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| **MEETING MINUTES – Sponsor Meeting** |
| DATE: January 21, 2015 |
| POSTING TIME: 01/25/15 09:33:14 PM EST |
| OWNER: Julia Kim |

Present: Joshua Cushion, Patrick Delallana, Julia Kim, Benjamin Mock, Mark Poindexter, Jasmine Vanderhorst

Time: 5:30 p.m. – 6:30 p.m.

Went over the quote receive from the mechanicals’ shop to build the frame for the antenna, which was priced at about $13,000 for parts and labor. Mark said he was going to talk with the people in order to get a breakdown on why it is so expensive for the structure, as it shouldn’t be that high. Pete stressed the importance on the cabling and how to route all the cables for each component inside the structure.

We went over the other parts that we were missing out on. Another VCO was found in stock from Digikey. Pete mentioned that Josh would probably have to get the software to control the VCO. The parts that have been ordered now are: power amplifier, low noise amplifier, variable attenuator, and fixed attenuators. The frequency multiplier is one thing that we’re having trouble with, but Josh found one that could work for us. DigiKey has the SPDT switch, while Pete still has to investigate on the SP4T switch. So far we’ve used around $33K from our budget. Josh is going to look into the X-band detector to be purchased and send the datasheet to Pete. Pete told Ben to buy 22 waveguide adapters for the antennas. Josh also looked into the frequency multipliers and sent the information to Pete.

In regards to the image formation calibration, Pete will send more information to Julia to work on. When we have the 8 horns going across and we take one of the arrays; if we take a point in space that’s really far away, let’s say one mile, then the distance from that point in space then each one of the horns will have a small difference in lengths but they’re essentially the same lengths. If you go way out in the far field, then the angles get real small. So all the lengths from that point in space to all the horns are essentially going to converge to the same value. If you take one mile squared plus the distance from the center of the arrays to the outer horns squared and take the square root, you will essentially get the one mile as the distance is just a few inches. This is the far field, which is the distance in space to all the points of the antennas are basically the same and done in wavelength.

The other thing to understand is the physical distance in terms of inches is an analogous number of degrees of phase in the traveling wave. So distance and degrees are interchangeable. So one can talk about the distance in terms of inches and it’s the same in terms of lambda. When a wave travels through space at 10 GHz, you can imagine a sine wave traveling through the air, the peaks will be one inch apart, which is 360 degrees or 1 lambda.

If you’re at the beach and you see the waves coming in, you can imagine it as a sine wave traveling in space. Just imagine that wave traveling at speed of light, which is the electromagnetic wave in space. The difference between the peaks is the wavelength and as the frequency changes in electromagnetic waves, the distance between those peaks changes which is how the wavelength changes with frequency. Higher frequency means that the peaks will be closer together in terms of physical distance, and that frequency corresponds to the 360 degrees when you go from peak to peak. Let’s say that there are two waves traveling in space and they meet and the peaks are lined up, then they’ll add. What we’re trying to do with the radar is to manage where those peaks are. If they’re at different distances, then we’ll have to compensate the differences so that they’ll align in space and add up properly. So what we’re trying to do with the calibration is to line up the waves in a way so that they’ll sum together like we want to. We’re not at far field as we’re 240 inches away, and if you measure the distance from a point 240 inches away to each one of the horns at a different distance, that’s a significant part of the wavelength. And that becomes one of the errors.

The other concept is that if we have these 8 horns and we’re in the far field about 2 miles away and the distances between each horn is the same. If I take the array and instead of having it at a point in space being at the boresight, orthogonal to the center point of the array out 2 miles, and have it rotated instead around its axis, then the target two miles away is off axis. What happens now is that since it is off-axis due to the rotation, then the path length to each horn is physically different. This is because the one at the top is further away than the one at the bottom, which would be closer.

If we take the vertical line of phase centers and rotate it around the center to a horizontal line, then the distance to the target is not the same anymore. What happens is as we go away from the center, it ends up being d\*sin (theta) away, where d is the distance between each one of the horn elements. The first distance is d\*sin(theta), the second one is 2d\*sin(theta), and increases as such. The distance d\*sin(theta) is what the processing algorithm takes into account. You’re looking at the energy arrives at different angles. If you look at the antennas in a vertical line and the target is at boresight, and if you translate the target vertically, then it’s the same thing as rotating the antennas on its axis. We’re going to have targets that are across the scene of about 4 feet, so each of the targets is going to present itself at a different angle relative to the antenna. That distance change is d\*sin(theta) and that’s what processing does, in which it decomposes the reflected energy into the different angles of arrival.

What happens when you go in closer, when the array is vertical and the target is at horsight, orthogonal way, now you have a path length difference between the target and each antenna and that causes a phase error. When you’re close up, there’s an added phase error that has to accounted for. So what the cal is mainly going to be compensating for is the fact that if you transmit out one antenna and then measure the distance from the transmit antenna to the target at 240 inches and then calculate the distance from the target to each of the receive horns, then each of the distances are going to be different. That difference in phase is what we have to calibrate for because the processing is assuming that the distance difference is zero between all the horns. So basically the distance from the transmit horn to the target, which is always going to be the same, has to be added to the distance from the target to the receive horns. The sum of those two distances is going to be different for each transmit to receive path and that difference is the error. There are going to be other errors in the hardware that have be compensated for as well.

The way to do that empirically is to place a trihedral 240 inches at the target and then we’ll transmit and receive out through each horn and get the data and use that as the calibration factor. Essentially what we’ll do is when we transmit and receive through each of the paths, we’ll get an I and Q value. If we take these values and go to the complex plane and plot them out, which is a vector with amplitude and phase, we’ll get an e to the j\*theta vector. What we’ll do is get a different e to the j\*theta vector for each transmit/receive combination and include that distance error and the hardware errors. What the goal would be is when we get the random I and Q values, what we want to end up doing when we have a point target, we want to end up with the I and the Q for every transmit/receive combination to be of amplitude 1 and constant phase. What the cal does is it forces the measured data to be amplitude 1 and the same phase for each one. So if you have a complex number, you have an I and a Q, you can write that in the form of e to the j\*theta, where theta is the inverse tangent.

Let’s say we do a transmit/receive and get an I of 1 and a Q of +0.5, so that would be 1 + j0.5, and multiply that by 1 – j0.5, we get a phase of zero as there is no imaginary part. The cal factor is going to be the conjugate of that measured data. When we have the constant amplitude and zero phase data for a point target at boresight. And when we go to the process, it’ll give us a high amplitude at zero degree. You force the data to give you the data that you want and that corrects the hardware errors and the path length differences. If you put targets at 40 inches, then the cal would break down; but this is another process that we would work on afterwards.