# An SDR testbed using USRP2 for demonstration of MIMO and other wireless techniques

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## Outline

- Platform
- Different projects
  - DSA
  - Positioning
  - MIMO
- MIMO Implementation
- Conclusion



## **Target Platform**

- GNU Radio
  - Free software toolkit for software radio development
  - Over 100 signal processing block available
  - Signal processing implemented in C++
  - Flow graph glued together with Python
- USRP2
  - Sample clock: 100 MHz
  - Gigabit Ethernet interface
  - Theoretical maximum bandwidth: 25 MHz
  - Cost approx.: \$2000





## **Dynamic Spectrum Access**

- Testbed to show DSA with OFDM
- System with one reciever and one transmitter
- Spectrum sensing using amplitude probability disitribution (APD) detector
- OFDM implementation
  - extending the GNU Radio implementation
  - selected subcarriers are used
  - preamble will not use occupied frequencies
- Experiences
  - Clock stability
  - External reference clock



## Indoor Positioning

- Radio positioning
- Heavy multipath propagation
- Testbed for algorithm evaluation
- Signal generator as transmitter
- Data collection from USRP2-setup
- Experiences
  - Timestamp synchronization
  - Shielding of hardware
  - Phase offset

Andreas Wernrud, Anders Johansson, Jouni Rantakokko, Patrik Eliardsson and Ulrika Uppman "Soldier and first responder RF-positioning in indoor environments" 13th International Association of Institutes of Navigation World Congress and Exhibition, 2009





### **Timestamp Synchronization**

- Synchronous reset of the DDC pipelines
- PPS triggered



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## MIMO Testbed

- Background and Motivation
- Hardware System Description
- Implementation Details
- Graphical User Interface

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"An SDR implementation of a MIMO Communication Testbed"

7th Karlsruhe Workshop on Software Radios, WSR'12, Karlsruhe 2012



## MIMO-technique

- MIMO-techniques can:
  - Increase bandwidth of a radio link
  - Increase robustness of a radio link
- MIMO in VHF-band
  - Small bandwidth
  - Spatial multiplexing vs. spatial diversity
- Demonstration of the benefits with MIMOtechniques in VHF-band.



### **Testbed Overview**

- 2 x 2 MIMO
- The receiver
  - Quad core 2.66 GHz, 12 GB RAM
- The transmitter
  - Dual core 3.06 GHz, 4 GB RAM
- USRP2-units are synchronized with an external time reference.





### Software development

- GNU Radio 3.4.0
- Starting point, available OFDM-example
- Extended with source coding, available gr-trellis
- Added Alamouti MIMO blocks, spatial diversity
- Minor modifications to the existing blocks



## Signal processing

Transmitter



Receiver





## **Graphical User Interface**

- 3 Different views
- Demonstration view
  - Show received data
  - Enlighten the difference between MIMO and SISO
- Technical view
  - Probes in signal processing
  - Frequency spectrum, constellation plots
- Control view
  - Control the USRP2-settings
  - IP-address, gain, center frequency etc.



### **Demo View**





## **Control View**

Benchmark GUI Notebook File	000
Demo view Technical view Control view	
Normal settings:	Expert settings:
Transmission mode: 💿 Image 🔿 File 🔿 Benchmark 🔿 BER	512 - Number of FFT bins
1000000.0 - Number of pixels to transmit	200 - Number of occupied FFT bins
- File containing input data	128 - Number of bits in the cyclic prefix
- File to be written with output data in mimo mode	Log all parts of flow graph to files (CAUTION: lots of data)
- File to be written with output data in siso mode	
401.0 - Packet size in bytes (incl 8 byte head CRC32)	USRP settings:
3125000.0 - Sample rate in Sps (in throttle or USRP)	192.168.20.2 - USRP address, first unit
- Enable discontinous transmission, burst of N packets [Default: continuous]	192.168.30.2 - USRP address, second unit
0.2 - Transmitter digital amplitude (0 <= AMPL < 1)	28500000.0 - USRP center frequency
qpsk - Modulation type (bpsk or qpsk)	4.0 - USRP rx gain in dB (0 <= GAIN < 31.5)
MIMO SISO	1.0 - USRP tx gain in dB (0 <= GAIN < 25.0)
Write all received packets (not only those that are ok)	
□ Verbose	Channel settings:
20 - Nr of received packets to make packet error rate average over	30.0 - SNR of the channel in dB
1/3 Code rate	0.0 - Frequency offset introduced by channel
Start (activates settings) Stop	1.0 - Clock rate ratio (sample rate difference) between two systems
Activate Settings Go back to default settings!	<ul> <li>Turn channel (AWGN, freq offset) off</li> <li>Enable multipath</li> </ul>
Status: off BER: PER:	N Pkt rcvd:



## **Technical View**





#### Measurements

- Indoor
- BER
- Higher BER than expected
- MIMO better than the reference SISO implementation





## Conclusion

- USRP2 and GNU Radio platform
- Used in several projects
  - DSA
  - Positioning
  - MIMO
- Will most likely be used in future projects
- Demonstration of the MIMO testbed here today!



#### Thank You! QUESTIONS?

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