Those Keplerian Elements

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All of the current crop of computer programs that are used to compute the position of a satellite and determine the corresponding antenna pointing angles use a basic set of numerical constants as inputs. These input constants are derived from classical astronomical motions and are called the primary Keplerian elements.

Numerous articles have appeared in various publications describing the virtues of some of these computer programs. These articles usually gloss over the mechanics of orbital motion because it is not possible for most amateurs to become instant experts in celestial mechanics. Even becoming acquainted with the terms will require some reasoned study. Here is a basic description of some of the terms associated with orbital mechanics. These descriptions will provide most of the known identification references to the specific element, so that you will recognize the term no matter how it is declared. These element descriptions will also be presented in the same order as they are commonly listed and used, so that sequential associations will also be recognized. Mathematical references will also be avoided; there are enough texts around that treat these elements in those terms.

Epoch, TØ: A fancy name for a specific reference time. This is the UTC date and time for which the Keplerian elements are defined. Epoch values may be stated in conventional dating methods of day, month and year (ddmmyyyy) followed by UTC clock time. Internally, all computer programs use a numeric day-of-year date reference, and many of us are more accustomed to stating the Epoch in this manner. For instance, 11 November 1987 is day number 315 of 1987, and most programs will accept the compound number of 85315.458333 for 1100 UTC on that date. The decimal portion of the number, .458333, is that fraction of the 24-hour period corresponding to the clock time of 1100 hours of day 315.

Inclination, IØ (degrees): Satellite orbits are best described as an elliptical motion within a flat plane in inertial space. The tilt of this plane with regard to the Earth's equator is the angle called Inclination. If IØ is zero degrees, then the orbit is in the equatorial plane, typical for most geostationary communications satellites, while a value of 90 degrees describes a polar orbit. See Fig 13-24.

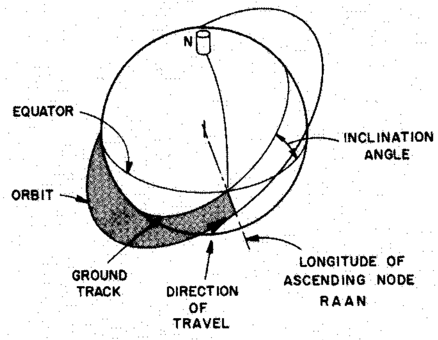

Fig 13-24—Inclination and RAAN.

Right Ascension of the Ascending Node (RAAN), OØ (degrees): This angle describes the location, with respect to the Earth's longitude coordinates, of the tilted orbital plane. Convention places the OØ at that point on the Earth's longitude scale (degrees west longitude) that the satellite track crosses the equator while traveling from the Southern Hemisphere to the Northern Hemisphere. See Fig 13-24.

Eccentricity, EØ: A dimensionless number that describes the shape of an ellipse. All orbits are elliptical motions of which the circle is only a special case. Since elipses can vary in shape, we need to know the "flatness" of the orbit. If the orbit is truly circular, then EØ = 0, but if the orbit is very flat, the value goes to EØ = 1.0, which is a straight line. Beyond this point, the "elliptical" orbit is no longer elliptical, but is either parabolic or hyperbolic and is no longer a closed, or periodic, orbit. See Fig 13-25.

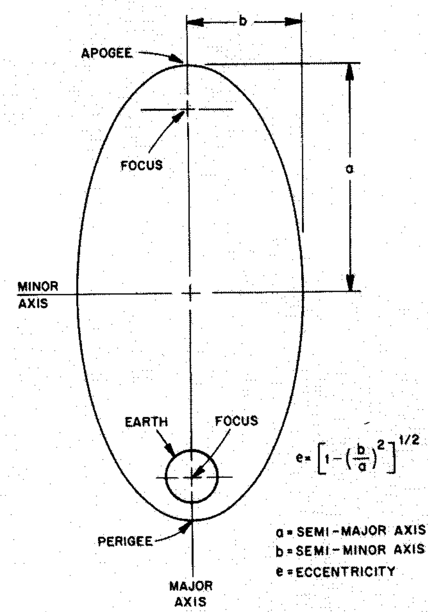

Fig 13-25—Eccentricity and semi-major axis.

Argument of Perigee, WØ (degrees): This awkward title is merely a statement of the position of the perigee, or lowest altitude point of the orbit, with respect to the RAAN. Measuring orbital position, in degrees, about the center of the Earth, starting from the ascending node crossing of the equator around to the perigee position, then, is the value of WØ. You can then reason that a value of WØ = 270 degrees means that the high point of the orbit, the apogee, will be at the most northerly latitude. Conversely, a value of WØ = 90 degrees places the apogee at the most southerly latitude. See Fig 13-26.

Mean Anomaly, MA, MØ (degrees): Another "strange" term, but if you read "anomaly" to be identical to "angle," it then starts to have meaning. MA is merely a statement of the angular position of the satellite in its orbit at the very moment of the reference time is set for the Keplerian elements. MØ is expressed in degrees centered on the Earth's center, starting from the perigee. Another use of MA is in the AO-10 computer for keeping track of time, since the orbital period is a constant time unit. The computer takes the full orbital revolution, from one perigee to the next perigee, and divides that time into a computer-usable number of 256 parts, rather than the conventional angular measurement of 360 degrees. AO-10 scheduling is done in increments of this version of MA, sometimes called "Phase."

Mean Motion, NØ (orbits per day): This is a very simple notation that merely expresses the number of orbits a satellite completes around the Earth for each UTC day. Orbital period can be easily derived from NØ by dividing 24 hours by NØ.

Semi-Major Axis, SMA, AØ (kilometers): The SMA is a dimensional measurement of one half of the total "length" of the longest axis of an ellipse. In Earth orbits, if the NØ is stated, the use of the SMA is not necessary as they are numerically related in a very direct manner. Most programs will accept either NØ or SMA as input but only use one or the other. The SMA is commonly not stated in lists of Keplerian elements for OSCAR satellites. See Fig 13-25.

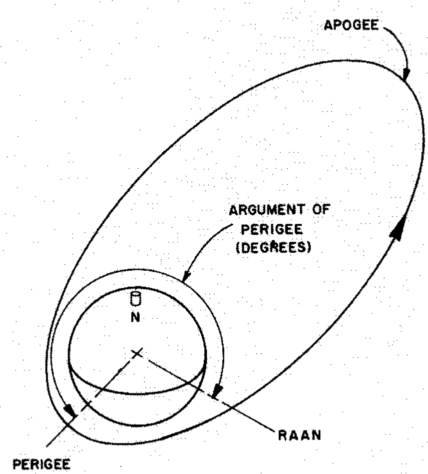

Fig 13-26—Argument of perigee.

Decay Rate, Drag Factor, N1 (orbits/day/day): These two separate names describe the same quantity, which is the first derivative of the Mean Motion. It is, as the name states, the rate of slowing down of an orbit. This factor has been a relatively recent addition to the orbital computations and assists greatly with prediction precision. For those satellites in low orbits, N1 becomes a rather high number, and its impact rather apparent.