High Power Ultra Wide Band Source

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Abstract – **Ultra Wide Band (UWB) sources provide valuable diagnostic tools for Electro Magnetic Compatibility (EMC) and Electro Magnetic Interference (EMI) design and analysis. By radiating electronic devices or systems with UWB energy, localized resonances can be determined for a better understanding of RF coupling mechanisms, and ultimately, the vulnerabilities of the device or system. Applied Physical Electronics reports the development of an UWB system for EMI/EMC testing in both laboratory and non-laboratory environments. The system is designed to deliver field strengths exceeding 600 kV/m at 1 m, with a spectrum of 125 MHz to 1.5 GHz. The antenna portion of the system has been tested with a low-power Marx generator source to demonstrate electric field strength of approximately 60 kV/m at 3 m. Development efforts continue to advance the system to the targeted field strength of 600 kV/m at 1 m, while compacting the system footprint for portability.**

Index Terms – **Electromagnetic compatibility, Electromagnetic interference**

I. INTRODUCTION

UWB sources serve in a number of applications, including imaging, radar, communications and electronic warfare and countermeasures. For EMI/EMC applications, the appeal of an UWB excitation is that the signal has sufficient spectral content to enable characterization of wide range of vulnerabilities with a single source. For radar applications, the ultra short impulses associated with an UWB source can be used for time domain imaging and are able to resolve small objects for target identification. UWB radiation has received attention in the defense community for use in electronic warfare and counter-measures. Traditional narrow band methods generate large amounts of energy in localized frequencies, which requires specific knowledge of a target's vulnerabilities. Conversely, UWB methods generate energy across a very wide range of frequencies, and require minimal prior knowledge of a target's vulnerabilities. One drawback of UWB, however, is that the energy content in any single frequency is low, hence may be below the disruption threshold of electronic systems when operated at long stand-off distances. However, in an effects testing environment, UWB has successfully demonstrated disruption and disabling of electronics and thus is well suited for testing the vulnerabilities of components or systems. Whereas traditional methods employ signal generators, or network analyzers to radiate a Device Under Test (DUT) with a frequency sweep to identify which wavelengths couple into the DUT, an UWB source can generate a similar energy spectrum with a single pulse, thus reducing the test duration and enabling repeated test cycles. As illustrated in Figure 1, an impulse generator directly sources an UWB antenna, such as a TEM horn. This source radiates the DUT, which is monitored with high speed probes, backed by high-speed real-time oscilloscope. This paper describes preliminary efforts made by APELC toward the system goal. This system will be portable and operational from a battery pack. Electrically, the system will generate electric fields in excess of 600 kV/m, normalized to 1 m, with energy delivered from 125 MHz to more than 1.5 GHz. The antenna structure has been designed and simulated, using CST Microwave Studio. Preliminary test results have been made, with the antenna sourced by a lower power Marx generator. Design concepts and proposed system configurations will be discussed.

II. BACKGROUND

UWB is typically defined with a frequency range from 100 MHz to 2 GHz, with a relatively flat magnitude across those frequencies. Because the spectral width of a pulse is inversely proportional to the time domain width, ultra short time domain pulses result in very wide spectral responses.

APELC takes the UWB definition into a more hardware dependent definition, correlating the antenna with the source pulse to define a usable energy spectrum for generating the UWB response. Consider the double exponential pulse of Figure 2 a), which has a characteristic 10 – 90% rise time and a characteristic fall time, or decay. In terms of the Fourier spectral response, this pulse results in frequencies from f_{rise} to dc. The frequency domain representation does not depict the system behavior from a transient energy stand point. Instead, APELC chooses to define the lower frequency limit by the half sinusoid that best encompasses the full source pulse, as illustrated in Figure 2 b). In this case, the frequency range is defined by f_{rise} to f_{pw}, where f_{pw} is related to the source pulse width. Quantitatively, consider a source pulse with a 10 – 90% rise time of 150 ps, and a full pulse width of 20 ns. By APELC's definition, the frequency spectrum is defined as from 25 MHz to 2.3 GHz.

This definition becomes obvious when the hardware design begins. A TEM horn may be characterized by an upper (λ_1) and lower bandwidth (λ_2) response, as illustrated in Figure 3. In most cases, the upper frequency limit poses few problems, with frequency cutoff values reaching more than 10 GHz; however, the typical lower frequency limit can pose a problem for long pulses. For example, a TEM horn with a lower frequency cutoff of 300 MHz will not radiate wavelengths longer than 3.33 ns. Thus, for a pulse of a 20 ns temporal width, approximately 17 ns of energy must be dissipated by the system. The excess energy must be dissipated with additional antenna loading with resistive elements, or the source must dissipate the energy, which can ultimately lead to corona build up on the antenna structure.

III. ANTENNA DESIGN

APELC has worked with linear half TEM structures with past efforts [1]. The linear half TEM structure is well suited for a single polarity pulse delivered by a Marx generator due to its unbalanced loading geometry. The linear half TEM antenna structure is illustrated in Figure 4. The basic structure is designed for a lower bandwidth cutoff of approximately 125 MHz, which requires a half wave length plate separation of approximately b = 1.2 m. The width of the structure, at the lower wave length cutoff is set to equal one wavelength, equaling the sum of the real and image plate separation distances, or 2 b = 2.4 m.

Because the Marx generator is coaxial in its geometry, a balun (or zipper) section must be used to transition from a coaxial geometry to parallel plate geometry. To better facilitate this transition, a short section of RG-220 connects the Marx generator to the antenna structure, and is modified to "unfold" from its natural coaxial geometry to the parallel plate geometry. As a result, the outer conductor of the coaxial line linearly unfolds to a plate geometry, over a short distance. Within this same distance, the center conductor expands in diameter, as it lifts away from the ground plane in a manner that maintains a 50 Ω impedance. Once the parallel plate geometry is obtained, the plates begin to expand in both the E and H directions to form the antenna structure.

IV. ANTENNA ANALYSIS

The performance of the antenna is simulated and analyzed using CST Microwave Studio. The simulated gain of the antenna is shown in Figure 5. The simulation results indicate a favorable gain response for much of the expected design range, from 125 MHz to 1.5 GHz. For a wide portion of this spectrum (300 MHz to 1.3 GHz), a gain of 10 dB is expected. Simulated directivity plots for the linear half TEM antenna are given for 100 MHz, 500 MHz, and 1 GHz in Figure 6.

Preliminary testing has been done using a 120 kV Marx generator designed to launch a 60 kV pulse onto a matched 50 Ω load, with a relatively slow rising pulse of approximately 2 ns. The radiated waveform is observed by a Farr Research probe (FRI-TEM01), located approximately 3 m from the antenna. The recorded measurement, as shown in Figure 7, provides initial information about the antenna's frequency response. As expected, a pulse of approximately 5 ns is radiated, with an electric field strength of 60 kV.

V. CONCLUSION

Applied Physical Electronics, L.C. has designed a linear half TEM horn antenna system for the purpose of effects testing electronics with RF radiation. The UWB method for testing is preferred over frequency sweeps because realtime responses that can be obtained. The APELC system has been designed for a large frequency response, from 125 MHz to 1.5 GHz. The basic design of the structure has been discussed and included simulations made with CST Microwave Studio to predict the antenna response in gain and field pattern. Initial time domain measurements have been made using a relatively low voltage Marx generator capable of delivering 60 kV to the matched antenna load.

Future efforts will more thoroughly analyze the antenna from range measurements and with the final 600 kV Marx generator.

VI. REFERENCES

[1] J.R. Mayes, W.J. Carey, W.C. Nunnally, and L.L. Altgilbers, "The Marx generator as an ultra wideband source", IEEE Pulsed Power Plasma Science, Vol. 2, 2001.

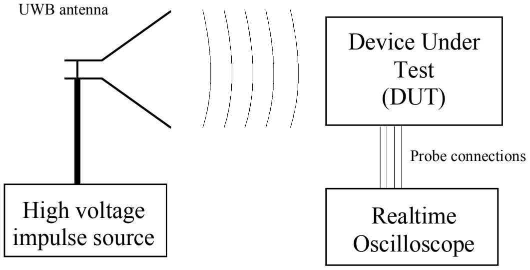
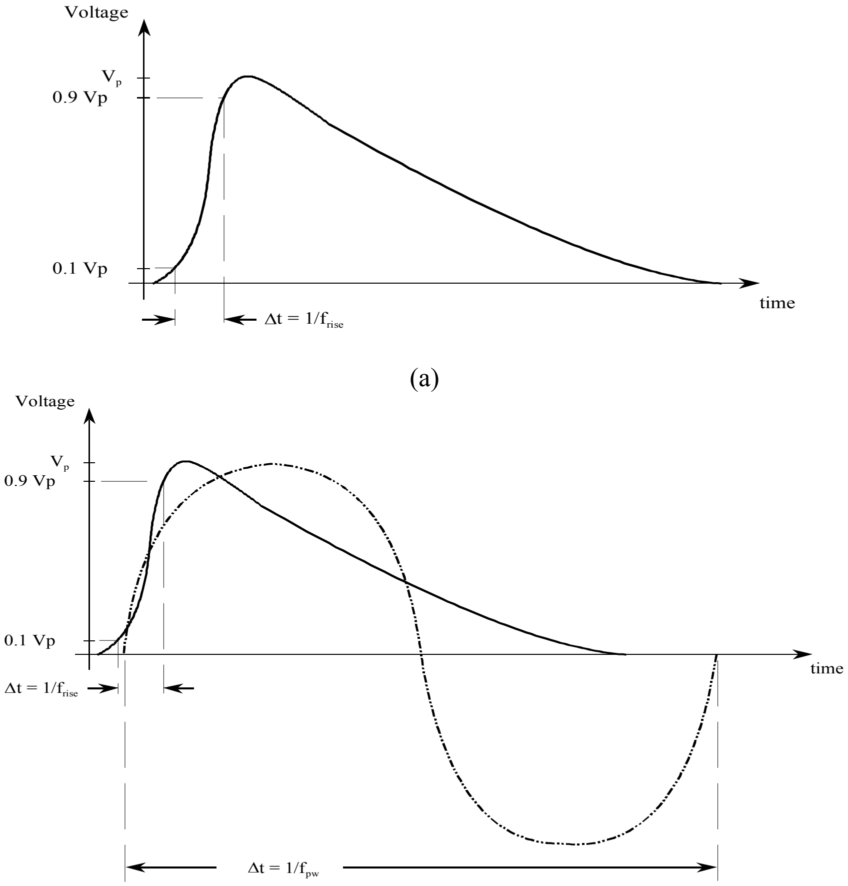


Figure 1. A conceptual UWB testing configuration for EMI/EMC.



(b)

Figure 2. UWB derived from a double exponential pulse, rise time and upper wavelength definition (a); UWB derived from a double exponential pulse, lower wavelength definition (b).

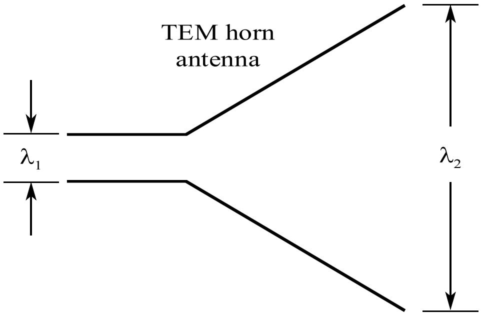


Figure 3. The basic TEM horn definition

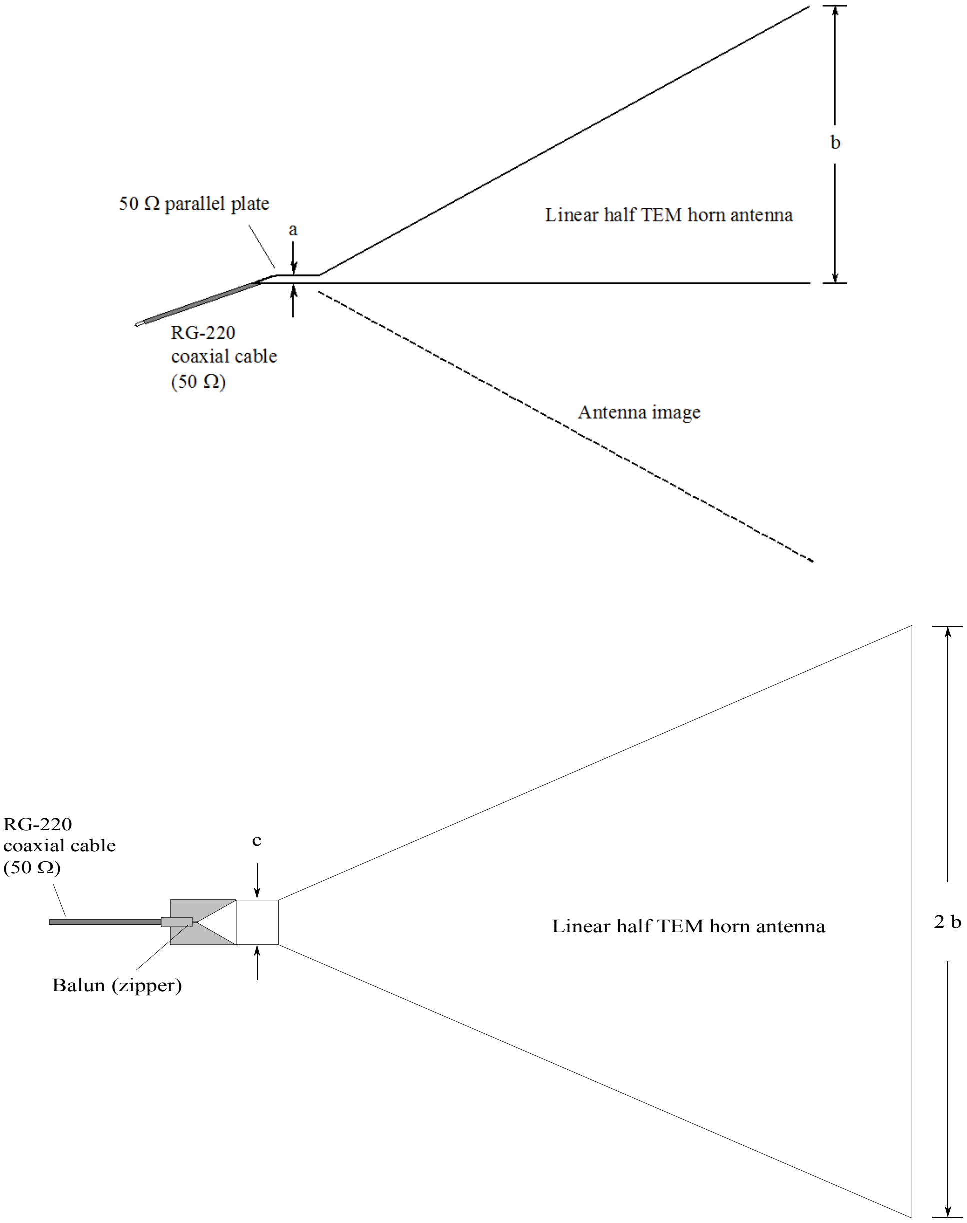


Figure 4. APELC deign of the linear half TEM horn antenna, side view (upper), top view (lower)

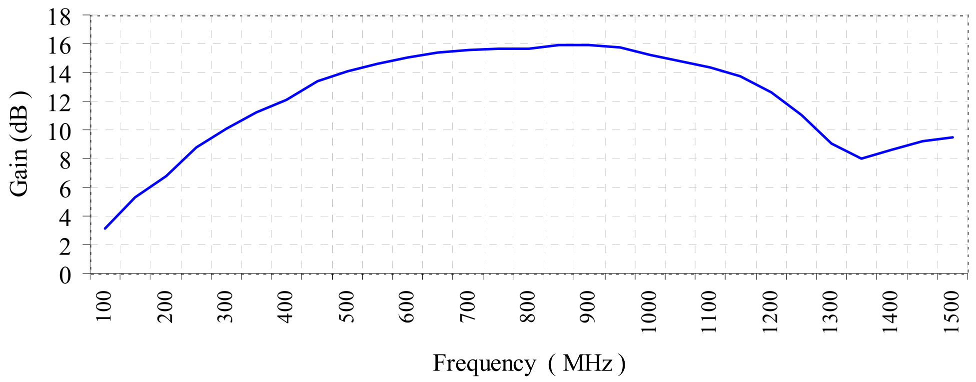
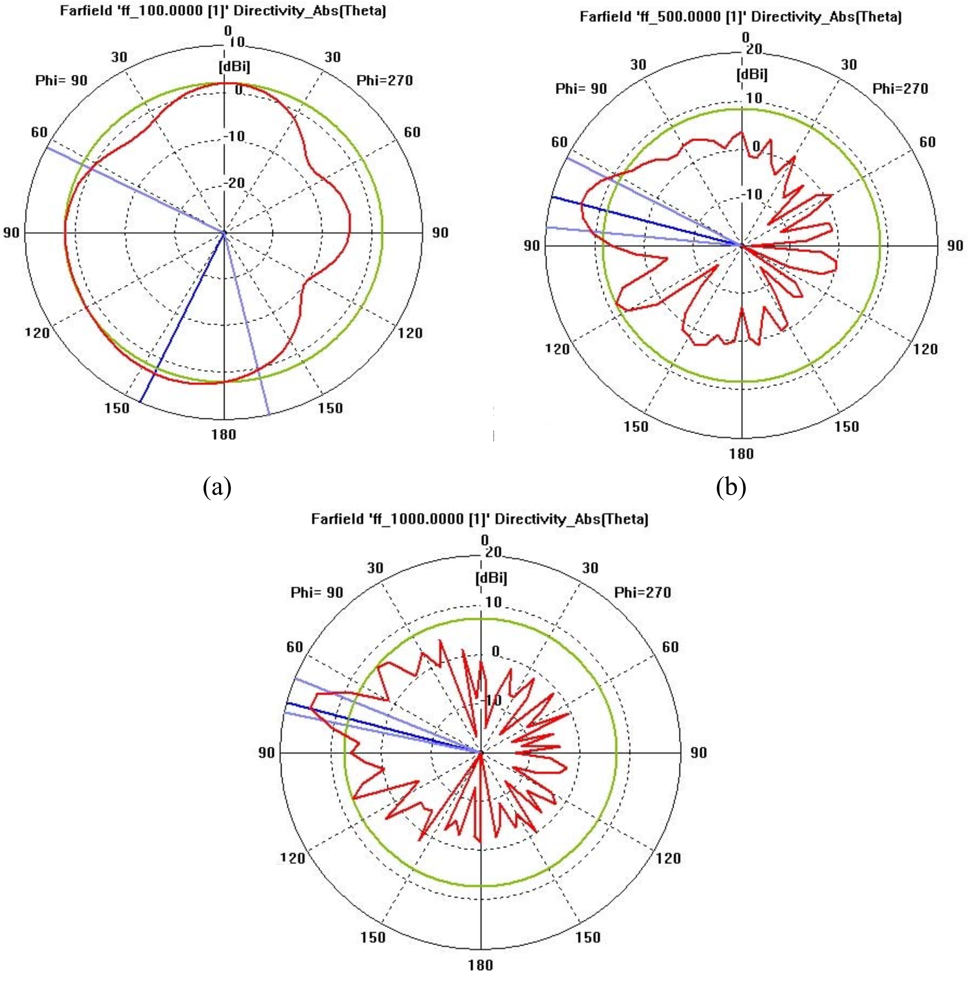


Figure 5. The simulated gain profile for the APELC linear half TEM antenna.


Farfield 'ff_100.0000 [1]' Directivity_Abs(Theta)

Farfield 'ff_500.0000 [1]' Directivity_Abs(Theta)

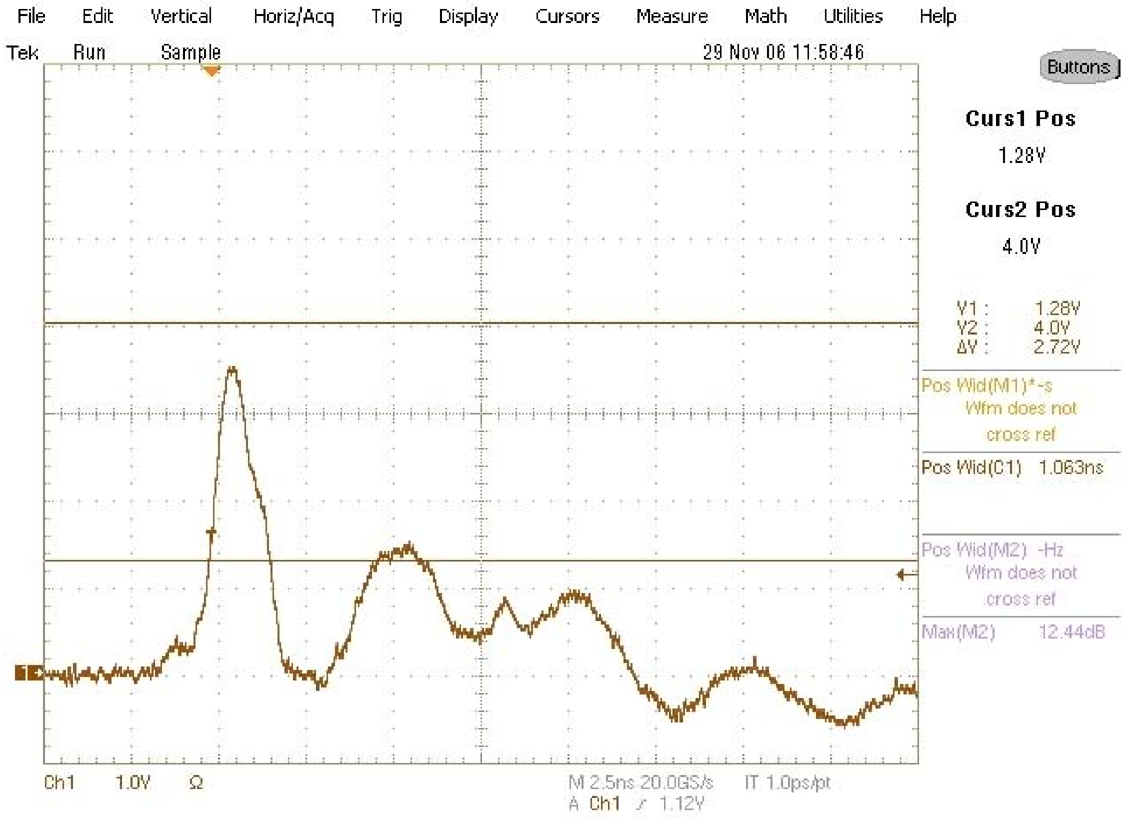
Farfield 'ff_1000.0000 [1]' Directivity_Abs(Theta)

(a)

(b)

(c)

Figure 6. Simulated directivity plots for the APELC linear half TEM horn antenna, (a) 100 MHz, (b) 500 MHz, (c) 1 GHz.



29 Nov 06 11:58:46

Curs1 Pos
1.28V

Curs2 Pos
4.0V

V1 : 1.28V
V2 : 4.0V
ΔV : 2.72V

Pos Wid(M1)*-s
Wfm does not
cross ref

Pos Wid(C1) 1.063ns

Pos Wid(M2) -Hz
Wfm does not
cross ref

Max(M2) 12.44dB

Ch1 1.0V Ω

M 2.5ns 20.0GS/s IT 1.0ps/pt
A Ch1 ⟋ 1.12V

Figure 7. An initial time domain measurement made from the APELC linear half TEM horn antenna when excited by a 60 kV pulse.