

Case Analysis of Electromagnetic Compatibility Correction for Electrical Fast Transient (EFT)

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ABSTRACT. *This article studies the electromagnetic compatibility of a certain type of ozone therapy instrument, and conducts research on the electrical fast transient pulse group test project. First, analyze the working principle of the product, and then test according to the test standard. After the product has a problem, perform problem diagnosis and analysis. Finally, two methods to improve the reliability of the product's electromagnetic compatibility are given, and the correctness of the method is proved through experiments And reliability, provide a basis for the actual electromagnetic compatibility rectification.*

KEYWORDS: *electromagnetic compatibility, ozone therapy device, electrical fast transient pulse group, case rectification*

1. Introduction



Figure. 1 Appearance of ozone therapy instrument

Figure 1 is an ozone therapy device produced by a company. The medical ozone therapy instrument has a broad-spectrum, high-efficiency and rapid sterilization effect, and can fully kill *Neisseria gonorrhoeae*, *Staphylococcus*, *Candida* and various venereal pathogens. Therefore, the medical ozone therapy instrument is suitable for disinfection and sterilization of hospital clinical, environmental and medical equipment. The product is simple to operate, economical and effective, and it is a new type of medical device preferred by various medical departments.

The working principle of the ozone therapy device is the application of high-voltage electrolytic oxygen. There is a component in the body of each ozone therapy device, which is the high-voltage discharge device. Connect the ozone therapy device to the oxygen tank, first open the oxygen valve, and then open the ozone therapy device to prepare ozone. The ozone therapy instrument prepares a mixture of "ozone + oxygen" gas.

2. Electrical fast transient pulse group experiment

The standard "GB/T 17626.4-2008 Electromagnetic Compatibility Test and Testing Technology Electric Fast Burst Immunity Test" (equivalent to the IEC61000-4-4 standard formulated by the IEC) specifies the fast transient burst test standards and test methods. As shown in Table 1.

Table 1 Test level of pulse group test

Level	Power port and protective ground (PE)		I/O signal, data and control ports	
	Peak voltage (kV)	repeat frequency (kHz)	Peak voltage (kV)	repeat frequency (kHz)
1	0.5	5/100	0.25	5/100
2	1	5/100	0.5	5/100
3	2	5/100	1	5/100
4	4	5/100	2	5/100
X	specific	specific	specific	specific
X is the open level, which must be specified in the special equipment technology				

Due to the application of radio frequency devices or switching devices and digital circuit control modules in the system, the ozone therapy instrument will not only produce a large amount of electromagnetic interference when it is working, but also be affected by noise from the external electromagnetic environment. According to the People's Republic of China Medicine The industry standard (YY-0505-2012), use the electric fast pulse group generator to carry out the experiment at the power supply port respectively. The peak voltage is plus or minus 1KV and 2KV, the repetition frequency is 5kHz, and the test duration is 60s. During normal operation, after the operation signal is given to the ozone therapy device from the operation panel, white thin smoke can be generated in the oxygen tank, and the program

response is timely and sensitive. The ozone therapy device failed the EFT immunity test after applying fast electrical pulses to the power terminal of the device. Its specific phenomenon is that the text on the display screen displays garbled characters and the treatment device does not work during the test. And only a power-off and restarting can return to normal, and it cannot return to normal itself. Figure 2 shows the fault diagram of the ozone therapy device when it receives EFT interference signals.



Figure 2 Failure diagram of ozone therapy instrument

3. Problem diagnosis and analysis

EFT mainly interferes with the power port and transformer port of the ozone therapy device in a conductive manner. The printed circuit board contains many sensitive electronic components such as MOSFETs, diodes, etc. When these circuit modules are impacted by an electric fast pulse group with a short rise time and a high repetition frequency, the charge is accumulated in the nonlinear energy storage element. The function of the local sensitive components is affected, and therefore the internal circuit of the ozone treatment device is disturbed, which seriously affects the normal operation of the ozone treatment device. According to the principle analysis, first check the ground wire. If the grounding is normal and intact, the display board has a display problem, so it is necessary to check the power supply wire. After disassembling the rear case, it can be seen that there are certain defects in the system design. The high-frequency switching device and the sensitive amplifier device are too close to the amplifier to receive too much high-frequency crosstalk; at the same time, the wiring between the circuit boards is messy and too long, forming Multiple loops equivalent to radiated interference antennas are created. The power lines on each PCB pole plate are simply grounded and there is no effective shielding measure. There is a motor used to generate ozone inside. Since the motor is a non-linear device, a large number of interference signals of different frequency bands will be coupled. These signals are not shielded and are therefore received by the display module of the ozone therapy device.

4. Corrective measures and theoretical analysis

When applying fast electrical pulses to the ozone therapy device, the influence of EFT on the ozone therapy device can be observed with an oscilloscope and voltage probe. In the experiment, 2KV of EFT interference is applied to the power port, and there will be a phenomenon of spike interference voltage. Figure 3 is the output waveform of the power output of the ozone therapy instrument after applying EFT.

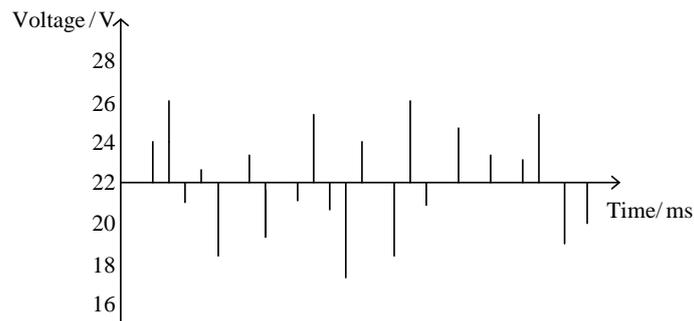


Figure 3 Waveform of the output terminal of ozone therapy

(1) Install EFT low-pass filter on the power line

The working mechanism of the low-pass filter is: when the normal current passes, the current forms a reverse magnetic field in the coil to cancel each other. The normal signal is mainly affected by the resistance of the coil; when the high frequency common mode noise current passes through the coil, A magnetic field in the same direction will be generated in the coil to increase the inductive reactance of the coil and make the coil present a high impedance state, thereby attenuating the high frequency common mode current and achieving the purpose of filtering. The capacitor has the function of absorbing harmonics and is used as an electrical bypass in the low-pass filter. It cooperates with the inductance to achieve impedance matching, making the filtering effect the strongest.

First, a conventional EFT filter is designed as shown in Figure 4. The inductance of the mode choke coil N1 and N2 is 2mH, and the capacitance C1 and C2 between the neutral wire and the live wire are about 20nF, and the capacitance C3 and C4 of the neutral wire and the ground wire and the live wire and the ground wire are 5nF.

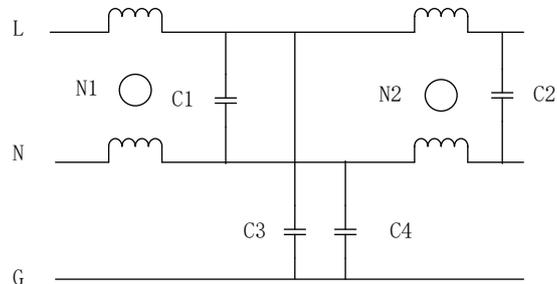


Figure 4 Common mode choke coil model

Since EFT has a large amplitude and extremely wide frequency band, but the energy is mainly concentrated in 1-100MHz, EFT interference is high-frequency electromagnetic interference, and the use of low-pass filters can greatly filter out the high-frequency noise injected into the circuit. However, due to the high energy of EFT pulses, the leading edge t_r of the single pulse waveform of the pulse group reaches 5ns, the pulse width reaches 50ns, and the pulse amplitude is quite large. This destined that the pulse group interference has extremely rich harmonic components, by the formula EMS-EFT -001 and EMS-EFT-001 can know the harmonic center frequency and wavelength. The basic EFT low-pass filter cannot filter out such wide-band noise, and the system will have screen flicker during the 2KV test. Therefore, the low-pass filter needs to be improved. Figure 5 shows the filter installation diagram.

$$f = \frac{1}{\pi t_r} = 64\text{MHz} \quad (1)$$

$$\lambda = \frac{v}{f} = \frac{3 \times 10^8}{f} \quad (2)$$



Figure 5 Filter installation diagram

By suppressing the parasitic parameters of the common mode choke coil, the self-inductance parasitic parameter suppression and the mutual inductance parasitic parameter suppression strengthen the role of the ground capacitance in the choke coil at high frequencies and eliminate the high-frequency equivalent series inductance. After testing, the ozone therapy device can also work normally when the voltage amplitude is raised to 2kV again, which shows that the effect of the EFT filter at this time is relatively ideal. The measurement result is shown in Figure 6, and the test result is more satisfactory.

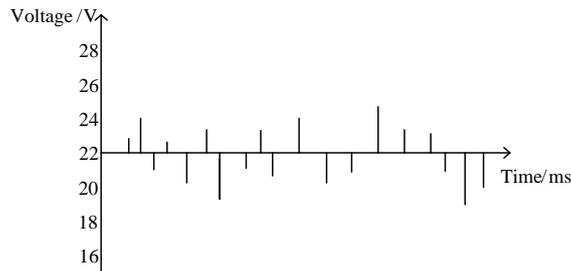


Figure 6 EFT test chart after modification

Table 2 Comparison of EFT test results after adding filters

Measures	Test Results	
	Voltage	result
No filter installed	2000V	Unqualified
Basic low pass filter		The effect is not ideal
Filter after balancing parasitic parameters		The filtering effect is stable and significantly reduced

(2) Magnetic ring on the power cord

The ferrite magnetic ring presents a high resistance state at medium and high frequencies, which is equivalent to connecting a differential mode inductance in series on the circuit transmission line, and this equivalent inductance has a very low quality factor. During operation, the magnetic ring causes the pulsed magnetic field generated by the high-frequency pulse current entering the power line to form an eddy current on the magnetic ring, which consumes high-frequency energy in the form of heat energy, so it has a good suppression of high-frequency differential mode interference signals. Function, different magnetic rings have different impedance characteristics. When designing the circuit, it is necessary to calculate so that the cut-off frequency of the magnetic ring falls exactly near the frequency of the interference signal. The ferrite magnetic ring is an absorptive filter component. Multi-turn winding can change the impedance characteristic of the magnetic ring. When used together, it can improve the filtering performance of the magnetic ring in the entire frequency band.

The magnetic ring can play a very important role in dealing with electromagnetic compatibility problems. The magnetic ring can not only filter the interference of the external environment to the system, but also prevent the interference inside the system from entering the spatial electromagnetic environment, which is very useful for filtering high-frequency interference. Good results, coupled with easy installation, are widely used. The way to add the magnetic ring is shown in Figure 7.



Figure 7 Winding the magnetic ring on the power cord

Table 3 Comparison of EFT test results after card magnetic ring

Measures	Test Results	
	Voltage	result
No magnetic ring	2000V	Unqualified
Single-turn coil magnetic ring		The display shows garbled and unstable characters
Multi-turn wire wound magnetic ring		The display has no garbled characters and stable display

5. Conclusion

After the above analysis and demonstration, a magnetic ring and an EFT filter were added to the ozone therapy instrument. After the rectification and all measures were installed, the test was performed. The results showed that the rectification measures were effective and reliable, and the ozone therapy instrument could interfere with the EFT test at the voltage level of 1KV and 2KV. Work normally under the environment.

Table 4 EFT test comparison table before and after rectification

Voltage level	Before rectification	After rectification
1KV	Button sensitivity is reduced, indicator light flashes abnormally	The button reacts normally under the pulse group, and the indicator light glows normally without flickering
2KV	Abnormal garbled text appears on the screen, accompanied by buzzing, and the machine does not work	There is no garbled display on the screen, and the machine does not beep and works normally before the end of the experiment

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