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(54) Acoustic transducers.

(57) A loudspeaker includes a high frequency transducer 13 and a low frequency transducer 14 mounted on a vertical baffle 12 forming the front of a cabinet 11, and having respective virtual acoustic sources 1 and 3. Each unit receives an amplified signal through an electrical filter to constitute a passive system, and a delay network is included in the path of the amplified signal to the high frequency unit 13 so as to introduce a delay such that the effective virtual acoustic source of the unit is displaced a distance *d*1 to the right so as to lie in the same vertical plane as the virtual source 3. The acoustic radiation from the two units thus appears to emanate from points in space situated in the same vertical plane, thereby avoiding time delay and phase distortions over the reproduced frequency band.

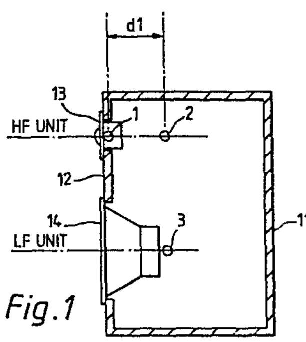

Fig.1

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TANNOY LIMITED

Acoustic transducers

This invention relates to acoustic transducers such as moving coil loudspeakers and is particularly concerned with such transducers which include two or more transducer units, each covering a specific frequency band. For example, in a high quality loudspeaker system it is commonplace to use a cone-type transducer for the lower frequencies and a dome-type sound radiator for the higher frequencies, each of these two transducer units having its band width controlled by an electrical filter. Thus in a passive system, with which the present invention is concerned, the amplified signal is passed to the low frequency unit through an electrical low-pass filter and to the high frequency unit through an electrical high-pass filter.

With any type of acoustic transducer it can be shown by measurement that the acoustic radiation appears to emanate from a single point in space which lies on the axis of symmetry, but which may or may not coincide with a point on the structure of the transducer. This point may be referred to as representing the virtual acoustic source (analogous to a virtual light source in optics) and it is found in general that the virtual source lies behind the actual energy source, e.g. the vibrating cone in a cone-type transducer. As already described, a cone-type transducer is frequently associated with a low-pass filter and this filter will have an associated phase response which will modify the phase of the signal passed to the transducer to an extent dependent on the frequency and the rate of change of amplitude response outside the pass band. The effect of such phase changes with frequency results in a shift of the virtual acoustic source when fed from the low-pass filter, the lower the cut-off frequency of the filter, the greater the rearward displacement of the virtual source from the original position.

However, the high-pass filter used with the high frequency unit does not exhibit the type of phase changes which introduce time delays and lead to displacement of the virtual source. Accordingly, in a composite transducer having a low frequency unit and a high frequency unit arranged with fixing points in the same vertical plane, the acoustic properties of the units together with the associated band width filters means that the virtual sources do not lie in the same vertical plane and further, if the transducer system were to be operated under these conditions the path length differences from high and low frequency units to an observer would give rise to time delay and phase distortions over the reproduced frequency band, especially in the cross-over region.

The most straight forward solution to this problem is the physical re-arrangement of the two transducer units so as to bring the two virtual sources into the same vertical plane which means that the high frequency unit needs to be displaced rearwardly in relation to the low frequency unit and the front of the enclosing cabinet has to be modified accordingly. For example, the front of the cabinet may be sloped rearwardly from the low frequency unit to the high frequency unit or, alternatively, each unit may be mounted in a separate vertical portion of the front of the cabinet with a rearwardly sloped ledge between them. Both forms of cabinet are difficult to build by conventional methods and the shape is not always aesthetically acceptable. If a sloping front for the cabinet is used, the direction of intended auditioning is away from the axis of symmetry of both transducer units and if a sloping ledge is used, this causes unwanted reflections and diffractions which interfere with the sound quality.

According to the present invention, an equivalent result is achieved, i.e. the two virtual sources are brought into the same vertical plane, by the inclusion of a delay network in the amplified signal to one of the units (normally the high frequency unit), the effect of the delay thus introduced being the same as if the virtual high frequency unit were spaced rearwardly by a distance equal to that travelled by the sound during the delay period.

This makes it possible to mount both the high frequency and low frequency transducing units in the same vertical plane, i.e. on a vertical baffle forming the front of the cabinet, thus overcoming the disadvantages referred to above. Exactly the same principle can be applied if the two transducer units are not separate physical entities, but form respective parts of a common structure, e.g. a so-called dual concentric loudspeaker in which the sound radiated by the high frequency unit passes through the centre of the magnetic system of the low frequency unit by way of a passage which is shaped to merge into the cone of the low frequency unit. The general principle is also applicable when there are more than two transducer units, radiating over different frequency ranges. As mentioned above, the delay is normally introduced into the amplified signal to the high frequency unit, but it may be introduced into the amplified signal to the low frequency unit where the physical displacement of units so demands.

The fact that the system is a passive one means that the delay network can be introduced without the need for any additional power source and the system can be used quite independently of any such power source. This is in contrast to an active system where, by definition, there is the assumption that any devices used are capable of amplifying signals. The amplification process is carried out by arranging for the input signal to linearly control a much larger static voltage or current produced by a power supply (e.g. a battery cell or an AC mains supply transformed to an appropriate voltage, rectified and smoothed). An active system therefore requires the inclusion of a power supply to provide the output signal and also to produce various other voltages and currents used by the active device in maintaining a linear transfer characteristic. As a consequence any considerations affecting the design of an active system are entirely irrelevant to the design of a passive system.

An example of an acoustic transducer in accordance with the invention, in the form of a loudspeaker having high frequency and low frequency transducer units, will now be described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is a diagrammatic cross sectional view through a cabinet showing the physical dispostion of two transducer units;

Figure 2 is a circuit diagram of a filter network used in conjunction with the two transducer units of Figure 1 and including an electrical delay network; and

Figure 3 is a circuit diagram of the delay network shown in Figure 2.

Turning first to Figure 1, the loudspeaker illustrated is shown as including a rectangular cabinet 11 having its front in the form of a vertical baffle 12 on which are mounted an upper, high frequency transducer 13 and a lower, low frequency transducer 14. The virtual acoustic sources of the two transducers are shown respectively as 1 and 3 and it will be seen that these do not lie in the same vertical plane, but are displaced horizontally by a distance dl.

The inclusion of the filter network shown in Figure 2 in the path of the amplified signal to the high frequency unit 13 introduces a time delay equivalent to the time taken for sound to travel the distance dl so that the effective virtual source of the unit 13 is located at 2, that is to say in the same vertical plane as the virtual source 3, thus ensuring that the high frequency and low frequency signals combine together with minimal time delay and phase distortions.

The greater part of the filter network shown in Figure 2 is quite conventional, consisting of a high pass portion 16 for supplying the high frequency unit 13 and a low pass portion 17 for supplying the low frequency unit 14. The novel feature of the network shown in Figure 2 lies in the electrical delay network shown in block form as N1 which, as can be seen, is connected between the conventional high pass network 16 and the high frequency unit 13. Various forms of delay network can be used for this purpose, and that illustrated in detail in Figure 3 is merely exemplary.

The delay network shown in Figure 3 is a second order, all pass network, the choice of component values being dependent on the operational frequency range desired. These values can readily be calculated by well known electrical network analysis methods. The network has input terminals 20 receiving input from the high pass portion 16 of the network shown in Figure 2, and produces an output signal for the high frequency unit le at terminals 21.

CLAIMS

1. An acoustic transducer including two transducer units each covering a separate frequency band and receiving an amplified signal through an electrical filter to constitute a passive system, and in which a delay network is included in the path of the amplified signal to one of the units so as to introduce a delay such that the acoustic radiation from the two units appears to emanate from points in space situated in the same vertical plane.

2. An acoustic transducer according to claim 1 in which the transducer units are mounted in the same vertical plane.

3. An acoustic transducer according to claim 1 in which the transducer units form part of a common structure.

4. An acoustic transducer according to any one of the preceding claims in which the delay network is included in the signal to the higher frequency unit.

5. An acoustic transducer according to claim 1 including more than two transducer units and more than one delay network such that the acoustic radiation from all the units appears to emanate from points in space situated in the same vertical plane.

6. An acoustic transducer according to any one of the preceding claims in which the delay network is enclosed within the enclosure of the transducer.

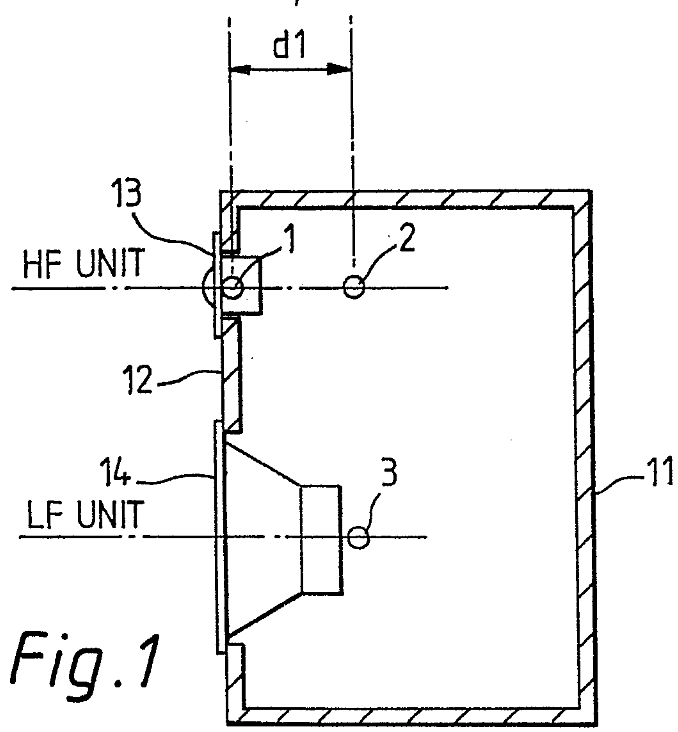

Fig.1

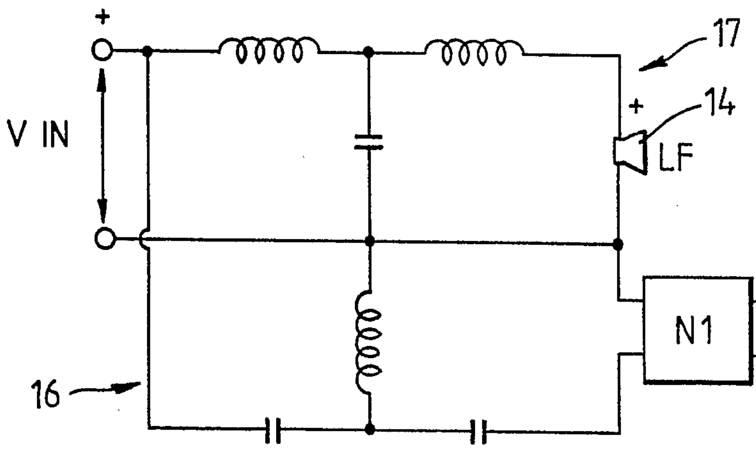

Fig.2

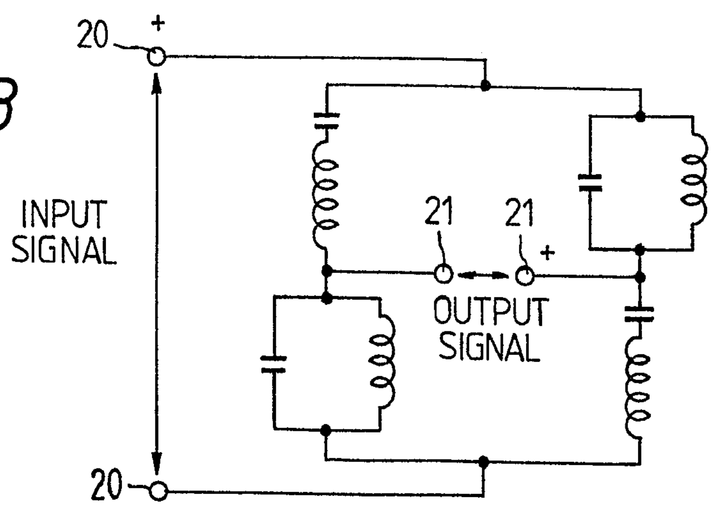

Fig.3