Implementation and Experimental Results of Superposition Coding on Software Radio

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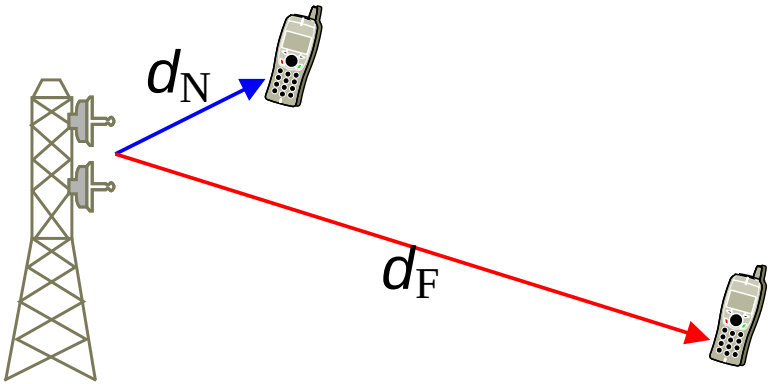
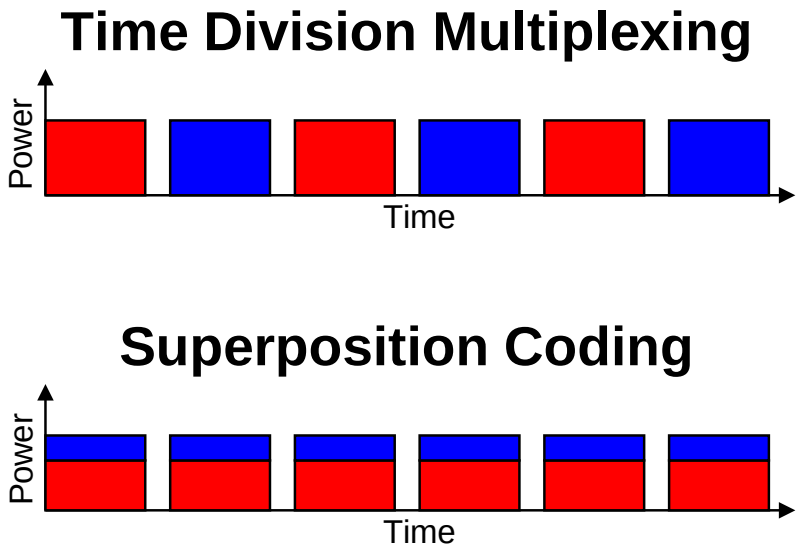
May 26, 2010

What is Superposition Coding?





- BS sends information to *two* users N (near) and F (far)
  $\leftrightarrow$ Communicating over a **Broadcast Channel** (BC)
- BS has full CSI: *Gaussian* BC [Cover72]
- BS has no CSI: *Fading* BC [Li01, Zhang09]
- Capacity achieved by **Superposition Coding** (SC) and **Successive Decoding** (SD)

Prior Work and Contributions

Prior Work

- Single-User MIMO-OFDM implementation [Mandke07, Li08]
- Signal Superposition on GNURadio [Li09]: No hardware

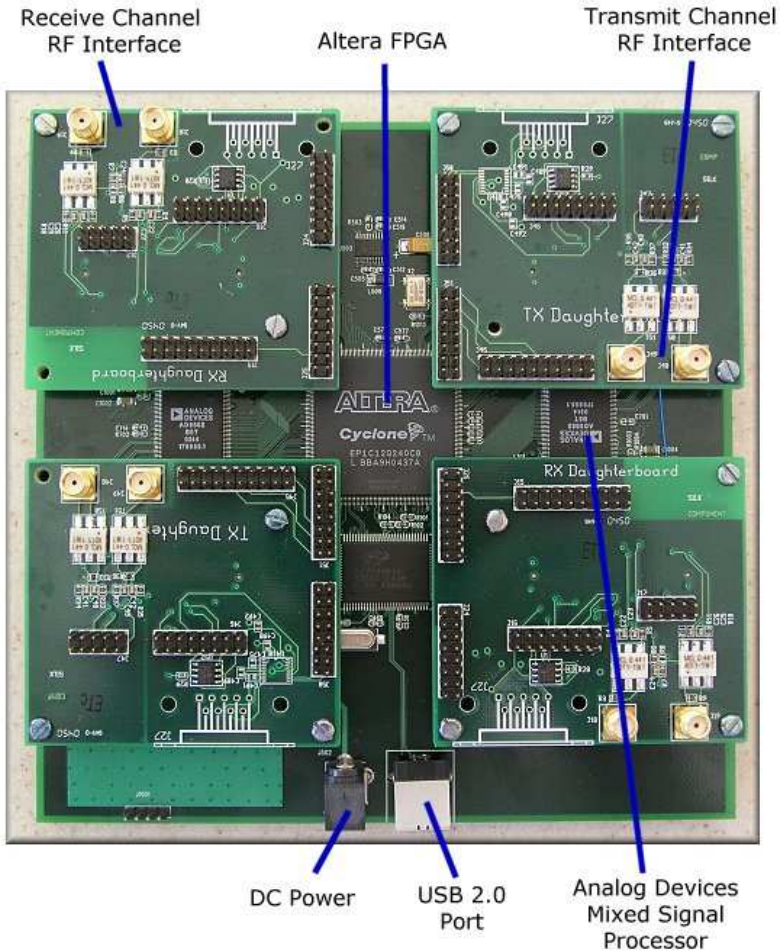
Our Contributions

1. First **Multi-user** OFDM PHY implementation using SC on the GNURadio/USRP platform
2. Packet Error Rate (PER) evaluation with USRP in loop

From Theory to Practice

	Complexity	Decoding Delay	Optimal?
Full SC	High	Large	**Yes**
	(Gaussian signalling)	(Long blocklength)	
Practical SC	Low	Design-dependent	**No**
	(Finite constellation)	(Adjustable)	

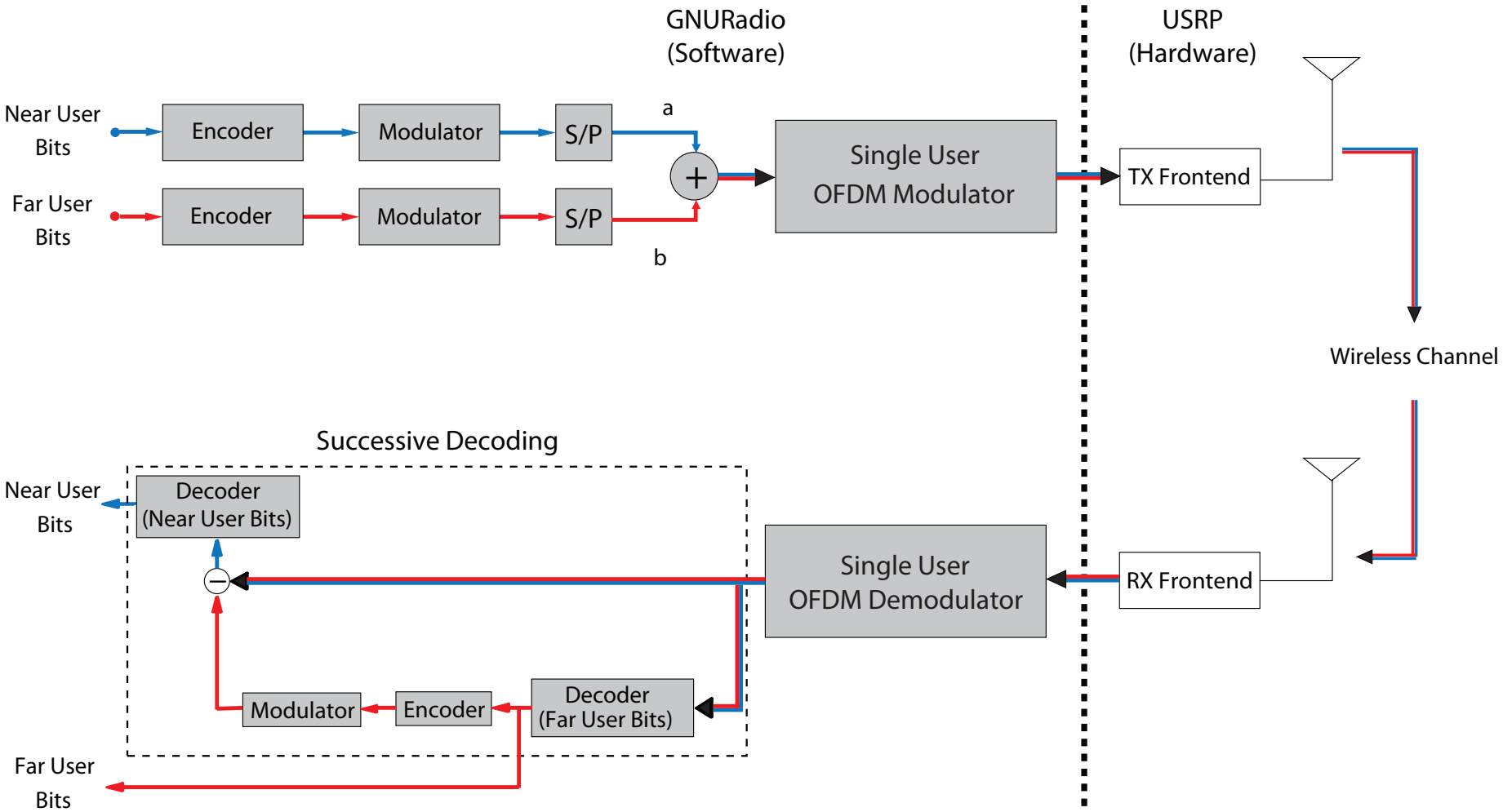
Implementation for Real-Time Processing



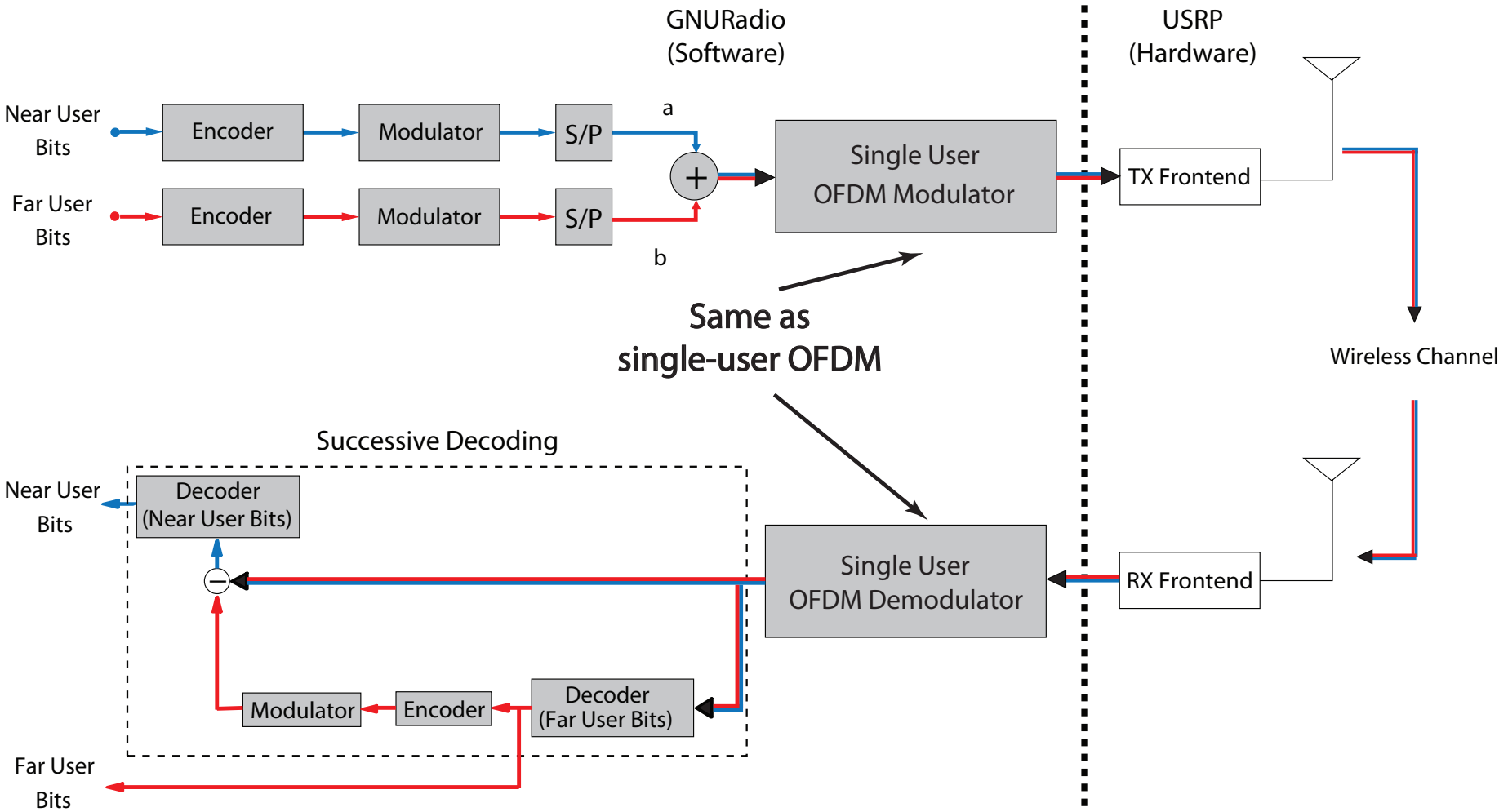
Close-up of USRP Board

- Hardware: USRP 1 (Analog and RF front-end)
  - Programmable Channelization
  - USB 2.0 Interface
- Software: GNU Radio (ver. 10923) & its built-in libraries
  - Open-Source
  - Real-time Signal Processing on a GPP

Top-level Block Diagram

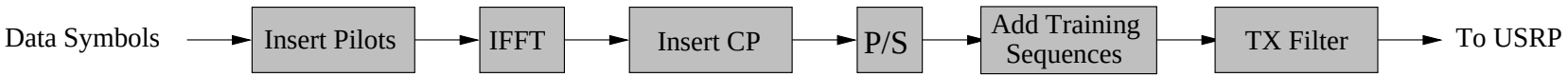


Top-level Block Diagram

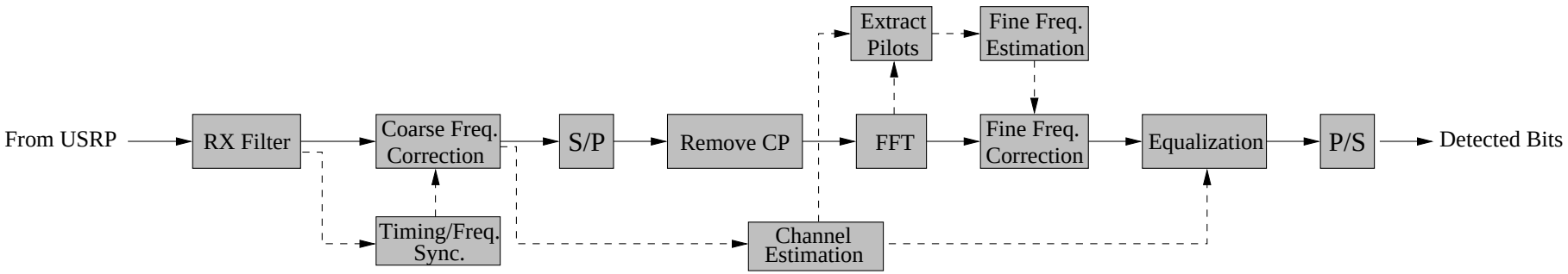


Single-User OFDM Blocks

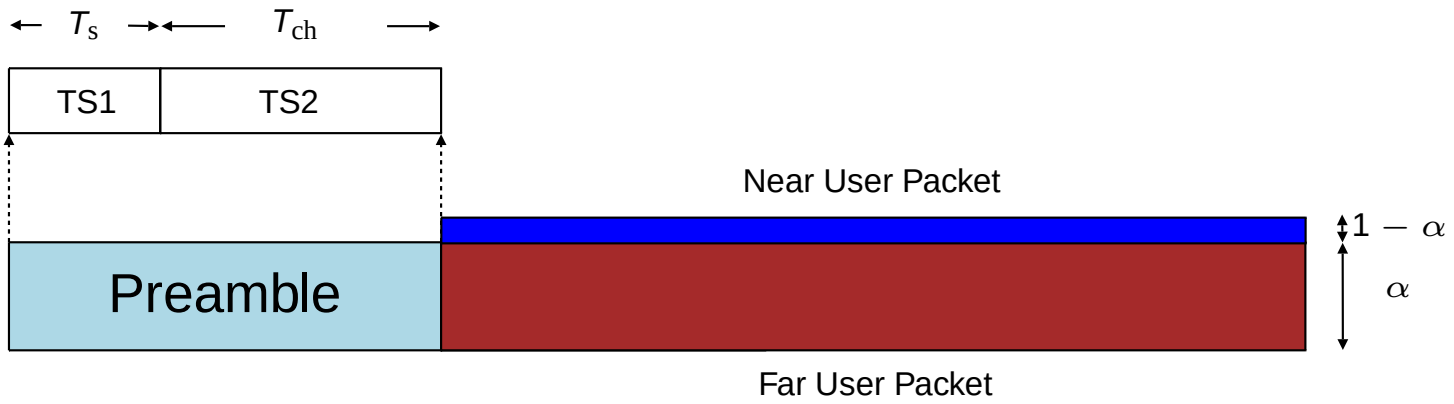
Modulator



Demodulator

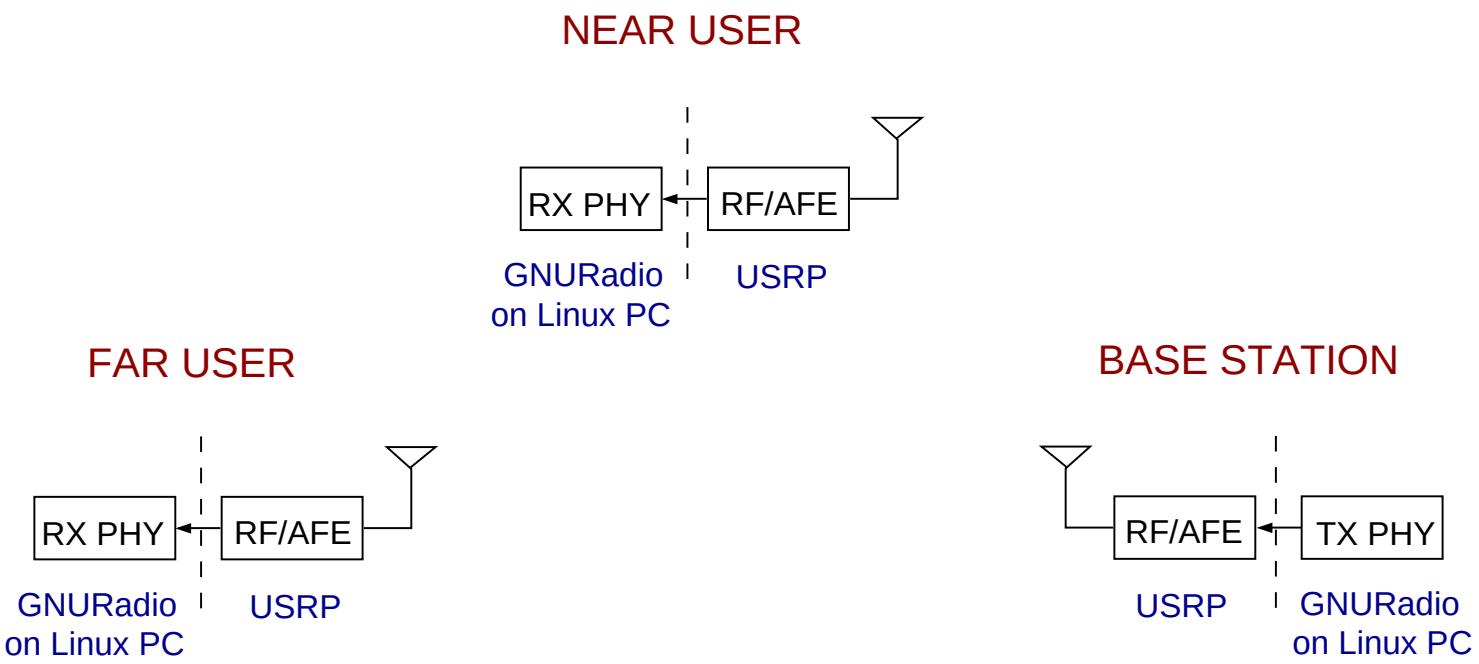


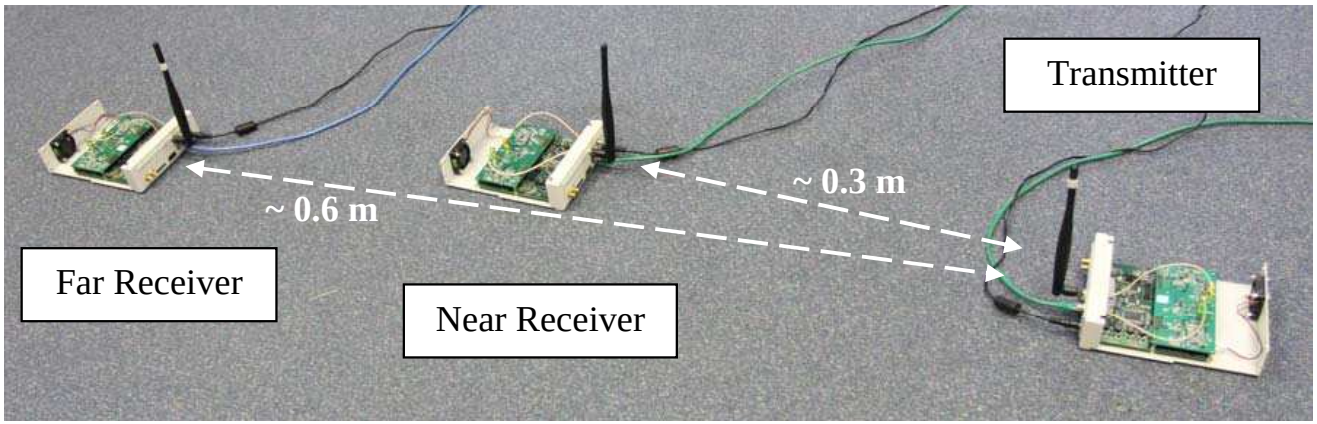
Frame Structure



- TS1: Packet acquisition, timing and frequency sync. Duration $T_s = 48\mu s$
- TS2: Channel Estimation. Duration $T_{ch} = 72\mu s$

Experimental Setup





System Parameters used in Experiments

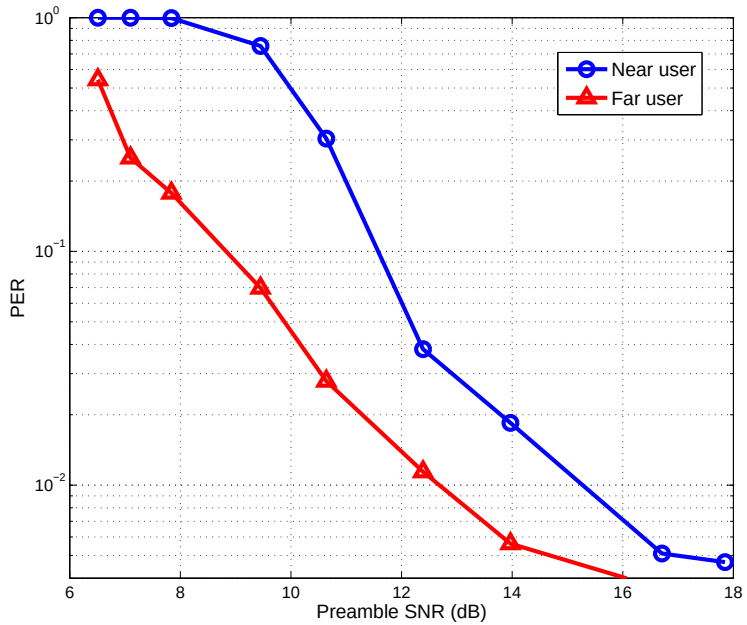
Center Frequency	903 MHz
System Bandwidth	1 MHz
Payload Size	0.5kBytes (incl. 4-Byte CRC)
Transmission Scheme	16-tone OFDM
Tones	8 data, 4 pilot, 4 null
CP Length	$4\mu s$
Modulation	Near User BPSK, Far User BPSK
Gen. Poly. for Conv. Code	$[133, 171]$
Code Rates	Near User 1/2, Far User 1/2
Power allocation α	0.8

Data rate: 250kbps

Training overhead: 120 μs. ($<$ 1% for packet size $>$ 512 bytes)

Experimental Results: PER at Near RX

Packet Size 512 bytes, $\alpha = 0.8$, premable SNR 6 dB above data SNR



Greater far user power assignment $\Longrightarrow$ Far PER is **smaller** than Near PER

Implementation loss at 1% PER $\sim$ 3 dB

Lessons Learned

Issue	Workaround
Cumbersome feedback loops	Single “master” GNURadio block
Non-ideal USRP TX path	Software pre-compensation
Large clock drift	Fine frequency tracking

Conclusions and Future Work

Conclusions:

- Designed and implemented a software-based real-time multiuser transmission system using single-user building blocks
- Software limitations of GNURadio platform limit the degree of modularity in the design

Future Work:

- Re-use the Successive Decoding module in other scenarios:
  - Cellular Uplink
  - Interference cancellation
- Circumvent software limitations by implementing all single-user blocks on FPGA