FAU DIVISION OF RESEARCH

Florida Atlantic University

Invention Disclosure Form

A. Instructions

The purpose of disclosing an invention to the Office of Technology Development is to record the description of, and circumstances in which, the invention was created, and to provide a basis for decisions regarding legal protection and commercialization. This form is a legally significant document that should be prepared carefully, and all sections must be completed. **Please sign the last page using ink-on-paper signatures, and e-mail the completed form to techdevelop@fau.edu.**

B. Title of Invention

1. Please provide a brief title for the invention, omitting any confidential information, acronyms, or trademarks.

The Air-Coupled Ultrasonic Transduction Inspection System

C. Description

1. Please provide a detailed description of the invention, including technical descriptions, advantages/ improvements over existing methods/devices/materials, possible modifications, etc. Please provide any related manuscripts, publications, presentations, posters, etc. with your submission.

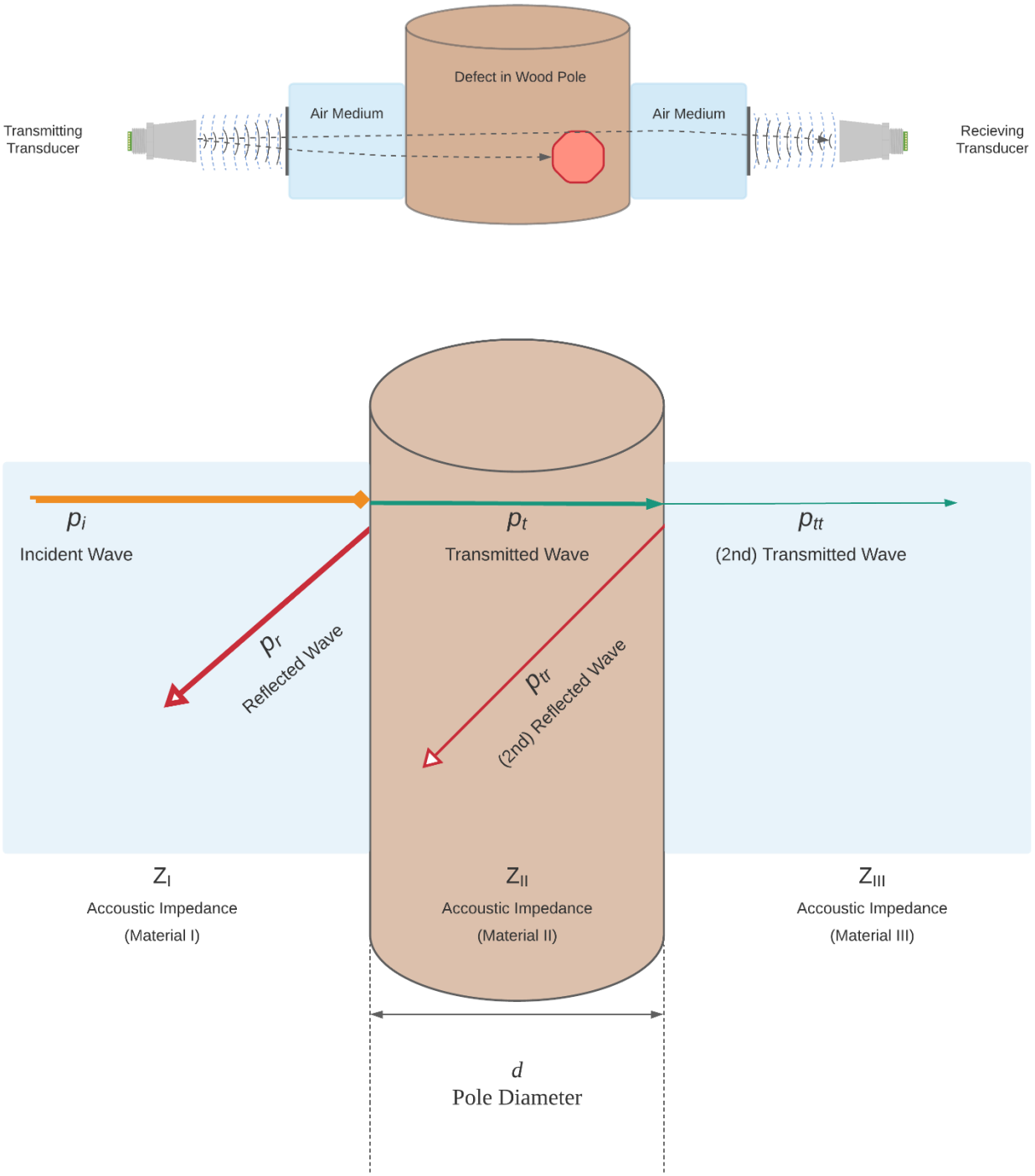
Sub-Section 1: Concept and Methodology

The invention was first conceptualized for a Senior Engineering Design project. The task presented to our group was to evaluate the condition of wooden utility poles, including the interior structure, in a non-invasive and non-destructive manner. Air-coupled ultrasound is a non-destructive, quantitative method that acoustically penetrates wood to detect rot, holes, cracks, and other defects without altering any element of the wood structure. High performance piezocomposite non-contact ultrasonic transducers present a commending argument for this functional requirement. Studies in a laboratory environment

(Vössing, 2018) have been conducted on wooden structures with their thickness measuring approximately 300 mm and densities of up to 500 kg/m3. For Chromated Copper Arsenate (CCA) type "C" (oxide) treated Southern Yellow Pine (wood treatment and species of the utility poles), the average thickness and density across all poles is approximated to be within the range of the two measurements given above. These transducers produce accurate, irrefutable, and cost-effective readings.

A technique and testing method known as through transmission will be used. This method involves two transducers: one transmitting unit and one receiving unit. The transducers will need to be placed at opposite sides of the pole, colinear across the diameter of the pole.

The acoustic impedance of air is approximately 415 Rayleigh, compare that to the large acoustic impedance of most wood structures being around 1.57 *X* 106 Rayleigh (Fleming, 2005). This impedance mismatch results in only a small fraction of energy being transmitted into the propagation medium. In oak wood, 99.94% of the incidence energy is reflected and only 0.06% is transmitted into the wood (David K. Hsu, 2009). There are multiple points of transmission loss that occur as the energy waves propagate from the transmitter to the receiver in through transmission. As the incident wave enters the first material or medium, a small fraction of the wave's energy is transmitted into the material while the rest is reflected. The process continues as the wave crosses the different mediums and finally reaches the receiving transducer. This process is illustrated in the figures below.



As stated above, reflected, and transmitted waves are generated as the result of acoustic waves traveling from one medium to another. The amount of energy transmitted from one medium to another depends on the ratio of their acoustic impedances. Wave velocity measurements in a cross section of red-pine utility poles has

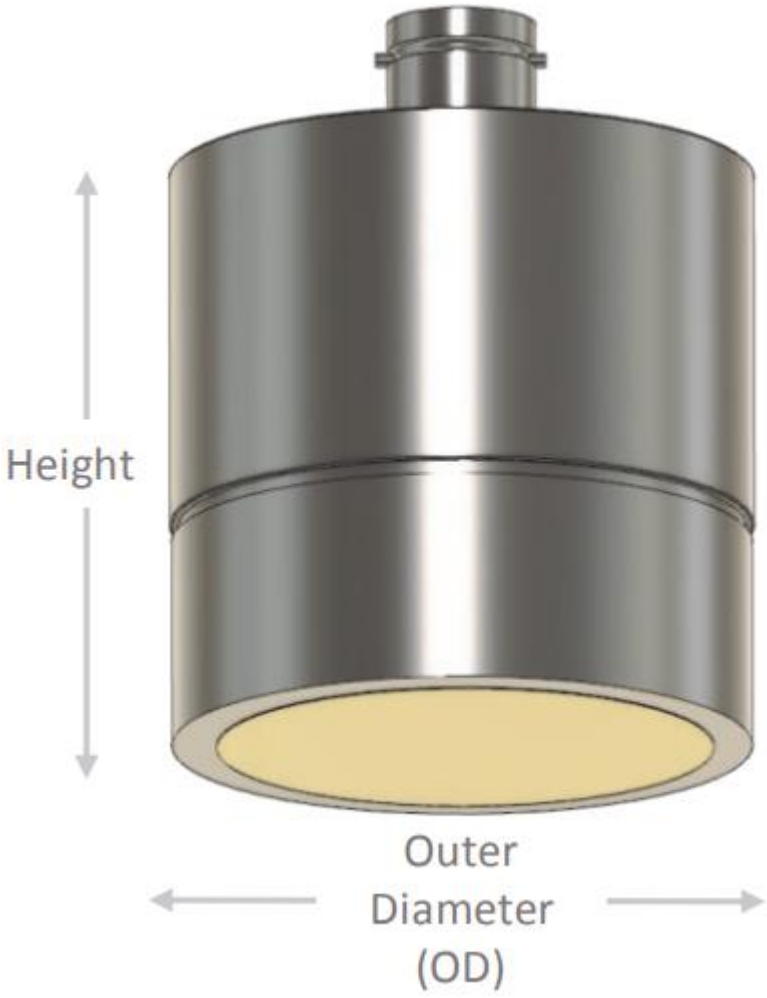
shown to decrease an average of 20% when encountering a hole or void in the radial direction across the pole (Fernando Tallavo, 2013). Furthermore, ultrasonic waves have been proven to detect decay areas as small as 6 cm in diameter (Tallav´o, 2009).

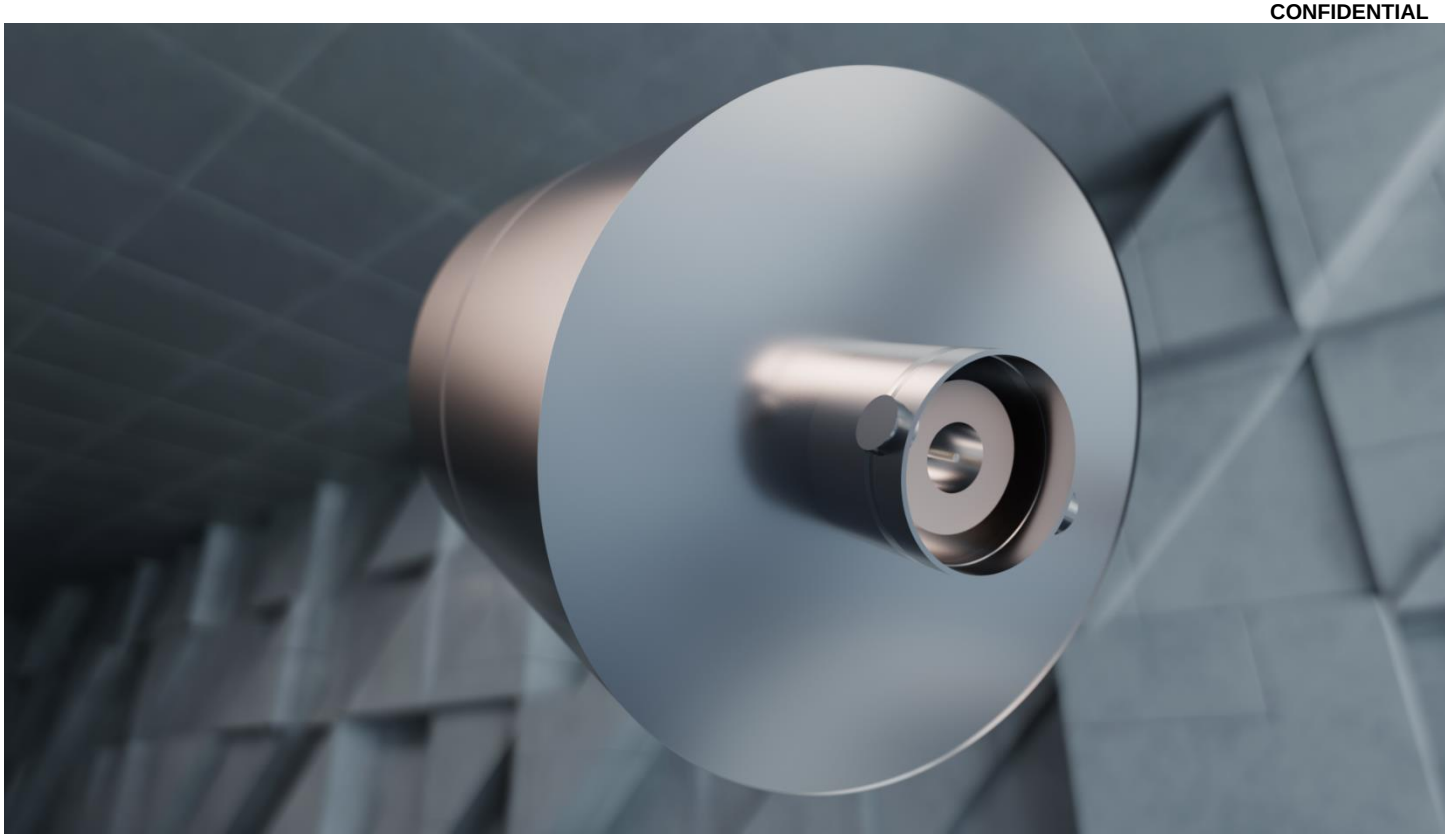
Scans will first be established using a baseline measurement showing no defects or degradation and an expression for the transmission coefficient is derived. The recorded time of flight will be taken continuously as the collar traverses up the pole. Any irregularities from inside the pole will affect the transmission amplitude and be measured and compared to the baseline observations. The sound waves will most likely not provide enough energy to reach the receiving transducer if there are any holes or cracks. A decrease in the amplitude of the transmitted signal, compared to the signal of no defects, indicates a flaw (Kaufmann, 2008).

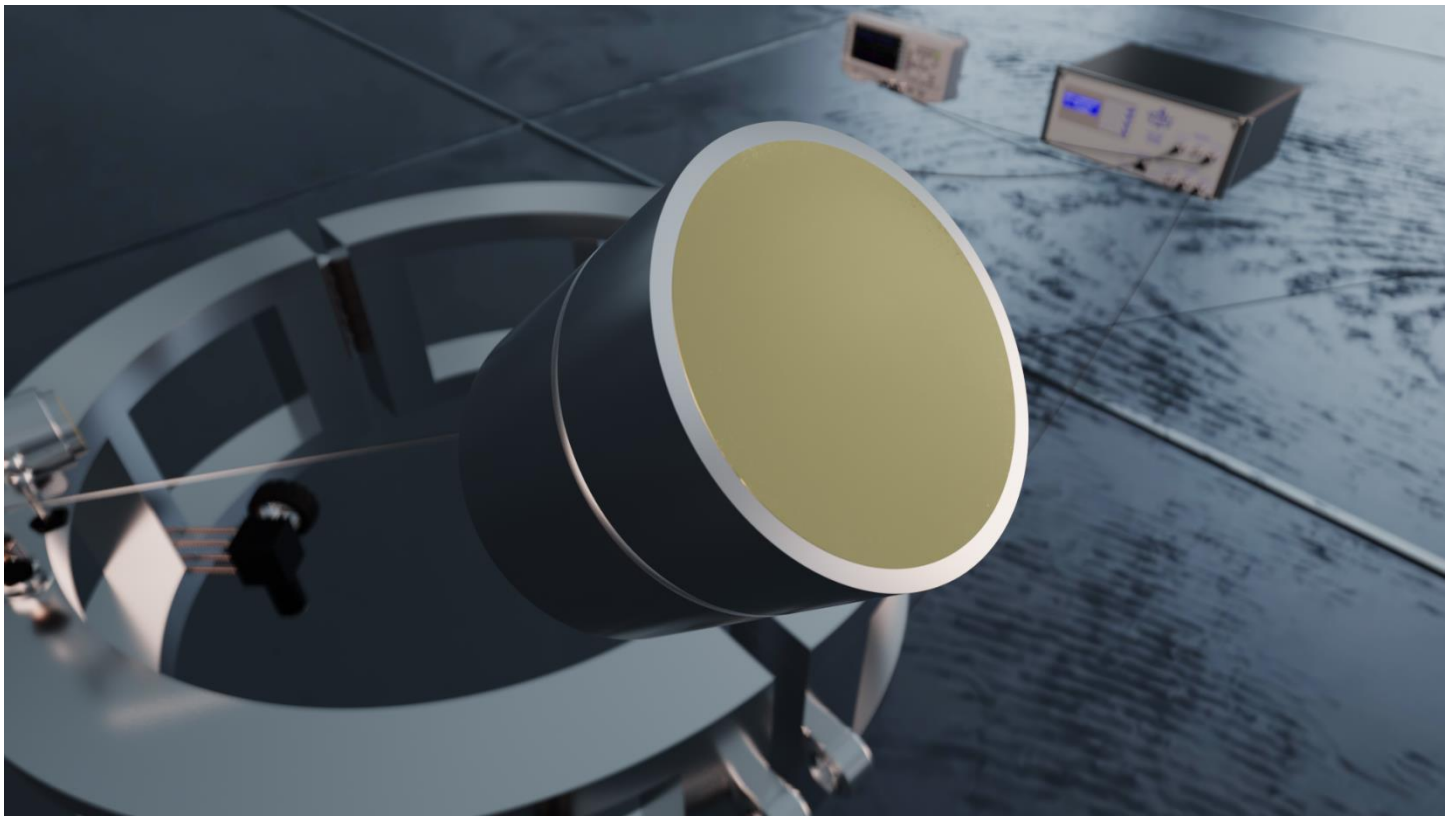
For our application it is appropriate to record and access multiple measurements and parameters. The measurement categories of time and attenuation domain will provide accurate results for identification and defect characterization. Time domain parameters include time-of-flight and velocity measurements for longitudinal waves. Attenuation domain provides data on fluctuations from reflected and transmitted signals (Bhardwai, 2002).

Sub-Section 2: Materials and Design

The NCG50-D63 and NCG50-D50 are high-performance piezocomposite non-contact ultrasonic transducers, with nominal frequencies of 50kHz and 63mm & 50mm face diameters. Since successful yet weakened propagation through the utility pole was achieved by two D50s', to ensure increased sensitivity and stronger signal impression we will use the D63 for the transmitting transducer and the D50 for the receiving transducer. The figure and 3D renders below show the structure of the NCG series transducers.


Height
Outer
Diameter
(OD)

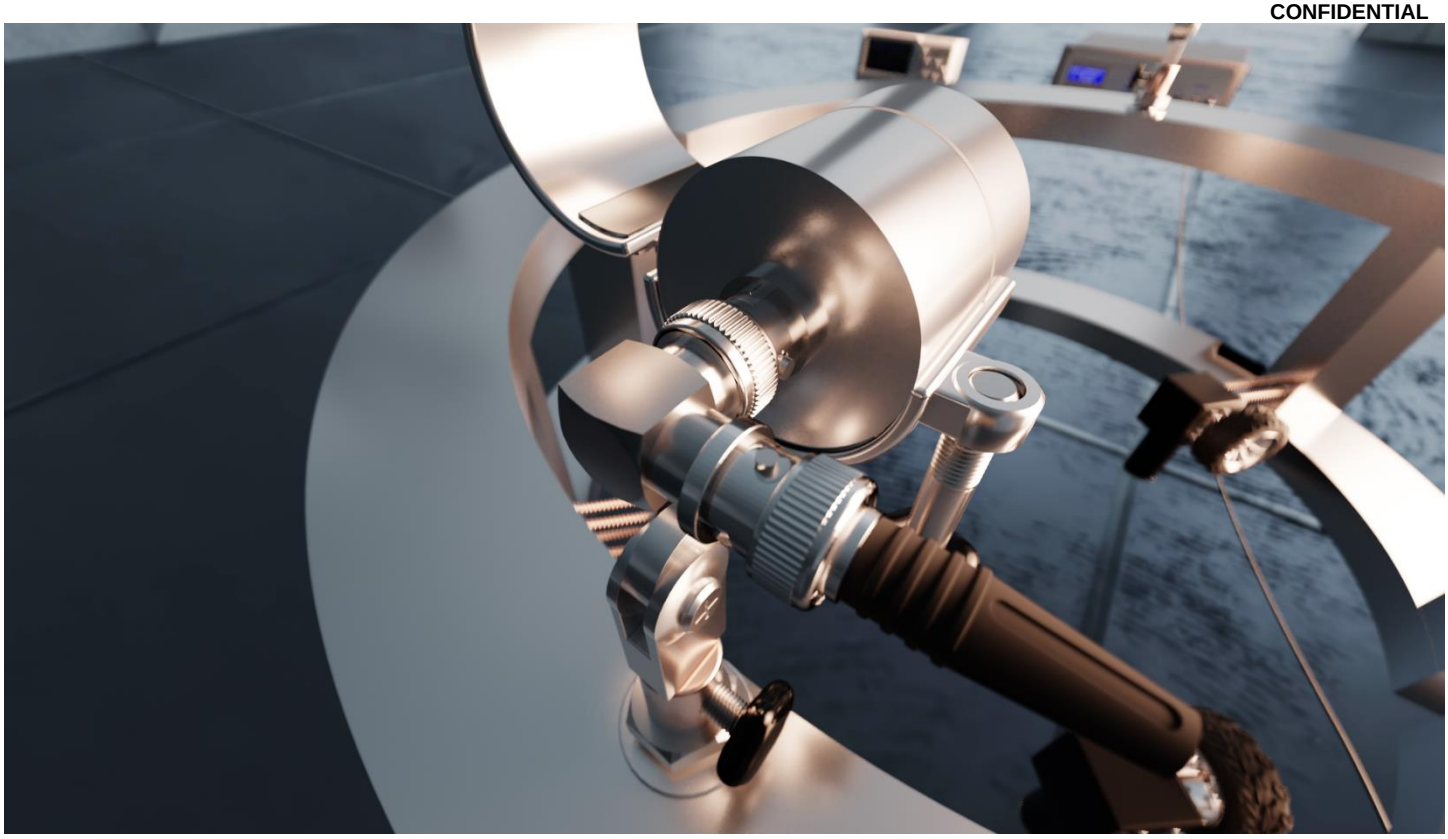




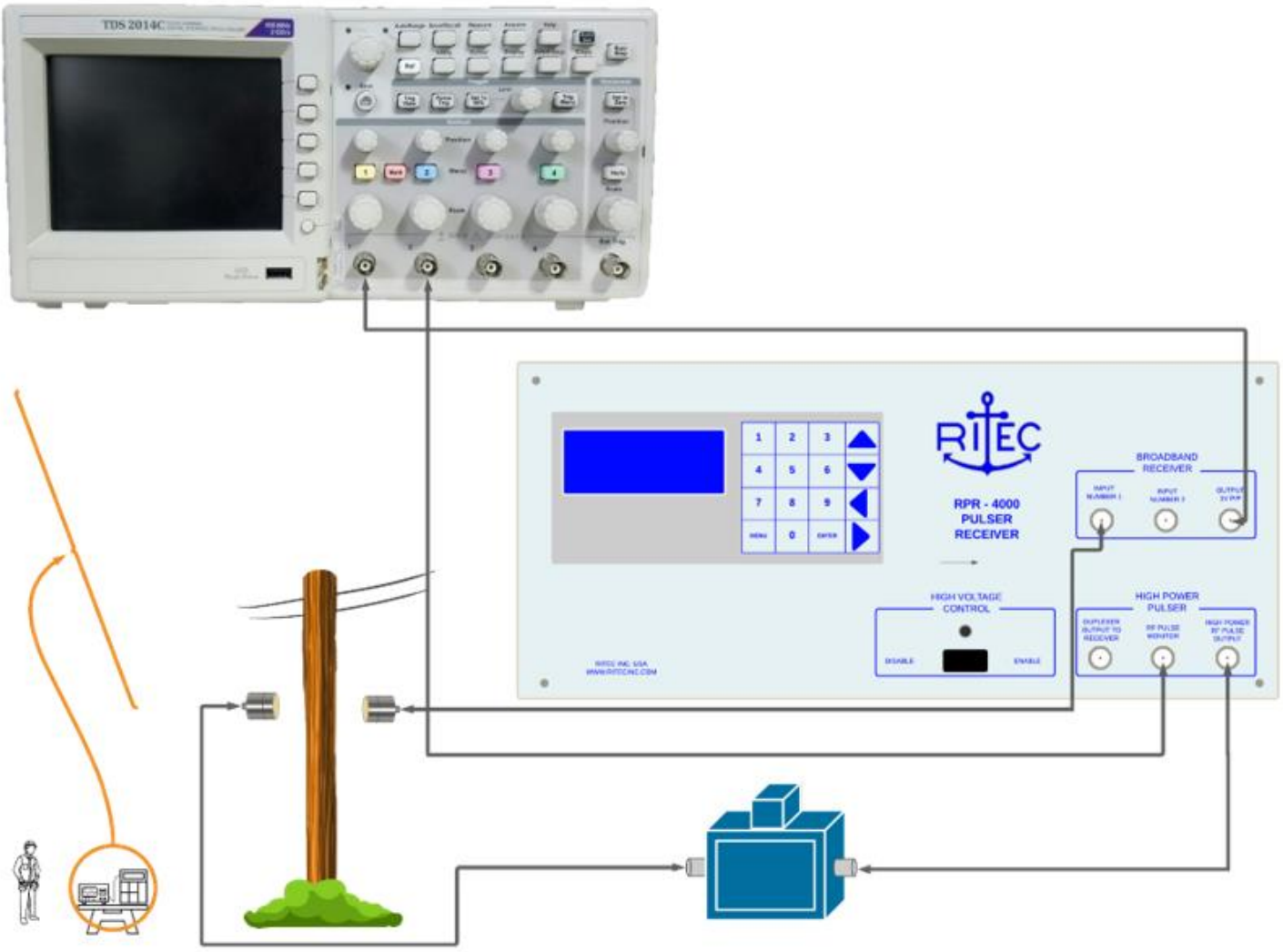
The transducers will be secured to the collar using a holding mechanism that is attached to the collar. The holding mechanism's main securing apparatus are thin, aluminum, and cylindrical plates that wrap around the transducer to hold it in place. Neoprene inserts are located on the inside of the plates to prevent any abrasion between the transducer and plates themselves.

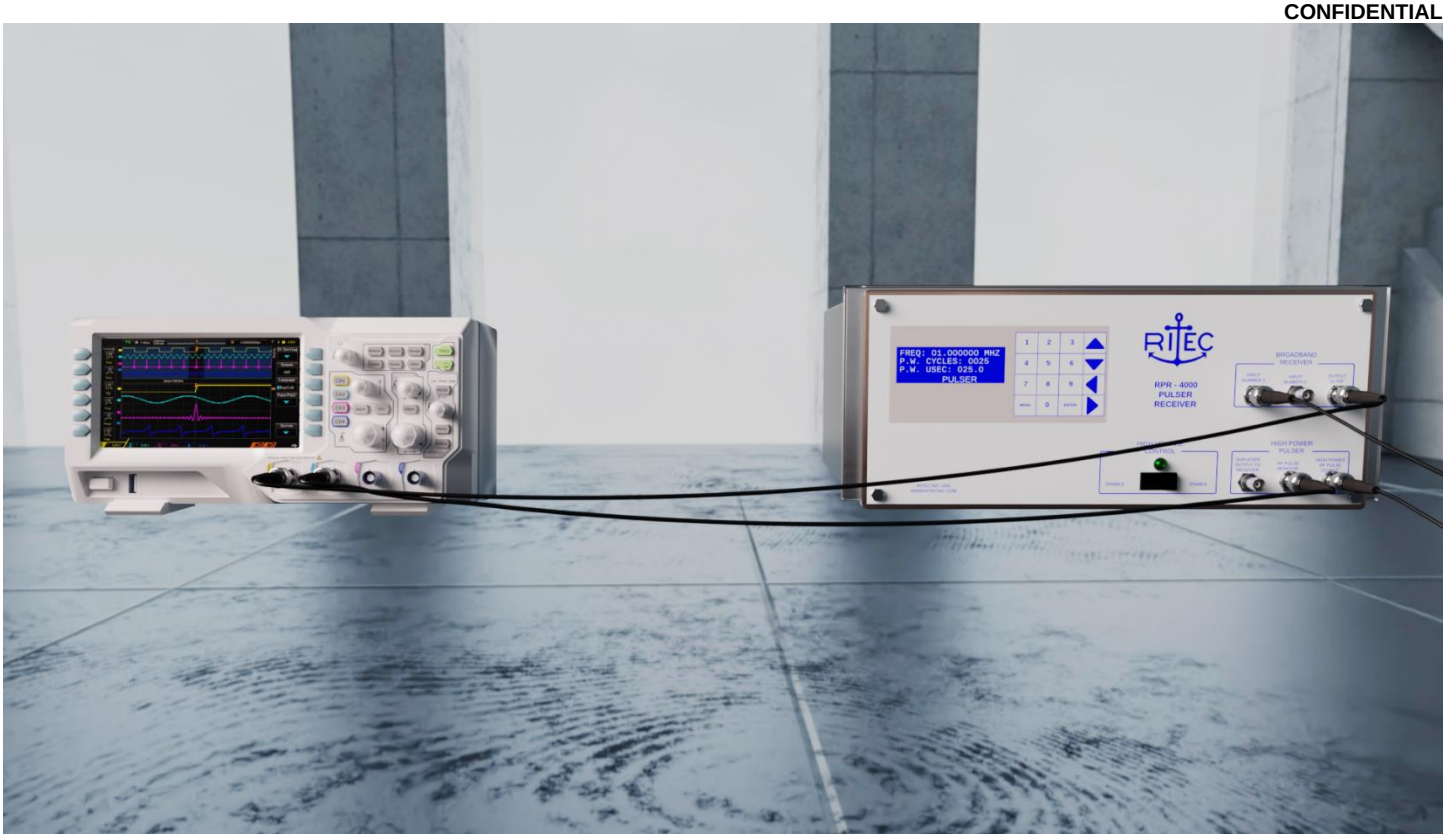
The plates will be able to open using a hinge on one side of the holder to allow for transducer insertion. A handle knob and screw are located on the opposite side of the hinge to secure the transducer in place and prevent any motion that might occur during operation.

The holder also features the ability to swivel in a vertical direction or angle by using a base hinge. This allows the operator to insert the transducer from a 180° angle if necessary. The 3D renders below illustrate the holding mechanism.

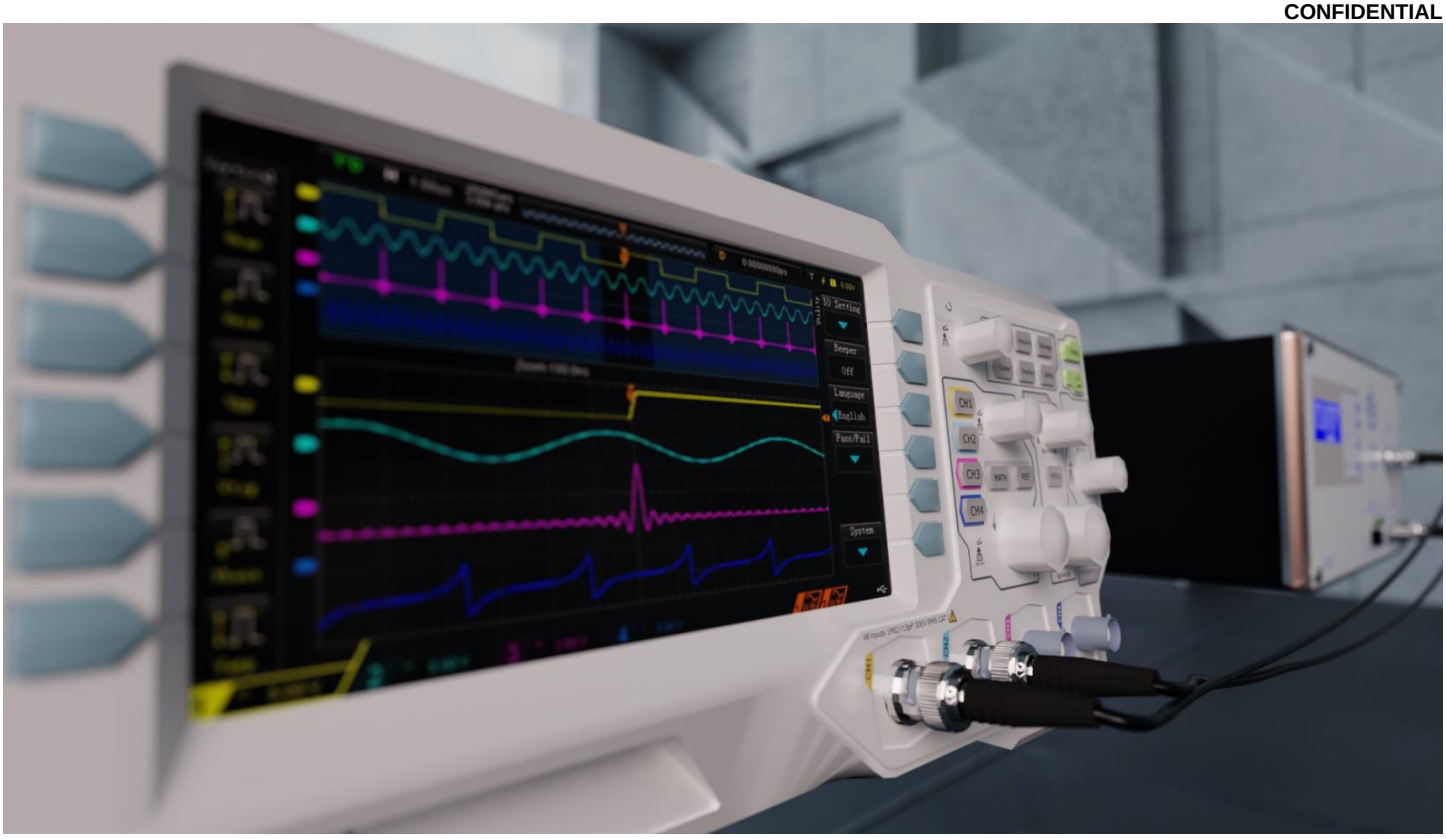


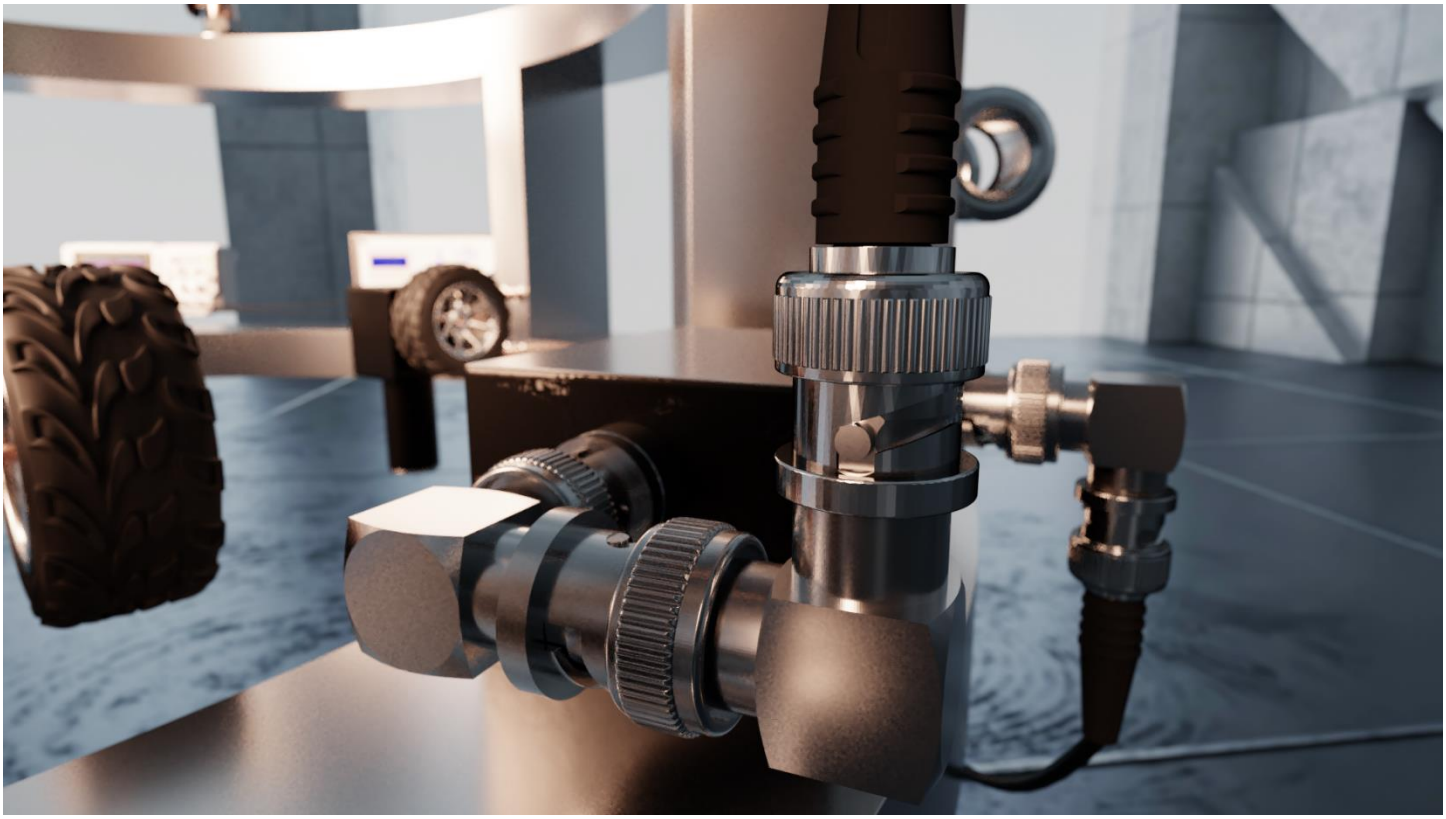
The RPR-4000 High Power Pulser/Receiver from RITEC, Inc. will be used to excite, drive, and receive the signals from the transducers. The transmitting transducer will be connected to the RT-150 Termination via BNC cable before being connected to the high power pulser. The RT-150 reduces reflections that can affect the shape of the toneburst as well as provide more control of the voltage amplitude. The receiving transducer will be connected to the broadband receiver which contains a microprocessor that controls the receiver gain, filter settings, and receiver input. The RPR-4000 has a front panel keypad and menu screens for controlling all the functions of the high-power pulser. The output of the broadband receiver and the RF pulse monitor will be connected to the TDS 2012C Oscilloscope from Tektronix, Inc. Except for the Duplexer (not needed), the following configuration is pictured in the figure and 3D renders below.


TDS 2014C
RITEC
RPR - 4000
PULSER
RECEIVER
BROADBAND
RECEIVER
HIGH VOLTAGE
CONTROL
DISABLE
ENABLE
HIGH POWER
PULSER


FREQ: 01.000000 MHZ
P.W. CYCLES: 0025
P.W. USEC: 025.0
PULSER
RITEC
RPR - 4000
PULSER
RECEIVER
BROADBAND
RECEIVER
HIGH POWER
PULSER


FREQ: 01.000000 MHZ
P.W. CYCLES: 0025
P.W. USEC: 025.0
PULSER
RITEC
RPR - 4000
PULSER
RECEIVER
BROADBAND
RECEIVER
INPUT
NUMBER 1
INPUT
NUMBER 2
OUTPUT
1V P/P
CONTROL
DISABLE
ENABLE
HIGH POWER
PULSER
DUPLEXER
OUTPUT TO
RECEIVER
RF PULSE
MONITOR
HIGH POWER
RF PULSE
OUTPUT


Beeper
Off
Language
English
Pass/Fail
System
CH1
CH2
CH3
CH4



Sub-Section 3: Modifications and Future Development

Prioritization will be given to identification or production of a battery or mobile power source capable of driving and sustaining the ACUTIS. In addition to being able to power the system, it would need to be able to be supported by the strength of the collar so the collar can stay secured to the pole. Another area of enhancement and functionality would be improvements in the data and signal processing. Added features such as being able to transmit the data (signals) wirelessly to a trained operator on the ground. This will provide real-time signal measurement to the operator enabling him to make a judgement on the status of the pole. Still, the technician would need to be trained in the procedures and methods used for operating an oscilloscope in addition to being able to make the correct judgements in identifying defects. A step forward from human judgements, the implementation of an artificial neural network to make statistically accurate decisions on the condition of the pole would greatly improve the functionality of the collar. Not only would it make decisions faster and more accurately than a human, but it would also negate the need for an operator who is trained to read signals and operate an oscilloscope. Although oscilloscope signal readings would suffice for defect detection, the transducers also contain the ability to perform C-Scan imaging. A C-Scan image could provide a more clear and definitive approach towards visually recognizing defects that would otherwise be distorted by signal analysis.

Sub-Section 4: Similar Patents and Designs

Through thorough research, I was unable to find an invention, device, or methodology similar to the proposed invention stated in this document. There has been research done using air-coupled ultrasonic transducers and wood materials, but nothing similar to the specific application and support structure (holder).

Sub-Section 5: References

*All of the above pictured diagrams, 3D renders, and photographs are included in the "ACUTIS System.zip" file. The file also contains additional information about the ACUTIS system including additional pictures, reference documents, video demonstration animations, material quotes, and proposal documents.

Bhardwai, M. C. (2002). High Transduction Piezoelectric Transducers and Introduction of Non-contact Analysis. *High Transduction Piezoelectric Transducers and Introduction of Non-contact Analysis*, 2.

Bhardwaj, M. C. (1987). Ultrasonic NDC - A Historical Perspective and Practical Concepts. *Ultrasonic NDC - A Historical Perspective and Practical Concepts*, 8.

David K. Hsu, D. U. (2009). NDE of lumber and natural fiber based products with air coupled ultrasound. *Iowa State University Center for Nondestructive Evaluation* , 1534.

Fernando Tallavo, M. D. (2013). Experimental and Numerical Methods for Detection of Voids in Wood Poles Using Ultrasonic Testing. *Experimental and Numerical Methods for Detection of Voids in Wood Poles Using Ultrasonic Testing*, 1.

Fleming, M. B. (2005). Noncontact ultrasound detection of exotic insects in wood packing materials. *Forest Prod. J. 55*, 33-37.

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Kommareddy, V. K. (2003). Air-coupled ultrasonic measurements in composites. *Retrospective Theses and Dissertations. 236*, 80.

Kommareddy, V. K. (2003). Air-coupled ultrasonic measurements in composites. *Iowa State University Capstones, Theses and Dissertations*, 7-8.

Labor, U. S. (n.d.). *Methods of Inspecting and Testing Wood Poles*. Retrieved from https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.269AppD

M. Luukkala, P. M. (1973). Metal plate testing using airborne ultrasound. *Ultrasonics*, 218-221.

NDT Resource Center. (n.d.). *Reflection and Transmission Coefficients (Pressure)*. Retrieved from NDT Resource Center: https://www.nde-ed.org/EducationResources/CommunityCollege/Ultrasonics/Physics/reflectiontransmission.htm

NextEra Energy. (n.d.). *FPL inspects one-millionth pole as part of storm and reliability preparations*. Retrieved from NextEra Energy: http://newsroom.nexteraenergy.com/FPL-inspects-one-millionth-pole-as-part-of-storm-and-reliability-preparations

RITEC Inc. (n.d.). RPR-4000 Pulser/Receiver. *RPR-4000 Pulser/Receiver*, 4.

Tallav´o, F. J. (2009). New Methodology for the Assessment of Decayed Utility Wood Poles Using Ultrasonic Testing. *New Methodology for the Assessment of Decayed Utility Wood Poles Using Ultrasonic Testing*, 12.

Vössing, K. G. (2018). Air-coupled ferroelectret ultrasonic transducers for nondestructive testing of wood-based materials. *Wood Science and Technology 52, 1527-1538*.

Whetzel, M. (2021, January 28). State College, PA.

D. Support

Florida Atlantic University is required to report all inventions made with federal funding to the relevant agency, so it is imperative that you provide details on all federally-funded inventions, in particular the agency and the grant number. Please provide all other potentially relevant grants, funds, collaborations, or materials received from third parties so that the university can report them appropriately, and determine if there are any pending license rights to the invention.

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1. Was the invention supported with federal funding?

☐ Yes ☒ No

If yes, please provide the agency name(s), grant number(s), and funding date(s). Please also indicate if the award was a sub-award.

2. Agency Name:

3. Grant Number:

4. Funding Date:

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5. Was the invention supported with state funding?

☐ Yes ☒ No

If yes, please provide the agency name(s), grant number(s), and funding date(s).

6. Agency Name:

7. Grant Number:

8. Funding Date:

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9. Was the invention supported with corporate funding (research agreements, consulting agreements, etc.)?

☐ Yes ☒ No

If yes, please provide the corporate entity name(s), contract number(s) and funding date(s).

10. Entity Name:

11. Contract Number:

12. Funding Date:

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13. Was the invention supported with IUCRC/CAKE funding?

☐ Yes ☒ No

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14. Was the invention supported with materials and/or data from a third party?

☐ Yes ☒ No

If yes, please provide the party name(s) and provided material(s).

15. Party Name:

16. Provided Material:

17. Party Name:

18. Provided Material:

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19. Was the invention supported with any other source of funding?

☐ Yes ☒ No

If yes, please provide the funding source(s).

20. Funding Source:

E. Disclosures

Please list any public disclosures of the invention, including planned future disclosures, and provide any related papers, posters, abstracts, presentations, etc. Public disclosures are those that are made to individuals not affiliated with Florida Atlantic University. Such disclosures may initiate a one year period within which a U.S. patent application must be filed, and may also preclude patent protection outside of the U.S.

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1. Have you publicly disclosed, or intend to publicly disclose, the invention?

☐ Yes ☒ No

If yes, please provide the type of disclosure(s) and date(s) that the disclosure was or will be made.

2. Disclosure:

3. Date:

F. Inventors

Please list all inventors. An inventor is defined as one who makes an intellectual contribution (either independently or jointly) to the conception and/or development of the invention. The first individual listed will be the Office of Technology Development's primary contact, and agrees to act as conduit of information with the other inventors.

Fill in the "Contribution %" to provide your assessment of each individual's contribution to the invention. Net income, if any, will be distributed according to the Florida Atlantic University Intellectual Property Policy.

If an inventor is not affiliated with FAU, please provide the name of that inventor's employer in the Employer/Department field.

If a FAU inventor is affiliated with more than one department, please list the names of each relevant department, and provide a breakdown of the "Contribution %" of that inventor applicable to each department. If this breakdown is not provided, then each department will be weighed equally.

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4. Contribution %:
5. Address:
6. Citizenship:
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8. E-mail:

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5. Address:
6. Citizenship:
7. Phone:
8. E-mail:

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5. Address:
6. Citizenship:
7. Phone:
8. E-mail:

Signatures

I hereby disclose this invention to Florida Atlantic University. I have reviewed and understand the Florida Atlantic University Intellectual Property Policy and confirm that I will abide by the same. I hereby assign and agree to assign my rights in this invention, and all resulting patents, to the Florida Atlantic University Board of Trustees.

Inventor 1 Matthew Maggio	Date 05/04/2021
Inventor 2	Date
Inventor 3	Date
Inventor 4	Date
Inventor 5	Date