HF Technology - Technical Newsletter
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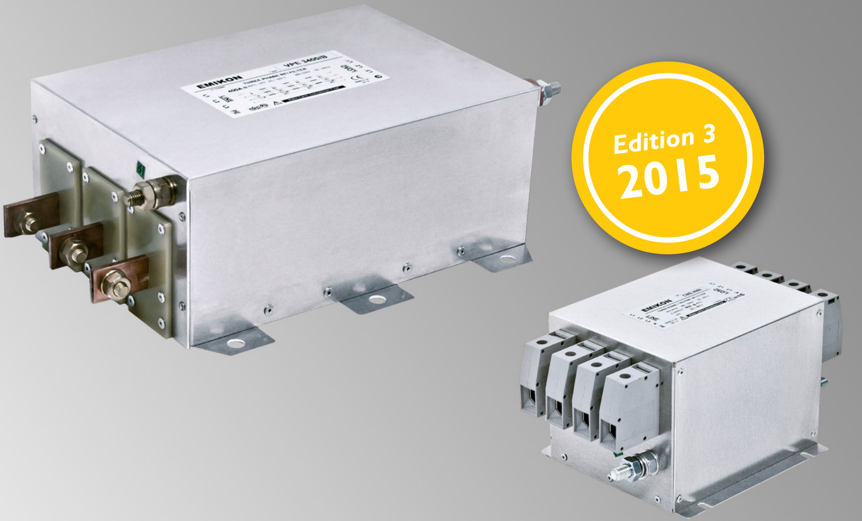
HF TECHNOLOGY



Edition 3
2015

EMI Filters

When interference is expected or a higher level of immunity is required

Filtering is used to limit the bandwidth of signals that are transferred, to pass a certain band or to exclude a certain frequency. They are often used when interference is expected or a higher level of immunity is required.

Bandwidth limitation is generally recommended as it relaxes the need for a high quality of connection in terms of EMC. This quality of connection is in EMC jargon expressed as the *transfer impedance* [Ω] and it includes connectors.

Filter types
Table 1 shows the filter types for signals that can be distinguished in general. The figures show that the input impedance as well as the output impedance have to be considered when selecting the right filter.

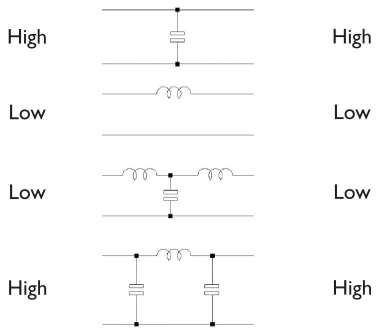


Table 1: Filter congurations.

A combination of filter topologies is also possible. Mains filters are more complex as they add attenuation for differential mode as well as common mode circuitry. An example of a mains filter is given in figure 1.

Figure 1: Example of a simple 1-phase mains filter.

The circuitry is clearly visible from the top label. It also shows where the line shall be connected to as well as the load. This implies that *the filter has an input and an output*: a non-filtered and a filtered port.

Specifications: the real world
Filter characteristics are quite often measured using generators and analyzers that have an impedance of 50 Ω. These impedances are hardly ever encountered in practice. Graph AA in figure2, for example, shows the attenuation Z for differential-mode interference. Graph Z shows the common-mode attenuation. Graph AA is taken using 0.1Ω / 100 Ω impedance according to CISPR 17.

About the author
Mathieu Melenhorst is working at Croon Elektrotechniek as specialist in lightning and EMC. Together with Dr. Ir. Mark van Helvoort Melenhorst co-wrote the book "EMC van Installaties – Op weg naar elektromagnetische compatibiliteit", issued by BIM Media, The Netherlands (ISBN 978-90-125-8552-1).

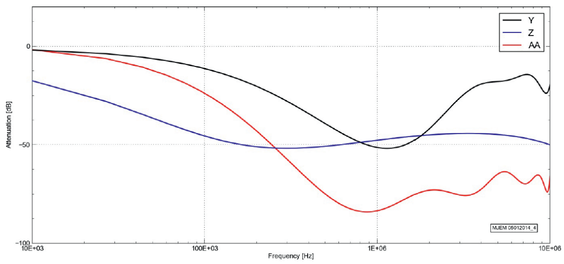


Figure 2: ***Common-mode, differential mode and mismatched filter characteristics***

From figure 2 it can be concluded that a strong impedance mismatch from the measured situation yield unanticipated results.
When *asymmetric* is specied, it refers to common mode: lines with respect to reference. When *symmetric* is specified, it refers to differential mode: line to line.

Mains Filters: separation of two Worlds
Mains filters are often used to separate to electromagnetic worlds. When properly implemented, these mains filters are to be found at the border of the two worlds or zones. An example is an EMC measurement enclosure: the mains filters are at the entrance of the room, keeping interference from the outside world, outside and preventing interference leaking from within. The same goes for cabinets: the filters are to be found at the entrance.

Mains filtering attenuate differential-mode interference as well as common-mode interference. As common-mode interference is often encountered in switching electronics like power supplies or frequency drives, this article will mainly focus on the common-mode aspects.

Keeping both worlds separated
Maximum attenuation of mains filters is obtained when the non-filtered cabling can't couple to the filtered cabling in any way. This might imply that one of these cables is optically covered. This will likely be the non-filtered cables.

Figure 3 shows an example where a wire (red) is routed in parallel to the filtered wire (green). The resulting measurement graph is shown in figure 4.

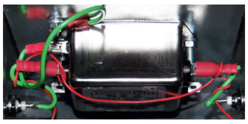


Figure 3:
Wire in parallel to filtered wire

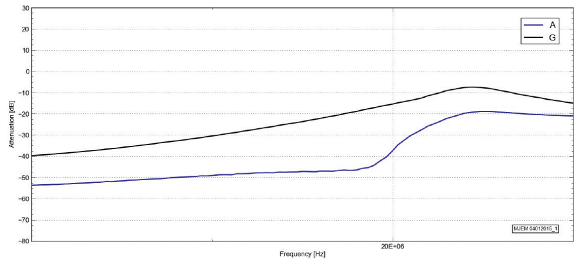


Figure 4: Parallel wire deteriorates attenuation

Graph A represents the achievable attenuation using the measurement yoke. Graph G shows that the common-mode attenuation decreases just because of the red wire that isn't connected anywhere.

Still, noise is couples from one side to the other, using this wire. This will happen in a similar way when groups of cables are neatly bundled in a cable tree.

Mounting issues
It is mandatory for every filter to operate correctly, that it is mounted the right way. This means that the contact surface area is of main importance. Mains filters are sometimes mounted on a non-conductive (painted) surface where the connection relies on a single wire. The effect on the common-mode attenuation is shown in figure 5.

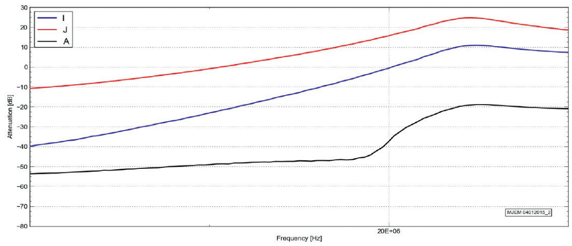


Figure 5: Attenuation affected by mounting issues.

Graph A shows the maximum achievable attenuation that is measured using the measurement yoke. Graph I shows the attenuation when the mains filter is connected to the yoke using a wire of 15 cm length. Graph J shows the attenuation with no connection between the yoke and the filter at all.

The most optimal results are achieved when the maximum surface contact is guaranteed. Figure 5 also shows that the attenuation can become negative, meaning amplication or resonance. The same effect is observed for low frequencies as figure 6 shows.

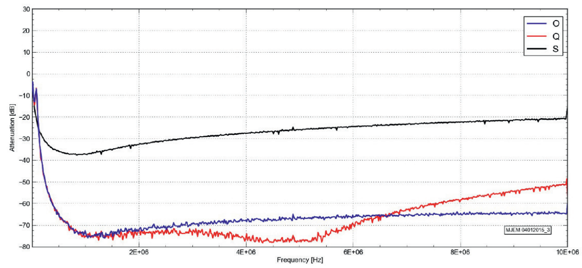


Figure 6: ***Attenuation affected by mounting issues: 0.01-10 MHz.***

It is evident that mains-related power is let-through. However, graph S shows that no connection at all provides the least attenuation. Graph Q, representing a wired connection, shows a major improvement over graph S. It is further improved connecting the case of the filter using its bottom surface as graph O shows. One can argue about the situation at 5 MHz, yet the wired contact is outperformed at increased frequencies as shown before.