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Deployment of Acoustical Alert Devices on Select DoD Vessels to Mitigate the Risk of Vessel Collisions with Marine Mammals

Leviathan Legacy Incorporated / Final Technical Report
Submitted: September 29, 2011

Deployment of acoustical alert devices on select DoD vessels to mitigate the risk of vessel collisions with marine mammals

TECHICAL REPORT **W912DY-08-2-0015**

Dynamac NASA boat operating with alarm at the Kennedy Space Center

Submitted: September 29, 2011

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ABSTRACT

Preparations for deployments of manatee alerting devices were conducted for several DoD vessels operating in the Kings Bay Submarine Base in Georgia and the Naval Air Command in Jacksonville, FL. Two modified prototype systems were developed and delivered for the deployments The systems were modified for vessels in a manner which would not interfere or alter the operational maneuverability or the respective conduct of the crew. The modified prototypes user friendly and more efficient than the original systems. Designed to alert manatees of approaching vessels and reduce the risks of collisions, the deployments are necessary to evaluate the robustness of the system during sustained continuous use by various crews and vessels. Observers have been trained to document manatee responses during normal operations. Manatee observers on these vessels offer an increased vigilance that ordinarily would not be in effect. Aside the prototype alarms from alerting manatees that are in the direct path of a vessel, boat observers offer an enhanced level of protection overall. Since the crews and vessels are not to deviate from normal operations the real world deployments pose no TAKE's on the manatees, but offers greater opportunities for protecting manatees. During the course of this project, environmental managers at both installations suspended facilitating deployments due to informal objections from regional USFWS liaisons. Similar modified devices have since been approved for deployment at an alternate installation at Cape Canaveral, Fl. We remain hopeful the original targeted installations in Kings Bay and Jacksonville will eventually facilitate deployments on DoD vessels in the near future.

STATEMENT OF PROBLEM

While manatees are repeatedly scarred and often killed by collisions with watercraft, the root causes of collisions, and how to effectively mitigate the frequency of collisions is greatly debated. Gerstein and Blue have argued since 1996 that near surface propagation characteristics and shallow-water transmission loss in concert with the manatees' unique auditory constraints are underlying sensory causes of many, if not most, of the collisions with boats and barges. While encounters with slow moving commercial vessels are often fatal, most encounters between recreational boats and manatees are not. Many individual manatees survive and bear the scars from multiple boat encounters. These encounters are so prevalent that manatees are routinely identified by characteristic scar patterns from boats and propellers. One individual recently killed by a fast moving boat exhibited 50 scar patterns from different boat collisions. Gerstein and Blue argued that the majority of fatal commercial and non-fatal recreational boat collisions result when the dominant lower frequency sounds of boats are attenuated near the surface and their propagation is limited in shallow water habitats. Lower intensity sounds produced by slower propeller rates are also more readily masked by ambient levels typically recorded in the Atlantic Intracoastal Waterway and other brackish and shallow water habitats.

A comprehensive series of controlled underwater psychoacoustic tests was conducted to measure and document the overall hearing abilities of the West Indian manatee. Pure tones, complex noise and real world sounds were presented to manatees under various controlled acoustical conditions. The results from more than 30,000 threshold trials definitively measured the manatees' overall range of hearing, sensitivity, masked thresholds, critical ratios, and directional hearing for pure tones, species specific calls and boat noise. Complementing these investigations, underwater acoustical measurements of manatee habitats and vessel noise propagation in these environments were conducted to evaluate the acoustical factors that render Florida manatees vulnerable to repeated collisions with vessels. Both low frequency cut-offs in shallow water and near surface boundary effects limit the propagation of low frequency sounds and the dominant low frequency spectra of slow moving boats. Slow speed zones implemented to protect manatees do not address the underlying acoustical challenges manatees face. Ironically, the strategy can also be counter-productive in turbid waters and exacerbate the problem, making vessels more difficult or impossible for manatees to detect; while increasing transect times and thus the opportunities for collisions. While manatees are not adapted for hearing the dominant low frequency spectra from watercraft they are well equipped to detect and locate higher frequency modulated sounds. This hearing sensitivity provides a narrow sensory window through which to alert manatees of approaching vessels. Understanding the propagation characteristics of their shallow water habitats Dr. Joseph E. Blue, an expert in sonar technologies and transducer design, conceived of a method to exploit the manatees' best hearing abilities and alert them to the presence of motor boats and commercial vessels. In 1998, he was awarded a Methods patent on the application of acoustic alarms to help manatees detect and locate approaching boats.

The efficacy of this technology was demonstrated during field tests with wild manatees in the North Banana river within the Kennedy Space Center in Florida. In 2007, these field tests were initiated at Cape Canaveral with wild manatees. These trials were continued through the 2008 and 2009 and successfully demonstrated the efficacy of the device for alerting manatees and eliciting directional avoidance reactions to controlled vessel approaches (Figure 1).

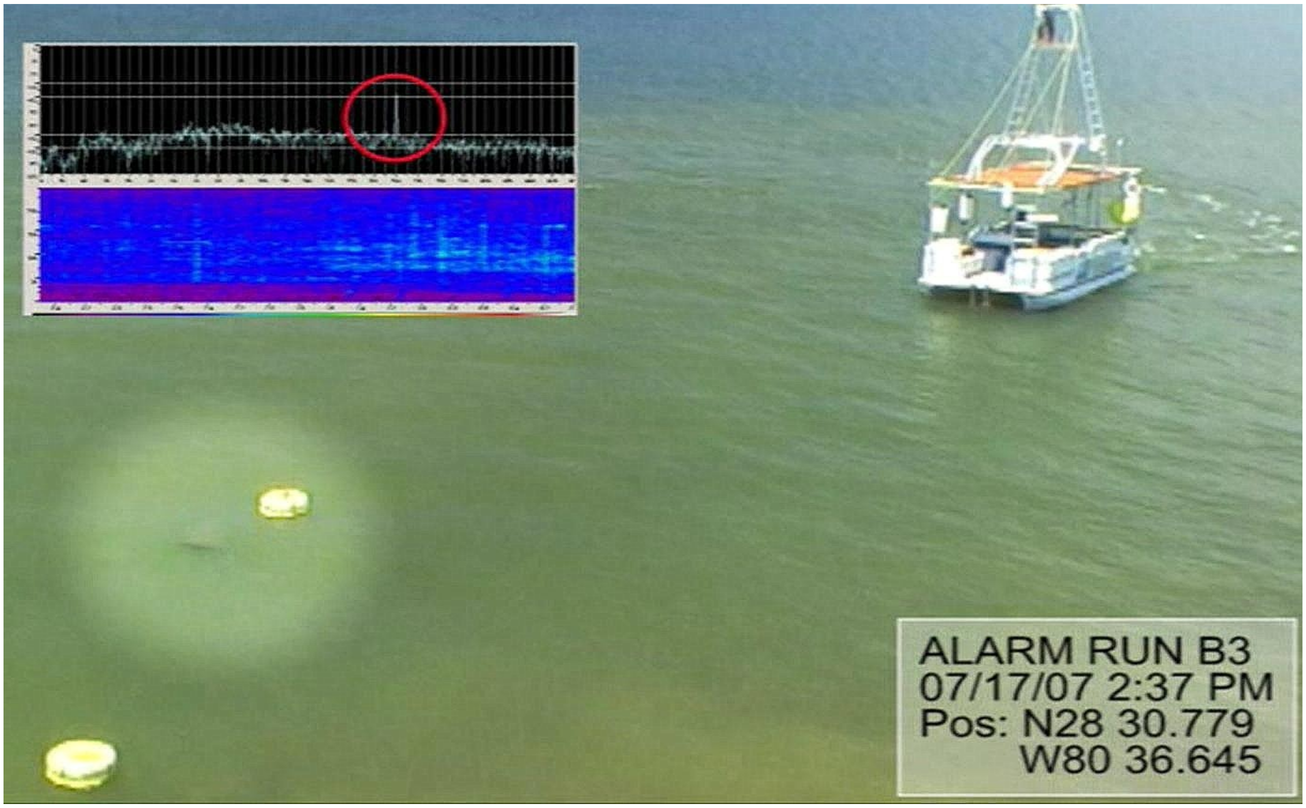


Figure 1. Manatee diving to avoid boat during alarm trial at NASA.

only 3% percent of the vessel approach trials without the device elicited any avoidance reactions from wild manatees, while 97% of the approach trials with the same vessel equipped with an alarm elicited strong avoidance reactions at safe distances from the approaching vessel. These changes were exhibited at distances ranging from 12 m to 30 m ahead of the bow. The mean response change in behavior was significantly greater during alarm trials (F=198, df=1, $p < 0.01$). The mean distance at which focal manatees responded was also significantly greater during alarm trials (F= 46.46, df=1, $p < 0.01$). These differences are illustrated in Figures 2 a and b.

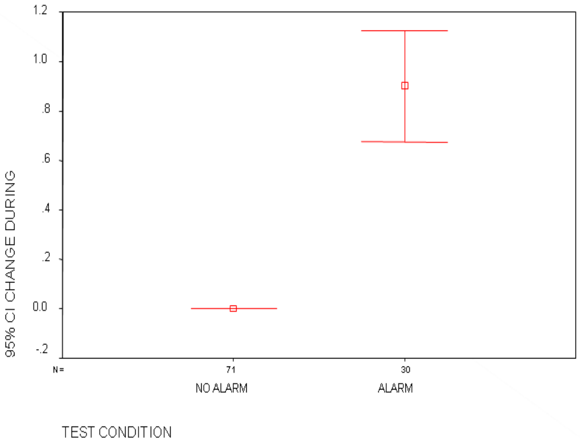


Figure 2a. Mean avoidance no-alarm vs. alarm

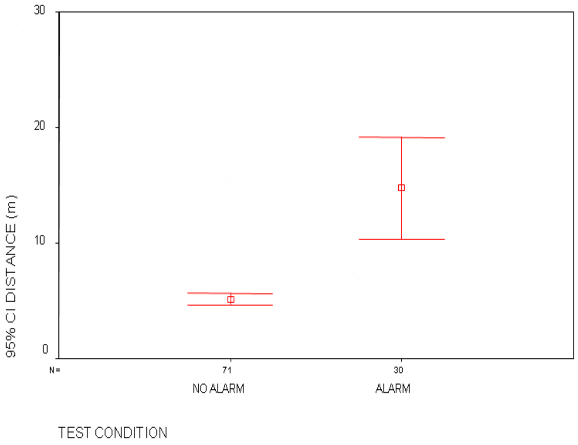


Figure 2b. Mean distance of reaction from bow

Encouraged by these results and the understanding of manatee hearing and acoustical propagation in their environments real world deployments at the Kings Bay Submarine and Jacksonville Air Command prototypes for deployment were developed.

THE ALARM

The original prototypes used for the field trials with wild manatees utilized nonlinear (parametric) acoustic methods to generate very narrow beam alarm sounds in front of the approaching boat. A detailed technical report on the theory, design and hardware specifications of these prototype devices was submitted in an earlier report to Legacy. In summary, the alarm system utilized parametric techniques to generate narrow 6° acoustical beams of sound directly ahead of the boat. They had single side band generators (SSB) combiners, power amplifiers and parametric acoustic projectors. These prototypes were robust and designed with flexibility so they could be modified and fine tuned by the operator in the field during tests with wild manatees.

For this project a modified projector system was delivered and tested prior to deployment. The amplification device chosen is more efficient and reliable than the original design. The system now utilizes an APEX PA09 linear power amplifier The APEX PA09 is driven from a ± 24 V DC supply. and is capable of sourcing 2 Amps (peak) to 1 MHz into a 500 uF load when supplied by a +/-30 VDC power supply. The PA09 is a linear class A-B amplifier which is at best 50% efficient which means that the other 50% of the energy is dissipated as heat. Heat buildup is dissipated using a shielded aluminum heat sink (Figure 3).

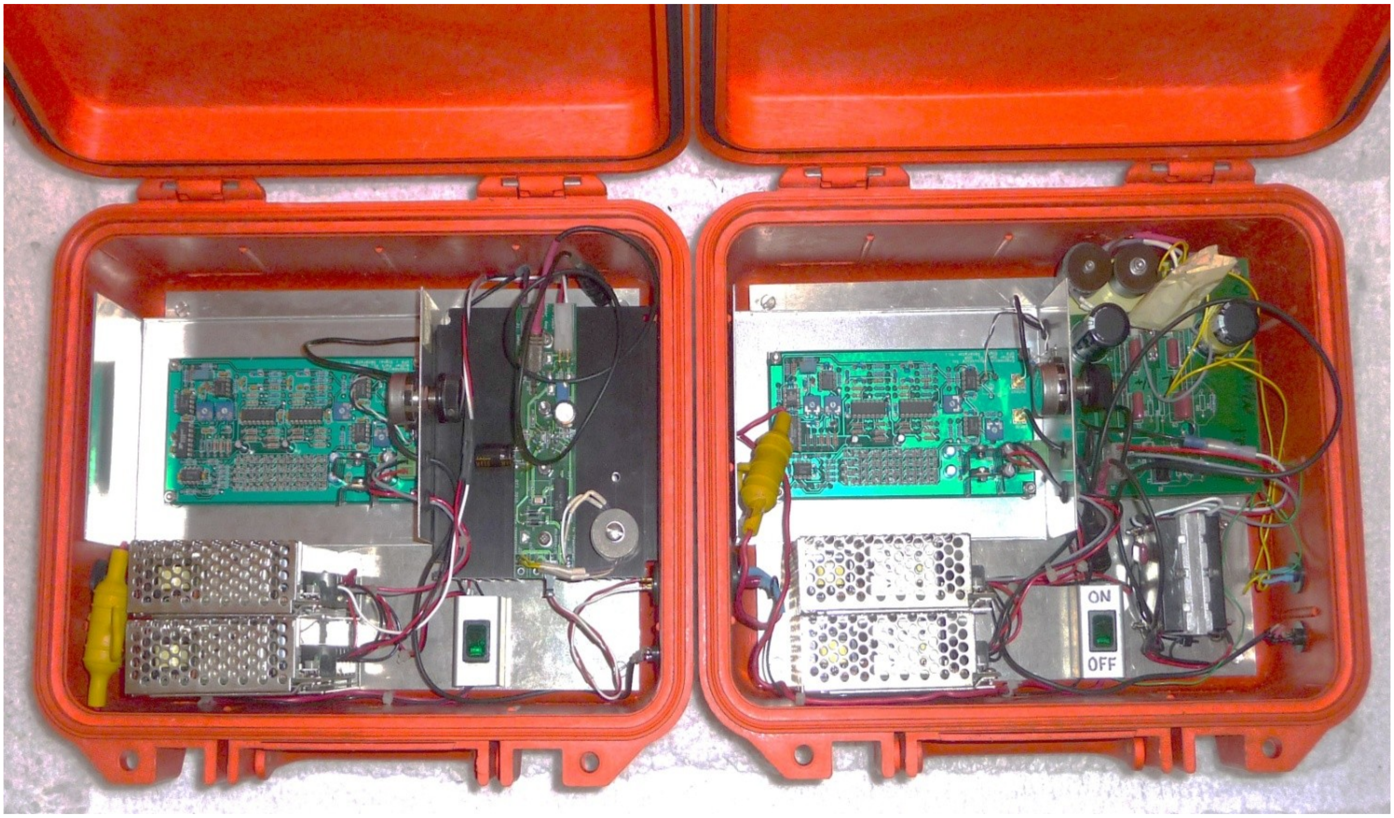


Figure 3. Modified SSB, combiner, with upgraded APEX PA09 linear power amplifier and heat sink.

The system modulates 10 kHz to 20 kHz input signals combined with a 200 kHz carrier. The 200 kHz carrier is the resonant frequency of the parametric projectors. The signal in Figures 4 and 5 is a 15 kHz single tone at 4 Volts peak-to-peak. The source power level (SPL) at the primaries is 199 dB. These measurements were made on the source using two hydrophones. The first hydrophone had calibrated sensitivity of -213 dBV/uPas @ 450 Hz. This hydrophone was used to measure the high frequencies. The second hydrophone was an ITC1042 hydrophone which was used to measure the low frequencies. The output of the ITC1042 was run through an RC low pass filter (1 pole) and then into a Stanford Research SR560. The SR560 provided 10 kHz band pass filtering. The output of the SR560 was run into a TDS2024B oscilloscope. The resulting received source levels of the parametric signals were 177.4 dB at 15 kHz and 180 dB at 20 kHz. This represents an improvement of 12 dB over the original amplifier.

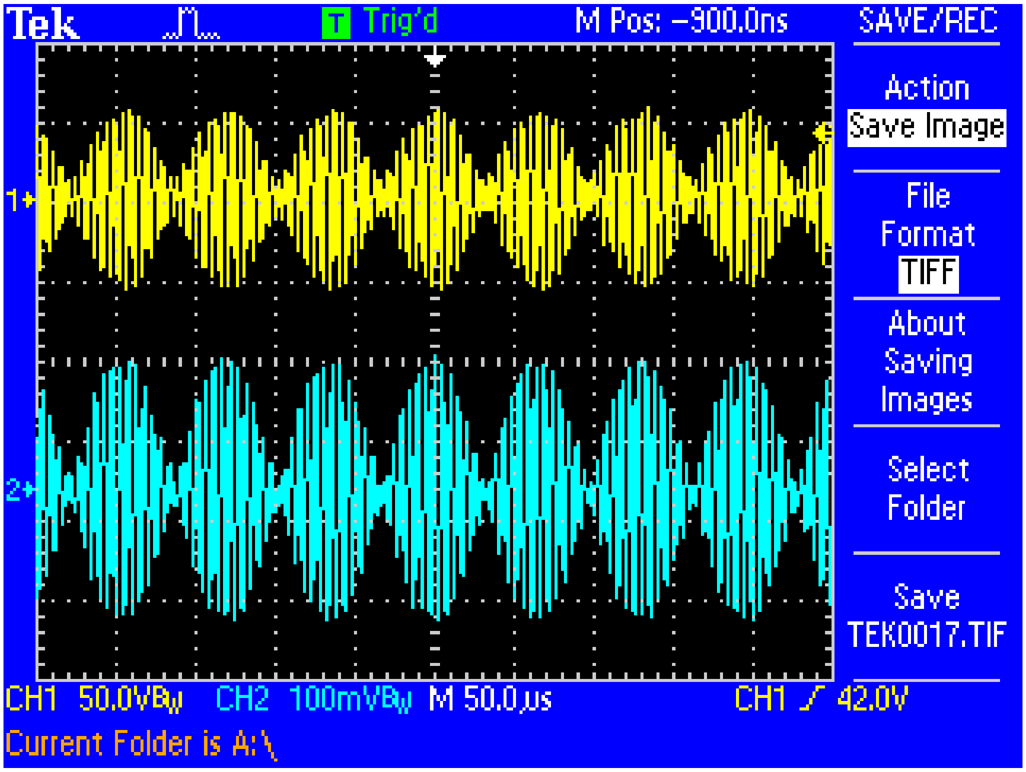


Figure 4 a – 15 kHz Modulated Time Domain Tx (Yellow) and Rx (Blue) Signal

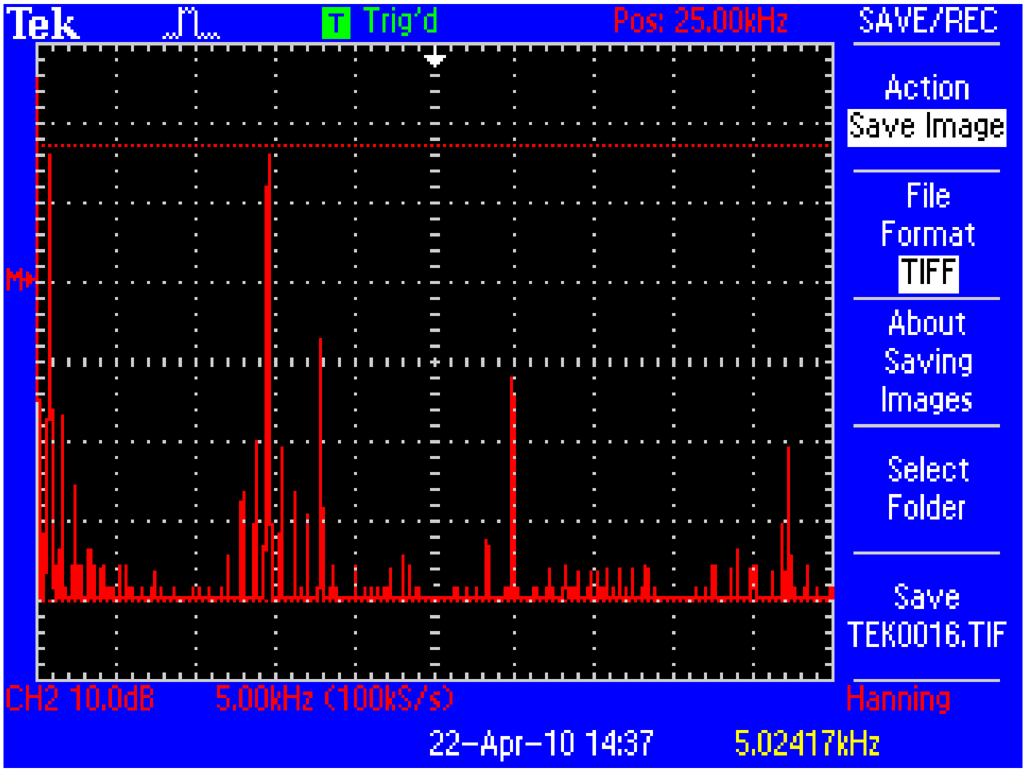
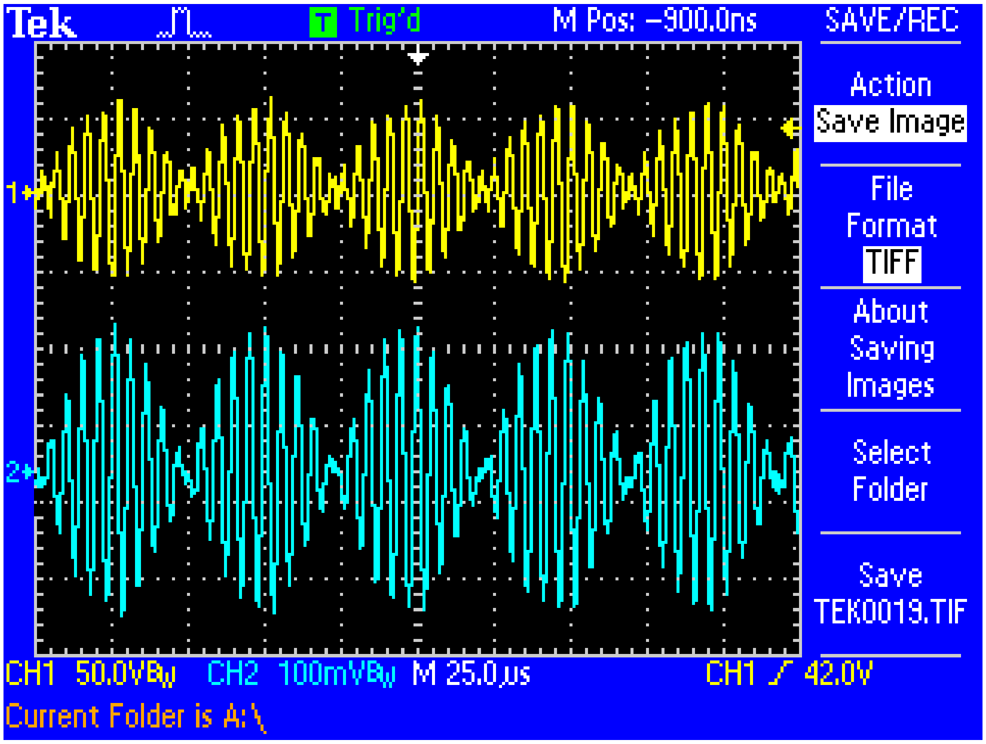


Figure 4 b – 15 kHz Hydrophone Rx Signal

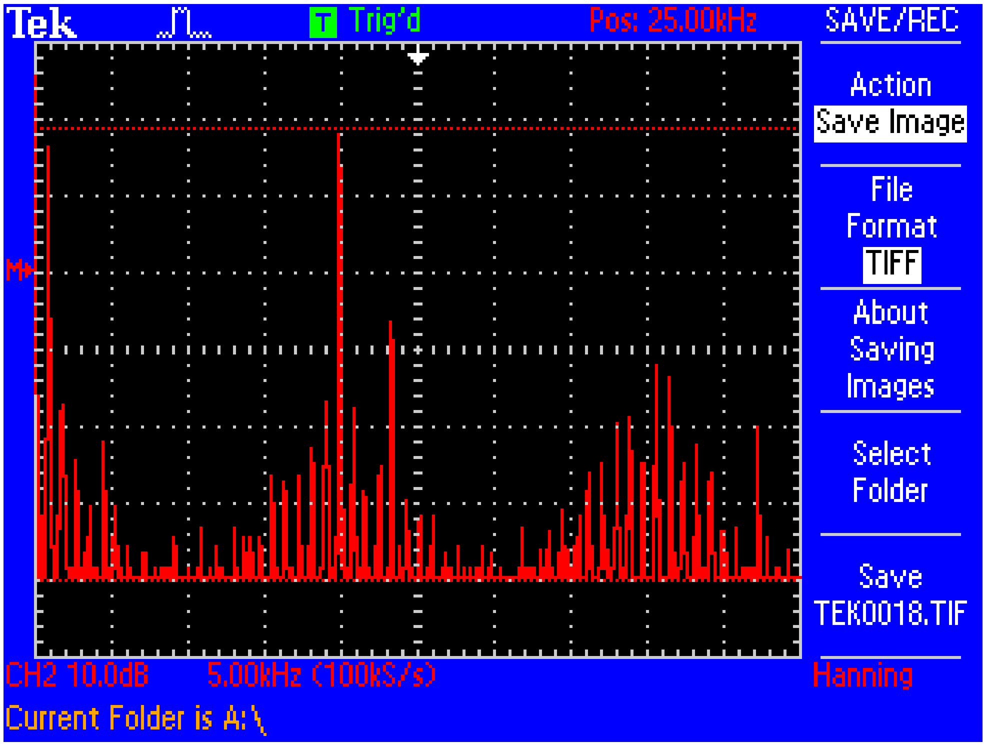


M Pos: -900.0ns

CH1 50.0V BW CH2 100mV BW M 25.0µs CH1 ⁄ 42.0V

Current Folder is A:\

Figure 5 a – 20 kHz Modulated Time Domain Tx (Yellow) and Rx (Blue) Signal



Pos: 25.00kHz

CH2 10.0dB 5.00kHz (100kS/s) Hanning

Current Folder is A:\

Figure 5 b – 20 kHz Hydrophone Rx Signal

MATCHING NETWORK AND ACOUSTIC PROJECTOR

A step-up transformer (4:1) is used to increase the voltage on the transducer since the maximum output of the amplifier is approximately +/-20 Vp-p. OTI removed the parallel tuning inductor since this inductor appeared to be saturating and limiting the total output to less than 6 Vp-p. Additionally, there no need for the inductor, which was on the origial system, since the amplifier can reliably drive a capacitive load (over 500 uF) (Figure 6) . In addition, a series tuning inductor was used to lower the impedance of the load impedance. Since the amplifier is voltage limited, it is necessary to maintain as low impedance as possible. The resulting low impedance load is also safer to work . The projector has a static capacitance of approximately 2.3 nF. The units have since been reliably run continuously at full power for 72 hours without failure. Ordinarily, they will not be operating at full capacity for more than 12 continuous hours. To limit user error during deployment the system can be adjusted automatically by the vessel speedometer or tachometer. A locking potentiometer on the outside of the ruggedized single side band enclosure can still be used manually override and adjust the gain of both primary frequencies equally as well.

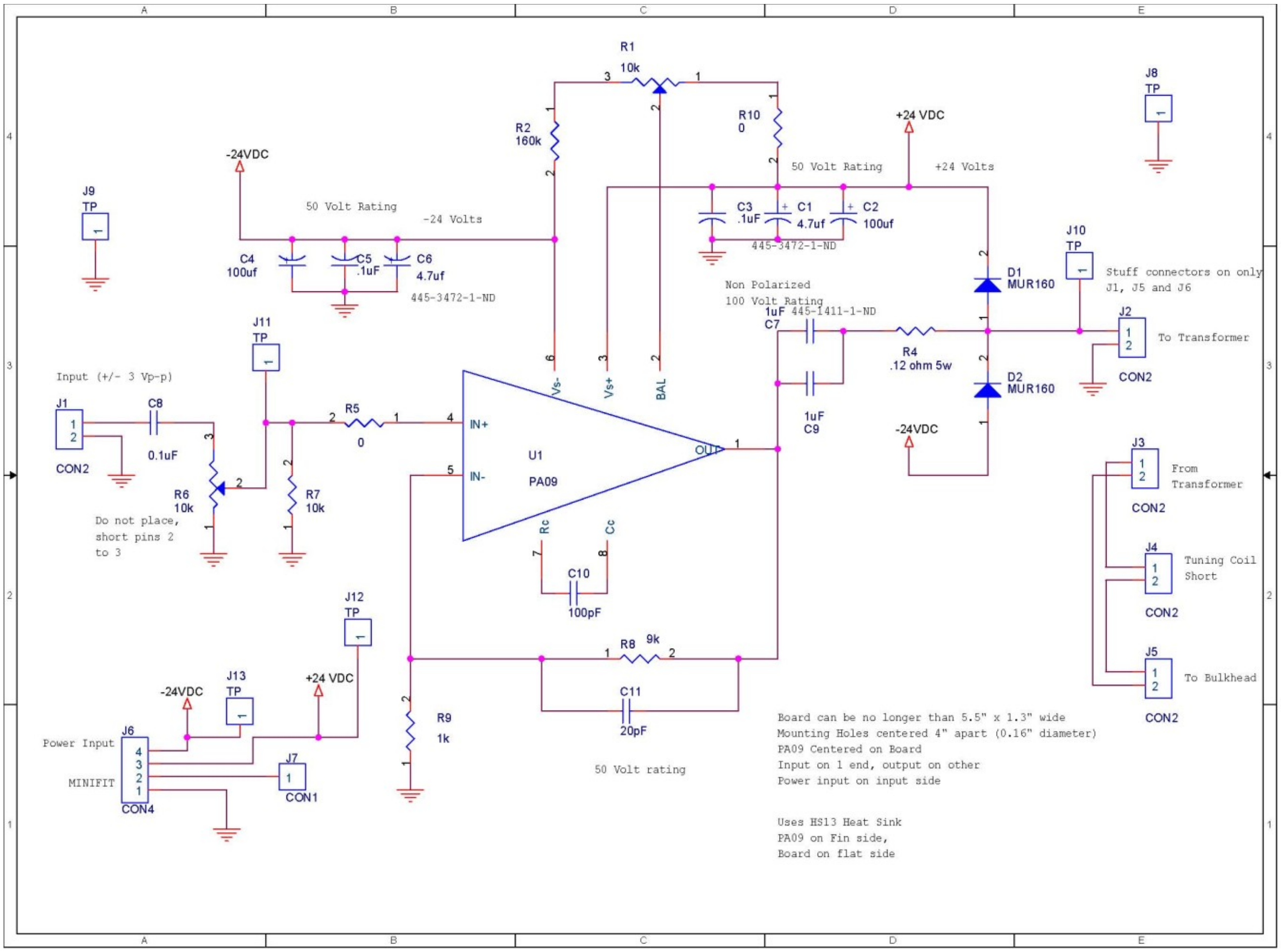


Figure 6. Schematic of SSB modulator 1

Two additional thickness mode resonance projectors projectors were built for this project. They are comprised of 45 element planar arrays with 5 rows of piezo electric piston elements, 9 elements per row (Figure 7 a and b).

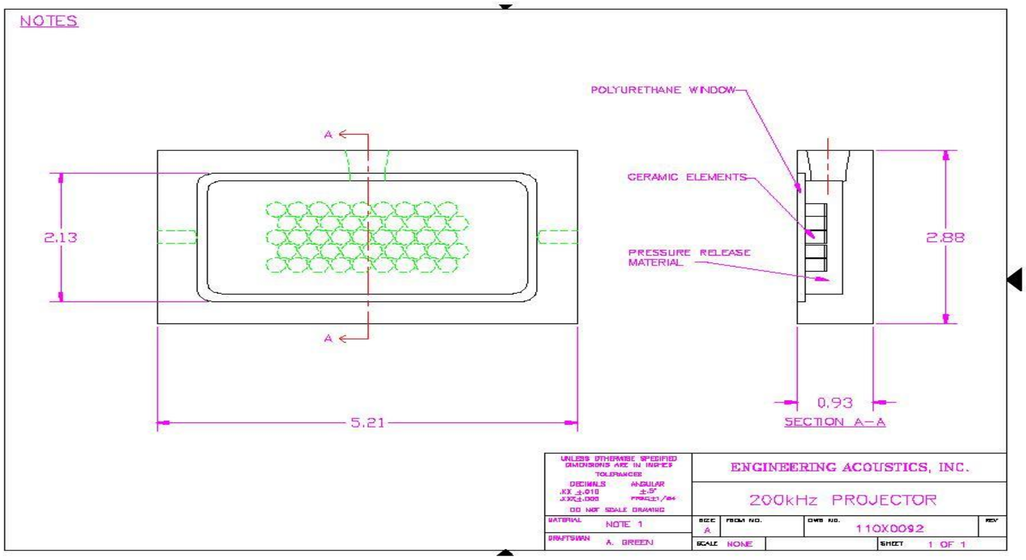


Figure 7 a. Schematic of parametric projectors

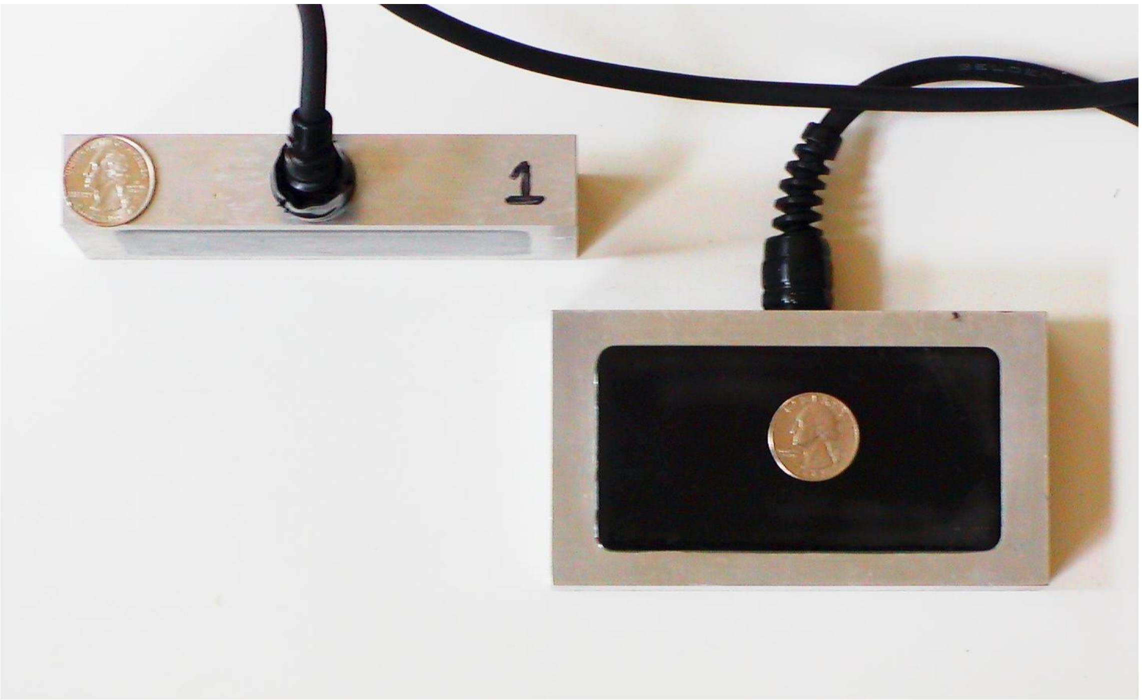


Figure 7 b.. Ruggedized projectors

The prototype projectors are ruggedized encased in 5" long x 3" high x 1” thick aluminum blocks. Each projectors consists of 45 ceramic elements that radiate on an axis source level of ~200 dB at both 210 kHz and 225 kHz, producing a narrow directional beam width of about six degrees.

Navy Type I ceramic was chosen for its good piezoelectric and thermal properties. Its high Curie point (~ 325° C) insured the projectors can withstand high temperatures that could build up should it be operated in a continuous wave mode. The projectors were encased in Aluminum 6030 and structurally reinforced for universal mounting. They have been mounted in an armature bolted to the center of the bow. The armature telescopes down to submerge the projector 1 meter below the surface at the bow in a forward facing position.

The size and shape of the alarm’s acoustic footprint was determined by the projector’s highly directional 6° beam width. The forward projecting parametric field formed like a cone expanding in a direct line ahead of the boat. At 50m the diameter of the sound field expanded to ~ 6m which was wider than the diameter calculated for the base of a cone; D = 2 x [H x tan (angle)] (angle of the isosceles triangle drawn 90° to the center of the base). At a 50m distance this is calculated as follows: D = 2 (50 x tan 3), D = 2 (50 x .052407779), D = 5.24m. .

BENEFIT

The device is a demonstrated effective technology to protect manatees and possibly other marine animals from injury of impact with vessels at DoD installations and during range and training operations. The device can be selectively activated when vessels are close-inshore. It has a selectable range that poses no security risk. The device alerts animals at safe distances to allow vessels to operate unimpeded at optimum speeds at all times. The deployment will serve as a model for deploying the alarm designed to alert North Atlantic right whales and other whales. Both alarm devices (one for manatees and one for right whales) negate the near surface and acoustical shadowing effects that past DoD Legacy funded research demonstrated make marine mammals vulnerable to ship strikes with large vessels. Aside from the direct military benefit, these devices benefit the civilian sector and could help protect manatees and whales throughout their ranges.

ACKNOWLEDGEMENTS

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