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Research on Modeling and Suppression Methods of Conducted EMI Noise

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ABSTRACT. *This article studies the mechanism and suppression methods of conducted EMI noise. First, it explains the generation mechanism of conducted noise, analyzes the difference between common mode conduction and differential mode conduction, and establishes a common mode conduction noise model and a differential mode conduction noise model. The methods for suppressing conducted EMI noise in different situations are finally verified through conducted noise suppression experiments to verify the correctness and reliability of the theory. The research in this article provides a theoretical basis for the actual EMC rectification.*

KEYWORDS: *conducted emission; common mode noise; differential mode noise; noise suppression*

1. Introduction

Conducted EMI noise is transmitted through the cable, which will affect the normal operation of itself and the surrounding electronic equipment, and at the same time produce certain high-frequency interference to the power grid, affecting the safety and reliability of the power grid [1-5]. According to GB 9254, the test frequency band of conducted EMI noise is 9kHz to 30MHz.

In engineering applications, the switch tube of the power converter, the radiator, and the digital chip inside the PCB will all generate conducted EMI noise. At present, a suitable EMI filter is generally designed at the output of the power supply to reduce the noise. However, the conducted EMI noise cannot be determined Therefore, most of the above-mentioned EMI filter designs rely on experience and experiments to continuously explore and try until the circuit parameters in the filter are determined. The filtering effect is not good and the hardware cost is high [6-8].

In order to solve the above problems, it is necessary to establish a conducted EMI noise model and its equivalent circuit, diagnose the noise generation mechanism, and determine the noise mode, so as to provide a theoretical basis for the design of EMI filter topology and circuit parameters [9-10].

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2. The generation mechanism of conducted EMI noise

In order to establish the conducted noise model, we must first study the conducted EMI noise test method, AMN topology and its high-frequency equivalent circuit. According to GB 9254, AMN and EMI receivers should be used to measure conducted EMI noise, as shown in Figure 1.

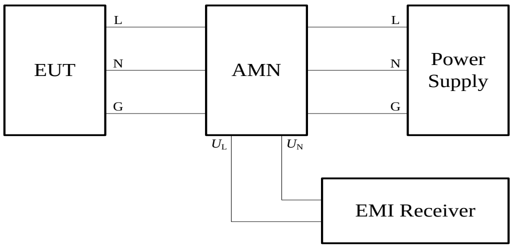

Figure. 1 Conducted EMI noise test method

In the figure, EUT is the device under test, AMN is the artificial power supply network, L, N, G are live wire, neutral/neutral and ground wire respectively, U_L and U_N are the conducted EMI noise of live wire and neutral wire respectively, the terminal of EMI receiver The impedance/input impedance is 50 Ω. In order to further reveal the test process of conducted EMI noise, it is necessary to study the structure of AMN, as shown in Figure 2.

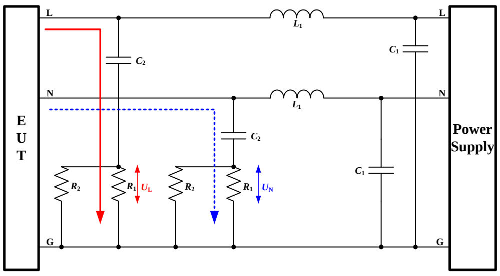

Figure. 2 AMN topology

As shown in Figure 2, C_1 and C_2 are capacitances of 1 μF and 0.1 μF, respectively; R_1 and R_2 are resistances of 50 Ω and 1 kΩ, respectively; L_1 is an inductance of 50 μH. Among them, C_1 and L_1 are used to filter the high frequency noise of 9 kHz-30 MHz in the power supply/grid and ensure the normal power frequency current; C_2 is used to extract the high frequency noise of 9 kHz-30 MHz in the EUT; R_2 is used for shunting ; R_1 is used to measure noise current and convert

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the current into voltage. It is worth noting that U_L and U_N are the total conducted EMI noise of live wire and neutral wire respectively.

3. Conducted noise model

Conducted noise interference is divided into common mode conduction and differential mode conduction. Therefore, to establish a complete conducted noise model, it is necessary to study the common mode and differential mode conduction separately.

3.1 Common mode conducted noise model

When using the methods shown in Figure 1 and Figure 2 to test the conducted EMI noise of the EUT, two results will be obtained, namely $U_L=U_N$ and $U_L \neq U_N$. Since the ratio of noise voltage to noise current is 50 Ω, the above two results can be expressed as $I_L=I_N$ and $I_L \neq I_N$. It is worth noting that no matter when $I_L=I_N$ or $I_L \neq I_N$, I_{DM} meets

$$I_L - I_{DM} = I_N + I_{DM} \tag{1}$$

In the formula, I_{DM} is the unbalanced noise current, that is, the differential mode noise current. When $I_L=I_N$, I_{DM} is zero; and when $I_L \neq I_N$, I_{DM} is not zero.

It can be seen from formula (1) that no matter IL=IN or IL≠IN, there is always ICM that satisfies

$$\begin{cases} I_{CM} = I_L - I_{DM} \\ I_{CM} = I_N + I_{DM} \end{cases} \tag{2}$$

In the formula, I_{CM} is the balanced noise current, that is, after removing the unbalanced noise current in the live line and neutral line noise, the remaining part should be equal, so it is called the balanced noise current, that is, the common mode noise current.

$$U_{CM} = U_{LG} = U_{NG} \tag{3}$$

In the formula, U_{CM} is common mode conducted EMI noise. It can be seen from (3) that the conducted EMI noise between the live wire-ground wire and the neutral wire-ground wire is equal in magnitude and in the same direction, which is common mode conducted EMI noise

$$U_{CM} = \frac{U_L + U_N}{2} \tag{4}$$

From equation (4) and Figure 2 we can see the equivalent circuit of common mode conducted EMI noise. As shown in Figure 3, U_{CM} is the common-mode noise

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source, 25Ω is the common-mode AMN equivalent test impedance, which is formed by two 50 Ω standard impedances in parallel, and Z_{CM} is the internal impedance of the common-mode noise source.

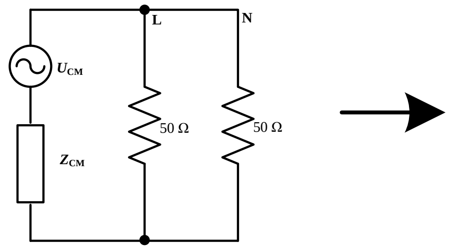

Figure. 3 Transmission path of common mode conducted EMI noise

3.2 Differential mode conducted noise model

From equation (1) and $I_{LN}= I_{DM}$ can be obtained

$$I_{DM}=\frac{I_L-I_N}{2} \tag{5}$$

Since the ratio of noise voltage to noise current is 50 Ω, it can be obtained from equation (5)

$$U_{DM}=\frac{U_L-U_N}{2} \tag{6}$$

From equation (6) and Figure 2, we can see the transmission path and equivalent circuit of differential mode conducted EMI noise, as shown in Figure 4 and Figure 5.

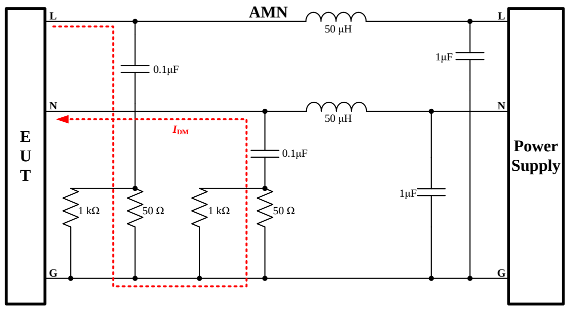

Figure. 4 Transmission path of differential mode conducted EMI noise

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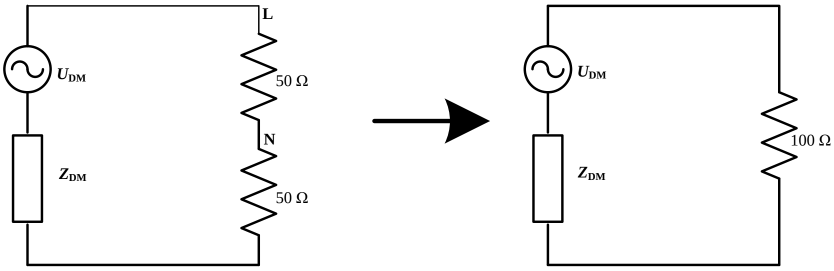

Figure. 5 Transmission path of differential mode conducted EMI noise

As shown in Figure 5, U_{DM} is a differential mode noise source, 100 Ω is the equivalent test impedance of differential mode AMN, which is formed by two 50 Ω standard impedances in series, and Z_{DM} is the internal impedance of the differential mode noise source.

4. Conducted EMI noise suppression method

(1) Crosstalk is the conducted EMI noise caused by the coupling of radio frequency electromagnetic fields generated by noise sources (including other cables, crystals or chips, etc.) near the cable into the cable. Therefore, the noise source of crosstalk is the spatial radio frequency electromagnetic field. However, in the actual functional circuit, the working state of other cables, crystal oscillators or chips cannot generally be changed, and electromagnetic shielding measures for cables are also difficult to apply (the shielding effectiveness is low and higher cost).

The traditional common mode choke coil can better suppress the common mode EMI noise in the line. When the differential mode noise in the live line and the neutral line flows into the common mode choke coil, because the direction of the differential mode current is opposite, the generated magnetic flux cancels each other out , The common mode choke coil has low impedance; and when the common mode noise in the live wire and the neutral wire flows into the common mode choke coil, the common mode current flows in the same direction and the generated magnetic flux is superimposed on each other, and the common mode choke coil has high impedance Therefore, the common mode choke can suppress common mode EMI noise.

(2) Under normal circumstances, in practical applications, only need to strengthen the grounding system of the PCB circuit can effectively suppress the conducted EMI noise caused by poor grounding.

(3) PCB circuit impedance mismatch will cause multiple reflections of the signal, and cause the high-order harmonics of the signal's main frequency to oscillate in the circuit, thereby generating conducted EMI noise. Generally, the characteristic impedance of the PCB circuit can be calculated, and the signal integrity analysis can

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be performed according to the characteristics of the transmitted signal, so as to match the impedance of the PCB circuit as much as possible. Impedance mismatch will produce multiple reflections and transmissions, but the key to the design of impedance mismatch is to increase the reflection coefficient of high-frequency noise as much as possible, reduce its transmission coefficient, and reduce conducted EMI noise. In addition, the above methods can improve the integrity of the transmission signal, but the high-frequency harmonics in the PCB circuit are not functional/useful signals. Therefore, if the high-frequency harmonics in the PCB circuit can be reduced, the conducted EMI noise can also be effectively reduced.

5. EMI noise suppression experiment

Conducted emission noise test was performed on a gyromagnetic photon thermotherapy instrument produced by a certain company. The test spectrum is shown in Figure 6.

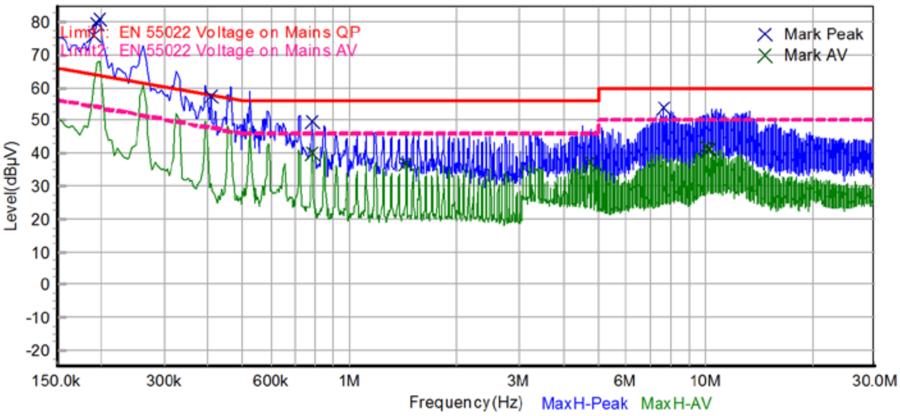

Figure. 6 Spectral diagram of conducted noise

The test result is shown in Figure 6. It can be clearly seen that the peak value and the average value have exceeded the standard. In the frequency range of 150K-600K, the standard exceeded the standard severely, and the other frequency bands did not reach the ideal condition. The original gyromagnetic photon hyperthermia instrument conducted disturbance indicators failed the test.

Based on the above analysis, this article designs a corresponding noise suppression scheme for it, with a common-mode inductor in series on the power line. The conduction noise of the gyromagnetic photon hyperthermia instrument mainly comes from the power line, followed by the internal high-frequency switching elements. Therefore, as shown in Figure 7, a common mode inductor is connected in series on the PCB power supply line to filter out the conducted noise from the power supply.

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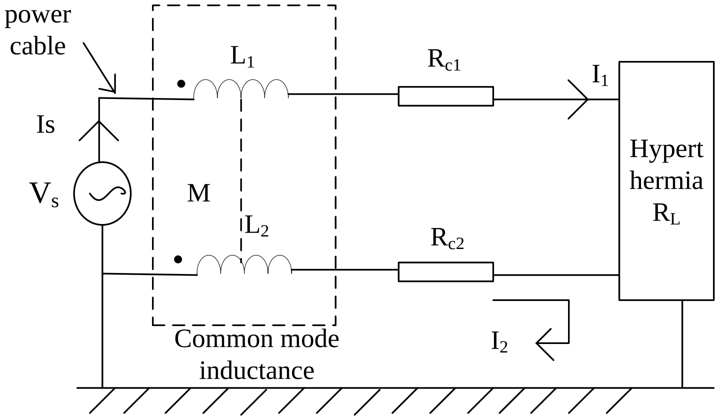

Figure. 7 The equivalent circuit diagram of adding a common mode inductor to the power line of the device under test

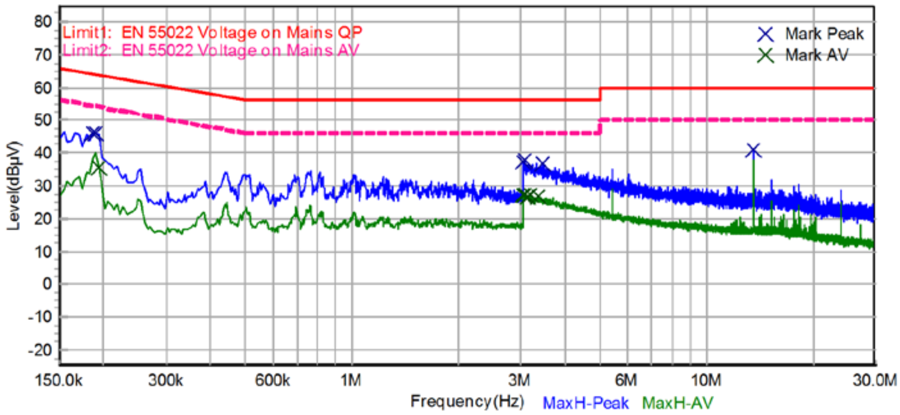

Figure. 8 Conducted noise after suppression

As shown in Figure 8, using the above-mentioned EMI noise suppression scheme, the conducted EMI noise of the gyromagnetic photon hyperthermia instrument is significantly reduced, and it successfully passes the test standard requirements.

6. Conclusion

In this paper, a common mode conducted noise model and a differential mode conducted noise model are established, and methods for suppressing conducted EMI

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noise under different conditions are studied. Finally, the correctness and reliability of the model are verified through conducted noise suppression experiments, which provides a great opportunity for EMC rectification solution.

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