Wireless Communications Channels
Lecture 8: Channel Sounding

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Recap

- Requirements for channel sounding signal
- Channel sounding methods
- Typical three directional channel sounding methods

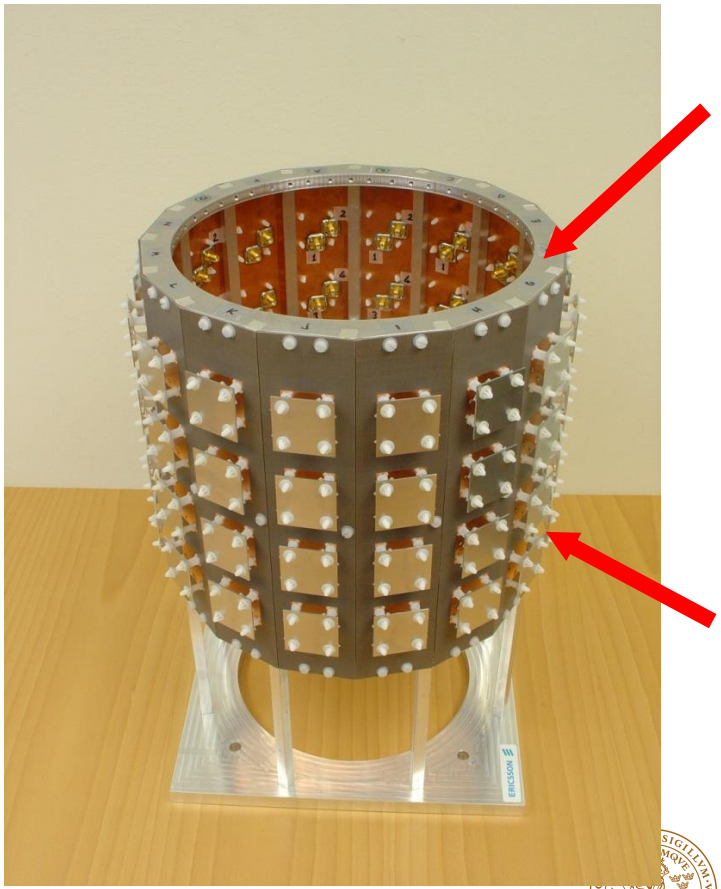
It’s all about measuring some delays…

In MIMO systems we use the fact that there are several paths between the transmitter and receiver

These paths are characterized by a

- time delay,
- phase shift,
- attenuation,
- angle of departure and
- angle of arrival

The angle of departure and angle of arrival result in a slight difference in time delay for each of the antenna elements



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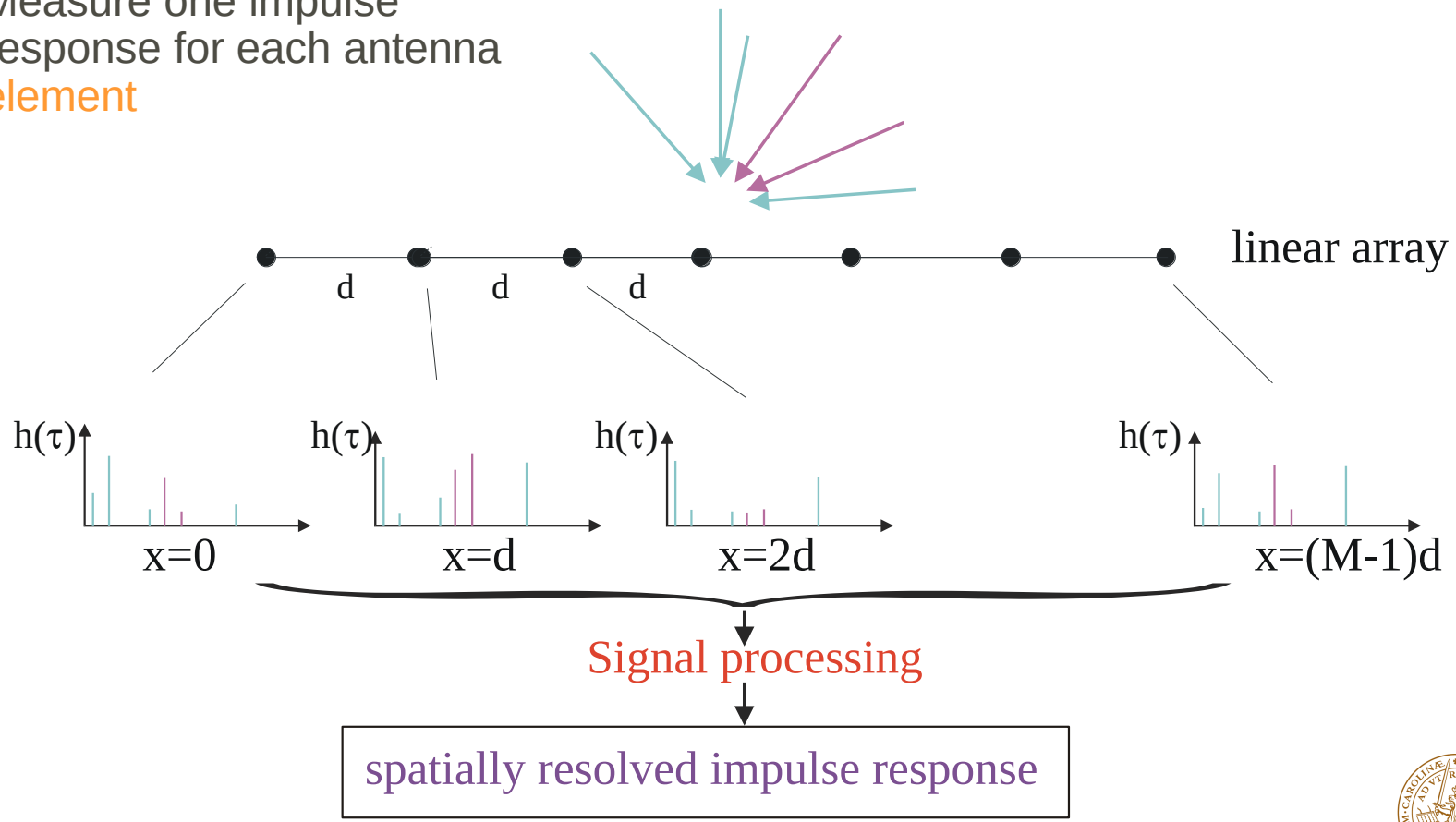
Channel sounding: Multielement array

- Measure one impulse response for each antenna element



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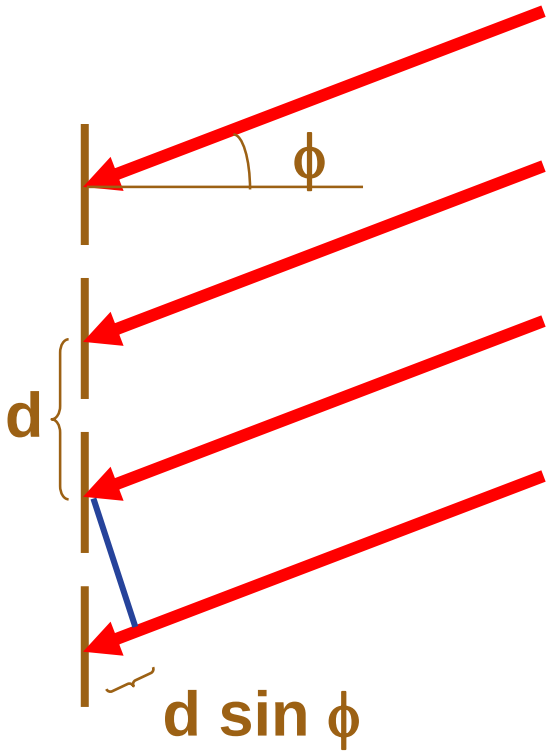
Directional analysis: DOA estimation



The DOA can also, e.g., be estimated by correlating the received signals with steering vectors.

$$\vec{a}(\phi) = \begin{pmatrix} 1 \\ \exp(-jk_0 d\cos(\phi)) \\ \exp(-j2k_0 d\cos(\phi)) \\ \vdots \\ \exp(-j(M-1)k_0 d\cos(\phi)) \end{pmatrix}$$

An element spacing of d=5.8 cm and an angle of arrival of ϕ =20 degrees gives a time delay of $6.6 \cdot 10^{-11}$ s between neighboring elements

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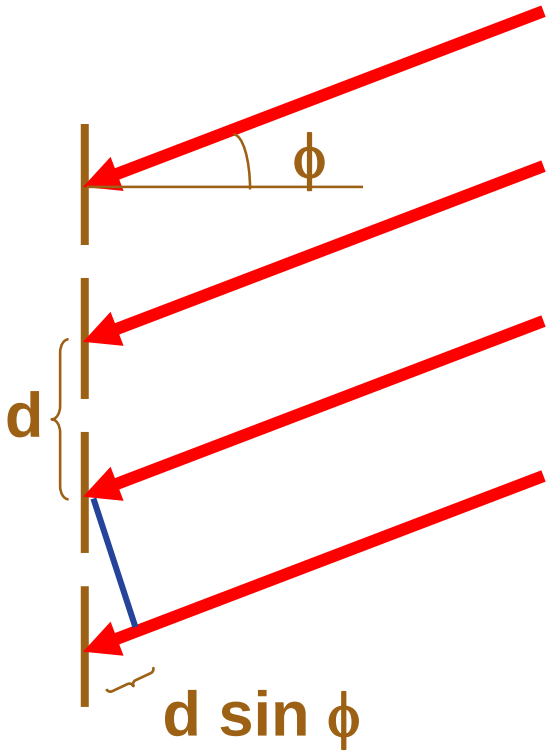
Directional analysis: DOA estimation



- Angular spectrum

$$P_{BF(\emptyset)} = \frac{a^{\dagger}(\emptyset) R_{rr} a(\emptyset)}{a^{\dagger}(\emptyset) a(\emptyset)}$$

R_{rr} is the correlation matrix of the received signal at the array

- Resolution is detemined by the the number of received antenna elements: $2\pi/N_r$
- So called beamforming

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High-resolution algorithms

In order to get better angular resolution, other techniques for estimating the angles are used, e.g.:

Separating useful signal subspace from the noise subsapce

- MUSIC: Multiple Signal Classification algorithm
- ESPRIT: Estimation of signal parameters via rotational invariance technique
- MVDR (Capon's beamformer): Minimum Variance Distortionless Response
- SAGE,
- ……

MUSIC

- Multiple Signal Classification algorithm
- Eigenvector decomposition and eigenvalues of the covariance matrix of the antenna array
- Subspace spectrum search

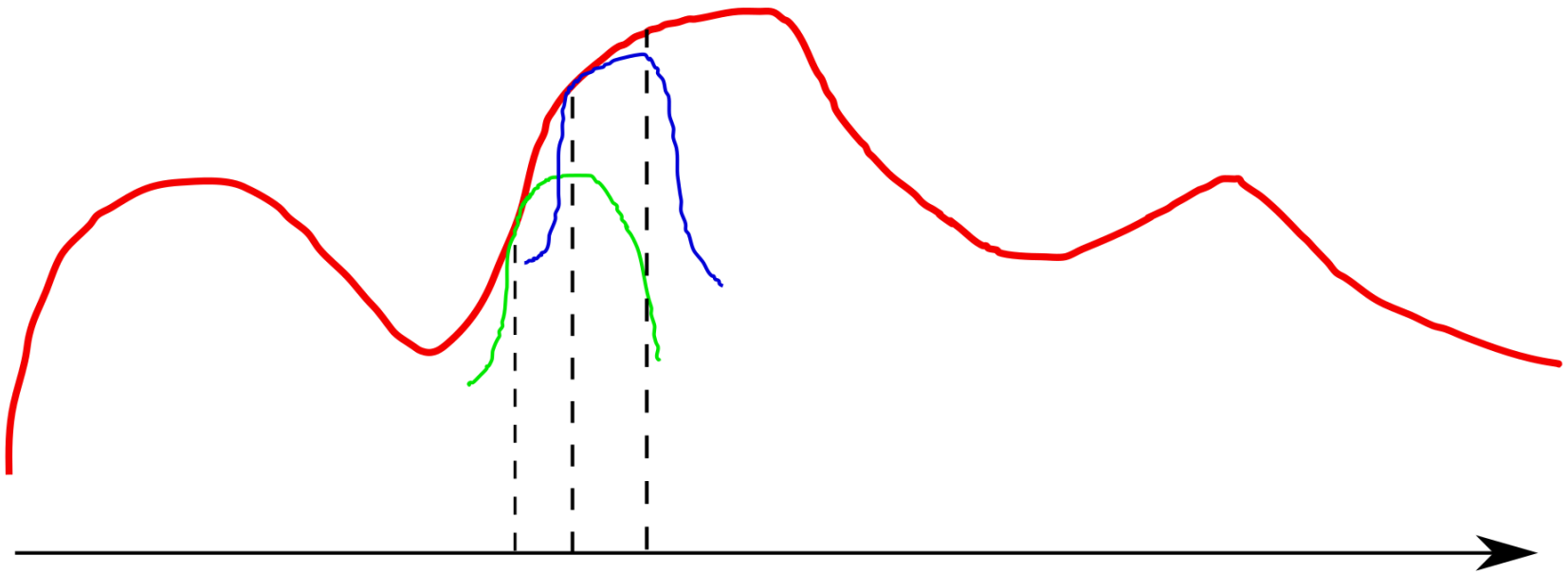
ESPIRIT

- The signal space is rotational invariant
- No need to search the whole pseudo-spectrum space
- Less sensitive to nise than MUSIC

MVDR

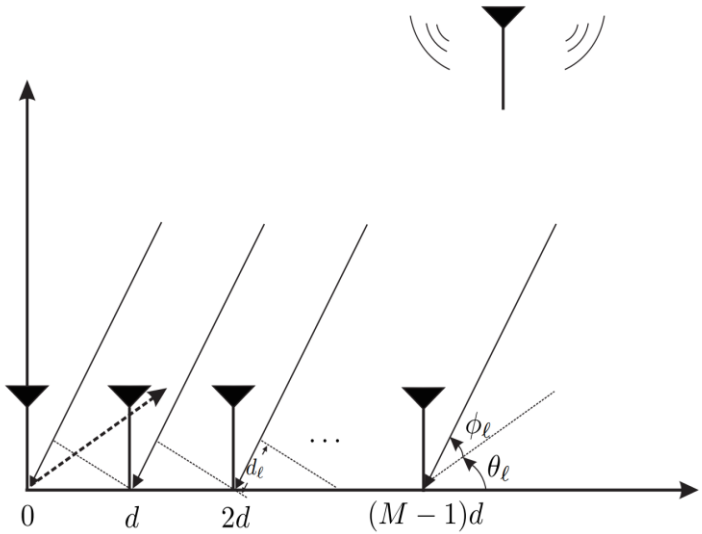
- Spatial filter coefficients (weights), determined by the correlation matrix and the steering vector
- Errors in array element position can degrade the performance

SAGE



iterative maximum likelihood method

SAGE



Everything is phase rotation, but caused by the change of propagation distance at different antennas

According to the array geometry and incident/departure angle, we have four steering vectors, for Tx array H V polarizations, and Rx array H V polarizations

$$\mathbf{a}_{\mathrm{TH}}(\theta_{\mathrm{T}},\phi_{\mathrm{T}}),\ \mathbf{a}_{\mathrm{TV}}(\theta_{\mathrm{T}},\phi_{\mathrm{T}}),\ \mathbf{a}_{\mathrm{RH}}(\theta_{\mathrm{R}},\phi_{\mathrm{R}}),\ \mathbf{a}_{\mathrm{RV}}(\theta_{\mathrm{R}},\phi_{\mathrm{R}})$$

$$\mathbf{X} = \left[\mathbf{a}_{\mathrm{TH}} \otimes \mathbf{a}_{\mathrm{RH}}, \mathbf{a}_{\mathrm{TH}} \otimes \mathbf{a}_{\mathrm{RV}}, \mathbf{a}_{\mathrm{TV}} \otimes \mathbf{a}_{\mathrm{RV}}, \mathbf{a}_{\mathrm{TV}} \otimes \mathbf{a}_{\mathrm{RV}}\right] \boldsymbol{\alpha} + \mathbf{Z}$$

where $\boldsymbol{\alpha} = \begin{bmatrix} \alpha_{\mathrm{HH}} \\ \alpha_{\mathrm{HV}} \\ \alpha_{\mathrm{VH}} \\ \alpha_{\mathrm{VV}} \end{bmatrix}$

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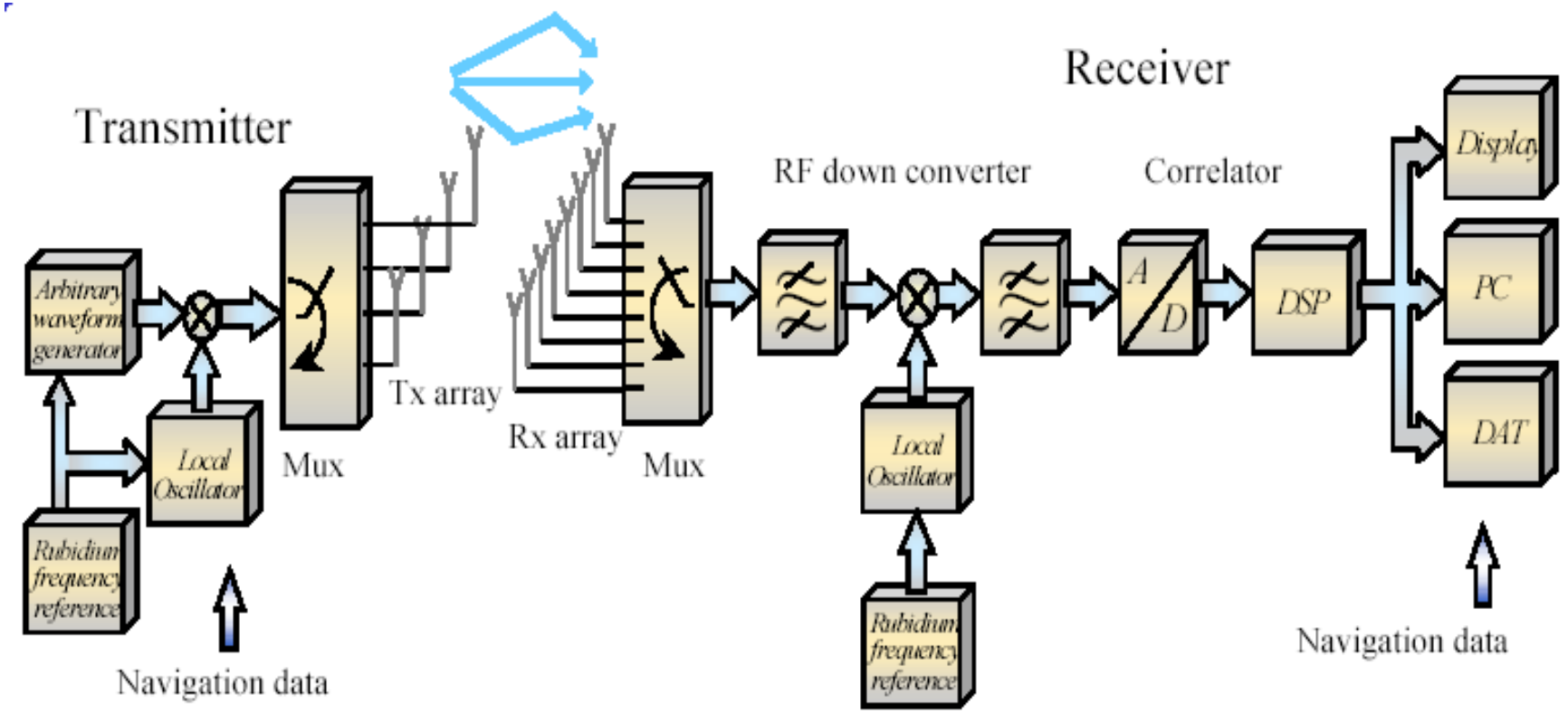
Lund University MIMO Sounder



Courtesy

MEDAV

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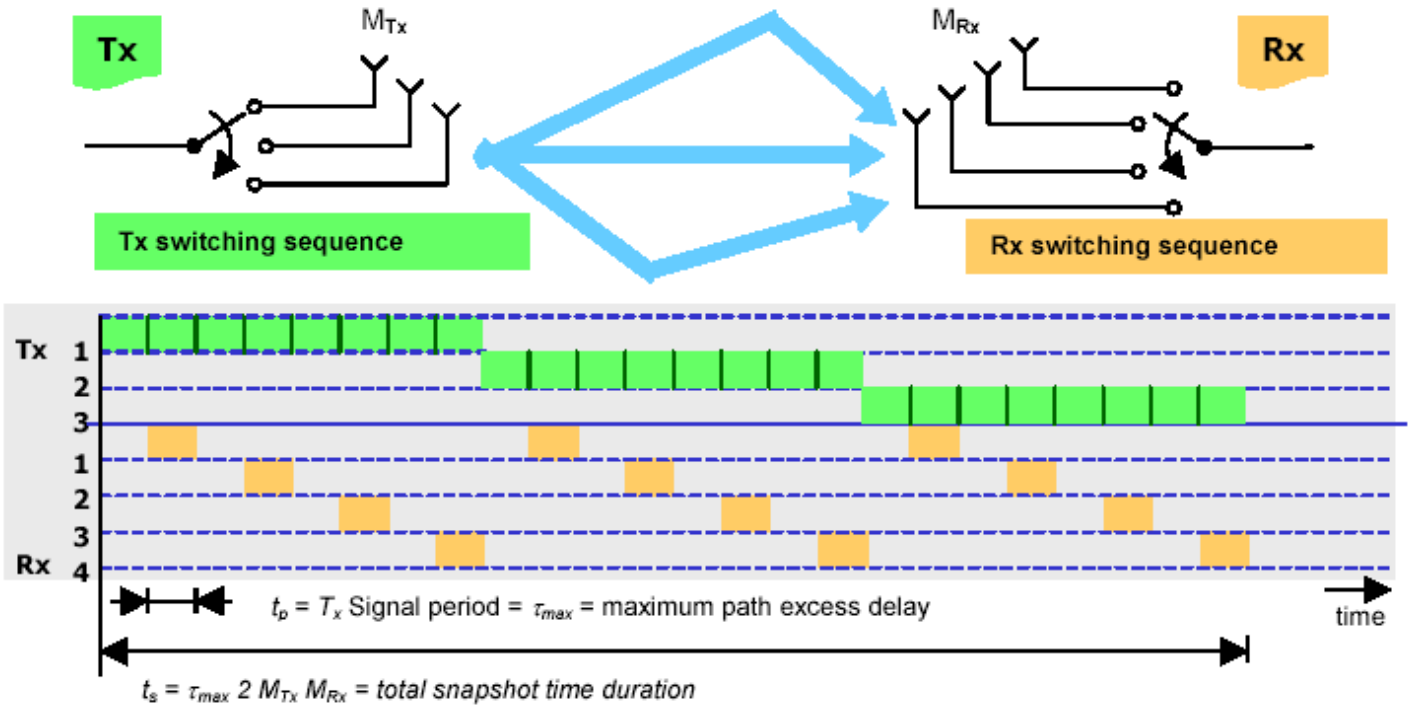
TX-RX timing diagram



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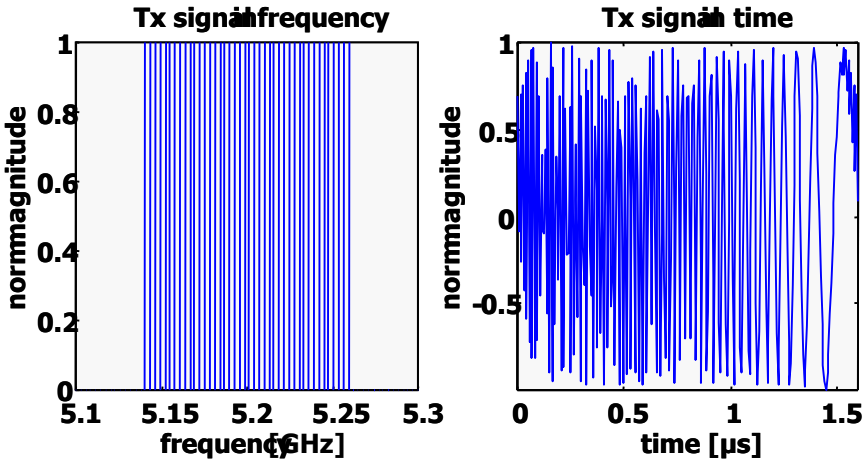
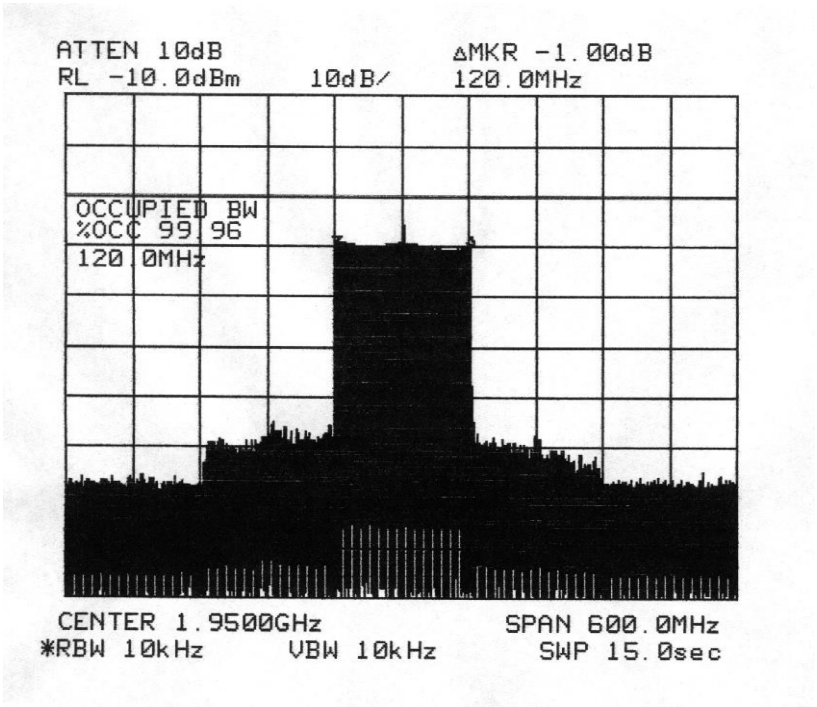
Test signal – Multicarrier spread spectrum





MLS - Test Squence

- periodic broadband Signal
- high Correlation Gain
- low Crest Factor
- inherently band limited
- flexible in generation
- multiband possibility (Up- /Downlink)

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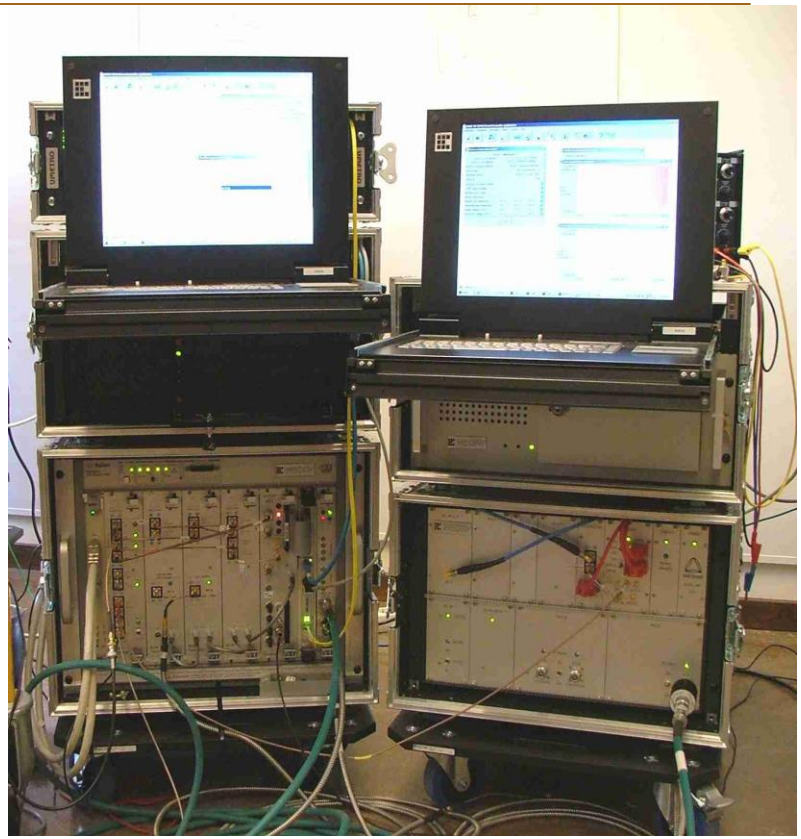
RUSK LUND broadband channel sounder

- A fast switched measurement system for radio propagation investigations at 300 MHz, 2 GHz and 5 GHz.
- Financed by Knut and Alice Wallenbergs stiftelse, FOI and LTH
- MIMO capacity limited by the switches, currently 32 elements at each side.



The measurement system

- 200 kg of batteries to allow for 6 hours of mobile measurements
- 640 MHz sampling frequency, to allow high Doppler frequencies
- 2 separate PCs to manage the data flow from the A/D converters
- Oven controlled rubidium clocks to maintain synchronization during wireless measurements
- GPS and wheel sensors to position the system
- Broadband patch antennas with 128 antenna ports at 2.6 GHz
- Circular 300 MHz antennas with a diameter of 1.5 m

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Lund SDR-based mm-Wave Channel Sounder

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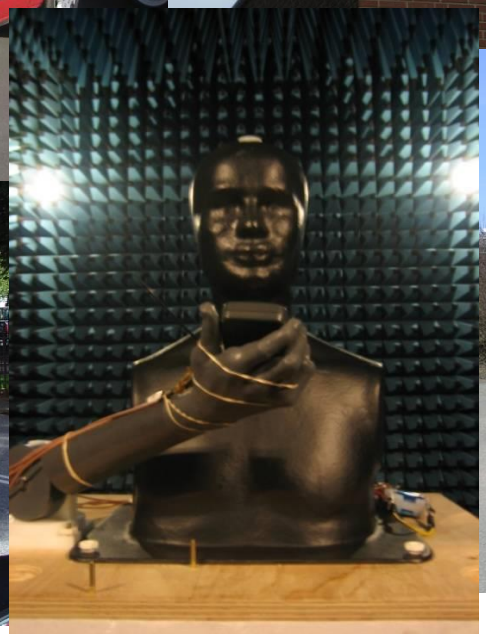
Lund SDR-based mm-Wave Channel Sounder

- Selectable channel bandwidth 1GHz, 2GHz
- Scheduler support for TX/RX control
- Non-squential switching over antenna pairs
- 256X128 MIMO channel sounder, smaller size of MIMO is configable
- High resolution in angular and delay domain
- CIR averaging for improved SNR
- CIR is stored for further post processing
- User friendly reconfigable system

Some real world examples



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How important are antennas?

To get good resolution we want large size arrays

4x16 dual polarized circular patch array

4x8 dual polarized rectangular array

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