IOWA STATE UNIVERSITY
College of Engineering

Lightning Talk 3
Millimeter-Wave Imaging Radar

Group 20: Nathan Ayers, Matthew Caron,
Michael Levin, Rodrigo Romero

Problem Statement

Researchers and students at Iowa State University need a method to analyze materials, beyond the surface of those materials. The researchers and students are working in CNDE at Iowa State University, but this is not a problem specific to people at Iowa State University, there are likely people working around the world on similar projects. The problem may occur at any point in an items lifecycle, requiring regular analysis of the material. The importance of this is crucial to ensure safe operation, where a material analysis of the inside of a material is required. Finally, we will design a product that will analyze a material to check for defects and communicate that to the analyzer.

Design Context- 3.1.1.Broader Context

Area	Context
Public health,safety, and welfare	The structural quality of a material is important to public safety if people depend on that material for transportation and other considerations.
Global, cultural, and social	As engineers, we are concerned with ethics at our core. So this will allow us to feel more assured of our designs, products, etc.
Environmental	This will allow a more precise input into when a structural component would need replacing, maximizing the life of a structural component, therefore reducing waste.
Economic	As discussed above, this could optimize a products life cycle, reducing waste. This will allow for a more economical product as waste equals loss.

3.1.2 User Needs

Users	Uses/Needs
Researchers	Needs to know how well a material will hold up over time, so they may research its strength properties.
Students	Needs something that is simple to use as a learning mechanism. Also need it to be well documented as it will otherwise not be useful to them.
Professional Engineers (working for companies)	Needs to be able to examine materials to get the most possible amount of life out of them, they also need this device or product to be within their price range, it must offer benefits against existing devices.

3.1.3 Prior Work/Solutions

Outside on nondestructive evaluation, mm wave scanners have uses that scan humans, they include:

- Airport TSA scanners
- Loss prevention in warehouses
- Package Verification

mm wave imaging radars for nondestructive evaluation is a well researched topic as well, with many well respected universities researching its benefits, and they have obviously built their own, Iowa State is one of those Universities but our design will be a useful aide to student researchers at Iowa State.

Pros (Our Design)	Pros (Other Designs)
Cheaper, can be produced for less than $1,000, with free student labor.	Will likely have multiple channels which will give more utility for high-end research.
It should have a very small physical footprint, at least that is our goal.	Likely to have less noise/error, as they built by career engineers/researchers.

3.1.4 Technical Complexity

Component/Subsystem	Justification/Description of Complexity
PCB Design/integration	This project requires the full design and testing of a PCB that allows for communication between an FPGA and a ADC and DAC respectively, the PCB will be designed from scratch.
FPGA programming	This project requires two different types of FPGA programming, SPI will require the programmer to manipulate the system clock to output a precise signal. The Signal Processing programming will require the programmer to separate Billions of signals per second into their real and imaginary components.
User Interface	An interface must be designed for the communication of the user to the FPGA, this interface must direct the FPGA to start sending signals and must return the processed output signals back to the computer and then organize them into a way that is friendly to our human eyes.
Integration	We must make all four of our parts work together, this will include soldering, code optimization, etc. This will be the most difficult part of the project, and the nature of this project requires each part to build off of another.

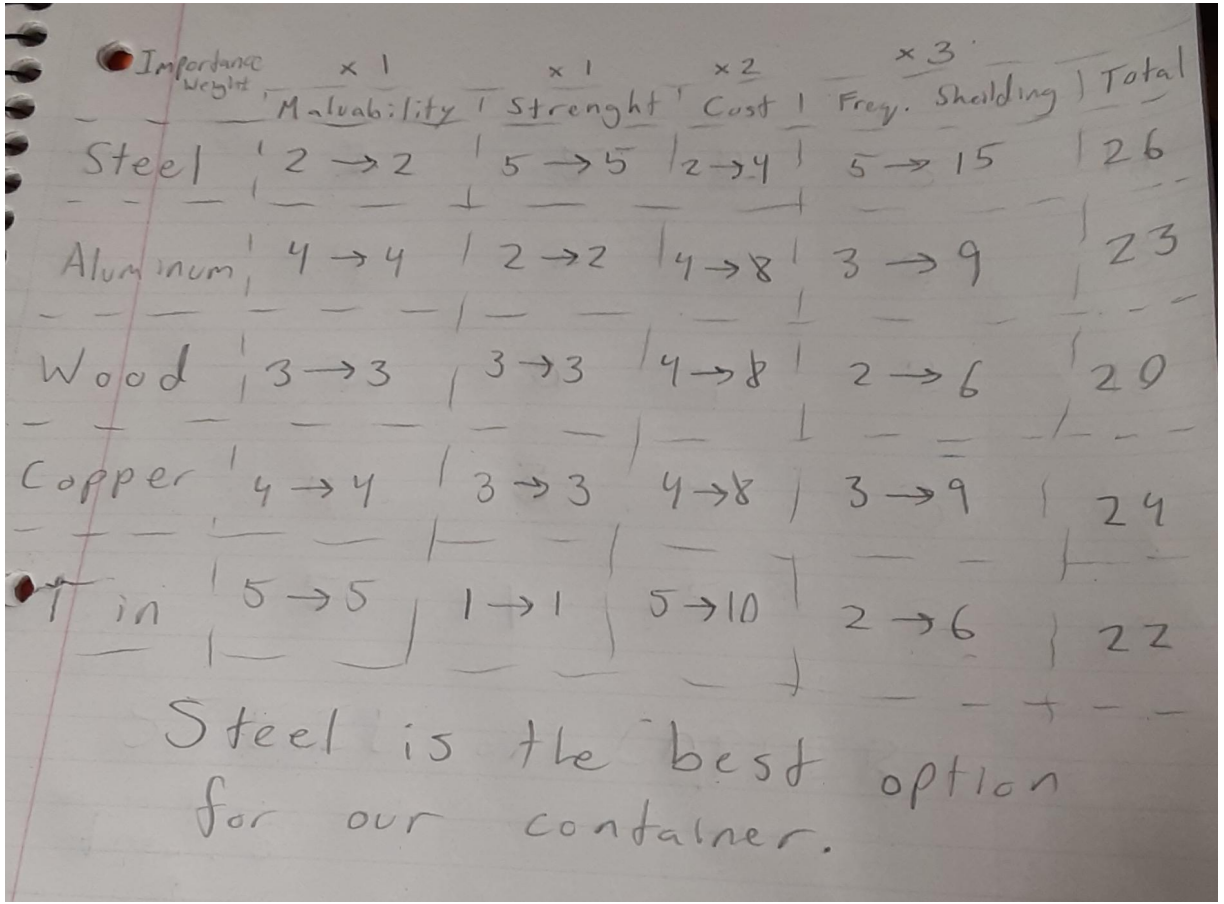
Design Decisions

For our project, we will have to decide on the frequency at which the data is being collected. We'll have to consider the tradeoffs between resolution of the images and the time and energy efficiency of collecting the data. We have to decide whether to use the built in USB or if we should attach a separate one for potentially better connection and faster data sharing. The container will also be important as the material has to be compatible with the high frequency device so it doesn't affect our results.

Ideations

Material of the container, we had talked about many different options. Steel is strong and can last a long time but is difficult to work with in a dynamic way. Aluminum is very malleable but can block EMF waves and could disrupt scans. Wood would be easy to work with and could be designed in fun ways but it’s not very professional which is something that will probably be important for our clients. Copper is cheap and provides shielding from outside interference. Tin is also cheap and malleable but it’s very soft and can be damaged easily.

Decision Making and Trade Offs



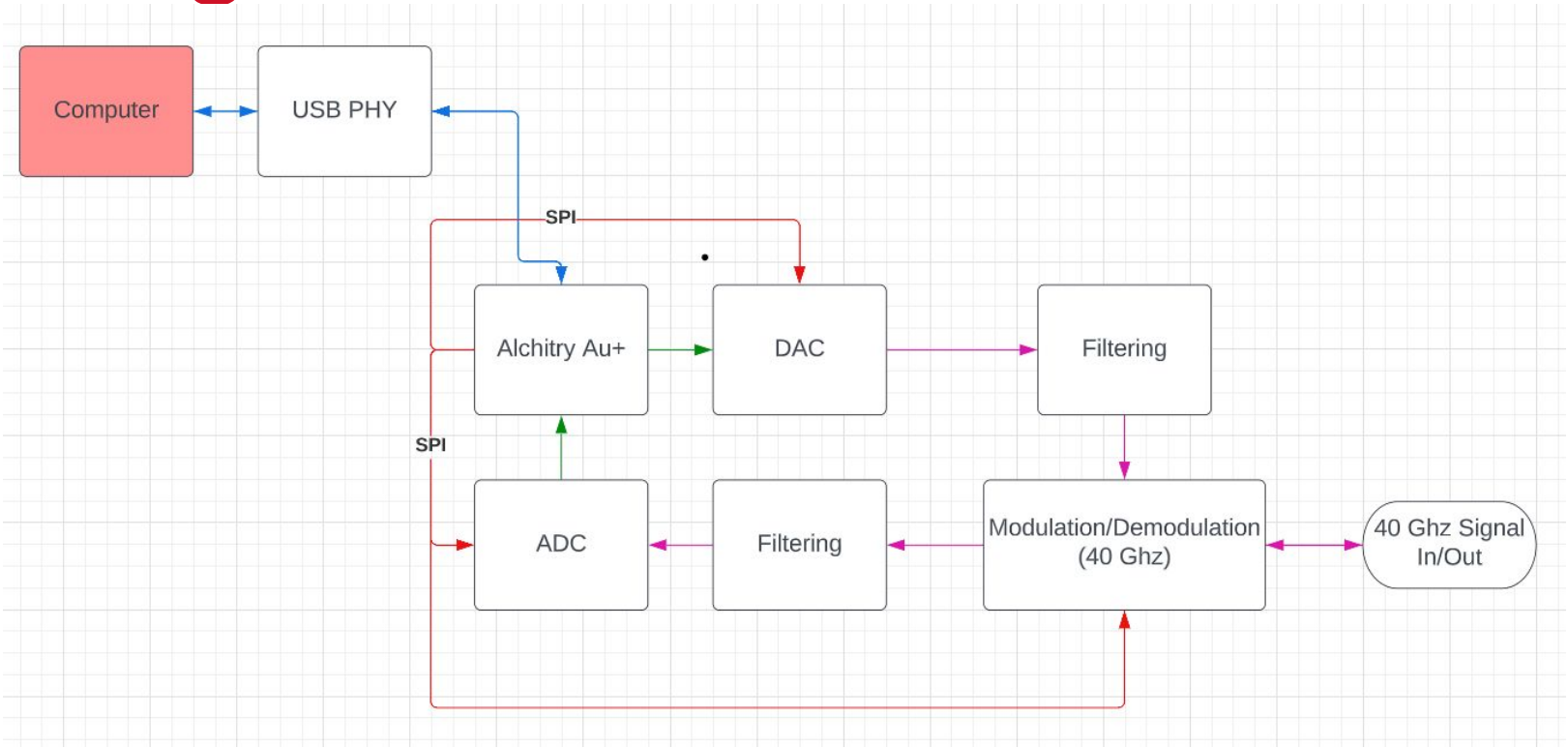
Importance Weight	×1 Malleability	×1 Strenght	×2 Cost	×3 Freq. Shielding	Total
Steel	2 → 2	5 → 5	2 → 4	5 → 15	26
Aluminum	4 → 4	2 → 2	4 → 8	3 → 9	23
Wood	3 → 3	3 → 3	4 → 8	2 → 6	20
Copper	4 → 4	3 → 3	4 → 8	3 → 9	24
Tin	5 → 5	1 → 1	5 → 10	2 → 6	22

Steel is the best option for our container.

Proposed Design

- Since hardware design, Implementation, and Testing takes a long time on our relatively short time scale we have already started designing the PCB. This PCB consists of…
  - Connecting to the Alchitry Au+ (FPGA)
  - Digital to analog conversion
  - Analog to digital conversion
  - A way of getting data off the Alchitry Au+: USB to the PC

Design Visual



Design Description

Measuring reflection and transmission coefficients are very important in the field of microwave engineering. The functionality of this device does exactly that. When the user starts a measurement the device will send out a 10 MHz signal that will modulate a 40 GHz signal and sent out from the device and be returned from there the FPGA will do calculations to determine reflection coefficients from the measurements and send the data back to the users computer via USB

Functionality

Ease of use is a priority in the project so we need to make the software of this device easy to use. So all the user needs to do is input frequency data then do the measurement. After the measurement the user can interpret the data and/or do extra calculations on the file sent from the device.

Areas of Concern and Development

Some of the concerns are related to the physical final product. Since we are in the stage of ensuring functionality we have not considered the case where the hardware will be enclosed, with this concern comes the reasoning about the best arrangement of the equipment for its ease of use.

Design Analysis

At this point, we have not built the proposed analysis, but the advancement we have for the moment suggests that the system will work properly and it will be a compacted hardware system.

The modifiable part of the system will be the display monitor to show the information, since this design will be in the lab, in the future it could be an improvement to the system if it becomes available to work out of the lab.