OnFILTER Advantage: CleanSweep® AC EMI Filters for Real-Life Applications

Yet another EMI filter? Aren't there enough EMI filters already inside your equipment? Most likely there is at least one, often several. Yet, you are reading this document, meaning there is still an issue with EMI. OnFILTER' solution is quite different - our EMI filters are designed to provide effective noise suppression in all circumstances, not just in artificial laboratory conditions where equipment is tested for compliance with EMC regulations, such as FCC and European EMC directive (for CE compliance). Our CleanSweep® AC EMI filters excel in real-life applications where most EMI filters offer either no or little attenuation, or even amplify noise.

Figure 1. Typical CleanSweep® AC EMI Filter

Electrical noise, also known as electromagnetic interference (EMI) on power lines and ground causes problems with normal operation of equipment and may lead to equipment and component damage. EMI is a significant problem in many environments - industrial, scientific, medical, data centers, aerospace and others.

EMI generated by equipment must confirm to electromagnetic emission regulations such as CE, FCC and others (Electromagnetic Compliance - EMC). No equipment may be sold unless it complies with these regulations' requirements. Why then would a equipment in full compliance with emission standards cause problems in real-life applications? And why would equipment that behaved so well in EMI immunity tests react so poorly to electrical disturbances once installed?

There is a number of reasons for that - some have to do with the equipment itself and some are caused by issues related to installation. Either way, the problem of managing EMI in power lines ultimately rests with the end-user. Let's review most critical issues that are at the heart of these problem.

There is a big discrepancy between requirements in EMC regulations and real-life applications. Here are just a few:

Regulatory EMC Test	**Your Facility**
Controlled environment	Unpredictable and varied environment
Short cables	Long cables
Nothing else is connected	Complex network of power and ground
50 Ohm termination on input and output	Wide range of impedances from 0.1 to 1000 Ohms
Continuous-type noise measurements specifically ignoring transients	Most of noise is transients, i.e. pulses and spikes

The absolute majority of EMI filters on the market are designed to meet EMC regulations. Equipment designers are encouraged to select the lowest-cost filter that attenuates EMI just enough to pass EMC requirements in the laboratory – anything more than that would be a waste of money since in the EMC laboratory environment a better filter won't improve the product's performance or add to product's value.

Signals on Real-Live Power Lines

Most of electrical noise on power lines and ground in real-life applications is composed of transient signals, not continuous waveforms. This is largely due to the origins of noise - commutation of power, relays, solenoids, operation of servo motors and VFD, switching power supplies, light dimmers and many other sources that we don't normally think about. It is also the transient signals that cause most of EMI problems.

Transient vs. Continuous Signals

Absolute majority of noise on power lines and ground are transients, i.e. short spikes. Figure 2a shows one of most typical EMI waveforms found on power lines - periodic spikes, or transients, synchronized with the AC mains' 50/60Hz voltage. Figure 2b illustrates how a slow quasi-peak detector used in EMC test artificially represents high peak levels with artificially low quasi-peak reading. The result is that a formally EMC-compliant equipment can be a source of very strong noise on power lines and ground. In short, compliance with EMC regulations means very little when equipment is in actual use.

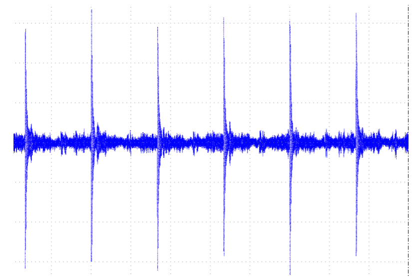


Figure 2a. Typical periodic spikes on power lines

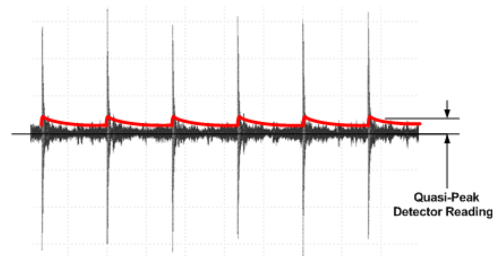


Figure 2b. Quasi-peak detector measurements of the same signal

Transformation of A Transient Signal

Most high-frequency spikes found on power lines originate as short transients with sharp rise time. However, they don't look exactly like that as they travel throughout the facility wiring. Figure 3 shows what happens with that transient signal. Facility wiring has distributed parasitic (i.e. unintentional) inductance and capacitance; wires themselves have resistance enhanced by skin effect of wires at high frequencies. Plus, other equipment connected to the same power line offers its own complex impedance. A combination of the above creates a low-pass filter with numerous resonance frequencies. The resulting waveform of such spikes looks like a much "slower" pulse with ringing determined not by the originating signal but by the complex impedance of the power line network. Figure 4 shows how a very short pulse (a) is converted to a much slower ringing signal (b). Typical spectrum of EMI signals on power lines is mostly under 1MHz. Strong ringing shown in Figure 4b have frequency of just 20kHz which wasn't present in the original signal.

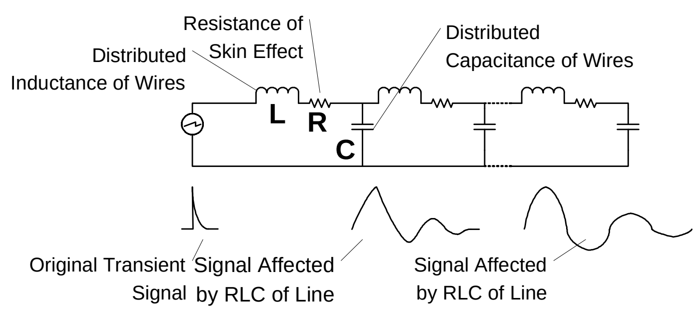
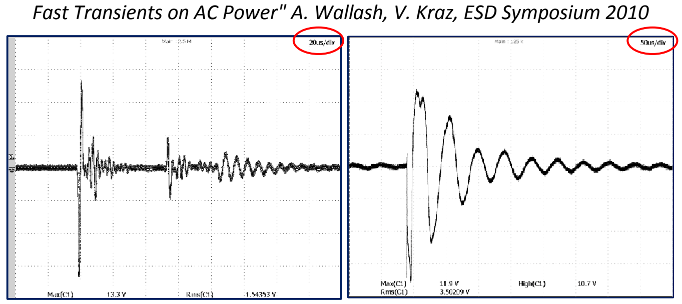


Figure 3. Transformation of a short pulse by power network
From " Measurement, Simulation and Reduction of EOS Damage by Electrical Fast Transients on AC Power" A. Wallash, V. Kraz, ESD Symposium 2010



a b

Figure 4. Original short pulse (a) is now a much "slower" pulse (b) with ringing. Note time base [20µS in (a) and 50µS in (b)]

Why would that matter and what implication does is have? Simply, an equipment manufacturer trying to comply with EMC requirements deals with short cables in the EMC lab with nothing else connected and all he sees is Fig. 4a - noise with the spectrum mostly in a higher frequency range (several MHz and above) and, according to regulations, with termination impedance of 50 Ohms. He employs EMI filter with good attenuation at these frequencies and his equipment passes the test. Once installed in your facility, your equipment delivers to its neighbors a very different signal (Figure 4b) with strong lower frequency content (tens and hundreds of kHz) for which there is no protection, either at the source in the "offending" equipment, or in the equipment that suffers from unwanted emission which may use similar power entry filter.

To illustrate it Figure 5 shows typical performance of a good-quality regular multi-stage EMI filter taken from a reputable manufacturer's data sheet. This type of filter is used for EMI compliance by many equipment manufacturers. While its attenuation is reasonable at higher frequencies - 1MHz and above, it is lacking at lower frequencies. But this is only at 50 Ohms termination as specified by EMC regulations. In real-life applications 0.1/100 Ohms (grey lines) this filter provides negative attenuation at lower frequencies, which is, of course, a euphemism for amplification. Note that the 0.1/100 Ohms curves end at 1MHz because there is no appreciable signal above it on power lines.

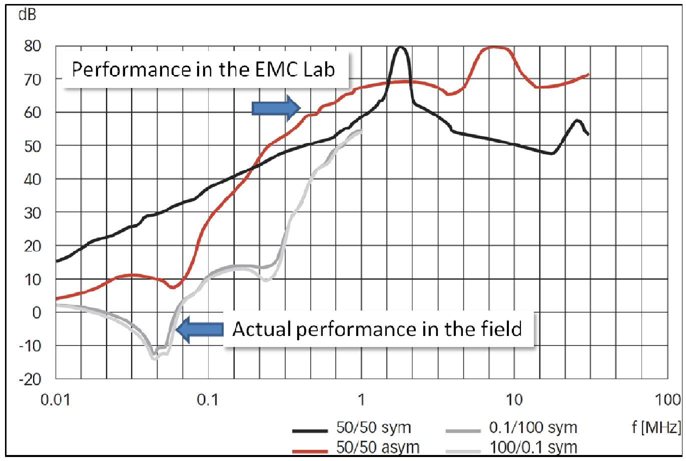


Figure 5. Typical attenuation of a regular EMC filter

Figure 6 illustrates practical implications of the filter specification of Figure 5. The upper (blue) trace in Figure 6 is noise on power line from an undetermined source (likely from some switched mode power supply); the bottom (purple) trace is noise after a good quality multi-stage EMI filter, all taken in actual application on real power lines. As seen, the noise after the conventional filter which is supposed to suppress it actually got higher. This is not a mistake - it is all in agreement with the filter's own specification as shown in Figure 5. In 50 Ohms termination the filter will hopefully perform better, but there is no power line in the world with 50 Ohms impedance.

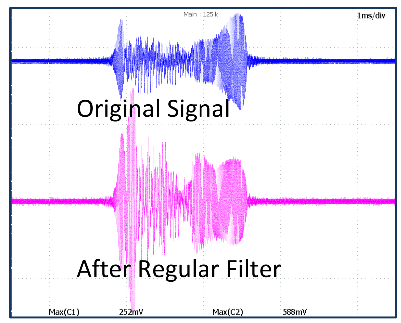


Figure 6. Regular EMC filter amplifies noise

Figure 7 shows the same power line noise passed through CleanSweep® AC EMI filter. As seen, whatever is left from noise is completely immaterial.

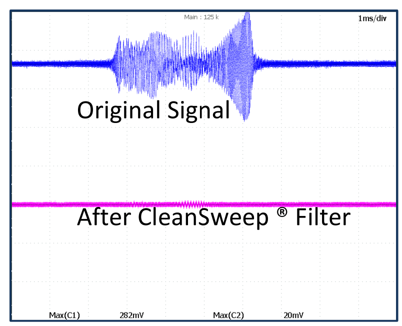


Figure 7. CleanSweep® EMI filter reduces noise

Another wrinkle in compliance test is that many regular EMI filters instead of suppressing EMI simply move higher frequency energy into lower frequency band as shown in Figure 8. This shows lower noise levels at one particular frequency, however high noise is still present, albeit "hidden" in another frequency band.

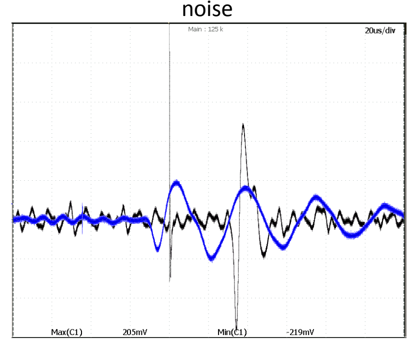


Figure 8. Shifting energy from one frequency band (black) to another (blue) by a regular EMI filter

CleanSweep® EMI Filters

Unlike regular EMC filters that are narrowly optimized for EMC compliance, CleanSweep® AC EMI filters are designed for real-life conditions where noise has broad spectrum extending into low frequencies and where termination impedance can be almost any - from a fraction of an Ohm at the source to open circuit at the load. CleanSweep® filters attenuate noise in both directions.

While designers of conventional EMI filters focus their attention on how to reduce cost while keeping minimally acceptable performance in very specific laboratory conditions, OnFILTER set a goal of achieving maximum performance in real-life applications. Figure 9 on the next page shows attenuation of a typical CleanSweep® filter in realistic 1/100Ohms environment. For comparison on the same chart is shown attenuation of a comparably-rated regular multistage filter from a reputable manufacturer tested in the same setup. Figure 10 shows typical performance of CleanSweep® filter in suppressing transient signals.

Uniquely, OnFILTER' CleanSweep® AC EMI filters provide filtering of noise not only on power lines but also on ground. Ground connects all equipment in the facility together facilitating propagation of noise. CleanSweep® AC EMI filters block this noise from reaching your sensitive equipment.

Transient Voltage Suppression

OnFILTER' CleanSweep® EMI filters perform another important function - effective suppression of strong transient voltage surges. Regular surge protectors clamp excessive voltage when it significantly exceeds peak voltage of normal power line signal (for 250V it would be 353V). This leaves power surges below clamping voltage intact. OnFILTER' CleanSweep® filters treat such transients as EMI and suppress them regardless of their voltage. Figure 11 shows how CleanSweep® filter deals with a power surge of 300V which would pass unnoticed by conventional surge protector. In combination with regular surge protectors, CleanSweep® EMI filters provide complete solution to suppression of power line surges.

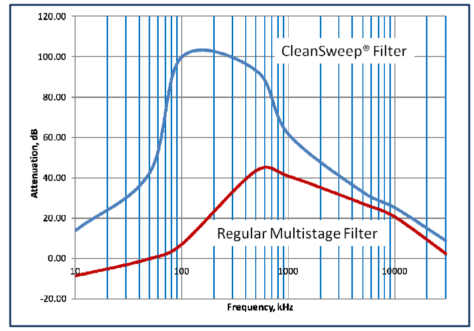


Figure 9. Attenuation of CleanSweep® EMI filter in 1/100 Ohms environment

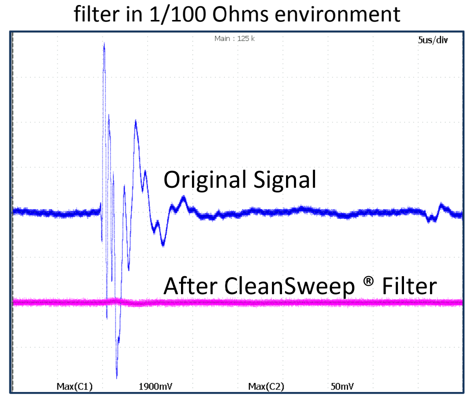


Figure 10. Attenuation of a typical transient signal by CleanSweep® EMI Filter

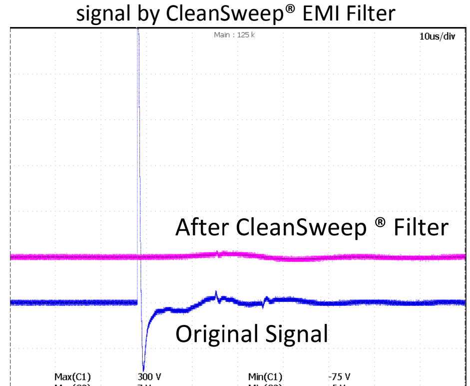


Figure 11. Attenuation of a power line surge signal by CleanSweep® EMI Filter

Filters for Variety of Applications

OnFILTER manufactures a variety of EMI filters for power lines. Our CleanSweep® AC filter product line includes filters rated at 120V and 250V; 3A to 30A with worldwide outlet options and terminal blocks. One model from CleanSweep line is specifically designed for soldering applications to prevent electrical overstress (EOS) during soldering.

Other lines of OnFILTER products include filters for servo motors and VFD, ground filters for facility and equipment, DC filters, and instrumentation for measurement of EMI on power lines and ground.

Our filters are safety-certified (ETL and CE) and are RoHS compliant. We also manufacture custom filters for specific applications. Some of our customized filters have DNV (marine) certification. Contact OnFILTER with any questions you may have. If you have some unique requirements, we may be able to help.

Conclusion

Users of sensitive electronic equipment until now didn't have many options in managing conducted EMI in their environment. A fully EMC-compliant equipment can be a source of significant noise; and when plugged into your power line and ground network, this noise gets new properties and propagates throughout the facility, causing equipment malfunction and EOS (Electrical Over-Stress) to sensitive components.

OnFILTER empowers you to resolve your EMI problems right at your facility without the need to redo the power lines and ground routing and without difficult changes inside the tools. OnFILTER' CleanSweep® AC filters plug between the wall outlet and your equipment providing it with noise-free power. Filters require no maintenance and are easy to install. Visit www.onfilter.com for complete product line and for additional technical information.