ΣCOM

The SIGMACOM service offers a large set of advanced scientific equipment's for the conception and test of new radio modules communication systems, (up to the millimeter wave range) and sensors. We can address wide area single hop or multi-hop networks as well as mixed radio-fiber connectivity for smart devices, implementing edge and near sensor computing to optimize rate, power consumption, reliability and/or latency. This service offers both software and hardware facilities to design, program and test both the analog and digital parts of smart and connected devices, up to 110 GHz. We can for example address the challenges related to IOT, 5G and beyond.

Head of SigmaCom
R. Kassi

- **Analog and digital communication systems** — **III. 1-8**
  - → Redha Kassi → David Delcroix
  - Telecom test bench
  - Software-defined radio
  - Multifunctional analog and digital I/O devices
  - Energy efficiency test bench
- **Optical communication systems** — **III. 9-12**
  - → Redha Kassi
  - Optical telecom testbed
  - Optical measurement bench

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ANALOG AND DIGITAL COMMUNICATION SYSTEMS

Real-Time Open Multi user RF communication Test-Bench with Controlled Channel

TELECOM TEST BENCH

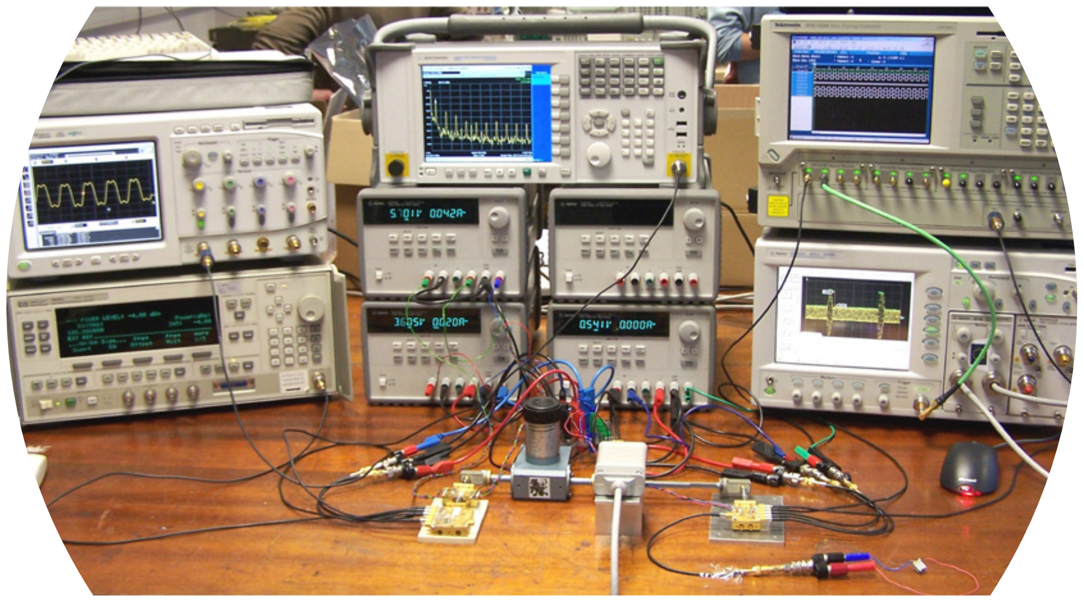
Rédha Kassi

This telecom test bench offers a wide range of state-of-the-art scientific equipment for the characterization of new radio modules and communication systems, covering frequencies up to the millimeter wave range. It is particularly well suited for wireless ad hoc networks for smart objects and sensors. In addition, the telecom platform aims at the generation and analysis of complex telecom signals to demonstrate new concepts for wireless communication links.

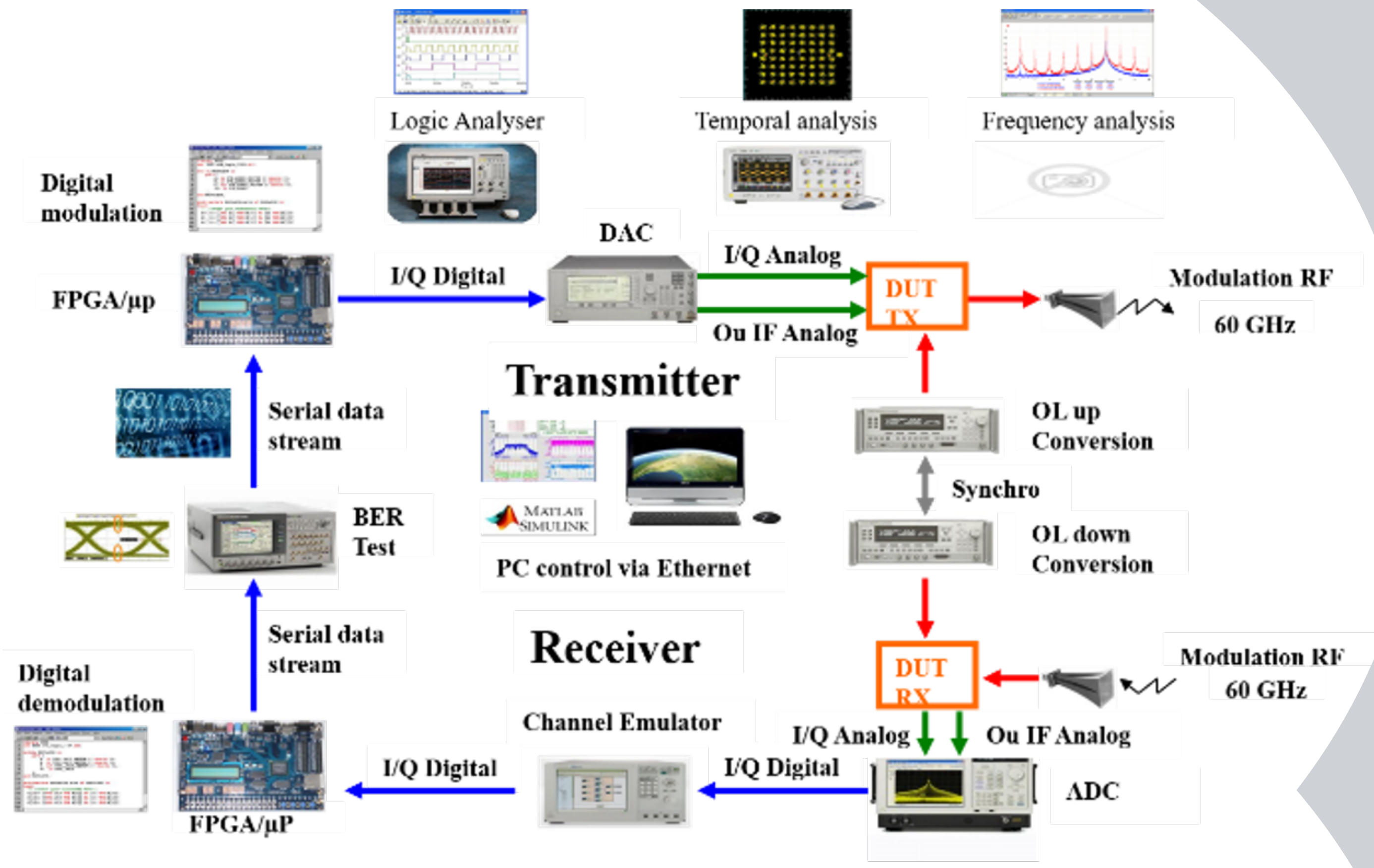
→ APPLICATIONS

- The bench includes a wide range of test systems and software that can provide a flexible and powerful environment to perform key telecom up to 60 GHz tests such as:
- Real-time characterization of a complex transmission and/or reception system, from baseband generation to RF transmission.
- Real-time characterization of a transmission/reception system from demodulation to data recovery with options to analyze RF signal integrity at each channel stage (EVM, channel power measurements, Occupied bandwidth, Modulation accuracy...), digital signal (BERT, PER, eye diagrams, jitter measurements), and mixed signals.
- Characterization of link robustness against real-time RF channel emulation, interference analysis.
- Physical testing of interoperability in heterogeneous sensor networks
- Testing the non-linearity of an amplifier on the communication channel and hard/soft correction.
- Testing frequency and phase synchronization.
- Testing clock accuracy and stability.
- Optimizing transmission packet size.
- Optimize the size of the synchronization preamble.
- Measure component temperature drift and impact on transmission.

Some measurement techniques can be used by the CHOP cluster for THz communications.



Mixed signal test bench for an UWB-IR communication system operating at 60 GHz



Characterization of a real-time communication

→ HIGHLIGHTS

Generation of complex analog, digital or mixed signals:

- Generation of vectorial signals up to 20 GHz with a 1 GHz analog bandwidth
- Generation of arbitrary wave form signals up to 1.25 Gs/s with a 15 bits resolution.
- Generation of arbitrary wave form signals up to 20 Gs/s with a 10 bits resolution.
- Pulse and data generation up to 3.35 Gb/s
- Frequency synthesizers up to 75 GHz

Time and frequency domain analysis of analog, digital or mixed signals:

- Automatic phase noise test set up (10 KHz - 110 GHZ), baseband noise, AM, FM measurement, variance, frequency meter.
- Vectorial signal analyzers up to 50 GHz with a potential 160 MHz analog bandwidth
- Sampling oscilloscopes up to 75 GHz
- Single shot oscilloscopes up to 12 GHz
- Spectrum analyzers up to 110 GHz
- Real time spectrum analyzer up to 14 GHz and 14 bits resolution
- Power meters up to 110 GHz
- Differential vectorial network analyzer (100 MHz-26.5 GHz) for RF circuits or radio
- Electrical Clock Recovery Module up to 2.5 Gb/s
- Logic analyzers up to 800 Mb/s for each of the 34 channels
- Bit Error Rate Test bench up to 13 Gb/s

Real time modelling for the channel propagation:
Baseband generator and channel emulator (4*2 or 2*4 MIMO Max, 24 multi-paths per channel, Channel BW 120 MHz, Sample rate 150 Msa/s Max)

Real time telecom signal generation and analysis

- modulation and demodulation for cellular (LTE/LTE-Advanced/LTE-A Pro FDD, GSM, GPRS, W-CDMA...) and non-cellular technologies (Wifi, Bluetooth, ZigBee, LoRa, SigFox, RFID...)

Software suite:

- Labview
- signal studio
- 89600 vsa

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ANALOG AND DIGITAL COMMUNICATION SYSTEMS

Multi-standard communication Gateway

USRP-2954

SOFTWARE-DEFINED RADIO

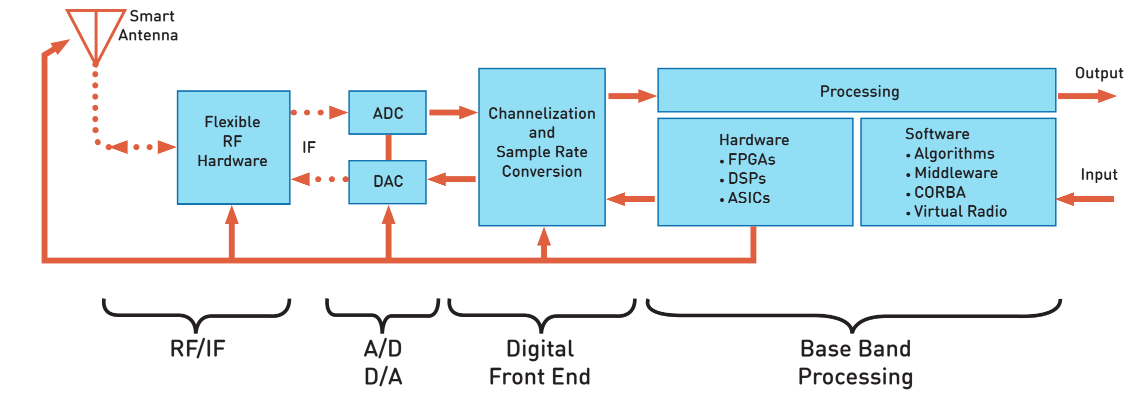
Rédha Kassi

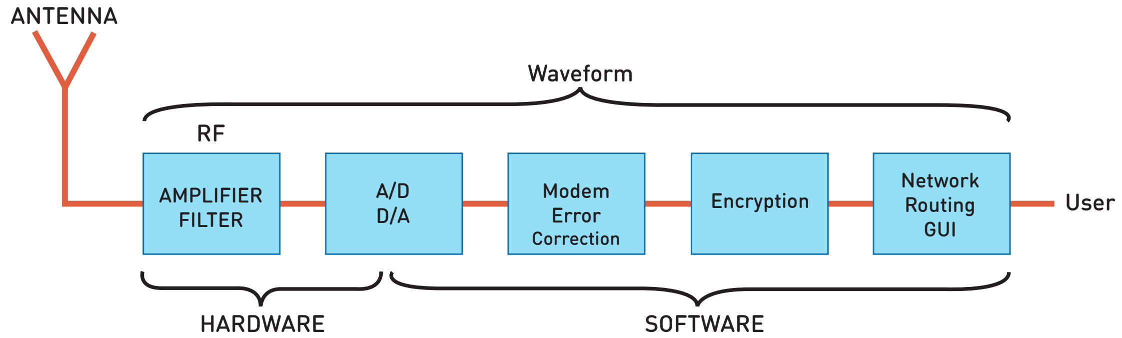
We offer a range of NI Universal Software Radio Peripherals (USRP) to define Software Defined Radios (SDRs) used for RF applications. These integrated hardware and software solutions enable rapid prototyping of wireless communication systems. NI USRP transceivers can transmit and receive RF signals in multiple bands. The USRP hardware architecture integrates RF analog front-ends (high-low conversion, filters, amplifiers), RF I/Q modulation-demodulation stage, ADCs and DACs, a processor or FPGA connected by wire to a host computer (PC or PXI chassis) for sending, and receiving properly formatted baseband I/Q data. The USRPs are programmed using the LabVIEW development environment. This solution offers great flexibility for software radio prototyping and communications research.

APPLICATIONS

The USRP hardware allows a wide range of applications.

- Dynamic access to the RF spectrum and real-time recording of signals over a long period of time.
- PHY and MAC layer research for robustness of radio links.
- Build custom transmission or reception protocols.
- Build multi-standard communication gateways
- Integrate USRP into a standard radio communication network to test new wireless algorithms (TDD, FDD) to improve communications.
- Test channel coding or source coding blocks
- Simulate channel degradation and verify the impact on transmissions.
- Implementing of MIMO technology





HIGHLIGHTS

Main hardware features of USRP

The USRP are equipped with a GPS-disciplined 10 MHz oven-controlled crystal oscillator (OCXO) reference clock. The GPS disciplining delivers improved frequency accuracy and synchronization capabilities. It is equipped with a reconfigurable FPGA

Transmitter:

- Number of channels 2
- Frequency range 10 MHz to 6 GHz
- Frequency step < 1KHz
- Maximum output power (Pout) 50 mW to 100 mW (17 dBm to 20 dBm)
- Gain range 0 dB to 31.5 dB
- Gain step 0.5 dB
- Maximum instantaneous real-time bandwidth 160 MHz
- Maximum I/Q sample rate 200 MS/s
- Digital-to-analog converter (DAC) Resolution 16 bit
- Spurious-free dynamic range (sFDR) 80 dB

Receiver:

- Number of channels 2
- Frequency range 10 MHz to 6 GHz Frequency step
- Frequency step < 1KHz
- Gain range 0 dB to 37.5 dB
- Gain step 0.5 dB
- Maximum input power (Pin) -15 dBm
- Noise figure 5 dB to 7 dB
- Maximum instantaneous real-time bandwidth 160 MHz
- Maximum I/Q sample rate 200 MS/s
- Analog-to-digital converter (ADC) Resolution 14 bit, sFDR 88 dB

Software suite

- Labview
- Labview FPGA Module
- Labview communications system design suite
- GNU Radio, Python, Matlab, Simulink, C/C++.

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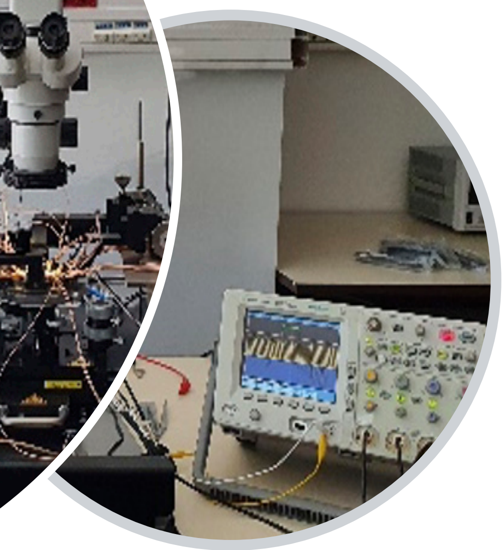
ANALOG AND DIGITAL COMMUNICATION SYSTEMS



Test bench of a neuromorphic system-on-chip

MULTIFUNCTIONAL ANALOG AND DIGITAL I/O DEVICES

Rédha Kassi

We offer several PXI chassis integrating a controller and different multi-channel I/O modules (analog, digital or mixed) allowing to realize several instruments adaptable for multiple test and measurement applications. The originality of this modular, synchronous, standardized solution is to quickly offer several specific instruments to generate, acquire, store and analyze different signals in a single chassis. The National Instrument programming environment is used to create or use software applications to drive the hardware, process, analyze stored data and/or visualize it in continuous time.

→ APPLICATIONS

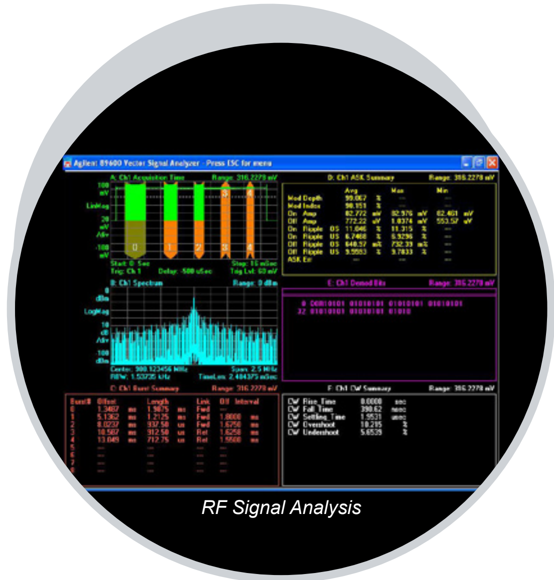
There are many test and measurement applications, the only limitations of which depend on the technical characteristics of the equipment.

- Generation (DAC) and acquisition (ADC) of data and control
- Instrumentation (function generator, AWG, digital signals, oscilloscope, spectrum analyser, ...)
- Wireless communication test (acquisition and real time generation of baseband or IF)

RF test bench

→ HIGHLIGHTS

- **16-bit PXI analog output module, 8 channels, 1 MS/s (8 TTL/CMOS 5V digital I/O lines)**
- **16 simultaneous 24-bit PXI analog inputs module (204.8 kS/s sampling rate, 114 dB, 4 gains, AC/DC coupled)**
- **PXIe, 16 AI (16 bits, 1,25 MS/s/ch), 4 AO, 48 DIO, module I/O multifunction**
- **100 MHz Bandwidth Transceiver Adapter Module (this module must be combined with a PXI FPGA)**
- **200 MHz digital I/O adapter module, 32 LVDS channels (this module must be combined with a PXI FPGA)**
- **Digitizer adapter module 50 MS/s, 14 bit, 16 channels (digitizer must be combined with a PXI FPGA)**



RF Signal Analysis

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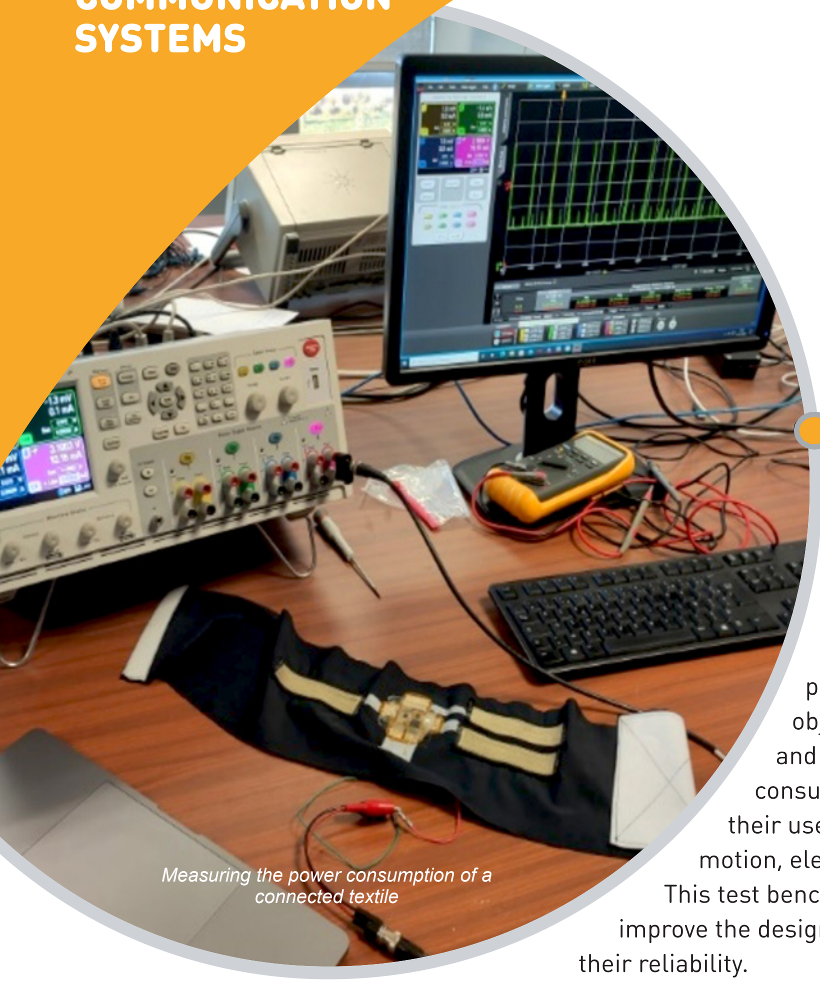
ANALOG AND DIGITAL COMMUNICATION SYSTEMS



Measuring the power consumption of a connected textile

ENERGY EFFICIENCY TEST BENCH

Rédha Kassi

This energy efficiency test bench offers the possibility of optimising the energy consumption of communicating objects for IOT, 5G and beyond, by enabling the energy impact of electronic systems to be measured precisely in a controlled environment through the choice of low-power hardware and software architectures. One of the objectives is to limit the frequent recharging of batteries and to maximise their lifespan. Knowing the AC/DC energy consumption of objects also makes it possible, depending on their use, to size ambient energy recovery technologies (solar cell, motion, electromagnetic, etc.) to create energy autonomous objects. This test bench allows numerous measurement possibilities in order to improve the design of objects to increase their performance and guarantee their reliability.

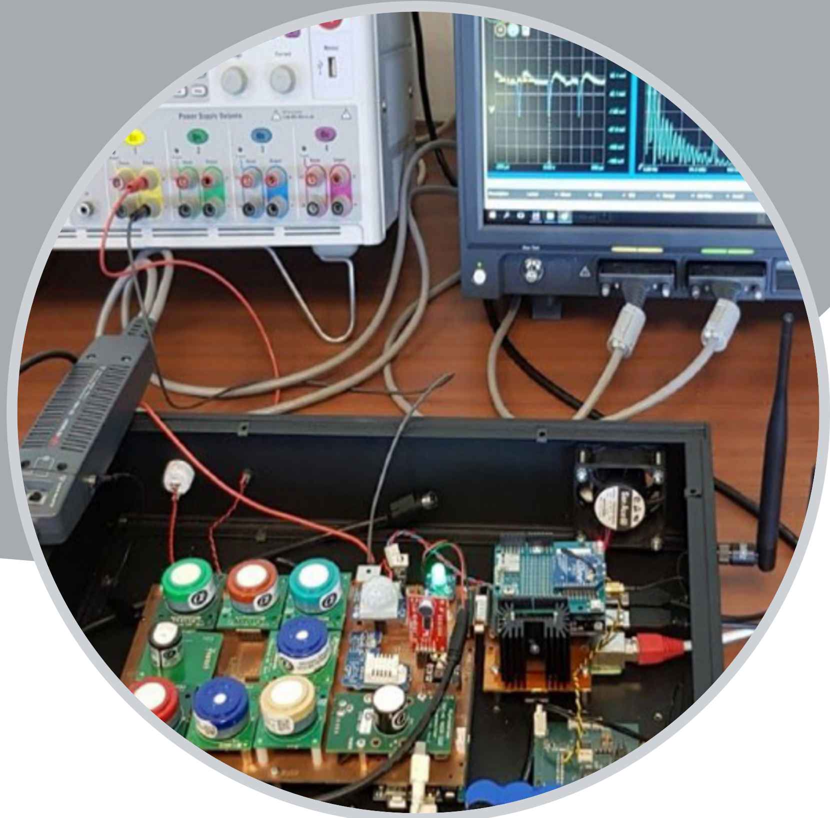
→ APPLICATIONS

Measure and analyse the power consumed by a system or the sub-systems of a complex object.

• To measure the current and voltage accurately over a wide dynamic range depending on the operating state of the object (on, standby, communication, ...)
• Measure the exact power consumption with sufficient bandwidth not to miss fast digital events.
• Synchronize the power consumption measurement with the software subroutines of the powered object to optimize processor scheduling and maximize the object's battery life.
• Correlate load consumption with RF events and events in the object's sub-circuits.
• Consider the impact of power consumption as a function of RF interference with other wireless devices in a real or controlled environment by combining it with the telecom test bench (influence of channel model, RF disturbance, interferer, electromagnetic pulse, ...).
• Test in difficult electromagnetic environments (C2EM: anechoic chamber, reverberation chamber)

Evaluating the battery characteristics of a device

• Visualize the evolution of the power consumed by an object according to its use and record it over a long period of time in a point file.
• Replay a stored point file to check the performance of a battery and estimate its lifetime.
• Characterize the charge and discharge of a battery over time.
• Analyze statistically (CCDF) the power consumed



Analysis of the energy consumption of a device under test

→ HIGHLIGHTS

Device current waveform analyzers

• Widest current measurement range: 100 pA to 10 A
• Capture fast transient effects of spikes with bandwidth up to 200 MHz
• Max sampling rate: 1GSa/s
• Purpose-built low power IoT chip or device characterization

DC power Analyzer and source measure unit

• 20W and 80W power generators
• Measure wide range of current from sub µA to 8 A and voltage in one pass
• Function as current / voltage source and e-load
• Purpose-built for battery drain analysis
• Long term data logging (up to 200 KSa/s, log current drain up to 1000 h, energy consumption measurements (Ah, Wh, Joules, Coulombs)
• Battery emulation mode
• Meter view (output voltage, current and power)
• Scope view (displays output voltage and current as a function of time)
• Data logger view (hours of measurements with a maximum time resolution of 20 µs can be logged internal memory or an external USB)
• CCDF (complementary cumulative distribution function) view (quantify the impact of design changes – hardware, firmware or software- on current flows in your design.
• ARB capability (step, ramp, staircase, sine, pulse, trapezoid, exponential, sequence, user defined; max size of 64000 waveform points, max bandwidth of 100 KHz, two quadrant operation)

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OPTICAL COMMUNICATION SYSTEMS

Measurements of an optical transmission

OPTICAL TELECOM TESTBED

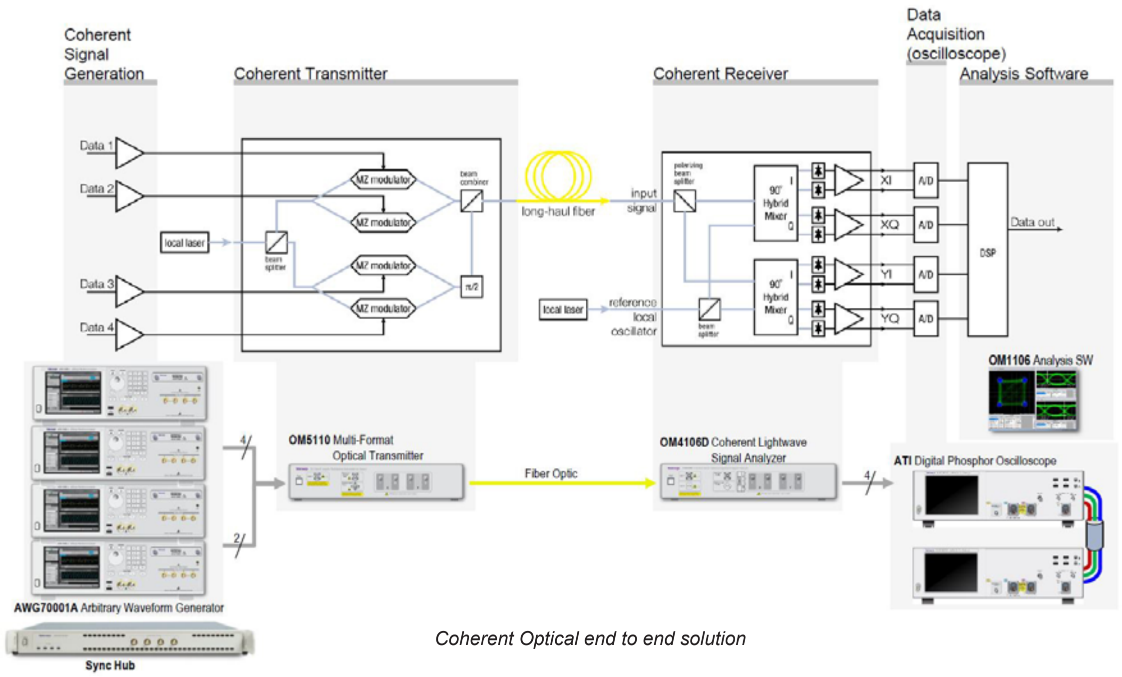
Rédha Kassi

This optical telecom testbed allows the exploration of technologies such as photonic space division multiplexing while combining coherent optical technology with wireless transmissions up to THz to support the insatiable demand for ever increasing data transmission capacity worldwide. This instrumentation test bench is a complex chain of very high speed coherent optical transmission systems that can generate, acquire and analyze the data transmission quality of optical communications systems that allow the combination of THz radio technologies. A software suite allows the instrumentation to be controlled and the transmission quality to be quantified in terms of BER, EVM and eye diagrams for different modulation standards at data rates up to 512 Gb/s. This bench, located at the IRCICA, is managed by the PHLAM and shared with the IEMN.

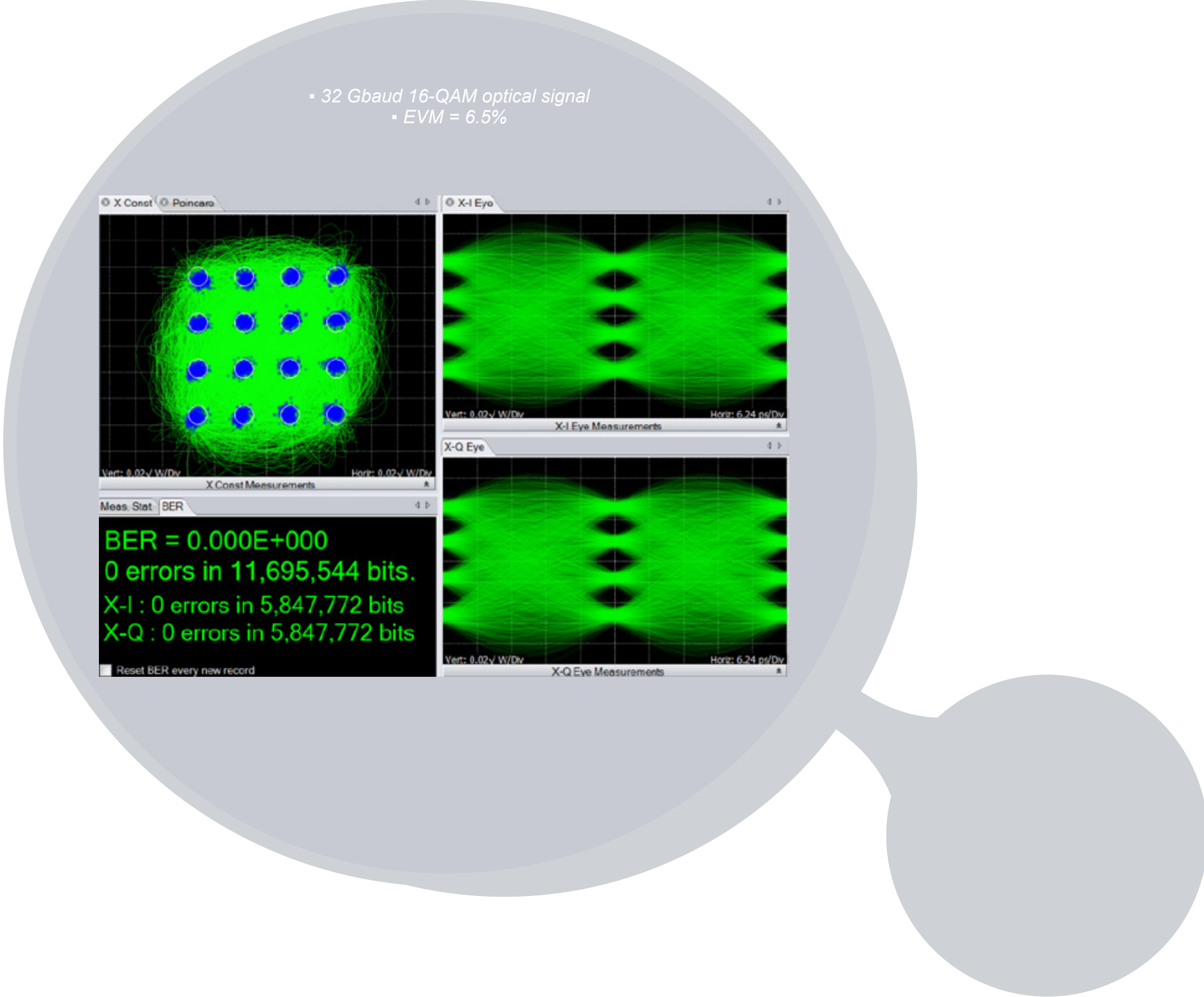
The instruments constituting the telecom testbed may also be used individually in experiments with high requirements, such as synchronized acquisition of fast electrical or optical signals (group of sampling oscilloscopes with 4 ATI ports at 70 GHz or 8 ports at 33 GHz); or the generation of complex electrical or optical signals (group of arbitrary function generators with 8 ports at 22 GHz).

→ APPLICATIONS

- Transmission quality (EVM, Q, BER) in optical fiber on optical carrier ;
- Transmission quality (EVM, Q, BER) in free-space on THz carrier ;
- Coherent modulation formats (N-QAM, 32 Gbaud) ;
- Digital signal processing (DSP, MIMO 4x4) ;
- Shaping and detection of fast optical signals (33 GHz) ;
- Spatial and modal multiplexing.
- Space-time coding
- Implementation of very high speed transmissions on new generation slightly multimode optical fibres using spatial multiplexing such as modal multiplexing to characterise crosstalk.
- Coupling coherent optics technology to wireless transceiver technology in the terahertz range.



Coherent Optical end to end solution



→ HIGHLIGHTS

This transceiver test bench has several instruments:

- Arbitrary Wave Generator (BW up to 15 GHz, 10 bit vertical resolution, DAC 50 Gs/s)
- Instruments for AWG synchronisation (random jitter 315 fs)
- Multi-format coherent optical transmitter and receiver (46 GBaud BPSK, PM-16 QAM, C or L band lasers or external, Ix, Qx, Iy and Qy base band signals)
- Real time oscilloscope (70 GHz, <7 ps rise time, 200 GS/s sample rate, 100fs jitter noise floor, single-ended 62,5 mv to 300 mv)
- Software generation of RF communication standards
- Display constellation diagrams, EVM, phase eye diagrams, Q-factor, Q-plot, BER,...
- Measures Polarization Mode Dispersion (PMD)
- Coherent lightwave signal analyzer software

Digital photonic transmission systems (10 Gb/s)

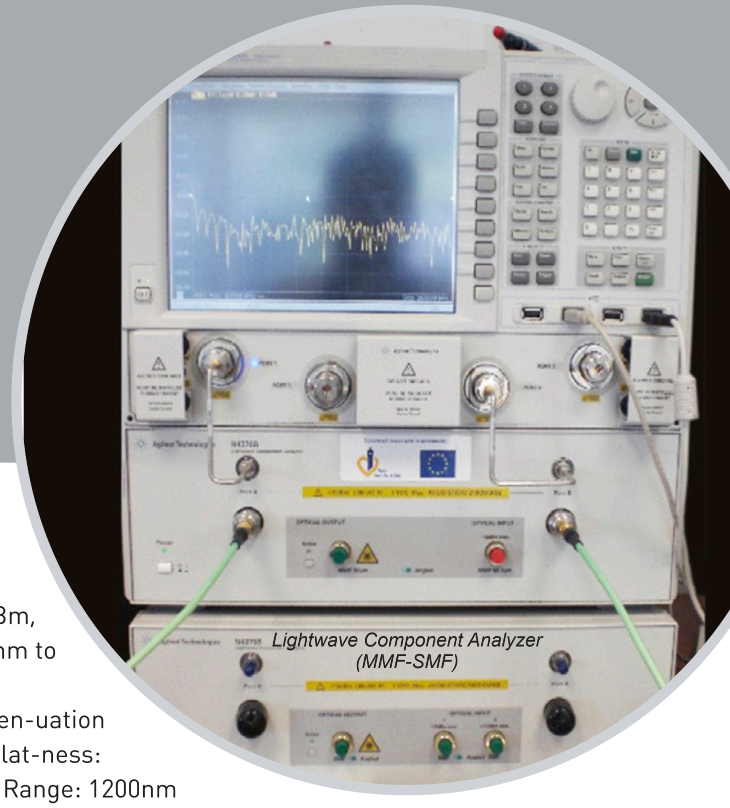
OPTICAL MESUREMENT BENCH

Rédha Kassi

We have specific instruments for the characterization of systems incorporating optical components. We can generate and analyze optical signals to verify the optical performance of fibers, photodiodes and electro-optical components. S-parameter, optical power and reflectometry measurements can be performed. These instruments are complementary to the optical telecom test bench for radio over fiber or the telecom test bench for communications over fiber.

APPLICATIONS

• Fiber radio requires an RF frequency response (from 10 MHz to 26.5 GHz) around an optical wavelength (850 nm, 1550 nm or 1310 nm) in order to accurately characterize an optical transmission chain by measuring the S parameters of electro-optical components (detector diodes, modulators) using a Lightwave Component Analyzer (LCA).
• Basic platform for testing 10 GbE optical and electro-optical components, Fiber Channel FC*8, FC*10, FC*16
• Qualitative analysis of modulated signals with an electrical spectrum analyzer or oscilloscope.



Lightwave Component Analyzer (MMF-SMF)

HIGHLIGHTS

Lightwave Measurement System:

• Variable Optical Attenuator Module for Multimode Fiber Applica-tions (50 µm and 62,5 µm, input power level up to 27 dBm, at-tenuation range: 0dB to 60 dB, wide wavelength range: 700 nm to 1400 nm)
• Variable Optical Attenuator Module with Angled Interface (atten-uation Range: 0dB to 60dB, High Input Power Level: 2W, Wavelength Flat-ness: < 0.05dB, High Attenuation Accuracy < 0.1dB, Wide Wavelength Range: 1200nm to 1700nm (SMF))
• Reference transmitter for Optical Receiver Stress Test (10MHz to 33 GHz typical electro-optical bandwidth, Optical wavelength1310 nm & 1550 nm Single Mode Fiber, Operational data rate 622 Mb/s to 14.2 Gb/s, Rise and fall times < 15 ps)
• Reference Receiver is an O/E converter optimized for transceiv-er loop-back test (Opto-electrical modulation bandwidth DC to 9.3 GHz (typical), Wavelength range 750 nm to 1650 nm, MMF 62.5 µm/125 µm, Op-erational data rate 622 Mb/s to 12.5 Gb/s, Rise and fall times < 35 ps)
• General Purpose Optical Power Head (Wavelength range 800 nm to 1700 nm, power range 40 dBm to -90 dBm, Low polarization dependence)

Lightwave Component Analyzer:

• Operation frequency range 10 MHz to 26.5 GHz
• Transmitter and receiver specifications MMF
• Optical input 62.5 µm
• Optical output 50 µm
• Input wavelength range 750 nm to 1650 nm
• Output wavelength 850 nm
• Transmitter and receiver specifications SMF
• Optical input/output 9 µm single mode angled
• Input wavelength range 1250 nm to 1640 nm
• Output wavelength 1310 nm and 1550 nm

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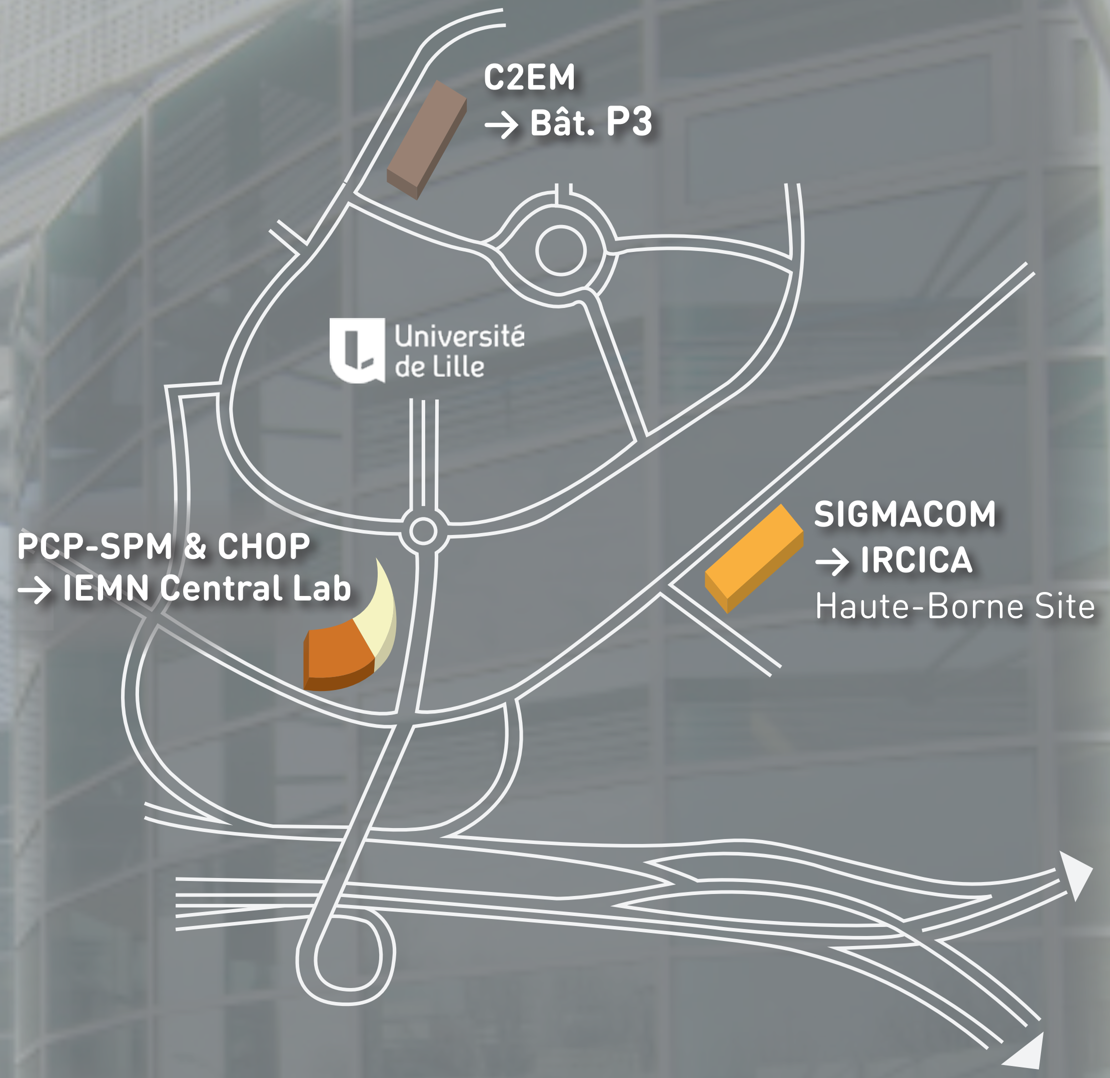

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