

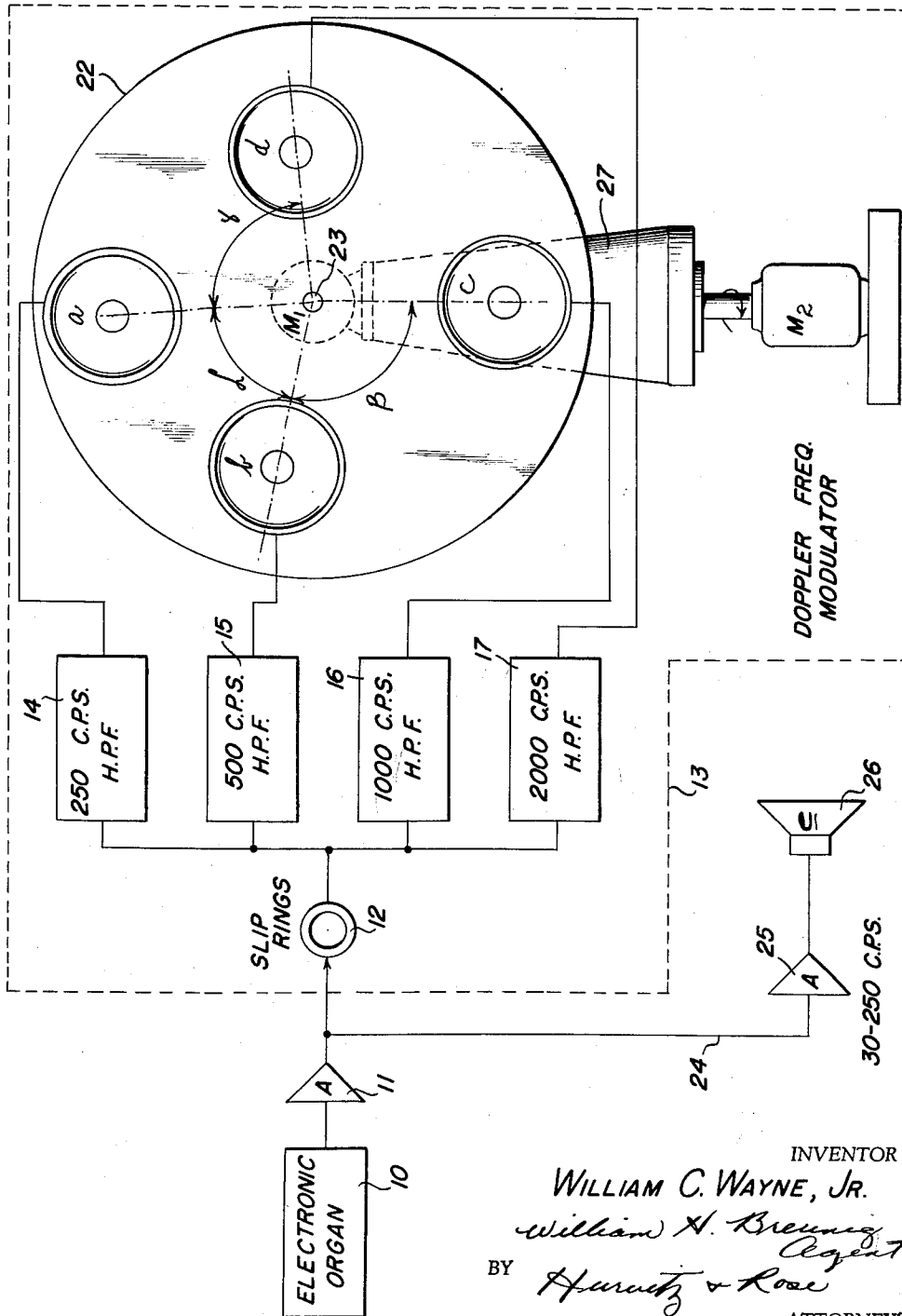
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SIMULATED MULTIPLE RATE GYRATING MODULATOR

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3,084,585 SIMULATED MULTIPLE RATE GYRATING MODULATOR

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The present invention relates generally to systems for achieving an ensemble effect in music by acoustically processing a band of audio frequencies, and more particularly by transducing the band of frequencies by means of a movable acoustic transducer system comprising plural transducers all rotating at the same speed, but to which are applied progressively increasing portions of the band so that the higher frequency portions of the band are transduced through a greater number of transducers and the lower frequency portions of the band through a smaller number of transducers.

The traditional pipe organ consists of many ranks of pipes which are invariably out of tune. Certain ranks of pipes, referred to as celestes, are purposely detuned by a considerable amount to produce a rich ensemble effect in the composite tone, which is especially desirable for use in ecclesiastical music. In my prior application for U.S. patent, 631,650 filed December 31, 1956, now Patent No. 3,004,460, I provided a system for electrically processing a musical frequency spectrum, from whatever source derived, so as to achieve a processed frequency spectrum which is capable of simulating the ensemble effect of pipe organs and more particularly the celeste effect and which is more flexible in respect to the variety of ensemble effects made available than is the traditional pipe organ.

In my prior application, I disclosed utilization of a plurality of wide band, single side band frequency shift modulators, each combined with a filter in a channel, and each channel serving to differently shift the frequency of a portion of an audio spectrum deriving from a musical instrument in such sense and degree as to provide the desired ensemble effect. The circuitry for accomplishing this objective is relatively simple and the system possesses the advantage that no moving mechanical parts are required.

It is well known to acoustically transduce audio spectra through a moving transducer, movement of the transducer being effected about a horizontal axis, so that the transducer points generally in a given direction at all times, but continually changes its position. This type of transduction achieves an apparent movement of the sound source about a room, and periodic frequency shifts due to Doppler effect, which is quite desirable. Doppler effect may be defined as that shift in frequency which occurs when a sound source moves relative to a stationary observer, the direction of frequency shift being upwards when the source approaches the observer. However, the system is objectionable in some degree for achieving ensemble effect because an obvious periodicity of motion of the transducer is involved.

It is also known to apply an audio spectrum to a horn rotating about a vertical axis, to achieve acoustic dispersion of sound, and more particularly it is known to transduce tones of different nomenclature via different rotating horns. Such systems are effective in enhancing musical effect, but may be objectionable in that they introduce periodicities of sound intensities, which may become obtrusive after a long period of listening.

It is an object of the present invention to provide transduction of audio acoustical energy, by means of plural transducers, preferably mounted on a baffle so that all move at the same speed about a common axis, in which a

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wide band audio spectrum is applied to the separate transducers via high pass filters having different cut off points. The cut off points may be harmonically related if desired, although this is not essential. To provide a specific example, without intending any limitation thereby, four transducers may be employed, the first of which may be supplied with a wide audio band representing music via a high pass filter having a cut off point at 250 c.p.s., the second via a high pass filter having a cut off point at 500 c.p.s., the third via a high pass filter having a cut off point at 1 kc., and the fourth via a high pass filter having a cut off point at 2 kc. Thereby the first speaker provides a Doppler frequency shift only for that portion of the audio band which extends above 250 c.p.s., at a rate equal to the rotation rate of the baffle. The second speaker, moreover, also supplies a frequency shift for the portion of the audio band extending upwardly of 500 c.p.s. The speakers together thus produce a Doppler frequency shift at twice the baffle rotation rate for frequencies above 500 c.p.s., but not for frequencies in the range 250 c.p.s. to 500 c.p.s. The third speaker then supplies a Doppler frequency shift for input frequencies extending above 1000 c.p.s. which, in combination with the first two speakers, occurs at a repetition rate equal to three times the rotational rate of the baffle. The last transducer, supplied via a 2000 c.p.s. high pass filter, produces Doppler frequency shift for the band above 2000 c.p.s., which occurs at a repetition rate equal to four times the baffle rotational rate when the outputs of all four transducers are considered in combination.

A modulation rate is thus introduced for different sub-bands of an audio band, which is proportional or approximately proportional to the center frequency of the sub-band. An analogous principle is utilized in the above identified application. In accordance with the present invention, however, the modulation is accomplished acoustically by means of moving transducers and the modulation rate is a function of or directly proportional to, the total number of transducers which simultaneously transduce any given sub-band.

A suitable rate of rotation for the transducer baffle is 1 r.p.s. with transducers positioned on a two-foot radius about the axis of rotation.

A separate speaker system which is stationary, may be utilized to radiate frequencies extending from the lower edge of the audio band, i.e., about 30 c.p.s. to the cut off point of the lowermost high pass filter, i.e., 250 c.p.s. in the above provided example.

Denominating the four speakers as *a*, *b*, *c* and *d* and the stationary speaker as *e*, the net effect of the system is to radiate frequencies from 30 c.p.s. to 250 c.p.s. without modulation from speaker *e*, to radiate all frequencies from 250 c.p.s. up from speaker *a*, effecting a modulation of 1 c.p.s. via that speaker, to radiate via speaker *b* all frequencies above 500 c.p.s., to radiate via speaker *c* all frequencies above 1 kc. and via speaker *d* all frequencies above 2 kc. In effect, the band from 500 c.p.s. to 1 kc. is modulated twice per second, despite the 1 c.p.s. rotation rate of the baffle, since radiation in this band occurs from two speakers *a* and *b*. Similarly, the band from 1 to 2 kc. has a component of modulation at 3 c.p.s., since this band is radiated by three speakers. The band above 2 kc., radiated by all four speakers, has a component of modulation at 4 c.p.s. By this means, input signal frequencies are modulated at rates appropriate to their positions on the frequency scale.

In addition to the primary features above described, however, the speakers may be non-uniformly positioned about the axis of rotation, which may introduce further complexity, and the latter may be enhanced by increasing the irregularity of speaker arrangement. Such irregu-

larity may be accomplished by utilizing unequal radii for the several speakers, or by utilizing unequal angular spacing therebetween, or by combinations of these. Further interest may be added by rotating the whole assembly about a vertical axis at about 0.1 r.p.s. in order that directivity patterns of the transducers change in time in this dimension also.

It is, accordingly, a broad object of the invention to provide a novel electro-acoustic modulator.

It is another object of the invention to provide a system for generating ensemble effects for electronic organs in which sub-bands of an audio spectrum representing organ music are differently modulated acoustically.

A further object of the invention resides in the provision of a system for acoustically modulating an audio spectrum to provide a chorus effect by channelling different sub-bands of the audio spectrum to separate gyrating acoustic transducers by means of high pass filters having different cut off points.

It is still another object of the invention to provide a system for generating chorus effects in electronic organ music by transducing separate sub-bands of an audio spectrum representing the organ music by means of separate acoustic transducers, the acoustic transducers being all rotated at the same speed about a common axis, but being supplied with audio energy via high pass filters having different cut off points, so that the higher frequency portions of the audio band are subjected to greater modulation frequencies by virtue of their transduction through greater numbers of moving transducers.

Still a further object of the invention resides in the provision of chorus effect for audio spectra by acoustically introducing complex phase and amplitude modulation of radiated acoustic energy at rates approximately proportional to the frequency of the energy.

It is still another object of the present invention to provide an acoustic transducing system including plural speakers rotated about a common axis, in which the speakers are non-symmetrically located with respect to the axis, either in respect to angular separations of the speakers, or radial distances of the speakers from the axis of rotation, or both.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of one specific embodiment thereof, especially when taken in conjunction with the accompanying drawings, wherein the single FIGURE of the drawings is a schematic representation primarily in terms of functional block diagram of a preferred embodiment of the present invention.

Referring now more specifically to the accompanying drawings, the reference numeral 19 denotes an electronic organ, which provides a wide band audio spectrum representing organ music. The audio spectrum provided by the source 10 is amplified in the power amplifier 11 and then supplied via slip rings 12 to an acoustic modulator, generally indicated by the reference numeral 13. The latter includes, in accordance with the present invention four filters, each of the high pass type. The filter 14 has a preferred cut off point at 250 c.p.s. The filter 15 has a preferred cut off point at 500 c.p.s. The filter 16 has a preferred cut off point at 1,000 c.p.s. and the filter 17 has a preferred cut off point at 2,000 c.p.s. The frequencies selected are in a measure arbitrary, although they approximate the values which are desirable in processing organ music.

Four acoustic transducers are provided, taking the form of speakers. These are identified respectively by the reference letters *a*, *b*, *c* and *d* speakers. The *a* speaker is coupled to the output of the high pass filter 14, the *b* speaker to the output of the high pass filter 15, the *c* speaker to the output of the high pass filter 16 and the *d* speaker to the output of the high pass

filter 17. The speakers *a*, *b*, *c* and *d* are mounted on a circular supporting baffle 22 which is rotated about a horizontal axis 23 by means of a suitable motor *M*₁, and the filters 14 to 17 may be preferably carried by the same plate in a physical embodiment of the invention in order that only two slip rings 12 be required.

The *a*, *b*, *c*, and *d* speakers are preferably not symmetrically placed in respect to the horizontal axis of rotation 23. So for example, the angle of separation α of the speakers *a* and *b* may be less than the angle β between *b* and *c*, and the angular separation γ of the speakers *a* and *d* may be less than that between *b* and *c*. Moreover, the radial displacements of the speakers from the axis of rotation of baffle 22 may be different, i.e., the *c* speaker may be at a greater radial distance than the *b* speaker, etc. In general, a relatively irregular arrangement of radii and angular separations is preferred, in order to introduce more complex character into the modulated or processed tones. On the other hand the system may be practiced with the speakers symmetrically placed, or with random or systematic selection of radii alone, or with random or systematic variation of angular separation alone, the radii remaining constant. The rate of rotation of the mounting plate 22 may preferably be 1 c.p.s.

In addition to the acoustic energy radiated by the *a*, *b*, *c* and *d* speakers, further acoustic energy may be radiated via a separate channel 24, which supplies an amplifier 25 and a speaker 26 in cascade. The amplifier 25 is illustrated as passing the band 30 to 250 c.p.s., i.e., as providing acoustic energy at frequencies lower than is provided by the modulator 13. However, if desired, the amplifier 25 may be wide band, and the speaker 26 may radiate the entire acoustic band supplied by the electronic organ 10 or any part thereof.

In operation, the audio band above 250 c.p.s. is radiated by the *a* speaker, the audio band above 500 c.p.s. by the *b* speaker, the audio band above 1,000 c.p.s. by the *c* speaker, and the audio band above 2,000 c.p.s. by the *d* speaker. By reason of the differences in physical locations of the *a*, *b*, *c* and *d* speakers, and further by reason of their preferred asymmetric relative positions, each speaker introduces a relatively irregular modulation of the audio sub-band radiated by it. However, the sub-band extending from 250 to 500 c.p.s. is radiated only by the *a* speaker, since the filters 15 and 16 and 17 are high pass filters with cut offs at or above 500 c.p.s. The band from 500 to 1,000 c.p.s. is radiated by the *a* speaker and by the *b* speaker, but only by these two, since the high pass filters 16 and 17 cut off at 1,000 c.p.s. or above. The band of frequencies from 1,000 to 2,000 c.p.s. is radiated by each of *a*, *b* and *c* speakers, but not by the *d* speaker, since the filter 17 cuts off at 2,000 c.p.s. The band above 2,000 c.p.s. is radiated by all the speakers *a*, *b*, *c* and *d*. It follows that the band 250 to 500 c.p.s. is modulated once per second, i.e., at the rate of rotation of the baffle 22, since this band is radiated by only a single one of the speakers. The band from 250 to 500 c.p.s. is modulated twice per second since the radiation of this band occurs from two speakers, *a* and *b*. The band from 1 to 2 kc. is modulated at 3 c.p.s. since it is radiated by three speakers, and the remainder of the band, i.e., the band above 2 kc., is modulated at 4 c.p.s., since radiation of this portion of the audio spectrum occurs from all of the speakers. There is thus achieved a proportion, at least roughly, between the frequency being radiated and the rate of modulation. In addition, there is achieved a randomness of modulation which is musically very pleasing. Transitions from one band or group of speakers to another are smooth since practical filters cut off somewhat gradually. The filter skirts overlap and thereby assure a gradual change from one modulation

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rate to another as the musician plays through a complete chromatic scale.

Considering the effect of the system on a single complex tone, played by depressing a single key of an organ, different partials of the tone will be modulated at different frequencies, in general, and the higher partials at the higher frequencies.

The baffle 22 and its motor M_1 may be mounted on a vertical standard 27, which may be rotated about a vertical axis by motor M_2 at a rate of 0.1 r.p.s. The directivity patterns of the speakers 18-21, incl., are thereby caused to vary about a vertical axis, to introduce further musical interest into the radiated acoustic energy. If desired, either motor M_1 or motor M_2 may be de-energized, while the other remains operative.

While I have described and illustrated one specific embodiment of my invention, it will be clear that variations of the details of construction which are specifically illustrated and described may be resorted to without departing from the true spirit and scope of the invention as defined in the appended claims.

What I claim is:

1. A device comprising a source of frequencies within the audio range, at least two channels connected to said source, a high pass filter in each channel, each filter having a radically different cut-off frequency, each of said channels having an acoustic transducer, said transducers being movable about at least one axis to produce a Doppler effect.

2. The combination according to claim 1, wherein said at least two channels are four channels.

3. The combination according to claim 1, wherein said cut-off frequencies are at least approximately octave-related.

4. The combination according to claim 1, wherein said transducers are movable about two axes simultaneously.

5. The combination according to claim 1, wherein said

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at least one axis is at least approximately horizontal and said transducers radiate at least approximately horizontally and have directional radiation patterns.

6. The combination according to claim 1 wherein said transducers are mounted on a baffle rotating about at least approximately a horizontal axis.

7. The combination according to claim 1 wherein said transducers are mounted on a baffle rotating about at least approximately a horizontal axis, and wherein said transducers are asymmetrically placed about said baffle.

8. The combination according to claim 1 wherein said transducers are mounted on a baffle rotating about at least approximately a horizontal axis, wherein said transducers are asymmetrically placed about said baffle, and wherein said baffle as a whole is rotating about at least approximately a vertical axis.

9. The combination according to claim 1 wherein said source of frequencies within the audio range is an electronic organ.

10. A system comprising an electronic organ providing frequencies within the audio range, a plurality of channels connected in parallel to said electronic organ, each of said channels including a high pass filter, the separate filters having radically different cut-off frequencies, an acoustic transducer coupled to each of said channels, and means moving said transducers about at least one axis to produce a Doppler effect.

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