Filter Selections Simplified with 0.1/100-Ohm Data

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The normalized results of a 0.1/100-ohm test can be used with much greater accuracy to predict the performance of the filter in a real application.

INTRODUCTION

Selecting the proper EMI line filter can be a hit or miss proposition. In light of this, most EMI filter manufacturers recommend that customers try their product in the final system configuration. Although the liberal sampling policies of filter vendors encourage this "try it and see" approach, there are associated costs to free samples – time and money. If the wrong sample was selected, the engineer must wait for the next one to arrive. If the selection was done while working in a test lab, a choice must be made between paying for unused lab time or losing the test slot while waiting for the next sample. There must be a better way!

LIMITATIONS

Specifications supplied by filter manufacturers are of limited use in selecting a filter. Some manufacturers provide schematics with the values of the components in the filters. Although this data is of interest to some, it borders on the theoretical and does not give a good indication of filter performance. What all manufacturers provide is insertion loss data in graphical or tabular format. Although this data is usually accurate, it is not a good indicator of filter performance in a real system.

The main reason for the limited use of insertion loss data is that data is measured in a 50-ohm test setup. Although this test standard is well-known, and is referenced in military specifications and by CISPR, it has very little to do with the real world applications of EMI filters.

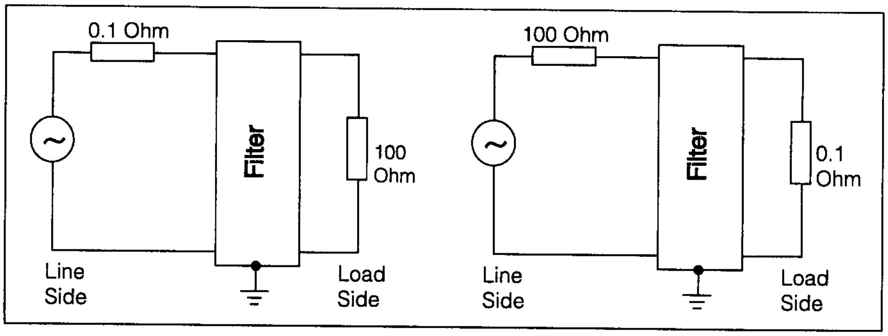

Figure 1. *Approximate Worst Case Test Diagram.*

In accordance with the test setup, the input and output are terminated into 50 ohms. Since most test equipment has 50-ohm terminations, test setup and measurement are quick, easy, and have little to do with the real world. However, when was the last time a piece of equipment was plugged into a line with a 50-ohm impedance? Or on the other hand, how many PFC-input power supplies show 50 ohms to the filter? The filter is usually terminated into an unknown impedance that depends on frequency. Since filter performance is largely dependent on termination impedance, 50-ohm curves can never represent a real application situation. The weaknesses of this measurement technique are well-known and are criticized in CISPR 17 and MIL-STD-220A, the very documents that define the setup!

ALTERNATIVE TECHNIQUES

Fortunately, CISPR 17 offers alternative measurement techniques. One is known as the "Approximate Worst Case Method." Under this test definition, the filter characteristics are measured with 0.1- and 100-ohm terminations on the line and load side. The test measurements are then repeated with the terminating impedences reversed (Figure 1). Like the 50-ohm test, the 0.1/100 test is not exactly real world. However, the normalized results can be used with much greater accuracy to predict the performance of the filter in a real application. Since the 0.1/100-ohm test is defined and repeatable, filter manufacturers can provide better performance information on their product to facilitate an evaluation of the product by end-users.

Experimental data show how effective the 0.1/100-ohm test method can be in evaluating filter performance. Figure 2 has four attenuation curves of a filter made between 10 kHz and 1 MHz, the range in which differential noise predominates. The curves are defined as follows. Curve A is "effective system attenuation." It is derived from many attenuation measurements of the subject filter with various types of equipment. Each unit under test is measured with and without the filter.

*See advertisement on page 59.

From this data an effective or real attenuation characteristic of the subject filter is defined and plotted. Curve B is the attenuation curve of the filter with 0.1 ohms on the input and 100 ohms on the output. Curve C is the same test made with the line and load impedances reversed. Curve D is the typical 50-ohm attenuation curve supplied by the manufacturer.

There are several items worth noting in this graph. First, the effective attenuation in Curve A should be compared with the 50-ohm data of Curve D. The 50-ohm data consistently shows better performance than the filter actually achieves in real applications. In the extremely critical range starting at 150 kHz, the 50-ohm data overstates real filter performance by almost 20 dB. Second, the 0.1/100-ohm Curves B and C approximate the effective attenuation extremely well, and performance is slightly understated. The last item of note is the additional information provided by the 0.1/100-ohm test.

How many times has a filter been put in a system only to find out the filter made things worse? Filters are passive networks of inductors and capacitors. In combination there will be unwanted resonances. The question is: How can they be predicted? The 0.1/100-ohm data offers a vehicle. Between 10 and 20 kHz the 0.1/100-ohm curves actually drop below the 0-dB line (Figure 2). Instead of attenuation there is now negative insertion loss or gain. A filter in a device with a fundamental in this frequency range will actually make the conducted noise problem worse! There is no filter problem here; it is just a fact of the components in the filter. With 50-ohm data this effect is never seen beforehand.

Figure 3 shows similar testing in the range where common mode noise tends to be dominant, up to 30 MHz. In this

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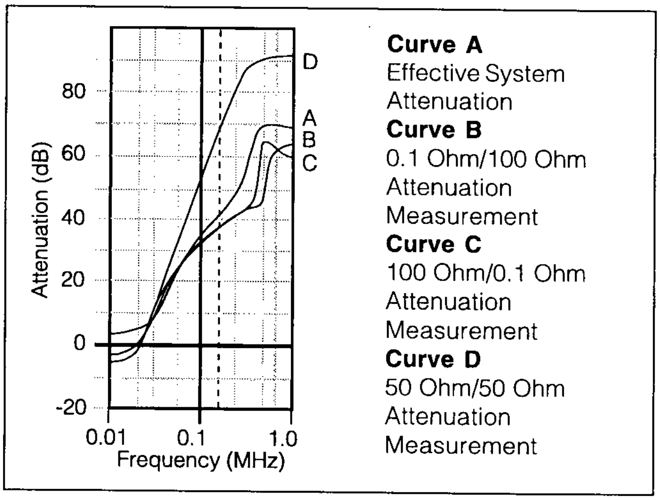


Figure 2. *Experimental Data between 10 kHz and 1 MHz.*

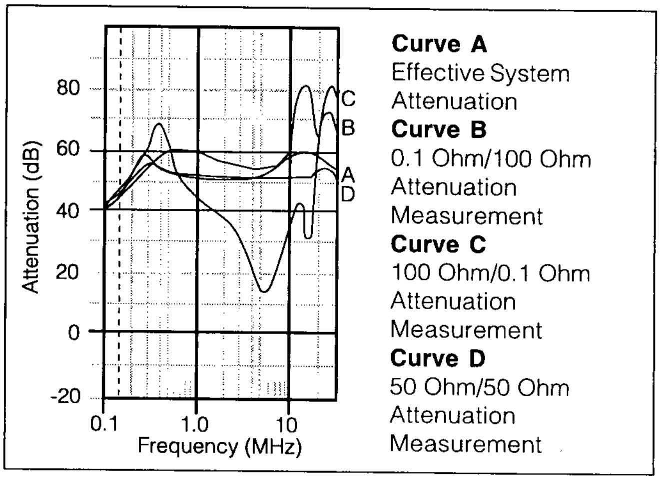


Figure 3. *Attenuation between 100 kHz and 10 MHz.*

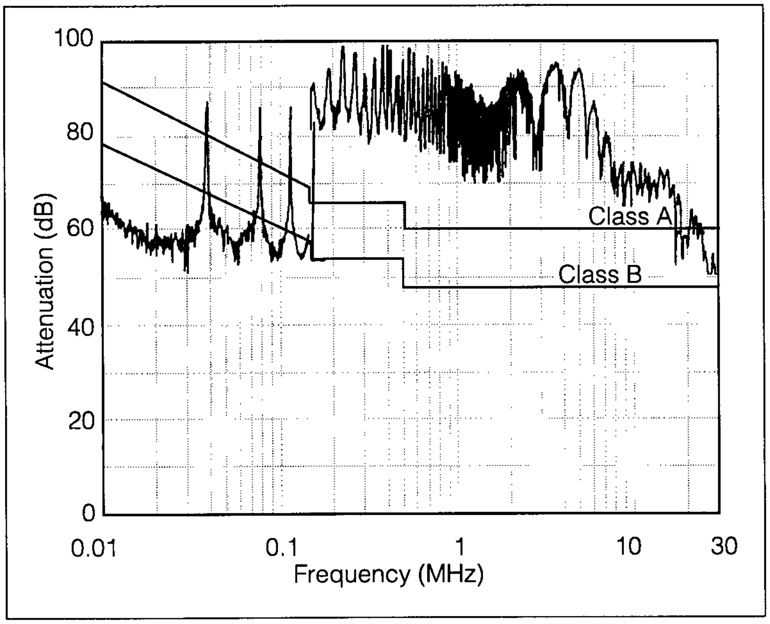
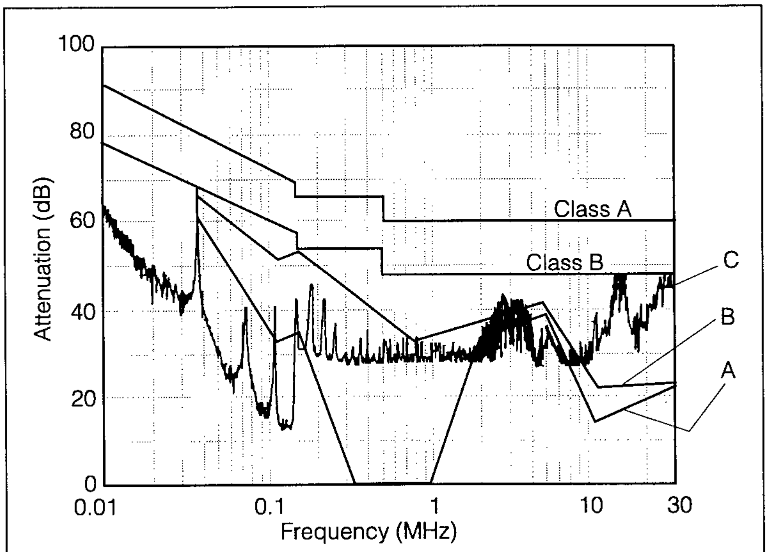


Figure 4. *Typical SMPS Output.*



Curve A
Noise Level Prediction with 50-Ohm Curves
Curve B
Noise Level Prediction with 0.1-Ohm/100-Ohm Curves
Curve C
Real System Noise Level After Filtering

Figure 5. *Unfiltered Output.*

range the effective attenuation and the 50-ohm data match much better. What is helpful with the 0.1/100-ohm data is the identification of insertion loss dips as shown in Curve C. This is a curve generated with the 0.1-ohm load on the load side, effectively placing the *y* capacitors on the line side. If the filter was placed in a system the wrong way, the insertion loss would be almost nonexistent at 6 MHz. Obviously, when one is dealing with frequencies above 10 MHz, good design practice is required to optimize filter performance. Proper grounding, bonding and cable routing are as important as any data that can be derived from insertion loss curves.

Does it all work? Figure 4 shows the unfiltered output of a typical switching power supply. Line A in Figure 5 is the noise profile predicted by 50-ohm data of the filter. Line B is the predicted noise profile based on the 0.1/100 data presented previously. Line C is the actual measured result.

CONCLUSION

It is very clear that the 0.1/100-ohm test gives a much better prediction of actual filter performance, with the area below 10 MHz almost in exact correspondence. As noted previously, above 10 MHz other factors influence filter performance. In the critical low frequency areas, the 50-ohm data is especially bad, with deviations of almost 20 dB. Based on 50-ohm data, a lower performance filter could have been selected with disastrous results. Manufacturers who have lost valuable test lab time after selecting a filter using 50-ohm data may want to ask filter vendors for 0.1/100-ohm data before the next time they go to the lab.

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