

Research on fast rise time EMP radiating-wave simulator

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Abstract. This paper presents an antenna of High altitude electromagnetic pulse (HEMP) radiating-wave simulator which expands the testing zone larger than the traditional transmission line simulator. The numerical results show that traverse electromagnetic (TEM) antenna can be used to radiate HEMP simulation radiating wave, but in low frequency band the emissive capability is poor. The experiment proves the numerical model is valid. The results of this paper show that TEM antenna can be used to HEMP radiating-wave simulator, and can prove the low frequency radiation capability through resistance loaded method.

1. Introduction

High altitude electromagnetic pulse (HEMP) is generated in high altitude nuclear explosive process, with fast rise time and wide frequency band. HEMP can cause severe interference to the electronic equipment even damaged. The HEMP simulator plays an important role for evaluate EUT immunity to high altitude electromagnetic pulse [1]. The traditional transmission HEMP simulator is based on transmission line such as parallel plate [2], GTEM cell [3] and TEM cell [4]; generate HEMP simulation wave similar to the excitation pulse in the transmission line. The rise time of the simulation pulse is restricted by the size of HEMP simulator, so that large type HEMP simulator can't produce fast rise time simulation electromagnetic pulse [5]. The large radiating-wave simulators were built in 1970s, for airplane and missile HEMP testing, such as Germany HPD and VPD [6] simulation system.

The HEMP radiating-wave simulator consists of a biconical-cylindrical cage antenna [7-8], a high voltage pulse source. The biconical-cylindrical cage antenna has some advantages such as constant impedance; wide working frequency band and large uniform test volume; but the disadvantages is obvious: (1) the biconical antenna is no directivity, so the radiation efficiency of antenna is low; (2) The size of antenna is very large, the length is longer than 300 m, so the antenna is very expensive [9].

This paper is to present how a fast rise-time EMP radiating-wave simulator is designed using TEM horn antenna. The experiment results show that can generate EMP as RS105 by TEM horn antenna instead of using transmission line or biconical-cylindrical cage antenna, and the matched load installed at the terminal of the TEM horn antenna can reduce the reflection of the terminal end edge. The merit

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of the fast rise-time EMP radiating-wave simulator using TEM horn antenna is that testing zone is larger and cheaper.

2. TEM antenna

The TEM horn is composed of two triangle plates, as shown in figure 1, $l=5.2$ m, $w=6$ m, $h=6$ m.

The impedance of the TEM antenna is [10]

$$Z_0 = \frac{240\pi}{\frac{2w}{h} + 1.393 + 0.677 \ln\left(\frac{2w}{h} + 1.444\right)} = 178\Omega \quad (1)$$

Where w is the width of the antenna and h is the height, l is the length.

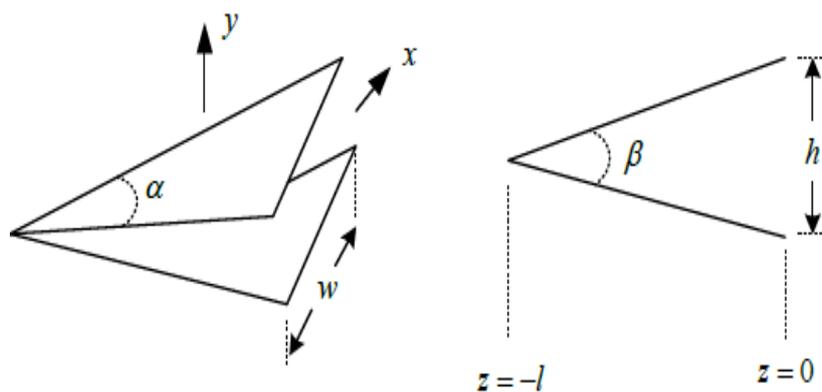


Figure 1. Diagram of the TEM horn antenna.

3. Simulation model and results

The CST simulation model is built as figure 2, the discrete port is applied between two plate apices. A double exponential excitation pulse is defined as equation 2.

$$V(t) = V_0 \times k(e^{-at} - e^{-bt}) \quad (2)$$

Where $V_0=50$ kV; $a=4.0 \times 10^7$ s⁻¹; $b=6.0 \times 10^8$ s⁻¹; $k=1.3$.

The radiation pulse waveforms at aperture and 3 m away aperture are shown in figure 3.

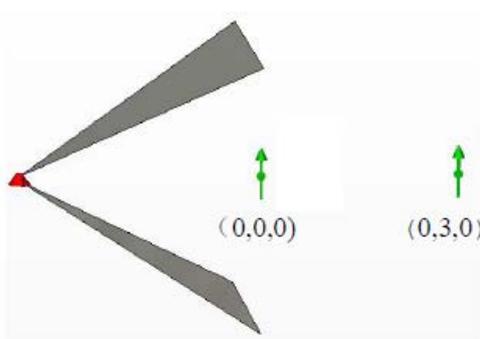


Figure 2. The model of the TEM horn antenna.

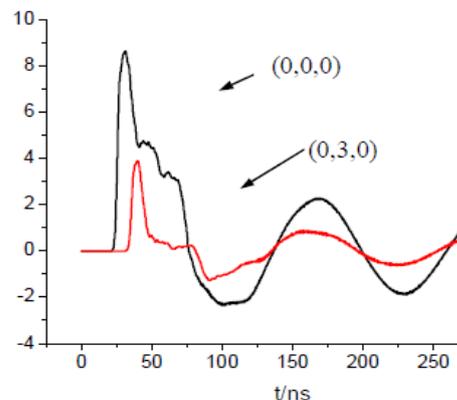


Figure 3. The radiation field waveform without loaded.

From figure 3, we can know that the radiation field strength decreased with the distance away the excitation port. The waveform is distorted and the waveform width becomes narrow. There is zero crossing and damped oscillation at the tail of the waveform, because the antenna end reflection and the oscillation period is the pulse current reciprocating time between the excitation port and the end edge. The reverse current from which the pulse source recharge will damage the source, and must avoid in high voltage engineering.

In order to reduce the reflection from TEM antenna end edge, the absorption load should be installed at the TEM antenna apexes. The matched load are composed of two 360 Ω parallel resistors, each resistor is installed at one apex of the TEM horn antenna, as shown in figure 4. The radiation pulse waveforms of aperture and 3 m away the aperture are shown in figure 5.

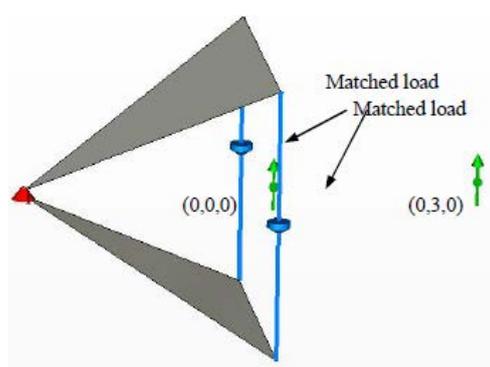


Figure 4. The simulation model TEM horn antenna with matched load.

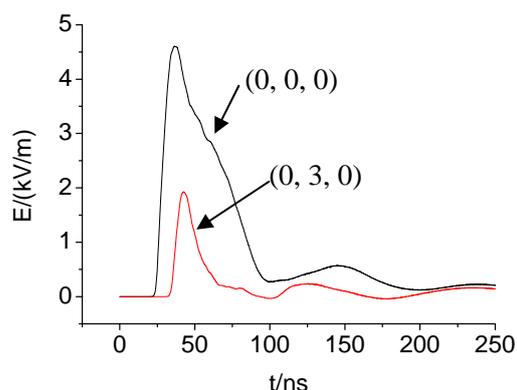


Figure 5. The radiation field waveform with matched loaded.

4. Experiment results

The experimental scheme is shown in figure 6, and the TEM antenna is shown in figure 7. The TEM horn is composed of two triangle plates ($L \times W \times H$, 1 m \times 2 m \times 1 m). The high voltage source charges the capacitor through current-limiting resistor. The gas switch breakdown when the voltage is high enough. The high voltage pulse is radiated by TEM horn antenna, the pulse field approximate with HEMP waveform of RS105 is formed. Using optical fibre filed meter test the pulse field, the oscilloscope and optical receiver are placed in EM shielding room.

4.1. Radiation field TEM horn antenna terminal opened

The radiation pulse field of antenna aperture and 3 m away aperture are shown in figure 8 and figure 9. Limit of the optical fibre filed meter only measure the waveform, and the field strength is only a relative value. From results we can know that reflection current from the TEM antenna cause the radiation pulse field oscillation.

4.2. Radiation Field TEM horn antenna terminal match load

In order to minish the terminal reflection, two 360 Ω resistors are installed at the apexes of the TEM horn antenna. The radiation field of aperture and 3 m aperture away are shown in figure 10 and 11.

The results show that the match loads effectively absorb the current, so that the oscillation is less. The radiation field 3 m aperture away is similar with double exponential pulse waveform, and the rise time is about 1-2 ns, the width is about tens of ns. The radiation pulse field waveform is approximate the HEMP RS105 waveform defined by MIL-STD-461F and other international standards.

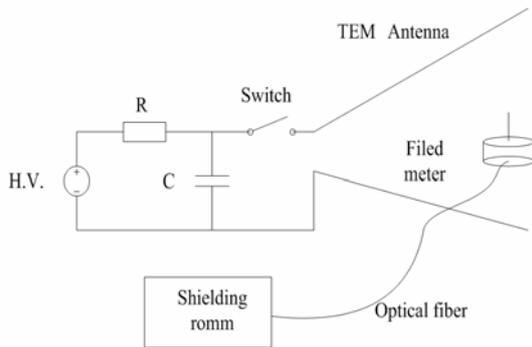


Figure 6. The working principle diagram.



Figure 7. Photo of TEM horn antenna.

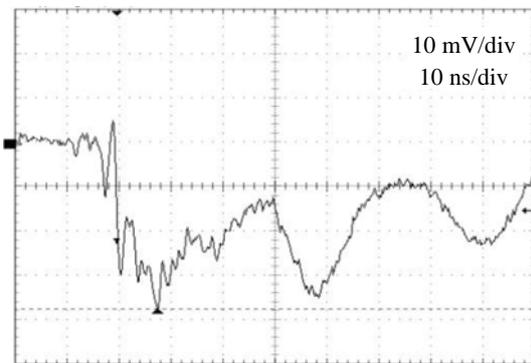


Figure 8. E-field waveform at TEM antenna aperture with terminal opened.

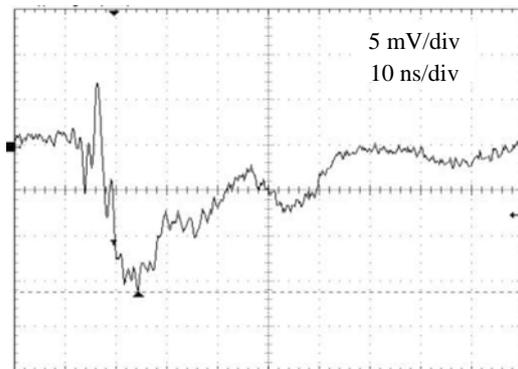


Figure 9. E-field waveform at 3 m away aperture with terminal opened.

If the experiments need higher field strength, the fast rise time radiating-wave simulator should use Marx generator as excitation pulse source and TEM horn antenna as radiation antenna, and then higher intensity radiation pulse field can be generated by the fast rise time EMP radiating-wave simulator.

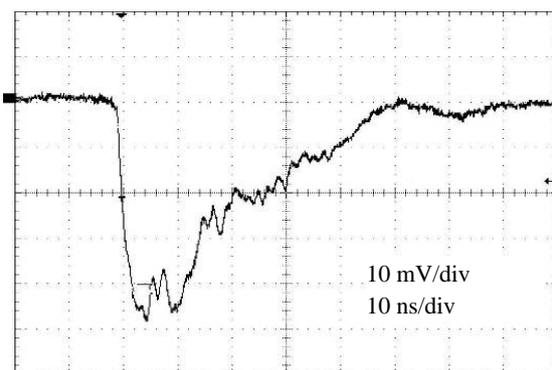


Figure 10. E-field waveform at TEM antenna aperture with matched loaded.

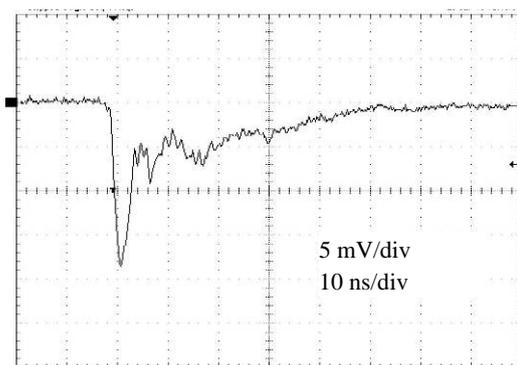


Figure 11. E-field waveform at 3 m away aperture with matched loaded.

5. Conclusions

In this paper, fast rise time EMP radiating-wave simulator is analyzed in numerical simulation and experiment method. The results show that TEM horn antenna can radiate the fast rise time pulse field such as RS105 HEMP. But the TEM antenna radiate ability is relatively poor in low frequency, and low frequency band need install matched loaded to absorb the oscillation current. In this paper, only to

introduce the basic principles, the actual fast rise time EMP radiating-wave simulator is designed, and the ultimate goal generates HEMP by TEM horn antenna.

Acknowledgments

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References

- [1] Radasky W A 2008 *IEEE International Symposium on Electromagnetic Compatibility* 1
- [2] Cai J, Wang B and Hu F 2010 *International Conference on Computer, Mechatronics, Control and Electronic Engineering* p 456
- [3] Schilling H, Schluter J and Peters M 1995 *10th IEEE International Pulsed Power Conference* p 1359
- [4] Vyvolokin A E and Neskopodov G F 1993 *IEEE International Pulsed Power Conference (USA: New York)* p 163
- [5] Zhen J, Hagness S C and Booske J H 2006 *IEEE Transactions on Biomedical Engineering* **53** 780
- [6] Baum C E 1978 *IEEE Trans. on EMC.* **26** 35.
- [7] Meng F, Xia H and Wang J 2007 *Journal of Microwaves* **23** 6
- [8] Tesche F M, Mo C and Shoup R W 1994 *IEEE Transactions on Electromagnetic Compatibility* p 331
- [9] Ronald F B and Clayborne D T 1978 *IEEE Transactions on Electromagnetic Compatibility* 240
- [10] Meng F 2011 *High power EM pulse technology* (BeiJing: National defense industry press)