Aug. 16, 1966 H. HURVITZ 3,267,198

MUSIC ENHANCEMENT

Filed March 4, 1964 2 Sheets-Sheet 1

FIG. 1

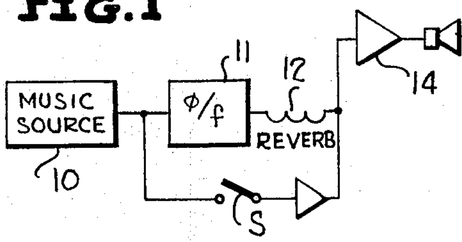


FIG. 2

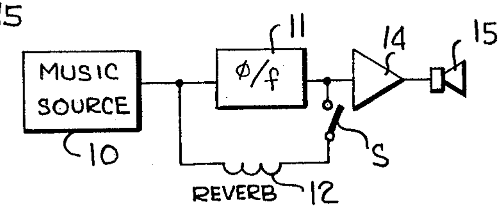


FIG. 3

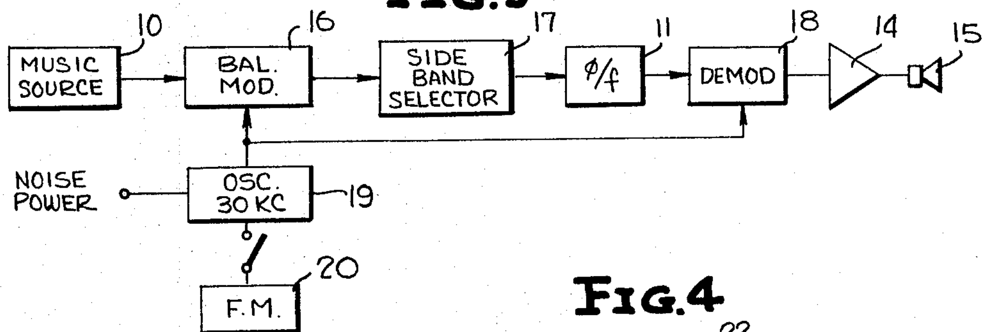
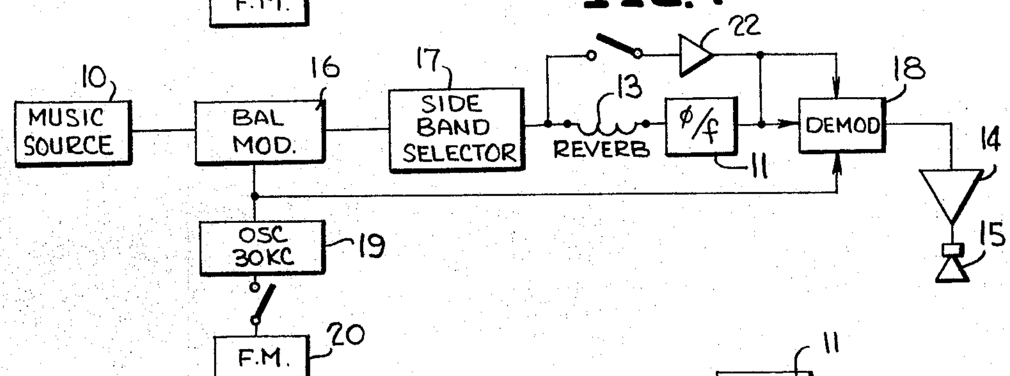


FIG. 4



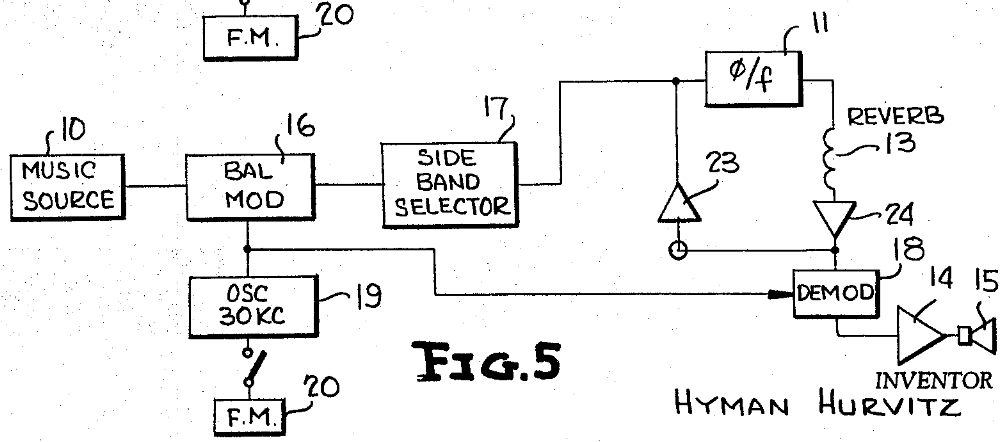


FIG. 5

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MUSIC ENHANCEMENT

Filed March 4, 1964 2 Sheets-Sheet 2

FIG. 6

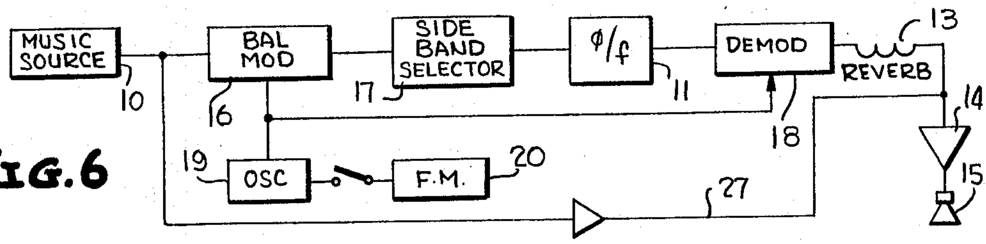


FIG. 7

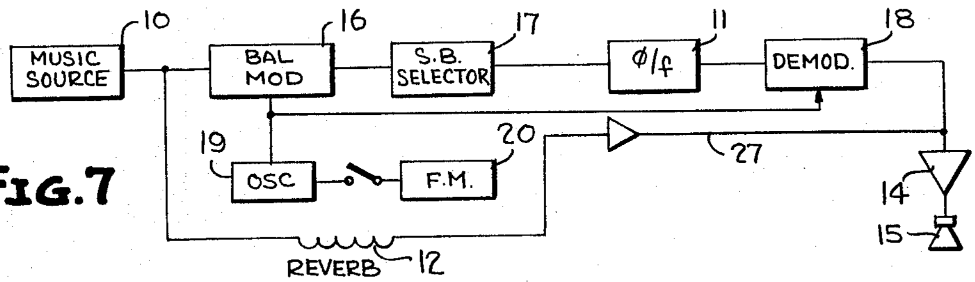


FIG. 8

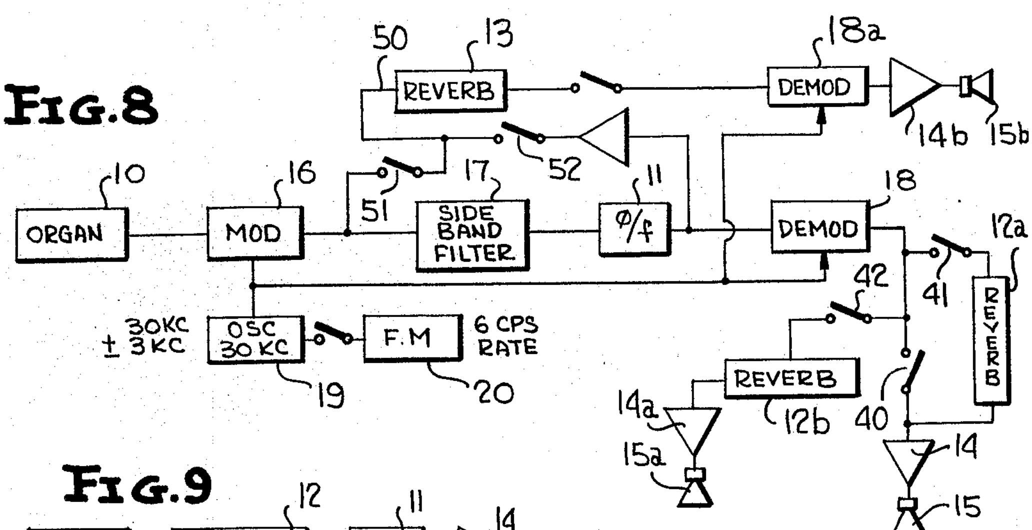


FIG. 9

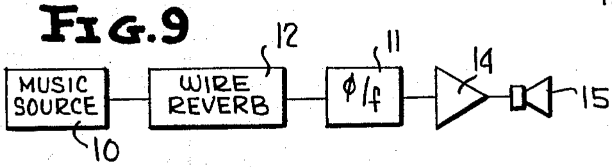
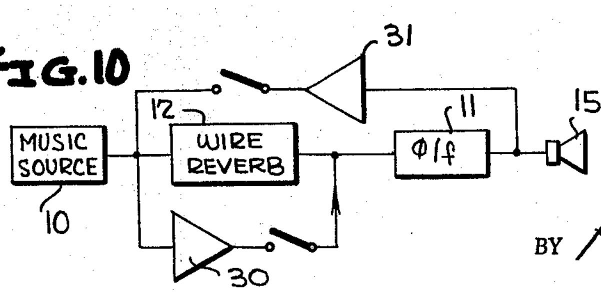


FIG. 10



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United States Patent Office

3,267,198

Patented August 16, 1966

3,267,198

MUSIC ENHANCEMENT

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Filed Mar. 4, 1964, Ser. No. 349,388

13 Claims. (Cl. 84—1.24)

The present invention relates generally to systems for enhancing the output of an electric organ system, and more particularly to such systems for imparting random phase relationships among the partials of the gamut of the tones and frequencies of an organ output, for imparting vibrato modulation to the output, for reducing the effect of resonance due to inclusion of a long line or other reverberator in the output of the organ, and for obtaining all these effects simultaneously by cooperating devices having simultaneous application to all the results.

A crucial concept involved is that of heterodyning the output of an organ, or other musical source, to a supersonic side-band, thereafter passing the supersonic side-band through a static circuit which shifts phase as a function of frequency, and thereafter heterodyning the supersonic side-band back to its original value. The heterodyning oscillator (or oscillators) may be frequency modulated over a fairly wide band, at a vibrato rate, in response to noise, or slowly and sinusoidally. The effect of such modulation is to continuously vary the phase relations among the partials of the music. Additionally, the rate of change of phase provides a frequency shift, so that the output sound frequencies vary at vibrato rate and are not constant in frequency while variable in phase. The frequency deviation can be adjusted by adjusting the slope of the ϕ/f filter, or the deviation of the oscillator, or both, but, inherently, higher frequencies may be deviated more than lower, even within the same complex tone.

In applying reverberators to organ outputs, these may be available in supersonic form, and may have been heterodyned to supersonic frequency for extraneous purposes, and in such case the required heterodyning facilities are already available for use in the present systems. However, in addition, the continuous change of frequency results in elimination of the audible effects of resonances due to the reverberator. This in turn implies that, where vibrato is not desired, or where the reverberator is to operate at audio frequency, as in the well known Hammond device, due to the frequency shifts and ϕ shifts which take place in the output of the present system, even if the heterodyne oscillator is varied only slightly in frequency, or at a rate far below the vibrato rate, resonances in the reverberator are masked to considerable extent. This occurs also in part because the ϕ/f circuit introduces delay in its own account, superposed on the delay of the reverberator, and this delay is a function of frequency, i.e. the network is dispersive. This implies that, in the present system, a single spring audio reverberator can be employed whereas Hammond (Meinema Patent #2,982,-819) requires two or three springs of different effective lengths to mask resonances.

Further, as explained in Kahn, U.S. Patent #3,060,389, the use of a suitable ϕ/f network can symmetrize the output band, i.e. eliminate peaks of signals due to phase addition of frequencies. This is particularly important in phase locked organs, i.e. those utilizing divider chains as tone generators, where many such peaks can occur. It is also of importance in a spring reverberative system wherein the driver of the reverberator cannot readily respond to such peaks, if the driver is economically designed.

The supersonic wire reverberator, developed by Baldwin Co., has advantages over the audio wire reverberator, but these may be overshadowed by increased costs. The increased costs derive only from the heterodyning requirements, because supersonic reverberators require only one spring and are relatively free of noise and effects of external vibration, whereas audio reverberators require multiple springs and special provision for eliminating effects of external vibration. This difficulty is overcome, according to the present system, in that a need for the heterodyning circuits exists in any event, and apart from the supersonic reverberator. But, if an audio wire reverberator is employed, having only one spring, slow (1 c.p.s.) frequency phase and delay variations, in the output of the system, as a function of frequency, mask the effect of wire resonances because of the continuous variation of the signal information. The resonances in reverberators occur at sub-sonic frequency separations and hence are most serious for low frequencies, and despite introduction of chorus effect into the music. In supersonic reverberators the frequency swings of the heterodyne oscillators can extend over thousands of cycles, to mask the resonances. Audio frequencies cannot be deviated to this extent. One effective way of masking resonances is to combine the reverberator output with the original or direct output, and this effect is enhanced by the ϕ/f network which reduces ϕ cancellation of the same frequencies deriving from the direct and reverberated channels.

Bode, who appears to have invented the ϕ/f network, was concerned with obtaining a linear variation of phase with frequency. Random variation also has its place, particularly in the music art. Assume, for example, that the Bode filter is designed to have a slope as a function of frequency that has as many variations of slope as possible. In such case, and employing a heterodyne system in which an audio band is heterodyned up to a supersonic band passed through the filter, and then heterodyned down to audio, the heterodyned steps being accomplished by a frequency modulated oscillator, then the new audio band will have residual variations of frequency due to the filter, equal at each frequency to the slope of the ϕ/f filter for that frequency, at that time, recalling that the band is sweeping. Hence each partial would be subjected to random frequency modulation.

It is, accordingly, an object of the present invention to provide a system for randomizing phase relations among the tone frequencies of an electrical music system.

It is a further object of the invention to provide vibrato modulation in the output of a musical instrument.

It is still another object of the invention to provide a phase randomized vibrato modulation of electrical music tones.

It is still another object of the invention to provide a dispersive reverberator network.

Another object of the invention resides in the provision of novel reverberators having minimum resonance effects.

A further object of the invention is to provide means for removing peaks of energy from organ music, and particularly from reverberated organ music, by introducing a circuit at the input, or output, or both, of the reverberator which has a phase delay and time delay variable as a function of frequency.

A further object of the invention is to provide circuitry for permitting electrical combination of reverberated and unreverberated signals, without appreciable phase cancellation.

Still another object of the invention is to provide a system for randomizing phase, amplitude and frequency, of an audio signal, as a function of time.

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:

FIGURE 1 is a block diagram of a modification of the invention having a dispersive reverberator;

FIGURE 2 is a block diagram of a modification of the system of FIGURE 1;

FIGURE 3 is a block diagram of a supersonic phase randomized music system;

FIGURE 4 is a block diagram of a modification of the system of FIGURE 3 employing a supersonic reverberator;

FIGURE 5 is a block diagram of a modification of the system of FIGURE 4;

FIGURES 6 and 7 are block diagrams of further modification of the system of FIGURE 5; and

FIGURES 8, 9 and 10 are block diagrams of variant audio systems employing wire reverberations and phase-frequency systems.

In the drawings, generally, **10** is a source of music, i.e. an electric organ, or a microphone, or a phonograph or tape recorder, or generally a transducer which produces a band of tone frequencies. **11** is a passive circuit of the Bode type (U.S. Patent #1,828,454) which provides a phase shift which is a preselected function of frequency, including linear and non-linear, of large slope but of flat amplitude characteristic, hereinafter called an ϕ/f filter. **12** is a wire reverberator of the audio type and **13** of the supersonic type. **14** are amplifiers and **15** speakers. **16** are balanced amplitude modulators, **17** single side band filters, **18** heterodyne demodulators, and **19** heterodyne oscillators, **20** frequency modulators for the oscillators **19**.

FIGURE 1

Music source **10** supplies tone signal in cascade to ϕ/f filter **11**, audio wire reverberator **12**, amplifier **14** and speaker **15**. A parallel path exists at will, via switch S, from source **10** to amplifier **14**. With switch S open, ϕ/f filter disperses the phases and time delays of the tone signal frequencies widely, while **12** produces a fairly uniform delay, but has resonances spaced apart sub-sonically. The signal applied to the delay line **12** is then symmetrical (U.S. Patent #3,060,389 to Kahn), and the overall effect is that of a dispersive reverberator. This is particularly valuable if **10** is an organ having phase locked tone generators, since the phases become dispersed, i.e. each frequency has a different delay time and phase, and phase delay per octave can be a random number, i.e. 27°, so that no two partials of a phase locked set of oscillators will ever coincide in phase.

If switch S is closed the reverberated and unreverberated signals add, but there is never complete phase cancellation for more than one partial of notes of any single nomenclature, because one path to amplifier **14** is dispersive and the other is not.

FIGURE 2

FIGURE 2 is generally like FIGURE 1, and has its advantages, but the fact that reverberator **12** is in parallel with ϕ/f filter **11** implies that the two inputs to amplifier **14** are attenuated more or less alike, whereas in FIGURE 1 the direct channel via switch S has no attenuation and the other channel has double attenuation.

FIGURE 3

The audio signal supplied by music source **10** is heterodyned to supersonic value in balanced modulator **16**, which is supplied with a frequency modulated oscillator. The supersonic frequency band can be varied at vibrato rate over a wide deviation, i.e. several kc. When this frequency modulated wave is treated by ϕ/f filter **11** the result is a varying phase superposed on a fixed phase separation among all the frequencies of the supersonic band. These are retained at the output of the modulator, so that the sound acoustically radiated by speaker **15** is provided with vibrato and also phase randomized by the noise power of oscillator **19**.

FIGURE 4

FIGURE 4 is essentially FIGURE 3 with a wire reverberator **13** added directly in series with ϕ/f network **11**. The ϕ/f network provides a dispersive reverberative characteristic, when taken in conjunction with the reverberator, which at least approximately has a fixed ϕ/f characteristic. Unreverberated signal can be added electrically to the output by channel **22** if desired, whereupon the phase cancellations usually produced by such addition are eliminated by the different phase shift characteristics of **11** plus **13**, as against **22**, i.e. if cancellation occurs for one partial of a tone all other partials will fail to cancel.

FIGURE 5

The system of FIGURE 5 follows that of FIGURE 4 except in that supersonic feed-back occurs from the output of reverberator **13** to the input of ϕ/f network **11**, via amplifier **23**. Amplifier **24** is used for isolation and amplifier **23** is low gain, i.e. less than 1 (cathode follower). By virtue of this feed-back, phase separations caused by ϕ/f network are increased, yet possibility of complete cancellation of more than an occasional partial does not exist.

FIGURE 6

This figure is similar to FIGURE 4, exept that the unreverberated sound is added to the output directly as audio, via channel **27**.

FIGURE 7

In this figure, compared with FIGURE 6, the supersonic reverberator **13** is removed and an audio reverberator **12** included in channel **27**.

FIGURE 9

This figure employs a music source, subject to reverberation in wire reverberator **12** and to ϕ/f randomizing in network **11**. The ϕ/f network **11** smooths out peaks of signal which occur in the output of reverberator **12**, and randomize phase of output of the music source. This is particularly valuable if **10** is a phase locked organ system, like the Orgasonic (Baldwin). The positions of **11** and **12** may be interchanged, to eliminate power peaks at the input of the reverberator.

FIGURE 10

This system is FIGURE 8 with addition of unreverberated signal via amplifier **30**, at will, to the audio output, and with audio feedback from the output of ϕ/f network **11** to the input of wire reverberator **12**, via amplifier **31**, at will. The feed-back amplifier **31** should have a gain of less than 1, to avoid danger of oscillation, but danger of phase cancellation of more than one partial of a complex tone is also removed by the ϕ/f network **11**. The latter also smooths out power peaks caused by the reverberator and randomizes the output phases of the music source, if a phase locked source is employed.

Where wide frequency deviations are employed, yet the audio band being processed includes low frequencies, say to 16 c.p.s., use of a single frequency conversion is inadequate to separate out single side bands, while permitting the frequency modulation. Double conversion may then be resorted to.

The output of music source **10** may inherently include vibrato or other modulation, i.e. tremolo, noise, etc. The heterodyne oscillators may be powered or biased by a noise source, in each of the figures containing a heterodyne oscillator, so that random variations of frequency and amplitude occur. These are communicated to the audio tones, in which also occurs noise randomization of phase, due to the presence of the ϕ/f network.

If the ϕ/f network has a ϕ/f characteristic providing a given phase shift per octave, rather than a linear characteristic, then phase shift is percentagewise, i.e. a 10% shift, for example can occur at 100 c.p.s. and at 5,000 c.p.s. That this is feasible is indicated by U.S. Patent #3,060,389 to Kahn, or by Lundry #2,859,414, particularly FIGURE 14. The Kahn circuit is particularly adapted to eliminating power peaks in audio circuits, and is for that purpose. It provides an inverse delay with frequency, i.e. higher frequencies are delayed less than lower frequencies. But phase shift is greater as a direct function of frequency. These characteristics are by no means inconsistent, since 2π radians at 1000 c.p.s. obviously involves less time than 2π radians at 100 c.p.s. by a factor of 10. Where the input to the Kahn network is frequency modulated, these characteristics oppose one another in producing frequency modulated outputs. But, frequency modulation due to phase delay is a function of slope of the phase delay curve, whereas frequency shift due to time delay is not.

As stated in the Kahn patent the network can be disposed to provide increased time delay with increasing frequency, if desired.

It is also clear that any time delay between modulator and demodulator, for example in FIGURES 3 to 8 inclusive, which is not compensated, will result in a change of output frequency at the speaker. This change is random, if oscillator **19** is randomly modulated, as by the noise source power supply. Hence, the system of FIGURE 3, for example, provides randomized phase, frequency and amplitude of output, and the phase and frequency variations can be arranged proportional to audio frequency by selecting ϕ/f network **11** to have a rising time delay and a rising phase delay slope as a function of frequency, and properly selecting the slope. This improvement obviously extends to each of FIGURES 3–8, if noise B+ is used for the local oscillator, and without requiring a frequency modulator.

In FIGURE 8, the output of organ **10** is applied to heterodyne modulator **16**, which is also supplied with output from oscillator **19**, say at 30 kc. The latter may be frequency modulated by modulator **20**, say at ±3 kc. deviation and at 6 c.p.s. rate.

One side band is selected by filter **17**. As in FIGURES 3 to 7, the filter **17** cannot always select only one sideband, due to the frequency modulation, if used, but this does not detract from the operation. So, the filter may have a pass band of 27–40 kc. Of course, if no F.M. is employed, a pass band of 30–40 kc. may be used.

The selected side band is phase dispersed by ϕ/f circuit **11**, and thereafter the audio is reconstituted by demodulator **18**. The audio may be radiated by speaker **15**, if switch **40** alone is closed; or via reverberator **13**, if switch **41** alone is closed. Or, switches **40** and **42** may be closed to provide pseudo stereo, via speakers **15** and **15*a***. Or, switches **41** and **42** may be closed.

A supersonic reverberator **13** may be applied in a separate channel **50**, having its own demodulator **18*a***, and speaker **15*b***. The input to reverberator **13** may be directly applied via switch **51**, or following ϕ/f filter **11**, via switch **52**.

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 music system, comprising a source of a band of tone signal, means for heterodyning said band of tone signal to a supersonic band, means for imparting to said supersonic band a variation of frequency, said last means comprising a circuit having substantially uniform amplitude versus frequency characteristic and a large shift of phase versus frequency, whereby shifts of frequency and relative phase with frequency occur in said supersonic band corresponding with said variation of frequency, and means for heterodyning the frequency varied supersonic

band to an audio band of tone signal, whereby phases of the band of tone signals are randomized, and amplitude peaks are eliminated in said band of tone signals.

2. The combination according to claim **1** wherein the rate of frequency variation is a vibrato rate.

3. In an organ system having a phase locked array of oscillators for generating tones of a single nomenclature, means for displacing the relative phases of the partials of said tones comprising a passive circuit having a transfer characteristic as a function of frequency for said tones which is flat for amplitude and sloping for phase.

4. In a music system, a source of complex tone signal, a wire reverberator having an input and an output, means connecting said source to said input, a passive circuit having a transfer characteristic as a function of frequency which is flat for amplitude and sloping for phase, means connecting said passive circuit in cascade with said wire reverberator to displace the phases of said complex tone signals.

5. In a music system, a source of a band of tone frequencies, a filter having a uniform attenuation characteristic as a function of frequency and a phase shift increasing continuously as a function of frequency over said band of tone frequencies, means for passing said band of tone frequencies through said filter, and a loudspeaker coupled to the output of said filter.

6. In a music system, an electric organ, an audio wire reverberator connected in cascade with said electric organ, a filter having a uniform attenuation characteristic as a function of frequency and a phase shift continuously increasing as a function of frequency connected in series with said audio wire reverberator, and a loudspeaker connected in series with said filter.

7. The combination according to claim **6** wherein is provided a feed-back path around said filter and said reverberator.

8. In a system for frequency modulating a band of frequencies, a filter having a pass band including a monotonic slope of phase as a function of frequency and a flat amplitude versus frequency characteristic, means for sweeping said band of frequencies with respect to said pass band.

9. In a system of frequency modulation of a band of audio frequencies, means for heterodyning said band of audio frequencies to a supersonic band of frequencies, said means including a heterodyne oscillator, means for varying the relative phases of the frequency components of said supersonic band of frequencies as a function of time, and means for heterodyning the phase varied frequency components to an audio frequency band, said last means comprising said heterodyne oscillator.

10. In a music system, a dispersive wire reverberator means having an input and output, a source of music connected to said input, a speaker connected to said output.

11. A music system according to claim **10** wherein is provided an unreverberated audio channel connecting said source of music and said speaker in shunt to said dispersive wire reverberator means.

12. In a music system, a filter having a flat frequency response with frequency and a monotonic phase shift as a function of frequency, a wire reverberator connected in parallel with said filter.

13. In a music system, a dispersive reverberator including a wire reverberator and a filter in series with said wire reverberator, said filter having a flat amplitude response with frequency and a monotonic variation of phase with frequency.

No references cited.

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