Using Software Defined Radios to teach Wireless Communication Courses

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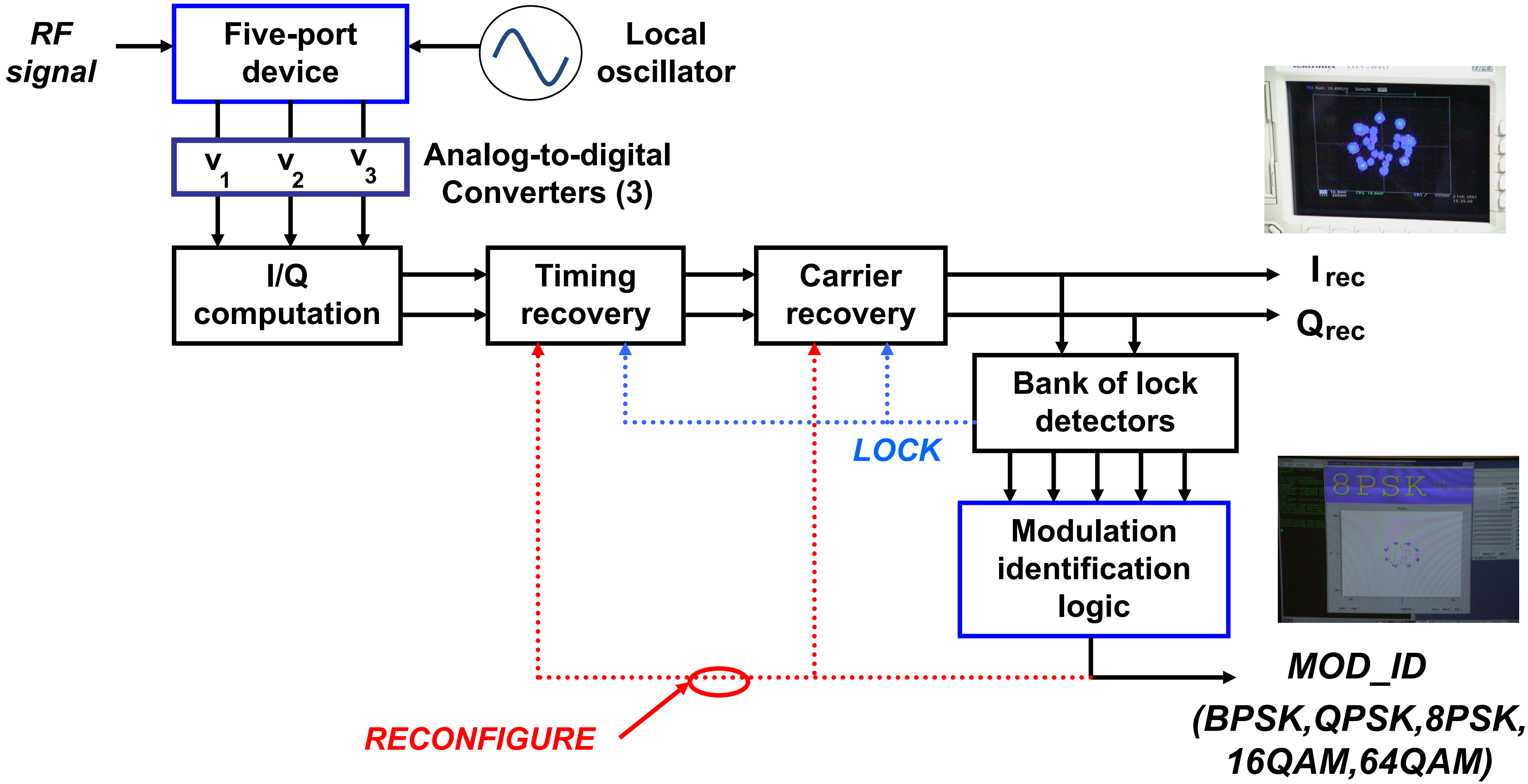
Presented at SDR-WInnComm 2014

Agenda

1. Background
2. Courses at SJSU using software-defined radios
3. Projects and opportunities
4. Discussion

1. Background

SDR receiver in Xilinx System Generator



"SOPRANO" Sony Computer Science Laboratories (Tokyo, Japan, 1999-2002) @SDR'03

Here are the 18 teams that have qualified for the Preliminary and Final Challenge Events:

Team Name	Affiliation	Location	Qualification Ranking*
Purdue	Purdue University, Raytheon BBN	West Lafayette, IN	1
Efficient Spectrum	Individual	Centreville, VA	2
WSL-NEU	Northeastern University	Boston, MA	3
Noisy Wolverines	University of Michigan	Ann Arbor, MI	4
MarmotE	Vanderbilt University, ISIS	Nashville, TN	5
Gator Wings	University of Florida	Gainesville, FL	6
Spartans	San Jose State University	San Jose, CA	7
RxTx	Individuals	San Diego, CA	8
VT-Hume	Virginia Tech	Blacksburg, VA	9
wasabi	Individual	Seattle, WA	10
VT CogRad	Virginia Tech	Blacksburg, VA	11

Qualified 7th place out of 90 contestants. Number one in California.

2. Courses at SJSU using software-defined radios

Infrastructure

- Eight USRP1 radios with RFX900 and BasicRx boards
- Eight USRP2 N210 radios with RFX900 boards
- Two USRP2 N210 radios with SBX boards (thanks to DARPA)
- Two USRP N200 radios with RFX900 boards (to run Matlab Simulink models)

SJSU courses using software-defined radios

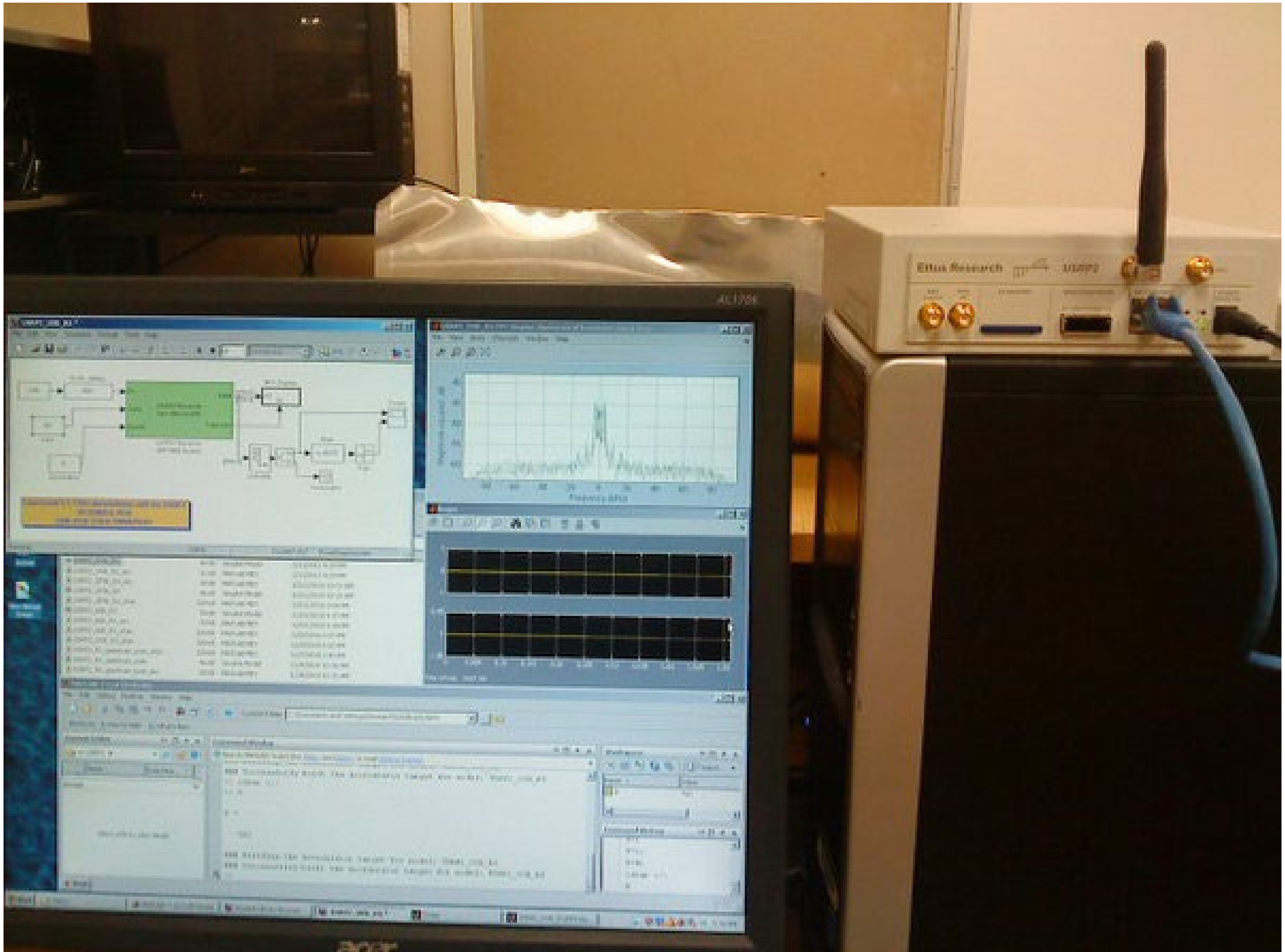
- Undergraduate courses
  - Principles of communication systems (EE160 lab)
  - Digital communication systems (EE161)

- Graduate courses
  - Advanced communication systems (EE252)
  - RFID systems (EE260)
  - Hands-on wireless communications (EE259)

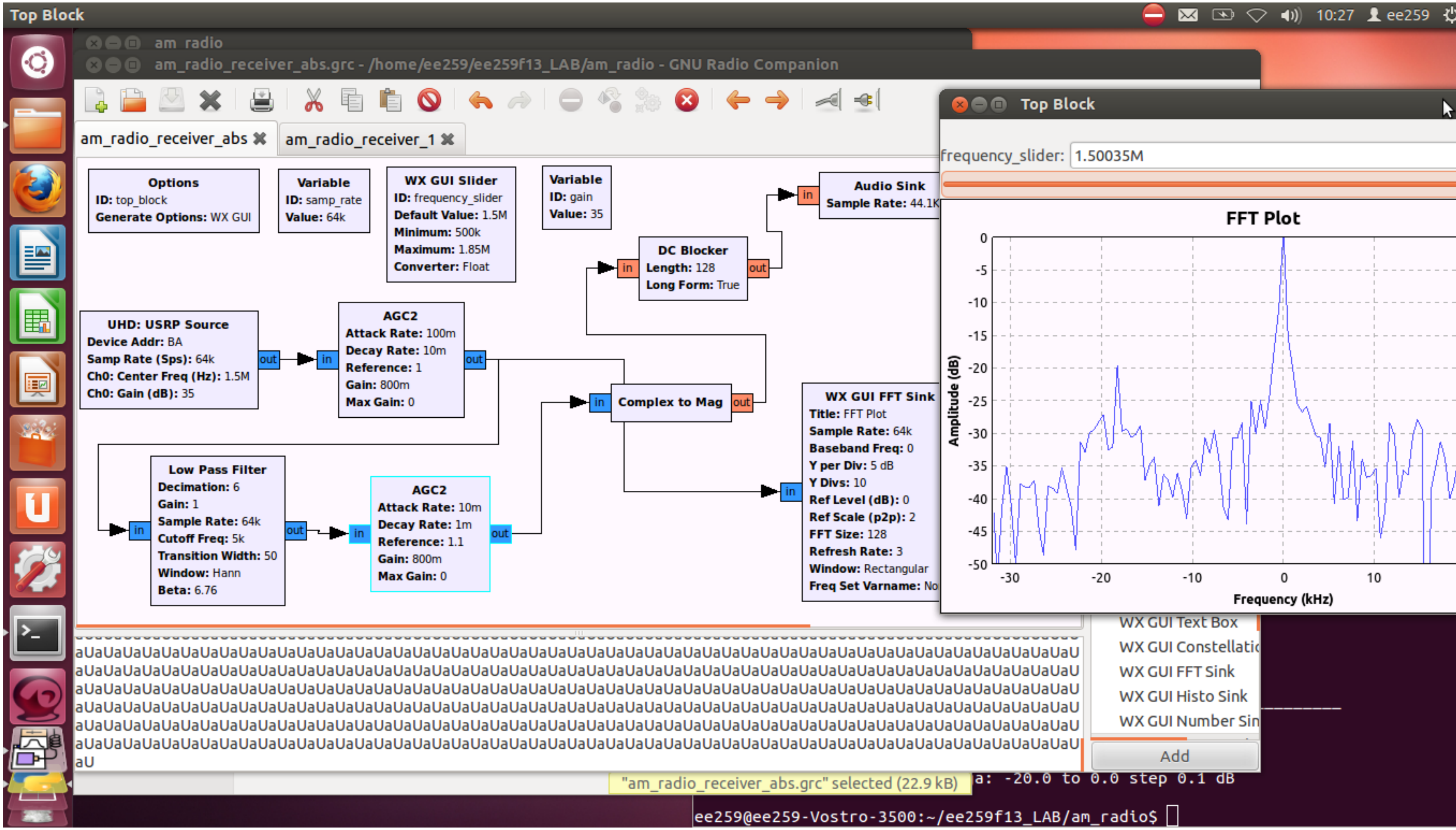
Principles of Communication Systems

- The course has a laboratory (3 hours/week)
- Since Fall 2011, software-defined radios are used with Matlab Simulink to demonstrate
  - Additive White Gaussian Noise (AWGN)
  - OOK, ASK and FSK digital communication schemes
  - Multipath effects in the received spectrum
- Starting this Fall 2014, radios will also be used with GRC to demonstrate receivers:
  - Amplitude modulation – Model from EE259 course
  - Frequency modulation – Model from EE259 course

USRP2 with MATLAB Simulink (FSK demo)



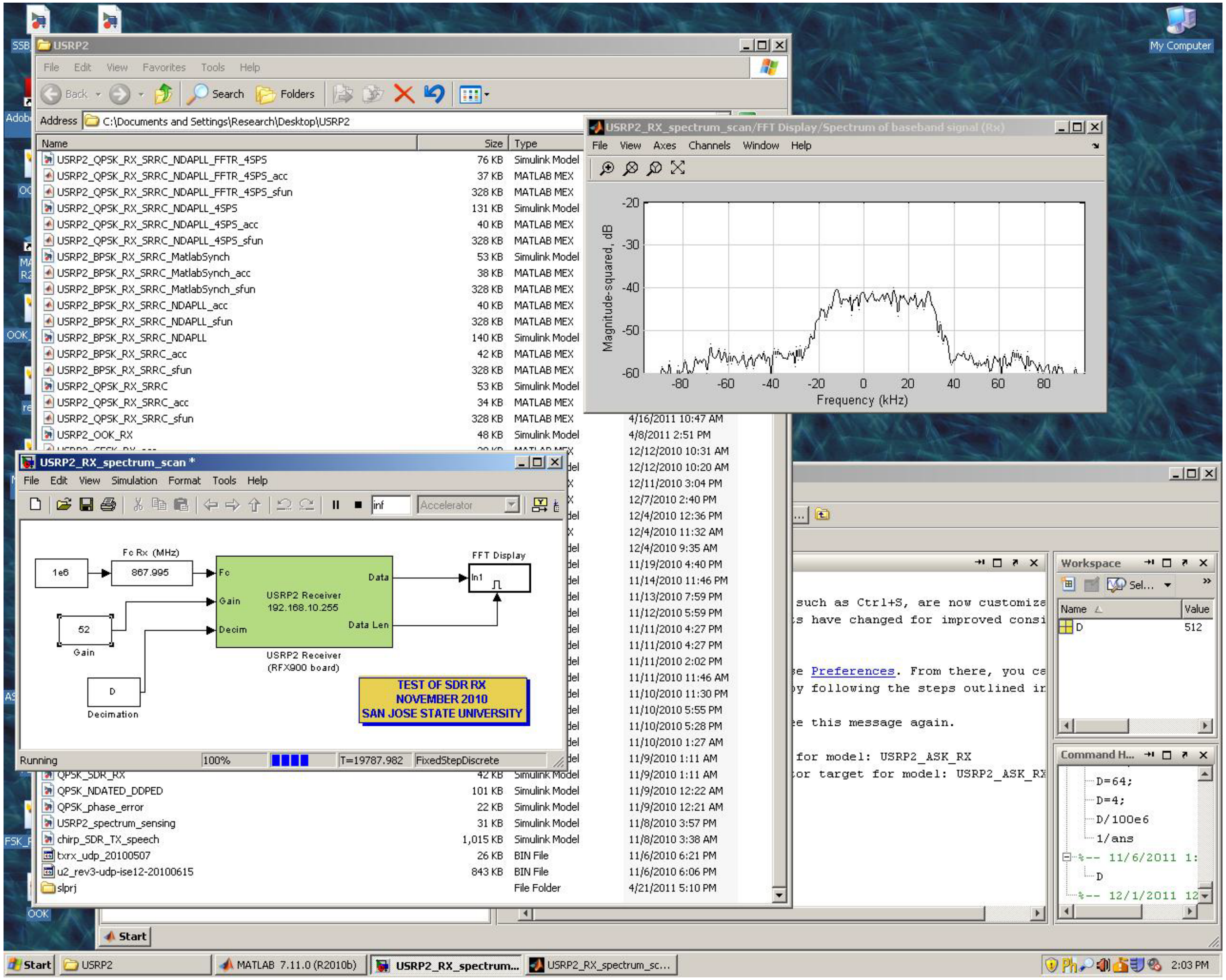
AM receiver with USRP2 and gnuradio (grc)



Digital Communication Systems

- This semester radios are used with Matlab Simulink to demonstrate received spectral densities
  - BPSK/QPSK modulation with SRRC pulses
  - Multipath effects
- Future plans (Spring 2015)
  - 16-QAM
  - Alamouti's 2x1 transmit diversity

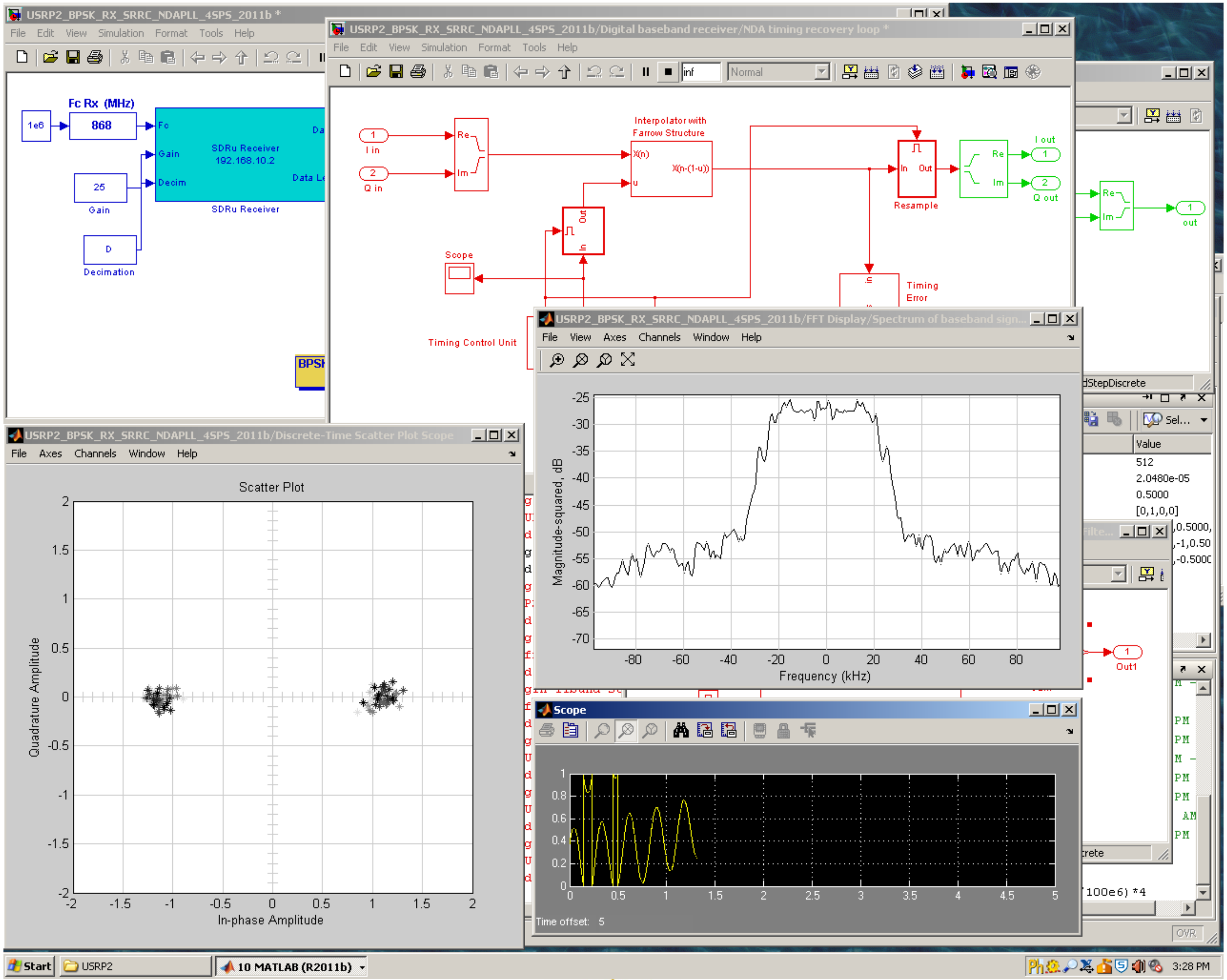
Raised-cosine spectrum



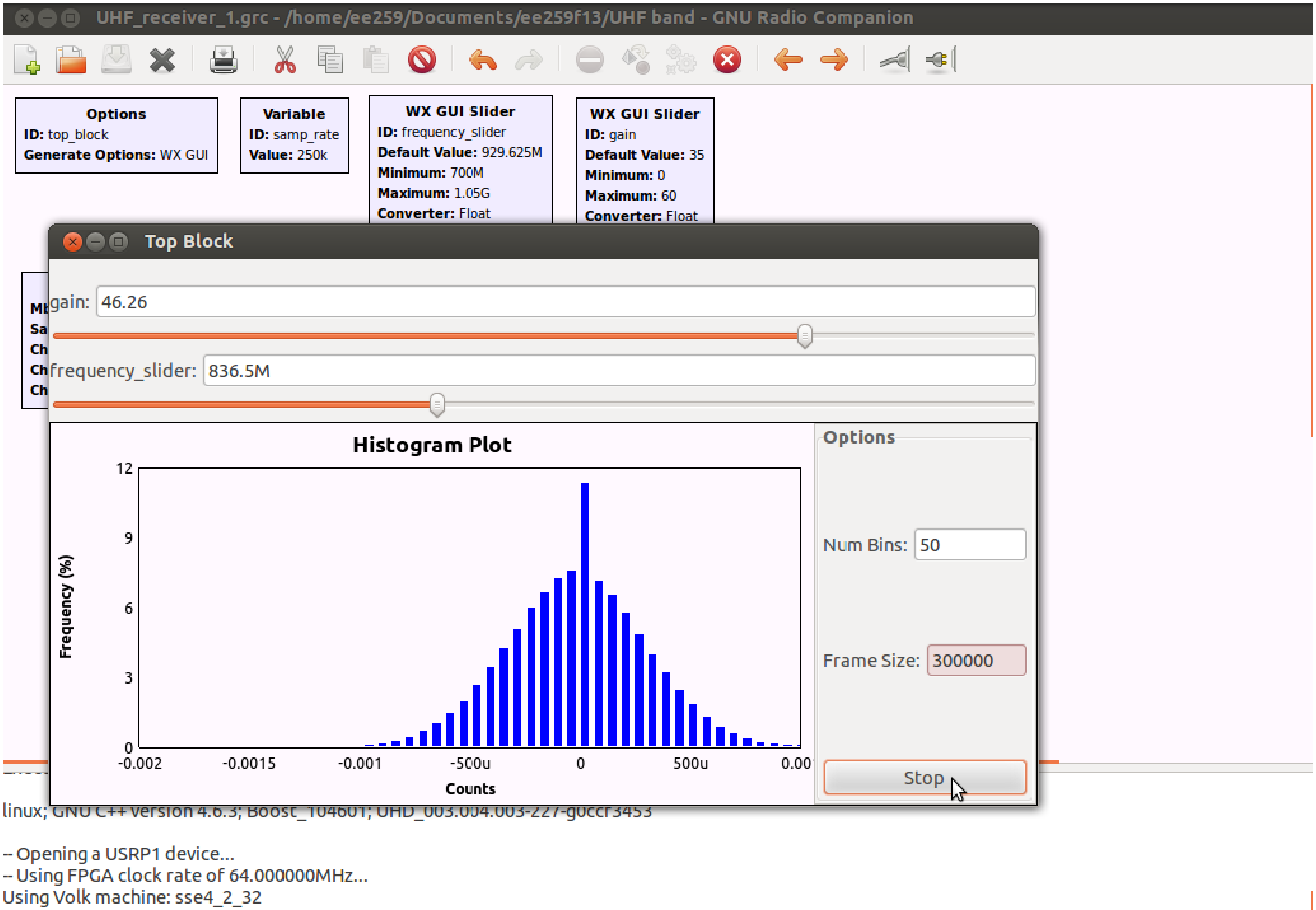
Advanced Communication Systems

- In Fall 2014 radios will be used to demonstrate
  - BPSK/QPSK with SRRC pulses with carrier/timing recovery
  - Both received spectrum and IQ plots
  - Multipath effects

BPSK with carrier/timing recovery



AWGN signal (USRP1 and grc)

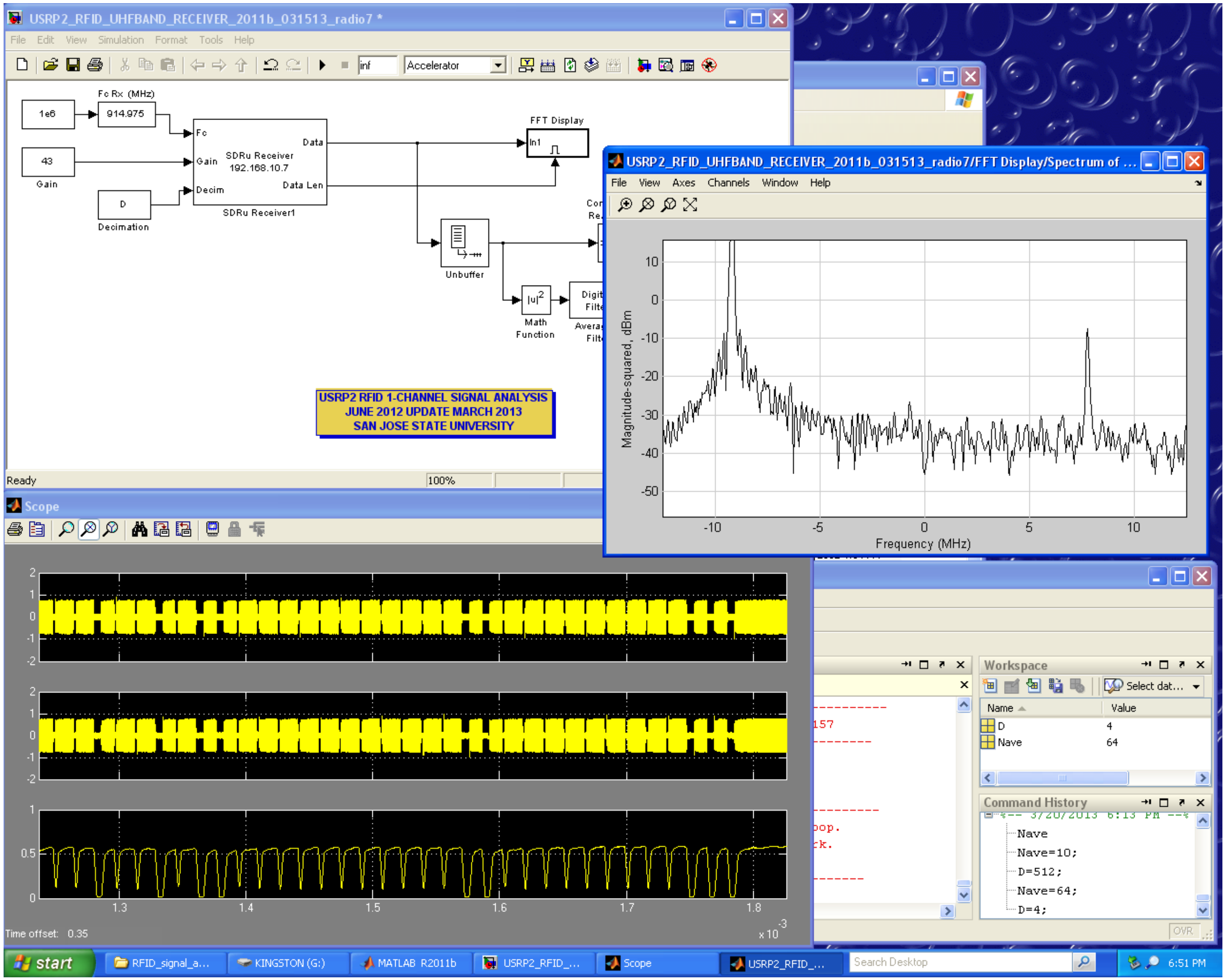


RFID Systems

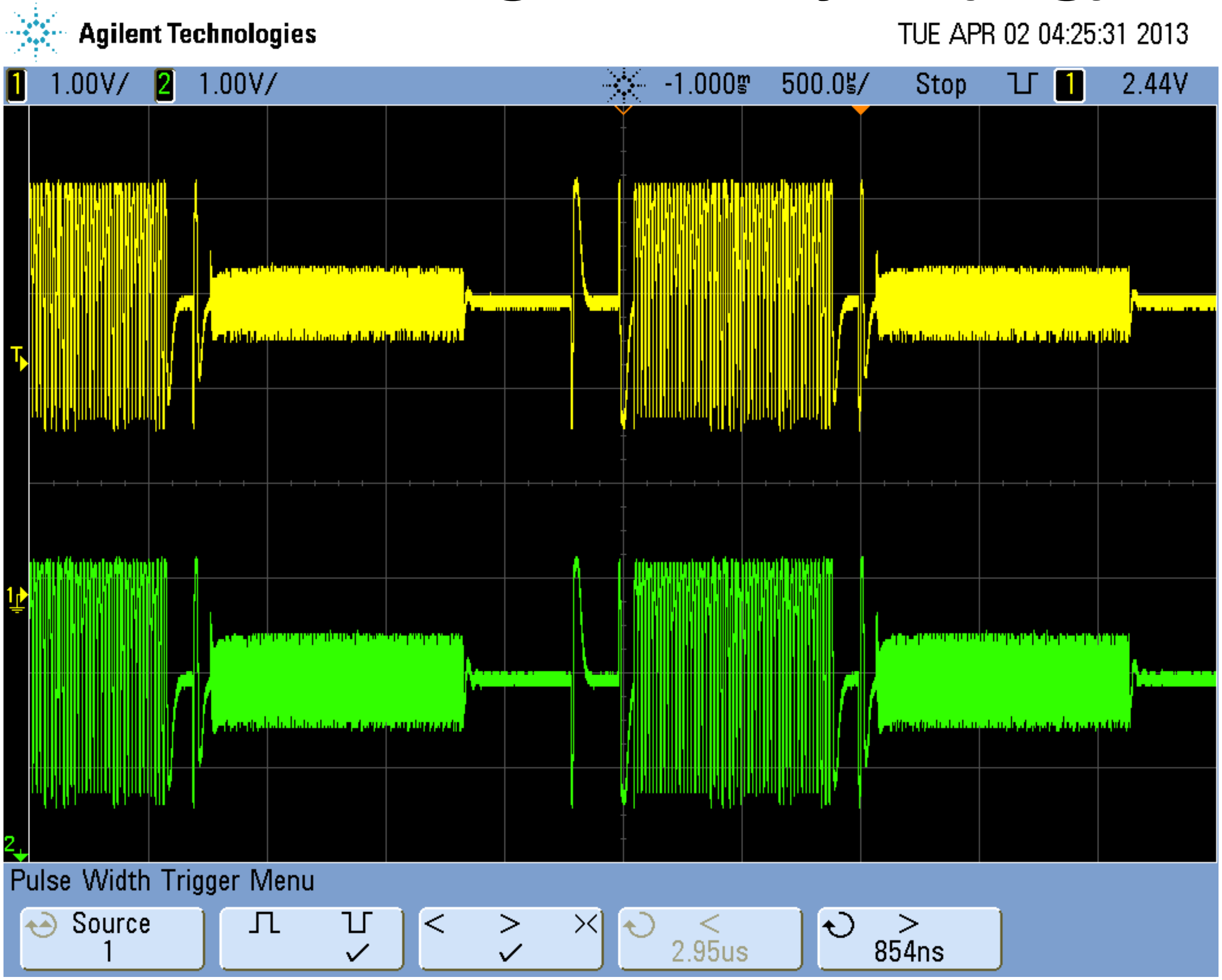
- Since Fall 2012 radios are used to demonstrate
  - Spectrum of UHF RFID reader
  - Received PIE signal via envelope detection

- Future plan
  - Impersonate a tag

UHF RFID signal analysis (reader)



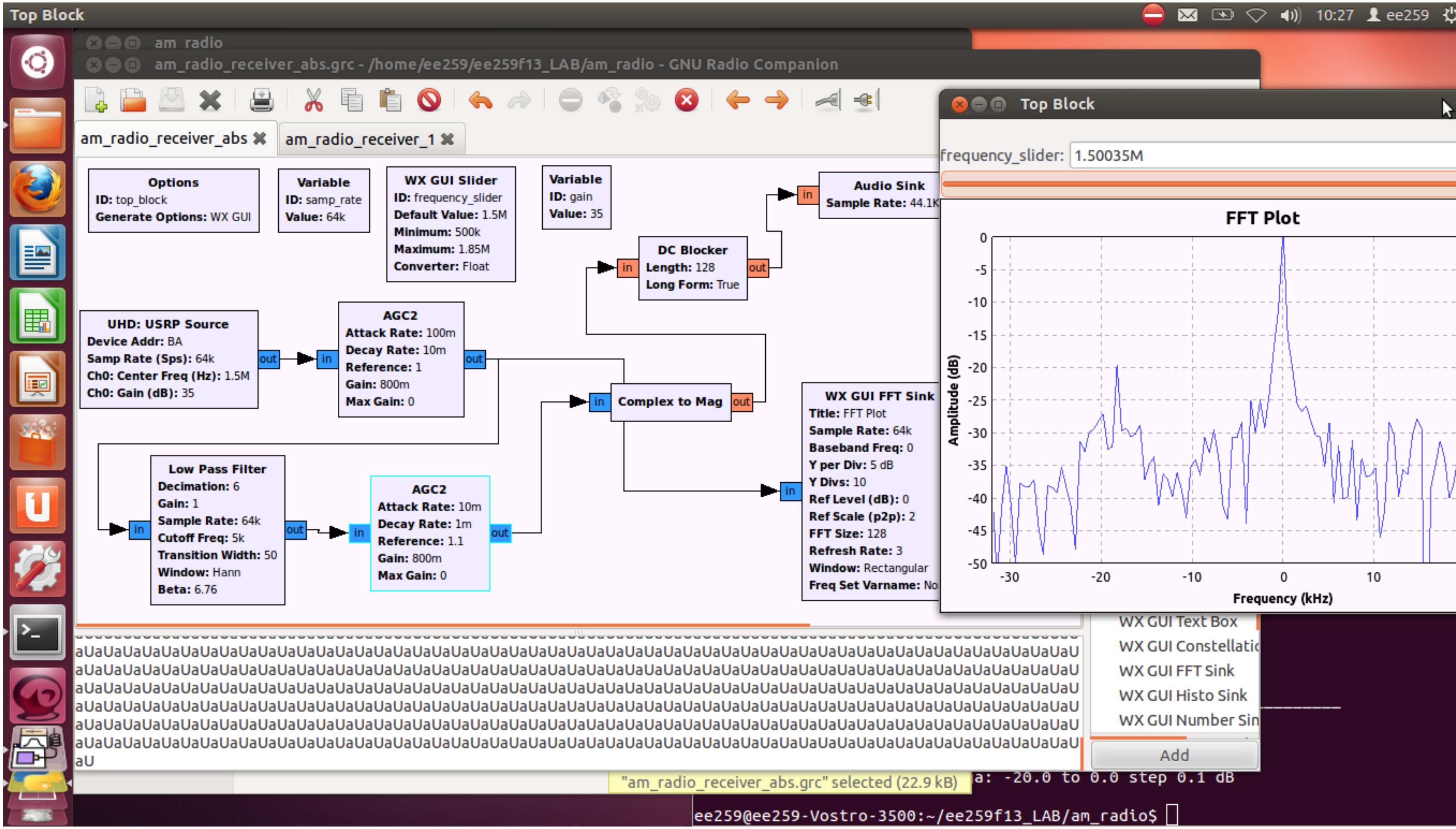
UHF RFID signal analysis (tag)



Hands-on Wireless Communications

- Course specific to software-defined radios
- Created by Professor Birsen Sirkeci in Fall 2009
- Needed to add communication theory lectures ...
- 50% of the time spent in lab where students build and run GRC models
  - AM/FM radio receivers (USRP1, BasicRx)
  - UHF spectrum scanning (USRP1, RFX900)
  - BPSK BER testing (NEW, USRP2, RFX900)
  - Channel sounding (USRP1/USRP2)

AM receiver with USRP1 and GRC



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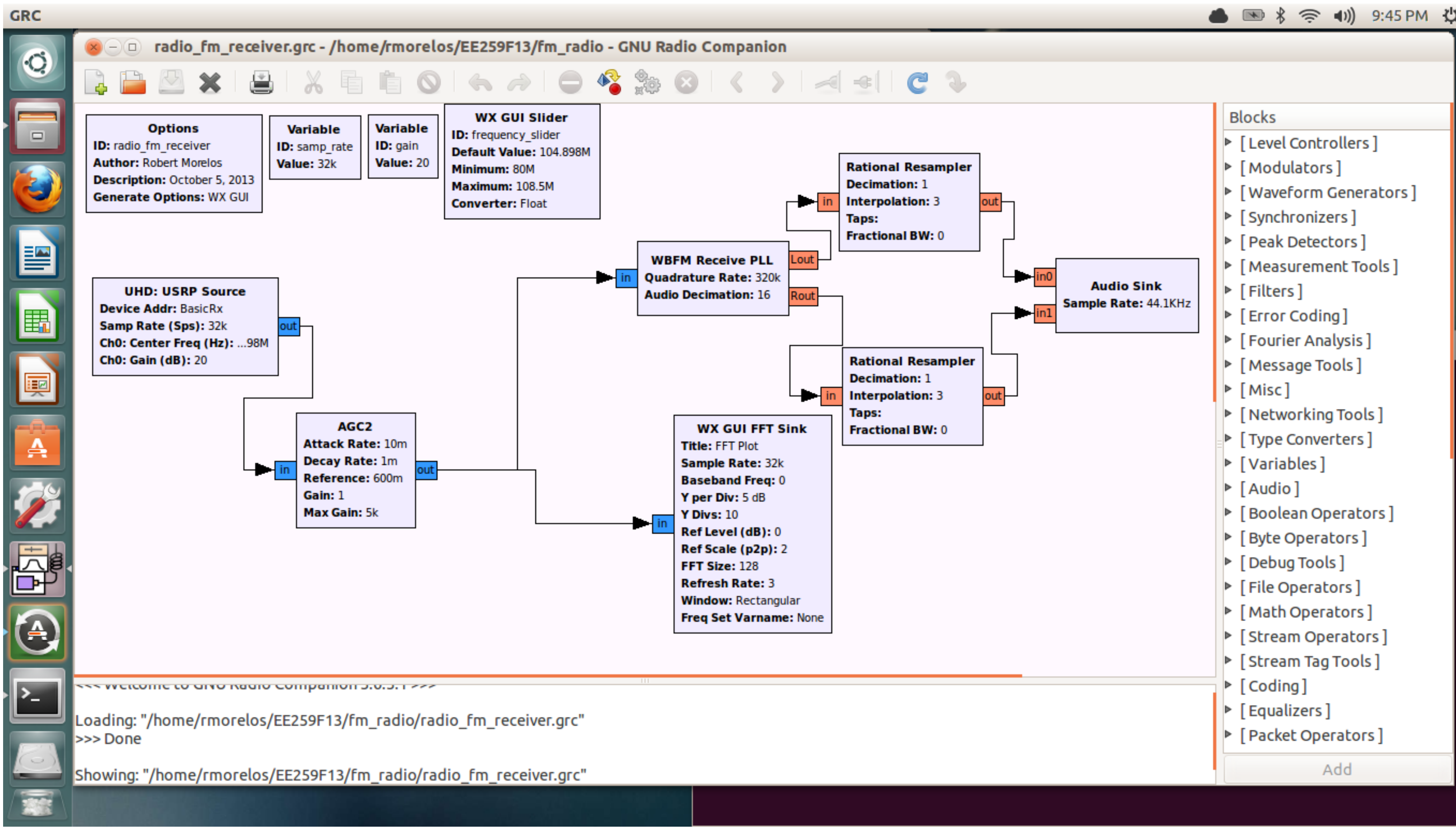
FM receiver using USRP1 and GRC



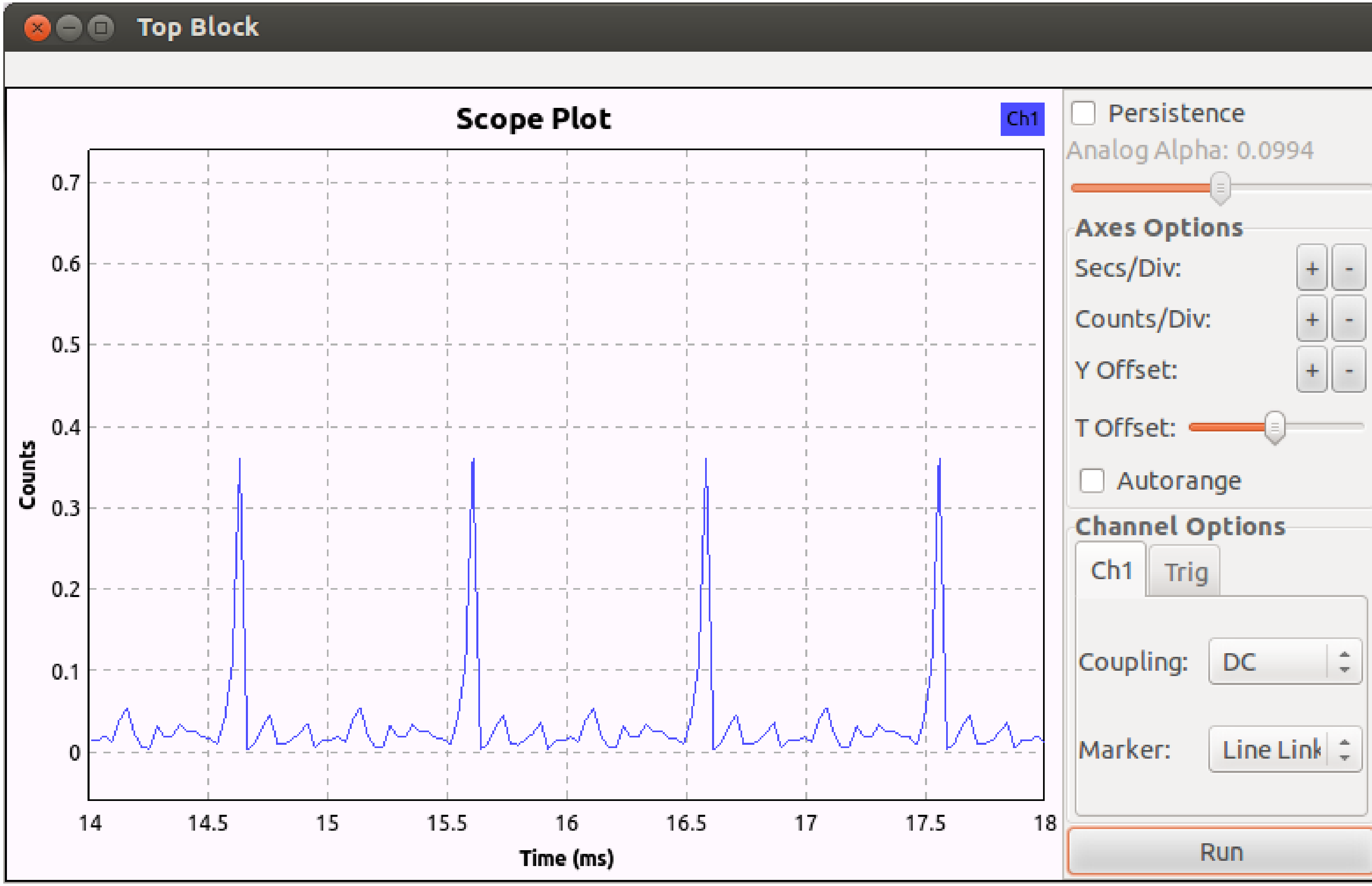
gnuradio BER measurements

– Using BER test benches from gr-digital/examples/narrowband

```
Freq. Offset: -10057 Hz  Timing Offset:   202890.8 ppm  Estimated SNR:  nan dB  BER: 0.166521
Freq. Offset: -6440 Hz  Timing Offset:   -41091.1 ppm  Estimated SNR: 13.6 dB  BER: 0.106164
Freq. Offset: -4799 Hz  Timing Offset:    20714.9 ppm  Estimated SNR: 21.1 dB  BER: 0.0389851
Freq. Offset: -2720 Hz  Timing Offset:    39660.7 ppm  Estimated SNR: 21.1 dB  BER: 0.0143975
Freq. Offset: -1020 Hz  Timing Offset:    -3572.2 ppm  Estimated SNR: 21.1 dB  BER: 0.00526963
Freq. Offset: -1625 Hz  Timing Offset:   -23650.1 ppm  Estimated SNR: 21.1 dB  BER: 0.00193846
Freq. Offset: -1837 Hz  Timing Offset:    33931.6 ppm  Estimated SNR: 21.1 dB  BER: 0.000714851
Freq. Offset: -2680 Hz  Timing Offset:    20160.6 ppm  Estimated SNR: 19.7 dB  BER: 0.000261785
^Crmorelos@ubuntu:~/gnuradio/gr-digital/examples/narrowband$ ./digital_bert_rx.py -m dbpsk -r 1M -f 1.825e9 --rx-gain=40
```

– Scripts do not work for nonbinary modulation formats?

Channel sounding



3. Projects and opportunities

Projects using software-defined radios

- Cooperative broadcasting
- Adaptive multicarrier communications (OFDM)
- RFID: Radio-frequency identification
- ECC: Error correcting codes
- MIMO: Multiple-antenna communication systems

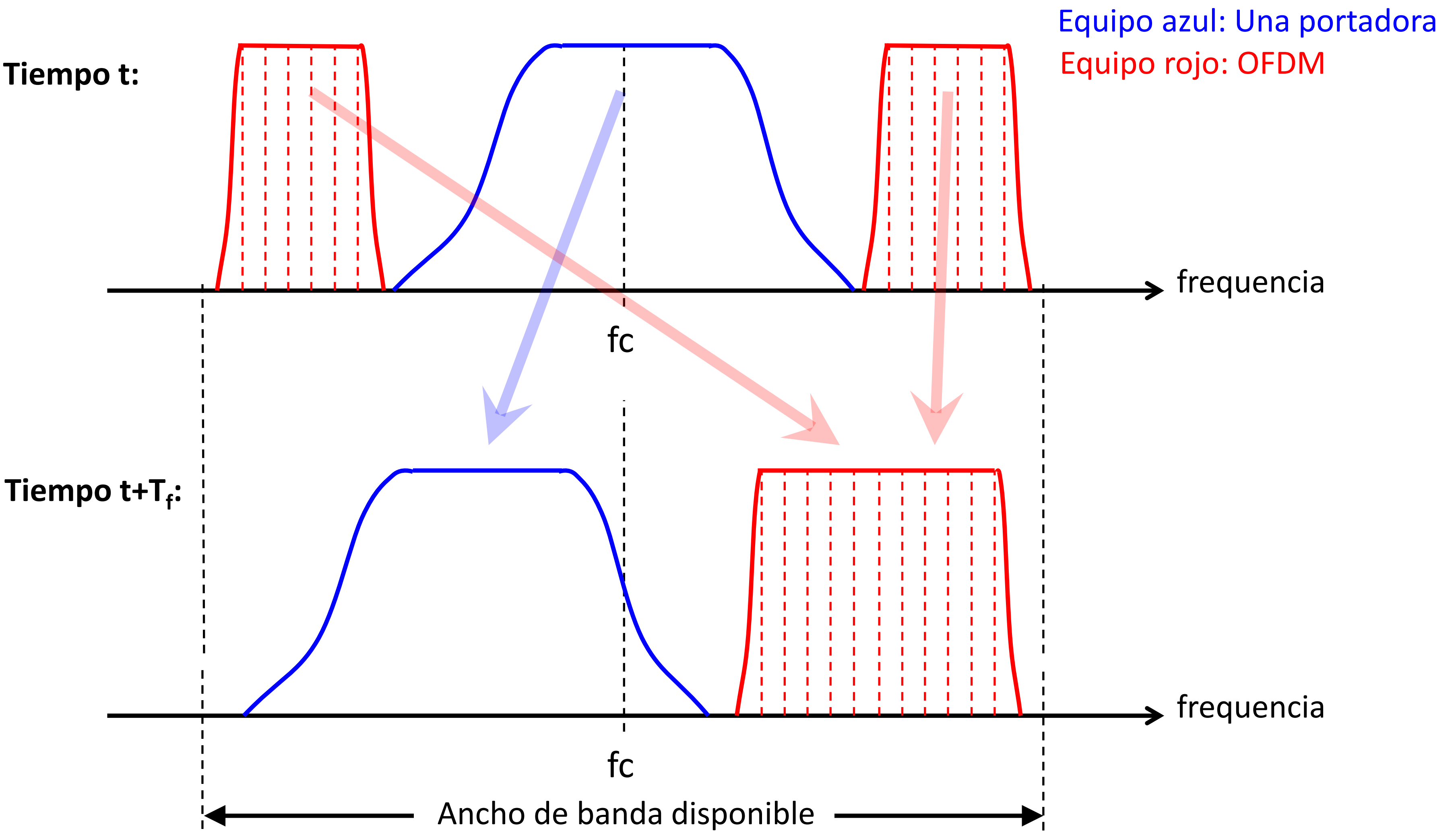
OFDM with gnuradio

- OFDM: Orthogonal Frequency Division Multiplexing
  - Inspired by DARPA Spectrum Challenge
    - Variable number of carriers (FFT length)
    - Variable modulation scheme (BPSK/QPSK/QAM)
    - Variable used-carrier pattern
    - Involves modifying scripts and programs written in python and C++

- Goal: Implement an intelligent radio link under interference from an RFID reader in the UHF band (902MHz – 928 MHz)

http://gnuradio.org

Adaptive OFDM: Cooperation example



Error correcting codes in gnuradio

- Implement encoder and decoder (hard decision) for the **BCH (32,21,6)** code used in **FLEX pager** (a gnuradio project)

- BCH codes (hard decision)
- BCH codes (soft decision)
- Turbo block codes using BCH codes (Pyndhia)
- Low density parity check codes (LDPC)

- GOAL: Implement intelligent radio links using BPSK/BFSK modulation and various error correcting codes

Opportunities

- Joint research projects
  - Easy exchange of information (python and c++)
  - Remote advising
  - Students can visit us (SJSU is in Silicon Valley!)
- Practical implementation of ideas and algorithms …
- Courses
  - Perfect combination between digital signal processing (DSP) and wireless communication systems
  - Helps attracting masters and Ph.D. students to the area

4. Discussion

Please send your ideas and comments to
robert.morelos-zaragoza@sjsu.edu

Experiences with software-defined radios

- "Virtual" experiments in wireless communication courses at SJSU are based on Matlab Simulink ...
- Students have a hard time building GRC models
  - No default parameter values, help is hard to find
- More "hack-on" than "hands-on" ?
  - Introduce python programming material in EE259: Professor Birsen Sirkeci for next EE259 in Fall 2014
- The leader of team **Spartans** in DARPA's contest took the EE259 course in Fall 2012 !!!

COMMENTS?