**Description**

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The problem of marine fouling is of long standing. Any object which remains under water for an extended period of time becomes coated with various types and numbers of marine organisms, which settle in a general progression and sequence. On a clean surface there first collects a coating of a fine detritus which is followed by a bacterial coating and then a scummy algal growth, then by the attachment of larvae, and the growth of adult population which varies dependent on what larvae settle first. The large and abundant growth of algae can create a severe "soft" fouling condition, and the calcareous shells of acorn barnacles and serpulids are the primary cause of "hard" fouling.

The presence of fouling on a vessel's hull has well known detrimental effects. It reduces the top speed of the vessel, increases the power consumption and decreases the maximum range. It may also accelerate corrosion of hulls and structures. On sonar domes it reduces sonar performance by severely increasing "flow noise" thereby reducing substantially the signal-to-noise ratio.

Numerous preventive or anti-fouling methods have been proposed, the most successful of which is presently the use of toxic paint coatings. The practical life of such coatings is generally less than a few years, and the application and renewal of the paint requires drydocking of the vessel. Water jets, steam jets, abrasive cleaners and scrubbing are effective for removing fouling, but are very time consuming and cost prohibitive for frequent use. Cleaning while afloat is a desirable goal since anti-fouling paints and coatings cannot solve the problem alone.

A number of underwater brushing systems for cleaning ships while afloat are in use. These scrubbing systems are effective but time consuming, expensive, damage the paint, and are difficult to employ frequently and require diver control on most surfaces.

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Growth of marine organisms on submerged surfaces has long been a problem. These organisms, including barnacles, mussels, marine worms, corals, anemones, sponges, and algae, attach themselves to any exposed surface of boats, ships, docks and other submerged or partially submerged structures. When these organisms attach themselves to the hulls of ships or boats, their presence hastens the breakdown of the outer finish of the hull as well as detracting from the performance of effected vessel. Another major issue that is created by the unchecked growth of these marine organisms is that vessels traveling significant distances unknowingly transport marine organisms native to one area of the world to other areas, where the native marine life, including vital food sources, might be endangered by the introduction of new species or varieties of organisms.

For boats and ships, probably the most common way of treating the build up of marine organisms, which happens quite rapidly when the vessel is moored or docked, is to have scuba divers scrape the submerged surface, such as the boat hull. Typically, this must be done every three to six weeks, and may be required even more frequently in tropical climates. Even with regular scraping, degradation of the surface of the hull make it is necessary to thoroughly clean and refinish or repaint the hull every few years. In order to accomplish this, the vessel must be removed from the water and placed in dry dock. All of these procedures can become quite costly, and may ultimately result in all but the most avid owners selling his or her boat after realizing that the cost of maintenance is too high.

The scraping and refinishing procedures are often enhanced by utilizing specialized marine paints which kill or repel the organisms, or provide a surface to which the organisms have difficulty firmly attaching. Typically, these paints contained tin or copper. However, as environmental regulations have become increasingly stringent, the use of most of these paints has been or will soon be prohibited. Such prohibition is primarily due to the harm these paints cause to the environment, particularly since their effectiveness arises from their toxicity to marine organisms.

A number of devices and methods have been disclosed in the past as means for addressing the problem of the growth of marine organisms on boat hulls. Many of these devices are intended for use in conjunction with specialized marine paints, and thus, have not been required to rely entirely on their own effectiveness.

**Biofouling** or **biological fouling** is the accumulation of [microorganisms](https://en.wikipedia.org/wiki/Microorganism), [plants](https://en.wikipedia.org/wiki/Plant), [algae](https://en.wikipedia.org/wiki/Alga), or [animals](https://en.wikipedia.org/wiki/Animal) on wetted surfaces. Such accumulation is referred to as **epibiosis** when the host surface is another organism and the relationship is not parasitic.

**Antifouling** is the ability of specifically designed materials and [coatings](https://en.wikipedia.org/wiki/Coatings) to remove or prevent biofouling by any number of organisms on [wetted](https://en.wikipedia.org/wiki/Wetting) surfaces.[[1]](https://en.wikipedia.org/wiki/Biofouling#cite_note-1) Since biofouling can occur almost anywhere water is present, biofouling poses risks to a wide variety of objects such as medical devices and membranes, as well as to entire industries, such as paper manufacturing, food processing, underwater construction, and desalination plants.[[2]](https://en.wikipedia.org/wiki/Biofouling#cite_note-Vladkova-2)

Specifically, the buildup of biofouling on marine vessels poses a significant problem. In some instances, the hull structure and propulsion systems can be damaged.[[3]](https://en.wikipedia.org/wiki/Biofouling#cite_note-Chambers-3) The accumulation of biofoulers on hulls can increase both the hydrodynamic volume of a vessel and the hydrodynamic friction, leading to increased [drag](https://en.wikipedia.org/wiki/Drag_%28physics%29) of up to 60%.[[4]](https://en.wikipedia.org/wiki/Biofouling#cite_note-V1-4) The drag increase has been seen to decrease speeds by up to 10%, which can require up to a 40% increase in fuel to compensate.[[5]](https://en.wikipedia.org/wiki/Biofouling#cite_note-V2-5) With fuel typically comprising up to half of marine transport costs, antifouling methods are estimated to save the shipping industry around $60 billion per year.[[5]](https://en.wikipedia.org/wiki/Biofouling#cite_note-V2-5) Increased fuel use due to biofouling contributes to adverse environmental effects and is predicted to increase emissions of carbon dioxide and sulfur dioxide between 38 and 72% by 2020.[[6]](https://en.wikipedia.org/wiki/Biofouling#cite_note-Salta-6)

A variety of [antifouling](https://en.wikipedia.org/wiki/Biofouling#Anti-fouling) methods have historically been implemented to combat biofouling. Recently, scientists have begun researching antifouling methods inspired by living organisms. This type of design imitation is known as [biomimicry](https://en.wikipedia.org/wiki/Biomimicry).

The NRG Marine Hull protection system utilizes the latest digital electronics and Ultrasonic transducer technology, by producing multiple bursts of ultra sonic energy simultaneously in a multiple range of frequencies.

This energy produces a pattern of alternating positive and negative pressure. The alternating pattern creates microscopic bubbles during periods of negative pressure and implodes them during periods of positive pressure in a phenomenon known as "cavitation."

The implosion creates a micro-jet action that not only provides the cleaning effect on the hulls surface below the water line, it also resonates and destroys single cell organisms such as algae. The removal of the initial link in the food chain inhibits the growth barnacles and other marine life that feed on the algae.

"Cavitation" is the rapid formation and collapse of millions of tiny bubbles (or cavities) in a liquid. Cavitation is produced by the alternating high and low pressure waves generated by high frequency (ultrasonic) sound. During the low pressure phase, these bubbles grow from a microscopic size until, during the high pressure phase, they are compressed and implode.

Ultrasonic antifouling has been used in industry for many years and has only, in the last 4-5 years, been adapted for use for Marine vessels. Basically our Digital Transducer Control Module sends a refined program of short ultrasonic wave burst signals to the Ultrasonic Transducer that is mounted onto your hull, this transducer emits these specific frequencies which are beyond the hearing range of humans. The Ultrasonic Sound waves emitted through your hull generate a barrier at a microscopic level of moving water molecules throughout the submerged hull area which destroys algae and barnacles, preventing them from attaching to your hull.

By using sound waves, ultrasonic antifouling can prevent the growth of algae, barnacles and slime on boat hulls and interiors, and can protect sea chests and box coolers as well. The technology has been employed internationally from Europe to Australia, Japan, Chile and the Caribbean, and implemented on commercial, military and recreational vessels. More recently, these systems have caught on with yacht owners in North America.

Fouled, rough hulls can slow boats and increase fuel consumption, and antifouling paints — while effective — can release toxins when a vessel is in the water or when coatings are scraped off in dry dock. Usage of ultrasound has grown following the International Maritime Organization’s ban over a decade ago on organotin in bottom paints, and because of moves to limit copper as an antifouling agent. Ultrasonic systems don’t rely on chemicals that can harm fish and mammals or pollute the air, and they can reduce vessel lift-outs for cleaning.

The cleaning abilities of sound waves have been recognized since before World War II. Starting in the 1950s, sound waves were utilized for this purpose in the food, agriculture, electronics, medical, aircraft and auto industries. While ultrasound’s marine applications have been acknowledged for decades, usage by commercial vessel operators has only gained traction in the past 15 years. To install a system, transducers are mounted inside a vessel’s hull, or on other internal features, along with a control box. Onboard generators or shore sources power the equipment.

“Wherever sea, river or estuary water touches a vessel or its internal equipment, biological organisms are at work, clogging pipework, encrusting the hull and propeller, increasing fuel consumption and requiring expensive remedial work,” said Darren Rowlands, director of NRG Marine Ltd. in the United Kingdom. “Antifouling is therefore an essential preventative measure that all commercial, military or leisure operators use to maintain smooth, fouling-free surfaces to reduce running costs and extend service intervals.”

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<https://www.lgsonic.com/product/control-algae-ponds-lg-sonic-e-line/>

**Summary**

[**http://www.google.com/patents/WO2012085630A1?cl=en**](http://www.google.com/patents/WO2012085630A1?cl=en)

**WO 2012085630 A1**

The present invention comprises an ultrasonic anti-fouling arrangement for an aquatic structure, the anti-fouling arrangement comprising at least two ultra-sonic transducers, the anti-fouling arrangement comprising at least two ultra-sonic transducers, at least one ultrasonic receiver, a transducer driver and a controller; wherein the transducers are acoustically coupled to the structure, whereby, in operation, ultrasonic vibrations can be transmitted, at least in part, through the structure; wherein the ultrasonic receiver is operable to detect ultrasonic signals to provide a response signal, the controller being operable to provide a control signal for the transducer driver whereby each transducer can be driven within a range of operating frequencies and operating voltages and wherein the controller can determine feedback from a response signal provided by the at least one ultrasonic receiver; whereby subsequent operation of the transducers is determined from such feedback.

MARINE ANTIFOULING RESONANCE SYSTEM

Field of the Invention

This invention relates to an ultra-sonic antifouling system: More particularly, this invention relates to a system and method of preventing, reducing and removing growth of marine organisms such as algae, seaweed and Crustacea on the underside of the hulls of ships, boats, yachts, ferries and other types of watergoing vessels and underwater structures. It is particularly useful for vessels and structures manufactured from steel, aluminium and fibreglass but is also relevant for vessels and structures manufactured from other materials provided that they conduct ultrasonic vibrations. The invention has application for sea going vessels and structures and also those in inland waterways.

Background of the Invention

Fouling organisms are aquatic flora and fauna that attach to and grow upon hard objects below the surface of the water. Fouling of the hulls of vessels and structures in an underwater environment has always been a serious problem. In this environment, marine organisms such as algae and weed together with barnacles, tunicates and other organisms which form encrustations colonize the part of the vessel or structure that is underwater.

The colonization by these organisms is referred to as "fouling" as they increase the weight and drag on the vessel thereby reducing the speed of the vessel underway. This increases fuel consumption and makes the vessel more difficult to handle, thus reducing the performance and efficiency of the vessel. In some cases, the effect is so significant that commercial vessel owners remove the vessel from the water every two weeks for cleaning. This has a significant commercial impact. There is not only the cost of cleaning but also the period of time that the vessel is out of service. This invention also has application to structures in the marine environment. There are many fixed structures in the marine environment such as jetties, harbours, marinas, research vessels and buildings such as platforms and underwater observatories e.g. for preservation of the environment, and other structures for industrial applications such as marine transport, for exploitation and processing of ocean resources including marine products, for exploitation and development of natural resources such as oil, gas and mineral resources, and pipelines associated with the aforegoing. On fixed structures, fouling increases weight and structural loading. Fouling may render walkways, steps and other parts of structures dangerous and more difficult to access. Fouling also affects structural integrity. It damages base paint, thereby exposing a vessel hull or fixed structure to corrosion. It may therefore also damage and affect the operation of the structure, parts and equipment and render these hazardous.

Algae and encrusting organisms inhabit ali the world's oceans, coastal waters, estuarine systems and inland waterways. A great number of factors play a role in determining growth and distribution at a particular location and time. Seasonal factors play a significant role with regard to water temperature, length of day and spawning habits.

Algae are a diverse group of photosynthetic plants. Their microscopic spores are present in the air, on soil and in the water and are dispersed widely. They are continually introduced into bodies of water by the wind, rain showers and storm water. They can grow rapidly, particularly in stagnant water when exposed to sunlight. Phosphates and nitrates in the water also encourage growth. An aigal bloom is difficult to eliminate. Cyanobacteria (often referred to as "slime algae") may also colonize the hull of a marine vessel or underwater structure. Slime algae forms a blanket like slime which can cover the entire underside of a ship's hull and is difficult to remove. It is also thought that algal growth is a pre-cursor to colonization by other marine organisms. Oxygen given off by the algae or by cyanobacteria (through photosynthesis) provides the necessary environment enabling the growth of encrustations such as barnacles and weed.

Fouling can be removed by mechanical and/or chemical means. However, these alternatives take time and are costly. This will involve logistical issues and may require a long wait. If a vessel hull is cleaned in dry dock, the vessel must be taken out of service. The costs are therefore significant as there is the cost of cleaning the vessel and the vessel down-time. Despite the above difficulties, particularly the cost of cleaning and the period of time that the vessel is out of service, in some cases the effect of fouling on fuel consumption and performance is so significant that it is necessary for owners of commercial vessel such as ferries to remove the vessel from the water every two weeks for cleaning. This has a substantial adverse impact upon operations.

Cleaning by mechanical and/or chemical means involves a risk of damage to the hull. Further, removal of encrustations by chemical means may give rise to regulatory and environmental issues. Depending upon the size of the vessel, it may not be practical to remove it from the water. A fixed structure cannot be removed for cleaning. Alternatively, a vessel or structure may be cleaned in the water. In this case, it is common practice to use divers. However, this involves inherent dangers to the divers and also potential damage to the hull or structure.

For the above reasons, there are strong commercial drivers to provide solutions to fouling.

To address this problem, paints and coating compositions have been developed which are designed to prevent corrosion resulting from oxidation at the surface of underwater structures. Although these slow corrosion, they do not necessarily prevent the attachment of marine organisms which release oxygen at the surface of the hull or structure and accelerate oxidation. These paints contain toxic agents such as zinc, lead, and copper. These are released into the water over time as salts thereby polluting the water and are therefore environmentally hazardous. Other paints have also been developed which are designed to prevent the attachment of marine organisms by slowly releasing marine growth inhibitors. These typically contain copper or tin salts which are released into the water over time and are also hazardous to the marine environment. The most toxic of these compositions are being banned. Although some of the compositions are less toxic, these tend to be less effective. Other paints, which are silicone based, have been developed which are designed to make it more difficult for marine organisms to cling to the hull.

The above paints and coating compositions are reasonably effective until the inhibitors are leached or the paint is damaged at which point fouling will re-occur. Removal of the fouling and re-painting is then required.

Other chemical solutions to anti-fouling have also been attempted such as applying sodium hypochlorite through tubing disposed external of the hull.

Another anti-fouling method for controlling or preventing the growth of algae and other encrustations of organisms which has been employed is to affix electrodes on the exterior of the hull adjacent to and on opposite sides of the keel of a vessel and to pass electrical current through the electrodes. The electrolysis of the sea water gives off chlorine and sodium hypochlorite adjacent to the vessel hull which is toxic to the algae, barnacles and other marine organisms. However, it is not possible to effectively control the concentration of anti-fouling substances at the surface of the hull and the release of these toxic agents into the water. It also gives rise to regulatory and environmental concerns. In addition, the electrodes require regular maintenance. Given the positioning of the electrodes, maintenance is particularly difficult.

One method of controlling or preventing the growth of algae and encrustations of organisms on marine vessels and underwater structures is to apply ultrasonic waves to the hull or structure. A transducer is used to convert electrical energy into ultrasound waves (which are above the normal range of human hearing). Typically, the transducer

5 is a piezoelectric transducer. A piezoelectric crystal changes size when current is applied.\* Applying an alternating current across a piezoelectric crystal causes it to oscillate at very high frequency thus producing high frequency sound waves. A control box sends electric signals to a transducer, mounted to the vessel hull or structure, which emits a series of low frequency ultrasonic sound waves. These ultrasonic waves are transmitted along the hull or structure. Sound waves are transferred into the liquid at the surface of the hull or structure. These sound waves cause ultrasonic cavitation. The sound waves that propagate into the liquid result in alternating high pressure (compression) and low pressure (rarefaction) cycles with rates depending upon the frequency. During the low pressure cycle, the ultrasonic waves create small momentary vacuum cavities or voids in the liquid commonly referred to as "bubbles". When the bubbles expand to a volume at which they can no longer absorb energy, due to the higher surrounding pressure the bubble collapses violently. The top of the cavity implodes to release gases and produce microscopic jets of liquid down the centre of the cavity. The cavitation threshold may also be affected by viscosity.

During the implosion very high temperatures (approx. 5.000K) and pressures (approx. 2,000 atm) are reached locally. These cavities are created tens of thousands of times each second. Accordingly, tens of thousands of bubbles experience cavitation every second. At 40 kHz, cavities are generated approximately 40,000 times per second. At 80kHz cavities are generated approximately 80,000 times per second. These implosions gently scrub the surface of the hull or structure, cleaning the surface and removing contaminants without damage to the hull or structure.

It is understood that the aigal cells are killed due to mechanical stress resulting from cavitation. The implosions rupture the gas vacuole of the algal cell causing the cell to collapse. This kills the algae which then cease to adhere and are dislodged from the hull or structure. This also prevents or inhibits the growth of barnacles and other „

6 encrustations. If the algae are unable to attach, subsequent colonizers such as barnacles and other encrustations do not join on.

Ultrasonic cleaning has a number of advantages. In particular, it does not involve the use and application of hazardous paints or coatings. Nor does it produce any toxic by-products. It is therefore safer for the user and is environmentally friendly. CA2618925 discloses a water-based anti-fouling composition which allegedly has minimal effect on the environment and on users because it does not involve the use of organic solvents.

US6285629 discloses an ultrasonic vibration device used for preventing deterioration of a submerged marine structure made from a piezoelectric ceramic plate with an electrode on each side thereof; power supply wires, connected to the respective electrodes, a support member for fixedly supporting the ultrasonic vibration device and transmitting g the vibration to the structure; and a resin coat for protecting the vibration device against seawater.

US5143011 discloses a system for inhibiting growth of barnacles and other marine life on the hull of a boat. The system includes a plurality of transducers or vibrators mounted on the hull and alternately energized at a frequency of 25 Hertz through a power source, preferably the boat battery and a control system. The system has two operating modes, one being continuous and the other operational through daylight hours only When the voltage falls below a predetermined level, the transducers are automatically de-energized.

US5532980 discloses resonators which operate underwater and provide continuous acoustic vibrations having a duty cycle of 3.65 seconds which includes a current drive period of .4 seconds.

WO01/58750 discloses an ultrasonic anti-fouling device hung outside a hull and arranged so that the vibrations are directed to run parallel to the surface of the hull. ?

US 5735226 discloses a marine anti-fouling system which continually powers a vibrational device at a frequency between 25 kHz and 60 kHz, some of the signal being enhanced by the driving of subatomic frequencies superimposed on the ultrasonic signals.

WO2009/150437 discloses an ultrasonic anti-fouling system in which the transducer is operable on a cyclic basis having an on period of between 10 & 60 seconds followed by an off period of between 5 & 60 minutes. This is based on the premise that for effective operation, operation does not need to be continuous. Accordingly, the transducer operates on a cycle for the length of time considered effective. This system has been developed to provide a low energy ultrasonic system designed to minimize the draw on current and to avoid continuous drain on power supply. The period of the cycle is varied in order to optimize effectiveness. Operating conditions are sought to be optimized based on location, time of year and hour of the day by enabling the controller to refer to a look-up table. Further aids such as a salinity detector, temperature sensor and ambient light sensor are also contemplated used in order to help determine preferred operating conditions. Although the use of more than one transducer is contemplated, the transducers transmit signals only (preferably in sequence).

Limitations of existing ultrasonic based systems are that there is often a low level of performance following installation and that the system is not effective over time. Further, systems tested in cooler waters may appear to operate effectively as the growth of organisms is slower. In warmer waters, whether or not the system is working effectively will be more readily apparent. While the use of ultrasonic waves in underwater cleaning systems is well known and has been proved to be effective in killing and removing algae and preventing barnacles, in practice ultrasonic anti-fouling systems do not appear to work effectively and reliably across a range of vessels (of different sizes and shapes) and operating conditions. Testing and feedback from users indicated that, in some cases, the system made no difference to growth of organisms, in .

8 others there was some evidence of operation but the effect was relatively minor, or the system appeared to operate initially but had limited effect over time. The above problems with effectiveness are considered to be due to a number of factors which will impact upon the effectiveness of the sound waves resonating in the hull. These factors include:

• Sound waves will reflect off the internal structure which will affect transmission of the signal.

• The efficiency at which different frequencies are conducted will also be affected by the hull density.

Vessels are typically comprised of a number of boxes (rib, stringers and the hull) which provide a barrier and tend to limit ultrasonic's effectively resonating in the hull. This is not unlike a large building with only one speaker for a public address system. For one transmitter, there will be audio black spots.

• If more than one transducer is used simultaneously, this can lead to wave interference between sound waves. In some cases, the waves may effectively cancel each other out.

• If the main power of the signal is transmitted directly through the hull, this is effectively operating as an echo sounding system (which is useful for measuring distance) but is not effective as a cleaning system. In order to be effective as a cleaning system, the signal must resonate along the hull or structure.

- There is significant variation in the size and shape of the hull of different vessels.

To address the above problems, the Applicants decided that it was necessary to design a system able to monitor the signal being transmitted to ensure the ultrasonic waves are resonating effectively along the hull and, if not, to provide means to adjust the frequency at which the system operates.

While some or all of these limitations with ultrasonic systems and consequential problems have been recognized in the prior art, and certain attempts have been made to overborne those issues, these existing systems do not monitor the resonance to determine whether the system is operating effectively.

Object of the Invention

The present invention seeks to provide an ultrasonic anti-fouling system which monitors the signal being transmitted to ensure the ultrasonic waves are resonating effectively along the hull and control means to adjust the frequency at which the system operates. This in built monitoring system is designed to enable effective performance of the system and preferably to improve and optimize effective performance of the system. Summary of the Invention

The present invention comprises an ultrasonic anti-fouling arrangement for an aquatic structure, the anti-fouling arrangement comprising at least two ultra-sonic transducers, the anti-fouling arrangement comprising at least two ultra-sonic transducers, at least one ultrasonic receiver, a transducer driver and a controller; wherein the transducers are acoustically coupled to the structure, whereby, in operation, ultrasonic vibrations can be transmitted, at least in part, through the structure; wherein the ultrasonic receiver is operable to detect ultrasonic signals to provide a response signal, the controller being operable to provide a control signal for the transducer driver whereby each transducer can be driven within a range of operating frequencies and operating voltages and wherein the controller can determine feedback from a response signal provided by the at least one ultrasonic receiver; whereby subsequent operation of the transducers is determined from such feedback. The ultrasonic transducer is driven in subsequent operation at a resonant maximum frequency by the controller. In this specification, it is to be understood that the term aquatic structure is intended to include boats and other aquatic vessels. The invention is particularly applicable to the hulls of boats and other aquatic vessels. However, it is also applicable to other aquatic structures and therefore the term structure is used to so as to encompass other aquatic structures such as a jetty. To assist in simplification, it is to be understood that in this specification the term jetty, is intended to include aquatic dockyard features such as buoys, landing stages, slipway, tracked slipway, breakwater, pontoon, pier, float, canal gate, surface water installations such as, but not limited to, wave power generating schemes, moving bridge equipment, underwater installations such as, but not limited to, stopcocks, optical fibre and other telecommunications equipment installations, oil-pipe, current-flow/tidal power generating schemes, and other dockyard and waterway features.

Preferably, the arrangement utilizes a plurality or network of transducers wherein each transducer is able to operate in both transmission mode and receiving mode, each transducer transmits ultrasonic wave signals and, when not transmitting, receives and monitors the signals, and provides feedback to the controller in order to determine which frequency (or frequencies) are effectively transmitted along the hull or structure and in order to allow operational changes to be made on the basis of the data received.

Typically, the transducers are positioned at (approximately equidistant) locations around the hull or structure so as to maximize transmission effects. However, the data from the one or more receivers enables optimum placement of the transducers to be determined.

A minimum of at least 2 transducers is required so that one is able to operate in transmission mode and one in receiving mode at any given point in time. The larger the vessel or structure, the more transducers that will be required to ensure adequate coverage.

Typically, the transducers are mounted upon the hull of a vessel or external part of the structure. The transducers may be located on the outside of the hull. Preferably, the ultrasonic receiver is acoustically coupled to the structure. However, , this is not strictly necessary. They may be glued directly into position in order to maximize the effective signal transfer. They may also be affixed by other means. Alternatively, they „ Λ

11 may also be located within the hull or external part of the structure and glued into position or affixed by other means. For example,' the transducer may be connected to the aquatic structure via a flange which retains the transducer in a body, an end face being provided with an ultrasonic transducer element, the transducer element being coupled to the hull via an acoustic couplant.

Each transducer is able to operate in both transmission and receiving mode. However, preferably the system ensures that the transducers operate in transmission mode sequentially so that only one transducer transmits at a time in order to avoid any potential wave interference. When not operating in transmission mode, each transducer operates as a receiver which provides feedback to the controller. This data is then processed by the controller to determine the optimal operational frequency.

Preferably, each transducer is able to run a test and transmit sequence. The test sequence involves an initial scan through a pre-set range of frequencies to determine the optimum frequency for that vessel or structure and the particular environmental conditions. Preferably, the scan is run over a frequency range of 25kHz to 80kHz at 5kHz increments for approximately 50 seconds. However, the scan could also be run over a wider frequency range of 15kHz to 80kHz. Alternatively, a narrower frequency range may be used. The remaining one or more transducers positioned around the vessel or structure act as receivers which measure the amplitude of the signal. This indicates the strength of transmission of the signal at that point. This data is fed back to the controller to enable it to determine the optimum operating frequency. The controller then sets the transducer to operate at that frequency for a set period. This sequence is repeated by each transducer in turn.

In operation, the system is switched on and a first transducer runs an initial scan through a pre-set range of frequencies to determine the optimum frequency for that vessel or structure and the conditions. Typically, the scan is run over a frequency range of 25kHz to 80kHz in .5kHz increments for approximately 50 seconds followed by a cooling off period. The remaining one or more transducers positioned around the vessel or structure act as receivers which measure the amplitude of the signal which indicates the strength of transmission of the signal at those points. This data is fed back to the controller to enable it to determine the optimum operating frequency. The controller then sets the transducer to operate at that frequency for a set period. This sequence is then followed by each transducer in turn.

Each transducer is able to operate in both transmission and receiving mode. However, preferably the system ensures that the transducers operate in transmission mode in sequence so that only one transducer transmits at a time in order to avoid any potential wave interference. When not operating in transmission mode, each transducer operates as a receiver which provides feedback to the controller. This data is then processed by the controller to determine the optimal operational frequency.

It is also envisaged that the period of transmission may be adjusted and set to suit the environmental conditions. This may be manually set by the user or may be set by the controller with reference to input data as to location (such as by means of a GPS), time of day, water temperature and light from various instruments and sensors. For example, in warmer waters, the period of transmission will typically need to be longer in order to effectively remove the algae and prevent regrowth. The time of year and length of daylight will also affect the period of transmission required.

Unlike other prior art systems, this system operates diagnostically rather than according to a pre-set frequency. This enables the system to adjust the frequency of the signal and period of transmission, as required, to take account of the vessel construction (material, size and shape) and environmental conditions.

This in-built monitoring system has a number of advantages. The monitoring system provides an in-built self checking system. This means that the system will be operational at installation without having to wait to determine whether the system is operating effectively. With a suitable display (or a PC using a serial terminal program), the actual effectiveness of each transducer can be monitored. Decisions can then be made as to the effectiveness of transducer position during installation and changes made at that time to ensure that the system is operating from the point of installation thus avoiding having to wait to see whether the system is working. If the system is not working effectively from the outset, the vessel or structure may subsequently need to be cleaned with consequential costs and downtime.

The invention also continues to monitor whether each transducer and the system is operating effectively during the life of the system. The system can also be compared against other systems on similar vessels. Changes which affect the operation of the system can be monitored and adjustments can be made to ensure the system is operating effectively. This enables the system to provide a constant and predictable level of performance. This will also assist in identifying component failure over time and, if necessary, components can be replaced.