

TITLE

Algae control by sweeping ultrasonic frequencies

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No.
5 63/587,344, filed October 2, 2023.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR
DEVELOPMENT

[0002] Not Applicable

BACKGROUND

10 **[0003]** 1. Field of Invention

[0004] This invention pertains to controlling algae, biofilm, diatoms, and bio-organisms in bodies of water by way of field sweeping ultrasonic sound pressure frequencies. More particularly, this invention pertains to underwater ultrasonic systems that emit a series of sweeping frequencies to control certain organisms in a
15 liquid.

[0005] 2. Description of the Related Art

[0006] Algae is a large, diverse group of photosynthetic organisms that often thrive in a water environment. When a body of water has an abundance of nutrients, algae thrives. Depending upon the type of algae, the algae growth may be
20 beneficial or detrimental to the health of the body of water. For example, filamentous green algae and blue-green algae (cyanobacteria) are known for adversely affecting the health of a body of water when they grow in abundance.

[0007] Filamentous green algae is generally considered a nuisance that interferes with boater access, recreation, and aesthetics of the body of water. Green
25 algae grows in mats, which can be physically removed from the water by raking or other means. An excess of blue-green algae form surface blooms that are thick scums on the surface, typically near the shoreline. Some species of blue-green algae produce potent toxins that affect other aquatic and animal life. Blue-green

algae are not edible, generally, and they produce an unpleasant odor when they decompose.

[0008] Control of undesirable algae, such as single cell, colonial, and filamentous green algae and cyanobacteria, commonly known as blue-green algae, can be accomplished by controlling the nutrient supply in the water. Without sufficient nutrients, the growth of algae will be limited. Unfortunately, controlling the nutrients in a body of water is often difficult because controlling the entry of nutrients into a body of water requires controlling the watershed. Both storm water drainage and agricultural drainage provide nutrients, and such sources are often difficult to manage.

[0009] Controlling undesirable algae by introducing chemicals into a body of water creates additional problems, particularly when the body of water contains other plant and animal life, such as commonly found in lakes, ponds, and streams. When the body of water is a swimming pool, hot tub, or spa, chemicals are often used to control or eliminate undesirable algae growth.

[0010] Another way to control undesirable algae growth is to reduce or remove the sunlight that the algae require for photosynthesis. Floating plants, such as lilies and lotus, block the sunlight from penetrating the surface, thereby restricting the light reaching the algae. Other aquatic plants are grown in bodies of water to absorb the nutrients that the algae require to flourish. For many bodies of waters, such as lakes and large ponds, adding plants is not practical.

BRIEF SUMMARY

[0011] According to one embodiment of the present invention, an algae control system that emits ultrasonic waves from a transducer excited with frequencies sweeping through a range is provided. The algae control system emits ultrasonic sound pressure frequency waves at frequencies that are lethal to bio-organisms and is averse to colonization of some microorganisms, such as biofilm. The ultrasonic frequencies are emitted at frequencies matching or close to matching the structural resonance of key components within algae such as the vacuole, internal cell structures, and mobility components such as flagella, thereby killing the organisms or incapacitating them. The mechanism that results in algae death varies depending upon the type of algae. For most algae, ultrasonic waves

incapacitates algae, causing the algae to sink. As the algae sink, their exposure to sunlight decreases and, over time, the algae dies.

[0012] To achieve critical structural resonance, a specific frequency is needed to be applied to each one of a variety of species of algae. In one embodiment, critical structural resonance is achieved for various algae by emitting a spectrum of frequencies, for example 20kHz to 120kHz, that is created in discrete frequencies such as every 100Hz between 20kHz and 120kHz resulting in 1000 discrete frequencies. If each discrete frequency is produced once per second, 1000 seconds is needed before the pattern of frequency production is repeated. It may be that only one of the 1000 frequencies is effective in achieving critical structural resonance. Generally, not all of the organisms in a harmful algal bloom (HAB) or colony will be disabled during a single sweep. If the sweeps are too far apart, the HAB or colony will survive and grow enough to reestablish the losses occurring during a single sweep. Increasing the number of frequencies produced per second will subject the HAB or colony to enough killing or incapacitating events to prevent the HAB or colony from surviving.

[0013] The algae control system includes a power supply unit, a controller or processor, an exciter, and at least one ultrasonic transducer unit configured to be positioned in a body of fluid, such as water. The power supply unit provides power and control signals to the transducer unit.

[0014] The controller or processor is a device that controls the ultrasonic transducer. The processor sends an excitation signal or frequency waveform to an exciter, which drives the transducer at that frequency to emit ultrasonic frequency waves. The excitation signal includes a series of pulses or gated events separated by a Time Off or zero signal state. Each pulse or gated event includes a series of discrete frequency signals within a sub-range of the full frequency range of operation. The sub-range for each pulse is different than the other pulses until all the sub-ranges are utilized. In this way, the emitted ultrasonic wave includes a multitude of frequencies within a short period.

[0015] Another aspect of control of algae that shares the water with other aquatic life, such as farmed fish, is to control the algae without adversely impacting the other aquatic life. If the algae in the water is incapacitated too quickly and sinks to the bottom where it accumulates before dying, oxygen in the water can be depleted to a level that other aquatic life cannot survive. To prevent such an occurrence, a gradual remediation startup cycle is used. The startup cycle includes multiple stages, where each stage lasts for a period and is tailored to gradually decrease the algae concentration without depleting the oxygen levels in the water below a level needed for other aquatic life to survive. For example, the first stage emits a spectrum of frequencies of ultrasonic waves for a period of 24 hours at a 20% duty cycle with a 5 second cycle time, and the second stage emits a spectrum of frequencies of ultrasonic waves for a period of 24 hours at a 25% duty cycle with a 4 second cycle time. The progression of stages continues until the end of the startup cycle, at which time, a steady state of ultrasonic waves is maintained with a specified duty cycle and cycle time. In one embodiment, the emission power of the ultrasonic waves varies with each stage.

[0016] In one such embodiment, an oxygen sensor monitors the dissolved oxygen levels of the water with the processor controlling the gradual remediation startup stages. For example, if the oxygen level drops below a certain level, the processor controls the transducer emissions to be at an earlier stage. Alternatively, if the oxygen level reaches a certain level, the processor controls the transducer emissions to be at the next stage.

[0017] In another embodiment, a sensor is responsive to the algae concentration in the body of water. The duration of each startup stage is determined by the detected algae concentration. For example, a high algae concentration results in the gradual remediation startup stages having a period of 48 or 72 hours.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0018] The above-mentioned features will become more clearly understood from the following detailed description read together with the drawings in which:

[0019] FIG. 1 is a block diagram of one embodiment of the algae control system.

[0020] FIG. 2 is a graph showing the excitation signal over time.

[0021] FIG. 3 is a graph showing the excitation signal with discrete frequencies over an expanded time scale.

5 [0022] FIG. 4 is a graph showing the excitation signal with discrete pulses for various discrete frequencies over an expanded time scale.

[0023] FIG. 5 is a functional flow diagram showing the process for sweeping the transducer frequency.

[0024] FIG. 6 is a block diagram of a second embodiment of the algae control system.

10 [0025] FIG. 7 is a graph showing two signals that are combined to form the excitation signal over time.

[0026] FIG. 8 is a functional flow diagram showing a second embodiment of the process for sweeping the transducer frequency.

15 [0027] FIG. 9 is a functional flow diagram showing one embodiment of the Set Up Cycle step of the process of FIG. 8.

[0028] FIG. 10 is a graph showing the gradual remediation startup stages over time.

[0029] FIG. 11 is a graph showing one embodiment of a first stage of the gradual remediation startup over an expanded time scale.

20 [0030] FIG. 12 is a functional flow diagram showing the process for performing the gradual remediation startup.

DETAILED DESCRIPTION

25 [0031] Apparatus and method for sweeping the frequency emitted by an ultrasonic transducer is disclosed. The ultrasonic control system is generally indicated as **100**. The excitation signal is generally indicated as **114**. The excitation signal **114-A**, **114-B**, **114-C** is illustrated over varying time intervals **114-A**, **114-B**, **114-C**. When the excitation signal **114** is referred to generically, it is referenced without the alphabetic suffix.

[0032] FIG. 1 illustrates a block diagram of one embodiment of the algae control system **100**. The system **100** includes a user interface **102**, a processor **104**, an exciter **106**, and a transducer **108**. The system **100** also includes a power supply **112**.

5 [0033] The user interface **102** allows for monitoring and control of the system **100**. In one embodiment, the user interface **102** is located remote from the other system components. For example, the user interface **102** is a computer or mobile device that communicates over the internet and/or wirelessly with the processor **104**. In another embodiment, the user interface **102** is local to the
10 processor **104** and allows configuration of the system **100** during installation, setup, and periodic maintenance.

[0034] The processor **104** is a computing device that executes programs and includes a processing unit, memory/storage unit, and input/output units for communicating with external devices, such as the user interface **102** and the excite
15 **106**. For example, the processor **104** is a system-on-a-chip (SOC) in which the processor **104** contains various components that perform the major functions of the processor **104**. In another embodiment, the processor **102** is a specialized device, such as a micro-controller or an application-specific integrated circuit (ASIC) that, in conjunction with other components, that implement the functions of
20 the system **100**. In one embodiment, the processor **104** includes a digital-to-analog converter (ADC) and/or a zero shift circuit that produces an excitation signal **114**.

[0035] The processor **104** outputs are connected to the exciter **106**. The processor output includes an excitation signal **114** that provides information to the exciter **106**. The excitation signal **114** causes the exciter **106** to control the
25 frequency and amplitude of the ultrasonic waves **110** emitted from the transducer **108**.

[0036] In one embodiment, the excitation signal **114** output from the processor **104** is a digital signal that resembles a square wave with an amplitude and a frequency. That is, the excitation signal **114** alternates between a digital on-
30 state **232** and an off-state **234** with a 50% duty cycle in which the on-state period **232** equals the off-state period **234**.

[0037] The exciter **106** receives inputs from the processor **104** and provides signals to the transducer **108**, which produces ultrasonic waves **110**. The power supply **112** provides power to the exciter **106**. The exciter **106** uses the power from the power supply **112** to energize the transducer **108** with a frequency and power level in accordance with the output signals from the processor **104**.

[0038] The transducer **108** receives signals from the exciter **106**. The transducer **108** is an ultrasonic vibration producing device, such as a piezoelectric crystal. The transducer **108** produces ultrasonic waves **110** in response to the signals from the exciter **106**. In the illustrated embodiment, a single transducer **108** is shown. In other embodiments, the system **100** includes multiple transducers **108**, with associated exciters **106**. The transducer **108** emits ultrasonic waves **110** into a body of water **120**. The body of water **120** includes one or more types of algae **122** that are to be controlled by the system **100**.

[0039] In one embodiment, a sensor **124** is submerged in the body of water **120**. The sensor **124** communicates with the processor **104**. In one such embodiment, the sensor **124** is responsive to the oxygen levels in the body of water **120**. In another embodiment, the sensor **124** is responsive to the concentration of algae in the body of water **120**. In yet another embodiment, the sensor **124** is responsive to both parameters, namely oxygen level and algae concentration.

[0040] The power supply **112** provides power to the processor **104** and the exciter **106**. In one embodiment, the power supply **112** is local to system **100**. For example, the power supply **112** includes a solar panel, a battery, and a charging system mounted on a raft or float under which is suspended a sonic head that includes the processor **104**, the exciter **106**, the transducer **108**.

[0041] FIG. **2** illustrates a graph showing the excitation signal **114** over time **216-A**. FIG. **3** illustrates a graph showing the excitation signal **114** with discrete frequencies over an expanded time scale **216-B**. FIG. **4** illustrates a graph showing the excitation signal **114** with discrete pulses for various discrete frequencies over an expanded time scale **216-C**. The vertical, or y-axis, **218** represents amplitude **A** of the excitation signal **114**. The horizontal, or x-axis, **216** represents time. FIG. **3** illustrates a portion of the pulse **212** shown in FIG. **2** with the expanded time scale **216-B**. A portion of the frequency streams **222**, **224**, **226** of the center graph are reproduced in the upper graph with the expanded time scale **216-C**.

[0042] Multiple parameters are used within the algae control system **100**. The following parameters define aspects of the system **100** as further illustrated in Figures 2-5 and described below:

[0043] Three related parameters include the **On Time 206-on**, the **Off Time 206-off**, and the **Duty Cycle** of the excitation signal **114**. Any two of these parameters defines the third. The excitation signal **114** includes a series of pulses **212**, **212'** interspersed with non-pulse, or zero signal, gaps **214**. One pulse **212** and one gap **214** define one Cycle **204** of the excitation signal **114**. The duration of the pulses **212**, **212'** define the On Time **206-on**. The duration of the gaps **214** define the Off Time **206-off**. The Duty Cycle is defined by the ratio of the On Time **206-on** to the combined duration of the On Time **206-on** and the Off Time **206-off**.

[0044] Another parameter is the **Amplitude** of the excitation signal **114**. In the illustrated graphs of FIGS. 2-4, the excitation signal **114** alternates between a fixed, positive amplitude and zero. In such an embodiment, the excitation signal **114** does not provide any information on the power of the emitted ultrasonic waves **110** other than a specific power level and no power corresponding to the signal On Time **206-on** and the signal Off Time **202-off** of the excitation signal **114**. In one such embodiment, the processor **104** includes another output that provides amplitude information to the exciter **106**.

[0045] In another embodiment, the amplitude of the excitation signal **114** varies according to the desired power of the emitted ultrasonic waves **110**. In one such embodiment, the processor **104** includes a digital-to-analog converter (DAC) to produce an excitation signal **114** with a variable amplitude.

[0046] Another set of related parameters include the **Lower Frequency Limit**, the **Upper Frequency Limit**, and the **Frequency Range**. Any two of these parameters defines the third. The frequency range is defined as the range of frequencies to be emitted by the transducer **108** in order to impact the algae and other bio-organisms desired to be controlled. In one embodiment, a single frequency range is defined for the algae control system **100**. For example, a Frequency Range of 20 kHz to 220 kHz, which has a Lower Frequency Limit of 20 kHz and an Upper Frequency Limit of 220 kHz. In such an example, the Frequency Range of 20 kHz to 220 kHz has a Frequency Bandwidth of 200 kHz. In other

embodiments, multiple Frequency Ranges are defined for the algae control system **100**.

[0047] Another parameter is the **Number of Discrete Frequencies 222, 224, 226** within one cycle **204** of the excitation signal **114**. In one embodiment, the pulse **212** includes a Number of Discrete Frequencies **222, 224, 226**, each having a discrete frequency period **220**. In one such embodiment, each of the discrete frequencies **222, 224, 226** sequentially increment. In such an embodiment, the Number of Discrete Frequencies **222, 224, 226** defines the Frequency Bandwidth for one cycle **204** of the excitation signal **114**.

[0048] Another parameter is the **Frequency Sub-Range**, which is a subdivision of the Frequency Range. The Frequency Sub-Range is defined by the lowest and the highest frequency of the Number of Discrete Frequencies **222, 224, 226**. During a single pulse **212, 212'**, the Discrete Frequencies **222, 224, 226** are all within the Frequency Sub-Range.

[0049] Another parameter is the frequency step or difference between each of the adjacent discrete frequencies within one cycle of the excitation signal **114**. For example, the Frequency Step is determined from the absolute value of one discrete frequency **222** subtracted from an adjacent discrete frequency **224**. Another way of determining the Frequency Step is to divide the Frequency Sub-Range by the Number of Discrete Frequencies **222, 224, 226**.

[0050] Another parameter is the **Number of Frequency Sub-Ranges** within the Frequency Range. The Number of Frequency Sub-Ranges is determined by dividing the Frequency Bandwidth of the Frequency Range by the Frequency Bandwidth of the Frequency Sub-Range

[0051] FIG. 2 illustrates an excitation signal **114-A** over a time scale **216-A**. The excitation signal **114** is a stream of pulses **212** having a pulse time **204**. The illustrated excitation signal **114-A** is represented as a square wave signal with a series of pulses **212, 212'** are separated by intervening zero signal periods **214**. In one embodiment, the output **114** from the processor **104** is a digital signal represented as a square wave that alternates between zero and the processor output voltage. In such an embodiment, the exciter **106** acts upon the output signal **114** to produce a signal suitable for the transducer **108**, such as an alternating current signal that swings about a zero voltage axis. In another

embodiment, the processor **104** includes a zero shift circuit and a shaping circuit that results in the excitation signal **114** being an alternating current signal that swings about a zero voltage axis between a positive and a negative voltage.

[0052] The pulse, or cycle, time **204** is the period that includes the pulse **212** on time **206-on** and non-pulse, or zero signal, **214** off time **206-off** of the excitation signal **202**. The On Time **206-on** of the excitation signal **114** is defined as the time difference between the signal Off Time **202-off** and the previous signal on time **202-on**. The Off Time **206-off** is the time gap **214** between successive pulses **212**, **212'**. The off time **206-off** of the excitation signal **114** is defined as the time difference between the signal on time **202-on'** and the previous signal off time **202-off**. The excitation signal **202** has a duty cycle defined as the ratio of the on time **206-on** of the excitation signal **114** divided by the total cycle time **204**. In one embodiment, the cycle time **204** is one second and the signal on time **206-on** is 0.6 seconds, which results in a duty cycle of 60% for a one second period.

[0053] FIG. **3** illustrates a portion of the pulse **212** of the excitation signal **114-B** over a time scale **216-B**. The pulse **212** includes a plurality of streams **222**, **224**, **226**. That is, the pulse **212** is not a direct current (dc) signal, but the pulse **212** includes a series of streams, or Discrete Frequencies, **222**, **224**, **226**, each having a discrete frequency within a frequency range.

[0054] In the illustrated embodiment, each Discrete Frequency **222**, **224**, **226** has substantially the same discrete frequency period **220**. That is, the first Discrete Frequency **222** has a first frequency that extends for a first discrete frequency period **220**. The second Discrete Frequency **224** has a second frequency that extends for a second discrete frequency period **220** that is of the same duration as the first discrete frequency period **220**. The third Discrete Frequency **226** has a third frequency that extends for a third discrete frequency period **220** that is of the same duration as the first discrete frequency period **220**. FIGS. **3** & **4** illustrate that the amplitude of each Discrete Frequency **222**, **224**, **226** is the same. In other embodiments, the amplitude of each Discrete Frequency **222**, **224**, **226** varies as determined by the processor **104**.

[0055] In one embodiment, the Discrete Frequencies **222**, **224**, **226** are sequential, with each Discrete Frequency **222**, **224**, **226** being separated from an adjacent Discrete Frequency **222**, **224**, **226** by a frequency step. In one such embodiment, the frequency step is equal to a specific frequency, for example, 2 Hz or 20 Hz. In another such embodiment, the frequency step is dependent upon the ability of the processor to produce specific frequencies. In one such embodiment, the processor **104** has a pulse width modulation (PWM) counter that defines the allowable Discrete Frequencies **222**, **224**, **226**. Integer increments of the PWM counter determine the minimum Frequency Step for a specific Discrete Frequency **222**, **224**, **226**. For example, one processor **104** with a clock frequency of 120 MHz and a frequency range of 18 kHz to 238 kHz has a frequency step ranging between 3 and 471 Hz.

[0056] In another embodiment, the Discrete Frequencies **222**, **224**, **226** are randomly selected from the Frequency Sub-Range. In one such embodiment, the processor **104** accesses a table of data to determine the next Discrete Frequency **222**, **224**, **226**.

[0057] FIG. 4 illustrates the Discrete Frequencies **222**, **224**, **226** included in a portion of the excitation signal **114-C** over an expanded time scale **216-C**. The first Discrete Frequency **222** has a series of pulses **232** separated by intervening zero signal periods **234** with the pulses **232** occurring at the first Discrete Frequency **222**. The second and third Discrete Frequencies **224**, **226** have a series of pulses **232** separated by intervening zero signal periods **234** with the pulses **232** occurring at the second and third Discrete Frequency **224**, **226**, respectively.

[0058] In the illustrated embodiment, each Discrete Frequency **222**, **224**, **226** varies by the amount necessary for the time period of each discrete frequency period **220** to encompass complete cycles of the Discrete Frequency **222**, **224**, **226**. That is, the preceding discrete frequency period **220-A**, **220-B**, **220-C** ends at the start of the pulse **232** for the current Discrete Frequency **222**, **224**, **226**.

[0059] FIG. 4 illustrates the Discrete Frequencies **222**, **224**, **226** as a series of direct current (dc) pulses **232** relative to non-pulse, or zero, amplitude level that is coincident with the time axis **216-C**. In another embodiment, the zero voltage amplitude level **416-C** is midway between the top and bottom of alternating current (ac) pulses **432**, **434**. That is, the excitation signal **114** has been processed by a zero shift circuit such that the excitation signal **114** includes positive pulses **432** and negative pulses **434** that swing about the zero level axis **416-C**. In another such embodiment, the pulses **432**, **434** are sinusoidal or some other waveform than the illustrated square wave.

[0060] FIG. **5** illustrates a functional flow diagram showing the process **500** for sweeping the transducer frequency for the algae control system **100**. The excitation signal **114** includes a series of sequential pulses **212**, **212'** separated by a non-pulse, or zero signal, **214** state. Each pulse **212** of the excitation signal **114** includes a first series of Discrete Frequencies **222**, **224**, **226** within a first Frequency Sub-Range. The next sequential pulse **212'** of the excitation signal **114** includes a second series of Discrete Frequencies **222**, **224**, **226** selected from a second Frequency Sub-Range.

[0061] The first step **502** is to start the process **500**. The first step **502** is performed when the process **500** is manually initiated, such as by a command from the user interface **102**, or upon power up of the system **100**.

[0062] The next step **504** is to generate the frequency signal. In one embodiment, the processor **104** generates a series of pulses **232** for a Discrete Frequency **222**. In one such embodiment, the processor **104** outputs an excitation signal **114** that is processed by the exciter **106** to drive the transducer **108**. In another embodiment, the processor **104** outputs an excitation signal **114** that is zero shifted and shaped so as to cause the exciter **106** to drive the transducer **108**.

[0063] The next step **506** is to start sending the ultrasonic waves **110** from the transducer **108**. In one embodiment, step **506** is implemented by the excitation signal **114** being received by the exciter **106**, which produces a signal suitable for the transducer **108** to be excited and transmit the ultrasonic waves **110** at the Discrete Frequency **222**.

[0064] The next step **508** is to determine if the elapsed time is less than the On Time **206-on** for the pulse **212** of the excitation signal **114**. The elapsed time is the duration of the time since either the start **502** or the performance of step **514** of selecting the next Frequency Sub-Range. Step **508** is performed by the processor **104**.

[0065] If step **508** determines that the elapsed time is not less than the On Time **206-on** for the pulse **212**, the step **510** to stop sending is performed. Step **510** to stop sending includes the processor **106** causing the excitation signal **114** to be at the Off time **206-off** state. Step **510** to stop sending also includes the transducer **108** stopping emitting of ultrasonic waves **110**.

[0066] After step **510**, the next step **512** is to pause for the Off Time **206-off**. Step **512** to pause includes the processor **104** holding the excitation signal **114** at the non-pulse, or zero signal, **214** state for the duration of the Off Time **206-off**. The pausing step **512** also includes the transducer **108** not emitting any ultrasonic waves **110**.

[0067] After the pause step **512**, the step **514** to select the next frequency sub-range is performed by the processor **104**. In one embodiment, the selection step **514** includes the processor **104** accessing a table of data to determine the next Frequency Sub-Range. In one such embodiment, the table of data contains information related to the desired Frequency Sub-Ranges from which the Discrete Frequencies **222**, **224**, **226** are selected. In various embodiments, the Frequency Sub-Ranges are either sequentially ordered or randomly ordered sub-divisions of the Frequency Range.

[0068] After the step **514** to select the next Frequency Sub-Range is performed, step **504** to generate the frequency signal is performed. In this way, the system **100** causes the transducer **108** to emit ultrasonic waves **110** in different Frequency Sub-Ranges with each pulse **212**.

[0069] If step **508** determines that the elapsed time is less than the On Time **206-on** for the pulse **212**, the step **516** to determine if the next Discrete Frequency is to be selected. In one embodiment, Step **506** includes comparing a preselected discrete frequency period **220** to the elapsed time that the current Discrete

5 Frequency has been transmitted by the transducer **108**. In such an embodiment, the discrete frequency period **220** is a fixed time that includes multiple discrete cycles of the Discrete Frequency.

[0070] If step **516** determines that the next Discrete Frequency is to be selected, step **518** to select the next Discrete Frequency is performed. In one

10 embodiment, step **518** is performed by incrementing the current Discrete Frequency **222**, **224**, **226** by a Frequency Step.

[0071] In one embodiment, the Discrete Frequencies **222**, **224**, **226** are sequential, with each Discrete Frequency **222**, **224**, **226** being separated from an adjacent Discrete Frequency **222**, **224**, **226** by a Frequency Step. In one such

15 embodiment, selection step **518** includes the processor **518** executing software to increment the Discrete Frequency **222**, **224**, **226** by minimum frequency value allowed by the capability of the processor **518**. For example, than a processor **104** with a lower clock frequency results in the processor **104** producing a frequency step larger than a processor **104** with a higher clock frequency.

[0072] In another embodiment, selection step **518** includes the processor

20 **104** accessing a table of data to determine the next Discrete Frequency **222**, **224**, **226**. In one such embodiment, the table of data contains information related to the desired Discrete Frequencies **222**, **224**, **226** to be generated and sent in steps **504** and **506**. In various embodiments, the Discrete Frequencies **222**, **224**, **226** are

25 either sequentially ordered or randomly ordered.

[0073] After step **518** to select the next Discrete Frequency is performed, step **504** to generate the frequency signal is performed. In this way, the system **100** causes the transducer **108** to emit ultrasonic waves **110** of sequential Discrete Frequencies with each pulse **212**.

[0074] If step **516** determines that the next Discrete Frequency is not to be selected, step **520** to continue sending the Discrete Frequency is performed. After step **520** to continue sending, step **508** to determine if the elapsed time is less than the On Time **206-on** for the pulse **212** of the excitation signal **114** is performed. In this way, the process **500** continues sending the Discrete Frequency until either step **508** determines it is time to stop sending or step **516** determines that the next Discrete Frequency is to be selected.

[0075] FIG. **6** illustrates a block diagram of a second embodiment of the algae control system **100'**. In the illustrated embodiment, the processor **104'** includes various functional modules **604**, **606**, **608**, **610** connected to an exciter **106'** and various sensors **622**, **624**, **626**. FIG. **7** illustrates a graph showing two signals, namely, the gated output signal **212** and the frequency signal **702**, that are combined to form the excitation signal **714** over time **216**.

[0076] In one embodiment, the processor **104'** includes a gated output PWM (pulse width modulation) module **604**, a frequency PWM module **606**, and a DAC power level module **608**. The exciter **106'** includes an enable input module **614**, a frequency input module **616**, and a power controller module **618**.

[0077] The gated output PWM module **604** in the processor **104'** produces a series of signals that result in pulses or gated signals **212**, **212'** defining the On Time **206-on** separated by a gap **214** equal to the Off Time **206-off**. Each pulse or gated signal **212** and gap **214** defines the total cycle time **204**. The enable input module **614** receives the gated signal **212** from the gated output PWM module **604**. The enable input module **614** allows the exciter **106'** to excite the transducer **108** during the On Time **206-on**. In one embodiment, the duty cycle **204** is 100%, that is, the Off Time **206-off** is zero.

[0078] The frequency PWM module **606** in the processor **104'** produces a signal that results in a series of discrete frequencies **702-1**, **702-2**, **702-3**, **702-4** during the On Time gated signal **212**, **212'**. The frequency input module **616** in the exciter **106'** receives the series of discrete frequencies **702-1**, **702-2**, **702-3**, **702-4** from the frequency PWM module **606**. The frequency input module **616** passes the frequencies **702-1**, **702-2**, **702-3**, **702-4** from the exciter **106'** to the transducer **108** during the On Time **206-on**.

[0079] The processor **104'** includes a first timer block and a second timer block. The timer blocks, in one embodiment, are implemented as hardware timers controlled by the central processing unit (CPU) or microcontroller of the processor **104'**. In another embodiment, the timer blocks are implemented via software programming executed by the processor **104'**. The first timer block communicates with the gated output PWM module **604** in the processor **104'** and provides the timing for the gated output, that is the first timer controls the On Time **206-on** and the Off Time **206-off**. The second timer block communicates with the frequency PWM module **606** in the processor **104'** and provides the timing for the frequency PWM module **606**. In another embodiment, a single timer block is used to communicate with the frequency PWM module **606** in the processor **104'** and provides the timing for the frequency PWM module **606** for the duration of the On Time **206-on** and then to provide a timing signal for the Off Time **206-off**. In such an embodiment, the functions of the gated output PWM module **604** and the frequency PWM module **606** are combined through the operation of the single timer block.

[0080] The DAC power level module **608** in the processor **104'**, in the embodiment where such a feature is enabled, provides a signal that is received by the power controller module **618** in the exciter **106'** to control the power applied by the transducer **108**.

[0081] In one embodiment, the algae control system **100'** includes a feedback system that includes one or more sensors **124** that include an underwater camera or optical sensor **622**, a fluorometer **624**, a sonar instrument **626**, and/or a dissolved oxygen sensor **628** that are in communication with a feedback I/O (input/output) module **610** in the processor **104'**. During operation of the system **100'**, the various sensors **622**, **624**, **626** monitor the effect of the various frequencies **702** emitted by the transducer **108** on the local bio-organisms. In this way, the processor **104'** determines which frequencies **702** or frequency bandwidths have the most significant impact on the local bio-organisms and the programming is altered to emphasize emitting such frequencies **702** or frequency bandwidths.

[0082] FIG. 8 illustrates a functional flow diagram showing a second embodiment of the process **500'** for sweeping the transducer frequency. FIG. 9 is a functional flow diagram showing one embodiment of the initializing step of the process of FIG. 8. FIG. **9** is a functional flow diagram showing one embodiment of the Set Up Cycle step **804** of the process of FIG. 8.

[0083] The first step **802** is to start the process **500'**. The first step **802** is performed when the process **500'** is manually initiated or upon power up of the system **100'**. The first step **802** includes initializing the Bandwidth Indexer to point to the first table entry. The Bandwidth Indexer is a programmed function in the processor **104'**. The Bandwidth Indexer maintains the Bandwidth Table. The Bandwidth Table contains data relating to the following fields: Bandwidth Index, Frequency, Gated Output or Duty Cycle, Power Level, and Cavitation.

[0084] In one embodiment, the Bandwidth Index is a parameter, such as a number, that sequentially identifies information related to each pulse or gated output **212**. Associated with each Bandwidth Index are the one or more Frequencies to be emitted during the pulse or gated output **212**. For example, one Bandwidth Index includes the Frequencies of 20,000 Hz, 20,005 Hz, 20,010 Hz, 20,015 Hz, and 20,020 Hz. The next Bandwidth Index includes the Frequencies of 33,000 Hz, 33,301 Hz, 33,302 Hz, and 33,303 Hz. Also associated with each Bandwidth Index is the Gated Output or Duty Cycle **204**. For example, the Duty Cycle is 75% with a period of 2 seconds divided as 1.5 seconds of On Time **206-on** and 0.5 seconds of Off Time **206-off**. In one embodiment, a Power Level field is also associated with each Bandwidth Index. For example, a Power Level for a particular Bandwidth Index is specified as 10% of full power. In one embodiment, a Cavitation field is also associated with each Bandwidth Index. In one example, Cavitation is specified as a Boolean value of true or false. The Cavitation field is used to control the application of additional power at spaced intervals so as to better induce cavitation around the transducer **108**.

[0085] After the first step **802** of starting, the next step **804** is the Set Up Cycle, which includes the first sub-step **902** of obtain data from the Bandwidth Table associated with the selected Bandwidth Index and the second sub-step **904** of computing variables. The first sub-step **902** of obtaining data from the Bandwidth Table includes reading data on the frequency, the Gated Output or Duty Cycle, the Power Level, and Cavitation. The second sub-step **904** of computing

variables includes computing the duration of each pulse or Gated Output **212** and the duration of each frequency. The duration of each frequency is determined by dividing the duration **206-on** of the Gated Output **212** by the number of frequencies (for example, four **702-1**, **702-2**, **72-3**, **702-4** as shown in FIG. 7)
5 associated with the selected Bandwidth Index (for example, the Bandwidth Index represented by the cycle **204** shown in FIG. 7).

[0086] After the step **804** of setting up the cycle, the step **806** of initiating the On Time is performed. During the initiating step **804**, the first timer block begins timing the On Time **206-on** and the second timer block begins timing the
10 first frequency **702-1**.

[0087] The steps **808**, **810** of adjusting the power level and sending the frequency are performed. For the embodiment where the exciter **106'** is capable of adjusting the power level of the transducer **108**, the step **808** of adjusting the power level includes the power level module **608** in the processor **104'**
15 communicating the associated Bandwidth Table power level to the power controller **618** in the exciter **106'**. The exciter **106'** then actuates the transducer **108** at the communicated power level. The step **810** of sending the frequency includes the frequency PWM module **606** communicating the associated Bandwidth Table frequency to the Frequency Input Module **616** in the exciter **106'**. The exciter **106'**
20 then actuates the transducer **108** at the communicated frequency **702**.

[0088] After steps **808**, **810** of adjusting the power level and sending the frequency are performed, the step **812** of determining if the frequency is done is performed. Step **812** includes checking the second timer block to determine if the duration of the frequency **702** has elapsed. If step **812** determines that the
25 frequency duration has not elapsed, then the step **812** loops back and is performed again.

[0089] If step **812** determines that the frequency duration **220** has elapsed, then the step **814** of determining if there are more frequencies is performed. Step **814** includes checking the Bandwidth Table to determine if there are remaining
30 frequencies **702** associated with the Bandwidth Index. If step **814** determines that there are more frequencies to send, then step **816** to increment to the next frequency listed in the Bandwidth Table for that Bandwidth Index is performed and then the process **500'** loops back to perform steps **808**, **810**. In this way, when a

specific Bandwidth Index has multiple associated frequencies, the frequencies are sequentially processed.

[0090] If step **814** determines that there are no more frequencies to send, then step **818** to initiate Off Time is performed. After step **818** is performed, step **820** of determining if the Off Time **206-off** is done is performed. Step **820** includes checking the first timer block to determine if the duration of the Off Time **206-off** has elapsed. If step **820** determines that the Off Time **206-off** duration has not elapsed, then the step **820** loops back and is performed again.

[0091] If step **820** determines that the Off Time **206-off** duration has elapsed, then step **822** to increment to the next Bandwidth Index in the Bandwidth Table is performed and then step **824** for determining if the end of the Bandwidth Index has been reached, that is, the last Bandwidth Index listed in the Bandwidth Table has been reached, is performed. If step **824** determines that the end of the Bandwidth Index has been reached, the process **500'** loops to the start step **802** to initialize the Bandwidth Indexer to point to the first table entry. If step **824** determines that the end of the Bandwidth Index has not been reached, the process **500'** loops to step **804** to perform the step **804** to set up the cycle using the Bandwidth Index incremented in Step **822**.

[0092] FIG. **10** illustrates a graph showing the gradual remediation startup stages **1002** over time **216**. Gradual remediation startup **1010** is an operating mode that allows for gradually reducing the concentration of algae **122** in a body of water **120** in order to avoid depletion of oxygen below a level that would be harmful to other aquatic life.

[0093] In the illustrated embodiment, the gradual remediation startup **1010** occurs with five remediation stages **1002-1**, **1002-2**, **1002-3**, **1002-4**, **1002-5**. Each stage **1002-1**, **1002-2**, **1002-3**, **1002-4**, **1002-5** has a duration **1004-1**, **1004-2**, **1004-3**, **1004-4**, **1004-5**. Each stage **1002** has the parameters of the excitation signal **114** adjusted so as to result in a desired kill rate of the algae **122** in the water **120**. The parameters of the excitation signal **114** include the stage duration time **1004**, the On Time **206-on-1**, the Off Time **206-off-1**, the amplitude or power of the emitted ultrasonic waves **110**, and the frequencies emitted.

[0094] In one embodiment, the stage duration times **1004** are preset and the gradual remediation startup **1010** is initiated with the final stage **1002-5** having a duration time **1004-5** that has no pre-defined end point. That is, the final stage **1002-5** is the steady state operating condition for the algae control system **100**.

5 [0095] In another embodiment, algae concentration is measured and the stage duration times **1004** are determined based on the measured concentration. For example, a very high algae concentration determines a long stage duration time **1004** of 72 hours as opposed to duration times **1004** of 48 or even 24 hours for lesser algae concentrations. In one such embodiment, the algae control system **100**
10 includes a sensor **124** that is responsive to the concentration of algae **122** in the water **120**. The processor **104** adjusts the various stage durations **1004** based on the algae concentration levels from the sensor **124** by increasing the durations **1004** for higher concentrations.

[0096] In another embodiment, the oxygen levels of the water **120** are
15 measured to ensure that the oxygen level does not fall below a level sufficient to ensure survival of desirable aquatic life, such as farmed fish. In one such embodiment, the algae control system **100** includes a sensor **124** that is responsive to the dissolved oxygen level in the water **120**. The processor **104** controls the various stage durations **1004** and order based on the oxygen levels from the sensor
20 **124**. For example, if the oxygen level falls to a certain level, one or more actions are initiated by the processor **104**. Those actions include sending an alert to a remote operator, pausing the current stage **1002** to allow the oxygen level to restore itself, stopping the current stage **1002** and starting a previous stage **1002**, or engaging external equipment, such as an aerator.

25 [0097] FIG. **11** illustrates a graph showing one embodiment of a first stage **1002-1'** of the gradual remediation startup **1010** over an expanded time scale **216-A**. The second through fifth stages **1002-2**, **1002-3**, **1002-4**, **1002-5** are similar to the first stage **1002-1'**, differing primarily in the duration of the Off Time **206-off-1**, which, in one embodiment, decreases for each subsequent stage **1002-2**, **1002-3**,
30 **1002-4**, **1002-5**.

[0098] The illustrated first stage **1002-1** includes a series of pulses **212-1**, **212-1**' separated by a gap **214-1** where the On Time **206-on-1** and the Off Time **206-off-1** define the cycle time **204-1**, as described above with respect to FIGS. 2-4. The series of pulses **212-1** repeat every cycle time **204-1** for the duration **1004-1** of the stage **1002-1**.

[0099] In one embodiment, the cycle time **206-1** for the first stage **1002-1** is five seconds with the On Time **206-on-1** being one second or less. The second stage **1002-2** has a cycle time **206-1** of four seconds with the On Time **206-on-1** being one second or less. The third stage **1002-3** has a cycle time **206-1** of three seconds with the On Time **206-on-1** being one second or less. The fourth stage **1002-4** has a cycle time **206-1** of two seconds with the On Time **206-on-1** being one second or less. The fifth stage **1002-2** is the steady state stage and has a cycle time **206-1** of one second with the On Time **206-on-1** being one second or less.

[00100] FIG. **12** illustrates a functional flow diagram showing one embodiment of the process **1200** for performing the gradual remediation startup **1010**. The remediation process **1200** is a method for bringing a high concentration of algae **122** to a lower concentration level for long-term management of the algae **122** in the body of water **120**. A portion of the high concentration of algae **122** is incapacitated in each stage **1002**, thereby gradually killing the algae **122** over a period of time while preventing drastic changes in dissolved oxygen content that could be harmful to other aquatic life.

[00101] The first step **1202** is to start the gradual remediation startup process **1200**. The first step **1202** is performed when the algae control system **100** is first started up and the environmental conditions warrant a gradual remediation of the algae concentration in a body of water **120**. Such remediation is warranted when the algae concentration is so high that steady state operation of the algae control system **100** will result in a massive rate of algae death, resulting in depletion of dissolved oxygen in the water **120**.

[00102] The next step **1204** is to determine the duration time **1004** for the stages **1002**. In one embodiment, the typical duration time **1004** is 24 hours. The 24 hour period covers both the daytime and nighttime hours to accommodate the behavior of algae over a full day cycle. As the algae concentration in a body of water

5 **120** increases, it is advantageous to increase the duration time **1004** so as to spread out the rate of increase of dead algae in the water **120**. Increments of 24 hours for the duration **1004** has the advantage of accommodating the behavior of algae over a full day cycle. In one embodiment, step **1204** for determining stage duration includes substeps of using a sensor **124**, such as a camera or optical

10 sensor **622** and/or a fluorometer **624**, to measure algae concentration, followed by another substep to compare the measured algae concentration level to a table containing data on algae concentration versus duration time. In another embodiment, step **1204** for determining stage duration includes a visual examination of the body of water **120** and an operator selecting an appropriate

15 duration **1004** based on the quantity of algae **122** observed during the visual examination.

[00103] The next step **1206** after step **1204** is to run the first remediation stage **1002-1**. The first remediation stage **1002-1** has a low intensity, compared to subsequent stages **1002-2**, **1002-3**, **1002-4**, **1002-5** such that a portion of the

20 algae **122** in the water **120** is incapacitated, leading to the eventual death of the algae **122**. The lower intensity is achieved by an extended off-time **206-off-1**, such as illustrated in FIG. 11, or, in other embodiments, by varying the power or discrete frequency period **220** or other characteristic of the emitted ultrasonic waves **110**.

[00104] After completion of the step **1206** for running the first remediation

25 stage **1002-1**, step **1208** for determining the water quality is performed. In one embodiment, the sensor **124** is an oxygen sensor. If the oxygen sensor **124** determines that the dissolved oxygen level is within acceptable limits, the water quality is determined to be good and the step **1210** of running the second remediation stage **1002-2** is performed. If step **1208** determines that the water

30 quality is bad, for example, at a level that may prove harmful to other aquatic life, then step **1206** for running the first remediation stage **1002-1** is repeated. In another embodiment, if step **1208** determines that the water quality is bad, an alert is generated and sent to the user interface **102**, which is either local or remote to the processor **104**.

[00105] After completion of the step **1210** for running the second remediation stage **1002-2**, step **1212** for determining the water quality is performed. In one embodiment, as in step **1208**, if the oxygen sensor **124** determines that the dissolved oxygen level is within acceptable limits, the water quality is determined to be good and the step **1214** of running the third remediation stage **1002-3** is performed. If step **1212** determines that the water quality is bad, for example, at a level that may prove harmful to other aquatic life, then in one embodiment step **1210** for running the second remediation stage **1002-2** is repeated, and in another embodiment, step **1206** for running the first remediation stage **1002-1** is repeated.

10 In another embodiment, if step **1212** determines that the water quality is bad, an alert is generated and sent to the user interface **102**, which is either local or remote to the processor **104**.

[00106] After completion of the step **1214** for running the third remediation stage **1002-3**, step **1216** for determining the water quality is performed. In one embodiment, as in step **1208**, if the oxygen sensor **124** determines that the dissolved oxygen level is within acceptable limits, the water quality is determined to be good and the step **1218** of running the fourth remediation stage **1002-4** is performed. If step **1216** determines that the water quality is bad, for example, at a level that may prove harmful to other aquatic life, then in one embodiment step **1214** for running the third remediation stage **1002-3** is repeated, and in another embodiment, step **1210** for running the second remediation stage **1002-2** is repeated, and in yet another embodiment, step **1206** for running the first remediation stage **1002-1** is repeated. In another embodiment, if step **1216** determines that the water quality is bad, an alert is generated and sent to the user interface **102**, which is either local or remote to the processor **104**.

[00107] After completion of the step **1218** for running the fourth remediation stage **1002-4**, step **1220** for determining the water quality is performed. In one embodiment, as in step **1208**, if the oxygen sensor **124** determines that the dissolved oxygen level is within acceptable limits, the water quality is determined to be good and the step **1222** of running the fifth remediation stage **1002-5** is performed. If step **1220** determines that the water quality is bad, for example, at a level that may prove harmful to other aquatic life, then in one embodiment step **1218** for running the fourth remediation stage **1002-4** is repeated, then in another embodiment step **1214** for running the third remediation stage **1002-3** is repeated, and in yet another embodiment, step **1210** for running the second remediation stage **1002-2** is repeated, and in still another embodiment, step **1206** for running the first remediation stage **1002-1** is repeated. In another embodiment, if step **1220** determines that the water quality is bad, an alert is generated and sent to the user interface **102**, which is either local or remote to the processor **104**.

[00108] The step **1222** of running the fifth remediation stage **1002-5** is performed until the process **1200** is stopped. Step **1222** for running the fifth remediation stage **1002-5** is a steady state operating mode and is intended to run continuously until environmental conditions warrant other measures or an operator desires to stop the process.

[00109] In other embodiments, the number of remediation stages **1002** varies. For example, for lower starting concentrations of algae **122**, the gradual remediation startup process **1200** performs only steps **1204**, **1208**, and **1214** for the first, third, and fifth stages **1002-1**, **1002-3**, **1002-5**.

[00110] In another embodiment, the remediation process **1200** does not include the steps **1208**, **1212**, **1216**, **1220** for determining water quality. In such an embodiment, the process **1200** performs the steps **1206**, **1210**, **1214**, **1218**, **1222** for running the stages **1002-1**, **1002-2**, **1002-3**, **1002-4**, **1002-5** in sequence, with each step starting when the previous step is completed.

- [00111] In one embodiment, the remediation process **1200** does not include the steps **1212**, **1216**, **1220** for determining water quality. In such an embodiment, step **1208** is performed simultaneously with steps **1206**, **1210**, **1214**, **1218** for running the stages **1002-1**, **1002-2**, **1002-3**, **1002-4**. Process
- 5 **1200** performs the steps **1206**, **1210**, **1214**, **1218**, **1222** for running the stages **1002-1**, **1002-2**, **1002-3**, **1002-4**, **1002-5** in sequence, with each step starting when the previous step is completed. In one embodiment, step **1208** for determining water quality is performed periodically while at least the first four stages are running during steps **1206**, **1210**, **1214**, **1218**. In another embodiment,
- 10 step **1208** for determining water quality is performed continuously while at least the first four stages are running during steps **1206**, **1210**, **1214**, **1218**. In both embodiments, if step **1208** determines that the water quality is good, steps **1206**, **1210**, **1214**, **1218**, **1222** for running the stages **1002-1**, **1002-2**, **1002-3**, **1002-4**, **1002-5** continue to run. If step **1208** determines that the water quality is bad or
- 15 not within limits, step **1208** initiates one or more actions that include sending an alert, pausing the currently running step **1206**, **1210**, **1214**, **1218**, **1222** for running the stage **1002**, and/or stopping the currently step **1206**, **1210**, **1214**, **1218**, **1222** and running a previous one of the steps **1206**, **1210**, **1214**, **1218**, **1222** for running the stages **1002-1**, **1002-2**, **1002-3**, **1002-4**, **1002-5**.
- 20 [00112] The ultrasonic control system **100**, **100'** includes various functions. The function of sweeping the frequency **222**, **224**, **226** over a duty cycle **204** is implemented, in one embodiment, by the processor **104** performing the steps illustrated in FIG. 5. In another embodiment, the function of sweeping the frequency **702** over a duty cycle **204** is implemented by the processor **104'** and
- 25 exciter **106'** performing the steps illustrated in FIGS. 8 and 9.

- [00113] From the foregoing description, it will be recognized by those skilled in the art that an ultrasonic control system **100**, **100'** has been provided. An ultrasonic transducer **108** emits sweeping frequencies **222**, **224**, **226**, **702** as determined by a processor **104**, **104'**. The ultrasonic transducer **108** emit a series
- 30 of sweeping frequencies **222**, **224**, **226**, **702** over a defined bandwidth where the bandwidths vary periodically in a randomized manner to subject bio-organisms to critical structural resonance that matches the natural critical structural frequency of the organisms, their internal structure, and mobility mechanisms, such as their flagella and vacuoles.

[00114] While the present invention has been illustrated by description of several embodiments and while the illustrative embodiments have been described in considerable detail, it is not the intention of the applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages
5 and modifications will readily appear to those skilled in the art. The invention in its broader aspects is therefore not limited to the specific details, representative apparatus and methods, and illustrative examples shown and described. Accordingly, departures may be made from such details without departing from the spirit or scope of applicant's general inventive concept.

CLAIMS

What is claimed is:

1. An apparatus for controlling bio-organisms, said apparatus comprising:

5 a processor having a gated output and a frequency output;

a transducer operatively connected to said processor, said processor causing said transducer to emit ultrasonic waves at a frequency corresponding to said frequency output when said gated output enables said transducer to emit said ultrasonic waves.

10 2. The apparatus of Claim 1 wherein said gated output defines an On Time and an Off Time, and said On Time enabling said transducer to emit ultrasonic waves at said frequency.

3. The apparatus of Claim 1 further including an exciter operatively connected to said processor, and said exciter driving said transducer.

15 4. The apparatus of Claim 3 wherein said processor includes a power level output signal received by said exciter, and said exciter causing said transducer to emit ultrasonic waves at a power level corresponding to said power level output signal.

20 5. The apparatus of Claim 1 wherein said processor maintains a Bandwidth Indexer that includes a Bandwidth Table storing data, said Bandwidth Table stores a plurality of Bandwidth Indexes, each Bandwidth Index having at least one associated Frequency and data corresponding to a duty cycle, said gated output and said frequency output corresponding to data associated with a selected Bandwidth Index.

25 6. The apparatus of Claim 5 wherein said Bandwidth Table stores a power level associated with each Bandwidth Index; said processor communicating with said exciter whereby said exciter causes said transducer to operate at said power level associated with said selected Bandwidth Index.

7. The apparatus of Claim 1 wherein said processor includes a first timer, said first timer controlling said frequency output for a time period equal to an On Time for said gated output, and said first timer controlling said gated output for an Off Time.

5 8. The apparatus of Claim 1 wherein said processor includes a first timer and a second timer, said first timer controlling said gated output, and said second timer controlling said frequency output.

9. The apparatus of Claim 1 wherein said processor is programmed to execute a program performing the following steps:

10 a) running a first stage whereby said transducer is caused to emit said ultrasonic waves for a plurality of first cycles, wherein said transducer emits said ultrasonic waves for a selected first stage duration, each one of said plurality of first cycles having a first stage on-time and a first stage off-time;

b) running a second stage whereby said transducer is caused to emit said
15 ultrasonic waves for a plurality of second cycles, wherein said transducer emits said ultrasonic waves for a selected second stage duration, each one of said plurality of second cycles having a second stage on-time and a second stage off-time, said second stage off-time being less than said first stage off-time; and

c) running a final stage whereby said transducer is caused to emit said
20 ultrasonic waves for a plurality of final cycles, said transducer emits said ultrasonic waves for a selected final stage duration, each one of said plurality of final cycles having a final stage on-time and a final stage off-time, and said final stage off-time being less than said second stage off-time.

25 10. The apparatus of Claim 9 further including a processor step for determining a stage duration before said processor step a) for running said first stage is performed, wherein said stage duration is equal to said first and second stage durations of said steps a) and b).

11. The apparatus of Claim 10 wherein said step for determining said stage duration includes the processor receiving an input from a sensor that is responsive to conditions indicative of a high algae concentration.

12. The apparatus of Claim 9 further including a processor step a1) for
5 determining water quality, if said step a1) determines that water quality is within limits, said step a1) performs at least one of the following actions that include sending an alert, pausing step a) of running said first stage, and stopping step a) of running said first stage.

13. The apparatus of Claim 9 further including a processor step b1) for
10 determining water quality, if said step b1) determines that water quality is within limits, said step b1) performs at least one of the following actions that include sending an alert, pausing step b) of running said first stage, and stopping step b) of running said first stage.

14. The apparatus of Claim 9 further including a processor step a1) for
15 determining water quality, said step 1) runs concurrently with said steps a) of running said first stage and b) of running said second stage, if said step a1) determines that water quality is within limits, said step a1) performs at least one of the following actions that include sending an alert, pausing step a) of running said first stage, pausing step b) of running said first stage, stopping step a) of running
20 said first stage and stopping step b) of running said first stage.

15. An apparatus for controlling bio-organisms, said apparatus comprising:

a processor having a frequency output, said frequency output including at least one frequency signal during an On Time and a zero signal during an Off Time;

5 an exciter operatively connected to said processor;

a transducer operatively connected to said exciter, said exciter causing said transducer to emit ultrasonic waves at a frequency corresponding to said frequency output during said On Time.

16. The apparatus of Claim 15 wherein said frequency output includes a plurality of frequency signals ordered serially during said On Time.

17. The apparatus of Claim 15 wherein said frequency output includes a plurality of frequency signals ordered serially during said On Time, and said plurality of frequency signals defined by an entry in a Bandwidth Table.

18. An apparatus for controlling bio-organisms having a gradual remediation startup, said apparatus comprising:

a transducer configured to emit ultrasonic waves at a frequency;

a processor operatively connected to said transducer, said processor executing a program performing the following steps:

a) running a first stage whereby said transducer is caused to emit said ultrasonic waves for a plurality of first cycles, said transducer emits said ultrasonic waves for a selected first stage duration, each one of said plurality of first cycles having a first stage on-time and a first stage off-time;

b) running a second stage whereby said transducer is caused to emit said ultrasonic waves for a plurality of second cycles, said transducer emits said ultrasonic waves for a selected second stage duration, each one of said plurality of second cycles having a second stage on-time and a second stage off-time, said second stage off-time being less than said first stage off-time; and

c) running a final stage whereby said transducer is caused to emit said ultrasonic waves for a plurality of final cycles, said transducer emits said ultrasonic waves for a selected final stage duration, each one of said plurality of final cycles having a final stage on-time and a final stage off-time, and said final stage off-time
5 being less than said second stage off-time.

19. The apparatus of Claim 18 further including a processor step for determining a stage duration before said processor step a) for running said first stage is performed, wherein said stage duration is equal to said first and second stage durations of said steps a) and b).

10 20. The apparatus of Claim 19 wherein said step for determining said stage duration includes the processor receiving an input from a sensor that is responsive to conditions indicative of a high algae concentration.

21. The apparatus of Claim 18 further including a processor step a1) for determining water quality, if said step a1) determines that water quality is within
15 limits, said step a1) performs at least one of the following actions that include sending an alert, pausing step a) of running said first stage, and stopping step a) of running said first stage.

22. The apparatus of Claim 18 further including a processor step b1) for determining water quality, if said step b1) determines that water quality is within
20 limits, said step b1) performs at least one of the following actions that include sending an alert, pausing step b) of running said first stage, and stopping step b) of running said first stage.

23. The apparatus of Claim 18 further including a processor step a1) for determining water quality, said step 1) runs concurrently with said steps a) of
25 running said first stage and b) of running said second stage, if said step a1) determines that water quality is within limits, said step a1) performs at least one of the following actions that include sending an alert, pausing step a) of running said first stage, pausing step b) of running said first stage, stopping step a) of running said first stage and stopping step b) of running said first stage.