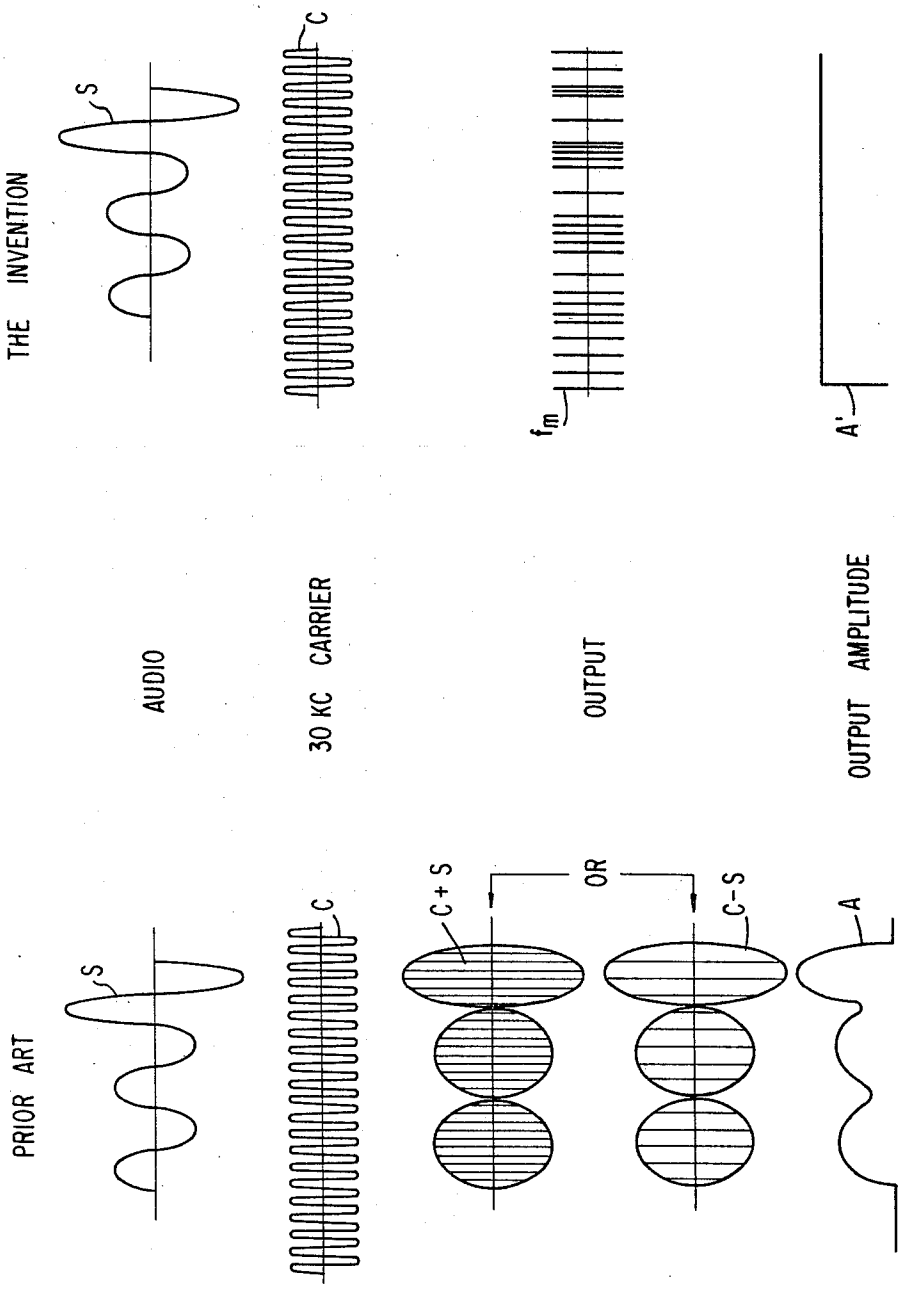
Aug. 27, 1968 W. T. CLARK III 3,398,810

LOCALLY AUDIBLE SOUND SYSTEM

Filed May 24, 1967 2 Sheets-Sheet 1

FIG. 1



INVENTOR

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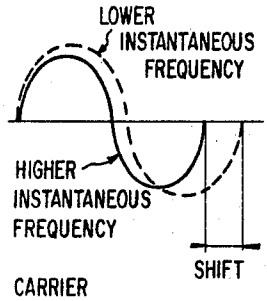
ATTORNEY

Aug. 27, 1968 W. T. CLARK III 3,398,810

LOCALLY AUDIBLE SOUND SYSTEM

Filed May 24, 1967 2 Sheets-Sheet 2

FIG.2



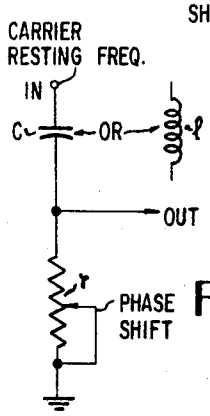


FIG.3

FIG.6

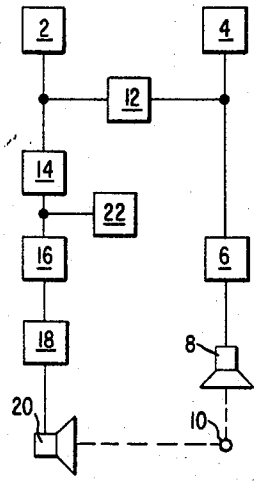
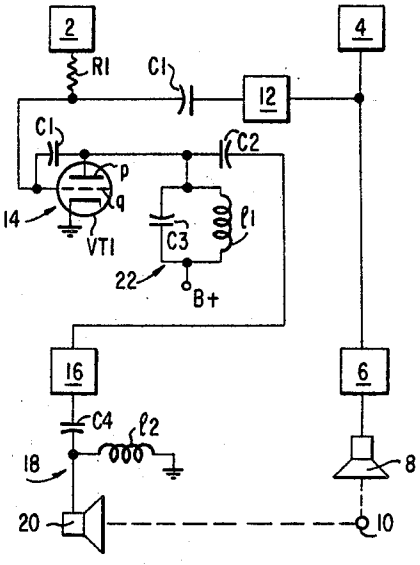


FIG.7



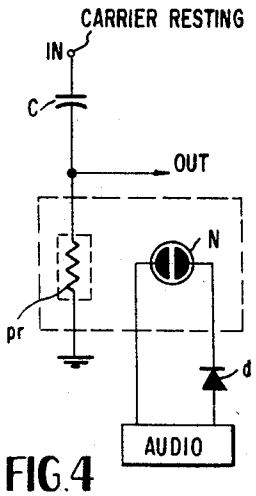


FIG.4

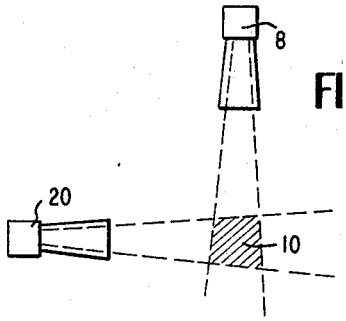


FIG.8

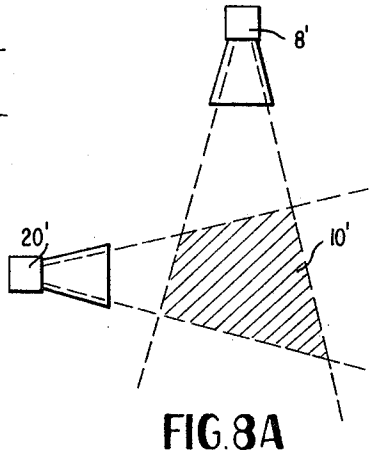


FIG.8A

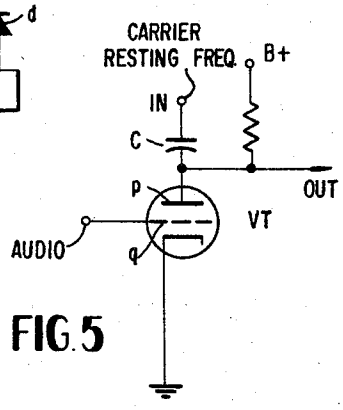


FIG.5

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3,398,810

LOCALLY AUDIBLE SOUND SYSTEM

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Filed May 24, 1967, Ser. No. 640,893
15 Claims. (Cl. 181—.5)

ABSTRACT OF THE DISCLOSURE

Two constant-amplitude beams of ultrasonic sound are directed to intersect at a region where sound intelligence is to be heard. One of the beams, i.e., a carrier, is phase modulated by an audio signal to a produce phase-shift in wave-fronts, the amplitude of the audio modulation being expressed in the degree of phase shift of the carrier, and the frequency of the audio modulation being expressed as the rate at which the phase shift takes place. At the region in which the two beams intersect, natural variations in amplitude of the reproduced sound occur because of difference in the phases of the modulated and unmodulated waves; the in-phase components of the modulated and unmodulated beams add, the out of phase components will cancel, and anything between will add or subtract to a greater or lesser degree.

(1) *Field.*—The invention is in the class of miscellaneous acoustical systems, supersonic.

(2) *Prior art.*—Sprague 1,616,639 discloses a high frequency sound system wherein two loud speakers are placed at opposite ends of an auditorium. An ultrasonic signal is fed to both speakers. The ultrasonic signal fed to one speaker is amplitude modulated by an audio signal to produce two side bands, one of which is filtered out. In the area of intersection of the waves output by the two speakers, the amplitude of audio sound is determined by the amplitude of the modulated wave. The speaker reproducing the modulated wave has no output between periods of modulation, and during modulation, the wave front produced thereby is audible as noise.

The object of this invention is to provide a sound system particularly adapted for displays at museums, art galleries and the like wherein no audible sound is reproduced except, for example, directly in front of a display. Thus, a spectator in front of one display will not hear cross-talk from an explanatory lecture relating to another display. To this end, it is intended to provide two intersecting beams of sound, neither of which produces audible intelligence or even audible noise when heard alone, but which do produce audible intelligence when combined in a comparatively small area of intersection. Also, by directing two such beams at a point of intersection in an auditorium or arena, selected portions of an audience can be singled out to receive audible intelligence while all others in the audience, even those in the beam paths, will hear nothing.

According to this invention, where there are two intersecting beams of ultrasonic sound, one of which, i.e., a carrier, is phase modulated by an audio signal, the area of intersection and, hence, spread of audio intelligence can be varied by similarly varying the resting frequency of the carrier and the other beam. The higher the frequency, the more directional will be the beams and, hence, the smaller will be the area of intersection. The same end can be accomplished by the use of acoustic lenses or by varying the physical construction of the transducers. The area of intersection may also be altered by varying the angle of incidence of the intersecting

beams. By such means, a readily definable area of audible intelligence may be created.

It is also contemplated that instead of beaming the unmodulated acoustical signal, a frequency-controlled supersonic whistle or like device may be used for flooding an area with unmodulated supersonic sound at the carrier's resting frequency; whereupon a beamed phase modulated acoustical signal from a directional transducer will produce a line of audible intelligence through the area. Another variation can be obtained using, for one transducer, a parabola which produces a cone-shape acoustical signal which may be used in connection with a non-directional transducer for the unmodulated acoustical signal, or in connection with a directional transducer for the same.

It is believed that the system may also have military applications for beaming instruction from an aircraft or a command post to a selected group of troops.

Furthermore, by placing two directional transducers in spaced opposition to one another, one being energized at the carrier's resting frequency and the other energized by the phase-modulated carrier, an area of audible intelligence will be produced between the two transducers.

These and other objects will be apparent from the following specification and drawing, in which:

FIG. 1 is a series of waveform diagrams illustrating the operation of the invention in comparison with the known prior art;

FIG. 2 is an elemental waveform diagram illustrating phase shift;

FIG. 3 is an elemental circuit diagram illustrating operation of a phase-shifting circuit;

FIG. 4 is a simplified circuit diagram illustrating one type of phase-shifting circuit;

FIG. 5 is a simplified circuit diagram illustrating another type of phase-shifting circuit;

FIG. 6 is a block diagram of one embodiment of the subject system;

FIG. 7 is a block diagram of the system of FIG. 6 showing some details of the components; and

FIGS. 8 and 8A are diagrams illustrating the effects of transducer signal spread on the areas of intersection of their acoustical signals.

Referring first to the left-hand portion of FIG. 1 which, in waveform diagram, represents the prior art, an audio signal S is used to amplitude-modulate a 30 kc. carrier C, thus producing two sidebands which are illustrated as $C+S$ and $C-S$, both of which vary in amplitude according to the amplitude of the audio signal. According to Sprague (supra), one or the other of the sidebands is filtered out, leaving an output which varies in amplitude A as diagrammed at the lower left-hand portion of FIG. 1. Etiher $C+S$ or $C-S$ is beat against another superaudible signal like the 30 kc. carrier, and the resultant is intended to produce audible intelligence at the area of intersection.

The right-hand portion of FIG. 1 diagrammatically illustrates the invention. As in the prior art, an audio signal S is used to modulate 30 kc. carrier. However, instead of using amplitude modulation, the carrier is phase modulated so as to produce a signal *fm* which is of constant amplitude A', but which varies in instantaneous phase according to the frequency of the modulating audio signal. Only the audio frequency is filtered out. The modulating audio signal produces phase-shift in the carrier which then contains two sidebands of variable frequency, both of which are propogated; the rate of phase shift is determined by the instantaneous rate of the audio frequency and the degree or angle of the phase shift is accomplished by the amplitude of the audio signal.

Once the theory of the invention is understood, many different circuits may be used for phase-shifting or fre-

quency-modulating one of the super-sonic signals. The basic requirements are that one acoustical signal of constant amplitude and frequency be beamed towards an area of intersection, and that there also be beamed towards the area of intersection another acoustical signal, or carrier, which is phase-shifted by the audio signal to be heard, in the manner elementarily illustrated in FIG. 1.

Referring next to FIG. 2, the wave form diagram illustrates the characteristics of a phase-shifted carrier wave resulting from modulation by audio frequency signals, the full line waveform representing modulation by an audio frequency signal of one amplitude and the dash line waveform representing modulation by an audio frequency signal of another amplitude.

FIG. 3 is a diagram illustrating the fundamentals of a phase shifting circuit. Let it be assumed that alternating current from an oscillator is input at "IN" and passed through either a capacitor *c* or inductance *l* in series with a variable resistor *r*. The phase of the "out" signal will shift according to the reactance of *c* or *l* relative to *r* at any given frequency. If $r=0.1$ the reactance of *c* or *l*, then the phase shift of the output signal approaches 90°. If $r=10x$ reactance of *c* or *l*, then the phase shift is substantially 0.

FIG. 4 illustrates one elemental type of phase-shifting device which is usuable in the subject system. Let it be assumed that a 30 kc. signal from an oscillator is input at "IN" across the series combination of capacitor *c* and photoresistor *pr*. This signal is be phase-shifted in accordance with the output of an audio amplifier labeled "audio." A neon tube N is connected by the output of the audio amplifier, with a diode *d* in one side of the tube circuit. Exposed to the illumination of the neon tube is a photoresistor *pr* whose resistance varies according to the illumination of the neon tube. In this instance, photoresistor serves the function of resistor *r* in FIG. 3. The phase of the output signal will be shifted according to the frequency and amplitude of the output of the audio amplifier. Suitable bias may be inserted for the nenon tube for predetermining the level of audio signal needed to fire it, or to assume linear operation.

FIG. 5 illustrates in elemental diagram a vaccum tube type of phase shifter. A carrier signal having, for example, a 30 kc. resting frequency is input to the plate *p* of vacuum tube VT via capacitor *c*, and an audio signal is fed in via grid *g*. Here again, the phase of the output signal will shift, as in FIG. 2, according to the frequency and amplitude of the audio signal. The tube acts like a variable resistor for the carrier signal, whose resistance is varied by the audio signal, like the variable resistors in FIGS. 3 and 4. There are many equivalent phase-shifting devices, the main difference between FIG. 4 and FIG. 5 is that the FIG. 4 device fully isolates the output from the audio signal.

FIG. 6 is a block diagram of one one form of the invention, and FIG. 7 illustrates the same form of invention with some of the details filled in. There is audio amplifier **2**, which is controlled by a suitable microphone, recorder-reproducer or the like device (not shown). The output of an oscillator **4**, which produces a supersonic signal, such as at 30 kc., is fed via an amplifier **6** to one acoustical transducer, i.e, a loudspeaker **8** directed at a point **10**. The output of oscillator **4** is also fed through an isolation amplifier **12**, to a phase-shift modulator **14** which is modulated by the audio signal from audio amplifier **2**. The output of the phase shift modulator **14** is fed via an amplifier **16** and high-pass filter **18** to another acoustical transducer, i.e., loudspeaker **20**. Preferably, a tank circuit device **22** is connected between phase-shift modulator **14** and amplifier **18** for trapping out audio frequency signals, the tank circuit serving as an adjunct to high pass filter **18**.

Netiher of the acoustical outputs of loudspeakers **8** or **20** is audible except at the region **10** of intersection. The phase-shifted acoustical output signal of speaker **20**, which varies on one side or the other from a 30 kc. resting frequency, beats against the 30 kc., acoustical output signal of speaker **8** to produce audible intelligence at the region **10** of intersection. Obviously, the extent of region **10** will vary in accordance with the spreads of the acoustical output signals of the speakers, the angle of incidence of the two acoustical signals, and other possible factors mentioned hereinbefore. FIGS. 8 and 8A diagrammatically illustrate the effect of variations in signal spread of the transducers. Obviously, the wider-angle signals from speakers **8'**, **20'** will produce a larger area of intersection **10'** than the area of intersection **10** of the acoustical signals from speakers **8**, **20**.

FIG. 7 illustrates some details of the block diagram of FIG. 6. In this form, audio amplifier **2** is connected through a resistor **R1** to the grid *g* of a vacuum tube **VT1**; and the output of isolation amplifier **12** may also be connected to grid *g* via a capacitor **C1**. Grid *g* is coupled to plate *p* of **VT1** via a capacitor **C2** which otherwise may comprise the internal capacitance of the tube. The plate *p* of **VT1** is connected via capacitor **C2** to amplifier **16**. Tank circuit **22**, comprising capacitor **C3** and inductance **L1** in parallel is connected between the plate output circuit of **VT1** and **B+** for absorbing any audio frequency signals. The high-pass filter **18** between amplifier **16** and speaker **4** may comprise a capacitor **C4** and inductance **L2** connected as shown.

In all embodiments, the phase-shifted acoustical output signal of speaker **20** is of constant desired amplitude and the output signals of both speakers **20** and **8** are above audible frequencies. The amplitude of the signal heard by the listener can be adjusted either by changing the amplitude of the audio signal fed to the phase-shifting device, or by varying the amplification of the signals fed to one or the other or both of the transducers, or by varying the phase-shifting capability of the phase-shifting device.

Ordinarily, it would be desirable that all or most of the audio signal be filtered out of the phase-shifted signal produced by transducer **4**. However, if desired, a low-level audio signal may be left in the phase-shifted signal for monitoring purposes.

If desired, separate oscillators operating at the same resting frequency, may be used, or instead of producing the unmodulated supersonic signal by an electronic means, a whistle or siren tuned to the resting frequency of the modulated signal may be used.

Another application of the subject system is for paging devices. Let it be assumed that a hospital corridor is flooded by the phase modulated acoustical signal. A doctor may carry on his person a local supersonic oscillator operating at the resting frequency of the modulated signal and a transducer. The interaction of the modulated and immodulated signals, in the region of the doctor, will produce an audible signal which the doctor can hear, but which will be inaudible at any appreciable distance away from the doctor.

The invention is not limited to the specific features described herein, but is intended to cover all substitutions, modifications and equivalents within the scope of the following claims.

I claim:

1. The method of creating locally audible sound which comprises:

phase-modulating a supersonic frequency carrier signal with an audio frequency signal carrying intelligence to be heard,

acoustically transmitting said phase-modulated supersonic carrier signal at substantially constant amplitude to a region,

and acoustically transmitting a supersonic frequency signal at the resting frequency of the carrier signal and at substantially constant amplitude to a portion of said region where audibility is desired in intersecting relationship with the other acoustically trans-

mitted signal, whereby the resultant of said acoustically transmitted signals produces an audible signal in the region of intersection thereof.

2. The method defined in claim 1, wherein one of said acoustical transmitted signals is transmitted predominantly in one direction.

3. The method defined in claim 1, wherein both of said acoustically transmitted signals are transmitted predominantly in respective different directions.

4. In the method defined in claim 1, the step of eliminating at least most of audio-frequency components from the phase-modulated carrier signal prior to the acoustical transmission thereof.

5. In the method defined in claim 1, the step of varying the amplitude of audible signal by correspondingly varying the amplitude of said audio signal.

6. In the method defined in claim 1, the step of varying the amplitude of the audible signal by varying the amplitude of one of said acoustically transmitted signals.

7. The method of creating locally audible sound which comprises,

flooding an area with a supersonic acoustical signal of a continuously fixed frequency at substantially constant amplitude,

and creating in a portion of said area a supersonic acoustical carrer signal of substantially constant amplitude having a supersonic resting frequency the same as the fixed frequency of the first acoustical signal but which is phase-modulated by an audio frequency signal bearing intelligence to be heard in said portion of said area.

8. The method of creating locally audible sound which comprises,

flooding an area with a supersonic acoustical carrier signal of substantially constant amplitude having a supersonic resting frequency which is phase modulated by an audio frequency signal bearing intelligence to be heard,

and creating in a portion of said area where said intelligence is to be heard a supersonic acoustical signal of substantially constant amplitude at the resting frequency as the carrier signal.

9. A system for producing a locally audible sound signal comprising:

first acoustical transducer means,

means for producing a carrier signal at a supersonic frequency,

means for phase-modulating said carrier signal in accordance with an audio signal bearing intelligence to be heard,

wherein the phase of the carrier signal output of the phase-modulating means is maintained at substantially constant amplitude but is shifted in degree in accordance with the amplitude of said audio frequency signal and in rate according to the frequency of said audio frequency signal,

means for energizing said first transducer means with the phase-modulated signal from said phase-modulating device,

second acoustically transducer means,

and means for energizing said second acoustical transducer means with a supersonic signal of substantially constant amplitude but which is equal in frequency to the resting frequency of the carrier signal,

whereby the first and second transducer means may be disposed to project their acoustical outputs in intersecting relationship in a region where locally audible sound is to be reproduced.

10. The combination claimed in claim 9, and means for filtering out audio frequency components from the output of the phase modulating means.

11. The combination claimed in claim 9, characterized by the fact that the acoustical output at least one of the transducers is predominantly in one direction.

12. The combination claimed in claim 9, characterized by the fact that the acoustical outputs of the transducers are predominantly in respective directions which intersect one another.

13. The combination claimed in claim 9, characterized by the fact that the first acoustical transducer means is arranged to flood an area with the acoustical output thereof and the second transducer means and the means for energizing the same are adapted to be carried upon the person and produce an acoustical signal immediately adjacent said person.

14. A system for producing locally audible sound comprising,

oscillator means for producing a supersonic frequency carrier signal of substantially constant amplitude,

first acoustical transducer means connected to said oscillator means for acoustically transmitting said supersonic carrier signal,

means for producing an audio frequency signal for hearing intelligence to be heard,

phase-shifting means connected to said oscillator means and to the last-named means for phase-shifting said carrier signal in accordance with said audio frequency signal in degree according to the amplitude of said audio frequency signal and in rate corresponding to the frequency of said audio frequency signal and of substantially constant amplitude,

and second acoustical transducer means connected to said phase-shifting means for acoustically transmitting said phase-shifted carrier signal, said first and second acoustical transducer means being so disposed with respect to one another that the acoustical outputs thereof intersect one another in an area where locally audible sound is to be heard.

15. The combination claimed in claim 14, and filter means connected between said phase-shifting means and the first acoustical transducer means for filtering out audio frequency components from the phase-shifted carrier signal.

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