Design of a Shielded Core Current

Mo Zhao*, Wei Wu, Jinx Li, Jinghai Guo, Yifei Liu, Wenbing Wang
State Key Laboratory of Intense Pulsed Radiation Simulation and Effect, Northwest Institute of Nuclear Technology Xi'an, China

*Corresponding author e-mail: zhaomo@nint.ac.cn

Abstract. Aiming at the problem that the signal noise ratio (SNR) can’t meet the requirement due to electromagnetic interference in the measurement of coupling current of transmission cable core line in electromagnetic pulse environment, a shielded core line pulse current probe is designed and developed. This paper introduces the measuring principle of the probe, the structure characteristics and development situation, given the characteristics of the probe sensitivity and parameters, such as spectrum method and the calibration parameters, and analyzes its usage in the experimental results show that the design of shielded conductor pulse current probe based on the structure of the original transmission has a better ability to resist electromagnetic interference and pulse signal measurement capability.

1. Introduction
High altitude nuclear electromagnetic pulse (HEMP) is one of the severe electromagnetic interference (EMI) in the normal operation of the weapon and equipment. The most important part of the weapon and equipment is the electronic system. The interference of electromagnetic pulse is mainly caused by the coupling of various cable cores in the electronic system to generate pulse current. The pulse current will be introduced into each functional circuit through the core wires, causing interference and even damage to the entire electronic system. The protection research of HEMP is based on the measurement and analysis of the cable’s pulse coupling current. The current measuring general use coil probe, the shield of cable must be opened when measuring the core current of cable. For this reason, the overall structure and the transmission characteristic of the cable is broken, it will cause the distortion of the transmission signal and introduce a large number of impact signal measuring electromagnetic interference at the same time. Aiming at the above problems, a shielded core line pulse current probe is designed and developed, which can be directly connected to the port of the shielded cable. The probe can accurately measure the current signal flowing through the shielded core line, without affecting the electrical connection state of the shielded cable in the device.

2. The principle and structure of the core pulsed current probe
The pulse current is usually measured by rogowsky coil. The basic principle of electromagnetic induction and the current measure is that any changes over time of current is always accompanied by a magnetic field changes over time. If there is a closing coil placed around the current, the coil will generate induced electromotive force, according to the different coil parameters, the relationship between voltage and source current into differential or proportional relationship. The probe is designed with cylindrical embedded structure, as shown in figure 1. The axis is the central conductor, and the
inner core of the standard cable transfer seat is connected at both ends. The outer layer is a metal shielding shell, which is connected to the shell of the cable holder. The probe measures the signal in the middle position, and the standard cable holder is used for lateral extraction. The core wire current sensor is the rogowisky base line, which is located around the central wire. Magnetic material is used as the measurement winding skeleton. The measurement signal outlet is horizontally placed in the middle of the probe, which is electrically insulated from the central wire and shielding shell of the probe. Since there are cable transfer seats at both ends, it can be conveniently connected with the cable, or connected between the cable and the device. At this point, the central conductor is connected with the cable core, and the outer metal shielding shell is connected with the shielding layer of the cable, which will not affect the normal working connection of the cable. Since the measured part of the signal is physically isolated from the measured core current, there is no electrical connection with the circuit under test, so the state of the measured core current will not be affected.

![Figure 1. The schematic diagram of core pulsed current probe](image1)

3. Technical indexes of the core current probe
Figure 2 developed for single core cables and double core cable port core pulse current probe, the probe inside the rogowisky coil, external shell designed cable interface, to ensure a good electrical connection and impedance matching conditions, can be convenient cable interface to connect with the electronics systems, core pulse electric current measurement.

![Figure 2. The physical picture of the core pulsed current probe](image2)

The current injection method was used to calibrate the core line pulse current probe. Figure 3 for port conductor current measurement probe calibration diagram, figure 4 real figure for calibration, signal...
source output pulse signal, power divider will pulse signal into completely equal two parts, respectively, the input to the conductor current systems and oscilloscope, conductor after termination matching 50 ohm load current measurement system, using the oscilloscope measurement of pulse signal amplitude divided by the current through the conductor can get 50 ohms, conductor current signal of the measuring system is input to the oscilloscope, compare the source signals and measurement, you can get the parameters of the probe sensitivity, response spectrum.

Figure 3. The calibration diagram of core pulse current probe

![Calibration Diagram](image)

Figure 4. The calibration of core pulse current probe

Calibration of sensitivity: if the amplitude of the input pulse signal measured by an oscilloscope is $V_1$, and the amplitude of the signal measured by the core current measurement system is $V_2$, then the sensitivity is

$$l = \frac{V_2}{V_1/50}$$

(1)

High-frequency calibration: if the rising edge of the input signal is $t_1$ and the rising edge of the detector's measurement waveform is $t_2$, then the response time of the detector itself is considered to be

$$t_0 = \sqrt{t_2^2 - t_1^2}$$

(2)

The upper limit of the response frequency can be calculated as

$$f_{\text{Hi}} = \frac{0.35}{t_0}$$

(3)

Low-frequency calibration: when the input signal is square wave signal, the detector measures a square wave with flat landing, and the lower frequency limit is calculated as

$$f_{\text{Lo}} = \frac{\delta}{2 \pi v_s t_p}$$

(4)
$V_s$ is the amplitude of the measured square wave, $t_p$ is the width of the square wave, and is the amplitude of the square wave decreased by $V_s$ within the width of $V_s$.

The calibration curve of the core line pulse current detector is shown in figure 5. According to the formulas (1) to (4), the bandwidth of the developed core line pulse current detector is 300Hz-240MHz after the calibration data is brought in.

![Figure 5. The calibration curve of core pulse current probe](image)

4. The typical application of current probe

Unmanned aerial vehicle (UAV) in the information age is increasing day by day, to the importance of the military and civilian UAV as a highly integrated information technology and equipment, its inner core electronic system vulnerable to strong electromagnetic pulse interference and even mutilate, eventually leading to unable to complete project tasks, carry out UAV strong electromagnetic pulse effect analysis, in order to determine the cause of system failure, access coupling into each subsystem is the prerequisite for internal response signal characteristics, core pulse current detector in the UAV effect of strong electromagnetic pulse test applications, has achieved abundant experimental data, figure 6 shows the coupling current measurement waveform of typical flight control computer and directional steering gear cable. With high signal to noise ratio of waveform data, it has good anti-electromagnetic interference ability and pulse signal measurement ability, which can provide data support for analyzing the mechanism of strong electromagnetic pulse effect in the core electronic system of UAV.

![Figure 6. The coupling current of the computer and the rudder line](image)
5. Conclusion
Developed core pulse current detector has the structure compact, easy to use, the characteristics of good performance, without destroying the original electromagnetic shielding structure on the basis of the system can complete electronic conductor current measurements, has good resistance to electromagnetic interference ability, the feature parameters meet the demand of the strong electromagnetic pulse effect research, on the basis of the participants in the follow-up work requirements of electronic system, the improvement and optimization of the core pulse current detector work.

References
[1] Dawn H Trout. The study of the bulk current injection technique as by comparison to induced current from radiated electromagnetic fields [C]. IEEE International Symposium on Electromagnetic Compatibility, 1996:412 - 417.
[2] Li bao-zhong, caliper pulse current detector [J]. Nuclear electronics and detection technology, 2004, 24 (6): 775 - 778. (in Chinese).
[3] Tan wei. Current injection technology in EMC testing [J]. Safety and electromagnetic compatibility, 2003, (4): 19 - 22.
[4] Zeng zhengzhong. Introduction to practical pulse power technology [M]. Xi 'an: shanxi science press, 2003.
[5] Liu xisan. High power pulse technology [M]. Beijing: national defense industry press, 2005.
[6] Wang ruihua. Pulse transformer design [M]. Beijing: science press, second edition, 1996.
[7] O 'handley R c. principles and applications of modern magnetic materials [M]. Beijing: chemical industry press, 2004.