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(54) **Ultrasonic transducer.**

(57) An ultrasonic transducer is characterized in that a diaphragm (13) is disposed at the centre of a laminated piezo-electric element (11) and the periphery of the diaphragm (13) is flexibly fixed to a housing (17) for the element (11) through a buffer member (20) of a resilient material such as elastic rubber in order to suppress mechanical oscillation.

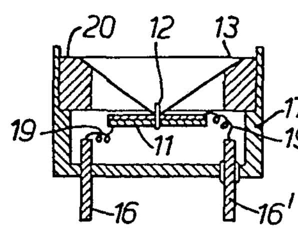

FIG. 3.

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ULTRASONIC TRANSDUCER

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, read-outs are not available until the element is made ready to receive the signals.

The present invention provides an ultrasonic transducer comprising a laminated piezo-electric element having a diaphragm at its central portion, and a housing for accommodating said laminated piezo-electric element therein, characterized in that a buffer member is disposed in contact with a peripheral portion 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 long being of the order of 2 milliseconds each.

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 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 connected 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 element (11) having a diaphragm (13) at its central portion, and a housing (17) for accommodating said laminated piezo-electric element therein, characterized in that a buffer member (20) is disposed in contact with a peripheral portion 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, characterized in that said diaphragm (13) is of a conical configuration and said laminated piezo-electric element (11) is in the form of a disc.

3. An ultrasonic transducer according to claim 2, characterized in that said conical diaphragm (13) has a ratio of height to bottom diameter within 0.3 through 0.5.

4. An ultrasonic transducer according to claim 1, cheracterized in that an acoustic absorbent material (26) is disposed within said housing (17).

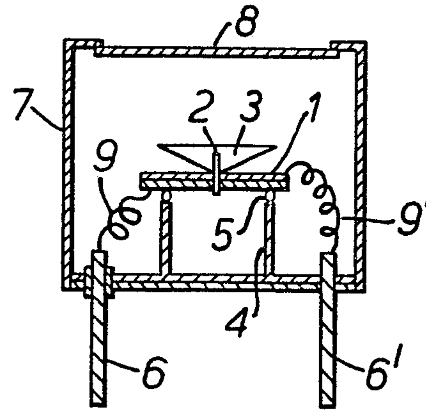


FIG.1.

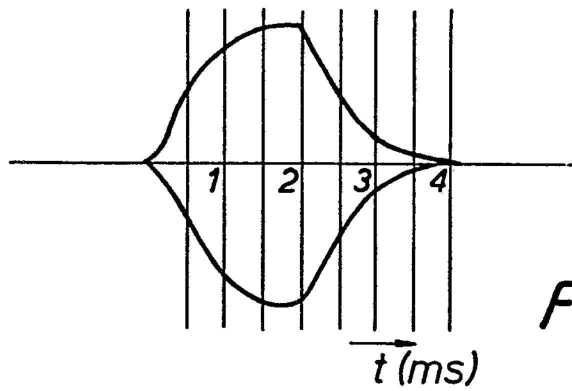


FIG.2.

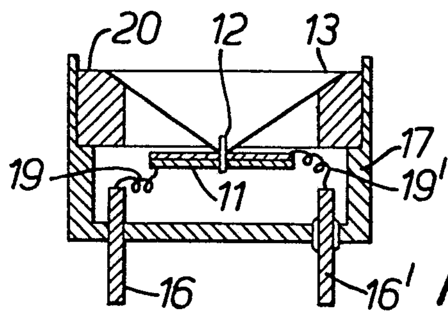


FIG.3.

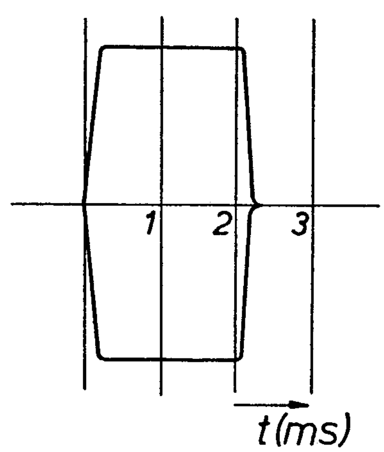


FIG.4.

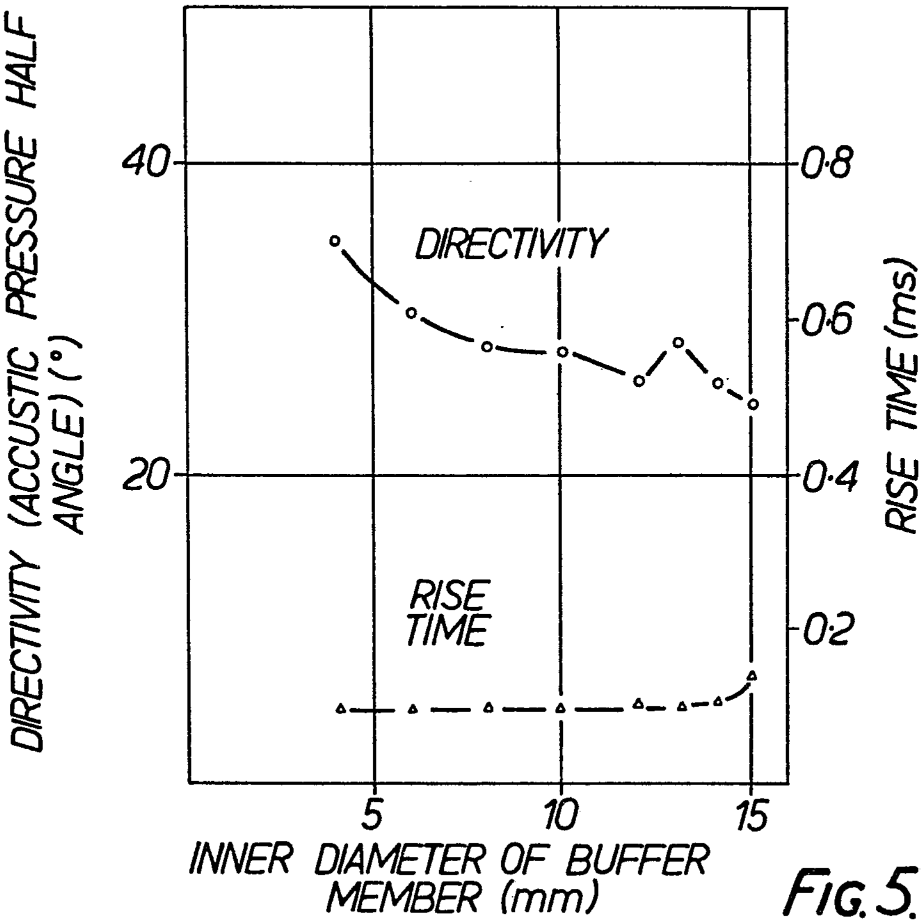

DIRECTIVITY (ACCUSTIC PRESSURE HALF ANGLE) (°)
40
20
0·8
0·6
0·4
0·2
RISE TIME (ms)
DIRECTIVITY
RISE TIME
5
10
15
INNER DIAMETER OF BUFFER MEMBER (mm)

FIG. 5.

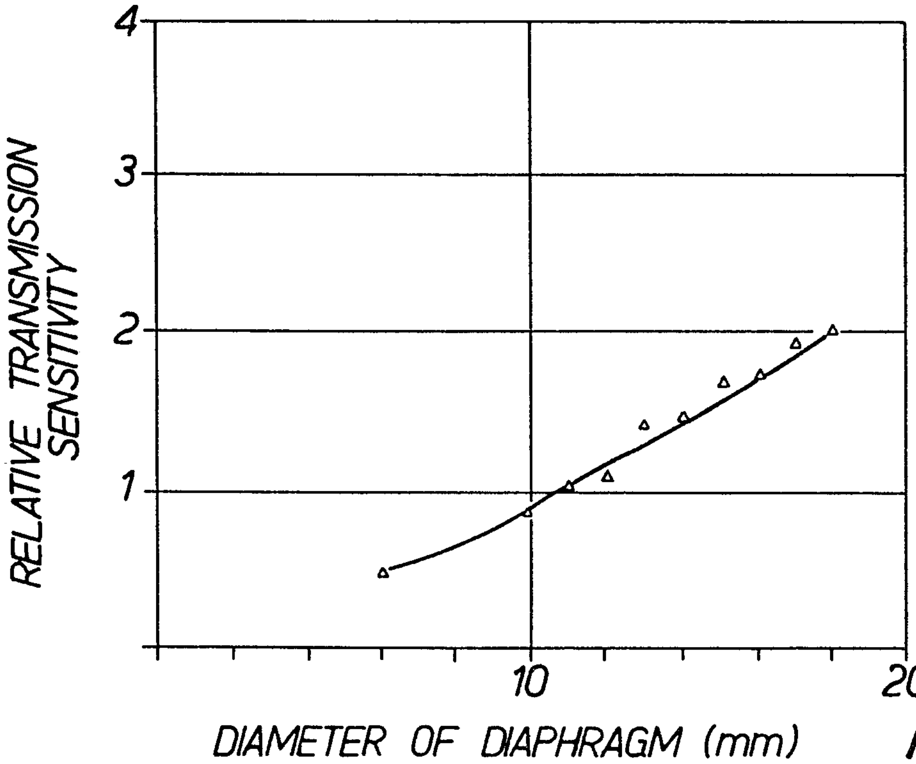
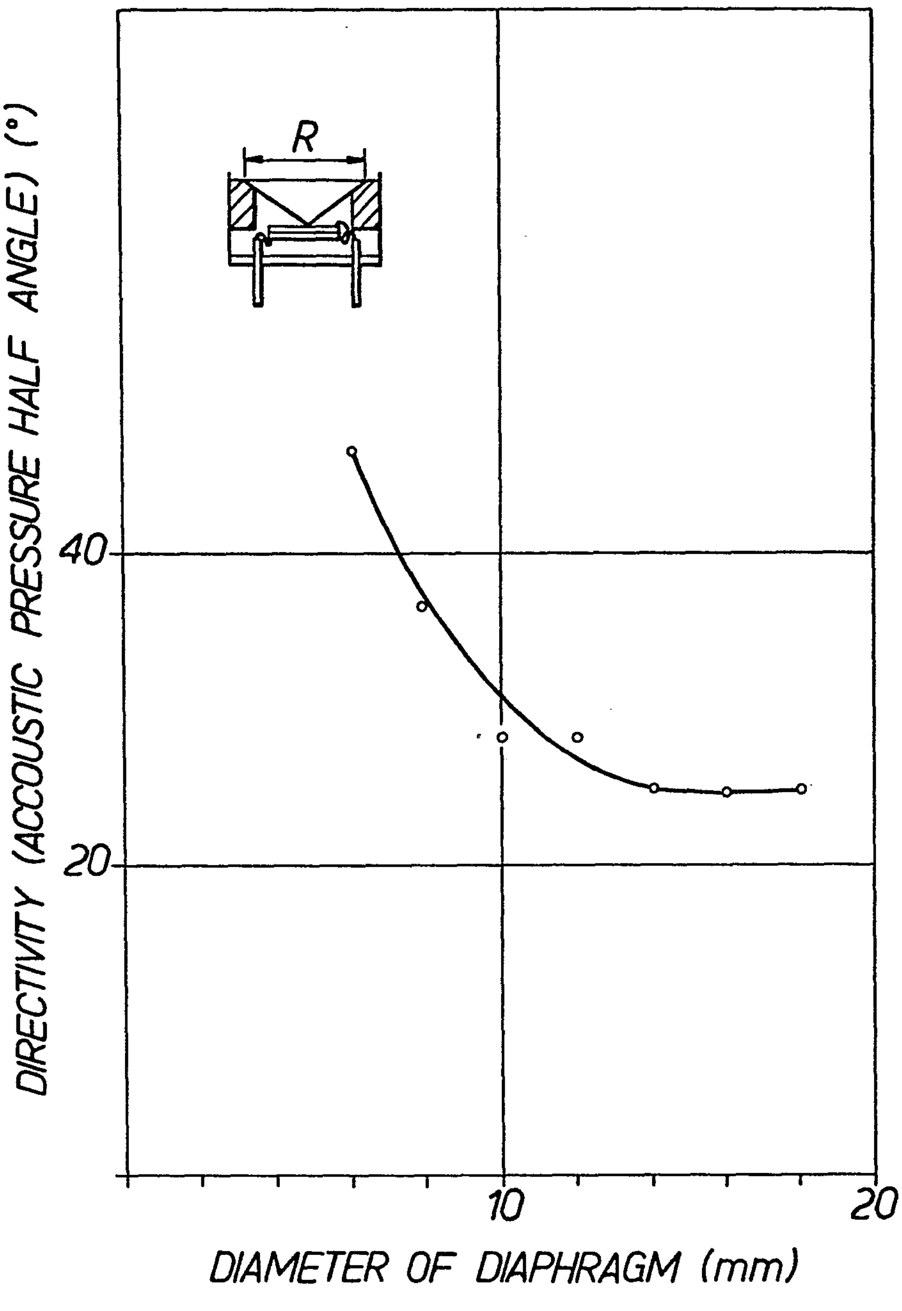

RELATIVE TRANSMISSION SENSITIVITY
4
3
2
1
10
20
DIAMETER OF DIAPHRAGM (mm)

FIG. 6.



R
DIRECTIVITY (ACCOUSTIC PRESSURE HALF ANGLE) (°)
40
20
10
20
DIAMETER OF DIAPHRAGM (mm)

FIG. 7.

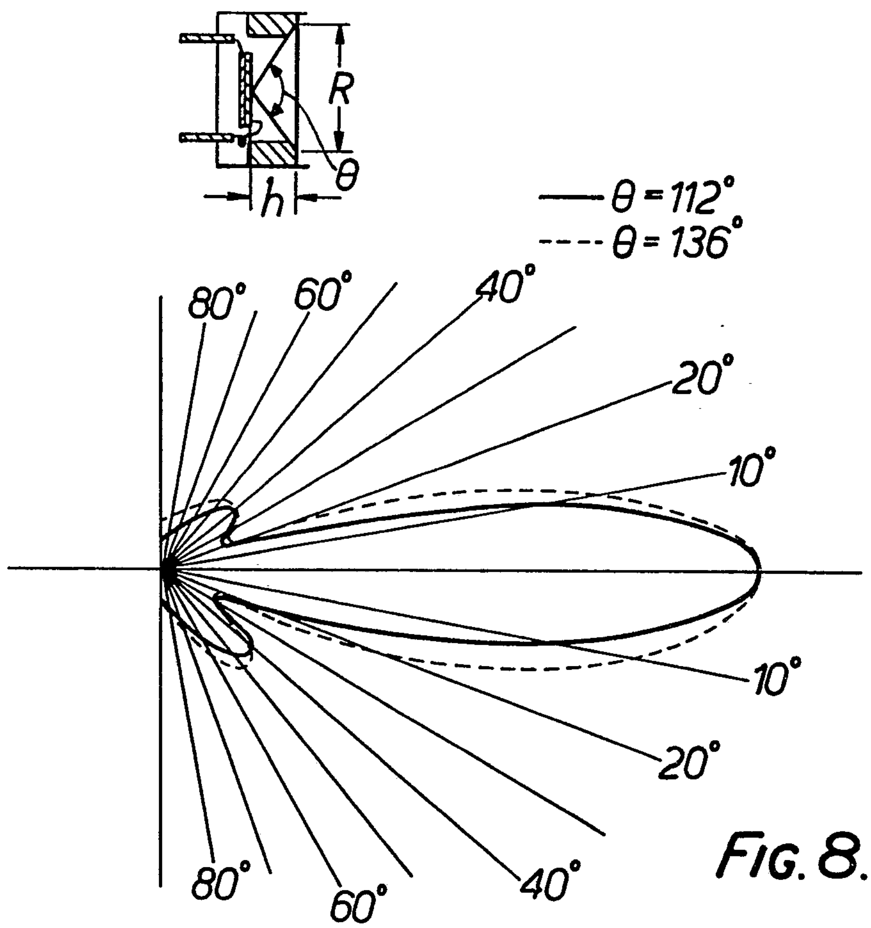


FIG. 8.

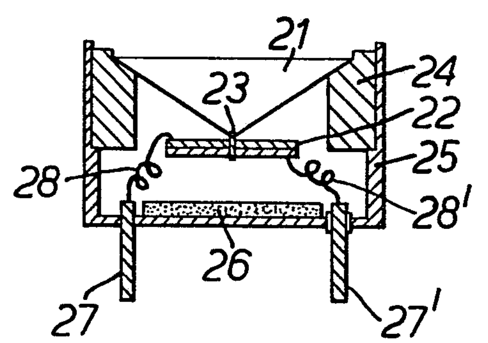


FIG. 9.

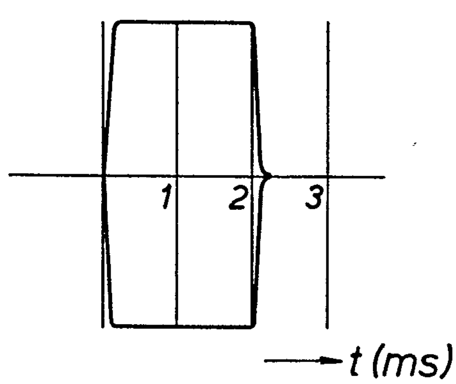


FIG. 10.

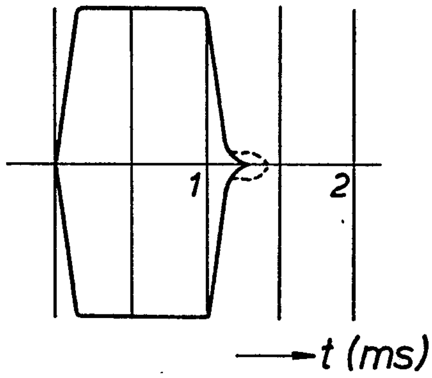

1
2
t (ms)

FIG. 11.

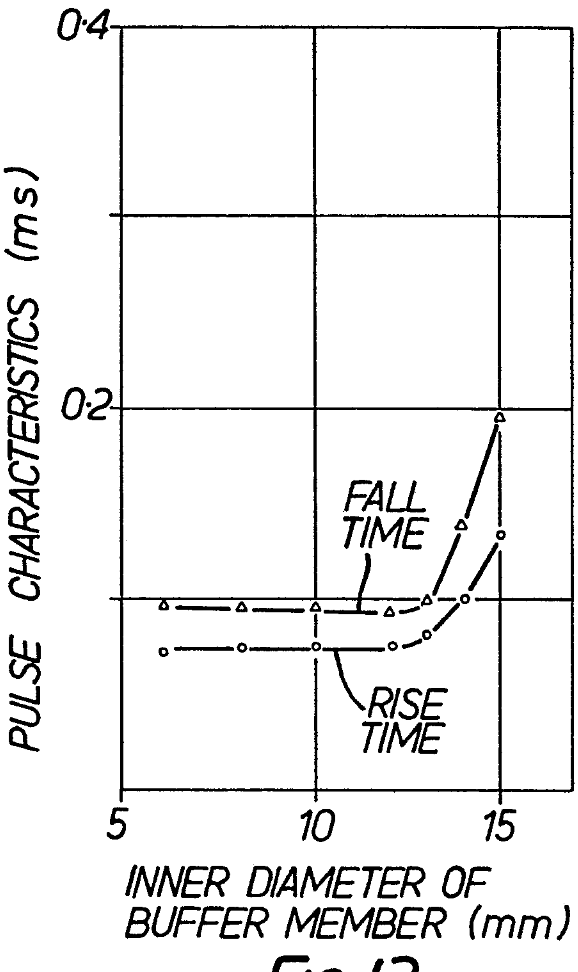

0·4
0·2
PULSE CHARACTERISTICS (ms)
FALL TIME
RISE TIME
5
10
15
INNER DIAMETER OF BUFFER MEMBER (mm)

FIG. 12.

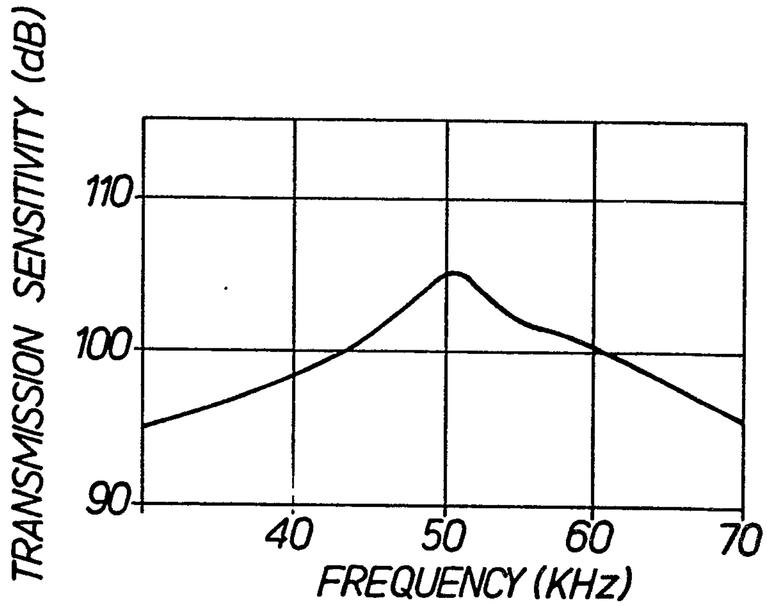

TRANSMISSION SENSITIVITY (dB)
110
100
90
40
50
60
70
FREQUENCY (KHz)

FIG. 13.

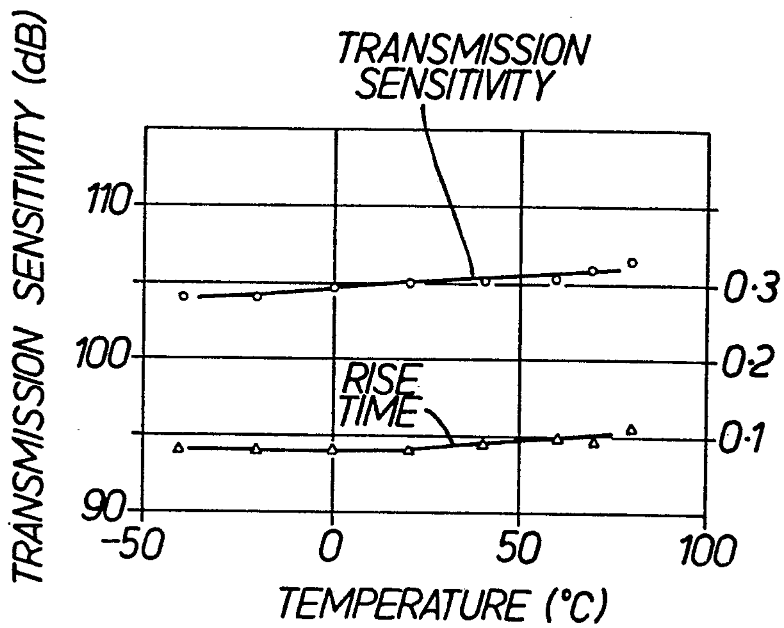

TRANSMISSION SENSITIVITY (dB)
TRANSMISSION SENSITIVITY
RISE TIME
110
100
90
0·3
0·2
0·1
−50
0
50
100
TEMPERATURE (°C)

FIG. 14.

0053947

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EUROPEAN SEARCH REPORT

Application number
EP 81 30 5827

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
Y,A	US - A - 3 749 854 (HIDEO MIFUNE) * Column 2, line 3 to column 4, line 49; figures * ---	1-3
Y	US - A - 3 360 664 (H.J. STRAUBE) * Column 5, line 64 to column 7, line 9; figures 7,8 * ---	1,2
Y	FR - A - 1 301 808 (VEGA) * Page 1, right-hand column, line 21 to page 2, left-hand column; figures * ---	1
A	US - A - 4 011 473 (F. MASSA) * Abstract; figure 2 * ---	1
A	US - A - 3 786 202 (H.W. SCHAFFT) * Abstract; figure 1 * -----	1,4

CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)

H 04 R 17/10

TECHNICAL FIELDS SEARCHED (Int.Cl. 3)

H 04 R 17/00
17/02
17/10
7/18
7/20
G 10 K 11/00

CATEGORY OF CITED DOCUMENTS

X: particularly relevant if taken alone
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E: earlier patent document, but published on, or after the filing date
D: document cited in the application
L: document cited for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	19-03-1982	MINNOYE