Spacecraft Tracking using the Petrie Ground Station

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Purpose ➔

The purpose of this test was to allow students to get a good understanding and apply the skills obtained throughout this course. In addition, there were two objectives which were needed to be accomplished by the end of this test. Those objectives are as follows: Conduct field testing and debug the tracking LabView software code by the student and allow student to get familiar with test performing like receiving equipment and operate parabolic antenna

Unfortunately, the Sat Tracker code did not work out, but this report would show what the code is and what is the procedure of the project from various angles. Moreover, the report will show where is the defect that lead the project to fail.

Introduction & Background ➔

As mentioned, the Petrie Ground Station test was proposed to allow students to control small dish antenna and measure the power levels over wide range of azimuth and elevation offsets to gauge the maximum power level. Moreover, the LabView code would be used to track weather satellites. Thus, this test was split in two main activities. Along with this there were several code modifications and changes made after P5 can be found in next section.

Procedure, Discussion, and Interpretation ➔

As mentioned above, the test was split in two activities. **Activity 1** was required to measure the antenna pattern and gauge the peak power. **Activity 2** was set to track the spacecraft and complete the software. A key thing to keep in mind in that the time zone we are working with is UTC time not Eastern so it was assumed the user will enter the tracking start and end time in UTC.

Activity 1: Measurements Petrie Ground Station Dish Antenna Pattern (why we tracked weather satellites and not GPS satellites L1 downlink?) this section would answer this question in detail.

The main thing to get out of this activity was to get a good understanding/knowledge about the level of accuracy to successfully track a satellite, where in our scenario it was **PRN 20380**. The antenna pattern is used to define the direction in which an antenna will radiate energy or receive energy radiated to it. For this test we will be using a parabolic dish where it functions by finding the feed at the focus of a revolved parabola surface. The antenna operates itself by setting the location of the feed to the satellite antenna. Then the energy is reflected from the surface to the focus of the receiving antenna. The focus is the point where the antenna gain is maximized.

For energy propagation we use concepts such as **HPBW**, **BWFN** and **solid angles**. HPBW stands for half-power beam width and can be estimated using the following formula:

$$\theta = k\frac{\lambda}{d}$$

where λ is the wavelength of the RF, d is the diameter of the dish and k is assumed to be 70. Thus, mathematically speaking it is evident that as the diameter gets larger the HPBW value gets smaller. Figure 1 displays the HPBW and BWFN. BWFN is defined to be the angular difference between the maximum peak and the one of the minimums on the main lob.

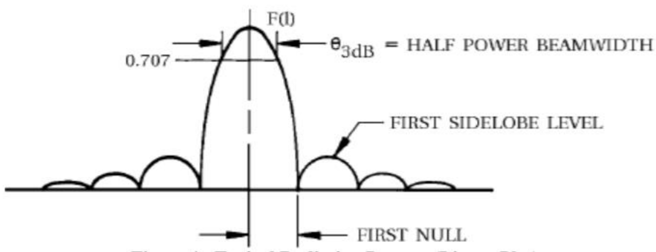


Figure 1: Shows the radiation pattern on a linear plot.

The solid angle can be calculated using the HPBW as follows:

$$\Omega = (2.39\ x\ 10^{-4})\theta_d^2$$

where θ_d is the HPBW in degree and the solid angle is measured in steradians units. Due to several factors such as structure support and surface imperfections not all the RF energy is received. Concepts such as antenna efficiency is used to get an approximate energy received with respect to the incoming energy flux by the following set of equations:

$$P_r = q\pi\frac{d^2}{4}\eta$$

where q is the radio flux and η is the antenna efficiency ranging from 55% to 70% and q can be found as follows:

$$q = fB$$

where f is the flux spectral density usually given in Jansky units and B is the receiver's bandwidth.

Antenna Pointing Angle System

The tracking antenna used for this test is controlled by azimuth and elevation. These two values have the following limits:

Elevation: 1 < EL < 90 and Azimuth: 3 < Az < 300.

It is known when the antenna is pointed at the horizon when the elevation is at zero deg and when the elevation is 90 deg we know that it is facing the zenith. For the azimuth is similar where when it is at zero deg it is facing north, when at 90 deg we know it is at East, when at 180 deg we know it is facing south and lastly when facing West is it at 270 deg. The dish antenna feed equipped by the tracking satellite antenna can be used by microwave transmissions from another transmitting antenna that is close to it.

The antenna under test (AUT) has an LO value of 1565 MHz, the receiver of the AUT has an IF frequency is then 135 MHz. Additionally, the RF -3dB bandwidth is found to be 30 MHz. Using all the provide knowledge we can observe the beam patterns of the antenna to figure out which direction contains the best RF signal.

The beam pattern can be defined as the amount of energy received as a function of the angular orientation of the incident signal.

Another key angle which is defined is called the Greenwich Mean Sidereal Time **(GMST).** GMST is defined as the angle between the Inertial X-axis and the earth fixed X-axis, which is measured in the XY Inertial plane. GMST can be calculated as follows:

$$GMST_{UT0} = 100.46061838 + mod(0.06570982 \times D, 24) \times 360$$

where D is number of days since J2000 to the midnight of the day. Using the result from above, the GMST for the exact time can be done as follows:

$$GMST_{UTC} = mod(GMST_{UT0} + \frac{1.002737909350795 \times UTC}{24} x360{,}360)$$

where UTC is hours since midnight of a day. The GMST angle is typically used to get the local hour angle (LHA) of a satellite of choice relative to the antenna located on earth. The LHA can be found by simply summing the GMST and the longitude of the antenna and subtracting that from the RA (**done via LabView**)

How did the change from the ARO to the Petrie Ground Station effect the activity?
For antennas which are quite large such as the one present at **ARO**, a different angle pointing system is in use. This angle system uses the local horizon as its reference plane and the North direction as the reference axis.

The pointing angles for this system can be found by working out the Az and EL from the given Dec and RA angles by using the following formula:

$$\vec{p} = [e_{1x} \quad e_{1y} \quad e_{1z}] \begin{Bmatrix} cos\,(Dec)cos\,(RA) \\ cos\,(Dec)sin(RA) \\ sin\,(Dec) \end{Bmatrix}.$$

Since these need to be converted into topocentric coordinates 3 rotations need to take place (**done in LabView**). They are as follows and are equated to the pointing vector components in the topocentric coordinates:

$$\vec{p} = [e_{1x} \quad e_{1y} \quad e_{1z}] \begin{Bmatrix} cosElsinAz \\ cosElcosAz \\ sinEl \end{Bmatrix}$$

$$\vec{p} = [e_{1x} \quad e_{1y} \quad e_{1z}][R_3 90°] * [R_2 lat] * [R_3(GMST + long)] \begin{Bmatrix} cos\,(Dec)cos\,(RA) \\ cos\,(Dec)sin(RA) \\ sin\,(Dec) \end{Bmatrix}$$

Following LAB 2 measurements ➔

We know the frequency of the transmitter is 1700 MHz so we can get λ by using a simple equation λ = c/f = 0.1765m thus using the equation listed in the background section: knowing d is approximately 1 m thus **HPBW** is approximately:

$\theta = k\frac{\lambda}{d} = 70 * \frac{0.1765}{1} = \mathbf{12.35\ deg}$ this is an approximate measurement.

For azimuth: we see the peak value on to be at 174.1 deg so the -3dB drop occurs at 177.1 and 163. 9 thus the experimental HPBW is 13.2 deg. For elevation we see the peak to be at 8.05 deg and the HPBW for this occurs at 14.6 deg.

The **BWFN** is found by taking the angular difference between the maximum of the main lob and one of the minimums of the main lob. For azimuth we can take such value to be 185.9 – 174.1 = 11.9 deg. Thus, the HPBW is 11.9 deg. And for elevation it is 17.6 – 8.05 = **9.55 deg.**

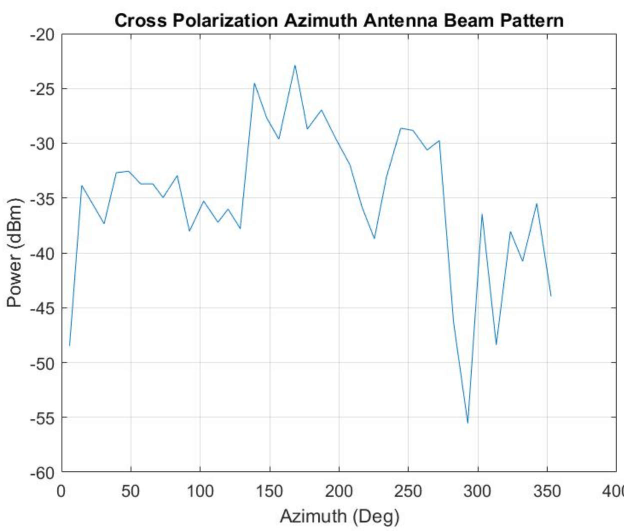
If we take the experimental averages of both the HPBW gives a value of **13.9 deg**.

Thus, solid angle can be found by using the following equation:

$$\Omega = (2.39\ x\ 10^{-4})\theta_d^2 = (2.39\ x\ 10^{-4})(13.9)^2 = \mathbf{0.046\ str}\ .$$

Due to project failing, I followed LAB 2 measurements to know the antenna azimuth/elevation antenna beam pattern (data obtained from LAB 2).

Az(deg)	**peak power (dBm)**	**Az(deg)**	**peak power (dBm)**	**Az(deg)**	**peak power (dBm)**
5.85	-48.48	**102.4**	-35.28	**207.8**	-31.97
14.63	-33.85	**112.7**	-37.21	**216.6**	-35.86
23.41	-35.75	**120**	-36.01	**225.4**	-38.71
30.73	-37.35	**128.8**	-37.79	**234.1**	-33.09
39.51	-32.69	**139**	-24.51	**244.4**	-28.63
48.29	-32.55	**147.8**	-27.68	**253.2**	-28.83
57.07	-33.71	**156.6**	-29.63	**263.4**	-30.62
65.85	-33.71	**168.3**	-22.87	**272.2**	-29.75
73.17	-34.96	**177.1**	-28.71	**282.4**	-46.3
83.41	-32.95	**187.3**	-26.96	**292.7**	-55.55
92.2	-38.03	**197.6**	-29.59	**303**	-36.45



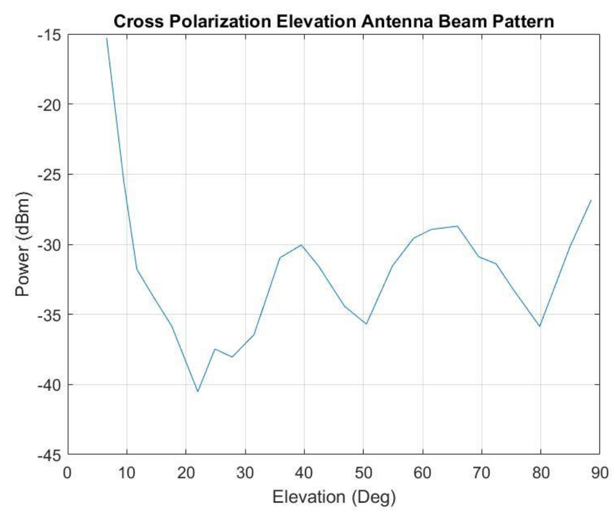


Figure 2: AZ / EL patterns

$$fB = 10.97 \text{ x } 1^{-23} * (30 * 10^{6})\ 3.27 * 10^{-15} \frac{\text{W}}{m^{2}},\ \ Assume\ \eta = 0.5\ \text{d} = 1\text{m}$$

The RF bandwidth of the front-end receiver is 30 MHz at the -3 dB points, flux density of **ANIK F2** (data obtain from the **Telesat, for test purpose only**) is about 119.4 dBW/m^2/MHz at 19:03:22.056 UTC (2004/04/24)

$$P_r = q\pi \frac{d^2}{4}\eta = \ 3.27 * 10^{-15} * \pi * \frac{(1)^2}{4} 0.5 = \textit{-44.2 dBm.}$$

As we see that the antenna efficiency was low and so was the diameter thus this made it difficult to obtain accurate data from/to the satellite. But in **ARO** trip it would be easy to detect satellite and obtain an accurate data in the end, due to big diameter of the satellite over there.

-50 to -79 dBm, then it is generally considered great signal

-80 to -89 dBm, then it is generally considered good signal

-90 to -99 dBm, then it is generally considered average signal

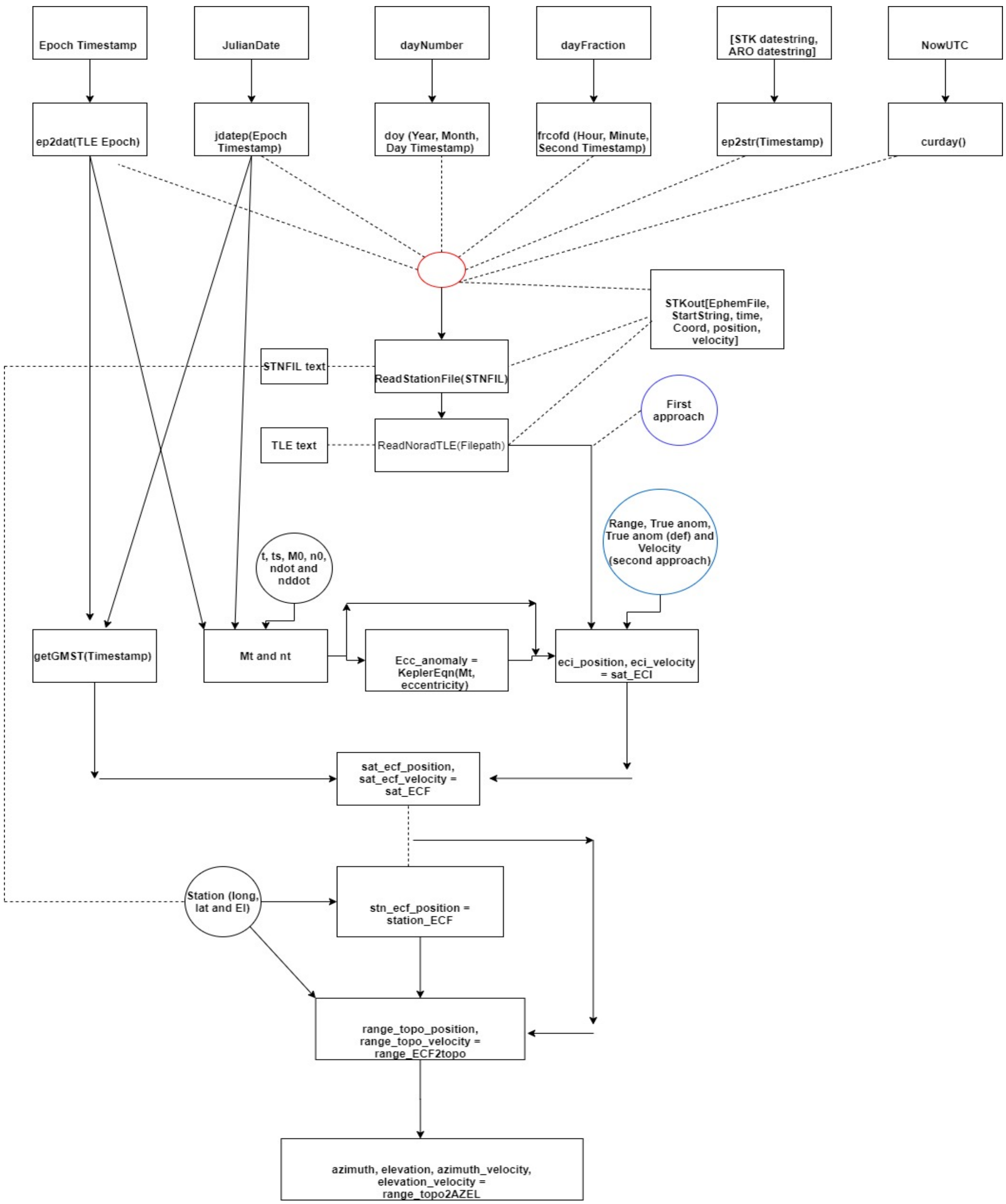
-100 to -109 dBm, then it is generally considered poor signal

-110 to -120 dBm, then it is generally considered very poor signal

In both plots displayed in the figures above shows the antenna patterns for both azimuth and elevation pattern (Figure 2). It is evidently visible that the graph displays main and side lobs for both situations. The key difference to note here is that the azimuthal plot has a bigger beam-width than the elevation plot. The azimuth beam width is found to be 0.6 deg and for elevation it is 0.18 deg. As we can see the elevation beam width is about 5 times smaller than the azimuthal beam width. But if we used the **ARO antenna**, both azimuth/elevation beam width would have similar beam width value due to antenna accuracy and size.

Activity 2: Sat tracker code and STK verifications

Due project failure, the report would go through the defects of the code and see where the issue is with. Going into details with each code and see where the mistake is from each lab (using **ProSat** inputs to check the outputs of LabView). But first we need to know the LabView tree of the project and follow it.



Code 1 ➔ (ep2str)

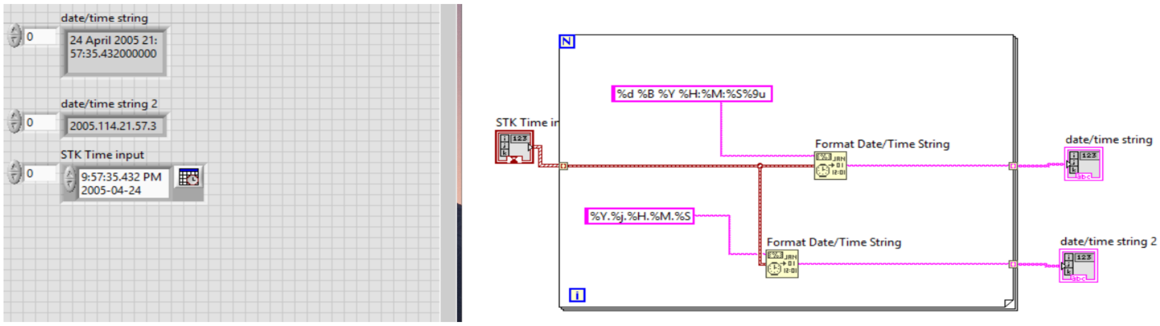


Figure 3: ep2str

Implementing the date required for the mission for the test (Epoch to String) with no errors.

Code 2 ➔ (curday)

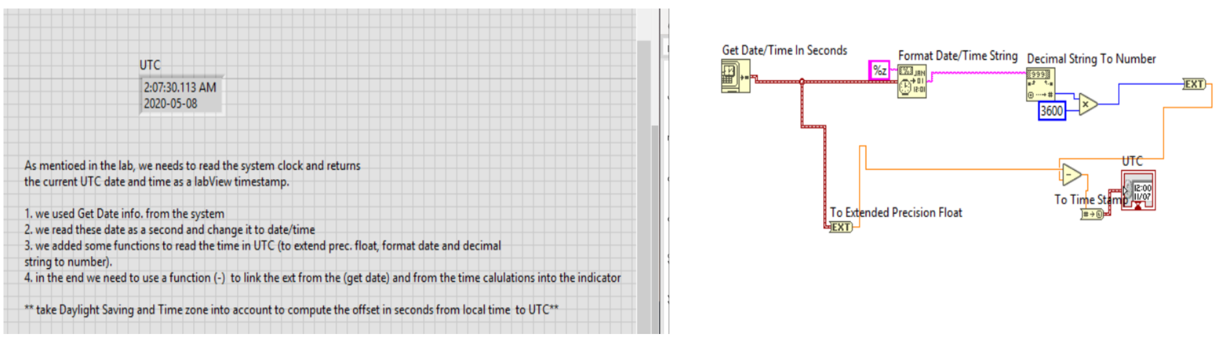


Figure 4: Curday

Implementing the date required for the mission for the test (Epoch to date in UTC) with no errors.

Code 3 ➔ (doy)

Figure 5: doy

The function "Day_Of_Year" calculates the day of the year for the specified date with no errors

Code 4 ➔ (epsdat)

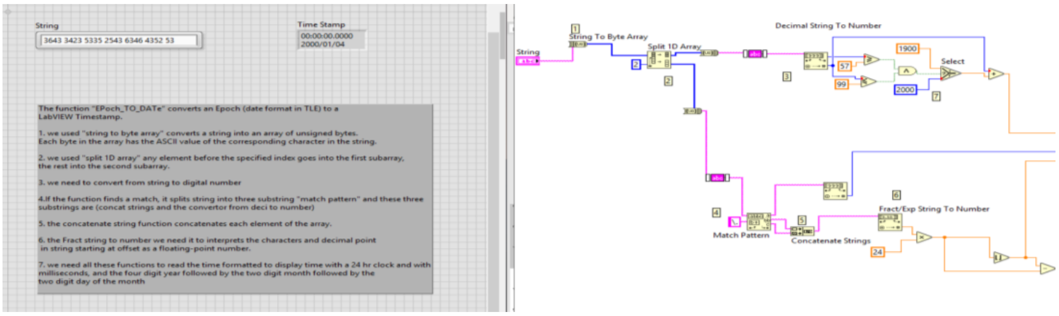


Figure 6: epsdat

Implementing the date required for the mission for the test (converts an epoch date to a LabView timestamp) with no errors

Code 5 ➔ (frcofd)

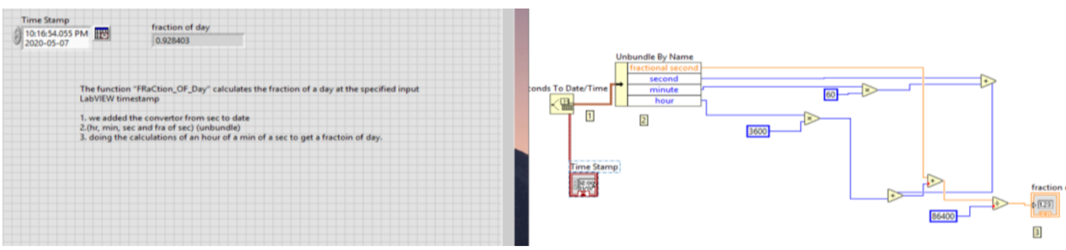


Figure 7: frcofd

Implementing the date required for the mission for the test (The function “FRACTION_OF_Day” calculates the fraction of a day at the specified input LabVIEW timestamp) with no errors

Code 6 ➔ (J.Day)

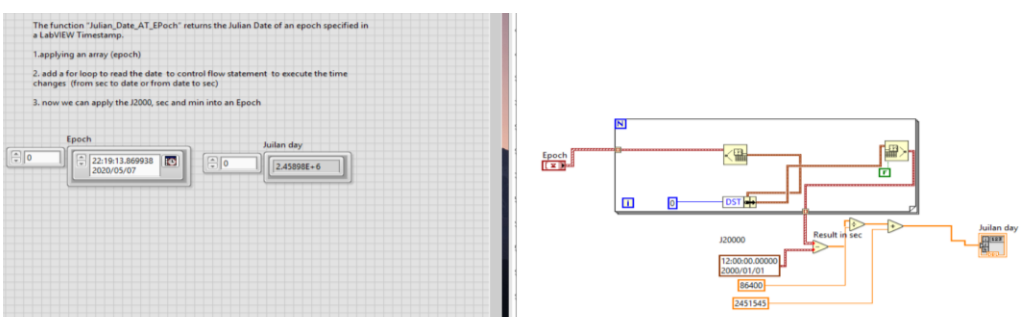


Figure 8: Julian Day

Implementing the date required for the mission for the test (The function “Julian_Date_AT_EPoch” returns the Julian Date of an epoch specified in a LabVIEW Timestamp). With no errors

Code 7 ➔ (ReadStation)

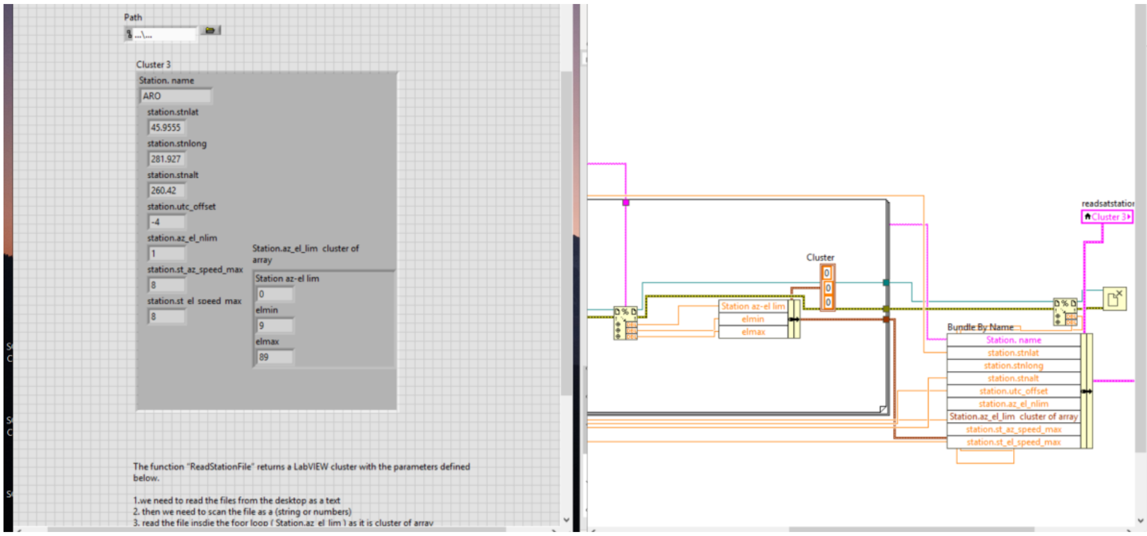


Figure 9: Read Station

Reading the station ARO file as mentioned in software specifications with no errors.

Code 8 ➔ (TLE)

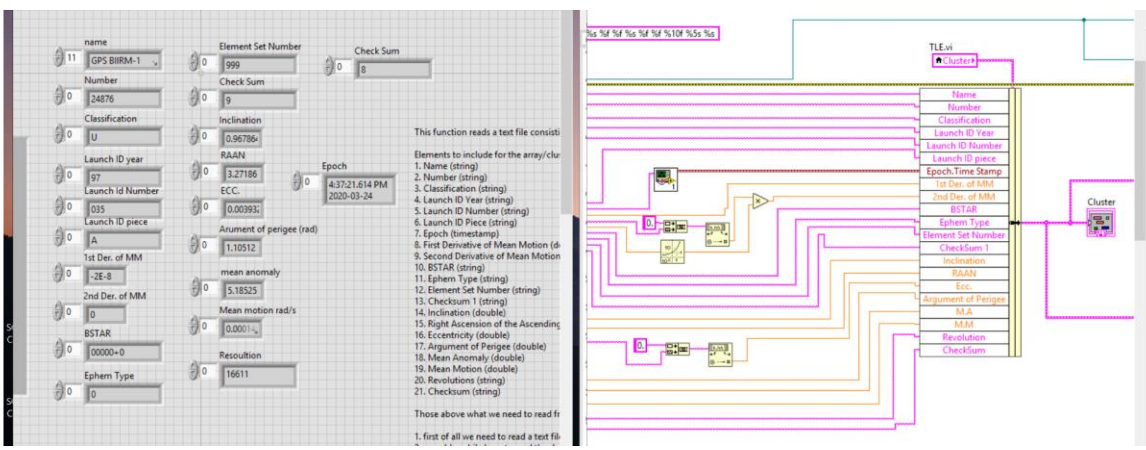


Figure 10: TLE

Reading the satellites file with no errors, re-reading new satellite with each run. Going through **lab 1** so far, no errors were found. As all the values are matched with the software specifications. This means, the issues might be found in **Lab 2**.

Lab 2 ➔ Code 1 ➔ (GetGMST)

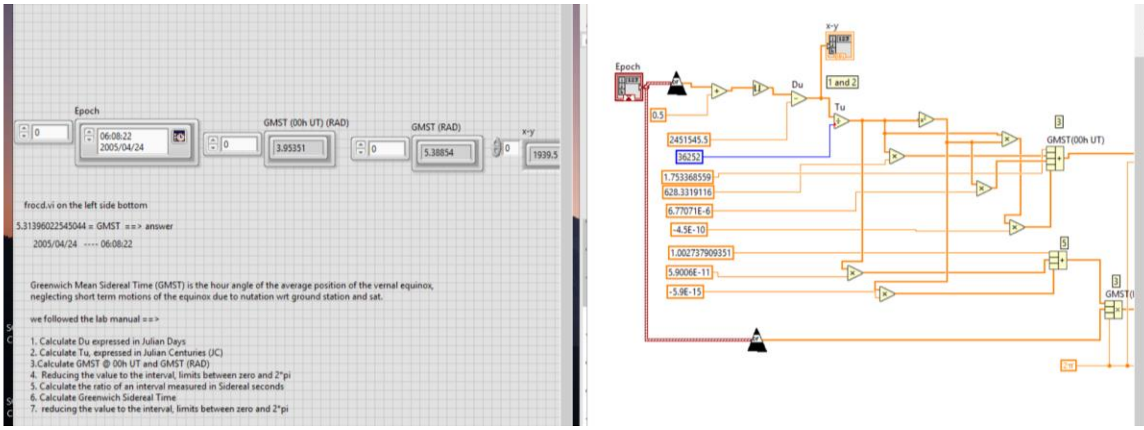


Figure 11: GMST

Implementing the date required for the mission for the test (insert the date required to obtain the Julian day) with no errors.

Code 2 ➔ (KeplerEquation)

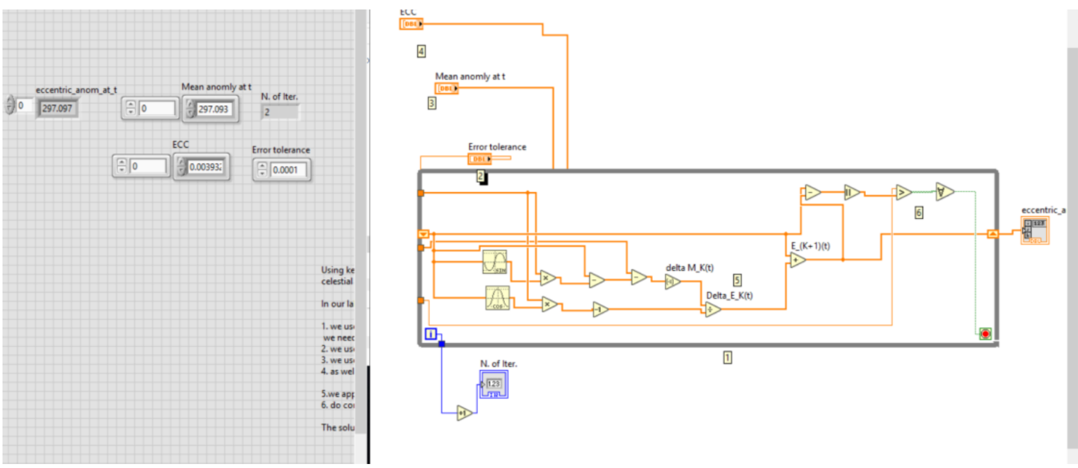


Figure 12: Kepler

Implementing the data required for the mission for the test (insert the data required from the TLE to obtain the eccentric anomaly at t) with no errors.

Code 3 ➔ (MeanAnom.Motion)

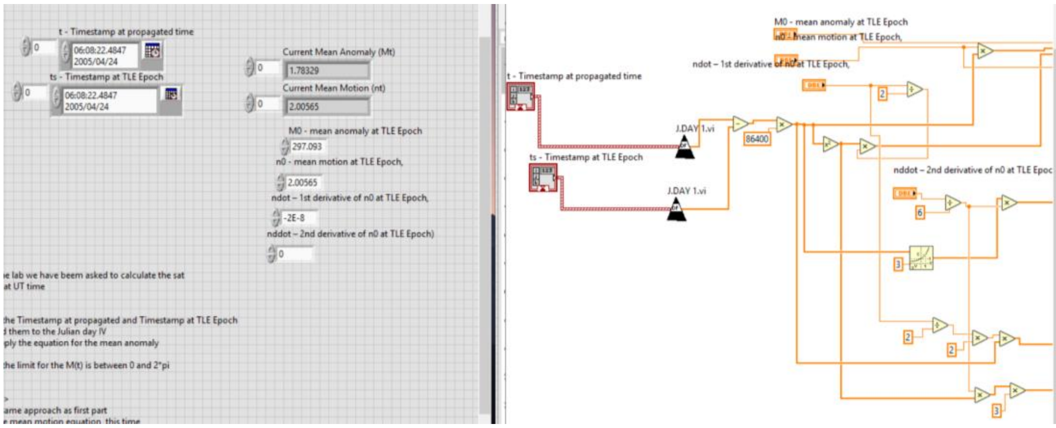


Figure 13: Mean anom. motion

Implementing the data required for the mission for the test (insert the data required from the TLE to obtain the Current mean anomaly and current mean motion at t) with no errors

Code 4 ➔ (ECF_Position)

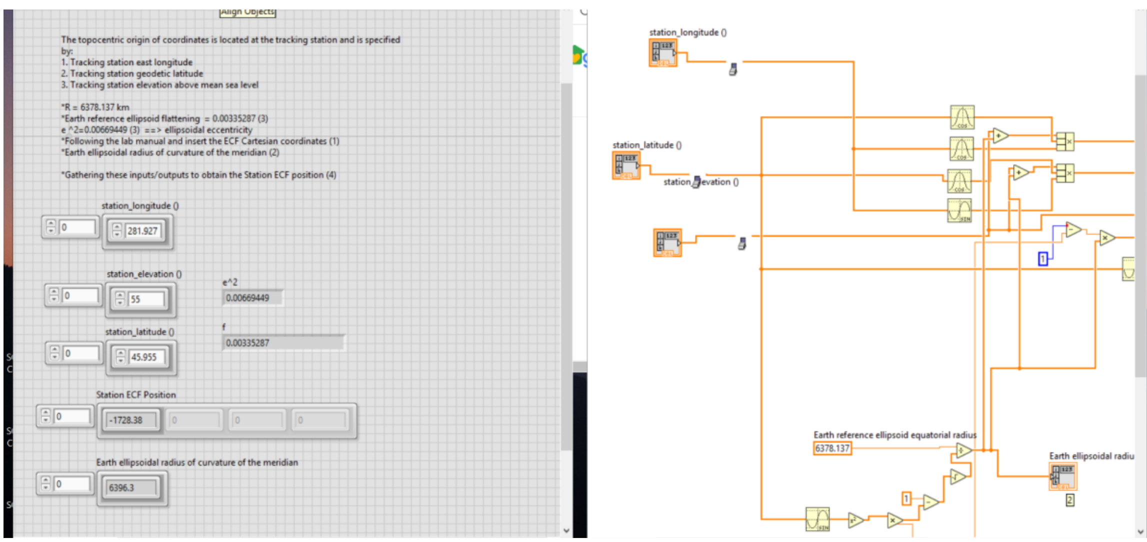


Figure 14: ECF_Position

The first **mistake** has been found is the ECF positions is in negative value, and the error occurred because the inputs were in Deg already not in Rad. So, the code does not need a converter.

Code 5 ➔ (ECI)

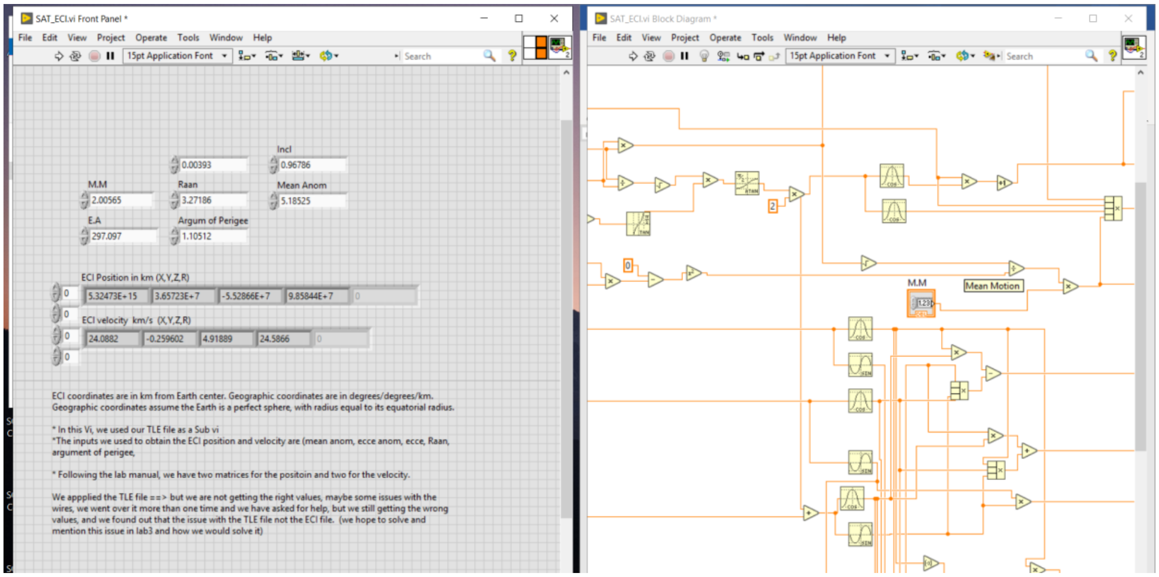


Figure 15: ECI

The second **mistake** was found is the outputs of **ECI** does not match with ProSat tester. And that means the results of the next few files would be wrong as well. This mistake might happen due to some mathematical equations in the code.

From this point we cannot proceed anymore, and the other codes have been verified already in Lab 3 and Lab 4. Has been mentioned already that there is issue with the outputs in Lab 3 and Lab 4, but we did not know where the source of the error is, but now we know where the mistake is. Since all the Codes work properly (as procedures) but does not show the right values. Therefore, the ECI needs to be fixed first so we can imply the other codes for Range topo, AZ, and EL. Since lab 2 we continued working on the other parts of the project to show how the procedures would be regardless the results.

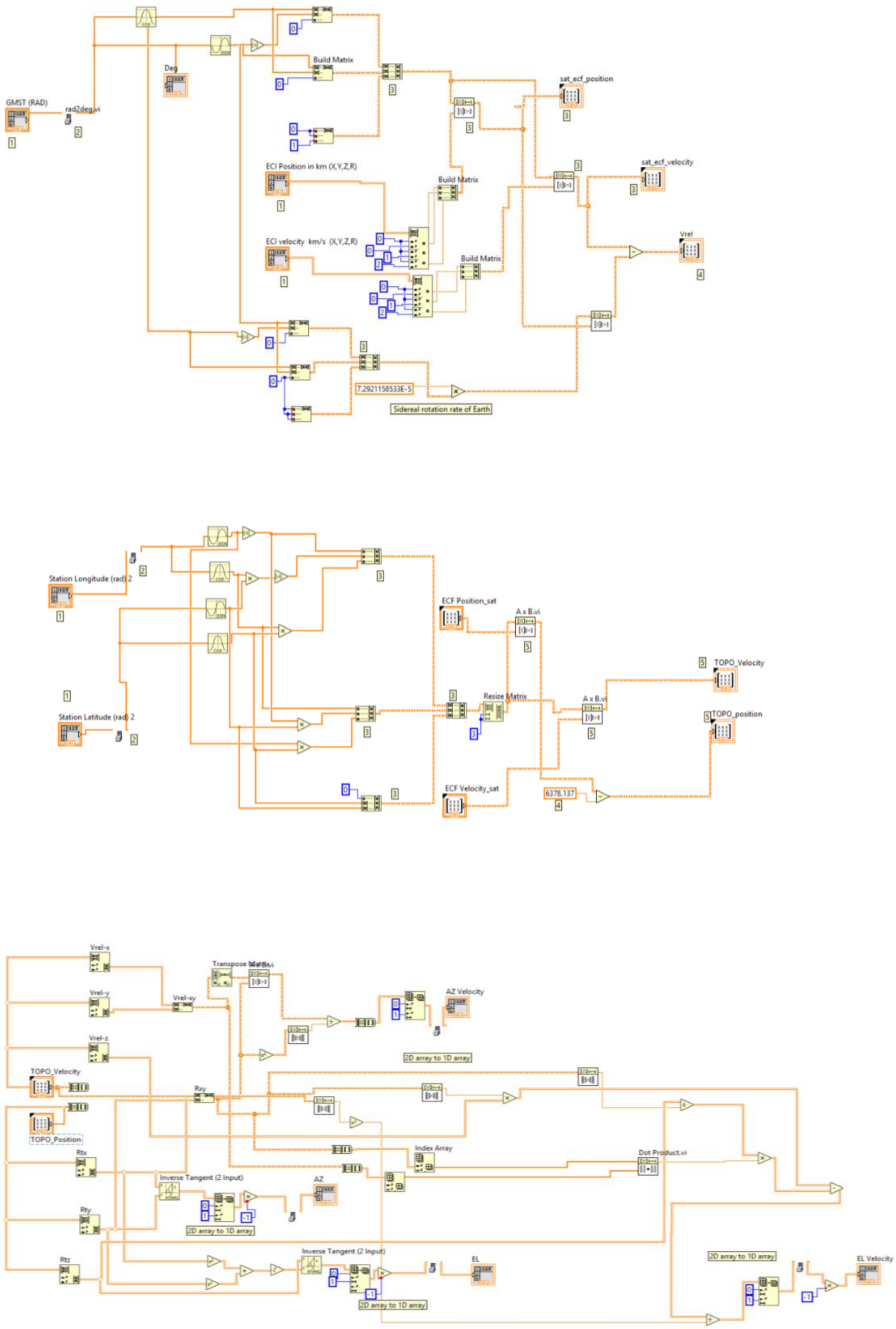
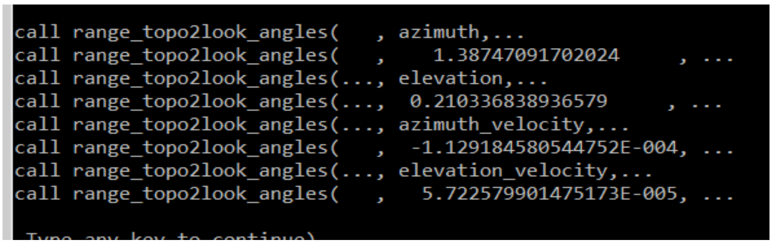
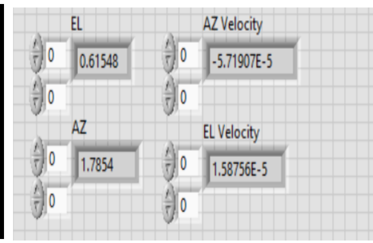


Figure 16: TOPO, AZ, EL, AZ rate and EL rate

Interestingly, when we put the right inputs from the ProSat into the inputs of the LabView such as (TOPO, Az and EL, figure 16) we obtained close values/outputs. But when we use the **TLE** file as input, it always shows error. Maybe the issue is the **Sub Vi** is not executable to do the process or maybe technical issue with LabView. As we know TLE file is working already and there is no error with the outputs.

➔ AZ/EL and AZ/EL rate (we still facing same issue, not accurate values)





STKOUT ➔

The function was outputting, this was more of small updates to make sure the file format was correct. Some small things such as correct number of decimal/stings places and the correct string format for the epoch date as well. Where we used a for loop to output a file. **Ep2dat** was used to make sure we are in the right datetime. The image below shows the code which was updated. We had an issue to display the STKOUT, but this is our results so far. We made sure that the output of STKOUT goes into a (. e) file so we can use this data and insert it into STK to make sure if our LabView results are right or wrong.

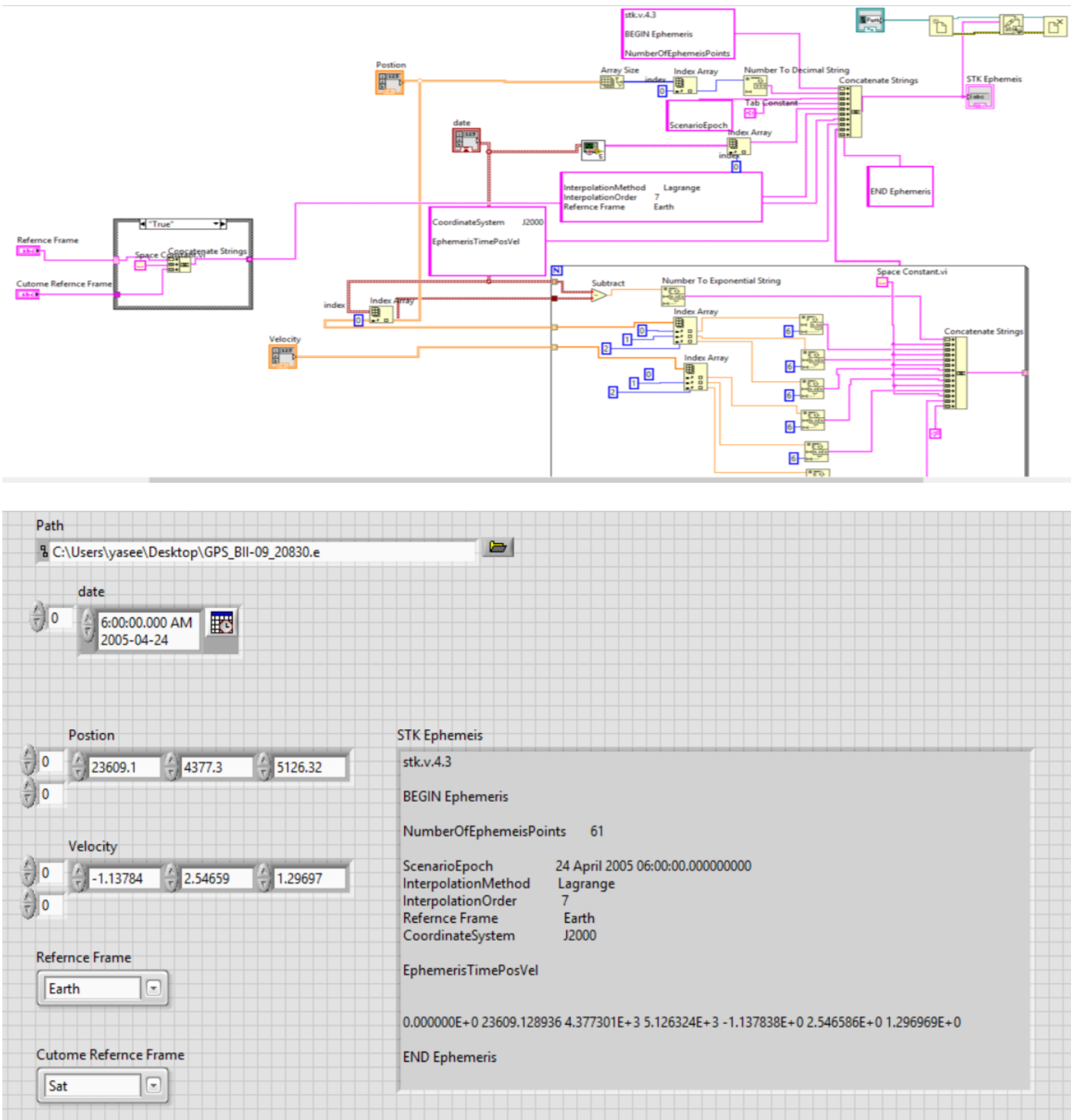


Figure 17: STKOUT

MAIN VI ➔

Our main Vi consist of three cases and one big while loop. First case contains TLE file and the station file. Second case contains the polar plot function. And third case contain the function to read the FAZEL file. This VI is under progress. Moreover, the code kept crushing, as it received a lot of data, so I had to keep running the code to receive data in the end.

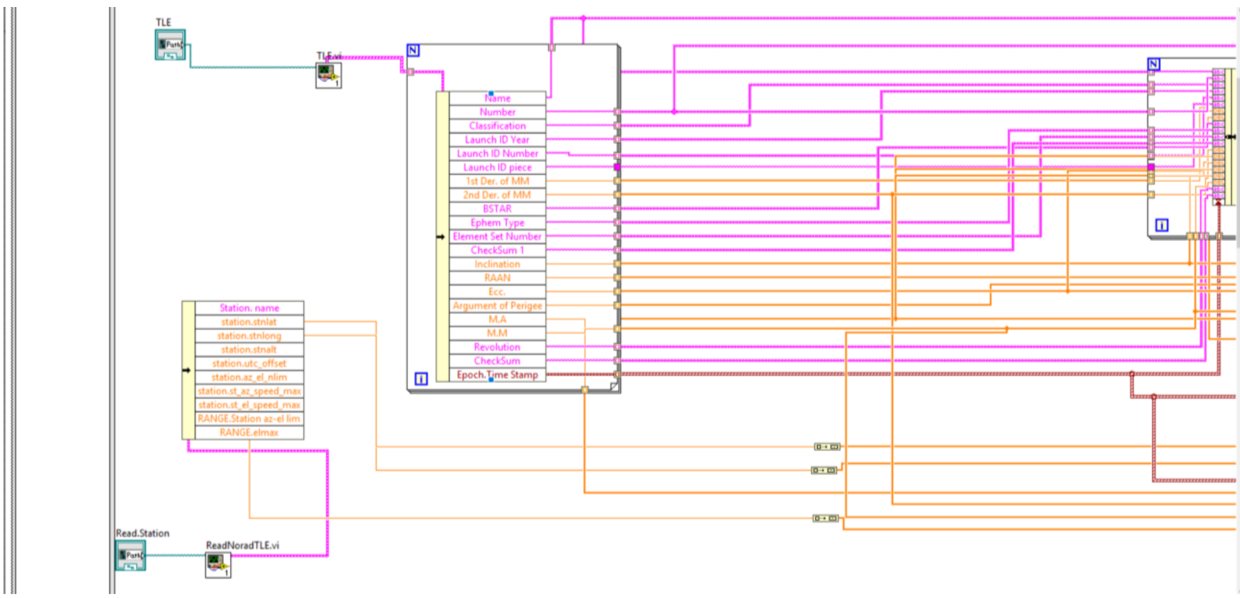


Figure 17: MAIN VI, case 1

Figure (18) shows the first case, contain the TLE file and the read station file. All the data coming out from the TLE is index.

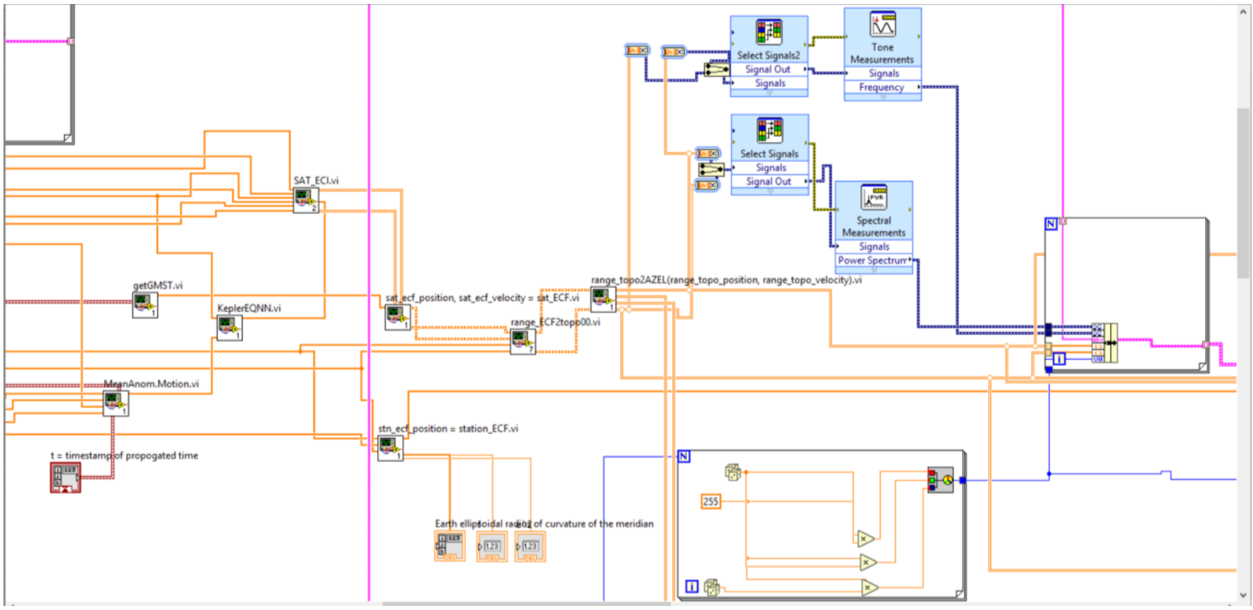


Figure 18: MAIN VI, case 2

This figure (19) shows the functions of all the sub vi from lab 2 and lab 1. Moreover, we connected the AZ and the EL to the signals generators so they can produce the frequency and the power spectrum (*we connected the signal to AZ and EL, as the antenna keep moving, so it always show signals and frequencies*). From here we can know the doppler shift and the Gain. We added the color function inside a loop. Then all these functions will be added together inside one loop to produce SAT DATA.

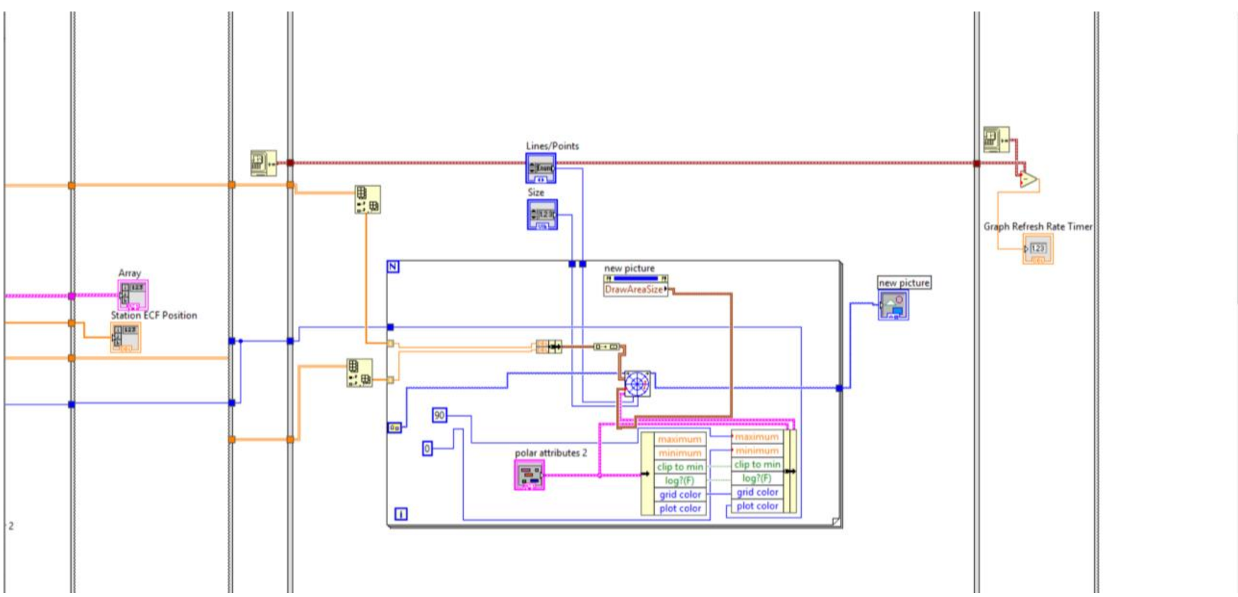


Figure 19: Main VI, polar plot

This figure (20) shows the functions to produce the AZ and EL on a polar plot. The idea behind this function is to insert the polar plot inside for loop and make sure there is MAX and MIN for the elevation from 1 deg to 89 deg. We did some changes to the arrays so it can be fit to the for loop. We combined the EL and AZ in one mixer and then directed to the polar function.

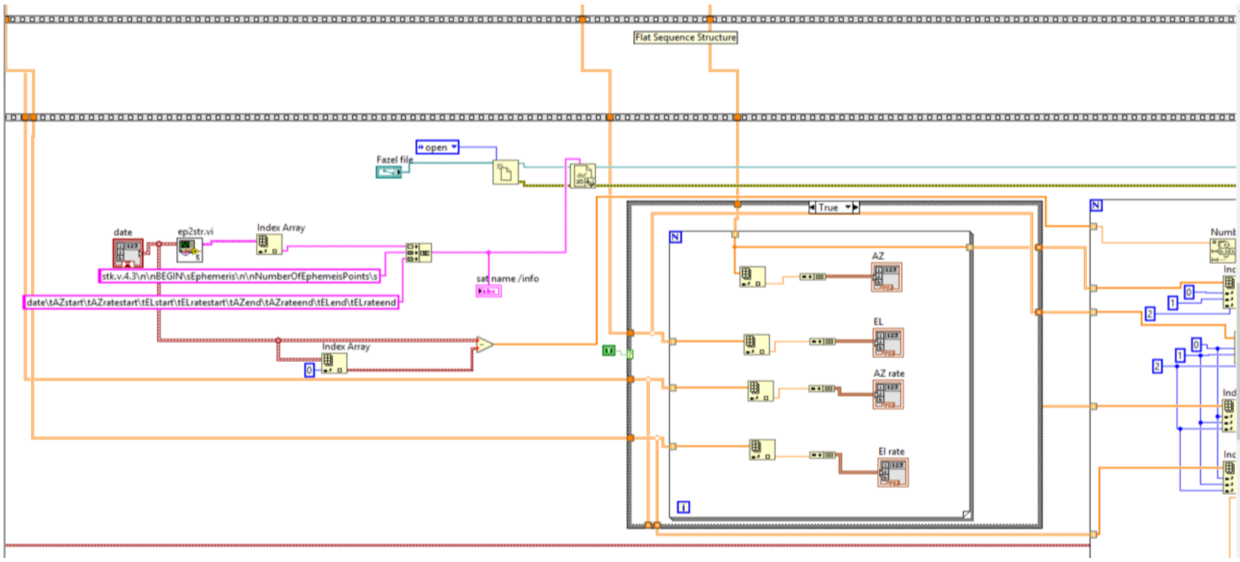


Figure 20: Main VI, FAZEL FILE

The third case is to test the FAZEL file (as we could not get work on the test day). However, we called the file, read the file and then insert it inside for loop (*calling AZ, EL, AZ rate and EL rate*)

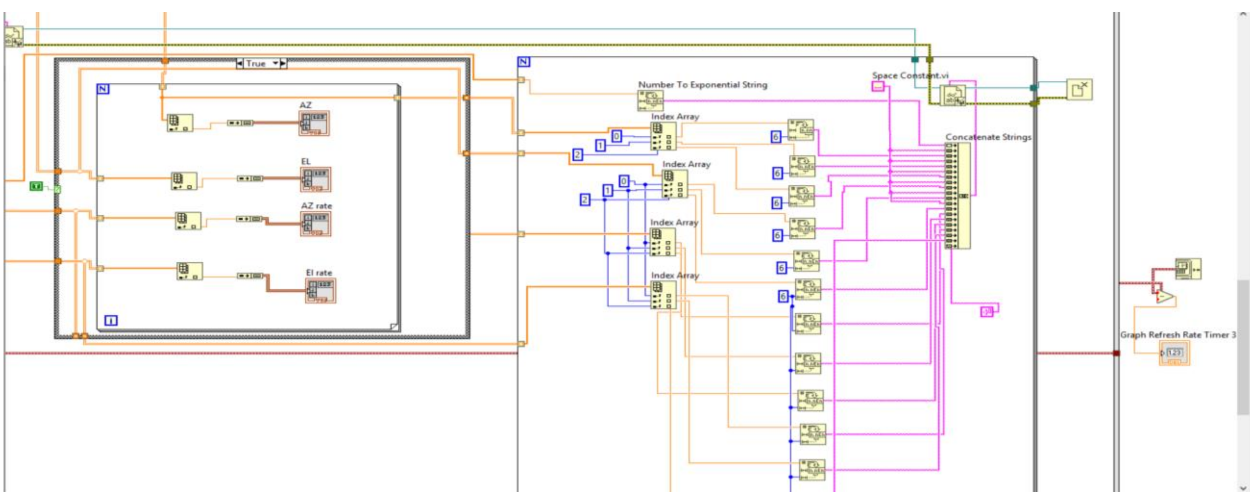


Figure 21: MAIN VI, CASE 3

The output of FAZEL file will be found as (. e) on desktop and then can be used in STK to verify LABVIEW results.

Some outputs of the Code ➔

Showing some results for SAT info, Sat data (frequency, power spectrum, polar plot, AZ and EL)

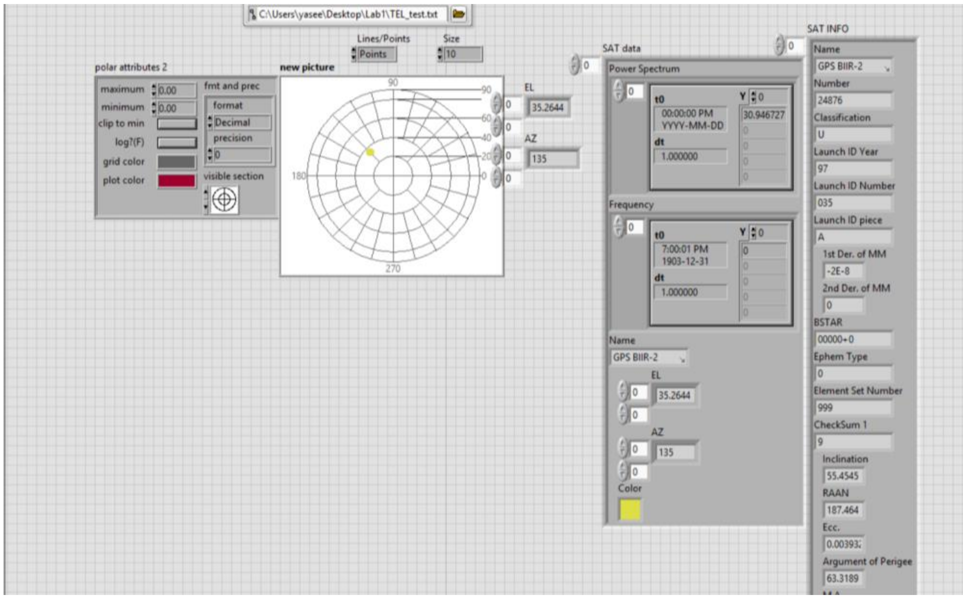


Figure 22: MAIN VI results

We used **STK** to verify the outputs from LabView as well

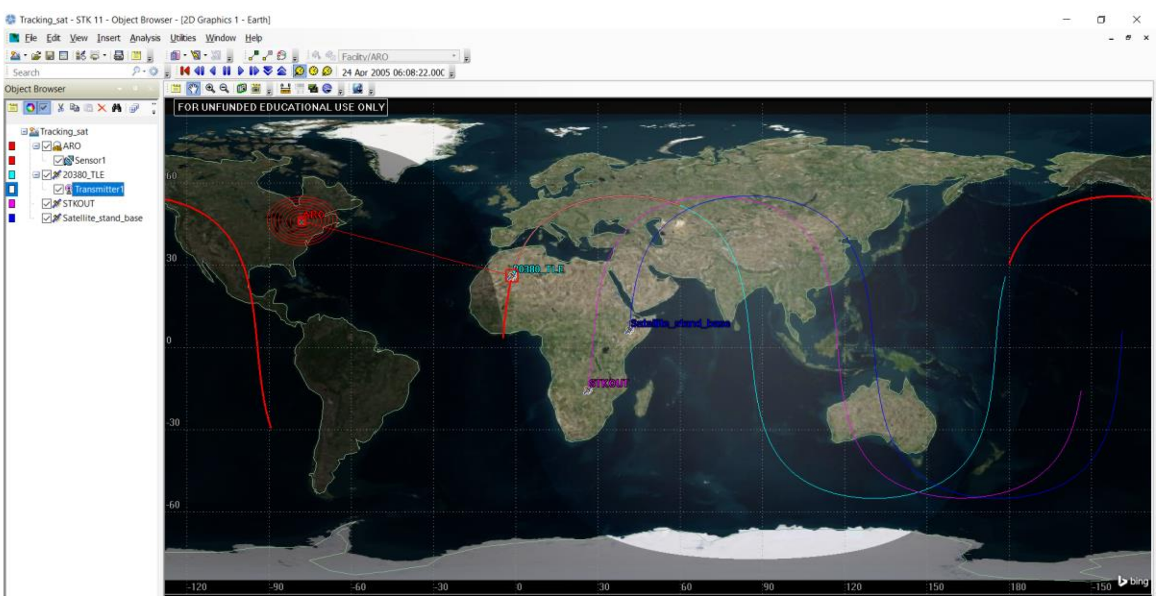


Figure 23: Showing Sat gaps

And this is was the results, all the satellites are away from 20380 the main satellite (big gap between satellites) (figure 23).

Next three results showing the different between (**20380, STKOUT and Standard Object sat**)

The AZ and El for 20380 sat

26 Apr 2020 21:44:30

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Facility-ARO-To-Satellite-20380_TLE: Inview Azimuth, Elevation, & Range

ARO-To-20380_TLE - AER reported in the object's default AER frame

Time (UTCG)	Azimuth (deg)	Elevation (deg)	Range (km)
24 Apr 2005 06:08:22.000	79.788	13.804	24370.985904
24 Apr 2005 06:09:22.000	79.390	13.992	24349.982257
24 Apr 2005 06:10:22.000	78.990	14.177	24329.291256
24 Apr 2005 06:11:22.000	78.589	14.360	24308.916797
24 Apr 2005 06:12:22.000	78.186	14.539	24288.862747
24 Apr 2005 06:13:22.000	77.780	14.715	24269.132924
24 Apr 2005 06:14:22.000	77.374	14.889	24249.731103
24 Apr 2005 06:15:22.000	76.965	15.059	24230.661027
24 Apr 2005 06:16:22.000	76.555	15.226	24211.926385
24 Apr 2005 06:17:22.000	76.144	15.390	24193.530827
24 Apr 2005 06:18:22.000	75.730	15.551	24175.477958
24 Apr 2005 06:19:22.000	75.315	15.709	24157.771336
24 Apr 2005 06:20:22.000	74.899	15.863	24140.414470
24 Apr 2005 06:21:22.000	74.481	16.014	24123.410822
24 Apr 2005 06:22:22.000	74.061	16.162	24106.763803
24 Apr 2005 06:23:22.000	73.640	16.306	24090.476774
24 Apr 2005 06:24:22.000	73.217	16.447	24074.553048
24 Apr 2005 06:25:22.000	72.793	16.584	24058.995886
24 Apr 2005 06:26:22.000	72.368	16.717	24043.808487
24 Apr 2005 06:27:22.000	71.941	16.847	24028.994004
24 Apr 2005 06:28:22.000	71.513	16.973	24014.555534
24 Apr 2005 06:29:22.000	71.084	17.096	24000.496113
24 Apr 2005 06:30:22.000	70.653	17.215	23986.818730
24 Apr 2005 06:31:22.000	70.221	17.330	23973.526306
24 Apr 2005 06:32:22.000	69.788	17.441	23960.621705
24 Apr 2005 06:33:22.000	69.354	17.548	23948.107736
24 Apr 2005 06:34:22.000	68.919	17.652	23935.987144

The AZ and EL for STKout sat

26 Apr 2020 21:45:38

FOR UNFUNDED EDUCATIONAL USE ONLY
Facility-ARO-To-Satellite-STKOUT: Inview Azimuth, Elevation, & Range

ARO-To-STKOUT - AER reported in the object's default AER frame

Time (UTCG)	Azimuth (deg)	Elevation (deg)	Range (km)
24 Apr 2005 08:44:57.593	39.435	1.004	25796.596883
24 Apr 2005 08:45:57.000	39.069	1.094	25787.436172
24 Apr 2005 08:46:57.000	38.699	1.182	25778.533809
24 Apr 2005 08:47:57.000	38.328	1.266	25769.984999
24 Apr 2005 08:48:57.000	37.957	1.348	25761.791675
24 Apr 2005 08:49:57.000	37.586	1.426	25753.955712
24 Apr 2005 08:50:57.000	37.214	1.500	25746.478927
24 Apr 2005 08:51:57.000	36.842	1.572	25739.363078
24 Apr 2005 08:52:57.000	36.469	1.640	25732.609864
24 Apr 2005 08:53:57.000	36.096	1.704	25726.220926
24 Apr 2005 08:54:57.000	35.723	1.765	25720.197842
24 Apr 2005 08:55:57.000	35.350	1.823	25714.542133
24 Apr 2005 08:56:57.000	34.976	1.878	25709.255257
24 Apr 2005 08:57:57.000	34.602	1.929	25704.338613
24 Apr 2005 08:58:57.000	34.228	1.976	25699.793533
24 Apr 2005 08:59:57.000	33.854	2.020	25695.621294
24 Apr 2005 09:00:57.000	33.480	2.061	25691.823106
24 Apr 2005 09:01:57.000	33.106	2.098	25688.400118
24 Apr 2005 09:02:57.000	32.732	2.132	25685.353417
24 Apr 2005 09:03:57.000	32.358	2.162	25682.684024
24 Apr 2005 09:04:57.000	31.983	2.189	25680.392899

The AZ and EL for standard object sat

26 Apr 2020 21:46:35

FOR UNFUNDED EDUCATIONAL USE ONLY
Facility-ARO-To-Satellite-Satellite_stand_base: Inview Azimuth, Elevation, & Range

ARO-To-Satellite_stand_base - AER reported in the object's default AER frame

Time (UTCG)	Azimuth (deg)	Elevation (deg)	Range (km)
24 Apr 2005 17:47:37.868	247.439	4.722	25398.345479
24 Apr 2005 17:48:37.000	247.685	5.058	25362.532202
24 Apr 2005 17:49:37.000	247.935	5.398	25326.244106
24 Apr 2005 17:50:37.000	248.187	5.740	25290.008485
24 Apr 2005 17:51:37.000	248.439	6.081	25253.826417
24 Apr 2005 17:52:37.000	248.693	6.422	25217.698974
24 Apr 2005 17:53:37.000	248.947	6.764	25181.627217
24 Apr 2005 17:54:37.000	249.203	7.105	25145.612200
24 Apr 2005 17:55:37.000	249.459	7.447	25109.654969
24 Apr 2005 17:56:37.000	249.717	7.789	25073.756564
24 Apr 2005 17:57:37.000	249.975	8.131	25037.918013
24 Apr 2005 17:58:37.000	250.235	8.473	25002.140339
24 Apr 2005 17:59:37.000	250.496	8.815	24966.424555
24 Apr 2005 18:00:37.000	250.757	9.157	24930.771669
24 Apr 2005 18:01:37.000	251.020	9.500	24895.182681
24 Apr 2005 18:02:37.000	251.284	9.842	24859.658581
24 Apr 2005 18:03:37.000	251.548	10.185	24824.200353
24 Apr 2005 18:04:37.000	251.814	10.528	24788.808974
24 Apr 2005 18:05:37.000	252.080	10.871	24753.485413
24 Apr 2005 18:06:37.000	252.348	11.214	24718.230634
24 Apr 2005 18:07:37.000	252.617	11.558	24683.045591
24 Apr 2005 18:08:37.000	252.886	11.901	24647.931232
24 Apr 2005 18:09:37.000	253.157	12.245	24612.888498
24 Apr 2005 18:10:37.000	253.428	12.588	24577.918325
24 Apr 2005 18:11:37.000	253.701	12.932	24543.021640
24 Apr 2005 18:12:37.000	253.974	13.276	24508.199365
24 Apr 2005 18:13:37.000	254.248	13.621	24473.452415

Link budget (R, f, RcvGain, System Gain)

This function was made to receive the value of the receiver's signal. Ideally, we would need to calculate a complete link budget. We utilized the following formula to calculate the receiver's link power:

$$C = \overbrace{PL_1G_t}^{EIRP}\ \overbrace{L_s}^{L_s=\left(\frac{c}{4\pi Rf}\right)^2}\ \overbrace{G_r}^{G_r=\frac{\pi^2 f^2 D_r^2 \eta}{c^2}}\ \overbrace{G_s}^{\text{System Gain}}$$

Here we use the receiver's EIRP, the free space loss, the receiver gain, and the system gain. The system gain is unknown at this point of time and will be calibrates as one of the first activities at Petrie Ground Station; but for simplicity sake just so nothing will be affected we set it at 0 dB which is obviously not correct, but it chose it as an arbitrary value. The receiver gain is provided by the station file and the EIRP is taken from STK and was calculated. The only thing we do not know is the free space loss, but it can be calculated using the formula listed. All the given parameters are either known or taken from the calculated values. To make all this easier we created this Received link function to calculate the link budget. The key thing to note is that the R listed in the equation given is the topocentric. Since we calculate this value it is outputted as a vector/matrix, so we simply take the average of it and use it for the loss calculations. (meanwhile we used function made by LabView to calculate the link budget, see figure 24). In LabView, there is two functions could be used to find the power spectrum and the doppler shift, these values will help us to find the link budget. See in next figure.

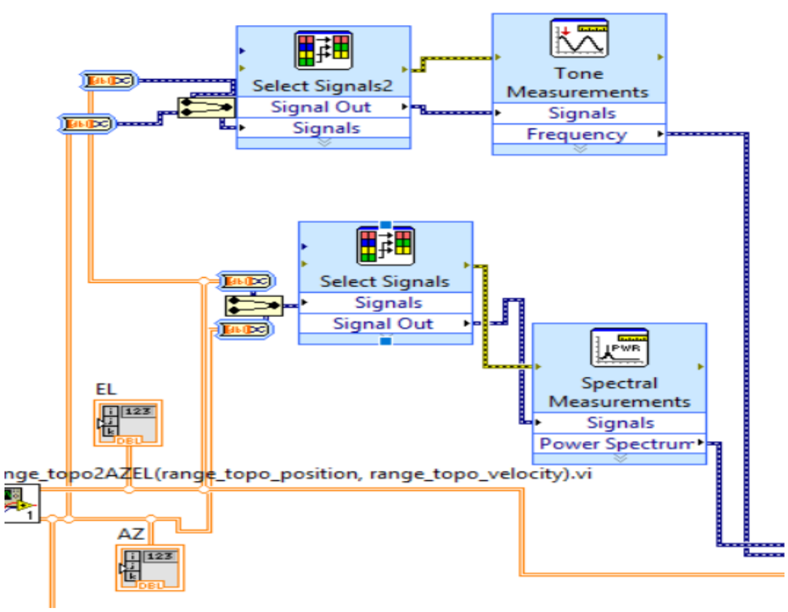

Figure 24: doppler and frequency

Link Budget. In satellite communication systems, there are two types of power calculations. Those are transmitting power and receiving power calculations. In general, these calculations are called as Link budget calculations. This function is simply done by reading the link file specified for the Petrie Ground Station and the specifications were given in the software specifications. We will make this by simply using the same procedure as we did with the station file. We created a file which stores all the parameters shown in the Link text file stored. We succeed to do that on STK as seen in figure (25, 26)

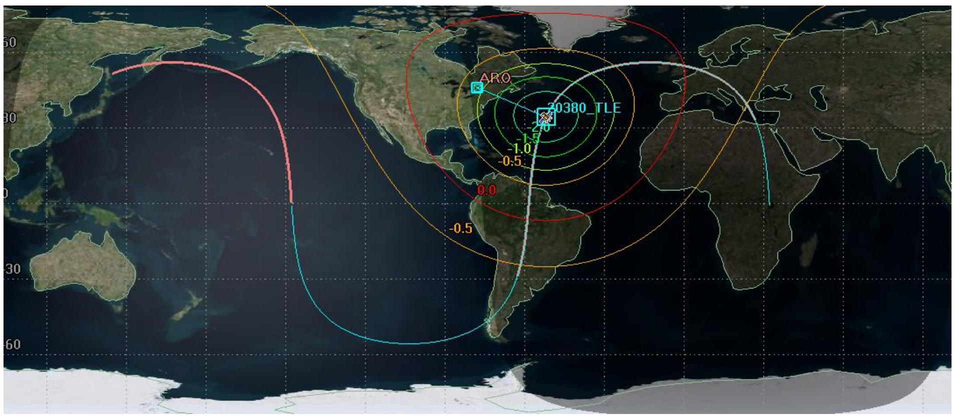

Figure 25: Transmission

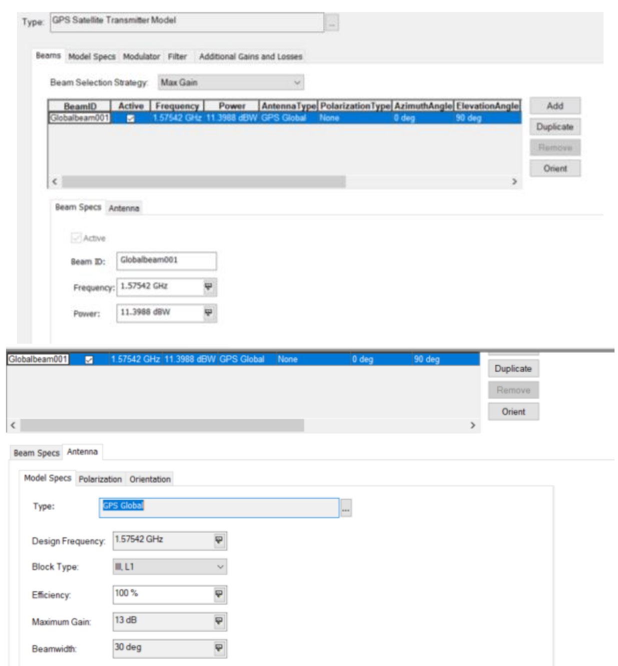

Figure 26: Transmission inputs

Link verification:

The link budget calculated using the receiver carrier power formula listed above in STK and see if it matches with the one calculated by our functions in LABVIEW. We compared the free space loss and the carrier power value in dBm with STK. the carrier power level in dBm were found to be **-30.223** in LabView (figure 22)

This is the STK verification:

Free Space Loss (dB)	Freq. Doppler Shift (GHz)	Rcvd. Iso. Power (dBm)	Rcvr Gain (dB)	Carrier Power at Rcvr Input (dBm)
184.2367	0.000	-128.119	54.5993	-73.520
184.2263	0.000	-128.102	54.5993	-73.503
184.2160	0.000	-128.086	54.5993	-73.486

They are not the same at that instance, but they are within reason, and assuring us the calculations are being done correctly.

Visibility Verification:

These are the access times found using STK and are used to verify the visibility made in STK to compute the AOS and LOS times. The first row is the AOS time and the second is the LOS time.

Access	Start Time (EpSec)	Stop Time (EpSec)	Duration (sec)
1	32004.208	41464.370	9460.162
2	62275.093	80062.028	17786.935
3	118157.337	127618.409	9461.072
4	148428.731	166215.204	17786.473

<u>STK Verification</u>

Orbit Verification:

We imported all the ephemeris files in the STK once again to see if we can match the expected orbit from the TLE file. The bad news was that they did not match. Due to some issued in LabView calculations, as we could not find where is the major issue so far.

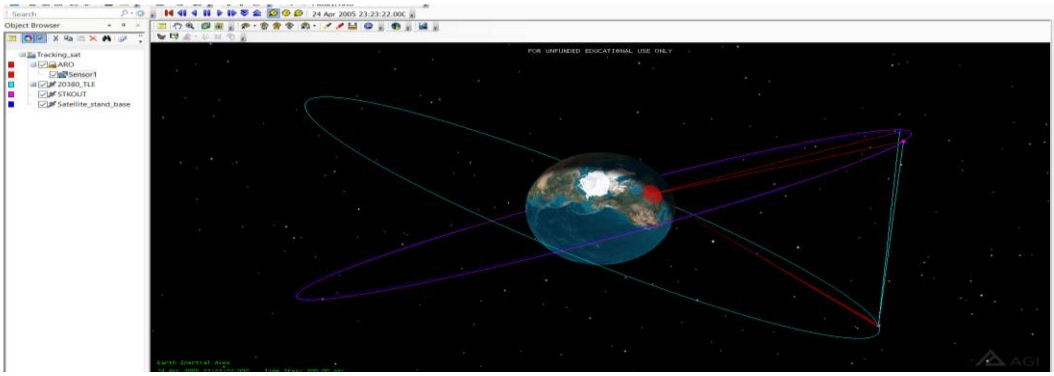

Figure 27: STK verifications

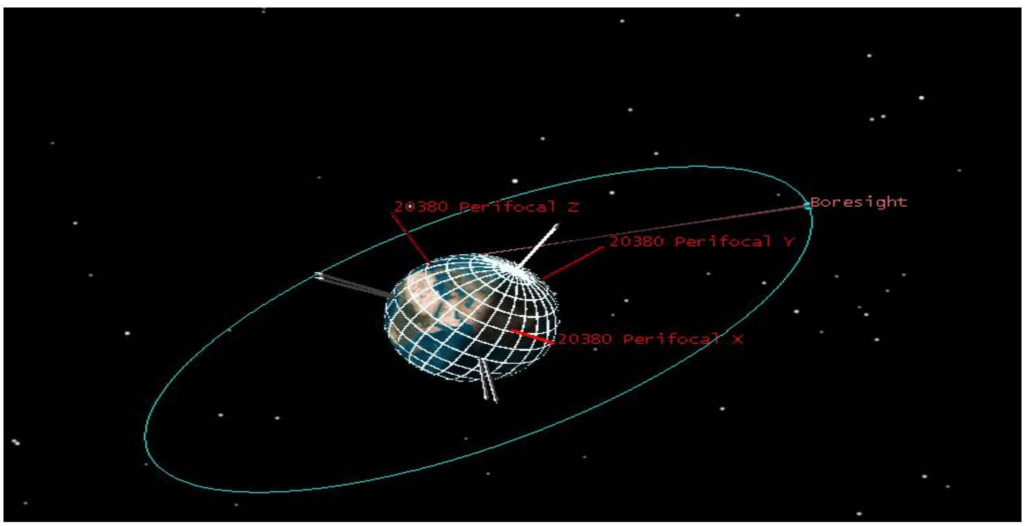

Figure 28: TOPO

After looking to this figure (27), the issued we had maybe because of the wrong **inclination** for our STK out and the standard object satellite. However, we imported the topocentric coordinate in the STK to view the orbit and this is the result we got, figure (27). The orbit is not correct as expected since it was verified with the STK Test model we had done

There was may be several reasons why this orbit is incorrect. We feel there must have been an issue with the LabVIEW since all the calculation take place over there. Moreover, there is also an equivalent possibility that the error may have occurred in STK

Debug Process➔

We used the same TLE used during the test to conduct this debugging process

Initially when we noticed the error the first thing was that we compared the look angles as that is what determined the AOS/LOS times. As mentioned in our lab P1 – P5 reports we used PRN – 20380 to test this out and it did not give us similar results to our peers. We compared the results to Joseph and Arial group as their code was functional and had gotten the correct values. Thus, is part did not lead to a positive result.

Next, we moved on the to all the coordinates in different coordinates system. First, we checked the perifocal ephemeris files. We did not find a proper match because we imported it into STK and did not matched. Then we followed the chain all the way until the topocentric coordinates. It is worth noting that for PRN- 20380 all coordinates did not match. So, then we decided to test using ephemeris files used another satellite to see if the issue with ephemeris file or the LabView Outputs. But as mentioned before, the whole issue was relating to the **ECI.**

The satellite chosen was **PRN-20380** so we compared the ephemeris files and found no match from ECI onwards. First, we investigated the LabView package as all the calculation which would be led to any sort of errors are done there. I revised the LabView functions and found mistakes in **ECI**.

Continuing the debugging process, we then outputted the ephemeris files and compared my output files to Josephs' group. Then I continued with the ECI, I modified code in ways which would do the same thing but in a different way to see how the response would be. However, I got different results when I implement the data in STKOUT. As seen in the next two result ➔

```
BEGIN Ephemeris

NumberOfEphemerisPoints   60

ScenarioEpoch            24 Apr 2005 06:08:22.222
InterpolationMethod      Lagrange
InterpolationOrder       7
CentralBody              Earth
CoordinateSystem         Custom CentralBody/Earth

EphemerisTimePosVel

2.75516731873000E+05 -1.60418020878801E+07 1.98392964134321E+07 7.19389036118810E+06 -2.32566586544440E+03 -6.81051821559418E+02 -3.03214802173222E+03
2.75576731873000E+05 -1.61807246421711E+07 1.97976647313762E+07 7.01169599872213E+06 -2.30498578215289E+03 -7.06491058927367E+02 -3.04126486044676E+03
2.75636731873000E+05 -1.63184014159042E+07 1.97545087199054E+07 6.82896181541609E+06 -2.28413877130701E+03 -7.31862971671045E+02 -3.05014298127413E+03
2.75696731873000E+05 -1.64548224484574E+07 1.97098324752557E+07 6.64570214475037E+06 -2.26312661616599E+03 -7.57165664268800E+02 -3.05878193967257E+03
2.75756731873000E+05 -1.65899778889951E+07 1.96636402061638E+07 6.46193134276274E+06 -2.24195110897155E+03 -7.82397250971116E+02 -3.06718131098578E+03
2.75816731873000E+05 -1.67238579870633E+07 1.96159362367411E+07 6.27766380044828E+06 -2.22061405232685E+03 -8.07555854059052E+02 -3.07534068978297E+03
2.75876731873000E+05 -1.68564531274903E+07 1.95667249934448E+07 6.09291389503849E+06 -2.19911725349257E+03 -8.32639610438195E+02 -3.08325969188962E+03
2.75936731873000E+05 -1.69877538214261E+07 1.95160110062009E+07 5.90769599996659E+06 -2.17746252540126E+03 -8.57646670114058E+02 -3.09093795362314E+03
2.75996731873000E+05 -1.71177506018264E+07 1.94637989494042E+07 5.72202463303895E+06 -2.15565170398371E+03 -8.82575176215334E+02 -3.09837512568529E+03
2.76056731873000E+05 -1.72464341417850E+07 1.94100935980428E+07 5.53591429159097E+06 -2.13368662896189E+03 -9.07423287359402E+02 -3.10557088018512E+03
2.76116731873000E+05 -1.73737952221942E+07 1.93548998393016E+07 5.34937949709552E+06 -2.11156914899036E+03 -9.32189171549817E+02 -3.11252490862660E+03
```

```
BEGIN Ephemeris

NumberOfEphemerisPoints   60

ScenarioEpoch            24 Apr 2005 06:08:22.222
InterpolationMethod      Lagrange
InterpolationOrder       7
CentralBody              Earth
CoordinateSystem         Custom CentralBody/Earth

EphemerisTimePosVel

2.81119510080000E+05 -3.53659082876167E+06 -1.62867021911990E+07 2.03443651836246E+07 3.72917118976874E+03 5.02674546039172E+02 1.07046706397282E+03
2.81179510080000E+05 -3.31270959944494E+06 -1.62559031815782E+07 2.04077862936971E+07 3.73367313728924E+03 5.24067251492482E+02 1.04367979709635E+03
2.81239510080000E+05 -3.08856722964511E+06 -1.62238218951274E+07 2.04695978425232E+07 3.73788012678496E+03 5.45416331299673E+02 1.01681310057133E+03
2.81299510080000E+05 -2.86418139649515E+06 -1.61904609976460E+07 2.05297951394958E+07 3.74179188150086E+03 5.66720064425307E+02 9.89869169110122E+02
2.81359510080000E+05 -2.63957029561928E+06 -1.61558233364949E+07 2.05883734959950E+07 3.74540814222473E+03 5.87976686946601E+02 9.62850263594833E+02
2.81419510080000E+05 -2.41475114839876E+06 -1.61199117118578E+07 2.06453286166967E+07 3.74872869166764E+03 6.09184533414130E+02 9.35758531535317E+02
2.81479510080000E+05 -2.18974149136391E+06 -1.60827290660651E+07 2.07006562504157E+07 3.75175333139640E+03 6.30341914324803E+02 9.08596161782760E+02
2.81539510080000E+05 -1.96455990601118E+06 -1.60442786185528E+07 2.07543520300295E+07 3.75448187546593E+03 6.51447048309876E+02 8.81365473157237E+02
2.81599510080000E+05 -1.73922321242692E+06 -1.60045633918722E+07 2.08064121487686E+07 3.75691418567778E+03 6.72498325455371E+02 8.54068575240056E+02
2.81659510080000E+05 -1.51374912409845E+06 -1.59635866528025E+07 2.08568327106180E+07 3.75905013644927E+03 6.93494057833142E+02 8.26707688927967E+02
```

The inclination, Raan and the argument of perigee were all correct from the TLE file, but some issues were found in the eccentric anomaly and mean motion. This was simply due to formatting error in the File I/O library. So, we completely overlooked this for the TLE used. The issue was the it was not reading the angle correctly from the TLE. The function was reading 1.921 deg where it was supposed to read 192.1 deg. Thus, the corrections were made.

Conclusion

In conclusion, this course was a great learning experience for me as we got valuable knowledge in LabView and STK. We learned different types of integrating techniques which would be beneficial for future application. Additionally, I worked with a great colleague where the colleague's dynamic was very easy going which led to understand the concept of the project. Although I was discouraged that my partner left me since lab 1 as I did not get the opportunity to get the software ready to go on the test day.

The objectives defined for this lab were not fully met but the amount of knowledge I acquired was satisfying. I was able to complete the full software but due to several silly errors described in this lab report, resulted in the set-back. Along with the coding portion, we applied concepts from all 3 units over this course. Concepts such as convolution from the analog section, bit rate form the digital section and HPBW from the RF section were deemed useful.

How did the change from the ARO to the Petrie Ground Station effect the activity?
Moreover, changing the place from ARO to Petrie Ground Station effects on the results in somehow. ARO has big antenna and the facility has more options and accessibilities for the users to obtain the values in easy way.

My next course of action would be to make this code word, make it much more user-friendly and make it in a GUI application. This course and the test day were very enjoyable and a fantastic learning experience.

This is the list of all the functions in the track project and the distribution of work.

Software (LAB1)	Function name	Author
LabView	Curday	Yaseen 100%
	Ep2str	Yaseen 50% & Andrew 50%
	frcofd	Yaseen 50% & Andrew 50%
	readstatoin	Yaseen 100%
	doy	Yaseen 50% & Andrew 50%
	epsdat	Yaseen 50% & Andrew 50%
	Julian.day	Yaseen 50% & Andrew 50%
	TLE	Yaseen 100%

Software (LAB2)	Function name	Author
LabView	ECI	Yaseen 70% & Andrew 30%
	Rad2deg	Yaseen 100%
	getGMST	Yaseen 100%
	KeplerEq	Yaseen 100%
	Mean.Anom.motion	Yaseen 100%
	range_ECF2topo	Yaseen 100%
	range_topo2AZEL(range_topo_position, range_topo_velocity)	Yaseen 100%
	sat_ecf_position, sat_ecf_velocity = sat_ECF	Yaseen 100%
	STKOUT	Yaseen 70% & Andrew 30%
	stn_ecf_position = station_ECF	Yaseen 100%

Software (LAB1, LAB2, LAB3, LAB4 and LAB5)	Function name	Author
STK	Testing	Yaseen (70%) & Andrew (30%)

Software (LAB5)	Function name	Author
LABVIEW	Main.VI	Yaseen 100%

Write-up (LAB1, LAB2, LAB3, LAB4 and LAB5) + Demonstration day	Author
	Yaseen 100%

Total percentage of each Lab in total ➔

	Group Member 1: Yaseen Al-Taie		Group Member 2: Andrew Persaud	
Activity	Software Development/STK	Report Content	Software Development/STK	Report Content
P1	68.75%		31.25%	
P2	94%		6%	
P3	100%		0%	
P4	100%		0%	
P5	100%		0%	
Demonstration	100%		0%	

YAS.	***AND.***
Signature Group Member 1	Signature Group Member 2