ULB

WIRELESS COMMUNICATIONS RESEARCH GROUP

OPERA.ULB.AC.BE

Conception of a complete OFDM communication channel

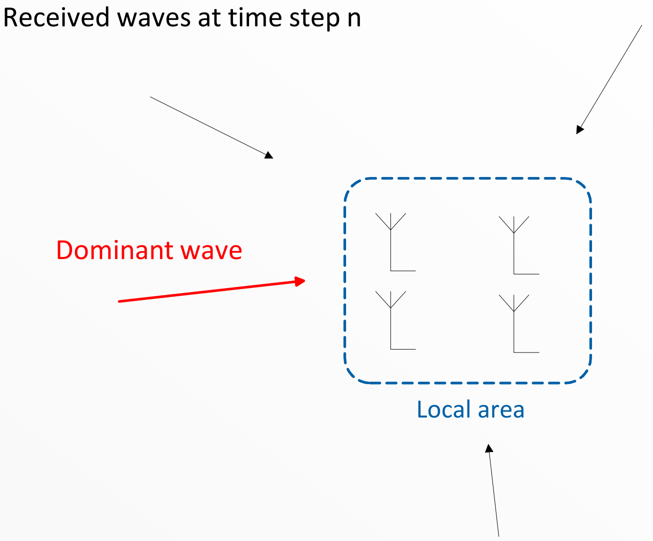
Statistical channel model

Each tap is composed by bunches of waves:

$$h_i(n) = \sum_k h_i(n,k)$$

where

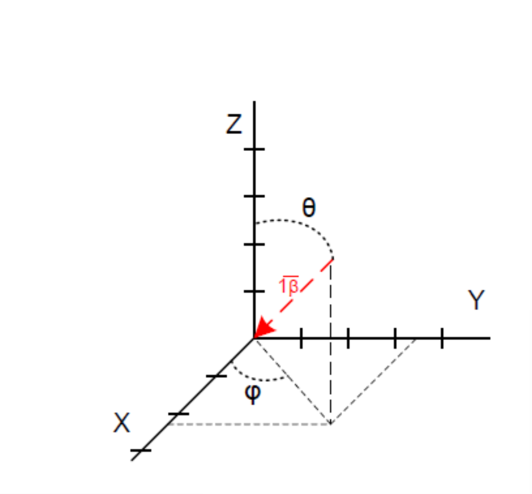
- $h(n,k) = a_k e^{j\Phi_k}$
- $\Phi_k = \phi_k - \vec{\beta}_k \vec{r}_i$



- ϕ_k is a random value with uniform distribution between 0 and 2π
- a_k is the amplitude of the wave

Virtual Multi-antenna receiver

$$h_i(n) = \sum_k a_k e^{j(\phi_k - \vec{\beta}_k \vec{r}_i)}$$



- ϕ_k depends on the IO's
- $\vec{r}_i$ is the position of the antenna
- $\vec{\beta}_k$ defines the direction of arrival of the wave

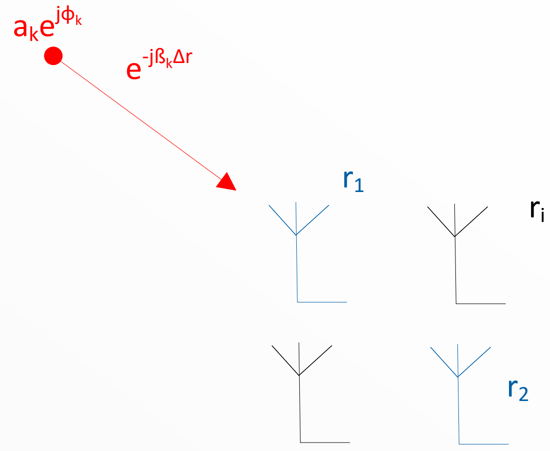
$$\vec{\beta}_k = \frac{2\pi}{\lambda}\left(\sin(\theta_k)\cos(\varphi_k)\,\vec{1}_x + \sin(\theta_k)\sin(\varphi_k)\,\vec{1}_y + cos(\theta_k)\,\vec{1}_z\right)$$

The room didn't changed

- The IO's and the direction of arrival are the same
- Equivalent to a multi-antenna receiver

Estimate the direction of arrival

$$h_i(n) = \sum_k a_k e^{j(\phi_k - \vec{\beta}_k \vec{r}_i)}$$



- ϕ_k depends on the IO's
- Phase rotation in the local area due to propagation $\vec{\beta}_k \vec{r}_i$

Beamforming equation:

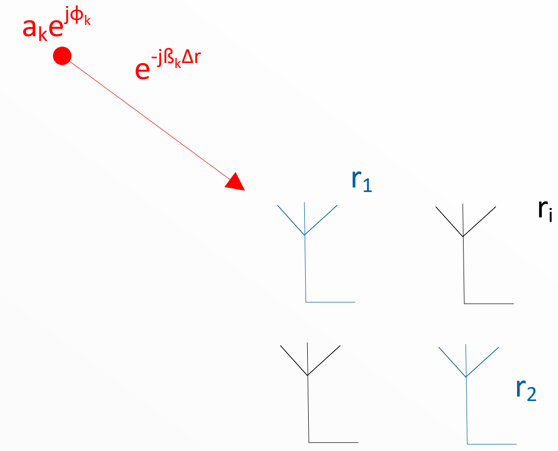
$$a_n(\theta,\varphi) = \frac{\sum_i h_i(n) B_i^*(\theta,\varphi)}{\sum_i |B_i(\theta,\varphi)|^2}$$

where

- $B_i(\theta,\varphi) = e^{-j\vec{\beta}_{(\theta,\varphi)}\vec{r}_i}$
- $\vec{\beta}_{(\theta,\varphi)} = \frac{2\pi}{\lambda}\left(\sin(\theta)\cos(\varphi)\,\vec{1}_x + \sin(\theta)\sin(\varphi)\,\vec{1}_y + cos(\theta)\,\vec{1}_z\right)$

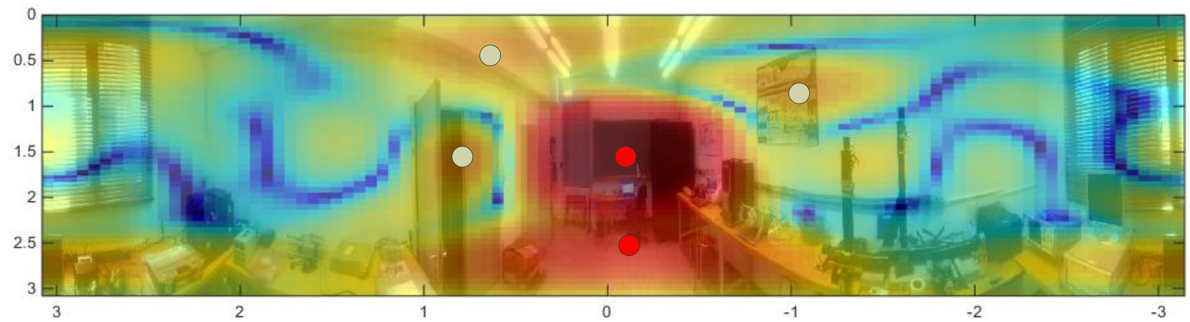
Estimate the direction of arrival

- $h_i(n) = \sum_k a_k e^{j(\phi_k - \vec{\beta}_k \vec{r}_i)}$
- $B_i(\theta, \varphi) = e^{-j\vec{\beta}_{(\theta,\varphi)}\vec{r}_i}$
- $a_n(\theta, \varphi) = \frac{\sum_i h_i(n) B_i^*(\theta,\varphi)}{\sum_i |B_i(\theta,\varphi)|^2}$



- $B_i(\theta, \varphi)$ specifies how the phase of a wave evolves in function of its position for a direction of arrival (θ, φ)
- $a_n(\theta, \varphi)$ evaluates if one of the waves $a_k e^{j\phi_k}$ comes from the direction (θ, φ)

Interpretation of $a_n(\theta, \phi)$

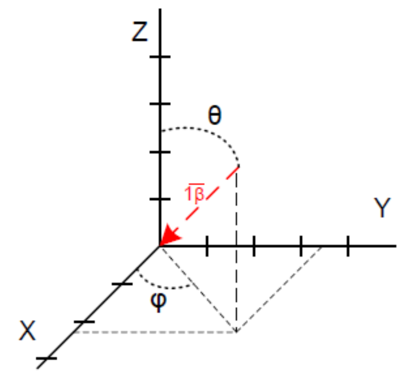


Tip: Only consider the most important direction for the interpretation

- Increase the threshold in the *findLocalMaxima* function

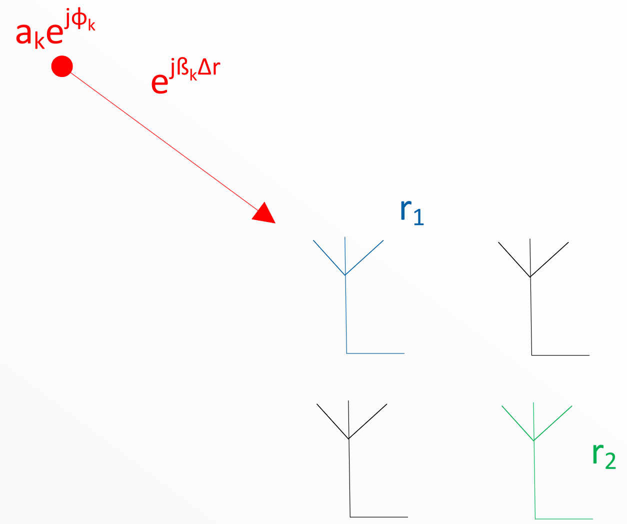
Parameters of the beamforming

- $\theta \in [0; \pi]$
- $\varphi \in [-\pi; \pi]$
- $X, Z \in [0:9]$; $Y \in [9:-1:0]$
- Antenna's are spaced 2cm apart



Build a new channel model

- $h_i(n) = \sum_k a_k e^{j(\phi_k - \vec{\beta}_k \vec{r}_i)}$
- $a_n(\theta, \varphi) = \frac{\sum_i h_i(n) B_i^*(\theta,\varphi)}{\sum_i |B_i(\theta,\varphi)|^2}$
- $B_i(\theta, \varphi) = e^{-j\vec{\beta}_k \vec{r}_i}$



- $\widehat{h_i}(n) = \sum_{(\theta,\varphi)} a_n(\theta, \varphi) e^{j(\phi_i - \vec{\beta}_k \vec{r}_i)}$
  - ϕ_i is a random phase
  - $\vec{\beta}_i \vec{r}_i$ specifies the position of the antenna

- This new model takes into account the position of the antennas
- Stochastic model because ϕ_i is random (position of the IO's)

Objective (1)

- Explain the beamforming method

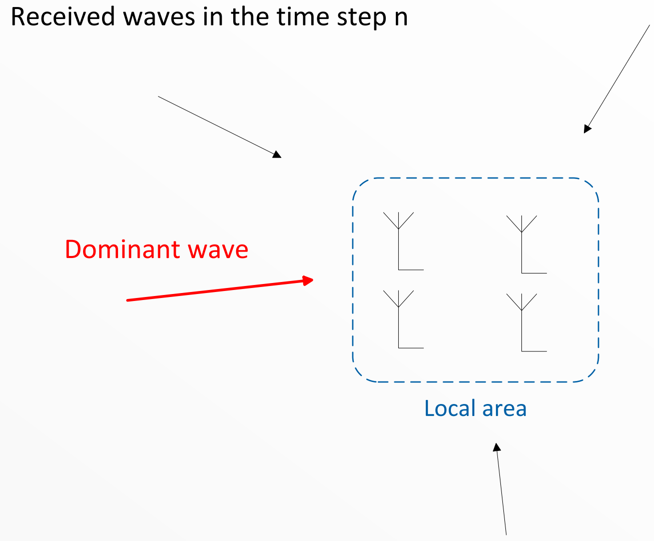
- Evaluate the angular spectrum for the LOS and NLOS scenario for the 20 MHz channel

- Build a new channel model based on the beamforming

Statistical channel model

Each tap is composed by bunches of waves:

$$\tilde{h}_i(n) = \sum_{(\theta,\varphi)} a_n(\theta,\varphi) e^{j(\phi_{(\theta,\varphi)} - \vec{\beta}_{(\theta,\varphi)} \vec{r}_i)}$$



- $\phi_{(\theta,\varphi)}$ is a random value with uniform distribution between 0 and 2π
- $a_n(\theta,\varphi)$ is evaluated with the beamforming
- For each realization, we have new $\phi_{(\theta,\varphi)}$

Spatial correlation

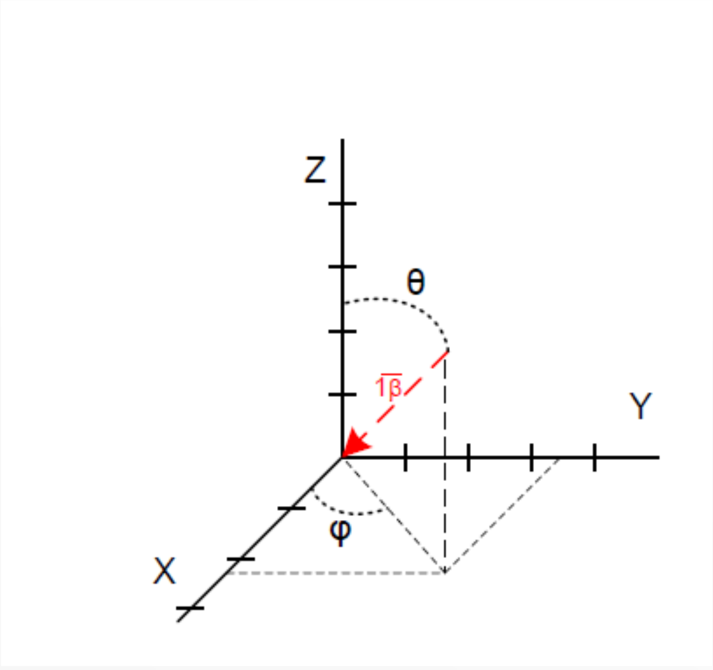
Spatial Correlation (along z-axis) : $R(\Delta z) = \frac{1}{2\pi}\int_{-\infty}^{\infty} S(u)\, e^{ju\Delta z} du$

Angular Spectrum $S(u)$ ($u = \beta \cos\theta$) :

$$2\pi S(u)\delta(u-u') \equiv \mathcal{E}[a(u)a^*(u')]$$

+ Uncorrelated Scattering assumption:

$$S(u) = \sum_{i=1}^{N_u} 2\pi |a(u_i)|^2 \delta(u-u_i)$$



Objective

- Evaluate the spatial correlation of the channel model you built in LOS and NLOS for each direction X, Y and Z separately, in narrowband and wideband.

- Compare to Clarke's Model