

Electromagnetic compatibility tests of a measuring system based on MFC piezoelectric transducers

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Abstract. This paper discusses the issue of dependability of a measuring system from the electromagnetic compatibility (EMC) point of view. During the tests, the equipment for conducting electromagnetic compatibility tests was used. The tests were carried out in accordance with the EMC Directive 2014/30/EU and the harmonized standard IEC 61000-4-6. The measuring system equipped with non-classical piezoelectric transducers called MFC was considered. The MFC transducer was used as a sensor connected to the NI 9191 CompactDAQ Chassis. During the research, the influence of conducted disturbances on the transmission wire was examined. One of the elements of the test bench was an EM-clamp (providing both inductive and capacitive coupling) consisting of a tube of split ferrite rings of two different grades, which can be clamped over the cable under test in a non-invasive way.

1. Introduction

Designing of new, more effective and advanced technical devices is the main element of the industry development [1-5]. This is why applications of new materials and new technologies of production are very important to achieve a high technological level and to be competitive. The implementation of new technologies and materials into all kinds of technical devices is a mean key of the global industry development because they open new doors and possibilities for designers and engineers [6-11]. It causes the possibility to achieve technical means that are for example cheaper and more effective [3,10,11]. Mechatronic systems are very significant elements of the technical development because they combine elements of various fields of science in order to achieve new effects that have never been achieved before. A very important element of such kind of devices is measuring system [12,13]. In this work the measuring system equipped with non-classical piezoelectric transducers called MFC was considered. The MFC transducer was used as a sensor connected to the NI 9191 CompactDAQ Chassis. It is the 1 Slot, Ethernet and 802.11 Wi-Fi CompactDAQ Chassis designed for small, remote or distributed sensor measurement systems. The Chassis was equipped with C series voltage input module. This paper discusses the issue of dependability of such a system from the electromagnetic compatibility (EMC) point of view. Nowadays, the electromagnetic fields have to be considered during all engineering works [13,14]. During the tests, the equipment for electromagnetic compatibility tests was used. The tests were carried out in accordance with the EMC Directive 2014/30/EU. Therefore, the research was performed in accordance with the requirements of the



industrial environment standard IEC 61000-6-2:2005 “Generic standards – Immunity for industrial environments”. Generic standards specify the environment conditions, and set minimal EMI resistance that equipment in this environment must meet. Moreover, these standards also provide the general and fundamental rules for meeting the EMC requirements. The basic standard includes the test set up, test procedure, acceptable error level, and accuracy of measurements. The IEC 61000-4-x series of standards are the best known examples for basic standards. During the tests, the authors decided to conduct the research according to the basic standard IEC 61000-4-6: “Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields”. Such standard relates to the conducted immunity requirements of electrical and electronic equipment to electromagnetic disturbances coming from intended RF transmitters in the frequency range 150 kHz up to 230 MHz. The object of this test is to establish a common reference for evaluating functional immunity when subjected to conducted disturbances. The source of the disturbance is an electromagnetic field coming from intended RF transmitters (generator and amplifier) that may influence the cables connected to the equipment under test (EUT). In many cases the untested cables can behave as passive receiving antenna and affect the performance of the equipment and communication protocol.

Other test parameters were also defined in accordance with the IEC 61000-4-6 standard for industrial environment requirements – the disturbances signal was AM modulated at 80% depth, and the disturbances level were set to 10 V. During the research, the influence of conducted disturbances on the transmission wire was examined. One of the elements of the test bench was an EM-clamp (providing both inductive and capacitive coupling) consisting of a tube of split ferrite rings of two different grades, which can be clamped over the cable under test in a non-invasive way [13,15,16].

Different types of sensors are applied in almost all kinds of modern technical devices. There is a possibility to use piezoelectric transducers that can work as actuators as well as sensors because of the direct and reverse piezoelectric effects. Therefore, piezoelectric materials are getting more and more popular and are also developed all the time to get new, more effective transducers offering better piezoelectric properties and efficiency. The main advantage of the Macro Fiber Composite (MFC) piezoelectric transducers is that they are produced as thin, elastic foils so they can be glued on almost every surface or can be laminated in intelligent structures used in variety of applications, such as vibration and noise damping, excitation of vibration, sensing and so on so actually used systems can be developed [17,18]. While using MFC’s as sensors, it is important to build up the measuring system resistant to interference that can occur during measurements.

Piezoelectric transducers can be applied in modern technical means, including mechatronic systems where they can be successfully used as sensors as well as actuators [17,19,20]. Conceptions of the mechatronic systems based on applications of piezoelectric transducers are presented for example in papers [21-24]. With the development of electronic systems, they have become more and more smaller and energy-efficient. Research on energy harvesting from other, alternative sources has quickly become a new area that will avoid problems with powering systems with very low power, placed in places where the traditional power sources cannot be used. Piezoelectric transducers are very useful elements in such kinds of power supply systems [25-29].

2. Electromagnetic compatibility tests of the measuring system in laboratory conditions

In the laboratory tests two Macro Fiber Composite (MFC) piezoelectric transducers were used. Both were glued on the surface of the cantilever beam made of aluminium alloy. The first one was used for vibration excitation. It was connected to the high voltage amplifier supplied by the wave generator. Harmonic electric voltage was applied to the transducer to generate harmonic excitation of the beam. The beam was excited by the MFC transducer with frequency equal to 7.1 Hz. It was the first natural frequency of the beam. In the case of excitation with the first natural frequency it was possible to obtain the highest values of the beam deflection amplitude. It was very important to obtain the maximum value of the electric voltage generated by the second MFC transducer which was used as a sensor of the beams deflection. According to the beam harmonic vibrations the MFC sensor generates harmonic electric voltage. This electric voltage was measured using NI 9191 CompactDAQ Chassis

equipped with C series voltage input module. The scheme of the beam with two MFC transducers bonded to its surface is presented in figure 1.

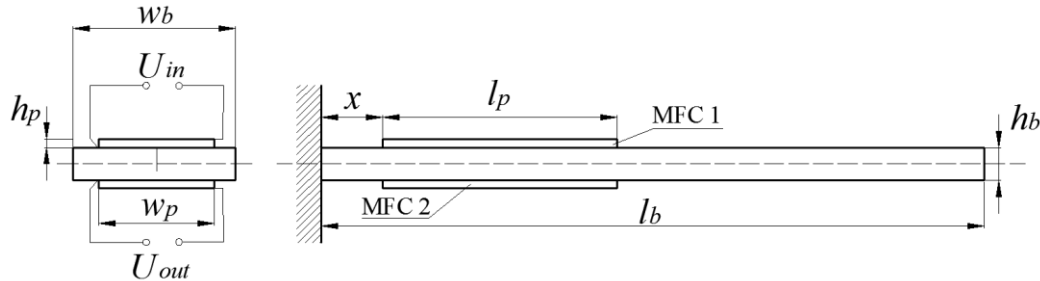


Figure 1. A scheme of the vibrating beam with two MFC piezoelectric transducers.

During the tests, the influence of conducted disturbances on the transmission wire between sensor and the measure module was examined. The test bench is presented in figure 2. The EM-clamp consisting of a tube of split ferrite rings of two different grades, which can be clamped over the cable under test in a non-invasive way was used in order to introduce disturbances into the system. The MFC sensor was connected to the measuring equipment using shielded wire but during the measurements the shield was connected as follows:

- disconnected on the both ends of the wire,
- connected only to the MFC transducer (to the negative potential wire), while the second end of the shield was disconnected,
- connected only to the NI 9191 chassis (to the ground connection on the module housing), while the second end of the shield was disconnected,
- both ends of the shield were connected properly (to the negative potential wire of the MFC transducer and to the ground connection on the module housing of the NI 9191 chassis).

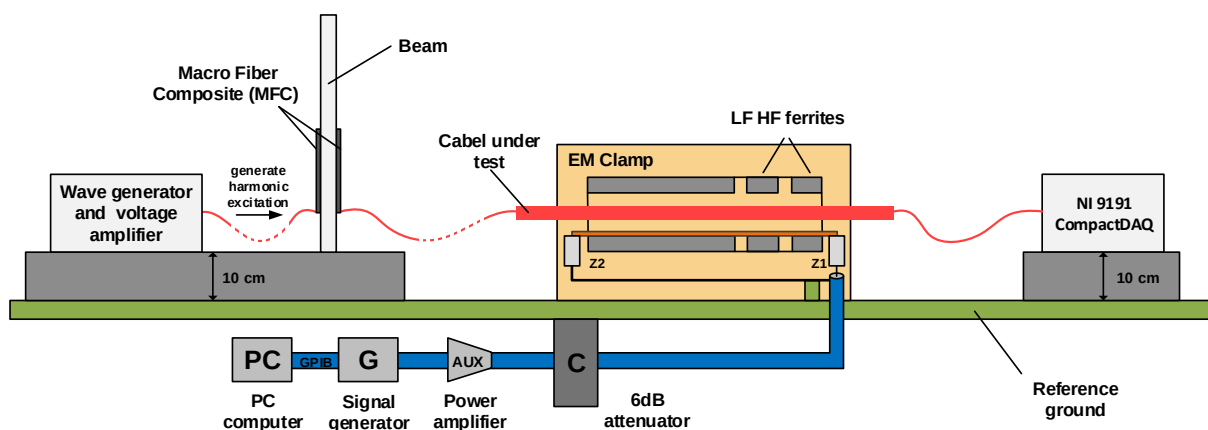


Figure 2. Test bench according to the EN 61000-4-6 standard.

During measurements the disturbances were generated on the transmission wire with agreement to the generated by the testing system signal with frequency from 150 kHz up to 20 MHz. The frequency of the disturbance was changed with the step of 100 kHz at every 3 seconds. What is more the signal of disturbance was modulated with the frequency 2 Hz.

Results of measurements of the generated electric voltage in the time domain are presented in figure 3 to 6. In figure 3 results obtained for the shield disconnected on the both ends of the wire are presented.

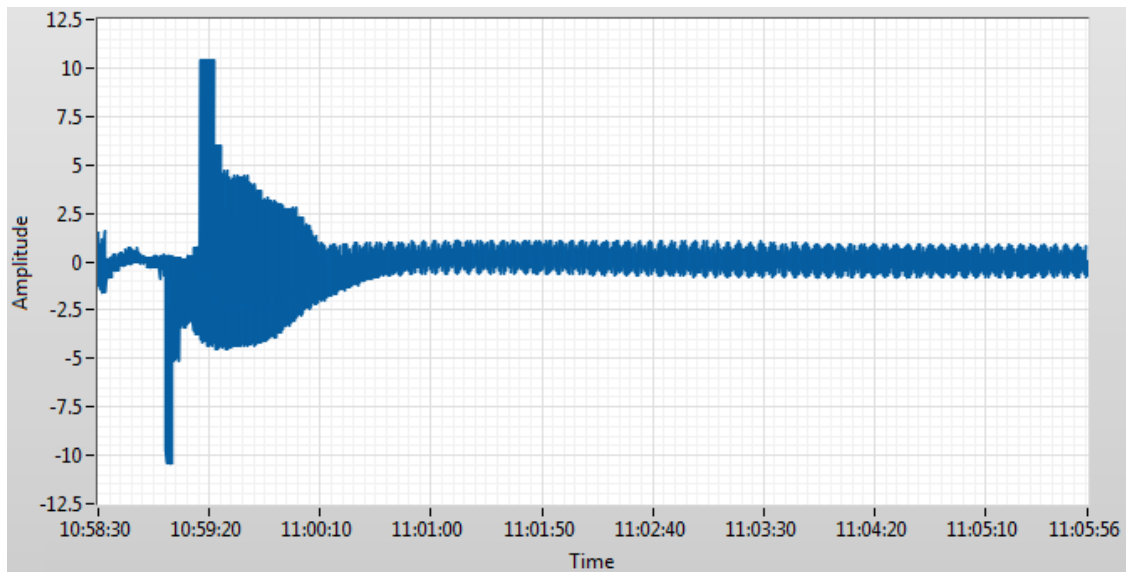


Figure 3. The electric voltage generated by the MFC transducer measured without connection of the shielding on both ends.

It could be clearly noticed that measurements were disturbed by the disturbance signal with the frequency from 150 kHz up to about 5 MHz. Similar results were obtained for the measurements with the shield disconnected on the one end of the transmission wire. What is more, the measured signal is disturbed by the frequency of disturbances up to about 8 MHz when the shield was connected only to the transducer (see figure 4) and up to about 10 MHz when the shield was connected only to the NI 9191 chassis and the second end of the shield was disconnected (see figure 5).

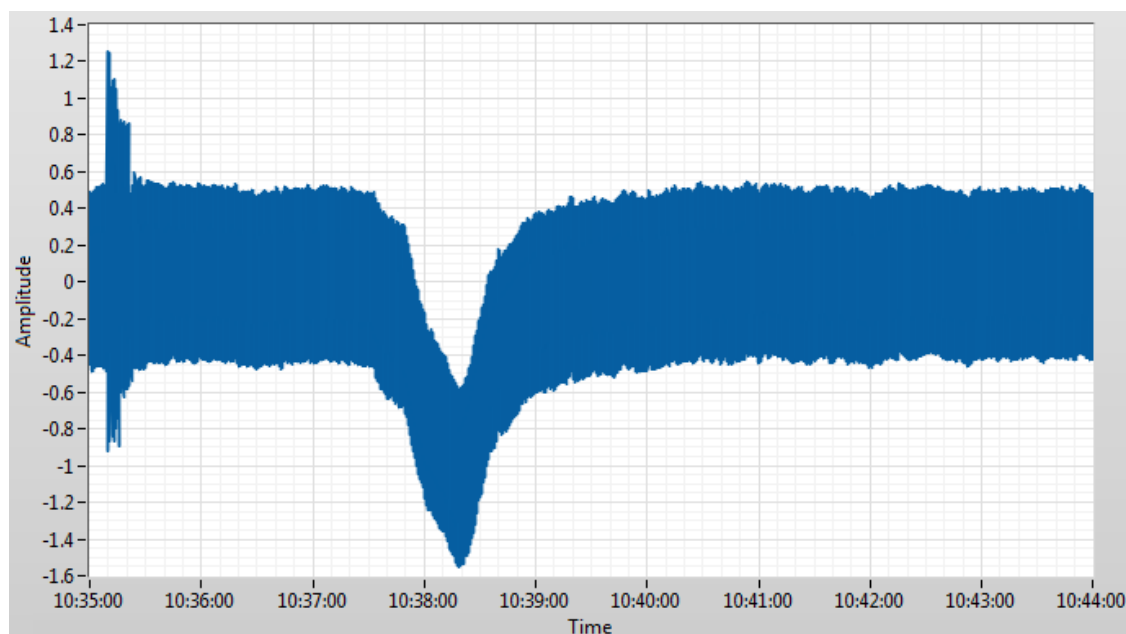


Figure 4. The electric voltage generated by the MFC transducer measured with the shielded wire, while the shield was connected only to the transducer and the second end was disconnected.

What is more, some influence of the disturbances on the measured signal could be noticed in the case of properly connection of both ends of the shield of the transmitting wire. It could be observed only in a very narrow range of the frequencies from about 500 kHz up to 1.5 MHz (see figure 6).

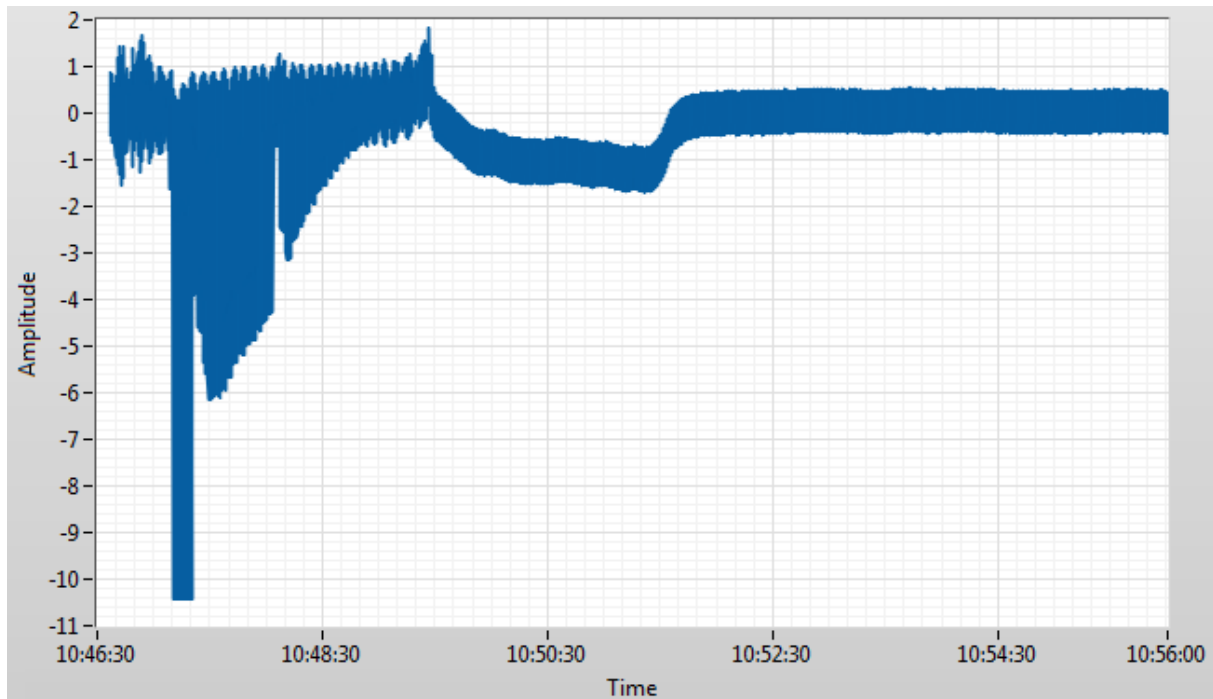


Figure 5. The electric voltage generated by the MFC transducer measured with the shielded wire, while the shield was connected only to the NI 9191 chassis and the second end of the shield was disconnected.

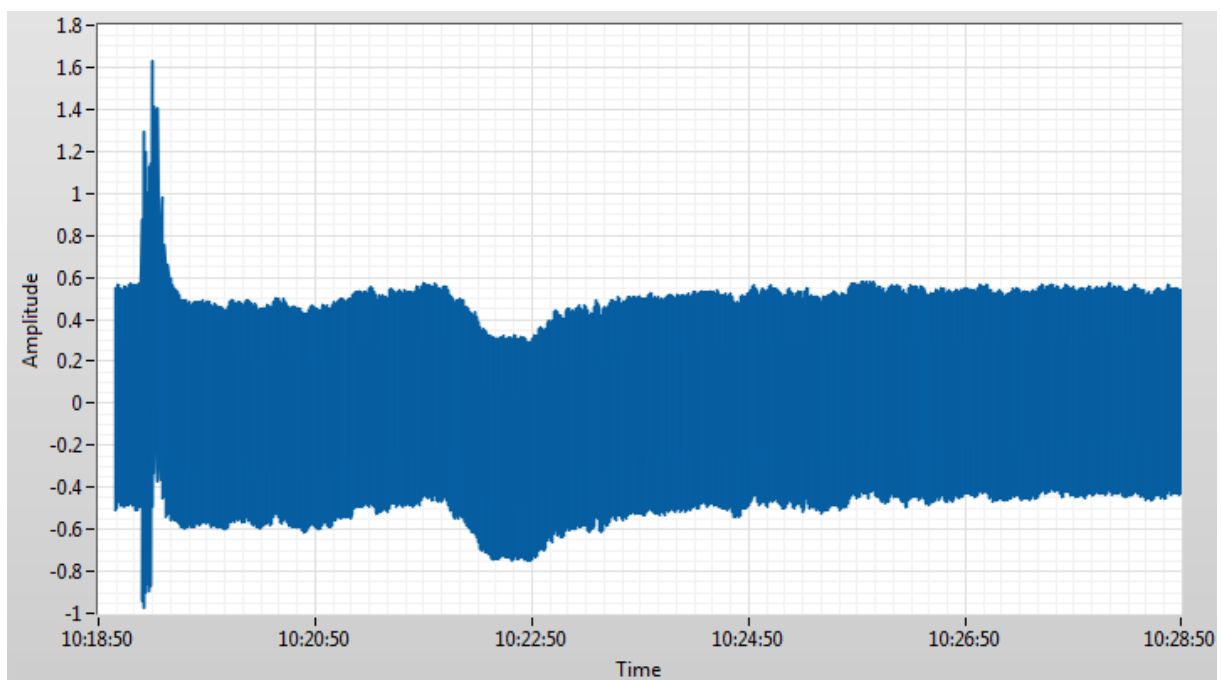


Figure 6. The electric voltage generated by the MFC transducer measured with the shielded wire. The shield was connected to the transducer and NI 9191 chassis.

In order to verify the obtained results of measurements a Fast Fourier Transform (FFT) of the measured signals was calculated. Obtained results are presented in figure 7. FFT results of the measured electric voltage in the case of measurements without connection of the shielding on both ends (the red chart) are juxtaposed with results of the measurements with the correct shielding (the blue chart).

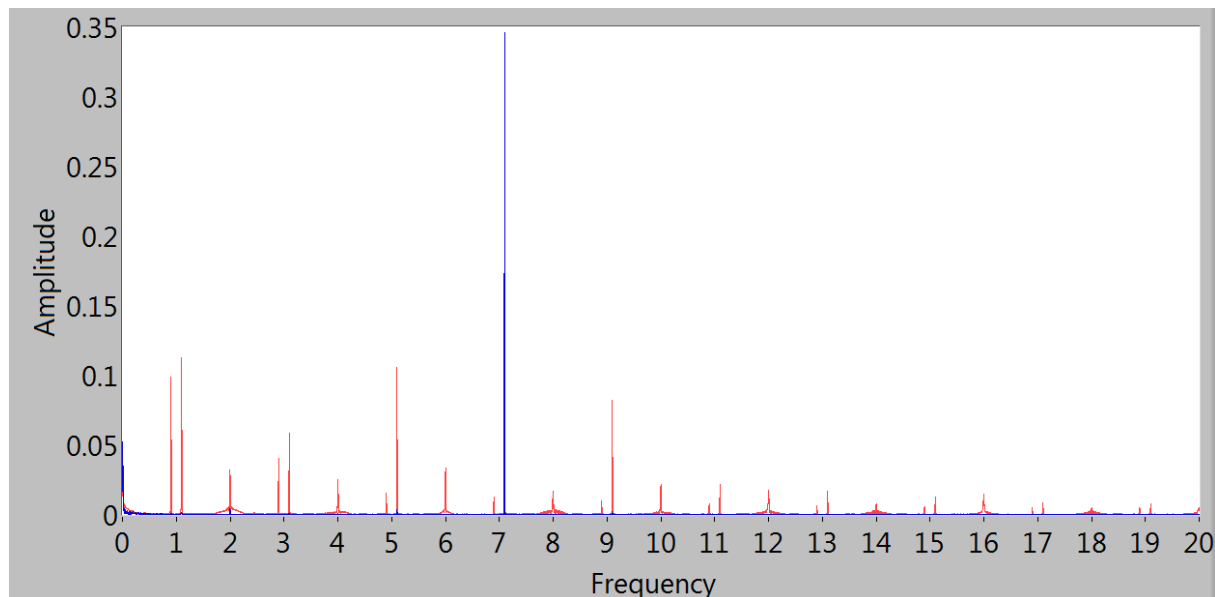


Figure 7. FFT results of the measured electric voltage in the case of measurements without connection of the shielding on both ends (the red chart) juxtaposed with results of the FFT analysis of measurements with the correct shielding (the blue chart).

3. Conclusions

It could be clearly noticed that the proposed measuring system is sensitive to the influence of conducted disturbances. Only by application of shielded wire as the transmission wire and proper connection of the shield on both ends of the wire, the influence of conducted disturbances can be eliminated. Analysing the results of the FFT analysis of measured signals presented in figure 7 it could be noticed that in the case of the properly applied shielded transmission wire measurements results are correct. During all measurements the MFC transducer was generating harmonic voltage with the frequency of the beam's excitation (7.1 Hz- the first natural frequency of the beam) and amplitude about 0.35 V. In case of improper connection of the shielding, the results of measurements are affected by the signal of disturbances. It is very important to take it into account during measurements carried-out using proposed system based on the Macro Fiber Composite sensors.

4. References

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