MEASUREMENTS OF ESD HBM EVENTS, SIMULATOR RADIATION AND OTHER CHARACTERISTICS TOWARD CREATING A MORE REPEATABLE SIMULATION or; SIMULATORS SHOULD SIMULATE

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ABSTRACT

Significant differences in test results are found when more than one brand of ESD simulator is used for immunity testing of electronic equipment. These problems prompted this work on fundamental measurements of ESD events and ESD simulators.

This paper describes the characteristics of the special equipment designed for the measurements describes the measurements, and compares the measurements to evaluate the effects of ESD testing repeatability.

INTRODUCTION

The purpose of the work reported here was to improve the knowledge of electro-static discharge (ESD) events with the goal of improving the accuracy and repeatability of ESD testing. Better simulators can only be made if the element to be simulated is more precisely defined. This was accomplished with new hardware specifically designed for these measurements.

The concerns of repeatability of ESD simulators testing brought together a number of engineers to attempt to make more accurate measurements of actual ESD events and simulators.

A manufacturer must provide sufficient ESD protection to electronic equipment to provide ESD immunity to the IEC 1000-4-2 level. Different simulators produce different threats as described elsewhere [1] [2] [3] [4]. When different simulators produce different threats and they all meet the minimum IEC 1000-4-2 specifications, confusion is created as to which should be used. If some threats are excessive, this can be considered as producing “overtesting”. The information presented here identifies the potential excessive threat levels of some ESD simulators.

Protecting electronic hardware from ESD damage or upset requires production testing with an ESD simulator to be certain that the Equipment Under Test (EUT) is immune to specified ESD threat levels. It is assumed by the user that the simulator meets the standard and that it provides true simulation. The IEC standards for ESD immunity testing were based on high voltage pulse measurements of many years ago with instrumentation that had slower risetimes than is now known to be necessary. The current pulse amplitude and waveform determinations of these older measurements was limited by the current viewing resistor bandwidths as well as the limited ability to produce waveforms to simulate these events. The initial standards could not be made more restrictive than the ability of the simulators to produce the current impulses as they were known to exist at the time.

Our work concentrated on identifying the amount of radiation produced by human body discharge events to the unintended pulse radiation produced by ESD simulators. With comparisons of the radiation from an actual Human Body Model (HBM) source and from different simulators, the magnitude of the problem of excess radiation is now known. Steps to reduce the unintended radiation to acceptable levels can now be taken.

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The unintended radiation is generated in excessive amounts by the simulators that we measured. ESD simulator radiation measurements have been made before [5] but without comparisons between the radiation from actual HBM events and the radiation from ESD simulators, the amount of excess is unknown. Our work shows that the pulse energy radiated from ESD simulators, significantly exceeds that from actual human discharges. Obviously a true simulator should not radiate more than that from a human body discharge.

Some of the present simulators do create excessive levels of unintended radiation, so apparently this part of the IEC standard is not, or cannot be, enforced.

The IEC standards only address unintentional pulse radiation, by stating that the simulator will not produce it. We have investigated this radiation, making preliminary measurements to determine the magnitude of excess energy. This excess energy problem creates a variable in ESD testing that increases the difficulty of manufacturing uniformly immune hardware. Protecting electronic circuits from this added disturbance requires unnecessary and added costs.

MEASUREMENTS OF RADIATION FROM ESD SIMULATORS

When an ESD "spark discharge" is made between a conductor and a ground plane a current begins to flow radially out from the discharge point along the surface of the ground plane. An equal and opposite current begins to flow away from the point of contact up the charged conductor. With a fast switch or a spark, fast transition Electromagnetic (EM) fields that can radiate in a short distance follow the leading edge of the two currents. The spark or switch is the source point of the EM radiation. The term "radiation" that is used to describe these effects is a simplied quasi optical assumption. The actual transmission of this energy over these close distances would require a complex analysis to thoroughly describe it.

The energy contained in the expanding EM field lines radiates as it moves further from the source. With a spark discharge to a ground plane, all of the current in the ground plane travels radially but from the spark location. Any radiation from these currents is directed up from the ground plane and away from the charged conductor that caused the spark.

An ESD discharge current to the surface of a ground plane is directed into a current viewing resistor (target) so that the current pulse from the discharge can be measured. An ESD discharge begins with a spark to the center of the target, and all of the current from that discharge flows through the resistors of that target. For accurate simulation of ESD sources, the discharge switch in a simulator should be located as close as possible to the end of the discharge tip. If the switch, like a spark, is located at the end of the tip, almost all of the current that flows through the switch or spark will flow through the target and can be measured.

If however, the discharge switch is located some distance from the simulator tip, some of the faster currents can be radiated from the switch and from the electrode to the tip and target. A significant source of radiation is the 330 ohm discharge resistor. This resistor is located closer to the contact tip than the high voltage discharge switch, and are both isolated from the target by the length of the discharge electrode.

The IEC standard only specifies that "the switch and discharge" resistor shall be placed as close as possible to the discharge electrode". But because the specification states that the discharge electrode shall be 50 mm. long, these potential radiators are prevented from closer spacing to the tip end which promotes radiation from them. Even if part of the discharge resistance is located in the discharge electrode, as at least one simulator does, the total radiation will be produced by: each resistor of the total discharge resistance, the interconnecting wires, and the switch. All of these sources are isolated from the tip of the discharge electrode and the radiation field is a rather complex assembly of all of these sources. Surface currents from the radiation will be different in the near and far fields as defined in the frequency domain.

Energy radiated before the current pulse reaches the target will not be measured by the target. If the radiated energy reaches the ground plane and induces currents into the ground plane, it is "excess energy" that has "skipped over" the target and was not measured by the target.

The part of the "radiated" energy that is converted into currents in the ground plane or that induces currents in the cables connected to the EUT can cause extra and unmeasured upset. The fastest transitions of ESD pulse energy is usually the most dangerous to electronic hardware because it has the highest frequencies. It can most easily find paths inside a metal enclosure through slots or openings.

If an ESD simulator is not carefully designed to avoid this radiation of excess energy, it can produce "overtesting" of the EUT. This is the "unintended radiation" identified in the 1000-4-2 Specification.

UNINTENDED RADIATION

The approach taken by Pommerenke [6] to analyze the electric and magnetic fields sources at the ESD event, (spark source) will provide information on the currents close to the simulator tip and as far out from that point as needed. Measuring radiation rom surface currents farther out beyond the target can help to identify energy that has not been measured by the target because it "skipped over" the target. If the problem was that simulators radiated 5 or 10% more energy than a HBM event, it could be overlooked; but if the excess radiation from a simulator is 300% higher than an HBM event, this is a major problem. For a basic measurement of "unintended radiation" at a distance a Barth Model 3004 TEM antenna was used to receive the radiation from ESD simulators. For recording the measurements we used two single shot HP 54720D digitizing scopes. They run at 8 Gigasamples and their single shot risetime capability is 175 ps for a –3 dB bandwidth of 2 GHz.

One digitizer was used to measure the amplitude from the target for each discharge to be certain that the current discharge amplitudes were consistent. An IEC target was placed in the center of a 70 inch high single width “rack mount” steel cabinet at about 44 inches from the floor. The current discharge amplitudes were constant within 5% and the waveforms were also similar for each shot. The other digitizer recorded the radiation impulse. The input throat of the antenna was placed at a distance of one meter from the target/ESD simulators.

The TEM antenna was measured with a HP 8510B network analyzer and found to have to have an SWR of 1.2 between 1.0 and 3.5 GHz and 1.6 between 0.7 and 10GHz. Figure 1. shows the TEM antenna in the position to measure the radiation at an angle of 0.0 degrees from a simulator on a stand. This was the position that usually received the maximum radiation.

Figure 2. shows the pulse response between a pair of these antennas at a separation of 5 meters with an input step function having a risetime of 50 ps. This pulse response was taken ion a HP 54120 sampling oscilloscope because it has a faster 35 ps risetime response and the pulses can be repeated many times to get a full sweep.

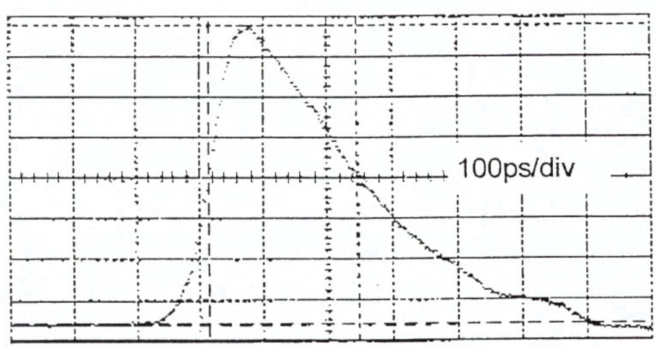


Figure 2: MEASURED PULSE RESPONSE BETWEEN TWO MODEL 3004 TEM ANTENNAS

Figure 2: Measured pulse response between two Model 3004 TEM antennas.

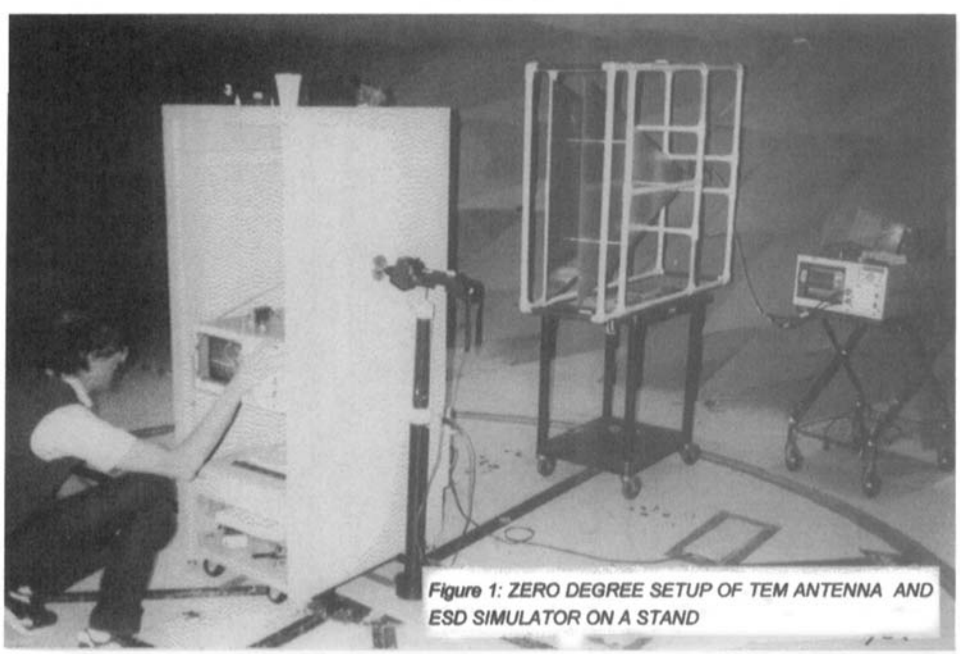


Figure 1: ZERO DEGREE SETUP OF TEM ANTENNA AND ESD SIMULATOR ON A STAND

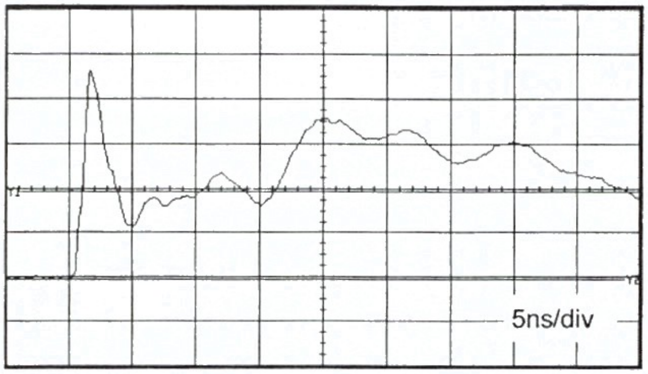


Figure 3: CURRENT DISCHARGE WAVEFORM

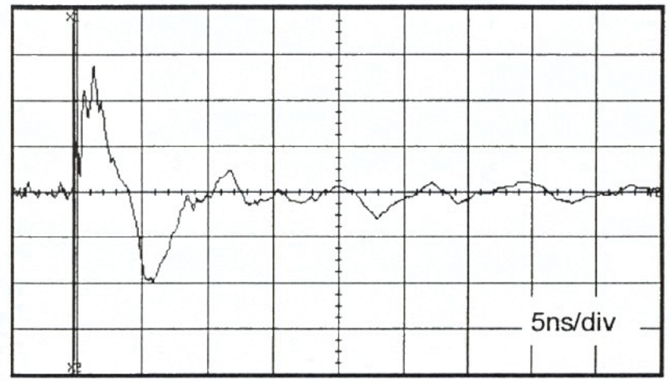


Figure 4: RADIATION FROM SIMULATOR

The calculated risetime for one receiving antenna is less than 40 ps with the 5 meter antenna separation. The closer spaced measurements made here would degrade the receiving antenna risetime to about 50 ps. The falling response after the initial rise is the typical differentiation of the radiated step function for antennas in the time domain.

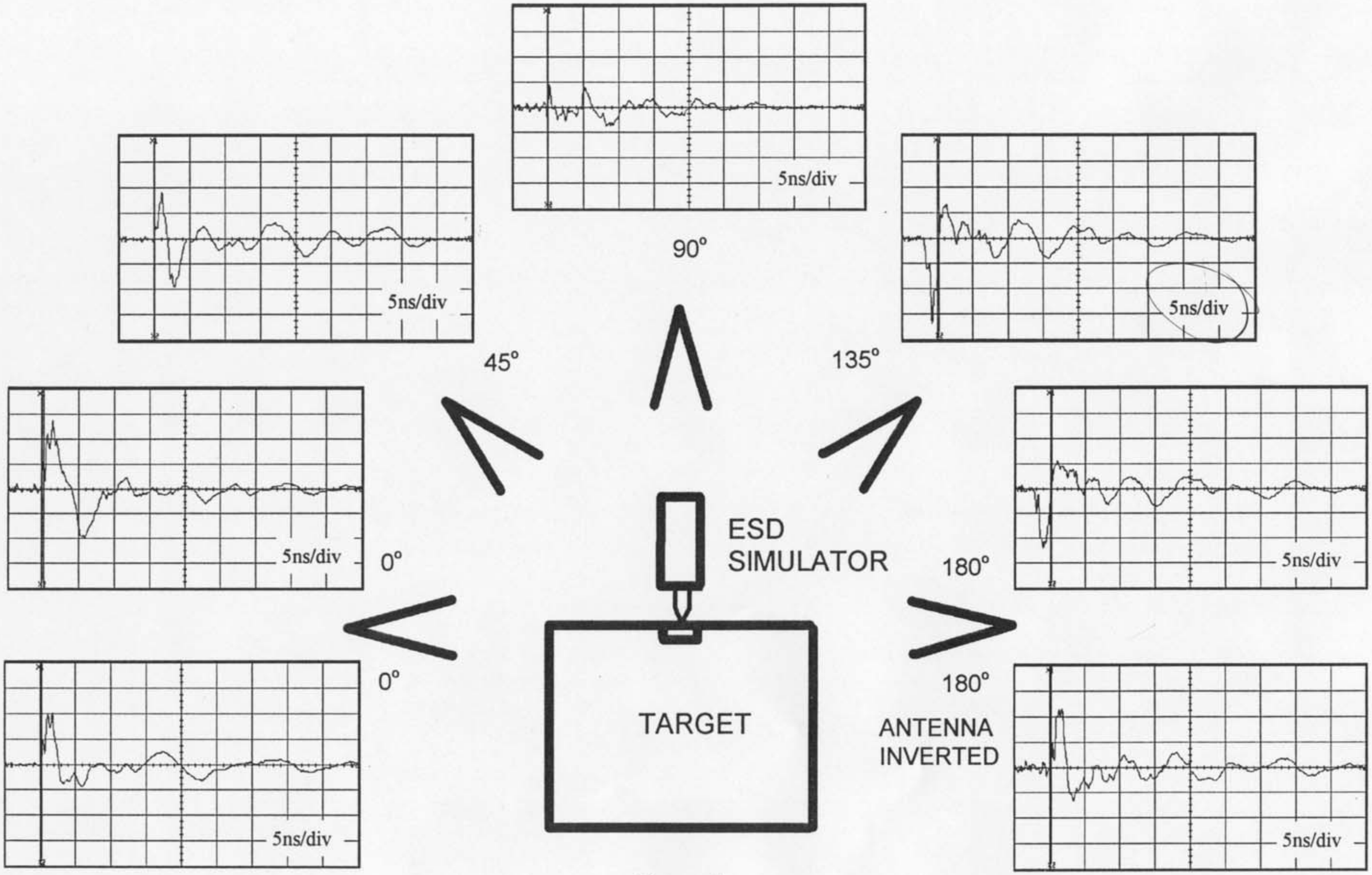
The radiation measurements were not made with a specific sensitivity in volts per meter; but were made to simply compare the radiation from different ESD simulators. The 50 ohm impedance TEM antenna has an opening of 0.142 meters and the radiation amplitudes could be calculated from this information.

Figure 3. shows the current discharge of a typical simulator into the IEC 1000-4-2 target, and Figure 4. shows the radiated field of that same discharge event.

The waveforms Fig. 5., show the radiation measurements made at different angles around (behind) the simulator while it was mounted on a stand with discharges into the IEC target.

Figure 1. showed the TEM antenna and a ESD simulator being set up for radiation measurements at 0 degrees. Figure 6. shows the antenna placed to measure radiation at a full 180 degrees from the starting position.

The peak levels of radiation from all of the simulators that we attested were surprisingly quite close. The IEC specification for the ESD simulation impulse is 0.7 to 1.0 ns risetime. This is equivalent to a –3 dB bandwidth of 350 to 500 MHz. The radiation shows significant amounts of energy in the 1.2 to 2.0 GHz range. If this radiation is converted to currents in the ground plane, it would create a significantly higher threat than that specified in IEC standards. The highest resonance frequencies found at 2.0 GHz is the limit of the HP 54720D digitizer. Higher frequency radiation may be present, and would cause a higher unintended threat level than the measurements shown here.



5ns/div
5ns/div
5ns/div
5ns/div
5ns/div
5ns/div
5ns/div
90°
45°
135°
0°
0°
180°
180°
ESD
SIMULATOR
TARGET
ANTENNA
INVERTED

Figure 5:

Figures 7, 8, 9, and 10. show the radiation received, all at an angle of 0 degrees, from four different simulators.

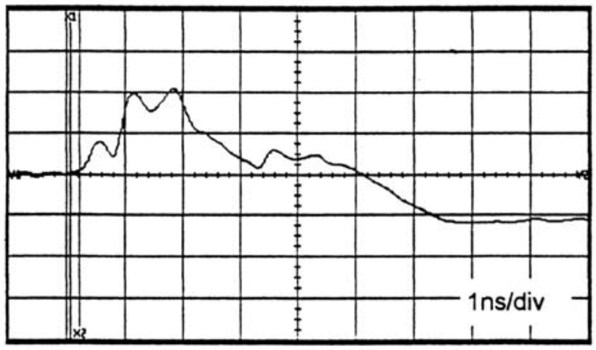


Figure 7: RADIATION FROM SIMULATOR "A"

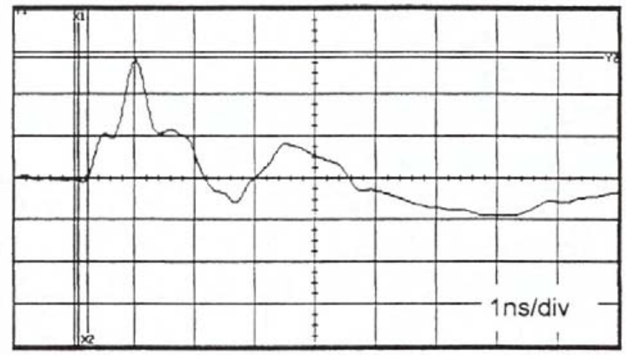


Figure 8: RADIATION FROM SIMULATOR "B"

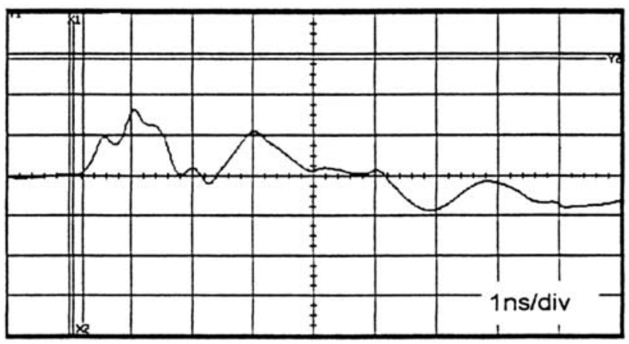


Figure 9: RADIATION FROM SIMULATOR "C"

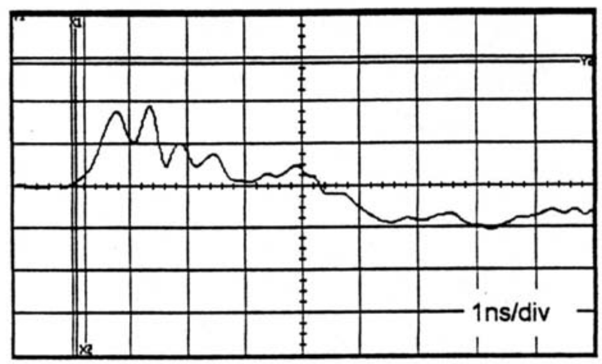


Figure 10: RADIATION FROM SIMULATOR "D"

The same antennas, attenuators, digitizers and 1 meter spacing were used again one month later to compare the amount of radiation between ESD simulators and a HBM discharge that should be simulated. The sweep speed and sensitivity are different than above; but they are the same for both Figure 11., and Figure 12. The antenna positioning, recording equipment and setup were identical for both measurements.

Figure 11 is the radiation from a simulator set at 4 kV. Figure 12 is the radiation from a human body (with screwdriver) 4 kV discharge.

The peak amplitude of the radiation from the simulator is 3.6 times the peak amplitude of the radiation from HBM discharge. The radiation from the simulator has much more structure (more high frequency components) than the human body discharge. The high frequency ringing is radiated from the simulator before it gets to the tip of the simulator and is therefore not measured by the target.

If this energy gets to the surface of the ground plane and is converted into currents, it will produce much higher ESD threats to the equipment under test than is indicated by current measured in the target. The excess radiation that we measured certainly increases the threat level and causes overtesting.

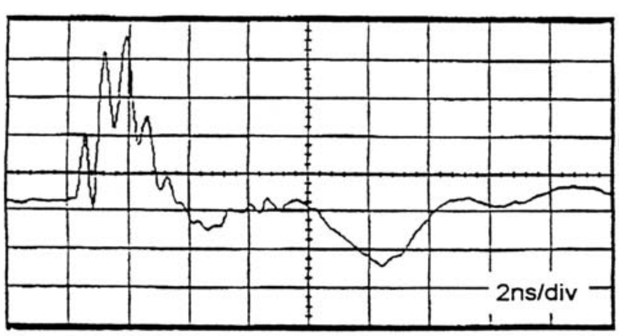


Figure 11: ESD SIMULATOR "A" RADIATION

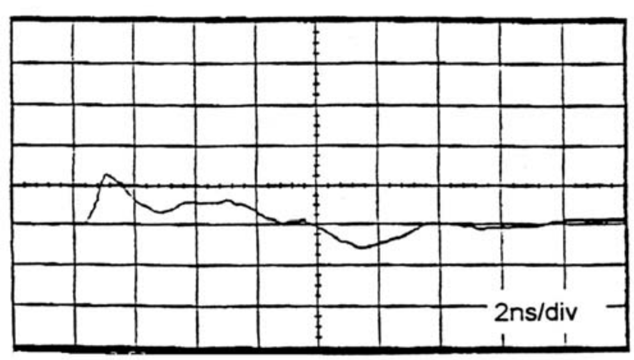


Figure 12: TYPICAL HBM RADIATION

CURRENT MEASUREMENTS

Significant differences were measured in the HBM current discharge waveforms and the waveforms from many different types of ESD simulators. Our measurements of HBM current discharge waveforms much more closely match the excellent work of Pommerenke [6] and others [7] than they match that of any simulator tested.

Current viewing resistor performance has been recently improved and a much wider bandwidth target is now available. [8]. This new target has been used with the fastest available transient digitizer for recent measurements of ESD events. [9] This new data is significantly different than the specifications outlined in the present IEC standards for simulated ESD testing waveforms. Because IEC standards cannot be changed for some time, there will be significant differences between the IEC standards and true simulation testing in the foreseeable future.

The present specification for current impulse risetime of 0.7 to 1.0 ns is correct for the voltages above 4 kV; but is not as fast as it should be for currents from actual ESD events below 3 kV. Our limited number of equalized measurements at 1,2 and 4kV show faster risetimes for current impulses from sparks originating from these lower voltage HBM discharges. More tests need to be made over a range of voltages with a large assortment of human bodies and with different and specific hand held metal discharge electrodes. Data collected made with this same fast flat response equipment can provide a newer data base from which to work.

The IEC standard has very wide tolerances for the time and amplitude of the ESD pulse simulator waveform specification. All of these wide tolerances add to the errors in current impulses produced by ESD simulators. The IEC standard, 801-2 (1000-4-2) was therefore a compilation of limited bandwidth measurement data on ESD events with the limited capability of existing simulators. The specifications do not limit excess energy in the form of high frequency ringing on the current waveform that is excess energy that can be applied to the EUT.

CURRENT DISCHARGE MEASUREMENTS

The pulse and frequency response of the IEC 1000-4-2 (Pellegrini) target has not been specified for risetime or bandwidth. To accurately measure the current discharge waveform of ESD simulators a method to calibrate the measuring device was needed.

A coaxial tapered line adapter, Barth Model 4610, was designed to permit measuring the IEC target in 50 ohm systems. It provides both fast and clean time domain pulse measurements and broad bandwidth flat response in the frequency domain.

This allowed a very well matched 50 ohm characteristic impedance coaxial transmission line to be connected directly to the 2 ohm contact disk of the IEC target design. The tapered line was 5 inches long, and air insulated. The inner conductor diameter is tapered up from the size of a type “N” connector to be able to connect to the two ohm contact of the IEC target. The full angle of the inner conductor is 6.0 degrees and the full angle of the outer conductor is 14.0 degrees. At the end of the tapered line, the O.D. of the inner conductor is 0.664 inch dia., and the I.D. of the outer conductor is 1.530 inch dia. A brass flange was fitted to the outer conductor with tapped holes to fit the IEC hole pattern of the target and provide a good ground plane connection.

The large diameter of the tapered inner conductor has a groove near the outer edge to hold a circle of silver filled rubber. The conducive rubber compresses against the uneven face of the 2.7 cm. Dia. Central target contact to allow for intimate electrical connection.

An HP 8510B network analyzer was used for frequency response testing of a pair of these tapered lines. The attenuation testing of a pair of these tapered lines. The attenuation increased smoothly to 0.3 dB at 18GHz and is perfectly acceptable. Although there are higher order modes in coaxial line this large, they are excited over very narrow frequency ranges. These mode resonances have been found to be unmeasurable in fast pulse systems because they are too narrow to be “shock excited”. The tapered line has less than 1% reflection coefficient to a 35 ps step function as measured with a HP 54120 sampling scope. The HP 8510B is well matched to 50 ohms and the reflection from the abrupt discontinuity between the 50 ohm tapered input line and the 2 ohm target causes a minimal error of less than 0.1 dB.

Three different targets made to the IEC specifications were measured with the tapered line on the HP 8510B network analyzer and all had approximately the same frequency response shown in Figure 13. The time domain pulse response measured on a typical IEC target is shown in Figure 14, at a sweep speed of 200 ps per division.

These IEC standard targets have insufficient flatness and bandwidth to be used for measurements of HBM discharges. The response of a IEC 1000-4-2 target cannot be relied on to be better than 4 dB at 2 GHz, which causes significant and erroneous overshoot to fast pulses. The use of ordinary PC board wire lead helixed resistors and the lack of a matched impedance metal housing puts inherent limits on the risetime (bandwidth) of this 2 ohm transducer. The large cmplitude versus frequency response deviations dictated that an improved target would be needed to produce accurate ESD event measurements. [10]

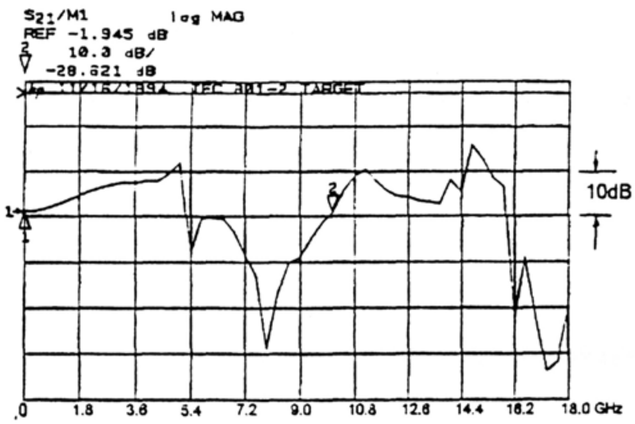


Figure 13: FREQUENCY RESPONSE Typical IEC target

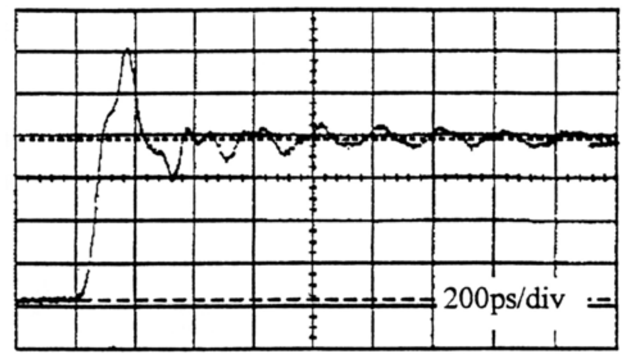


Figure 14: PULSE RESPONSE Typical IEC target

The first requirement for accurately characterizing the complete HBM current discharges is that a measuring system faster than the fastest impulse expected must be used. HBM discharges have been measure to be much faster than 0.7 to 1.0 ns risetime. Therefore to identify the fastest risetime of HBM pulses, a target was needed that was significantly faster than the fastest ESD pulses expected from HBM discharges. A flat response across this frequency range was also necessary for accurate measurements.

A Barth Model 4603 one ohm target was designed to provide flat response to 12 GHz so that ESD simulators and HBM events could be accurately characterized. This target has a .266 in. dia. Contact disk. It was measured with a smaller, air insulated tapered 50 ohm transmission line, the Barth Model 4611 which has a shorter taper length with the same angles as the large model 4610, to provide a 244 dia. Inner conductor to contact the target disk. The large end of the tapered inner conductor has a shallow hole leaving a thin wall near the outer edge to hold a wire knit mesh "fuzz button" to make a low resistance connection to the one ohm target contact. A brass flange was fitted to the outer conductor with tapped holes to fit the IEC hole pattern of the target and provide a good ground plane connection.

The frequency response of this one ohm target is shown in Figure 15. The time domain response of this target is shown below in Figure 16. at a sweep speed of 50 ps per division.

A special Sandia Labs Tektronix SCD5000 that was software equalized [11] to be 3 db down at 16 GHz, was used with the 12 GHz one ohm resistor target to acquire different ESD waveforms. These two very wide bandwidth elements provided a very fast measuring system to produce single shot records with a pulse response capability of better than 35 ps risetime.

Pulses from two different simulators set at 4 kV and two different human body discharges also at 4 kV were recorded with this system and are shown in figures 17 through 24. Two recordings of each were made to get the complete waveform data.

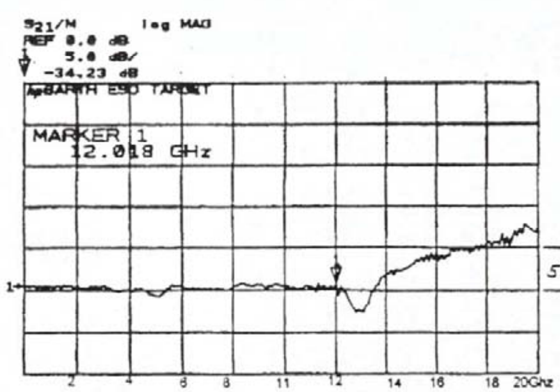


Figure 15: FREQUENCY RESPONSE Model 4603 Target

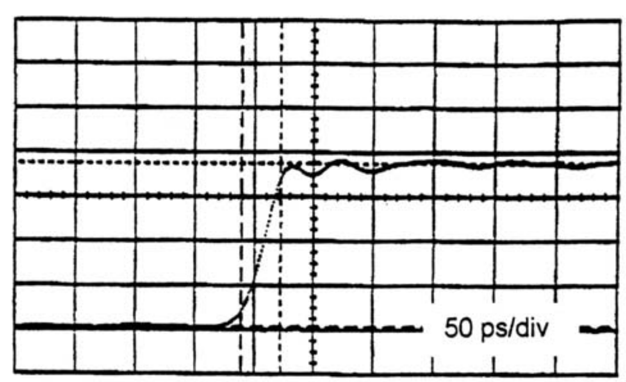


Figure 16: PULSE RESPONSE- Model 4603 target

The first records were made at 10 ns per division, to show the whole pulse out to 100 ns time, and the second records were made at 0.5 ns per division to show the risetime details. All of the 0.5 ns per division records made are software corrected to 35 ps risetime. The software equalized Tektronix SCD 5000 at Sandia National Labs used with the 12 GHz target captured both human body discharges and ESD simulators with a risetime capability of 35 picoseconds.

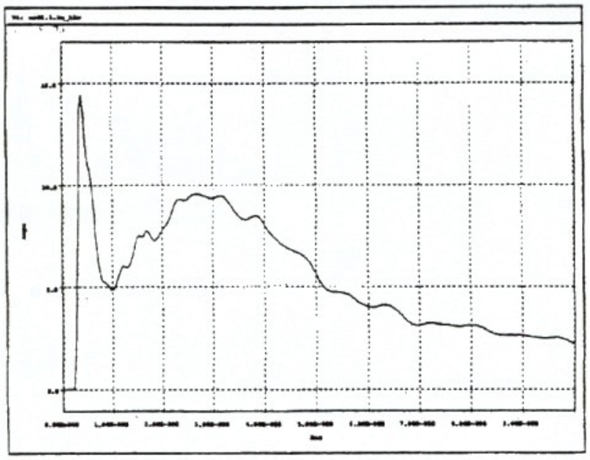


Figure 17: ESD SIMULATOR "A" AT 10 ns./DIV

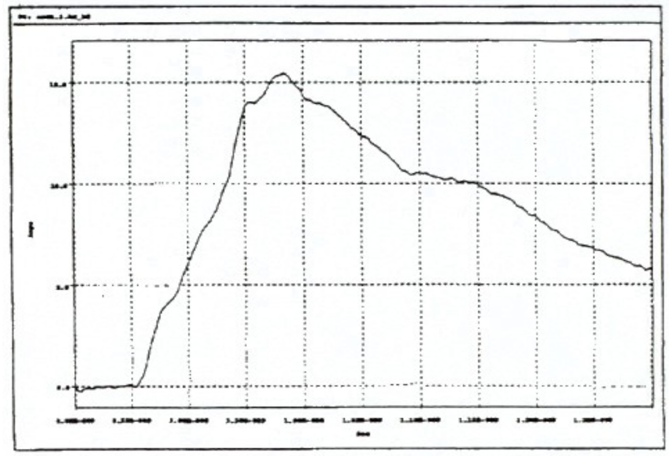


Figure 18: ESD SIMULATOR "A" AT 0.50 ns./DIV

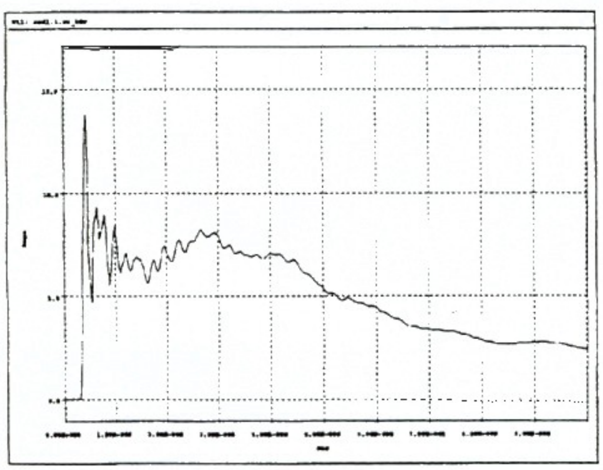


Figure 19: ESD SIMULATOR "B" AT 10 ns./DIV

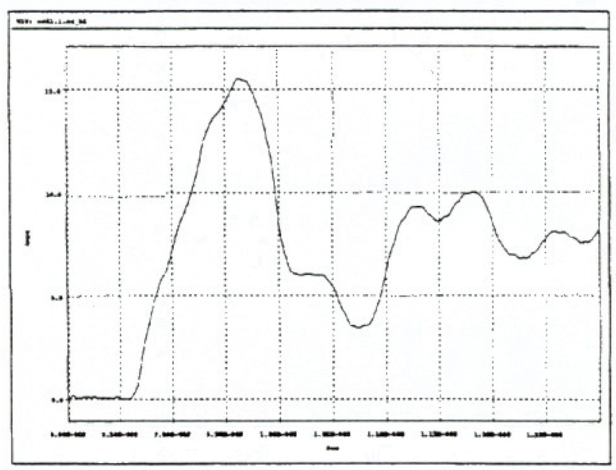


Figure 20: ESD SIMULATOR "B" AT 0.50 ns./DIV

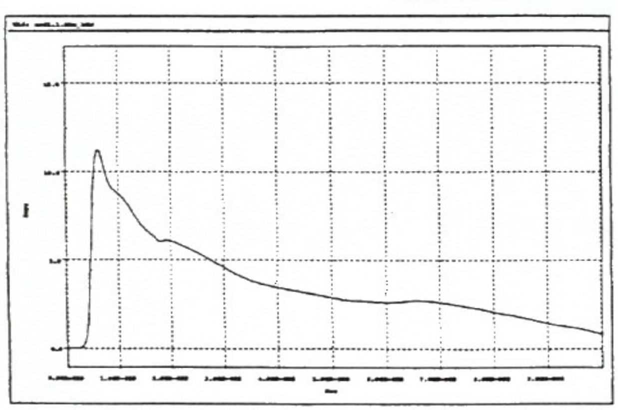


Figure 21: HBM DISCHARGE "1" AT 10 ns./DIV

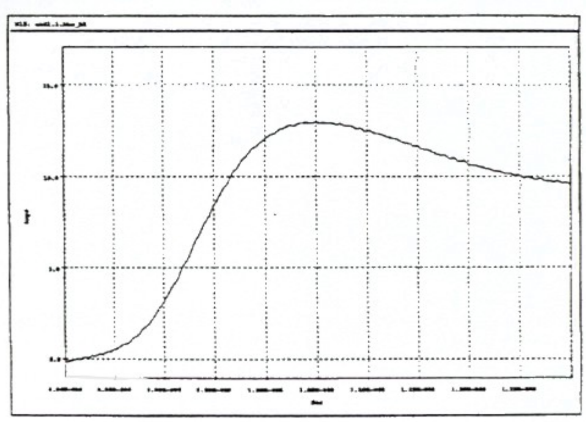


Figure 22: HBM DISCHARGE "1" AT 0.50 ns/ DIV

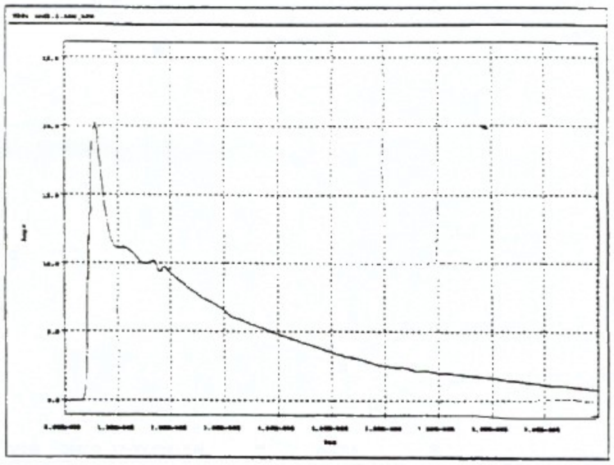


Figure 23: HBM DISCHARGE "2" AT 10ns./DIV

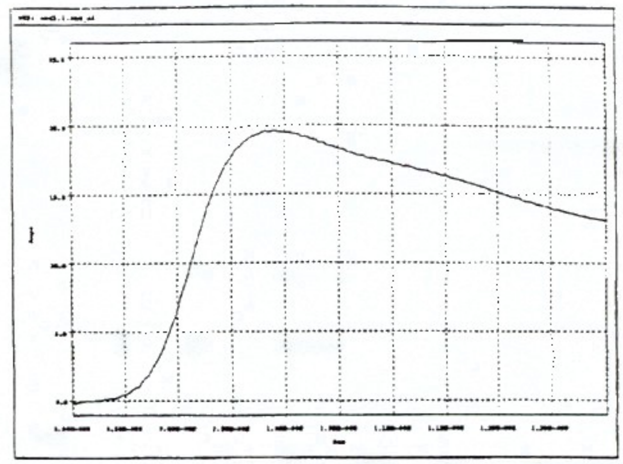


Figure 24: HBM DISCHARGE "2" AT 0.50 ns./DIV

The ESD simulators that have been built to meet the present standards are significantly different from actual ESD events and they are even more different from each other. The different brands of simulators produce very different waveforms and produce different ESD immunity levels when testing EUT. These differences only become obvious when two or more different brands of ESD simulators are used to test the same piece of equipment.

So while the IEC standard specifies a definite threat level, it allows an excessive threat by permitting energy that can be significantly above the specified minimum from more than one source in each gun.

CONCLUSIONS

The 1000-4-2 ESD standards is ill defined in some critical aspects of its specifications. The wide tolerances listed in the specifications allow for an excess threat from the ESD simulators that were investigated. The economic consequences of IEC 1000-4-2 are important to both users and manufacturers of the regulated test hardware.

All simulators are certified by their manufacturer as complying with the IEC standard for ESD testing. However, significant differences in test results have been found when more than one brand of ESD simulator is used to measure the immunity levels of Equipment Under Test (EUT). The dilemma is: which simulator should therefore be used to measure the immunity level for compliance testing?

Protecting electronics to the levels in the present IEC requirements have significant costs and therefore it is desirable that ESD testing not be excessive or have tolerances that are wider than necessary. Another problem that may be minor by comparison to the problems described above is that some of the existing simulators were found to use discharge resistors with an uncontrolled voltage coefficient. This variation is resistance during a HV pulse is part of the necessary wide tolerances for simulator discharges currents and may have to be addressed as accuracies are improved. [12]

The complicated combinations of ESD characteristics is difficult to evaluate for excessive threats. Specific comparisons will have to wait for a simulator that much more closely simulates HBM discharges.

DESCRIPTION OF AN IMPROVED ESD PULSE RADIATION RECEIVING SYSTEM

The following information describes a time domain conducted and radiated measuring system being built to make comparison measurements between the radiation of simulated and actual fast pulse and ESD events. Particular emphasis is directed at accurate measurements of the fastest (less than 500 ps risetime) radiated energy.

It consists f a large, rotating two meter diameter, vertical ground plane with the 12 GHz target mounted in the center. Discharge currents are measured by the target and radiated energy will be picked up with a reflector feeding into TEM horn antenna. These two measurements will be able to characterize the amplitude and time history for both sources of energy threats.

Focusing energy from the central source into a TEM horn will be done with an elliptical reflector located at the edge of the ground plane. The 2 meter ground plane and receiving antenna can be rotated through a full 360 degree around the source. The elliptical reflector will focus the energy radiated from the center of the ground plane into the vertex of the TEM horn. Focusing the energy into the same converging angle as the TEM horn will provide added fast pulse fidelity capabilities.

Rotating the complete ground plane, target and receiving antenna will allow measurements of the radiated energy from all angles of a stationary source.

Locating the TEM pickup horn one meter from the elliptical reflector will allow a relatively long horn that can cleanly capture the fastest parts of the radiated waveform with a relatively long time history.

A microwave absorber will need to be placed between the source and the TEM to prevent direct pickup of early radiation from the source. Note that the reflection process will invert the polarity of the radiated impulse at the TEM horn.

Because the switch in simulators is not located at the end of the discharge electrode, the energy radiated from an unshielded simulator can originate from the location of the switch and the discharge resitor. If it is found necessary to focus on the primary radiating point of a simulator, the TEM horn, or elliptical reflector or both, can be tilted slightly.

This receiving antenna is effectively at a distance of 1 meter from the central source because that is where the focusing reflector is located. Being this far out from the radiation source at the center will not be as useful as a current probe that can be moved closer to the source. It is however a simple method of measuring the unintended radiation from ESD simulators and from HBM discharges that travel out from the center along the surface of the ground plane.

CALIBRATION OF RADIATION SENSORS

Calibration of the elliptical reflector/TEM antenna described above or other surface current monitors can be accomplished as follows:

Half of a biconical antenna (a monocone radiator perpendicular to a ground plane) can be placed on the axis of the ground plane with the driven location connected to the center contact of the target. [13]

It will be driven with a fast high voltage pulse fed through low loss coax to the apex of the cone. This source can provide a known step function radiation pulse to test the reception of the antenna system. At the same time it will also provide a current pulse to characterize the current sensitivity of the target in a different manner than the tapered line technique previously described. It can provide calibration of radiation amplitude by knowing the source current/voltage amplitude.

This type of antenna has a well defined characteristic impedance for this calibration and has a clean and fast time domain pulse shape. Driving the monocone with a clean 40 ps risetime high voltage pulse can provide an excellent calibration source. The radiation from this known radiator will produce surface electric and magnetic fields. This source will also supply known voltage and current pulses to calibrate the TEM horn antenna. The known fields can also be used to calibrate E and H field sensors described by Pommerenke [2] that can be located at any distance fro the center on this rotating ground plane.

PROBLEMS WITH PRESENT ESD TESTING

1. Wide tolerances on the IEC current amplitudes specifications.
2. Poorly defined waveforms in the IEC specification slows excessive high frequency currents.
3. One risetime “fits all” voltages in the IEC specifications.
4. ILL defined and unenforced requirements on unintended radiation.

SOLUTIONS TO THE PROBLEMS WITH PRESENT ESD TESTING

The simplest solution is a new ESD simulator that:

1. Meets the basic IEC 1000-4-2 standard specification.
2. Has closer tolerances for better reproducibility. (higher accuracy)
3. Has a current discharge waveform that more closely matches HBM discharges.
4. Has the ability to produce faster risetime discharges that occur at lower voltages, to match the HBM events rather than the “all encompassing” IEC specification of 0.7 to 1.0 ns.
5. Produces the same radiation as a HBM discharge; but does not produce excessive radiation. (Unintended radiation)

These measurements provide some guides to designing an improved simulator that more closely simulates real ESD events. First it should produce pulse radiation equal to, but not greater than that of an HBM discharge. Secondly it should produce pulse radiation equal to, but not greater than that of an HBM discharge. Secondly it should produce a current waveform that more closely matches that of actual HBM discharges. The hardware and measurements described here can be a useful starting point to designing improved ESD testers.

When such an ESD simulator is produced it can be used to compare more realistic threat levels to that produced by present simulators. This comparison will provide real world practical and working measurement of threats to compare an optimum simulator to present simulators. This is the only way to clearly identify the amount of excessive threat produced by present simulators.

Our tests were made to try to pin down ESD threat levels with fundamentally sound measurements. The measurement hardware used for this testing is clearly described. Reliable testing in this technology is difficult and tolerances should be improved to reduce the amount of overtesting. This information can abe used to design more repeatable simulators that more closely simulate actual HBM discharges.

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