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A NOVEL TUBE DEVICE FOR MEASURING HYDROACOUSTIC PROPERTIES OF HOMOGENEOUS AND LAYERED MATERALS

D Brebeck

FHAK Fraunhofer Forschungsgruppe für Hydroakustik, Germany

1. INTRODUCTION

The investigation of acoustical material properties is an important part of research and development in underwater acoustics. Besides other experimental arrangements the pulse tube is very important tool in that field.

With such a pulse tube one can determine the echo reduction of test materials at normal incidence for small cylindrical test samples.

The presented test facility eliminates former disadvantage of pulse tubes , namely the unwanted sound propagation along the tube wall. Additionaly, the device can be used as a standing wave tube. Thus, one can evaluate not only the echo reduction but also the impedance of the test sample with regard to magnitude and phase.

2. MECHANICAL PROPERTIES

The experimental arrangement consists of a water filled stainless steel tube. The tube length is determined by the lower frequency limit, i.e. the tube has to be as long as the wave length of the lowest measuring frequency.

The inner diameter of the tube and the compliance of the tube wall determine the upper frequency limit. If only the fundamental mode is propagated in the fluid, this diameter is defined by approximately one third of the maximum wavelength of the operating frequency.

It is advantageous to set up the tube in a vertical position. In this way the filling and draining will be easy and air bubbles can ascend fast to be collected in a vacuum pump device.

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2.1 Fundamental Principles
In conventional tubes the following problem arises: by projecting waterborne sound into the fluid, structural sound in the tube wall is excited as well. This occurs specificly by the projector at his mounting point, but also by the pressure fluctuations in the water column.

At the presented pulse tube device the spread of structure borne noise along the wall is prevented by special arrangements carried out at the tube wall. Moreover, it is very important to limit the exciting force to the fundamental mode using a special arrangement of the projector.

The projector is coupled to a heavy backing mass with a impedance compared to the input impedance of the water column as well as of the tube wall. This wall consists of a sandwich construction of two thin concentric shells. The gap between is filled with bitumen. Thus, the propagation of sound in the wall is practically suppressed.

In addition, the sandwich construction allows the measurement of the local sound pressure in the water column by mounting suitable accelerometers at the outside of the inner part of the wall.

With several accelerometers attached at various distances this device can be used to measure the standing wave field within the fluid.

2.2 Dimensions
The tube is about 400 cm long with an inner diameter of 5 cm and is mounted in vertical position.

The tube head at the top can be opened for the insertion of the test specimen. The test specimen is 5 cm in diameter and mounted onto a heavy mass serving as an acoustic hard backing.

2.3 Temperature, Pressure
The pulse tube device is furnished with a temperature control system. The temperature of the water can be choosen between 2°C and 30°C. This setup allows one to investigate the influence of temperature on the behavior of the test specimen.

An other important environmental parameter in underwater acoustics is the pressure. The pressure in the tube can be varied from 1 bar to 50 bar to investigate the influence of pressure on the acoustic properties of the material under test.

At all the measurements it is very important to have a pure water without anygas bubbles. By a partial evacuation befor each measurement the water will be degased, i.e. the existing gas bubbles expend and rise to the top. At the upper end of the tube the gas will be assembled and exhausted.

3. ACOUSTIC DEVICE

The acoustic device consists of electroacoustic transducers to excite the sound field in the water column of the tube and to pickup the sound pressure at different locations along the tube.

3.1 Excitation by Transducer

The exciting element is a piezoceramic transducer, wich is mounted to a heavy backing mass and installed at the lower end of the tube. Its resonance frequency of 20 kHz is chosen close above the upper frequency limit of the operating range from 0.5 to 15kHz. The 12 dB/octave ascending frequency dependence is compensated by a preemphasis at the exciting generator.

3.2 Pickup by Hydrophone

The echo reduction of a test specimen is determined by comparing the direct with the reflected pulse. For this purpose the signal is picked up in the middle of the tube by a hydrophone (Fig.1). This hydrophone has to be sufficiently sensitive and small enough not to disturb the sound field in the fluid. The cylindric hydrophone comes into the tube sidewise such that the direct and the reflected sound pulses are received with the identical sensitivity.

3.3 Pickup by Accelerometer

The standing wave field is picked up with small accelerometers, attached to the outer surface of the thin inner tube (Fig.2). Due to the high damping capability, wich suppresses the sound propagation along the tube wall, it is possible to measure accurately the local sound pressure in the fluid. For this purpose eight accelerometers are mounted in the upper half of the tube, from wich three appropriate accelerometers are selected depending on the operating frequency.

4. ELECTRICAL DEVICE

The entire tube experiment is computer-controlled , i.e. the sound excitation, detection, and processing is carried out automatically. Thereby two operating methods are available, the pulse- and the standing wave-measuring method.

4.1 Pulse Measuring Method

The pulse measuring method is used to determine the echo reduction of a test material. Short pulses of variable frequency are emitted by the transducer and received by the hydrophone, first as direct signals and second as reflected signals from the test specimen.

Two methods of data processing are applicable in the current setup: peak amplitude detection and FFT analysis.

For the peak amplitude detection the pulse received by the hydrophone is evaluated with regard to its maximum amplitude. This value is used for further processing. With the aid of a receiving time window, wich can be set to selectable position and duration, the transient parts of the signal can be cut off to increase the dynamic range. However, the application of the peak value evaluation is only permitted, if the transmitted as well as the received pulses are quasi-stationary and clearly distinguish-able. This is for thin homogeneous material samples always the case.

For thick or inhomogeneous material samples the reflected signal often can not reach a stationary state, but shows mainly a transient behavior. In this case, the FFT analysis can be applied eventually, where the signal under study has to be subjected to a time window function.

4.2 Standing Wave Method

This method employs pulses of longer duration, such that direct and reflected signals interfere to form a standing wave. Position and amplitude of maxima and minima depend on the impedance of the material under test. With the aid of the accelerometers attached to the inner tube wall the position and amplitude of maxima and minima can be found by variation of the operating frequency. Therefore, the measured sound pressures from three selected accelerometers are used in a computer program to calculate the impedance of the material in magnitude and phase as a funktion of frequency.

5. FIRST EXPERIMENTAL CHARACTERISTICS

Typical signal traces of the two operating modes are shown in Figures 3 and 4.

Figures 3A and 3B show two oscillograms of the device in the pulse mode:

Trace 1: electrical pulse, 5 kHz
Trace 2: direct and reflected pulse, received with the hydrophone in the middle of the tube
Trace 3: direct and reflected pulse, received with the accelerometer in the middle (Fig.3A) and in the upper third (Fig.3B) of the tube
Trace 4: Variable time window, adjusted to the reflected pulse

Figures 4A and 4B show two oscillograms of the device in the standing wave mode:

Trace 1: electrical pulse, 10.9 kHz (Fig.4A), 10.2 kHz (Fig.4B)
Trace 2: overlapping direct and reflected pulse at a maximum point (Fig.4A) and a minimum point (Fig.4B). Receiver: Accelerometer in the upper quarter of the tube
Trace 3: Variable time window, adjusted to the overlapping region

6. CONCLUSIONS

This paper describes a tube facility for investigations in underwater acoustic. The purpose is the measurement of physical parameters of materials. The device can be driven in the pulse mode and in the standing wave mode. The pulse mode delivers the echo reduction of a test material at normal incidence and the standing wave mode the imput impedance of the material in magnitude and phase.

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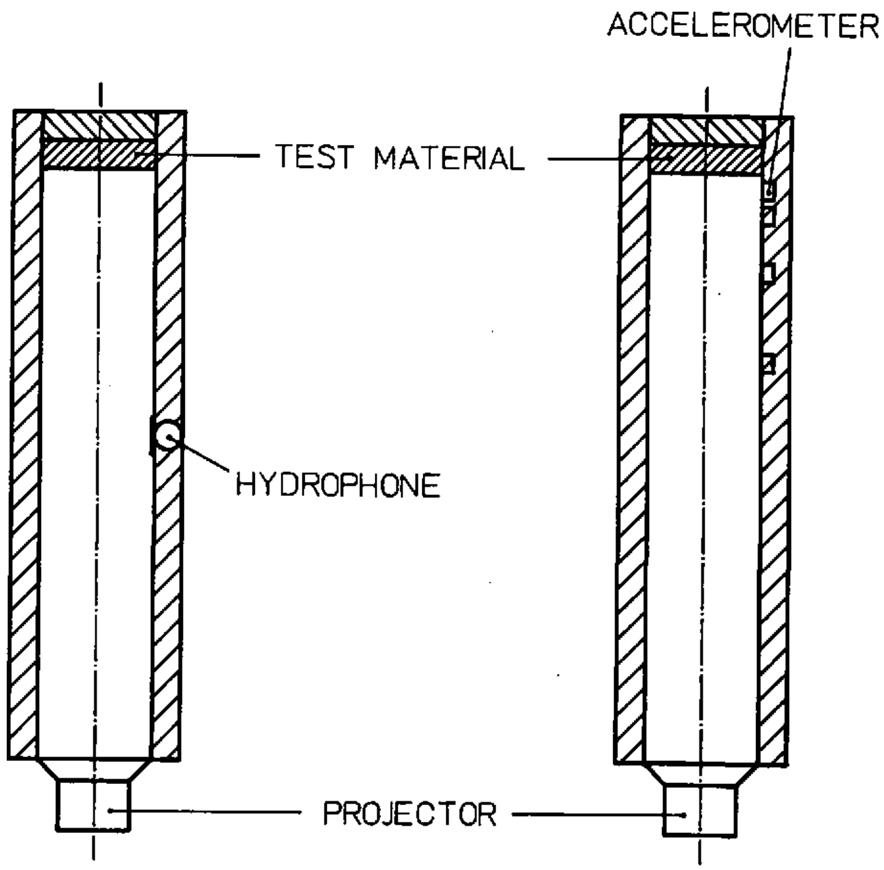

Fig. 1 Pulse Tube **Fig. 2 Standing Wave Tube**

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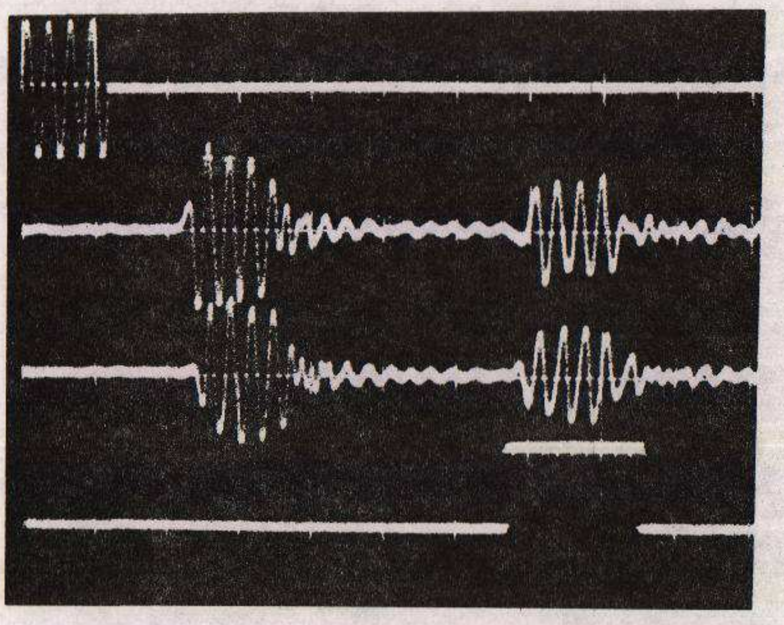

Fig. 3 A

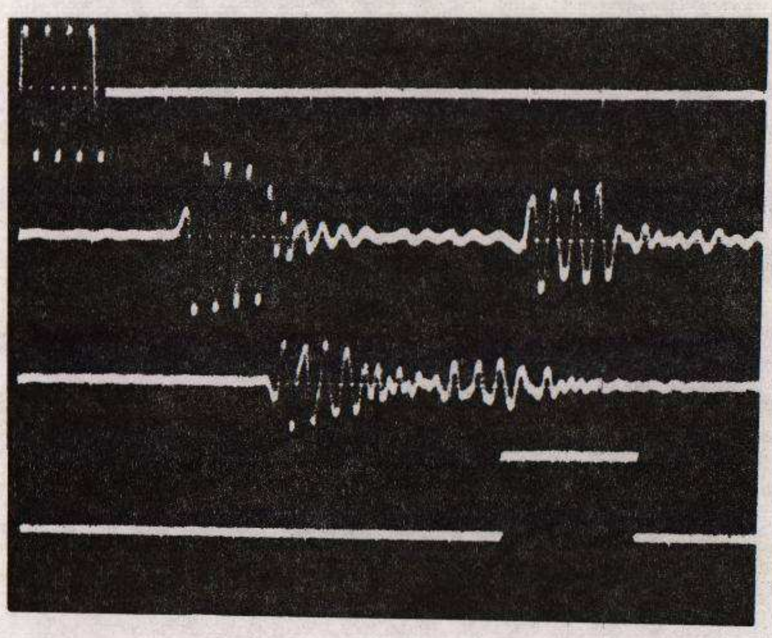

Fig. 3 B

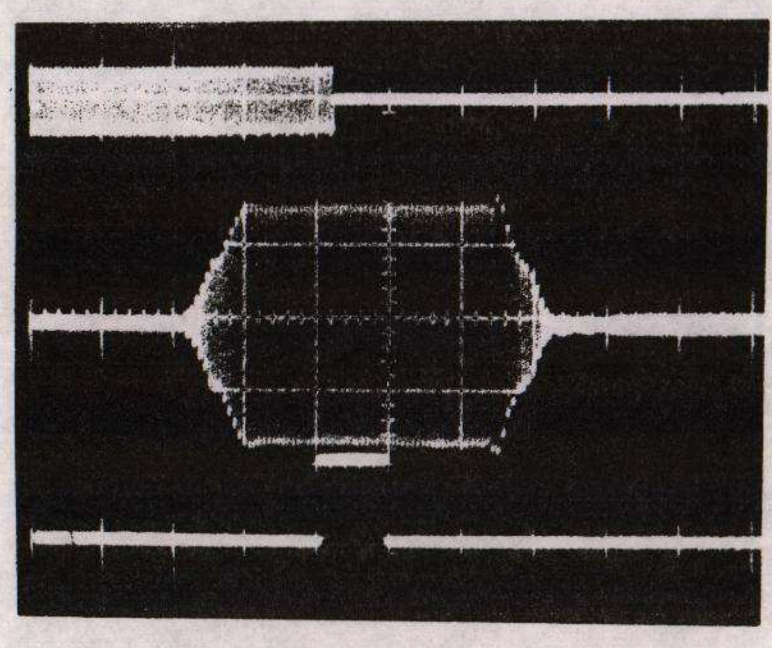

Fig. 4 A

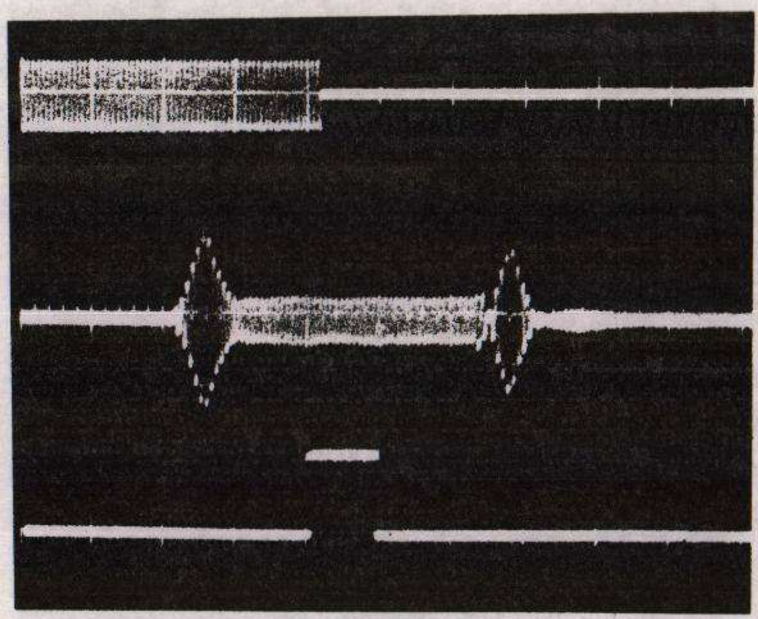

Fig. 4 B