# Wireless Communications Channels
# Lecture 7: Channel Models

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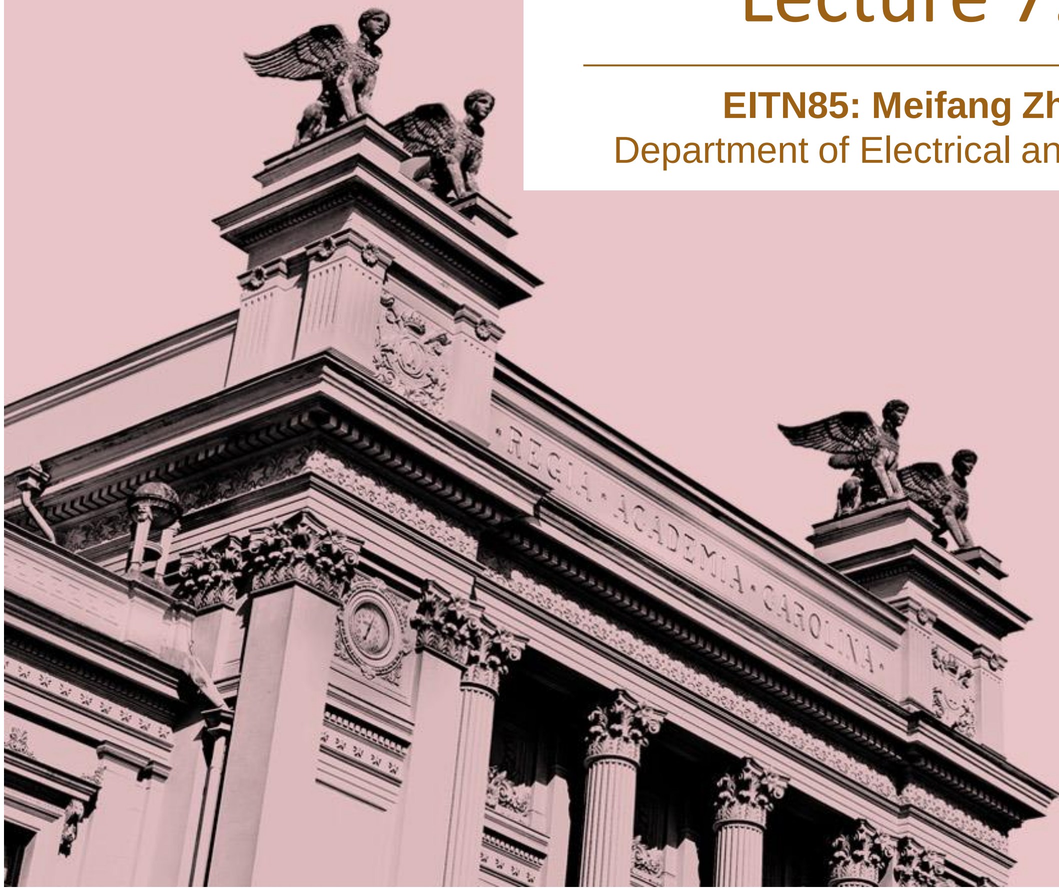

# Recap:

**By given a channel transfer function of a radio channel, which procedure you gonna take to determine its coherence bandwidth with correlation coefficient defined as 0.5?**



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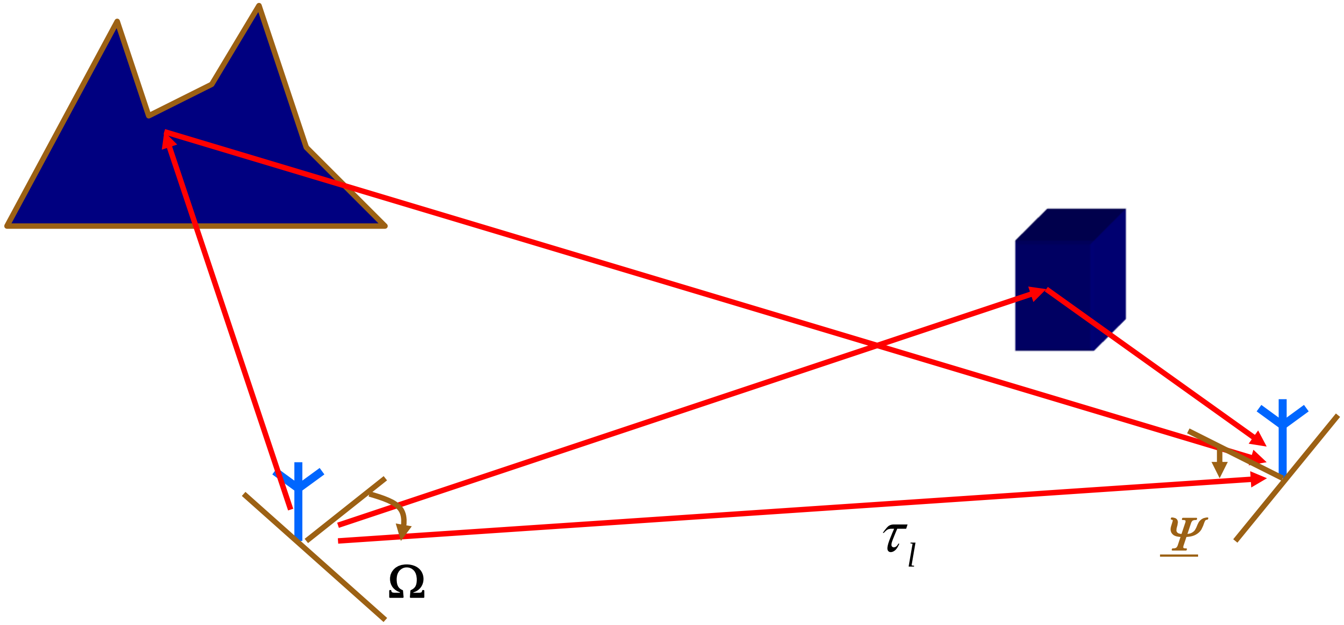
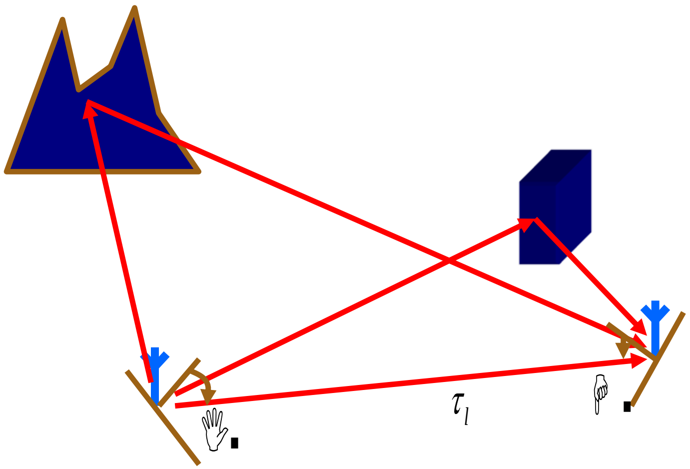
# Recap: Physical interpretation



# Recap: Angular spread

$$E\{s^*(\Omega,\Psi,\tau,\nu)s(\Omega',\Psi',\tau',\nu')\} = P_s(\Omega,\Psi,\tau,\nu)\delta(\Omega-\Omega')\delta(\Psi-\Psi')\delta(\tau-\tau')\delta(\nu-\nu')$$




double directional delay power spectrum

$$DDDPS(\Omega,\Psi,\tau) = \int P_s(\Psi,\Omega,\tau,\nu)d\nu$$

angular delay power spectrum

$$ADPS(\Omega,\tau) = \int DDDPS(\Psi,\Omega,\tau)G_{MS}(\Psi)d\Psi$$

angular power spectrum

$$APS(\Omega) = \int ADPS(\Omega,\tau)d\tau$$

power

$$P = \int APS(\Omega)d\Omega$$



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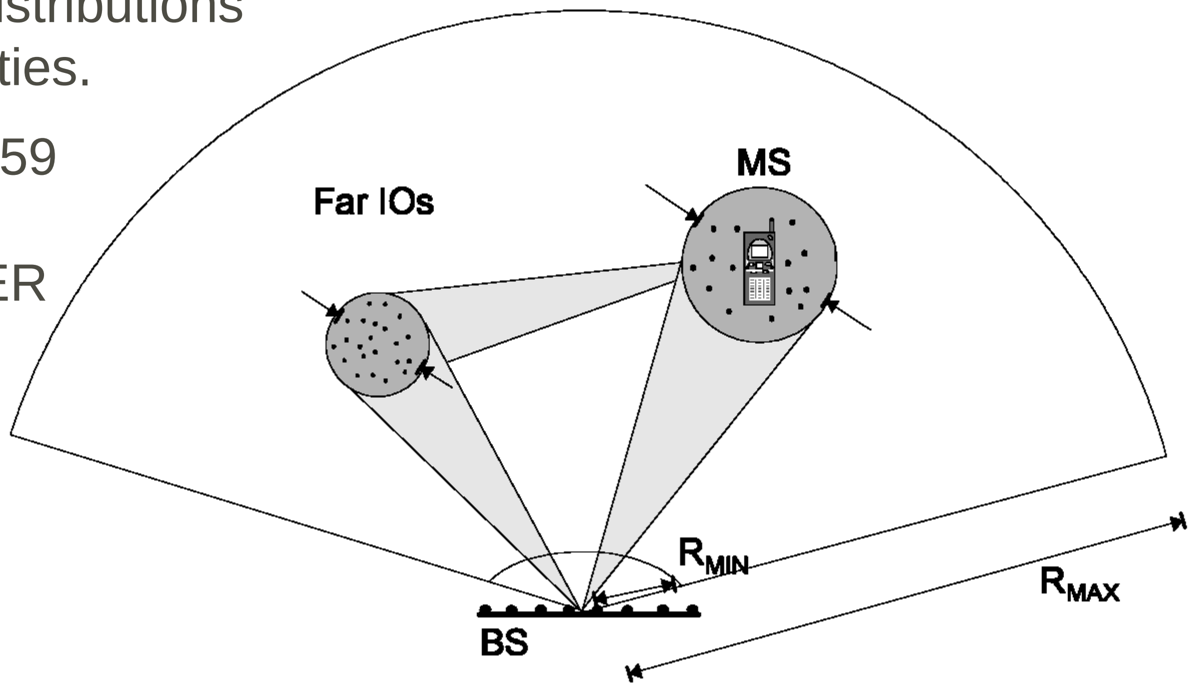
# Geometry-Based Stochastic Channel Model (GSCM)

Assign positions for scatterers according to given distributions

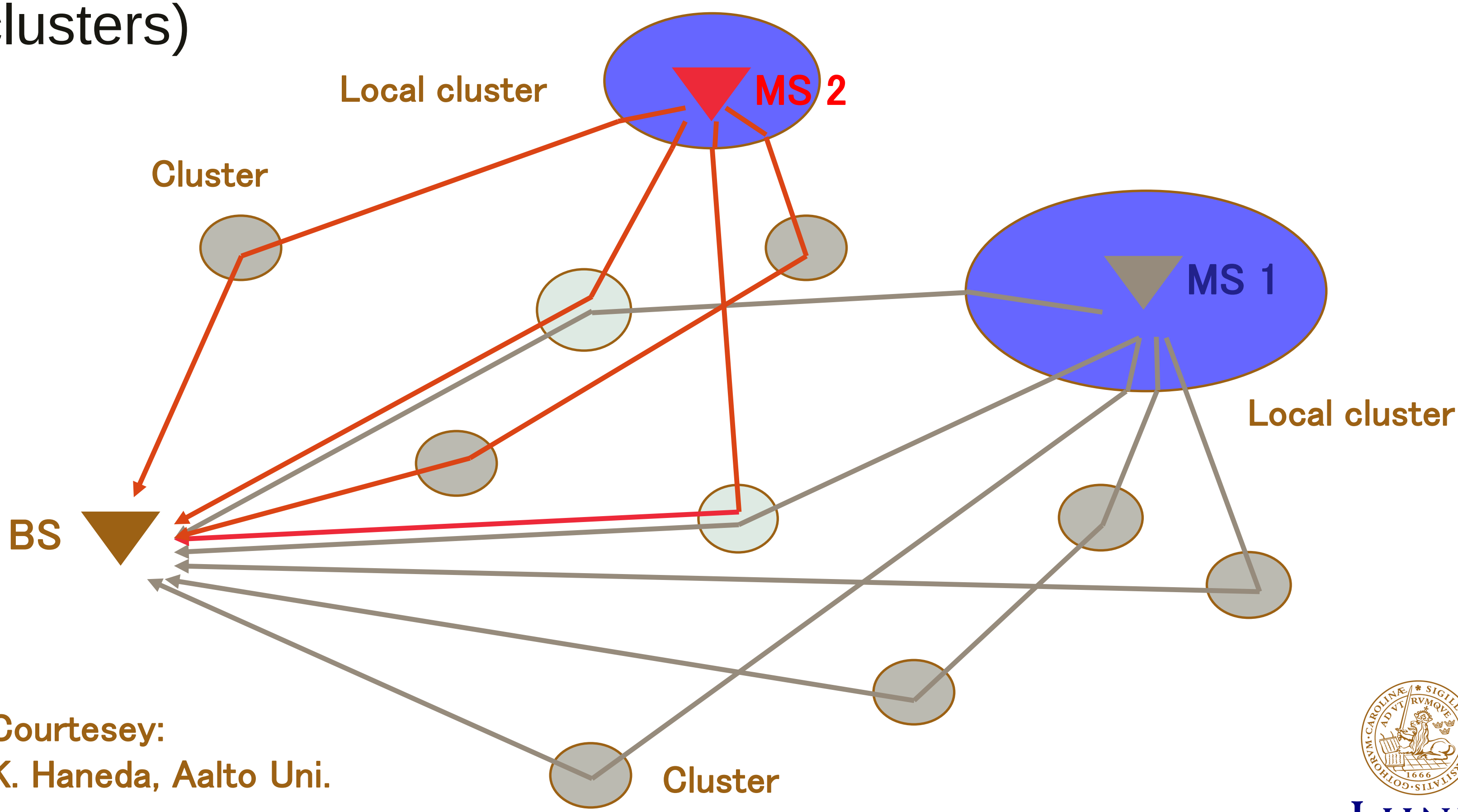
Derive impulse response given the scatterers and distributions for the signal properties.

Used in the COST 259 model, COST 273, COST 2100, WINNER 3GPP/3GPP2



# Geometry-Based Stochastic Channel Model (GSCM)

Create an ”imaginary” map for radio wave scatterers (clusters)




Courtesey:
K. Haneda, Aalto Uni.



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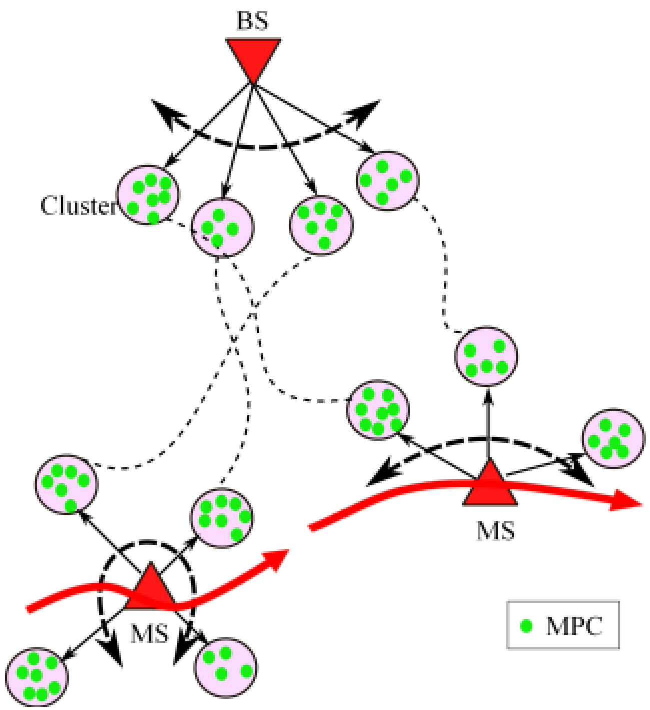
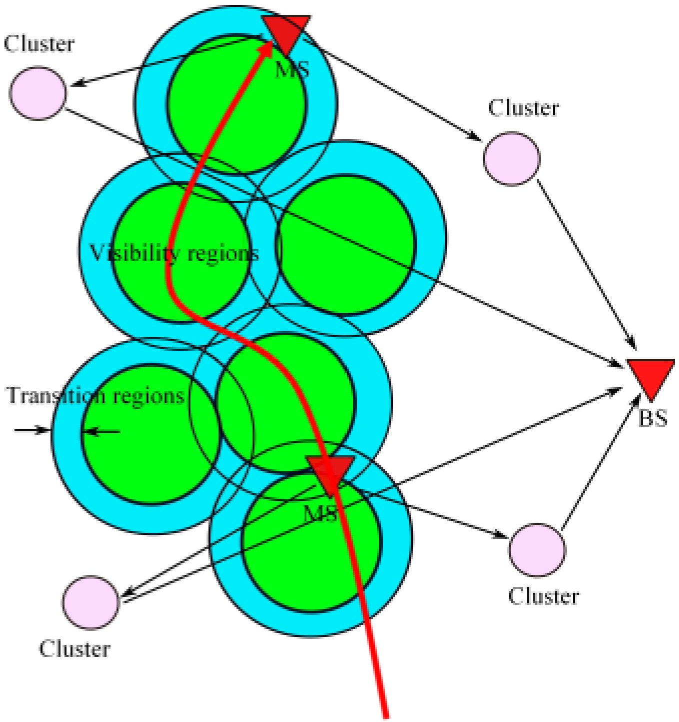
# WINNER II




- Each large circle represents a multi-path cluster
- Green dots: multipath components
- As MS moving, different clusters will be active
- Clusters are with same size
- Large scale parameter is not auto updated

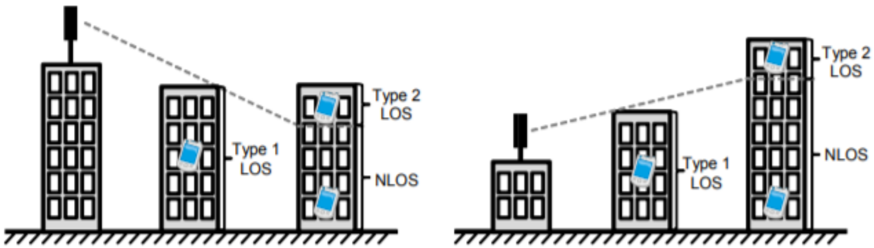
# COST2100




- For each cluster, introduce an associated transition and visibility region
- As MS moving, different clusters will be active with smooth transimition
- Clusters are with different sizes
- Need a complex parameter inputs for each scenario

# Wideband models
# ITU-R model for 4G

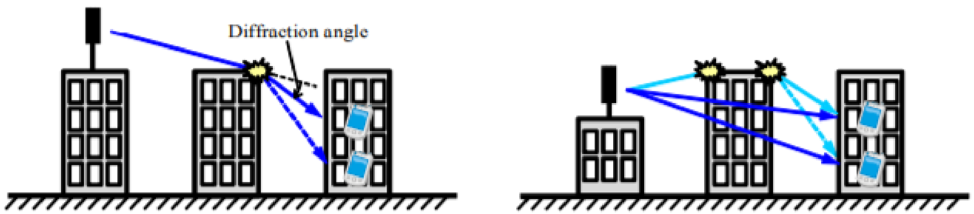
- A three-dimensional (3D) spatial channel model (SCM)




(a) 3D-UMa scenario (b) 3D-UMi scenario

$$\mathrm{PL}^{\mathrm{4G(b)}}_{\mathrm{3D\ UMi\ LOS}} = 40.0\log(d) + 28.0 + 20\log(f) - 9\log[(d_{\mathrm{break}})^2 + (h_{\mathrm{t}} - h_{\mathrm{r}})^2].$$

Pathloss




(a) 3D-UMa scenario (b) 3D-UMi scenario

$$\mathrm{PL}^{\mathrm{4G}}_{\mathrm{3D\ UMi\ NLOS}} = 36.7\log(d) + 22.7 + 26\log(f) - 0.3\,(h_{\mathrm{r}} - 1.5)\,.$$

@ B. Mondal, ”3D Channel Model in 3GPP ”



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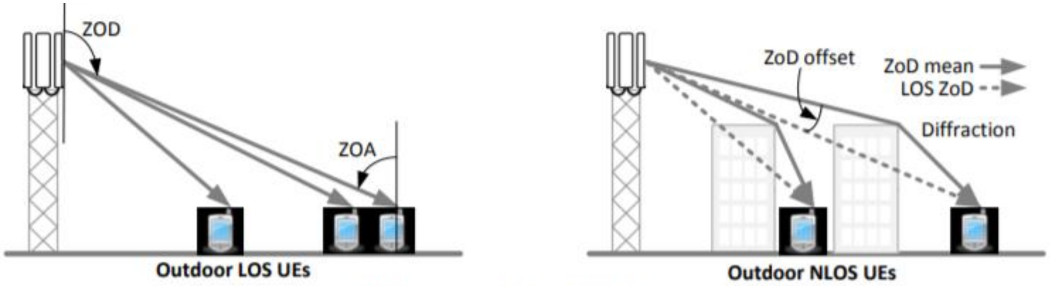
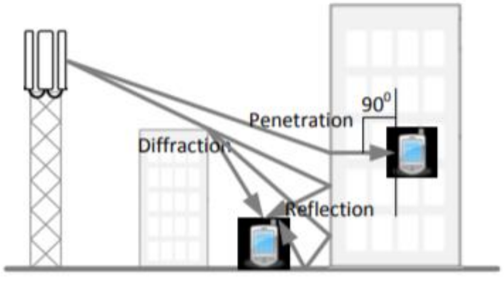
# Wideband models
# ITU-R model for 4G

- A three-dimensional (3D) spatial channel model (SCM)



(b) ZOD in outdoor LOS and NLOS conditions

Fast fading



(c) ZOA in indoor and outdoor NLOS conditions

**azimuth angles of departure and arrival (AOD and AOA) and zenith angles of departure and arrival (ZOD and ZOA)**

**@ B. Mondal, ”3D Channel Model in 3GPP ”**



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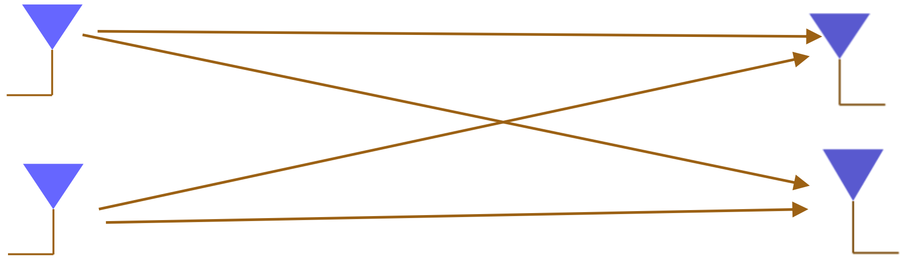
# The MIMO channel

**channel matrix**

$$\boldsymbol{H}(\tau) = \begin{bmatrix} h_{11}(\tau) & h_{12}(\tau) & \cdots & h_{1M_{\mathrm{Tx}}}(\tau) \\ h_{21}(\tau) & h_{22}(\tau) & \cdots & h_{2M_{\mathrm{Tx}}}(\tau) \\ \vdots & \vdots & \ddots & \vdots \\ h_{M_{\mathrm{Rx}}1}(\tau) & h_{M_{\mathrm{Rx}}2}(\tau) & \cdots & h_{M_{\mathrm{Rx}}M_{\mathrm{Tx}}}(\tau) \end{bmatrix}$$

**signal model**

$$\boldsymbol{y}(t) = \sum_{\tau=0}^{D-1} \boldsymbol{H}(\tau) \cdot \boldsymbol{x}(t-\tau)$$



# MIMO :Kronecker channel model

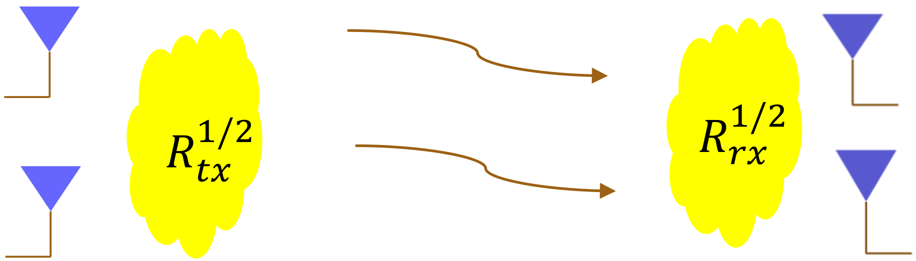
- Scattering at transmitter and receiver is independent
- i.i.d Rayleigh fading model

$$H = R_{rx}^{1/2} H_{i.i.d.} R_{tx}^{1/2}$$

$R_{rx}^{1/2}$ is the receive correlation matrix

$R_{tx}^{1/2}$ is the transmit correlation matrix

$H_{i.i.d.}$ is an independent and identically distributed channel, zero mean, unit variance



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# Deterministic modeling methods

Solve Maxwell's equations with boundary conditions

Problems:

- Data base for environment
- Computation time

"Exact" solutions

- Method of moments
- Finite element method
- Finite-difference time domain (FDTD)

High frequency approximation

- All waves modeled as rays that behave as in geometrical optics
- Refinements include approximation to diffraction, diffuse scattering, etc.



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# Ray launching

TX antenna sends out rays in different directions

We follow each ray as it propagates, until it either

– Reaches the receiver, *or*

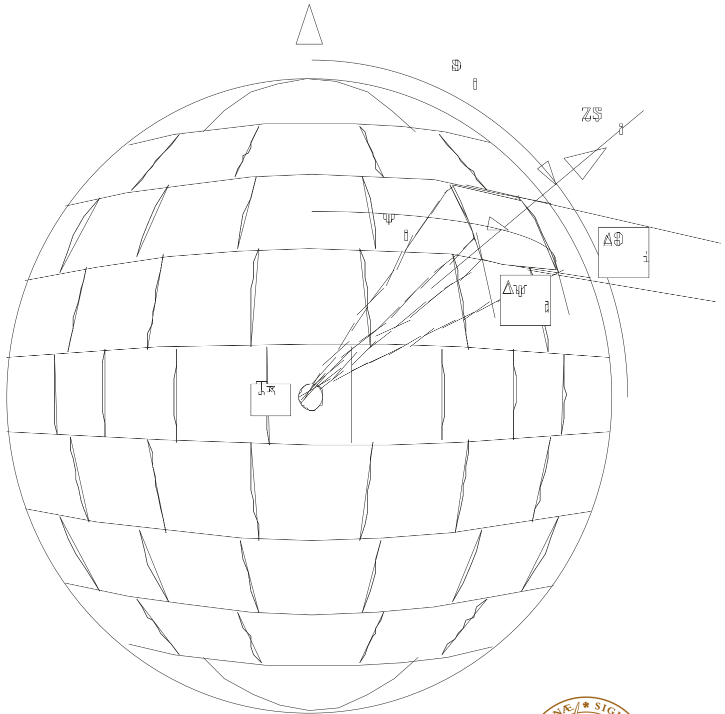
– Becomes too weak to be relevant

Propagation processes

– Free-space attenuation

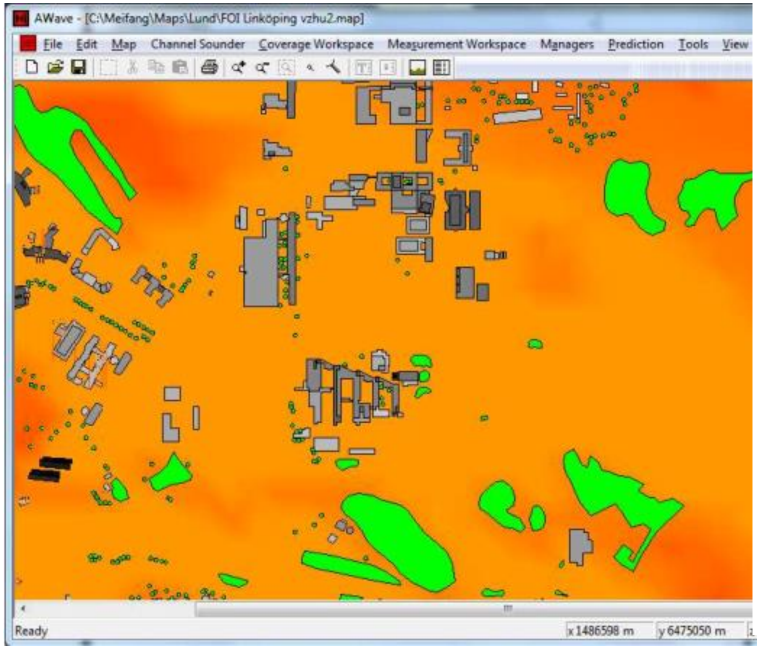
– Reflection

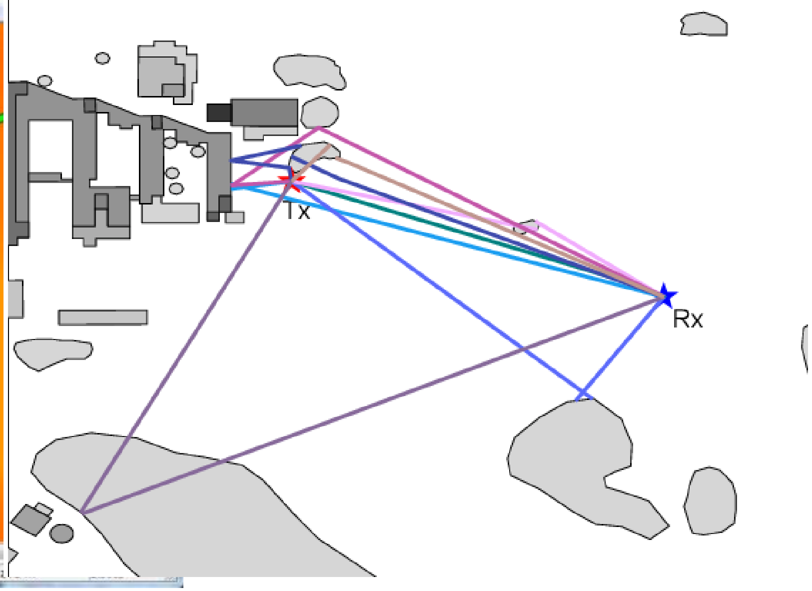
– Diffraction and diffuse scattering: each interacting object is source of multiple new rays



Predicts channel in a whole *area* (for one TX location)

# Ray launching example



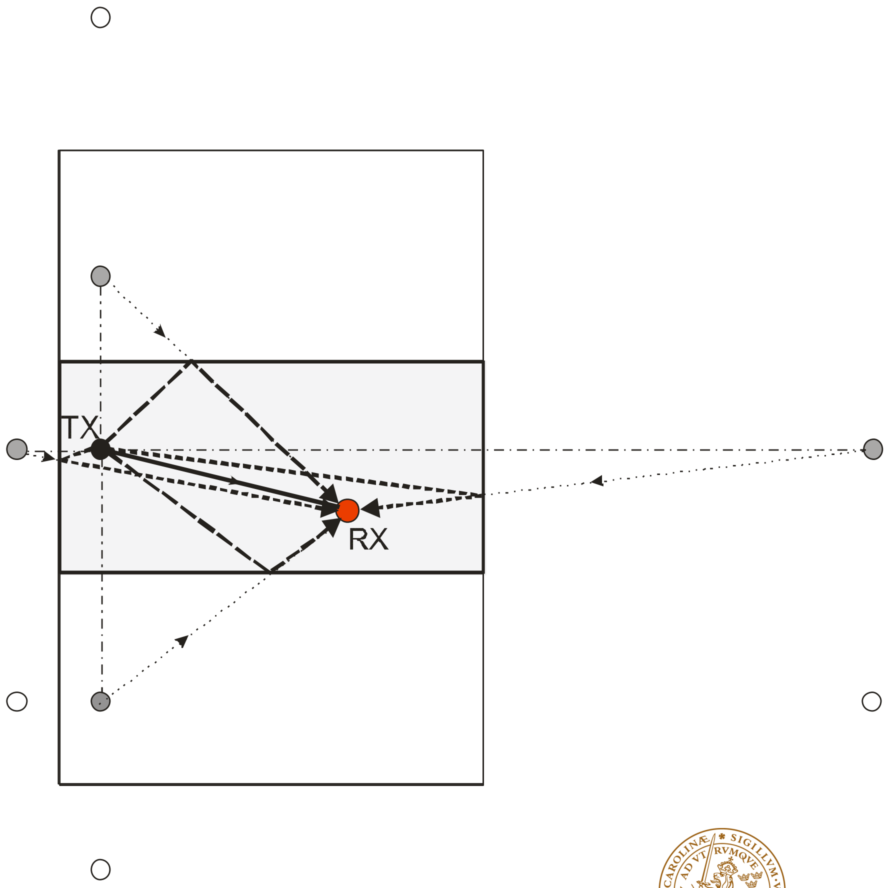


# Ray tracing

Determines rays that can go from one TX position to one RX position

- Uses imagining principle
- Similar to techniques known from computer science

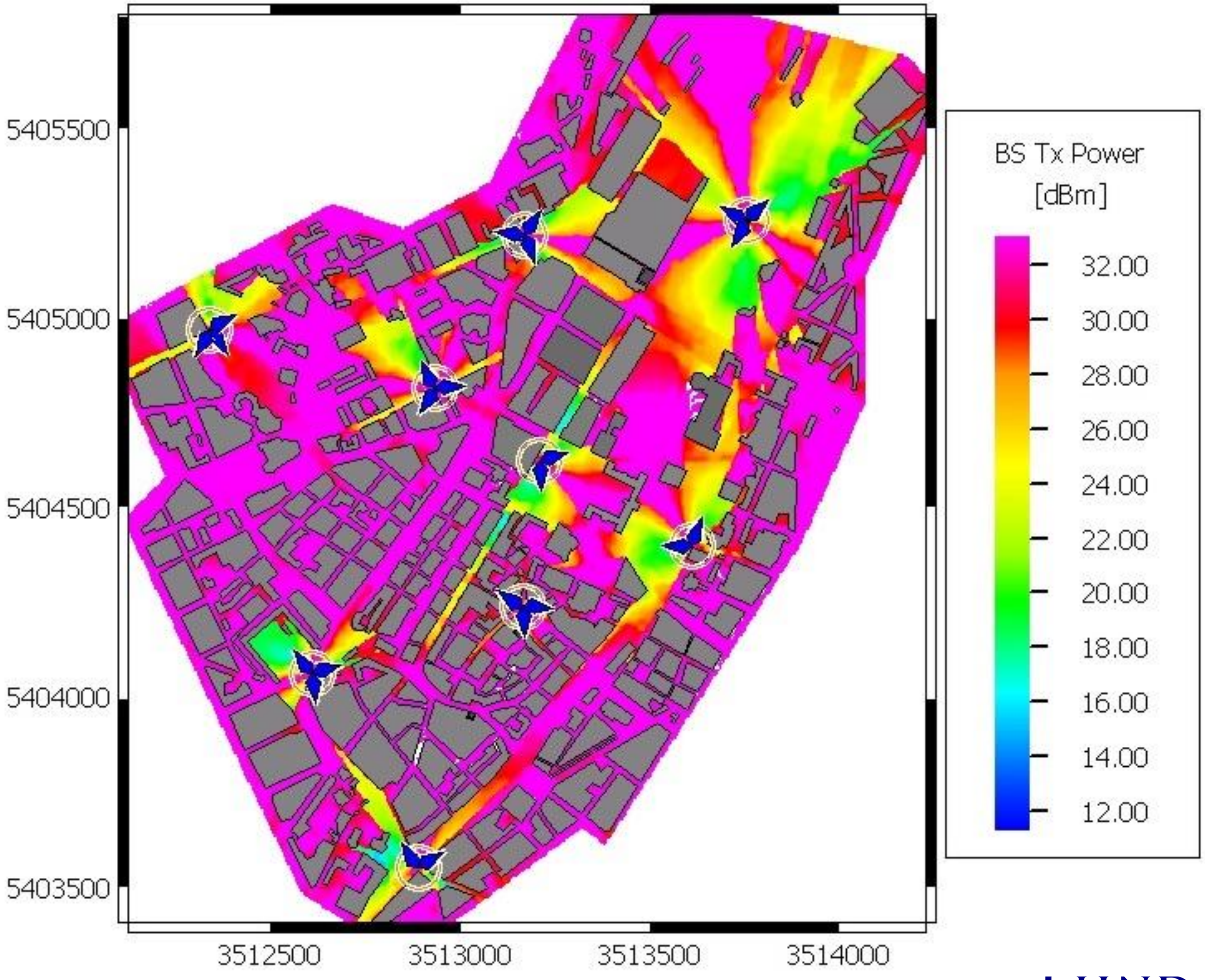
Then determine attenuation of all those possible paths



# Example: Ray tracing

Required base station power to connect to a WCDMA cell phone. Example from Stuttgart.

Courtesey: Awe-communications



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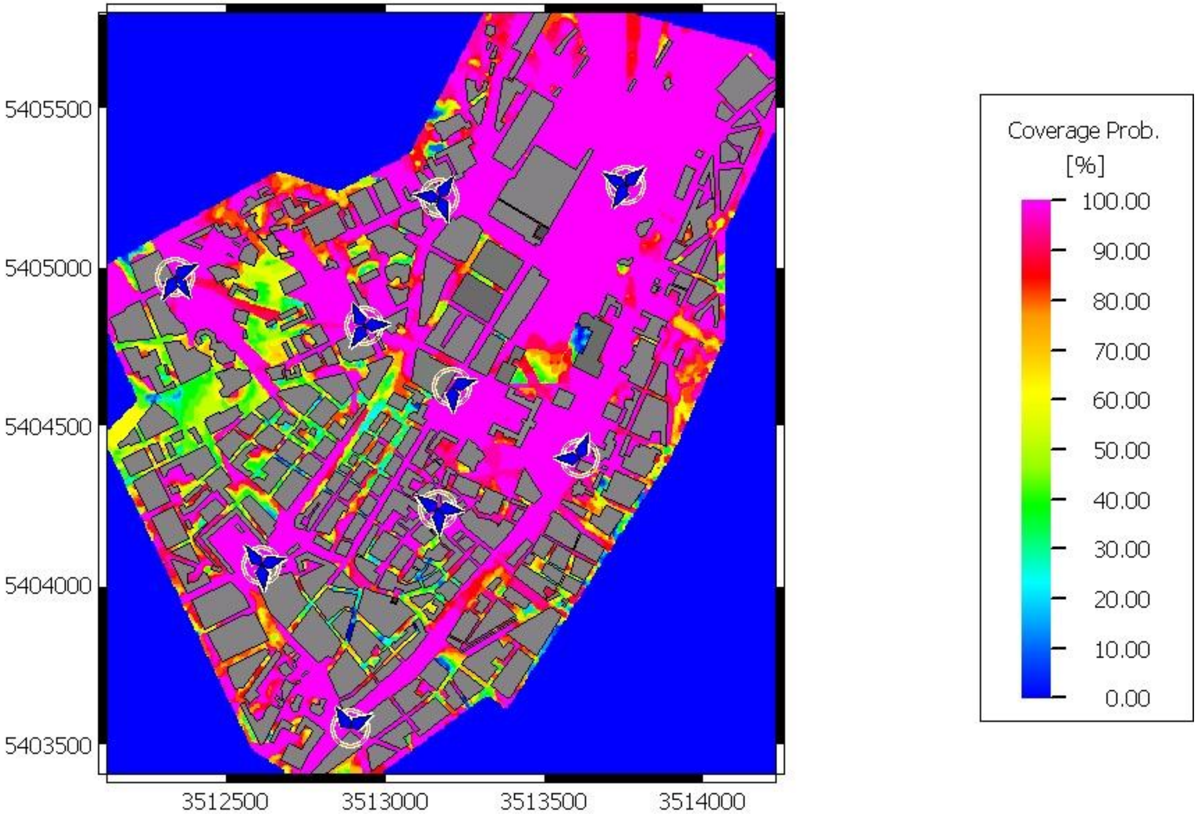
# Example: Ray tracing

Coverage for a WCDMA cell phone. Example from Stuttgart.

Courtesey: Awe-communications Propagation Models



# Discussions: Future channel models

Center frequency

Bandwidth

Large number of antenna array

Different type of antennas

Mobility

Spatial/temporal/frequency consistency

Pratical computational complexity

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