electric Field Polarization: ☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random

Far field range condition met at 40 m ☐ n/a

3dB beam angle at far field condition 6 m (hor) 4 m (ver)

Far field radiated Voltage (rE): 170 kV ☐ n/a

Max. peak Field Level 17 kV/m (hor) ☐ n/a
kV/m (ver)
kV/m (circ./eli.)
kV/m (rand.)

at 10 m

Exposed area at max peak E-field 1,6 m^2

Min. peak Field Level 4 kV/m ☐ n/a
kV/m (ver)
kV/m (circ./eli.)
kV/m (rand.)

at 10 m

Exposed area at min peak E-field 1,6 m^2

Min. Pulse Rise Time: 0,23 ns (10%-90%) ☐ n/a

Pulse Width: 2,0 ns (T_{FWHM}) ☐ n/a

Center Frequency (f_c) MHz ☐ n/a

Energy-Bandwidth (B_{90EB})

Bandwidth Classification hyperband

Max Pulse repetition frequency (per burst) 900 Hz
☒ single shot possible

Length of Bursts unlimited s

Min. Time betw. Bursts ☒ n/a

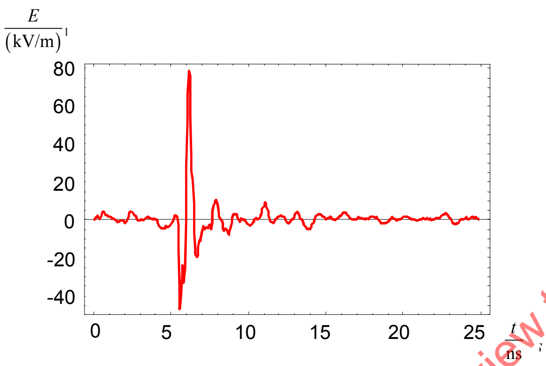
Max. Number of Bursts unlimited ☐ n/a

Other:

Comments

Simulator

Typical time-domain waveform



Typical frequency spectrum

Not available

Other technical information

General description

Not available

Available instrumentation

– Electric and magnetic field probes up to 10 GHz bandwidth
– Current probes up to a bandwidth of 3 GHz
– Several fibre optic lines up to a bandwidth of 1,8 GHz
– Transient recorders and fast digital scopes with a single shot bandwidth of 7 GHz
– Modern PC-based data acquisition with mathematical features.

Auxiliary test equipment

Not available

AVTOARRESTOR, Ukraine

1. General information

Simulator type: **sub-hyperband**

Major simulator Dimension(s): 4,0 m (high) by 3,2 m (wide) by 3,5 m (long)

Max. test volume dimensions: m (high) by m (wide) by m (long) ☐ n/a

Comments

2. Administrative Information

Location: **Kharkov. Ukraine**

mobile ☒ yes ☐ no

outdoor ☒ yes ☐ no

indoor ☒ yes ☐ no

Owner: Research & Engineering Institute "Molniya" NTU "KhPI"

Type of Organization Government

Point of Contact: Dr. Vladimir Kravchenko

Address Shevchenko str. 47, Kharkov, 61013, Ukraine

Phone :

Fax : 380-057-7076133

E-mail : nipkimolniya@kpi.kharkov.ua

URL :

Status: Operational

Initial Operation Date: 1996 ☐ n/a

Date of Disassembly (in case of unavailable)

3. Availability

	Yes/No	Restrictions
Government users:	Yes	
Industry users:	Yes	

Comments

4. Electromagnetic Characteristics

A. Wideband and ultra wideband simulator (mesoband , sub-hyperband and hyperband)

Electric Field Polarization: ☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random

Far field range condition met at 5 m ☐ n/a

3dB beam angle at far field condition 2 m (hor) 2 m (ver)

Far field radiated Voltage (rE): 1500 kV ☐ n/a

Max. peak Field Level 300 kV/m (hor) 300 kV/m (ver) kV/m (circ./eli.) kV/m (rand.) ☐ n/a

at 5 m

Exposed area at max peak E-field 4 m^2

Min. peak Field Level 10 kV/m 10 kV/m (ver) kV/m (circ./eli.) kV/m (rand.) ☐ n/a

at 150 m

Exposed area at min peak E-field 400 m^2

Min. Pulse Rise Time: 0,7 ns (10%-90%) ☐ n/a

Pulse Width: 35 ns (T_{FWHM}) ☐ n/a

Center Frequency (f_c) 400 MHz ☐ n/a

Energy-Bandwidth (B_{90EB}) 90 – 500 MHz

Bandwidth Classification sub-hyperband

Max Pulse repetition frequency (per burst) 10 Hz ☐ single shot possible

Length of Bursts 5 s

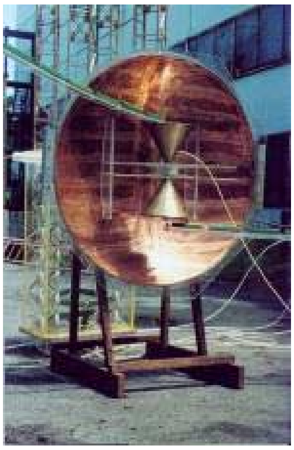
Min. Time betw. Bursts 300 s ☐ n/a

Max. Number of Bursts 5000 ☐ n/a

Other:

Comments

Simulator



Typical frequency spectrum

Not available

Typical time-domain waveform

Not available

Other technical information

General description

Not available

Available instrumentation

Not available

Auxiliary test equipment

Not available

7.2 Narrowband simulator

HPM 3 GHz, 6 GHz and 9 GHz, Czech Republic

1. General Information

Simulator Type:	**hypoband - narrowband**
Major Simulator Dimension(s):	1,5 m (high) by 0,7 m (wide) by 2,0 m (long)
Max. Test Volume Dimensions:	m (high) by ☒ n/a m (wide) by m (long)
Comments	

2. Administrative Information

Location:	**Vyskov, Czech Republic**
mobile	☒ yes ☐ no
outdoor	☒ yes ☐ no
indoor	☒ yes ☐ no
Owner:	VOP-026 Sternberk, s.p.
Type of Organization	Industry
Point of Contact:	Libor Palisek
Address	V. Nejedleho 691 Vyskov
Phone :	+420 517 303 638
Fax :	+420 517 303 605
E-mail :	l.palisek@vtupv.cz
URL :	www.vop.cz
Status:	Operational
Initial Operation Date:	2001
Date of Disassembly	☐ n/a (in case of unavailable)

3. Availability

	Yes/No	Restrictions
Government users:	Yes	
Industry users:	Yes	
Comments		

4. Electromagnetic Characteristics

B. Narrowband (hypoband simulator)

Frequency Range	GHz	
Coverage of frequency range	tunable	
Number of spot frequencies		☐ n/a

B.1. Tunable Simulator

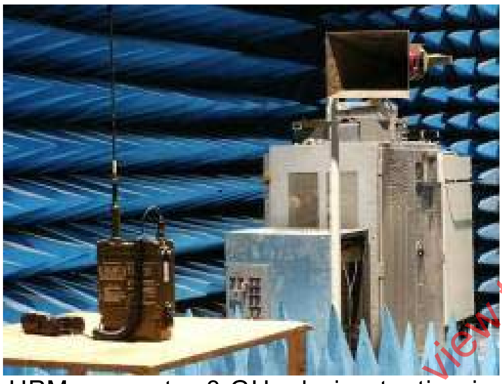
Max. Pulse-Power	MW	
Electric Field Polarization:	☐ Vertical ☐ Horizontal ☐ Circular/Elliptical ☐ Random	
Far field range condition met at	m	☐ n/a
Nominal test distance	m	☐ n/a
3dB beam angle	(hor)	(ver)
at	far field condition	
Max. rms peak E-field	kV/m	☐ n/a
at	far field condition	
Exposed area	m²	
at	far field condition	
Far field radiated Voltage (rE):	kV	☐ n/a
Min. Pulse Rise Time:	ns (10%-90%)	☐ n/a
Max. Pulse Width:	µs (T_{FWHM})	☐ n/a
Max Pulse repetition frequency (per burst)	Hz ☐ single shot possible	
Length of Bursts	s	☐ n/a
Min. Time betw. Bursts	s	☐ n/a
Max. Number of Bursts		☐ n/a
Antenna Gain	dB	☐ n/a
Other:		
Comments		

B.2. Simulator with spot frequencies

Frequency	2,7 GHz	6,5 GHz	9,3 GHz	GHz	GHz
Max. Pulse-Power	0,5 MW	0,5 MW	0,2 MW	MW	MW
Electric Field Polarization:	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random	☐ Vertical ☐ Horizontal ☐ Circular/Elliptical ☐ Random	☐ Vertical ☐ Horizontal ☐ Circular/Elliptical ☐ Random
Far field range condition met at	1 m ☐ n/a	1,3 m ☐ n/a	0,2 m ☐ n/a	m ☐ n/a	m ☐ n/a
Nominal test distance	1 m ☐ n/a	1 m ☐ n/a	1 m ☐ n/a	m ☐ n/a	m ☐ n/a
3dB beam angle at	22 (hor) 22 (ver) far field condition	25 (hor) 25 (ver) far field condition	30 (or 10) (hor) 30 (or 10) (ver) far field condition	(hor) (ver) far field condition	(hor) (ver) far field condition
Max. rms peak E-field at	35 kV/m nominal test distance	30 kV/m nominal test distance	15 kV/m nominal test distance	kV/m far field condition	kV/m far field condition
Exposed area at	0,15 m^2 nominal test distance	0,2 m^2 nominal test distance	0,3 m^2 nominal test distance	m^2 far field condition	m^2 far field condition
Far field radiated Voltage (rE):	35 kV ☐ n/a	30 kV ☐ n/a	15 kV ☐ n/a	kV ☐ n/a	kV ☐ n/a
Min. Pulse Rise Time (10%-90%):	ns ☐ n/a	ns ☐ n/a	ns ☐ n/a	ns ☐ n/a	ns ☐ n/a
Max. Pulse Width (FWHM):	2,5 µs ☐ n/a	1,75 µs ☐ n/a	0,5 µs ☐ n/a	µs ☐ n/a	µs ☐ n/a
Max Pulse repetition frequency (per burst)	800 Hz ☐ single shot possible	800 Hz ☐ single shot possible	2000 Hz ☒ single shot possible	Hz ☐ single shot possible	Hz ☐ single shot possible
Length of Bursts	unlimited s ☐ n/a	unlimited s ☐ n/a	unlimited s ☐ n/a	s ☐ n/a	s ☐ n/a
Min. Time betw. Bursts	s ☒ n/a	s ☒ n/a	s ☒ n/a	s ☐ n/a	s ☐ n/a
Max. Number of Bursts	unlimited ☐ n/a	unlimited ☐ n/a	unlimited ☐ n/a	☐ n/a	☐ n/a
Antenna Gain	19 dB ☐ n/a	18 dB ☐ n/a	16 dB ☐ n/a	dB ☐ n/a	dB ☐ n/a
Other:					
Comments					

Simulator

HPM generator 3 GHz

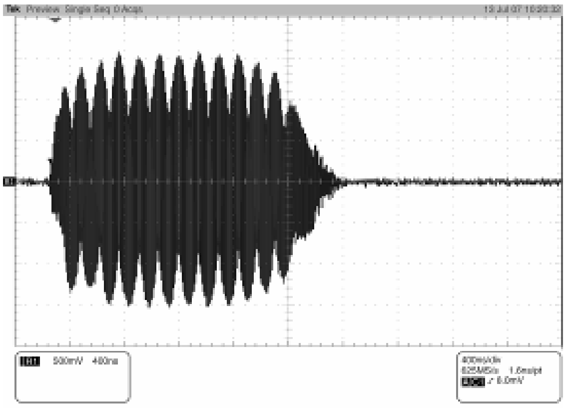


HPM generator 3 GHz during testing in semianechoic chamber

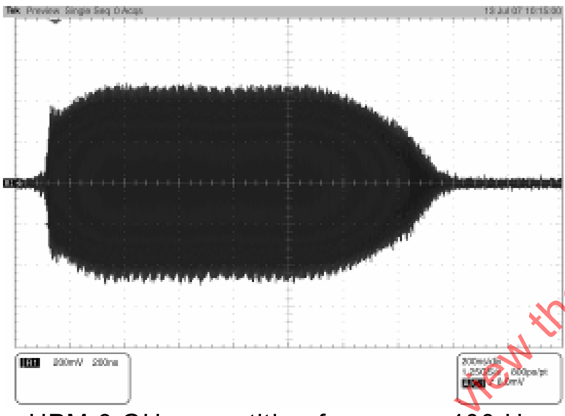
HPM generator 6 GHz

HPM generator 9 GHz with antenna 3 dB beam angle = 10°

Typical time-domain waveform

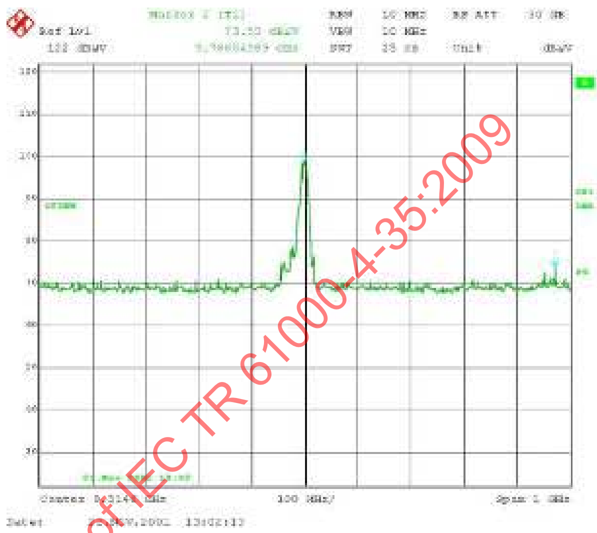


HPM 3 GHz, repetition frequency 800 Hz



HPM 6 GHz, repetition frequency 400 Hz

Typical frequency spectrum



HPM 9 GHz frequency spectrum

Other technical information

General description

HPM generators are modified radars where magnetron tubes are used. Suitable horn antennas are connected with generators through the waveguides.

Note only for generator 9 GHz:

It is possible to use single shot mode as well as repetition rate mode with possibility to change repetition frequency from 1 Hz up to 2 kHz. It is possible to change the number of generated pulses from 1 up to unlimited.

Available instrumentation

– Field strength Meter NARDA Model 8718B with probe NARDA Model 8721D
– Optical line up to a bandwidth 3 GHz
– High voltage and regular attenuators
– Digital scope with a single shot bandwidth 7 GHz (20 Giga sample /s)
– Current probes up to a bandwidth 1 GHz
– Measurement receivers up to a bandwidth 40 GHz
– Receiving EMC antennas up to frequency 40 GHz
– Shielded video camera with monitoring system

Auxiliary test equipment

Not available

HYPERION, France

1. General Information

Simulator Type:	**hypoband - narrowband**	
Major Simulator Dimension(s):	20 m (high) by 20 m (wide) by 20 m (long)	
Max. Test Volume Dimensions:	7 m (high) by 7 m (wide) by 7 m (long)	☐ n/a
Comments		

2. Administrative Information

Location:	**Gramat, France**	
mobile	☐ yes	☒ no
outdoor	☐ yes	☒ no
indoor	☒ yes	☐ no
Owner:	Centre d'études de Gramat (CEG)	
Type of Organization	Government	
Point of Contact:	Dominique J. Sérafin	
Address	Centre d'études de Gramat 46500 Gramat, France	
Phone :	33-565105446	
Fax :	33-565105342	
E-mail :	Dominique.Sérafin dga.defense.gouv.fr	
URL :		
Status:	Operational	
Initial Operation Date:	2002	☐ n/a
Date of Disassembly	(in case of unavailable)	

3. Availability

	Yes/No	Restrictions
Government users:	Yes	
Industry users:	Yes	
Comments		

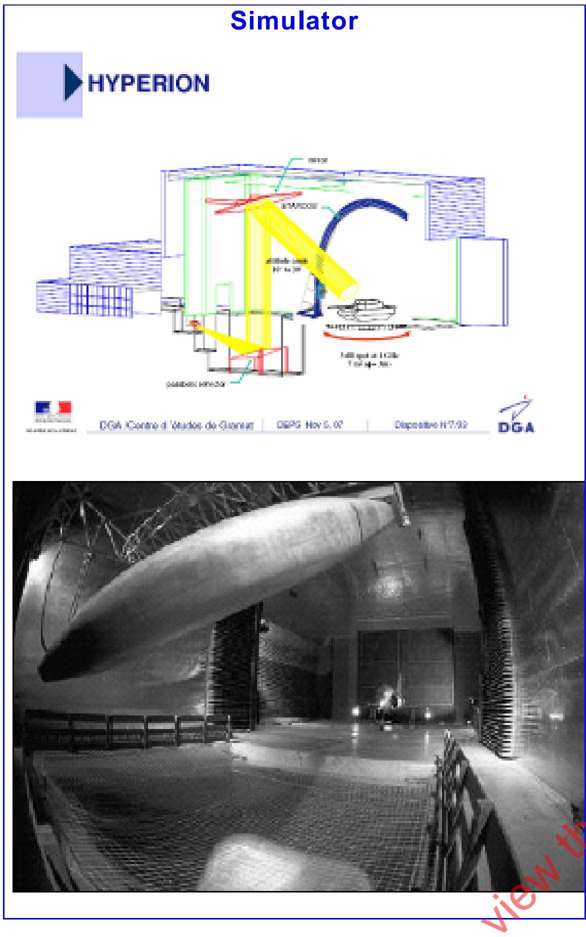
4. Electromagnetic Characteristics

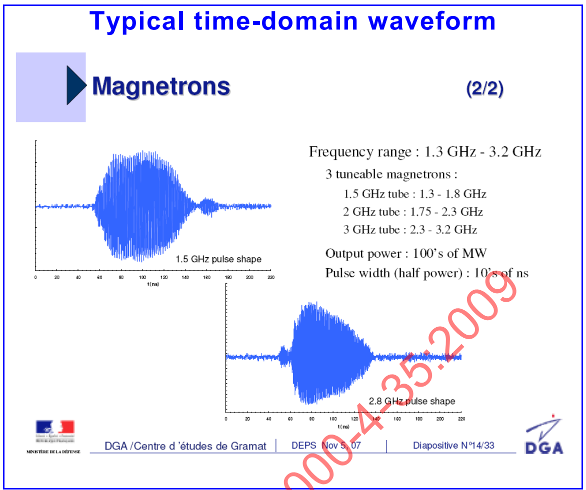
B. Narrowband (hypoband simulator)

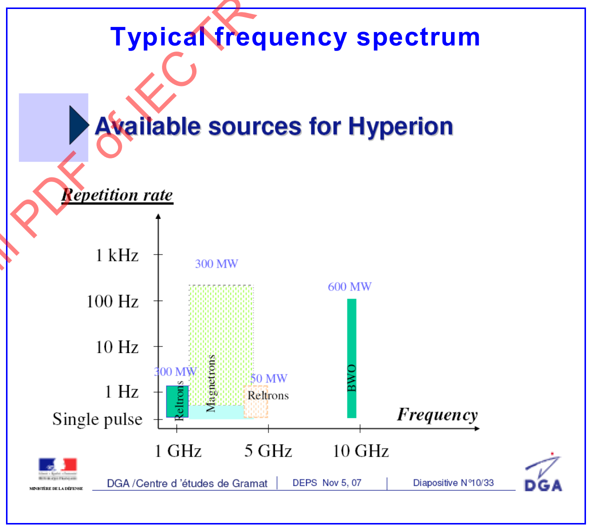
Frequency Range	0,72 - 3,00 GHz	
Coverage of frequency range	tunable	
Number of spot frequencies		☒ n/a

B.1. Tunable Simulator

Max. Pulse-Power	400 MW	
Electric Field Polarization:	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random	
Far field range condition met at	m	☐ n/a
Nominal test distance	m	☐ n/a
3dB beam angle	(hor)	(ver)
at		
Max. rms peak E-field	60 kV/m	☐ n/a
at		
Exposed area	m^2	
at		
Far field radiated Voltage (rE):	kV	☐ n/a
Min. Pulse Rise Time:	20 ns (10%-90%)	☐ n/a
Max. Pulse Width:	> 0,3 μs (T_{FWHM})	☐ n/a
Max Pulse repetition frequency (per burst)	10 Hz ☒ single shot possible	
Length of Bursts	10 - 200 s	☐ n/a
Min. Time betw. Bursts	s	☐ n/a
Max. Number of Bursts	unlimited	☐ n/a
Antenna Gain	dB	☐ n/a
Other:		
Comments	The frequency coverage is achieved via a set of two tunable reltrons (which covers the band below 1,44 GHz) and two magnetrons for the band 1,3 – 1,8 GHz and 2,4 – 3,0 GHz respectively. Length of bursts and min. time betw. bursts depends on pulse repetition rate and number of pulses per bursts	


Simulator
HYPERION
DGA /Centre d 'études de Gramat
DEPS Nov 5, 07
Diapositive N°7/33
DGA


Typical time-domain waveform
Magnetrons
(2/2)
Frequency range : 1.3 GHz - 3.2 GHz
3 tuneable magnetrons :
1.5 GHz tube : 1.3 - 1.8 GHz
2 GHz tube : 1.75 - 2.3 GHz
3 GHz tube : 2.3 - 3.2 GHz
Output power : 100's of MW
Pulse width (half power) : 10's of ns
1.5 GHz pulse shape
2.8 GHz pulse shape
DGA /Centre d 'études de Gramat
DEPS Nov 5, 07
Diapositive N°14/33
DGA


Typical frequency spectrum
Available sources for Hyperion
Repetition rate
1 kHz
100 Hz
10 Hz
1 Hz
Single pulse
300 MW
600 MW
300 MW
50 MW
Reltrons
Magnetrons
Reltrons
BWO
Frequency
1 GHz
5 GHz
10 GHz
DGA /Centre d 'études de Gramat
DEPS Nov 5, 07
Diapositive N°10/33
DGA

Other technical information

General description

Hyperion is a compact range concept. It includes

a) a large room devoted to the microwave sources and the associated pulse power,

b) a below 0 parabolic antenna and a movable mirror from 0 to 15 m high,

c) a test zone including a turntable where systems under test are located.

A variety of sources are available. However, repetitive tunable magnetrons are more often used.

Systems under test enter Hyperion through large doors.

It is a semi-anechoic chamber allowing an easy operation in a safe and secure environment.

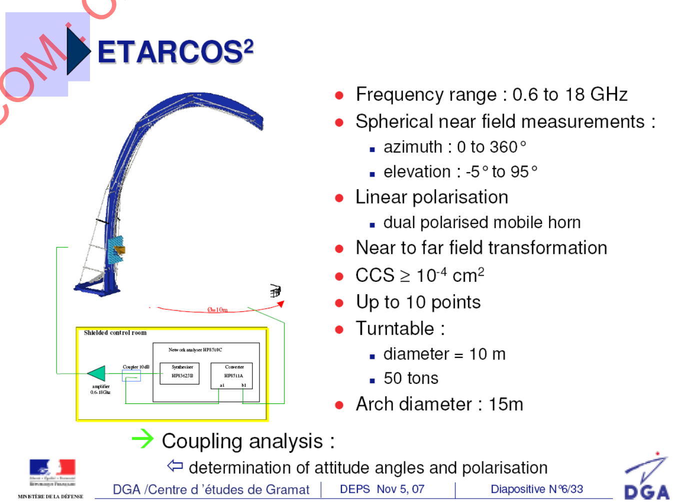
It fits for systems such as aircrafts, missiles, radar systems, communication systems.

Available instrumentation

Measurement systems to control the good operation of the microwave sources, to quantify the radiated fields and to analyze the response of the systems under test are located in a spacious faraday cage. It includes, transient digitizers, computers, scopes, electromagnetic sensors, current and voltage probes. Specific systems to operate and to control the system under test can be used.

Auxiliary test equipment

ETARCOS is an arch with a movable microwave device operating in the frequency band 600 MHz to 18 GHz to determine the major coupling paths of the microwave radiations according to angles and polarization.



MELUSINE, France

1. General Information

Simulator Type:	**hypoband - narrowband**	
Major Simulator Dimension(s):	6 m (high) by 12 m (wide) by 100 m (long)	
Max. Test Volume Dimensions:	4 m (high) by 4 m (wide) by 10 m (long)	☐ n/a
Comments		

2. Administrative Information

Location:	**Gramat, France**	
mobile	☐ yes	☒ no
outdoor	☐ yes	☒ no
indoor	☒ yes	☐ no
Owner:	Centre d'études de Gramat (CEG)	
Type of Organization	Government	
Point of Contact:	Dominique J. Sérafin	
Address	Centre d'études de Gramat 46500 Gramat, France	
Phone :	33-565105446	
Fax :	33-565105342	
E-mail :	Dominique.Sérafin dga.defense.gouv.fr	
URL :		
Status:	Operational	
Initial Operation Date:	2002	☐ n/a
Date of Disassembly	(in case of unavailable)	

3. Availability

	Yes/No	Restrictions
Government users:	Yes	
Industry users:	Yes	
Comments		

4. Electromagnetic Characteristics

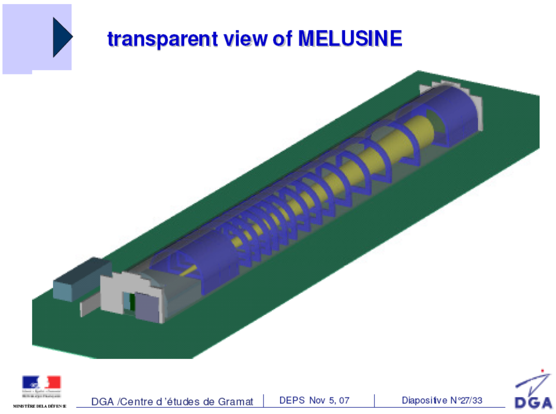
B. Narrowband (hypoband simulator)

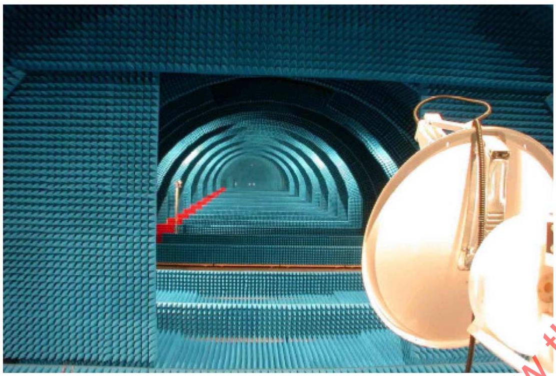
Frequency Range	0,72 - 3,00 GHz	
Coverage of frequency range	tunable	
Number of spot frequencies		☒ n/a

B.1. Tunable Simulator

Max. Pulse-Power	MW		
Electric Field Polarization:	☒ Vertical ☐ Circular/Elliptical ☐ Random	☒ Horizontal	
Far field range condition met at	m		☐ n/a
Nominal test distance	m		☐ n/a
3dB beam angle	(hor)	(ver)	
at			
Max. rms peak E-field	60 kV/m		☐ n/a
at			
Exposed area	m^2		
at			
Far field radiated Voltage (rE):	kV		☐ n/a
Min. Pulse Rise Time:	ns (10%-90%)		☐ n/a
Max. Pulse Width:	µs (T_{FWHM})		☐ n/a
Max Pulse repetition frequency (per burst)	10 Hz ☒ single shot possible		
Length of Bursts	s		☐ n/a
Min. Time betw. Bursts	s		☐ n/a
Max. Number of Bursts			☐ n/a
Antenna Gain	dB		☐ n/a
Other:			
Comments			

Simulator





Typical time-domain waveform

Not available

Typical frequency spectrum

Not available

Other technical information

General description

MELUSINE is an indoor facility for HPM testing of complete systems. It takes benefit of a long reinforced concrete tunnel to deliver a variety of electromagnetic radiations on targets located few tens of meters away from the sources.

This simulator is appropriate for vulnerability assessment or HPM demonstrator's evaluation.

The simulator is composed of

a) a source area on one end of the tunnel with screen rooms, sources, the associated pulse power and antennae,

b) the tunnel zone with anechoic material disposed all along on many rings,

c) the test zone itself including an arch with anechoic material to minimize the reflections; the test zone can be anywhere from 20 m to 80 m away from the sources depending on requirements. Systems under test enter MELUSINE through a large door. It has been designed to be operated safely and securely; X ray protection is specially reinforced.

It can be used for moving or fixed targets, IEDs and other purposes.

Available instrumentation

Instrumentation is available to monitor the correct operation of the microwave devices and to measure response of the system. A variety of transient digitizers, electromagnetic sensors, current and voltage probes are available in a large screen room. Specific measurement system and emulation devices can be used for devices under test.

Auxiliary test equipment

Not available

EMCC Dr. Rašek HIRF-Simulator, Germany

1. General Information

Simulator Type:	**hypoband - narrowband**
Major Simulator Dimension(s):	m (high) by m (wide) by m (long)
Max. Test Volume Dimensions:	m (high) by ☒ n/a m (wide) by m (long)
Comments	

2. Administrative Information

Location:	**Ebermannstadt, Germany**
mobile	☒ yes ☐ no
outdoor	☒ yes ☐ no
indoor	☒ yes ☐ no
Owner:	EMCCons DR. RAŠEK GmbH & Co. KG
Type of Organization	Industry
Point of Contact:	
Address	EMCCons DR. RAŠEK GmbH & Co. KG. Moggast, Boelwiese 4-8 91320 Ebermannstadt, Germany
Phone :	+49 9194 9016
Fax :	+49 9194 8125
E-mail :	emplab@emcc.de
URL :	www.emcc.de
Status:	Operational
Initial Operation Date:	☐ n/a
Date of Disassembly	(in case of unavailable)

3. Availability

	Yes/No	Restrictions
Government users:	Yes	
Industry users:	Yes	
Comments		

4. Electromagnetic Characteristics

B. Narrowband (hypoband simulator)

Frequency Range	GHz	
Coverage of frequency range	spot frequencies	
Number of spot frequencies	5	☐ n/a

B.1. Tunable Simulator

Max. Pulse-Power	MW	
Electric Field Polarization:	☐ Vertical ☐ Horizontal ☐ Circular/Elliptical ☐ Random	
Far field range condition met at	m	☐ n/a
Nominal test distance	m	☐ n/a
3dB beam angle	(hor)	(ver)
at	far field condition	
Max. rms peak E-field	kV/m	☐ n/a
at	far field condition	
Exposed area	m^2	
at	far field condition	
Far field radiated Voltage (rE):	kV	☐ n/a
Min. Pulse Rise Time:	ns (10%-90%)	☐ n/a
Max. Pulse Width:	µs (T_{FWHM})	☐ n/a
Max Pulse repetition frequency (per burst)	Hz ☐ single shot possible	
Length of Bursts	s	☐ n/a
Min. Time betw. Bursts	s	☐ n/a
Max. Number of Bursts		☐ n/a
Antenna Gain	dB	☐ n/a
Other:		
Comments		

B.2. Simulator with spot frequencies

Frequency	1,300 GHz	2,993-3,002 GHz	5,45-5,825 GHz	6,325 GHz	6,52 GHz
Max. Pulse-Power	1 MW	2,6 MW	175 kW	225 kW	250 kW
Electric Field Polarization:	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random
Far field range condition met at	m ☐ n/a	m ☐ n/a	m ☐ n/a	m ☐ n/a	m ☐ n/a
Nominal test distance	m ☐ n/a	m ☐ n/a	m ☐ n/a	m ☐ n/a	m ☐ n/a
3dB beam angle at	(hor) (ver) nominal test distance	(hor) (ver) nominal test distance	(hor) (ver) nominal test distance	(hor) (ver) nominal test distance	(hor) (ver) nominal test distance
Max. rms peak E-field at	kV/m nominal test distance	kV/m nominal test distance	kV/m nominal test distance	kV/m nominal test distance	kV/m nominal test distance
Exposed area at	m^2 nominal test distance	m^2 nominal test distance	m^2 nominal test distance	m^2 nominal test distance	m^2 nominal test distance
Far field radiated Voltage (rE):	kV ☐ n/a	kV ☐ n/a	kV ☐ n/a	kV ☐ n/a	kV ☐ n/a
Min. Pulse Rise Time (10%-90%):	ns ☐ n/a	ns ☐ n/a	ns ☐ n/a	ns ☐ n/a	ns ☐ n/a
Max. Pulse Width (FWHM):	1 µs ☐ n/a	5 µs ☐ n/a	0,25-2,5 µs ☐ n/a	1 µs ☐ n/a	1 µs ☐ n/a
Max Pulse repetition frequency (per burst)	1000 Hz ☒ single shot possible	1000 Hz ☒ single shot possible	1000 Hz ☒ single shot possible	1000 Hz ☒ single shot possible	1000 Hz ☒ single shot possible
Length of Bursts	s ☐ n/a	s ☐ n/a	s ☐ n/a	s ☐ n/a	s ☐ n/a
Min. Time betw. Bursts	s ☐ n/a	s ☐ n/a	s ☐ n/a	s ☐ n/a	s ☐ n/a
Max. Number of Bursts	unlimited ☐ n/a	unlimited ☐ n/a	unlimited ☐ n/a	unlimited ☐ n/a	unlimited ☐ n/a
Antenna Gain	dB ☐ n/a	dB ☐ n/a	dB ☐ n/a	dB ☐ n/a	dB ☐ n/a
Other:	Radiation pattern depend on type of antenna	Radiation pattern depend on type of antenna	Radiation pattern depend on type of antenna	Radiation pattern depend on type of antenna	Radiation pattern depend on type of antenna
Comments	Various antennas are available	Various antennas are available	Various antennas are available	Various antennas are available	Various antennas are available

Frequency	7,7-8,52 GHz	8,5-9,6 GHz	15,5-17,5 GHz	36,41-37,15 GHz	0,4-18 GHz
Max. Pulse-Power	270 kW	250 kW	135 kW	28 kW	5-10 kW
Electric Field Polarization:	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random
Far field range condition met at	m ☐ n/a	m ☐ n/a	m ☐ n/a	m ☐ n/a	m ☐ n/a
Nominal test distance	m ☐ n/a	m ☐ n/a	m ☐ n/a	m ☐ n/a	m ☐ n/a
3dB beam angle at	(hor) (ver) nominal test distance	(hor) (ver) nominal test distance	(hor) (ver) nominal test distance	(hor) (ver) nominal test distance	(hor) (ver) nominal test distance
Max. rms peak E-field at	kV/m nominal test distance	kV/m nominal test distance	kV/m nominal test distance	kV/m nominal test distance	kV/m nominal test distance
Exposed area at	m^2 nominal test distance	m^2 nominal test distance	m^2 nominal test distance	m^2 nominal test distance	m^2 nominal test distance
Far field radiated Voltage (rE):	kV ☐ n/a	kV ☐ n/a	kV ☐ n/a	kV ☐ n/a	kV ☐ n/a
Min. Pulse Rise Time (10%-90%):	ns ☐ n/a	ns ☐ n/a	ns ☐ n/a	ns ☐ n/a	ns ☐ n/a
Max. Pulse Width (FWHM):	0,5-1,5 µs ☐ n/a	0,5-1,5 µs ☐ n/a	2,5 µs ☐ n/a	0,15-1 µs ☐ n/a	20 µs ☐ n/a
Max Pulse repetition frequency (per burst)	1000 Hz ☒ single shot possible	1000 Hz ☒ single shot possible	1000 Hz ☒ single shot possible	6000 Hz ☒ single shot possible	10000 Hz ☒ single shot possible
Length of Bursts	s ☐ n/a	s ☐ n/a	s ☐ n/a	s ☐ n/a	s ☐ n/a
Min. Time betw. Bursts	s ☐ n/a	s ☐ n/a	s ☐ n/a	s ☐ n/a	s ☐ n/a
Max. Number of Bursts	unlimited ☐ n/a	unlimited ☐ n/a	unlimited ☐ n/a	unlimited ☐ n/a	unlimited ☐ n/a
Antenna Gain	dB ☐ n/a	dB ☐ n/a	dB ☐ n/a	dB ☐ n/a	dB ☐ n/a
Other:	Radiation pattern depend on type of antenna	Radiation pattern depend on type of antenna	Radiation pattern depend on type of antenna	Radiation pattern depend on type of antenna	Radiation pattern depend on type of antenna
Comments	Various antennas are available	Various antennas are available	Various antennas are available	Various antennas are available	Various antennas are available

Simulator

Not available

Typical time-domain waveform

Not available

Typical frequency spectrum

Not available

Other technical information

General description

The EMCC Dr. Rasek HIRF-Simulator consists of following components:

- Multipurpose modulators and power supplies.
- RF power units
- Various antennas

Within one frequency band all components are interchangeable.

All components are mobile.

Available instrumentation

Not available

Auxiliary test equipment

Not available

SUPRA, Germany

1. General Information

Simulator Type:	**hypoband - narrowband**
Major Simulator Dimension(s):	m (high) by m (wide) by m (long)
Max. Test Volume Dimensions:	3,0 m (high) by 3,0 m (wide) by 15,0 m (long) ☐ n/a
Comments	

2. Administrative Information

Location:	**Munster. Germany**
mobile	☐ yes ☒ no
outdoor	☐ yes ☒ no
indoor	☒ yes ☐ no
Owner:	WIS
Type of Organization	Government
Point of Contact:	GF 320 HPM-Simulation
Address	P.O. Box 1142 29623 Munster, Germany
Phone :	+49 5192 136 462
Fax :	+49 5192 136 355
E-mail :	WIS320HPM.bwb.org
URL :	http://www.bwb.org/
Status:	Operational
Initial Operation Date:	2002 ☐ n/a
Date of Disassembly	(in case of unavailable)

3. Availability

	Yes/No	Restrictions
Government users:	Yes	
Industry users:	Yes	
Comments		

4. Electromagnetic Characteristics

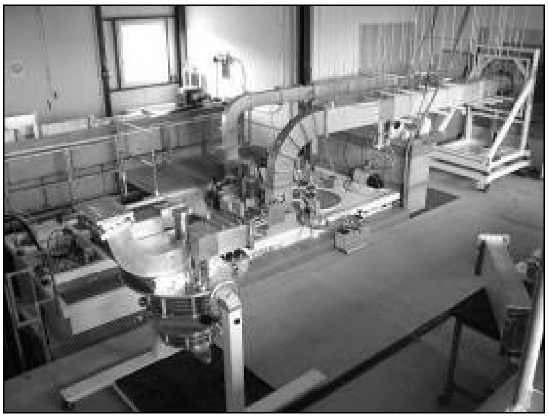
B. Narrowband (hypoband simulator)

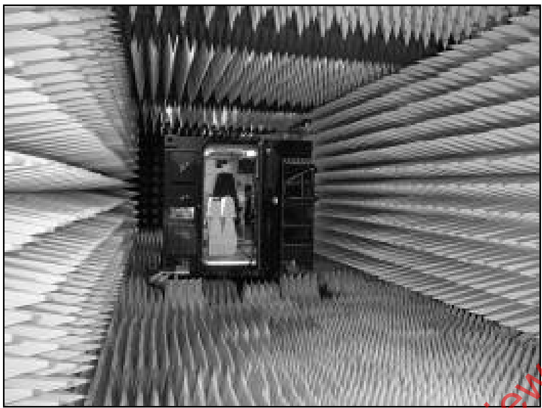
Frequency Range	0,675 - 3,00 GHz	
Coverage of frequency range	tunable	
Number of spot frequencies		☒ n/a

B.1. Tunable Simulator

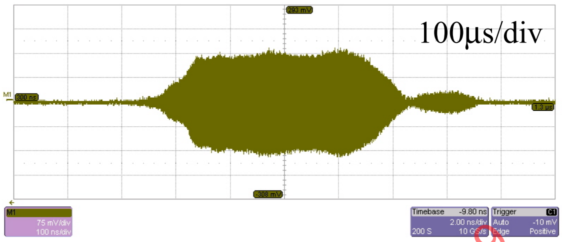
Max. Pulse-Power	400 MW	
Electric Field Polarization:	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random	
Far field range condition met at	15 m	☐ n/a
Nominal test distance	9 m	☐ n/a
3dB beam angle	3 m (hor)	3 m (ver)
at	far field condition	
Max. rms peak E-field	75 kV/m	☐ n/a
at	far field condition	
Exposed area	9 m^2	
at	far field condition	
Far field radiated Voltage (rE):	1125 kV	☐ n/a
Min. Pulse Rise Time:	20 ns (10%-90%)	☐ n/a
Max. Pulse Width:	> 0,3 µs (T_{FWHM})	☐ n/a
Max Pulse repetition frequency (per burst)	10 Hz ☒ single shot possible	
Length of Bursts	10 - 100 s	☐ n/a
Min. Time betw. Bursts	10 - 300 s	☐ n/a
Max. Number of Bursts	unlimited	☐ n/a
Antenna Gain	20 dB	☐ n/a
Other:		
Comments	Length of bursts and min. time betw. bursts depends on pulse repetition rate and number of pulses per bursts	

Simulator

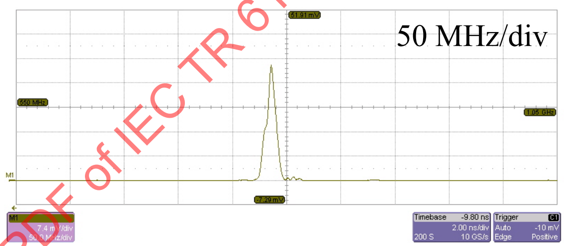




Typical time-domain waveform



Typical frequency spectrum



Other technical information

General description

Basically, the HPM-generator-system of SUPRA consists of a Thyratron-triggered, repetitive 1,4 MV PFN-Marx generator and one set of 8 High-Peak-Power Super Reltron tubes, each provided with motor controls for frequency- and output power-tuning. The frequency coverage extends from 675 MHz to 3 GHz with no gaps in coverage. The repetition rate is adjustable and extends from single shot up to 10 pulses per second. A maximum of 100 pulses can be contained in one burst; the pulses contain at least 300 cycles. Pulse widths are at least 300 ns for frequencies above 1 GHz.

The microwaves are radiated into a 20 m long, anechoic chamber mainly furnished with non-combustible, pyramidal absorbers. From a shielded control room, and via optical fibres, the whole system is remote-controlled by a computer. Two 10 dB wave-guide attenuators can be inserted if field levels have to be reduced, or minimized. Then, minimum fields as low as (3 to 5) kV/m can be provided at a distance of 15 m from the antenna(s).

Available instrumentation

- Electric and magnetic field probes up to 3 GHz bandwidth
- Current probes up to a bandwidth of 3 GHz
- Several fibre optic lines up to a bandwidth of 3 GHz
- Transient recorders and fast digital scopes with a single shot bandwidth of 7 GHz
- Modern PC-based data acquisition with mathematical features.

Auxiliary test equipment

The antenna system of SUPRA can be connected to one port of a vector network analyser to perform low level transfer function measurements.

SP Faraday, Sweden

1. General Information

Simulator Type:	**hypoband - narrowband**	
Major Simulator Dimension(s):	m (high) by m (wide) by m (long)	
Max. Test Volume Dimensions:	3,0 m (high) by 3,0 m (wide) by 15,0 m (long)	☐ n/a
Comments		

2. Administrative Information

Location:	**Borås, Sweden**
mobile	☐ yes ☒ no
outdoor	☐ yes ☒ no
indoor	☒ yes ☐ no
Owner:	SP Technical Research Institute of Sweden
Type of Organization	Research Institute
Point of Contact:	Krister Kilbrandt
Address	Box 857, Brinellgatan 4 SE-501 15 Borås, Sweden
Phone :	+46 10 5165581
Fax :	+46 33 121930
E-mail :	krister.kilbrandt@sp.se
URL :	www.sp.se
Status:	Operational
Initial Operation Date:	☐ n/a
Date of Disassembly	(in case of unavailable)

3. Availability

	Yes/No	Restrictions
Government users:	Yes	
Industry users:	Yes	
Comments		

4. Electromagnetic Characteristics

B. Narrowband (hypoband simulator)

Frequency Range	1,1-1,5 (1,1-12,5) GHz	
Coverage of frequency range	tunable	
Number of spot frequencies		☒ n/a

B.1. Tunable Simulator

Max. Pulse-Power	0,0385 MW	
Electric Field Polarization:	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random	
Far field range condition met at	m	☐ n/a
Nominal test distance	1 m	☐ n/a
3dB beam angle	0,6m (hor) 0.3m (ver)	
at	nominal test distance	
Max. rms peak E-field	6,0 kV/m	☐ n/a
at	nominal test distance	
Exposed area	m^2	
at	nominal test distance	
Far field radiated Voltage (rE):	kV	☐ n/a
Min. Pulse Rise Time:	ns (10%-90%)	☐ n/a
Max. Pulse Width:	µs (T_{FWHM})	☐ n/a
Max Pulse repetition frequency (per burst)	Hz ☐ single shot possible	
Length of Bursts	s	☐ n/a
Min. Time betw. Bursts	s	☐ n/a
Max. Number of Bursts		☐ n/a
Antenna Gain	17,3 dB	☐ n/a
Other:		
Comments		

Simulator

Typical time-domain waveform

Not available

Typical frequency spectrum

Not available

Other technical information

General description

Faraday is built as an EMC test chamber for vehicles and other large objects. It is equipped with a radar pulse simulator powered by TWT amplifiers. It covers four separate bands: 1,1 GHz to 1,5 GHz, 2,6 GHz to 3,5 GHz, 5,4 GHz to 8,0 GHz and 8,2 GHz to 12,5 GHz. The L-band is detailed in the form above. The field-strengths that can be achieved in the four bands are 6,0 kV/m, 1,7 kV/m, 1,4 kV/m and 1,4 kV/m respectively at 1 m distance from the antenna.

The TWT amplifiers are fed by an RF-generator which in turn is modulated by a signal generator. The maximum duty cycle is 1 % in the L-band and 6 % in the other bands.

Available instrumentation

- E-field probes
- Optoelectronic links
- GSM, GPS, DAB, etc. emulation

Auxiliary test equipment

6-wheel chassis dynamometer for vehicle testing.

MTF, Sweden

1. General Information

Simulator Type: --------

Major Simulator Dimension(s): m (high) by m (wide) by 12 m (long)

Max. Test Volume Dimensions: m (high) by m (wide) by m (long) ☒ n/a

Comments

2. Administrative Information

Location: **Linköping, Sweden**

mobile ☒ yes ☐ no

outdoor ☒ yes ☐ no

indoor ☐ yes ☒ no

Owner: Swedish Defence Material Administration, FMV

Type of Organization Government

Point of Contact: Mr. Per Hagström

Address Combitech AB, SE-58188 Linköping, Sweden

Phone : +46 13 184548

Fax : +46 13 185111

E-mail : per.hagstrom@combitech.se

URL : www.combitech.se

Status: Operational

Initial Operation Date: January 1993 ☐ n/a

Date of Disassembly (in case of unavailable)

3. Availability

	Yes/No	Restrictions
Government users:	Yes	
Industry users:	Yes	

Comments MTF is owned by FMV and operated by Saab Communication.

4. Electromagnetic Characteristics

B. Narrowband (hypoband simulator)

Frequency Range GHz

Coverage of frequency range spot frequencies

Number of spot frequencies 5 ☐ n/a

B.1. Tunable Simulator

Max. Pulse-Power MW

Electric Field Polarization: ☐ Vertical ☐ Horizontal ☐ Circular/Elliptical ☐ Random

Far field range condition met at m ☐ n/a

Nominal test distance m ☐ n/a

3dB beam angle (hor) (ver)

at far field condition

Max. rms peak E-field kV/m ☐ n/a

at far field condition

Exposed area m^2

at far field condition

Far field radiated Voltage (rE): kV ☐ n/a

Min. Pulse Rise Time: ns (10%-90%) ☐ n/a

Max. Pulse Width: µs (T_{FWHM}) ☐ n/a

Max Pulse repetition frequency (per burst) Hz ☐ single shot possible

Length of Bursts s ☐ n/a

Min. Time betw. Bursts s ☐ n/a

Max. Number of Bursts ☐ n/a

Antenna Gain dB ☐ n/a

Other:

Comments

B.2. Simulator with spot frequencies

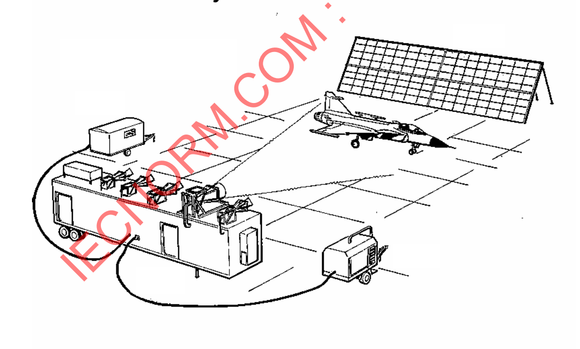
Frequency	1,300 GHz	2,857 GHz	5,710 GHz	9,300 GHz	15,00 GHz
Max. Pulse-Power	25 MW	20 (PCS: 140) MW	5 MW	1 MW	0,25 MW
Electric Field Polarization:	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random
Far field range condition met at	< 12 m ☐ n/a	< 12 m ☐ n/a	< 12 m ☐ n/a	< 12 m ☐ n/a	< 12 m ☐ n/a
Nominal test distance	15 m ☐ n/a	15 m ☐ n/a	15 m ☐ n/a	15 m ☐ n/a	15 m ☐ n/a
3dB beam angle at	2,8 m (hor) 2,8 m (ver) nominal test distance	2,4 m (hor) 2,4 m (ver) nominal test distance	2,0 m (hor) 2,0 m (ver) nominal test distance	1,6 m (hor) 1,6 m (ver) nominal test distance	1,1 m (hor) 1,1 m (ver) nominal test distance
Max. rms peak E-field at	30 kV/m nominal test distance	30 (PCS: 80) kV/m nominal test distance	17 kV/m nominal test distance	10 kV/m nominal test distance	6 kV/m nominal test distance
Exposed area at	6,2 m^2 nominal test distance	4,5 m^2 nominal test distance	3,1 m^2 nominal test distance	2,0 m^2 nominal test distance	0,95 m^2 nominal test distance
Far field radiated Voltage (rE):	450 kV ☐ n/a	450 (PCS:1200) kV ☐ n/a	255 kV ☐ n/a	150 kV ☐ n/a	90 kV ☐ n/a
Min. Pulse Rise Time (10%-90%):	100 ns ☐ n/a	100 ns ☐ n/a	300 ns ☐ n/a	80 ns ☐ n/a	60 ns ☐ n/a
Max. Pulse Width (FWHM):	5 µs ☐ n/a	5 (PCS: 0,4) µs ☐ n/a	5 µs ☐ n/a	3.8 µs ☐ n/a	0,53 µs ☐ n/a
Max Pulse repetition frequency (per burst)	1000 Hz ☒ single shot possible	1000 Hz ☒ single shot possible	1000 Hz ☒ single shot possible	1000 Hz ☒ single shot possible	2100 Hz ☒ single shot possible
Length of Bursts	10 s ☐ n/a	10 s ☐ n/a	10 s ☐ n/a	10 s ☐ n/a	10 s ☐ n/a
Min. Time betw. Bursts	50 s ☐ n/a	50 s ☐ n/a	50 s ☐ n/a	50 s ☐ n/a	50 s ☐ n/a
Max. Number of Bursts	unlimited ☐ n/a	unlimited ☐ n/a	unlimited ☐ n/a	unlimited ☐ n/a	unlimited ☐ n/a
Antenna Gain	30 dB ☐ n/a	30 (CA: 37) dB ☐ n/a	30 (CA: 40) dB ☐ n/a	30 dB ☐ n/a	30 dB ☐ n/a
Other:	Maximum PRF and maximum pulse length cannot be attained simultaneously	Maximum PRF and maximum pulse length cannot be attained simultaneously	Maximum PRF and maximum pulse length cannot be attained simultaneously	Maximum PRF and maximum pulse length cannot be attained simultaneously	
Comments		values in brackets: PCS: Pulse compressor system CA: Cassegrain Antenna	values in brackets: CA: Cassegrain Antenna		

Simulator

MTF with standard antennas

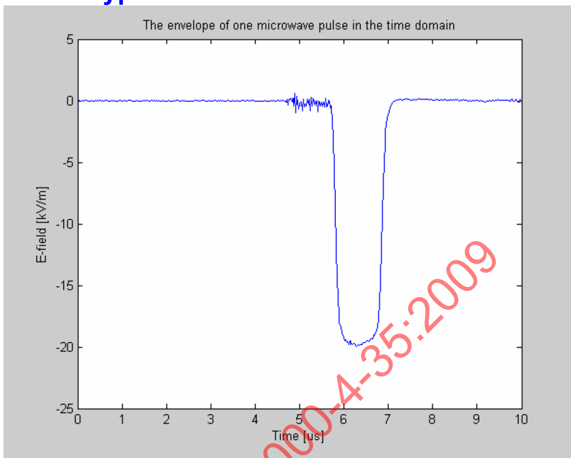
MTF with Cassegrain antennas
for S- and C-band

Overview of the MTF-system



Overview with the control trailer at the left and the diesel generator at the right.

Typical time-domain waveform



The envelope of a 1 µs S-band pulse.

Typical frequency spectrum

Not available

Other technical information

General description

The MTF generates high E-field levels at five spot frequencies in the L- , S-, C-, X- and Ku-band. At the three lowest bands the signals are magnified to test levels by klystron tubes and for the two highest bands magnetron tubes are used. The output test fields are pulse modulated with 0,1 µs to 5 µs pulse length and from single pulse up to 1 kHz (2,1 kHz at Ku-band) PRF.

The test facility is located outdoors and the nominal test distance is 15 m. The MTF is powered by a 230-V, 540-kVA, AC, diesel generator. Supervision and control of the test objects can be performed from a shielded trailer connected to the system. All units are mobile.

Available instrumentation

Oscilloscope: Tektronix TDS 754D

E-field probe (average): Narda 8621D

E-field probe (peak): Hot electron sensor for L- to Ku-band acquired from Semiconductor Physics Institute in Vilnius, Lithuania.

Shielded video camera with fiber optic line

Current probes up to a bandwidth of 100 MHz

Several fiber optic lines up to a bandwidth of 1 GHz

Fast digital scopes with a single shot bandwidth of 500 MHz

Spectrum analyzers, up to 40 GHz

Auxiliary test equipment

The S-band is equipped with a Dual Resonator Pulse Compressor System. The PCS stores the microwave energy in cavity resonators during the pulse, then switches the energy out in form of a shorter pulse length but with much higher amplitude. The E-field peak level increases from 30 kV/m to 80 kV/m. The pulse length is 0,4 µs.

The original horn antennas for S-band and C-band can be changed to Cassegrain antennas. This makes it possible to use test distances of a couple of hundred meters.

ORION, United Kingdom

1. General Information

Simulator Type:	**hypoband - narrowband**
Major Simulator Dimension(s):	2,5 m (high) by 12 m (wide) by 3 m (long)
Max. Test Volume Dimensions:	3 m (high) by ☐ n/a 15 m (wide) by 7 m (long)
Comments	Test volume at 70 m range

2. Administrative Information

Location:	**Pershore, UK**
mobile	☒ yes ☐ no
outdoor	☒ yes ☐ no
indoor	☐ yes ☒ no
Owner:	UK MoD - operated by QinetiQ
Type of Organization	Government
Point of Contact:	Mr. B. Kerr
Address	Malvern Technology Park, BLB123, St Andrews Road, Malvern, WR14 3PS
Phone :	+44 (0) 1684 894949
Fax :	+44 (0) 1684 896791
E-mail :	bakerr@qinetiq.com
URL :	www.qinetiq.com
Status:	Operational
Initial Operation Date:	1996 ☐ n/a
Date of Disassembly	(in case of unavailable)

3. Availability

	Yes/No	Restrictions
Government users:	Yes	
Industry users:	Yes	
Comments		

4. Electromagnetic Characteristics

B. Narrowband (hypoband simulator)

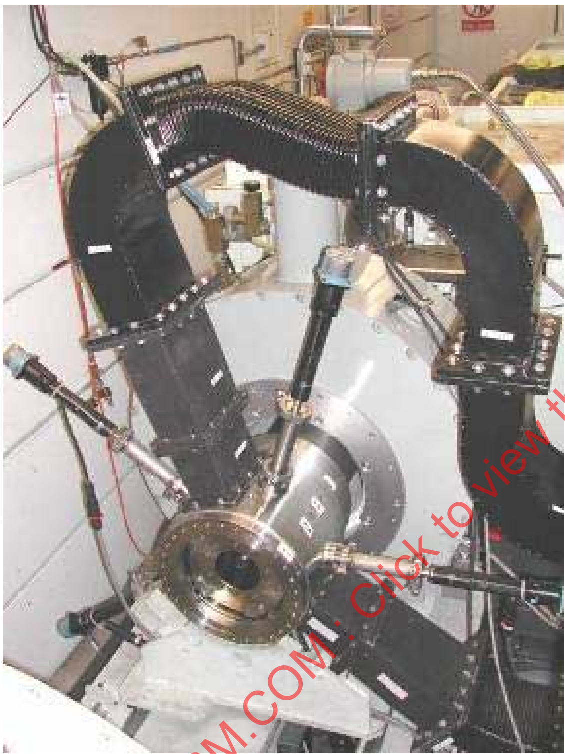
Frequency Range	1,07 to 3,00 GHz	
Coverage of frequency range	tunable	
Number of spot frequencies		☒ n/a

B.1. Tunable Simulator

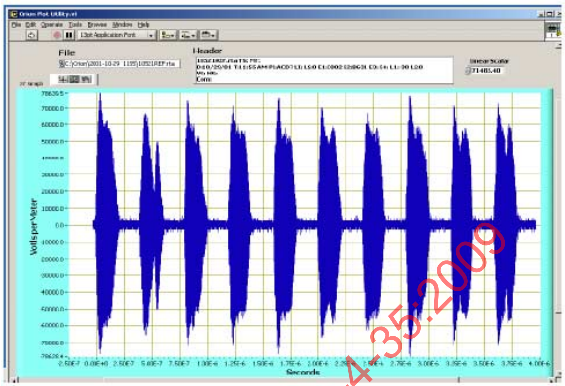
Max. Pulse-Power	≥ 300 MW	
Electric Field Polarization:	☒ Vertical ☒ Horizontal ☐ Circular/Elliptical ☐ Random	
Far field range condition met at	15 m	☐ n/a
Nominal test distance	70 m	☐ n/a
3dB beam angle	(hor) 7.5 m (ver)	
at	far field condition	
Max. rms peak E-field	30 kV/m	☐ n/a
at	far field condition	
Exposed area	105 m^2	
at	far field condition	
Far field radiated Voltage (rE):	2300 kV	☐ n/a
Min. Pulse Rise Time:	20 ns (10%-90%)	☐ n/a
Max. Pulse Width:	0,25 µs (T_{FWHM})	☐ n/a
Max Pulse repetition frequency (per burst)	100 Hz ☒ single shot possible	
Length of Bursts	Max 10 s	☐ n/a
Min. Time betw. Bursts	8 mins	☐ n/a
Max. Number of Bursts	unlimited	☐ n/a
Antenna Gain	26,7 dB	☐ n/a
Other:		
Comments	Length of bursts (1000 max per burst) and min. time betw. bursts depends on pulse repetition rate and number of pulses per bursts, nominally 5 mins up to 8 min. The pulse width reduces to 50 ns above 2 GHz.	

HPM Simulator

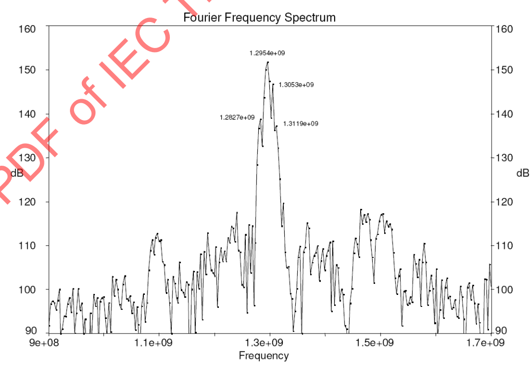
HPM Magnetron



Typical time-domain waveform 1,3 GHz



Typical frequency spectrum 1,3 GHz



Other technical information

General description

Orion is a magnetron based HPM simulator. The prime power source for Orion consists of two, three phase diesel generators. The generator drives the charging system PFN where the output of the generator is converted to a 0 to 30 kV DC supply. This supply is then coupled into the power modulator where the DC voltage is stepped up to 1 MV with a 500 ns pulse width. The primary modulator is a magnetron. In the magnetron approximately 10 % to 20 % of the electrical power is converted to RF power, resulting in ≥300 MW of microwave power extracted from the magnetron.

The Orion simulator is housed outdoors and can therefore accommodate very large test objects. A great deal of flexibility is therefore possible such that smaller test objects can be located closer to the antenna to achieve higher fields.

Available instrumentation

– Electric and magnetic field probes up to 3 GHz bandwidth
– Several fibre optic lines up to a bandwidth of 3 GHz
– Transient recorders and fast digital scopes with a single shot bandwidth of 7 GHz
– Modern PC-based data acquisition with data processing features

Auxiliary test equipment

Not available

Radio Frequency Environment Generator (REG), United Kingdom

1. General Information

Simulator Type:	**hypoband - narrowband**
Major Simulator Dimension(s):	5 m (high) by 20 m (wide) by 5 m (long)
Max. Test Volume Dimensions:	unlimted m (high) by ☒ n/a 50 m (wide) by 50 m (long)
Comments	

2. Administrative Information

Location:	**Boscombe Down, UK**
mobile	☐ yes ☒ no
outdoor	☒ yes ☐ no
indoor	☐ yes ☒ no
Owner:	UK MoD, operated by QinetiQ
Type of Organization	Government
Point of Contact:	Peter Sumner
Address	MOD Boscombe Down, Salisbury, Wiltshire, SP4 0JF, UK
Phone :	+44(0) 1252 392612
Fax :	+44 (0) 1252 397058
E-mail :	pgsumner@qinetiq.com
URL :	www.QinetiQ.com/emc
Status:	Operational
Initial Operation Date:	1993 ☐ n/a
Date of Disassembly	(in case of unavailable)

3. Availability

	Yes/No	Restrictions
Government users:	Yes	
Industry users:	Yes	UK MoD approval
Comments		

4. Electromagnetic Characteristics

B. Narrowband (hypoband simulator)

Frequency Range	GHz	
Coverage of frequency range	tunable	
Number of spot frequencies		☐ n/a

B.1. Tunable Simulator

Max. Pulse-Power	MW	
Electric Field Polarization:	☐ Vertical ☐ Horizontal ☐ Circular/Elliptical ☐ Random	
Far field range condition met at	m	☐ n/a
Nominal test distance	m	☐ n/a
3dB beam angle	(hor)	(ver)
at	far field condition	
Max. rms peak E-field	kV/m	☐ n/a
at	far field condition	
Exposed area	m^2	
at	far field condition	
Far field radiated Voltage (rE):	kV	☐ n/a
Min. Pulse Rise Time:	ns (10%-90%)	☐ n/a
Max. Pulse Width:	µs (T_{FWHM})	☐ n/a
Max Pulse repetition frequency (per burst)	Hz ☐ single shot possible	
Length of Bursts	s	☐ n/a
Min. Time betw. Bursts	s	☐ n/a
Max. Number of Bursts		☐ n/a
Antenna Gain	dB	☐ n/a
Other:		
Comments		

B.2. Simulator with spot frequencies

Frequency	1,33 GHz	3,2 GHz	5,6 GHz	9 GHz	16.5 GHz
Max. Pulse-Power	Up to 1 MW	Up to 0.5 MW	Up to 0.5 MW	Up to 0.5 MW	Up to 0.5 MW
Electric Field Polarization:	☐ Vertical ☐ Horizontal ☒ Circular/Elliptical ☐ Random	☐ Vertical ☐ Horizontal ☒ Circular/Elliptical ☐ Random	☐ Vertical ☐ Horizontal ☒ Circular/Elliptical ☐ Random	☐ Vertical ☐ Horizontal ☒ Circular/Elliptical ☐ Random	☐ Vertical ☐ Horizontal ☒ Circular/Elliptical ☐ Random
Far field range condition met at	15 m ☐ n/a	15 m ☐ n/a	15 m ☐ n/a	15 m ☐ n/a	15 m ☐ n/a
Nominal test distance	15 m ☐ n/a	15 m ☐ n/a	15 m ☐ n/a	15 m ☐ n/a	15 m ☐ n/a
3dB beam angle at	±0,64m (hor) ±1,5m(ver) nominal test distance	±0,4m (hor) ±1,0m(ver) nominal test distance	±0,4m (hor) ±1,0m(ver) nominal test distance	±0,38m (hor) ±0,87m(ver) nominal test distance	±0,4m (hor) ±0,84m(ver) nominal test distance
Max. rms peak E-field at	30 kV/m nominal test distance	30 kV/m nominal test distance	23,4 kV/m nominal test distance	26,8 kV/m nominal test distance	27,5 kV/m nominal test distance
Exposed area at	1 m^2 nominal test distance	1 m^2 nominal test distance	1 m^2 nominal test distance	1 m^2 nominal test distance	1 m^2 nominal test distance
Far field radiated Voltage (rE):	kV ☐ n/a	kV ☐ n/a	kV ☐ n/a	kV ☐ n/a	kV ☐ n/a
Min. Pulse Rise Time (10%-90%):	ns ☐ n/a	ns ☐ n/a	ns ☐ n/a	ns ☐ n/a	ns ☐ n/a
Max. Pulse Width (FWHM):	1 µs ☐ n/a	0,6 µs ☐ n/a	1 µs ☐ n/a	1 µs ☐ n/a	1 µs ☐ n/a
Max Pulse repetition frequency (per burst)	1000 Hz ☐ single shot possible	1000 Hz ☐ single shot possible	1000 Hz ☐ single shot possible	1000 Hz ☐ single shot possible	1000 Hz ☐ single shot possible
Length of Bursts	unlimited s ☐ n/a	unlimited s ☐ n/a	unlimited s ☐ n/a	unlimited s ☐ n/a	unlimited s ☐ n/a
Min. Time betw. Bursts	s ☒ n/a	s ☒ n/a	s ☒ n/a	s ☒ n/a	s ☒ n/a
Max. Number of Bursts	unlimited ☐ n/a	unlimited ☐ n/a	unlimited ☐ n/a	unlimited ☐ n/a	unlimited ☐ n/a
Antenna Gain	dB ☐ n/a	dB ☐ n/a	dB ☐ n/a	dB ☐ n/a	dB ☐ n/a
Other:					
Comments					

Frequency	24 GHz	34.86 GHz	GHz	GHz	GHz
Max. Pulse-Power	Up to 50 kW	Up to 50 kW	MW	MW	MW
Electric Field Polarization:	☐ Vertical ☐ Horizontal ☒ Circular/Elliptical ☐ Random	☐ Vertical ☐ Horizontal ☒ Circular/Elliptical ☐ Random	☐ Vertical ☐ Horizontal ☐ Circular/Elliptical ☐ Random	☐ Vertical ☐ Horizontal ☐ Circular/Elliptical ☐ Random	☐ Vertical ☐ Horizontal ☐ Circular/Elliptical ☐ Random
Far field range condition met at	15 m ☐ n/a	15 m ☐ n/a	15 m ☐ n/a	15 m ☐ n/a	15 m ☐ n/a
Nominal test distance	15 m ☐ n/a	15 m ☐ n/a	15 m ☐ n/a	15 m ☐ n/a	15 m ☐ n/a
3dB beam angle at	±0,4m (hor) ±0,8m(ver) nominal test distance	±0,4m (hor) ±0,5m(ver) nominal test distance	m (hor) m(ver)	m (hor) m(ver)	m (hor) m(ver)
Max. rms peak E-field at	8,3 kV/m nominal test distance	6,7 kV/m nominal test distance	kV/m	kV/m	kV/m
Exposed area at	1 m^2 nominal test distance	1 m^2 nominal test distance	m^2	m^2	m^2
Far field radiated Voltage (rE):	kV ☐ n/a	kV ☐ n/a	kV ☐ n/a	kV ☐ n/a	kV ☐ n/a
Min. Pulse Rise Time (10%-90%):	ns ☐ n/a	ns ☐ n/a	ns ☐ n/a	ns ☐ n/a	ns ☐ n/a
Max. Pulse Width (FWHM):	1 µs ☐ n/a	0,8 µs ☐ n/a	µs ☐ n/a	µs ☐ n/a	µs ☐ n/a
Max Pulse repetition frequency (per burst)	1000 Hz ☐ single shot possible	1000 Hz ☐ single shot possible	Hz ☐ single shot possible	Hz ☐ single shot possible	Hz ☐ single shot possible
Length of Bursts	unlimited s ☐ n/a	unlimited s ☐ n/a	unlimited s ☐ n/a	unlimited s ☐ n/a	unlimited s ☐ n/a
Min. Time betw. Bursts	s ☒ n/a	s ☒ n/a	s ☐ n/a	s ☐ n/a	s ☐ n/a
Max. Number of Bursts	unlimited ☐ n/a	unlimited ☐ n/a	unlimited ☐ n/a	unlimited ☐ n/a	unlimited ☐ n/a
Antenna Gain	dB ☐ n/a	dB ☐ n/a	dB ☐ n/a	dB ☐ n/a	dB ☐ n/a
Other:					
Comments					

Simulator

Typical time-domain waveform	Typical frequency spectrum
Not available	Not available

Other technical information

General description

The REG generates high E-fields at 7 spot frequencies in the microwave frequency range. There is some tunability up to 10 % at each frequency.

HF, VHF, and UHF high level capability is also available.

The REG facility is housed outdoors and can therefore accommodate very large test objects. A great deal of flexibility is therefore possible in such a way that smaller test objects can be located closer to the antenna to achieve higher fields. Measurement instrumentation and control of the test objects can be performed from a shielded test room.

Available instrumentation

Full instrumentation of E-field available (antenna, optical links, etc.)

Full test object instrumentation available (current probes, field probes)

Instrumentation and test Electro Explosive Devices (EEDs)

Auxiliary test equipment

Not available

7.3 Reverberation chambers

Large Magdeburg Reverberation Chamber, Germany

1. General Information

Simulator Type: **hypoband - narrowband**
Major Simulator Dimension(s): 3,45 m (high) by 6,5 m (wide) by 7,9 m (long)
Max. Test Volume Dimensions: 2 m (high) by 2 m (wide) by 3 m (long) ☐ n/a
Comments

2. Administrative Information

Location: **Magdeburg, Germany**
mobile ☐ yes ☒ no
outdoor ☐ yes ☒ no
indoor ☒ yes ☐ no
Owner: University of Magdeburg, IGET
Type of Organization University

Point of Contact: Dr. Krauthäuser
Address Universitätsplatz 2 39106 Magdeburg, Germany
Phone : +49 391 6712195
Fax : +49 391 67 11236
E-mail : hgk@ieee.org

URL : www.ovgu.de/krauthae

Status: Operational
Initial Operation Date: 1999 ☐ n/a
Date of Disassembly (in case of unavailable)

3. Availability

	Yes/No	Restrictions
Government users:	Yes	
Industry users:	Yes	
Comments		

4. Electromagnetic Characteristics

B. Narrowband (hypoband simulator)

Frequency Range 0,2-10,6 GHz
Coverage of frequency range tunable
Number of spot frequencies ☐ n/a

B.1. Tunable Simulator

B.2. Simulator with spot frequencies

B.3. Reverberation Chamber

Lowest Usable Frequency (LUF) in accordance with IEC 61000-4-21 200 MHz
Chamber Q at GHz
Min. Pulse Rise Time: µs (10%-90%) ☒ n/a
Modes of operation ☐ Continuous Stirring ☐ Stepped / Tuning ☒ Both

Other:
Comments only cw signals