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HIGH-VOLTAGE MONITORING EQUIPMENT USING ACOUSTIC PROCESSING

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Abstract: *In the last decades, naval propulsion has developed in the high-voltage domain. This domain is represented here by 3.3kV, 6,6kV and 11,5kV. The electrical energy is supplied using these voltages to lower the currents for a big power demand. These voltages used for propulsion and reefers have the advantage of being more efficient than the conventional low voltages.*

The monitoring of the equipment that produces high-voltage energy is done with thermo-vision cameras and insulation resistance measurement. Our project proposes a different monitoring using acoustic holography.

High-voltage equipment produce noise that can be identified using vibration and acoustic measurements. The high-voltage equipment onboard commercial ships emit noise from electromagnetic components in the medium at high frequency range. As noise sources, the power transformers, inductors, switchers etc. represent sources that can be investigated using acoustic holography and thus the noise produced by each of them can be determined. The noise from these components is in the 20Hz-20kHz frequency range, and sometimes over 20 kHz. Many of the noises produced by the equipment are in the audible domain and so they can be heard during functioning.

One of the advantages of this technique is that it is a non-invasive technique. It uses a microphone array that is placed around the equipment and thus the noise emitted by the equipment is mapped. The technique is similar to the intensimetry method, but here is measured the sound pressure level instead of sound intensity level. Thus, the results can be correlated rapidly with the noise limits from the standards that are expressed in terms of SPL (Sound Pressure Level).

Key words: High Voltage, monitoring system,simulation,Sound Pressure Level

INTRODUCTION

In the last decades, naval propulsion has developed in the high-voltage domain. This domain is represented here by 3.3kV, 6,6kV and 11,5kV. The electrical energy is supplied using these voltages to lower the currents for powering the refrigerated containers, namely the reefers. These voltages used for propulsion and reefers have the advantage of being more efficient than the conventional low voltages.

The monitoring of the equipment that produces high-voltage energy is done with thermo-vision cameras and insulation resistance measurement. Our project proposes a different monitoring using acoustic holography. Other types of modern approaches on HV monitoring are presented in [1]–[6]. High-voltage equipment produce noise that can **be identified using vibration and acoustic measurements**[7], [8].The high-voltage equipment on-board commercial ships emit noise from electromagnetic components in the medium at high frequency range. As noise sources, the power transformers, inductors, switchers etc. represent sources that can be investigated using acoustic holography and thus the noise produced by each of them can be determined. The physical phenomena behind the noise produced by these components are: magnetostriction, commutation, electrical current circulation. Another phenomenon is the corona effect, but is associated with **voltages that are rarely**. The technique is similar to the intensimetry method, but here is measured the sound pressure level instead of sound intensity level. Thus, the results can be correlated rapidly with the noise limits from the produced on-board ships. The noise from these components is in the 20Hz-20kHz frequency range, and sometimes over 20 kHz. Many of the noises produced by the equipment are in the audible domain and so they can be heard during functioning.

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THE MATHEMATICAL APPROACH

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The Figure 1 illustrates the geometry of the measurement problem. The sound pressure is measured over a plane *z* = 0 in the near field region of a sound source. All parts of the source are assumed to be in the half space *z* < –*d*, *d* being the smallest distance between the source and the measurement plane. The half space z ≥ –*d* is assumed to be source-free and homogeneous. The time domain sound pressure field *p* (**r**,*t*) fulfils the homogeneous wave equation in the half space z ≥ –*d*:*c*being the propagation speed of sound.

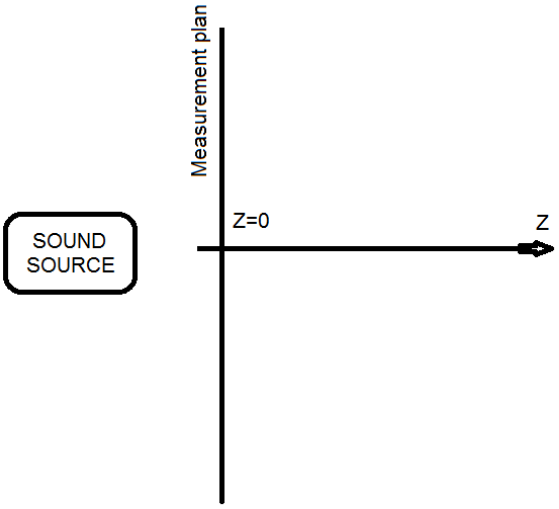

Figure 1. The geometry of measurement problem

$$\nabla^2 p - \frac{1}{c^2}\frac{\partial^2 p}{\partial^2 t} = 0 \quad z \geq -d \qquad (1)$$

$$p(x, y, z, t) = \frac{1}{2\pi^3}\iiint_{-\infty}^{+\infty} P(k_x, k_y, z, \omega)\, e^{-j(k_x x + k_y y - \omega t)}\, \delta k_x \delta k_y \delta\omega \qquad (2)$$

LabVIEW SIMULATION

$$P(k_x, k_y, z, \omega) = \iiint_{-\infty}^{+\infty} p(x, y, z, t)\, e^{j(k_x x + k_y y - \omega t)}\, \delta x \delta y \delta t \qquad (3)$$

$$\left(\frac{\partial^2}{\partial z^2} + k_z^2\right) P(k_x, k_y, z, \omega) = 0 \qquad (4)$$

$$P(k_x, k_y, z, \omega) = P(k_x, k_y, 0, \omega)\, e^{-j(k_z z)} \qquad (5)$$

For any given *z*-coordinate, we now introduce the following Fourier transform pair of sound pressure in three dimension (*x*,*y*, *t*): This pair exists for any *xy*-plane with z ≥ –*d*. If we insert the Fourier transform expression (2) for *p*(**r**,*t*) into the wave equation (1) and take the Fourier transform, we obtain the following one-dimensional differential equation in *z*: Here, *k* ≡ ω/*c* is the wave number, ω is the temporal angular frequency and (*kx*,*ky*) are the spatial angular frequencies. When all sources of the sound field are in the half space z < –*d*, then the complete solution to (4) can be written as (5): where *kz*is a function of the angular frequencies (*kx*,*ky*,ω). The circle in the spatial frequency plane which is defined is called the radiation circle. High spatial frequencies outside the radiation circle (evanescent waves) are seen from (5) to be exponentially attenuated in the direction away from the source. Since the sound pressure field is measured in the plane *z* = 0, the plane wave spectrum *P* can be obtained from equation (4) with *z* = 0. Equations (5) then allow the sound pressure field *p* for any z ≥ –*d* to be calculated.

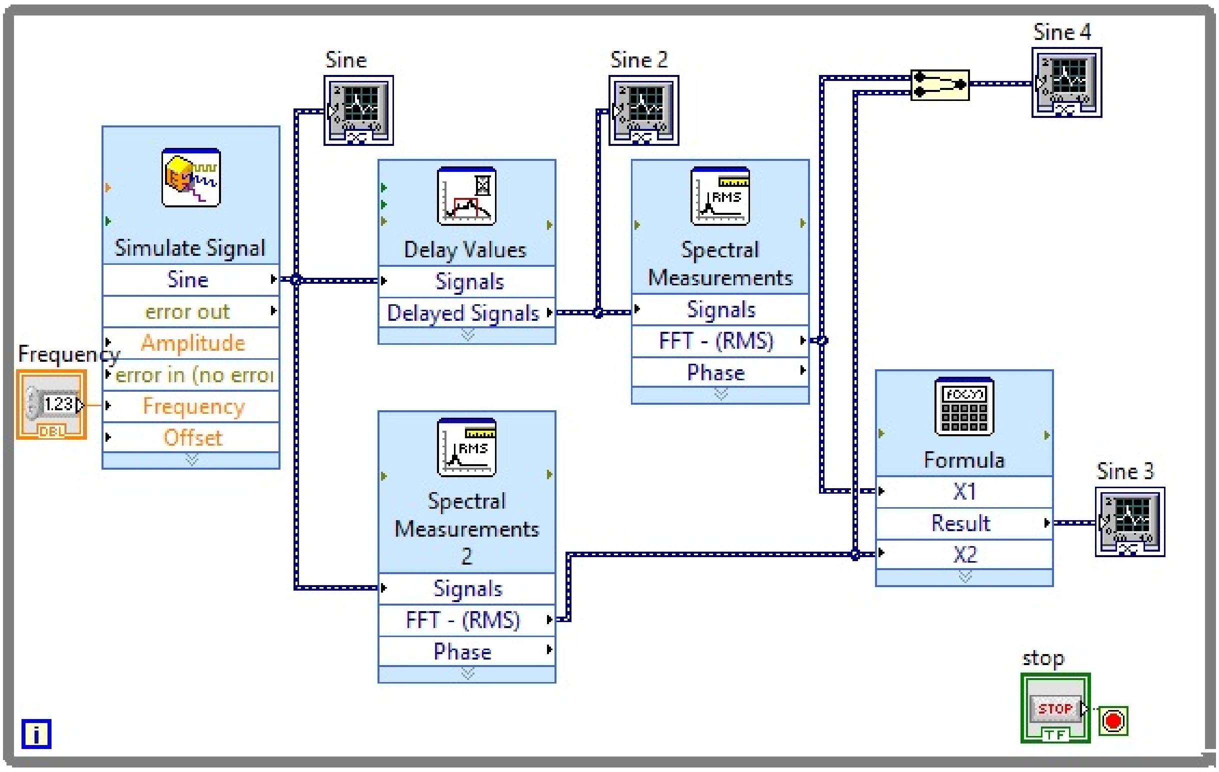

Figure 2. Block diagram of the HV monitoring equipment in LabView

The Figure 2 represents the block diagram of the operational principle simulation. It is simulated a sinusoidal signal at 1 KHz, which is applied to a FFT virtual instrument and also to a delay virtual instrument. After the delaying block it is also applied a FFT. Both signals from FFT blocks are compared in Formula block and displayed on a graph. As you can see in the Figure 3 the signal is constant over our time check window. This means that the HV equipment works proper.

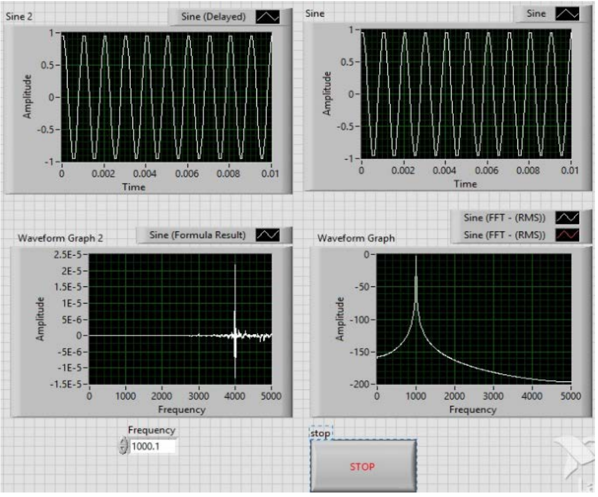

Figure 3. Front panel results for no disturbing signal

In the Figure 4 the signals are different which means that the sound emitted by the HV equipment has changed significant. It is easy to notice the both signals 1000 KHz (the good one) and 2000 KHz (the unwanted one) in the right hand bottom side graph. Also in the left hand bottom side graph one can see the resulted signal after comparison, which has a significant amplitude. This amplitude level can trigger an alarm.

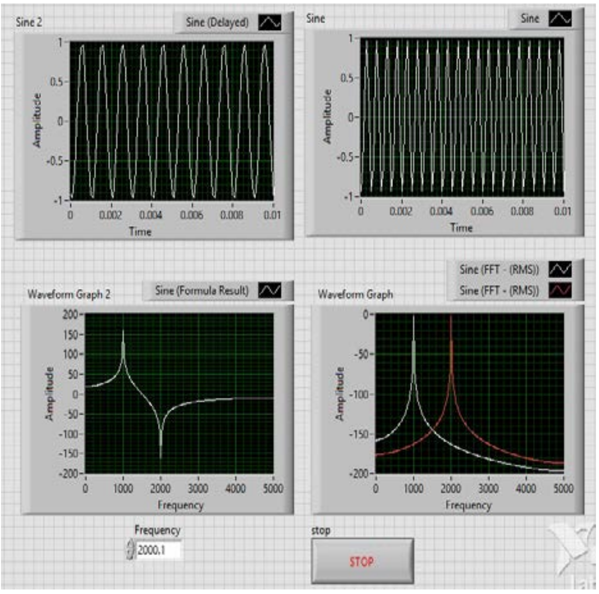

Figure 4. Front panel results with a disturbing signal

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Conclusion

The simulation shows that the idea to compare the direct signal and delayed signal over a time window is working well. This method can be used to create a monitoring system which can detect in real time a malfunction of an HV equipment. In the future we will do experiments with a demonstrator to prove the simulated results obtained at this stage of research.

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