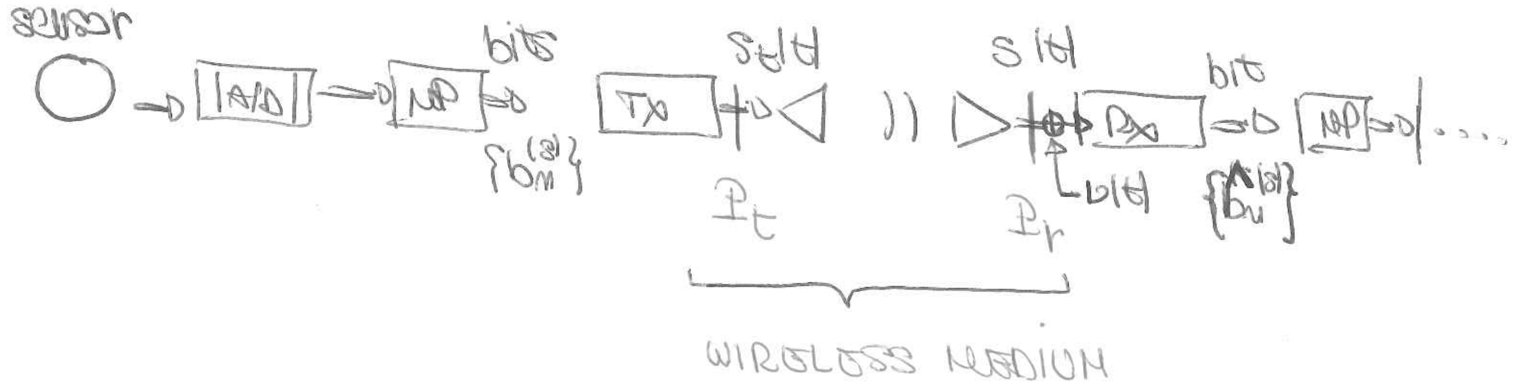
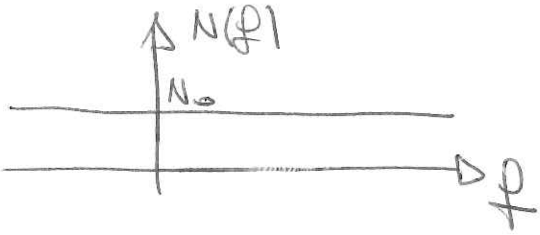
WIRELESS MEDIUM



We recall that:

$T \Rightarrow$ duration of $s_T(t) \Rightarrow$ of $s(t)$

AWGN $\Rightarrow$ model it summing to $s(t)$, $w(t)$, where $w(t)$ is a Gaussian r.v.

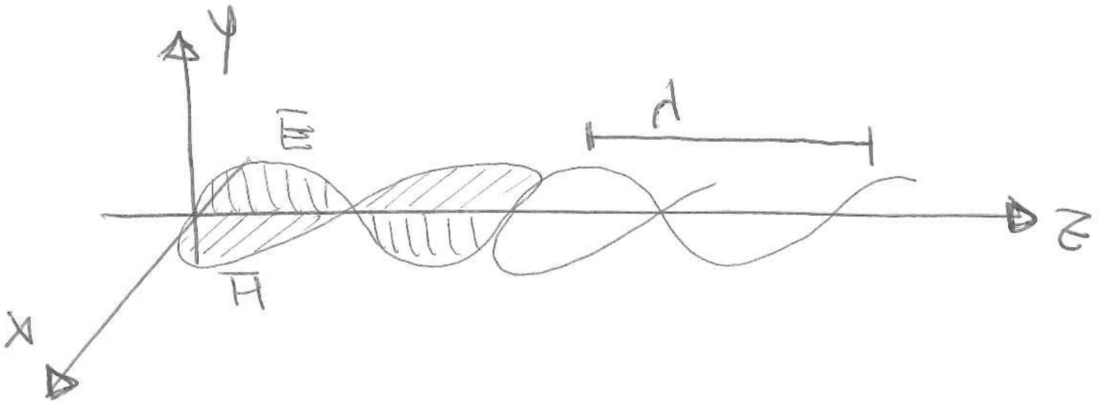


N_0 = bilateral power spectral density of the gaussian noise

$$SNR \triangleq \frac{E_r}{E_N} = \frac{P_r \cdot T}{\underbrace{k \cdot T_{ant}}_{2N_0} \cdot R_b \cdot T}$$

Wireless medium $\rightarrow$
- transmit antenna
- propagation medium
- Receiver antenna

- Propagation of EM waves:



the EM wave is composed of two components, the electric and the magnetic fields, which oscillate in phase, perpendicular are to each other and perpendicular to the direction of wave propagation

→ Waves interacts with bodies of size $\sim\lambda$
$a > \lambda$

$E_t = P_t \cdot T$

$E_r = P_r \cdot T$

$$P_r \overset{?}{\propto} P_t$$

ANTENNAS

- Isotropic antenna ⇒ It radiates uniformely over all directions
- Directional antenna ⇒ It tends to radiates in one direction

- Antenna gain: (Hp: transmit antenna)

$$G_t \triangleq \frac{C_0}{C_d}$$

$C_d \Rightarrow$ Radiated Power

$C_0 = C_0(\theta) \Rightarrow$ Power radiated by an isotropic antenna having in the direction θ the same effect of the considered antenna

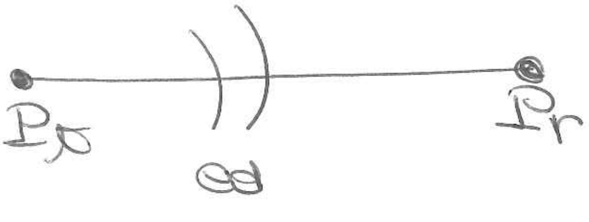
$G_t > 1$ in the direction of the radiation

$G_t < 1$ " " " " not "

$G_t = 1 \ \forall \theta \rightarrow$ Isotropic Antenna

- Antenna efficiency

Hp: transmit antenna



Part of the transmit power is wasted in heat and not radiated. provides a measure on how many heat is wasted

$\overset{\uparrow}{\eta_t} =$ efficiency

$C_d = \eta_t \cdot P_t$

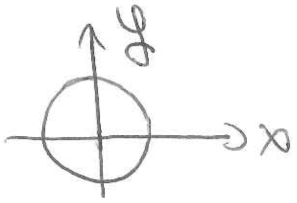
waves are efficiently generated if the size $\sim \lambda$ $(\eta_t \to 1)$

$\Rightarrow$ Low size antennas require high frequencies

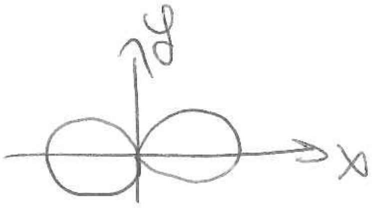
- Antenna Radiation Diagram.

Represents the antenna gain in the different directions of the space.

E.g.: polar diagram:

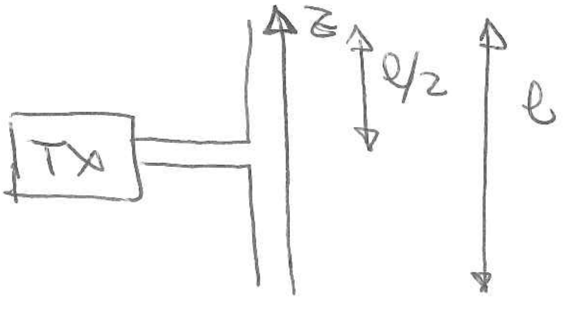


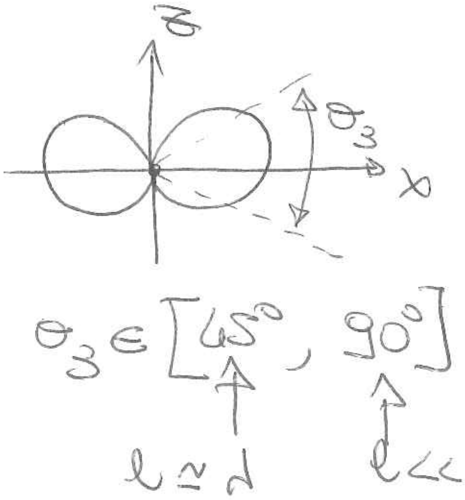
isotropic antenna



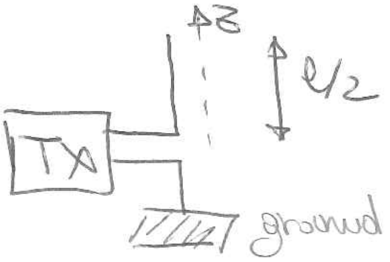
directional antenna

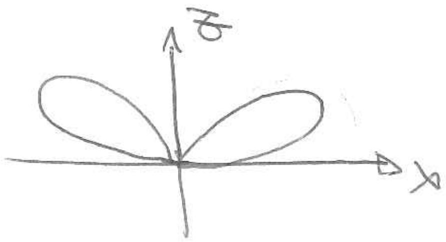
- Dipoles antenna:





- Half dipole antenna:





- ISM band: 2,4 GHz $\rightarrow \lambda \simeq 12$ cm
  $\lambda/2 \simeq 6$ cm

- coming back to: $P_r \overset{?}{\propto} P_t$

case 1: FREE SPACE conditions satisfied.

- no obstacles
- perfect dielectric
- isotropic → medium has the same characteristics in all directions
- homogeneous → medium has the same characteristics in all points
  it is crossed

If these conditions are satisfied ⇒ FRIIS' FORMULA

$$P_r = P_t \cdot \eta_t \cdot G_t \cdot \frac{1}{\left(\frac{2\pi d}{\lambda}\right)^2} \cdot \eta_r \cdot G_r$$

where: G_r = antenna gain at receiver

η_r = " efficiency "

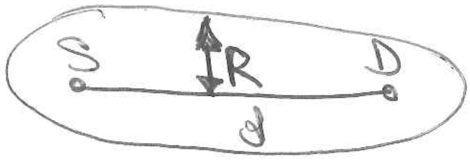
$P_r \propto P_t$ $\qquad$ $P_r \propto d^{-2}$

- Fresnel elipsoid ⇒

elipsoid obtained through a rotation of an ellipse having S and D as focal points.

The semi-minor axis is:

$$R = \sqrt{\frac{\lambda \cdot d}{4}}$$



If the Fresnel elipsoid is free ⇒ Friis' Formula

case 2: If free space conditions are not satisfied:

$$P_r = P_t \cdot G_t \cdot \eta_t \cdot \frac{1}{\left(\frac{4\pi}{\lambda}\right)^2} \cdot \frac{1}{d^{\beta}} \cdot G_r \cdot \eta_r$$

$$P_r \propto d^{-\beta}$$

β = propagation coefficient

$$\beta \in [2 \div 4]$$

In dB:

$$P_r[dBW] = P_t[dBW] - L[dB]$$

By setting: $\eta_t = \eta_r = G_r = G_t = 1$

$$\Rightarrow L[dB] = \underbrace{10\log_{10}\left(\frac{4\pi}{\lambda}\right)^2}_{k_0} + \underbrace{10\cdot\beta\cdot\log_{10}\cdot d}_{k_1\cdot\log(d)}$$

LINK BUDGET (free-space conditions)

$$SNR = \frac{P_t\cdot T}{k\cdot T_{sist}\cdot R_b\cdot T} = \frac{P_t\cdot T}{k\cdot T_{sist}\cdot R_b\cdot T}\cdot\eta_t\cdot\eta_r\cdot G_t\cdot G_r\cdot\frac{1}{\left(\frac{4\pi d}{\lambda}\right)^2}$$

$$= \frac{E_t}{k\cdot T_{sist}\cdot R_b\cdot T}\cdot\eta_t\cdot\eta_r\cdot G_t\cdot G_r\cdot\frac{1}{\left(\frac{4\pi d}{\lambda}\right)^2}$$