A Hardware Demonstrator for MIMO-Communication Systems: Application to Blind Source Separation

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MIMO-Transmitter
- transmission frequency 2.4 GHz ISM-band
- transmission power +17 dBm (50 mW)
- direct conversion transmitter and receiver (AD 8346/8347)
- analog IQ-balanced: 16 MHz (depending on receiver filters)
- 12 bit A/D converter (AD 9761)
- 12 bit A/D converter (AD 9432)
- sampling frequency: 10 MHz, 40 MHz, 50 MHz, PLL and external input
- maximum memory depth 512k (Fs) resp. 1024k (Rs) IQ-samples
- PC-connection (data and control) using the USB interface
- external connectors for the 2.4 GHz carrier frequency and (10MHz) reference frequency
- control software for data transfers and settings (used memory depth, sampling frequency, automation of multiple measurements)
- binary file for each channel alternating Q-sample as 16 bit integer
- easy interfacing with Matlab or other tools

Real-time Transmission <-> Off-line Processing

Frequency Responses of the MIMO channel
- fast measurement scheme for varying channels
- range of a chirp-like signal \( a(x) \) designed in frequency domain
- estimation of the crest factor (maximum amplitude/EMI)
- quadratic phase term
- cyclic repetition of the signal \( a(x) \)
- multiplexing scheme: access all Tx/Rx combinations
- no wired connection between transmitter and receiver necessary
- only coarse synchronization necessary to receive signal \( x(t) \)
- measurement of magnitude and phase possible
- (up to a linear phase uncertainty \( \Rightarrow \) circular time shift)
- averaging not mandatory, because \( a(x) \) is exactly flat

Where:
\[
M(x) = \frac{1}{N} \sum_{k=0}^{N-1} \text{IDFT}_{\text{tap}} \{ i \} \\
\text{IDFT}_{\text{tap}} \{ i \} = DFT_{\text{tap}} \{ \text{IDFT}_{\text{tap}} \} \\
R_x(n) = DFT_{\text{tap}} \{ \text{IDFT}_{\text{tap}} \} \\
H(n) = \frac{R_x(n)}{M(n)}
\]

MIMO-Receiver
- 4 transmit and 4 receive antennas
- 3 measurements of spatially and temporally uncorrelated
- (not channel sounding)
- spatial-only processing (JADE)
- 8 times oversampling (no interpolation necessary)
- parallel sending of signals
- different signals to illustrate the feasibility of the set-up

Blind Source Separation (BSS) Set-Up for Communication Applications
- Motivation: range of SS algorithms for timing, frequency and phase estimation possible
- synchronization / frequency estimation after the separation, arbitrary communication signals can be mixed together
- spatial-only processing - JADE
- 8 times oversampling (no interpolation necessary)
- parallel sending of signals
- different signals to illustrate the feasibility of the set-up

QPSK at 1PSK position

Blind Initialization of an Iterative Detection Scheme
- Motivation:
  - SS-only approach designs a linear spatial filter with very low signal knowledge
  - \( \Rightarrow \) bad performance, because finite alphabet is not used
  - VB-LAST: 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)

- simulation - symbol rate
- 4 transmit and 4 receive antennas
- 500 symbols
- QPSK modulation
- nearly reaching VB-LAST performance with known channel matrix
- about 10dB gain at \( 10^{-3} \) compared to the SS-only approach

\( \Rightarrow \) utilization of the finite symbol alphabet is mandatory for communication applications!