UNIVERSITÄT BREMEN

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MIMO Measurements of Communication Signals and Application of Blind Source Separation

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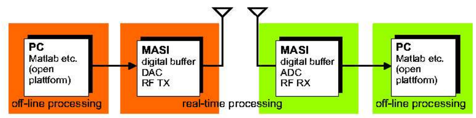
MIMO Measurement Setup

- MASI Multi Antenna System for ISM-band Transmission

- realistic testing of algorithms
- real transmission with all hardware impairments



- transmission frequency: 2.4 GHz ISM-band (5MHz channel stepsize / 8 frequencies possible)
- transmission power: +17 dBm (50 mW)
- direct conversion transmitter and receiver (AD 8346/8347)
- 12 bit D/A converter (AD 9765)
- 12 bit A/D converter (AD 9432)
- sampling frequencies: 10 MHz, 40 MHz, 50 MHz, PLL and external input
- maximum memory depth 512k (Tx) resp. 1024k (Rx) I/Q-samples

- interfacing to most common simulation tools by simple file format

Frequency Responses of the MIMO Channel

- fast measurement scheme for varying channels
- usage of a chirp-like signal $m(k)$ designed in frequency domain
- optimization of the crest factor (maximum amplitude/RMS) => quadratic phase increment
- cycling repetition of the signal

$$M(n) = e^{-j\frac{\pi}{N_{\mathrm{DFT}}}n^2}$$

$$m(k) = \mathrm{IDFT}_{N_{\mathrm{DFT}}}\{M(n)\}$$

- multiplexing scheme to measure all TX/RX combinations
- no wired connection between transmitter and receiver necessary
- only coarse synchronization necessary to receive signal $r(k)$

$$R(n) = \mathrm{DFT}_{N_{\mathrm{DFT}}}\{r(k+k_{\mathrm{offset}})\}$$

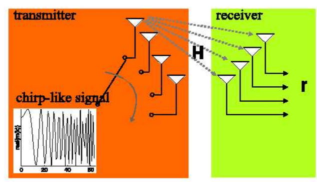
- measurement of magnitude and phase possible (up to a linear phase uncertainty <=> circular time shift)
- averaging not mandatory, because $M(n)$ is exactly flat

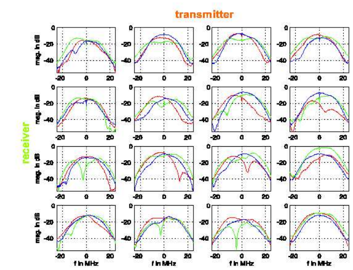
$$H(n) = \frac{R(n)}{M(n)}$$

- consequence of a time shift by k_{shift} (coarse synchonization)

$$H_{\mathrm{shift}}(n) = \frac{\mathrm{DFT}_{N_{\mathrm{DFT}}}\{r(k+k_{\mathrm{offset}}+k_{\mathrm{shift}})\}}{M(n)} = H(n)e^{j\frac{2\pi}{N_{\mathrm{DFT}}}nk_{\mathrm{shift}}}$$

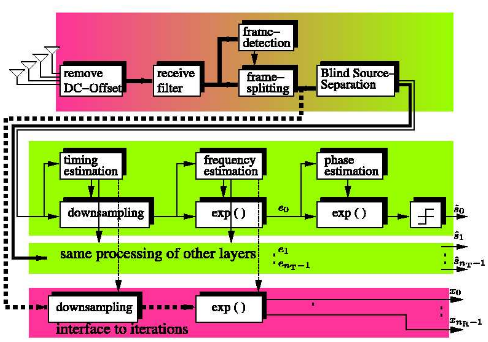
- 4 transmit and 4 receive antennas
- λ/2 ULA
- 3 measurements of digital to digital channel (not channel sounding)
- $N_{\mathrm{DFT}} = 128$
- sampling frequency $f_s = 50$ MHz
- distance transmitter <=> receiver: 5m





- small shift of receiver between measurements
- about ±16MHz bandwidth (filter limits in hardware)

Blind Source Separation (BSS) Setup for Communication Applications



motivations for iterative processing:

- BSS-only approach designs a linear spatial filter with very low signal knowledge => bad performance, because finite alphabeth is not used

- VBLAST: powerful detection algorithm for MIMO-diversity transmissions
- successive interference cancellation

- turbo principle: iteration between data decisions and channel estimations

- free running turbo/decision loop (overall algorithm remains blind)

- problem? After applying BSS and decising symbols, we get separated signals that are permuted $\mathbf{P}$ and rotated $\mathbf{\Phi}$. $\hat{\mathbf{S}} = \mathbf{\Phi}\mathbf{P}\mathbf{S}$

- What is the estimation result when applying rotated and permuted symbols for channel estimation?

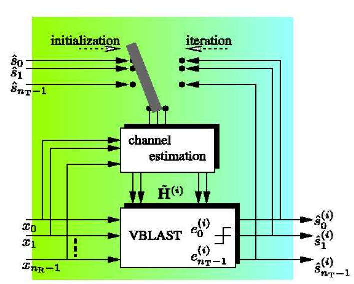
- Assumption: transmission model without noise $\mathbf{X} = \mathbf{H}\mathbf{S}$

motivations for BSS in communication applications:

- usage of SISO algorithms for timing, frequency and phase estimation possible
- synchronization / frequency estimation after the separation
- arbitrary communication signals can be mixed together

we use:

- spatial-only processing - JADE
- 8 times oversampling (no interpolation necessary)
- parallel transmission of signals
- different signals to illustrate the feasibility of the set-up
- distance transmitter <=> receiver: 5m



$$\tilde{\mathbf{H}} = \mathbf{X}\cdot\hat{\mathbf{S}}^{+} = \mathbf{X}\cdot\hat{\mathbf{S}}^{\mathrm{H}}\left(\hat{\mathbf{S}}\cdot\hat{\mathbf{S}}^{\mathrm{H}}\right)^{-1} \quad \text{estimation with pseudo inverse}$$

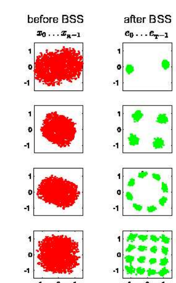
$$\tilde{\mathbf{H}} = \mathbf{H}\underbrace{\mathbf{S}\cdot\mathbf{S}^{\mathrm{H}}}_{\approx\sigma_s^2\mathbf{I}}\mathbf{P}^{\mathrm{H}}\mathbf{\Phi}^{\mathrm{H}}\left(\mathbf{\Phi}\mathbf{P}\underbrace{\mathbf{S}\cdot\mathbf{S}^{\mathrm{H}}}_{\approx\sigma_s^2\mathbf{I}}\mathbf{P}^{\mathrm{H}}\mathbf{\Phi}^{\mathrm{H}}\right)^{-1} \quad \text{uncorrelated signals}$$

$$= \mathbf{H}\mathbf{P}^{\mathrm{H}}\mathbf{\Phi}^{\mathrm{H}}\left(\mathbf{\Phi}\underbrace{\mathbf{P}\mathbf{P}^{\mathrm{H}}}_{=\mathbf{I}}\mathbf{\Phi}^{\mathrm{H}}\right)^{-1}$$

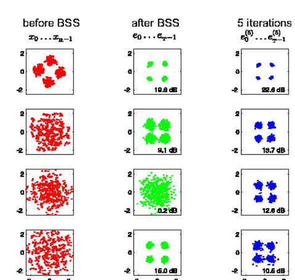
$$= \mathbf{H}\mathbf{P}^{\mathrm{H}}\mathbf{\Phi}^{\mathrm{H}}\left(\underbrace{\mathbf{\Phi}\mathbf{\Phi}^{\mathrm{H}}}_{=\mathbf{I}}\right)^{-1}$$

$$\tilde{\mathbf{H}} = \mathbf{H}\mathbf{P}^{\mathrm{H}}\mathbf{\Phi}^{\mathrm{H}} \quad \text{permuted and rotated channel matrix}$$

- 4 transmit and 4 receive antennas
- separation of BPSK, QPSK, 8PSK and 16QAM



- 4 transmit and 4 receive antennas
- QPSK modulation



- overall gain by iterative process
- 10dB gain at 10^{-3} by iterations shown in simulations: J.Rinas and K.D. Kammeyer: "Comparison of Blind Source Separation Methods based on Iterative algorithms", in *5th International Conference on Source and Channel Coding*, Erlangen, Germany, January 2004, accepted