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Progress is described on the design of a system for secondary calibration of acoustic emission transducers. Experimental secondary calibrations indicate that a 3.3 cm thick steel plate is not a suitable transfer block, and that the transfer block should be more like a semi-infinite medium.

Simulated acoustic emission sources have been studied theoretically and experimentally. Hertzian impact experiments have been carried out, and source waveforms have been reconstructed from experimental data using an inverse Green's function for the plate. Moderate agreement was obtained between Hertzian theory and the experimental results.

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Ultrasonic Measurements Research: Progress in 1988

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ABSTRACT

Progress is described on the design of a system for secondary calibration of acoustic emission transducers. Experimental secondary calibrations indicate that a 3.3 cm thick steel plate is not a suitable transfer block, and that the transfer block should be more like a semi-infinite medium.

Simulated acoustic emission sources have been studied theoretically and experimentally. Hertzian impact experiments have been carried out, and source waveforms have been reconstructed from experimental data using an inverse Green's function for the plate. Moderate agreement was obtained between Hertzian theory and the experimental results.

The Green's tensor for an isotropic layer overlay on an isotropic half-space was solved using the "generalized ray" expansion technique and Willis inversion method. A FORTRAN code for the computation of the Green's tensors was developed. The cases of both a welded- and a liquid-coupled interface were considered with both the source and the detector on the top surface of the layer.

SECONDARY CALIBRATION OF ACOUSTIC EMISSION TRANSDUCERS

The objective of this effort is to devise an inexpensive and convenient system for the transfer of calibration of acoustic emission transducers.

A priori, any system that would place the source transducer in face-to-face contact with the receiving transducer has been rejected. It has been established that the mechanical impedance of a receiving transducer interacts significantly with that of the driving object on which it is mounted. (See 1987 Summary Report for this project, Figs 2, 3, 4.) The mechanical impedance of a transducer is likely to be a complicated function of frequency, and there is no known way to calculate or measure this impedance. Therefore, the interaction between the mechanical impedances of two transducers placed face-to-face would produce results that would be impossible to analyze.

The choice of a (calibration) block to be interposed between the source and receiving transducers is dictated by the necessity that the propagation modes in the block be calculable and that the block have a mechanical impedance that matches that of the medium on which the transducer is to be used.

As a first attempt, a steel plate, 3.3 cm thick by 90 cm square, was tried as a calibration block. Elasticity theory predicts the transfer function for the plate [1], and experimental results using a capillary-break source and an NBS conical transducer receiver agree with the theory. (See 1987 Summary Report for this project, Fig 1.)

Two alternative schemes have been considered for the secondary calibration system. Both schemes use a source on the surface of the block and two receivers equally spaced from the source. One of the receivers is the reference transducer (RT) and the other is the transducer under test (TUT). In one scheme, the source is a capillary break and the receivers feed transient recorders followed by Fourier analyzers (Fig 1). In the other scheme, the source is an NBS conical transducer driven by a tone burst. The receiver signals are gated to remove reflections and other unwanted signals, and the transfer function at each frequency is measured directly by means of a variable attenuator and detector (Fig 2). In both schemes, the transfer function obtained using the TUT is divided by that obtained using the RT, frequency by frequency.

Scheme 1 and scheme 2 were both tried on the 3.3 cm steel plate using a TUT having a wear face diameter of approximately 1.5 cm. Results of both tests (Figs 3, 4) can be compared with the primary calibration (Fig 5) for the TUT, and it can be seen that both schemes give bad results.

If the large NBS calibration block is substituted for the 3.3 cm steel plate, then the results are in reasonable agreement with the normal calibration (Fig 6, 7).

The explanation for the failure of the 3.3 cm plate as a calibration block is believed to lie in the complicated interaction between the motion on the surface of the plate and the aperture effect of the transducer. The fact that a point transducer, such as the NBS conical transducer, produces a correct waveform for the plate indicates that point transducers could be calibrated on the plate, but the extended transducer does not calibrate correctly. The features of the plate waveforms resulting from a step-function force source vary markedly with distance from the source and travel with different speeds. The aperture effect of the transducer is different for each feature of the waveform. For consistency in the calibration of extended transducers, it is necessary that the waves on the surface of the calibration block mimic those on the surface of the primary calibration block.

The results obtained using the extended transducer on the steel plate impugn all experiments in which extended transducers are used on plates. For meaningful results it is essential to use point transducers.

We believe that a steel block 20 cm thick by 40 cm square would be a good compromise: working time would be sacrificed, with attendant loss of low frequency accuracy, but the surface pulse waveforms would replicate those of the large block within the working time.

SIMULATED ACOUSTIC EMISSION SOURCES

(1) Ball Impact. Hertzian theory predicts the dynamic stresses for an elastic ball colliding with an elastic half space. Combining this theory with elastic plate theory, one can calculate displacements in a plate resulting from collision with a ball.

It is easy to drop a ball onto a plate from a known height so that the impact will be a source having known properties. Ball bearings having sizes between 1/16 inch (0.15875 cm) and 3/8 inch (0.9525 cm) have been dropped onto an 8.9

cm thick glass plate from a height of 3 cm. An NBS conical transducer located on the bottom of the plate opposite the source was used to measure the dynamic normal displacement at that point. The transducer had been calibrated by a capillary-break experiment on the same plate.

In this experiment, the source waveform may be recovered by convolving the transducer output waveform with the inverse Green's function for the plate and the inverse transfer function of the transducer. The inverse Green's function for the plate has been calculated, but the inverse transfer function of the transducer is difficult to determine accurately. The forward transfer function of the transducer has been determined by the calibration experiment, but noise becomes a problem when inversion is attempted. Solutions to this problem may involve better calibration techniques or better filtering of the data in the inversion process.

The experimental waveforms from the dropping ball experiments have been convolved with the inverse Green's function of the plate in an attempt to recover the source waveforms. Comparison of these source waveforms with those calculated from Hertzian theory shows some discrepancy which we attribute to the fact that it has not yet been possible to compensate for the transducer's transfer function. Resolving the discrepancy is an important goal of this effort.

(2) Repetitive Transient Sources. Electronically triggered sources which act to apply mechanical transient forces are desirable for several reasons: Signal averaging may be applied to increase signal-to-noise ratio and accuracy, and Fourier analysis can be applied to obtain transient waveforms without using a digital transient recorder.

A piezoelectric device which applies a static load to a surface and then suddenly removes that load (like the capillary break) is thought possible to build. A device of this sort has been designed, but not yet built. In the design, a parabolic interface between steel and brass acts as an acoustic lens to focus a rarefaction wavefront onto the point of contact between the device and the driven object.

TRANSIENT GREEN'S TENSORS FOR A LAYERED HALF-SPACE

To understand the influence of the interface conditions on the behavior of transient waves in a structure, the Green's tensor for an isotropic layer overlay on an isotropic half-space was solved using the "generalized ray" expansion technique and Willis inversion method [2]. The derivatives of the Green's tensor with respect to spatial coordinates are easily obtained. A FORTRAN code for computation of the Green's tensors was developed. Both the cases of both a welded- and a liquid-coupled interface were considered when both the source and detector are located on the top surface of the layer. Computed results show that changes of the interface joint condition have a great influence on the behavior of transient waves, especially the head waves. For example, when the interface joint conditions vary from welded to liquid coupled, some of the first few head waves nearly vanish while the first few regular reflected rays are unaffected. Such phenomena can be used to evaluate bond quality in composite materials whose overall strength, closely linked to the integrity of interlaminar bonding, can be assessed most practically by means of ultrasonic testing.

REFERENCES

1. N.N. Hsu, "Dynamic Green's Functions of an Infinite Plate - A Computer Program," NBS Internal Report, NBSIR 85-3234, Aug. 1985.

2. S. Ren, N.N. Hsu and D.G. Eitzen, "Transient Green's Tensors for a Layered Solid Half-Space with Different Interface Conditions," to be in J. Acoust. Soc. Am.

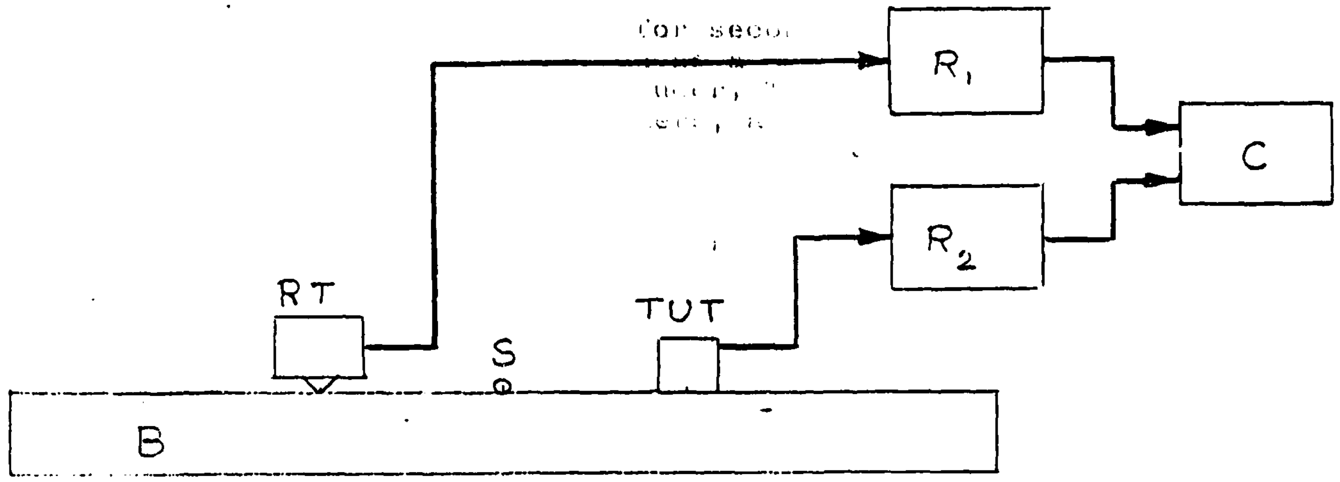

Figure 1. Schematic diagram of scheme 1 for secondary calibration of AE transducers. S is a transient source such as a capillary break, B is the transfer block, RT is the reference transducer, TUT is the transducer under test, R_1 and R_2 are transient recorders, and C is a computer.

SECONDARY CALIBRATION SCHEME

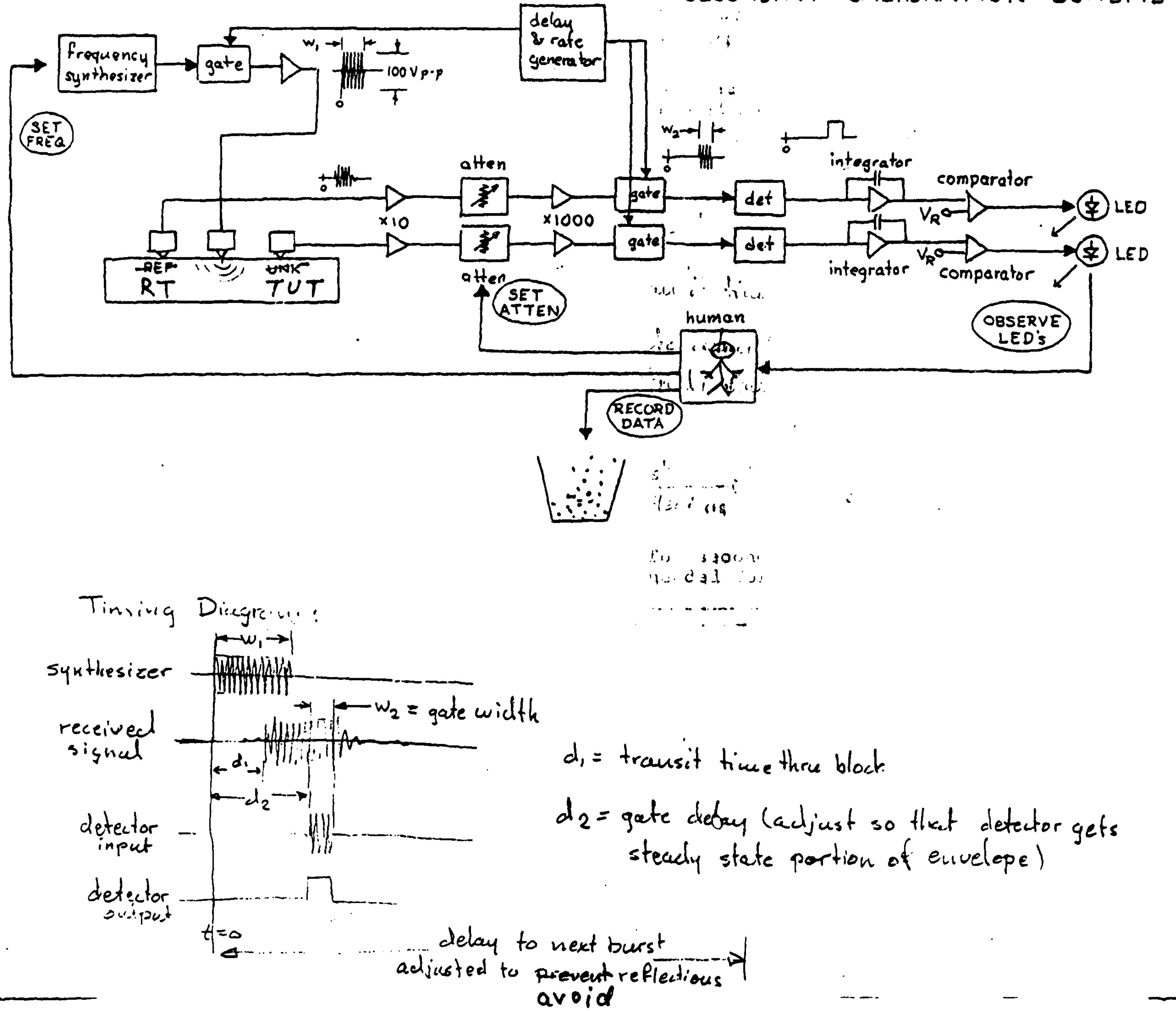

Figure 2. Schematic diagram of scheme 2 for secondary calibration of AE transducers. No transient recorders are needed for this scheme.

Figure 3. Test secondary calibration performed according to scheme 1 on a 1.5 cm diameter AE transducer using a 3.3 cm thick by 90 cm square steel plate as the transfer block. The reference transducer was an NIST ~~NBS~~ SRM 1856 conical transducer.

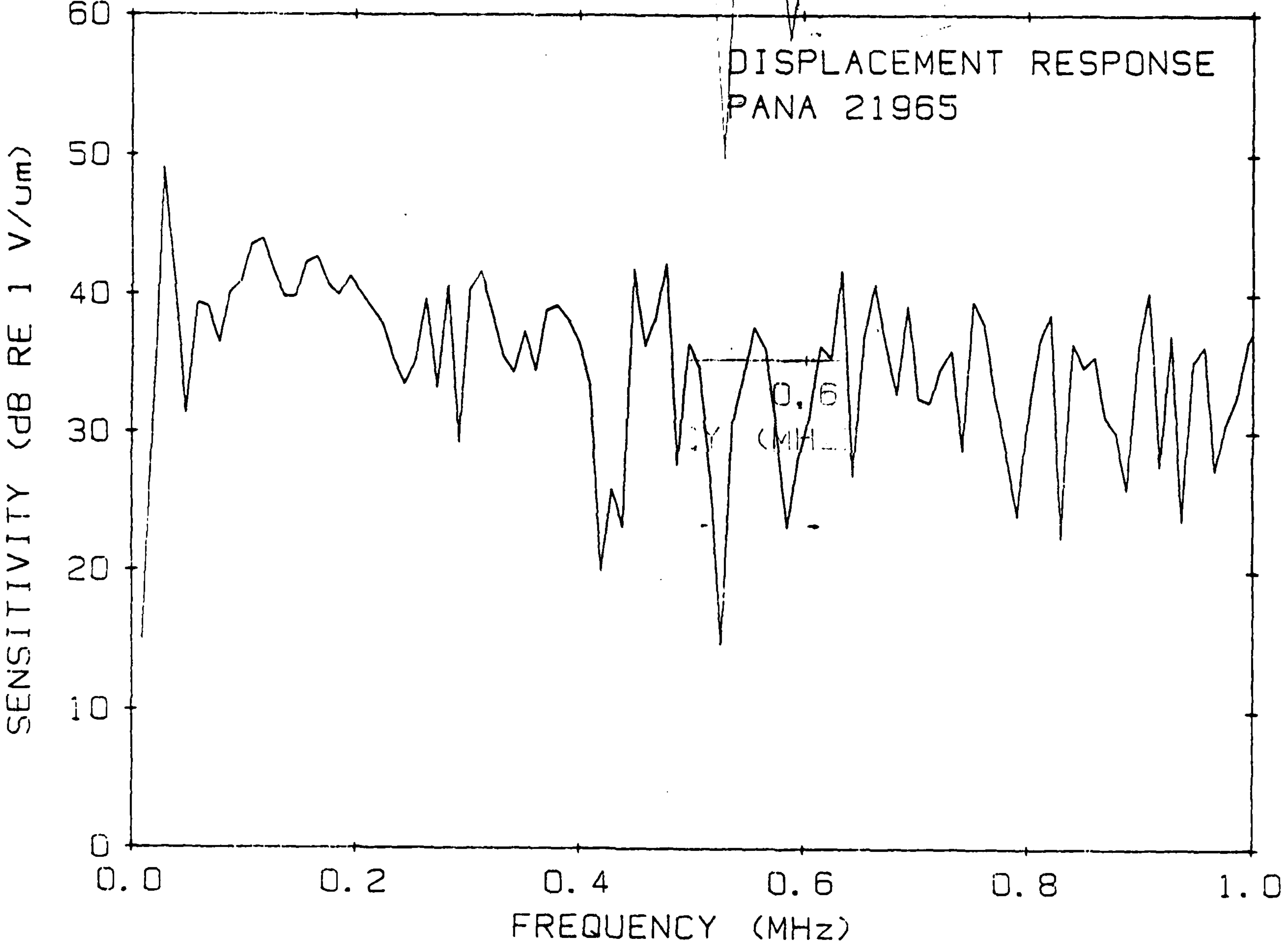

Figure 4. Test performed on 3.3 cm by 90 cm square steel plate. This test was similar to scheme 2 except that the reference signal was derived from a calculation instead of a reference transducer. The source was an NBS conical transducer, and the transducer under test was the 1.5 cm diameter AE transducer.

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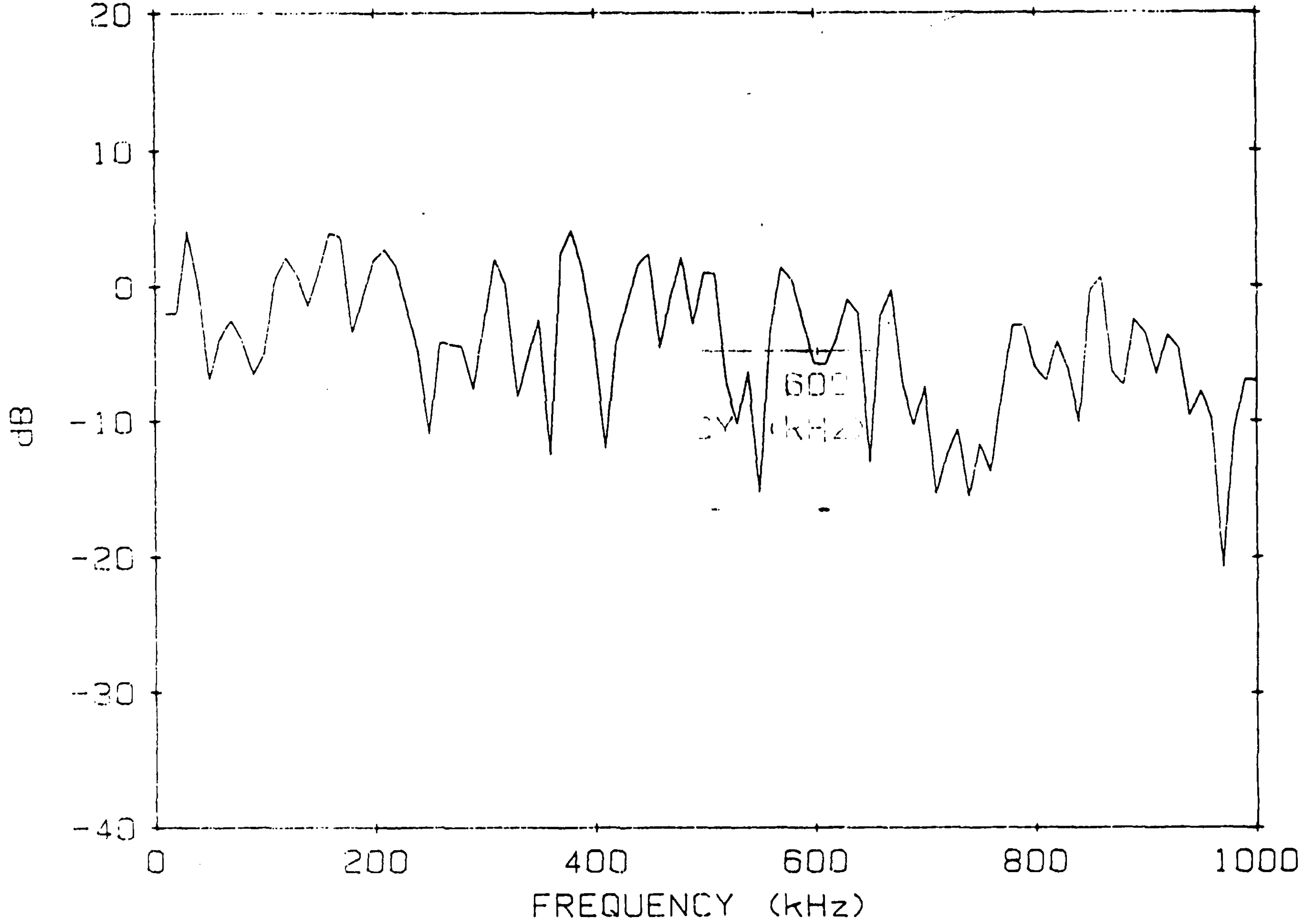

Figure 5. Primary calibration of the 1.5 cm diameter AE transducer.

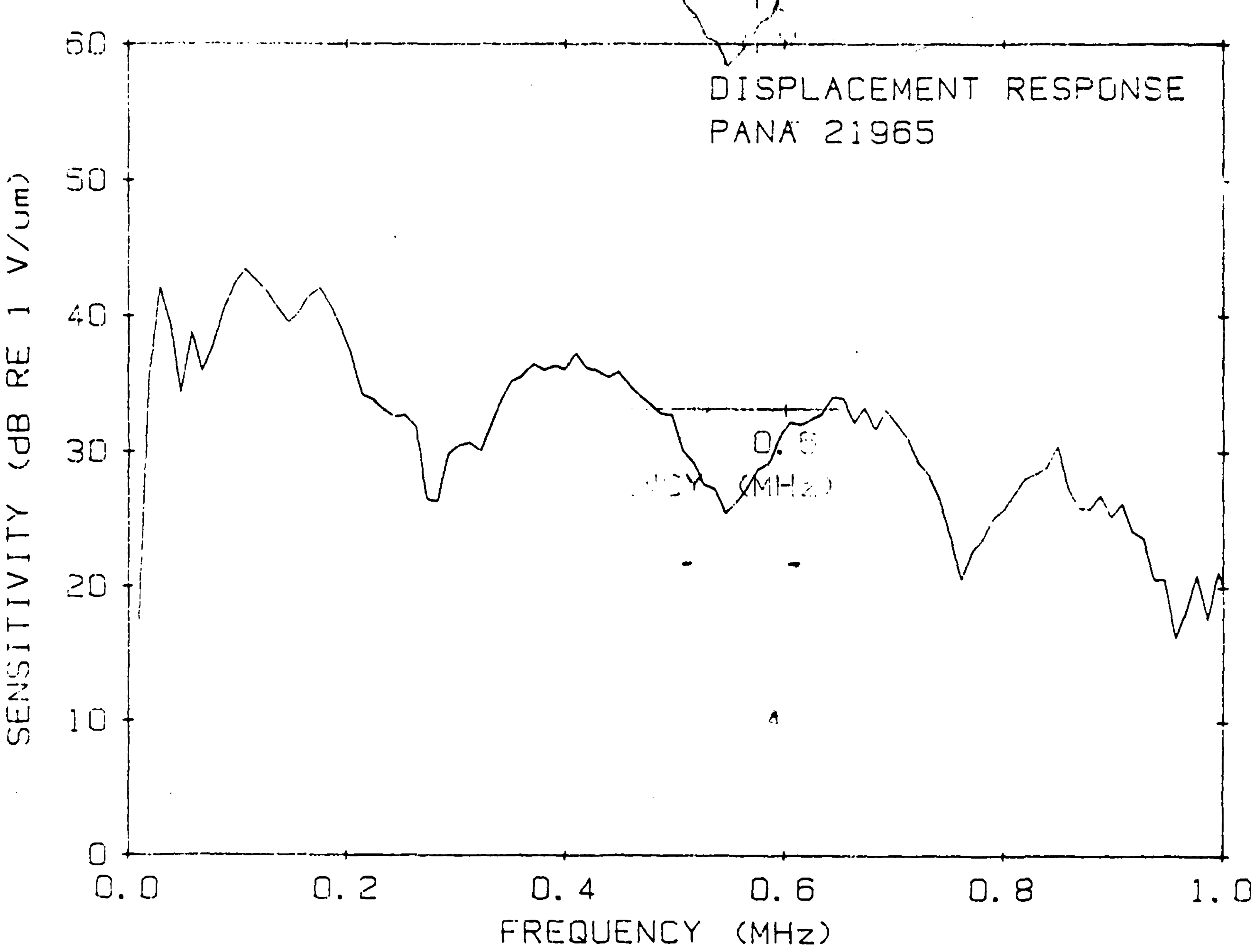

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Figure 6. Test secondary calibration performed according to scheme 1 on the 1.5 cm diameter AE transducer using the NBS primary calibration block as the transfer block. All conditions were the same as in Fig. 3 except the transfer block.

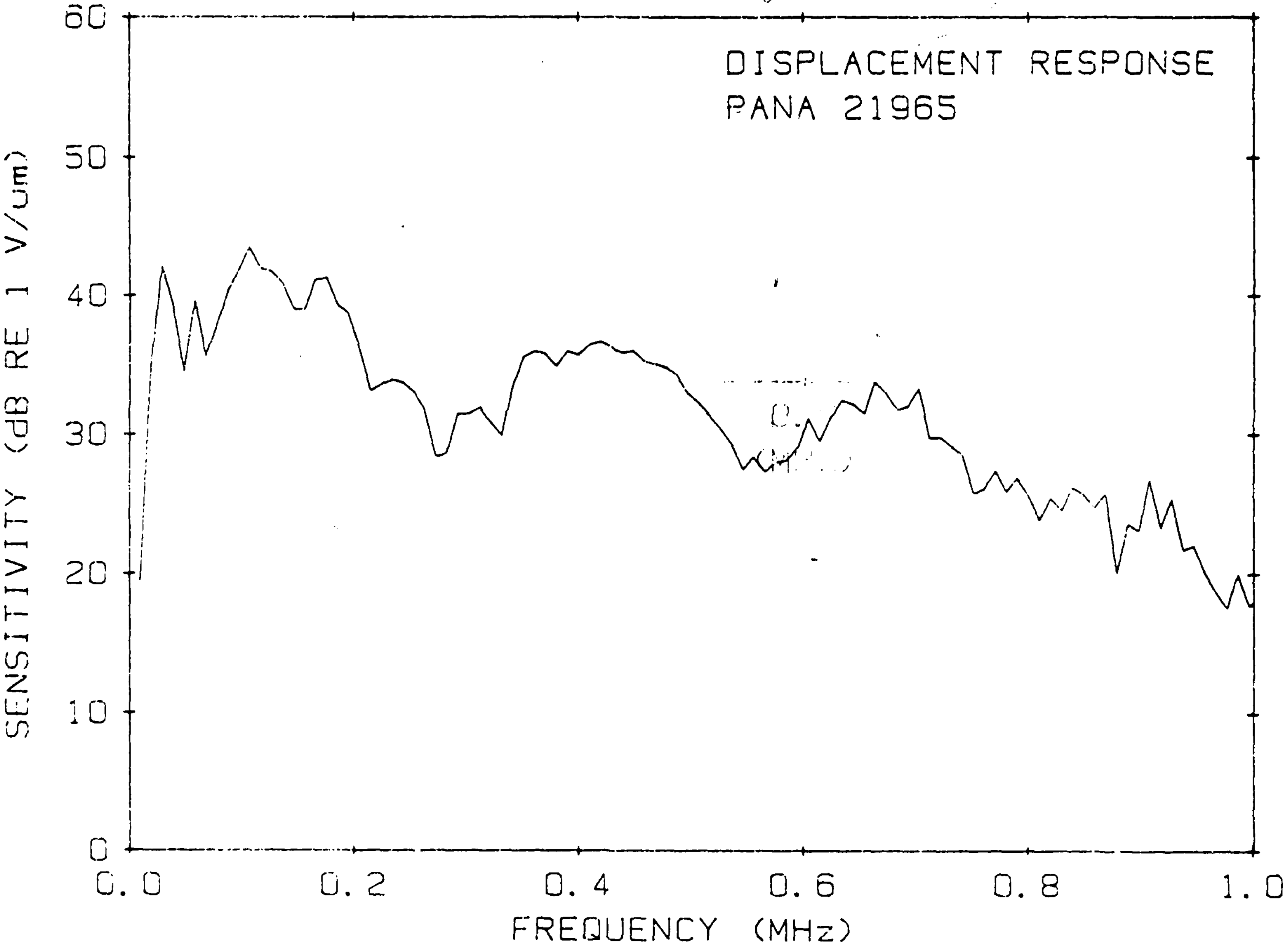

Figure 7. Test performed according to Scheme 2 on the ~~NBS~~ NIST primary calibration block. All conditions were the same as in Fig. 4 except the transfer block.