A COMPARISON OF DIFFERENT TYPES OF PROBES FOR DETECTING ELECTROMAGNETIC EMISSION

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Abstract: This paper deals with a comparison of different types of probes for detecting electromagnetic emission (EME). The matter of investigation is EME from a model which generates cracks of samples under load. This article provides a description of probes for EME measurement signals. The novelty of the approach lies in the fact that the physical model was used instead of real samples under uniaxial load of composite materials. The author also describes the experiment conducted for obtaining signals and analyses the digitized signals as waveforms and spectra. Appropriate conclusions were made according to the comparative analysis.

Keywords: electromagnetic emission, acoustic emission, cracks, capacitance sensor, probes

1. INTRODUCTION

Signals of electromagnetic and acoustic emissions appear during cracks generation when a solid is exposed to mechanical loading (tensile, compressive, shear, torsion, etc.). Generation of electromagnetic emission is related to electric charge redistribution during cracks creation and development and it is in the frequency range from tenths of Hz up to the gamma radiation. Acoustic emission appears due to release of elastic energy during this process and it is in frequency range of ultrasonic waves [1].

The main advantage of EME and AE is their ability to be detected already in stressed stage, which prevents the macroscopic dislocation in solids. A comparative analysis of several kinds of probes for measuring EME signals was carried out. It is possible to evaluate the possibility of measuring the electromagnetic field by means of antennas. Ideally, the ratio of noise signal measurement of the probe should be the same as in capacitance sensor or better. (More information about capacitance sensor can be found in [2]). However, it is not easy to achieve this in practice. As a result, the probe, which may be an adequate replacement of capacitance sensor, was found. This means that it can be used to measure the EME, and it will not distort the signals and measurements will be interchangeable with the measurements conducted using capacitance sensor.

2. MEASUREMENT SYSTEM

Figure 1 shows a diagram of the EME measurement using the capacitance sensor. Figure 2 shows measurement system with antennas. The AE channel consists of a piezoelectric acoustic sensor (30 kHz ~ 1 MHz), the low-noise preamplifier PA31 and the amplifier AM22 with a set of filters. The total AE channel gain is 60 dB, the frequency range is from 30 kHz to 1.2 MHz. Piezoelectric sensors from different makers are used for AE signal measurement. These sensors meet the requirements of the AE signal frequency band (at least up to 1 MHz).

The EME channel consists of a capacitance sensor, in which the dielectric is the stressed sample, a high pass-filter-type load impedance Z_L, a low-noise preamplifier PA31, and an amplifier AM22 with a set of filters. The total EME channel gain is 60 dB for antennas (and 20 dB for capacitance sensor), the frequency range is from 30 kHz to 1.2 MHz and the sampling rate is 5 MHz (50 MHz for probes of H-type). This sensor is composed of the specially made adjustable bracket with two electrodes, into which the rectangular samples of the material under study can be easily inserted. In our case, instead of the actual sample we used his model (Figure 3) in the inside of which piezoelectric elements are located. They were excited by the action of the pulse duration of 1 ms and 2 ms period. Amplitude of impulses was 10 V. Piezoelectric element able to generate electromagnetic field, corresponds to the real EME, and AE.

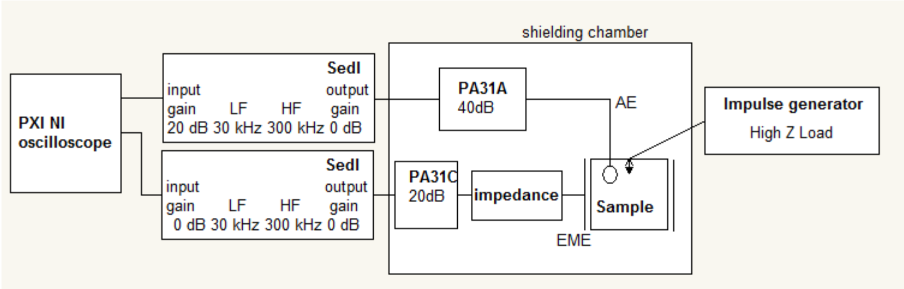

Figure 1: Measurement system with a capacitance sensor.

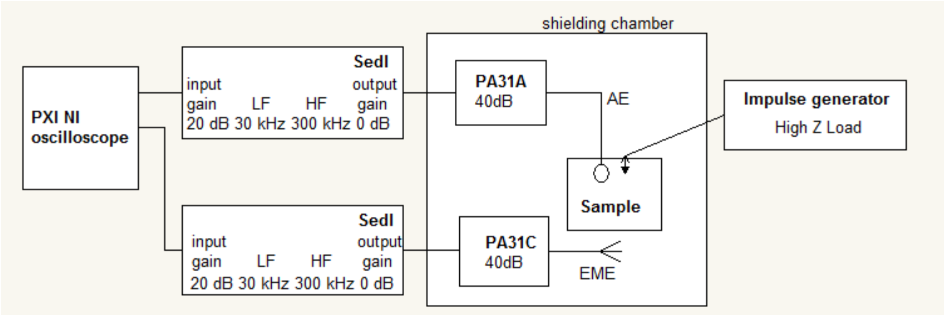

Figure 2: Measurement system with an antenna.

Both signal types, EME and AE, are sampled by a NI PCI-6111 interface card and then transferred to the computer for further processing. The entire measurement system is computer controlled, with software developed under the LabVIEW environment. The complex software package enables finding the typical events in the individual data channels, saving these events as separate files and describing their basic parameters (event start/end time, maximal amplitude, RMS value, energy, etc.). Processing and evaluation of these parameters occurs simultaneously (in real time) with the measurement process [2, 3]. Signals were digitized at a sampling frequency of 5 MHz (50 MHz for probes of H-type). Data processing was done with the program MatLAB [4].

Figure 3: Model which generate cracks of samples under load.

2.1. PRE-TESTING PREPARATION AND INVESTIGATION

Table 1 shows the parameters [5] of antennas under investigation, and presents their views. Some of them are designed to measure H-Field, others for measuring E-Field.

№	Model 7405	Probe Type	Primary Sensor	E/H Or H/E Rejection	Upper Resonant	View
1	901B	6.0 cm Loop	H-Field	41 dB	790.0 MHz	
2	902B	3.0 cm Loop	H-Field	29 dB	1.5 GHz	
3	903B	1.0 cm Loop	H-Field	11 dB	2.3 GHz	
4	904B	3.6 cm Ball	E-Field	30 dB	> 1.0 GHz	
5	905B	6.0 mm Stub Tip	E-Field	30 dB	> 3.0 GHz	

Table 1: Specifications: electrical characteristics of probes.

2.2. EXPERIMENT

Figures 4 to 5 show waveforms of signals EME measured using the capacitance sensor with a plate and the one with two plates. As we see, these figures are the same and they have low noise, and both of them have perfect impulse form. Figures 6 to 7 show waveforms of signals EME measured using antenna 6 cm Loop and antenna 3 cm Loop. Judging by these figures, they are the same and they have a high noise. Both of them have very short durations of impulses, which was found only after increasing the sampling rate up to 50 MHz. Figures 8 to 9 show waveforms of signals EME measured using antenna 3.6 cm Ball and antenna 6 mm Stub. Comparing these figures we can see that they are not the same. The impulse on figure 8 has a higher noise and a shorter duration than the impulse on figure 9.

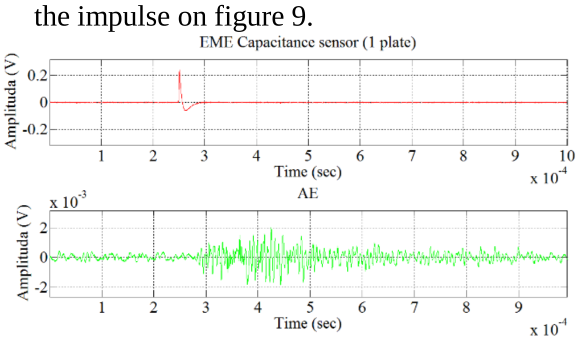

Figure 4: Continuous EME(capacitance sensor 1 plate) and AE signals.

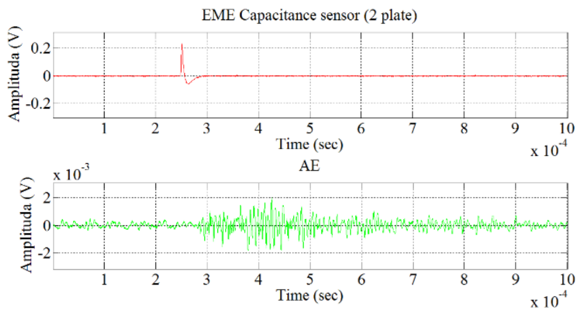

Figure 5: Continuous EME(capacitance sensor 2 plates) and AE signals.

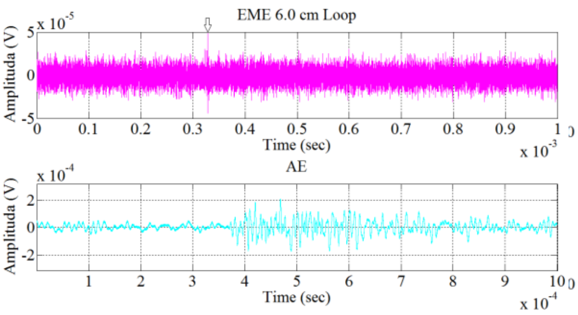

Figure 6: EME impulse from antenna 6 cm Loop and appropriate signal of AE.

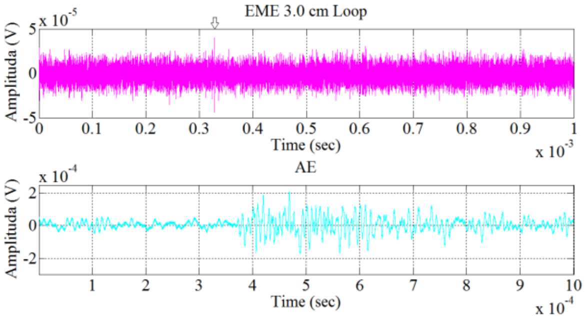

Figure 7: EME impulse from antenna 3 cm Loop and appropriate signal of AE.

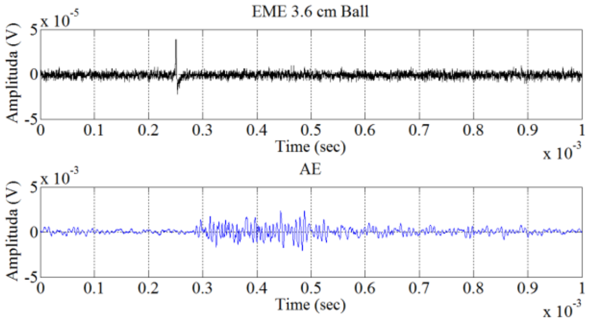

Figure 8: EME impulse from antenna 3.6 cm Ball and appropriate signal of AE.

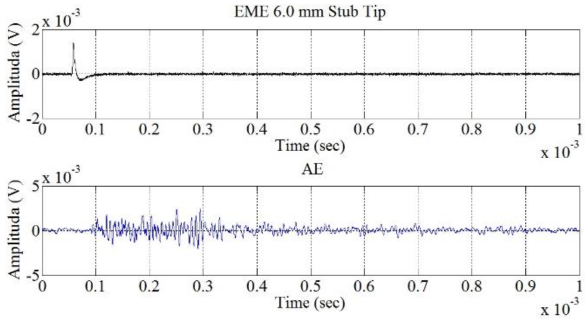

Figure 9: EME impulse from antenna 6 mm Stub Tip and appropriate signal of AE.

The capacitance sensor and antenna 6 mm Stub Tip are more suitable for measurement and detection of EME signals up to several units of MHz. The E-type antenna gives the result (waveforms and spectra of signals) which is almost the same as for the capacitance sensor. Waveform of H-type antenna is difficult to interpret.

2.3. SPECTRAL ANALYSIS

Figure 10 shows spectra of the E-type antennas and appropriate backgrounds. As we can see on this figure, the spectra of signals are not the same. The difference between spectrum of signal for 6.0 mm Stub Tip and background is 1E3. The difference between spectrum of signal for 3.6 cm Ball and background almost does not exist. Figure 11 shows spectra of the H-type antennas and appropriate backgrounds. Judging by this figure, the spectra of signals are the same. And on the frequency 9.5 MHz we can see some resonance. Figure 12 shows spectra of the capacitance sensor with a plate and the one with two plates and appropriate backgrounds. On this figure, the spectra of signals prove to be the same. The difference between the spectra of signals and backgrounds is 1E7.

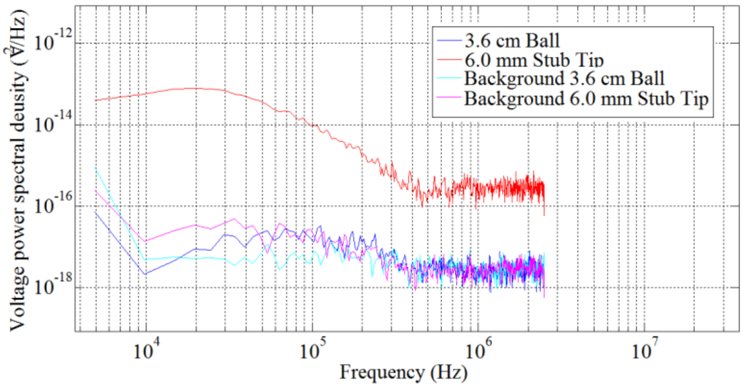

Figure 10: Voltage power spectral densities of EME impulses, comparison of E-types antennas.

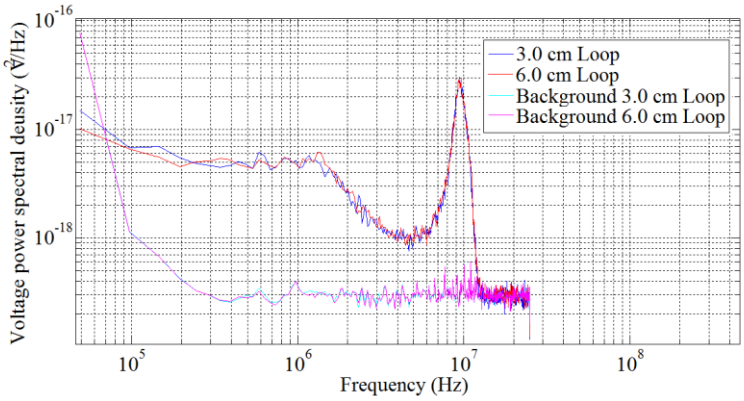

Figure 11: Voltage power spectral densities of EME impulses, comparison of H-types antennas.

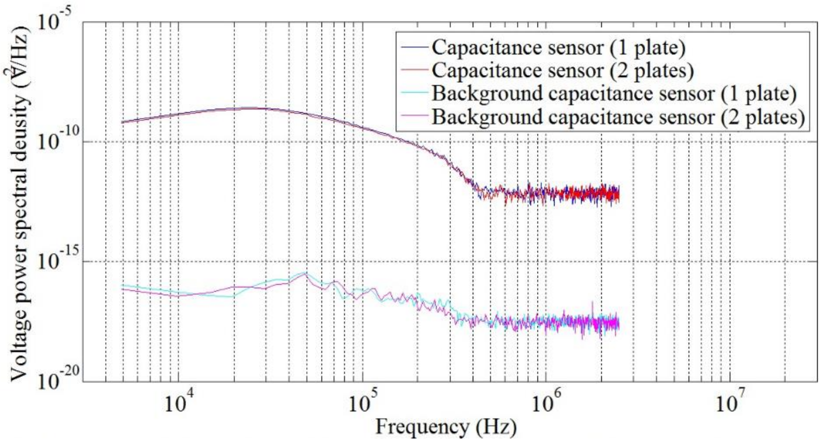

Figure 12: Voltage power spectral densities of EME impulses, comparison of capacitance sensor with 1 plate and capacitance sensor with 2 plates.

The data obtained prove that capacitance sensor and antenna 6 mm Stub Tip are more suitable for measurement and detection of EME signals.

3. CONCLUSION

The capacitance sensor and antenna 6 mm Stub Tip are more suitable for measurement and detection of EME signals up to several units of MHz.

Antena 6 mm Stub is usable for detecting only EME impulses with high amplitudes.

The E-type antenna gives the result (waveforms and spectra of signals) which is almost the same as for the capacitance sensor.

The capacitance sensor with a plate gives the same result as the one with two plates.

ACKNOWLEDGMENTS

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