Warren J. Baker Endowment
fo Excellence in Project-Based Learning
Robert D. Koob Endowment *for Student Success*

PROPOSAL NARRATIVE

(Max. of 3 pages including figures/tables but excluding budget page, 1" margins, 12-point font. See Sec.XII of RFP for more details.)

Proposals not complying with format guidelines will not be considered.

I. Project Title

Can Dielectric Lenses Lower the Energy Threshold of the ANITA Neutrino Telescope?

II. Abstract

Ultra-wideband antennas are one of the most effective tools used in detecting High Energy (HE) Neutrinos and are used often in radio astrophysics experiments such as the ANtarctic Impulsive Transient Antenna (ANITA) experiment. However, experiments such as ANITA need to lower the energy threshold in order to more effectively detect HE Neutrinos. This calls for a higher signal to noise ratio in the antenna system so as to detect weaker signals from lower energy neutrinos. The ability to detect a wider range of neutrinos comes from increasing the gain of the antenna system, which may be achieved by placing a dielectric lens in front of the gain horn opening [1]. However, by adding a lens to the antenna, you increase the amount of noise in the system, making it harder to detect any incoming signals. With this project, I will be simulating and creating a dielectric lens to be attached to a 4"x4" dual polarized, quad-ridged gain horn in the Microwave Anechoic Chamber Lab. There, I will determine the exact effects the dielectric lens will have on the antenna's noise figure and whether the gained signal outweighs the noise that the added mass will produce.

III. Introduction

Neutrinos are extremely important in astrophysical research due to their ability to travel over long distances unabsorbed and unaffected by interstellar magnetic fields. These chargeless elementary particles are produced through weak interactions such as nuclear fusion and β decay, giving insight into galaxy evolution. Since these neutrinos are difficult to detect, one of the most promising neutrino detection techniques is radio detection, which is used by the ANtarctic Impulsive Transient Antenna (ANITA) experiment. Neutrinos can be detected by taking advantage of the Askaryan emission, where the neutrinos interact with a dense dielectric to produce a secondary shower of charged particles that emit coherent radio waves.

ANITA is a long-duration balloon flying a payload of custom made high-gain antennas over the Antarctic ice, measuring the radio signals given from the neutrino interactions with the ice. The antennas, made by the commercial company Antenna Research Associates, are linearly polarized with two orthogonal feeds and gain from 6 - 10 dBi over a range of 180 MHz - 1 GHz. Each is a squared meter at the opening and has a beam-width of 22.5 degrees Arranging 16 in a ring accounts for full circular coverage of the ice [2].

The goal of developing a dielectric lens is to increase the gain of the antennas so as to better detect the faint, broadband impulses from the ice (dielectric). However, by adding a lens to the antenna, you increase the amount of noise in the system, making it harder to detect the radio waves coming from the neutrinos. By assuming the temperature of the observed is 240K and the noise temperature of the system without the lens is 100K, then the noise power of the system in the Antarctic will be approximately -83.1 dBm. However, adding mass to the antenna system will increase its overall temperature and thus produce more noise. If we assume that including the lens will increase the temperature of the system to 150K, the resulting noise power of the system will be approximately -82.5 dBm, which is a significant difference when detecting neutrinos. By adding a lens to the horn, the estimated increase in signal strength is about 5 dBi [3] .

This project will determine the exact effects the dielectric lens will have on the antenna's noise figure and whether the new noise figure is far outweighed by the gain the dielectric material provides to the signal. The challenge is to create a dielectric lens that is low cost for scalability purposes, light-weight to stay within the 5000 lb balloon payload weight limit, and minimally adds to the noise figure.

IV. Objective(s)

The main objectives that the ANITA Dielectric Lens Project will reach during the allotted timeline are as follows:

1. Preliminary Simulations on HFSS: The radiation pattern and signal return loss of the simplified horn and geometry of the dielectric lens will be simulated using the High Frequency Structure Simulator.
2. Ordering the raw materials: The raw materials will be ordered from Antenna Research Associates Inc., US Plastic Corp., and Pasternack to remain cost and time sensitive.
3. Manufacture o lens following pre-made simplified and scaled design: The dielectric lens will be manufactured following the optimized design calculated using HFSS.
4. Assemble horn model for testing: Once all the necessary parts are machined, the lens will be strategically mounted to the horn and ready for testing.
5. Test in Anechoic Chamber and collect data to compare to simulations: The model will be tested in the Microwave Lab Anechoic Chamber to acquire data, which will be compared to the data from earlier simulations in HFSS.

The overall goal of the development of the dielectric lens for this wideband antenna is to improve the gain as uniformly as possible along the range of 180 MHz to 1GHz while taking into account the increase in mass and noise temperature. Building a physical model of the horn and lens will help determine if the increased power gain outweighs the increased noise figure from the added dielectric material.

V. Methodology

Using simulations in the High Frequency Structure Simulator (HFSS) by Ansoft, the dielectric lens geometry, the expected gain, and the directionality will be simulated before the development of a physical model. Once the simulations have been generated, a scale model of the lens will be machined with assistance from the Materials and Mechanical Engineering Departments. The lens will be attached to the horn directly to reduce the weight of unnecessary mass from mounting materials. Mentorship from Dr. Stephanie Wissel, Dr. Dean Arakaki, and the members of the NuRad Group (Cal Poly student-faculty research group) will

provide guidance with tests run in the Microwave Anechoic Chamber as well as with the theory behind this project.

VI. Timeline

ANITA Dielctric Lens Development Project Milestones

	Spring Quarter 2016										Fall Quarter 2017										
Week :	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**
Simulations of horn and lens in HFSS																					
Developing scaled model in CAD as machining template																					
Ordering raw materials																					
Machining of materials																					
Assembly of horn and lens / callibration																					
Tests in Anechoic Chamber																					
Compilation of data into final report																					
APS Conference																					

VII. Final Products and Dissemination

The completion of the project will result in a quarter scale model of a simplified ANITA horn and a dielectric lens to fit the model. The data acquired from simulations in the High Frequency Structural Simulator (HFSS) and testing this model in the Cal Poly Anechoic Chamber will be presented during an ANITA collaboration teleconference call and at the American Physical Society meeting in the 2016 Far West Section in Davis, CA, October 28-29.

VIII. Budget Justification

By strategically developing a scaled down model to test, the cost of materials that make up the lens and the time it would take to manufacture are significantly lessened. The PTFE is the proposed dielectric material that will be shaped to form the lens at the opening of the gain horn. The cost incurred through manufacturing the lens on the Cal Poly campus is overall much more cost effective than ordering it custom made by a private company. The lens will be attached to the horn opening directly using small nuts and bolts. The effect these additional pieces on the edge of the horn and lens should have minimal effects on the radiation pattern, but will be taken into account during the physical tests. The results acquired from simulations will be compared to data acquired through physical testing and presented in the APS Far West Section in Davis, CA.

IX. References

1. J. P. Thakur, et al. "Large Aperture Low Aberration Aspheric Dielectric Lens Antenna for W-Band Quasi-Optics". *Progress in Electromagnetics Research,* PEIR 103, 57-65, 2010.
2. P. W. Gorham, et al. "The Antarctic Impulsive Transient Antenna ultra-high energ neutrino detector: Design, performance, and sensitivity for the 2006–2007 balloon flight". *Astroparticle Physics*, 32, 10–41, 2009.
3. Piksa, Petr, Stanislav Zvanovec, and Petr Cerny. "Elliptic and hyperbolic dielectric lens antennas in mm-waves." *Radioengineering* 20.1 (2011): 270-275.

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Student Applicant(s): *Alexandra Crawford*	
Faculty Advisor: *Dr. Stephanie Wissel*	
Project Title: *Can Dielectric Lenses Lower the Energy Threshold of the ANITA Neutrino Experiment?*	**Requested Endowment Funding**
Travel *subtotal*	**$ 405**
Travel: In-state	**$ 405**
Travel: Out-of-state	**$**
Travel: International	**$**
Operating Expenses *subtotal*	**$ 1745**
Non-computer Supplies & Materials	**$ 1700**
Computer Supplies & Materials	**$ 20**
Software/Software Licenses	**$**
Printing/Duplication	**$**
Postage/Shipping	**$**
Registration	**$ 25**
Membership Dues & Subscriptions	**$**
Multimedia Services	**$**
Advertising	**$**
Journal Publication Costs	**$**
Contractual Services *subtotal*	**$ 350**
Contracted Services	**$ 350**
Equipment Rental/Lease Agreements	**$**
Service/Maintenance Agreements	**$**
TOTAL	**$ 2500**

PROPOSAL BUDGET

CAL POLY
SAN LUIS OBISPO
Physics Department

Tel 805-756-2448
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January 31, 2016

Michael D. Miller
Baker and Koob Endowments Coordinator, Cal Poly
1 Grand Avenue
San Luis Obispo, CA 93407

To Michael Miller and Members of the Baker / Koob Endowments Committee,

With this letter, I endorse Alex Crawford's proposal to perform a trade study of using dielectic lenses in experiments searching for the highest energy neutrinos by observing the radio frequency radiation they produce. The goal is to increase the antenna gain enough that the costs associated with added weight and the noise temperature of the dielectric lens are minimal.

Alex has been leading this effort since the Fall quarter, largely focusing on simulation development. While the simulations will estimate the increase in gain adequately, comparsions with data are necessary especially for measuring added noise figure. It is quite sensible to use a lower cost scale model, as the full-scale ANITA horns are large (1 m x 1 m) and expensive (>$5k). If Alex finds that the dielectric lenses are worth the upgrade, her design may be put to use in either the next ANITA flight (ANITA-5) or other successors to the experiment.

Alex is an exceptionally hard-worker and enthusiastic about her project. I first mentioned it in passing to her several months ago, and she took it and ran with it, identifying several lens geometries and production techniques within the first week. What drives her is the potential payoff: that hardware that she designs and characterizes could be used on a NASA mission to detect the highest energy neutrinos. Because of that I recommend Alex Crawford's project whole-heartedly.

Sincerely,

Stephanie Wissel
swissel@calpoly.edu