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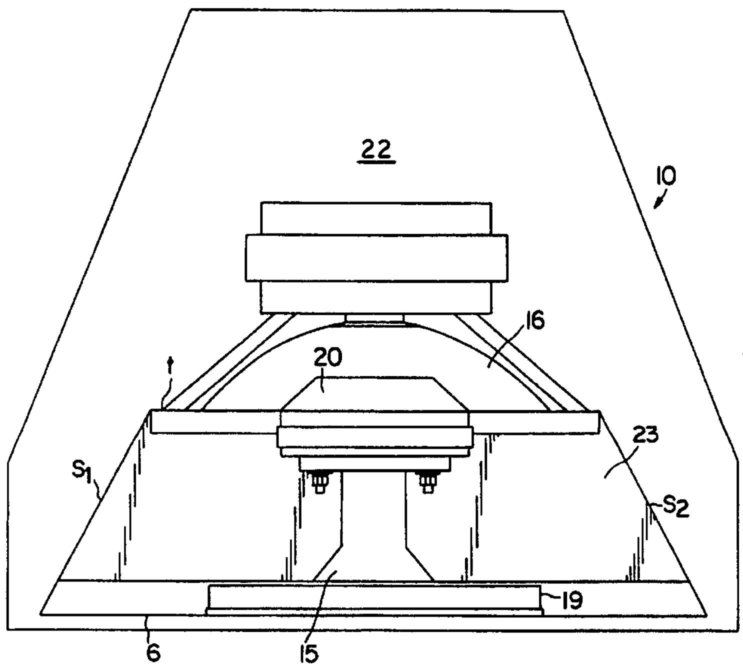
(57) Abstract

A compact loudspeaker system design in which reflection is attenuated and roll-off enhanced by the specific placement of absorbent material (23) between a first driver (16) and a second driver (20), the second driver (20) being used in a frequency range higher than the frequency range in which the first driver (16) is used, the second driver (20) being positioned in front of the first driver (16) with respect to the direction of sound radiation, either in free space or in a speaker cabinet. In a further embodiment, acoustic output above the passband and/or the frequency range in which a single driver is used is attenuated by placement of absorbent material in front of the single driver.



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SPEAKER DESIGN WITH ATTENUATED REFLECTION

BACKGROUND OF THE INVENTION

Speaker configuration and cabinet construction play a significant role in acoustical fidelity and performance of a loudspeaker system. As sound is radiated from a speaker cone, vibrational energy is transmitted in and around the cabinet, which can cause undesirable distortions in the sound. Conventionally, such distortions have been minimized in part by use of sound absorbent material such as fiberglass insulation placed in the cabinet behind the speaker components to absorb some of the generated vibrational energy. The absorbent characteristics of the fiberglass insulation material reduce the effect of standing waves within the cabinet and also may increase the apparent volume. The speakers are generally mounted in the cabinet such that their sound is radiated from the front of the cabinet toward the listener, and the absorbent material is positioned in the rear of the cabinet behind the speakers. Indeed, conventional wisdom dictated that the sound absorbent material be carefully placed in the cabinet so as to avoid absorbing sound which is desired to radiate directly from the speaker elements unimpeded.

With certain designs, however, attenuation of reflection that occurs in front of the transducers may be desirable.

SUMMARY OF THE INVENTION

The present invention provides a compact loudspeaker system design in which reflection is attenuated and roll-off enhanced by the specific placement of absorbent material between a first driver and a second driver, the second driver being used in a frequency range at least a portion of which is higher than the frequency range that the first driver is used in, the second driver being positioned in front of the first driver with respect to the direction of sound radiation, either in free space or in a speaker cabinet. The invention may be applied, for example, in the EAW KF695 loudspeaker, which is a three-way full range loudspeaker system designed to be compact, in which two acoustical transducers are coaxially arranged in a speaker cabinet. This design results in frequency responses from the acoustical transducers which show some anomalies due to reflections within the cabinet cavity. The present invention is directed to minimizing the reflections that are encountered and enhance roll-off with such designs and the like by the strategic selection and placement of absorbent material. The present invention may also be applied to 2-way, 4-way, etc. systems.

In a further embodiment, the present invention provides for the specific placement of absorbent material in front of a single driver (i.e., no second driver mounted in front of the single driver) in order to attenuate acoustic output above the passband of the driver, and/or above the frequency range in which the driver is used, and enhance roll-off.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a front view of the loudspeaker design;

Figure 2 is a front view of the loudspeaker design with the absorbent material in place;

Figure 3 is a top view of the loudspeaker design with the absorbent material in place;

Figure 4a is a top view of the absorbent material;

Figure 4b is a front view of the absorbent material;

Figure 4c is a side view of the absorbent material;

Figure 5 is graph of the frequency response of a high frequency horn in a cabinet;

Figure 6 is a graph of the frequency response of a high frequency horn in a cabinet with reflection attenuated in accordance with the instant invention;

Figure 7 is a graph of the time response of a high frequency horn in a cabinet;

Figure 8 is a graph of the time response of a high frequency horn in a cabinet with reflection attenuated in accordance with the instant invention;

Figure 9 is a graph of the frequency response of a woofer in a cabinet with no high frequency horn mounted therein, both with and without reflection attenuated;

Figure 10 is a graph of the time response of a woofer in a cabinet with no high frequency horn mounted therein;

Figure 11 is a graph of the time response of a woofer in a cabinet with no high frequency horn mounted therein, with reflection attenuated in accordance with the present invention;

Figure 12 is a graph of the frequency response of a woofer with high frequency horn mounted in a cabinet both with and without reflection attenuated;

Figure 13 is a graph of the time response of a woofer with a high frequency horn mounted in a cabinet;

Figure 14 is a graph of the time response of a woofer with a high frequency horn mounted in a cabinet with reflection attenuated in accordance with the present invention;

Figure 15 is a graph of the frequency response of a woofer with a high frequency horn mounted in a cabinet both with and without reflection attenuated;

Figure 16 is a graph of the time response of a woofer with a high frequency horn mounted in a cabinet, showing reflection attenuated;

Figure 17 is a graph of the frequency response of a woofer with a high frequency horn mounted in a cabinet both with and without reflection attenuated;

Figure 18 is a graph of the time response of a woofer with a high frequency horn mounted in a cabinet, showing reflection attenuated;

Figure 19 is a graph of the frequency response of a woofer in a cabinet measured at a 30° angle both with and without reflection attenuated;

Figure 20 is the time response of a woofer in a cabinet measured at a 30° angle without reflection attenuated;

Figure 21 is the time response of a woofer in a cabinet measured at a 30° angle with reflection attenuated in accordance with the present invention;

Figure 22 is the frequency response of a woofer with a high frequency horn mounted in a cabinet both with and without reflection attenuated;

Figure 23 is the time response of a woofer with a high frequency horn mounted in a cabinet with reflection attenuated in accordance with the present invention;

Figure 24 is a top view of the loudspeaker design with absorbent material in place in accordance with one embodiment of the present invention;

Figure 25 is graph of the frequency response of a high frequency horn in a cabinet without reflection attenuated;

Figure 26 is a graph of the frequency response of a high frequency horn in a cabinet with reflection attenuated in accordance with the instant invention;

Figure 27 is a graph of the time response of a high frequency horn in a cabinet without reflection attenuated;

Figure 28 is a graph of the time response of a high frequency horn in a cabinet with reflection attenuated in accordance with the instant invention;

Figure 29 is a graph of the frequency response of a woofer in a cabinet both with and without reflection attenuated;

Figure 30 is a graph of the time response of a woofer in a cabinet without reflection attenuated; and

Figure 31 is a graph of the time response of a woofer in a cabinet with reflection attenuated in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Turning now to Figure 1, there is generally shown at 10 a loudspeaker system including a cabinet 12, which may be formed of wood, steel, plastic, medium density fiberboard, etc., depending upon the application. The cabinet is 33.25" high, 24.625" wide, and 19.75" deep, and has a port 13. In the embodiment shown, the cabinet 12 houses a first acoustical transducer 14 such as a middle frequency horn, a second acoustical transducer 15 such as a high frequency horn, and a third acoustical transducer 16 such as a woofer. It will be recognized by those skilled in the art that the specific acoustical transducers used depend upon the desired application. For purposes of illustration, the aforementioned middle frequency horn, high frequency horn and woofer or low frequency driver will be referred to as the first, second and third acoustical transducers, respectively, but such reference should not be construed as limiting the loudspeaker design to these specific components; the use of absorbent material in accordance with the present invention covers any design where one driver is in front of another, and the rear driver is used in a frequency range lower than the front driver, and the absorbent material is placed in at least a portion of the area between the two drivers to absorb sound in the range above the passband of the rear driver and/or above the frequency range in which the rear driver is used. In a further embodiment, the use of absorbent material in accordance with the present invention encompasses any design where the acoustic output of a single driver (such as a low or mid-range driver) is attenuated above the passband and/or above the frequency range in which the single driver is used, without a second driver mounted in front thereof, the absorbent material being placed in front of the single driver. Stanchions 17 and 18 are secured in cabinet 12 for mounting the second acoustical transducer 15 in front of and preferably coaxially with the third acoustical transducer 16. In the embodiment shown, the second acoustical transducer 15 is a high frequency horn and is mounted on stanchions 17, 18 via horn flange 19.

Figure 3 illustrates the relative position of the various components of the loudspeaker system in one embodiment of the present invention wherein the cabinet 12 has a generally trapezoidal shape. High frequency horn 15 has a horn flange 19 and is driven by a high frequency compression driver 20. The woofer 16 is mounted in a recessed area 22 of cabinet 12 facing forward and surrounded by interior and exterior walls of the cabinet. This provides adequate depth to allow the high frequency driver/horn to be mounted in front of the woofer 16 cone and, in the embodiment shown, coaxially with respect to the woofer 16. In a suitable embodiment, the front plane of the woofer 16 is placed about 6 inches, most preferably about 5⅝ inches behind the termination of horn 15 for mechanical clearance. A third acoustical transducer such as a middle frequency horn (see Figures 1 and 2) can be mounted above or below the low/hi frequency section of the cabinet 12.

With such designs, reflection in the cabinet cause anomalies in the frequency response of the various transducers. In order to attenuate such reflections, absorbent material of suitable density, weight, size and shape is positioned in the cabinet between the transducers. In the embodiment shown in Figure 2, the low frequency cavity is filled loosely with absorbent material 23 in front of woofer 16. The particular absorbent material used is conventional, and may include rigid foam, fiberglass, such as standard fiberglass used for insulation, polyester fiber, felt, wood pulp, rock wool, mineral wool, cotton, glass fiber, sponge rubber, or a combination of such materials. Preferably the absorbent material is a virgin staple polyester fiber, #6 Denier having a density of 12.5 oz./ft^3 at ± 20°, and is enclosed in a grille cloth material and sewn thereto in order to create a "pillow" having well defined corners. In this way, points of attachment and placement of the absorbent material in the speaker system can be kept constant and reproducibility can be achieved. The absorbent material 23 can be attached by any suitable means, such as by the use of Velcro 50, a suitable adhesive, etc. So encapsulating the absorbent material also helps to keep the absorbent material from contacting the cone of woofer 16, which could inhibit cone movement and cause a decrease in output at lower frequencies. The absorbent material can be placed anywhere between the two drivers, such as adjacent to the rear driver, adjacent to the front driver, in several different planes between the drivers with gaps therebetween, distributed evenly between the drivers, etc., depending upon the frequency ranges in which the drivers are used, the configuration, etc. The weight and thickness of the absorbent material will depend upon the material used as well as the application. To absorb sound at lower frequencies, a thicker and/or more dense material would be used. At higher frequencies, a less dense and/or thinner absorber would be used. The absorber could be as thin as a fraction of an inch (e.g., a thin sheet of foam) in a 2-way mid/high frequency design with a high crossover point, and as thick as a few feet where the rear driver is a subwoofer and attenuation above 100 Hz is not a problem.

In the embodiment of Figure 3, cabinet walls b, t, s_1 and s_2

are designed such that the horn, the absorbent material and the woofer in the cabinet 12 are arranged in the form of a trapezoid. Specifically, the plane of the termination point of the horn is positioned along base wall b of the trapezoid, the sides of absorbent material 23 are positioned along the respective side walls s_1 and s_2 of the trapezoid, and the front plane of woofer 16 cone is positioned along top wall t of the trapezoid. The particular dimensions (± ⅛) of the absorbent material 23 for such an application are a base width of 21.3", a top width of 18.3", a height of 15.6", a thickness of 2.7", and a center aperture (the center of which is 7.8" from the top and 10.6 inches from the front side) having a 6.5" radius, as shown in Figures 4a, 4b and 4c. The aperture 30 is provided through the material 23 to accommodate the high frequency horn driver.

Sufficient absorbent material is placed in the low-frequency cavity so as to reduce the reflection in the cavity without significantly attenuating the woofer output at lower frequencies. The particular amount, weight, density, thickness and composition of absorbent material used will depend upon the allowable low-frequency attenuation, crossover frequencies, cabinet shape, etc., and will be readily ascertainable by those skilled in the art, depending upon the particular application. In the embodiment where the low frequency driver is arranged behind the high frequency horn, and therefore the absorbent material is placed in front of the low frequency driver, the absorbent material serves the additional function of enhancing roll-off. That is, as the frequency increases, since the absorbent material absorbs high frequency sound, it enhances the decrease in the output of the low frequency driver, thereby enhancing the perceived performance of the middle frequency horn.

The present invention is also applicable to speaker designs which do not utilize a cabinet. For example, absorbent material could be placed between transducers in free space 2-way designs in which a domed tweeter is mounted coaxially in a woofer, such as the L8/CX2 system sold commercially by Eastern Acoustic Works, Inc.

In a further embodiment where it is desired to attenuate acoustic output of a single driver, the absorbent material is simply mounted in front of the driver as shown in Figure 2, but without the high frequency driver 15 mounted therein.

The following experiments were carried out to compare the frequency and time responses of coaxially designed loudspeaker systems with and without the absorbent material in place. The parameters of the measurements are indicated in each of the Figures.

EXAMPLE 1

A KF695 high frequency horn and a 15" woofer, commercially available from Eastern Acoustic Works, Inc., were mounted in a cabinet cavity having the shape shown in Figure 3. The sound-pressure level of the high frequency unit was measured versus frequency, and a graph of the results is shown in Figure 5. A sheet of # 6 Denier polyester fiber absorbent material was then placed in the cabinet around the horn, and the frequency response was again measured, and the results are shown in Figure 6. A comparison of Figures 5 and 6 demonstrates the attenuated reflection, especially in the frequency range of 1-2 kHz.

EXAMPLE 2

The sound-pressure level versus time was plotted for the same measurement used in Example 1. Figure 7 shows the results without absorbent material in place; Figure 8 shows the results with absorbent material in place. A comparison of the graphs demonstrates that reflection is attenuated, especially from 3-4 mS, when the absorbent material is in place in accordance with the present invention.

EXAMPLE 3

The high frequency horn was removed from the cabinet. The frequency response (Figure 9) and the time response (Figures 10 and 11) of the woofer were measured at a distance of 0.75 meters from the cabinet, both with a full sheet of #6 Denier polyester fiber (16" x 45" x 2.7") evenly distributed in front of the woofer across the woofer cavity, and without a full sheet of absorbent material in place. The graphs of frequency response show little effect at low frequencies (0.04-0.2 kHz), and more pronounced effect as the frequency increases beyond 0.2 kHz. Figures 10 (time response without absorbent material) and 11 (time response with absorbent material) show the high frequency attenuation as a smoothing of the time response.

EXAMPLE 4

Example 3 was repeated, except that the high frequency horn was mounted coaxially with the woofer, and the frequency response and time response of the woofer were then measured. Figures 12-14 show that the reflection was attenuated in the case where absorbent material was used, especially at frequencies above 0.2 kHz.

EXAMPLE 5

Example 4 was repeated, except that a pillow of absorbent material was constructed having a top 15.25", a bottom 21.3", a height 15.6" and a thickness 5.6". The material was #6 Denier polyester fiber (in the amount used in the previous Example) with a grille cloth sewn on the outside to encompass the fiber. Figures 15 and 16 (time response with pillow of absorbent material) demonstrate significant low frequency attenuation at 1.5 dB, which is higher than the desired maximum 0.5 dB.

EXAMPLE 6

Example 5 was repeated, except that 1/2 a sheet of the absorbent material was removed from the pillow, thereby resulting in remaining absorbent material having the dimensions shown in Figures 4a, 4b and 4c. Figures 17 and 18 demonstrate the acceptable low frequency attenuation at 0.5 dB and attenuation of reflection at higher frequencies.

EXAMPLE 7

The high frequency horn was removed from the cabinet, and a full sheet of absorbent material was placed across the woofer as in Example 3. The frequency response and time response were measured at a 30° angle from the front of the cabinet, and the results shown in Figures 19-21.

EXAMPLE 8

The high frequency horn was again mounted coaxially with the woofer, and a 2 inch thick piece of SONEX foam absorbent material was positioned in place as shown in Figure 24. The frequency response and time response were measured, and the results are shown in Figures 22 and 23. Reflections were attenuated somewhat, but the response peak was increased at 250Hz.

EXAMPLE 9

A KF695 high frequency horn and a 15" woofer, commercially available from Eastern Acoustic Works, Inc., were mounted in a cabinet cavity having the shape shown in Figure 3. The sound-pressure level of the high frequency unit was measured versus frequency, using an 8 mS time window. A graph of the results is shown in Figure 25. A 2" thick piece of standard fiberglass insulation was then placed in the cabinet around the horn, the frequency response was again measured, and the results are shown in Figure 26. A comparison of Figures 25 and 26 demonstrates the attenuated reflection, especially in the frequency range of 1-2 kHz.

EXAMPLE 10

The sound-pressure level versus time was plotted for the same measurement used in Example 9. Figure 27 shows the results without absorbent material in place; Figure 28 shows the results with the 2" thick fiberglass insulation absorbent material in place. A comparison of the graphs demonstrates that reflection is attenuated when the absorbent material is in place in accordance with the present invention. In particular, the absorbent material eliminated the anomaly that occurred at 3 mS.

EXAMPLE 11

Example 10 was repeated, except that the frequency response and time response of the woofer were measured with a 20 mS time window. Figures 29-31 show that the reflection was attenuated in the case where absorbent material was used, especially at frequencies above 0.2 kHz.

What is claimed is:

1. A loudspeaker system comprising a first driver used in a first frequency range, a second driver used in a second frequency range at least a portion of which is higher than said first frequency range, said first driver being positioned behind said second driver relative to the direction of sound radiation thereof, and means between said first and second drivers for absorbing sound in the range above the frequency range in which said first driver is used.

2. The loudspeaker system of claim 1 wherein said means for absorbing sound absorbs reflections.

3. The loudspeaker system of claim 1 wherein said means for absorbing sound enhances the roll-off of said first driver.

4. The loudspeaker system of claim 1 wherein said first and second drivers are positioned coaxially.

5. The loudspeaker system of claim 1 wherein said first driver comprises a woofer.

6. The loudspeaker system of claim 1 wherein said second driver comprises a high frequency horn.

7. The loudspeaker system of claim 1, further comprising a third driver.

8. The loudspeaker system of claim 1 wherein said first and second drivers are mounted in a cabinet.

9. The loudspeaker system of claim 1 wherein said means for absorbing sound comprises polyester fiber.

10. The loudspeaker system of claim 1 wherein said means for absorbing sound comprises fiberglass.

11. A loudspeaker system comprising a cabinet having an

interior trapezoidal chamber defined by a front wall, a rear wall, and two side walls connecting said front wall to said rear wall; a first transducer mounted in said front wall of said trapezoidal chamber; a second transducer in said rear wall of said trapezoidal chamber; and means between said first and second transducers in said trapezoidal chamber for absorbing sound in the range above the frequency range in which said second transducer is used.

12. The loudspeaker system of claim 11 wherein said first transducer and a second transducer are mounted coaxially.

13. The loudspeaker system of claim 11 wherein said first transducer is a woofer and said second transducer is a horn.

14. The loudspeaker system of claim 11, further comprising a third transducer in said cabinet.

15. The loudspeaker system of claim 14 wherein said third transducer is outside said cabinet chamber.

16. The loudspeaker system of claim 11 wherein said means for absorbing sound comprises polyester fiber.

17. The loudspeaker system of claim 11 wherein said means for absorbing sound comprises fiberglass.

18. The loudspeaker system of claim 11 wherein said means for absorbing sound absorbs reflections.

19. The loudspeaker system of claim 11 wherein said means for absorbing sound enhances the roll-off of said second transducer.

20. A loudspeaker driver comprising means for absorbing sound above the frequency range in which said driver is used, said means comprising sound absorbing material positioned in

front of said driver in the direction of sound radiation.

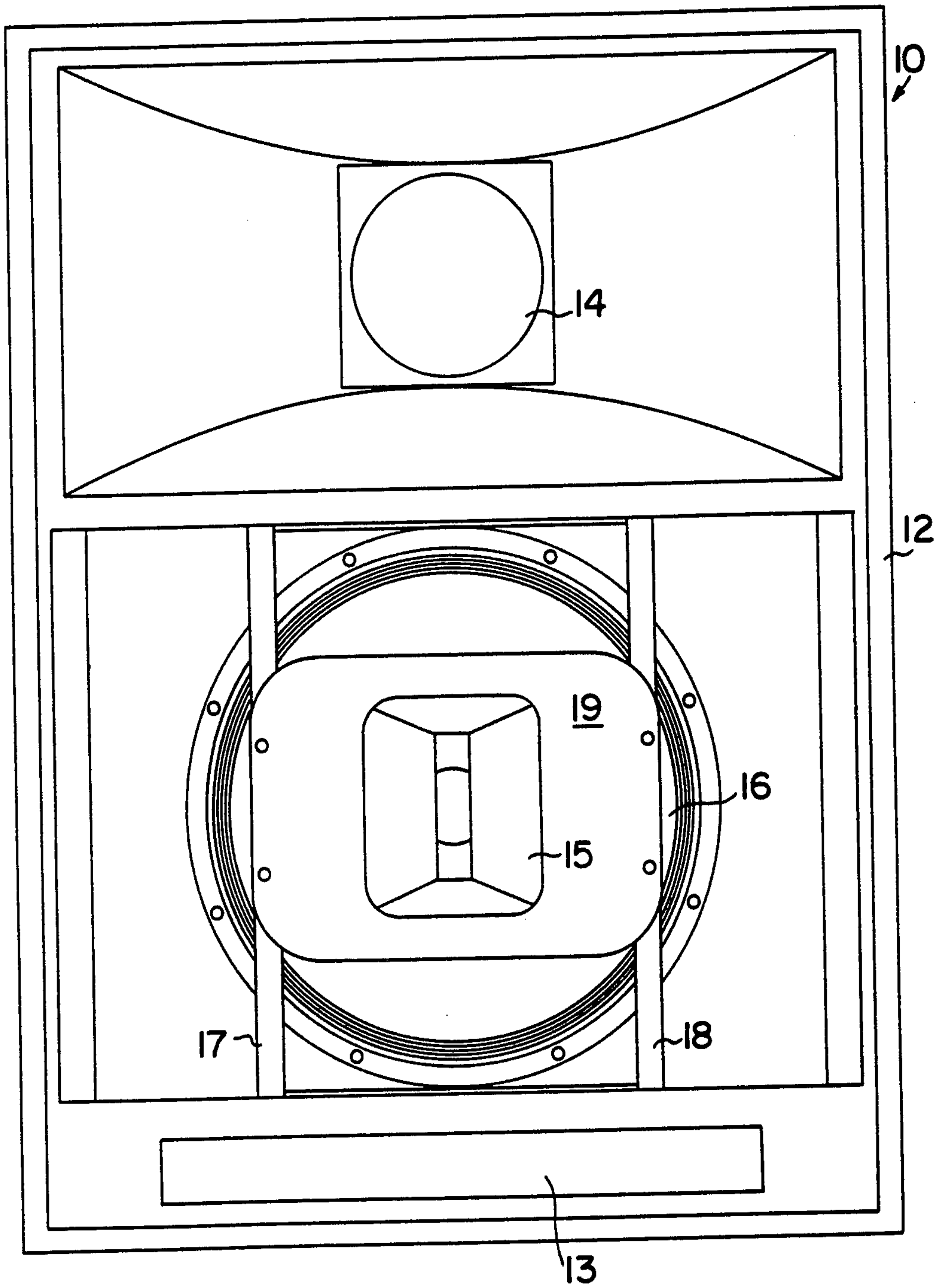


FIG.1

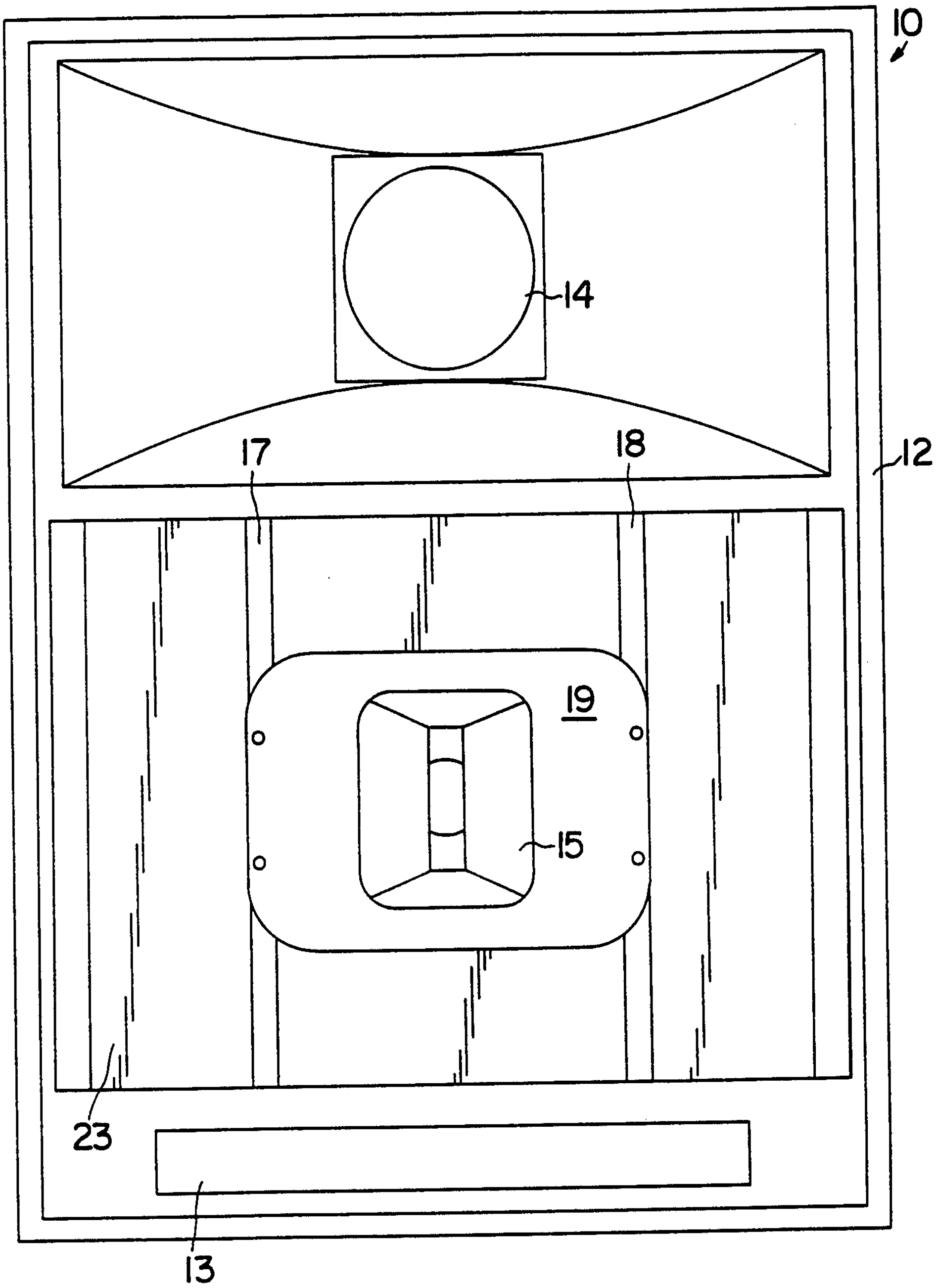


FIG. 2

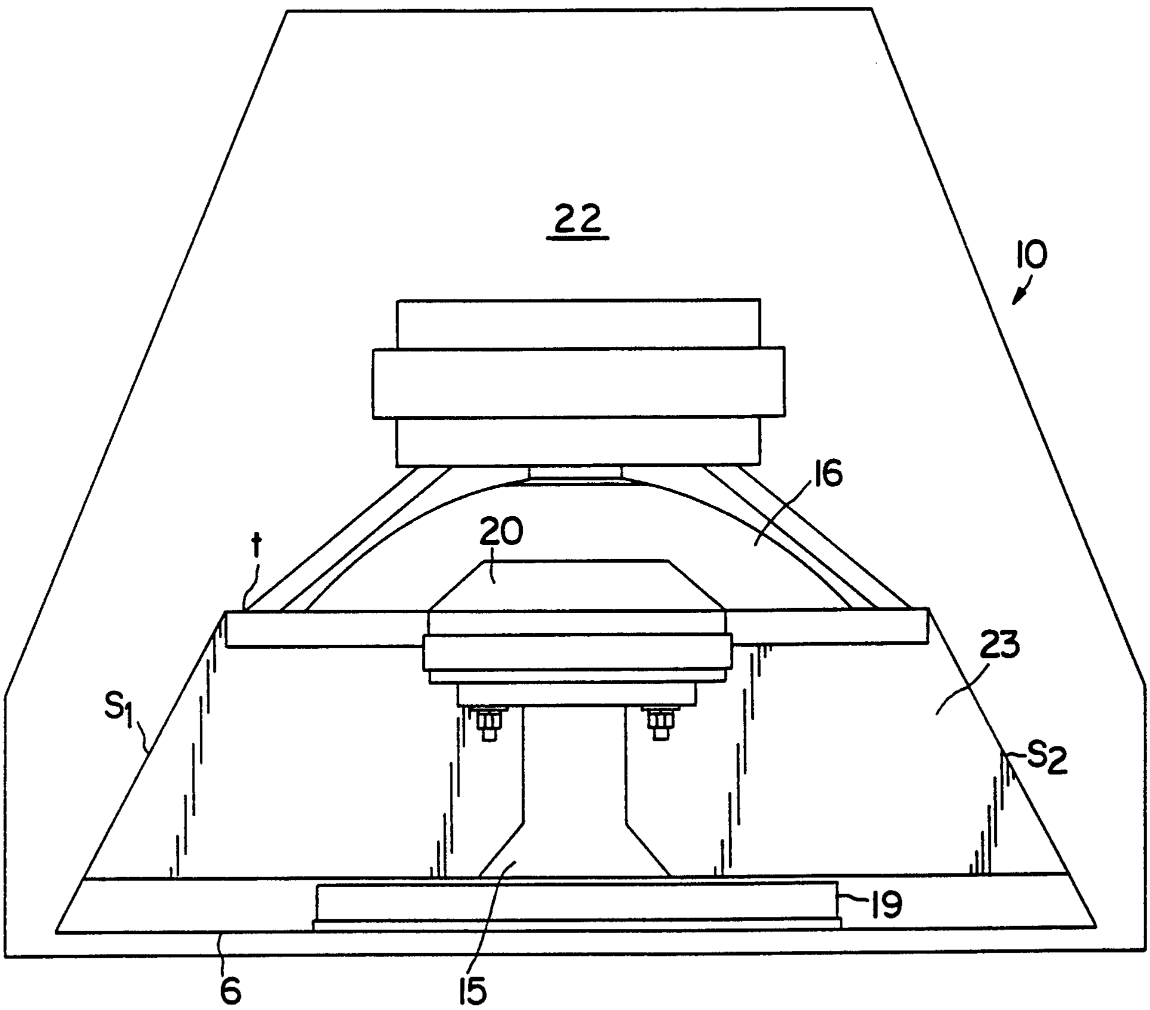


FIG. 3

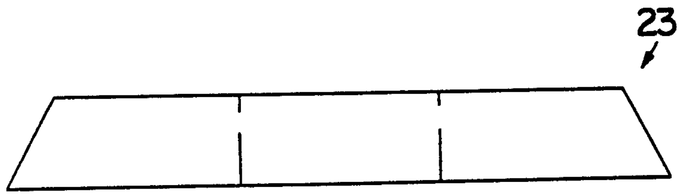


FIG.4a

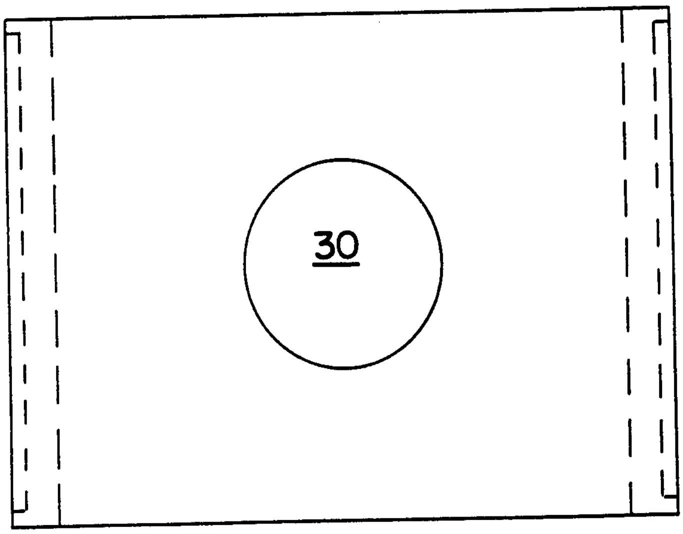


FIG.4b

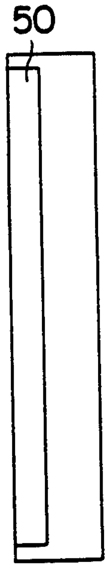
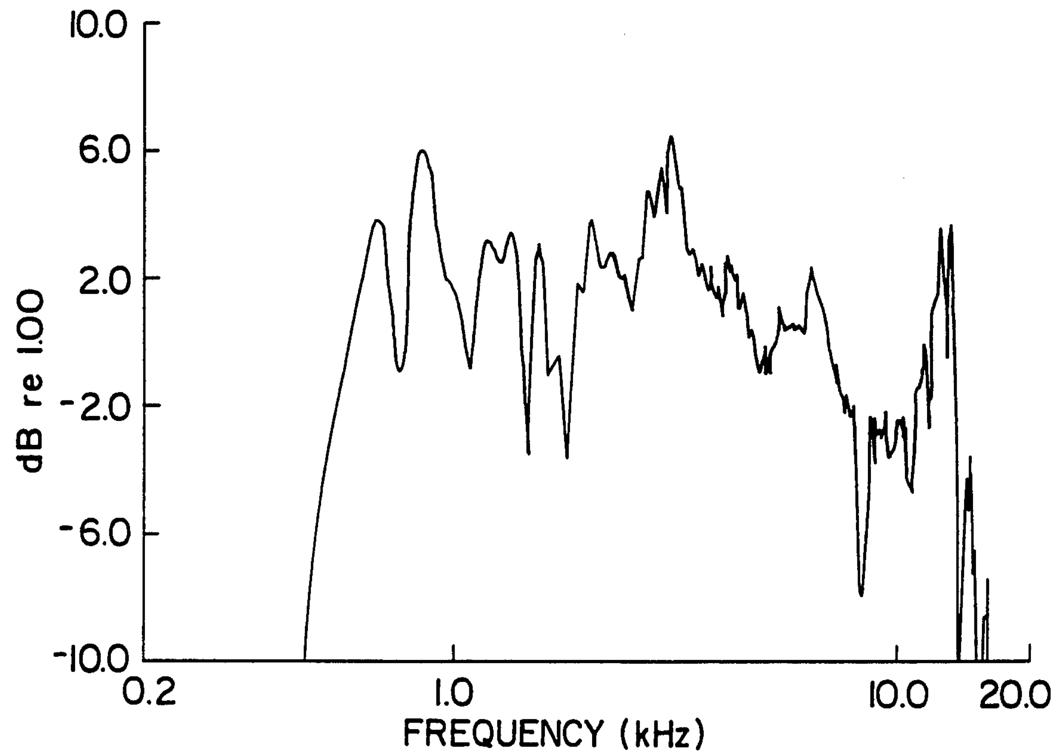


FIG.4c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2.0
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-10.0
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1.0
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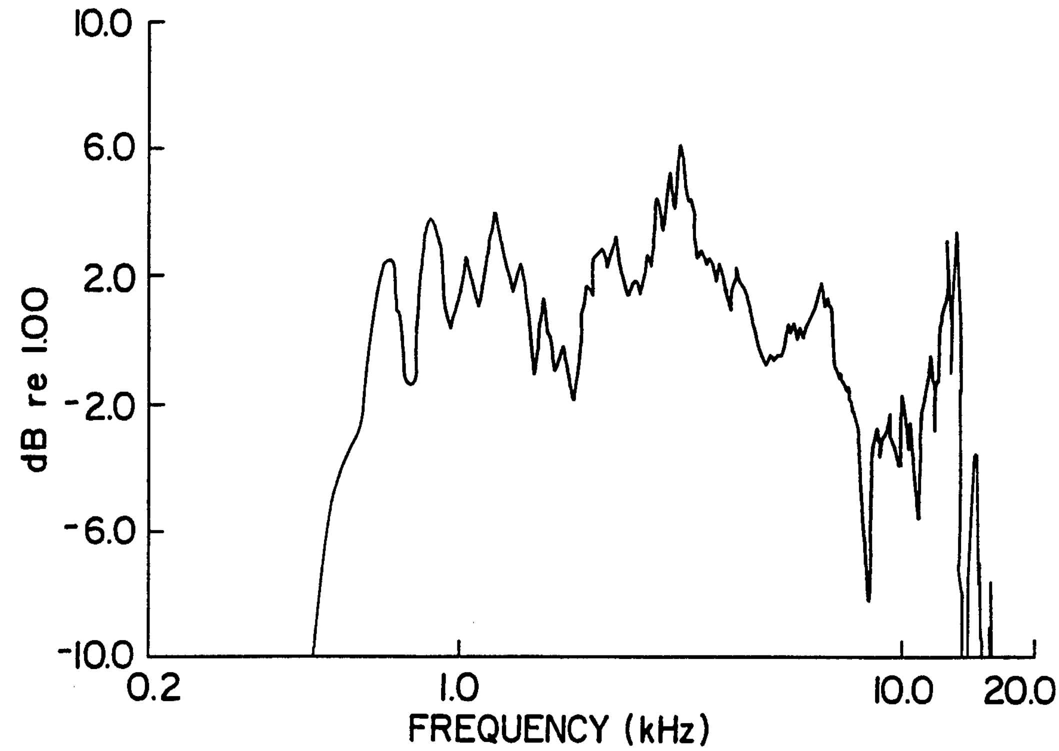
20.0
FREQUENCY (kHz)

FIG. 5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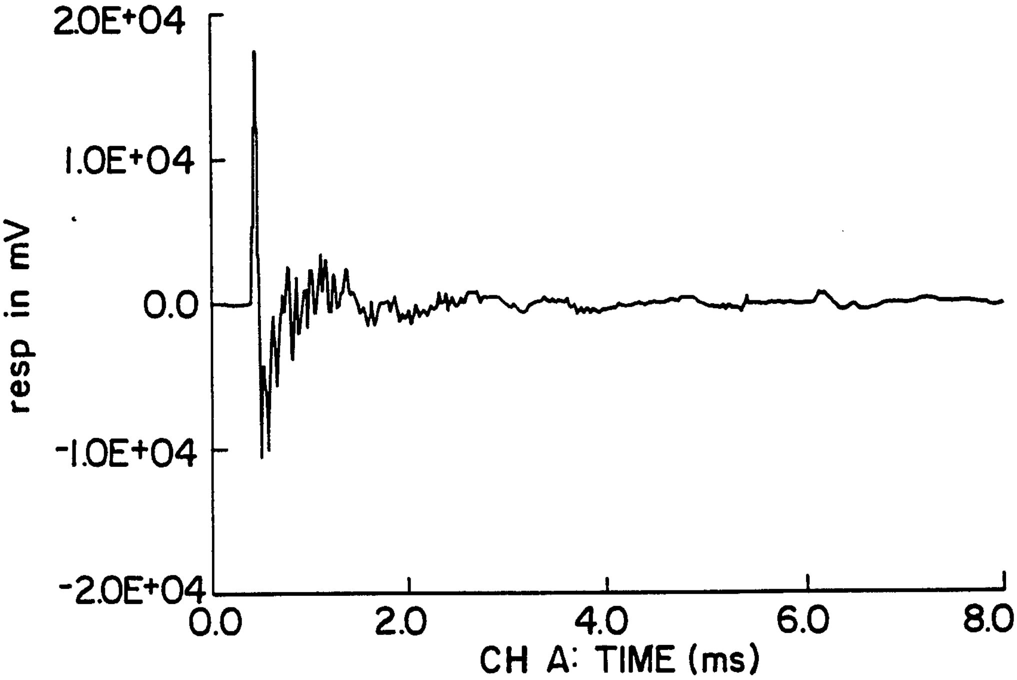
dB re 1.00
0.2
1.0
10.0
20.0
FREQUENCY (kHz)

FIG. 6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1.0E+04
0.0
-1.0E+04
-2.0E+04
resp in mV
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2.0
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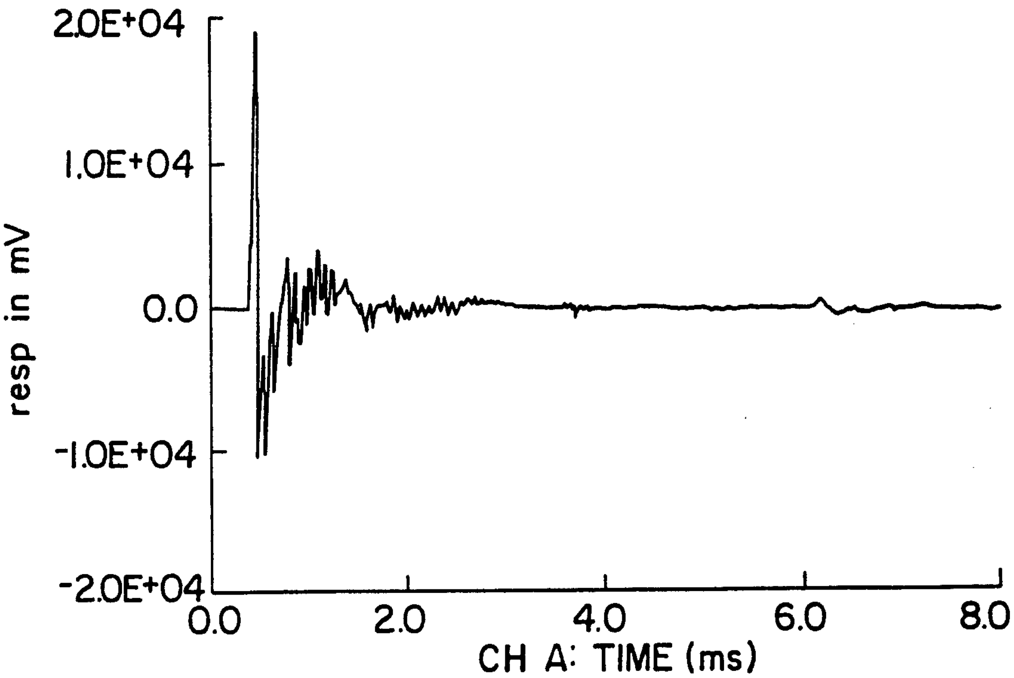
6.0
8.0
CH A: TIME (ms)

FIG. 7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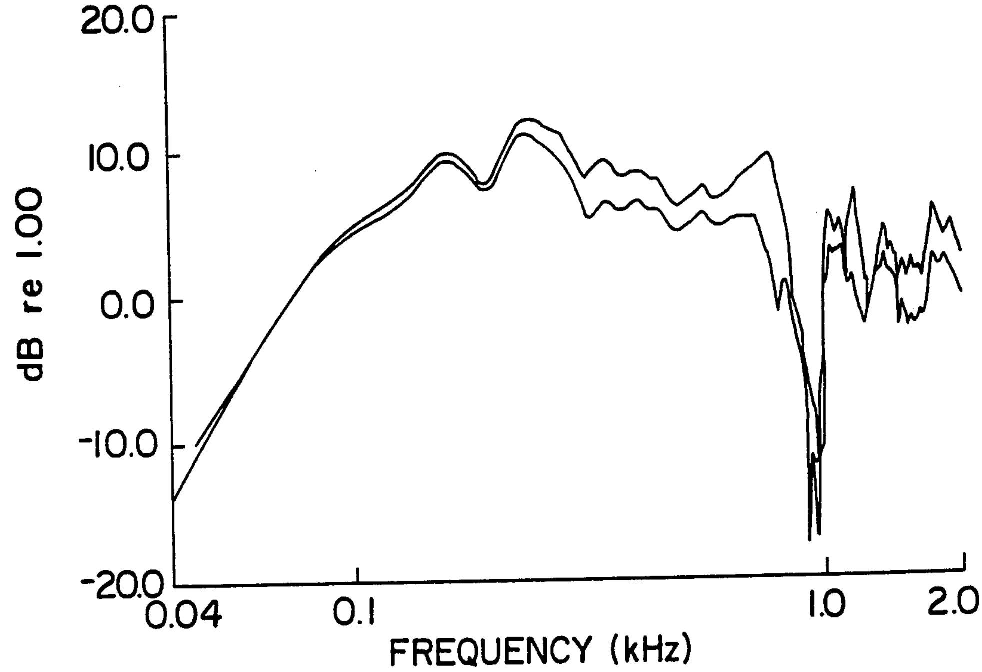
6.0
8.0
CH A: TIME (ms)

FIG. 8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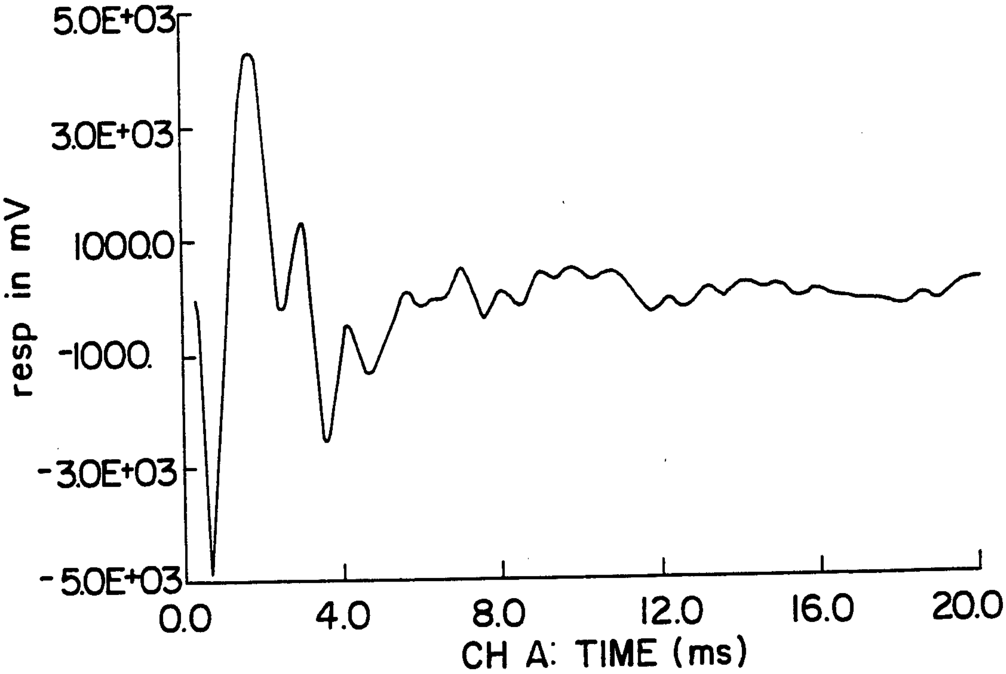
10.0
0.0
-10.0
-20.0
dB re 1.00
0.04
0.1
1.0
2.0
FREQUENCY (kHz)

FIG. 9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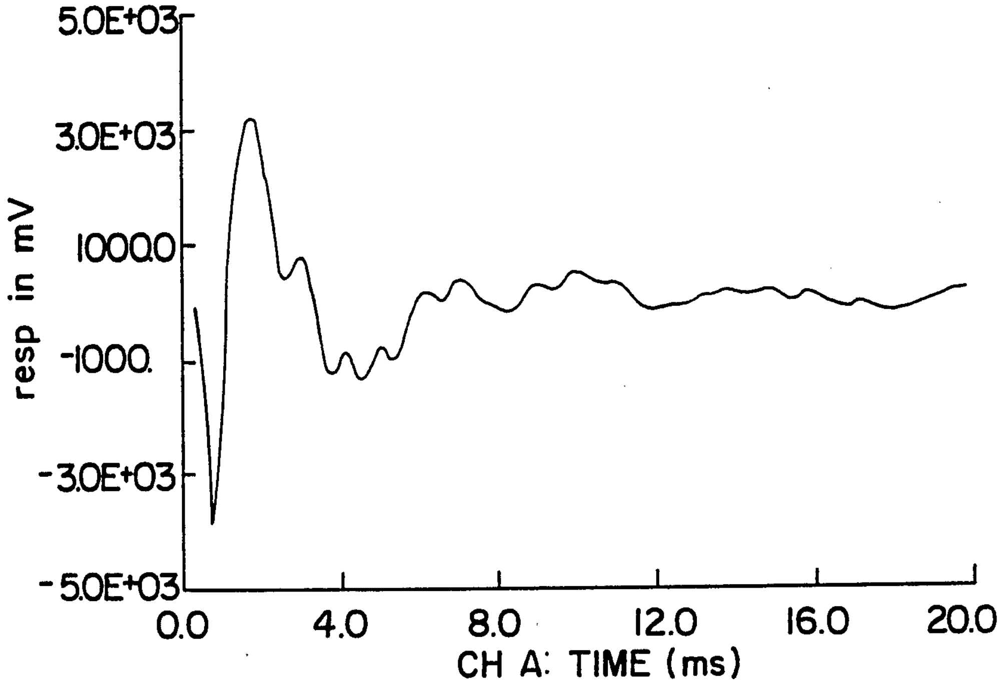
CH A: TIME (ms)

FIG. 10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resp in mV
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16.0
20.0
CH A: TIME (ms)

FIG.11

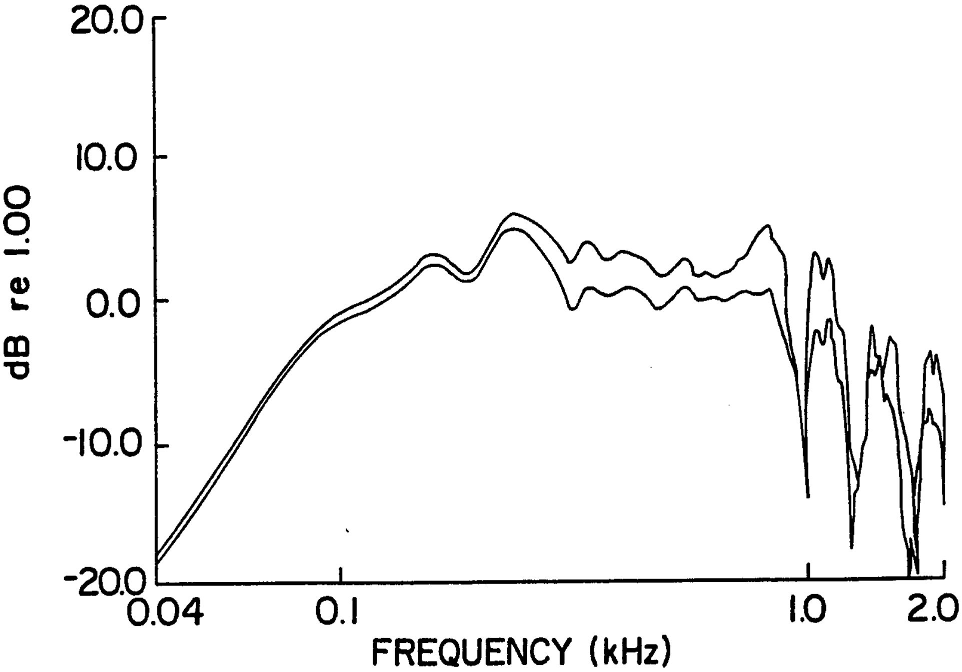

20.0
10.0
0.0
-10.0
-20.0
dB re 1.00
0.04
0.1
1.0
2.0
FREQUENCY (kHz)

FIG.12

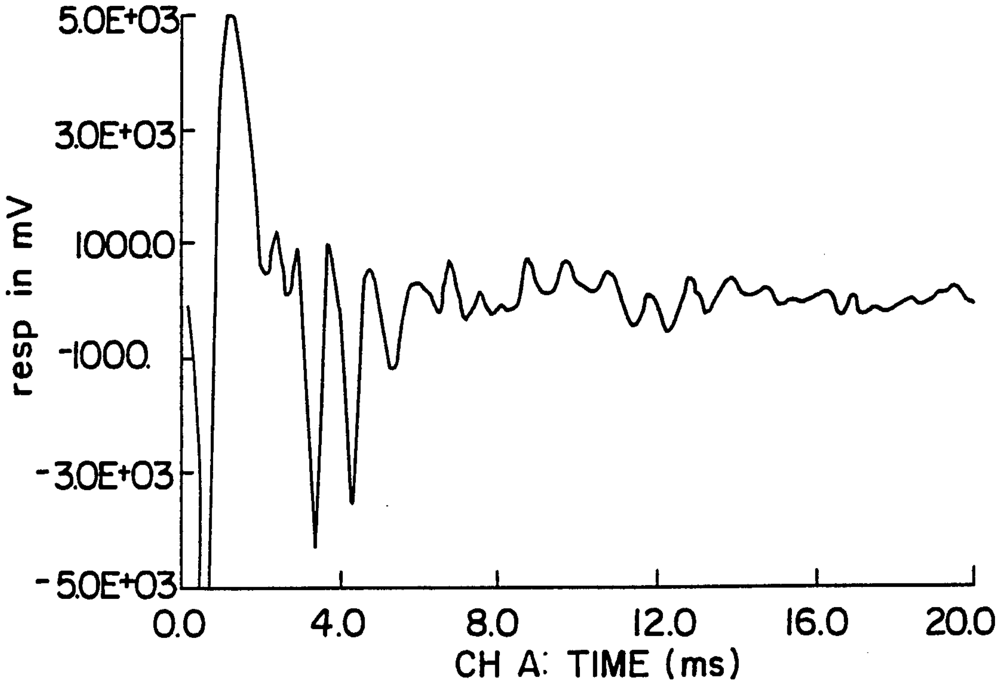

5.0E+03
3.0E+03
1000.0
-1000.
-3.0E+03
-5.0E+03
resp in mV
0.0
4.0
8.0
12.0
16.0
20.0
CH A: TIME (ms)

FIG. 13

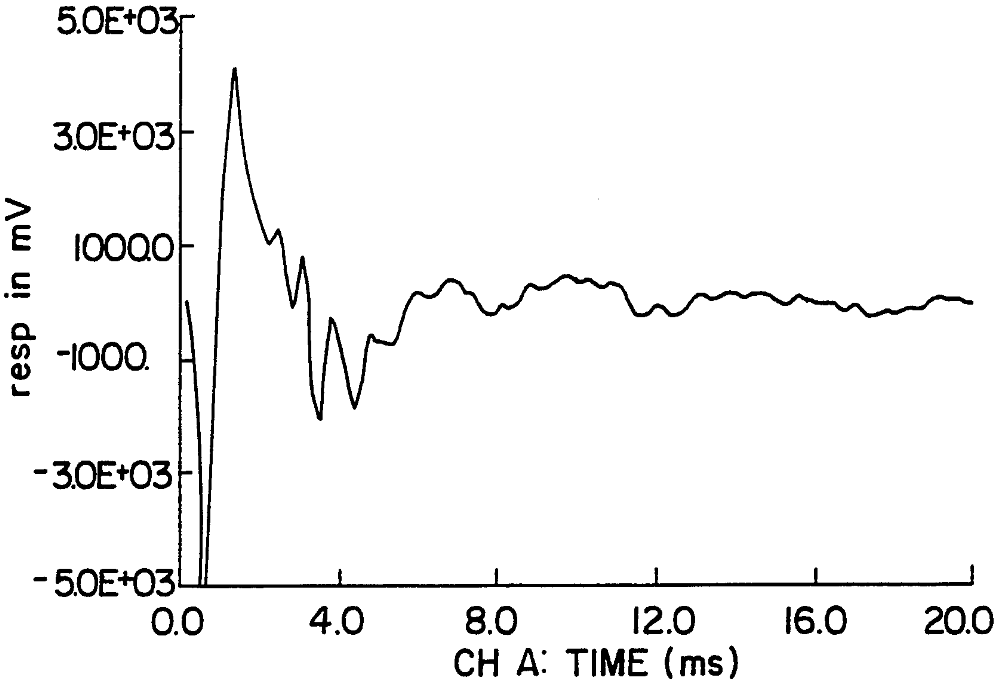
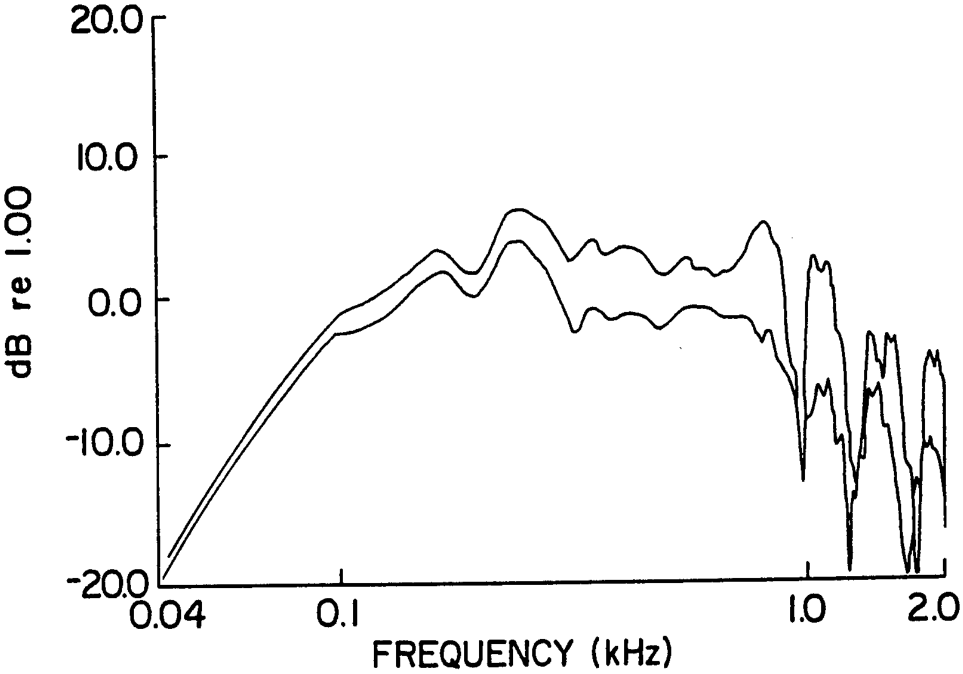
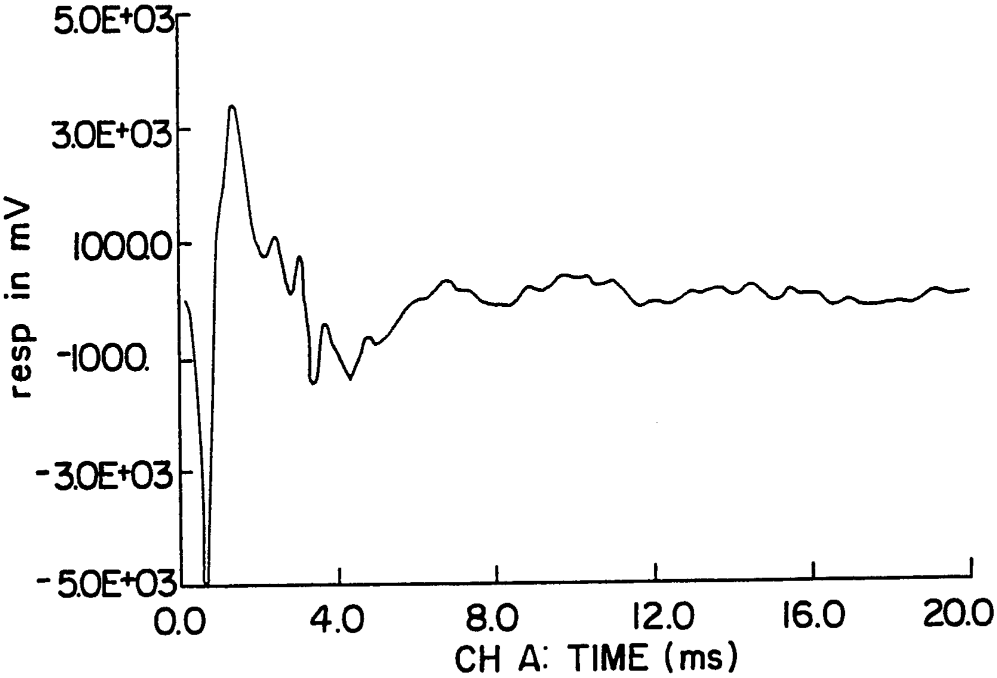

5.0E+03
3.0E+03
1000.0
-1000.
-3.0E+03
-5.0E+03
resp in mV
0.0
4.0
8.0
12.0
16.0
20.0
CH A: TIME (ms)

FIG. 14


20.0
10.0
0.0
-10.0
-20.0
dB re 1.00
0.04
0.1
1.0
2.0
FREQUENCY (kHz)

F I G. 15


5.0E+03
3.0E+03
1000.0
-1000.
-3.0E+03
-5.0E+03
resp in mV
0.0
4.0
8.0
12.0
16.0
20.0
CH A: TIME (ms)

F I G. 16

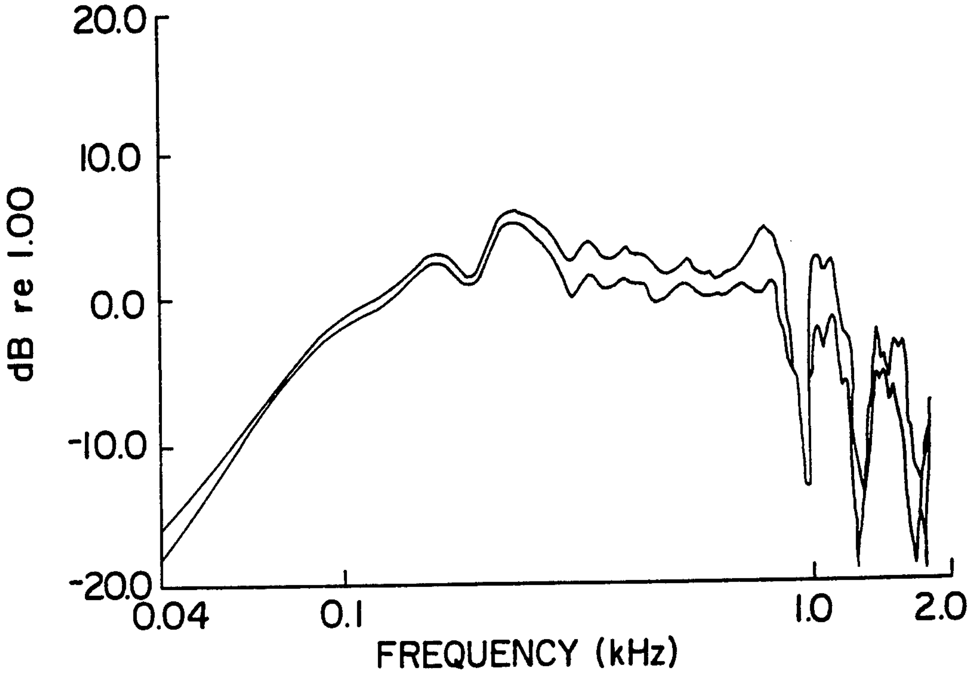

20.0
10.0
0.0
-10.0
-20.0
dB re 1.00
0.04
0.1
1.0
2.0
FREQUENCY (kHz)

FIG. 17

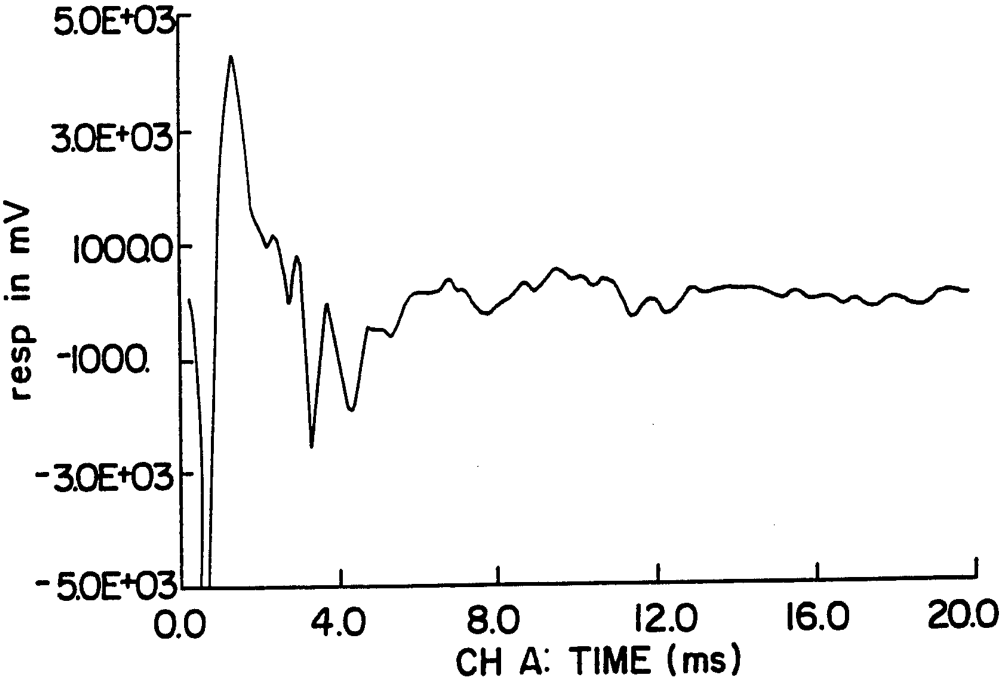

5.0E+03
3.0E+03
1000.0
-1000.
-3.0E+03
-5.0E+03
resp in mV
0.0
4.0
8.0
12.0
16.0
20.0
CH A: TIME (ms)

FIG. 18

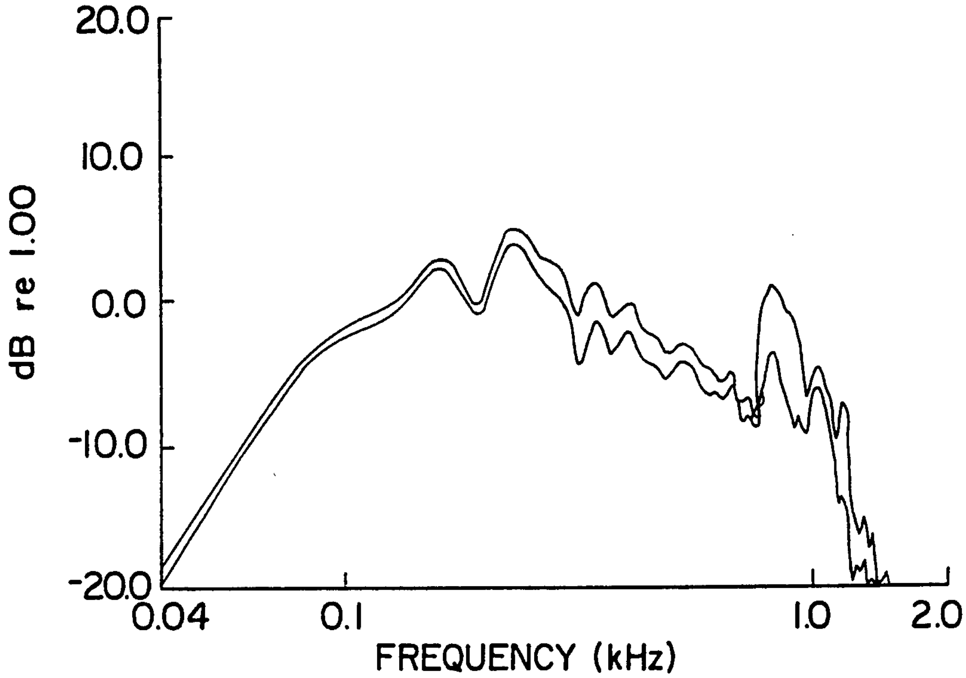

20.0
10.0
0.0
-10.0
-20.0
dB re 1.00
0.04
0.1
1.0
2.0
FREQUENCY (kHz)

FIG.19

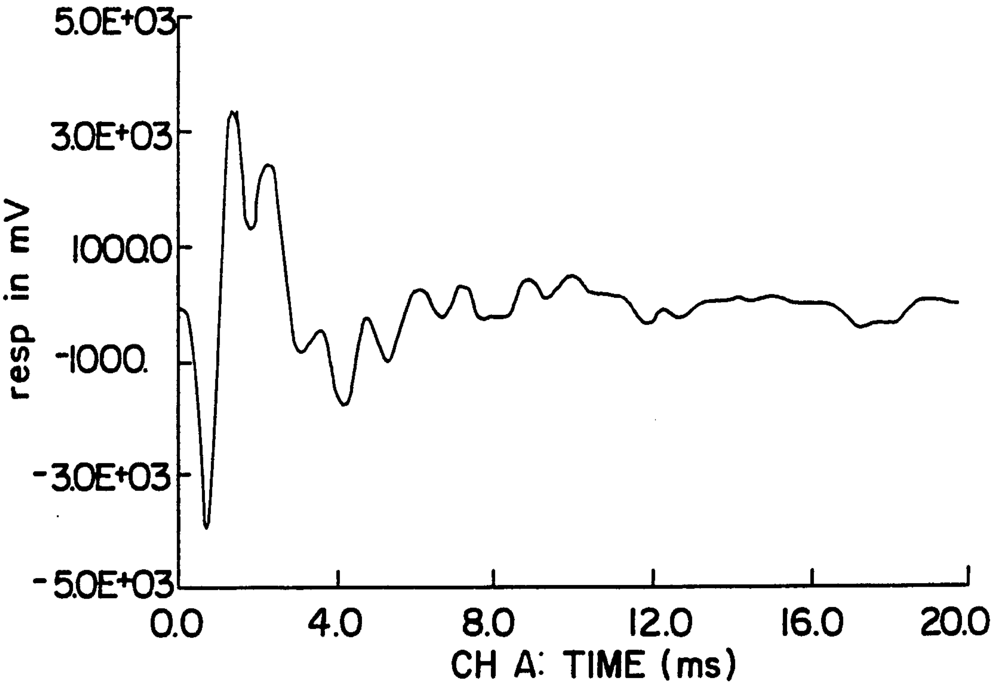

5.0E+03
3.0E+03
1000.0
-1000.
-3.0E+03
-5.0E+03
resp in mV
0.0
4.0
8.0
12.0
16.0
20.0
CH A: TIME (ms)

FIG.20

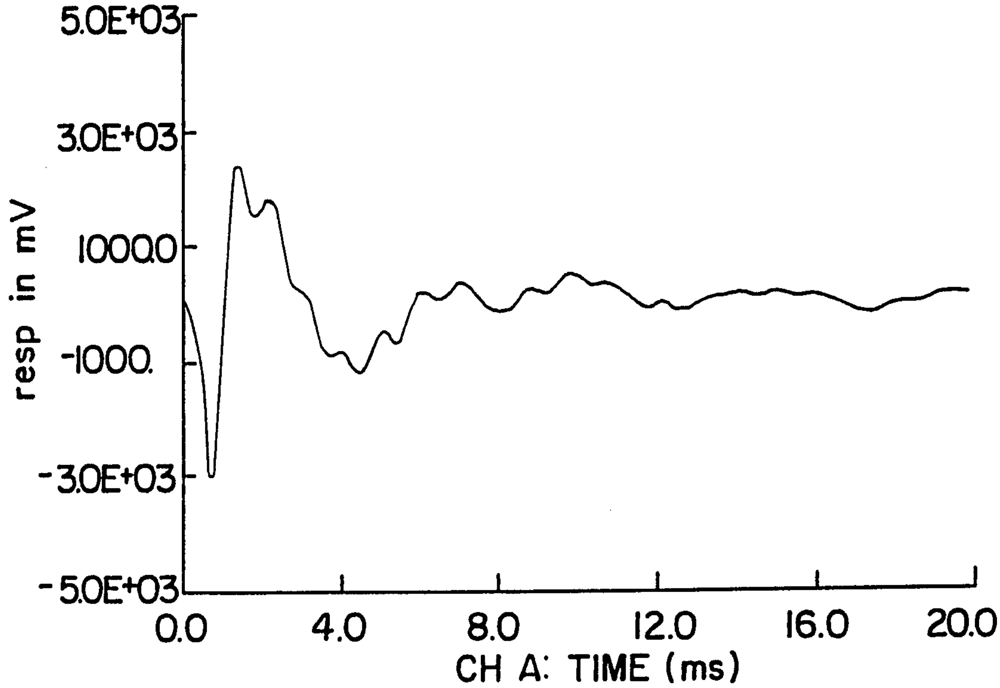

5.0E+03
3.0E+03
1000.0
-1000.
-3.0E+03
-5.0E+03
resp in mV
0.0
4.0
8.0
12.0
16.0
20.0
CH A: TIME (ms)

FIG. 21

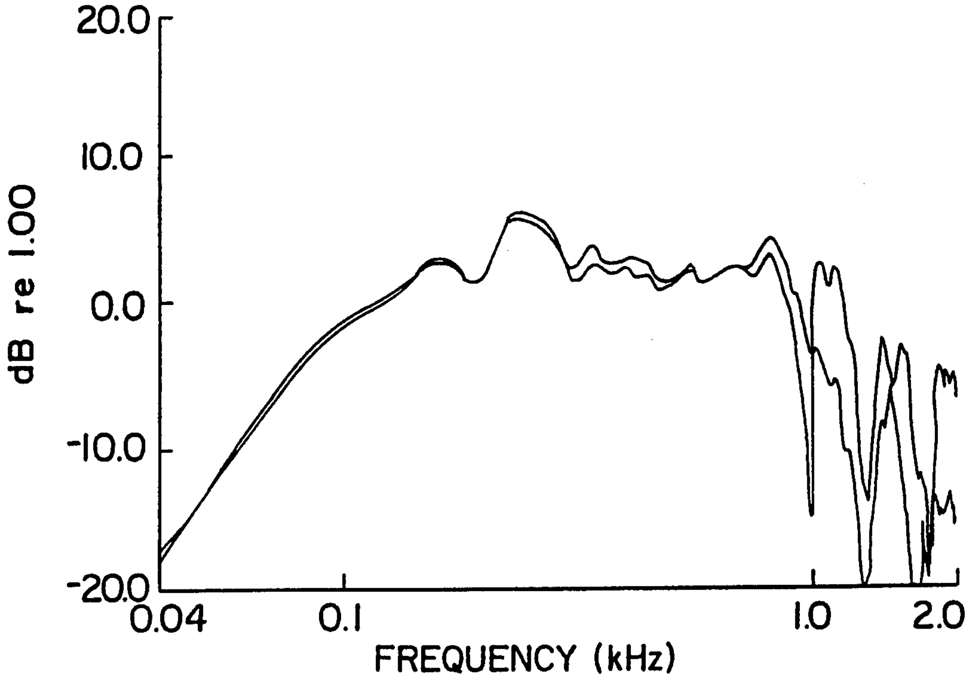

20.0
10.0
0.0
-10.0
-20.0
dB re 1.00
0.04
0.1
1.0
2.0
FREQUENCY (kHz)

FIG. 22

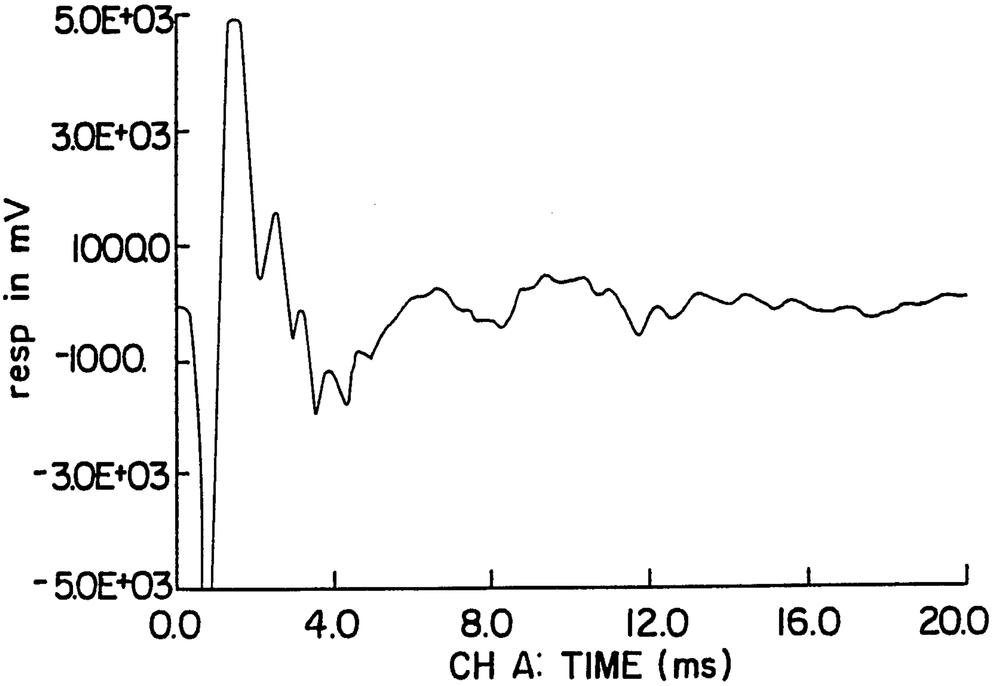

5.0E+03
3.0E+03
1000.0
-1000.
-3.0E+03
-5.0E+03
resp in mV
0.0
4.0
8.0
12.0
16.0
20.0
CH A: TIME (ms)

FIG. 23

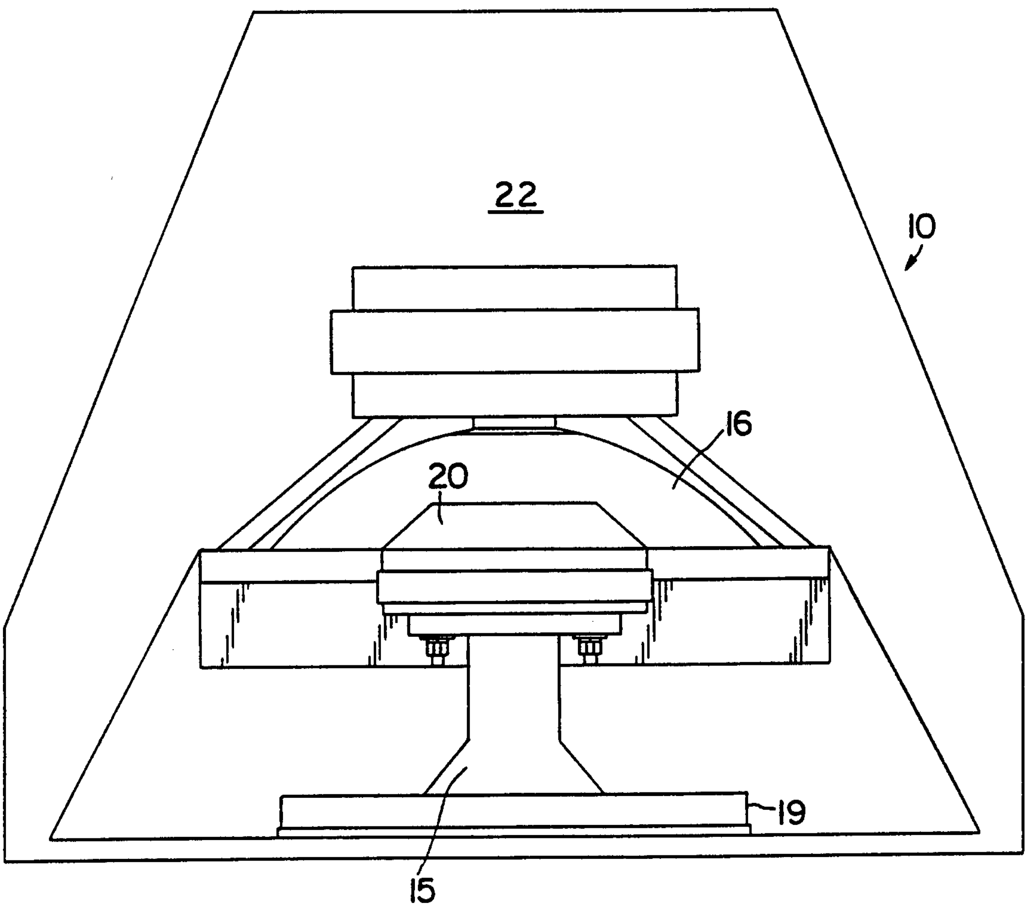

22
10
16
20
19
15

FIG. 24

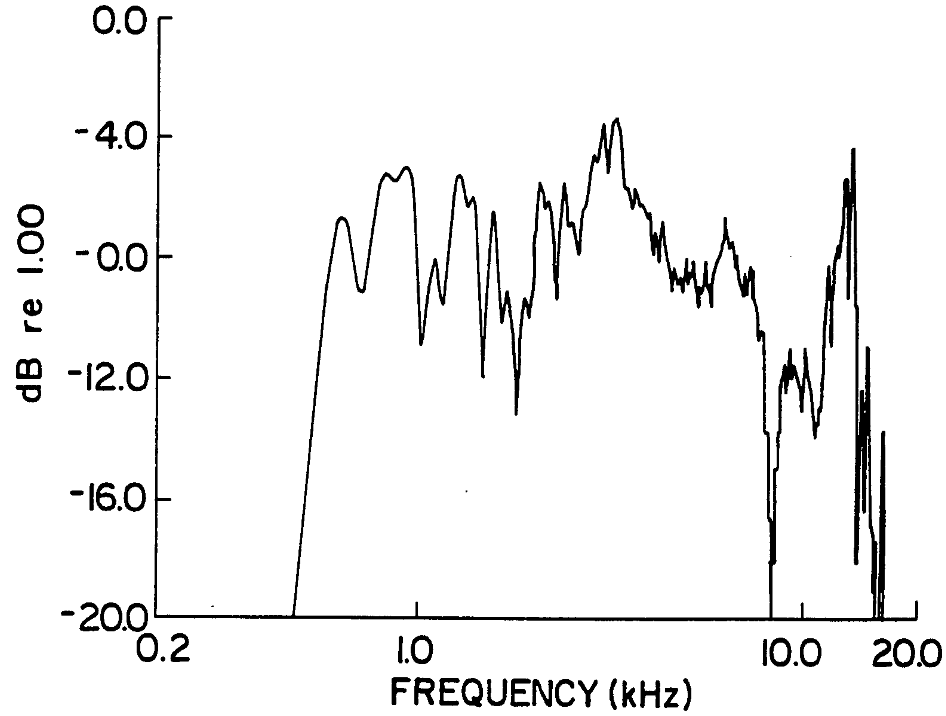

0.0
-4.0
-0.0
-12.0
-16.0
-20.0
dB re 1.00
0.2
1.0
10.0
20.0
FREQUENCY (kHz)

FIG. 25

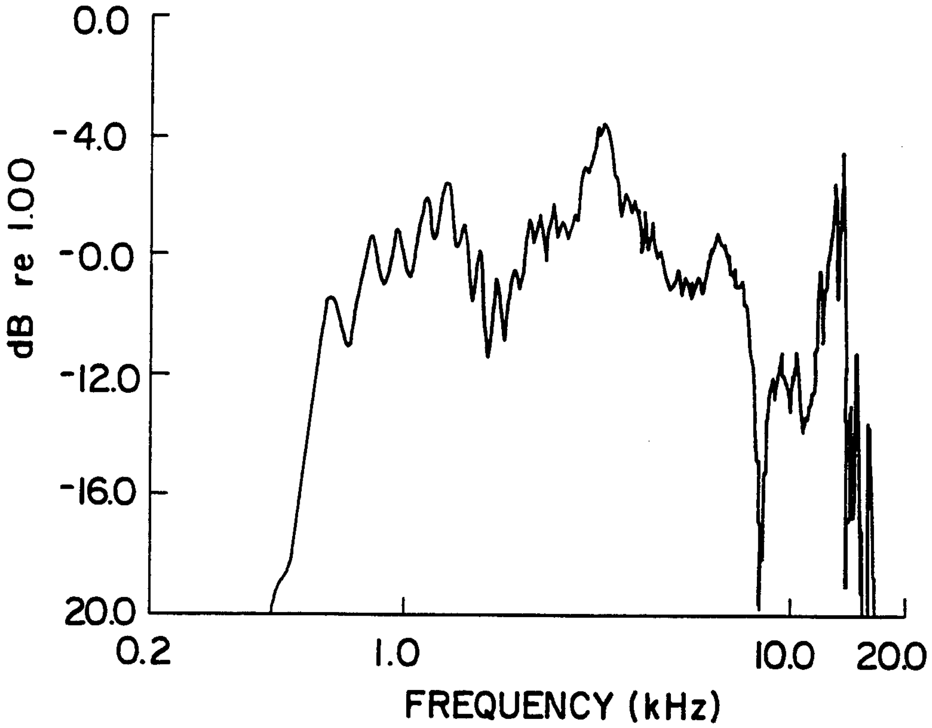

0.0
-4.0
-0.0
-12.0
-16.0
20.0
dB re 1.00
0.2
1.0
10.0
20.0
FREQUENCY (kHz)

FIG. 26

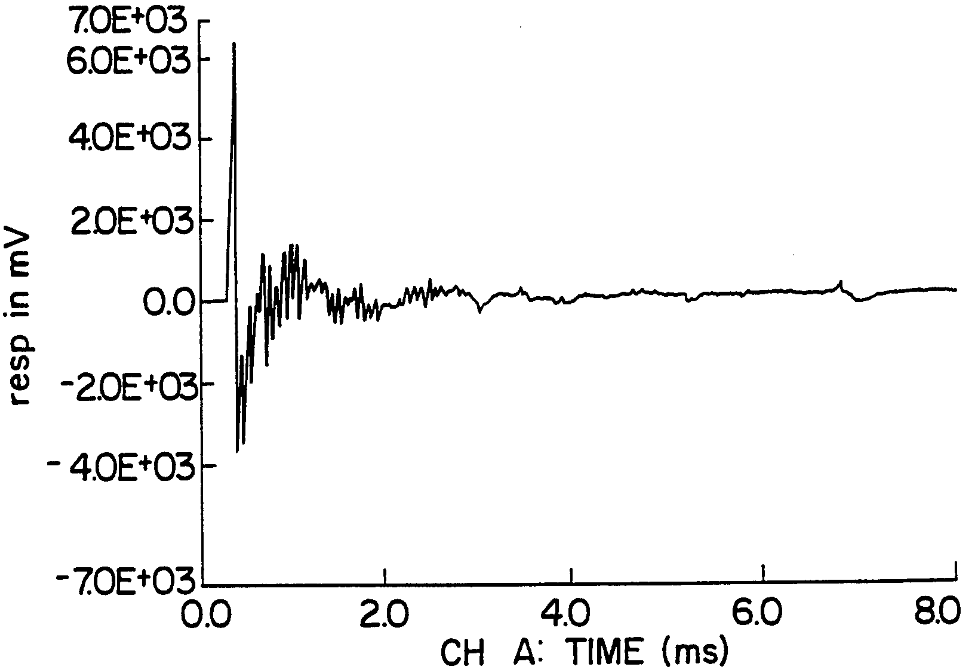

7.0E+03
6.0E+03
4.0E+03
2.0E+03
0.0
-2.0E+03
-4.0E+03
-7.0E+03
resp in mV
0.0
2.0
4.0
6.0
8.0
CH A: TIME (ms)

FIG.27

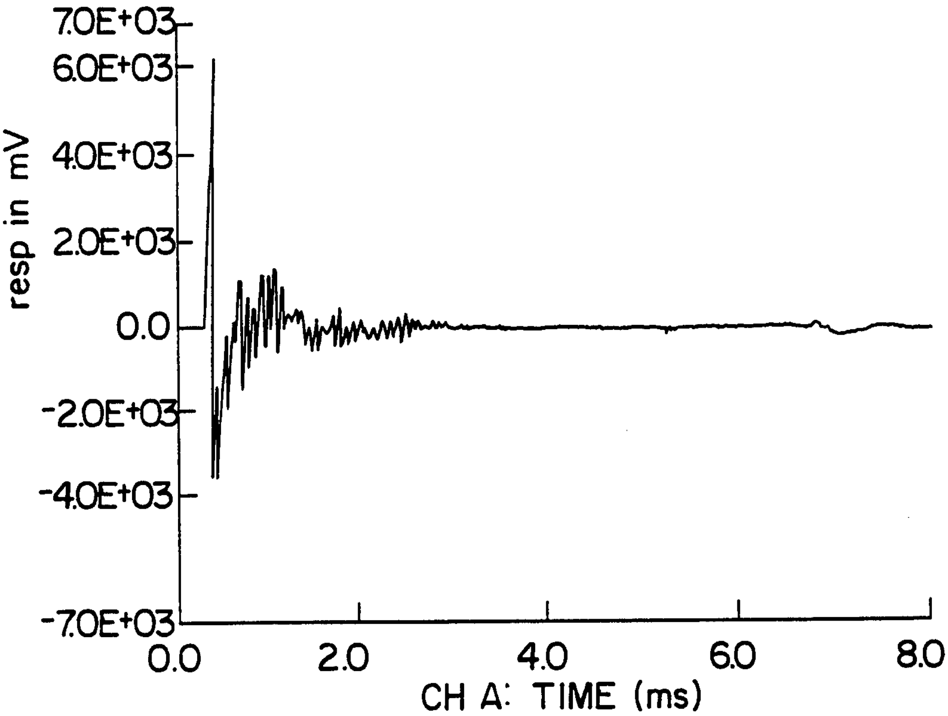

7.0E+03
6.0E+03
4.0E+03
2.0E+03
0.0
-2.0E+03
-4.0E+03
-7.0E+03
resp in mV
0.0
2.0
4.0
6.0
8.0
CH A: TIME (ms)

FIG.28

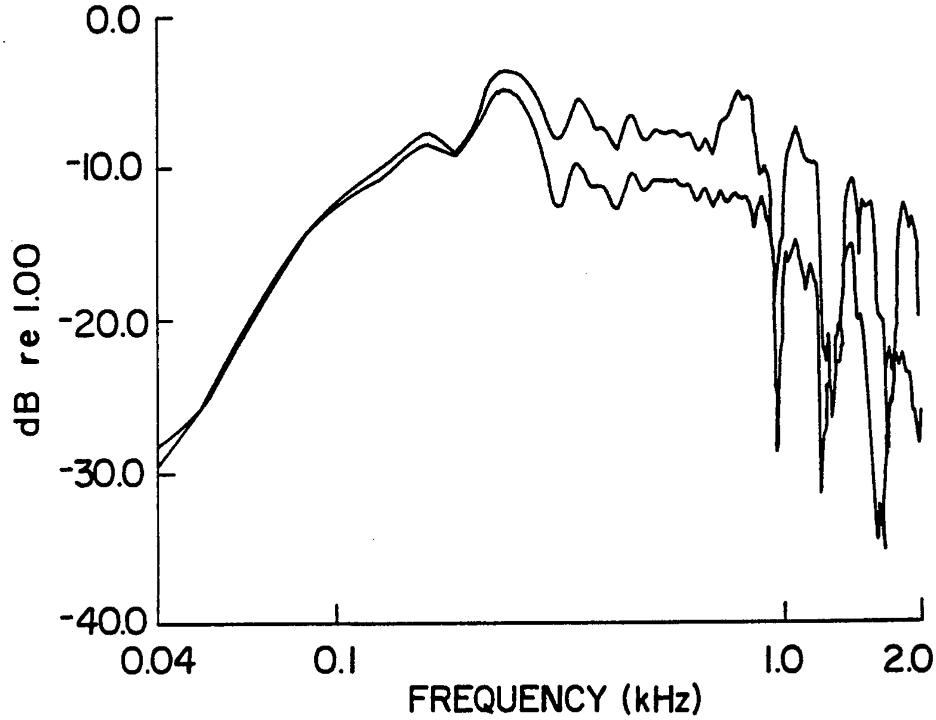

0.0
-10.0
-20.0
-30.0
-40.0
dB re 1.00
0.04
0.1
1.0
2.0
FREQUENCY (kHz)

FIG. 29

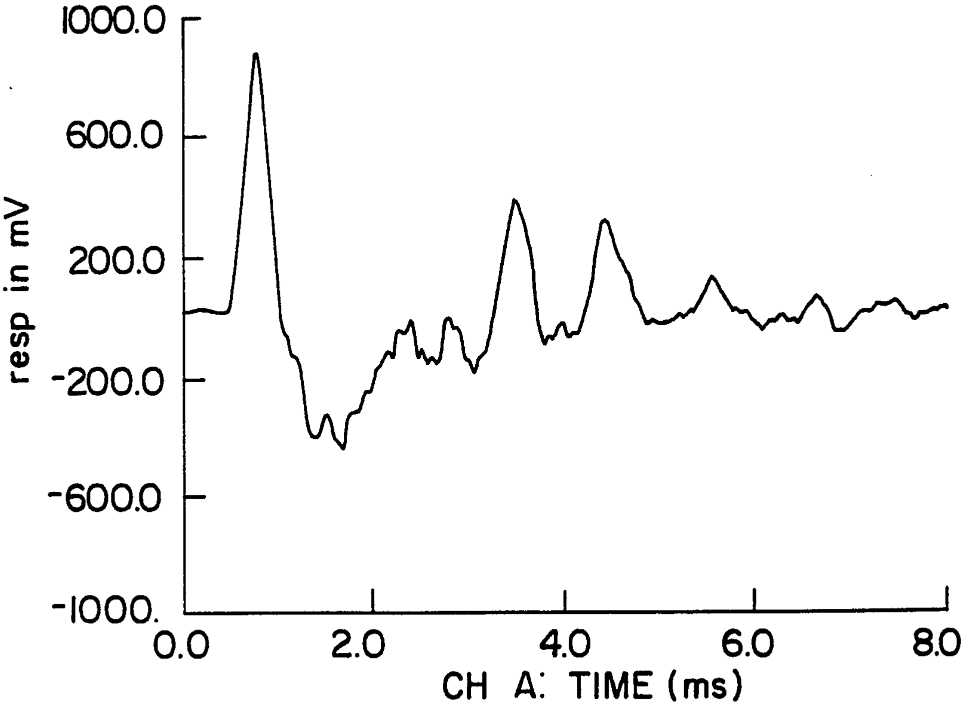

1000.0
600.0
200.0
-200.0
-600.0
-1000.
resp in mV
0.0
2.0
4.0
6.0
8.0
CH A: TIME (ms)

FIG. 30

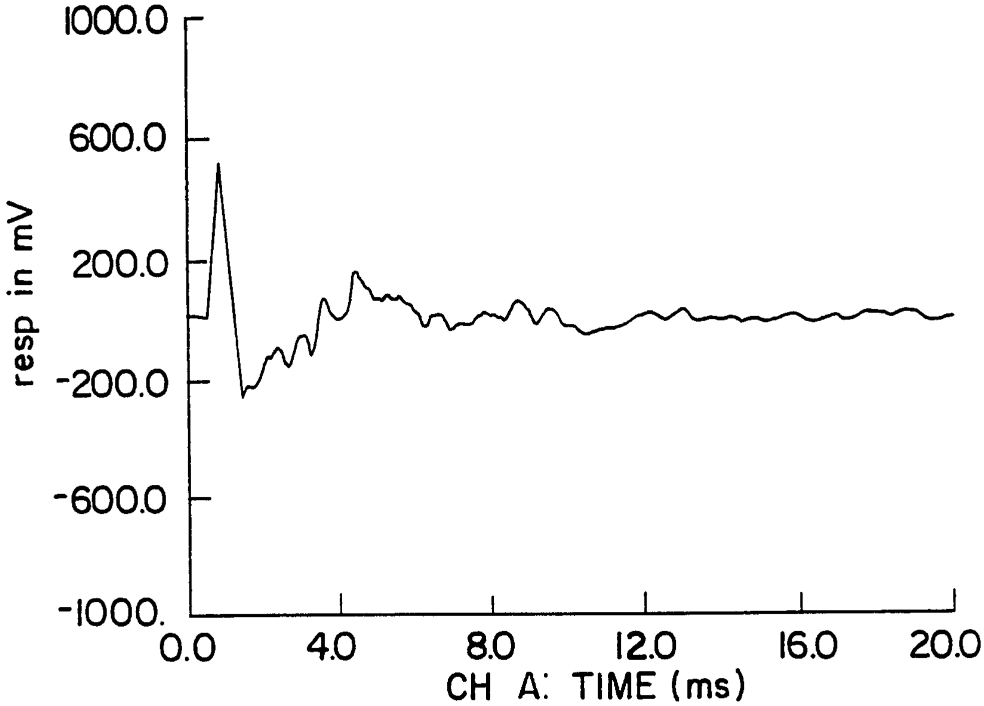

1000.0
600.0
200.0
-200.0
-600.0
-1000.
resp in mV
0.0
4.0
8.0
12.0
16.0
20.0
CH A: TIME (ms)

FIG. 31

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/10976

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :H04R 25/00; H05K 5/00
US CL :381/182, 199, 158; 181/144
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 381/182, 194, 199, 158, 156, 146; 181/144, 147

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---- Y	US, A, 4,554,414 (HOUSE) 19 November 1985, see Fig. 1, column 3, line 42.	1-5, 7-10, 20 ----------- 6
Y	US, A, 4,283,606 (BUCK) 11 August 1981.	6
X	JP, A, 61-247196, (MASANOBU), 04 November 1986, see Figs. 1-2.	20
X ---- Y	US, A, 3,155,774 (HOWELL) 03 August 1961, see Figs. 1-2.	1-10 ---------- 11-19
Y	US, A, 5,109,423 (JACOBSON et al) 28 April 1992, see Figs. 1-6.	11-19

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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"A" document defining the general state of the art which is not considered to be part of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 JANUARY 1995	06 MAR 1995

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/10976

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP, A, 5-137188 (SANGO) 01 June 1993, see Fig. 1.	20