Alt Az from Right Ascension and Declination. (<http://www.stargazing.net/kepler/altaz.html>, practical astronomy with your computer, foundation of celestial mechanics)

Right ascension (RA) and declination (Dec) is an Earth centered celestial coordinate system which is independent of the viewer’s current time and location. The declination of a celestial object is the angle between two lines, one from the center of the Earth to the equator and the other from the center of the Earth to the object. Right ascension is analogous to longitude. It is measured from the vernal equinox–the point in the sky where the sun crosses the celestial equator from South to North–and increases eastward (Foundation of Celestial Mechanics, Collins). RA/Dec is important because it is the most common method of listing the coordinates of celestial objects. Converting these coordinates to Alt/Az is necessary for them to be useful to an observer.

The information required to convert from RA/Dec to Alt/Az is: right ascension (RA) and declination (Dec) of the object, latitude (lat) and longitude (long) of the observer, and the time and date of observation.

The first step is to find the decimal number of days elapsed from the reference date (fundamental epoch) of the RA/Dec coordinates used, usually J2000. The process is:

1. find the observation time in universal time (UT)
2. convert the observation time to a decimal number of days.
3. Lookup the number of days to the beginning of the month.

|  |  |  |
| --- | --- | --- |
| Month | Normal Year | Leap Year |
| January | 0 | 0 |
| Febuary | 31 | 31 |
| March | 59 | 60 |
| April | 90 | 91 |
| May | 120 | 121 |
| June | 151 | 152 |
| July | 181 | 182 |
| August | 212 | 213 |
| September | 243 | 244 |
| October | 274 | 274 |
| November | 304 | 305 |
| December | 334 | 335 |

1. Lookup the number of days from J2000 to the beginning of the year.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Year | Days | Year | Days | Year | Days |
| 2018 | 6573.5 | 2024 | 8764.5 | 2030 | 10956.5 |
| 2019 | 6938.5 | 2025 | 9130.5 | 2031 | 11321.5 |
| 2020 | 7303.5 | 2026 | 9495.5 | 2032 | 11686.5 |
| 2021 | 7669.5 | 2027 | 9860.5 | 2033 | 12052.5 |
| 2022 | 8034.5 | 2028 | 10225.5 | 2034 | 12417.5 |
| 2023 | 8399.5 | 2029 | 10591.5 | 2035 | 12782.5 |

The next step is to find the local sidereal time (LST). Sidereal time references the stars instead of the Sun and thus only tracks the rotation of the Earth and not the orbit of the Earth around the sun. A sidereal day is about 4 minutes shorter than a solar day. LST can be approximated by the following formula (http://www.stargazing.net/kepler/altaz.html#twig07):

This results in the local sidereal time in degrees to an accuracy of ~0.3 seconds.

Next, hour angle (HA) in degrees is calculated from LST and RA to account for the rotation of the Earth:

Finally, Altitude (Alt) and Azimuth (Az) can be calculated:

Gudgel Results –

Mr. Gudgel had three primary factors he tested: slew rate, repeatability, and point rotation.

Slew rate –

Mr. Gudgel’s system was built around positioning only and did not include the ability to control slew rate. Only when changing motor supply voltage did his slew rate change. Although his motors were rated for 24V, he tested for the slew rate at 15V. At this voltage his slew rate was ~0.70 degrees / second which (Did or did not meet his requirements)

Repeatability –

To test repeatability, Mr. Gudgel used an optical system with static test images spaced across its field of view. He manually aimed the telescope at each test image, noted the resulting altitude and azimuth angles, and then took a photo of the target image. He then commanded the telescope to return to those angles, and took a second photo. Overlaying these two images allowed him to find an error distance and error angle.

The results of this test were less than satisfactory. Among the five test images he used, he had error distance ranging from 0.5 cm to 2.8 cm and error angle ranging from 0.04 degrees to 0.26 degrees.

Point rotation –

To test image rotation, Mr. Gudgel aimed the telescope at one of the static test images used for the repeatability testing and took a series of photos with the altitude and azimuth angles held constant while varying the image rotation angle. He compared the photo of image rotation = 0 degrees to each other commanded rotation which allowed him to test actual image rotation angle vs commanded angle.

Overall-

Overall, Mr. Gudgel felt the system showed that it could theoretically be capable of meeting the goals he set but that the system as implemented did not. He attributed this primarily to compounding tolerances in manufacturing the hardware. He felt that with better manufacturing processes and tighter tolerances the system could be used for celestial observation as desired.