Mounts and Coordinate Systems

Part 2: Our Mounts

By Dan Lessmann

A Quick Review

Last month we looked at coordinate systems and found there are two systems that we commonly use.

Altitude-Azimuth Coordinates

A local or terrestrial coordinate system with the origin located wherever and whenever you are with axes defined by the horizon and due north. Altitude is measured either positive, above the horizon, or negative, below the horizon and can be from -90° to +90°. Azimuth is the bearing from true north and can be from 0° to +359°.

Since this is a local coordinate system it has some distinct disadvantages in that the coordinate of a celestial object is fixed only for a particular time and location.

Equatorial Coordinates

Also called Polar Coordinates. A celestially based coordinate system with the origin located at the vernal equinox and axes of the celestial equator and the celestial meridian, an arbitrary meridian running from the north celestial pole through the Vernal Equinox to the south celestial pole. We found that measurements along the equator are in right ascension and measured in hours of 15° each with 24 hours making one full sidereal rotation. Measurements along the celestial meridian are in declination and are measured in degrees with declinations in the northern celestial hemisphere being positive and in the southern being negative.

Since this system is celestially based, an object will always have the same equatorial coordinates but these coordinates will be revised from time to time to account for precession and other relativistic motions. Each time these coordinates are revised a new astronomical epoch is established. We're currently using J2000 coordinates for the epoch established in January of 2000.

Time for Some Hardware

Now we're going to look at mounts and how we use them. Let's start with the simplest mount type.

Altitude-Azimuth Mount General Configuration

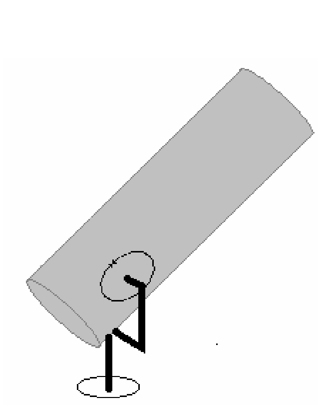

Figure 1—Alt-Az Mount

Figure 1 shows the general configuration of an altitude-azimuth mount. You can see the two axes of rotation. At the bottom is the azimuth rotation around the vertical axis and up near the optical tube is the altitude rotation around the horizontal axis; real simple and easy to understand.

If such a mount has tracking capability it's important that the mount is leveled prior to alignment. Any tip or tilt of the axes off of level will cause the mount to track inaccurately.

Higher end tracking scopes on alt-az mounts can electronically compensate for some tip and tilt. Correcting factors are determined during the alignment procedure. However any tracking mount will perform at its best if it's leveled prior to alignment.

The Dobsonian Mount

This mount is usually just called a "Dob". In its simplest form it's an alt-az mount that consists of a wood rocker box that has a lazy-Susan kind of bottom to allow rotation in the azimuth axis around the vertical and a pivot cradle to allow rotation in the altitude axis around the horizontal.

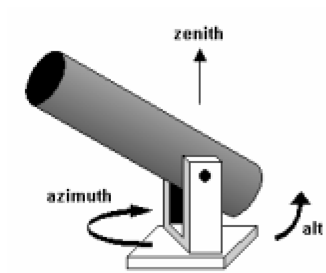

Figure 2—Dobsonian Mount

Many of our members say they own Dobs and they do. But don't confuse the label "Dob" as having anything to do with the telescope itself. Usually a scope that uses a Dobsonian mount is a Newtonian reflector but it doesn't have to be. Any type of telescope could be mounted on a Dobsonian mount. That said, you'll rarely see anything but a reflector on a Dobsonian.

The advantages of a Dobsonian mount are its simplicity, its low cost and the fact that they are easily home built. They are also advantageous for larger aperture reflectors because the short design keeps the eyepiece at the top of the tube at a reasonable height for most observations. That lazy-Susan base you see in the figure usually sits on the ground. This is why these mounts are so popular with owners of reflectors. In contrast, this is a disadvantage for telescopes that have their eyepiece mounted at the rear.

Another disadvantage of these mounts is that they are somewhat difficult to motorize for tracking purposes although this can certainly be done and is more and more.

The Alt-Az Fork Mount

Mechanically, this design is actually the same as the Dobsonian mount in that it has a vertical azimuth axis and a horizontal altitude axis with the optical tube supported on either side by vertical supports in the form of

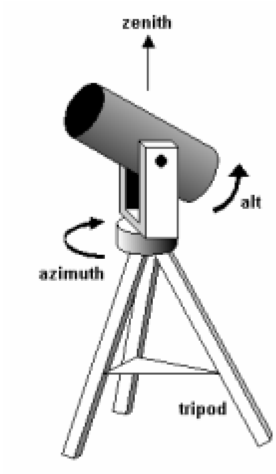

Figure 3—Alt-Az Fork Mount

fork arms. However, pretty much all of the alt-az fork mounts you'll see are commercially manufactured and usually are used with catadioptric scopes like Schmidt-Cassegrains or smaller refractors, spotting scopes and binoculars.

This type of mount is almost always mounted on a tripod or a pier since the telescopes most commonly used with it have the eyepiece mounted at the rear of the optical tube.

Fork mounts are easily motorized for tracking and commercial ones for larger scopes typically are. Since it's necessary to track simultaneously in both axes, there are two sets of motors and worm gears. One will be mounted in the base of the mount to rotate in the azimuth axis and the other is mounted in one or the other fork arm to rotate in the altitude axis.

Okay. That's the two most common alt-az mounts. Now we get to the weird stuff.

Equatorial Mount – General Configuration

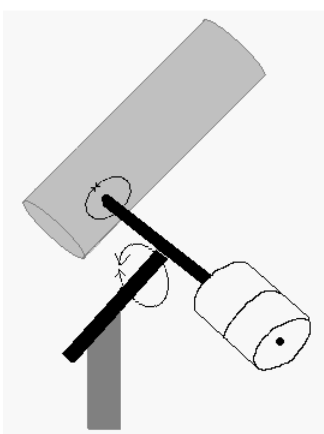

Figure 4—Equatorial Mount

Figure 4 shows the general configuration of an equatorial mount, also called a polar mount. Again, there are two axes of rotation. The right ascension axis is the one mounted to the pier and is aligned parallel with the polar axis of the earth. The declination axis is the one with the counterweights and the optical tube and is parallel with the plane of the celestial equator. There are other types of equatorial mounts but they all share these same axes and orientations.

So as shown in this diagram and assuming it's properly aligned, you're standing on the east side of the telescope looking toward the west and the north celestial pole is to your upper right.

You know, looking at this figure, and imagining it oriented as described, you might be wondering, "What's the big deal? Why does he say this is confusing?" What's confusing is achieving that alignment in the first place (actually that's more difficult than confusing) and the motions necessary in these axes to get to another part of the sky other than due north.

I'll get to that and, hey, maybe it's just me! Regardless, using and aligning an equatorial mount is more complicated than an alt-az mount at least when you're starting out.

German Equatorial Mount

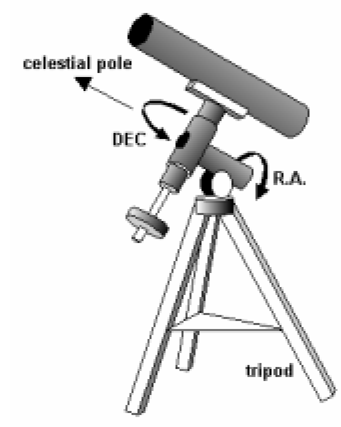

Figure 5—GEM Mount

The mount shown in Figure 5 is a *German Equatorial Mount* or GEM. We'll assume it's setup out at AHL, i.e., in the northern hemisphere, so it is pointed at the NCP and you're standing west and a little north of this scope. Since it's pointed to the NCP it's pointing to a declination of 90° and no right ascension or actually all right ascensions since the right ascension meridians all meet up there. A scope so aligned is said to be aligned to German Equatorial North.

GEM mounts are the most common of all of the equatorial mounts and they all look more or less like this. There's a method to mount the optical tube as shown on the top with some sort of a counterweight arrangement below. By sliding the optical tube forward and back and by moving the counterweights up and down on the counterweight rod, it's possible to balance the scope in both axes. If this is a tracking mount, this is critical for proper tracking and in fact, leaving things out of balance can damage the mount's worm gears and other components.

Equatorial mounts must be accurately leveled to track properly. Good ones include a couple of sprit levels permanently mounted on the base for this purpose. Others will have bubble levels. Some may not have any levels but should always have a flat location where a level can be situated to level the tripod and the mount's base. Stay away from mounts that don't have such a location.

Some equatorial mounts are not motorized so they don't sidereal track. Others have a tracking motor only in the right ascension drive that being all the tracking necessary for a properly aligned mount. Such mounts are said to have "clock drives" as they rotate at near the same rate as a 24 hour clock. That is they rotate about the R.A. axis once per sidereal day.

Equatorial Fork Mount

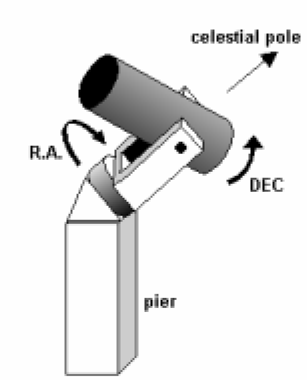

Figure 6—Equatorial Fork Mount

These are usually alt-az fork mounts that have one addition, an equatorial wedge. The idea's pretty simple really. By adding a wedge under the mount's base, we can tilt what was the azimuth axis parallel to the earth's axis turning it into a right ascension axis. Of course that also changes the altitude axis to a declination axis.

Was that clear? Think of it this way. If you observe from the North Pole of the earth, an alt-az mount *is an equatorial mount as well*. This is because the local azimuth axis is parallel to the earth's axis at the poles. Dress warmly though. If you're a wimp like me and wish to observe from warmer latitudes you must compensate for the change in latitude of 90° down to whatever latitude you choose. Around here that's about 35° N. So the azimuth axis has to be tipped to the north the difference of 90° less 35° or 55° to the north to compensate for coming down south.

As you can see in the figure, a properly aligned equatorial fork mount will have its forks pointing towards the celestial pole. So, assuming that celestial pole is the one up here in the north, your standing to the east and a little bit north of the scope shown in the figure and the tube is pointed to something in the southeast sky at a declination of around -15° or so.

Equatorial fork mounts need not be mounted on a pier but they commonly are and are usually permanently mounted in an observatory in this case. Of course, it's a simple enough matter to take the scope and mount off the wedge and mount the wedge to a tripod instead.

Why Add A Wedge? Field Rotation

Why would someone who has a tracking alt-az fork-mount want to add a wedge? That's more cost and a more complicated setup with more junk to haul around. The reason why is field rotation.

Figure 7 shows the body of the constellation Orion at three different times on the same winter night. You can see, as Orion rises in the southeast that it lies on its right side (your left), rotates to vertical in the south and finally sets lying on its left side in the southwest. Orion and all of the sky around it rotate from rise to set around the earth's axis. An alt-az mount does not rotate with the sky. Instead it swivels the scope around its two localized axes to follow so Orion will appear to rotate within the field of view just as shown in the image.

An equatorial mount compensates for the rotation of the field by rotating around the earth's axis in R.A. in the opposite direction of the earth's spin. That is, it rotates just as the sky rotates so the field of view will remain the same all night long.

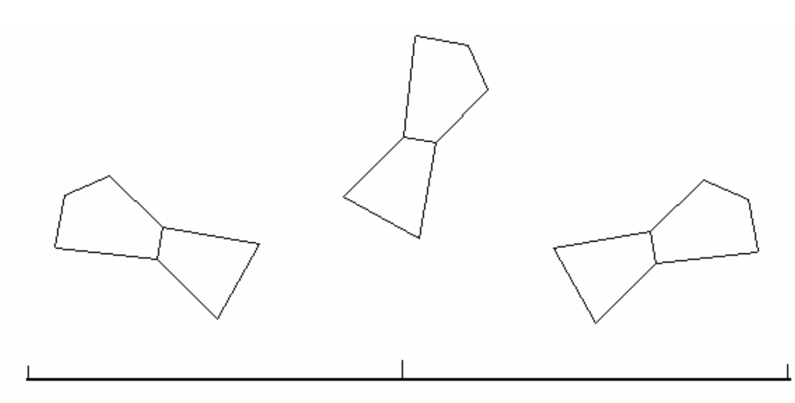

Figure 7—Field Rotation of Orion

To see the effect of this yourself, look again at the left figure. Now, without moving your eyes, move your head up and right to the center figure. Your head's motion is the same motion an alt-az mount will make and obviously the two images are oriented differently.

Now look back at the left image but this time, tilt your head to the left so that Orion is vertical in your field of view. Now tilt your head to the right to bring the center image into the center of your view and then farther to the right to bring the right image into the center of your view. This rotation about a single axis is the motion made by an equatorial mount so Orion is always standing up in the field of view.

There is no truly compelling reason I know of for adding a wedge if you're going to observe visually but astrophotography is different. Without an equatorially mounted scope exposure times are severely limited due to field rotation.

Equatorial Confusion

I don't know. Maybe it *is* just me but I still have to think about this to keep it straight. I've got a small Newt mounted on a GEM and it's a computerized GOTO mount so I can select an object from a menu and the mount will slew the scope to that point for me. When I first started using it years ago I kind of just stared at the thing with a puzzled look like a deer in headlights. It would start swiveling around in what appeared to me to be all kinds of crazy directions but it always seemed to get where it was going. I just never could quite figure out how it pulled it off. Today I'm a lot older and I like to think wiser so instead of staring with a puzzled look I stare with a thoughtful look but I'm still confused sometimes.

I don't know for sure but I can't help but get back to how our brains are wired. We think in terms of up and down, left and right, North and South, etc. In other words we think in terms of altitude-azimuth coordinates.

With alt-az, it's simple for us to think in terms of moving say to the southwest and up at the same time. Go ahead and do that. Imagine a reflector on a Dob mount pointed due north at the horizon and you're standing on it's right side or east of the scope.

Now imagine the motion necessary to move the scope to Sirius in the southwest and about 30° up. Simple right? You push the front of the scope away from you toward the west and lift up at the same time. Bang! There's Sirius in the field of view.

Polar mounts could care less about how we're wired so we've got to adapt to their way of thinking and here's how. First, forget about the horizon and up and down. This thing cares nothing about the horizon, the zenith or compass headings. Once it's aligned, all it knows or cares about is where the celestial north pole is and sidereal motion and time. Second, forget about tracking in two axes at the same time, especially since well aligned equatorial mounts don't need to do this.

Imagine you're standing next to the GEM mounted scope in Figure 8. This one's pointed at the NCP so your standing to its northwest and Sirius is over and just a bit in front of your right shoulder. Remembering that you can pivot only around the axes shown by the R.A. and Dec. rotational arrows, move that scope in your mind to Sirius.

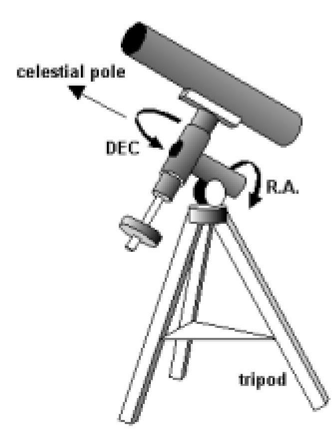

Figure 8—GEM at NCP

If you're like me, you're scratching your head right now trying to figure out how to pivot the thing from the top of the tripod like an azimuth axis. If this was easy for you, then one of us is really weird or you've been using a polar mount for a while! I'm going to assume that we're both normal and both confused.

The way around this confusion is to stop thinking about Sirius being in the southwest. Instead Sirius is at some right ascension and declination. At the time I'm writing this it's April 23rd and about an hour before sunset. Sirius is indeed in the southwest and I'd be getting ready to take a look at it and other things if it weren't for the clouds that are in the way. However, where Sirius is, where it always is, is at R.A. 6h 45m, Dec. -16° 45' for the J2000 epoch.

So, imagine yourself standing at your favorite observing site northwest of that GEM mounted scope. Now turn to face south and look up about 45° above the horizon. Behind and above your head is Polaris with the north celestial pole right next door. In front of you, about a fist width above where you're looking is the celestial equator. A great circle coming up from due east and swooping about 35° south of the zenith then swooping back down to due west. At this time of year in April, it's quite a way further south of the ecliptic where the planets play; about 15° further, or a fist and a half. Sirius is still further south of that great circle a little over 16° or another fist and a half.

Right above you, running from the NCP south to the SCP and through the zenith is the local meridian and right now it's about 45 minutes after eight; not in local time but in right ascension or sidereal time; that is, the meridian of about 8h 45m R.A. is directly overhead right now and passes through the zenith and the local meridian. So Sirius is two hours to the west of that or about three fists or thirty degrees. See it? Okay. Now we know where Sirius is.

Now let's move the scope *one axis at a time.* First, flip the scope around the declination axis to a little past -16° declination. Remember it's at 90° Dec. right now. First move it to 0° by moving the front of the tube toward you. This will be due west and aligned with the celestial equator. Of course 0° declination is also due east and either way we'll do for us but we're looking to the west so we rotate to the west. Now keep rotating in that direction another 16° plus almost another degree. That's -16° 45' the declination of Sirius.

Now stop and look at the scope. In your mind, you should see the scope pointing almost 17° south of due west and a little below the horizon. So from the vantage point in Figure 8, you're looking at the right side of the scope pointed a little bit down below the horizon.

Now let's move in right ascension. At the meridian, where the right ascension axis is pointing now, it's 8h 45'. Huh? Yes! Forget the scope for a minute and look at where the counterweight rod is pointing instead. It's still aligned in its German Equatorial North position so it's pointing right at the intersection of the local meridian and the celestial equator or at 8h 45' R.A.

We're going to move -2h from the current sidereal time to get to Sirius at 6h 45'. Subtracting hours of R.A. is like going back in time so we have to rotate the rod counterclockwise (backward in time like a clock) or we need to push the scope back toward the east. That is, from our vantage point in the figure, we're going to rotate counterclockwise by pushing the scope away from us and pulling the counterweight toward us around the right ascension axis. As you picture this, look at what happens to where the scope is pointing. You pull the front of the scope back above the horizon as you do this but you've not changed the declination at all with this motion. You're moving the front of the scope along about a -17° parallel to the celestial equator which means farther to the south from our vantage point up here in the northlands. Eventually you've moved those two hours and there's Sirius in the field of view.

Let's try another one. How about Polaris, which has equatorial coordinates of 2h 36m, 89° 17'. Okay, declination first. Flip the scope back around from the southwest towards the north. BANG! You just ran the back of the tube into the east tripod leg. Okay, R.A. first but just get it back to German equatorial north with the counterweight rod pointing down toward the ground and up to the meridian.

Now declination. Pull the front of the tube back around to point back up to the NCP and then pull off of that about ¾° in either direction. The full moon is about ½ of a degree wide so about a moon and a half will do. Now we're more or less at the declination of Polaris and, instead of worrying about the current sidereal time, we'll just sweep along this declination to find Polaris. While looking in the eyepiece, rotate the scope around the R.A. axis until a bright star appears in the center of the field of view. That's Polaris. If this is a tracking mount, we can lock down the R.A. drive clutch now and just let the mount track. What will it do? Well, right now, the scope is lying on the west side of the mount and the counterweight rod is on the east side. That's because Polaris' right ascension of 2h 36' is almost 6h west of the current sidereal time straight up. 6h of R.A. is ¼ of a sidereal day or 90°. As time rolls on, the mount will continue to track Polaris and the scope will begin to move from the west around toward the ground and the rod will begin to move up toward the local meridian. Eventually of course, the scope's going to hit the tripod again but, if the scope were removed, the mount would just continue to rotate around making almost, but not quite, one complete revolution every solar day and exactly one compete revolution every sidereal day. That's the same as the motion of Polaris.

As you can see, if you can break the alt-az habit of thinking in up and down and north and south and combinations of these directions simultaneously, and instead treat the movements in declination and right ascension as two totally separate movements it's easier to see how a GEM moves and works.

By setting the declination first, any movement in right ascension will be along a celestial parallel that passes through your intended target as we saw with Polaris. If you can be accurate in declination you can sweep along that parallel and eventually hit your target. The problem is being accurate. Which gets us too…

Scope Alignment

It's easy to align a manual Dobsonian mount. Put the scope in its cradle on the mount. You're done! Only scopes that sidereal track, or that don't track but are equatorially mounted, need to be aligned. Procedures vary from scope to scope but the following is a rough outline of the procedures that are common for most scopes that have GOTO capability.

What You've Got to Know First

For any GOTO scope or mount, you need three pieces of information. You must know your location on the surface of the earth, where north is and the time of day. Some more advanced scopes can find this out for you using GPS and internal compasses but most will not.

Second, Get Level

Any tracking scope will track better if the tripod it's sitting on is leveled prior to alignment. If spirit levels or a bubble level are not built into your mount or tripod, go to the hardware store and get a torpedo level. These are small and easy to use to level the tripod's base. I kid you not, your tracking will be much better if the tripod is leveled in advance and this is essential for equatorial mounts. This is true even if your mount can accommodate tilt and tip.

Aligning an Alt-Az Mount

As I said, procedures are going to vary from model to model but all alt-az mounts will eventually do the same thing. They will establish a reference plane between themselves and two stars. Once this model is in their gizzards, they can then determine where an object is in the sky and the motions necessary in their two axes to track it.

The alignment procedures will normally go something like this:

1. Enter your location in longitude and latitude.
2. Enter the current time (some scopes expect military time while others allow you to select AM or PM). Normally you'll be asked about daylight savings time too. If you get this wrong, all of your scope's go to positions will be off by one hour of R.A. or fifteen degrees.
3. Point the scope to what you believe to be true north.
4. The scope will select an alignment star from its database. Alignment stars are invariably the brightest stars in the area and you'll learn them as the scope continues to use them from session to session. The scope will slew to where it believes the alignment star should be. Usually it will be off by quite a few degrees so you adjust the position of the scope using the controller to center the star in the scope's field of view.
5. The scope will slew to a second alignment star that is at least 90° away from the first star. Again you line up the scope on that star.

You're done but what you've done is defined three points that make up a triangle from your scope to those two stars. Three points define a plane and the scope can now calculate the locations of objects and the motions required to track relative to that plane. Internally, the scope can rotate that plane as time passes and keep your tracking and go to positions accurate as it does.

Aligning an Equatorial Mount

Okay to align a GOTO scope equatorially (also called polar alignment), you still have to know a few additional things just as you do with alt-az. You've got to know where you are on the surface of the earth and you have to know the exact time at the time you align the scope.

Most scopes use a procedure similar to the following.

1. Enter your location in longitude and latitude.
2. Enter the current time again accounting for daylight saving time.
3. Null out both axes by placing them in German Equatorial North positions.
4. The slope will slew to where it believes Polaris is and you now manually adjust the azimuth and altitude of the mount. Huh? Did he say azimuth and altitude? Yep. The mount will have manual adjustments that allow you to slew the scope and the mount itself in alt-az axes. What you're doing is tweaking the mount to your exact current latitude and making sure the mount's R.A. axis is pointing to the NCP. When you're done, Polaris is centered in the field of view.
5. The scope will normally slew to another star that is some degrees away from Polaris usually somewhere near the celestial equator and substantially east or west of the meridian. You electronically align the scope to this using the hand controller.

The purpose of this second alignment star is to establish the amount of tilt if any of the tripod east and west and any error in your time entry. If you've leveled the tripod and entered the time accurately, very little adjustment should need to be made to center the second star. If there's a bunch, you've done something wrong, probably during the entry of the time.

Using a Polar Alignment Scope

Most equatorial mounts have a hole parallel to the R.A. axis that can accept a polar alignment scope. This scope is designed to help align the mount to the NCP. Most have an image displayed that allows you to align on Polaris and while orienting the scope in R.A. to align both the Big Dipper and Cassiopeia. Again, after rotating the telescope in R.A. to match the orientation of these constellations, you use the mount's azimuth and elevation controls to center Polaris in the reticule. After doing so, you'll have a reasonable polar alignment. Certainly one that is accurate enough for visual observations.

I Don't Have a Polar Alignment Scope

Not a problem. You can do essentially the same thing using the main tube. Set the scope in German Equatorial North and sight through the eyepiece. You should see Polaris and several other stars. Now rotate the scope in R.A. while continuing to look through the eyepiece. If you're well aligned, the stars will sweep circles around the center of the field. If they don't maintain a consistent distance from the center of rotation, adjust in azimuth and/or altitude until they do. When they do, the scope is pointing to the NCP.

That's it for this month. Next month we're going to look at some more advanced topics with our mounts. Then, I'm sure you'll be happy to know, we've pretty much covered hardware and can look at some astronomy!