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| **MEETING MINUTES – Sponsor & Team Meeting** |
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| OWNER: Julia Kim |

**Present: ECE advisor Dr. Foo, ECE coordinator Dr. Frank, Matthew Cammuse, Patrick Delallana, Julia Kim, Benjamin Mock, Mark Poindexter, Jasmine Vanderhorst**

Time: 4 p.m. – 5:30 p.m.

We expressed the concern that was brought up in the meeting with the M.E. advisors regarding human testing; however, Mr. Stenger informed us that there would not be any human testing involved, instead it would be done with mannequins. The mannequin (target) would have to be supported with a tripod or something in that fashion. The goal for the project is not to become a product, but instead to understand the basics for when we enter the real world and have to deal with transmit/receive equipment, whether it’s communications, radars, etc. We should do enough to where we’re successful and also get the most learning benefits.

We have to fulfill certain ABET requirements, and one of them is that students have to design something with realistic constraints, which includes health, safety, environmental. So we have to address those issues in our report and discuss what kind of testing would be needed if this were to become a real product. The prototype is a proof of concept.

There’s a standard on flux which is about 10 mW/cm2, but we should investigate more in order to verify the value. Then that can be calculated with the aperture.

We asked if it’s feasible to complete the project within the two semesters. Mr. Stenger said that it is. He suggested that for programming, we could start with VHDL code to generate different pulses, different pulse periods and said that the code is pretty straightforward. He said that the code could be broken up in different functions, and if we’re successful there, we can keep building up. If there are any challenges or issues that we can’t get past, then there are backup plans where we can use test equipment. The less advanced option diagram is a good baseline, and as we progress and exceed expectations with the programming and getting things to work, then we could adapt some of the more advanced features from the more advanced diagram. If we’re having too many problems, we can go do the more simplified option where the test equipment does most of the work, and the only difficulty would be setting that up.

From a programming standpoint, it would be divided into different subroutines and try to get each one working. For example, we need to generate a pulse signal, but if we can’t get to that then we have a pulse generator. Another subroutine is: The VCO for setting up the frequency is set up as D/A, and on the FPGA, the slider switches on the demo board can be used to represent a digital word and then to output some analog voltage to a VCO. And then for the A/D, we input a signal and sample it and show that we can turn that voltage level into a digital word in memory. If we can get the different subroutines, then they can be combined together and coordinated together in time with VHDL using counters. Another subroutine would be for the A/D, if we can sample a voltage and put it in memory, then we can output it to one of the pixels on the display.

When it comes to the RF, once we agree on the components and do the modeling, we can work some of the parts and individually cascade them. Not put the whole together, but just like put the switch after the VCO and then show that we can control it with the FPGA pulser and show that the RF goes from one path to the other to the detector and switching it up at the appropriate time. So we would build this up in stages and add a component and evaluate it, and if it works correctly then add another component and so on. We would build it in pieces and as we verify, then add on more, such as add a switch, then add one as doublers, then check its output, add a power amp, then check its output, add an isolator, and so on.

For the simplest option using test equipment, the FPGA only has to create pulses, like a timing generator. And the rest of it is all test equipment and signal process. Everything gets sampled on the scope and gets recorded.

The block diagram provided by Mr. Stenger is just a rough sketch, as there are no filters, additional attenuators, power supply, etc. There’s still a lot of work to be done and is meant to get us started in the right direction.

For the less advanced option diagram, there are two modes: transmit and receive modes. For the transmit mode, there’s a VCO (Voltage Controlled Oscillator) and you apply voltage and outconv it on a RF signal, which goes up to 5GHz. We can have a separate analog voltage source that just connects to this or the FPGA generator will take the slider switches and D/A converter, which would create the analog voltage that would set the output frequency. Then that goes from a SPDT switch, which takes you to the transmit path where the switch would be switched up. So that switch would have to be a fast one because the pulse has to be created using that switch since the VCO can’t be turned on/off fast enough to do a 20ns pulse. The switch is a FET switch that has an internal driver (data sheet was sent on it) and switches at around 8ns. The FPGA is a 3V one, and 0 – 3 V can turn that switch on, but we need to worry about the propagation delay and distortion because it’s high speed and can’t just use wires. It switches up to the up position, then routes over to the right, then to another switch, which switches up, goes to a time multiplier, which multiplies it up to 10GHz. Then goes to the path where we can control the power, then goes to a power amp and out to the antenna. That signal goes out, the 20ns pulse and under that 20ns pulse there’s a sine wave. If the target is 20ft away, as the leading edge of the pulse hits the target, the trailing part of the pulse will just then be leaving the antenna at 10 ns/ft. That pulse scatters off the target, reflects back, and 20ns later, you want to be able to receive because that leading edge of the pulse is going to take 20ns to get back to the receiving antenna. The SPDT after the VCO has to be switched really fast within 20ns so that you can start to receive because that switches the VCO signal over to the L port of the IQ demodulator. That path has to have a x2 on the diagram. The receive signal that’s coming back through one of the receive antennas, goes through the LNA, attenuator and into the demodulator mixes with the L port signal, which are both the same frequency. When they mix together, the IQ demodulator brings out an I and a Q portion, which represent the phase difference between the L port signal and what you receive. So if you plot I part on the x axis and the Q part on the y axis and draw vectors, then that’s the amplitude and phase of the signal. The key is to determine the amplitude and phase from the signals coming in through the horn antennas. All the receivers should be receiving the same signals because everything is balanced. When you FFT the signals, you get a sinc function which corresponds to a target at the center of your scene. If you take your target and shift it over laterally, then there would be a phase shift over the elements and that phase is now manifested in the I and Q for each one of the receive horns. Then you get an amplitude that’s probably similar but also a phase slope. When you FFT that, you get a since function that’s shifted over, which represents the target that has shifted over.

The switches aren’t perfect, so if the x2 that is in the diagram by the SPDT wasn’t there, then some of the fundamental energy is leaked into the transmit port while it is receiving. So the signal that comes out of the transmit path has the potential to leak over to the receive, which would impair the scatter energy from the target, which is low signal. The x2 reduces the signal by a little bit, and the output goes down dramatically; it is used to provide isolation.

Antenna Aperture diagram:

When you transmit out the upper transmit antenna shown there and receive into number one, then a phase center has been created, which means that you equivalently achieved a single antenna that would have a transmit/receive behind it halfway in between that transmit aperture and receive aperture. So the phase center is basically a transmit/receive aperture. Then when you go to #2, if you go halfway between receive #2 and the top transmit, then you’ve created another aperture. So if one wasn’t put on top and at the bottom, then only half the space would be filled out with phase center apertures. So if you make the distance ½ d to the first receiver, then it looks like you have 16 phase centers. So when you transmit/receive, you’ll have 16 transmit/receive conditions, and for each one of those 16 phase centers will generate an amplitude and a phase, which would be FFT’d to create an image. The idea here is to get 16 phase centers that are equally spaced at ½d, so you would transmit out the top transmitter and go through all 8 receives, and then you would switch down to a transmitter that’s underneath on the low side and go through all the same 8 receivers again and create the other 8 phase centers.

For now, we’ll be doing 1 dimensional array, and if things go smoothly, then we can go to other dimensions. When we change frequency and track amplitude and phase for each receive aperture, then that gives us our depth, which would make it 3D.

For the antenna part:

We need to verify we have 16 phase centers. Also learn about the array factor and calculate the array factor for a 16 element array where you can change the space in between the elements in terms of lambda at the frequency and then if you know the horn, which is what the antenna pattern is at each horn and the horn would be defined by an aperture that gives a 3DD beam width that expands the scene at 20ft. So if the beam width of that aperture is 3degrees, you take that and project it 20ft away and see what extends at 20ft. You take that pattern and multiply it by the array factor, which would give the antenna pattern for the array. The array factor, which is your pattern where every radiator is radiating in all direction, you take that pattern and multiply it by the element pattern, which is the pattern for each horn, and the grading gets knocked down because the energy can’t radiate out of that. If you separate these elements further apart, you’ll end up with a bigger, longer aperture which ultimately will allow you to find a resolution in the scene area but what happens is that at some point, you’ll create side lops in the scene area which would create ambiguity. For frequency, 10 GHz would be good.

There’s going to be a phase error across the horns to a point target 20ft away, so we would have to calibrate for that error with a phase correction (called focusing), so we would point these all to the same scene. There would a little bit of a phase error because the path lines from the target to each horn would be slightly different. In general, systems like these would need to be calibrated. So would need to evaluate the path line difference from the target to each horn and look at that in terms of degree or in terms of lambda at the frequency.

In the performance characteristics, we’re basically going to derive the scene extent and the cross-range resolution. For a given horn aperture that is illuminating a scene, if you spread them apart, you’ll end up with tighter resolution but also with ambiguity. The idea is to keep the grading out of the scene so as not to get any ambiguity.

Whoever is doing the ADS design should start looking at the components and their performances and then build an ADS model of the transmit path separately and the receive path.

For the mechanical engineering members:

Need to find a way to support the horns next to each other in a line and then be able to point them at the scene with a laser for good alignment. Distance should be adjustable so that the antenna can be rotated. There would be 8 horn antennas and would be transitioning through a coax, so rope 2 transmit cables and 8 receive cables to a switch, and have the cable back to an LNA. So, two parts: antenna structure in good alignment and be able to adjust them to align them with a laser. There’s also the components and back, the cabling, what kind of plate the components would mount to, whether it would be in a box, etc. The antennas can be aligned manually or mechanically (this option would be more preferable), although it can be done with dial plate adjustment in horizontal and vertical.

For the industrial engineering members:

Some tasks would be: health and safety, manufacturability, portability, project management, scheduling and analysis. Also survey what rooms are available. For portability: it’d be nice if it was configured where it wasn’t laid out over a bench but instead, consolidated in a modular form and be able to be taken apart easily to set up outside if needed.

Someone has to be in charge of the radar range equations in an Excel spreadsheet that does the full-fledged T/R through the aperture of the scatter and back to predict the mV level that we would ultimately read. It would allow us to the see the variables that we need and the values.

For the FPGA, a list of programming tasks would be provided in order to see if the codes can be generated.

Have to find out where testing can be done and see whether to put up absorbers, which can be erected on plywood implemented by Industrial Engineers. Mechanical engineers and industrial engineers can look into whether there are any 20ft+ room that can be used to test.

For test equipment, we can see if we can borrow from Tektronics, which would be a backup. We can look into the performance they can provide for generating waveforms and compare it to what we’re doing. It is likely that they would let us borrow equipment needed for a reasonable amount of time.

Discussed when Mr. Stenger would be able to visit, and we determined tentatively for October 21st before our presentation on October 24th. Decided to hold next teleconference next Thursday October 2nd at 5 p.m.