# A RADIATED MODE NEMP SIMULATOR

**In-house testing to requirements set forth in MIL-STD-461/462 is possible with a radiated-mode NEMP simulator.**


## A. TEHORI, C. GOLDSTEIN, S. ECKHOUSE, M. BEN-HORIN, RAFAEL/ELGAL, HAIFA, ISRAEL.


## INTRODUCTION

A nuclear explosion creates an intense electromagnetic field that reaches amplitudes of tens of kilovolts per meter with a rise time of a few nanoseconds. The spatial dependence and waveshape of the electric and magnetic field thus created are closely correlated to the height above earth at which the explosion occurs. An atmospheric burst will create intense electromagnetic fields traveling to distances up to a few thousand kilometers from the burst. Thus, for example, a single exo-atmospheric burst will cover the entire area of the continental USA. The threat of a high-altitude burst (HEMP) is therefore regarded as the most significant EMP threat. Figure 1 shows a typical pulse shape for a high-altitude burst.

EMP simulation and testing have become significant aspects of the EMP hardening process. One reason is that the EMP threat is not realized during the normal life of the system. Hence, in order to harden a system properly, one usually simulates the EMP conditions for the system. Simulation can be done in a number of ways varying in complexity, price and accuracy.

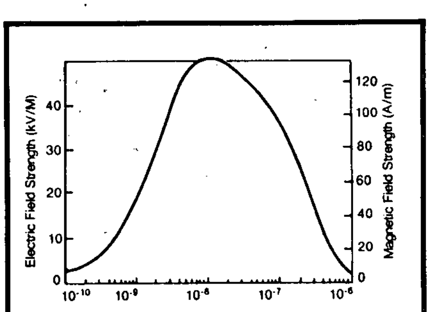


**Figure 1. Generalized High-altitude EMP Electric and Magnetic-field Time Waveform.**

Presented here is a radiated-mode HEMP simulator which makes in-house testing feasible according to MIL-STD-461/2 (RSO5). The simulator is a compact system comprising a 100kV pulse generator and a parallel plate antenna (internal dimensions, 2m x 2m x 1m). Additionally, E- and H-field sensors are required for measurements within the antenna's working volume.

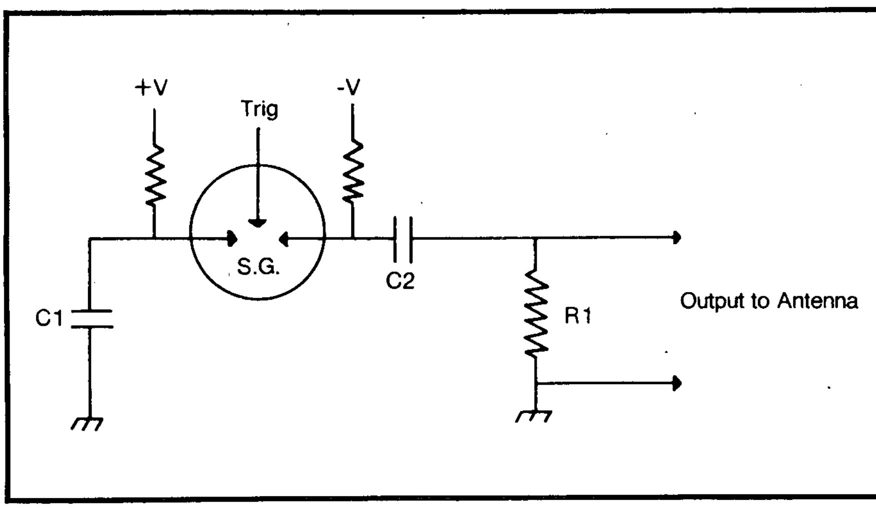


**Figure 2. Schematic Diagram of the 100kV Generator.**

## DESCRIPTION OF THE SIMULATOR

### *The Generator*

A schematic diagram of the pulse generator is shown in Figure 2. This is a two-stage Marx generator with a maximum output voltage of 100kV and rise time of 5ns. Marx generators can reach very high voltages by coupling in series, when discharged, a series of capacitors which have been charged in parallel. This generator consists of two 10nF high voltage capacitors and a 3-electrode triggerable spark gap. A high voltage dc power supply charges the capacitors, one positive, the other negative, as shown in Figure 2. The maximum charging voltage is $V_{max} = \pm 50kV$. When triggered, the spark gap short circuits and couples the two capacitors in series. The output voltage is thus twice the voltage with a maximum output of 100kV. The parallel plate antenna in the system has a 100-ohm characteristic impedance and is terminated with a 100-ohm load. The generator's output capacitance is 5nF, and the decay time constant on a 100-ohm load is RC = 500ns. The generator's output voltage pulse on a 50-ohm load is shown in Figure 3.

## THE PARALLEL PLATE ANTENNA

### *Background*

Radiated mode EMP simulators would give ideal simulation if it were possible to repeatedly create a field distribution over the surface of a volume enclosing the system being test-

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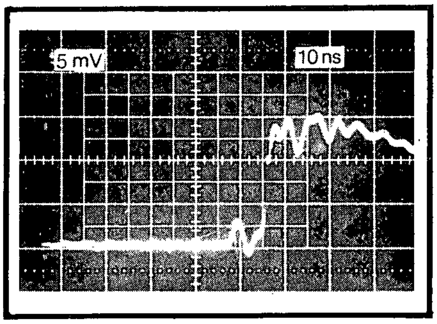


**Figure 3. Generator's Output Voltage on 50 ohm Load.**

ed in a manner identical to that obtained from an actual nuclear burst. The EMP created by a high altitude burst is a TEM wave, with wide bandwidth spectra content, traveling in free space. In order to simulate it, a transmission line suitable for such a wave has to be built. A parallel plate system is a common choice for this application.

In this configuration, the two plates create the two conductors of the transmission line. The plate structure is designed in such a way that it creates a constant characteristic impedance transmission line for an electrical signal traveling along the line. The basic assumption for such a structure is that the electromagnetic field between the plates is mainly a TEM mode. This assumption is usually justified for plate spacing on the order of a few meters and for typical EMP waveshapes. For larger plate separation, special care should be taken in the design of the guided wave simulator in order to ensure a relatively clean TEM mode. The radiated object's maximum size is limited by the plate spacing. Thus, it is recommended to limit the size of the EUT along the E-field lines to one third of the spacing between the plates in order not to distort the E- and H-fields.

## THE PARALLEL PLATE DESIGN

The plates of the antenna are made of solid sheets of aluminum. The volume, not including the conical sections, is 2m x 2m x 1m. The exact dimensions of the system are shown in Figure 4. The angle of the conical section is approximately 30 degrees. Such a wide angle is not recommended for a large simulator, but for a small parallel plate, the gain in space compensates for the small degradation in performance. The antenna structure is placed on an insulated stand.

The feeding end of the antenna connects to the 100kV generator by a high voltage coaxial cable. The other end of the antenna is terminated with 100-ohm matched termination. The antenna dimensions determine the characteristic impedance to be 100 ohms. The system is shown in Figure 5.

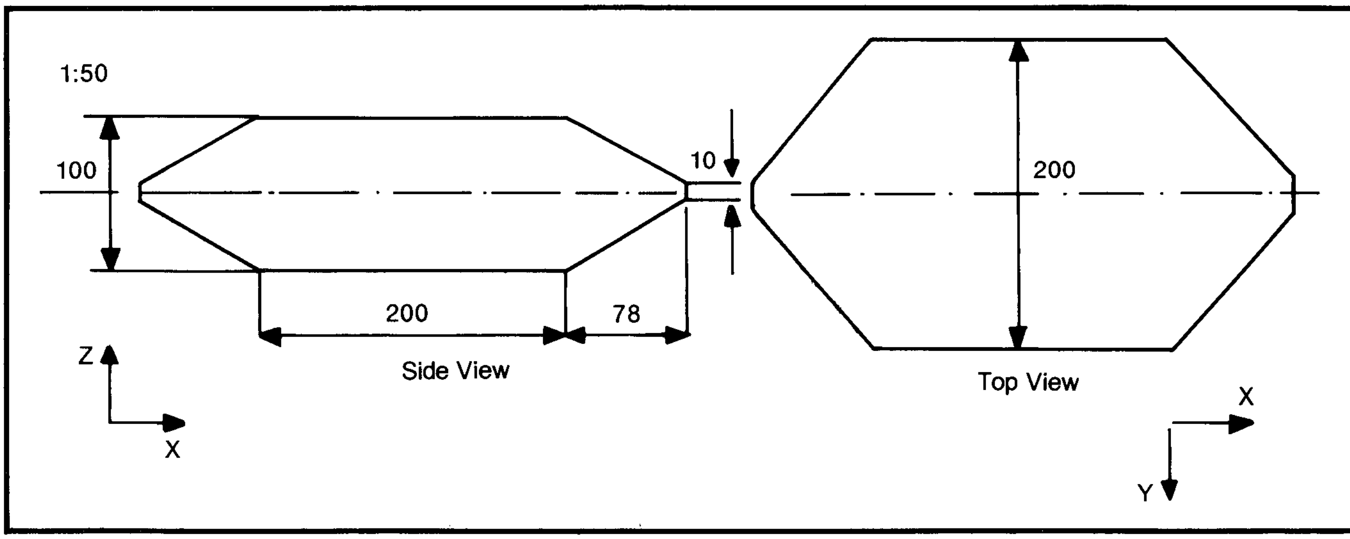


**Figure 4. Dimensions of the System.**

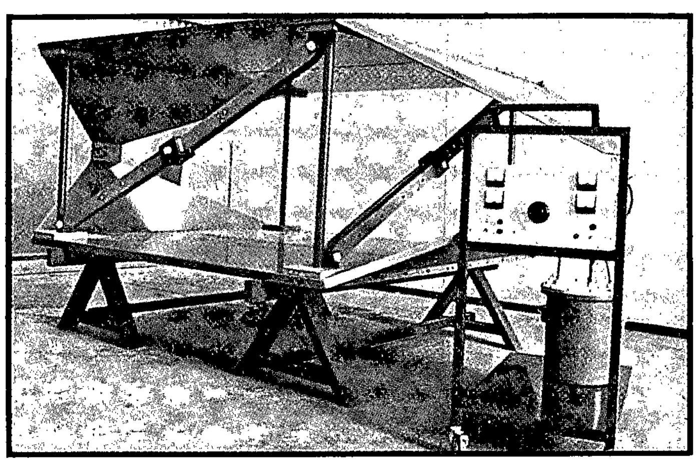

**Figure 5. A Generator and A Parallel Plate Antenna Forms an EMP Simulation System.**

## THE DISTRIBUTION OF E- AND H-FIELDS WITHIN THE SIMULATOR

The electric and magnetic fields were measured using fast sensors specially designed for the measurement of EMP fields. All these sensors measure the time derivative of the

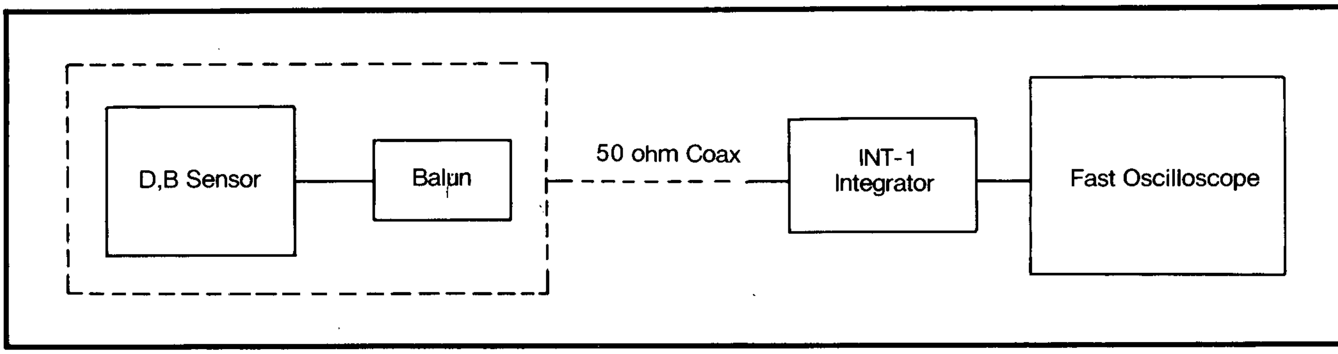


**Figure 6. Block Diagram of the Test Measurement Setup.**

field. The output of each sensor, therefore, was integrated in order to obtain the appropriate field.

The ground plane measurements were performed using D-Dot and B-Dot sensors. The free-field measurements between the plates were performed using differential sensors which incorporate a balun which transforms the balanced output into unbalanced output. A 10-microsecond passive integrator was used. A block diagram of the measurement is given in Figure 6.

Figure 7 shows the coordinates system used for mapping the field distribution within the working volume.

The field distribution within the volume of the parallel plate antenna is given in Figure 8. The pulse generator is charged here only to half its maximum voltage, i.e., 50kV. This means that twice the amplitudes can be achieved with the generator fully charged. As seen from Figure 8, E- and H-fields in the working volume are uniform to within 20%. Also, $E_y$ $E_x$ $H_x$ and $H_z$ Vectors are attenuated by at least 40dB compared to the $E_z$ and $H_y$ Vectors of the TEM mode.

The shape of E- and H-fields in the working volume of the simulator are seen in Figures 9 through 12. In these cases, the generator is fully charged to 100 kV.

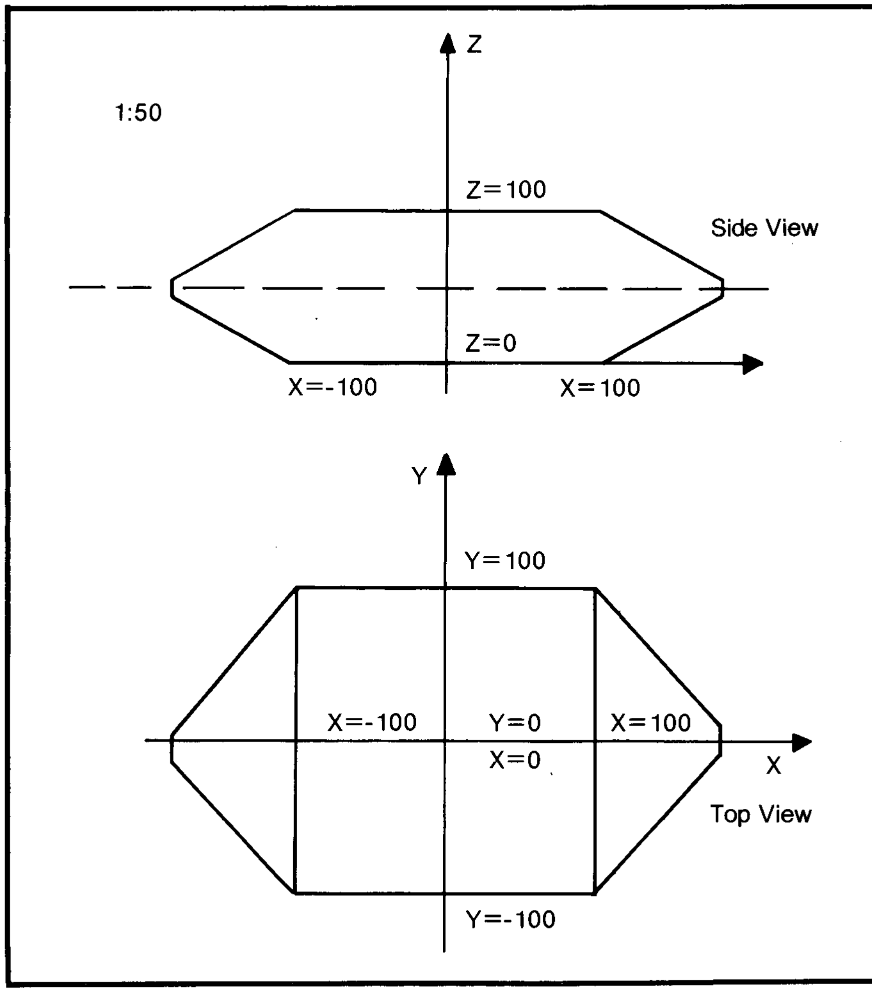


**Figure 7. Coordinates System for Field Distribution.**

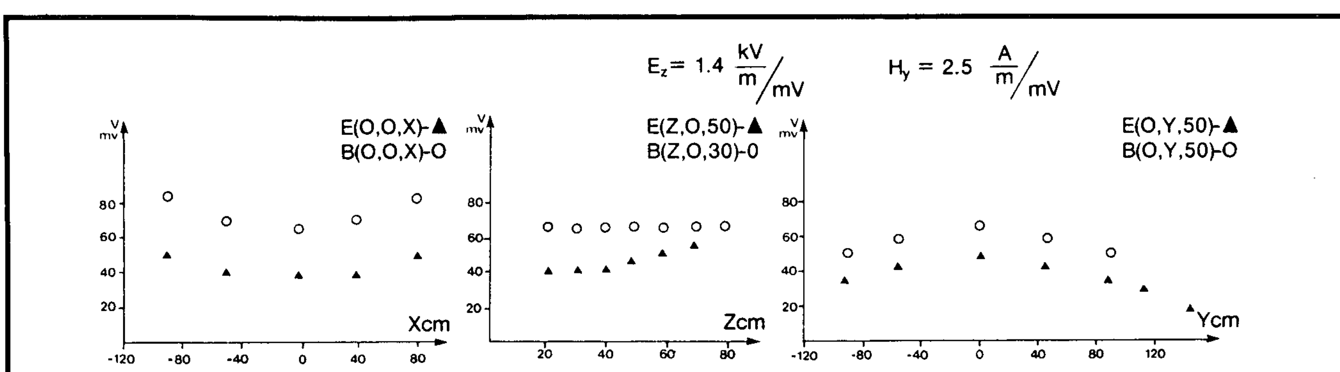


**Figure 8. A Field Distribution in a Parallel Plate Antenna for an EMP Pulse.**

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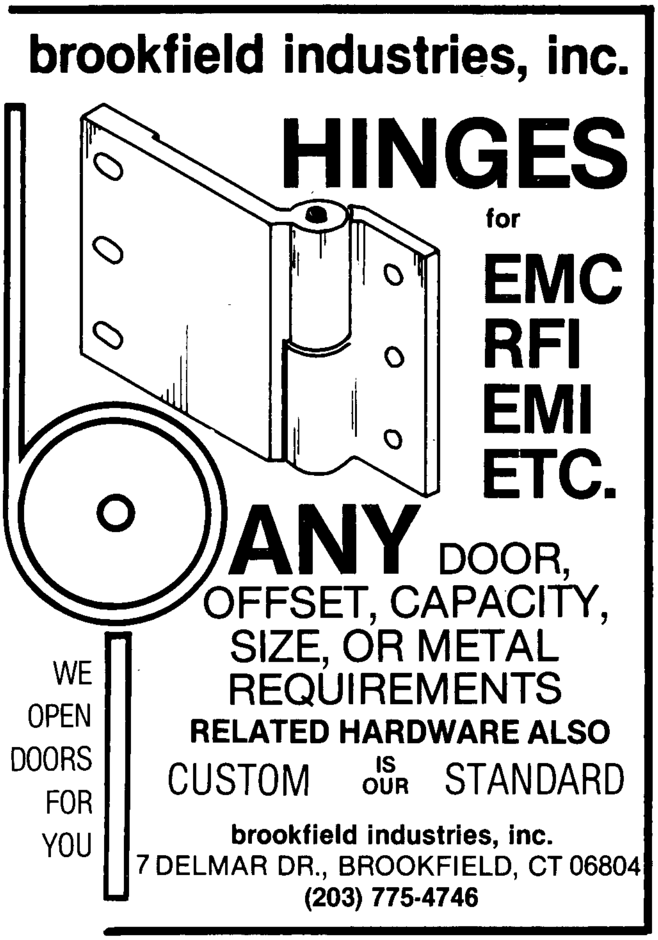


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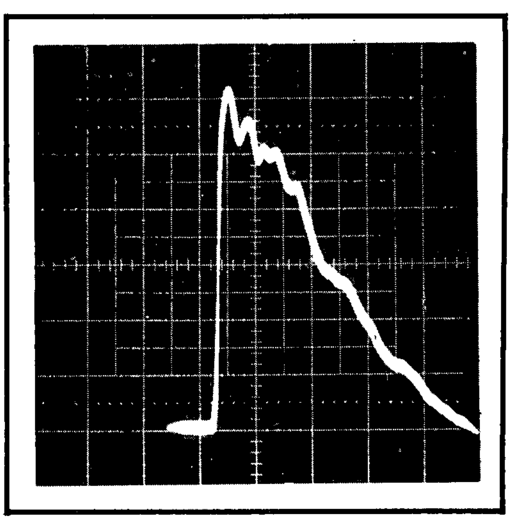

**Figure 9. E-field (Vertical) at Center of Parallel Plate. Measured with MDE-1. Charged at ±50kV. 8(kV/small div.; 50ns/small div.)**

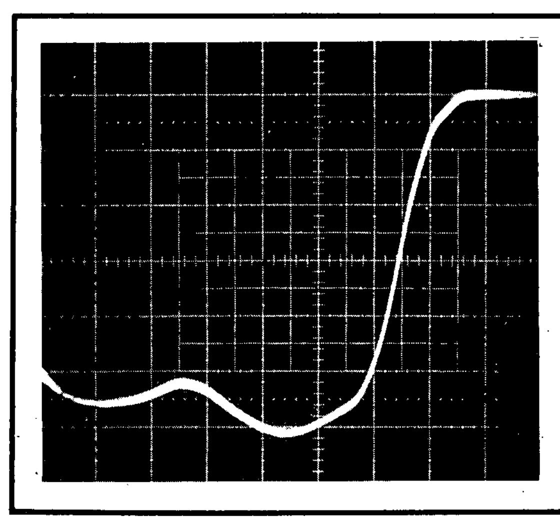

**Figure 10. Same as Figure 9, only 5(ns/small div.)**

Figure 11. H-field (Horizontal) at Center of Parallel Plate. Measured with MDM-1. EM-103 charged at ±50kV 20(A/M/small div.); 50(ns/small div.)

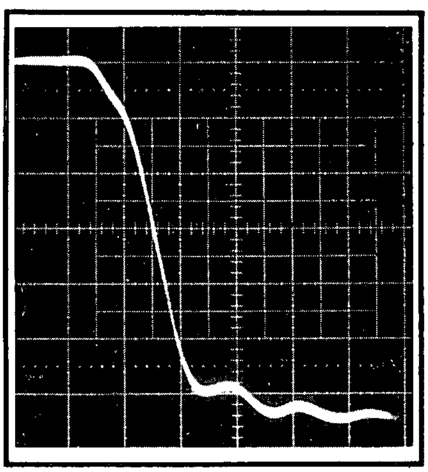

Figure 12. Same as Figure 11, only 5(ns/small div.).


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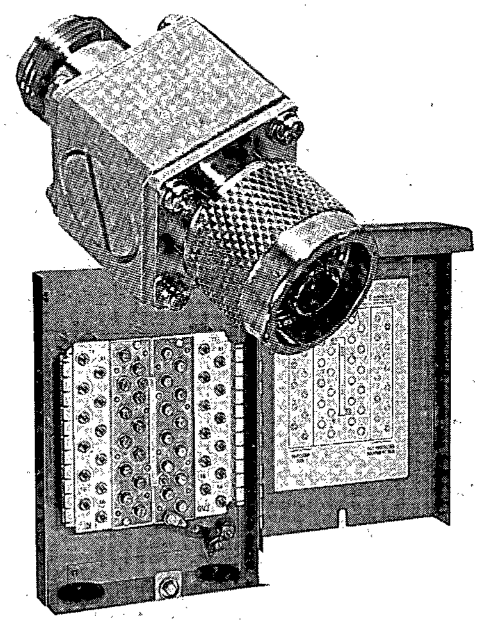

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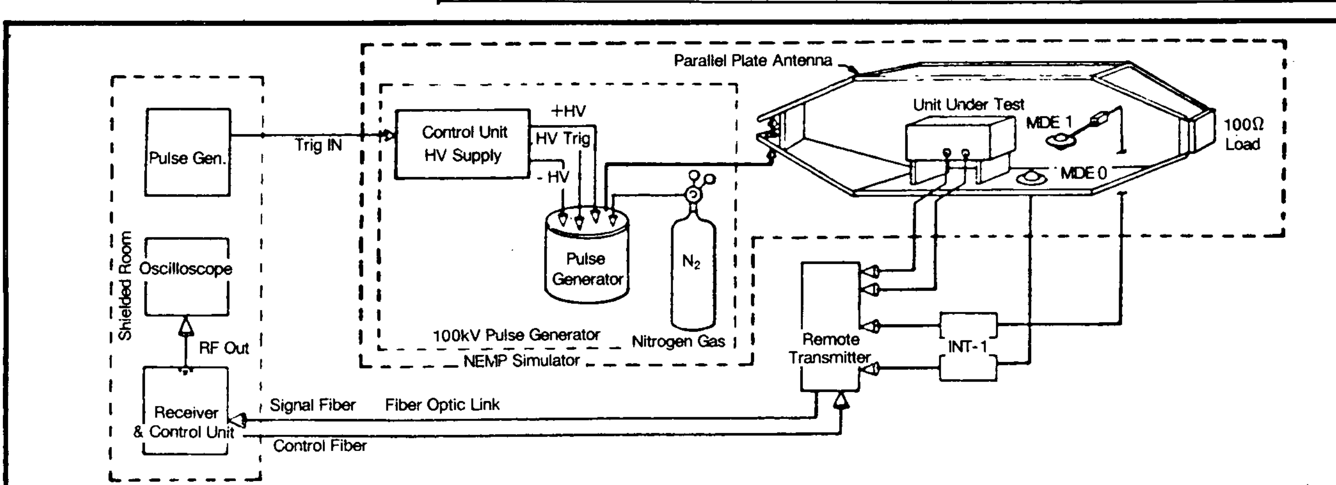


Figure 13. A Typical NEMP Test Configuration.

## TESTING EQUIPMENT OR SUBSYSTEM SUSCEPTIBILITY TO RADIATED EMP

The radiated test within the parallel plates is applicable for equipment and subsystems. It is not for interconnecting cable which, when fully extended, exceed the working volume. The EUT should be placed in several orientations to cover all possible coupling polarizations. Due to the nature of the fields generated by the system, special test methods become necessary in order to achieve uncontaminated results. Most test equipment shielding is inadequate to prevent interference from the high fields generated. Also, any cable coming out from the parallel plates will pick up voltage and current. In order to avoid all this, several steps must be taken:

- All the measuring equipment should be placed within a shielded room.
- Any cabling for taking internal measurements within the equipment under test should be routed below the antenna itself. This includes connection to the field sensors. The use of fiber-optic link is recommended.
- Any wiring not intended to be exposed to the field should be kept minimal in length, well shielded, and preferably run in parallel to the simulator plates.

A typical NEMP test with the parallel plate system is shown in Figure 13.

By following the test set-up and parameters detailed above, reliable EMP simulation and testing can be accomplished in-house.


### Acknowledgment

This article is provided through the courtesy of Amplifier Research Corporation, Souderton, PA. ■



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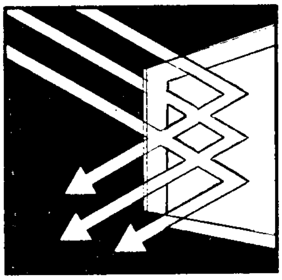

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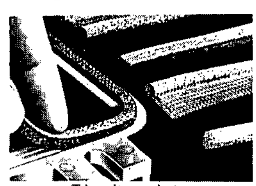

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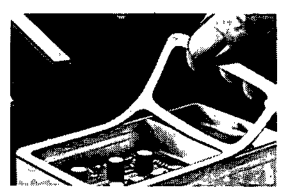

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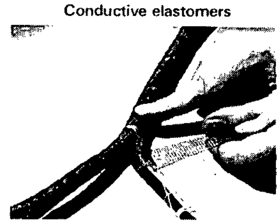
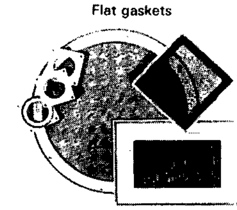


Shielding tape



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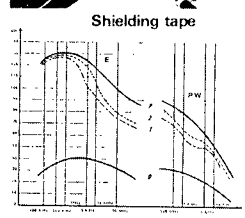

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