

Curriculum Vitae

Keenan R. Ball

Occupation description: Engineer
Present title: Senior Engineer
Department: AOP&E
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EDUCATION:

B.S.: Electromechanical Engineering, 2000, Wentworth Institute of Technology
M.S.: Electrical Engineering, 2003, University of Massachusetts Dartmouth

Thesis Title: "Localization of dolphin whistles using frequency domain beamforming of a narrow aperture handheld audio/video array"

PROFESSIONAL EXPERIENCE:

Woods Hole Oceanographic Institution, Woods Hole, MA
Senior Engineer, February 2015 - Present
Research Engineer, December 2006 - Present
Engineer II, October 2002 – December 2006

Foster-Miller Inc., Waltham, MA
Electromechanical Engineer, May 1998 – September 2000
(2) Cooperative Semesters and Full Time Staff

Varian Ion Implant Systems, Gloucester, MA
Value Engineer, May 1997 - September 1997
Cooperative Semester

Pitco Frialator Inc., Concord, NH
Designer's Assistant, January 1995 - September 1995

AWARDS:

Spring 2000, Wentworth Beatty Award for highest GPA of graduating class.
Fall 2000, Full scholarship to University of Massachusetts Dartmouth.
Summer 2002, Full Fellowship to the Physical Acoustic Summer School (PASS).

RESEARCH INTERESTS:

Use of acoustic arrays to study marine mammal communications, transducer and acoustic array design and implementation; acoustic communication systems in AUVs; design of electronics and mechanical hardware for use with acoustic communication systems.

PROFESSIONAL ACTIVITIES:

Outside WHOI (Other than Attendance at Society/National Meetings):
June 2002, Attended the Physical Acoustic Summer School at Asilomar, CA

PARTICIPATION IN EDUCATION PROGRAM:

Costas Pelekanakis (Joint Program Student): Provided test setup and engineering support for his project. The goal is to transmit real-time video through an acoustic channel.

SUPERVISION AT WHOI:

Karlen Wannop, Assign project work, various periods during November 2002-Present.

Tyler Andrade, May 2006-June 2010

Melissa Patrician, May 2008 – September 2009

Scott Hiland, September 2011 – January 2012

Tyler Johnson, Assign project work May 2013 - Present

CRUISE PARTICIPATION:

05/2003 Newport, RI. Spatial Modulation testing at GAITR. Set up and operated recording gear. Assisted Dan Kilfoyle by recording signals received on multi-element arrays.

06/2003 Newport, RI. Preparations for AUV Fest at Stillwater Basin. Provided micromodem and acoustic communication support for FMI, CSS and CETUS.

07/2003 Panama City, FL. Preparations for AUV Fest 2003. Provided micromodem support for FMI, CSS and CETUS.

08/2003 Keyport, WA. AUV Fest 2003. Provided micromodem support for FMI, CSS, CETUS and REMUS groups. Prepared test field for acoustic communication operations. Assisted in deployment of REMUS vehicles during tests involving REMUS. Operated REMUS topside during REMUS operations involving FMI, CSS and CETUS.

11/2003 La Spezia, Italy. Spatial modulation testing for Dan Kilfoyle. Set up and operated recording gear. Deployed and recovered acoustic transducer arrays. Assisted Dan Kilfoyle and Lee Freitag by recording and archiving signals received on the multi-element arrays.

5/2004 Panama City, FL. Preparations for CJTFEX. Provided Micromodem hardware support for FMI and CSS groups.

6/2004 Jacksonville, NC. CJTFEX Demonstrations. Provided Micromodem support for FMI, CSS and REMUS groups. Prepared test field for acoustic communication operations. Assisted in deployment and recovery of REMUS vehicles during tests involving REMUS. Prepared collected data from REMUS for presentation.

11/2004 Kyle of Lochalsh, Scotland. US/UK Interoperability Testing. Cooperative testing with Quinetic to transmit and receive signals from WHOI and Quinetic modems. Recorded signals transmitted from buoys, bottom nodes and fixed arrays from both land and ship based operations.

5/2005 Panama City, Fl. Preparations for AUV Fest 2005. Provided Micromodem hardware support for FMI, CETUS, FAU and CSS groups.

6/2005 Keyport, WA. AUV Fest 2005. Provided micromodem support for FMI, CSS, CETUS, FAU, Bluefin and REMUS groups. Prepared test field for acoustic communication operations. Assisted in deployment of REMUS vehicles during tests involving REMUS. Operated REMUS topside during REMUS operations involving FMI, CSS and CETUS.

9/2005 Buzzard's Bay, MA Through-Hull Experiments. Organized and performed testing aboard the Enterprise at the Mass Maritime Academy. Transmitted and received signals at various ranges along the length of the ships hull. Performed initial data analysis and prepared data for Milica Stojanovic at MIT.

9/2005 Buzzard's Bay, MA Spatial Modulation. Organized and performed multi-boat operations between the Mytilus and the Tioga in the Buzzard's Bay area. Signals were transmitted from the an acoustic

- array on the Mytilus and received one of two acoustic arrays on the Tioga. Configured and monitored recording system. Provided assistance to Dan Kilfoyle.
- 11/2005 Buzzard's Bay, MA Through-Hull. Organized and performed testing aboard the Enterprise at the Mass Maritime Academy. Transmitted and received signals at various ranges along the length of the ships hull. Performed initial data analysis and prepared data for Milica Stojanovic at MIT.
- 11/2005 Buzzard's Bay, MA Spatial Modulation. Organized and performed multi-boat operations between the Mytilus and the Tioga in the Buzzard's Bay area. Signals were transmitted from the an acoustic array on the Mytilus and received one of two acoustic arrays on the Tioga. Configured and monitored recording system. Provided assistance to Dan Kilfoyle.
- 12/2005 Buzzard's Bay, MA Spatial Modulation. Organized and performed multi-boat operations between the Mytilus and the Tioga in the Buzzard's Bay area. Signals were transmitted from the an acoustic array on the Mytilus and received one of two acoustic arrays on the Tioga. Configured and monitored recording system. Provided assistance to Dan Kilfoyle.
- 06/2006 Buzzard's Bay, MA Spatial Modulation. Organized and performed multi-boat operations between the Mytilus and the Tioga in the Buzzard's Bay area. Signals were transmitted from an acoustic array on the Mytilus and received one of two acoustic arrays on the Tioga. Configured and monitored recording system. Provided assistance to Dan Kilfoyle.
- 08/2006 Monterey Bay, CA PLUSNET. Deployed moored dual band acoustic modem nodes to support multi-platform, multi-boat acoustic network configurations aboard the New Horizon. Configured and monitored recording systems during overnight operations. Over night operations consisted of transmitting acoustic signals from transducers mounted on a V-Fin towfish on the Shana Rae which were then received on an acoustic array deployed from the New Horizon. Provided support for modem systems installed in AUV/UUV.
- 06/2007 Panama City Beach, FL AUVFEST/SIGNALEX. Co-organized and performed multi-boat operations between the Captain Law and the Captain Kelly in the Gulf of Mexico off of Panama City Beach, FL Test were a cooperative effort with SPAWAR and HRS. Test signals were transmitted from an acoustic array deployed from the Captain Kelly and received an acoustic array deployed from the Captain Law. Modem signals were transmitted from deck gear installed on the Captain Kelly and were received via a VSW buoy deployed near the Captain Law as well as on an acoustic array deployed from the Captain Law. Configured the transmission and recording systems. Monitored and operated the recording gear.
- 08/2007 Buzzard's Bay, MA VHF Testing. Organized and performed multi-boat operations between the Mytilus and the Tioga in the Buzzard's Bay area. VHF signals were transmitted from an acoustic array on the Mytilus and received on an acoustic array on the Tioga. Configured, monitored and operated our new PXI DAQ recording system.
- 09/2007 Keport , WA PLUSNET. Prepared hardware for the deployment of moored dual band acoustic modem nodes to support multi-platform, multi-boat acoustic network configurations. Provided support for modem systems installed in various AUV/UUV. Setup and operated the shore side command center for the deployed moorings.
- 02/2008 Buzzard's Bay MA APS VHF Testing. Coordinated and deployed APS designed tripods and VHF LIU systems from the Tioga. Recorded acoustic signals from using our PXI DAQ recording system to verify the APS results.
- 03/2008 Buzzard's Bay MA VHF Testing. Organized and performed multi-boat operations between the Mytilus and the Tioga in the Buzzard's Bay area. VHF signals were transmitted from an acoustic

- array on the Mytilus and received on an acoustic array on the Tioga. Configured, monitored and operated our PXI DAQ recording system.
- 04/2008 Buzzard's Bay MA VHF Testing. Organized and performed multi-boat operations between the Mytilus and the Tioga in the Buzzard's Bay area. VHF signals were transmitted from an acoustic array on the Mytilus and received on an acoustic array on the Tioga. Configured, monitored and operated our PXI DAQ recording system.
- 04/2008 AUTECH, Bahamas PLUS. Deployed moored dual band acoustic modem nodes to support multi-platform, multi-boat acoustic network configurations aboard the R.V. Revel. Configured and monitored recording systems during overnight operations. Overnight operations consisted of transmitting acoustic signals from transducers mounted on a V-Fin towfish deployed from the R.V. Revel which were then received on and moored systems. Alternatively transmissions from the moored systems were received on the V-fin or using an over the side hydrophone array. Provided support for modem systems installed in AUV/UUV.
- 07/2008 La Spezia, Italy GLINT08 Deployed and operated newly developed recorder buoys. Using a wifi link to each of the deployed buoys acoustic signals were recorded from buoy to buoy and ship to buoy transmissions. Developed Matlab scripts to synchronize transmissions and recordings to a predetermined GPS time.
- 04/2009 AUTECH Bahamas PLUS. Configured, Deployed and Monitored multiple VSW drifter buoys to for nighttime acoustic trials. Overnight operations consisted of transmitting acoustic signals from transducers mounted on a V-Fin towfish deployed from the R.V. Endeavor which were then received on the drifter buoys systems.
- 07/2009 Kauai, HI PLUS. Deployed moored dual band acoustic modem nodes to support multi-platform, multi-boat acoustic network configurations. Configured, Deployed and Monitored multiple VSW drifter buoys and recorder buoys for nighttime acoustic trials and for cooperative events with autonomous underwater vehicles. Overnight operations consisted of transmitting acoustic signals from transducer;s mounted on a V-Fin towfish deployed from the R.V. Knorr which were then received on the drifter buoy and recorder buoy systems.
- 02/2010 Monterey, CA for NSF MARS Node installation. Installed MARS Acomms node on wet nose simulator to verify end to end communications of acomms node on MARS cabled observatory. Dry run of deployment via ROV Ventana. ROV malfunctions scrapped actual deployment.
- 02/2010 Monterey, CA for NSF MARS Node installation. Deployment of Acomms node on MARS observatory via ROV Ventana, and ship based deployments of (4) remote acoustic communications nodes. After all gear was deployed system benchmarking of recording sub-system, and acoustic communications links were performed at MBARI.
- 06/2010 MACE 2010 from WHOI aboard Knorr. Configured, deployed, monitored, and recovered VSW recorder buoys for near real-time signal checkout of MACE acoustic signals. 24 hour continuous operation allowed for monitoring of signals to verify transmissions were correct as sub-surface gear could only provide information once fully recovered.
- 08/2010 San Diego, CA for PLUS SCORE range checkout. Configured, deployed, monitored and recovered (2) VSW drifter buoys designed to replicate MK84 pinger functionality on the SCORE range. Goal was to verify tracking capabilities of the range when using Micromodem hardware as the source.
- 09/2010 John Adams Installation from WHOI aboard Mytilus. Installed Freewave and Acoustic Modem Base stations on MVCO ASIT for communications links to remote buoys and sub-surface nodes.

- 10/2010 QinetiQ Hull Inspection Testing at Battleship Cove in Fall River MA. Performed a feasibility experiment using COTS Micromodem hardware as well as lab based data acquisition gear to transmit data from a vehicle attached to the hull of a ship and then receive and decode it on small vessel located several hundred meters from the ship.
- 12/2010 John Adams deployment from WHOI aboard Tioga. Deployed (1) Whale Buoy system and (4) sub-surface comms nodes for initial physical layer and network protocol testing.
- 06/2011 Kauai HI for KAM11 Experiment. Developed real time feedback routine for use with the NSF recorder buoys running a Matlab based real time matched filter detector. Supported (4) doctoral students both on shore and at sea. The goal of the project was to perform real time adaptive modulation experiments between an acoustic source deployed from the research vessel Kilo Moana and received and processed on the moored recorder buoys.
- 06/2011 SAIC Dock Testing. Performed end to end testing of the Waveglider and bottom systems with SAIC.
- 06/2011 DSOP WHOI. Deployed two cRIO recorder moorings to ocean bottom separated by a fixed distance. A third mooring was configured to drop and rise slowly in the water column whilst transmitting acoustic modem signals. The transmitter was deployed at multiple ranges. The recordings produced allowed for analysis of RAP and propagation models for the DSOP program. Three Liquid Robotics Wavegliders outfitted with acoustic modems were deployed to communicate with instruments on the ocean bottom in a joint effort with APS and MIT.
- 09/2011 DSOP HI. Deployed two cRIO recorder moorings to ocean bottom separated by a fixed distance. A third mooring was configured to drop and rise slowly in the water column whilst transmitting acoustic modem signals. The transmitter was deployed at multiple ranges. The recordings produced allowed for analysis of RAP and propagation models for the DSOP program.
- 02/2012 DSOP Okinawa. Deployed two cRIO recorder moorings to ocean bottom separated by a fixed distance. A third mooring was configured to drop and rise slowly in the water column whilst transmitting acoustic modem signals. The transmitter was deployed at multiple ranges. The recordings produced allowed for analysis of RAP and propagation models for the DSOP program. Two bottom landers were deployed to the ocean bottom to provide a long term communication link to a Liquid Robotics Waveglider on the surface.
- 10/2013 DSOP Okinawa. Recovered and deployed Liquid Robotics Wavegliders on the surface fitted with acoustic modem hardware for communications to sensors deployed on the ocean bottom.
- 10/2013 Buzzard's Bay MA. Deployed (2) Recorder Buoy systems in Buzzard's Bay and then towed and acoustic source deployed from the Tioga. Recorded transmitted signal at a range between 500m and 2km.
- 02/2014 Yellowknife Canada. Pre-cruise assembly and testing of MIZ Arctic buoys prior to transfer and deployment out of Sachs Harbour Canada in support of the ONR MIZ program.
- 05/2014 Provincetown, MA. Deployed SV2 and SV3 Wavegliders of the RV Discovery with DMON recorders and GoPro cameras attached to achieve baseline noise measurements of the systems in calm sea state.
- 05/2014 Buzzard's Bay, MA. Deployed SV2 and SV3 Wavegliders of the RV Discovery with DMON recorders and GoPro cameras attached to achieve baseline noise measurements of the systems in calm moderate sea state.

07/2014 Prudhoe Bay, Alaska. Deployed (2) SV3 Wavegliders equipped with 900Hz acoustic modem systems south of the MIZ in the arctic ocean in support of the ONR MIZ program.

09/2014 Martha's Vineyard, MA. Deployed (3) SV2 Wavegliders to support long range RF communication tests in collaboration with ARL-UT.

PAPERS IN REFEREED JOURNALS AND BOOKS:

Bingham, B., N. Kraus, B. Howe, L. Freitag, K. Ball, P. Koski, and E. Gallimore, "Passive and Active Acoustics Using an Autonomous Wave Glider", *Journal of Field Robotics* 29: 911-923, 17 April 2012, doi: 10.1002/rob.21424,

URL: <http://onlinelibrary.wiley.com/doi/10.1002/rob.21424/abstract>

Li, B. Huang, J. Zhou, S. Ball, K.R. Stojanovic, M. Freitag, L. Willett, P., "MIMO-OFDM for High-Rate Underwater Acoustic Communications," *IEEE Journal of Oceanic Engineering*, vol.34, no.4, pp.634-644, Oct. 2009. doi: 10.1109/JOE.2009.2032005.

Baumgartner, M.F., L. Freitag, J. Partan, K. R. Ball, and K. E. Prada, "Tracking Large Marine Predators in Three Dimensions: The Real-Time Acoustic Tracking System," *IEEE Journal of Oceanic Engineering*, Vol.33, No.2, April 2008, pp.146-157. doi: 10.1109/JOE.2007.912496

Ball, K.R., Buck, John R., "A beamforming video recorder for integrated observations of dolphin behavior and vocalizations", *Letters to the Editor, J. Acoust. Soc. Am.*, vol. 117, no. 3, pp. 1005-1008, March 2005.

OTHER PUBLICATIONS:

M. Grund, K. Ball, "A Mobile Communications Gateway for AUV Telemetry," *Proc. IEEE Oceans Conf. 2013*, San Diego, CA, 2013. Submitted and Accepted.

Freitag, L.; Ball, K.; Koski, P.; Singh, S.; Gallimore, E., "Acoustic communications for deep-ocean observatories: Results of initial testing at the MBARI MARS node," *OCEANS 2010 IEEE - Sydney*, vol., no., pp.1,6, 24-27 May 2010
doi: 10.1109/OCEANSSYD.2010.5603958

Singh, S.; Webster, S.E.; Freitag, L.; Whitcomb, L.L.; Ball, K.; Bailey, J.; Taylor, C., "Acoustic communication performance of the WHOI Micro-Modem in sea trials of the Nereus vehicle to 11,000 m depth," *OCEANS 2009, MTS/IEEE Biloxi - Marine Technology for Our Future: Global and Local Challenges*, vol., no., pp.1,6, 26-29 Oct. 2009

Freitag, L., K. Ball, J. Shusta, S. Singh, P. Koski, E. Gallimore "Underwater Acoustic Networking Development and Demonstrations at WHOI," in Proc. Underwater Acoustic Measurements Technologies and Results Conference, Nafplion, Greece, June, 2009.

Mason, S.F.; Berger, C.R.; Shengli Zhou; Ball, K.R.; Freitag, L.; Willett, P., "Receiver comparisons on an OFDM design for Doppler spread channels," *OCEANS 2009 - EUROPE*, vol., no., pp.1,7, 11-14 May 2009
doi: 10.1109/OCEANSE.2009.5278224

Mason, S.; Berger, C.; Shengli Zhou; Ball, K.; Freitag, L.; Willett, P., "An OFDM Design for Underwater Acoustic Channels with Doppler Spread," *Digital Signal Processing Workshop and 5th IEEE Signal Processing Education Workshop, 2009. DSP/SPE 2009. IEEE 13th*, vol., no., pp.138,143, 4-7 Jan. 2009

Zheng Peng, Jun-Hong Cui, Bing Wang, Keenan Ball, and Lee Freitag. 2007. An underwater network testbed: design, implementation and measurement. In *Proceedings of the second workshop on Underwater*

networks (WuWNet '07). International Conference on Mobile Computing and Networking (MOBICOM), Montreal, Quebec, Canada. ACM, New York, NY, USA, pp. 65-72, Sept. 2007.
<http://doi.acm.org/10.1145/1287812.1287826>

Grund, M.; Freitag, L.; Preisig, J.; Ball, K., "The PLUSNet Underwater Communications System: Acoustic Telemetry for Undersea Surveillance," *OCEANS 2006*, vol., no., pp.1,5, 18-21 Sept. 2006
doi: 10.1109/OCEANS.2006.307036

Freitag, L., M. Grund, J. Partan, S. Singh, P. Koski, K. Ball, "The WHOI Micro-Modem: An Acoustic Communications and Navigation system for Multiple Platforms", Proc. Oceans 2005, Washington, D.C. Sept. 2005.

Freitag, L.; Grund, M.; Singh, S.; Partan, J.; Koski, P.; Ball, K., "The WHOI micro-modem: an acoustic communications and navigation system for multiple platforms," *OCEANS, 2005. Proceedings of MTS/IEEE*, vol., no., pp.1086,1092 Vol. 2, 17-23 Sept. 2005
doi: 10.1109/OCEANS.2005.1639901

PAPERS PRESENTED AT MEETINGS (ABSTRACT ONLY) AND SELECTED TALKS:

Acoustic Communications Technology for Undersea Coastal Sensor Networks, L. Freitag, K. Ball, S. Singh, E. Gallimore, J. Shusta, and P. Koski, Coastal Environmental Sensing Networks Conference, UMass Boston, MA, July, 2009.

Very Broadband High Frequency Underwater Acoustic Communications, L. Freitag, S. Singh, and K. Ball, ASA/ECUA, Paris, July 2008, Abstract DOI: [10.1121/1.2935847](https://doi.org/10.1121/1.2935847)

A Beamforming Video Recorder for Integrated Observations of Dolphin Behavior and Vocalizations, Acoustical Society of America, Nashville, TN, May 2003.