Application Note

Multichannel acoustical measurements using the Multichannel Analysis System Type 3550

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Application areas

- Noise surveys of engines, gear boxes, compressors etc.
- Spatial transformation of sound fields
- Transient analysis
- Rotating machinery

Many channels or multichannel?

A clear distinction needs to be made between many channels and multichannel. For decades virtually the only acoustical parameter used to describe acoustical fields in an industrial environment was the scalar quantity, sound pressure level measured using a single channel system such as a sound level meter. For the determination of sound power from sound pressure according to standards such as the IS0 series 3740 to 3747 and their equivalents in AFNOR and ANSI, many measurement points are required. To reduce the measurement time, many channels are required i.e. many single channels measured either serially by means of a multiplexer or in parallel. Manufacturers of noise producing machines (e.g. cars, aeroplanes, washing machines) are increasingly demanding more information about the acoustical radiation properties of their products. This has stimulated the development of dual channel instrumentation for the measurement ofthevector quantity, sound intensity, which quantifies the rate and direction of energy flow. Sound intensity has become the basis

Fig. 1 Multichannel Analysts System 3550 comprising an analyser and two data acquisition units each containing 8 input modules

of industrial methods for the evaluation of sound radiation by means of source ranking and source mapping. However many research and development laboratories wish to go still further, to obtain a more complete picture of the sound field by means of, for example partial and multiple coherence analysis and source modelling using spatial transformation of sound fields. Such measurements require multi-channel systems.

Multichannel measurements

The extension from one to two simultaneous channels was much more than a mere doubling of the measurement capacity. Projecting two signals towards each other yielded the cross spectrum which contains both amplitude and phase information. A new domain of signal processing opened up, resulting in new functions such as frequency response, coherence and their derivatives used for the analysis of linear relationships between input and output signals. These methods developed to produce operational deflection shape and modal analysis techniques. By using a fixed reference transducer and a movable microphone, researchers in the automotive industry have performed acoustical modal analysis and operational deflection shapes inside vehicle cabins.

In a similar-way, multichannel analysis is much more than just adding the capacity to measure more inputs and more outputs. As soon as the dual channel situation of one output and one input is changed to one (or more) output and two (or more) inputs, the realm of Multiple-Input/Multiple-Output (MIMO) is entered. The innovation is found in the multiple input where the cross products of the input signals are measured. MIMO is in fact merely an extension of the Multiple-Input/Single-output situation. Multiple input measurements open up new application areas, such as selective sound intensity measurements, improved spatial transformation of sound fields measurements, and advanced correlation analysis such as partial coherence and principal component decomposition analysis.

Instrumentation for multichannel acoustical measurements

A truly modular FFT-based system which enables the user to start with a two channel system and to expand the facility to 16 parallel channels is the Multichannel Analysis System Type 3550 shown in Fig.1, consisting of an analyser and two multichannel data acquisition units, each equipped with 8 input modules. Each input module can accept a Brüel & Kjær microphone, a direct input and a charge input. Each sound intensity module contains two sound intensity sockets. A maximum of 16 microphones or 8 sound intensity probes can be used. Combinations of both are of course allowed, as is the use of other transducers. Other modules exist (e.g. generators) but these are outside the scope of this note.

Noise surveys of engines, gears, compressors etc.

From the 1/1/93 European Community directives come into force concerning the airborne noise emmissions of machinery. Where the sound pressure level of the machine exceeds 85dB(A) at the work station then the sound power level of the machine must be stipulated. Peak C weighted instantaneous pressure levels where this exceeds 130dB re 20μPa and equivalent continuous Aweighted sound pressure level where this exceeds 70dB(A) must also be stipulated for all workstations. These directives will have a very strong influence on both export and import of all manner of machines. Manufacturers must be able to make fast measurements of sound power without disturbing production which means measurements will have to be performed in or all least near to the production site. Sound intensity is an obvious candidate to tackle this task.

Up to 8 components of intensity can be measured simultaneously using the 3550 with two data acquisition units equipped with intensity modules. The intensity probes can be positioned over a test surface for rapid sound power measurement (Fig.2), arranged in a column for fast mapping measurements (Fig.3) or configured as 3D intensity probes. The Mapping and sound power program WT9378 can be used to control the data acquisition and the presentation of the results. By using a three channel configuration of the 3550, selective intensity can be performed where the intensity coherent with a reference signal is measured (Fig.4).

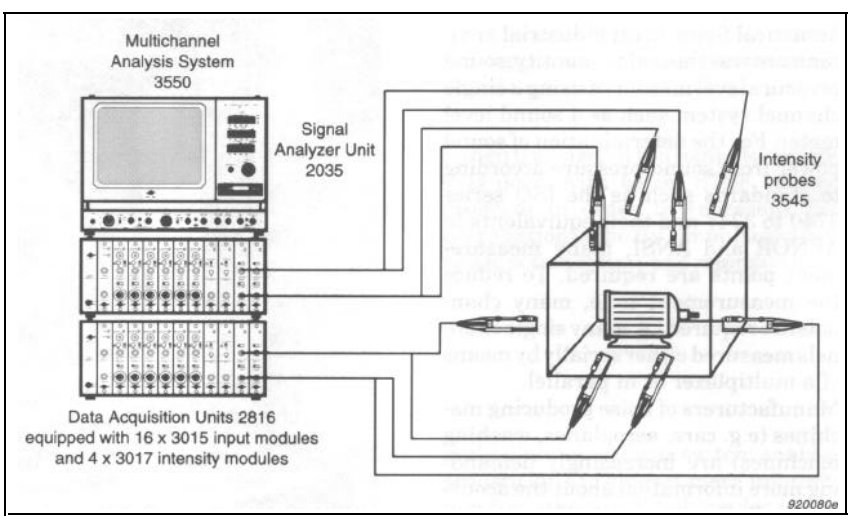

Fig. 2 Soundpower measurement using a Multichannel Analysis System equipped with 8 intensity probes

STSF, Spatial Transformation of Sound Fields

STSF involves a planar scan of an array ofmicrophones over a test object. The cross spectra between a small number of reference transducers are measured, and also the cross spectra between each reference transducer and every scan position. From these cross spectra a complete model of the sound field is established by means of a principal component decomposition technique.

Automotive applications of the STSF technique include noise surveys in test cells of engines and gear boxes, on dynamometer test rigs of power trains and whole vehicles, studies of tyre noise, calculation ofthe far-field radiation patterns of vehicles, simulation of source attenuation, inclusion and exclusion of partial noise sources in the total acoustical model and measurements in wind tunnels.

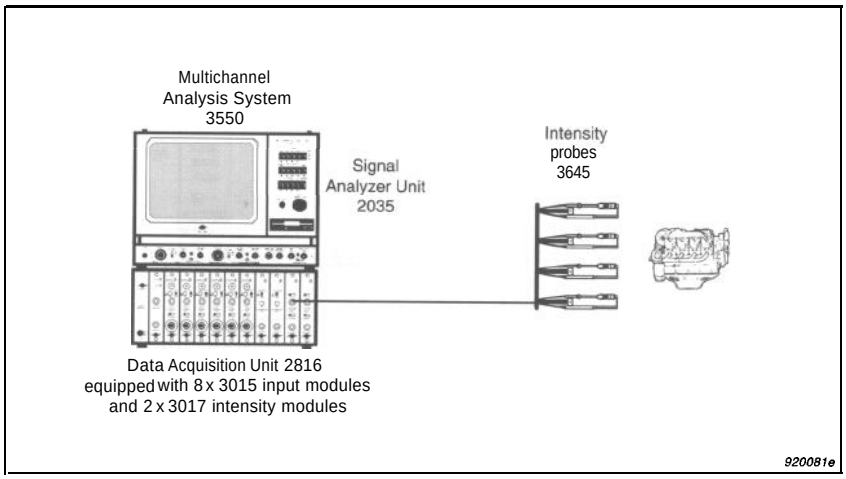

Fig. 3 Data collection for sound intensity mapping using an array of 4 intensity probes

Transient analysis

Transients are often the object of an acousticians investigation e.g. explosions, impacts, cylinder firing, impulse response of rooms. One approach is to capture the entire time signal and to analyse it afterwards.

Time capture mode

The time capture mode enables storage of 64K samples in internal memory (RAM) in single channel or 2 x 32K samples in dual channel. The time samples can afterwards be displayed and analysed in many different ways to extract the desired information. Short term FFT's with user specified transform size and overlap, can be performed and displayed in 3D maps. This feature is useful for the analysis of non-stationary signals and transients. Scan average and l/n synthesis can be performed on transients captured in the time buffer. The time capture mode is also used for high resolution analysis of stationary signals for diagnostic purposes. Up to 25600 line spectra can be obtained in single-channel mode and in dual-channel mode up to 12800 line spectra can be calculated.

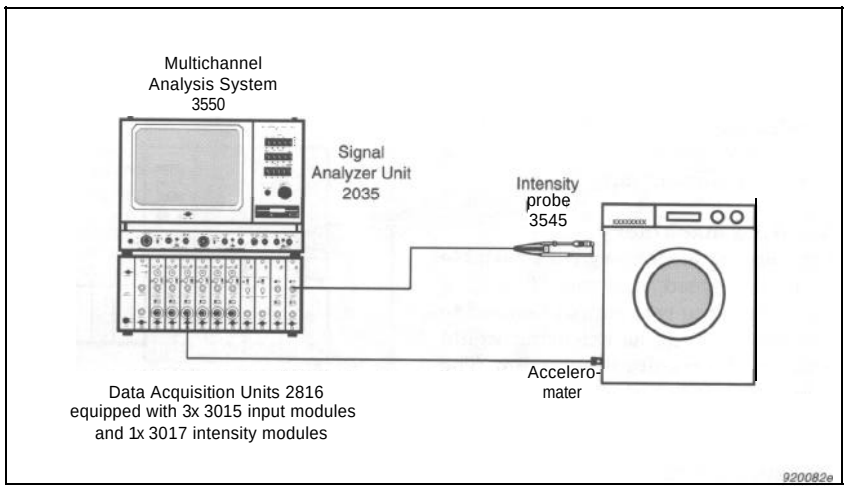

Fig. 4 Noise survey **using** *the selective intensity technique*

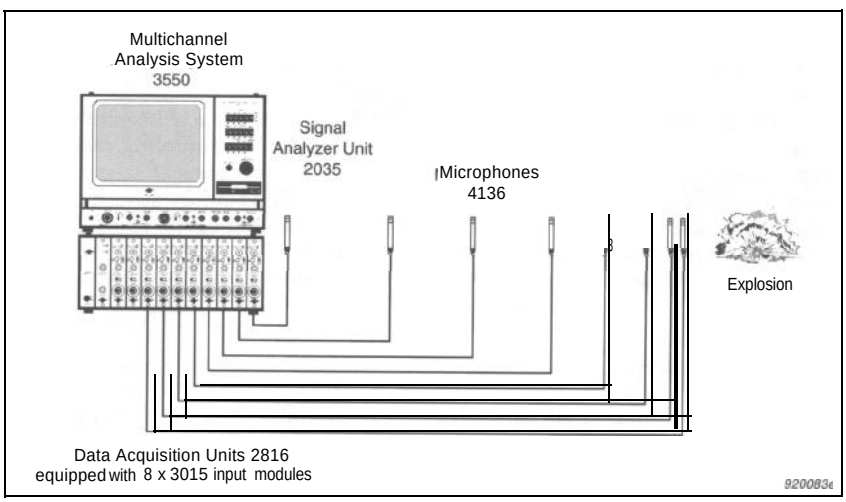

Fig. 5 Analysis of short transients using multichannel **dual** *spectrum averaging*

Multichannel dual-spectrum averaging

Up to 16 channels may be used. The maximum number of line spectra for each channel is 800. A number of approaches are available:

- Time capture mode
- Multichannel dual spectrum averaging mode

* Time history mode

An application is the measurement of impulses by means of a number of microphones (or hydrophones) at various distances from the test source. A trigger signal is set on the first microphone and suitable time delays are set of the other channels to bring the signal into the measuringwindow (Fig.5).

Time History mode

In the Time History mode the analyser acts like a digital tape recorder. The signal comes into the analyser is digitised, stored temporarily in RAM and loaded down onto disc as fast as possible. The main parameters to be set in this mode are the frequency range and the number of channels.

In an investigation on the passage of a high speed train, eight pressure microphones arranged 50cm apart were set in a vertical array about 2m from the train (Fig.6). Using the Time History mode which is available in the Extended Software Type 7639, 640k samples can be recorded onto the disc without dataloss. With 8 channels this corresponds to 80K samples/channel. A **frequency** range of 6.4kHz i.e. a sampling frequency of 16384Hz (6400Hz x 2.56) yields 5 seconds of time data (80Ksamples = 81920 samples = 5sec x 16384 samples/sec). This data can be recalled and analysed at will. In 5sec the train moves 555m (400km/hr), so 5sec is a sufficient data length.

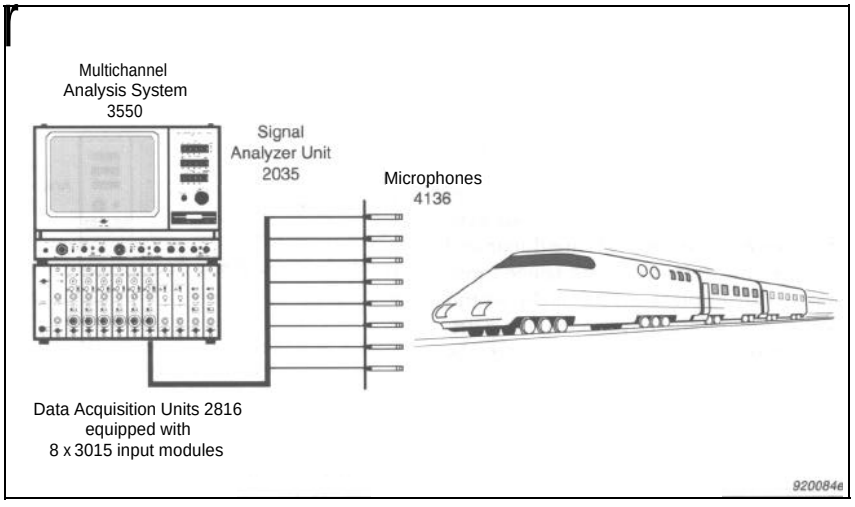

Fig. 6 Drive pass noise of a high speed train recorded using the multichannel time history mode

Rotating machinery

For rotating machinery with variable rotational speed, instruments with a fixed sampling rate cannot be used to perform analysis as smearing would occur in the resultant spectrum. The sampling frequency needs to be linked to the speed of rotation. This is basically the tracking technique used in the automotive industry for order analysis. Furthermore repetative signals (deterministic signals) can be averaged together to suppress unwanted background noise. In the 3550, this technique is known as signal enhancement using tracking.

In the aerospace industry, there is great interest in investigating boundary vortex interaction (BVI) impulse noise from rotors whose tips are moving at supersonic speeds. This problem is being tackled by using a 3550 with a linear array of 16 microphones mounted under the rotor of a helicopter in a test cell (Fig.7). The sampling rate is controlled by an external trigger which monitors 512 equally spaced markers placed around the rotor shaft. The time signal is enhanced by averaging successive time blocks together. The data is then transferred to a computer where it is dealt with by an STSF related program in order to represent the propagation of the BVI impulsive noise as a function of time and rotor position.

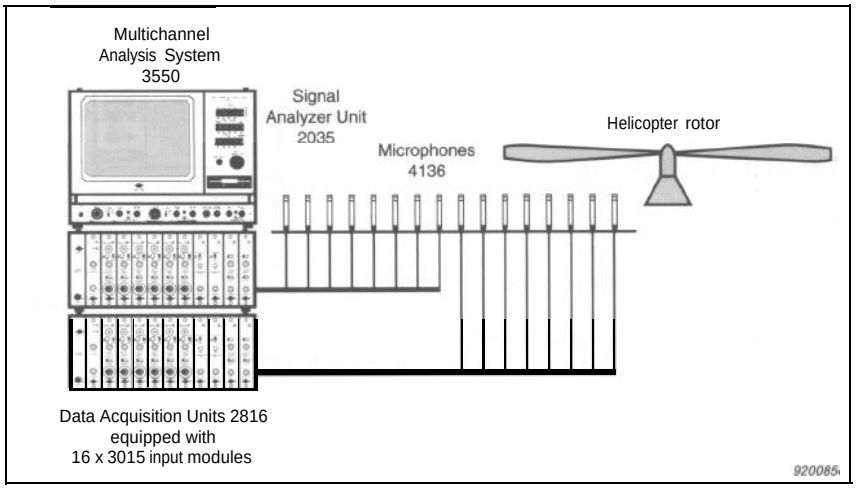

Fig. 7 Investigation ofboundary vortexinteraction impulse noiseona helicopterrotor using a linear array of 16 microphones

Summary

The extension from dual to multichannel measurements means an inevitable increase in the complexity of the instrumentation. However, the excellent human interfacing of the 3550 system has minimised the work involved in the manipulation of the numerous channels. This means that the multichannel analysis system enables acousticians to extract more information from the sound field under investigation in less time.

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