Signal correlation for mobile terminals having diversity antennas

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COST284 meeting, Chexbres, March 2-4, 2005

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Outline

- Diversity and MIMO
- Pattern and polarisation diversity
- Antenna correlation
- Estimating correlation from radiation patterns

Diversity for mobile phones

- Diversity can combat the effects of fading and interference
- Diversity solutions give better call quality, higher data rates and increased network capacity
- Components of diversity:
  - Multiple antennas in terminals/base stations
  - Tx diversity, Rx diversity
  - MIMO (multiple input multiple output)
  - Effect of the user and the radio channel
  - RF architecture: single or multiple RF chains
  - Receiver algorithms: maximum ratio combining, interference cancellation

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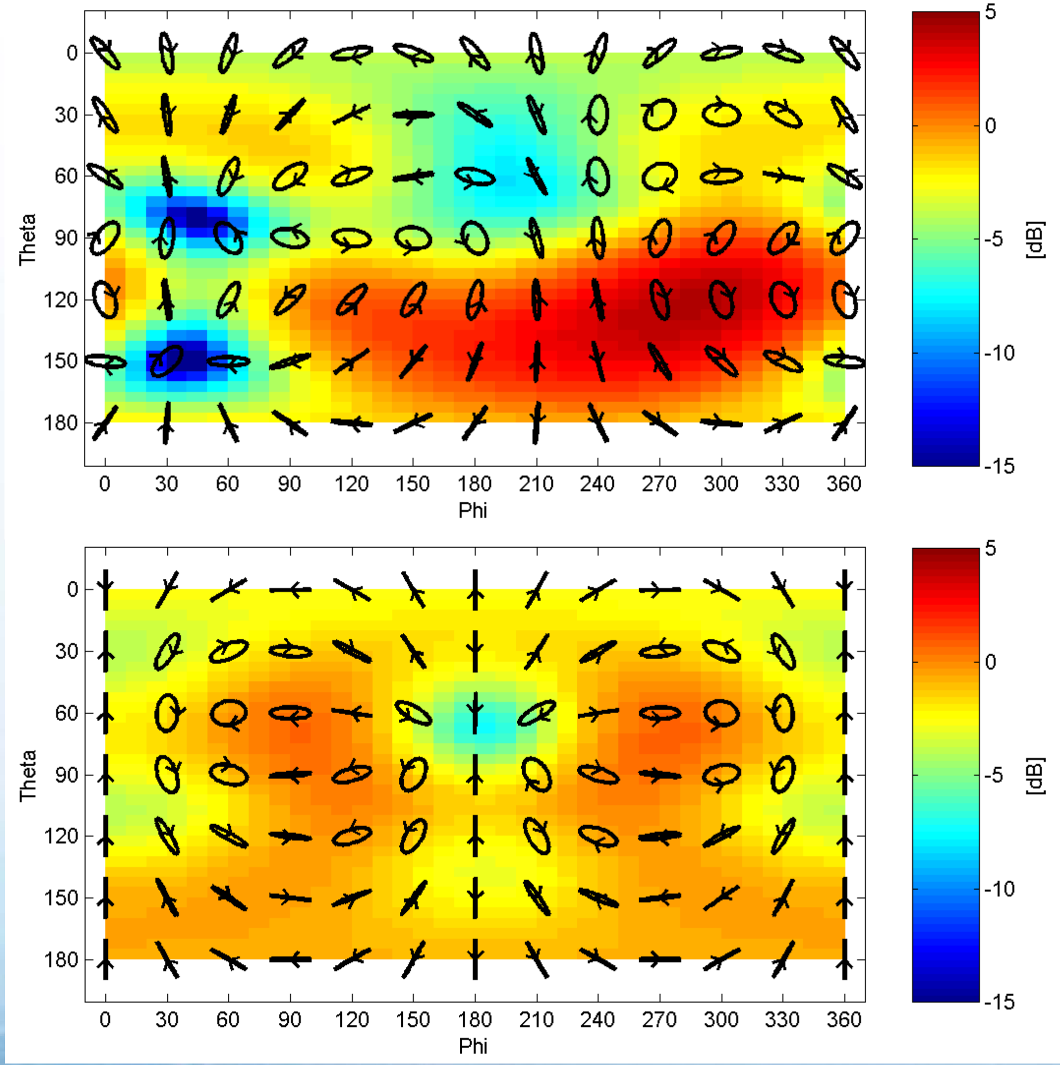
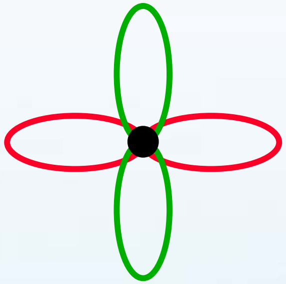
Pattern and polarisation diversity

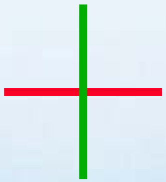
Main



Diversity

- In mobile terminals, diversity is a combination of pattern and polarisation diversity
- Pattern diversity





- Polarisation diversity (vertical/horizontal)

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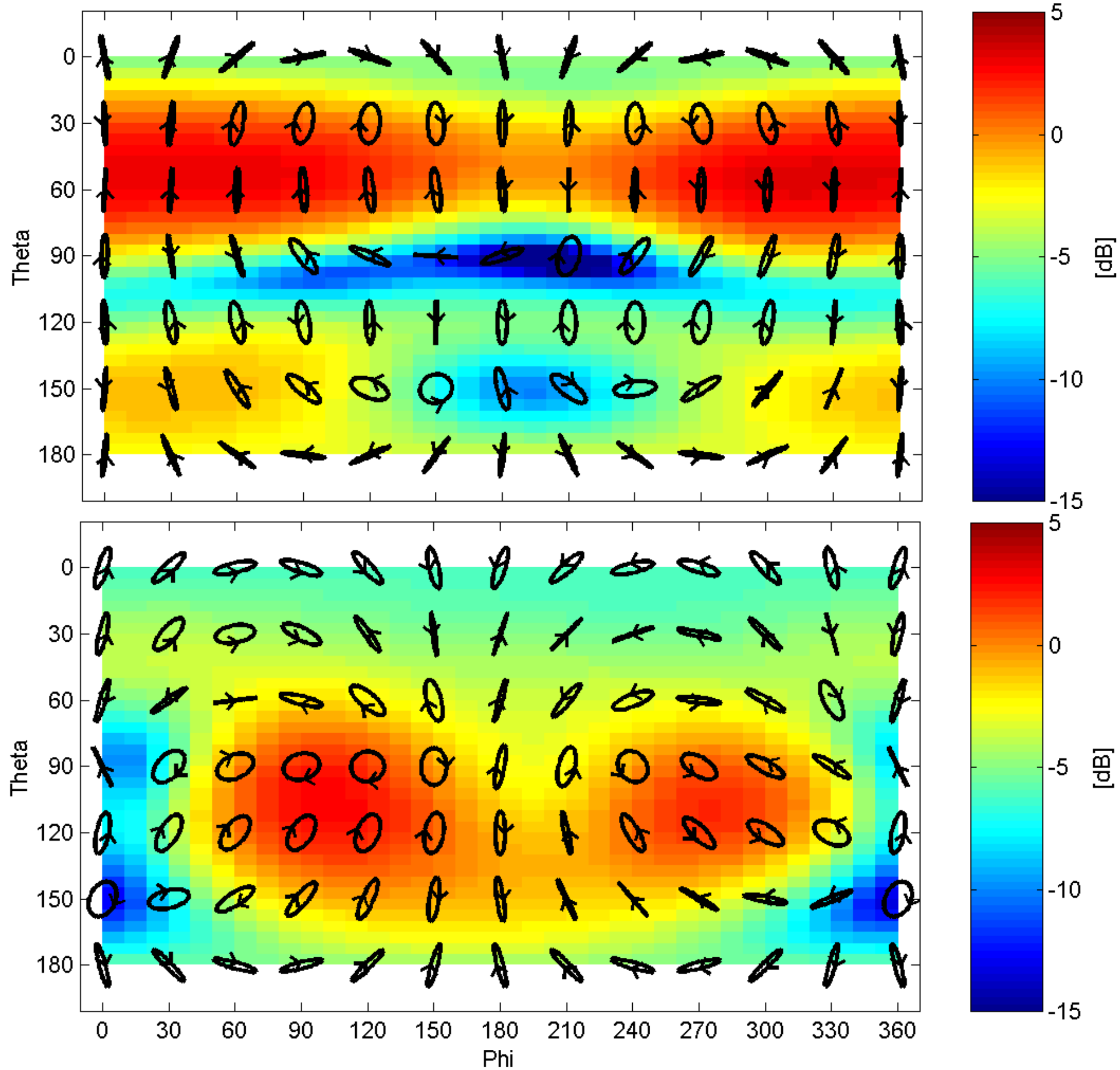
More diversity antennas



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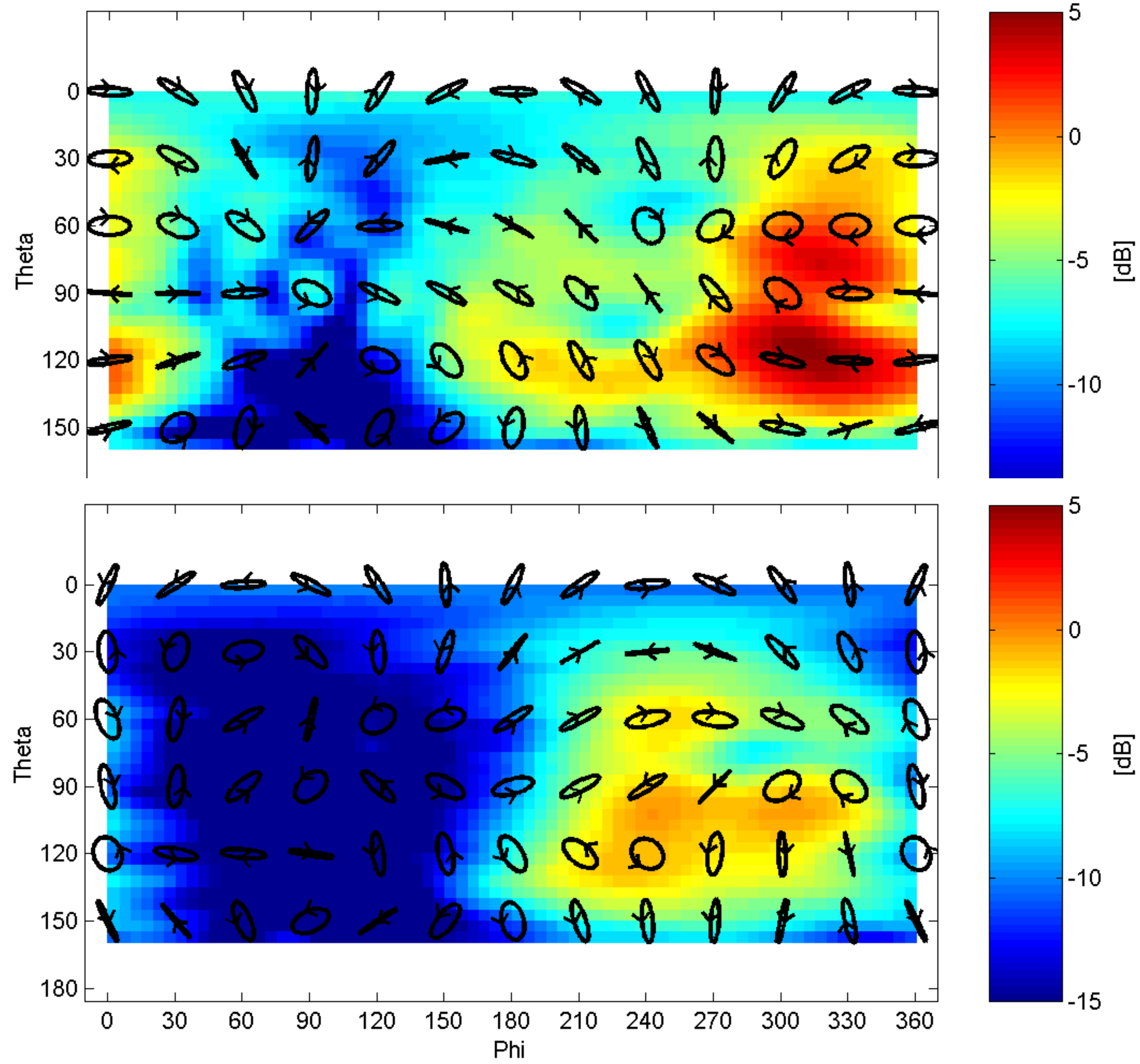
Effect of the head

Main

Diversity



Correlation

- A good diversity antenna gives low correlation between the signals from the main and diversity antennas
- Power imbalance and efficiency are also important
- A good isolation does not guarantee low correlation
- What does correlation depend on:
  - Antennas
  - User interaction
  - Radio environment
- Correlation estimation and measurement
  - Estimation of the correlation from radiation patterns and estimated distribution of power in the radio channel
  - Correlation can be measured in real radio environments
  - Simulations in e.g. reverberation chambers

Notation

- Complex radiation pattern (amplitude and phase): G_V and G_H
- Radiation pattern as a two-component column vector

$$G = \begin{pmatrix} G_V \\ G_H \end{pmatrix}$$

- Solid angle Ω as shorthand for θ and ϕ, $d\Omega = \sin\theta d\theta d\varphi$
- Incoming power distribution in the radio channel: P_V and P_H (complex)
- Correlation matrix for the radio channel:

$$C = \begin{pmatrix} E[P_V(\Omega_1)P_V(\Omega_2)^*] & E[P_V(\Omega_1)P_H(\Omega_2)^*] \\ E[P_H(\Omega_1)P_V(\Omega_2)^*] & E[P_H(\Omega_1)P_H(\Omega_2)^*] \end{pmatrix}$$

- Note: all correlation formulas are nonnormalized for simplicity

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A new correlation formula

- The standard formula assumes that the horizontal and vertical components of the radio channel are uncorrelated:

$$\rho = \int_{\Omega} \left[G_{1H} G_{2H}^{*} P_{H} + G_{1V} G_{2V}^{*} P_{V} \right] d\Omega$$

- New formula: correlation from radiation pattern vectors G1 and G2:

$$\rho = \iint G_1(\Omega_1)^H C(\Omega_1, \Omega_2) G_2(\Omega_2) d\Omega_1 d\Omega_2$$

- Previous expression by Vaughan and Bach Andersen

$$\rho = \iint trace[\Gamma(\Omega_1, \Omega_2) C(\Omega_1, \Omega_2)] d\Omega_1 d\Omega_2$$

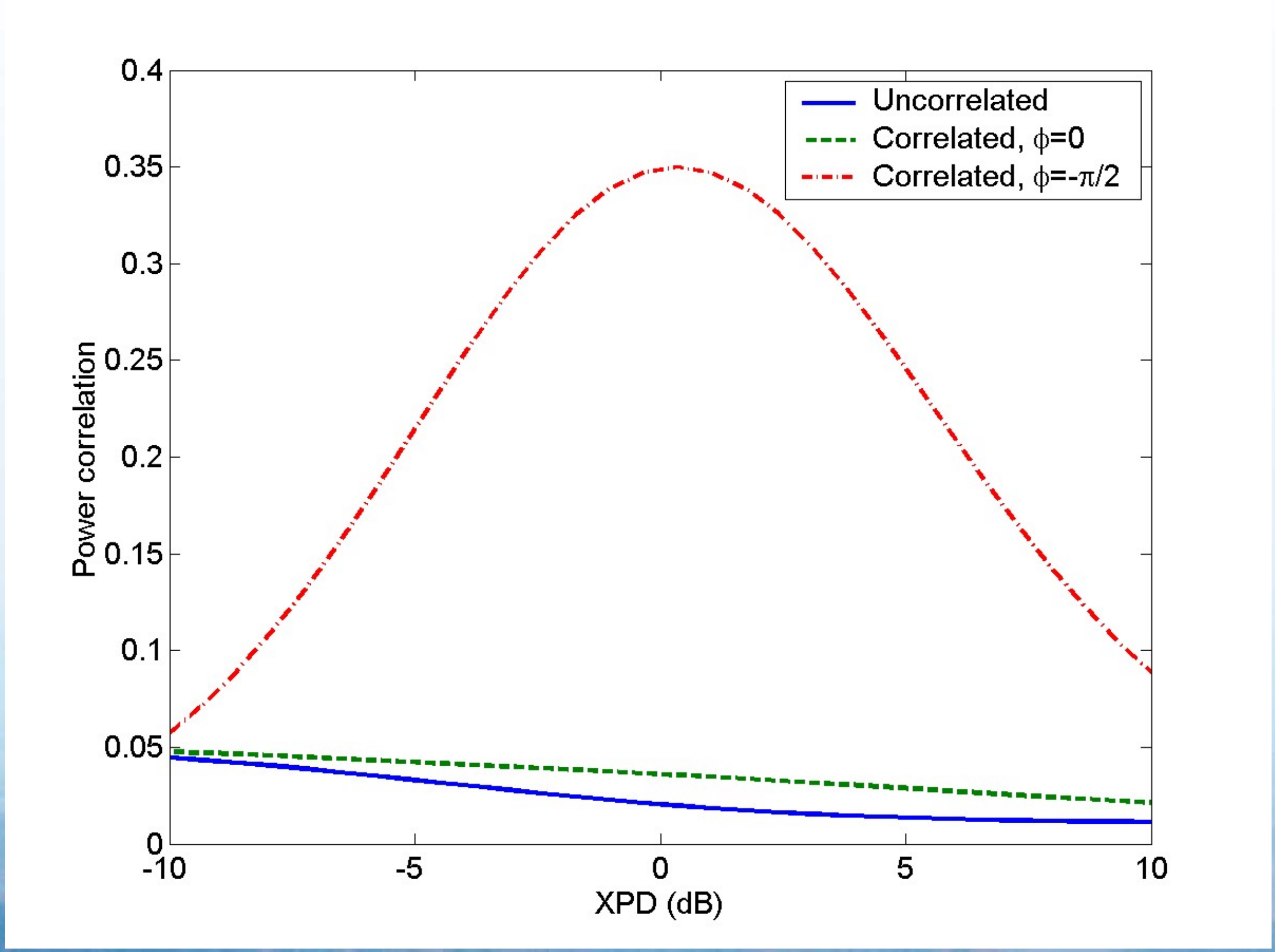
$$\Gamma(\Omega_1, \Omega_2) = G_2 G_1^H$$

- Correlation expression when different directions are uncorrelated

$$\rho = \int G_1(\Omega)^H C(\Omega, \Omega) G_2(\Omega) d\Omega$$

Effect of the correlation of the polarisations

- Uniform incoming power distribution
- XPD is the ratio of the vertical to horizontal power in the radio channel



Time averaging in the radio channel

- Long-term time average of the radio channel
  - Polarisations become uncorrelated in the radio channel
  - Direction of arrival is uniform in the azimuth direction and Gaussian-like in the elevation direction
  - Correlation is estimated as one value, does not show how the correlation varies in different radio environments
- Short-term average of the radio channel
  - Polarisations are correlated, especially for the case of slanted 45 degree base station antennas or circularly polarised antennas
  - Direction of arrival is nonuniform in both the azimuth and elevation directions
  - Correlation is obtained as a probability distribution

Conclusions

- Practical antennas combine polarisation and pattern diversity
- The polarisation state of a terminal is complicated
- Correlation depends on antennas, radio channel and user interaction
- Correlation can be estimated from antenna radiation patterns and a radio channel model
- A new formula for the correlation has been derived that takes into account the correlation between polarisations in the radio channel
- Good diversity antenna: low correlation + good efficiency