DESIGN AND PERFORMANCE OF A 2M EUT MIL STD 461(RS-105) TEST SYSTEM

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Abstract

Applied Physical Electronics, L.C. (APELC) has built a moderate scaled test system to meet MIL STD 461, under the RS-105 test configuration. The system is designed to test objects of up to 2 m x 2 m x 2m, with peak electric fields of up to 60 kV/m. This system uniquely uses a coaxial Marx generator, coupled with a planar peaking circuit to produce the MIL STD waveform, which is characterized by a 1.8 – 2.8 ns rise time, and a pulse width of approximately 23 ns. This paper will describe the pulsed power source, as well as the nuances of driving a guided wave structure.

I. INTRODUCTION

Military Standard (MIL STD) 461G [1] describes how to test subsystems for electromagnetic compatibility. Within the standard is the RS-105 test method, which determines the susceptibility to the High-altitude Electro Magnetic Pulse (or HEMP). The standard describes the test arrangement, as shown in Figure 1.

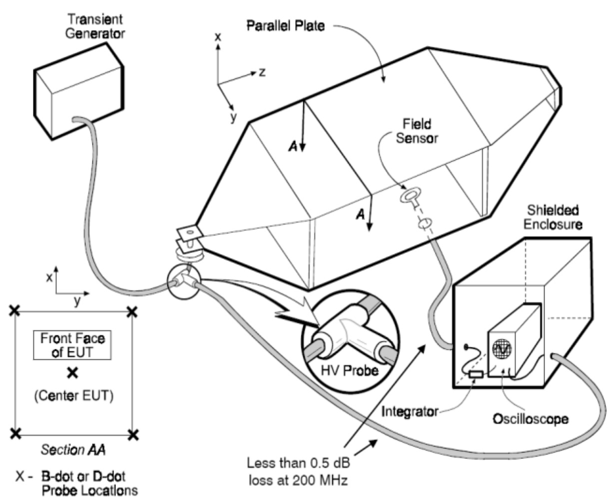

Figure 1. The suggested hardware configuration for the MIL STD 461G (RS-105 test method).

A pulse is launched onto a parallel plate, TEM structure, which is resistively loaded to avoid unwanted reflections. The standard then defines the characteristic waveform, shown in Figure 2, which is a double exponential pulse, characterized by a 1.8 – 2.8 ns rise time, and a Full Width Half Maximum (FWHM) of 23 ns ± 5ns. A peak electric field strength of 50 kV/m is required.

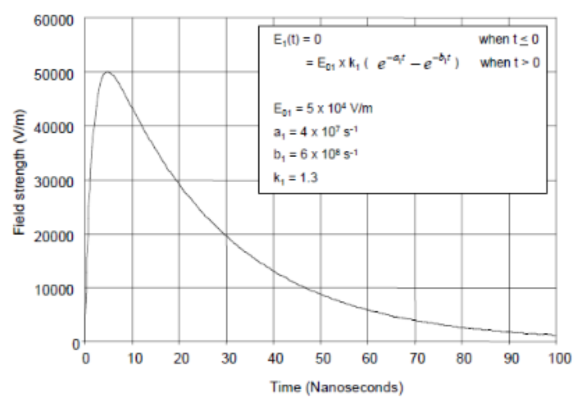

Figure 2. The required waveform necessary to perform the MIL STD 461G (RS-105 test method).

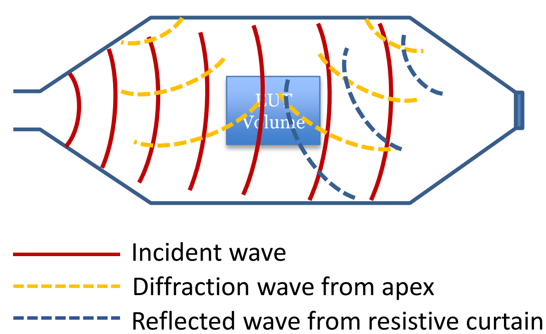

Figure 3. An illustration of unwanted waves generated by the suggested geometry.

The geometry described in the standard presents problems posed by reflections, caused by all the bends in the structure. As illustrated in Figure 3, major bends throughout the structure create diffracted waves off the corners located near the input, and reflected waves off the corners near the load. The unwanted waves distort the primary signal, often pulling the system out of specification.

II. THE SYSTEM DESIGN

The preferred antenna geometry is shown in Figure 4. This line was proposed by Giri and Baum [2], and is accepted as the standard. The benefit of this geometry is that the single corner is moved well away from the test volume. There are no diffracted waves caused ahead of the test volume, and the reflected waves come very late time in the pulse, and are reduced by the 1/r field propagation.

The structure size is also defined in the MIL STD, and is designed to minimize interactions between the structure and the test article. Generally, the test volume, or Enclosure Under Test (EUT) volume can be described as L_{EUT} x W_{EUT} x H_{EUT}, and the surrounding structure must have the minimum dimensions of:

$$L_{structure} = 2 \times L_{EUT}$$

$$W_{structure} = 2 \times W_{EUT},$$

$$H_{structure} = 3 \times H_{EUT}$$

In reality, the structure must be substantially longer, in order to maintain the pulse into the EUT volume and create the desired impedance. Antenna angles between 14 – 17 degrees are common. Table 1 provides the antenna/structure design parameters, with the antenna dimensions derived directly from the standard. The final structure dimensions include the mechanical supports and guy wires.

The antenna is simply a wire structure forming a linear half-TEM horn antenna, often called a conical horn antenna. For this design, the top plate is created by twenty 1/8 inch stainless steel cables; and the ground plane is created by a wire mesh, cut slightly larger than the top plate to minimize fringing effects.

The design of this system was robust, allowing for a wind loading of 80 MPH, and a maximum wire sag of 6 inches with ice loading. Furthermore, all elements of the support structure were designed to be non-conductive. The vertical supports were made of 12 inch diameter fiberglass poles. The horizontal beams are glue-laminated beams. Phillystrand guy wires maintain position and lateral stability.

Prior to construction, the structure was modeled and simulated using Remcom (FDTD). The primary focus was to ensure that the rise edge of the pulse propagates the structure. It was also critical to ensure that the peak electric field strength does not fall more than 6 dB throughout the EUT volume. Finally, the model was used to finalize the impedance of the structure, and thereby the voltage required from the pulsed power to create the peak electric field.

Figure 5 provides sample waveforms from the simulation. The graphic shows two pulses, one entering the EUT volume, and the second leaving the EUT volume. In this case, the rise time of pulse is maintained, and the amplitude drops approximately 10%- well within the required 6 dB required by the MIL-STD.

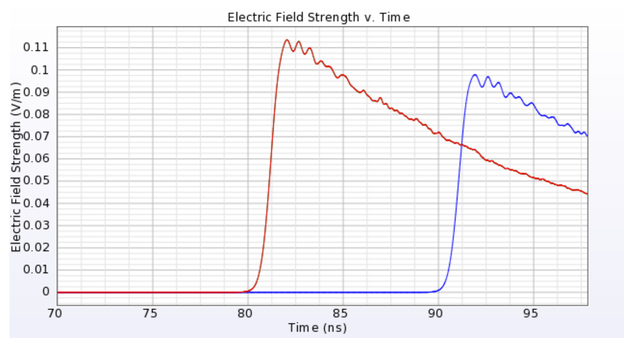

Figure 5. Sample results from the Remcom model, describing the pulse propagation through the EUT volume.

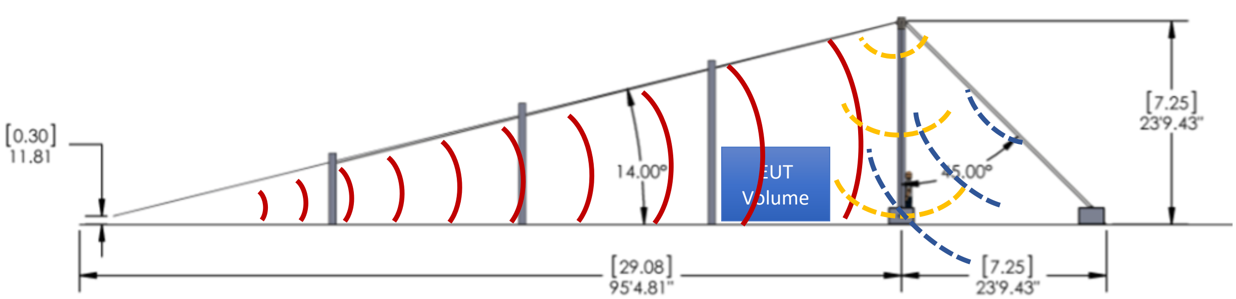

Figure 4. Conical antenna and wave propagation

Table 1. Structure parameters

Parameter	Value	Units
Nominal impedance	110	Ω
Maximum EUT dimensions		
Height	2	m
Length	2	m
Width	2	m
Antenna		
Angle	14	Deg
Apex height	7.7	m
Length	29.7	m
Width	10	m
Structure		
Height	7.7	m
Length	37.5	m
Width	26.9	m

The pulsed power requirements were driven directly by the Remcom model. With a 6 m structure height at the EUT, a minimum 300 kV voltage pulse is required to meet the standard (50 kV/m). With a propagation loss of approximately 20% to the EUT volume, a voltage of at least 360 kV is needed.

The pulsed power system is described in Table 2, and shown in Figure 6. A coaxial Marx generator was built to deliver a maximum erected voltage of 455 kV (13 stages, with a maximum 35 kV charge voltage). Since the generator is coaxial, and the antenna is planar, the peaking circuit was designed as planar to match the antenna. This geometry negates the need for a zipper section, and substantially increases the voltage efficiency of the overall system.

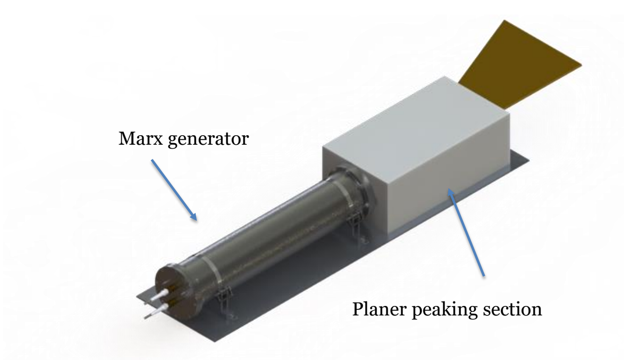

Figure 6. The pulsed power source, including a compact Marx generator and a planar peaking circuit.

Table 2. Pulsed power parameters

Parameter	Value	Units
Marx generator		
Number of stages	13	-
Peak erected voltage (matched load)	455	kV
Maximum charge voltage	35	kV
Maximum energy per pulse	30	J
Capacitance per stage	3.76	nF
Erected capacitance	289	pF
Series inductance	500	nH
Source impedance	41	Ohms
Peaking		
Capacitance	50	pF
Inductance	100	nH

III. RESULTS

The system was tested for its performance in delivering the required pulse throughout the EUT volume. Figure 7 provides a sample waveform of the pulse entering the structure, using a ground plane D-dot probe (AD-110) near the launch point. The perturbations in the waveform are due to the vertical supports located at 70 ns intervals. The load is approximately 200 ns from the point of measurement. Figure 8 provides a waveform, measured at 24 m from the source, and inside the EUT volume. This measurement is made with a free field probe (AD-55). At 75 ns, there is an abrupt change in the waveform due to a mismatch of the load. However, with this occurring so late in time, the pulse characteristics fall well within the temporal requirements of the standard.

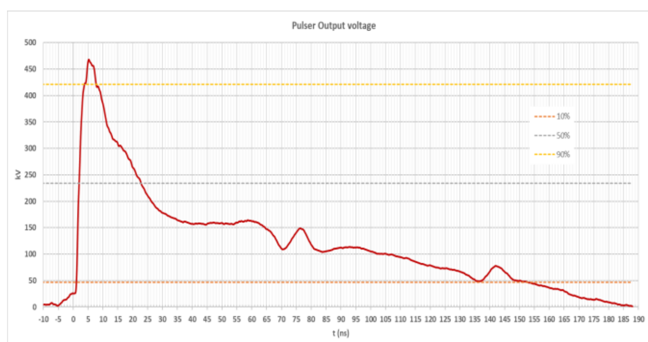

Figure 7. A sample waveform of the pulse launched onto the antenna.

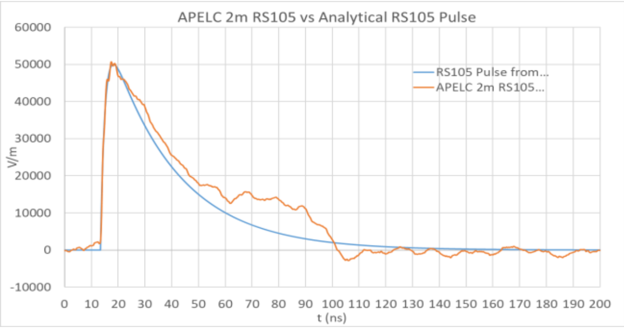

Figure 8. A sample radiated waveform compared to the ideal waveform

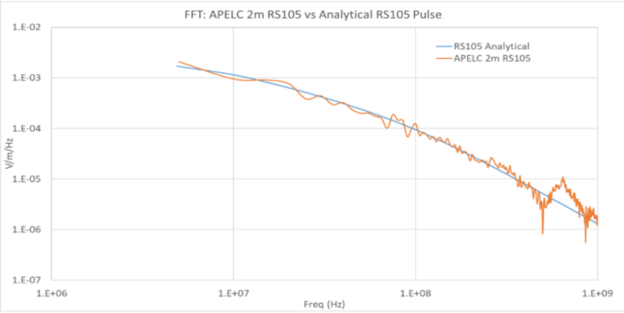

Figure 9. A comparison of the spectral content between a measured pulse and the theoretical waveform.

Ultimately, the waveforms and respective frequency responses must compare with those described in the MIL STD. Figure 8 also provides a sample measured waveform compared against the theoretical waveform. The early and mid-pulse follows the theoretical shape very well. However, there appears to be some additional, unwanted late-time, low frequency energy in the tail of the pulse due to the mismatch at the load. As shown in the spectral view of Figure 9, the high frequency tracks the desired spectrum closely; however, moving to the left of the curve, there is some deviation from the theoretical trace.

IV. CONCLUSION

A test structure meeting the MIL STD 461G (RS-105 test method) was designed and built for objects up to 2 m^3. The structure was design to the standard, and simulated using Remcom. The pulsed power was designed from the simulation results, and brought in a novel method to avoid the inefficient zipper section, by using a planar peaking circuit to match the planar load geometry. The experimental results match well to the standard, with a few deviations in the waveform due to load reflections. Future work will focus on minimizing these unwanted perturbations.

V. REFERENCES

[1] MIL-STD-461G, "Department of Defense Interface Standard: requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment." *US Department of Defense: March* (2015)

[2] D. V. Giri, "Design Guidelines for Flat-Plate Conical Guided-Wave EMP Simulators With Distributed Terminators." (1996)

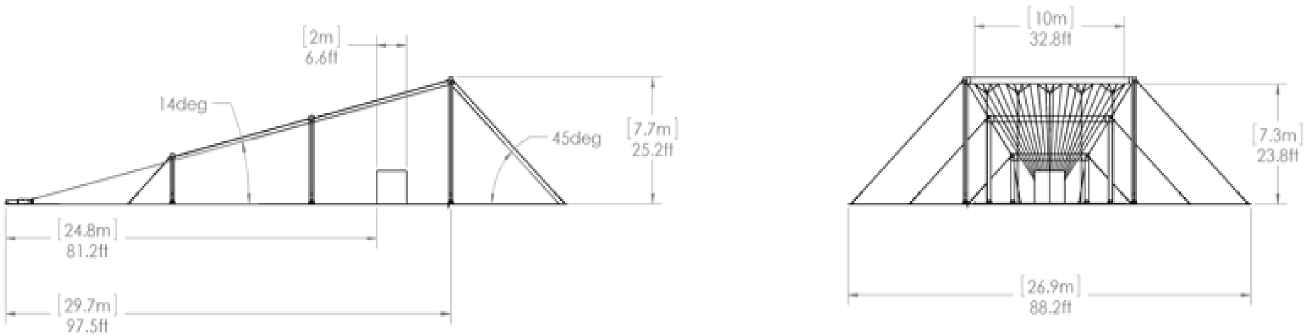

Figure 10. Dimensioned drawings of the simulator