Cornell Bioacoustics
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A Low-cost HF Projector Design

1. Overview

This technical article covers the fabrication of a high-frequency projector for use in comparative calibrations of hydrophones.

2. Design Criteria

The desired operational range of this design is from $\leq$ 15KHz to $\geq$ 60KHz with output power of $\geq$140dB. The linearity is not critical as the unit will be used for comparative calibrations. It should be able to be driven by a conventional audio amplifier at 8 Ohm impedance.

3. Projector Design & Fabrication

A PVDF piezo film transducer will be used based on cost and ease of fabrication. Specifically we will use Amp Sensor's speaker element, p/n 0-1000420-0 with a cost of roughly $20. The manufacturer quotes an output for this film of between 80 and 95dB SPL, free air which translates to 141.5 to 156.5dB SPL in water.

In order to reach the optimum efficiencies of the piezo element, it needs to be bent into a radius (to provide the necessary pumping action). Using readily-available materials, 2" diameter PVC pipe was selected.

The PVC is cut in half length-wise to be used as the basic form. The outside surface of the PVC form is covered with Scotch mounting tape (cat. #114), and the piezo film centered and pressed firmly to that surface. The piezo leads are then brought over the edge of the PVC form to the inner area. Double-sided tape can be used to hold it in place. The leads to the transformer and amplifier are then soldered to the piezo's leads.

Due to the high impedance nature of the piezo film, an impedance-matching transformer is necessary to efficiently couple the amplifier's power to the element. For our use, an inexpensive Radio Shack transformer was employed (8 Ohm: 1K Ohm).

The impedance matching transformer is connected with 8 Ohm side towards amplifier and 1K side to projector (black center tap is not used). For convenience-sake, the diagram shows the transformer mounted and potted within the projector itself. *You may want to consider mounting this in-line to the cable where it will be accessible should it breakdown from being over driven.*

For potting, a standard plastic water bottle (the squeeze-type with the straw coming out that seems to be sold everywhere) was used as a mold. A plastic divider was inserted into the bottle to reduce the amount of potting material needed and to provide a flat back to the projector for easier handling and orientation. The divider was secured using a hot-melt glue gun. Refer to the document Fabrication of the PVDF Hydrophone Design for information on working with the epoxy and potting configurations such as this.

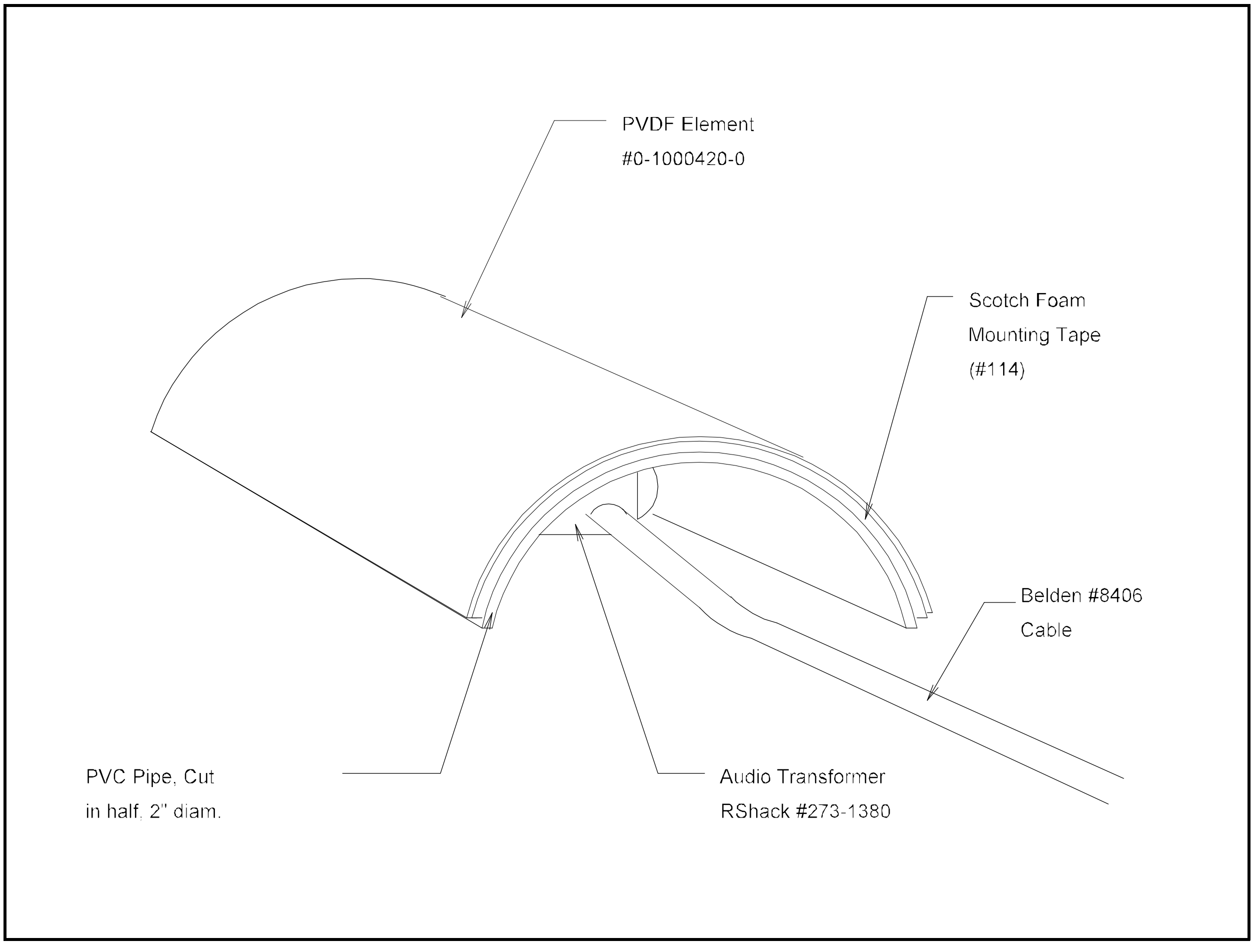

Figure 1. High Frequency Projector Components (before potting).

4. Testing and Final Characteristics

The completed projector was tested by inserting it into a tank in a similar arrangement to that described for hydrophones in the document Hydrophone Usage and Deployment. In this case, the distance between the calibrated reference hydrophone (a B&K 8103) and the fabricated projector was 10cm. The 'proximity criterion' test was performed satisfactory to validate low or no incidence of reflections that might affect the test results.

4.1 Test Equipment

The projector was powered by a Crown 30-30 amplifier, with a Kron-Hite 1000A signal generator feeding into the amplifier. The Kron Hite output was taken from the Lo output jack. The amplifier was set to maximum power output (30W rated).

4.2 Maximum Projected Power

To determine the maximum power out, the signal generator was set to maximum output from the Lo jack (~1.8V pk-pk sine wave). A frequency step was then performed from 5KHz to 70KHz. At 20KHz, the impedance transformer melted down, so the test was aborted and the data derived to that point used in the final calculations.

The frequency of 10KHz was used to determine the peak projected power based on fairly consistent numbers through that region from the reference hydrophone. At 10KHz an output of 3.2mV was seen from the reference hydrophone (at 10mm). The reference hydrophone had a open-circuit voltage sensitivity of 26.3uV/Pa (26.3uV for 120dB re 1V/uPa at 1 meter). Using the formula: $120dB + 20\log(e_1/e_0)$, this recorded output of 3.2mV translated to 161.7dB re 1V/uPa at 0.1 meter. A similar formula was then used to extrapolate the power output at 1 meter: $20\log(d_1/d_0)$, where d_1 is 1 meter and d_0 is 0.1 meter. This showed us a 20dB change from 0.1m to 1m, giving us an SPL of **141.7dB re 1V/uPa at 1 meter**.

4.3 Frequency Response

After the transformer was replaced, the frequency response was again evaluated with the calibrated reference hydrophone in the same position. In this case, the signal generator's output was set to 50% (0.25V pk-pk sine wave output). The frequency was again stepped from 5KHz to 70KHz and the reference hydrophone's output recorded.

Following the stepped procedure, a quick scan of the full frequency range of the generator was performed to see what the absolutely minimum and maximum response was. The plotted results are presented in the appendices beginning on page 5.

5. Summary

The fabricated projector showed a frequency response of 3KHz to 80KHz (5Khz to 70KHz plotted) with a peak projected SPL of 141.7dB re 1V/uPa at 1 meter underwater as tested. Should a higher power matching transformer have been available, it is conceivable that the manufacturer's claims of 156dB maximum power could have been validated.

The design is reasonably low-cost and easy to fabricate, and for low-volume testing of underwater devices, this approach may serve your needs well. When using the device however, one should use caution so as not to overdrive the impedance matching transformer.

☞ The audio amplifier you use for your work should be checked for its frequency response. Specifically, will it cover the range of frequencies this projector covers.

Appendix A. Response curve

In reviewing the response curve for this fabricated device, one must take into account that the impedance matching transformer has its own set of variations by frequency. As a result, the response curve must be interpreted for the completed unit -- not for the piezo element itself.

The formula used to calculate the 'dB Response' is shown below the heading for that column and is based on those already discussed. In this case, the 120dB figure is the hydrophone's open voltage sensitivity reference (for the 0.0263mV response), while the 20dB figure represents the extrapolated loss when moving from the 0.1 meter distance to the 1 meter figure used as a standard.

The response data and plot follows on the next page.

Appendix B. Sources

Cable
Newark Electronics supplies Belden cable. 800-462-3153
-- We used Belden Brillance Microphone cable, type 8406
(call for local rep).

Miscellaneous Hardware
McMaster-Carr 908-329-6666

Piezo Film (p/n #0-1000420-0 w/leads)
Amp Sensors 215-666-3545
-- Also request bulletin #65709, speaker element design.

Potting Epoxies
Conap 716-372-9650

Impedance-matching transformer (p/n 273-1380), etc.
Radio Shack -- local --