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SDR in Undergraduate Engineering Education

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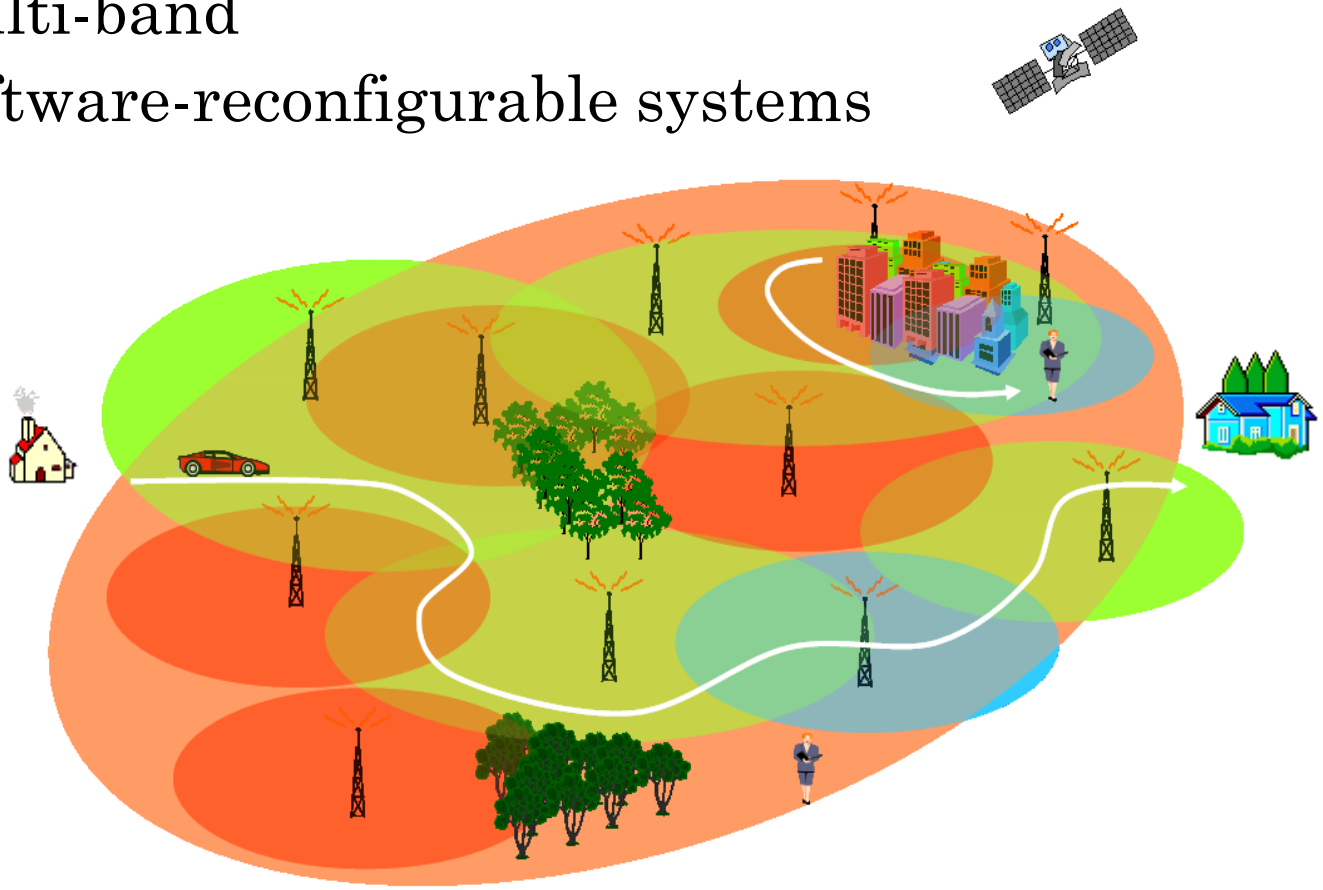
New Technologies for Radio Systems

- Multi-service
- Multi-standard
- Multi-band
- Software-reconfigurable systems



Context: University Education

- Present the necessary theoretical background
- Teach practical engineering tools beyond simulation environments
- Prepare students for their profession or grad school
- Digital Techniques for Communications (DTC): undergraduate compulsory subject at the EPSC
- DTC provides theoretical background and hands-on experiences to engineering students for solving radio engineering problems

DTC: Course Overview – Theoretical Part

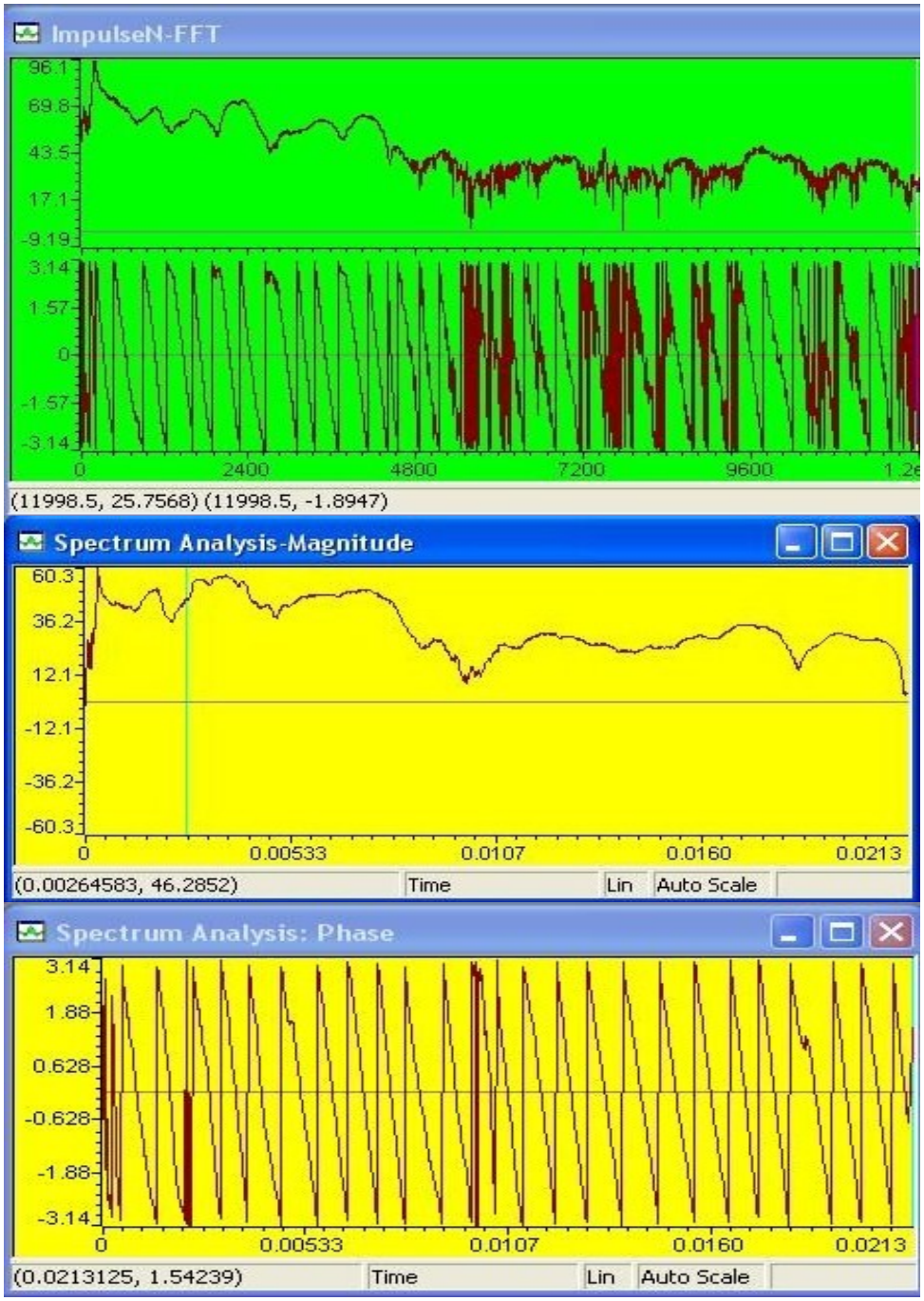
- Sampling theory and data converters
- Efficient IQ modulation,
- Phase-locked loops (PLLs),
- Direct digital synthesis (DDS).

DTC: Course Overview – Practical Part

- DSK TMS320C6416 (fixed-point DSP @ 1 GHz, 16-bit stereo codec @ 48 kHz)
- 5 Laboratory exercises :
  - Lab-0: Introduction to CCS
  - Lab-1: Channel Analysis
  - Lab-2: QPSK Modulator and Demodulator
  - Lab-3: Efficient QPSK Modulator and Demodulator
  - Lab-4: Completing the Communications System

Lab-1: Channel Analysis

- Analyze the transmission channel: codec, speakers, analog amplifiers, and the radio link.
- Each group uses a different pair of speakers, the channel differs from group to group
- Objective: determine the suitability of the speakers and identify the usable and unusable frequency bands.

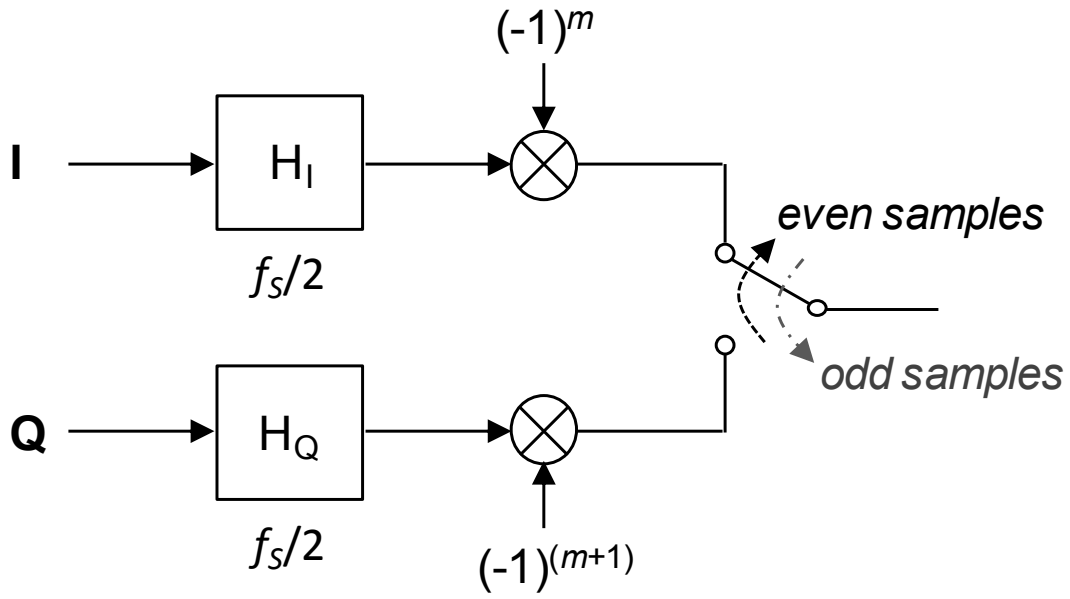

ImpulseN-FFT
96.1
69.8
43.5
17.1
-9.19
3.14
1.57
0
-1.57
-3.14
0
2400
4800
7200
9600
(11998.5, 25.7568) (11998.5, -1.8947)
Spectrum Analysis-Magnitude
60.3
36.2
12.1
-12.1
-36.2
-60.3
0
0.00533
0.0107
0.0160
0.0213
(0.00264583, 46.2852)
Time
Lin
Auto Scale
Spectrum Analysis: Phase
3.14
1.88
0.628
-0.628
-1.88
-3.14
0
0.00533
0.0107
0.0160
0.0213
(0.0213125, 1.54239)
Time
Lin
Auto Scale

Lab-2: QPSK Modem

- Information: phrase of 32 characters chosen by each group/bit sequence loaded from a file
- Relation between the symbol and the sampling rate 1:8, 1:16, or 1:32
- Route-raised cosine pulse-shaping filter providing 20 dB attenuation
- Carrier frequency is 5 kHz.
- Bit error rate (BER) measurements and analysis carried out in two ways: bypassing the channel and including it

Lab-3: Efficient QPSK Modem

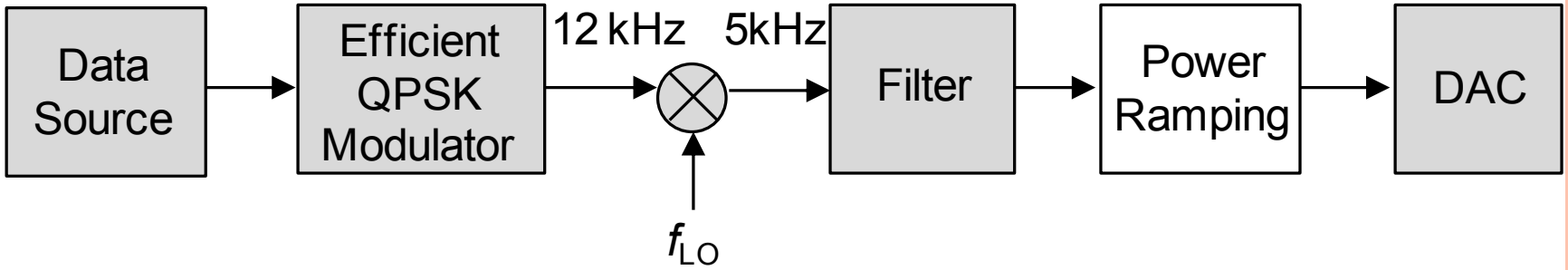
- Based on the principle of *Double Nyquist Digital Product Detector* [1]



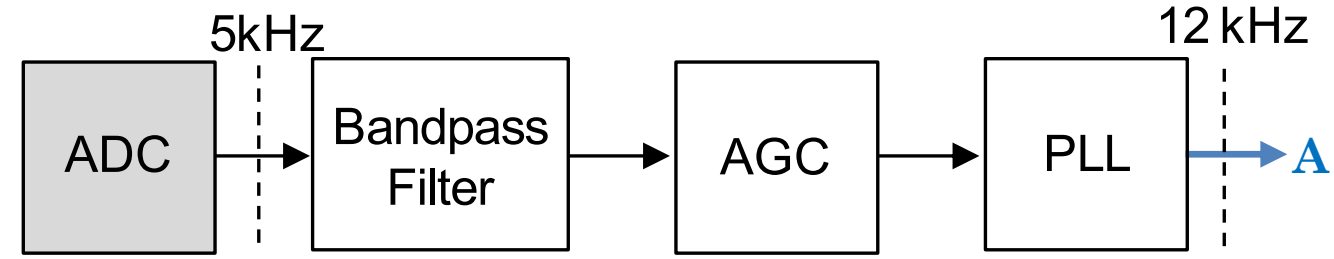
[1] L. E. Pellon, "A double Nyquist digital product detector for quadrature sampling", IEEE Trans Signal Proc., vol. 40, no. 7, July 1992.

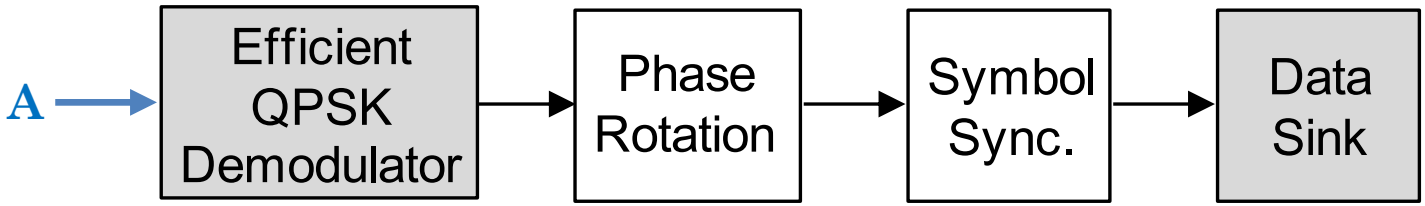
Lab-4: Completing the Communications System

Transmitter



Receiver





Module	DSP cycles
Data source	426
Efficient QPSK modulator	1687+64
Frequency translation to 5 kHz	82
Image rejection filter	675
Power ramping	67
Channel selection filter	1388
Frame detection	76
AGC	1158
PLL	9930
Efficient QPSK demodulator	2006+64
Phase synchronization	5800
Symbol synchronization	404
Bit decision	100

SDR Practices

- **Fixed-Point DSP Programming**
  - Programming challenges to students
  - Dynamic range consideration
- **Real-Time Processing**
  - Modular design
  - Processing sample-by-sample
  - Cycle count and analyze the effect of real-time violations
- **Processing Gain vs. Processing Efficiency**
  - Simple designs which just meet the *QoS* requirements

Lessons Learned

- 7 years (14 semesters) of experience
- Regular discussions about what the students should learn and revisions of course material
- Low average score
- The evaluation process penalizes delays
- New methods for improving the learning process, initial phase is critical
- Conclusion: Revision of the first laboratory sessions to be more guided

Conclusions

- DTC provides hands-on experience on fixed-point DSP programming, emphasizing on *modular* and *flexible* communications system designs
- DTC points out some real-world problems in wireless communications system design at an early stage of the engineering education
- Extra effort needed for the students to understand and take benefit from DTC
- Several students joined our research team for doing undergraduate and graduate projects on SDR