Near-Field MIMO
for Chip-to-Chip Communication

Antennas, Matching Networks
Information Capacity

Josef A. Nossek & Michel T. Ivrlač

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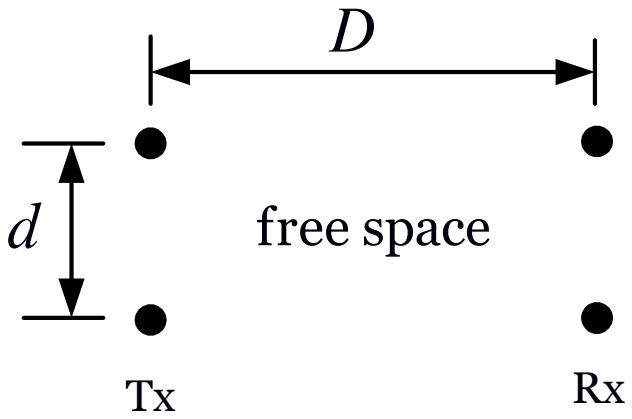
Technische Universität München
Institute for Circuit Theory and Signal Processing

Chip-to-Chip Communication

- Radio interconnects
- Multiple antennas at both ends of the link
- Array gain, multi-streaming, diversity and interference management
- Time-invariant propagation properties
- Interference from IC electronics and other radio interconnects
- Short-range communication, strong line-of-sight (LOS)
- Near-field MIMO looks promising

- Low signal attenuation
- Antenna scattering supplements/replaces multi-path propagation
- Supports multi-streaming even in compact LOS scenarios
- Perfect MIMO system possible with arbitrary geometric aspect ratio

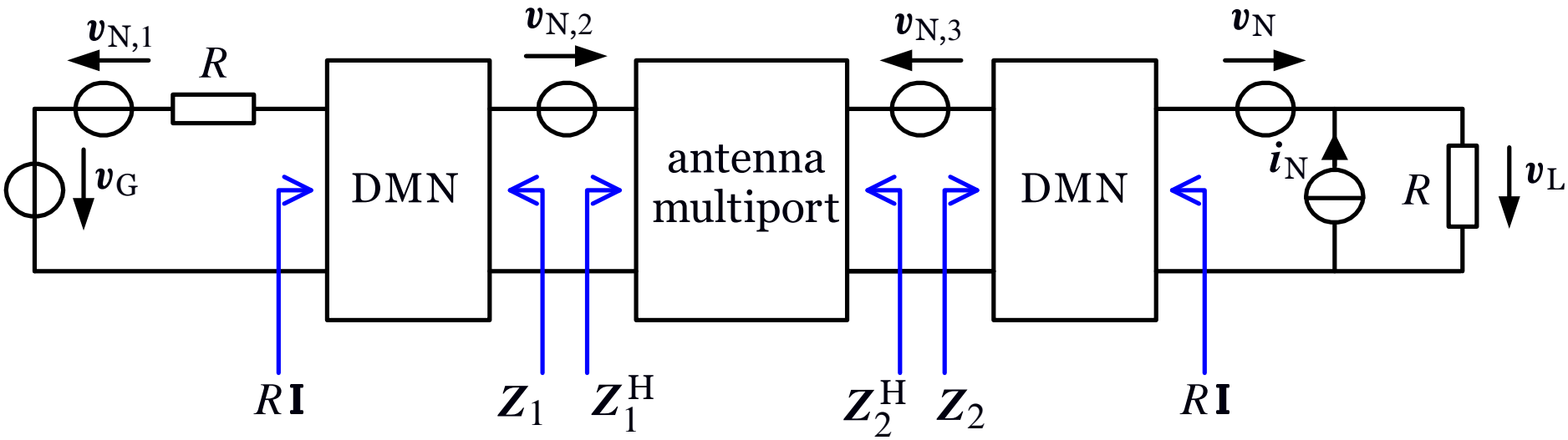


$\lambda/2$ dipoles

$\forall (d, D) : \exists \lambda$ such that 2 equally strong channels can be established.

For $D \geq d$, there is $D < \lambda/2$.

$\boldsymbol{v}_{\mathrm{N},1}$, $\boldsymbol{v}_{\mathrm{N},2}$, $\boldsymbol{v}_{\mathrm{N},3}$: thermal equilibrium noise

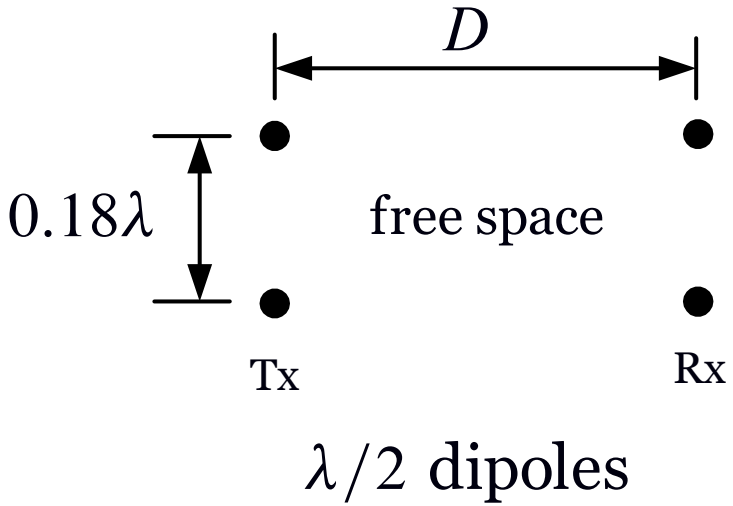


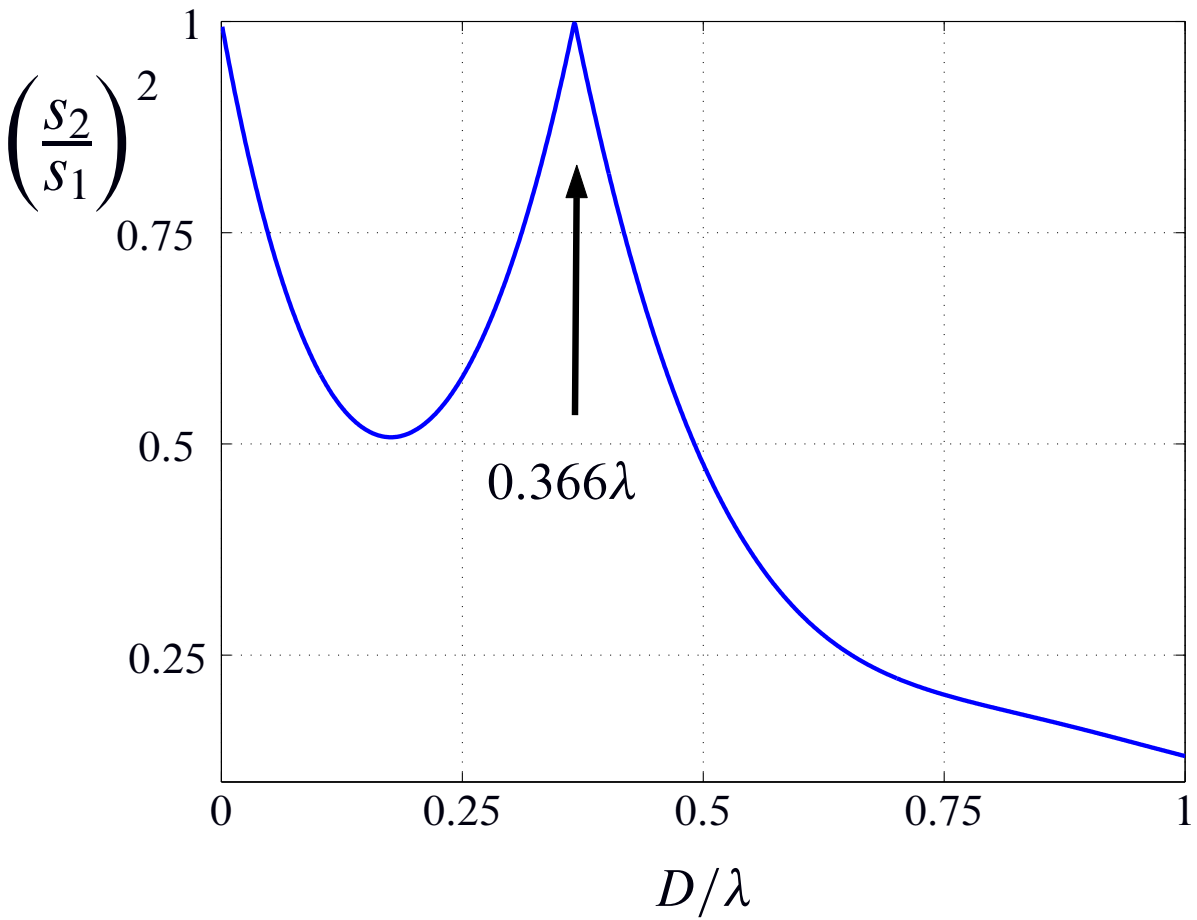
$$\boldsymbol{v}_{\mathrm{L}} = \boldsymbol{H}\boldsymbol{v}_{\mathrm{G}} + \boldsymbol{\vartheta}\,, \quad \boldsymbol{\vartheta} \sim \mathcal{CN}\left(\mathbf{0}, \sigma_{\vartheta}^2 \mathbf{I}\right), \quad P_{\mathrm{rad}} = \mathrm{E}\left[\|\boldsymbol{v}_{\mathrm{G}}\|_2^2\right]/4R$$

$$\boldsymbol{H} = \boldsymbol{U}\begin{bmatrix} s_1 & 0 \\ 0 & s_2 \end{bmatrix}\boldsymbol{V}^{\mathrm{H}}, \quad \boldsymbol{x} = \boldsymbol{V}^{\mathrm{H}}\boldsymbol{v}_{\mathrm{G}}, \quad \boldsymbol{y} = \boldsymbol{U}^{\mathrm{H}}\boldsymbol{v}_{\mathrm{L}}$$

$$y_i = s_i x_i + \eta_i\,, \quad \boldsymbol{\eta} \sim \mathcal{CN}\left(\mathbf{0}, \sigma_{\vartheta}^2 \mathbf{I}\right), \quad P_{\mathrm{rad}} = \mathrm{E}\left[\|\boldsymbol{x}\|_2^2\right]/4R$$

Near-Field MIMO Example





Example:

$d = 5\,\text{mm}$

$D = 10\,\text{mm}$

$f = 10.8\,\text{GHz}$

$a = 11\,\text{dB}$, 8% of P_{rad} is received

- Investigate more suitable antenna types (smaller, 2D, 3D?)
- Take realistic propagation environment into account
- Take interference from the environment into account
- Analyze broadband behavior
- Determine suitable frequency bands
- Design broadband decoupling and matching networks
- Obtain channel capacity