Løsningsforslag – Proposed solution

EKSAMEN I EMNE

TTT4234 ROMTEKNOLOGI I

Mandag 13. desember 2010

Tid. Kl. 0900 - 1300

EXAM IN COURSE

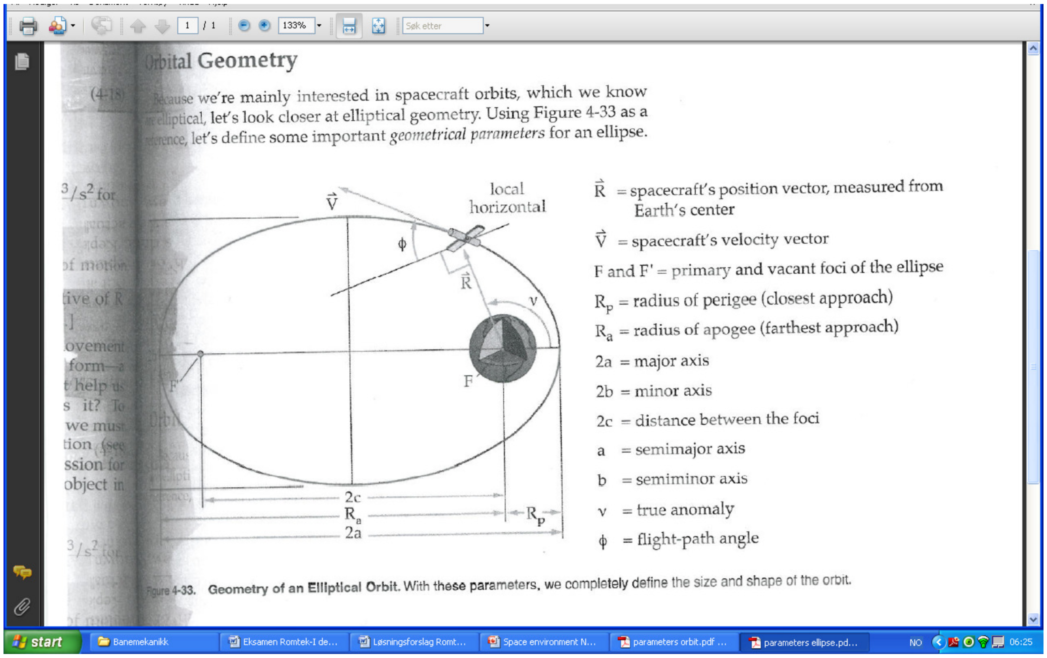
TTT4234 SPACE TECHNOLOGY I

Monday December 13, 2010

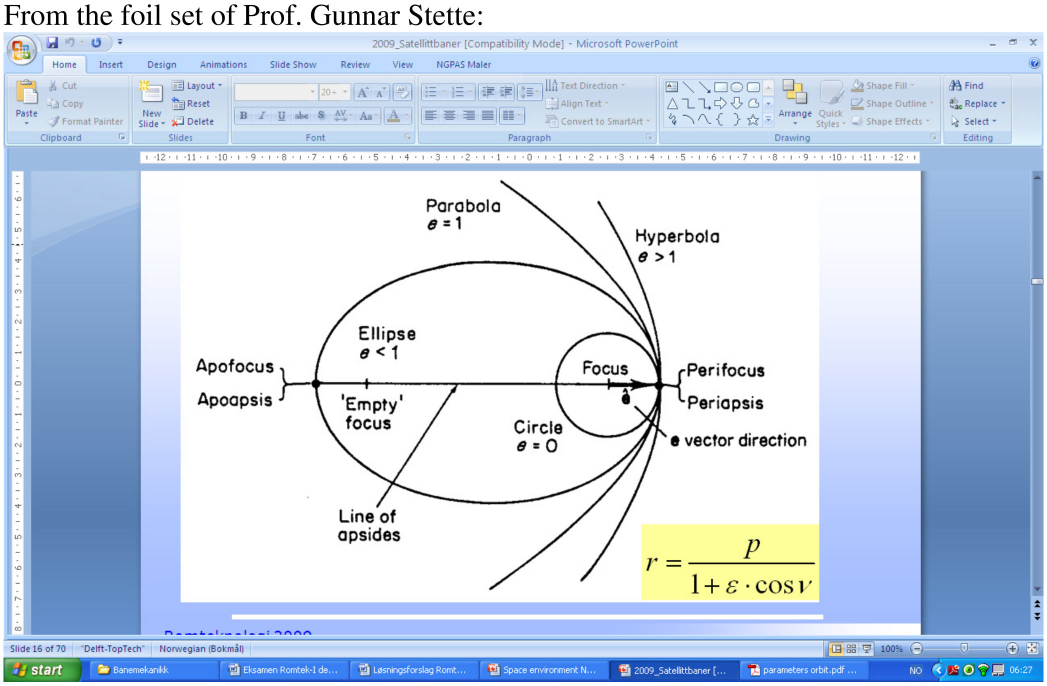
Time: 0900 - 1300

Exercise 1: Orbital elemets

1a) Semi major axis a, distance between foci c. They give the foci and the eccentricity e=c/a

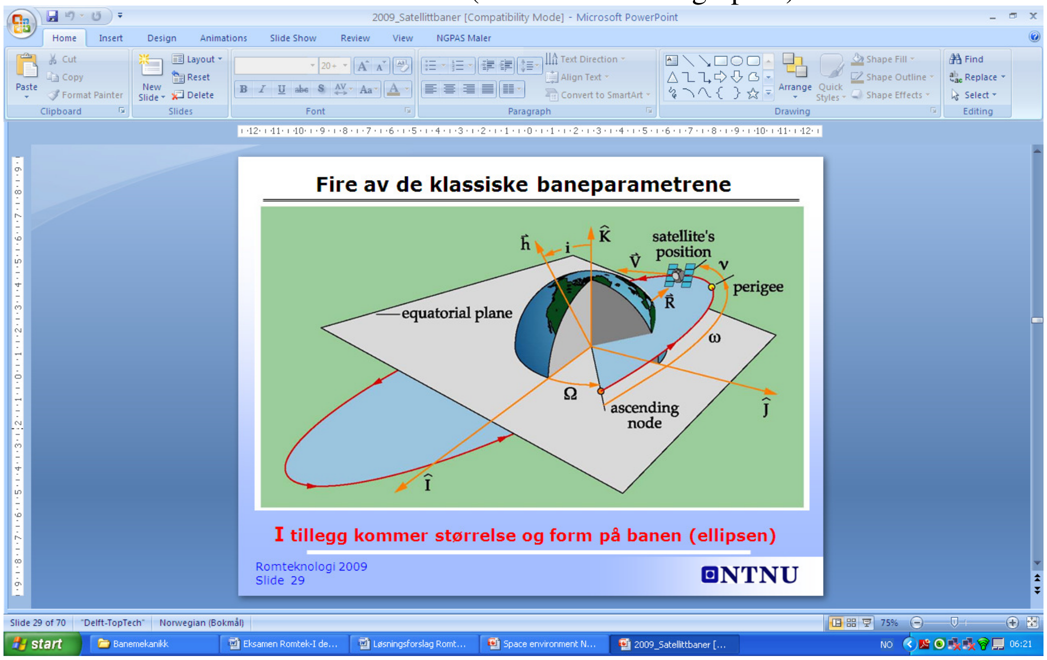


1b) e=0 circle, 0<e<1 ellipsoid, e=1 parabola, e>1 hyperbola
From the foil set of Prof. Gunnar Stette:



1c) In the geocentric coordinate system where the X-axis is defined towards the vernal equinox, which is also the stellar constellation Aries, and the Z-axis goes through the North Pole (then the Y-axis is given), the six orbital parameters are: a: semi major axis, e: eccentricity, i: inclination, Ω: right ascension of the ascending node, ω: the angle of the perigee, ν: true anomaly (the position of the satellite in the orbit).

From the slides of Prof. Gunnar Stette (and Understanding Space):



1d) True anomaly, ν, is the only time varying orbital parameter.

1e) a is constantly equal to the distance between the satellite and the centre of the earth, e=0, i=0. Ω, ω, and ν are undefined.

1f) A Molniya orbit is a highly elliptical orbit, a HEO. The particular inclination of 63.4º prevents the perigee from drifting and assures that the footprint on earth is constant. The orbital period is chosen to 12 hours (by Kepler's third law, this gives the value of the semi major axis, a). Hence the satellite is geo synchronous and pseudo geostationary, and will spend most of its time over the main coverage area defined. If this is on the north hemisphere, it will also be visible when it is on the "night side", e.g. a satellite meant to cover Siberia in daytime, may also be used when above Canada at night. The satellite only uses one of the twelve hours of the orbital period over the southern hemisphere (by Kepler's second law). The perigee is at 548 km above the earth, and the apogee at 39957 km. This orbit was used extensively by the Soviet Union, as they did not have access to any launch locality near the equator, and as they wanted to be independent from other countries, and prevent insight to their affairs, as launching from equator is not necessary for this orbit.

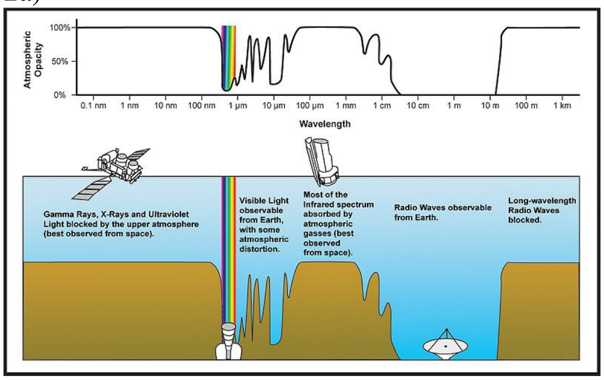
1g) A transfer orbit is an elliptical orbit with the earth in one of the foci, and the perigee at least 200km above the earth surface to prevent atmospheric friction, and the apogee touches the GEO orbit. From an initial circular orbit 200km above the earth, the satellite is given additional speed in the perigee in order to enter the elliptical orbit. It is then given extra speed in apogee to enter the circular GEO orbit at

36000km above earth.

Exercise 2: Earth observation.

Below is all info given in V. Paxal's lecture Earth observation. Not all was expected as response to the exercise.

2a)



2b)

The size of the aperture, and the wavelength of radiation, determines the smallest object we can see – the resolution

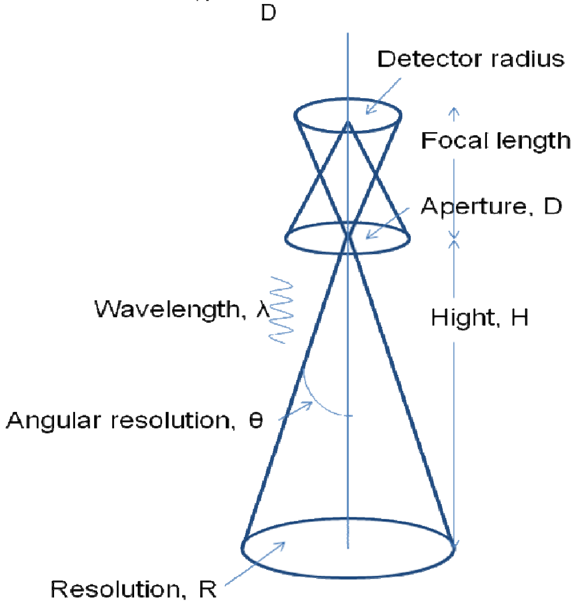
Defenitions

Angular resolution:

$$\theta = \frac{1.22\,\lambda}{D}$$

Resolution:

$$R = \frac{2.44\,\lambda H}{D}$$

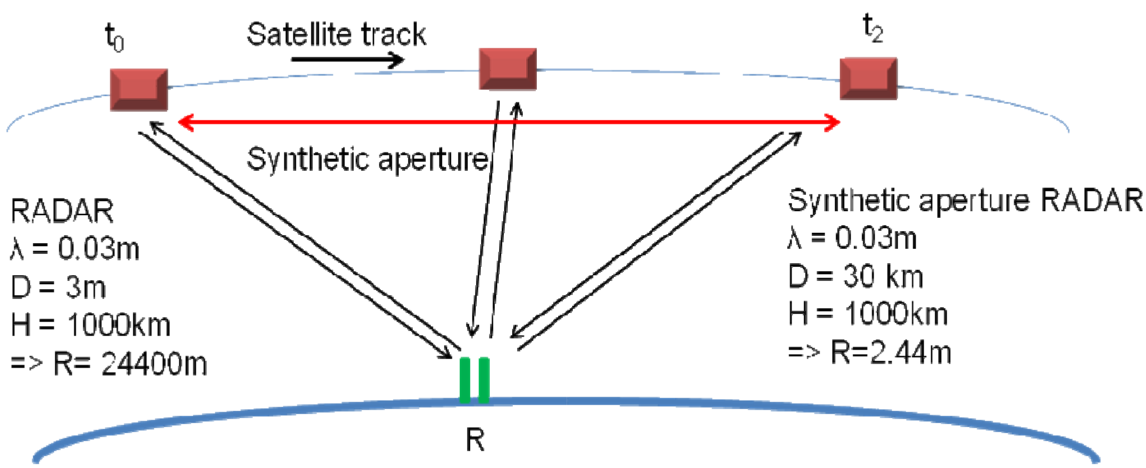


2c)

- The resolution is determined by the wavelength, for the same H and D.
- Light has a short wavelength, and hence a good resolution, but is not practical due to clouds and darkness.
- Radio waves have better penetration in the atmosphere, but give poor resolution.
- This can be remedied by using synthetic aperture or pulse compression.

2d)

The transmitted pulses and the reflections are processed wrt amplitude, phase and position. The RADAR aperture will then be equivalent to an aperture equal to the distance of the satellite track. This gives a large synthetic aperture.

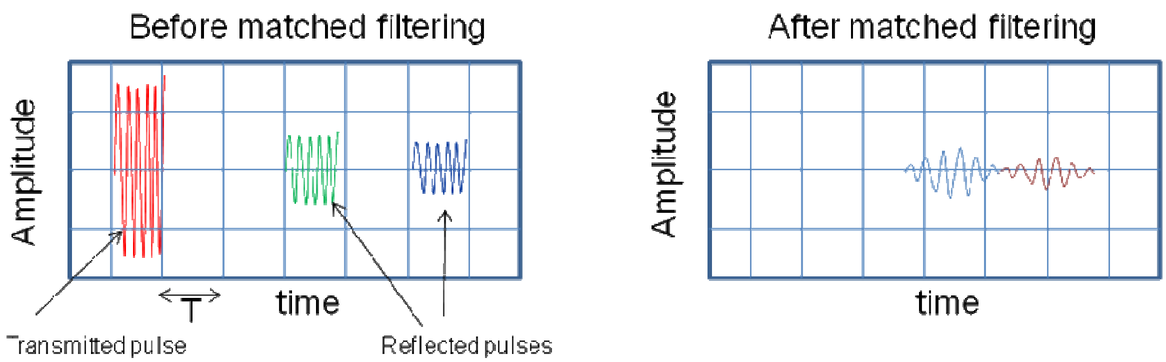


2e)

The simplest signal, *s(t),* a pulse radar can transmit is a sinusoidal pulse of amplitude *A* and carrier frequency f_0, truncated by a rectangular function $\Pi(t)$ of width *T*.

$s(t) = \Pi(t)\times Ae^{2i\pi f_0 t}$

The cross correlation between the transmitted signal and the reflected signal *r(t)* gives a time shifted sinusoidal pulse, truncated by a triangular function $\Lambda(t)$ of width $2T$.



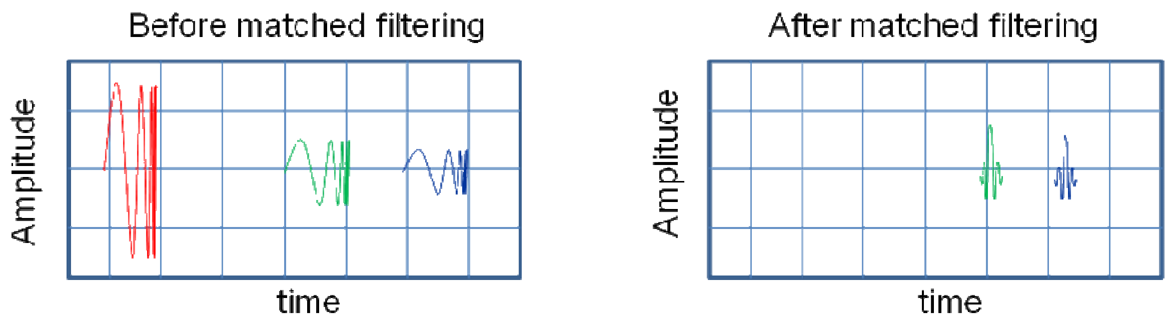
In order to be able to separate the pulses at reception, the distance between the reflected pulses must be superior to T.

The range resolution is $R=cT/2$. To improve the resolution T must be reduced.

But, the signal to noise ratio at reception: SNR= $\xi^2 A^2 T/\sigma$, where σ is the standard deviation of the noise.
Hence, to maintain detection of the signal, T can not be reduced.
Problem: how can we obtain a large enough pulse with acceptable resolution?

- The transmitted signal must have a long enough pulse in order to maintain a correct energy budget
- The signal width after matched filtering must reduce the signal pulse time; pulse compression.

The pulse being of finite length, the amplitude is a rectangle function, $\Pi(t)$. If the transmitted signal has a duration T, begins at t = -T/2 and linearly sweeps the frequency band Δf centered on carrier f_0:
$s(t) = \Pi(t) \times A e^{2i\pi(f_0 + \Delta f t/2T)t}$
This is called a linear chirp; a signal where the frequency varies linearly with time.



The -3dB width of the main lobe is $T' = 1/\Delta f$. The side lobes can be filtered out.
The resolution range is thus $R = c/(2\Delta f)$.
The pulse compression ratio is $C = T/T' = T\,\Delta f$. The goal is to have $C > 1$, it is usually between 20 and 30.

Same type of techniques as used by sonars and bats.

2f) E.g. the TOPEX/Poseidon was the first mission to demonstrate that the Global Positioning System could be used to determine a spacecraft's exact location and track it in orbit. Knowing the satellite's precise position to within 2 centimeters in altitude was a key component in making accurate ocean height measurements possible. The precision of determining the satellites position, will of course give the minimum value for the precision of determining the observed object's position.
Correction for atmospheric and instrumental effects is necessary, but when performed, the TOPEX/Poseidon distance measurements are accurate to 3-4 centimeters.

Exercise 3: Free fall experiments in drop tower

See separate solution paper.

Exercise 4: Description. Choose one of the two topics below.

4a) Temperature differences in space:

- Solar temperature: ~5700°K (black body)

- Earth temperature: ~255°K (infrared)
- Space temperature: ~4°K

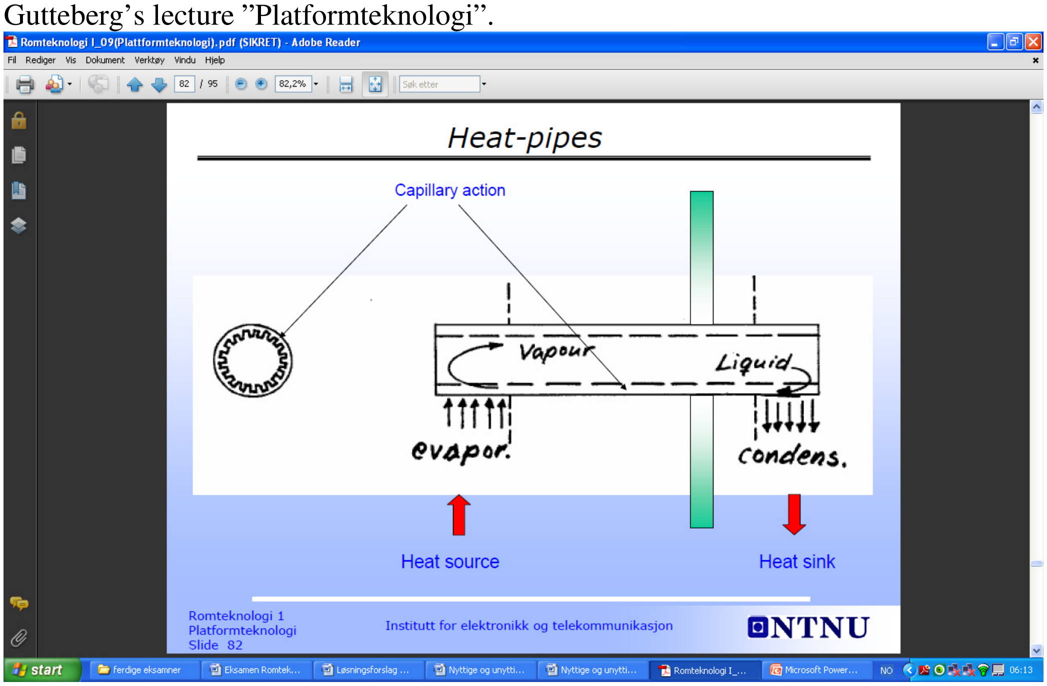
Teperature intervals for different functions on a satellite:

Batteries:	0 to 20°C
Solar panels:	-100 to 50°C
Electronics:	-10 to 60°C
Fuel:	10 to 50°C

Passive thermal control by using different types of material coating and/or heatpipes.
Active thermal controle by using heating and cooling equipment.

Coating:
Pick the formulas in the formula sheet. You obtain thermal equilibrium when $P_{abs} = P_{em}$. Then, the equilibrium temperature will be $T = (\alpha \cdot S/4 \cdot \varepsilon \cdot \sigma)^{1/4}$, and depend on the ratio α/ε. Discuss this ration by selection different values for α and ε given in the formula sheet.

Heat pipes:
Base don evaporation and condensation of a liquid. See slide no. 82 in Prof. Odd Gutteberg's lecture "Platformteknologi".



Electrical heating:
In order to assure a minimum temperature, the heater may be controlled by a thermostat or a remote control.

4b) See separate solution paper.