EE/CprE/SE/CYBE 491 WEEKLY REPORT 05

2/28/2022 - 3/6/2022
Group: 07
Project: Wireless Energy Harvesting
Client: Dr. Jiming Song
Team: Benjamin Brown, Christopher Marting, Greg Schmitt, Jacob Walczak, Sam Runkel, Tanner Garity

Weekly Summary: During this week we had a meeting with our advisor, Dr. Song. We discussed the board we will be using to initially test out our project. We went ahead and ordered the *RFD102A-TB*
https://www.rfdiagnostics.com/store/rfd102a-tb-60hz6ghz-energy-harvesting-test-board
Additionally, during our meeting with Dr. song, he showed us a yagi uda array and briefly went over how it works and talked about some of the specifications. During our weekly team meeting, we did some research on yagi udas and specifically researched the implementation of a dual band yagi uda. We also discussed several testing procedures to see if we are getting an output from the testing board. For example we could use a voltmeter to see if we are getting an output. Then we could use LEDs to visualize our output current and voltage. We also discussed testing the distances between the transmitting signal and our receiving antenna. Jacob and Chris figured out the length of components for a 6 inch yagi uda antenna at 2.4 GHz and simulated the antenna is CST studio to get a rough estimate on how it would work.

Weekly Accomplishments:
Benjamin Brown - According to the datasheet for our testing board,
https://static1.squarespace.com/static/5ced8508bd23380001a232de/t/5dc983aea4e3ae3943e0563f/1573487536809/RFD102A_latest.pdf
a recommended load on the DC output is 1-10kOhms for maximally efficient power transfer. The module is capable of producing a maximum of 18mA DC current into a 50-Ohm load however this is under a stressed condition. A better design target is between 1mA - 10mA.
We want to find a load that we can visually see being affected by the 18mA. We could possibly use a LED sense they need 20mA for FULL BRIGHTNESS. The maximum current for the standard 5mm diameter LEDs is typically 20mA. Therefore, 15mA and 10mA are ideal values for most circuits. LED lights require a certain voltage, such as 24 or 12V. Additionally, we can always set up the output of the testing board to a voltmeter and test the output voltages and currents to see what kind of output we are getting.

Christopher Marting - I researched how to design and the materials that would be used/needed to create our own yagi uda antenna, along with how to design and simulate a yagi uda antenna in CST studio to get an idea on how well a 6 inch long yagi uda antenna will work.

Sam Runkel - I researched different antenna simulation software that we could use for designing and testing our antenna. The most useful one I found was actually an online calculator that allows us to put in some basic information like the frequency, length and number of elements and then outputs the spacing of elements and the estimated gain. Here is a link to the calculator: https://www.changpuak.ch/electronics/yagi_uda_antenna_DL6WU.php. It was a good starting point for designing our own antenna. I also researched the best testing methods to use on our board. We will need to initially get just our open circuit voltage as a baseline then after that I have a few different ideas such as one or multiple LEDs in series, or simply just a resistor which will allow us to measure the voltage across and then calculate the total power output.

Jacob Walczak - I personally researched the possibility of a dual-band yagi uda antenna and found a paper with some explanation. Before designing this antenna, I plan on discussing if it is worth it with Dr. Song. I also assisted Chris in designing and simulating the yagi uda antenna that we plan on using for our project later down the line in CST studio.
The paper I found: https://ieeexplore.ieee.org/document/5696456

Tanner Garity- Researched RF-DC rectifier circuits further for max power efficiency. I also researched diodes for bais matching for our circuit in order to reduce power consumption. Additionally, I also added to the discussion on purchasing the project circuit board.

Greg Schmitt - I set out to research how we could make RF to DC power converter circuits if the need arose to create custom, impedance-matched circuits. Some promising solutions include the use of simple diode bridge rectifiers, MOSFET bridge rectifiers, Gate Cross-Coupled Rectifiers (GCCR) and Negative Voltage Converters (NVC). The pros and cons of each individual solution mostly consist of power harvesting efficiency and its associated circuit complexity, respectively. The article in which this data was collected also provided preliminary efficiency test results of each circuit, and the data points to NVCs and GCCRs to perform the best of all solutions so far (~90-99% delivery efficiency in the case of the NCV).
Rectifier article: Comparison of passive rectifier circuits for energy harvesting applications | Semantic Scholar

<u>Yagi-uda Simulation data:</u>
This section provides all the data we figured out and found using the CST studio simulation software. This is all just rough testing to see if we could get the software to work appropriately but we found actual values that we plan on using for the creation of our own yagi uda antenna later on. The material we are debating on using is copper (annealed), so that is the material we specified in our simulation. All the rest of the data is below.

Yagi frequency: 2.4 GHz
Diameter for all components: 0.1 cm
Total Yagi length: 5.937 inches
Reflector length: 13.125 cm
Dipole length: 12.5 cm
Director 1 length: 11.875 cm
Director 2 length: 11.25 cm
Director 3 length: 10.625 cm
Director 4 length: 10 cm
Accuracy used in simulation: -50 dB

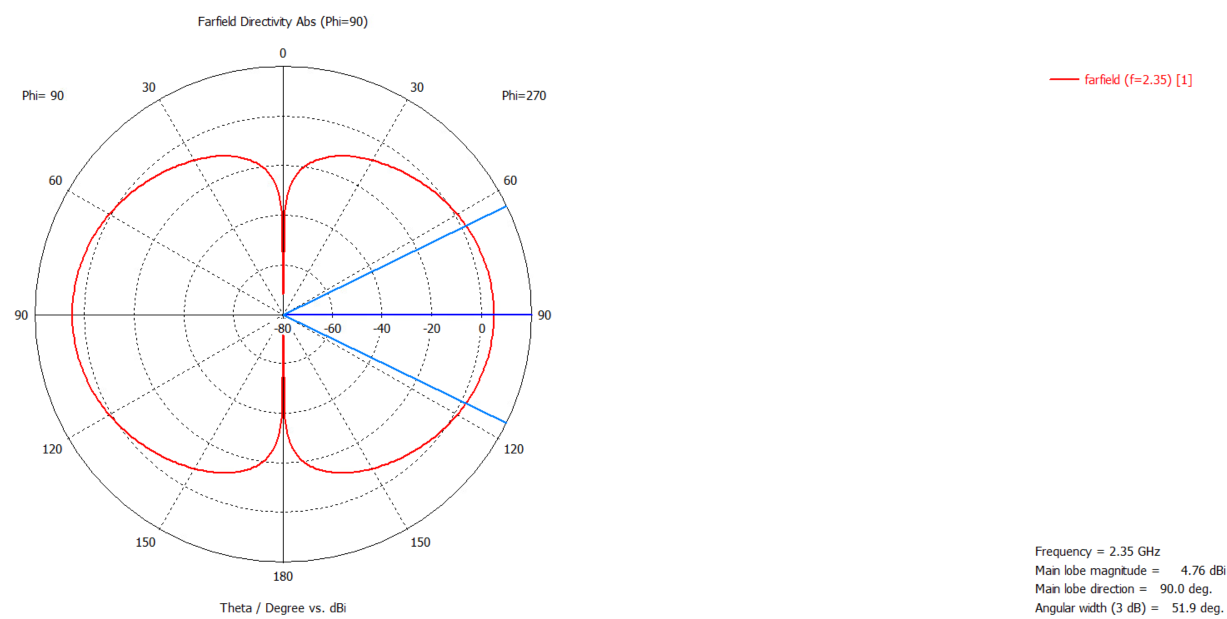

Figure 1. Farfield Phi 1D

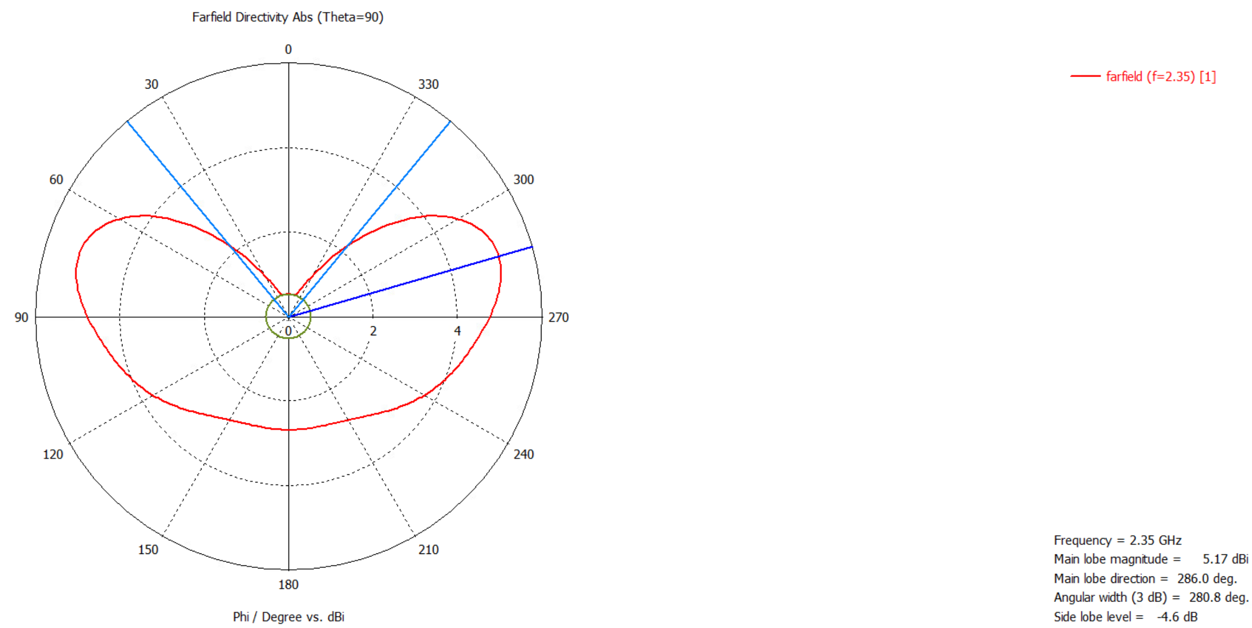

Figure 2. Farfield Theta 1D

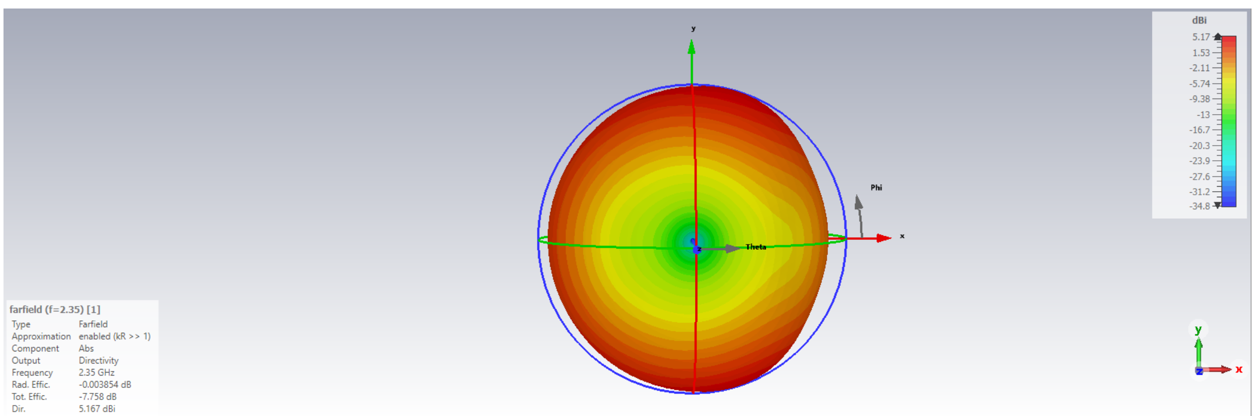

Figure 3. Farfield 3D

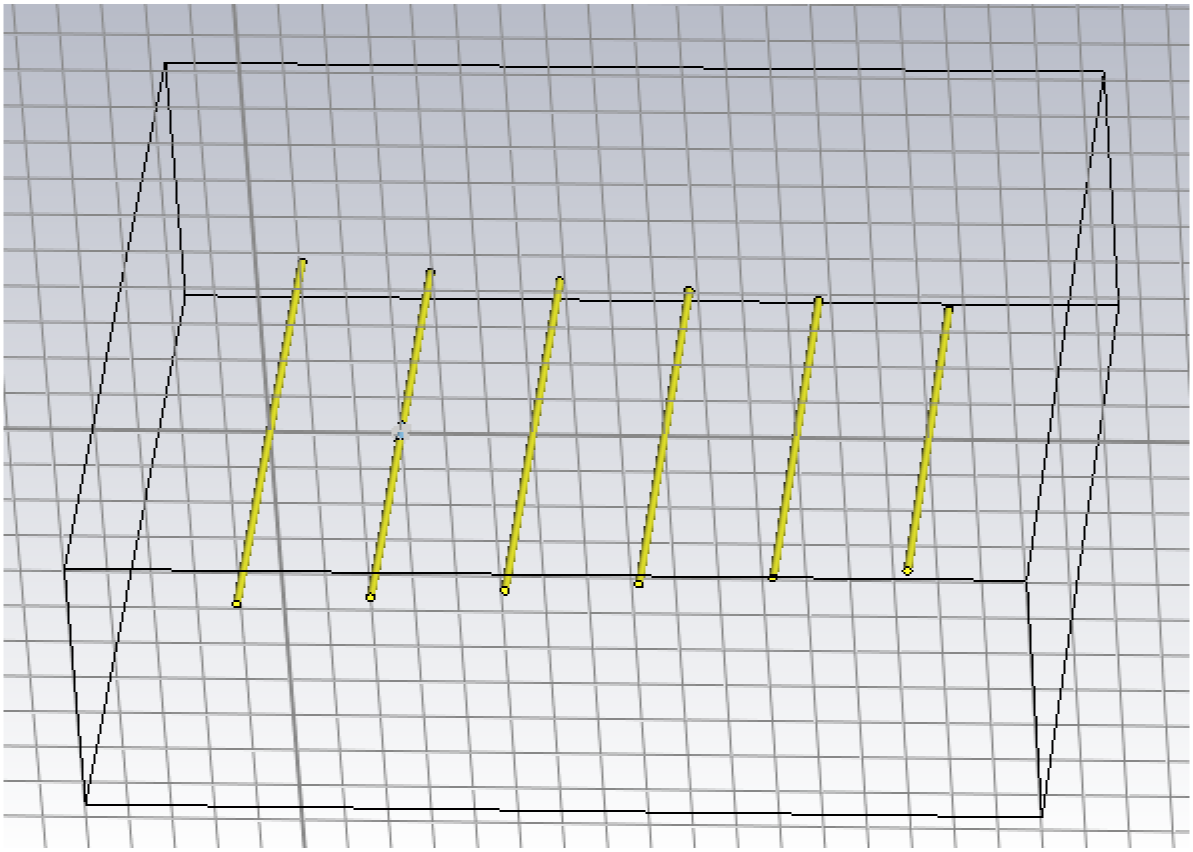

Figure 4. Simulated Yagi Uda Design

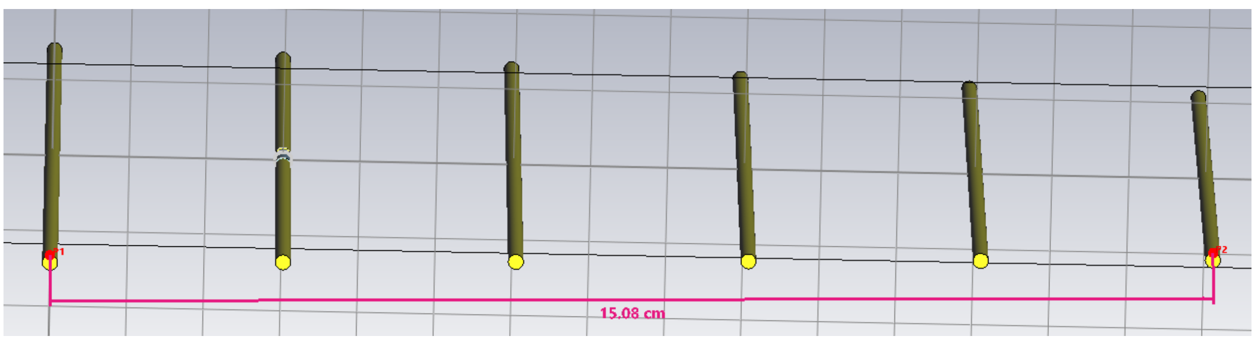

Figure 5. Close-up of Simulated Design Showing Length

<u>Plans for upcoming week:</u>

1. Meet with Dr. Song and discuss initial antenna design, board being ordered, and anything else before spring break.

Individual contributions:

Name	Individual Contributions	Hours this week	Hours cumulative
Benjamin Brown	● Researched testing parameters to visualize the output from the testing board -2 hours ● Researched the specifications of LEDs(Currents & Voltages) compared to our testing board output -1 hour ● Researched how we could implement a dual band yagi uda into our project - 0.5hours ● Group meeting with teammates to discuss project - 1hour	4.5	16
Jacob Walczak	● Research for the dual-band yagi uda - 1 hrs ● Designing and simulated the yagi uda antenna with Chris - 3.5 hrs ● Group meeting to discuss project plans and what to research. - 1 hrs	5.5	17
Greg Schmitt	● Researched possible RF-DC rectifier circuits that would offer peak power delivery efficiency - 3 hr ● Researched working dynamics and design of yagi-uda antennas - 1hr ● Group meeting with advisor/client - 1hr	5	16
Christopher Marting	● Researched yagi uda designs and how to make them - 1.5hr ● Designed and simulated a yagi uda antenna in CST studio - 3.5hr	6	17.5

Name	Individual Contributions	Hours this week	Hours cumulative
	• Group meeting - 1hr		
Sam Runkel	• Researched simulation software such as yagi calculator. -1hr • Researched methods for testing the open and closed resistive load voltage and power output of the board -1.5hr • Ordered our first testing board through ETG -0.5hr • Team meeting - 1hr	4	16
Tanner Garity	• Researched diode specifications and compared to our testing board -1 hour • Researched possible RF-DC rectifiers that could offer peak power efficiency - 2 hr • Advisor/Client meeting- 1hr	4	16