Overview of IEEE Standard 1560: Standard for Methods of Measurement of Radio Frequency Power Line Interference Filter in the Range of 100 Hz to 10 GHz

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Purpose of IEEE Standard 1560

Many commercial and industrial electrical environments contain equipment that is sensitive to radio-frequency (RF) interference. Theft detectors, digital sensors, and medical-telemetry systems have all been known to malfunction in the presence of RF interference that is conducted into such systems via their attachment to the power source. EMI/RFI filters specified to typical 60 and 100 dB attenuation levels are used in these and many other applications to prevent unwanted signals on power lines from disturbing the operation of these devices.

The main standard used to measure filter insertion loss (synonymous for matched impedance attenuation, typically 50 ohms), is Mil-Std-220B. Mil-Std-220B was developed for matched impedance communication systems to test mobile radio filter suppression capacitors in 1952 (which in reality matched impedances virtually never happens over a broad frequency range between the filter output and the input to the connected product). Hence, it has been labeled unrealistic for mismatched power sources and load impedances found in almost all power applications.

Unfortunately, Mil-Std-220B, which is considered only a face lifted version of its predecessor, Mil-Std 220A, has become the industry norm, largely because of the lack of a viable alternative....until now. The problems associated with the test methods defined in Mil-Std-220B have been known since it was first used. In fact, the standard itself warns users about its limitations. Nevertheless, this standard has been referenced in other standards and applied in thousands of applications throughout the military and commercial industries to characterize power-line filters. Since then, other methods have been discussed and developed that attempt to model "real world" attenuation by requiring varying the power source and load impedance. As

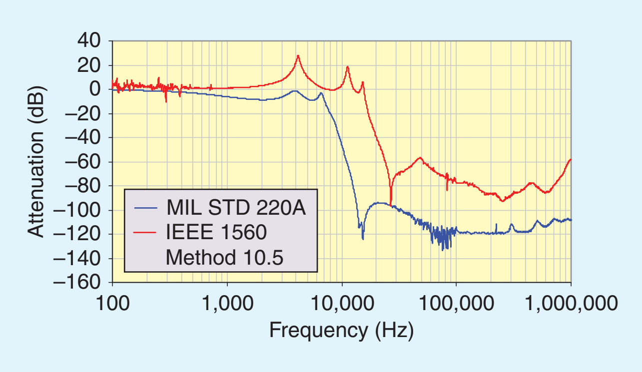

Fig. 1. Generic 50 Amp Filter Measured Using Mil-Std-220B and IEEE 1560 Method 10.5 with 30 Amp Loading.

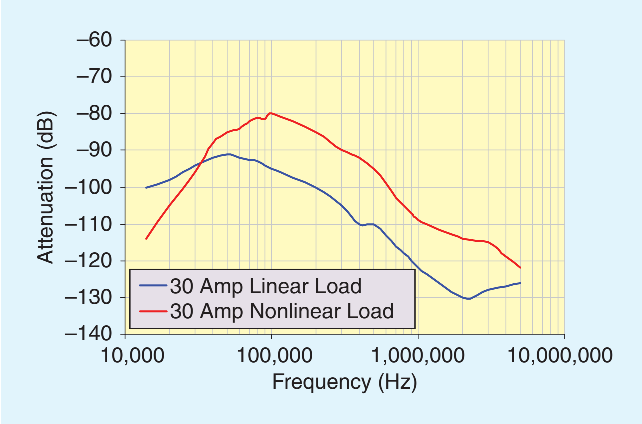

Fig. 2. Measurement Results for Linear and Nonlinear Loading with the Same RMS Current Value.

Figure 1 illustrates, the Mil-Std-220B method gives a much different expected value for attenuation than the more realistic test method in clause 10.5 (Current Injection) found in IEEE Standard 1560, which is the subject of this article.

To date, however, none of these measuring methods have replaced Mil-Std-220B. IEEE 1560 still supports the continued use of the much-beleaguered matched impedance test as the preferred choice for high frequency performance characterization and for quality assurance. Additionally, the usefulness of IEEE 1560 is the fact that it addresses power quality issues and critical RF performance factors below 100 kHz for realistic loads and sources which is not addressed in Mil-Std-220B.

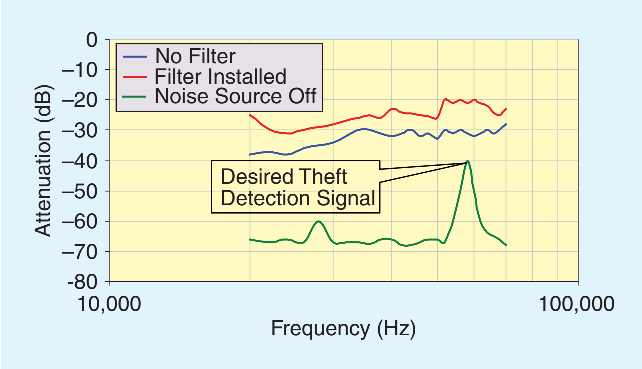

Fig. 3. Filter Gain Across the Attenuation Band.

IEEE 1560 Working Group Efforts

The IEEE EMC Standards Development Committee, Technical Committee - 4 (TC-4) – EMI Control, filter working group has been engaged in evaluating filter standards and methods of filter characterization for some time. These efforts were directed at bringing about standardized test methods for the effective measurement and specification of filters in a more realistic use. After conducting a literature search and review of several existing standards and methods, the following key areas were chosen for review:

1) Effectiveness of LISNs (Line Impedance Stabilization Networks) below 100 kHz as a source impedance
2) Standardized AC source impedances
3) Standardized product load impedances and nonlinear load characteristics
4) Waveshape quality measurements under nonlinear loading
5) AC filters used in DC applications
6) Matched impedance measurements above 10 MHz
7) Extended range from 100 Hz to 10 GHz techniques
8) Repeatable and standardized current injection test methods

The working group members considered all the possible variables that previous standards did not recognize. Figure 2 illustrates such a case when two different loads are tested at the same RMS value of current through the load and shows a difference due to inductor saturation.

As shown in Figure 2, the load characteristics are very important. These differences as well as others have resulted in numerous cases of unnecessary costs (thousands of US dollars) being spent to mitigate EMI for what might have been due to misjudging the load characteristics.

Within IEEE 1560 is guideline for the use of s-parameter data for designing power line filters. When the s-parameters can be determined, a filter can be designed by using predictive models as discussed in the standard's annex to operate maximally in a specified environment, particularly where the source and load impedances are not matched. The application of improved test methods to better determine the performance of power-line filters will also result in filter components that are less stressed in the field, as well as a reduction in component failures caused by overheating.

Figure 3 further illustrates a real world application gone wrong in an attempt to mitigate an EMI problem with a department store theft detection system, where a gain of 10 dB over the normal noise occurred instead of the expected −60 dB attenuation in the low pass filter design. In Figure 3, the desired signal to be detected is the green trace with a peak around −40 dB, the signal was captured with the interfering noise source off. As can be seen, when the noise source is on – the blue trace – it covers the desired signal by 10 dB. However, when the off the shelf filter was installed, the noise source – the red trace – was magnified by another 10 dB. This phenomenon was due to the difference in source impedance. When the suspect filter was tested in the lab using Mil-Std-220B, the filter behaved as expected. Using IEEE 1560 Method contained in clause 10.4–"Variable Source Impedance with Current Injection"–, an 8 dB gain was observed with less than 50 ohm source impedance.

Conclusion

Traditional methods for predicting the insertion loss of a power-line filter are simply not accurate at all times. Often, filters are selected based upon specifications resulting from matched-impedance, no-load testing and the impedance characteristics of different power sources and loads are overlooked.

IEEE 1560 provides a set of test methods to achieve more realistic attenuation data by using techniques of RF current injection, which can determine filter load performance and waveform quality without complicated test setups. The test methods defined in IEEE 1560 will not only give a better indication of the expected performance of power-line filters, but they will also avoid many problems associated with testing under nonlinear load and mismatched-impedance conditions, which affect the performance of power line filters.

Bibliography

[1] A. Tucker, *100/0.1 Ohm Filter Terminations and Other Extreme-Valued Affects*, 1989 International Symposium on EMC, 8–10 Sept., 1989, Nagoya, Japan, pp. 828–833, Vol. 2.

[2] H. Weidmann and W. J. McMartin, *Two Worst-Case Insertion Loss Test Methods for Passive Power-Line Interference Filters*, IEEE January 11, 1968.

[3] Heinze M. Schlicke, *Assuredly Effective Filters*, IEEE Transactions on Electromagnetic Compatibility, Vol. EMC-18, No. 3 June 1976.

[4] J.R. Fischer et at., *Evaluating filters in situ under heavy load currents and normal working impedances*, presented at the IEEE Electromagnetic Compatibility Symposium, Washington, D.C., July 1967.

[5] Robert E. Hassett, *EMI Filter Characteristics and Measurement Techniques*, Interference Technology Engineers' Master (ITEM) 1997.

[6] S. Eisbruck and F. Giordano, *A Survey of Power-Line Filter Measurement Techniques*, IEEE Transactions on Electromagnetic Compatibility, Vol. EMC-10, No. 2 June 1968.

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