GROUND SEGMENT

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CONTENTS

FREQUENCIES

- C-Band: 4 / 6 GHz
- X-Band: 8 / 10 GHz
- Ku-Band: 11 / 14, 12 / 14 GHz
- Ka-Band: 20 / 30 GHz

- Always higher uplink frequency (efficiency reasons)

TYPES OF GROUND STATIONS

- Large stations (operators' head-ends, TV feeder links, hub stations)
- VSATs (very small aperture terminals)
  - one-way
  - interactive
- TV Receive-Only (TVRO)

LARGE STATIONS

- INTELSAT-A
- TV, telephony, data
- up to 32 m

MEDIUM-SIZED STATIONS

- VSAT hubs
- TV uplinks
- up to 9.5 m antenna dia-meter

FIXED MEDIUM-SIZE STATIONS

VSATs

Very Small Aperture Terminals

- up to 3.7 m antennas
- typically 1.2...1.8 m

LOW-COST TERMINAL

TRANSPORTABLE STATIONS

Trailer-mounted Terminal

Satellite News Gathering Terminal

NOMADIC TERMINAL

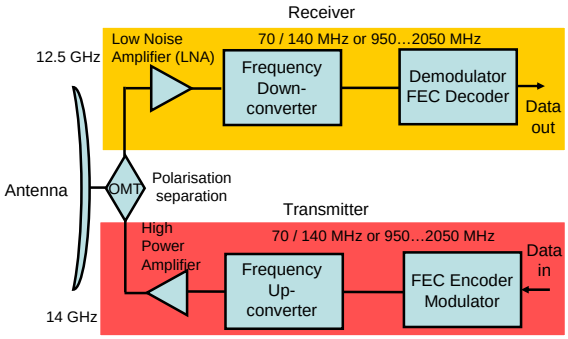
MOBILE TERMINAL

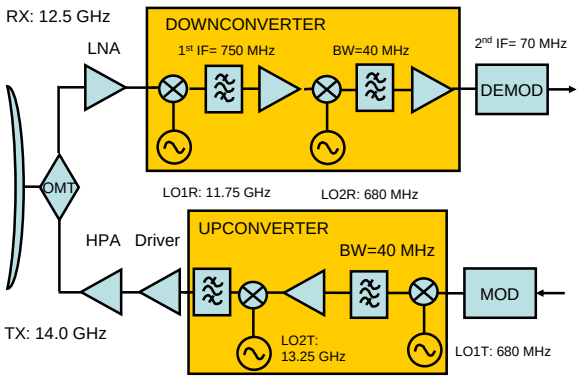
MOBILE ANTENNA

TV RECEIVE ONLY (TVRO)

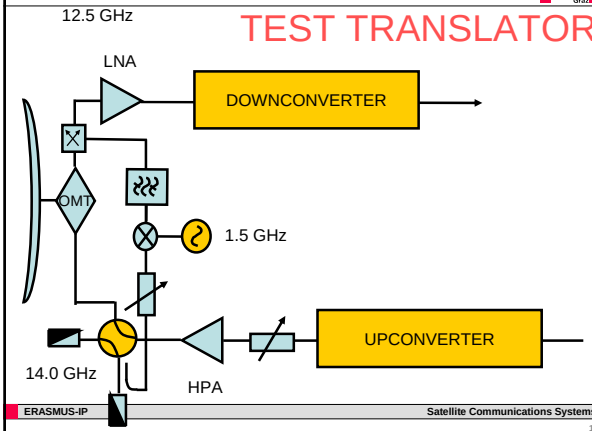
- 35...120 cm (Ku)
- 3 m (C)

ARCHITECTURE





TEST TRANSLATOR



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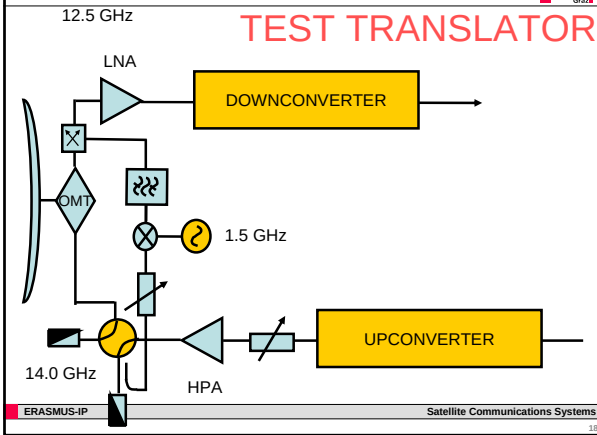
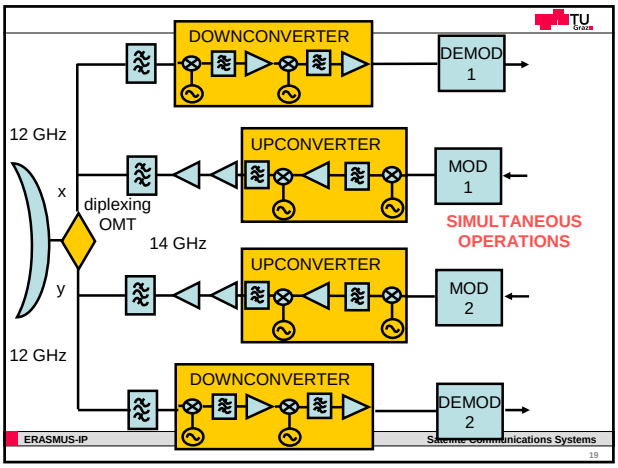
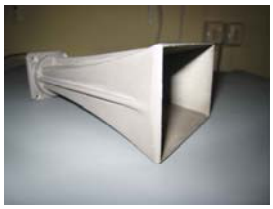
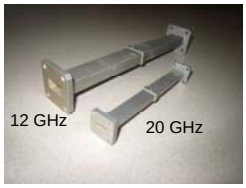




ANTENNAS

- Horn antenna





Waveguide ("transmission line" for microwaves)
transport of electromagnetic energy

PARABOLIC ANTENNAS

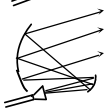
- Primary focus feed
- With subreflector
  - Cassegrain
  - Gregory
  - Advantage: feed close to RF equipment

OFFSET ANTENNA

Primary focus offset

Offset-Cassegrain

Offset-Gregory

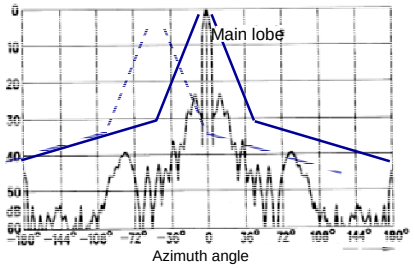


OFFSET ANTENNAS

- higher efficiency, less shielding
- antenna angle steeper, less risk of snow remaining in dish
- electrical elevation angle is not mechanical elevation angle (subtract antenna offset ~20° !)

ANTENNA PATTERN

- Gain plotted versus azimuth (or elevation) angle
- Antenna sidelobes below certain mask
  - G= 29-25logΘ



ANTENNA GAIN

- Depends on diameter, wavelength, efficiency
- G…antenna gain [dB]
  λ...wave lenghth [m] , $\lambda = c/f$
  η...efficiency (depends on surface accuracy, shielding)

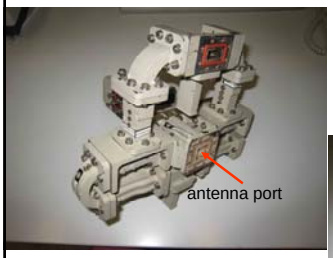
Example: D = 2.4 m, f = 14 GHz, $\eta = 60\ \%$

$$G = 10\log\left(\eta\frac{\pi^2 D^2}{\lambda^2}\right) = 10\log\left(0.6\frac{\pi^2 2.4^2}{\left(\frac{3E8}{14E9}\right)^2}\right) = 48.7dB$$

DUAL POLARISATION

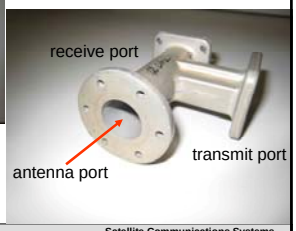
- Orthogonal polarizations used, same frequency can be used twice
  - Horizontal / vertical (linear)
  - Left-hand / right-hand (circular)
- Ortho-mode Transducer (OMT) separates polarised waves
  - must have a good cross-polar discrimination (XPD)
  - 25 dB minimum
  - 30...35 dB (@1 deg. off boresight)
- Otherwise cross-talk, interference to other users
- Proper alignment of OMT vital

OMT



High-performance OMT
XPD: 48 dB

Low-cost OMT
XPD: 25 dB



EIRP

- **Effective isotropic radiated power:** power emitted by an isotropic antenna to produce same peak power density (in far field) as a (directional) antenna in the direction of maximum gain
- EIRP [dBW] = P[dBW] + G[dB]

FIGURE OF MERIT

- Relationship between antenna gain and receiver noise temperature
- G/T [in dB/K]
- G/T [dB/K] = G [dB] – 10 log T [K]
- Good value for a 2.4 m antenna with 80 K LNA : 28 dB/K
- Receive signal/noise ratio derived from link budget:

$$\frac{E_b}{N_o} = EIRP_{[dBW]} - L_{all[dB]} + \left(G/T\right)_{[dB/K]} - k_{[dBJ/K]} - B_{[dBHz]}$$

L…sum of all losses, k…Boltzman constant, B…bandwidth

ANTENNA POINTING

- manual
- motor-driven (can be used for tracking)
  - azimuth
  - elevation
  - polarization
- beacon signal from satellite used to optimize pointing

1) determine local position (GPS)
2) calculate azimuth, elevation, polarisation angles
3) adjust elevation angle (inclinometer)
4) coarse alignment of azimuth (compass, GPS)
5) search for beacon (spectrum analyzer)
6) fine adjustment of elevation, azimuth for maximum signal level
7) adjust polarisation

TRACKING

- for larger earth stations
  - compensation of small half-power beamwidth
  - satellite movement
  - compensation of wind force
- inclined-orbit satellites

METHODS

- program track
- step-track
- monopulse system

- beacon signal to find maximum RX signal strength

PROGRAM TRACK

- employ orbit calculations
- enter spacecraft orbital elements
  - updated regularly
  - after orbital maneuver
- calculate azimuth, elevation
- use data to control azimuth/ elevation actuators

STEP TRACK

- simple algorithm
- antenna moved a discrete step
  - if signal increases, carry on in this direction
  - if signal decreases, go back

- satisfactory for most applications

ANTENNA MOUNTS

- stable
- withstand wind load
- non-penetrating mount with frame for semi-permanent installations
- should have azimuth/ elevation reading

- grounding!

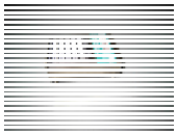
ANTENNA HEATING

- surface heated by foils
- remove ice, snow
  - high attenuation
  - distortion of antenna diagram
- control system to keep temperature constant

COMPONENTS

Mixer:
analogue multiplier

Phase-locked
oscillator



XTAL reference
oscillator

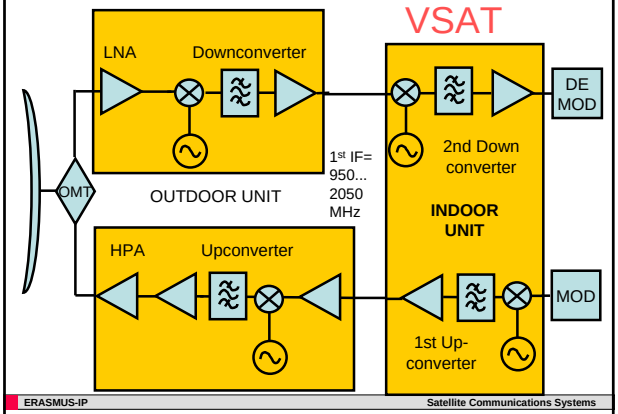
Amplifier

Waveguide switch

VERY SMALL APERTURE TERMINALS -VSATs

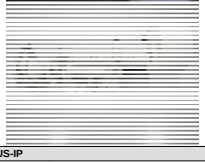
- RF Front-end cost-optimised
- Small outdoor unit, directly mounted on or near feed of antenna
  - Low noise downconverter block (LNB)
  - Upconverter and high-power amplifier

VSAT



LOW NOISE AMPLIFIER

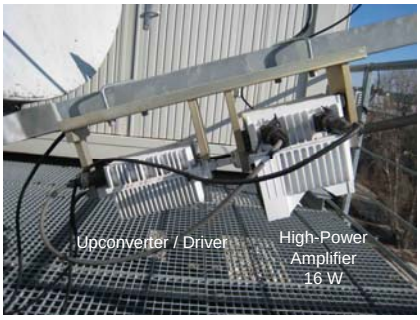
- Solid-state
- GaAs-FET, HEMT
- High gain
- Low noise power
- T= 65, 80, 120, 160 K (Ku)
- T = 30 K (C)



HIGH POWER AMPLIFIER (HPA)

- SSPA (solid state power amplifiers)
  - 1,2,4,8,16,40, 80, 100 W for Ku-band
  - up to 300 W for C-band
- Higher power:
  - Travelling Wave Tube TWTA (100 W...kW)
    - bandwidth: 0.7 GHz (Ku), 3 GHz (Ka)
  - Klystrons (very high power: up to 3 kW)
    - bandwidth: 150 MHz

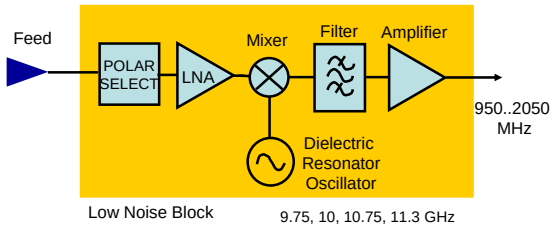
HIGH POWER AMPLIFIER



TV RECEIVE-ONLY (TVRO)

- simple
- low-cost
- outdoor mount
- water-tight receiver unit
- single cable for intermediate frequency, power, control

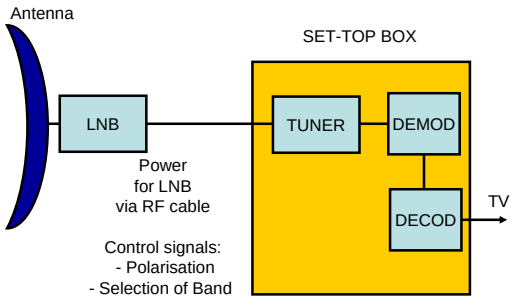
LOW-NOISE BLOCK



Low Noise Block

9.75, 10, 10.75, 11.3 GHz

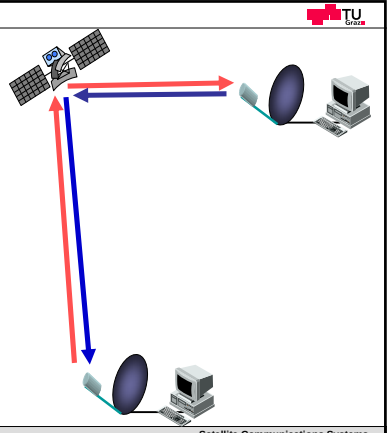
TVRO



LNB / SET-TOP BOX

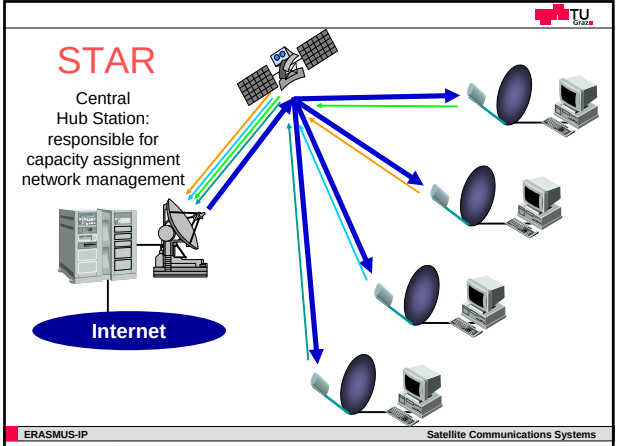
TOPOLOGIES

POINT-TO-POINT

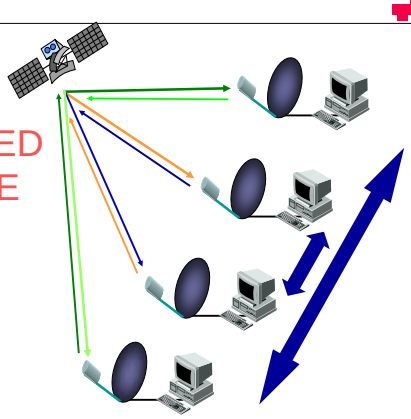


STAR

Central Hub Station: responsible for capacity assignment network management



MESHED MODE



STAR / MESH

- Star topology suitable if data flow is always to/from central site (e.g. Internet via satellite)
- If satellite terminals need to communicate with each other, traffic has to be routed via central hub station
- Double satellite hop (ca. 500 ms) prohibits interactive applications (voice, video conference,…)

- In mesh mode only single hop (250 ms)
- Any terminal can communicate with any other terminal without a hub