United States Patent

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[54] **MODULATED SIGNAL GENERATOR**
14 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** **116/137,** 137/81.5, 235/201
[51] **Int. Cl.** **B06b 3/00**
[50] **Field of Search** ..... 116/137, 65, 137(A), 147, 23, 24; 259/1; 158/118; 235/201; 200/81; 137/81.5

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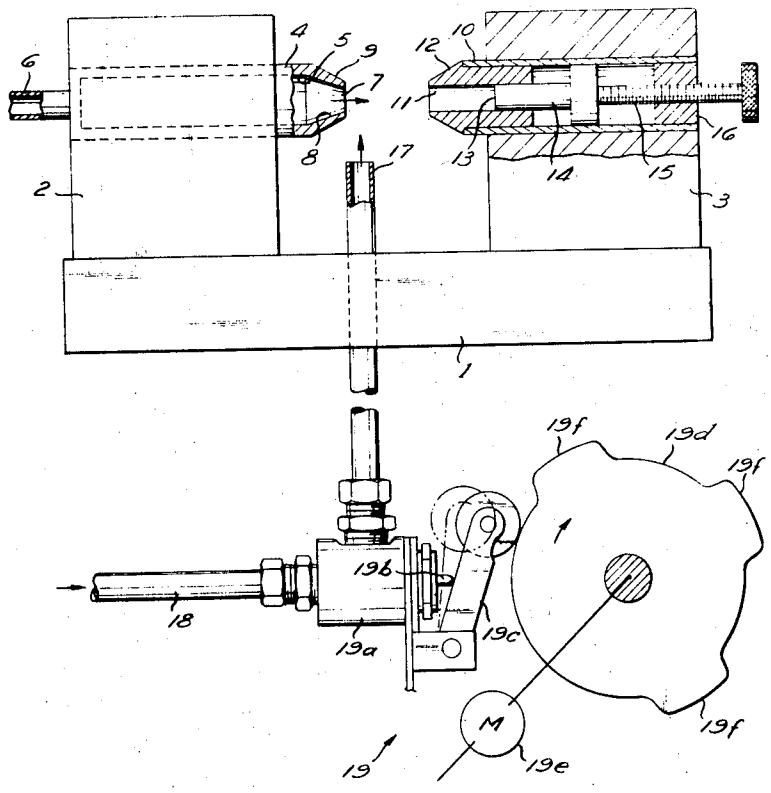
ABSTRACT: A signal generator adapted to generate a high frequency signal in an ambient gas by impinging a high speed power stream of gas on a cavity in a member, and to modulate the signal by a stream of fluid that intersects the power stream.



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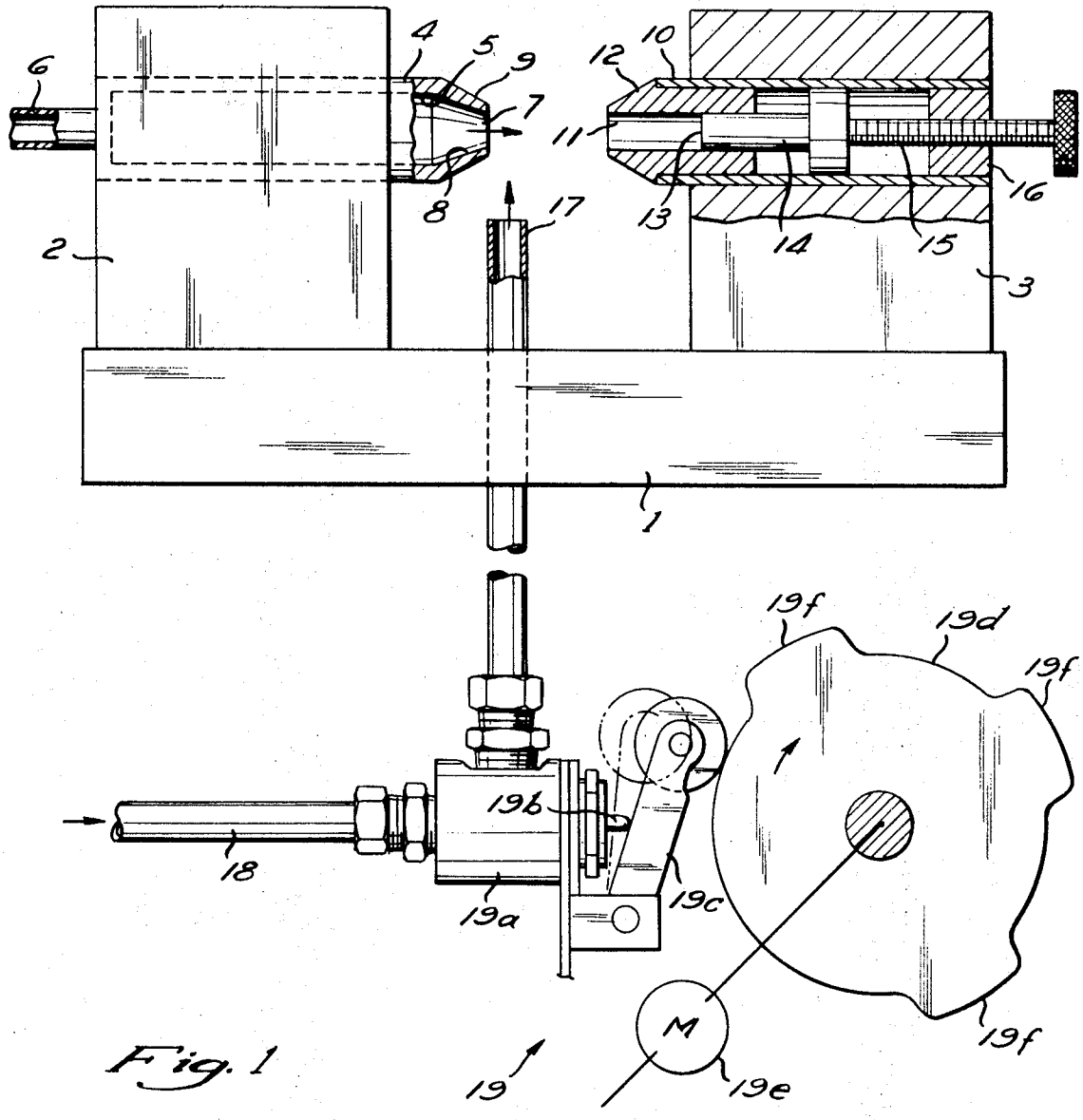

Fig. 1

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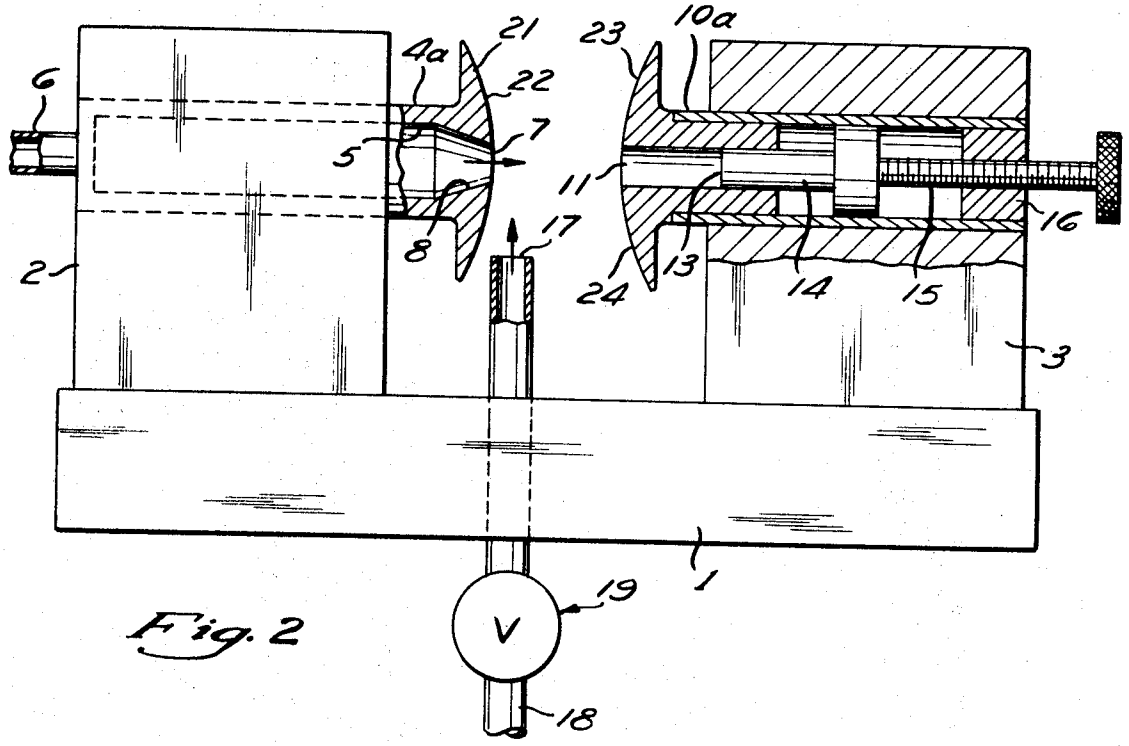

Fig. 2

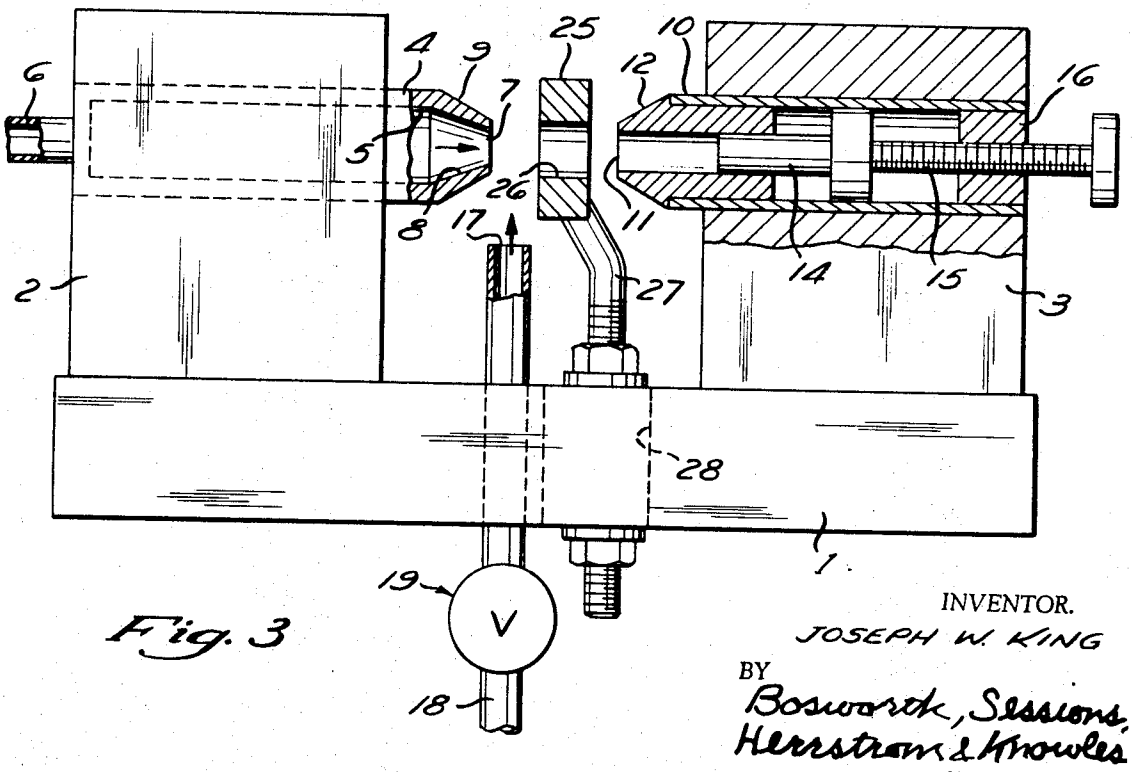

Fig. 3

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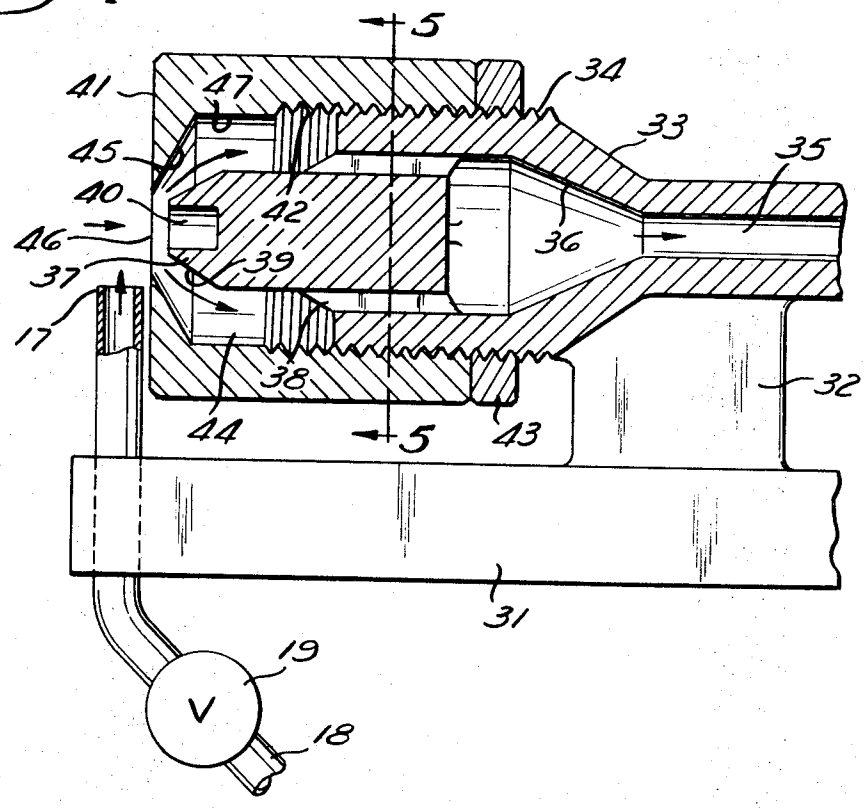
Fig. 4



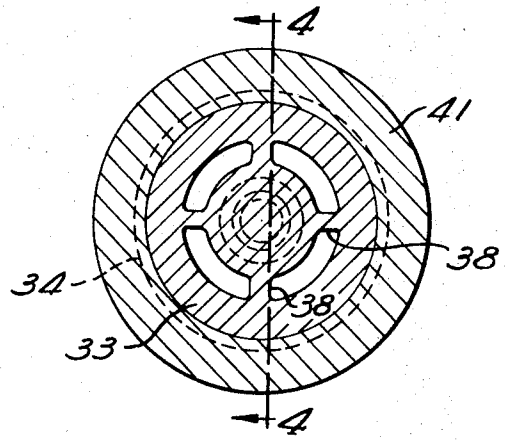


Fig. 5

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MODULATED SIGNAL GENERATOR

BACKGROUND OF THE INVENTION

Modulated high frequency signals in an ambient gas such as air are useful for various purposes, particularly when the signals are ultrasonic, that is, having frequencies greater than those that affect the human ear. Ultrasonic signals modulated in suitably coded patterns can be used through suitable receiving means to control apparatus at a distance. Ultrasonic signals modulated in suitably coded patterns can be used through suitable receiving means to control apparatus at a distance. Ultrasonic signals have been proposed for pest control; modulation of the signals according to the invention can substantially increase pest-deterring effects. When ultrasonic signals are used to promote atomization of fluids, modulation may be helpful in causing or desirably varying atomization.

While various means have been proposed for modulating high frequency signals, these means in general have been quite complicated and usually have been employed in connection with apparatus for producing underwater ultrasonic signals.

SUMMARY OF INVENTION

An object of the invention is the provision of apparatus for generating a modulated high frequency, preferably ultrasonic, signal, in air or other gas. Another object is the provision of such apparatus in which the signal is modulated by a stream of fluid such as air or other gas laterally impinging on a power jet of air or other gas that produces the signal. A further object is the provision of such apparatus in which the modulating stream is emitted at a varying rate of flow, frequency, and/or intensity such as to cause a desired modulation of the signal. A further object is the provision of such apparatus in which the intensity of the signal can be readily varied. A further object is the provision of such apparatus that is simple and sturdy in construction and can be manufactured at reasonable cost.

According to the invention, the apparatus comprises a jet-producing member for causing a power jet of air or other gas to travel at high speed to impinge on a cavitied member providing an opposed cavity, these parts being proportioned and spaced to provide the desired propagation of waves in accordance with known principles of jet generators, such as the Hartmann whistle, when the power jet travels at a sufficiently high speed. According to the invention a modulating stream of fluid such as air or other gas is directed laterally of the power jet to intersect the power jet in the vicinity of the cavity, this modulating stream being varied, as by having a varying rate of substantially continuous flow, or a flow interrupted to form pulses of a desired or predetermined frequency and intensity, to cause the desired modulation of the signal developed from and propagated by the power jet. Preferably, the modulating stream is caused to impinge on the jet stream between means for emitting the jet and the cavity.

These and other objects and features of the invention will become apparent from the following description of several embodiments of the invention in conjunction with the accompanying drawings, in which:

FIG. **1** is a side elevation of a preferred embodiment of the invention, parts being broken away to show the construction thereof;

FIG. **2** is a modification of the embodiment of FIG. **1**, parts being broken away for clearness;

FIG. **3** is another modification of the invention, showing a side elevation with parts also broken away;

FIG. **4** depicts another modification of the invention, in which the power jet is a stream of air that is sucked into a housing by subatmospheric pressure, this figure being a cross section along line **4–4** of FIG. **5**; and

FIG. **5** is a section along line **5–5** of FIG. **4**.

In the embodiment of FIG. **1**, a base **1** rigidly carries two supporting members **2** and **3**. Supporting member **2** carries a jet-producing member **4**, having an elongated chamber **5** communicating at one end with a tube **6** through which air is supplied under substantial pressure, and at the other end with an opening **7**. The end portion **8** of chamber **5** is tapered, being shown as an internal frusto-conical wall shaped and sized according to the known principles of Hartmann whistles to eject a high velocity power jet of air through opening **7**. The end portion **9** of the exterior wall of the member **4** is also tapered, being frusto-conical from a larger to a smaller diameter.

The other supporting member **3** carries a cavitied member **10** having a cavity **11**, with a closed bottom end, opposed to opening **7** through which the power jet of air discharges. The end portion **12** of the exterior of cavitied member **10** nearest the jet-producing member **4** is tapered, being of frusto-conical shape and this end portion and the cavity are shaped and sized in accordance with known principles of a Hartmann whistle. The diameter and depth of the cavity are such as to provide the desired resonating effect.

In the manner of a conventional Hartmann whistle, a power jet of air discharging through opening **7** of member **4** toward and impinging upon cavity **11** will, when the jet velocity approaches or surpasses the speed of sound in the ambient air, cause air in the jet to flow in paths that cross over because of the unstable pressure regions that arise because oblique shock waves are produced at the circumference of the jet; these shock waves are inclined at approximately the Mach angle, and are reflected in a changed direction at the point of meeting between the moving air stream and the surrounding ambient air. In accordance with known principles or Hartmann whistles, the resonant cavity **11** is located in the jet stream at a position corresponding to a point of flow instability, so that the air in the chamber bore **5** of the power jet member is excited into resonance to cause an ultrasonic signal.

In the embodiment of FIG. **1**, the depth of the cavity **11**, and hence the frequency of the ultrasonic signal, may be adjusted over a substantial range since the bottom of the cavity is the end face **13** of a piston member **14**, the longitudinal position of which in the bore forming the cavity **11** is adjusted by manual rotation of a member **15** that is threaded into the remote end **16** of the cavitied member **10**.

A modulating flowing stream of air is discharged with a varying flow laterally into the power jet, preferably perpendicularly to the axis of the power jet as it travels toward the cavity **11**. In FIG. **1**, the modulating air stream intersects the power jet between opening **7** and cavity **11**, and preferably as near as possible to opening **7**. The air is supplied to conduit **17** from a suitable source, such as a tube **18** connected to a source of air at a suitable pressure. The maximum speed of the modulating air stream discharged from conduit **17** may be in a wide range including relatively slow subsonic speeds to ultrasonic speeds; the modulating air stream may be discharged as a continuously flowing stream at a varying rate, or it may be interrupted by pulses in a predetermined pattern, to achieve the desired modulation of the power jet. Intersection of the modulating air stream with the power jet deflects the power jet so that a jet of less intensity impinges on the cavity **11**, and the amplitude and hence intensity of the high frequency signal is modulated in accordance with the flow variation characteristics of the modulating stream.

The desired variation of the modulating stream can be achieved by suitable manually or automatically operable valve means. The automatically operated valve means generally indicated as **19** in FIG. **1** comprises an air control valve **19*a*** such as the "Clippard" Model MAV-2 direct acting normally closed two-way poppet valve, manufactured by Clippard Instrument Laboratory, Inc. of Cincinnati, Ohio; this valve has a stem **19*b*** that is normally biased outwardly to keep the valve closed; the stem is moved inwardly to open the valve by cam follower means **19*c*** that is depressed by a rotating cam **19*d*** driven by a suitable motor **19*e***; the cam has raised portions **19*f*** that depress stem **19*b*** to open valve **19*a*** and permit flow of air from source **18** through the tube **17** in pulses the length and timing of which are determined by the angular spacing and length of cam portions **19*f***. Therefore, the power jet that impinges on cavity **11** is disrupted by the modulating air pulses

emitted from conduit 19, to cause interruptions in the ultrasonic signal corresponding to a pattern caused by cam portion 19*f*. Of course, the cam surface can be designed to provide other variations in the flow of the modulating stream of air; for example, the cam surface could be designed in a known manner to cause the modulating stream to flow for most of the time and be interrupted periodically, so that the power jet would produce pulsed ultrasonic signals corresponding to the interrruptions in the modulating stream.

If desired a continuous but varying flow of air in the modulating stream can be achieved, as by using as valve 19*a* in FIG. 1, in place of the MAV-2 poppet valve, a Model MAR-1CP "Clippard" pressure controller that produces pressure changes in a continuously flowing stream of air or other gas in accordance with travel of a plunger, and depressing the stem of the plunger by cam 19*d* of a shape to provide the desired timing and position of the plunger.

FIG. 2 discloses a modification having at the discharge end of the jet-producing member 4*a* a portion 21 that extends transversely of the power jet and has a curved transverse surface 22, so that the power jet discharge opening 7 is essentially at the center of surface 22. Another transverse portion 23 having a curved transverse surface 24 is associated with cavitied member 10*a* that provides a closed end cavity 11; so that the open end of the cavity 11 is at the center of surface 24. Each of these curved surfaces is preferably a portion of a sphere, but may be otherwise curved.

A modulating stream of air is discharged from a conduit 17 connected to a source of air or other gas 18 through a manually or automatically operable modulating valve means, generally indicated at 19, that may be as described in connection with FIG. 1. The modulating stream of air is discharged to intersect the power jet discharged from the opening 7 of the jet-producing member 4*a*, in close vicinity to the member 21, preferably so that the modulating stream can sweep across at least a portion of curved surface 22. Transverse surfaces 22 and 24 aid in separation of the fundamental frequencies and reduce random noise. They also promote efficiency of generation of the ultrasonic signal, and effectiveness of the modulation. Operation of the apparatus is otherwise the same as that of FIG. 1.

FIG. 3 depicts another embodiment of the invention, in which there is an intermediate member 25 mounted between the opposed ends of a jet-producing member 4 and a cavitied portion 10 providing a closed end cavity 11; and located so that a conduit 17 can eject a modulating flowing stream of air between the jet-producing member and the intermediate member. Intermediate member 25 has a generally cylindrical opening 26 that is coaxially aligned with, and that approximates but preferably is somewhat larger in diameter than, the opening 7 of the jet-producing member 4 and the cavity 11 of the cavitied member 10. Intermediate member 25 is adjustably supported by a bracket 27 that is clamped to the base member 1 in a longitudinal slot 28 extending through the base member. The intermediate member thus may be adjusted axially toward or away from each of the jet-producing member and the cavitied member, or moved laterally to a limited degree by partially rotating it around the axis of the offset lower portion of bracket 27, so that the power jet is confined as it passes from opening 7 to cavity 11. The valve means 19 may be as described in connection with FIG. 1.

The intermediate member makes possible a purer tone of the ultrasonic signal and greater efficiency of sound generation than is possible in the embodiment of FIG. 1. Operation of the apparatus is otherwise the same as that of FIG. 1.

In the embodiment of FIGS. 4 and 5, formation of the power jet, its impingement on a cavity and generation of an ultrasonic signal are not, as in previous embodiments, produced by a jet of air under superatmospheric pressure, but are induced by a pressure below the ambient air pressure. In this embodiment, the base member 31 rigidly carries, by a supporting portion 32, an inner member 33 having an exterior thread 34 and an interior passage 35 having an enlarged front portion 36. Member 33 also includes a cavitied member 37 that is supported from the interior wall of the passage portion 36 by vanes 38 (FIG. 5) to provide gas passages between portion 37 and passage 36. Member 37 has an exterior front end portion 39 that is frusto-conical, surrounding a cavity 40, having a closed bottom, in member 37.

An outer member 41 constituting a jet-producing member, is supported by the member 33, having internal thread 42 that engages the thread 34 of member 33, to make possible axial adjustment. A nut 43 locks member 41 on member 33. Member 41 has an interior chamber 44 having a transverse frusto-conical interior front wall 45 having a central opening 46 and terminating in a generally cylindrical interior wall 47. The space between the interior of chamber 44 and the exterior of the cavitied member 37, and the portion of the chamber defined by frusto-conical interior wall 45 and frusto-conical exterior wall 39 together with their relation to the opening 46 in member 41, are all shaped and related according to known Hartmann whistle principles to cause the creation of ultrasonic sound when a power jet of air is drawn through opening 46 into the assemblage to impinge on cavity 40 at a sufficient speed due to a suitable subatmospheric pressure maintained in passage 35.

There is also provided a conduit 17, connected to suitable source 18 of air under pressure, to discharge a modulating flowing stream of air that laterally intersects the power jet of air adjacent opening 46 and cavity 40. Valve means 19, which may be like that described above in connection with FIG. 1, is provided to vary or interrupt the stream of air emanated by conduit 17 and cause modulation of the ultrasonic signal emitted by the generator.

Although the embodiments illustrated have been described in connection with the use of air as the gas for the power jet and for the modulating stream, it is apparent that other gases may be used for either or both the power jet and modulating stream. Thus it is possible to use air for the power jet stream, and a different gas lighter or heavier than air for the modulating stream, or to use air as the modulating jet stream and a fluid other than air for the power jet stream. For example, if hydrogen is used for the power jet the ultrasonic frequency can be substantially increased.

It is possible, according to the present invention, to convert ultrasonic signals to audible signals by modulating the power jet with a modulating stream having a frequency in the audible range. By utilizing a modulating stream having a frequency above or below the audible range, it is possible to produce modulated ultrasonic, and hence inaudible, signals.

Modulating valve means different from that disclosed may, of course, be employed.

Although the invention has been described in connection with signal generators operating on the principle of the Hartmann whistle, in which connection it provides exceptional advantages, the invention may also be employed in connection with other types of jet generators for signals, such as those operating on the principle of the Galton whistle.

By means of the present invention, it is possible readily and simply to produce modulated ultrasonic signals of high intensity and desired accuracy of modulation, as in the range of about 20,000 to about 100,000 cycles per second, or of even higher frequencies. Such signals can be used, through suitable receiving means, to control apparatus at a distance without the use of electromagnetic waves, wires, or physical power-conducting means such as hydraulic means; such signals also can be used for various other purposes.

Various modifications other than those indicated above will be apparent to those skilled in the art. It is intended that the patent shall cover, by suitable expression in the appended claims, whatever features of patentable novelty reside in the invention.

I claim:

1. Apparatus for generating a modulated high frequency signal in an ambient gas, comprising first nozzle means defining a jet-producing member adapted to produce a gaseous jet

stream at a speed at least approximating the speed of sound in said ambient gas, a cavitied member stationed in said jet stream and having its cavity positioned with respect to said stream and said first nozzle means to resonate and generate waves of sonic or supersonic frequency, means to modulate said waves comprising second nozzle means positioned laterally of said jet stream and adapted to discharge a fluid jet stream intersecting the first mentioned jet stream prior to its reaching the cavitied member to modulate said generated waves in accordance with the flow characteristics of said fluid jet stream, and means to modulate the fluid jet stream itself before it intersects the gaseous jet stream, thereby to vary the modulations induced in said generated waves.

2. The apparatus of claim 1 in which said jet-producing member induces the flow of gas in said jet by a pressure below the pressure of the ambient gas.

3. The apparatus of claim 1 in which said jet-producing member for emitting a jet stream of gas has a chamber terminating in a discharge opening through which the gas passes, said chamber being tapered from a larger cross section to a smaller cross section of the opening in the vicinity of the opening.

4. The apparatus of claim 1 in which said cavitied member providing a cavity is a member having a tapered exterior portion in the vicinity of the cavity that tapers to substantially the size of said cavity opening from a larger dimension.

5. The apparatus of claim 1 in which said jet-producing member for emitting a jet of gas has a chamber terminating in a discharge opening through which the gas passes, said chamber being tapered from a larger cross section to a smaller cross section of the opening in the vicinity of the opening; and in which said cavitied member providing a cavity is a member having a tapered exterior portion in the vicinity of said cavity that tapers to substantially the size of said cavity opening from a larger dimension.

6. The apparatus of claim 2 in which said cavitied member is a member having a cavity in one end thereof and having an exterior configuration that is tapered in the vicinity of the cavity from a larger dimension, in which said jet-producing member for causing flow of a jet of gas provides a chamber surrounding said cavitied member and having a generally transverse tapered interior wall in the vicinity of the tapered exterior wall of said cavitied member and an opening in said transverse wall opposite said cavity, and in which said second nozzle means is located adjacent said opening in said transverse wall.

7. The apparatus of claim 1 in which at the end of said jet-producing member nearest said cavitied member and at the end of said cavitied member providing a cavity there are portions that provide surfaces that extend transversely of the direction of the flowing jet stream of gas, which transversely-extending surfaces face each other, and in which apparatus said second nozzle means is located between said transversely-extending surfaces.

8. The apparatus of claim 7 in which said transversely extending surfaces are convexly curved.

9. The apparatus of claim 1 comprising means providing a generally cylindrical passage in a portion of the space between said first nozzle means and the cavity in said cavitied member.

10. The apparatus of claim 9 in which said passage is substantially the size of the opening through which said jet stream of gas is emitted from said jet-producing member.

11. The apparatus of claim 9 in which said means second nozzle for discharging a stream of fluid is located between said opening of said jet-producing member and said means providing a cylindrical passage.

12. The apparatus of claim 1 wherein said modulating means for the fluid jet stream is adapted to vary its flow.

13. The apparatus of claim 1 wherein said modulating means for the fluid jet stream is adapted to discharge a substantially continuously flowing stream of said fluid at a varying rate.

14. The apparatus of claim 1 wherein said modulating means for the fluid jet stream is adapted to discharge said fluid in pulses of predetermined length and intensity.