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Rogers et al.

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[54] **STANDING WAVE ACOUSTIC PARAMETRIC SOURCE**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 316,605, Dec. 19, 1972, abandoned.

[52] **U.S. Cl.** **340/10,** 310/8.2, 310/8.1;8.2

[51] **Int. Cl.** **H04b 13/00**

[58] **Field of Search** .... 340/8, 10, 12, 13, 8 LF, 340/9

[56] **References Cited**

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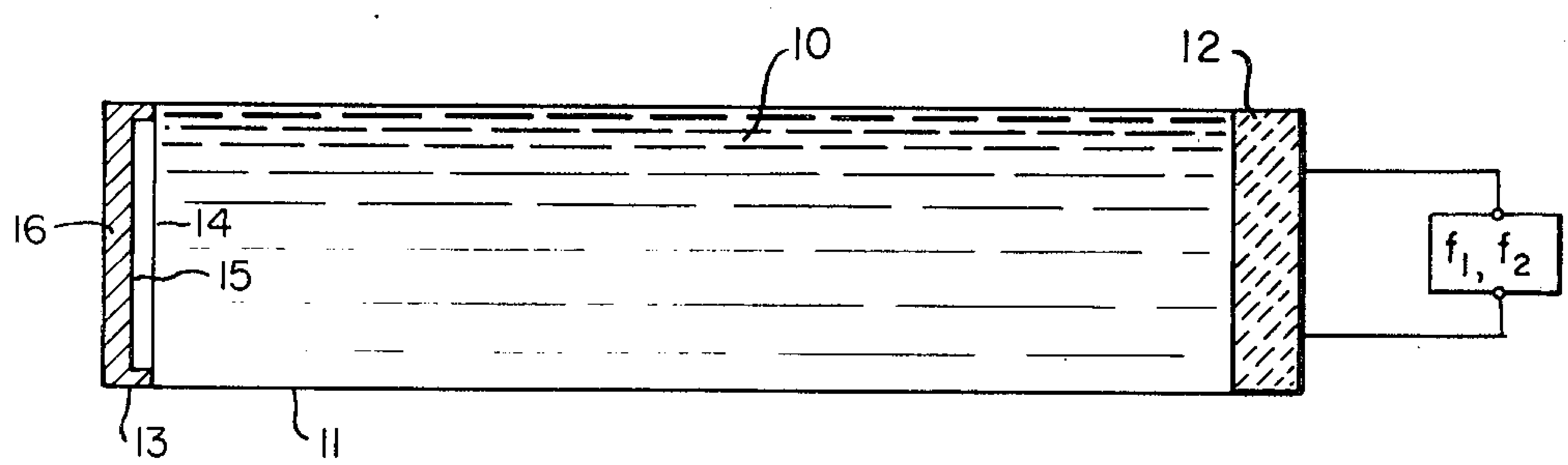
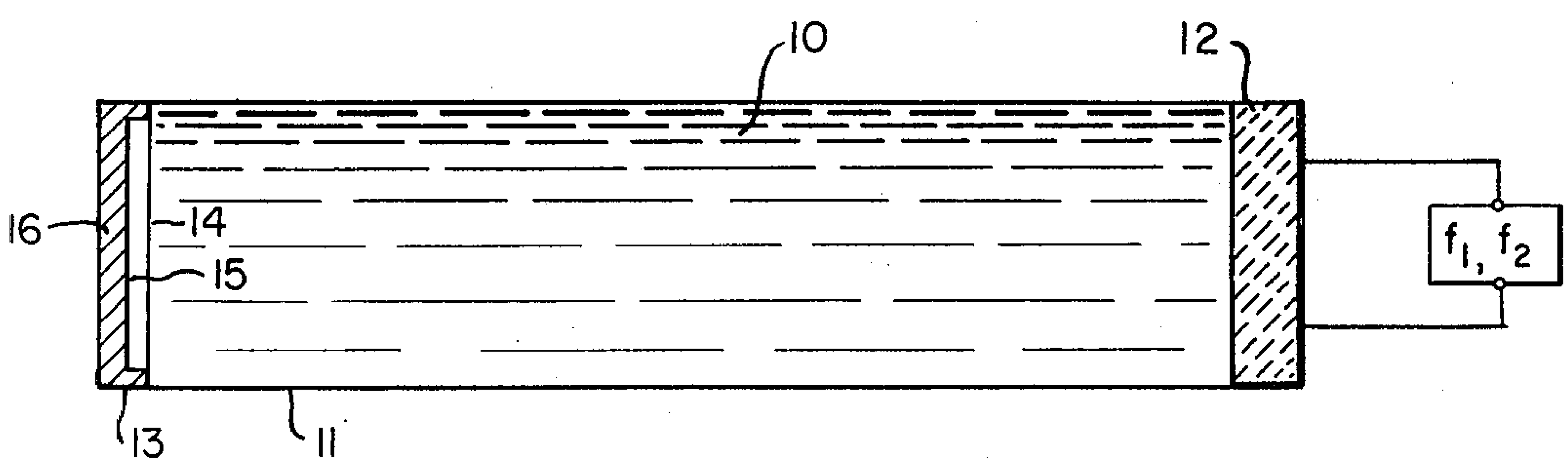
[57] **ABSTRACT**

A piston type transducer in combination with a thin wall waveguide which is terminated by a thin plug of pressure release material to form a resonant cavity. The transducer is driven simultaneously at two closely spaced high intensity, high frequency signals. The two frequencies are chosen to be either neighboring resonances or to be within the bandwidth of a single resonance. A low frequency acoustic wave is generated by the nonlinear interaction of the two high frequency standing waves in the fluid within the resonant cavity and radiates omnidirectionally into the surrounding medium through the thin walled waveguide.

5 Claims, 1 Drawing Figure

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12
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f_1, f_2
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STANDING WAVE ACOUSTIC PARAMETRIC SOURCE

CROSS REFERENCE TO A RELATED APPLICATION

This application is a continuation-in-part of application Ser. No. 316,605, filed Dec. 19, 1972, now abandoned.

BACKGROUND OF THE INVENTION

This invention is directed to sonar transducers and more particularly to omnidirectional, low frequency underwater sound sources.

Heretofore, very large, massive underwater sound devices have been required to radiate effectively low frequency (<1 KHz) sound underwater. In the past, the generation of narrow beam, low frequency acoustic radiation from a relatively small piston source has been accomplished by the use of a traveling wave acoustic parametric source (TWAPS). In such devices, a small source is driven simultaneously by two signals of high frequency f_1 and f_2, and a low frequency wave at the difference frequency $f_1 - f_2$ is generated by the nonlinear interaction of the high frequency sound waves in the water medium. The desirability of such a device is enhanced by the lack of sidelobes in the radiation pattern and by the relatively large bandwidth at the difference frequency. The chief disadvantage of the TWAPS is the low efficiency of the conversion due to the absorption and diffraction of f_1 and f_2 and to the nonlinear generation and subsequent absorption of both the harmonics of f_1 and f_2 and the sum frequency wave $f_1 + f_2$. For certain applications, the high directivity, inherent with the TWAPS due to the long interaction region, may also be a disadvantage.

SUMMARY OF THE INVENTION

A piston transducer is mounted in one end of a waveguide. The waveguide is terminated by a thin plug of "soft" pressure release material to form a resonant cavity. The transducer is driven simultaneously by two closely spaced high intensity, high frequency signals of frequencies f_1 and f_2 creating standing waves within the cavity. A low frequency $f_d = f_1 - f_2$ is generated by the nonlinear interaction of the two high frequency standing waves in the fluid within the resonant cavity. The thin wall of the waveguide is designed to be highly reflective at the high frequencies f_1 and f_2. The cavity is designed to be resonant or nearly resonant at both f_1 and f_2 to provide a very high energy density within the cavity and hence a very strong nonlinear interaction. The low frequency sound generated by this interaction cannot be contained by the relatively thin walls and ends of the cavity and thus is radiated into the surrounding medium. The soft reflector which terminates the cavity serves the following purpose:

1. It acts as a good reflector at high frequencies to ensure high energy densities for both f_1 and f_2.
2. It acts as an acoustic window for the low frequency wave, because it is acoustically thin at these frequencies.
3. The phase shift of 180° which accomplishes reflection from a soft material serves to inhibit the growth of harmonics in the cavity.

STATEMENT OF THE OBJECTS

It is therefore an object of the present invention to

provide an underwater sound transducer which is an effective radiator at low frequencies.

Another object is to provide an underwater transducer which is light in weight and smaller in size than such prior art transducers with an equivalent performance.

Other objects and advantages of this invention will become obvious to one skilled in the art from the following description considered with the drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic representation of a transducer made in accordance with this invention.

DESCRIPTION OF THE DEVICE

Now referring to the drawing, there is illustrated schematically a thin wall cylindrical acoustic waveguide having for example a thickness of about 1/64 to about 1/32 inch, an inside diameter of about 2 to 5 inches and a length of about 3 to 7 inches. Such a device would be designed to produce a low frequency f_d less than about 1 KHz using two high frequency signals f_1 and f_2 both about equal to 100 KHz. A piston type transducer **12** such as lead zirconate titanate, barium titanate, or piezoelectric, is mounted at one end of the waveguide in order to transmit sound waves within the waveguide. The waveguide is terminated at its opposite end by a thin plug of pressure release material **13** such as a thin, air backed mica sheet **14** in which the air backing **15** is enclosed by a thin brass sheet **16** through which low frequencies will be transmitted to form a resonant cavity. The cavity is filled with a fluid **10** such as water, carbon tetrachloride, or perfluoroheptane that has a sound-speed equal to or substantially less than that of the surrounding medium. The transducer is driven simultaneously by two closely spaced high intensity, high frequency sinusoidal current components of equal amplitude at frequencies f_1 and f_2 close to a resonance frequency of the system. Such high frequency signal systems are well known in the art and are not shown for simplification of the drawing. Such systems have been disclosed in an NRL Report **7513**, "Adaptation of the NRL Acoustic Research Tank Facility for Experiments in Parametric Sonar, with Preliminary Results," by Anthony I. Eller dated Jan. 29, 1973, and published by the Naval Research Laboratory, Washington, D.C. 20375. Other suitable transducer driving systems have been set forth in the References cited in the NRL Report 7513. The high intensity, high frequency signals are chosen to be either two neighboring resonance frequencies of the cavity (hereafter referred to as operating mode 1) or two frequencies within the bandwidth of a single resonance of the cavity (hereafter referred to as operating mode 2). The nonlinear interaction of the two high frequency standing waves within the resonant cavity generates a low frequency acoustic wave of frequency $f_d = f_1 - f_2$ where f_2 is less than f_1. The waveguide must be at least one-half wavelength long at the difference frequency when operating mode **1** is used, but it may be as short as one-quarter wavelength at the high frequency when operating mode **2** is used. It is therefore expected that only operating mode **2** will be used for very low frequency applications. The thin wall is designed to be highly reflective at the two high frequencies f_1 and f_2, but by virtue of its thinness, it is transparent acoustically at the low frequency f_d. The cavity is resonant or nearly resonant at both f_1 and f_2 to provide a very high energy density within the cavity. This produces a very strong nonlinear interaction between the two high frequencies f_1 and f_2 and results in a large acoustic output at the low frequency f_d. The low frequency sound generated by the nonlinear interaction cannot be contained by the relatively thin walls and end plug; therefore, the low frequency waves are radiated into the surrounding medium omnidirectionally. In operating mode **2** the device can be made short enough to insure that the low frequency will be radiated omnidirectionally. In operating mode **1**, with water as the fluid in the cavity, the radiation will be dipolar.

The soft pressure release material which plugs the end of the cavity acts as a good reflector at high frequencies to insure high energy densities within the cavity for both f_1 and f_2. The plug acts as an acoustic window for the generated low frequency wave, because it is acoustically thin in the low frequency range.

The pressure release reflector inhibits the growth of both the sum frequency and harmonics of the primary frequency. This occurs because each frequency component in a plane wave undergoes a 180° phase shift upon reflection from a pressure release boundary. Consider a sinusoidal wave leading the piston. As the wave propagates, harmonics are generated with a fixed phase relationship to the fundamental. Ignoring dispersion, the phase relationship is maintained while the "most stable" waveform, the sawtooth is approached. When the distorted wave is reflected back from the pressure release end, the 180° phase shift produces a "least stable" waveform or a reverse sawtooth. During subsequent propagation back to the piston, new harmonic generation cancels the existing harmonic content, and the waveform tends to return to a sinusoid. Thus, relatively little energy will be lost as a result of competing nonlinear interactions.

The fluid in the cavity may be water or any other fluid which has a specific acoustic impedance that lies within the range from about 0.5 Kg $sec^{-1}m^{-2}$ to about 5.0 Kg $Sec^{-1}m^{-2}$. It may be desirable, for example, to use a fluid with a sound/speed lower than that of water in order to decrease the overall length of the device or to use a fluid with a higher parameter of nonlinearity in order to achieve a larger nonlinear conversion. The device of this invention is a small underwater sound source which is an effective radiator at low frequencies.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed and desired to be secured by Letters Patent of the United States is:

1. A device for producing omnidirectional, low frequency acoustic waves, which comprises:

a thin wall acoustic waveguide having a first and second open end;

a transducer secured to said first open end of said waveguide;

a plug of pressure release material closing said second open end of waveguide to form a resonant cavity;

a fluid filling said acoustic waveguide between said transducer and said pressure release material;

a first and second high intensity, high frequency signal producing means connected with said transducer for simultaneous operation thereof producing first and second high intensity, high frequency standing waves within said resonant cavity;

said first standing wave having a frequency higher than said second standing wave;

said pressure release material inhibiting the growth of sum frequencies and harmonics whereby a low frequency output wave is generated by a nonlinear interaction of the two high frequency standing waves in the fluid within said waveguide, and

said wall thickness is sufficiently thin that said wall is transparent to said low frequency while reflecting said first and second high frequency signals.

2. A device as claimed in claim **1**, wherein:

the frequencies of said first and second high intensity, high frequency standing waves are neighboring resonance frequencies of said resonant cavity.

3. A device as claimed in claim **2**, wherein:

the frequencies of said first and second high intensity, high frequency standing waves are both within the bandwidth of a single resonance of said resonant cavity.

4. A device as claimed in claim **1**; wherein,

said thin wall acoustic waveguide has a thickness of from about 1/64 inch to about 1/32 inch, an inside diameter of from about 2 inches to about 5 inches, and a length of from about 3 inches to about 7 inches.

5. A device as claimed in claim **1**; in which,

said pressure release material is formed by a thin brass sheet backed by a thin sheet of mica with air in between said brass and mica.

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