EMP Footlocker: A Portable High-Power Electromagnetic Source For Mobile Platforms

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Abstract

International interest in electronic-warfare tools which can deliver scalable, non-lethal effects on potential targets, such as drones, has led to the development of portable high-power electromagnetic sources. Subsequent testing has indicated that such sources can be useful for studying effects on critical infrastructure, asymmetric threat hardware, and electronic systems. One particular application and has led Applied Physical Electronics LC to develop a mobile, high-power, electromagnetic pulse generator which uses a wideband antenna and an integral reflector to meet the unique needs of its intended task. This paper discusses APELC's development of the "EMP Footlocker", its mechanical characteristics, control scheme, and electromagnetic signature.

I. INTRODUCTION

International interest in electronic-warfare tools which can deliver scalable, non-lethal effects on targets has led to the development of portable high-power electromagnetic sources. Such sources have applications in the protection against drones and drone-swarms, vehicle stopping, and for signature-free disruption of various electronic devices. Subsequent testing has indicated that such sources can be useful for studying effects on critical infrastructure, asymmetric threat hardware, and electronic systems. One particular application and has led Applied Physical Electronics LC to develop a mobile, high-power, electromagnetic pulse generator which uses a wideband antenna and an integral reflector to meet the unique needs of its intended task.

High-power electromagnetic sources have been well surveyed by Prather and their effects and applications have been discussed more recently by Kreth and Baurer respectively [1-3]. The international interest in such sources comes in part from entities which need scalable, non-lethal effects to control access and assert will against asymmetrical threats, vehicles, drones, and drone swarms. Recent market application needs include directivity, a wide bandwidth, portability, and a minimization of back-lobe electric field on collateral, friendly electronic systems. In addition a candidate system would need to live and operate in harsh environments and of course, be effective at range. APELC has used this motive to develop its EMP Footlocker system. This paper discusses APELC's development of the EMP Footlocker, its mechanical characteristics, control scheme, and electromagnetic signature.

II. ANTENNA

The central technical component of the system is its antenna. For the subject application the antenna group needs to provide beam directivity, minimize back-lobe electric field, be efficient at high power, and balance the competing goals of target frequency, compact size, and high-voltage operation.

APELC has incrementally matured its "fat" dipole antenna design specifically to balance high-power and compact size for a variety of frequencies and various application. Depth on this family of antennas can be found in [4,5]. The APELC fat dipole in the subject system is combined with a corner reflector to increase gain in the far field and minimize back lobe electric field [6-8]. The antenna and reflector geometry in the Y-Z plane is shown in Figure 1 along with the normalized electric field intensity during a pulse event.

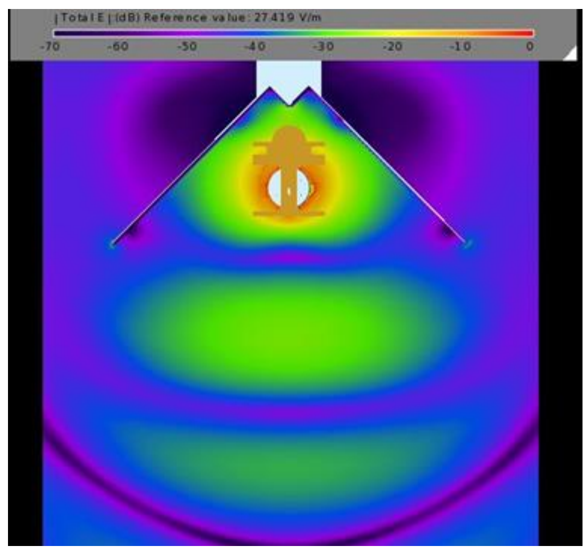

Figure 1. X-Y plane (bird's-eye) view of simulated normalized electric field pattern near the antenna-reflector pair

III. SYSTEM INTEGRATION

The system integration sought to combine simple fiber-optically isolated user controls, transient-protected HVPS, gas-insulation pressure and flow control with vibration-resistant shock mounts and a water-resistance and impact resistant environmental enclosure. The footlocker housed in its

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environmentally protected housing is shown in Figure 2. The skeleton of the system can be easily removed to permit laboratory or anechoic-chamber testing or it can be left housed in its environmental case to resist water, debris, or impact.

Figure 2. EMP footlocker housed in its environmental enclosure.

The basis pulser in the footlocker is APELC'S 10-stage wave-erection Marx generator. The Marx generator is charged to 33 kV by a DC high-voltage power supply (HVPS). Once triggered, the Marx erects to an open-circuit voltage of 330kV. The function of the pulser is to quickly charge the antenna resonator to a high voltage state. In addition, the pulser needs to be compact, able to pulse at a 10-Hz PRF and durable in an environment with extreme electromagnetic transients. The Marx generator uses compressed dry breathing air for both insulation and gas switches.

The Marx generator is mounted immediately proximate to the antenna, inside the corner reflector as shown in Figure 3. This positioning serves to improve efficiency and separate high-transient sources from the power and control electronics located behind the reflector.

The controls for the footlocker include a handheld fiber-optically controlled remote which controls triggering, single-shot or repetitive mode, and pulse repetition frequency (PRF). The remote also features an auxiliary TTL trigger input (BNC) which permits synchronization with external test and measurement equipment. The controls are shown in Figure 4 for both the handheld remote and the interface panel. The environmental enclosure is shown in Figure 4. Typical usage involves selecting the output power level at the interface panel by adjusting the antenna pressure. Then the operator can remotely control fire commands using the fiber-optic remote control. Additional functions at the interface panel include Marx and antenna purge buttons, gas shutoff valve, and indicators for low-battery and low-gas conditions. Figure 5 shows the dimensioned drawing of the enclosed system.

Figure 3. Footlocker skeleton showing the Marx generator mounted behind the antenna inside the corner reflector.

Figure 4. (left) handheld fiber-optic controller, (right) (right) Interface Panel: (A) Power switch, (B) low air light, (C) low battery light, (D) push/pull circuit breaker, (E) charge port, (F) cylinder pressure gauge, (G) gas shut-off valve, (H) antenna pressure gauge, (I) antenna pressure adjustment, (J) Marx pressure gauge, (K) Marx pressure adjustment.

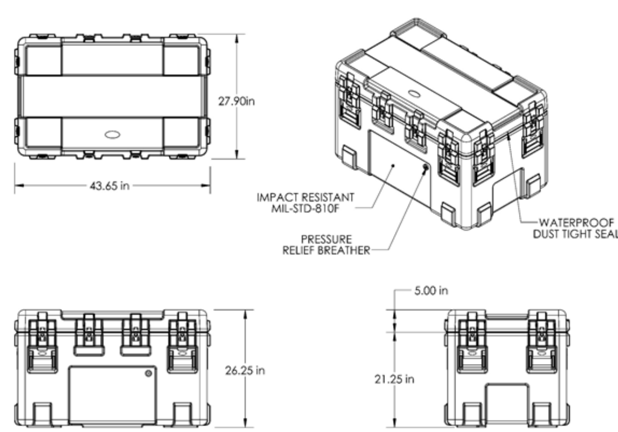

Figure 5. Dimensioned drawings of the environmental enclosure.

IV. SIMULATION DATA

The pulser, antenna, and reflector were modeled using Remcom Xfdtd 7 to optimize and asses their characteristics [9]. During a pulse event, the antenna resonator is charged by the Marx generator. When the resonator nears its peak charge voltage, it breaks down. After breakdown the antenna rings down and radiates. Figure 6 shows the simulated charge and breakdown voltage waveform evaluated at the resonator. Figure 7 shows the simulated radiated electric field waveform as evaluated at the 10m range.

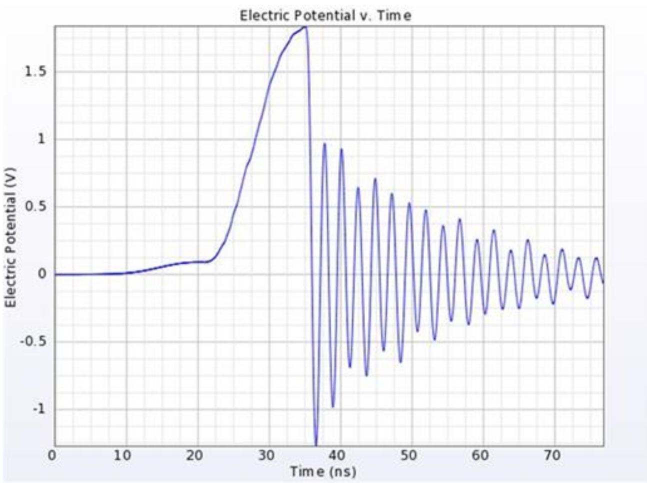

Figure 6. Simulated normalized voltage of the resonator potential during charge and breakdown.

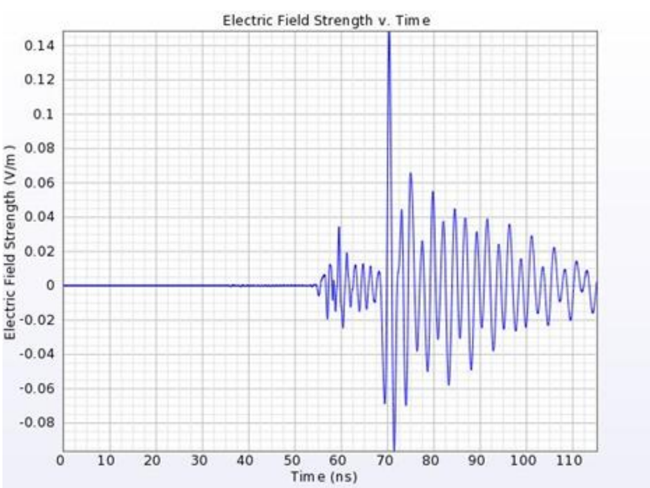

Figure 7. Far-field normalized electric-field waveform at 10m range.

The simulated radiated electric field, measured in the far field tracks closely the electric potential at the resonator in terms of frequency and amplitude decay. The bandwidth of the radiated signal in the near field can be seen in the FFT represented in Figure 8. Here the signal bandwidth is approximately 50 MHz centered near the 420 MHz center frequency. This simulated signal is much lower than the measured bandwidth as shown in the next section. It is thought that this is due to an inaccurate representation of loss in the Xfdtd simulation.

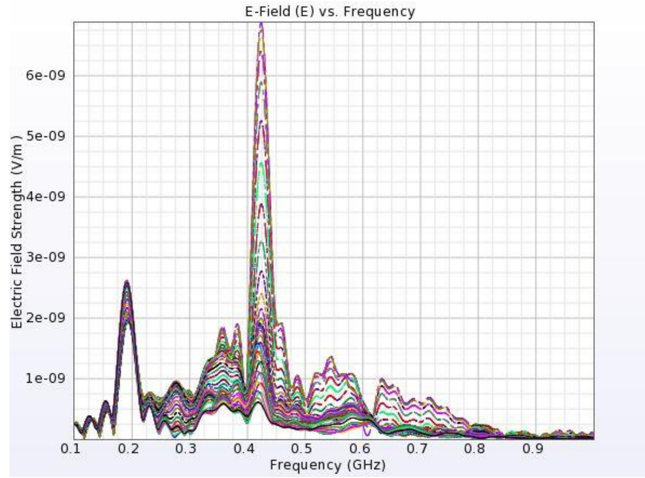

Figure 8. Electric field vs frequency as measured at points on the perimeter of a surface of a sphere @1m range.

V. EXPERIMENTAL RESULTS

The characteristic measurements for this system are the measurement of the radiated electric field in the far field, the X-Y plane (azimuth) field pattern, and the Y-Z plane (altitude) field pattern. Electric field measurements are made with a Prodyn AD-55 free-space D-dot probe at a range of 10m from the antenna unless otherwise stated.

The azimuth field pattern is shown in Figure 10. As seen here, the back-lobe attenuation at 180 degrees from bore was found to be <-18dB. The pattern matched closely with the single-frequency field plot from the simulation data. The 3-dB beam width was measured to be approximately 40 degrees.

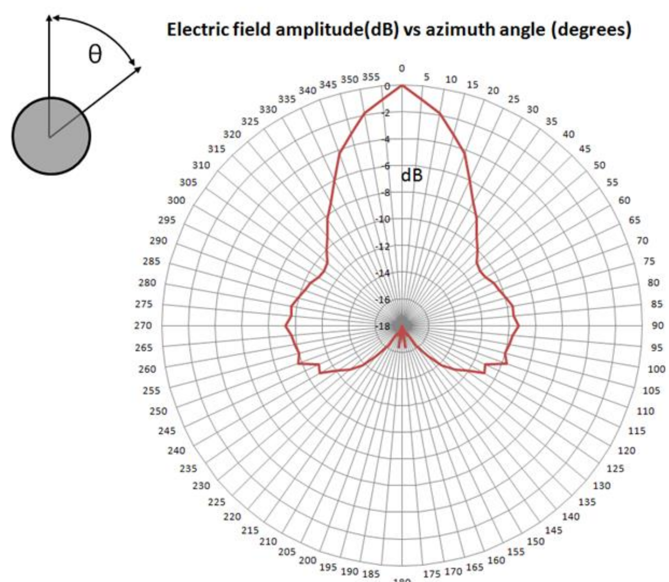

Figure 9. Electric-field amplitude vs azimuth angle as measured @10m range

The electric field waveform was measured at 10m range using the same Prodyn AD-55 probe.. The waveform has a standard ring-down characteristic as shown in Figure 10. About six half-cycles occur in 10 ns with the latter cycles broadening in frequency and decaying in amplitude. The FFT of the waveform can be seen in Figure 11. The FFT data shows that the bandwidth of the measured pulse to be approximately 200 MHz.

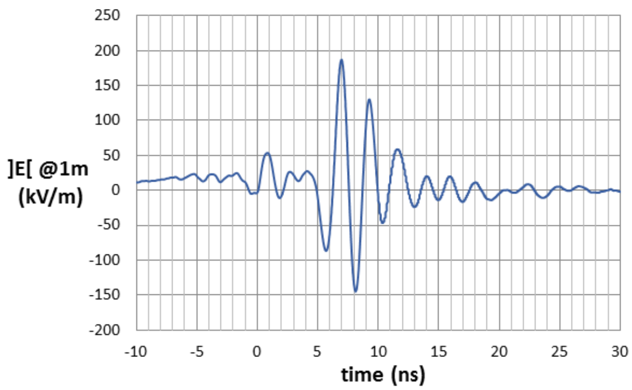

Figure 10. Electric-field amplitude waveform as measured @10m range.

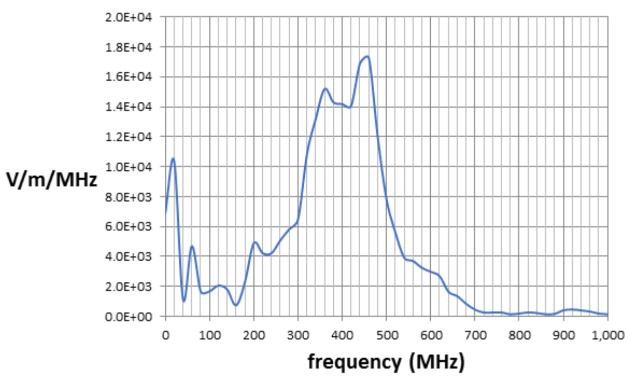

Figure 11. Electric-field amplitude vs frequency as measured @10m range

Finally the antenna pressure was ramped from atmospheric to 300 PSI and the peak electric field was recorded in steps of 50 PSI. Figure 12 shows the range of radiated peak electric field possible by adjusting antenna pressure.

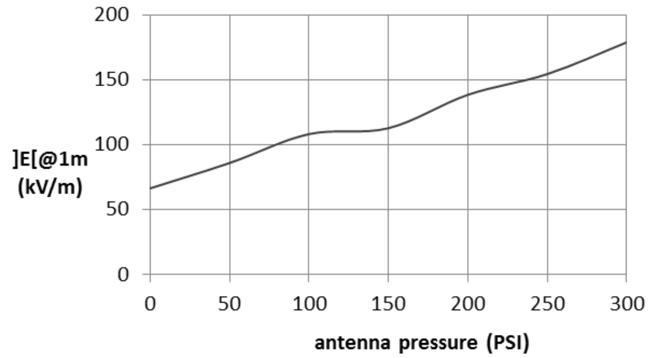

Figure 12. Peak-electric-field amplitude as a function of antenna pressure as measured in the far field and normalized to 1m.

VI. SUMMARY

The EMP footlocker represents a completely self-contained, portable, and environmentally resistance high-power electromagnetic source. The peak radiated electric field is 170 kV/m @ 1m. The antenna exhibits a center frequency of 420 MHz and a bandwidth of 200 MHz. The maximum PRF is 10 Hz. It can operate using on-board battery and air for over 10 hours and is housed in an environmentally protected and impact resistant enclosure.

REFERENCES

[1] Prather, William D., et al. "Survey of worldwide high-power wideband capabilities." Electromagnetic Compatibility, IEEE Transactions on 46.3 (2004): 335-344.J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[2] Kreth, Adrian, et al. "Identifying electromagnetic attacks against airports."Aerospace EMC, 2012 Proceedings ESA Workshop on. IEEE, 2012.

[3] Brauer, F., F. Sabath, and J. L. Ter Haseborg. "Susceptibility of IT network systems to interferences by HPEM." Electromagnetic Compatibility, 2009. EMC 2009. IEEE International Symposium on. IEEE, 2009.

[4] Holt, T. A., et al. "Modular, high-power, wideband transmitters for electromagnetic environmental effects (E3) testing." Pulsed Power Conference (PPC), 2011 IEEE. IEEE, 2011.

[5] Mayes, J. R., et al. "A compact high power wideband system." Power Modulator and High Voltage Conference (IPMHVC), 2010 IEEE International. IEEE, 2010.

[6] Kraus, John D. "The corner-reflector antenna." Proceedings of the IRE 28.11 (1940): 513-519.

[7] Klopfenstein, R. W. "Corner reflector antennas with arbitrary dipole orientation and apex angle." Antennas and Propagation, IRE Transactions on 5.3 (1957): 297-305.

[8] Moullin, E. B. "Theory and performance of corner reflectors for aerials." Journal of the Institution of Electrical Engineers-Part III: Radio and Communication Engineering 92.18 (1945): 58-67.

[9] REMCOM Xfdtd 7, http://www.remcom.com/xf7 315 South Allen Street, Suite 416, State College, PA 16801 USA