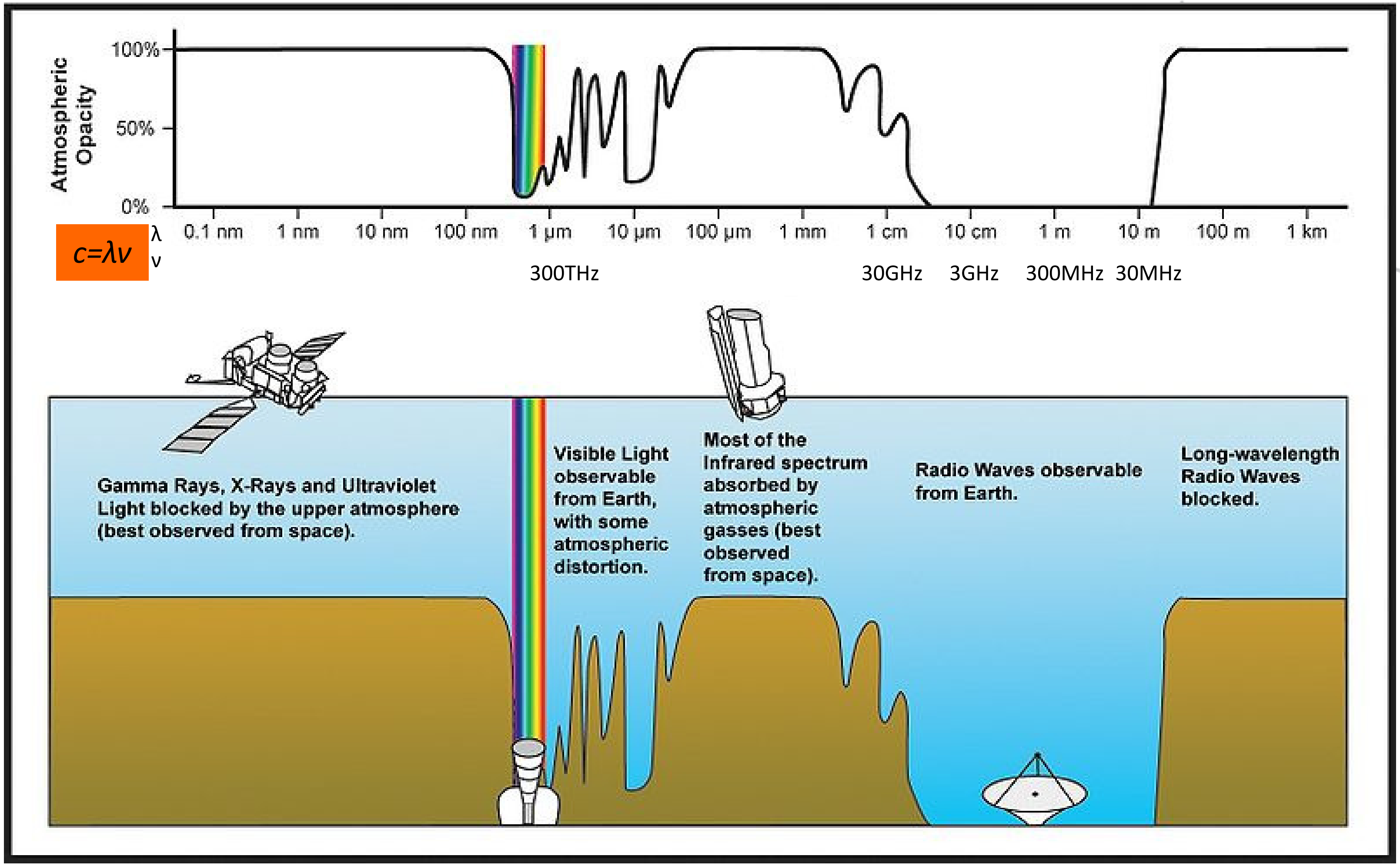
Atmospheric windows



Free space loss: $L_0=(4\pi d/\lambda)^2=(4\pi d\nu/c)^2$

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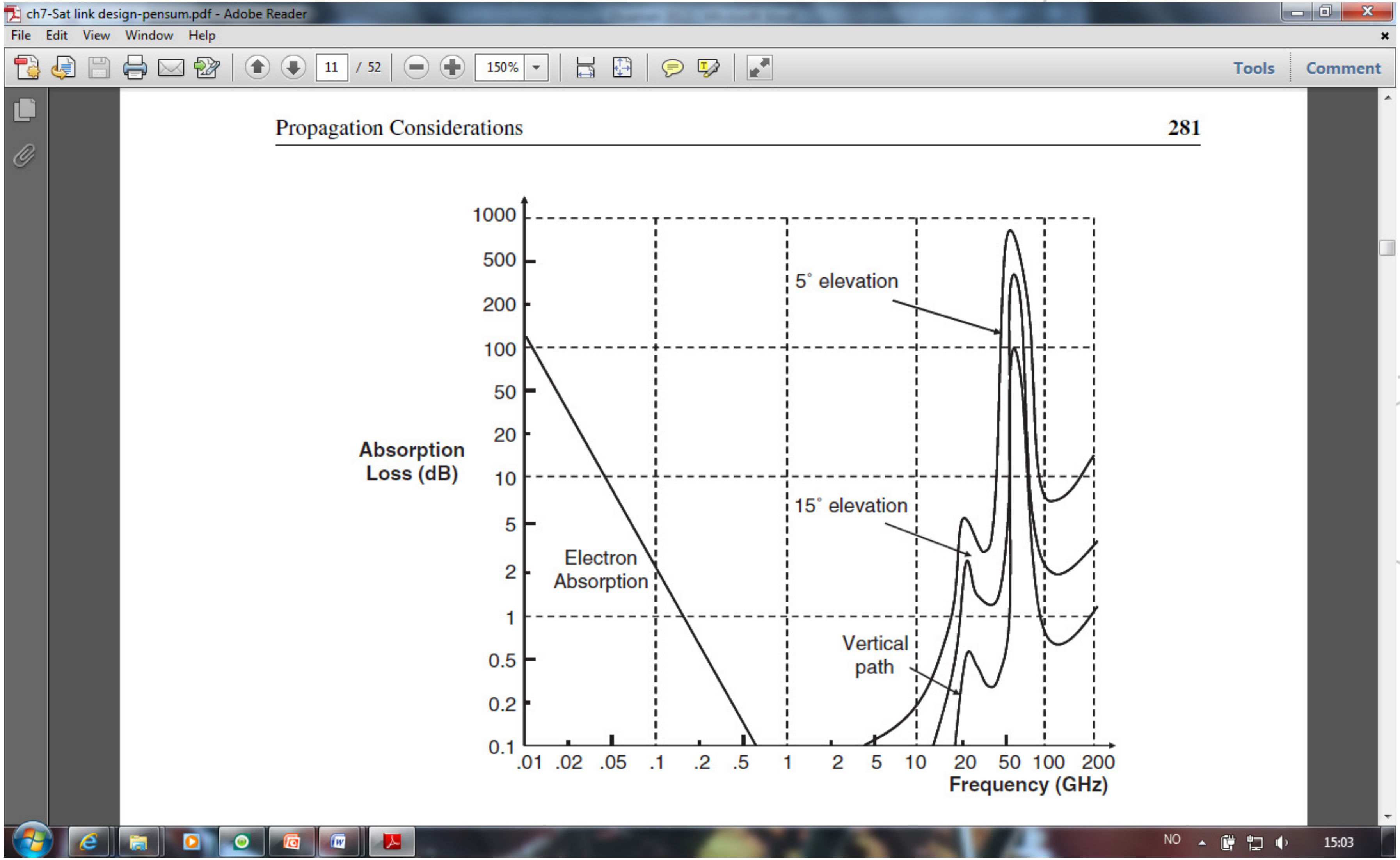

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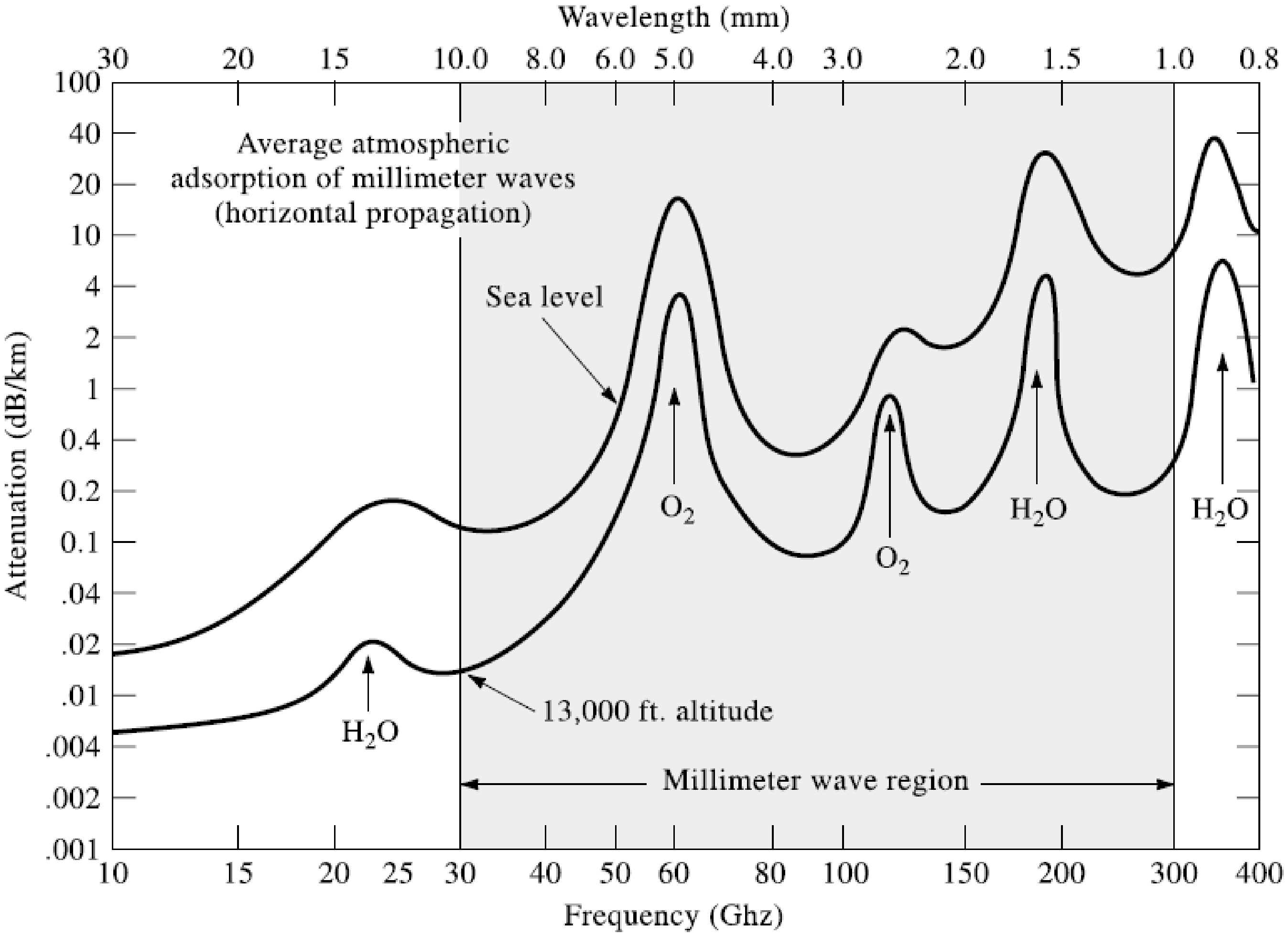
Attenuation in the atmosphere



From http://www.qsl.net/va3iul/Antenna/Basics_of_Radio_Wave_Propagation.pdf

Aperture

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

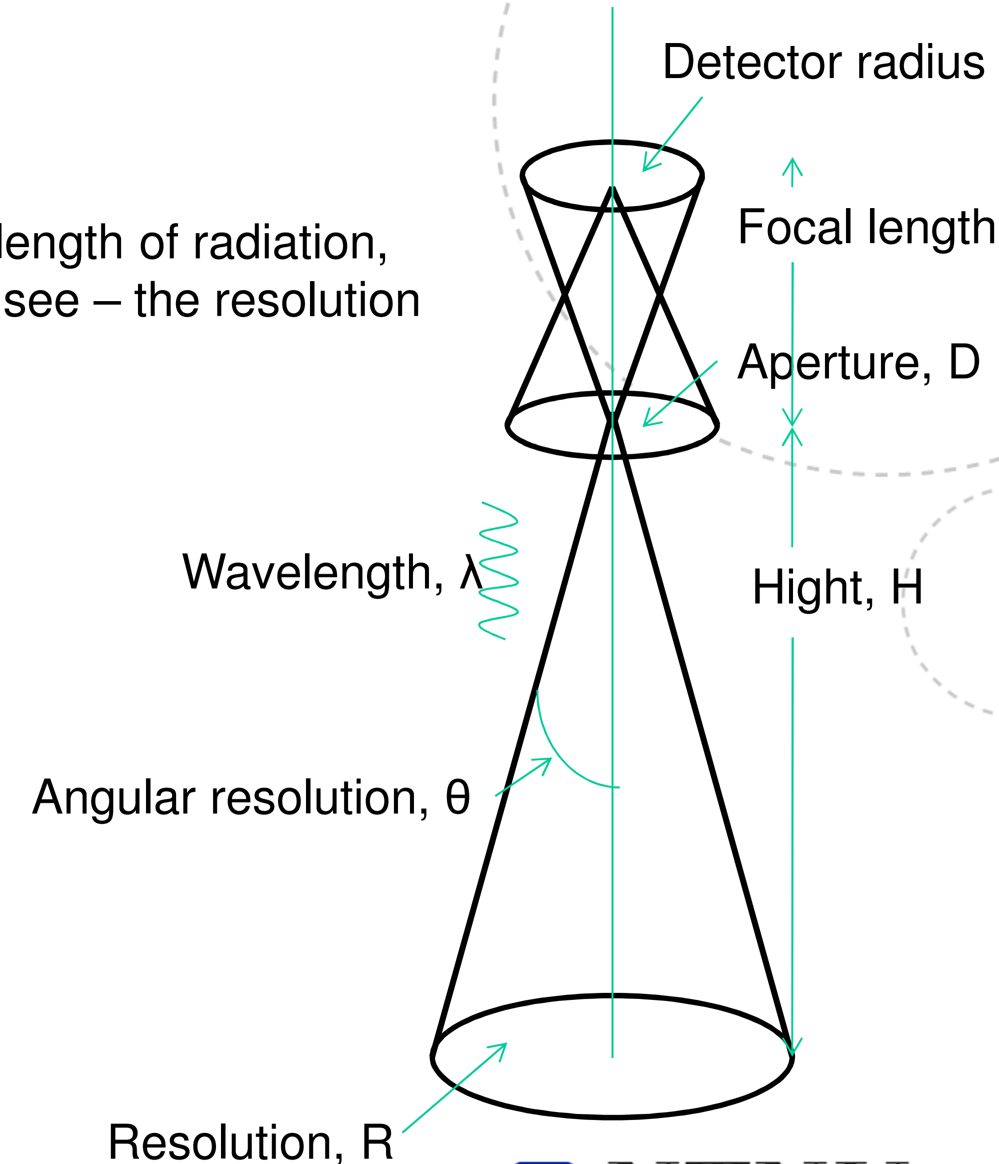
Defenitions

Angular resolution:

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

Resolution:

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



Resolution problem

- The resolution is determined by the wavelength
- 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 athmosphere, but give poor resolution.
- This can be remedied by using synthetic aperture or pulse compression.

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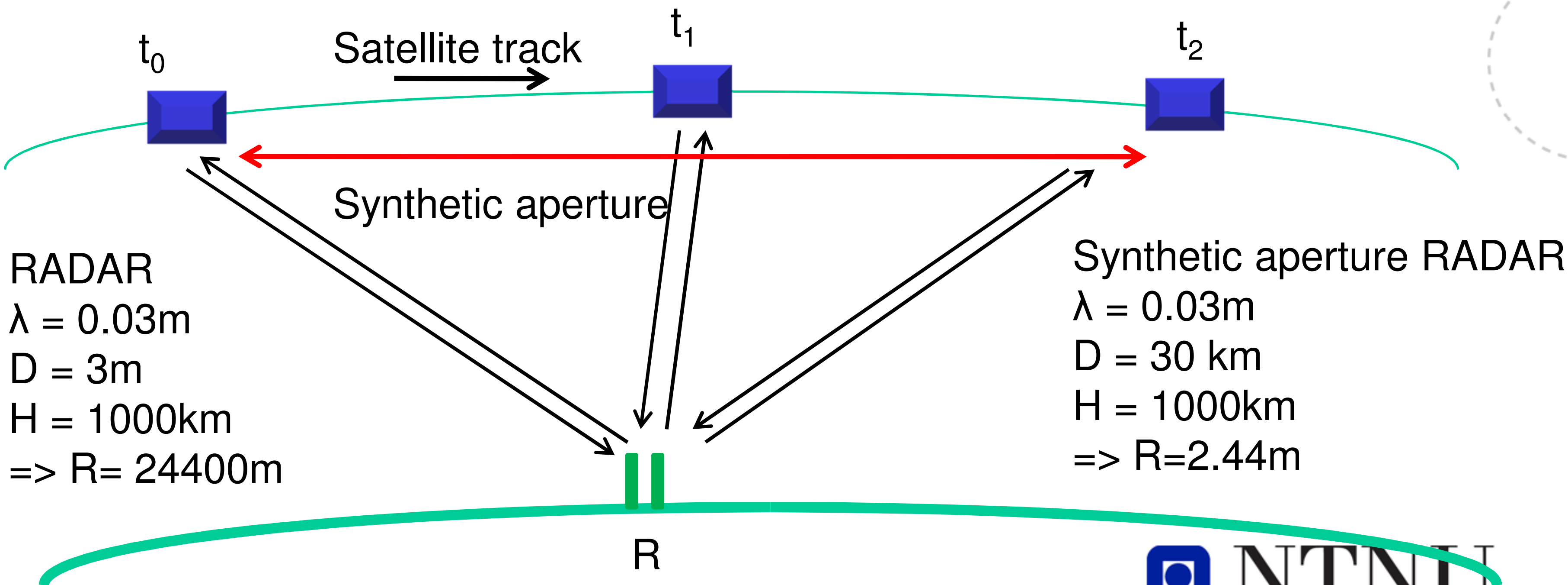
Synthetic aperture

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.



Pulse signal detection

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.

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

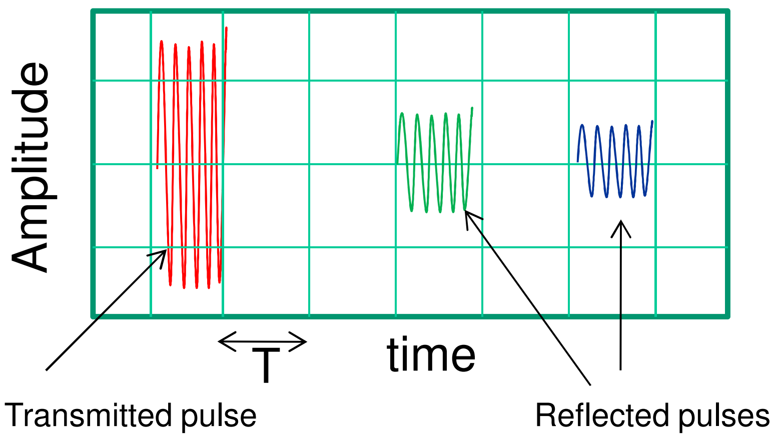
The cross correlation between the transmitted signal and the reflected signal $r(t)$ gives a time shifted sinusoidal pulse, truncated by a triangular function $\Lambda(t)$ of width $2T$.

$$<s,r>(t)=\xi\times A^2\,\Lambda((t-t_r))\,e^{2i\pi f_0(t-t_r)}+n(t)$$

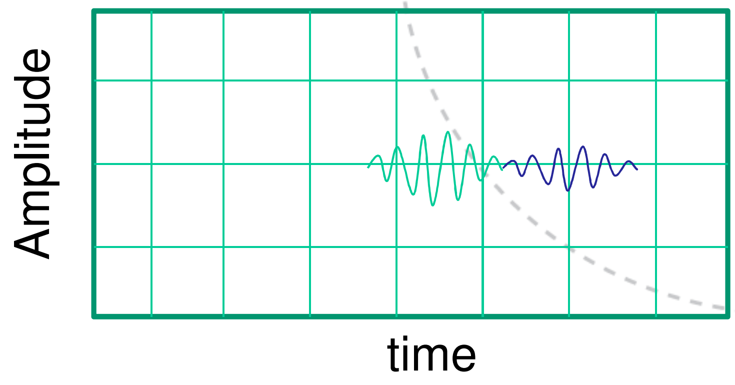
ξ is an attenuation factor,

$n(t)$ is noise, assumed additive white gaussian (AWGN).

Before matched filtering



After matched filtering



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 $R=c\cdot T/2$. To improve the resolution T must be reduced.
c is the speed of light.

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.

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Chirp signals

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.

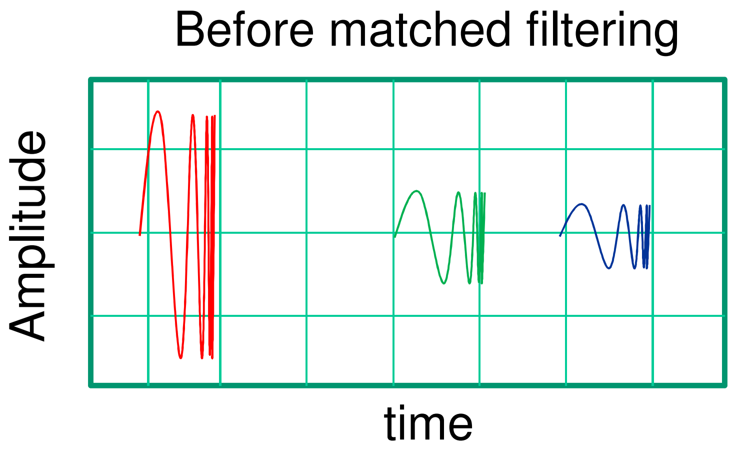
The pulse being of finite length, the amplitude is a rectangle function, $\Pi(t)$. If the transmitted signal has a duration T, begins at t = -T/2 and linearly sweeps the frequency band Δf centered on carrier f_0:

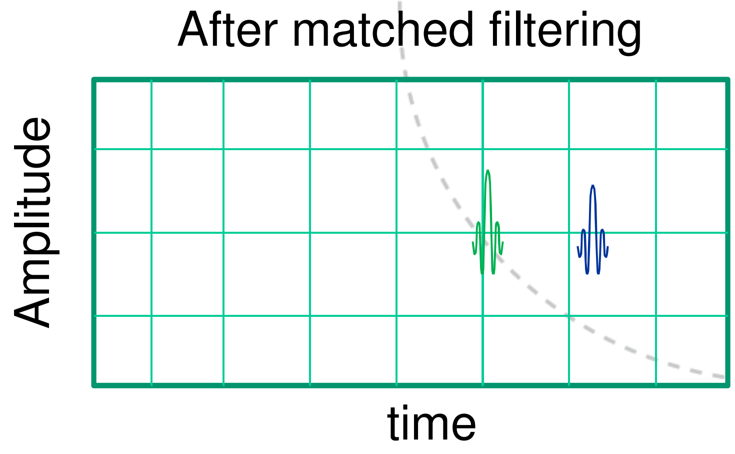
$$s(t) = \Pi(t) \times A e^{2i\pi (f_0 + \Delta f t/2T)t}$$

This is called a linear chirp; a signal where the frequency varies linearly with time.

After matched filtering, the signal becomes:

$$<s,r>(t) = \xi \times A^2 \,\mathrm{T} \times \Lambda((t-t_r)) \times sinc(\pi \Delta f t \Lambda((t-t_r))) \times e^{2i\pi f_0 (t-t_r)} + n(t)$$





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.

Pulse compression by pulse coding

- Phase modulation is a commonly used alternative technique; in this case, the pulse is divided in *N* time slots of duration *T/N*. The N time slots are given amplitude +1 or -1 according to Barker codes. As with a linear chirp, pulse compression is achieved through intercorrelation.

- The advantage of the Barker codes is their simplicity, but the pulse compression ratio is lower than in the chirp case and the compression is very sensitive to frequency changes due to the Doppler effect if that change is larger than *1/T*.

- Barker code pulse compression is a direct sequence spread spectrum technique with low autocorrelation properties.

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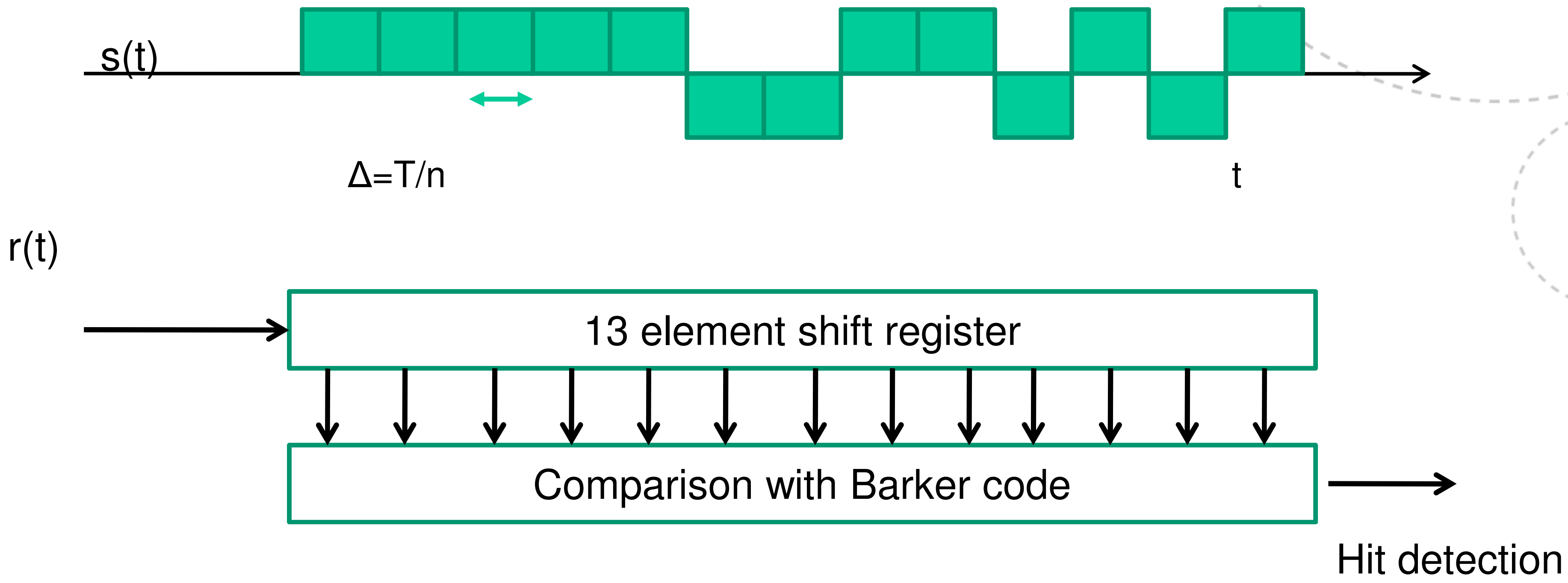
Barker code of length 13



$\langle s,r\rangle(t-k\Delta)=$ 13 when $k=0$, otherwise close to 0

Navigation, GPS

- Global satellite navigation system developed by US DoD
- Constellation of between 24 and 32 MEO satellites
- Determination of location, time and velocity
- A variety of applications, also for synchronisation (earth quakes, cellular networks...)