HEALTH MONITORING OF AIRCRAFT

BY NONLINEAR ELASTIC WAVE SPECTROSCOPY

AERONEWS

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PROJECT COORDINATOR: Prof. KOEN VAN DEN ABEELE

Deliverable D14

Description of hardware and software requirements for NEWS measurement systems

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Project coordinator name: Koen Van Den Abeele
Project coordinator organization name: KULeuven

Report author: Peter Armitage (Exeter University) final version (confidential)

DOCUMENT IDENTIFICATION SHEET

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OBJECTIVES, SCOPE AND METHODOLOGY

1.1 OBJECTIVES

The objective of this report are to provide a hardware and software specification for a Non-linear Elastic Wave Spectroscopy testing system (NEWS system) intended for use in the monitoring and identification of defects within composite aircraft components. The document achieves this by:-

a) Identifying the principle methods to detect structural defects in composite material by means of Non-linear Elastic Wave Spectroscopy.

b) Describing some common modes of failure in composite materials

c) Determining the optimal positioning and accessibility of sensors and actuators used in a typical testing procedure.

d) Selecting suitable enabling technology.

e) Reviewing suitable methods to process and display data.

This document draws on earlier work packages undertaken by members of the research consortium. The report is deliverable D14 of the European Sixth framework program Contract number AST3-CT-2003-502927, Health Monitoring of Aircraft by Nonlinear Elastic Wave Spectroscopy.

1.2 SCOPE

The document contains the following main chapters:-

Chapter 2: Identification of the available non linear elastic wave testing methods.
This is intended to give a general overview of the currently known methods to determine defects in composite materials by examining the effects produced by the non linear mechanical stress-strain relationships, resulting from a defect, and its effect on the physical properties of an elastic wave propagating in the material.

Chapter 3: Testing vulnerable aircraft components. This is intended to provide an outline of typical defects encountered in composite aircraft components and the problems in evaluating and locating them. The problem accessibility when generating and taking measurements of elastic waves is addressed, together with possible solutions to improve the measurement process, for example by considering transducers that are embedded within the composite material, or transducers that can be presses against or held near the surface of the component under test.

Chapter 4: Proposed system specification. This is a provisional specification for a NEWS measurement system. Details are given for the technology selected to implement the NEWS testing regime. An outline is given for methods by which data can be transferred from the transducers to the data recording and display electronics, together with suggested graphics formats to enable interpretation of the data.

1.3 METHODOLOGY

Information to compile this report was obtained from the following sources:-

a) Consortium work package reports and presentations.
b) Experimental results obtained by consortium members.
c) Library and internet data bases.
d) Aviation and other standards.

The overall aim of this document is to provide a provisional specification for a NEWS measurement system, taking into account the current technology, cost and availability of sensors and actuators.

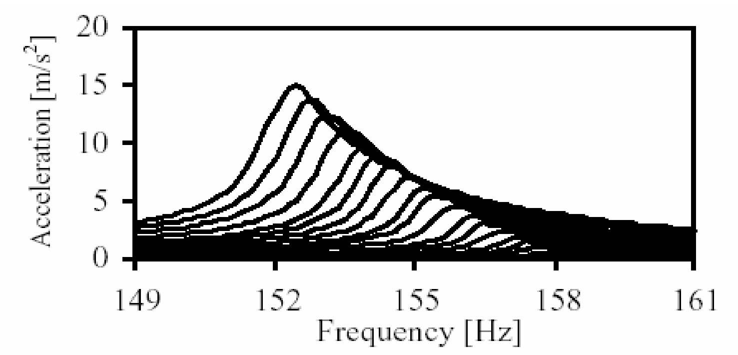
2 IDENTIFICATION OF THE AVAILABLE NON LINEAR ELASTIC WAVE TESTING METHODS

2.1 INTRODUCTION

The most widely used procedure of ultrasonic testing of materials is the pulse echo method. In applications requiring the testing of composite materials this method is found not to work due to multiple reflections and wave scattering that occurs within such materials.
In order to test composite materials a new method known as Non Linear Spectroscopy has been developed over the past few years. This technique examines the spectral content of an elastic wave as it passes through or near a defective region. Defects will produce a non linear stress-strain relationship, either due to hysteresis, plastic deformation or other non linear motion, this can be detected by examining properties in the frequency domain.
Recent advances made by the consortium partners have enable this technique to be extended to the location of defects by time reversal acoustics, this involves reversing the direction of acoustic wave propagation back to their point of origin.

2.2 NON LINEAR SPECTROSCOPY

This involves the study of the non linear response of a single, or a group of, resonant modes within the material. Resonance frequency shifts, harmonics and damping characteristics are analyzed as a function of the resonance peak acceleration amplitude.
Within the consortium the current frequency range that has been investigated is up to 20KHz, but typically 2KHz produces the most promising results for the composite materials used in aircraft components.
An example of frequency shift with applied acceleration for a defective composite material (concrete) is given below:-



The resonant frequency shifts to a lower value as the acceleration is increased.

Damage assessment in Reinforced Concrete using Nonlinear Vibration Techniques, K. Van Den Abeele and J. De Visscher, Cement and

Equipment requirements:-

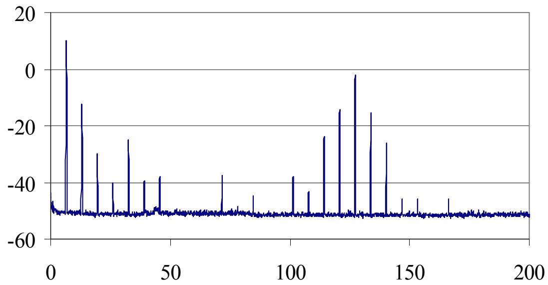
a) One high powered actuator providing a single frequency
b) One broad band, low distortion sensor
c) A means to record data and provide an amplitude and spectral plot

The actuator may be required to transmit at different frequencies.

2.3 NON LINEAR MODULATION

This method consists of exciting a sample with continuous waves of two separate frequencies simultaneously, and inspecting the harmonics of the two waves and their sum and difference frequencies (sidebands).
Within the consortium the following frequencies have been investigated.

1) Two high frequencies sources in the range 500KHz to 10MHz
2) One high (above 100KHz) and one low (below 10KHz) frequency source
3) One high (1 to 10MHz) and one very low (below 100Hz)



Example of Harmonics and sidebands produced by a small crack in a metal component.

Driving frequencies 127KHz and 6.5KHz

Van Den Abeele *et al*., Res. Nondestr. Eval. 12/1, 17-30, 2000

Equipment requirements:-

a) Two high powered actuators providing two frequencies
b) One very broad band sensor
c) A means to record data and provide an amplitude and spectral plot

Within the consortium a single actuator has been developed, by DAKEL, that is dual frequency, these transmit at 1MHz and 3MHz and another version transmits 2MHz and 6MHz.

2.4 NON LINEAR PROPAGATION

This involves the study of the effects of a materials non linearity on the propagation of an elastic wave. Four effects are considered relevant to NEWS applications.

Harmonics, Attenuation and Velocity

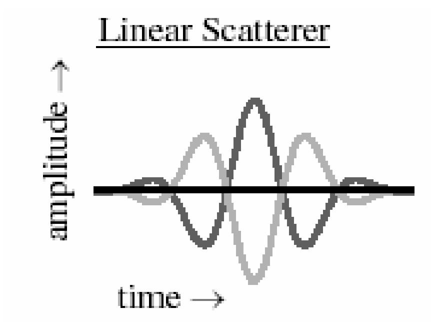
Under certain conditions harmonics and overtones will be produced as an elastic wave passes through a material that exhibits a non linear stress-strain relationship (ie, does not obey Hooke's law) or produces a non symmetric wave, a difference in amplitude between the compression and rarefaction. The formation of these harmonic and additional frequencies is amplitude dependant, and will produce a different series of frequencies if the materials non linearity approximates to a square or to cubic law.
Attenuation is a function of frequency for all materials. Departure from the expected attenuation verses frequency relationship is indicative of a material defect.
The velocity of propagation is a function of the materials elasticity, geometry, the wave length and wave type of the propagating elastic wave. Departure from the expected or observed velocity is indicative of a defective material.

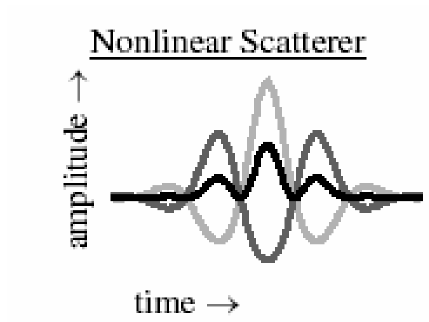
Equipment requirements:-

a) One wideband actuator, providing a pulse or frequency burst.
b) One or more wideband sensors located along the material under test
c) A means to record the data, and a means to display them.

Pulse Inversion

Two pulses that are 180 deg out of phase are sent through the material back to back. The returned signals are summed.
In the absence of defects (linear propagation) the summation produces a signal void (Null), shown below. In effect the two waveforms "cancel" each other.
In the presence of defects (non linear propagation) the signal becomes distorted, the summation of the two pulses will no longer produce a signal void.





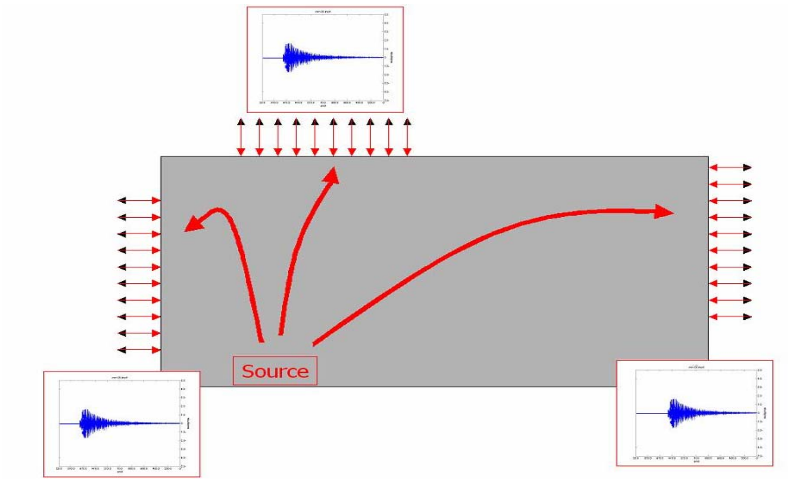
Within the consortium sensors and actuators with bandwidths up to 1MHz have been used in experimentation. Ideally bandwidths up to 20MHz would give greater resolution for this method.

Equipment requirements:-

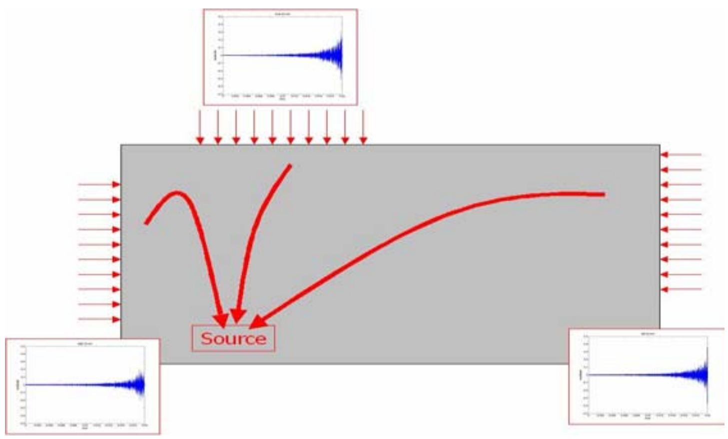
a) One wideband actuator providing two pulses, one reversed, in succession
b) One wideband sensor
c) A means to record two sets of data, and a means to sum and display them.

Time Reversal

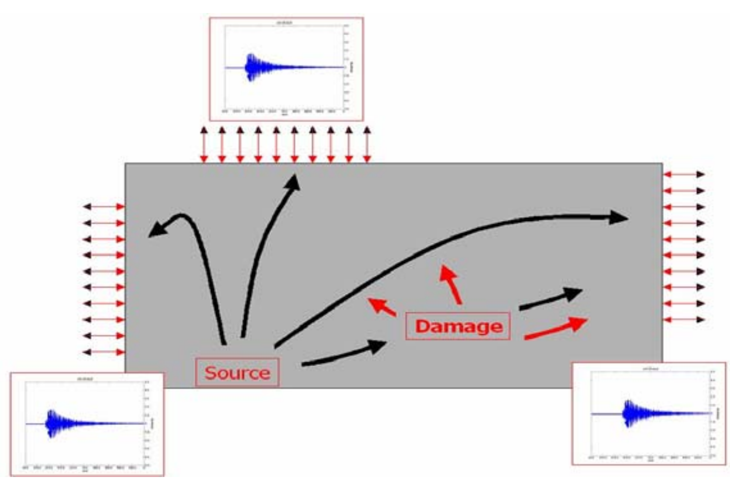
This technique is being investigated by the consortium partners under WP2 (numerical modeling and simulation of elastic wave propagation). It involves effectively reversing the direction of propagation of an elastic wave, returning the energy back to its point of origin. The principle is illustrated in the following drawings.



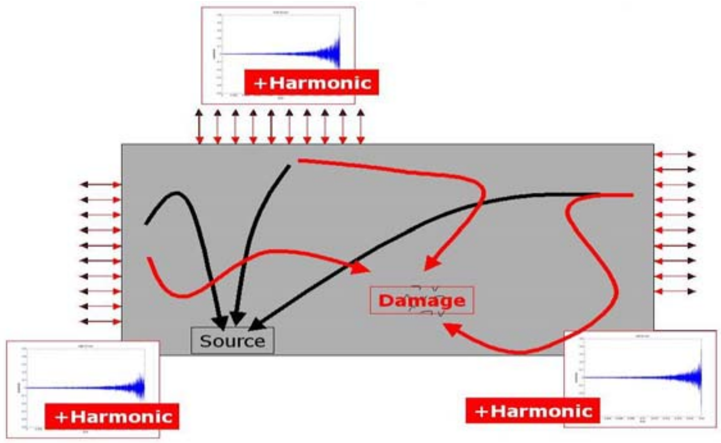
A source transmits acoustic wave. Signal received and recorded at the outer regions of the material



The receive positions now become transmit positions.
The recorded signals at each point is reversed in time order and transmitted back into the material.
The sound wave path traces back along its original path.
The energy is finally returned to the source position



In a material that contains a non-linear defect a source will cause the generation of harmonics at the damage site.



Transmitting back the time reversed signals will result in two concentrations of sound energy, one at the originating source and the other at the defect.

This method provides a locating mechanism for the defect, it will function in all types of composite materials, since the sound ray path is always traced back to its point of origin regardless of the route. The process is often referred to as phase conjugation.

Equipment requirements:-

This is by far the most complicated system requirement. An array of transducers will be required, each element of this array will have to be pre-programmed to serve as a receiver or a transmitter. It will be required to receive and record data, process this data (remove source and enhance harmonics) time reverse the data and then down load this to transmit into the material. Precise synchronization of all the transducers is essential for this technique to work. The estimated frequency requirements are 10KHz to 20MHz, however the phase relationship between the transducer elements is critical in establishing a full energy transfer back to the origin. Both time and special aliasing must be considered and therefore the sampling rate is likely to be increased to five or ten time the maximum frequency, this is higher than the usual Nyquist frequency.

SUMMARY

TECHNIQUE	configuration	application	Frequency range
Non linear Spectroscopy			
Resonant frequency shift	T&R in close proximity	2 wide band transducers	0 to 20KHz (typically 2Khz)
Reverberation, harmonic and overtone generation	T&R in close proximity	2 wide band transducers	0 to 20KHz
Non linear Modulation			
2 high frequencies detects harmonics and inter-modulation products	T_{f1}, T_{f2} & R in near proximity	3 transducers narrow band actuators, wide band sensor	500KHz to 10MHz
1 high 1 low frequency detects side bands, harmonics and mod index	T_{f1}, T_{f2} & R in near proximity	3 transducers narrow band actuators, wide band sensor	50Khz to 500KHz
1 high 1 very low frequency power vibration detects inter-modulation products and sine burst	T_{f1}, T_{f2} & R in far proximity	3 transducers narrow band actuators and sensors	F_H = 1 to 10 MHz F_L = 0 to 100Hz
Non linear Propagation			
Pulse inversion	T&R in far proximity	2 wide band transducers	1MHz to 20MHz
Harmonics	T&R in far Proximity	2 wide band transducers	0 to 20KHz
Time reversal	T_1/R_1, T_2/R_2 to T_N/R_N in far proximity	Large array wide band transducers	10KHz to 10MHz
Attenuation	T&R in far proximity	2 narrow band transducers	10KHz to 10MHz

3 TESTING AIRCRAFT COMPONENTS

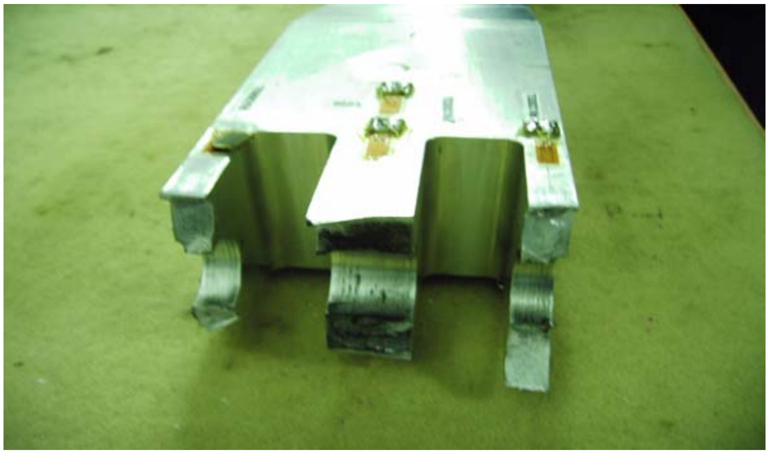
3.1 MODES OF FAILURE

The work package WP1.1 involved the gathering and assessment of information regarding aircraft structure, critical parts and driving failure scenarios. These are detailed in deliverables D1 and D2, broadly most causes of failure can be classified into:-

a) Fatigue
b) Corrosion
c) Wear
d) Thermal shock
e) Mechanical shock (impact)
f) Mechanical stress (Buckling)

Example of wing buckling

Partner VZLU
Czech Republic



Example of mechanical Failure of an aircraft component

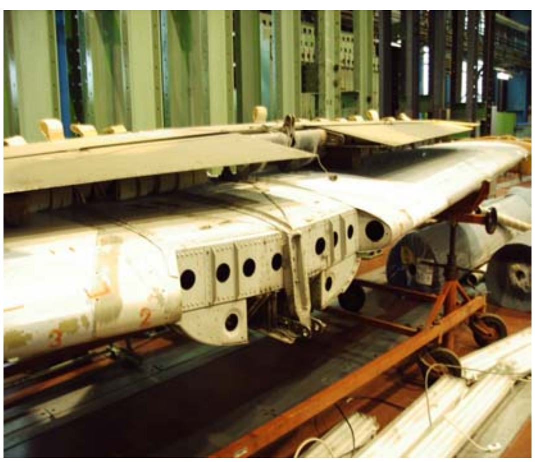
Partner VZLU
Czech Republic

The goal of AERONEWS is to be able to produce a system that will generally monitor the health of an aircraft, but also detect impeding failure, or to assess the extent of damage should it be involved in an accident.

3.2 ACCESSIBILITY

Accessibility to the particular areas or sub-assemblies of the aircraft will be one of the main obstacles to a maintenance, health monitoring and testing regime. The group of pictures indicate the problems involved.
A hand held instrument with contact transducers would have to be of small enough size to reach internal structures.
Alternatively permanently fitted transducers can be placed in awkward locations, and the instrumentation either permanently wired to them, or temporally connected for testing.

Partner VZLU
Czech Republic



The AERONEWS system must be configurable to allow different structures and arrangements of transducers so that access can be obtained to the aircraft parts.

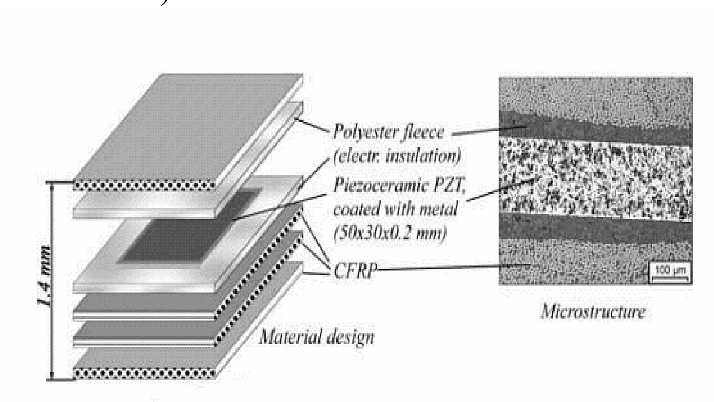
For large aircraft structures ideally there is a requirement to test large areas as quickly as possible. In cases such as this large arrays of transducers are beneficial.

For small component parts there is a requirement to provide detailed, high resolution testing. The time factor is not so critical as only small regions need to be tested.
Two high frequency transducers may be sufficient for these applications.

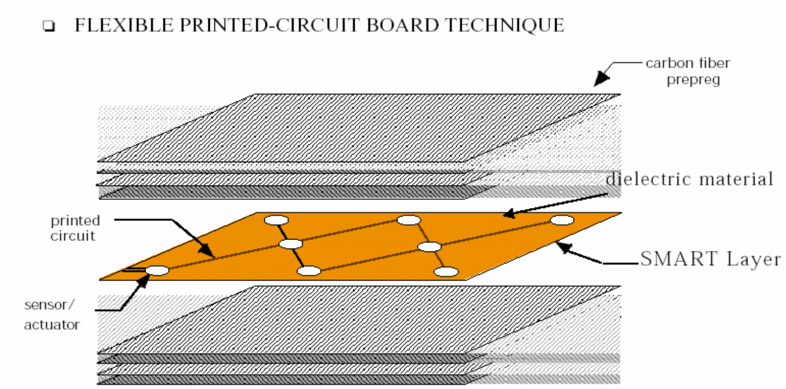
3.3 EMBEDDED TRANSDUCERS

Embedding transducers into aircraft structural components takes three main forms:-

1) The transducer is a part of the aircraft structural component
2) The transducer is fitted within the structural component at manufacture
3) The transducer is bonded to the surface of the aircraft component



Transducer manufactured as part of aircraft component



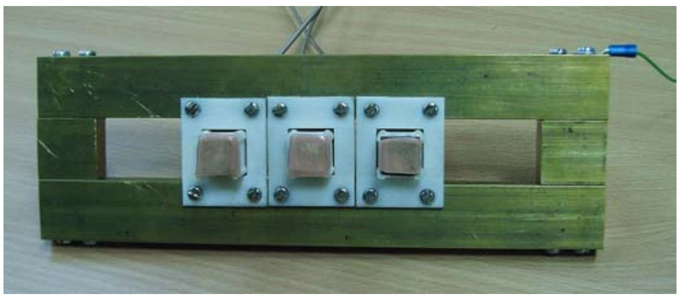
Transducers inserted during manufacture of aircraft part

Transducers permanently bonded to the surface of the aircraft part.

The electronics of the AERONEWS system must be versatile enough to accommodate all the designs types of transducer and configurations. Embedded transducers have fixed characteristics and configurations.

3.4 CONTACT TRANSDUCERS

Contact transducers can only be applied to the surface and are coupled to it by sold metal / rubber / plastic, liquid gel, or a dry contact. They are by design removable and positioned as required for the testing.
The advantage of such transducers is that different configurations of sensor and actuator can be assembled to match the requirements of a particular test or test object. The configuration can later be disassembled and re-used for another application.



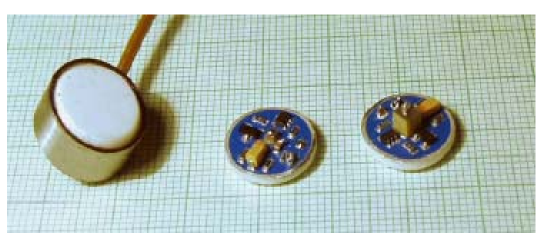
Array of three spring loaded contact transducers, with plastic coupling to the component under test.

Developed at Exeter University

One spring loaded transducer that functions both as a receiver and a actuator. The device has pre-amplifier and a power amplifier electronics incorporated. Solid or gel couplent can be used.
Frequency range of transducer = 100KHz to 400KHz
Frequency range of electronics = DC to 2.5MHz

Developed at Exeter University

With this design, the electronics can be fixed and a change of transducer made to alter the operating frequency range, or to change from broad band to narrow band.



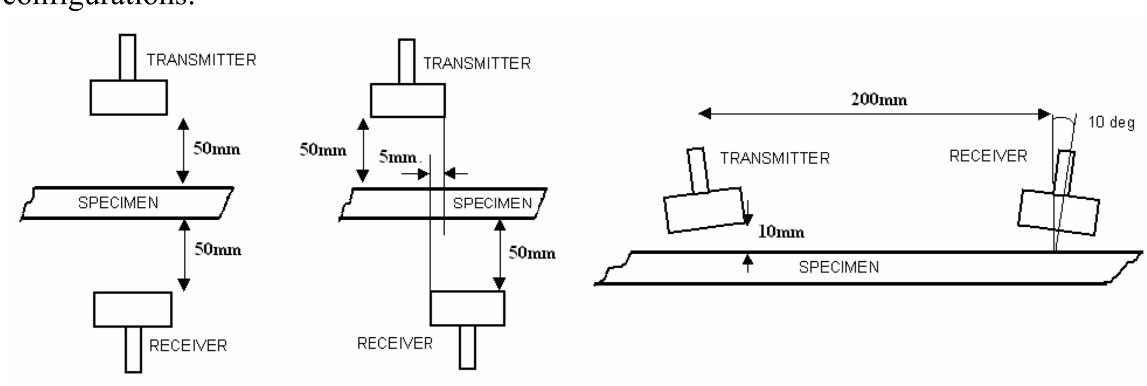
Above transducers developed by DAKEL, left a Langevine power actuators 25KHz and 50KHz, right PZT plate sensor with pre-amplifier, broadband 200KHz to 600KHz

3.5 NON CONTACT TRANSDUCERS

These are transducers that do not need to be in physical contact with the aircraft component under test. They mainly fall into three categories, optical, electromagnetic and air coupled.
Within the consortium Optical and Air coupled transducers have been investigated in considerable detail, both have the advantage that the “stand off” distance, that is the distance between transducer and test material, can be relatively large.

Air coupled transducers

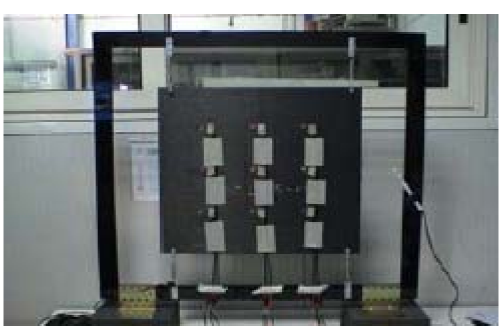
These in general function at frequencies below 400KHz, and typically less than 50KHz.
The “stand off” distance depends on frequency but is usually in the order of 50mm (at 50KHz). One transmitter and one receiver transducer are often used in the following configurations:-



ref: Ultrasonic Air-Coupled Inspection of Advanced MaterialJan O. Strycek and Hanspeter Loertscher, QMI Inc., 919 Sunset Drive, Costa Mesa, CA 92627

Optically coupled transducers

Within the AERONEWS consortium Optically coupled transducers have been used in various combinations. The University of Naples uses a laser vibrometer as a sensor and an array of piezoelectric actuators bonded to the aircraft component under test.
This arrangement is shown in the photographs below:-



Panel with PZT actuators Laser Vibrometer Sensor

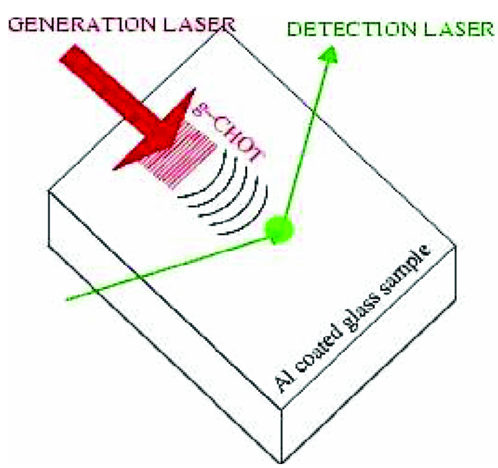
Some example laser vibrometers have the specifications:-

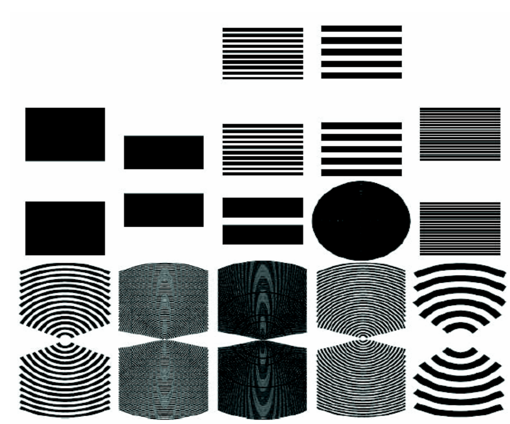
Polytec PDV-100
frequency range 0.5Hz to 22KHz
working distance 0.2 to 30m
analogue output +/- 4 Volts
digital output 24bit (48Ksamples/second)

Polytec HSV-2000
frequency range 0 to 250KHz
analogue output +/- 8 Volts

Some versions will function up to 30MHz

The University of Nottingham is developing a laser acoustic source and detection system based on the CHOT (Cheap Optical Transducer). G-CHOT is for optical acoustic generation and d-CHOT is for optical acoustic detection.





The diagram above shows the working principle. Patterns drawn onto the surface of the sample, g-CHOTs generate ultrasound by providing the necessary optical absorption contrast to generate laterally modulated thermal stress waves, the multi-lined patterns providing a focusing transmission array. The d-CHOT is a pattern which reflects light and acts in effect as a reflective phase grating.
The working frequency investigated in their research is 82MHz.

Other investigations within the partnership involve embedding optical fibers into the composite aircraft components, the fibers will act as sensors, signals are measured by shining light down them and examining the reflections and refractions of gratings cut into their surface. Frequency range and output have yet to be determined.

Electromagnetic transducers

Electromagnetic acoustic transducers (EMATS) were examined briefly, their “stand off” distance is small, typically less than 1mm. They only function on metal (conductive) structures, for insulating composite materials metal disks would need to be embedded within the structure, this would add weight and may weaken the composite.
Typical frequencies of operation for the types of aircraft components investigated under the AERONEWS project are in the range10KHz to 5MHz.
The driving electronics (pre-amplifier and power amplifier) is very different for that of piezoelectric transducers, it is required to drive low impedance very inductive devices.

For all these non contacting sensor and actuators to be integrated into a complete NEWS testing system, a general electronics platform has to be designed, from this platform bespoke electronics are built to provide an interface to the devices.

4 PROPOSED SYSTEM SPECIFICATION

4.1 INTRODUCTION

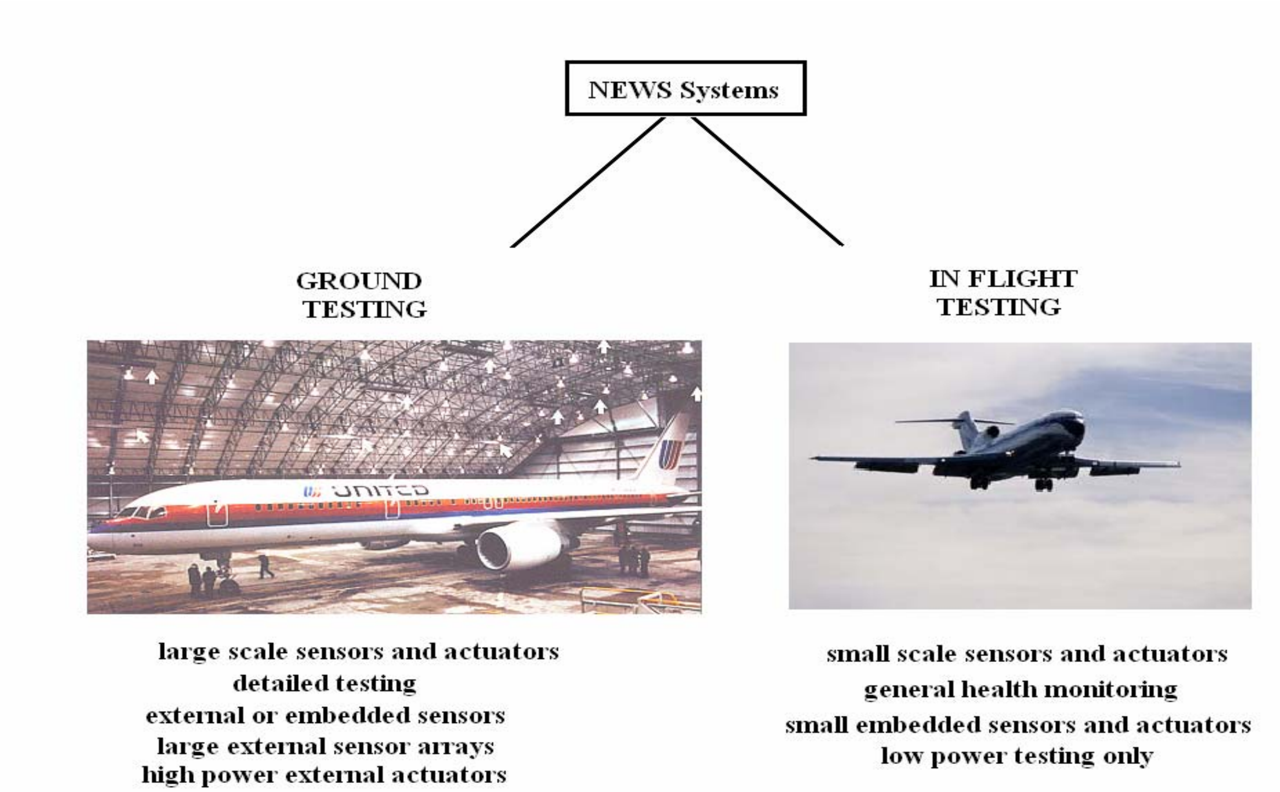
This section of the report provides a provisional hardware and software specification for a Non linear Elastic Wave Spectroscopy (NEWS) testing system. An overview is given of the systems and why we selected certain technology in its design.
Two design routes have been proposed, the first being the sampled data system, which has its origins in an instrument for ultrasonic testing of concrete structures. The second, the continuous monitoring system, has its origins in an acoustic emission monitoring system.

It was decided that two approaches were necessary in order to encompass all the requirements of the NEWS system. Principally the continuous monitoring system is suited for transducers that are permanently embedded into aircraft structures, for both in-flight and ground testing. The sampled data system is suited to manual contact testing of aircraft structures and components whilst the plane is on the ground, including testing procedures that require adoption to different transducer configurations.

Included in this report is a first analysis of the required data flows, remote communication methods and some suggested means by which to display the data graphically. The final solutions to these problems will be obtained over the next year, on the completion of experimental testing of the prototypes.
The final year of the project will examine in detail how best to present the data for interpretation by different operators.

4.2 OVERVIEW OF THE SYSTEM

The system requirements identify the following testing scenarios:-

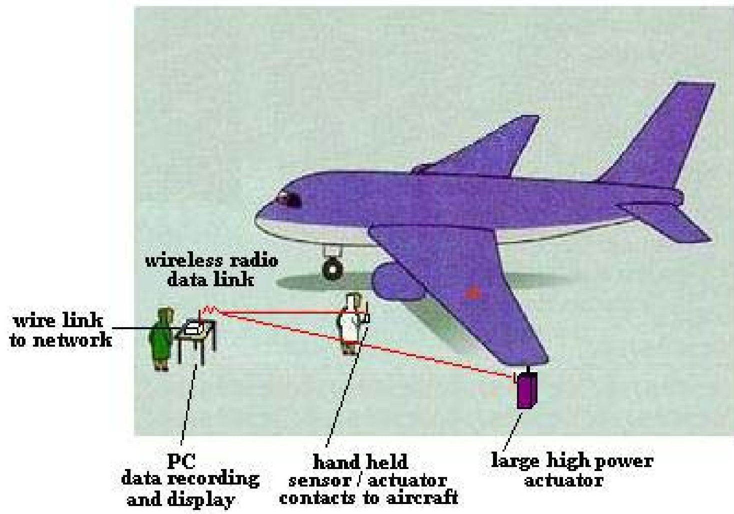


The AERONEWS system is applied in two different ways.

The first application is to perform periodic tests of aircraft whilst they are on the ground, as part of a routine maintenance program carried out over its lifetime.
These tests produce data that will record the long-term state of the aircraft (its health).
Since the aircraft is on the ground very large testing apparatus can be used, and aircraft structures can be examined in detail.

The second application is for in-flight testing. These tests provide continuous “real time” testing whilst the aircraft is in flight. The data produced will provide advanced warning of impending structural failure. It will also provide a record log of general changes in the state of the aircraft.
Since the aircraft is in flight only small testing apparatus can be used, and examinations made in a local and general way.

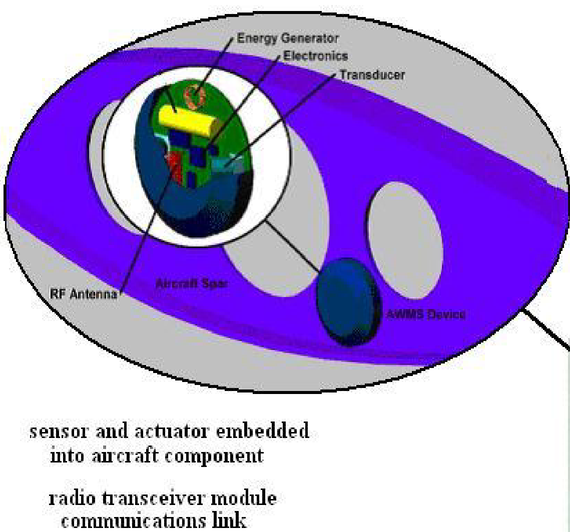
The NEWS system requires the use of a wide range of acoustic sensing and actuation, From low frequency high powered “shakers” working at frequencies in the range 1 to 200Hz, that will deflect large aircraft structures, to localized lower powered ultrasonic transducers working up to 10MHz or above.

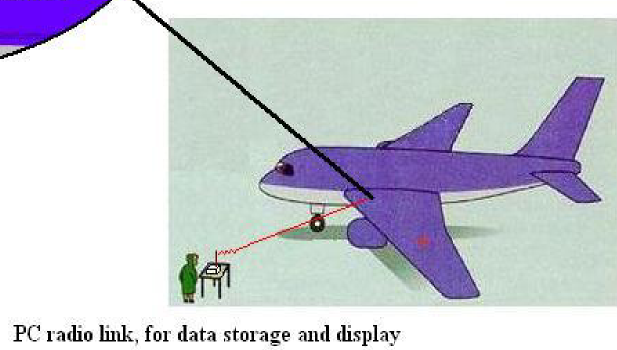


Whilst on the ground aircraft tested by contact transducer instrumentation, interconnected via wire links or radio.

Embedded transducers accessed by radio or wire linked communication, whilst on the ground.

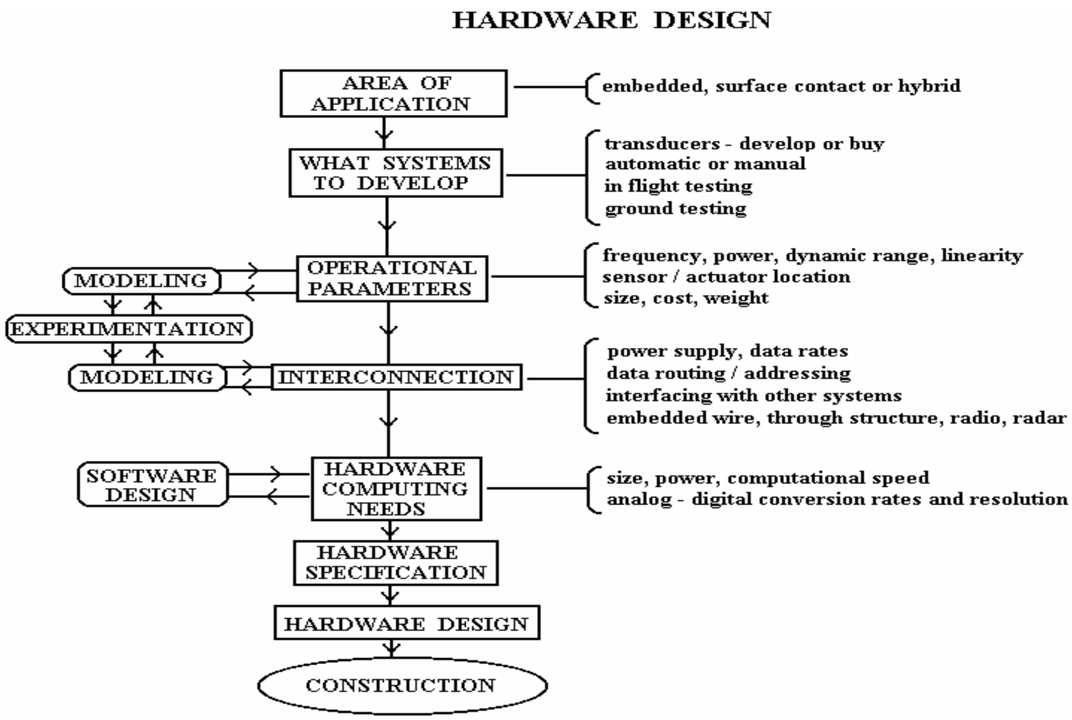
Alternatively embedded transducers wire linked to instrumentation whilst in flight.

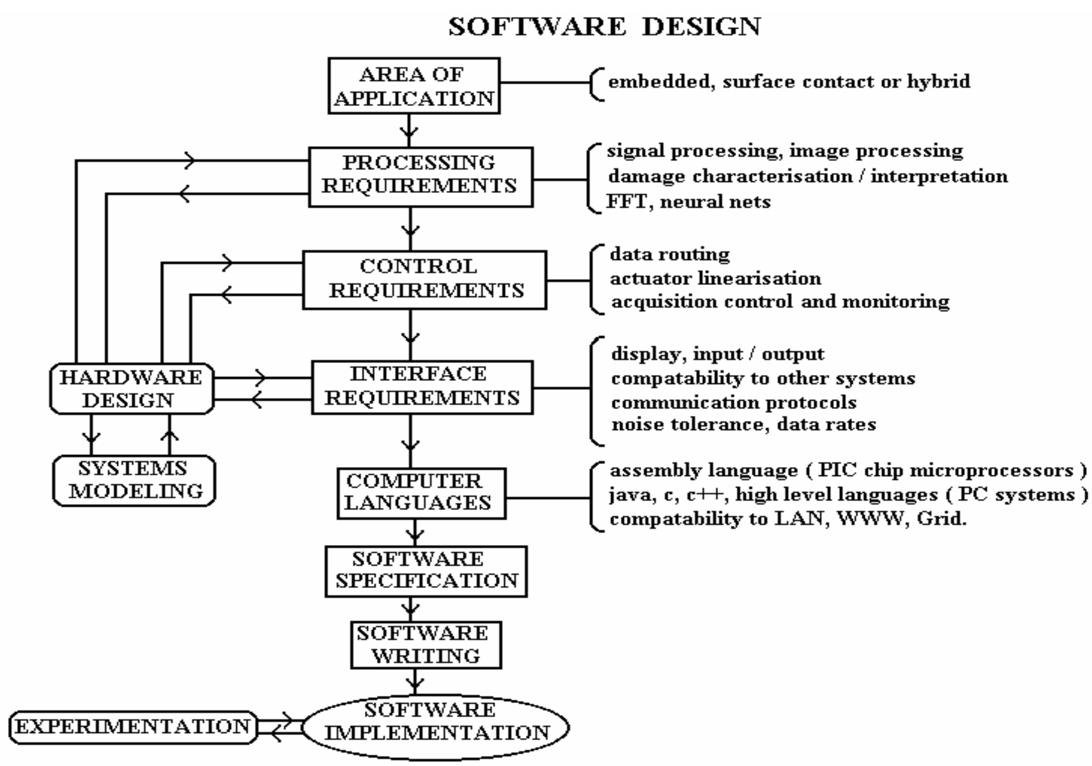




4.3 TECHNOLOGY SELECTION

The Hardware and Software design process:





During the course of the last two years the following selection and decisions have been made:-

The system should comprise of a mixture of embedded, contact and non contact transducers.

Transducers for specialist applications should be developed and provided by the partners. Other transducers purchased.

System designed to operate both on the ground and in flight.

The system should be capable of operating over the frequency range 1Hz to 20MHz.
This should cover practically all the techniques outline previously.

The linearity of the electronics and the transducers should have a distortion factor better than 0.1% THD (-60dB). Indications are that non linearity in defective composite materials is in the order of 2% THD or greater.

The dynamic range of the system must be greater than 76dB
(14 bit analogue to digital and digital to analogue converters will achieve this)

The embedded transducers will be arranged in a fixed layout depending upon the specific application, operating frequency and aircraft component geometry.
In most applications each individual transducer will be connected to a central muli-channel data acquisition and processing unit. Details of this unit are given in the section 4.5 The continuous monitoring system.

The contact transducers will have a variable array structure. To minimize cost, all the elements of the array, comprising the transducer and supporting electronics are identical and will be connected via a single parallel bus to the data acquisition and processing unit.
The transducers within each element can be changed for specific applications.
Details of this are given in section 4.4 The sampled data system.

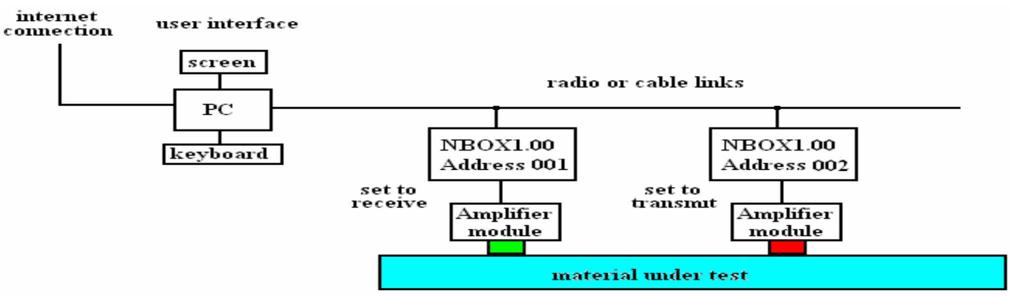
The communication links between transducers and the data acquisition units will be either wire connections, or radio. Due to problems with international safety standards for use of radio equipment in and near airports the radio communication will be using IEEE 802.11 b wireless LAN/WLAN standard. This operates at 2.4GHz, with a range up to 100m, and data rate transfers up to 11Mbits/second.

Within the software design some of the various graphical display methods that have been examined within the consortium are, Bispectrum, 2D distortion plots (2nd and 3rd harmonics) and general amplitude spectrum displays.
It is too early at this stage in the development to focus on one particular graphical or software processing technique. However the system is designed to be flexible enough to accommodate any subsequent requirements.

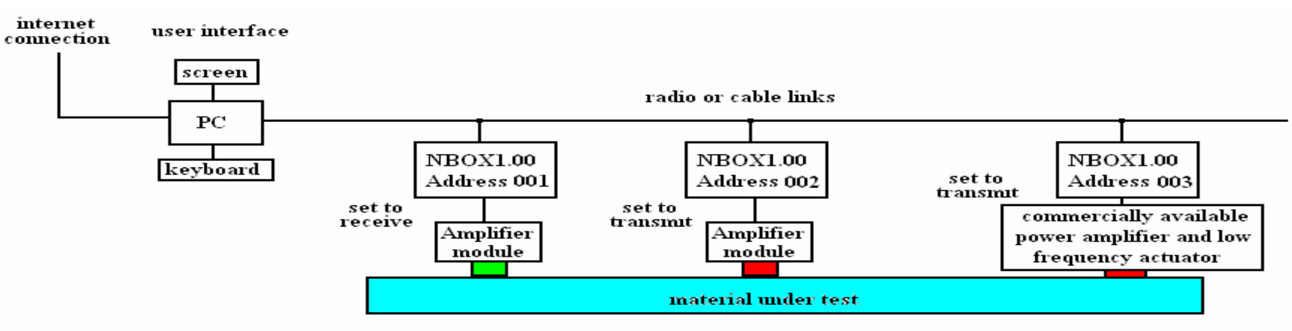
4.4 THE SAMPLED DATA SYSTEM

The sampled data system being developed at Exeter University, comprises a platform of SMART electronics elements (NBOX's) interconnected via a parallel data bus, or common, broadcast radio link. Each NBOX is connected to a transducer via an analogue amplifier module. Element array connectivity is built dependent upon the required application. Each element can be act as a sensor or actuator. Examples of connectivity are given below.

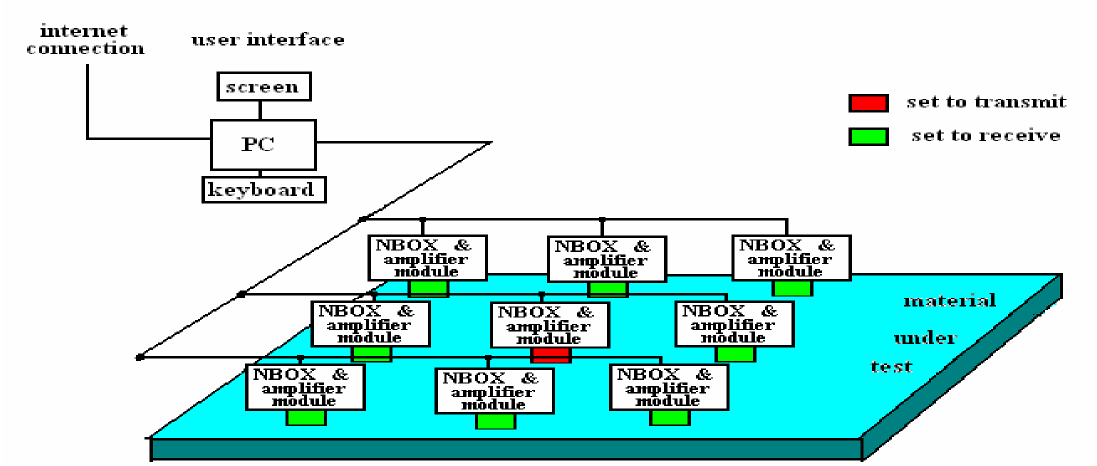
Non-linear spectroscopy (harmonics, overtones and resonant frequency shift)



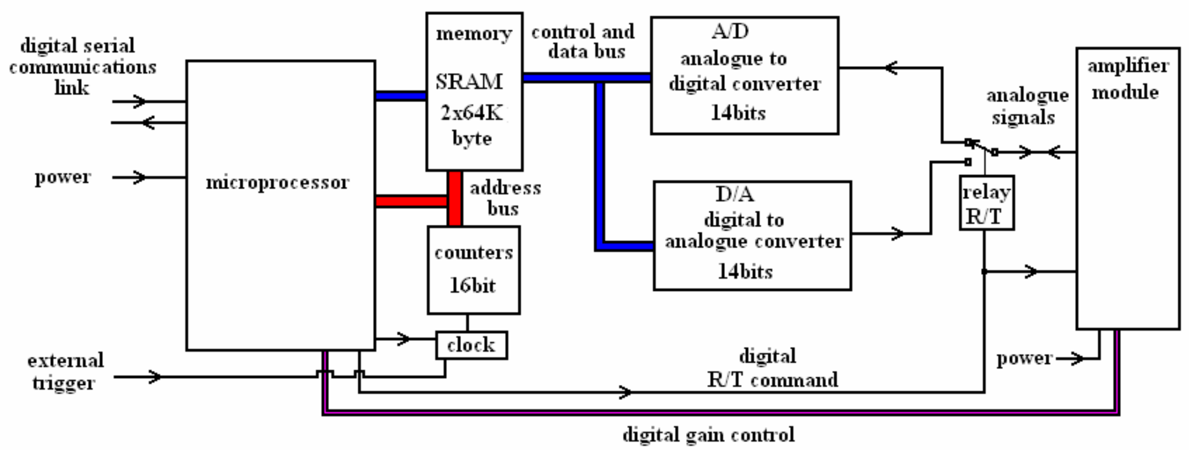
Non-linear modulation (sine burst, sidebands and modulation products)



Non-linear propagation(time reversal NEWS)



The NBOX schematic diagram



The NBOX specification

Each NBOX consists of a single module that can be configured to act as an actuator or a sensor. Each module has its own address for the reception of commands, and connected to a parallel bus, accommodating up to 256 modules.

Digital communication:-

RS 232 serial link	4800 to 115K baud, 8data bits, 1 stop bit, no parity
PC USB serial link	to 1M baud (converted to TTL data bus)
External trigger	TTL to start sample / fire actuator (delay < one sample period)
Software trigger	software command via serial link (delay approx 1msec)
Connectivity	common parallel receive-transmit data bus
Module address	up to 256 individual addresses per node
Protocol and standard	IEEE 1451

RECEIVER MODE

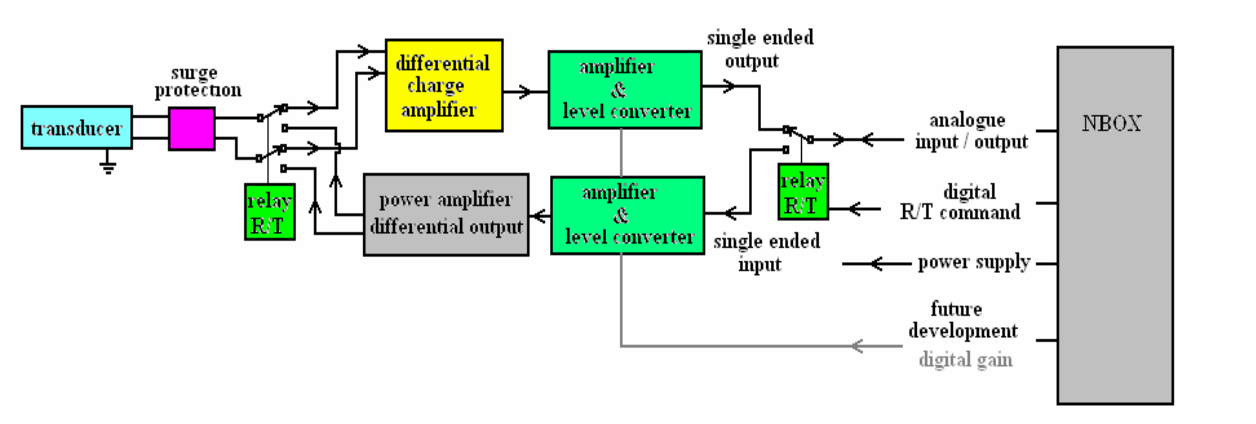
Number of channels = 1
Output Voltage = 0 to 4volts
Resolution = 14bits
Maximum samples = 64K
Sampling period = 2usec to 25nsec
Frequency response = DC to 20MHz

TRANSMITTER MODE

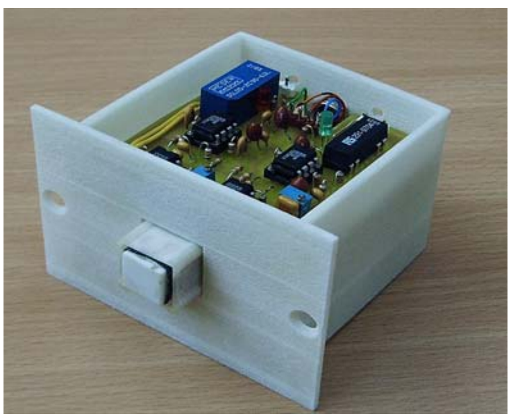
Number of channels = 1
Input Voltage = 0 to 4volts
Resolution = 14bits
Maximum samples = 64K
Sampling period = 2usec to 25nsec
Frequency response = DC to 20MHz

Microprocessor PIC micro controller chip programmed in assembly language
Power supply +5Volts, +/- 15 Volts for external amplifier unit
Sampling period selected by plug in crystal (range 500KHz to 40MHz)
Circuit board 80mm by 150mm. EMC compliant enclosure

The amplifier module schematic diagram



The amplifier module specification



Analogue input (transmit mode) = 4 Volts max
Analogue output (receive mode) = 4 Volts max
R / T command = 5 volts (50ma) for transmit, zero volts or not connected for receive
Transmitter output = 30 volts peak to peak, 50ma max
Receiver frequency bandwidth = DC to 3.5MHz (-3dB)
Transmitter frequency bandwidth = DC to 3MHz (-3dB)
Power supply = +/- 15volts (200ma)

Transducer specification

Removable, spring loaded, differential connections to active element with earth shield

Current transducer: PZT/composite piezoelectric, broadband receiver and transmitter, 100KHz to 400KHz +/- 6dB. Acoustic impedance 12Mrayls. Front face ceramic.

4.5 THE CONTINUOUS MONITORING SYSTEM

The continuous monitoring system being developed by DAKEL comprises a central unit that contains data acquisition, processing and transmission electronics. The transducers, which will mainly be embedded, are connected via wires to a single unit. In extended systems a plurality of these units are located at various positions around the aircraft, each connecting to local transducers. The units inter communicate via wire links or radio (USB WI-FI) to a central computer for data analysis and display.

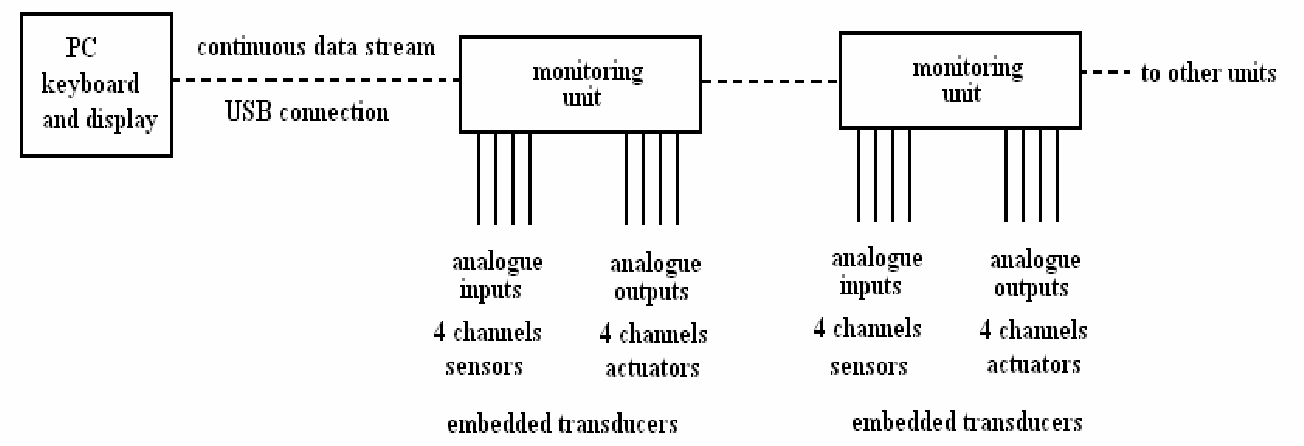
Photograph below shows the unit DAKEL DTR-1012AQPU, this is a prototype that is now in service. Its specification is:-

Resolution = 12 bit
Analogue input channels = 4
Sampling frequency 2Msamples/second
Connection = USB 2.0 (standard B-type connector)
Data rate = 16Mbits/second
Mode = Isochronous (channels synchronized within unit)

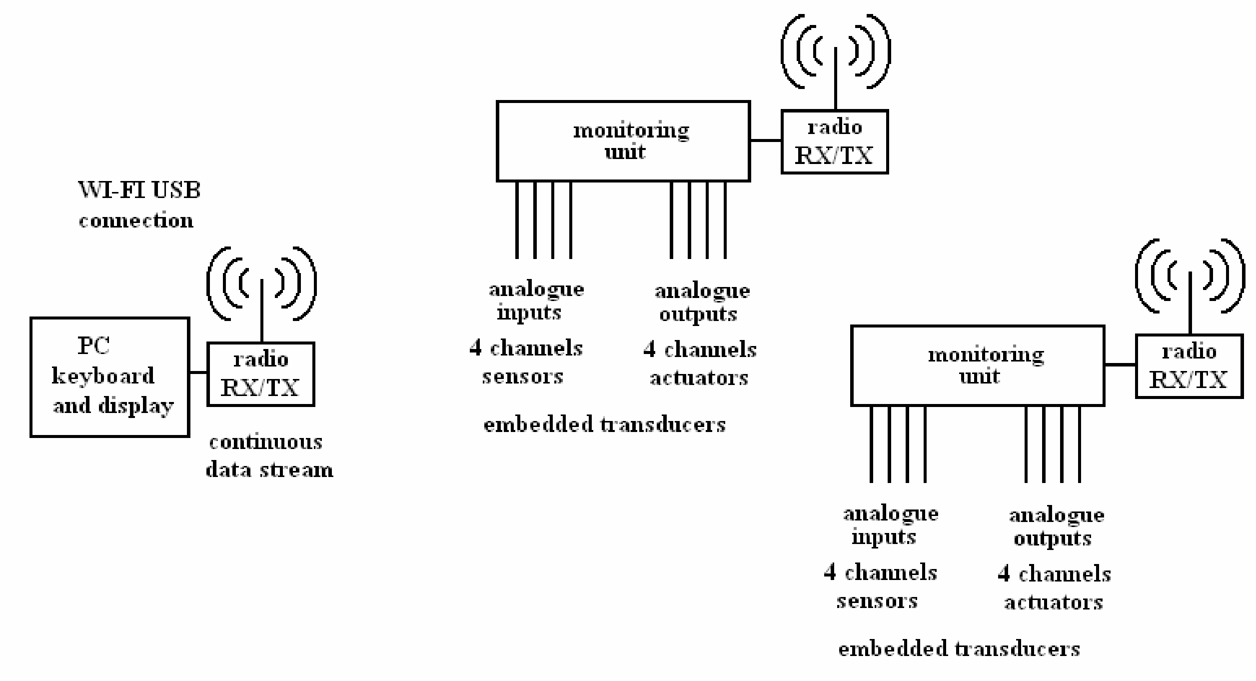
The next generation of unit, currently under development, includes transmitter channels, its provisional Specification is given below:-

Unit ID = DAKEL DTR-1012BAQPU
Resolution = 12 bit
Analogue input channels = 4
Analogue output channels = 4
Sampling frequency 2Msamples/second
Connection = USB 2.0 (standard B-type connector)
Data rate = 16Mbits/second
Mode = Isochronous (channels synchronized within unit)

Possible configuration scenarios:



Monitoring units act as nodes and wire connected together. Each node connects to embedded sensor and actuators. Data fed continuously to PC for monitoring.



Monitoring units act as nodes and radio (WI-FI) connected together. Each node connects to embedded sensor and actuators. Data fed continuously via radio link to PC for monitoring.

4.6 SOFTWARE SPECIFICATION

It is still too early in the research and development program to form a definitive specification for the software. The decisions that have been made so far are:-

The microprocessors, used within the sampled data system, to be programmed in Assembly language.

A standard IBM portable computer, or in the case of the sampled data system a small lap top computer, to be used for the sending of control information, data receiving, processing and display.

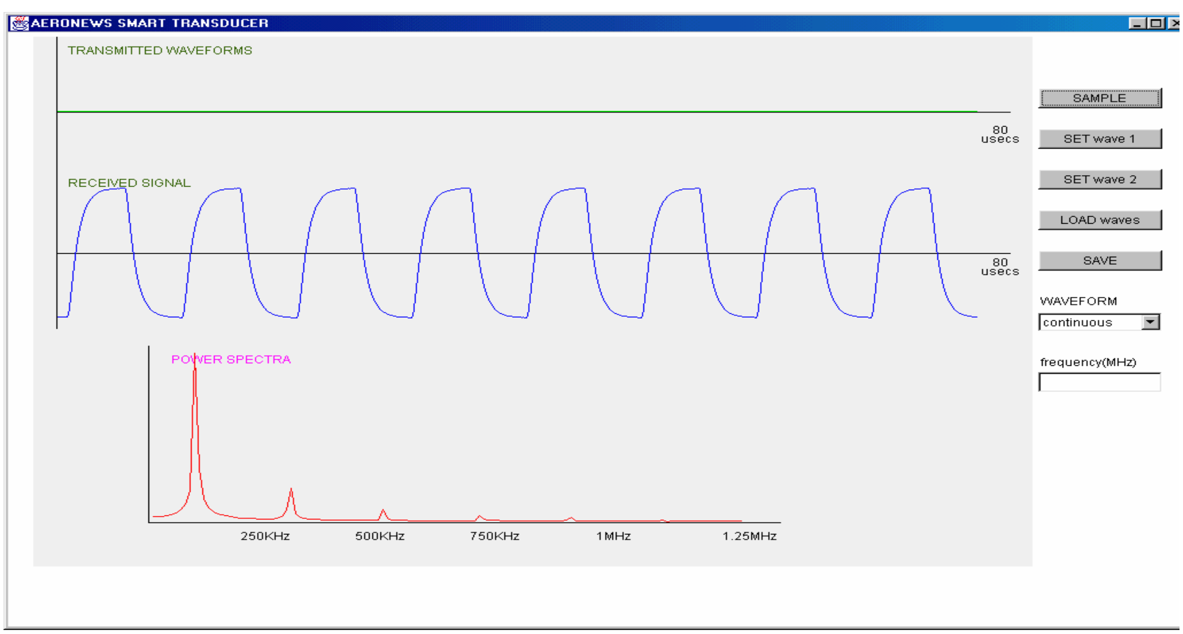
The software to run under either a Windows or Linux operating system

The software to run on the PC or lap top to be written in Java or C++
These languages should be able to run on either of the above operating systems.
Java being cross platform will run under both. Java will also provide direct compatibility to USB WI-FI , Local Area Networks (LAN) , World Wide Web (WWW), and the grid.

The microprocessors will be programmed with power up reset, to provide fast boot up on power failure or computer malfunction. A watch dog timer on both the microprocessor and the PC prevent a "lock up" situation occurring during data transmission.

The radio links will be provided with Manchester encoding or other form of data whitening, cyclic redundancy checking (CRC), automatic repeat request (ARQ) and forward error correction (FEC), to enable accurate data flow.

The simplest possible display is given below for simulated data. The spectra are obtained by using a Fast Fourier Transform (FFT) running on the PC.



CONCLUSIONS

A provisional specification is given for the AERONEWS testing and health monitoring system. The hardware specification is comprehensive, and prototypes based on it are being constructed. These prototypes will be used on actual aircraft components in May 2006 when undertaking a series of tests at VZLU in Prague.
The Software specification will evolve as the experimentation phase progresses, and when we gain greater understanding of the logistics in the testing procedures and data analysis.