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AM/FM HYDROACOUSTIC GENERATOR

Filed May 13, 1966

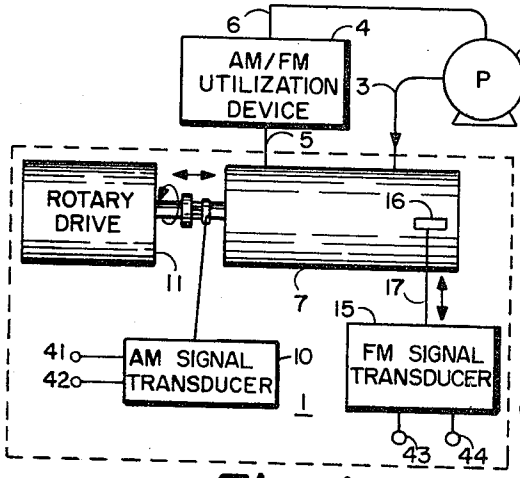


Fig. 1

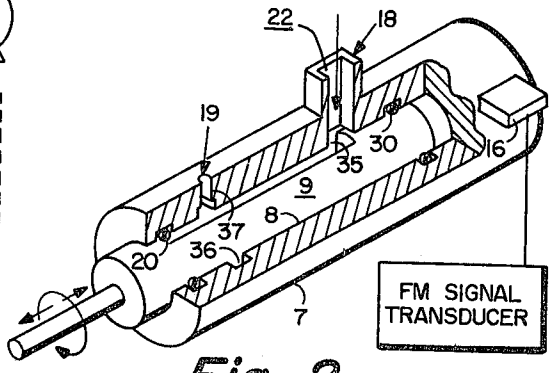


Fig. 2

Fig. 3

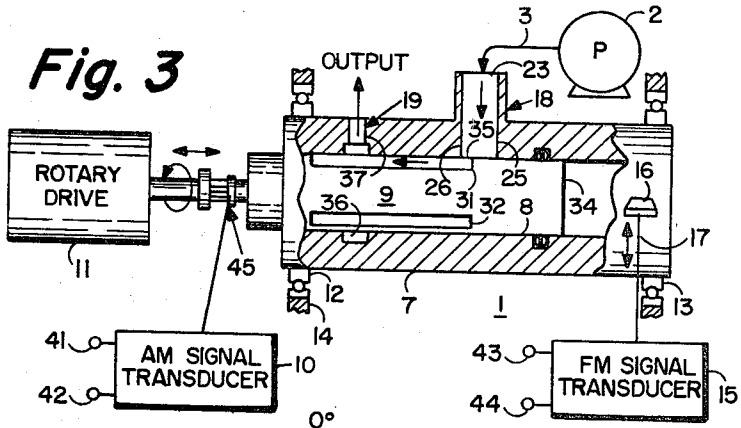


Fig. 4

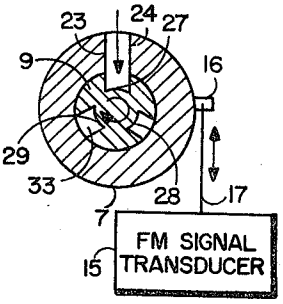
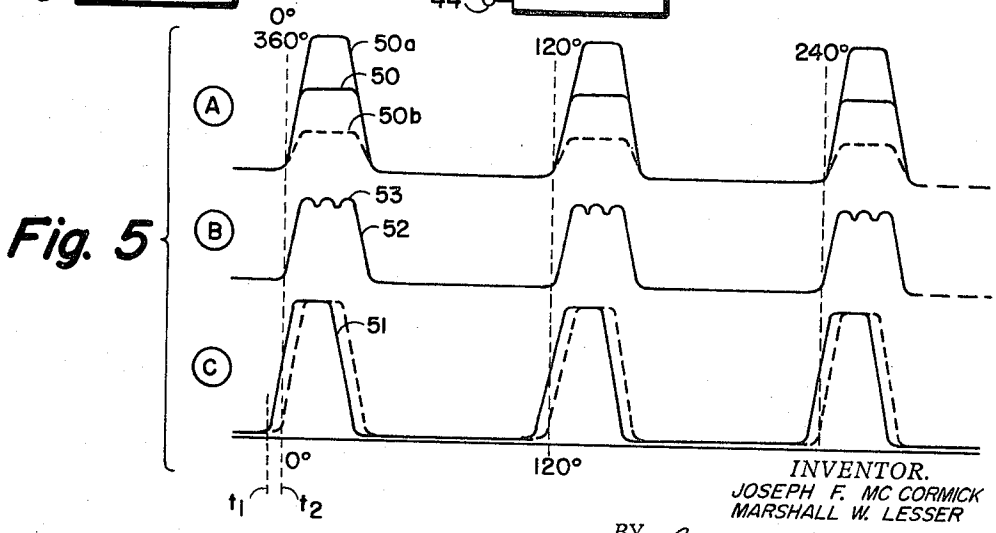


Fig. 5



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AM/FM HYDROACOUSTIC GENERATOR

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5 Claims. (Cl. 340—8)

ABSTRACT OF THE DISCLOSURE

An AM/FM hydroacoustic oscillator is described comprising a housing having inlet and outlet ports through which fluid (under pressure) flows, and a spool disposed in the housing having a channel cut therein, the spool being adapted for rotation and translation movement with respect to its axis so that when the spool is translated the flow area through the oscillator is varied to produce amplitude oscillation of the fluid flow. FM oscillation is accomplished by cyclically rotating the housing in relation to the spool.

The present invention relates to a hydroacoustic system and particularly to an improved AM/FM hydroacoustic generator.

Hydroacoustic generators for converting a steady flow of hydraulic fluid into an alternating flow of hydraulic fluid are well known to those skilled in the art. Such generators modulate an otherwise steady flow of fluid under pressure to derive alternating hydraulic energy or acoustic energy. Hydroacoustic generators are particularly useful for underwater communication systems since high levels of acoustic energy may be coupled to a load, such as surrounding water, through a flexural disc or moving piston transducer. One of the pressing problems of such systems is that of pulse shaping and modulating the acoustic energy for the transmission of information.

Accordingly, it is an object of the present invention to provide an improved AM/FM hydroacoustic generator.

It is another object of the present invention to provide an improved hydroacoustic generator wherein a steady flow of fluid under pressure can be modulated in amplitude or frequency in response to an input signal.

It is yet another object of the present invention to provide an improved hydroacoustic generator wherein amplitude, frequency and phase of the output signal thereof is subject to independent control.

It is a still further object of the present invention to provide an independent selective control device for amplitude and frequency modulation of the output energy from a hydroacoustic generator.

Briefly described, an improved AM/FM hydroacoustic generator embodying the invention has a housing and a spool mounted in the housing, for rotation and for linear motion. The spool includes at least one longitudinal channel for the flow of fluid under pressure. The housing includes an inlet porting structure coacting with one end of the channel, and an outlet porting structure coacting with the other end of the channel, through which porting structures fluid may flow into and out of the channel. Such flow occurs each time the channel traverses the inlet and outlet porting structure during rotation of the spool. The walls at the one end of the channel and the inlet porting structure define a variable inlet orifice which may be varied by linear motion of the spool to produce an amplitude modulated fluid flow and varied by rotation of the spool to generate a fluid flow which is modulated at a certain frequency which may be termed a carrier frequency. The inlet orifice may also be varied by shifting or rotating the housing relative to the spool in time relationship with the channel to produce a phase shift of the output flow at its carrier frequency. Means are provided for continuously rotating the spool to establish the carrier frequency at which acoustic energy may be generated from the fluid flow energy.

In accordance with the invention, means including an input signal responsive transducer are coupled to the spool for moving the spool in a linear motion while the spool is being rotated to increase or decrease the flow area of the inlet orifice in response to the input signals. The linear motion of the spool thus amplitude modulates the fluid flow through the inlet orifice. The modulated fluid flow passes through the orifice into the channel then through the outlet porting structure to a utilization device or load. A motion transducer, responsive to input control signals, is coupled to the housing for rotating the housing relative to the rotating spool to phase shift the opening and closing of the inlet orifice for each rotation of the spool. A phase shift of the opening and closing of the inlet orifice for each cycle not only produces a phase shift, but also a frequency modulation of the acoustic energy. The acoustic energy may be frequency modulated on the carrier frequency.

The invention itself, both as to its organization and method of operation, as well as additional objects and advantages thereof, will become readily apparent from a reading of the following description in connection with the accompanying drawings in which:

FIG. 1 is a schematic view of the hydroacoustic generator connected to a utilization device in accordance with the invention;

FIG. 2 is a perspective view of the hydroacoustic generator of FIG. 1, partly in section, to show details of the hydroacoustic generator;

FIG. 3 is a fragmentary side view of the hydroacoustic generator of FIG. 1;

FIG. 4 is a cross-sectional view taken along line 4—4 of the hydroacoustic generator of FIG. 3, and

FIG. 5 discloses wave form diagrams to be utilized in the understanding of the operation of the hydroacoustic generator shown in FIGS. 1–4.

Referring now to FIG. 1, a block diagram of a hydroacoustic system employing the hydroacoustic generator **1** of the invention is shown. The hydroacoustic generator **1** receives a steady or DC flow of fluid under pressure from a pump **2** by way of an inlet line **3**. The hydroacoustic generator **1** may amplitude or frequency modulate the steady flow of fluid in a manner to be described hereinafter and apply the modulated fluid flow to a utilization device **4** through an outlet line **5**. The utilization device **4** may be any load such as, for example, an underwater sound transducer having a piston or flexural disc which is vibrated in a longitudinal or flexural mode in response to an amplitude or frequency modulated fluid flow thereat (see for example Patent No. 2,792,804). The utilization device **4** may also be a device which is driven or actuated by a modulated fluid flow such, for example, as sonic process equipment and the like. The fluid is recirculated through the system by a return line **6** connected between the utilization device **4** and the pump **2**, thus completing a hydraulic circuit.

Referring to FIGS. 2–4, hydroacoustic generator **1** is shown in each of these figures. Only the essential elements of the invention are shown. Pipe fittings, flexible joints, and other fittings well known to those skilled in the art have been omitted to more clearly show the invention.

The hydroacoustic generator **1** comprises a housing **7** having a bore or cylindrical chamber **8**, a spool **9** mounted in the chamber **8** for both linear and rotational motion therein, a rotary drive **11** and an AM signal transducer **10** connected to the spool **9** by a coupler **45**. The spool **9** may be rotated at different selected speeds by the rotary

drive 11. The spool 9 may be driven selectively in a linear motion by the AM signal transducer 10. Input signal transducer 10 may be one of the type of drive means comprising a piezoelectric, magnetostrictive electrostrictive transducer, or other motive transducer (not shown) for selectively moving the spool 9 in a linear motion in response to an amplitude moduated input signal. The rotary drive could be a motor, synchro-motor, or other electrical, mechanical or fluid drive. The coupler 45 couples the rotational power from the rotary drive 11 to the spool 9 and linear motion to the spool 9 for the AM signal transducer 10. The AM signal transducer 10 includes input terminals 41 and 42 for applying the AM input signal thereto.

The housing 7 is mounted for rotation on outboard bearings 12 and 13 fixed to a frame 14, shown in a fragmentary view in FIG. 3. The housing 7 is rotatable about the spool 9. The housing 7 may be rotated or angularly displaced relative to the spool 9 by an FM signal transducer 15 coupled, for example, to the housing at a lug 16 by a linkage 17, or other comparable mechanical or hydraulic connection. The FM signal transducer 15 may, for example, be any one of the type which moves the linkage 17 up and down in response to a frequency modulated input signal applied to input terminals 43 and 44. The FM signal transducer 15 may comprise, for example, a stack of piezoelectric, or electrostrictive elements which vibrate in a thickness mode in response to a frequency modulated input signal.

The housing 7 includes an inlet porting structure 18 and an outlet porting structure 19 communicating with the chamber 8. The inlet and outlet porting structures 18 and 19 are connected to the inlet and outlet lines 3 and 5 respectively. The inlet and outlet lines 3 and 5 are flexible or movable so as to allow the housing 7 to be shifted or rotated by the FM signal transducer 15. Fluid seals such as O-rings 20 and 30 are disposed in the housing 7 on opposite ends of the spool 9 to provide a fluid seal around the spool 9 or, alternatively, this function could be provided through a close fitting of spool 9 to bore 8.

The inlet porting structure 18 includes a substantially rectangular port 22 having sides 23 and 24 parallel to the longitudinal axis of the chamber 8 and sides 25 and 26 transverse to the longitudinal axis of the chamber 8. It should be understood, however, that the invention is not limited to the shape of the port 22. In fact, it may be desirable to employ other shaped ports to shape the pulse waveform of the output of the hydroacoustic generator 1 so as to achieve a modified pulse waveform from that provided by a rectangular shaped port. The port 22 has a width along the periphery of the spool which may suitably be a fractional part of the periphery of the chamber 8. The length of the port 22, as measured along the length of the channel, is a function of the linear movement of the spool 9. The length of the port 22 is generally slightly less than the maximum linear movement of the spool 9. However, the length of the port 22 may be made to exceed the linear movement of the spool 9 to establish a DC level about which the fluid flow may be amplitude modulated.

The spool 9 includes one or more channels along the length thereof. The spool 9 of the hydroacoustic generator 1 is illustrated as having three channels 27, 28 and 29 of equal length and spacing. The number of channels establishes the carrier frequency of the generator 1 for a given rotational speed of the spool 9. Each of the channels 27, 28 and 29 terminate at one end thereof at 31, 32 and 33, respectively, a given radial distance from one end 34 of the spool 9. The channels 27, 28 and 29 have a given width which may be less than, more than, or equal to the width of the port 22 measured across sides 23 and 24 to shape the pulse waveform output of the hydroacoustic generator 1 in the manner to be described hereinafter.

The port 22 and each of the channels 27, 28 and 29 define a variable inlet orifice 35 whose flow area may be varied in three different ways:

(a) When the spool 9 is rotated, each of the channels 26, 28 and 29 sequentially traverses the port 22 and changes the flow area of the variable inlet orifice 35 periodically.

(b) By moving the spool 9 linearly while it is being rotated, each one of the channels 27, 28 and 29 traverses different cross-sections of the inlet port 22, thereby changing the flow area.

(c) By rotating or shifting the housing 7 rotationally relative to the spool 9 as each channel 27, 28 and 29 traverses the port 22.

The fluid from the pump 2 passes through the inlet orifice 35 into the channels 27, 28 and 29 sequentially each time the channels 27, 28 and 29 traverse the port 22. The fluid flows from the channels 27, 28 and 29 into the outlet porting structure 19 to the utilization device 4.

The outlet porting structure 19 includes an annular chamber 36 in the housing 7 encircling the spool 9 and a fluid passage 37 communicating with the circular chamber 36 and the output line 5. The operation of the hydroacoustic generator 1 would be substantially similar if the porting arrangement of orifice 35 and 37 were to be interchanged with the annular groove 36 at the inlet and the variable orifice at the outlet.

During the operation of the hydroacoustic generator 1, the rotary drive 11 continuously rotates the spool 9 at a selected speed. The pump 2 at the same time supplies a constant source of fluid under pressure to the inlet porting structure 18. Initially, the spool 9 may be adjusted so that the ends 31, 32 and 33 of the spool 9 lie on an imaginary circle midway between the transverse sides 25 and 26 of the port 22. When the spool 9 is thus rotated relative to the port 22, the inlet orifice 22 is opened halfway each time one of the channels 27, 28 and 29 traverse the inlet port 22. Each time the inlet orifice 35 is opened halfway, a pulse 50 (FIG. 5, waveform A) of high pressure fluid is applied to the utilization device 4 through the outlet porting structure 19. Three pulses 50 are applied to the utilization device 4 for each revolution of the spool 9, since three channels are used. Thus, the steady flow of fluid supplied by the pump 2 is modulated in response to the rotation of the spool 9. Since the spool 9 is rotated at a constant speed, the frequency of the pulse 50 is a function of the rotation speed of the spool 9. By keeping the rotational speed of the spool 9 constant, the pulses 50 occur at a steady carrier frequency.

The output of the hydroacoustic generator 1 may be amplitude modulated by applying an ampltitude input modulated signal to the transducer 10 at terminals 41 and 42. The transducer 10 linearly moves the spool 9 and the ends 31, 32 and 33 of the channels 27, 28 and 29 through the coupler 44 about the midway position, causing the flow area of the inlet orifice 35 to vary directly. The coupler may be any suitable linkage which translates the motion of the transducer into linear motion of the spool without interference with the rotational motion of the spool. Variation of the flow area of the orifice causes an amplitude modulation of the pulse 50 (FIG. 5, waveform A). The amplitude of the pulse 50 may vary between a maximum as shown by the pulse 50*a* or to some lesser pulse amplitude as shown by pulse 50*b*.

In accordance with the invention, the time occurrence of each of the pulses 50 may be phase shifted by applying a signal to the transducer 15. When a cyclic input signal is applied to the FM signal transducer 15 at terminals 43 and 44, the housing 7 is rotated or cyclically shifted relative to the spool 9. The time occurrence of the channels 27, 28 and 29 relative to the inlet port 22 is shifted by rotation of the housing 7, thus permitting the inlet orifice 35 to open before the normal 0°, 120° and 240° of revolution of the spool 9. The waveform C of the pulse shown in FIG. 5 illustrated the phase shift of a pulse 51 which normally would have occurred at 0° or time t_2 but has been advanced to time t_1 by the shift of the housing 7 and the inlet porting structure 18 relative to the spool 9. By phase shifting of the output pulse 51

by varying amounts (viz. cyclically) a frequency modulation of the output pulse **51** is achieved.

In FIG. 5, the waveform B shows the modulation of a carrier frequency pulse **52**. The carrier pulses **52** may be modulated by exciting the housing in a rotational mode relative to the spool **9** each time channels **27**, **28** and **29** traverse the inlet port **22**. The undulations **53** show the frequency modulation.

From the foregoing description it will be apparent that there has been provided an AM/FM hydroacoustic generator that amplitude and frequency modulates an otherwise steady flow of fluid under pressure. The selective amplitude and frequency modulation is accomplished by independent control of input signals to a linear spool motion signal transducer **10** of separate input signal to the rotational motion signal transducer **15**.

While a preferred embodiment of the invention has been described, it should be understood that variations and modifications thereof within the spirit of the invention will undoubtedly suggest themselves to those skilled in the art. For example, the housing **7** may be stationary, and the inlet porting structure may be moved relative to the rotating spool **9** by the transducer **15**. Accordingly, the description should be taken merely as illustrative and not in any limiting sense.

What is claimed is:

1. A hydroacoustic generator comprising

(a) a housing having an inlet and an outlet porting structure extending radially of said housing and spaced from each other longitudinally of said housing axis,

(b) a spool disposed in said housing along the longitudinal axis thereof for rotational and linear movement with respect to said axis,

(c) said spool having at least one channel along the length thereof communicating with said inlet and outlet porting structure when rotated thereacross,

(d) means connected to said inlet porting structure for applying a fluid under pressure thereto,

(e) drive means for rotating said spool, and

(f) means for shifting said housing and said spool rotationally with respect to each other for modulating the flow of fluid through said generator in frequency.

2. The invention defined in claim **1** where said means set forth in subparagraph (f) includes an electrical signal responsive transducer.

3. The hydroacoustic generator defined in claim **1** further including means for rotatably supporting said housing.

4. The hydroacoustic generator defined in claim **1**, further including amplitude means for moving said spool and said housing linearly with respect to each other while said spool is being rotated for modulating the flow of fluid through said generator in amplitude.

5. The invention set forth in claim **4**, wherein said amplitude means includes another electrical signal responsive transducer.

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