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Description

This invention relates to an ultrasonic transducer using a laminated piezo-electric element, and more particularly to an ultrasonic transducer with improved sensitivity characteristics and improved pulse characteristics (transition characteristics).

Ultrasonic transducers for use in the air have been proposed and include laminated piezo-electric ceramic elements which are designed to work at resonance or anti-resonance points. Further, because the mechanical impedance of air is substantially smaller than that of the piezo-electric ceramic element, the laminated element is bonded to a diaphragm in an attempt to reduce mechanical impedance.

When one wishes to provide readouts within a short period of time using a previously proposed ultrasonic transducer, a particular signal can be received before the preceding signal received by the transducer has disappeared because of long rise and fall times, thus making measurements inaccurate.

Furthermore, in the case where transmission and reception of ultrasonic radiations are performed with a single element, it takes a substantial amount of time to make the element ready to receive the signals after transmission of the signals. Of course, readouts are not available until the element is made ready to receive the signals.

Patent US—A—3786202 discloses an acoustic transducer in which a piezo electric element is supported at its central portion by a conical diaphragm which is contacted at its rim by the transducer housing.

The present invention provides an ultrasonic transducer comprising a laminated piezo-electric disc-shaped element, a conical diaphragm connected at its apex to the centre of said element and thereby supporting said element, and a housing for accommodating said laminated piezo-electric element therein, characterised in that a buffer member is disposed between and in contact with the periphery of said diaphragm and an inner side wall of said housing, wherein said diaphragm is flexibly fixed and held within said housing through the use of said buffer member.

An advantage of a preferred form of the transducer is that response time of the transducer is shorter. Further, the transducer exhibits excellent transmission sensitivity and directivity.

Preferably, the diaphragm is disposed at the centre of the laminated piezo-electric element and the periphery of the diaphragm is flexibly secured on a housing by way of a buffer member made of elastic rubber or the like so as to suppress mechanical oscillation.

In order that the present invention be more readily understood, embodiments thereof will now be described by way of example only, with reference to the accompanying drawings, in which:—

Figure 1 is a cross sectional view of a previously

proposed ultrasonic transducer;

Figure 2 is a graph showing the pulse characteristics of the above illustrated transducer;

Figure 3 is a cross sectional view illustrating an ultrasonic transducer constructed according to an embodiment of the present invention;

Figure 4 is a graph showing the pulse characteristics of the above illustrated embodiment;

Figure 5 is a graph showing the relationship between rise time and the inner diameter of a buffer member and that between directivity (acoustic pressure half-angle) and the inner diameter of the buffer member;

Figure 6 is a graph showing the relationship between the diameter of a diaphragm and transmission sensitivity of the illustrated embodiment;

Figure 7 is a graph showing the relationship between the diameter of the diaphragm and directivity (acoustic pressure half-angle);

Figure 8 is a graph showing the relationship between the angle of the top of the diaphragm and directivity;

Figure 9 is a schematic view of an ultrasonic transducer according to another embodiment of the present invention;

Figure 10 is a view showing the pulse characteristics of the ultrasonic transducer as shown in Figure 9;

Figure 11 is a view showing the effect of an acoustical absorbent;

Figure 12 is a graph showing the relationship between the inner diameter of the buffer-member and the pulse characteristics of the alternative embodiment;

Figure 13 is a graph showing the frequency dependency of transmission sensitivity; and

Figure 14 is a graph showing the temperature dependency of pulse characteristics and transmission sensitivity.

The structure and operating properties of a previously proposed ultrasonic transducer are illustrated in Figures 1 and 2 and will be described so as to enable a better understanding of the present invention.

As indicated in Figure 1, an end of a coupling shaft 2 is fixed to pass through a central portion of a laminated piezo-electric element 1 with the remaining end thereof being secured to a diaphragm 3. The laminated piezo-electric element 1 is mounted at nodes of oscillation via a flexible adhesive 5 on tips of supports 4. There is further provided terminals 6 and 6', a housing 7 for protecting the laminated piezo-electric element 1 and so forth against the outside world, a protective mesh 8 disposed at a top portion of the housing and lead wires 9 and 9' for electrically connecting the laminated piezo-electric element 1 to the terminals 6 and 6'.

Figure 2 depicts the waveform of radiation transmitted when the ultrasonic transducer is supplied with a plurality of pulses. It will be noted that the response of the transducer, i.e. the rise time and fall time, is of the order of 2 milliseconds for each response.

Specific embodiments of the present invention

will now be described by reference to the drawings.

Figure 3 is a cross sectional view of an ultrasonic transducer according to a first embodiment of the present invention. A diaphragm 13 typically of metal or plastics is fixed to a coupling shaft 12 which is disposed at a central portion of a laminated piezo-electric element 11 made of a suitable piezo-electric ceramic material. The diaphragm 13 is of a conical configuration and the laminated piezo-electric element 11 is in the shape of a disc. A peripheral portion of the diaphragm 13 is flexibly secured to an inner side wall of a cylindrical housing 17 through the use of an annular buffer member 20 of a resilient material such as rubber or the like in order to suppress mechanical oscillation. Further, the diaphragm 13 and the laminated piezo-electric element 11 are disposed at the centre of the housing 17 through the buffer member 20. A pair of terminals 16 and 16' are electrically connected to the laminated piezo-electric element 11 via lead wires 19 and 19'.

Figure 4 depicts the pulse characteristics of the ultrasonic transducer of the above described structure, indicating that the rise time and fall time of a pulse were less than 0.2 millisecond.

Figure 5 indicates the rise time and directivity (acoustic pressure half-angle) as a function of the inner diameter of the annular buffer member 20. In the illustrated embodiment, the diameter of the diaphragm 3 was 16 mm.

Figure 6 is a graph showing the relationship between the diameter of the diaphragm 13 provided for the disc-like laminated piezo-electric element (diameter: 10 mm) and transmission sensitivity, indicating that the greater the diameter of the diaphragm 13 the greater transmission sensitivity.

Figure 7 is a graph showing the relationship between the diameter of the diaphragm 13 and directivity (acoustic pressure half-angle). It is clear from Figure 7 that the ultrasonic transducer manifests acute directivity when the diaphragm of a diameter becomes greater.

In addition, Figure 8 shows the relationship between the angle of the top of the conical diaphragm 13 and directivity. The sharpest directivity was obtained when the conical diaphragm with 0.3—0.5 of height(h)-to-bottom diameter (R) ratio was used.

Figure 9 is a cross sectional view of an ultrasonic transducer according to another embodiment of the present invention. In Figure 9, a diaphragm 21 typically of metal or plastics is fixed to a coupling shaft 23 which is disposed at a central portion of a laminated piezo-electric element 22 made of a proper piezo-electric ceramic material. A peripheral portion of the diaphragm 21 is fixedly secured in an inner side wall of a cylindrical housing 25 through the use of an annular buffer member 24 of resilient material such as rubber or the like to suppress mechanical oscillation. In addition, an acoustic absorbent material 26 is disposed at the bottom of the housing 25. A pair of terminals 27 and 27' are con-

nected electrically to the laminated piezo-electric element 22 via lead wires 28 and 28'.

The distinction of the ultrasonic transducer as shown in Figure 9 from that of Figure 3 is the provision of the acoustic absorbent material 26 on the bottom wall of the housing 25. The provision of the acoustic absorbent material 26 assures further improvement in the pulse characteristics.

The pulse characteristics of the ultrasonic transducer of the above detailed structure are depicted in Figure 10, which indicates that the rise time and fall time of a pulse were shorter than 0.1 ms. It is noted that Figure 10 was plotted with pulse envelop lines although there were in fact three or four waves before the pulse rose completely.

Figure 11 shows the effect of the above described acoustic absorbent material 26 on the pulse characteristics, indicating a remarkable improvement in the rise time.

Figure 12 represents the relationship between the inner diameter of the annular buffer member 24 and the rise time and fall time. The diaphragm 21 used had a bottom diameter of 16 mm and the laminated piezo-electric element 22 was of a diameter of 10 mm and a thickness of 0.5 mm.

In Figure 13, there is illustrated the frequency dependency of the transmission sensitivity of the ultrasonic transducer designed with the above exemplified dimensions.

Figure 14 depicts the temperature dependency of the pulse characteristics and transmission sensitivity. As compared with those at 20°C, the rise time showed no substantial variation at -20°C and increased by 12% at 60°C while the transmission sensitivity declined by 5% at -20°C and increased by 5% at 60°C. It is understood that the pulse characteristics showed no variation even when the protective mesh was disposed at the front of the housing 17.

As noted earlier, the ultrasonic transducer shows improved pulse characteristics and improved transmission sensitivity as well as a shortened pulse rise time and fall time. Furthermore, it is stronger and simpler in structure with a lower profile and is easier to assemble than the previously proposed device, all as a result of flexibly fixing and holding the diaphragm within the housing.

Claims

1. An ultrasonic transducer comprising a laminated piezo-electric disc-shaped element (11) a conical diaphragm (13) connected at its apex to the centre of said element (11) and thereby supporting said element (11) and a housing (17) for accommodating said laminated piezo-electric element therein, characterised in that a buffer member (20) is disposed between and in contact with the periphery of said diaphragm (13) and an inner side wall of said housing (17), wherein said diaphragm (13) is flexibly fixed and held within said housing (17) through the use of said buffer member (20).

2. An ultrasonic transducer according to claim

1, characterised in that said conical diaphragm (13) has a ratio of height to bottom diameter within 0.3 through 0.5.

3. An ultrasonic transducer according to claim 2, characterised in that an acoustic absorbent material (26) is disposed within said housing (17).

Revendications

1. Transducteur ultrasonore comportant un élément piézo-électrique (11) stratifié en forme de disque, un diaphragme conique (13) assemblé par son sommet sur le centre dudit élément (11) et supportant ainsi ledit élément (11) et un boîtier (17) pour recevoir ledit élément piézo-électrique stratifié, caractérisé en ce qu'une pièce tampon (20) est disposée entre et en contact avec la périphérie du diaphragme (13) et une paroi latérale intérieure du boîtier (17), de manière que ledit diaphragme (13) soit fixé et maintenu de façon souple dans ledit boîtier (17) par l'utilisation de ladite pièce tampon (20).

2. Transducteur ultrasonore selon la revendication 1, caractérisé en ce que ledit diaphragme conique (13) a un rapport entre la hauteur et le diamètre à la base compris entre 0,3 et 0,5.

3. Transducteur ultrasonore selon la revendication 2, caractérisé en ce qu'une matière absor-

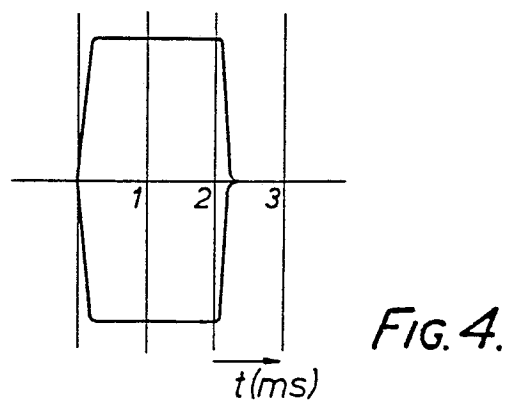
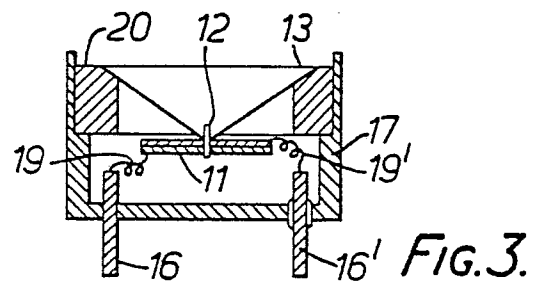
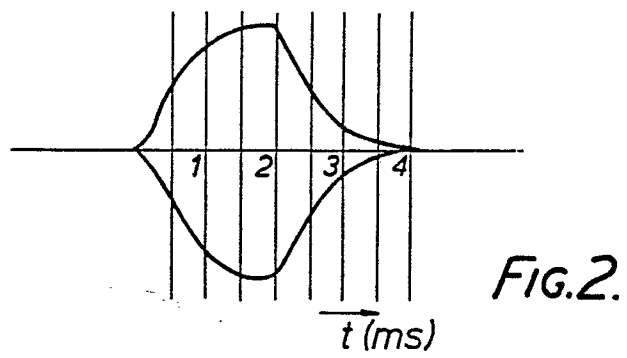
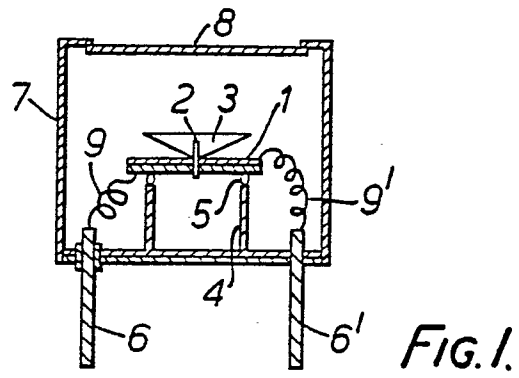
bante acoustique (26) est disposée dans ledit boîtier (17).

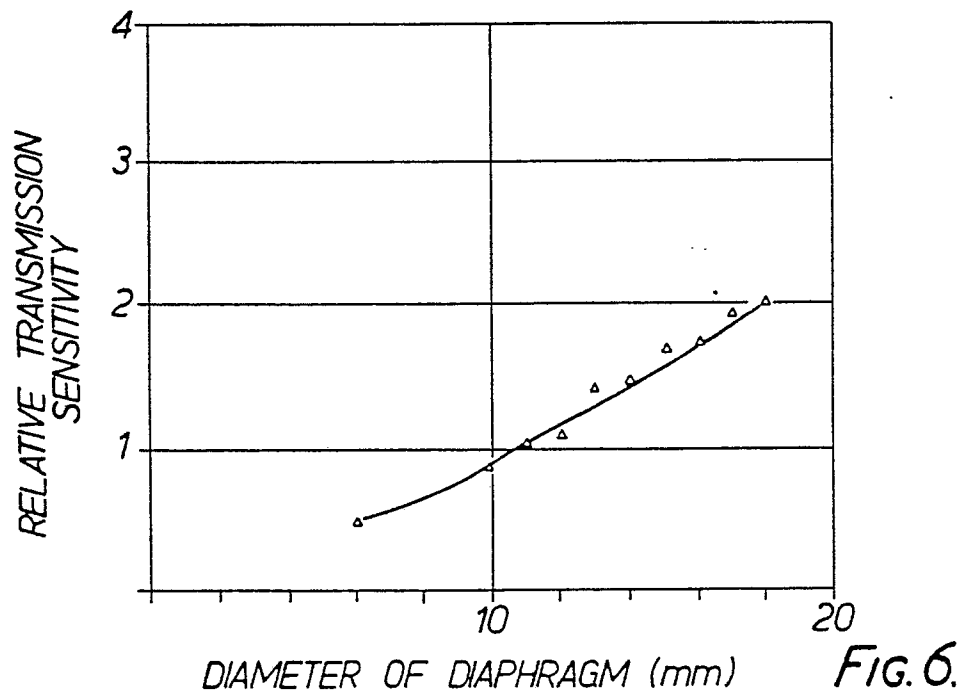
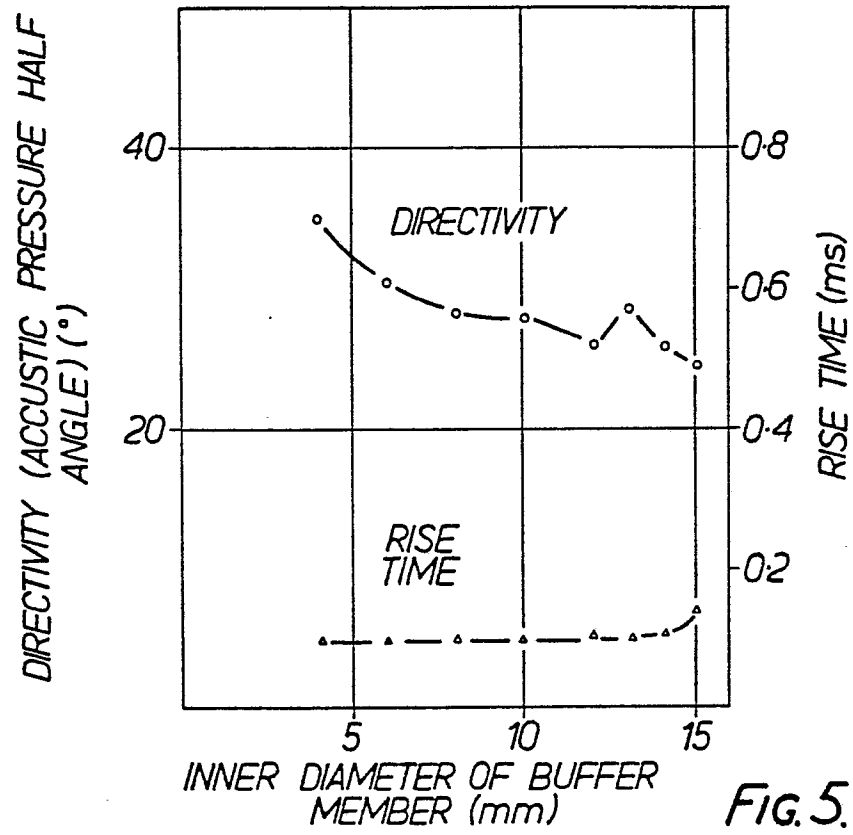
Patentansprüche

1. Ultraschallwandler mit einem laminierten, scheibenförmigen piezoelektrischen Element (11), einer kegelförmigen Membrane (13), welche an ihrem Scheitel mit dem Mittelpunkt des Elements (11) verbunden ist und das Element (11) dadurch trägt, und einem Gehäuse (17) für die Unterbringung des laminierten piezoelektrischen Elements darin, dadurch gekennzeichnet, daß ein Pufferelement (20) zwischen dem Umfang der Membrane (13), und in Berührung damit, und einer inneren Seitenwand des Gehäuses (17) angeordnet ist, wodurch die Membrane (13) durch die Verwendung des Pufferelements (20) flexibel fixiert und in dem Gehäuse (17) gehalten ist.

2. Ultraschallwandler nach Anspruch 1, dadurch gekennzeichnet, daß die kegelförmige Membrane (13) ein Verhältnis von 0,3 bis 0,5 zwischen ihrer Höhe und ihrem Bodendurchmesser aufweist.

3. Ultraschallwandler nach Anspruch 2, dadurch gekennzeichnet, daß ein akustisch absorbierendes Material (26) innerhalb des Gehäuses (17) angeordnet ist.





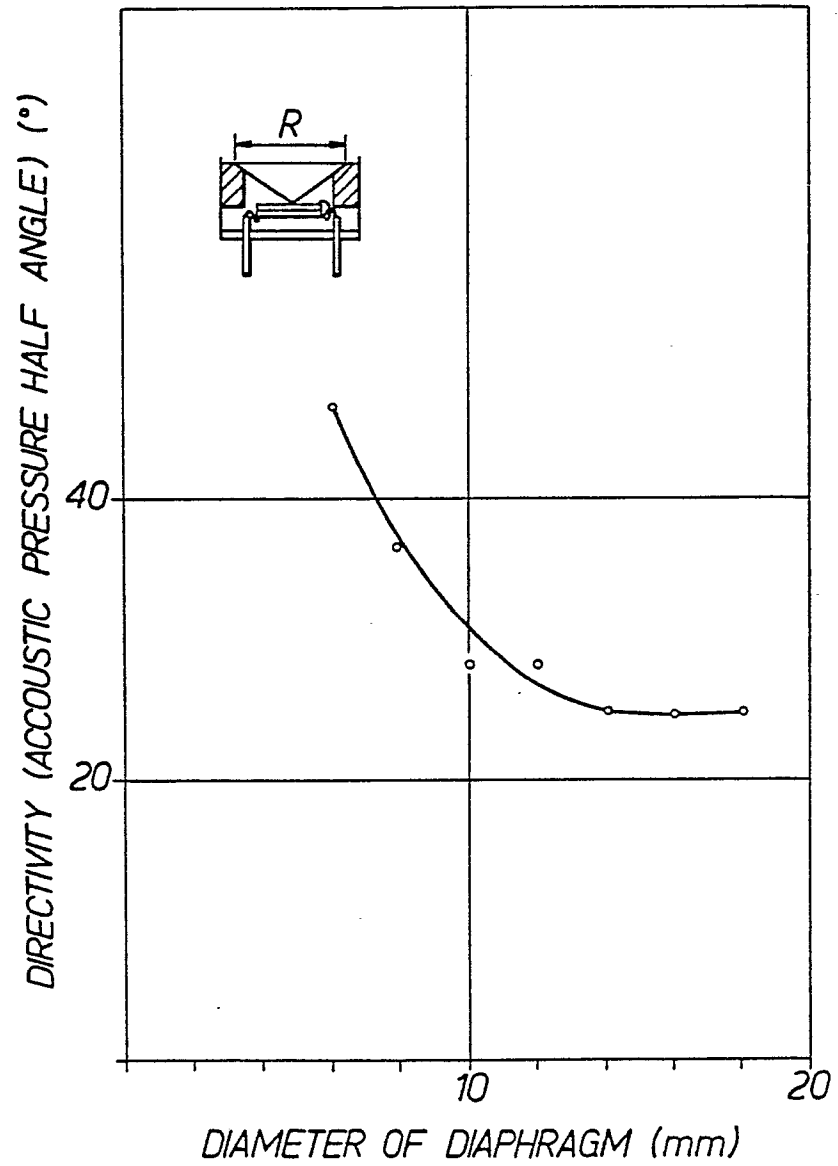


Fig.7.

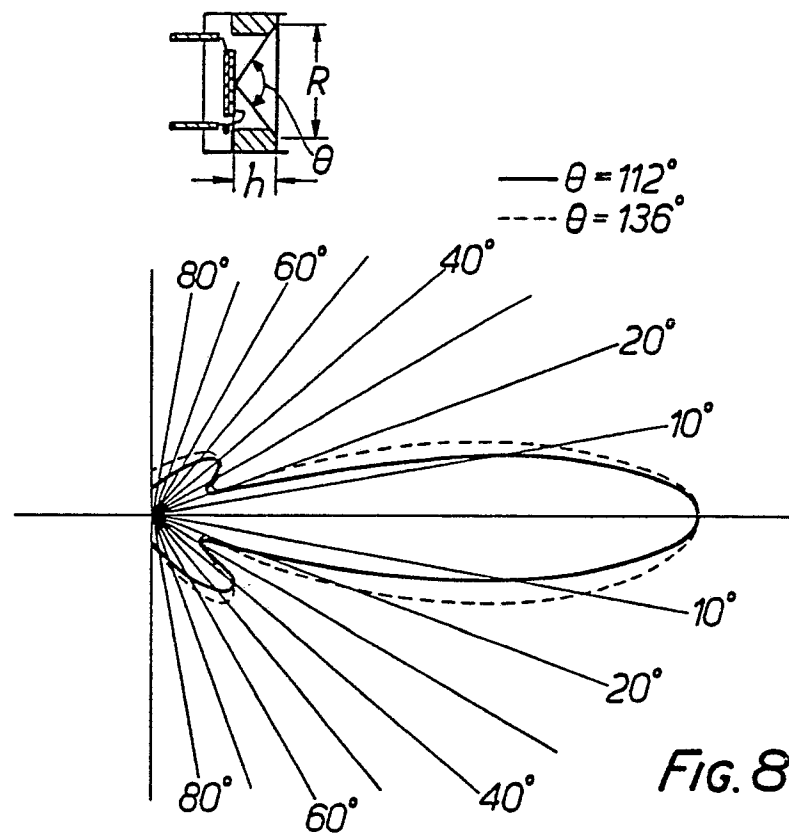


FIG. 8.

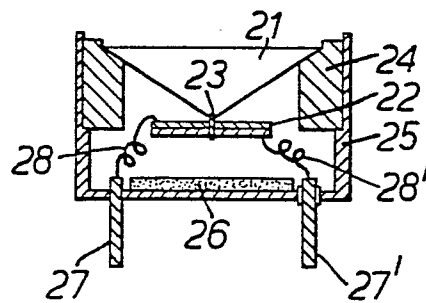


FIG. 9.

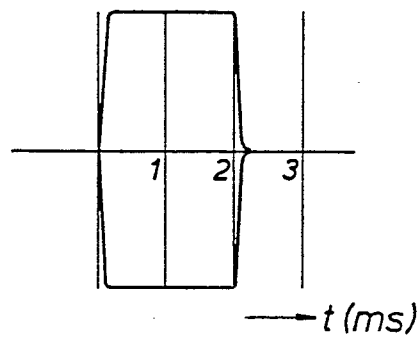


FIG. 10.

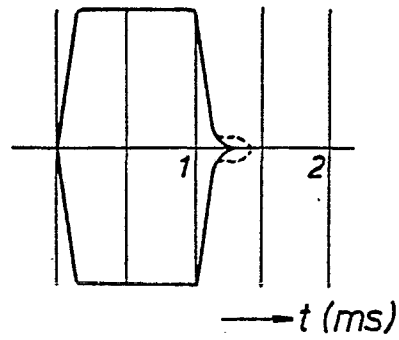


Fig. 11.

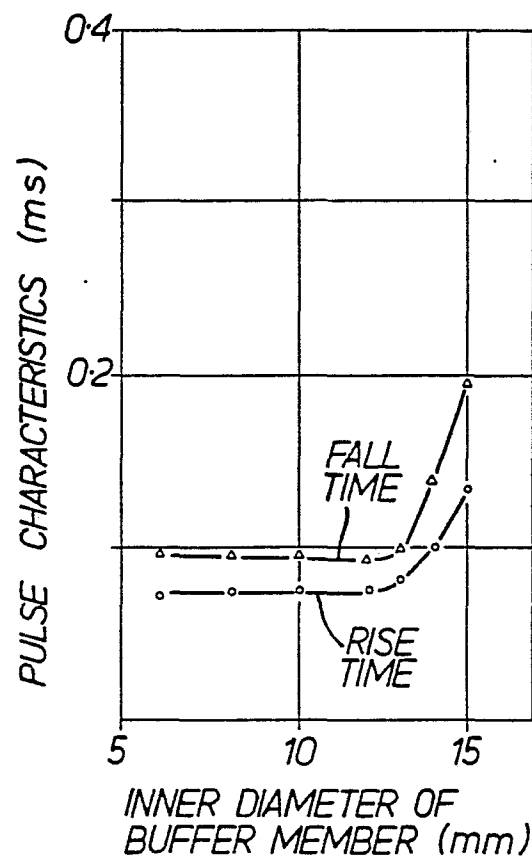


Fig. 12.

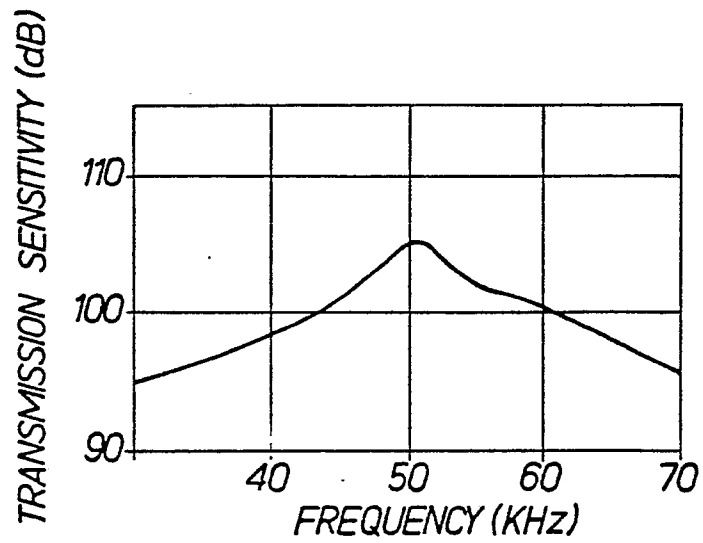


Fig.13.

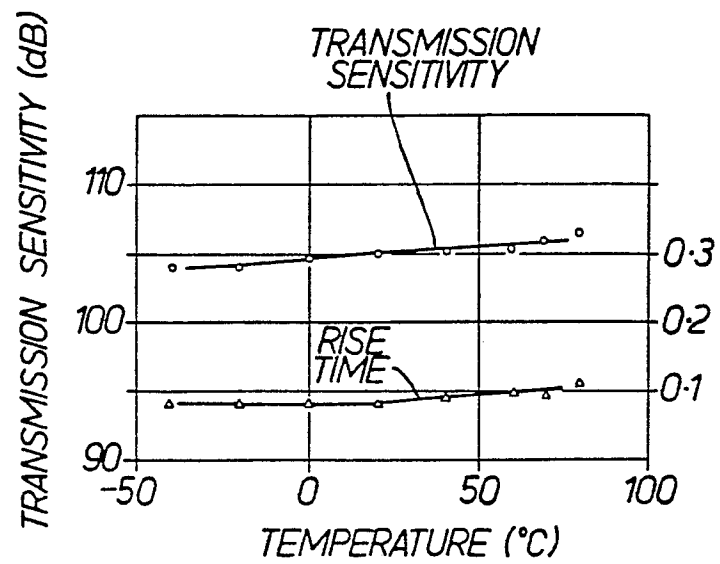


Fig.14.