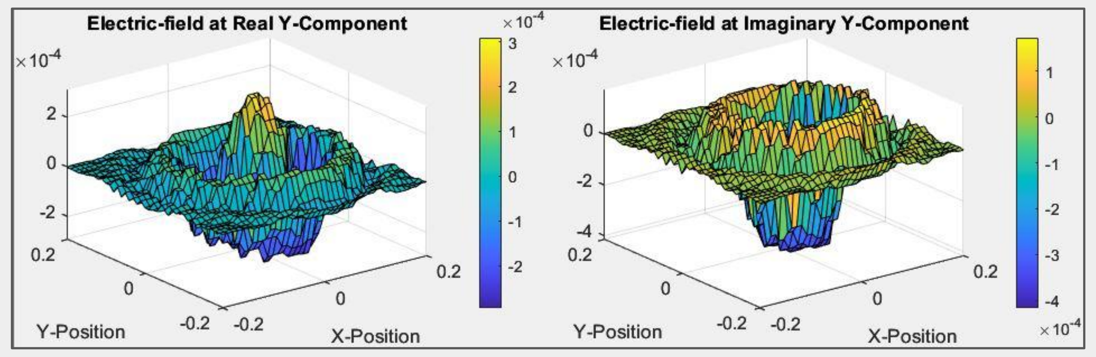
Colorado State University Antenna Test Range

What is the ATR

An ATR consists of a room with metal sheeting to operate as a faraday cage with electromagnetic absorbent foam spikes to absorb any internal reflection.



During this semester, significant changes made to the ATR include:

- Anechoic chamber
  - New antenna mount
  - Creation of phased array antenna
- PNA/Motor controller
  - Relay installation and motor controller replacement
- Software
  - Near-to-far field transform

Technologies used:

- C#/C++
- MATLAB
- WIPL-D
- SQL
- PowerShell
- ANSYS Workbench
- Raspberry Pi
- Arduino Uno
- PNA
- Motors/Controllers

Functional Evaluation

Objective:

- Improve documentation of ATR
- Understand the mechanical function of ATR
- Identify possible errors and inaccuracies

Scanning Evaluation:

- Improve reliability of mechanical systems and increase accuracy of elevation, azimuth, vertical, and polarization scans

Mechanical Evaluation:

- Support structures:
  - Conduct static and dynamic tests on the structural components and motor system for accuracy and quality of life purposes
- Traversal system for antennas:
  - Determine range of motion and degree of freedom of ATR

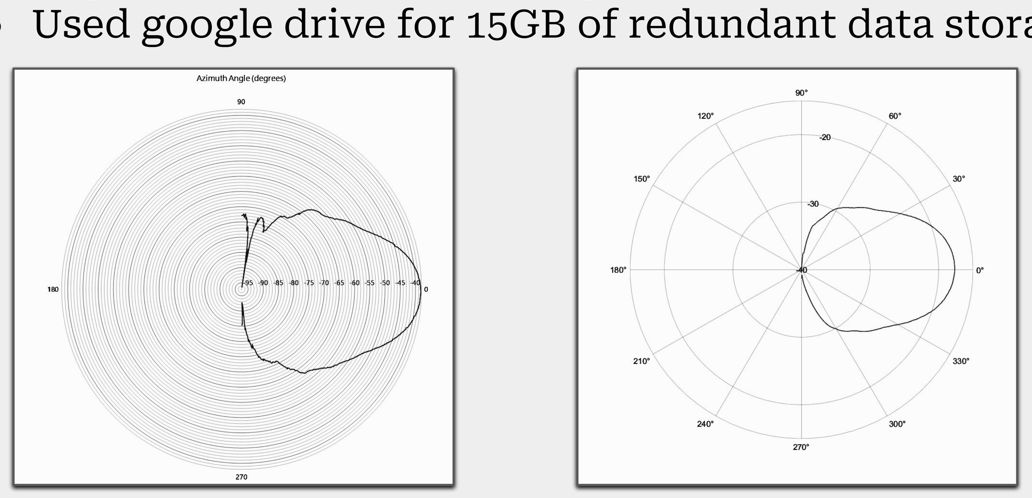
Storage/Equipment Protection Evaluation:

- Protection from static shock and power surges
- No redundant data storage
- No ability for remote scanning

Results:

Conducting a functional analysis allowed the ATR team to achieve the stated objective and develop documentation of the ATR for future teams. Additionally, the team identified areas of concern and addressed the areas including:

- Redesign antenna mounting system
- Replaced motor controllers
- Implemented SQL server express for data searching
- Used google drive for 15GB of redundant data storage



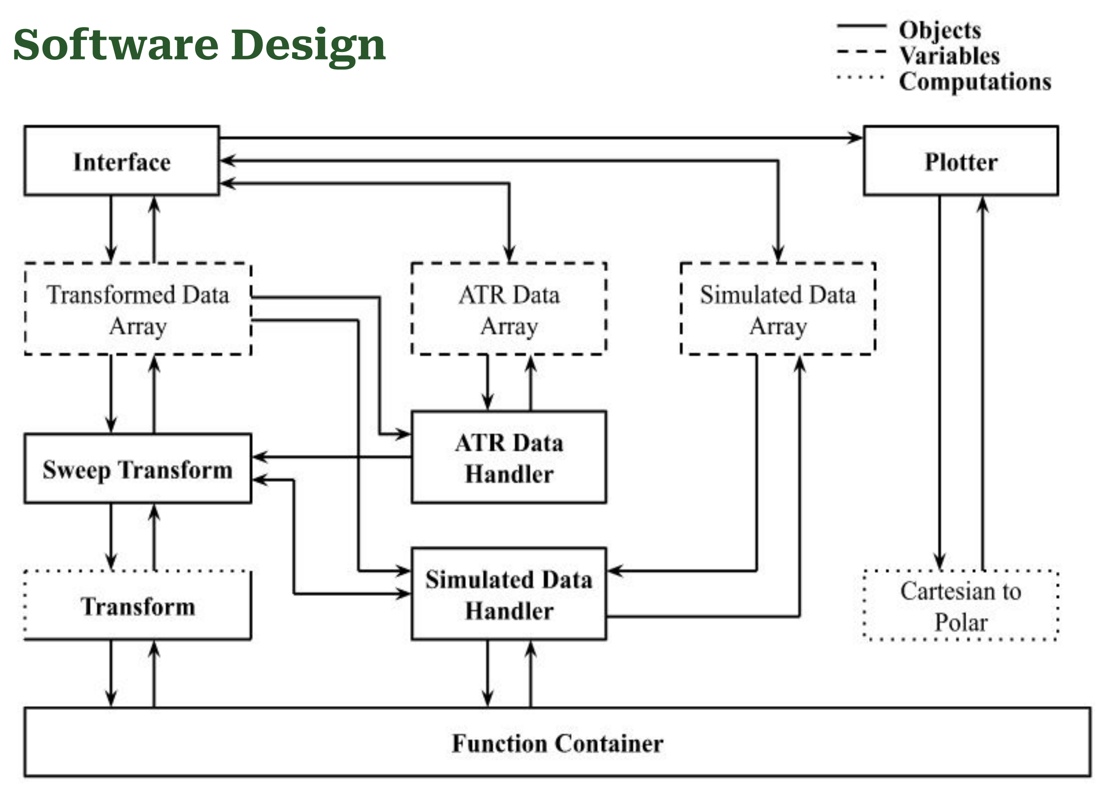
Azimuth scan of horn antenna (Left: before modifications of ATR; Right: after modifications of ATR)

Near-field to Far-field Transformation

Objectives

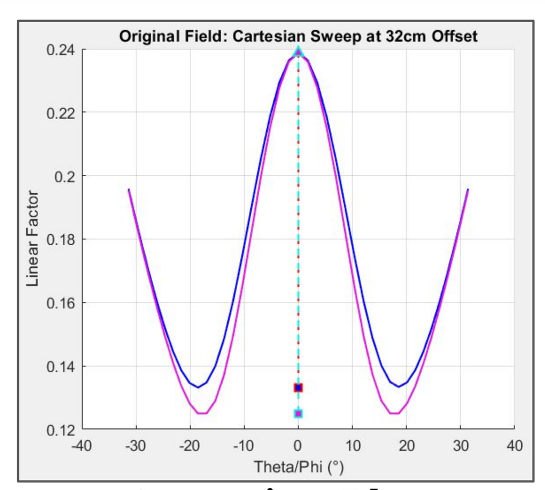
- Convert a near-field radiation pattern into a far-field radiation pattern using a discrete computational algorithm
- Provide an easy-to-use software for future CSU ATR teams to transform, measure, and plot various simulated and measured electromagnetic fields

Software Design



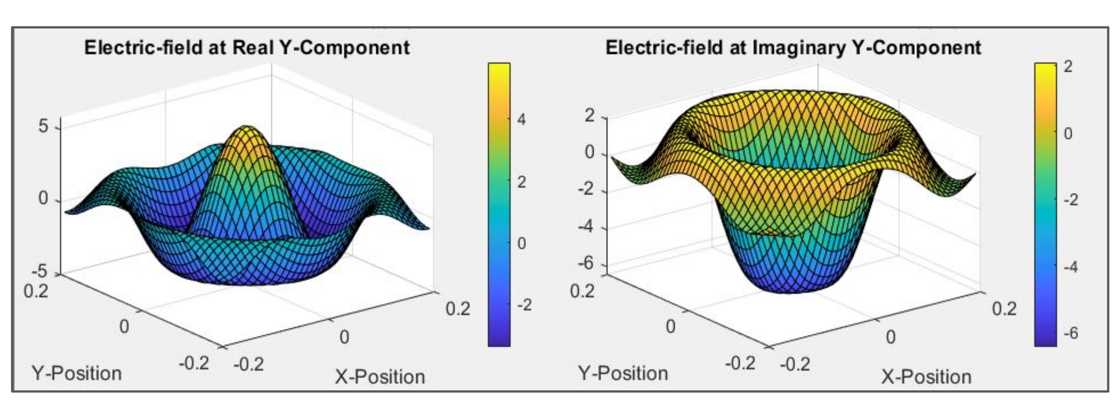
Software Capabilities

- The Software was designed to provide an easy-to-use multi-tool for ATR data interpretation and manipulation

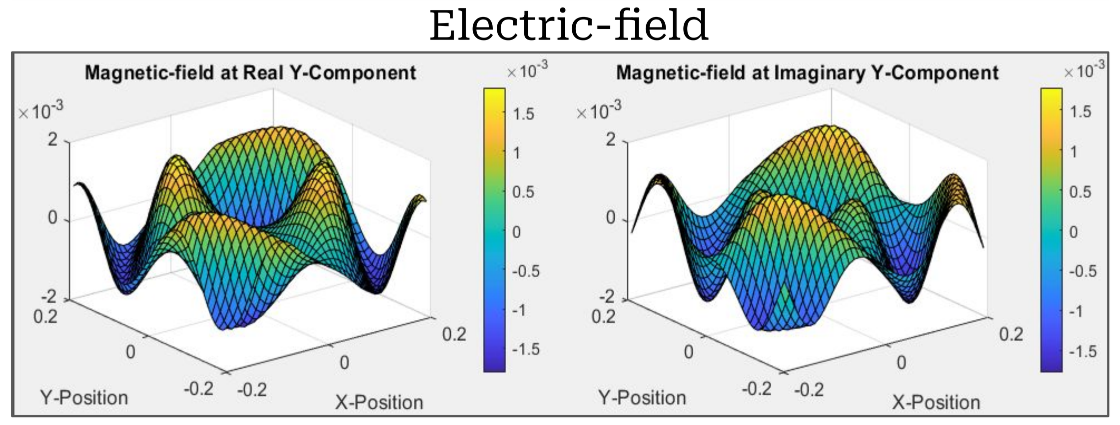


Cartesian Plot

- *Visual*
  - 2D & 3D Heatmaps
  - Polar Radiation Pattern Plots
  - Cartesian Radiation Pattern Plots
- *Computational*
  - Theta and & Phi Axis Transformations
  - Polynomial Regression Line Fitting
  - Simulated and Measured Data Interpretation



Electric-field



Magnetic-field

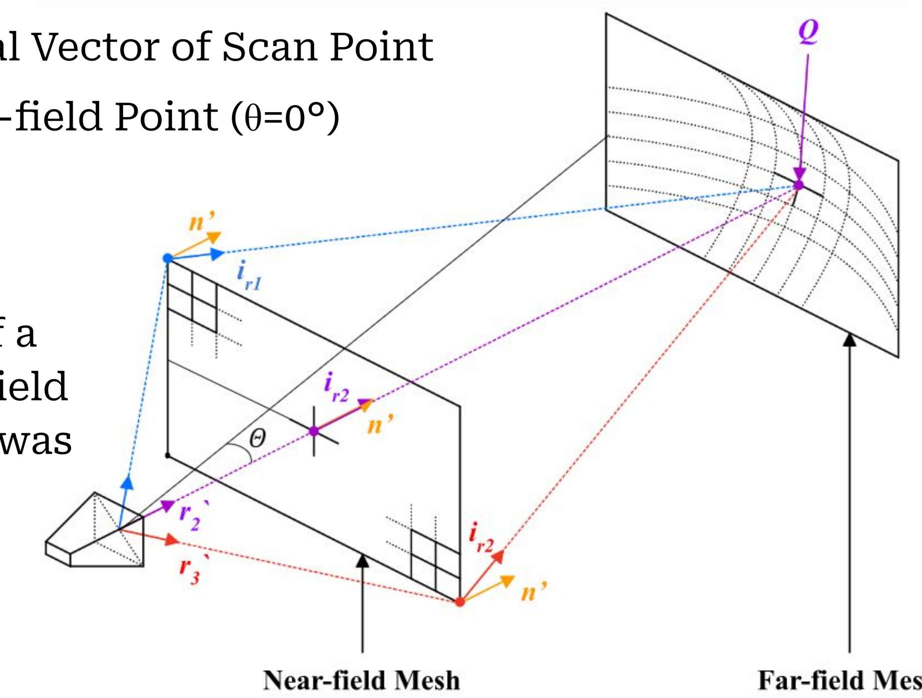
Transform

$$E^{sc}(r) = \frac{e^{-jk_0 r}}{4\pi r} \oint_{S_1} \{n' \times [\nabla' \times E(r')] + jk_0 [n' \times E(r')] \times i_r\} e^{jk_0 i_r \cdot r'} dS'$$

- Important Visual Components
  - r' ≡ Unit Direction Vector to Near-field from Antenna
  - i_r ≡ Unit Direction Vector to Far-field from Scan Point
  - θ ≡ Angle Between Normal Vector and Far-field Point
  - n' ≡ Unit Normal Vector of Scan Point
  - Q ≡ Central Far-field Point (θ=0°)

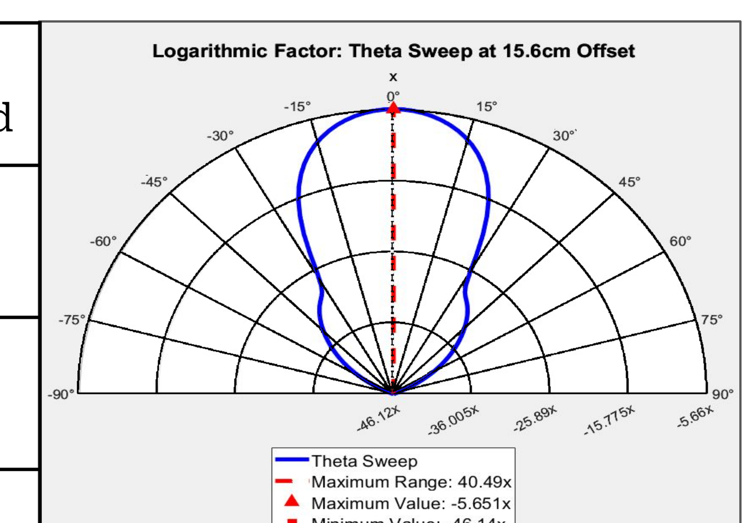
Results

- The conversion of a near-field to far-field radiation pattern was successful with a relatively small margin of error

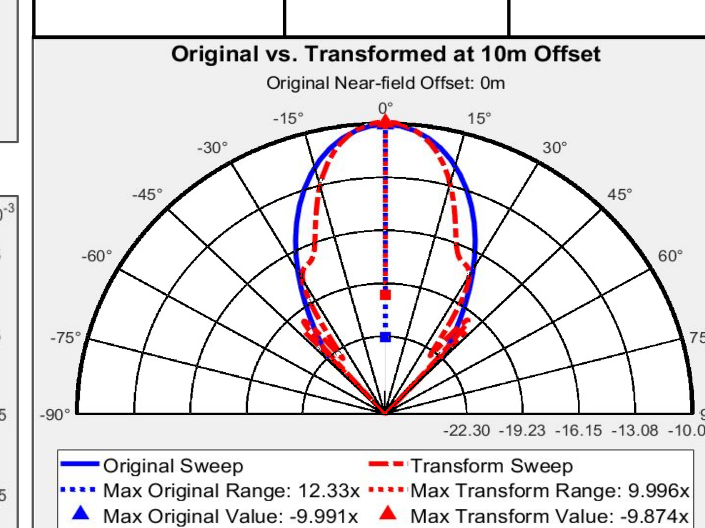


- *Observations*
  - Each transformed point needs to be multiplied by 5 because the rectangular mesh occupies only ⅕ of the total surface
  - The field curl can be approximated, but the transform becomes less accurate the closer the far-field point gets
- *Future Work*
  - The transform can be implemented with spherical and cylindrical scans, not just cartesian
  - More scans from the ATR can be transformed, including not just the Y-component, but the X and Z components

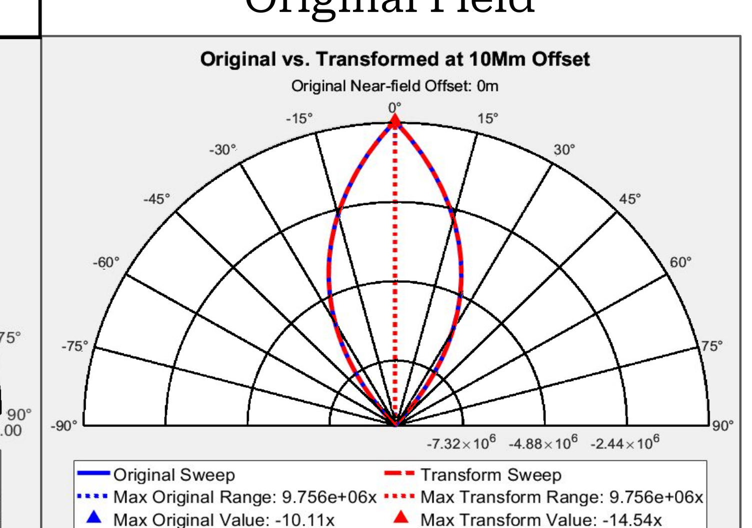
Error	10m Far-field	10Mm Far-field
Range Error	18.9%	~0%
Max Error	1.17%	43.8%
Min Error	11.0%	~0%



Original Field



10m Transform



10Mm Transform

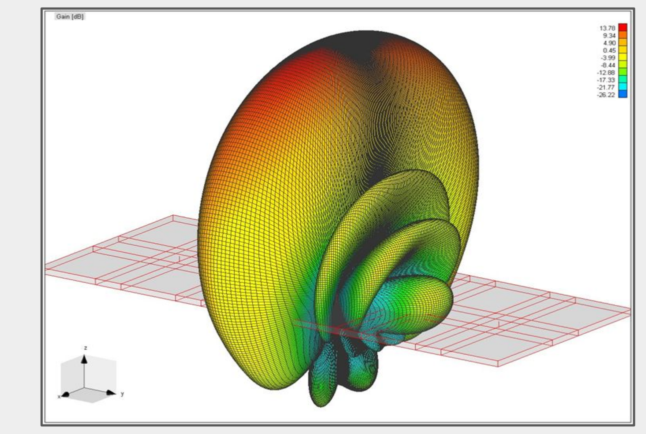
5-Element Patch Antenna Array

Background

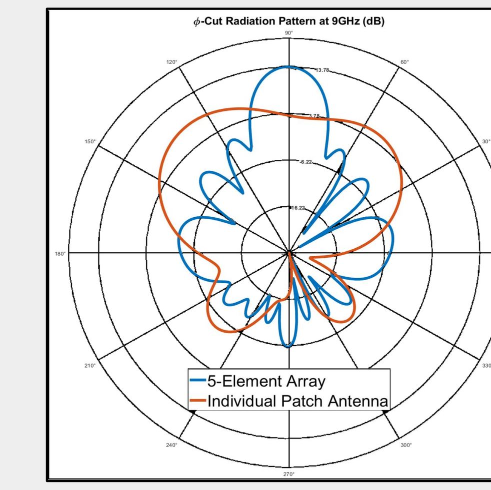
- Radiation pattern is a key characteristic of an antenna
  - Can be altered by power or phase fed to antenna
- Arraying antennas will create a more directed main beam
- Found in satellite communications, wireless networks, and radar systems

Objective

- Design antenna array consisting of 5 patch antennas
- Operate in phase within the X-band (8 GHz - 12 GHz)
- Manufacture broadside array and test using the CSU ATR



WIPL-D Simulated Radiation Pattern at 9 GHz



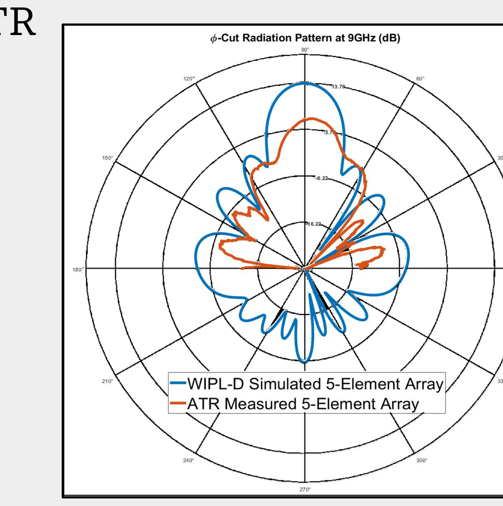
WIPL-D Simulated Radiation Pattern at 9 GHz

Procedure

- Design an individual patch to operate in X-Band
  - Simulate in WIPL-D to visualize radiation pattern
- Add the individual patch into a 5-element array setup
- Manufacture PCB with Advanced Circuits
- Measure antenna array in ATR

Results

Objective was met as the two plots appear very similar, indicating that the measured radiation pattern matches the theoretical radiation pattern at a frequency of 9 GHz which is the X-band.



CSU ATR Measured Radiation Pattern at 9 GHz

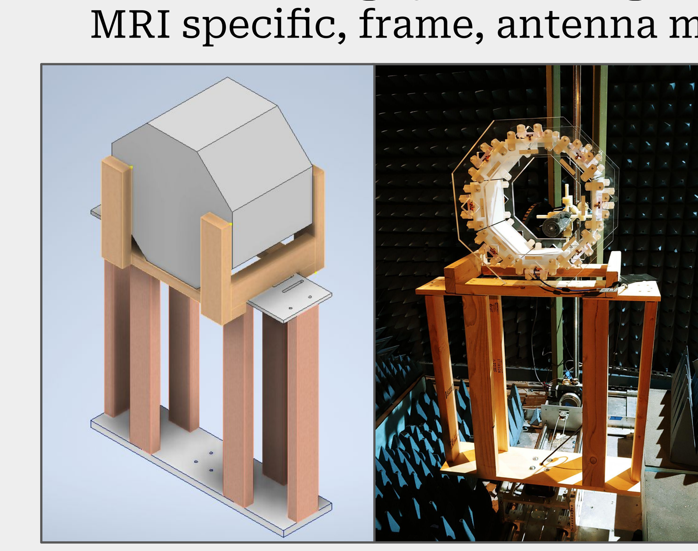
Antenna Mount

Objectives

- Antenna aperture wasn't at center of rotation, affected scan quality
- Integrate MRI coil mounting system for MRI team

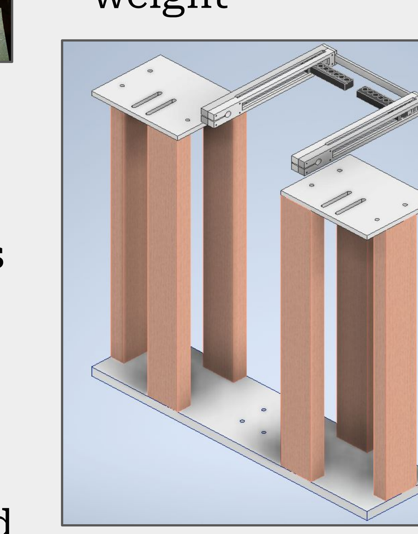
Designing the New Mount

- Reduced costs by reusing parts (motor, bearings, hardware)
- New mounting system designed in three components, MRI specific, frame, antenna mount



MRI Mount on Frame

- MRI specific mount and frame were made of wood
- Stress analysis performed, frame can hold significant weight
- Antenna mount designed to be used with several antenna types and sizes
- Mount 3d printed, weight was optimized



Antenna Mount CAD Model

Result

- Verified scan accuracy improved
- Data obtained for MRI team and patch array
- Mount too heavy for motor config., weaker than motor rating

Quality of life

- Raspberry Pi for remote viewing
- Added a relay to the motor controller
- Installed an SQL server instance
- Created a redundant storage system
- Designed new motor controller case

Future

- Outreach and education
- Increased stability of the vertical wall motor
- Increase the number of redundancy systems for the measured antenna and motor system
- Increase the quality and power output of current motor controller boards

Contributors

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