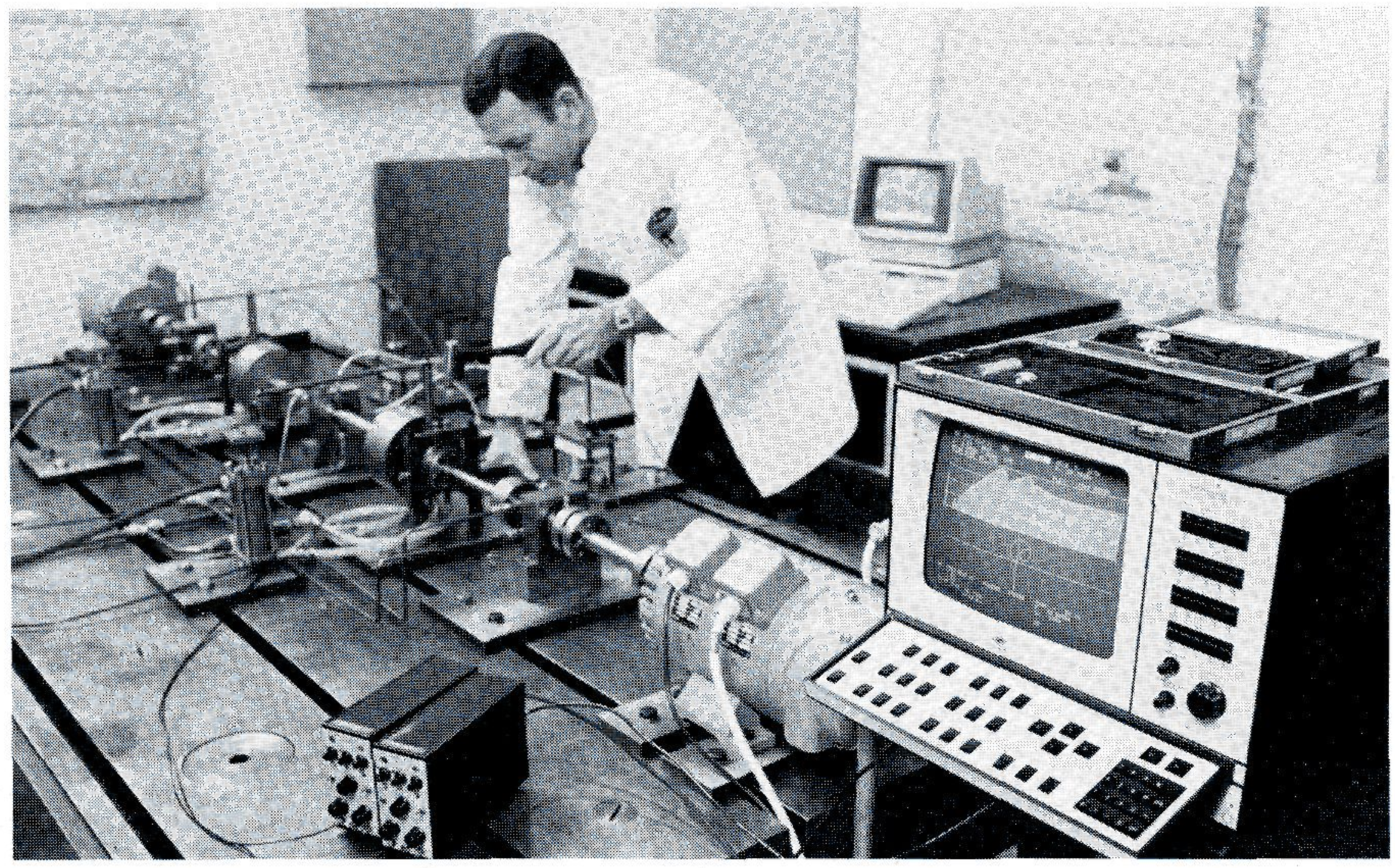
Brüel & Kjær application notes

Mobility Measurements

Brüel & Kjær Dual Channel Analyzers Types 2032 and 2034 make fast, easy and accurate mobility measurements on structures. Equipped with only a force hammer and an accelerometer, even the novice can begin to explore the dynamic behaviour of structures.

This brief note gives an introduction to this important application area and outlines the theoretical background and experimental techniques available to us.



Making Mobility Measurements on a rotor. The hammer provides a known, measured, force input. An accelerometer measures the vibration. The Brüel & Kjær Dual Channel Analyzer computes the Mobility Function

Why are we concerned with structural dynamics?

As economic constraints become tighter, we can no longer afford the problems caused by structures, such as machines on a factory floor, which vibrate excessively. Breakdowns and human discomfort are just two of the problems we often face. A noisy machine is probably not an efficient one.

As we strive to develop faster, lighter and cheaper structures, we must have the expertise and experimental techniques at hand to deal with the vibration problems which ensue. We must also be able to characterize structures. To these ends, simple mobility measurements can help.

What is mobility?

Put very simply, mobility is a measure of how easy it is to vibrate a structure. Consider it the opposite of impedance, which tells us how difficult it is to do the same. When dealing with structures, where we might make measurements at many points, we use the mobility function.

We define mobility in terms of the dynamic force acting at a point and the velocity resulting. In other words

$$Mobility = \frac{Velocity}{Force}$$

Mobility is a *complex* system descriptor. The mobility is frequency dependent and it gives the magnitude and phase relationships which exist between the excitation and the vibration response. We plot the mobility of a structure against frequency and in this way determine the characteristic mobility function. We call this the "frequency response" of the structure. We also use

$$Accelerance^1 = \frac{Acceleration}{force}$$

$$Compliance^2 = \frac{Displacement}{force}$$

When plotted against frequency these mobility functions provide the same information. However, the scaling of the mobility is frequency weighted and depends on whether we have measured acceleration, velocity or displacement. Simple post-processing enables us to change between them.

1 also called inertance

2 also called receptance

How do we measure mobility?

Essentially, we measure the dynamic behaviour of a structure to a forced input. We can measure the response i.e the vibration, using a vibration transducer. We use piezoelectric accelerometers in most cases.

Note. The mass of the accelerometer must not be so high as to change the vibration it was put there to measure. This is important when measuring the vibration of light structures.

We often use a force hammer and "tap" the structure to give the force input. A force transducer in the tip of the hammer produces a signal of the force pulse. We can also use a vibration exciter. A force transducer be-

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tween the measurement point and the shaker produces the force signal. Only with the latter method can we chose the type of excitation signal. The built-in generator of the 2032 and 2034 provides random, pseudo-random and sine signals to drive the vibration exciter.

The signals from the force transducer and accelerometer are fed into the two channels of the analyzer. Most transducers require an external preamplifier between themselves and the analyzer. Brüel & Kjær line-drive accelerometers have built-in preamplifiers. These can be plugged directly into the analyzer.

The analyzer simultaneously measures the force and response, converts them into a digital signal and computes their Discrete Fourier Trans-

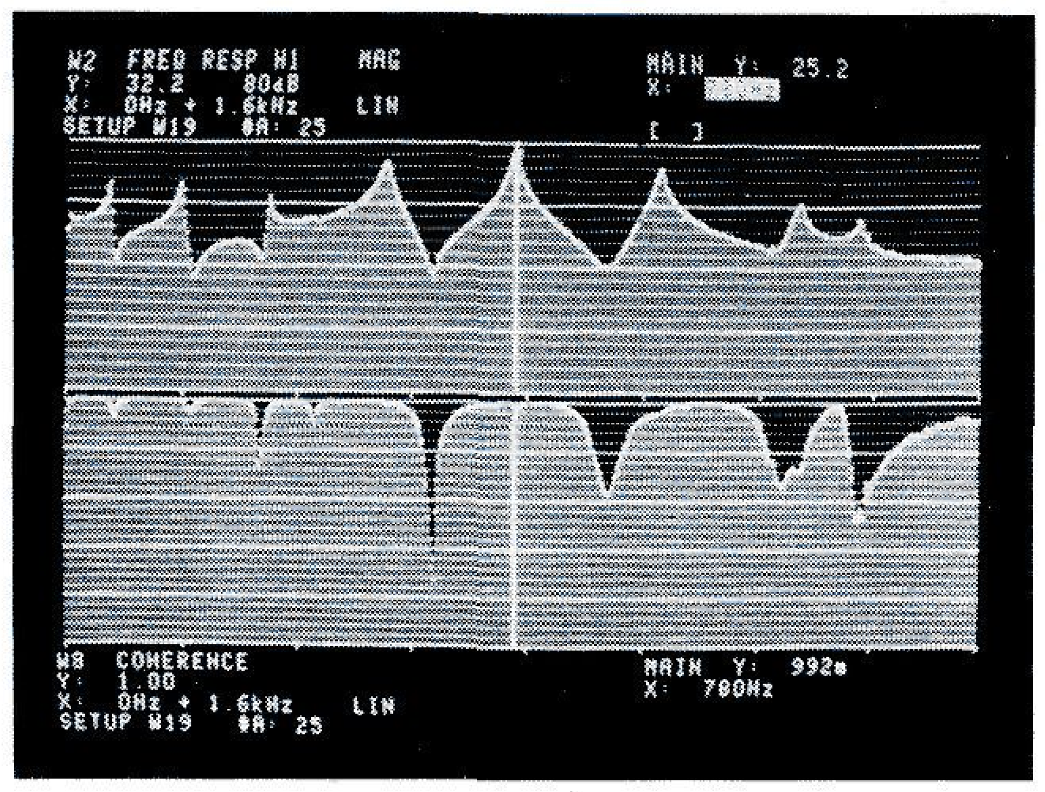

Fig.1. A typical mobility function and coherence function displayed on the screen of the 2034

form (DFT). High speed computation then produces the mobility function. During and after the measurement a range of post-processing facilities are avaliable to us. We can display the mobility function in many different formats (magnitude-frequency, phase-frequency, Nyquist and Bode Plots). We can convert from acceleration to mobility to compliance by integrating. We can look at the time domain equivalent of the mobility - the impulse response - by using the inverse Fourier Transform. We can calculate the damping this way. Another function - the coherence - tells us about the validity of the measurement.

Sometimes it is not possible to provide a controlled and measured input into a structure. Take a large building for example. Even the largest shakers or impactors will not be able to impart sufficient energy at frequencies other than the resonance frequency to a structure this size. Instead, we must assume a knowledge of an input, such as a controlled explosion for example, and proceed from there.

What can we use mobility measurements for?

Trouble-Shooting. High vibration and noise levels in structures are caused by a high force input, or by amplification of a "normal" force input by unwanted resonances. The mobility function shows us these structural resonances. A structural resonance represents a structural weakness. Problems arise when the excitation frequencies encountered in normal operation coincide with the resonance frequencies.

Materials Testing. We can calculate the internal damping, or "loss factor" of materials from the mobility function. We can measure on concrete, asphalt, metals, plastics and composite materials.

Design. We can predict the dynamic interaction of interconnected systems using a knowledge of the mobility of the individual parts. Vibration isolators and machinery mounting can be optimized.

Quality Control We can detect hidden faults, non-uniformities or tolerances deviations of items by comparing the mobility function of a standard with a recently manufactured item.

Mathematical Modelling Mobility measurements taken at many points can form the building blocks of a mathematical model of the structure. This is the basis of modal analysis. Existing mathematical models, such as a Finite Element model, can be verified.

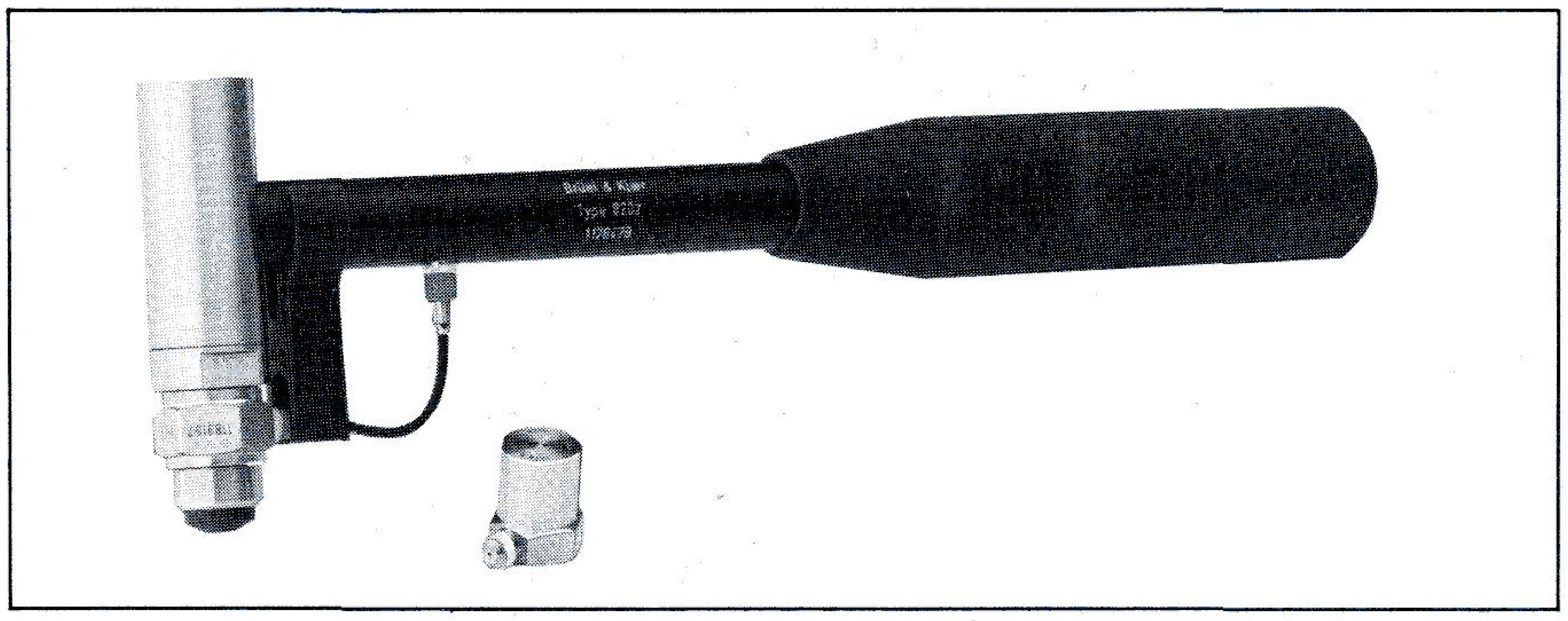

Fig.2. An impact hammer and accelerometer-the front end of a mobility measurement system

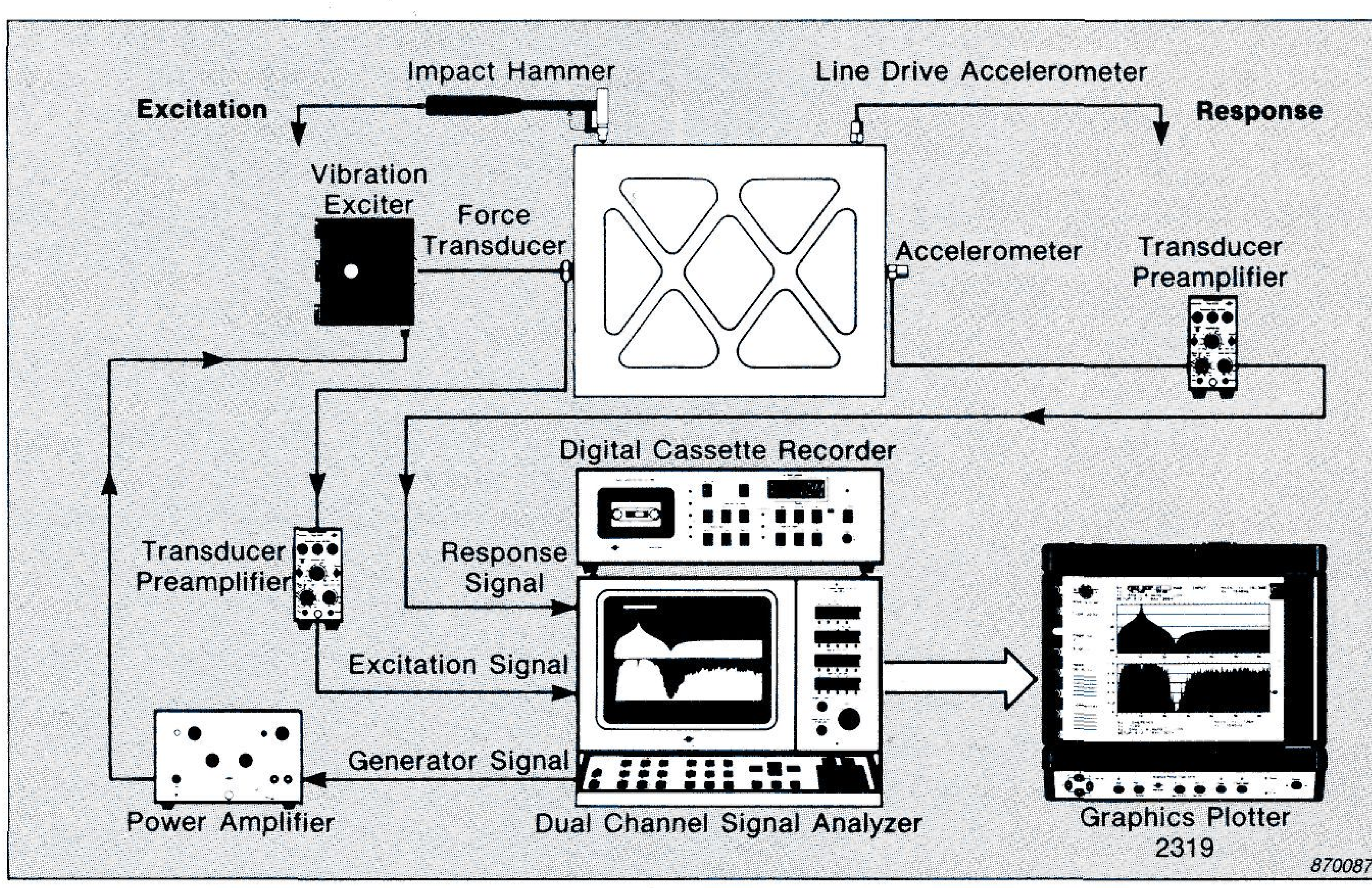

Fig.3. A range of mobility measurement- and documentation-equipment is available from Brüel & Kjær

Brüel & Kjær

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