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Improvements on a Low-Cost Experimental Tetrahedral Ambisonic Microphone

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ABSTRACT

An earlier paper [1] made a comparison of two low-cost tetrahedral ambisonic microphones, an experimental microphone and a Core Sound TetraMic, using a Soundfield MKV or SPS422B as a standard for comparison. This paper examines improvements to the experimental device, including that suggested in the "future work" section of the original paper. Modifications to the capsules and a redesign of the electronics package made significant improvements in the experimental microphone. Recordings were made in natural environments and of live performances, some simultaneously with the Soundfield standard. Description of the recording process is included. Of interest is the use of the low-cost "do-it-yourself" surround microphone for student and experimental education.

1. INTRODUCTION

Further development of the experimental microphone introduced in a previous paper [1] resolves many of the technical issues associated with using an experimental ambisonic microphone. The recent introduction of relatively low-cost commercial ambisonic microphones has created a greater interest in surround recording. A proven "do-it-yourself" experimental tetrahedral ambisonic microphone would make surround recording a reality for many students, educational institutions, and experimenters.

The "new and improved" microphone, dubbed *Experimental 2* or *Exp2*, was built on the knowledge and experience gained from the original design, including the feedback from the musicians whose performances were recorded and the results from the listener survey of those recordings made with the original device, now called *Experimental 1* or *Exp1*.

The previous paper contained a list of "future work" which was used as a starting point for the updated version, named *Experimental 2* or *Exp2*. Added to the list was the desire for a device that other students and experimenters could build on their own. Except for the power supply, only the electret capsules and the basic tetrahedral frame remained in the new design, yet those were also modified.

2. SYSTEM REDESIGN

An observation made by some whose recitals the author was permitted to record with Experimental 1 was that the original microphone was "large." Esthetics was not a primary concern in the original construction; however, lessons are learned as one presents such devices for public scrutiny.

The electronics circuitry was laid out on perfboard and housed in a 6x8x4-inch gray box [2], not very conducive to an orchestral performance environment. Resizing was a priority, and a printed circuit board design for the preamps was a logical solution to reduce the dimensions of the electronics housing. The electronics package of Experimental 2 is 4.5x2.625x3.25 inches including the battery compartment (Fig. 1).

A repeatable gain structure was also an important criterion for the new electronics. The microphone is to be used in a wide range of recording environments, from quiet outdoor ambience to percussion and pipe organs to jet aircraft and fireworks. Gain adjustments on Exp1 were made with a multiturn pot, one for each channel, making gains difficult to reset accurately across the system, especially in a hurry.

The THAT 1512 opamp was chosen for Experimental 2 because, along with its low noise figure and low current requirements, its gain is set with a single resistor. Two pins on the IC are dedicated to gain. Jumpers on each pc board allow for five fixed preamplifier gain settings: -6dB and 10dB increments from 0 to +30dB. The option to use a 4-pole, 5-position switch was deferred to the need for a small housing. Gain is set by removing one end plate from the electronics housing and moving one jumper per preamplifier and the settings are very repeatable.

The 4 ¼-inch TRS jacks used by Exp1 were replaced with a direct connection of a quad-pair snake cable to the preamplifier outputs, further enabling a more compact device. The output of the original design was a b-format 4-channel matrixed output requiring output amplifiers after the a- to b-format matrix. The new design has a-format outputs (4 capsule preamp/ output circuits), a 50% reduction in the number of opamps.

Figure 1 – Experimental 2 standing nude without a windscreen.

Figure 2 – Mounting of the tetrahedral to a pipe and mounting flange.

The maximum sound pressure level (SPL) that Exp1 could be subjected to was about 120dB. At higher levels, the electret capsules would clip with no output for several milliseconds before recovering.

Panasonic WM-55A103 capsules are manufactured with one pin of its internal FET connected to the capsule case. Siegfried Linkwitz [3] suggests cutting the connecting tabs as a modification to the capsule, thereby separating the FET from the case. The result is a 3-terminal connection to the capsule, allowing the FET to be biased more appropriately in a source-follower mode.

The Linkwitz modification eliminated the clipping problem and resulted in considerable additional gain from the capsule. The authors only had access to an SPL meter with a maximum level of 126dB, but clap stick tests indicate a far greater output is available without clipping or distortion from the capsule.

Except for confirmation of the Linkwitz modification, no electrical breadboard tests were attempted prior to the layout of the printed circuit boards from the schematics. The enclosure would house two pc boards, each 2.5 inches wide and up to 4.25 inches long, and space was needed at each end for wiring and mechanical connections. Two preamplifiers fit on a single 3.8-inch long pc board while allowing access to the gain jumper pins for two preamplifiers.

The tetrahedral of Exp1 was supported by a single 12-guage (AWG) wire which was subject to bending during storage and transportation. The result was often a misaligned tetrahedral. Furthermore, the Exp1 capsule system was terminated with a 5-pin DIN connector. The redesigned system maintains the original tetrahedral, but replaces the single #12 wire with a u-shaped wire soldered to a short tube intended for lighting fixtures and then connected to the microphone housing via a flanged mounting (Fig. 2). Wiring to the capsules is routed through the tube into the housing.

The modified construction of the tetrahedral and its attachment to the electronics housing is mechanically and electrically more rugged than that of Exp1, and its orientation is maintained with greater confidence. There is less danger of it being bent and disoriented during handling and transport.

The remaining item on the wish list is phantom powering. Early testing results were not satisfactory due to added hiss in the output and considering that the two 9-volt batteries have a 7-8 hour useful operating life, this item has not been a priority. However, two advantages exist for a phantom powered device: battery replacement would not be needed (although the system would draw additional current for the interface to provide 48-volts) and it would cut the physical size of the microphone enclosure in half.

3. EARLY TESTING

The recording rig used for Exp2 is the same as Exp1: a Focusrite Sapphire Pro 26 i/o preamplifer/firewire interface with a MacBook Pro laptop and Logic Pro software. Housed in an SKB Studio Flyer case, the rig is completely portable. The internal laptop battery can power the computer and the interface for more than 2 hours. It can also be powered from AC lines or from an inverter in a vehicle.

The initial Experimental 2 field recordings were made in the waters of the upper Llano River in central Texas (Fig. 3), followed by a group of feral cats eating dry cat food scattered around the microphone.

Figure 3 – Exp2 with its furry windscreen. The first outdoor recordings included several sessions in the Llano River.

4. RECORDINGS

The first public concert recording, also captured with a Soundfield MkV microphone, was a pipe organ holiday sing-along concert at the Butler School of Music at the University of Texas at Austin (Fig. 4). Soon to follow was a recording of a worship service including the Vivaldi *Gloria* at the First Baptist Church of Austin where Exp2 successfully drove microphone lines exceeding 200 feet in length. Playback of the decodes of these recordings on a 4.1 system (no front center channel) demonstrated good, unequalized frequency response and localization characteristics form Exp2.

The neighborhood fireworks show around New Years gave the author ample opportunity to test the transient response of Exp2 while recording directly under the exploding arsenals. Exp2 did not clip once.

Northwest of Austin is McNeil, Texas, the home of Austin White Lime and the site of the crossing of two major railroad tracks, the Union Pacific and the Austin and Western. Amtrak uses the Union Pacific tracks. Exp2 was set on a desk stand placed on the ground about 25 feet from the Austin and Western Line and about 50 feet from the Union Pacific Line. Playback of the freight trains and Amtrak passenger trains passing by were impressive. There was no sign of clipping or overload once the Focusrite interface gains were determined (10dB attenuation!). SPL levels peaked at 117dB.

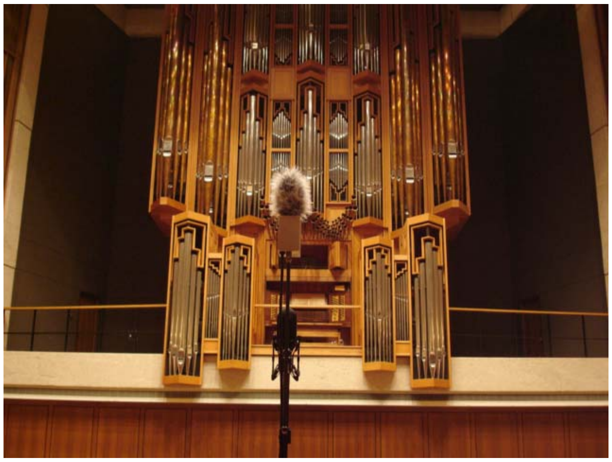

Figure 4 – Exp2 with windscreen hovering over a Soundfield MkV at the Holiday Organ Concert at Bates Recital Hall. One observer noted the Experimental Microphone "looks like a varmint on a stick."

During a recording session in Jessen Auditorium with the Aeolus string quartet, the author had the opportunity to position Exp2 in the center of the quartet and make a short, but truly surround recording of this UT graduate student quartet. Two additional recordings were made in Bates Auditorium: The UT Percussion Group, Tom Burritt, Director, and the UT Wind Symphony, Robert Carnochan, Director.

5. TECHNICAL TESTS

The first test on Exp2 was a noise floor test. With the internal gain of Exp2 at +20dB, the author wrapped the microphone inside of two winter sleeping bags and turned the gains of the Focusrite interface to their full levels (+60dB). The test was performed inside a front room of the author's well-insulated home. Hardly a scientific test, but the noise floor of the system was low enough to hear a car pass by outside, some 60 feet from the microphone (Fig. 5)

More realistic testing was performed in Jessen Auditorium with clap sticks. Clap sticks were made from two 12-inch long 2x4 pieces of lumber hinged at one end. Exp2 was placed on a mic stand in the seating area about 40 feet from the stage apron. With the internal gain of Exp2 set at +10dB. The Focusrite gains were preset at -60dB with a tone generator input of -50dB. The author stood on the stage apron and made a series of 4 claps before rotating the microphone in 90-degree increments; the test was then repeated using 45-degree increments.

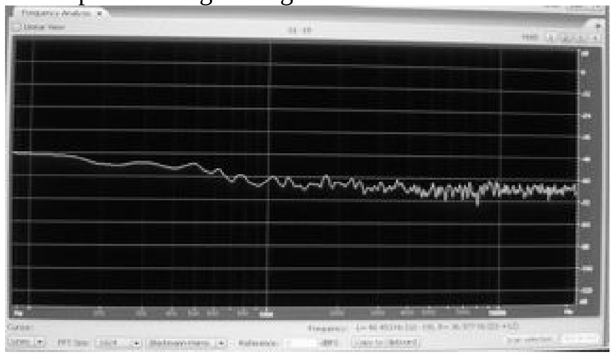

Figure 5 – Sleeping bag noise floor test. The low frequency noise is at -48dB while the high frequency is within the -60 to -72db range.

The results were normalized (a 6dB addition) and plotted for localization accuracy. Another test using a 1kHz test tone in a live recording room yielded similar results.

Table 1 displays the data from the individual capsules of the live room tests, corrected as noted. The largest fault is at the 270-degree rotation, ±1.4dB. Excel charts of the data seem to indicate that room reflections may have slightly skewed the results from one location to the other. Individual capsules are designated as LFU (left front up), RFD (right front down), RBU (right back up), and LBD (left back down). Note that this is the mathematical rotation of the capsules, not the normal channel assignment order of LFU, RFD, LBD, and RBU.

	LFU	RFD	RBU	LBD
0-degrees	0.0	0.0	-11.7	-9.7
90-degrees	-1.0	-7.8	-8.3	-0.9
180-degrees	-7.3	-7.7	-0.8	-1.1
270-degrees	-7.2	-0.5	-1.3	-9.9

Table 1 - 1kHz tone recorded by Exp2, normalized to 0dB. A correction of -1.0 db was added to RBU and LBD.

Frequency response tests are of little significance if the sound of the resulting recordings is not acceptable to the listener. Without access to an anechoic chamber, the results of such a test, even with a known reference microphone does not mean the test is accurate nor does it mean that the experimental microphone is not satisfactory for its intended purpose. Therefore, as in the listener survey with Exp1, the authors shall leave the listeners to determine if it meets their need for an ambisonic microphone suitable for educational and experimental use.

6. INTO THE FUTURE

The parts cost of this microphone was about $250 (US), including both the foam and furry windscreens and the output cable with connectors. The prior paper offered proof-of-performance that a DIY device was capable of excellent recordings. This paper refines the lessons learned from Experimental 1 into a device rugged enough for field recording, yet acceptable in a concert hall. Its applications include surround recording for radio, television, film, and games, and purposed as being an excellent educational tool.

As a tool for surround recording for experimental and educational uses, documentation of this project is being developed with schematics, printed board files, photographs, a parts list with sources, and a do-it-yourself guide for others to construct the microphone. A graduate student at the University of Stavanger in Norway has built a copy of Experimental 2, and feedback from both the student and professor continues to help the authors hone the documentation package.

7. ACKNOWLEDGEMENTS

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Thanks to Mark Drews, Stavanger University, Norway, for advising his student and to his student for taking on the project of building a copy of Experimental 2 and adding their experience to the success of this project.

8. REFERENCES

[1] Hemingson, Dan & Sarisky; *A Practical Comparison of Three Tetrahedral Ambisonic Microphones*, 126th AES Convention Munich May09. http://danh.coffeecup.com/pdf/AES_126_7676-2.pdf

[2] http://actlab.us/actlab/danh/Soundscapes/Page13.html

[3] http://www.linkwitzlab.com/sys_test.htm , under the section titled “Microphone.”

NOTE: Reference section URL’s updated November 24, 2015.