

- [54] METHOD FOR ADJUSTING THE
RESONANT FREQUENCY AND MOTIONAL
ELECTRICAL IMPEDANCE OF A
VIBRATING DIAPHRAGM
ELECTROACOUSTIC TRANSDUCER**

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Related U.S. Application Data

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- [51] **Int. Cl.**..... **H04r 17/00**

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324/56; 179/110 A, 115 R, 115.5 ES

- [56]
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Primary Examiner—J. D. Miller

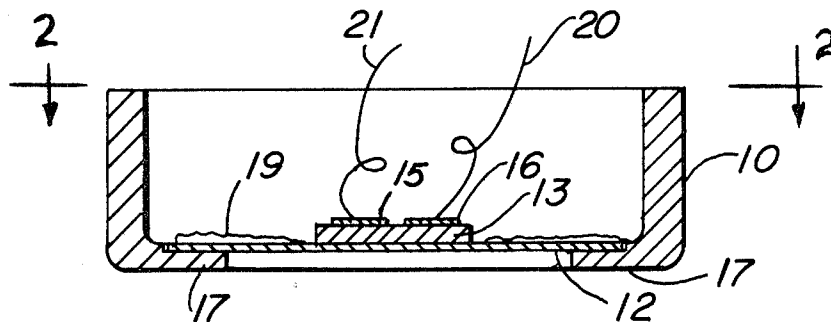
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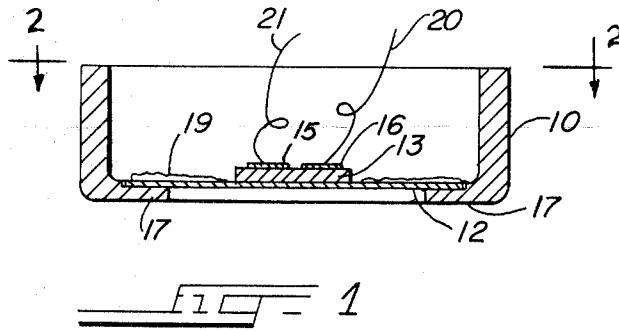
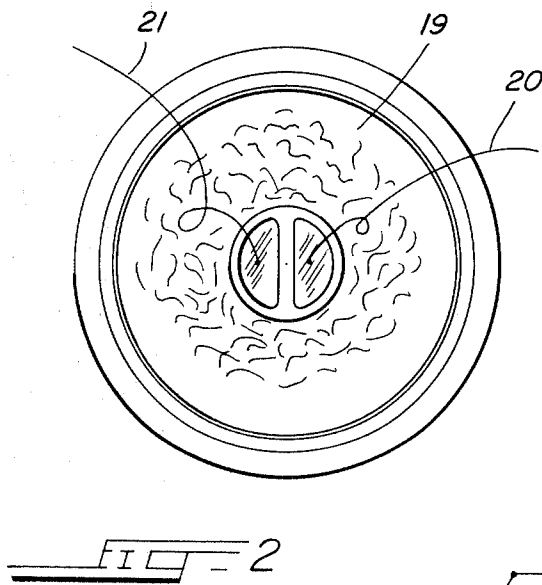
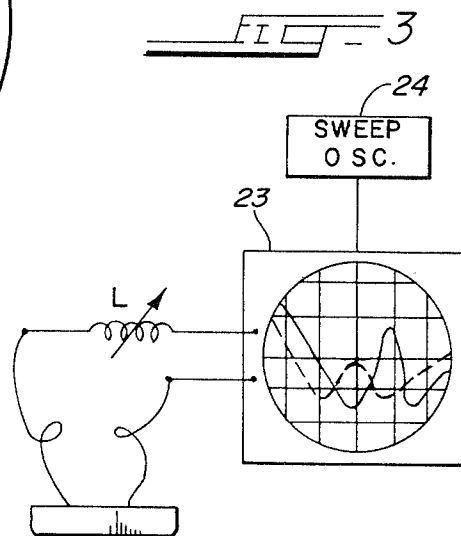
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[57] **ABSTRACT**

An operator applies a viscous paste over the surface of a clamped diaphragm in a transducer operating in a flexural resonant mode. The operator literally "paints on" the desired resonant frequency and impedance characteristic of the transducer. These characteristics are continuously monitored, on a suitable meter, while the operator is applying the paste.

7 Claims, 3 Drawing Figures





METHOD FOR ADJUSTING THE RESONANT FREQUENCY AND MOTIONAL ELECTRICAL IMPEDANCE OF A VIBRATING DIAPHRAGM ELECTROACOUSTIC TRANSDUCER

This is a division of application Ser. No. 79,219, filed Oct. 8, 1970.

This invention relates to electroacoustic transducers and more particularly to transducers of the vibratile diaphragm type. Reference is made to a co-pending application Ser. No. 10,748, filed Feb. 12, 1970, now U.S. Pat. No. 3,638,052, issued Jan. 25, 1972, by Frank Massa, entitled "ELECTROACOUSTIC TRANSDUCERS OF THE BILAMINAR FLEXURAL VIBRATING TYPE," and assigned to the same assignee as this invention. The co-pending application shows a similar transducer.

This invention applies to transducers which employ a clamped vibratile diaphragm driven in a flexural resonant mode of vibration. This type of transducer may be operated at either its fundamental resonance or in an overtone mode. When manufacturing large quantities of this type of transducer, it is difficult to control the tolerances of the elements which form the vibrating system. Usually, excessive costs are required to achieve a high degree of uniformity in the transducer frequency response and impedance characteristics.

Accordingly, an object of this invention is to provide transducers of the flexural diaphragm type which achieve a high degree of uniformity in performance characteristics, at very low cost. In this connection, an object is to provide transducers which can be manufactured in large quantities and at low cost, and with acceptable tolerances.

Another object of this invention is to compensate for normally occurring variations in diaphragm dimensional tolerances and variations in assembly tolerances.

A still further object of this invention is to provide low-cost transducers for mass production fabrication, which achieve very accurately controlled uniformity in performance characteristics.

Another object of this invention is to provide a method for adjusting the resonant frequency and impedance of a transducer of the vibratile diaphragm type.

In keeping with one aspect of this invention, these and other objects are accomplished by providing a vibratile disc driven by a piezoelectric transducer. The disc vibrates at its desired mode of vibration. The frequency of this mode is then adjusted to the desired value by brushing a quantity of viscous paste onto the surface of the disc. By further distributing the material over the surface, the impedance of the transducer is brought to a desired value.

These and other objects, features, and advantages of the invention will become more apparent from a study of the following description of an illustrative embodiment of the invention when taken in conjunction with the following accompanying drawings, in which:

FIG. 1 is a cross-sectional view of the vibratile diaphragm portion and housing structure of a transducer assembly incorporating one illustrative embodiment of this invention;

FIG. 2 is a plan view of the structure shown in FIG. 1 and taken along the line 2—2 thereof; and

FIG. 3 is a schematic diagram illustrating the method of making a final adjustment of the resonant frequency

and impedance characteristic of the transducer during mass production thereof.

The inventive transducer comprises a ring clamp 10, diaphragm 12, and piezoelectric disc transducer 13. The diaphragm 12 acts as a clamped vibratile disc. The piezoelectric disc 13 acts in its simple flexural mode, driven by a pair of electrodes 15, 16.

More particularly, the reference character 10 identifies a rigid, somewhat cup-shaped, housing structure having an upstanding annular wall with an inwardly turned ledge 17 at the bottom thereof. Rigidly attached to the ledge 17 is the circular diaphragm 12 which may be bonded thereto at its periphery, by epoxy or any other suitable means. A polarized piezoelectric ceramic disc 13 is bonded to the inside center of the diaphragm 12, by any suitable rigid cement, such as epoxy. The disc 12 is here shown as being less than one-half the diaphragm area.

This invention may be applied to virtually any type of diaphragm assembly, such as the assemblies illustrated in the above-mentioned co-pending application, for example. However, the invention is equally applicable to frequency control of a diaphragm, whether the diaphragm is or is not clamped at its periphery. The ceramic disc 13 supports the split electrodes 15 and 16 which have electrical conductors 20 and 21 connected thereto. The polarization of the disc and the advantages of the split electrode construction are explained in U.S. Pat. No. 2,967,957.

The diaphragm and ceramic disc dimensions are selected to suit the desired band of frequency operations. More particularly, during manufacture the thickness tolerances of the diaphragm material are deliberately set on the high side. Therefore, any production variations cause the resonant frequency of the transducers to fall out entirely on the high side of the desired limit.

According to the invention, the high frequency elements are brought down to the desired resonance frequency by adding a film of vibrational lossy or rubbery material 19 to the surface of the vibratile diaphragm disc after assembly of the transducers. A suitable material for this application is silicone rubber, which vulcanizes at room temperature. One example of such a material is a product currently sold by Dow Corning, under the trademark "SILASTIC." This silicone rubber material may be painted on with a brush and distributed over the surface of the diaphragm, as required to achieve the desired value of resonance frequency and impedance. The reduction in resonant frequency is determined by the amount of the material which is applied to the diaphragm. The distribution of the material introduces a magnitude of mechanical resistance which, in turn, adjusts the magnitude of the electrical impedance of the transducer.

Other forms of lossy material include discrete layers of material, such as a film with a pressure sensitive adhesive. Also, the material may be added by other means, such as a low melting point solder-like material.

FIG. 3 illustrates a method for monitoring the final adjustment of resonance frequency and impedance. This adjustment requires only a few seconds on the part of a trained operator. More particularly, to adjust an individual transducer to a precise manufacturing tolerance, the transducer is connected in a series circuit including a variable inductance L and the input terminals of an impedance measuring instrument 23. The instrument 23 displays the impedance of the transducer on

the vertical scale of an oscilloscope tube, as the frequency range is swept along the horizontal scale under the control of a signal generated by the sweep oscillator 24. A graphical representation which is typical of the pattern obtained on the oscilloscope is illustrated by the solid line.

The procedure for adjusting the transducer characteristics is as follows:

1. Adjust the inductance L to obtain a unity power factor, which is achieved when the height of the peak on the solid curve becomes minimum.
2. Apply damping material 19 to the surface of diaphragm 12. Brush on the material to move the peak down in frequency to the desired value, as illustrated by the dotted curve.
3. Distribute the material 19 over the diaphragm surface to vary the mechanical damping until the height of the peak on the dotted curve is decreased to a specified magnitude. In FIG. 3, the desired impedance is illustrated as the center horizontal line on the oscilloscope screen. The center vertical line represents the desired resonance frequency value for the transducer.

Thus, I have shown an exemplary transducer design employing a vibratile diaphragm element which can be very simply and economically manufactured in large quantities. There is an accurately controlled response and impedance characteristic.

The type of vibratile structure described above was selected to illustrate the basic principles of my invention. The invention itself is the method of achieving high precision, low-cost control over uniformity of characteristics during manufacturing. Those skilled in the art will readily perceive how to apply the teachings of my invention to other types of vibratile diaphragm structures. For example, these diaphragms may be circular, square, clamped edge, or free edge. Also, the invention applies to other types of flexural vibrating transducer structures, such as reed surfaces. Therefore, it should be understood that various modifications may be made without departing from the true spirit and scope of the invention, and the claims are to be construed to cover all equivalent structures.

I claim:

1. A method of manufacture for adjusting the resonance frequency of an electroacoustic transducer which includes a vibratile diaphragm, said frequency adjusting method including the steps of:

- a. applying of a non-uniform layer of liquid for forming a thin film of flexible, vibrational lossy material over at least a selected portion of the surface of said vibratile diaphragm,
- b. observing said diaphragm in a dynamic state while said liquid is being applied to said diaphragm, said selected portions being individually determined for each individual transducer responsive to the observations, and
- c. distributing material over the surface of the diaphragm until the desired resonance frequency is obtained, and
- d. drying said liquid to provide said film in the form selected in step (b).

2. The method of manufacture set forth in claim 1 wherein the distribution of said non-uniform layer is selected for adjusting the electrical impedance of the electroacoustic transducer which includes said vibratile diaphragm, said adjusting method including the appli-

cation of said thin film of vibrational lossy material to at least a circular portion of the surface of said vibratile diaphragm.

3. The method of manufacture set forth in claim 1 wherein the distribution of said non-uniform layer is selected for adjusting both the resonance frequency and the electrical impedance of the electroacoustic transducer which includes said vibratile diaphragm, said adjusting means including a thin film of rubbery material attached to at least a circular portion of the surface of said vibratile diaphragm.

4. A method of lowering the resonant frequency of an electroacoustic transducer which includes a vibratile diaphragm, said method including the following steps:

1. measuring the resonant frequency of the transducer;
2. selectively adding a thin layer of flexible vibrational lossy material to at least a circular portion of a surface of the diaphragm radially disposed about and away from the center thereof; and
3. locally and non-uniformly adjusting the amounts of said added material until the resonant frequency measures the desired value.

5. A method of adjusting the magnitude of the motional electrical impedance of an electroacoustic transducer which includes a vibratile diaphragm, said method including the following steps:

1. measuring the impedance of the transducer at the desired frequency of operation;
2. selectively adding a thin non-uniform layer of flexible material over a substantial portion of said diaphragm, said material having a high impedance to mechanical motion and being selectively located on at least those portions of the surface of the diaphragm which vibrates at higher amplitudes; and
3. distributing the material over the diaphragm surface until the desired magnitude of impedance is measured.

6. A manufacturing method of adjusting the resonant frequency and electrical impedance of an electroacoustic transducer comprising a vibratile diaphragm driven by a polarized ceramic element, said method including:

1. The generation of a variable frequency signal for driving said transducer;
2. the adjustment of a variable inductance connected in series with said transducer and variable frequency signal generator;
3. connecting a motional impedance indicating meter across said transducer and series variable inductance;
4. adjusting said variable inductor until the meter indicates that the impedance magnitude at the resonance peak value is a minimum;
5. applying a thin film of material with a vibrational loss characteristic to at least a portion of the surface of the diaphragm and adjusting the amount of said applied material to move the resonance to a desired frequency; and
6. spreading the film of said material to specific regions of the diaphragm surface until the magnitude of the motional impedance at the resonance peak value is adjusted to the desired value.

7. A method for adjusting the resonance frequency and the motional impedance of an electroacoustic transducer of the vibratile diaphragm type including the following steps:

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- 1. connecting the electrical terminals of the transducer to an impedance measuring instrument, which instrument displays impedance magnitude along a first coordinate axis and frequency along a different coordinate axis;
- 2. connecting a variable frequency oscillator to supply a varying frequency electrical signal to the transducer;
- 3. observing the two dimensional graphical display of impedance versus frequency on said impedance measuring instrument;

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- 4. distributing a controlled non uniform layer of soft and flexible adhesive material over a substantial portion of the surface of said transducer; and
- 5. selectively varying the local amount and distribution pattern of said adhesive material in a random manner until the observed impedance versus frequency characteristic indicates the desired resonance frequency and desired impedance magnitude.

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