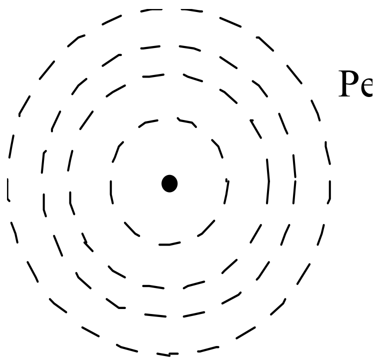
Microwave applications

Applications

- Reminder : Friis formula
- RADAR
- Telecommunication applications

- Heating
- Medical applications
  - diathermy, hyperthermia, Thermography, Tomography

Friis' formula

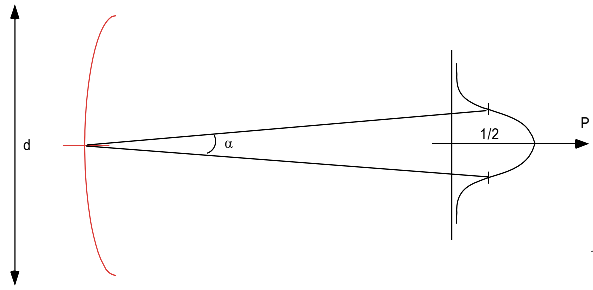


Consider an isotropic source. The power density radiated by this source at a distance R is equal to:

$$p = \frac{P_e}{4\pi R^2}$$

Friis' formula

If we consider a real antenna (non isotropic), we obtain



$$p = \frac{P_e g_e(\theta, \varphi)}{4\pi R^2}$$

g_e : gain of the antenna

EPFL

Friis' formula

The received power at a point R is given by :

$$P_e = \frac{P_e g_e(\theta,\varphi)}{4\pi R^2} ds$$

Which yield for an receiving antenna having an effective aperture Ae

$$P_e = \frac{P_e g_e(\theta,\varphi)}{4\pi R^2} A_e(\theta,\varphi)$$

Thus finally, we obtain Friis' formula

$$\frac{P_r}{P_e} = g_r(\theta,\varphi) g_e(\theta,\varphi)\left(\frac{\lambda}{4\pi R}\right)^2$$

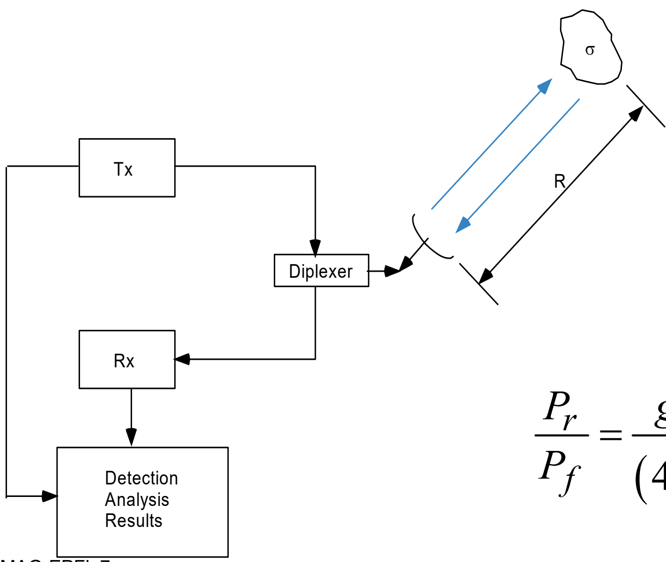
EPFL

Reminder

The antenna gain and effective aperture are linked by :

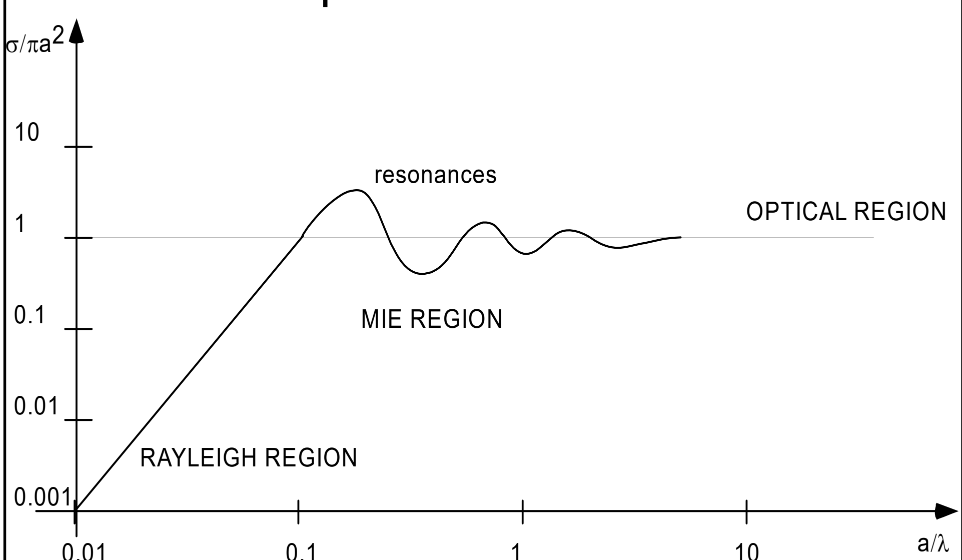
$$A_e(\theta,\varphi) = g(\theta,\varphi)\frac{\lambda^2}{4\pi}$$

Radio Detection And Ranging

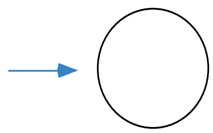
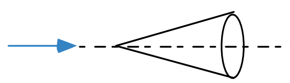


$$\frac{P_r}{P_f} = \frac{g^2 \lambda^2 \sigma}{(4\pi)^3 R^4}$$

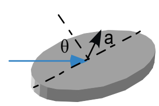
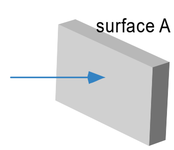
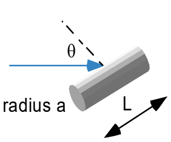
Equivalent RADAR surface



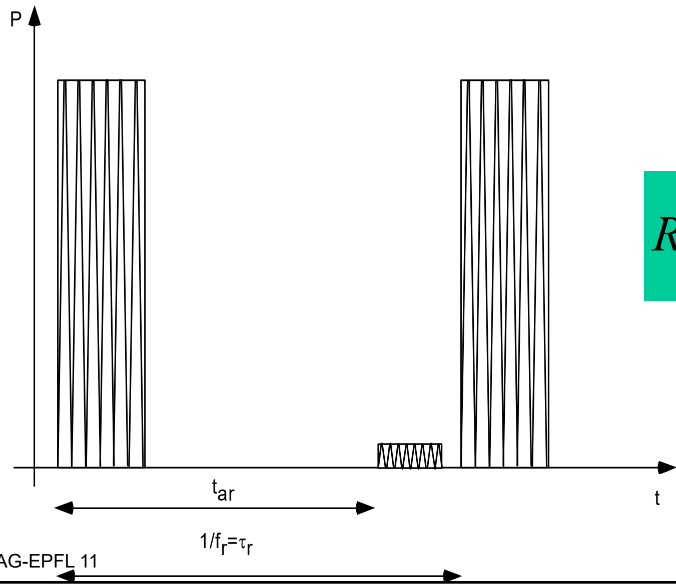
Equivalent RADAR surface : Optical limit

	PEC targets	optical limit of effective radar surface
sphere		πa^2
cone (axial incidence)		$\dfrac{\lambda^2 \tan^4\theta}{4\pi}$

Equivalent RADAR surface : Optical limit

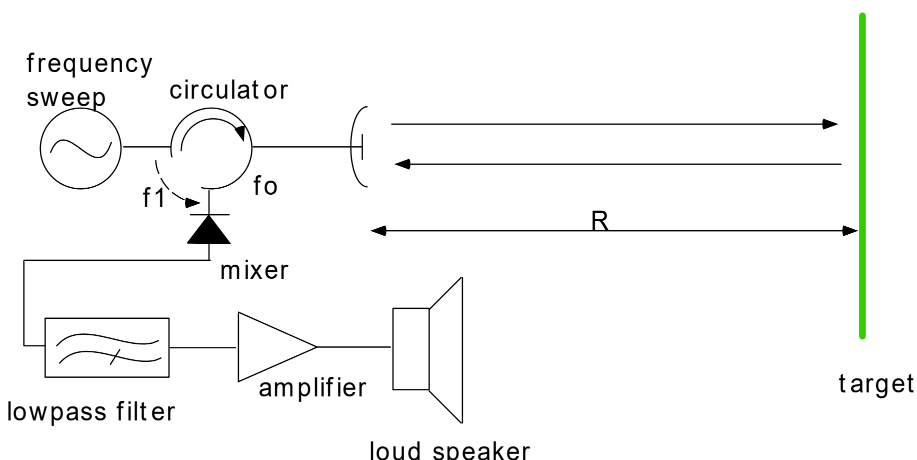
disk		$\pi a^2 \cot^2\theta J_1{}^2(4\pi a/\lambda \sin\theta)$
large planar surface		$\dfrac{4\pi A^2}{\lambda}$
circular cylinder		$\dfrac{a\lambda \cos\theta \sin^2(2\pi L \, 1/\lambda \sin\theta)}{2\pi \sin^2\theta}$

Pulse RADAR



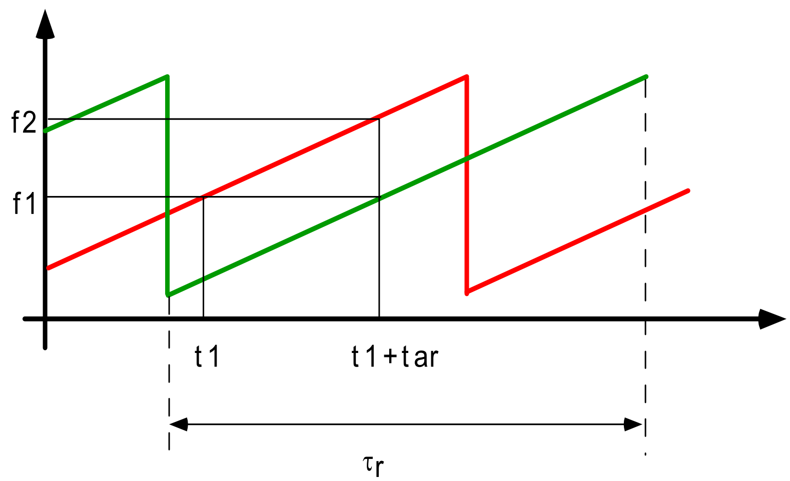
$$R = \frac{c_o t_{ar}}{2}$$

Chirp RADAR

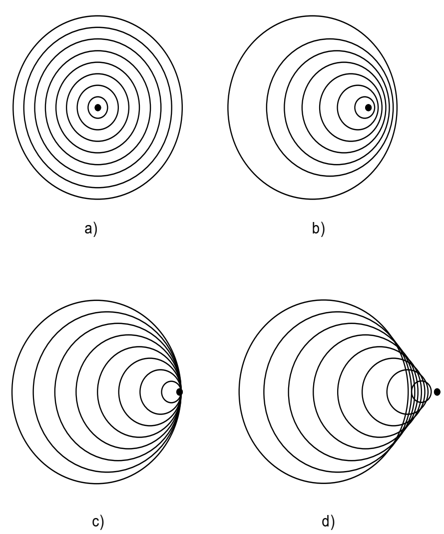


$$R = \frac{co\ tar}{2} = \frac{co\Delta f}{2m}$$

Chirp RADAR



Doppler effect

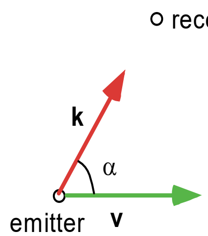


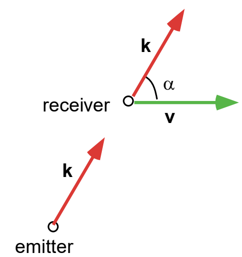
A moving source

Doppler RADAR

$$f_r = \frac{f_o}{\left(1+\frac{v}{c}\cos\alpha\right)}$$

$$f_r = f_o\left(1+\frac{v}{c}\cos\alpha\right)$$



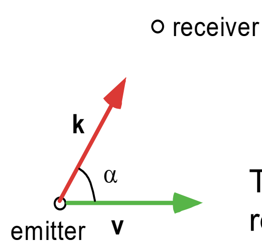


static receiver
moving emitter

moving receiver
static emitter

Doppler RADAR

$$f_r = \frac{f_o}{\left(1+\frac{v}{c}\cos\alpha\right)}$$

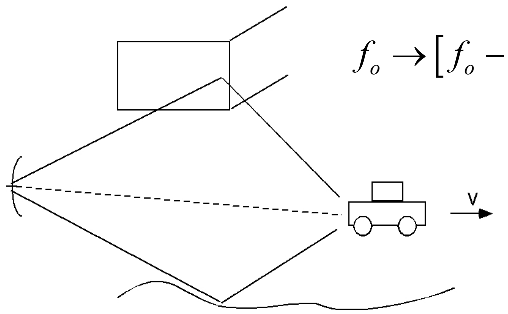


Thus, for α=0 and for the emitter and receiver placed at the same location, and for a car moving away from the RADAR

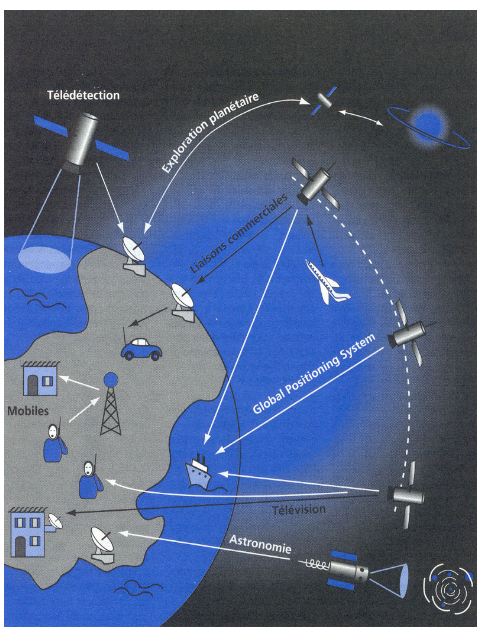
$$f_r = f_o \frac{\left(1+\frac{v}{c}\right)}{\left(1-\frac{v}{c}\right)} \approx f_o\left(1+2\frac{v}{c}\right) \quad \text{Thus} \quad v = \frac{c}{2}\frac{\Delta f}{f}$$

Example : frequency shift in a cell phone

For a cell GSM 900 phone system (Tx 890-915 MHz, RX 935-960 MHz) and a vehicle having a velocity of 140 km/h, there will be a spread of the spectrum of 248 Hz

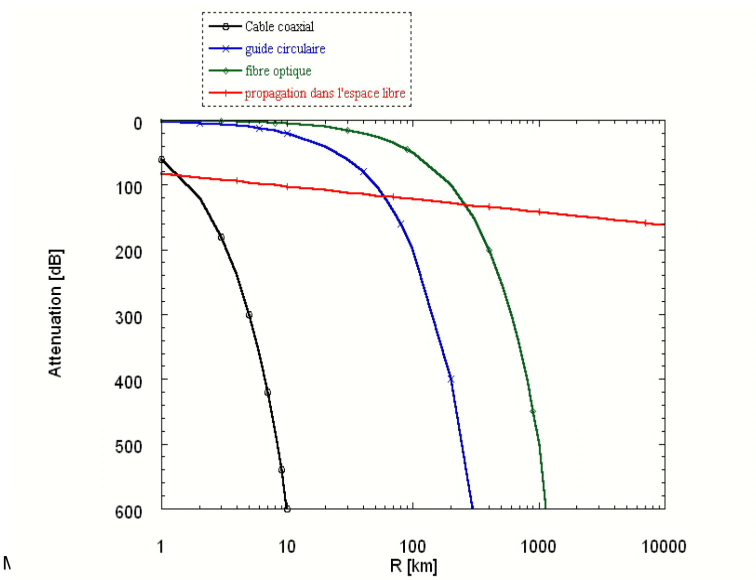


$$f_o \rightarrow \left[f_o - \Delta f ; f_o + \Delta f \right] \;\; ; \; \Delta f = \frac{f_o v}{c}$$



Telecommunication

Attenuation in free space

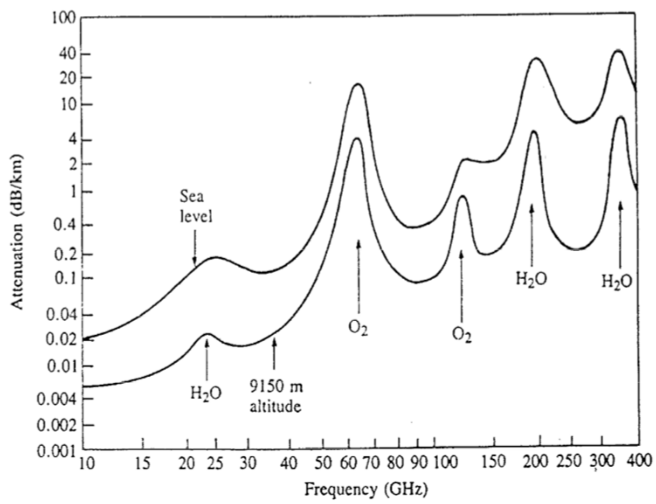


Friis' formula

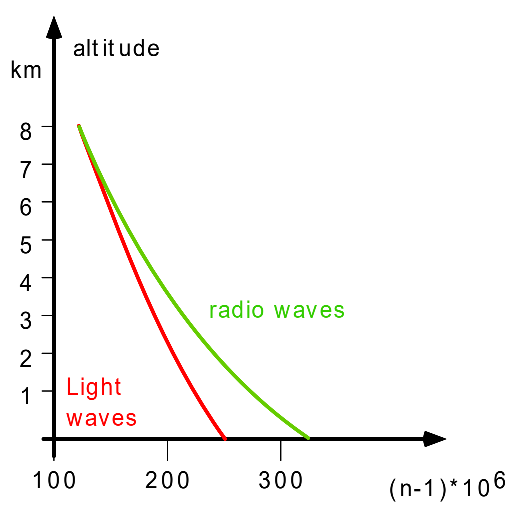
$$P_r = P_f g_1 g_2 \left(\frac{\lambda}{4\pi L} \right)^2$$

- Pr is the received power
- Pf is the transmitted power
- g1,g2 are the antenna gains
- λ is the wavelength
- L is the distance between the antennas

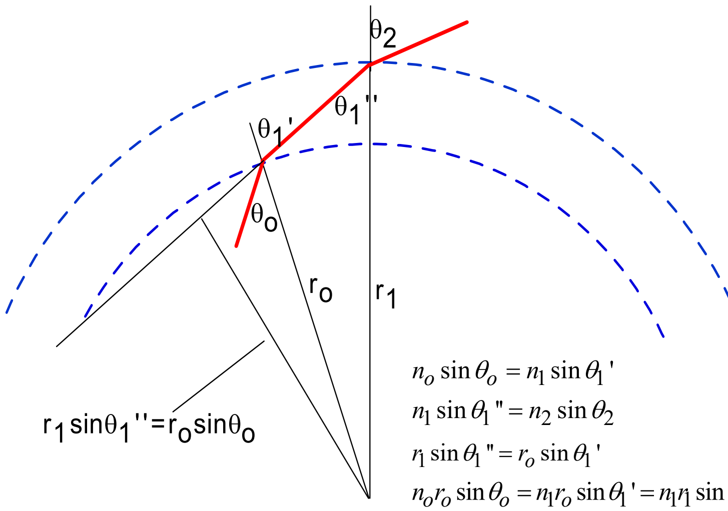
Attenuation in the atmosphere



Inhomogeneity of the atmosphere

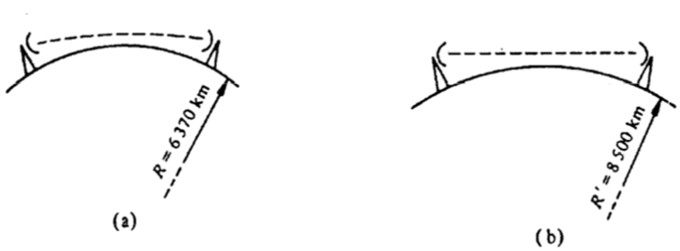


Inhomogeneity of the atmosphere



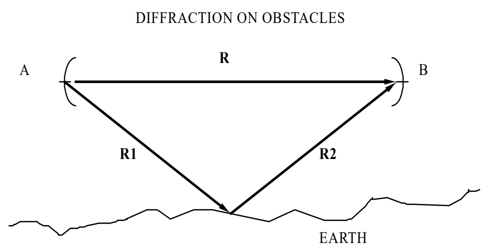
$$n_o \sin\theta_o = n_1 \sin\theta_1'$$
$$n_1 \sin\theta_1'' = n_2 \sin\theta_2$$
$$r_1 \sin\theta_1'' = r_o \sin\theta_1'$$
$$n_o r_o \sin\theta_o = n_1 r_o \sin\theta_1' = n_1 r_1 \sin\theta_1'' = n_2 r_2 \sin\theta_2$$
$$nr \sin\theta = n_o r_o \sin\theta_o$$

Inhomogeneity of the atmosphere



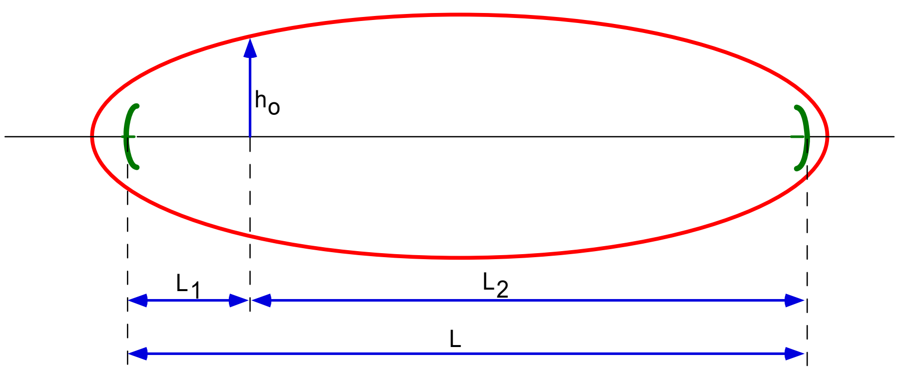
Fictive Earth radius

Diffraction on obstacles



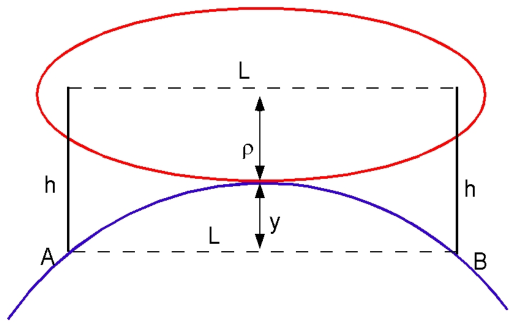
$$|\mathbf{R}_1|+|\mathbf{R}_2|-|\mathbf{R}|=\frac{\lambda}{2}$$

Diffraction on obstacles

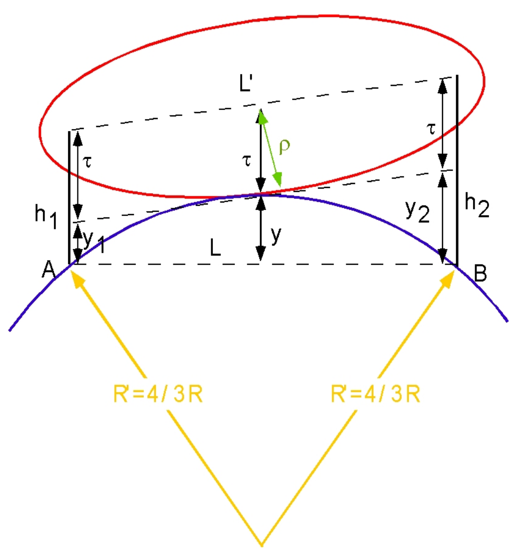


1st Fresnel ellipsoid : $h_o=\sqrt{\frac{\lambda L_1 L_2}{L}}$ $\rho=\frac{1}{2}\sqrt{\lambda L}$

Obstacle free link



Obstacle free link

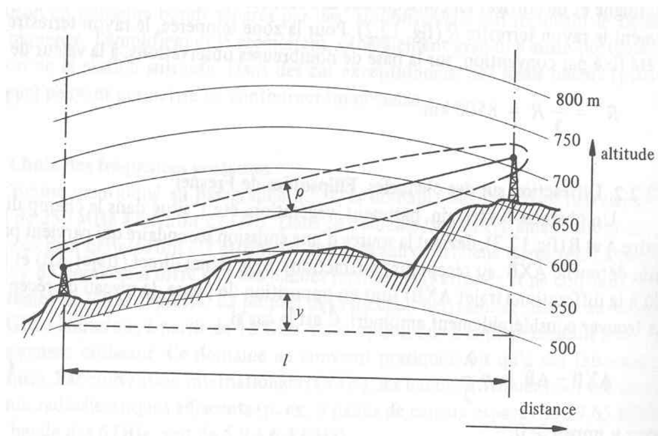


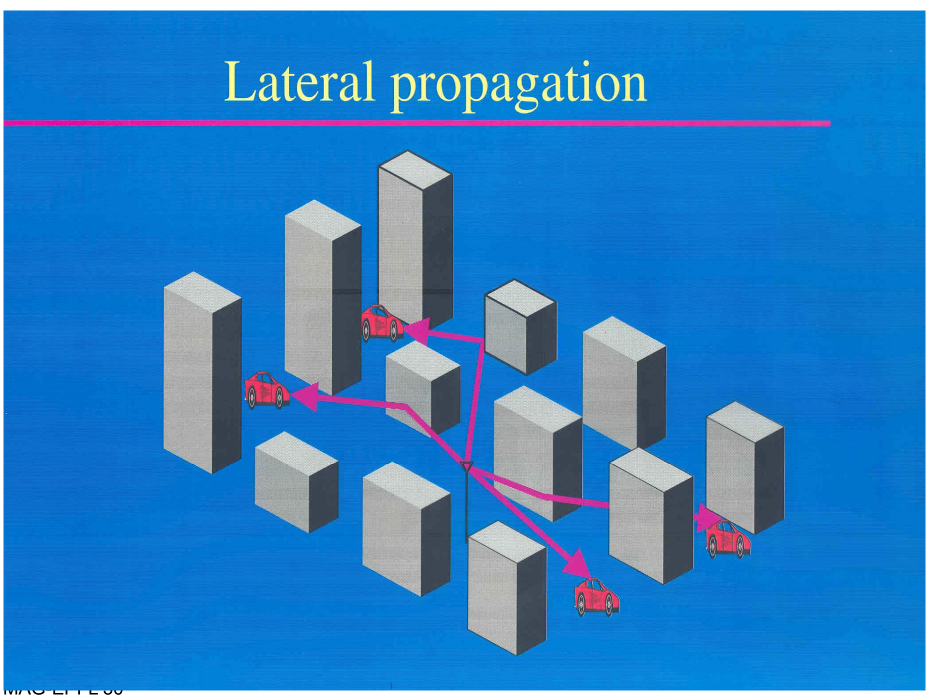
Assumptions :

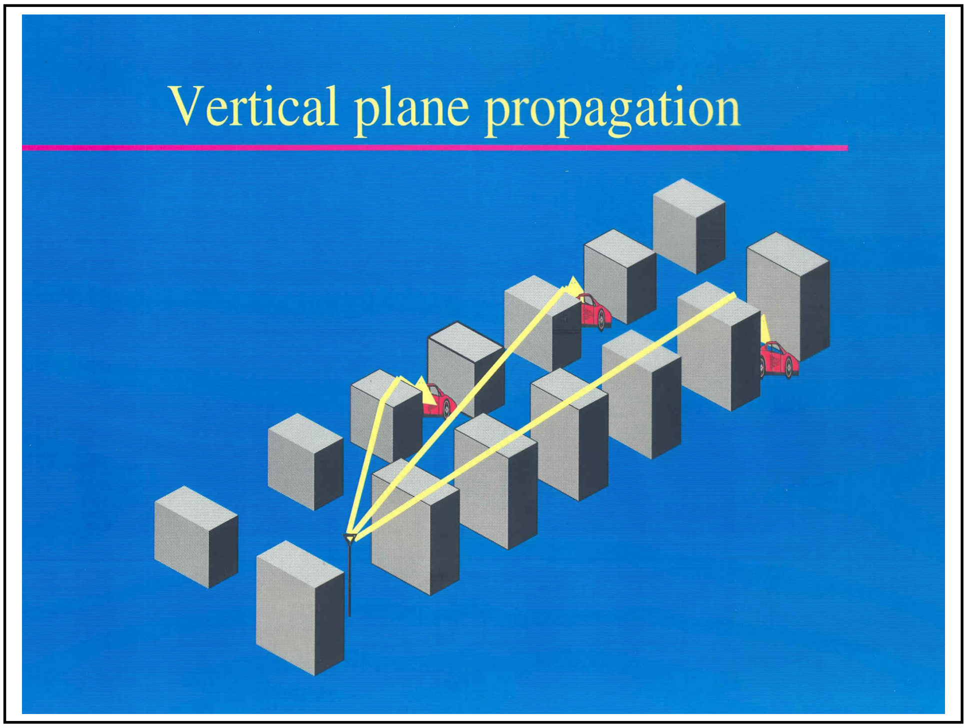
$\tau=\rho$

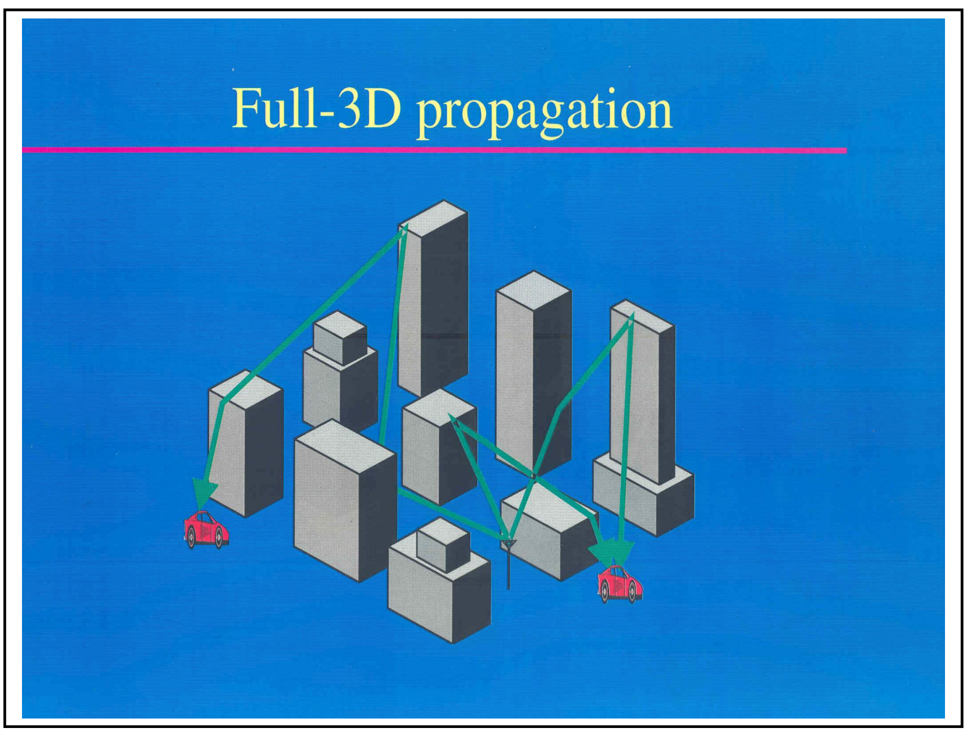
$L'=L$

Obstacle free link



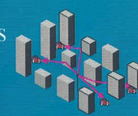


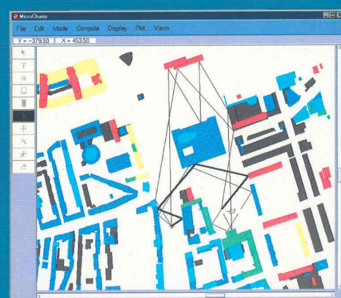

Vertical plane propagation


Full-3D propagation

Models (1/3)

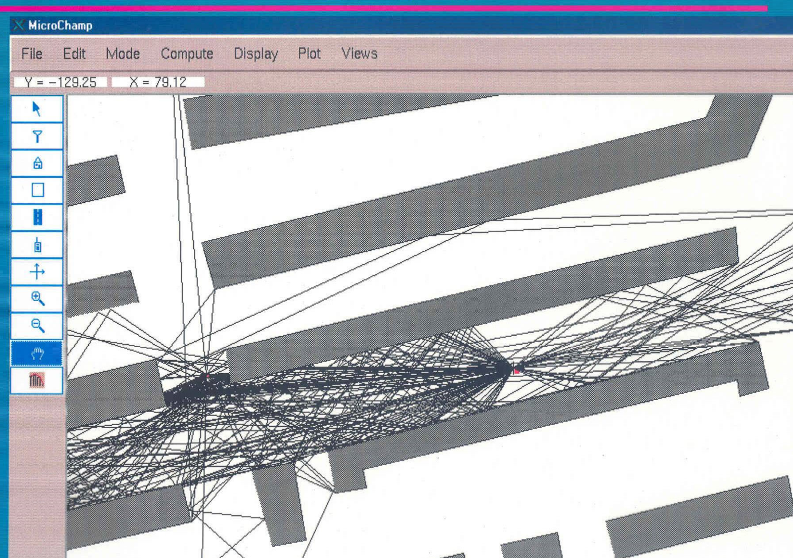
- 2D ray tracing
  - Reasonable approximation of lateral propagation when Tx is below most bldg. heights
  - User Interface to ease the investigations



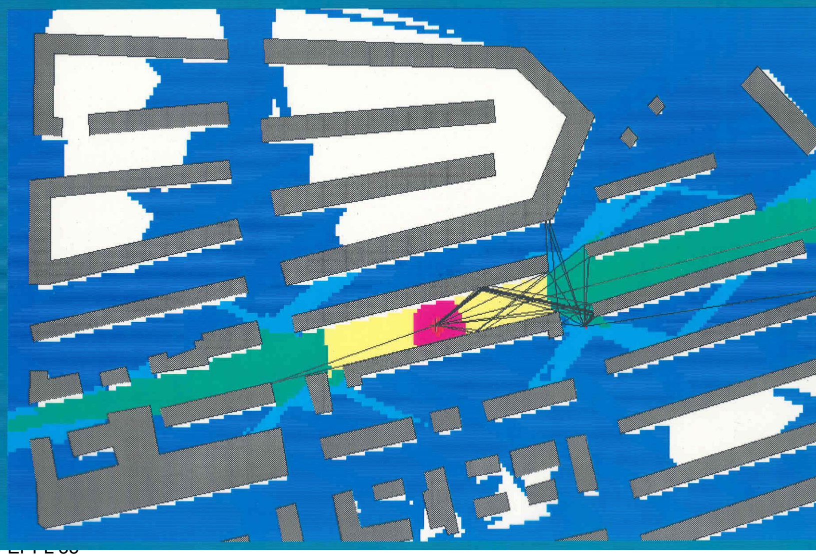


  - Developed at EPFL/Swiss Telecom

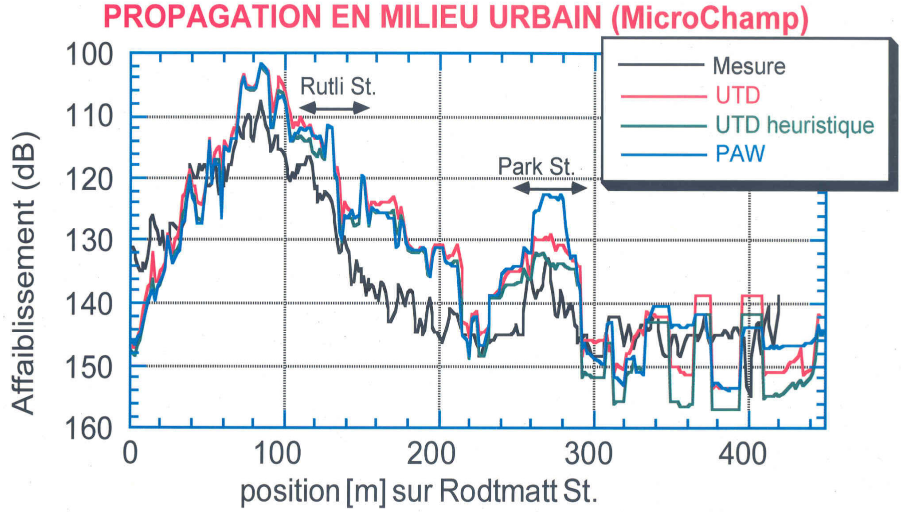
Lateral propagation



Vertical plane propagation



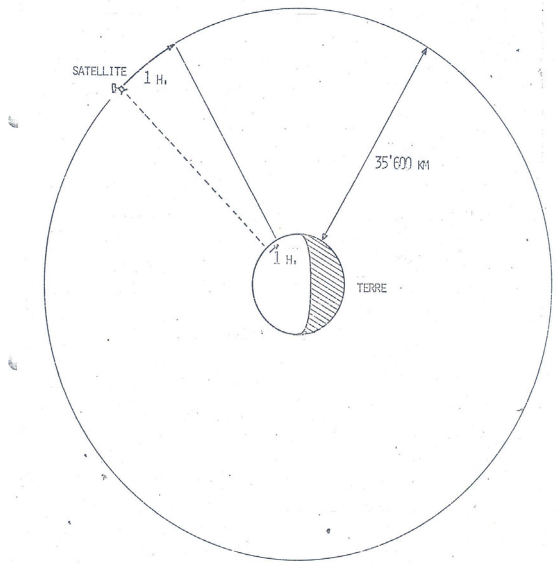
PROPAGATION EN MILIEU URBAIN (MicroChamp)



Application d'un logiciel pour la planification des liaisons avec les mobiles. Comparaison de plusieurs modèles de diffraction avec les valeurs mesurées (tiré d'une thèse de doctorat)

EPFL

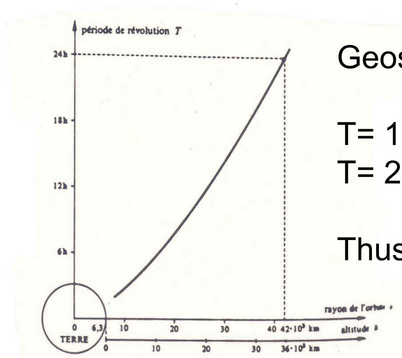
Satellite communication



EPFL

The 3rd Keppler law allows to determine the revolution period T of a satellite as a function of its elliptical orbit half axis a or its altitude h=a-R

$$T = 2\pi\sqrt{\frac{a^3}{GM}} = 2\pi\sqrt{\frac{(h+R)^3}{GM}}$$



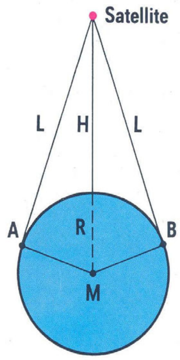
Geostationary orbit :

T= 1 sideral day
T= 23 h 56 m 4 sec

Thus h= 35786

EPFL

SIEMENS

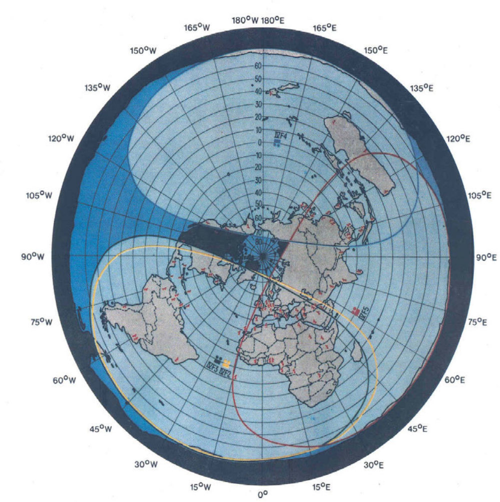


H	Geostationary height of satellite	36 000 km
R	Earth's radius	6 378 km
2L	Distance A–Sat–B	78 000 km
c	Speed of light	300 000 km/s
t	Transmission time	260 ms
a_0	Basic free–space transmission loss on one path section	approx. 200 dB at 6 GHz

Data for geostationary satellites

bt 035/40

EPFL



Satellites
E East
W West

Intelsat telecommunication–satellite system

bt 035/39

EPFL