LCIE
Laboratoire de Moirans
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GENERAL INFORMATION

FCCID: 2AC3Z-CAC1005000

1.1. Product description

Three axis accelerometers wireless data collector with two possibilities to power the product, through Li-ion battery (4V2 / 2,9Ah) or through AC/DC block (5V / 1A), also use to charge internal battery.

Interfaces: USB, 2.4GHz ISM Band WiFi

Signal acquisition through WiFi.

Embedded accessory:

- Temperature sensor
- Accelerometer
- User storage memory

Wireless sensor engineering

ACOEM, a newly created structure inheriting and gathering all expertise from its daughter brands 01dB dedicated to environmental noise control, ONEPROD for Condition Monitoring, and METRAVIB for NVH engineering and material testing equipment, has completely renewed the ONEPROD product range featuring among other customer centered deliverables, wireless measurement solution.

ONEPROD is focused on providing smart and simple to use solutions in the complex domain of condition based monitoring for rotating machineries. Latest development includes a powerful supervision tool to communicate global warning indicators of machinery health, easy to deploy wireless online (**EAGLE**) and offline (**FALCON**) CMS solutions and the mighty MVX solutions for application requesting advanced processing and wired measurements.

This paper is not met to cover all the customer benefit of using wireless accelerometer, but rather to cover some of the performances issues met during the development. The target for **FALCON** is "offline" condition monitoring based on vibration measurement, meaning that the entire product has been carefully designed to ease the life of maintenance technicians performing their inspection routes throughout plants and various production sites.

The intent for ACOEM is to use wireless technologies in a way that the end result is totally transparent to the user as far as metrological performance is concerned. This is easily stated but requires thorough control of the dynamic behavior of the transducer.

ACOEM could rely on its METRAVIB brand expertise on material dynamic characteristics, design, and a history of over 50 years of custom sensor developments for specific applications such as underwater, high temperature, ultra high sensitivity accelerometers, microphones and pressure sensors.

The FALCON wireless sensor

Our "**FALCON**" wireless transducer is a wireless unit containing a three axis accelerometer, signal processing and power management boards, and rechargeable battery.

Design constrains includes global ergonomics, resistance to harsh environment, and uncompromised frequency response.

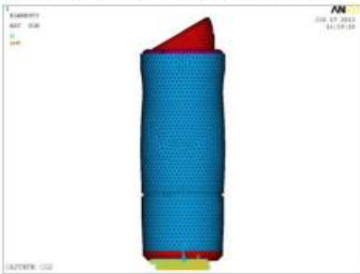
The latter has required extensive simulation and testing, relying on merely all the engineering knowledge of ACOEM to issue this sensor in due time.

Wireless sensor construction

As one could expect, the sensing elements are located as close as possible to the measured surface, i.e. on the base of the sensor, the rest of the volume being occupied mainly by the battery and electronic boards. The assembly is therefore way heavier than its wired counterparts, bringing along dynamic behavior of all inner components.

Design & modeling challenge

Once all space claim for all components was fixed and all the tradeoffs between weight, dynamic response and autonomy had been done, the detailed design took place along with the first in depth simulations.

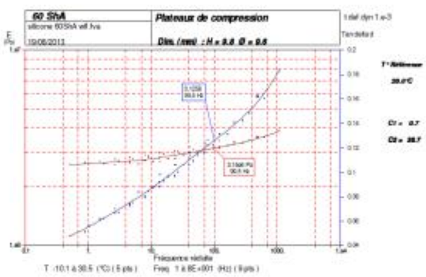


The model needed to be representative as much as possible of the behavior at high frequency, and extreme care had to be taken in the modeling process to ensure best result reliability. In particular, the elastomeric material behavior had to be taken into account: how will the modulus and damping factor of the material would evolve at high frequency and under operational temperatures?

Material Testing

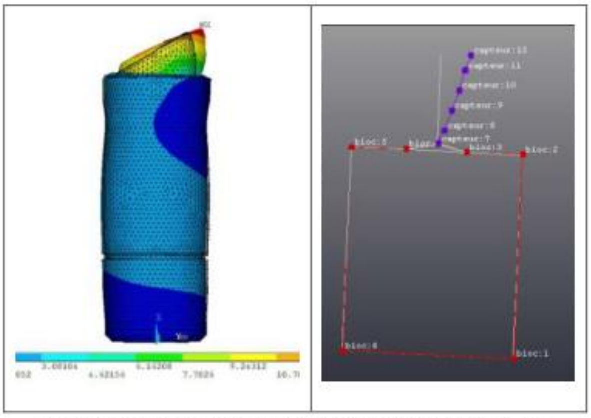
Metravib DMA and close up on a test fixture in thermal chamber

The answer was given quite thoroughly through DMA testing. DMA stands for Dynamic Material Analysis, a historical competency for METRAVIB. A test sample of material is placed in a specially designed clamp, putting on the sample the desired type of loading : traction / shear / flexion / torsion…This clamp is inside a volume in which temperature and hygrometry are controlled. A sine displacement is then applied on one side of the fixture and the transmitted force is measured. The analysis of those quantities, combined with the dimensions of the sample lead to a complete knowledge of the material modulus and damping factor among other characteristics.



Results and modal correlation

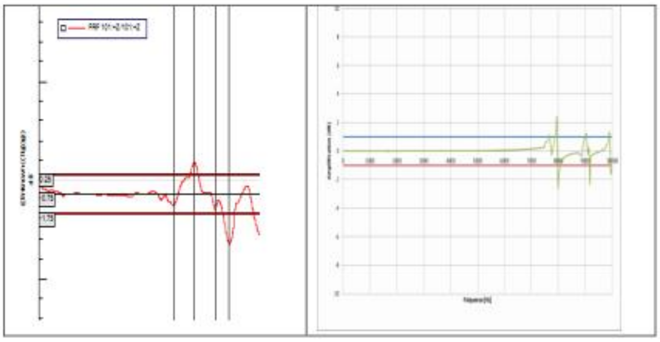
Once the initial design intent material was characterized, the Finite Element model was updated with its material properties and results were analyzed against first modal test results allowing for fine model tuning using dedicated tools.



First mode of the complete sensor in the 8kHz range (left, simulation, right: Test)

Design goals and Improvement methodology

The objective of this sensor is to obtain a 10kHz flat frequency response (+/- 1dB) for the Z axis direction. The first measurement and computation analysis have shown that the design goals were not fulfilled at particular mode frequencies.



Experimental (left) and numerical (right) vertical dynamic response before design improvement

In order to reduce the sensitivity of the sensor to the dynamic response of critical modes, an improvement methodology using the Finite Element model has been applied through a sensitivity analysis on stiffness and damping of different parts of the sensor, an identification of structural parts having a significant contribution on the response of the sensor, an implementation of technical solutions by adding damping material, a local stiffness increasing and a definition of the properties of the damping materials.

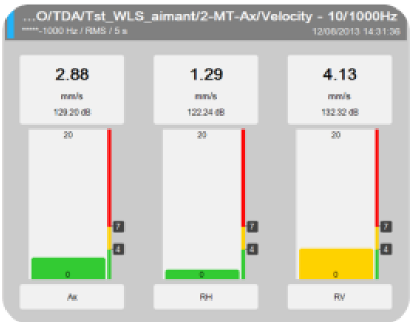
The correlated, and material properties-updated model used pointed out design parameters to put under control or to modify in order to achieve this objective. In particular for the inner elastomeric parts, the METRAVIB material database was used, and design goals for material properties (modulus and damping) were then perfectly determined. The properties of the defined damping materials were then implemented in the computation model to validate the dynamic sensitivity of the sensor.

Test validation

Testing with a reduced number of parameters could start. For the Z axis, a metrological bench was used with standard procedure up to 20kHz on standard fixed frequencies. For development and correlation purpose, a standard shaker was used running frequencies sweeps. The ripples observed in the response curve were then compared to simulation results leading to a validation of the computation results and the design improvements. Other axes were tested with dedicated fixtures and alternative test methods (impact test on decoupled mass).

Conclusion

A thorough control of material properties associated with precise simulation and measurement expertise combined with model updating analysis lead to success for the design of this new sensor, with only necessary testing needed for the time to market constraints. The obtained performance of our **FALCON** wireless sensor met the committed targets and opens fields of opportunity for other applications aside CMS.



- Bandwidth: 20 kHz on all axes
- Frequency range at 3 dB:
  - 15 kHz (Z)
  - 6 kHz (XY)
- Full scale: 80 g
- Signal-to-Noise ratio: 80 dB
- Accuracy: +/- 3%

1.2. Tested System Details

Power supply:
During all the tests, EUT is supplied by V_{nom}: 3.7DC
For measurement with different voltage, it will be presented in test method.

Name	Type	Rating	Reference / Sn	Comments
Supply1	☐ AC ☑ DC ☐ Battery	(primary 100-240V 50-60Hz) / 5Vdc	KSA0060500100D5U	/
Supply2	☐ AC ☐ DC ☑ Battery	(3.7Vdc – 2.9Ah)	Lithium Ion Battery	/

Inputs/outputs - Cable:

Access	Type	Length used (m)	Declared <3m	Shielded	Under test	Comments
Supply1	miniUSB Port (Secondary of Switching power supply)	1	☑	☐	☑	/

Auxiliary equipment used during test:

Type	Reference
Laptop	HP Probook 470Gi
Test PCB	Test PCB, CAH1095 Rev.C / P300PCB600C plug on P300PCB605A board
Falcon	10212

Software / Firmware

WLS firmware : v1.08
PDA unitest : v7.0.2.11 (14 decembre 2009)

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Equipment information:

<table>
<tr><td>Type:</td><td colspan="6">WIFI</td></tr>
<tr><td>Frequency band:</td><td colspan="6">[2400 – 2483.5] MHz</td></tr>
<tr><td>Sub-band REC7003:</td><td colspan="6">Annex 3 (a)</td></tr>
<tr><td>Standard:</td><td>☑ 802.11 b</td><td>☑ 802.11 g</td><td colspan="3">☐ 802.11 n HT20</td><td>☐ 802.11 n HT40</td></tr>
<tr><td>Spectrum Modulation:</td><td colspan="2">☑ DSSS</td><td colspan="4">☑ OFDM</td></tr>
<tr><td>Number of Channel:</td><td colspan="6">11</td></tr>
<tr><td>Spacing channel:</td><td colspan="6">5MHz</td></tr>
<tr><td>Channel bandwidth:</td><td colspan="2">☑ 20MHz</td><td colspan="4">☐ 40MHz</td></tr>
<tr><td rowspan="3">Transmit chains:</td><td>☑ 1</td><td>☐ 2</td><td colspan="3">☐ 3</td><td>☐ 4</td></tr>
<tr><td>☑ Single antenna</td><td colspan="3">☐ Symmetrical</td><td colspan="2">☐ Asymmetrical</td></tr>
<tr><td>Gain 1: 3dBi Peak</td><td colspan="2">Gain 2: dBi</td><td colspan="2">Gain 3: dBi</td><td>Gain 4: dBi</td></tr>
<tr><td>Beam forming gain:</td><td colspan="3">☐ Yes: dB</td><td colspan="3">☑ No</td></tr>
<tr><td>Receiver chains</td><td>☑ 1</td><td colspan="2">☐ 2</td><td colspan="2">☐ 3</td><td>☐ 4</td></tr>
<tr><td>Type of equipment:</td><td>☑ Stand-alone</td><td colspan="3">☐ Plug-in</td><td colspan="2">☐ Combined</td></tr>
<tr><td>Ad-Hoc mode:</td><td colspan="2">☑ Yes</td><td colspan="4">☐ No</td></tr>
<tr><td>Duty cycle:</td><td>☐ Continuous duty</td><td colspan="3">☐ Intermittent duty</td><td colspan="2">☑ Continuous operation</td></tr>
<tr><td>Equipment type:</td><td colspan="2">☑ Production model</td><td colspan="4">☐ Prototype</td></tr>
</table>

<table>
<tr><th colspan="3">DATA RATE</th></tr>
<tr><th colspan="3">802.11b</th></tr>
<tr><th>Data Rate (Mbps)</th><th>Modulation Type</th><th>Modulation
Worst Case</th></tr>
<tr><td>1</td><td>DBPSK</td><td>☑</td></tr>
<tr><td>2</td><td>DQPSK</td><td>☐</td></tr>
<tr><td>5.5</td><td>DQPSK</td><td>☐</td></tr>
<tr><td>11</td><td>CCK</td><td>☑</td></tr>
<tr><th colspan="3">802.11g</th></tr>
<tr><th>Data Rate (Mbps)</th><th>Modulation Type</th><th>Modulation
Worst Case</th></tr>
<tr><td>6</td><td>BPSK</td><td>☑</td></tr>
<tr><td>9</td><td>BPSK</td><td>☐</td></tr>
<tr><td>12</td><td>QPSK</td><td>☐</td></tr>
<tr><td>18</td><td>QPSK</td><td>☐</td></tr>
<tr><td>24</td><td>16-QAM</td><td>☐</td></tr>
<tr><td>36</td><td>16-QAM</td><td>☐</td></tr>
<tr><td>48</td><td>64-QAM</td><td>☐</td></tr>
<tr><td>54</td><td>64-QAM</td><td>☑</td></tr>
</table>

DATA RATE								
802.11n HT20 / HT40 (Table 1)								
Available for EUT	**MCS Index**	**Spatial streams**	**Modulation**	**Data Rate (Mbps)**				**Worst Case Modulation**
				(GI = 800ns)		**(GI = 400ns)**		
				20MHz	**40MHz**	**20MHz**	**40MHz**	
☑	0	1	BPSK	6.5	13.5	7.2	15	☑
☑	1	1	QPSK	13	27	14.4	30	☐
☑	2	1	QPSK	19.5	40.5	21.7	45	☐
☑	3	1	16-QAM	26	54	28.9	60	☐
☑	4	1	16-QAM	39	81	43.3	90	☐
☑	5	1	64-QAM	52	108	57.8	120	☐
☑	6	1	64-QAM	58.5	121.5	65	135	☐
☑	7	1	64-QAM	65	135	72.2	150	☑
☐	8	2	BPSK	13	27	14.4	30	☐
☐	9	2	QPSK	26	54	28.9	60	☐
☐	10	2	QPSK	39	81	43.3	90	☐
☐	11	2	16-QAM	52	108	57.8	120	☐
☐	12	2	16-QAM	78	162	86.7	180	☐
☐	13	2	64-QAM	104	216	115.6	240	☐
☐	14	2	64-QAM	117	243	130.3	270	☐
☐	15	2	64-QAM	130	270	144.4	300	☐
☐	16	3	BPSK	19.5	40.5	21.7	45	☐
☐	17	3	QPSK	39	81	43.3	90	☐
☐	18	3	QPSK	58.5	121.5	65	135	☐
☐	19	3	16-QAM	78	162	86.7	180	☐
☐	20	3	16-QAM	117	243	130	270	☐
☐	21	3	64-QAM	156	324	173.3	360	☐
☐	22	3	64-QAM	175.5	364.5	195	405	☐
☐	23	3	64-QAM	195	405	216.7	450	☐
☐	24	4	BPSK	26	54	28.9	60	☐
☐	25	4	QPSK	52	108	57.8	120	☐
☐	26	4	QPSK	78	162	86.7	180	☐
☐	27	4	16-QAM	104	216	115.6	240	☐
☐	28	4	16-QAM	156	324	173.3	360	☐
☐	29	4	64-QAM	208	432	231.1	480	☐
☐	30	4	64-QAM	234	486	260	540	☐
☐	31	4	64-QAM	260	540	288.9	600	☐

The EUT is set in the following modes during tests with simulator / software PDA unitest : v7.0.2.11 (14 decembre 2009)

- Permanent emission with modulation on a fixed channel in the data rate that produced the highest power
- Permanent reception

Conducted Configuration :

RF board from WLS sensor is set on PCB test board in order to receive specific command from external Laptop

Radiated Configuration :

WLS sensor communicate with Falcon Board

1.3. Test Methodology

Both conducted and radiated testing were performed according to the procedures in ANSI C63.4-2003, FCC Part 15 Subpart C.
Radiated testing was performed at an antenna to EUT distance of 10 meters. During testing, all equipment's and cables were moved relative to each other in order to identify the worst case set-up.

1.4. Test facility

Tests have been performed from September 22nd to 25th , 2014.

This test facility has been fully described in a report and accepted by FCC as compliant with the radiated and AC line conducted test site criteria in ANSI C63.4-2003 in a letter dated March 25^{th}, 2008 (registration number 94821). This test facility has also been accredited by COFRAC (French accreditation authority for European Union test lab accreditation organization) according to NF EN ISO/IEC 17025, accreditation number 1-1633 as compliant with test site criteria and competence in 47 CFR Part 15/ANSI C63.4 and EN55022/CISPR22 norms for 89/336/EEC European EMC Directive application. All pertinent data for this test facility remains unchanged.