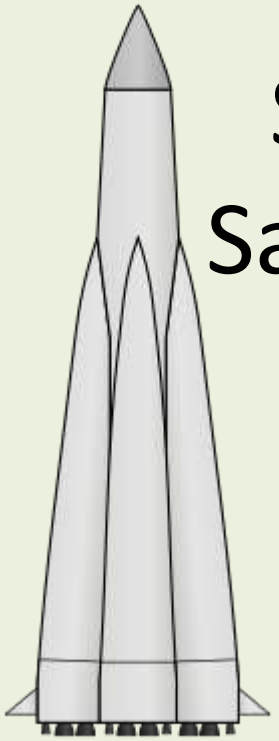
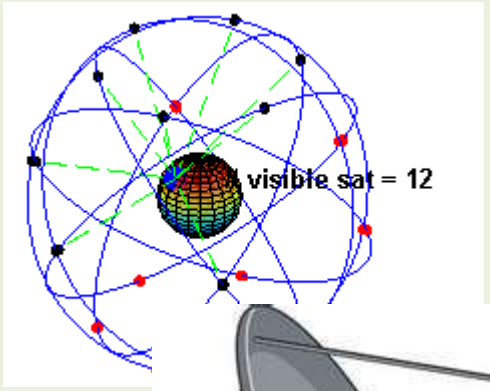


Satelitné technológie a služby
Satellite technology and services
2013/14

Exercises
1 and 2



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0:/_materialy/materialy_macekova/STS_denni_cvicenia/

Approximate plan of topics of exercises

- semestral work – the tasks and requirements
- term ‘Satellite system’, its parts, up/down link , satellite services, classification of sat. systems (LEO, MEO, GEO,...), satellite services
- satellite bands
- useful software / applications for searching parameters of satellites and sat. receiving
- the data for setting satellite receiver (terms, satellite parameters, angles for antenna setting)
- calculation of delay of sat. signal
- antennas; describing of construction, el. parameters, Gain of antenna
- DVBS/S2, MPEG-2, MPEG-4, principles, transport stream mapping
- satellite receiver – outdoor and indoor unit, DVB-S/S2 receivers
- DreamBox - smart equipment, configuration, streaming, transport stream evaluation
- GPS – principles (demonstrations)
- parameters of satellite transmission (gains, attenuations, energy of signal in dB, surface density of power, noise temperature, ...)
- link budget of satellite link (= energy budget)

****

- 2 tests (each for 10 points, examples and theory of lectures of prof. Marchevský), semestral project (10 points, text document ; requirements - see next page)

STS_semestral work requirements, Feb. 2014:

- Convert text from .pdf file into the TU-template **.doc** or **.docx** for theses (https://etd.lib.tuke.sk/Sablony.aspx): structured text (head levels, normal text, ...,Fig. number and figure name, use **Equation Tool** for writing mathematical relations, number of equations, Reference literature [xy],…, cross references
- Skip irrelevant parts and pages of template as Title, abstract, etc.
- Design **figures (yourself**) – graphical figures, in MS-Visio or Corel, and send also separate files with figure data for repeated editing (charts, tables, network architectures, etc.).
- design tables yourself also
- Send finished file and figure files to Mr. P. Babič, who will complet and format all texts into combined file.
-
- The term: at least before 10-th week of semester (i.e. until April 18th 2014)

Basic components of satellite communications

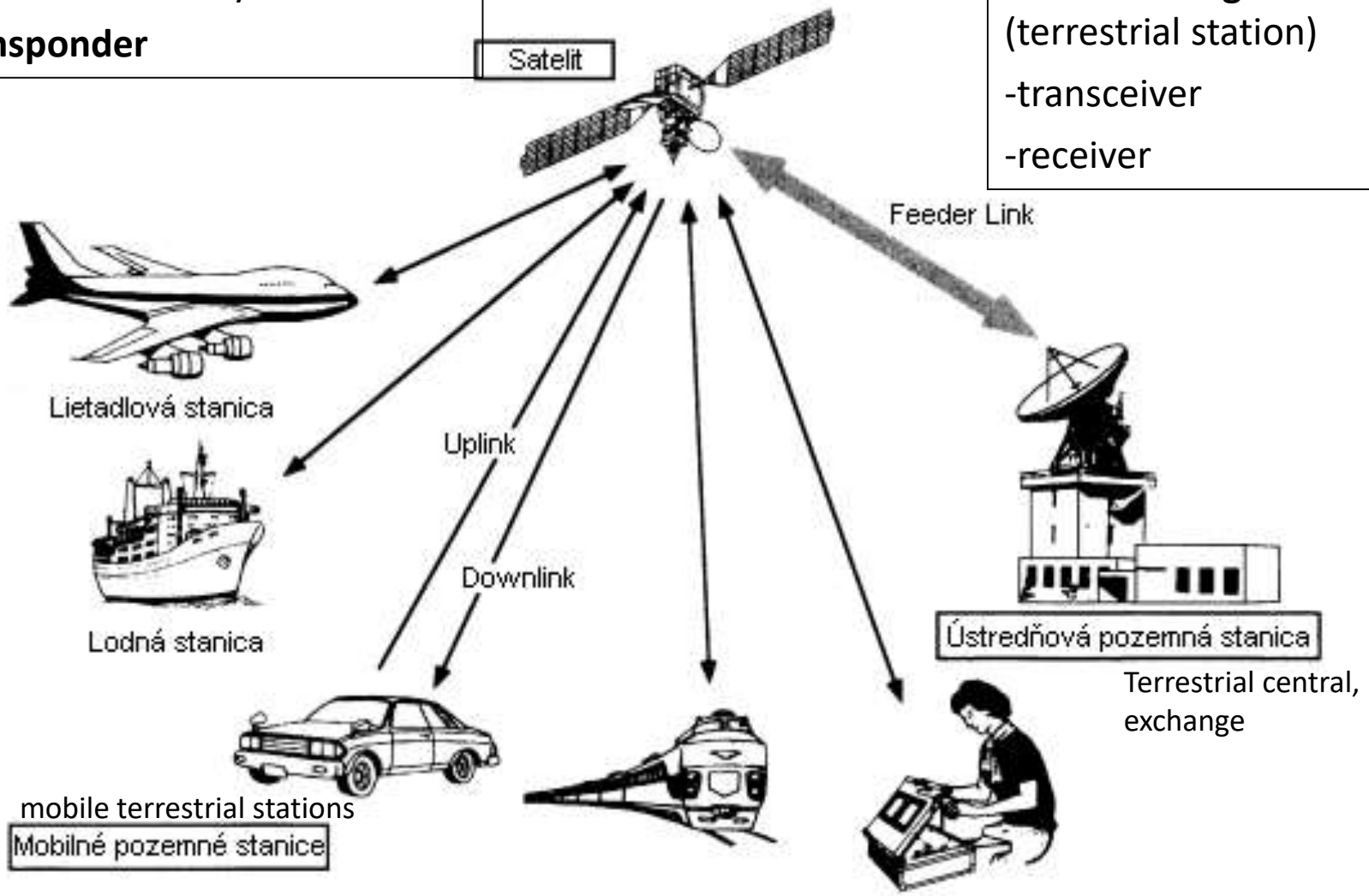
Space segment (satellite):

- propulsion system
- controle telemetry
- **transponder**

Terrestrial segment
(terrestrial station)

-transceiver

-receiver



+ Transmission systems (coding, modulations, data protection,...)

Terms

- uplink
- downlink
- **feederlink** – communication link between terrestrial central station and satellite (high capacity/transmission rate)

- **transponde r (**Transmitter + Responder) – automatic equipment on the board of satellite; it receives multiplexed signal from terrestrial station, amplifies it and again sents it as multiplex (on the other carrier frequency) down to Earth receivers. The transponder parameters are the parameters of multiplex channel (carrier /frequency, frequency band, bit rate, type of encoding, number of TV and radio stations in the multiplex/bouquet, etc.)
- **LOS** – **line-of-sight** – often condition for receiving of satellite signal

Transparent satellites (older): signal processing is realized in the terrestrial stations

Modern sat. systems:

- quick data transmission, protocols IP, SAT ATM

- dynamic utilization of spectrum (**Bandwidth on Demand) , statistical multiplex**

- **Onboard Processing** Satellites: satellites with ATM switches and packet routing to addressed users by means of separated antenna beams (**Spot Beams)**

- **hybrid networks –** transmission by means of any medium (free cosmic space, free space in Earth atmosphere, various types of cables, ...). It is possible just by utilizing standardized rules/protocols (TCP/IP, ATM)

Satellite services

- intercontinental voice services (telephone calls) and TV transmissions (not broadcast)
- radio- and TV broadcasting for households anywhere in the world
- mobile communications for users on the sea, in the air, in the remote places, by means of little portable or pocket apparatus ; GSM systems, UMTS, ...
- access to Internet and Internet services (TCP/IP): initial were VSAT systems (Very Small Aperture Terminals – fixed satellite networks, dedicated for interconnecting branch offices of multinational companies, for providing multimedia communication broadband services and narrowband services)
- radio positioning systems and radio navigation systems: GPS (Global Positioning System, USA), Galileo (EU), Glonass (Russian), Beidou Navig. Syst. (China)
- meteorology
- standard frequency and time signals
- amateur services
- intersatellite services

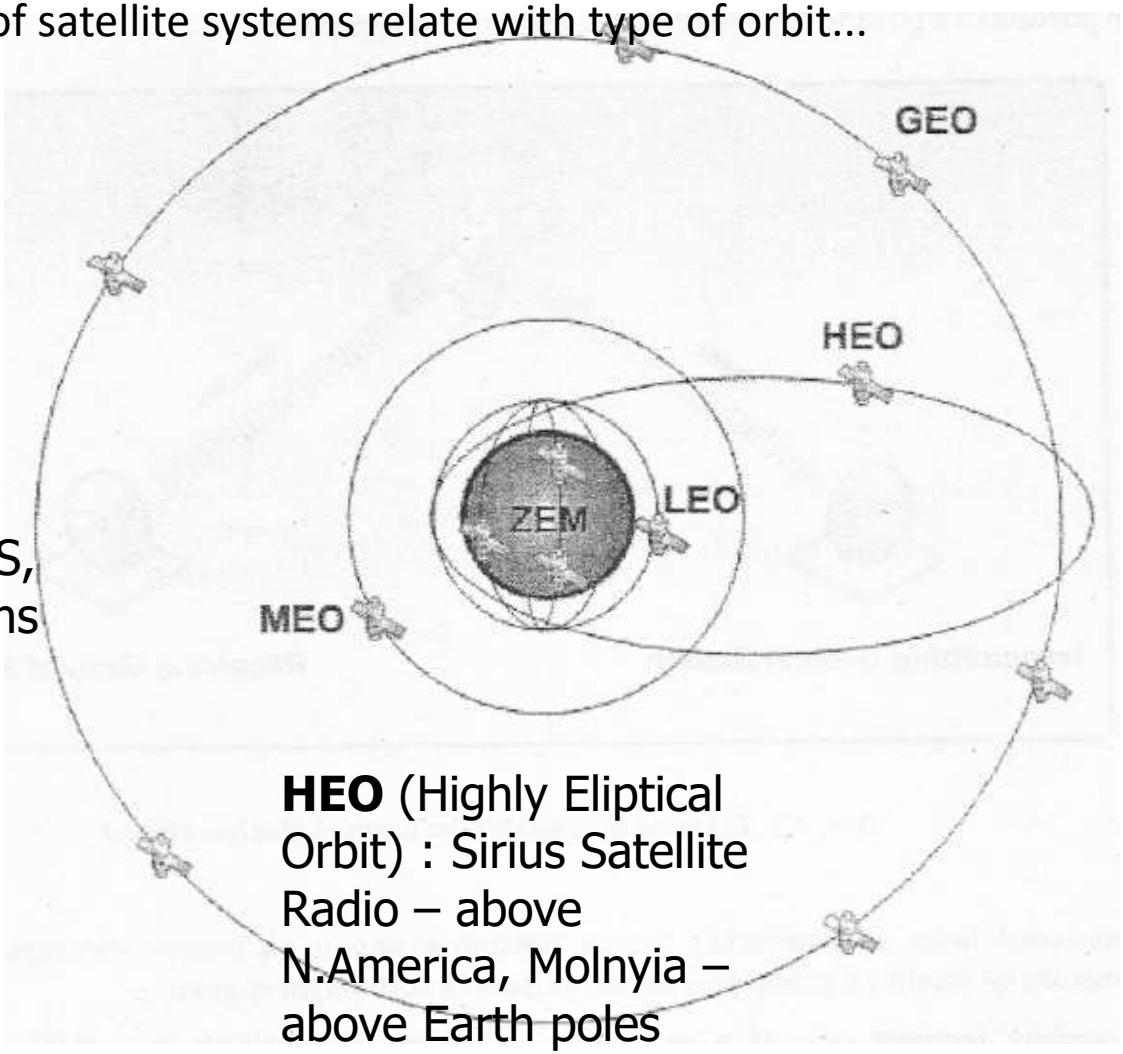
➢ Classification of satellite systems in accordance with type of orbit

- many other characteristics of satellite systems relate with type of orbit...

LEO (Low Earth Orbit): Argos, Orbcomm, Iridium, Teledesic, Globalstar, Skybridge

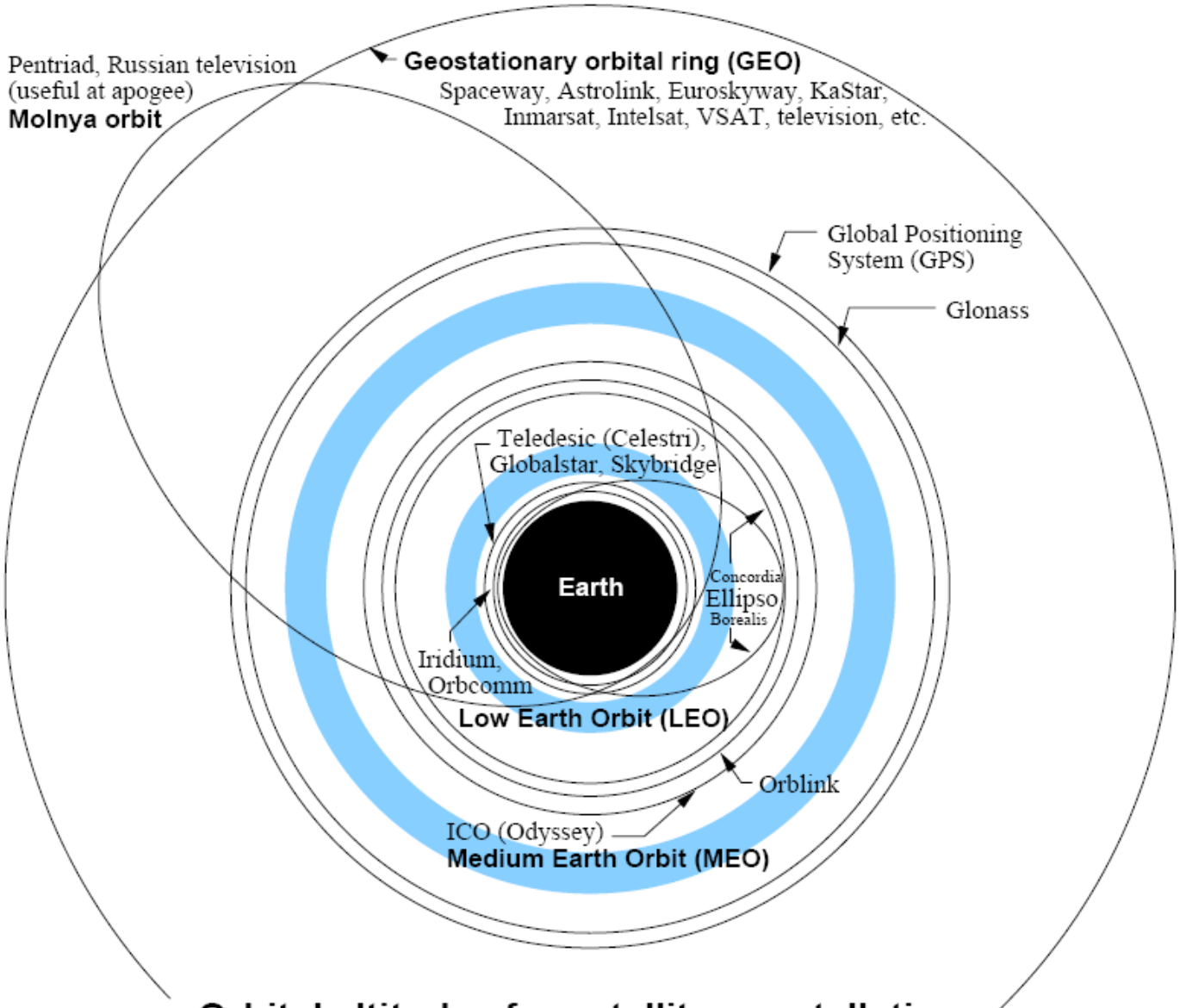
MEO (Medium Earth Orbit) : Odyssey, GPS, Glonass, Galileo – european-similar to GPS, Telstar - communications

GEO (Geostationary Earth Orbit) : Thuraya, Inmarsat (marin communications), cca 36000km above equator



HEO (Highly Eliptical Orbit) : Sirius Satellite Radio – above N.America, Molnyia – above Earth poles

Fig. Illustration of shapes and dimensions of types of satellite orbits



Orbital altitudes for satellite constellations

peak radiation bands of the Van Allen belts (high-energy protons)

orbits are not shown at actual inclination; this is a guide to altitude only

from Lloyd's satellite constellationshttp://www.ee.surrey.ac.uk/Personal/L.Wood/constellations/

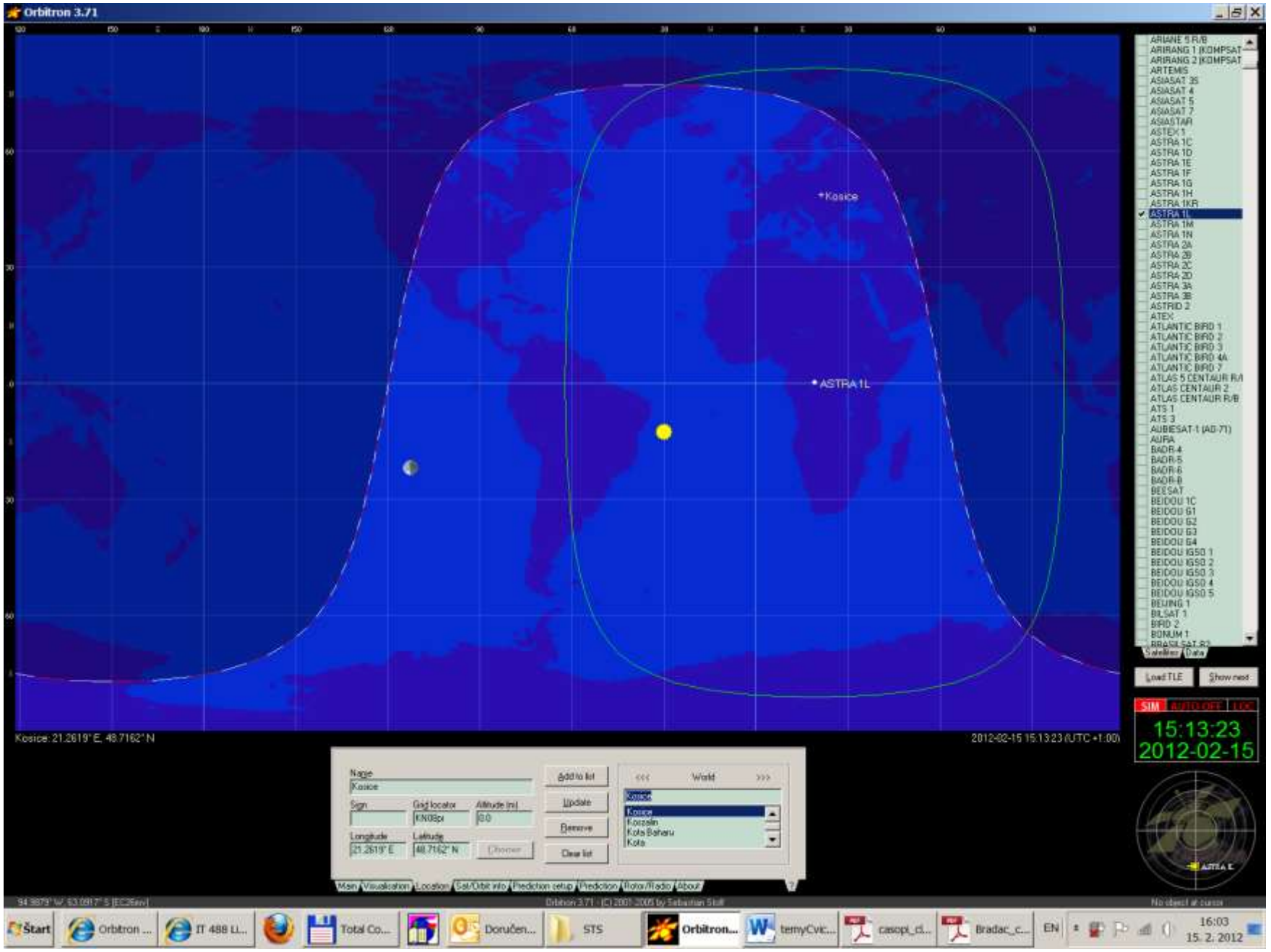
Basic parameters of described types of orbits

Parameter	LEO	MEO	GEO	HEO
altitude [km]	500 – 3000	10 000 – 14 000	35 786	500 - 50 000
periode [hours]	1 - 3	6 – 8	23.93	3 – 24
delay [ms]	6 – 30	70 – 120	240 – 280	50 – 320
time of visibility	few minutes	fwe minutes	24 h.	2 – 12 h.
signal quality	good	middle	weak	weak (dithering)
satellite controlling	complex	middle complex	simple	complex
launching costs	low	high	high	high
surface	broad	middle broad	little	broad

- hand-off needful

-many satellites for continuous coverage of Earth surface

-it is necessary to track the satellite (steerable antenna) or to use omnidirectional terrestrial antenna



Demonstration of window of Orbitron (free download from http://www.stoff.pl/ + actualization TLE from http://www.stoff.pl/downloads.php)

All radiofrequency bands : defined by RR (Radio Regulations) and ITU (International Telecomm. Union)

- satellite bands

band number	Name and purpose	Alphabet symbol	Frequency
4	VLF		3÷30 kHz
5	LF		30÷300 kHz
6	MF		300÷3GHz
7	HF		3÷30 MHz
8	VHF (TV and others)		30÷300 MHz
9	UHF (TV and others)		300 MHz÷3 GHz
10	**SHF** (Super High Frequency) **3÷30 GHz**	L - band	1÷2 GHz
		S - band	2÷4 GHz
		C - band	4÷8 GHz
		X - band	8÷12 GHz
		Ku - band	12÷18 GHz
		K - band	18÷27 GHz
11	**EHF** (Extremely High) **30÷300 GHz**	Ka - band	27÷40 GHz
		Millimeter waves	40÷300 GHz
12	THF (Tremendously...)	Submillimeter waves	300÷3000 GHz

frequency bands more detailed

EARTHSTATION FREQUENCIES		
BAND	**FREQUENCY**	
IF (Intermediate)	70 - 150 MHz	
L	800 - 2150 MHz	
SATELLITE FREQUENCIES (GHz)		
BAND	**DOWNLINK**	**UPLINK**
C	3.700 - 4.200	5.925 - 6.425
X (Military)	7.250 - 7.745	7.900 - 8.395
Ku (Europe)	FSS: 10.700 - 11.700 DBS: 11.700 - 12.500 Telecom: 12.500 - 12.750	FSS & Telecom: 14.000 - 14.800 DBS: 17.300 - 18.100
Ku (America)	FSS: 11.700 - 12.200 DBS: 12.200 - 12.700	FSS: 14.000 - 14.500 DBS: 17.300 - 17.800
Ka	~18 - ~31 GHz	
EHF (Extremly High)	30 - 300 (millimeter band)	
V	36 - 51.4	

DBS = Direct Broadcast Satellite (Consumer direct-to-home Satellite TV)
FSS = Fixed Satellite Service (Geostationary Comms Satellites for TV/Radio stations and networks)
(Hz = Hertz, MHz = Megahertz, GHz= Gigahertz)

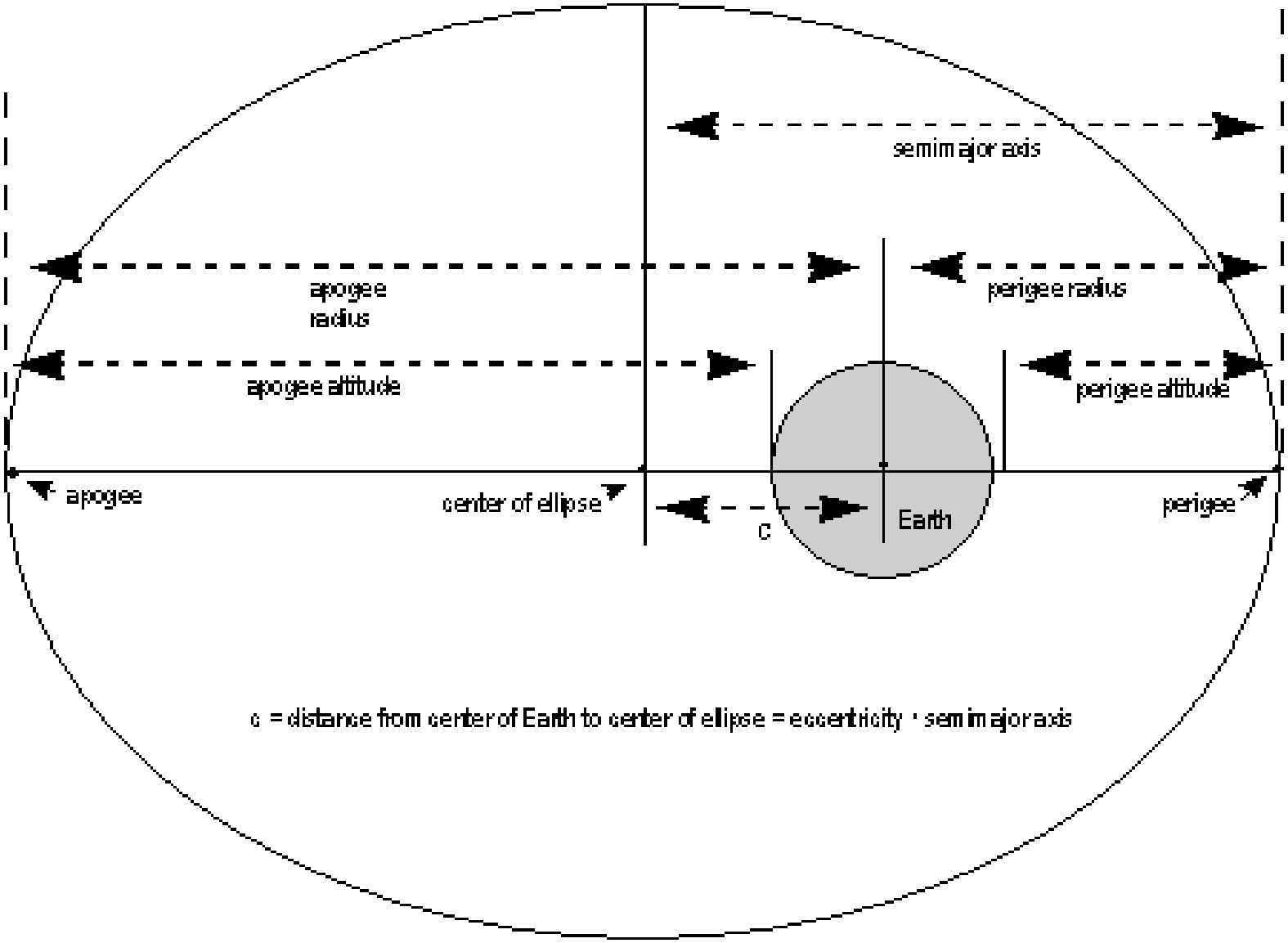
http://www.inetdaemon.com/tutorials/satellite/satellite-frequency-bands.shtml

Tab. : Examples of up a down satellite links (note: the higher frequency is uplink)

Name of Band	Frequencies [GHz]	Direction	Service	Bandwidth [MHz]
L	1.5 – 1.6	down	mobile	100
	1.6 – 1.7	up	mobile	100
S	2.5 – 2.6	down	radio broadcast	100
C	3.4 – 4.2	down	fixed	800
	4.5 – 4.8	down	fixed	300
	5.9 – 7.0	up	fixed	1100
X	7.2 – 7.7	down	military	500
	7.9 – 8.4	up	military	500
Ku	10.7 – 11.7	down	fixed	1000
	11.7 – 12.5	down	radio broadcast	800
	12.5 – 12.75	down	fixed	250
	12.75 – 13.25	up	fixed	250
	14.0 – 14.8	up	fixed	800
	17.3 – 18.3	up	fixed	1000
Ka	17.7 – 20.2	down	fixed	2500
	20.2 – 21.2	down	mobile	1000
	22.5 – 23.0	down	radio broadcast	500
	27.0 – 30.0	up	fixed	3000
	30.0 – 31.0	up	mobile	1000

Parameters Determining Orbit Size and Shape - orbital elements

Semimajor Axis	Half the distance between the two points in the orbit that are farthest apart
Apogee/Perigee Radius	Measured from the center of the Earth to the points of maximum and minimum radius in the orbit
Apogee/Perigee Altitude	Measured from the "surface" of the Earth (a theoretical sphere with a radius equal to the equatorial radius of the Earth) to the points of maximum and minimum radius in the orbit
Period	The duration of one orbit, based on assumed two-body motion
Mean Motion	The number of orbits per solar day (86,400 sec/24 hour), based on assumed two-body motion
Eccentricity	The shape of the ellipse comprising the orbit, ranging between a perfect circle (eccentricity = 0) and a parabola (eccentricity = 1)


semimajor axis
apogee
radius
perigee radius
apogee altitude
perigee altitude
apogee
center of ellipse
c
Earth
perigee
c = distance from center of Earth to center of ellipse = eccentricity * semimajor axis

Orientation of Orbital Plane in Space

Parameter	Definition
Inclination	The angle between the orbital plane and the Earth's equatorial plane (commonly used as a reference plane for Earth satellites)
Right Ascension of the Ascending Node	The angle in the Earth's equatorial plane measured eastward from the vernal equinox to the ascending node of the orbit
Argument of Perigee	The angle, in the plane of the satellite's orbit, between the ascending node and the perigee of the orbit, measured in the direction of the satellite's motion
Longitude of the Ascending Node	The Earth-fixed longitude of the ascending node

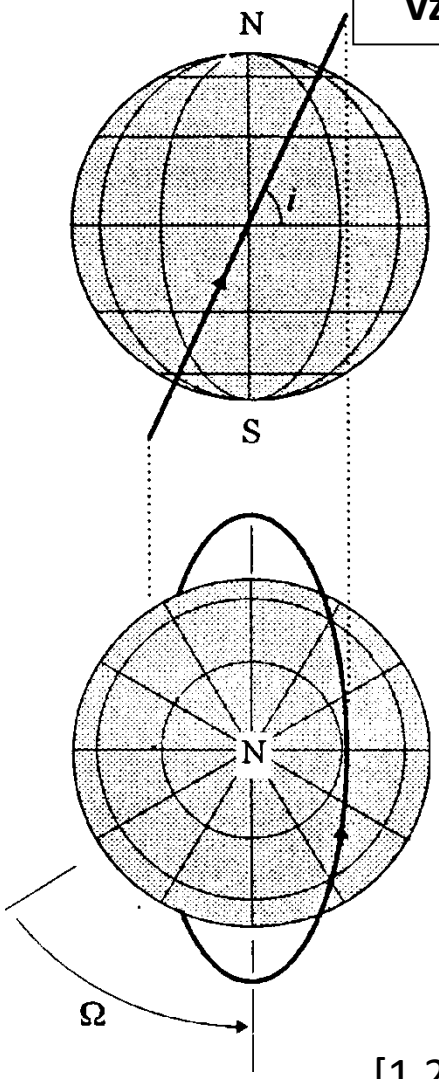
The ascending node (referenced in three of the above definitions) is the point in the satellite's orbit where it crosses the Earth's equatorial plane going from south to north.

Po slovensky: orientácia obežnej roviny a obežnej dráhy v priestore:

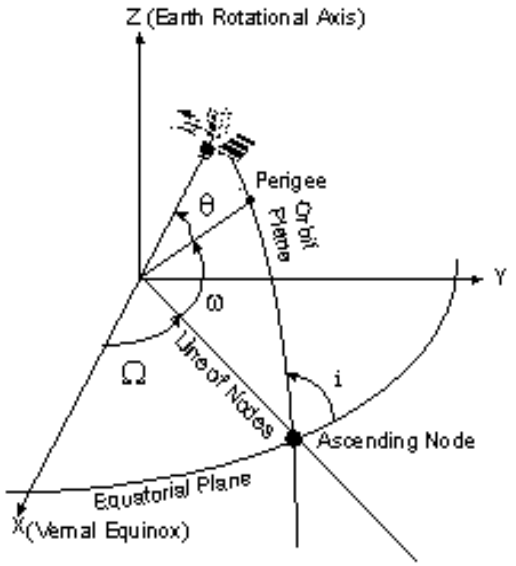
inklinácia i – uhol medzi rovinou obehu a rovinou rovníka Zeme

uzol (node) – bod, v ktorom satelit prechádza rovinou rovníka

vzostupný uzol (ascending node) – ten, kde sat. prechádza z juhu na sever

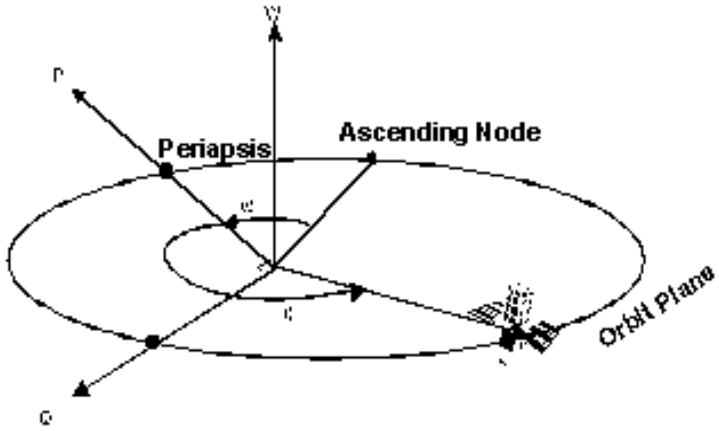


[1,2]



Orbit Geometry

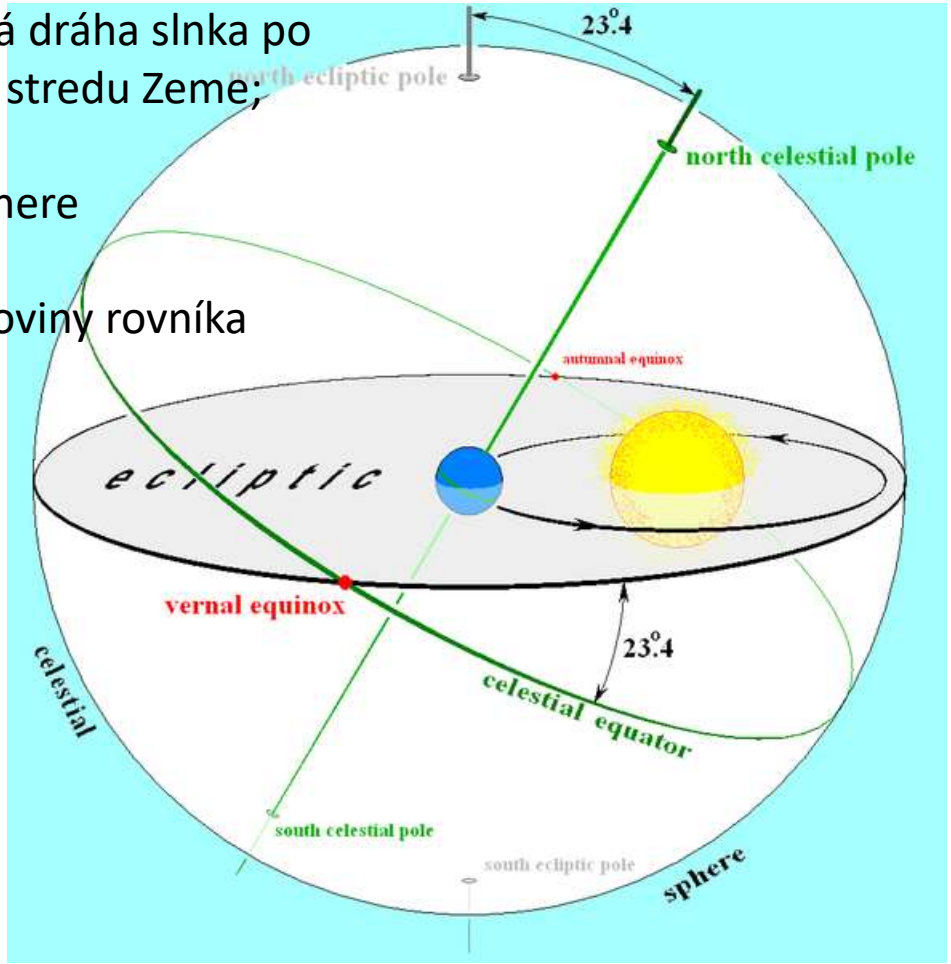
- **orientácia vzostupného uzla (uhol Ω)** – vzhľadom k referenčnému smeru, ktorým je smer na rovníkovej rovine od stredu Zeme k **jarnému bodu** (Vernal equinox – First Point of Aries)



Legend:
- Ω = right ascension of ascending node
- ω = argument of perigee/periapsis
- i = inclination
- θ = true anomaly

Pojmy - anglické vs. slovenské :

jarný bod = vernal equinox
ekliptika = ecliptic – zdanlivá dráha slnka po nebeskej sfére z pohľadu zo stredu Zeme; tiež rovina tejto dráhy
nebeská sféra = celestial sphere
nebeský (svetový) rovník = celestial equator (priemet roviny rovníka Zeme na nebeskú sféru)



obr. – zdroj: http://en.wikipedia.org/wiki/File:Earths_orbit_and_ecliptic.PNG

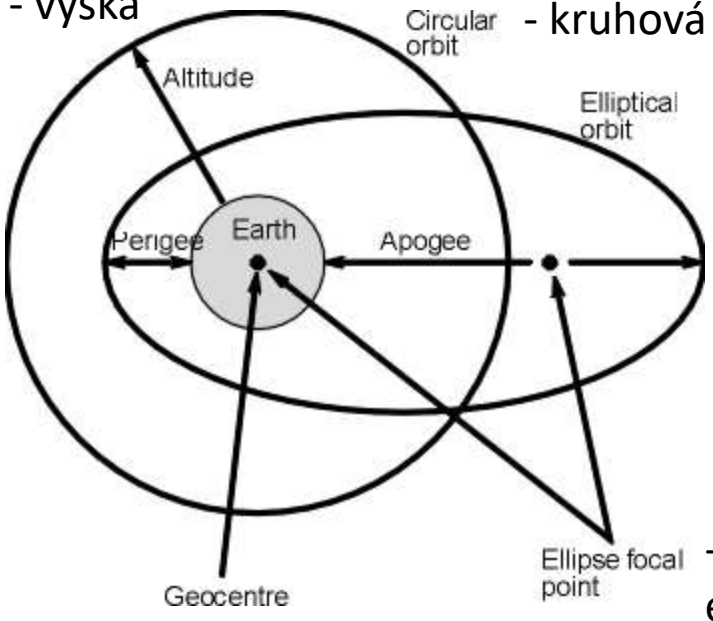


Fig.: Orbits; terminology

source: www.radio-electronics.com/info/satellite/sate...

Velocity of satellite – lowest in apogeum, highest in perigeum

Periode *of circulation in ellipse or circle:*

(regarding to inertial space – to background, which doesn't change its velocity):

$T^2 = (4\ \pi^2\ a^3) / \mu$

a – semimajor axis

μ – Kepler constant= $\boldsymbol{G.m_E}$

For GEO: 23 h. 56 min. 4,1 s.

= sidereal day, not solar day (solar day takes 24h.)

Problems of anomalies of orbit

GEO orbit is not exactly cyclic, not even is exactly above equator (not zero inclination)

- GEO orbit is permanently influenced by Sun and Moon forces → orbit distortions (position oscilations – L,R,Z oscilations; R-Radial, L-tangential, Z-perpendicularly to plane R,L

- distortions must be systematically corrected (satellite driving from Earth - TT&C - Tracking Telemetry and Command Station)

- distortions caused by irregular gravitational forces from non-spherical Earth (at the poles, radius of the Earth is < about 21 km in comparision with *r* at equator)

- pri inklinácii eliptickej dráhy 63,4 ° sa porucha neobjavuje (a to platí zrejme pre ktorúkoľvek planétu → satelity s touto inklináciou niekde inde v kozme môžu byť umelé ☺) [4]

Other parameters needed for communications with satellite:

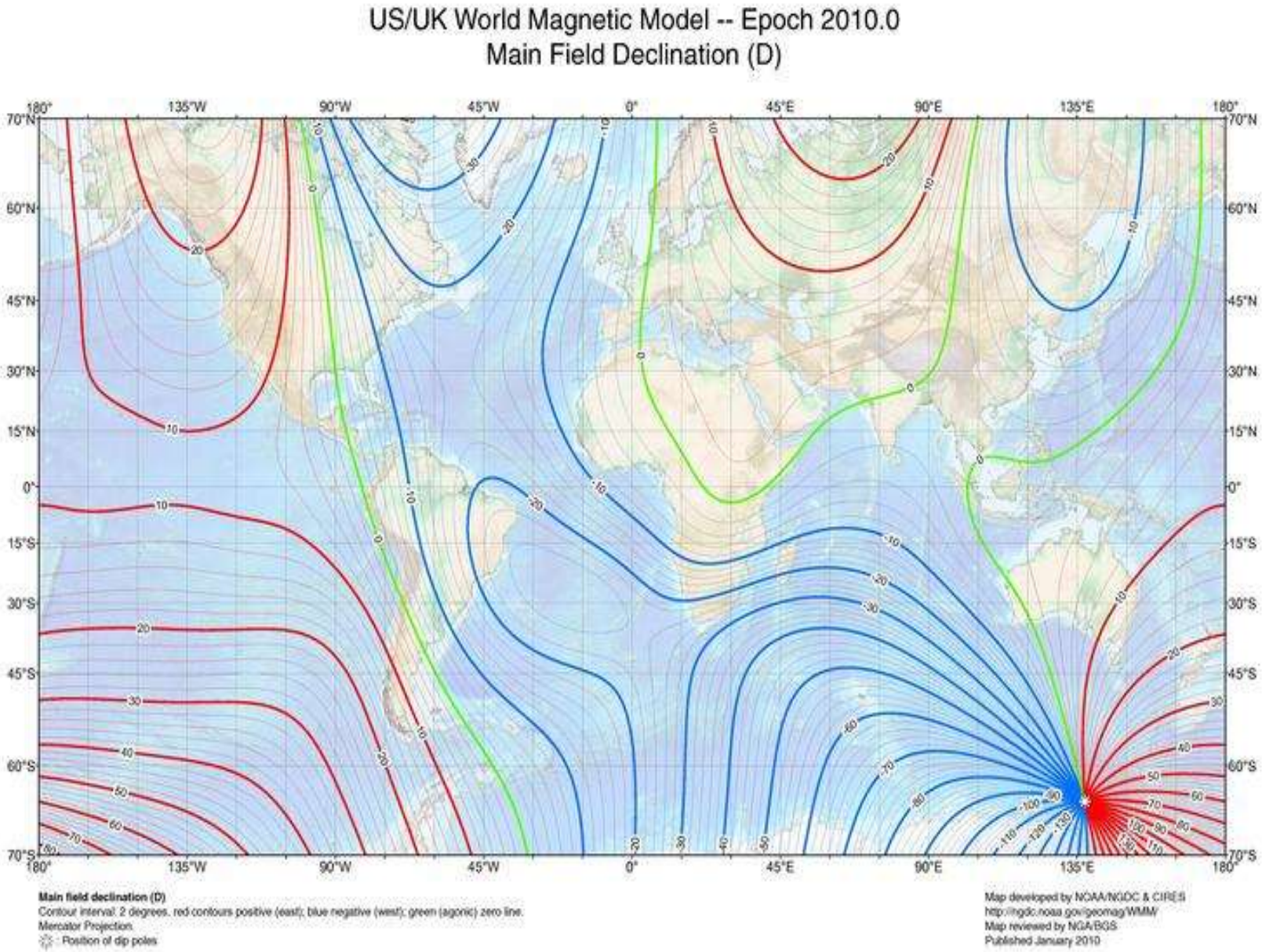
- **separation** angle between satellites on the same orbit (at GEO systems...2° to 3°)

- **elevation** (angle above horizon) and **azimuth** (angle of right-left turning of antenna) of visible satellite from given place on the Earth surface, **dĺžka** (šikmej) zostupnej dráhy družice

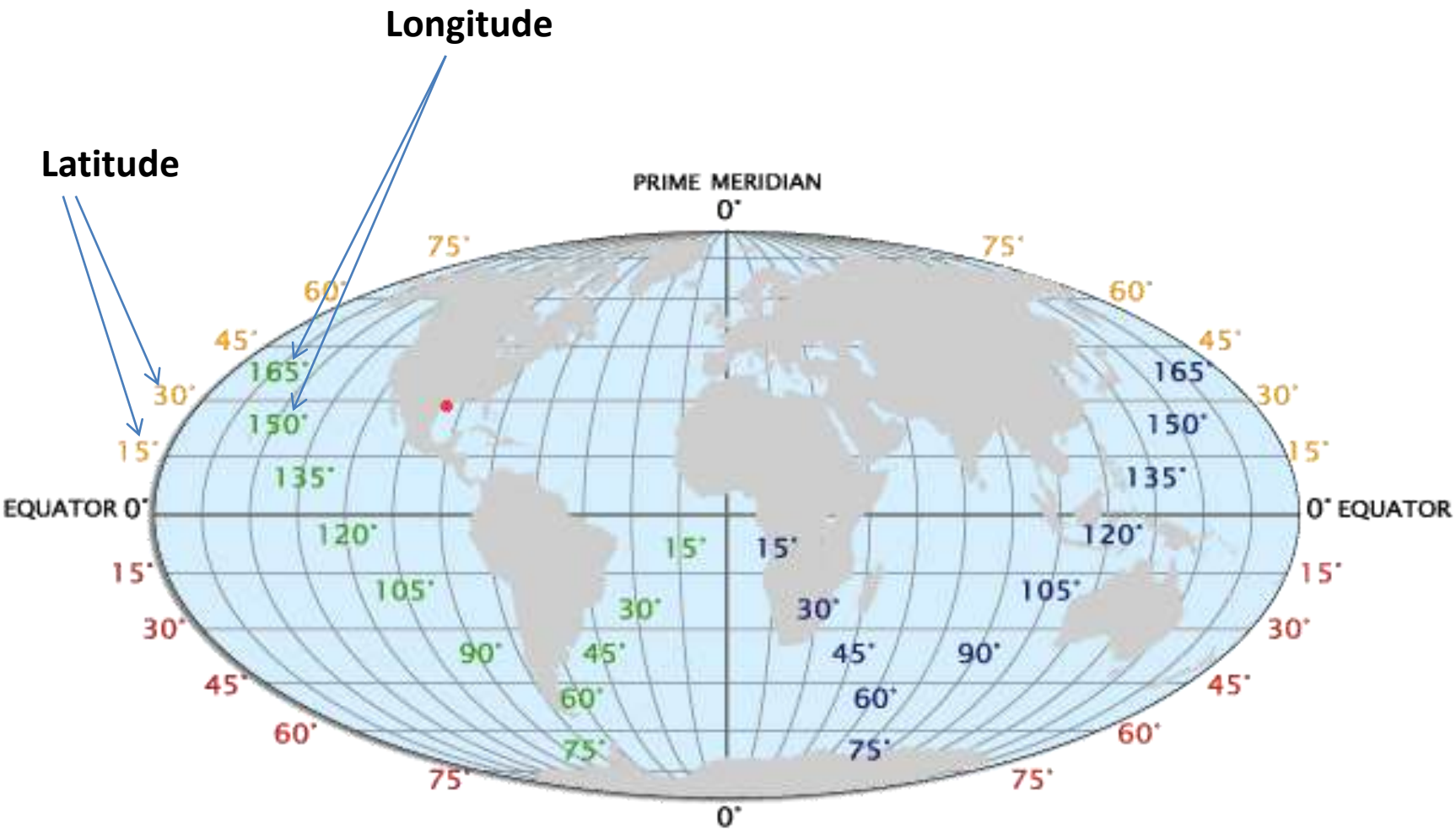
-**Magnetic declination -** is the angle between compass north (the direction the north end of a compass needle points) and true north (the direction along the earth's surface towards the geographic North Pole). The declination is positive when the magnetic north is east of true north. The term **magnetic variation** is a synonym, and is more often used in navigation. (**Isogonic** lines – see next slide - are where the declination has the same value, and the lines where the declination is zero are called **agonic lines**.)

-**Latitude** – see slide+2 – (*shown as a horizontal line on the map*) is the angular distance, in degrees, minutes, and seconds of a point north or south of the Equator. Lines of latitude are often referred to as **parallels**.

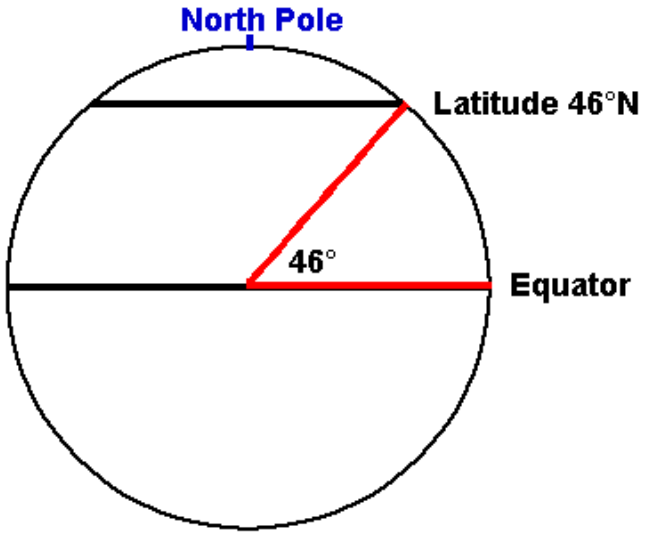
- **Longitude** (*shown as a vertical line*) is the angular distance, in degrees, minutes, and seconds, of a point east or west of the Prime (*Greenwich*) Meridian. Lines of longitude are often referred to as **meridians**.



http://en.wikipedia.org/wiki/Magnetic_declination



source: http://www.worldatlas.com/aatlas/imageg.htm

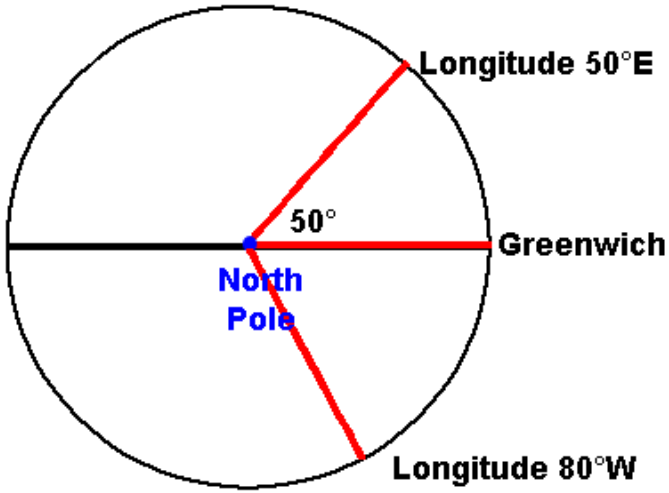


Geographical data:

terrestrial latitude [°]

longitude [°]“

They appear in equations for Azimuth and Elevation (Az, El)

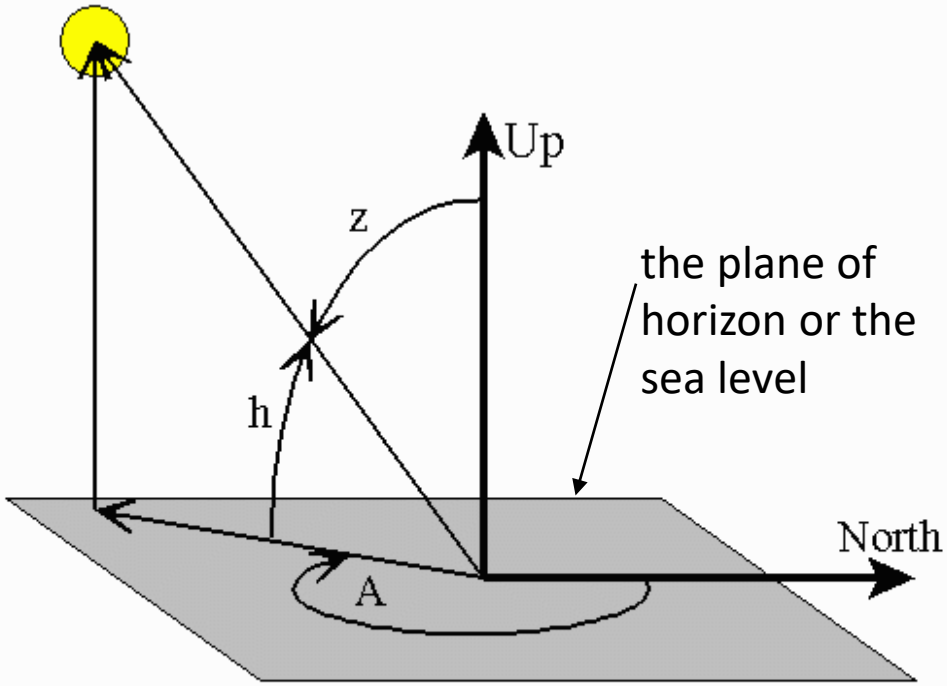


www.sailtrain.co.uk/.../images/latitude46.gif

Position of satellite and setting of receiving antenna - azimuth and elevation

AZIMUTH – oriented angle in the horizontal plane – between given direction and north direction (from the view of user)

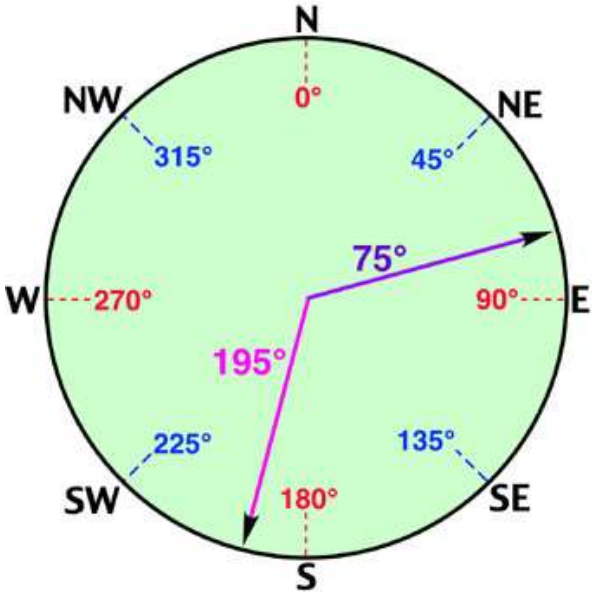
- another view

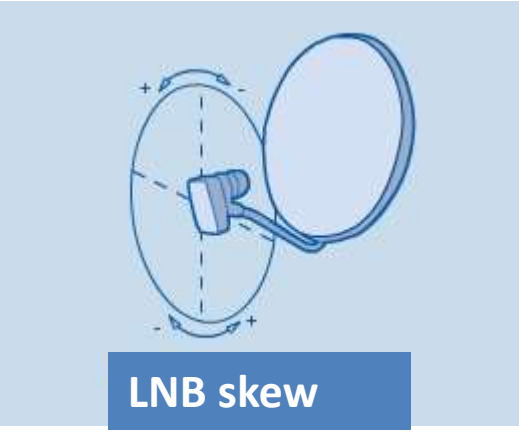


h = elevation angle, measured up from horizon

z = zenith angle, measured from vertical

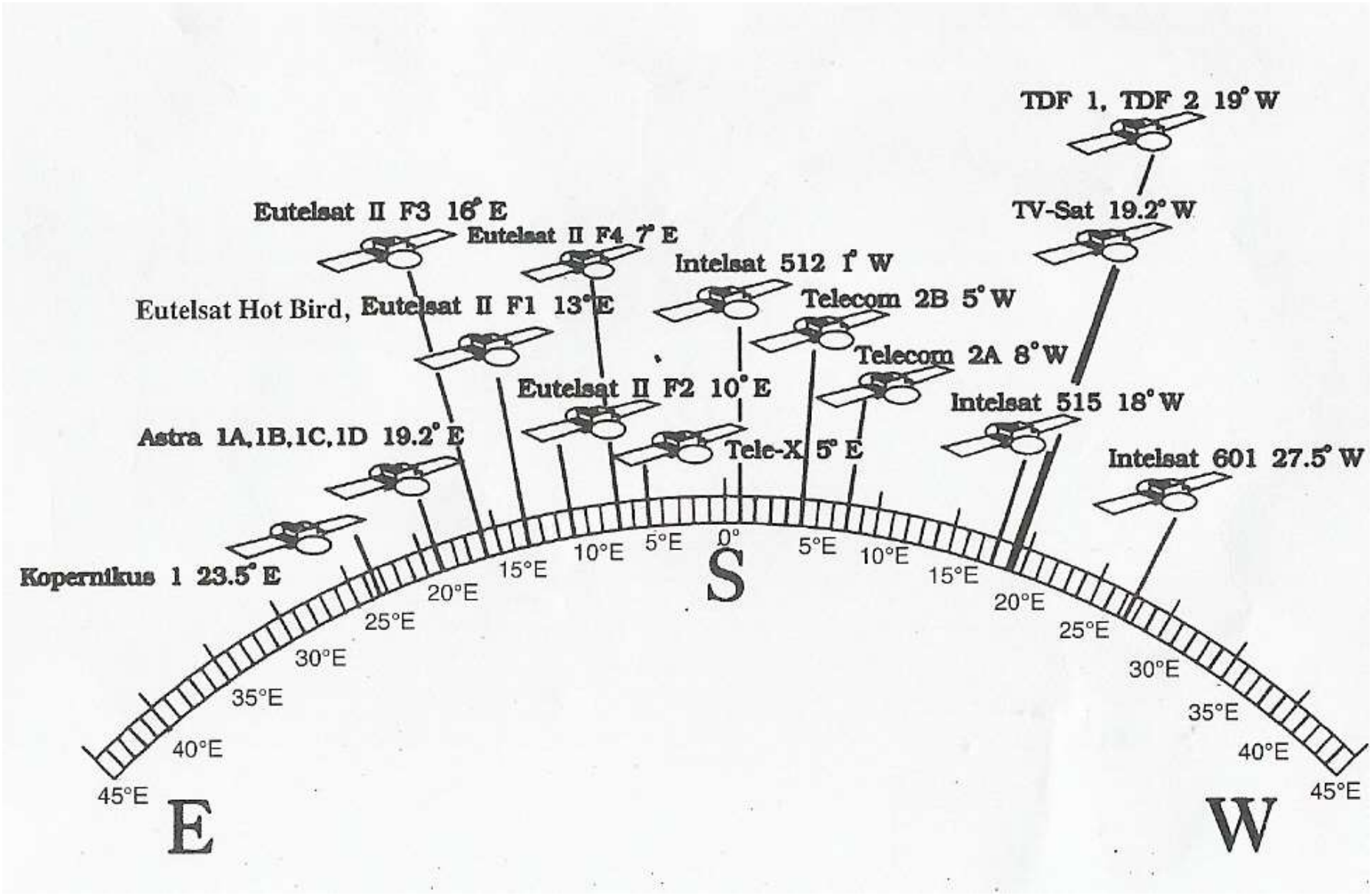
A = Azimuth angle, measured clockwise from North





Elevation (h) – angle in vertical plane measured from horizontal plane to the line of sight

Choice of satellite...



or from another accessible information ...

Name	NORAD ID	Int'l Code	Launch date	Period [minutes]	Longitude	Action
INTELSAT 16	36397	2010-006A	February 12, 2010	1538.2	0°	Track it
TELECOM 2C	23730	1995-067A	December 6, 1995	1470.3	145.9° W	Track it
INMARSAT 2-F1	20918	1990-093A	October 30, 1990	1436.1	142.1° W	Track it
GALAXY 15	28884	2005-041A	October 13, 2005	1436.1	133° W	Track it
DIRECTV 7S	28238	2004-016A	May 4, 2004	1436.1	119.1° W	Track it
ECHOSTAR 7	27378	2002-006A	February 21, 2002	1436.1	118.9° W	Track it
GSTAR 1	15677	1985-035A	May 8, 1985	1436.1	105.7° W	Track it

References:

[1] J. Montana: Introduction to Satellite Communications, George Mason Univ. 2003 (presentation)

[2] Mobilné satelitné komunikácie (Preklad [4])

[3] M.O.Kolawole: Sat. Comm. Engineering.,Marcel Dekker, 2002, USA

[4] S.Omori, H. Wakana, S. Kawase: Mobile satellite Communications, 1998, Artech House, USA.