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71 Applicant: **Carver Corporation**
20121 48th Avenue W.
Lynnwood, WA 98036(US)

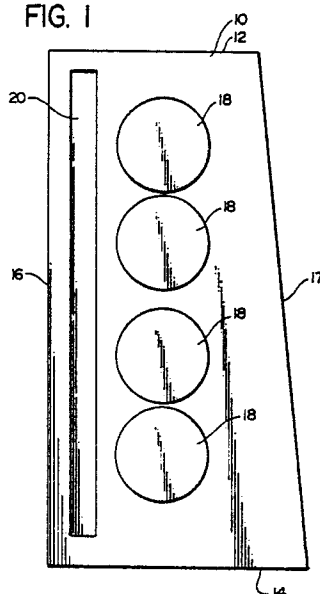
72 Inventor: **Carver, Robert W.**
330 Avenue A
Snohomish, WA 98290(US)
Inventor: **Croft, James J.**
911 N. 68th Street
Seattle, WA 98103(US)

74 Representative: **Schumann, Bernard Herman**
Johan et al
OCTROOIBUREAU ARNOLD & SIEDSMA
Sweelinckplein 1
NL-2517 GK The Hague(NL)

54 **Loudspeaker apparatus and method.**

57 An open-back baffle loudspeaker having a higher baffle cut-off frequency and a lower resonant frequency of possibly 25-50Hz. The loudspeaker is made with a relatively high "Q" (e.g., between 2 to 4) so that the effect of the "Q" on amplitude counteracts the effect of baffle roll-off, thus causing the amplitude of the output of the loudspeaker to remain substantially constant from the baffle cut-off frequency to the resonant frequency. The result is a loudspeaker which can more faithfully reproduce relatively low frequency sounds.

FIG. 1



LOUDSPEAKER APPARATUS AND METHOD

Background of the InventionField of the Invention

5

The present invention relates to an open-back baffle type loudspeaker, and more particularly to such a speaker that is particularly effective in reproducing low frequency sound.

10 Background Art

In a loudspeaker of the open-back baffle type (sometimes called a dipole speaker), the baffle itself is a planar plate-like member, having the speaker itself mounted in the baffle. Since the forward face and the rear face of the baffle are open, the diaphragm which oscillates to create the sound not only creates forward
15 traveling sound waves, but also 180° out-of-phase sound waves which emanate rearwardly from the diaphragm.

If the baffle were infinitely large, then it would shield the forwardly traveling sound waves from those which are emitted rearwardly from the diaphragm. However, for practical reasons, the planar area of the baffle must be maintained within reasonable dimensions. This results in a phenomenon called low
20 frequency cut-off or low frequency roll-off. It is to be recognized that the out-of-phase sound which travels rearwardly from the speaker also travels laterally and around the edge of the baffle and forwardly to create what can be an interfering wave pattern. At the higher frequencies, this is not a significant problem, but at lower frequencies, there is created an interference pattern where the sound emanated from the rear of the speaker tends to cancel out the low frequency sound which is emitted forwardly from the front of the
25 loudspeaker.

This is discussed in an article entitled "Dipole Radiator Systems", authored by R. J. Newman, this article being printed in the Journal of The Audio Engineering Society, January and February of 1980, Volume 28, Nos. I/II. This article points out that when the average baffle dimension (i.e., the average of the dimensions measured from edge to edge of the baffle) is at or less than one half of the wavelength of the
30 sound, the front to back cancellation of the driver output begins to occur. At the cut-off frequency, the amplitude of the output begins to drop at a rate of approximately 6 decibels for each octave reduction in frequency until the resonant frequency of the speaker is reached. Thereafter, as the frequency drops lower, the reduction in amplitude is 18 decibels for each octave that the frequency is reduced.

The result is that quite commonly dipole loudspeaker systems are rather poor in producing the low
35 frequencies of the audio signal. In the above-noted article authored by Mr. Newman, there is a suggestion that the signal itself can be strengthened in the lower frequency range relative to the higher frequencies to compensate for this low frequency roll-off or cut-off by adding a separate active equalization system.

40 Summary of the Invention

It is an object of the present invention to provide a loudspeaker system and method of the open-back baffle type which is particularly adapted to properly produce a sound in the low frequency range (e.g., as low as 25Hz or possibly lower).

45 The loudspeaker assembly comprises a generally planar open-backed baffle having a predetermined planar area and crosswise dimensions, and providing a speaker area located in the baffle. A diaphragm means is moveably mounted at the speaker area. The diaphragm means is mounted to the baffle by a resilient mounting means in a manner to locate the diaphragm means at an intermediate location and permit fore and aft movement from the intermediate location while yielding the resisting such movement.

50 There is a motor means to drive the diaphragm on its fore and aft movement, the motor means comprising a magnet means to create a magnetic field and a voice coil means positioned in the magnetic field. The magnet means and the voice coil means are mounted so as to be moveable relative to one another. One of the magnet means and the voice coil means is connected to the diaphragm so as to be moveable therewith, and the other of the magnet and voice coil means is connected to the baffle.

The assembly has a predetermined baffle cut-off frequency of a first frequency value, such that the

assembly is characterised to produce a roll-off effect such that amplitude of the speaker output is diminished as a function of frequency diminishing from the value of said cut-off frequency.

The assembly has a resonant frequency of a second value lower than the first frequency value. The assembly has a predetermined "Q" factor of a value such to produce a "Q" effect such that the assembly is characterised in that amplitude of the speaker output is increased as a function of frequency diminishing toward the value of the resonant frequency.

The assembly is further characterised in that the "Q" factor effect substantially offsets the roll-off effect to provide an output having an amplitude response within a predetermined amplitude range from cut-off frequency to resonant frequency.

In the preferred form, the voice coil means is connected to the diaphragm means and the magnet means is connected to the baffle. Desirably, the "Q" factor of the assembly is as least as great as about 2, and other forms at least as great as about 3. The preferred range of the "Q" factor is between 2 to 4.

In further embodiment, the assembly comprises a plurality of speaker units, each of which comprises a related diaphragm means, a related mounting means, and a related motor means. At least a first one of the units has a "Q" factor of a lower value, and at least a second of said units as a "Q" factor of a higher value. More specifically, the second unit has a resonant frequency of a lower value, and a first unit has a resonant frequency of a higher value.

The diaphragm means has a predetermined diaphragm area, and the assembly has a moving mass comprising the diaphragm means and components of the assembly that move therewith. The assembly is characterised in that the ratio of the diaphragm area, expressed in square inches, to the mass of the moving mass, express in grams, is at least 2 to 1. Desirably, this ratio is at least 4 to 1, or possibly greater.

In the present embodiments, the resonant frequency is at least as low as about 50Hz, an in another embodiment at least as low as 25Hz.

In the method of the present invention, a loudspeaker assembly is provided as indicated above. Then the baffle cut-off, the "Q" factor and the resonant frequency are selected, so that in operating the speaker, the "Q" factor effect substantially offsets the roll-off effect to produce the desired amplitude response.

Other features of the present invention will become apparent from the following detailed description.

30 Brief Description of the Drawing

Figure 1 is a front elevational view of a speaker assembly incorporating teachings of the present invention;

Figure 2 is a side elevational view thereof;

35 Figure 3 is a sectional view of a woofer of the present invention, with the section taken through a longitudinal center line of the woofer;

Figure 4 is a secitonal view of only the motor of the woofer in Figure 3;

Figure 5 is a graph plotting amplitude against frequency and illustrating the effect of various "Q" values on amplitude as a function of frequency;

40 Figure 6 is a graph similar to Figure 5, but illustrating the effect of baffle cut-off or roll-off;

Figure 7 is a graph illustrating the operating characteristics of one embodiment of the present invention, where the "Q" = 4, the cut-off frequency equals 100Hz and the resonant frequency equals 25Hz;

Figure 8 illustrates the operating characteristics of a second embodiment, where the "Q" = 2, the baffle cut-off frequency equals 100Hz and the resonant frequency equals 50Hz;

45 Figure 9 is a graph similar to Figures 7 and 8, showing yet a third embodiment, where four woofers are provided, having different "Q" characteristics;

Figure 10 is a simplified circuit diagram of one type of shaping circuit; and,

Figure 11 is a circuit diagram of a second type of shaping circuit.

50 Description of the Embodiments

The substance of the present invention is that the operating characteristics of certain speaker components that in and of themselves already exist in the prior art are selected and combined in such a way as to provide a loudspeaker system and method with exceptional capability of reproducing low frequency sounds. It is believed that a clearer understanding of the present invention will be obtained by first describing the physical makeup of the speaker, and then discussing the selected operational characteristics of the same and how these interact to provide the unique benefits of the present invention.

In Figures 1 and 2, there is shown a dipole speaker system having a planar baffle 10 having upper and lower edges 12 and 14, and two side edges 16 and 18. Four woofers 18 are mounted to the baffle 10 in a vertical array at approximately the vertical center line of the baffle plate 10. A mid and high frequency speaker component 20 is also mounted to the baffle 10 adjacent to the edge 16, and this component 20 can be of prior art construction if desired.

To describe the construction of each of the woofers 18, reference is now made to Figures 3 and 4. Figure 3 is a sectional view taken substantially through the forward to rear center axis 19 of the woofer 18. In general, the components of the woofer 18 are symmetrical about this center axis. The main components of the woofer 18 are a cone or diaphragm 20 which oscillates to produce the actual sound; a yielding and resilient cone mounting structure which in this embodiment comprises an annular surround 22 and an annular spider 24; a motor 26 (made up of a fixed magnet 28 and a voice coil 30; and a mounting member 32).

As a preliminary comment, it should be pointed out that each of these components 20-32 are in and of themselves known in the prior art, and the physical arrangement of these components as illustrated in Figures 3 and 4 also is known in the prior art. However, the selection and combination of the components with certain operating characteristics is unique in the present invention.

The diaphragm or cone 20 has, as shown herein, the configuration of a truncated cone, having a forward circular edge 34 connected to the surround 22. The surround 22 is an annular member, whose inner edge is connected to the cone front edge 34, and whose outer edge 36 is connected to an outer forward flange 37 of the mounting member 32. The surround 22 is, in a section line taken perpendicular to a peripheral center line, of a curved or corrugated configuration, and it is made of a resilient yielding material.

The spider 24 is an annular member which, in a section taken perpendicular to a peripheral center line of the spider 24, of a corrugated configuration. This spider 24 is also made of a yielding resilient material, with the outer circumferential edge 38 of the spider being connected to the mounted member 32, and the inner circular edge 40 of the spider 24 being connected to the rear edge of the cone 20. The surround 22 and the spider 24 collectively provide the resilient mounting for the cone 20. These components 22 and 24 holds the cone or diaphragm 20 in an intermediate position, but will resiliently deflect both forwardly and rearwardly to permit the cone 20 to oscillate so as to produce the sound output, with the surround 22 and the spider 24 acting to restore or urge the cone 20 toward its middle position.

The magnet 28 of the motor 26 has an outer annular portion 42 and an inner cylindrical portion 44 which are positioned relative to one another to form an annular gap 46. This magnet 26 can conveniently be made as two components, where the cylindrical portion 44 is formed integrally with a back plate 48 that is in turn attached to the outer annular portion 42.

The voice coil 30 comprises a hollow cylindrical member 50 made of plastic or aluminum, and a coil 52 is wound around the cylinder 50. The forward edge of the cylinder 50 is connected to the rear central circular edge of the cone or diaphragm 20. The voice coil 30 is positioned in the annular gap 46.

The basic operation of the woofer 18 is well known in the prior art. The amplified audio signal is directed to the voice coil 30 so that it interacts with the field created by the magnet 28 so as to cause movement of the voice coil 30, and hence movement of the cone 20, thus producing the sound output.

With the basic physical components of the woofer 10 and the overall speaker assembly having been described, let us now turn our attention to some of the operating components of such a speaker system.

In Figure 5, there is shown a graph illustrating various "Q" curves, where amplitude is plotted against frequency. The term "Q" can be described as a damping coefficient, and the value of "Q" has an inverse relationship to its damping ability. In other words, with a high "Q" factor, there is less damping of the movement of the cone 20 and voice coil 30, while at lower values, there is greater damping. In general, the "Q" is inversely related to the strength of the magnet 28 of the motor 26. (The method of ascertaining "Q" is already well known in the prior art, and this is described in a catalog entitled Loudspeaker Systems Design authored by Mr. James C. Carroll of EMS Incorporated, Knoxville, Tennessee, bearing a copyright notice of 1978. This article is being submitted with this application as part of the prior art statement. In that particular article the term "Q" is designated "Q_T".)

In general, it is the common practice in designing open-back baffle speakers to keep the "Q" factor at a value of about 0.7 to 1.0. The reason for this is that with such a "Q" value, at frequencies down to the resonant frequency of the speaker system, the effect of "Q" is that it will tend to keep the amplitude substantially constant, thus providing a more faithful reproduction of the audio signal. If the "Q" is made too low (i.e., "Q" = 0.2), then the amplitude begins to drop off before reaching resonance frequency. On the other hand, if the "Q" is made higher ("Q" = 2 or "Q" = 4), then the amplitude tends to rise as the resonant frequency is approached. Further, as the "Q" reaches a level as high as, for example, 4, the rise in amplitude is somewhat more complex, in that the amplitude begins to rise rather sharply at a frequency

closer to the resonant frequency. For these reasons, to the best knowledge of the Applicant, incorporating a "Q" factor much above 1.0 is avoided in the prior art.

Let us proceed now to an examination of how the various operating characteristics of an open-back baffle loudspeaker system (including the "Q" factor) relate to the efficiency of the speaker. When the speaker is mounted to a single plate or baffle, which is not part of an enclosed box or speaker cabinet, the applicable equation for efficiency is the "Thiel Small Equation" which is :

$$E = \frac{F_0^3 A}{QK}$$

where:

F_0 = the resonant frequency

A = the area of the diaphragm

K = the spring constant (i.e., the stiffness of the spring)

Q = a damping constant.

The resonant frequency can be determined by the following equation:

$$F_0 = \frac{1}{2\pi} \sqrt{\frac{K}{m}}$$

where:

F_0 = the resonant frequency

K = the spring constant

M = total moving mass of the diaphragm and those components that move with it

It is evident that as the spring coefficient rises (i.e., the spring becomes stiffer), the resonant frequency goes up. Also, as the mass becomes greater, the resonant frequency goes down.

Now by making substitutions in the equation noted above, we can arrive at the following:

$$E = \frac{F_0^3 A}{QK} = \frac{\left[\left(\frac{K}{m}\right)^{\frac{1}{2}}\right]^3 A}{QK} = \frac{K^{\frac{3}{2}} A}{Qm^{\frac{3}{2}} K} = \frac{K^{\frac{1}{2}} A}{Qm^{\frac{3}{2}}} = \frac{F_0 A}{Qm}$$

Now let us turn our attention back to the concept of baffle rolloff or cutoff, and reference is made to Figure 6. As indicated in the aforementioned article of Mr. Newman, the baffle cutoff begins at point "a" in Figure 6, where the average crosswise dimension of the baffle equals one half of the wavelength. This decline in amplitude is at a rate of about 6 decibels for each octave drop in frequency until we reach point "b" of Figure 6, which is a resonant frequency, after which the dropoff is at a steeper curve, which is approximately an 18 decibel drop for each octave drop in frequency. (It should be pointed out that the graphs of Figure 5 and Figure 6 are not intended to give precise values, nor are the curves intended to be precise representations of these characteristics. Rather, these are provided from free-hand sketches to illustrate the principals of the operating characteristics.)

In the combination of the present invention, the resonant frequency is selected to be at a location below the baffle cutoff frequency (indicated at "a" in Figure 6), and this resonant frequency is further selected to be of a value at which (and above which) the lower frequencies are reproduced at an amplitude comparable to the amplitude through the higher range of frequencies. In general, the resonant frequency will be selected to be at a value between 25-50Hz, and in the presently preferred embodiment, it is at about 25Hz, or slightly above.

Further, the "Q" factor is selected to be at a value much higher than that which is normally selected for open-back baffle speakers, and in general is between a value of 2 to 4. This "Q" factor is selected so that

its function of increasing amplitude as the frequency becomes smaller toward the resonant value substantially counterbalances the effect of baffle roll-off, so that the amplitude remains substantially constant from the location of baffle roll-off or cut-off to the resonant frequency. Below the resonant frequency, the amplitude drops off relatively sharply.

5 However, as the "Q" is made higher, it is evident from the efficiency equation given above that this has the effect of diminishing efficiency. Further, since the resonant frequency is made relatively low, this has a further tendency to lower the efficiency. To counteract this, the total moving mass (i.e., the diaphragm and the components that move with it) is made as small as possible, and the area of the diaphragm is made as large as possible. With regard to the calculation of the total moving mass, the total mass of the cone 20 and
10 of the voice coil 30 is included. With regard to the mass of the surround 22 and the spider 24, only a portion of the total mass of these components is included in the calculations, since the radial inward portions of these components 22 and 24 move substantially the same distance as the cone 20, while the radially outward portions move a much smaller distance. In general, it is adequate to calculate the total moving mass as including half of the total mass of the surround 22 and the spider 24.

15 Likewise, in calculating the total area of the diaphragm or cone 20, the planar frontal area of the cone 20 is included (as opposed to the actual area of the surface of the truncated cone that forms the diaphragm or cone 20), and about half of the area of the surround 22 is included.

In a prototype a 12 inch diameter woofer, having a cone 20 of a diameter of $9\frac{1}{2}$ inches, the total moving mass was about 35 grams. The mass of the cone 20 can be reduced until the cone 20 begins to deflect to
20 too great of a degree. Further investigation in the optimization of the selection and arrangement of materials indicates that the total moving mass for a 12 inch woofer having the $9\frac{1}{2}$ inch diameter cone may be made as low as 16 to 18 grams.

To arrive at the desired resonant frequency, since it is desired to have the moving mass as small as possible, first the materials and configuration for the moving mass are selected. Then the spring constant is
25 modified to properly match the total moving mass to give the desired resonant frequency.

Thus, the preferred ratio of the cone or diaphragm area (given in square inches) to the total moving mass (given in grams) would likely be as high as 2 to 1, and possibly as high as 4 to 1. Desirably, this ratio could be made yet higher. This, of course, can be varied further, depending upon the availability of materials of sufficient strength-to-weight ratio to get yet further optimization.

30 In one preferred prototype, the characteristics of a single one of the woofers 18 is as follows:

resonant frequency = 23.4Hz

$Q_t = 2.36$

$Q_E = 4.12$

$Q_m = 5.5$

35 DC resistance of the voice coil 2.90

Maximum impedance at resonant frequency = 7 ohms

Total moving mass = 34.4 grams

Area of the diaphragm = 75 square inches

Obviously, the various "Q" values, the selection of components to arrive at a given roll-off frequency,
40 and also the resonant frequency can be selected in various combinations to obtain certain desired results. Examples of these will be given below.

With reference to the graph of Figure 7, this illustrates characteristics of a speaker assembly, where there is a roll-off curve having a cut-off frequency of 100Hz, the speaker has a resonant frequency of 25Hz, and there is a "Q" of 4. This "Q"-curve is such that when its effect on frequency is combined with
45 frequency roll-off prior to any shaping or modification of the curve, there would be about a 3db drop at the 50Hz level, and this is illustrated in Figure 7. However, in this particular illustration, the "Q"-curve is "shaped" by circuitry in the crossover network to mute higher frequency values. (This will be explained below.) With this shaping, we arrive at a resultant amplitude curve which is fairly constant except for a small rise at the resonant frequency. In some instances, this may be a desirable result, depending on certain
50 other factors.

A second example is given in the graph of Figure 8. In this instance, the cut-off frequency is 100Hz, and the resonant frequency is 50Hz, with the "Q" being at 2. In this instance, the effects of the "Q" and the roll-off substantially compensate for one another without any shaping of the "Q"-curve.

A further example is given in Figure 9, and this illustrates how a plurality of woofers 18 can be selected
55 with different resonant frequencies and "Q's" so as to obtain relatively constant amplitude values all the way to the lower resonant frequency. In this instance, the cut-off frequency remains at 100Hz; the resonant frequency of two of the woofers is at 40Hz, while the resonant frequency of the other two woofers is at 25Hz. It can be seen that the resultant curve is substantially flat until we pass the lower resonant frequency

level of 25Hz. One disadvantage of this approach is that at the very low frequencies, the effective sound output is coming more from the two woofers with the lower resonant frequencies, but in an effective way to obtain the desired output.

In the discussion above relating to the combination of elements shown in Figure 7, it was indicated that the effect of the "Q" factor could be modified by shaping through the crossover network. This term "crossover network" refers rather broadly to all of the electrical components which not only provide for crossing over the signals, but also for a certain shaping of the signals to optimize performance. Since these are well known in the art, these will not be described in any detail herein, except to cite briefly two examples. Figure 10 is a simplified illustration of a circuit diagram to mute higher frequencies while passing on the lower frequency portions of the signal. Figure 11 is an illustration of a somewhat more sophisticated circuit to accomplish shaping. It is well within the skill of the art to select the values to obtain the proper response in the shaping of the curve.

Also, it is to be understood that while the present invention is shown as being incorporated in a total speaker system, it could also be used as a sub-woofer in combination with an existing speaker system where the lower frequency sound is not produced properly.

Also, various modifications could be made in the present invention without departing from the basic teachings thereof.

20 Claims

1. A loudspeaker assembly comprising:
 - a. a generally planar open-backed baffle having a pre-determined planar area and cross-wise dimensions, and providing a speaker area located in said baffle,
 - 25 b. a diaphragm means movably mounted at said speaker area,
 - c. a resilient mounting means mounting said diaphragm means to said baffle in a manner to locate said diaphragm means at an intermediate location and permit fore and aft movement from said intermediate location while yieldingly resisting said movement,
 - d. a motor means to drive said diaphragm on its fore and aft movement, said motor means
 - 30 comprising magnet means to create a magnetic field and a voice coil means positioned in said magnetic field, with said magnetic means and said voice coil means mounted so as to be movable relative to one another, one of said magnet means and said voice coil means being connected to said diaphragm so as to be movable therewith, and the other of said magnet and voice coil means being connected to said baffle,
 - e. said assembly having a predetermined baffle cutoff frequency of a first frequency value with said
 - 35 assembly being characterized to produce a rolloff effect such that amplitude of the speaker output is diminished as a function of frequency diminishing from the value of said cutoff frequency,
 - f. said assembly having a resonant frequency of a second value lower than said first frequency value,
 - g. said assembly having a predetermined "Q" factor of a value which is such to produce a "Q" effect such that said assembly is characterized in that amplitude of the speaker output is increased as a function
 - 40 of frequency diminishing toward the value of said resonant frequency,
 - h. said assembly being further characterized in that the "Q" factor effect substantially offsets the rolloff effect to provide an output having an amplitude response within a predetermined desired amplitude range from cutoff frequency to resonant frequency.
2. The assembly as recited in Claim 1, wherein said voice coil means is connected to said diaphragm
- 45 means and said magnet means as connected to said baffle.
3. The assembly as recited in Claim 2, wherein said "Q" factor of the assembly is at least as great as about 2.
4. The assembly as recited in Claim 3, wherein said "Q" factor is at least as great as about 3.
5. The assembly as recited in Claim 1, wherein said "Q" factor is between 2 to 4.
- 50 6. The assembly as recited in Claim 1, wherein said assembly comprises a plurality of speaker units, each of which comprises a related diaphragm means, a related mounting means, and a related motor means, at least a first one of said units having a "Q" factor of a lower value, and at least a second of said units having a "Q" factor of a higher value.
7. The assembly as recited in Claim 6, wherein said second unit having a higher "Q" value has a
- 55 resonant frequency of a lower value, and said first unit having a lower "Q" value has a resonant frequency of a higher value.

8. The assembly as recited in Claim 1, wherein the diaphragm means has a predetermined diaphragm area, and said assembly has a moving mass, comprising said diaphragm means and components of said assembly that move therewith, said assembly being characterized in that the ratio of the diaphragm means area, expressed in square inches, to the mass of the moving mass, expressed in grams, is at least about two-to-one.
9. The assembly as recited in Claim 8, wherein said ratio is at least about four-to-one.
10. The assembly as recited in Claim 1, wherein said resonant frequency is at least as low as about 50 Hz.
11. The assembly as recited in Claim 10, wherein said resonant frequency is at least as low as about 25 Hz.
12. The assembly as recited in Claim 1, wherein
 - a. said "Q" factor of the assembly is at least as great as about 2,
 - b. the diaphragm means has a predetermined diaphragm area, and said assembly has a moving mass, comprising said diaphragm means and components of said assembly that move therewith, said assembly being characterized in that the ratio of the diaphragm means area, expressed in square inches, to the mass of the moving mass, expressed in grams, is at least about two-to-one.
13. The assembly as recited in Claim 1 wherein said resonant frequency is at least as low as about 50 Hz.
14. The assembly as recited in Claim 12, wherein
 - a. said "Q" factor is between 2 to 4,
 - b. said ratio is at least about four-to-one.
15. The assembly as recited in Claim 14, wherein said resonant frequency is at least as low as about 25 Hz.
16. A method of producing sound from a loudspeaker assembly comprising:
 - a. a generally planar open-backed baffle having a pre-determined planar area and cross-wise dimensions, and providing a speaker area located in said baffle,
 - b. a diaphragm means movably mounted at said speaker area;
 - c. a resilient mounting means mounting said diaphragm means to said baffle in a manner to locate said diaphragm means at an intermediate location and permit fore and aft movement from said intermediate location while yieldingly resisting said movement,
 - d. a motor means to drive said diaphragm on its fore and aft movement, said motor means comprising magnet means to create a magnetic field and a voice coil means positioned in said magnetic field, with said magnetic means and said voice coil means mounted so as to be movable relative to one another, one of said magnet means and said voice coil means being connected to said diaphragm so as to be movable therewith, and the other of said magnet and voice coil means being connected to said baffle,
 said method comprising:
 - a. providing said assembly with a predetermined baffle cutoff frequency of a first frequency value with said assembly being characterized to produce a rolloff effect such that amplitude of the speaker output is diminished as a function of frequency diminishing from the value of said cutoff frequency,
 - b. providing said assembly with a resonant frequency of a second value lower than said first frequency value,
 - c. providing said assembly with a predetermined "Q" factor of a value which is such to produce a "Q" effect such that said assembly is characterized in that amplitude of the speaker output is increased as a function of frequency diminishing toward the value of said resonant frequency
 - d. utilizing the "Q" factor effect to substantially offset the rolloff effect to provide an output having an amplitude resonance within a predetermined desired amplitude range from cutoff frequency to resonant frequency.
17. The method as recited in Claim 16, wherein said "Q" factor of the assembly is at least as great as about 2.
18. The method as recited in Claim 16, wherein the diaphragm means has a predetermined diaphragm area, and said assembly has a moving mass, comprising said diaphragm means and components of said assembly that move therewith, said method further comprising providing the ratio of the diaphragm means area, expressed in square inches, to the mass of the moving mass, expressed in grams, at least about two-to-one.
19. The method as recited in Claim 16, wherein said resonant frequency is at least as low as about 50 Hz.
20. The method as recited in Claim 16, wherein
 - a. said "Q" factor of the assembly is at least as great as about 2,

b. the diaphragm means has a predetermined diaphragm area, and said assembly has a moving mass, comprising said diaphragm means and components of said assembly that move therewith, said method further comprising providing the ratio of the diaphragm means area, expressed in square inches, to the mass of the moving mass, expressed in grams, at least about two-to-one,

5 c. the resonant frequency is at least as low as about 50 Hz.

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Neu eingereicht / Newly filed
Nouvellement déposé

FIG. 1

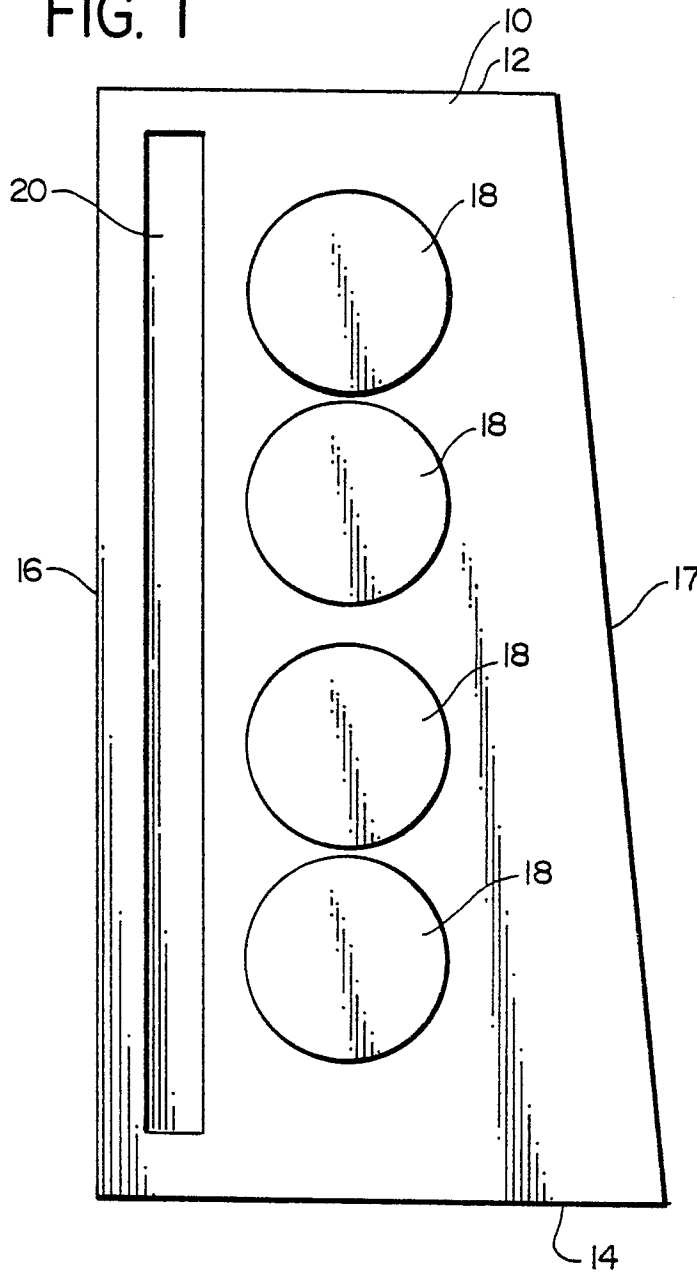
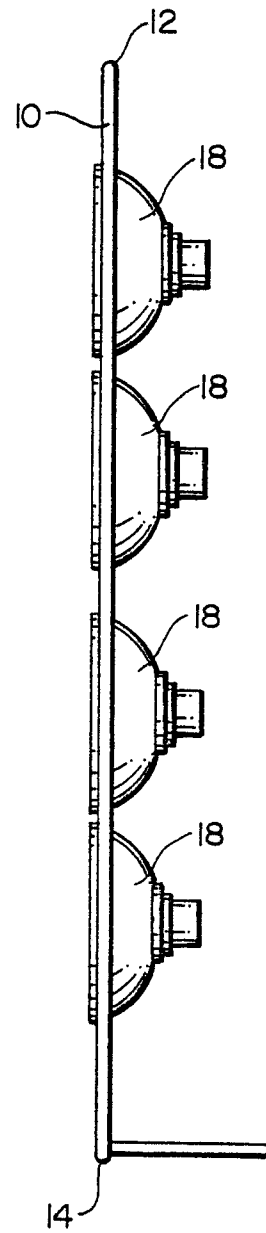


FIG. 2



Neu eingereicht / Newly filed
Nouvellement déposé

FIG. 3

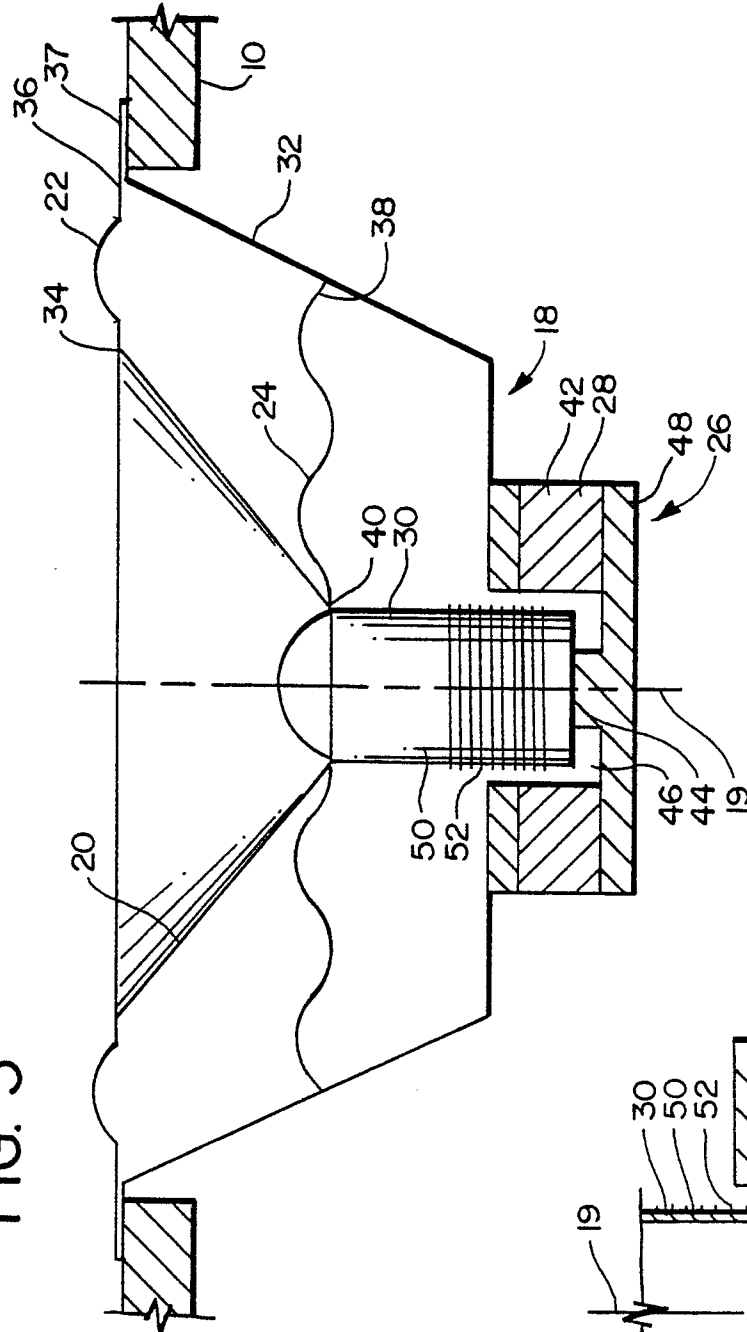
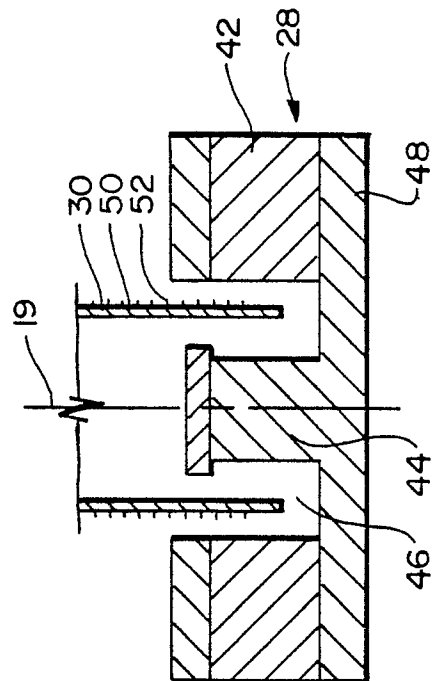


FIG. 4



For Engineering / Study Use
No Distribution Allowed

FIG. 5

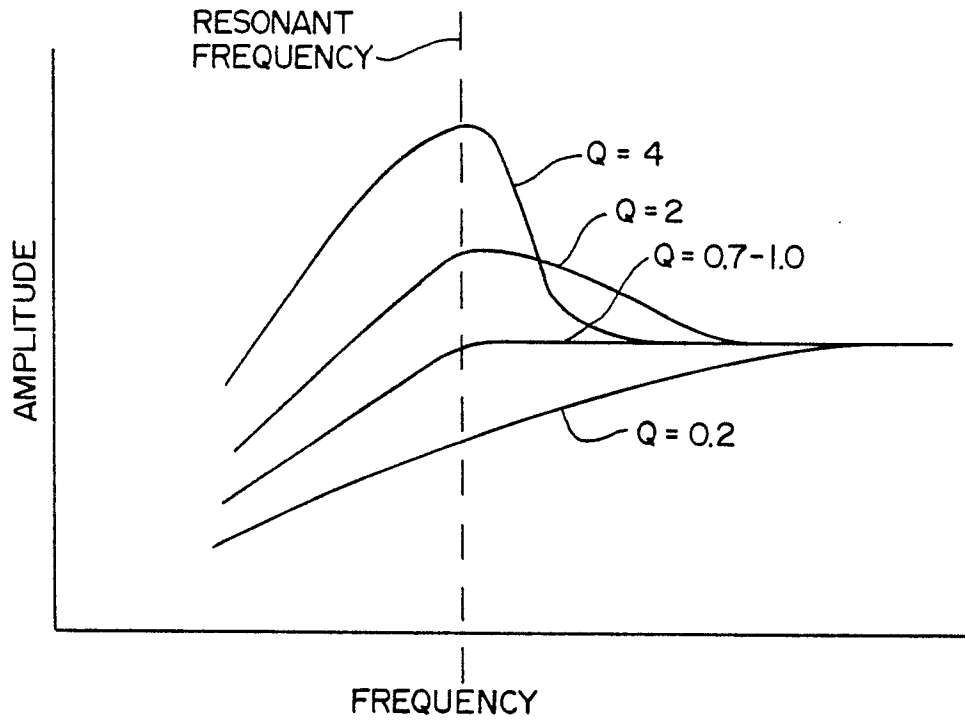
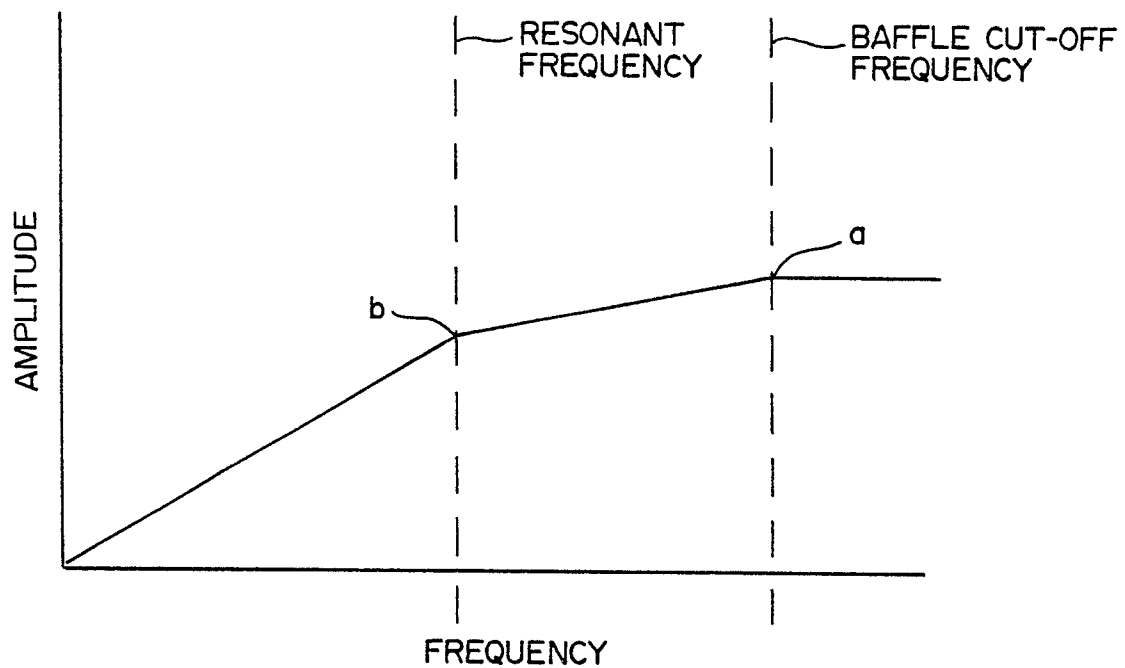


FIG. 6



Neu eingereicht / Newly filed
Nouvellement déposé

FIG. 7

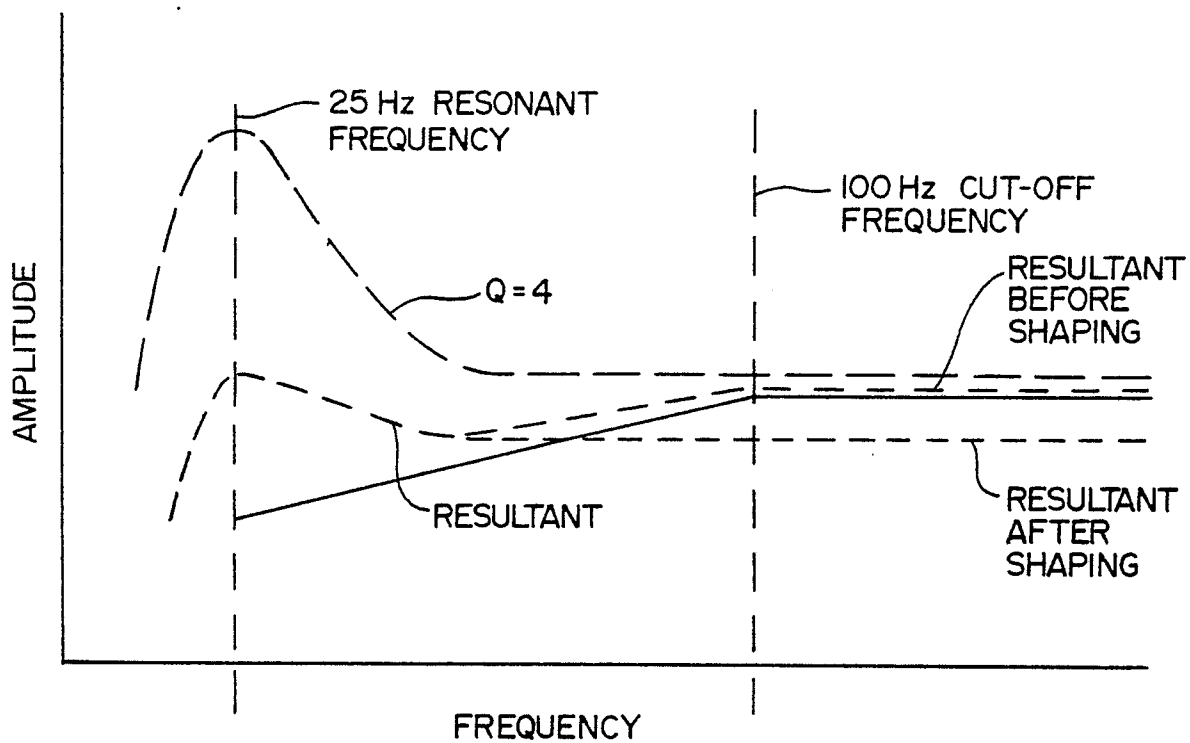
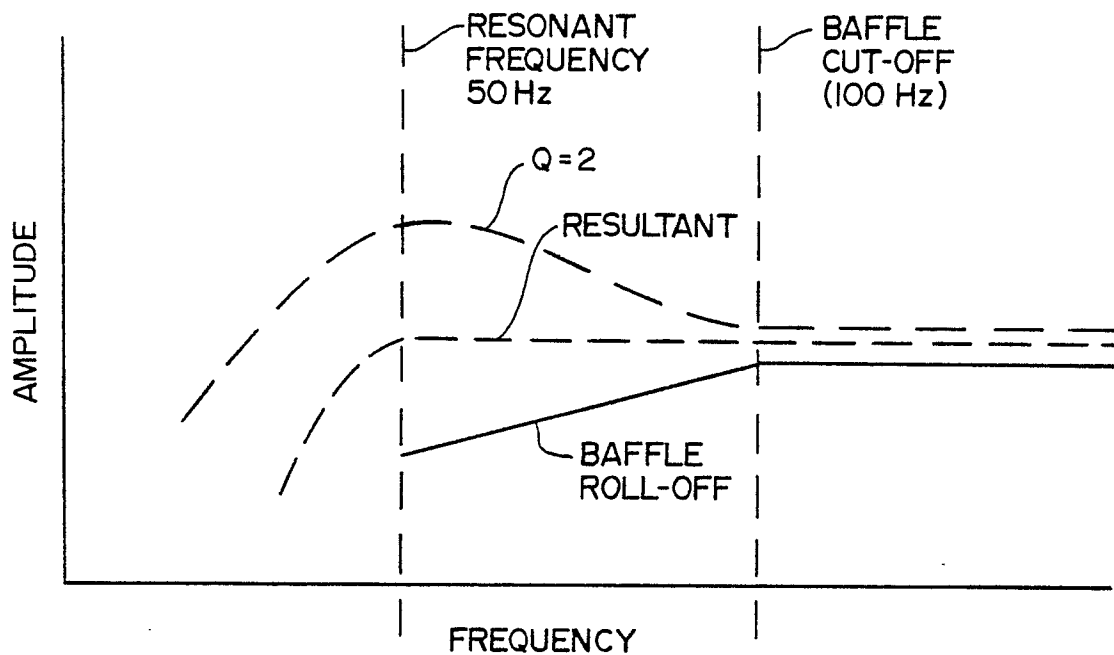


FIG. 8



BAD ORIGINAL

Nou eingereicht / Nowly filed
Nouvellement déposé

FIG. 9

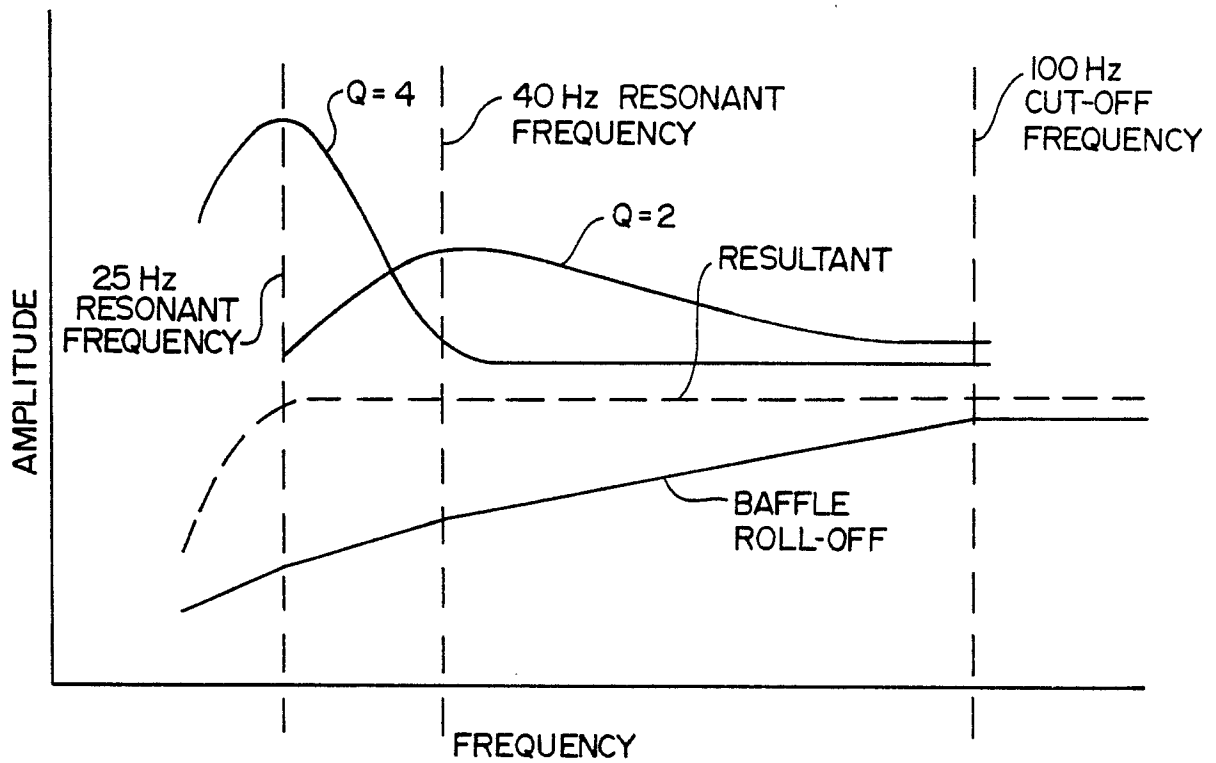


FIG. 10

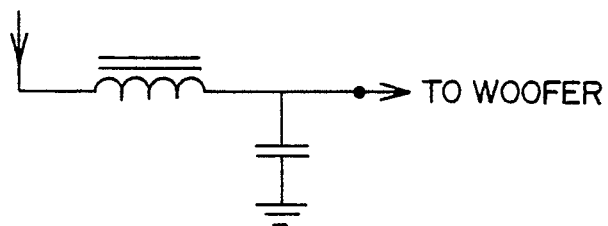
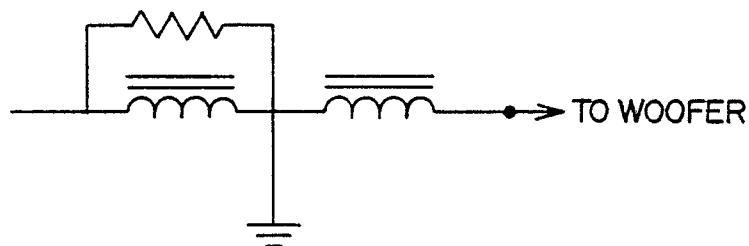


FIG. 11



BAD ORIGINAL