Mounts and Coordinate Systems

Part 3: Some Advanced Techniques For Mounts

By Dan Lessmann

Last month we looked at the basic mount types and methods for aligning them. This month's article, and the last for this series is going to be dealing with aspects of both alt-az and polar mounts as they relate to more demanding disciplines such as long exposure astrophotography. We'll also look at some techniques we can use with polar mounts to find our way around the sky. Let's start with the latter.

Using Setting Circles

Have you ever noticed those little lines and numbers that go around the axes on some mounts? Those are setting circles and they are used for pointing the telescope to a particular polar coordinate. Setting circles are generally used only with polar aligned scopes although there are some applications that will work with alt-az as well.

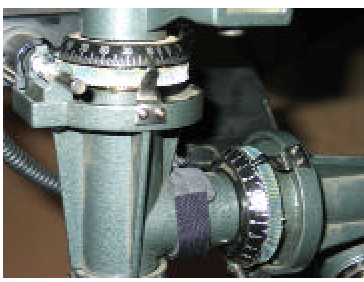

Figure 1—Setting Circles

Figure 1 shows the setting circles on a GEM. The one upper left is the declination axis setting circle and the one lower right is the R.A. setting circle. The appearance of setting circles will vary quite a bit from mount to mount but they all work the same way. Let's start with the easy one.

Declination Setting Circles

Declination circles identify the declination the telescope is pointed toward. Because declination is the same no matter where or when you are, declination circles often can't be calibrated. That is they are often set and locked at the factory. Other mounts will allow you to calibrate these circles but this is normally a one time thing. Circles can appear as shown in Figure 1 or they can look like the one shown in Figure 2. This is the declination circle on an SCT.

The circle is graduated from 0° to 90° in both directions from zero replicating the possible ranges of declination from 0° to +90° and 0° to -90°. In alt-az mounts, the declination circle measures altitude and there is some utility for this but, because the altitude of an object changes over time in alt-az, it's usually easier to star hop to an object.

Figure 2—Dec. Setting Circle, SCT

On the other hand, declination circles on polar mounts have great utility. Because the declination is constant regardless of the time in equatorial coordinates, it's a simple matter to "dial in" a declination using the circle and then sweep along this declination, that is, along the parallel of the declination, to find a particular object.

This is identical to the method we used above to locate Polaris and Sirius last month. For Polaris, we set the declination to 89° 17' and swept in R.A. until we located Polaris. We did the same thing while locating Sirius and now you know how we can point the scope to exactly -16° 45' declination. If you know the declination of an object and you generally know where in the sky it should be in R.A. you can usually use this method to locate that object and this is often easier than star hopping. But this method works only if your scope is polar mounted and aligned.

Right Ascension Setting Circles

This one's a very different critter and it's usually used very differently. Let's first look at how it's graduated. This is measuring right ascension so it's graduated in R.A. hours and minutes. Figure 3 shows part of the R.A. setting circle on an SCT. First notice that there are two scales, one on the outside of the circle and one on the inside.

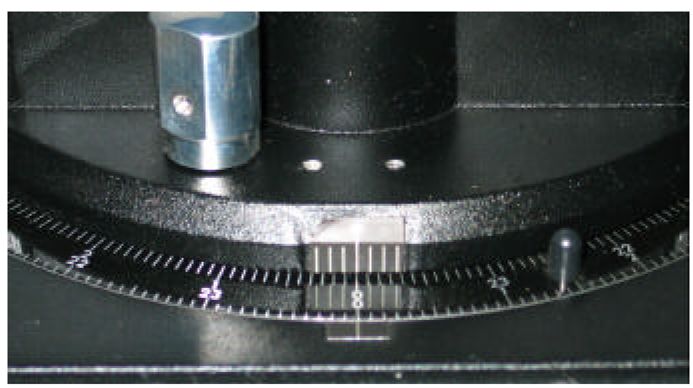

Figure 3— R.A. Setting Circle, SCT

The graduations are identical but the numbers are different. One set of numbers is used for the northern hemisphere and the other is used for the southern. In the case of the circle shown, the outside set of numbers is the one for the northern hemisphere and you can see that the graduations run from 0h through 23h then back to 0h going around toward the right or from west to east when this scope is polar aligned.

The current setting of this setting circle is at 0h 0m but that doesn't mean this scope is pointing to the vernal equinox in Pisces. You must first dial in the current sidereal time for this circle's values to have any meaning.

This particular circle is a *driven* circle. That means that when I set up the scope I can dial in the current sidereal time using the index mark on the base of the mount, the index mark closest to us in the Figure 3 and toward the bottom in Figure 4, and the circle will sidereal track along with the scope as time progresses. So, for our Sirius example last month, my last step in alignment while the scope is still pointed at the NCP would have been to dial in 8h 45' on this setting circle as shown in Figure 4. By doing so, I have set a sidereal clock. The inner index mark, the one on the inside of the ring, now reads the actual right ascension of where the scope is pointing and I can now use this circle much like I can use a declination circle.

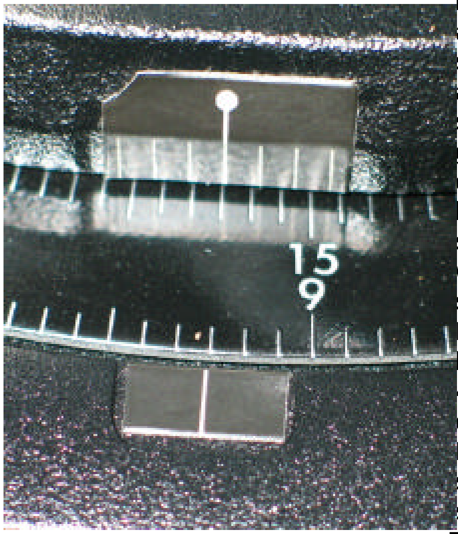

Figure 4—R.A. Index Marks

Okay but how do you know the current sidereal time? Well there are certainly ways to get this information. Many computer programs will tell you this time but we're out in the field and left all of the computer gadgets at home. So we need another way and it's incredibly simple to do. Pull out your star chart and look up the right ascension of say Capella. You'll find it's about 5h 17m. Now slew the scope to center Capella in the eyepiece then set the R.A. setting circle to 5h 17m on the *inner* index mark. The outer index mark now reads the current sidereal time. The sky itself will act as a big sidereal clock for you this way. You just need to know the R.A. of a few easy to find stars from season to season. For accuracy, these objects need to be away from the NCP. Capella works well at a declination of 46° and so does Vega (one of these is always above the horizon from our latitude) but anything north of these and the meridians start bunching up to tight. Using stars closer to the celestial equator will result in more accurate R.A. settings on the circle.

Okay. The setting circle above is driven so once set, it's going to track sidereal time for me. But what if the circle is not driven? Again the problem is simple. Select an object, we'll call it object A, near the equator with a known R.A. and center it in the field of view. Then reset the declination axis to the declination of the object you're looking for, object B. Now set the R.A. setting circle to the R.A. of object A and simply slew the scope to the R.A. of object B. We can't dawdle in this process because time marches on and the R.A. setting circle doesn't march with it. Depending on focal lengths and fields of view, it doesn't take long for the local sidereal time to make that initial R.A. setting invalid. Remember things are moving up there at 1° every four minutes.

How Accurate Does a Polar Alignment Need to Be?

This depends on what you're doing. If the night's agenda is all visual observations, you're most likely good enough with what you've got. If something more demanding is planned, like long exposure astrophotography, you're not done aligning yet.

Drift Alignment

This technique allows you to establish very accurate polar alignment. Generally, for long exposure astrophotography, you need to try for alignments within just a few arcseconds of perfect or less. While this procedure is a bit time consuming, it is the best way to achieve these kinds of accuracies.

First, let's be sure we're clear on exactly what would represent perfect polar alignment. This is really simple. A perfectly aligned equatorial mount will have its R.A. axis exactly parallel to the axis of the earth which means the axis points at both the NCP and SCP. That's all there is to it. Figure 5 shows what the result of this perfect alignment looks like.

Were looking south in this figure. Down below the horizon is the south celestial pole. The parabolic curve is a two dimensional projection of the three dimensional path a star will take as it transits from east to west through the night as viewed up here in the northern hemisphere. The dots represent that star's location at various times during the night.

A perfectly aligned equatorial mount that also has perfect

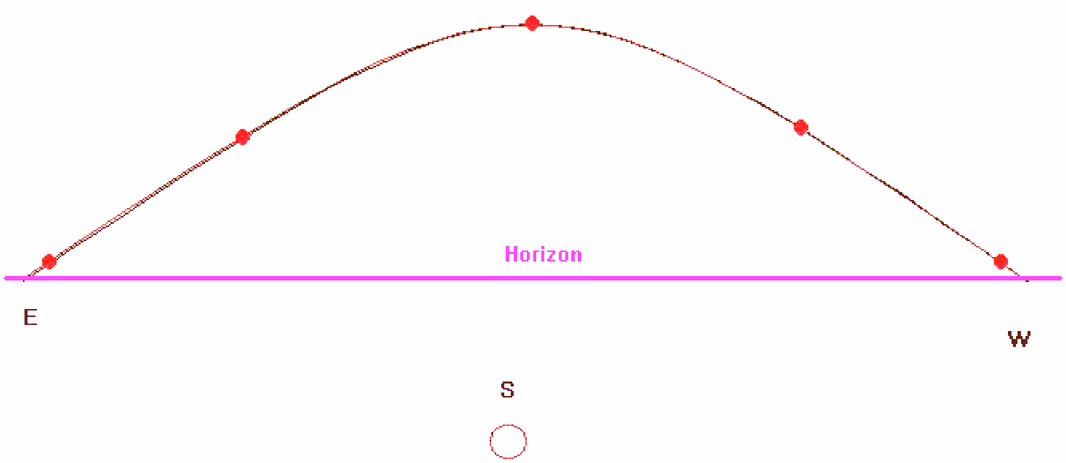

Figure 5—Perfectly Aligned Mount Track

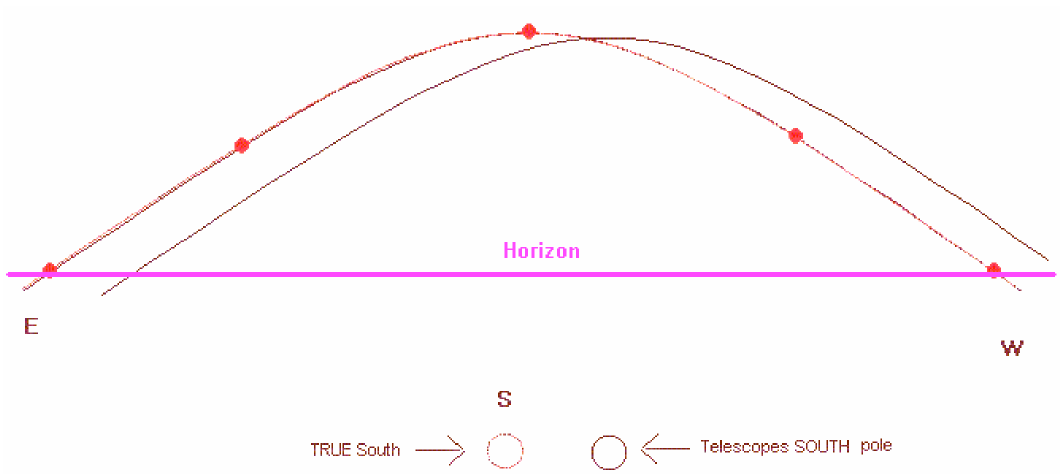

Figure 6—Polar Alignment Error in Azimuth—Mount To East of NCP

sidereal tracking will track that star with no relative motion or drift in the field of view theoretically forever. Unfortunately, neither perfect alignment nor perfect tracking are achievable.

A polar aligned mount can have alignment error in only two directions, either in altitude or in azimuth. Of course any combination of these errors is possible but we test and correct for them separately. Altitude error means the R.A. axis is pointing either above or below the NCP. Azimuth error means the R.A. axis is pointing either east or west of the NCP. Either error results in tracking errors in the form of image drift.

You'll need a reticule eyepiece for drift alignment and that eyepiece needs to be oriented in the scope such that the reticule crosshairs are oriented close to vertical and horizontal when the mount is pointing toward the pole. Procedures for drift alignment are slightly different for the northern and southern hemisphere in that the directions of drift are reversed for the same error. For the rest of this discussion, we'll assume we're performing a drift alignment in the northern hemisphere.

Okay. Two possible errors in two separate axes so we do two drift tests. Let's start with azimuth.

Detecting and Correcting Azimuth Error

Figure 6 shows an error in azimuth alignment where the R.A. axis is pointed east of the NCP. Again, the figure is oriented where you're facing south so the telescope's South Pole is to the west of the SCP in this figure. The two tracks show both the star's track and the track of the telescope.

Figure 7 shows the result of this error as it will appear in the field of view of the eyepiece.

First, let's note a couple of things. Look at the two left telescope fields in this figure and note the small degree of change in position of the star within the fields. Now compare that to the two images at the top of the tracks at the meridian. Note how much more drift is evident in these fields.

Errors in azimuth are most evident near the meridian so we select a star that is just to the east of the meridian, say no more than 10° east and within 10° of the celestial equator for our azimuth drift test.

Now note the direction of drift up near the meridian is vertical. So the horizontal reticule axis is the only one we're concerned about. So, step 1 of the azimuth test…

Select a star within 10° of the celestial equator and within 10° of the meridian. Center this star in the field of view either left or right of the vertical reticule axis such that the star is just above or below the horizontal axis. That is, just touching the axis but not obscured by it. Slightly defocusing the star to a small disk with sharp edges can help with this and, if you have double crosshairs, defocusing to a disk that fills the space between them is a good method.

Step 2… Wait. We need to let the scope track for a while to let any drift occur. How long we wait depends on the amount of error present and the accuracy we wish to achieve but let's give it at least ten minutes for this first iteration. Ten minutes allows the scope to track 2 ½° or about five moon widths. One other thing, in all of these steps, *it's best to not watch the image as the scope tracks.* What we're looking for is a change from one point to another. If we watch the image we aren't as likely to see this change. So, for our first iteration, we'll check it at five minutes. If there's a discernable change, we need to make a correction. If not, we let it track for another five minutes and check again.

Okay. Let's assume we detect some drift at our first five minute check and let's say that drift is down. That is, the star has drifted down in the field of view. This is the scenario shown in Figure 7 Our first rule…

Rule Number 1 – When drift aligning in azimuth, a motion of the star down in the field of view indicates that the R.A.

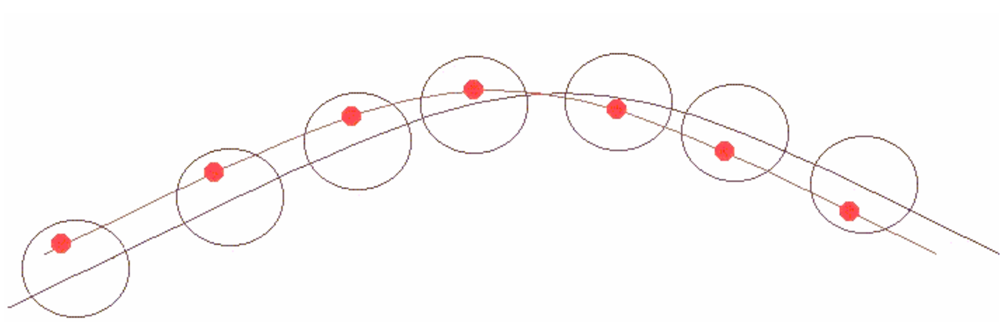

Figure 7—Appearance of Drift of a Star in Eyepiece—Mount To East of NCP

axis of the mount is pointed east of the north celestial pole. Correct to the west.

The amount of correction needed is dependent on a lot of things, the focal lengths of your scope and reticule eyepiece and how much drift is observed. This is a trial and error kind of test but, with experience, you'll be able to make educated guesses for the amount of correction required. A good start is to adjust the azimuth to correct half of the observed drift. That is, if the drift is a full unfocused disk, correct for half of the disk.

Now let's assume that the motion of the star is upward in the field of view. That brings us to our second rule…

Rule Number 2 – When drift aligning in azimuth, a motion of the star up in the field of view indicates that the R.A. axis of the mount is pointed west of the north celestial pole. Correct to the east.

Once you've made a correction, re-align the star to the reticule crosshair and repeat the process until little or no discernable drift is detected for the test period you've chosen. Also note that if the star being tested moves considerably away from the meridian, you should select a different star for subsequent testing.

Detecting and Correcting Altitude Error

Figure 8 shows the result of an altitude error in polar alignment, that is, where the R.A. axis of the mount is pointed north or south of the celestial pole. In this case, the error is north of the pole so the R.A. axis is pointed below the true SCP.

Once again we're looking south in this figure. Note that the drift in this axis is also vertical. Now note a few differences in this figure from Figure 7. The maximum relative drift for this axis is not near the meridian but is instead near the horizon. Also note that when the star crosses the meridian, the direction of drift changes. So step 1 of the altitude test…

Select a star that is within 20° to 30° of the eastern or western horizon and within 10° of the celestial equator. Align that star just above or below the horizontal crosshair of the reticule, that is, the crosshair that is horizontal at the NCP. This will be more vertical to you down at the equator and the horizon. We want to be near the horizon but not so close to the horizon that atmospheric shimmer affects the results of the test. How far above the horizon depends on the seeing for that night but generally speaking the lower that better as the error shows up quicker.

Step 2… Wait. Just as in the azimuth drift test we need to wait for the error to appear. The same procedures apply. Give it five minutes and check, then ten and check, etc. for as long as you wish to test. The longer you test the better your alignment will be in this axis.

Let's assume you get some drift after five minutes and that drift is up. That is, the star drifts up in the field of view. Our third rule…

Rule Number 3 – When drift aligning in altitude using a star near the eastern horizon, a motion of the star up in the field of view indicates that the R.A. axis of the mount is pointed above the north celestial pole. Correct down.

When drift aligning in altitude using a star near the western horizon, a motion of the star up in the field of view indicates that the R.A. axis of the mount is pointed below the north celestial pole. Correct up.

You can see that the rules for altitude testing come in two parts and are dependent on where your test star is located.

Rule number 4 is rule number 3's opposite of course.

Rule Number 4 – When drift aligning in altitude using a star near the eastern horizon, a motion of the star down in the field of view indicates that the R.A. axis of the mount is pointed below the north celestial pole. Correct up.

When drift aligning in altitude using a star near the western horizon, a motion of the star down in the field of view indicates that the R.A. axis of the mount is pointed below the north celestial pole. Correct up.

As with azimuth testing, if your test star rises to high in the east or sets to low in the west, select a new star for subsequent testing.

Why should the test star be near the celestial equator for these procedures? Of all the parallels projected on to the celestial sphere, the celestial equator is the one of greatest diameter. A star tracking along this great circle has the greatest relative motion for the same period time and will therefore show any drift error faster and better. A relatively large drift error may not be observable with a star near the NCP no matter how long you observe while it may show up in just a couple of minutes with a star near the equator.

Now for the really bad news. Making an adjustment in either axis to correct for drift alignment affects the other axis unless your mount is perfectly level which is unlikely. So, after you've finished drift aligning the second axis, you need to repeat the test for the first axis if you made changes to the second axis. Further, if you must make adjust-

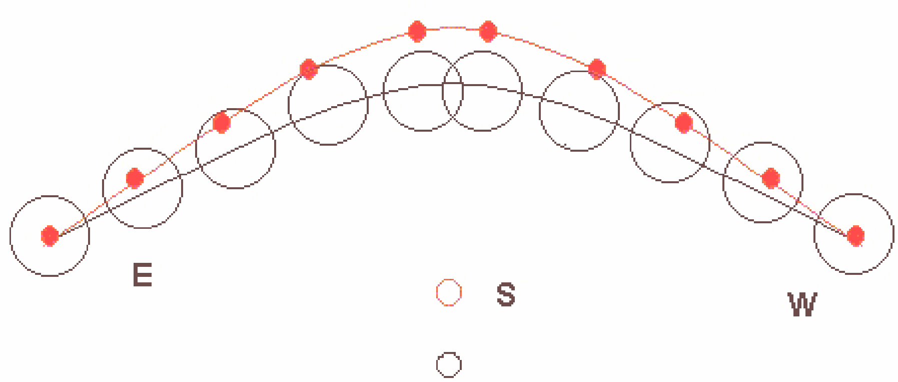

Figure 8—Appearance of Drift of a Star in Eyepiece—Mount Above NCP

ments to the first axis during the second test, you must then retest the second axis and so on until no further adjustments are required in either axis.

Obviously drift alignment can be a lengthy affair and needs to be done only for the most demanding applications or for permanent pier mountings as it's a one time exercise.

Why do we ignore the vertical (when pointed to the NCP) crosshair of the reticule while drift aligning? This is obvious when we stop thinking in alt-az and start thinking equatorially. The vertical cross hair measures in the R.A. axis so any drift from this crosshair is showing tracking error, not alignment error. This information can be of value of course and leads us to…

PEC

Or Periodic Error Correction. All tracking mounts use mechanical components that drive the telescope around one or both axes. These include motors and usually quite a few gears making up the drive train for that axis. No components of the drive train are manufactured perfectly. Gears will be slightly out of round or will have slightly malformed teeth and bearings in motors and on gear shafts can cause drag in places. All of these imperfections in the drive train result in periodic error.

Why periodic? Suppose a tooth on a particular gear causes a jump in an axis each time it meshes with some other gear. This means this jump will occur periodically each time that particular alignment of the gears occurs. Periodicity of error can be many times per minute to once per sidereal day depending on which component of the drive train causes the error.

Since it's not possible to manufacture a perfect drive train, advanced mounts include an electronic correction for the imperfections. Sensors built into the drive train detect where each component is in its cycle and if periodic error correction data is available, the electronics will vary the speed of the drive motor to accommodate for each error as it is encountered. This "smoothes out the bumps" in the tracking.

What's required from you is following the procedures for your mount to generate the PEC data. Normally this is a matter of tracking on a particular star for some period of time while manually making slewing corrections with the keypad to keep the star centered in the field. You'll need your reticule eyepiece to do this of course as you need to maintain very accurate alignments of the star in the field of view.

You can also use a CCD or CMOS camera for gathering PEC data and this is preferred as your computer will send much more accurate tracking corrections to the mount than you can do manually.

For alt-az mounts, PEC data is gathered for both drives since alt-az must track in both axes simultaneously. For polar mounts, it's normally necessary to have PEC data only for the R.A. axis since this axis is the one used to sidereal track.

One more consideration on PEC. If you substantially change the balance of your optical tube, say by hanging a new piece of equipment, the PEC data you've gathered will now be invalid. So before doing any PEC procedures, first make sure you're tube is in good balance and then rebalance after adding the new equipment. You may choose to gather new PEC data regardless but as long as the balance is more or less the same for both configurations, one set of PEC data will do for both.

Obviously drift alignment and PEC need to be done only for the most stringent of tracking applications but, if your telescope is equatorially mounted, using setting circles to locate objects is often an easier method than star hopping.

That's it for hardware unless you would like more. No? Good! Next month, we'll be taking a look at a bit of cosmology so we're moving away from the techie aspects and into the science aspects of our hobby.

Until then… *Clear Skies!*