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MECHANICAL RESONANCES SEARCH ON THE HELICOPTER EQUIPMENT APPLYING THE BANG TEST

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Abstract. *This paper presents the requirements, procedures for testing to search the resonance on the embedded equipment and the results obtained. During flight mission, a helicopter's structure undergoes significantly dynamic loads from aerodynamic flow and vibrations induced by the engine and rotors. For a first installation of equipment on a helicopter or when modifications are made, the potential change in structural behavior can be critical and it is recommended to perform a test of resonance search, a so called bang test, in order to check if there is no mechanical resonances of these equipment near to the main excitation frequencies of the helicopter. Measurements were performed on helicopter on jacks, equipment completely wired and without dampers at the bang test; pulse excitation is generated by an impact hammer, according to X, Y and Z axes. Measurement of the acceleration response, in the opposite pulse direction, was performed applying an impact on the equipment with 5 impacts/measurements in which axes. Measurements were performed on the Antenna in order to find the natural frequencies and compare with the main frequencies of the helicopter. Two frequencies were found 28Hz and 106Hz in the three axes and this behavior was due to geometry of the Antenna.*

Keywords: *Helicopter, Structural modification, Bang test, Mechanical resonances and Vibration modes.*

1. INTRODUCTION

Ground resonance is instability on helicopters when the rotor is spinning on or near the ground, and that probably result in the destruction of the structure (Nahas,1984). Ground resonance is one of the most dangerous situations a helicopter pilot can face (Jhinaoui *et al*, 2010). At first installation of an optional on helicopter, it is recommended to make sure that there is no mechanical resonance by performing a so called bang test; the results of this test qualify the equipment to be installed without interference with the primary resonance modes of the helicopter structure caused by the rotor excitation.

This type of test is often preliminary with a measurement flight and the objectives are: The indication of the frequency ranges to be monitored during the analysis of the measurements in flight (if needed) and validation of the equipment tested in order to use it in normal flight conditions. The bang test has also a direct safety aspect and it has therefore to be achieved imperatively before the first flight and results are to be reported and communicated to the flight test team in charge of evaluation.

The applications are multiple and have to be done on the mechanical assemblies concerning elements of flight test installation such as on board computer, recorder, panel, nose boom wind vane, camera; the optional external ones such as sight, armament, additional tank, winch, antenna, rear view mirror, radar, infrared camera, land gear, and the avionics equipment such as: radio, computer, battery.

The bang test can also be used during development for simple evaluation such as model adaptation or for quantification of a given modification on the structure: stabilizer, flap, running board, dashboard, resonator; the mechanics: flight control systems, pump, power unit, nozzle, pipe and finally isolated components: blade suspended into free/free and shafts.

Generally one will perform a bang test on any equipment likely to present a mechanical resonance near to the main excitation frequencies of helicopter in most cases $b\Omega$ and multiple where b is number of blades and Ω is related to the rotor speed (Jhinaoui, *et al.*, 2010); in general main rotational speeds of the drive system in the tested environment.

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2. SET UP VALIDATION

The aim of this test set-up is a simple test to verify the overall testing set. An aluminum bar fixed on the structure was used as Device Under Test (DUT), Hammer excitation was applied at fixed point of the structure and an accelerometer was roving through the aluminum bar, in the same axes of the excitation, in order to make the measurement. The data acquisition and analysis were performed using the software called LabShop® from Brüel & Kjer (B&K).

2.1 Analyzer setting:

The following settings were used to configure the data acquisition equipment.

- ✓ **Channel 1:** Impact hammer; **Transducer nominal sensitivity:** 2.27mV/N;
- ✓ **Channel 2:** accelerometer; **Transducer nominal sensitivity:** 10mV/(ms^{-2});
- ✓ **High pass filter:** 0.7 Hz;
- ✓ **Bandwidth analysis:** 100 Hz/400 Lines; **Resolution:** 250m Hz; **FFT time:** 4s;
- ✓ **Window:** Transient (hammer) and Exponential (accelerometer);
- ✓ **Average type:** linear; **Average number:** 5; **Overlap:** Fixed;
- ✓ **Trigger:** channel 1 (delayed 40ms);
- ✓ **Analysis mode:** Baseband; **Center frequency:** 50 Hz;

2.2 Window adjustment :

The leakage can be minimized using the correct weighting functions referred to as a window and was applied to the hammer and measured data. Based on (Schwarz and Richardson, 1999), the transient window preserves the samples in the vicinity of the impulse and removes the noise from all of the other samples in the force signal by making them zero. The exponential window is applied to the impulse response signal and also is used to reduce leakage in the spectrum of the response forcing the signal decays to zero at the end of the sampling window.

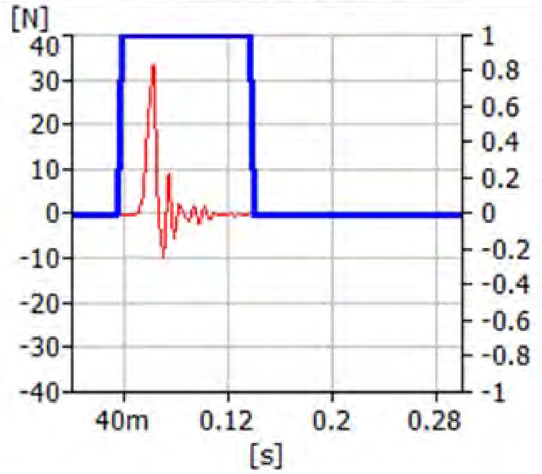
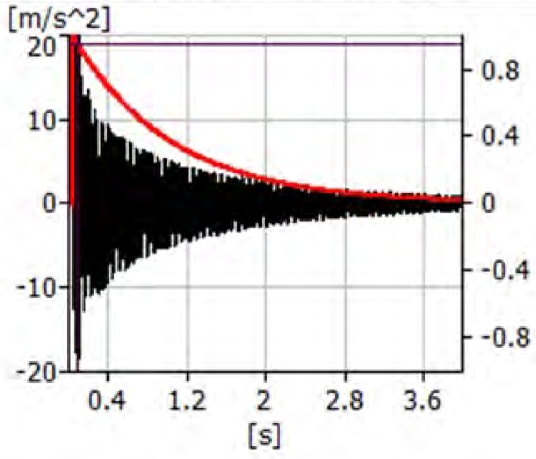
<table>
<tr><th>Hammer excitation</th><th>Accelerometer measured</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Window: transient (blue)</td><td>Window: exponential (red)</td></tr>
<tr><td>Shift: 40 ms</td><td>Shift: 40 ms</td></tr>
<tr><td>Length: 100ms</td><td>Lenght: 1 s</td></tr>
</table>

Figure 1. The transient and exponential windows.

2.3 Tip Hammer Validation

The rubber tip used in the hammer to excite the structure should be validated to force the data better satisfy the periodicity and the time of the Fourier Transform process, thereby minimizing the distortion effects of leakage. The input spectrum must excite all the frequency range (100 Hz) and the decay has to be below the 10dB (Schwarz and Richardson, 1999), Figure 2 shown that the chosen tip was appropriated, the decay achieved was 4.5dB and the response was well characterized inside the 100Hz bandwidth.

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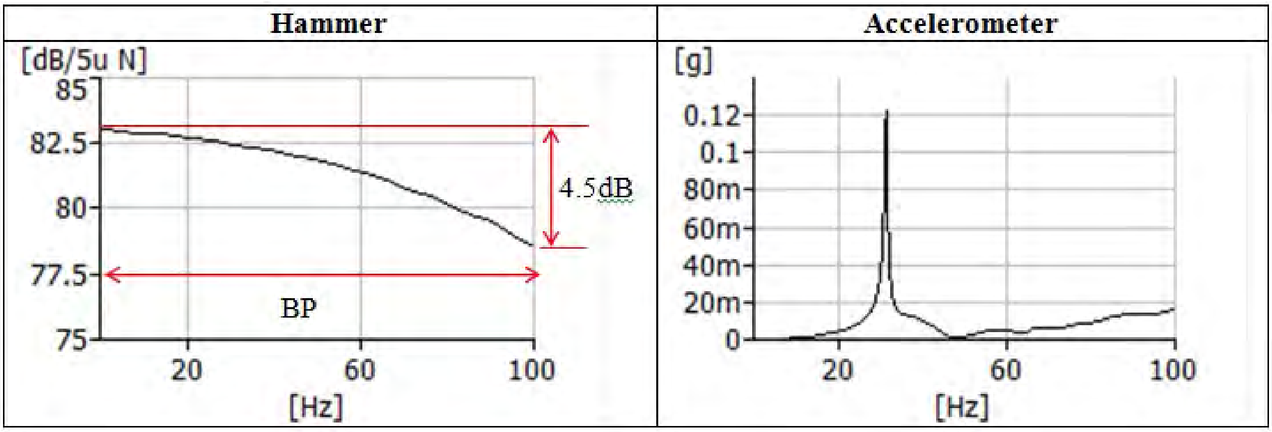

Figure 2. Spectrum Validation.

2.4 Transfer function Validation

The transfer function validation take in account that the frequency should match with the criteria of phase inversion of 180° and coherence greater than 0.8, according to Ewins (2000). As can be seen below, the measurement done on the aluminum bar found the resonance frequency of 31.5 Hz fit well with the criteria and the measurement set-up can be validating to be used regularly.

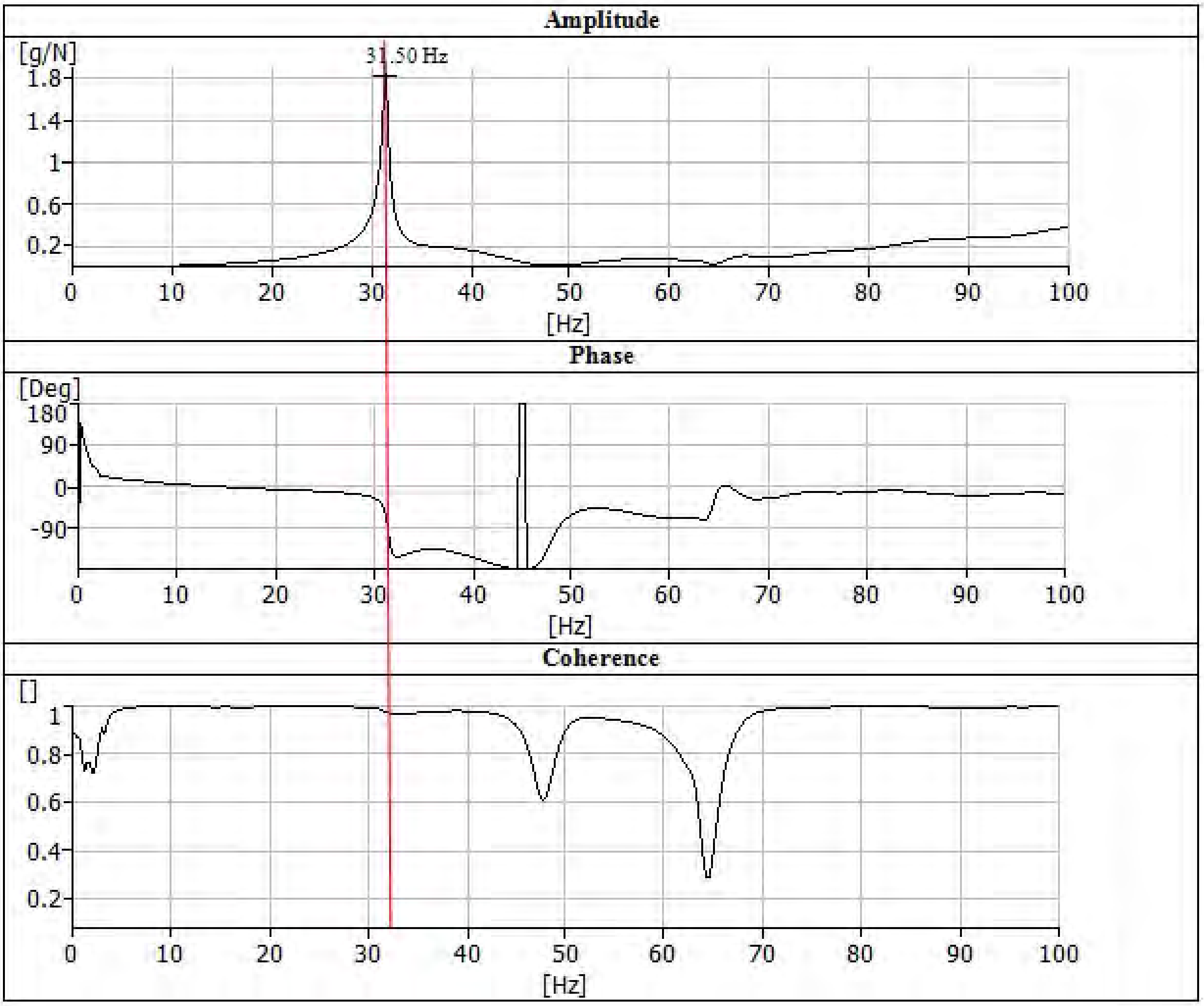

Figure 3. Tranfer function validation.

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3. TEST CONFIGURATION

The test was performed to present a mechanical resonance in the equipment called Antenna and find out if the frequencies are located close to the main excitation frequencies of helicopter. The helicopter frequencies are described by *b*Ω (omega) and multiple, where *b* is number of blades and Ω is related to the rotor speed. The tests were performed applying hammer excitation on the three axes of the equipment and measurements were taken using the cross-spectrum techniques based on transfer function H1(Bendat and Piersol,2000). The primary objective of the bang test was providing identification of the Antenna resonance frequencies and compares the results with the main frequencies of the helicopter. The helicopter frequencies analysis was done considering excitation frequencies based on MR = 326 rpm.

- ✓ 3/rev Main Rotor (bΩMR): 19.8 Hz
- ✓ 6/rev Main Rotor (2bΩMR): 39.6 Hz
- ✓ 1/rev Tail Rotor (ΩTR): 59.5 Hz

3.1 Equipment

The antenna is part of the transceiver VHF-FM TK-7160H KENWOOD. Figure 4 shows the antenna position on the helicopter tail boon and points of the hammer impact and the accelerometer used to measure signal in the Y and Z axes. To carry out the measurements in X axis, position of hammer and accelerometer was inverted.

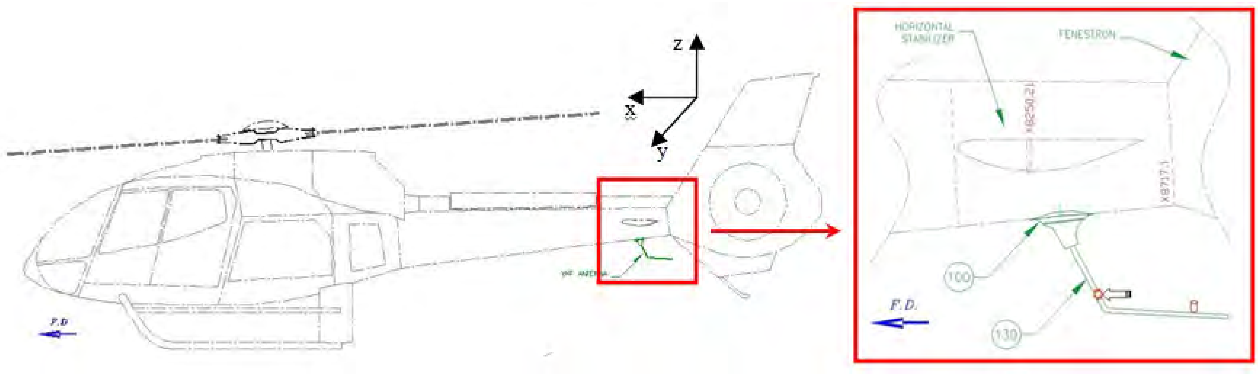

Figure 4. Antenna and the position of hammer impact and accelerometer.

3.2 Measurement Condition

During tests, data acquisition and analysis were performed using a Brüel & Kjær PULSE™ analyzer system consisting of 6 channel Type 3050-B-6/0 module connected to a HP PC running PULSE™ software. Data acquisition and validation were performed using PULSE Labshop™ software and the impact signal was generated by an impact hammer type 8206 from B&K. The response was measured using 2 (two) B&K uni-axial Accelerometer Type 4514-B-004 of the piezoelectric type.

Measurements were done applying an impact on the equipment with 5 impacts/measurements in which axes. One accelerometer was used in the cross-axes in order to make sure that no resonances were excited due to transverse modes and all measurements analyzed, use the cross spectrum average of the 5 impacts/measurements and the data are presented in form of transfer function/coherence graphics.

4. RESULTS

The analysis of the antenna was done using hammer impact excitation. The purpose was to find the resonances frequencies of the antenna and know the position related to the helicopter resonances due to the main and tail rotor. The measurements will show if there are some coupling effects between the resonances frequencies of the antenna and the helicopter. The measured frequencies of the antenna are shown below and it can be seen that only two resonances were found on the frequencies range of 200 Hz.

Using the results of this test and comparing it with the calculated frequencies of the rotor (main and tail) made it possible to find the critical resonances frequencies, that is, where the natural frequency is overlapping the helicopter frequencies and at the same time these beat frequencies can significantly influence the structural and electronic behavior of the antenna.

The transfer functions are presented on plots showing Amplitude and on Phase of signal measured on the three axes (X, Y and Z). The main frequencies of the helicopter rotors (main and tail) are assigned in red. In order to qualify the frequency as resonance should be simultaneously an amplification on the amplitude of the transfer function and a "phase rotation of 180°" as can be seen clearly in the graph. As can be seen in Figures 5,6 and 7, measurement have been done in the three axis and the measured frequencies of 28 Hz and 106 Hz were not close to the aircraft main excitation frequencies, however these frequencies would not affect the flight safety.

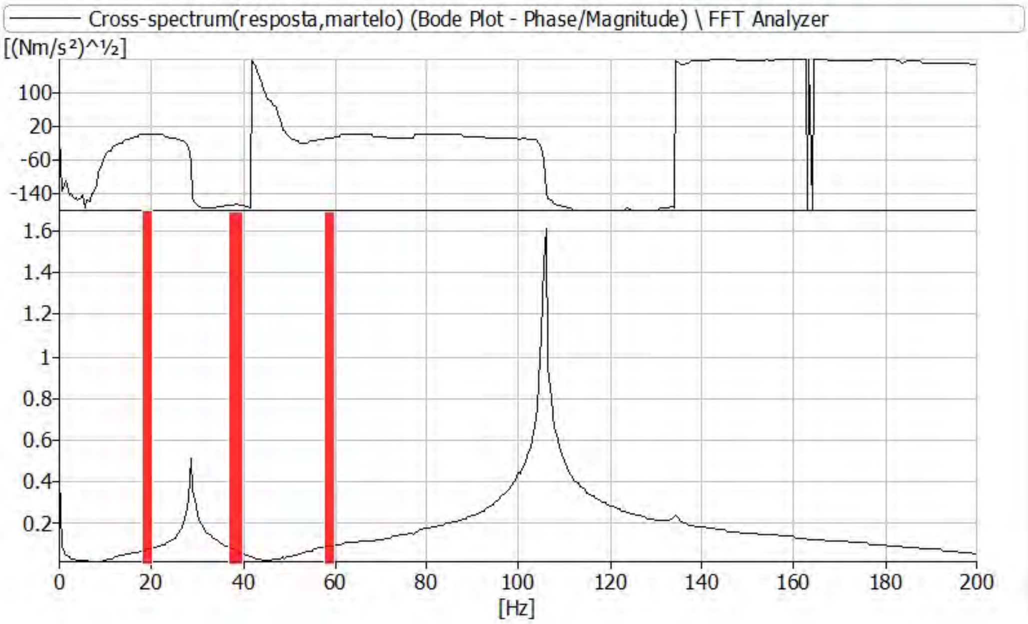

Figure 5. Transfer function (H1) of X axes presented as phase and frequency.

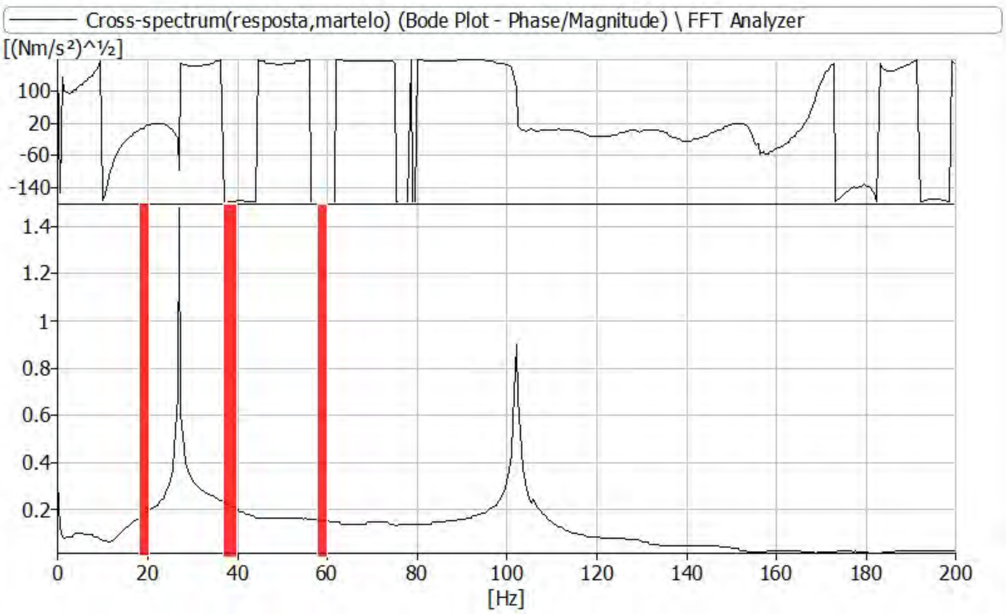

Figure 6. Transfer function (H1) of Y axes presented as phase and frequency.

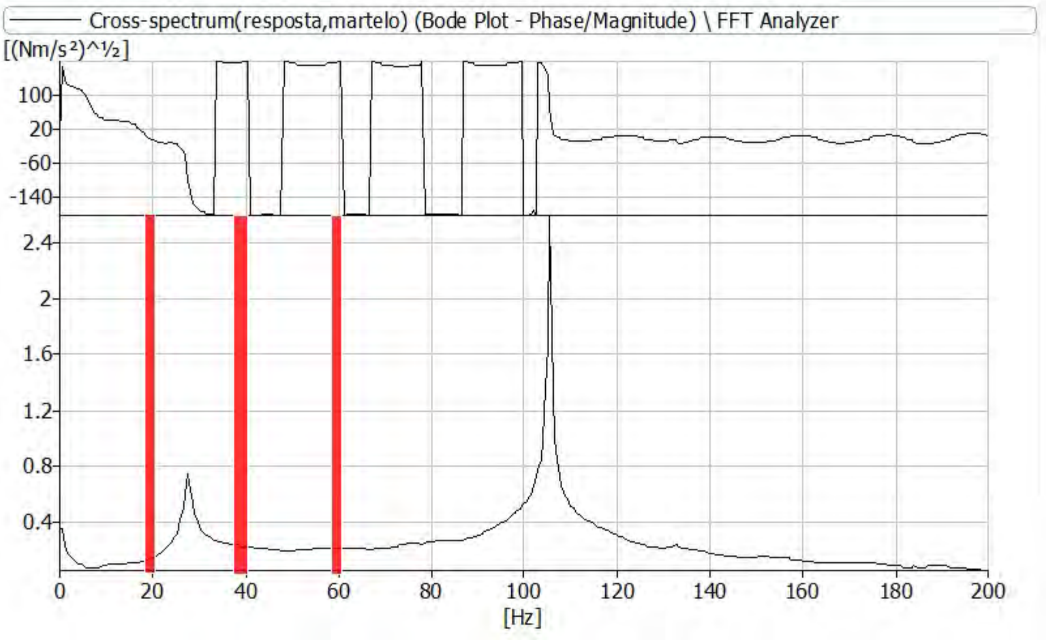

Figure 7. Transfer function (H1) of Z axes presented as phase and frequency.

The antenna has a particular and very symmetrical geometry which led to results of the two resonance frequencies are present in three axes. The Coherence function, greater than 0.8, should be used to validate the measurement and, as can be seen in Figure 8, for the resonance frequencies at 28 Hz and 106 Hz (dark blue arrows) coherence value is close to 1.

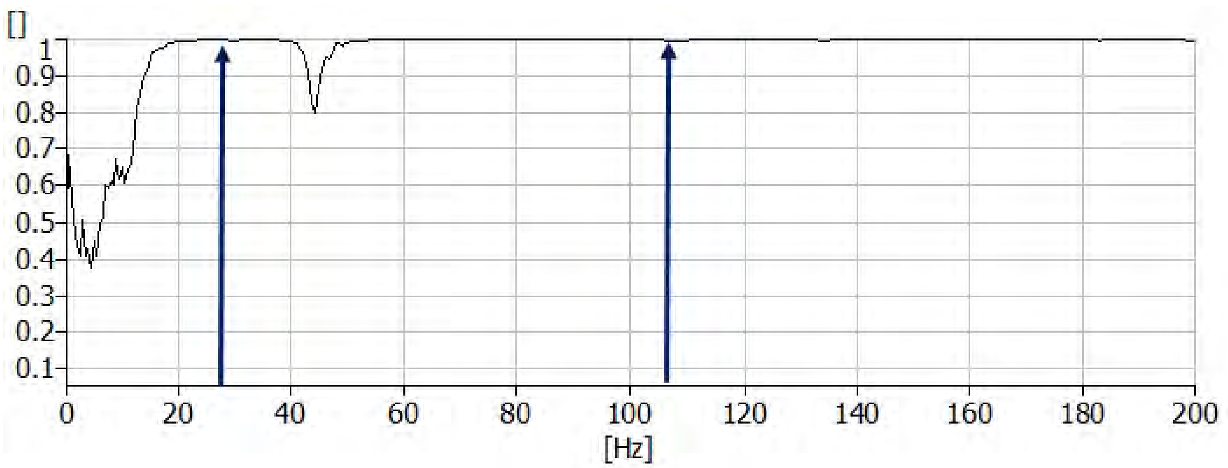

Figure 8. Coherence.

5. CONCLUSION

This paper presents the experimental set-up criteria using transient and exponential windowing technique; these approach reduce the leakage in the spectrum of the response and preserves the sample in the vicinity of the impulse signal, removing the noise by making the force signal go down to zero during the FFT computational time.

Measurements were performed on the Antenna in order to find the natural frequencies and compare with the main frequencies of the helicopter. Two frequencies were found 28Hz and 106Hz in the three axes; this behavior was due to geometry of the Antenna. As the frequencies of the Antenna do not match with the aircraft main frequencies, the Antenna can be attached to the helicopter without critically reducing flight performance.

As future work, it is possible to evaluate a modal calculation and compare with experimental results.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

Bendat, J. S.; Piersol, A. G., *Random Data: Analysis and Measurement Procedures.* 3ª Edição. New York: John Wiley and Sons, 2000.

Ewins, D. J. *Modal Testing: Theory and Practice. Research Studies Press* LTD, 2000.

Jhinaoui, A.Mevel, L.Morlier, J. Sanches, L."Ground resonance monitoring for hinged-blades helicopters: statistical CUSUM approach". INRIA - Institut National De Recherche En Informatique Et En Automatique. N°7431, October, 2010.

Nahas, M.N. "Helicopter ground resonance - a spatial model analysis". Aeronautical Journal, 88:299-308, 1984.

Schwarz, B. J. Richardson, M. H. "Experimental Modal Analysis" CSI Reliability Week, Orlando, FL.October, 1999.

8. RESPONSIBILITY NOTICE

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