Tech Expo, Spring 2026 – Team 43

Radio Frequency Brain Stimulation

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Objective

To design and validate a safe, human-scale RF stimulation system by developing a head phantom, integrating precise temperature sensors, and evaluating antenna configurations capable of delivering proper near field radiation patterns while maintaining tissue temperature increases below 0.5 °C.

Customer Background and Project Requirements

A doctor from IU has developed a technique to stimulate the brain with RF signals with the potential of treating Alzheimer's in humans. Because this method has previously been tested on mice, the likelihood of having positive effects on humans is high. The goal is too lower Aβ proteins and stop disease progression using a safe, noninvasive strategy [1]. Currently, a treatment has not been developed for humans due to the poor penetration depth of EMF devices to the human brain, thus making it essentially ineffective in reaching deep memory areas. The only known side effect is a body temperature rise of 1.3 degrees in test mice [1]. For humans, a temperature rise over 0.5 degrees causes tissue damage to the epidermis.

[1] Perez, Felipe, et al. "*A Novel Design of a Portable Birdcage via Meander Line Antenna (MLA) to Lower Beta Amyloid (Aβ) in Alzheimer's Disease.*" **IEEE Journal of Translational Engineering in Health and Medicine**, 24 Apr. 2025, doi:10.1109/JTEHM.2025.3559693.

Project Requirements:

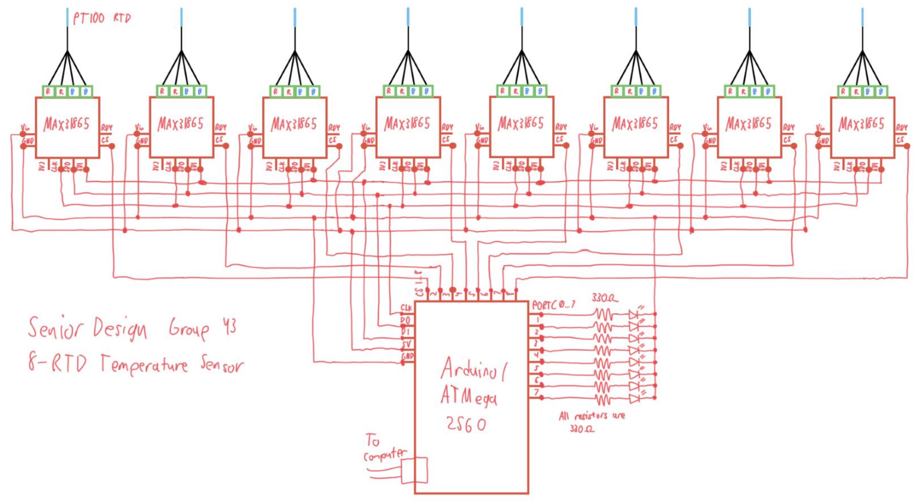
- Create a phantom head for testing
- Develop temperature sensors to read the internal temperature of the phantom head
- Research antennas with an increased efficiency compared to the original birdcage design
- Analyze MRI images for AI models
- Keep the temperature from increasing by 0.5 degrees Celsius to maintain safety standards

Experimentation and Concepts

The antenna setup consists of using a single dipole antenna, a pre-amp, a signal generator, and a spectrum analyzer. The signal generator is turned on and set to output a 64MHz signal at 0dBm to the preamplifier using a BNC-to-BNC cable. This is set accurately by measuring the direct output of the signal generator with the spectrum analyzer. This signal is then sent to the dipole antenna next to the head model.
The signal being sent would affect the ballistics gel which is similar to human tissue, and the temperature change due to the signal would be read with the temperature sensors. The safe limit for brain temperature increase is 0.5°C. The goal for the experiment is to see if the low powered signal has any effect on brain temperature, and if increasing the signal strength would cause damage to the brain matter.
The proposed treatment this experiment is based on calls for a complete birdcage of antennas that surround the brain. The goal of this experiment is to see if a birdcage would be a viable option to give this treatment. Using just one dipole antenna will give an idea on how a full birdcage would affect the brain, both positively and negatively in terms of successful or damaging outcomes.

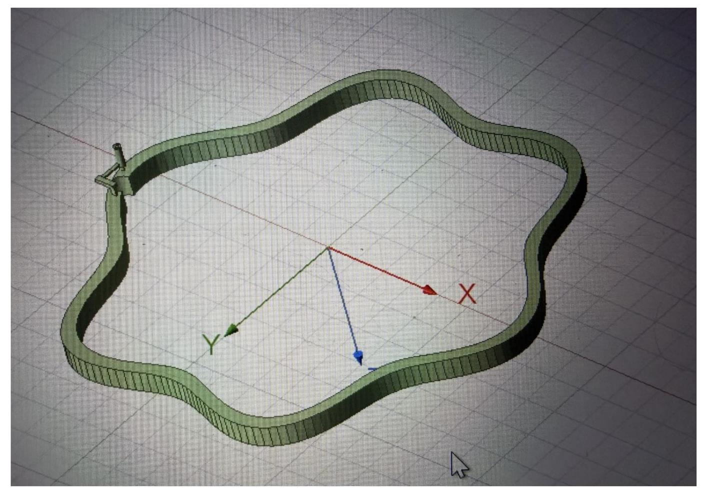
Final Designs

The temperature sensor is made up of 8 resistance temperature detectors (RTD) . Each RTD is connected to a MAX31865 breakout board to read the sensor data. That sensor data is then sent to a microcontroller which can send data to a computer so we can view the temperature. The sensors have Class A accuracy (± 0.15°C), which allows us to easily calibrate the sensors as well as provide clear data for us to read and display.

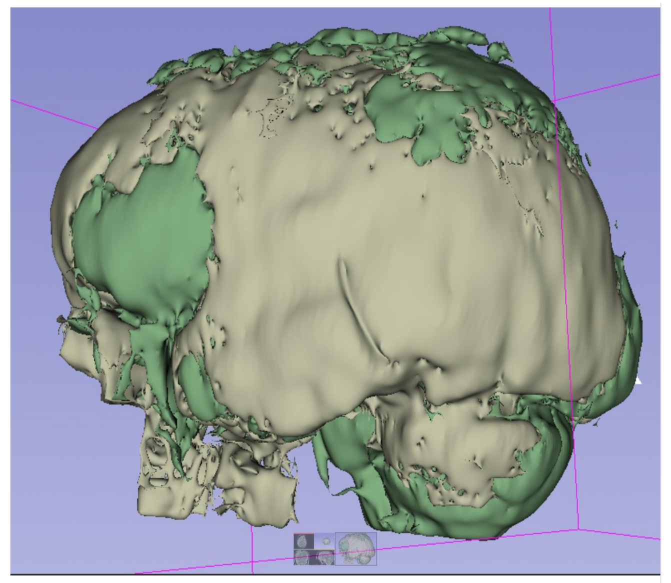


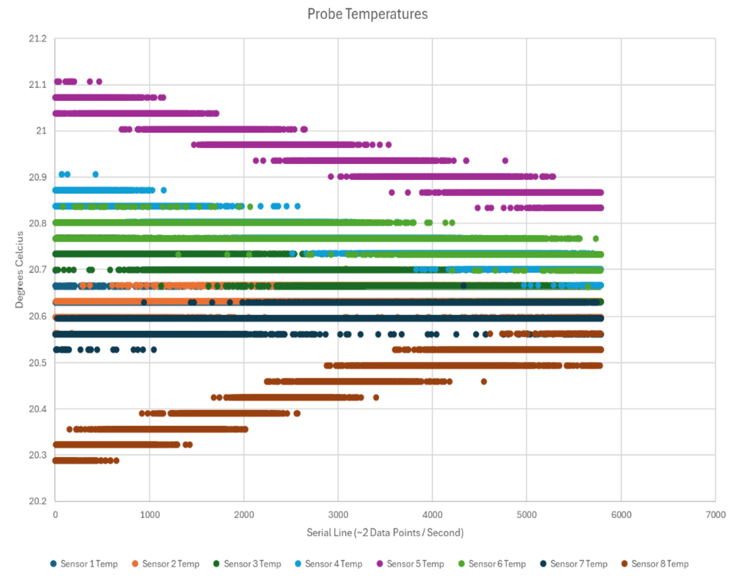
The phantom head was 3-D printed and filled with ballistics gel once completed. The temperature sensors were then placed inside to track the temperature changes through experimentation. This will track the safety of the patient with internal brain temperature and if the signal is truly affecting the brain matter during treatment.

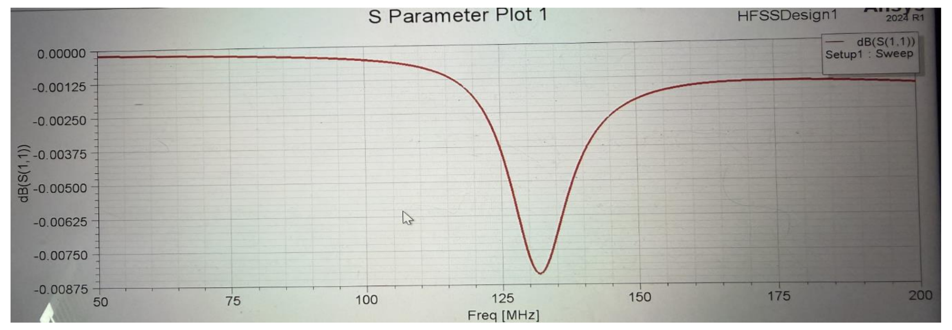
The antenna design is made up of 6 rounded dipoles strung together to form a loop. In the center, the head will be placed to received the most direct radiation as possible. Using dipoles the efficiency increases by 5% while rounding increases this percentage by more. The other side of the antenna is grounded to the outer shielding of the dielectric to diverge excess power. At 125Mhz, this could be replicated at a larger scale to achieve 64MHz since the antenna is, at most, 15cm away from the head.



Testing and Results







The team successfully created a phantom head and placed 8 student-built temperature sensors inside. For the results, the amplifier output measured 23mW for 55 minutes. Here, the temperature changed on average 0.034052 degrees in a controlled environment.

10 segmentations of the brain were developed and used to start building the AI portion of this project through a team of graduate students.

Finally, the antenna design achieved a resonant frequency around 130MHz. Though this is not 64MHz, using capacitors to load the antenna can cause that frequency to move down closer towards 64MHz. The port is 51.03 Ohms which is very close to the desired 50 Ohms for port matching.

Conclusion and Recommendations

Phantom Head: In the future, a phantom head with permittivity ratings matching those of grey matter, white matter, skull and brain material will be needed to collect better results. This can cause the temperature change to increase or decrease depending on how the material reacts.
Temperature Sensors: For quicker temperature data to be measured inside the phantom head, thermocouples would be a better option. Given our budget and time constraints, we instead went with RTDs for temperature measurement.
Antenna Design: Time constraints have caused the physical implementation of the antenna to be delayed. Since the antenna is so complex, the idea would need to be shipped off site to develop a professional grade antennas.
Brain Segmentation: There were a lot of issues with the density and connectivity of the .stl files produced from the segmentations. A lot of work was put into solving this issues and streamlining the segmentation process and creating clear and comprehensive documentation is absolutely necessary in the future of the segmentation process.