Efficient debugging with Common and Differential Mode Separation Technics to conduction interference

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Summary: This article introduces the Theory of common mode (CM) and differential mode (DM) separation for Switching Mode Power Supply interference, and at the same time analyzes the effect of the filter's components for reducing common mode and differential mode interference. For instance, the author do further conduction debug in a 60W Flyback power supply and get 20DB margin.

Keyword: Conduction Interference, Common mode, differential mode separation, debugging

How to debug Switching Mode Power Supply interference in fast, high efficiency and low cost way is always a difficult problem for engineers. Commonly changing the filter components not only takes too much time that may not reach the best effect but also increases the cost.

According to the characteristics of the Conduction electromagnetic interference, it can be separated as CM interference and DM interference. CM is defined as the unexpected Potential difference between any conductor and reference ground. DM interference is defined as the unexpected Potential difference between any two Current carrying conductors. Reference to Figure 1.

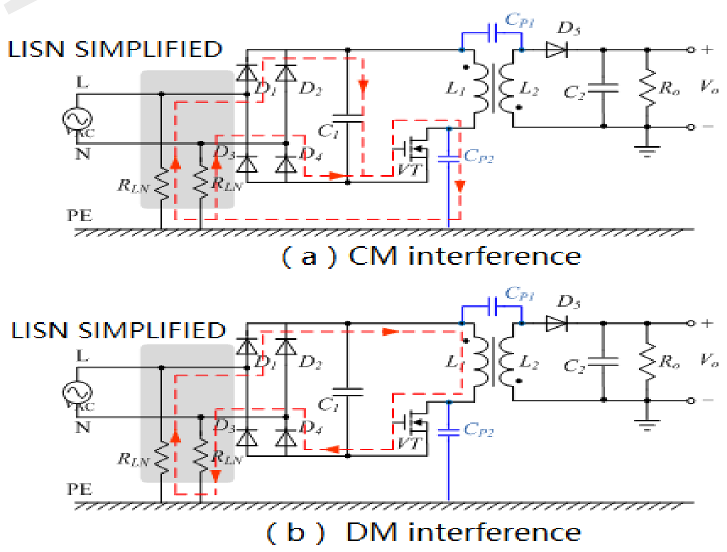

Figure 1 signal analysis of CM /DM interference of Flyback switching power supply

The theory of the filter components is different for CM/DM signal. As a result, we can totally adjust corresponding components according to voltage of CM or DM signal. This can largely decrease the development time and cost, helping the users to win market opportunities.

For this, Shenzhen Zhiyong Electronics Co., Ltd (CYBERTEK) provide a solution of highly efficient debugging using CM/DM separation technic. This solution includes digitalized receiver EM5080A, the LISN with CM/DM separation EM5040B, Filter Debug Fixture EM50401 and isolation transformer EM5060. Please refer to Figure 2 and 3.

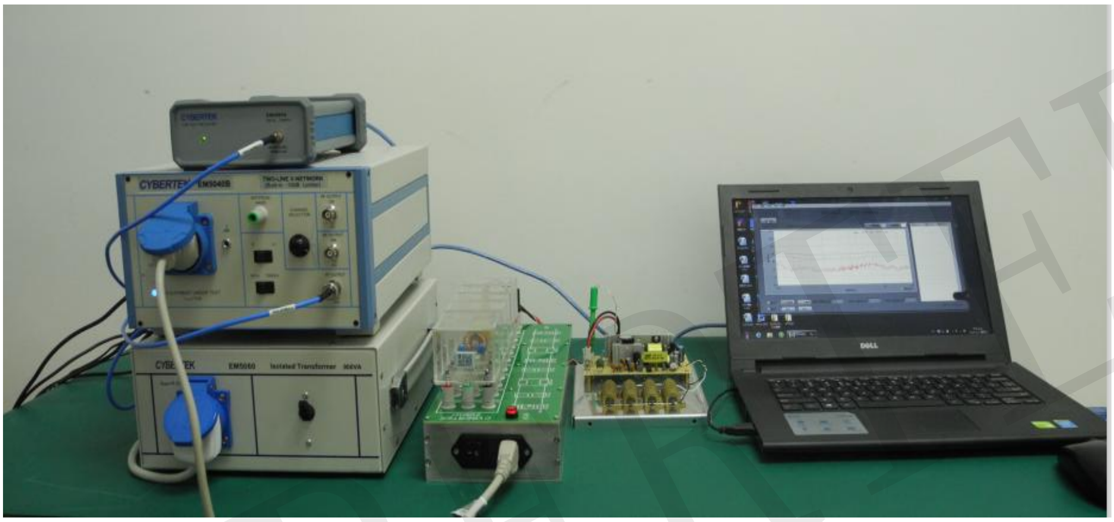

Figure 2 CYBERTEK Solution for highly efficient conduction debugging

Figure 3 EM50401

(This product has specialized wiring terminal which allow the users not only use the standard EM50401 components we provide, but also can connect any components on it.)

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EM50401 Components		
Name	Specification	Quantity
Y Capacity	2200pF	3
	4700pF	3
X Capacity	0.1uF	3
	0.22uF	3
	0.47uF	3
	1uF	3
	2uF	3
CM inductance	1.2mH	2
	8mH	2
	30mH	2
DM inductance	30uH	2
	70uH	2
	100uH	2

Example: study on 60W Fly back switching power supply's conduction debugging

Devices list

Name	Brand	Type
Receiver	CYBERTEK	EM5080A
LISN	CYBERTEK	EM5040B
Isolation Transformer	CYBERTEK	EM5060
Debug Fixture	CYBERTEK	EM50401

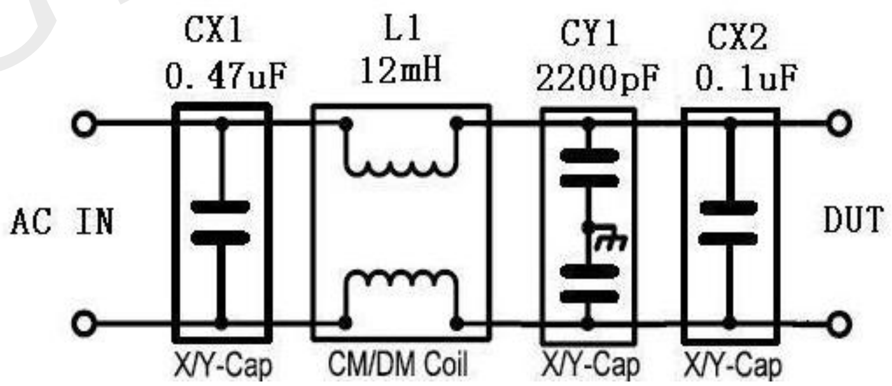

Figure 4 60W power's filter circuit

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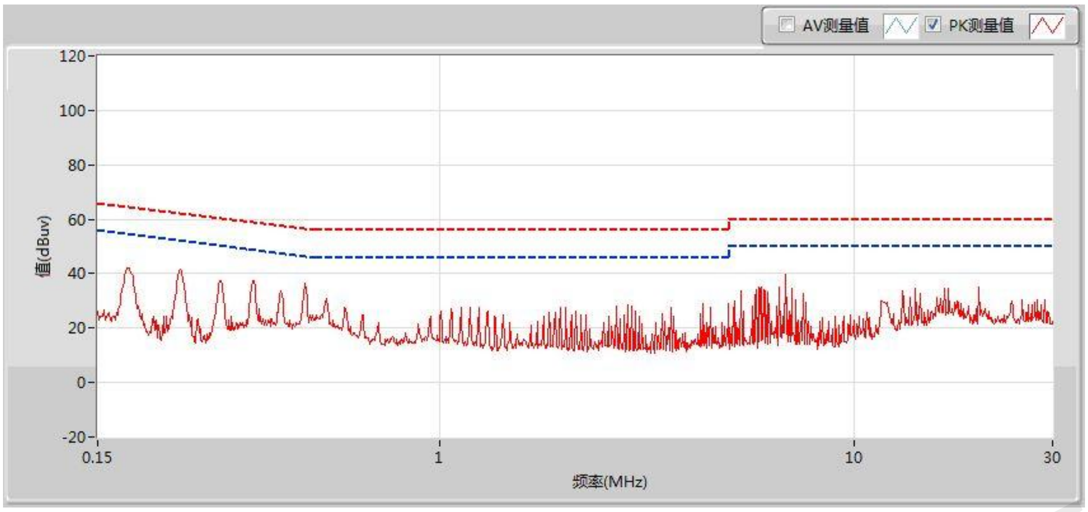

Figure 5 the conduction curve when original filter components is moved to EM50401

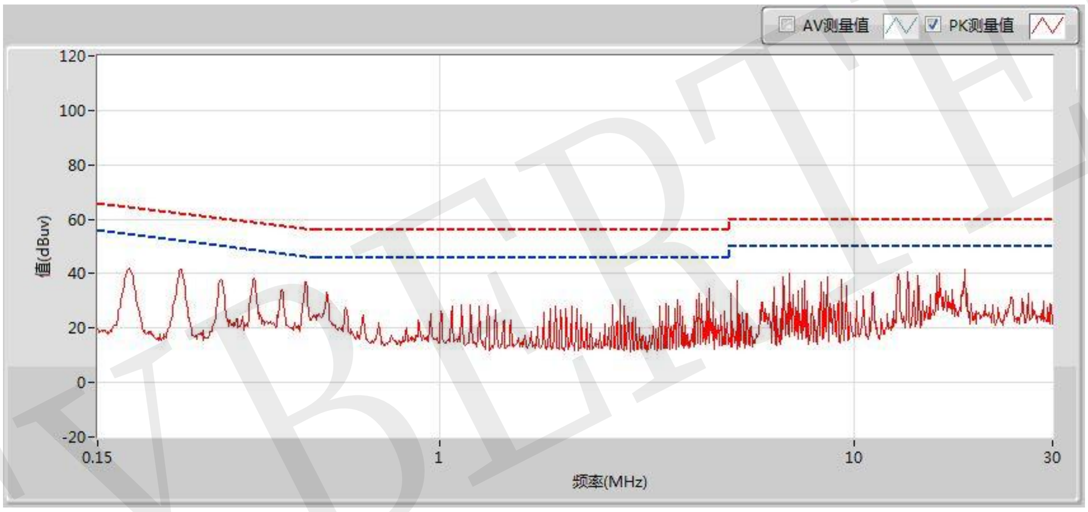

Figure 6 the CM curve when original E filter components is moved to EM50401

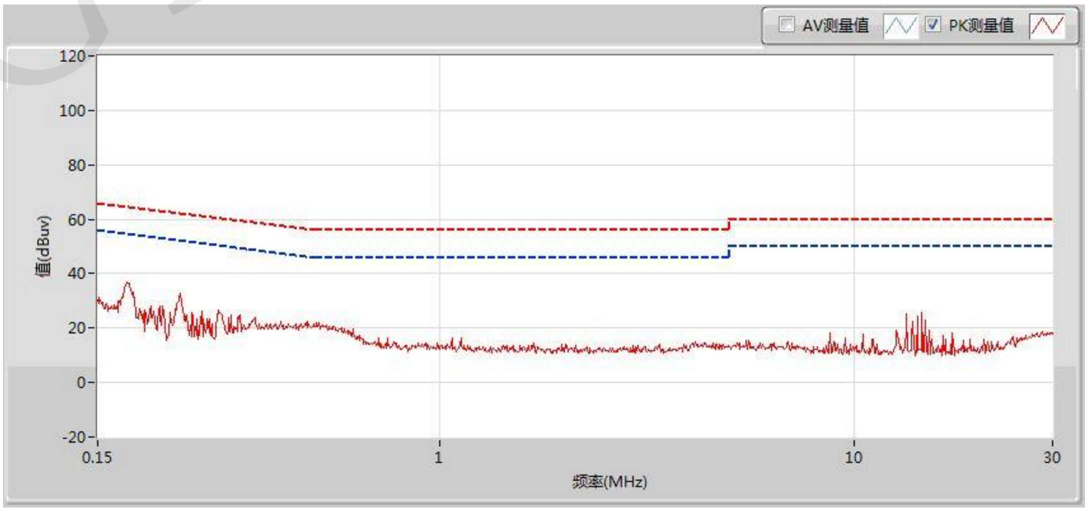

Figure 7 the DM curve when original filter components is moved to EM50401

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First: Study on X Capacitor

According to the CM /DM curve above, we can find that the main problem is the CM interference of this power supply, and the DM interference is already low enough. Then we can try these operations

- ✧ Based on the original filter circuit, CX2 is increased to 0.47U to see if there's improvement. (Refer to Figure 8, 9 and 10):

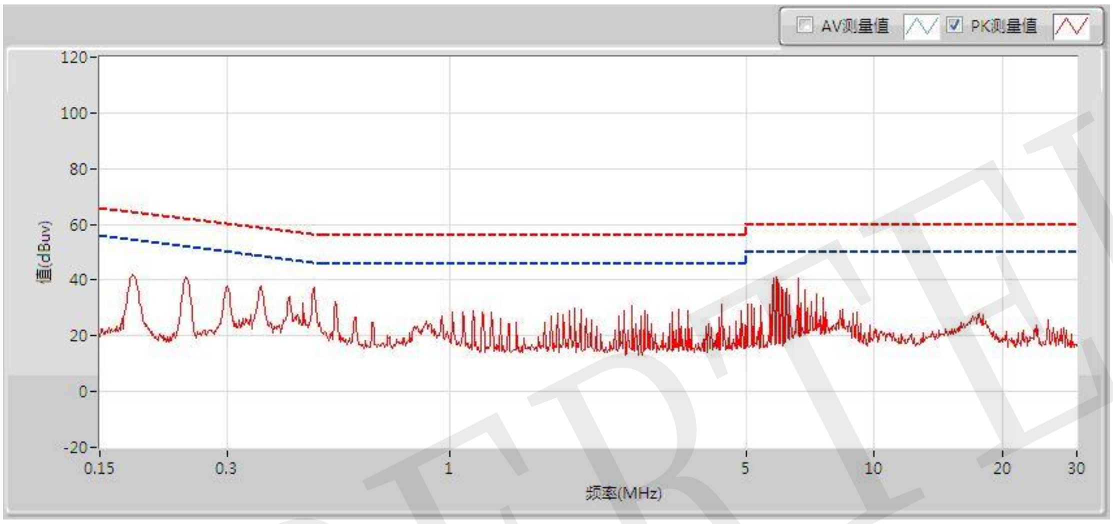

Figure 8 Conduction curve for Enlarged CX2 of 0.47U, no improvement

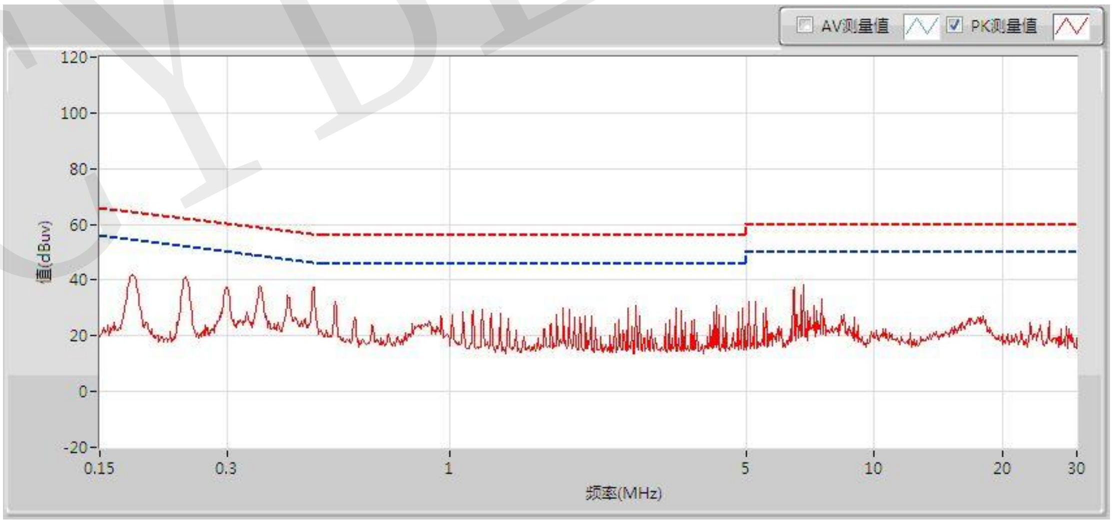

Figure 9 CM curve for Enlarged CX2 of 0.47U, no improvement

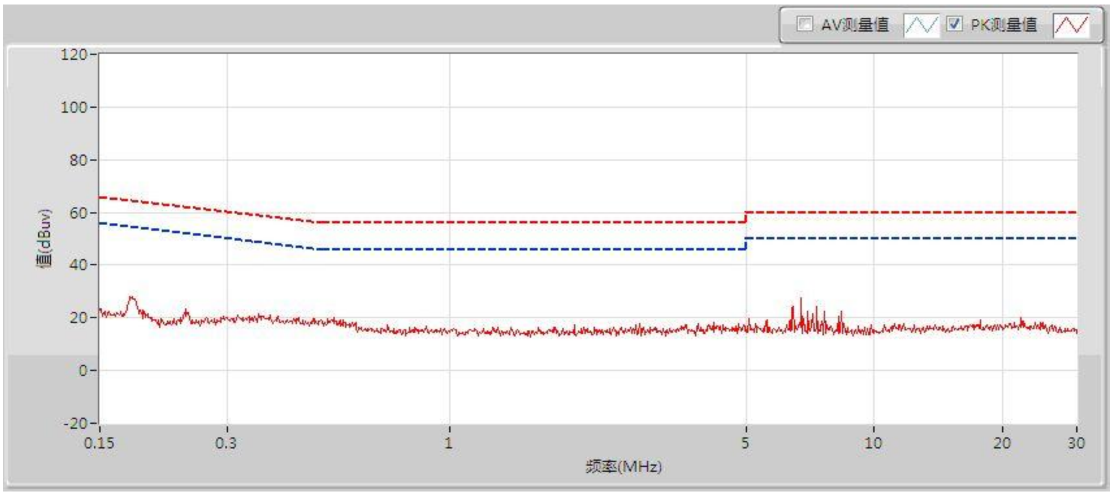

Figure 10 DM curve for Enlarged CX2 of 0.47U, no improvement

- Reducing CX1 capacitor to 0.1U based on original filter circuit (Refer to Figure 11, 12 and 13):

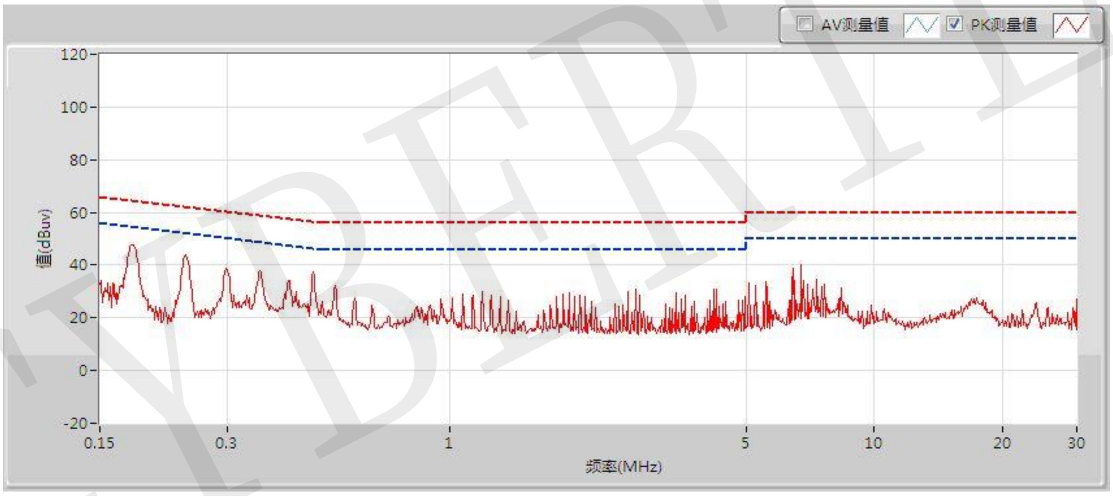

Figure 11 Conduction curve for Reduced CX1 of 0.1U, lower frequency range gets worse

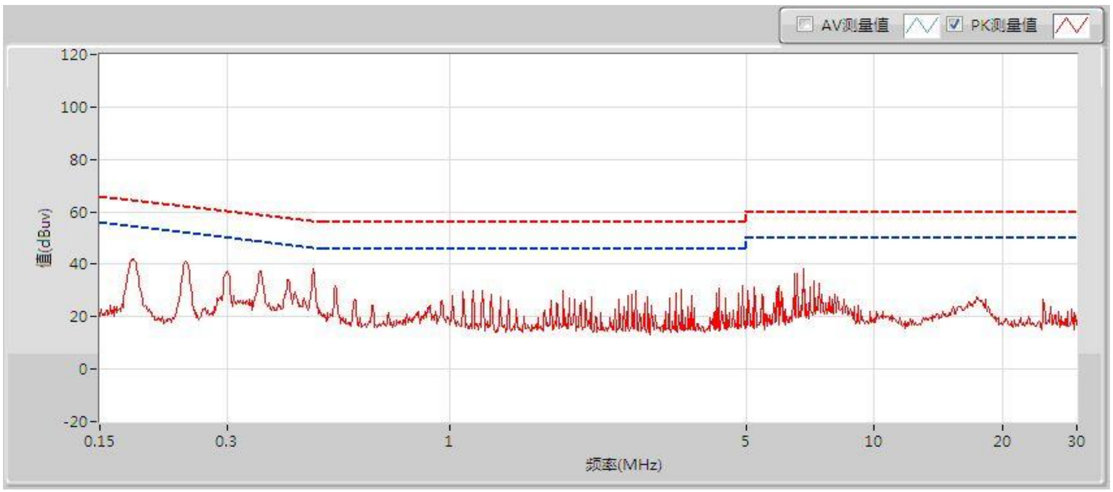

Figure 12 CM curve for Reduced CX1 of 0.1U, no improvement

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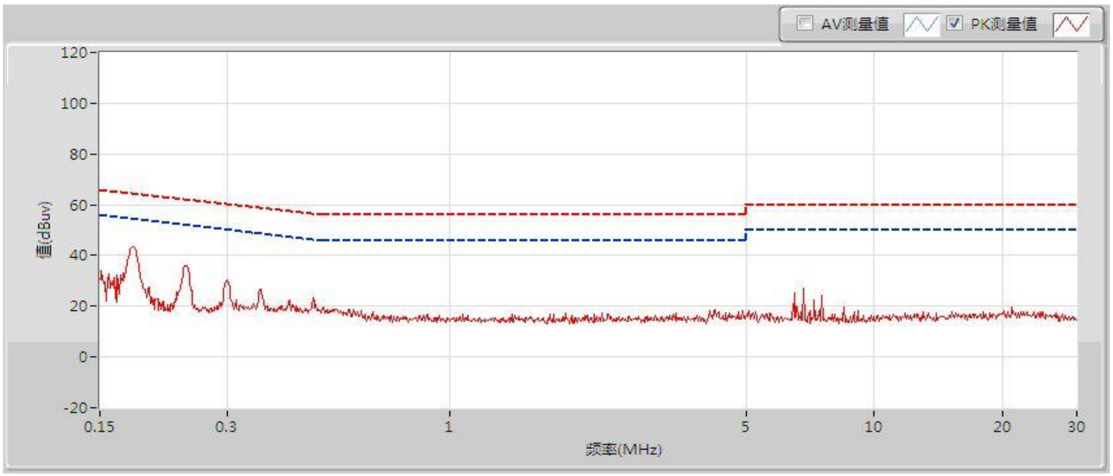

Figure 13 DM curve for Reduced CX1 of 0.1U, lower frequency range gets worse

Conclusion: X capacitor is effective only for DM interference. When CM interference is main, it's useless to increase X capacitor for the reduction of CM interference.

Second: Study on CM inductance

Reduce the CM inductance L1 to 1.2MH based on original filter circuit. (Refer to Figure 14, 15 and 16)

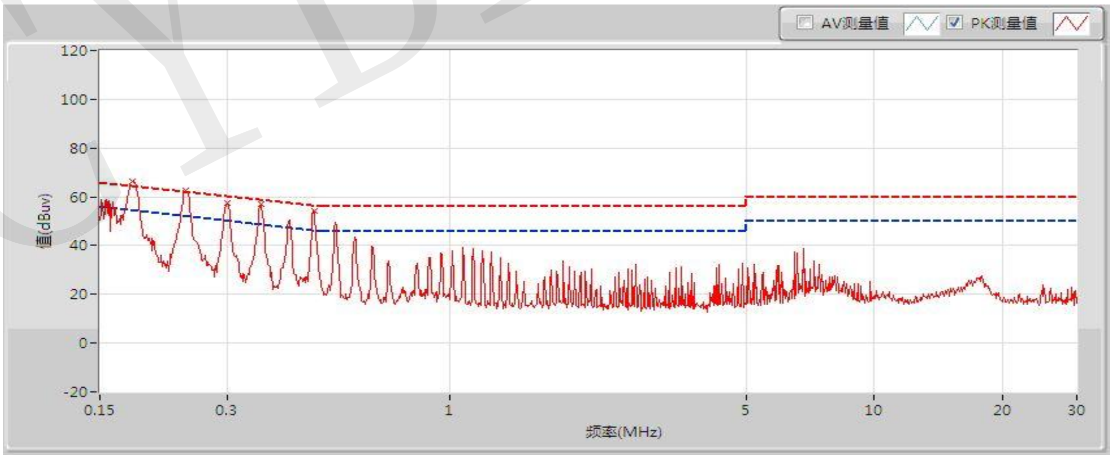

Figure 14 Conduction Curve of Reduced CM Inductance L1 of 1.2 MH, Worsen

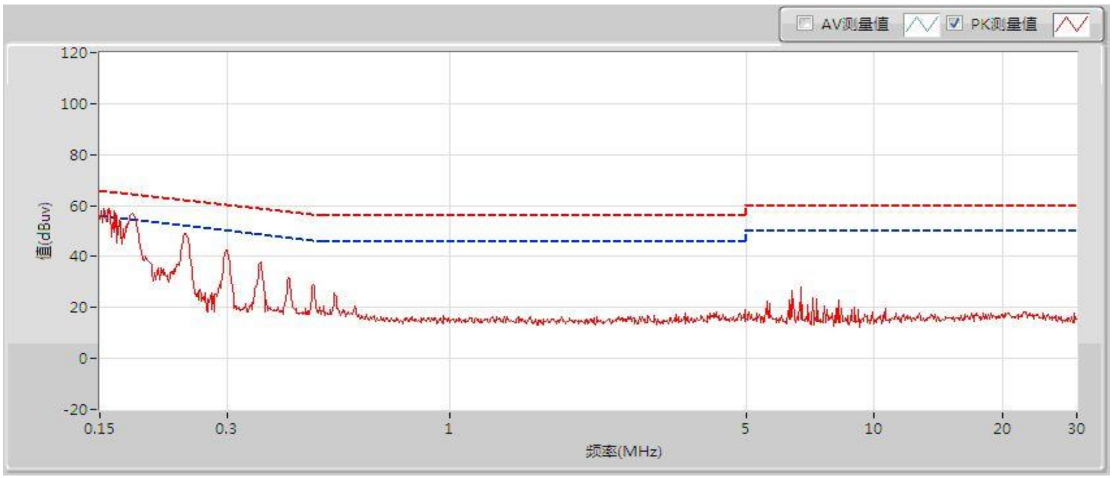

Figure 15 DM Curve of Reduced CM Inductance L1 of 1.2 MH, Lower Frequency get worsen

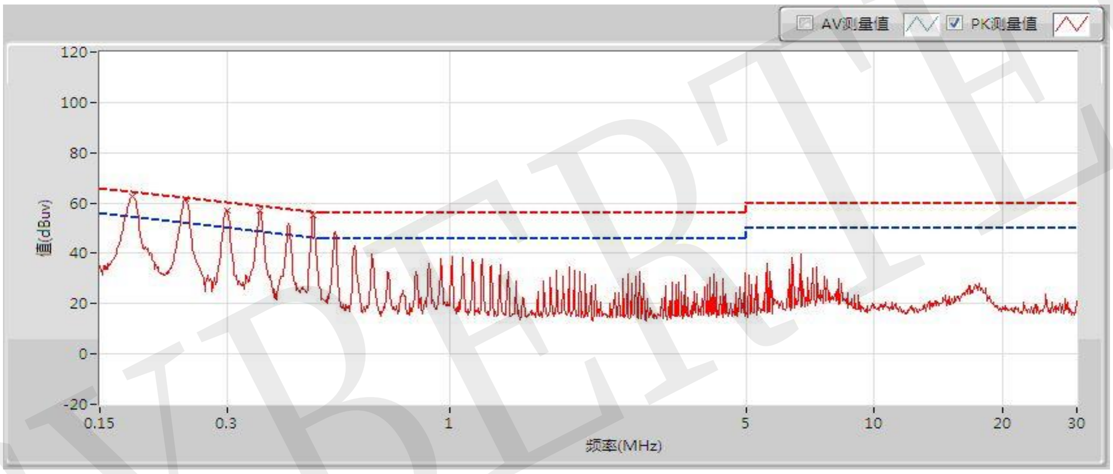

Figure 16 CM Curve of Reduced CM Inductance L1 of 1.2 MH, Worsen

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Conclusion: The function of the low pass filter (Figure 28) formed by CM inductance and Y capacitor is to absorb CM interference. Also, the CM inductance has some leakage inductance so it can perform as the DM inductance and form low pass filter with X capacitor too. This can avoid singly using DM inductance and reduce cost.

Third. Study on Y capacitor

Cancel the CY1 capacitor based in original filter circuit. (Refer to Figure 17, 18, 19)

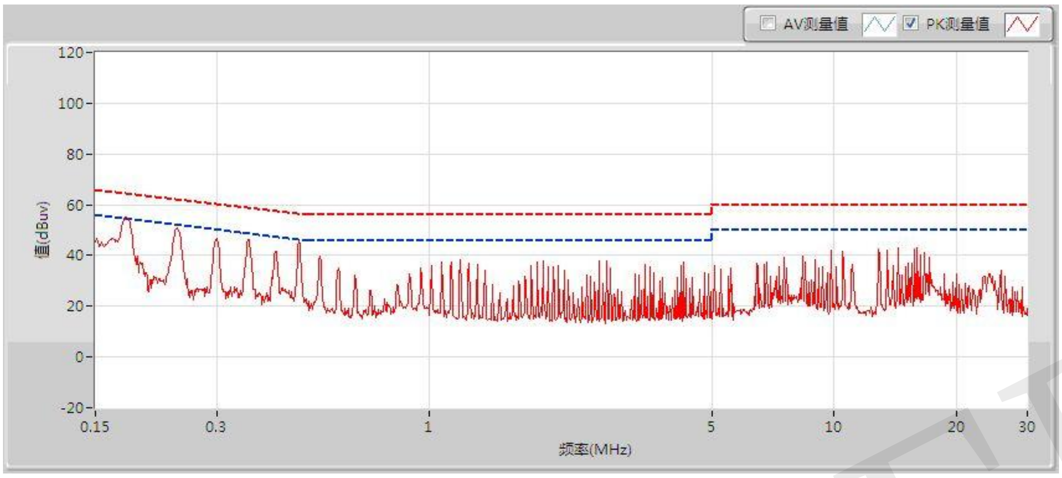

Figure 17 Conduction curve without CY1 capacitor, worsen

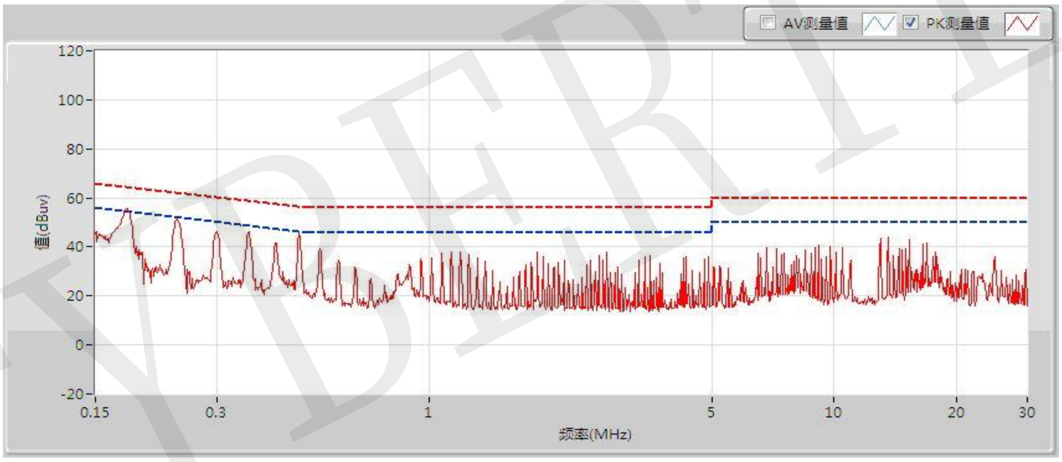

Figure 18 CM curve without CY1 capacitor, worsen

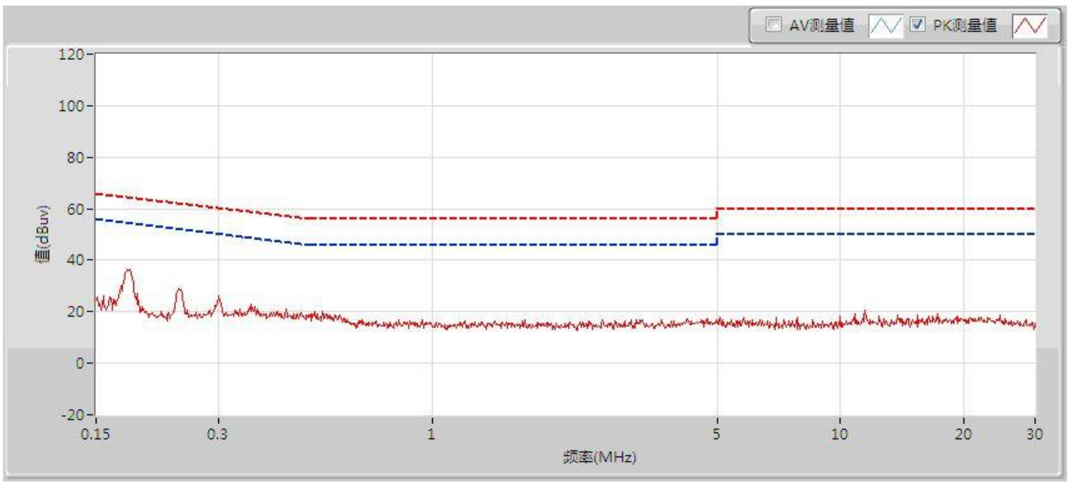

Figure 19 DM curve without CY1 capacitor, no change

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Conclusion: The function of Y capacitor is (Form low pass filter with CM inductance, refer to Figure 28) to absorb CM interference. But the Y capacitor can't be large or it will cause safety problem due to large leakage current. Medical power supply has strict requirement for leakage so normally it won't use or use Y capacitor only with small capacity. This brings big challenge to the debugging of conduct interference.

Fourth. Margin reached 20DB after fully debugged

To further reduce the conduction interference of this power supply, we can use a two stage filter.

- Normally we add CM inductance and Y capacitor to suppress CM. If we add 30mH CM inductance in the DUT port of the filter circuit, although the low frequency range performs good, the high frequency range rises rather than reduces. The CM scan curve is shown below:

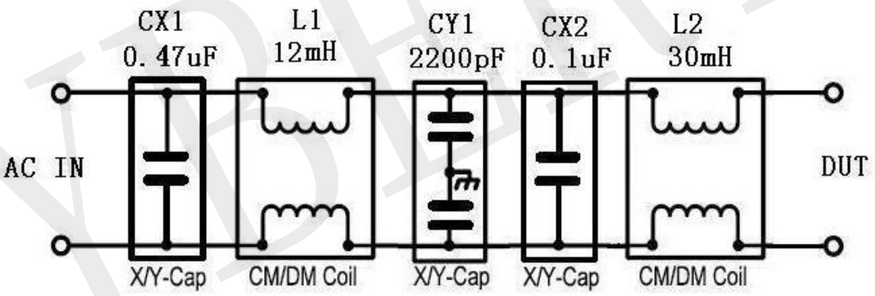

Figure 20

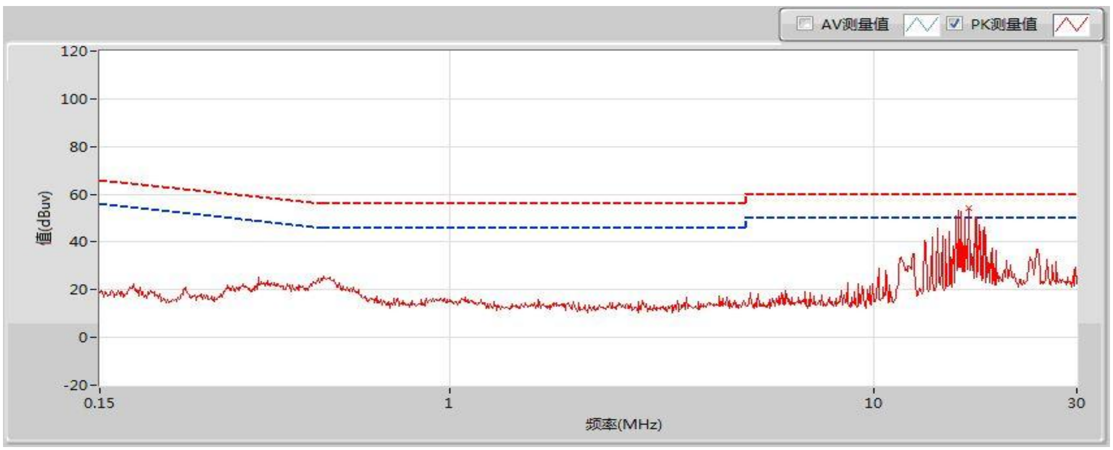

Figure 21 CM curve

✧ Reduce the 30mH CM inductance to 1.2mH CM inductance, the CM scan curve is shown below:

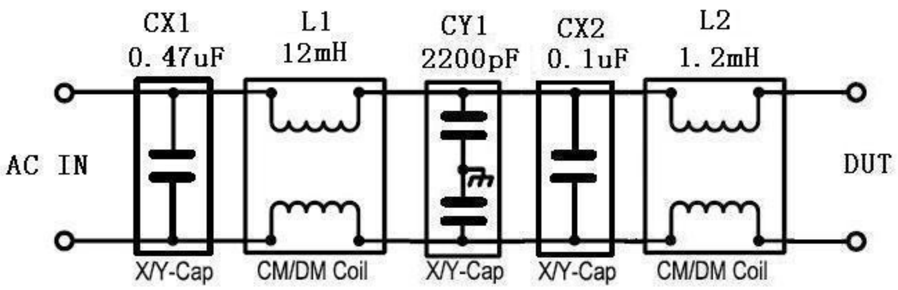

Figure 22

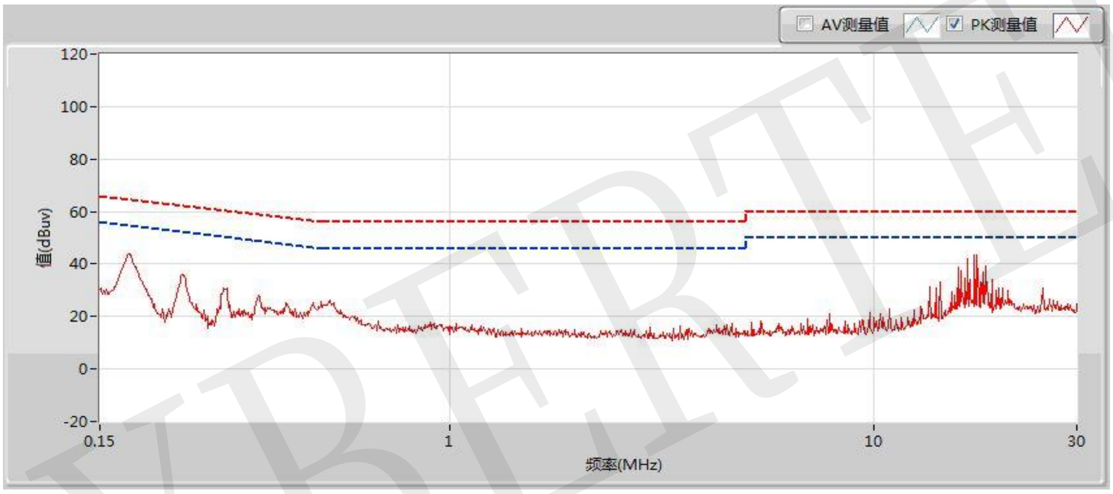

Figure 23 CM curve

Conclusion: The increase of CM inductance is effective for reducing the conduct interference of low frequency range band, but large CM inductance is not that useful for high frequency range band because the large number of turns make the distributed capacitance too large. Because of the cost issue large CM inductance should also be denied.

✧ Add Y capacitor at 1.2mH CM inductance (Close to DUT port), its CM scan curve is shown below:

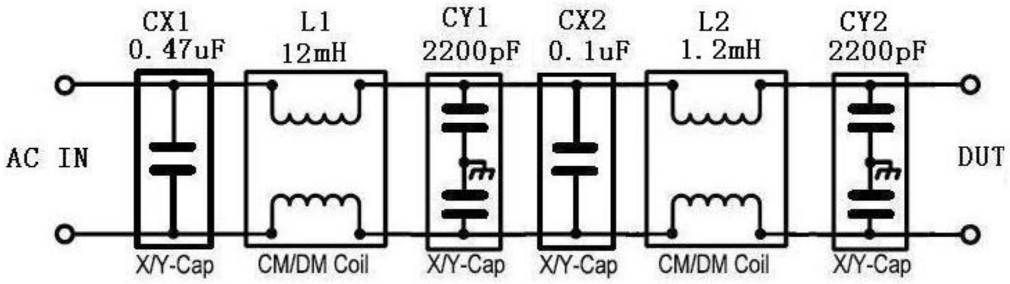

Figure 24 Filter Circuit

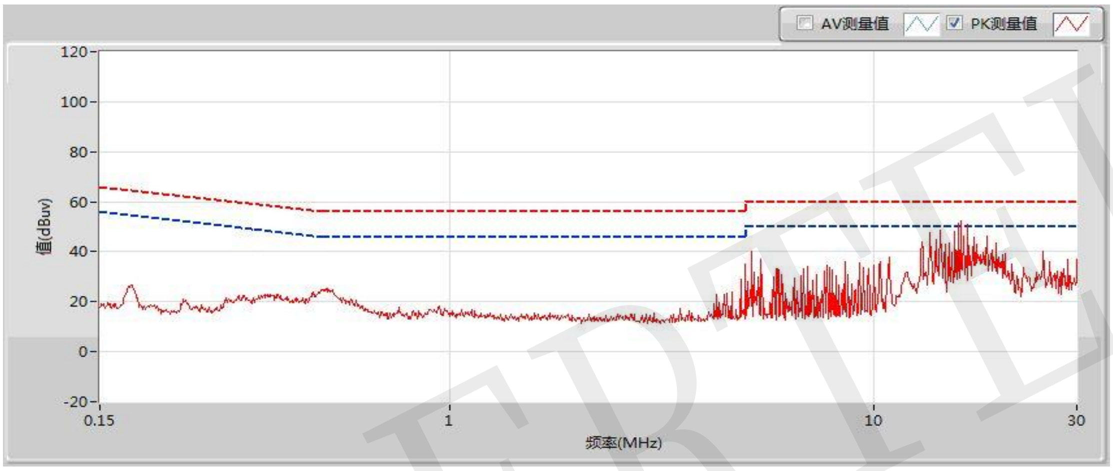

Figure 25 CM curve

✧ Adjust the position of the Y capacitor to the AC IN side of the CM inductance and form LC low pass filter. Its ideal CM curve is shown below:

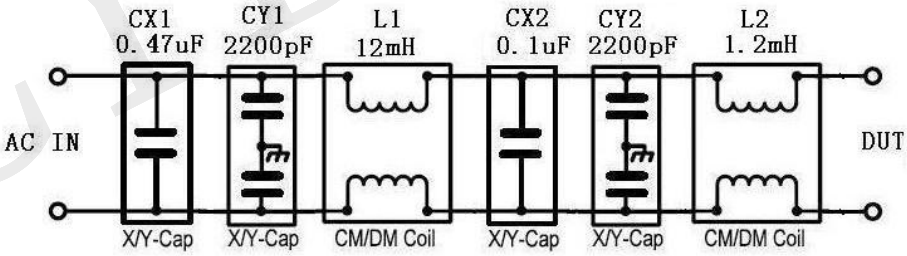

Figure 26 Filter Circuit

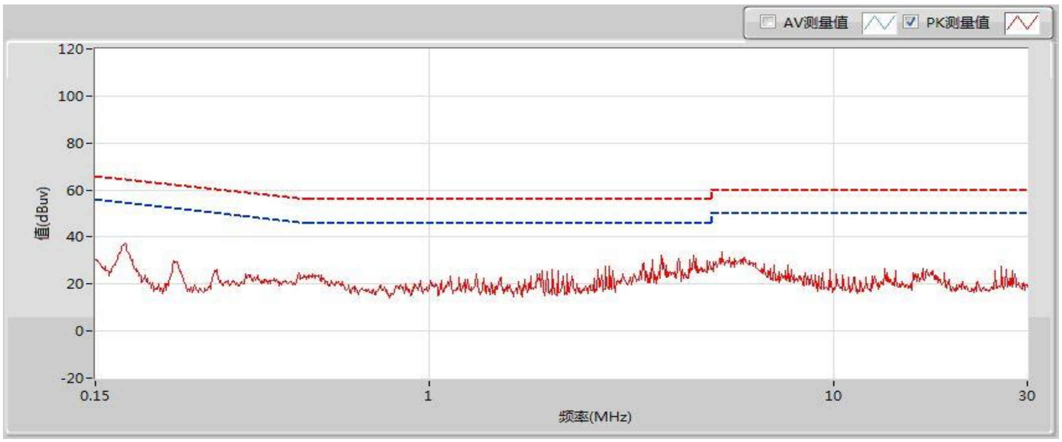

Figure 27 CM curve

Conclusion: CM inductance and Y capacitor should form topology of a LC low pass filter through the direction of interference signal. Also, DM inductance and X capacitor follow the same rule.

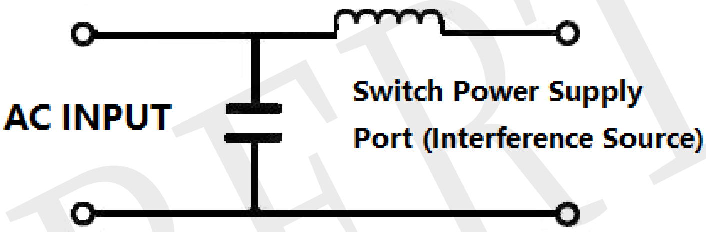

Figure 28 Filter operating direction

- ✧ If the position of two CM inductance is reversed, the low frequency range band will rise a lot. So, when debugging, small CM inductance should be close to the DUT port.

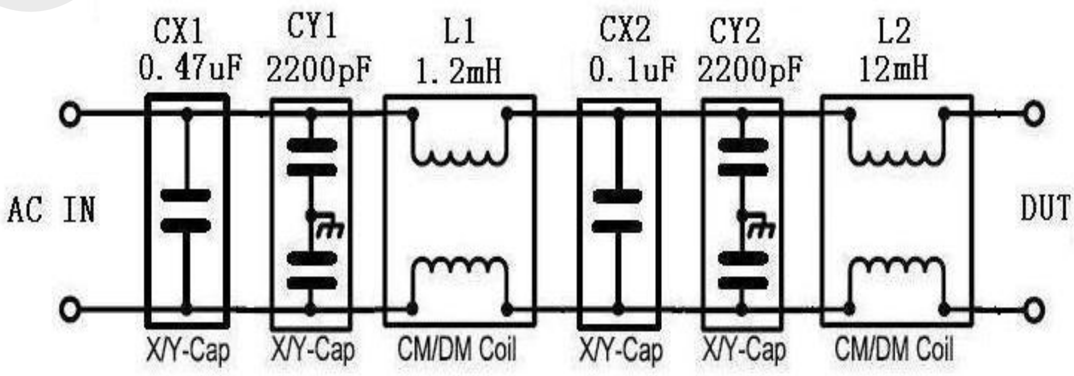

图 29

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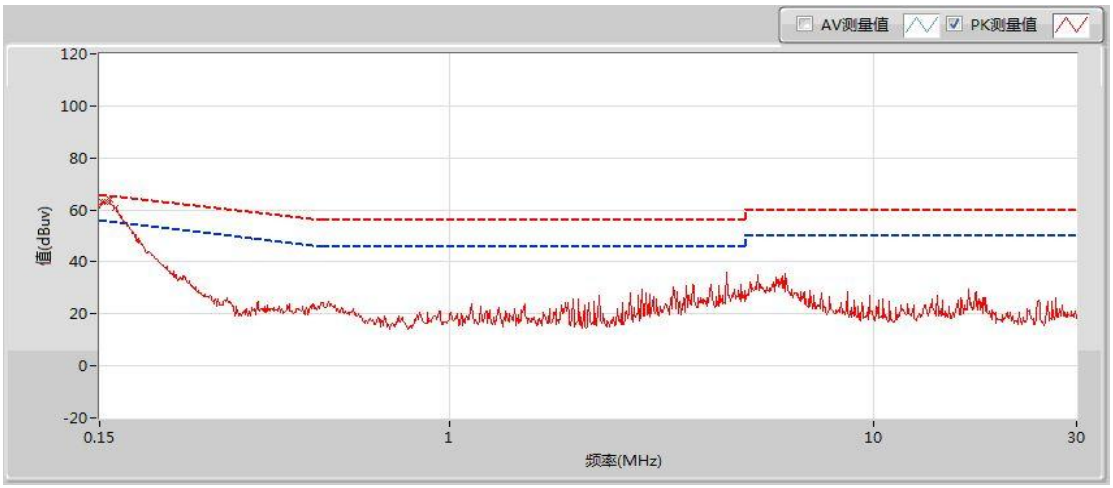

Figure 30 CM curve

Conclusion: small CM inductance should be close to DUT port to oppose high frequency range band interference as prior

✧ The comparison of the conduct test curve before/after debugging.

- Before:

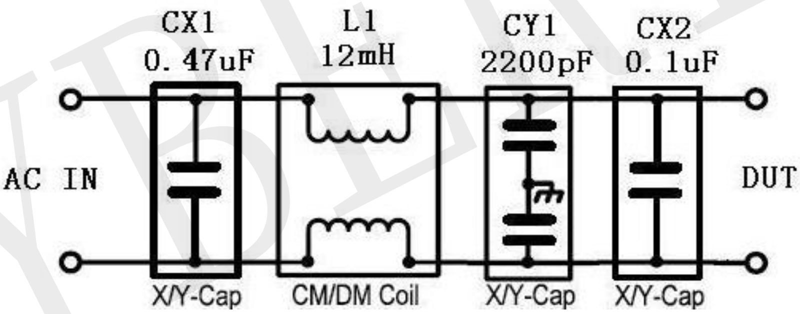

Figure 31 Filter before debugging

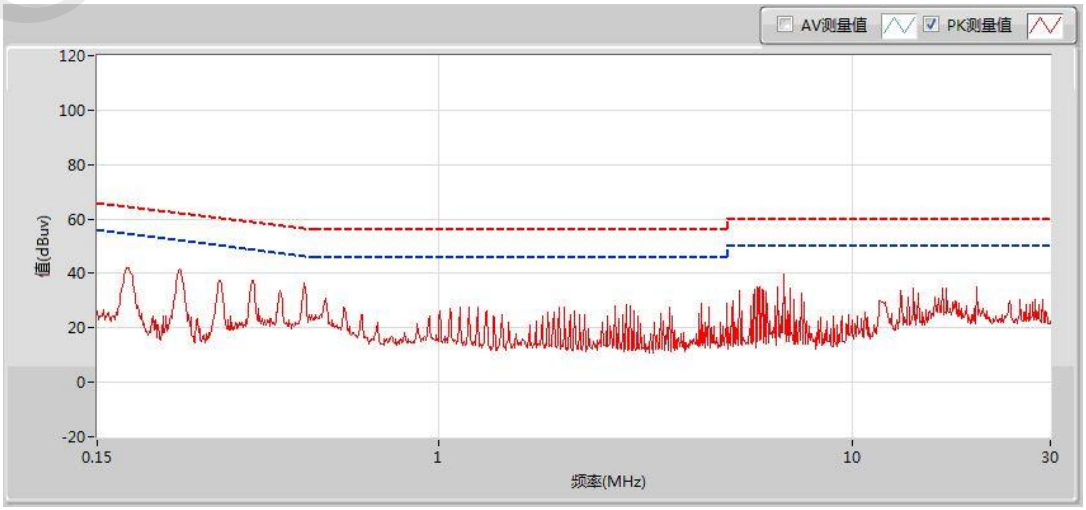

Figure 32 Conduction test curve before debugging.

- The conduction interference after debugging is small with average margin of 20DB

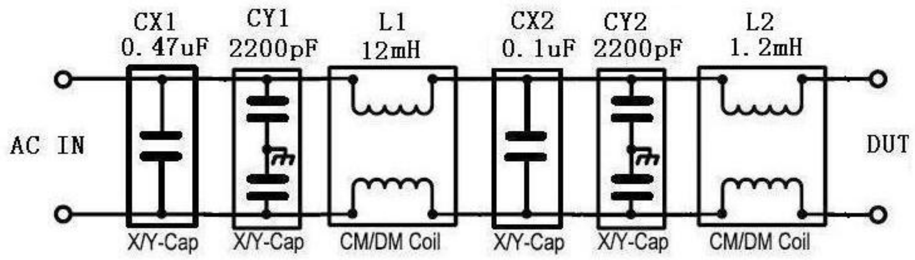

Figure 33 Filter after debugging

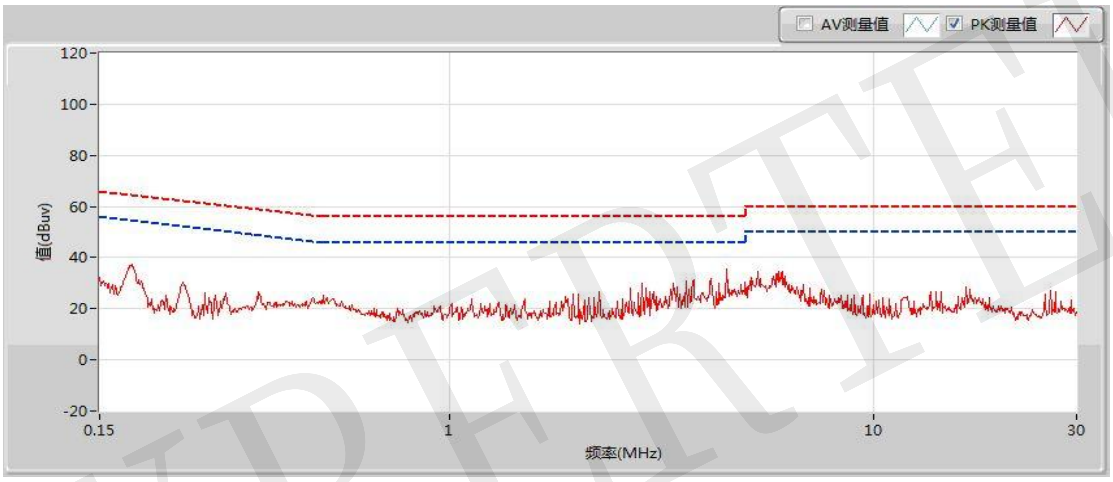

Figure 34 Conduct test curve after debugging

PS: EMI debugging Tips

Frequency	Phenomenon	Solution
9K-1M	Mainly DM	X capacitor, DM inductance
1M-5M	Mixture of CM and DM	X capacitor, DM inductance, Y capacitor, CM inductance
5M-30M	CM	Y capacitor, CM inductance
30-50M	Caused by the high speed switch of MOSFET	
50M-200M	Caused by the reverse recovery Current of the diode	
200M-1000M	The emission of the switching power supply is relatively low	High-speed digital Circuit, clock and RAM/CPU Mainly

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