Lecture(3)
chapter2.2

2.2 LOOK ANGLE DETERMINATION

Navigation around the earth's oceans became more precise when the surface of the globe was divided up into a gridlike structure of orthogonal lines: latitude and longitude. Latitude is the angular distance, measured in degrees, north or south of the equator and longitude is the angular distance, measured in degrees, from a given reference longitudinal line. At the time that this grid reference became popular, there were two major seafaring nations vying for dominance: England and France. England drew its reference zero longitude through Greenwich, a town close to London, England, and France, not surprisingly, drew its reference longitude through Paris, France. Since the British Admiralty chose to give away their maps and the French decided to charge a fee for theirs, it was not surprising that the use of Greenwich as the zero reference longitude became dominant within a few years. [It was the start of .com market dominance through giveaways three centuries before E-commerce!] Geometry was a much older science than navigation and so 90° per quadrant on the map was an obvious selection to make. Thus, there are 360° of longitude (measured from 0° at the *Greenwich Meridian*, the line drawn from the North Pole to the South Pole through Greenwich, England) and ±90° of latitude, plus being measured north of the equator and minus south of the equator. Latitude 90° N (or +90°) is the North Pole and latitude 90° S (or −90°) is the South Pole. When GEO satellite systems are registered in Geneva, their (subsatellite) location over the equator is given in degrees east to avoid confusion. Thus, the INTELSAT primary location in the Indian Ocean is registered at 60° E and the primary location in the Atlantic Ocean is at 335.5° E (not 24.5° W). Earth stations that communicate with satellites are described in terms of their geographic latitude and longitude when developing the pointing coordinates that the earth station must use to track the apparent motion of the satellite.

Coordinate System 1

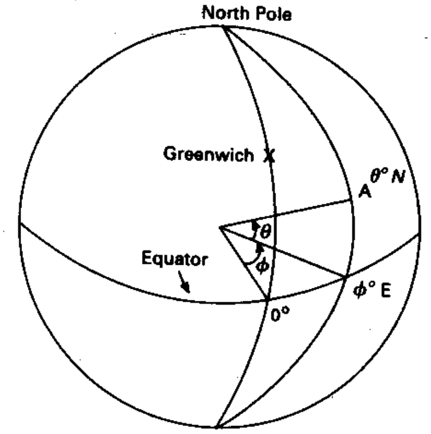
- **Latitude:** Angular distance, measured in degrees, north or south of the equator.

  L from -90 to +90 (or from 90S to 90N)
- **Longitude:** Angular distance, measured in degrees, from a given reference longitudinal line (Greenwich, London).

  l from 0 to 360E (or 180W to 180E)

4

Coordinate System 2



Latitude (θ°N) and longitude (ϕ°E) of a point A.

(Source: M.Richaria, Satellite Communication Systems, Fig.2.9)

5

The coordinates to which an earth station antenna must be pointed to communicate with a satellite are called the *look angles*. These are most commonly expressed as *azimuth* (Az) and *elevation* (El), although other pairs exist. For example, right ascension and declination are standard for radio astronomy antennas. Azimuth is measured eastward (clockwise) from geographic north to the projection of the satellite path on a (locally) horizontal plane at the earth station. Elevation is the angle measured upward from the local horizontal plane at the earth station to the satellite path. Figure 2.10 illustrates these look angles. In all look angle determinations, the precise location of the satellite is critical. A key location in many instances is the subsatellite point.

LOOK ANGLES 1

- **Azimuth:** Measured eastward (clockwise) from geographic north to the projection of the satellite path on a (locally) horizontal plane at the earth station.
- **Elevation Angle:** Measured upward from the local horizontal plane at the earth station to the satellite path.

7

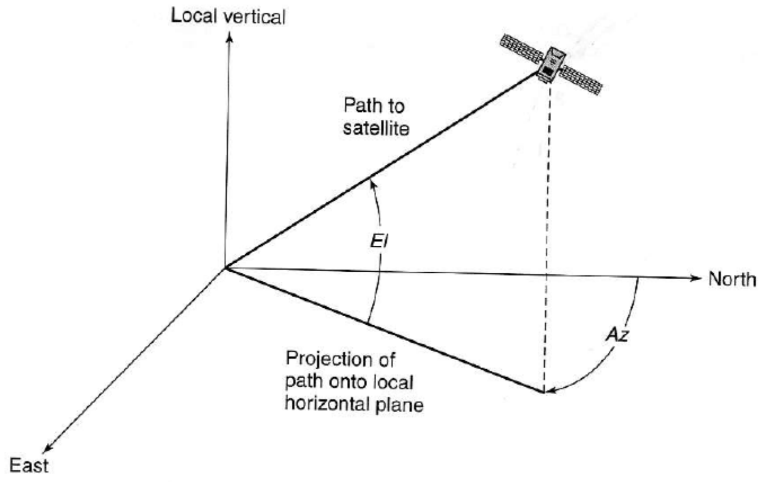


FIGURE 2.10 The definition of elevation (*El*) and azimuth (*Az*). The elevation angle is measured upward from the local horizontal at the earth station and the azimuth angle is measured from true north in an eastward direction to the projection of the satellite path onto the local horizontal plane.

The Subsatellite Point

The subsatellite point is the location on the surface of the earth that lies directly between the satellite and the center of the earth. It is the *nadir* pointing direction from the satellite and, for a satellite in an equatorial orbit, it will always be located on the equator. Since geostationary satellites are in equatorial orbits and are designed to stay "stationary" over

the earth, it is usual to give their orbital location in terms of their subsatellite point. As noted in the example given earlier, the Intelsat primary satellite in the Atlantic Ocean Region (AOR) is at 335.5° E longitude. Operators of international geostationary satellite systems that have satellites in all three ocean regions (Atlantic, Indian, and Pacific) tend to use longitude east to describe the subsatellite points to avoid confusion between using both east and west longitude descriptors. For U.S. geostationary satellite operators, all of the satellites are located west of the Greenwich meridian and so it has become accepted practice for regional systems over the United States to describe their geostationary satellite locations in terms of degrees W.

To an observer of a satellite standing at the subsatellite point, the satellite will appear to be directly overhead, in the *zenith* direction from the observing location. The zenith and nadir paths are therefore in opposite directions along the same path (see Figure 2.11). Designers of satellite antennas reference the pointing direction of the satellite's antenna beams to the nadir direction. The communications coverage region on the earth from a satellite is defined by angles measured from nadir at the satellite to the edges of the coverage. Earth station antenna designers, however, do not reference their pointing direction to zenith. As noted earlier, they use the local horizontal plane at the earth station to define elevation angle and geographical compass points to define azimuth angle, thus giving the two look angles for the earth station antenna toward the satellite (*Az*, *El*).

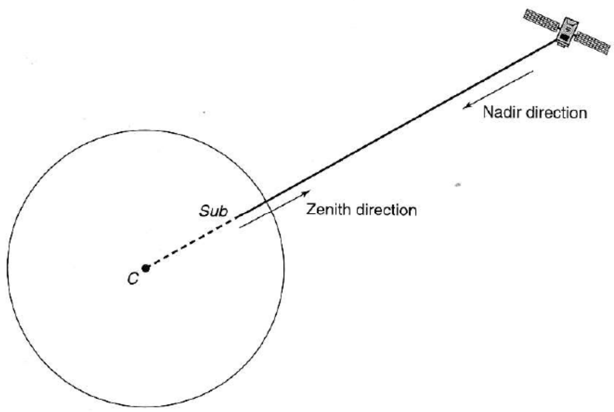
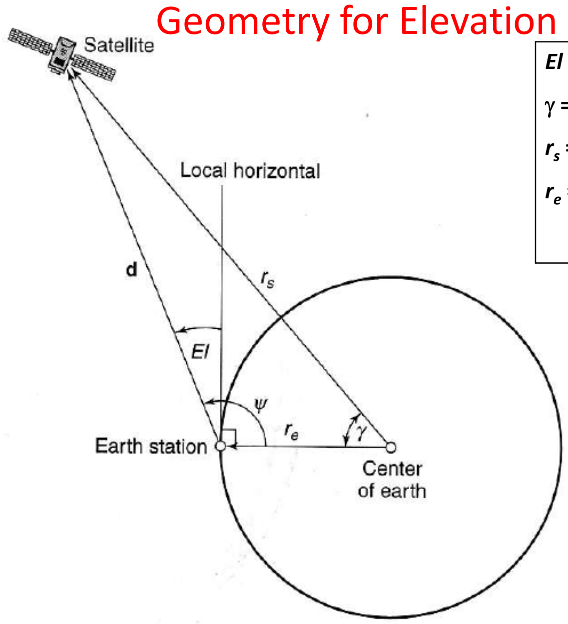


FIGURE 2.11 Zenith and nadir pointing directions. The line joining the satellite and the center of the earth, *C*, passes through the surface of the earth at point *Sub*, the subsatellite point. The satellite is directly overhead at this point and so an observer at the subsatellite point would see the satellite at zenith (i.e., at an elevation angle of 90°). The pointing direction from the satellite to the subsatellite point is the nadir direction from the satellite. If the beam from the satellite antenna is to be pointed at a location on the earth that is not at the subsatellite point, the pointing direction is defined by the angle away from nadir. In general, two off-nadir angles are given: the number of degrees north (or south) from nadir; and the number of degrees east (or west) from nadir. East, west, north, and south directions are those defined by the geography of the earth.

Geometry for Elevation Calculation



El **= ψ - 90°**

γ = central angle

r_s = radius to the satellite

r_e = radius of the earth

FIGURE 2.12 The geometry of elevation angle calculation. The plane of the paper is the plane defined by the center of the earth, the satellite, and the earth station. The central angle is γ. The elevation angle *El* is measured upward from the local horizontal at the earth station.

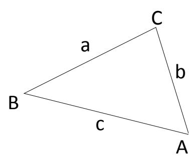
Satellite Coordinates

- SUB-SATELLITE POINT
  - Latitude L_s
  - Longitude l_s
- EARTH STATION LOCATION
  - Latitude L_e
  - Longitude l_e
- Calculate γ, ANGLE AT EARTH CENTER

Between the line that connects the earth-center to the satellite and the line from the earth-center to the earth station.

Slant path geometry

- Review of plane trigonometry
  - Law of Sines
  - Law of Cosines
  - Law of Tangents



$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$

$$c^2 = a^2 + b^2 - 2ab\cos C$$

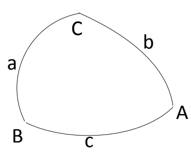
$$\tan\frac{C}{2} = \sqrt{\frac{(d-a)(d-b)}{d(d-c)}}, d = \frac{a+b+c}{2}$$

- Review of spherical trigonometry
  - Law of Sines
  - Law of Cosines for angles
  - Law of Cosines for sides

$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$

$$\cos a = \cos b \cos c + \sin b \sin c \cos A$$

$$\cos A = -\cos B \cos C + \sin B \sin C \cos a$$



Elevation Angle Calculation

Figure 2.12 shows the geometry of the elevation angle calculation. In Figure 2.12, $\boldsymbol{r}_s$ is the vector from the center of the earth to the satellite; $\boldsymbol{r}_e$ is the vector from the center of the earth to the earth station; and $\boldsymbol{d}$ is the vector from the earth station to the satellite. These three vectors lie in the same plane and form a triangle. The central angle γ measured between $\boldsymbol{r}_e$ and $\boldsymbol{r}_s$ is the angle between the earth station and the satellite, and ψ is the angle (within the triangle) measured from $\boldsymbol{r}_e$ to $\boldsymbol{d}$. Defined so that it is nonnegative, γ is related to the earth station north latitude L_e (i.e., L_e is the number of degrees in latitude that the earth station is north from the equator) and west longitude l_e (i.e., l_e is the number of degrees in longitude that the earth station is west from the Greenwich meridian) and the subsatellite point at north latitude L_s and west longitude l_s by

$$\boxed{\cos(\gamma) = \cos(L_e)\cos(L_s)\cos(l_s - l_e) + \sin(L_e)\sin(L_s)} \tag{2.31}$$

The law of cosines allows us to relate the magnitudes of the vectors joining the center of the earth, the satellite, and the earth station. Thus

$$d = \boldsymbol{r}_s\left[1 + \left(\frac{\boldsymbol{r}_e}{\boldsymbol{r}_s}\right)^2 - 2\left(\frac{\boldsymbol{r}_e}{\boldsymbol{r}_s}\right)\cos(\gamma)\right]^{1/2} \tag{2.32}$$

Since the local horizontal plane at the earth station is perpendicular to $\boldsymbol{r}_e$, the elevation angle El is related to the central angle ψ by

$$\boxed{El = \psi - 90^\circ} \tag{2.33}$$

By the law of sines we have

$$\boxed{\frac{r_s}{\sin(\psi)} = \frac{d}{\sin(\gamma)}} \tag{2.34}$$

Combining the last three equations yields

$$\boxed{\cos(El) = \frac{r_s \sin(\gamma)}{d}}$$

$$= \frac{\sin(\gamma)}{\left[1 + \left(\frac{r_e}{r_s}\right)^2 - 2\left(\frac{r_e}{r_s}\right)\cos(\gamma)\right]^{1/2}} \tag{2.35}$$

Equations (2.35) and (2.31) permit the elevation angle El to be calculated from knowledge of the subsatellite point and the earth station coordinates, the orbital radius r_s, and the earth's radius r_e. An accurate value for the average earth radius is 6378.137 km[1] but a common value used in approximate determinations is 6370 km.

THE CENTRAL ANGLE γ

γ is defined so that it is non-negative and

cos (γ) = cos(*Le*) cos(L_s) cos(l_s – l_e) + sin(L_e) sin(L_s)

The magnitude of the vectors joining the center of the earth, the satellite and the earth station are related by the law of cosine:

$$d = r_s\left[1+\left(\frac{r_e}{r_s}\right)^2 - 2\left(\frac{r_e}{r_s}\right)\cos(\gamma)\right]^{1/2}$$

17

ELEVATION CALCULATION - 1

By the sine law we have

$$\frac{r_s}{\sin(\psi)} = \frac{d}{\sin(\gamma)}$$ Eqn. (2.57)

Which yields

$$\cos(El) = \frac{\sin(\gamma)}{\left[1+\left(\frac{r_e}{r_s}\right)^2 - 2\left(\frac{r_e}{r_s}\right)\cos(\gamma)\right]^{1/2}}$$ Eqn. (2.58)

18

Azimuth Angle Calculation

Because the earth station, the center of the earth, the satellite, and the subsatellite point all lie in the same plane, the azimuth angle *Az* from the earth station to the satellite is the same as the azimuth from the earth station to the subsatellite point. This is more difficult to compute than the elevation angle because the exact geometry involved depends on whether the subsatellite point is east or west of the earth station, and in which of the hemispheres the earth station and the subsatellite point are located. The problem simplifies somewhat for geosynchronous satellites, which will be treated in the next section. For the general case, in particular for constellations of LEO satellites, the tedium of calculating the individual look angles on a second-by-second basis has been considerably eased by a range of commercial software packages that exist for predicting a variety of orbital dynamics and intercept solutions (see reference 13 for a brief review of 10 software packages available in early 2001).

AZIMUTH CALCULATION - 1

More complex approach for non-geo satellites. Different formulas and corrections apply depending on the combination of positions of the earth station and subsatellite point with relation to each of the four quadrants (NW, NE, SW, SE).

A simplified method for calculating azimuths in the Geostationary case is shown in the next slides.

20

Specialization to Geostationary Satellites

For most geostationary satellites, the subsatellite point is on the equator at longitude l_s, and the latitude L_s is 0. The geosynchronous radius r_s is 42,164.17 km[1]. Since L_s is zero, Eq. (2.31) simplifies to

$$\boxed{\cos(\gamma) = \cos(L_e)\cos(l_s - l_e)} \tag{2.36}$$

Substituting r_s = 42,164.17 km and r_e = 6,378.137 km in Eqs. (2.32) and (2.35) gives the following expressions for the distance d from the earth station to the satellite and the elevation angle El at the earth station

$$\boxed{d = 42{,}164.17[1.02288235 - 0.30253825\cos(\gamma)]^{1/2}\ \text{km}} \tag{2.37}$$

$$\boxed{\cos(El) = \frac{\sin(\gamma)}{[1.02288235 - 0.30253825\cos(\gamma)]^{1/2}}} \tag{2.38}$$

For a geostationary satellite with an orbital radius of 42,164.17 km and a mean earth radius of 6378.137 km, the ratio r_s/r_e = 6.6107345 giving

$$El = \tan^{-1}[(6.6107345 - \cos\gamma)/\sin\gamma] - \gamma \tag{2.39}$$

To find the azimuth angle, an intermediate angle α must first be found. The intermediate angle α permits the correct 90° quadrant to be found for the azimuth since the azimuthal angle can lie anywhere between 0° (true north) and clockwise through 360° (back to true north again). The intermediate angle is found from

$$\boxed{\alpha = \tan^{-1}\left[\frac{\tan|(l_s - l_e)|}{\sin(L_e)}\right]} \tag{2.40}$$

Having found the intermediate angle α, the azimuth look angle Az can be found from:

Case 1: Earth station in the Northern Hemisphere with

(a) Satellite to the SE of the earth station: $Az = 180° - \alpha$ (2.41a)

(b) Satellite to the SW of the earth station: $Az = 180° + \alpha$ (2.41b)

Case 2: Earth station in the Southern Hemisphere with

(c) Satellite to the NE of the earth station: $Az = \alpha$ (2.41c)

(d) Satellite to the NW of the earth station: $Az = 360° - \alpha$ (2.41d)

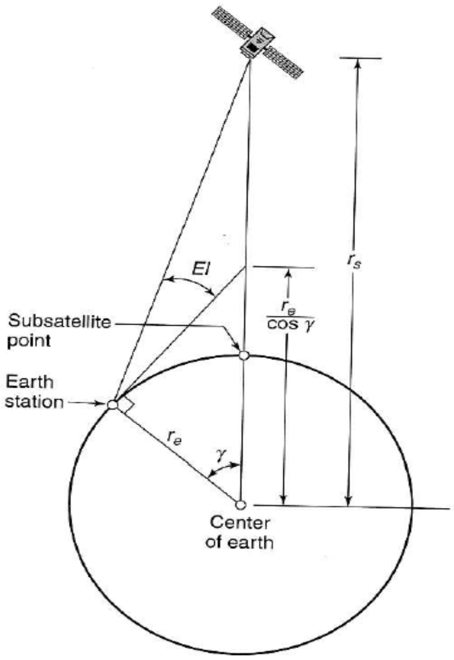


FIGURE 2.13 The geometry of the visibility calculation. The satellite is said to be visible from the earth station if the elevation angle *El* is positive. This requires that the orbital radius r_s be greater than the ratio $r_e/\cos(\gamma)$ where r_e is the radius of the earth and γ is the central angle.

GEOSTATIONARY SATELLITES

We will concentrate on the **GEOSTATIONARY CASE**
This will allow some simplifications in the formulas

- SUB-SATELLITE POINT
  (Equatorial plane, Latitude $\mathbf{L_s} = 0^o$
  Longitude $\mathbf{l_s}$)
- EARTH STATION LOCATION
  Latitude $\mathbf{L_e}$
  Longitude $\mathbf{l_e}$

24

THE CENTRAL ANGLE γ - GEO

The original calculation previously shown:

$\cos(\gamma) = \cos(L_e)\cos(L_s)\cos(l_s - l_e) + \sin(L_e)\sin(L_s)$

Simplifies using $L_s = 0^o$ since the satellite is over the equator:

$\boxed{\cos(\gamma) = \cos(L_e)\cos(l_s - l_e)}$ (eqn. 2.66)

25

ELEVATION CALCULATION – GEO 1

Using $\boldsymbol{r_s}$ **=** 42,164 km and $\boldsymbol{r_e}$ **=** 6,378.14 km gives

$\boldsymbol{d} = 42{,}164\ [1.0228826 - 0.3025396\cos(\gamma)]^{1/2}$ km

$$\cos(El) = \frac{\sin(\gamma)}{[1.0228826 - 0.3025396\cos(\gamma)]^{1/2}}$$

NOTE: These are slightly different numbers than those given in equations (2.67) and (2.68), respectively, due to the more precise values used for r_s and r_e

26

ELEVATION CALCULATION – GEO 2

A simpler expression for *El* (after Gordon and Walter, “Principles of Communications Satellites”) is :

$$El = \tan^{-1}\left[\frac{\left(\cos\gamma - \frac{r_e}{r_s}\right)}{\sin\gamma}\right]$$

27

AZIMUTH CALCULATION – GEO 1

To find the azimuth angle, an ***intermediate angle, α***, must first be found. The intermediate angle allows the correct quadrant (see Figs. 2.10 & 2.13) to be found since the azimuthal direction can lie anywhere between 0° (true North) and clockwise through 360° (back to true North again). The intermediate angle is found from

$$\alpha = \tan^{-1}\left[\frac{\tan\left(\left|l_s - l_e\right|\right)}{\sin\left(L_e\right)}\right]$$

NOTE: Simpler expression than eqn. (2.73)

28

AZIMUTH CALCULATION – GEO 2

Case 1: Earth station in the Northern Hemisphere with
(a) Satellite to the SE of the earth station: $Az = 180^{o} - \alpha$ (b)
Satellite to the SW of the earth station: $Az = 180^{o} + \alpha$
Case 2: Earth station in the Southern Hemisphere with
(c) Satellite to the NE of the earth station: $Az = \alpha$ (d)
Satellite to the NW of the earth station: $Az = 360^{o} - \alpha$

29

Visibility Test

For a satellite to be visible from an earth station, its elevation angle El must be above some minimum value, which is at least 0°. A positive or zero elevation angle requires that (see Figure 2.13)

$$\boxed{r_s \geq \frac{r_e}{\cos(\gamma)}} \tag{2.42}$$

This means that the maximum central angular separation between the earth station and the subsatellite point is limited by

$$\boxed{\gamma \leq \cos^{-1}\left(\frac{r_e}{r_s}\right)} \tag{2.43}$$

For a nominal geostationary orbit, the last equation reduces to $\gamma \leq 81.3°$ for the satellite to be visible.

VISIBILITY TEST

A simple test, called the ***visibility test*** will quickly tell you whether you can operate a satellite into a given location.

A positive (or zero) elevation angle requires (see Fig. 2.13)

$$r_s \geq \frac{r_e}{\cos(\gamma)}$$

which yields

$$\gamma \leq \cos^{-1}\left(\frac{r_e}{r_s}\right)$$

Eqns. (2.42) & (2.43)

31

EXAMPLE 2.2.1 ***Geostationary Satellite Look Angles***

An earth station situated in the Docklands of London, England, needs to calculate the look angle to a geostationary satellite in the Indian Ocean operated by Intelsat. The details of the earth station site and the satellite are as follows:

Earth station latitude and longitude are 52.0° N and 0°.
Satellite longitude (subsatellite point) is 66.0° E

Step 1: Find the central angle γ

$$\cos(\gamma) = \cos(L_e)\cos(l_s - l_e)$$
$$= \cos(52.0)\cos(66.0) = 0.2504$$

yielding $\gamma = 75.4981°$
The central angle γ is less than 81.3° so the satellite is visible from the earth station.

Step 2: Find the elevation angle El

$$El = \tan^{-1}[(6.6107345 - \cos\gamma)/\sin\gamma] - \gamma$$
$$= \tan^{-1}[(6.6107345 - 0.2504)/\sin(75.4981)] - 75.4981$$
$$= 5.847°$$

Step 3: Find the intermediate angle α

$$\alpha = \tan^{-1}\left[\frac{\tan|(l_s - l_e)|}{\sin(L_e)}\right]$$
$$= \tan^{-1}[(\tan(66.0 - 0))/\sin(52.0)]$$
$$= 70.667°$$

Step 4: Find the azimuth angle
The earth station is in the Northern Hemisphere and the satellite is to the southeast of the earth station. From Eq. (2.41a), this gives

$$Az = 180° - \alpha = 180 - 70.667 = 109.333° \text{(clockwise from true north)}$$ ■

Note that, in the example above, the elevation angle is relatively low (5.85°). Refractive effects in the atmosphere will cause the mean ray path to the satellite to bend in the elevation plane (making the satellite appear to be higher in the sky than it actually is) and to cause the amplitude of the signal to fluctuate with time. These aspects are discussed more fully in the propagation effects chapter. While it is unusual to operate to a satellite below established elevation angle minima (typically 5° at C band, 10° at Ku band, and in most cases, 20° at Ka band and above), many times it is not possible to do this. Such cases exist for high latitude regions and for satellites attempting to reach extreme east and west coverages from their given geostationary equatorial location. To establish whether a particular satellite location can provide service into a given region, a simple visibility test can be carried out, as shown earlier in Eqs. (2.42) and (2.43).

A number of ...

... in Eqs. (2.42) and (2.43).

A number of geosynchronous orbit satellites have inclinations that are much larger than the nominal 0.05° inclination maximum for current geosynchronous satellites. (In general, a geosynchronous satellite with an inclination of <0.1° may be considered to be geostationary.) In extreme cases, the inclination can be several degrees, particularly if the orbit maneuvering fuel of the satellite is almost exhausted and the satellite's position in the nominal location is only controlled in longitude and not in inclination. This happens with most geostationary communications satellites toward the end of their operational lifetime since the reliability of the payload, or a large part of the payload, generally exceeds that of the lifetime of the maneuvering fuel. Those satellites that can no longer be maintained in a fully geostationary orbit, but are still used for communications services, are referred to as *inclined orbit* satellites. While they now need to have tracking antennas at the earth terminals once the inclination becomes too large to allow the satellite to remain within the 1-dB beamwidth of the earth station antennas, substantial additional revenue can be earned beyond the normal lifetime of the satellite. Those satellites that eventually reach significantly inclined orbits can also be used to communicate to parts of the high latitude regions that were once beyond reach, but only for a limited part of the day. The exceptional reliability of electronic components in space, once they have survived the launch and deployment sequences, has led spacecraft designers to manufacture satellites with two end-of-life criteria. These are: end of design life (EODL), which refers to the lifetime expectancy of the payload components and end of maneuvering life (EOML), which refers to the spacecraft bus capabilities, in particular the anticipated lifetime of the spacecraft with full maneuver capabilities in longitude and inclination.

Current spacecraft are designed with fuel tanks that have a capacity that usually significantly exceeds the requirement for EODL. Once the final mass of the spacecraft (without fuel) is known, a decision can be made as to how much additional fuel to load so that the economics of the launch and the anticipated additional return on investment can be balanced. Having additional fuel on board the spacecraft can be advantageous for many reasons, in addition to adding on-orbit lifetime. In many cases, satellites are moved to new locations during their operational lifetime. Examples for this are opening up service at a new location with an older satellite or replacing a satellite that has had catastrophic failure with a satellite from a location that has fewer customers. Each maneuver, however, consumes fuel. A rule of thumb is that any change in orbital location for a geostationary satellite reduces the maneuvering lifetime by about 1 month. Moving the satellite's location by 1° in longitude takes as much additional fuel as moving the location by 180°: both changes require an acceleration burn, a drift phase, and a deceleration burn. The 180° location change will clearly take longer, since the drift rates are the same in both cases. Another use for additional fuel is to allow for orbital perturbations at any location.

EXAMPLE OF A GEO LOOK ANGLE ALCULATION - 1

FIND the **Elevation** and **Azimuth** Look Angles for the following case:

Earth Station Latitude	52^o N
Earth Station Longitude	0^o
Satellite Latitude	0^o
Satellite Longitude	66^o E

London, England
Dockland region

Geostationary INTELSAT IOR
Primary

EXAMPLE OF A GEO LOOK ANGLE ALCULATION - 1

Step 1. Find the central angle γ

$\cos(\gamma) = \cos(L_e)\cos(l_s - l_e)$

$= \cos(52)\cos(66)$

$= 0.2504$

yielding $\gamma = 75.4981^o$

Step 2. Find the elevation angle *El*

$$El = \tan^{-1}\left[\frac{\left(\cos\gamma - \frac{r_e}{r_s}\right)}{\sin\gamma}\right]$$

EXAMPLE OF A GEO LOOK ANGLE ALCULATION - 1

Step 2 contd.

El = $\tan^{-1}$[(0.2504 – (6378.14 / 42164)) / sin (75.4981)]
= 5.85°

Step 3. Find the intermediate angle, α

$$\alpha = \tan^{-1}\left[\frac{\tan\left|\left(l_s - l_e\right)\right|}{\sin\left(L_e\right)}\right]$$

= $\tan^{-1}$ [(tan (66 - 0)) / sin (52)]

= 70.6668

EXAMPLE OF A GEO LOOK ANGLE ALCULATION - 1

The earth station is in the Northern hemisphere and the satellite is to the South East of the earth station. This gives

Az = 180° - α
= 180 – 70.6668 = 109.333° (clockwise from true North)

ANSWER: The look-angles to the satellite are

Elevation Angle = 5.85°

Azimuth Angle = 109.33°

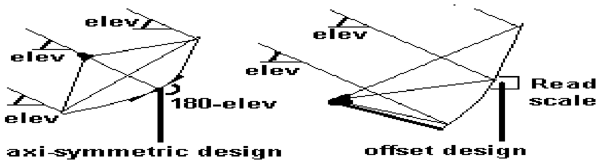
OPERATIONAL LIMITATIONS

- For Geostationary Satellites
  $\gamma \leq 81.3^o$
- This would give an elevation angle = 0^o
- Not normal to operate down to zero
- usual limits are C-Band 5^o
  Ku-Band 10^o
  Ka- and V-Band 20^o

41

extra

Azimuth and elevation refer to the satellite TV dish pointing angles.



Elevation

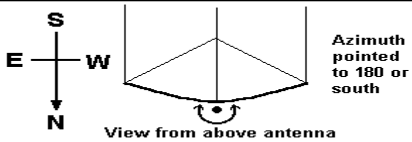
Elevation refers to the angle between the dish pointing direction, directly towards the satellite, and the local horizontal plane. It is the up-down angle.

When your dish is pointed almost straight up the elevation angle is **nearly 90 degrees**. Sites near the equator may require you to point to **almost 90 deg** elevation angle when the longitude of the satellite is similar to the longitude of the site location. In high elevation cases watch out for the possibility of rain water collecting in the dish. It is easy to set up the elevation angle accurately, using:

(a) a scale marked on the mount bracket. This is almost essential for 'offset antennas' with the feed at the bottom on an arm. Make sure the pole mount is vertical using a bubble level or weighted string in two positions at right angles around the pole. The offset angle may be documented in the installation instructions.

(b) using an inclinometer. These typically have a bubble level and a rotary scale marked in degrees. Think about low angles (near zero), the 45 deg half way angle and high angles (towards 90 deg) and make sure that your scale readings make sense. You may need to add or subtract 90 or 180 deg and even to read the scale backwards. If you are using an axi-symmetric dish the back of the dish is normally at right angles to the beam and there may be some suitable flat part where you can apply the inclinometer.

(c) If you don't have an inclinometer then make an inclinometer using a piece of card, a length of cotton and a small weight (small metal nut, for example). Make a hole near one edge and insert the thread so that the weight dangles across the card. Draw on the card the exact elevation angle required using a school compass or two lines at right angles and trigonometry (tan function suggested) at Start, Programmes, Accessories, Calculator, Scientific mode. This kind of home made device can be far more accurate that a small inclinometer sold in a DIY store. For large dishes a long plumb line can be used and sideways measurements used with tan tables to determine angles accurately.



Azimuth refers to the rotation of the whole antenna around a vertical axis. It is the side to side angle.

Typically you loosen the main mount bracket and swing the whole dish all the way around in a 360 deg circle.
By definition North is 0 deg, East is 90 deg, South is 180 deg and west is 270 deg. North can also be called 360 deg.

Note that you find a satellite by pre-setting the elevation accurately and then swinging the whole antenna boldly in azimuth till the signal locks up - so an approximate azimuth angle is normally sufficient. The dish pointing calculator gives the required azimuth angle both relative to true north and relative to magnetic compass north.

When using a magnetic compass keep away from metal structures. This is obviously a problem in many cases both with the antenna steelwork and building structures. If, for example, you have a close angle clearance problem with say an adjacent wall then you may need to walk some distance away and sight towards the satellite from say 50 yards back. Large scale precision maps / plans can be useful in accurately defining angles. Also consider long range views of say church towers that might provide an accurate azimuth reference.

If you are in the northern hemisphere then remember that the sun rises in the east, reaches its highest angle at due south and sets in the west. If you are in the southern hemisphere then remember that the sun rises in the east, reaches its highest angle at due north and sets in the west. If you are away from the equator and it is a sunny day you can approximately determine south simply by considering where the sun is and the general time of day. To calculate sun or moon angles at any time go here http://aa.usno.navy.mil/data/docs/AltAz.php Sun or moon altitude is the same thing as elevation angle. If you are near the equator note where the sun rose this morning - that is approximately east.
The north pole star gives a good fix if you are in the northern hemisphere and not too close to the equator. Here is how to find true north using the pole star. Some GPS receivers show a view of the sky with the sun and moon marked. Line up with one of these and you have a good bearings. Also with GPS you can walk a while in a straight line and determine the azimuth bearing angle of that line.