Polar Mount Antennas
Motorised Antennas for Satellite Reception

Adolf Oberhuber

If you consult the relevant literature you will find that no or – at most – insufficient background information is available about how this type of motorised polar mounted antennas actually works. The same is true for the required formulas and their derivation. The following illustrations are meant to provide answers to all questions in association with a polar mount. This also includes, inter alia, various size determinations for positions as well as calculations for the satellite orbit based on a specific example. Altogether this report is a collection of data and calculations which, the author believes, have hitherto been scattered across an endless number of publications and accounts. For the sake of completeness and reference, technical terms and their origin will be explained in a separate addendum at the end.

Without exception, all calculations and remarks are for the northern hemisphere. If you live south of the equator you need to interpret them accordingly, such as antenna alignment to the north instead of the south, inclination of the rotation axis towards the south instead of north and so on. For all calculations you merely need a standard 10-digit electronic calculator capable of performing trigonometric operations. If you intend to receive several satellites at once you may choose one of the following set-ups:

1. Several antennas:

Usually, such a set-up is only chosen for commercial applications as it requires a lot of space and also is more costly than other solutions.

2. A single antenna with two or more LNBs:

This design is intended for multi-user layouts that have to make sure each user has unrestricted access to all transmissions of all satellites at any time. Naturally, if several LNBs are attached to a single antenna they cannot all be in the precise focus of the parabolic dish, which means that they are slightly out of focus. However, reception is only possible if the satellites are rather close to each other and if the antenna has a certain (larger) diameter.

3. Polar mount antennas:

For single users interested in maxing out their reception possibilities a polar mounted motorised antenna is an interesting solution. As the name implies, the axis around which the antenna rotates is mounted in a pole-to-pole direction, i.e. in parallel to the axis of the earth. Such a set-up does not restrict the number of receivable satellites, provided they can be 'seen' from the location of the antenna. It is no big deal to receive 15 to 20 satellites without exceedingly elaborate equipment.

In general, if a satellite antenna is to be rotated with a motor you would need two motors – one for the rotating movement (azimuth) to the selected satellite and the other one for adjusting the dish to account for the differing heights above the ground (elevation). Mounting the rotation axis in parallel to the rotations axis of the earth, i.e. in a pole-to-pole direction, alleviates this problem so that only one motor is required. However, this can only be achieved with a more complicated and extremely precise installation and alignment of the rotation axis.

Dealing with the installation of satellite receptions systems – both in theory and practice – requires gaining an understanding of sizes and proportions relating to different sizes. As even the relevant sizes and their derivations are hard to come by, the following will establish all relevant data.

Before performing any calculations it is paramount to recall the interdependencies between the earth and satellites. This may also provide a welcome opportunity to correct some common misconceptions.

The earth

Due to its rotation the diameter of the earth at the equator is larger than the distance between the north pole and the south pole, which means the earth does not have an exact spherical shape. However, the differences associated with this fact can be neglected for our calculations, so that we accept the established median radius of the earth of 6,731 km as given.

Historically and depending on the purpose, positions and directions are

© 2012 www.Thai-D.com/sat-art

defined using varying systems. Unless exact definitions rule out any ambiguities, one sometimes needs almost investigative skills to find out without doubt what is actually mean when reading about a position.

The equator can be established as the zero-point for the geographic latitude. Towards the north the range extends to 90 degrees north, or +90 degrees, towards the south it is 90 degrees south or -90 degrees to the pole(s).

As regards the geographic longitude an artificial zero-point had to be determined. The meridian crossing the Greenwich observatory near London with its line from the north pole to the south pole has been accepted as zero meridian since 1884. From this meridian, the circle is divided into 360 degrees towards the East. This system is derived from astronomy which also employs a left system (seen from the north pole) for projections from the earth's surface into space. This way the position of celestial bodies such as satellites in a geostationary orbit can be precisely defined.

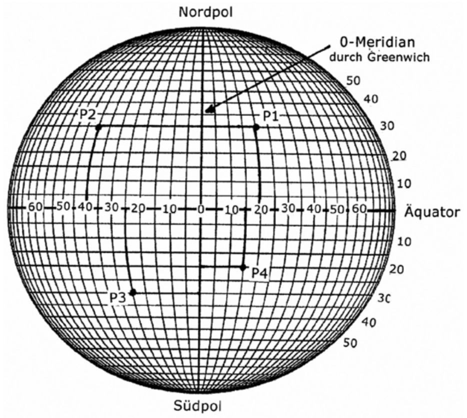


Fig. 1 features four points with their positions, which are listed in the table below with their used designations.

In Europe the relative designations are predominant, based on the zero meridian towards west or east. While this is the most complex and longest designation it is one that leaves no room for misinterpretation. As satellites are positioned near the equator, it is not necessary to also give the latitude as it is always zero degrees.

When installing a polar mount antenna the most important parameter – apart from the exact positioning of the mast pointing north from its horizontal installation – is the precise determination of the southerly direction at the location. In most cases a compass will be used to find the exact south. However, the results are frequently inaccurate and problematic in principle, as the following sources of error clearly demonstrate:

1. The magnetic north pole as indicated by the magnetic needle of a compass is not the same as the geographic north pole and shifts from year to year. This is also the reason way nautical charts – which have to show the exact geographic north – have to be redrawn almost every year and are sold with revised information in certain intervals. To give you an understanding of the deviation look at the following comparison for a specific point in time:

The magnetic north pole was situated north of Canada at
- approx. 100 degrees western longitude and
- approx. 75 degrees northern latitude
- and that was approx. 1,500 km away from the geographic north pole.

The magnetic south pole was approx. 2,500 km away from the geographic south pole and was situated at
- approx. 140 degrees eastern longitude and
- approx. 65 degrees southern latitude.

The further north we move, the larger the deviation caused by a compass becomes (depending on the geographic longitude, however).

2. Below the surface conditions may exist that influence the magnetic field.

3. Objects made of metal (such as metal roofs, railings, concrete reinforcements etc.) may be located close to where the compass is used. Theses objects may severely interfere with the magnetic field.

	Absolute	Relative	Relative, in use
P1	20/30 degrees	+20/+30 degrees	20 degrees eastern longitude/30 degrees northern latitude
P2	320/30 degrees	-40/+30 degrees	40 degrees western longitude /30 degrees northern latitude
P3	335/-30 degrees	-25/-30 degrees	25 degrees western longitude /30 degrees southern latitude
P4	15/-20 degrees	+15/-20 degrees	15 degrees eastern longitude /20 degrees southern latitude
Sat. Astra	19,2 degrees	+19,2 degrees	19,2 degrees east
Sat. Hispasat	330 degrees	-30 degrees	30 degrees west

4. Even the sunspot activity may distort the earth's magnetic field.

5. The glass protecting the magnetic needle may become electrostatically charged and then causes massive measurement errors if one is not cautious enough. Plastic coverings are particularly problematic in this regard.

If all these issues are taken care of a compass may actually deliver quite satisfying results. Still, the most reliable determination of the southerly direction is by locating a satellite that is as close as possible in the exact south when seen from the given location of the antenna. As a rule of thumb, satellites are mostly spread with a 3-degree spacing, which makes this method very accurate. Generally however, you will first have to find out the exact position given in geographic longitude and latitude of the location of the antenna. If you need help obtaining these parameters please approach your local TV installer, check the Internet or look at special maps. If you know somebody owning a handheld GPS device this would also be a convenient way of finding out where exactly you are.

The 'bad habit' of giving the deviation of satellites from a southern direction towards the east or the west (azimuth) by stating the compass course is gaining ground. This requires that we have to take into account that a compass has its zero point in the north, which means that south is at 180 degrees. The compass rose is divided into 360 degrees and constitutes a right system:

0 north, 90 east 180 south 270 west.

If we assume that a satellite is positioned three degrees east of the southern direction, it has a compass reading of 177 degrees. It would be easier to simply state 3 degrees east, or azimuth +3 degrees (east).

There are cases when older marching compasses are being used to determined the exact south. These also have their zero point in the north, but the full circle is divided into 64 segments (with one segment equalling 5.625 degrees) and it is a left system:

0 north, 16 west, 32 south, 48 east.

The satellites

Satellites have to remain in their position relative to the surface of the earth so that transmissions from them can be used commercially – they have to be positioned geo-stationary so that a fixed antenna can receive signals. Therefore, satellites have to meet the following conditions:

1. The have to rotate above the equator.
2. The have to move in the same direction as the earth.
3. The have to be positioned at a distance from the earth that allows them to take 24 hours for one full rotation (precisely $23^h\ 56^m\ 04^s$).

In order to fulfil these conditions Kepler's third law of planetary motion has to be applied:

The square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit.

According the Kepler's first law of planetary motion the orbit is an ellipse. In our case the ellipse comes very close to a circle. The great elliptic axis a is thus replaced by the radius R, and the satellite's mass m can be neglected when compared to the earth's mass M. Applying Kepler's third law we thus arrive at the following constants:

$U = 23^h\ 56^m\ 04^s = 86\,164$ sec
U = rotation time
$G = 6{,}668.10^{-11}\ \mathrm{N.m^2.kg^{-2}}$
G = gravitation constant
$M = 5{,}976.10^{24}$ kg
M = earth's mass

$$R=\sqrt[3]{\frac{U^2.G.M}{4.\pi^2}}=\sqrt[3]{\frac{86164^2.6{,}668.10^{-11}.5{,}976.10^{24}}{4.\pi^2}}=$$

$$=4{,}215985.10^7\,\mathrm{m}\cong 42160\,\mathrm{km}$$

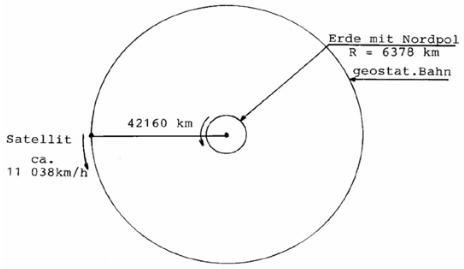


Fig.2

The speed of the satellite is this:

$$v=\frac{2.R.\pi}{T}=\frac{2.42160.\pi}{24}\cong 11038\ \mathrm{km/h}$$

(The satellites are positioned at 42,160 – 6,378 km = approx. 36,000 km above the equator)

Polar mount antennas

If we were able to install a motorised antenna on the north pole or at the centre of the earth it would be possible to receive signals from all geo-stationary satellites – at least in theory. However, this would not be realistic even on the north pole as all satellites are below the horizon and therefore cannot be received. From this it follows that the reception range of an antenna that is directed towards the south and aligned towards the east or west is largest at the equator and gradually decreases the more we move north. At a northern and southern latitude of 80 degrees the range is zero. Calculations we will perform at a later stage will provide a scientific framework for this statement. As antennas realistically can only be set up on the earth's surface the proportions and relations of figure 3 apply.

The antenna is installed at a certain position P on the earth, with a northern latitude φ. If we now align the antenna to face precisely south, for example pointing to satellite S1 and rotate it around the axis PP' that has a pole-to-pole alignment until it points to satellite S2 it will not be able to exactly meet it as the antenna's radius is smaller than the distance PS2. It meets the equator plane at point S2', i.e. somewhat lower. This in turn suggests that the elevation (see fig. 5) of the antenna has to be increased. The bigger the deviation from a precise southern direction, the bigger the margin of error. A check calculation was performed to find out of this margin of error that needs to be taken into account in practice: At the geographic latitude of 47 degrees and a ω value of 60 degrees the error is -0.41 degrees, which is negligible.

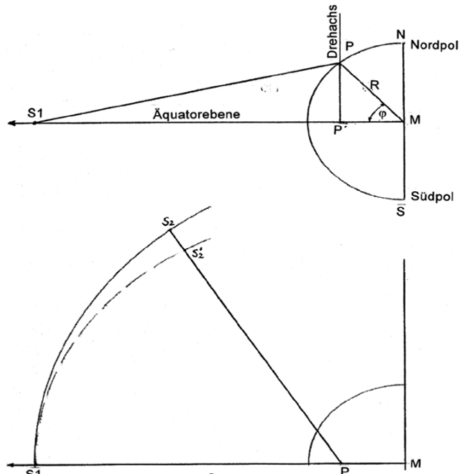


Fig. 3

M = centre of the earth
R = radius of the earth (6,371 km)
P = location of the antenna
φ = northern latitude of P
S1 = southern direction
S1 and S2 are satellites (fictitious)
MS1 = MS2 = radius of the satellites' orbit (42,160 km)
PS1 = PS2` = radius of the motorised dish

If a spectator stands at location P and 'looks' in the direction of the satellites, what he sees appears to be similar to Fig. 4a. A satellite that is positioned in the exact south appears higher and those satellites that are located to the east or west appear closer to the horizon until they disappear below the horizon. Because of the earth's gravity spectators see the horizon as a horizontal line (see also Fig. 8).

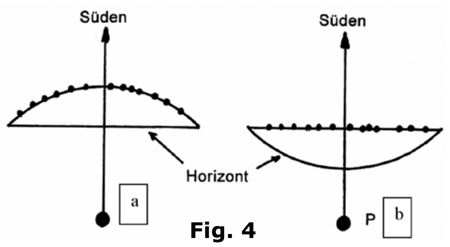


Fig. 4

A very different situation emerges when we deal with a polar mount antenna, as it rotates around the polar axis and 'sees' satellites next to each other in a straight line (which is why polar mount antennas are used in the fist place). However, when the dish rotates the distance to the horizon changes, as Fig. 4b illustrates. Naturally, the antenna cannot perform an arc-like movement, because it only rotates around a single axis, which is aligned in parallel to the pole-to-pole line.

What we have learned so far clearly highlights the advantages of a motorised polar mount antenna when it comes to receiving a multitude of satellites and their respective channels. Such a set-up is not even very complex, with the single biggest issue probably being a suitable location to install the antenna. What you also need is a receiver which is capable of controlling a motor, as an extra device for motor control does not make sense. If you are computer-literate and both your receiver and your PC feature an RS-232 interface even the tiresome task of organising thousands of channels becomes manageable quite easily and if you connect your receiver to your PC you will end with a fully-fledged information centre that leaves nothing to be desired. Language barriers can easily be overcome with the help of images and the Internet as well as TELE-satellite magazine are valuable sources of information for satellite enthusiasts.

Elevation towards the south

One of the determining factors for the successful installation of a polar mount antenna is the mast which needs to be inclined as precisely towards the north from its vertical position as possible. You may always correct a slight north-south deviation at a later stage when fine-tuning the complete system, whereas an imprecise east-west alignment can only be adjusted by moving the antenna mast.

Another underlying condition is knowing the precise geographic longitude and latitude of the antenna location – at least everything except the decimal places. As mentioned in the introduction these data can be obtained from specialists in the field or from friends owning a handheld GPS device. The geographic longitude is of particular importance, as it plays a crucial role for calculating the correct elevation and determining the southern direction. A compass should only be relied on as general guidance for identifying a southern direction, as its use it too error-prone.

It is much better to look for a satellite that is positioned as closely to the geographic longitude as possible. This of course requires a TV or monitor to verify the result and to avoid pointing the antenna to the wrong satellite (as satellites can be positioned rather close to each other). Fig. 5 indicates the correct angles which are required for the calculations that follow.

M = centre of the earth
N = north pole
P = location of the antenna
φ = geographical latitude of the location
R = 6,371 radius of the earth
MS = 42,16 radius of the satellite's orbit
ε = elevation

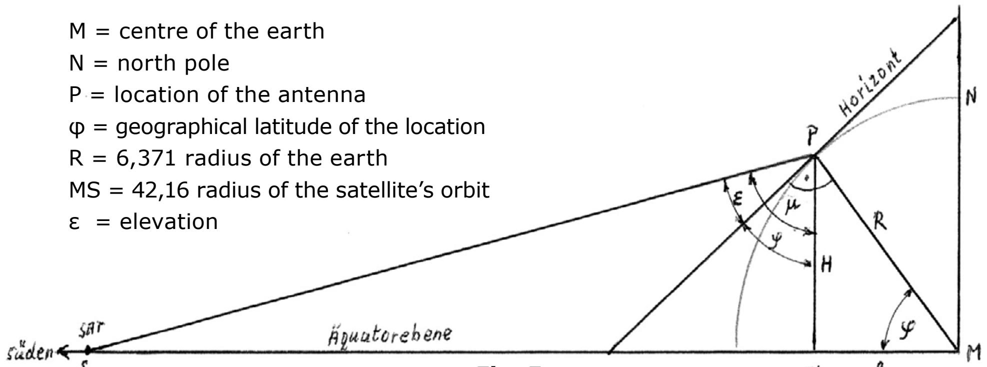


Fig. 5

$$tg\mu=\frac{P\grave{}S}{H}=\frac{42{,}16-6{,}371.\cos\varphi}{6{,}371.\sin\varphi}$$

$P\grave{}S = 42{,}16 - 6{,}371.\cos\varphi$
$\varepsilon = \mu - \varphi$

This means the elevation ε towards the south is:

$$\varepsilon = \mathrm{arctg}\,\frac{6{,}6175-\cos\varphi}{\sin\varphi}-\varphi$$

(Note that the radii of the earth and the satellite's orbit are shortened in the calculations.)

Figure 6 shows the angle by which the rotation axis for the antenna has to be inclined towards the north so that it is in parallel to the pole-to-pole axis.

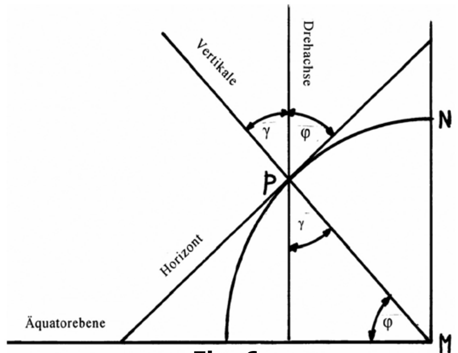


Fig. 6

Inclination towards the north against the horizontal level is: φ (conforms to geographical latitude)

Inclination towards the north against the horizontal level is: γ = 90 - φ

Inclination of the antenna towards the satellite

Once the rotating axis is inclined to the north by the appropriate angle the antenna has to be rotated downwards by the angle δ against the right angle towards the rotating axis, so that it 'looks' directly to a satellite that is south of the location.

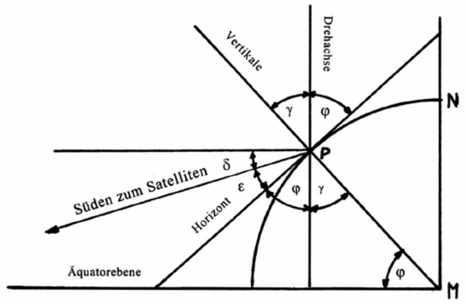


Fig.7

Angle δ is defined as declination (deviation).

$$\delta = 90-\varphi-\varepsilon$$

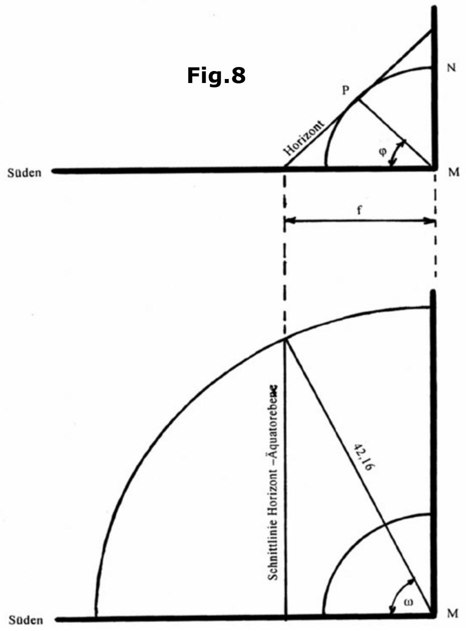
$$\delta = 90-\varphi-(\mathrm{arctg}\,\frac{6{,}6175-\cos\varphi}{\sin\varphi}-\varphi)$$

$$\delta = 90-\mathrm{arctg}\,\frac{6{,}6175-\cos\varphi}{\sin\varphi}$$

Maximum reception range

Naturally, a general calculation example like the one above cannot take into account local factors such as buildings, trees etc. that might influence reception at the respective location. The only value that can be calculated is the maximum angle that is limited by the horizon. This angle is calculated from the south towards east and west.

Fig.8



$$f=\frac{6{,}371}{\cos\varphi}\qquad \cos\omega=\frac{f}{42{,}16}=\frac{6{,}371}{42{,}16.\cos\varphi}$$

$$\omega_{\max}=\arccos\frac{1}{6{,}6175.\cos\varphi}$$

The maximum reception range ω depends on the geographic latitude of the location of the antenna, gradually decreases the further north the location is situated, and reaches zero at 81 degrees northern latitude. The maximum reception range can be achieved at the equator at 81 degrees. Of course this is only true for satellites with a geo-stationary orbit.

The angle ω is calculated starting from a southern direction towards east or west. In order to find the largest possible number of available satellites (azimuth) the following formula applies:

Towards east: λ + ω

(The correct algebraic sign has to be used for the geographic longitude λ of the location of the antenna)

Towards west: λ - ω

(λ is positive for all positions east of the zero meridian.)

Polarisation

Figure 4b illustrates that the elevation changes automatically when the antenna is rotated. This at the same time implies that the antenna's orientation towards the satellites remains unaffected and the polarisation levels are the same for all receivable satellites and therefore need not be changed. Nevertheless, most receivers with integrated motor control come equipped with a device that corrects any possible tilt of satellites.

An LNB with built-in positioner can achieve this with either a coil with electric current flowing through it or an impulse-controlled tongue. Both options require a dedicated separate circuit from the receiver to the LNB. However, such measures are mostly obsolete these days as satellites can be controlled much more precisely than what used to be the case.

Parabolic/offset antennas

Figure 9 compares two basic antenna types for wavelengths of a few centimetres (approx. 10 GHz). For professional applications only parabolic antennas with a central reception unit (LNB) are in use, while for private reception offset antennas as shown in figure 9a are used up to a size of approximately 1.2 metres. With its more upright position an offset antenna is less exposed to the elements (rain, snow) and thus more convenient to operate in the private sphere.

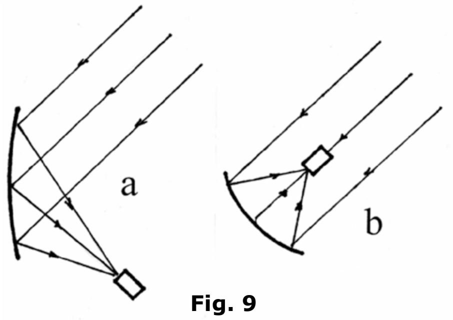


Fig. 9

Motor control

Traditionally, motorised antennas are powered by an actuator which consists of a shaft whose length is varied with the help of a DC motor. Such a motor has a uniform supply voltage of 36 V and changes its direction through switching the poles. A photocell is integrated in the motor for exact positioning. It creates the impulses for positioning through a perforated disc.

When this technology first surfaced external control devices had to be used to control the antenna's movements. Soon, however, new receiver models were introduced which were able to perform all required tasks and offered on-screen displays to set up the system in the first place.

36 V power packs usually supply current with at least 2 ampere, while the motors that are used generally require less than 1 A. Unfortunately, however, these devices are disappearing very fast and in most instances are replaced by so-called H-H motors.

Plus: sturdy design, hardly any repairs needed, suitable also for larger antennas.

Minus: separate circuit (5 wires) must lead to antenna, (+ and -36 Volt, ground, +5 V for electronics, impulse circuit)

DiSEqC

As more and more control functions had to be provided for one or more antennas and/or LNBs new and intelligent ways had to be found for providing control impulses via existing antenna cables. It then was a logical step to also integrate motor control into this system and using the regular antenna cable for impulse transmission (DiSEqC). As LNBs are supplied with 13 or 18 V depending on the polarisation level it made sense to use the same voltage for the motors as well. A current of between 0.2 and 0.3 A is required for these motors and can easily be generated by suitable receivers.

Plus: No separate line to the antenna required; DiSEqC via existing antenna cable is used instead. If motor is detached for repair there is still reception of one satellite, for example Astra.

Minus: As the current for the motor is 13 V or 18 V depending on the polarisation level of the received signal, both the speed and force of the rotation movement vary. Not suitable for very large dishes.

H-H

So-called H-H motor controls have been promoted by various companies for some time now. However, they do not fall into the polar mount category as their movement rather follows the circular line-up of satellites above the horizon that is shown in figure 4a. The antenna cable transmits all control signals. Due to their design H-H motor controls have to be physically attached to the antennas, which means that any repair requires the complete antenna to come down from the roof.

Plus: Rather easy installation, because all you need to know is the geographic latitude and the southern direction.

Minus: If repairs are necessary there is nothing left for reception. Only suitable for small dishes.

Practical example

We chose Munich is the location for our practical example. First, we collected all relevant data referring to our location and then performed all required calculations we might ever need for installing our antenna:

Geographic longitude:
λ = 12,1 degrees east
Geographic latitude:
φ = 48,1 degrees north
Verification of the reception range:

$$\omega = \arccos - \frac{1}{6{,}6175 . \cos 48{,}1} \cong 77\ Grad$$

This means, in general the range to the east λ + ω = 12 +77 = 89 degrees and to the west λ - ω = 12 – 77 = -65 degrees for the reception of satellites – azimuth +89 to -65 degrees. In actual fact, however, we will probably only be able to really receive satellites between the Hispasat 30 degrees west (azimuth 42.1 degrees west) and the Panam-Sat 45 degrees east (azimuth 32.9 degrees east). Between these positions there are approximately 20 satellites transmitting more than 1500 free-to-air channels.

Next we have to perform all additional calculations, even though not all might be needed, depending on the make and model of the antenna:

$$\text{Elevation}: \varepsilon = \ arctg \frac{6{,}6175 - \cos 48{,}1}{\sin 48{,}1} - 48{,}1 \cong 35\ Grad$$

$$\text{Deklination}: \ \delta = 90 - \text{arctg} \frac{6{,}6175 - \cos 48{,}1}{\sin 48{,}1} \cong 7{,}1\ \text{Grad}$$

Inclination of the rotating axis towards the north:

φ = 48,1 degrees against the horizontal line

γ = 90 - φ = 90 – 48,1 = 41,9 against the vertical line

Once all calculations are finished we have to look for a suitable spot to install the antenna. While perfect reception is the number one focus we nonetheless have to take into account other factors such as a robust support for the antenna mast (making it windproof and earthing it) and any restrictions or limitations that exist at the location. Of course all regulations by local authorities must be adhered to as well.

We recommend contracting a specialised company for installing the antenna mast. This way you can make sure (i.e. they must make sure) the mast can take high wind loads and is protected against damage from lightning. Authorised businesses can also be expected to know local regulations and are responsible for not breaking any rules.

Now that all queries are solved the next step is buying the technical equipment. If you're not the tech-savvy kind feel free to ask a specialist for assistance.

As far as assembly is concerned you start out with the antenna support and with adjusting the antenna according to the calculated values with the help of the existing marking on the support. Next, the support is attached to the antenna mast and the antenna itself with the LNB is attached to the support. You then need to connect a monitor or TV to the antenna before you start rotating the antenna until signals from a southern satellite can be received. We recommend Hotbird at 13 degrees east, as it almost exactly (only 0.9 degrees deviation) corresponds to the geographic longitude of Munich. To make sure you're hooking to the correct satellite it is paramount to select a channel from that particular satellite. The following channel, for example, can be used for Hotbird:

ZDF digital 11,054 GHz vertical
Symbol rate 27 500
SID 8011
Video PID 570
Audio PID 571
PCR PID 570

Please make a point in setting all required parameters, as the same channel with the same name is also broadcast from ASTRA. Also make sure that the marking for south on the antenna support is adjusted precisely while the complete construction is rotated on the mast.

Once you can confirm reception of Hotbird all that is left to do is tighten the fixing screws before you can rotate the antenna for the first time to its limit stops, and check if the motor works satisfactorily using a soft stop mechanism that is available with most receiver types and prevents the antenna from striking any obstacle that might be in its way.

In case a satellite close to the limit stops cannot be received or comes in only weakly you can slightly bend the antenna up or down to find out which of the two scenarios shown in figure 10 you are faced with. It is now that a less than perfect installation of the antenna mast shows its unwelcome consequences:

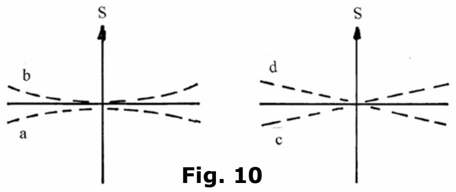


Fig. 10

a: The rotation axis is not enough to the north

b: The rotations axis is too much to the north

c: The mast leans towards the east

d: The mast leans towards the west

Mishaps like these can be rectified by readjusting elevation and inclination of the rotation axis – but always starting from a southern direction.

Addendum Compilation

λ = geographic longitude
φ = geographic latitude
ε = elevation towards south

$$\varepsilon = \text{arctg} \frac{6{,}6175 - \cos \varphi}{\sin \varphi} - \varphi$$

δ = declination

$$\delta = 90 - \text{arctg} \frac{6{,}6175 - \cos \varphi}{\sin \varphi}$$

ω = reception angle from the south

maximum no. of satellite positions (azimuth):

towards west: λ - ω
towards east: λ + ω

$$\omega_{\max} = \arccos \frac{1}{6{,}6175 . \cos \varphi}$$

inclination of the rotation axis towards north:

against the horizontal level: φ
against the vertical level: γ = 90 – φ
radius of the earth = 6,371 km
orbit of the satellites = 42,160 km

Technical terms

Equator *(Latin)**:** balancer*

Azimuth *(Arab)**:** angle between the meridian of the location of observation and the vertical circle of a heavenly body*

Declination *(Latin)**:** deviation*

DiSEqC *(acronym)**:** Digital Satellite Equipment Control. Transmission of data via the antenna cable by way of impulse controls using the 22 kHz tone. Developed by Philips and offering almost endless options. Even return channels can be implemented for more complex control set-ups.*

Elevation *(Latin)**:** heightening, increase*

Geodetic system *(Gea = Greek: earth)**:** system of imaginary lines covering the earth.*

Horizon *(Greek)**:** skyline, horizontal level*

Kepler: *Natural scientist 1571 – 1630. Kepler's laws of planetary motion:*
1. The orbit of every planet is an ellipse with the sun at a focus.
2. A line joining a planet and the sun sweeps out equal areas during equal intervals of time.
3. The square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit.

LNB*: Low Noise Block Converter (converter positioned in the focal point of the parabolic antenna and using an oscillator to convert the satellite frequencies into 950 to 2150 MHz, which then are transmitted to the receiver via the antenna cable)*

Meridian *(Latin)**:** length, longitudinal circle. (0-meridian: longitudinal circle from the north pole via Greenwich near London to the south pole. Generally acknowledged as the zero meridian since 1884).*

Monitor *(Latin)**:** device for observing images, video screen.*

Polar *(Greek)**:** pivotal point; polar mount: mounted in a pole-to-pole direction.*

Polarisation *(Latin)**:** direction (of waves).*

Satellite *(Latin)**:** companion.*

Greek characters that have been used:
λ Lambda δ Delta ω Omega π Pi
γ Gamma ε Epsilon μ My φ Phi

Literature: *Prof. Dr. Hans Heinrich Voigt, Göttingen university observatory „ Abriss der Astronomie" ("Abstract of Astronomy")*