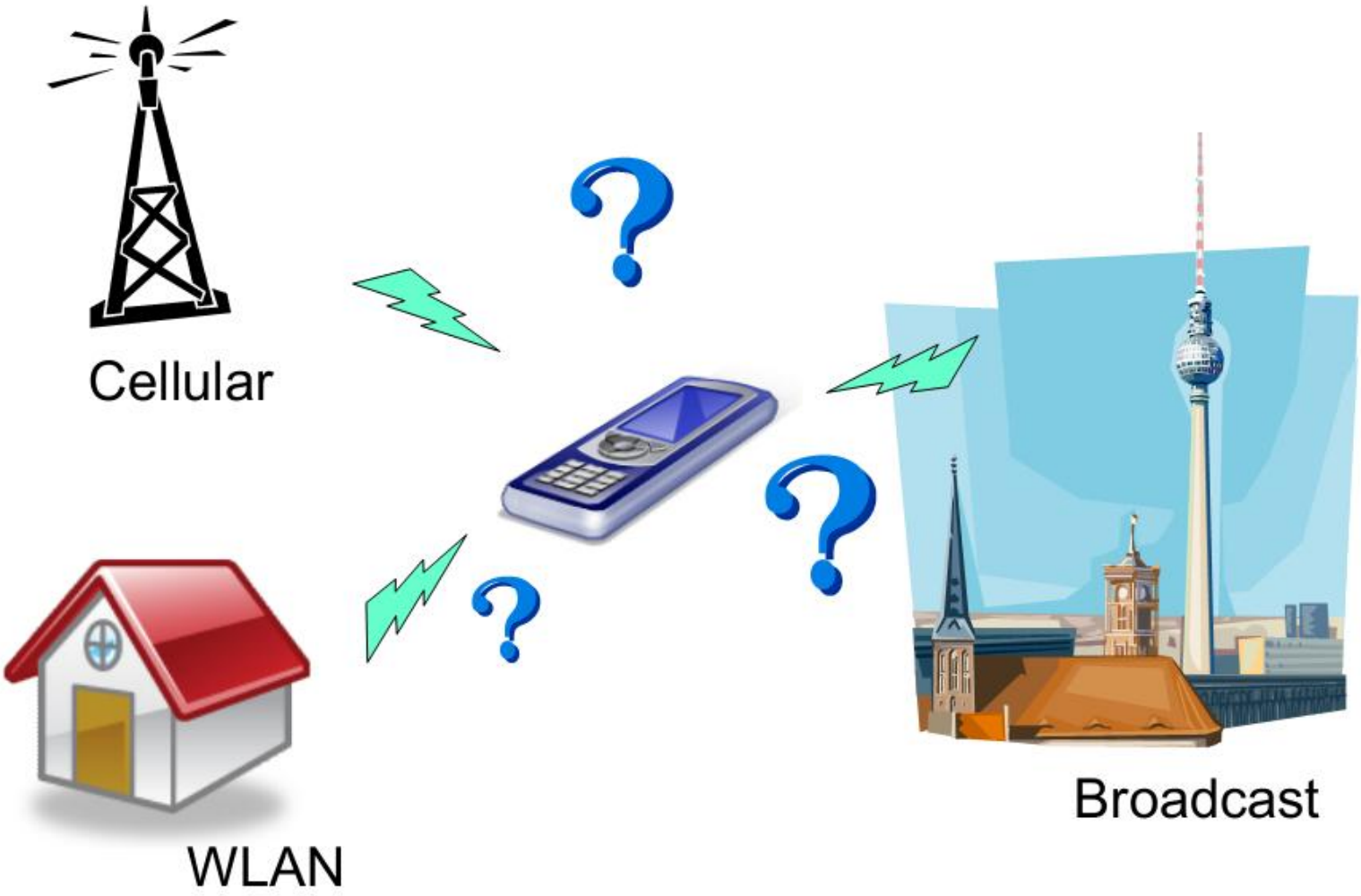
A VERSATILE SPECTRUM SENSING ENGINE FOR MOBILE DEVICES

CREW TRAINING DAYS, BRUSSELS, FEBRUARY 2013

MATTIAS DESMET, IMEC

imec

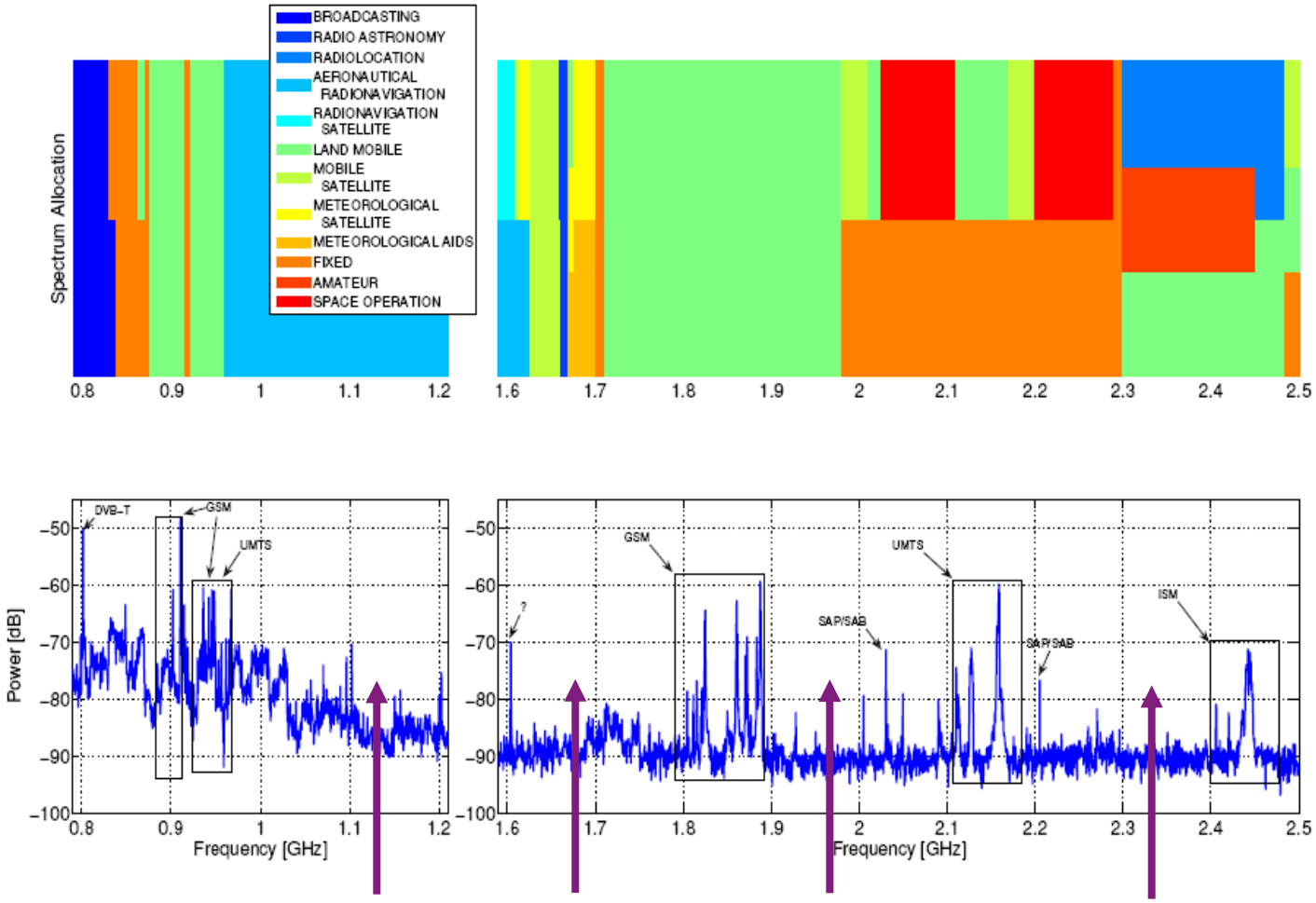
“EVERYTHING IS WIRELESS”



HIGHER ENERGY EFFICIENCY IS NEEDED

Source: J. Glossner: Trends in Low Power Handset Software Defined Radio, 2007

ALLOCATED SPECTRUM USAGE



SENSING @ IMEC

- Opportunistic spectrum access
- No sensing = no cognitive radio
- To measure is to know
- Sensing data is outdated immediately

MULTI-BAND SPECTRUM SENSING

- Analog front-end
  - Small area, low power
  - Highly reconfigurable
  - Low LO settling time
- Digital front-end
  - Small area, low power
  - Filtering, auto/cross-correlation, Multi-band energy detection
- Functionality
  - Low power

OVERVIEW

- Introduction
- **Purpose of imec's Sensing Engine**
- Overview of the different components
- Different modes of operation
  - Specifications
  - Generated output
- Examples of usage
- Hands-on / demonstration

PURPOSE OF IMEC'S SENSING ENGINE IN WILAB

- Provide ready-for-use flexible sensing solution
- Easy accessible and configurable
- Controllable environment

- Generate sensing data for
  - testing or verifying postprocessing functionality
  - evaluation or characterization of different scenario's

- Allow implementation of sensing algorithms and techniques

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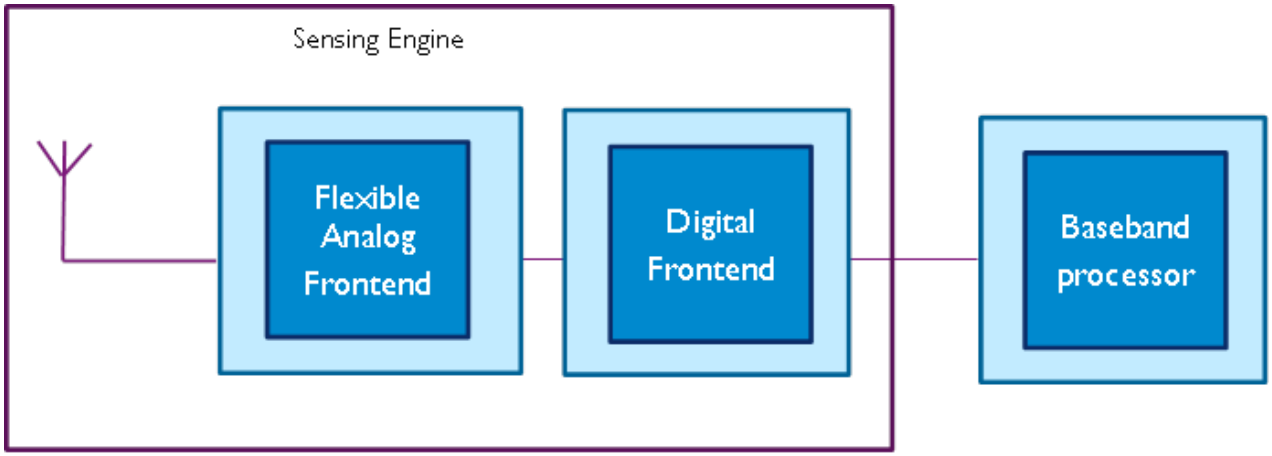
OVERVIEW OF THE DIFFERENT COMPONENTS

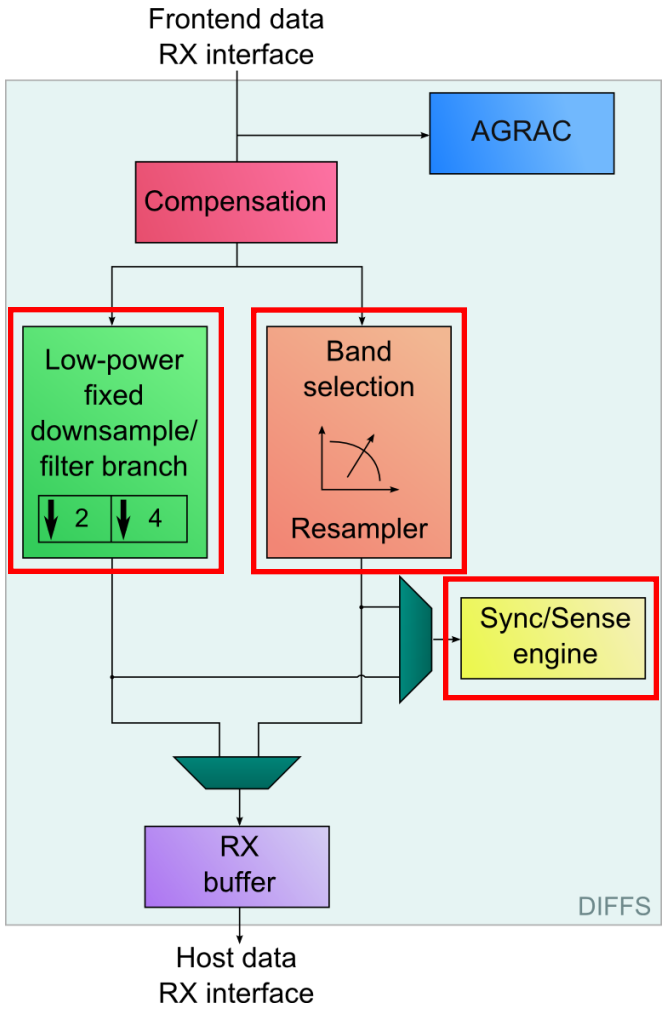
- DIFFS
- Spider
- Scaldio
- WARP



OVERVIEW OF THE DIFFERENT COMPONENTS: DIFFS

- Digital Frontend for Spectrum Sensing

SENSING-ENABLED DFE READY FOR THE FUTURE

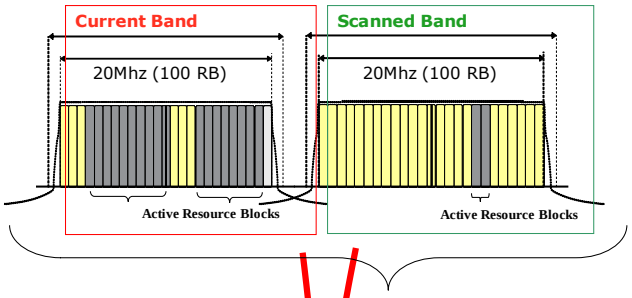


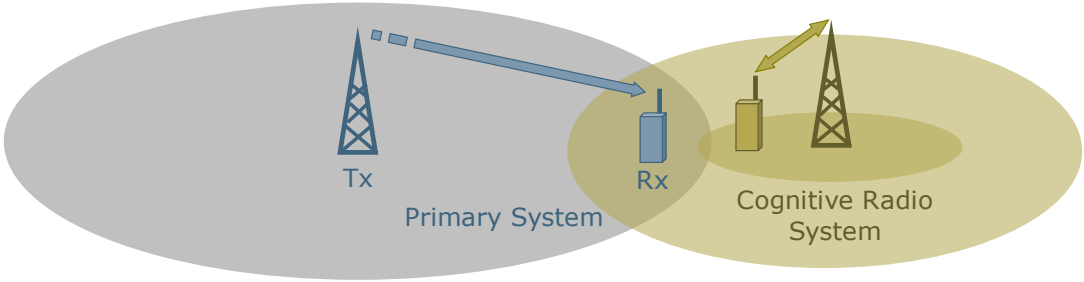
Low-power synchronization

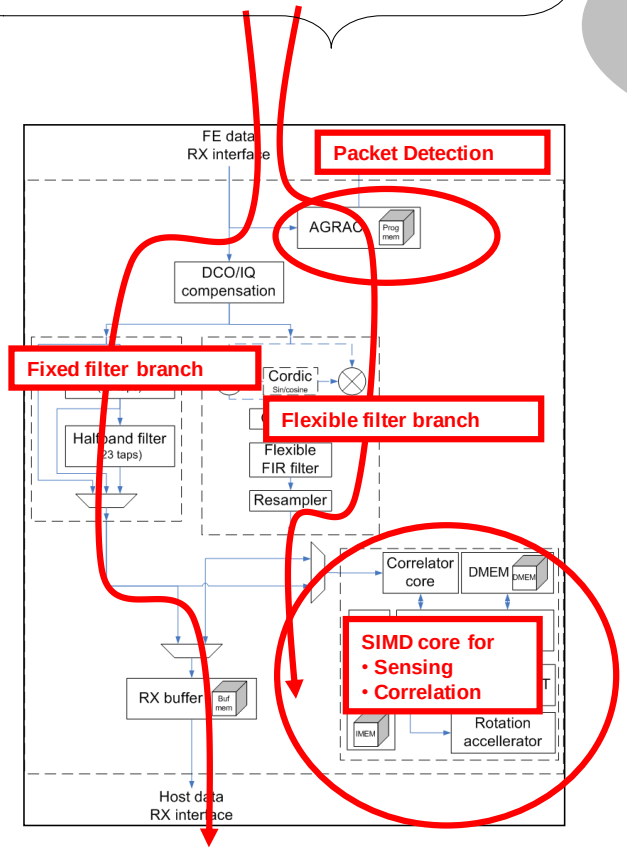
Flexible filter/mixer/resampler
- support for ΣΔ
- future standards
- concurrent reception/sensing

Sync/sense engine: SIMD
- dedicated accelerator cores
- capable of "sensing" + "syncing"

A KEY ENABLER FOR CR SYSTEMS







E.g. LTE neighboring cell detection

E.g. 802.11af support

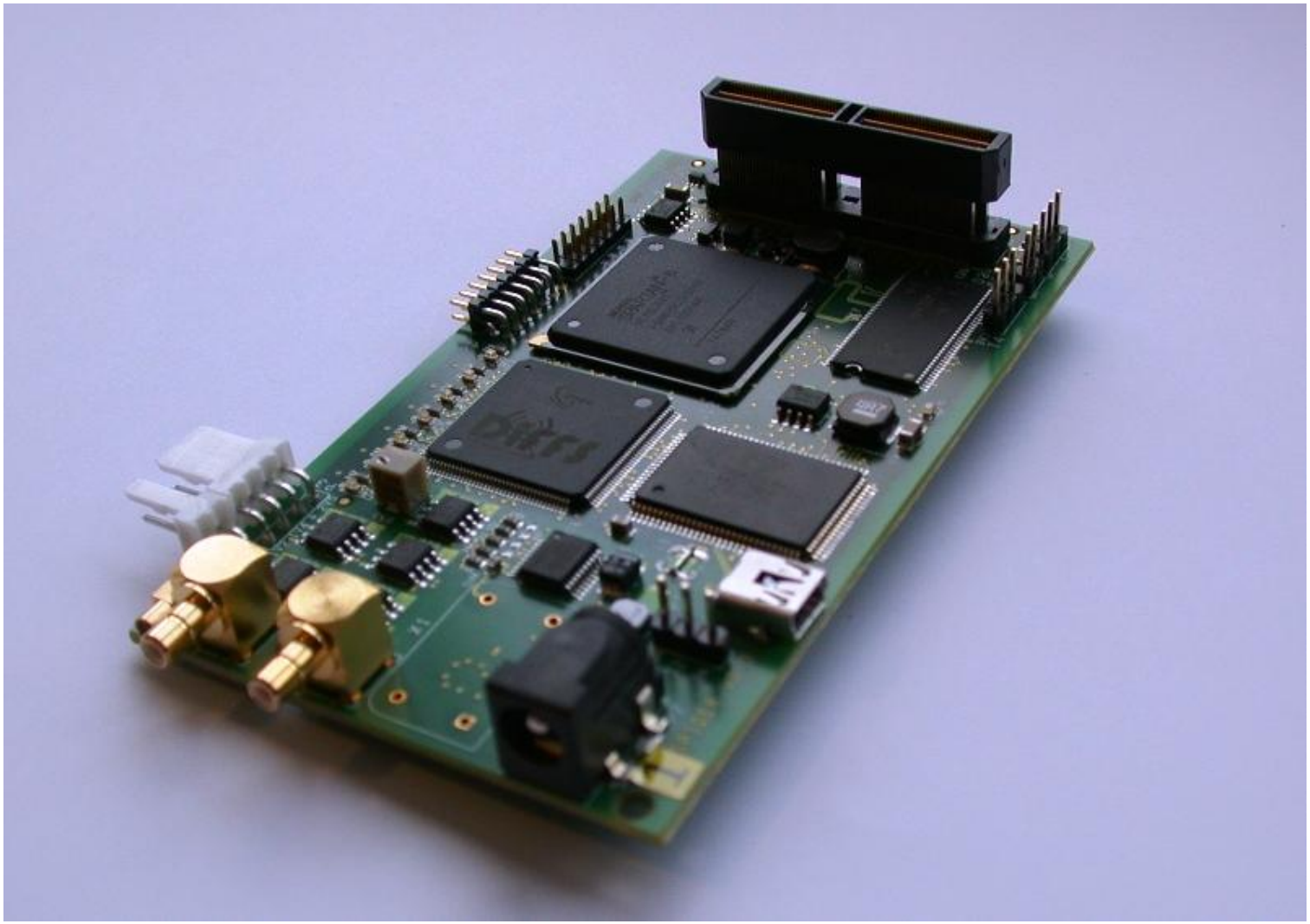
DIFFS POWER RESULTS

Excellent match with postlayout figures

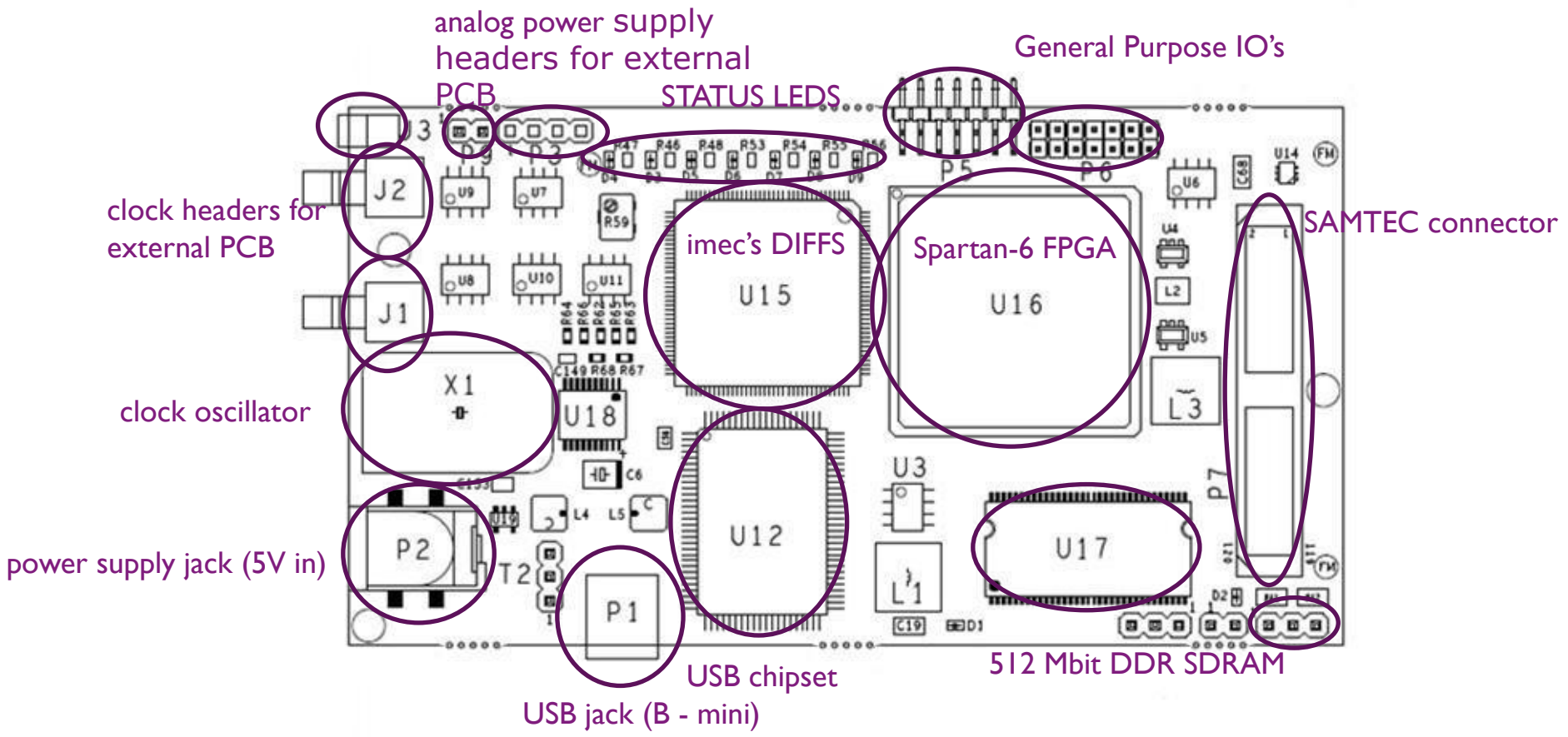
Mode	Postlayout (mW)	Measured (mW)	DFE 90 nm (mW)
Leakage	1.2	1	-
WLAN wait	2.6	3	16
WLAN sync	4.7	5	35
LTE sync	21.2	23	-
DVB cyclostat	6.5	8	-
LTE sensing	19.8	21	-

All functional modes have been verified on the hardware with generated signals.

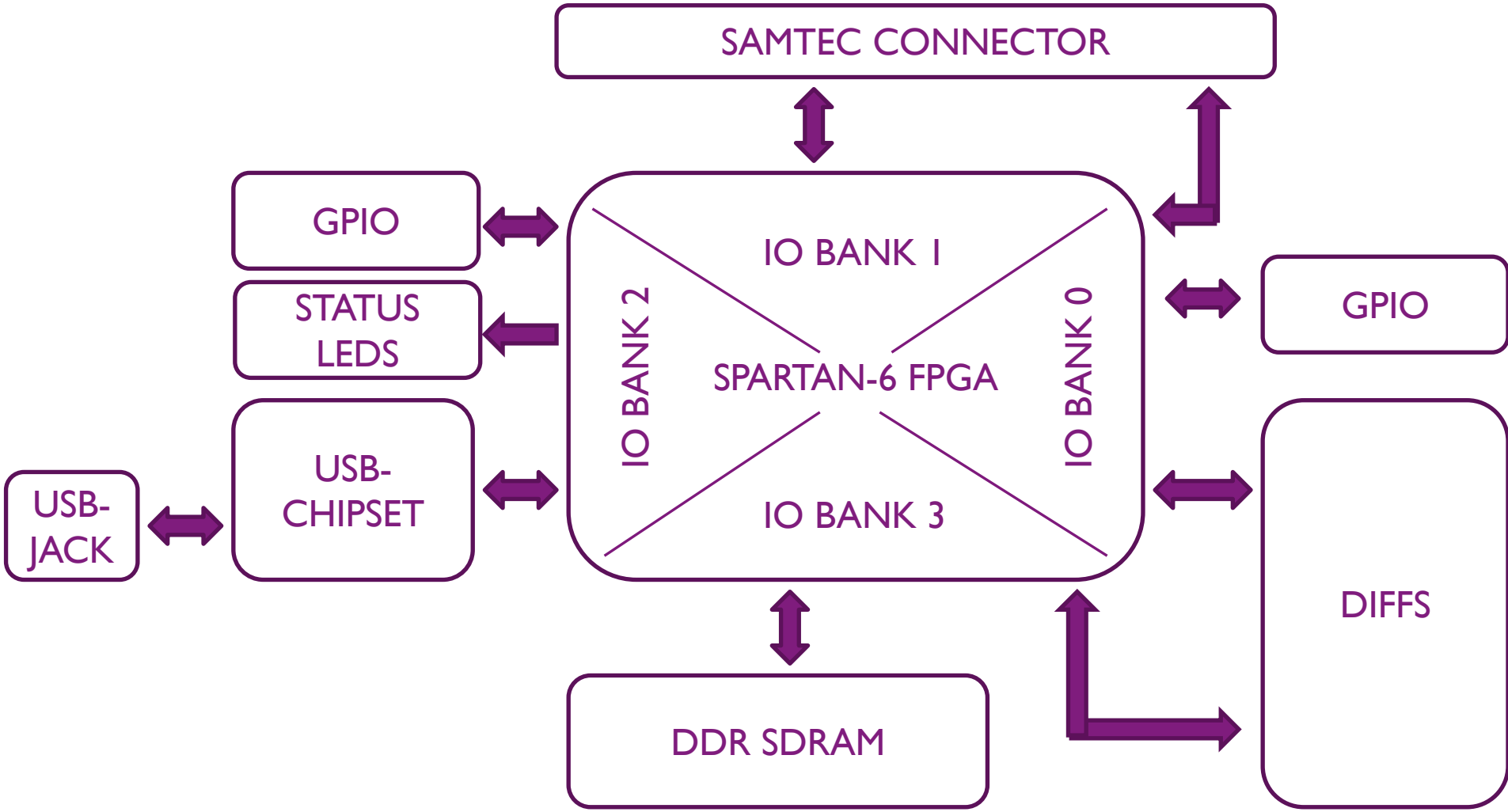
OVERVIEW OF THE DIFFERENT COMPONENTS: SPIDER



COMPONENTS



FUNCTIONALITY (1): FPGA CONNECTIONS



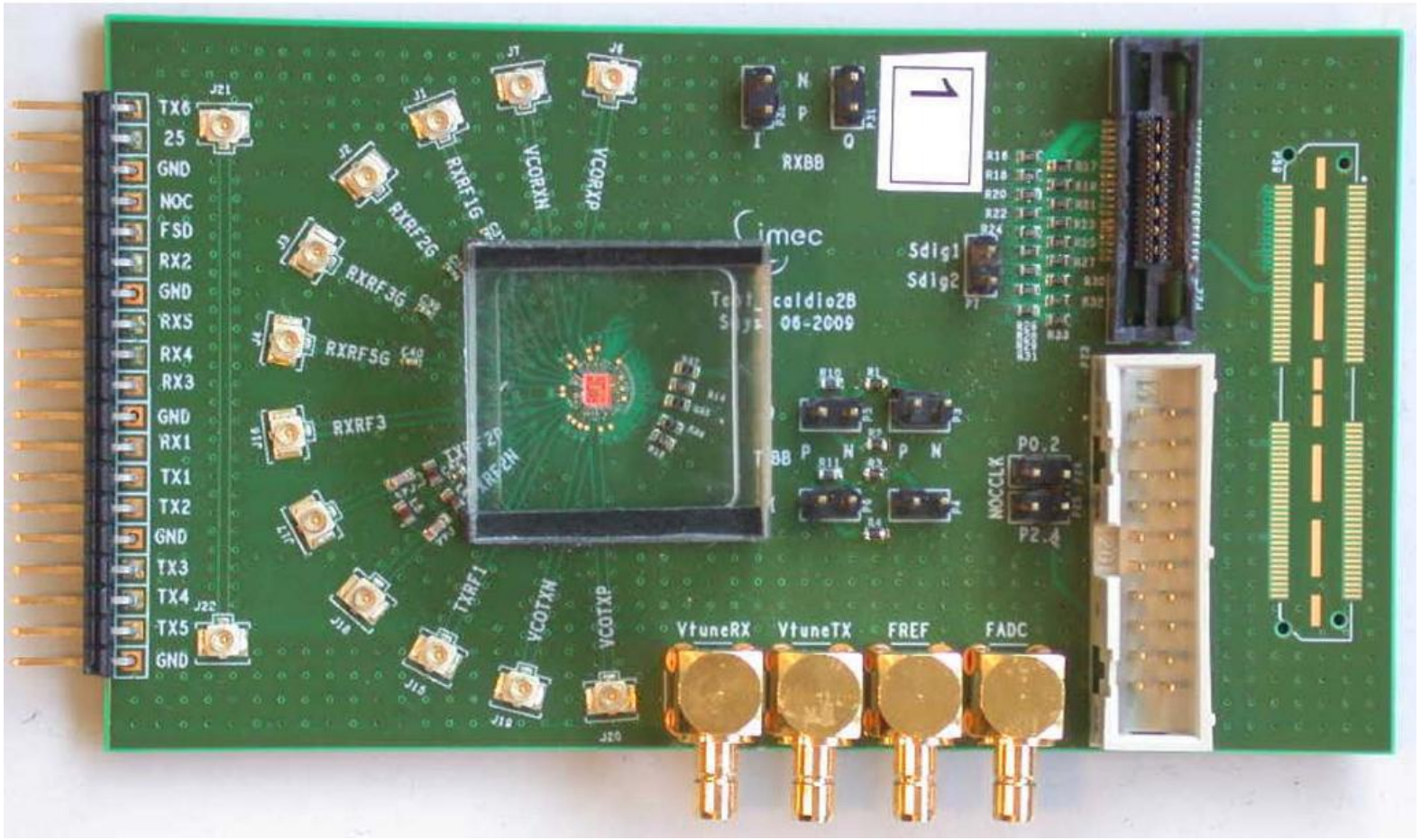
FUNCTIONALITY (2): CONNECTIVITY

- USB-interface
  - FPGA-interface burst rate up to 57 Mbyte/s (16bit @ 30MHz)
  - feeds 2.5 W @ 5 V to the board
- clocking
  - clock oscillator socket (input clocks up to 133 MHz)
  - 2 SMB jacks & 1 MMCX jack (copies of oscillator clock)
- power supply connectors
  - 5 V – GND header
  - 1.2 V – 1.4 V – 2.5 V – GND header

FUNCTIONALITY (3): CONNECTIVITY

- SAMTEC 120 pin connector
  - 2 pins with LVPECL clock (copy of oscillator clock)
  - 5 pins connected to Bank 0 of the FPGA (VCCIO = 2.5 V)
  - 112 pins connected to Bank 1 of the FPGA (VCCIO selectable from 2.5 V and 3.3 V through jumper T4)
  - 1 pin indicating the selected VCCIO
- GPIO
  - 4 connected to Bank 0 (VCCIO = 2.5 V)
  - 8 connected to Bank 2 (VCCIO = 3.3 V)

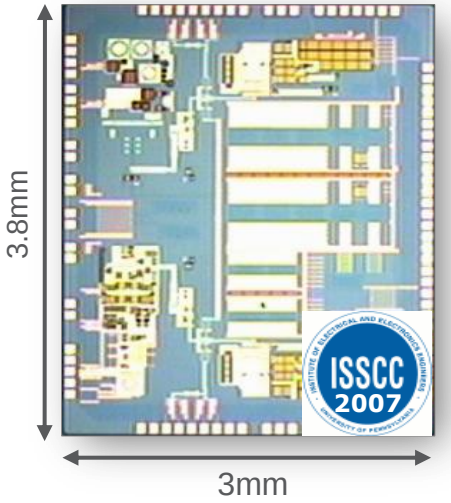
OVERVIEW OF THE DIFFERENT COMPONENTS: SCALDIO



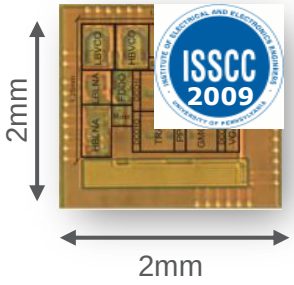
IMEC'S SCALABLE RADIOS
AN OUTSTANDING FAMILY

2006 | 2008 | 2009 | 2010

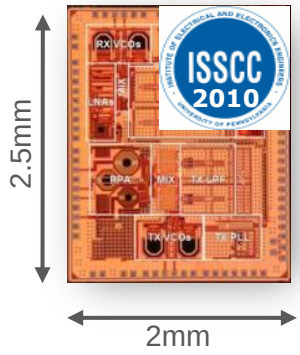
130nm



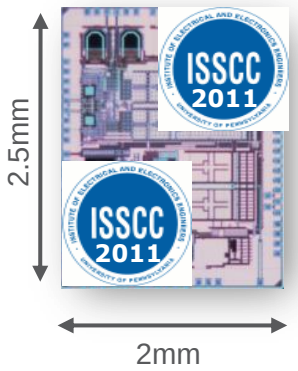
45nm



40nm



40nm



Scaldio-1
World's first SDR front-end

130nm digital CMOS 1.2V

Tx:	0.8-5GHz
Rx:	0.1-5GHz
2x PLL:	0.1-5.5GHz
Pdc:	50-130mW

Scaldio-2A
SDR Rx with power, area & performance competitive to SotA single- mode

45nm digital CMOS 1.1V

Rx:	0.1-6GHz
PLL:	0.1-6GHz
Pdc:	50-110mW

Scaldio-2B
5 mm^2 SDR transceiver incl. ADC competitive to SotA single-mode

40nm LP CMOS 1.1/2.5V

Tx:	0.8-2.8GHz
Rx:	0.1-5GHz
2x PLL:	0.1-6GHz
Pdc:	50-150mW

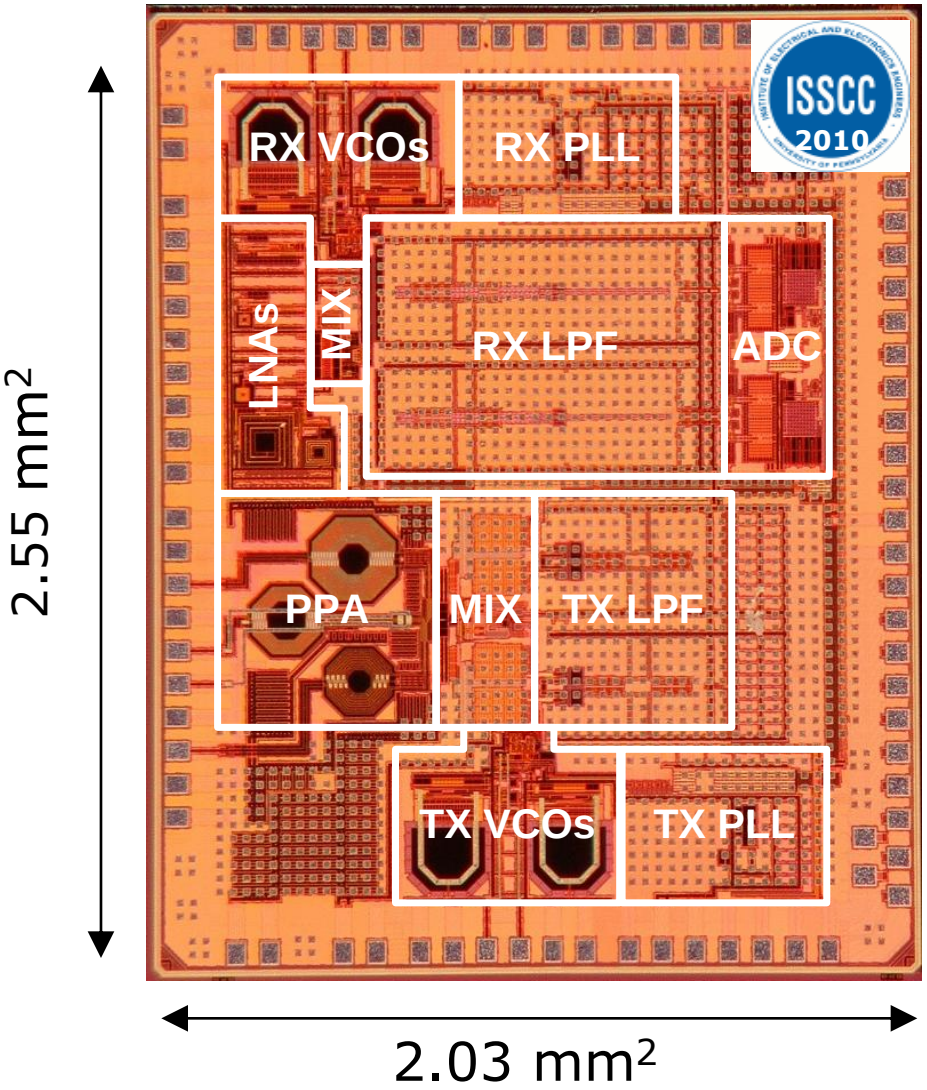
Scaldio-2C
SAW-less SDR transceiver incl. low-noise Tx and highly linear Rx

40nm LP CMOS 1.1/2.5V

Transmitter:	0.5-5.5GHz
Receiver:	0.4-6GHz
2x PLL:	0.1-6GHz
Pdc:	50-150mW

SCALDIO-2B: A 5 MM^2 RECONFIGURABLE TRANSCEIVER IN 40NM CMOS (TAPE-OUT APRIL 09)

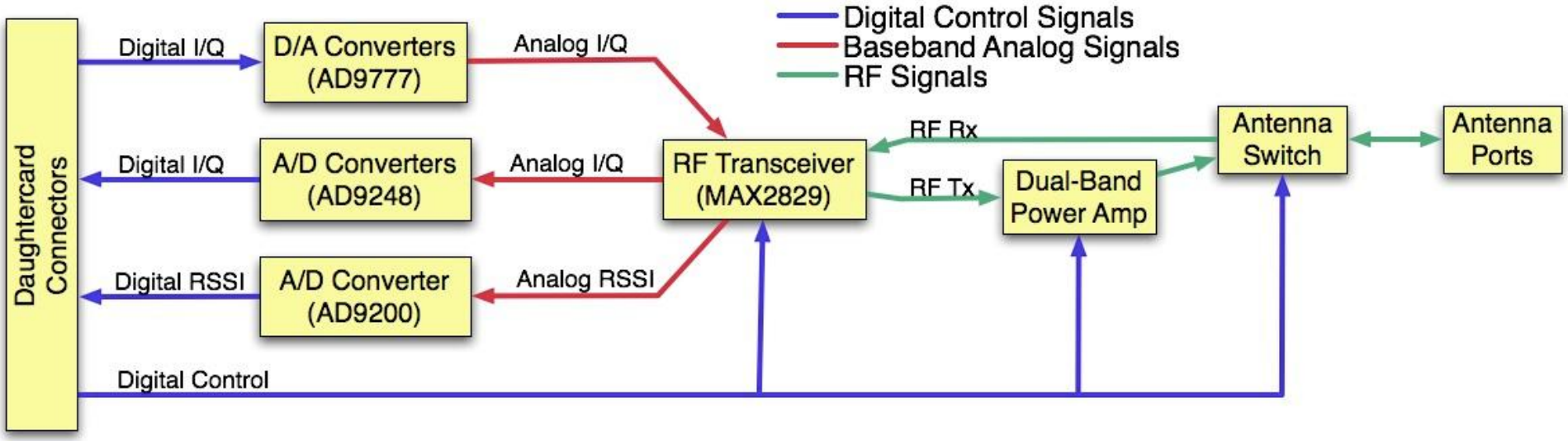
- Low Noise Direct Up-conversion full transmitter
  - Out-of-band noise floor compatible with SAW-less WCDMA/LTE requirements
- Improved receiver incl. ADC
  - Improved linearity
  - On-Chip 10b 65MS/s SAR ADC
- With performance, power and area competitive with SotA single-mode radios
  - Area: 5mm^2 (incl. 2 Freq synth,ADC)
  - Power: 40 – 100mW, depending on mode
- 40nm digital 1.1/2.5V CMOS TSMC technology



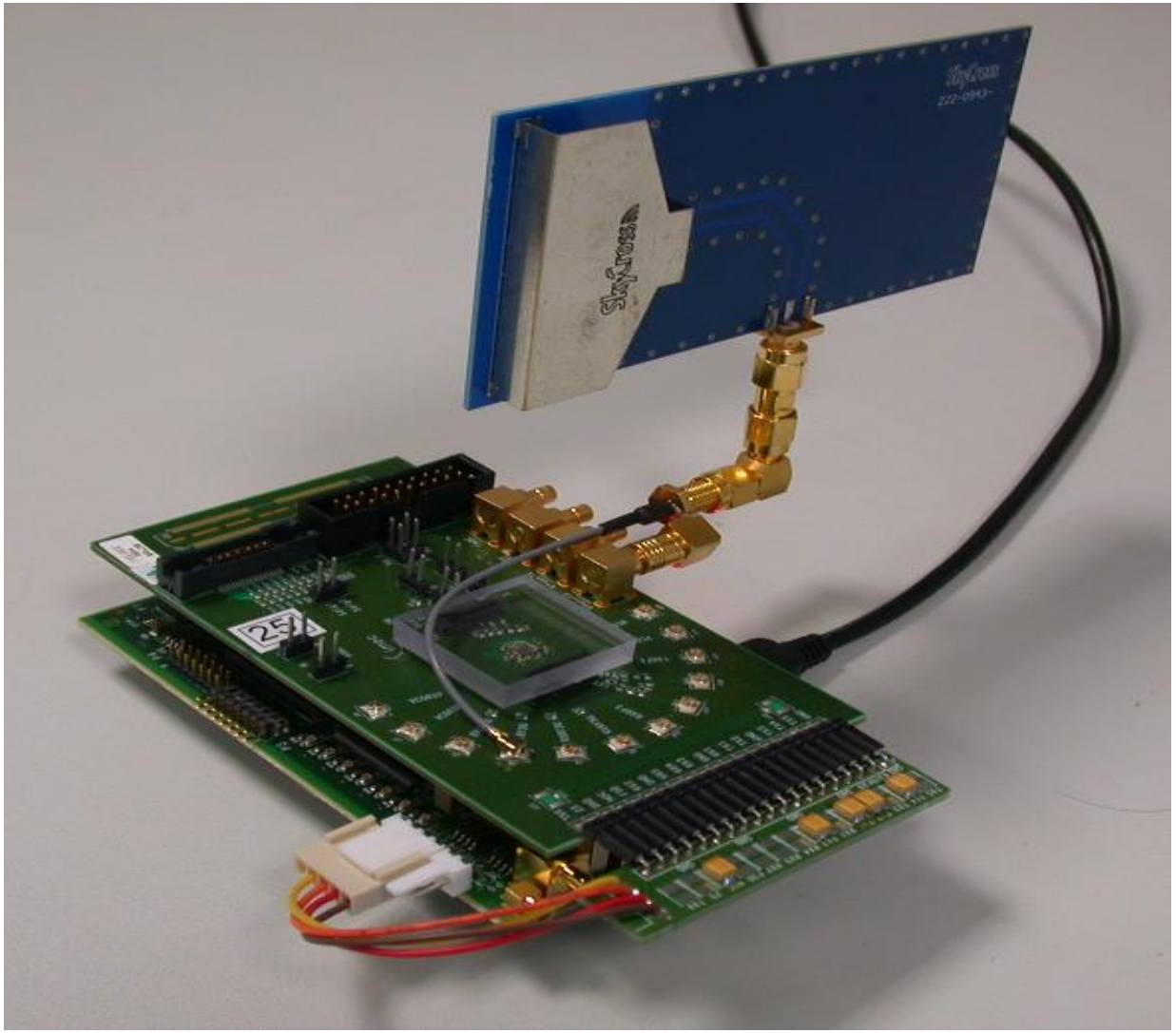
OVERVIEW OF THE DIFFERENT COMPONENTS: WARP

WARP RADIO BOARD

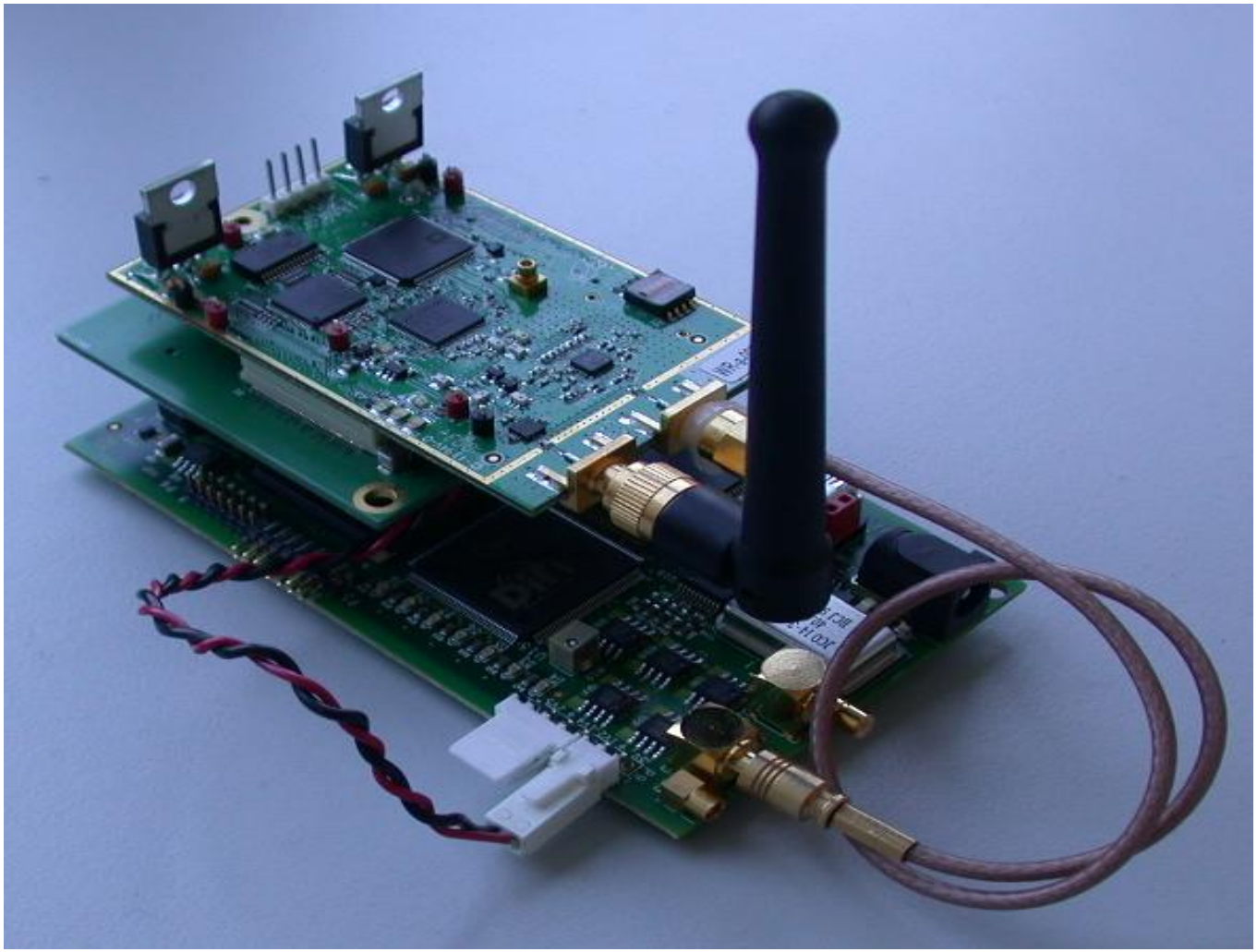
- Wireless Open Access Research Platform developed at Rice University
- Dual-band IEEE 802.11a/b/g Transceiver
- 2 antenna ports, MIMO capable
- On board DAC, ADC, RSSI ADC and dual band PA



SENSING ENGINE WITH SCALDIO



SENSING ENGINE WITH WARP RADIO BOARD



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DIFFERENT MODES OF OPERATION

- FFT-sweep
  - Full Analog Frontend frequency range
    - 500 MHz – 6 GHz for Scaldio
    - 2.4 GHz – 2.5 GHz and 4.9 GHz – 5.875 GHz for WARP Radio board
  - 128-points hardware accelerated FFT for each 20 MHz subband (“channel”)
  - Programmable RX gain

- Output:
  - Power value in dBm
  - 128 bins per channel

DIFFERENT MODES OF OPERATION

- WLAN-G
  - IEEE 802.11g power assessment
    - 14 channels
    - Accumulated power value for x samples
  - Fast reconfiguration and "processing"
  - Programmable RX gain
  - Programmable threshold

- Output:
  - 1 dimensionless power value per channel
  - Binary comparison to threshold

DIFFERENT MODES OF OPERATION

- WLAN-A
  - IEEE 802.11a power assessment
    - 23 channels
    - Accumulated power value for x samples
  - Fast reconfiguration and "processing"
  - Programmable RX gain
  - Programmable threshold

- Output:
  - 1 dimensionless power value per channel
  - Binary comparison to threshold

DIFFERENT MODES OF OPERATION

- Zigbee
  - IEEE 802.15.4 power assessment
    - 16 channels
    - Accumulated power value for x samples
  - Fast reconfiguration and "processing"
  - Programmable RX gain
  - Programmable threshold

- Output:
  - 1 dimensionless power value per channel
  - Binary comparison to threshold

DIFFERENT MODES OF OPERATION

- Other sensing modes, not (yet) available on CREW Sensing Engine
  - DVB-T cyclostationary detection
  - Other FFT-sweep modes (16/32/64 points)
  - IEEE 802.15.1 Bluetooth sensing
  - ADC-samples logging
  - ...

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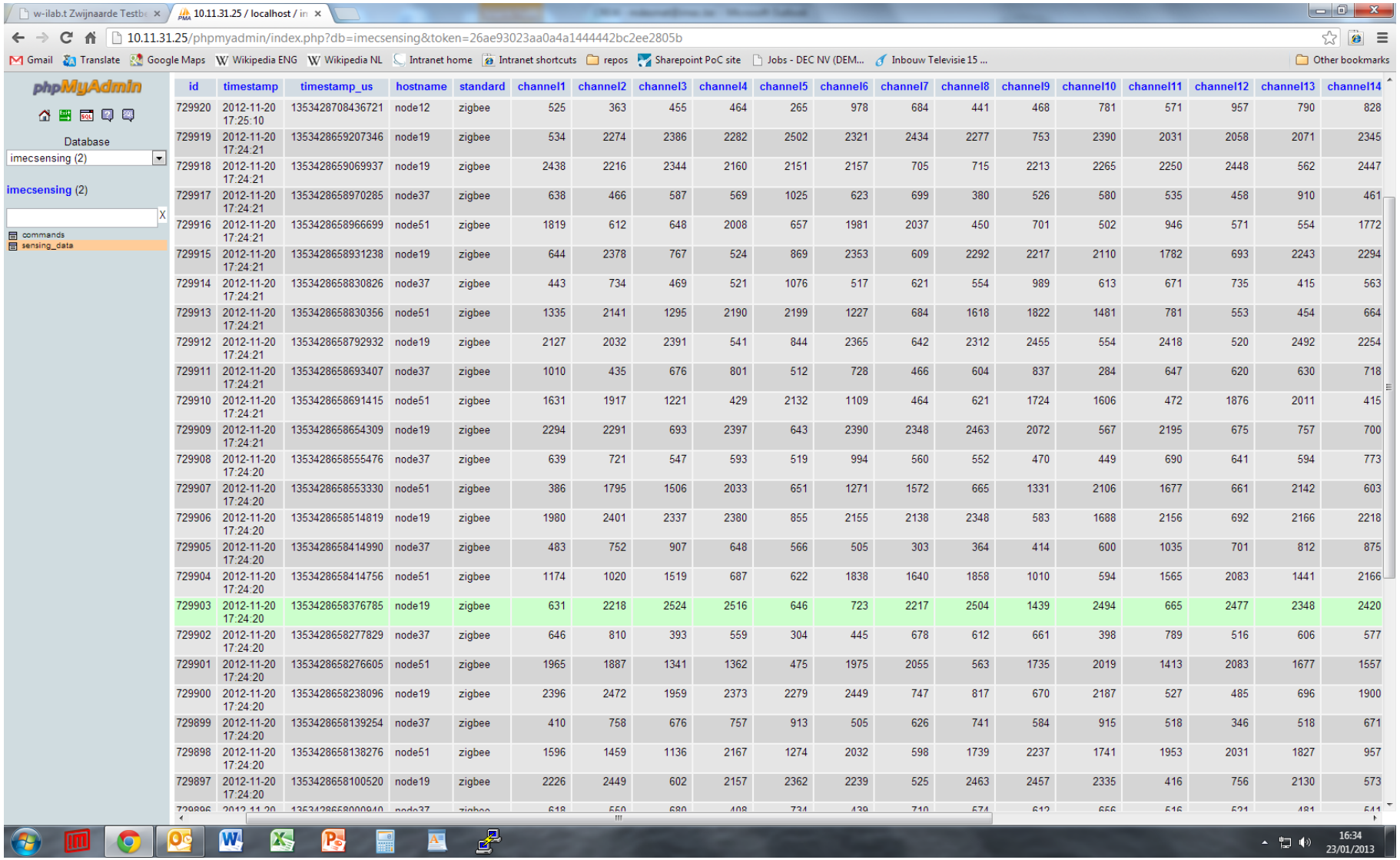
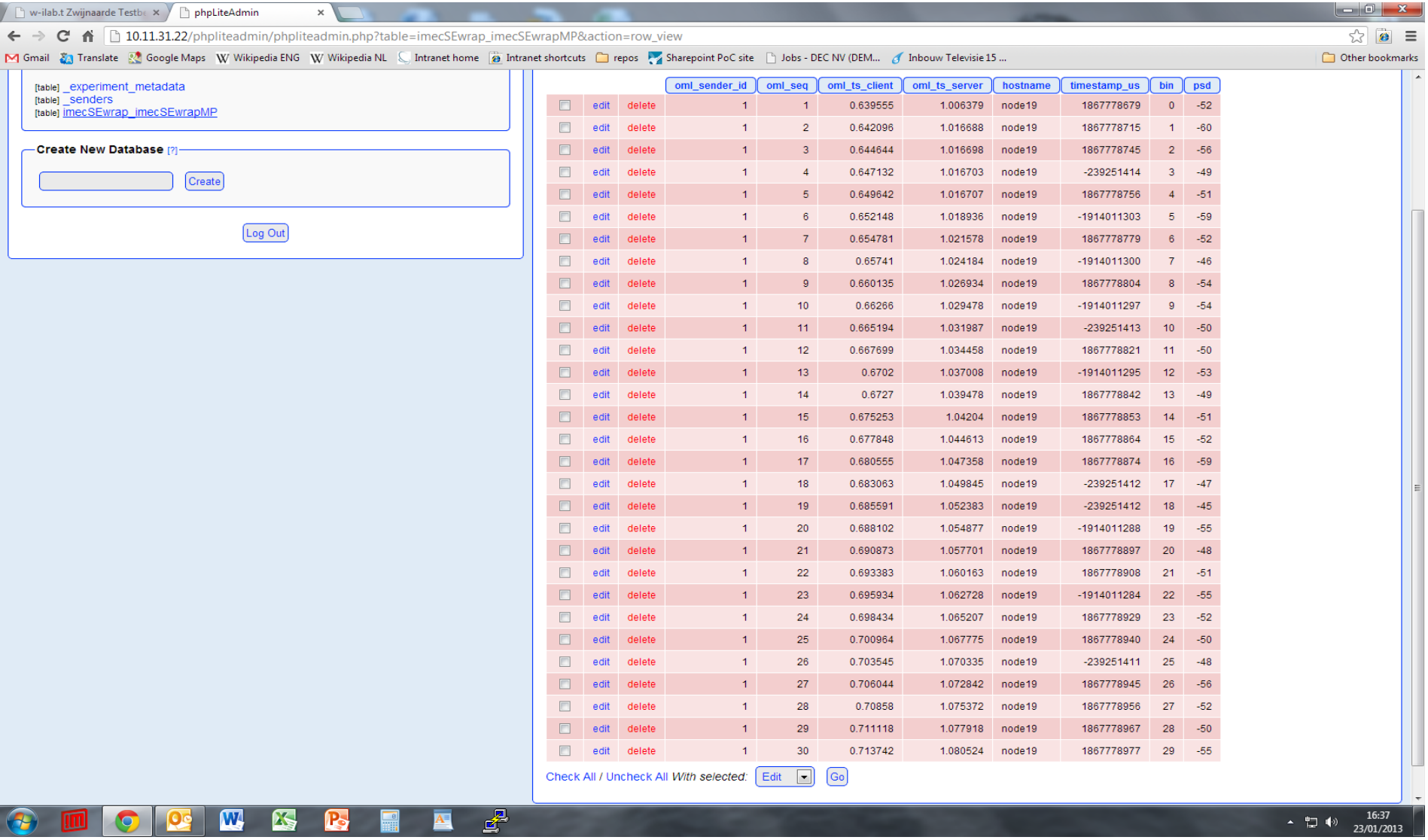
EXAMPLES OF USAGE
ZIGBEE MODE



id	timestamp	timestamp_us	hostname	standard	channel1	channel2	channel3	channel4	channel5	channel6	channel7	channel8	channel9	channel10	channel11	channel12	channel13	channel14
729920	2012-11-20 17:25:10	1353428708436721	node12	zigbee	525	363	455	464	265	978	684	441	468	781	571	957	790	828
729919	2012-11-20 17:24:21	1353428659207346	node19	zigbee	534	2274	2386	2282	2502	2321	2434	2277	753	2390	2031	2058	2071	2345
729918	2012-11-20 17:24:21	1353428659069937	node19	zigbee	2438	2216	2344	2160	2151	2157	705	715	2213	2265	2250	2448	562	2447
729917	2012-11-20 17:24:21	1353428658970285	node37	zigbee	638	466	587	569	1025	623	699	380	526	580	535	458	910	461
729916	2012-11-20 17:24:21	1353428658966699	node51	zigbee	1819	612	648	2008	657	1981	2037	450	701	502	946	571	554	1772
729915	2012-11-20 17:24:21	1353428658931238	node19	zigbee	644	2378	767	524	869	2353	609	2292	2217	2110	1782	693	2243	2294
729914	2012-11-20 17:24:21	1353428658830826	node37	zigbee	443	734	469	521	1076	517	621	554	989	613	671	735	415	563
729913	2012-11-20 17:24:21	1353428658830356	node51	zigbee	1335	2141	1295	2190	2199	1227	684	1618	1822	1481	781	553	454	664
729912	2012-11-20 17:24:21	1353428658792932	node19	zigbee	2127	2032	2391	541	844	2365	642	2312	2455	554	2418	520	2492	2254
729911	2012-11-20 17:24:21	1353428658693407	node37	zigbee	1010	435	676	801	512	728	466	604	837	284	647	620	630	718
729910	2012-11-20 17:24:21	1353428658691415	node51	zigbee	1631	1917	1221	429	2132	1109	464	621	1724	1606	472	1876	2011	415
729909	2012-11-20 17:24:21	1353428658654309	node19	zigbee	2294	2291	693	2397	643	2390	2348	2463	2072	567	2195	675	757	700
729908	2012-11-20 17:24:20	1353428658555476	node37	zigbee	639	721	547	593	519	994	560	552	470	449	690	641	594	773
729907	2012-11-20 17:24:20	1353428658553330	node51	zigbee	386	1795	1506	2033	651	1271	1572	665	1331	2106	1677	661	2142	603
729906	2012-11-20 17:24:20	1353428658514819	node19	zigbee	1980	2401	2337	2380	855	2155	2138	2348	583	1688	2156	692	2166	2218
729905	2012-11-20 17:24:20	1353428658414990	node37	zigbee	483	752	907	648	566	505	303	364	414	600	1035	701	812	875
729904	2012-11-20 17:24:20	1353428658414756	node51	zigbee	1174	1020	1519	687	622	1838	1640	1858	1010	594	1565	2083	1441	2166
729903	2012-11-20 17:24:20	1353428658376785	node19	zigbee	631	2218	2524	2516	646	723	2217	2504	1439	2494	665	2477	2348	2420
729902	2012-11-20 17:24:20	1353428658277829	node37	zigbee	646	810	393	559	304	445	678	612	661	398	789	516	606	577
729901	2012-11-20 17:24:20	1353428658276605	node51	zigbee	1965	1887	1341	1362	475	1975	2055	563	1735	2019	1413	2083	1677	1557
729900	2012-11-20 17:24:20	1353428658238096	node19	zigbee	2396	2472	1959	2373	2279	2449	747	817	670	2187	527	485	696	1900
729899	2012-11-20 17:24:20	1353428658139254	node37	zigbee	410	758	676	757	913	505	626	741	584	915	518	346	518	671
729898	2012-11-20 17:24:20	1353428658138276	node51	zigbee	1596	1459	1136	2167	1274	2032	598	1739	2237	1741	1953	2031	1827	957
729897	2012-11-20 17:24:20	1353428658100520	node19	zigbee	2226	2449	602	2157	2362	2239	525	2463	2457	2335	416	756	2130	573

EXAMPLES OF USAGE
FFT SWEEP



			oml_sender_id	oml_seq	oml_ts_client	oml_ts_server	hostname	timestamp_us	bin	psd
	edit	delete	1	1	0.639555	1.006379	node19	1867778679	0	-52
	edit	delete	1	2	0.642096	1.016688	node19	1867778715	1	-60
	edit	delete	1	3	0.644644	1.016698	node19	1867778745	2	-56
	edit	delete	1	4	0.647132	1.016703	node19	-239251414	3	-49
	edit	delete	1	5	0.649642	1.016707	node19	1867778756	4	-51
	edit	delete	1	6	0.652148	1.018936	node19	-1914011303	5	-59
	edit	delete	1	7	0.654781	1.021578	node19	1867778779	6	-52
	edit	delete	1	8	0.65741	1.024184	node19	-1914011300	7	-46
	edit	delete	1	9	0.660135	1.026934	node19	1867778804	8	-54
	edit	delete	1	10	0.66266	1.029478	node19	-1914011297	9	-54
	edit	delete	1	11	0.665194	1.031987	node19	-239251413	10	-50
	edit	delete	1	12	0.667699	1.034458	node19	1867778821	11	-50
	edit	delete	1	13	0.6702	1.037008	node19	-1914011295	12	-53
	edit	delete	1	14	0.6727	1.039478	node19	1867778842	13	-49
	edit	delete	1	15	0.675253	1.04204	node19	1867778853	14	-51
	edit	delete	1	16	0.677848	1.044613	node19	1867778864	15	-52
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	edit	delete	1	23	0.695934	1.062728	node19	-1914011284	22	-55
	edit	delete	1	24	0.698434	1.065207	node19	1867778929	23	-52
	edit	delete	1	25	0.700964	1.067775	node19	1867778940	24	-50
	edit	delete	1	26	0.703545	1.070335	node19	-239251411	25	-48
	edit	delete	1	27	0.706044	1.072842	node19	1867778945	26	-56
	edit	delete	1	28	0.70858	1.075372	node19	1867778956	27	-52
	edit	delete	1	29	0.711118	1.077918	node19	1867778967	28	-50
	edit	delete	1	30	0.713742	1.080524	node19	1867778977	29	-55

EXAMPLES OF USAGE

Video?

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HANDS-ON / DEMONSTRATION

- See iMinds training

A VERSATILE SPECTRUM SENSING ENGINE FOR MOBILE DEVICES

QUESTIONS?

REMARKS / FEEDBACK

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imec