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Radiated emissions comparison of seven-stage modal filter constructions for Ethernet 100Base-T network protection

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Radiated emissions comparison of seven-stage modal filter constructions for Ethernet 100Base-T network protection

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Abstract. The authors consider Ethernet protection devices based on modal filtering. Radiated emission measurement results for three modal filter constructions are presented. It is shown that the improved construction of a non-resistive filter has lower emission levels than the original one.

1. Introduction
Today, Ethernet 100Base-T (Fast Ethernet) technology is widely used for data transmission for the small local networks and large companies' networks organization. The main threat to such networks until recently was hacker attacks and the computer viruses, which are software implemented. However, the creation of powerful electromagnetic radiation compact generators, capable of adversely affecting electronic equipment, has significantly changed the priorities in the field of information security [1]. Today, the problem of protection against intentional electromagnetic interference is put forward as an important one [2]. Therefore, the development of devices for network equipment protection from electromagnetic interference is urgent. To protect equipment from conductive interference, surge arresters, varistors, TVS-diodes or galvanic transformer isolation are widely used. Modal filters (MF) are also proposed, in which no radioelectronic components are used, and special structures are used that facilitate the decomposition of dangerous high-voltage ultrashort pulses (USP) and up to several hundred picoseconds [3] for smaller pulses [4-6]. MF has a high resource, uses cheap material and is resistant to radiation.

The first MF constructions for Ethernet network protection were presented in [7]. The disadvantage of these constructions is that the width of the half-turns at each stage of the MF is not the same. This can lead to a high level of radiated emissions [8]. In this regard, an improved construction with aligned half-turns width has been developed [9]. The purpose of this paper is to measure and compare the radiated emissions of different MF constructions.

2. Modal filter layouts for Ethernet
MF constructions are two-sided printed circuit boards, the layouts of which are shown in Figure 1. The MF provides protection of the receiving and transmitting channels separately. MF conductors have the following dimensions: width – 0.3 mm, thickness – 0.105 mm. The conductor material is copper, and the substrate is FR-4 [10, 11]. The length of the resistive MF 1 is 2500 mm, and the length of the non-resistive MF 4 and the improved MF 4 is 1300 mm.

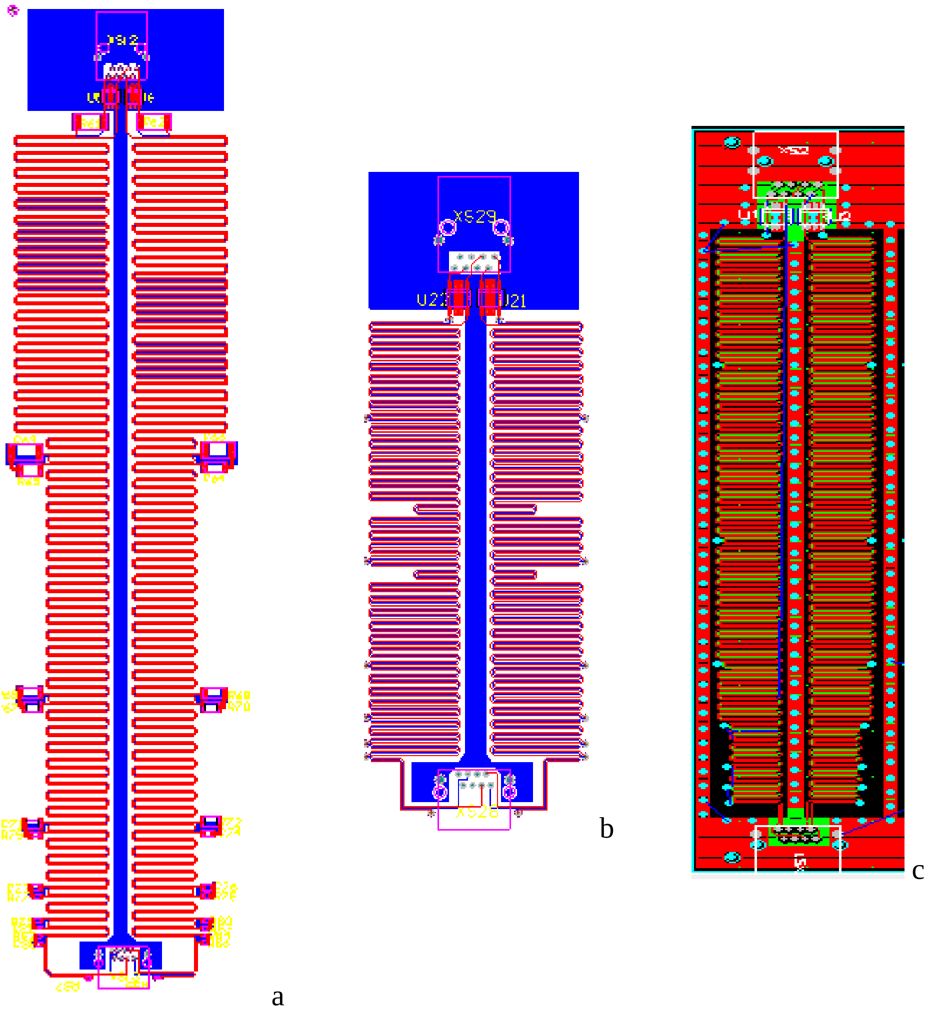


Figure 1. MF 1 (a), original MF 4 (b), and improved MF 4 (c) constructions

3. Comparison of the MF 1 and MF 4 emissions

Measurements of the emissions from seven-stage MF 1 and MF 4 were made. For this, the RSA6100B Tektronix spectrum analyzer and the magnetic field intensity sensor (Beehive electronics 100 C) were used. MFs were connected to the Ethernet network, and the field sensor was located 0.5 cm above the MF surface and moved along the MF length. The measurement results are shown in Figure 2.

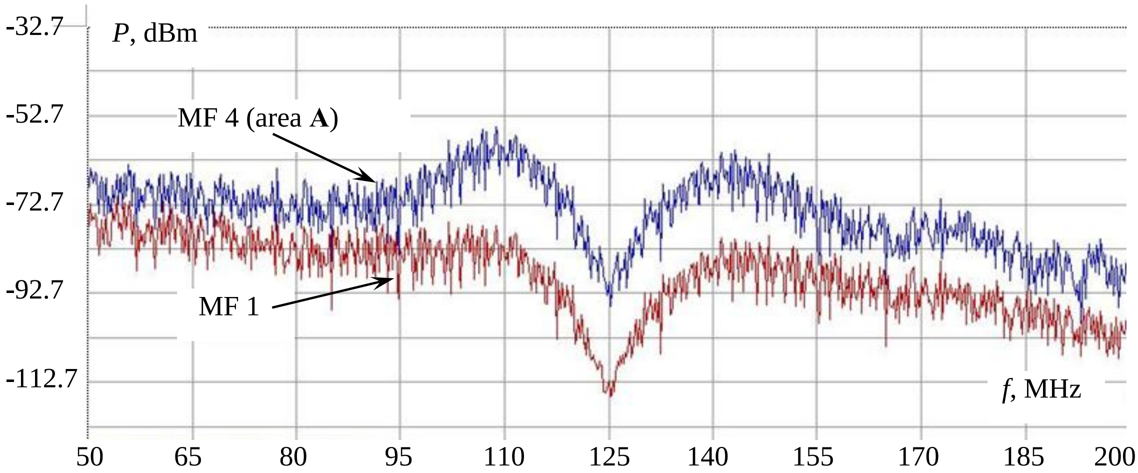


Figure 2. Frequency dependences of signal power at the RSA6100B Tektronix input of when the magnetic field intensity from seven-stage MF 1 and MF 4 is measured

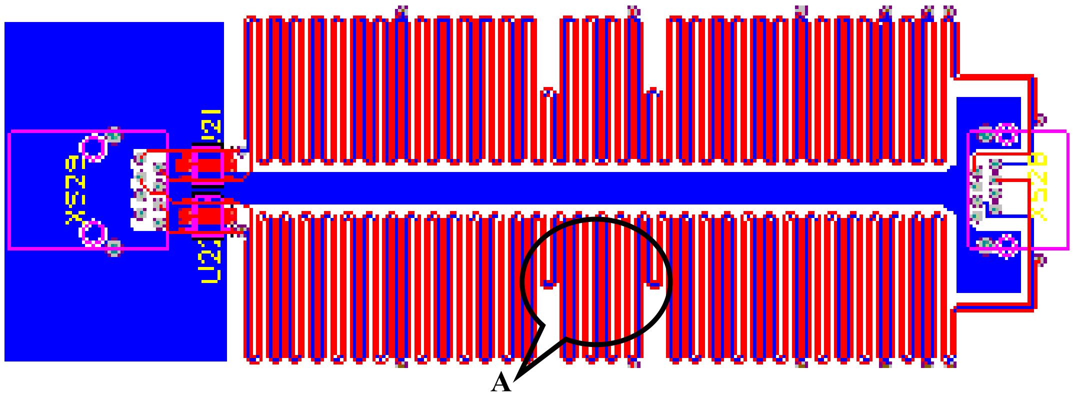


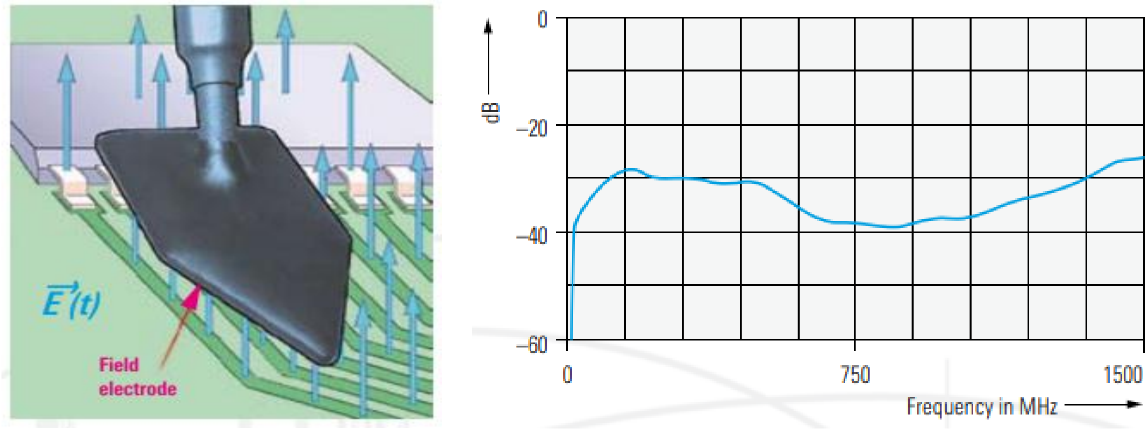
Figure 3. Measuring area of the MF 4 emission

Based on the measurements results shown in Figure 2, the following conclusions are drawn. When moving the sensor along the entire length of the MF 1, its readings do not change. In the range from 50 to 110 MHz, the power varies from minus 70 to minus 80 dBm, and at 125 MHz (the first resonance frequency) - drops sharply to minus 113 dBm. For MF 4 to section **A** (Figure 3), the frequency dependence is almost identical to MF 1. When the sensor is positioned above section **A** of MF 4 (the length of one turn decreases almost 2 times), the power is increased by 20 dBm in the frequency range from 95 to 155 MHz.

Thus, the presented experimental results show a decrease in the power of the radiated emissions from the MF at the first resonance frequency by 43 dBm relative to the power at low frequencies. In addition, an 20 dBm increase of the emissions power radiated from sections with different lengths of turns was revealed, which indicates the expediency of removing such sections in real constructions.

4. Comparison of the MF 4 and improved MF 4 emissions

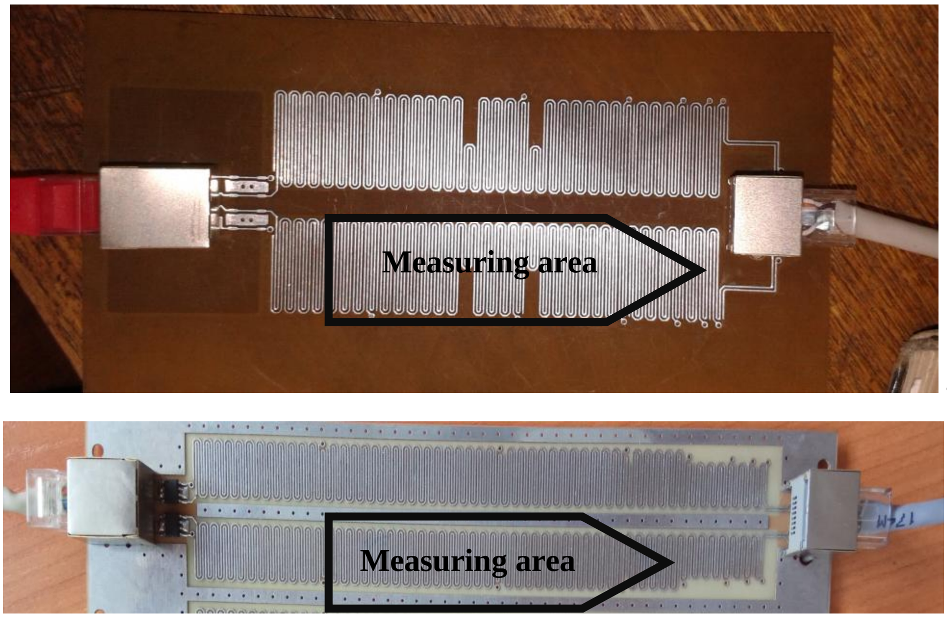
For the full-scale experiment, the electromagnetic radiation analyzer R&S ESR EMI Test Receiver was used. As a sensor, the RS E 02 probe [12] was used, which has a measurement surface area of about 2 cm×5 cm. The principle of the probe operation and its frequency characteristic are shown in Figure 4.



a b

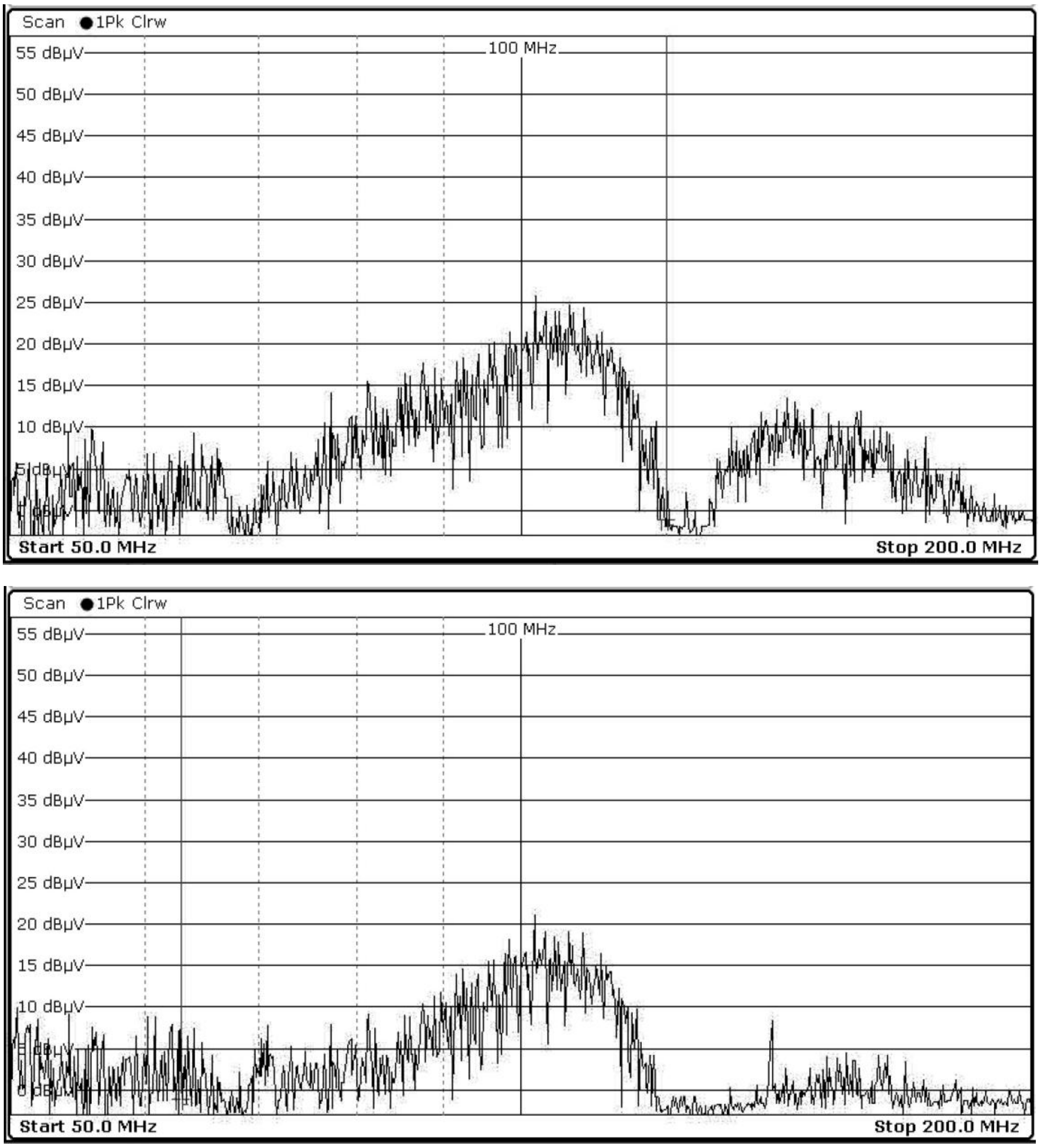
Figure 4. Principle of operation (a) and frequency characteristic (b) of the probe RS E 02

During the measurements, MFs were connected in the gap between the personal computer and the Fast Ethernet network outlet (Figure 5). Then the data transmission (audio, video, ICMP) was emulated. In the experiment, the sensor was located above the central part at a distance of 10 mm from the MF. The measurements are performed at the frequency range from 50 MHz to 200 MHz. The resulting diagrams, including the attenuator (10 dB) for the original MF 4 and the improved MF 4, are shown in Figure 6.



a
b

Figure 5. Original (a) and improved (b) MF 4 connected to Fast Ethernet



a

b

Figure 6. Voltage at the output of the electric field sensor (dBμV)
for the original (a) and improved (b) MF 4 connected to Fast Ethernet

The graphs in Figure 6 show that the resonance frequency in both cases is 130 MHz. The maximum voltage value at the sensor output when emissions are measured from the original MF construction is 25 dBμV, while from the improved construction – 20 dBμV. In addition, the maximum voltage at frequencies above the resonance frequency for the improved construction is 8 dBμV, while for the original – 13 dBμV.

5. Conclusion

In this paper, three MF constructions were considered. The presented experimental results revealed an increase in the power of the radiated MF emissions by 20 dBm from the sections with different lengths of turns, which showed the expediency of removing such sections in real constructions. It is shown that the maximum voltage value at the sensor output when emissions measured from the improved MF 4 construction is 5 dBμV less than the original construction.

6. Acknowledgments
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