This application is related in subject matter to a copending application of Brombaugh et al., Ser. No. 132,418, filed Aug. 18, 1961, now Patent No. 3,246,264 and assigned to the assignee of the present application.

This application is related in subject matter to a copending application of Bissonette et al., Ser. No. 102,443, filed Apr. 12, 1961, now Patent No. 3,158,853, entitled, Music Enhancing System, assigned to the assignee of the present application.

The present invention relates generally to systems for producing reverberation artificially at ultrasonic frequencies, and more particularly to systems utilizing a reverberatory unit capable of improving the quality of sound by superimposing thereon both reverberatory and chorus effects, the reverberatory unit including a long ultrasonic delay line.

It has long been known in the art of sound generation and reproduction, and more particularly in the art of electronic organs and electronic music production, that improvement in the quality of sound generated by such instruments may be attained by introducing reverberation artificially. It has also been long known that the tonal qualities of electronic musical instruments, such as electronic organs, may be improved by processing the tones generated directly by the instruments, by adding chorus effect thereto. The desirability of adding chorus effect to electronic organ tones in particular, may derive in part from the lack of randomness in the output of some types of organs and the chorus effect may involve the generation of new frequencies or the continuous or random modification of the relative phases and/or amplitudes of the normal frequency components of the tones as produced directly by the instruments.

Elongated helical spring devices have been utilized for introducing reverberatory effects, but these have always hitherto been operative in the audio frequency range. Such springs have been vibrated or driven in various modes, and more particularly in the longitudinal, the transverse and the torsional modes, design formulas for devices operating in such modes being provided in the U.S. Patent to Wegel 1,852,795. Such helical spring delay devices have been found to have considerable flutter, and accordingly, in practice reverberatory devices utilizing helical springs have required a plurality of such springs of different length, all operated in parallel. It is characteristic of such springs that they have high attenuations at the high audio frequencies, and furthermore it is extremely difficult to drive such springs uniformly over the required number of octaves, so that audio frequency reverberative devices consisting essentially of one or more helical spring delay lines have frequency characteristics that are hard to compensate for.

As a further difficulty, audio frequency delay lines employed in reverberatory devices possess the basic defect that any mechanical disturbance of the springs results in generation of signals which fall within the same audio frequency band as the desired tonal signals, and which consequently cannot be reduced by filtering. On a theoretical basis it might appear that the noise can be eliminated by vibrating the helical springs torsionally in response to the desired signal, since the disturbances are not normally torsional. Nevertheless, limitations in practical designs of transducers and the random character of perturbations radically reduce the improvements which may be attained by this expedient.

While the recited properties of audio frequency delay lines in the form of helical springs have not destroyed their usefulness as reverberatory devices, and while quite adequate delay lines have been achievable by means of relatively small springs, such reverberatory devices have not been wholly successful in improving the tonal quality of electronic organs or other musical instruments, because of the limitations inherent in helical springs as audio frequency mechanical transmission lines.

In summary, then, audio frequency spring reverberators are limited in usefulness by their poor frequency characteristics, by difficulties in achieving a drive over the required number of octaves, and by their susceptibility to mechanical noise or perturbations.

According to the present invention an audio frequency band representative of music, such as may, for example, be derived from a conventional electronic organ, is converted to an ultrasonic band and the latter subject to reverberatory delays in a helical wire delay device. The direct output of the reverberatory device may then be filtered to remove audio frequencies, thereby eliminating substantially all direct signals due to mechanical audio frequency disturbances of the helical spring. The ultrasonic band of frequencies may be converted to an audio frequency band and the converted band of signals may be electro-acoustically transduced.

The general concept of generating reverberations at ultrasonic frequencies is known to the art, being disclosed, for example, in U.S. Patent No. 2,518,177 to William B. Phelps, and in U.S. Patent No. 2,421,424 to Donald Krueger. However, devices of the latter type have not herefore utilized long helical wire springs as delay devices. One reason for this failure has been that the design formulas provided as disclosed on the Wegel patent, hereinabove referred to, and similar design formulas available from other sources, have appeared to indicate that helical wire delay lines are almost totally ineffective at ultrasonic frequencies, both because of the large attenuations involved in traveling along the delay line at these frequencies, and also because of the short total pulse travel time achievable for a given spring because of the increased velocity of travel of the vibrations at the higher frequencies. Reverberation times of the order of 1 to 3 seconds are required in order to achieve satisfactory musical effects, and while these have been readily achieved at audio frequencies, they have been very difficult to achieve at ultrasonic frequencies when designs were attempted based on the Wegel formulas, and also on the basis of results attained empirically.

The value of a helical wire spring as a reverberatory delay device appears, to the best of my knowledge, to derive from utilization of a type of vibration which is foreign to any of those discussed in the Wegel patent. It appears that the vibrations which are induced in these helical springs exist primarily in planes substantially perpendicular to the axis of the spring and may be represented by transverse vibrations traveling along the wire of which the spring is fabricated. Calculations indicate that such vibrations travel along the spring as if the spring were a straight wire not under tension, at least to a first approximation. This effect has been observed experimentally in springs fabricated of beryllium copper, and having diameters of the order of 1/4" to 3/4". This effect presumably occurs for other materials, but appears to be useless in such materials as have been tested, in the sense that it has, to date, proved impossible to construct a delay device having a sufficient reverberation time, of these materials. Furthermore, it has been found that even with beryllium copper as a spring material, a spring having an outer diameter of the order of 1/4" is not particularly ef-
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3. While a spring having a diameter of the order of 1\% provides an extremely brassy and noisy output. The diameter which is involved in an ultrasonic reverberation unit, is relatively small in comparison with spectrum width on a percentage basis in an audio reverberator. This fact enables an ultrasonic reverberator to have, on the average, a flat frequency characteristic over the entire audio spectrum of interest, i.e. low attenuation exists at least adjacent to any given frequency.

An ultrasonic reverberation unit in the form of a long line, having a length of the order of 900 wavelengths, has the property that a very small change in the frequency of a vibration traveling along the line, or a very small change in the wave propagation characteristics of the line, will result in a considerable change in phase in the course of one passage along the delay device. For example a change of frequency of one part in 3600 produces a phase shift of the order of \( \lambda/4 \) in one passage along a delay device having the length of 900 \( \lambda \), where \( \lambda \) is wavelength. Since frequency is related to the time that each signal passes many times therethrough, the net change in phase shift for a very slight change in frequency can be very considerable, before the signal decays to unusable level. The consequence of this characteristic of the ultrasonic delay line is that for a spectrum of input frequencies many resonances occur on the order of 100 or more, the resonance frequencies being separated by small increments of frequency, of the order of several cycles per second. Certain frequencies of the ultrasonic spectrum are accordingly accentuated and certain others are diminished and in the limit may be decreased to zero.

Whence consists of an ultrasonic carrier plus upper and lower side bands, the resonant characteristics of the ultrasonic transmission line can have the effect for any particular side band frequency of accentuating the upper side frequency and decreasing the lower side frequency, or vice versa, or of shifting the relative phases of the upper and lower side band frequencies from the phase relation which is normal for an amplitude modulated signal. In the alternative the carrier frequency may find a resonant or an anti-resonant point, while given side band frequencies may be relatively unaffected, or affected differently. The net result of these variations in spectrum characteristic caused by the ultrasonic delay line, which are extremely complex, and which can be considered to occur at random, is to introduce a form of frequency randomization into the music in superposition of the reverberative effect.

As a result of the frequency response characteristics of the ultrasonic delay line, particularly as a result of the large number of closely spaced resonances which occur, chorus effects may be generated by varying the frequency of the ultrasonic carrier, or by mechanically changing the transmission characteristics of the delay line, as by perturbing the latter mechanically. The mechanical perturbations, or the variations in carrier frequency may preferably be random, but cyclical variations if of sufficiently long term character are not unpleasant.

One of the consequences of the multiple resonances inherent in the ultrasonic long line reverberation device is the possibility that the carrier frequency itself may be eliminated. In such case an amplitude modulated signal passed along the delay line cannot be demodulated by means of a simple detector. In accordance with a feature of the present invention the detector occurs by means of a demodulator which is continuously connected with an ultrasonic oscillator at carrier frequency. This technique may be referred to as enhanced carrier technique, and has certain important advantages.

Where the driving transducer in an ultrasonic reverberator system must supply the ultrasonic delay line with both the carrier and the side bands, the carrier must be deviated to the side bands alone, in distinction to the carrier, is radically reduced. The total driving voltage is made up in major part of carrier, and in minor part of side band frequencies which truly carry the desired information. In order to assure the presence of carrier at the input substantially at all times, the carrier must have a large amplitude relative to the side bands, i.e. the depth of modulation cannot be very great. This represents a design safety factor, but serves further to reduce the efficiency of the system in terms of effective output for a given driving voltage. By utilizing the enhanced carrier technique, the carrier may be reduced in amplitude, i.e. 100% modulation may be employed, or in the limit the carrier may be dispensed with entirely in transmission, i.e. suppressed carrier transmission may be utilized, resulting in radically increased efficiency of operation of the overall system.

Not only may suppressed carrier transmissions be utilized in accordance with the present invention but it is also feasible to utilize single side band modulators, where the carrier is re-introduced at the demodulator, although the types of audio effects which are produced when the various kinds of modulation are utilized are slightly different.

In the case of transmission of a carrier plus side bands the relative phases and amplitudes of the carrier and the separate side bands may be modified at random, introducing a form of phase modulation superposed on the amplitude modulation, i.e. the signals as they appear at the output of the delay line are not only amplitude modulated but are in part phase modulated and in part amplitude modulated. The same may be true in respect to carrier suppressed transmissions wherein the re-inserted carrier may have any random phase relation to the two side bands so that either phase modulation or pure amplitude modulation or combinations of these may occur, the combinations being predominant. In the case of single side band transmission, the phase relations of the carrier and side bands are no longer of any importance, and the effects which occur are largely due to random enhancement of various frequencies in the spectrum.

The mathematical properties of the long ultrasonic delay line in the form of a helical spring indicate that such a delay device is frequency dispersive, i.e. that the velocity of propagation of waves along the delay device varies with frequency. More specifically, it has been found that wave length is inversely proportional to the square root of frequency. The dispersive character of the ultrasonic delay line in itself introduces relative phase shifts of the corresponding upper and lower frequencies of an amplitude modulated signal. The dispersive effects are probably largely masked by the amplitude or resonance effects of an ultrasonic delay line, but nevertheless they serve to enhance random variations of phase and amplitude of the various frequencies making up the spectrum being processed by the delay line. Moreover, where either the frequency of the carrier or the mechanical characteristics of the line, is continually varied, there results a continual mutual interchange of phase positions of the frequency components of the audio frequency band, superposed on those changes which occur due to the multiple resonances of the line, and these are equivalent to the generation of new frequencies, or in any event serve to reduce the monotonous effect inherent in some types of music due to the phase locked character of the tones generated by the instruments involved.

The character of the reverberations generated by an ultrasonic long delay line may be very considerably enhanced by introducing multiple reflections into the line, so that the line acts effectively as would a plurality of lines of different lengths. It has been found that the reflections may be introduced in an ultrasonic delay line...
which takes the form of a coiled helical spring, by introducing a mass load at a point along the line, in the form of a dead weight such as a mass of solder, or in the alternative by suspending the spring at one or more points intermediate its ends, from a resilient device. Either of these expedients may be utilized to introduce reflection of the order of 50%, in which case approximately half the wave energy is reflected from the point of reflection and the remainder travels along the transmission line to be reflected from its ends. The distance to points of reflection may be selected to be incommensurate with the total length of line involved.

In the case of electronic organs in particular, and in the case of certain other musical instrument, frequency vibrato is resorted to. Such vibrato has the effect of superposing a small periodic variation of frequency of the ultrasonic frequency band applied to reverberator of the present invention. It follows that a musical spectrum subjected to frequency vibrato, and to reverberation according to the present invention, also incorporates a chorus effect which is at least subjectively random because of its complexity. The problem of fabricating a system according to the broad invention, becomes essentially one of devising effective and economical circuitry for the purpose.

According to the present invention, a particularly simple modulator-demodulator is provided, which includes two pairs of diodes, connected in parallel and all similarly poled. A wide band audio signal is applied to the junction of one pair of diodes and an ultrasonic carrier is applied across the diodes. There results a chopping of the audio envelope by the carrier. The chopped audio envelope is then conducted through a capacitance circuit to a driving element for an ultrasonic delay line. The chopping process together with the capacitive coupling produces a pair of side-bands, with carrier suppressed.

The output of the ultrasonic delay line is capacitively coupled to the junction of the remaining pair of diodes. Heterodyning occurs at this point, between the original carrier and the carrier suppressed side bands, which reconstitutes the audio signal.

In driving the electro-mechanical transducer of an ultrasonic electromagnetic delay line from an ultrasonic modulator, supplied with ultrasonic carrier and audio signal, some audio signal may leak through to the transducer, and in addition harmonics of the desired modulation products may be present. These may, obviously, be removed by means of audio filtering. In deriving signal from the mechanico-electrical transducer at the output of the delay line, it is desired to remove any of these undesired components which had not been removed at the input, and in addition noise signals may be present in the output due to electrical and mechanical pickup by the delay line. The latter should also be removed.

In order to provide effective filtering of all but desired side-band frequencies, at the input and output of the ultrasonic delay line, filtering provision is incorporated in the drive and output amplifiers, in the form of series tuned circuitry. Use of series tuned circuits for filtering enables utilization of not only the filtering properties of the circuitry, but also inherent resonant rise of voltage and impedance matching characteristics of such circuitry. Therefore, maximum gain-bandwidth figures are attained and optimum impedance matching, with considerable economy of circuit components.

It is, accordingly, a broad object of the present invention to provide a novel modulator-demodulator for a wide audio band, constituted essentially of four diodes and associated input and output signal coupling circuitry, wherein one pair of diodes generates carrier suppressed side-bands by heterodyning an audio band with a carrier, and the remaining pair heterodynes the side bands with the carrier to reconstitute the audio band.

It is a further object of the invention to provide a novel system of ultrasonic reverberation, for music, which employs particularly effective and economical circuitry for the purpose.

It is another object of the present invention to provide novel driving circuitry and signal responsive circuitry for the input and output transducers of an ultrasonic electro-mechanical delay line.

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 schematic circuit diagram of a modulator-demodulator, according to the invention;

FIGURE 2 is a complete schematic circuit diagram of a system according to the invention; and

FIGURE 3 is a plot of wave forms, useful in explaining the system of FIGURES 1 and 2.

Referring to FIGURE 1 a carrier signal source 1 is connected across the primary winding 2 of a transformer 3. The secondary winding 4 of the transformer 3 has a grounded center-tap 5. Two non-linear elements 6 and 7, which are shown as diodes, are connected in front-to-back relationship across the secondary winding 4, the cathode of the non-linear element 6 being connected to the anode of the non-linear element 7. Two additional non-linear elements 8 and 9, which are shown as diodes, are also connected in front-to-back relationship across the secondary winding 4, the cathode of the non-linear element 8 being connected to the anode of the non-linear element 9. The non-linear elements 6, 7, 8 and 9 are thus poled in the same direction across the secondary winding 4, the anodes of the non-linear elements 6 and 8 and the cathodes of the non-linear elements 7 and 9 having common terminals. An audio signal source AS, such as an electronic organ or other music source, is connected to the conjugate terminal 11 between the cathode of the non-linear element 6 and the anode of the non-linear element 7. The source AS and terminal 11 are also connected through condenser 10 to a delay network 12 having transmission line properties. The output of the transmission network 12, which may include amplifying elements, is coupled through a low pass filter 13 to an output reproduction system RS, and also to the conjugate terminal 14 between the cathode of the non-linear element 8 and the anode of the non-linear element 9.

The non-linear elements 6 and 7 serve to modulate the carrier produced by the carrier source 1, with the signal appearing at the input terminal 10. The non-linear elements 8 and 9 serve to demodulate the side band frequencies transferred by the transmission network 12 by beating the side band frequencies with the carrier signal.

Essentially, the diodes 6, 7, 8 and 9 are subjected to carrier amplitudes greater than the amplitude of the points of highest amplitude in the audio signal. The audio envelope is thus chopped by the carrier, without modification of envelope except as occurs due to chopping. The chopped audio signal appears at terminal 11.

Terminal 11 is coupled to the input of transmission network 12 through a coupling capacitor 10 which has a high impedance to audio frequencies. Thereby, audio envelope directly deriving from audio music source AS is highly attenuated, as applied to transmission network 12, and the chopped wave occurring at terminal 11 is transferred to transmission network 12 in a form which is symmetrical about a zero level base line, for carrier frequency, and hence represents side bands with carrier suppressed.

The output of transmission line network 12 is applied to the junction 14, where it is heterodyned with the carrier supplied from source 1. One of the heterodyne products is a replica of the original audio envelope, as modified however, by the transmission network 12. That replica is selected by low pass or audio filter 13, and applied
to the reproduction system, RS, for example, a loud speaker.

Application of side-bands only to the transmission channel 12 assures transmission of carrier bearing signal frequencies while detection by heterodyning with the same carrier as originally utilized to generate side bands assures that a replica of the original signal will be reproduced, subject to such alterations as are introduced by the transmission network 12. Insofar as the latter is linear, no shifts of frequencies will be introduced.

Referring now more particularly to FIGURE 2 of the accompanying drawings, an audio input signal lead 20 supplied a broad band of audio signals, representing music, across a resistance 21, one side of which is grounded. The audio signal is coupled through capacitor 22 and large resistance 23 to lead 24, which is connected to terminal 11, at the junction of diodes 6 and 7. At circuit point (1) appears a complex audio signal, represented by sine wave 101, for simplicity. At point (2) appears carrier 102, in one phase, and in opposite phase at point (2a).

The carrier is applied as a chopping signal, across diodes 6, 7, to the audio envelope applied to terminal 11, so that chopped audio wave form 103 appears at lead 24, and hence at terminal 25.

Capacitor 26 couples the signal appearing on terminal 25 to an ultrasonic amplifier 30. Capacitor 26 is quite small (68 mfd.), attenuating audio frequency and passing ultrasonic frequencies. The amplifier 30 contains across its output circuit a parallel tuned circuit, comprising inductance 31 and the capacity of transducer 35a, resonant to the ultrasonic frequencies, of sufficiently low Q to pass the ultrasonic side bands with low attenuation, but sufficiently high to greatly attenuate audio frequencies and harmonics of the ultrasonic carrier.

The wave form 103 at point (3) illustrates the result of the ultrasonic chopping process on wave form 101. At point (4) is indicated the wave form 104, produced by the capacitor 26. The change may be described as elimination of audio frequency components from wave form 103, or as rendering the wave form 103 symmetrical with respect to zero base line.

Elimination of harmonics of the ultrasonic side bands by tuned circuit 31, 32 provides a signal wave form 105, containing only side band frequencies, and from which sharp corners introduced by the chopping process have been removed.

The wave form 105 is applied to the input of an ultrasonic mechanical delay line 35, corresponding with that described in detail in the application of Bissonette et al., above referred to. At its output the delay line 35 is coupled through a tuned circuit comprising inductance 36 and capacitor 41, and closed switching circuit 42, to potentiometer 43, which in turn supplies signal to low pass filter 45.

The switching circuit 42 includes three switch points 46, 47, 48. Point 46 is blank, and disables the output. Point 47 is connected to potentiometer 43 through a voltage dropping resistance 59, to operate at low level, and point 48 supplies full output to filter 45, subject to such attenuation as is provided by the adjustable potentiometer 43. A permanent path to ground for capacitor 41 is provided by very high resistance 51.

Filter 45 supplies its signal to audio amplifier 52 (plot 107), which also acts as a linear mixer, since audio input lead 20 is coupled to the input of amplifier 52 by filter circuit 53. The output of amplifier 52, at lead 54, then includes the original audio band, plus the reverberated audio band.

The problem exists, in the system of the invention, of driving the ultrasonic delay line 35 at high efficiency, and at side band frequencies only, i.e. to provide impedance matching between an ultrasonic signal source, subject to audio components, and a load, while filtering out the audio components and harmonics of the desired side band frequencies. To accomplish these objectives simultaneously by means of a simple circuit, I employ the parallel resonant circuit comprising inductance 31 and the output of driving crystal 35a. Capacitor 32 is a D.C. blocking element and resistor 33 prevents charge build-up on driver crystal 35a. Damping of the resonant circuit is provided primarily by the plate resistance of triode 30a, and partly by resistor 33. The terminals of the input transducer 35a for delay line 35 are connected across resistance 33a. The parallel resonant circuit is damped sufficiently that it responds to the ultrasonic frequencies, but rejects the audio band and the undesired harmonics. In order to provide an impedance match to the anode of amplifier tube 36a, of amplifier 30, the latter is connected to a mid-tap of inductance 31, which is made variable to afford facility for tuning. The inductance 31 provides an impedance for the anode of triode 30a, at its upper half, a resonant circuit component in its totality, and part of an output coupling circuit in its lower half, as seen in FIGURE 2. The series resonant circuit provides a band-pass filtering and matching facilities, and is nevertheless a low loss circuit, providing a resonant rise of driving current driving transducer 35a.

At the receiving end of the delay line 35 is provided a receiving transducer 35b, and a circuit comprising a coupling condenser 36a and approximately half of inductance 36, both across receiving transducer. The entire inductance 36 is connected in series with coupling capacitor 37 and a grid resistance 37a for triode 38a of amplifier 38. The capacity of transducer 35b in parallel with the lower half of inductance 36 provides a parallel resonant output circuit which is shunted across a auto-transformer action in inductance 36, which provides high driving level for vacuum tube 38a. At the same time the output resonant circuit operates to filter out both audio signal, noise due to pick-up, both electrical and mechanical, in the delay line 35, and harmonics of the desired side-band frequencies which are generated in the chopping process at terminal 11.

While the present invention is operative when utilizing a wide variety of transducers, it is preferred to utilize transducers of the character and type disclosed in the application for U.S. patent, above referred to, filed in the name of Brombaugh et al.

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 is claimed is:

1. A modulator-demodulator, comprising a first diode, a second diode, a third diode, a fourth diode, said first and second diodes being connected in series, said third and fourth diodes being connected in series with each other, said third and fourth diodes taken in series being connected in parallel with said first and second diodes taken in series, a source of audio signal connected to the junction of said first and second diodes, an output signal from the junction of said third and fourth diodes, and a source of high frequency carrier signal connected in balanced relation across said first and second diodes, said source of high frequency carrier signal having a midpoint connected to a point of reference potential and providing said high frequency carrier signal in a push-pull output signal, output associated with said point of reference potential, wherein and is further provided a high pass coupling circuit including series capacitance coupled to said junction of said first and
second diodes, a transmission network coupled to said coupling circuit, said transmission network having an output lead, means connecting said output lead to said junction of said third and fourth diodes, and an audio output circuit coupled to said last named junction.

2. A modulator-demodulator, comprising a first diode, a second diode, a third diode, a fourth diode, said diodes being all similarly poled, said first and second diodes being connected in series, said third and fourth diodes being connected in series with each other, said third and fourth diodes taken in series being connected in parallel with said first and second diodes taken in series, a source of audio signal connected to the junction of said first and second diodes, an output circuit connected to the junction of said third and fourth diodes, and a source of high frequency carrier signal connected in balanced relation across said first and second diodes, said source of high frequency carrier signal having a midpoint connected to a point of reference potential and providing said high frequency carrier signal in push-pull relation with respect to said point of reference potential, wherein is further provided a high pass coupling circuit including series capacitance coupled to said junction of said first and second diodes, a transmission network coupled to said coupling circuit, said transmission network having an output lead, means connecting said output lead to said junction of said third and fourth diodes, and an audio output circuit coupled to said last named junction, and wherein said transmission network is an ultrasonic delay line and said carrier is an ultrasonic carrier.

3. A modulator-demodulator circuit, including a first circuit consisting of two series connected diodes, a second circuit consisting of two series connected diodes, said first and second circuits being connected in series with each other, a balanced source of carrier signal connected across said first and second circuits, an audio input terminal and side band output terminal connected to the junction of the diodes of said first circuit, and an audio output circuit and side band input circuit connected to the junction of the diodes of said second circuit.

4. The combination according to claim 3 wherein said diodes are all identically poled.

5. The combination according to claim 3 wherein is provided a low pass input circuit and a high pass output circuit connected to the junction of the diodes of said first circuit.

6. The combination according to claim 3 wherein is provided a high frequency input circuit and a low pass output circuit connected jointly to the junction of the diodes of said second circuit.

7. The combination according to claim 3 wherein side bands are generated by said first circuit, and means for feeding said side bands back to said second circuit for heterodyne demodulation therein.

8. An amplifier, comprising an amplifying element having input electrodes and a signal output electrode, a source of power, a parallel resonant circuit comprising an inductance and a capacitance, said capacitance being inherent in a transducer, means for feeding said source of power and said inductance in series with each other, a resistance coupled to said inductance, a terminal connected to a point of said inductance intermediate its end, means connecting said signal output electrode directly to said terminal, said transducer being connected across said resistance, said resistance being connected to a point of reference potential in common with one of said input electrodes, means applying an input signal band of ultrasonic frequencies to said input electrodes, said parallel resonant circuit being resonant to said band of frequencies, said amplifying element and said resistance providing damping resistance for said parallel resonant circuit which establishes a circuit Q adapted to pass substantially only said band of ultrasonic frequencies.

9. In combination, a source of signals including audio components, ultrasonic components and harmonics of said ultrasonic components, an amplifier having an input circuit and an output circuit, means coupling said source of signals to said input circuit, said output circuit comprising a circuit series resonant to said ultrasonic components, an ultrasonic mechanical delay line having an input transducer and an output transducer, and means coupling said input transducer directly to said series resonant circuit.

10. The combination according to claim 9 wherein is provided a further series resonant circuit tuned to said ultrasonic components, means connecting said output transducer in series with said further series resonant circuit, and an output amplifier having an input circuit connected to a point of said further resonant circuit exhibiting a resonant rise of signal voltage.

11. The combination according to claim 10 wherein said first mentioned resonant circuit is connected and arranged to provide a matching load circuit for said first mentioned amplifier, impedance matching coupling circuit between said input transducer and said load circuit, and a band-pass filter accepting said ultrasonic components and rejecting said audio components and harmonics of said ultrasonic components.

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