Research and education in the Laboratory for Computer-aided design in communications in Technical university-Sofia

Galia Marinova, associate professor, Ph.D.

Technical University – Sofia,
on ERASMUS+ Teaching mobility in SUPELEC

gim@tu-sofia.bg

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COURSES

• Computer-aided design – Bachelor in Telecommunications, compulsory

• Computer-aided design of digital communication circuits with VHDL, Bachelor in Telecommunications, optional

• Nanocommunication devices and networks
  Master “Microtechnologies and nanoengineering”, compulsory - New

• Internet based Computer-aided design, Master in Telecommunications, optional

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
Outline

• Recent research projects:
  • Research on pseudo random bit sequences for compressive sensing applications
  • Online assisted platform and Cloud technologies for Computer-aided design of communication circuits and systems

• New course probated the last academic year
  • Nano communication devices and networks

Master “Micro technologies and Nano engineering”, compulsory

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
I. Research on pseudo random bit sequences for compressive sensing applications

Compressive sensing is applied when the signal is sparse in some area. In Compressive sensing approach, samples are acquired randomly at sub-Nyquist sampling rates by projecting the input signal on random signals. The random demodulator is a CS based receiver, where constraints on the receiver bandwidth due to ADC sampling rate are alleviated.

Sensing matrix should satisfy the Restricted Isometry Property (RIP). The quality of random signals determines the signal quality reconstruction.

M-sequences, Kasami, Golden pseudorandom bit sequences and random generator circuits are studied through NIST test suite in order to estimate their abilities to be used for Analog-to-information converters and sub-Nyquist communication receivers based on compressive sensing.

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
MATLAB bit sequence from the computer is used for the test of CS and signal reconstruction – **512 bits identical for sampling and reconstruction**

**Looking for a PRBS circuit to integrate with the FPGA firmware**
PRNG in MATLAB

- **Mersenne Twister** is a pseudorandom number generator (PRNG). It is the most widely used PRNG. Its name derives from the fact that its period length is chosen to be a Mersenne prime.

- The Mersenne Twister was developed in 1997 by Makoto Matsumoto and Takuji Nishimura.

- It passes most, **but not all**, of the stringent **TestU01** (2007, by Pierre L’Ecuyer and Richard Simard of the University of Montreal) randomness tests.
RANDOM AND OTHER SEQUENCES FOR COMPRESSION SENSING APPLICATIONS

• **M-sequences**

• **Kasami sequences**
  promote for CS on SNR estimates

• **Golden sequences**

• **Chaotic sequences**
  L. Yu, J.P. Barbot, G.Zheng, H. Sun, Compressive Sensing with Chaotic Sequences,

• **Deterministic sequences (periodic, obtained from a set of FZC, Frak-Zadoff-Chu sequences)**
  P. Zhang, L. Gan, S. Sun, Cong Ling, Deterministic sequences for compressive MIMO channel estimation, 2 November 2013

• **Marsenne Twister PRBS from MATLAB**, used in D. Bao and alt.

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
7 PRBSG studied

• MATLAB (Marsenne Twister) PRBSG [0,1] from PC

• PRBSG as 9-bit Fibonacci LFSR used in SMIQ03B signal vector generator (511 bits)

• PRBSG as 16-bit Fibonacci LFSR used in SMIQ03B

• PRBSG as 21-bit Fibonacci LFSR used in SMIQ03B

• PRBSG as 8-bit Galois LFSR (255 bits)

• Kasami bit sequence generator

• Gold sequence generator

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
PRBS circuits
Fibonacci LFSR circuits for M-sequences and Galois

Fig. 1. PRBSG as 9-bit Fibonacci LFSR used in SMIQ03B signal vector generator

Fig. 2. PRBSG as 8-bit Galois LFSR

Fig. 3. PRBSG as 16-bit Fibonacci LFSR used in SMIQ03B signal vector generator

Fig. 4. PRBSG as 21-bit Fibonacci LFSR used in SMIQ03B signal vector generator

Three of the LFSR circuits are from SMIQ03B Rohde&Shwartz signal vector generator

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
PRNG circuits
Kasami-code generator and Gold sequence generator

http://www.wu.ece.ufl.edu/books/EE/communications/CDMA/CDMA.htm

Kasami-code generator scheme

Gold sequence generator for the preferred pair

\[ g_1(x) = x^3 + x + 1 \]
\[ g_2(x) = x^3 + x^2 + 1 \]

S. Kalita, P. Salun, A New Modified Sequence Generator for Direct Sequence Spread Spectrum (DSSS), NCECS, September, 2011

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
MT works in 2 steps: recurring (form of LFSR) and tempering (multiplying by a Tempering matrix T for a better equidistribution).

A. Jagannatam, Marsenne Twister – a pseudo random number generator and its variants, cryptography.gmu.edu/~jkaps/download.php
Our approach

Testing test suites before integrating PRBSG in the A2I converter prototype and calculating SNR;

To avoid falling in specific cases, usually sine wave signal were used as input in papers on the topic;

First to select the best PRBSG candidates for CS based on tests for randomness and then to test on the A2I prototype.

G. Marinova, SCE Seminar, SUPELEC, Rennes, 18.06.2015
TEST suites for randomness

**TESTU01** - (2007, by Pierre L’Ecuyer and Richard Simard of the University of Montreal) randomness tests
- Small crush (10 tests)
- Crush (60 tests)
- Big crush (45 tests)


Integrates the 15 most powerful statistical tests, based on null hypothesis testing. Shi-square is the reference distribution.

Some of the tests have subtests.

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
1. The Frequency (Monobit) Test,
2. Frequency Test within a Block,
3. The Runs Test,
4. Tests for the Longest-Run-of-Ones in a Block,
5. The Binary Matrix Rank Test,
6. The Discrete Fourier Transform (Spectral) Test,
7. The Non-overlapping Template Matching Test,
8. The Overlapping Template Matching Test,
9. Maurer's "Universal Statistical" Test,
10. The Linear Complexity Test,
11. The Serial Test,
12. The Approximate Entropy Test,
13. The Cumulative Sums (Cusums) Test,
14. The Random Excursions Test, and
15. The Random Excursions Variant Test.
Specific Goals of the research

• Do Kasami sequence pass the NIST tests? To verify V.Singal and alt.
• Do PRBSG in the signal vector generator SMIQ03B of Rohde&Shwarz pass the NIST tests?
• Do MATLAB MT PRBSG pass the NIST tests? To verify D.Bao and alt.
• Do Galois and Gold sequences pass the NIST tests?
• Comparison with published test results.

Which PRBSG is a good candidate for CS applications?

• Other applications.

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
NIST test applied for 512 bit long sequence generated by each PRBSG

• Only 10 tests from NIST test suite are applicable for sequence with such length: 1-7 and 11-13.

• Test 7 has 24 subtests for different templates and different length blocks can be considered.

• The other 5 tests are applicable for sequences with length superior than $10^6$, not applicable for 512 bit sequence.
Results from the NIST tests (1)
P-value > 0.01

- Poor results for SMIQ 21bit
- Kasami suit needs additional evaluation for different polynomials.
- Good results for MATLAB and Gold

Results to be published soon.

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
Comparison with Published test results
Test suites for randomness PRNGs - TESTU01 and NIST

M. Babaei, M. Farhadi

Introduction to Secure PRNGs, Int.J. communications, network and system sciences, 2011, 4, 616-621

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015

**Table 1. Results of TestU01 for various PRNGs.**

<table>
<thead>
<tr>
<th>Generators</th>
<th>$\log_2$</th>
<th>$t$-32</th>
<th>Small Crush</th>
<th>Crush</th>
<th>Big Crush</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCG$^a$</td>
<td>24</td>
<td>3.9</td>
<td>14</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LCG$^b$</td>
<td>57</td>
<td>4.2</td>
<td>1</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>LFib$^c$</td>
<td>85</td>
<td>3.8</td>
<td>2</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>MSM</td>
<td>101</td>
<td>3.0</td>
<td>5</td>
<td>45</td>
<td>-</td>
</tr>
<tr>
<td>Chaotic MSM$^d$</td>
<td>27</td>
<td>3.2</td>
<td>9</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>MPM</td>
<td>105</td>
<td>3.2</td>
<td>7</td>
<td>47</td>
<td>-</td>
</tr>
<tr>
<td>Chaotic MPM$^d$</td>
<td>29</td>
<td>3.4</td>
<td>10</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>Fibonacci LFSR</td>
<td>30</td>
<td>4.1</td>
<td>17</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Glaois LFSR</td>
<td>31</td>
<td>4.0</td>
<td>15</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chaotic LFSR$^d$</td>
<td>32</td>
<td>4.2</td>
<td>9</td>
<td>12</td>
<td>14</td>
</tr>
</tbody>
</table>

a: $(2^{24}, 16598013, 12820163);$  

b: $(2^{59}, 13^{13}, 0);$  
c: $(2^{31}, 55, 24);$  
d: logistic map.

Linear congruential generator (LCG); Knuth Lfib – deterministic but random looking data, non cryptographic; MSM (middle-square method) RNG

M. Babaei, M. Farhadi support the idea that **chaotic logistic map (combined with LFSR through XOR)** is able to promote the performance of classic PRNGs.

M. Babaei, M. Farhadi, Introduction to Secure PRNGs, Int.J. communications, network and system sciences, 2011, 4, 616-621
7 tests from NIST test suite are applied (1-6,13)

**Table 2. Results of NIST for various PRNGs (Part 1).**

<table>
<thead>
<tr>
<th>Generators</th>
<th>Frequency</th>
<th>Block Frequency</th>
<th>CuSums Forward</th>
<th>CuSums Backward</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCG(^a)</td>
<td>0.804645</td>
<td>0.764534</td>
<td>0.193567</td>
<td>0.002323</td>
</tr>
<tr>
<td>LCG(^b)</td>
<td>0.985634</td>
<td>0.893467</td>
<td>0.229087</td>
<td>0.012678</td>
</tr>
<tr>
<td>LFib(^c)</td>
<td>0.875379</td>
<td>0.026789</td>
<td>0.679834</td>
<td>0.126789</td>
</tr>
<tr>
<td>MSM</td>
<td>0.908733</td>
<td>0.128908</td>
<td>0.873456</td>
<td>0.09367</td>
</tr>
<tr>
<td>Choatic MSM(^d)</td>
<td>0.804645</td>
<td>0.322901</td>
<td>0.265567</td>
<td>0.090388</td>
</tr>
<tr>
<td>MPM</td>
<td>0.83733</td>
<td>0.127835</td>
<td>0.783606</td>
<td>0.091678</td>
</tr>
<tr>
<td>Choatic MPM(^d)</td>
<td>0.96372</td>
<td>0.762609</td>
<td>0.126709</td>
<td>0.201289</td>
</tr>
<tr>
<td>Fibonacci LFSR</td>
<td>0.535558</td>
<td>0.256881</td>
<td>0.125567</td>
<td>0.558502</td>
</tr>
<tr>
<td>Glaois LFSR</td>
<td>0.269087</td>
<td>0.269087</td>
<td>0.390767</td>
<td>0.389001</td>
</tr>
<tr>
<td>Choatic LFSR(^d)</td>
<td>0.606499</td>
<td>0.483676</td>
<td>0.553505</td>
<td>0.769260</td>
</tr>
</tbody>
</table>

\(^a\): (2\(^24\), 16598013, 12820163); \(^b\): (2\(^59\), 13\(^13\), 0); \(^c\): (2\(^31\), 55, 24); \(^d\): logistic map

**Table 3. Results of NIST for various PRNGs (Part 2).**

<table>
<thead>
<tr>
<th>Generators</th>
<th>Runs</th>
<th>Long Run</th>
<th>Rank</th>
<th>FFT</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCG(^a)</td>
<td>0.876522</td>
<td>0.003634</td>
<td>0.347851</td>
<td>0.000147</td>
</tr>
<tr>
<td>LCG(^b)</td>
<td>0.753678</td>
<td>0.125620</td>
<td>0.892736</td>
<td>0.000951</td>
</tr>
<tr>
<td>LFib(^c)</td>
<td>0.595634</td>
<td>0.0913576</td>
<td>0.012673</td>
<td>0.000566</td>
</tr>
<tr>
<td>MSM</td>
<td>0.463678</td>
<td>0.001237</td>
<td>0.347851</td>
<td>0.000159</td>
</tr>
<tr>
<td>Choatic MSM(^d)</td>
<td>0.569766</td>
<td>0.066673</td>
<td>0.248649</td>
<td>0.000159</td>
</tr>
<tr>
<td>MPM</td>
<td>0.67364</td>
<td>0.087367</td>
<td>0.001267</td>
<td>0.000159</td>
</tr>
<tr>
<td>Choatic MPM(^d)</td>
<td>0.88383</td>
<td>0.283709</td>
<td>0.337328</td>
<td>0.000159</td>
</tr>
<tr>
<td>Fibonacci LFSR</td>
<td>0.578382</td>
<td>0.012343</td>
<td>0.859903</td>
<td>0.000159</td>
</tr>
<tr>
<td>Glaois LFSR</td>
<td>0.369001</td>
<td>0.155672</td>
<td>0.790510</td>
<td>0.000159</td>
</tr>
<tr>
<td>Choatic LFSR(^d)</td>
<td>0.425020</td>
<td>0.174249</td>
<td>0.967341</td>
<td>0.000159</td>
</tr>
</tbody>
</table>

\(^a\): (2\(^24\), 16598013, 12820163); \(^b\): (2\(^59\), 13\(^13\), 0); \(^c\): (2\(^31\), 55, 24); \(^d\): logistic map.
Comparison of test results with publication

Differences: real numbers (0,1) uniformly distributed, not bit sequence
MATLAB, Kasami and Gold are not tested
What LFSRs are tested?
Only 7 tests performed
Nonoverlapping Template Matching test not performed
Similarities - confirmation: Poor results on FFT tests for M and Galois.

Conclusion:
MATLAB PRBSG shows good results on NIST tests.
**MT circuit for bit sequence deserves to be built and studied.**
Circuits (LSFR, Galois) studied don’t achieve its performance.
SMIQ03B PRBSGs, especially the 21 bit are not especially successful.
Kasami needs to be studies for more polynomials..
Gold should be considered more seriously. The Improved one.
**CS needs its PRBSG on a circuit.**

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
Environment for design and test of Digital communication circuits

Galia Marinova¹, Zdravka Tchobanova · Simulation, Measurement and Test Environment for Pseudo Random Number Generator Circuits, IMEKO’2014, Benevento, Italy

Now student Krasimira on ERASMUS+ mobility in Benevento continues the research

Galois pseudo-random number generator described in VHDL, simulated, programmed on FPGA, measured and tested for uniformity of the sequence generated

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
Other applications: testing VHDL codes of convolutional coders and Viterbi decoders

Convolutional coder with $L=33$

Block diagram and circuit

Verification:
PRBSG + Convolutional coder + Noise + Viterbi decoder

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
Other applications of the results for PRBSG

- Equalizer,
- Cryptography,
- CS in Smart micro grids,
- etc.
This platform is developed to integrate more than **250 online tools**, which are first studied, tested, selected and provided with **unified passports** in order to be used for solving design tasks in communications.

**Cloud technologies** are used to share designs and documents connected to the use of the tools integrated in the platform.
Motivation

• Boom of free online tools and full platforms
• Open source platforms

• CAD tool providers are reacting – Cadence EDA360 vision for integration and Software defined design of hardware

• The first version of the portal we created was in Bulgarian language and we received lots of demands to provide an English version
Structure of ONLINE-CADCOM Panels on the home page

G. Marinova, O. Chikov, Methodology for tools integration in the Online assisted Platform for Computer-aided design in communications, ICEST’2015, 24-26 June 2015, Sofia, Bulgaria

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
In Panels CAD tools are classified in categories. Categories of online CAD tools in Panel 1 are:

- RF and microwave design (*RF/MW*);
- Antenna design (*Ant*);
- Audio design (*Aud*);
- Analog design (*A*);
- Interface circuit design of ADC, DAC, etc. (*Int*)
- Digital design (*D*);
- Power supply design (*PS*).

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
Categories of online CAD tools in Panel 2:

- Printed circuit board design (PCB);
- Elements - resistors, capacitors, inductors, transformers, crystal oscillators, heat-sinks, etc. (Elem);
- Electric installation design (EI);
- Nanotechnology design (Nano);
- Outcome to prototype - Development boards, PCBs, FPGA/CPLDs, USRPs, Arduino controller, etc. (P).
# Tools characterization passports in Online-CADCOM

## Table 1. Characterization passport of online CAD tools

<table>
<thead>
<tr>
<th>Type of Online CAD tool</th>
<th>Online calculator</th>
<th>Online platform</th>
<th>Module in Online Platform</th>
<th>Free downloadable tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel/Category</td>
<td>Panel 1, 2</td>
<td>Categories from Fig.1 (Ant, Aud, RF/MW, A, Int, D, PS, PCB, Elem, EL, Nano, P)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Application area</td>
<td>Subcategories</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Functions</td>
<td>Parameter calculation, Behavior, Synthesis, Analysis, Topology, Topology - Behavior Extraction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Levels of abstraction covered</td>
<td>Transistor, Logic, RTL, Architecture, System</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connections Input/output</td>
<td>List of input and output connections to other online CAD tools</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verification tool</td>
<td>Simulator with high level of reliability which can verify the online tool results, ex.: ORCAD/PSpice, MATLAB, etc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equivalence or application area coverage</td>
<td>Sets of online CAD tools with application area equivalence or overlap</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Qualitative Features</td>
<td>Theory fundament provided, Friendly interface, Graphical illustrations, Traces and Waveforms building, Animation, 3D</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantitative features</td>
<td>Number of parameters calculated, Number of modules in a platform, Number of circuits, ICs or topologies in a data base, Number of models, Number of elements, Number of component providers</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
Examples of Equivalence, Overlapping and connections

Fig. 2. Equivalence, functional area overlapping and connections of online tools for filter design

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
Additional options and software realization

Online-CADCOM develops and supports:

• Documents and links to Standards, Protocols and Specifications;
• Links to portals and platforms;
• Knowledge base containing E-learning content, Tutorials for complex task solutions in the multitool environment, Design Projects, Glossary;
• Economical estimation;
• Outcome to prototype;
• Links to Optimization tools.

These options are positioned in a separate left Panel 3 on home page.

Software realization: Ognyan Chikov

Online-CADCOM is developed using HTML and PHP languages and MySQL for the Database. The software architecture template MVC Framework is applied to separate Model, View and Controller parts. The Content management system permits the actualization of the platform independent of the web developer. The language CSS is used for the interface style.

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
Some examples

Ex.1. PORTALS for SDR

OPEN SOURCE

• GNURADIO

• OSSIE - SCA-Based Open Source Software Defined Radio
  http://ossie.wireless.vt.edu/
  at Wireless@Virginia Tech
  SCA – Software communications architecture

With license

• LABVIEW

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Ex.2. SmartCircuitCalc – Online circuit calculator developed as a final thesis project


Hartley oscillator circuit designed in SmartCircuitCalc and then simulated in ORCAD/Capture and ORCAD/PSpice environment
Colpits oscillator circuit designed in SmartCircuitCalc and simulated in PSpice

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
Ex.3. Bandstop filter synthesized in Webench power designer then verified in Cadence/ORCAD/Pspice

Gain and phase in frequency domain for the band stop filter in Webench Power Architect tool

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
Electrical circuit of the Bandstop filter in ORCAD Capture 16.6

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
Ex.4. Design of SMPS for μP and FPGA in Webench Power Architect

- Analysis of different architectures of the power supply of a μP

Comparison of efficiency, footprint and cost of 3 architectures

Sequencing

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
Ex.4. SMPS designs for the notebook in PowerEsim

www.poweresim.com

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1. Buck PNP

2. Dual VIN Sync-Buck

3. Sync. Buck DC-DC

4. Buck DC-DC

5. Flyback AC/DC

---

Topologies and efficiency coefficients of the SMPS designs in PowerEsim:

<table>
<thead>
<tr>
<th>SMPS topology in PowerEsim</th>
<th>Efficiency coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buck PNP</td>
<td>67%</td>
</tr>
<tr>
<td>Dual VIN Sync Buck</td>
<td>5%</td>
</tr>
<tr>
<td>Sync Buck DC-DC</td>
<td>33%</td>
</tr>
<tr>
<td>Buck DC-DC</td>
<td>87%</td>
</tr>
<tr>
<td>Flyback AC/DC</td>
<td>85.58%</td>
</tr>
</tbody>
</table>

---

G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
Unique design solution for the SMPS for a notebook in Webench Power Architect
Ex. 5. A PROMETHEE – Based Approach for Multiple Objective Voltage Regulator Optimization


G. Marinova, SCEE seminar, SUPELEC, Rennes, 18.06.2015
Ex.6. Hierarchical projects in Cadence ORCAD design suit 16.6 - Intelligent pdf file creation in ORCAD Cloud
Welcome to Online-CADCOM
Online assisted Platform for Computer-aided design in communications
## PCB Design tools category and Passport of the tool Saturn

### PCB Design

<table>
<thead>
<tr>
<th>Tool Name</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>SATURN PCB DESIGN TOCTRL</td>
<td><img src="image1" alt="SATURN PCB DESIGN TOCTRL" /></td>
</tr>
<tr>
<td>TECHNIK</td>
<td><img src="image2" alt="TECHNIK" /></td>
</tr>
<tr>
<td>SELEKTRONIK</td>
<td><img src="image3" alt="SELEKTRONIK" /></td>
</tr>
<tr>
<td>WORDPRESS</td>
<td><img src="image4" alt="WORDPRESS" /></td>
</tr>
<tr>
<td>EMLAB</td>
<td><img src="image5" alt="EMLAB" /></td>
</tr>
<tr>
<td>TI PCB THERMAL CALCULATOR</td>
<td><img src="image6" alt="TI PCB THERMAL CALCULATOR" /></td>
</tr>
<tr>
<td>EEWEB</td>
<td><img src="image7" alt="EEWEB" /></td>
</tr>
</tbody>
</table>

### Tool Passport

<table>
<thead>
<tr>
<th>Type of Online CAD tool</th>
<th>Online Calculator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel/Category</td>
<td>Panel 2, PCB Design</td>
</tr>
<tr>
<td>Application Area</td>
<td>PCB Design</td>
</tr>
<tr>
<td>Functions</td>
<td>Parameter Calculation</td>
</tr>
<tr>
<td>Levels of abstraction covered</td>
<td>Transistor</td>
</tr>
<tr>
<td>Connections Input/Output</td>
<td>OrCAD Layout/ OrCAD PSpice</td>
</tr>
<tr>
<td>Verification tool</td>
<td>Saturn PCB Design</td>
</tr>
<tr>
<td>Equivalence or application area coverage</td>
<td>Saturn PCB Design; EMC Lab; Seletronik; Technik impedance calculator; JPC Microstrip &amp; Stripline calculator;</td>
</tr>
<tr>
<td>Qualitative Features</td>
<td>Saturn PCB Design; EMC Lab; Seletronik; Technik impedance calculator; JPC Microstrip &amp; Stripline calculator;</td>
</tr>
<tr>
<td>Quantitative Features</td>
<td>Number of parameters calculated: 18; Number of modules in a platform: 9; Number of topologies: 9 PCB topologies;</td>
</tr>
</tbody>
</table>

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III. Nanocommunication devices and networks
Master “Microtechnologies and nanoengineering”, compulsory

• Inspired by the course Nanocommunication networks in the Nanocommunications center in Tampere University of Technology, Finland


• Authors and Lecturers: Dr. Ian F. Akyildiz, Dr. Yevgeni Koucheryavy, Sasitharan Balasubramaniam, Dr. Olga Kara, Ali Barbar, Dmitri Moltchanov and alt.

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Nanocommunication devices and networks
Master “Microtechnologies and nanoengineering”, compulsory

Nanocommunication networks
The classical paradigm of communications requires full revision at nano-level.

2 main ways of communications:
• Based on electromagnetic communication
• Based on molecular communication (bacterial, neural, DNA)
Two ways of electromagnetic communication

- **Nanotube radio** can receive and demodulate electromagnetic wave – electromagnetic vibrating carbon nanotube, can decode amplitude and frequency modulated wave.

- **Nano-antennas** from graphene for potential electromagnetic transmitters in the **Tera Herz band**.

**From 0.3 to 3 THz**, 1 THz = 10^{12} Hz. Wavelength of the emission in the tera Herz band are respectively from 1 mm to 0.1 mm (or 100 μm).
Electronic nano devices and chips

The advance in **carbon and molecular electronics** created a new generation of electronic components at nanolevel:

- Nano bateries
- Nano **energy harvesting systems**
- Nano memories
- Logical circuits at nanolevel
- Nano antenans.

- **Human organes-on-a-chip.**

http://wyss.harvard.edu

Lung-on-a-chip
All the theory of communications has to be rethought and reinvented
Possible new modulation techniques and capacity analysis

New **modulation scheme** based on the exchange of femtosecond-long pulses, spread in time:

**TS-OOK (Time Spread On/Off Keying Mechanism)**

- New **protocol**
  - Time between pulses $\gg$ Pulse width
  - Permits the simultaneous transmission from different users, almost without collisions
  - Performance analysis in terms of individual user achievable information rate and network capacity

– New **statistical model of interference in the THz band** is developed.

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Possible new modulation techniques and capacity analysis

A logical “1” is encoded with a pulse:
- Pulse length: $T_p = 100$ fs
- Pulse energy: $< 1$ pJ

A logical “0” is encoded with silence:
- Ideally no energy is consumed!!!
- After an initialization preamble, silence is interpreted as 0s

Pulses are spread in time to simplify the transceiver architecture


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Modulations and protocols

Time Spread On-Off Keying (TS-OOK) Protocol


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Nanotube radio

Block diagram for a traditional radio. All four essential components of a radio, antenna, tuner, amplifier, and demodulator may be implemented with a single carbon nanotube.


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Schematic of the nanotube radio and Transmission electron micrographs

(a) Schematic of the nanotube radio. Radiotransmissions tuned to the nanotube resonance frequency force the charged nanotube to vibrate. Field emission of electrons from the tip of the nanotube is used to detect the vibrations and also to amplify and to demodulate the signal. A current measuring device such as sensitive speaker, monitors the output of the radio.

(b) Transmission electron micrographs of a nanotube radio off and on resonance during a radio transmission.


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Illustration of nanotube radio functionality

Emitted and received audio waveforms and frequency spectrum for 2 s. of the song “Good Vibrations” of Beach Boys.

Nanotube radio reproduces correctly the audio signal and the song can easily be recognized by ear (audio files are available in Supporting Information) to the article.

http://pubs.acs.org/doi/suppl/10.1021/nl0721113

Application of nanocommunications and which tools?

INTERNET of nanoThings

• Body area network
• Smart cities

WHICH TOOLS to use for the new course?

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Tools used for exercises in the course “Nanocommunications devices and networks”

Fullerene and nanotube design in Nanotube Modeler

DNA assembly in Molecular Origami (Wyss, Harvard)

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Tools used for exercises in the course “Nanocommunications devices and networks”

Antenna design in AMANOGAWA

Peptide dynamics simulation and temperature simulation in NanoEngineer

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Simulations in Nanohub
https://nanohub.org/

V-A curve of a memristor in NanoHub
Cadence ORCAD/PSpice, also

Power of a piezogenerator in NanoHub

+ COMSOL MULTIPHYSICS licences
interface with MATLAB

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International cooperation
Students from India on internship in TUS

ERASMUS+ projects 2014-2020

- University Sannio, Benevento, Italy,
- Ecole Supérieure d’Electricité (SUPELEC), Rennes, France
- University Leibnitz, Hannover, Germany
- Universita Politecnica de Cataluny,a, Barcelona, Spain.

RILA project – 2015-2016, PHC

USRP-BASED SDR FOR COGNITIVE RADIO:
PLATFORM FOR COOPERATIVE SPECTRUM
SENSING AND PRIMARY USER LOCALIZATION
(PSULO)

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International cooperation
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THANK YOU!