Impulse Radar Technology – Fundamentals and Applications

novelda

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OUTLINE

- Novelda Company Brief
- UWB Radio Fundamentals
- Novelda Impulse Radar Technology
- Radar Application Examples
- Recent Developments CMOS Radar
- Conclusion

novelda NANOSCALE IMPULSE RADAR

NOVELDA COMPANY BRIEF

NOVELDA AS

- A fabless semiconductor company specializing in Nanoscale wireless low-power technology for ultrahigh-resolution impulse radar

- Developing CMOS impulse radio standard components, as well as Application Specific Integrated Circuits

- Applications for our technology spans a wide range of areas from medical and industrial high precision sensors to personalized wireless healthcare and more

COMPANY BACKGROUND

Founded in September 2004 by:

- Dag T. Wisland – CEO/Associate professor Univ. of Oslo
- Tor Sverre (Bassen) Lande – Professor Univ. of Oslo
- Einar Nygård – Industrial IC management / Entrepreneur
- Eirik Næss-Ulseth – Business developer / Entrepreneur

Core business:

- Focus on impulse radio technology in CMOS
- Product/Market: Low-energy, short-range, high-precision impulse radar
- R&D driven development
    - EU/RCN/IN projects

NOVELDA EXPERTISE

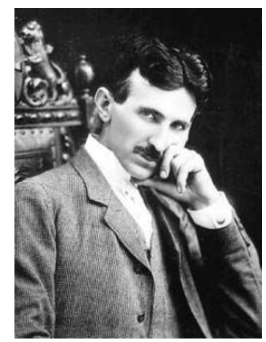
- **Micro-/nano electronics and electrical engineering**
- **17 employees** - 3 Ph.D, 11 M.Sc., 3 B.Sc.
- **Advisory board** - 2 Professors
- **Management group** with up to 28 years R&D experience
- **International Cooperation** with several acknowledged universities and research facilities

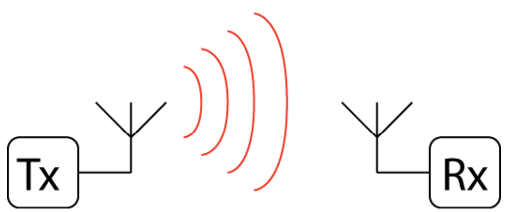
novelda NANOSCALE IMPULSE RADAR

UWB RADIO FUNDAMENTALS

HISTORY OF RADIO

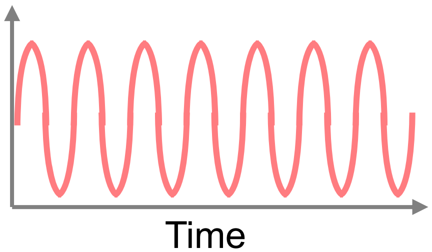
- Everything started with sparks!
- Heinrich Rudolf Hertz
  - Wireless with sparks (1886-89)
- Guglielmo Marconi
  - Long distance radio
    - > 1.5 km in 1895
- Nikola Tesla
  - Father of radio telegraph (patent 1891)
- It all started with the spark…

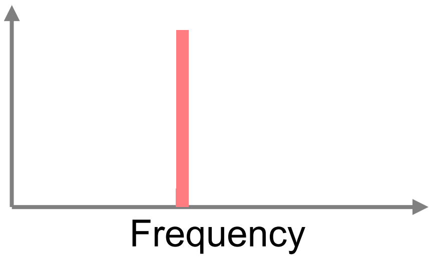




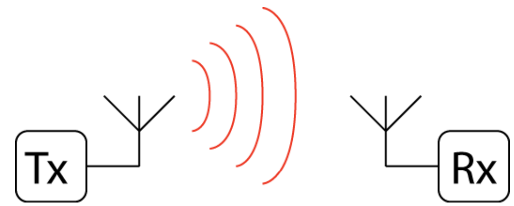
WHERE DID THE SPARK GO?

- Dominant in these early days
  - Transatlantic telegraph (Morse)
  - Hard to share
    - Significant interference
- Carrier based radio (1910)
  - Coding on top of narrowband carrier
  - Sharing by coordinating carrier frequencies
    - Still the way radio works

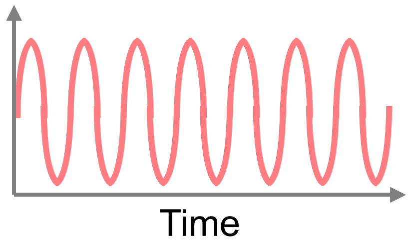


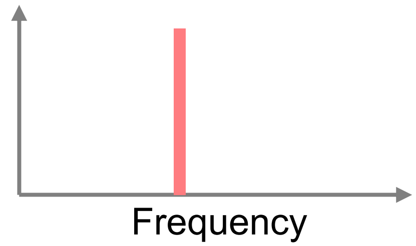


IMPULSE ↔ CARRIER

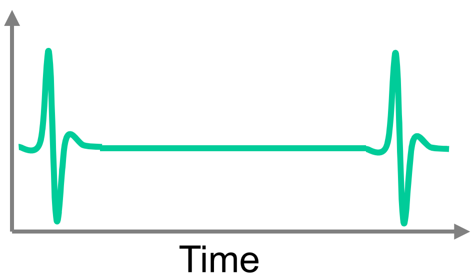


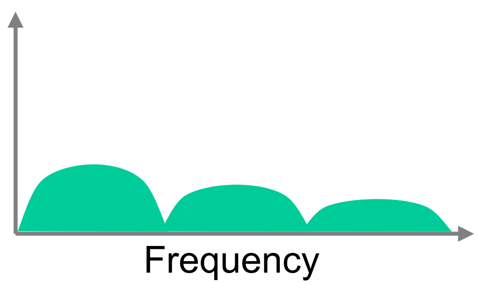
- Carrier based radio





  - Narrow frequency band
  - Carrier → no information, but significant energy
- Impulse radio



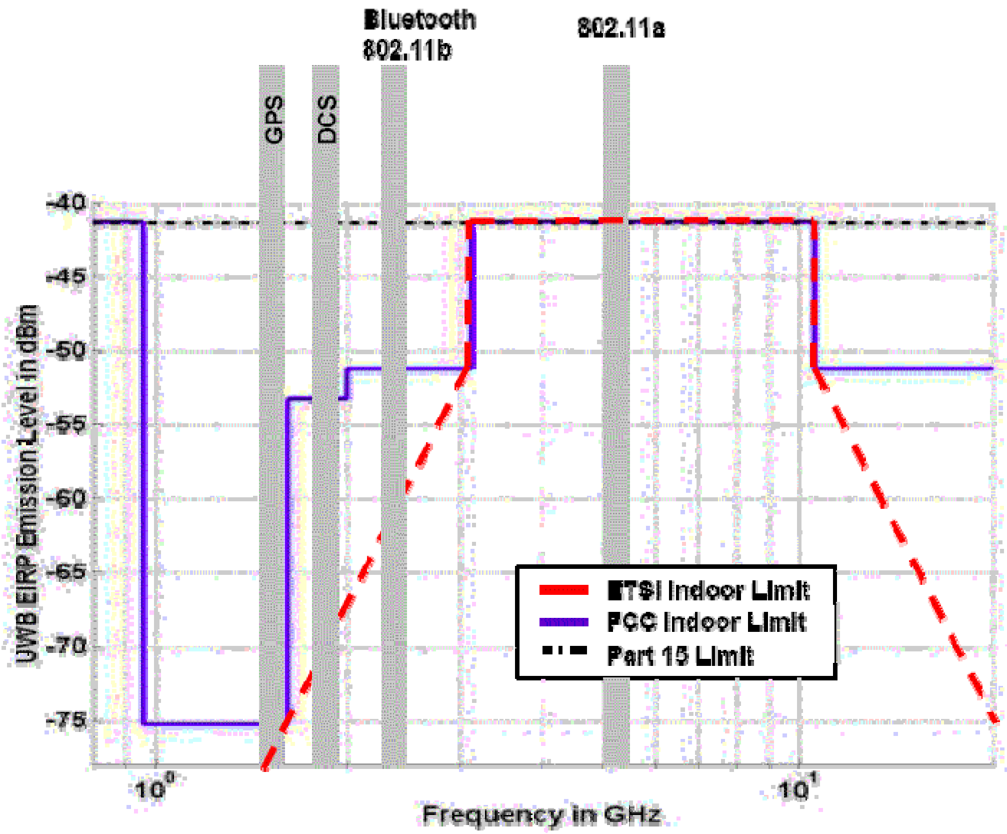


UWB

  - Wide frequency band
  - No power demanding carrier

WHY IMPULSE RADIO NOW?

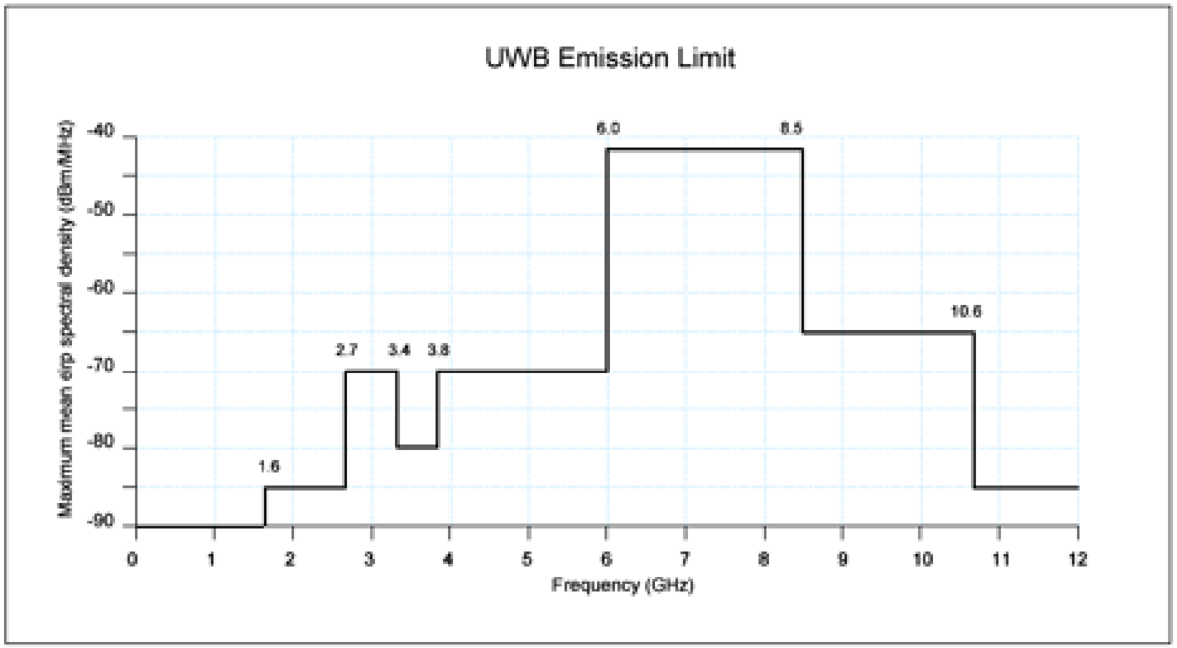
- Legal transmission!
  - FCC in 2000/2002
    - 3.1-10.6GHz
    - 7.5Ghz wide band
- Low energy emission
  - EIRP<-41.3dBm/MHz
  - Close to noise…
- Significant signal interference
  - Wireless networks
    - WiFi 802.11a



Largest unlicensed frequency band ever released!

EUROPEAN / ASIAN RESTRICTIONS

- 6.0 GHz – 8.5 GHz



IMPULSE RADIO FEATURES

- Different from narrow band radio
  - Time domain processing
    - No mixers like standard radio (frequency)
  - No carrier
  - More channels easy (traded for bandwidth)
  - Different penetration properties
  - Different trade-offs
  - Technology friendly
    - Speed – virtue of modern technology
  - New features
    - High accuracy ranging
    - Short range radar

IMPULSE RADAR

- Impulse radar
  - Old technology
  - Hülsmeyer patent
- World War II development
  - USA, Soviet, Germany, England
  - Frequency based systems
- Ground Penetrating Radar (GPR)
  - Industry and defense
    - Look into ground
    - Hard to make


N° 13,170 A.D. 1904

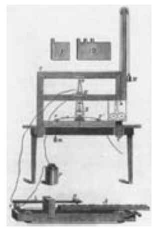
Date of Application, 10th June, 1904—Accepted, 22nd Sept., 1904

COMPLETE SPECIFICATION.

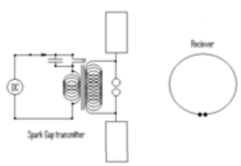
"Hertzian-wave Projecting and Receiving Apparatus Adapted to Indicate or Give Warning of the Presence of a Metallic Body, such as a Ship or a Train, in the Line of Projection of such Waves".—

NOVELDA RADAR TECHNOLOGY

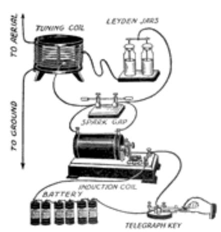
FROM RESEARCH TO PRODUCT

Samuel Morse – Pulse coding

Heinrich Hertz – Pulse comm.

Guglielmo Marconi – Radio system

Idea

Market need

Enabling technology

People – Competence

R&D

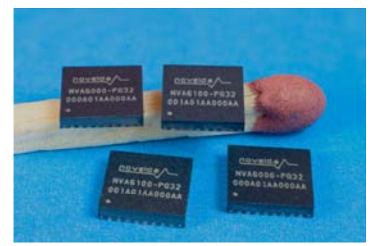
Soft funding

VC funding

Subcontractors

=

Competitive advantages

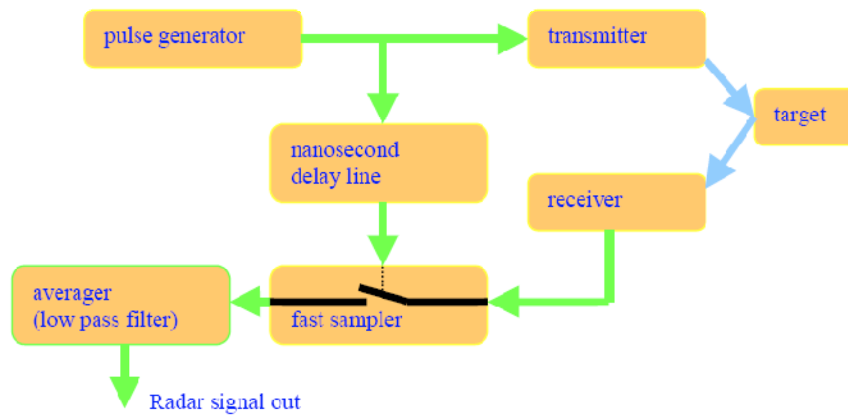


Novelda NVA6100

Nanoscale Impulse Radar

MICROPOWER IMPULSE RADAR

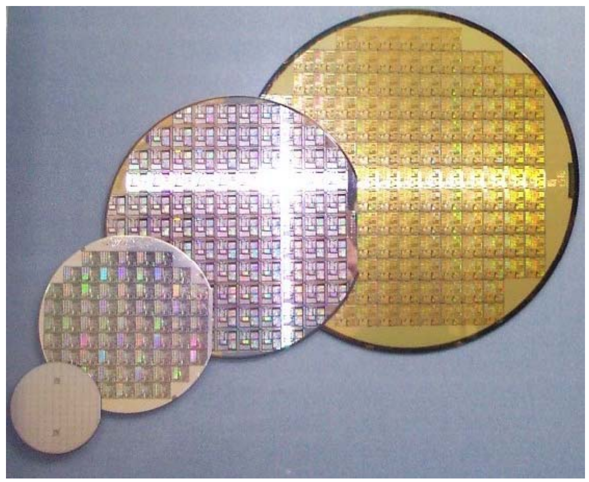
- Tom McEwan (1994)
  - Lawrence Livermore National Laboratory (LLNL)
- Integrating Peak Detector
  - Analog lossy integrator
  - Single sampler
  - Noise-like pulses
  - Unavailable in low voltage digital CMOS
- E. M. Staderini Medical Radar
  - Home made McEwan radar
- First Novelda proof-of-concept (2005)



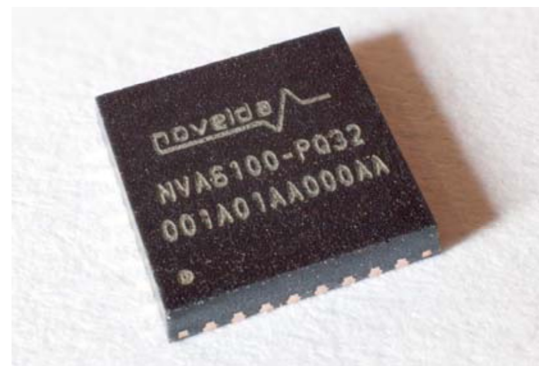
ENABLING TECHNOLOGY

- **Question:**
  - How to capture electromagnetic pulses traveling with speed of light achieving millimeter spatial resolution
  - Keep a small physical size and low unit cost
- **Answer:** Nanometer CMOS technology (<90 nm)

Silicon bar
Material technology

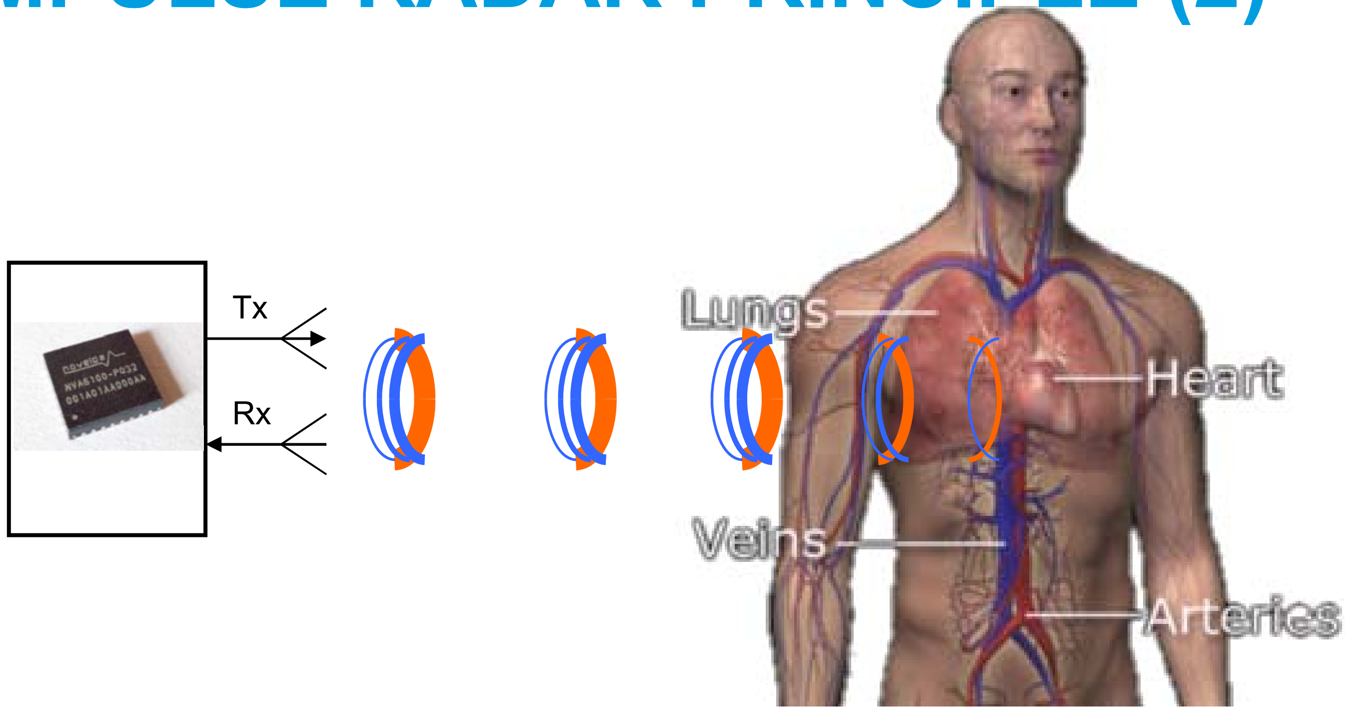


Nanoelectronic system design (IP)
Advanced CMOS production



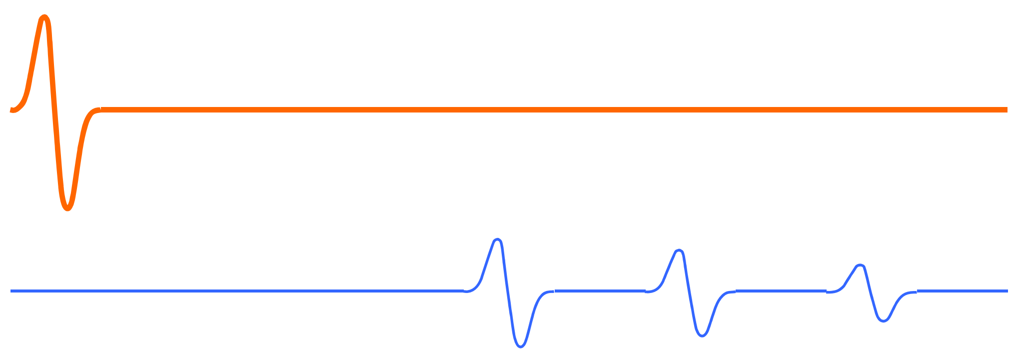
Final IC product
Advanced packaging

IMPULSE RADAR PRINCIPLE (2)



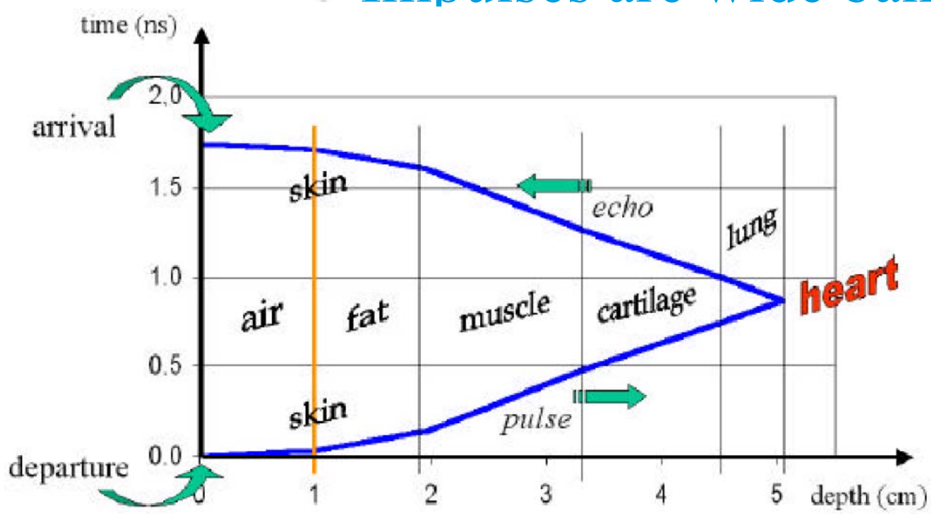
Transmitted
Pulse (Tx)

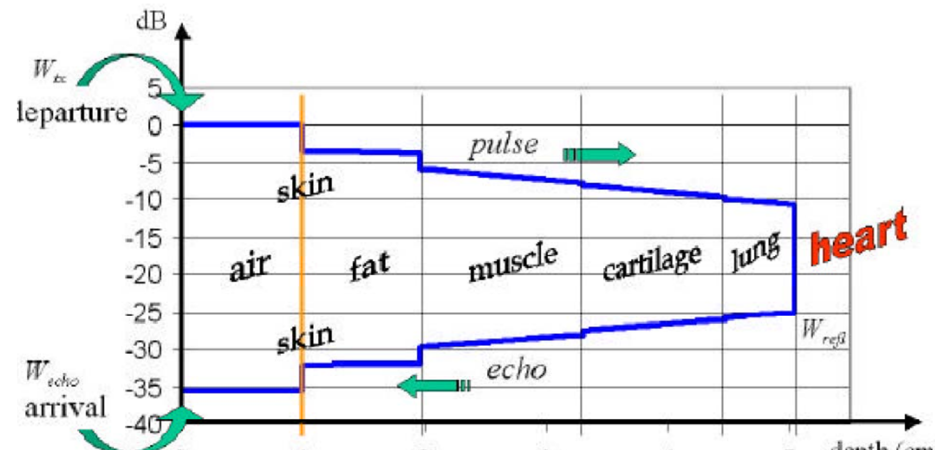
Received
Pulse (Rx)



PENETRATION ABILITIES

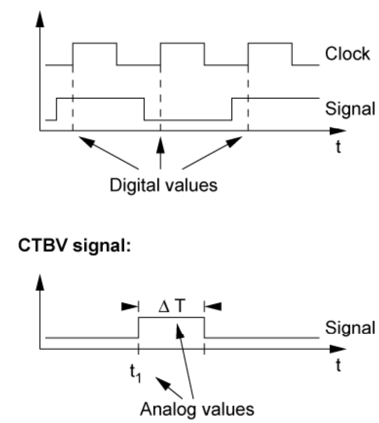
- Pulses penetrate heavy matter
  - Body penetration
    - Layered structure
      - Reflection and penetration due to resonance
      - Always some frequency with wavelength proportional to layer thickness
    - Impulses are wide band covering large frequency range





CTBV DOMAIN

- Time domain processing
  - Exploring technology speed
    - 90nm → 12ps inverter delay
  - Binary for low supply voltage
    - 1V → binary values
- Continuous Time – Binary Value



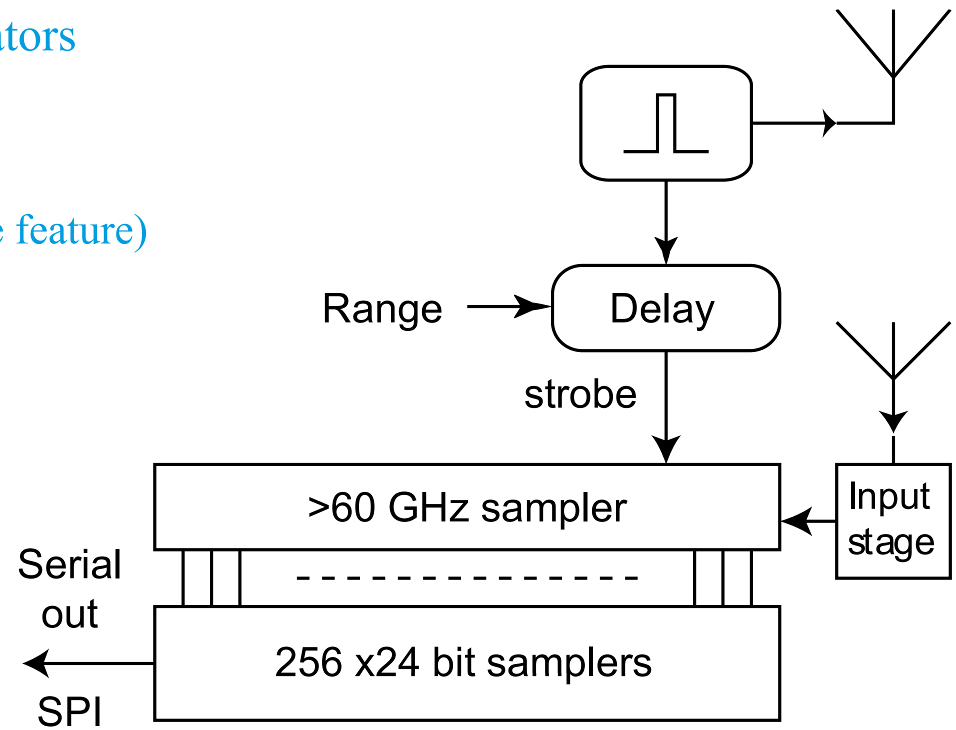
Time

Value	Discrete	Continuous
Binary	Digital	CTBV Neuromorphic/spike
Continuous	Analog sampled–data (switched–cap)	Analog

- No high speed clock
  - Power efficient
  - Continuous time like "infinite" clock

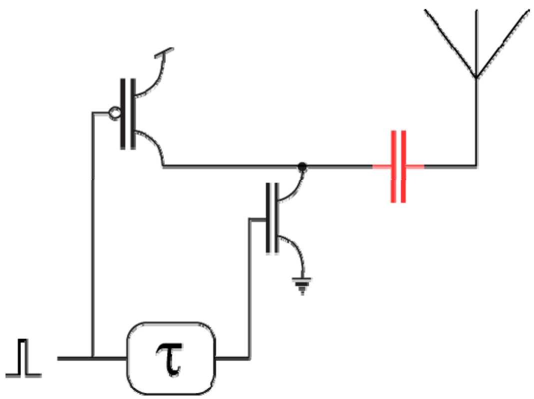
CTBV IMPULSE RADAR

- Single chip CMOS impulse radar – $1mm^2$ silicon
  - High speed sampler
    - Millimeters resolution
  - Single pulse → multiple depth
    - 128 parallel digital integrators
      - 256 in 2. generation
    - Covering ≈ 27 cm depth
      - Multiple ranges (unique feature)
  - Power efficient
    - 1.1V supply
    - No high speed clock
    - Low speed SPI readout
    - ≈ < 30mA total

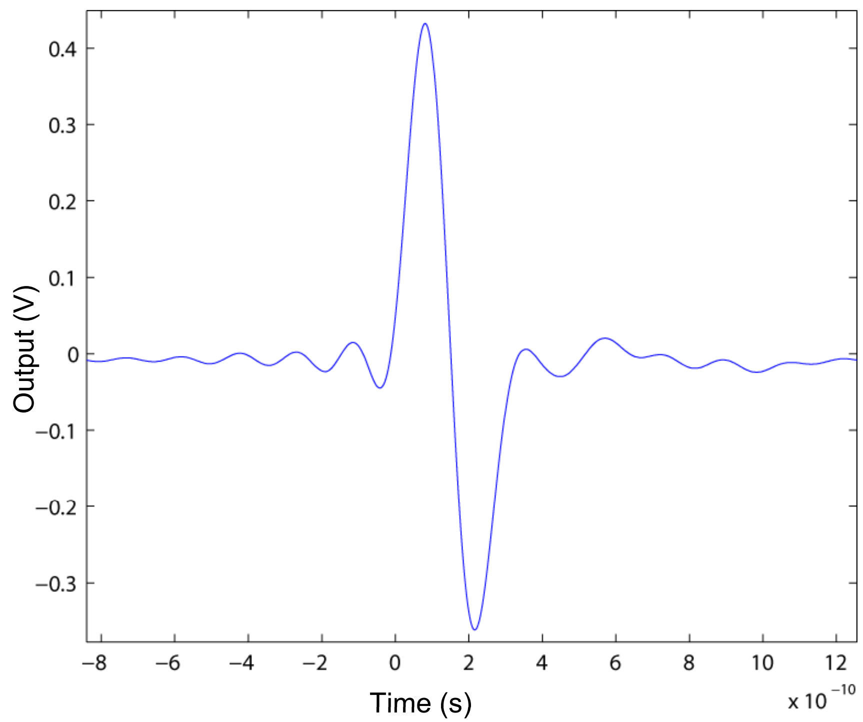


CTBV PULSE GENERATOR

- Dual slope generator
  - Power efficient
    - No stand-by power
  - No oscillator/clock
  - Limited signal swing



Measured dual slope

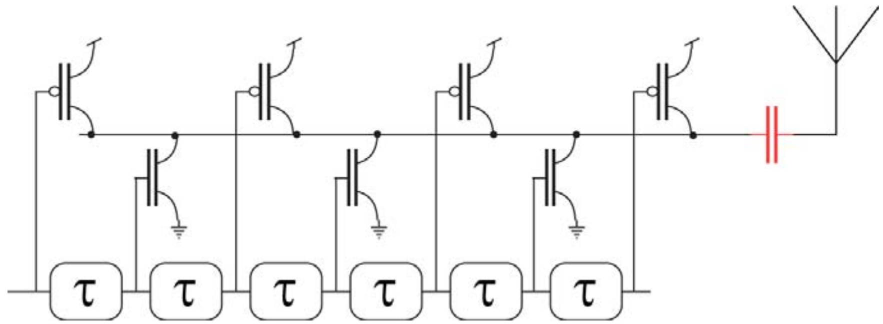


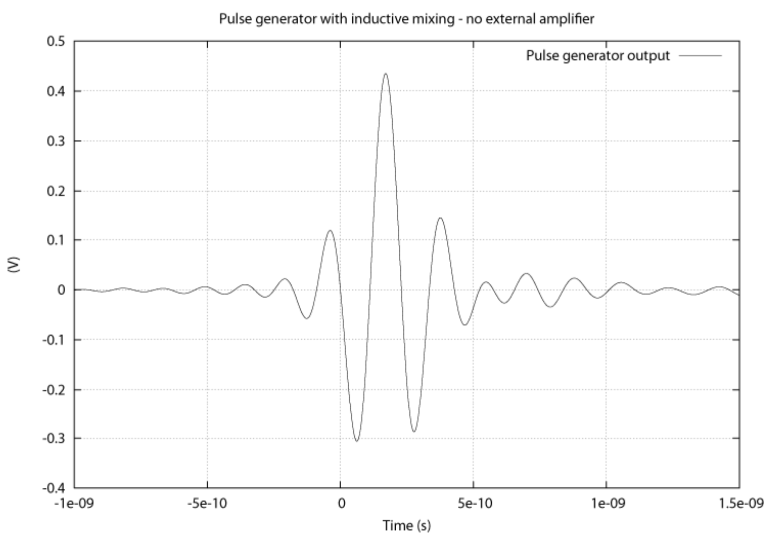
90nm STMicroelectronics process
50 Ω load with cable to scope

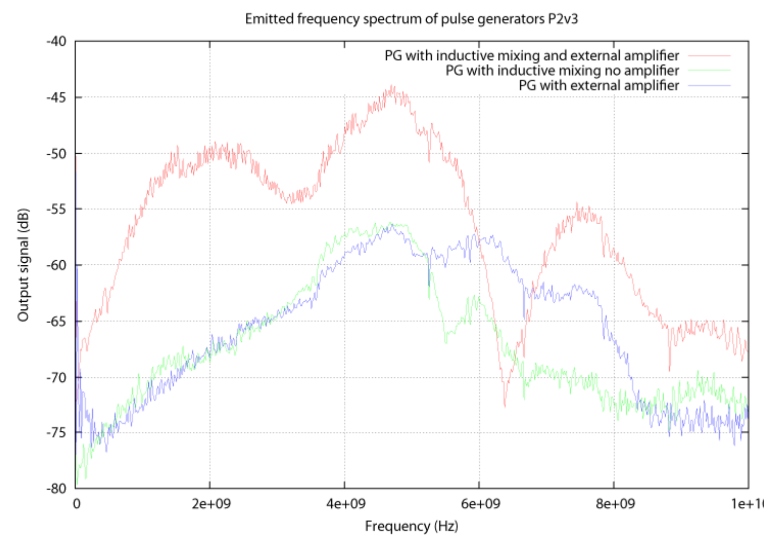
Period ≈ 300 ps

HIGHER ORDER GAUSSIAN

- Longer cascade
  - Scaling sizes





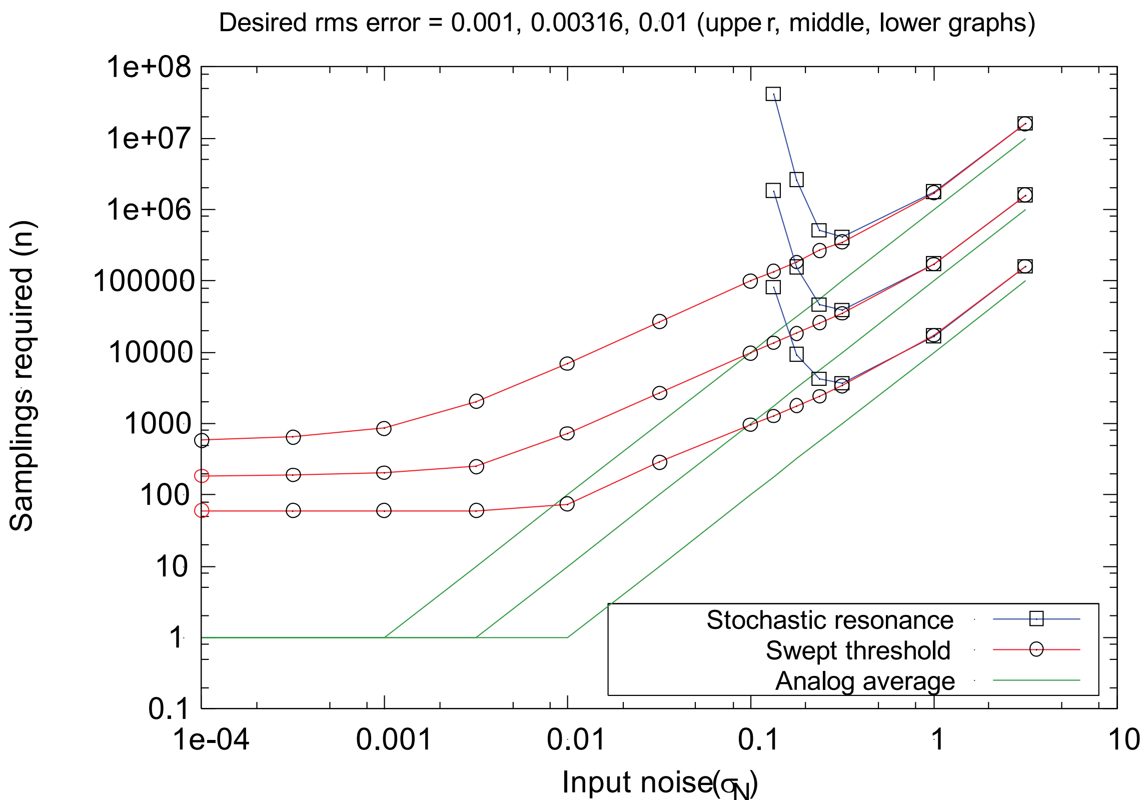


- No oscillator
- No stand-by power

- Works in digital CMOS
- Limited signal swing

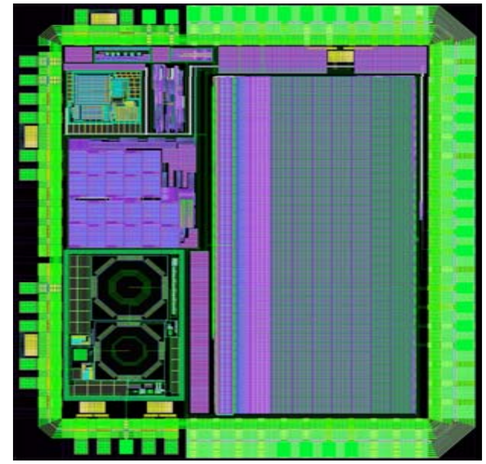
RADAR PERFORMANCE

- Reflected energy is low!
  - Buried in noise
  - Only recoverable with heavy integration

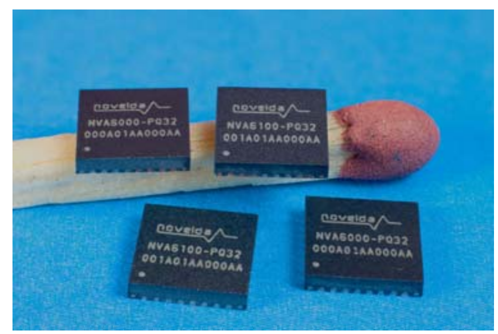


In noisy environments Swept threshold sampling is approaching an ideal integrator in performance!

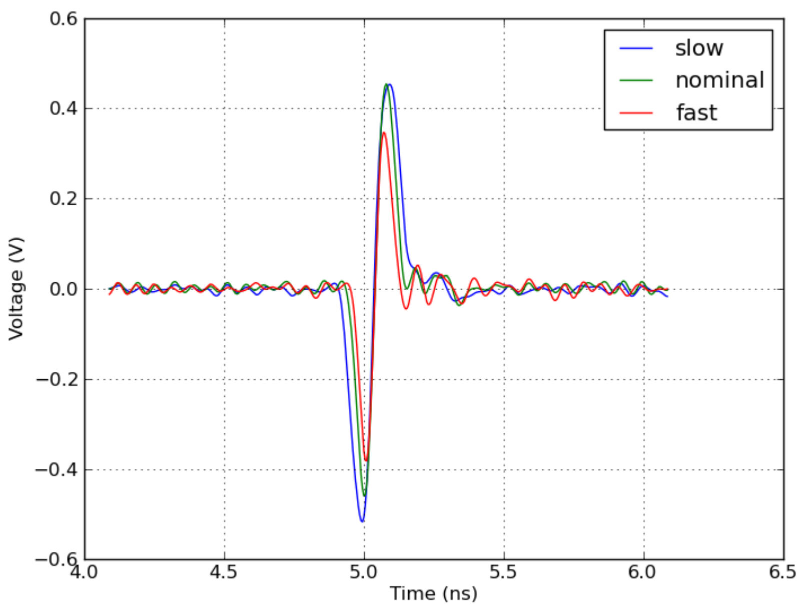
NVA6XXX NANOSCALE IMPULSE RADAR

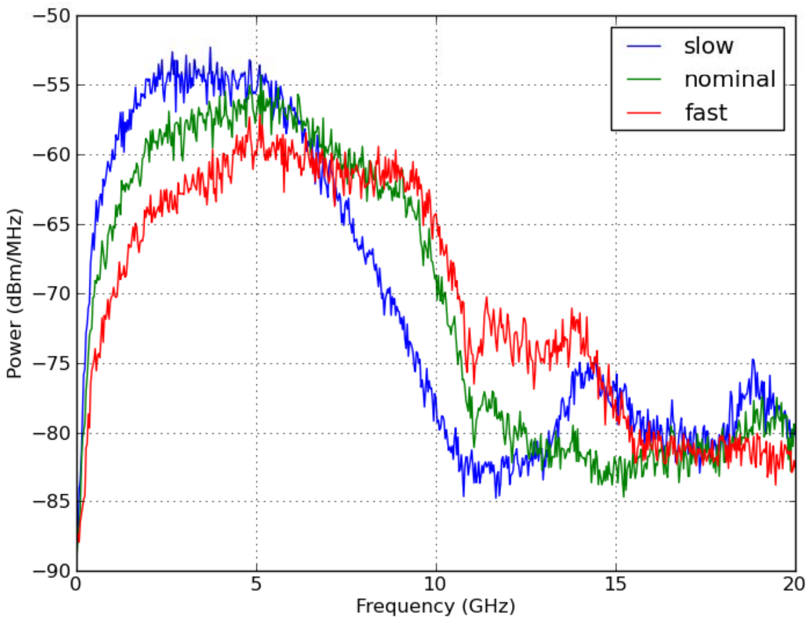


- **Single chip** Impulse RADAR
- Close Range Operation **0-60m**
- High-resolution, millimeter range
  - Sub mm with interleaved sampling
- High speed > 30GHz sampling rate
- Depth perception, 512 simultaneous depths
- Low energy
- Small size, CMOS
- TX frequencies
  - 0.7 GHz – 2.4 GHz (Medical)
  - 3.1 GHz – 5.6 GHz (US market)
  - 6.0 GHz – 8.5 GHz (EU/Asian market)

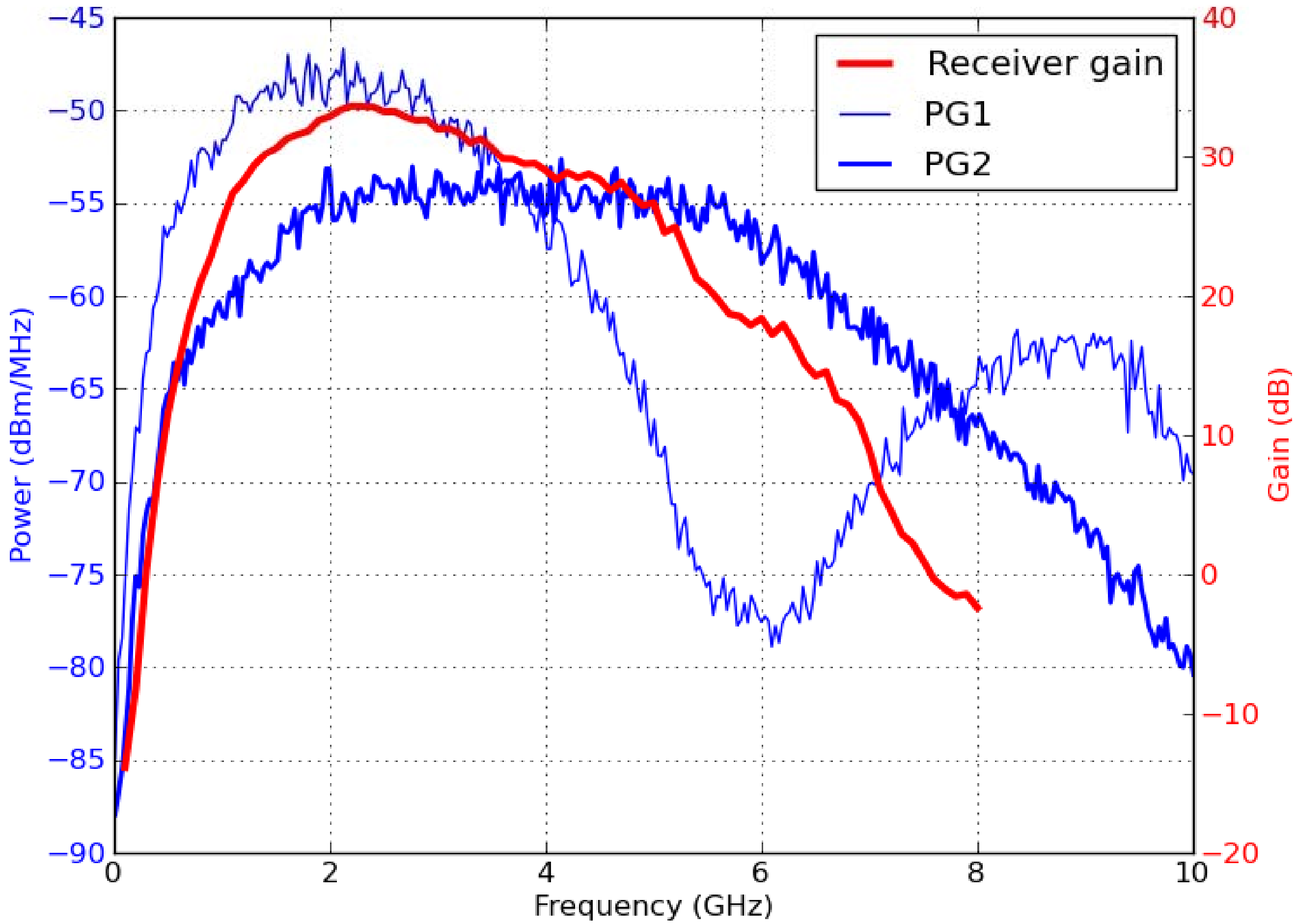


MEASURED TX FREQUENCY TUNABILITY

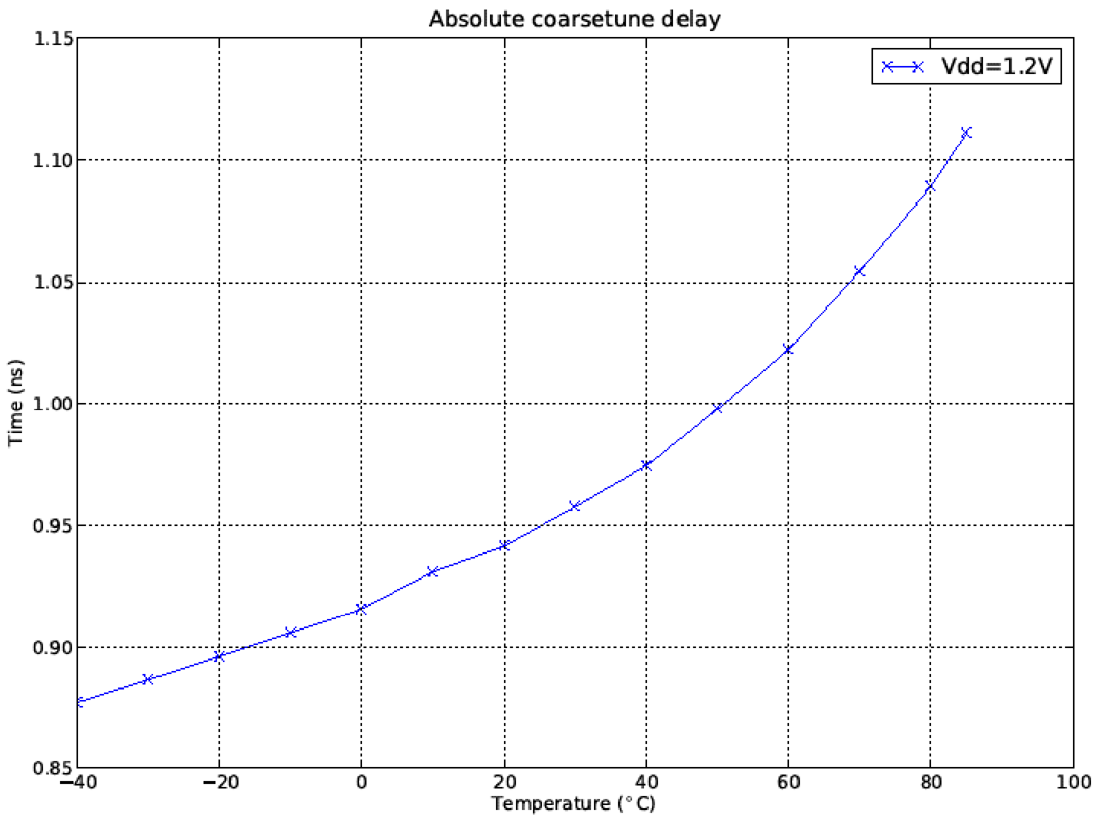




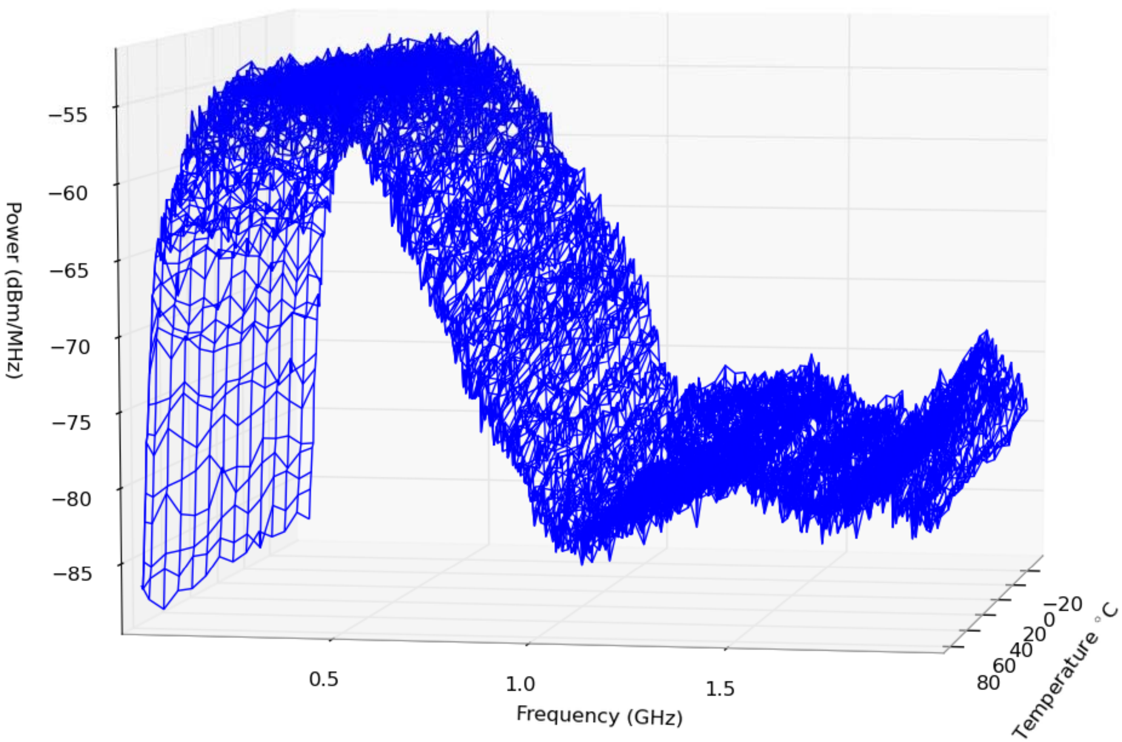
MEASURED TX/RX SPECTRUM



MEASURED TIME DELAY TEMPERATURE SENSITIVITY



MEASURED TX TEMPERATURE SENSITIVITY (MED. VERSION)



RADAR APPLICATION EXAMPLES

NVA R6XX DEVELOPMENT KITS

NVA R6XX DEVELOPMENT KITS

Common features

- Close Range Operation, 0-60m
- High-resolution
- Simultaneous observation of 512 depths with programmable depth resolution
- High speed; > 30GHz Sampling rate
- Ultra low RF emission (< FCC Part 15 limit)
- GUI
- C-library with API, Matlab examples

Two hardware modules

- Reference RF design with Digital SPI interface and SMA connectors for RX and TX
- IO module featuring a Micro controller with USB 2.0 Full speed and JTAG interface

NVA R6XX DEVELOPMENT KIT VERSIONS

Novelda R620 – Q4 2010:

- Single chip CMOS NVA6000P Impulse RADAR
- Transmit bandwidth (-10dB) from **6 GHz to 8.5 GHz**
- Designed for ETSI/FCC compliant

Novelda R630 – TBA:

- Single chip CMOS NVA6100P Impulse RADAR
- Transmit bandwidth (-10dB) from **0.7 GHz to 2.4 GHz**

Novelda R640 - Released:

- Single chip CMOS NVA6100P Impulse RADAR
- Transmit bandwidth (-10dB) from **3.1 GHz to 5.6 GHz**
- Designed for FCC compliant

Novelda R650 – TBA:

- Single chip CMOS NVA6000P Impulse RADAR
- Square pulse with adjustable **pulse-width from <100ps to >1ns**

APPLICATION EXAMPLES

AUTOMATION

Gas/fluid
Level detection/gauging
Automotive
Inspection

HEALTH & RESCUE

Monitoring vital Signs;
breath, pulse,
blood pressure,
stress, sleep, etc
Diagnostic sensors

GREEN

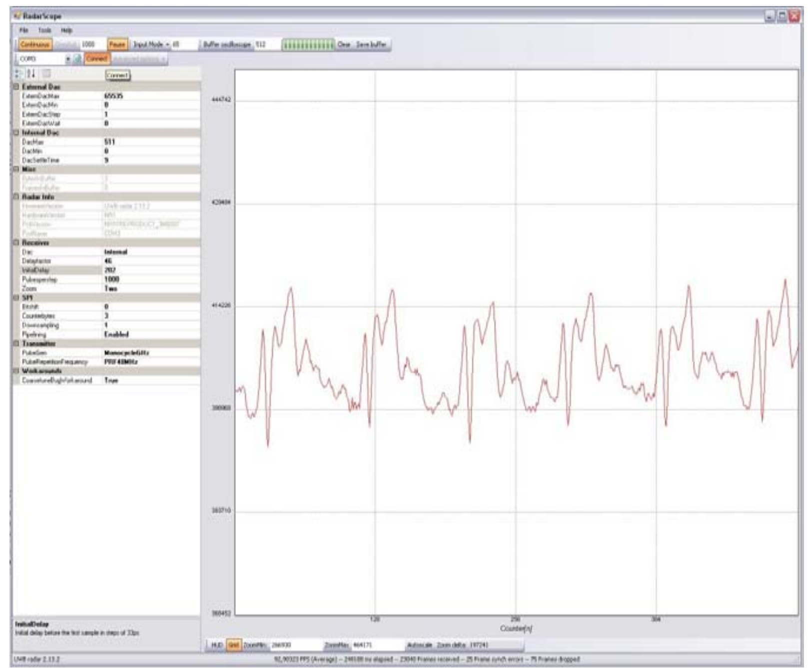
Energy automation
Snow measurements
Structures

DEFENSE

Soldier monitoring
Surveillance
Line of sight and
through the wall

APPLICATION EXAMPLE
REMOTE PULSE MEASUREMENTS

- Non-invasive
- Measures mechanical movement
  - Improved diagnostics quality
  - Early sign disease detection
- Skin/Fat/Tissue penetration
  - Ultra Wideband Radio
- Low cost (Single IC)
  - Physicians
  - Sport/Leisure
- Low energy / Small size
  - Long battery lifetime
  - Sport watch



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RECENT DEVELOPMENT CMOS RADAR

RECENT CMOS RADAR DEVELOPMENT

- JSSC 2010
  - 77 GHz FMCW (Toshiba Corp.)
- ISSCC 2010
  - 77 GHz FMCW (Nat. Taiwan Univ.)
- IEEE Radar Conference 2010
  - 77 GHz FMCW radar (Univ. of Melbourne)
- VLSI Symp. 2009
  - 77 GHz FMCW radar (Toshiba Corp.)

CONCLUSIONS

- “Real UWB” impulse radar is feasible in standard CMOS using the CTBV approach
- mm-precision ranging is achievable
- Impulse radar penetrates human tissue
- Calibration mechanisms must be employed to cope with delay variation
- **Commercial UWB is not dead!**

ACKNOWLEDGEMENTS

- Thanks to RCN for funding our R&D through the "UWBPOS" and "CARDIAC" projects
- Thanks to "Bassen" for providing nice slides on UWB/Impulse radar fundamentals
- Thanks to Nanoelectronics Group at Dept. of Informatics, Univ. of Oslo for fruitful R&D cooperation


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NANOSCALE IMPULSE RADAR
THANK YOU FOR YOUR ATTENTION!
QUESTIONS?