

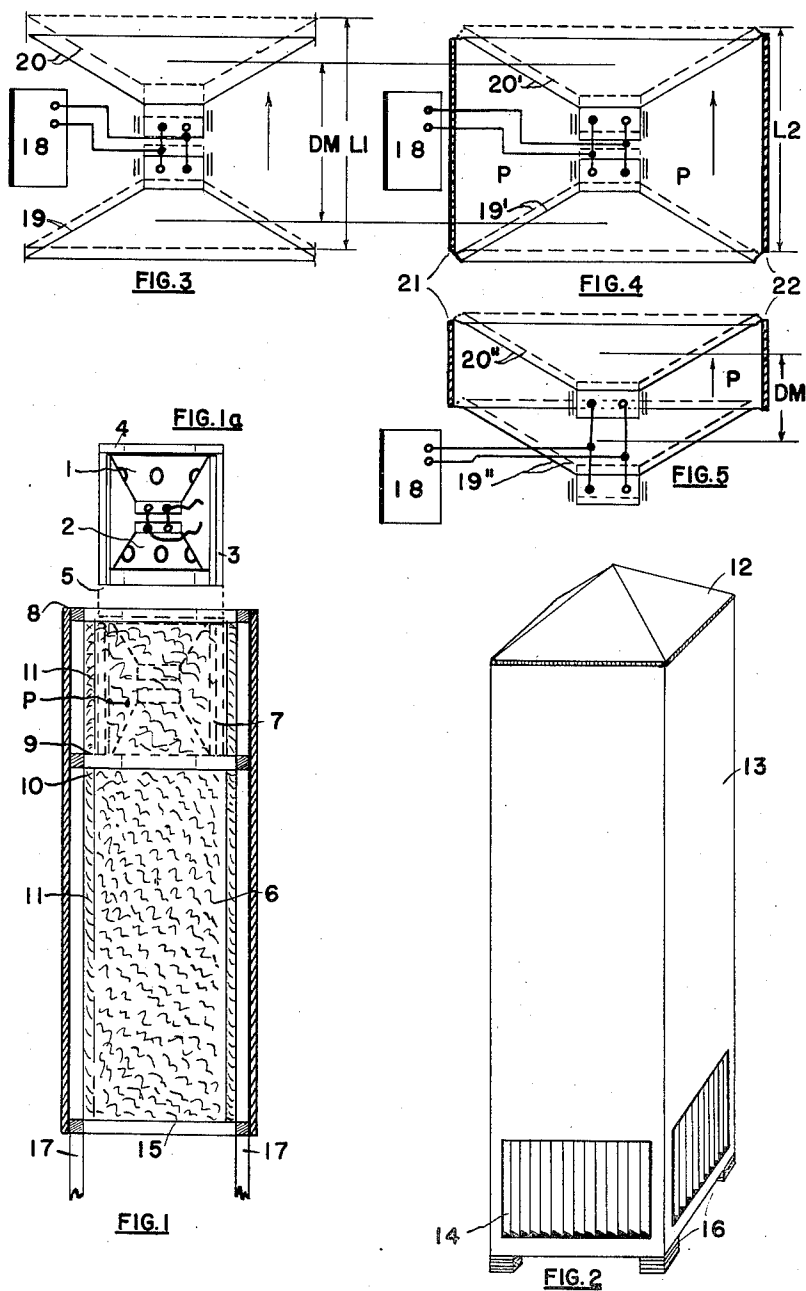
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SOUND REPRODUCING SYSTEMS

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SOUND REPRODUCING SYSTEMS

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This invention relates to sound reproducing systems, especially those designed to provide audio waves, in a living space, that stem from radio, public address, or recorded material.

Prior art arrangements for reproducing sound inherently suffer from a tendency toward amplitude distortion of the complex sound wave due to the fact that all vibratile agencies which possess mass exhibit a mass-resonance characteristic which causes them to operate very much more efficiently at frequencies at or near a mass-resonance value than at any other frequency. The mass-resonance effect is characterized by a very pronounced fundamental value and a number of modes whose mathematical sequence tends to be geometric but whose magnitude is a function of design of the whole system.

It is possible to construct a single speaker having a very high flux density in the field of the actuating agency, for example, a "voice coil" floating in a magnetic field, wherein the said flux, if made large enough will exert an acceptable control effect over the tendency of the vibratile system to exhibit sharp peaks of efficiency at certain frequencies.

Such prior art arrangements have proved acceptable at the various modes and harmonics of the fundamental but the cost of the magnetic field has proved to be very high, and to produce a field so dense that it will effectively damp the efficiency of the system in the region of the fundamental or main mass-resonance characteristic has been found to be completely uneconomic.

It is the main object of this invention to provide a system for reproducing sound from an electric wave source, which achieves an acceptable standard of uniform sound amplitude from a wave source of rapidly varying frequency but of uniform wave amplitude, and at a cost which is economically practicable.

It is a further object to provide a system of the kind indicated which provides the said uniform response without one requiring to employ a very high and therefore costly magnetic flux to effect the required damping. This is achieved by providing a pneumatic chamber mutually damping a pair of vibratile agencies in such a manner as to limit the tendency of the said vibratile agencies to exhibit excessive excursion at frequencies to which they would otherwise respond with undesired eagerness.

In a further aspect the invention includes in combination a pair of vibratile agencies, each controlled by an actuating device such as a voice coil or "motor," a plurality of wall members intersecting to define a chamber, a first sound reproducer controlled by one of said motor and including one said vibratile element forming the greater portion of one wall of said chamber, a second sound reproducer controlled by a second said motor and including a second said vibratile element forming the greater portion of a second wall of said chamber and means for exciting the motors in such phase that the two vibratile members tend to move in synchronism but not always at the same amplitude at a

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stated frequency. The mass-resonance characteristic of one of the two vibratile elements is made to be different from that of the other so that the vibratile elements, for example, speaker "cones," do not resonate at the same frequency.

In still another aspect the motors of the combination indicated are connected to operate in parallel to receive the electric sound wave so that the energy is divided between them in a ratio which is proportional to the magnitude of the load reflected into each motor by its associated vibratile element.

The construction indicated may include some sort of baffle to separate the free faces of the speaker vibratile elements so as to prevent cancellation of sound waves by anti phasal collision in free space.

In a preferred embodiment of the invention such a baffle has the form of a substantially anechoic duct having one opening juxtaposed to receive the sound waves from one of the vibratile elements and its other end open to free space, the duct being made long enough to prevent sound wave cancellation in free space of the waves of interest in the field of application.

Two speakers of conventional form and having relatively low flux density in the motor field are connected as described above and the chamber encloses the inner faces of the cones so as to provide a coupling air column between them from which the air cannot rapidly escape. The outer faces of the cones or vibratile elements may look into free space provided there is a baffle barrier between them. In an idealized form this would be an infinite wall so that the free space impedance looking at the face of each cone is the same. However, this ideal condition is rarely available in the field of utility so I have provided in my preferred example of construction an expedient or substitute for the infinite baffle in the form mentioned above, the anechoic duct.

The speakers may be mounted in any specified wall of the chamber and more than two can be used provided they are all correctly phased to make the chamber exhibit a constant volume when none of the speakers is responding at its resonant mode, but the applicant prefers a construction employing only two speakers for each chamber, and having the speakers mounted in opposite walls thereof.

The invention will now be further described by way of example and with reference to the accompanying drawings wherein:

Figure 1 is a sectional view of a chamber recess and anechoic duct assembly.

Figure 1a shows a frame and mounting facility for two speakers and is dimensioned to sleeve into the chamber recess of Figure 1.

Figure 2 is a perspective view of a complete speaker system including a baffle-duct.

Figures 3, 4, and 5 are diagrams used in conjunction with the text to explain how the invention operates when connected to a source of audio-electric wave energy.

Refer now to these drawings, first to Figures 1, 1a and 2. Items 1 and 2 are conventional moving coil permanent field loud speakers of well known type having, if desired but not necessarily, a relatively low gaussian merit factor—say a flux density in the voice coil gap of the order of 8,000 gauss. These are mounted in a frame 3 which is capped at the top and bottom by plates 4 and 5. These plates are apertured to receive the mounting baskets of the respective speakers so that each plate and its co-operating speaker form a wall, the greater part of which comprises the vibratile element of a speaker. The two thus constituted walls are in opposed attitudes and are held in position by the frame 3.

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Structure 6 is a duct and 7 is an extension of 6 designed to receive the assembly of Figure 1a in sleeved relation so that a chamber P is formed by the intersecting walls of 7 and of the plates 4 and 5 which seal off the chamber at the intersecting edges at the top and at the level 9. Blocks 10 may be set to determine the level 9 by abutting the wall 5. The recess 7 when the speaker and frame assembly is inserted therein becomes a chamber P containing the speaker mechanisms and connections and a residual quantity of air which is virtually sealed in so that it cannot readily escape but bears upon the respective vibratile speaker elements.

The chamber P and duct 6 are preferably lined with resilient material 11 having a low coefficient of reflectivity so that sound vibrations therein are not able to build up standing waves at the frequencies of interest. Several well known resilient materials are suitable such as loosely filled wool blocks, spun glass, fibre matting, or the like.

The duct-chamber combination may be erected upon a timber framework covered with wood, cane board or other suitable sheeting. The materials of the inclosures should be preferably of low sound conductance and of limp texture so as to inhibit the development of vibration. Cane board has been found excellent and may be overlaid externally by fine veneers or by cloth, tapestry, or the like. Figure 2 depicts an example of the structure of Figure 1 which has been fitted with a dust cap 12 of sheer silk, sides 13 of gold lamé, and a mahogany grill work 14 at the "free space" end 15 of the duct 6. The assembly sits on feet 16 which may be simply corner blocks of wood. Timbered frame members 17 wherever they join or are braced should be glued so that there will be no slidable joints to develop "sizzle" when vibrated. The sheeting or cane board should also be glued onto the frame in addition to any screws or nails used in assembly.

It will be evident that when the speaker and frame assembly Figure 1a is nested in the top end of the assembly shown in Figure 1, the region occupied by the combination comprises a virtually sealed chamber P having resilient but substantially non-vibrating side walls and top and bottom walls comprised mostly of the vibratile elements of the speakers, that is, the so called "cones." If these cones are driven in phase by a signal, the cones will tend to operate in synchronism and the pressure in the chamber P will not change much so long as the behaviour of the two cones is identical. It will also be evident that if the behaviour of both cones was always, for all frequencies, identical, the principal gain from the construction would be an increase in power capability due to presence of two speakers instead of only one. When a speaker responds to a low frequency at which the vibratile mechanism is resonant there will be a large cone excursion for a given signal input and both speakers being exactly the same will move in synchronism and the air in chamber P will simply oscillate back and forth with the signal, exhibiting only small inertial pressures and attenuations at the cone surfaces when the direction of motion reverses at the end of a cone excursion.

However, one of the main objects of the invention is to correct non-linear behaviour of the vibratile system in the presence of wide variations in applied frequency, and this is achieved by making the mass-resonance characteristic of one said vibratile element different by a predetermined amount from that of the co-operating vibratile element. When this is done, and when at the same time the two speakers are otherwise substantially identical and are connected in parallel, phase aiding, to the same signal source, the behaviour of the system becomes quite different.

Figures 3, 4 and 5 will now be used to explain how the system now behaves.

Figure 3 is a diagrammatic representation of two cone speakers 19, 20 set back to back in free space. The voice coils are in parallel co-phasal connection to a signal source 18. When a half wave of signal actuates the two cones

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simultaneously they both move in substantially the same degree and in the same direction such as that of the arrow. When served by a frequency at which the moving coil system of one or other of the speakers is resonant, there is a relatively large excursion of that system and the impedance of the voice coil rises sharply tending to limit the energy in the latter: in fact the "back current" E. M. F. and consequent rise in the impedance of the system at resonance is the only thing that keeps prior art loud speakers from literally exploding when they "hit" resonance. Now if the second speaker system has a different mass-resonance characteristic at the instant when the first system is responding to a specified frequency and amplitude of applied signal, the voice coil impedance of the second system will be lower than that of the resonating first system and being in parallel therewith will draw more energy from the signal source than will the resonant one. This will tend to reduce the excursion of the first vibratile element at resonance. This effect in itself is not sufficient to reduce the relative response of the two systems to a level of equality, however.

Now refer to Figure 4 where the two speakers of Figure 3 have been enclosed at their edges by means 21, 22 to form a chamber P in which the cones are no longer in free space separately but are only in free space as a pair, and the air in chamber P couples the inner cone faces so that if one of the cones moves at an amplitude different from that of the other cone, the air column in P will exert a control upon both cones but the control will be greater upon the one which tends to have the greatest excursive amplitude.

The construction now embraces two agencies which both tend to limit any change in the relative amplitude of the two cones when both are vibrating at the same frequency. Firstly the parallel connection of the motors, as the voice coils may properly be called, determines by well known electrical laws that the one which is laboring the most (the one which is not driving a resonant load) will draw most of the energy from the line and the lightly loaded motor will "see" a lower energy source and therefore lower its amplitude of effort. At the same time the air column in chamber P will become non-uniform in pressure as soon as the volume of the chamber changes. This change occurs whenever one cone displays an excursion 20' that is greater than that of its paired mate 19'. For example, if cone 20' tries to move upward with the arrow one quarter inch while cone 19' moves upward only one sixteenth inch, the volume of the chamber will increase by an amount proportional to a difference of three sixteenths of one inch, and the air pressure in P will be attenuated and will pull on both cones tending to increase the upward motion of cone 19' and to pull back the cone 20' (which is the one that is trying to run away). The net result is a control effecting equalization of the excursion amplitudes of the two cones. It will be seen in Figures 3 and 4 that the chamber length L1 is greater than length L2.

If it is the lower cone 19' which tends to make the greatest excursion (rather than 20') there will be compression in the chamber instead of expansion and the cone 20' will be urged outwardly while the cone 19' is restrained, thus again tending strongly to equalize the excursions of the two cones. If the energy is moving in the opposite direction (as it does of course during a complete cycle of a wave) the same action takes place—expansion or compression if one or other of the cones tends to move away in amplitude from its mate; at frequencies which do not excessively excite one speaker but cause both speakers to exhibit the same amplitude of excursion, the chamber volume remains unchanged during the wave cycle and the air therein merely oscillates with the vibratile walls of the chamber constituted by the speaker cones so that they work simply as a tandem pair.

Since speakers are normally power rated below the

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level at which a fundamental surge would cause risk of "take off" or damage to the mechanism, it is evident that the speakers arranged according to my teachings can be very substantially up-rated since their "take-off" (critical frequency response) is controlled by the action of the chamber, and the co-operating parallel "co-phasal" electrical connections.

This control can be increased to almost any desired degree by suitably defining the dimensions of the chamber P and its degree of sealing.

In the example depicted in Figure 4, the dimension DM was made six inches and seems in the practical sense to be quite satisfactory for the ordinary applications where the sound level demanded of the system is of the order of about ten peak watts. Figure 5 shows the two cones 19", 20" arranged in the same physical attitude so that one of the field and voice coil mechanisms is outside the cavity and the total volume of the chamber P can be thereby reduced. Since the air column in Figure 5 is much shorter than that of Figures 1a, 3 and 4, the pneumatic control can be made much greater because the dimension DM is now much less and is approaching the value of the total possible change in DM under signal conditions; for example, the three-sixteenths inch "tendency" of change between speakers 19" and 20" effects a much greater ratio of change as between a six inch mean length and, say, a two and one half inch mean length for DM in Figure 3. However such efforts at increasing the pneumatic control can be carried too far and there is a further phenomena about which the constructor should be warned. DM can be accidentally made of such magnitude as to, itself, establish a one-quarter or other sub-multiple standing wave in the chamber at high powers which will cause a "slot" in the system response at a point in the frequency spectrum where it could be annoying. However, on the other hand, the distance DM can be deliberately made to effect a "slot" at some point in the audio range where such an effect is desired, for example at 9 kc. The applicant has found the six inch value for DM to be a very practical one for normal application of use but the exploration of other values of DM has been found fascinating and productive where highly specialized speaker systems are needed.

The construction depicted in Figure 2 radiates both high and low frequencies toward the ceiling of a room and the duct 6 absorbs most of the "highs" and directs the unabsorbed frequencies downward to the floor where these longer, low frequency waves easily reflect and disperse outwardly. This arrangement provides an effect similar to that achieved by multiple speaker systems employing frequency dividing networks and/or hybrid circuits and results in a special dispersion of complex sounds such as emanate from a symphony orchestra; the resulting improvement in "presence" is very noticeable.

It is of course well known that some form of baffle is necessary with all systems using vibratile agencies for setting up the sound patterns in the air of a listening room. The duct 6 in my exemplified construction provides this baffle effect and also adds the feature of a frequency dividing agency, to improve "presence." However the basic arrangement of the two speakers operating into a pneumatic control coupling cavity can be used very effectively with other forms of baffle such as a wall (infinite baffle), corner horn or other "enclosure." It should however be borne in mind that with my invention no resonant cavity or Helmholtz device is necessary and in fact all such devices should be specifically avoided since the chamber P in conjunction with the parallel co-phasal operation of the cones when properly adjusted completely remove all the undesired resonances and "booms" present in prior art combinations and the use with my invention of any resonant agency whatever will introduce undesirable effects. It should also be noted that all cavities, chambers, ducts and the like tend to exhibit resonance effects. One can reduce these tend-

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encies to any desired degree by the use of sound damping materials in the chambers, ducts, or cavities. However, the "any desired degree" can become an expensive one where high audio sound power is encountered. It is usually more practical to set up multiple assemblies of a system wherein cavities or chambers of any kind are used at very high powers. The duct, and chamber of the invention herein exemplified can be readily padded to a point where no detectable standing wave effects arise up to peak powers of about 10 watts, although the speaker system, rigidly controlled by the pneumatic and electrical damping by which it is characterized, enables the speakers themselves to be operated without risk of damage at powers up to six times the rated power of each individual speaker.

It should now be evident that the invention provides a very inexpensive means for obtaining a flat response in a sound reproducing system. The confined air in pressure chamber P levels off the peaking tendencies which characterize all vibratile agencies presently known in this art. Its effect can be made as "rigid" as desired by suitably confining the air in the chamber against the possibility of rapid escape, and by making the chamber of suitable length DM. The result is further enhanced by operating the actuating "motors," that is, voice coils or the like, in parallel connection to the electric wave source.

It is also evident that the exemplary construction can be varied in many ways without departing from the essential combination defined by my teachings.

All combinations of two speakers coupled by a cavity either as in Figure 4 or in Figure 5 can be set up in chambers of different form and shape and length without departing from the spirit of my invention and all such arrangements are to be regarded as lying within the ambit of the appended claims.

What I claim is:

1. A sound reproducing system comprising in combination a plurality of wall members intersecting to define an air chamber, a first sound reproducer having a vibratile element positioned to form a major portion of one said wall, a second sound reproducer having a vibratile element positioned to form a major portion of a second said wall, the said first and second vibratile elements having substantially identical mechanical parameters but differing fundamental resonance characteristics, electromotive actuating agencies associated one with each vibratile element, electric circuit means interconnecting said actuating agencies in such phase as when energized by a signal to urge one said vibratile element outwardly of the chamber when the other vibratile element is being urged inwardly of the said chamber.

2. A sound reproducing system comprising in combination a plurality of wall members intersecting to define an air chamber, a first sound reproducer having a vibratile element positioned to form a major portion of one said wall, a second sound reproducer having a vibratile element positioned to form a major portion of a second said wall which is oppositely positioned with respect to said one wall member, the said first and second vibratile elements having differing fundamental resonance characteristics, electromotive actuating agencies associated one with each vibratile element, electric circuit means interconnecting said actuating agencies in such phase as when energized by a signal to urge one said vibratile element outwardly of the chamber when the other vibratile element is being urged inwardly of the said chamber, and a duct positioned to receive sound waves from one of said vibratile elements into one end, the other end of said duct being substantially open to free space.

3. A construction as defined in claim 2 wherein the said walls defining an air chamber include upon the inner surfaces, other than those comprised of vibratile

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members, resilient material coatings which are characterized by a low coefficient of sound reflectivity.

4. A construction as defined in claim 2 wherein the said duct includes within its interior surfaces resilient material coatings which are characterized by a low coefficient of sound reflectivity.

5. A construction as defined in claim 2 wherein the said duct is of tubular form and includes extending walls designed to comprise the remainder of the said plurality of wall members intersecting to form the chamber, the structure including the duct, chamber and included sound reproducing devices being further designed to stand erect a predetermined distance above a supporting floor so that sound from the upper vibratile element will be projected upwardly and the sound waves from the lower vibratile element will be projected, at least in part, downwardly through the said duct toward the said supporting floor.

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