Cover page

Title*: Ultrasonic NDT based on Lamb waves : Development of a dedicated drive and monitoring electronic*

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ABSTRACT

Lamb waves have been applied to several Non Destructive Testing (NDT) cases in health monitoring. In the aeronautic field, there is a need for more inspection. It would be particularly beneficial if the NDT system could be embedded in the aircraft part to be monitored. In that case, the monitoring strategy would not be necessarily based on regular visit and conventional NDT hardware, for instance based on C-scan.

In order to get an embedded NDT system, both the emitters and receivers need to have a low profile. Ultrasonic guided waves, such as Lamb waves may be particularly efficient, as they can inspect a large area with a minimum number of receivers. Conventional wedge emitters cannot be used in such embedded applications.

CEDRAT TECHNLOGIES SA, in the frame of the 6th STREP Framework program AISHA project, has defined a piezo patch configuration and the dedicated drive and monitoring electronic. As Lamb waves are dispersive, it is advisable to use a sine tone burst for the emission signal. Lamb waves as well their generation have been modelled by using the ATILA software [7].

The proposed paper recalls the Lamb waves principle, briefly introduces the part prototype in which the Lamb waves are propagating and focuses on the electronic, further called LWDS45. The architecture of this electronic is described. It uses two DDS for the sine tone burst generation, a power amplifier, specially developed for high frequency capacitive load and sensing receivers including pre-amplifiers. The use of this electronic is envisaged on real case aircraft parts by several partners of the AISHA project.

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INTRODUCTION

Lamb waves have been during the two past decades the subject of extensive research. Since their discovery in the early 1920 [1], their behavior have been better understood through Finite Element Simulations [2,3], and their suitability to detect cracks in some circumstances was shown [4,5]. However, to get an embedded system (Health Monitoring System) several steps and technology improvements still remain.

PIEZO PATCHES AND MODELLING

Some piezo transducers are necessary to generate and sense the Lamb waves. Wedge type transducers have been commonly used ; however, they are not suited to an integration in the plate to be monitored.

Piezo patches have been investigated as Lamb wave generators [3] : it is however difficult to predict analytically their coupling with the Lamb waves. The finite Element Method can be used to estimate their suitability. Therefore, a plane strain two-dimensional FEM model has been prepared and run in transient analysis at various frequency (Figure 1). The speed of the Lamb wave mode was monitored by looking the time of flight.

The two Lamb waves mode a0 and s0 are more commonly used in NDT applications : they may be identified by their difference of speed. Getting higher frequency leads to a greater number of modes, leading to a more complex analysis.

The comparison on the wave speed with an analytical solution and the measurements is presented on the Figure 3. It shows that the Lamb wave is dispersive (e.g. the speed of the wave depends on the frequency). The comparison shows a rather good agreement : the discrepancy increases with the frequency, which may be attributed to the fact that at those higher frequencies, the mesh becomes coarse.

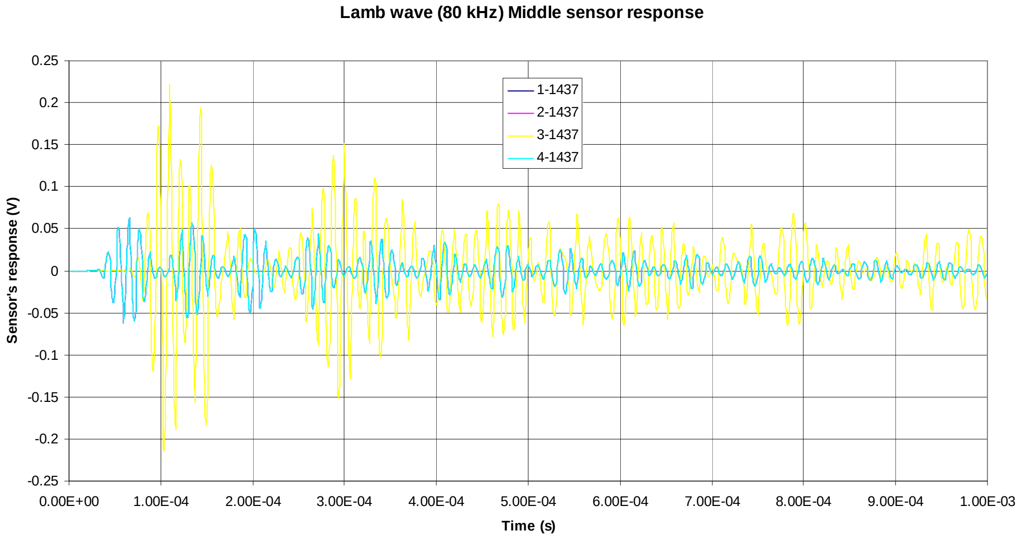

Figure 1. Finite Element Modeling of the piezo patch used as Lamb waves generators

The strategy for using these modes in a NDT application may be complex, as it needs to take into account the echoes (figure 2).

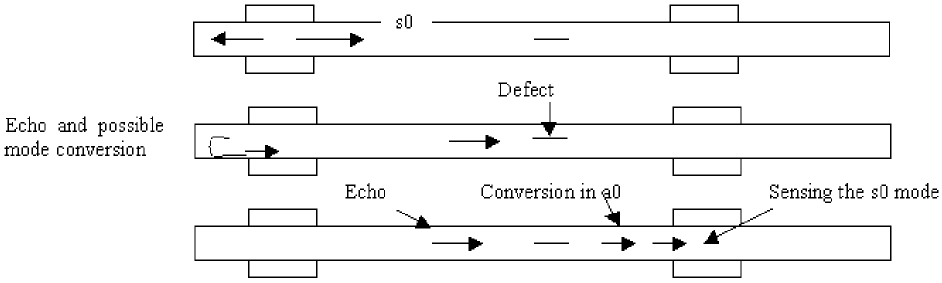

Figure 2 : Possible occurrence of echoes that could jeopardise the defect detection

EXPERIMENTAL VALIDATION

The application has been experimented on a prototype plate (Figure 3), including several piezo patches. A first step was to show that the Lamb waves mode a0 and s0 were effectively excited. The speed was measured through the time of flight between two patches.

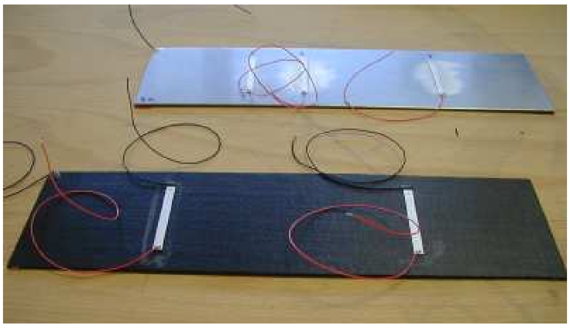

Figure 3 : View of a carbon composite and a metallic plate

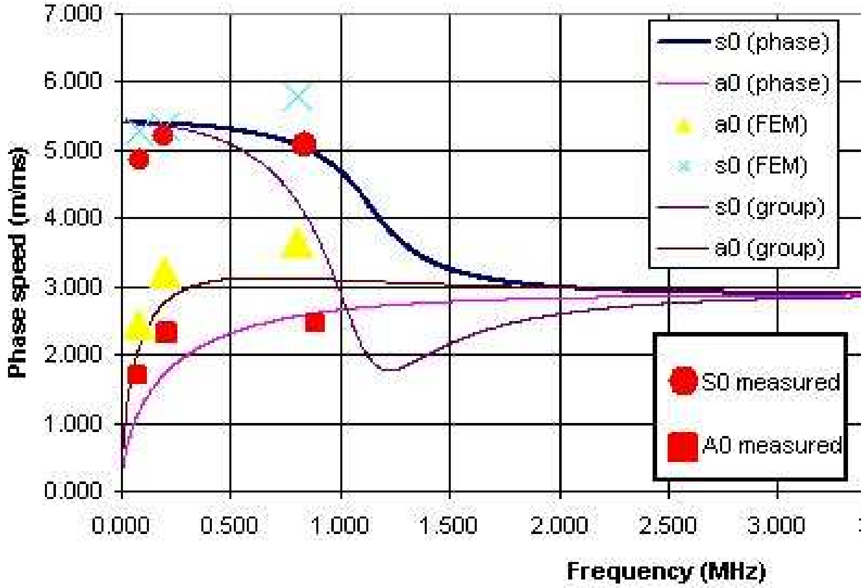

Figure 4 : Comparison of the measured wave speeds with the computed speeds.

The comparison (Figure 4) shows a good agreement: the measurement uncertainty is sometimes linked to the determination of the arrival time of the echo.

It is considered that the bulk piezo patches are currently operational for testing and best adapted to operational needs in the frame of the project for testing purpose and other field tests.

DRIVE AND MONITORING ELECTRONIC

The electronic LWDS45 is dedicated to the supply and measurement of piezoelectric ceramics. This system consists in :

- 1 linear power supply providing a continuous voltage from the main power,
- 2 linear amplifiers dedicated to capacitive loads allowing excitation of piezoelectric actuators between –10V and +10V,
- 2 burst signal generators with adjustable gain,
- 4 instrumentation amplifiers allowing to measure the voltage of the piezoelectric sensing patches with adjustable gain and filter,
- 2 multiplexer stages to select output function,
- A micro controller allowing to set up the whole system,
- A USB communication to the PC.

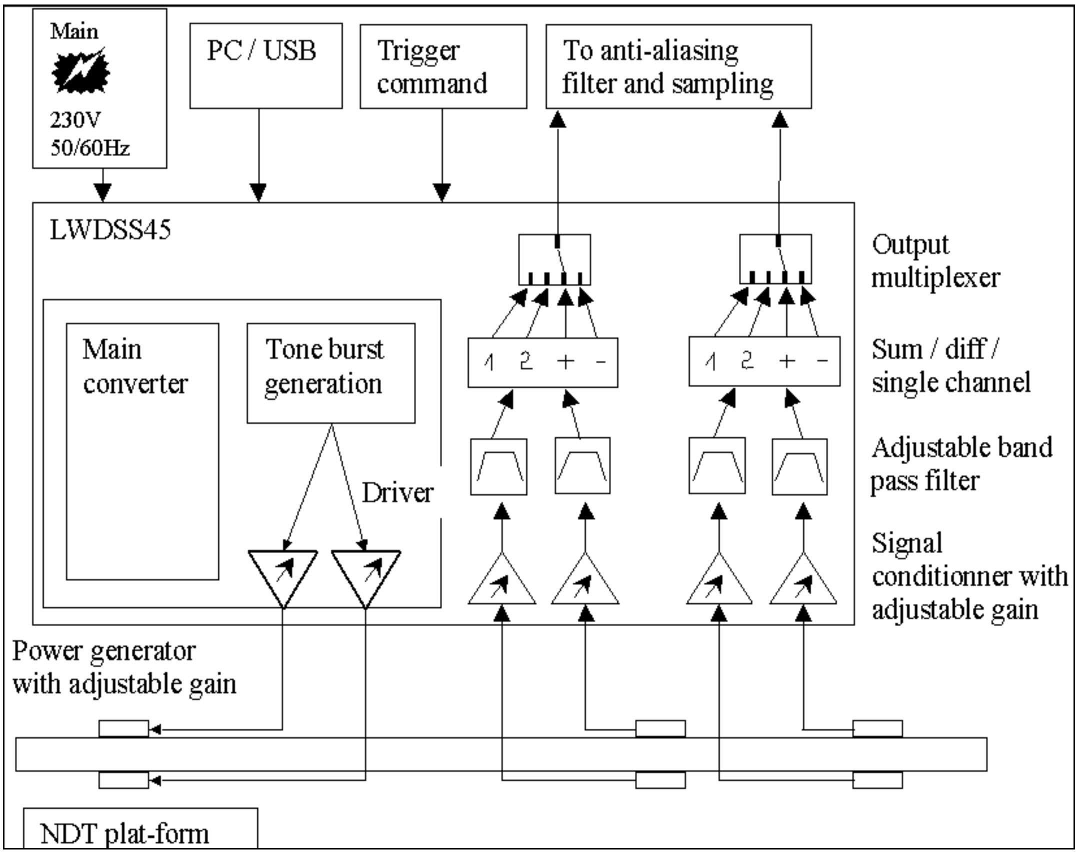

Figure 5: Synoptic of the LWDS45

The purpose of the Lamb Waves Drive and Sensing LWDS45 is to perform the generation of a windowed sine tone burst signal on a first set of piezo patches, upon the reception of a triggered command signal, and to sense up to 4 low level signals on a second set of sensors patches. The sine tone burst generation was the preferred generation solution in order to limit the dispersion of the waves.

The use in combination of a micro controller and a DDS (Digital Data Synthesizer) offers a well suited solution for rapidly testing configuration for NDT application by generating a Hanning-windowed smoothed tone burst.

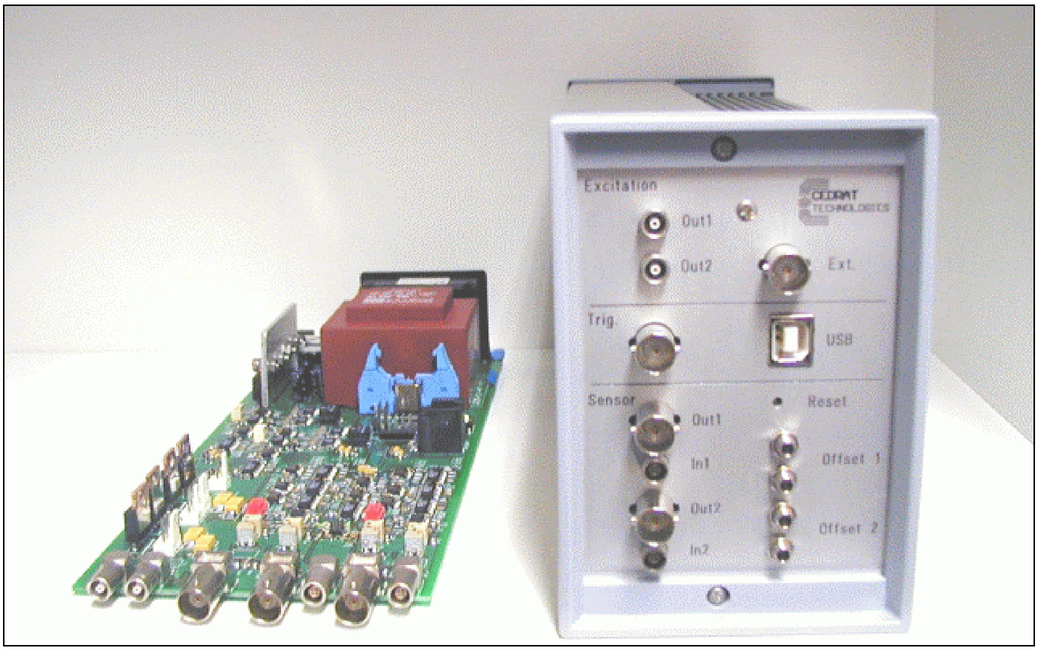

Figure 6: View of the LWDS45 drive and monitoring electronic

Many parameters are easily adjustable from the number of sine periods to the phases between two channels as well as the frequency step, gain, filter, etc…
The frequency step resolution can be adjusted from 1Hz to 100kHz. This resolution could be decreased down to 0.15Hz. This step adjustment allows to rapidly make frequency sweep in order to search the most adapted frequency for the NDT. The frequency range of the electronic is from 8kHz to 1.25MHz

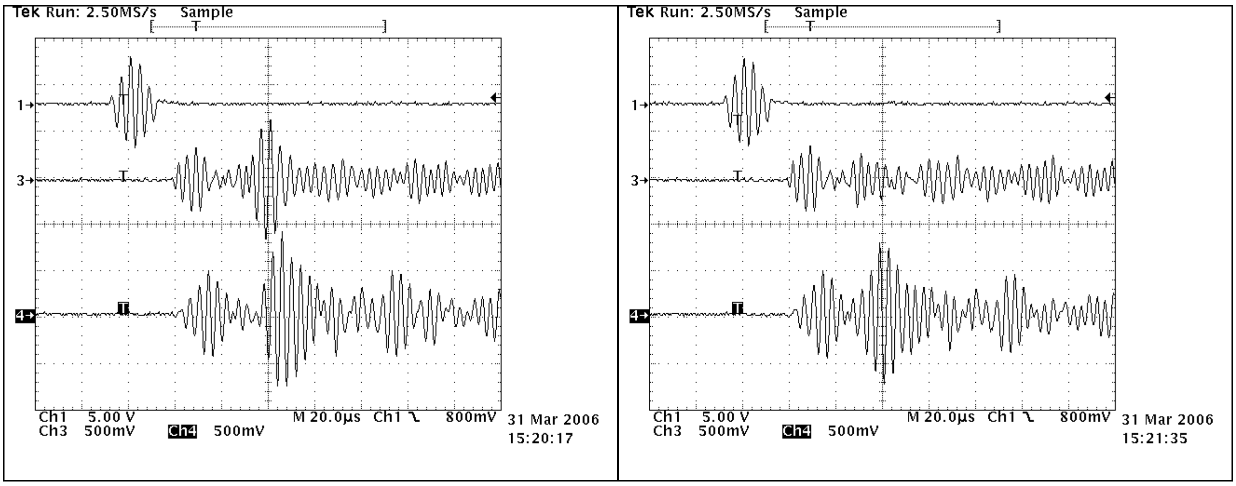

Figure 7: Example of a generated pulse and received signal w/ and w/o default

The LWDS45 is connected to the PC via a USB cable and several devices can be simultaneously connected in order to extend the number of available channels. The interface used for the communication can be based either on USB or on a more conventional RS232 serial communication. This allows the user to build himself some extension for a better integration with his own tools or with his acquisition system. All the command are based on a mnemonics like format which allow a rapid setting from the keyboard. Current settings can be safely saved on the non volatile memory of the micro-controller for a further recall. Adjustable gains are available for the excitation and allow to set the excitation level depending of the patch type, the distance of transmission or the material under test. Adjustable gain and band-pass filter are also available for the sensor signal and a last stage allow to select one or another sensor signal, their sum or their difference.
The generation and the detection of the Lamb waves were achieved on an aluminum plates and also on a carbon fiber plates providing sufficient gain to get a proper signal.

CONCLUSIONS AND PERSPECTIVES

The NDT concept and the use of the drive and monitoring electronic LWDS45 is intended to be used in aircraft applications. A real case application is being considered after the knowledge gained with the prototype plates. For those tests, a carbon composite tail boom from a EC135 as well as a rivets assembled aluminum tail boom of an MI8 (Figure 8) will be used for the real scale tests.

Figure 8 : View of a real structure being tested in the AISHA project (courtesy of TU Riga)

Further improvements could be added to the current electronic:

- Increasing the number of sensing channel and / or multiplexing of the sensor input to support array of patches,
- Support for pulsed-echo measurement,
- TEDS support (Transducer electronic datasheet) to allow plug and play capability to the sensor. It will be then able to perform identification and auto calibration,

- integration DC/DC converter instead of AC/DC main supply in order to allow battery operations,
- ADC (Analog to Digital Converter) to feature a complete PC solution.

The current design offers a very compact solution (portable solution during aircraft taxi period) compared to all the lab instruments needed to setup this kind of NDT measurements.

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