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THE PROBLEM OF CORRECT CHOICE OF FERRITE BEADS

A ferrite bead is a passive electrical element used to suppress high-frequency noise in electric circuits. This is one of the simplest and the cheapest type of filters. Thus, such filters are widely used in electric and electronic apparatus for both domestic and industrial purposes. It would seem that such a wide application of these elements suggests that methods for their correct selection and use are well-defined. However, this is not quite true. Table 1, figures 11.

Key words: **ferrite, filters, electromagnetic pulse.**

Ферритовый фильтр – пассивный электрический компонент, использующийся для подавления высокочастотных помех в электрических цепях. Это один из самых простых и дешёвых типов фильтров. Очевидно, именно поэтому фильтры такого типа нашли самое широкое применение в электронной и электротехнической аппаратуре как бытового, так и промышленного назначения. Казалось бы, при такой широкой распространенности этих элементов методика их правильного выбора и применения должна быть хорошо всем известна. Увы, на самом деле все оказалось не так просто. Табл. 1, рис. 11.

Ключевые слова: **ферриты, фильтры, электромагнитный импульс.**

The ferrite bead is the simplest type of the filter: it is characterized by low cost and significant attenuation of short electromagnetic pulses (similar to high-frequency signal) in conductors connected to electronic apparatus. It is shaped as a ring (cylinder) filter put on the conductor (see Fig. 1).

Fig. 1. Ferrite Elements (FE) of Ferrite Bead Filters

The impedance of the winding consists of one or several turns of a control cable run through the ferrite ring and is too low both for low-frequency operating signals and for commercial frequency alternating current At the same time it is too high for high-frequency (short pulse) signals within the selected frequency range which depends on the number of turns, material and size of the ring itself. This results in significant attenuation of pulse and high-frequency noise penetrating such cables. Attenuation provided by such filters is in the range of 10-15 dB.

Numerous companies manufacture dozens of such filter types both miniature, designed to be installed on the printed circuit boards inside the apparatus (see Fig. 2), and those suitable for the installation on the conductor (cable) itself. For the sake of installation convenience such filters are often made as two matching semi-rings (semi-cylinders) located in snap-in plastic covers. This provides fast and convenient installation of the filters on the conductors (see Fig. 3).

Fig. 2. Miniature Filters Built Based on Ferrite Elements (FE) and Designed for Installation on a Printed Circuit Board

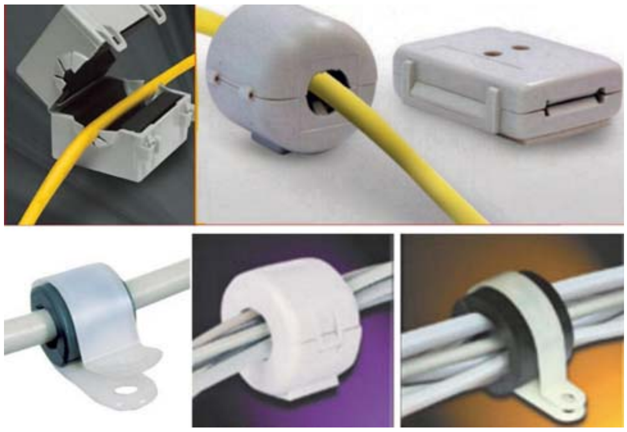

Fig. 3. Design of Ferrite Beads Providing Fast and Convenient Installation on Conductors

Such filters can be widely used in electronic equipment: in control circuits, in circuits of logical and pulse signal transmission, and in communication circuits (see Fig. 4).

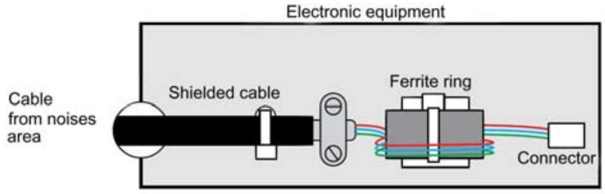

Fig. 4. Ferrite Ring Filter Installed on a Control Cable Entering the Electronic Equipment

FE-based filters are manufactured by numerous companies as given in Table 1.

Frequency ranges shown in Table 1 do not correspond to the certain filter type, but describe the frequency area provided by certain companies. Actual frequency ranges of certain filter types are much lower than shown in Table 1. Fig. 5 shows examples of frequency ranges of different types of materials used in FE manufactured by Fire-Rite Products Corp.

Table 1

Frequency Response of FE-based Filters Manufactured by Different Companies

Company name	Frequencies intervals for filters produced by companies, MHz
Fire-Rite Products Corp.	1 – 1000
Ferrishield	30 – 2450
Ferroxcube	0.2 – 200
Murata	Miniature filters for PCB mounting
NEC/Tokin	0.1 – 300
Parker Chomerics	30 – 200
Laird	30 – 2000
TDK	10 –500
Leader Tech, Inc	1 – 2450
Wurth Elektronik	Miniature filters for PCB mounting

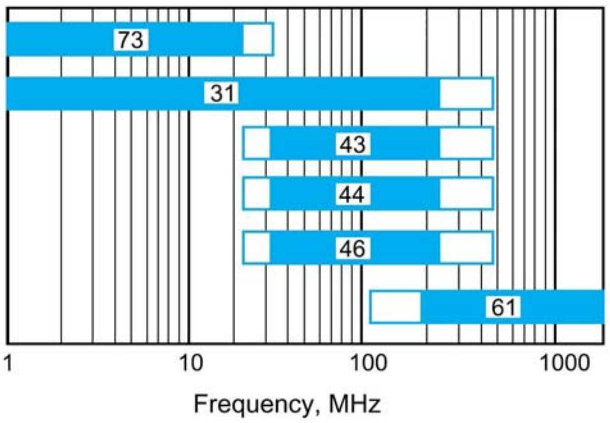

Fig. 5. Frequency Ranges of Different Material Types (designated by numbers) used in FE Manufactured by Fire-Rite Products Corp.

Despite the apparent simplicity and cheapness (1-10 USD) ferrite filters are not as simple as they seem. Their effectiveness depends on the numerous parameters, such as: material type, equivalent frequency of current pulse to be attenuated, size of FE, number of turns of the conductor passed-through the FE, the value of the DC-component in the conductor, temperature, etc.

The frequency response of the filter depends on several parameters, primarily on the FE material type. Manganese-zinc ferrites (Mn-Zn) with relative magnetic permeability (magnetic inductive capacity) μ = 600 – 20.000 are usually used for frequency range of 0.1 MHz – 2 MHz, and for 1MHz – 2.45 GHz – nickel zinc ferrites (Ni – Zn) with relative magnetic permeability μ = 15 – 2000 are used. Different ferrite mixes are also used during the manufacture.

Apart from the frequency response the impedance – is another very important parameter of FE-based filter. It defines the level of noise suppression.

To a large extent the impedance of FE-based filter is also determined by the type of material used and by the operating frequency (see Fig. 6).

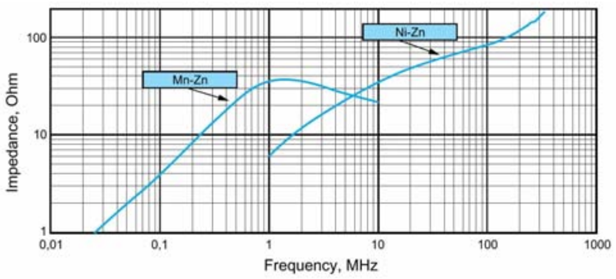

Fig. 6. Dependency of the Impedance of FE-based Filter on the Material Type and Frequency

As FE-filter has inductance, capacitance and active resistance (see Fig. 7), it is apparent that filter frequency response and impedance also depend on FE size (particularly on its length, see Fig. 8).

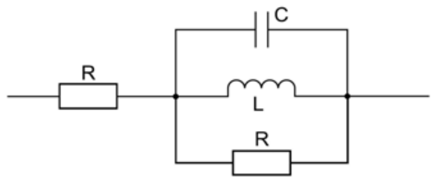

Fig. 7. Equivalent Circuit of FE-based Filter

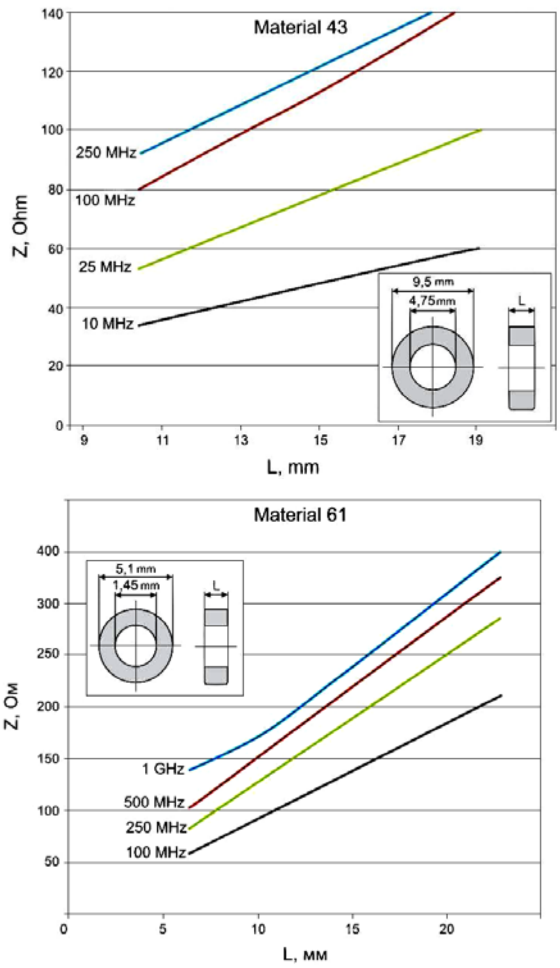

Fig. 8. Dependence of Filter Impedance Z on the Ferrite Element Length L made of two types of material (43 and 61) manufactured by the Fire-Rite Products Corp.

As shown in Fig. 8, the filters having longer FE always have higher impedance with all other parameters being equal. This results from higher inductance of filters with long FE.

To a large extent the impedance of FE-based filters also depends on the number of wire turns passed through the FE (see Fig. 9). As shown in Fig. 9 the starting impedance of the filter with several wire turns is great compared to the one-turn filter. However, the further increase in noise frequency makes filters with several turns less effective compared to filters with one turn which can result from the higher capacitance of the filter with several turns.

Also, FE-based filters have another unpleasant characteristic: their properties depend on the value of the DC-component of the passing current (see Fig. 10). This results from the change of FE magnetic properties under the existence of the DC-component of the current.

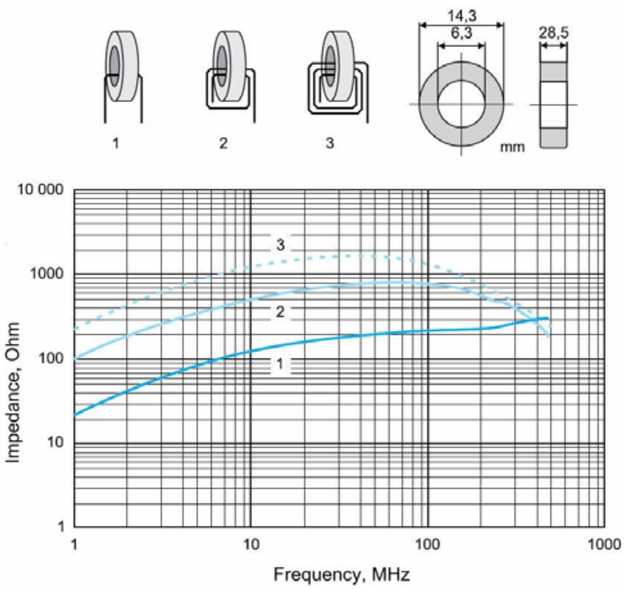

Fig. 9. Typical Dependency of Filter Impedance on the Number of Turns (designated as 1-3) Passed through the FE

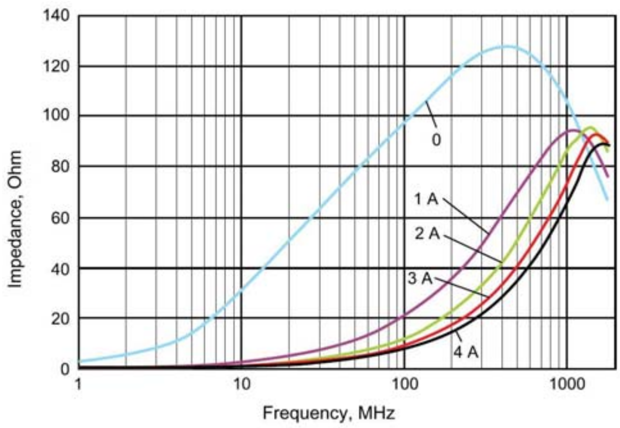

Fig. 10. Influence of the DC-component on Filter Characteristics

The presence of inductance and capacitance in the filter equivalent circuit (see Fig. 7) provokes the hazard of resonance under the certain frequencies. This can lead to another problem of such filters – such as amplification of noise instead of its attenuation.

So, if there are so many factors influencing the filter parameters, what are the basics to correctly select the filter ensuring effective protection against electromagnetic noise under a wide frequency range? It is tricky. This is especially due to 1) unavailability of standards unifying the procedure for measuring the parameters of such filters, and 2) different methods of measurement used by different manufacturers. Due to all these problems it is almost impossible to compare the parameters of filters produced by different manufacturers.

According to the above analysis the following method for the correct selection of FE-based filter can be recommended:

1. In order to ensure the effective noise suppression within the maximum frequency range it is required using at least three in-series filters installed on the same conductor (cable). Such filters should be made of different materials providing maximum filter impedance within low- (0.1 MHz), medium- (300 to 500 MHz) and high-frequency range (2 to 2.45 GHz). Three filters installed in-series on the same conductor also allows for eliminating the resonance, as they have different characteristics and thus significantly different resonant frequencies.
2. Manufacturer data can be used only for preliminary filter selection. Afterwards it is required to test the noise suppression effectiveness within the full frequency and current range needed for the customer.

This test can be done on the unit consisting of the high-frequency pulse generator simulating the noise signal within the actual frequency range, and of the receiving unit, such as oscilloscope, spectral analyzer or electronic voltmeter with the extended frequency range. The generator should be connected to the input of the receiver using the cable equipped with the filters (see Fig. 11). The measured generator output voltage within the required frequency spectrum (with and without filters installed on the cable) characterizes the value of signal attenuation on the filters and enables selecting the proper set of filters providing necessary attenuation of high-frequency signal, as well as ensuring that there is no resonance within the full frequency operating range.

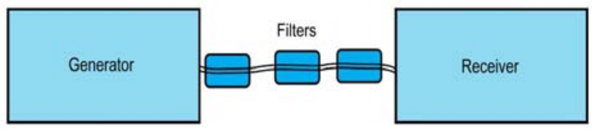

Fig. 11. Test Unit Designed to Check the FE-based filter effectiveness

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