COST-289 Meeting Fall 2005

3-4 November 2005, Madrid, Spain

UWB Technologies

Álvaro Álvarez Vázquez

Summary

- Our Company
- Introduction
- History Overview
- UWB Signals
- Propagation of UWB signals
- UWB Systems and Technology
- Applications
- Bibliography

Our Company

- ACORDE was created in 1999 as a spin-off company of DICOM, Department of Communication Engineering of the University of Cantabria.
- ACORDE is located at the Center for the Industrial Development of Cantabria (CDTUC), a specialized center for high-tech and research companies.
- Quality guaranteed…
- November 2001: ISO 9001:2000
- In preparation: PECAL

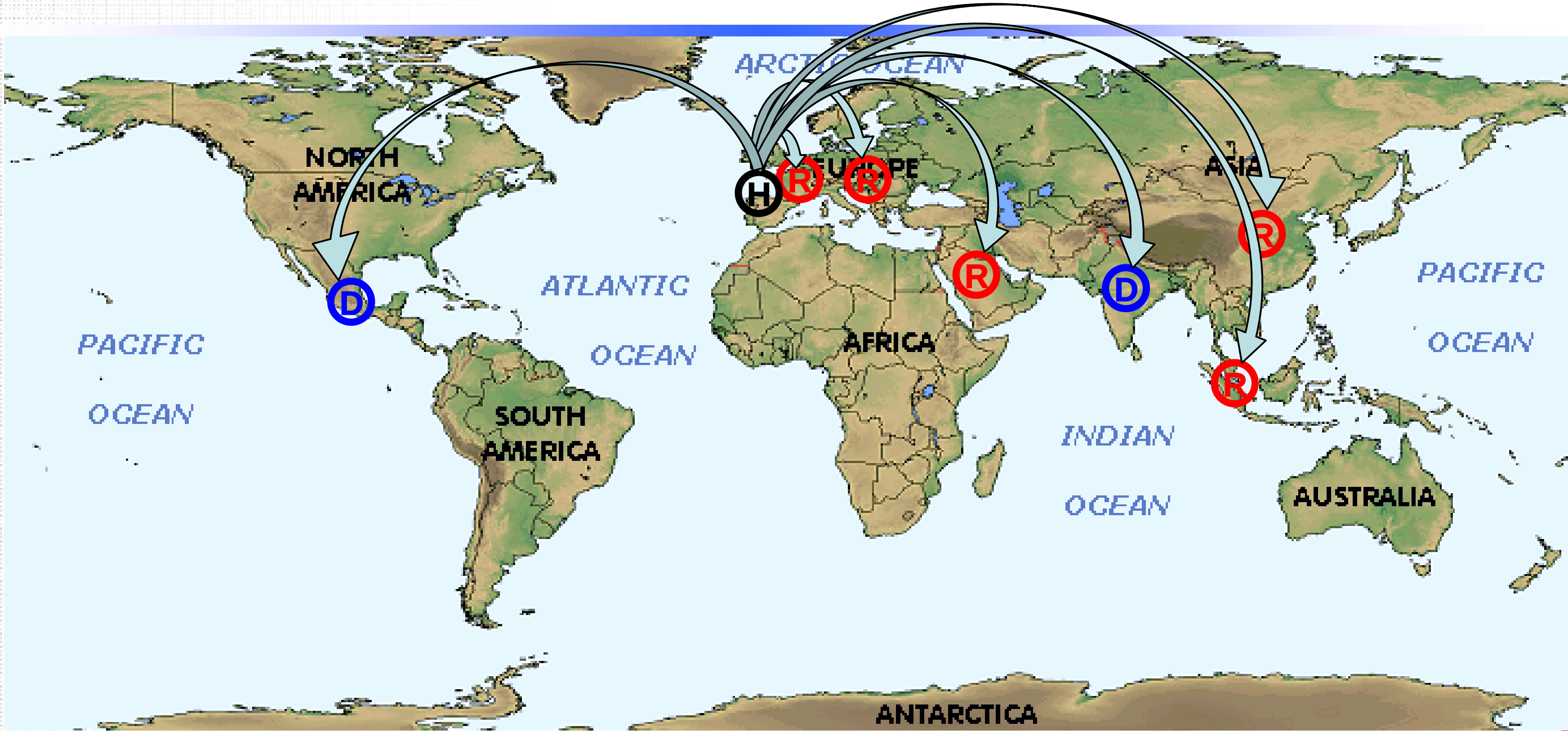
Company Profile

- Activities:
  - Design and Development of components, equipment and systems for telecommunications
  - Provide Engineering and R&D services to other industries, telecom manufacturers, system engineering companies and service providers
  - Development of prototypes, small and medium series and turn-key products
- Commercial Strategy:
  - Our aim is to satisfy our customers providing personal support by implementing our resources & technology in your needs
  - Our technical department is in constant state of alert to provide the RMA as soon as possible in order to return-back the repaired equipment to our customers, typically less than 15 days

ACORDE Customers

- Alcatel Espacio
- EADS
- Indra
- Telefonica
- Informatica El Corte Ingles
- INTA-INSA (Maspalomas)
- SENER
- IZAR

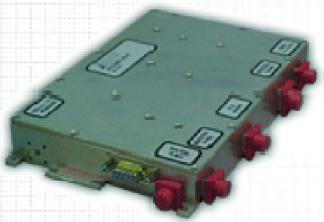
Offices & Delegations

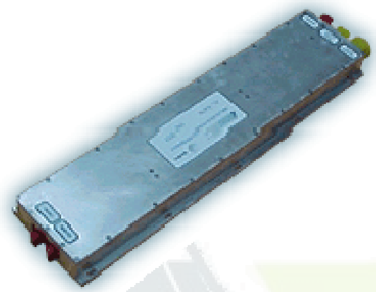


- **Headquarters:** Santander (Spain – EU)
- **Sales Offices:** Madrid (Spain - EU)
- **Commercial Representatives:** China, Indonesia, Saudi Arabia, Austria, France
- **Delegations:** India, Mexico* (for North America – USA & Canada)

Products

- Equipment for Satellite Communications:
  - Transceivers for V-SAT: C, X, Ku, & Ka bands
  - Civil and Military Applications
  - Frequency Converters: C- X, Ku & Ka bands
  - Solid State Power Amplifiers C-Band (100W), X (40 W), Ku (16 W) & Ka (2W)
  - Ku Extended Bandwidth (750 MHz BW)





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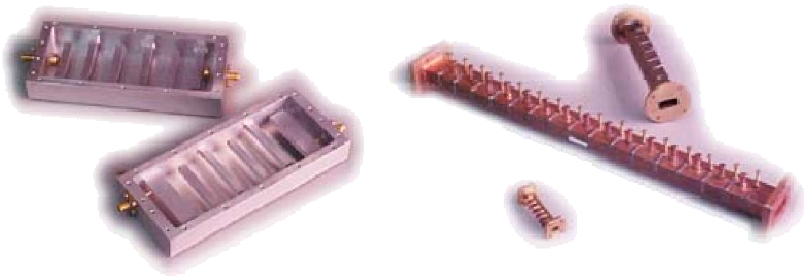
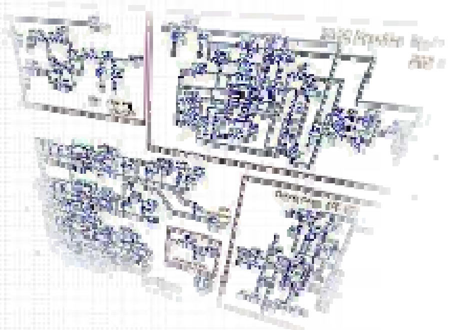
Products

– High stability and low phase noise Synthesizers and Oscillators for civil and military systems
– High Frequency Components up to 50 GHz
– Filters:
  - Waveguide Filters
  - Cavity Filters
  - Dielectric Resonator
  - Micro-strip

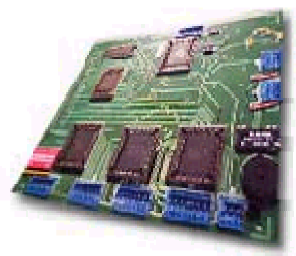


– Power Suppliers and Control & Monitoring Cards



Products

- Home Automation and Control Devices:
  - Control Systems
    - Surveillance and Tele-measurement via radio: short range communications + GSM or GPRS links
    - Monitoring and Control through GSM and Internet



Previous Projects

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  - H ... iFi to
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Previous Projects

- Radio over Fiber Distribution (UMTS)
  - Bidirectional distribution of UMTS from the base station (B node) to remote terminals.
  - Broadband Distribution:
    - GSM900
    - GSM1800
    - UMTS
    - WLAN
- MARECS
  - Receiver & Transmitter for the SMART1 mission of ESA: Moon Exploration
  - L-, X, Ka bands down-converters with very low phase noise and very high phase estability with temperature changes.
  - The especification of phase estability is critical and and probably is the first time this requirements is implemented mainly in the Ka band.

Research and Development:

- **V Framework Program**
  - WINE (Wireless Internet Networks)
  - WIND-FLEX (Wireless Indoor Flexible High Bitrate Modem Architectures)
  - U.C.A.N. (Ultra Wideband Networks for Ad-Hoc Concepts)
- **VI Framework Program**
  - MAGNET (My Personal Adaptive Global Net)
  - PULSERS (Pervasive Ultra-wideband Low Spectral Energy Radio Systems)
  - 4-MORE
  - WISE
- **GALILEO**
  - GREAT
  - POSIRIS
- **PROFIT**
  - **ONDA (UWB Related)**

Research and Development:

- MMIC Design and Test
  - ACORDE is a fabless company, we study, design, simulate, and test our own MMICs, which are manufactured by external foundries
    - AsGa: Ohmic → Shipped satellite circuits, power applications and very low noise amplifiers
    - SiGe: Freescale (former Motorola → Mobile applications, high speed digital circuits, low cost, low power applications)
  - Design and simulation capabilities:
    - ADS (system level and circuit level simulations)
    - Cadence (circuit level simulations and layout)
  - Test capabilities

Research and Development:

- MMIC Design and Test
  - Test & Measurement Capabilities:
    - Class 10K and Class 1K Clean Room
    - Probe Station for on-wafer and on-chip measurements
    - 20 GHz Transient Analyzer
    - 50 GHz VNA
    - 500 MHz DSO
  - Integration
    - Wire bonding
    - Flip chip facilities

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ADVANCED COMMUNICATIONS RESEARCH & DEVELOPMENT

Introduction

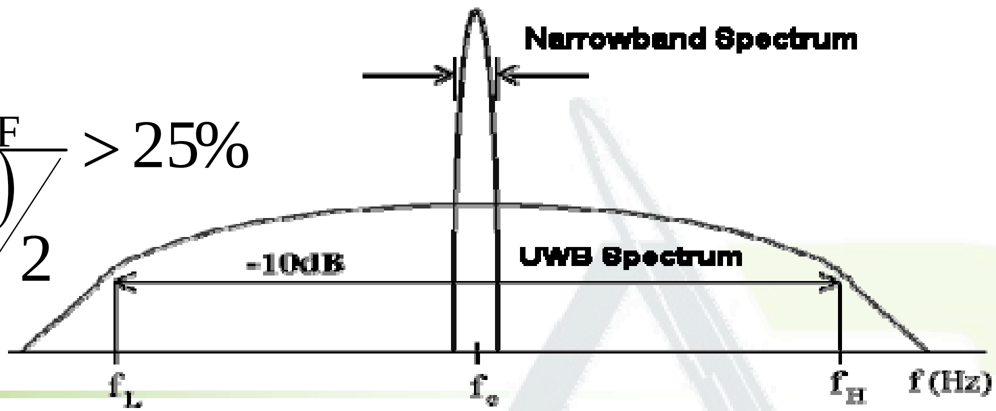
What is UWB?

"Any emitting device where the fractional bandwidth is greater Than 0.25 Or Occupies 500 MHz or more of the Spectrum or more of the Spectrum" (FCC - 2003)

- Signal @ 4 GHz is UWB if BW > 500 MHz
- Signal @ 1 GHz is UWB if BW > 250 MHz

Fractional Bandwidth

$$FBW = \frac{BW}{f_C} = \frac{f_{SUP} - f_{INF}}{\left(f_{SUP} + f_{INF}\right)/2} > 25\%$$



What is UWB? (II)

"UWB" is also known as: Impulse radio, Carrier-free, Baseband Radio, Time domain Signals or Pulsed Radar

✓ UWB do not concentrate the RF energy → Radio Power spread over several GHzs

✓ UWB is much wider than conventional narrowband and wideband signals

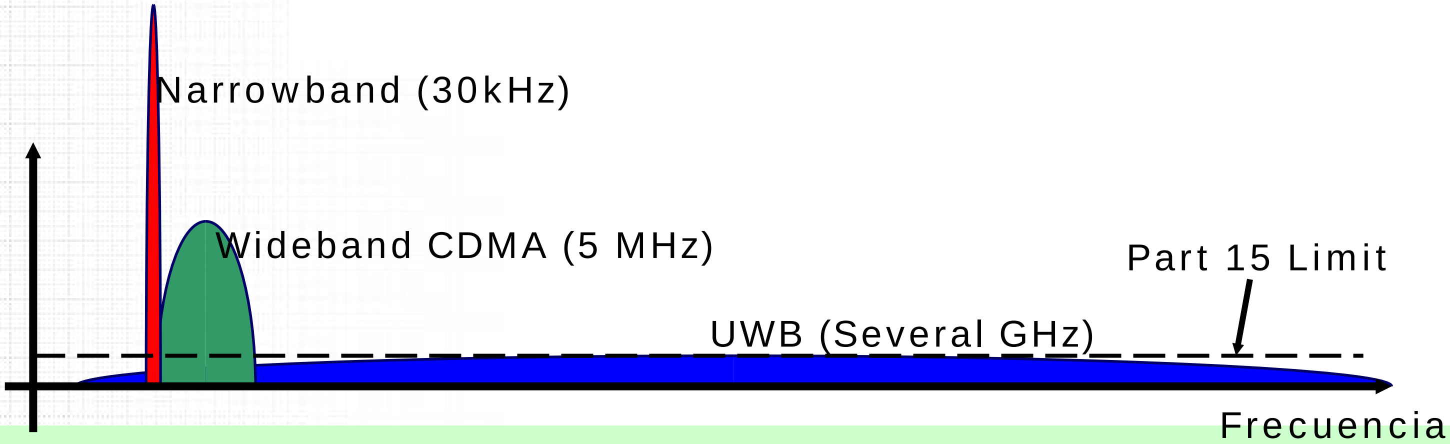
✓ UWB could be transmitted below thermal noise (seems to be *random noise*)

What is UWB? (III)

UWB signals:

- Pulsed signals → Gaussian, Rayleigh, Laplacian pulses, Wavelets, Doublets, Hermitical Polynoms, etc…
- High Frequency Chirps
- Dumped Sinusodials → (Their intentional use is forbidden)
- Direct Sequence Spread Spectrum
- Time Hopping Spread Spectrum
- Frequency Hopping Spread Spectrum

UWB Spectrum

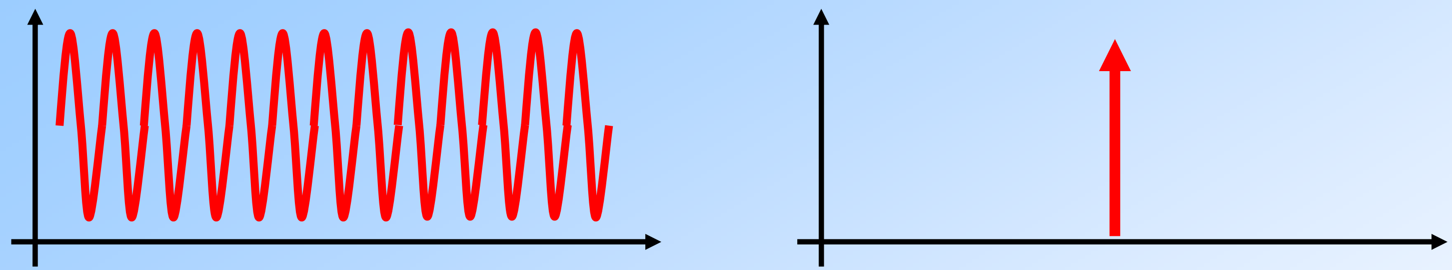


Large bandwidths allow:

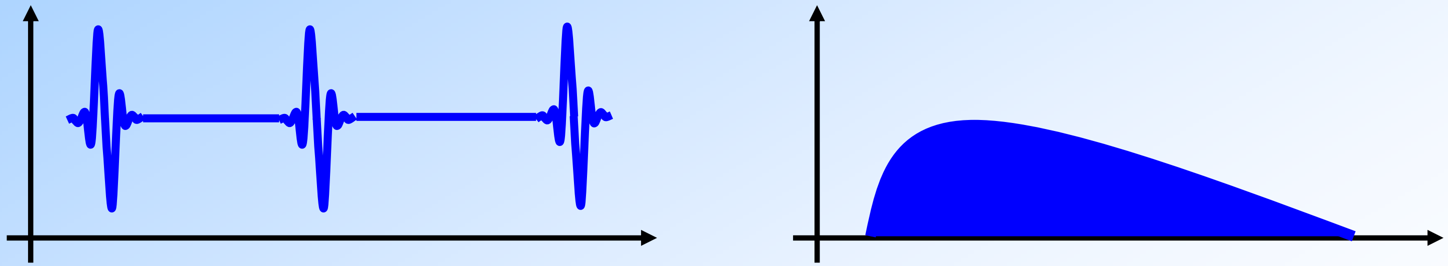
- ✓ Reduce the multipath fading
- ✓ Increase system capacity (Shannon Theory)
- ✓ Achieve low power spectral densities → **Spectrun re-use**
- ✓ Low interception probability

Time Domain UWB

Narrowband Signal (Sinusoidal Carrier)



UltraWideband (Pulsed)



- UWB BW > 500 MHz
- UWB do not use continuous carriers
- UWB works in the time domain → Radar applications

History Overview

UWB History

-1000 No Radio communications.. but they were broadband pulsed communications → Tam Tam!!

1870 First radio transmissions → Hertz → Spark gaps = UWB in nature

Morse Tx

1880 Morse Code and Telegraphy → Radio Expansion → Pulsed transmission

UWB History (II)

1900 New concept → Carriers → Radio channels

1912 Radio regulation → Hertz radio is forbidden

1920 Radio communications quick grow → New modulation schemes

1940 Shannon Theorem → System Capacity

$$C = BW \cdot \log_2\left(1 + S/N\right)$$

UWB History (III)

1950	UWB comes back → Localization & RADAR
1960	First patents on UWB
1970	UWB fully analog → UWB analog + digital
1990	UWB Impulse Radio for communications (USC)
1998	First Commercial products for handheld applications

PULSON, Trinity….

Collision Avoidance, GPR…

UWB History (III)

2000	Europe starts its work on regulation
2002	UWB products were approved for the US market
2003	The IEEE starts the standardization process for UWB communications → IEEE 802.15.3 for HDR and IEEE 802.15.4ª for LDR and localization (RADAR basis)
2004	Co-existence trials performed by the CEPT
2005	New applications

TODAY…..

UWB Regulation Background

USA

February 1998 – U.S. Radar, Time Domain & Zircon request a commercial license for their Ground Penetration Radars and short range communications

September 1998 – FCC releases the first Notice of Inquiry in order to study the operation of UWB systems

May 2000 – FCC → Proposed Rules for Comment:

- Regulation
- UWB definition
- Frequency band
- Test and Evaluations
- Emission Limits
- Measurment Procedures
- Other issues

2000/2001 – NTIA starts a measurement campaign of UWB systems over GPS

UWB Regulation Background (II)

EU

The CEPT (SE24) start an study on the regulation of UWB in Europe → Spectrum sharing below 6 GHz

The ETSI (TG31a) starts the standardization process in Europe → Tests

Japan

The MPT (Ministry of Post and Telecommunications), starts the regulatory process dealing with the industry.

The MPT grant free evaluation licenses for UWB systems

ITU ITU-R (Study Group 1) is working on a UWB specific recommendation

US Present Status

The FCC has approved the UWB systems under the following assuptions:

- ❑ Graphical and RADAR Systems
  - GPR (Ground Penetrating Radars), Wall Imaging Systems (f< 960 MHz, 3.1 GHz – 10.6 GHz)
  - Through–Wall Imaging systems (f< 960 MHz, 1.99 GHz – 10.6 GHz)
  - Medical Systems (3.1 GHz – 10.6 GHz)
  - Surveillance Systems (1.99 GHz – 10.6 GHz)
- ❑ Communications: 3.1 GHz - 10.6 GHz
- ❑ Vehicle Radar (anti-collision): Centered @ 24 GHz

European Present Status

2 groups are tracking the regulatory and standardization process for UWB:

CEPT SE24

- ✓ European Conference of Postal and Telecommunications Administrations Spectrum Engineering Committee 24
- ✓ It is currently studying the compatibility of UWB and other service below 6 GHz
- ✓ The results will be delivered to the national agencies
- ✓ In charge of the European contribution to the ITU-R TG 1/8

European Status (II)

ETSI TG31a:

- Focused on viability studies and test
- Working on Co-existence experiments (from July 2004)

TG31b:

- UWB for vehicles
- Analyzing the measurement results

CEPT SE24 Draft Report – Article 1

Protection of fixed services below 6 GHz

BW: 3.41-3.6 GHz, 3.6-4.2 GHz y 4.4-5.0 GHz, some of them 20 dB below the FCC mask

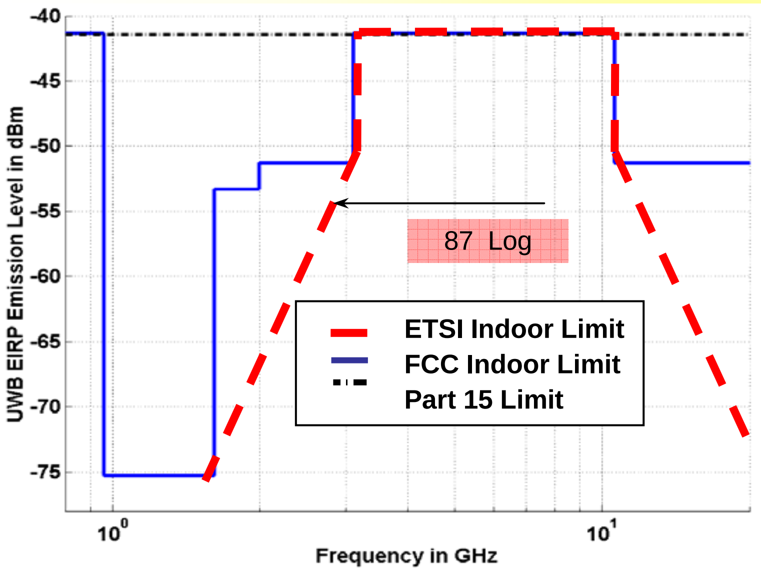
As in the FCC : 3.1-3.41 GHz y 4.2-4.4 GHz

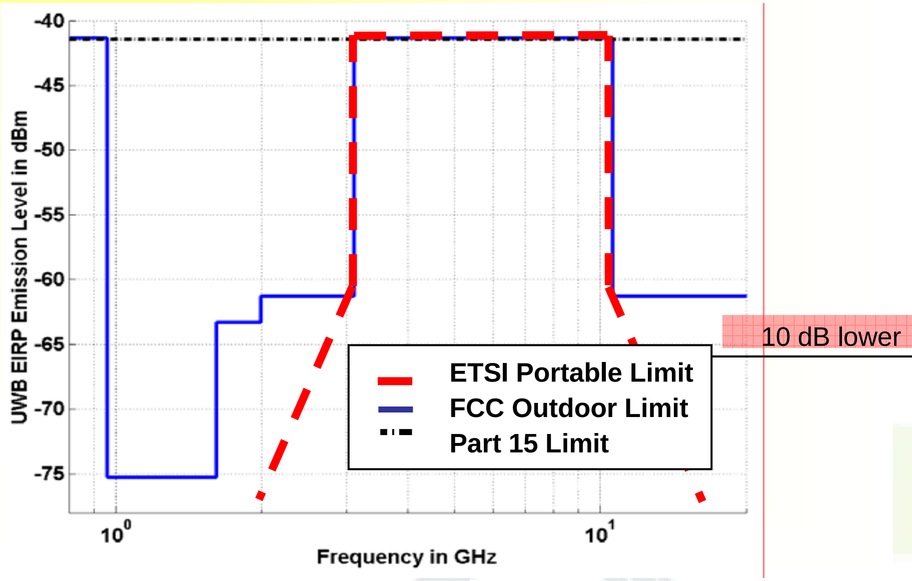
Those results will be delivered to the ITU-R TG 1/8

Comparison

US vs. Europe. Main differences:

- Emission mask (PSD)
- Device Category
  - EEUU: Indoor & Handheld
  - Europe: Indoor & Portable





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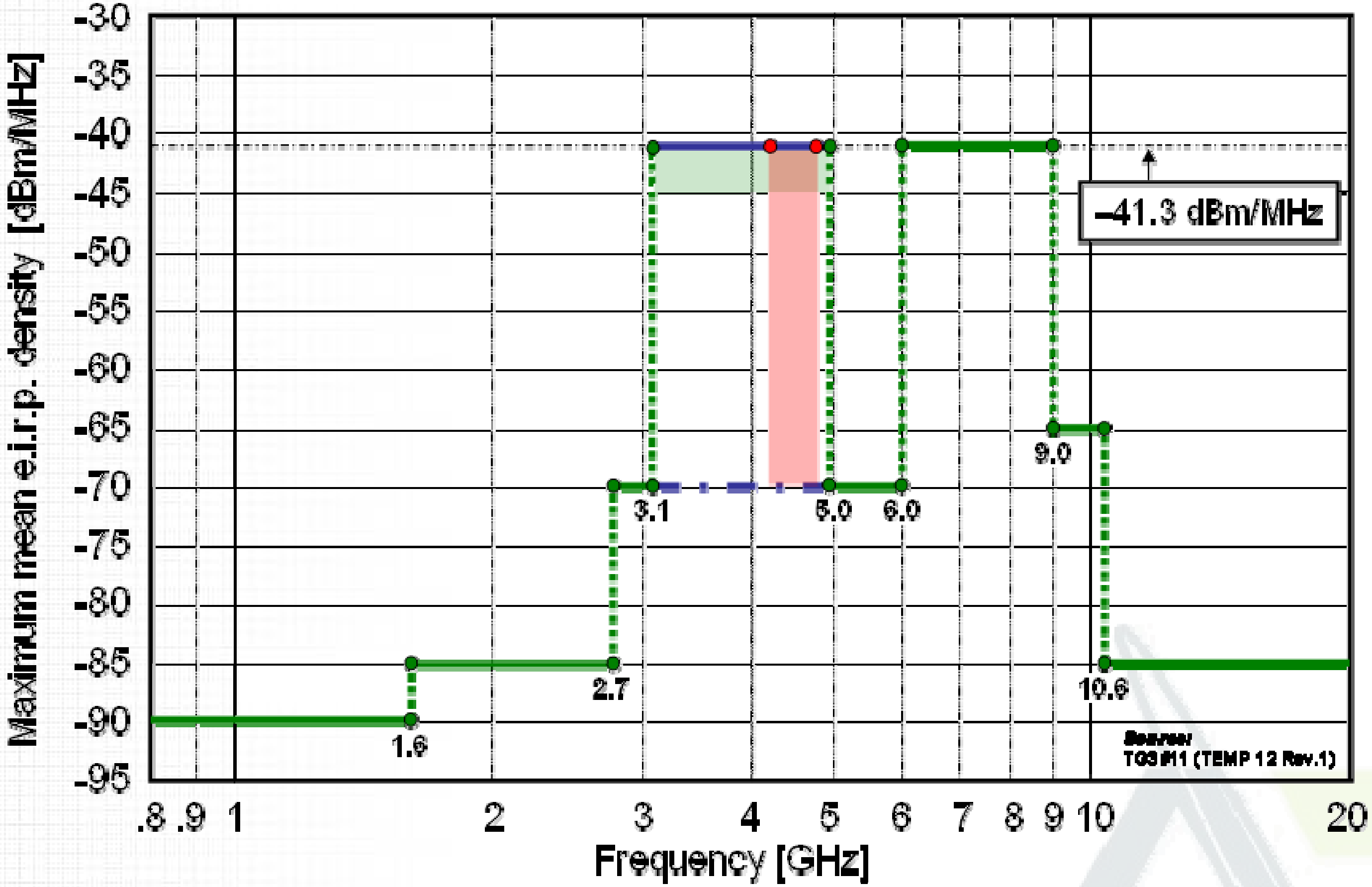
Latest European Proposal (Sept. 2005)

CEPT ECC#11 Draft UWB Mask



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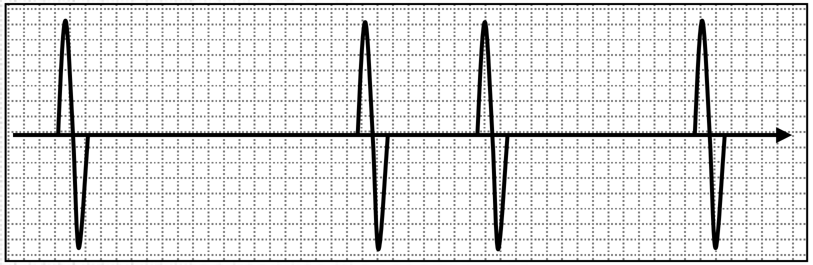
UWB Signals

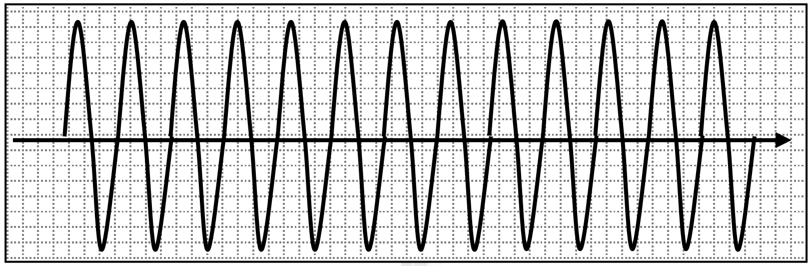
UWB Main Characteristics

UWB is UWB due its large bandwidth.

Large bandwdith = Non periodical signal (a periodic signal has spectrum peaks)

Large bandwidth → Avoid periodicity → Pulsed signals →Break with traditional carrier systems





Before UWB → Superheterodine receivers, with frequency conversions, LO's, mixers…

Now → Pulse generators and signal correlators

UWB Main Characteristics (II)

Main Properties:

✓ Low power spectral densities and large bandwitdh (from 500 MHz to several GHz)

✓ Low interference with other radio systems (Co-existence)

✓ Relative high peak instantaneous power vs. low average transmitted power (below thermal noise)

✓ Processing gain → Peak versus average transmitted power

UWB Main Characteristics (III)

✓ Pulse widths (time domain) from hundred of picoseconds (monoband) to few nanosecond (multiband)

✓ Spectrum shape dependant on the pulse shape. Spectrum peaks caused by modulation and coding

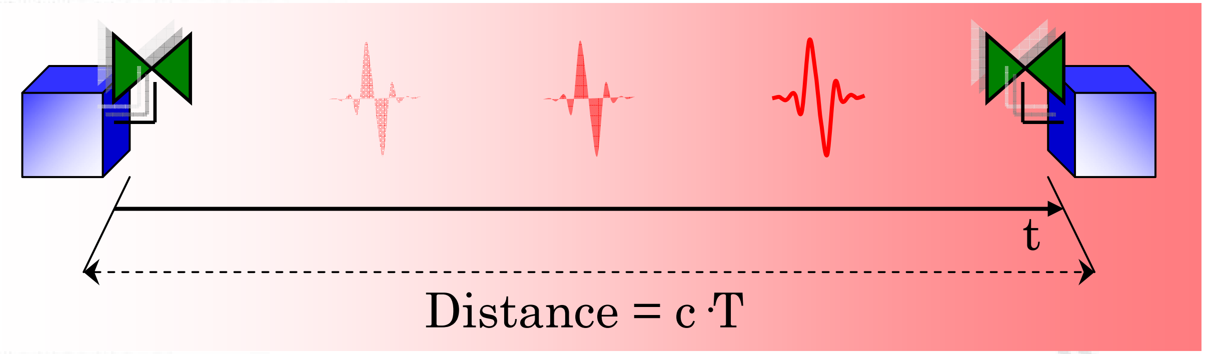
✓ Low frequency UWB signals are able to be propagated in harsh environments and through wall, ground or forest → Many interesting applications

✓ Allow both localization (RADAR) and communications to be done with the same system

UWB Main Characteristics (IV)

✓ Large capacity for short range applications

✓ Allow very precise ranging, localization and positioning (due to signal propagation delay of the transmitted pulses)

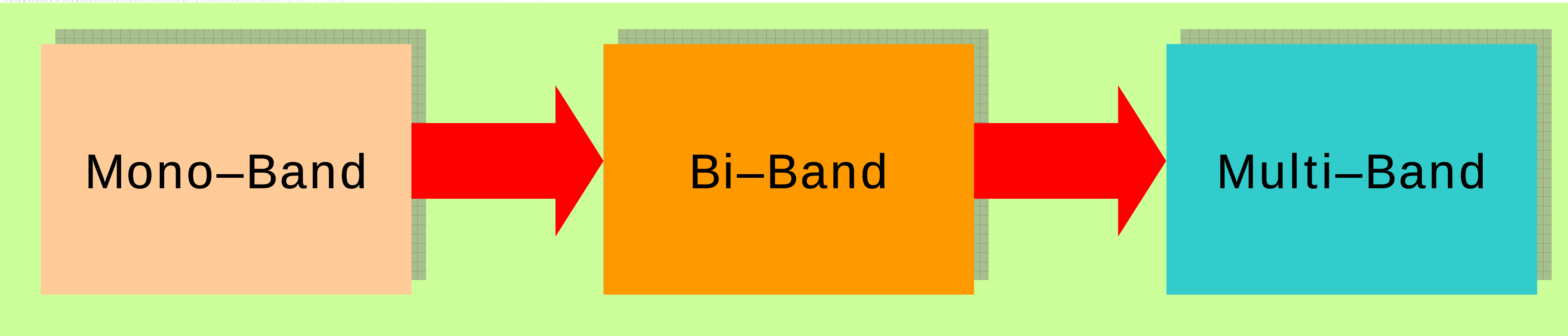


✓ Ideal for Ad-Hoc Networking (communication positioning and smart routing)

UWB Signals

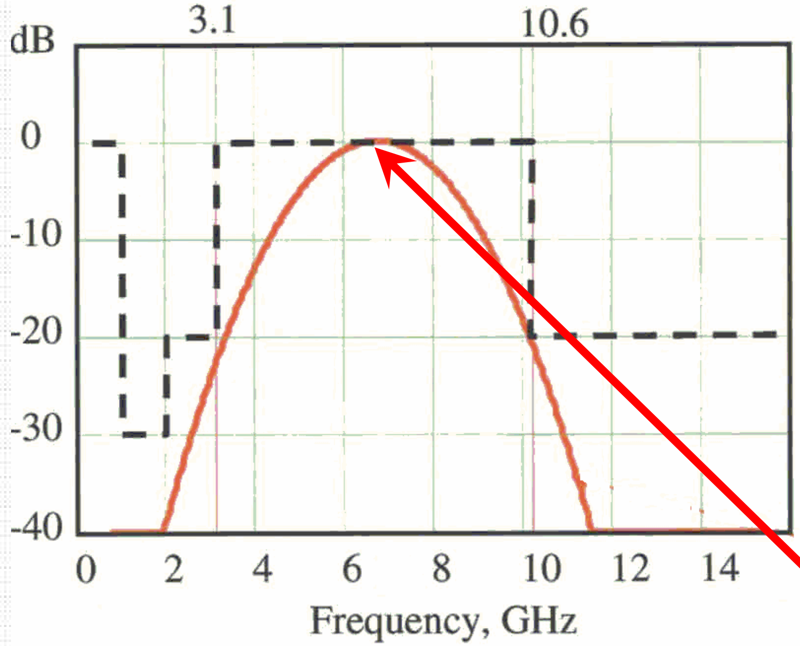
Nowadays, UWB is what the FCC defines. This definition opens many options:

- 5 years ago → UWB = Impulse Radio
- 4 years ago → UWB = Impulse Radio + Multiband – Pulses
- 3 years ago → UWB = Impulse Radio + MB–Pulses + MB–OFDM + MB–CDMA + FM–UWB + Chirp-UWB
- Today → UWB = Everything with BW > 500 MHz and between 3.1 – 10.7 GHz



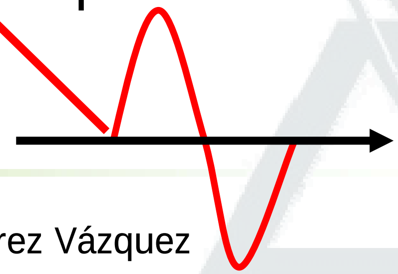
Monoband Impulse Radio UWB

Original UWB, based on the transmission of radio impulses. This solution:



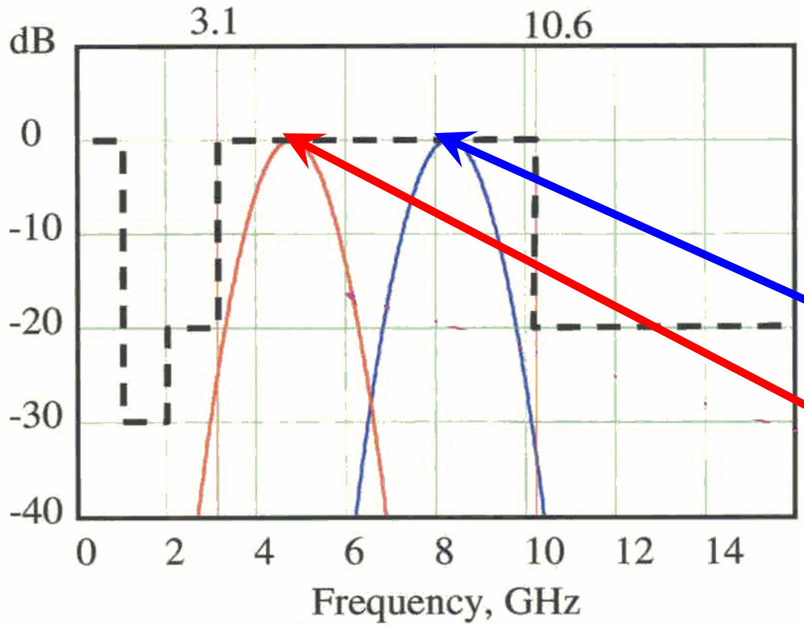
- Takes benefit from multipath
- Makes use of filtered pulses
- Not flexible in the freq. doma
- Provides fine time resolution

→ State of the art technology for Chip (IC) implementation



Biband Impuse Radio UWB

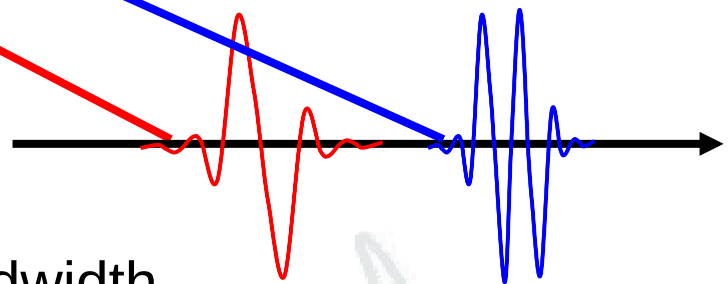
Evolution from monoband



Avoids the 5 GHz band-ISM

Relax system requirements

Cost Reduction

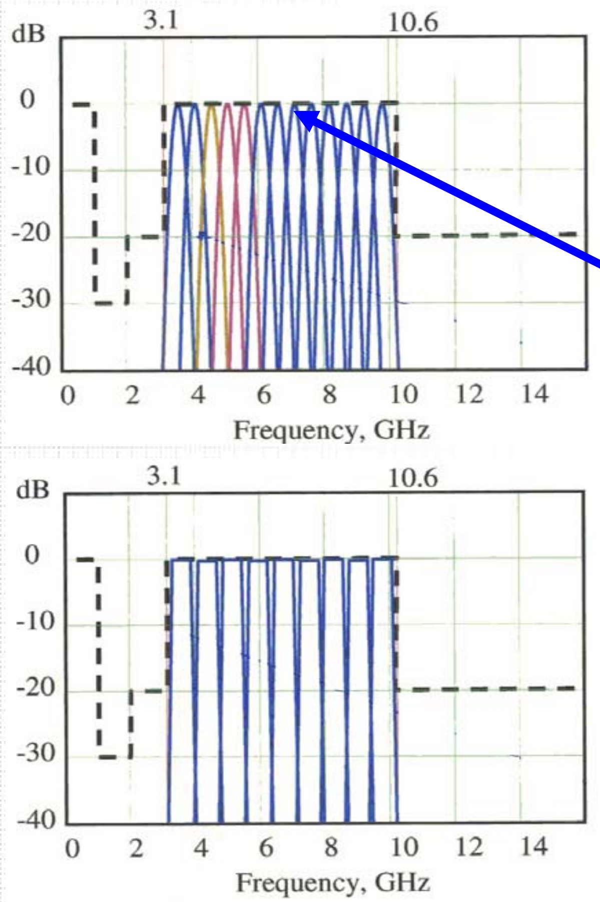


Pulse width defines the UWB bandwidth

Pulse cicles defines the center frequency

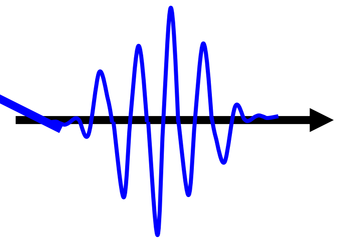
The signal envelope provides information on the power

Multiband Impuse Radio UWB



The multiband solution provides:

- Spectrum flexibility
- FD/TD Multiplexing
- RF complexity (oscillator)



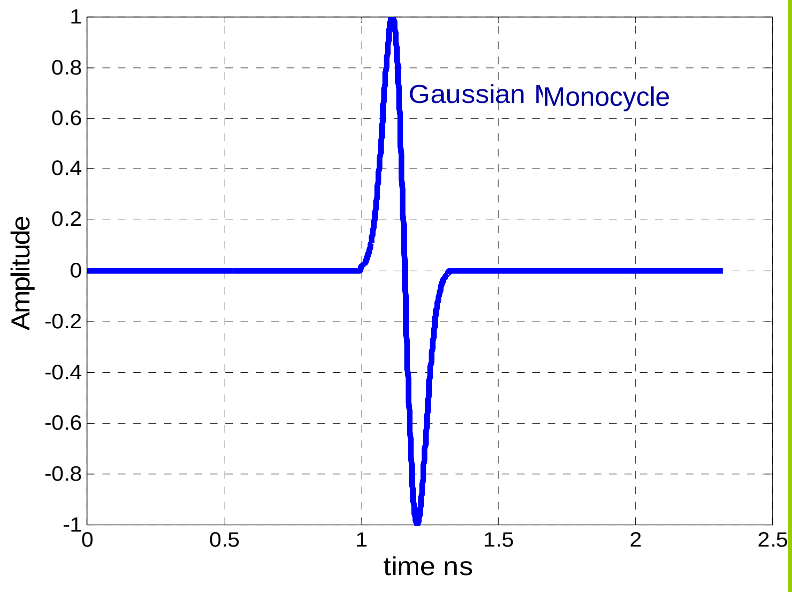
→ UWB-OFDM option:

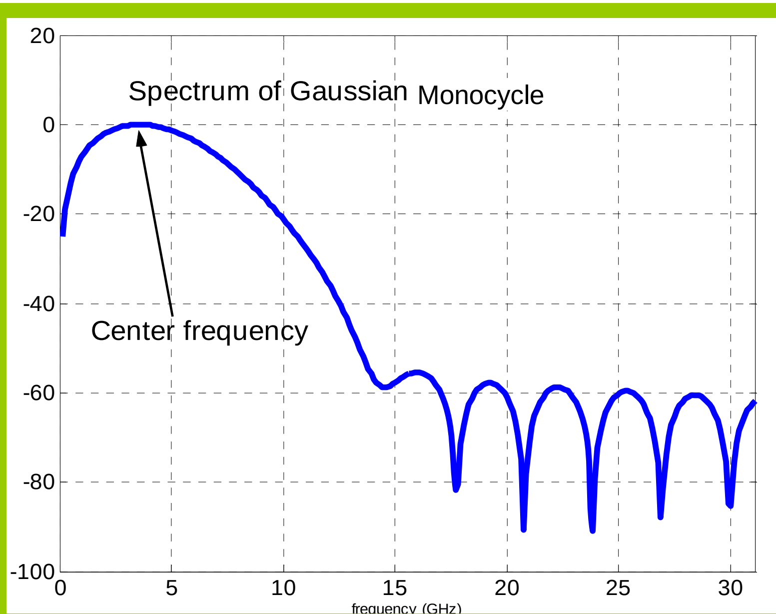
- Fine frequency control
- Increased processing complexity

Impulse Radio

Impulse Radio is the first solution when trying to achieve large bandwidths

It is based on the transmission of a short RF burst or short time electrical impulse

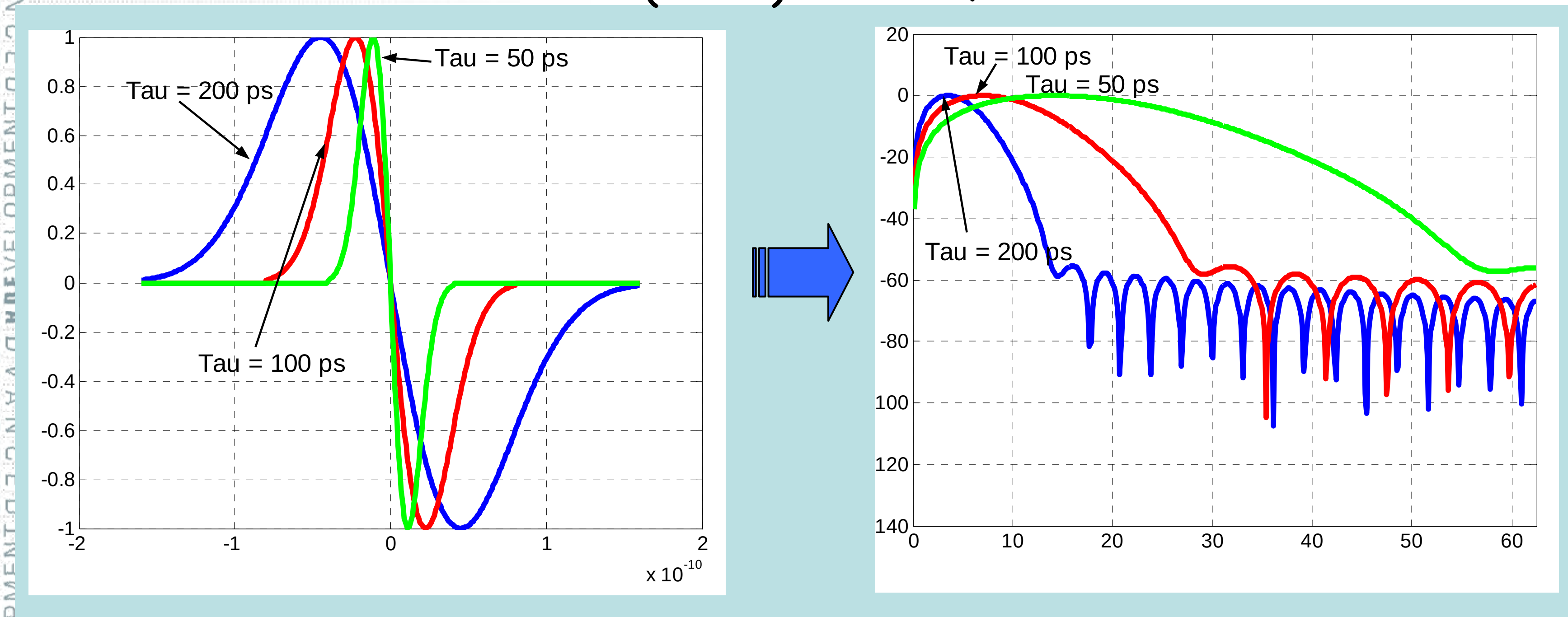




Impulse Radio (II)

Signal bandwidth is directly related to the pulse width → The shorter the pulse the wider the spectrum

$$f_c = 1/\tau$$
$$BW(3dB) = 116\% f_c$$
$$BW(10dB) \approx 180\% f_c$$



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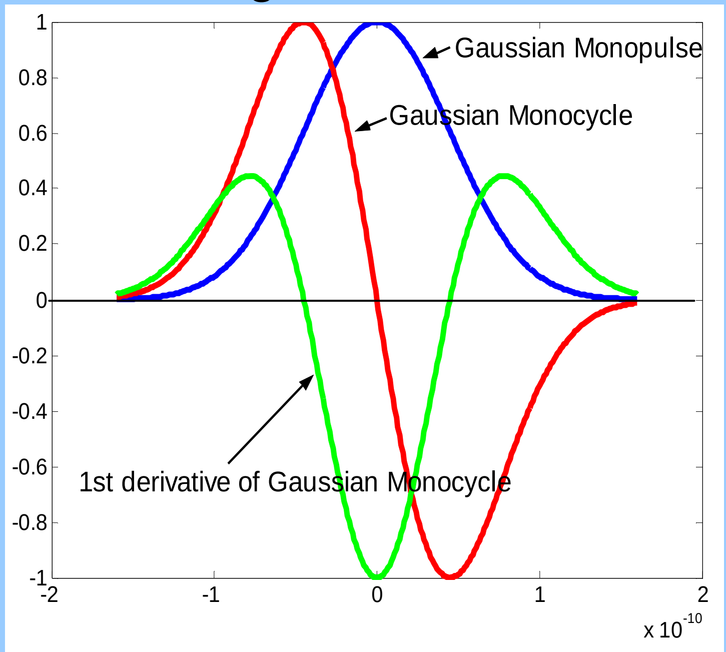
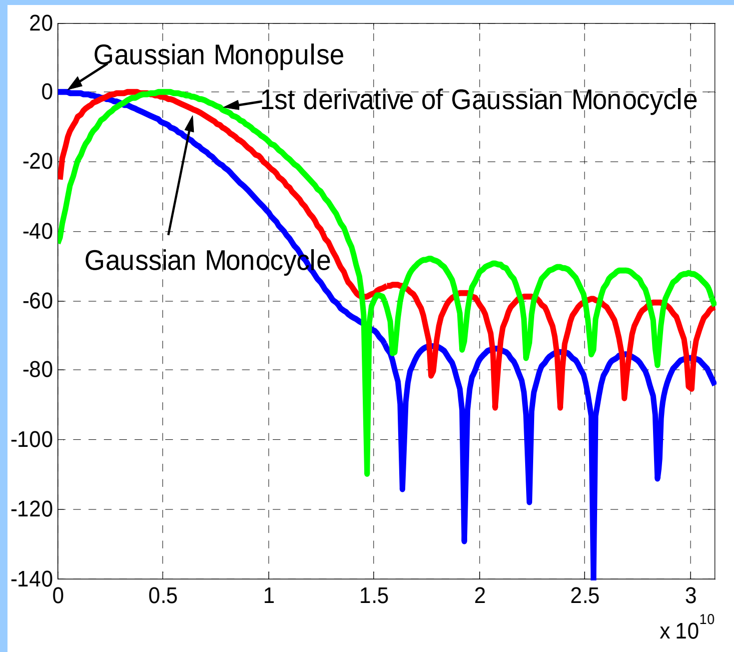
Impulse Radio (IV)

To carry out with regulatory rules → Signal spectrum within the PSD masks → Filtering below 3.1 GHz (filter ~ signal derivation) or upconversion

Pulse filtering → Derivative





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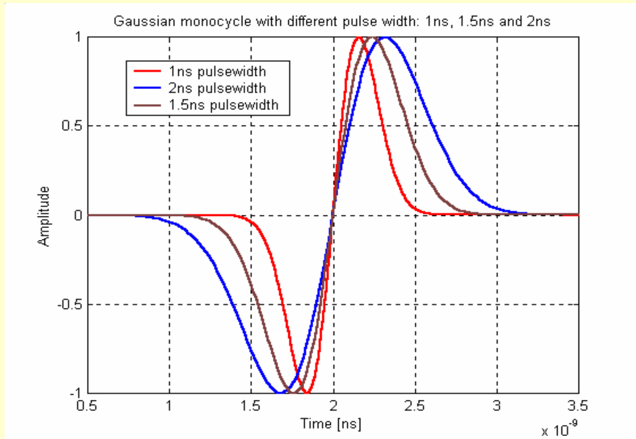
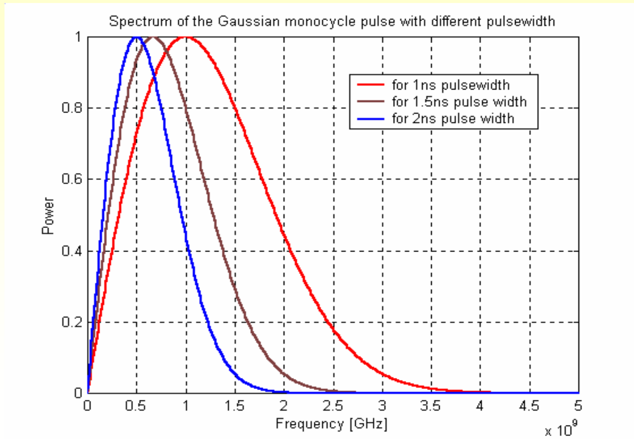
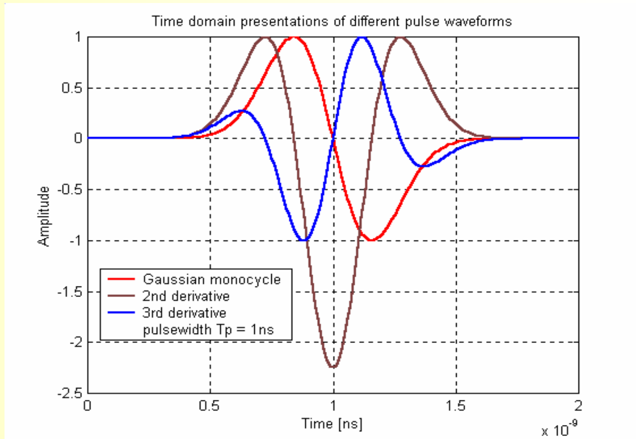
Time vs. Frequency Domain

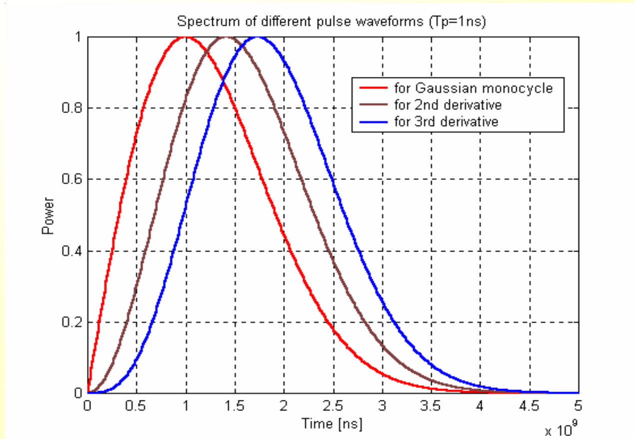
Pulse width (ns) → Bandwidth (GHz)





Zero Cross (ns) → Center frequency (GHz)



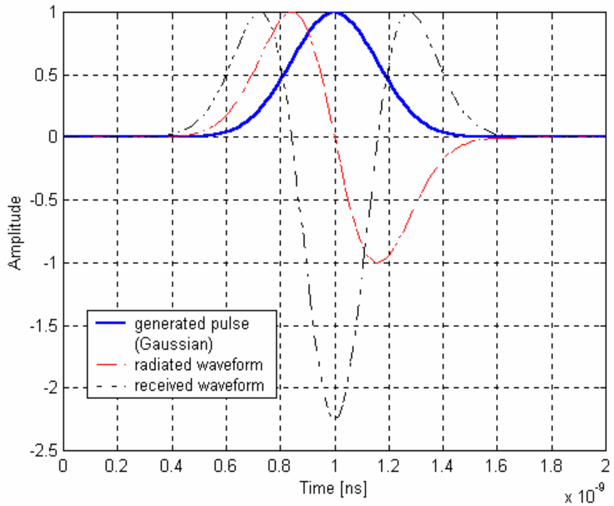


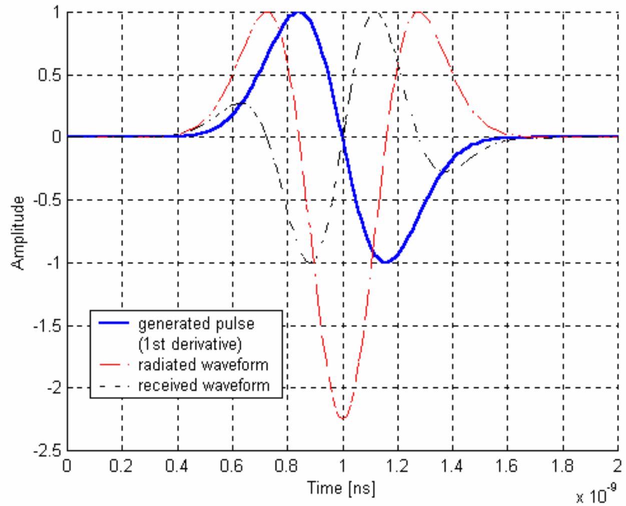
Antenna Effect

Maxwell equations → The radiated field is proportional to the derivate of the electrical current through the antenna

With narrowband signals → 90º phase shift (sin → cos) → No influence

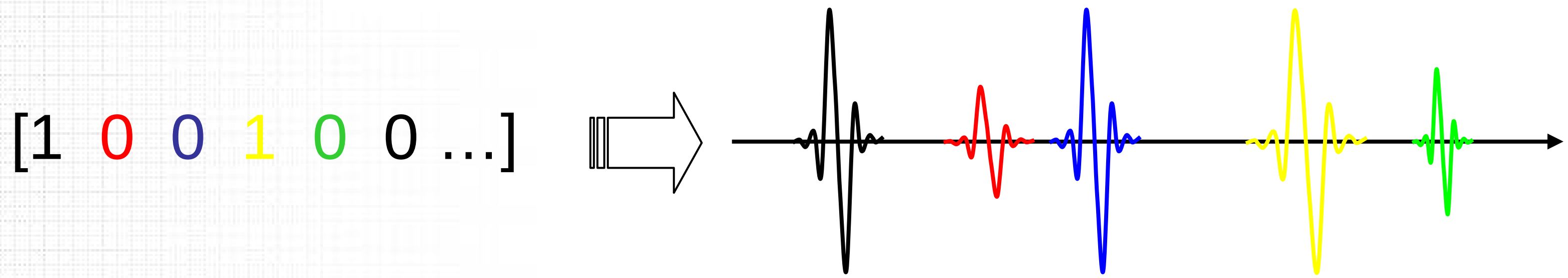
The Rx pulse is the second derivative of the Tx one



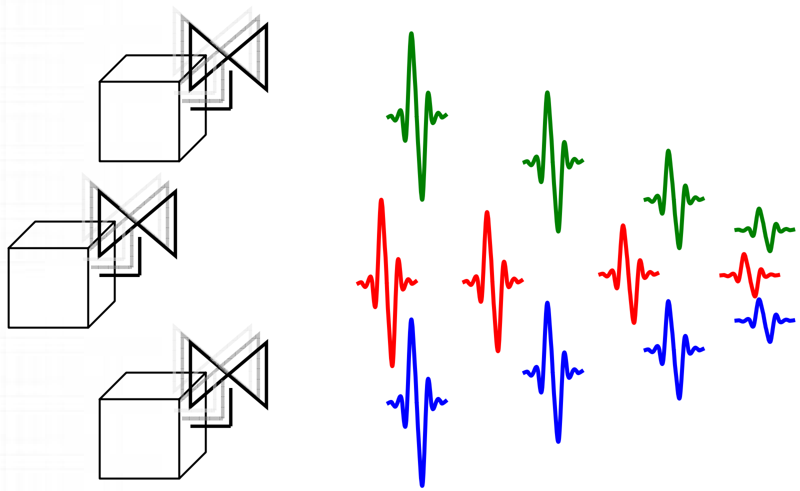


Modulation and Multiple Devices Configuration

Modulation: How the information is placed into the UWB signal

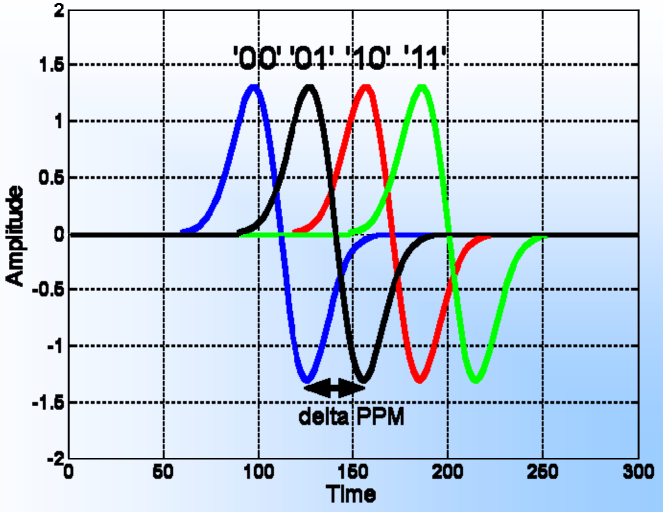


Multi-user coding: How several users could make use of the same network

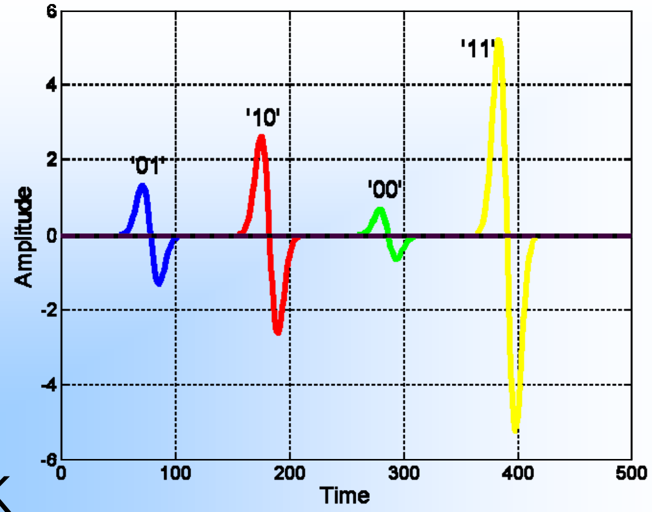


UWB-IR Modulations

PPM



PAM



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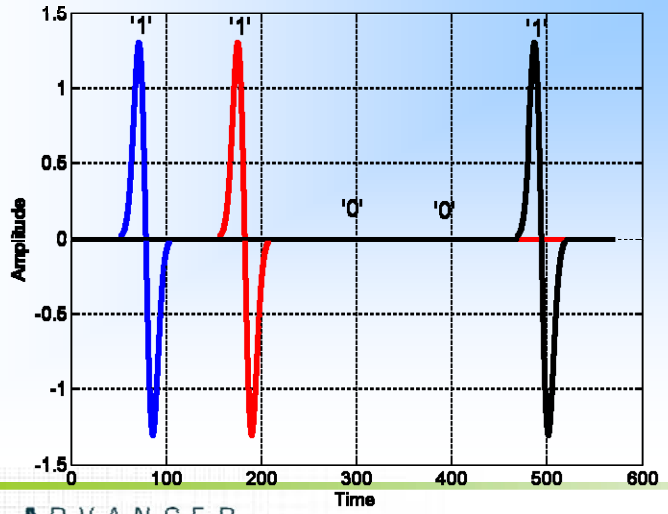
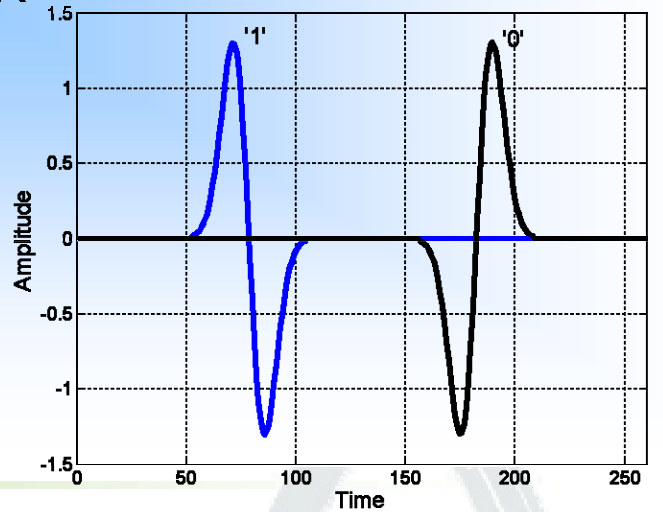


BPSK



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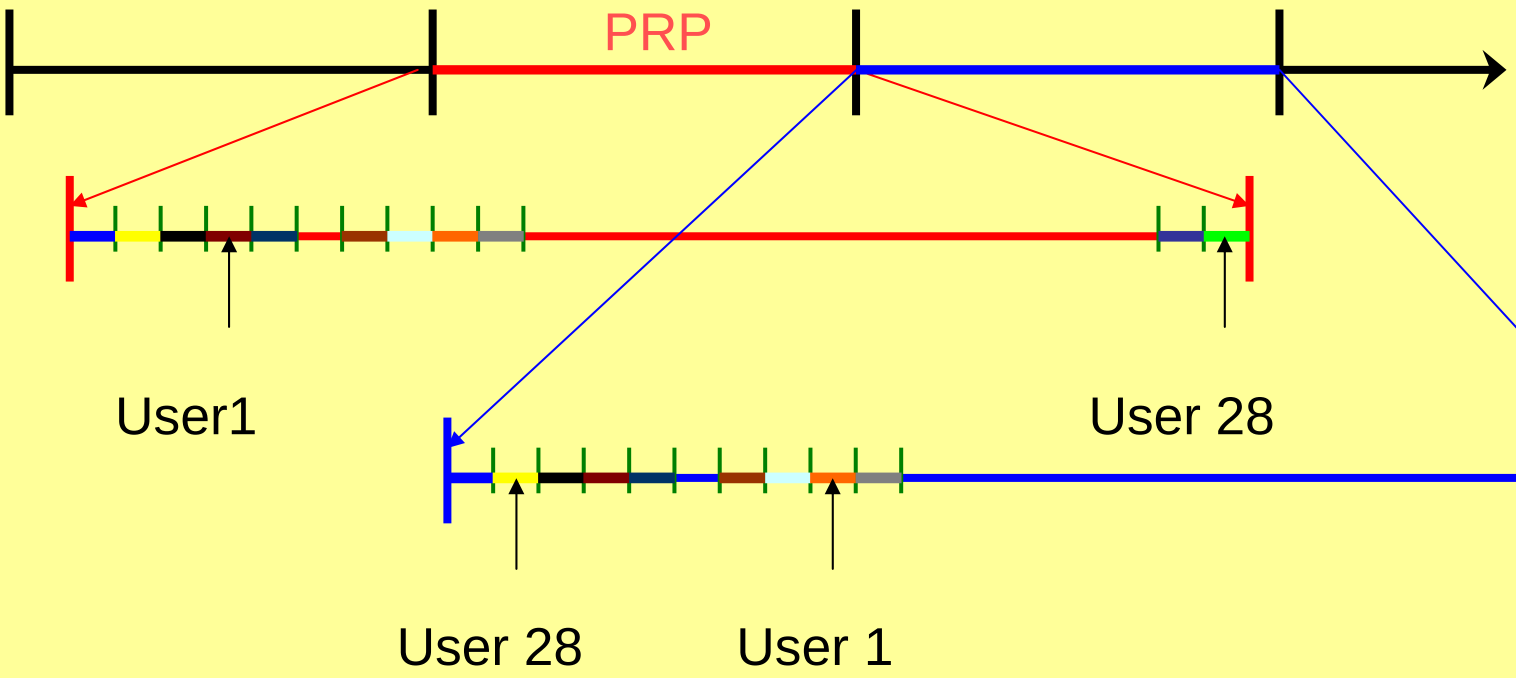
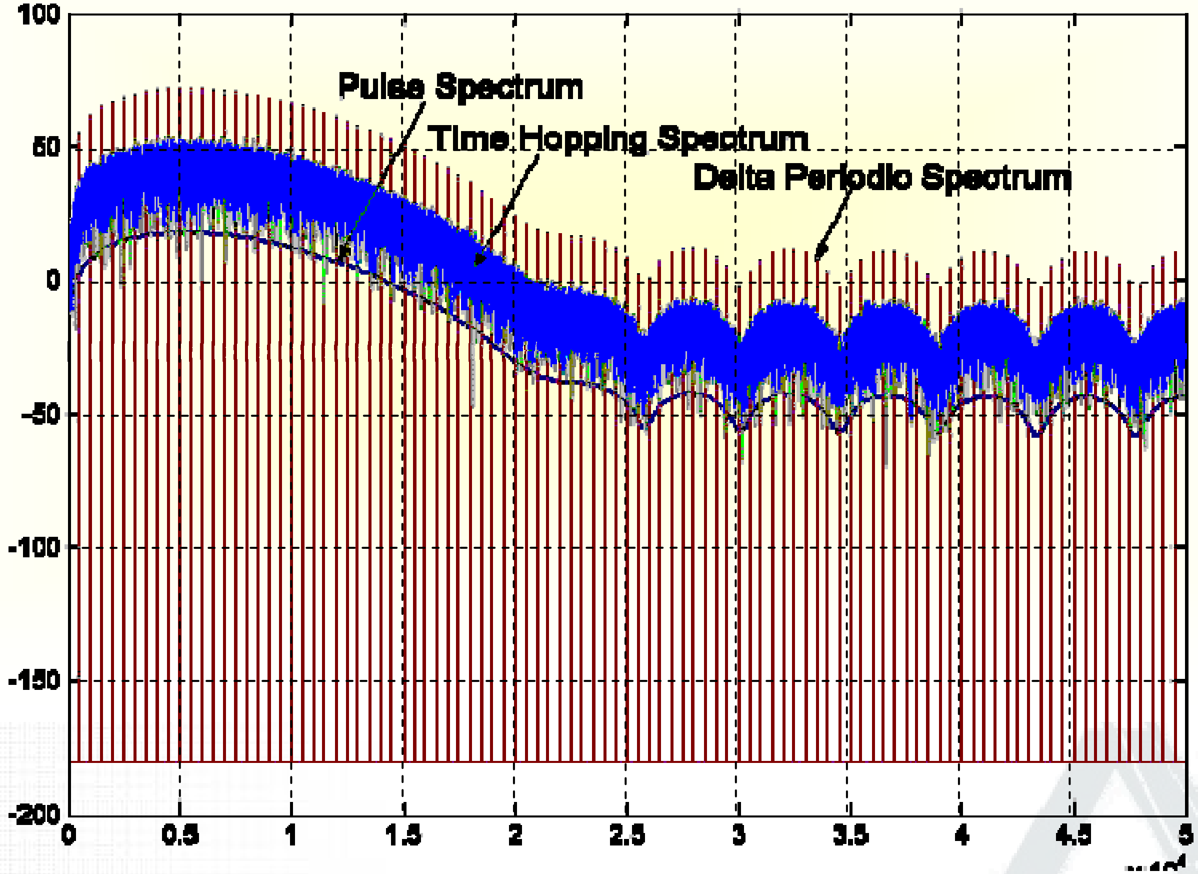
Multi-User Coding

Original Idea: Time-hopping → Every PRP is divided into different slots, and each user has its own slot. In the next PRP, the user slot might vary



Time Hopping Spectrum

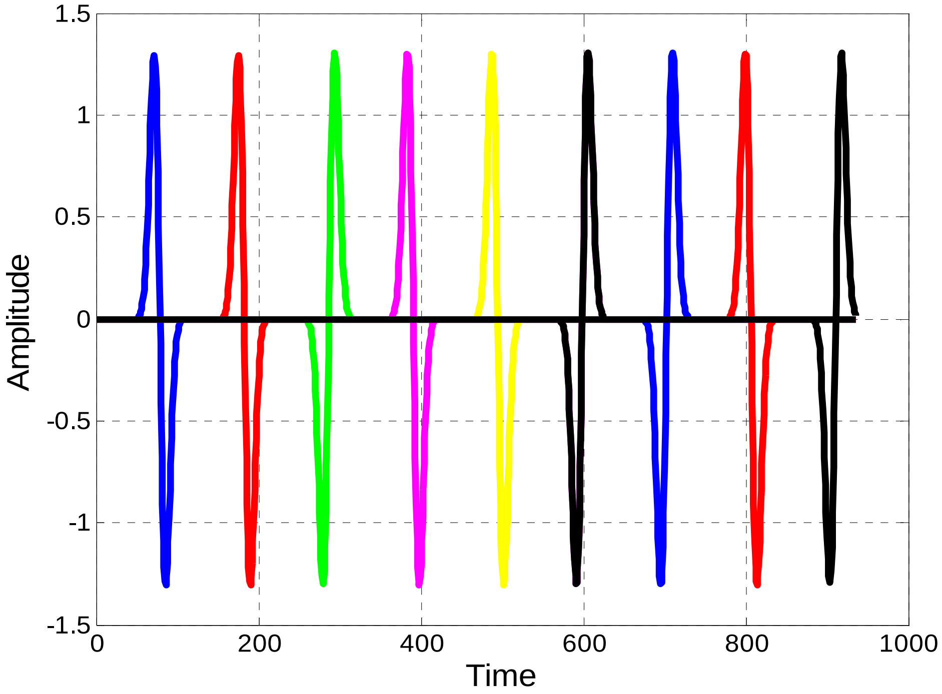
Spectrum Effect → Spectrum Smoothing

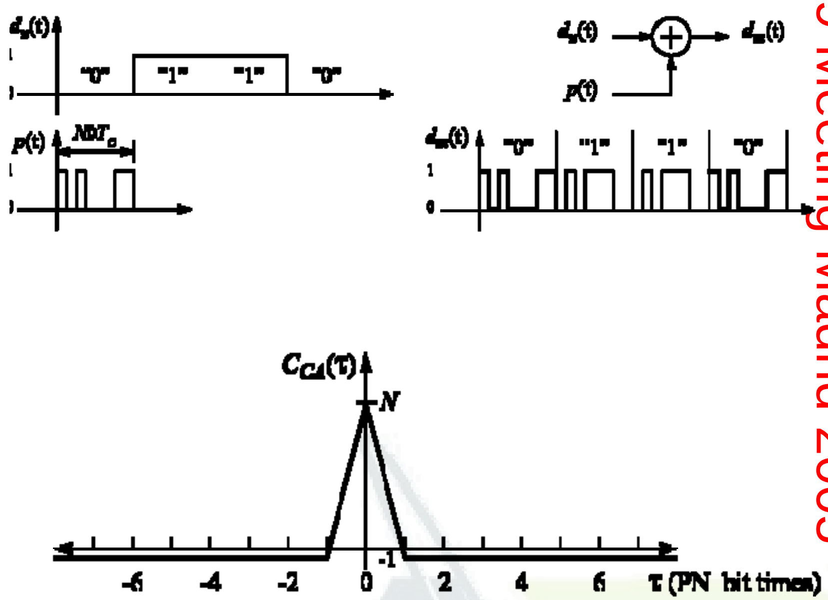


From Impulse Radio to CDMA

CDMA – Code Division Multiple Access

Digital code sequence translated to analog signals





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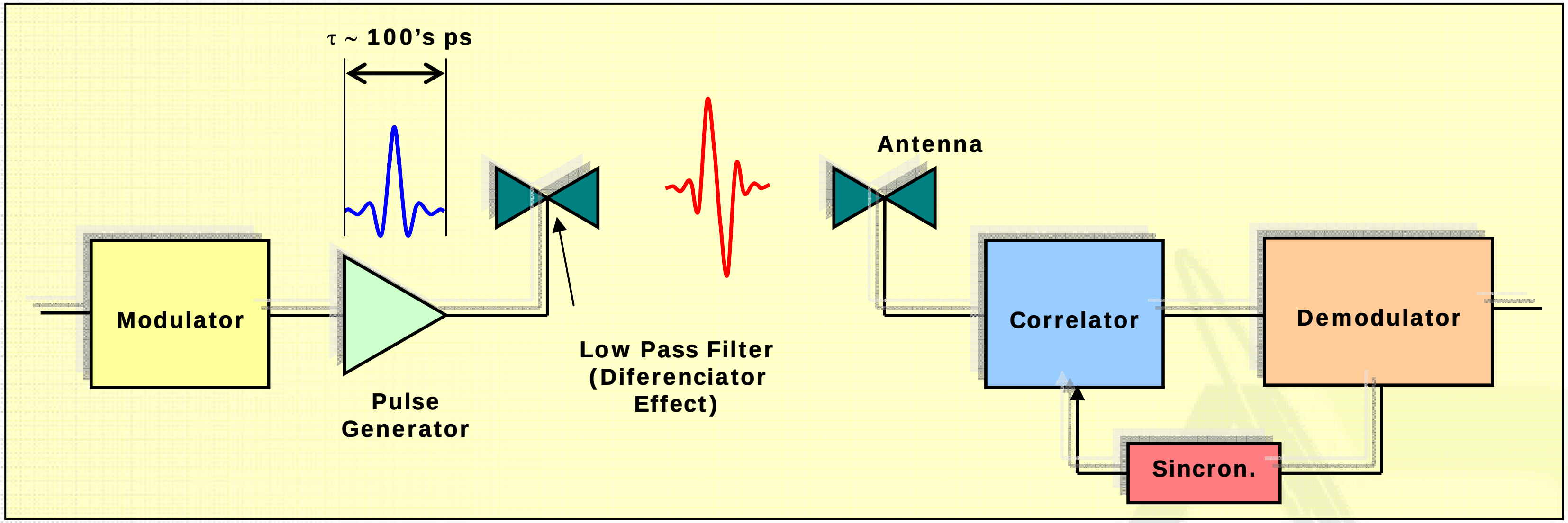
Impulse Radio System

Main properties

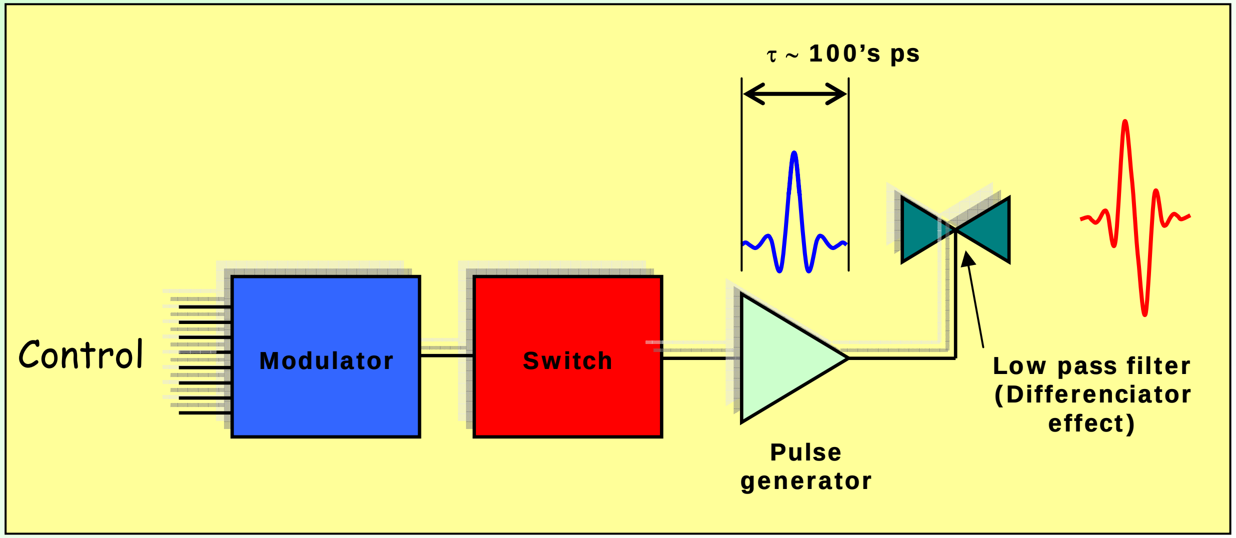
- Do not use carriers
- Requires accurate synchronization (ps range)
- Digital concept for transceiver design (tech. limits forces to employ analog circuits)



Impulse Radio UWB Transmitter

Components

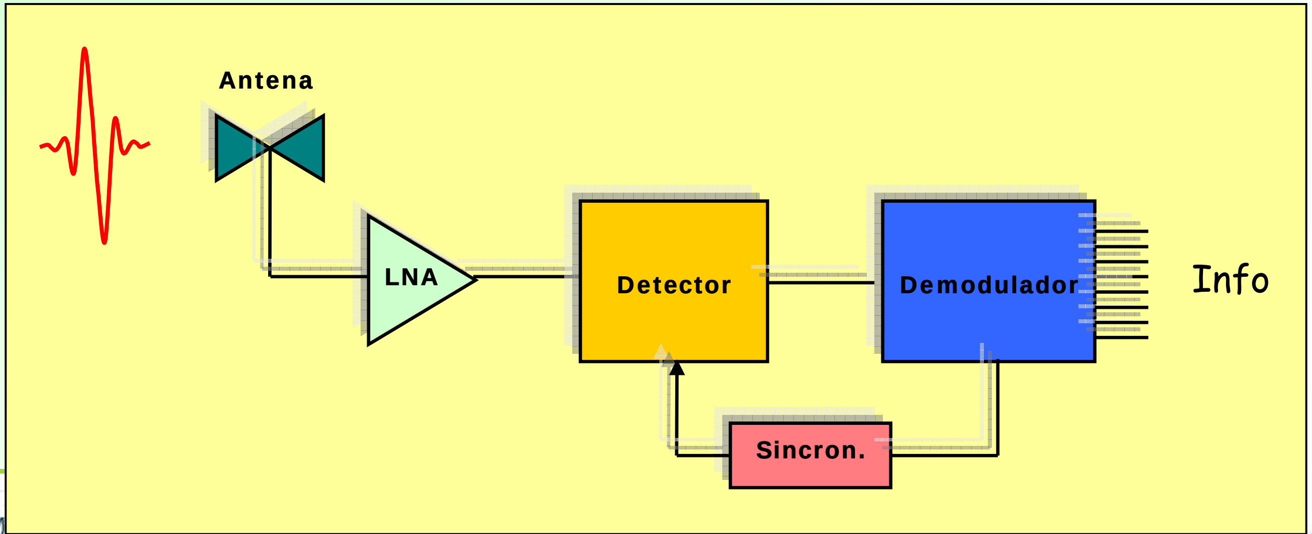
- ✓ Modulator/Coder and switch
- ✓ Pulse generator
- ✓ Antenna



Impulse Radio UWB Receiver

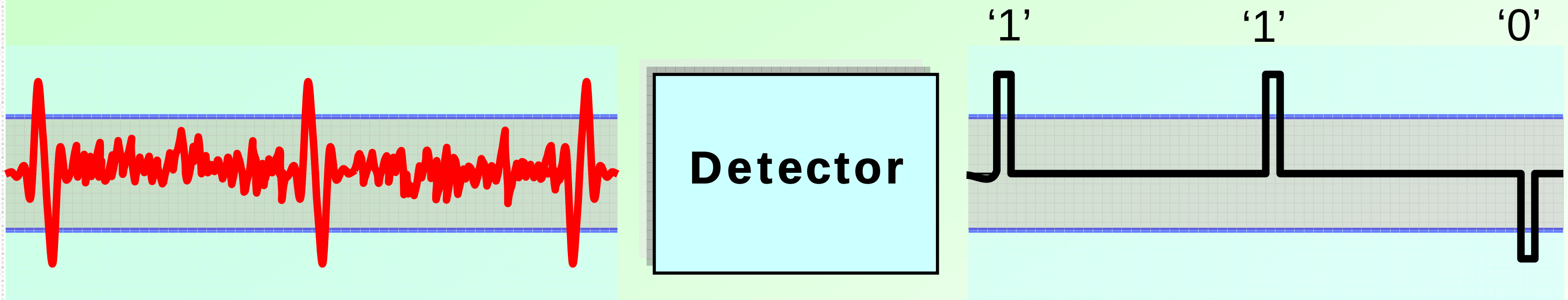
Components:

- ✓ Antenna + LNA
- ✓ Signal Detector
- ✓ Demodulator/Decoder
- ✓ Synchronization module

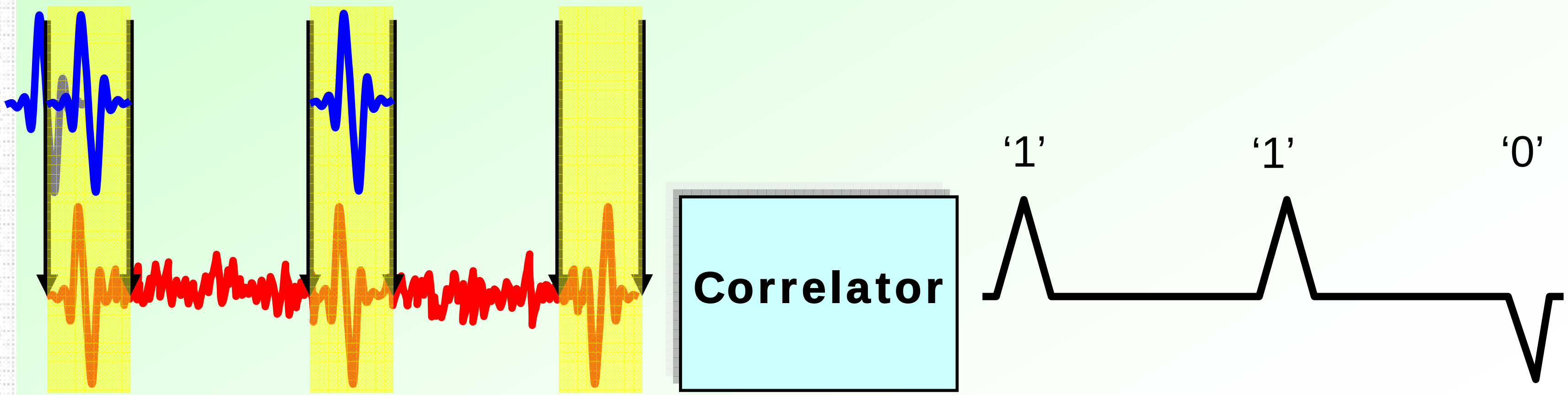


Impulse Radio Signal Detection

Threshold Detector (Voltage or Energy) – Non-coherent Rx

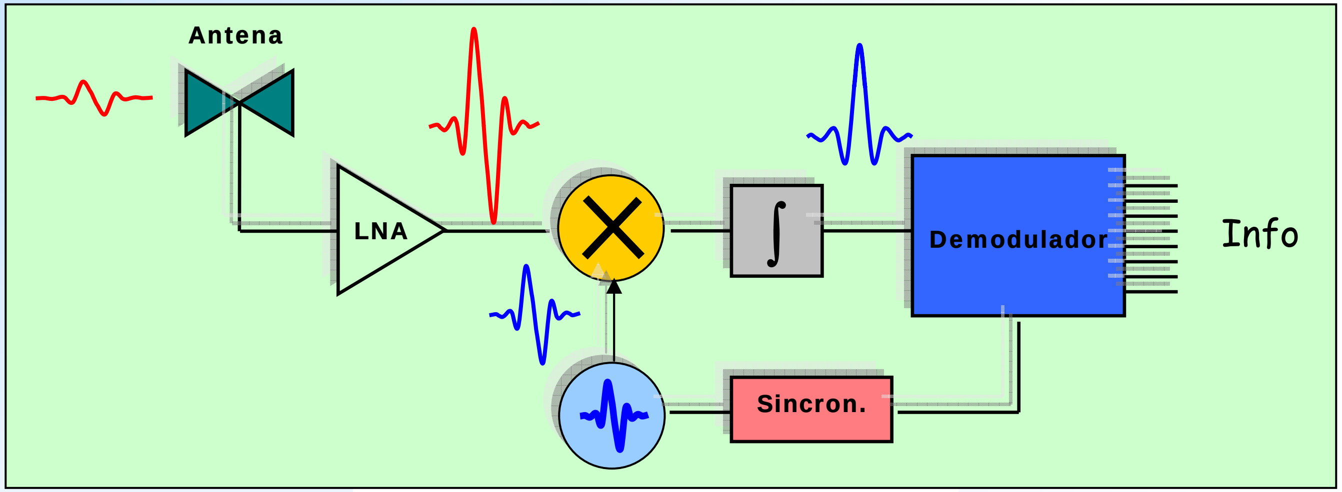


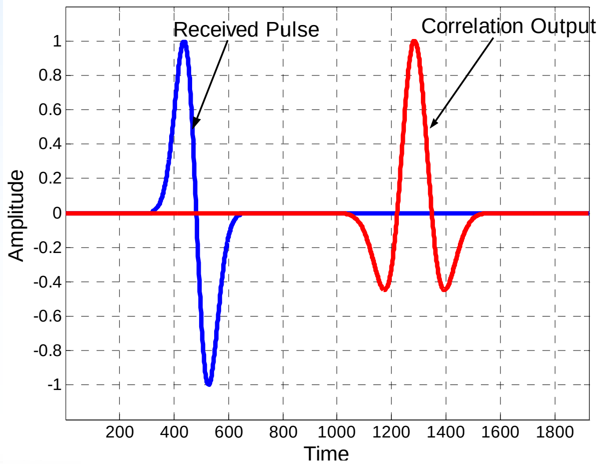
Correlator – Matched filer – Coherent Rx



Impulse Radio Signal Detection (II)

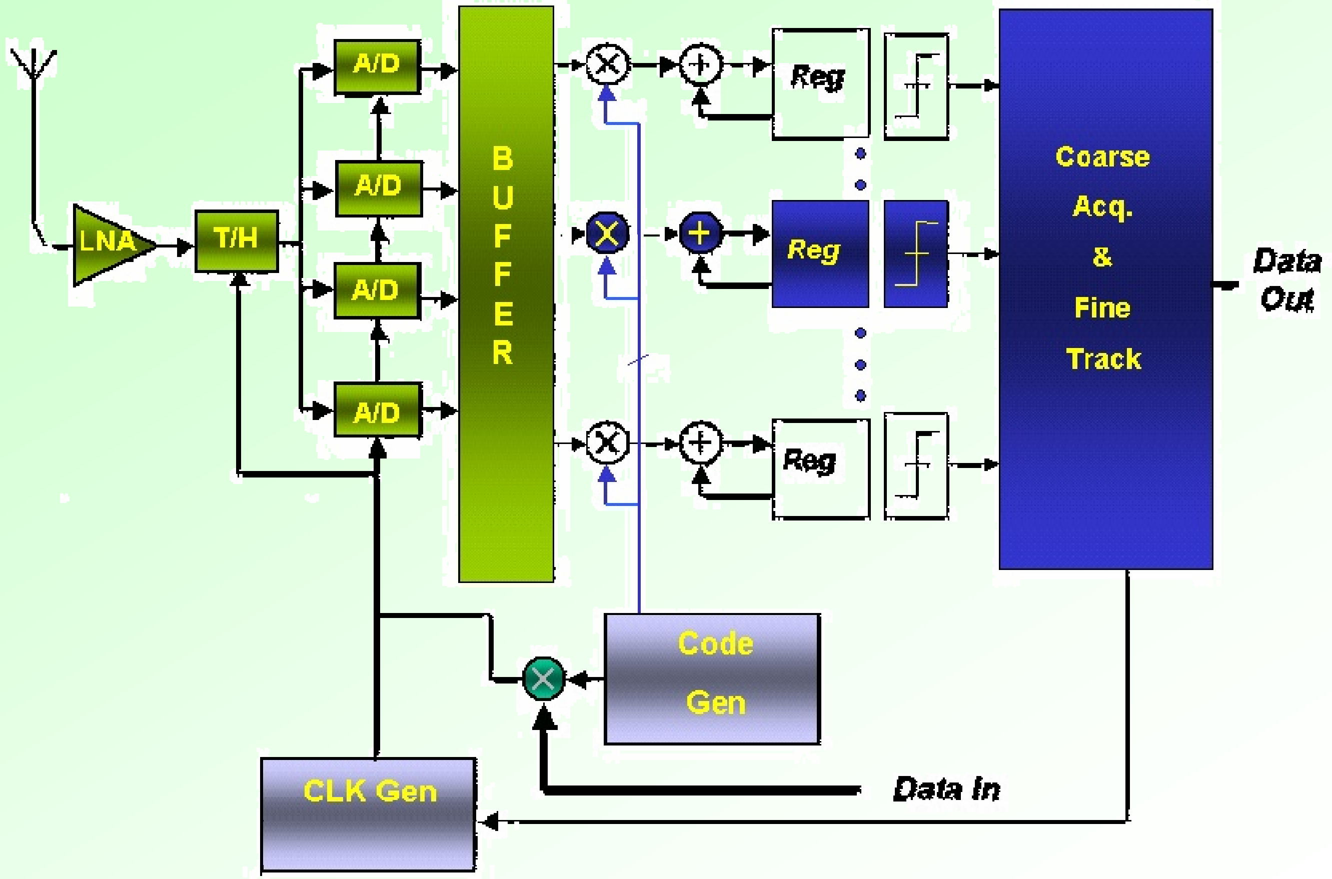
Analog Correlation





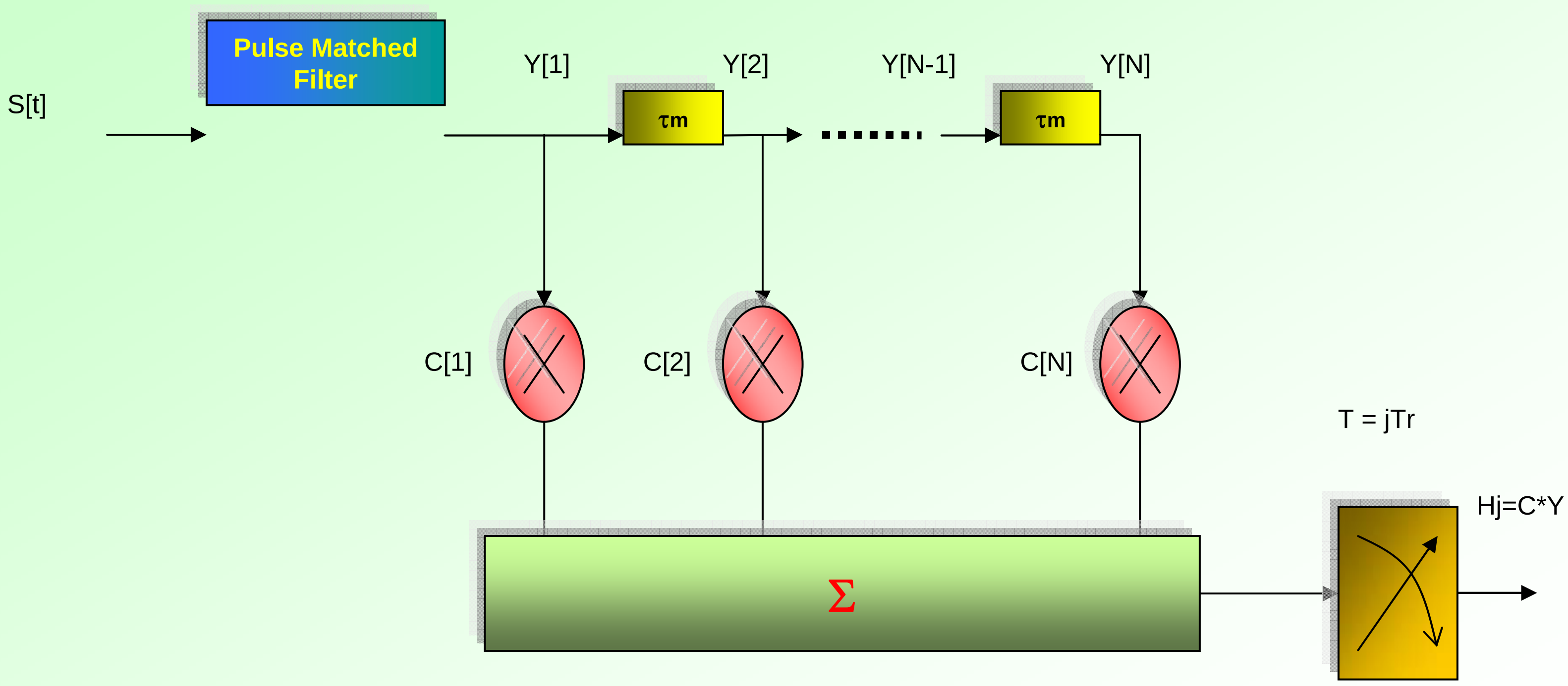
Impulse Radio Signal Detection (III)

Digital Correlator



Impulse Radio Signal Detection (IV)

Rake Receiver: (Multipath discrimination)



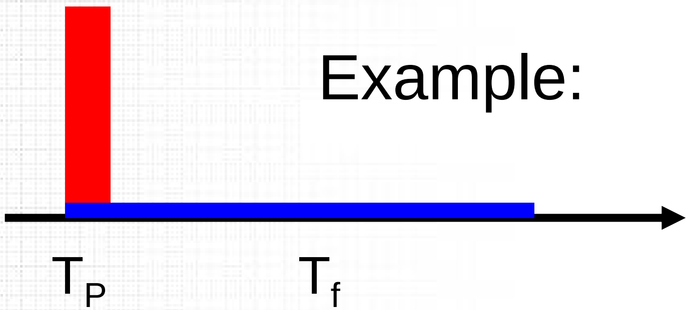
Coherent Integration

Coherent Integration: Energy addition on reception, to reduce false alarm detection probability

Mandatory in low SNR scenarios → High N_S → High processing gain

Processing Gain $$PG = 10.\log\left(\frac{T_f}{T_P}\right) + 10.\log(N_s)$$

→ Gain due to the duty-cicle (Peak vs. average power) + N_S Gain



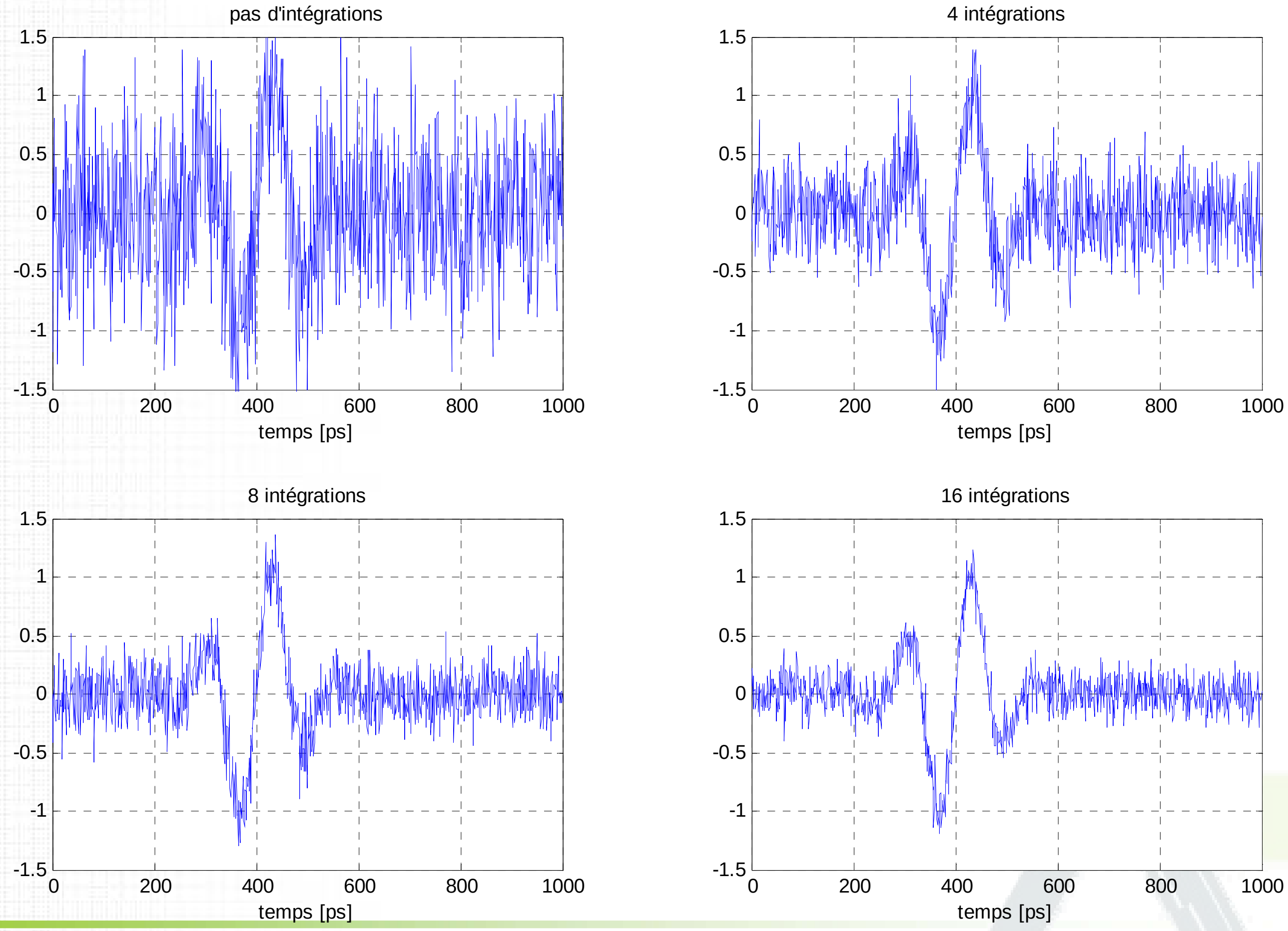
Example: $T_P/T_f = 0.01$ → GP = 20 dB

Ns 1= 10 → GP = 10 dB

TotalGP = 20 + 10 = 30 dB

Coherent Integration (II)

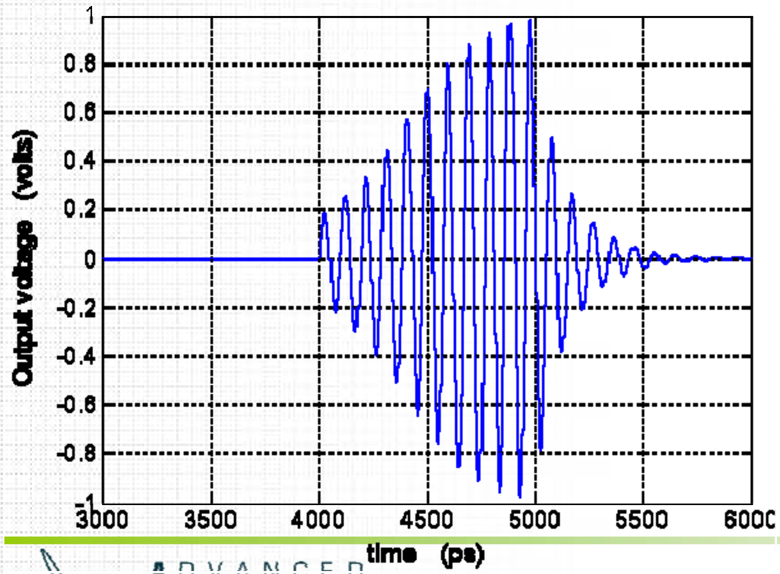
Received Signal → 4 times avrg. → 8 times → 16 times.

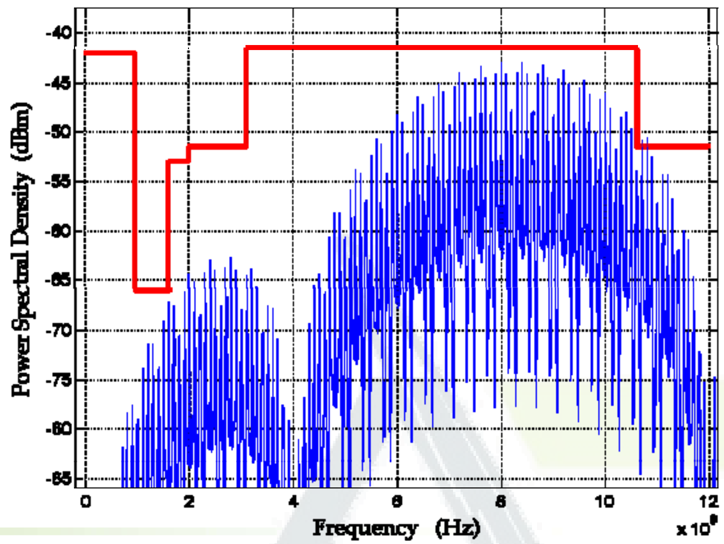


UWB Multiband: RF Pulse or RF Burst

Simplest multiband solution: Modulated pulse (carrier)

- ✓ Shifts the signal center frequency
- ✓ Avoid interferences
- ✓ Allow frequency channels and multiusers/systems
- ✓ Wider pulses (ps → ns) → ADC characteristics relax

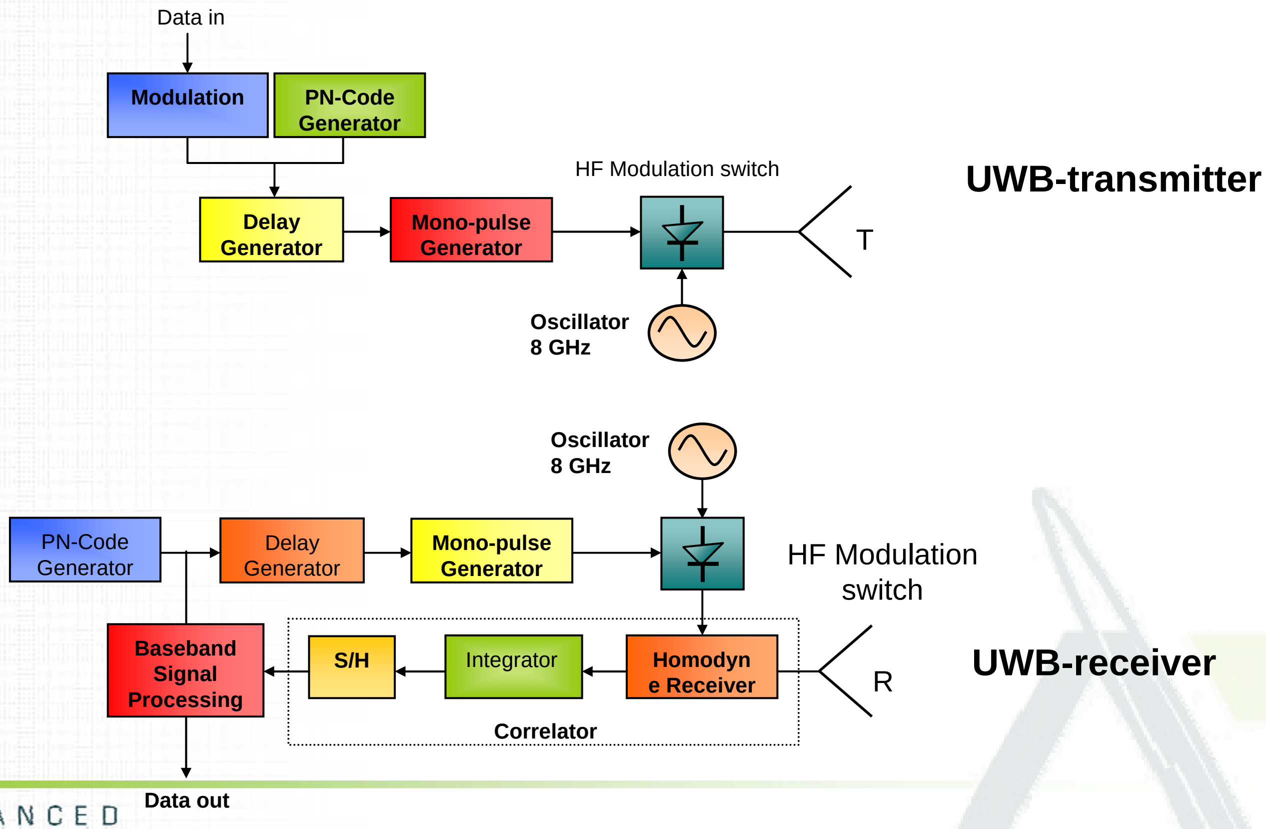




UWB Multiband: RF Pulse or RF Burst (II)

Two implementation alternatives:

- Mixer + Oscillator



UWB Multiband: RF Pulse or RF Burst (III)

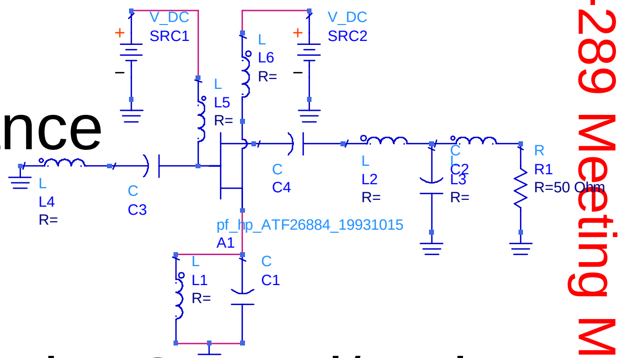
Main Properties:

✓ Oscillation always ON → Transient start-up avoidance

✓ Problems:

- ✓OL isolation → OL leakages avoidance
  - Good Impedance matching
  - OL – RF mixer isolation
- ✓ Spurious frequencies generated by the OL and/or the mixer…

  → OL optimization for low spectral components generation and low phase noise



UWB Multiband: RF Pulse or RF Burst (IV)

Homodine Receiver:

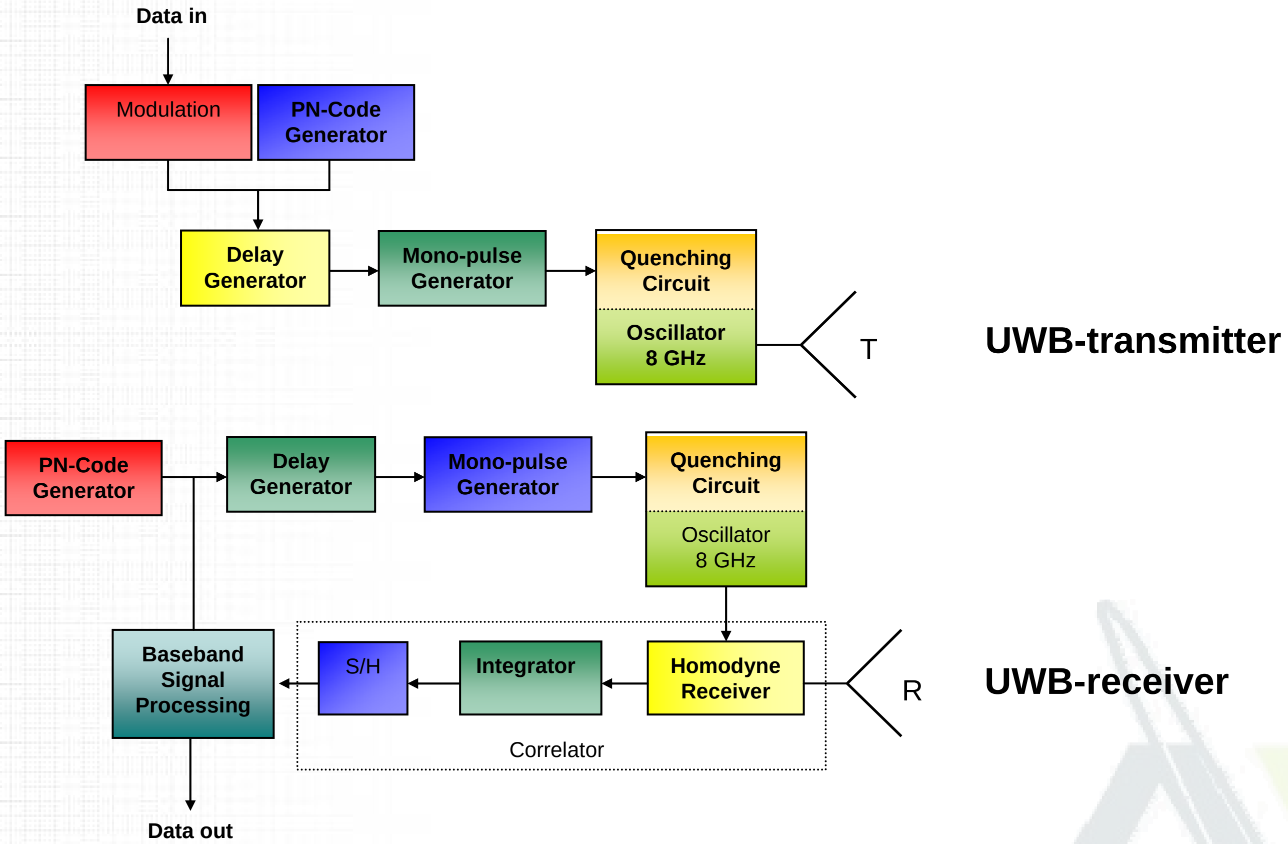
✓Direct frequency downconversion (no IF on the receiver chain)

✓ Very simplex architecture → Low Cost

✓ Baseband mixer output → Care with the fliker noise on the OL and nixer

UWB Multiband: RF Pulse or RF Burst (V)

- Dumped Oscillator



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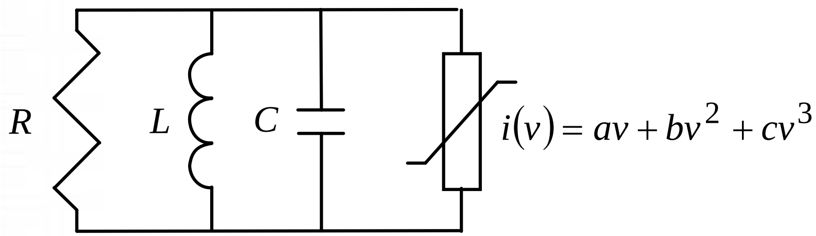
UWB Multiband: RF Pulse or RF Burst (VI)

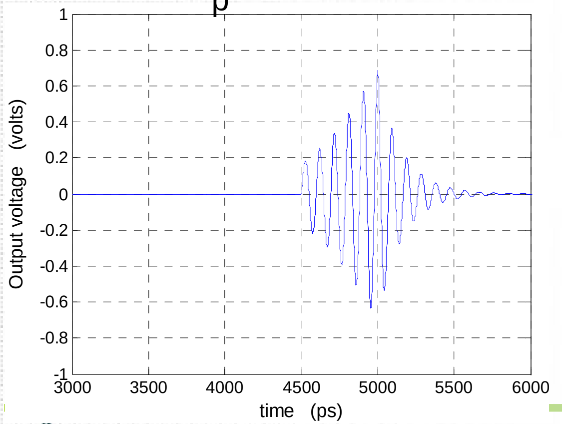
Transients on Dumped Oscillators are based on a thrid-order non linearity:

Example: Circuit parameters optimized for f_C = 10.5 GHz

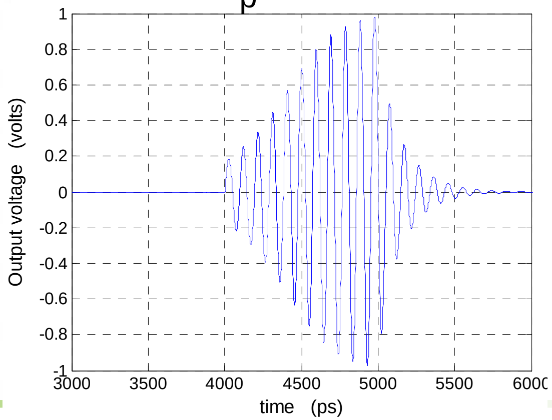


Pulse bandwidth:

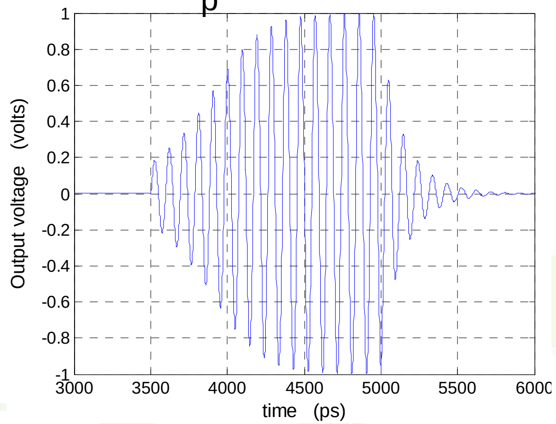
t_p = 0.5 ns



t_p = 1 ns

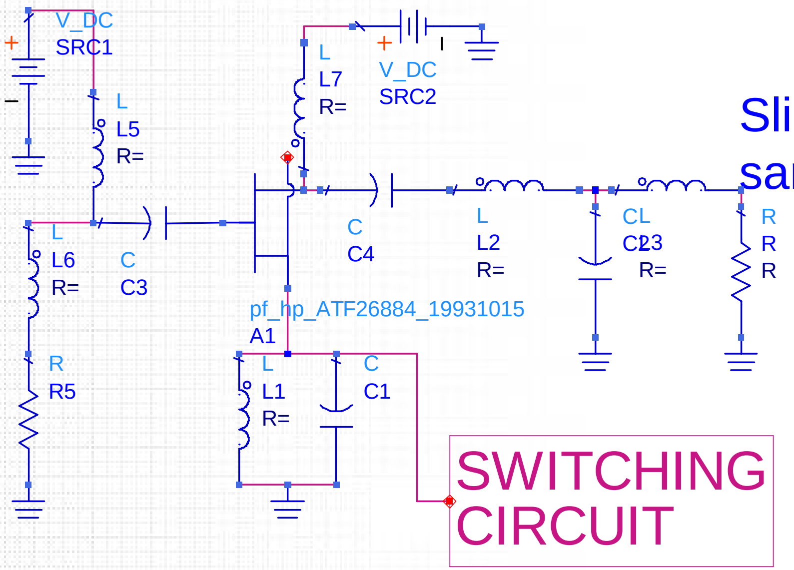


t_p = 1.5 ns



UWB Multiband: RF Pulse or RF Burst (VII)

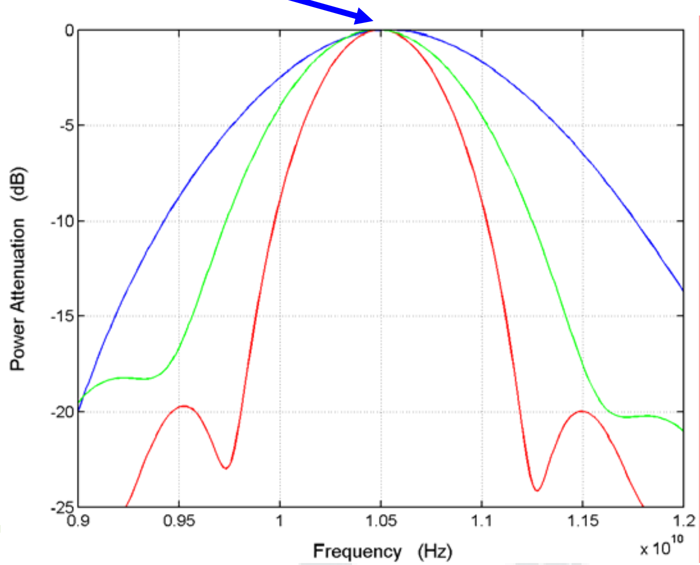
OSCILLATOR AT 8 GHZ



Pulse power spectrum:

- 0.5ns pulse
- 1ns pulse
- 1.5ns pulse

Sliding effect: The center freq. is not the same on the stationary and transient stages



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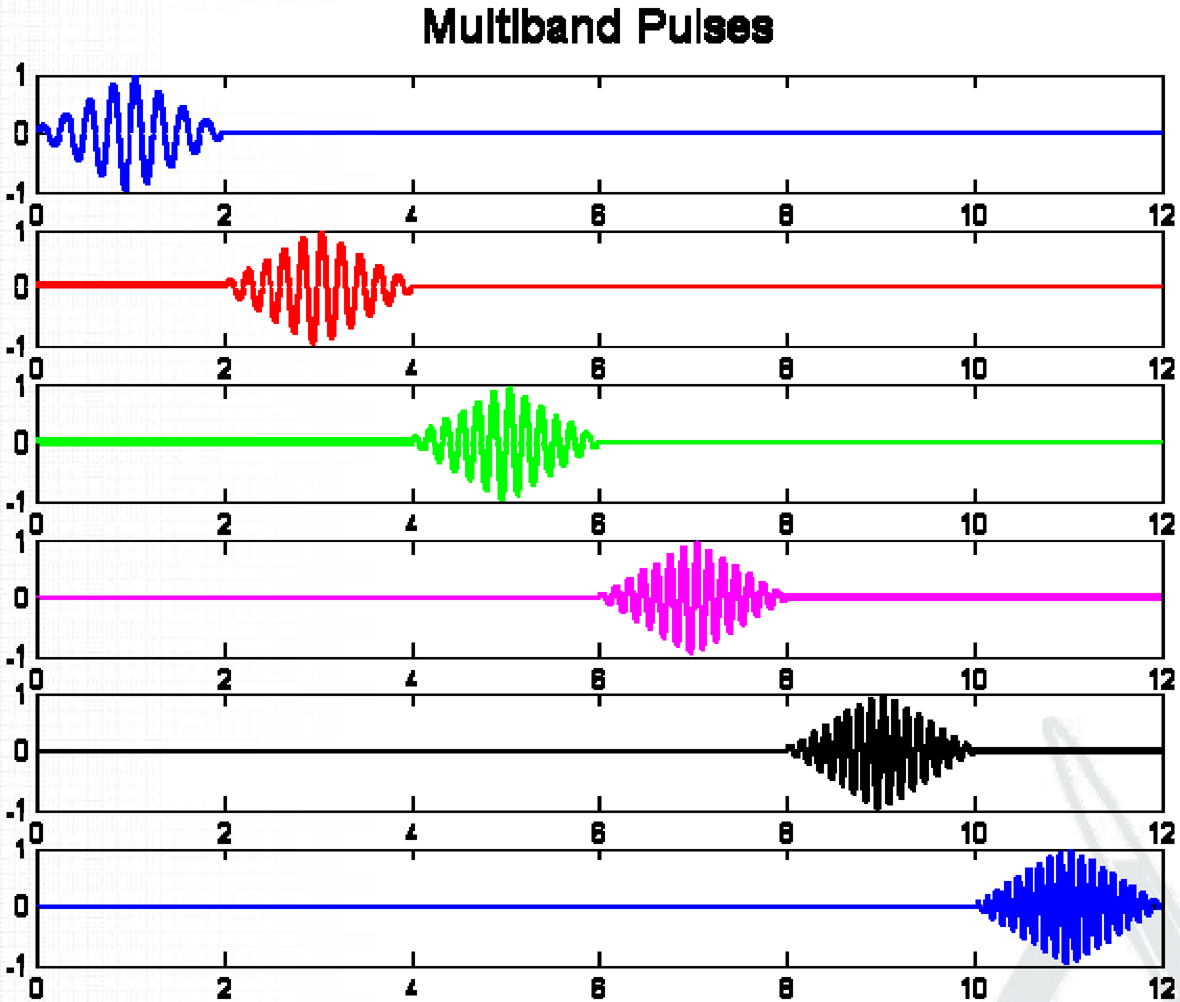
UWB Multiband: RF Pulse or RF Burst (VIII)



UWB IEEE Status

UWB system candidates for the 802.15.3 standard

- Multiband approaches → Avoid interference problems.
- Focused on HDR & VHDR applications (data transfer, multimedia and PAN & WLAN scenarios)
- Stopped due to disagreement in the core group → 75% agreement is required for standard approval
- Several Proposals → 2 final proposals ~ 2 different groups
  - ✓ Direct Sequence (DS-UWB) → UWBFORUM
  - ✓ OFDM-UWB → MBOA

Propagation of UWB Signals

UWB Propagation Channel

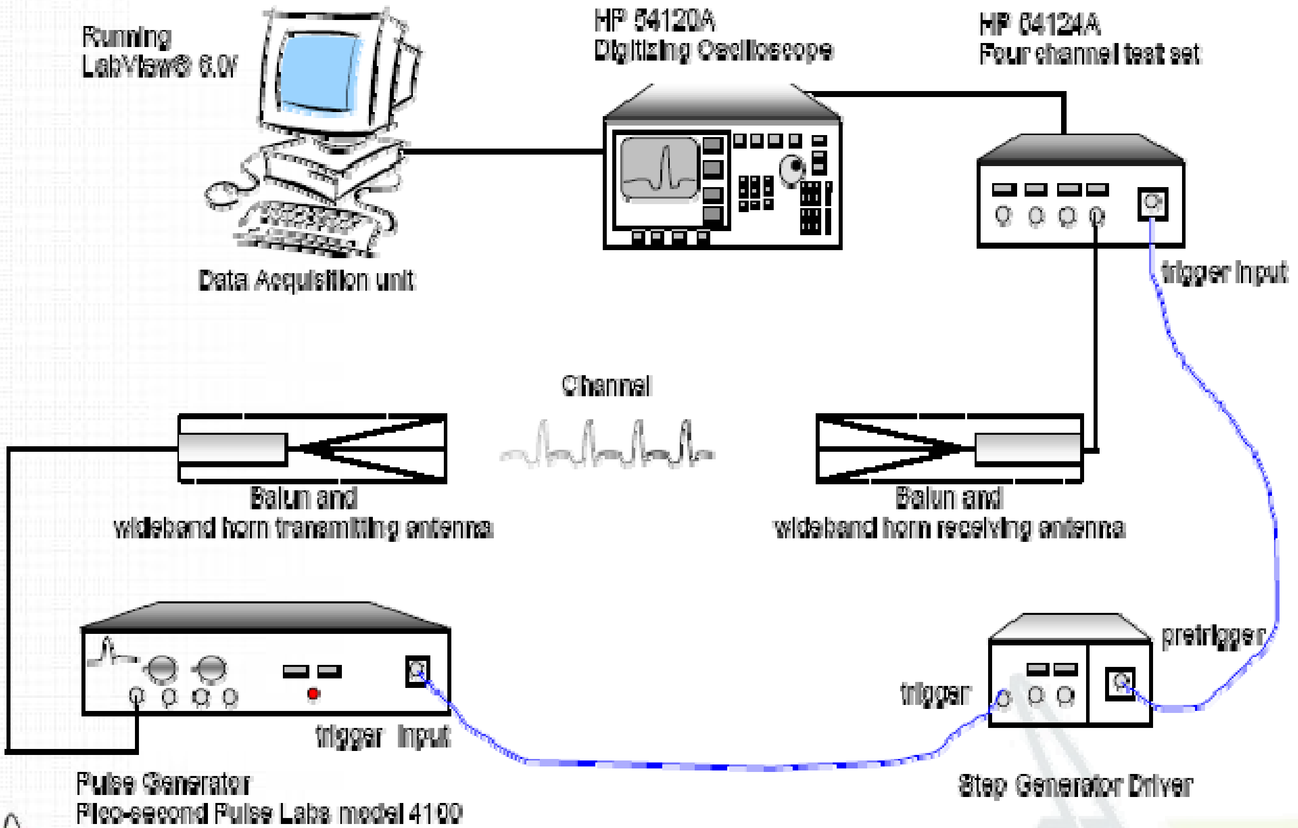
- ✓ Knowledge of the signal propagation characteristics is required for communications and radar systems
- ✓ Interference to narrowband communications and other electronic systems
- ✓ Resistance of UWB to interference.
- ✓ Must understand channel effects to fully exploit the unique properties of UWB.
  - – Affects system waveform/modulation/receiver design.
  - – Material/shape/range of objects affect radar signature.

UWB Propagation Channel (II)

Channel Characterization

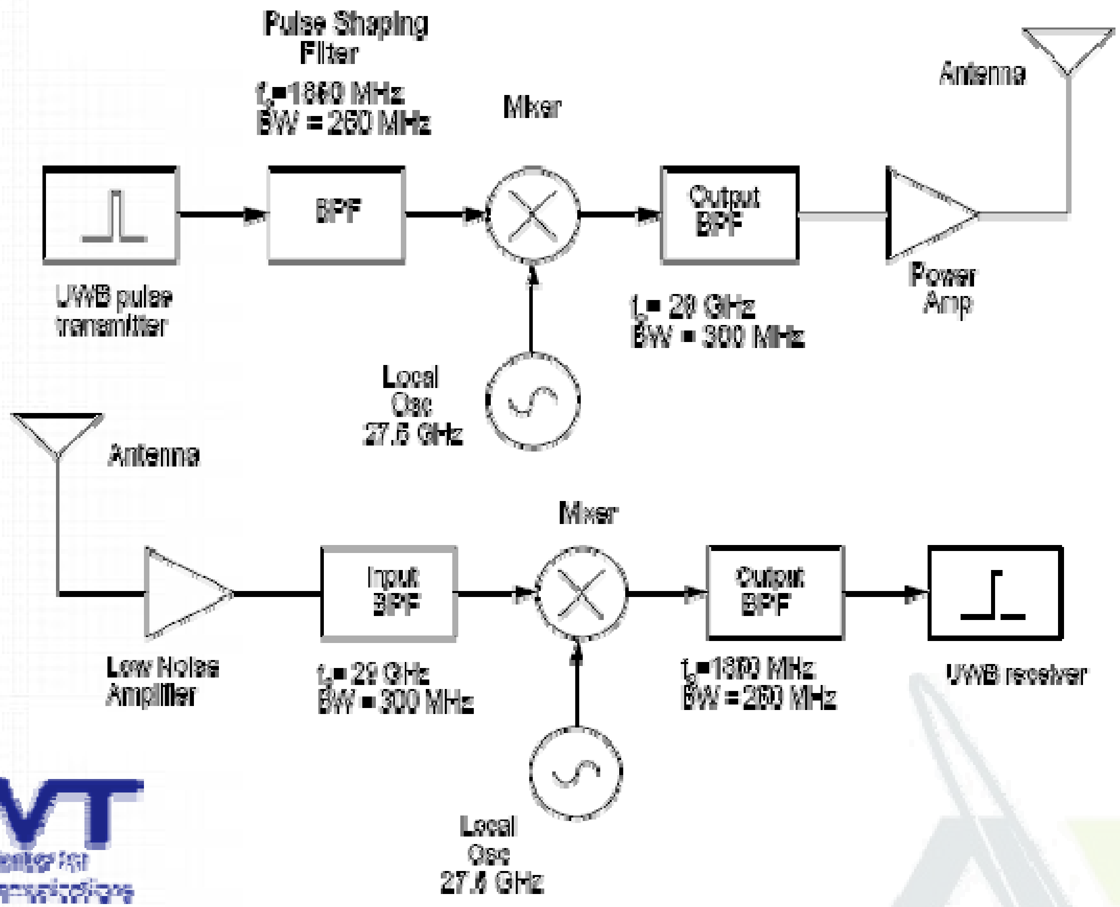
- Why? → System design and simulations…
- Where? → Indoor and Outdoor scenarios, but mainly for indoor LOS and NLOS environments
- How? → Two different alternatives for the measurement process
  - Time Domain measurements (pulse generator + antennas + digital oscilloscope)
  - Frequency Domain measurements (with a Vector Network Analyzer)

TDL Baseband Channel Sounder



TIME DOMAIN LABORATORY

CWT Bandpass Pulse Sounder



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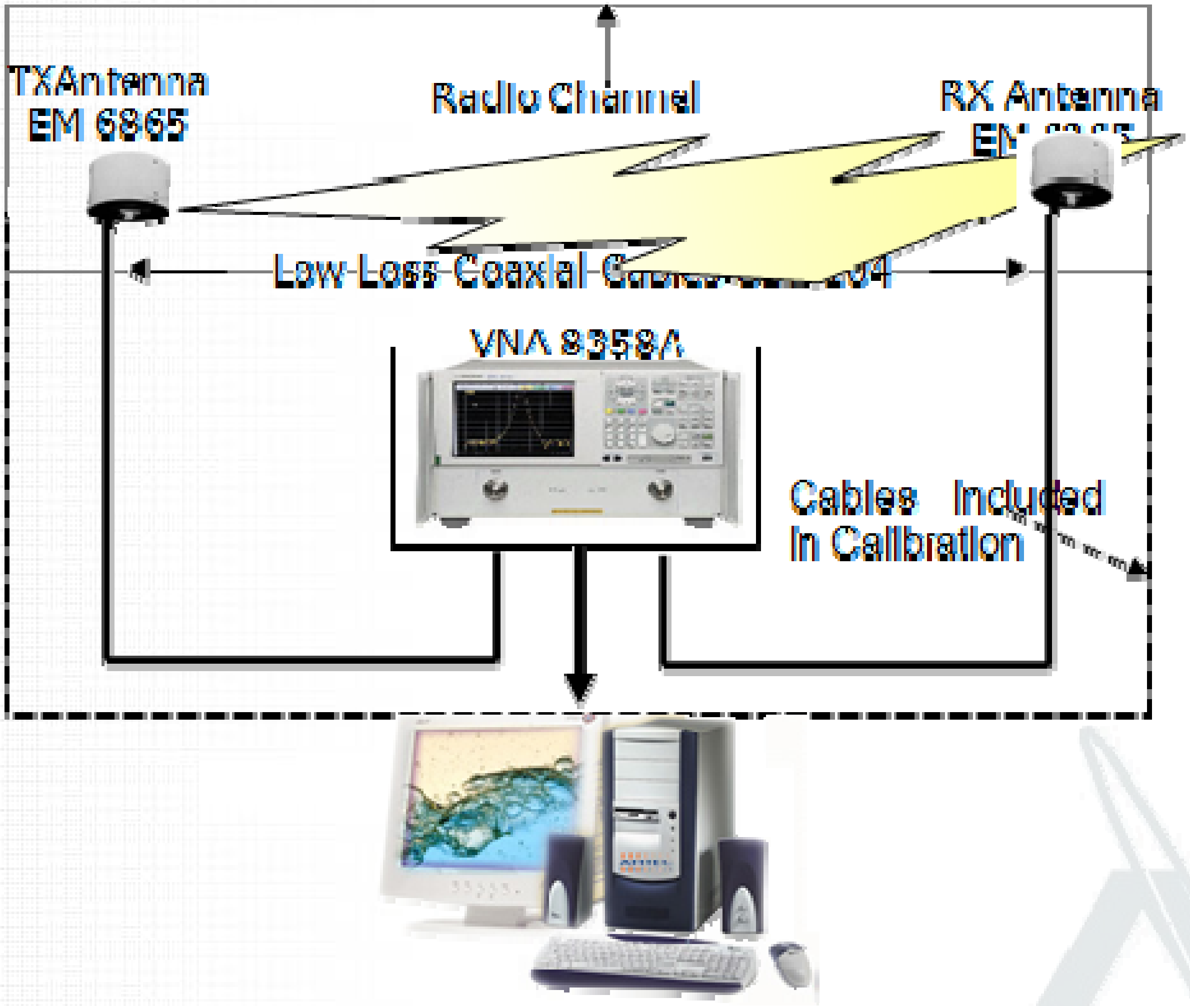
ACORDE Channel Sounder



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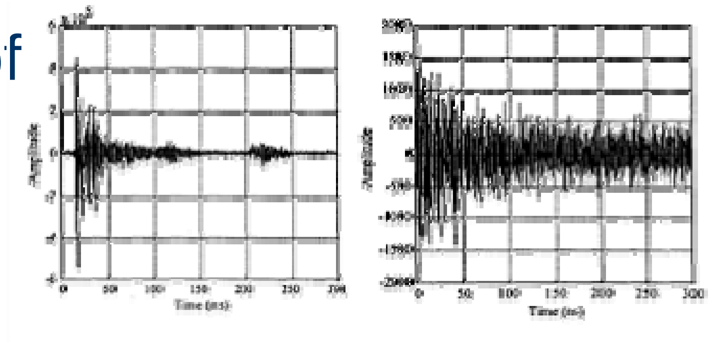
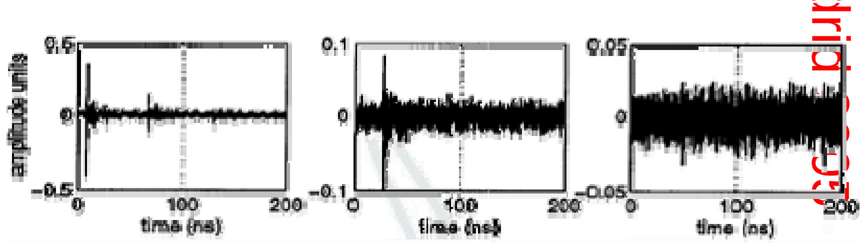
UWB Propagation Channel (IV)

- Indoor
  - Within a room (LOS, NLOS), Between rooms/floors, Down hallways
  - Will investigate the impact of
    - distance
    - Rx/Tx Antenna Height
    - antenna polarization
- Indoor-to-outdoor
- Outdoor
  - Campus environment
  - Rural, Hilly, Impact of foliage
  - Urban
  - "Low altitude"
- In Vehicle, Automotive, airliner



Ex: Indoor Measurements



Ex: Outdoor Measurements

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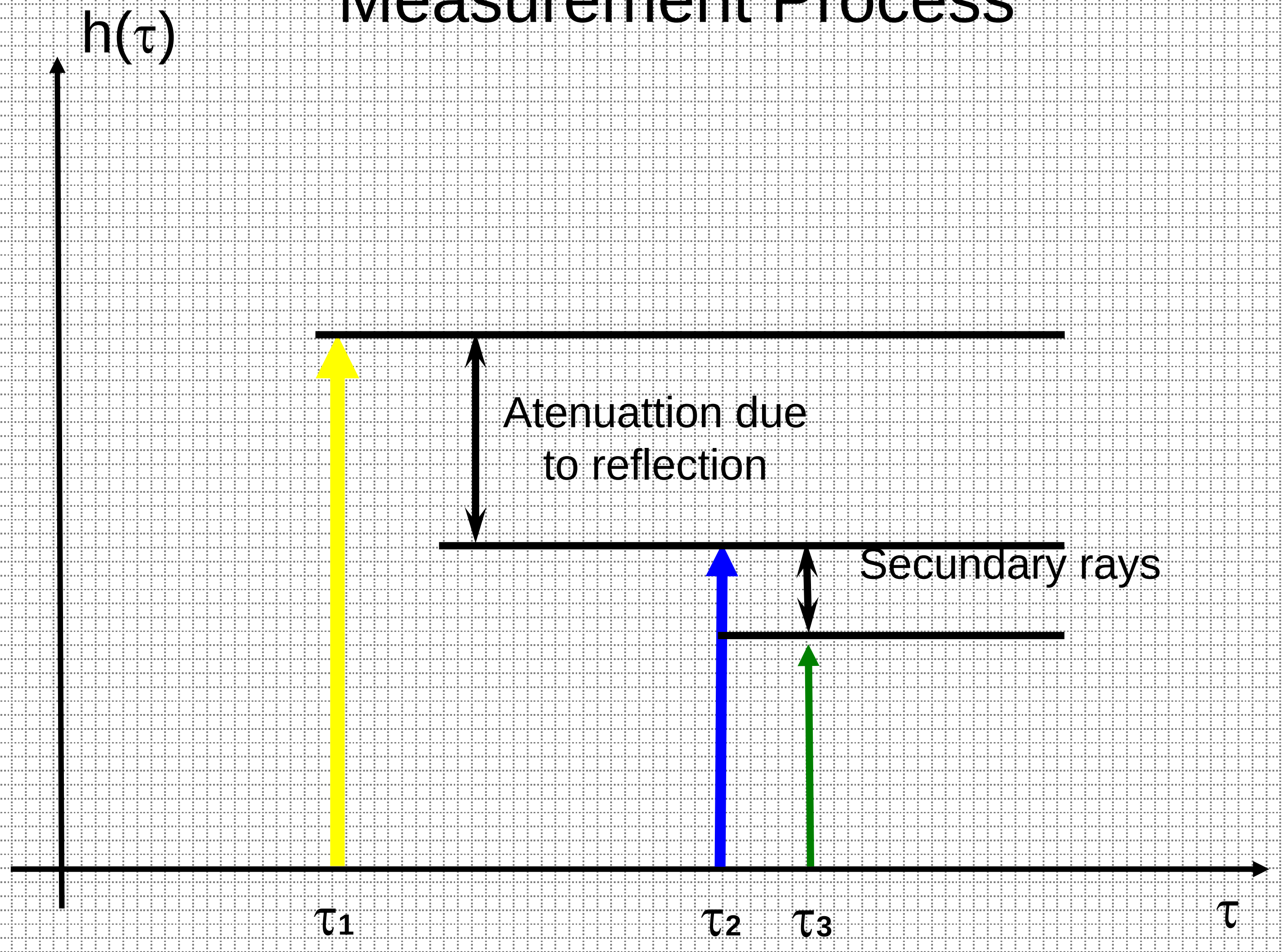
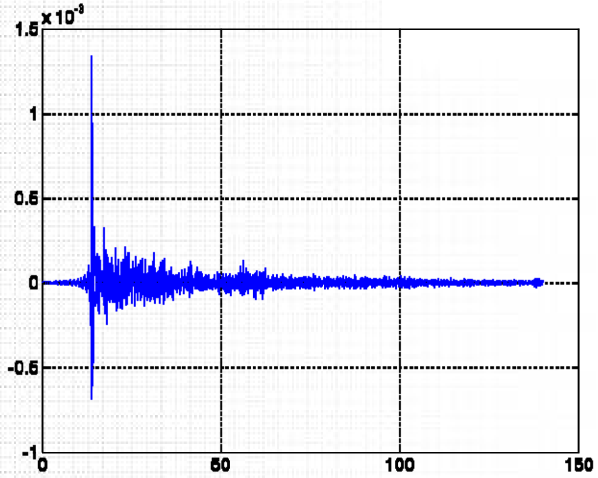
Measurement Process

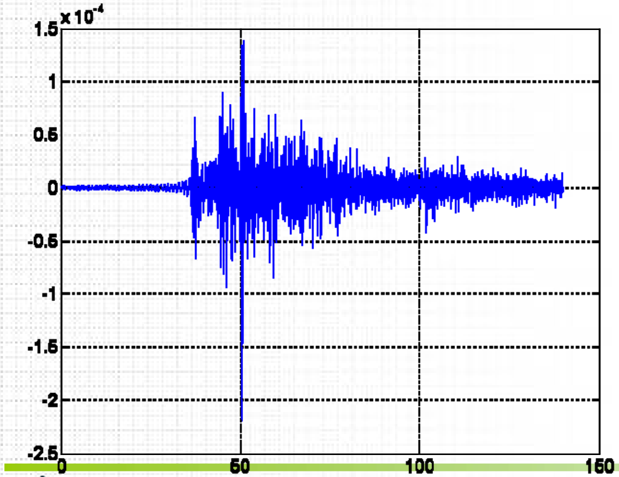


UWB Propagation Channel (V)

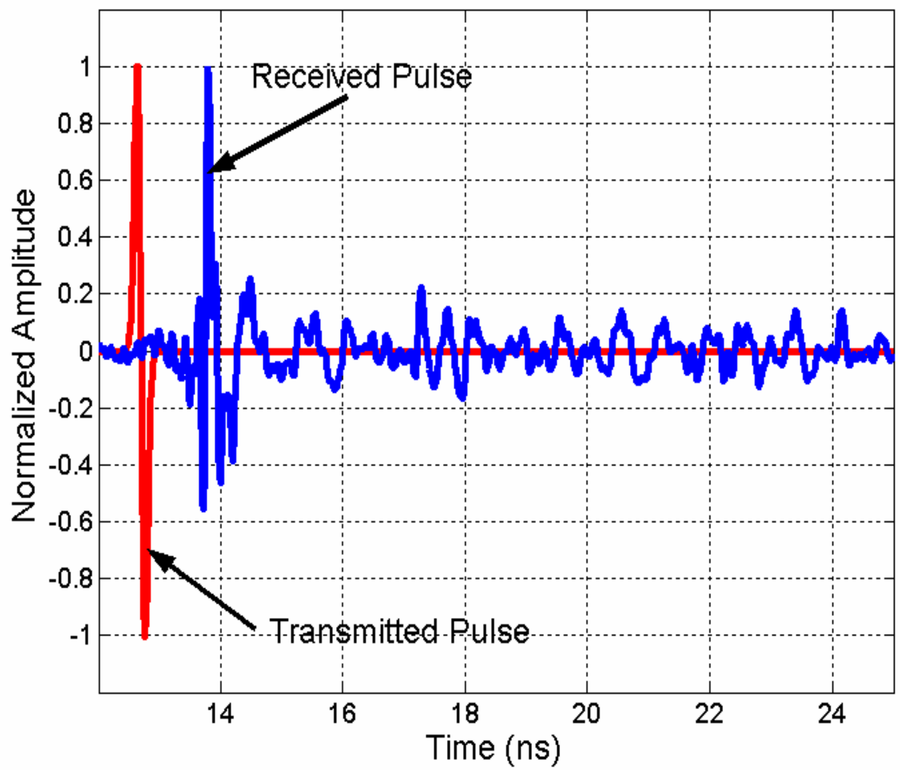
LOS



NLOS



Received Pulse



UWB Channel Models

- "System" models
  - path loss estimation
  - appropriate for link budget analysis and interference prediction
  - perhaps similar to Hata model for cellular
- "Receiver" models
  - multipath statistical characterization
  - appropriate for receiver design
  - perhaps similar to Hashemi model or Saleh/Valenzuela model for wideband indoor

UWB Systems and Technology

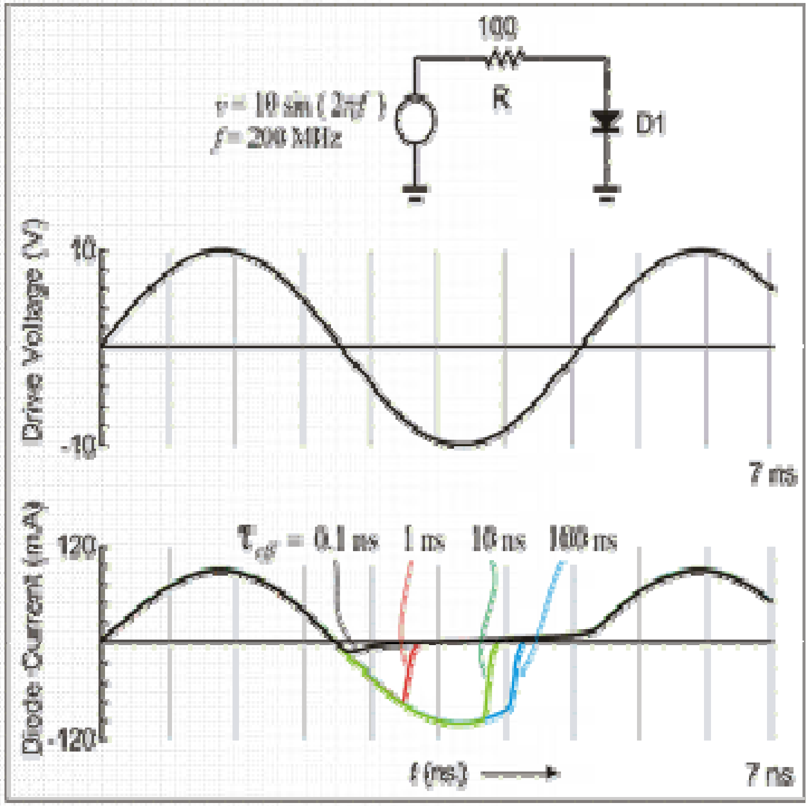
Impulse Radio UWB System Design

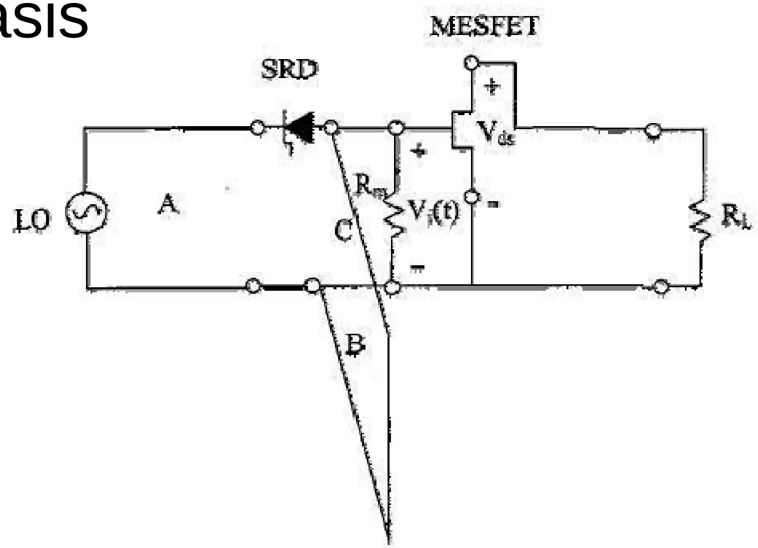
Main Components:

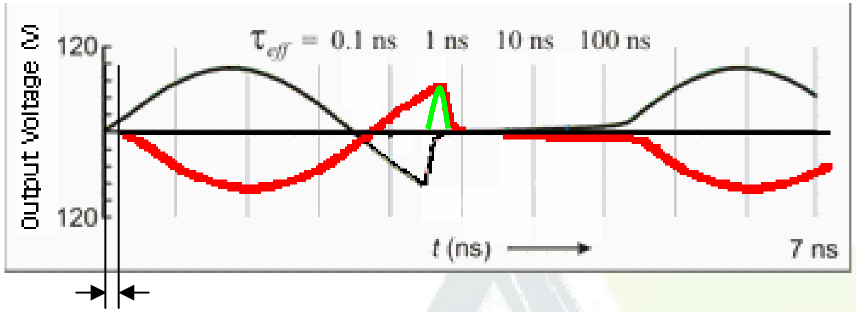
- Transmitter - Signal Generator
  - ✓Analog Pulse generators: Step Recovery Diode, Avalanche Transistor, Tunnel Diode
  - ✓ Digital Pulse generators: High Speed Logic, CMOS programmable
- Tx/Rx RF sub-systems
- Receiver - Impulse Radio UWB Signal Detector
  - ✓ Threshold Detectors
  - ✓ Correlators
  - ✓ RAKE receivers and advanced techniques

Step recovery Diode Pulse Generator

SRD (Step Recovery Diode) Basis

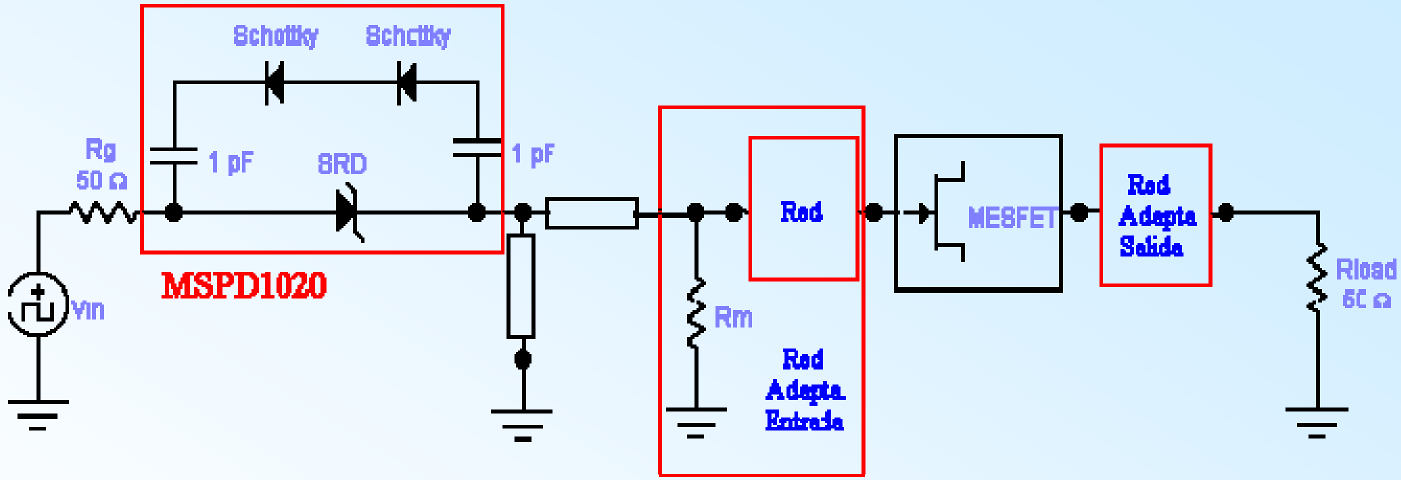


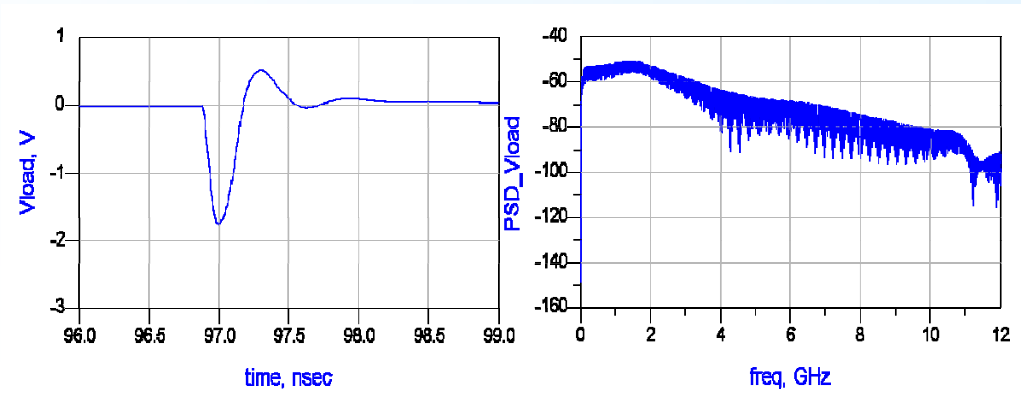


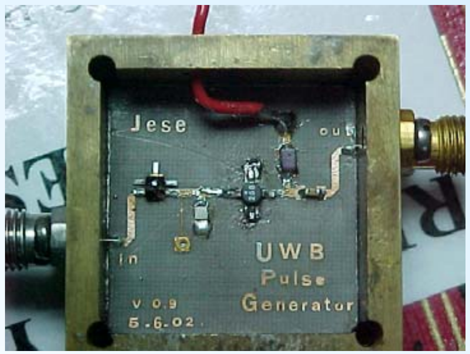


Step recovery Diode Pulse Generator (II)

ACORDE Design – 1st prototype – 2002

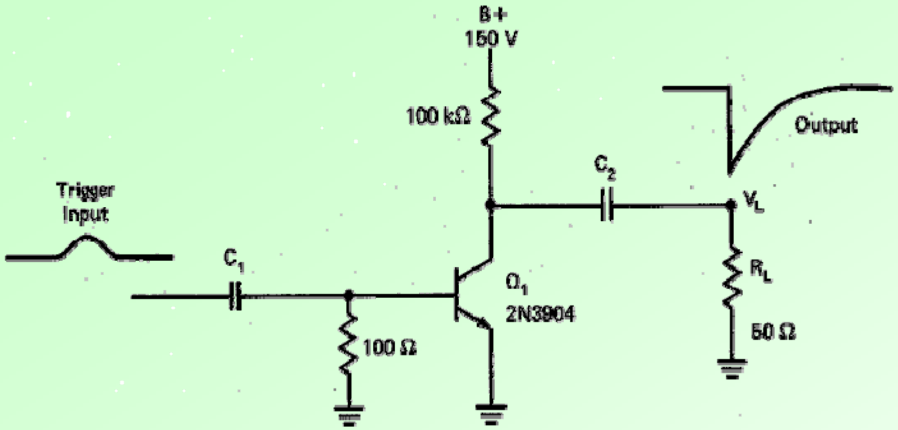


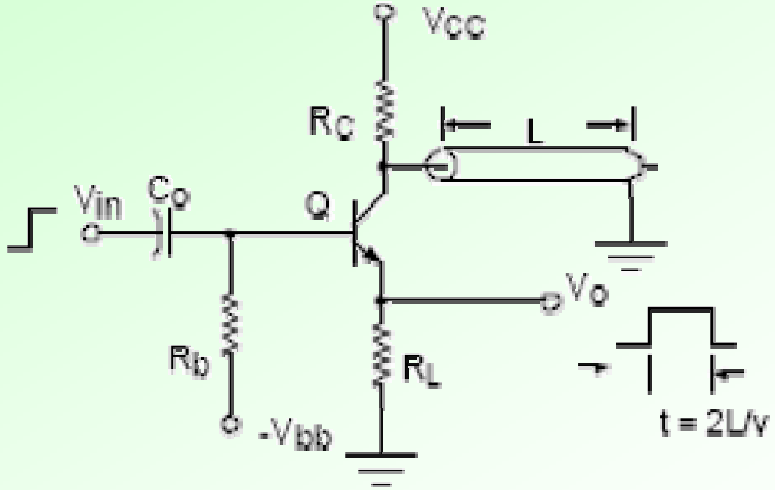


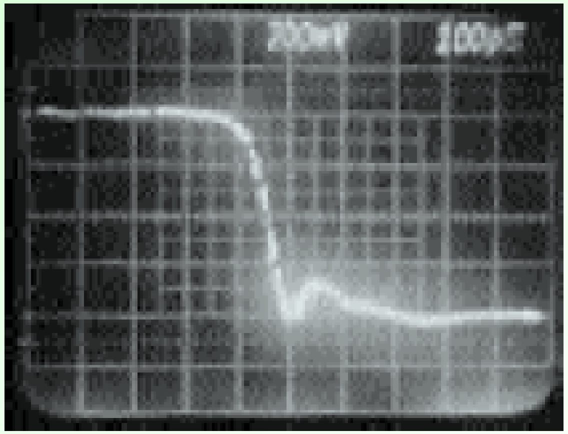


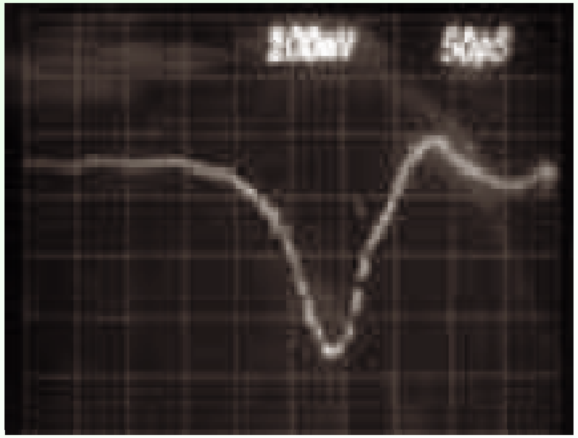
Avalanche Transistor Pulse Generator

Generator Circuit



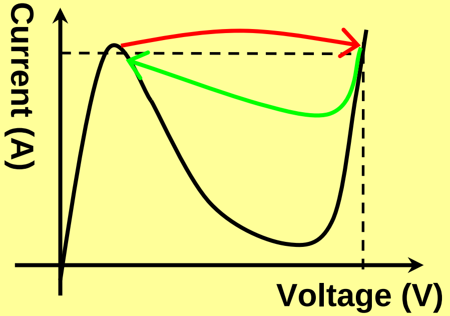


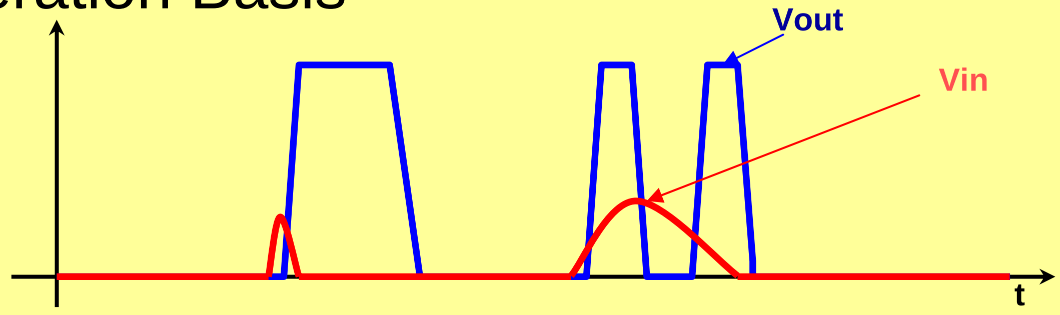


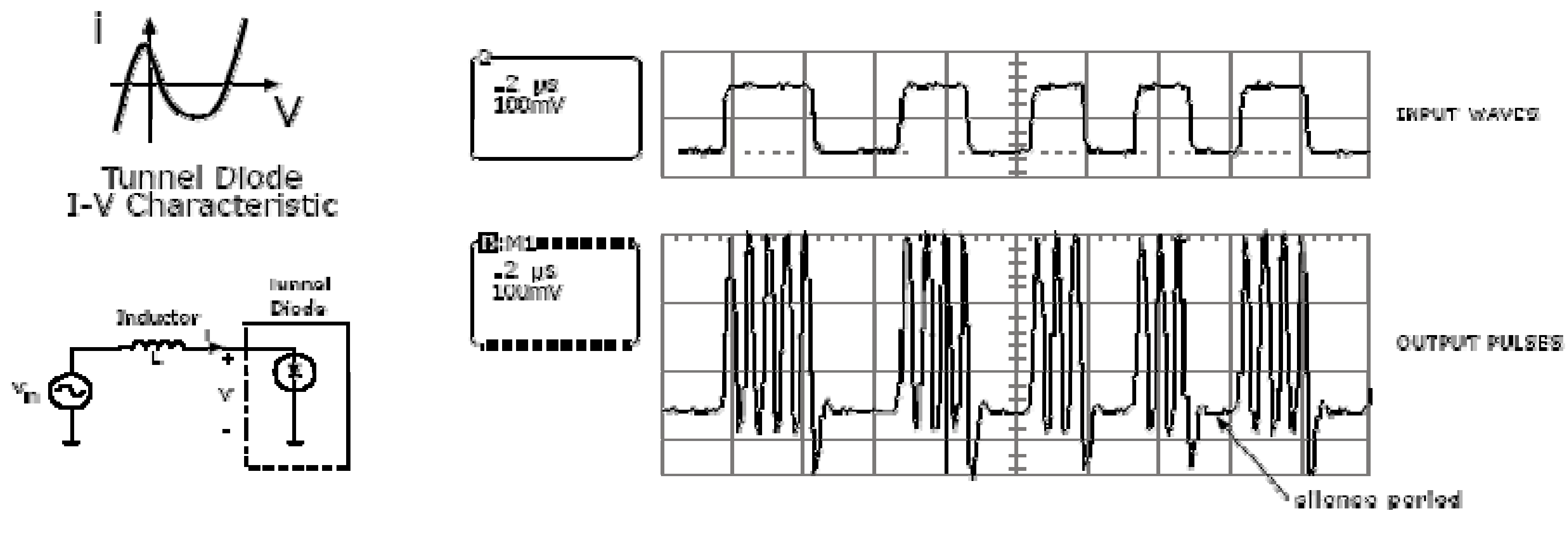


Tunnel Diode Pulse Generator

Tunnel Diode Generation Basis

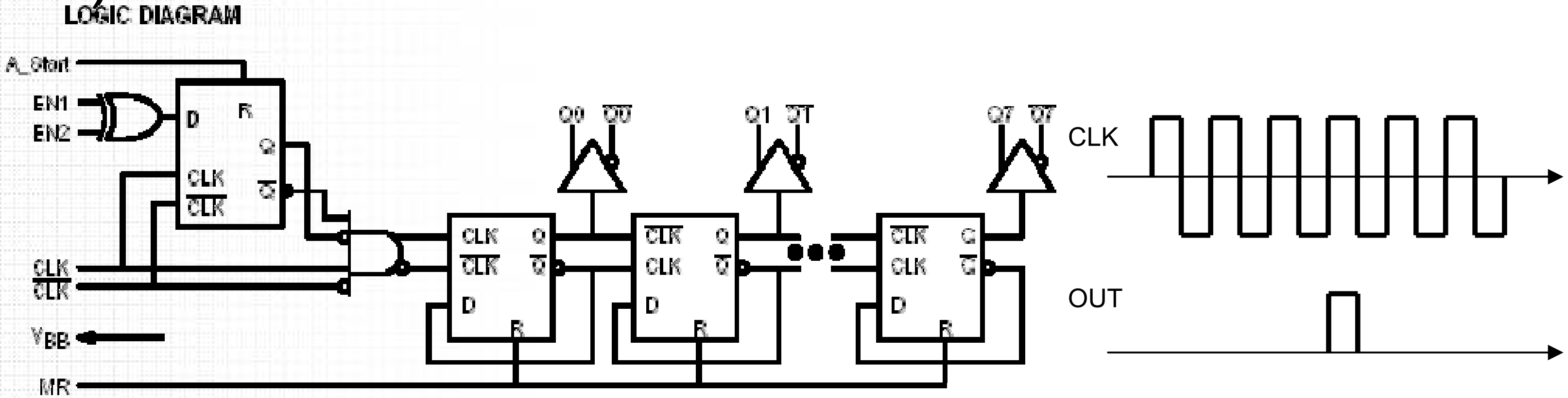




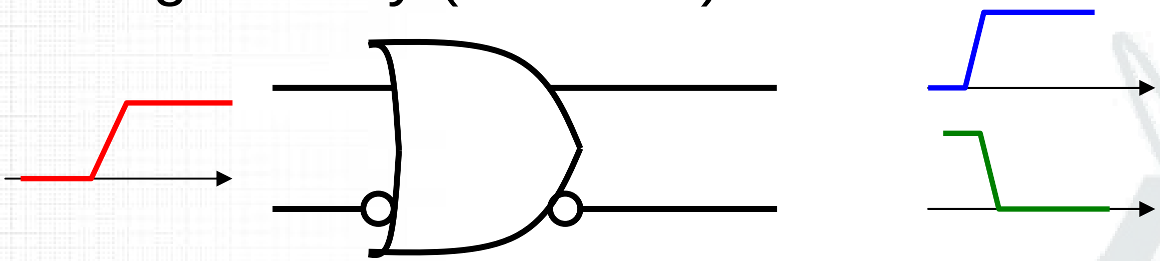


High Speed Logic Pulse Generator

High Speed ASICS (SiGe) → High Speed Counter (13,33 GHz)

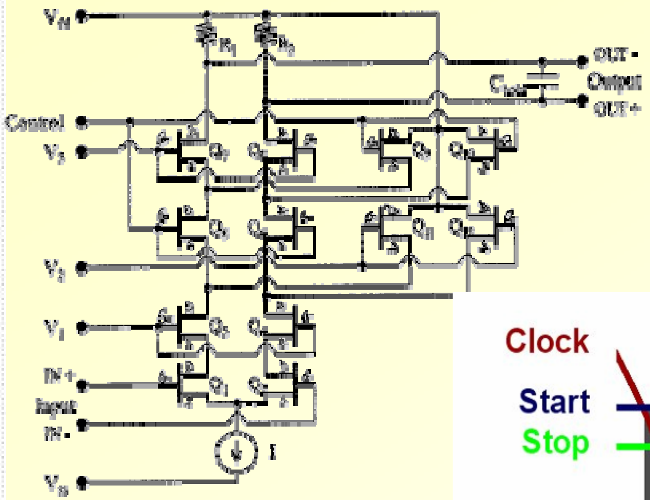


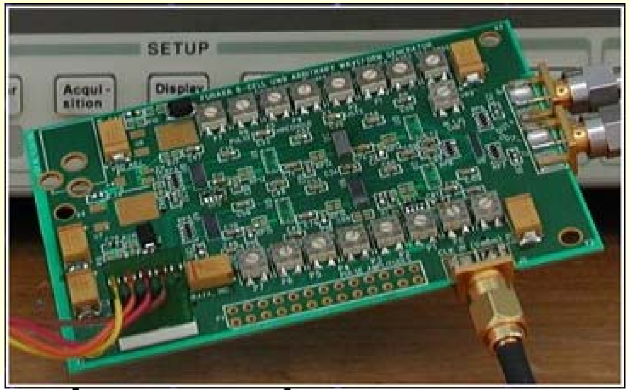
ECL → Logic family (till 4GHz)

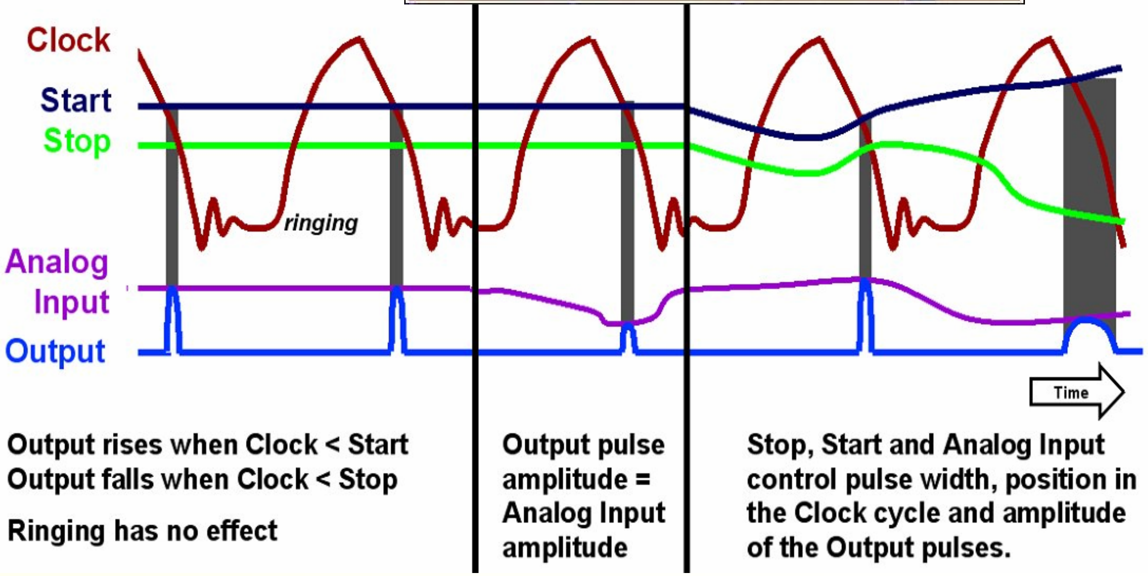


CMOS Programmable Pulse Generator

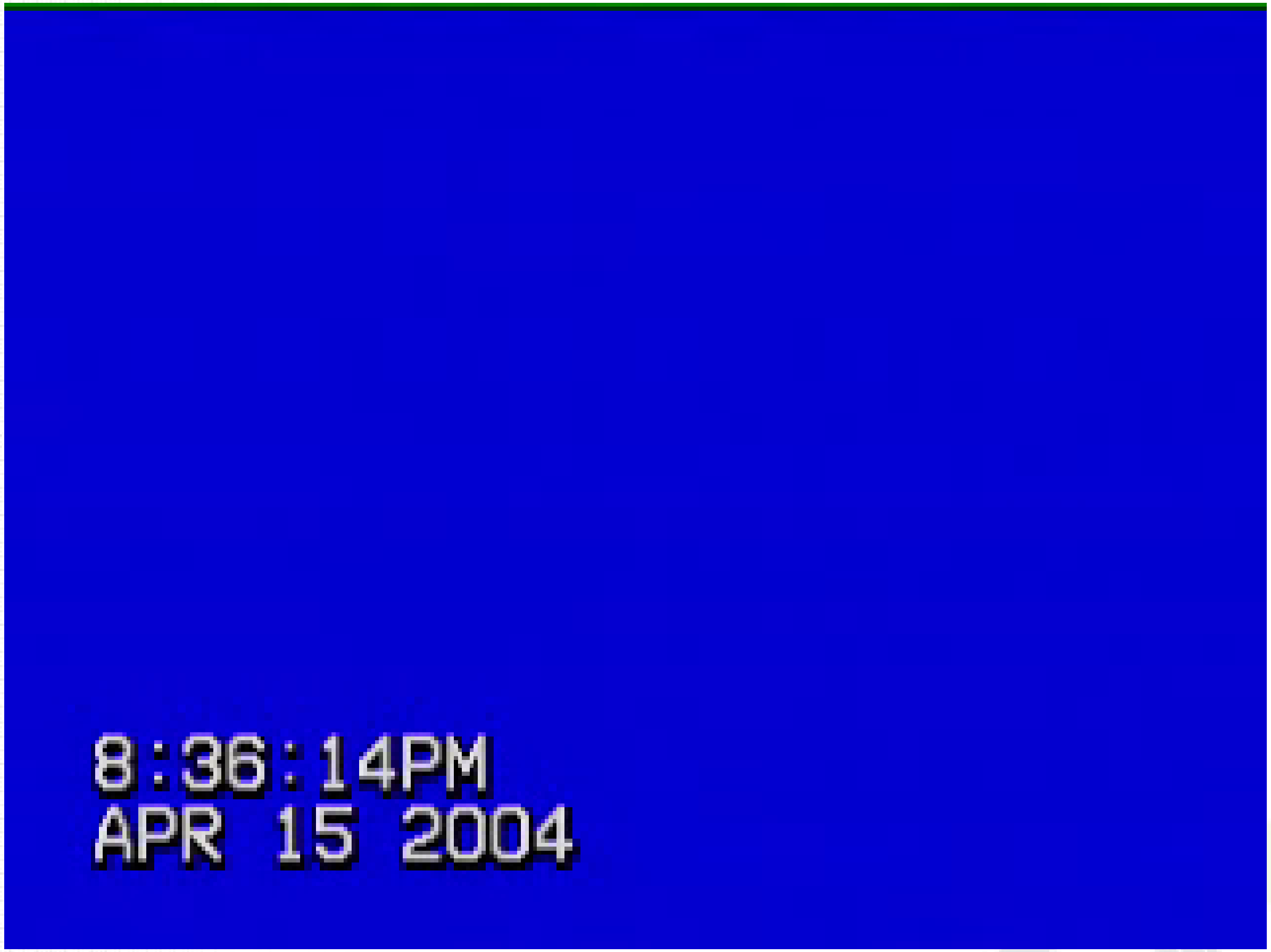
Libove Gate Architecture







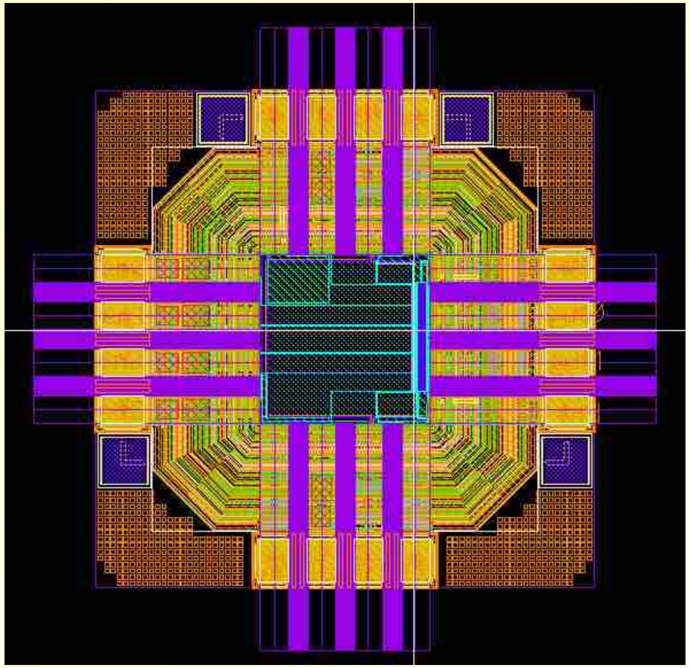
Pulser/Sampler Example

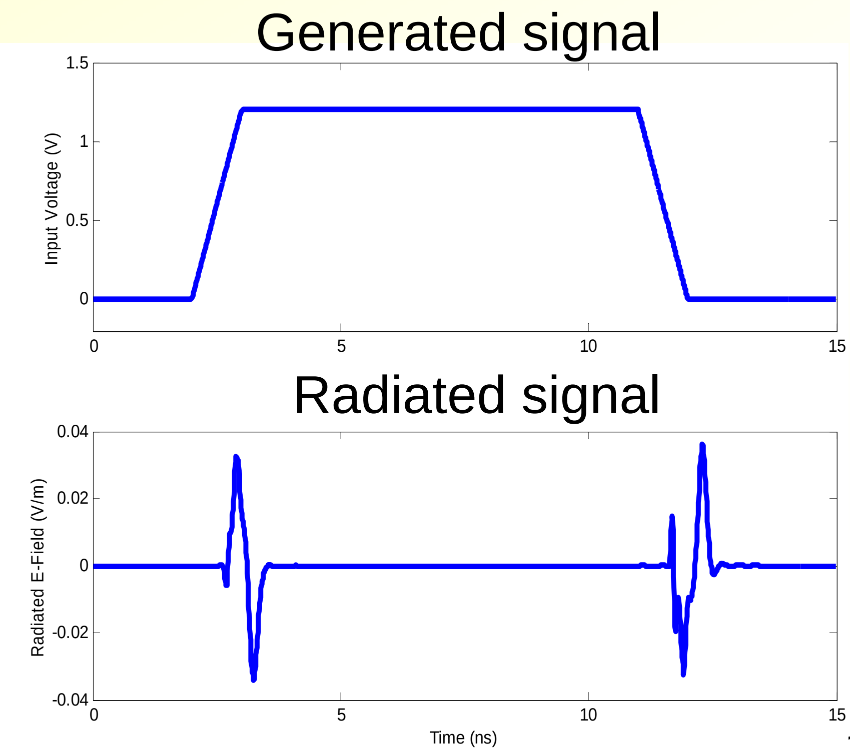


CMOS Programmable Pulse Generator (II)

University of Berkeley design

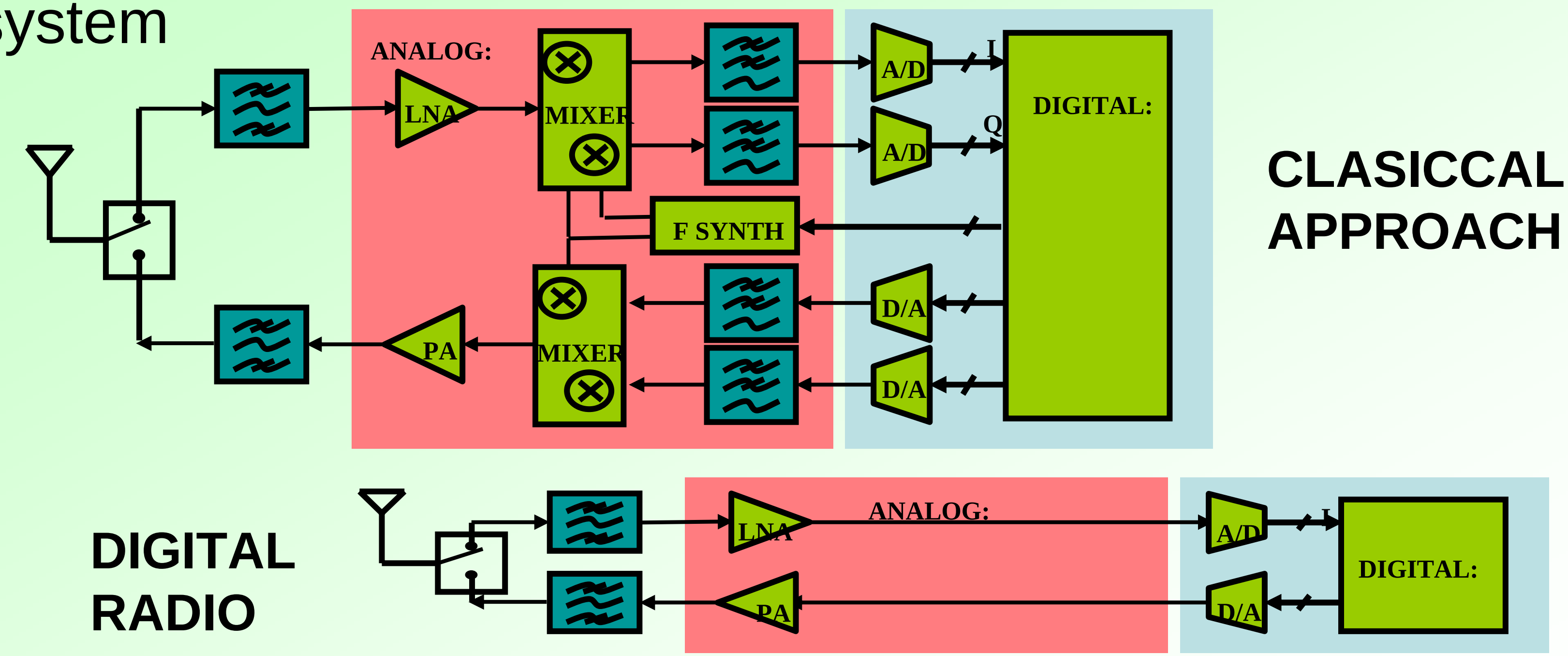
Long pulses BUT with high speed state transfers (100's ps) → Derivative effect of the antenna → Gaussian Doublets





RF Sub-systems

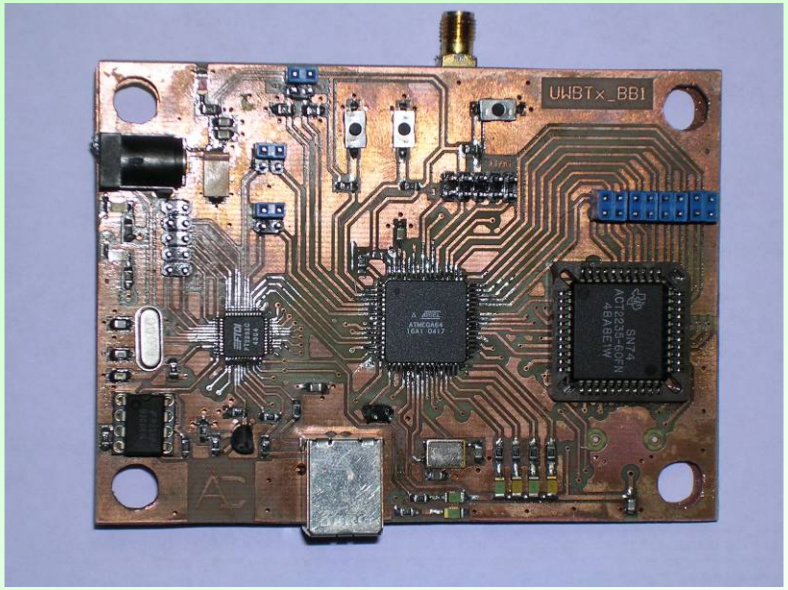
RF front-end → UWB goes towards a full digital radio system

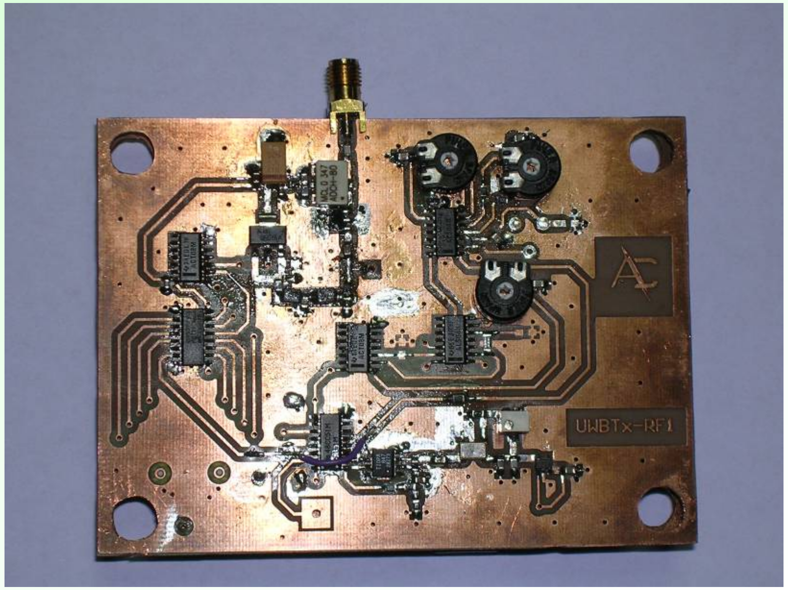


Avoidance of high-Q filters, mixers, frequency synthesizers, high linearity power amplifiers… → **Cost Reduction!!**

IR-UWB Transmitter Prototype

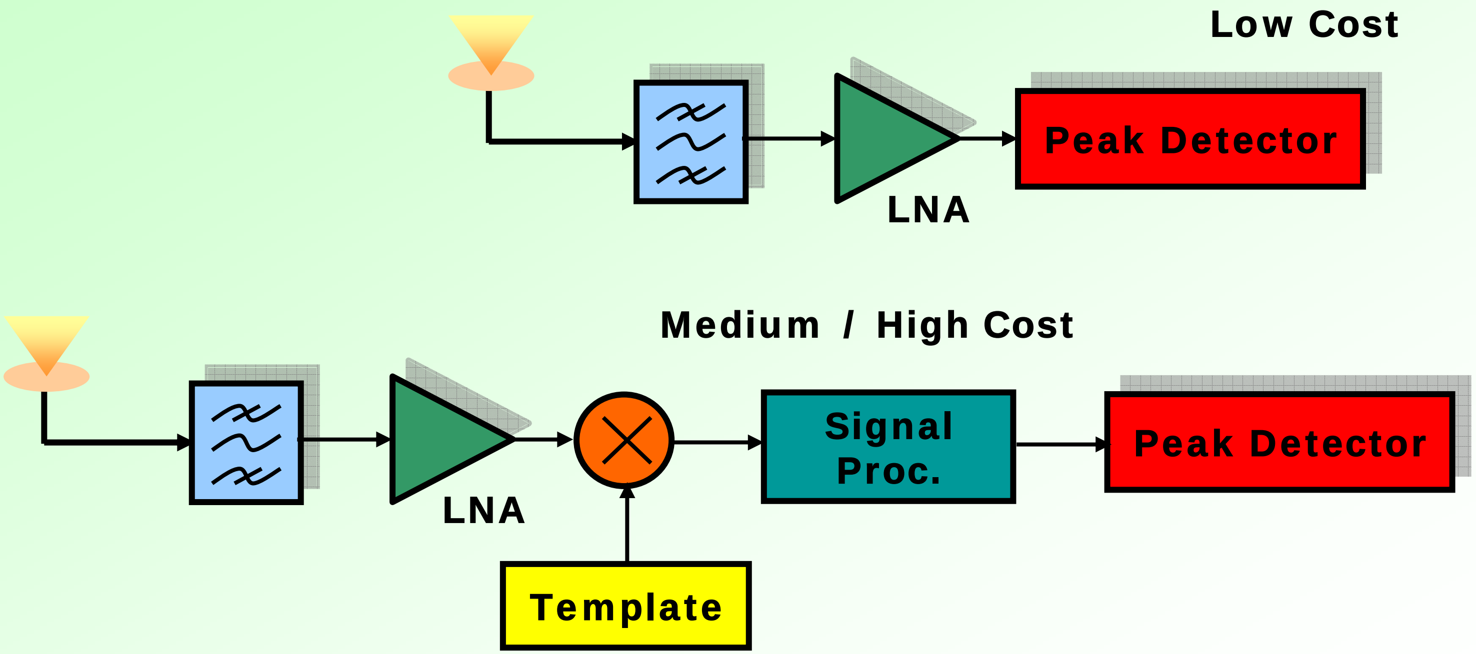
ACORDE design → OOK modulation, for MDR and LDR with location and tracking capabilities





Alternatives

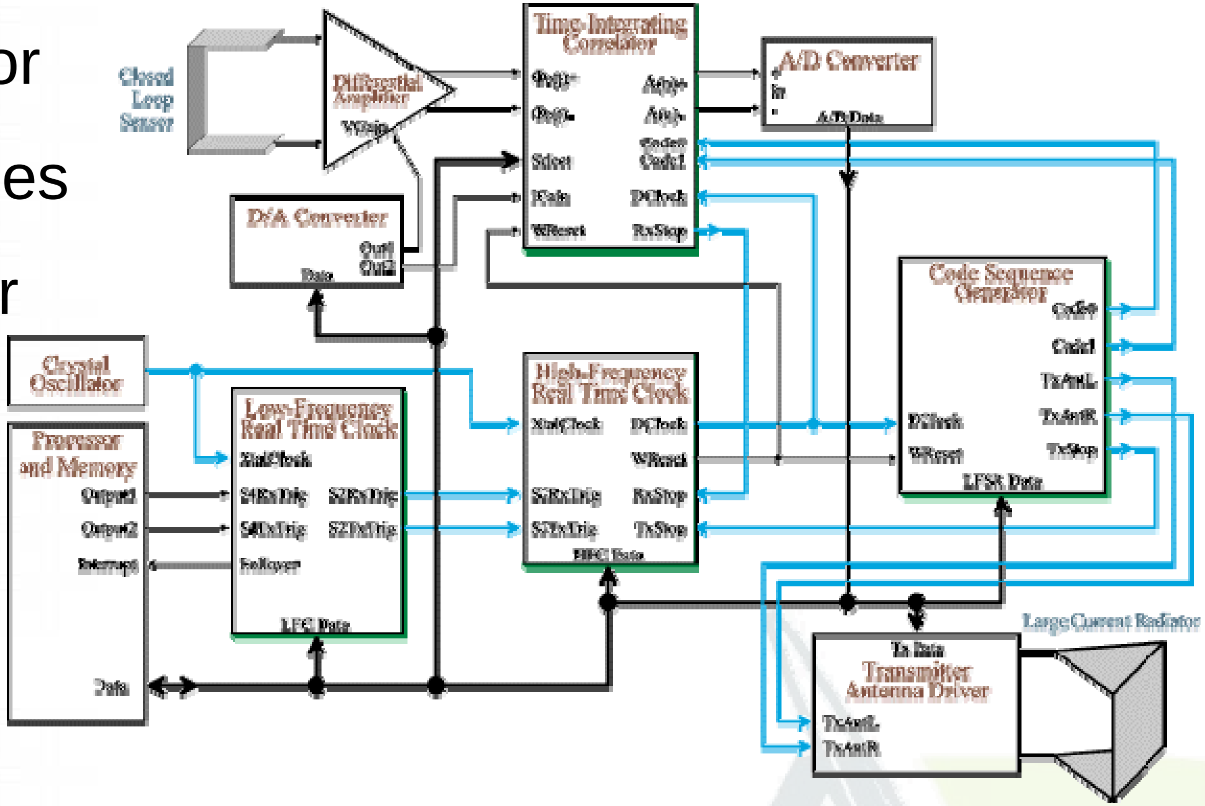
Architecture dependant on the application and system requirements → Cost / Power Consumption / Performance



UWB Localizer and Positioner

Main properties

- Analog correlator
- Coded sequences
- 32 tap correlator



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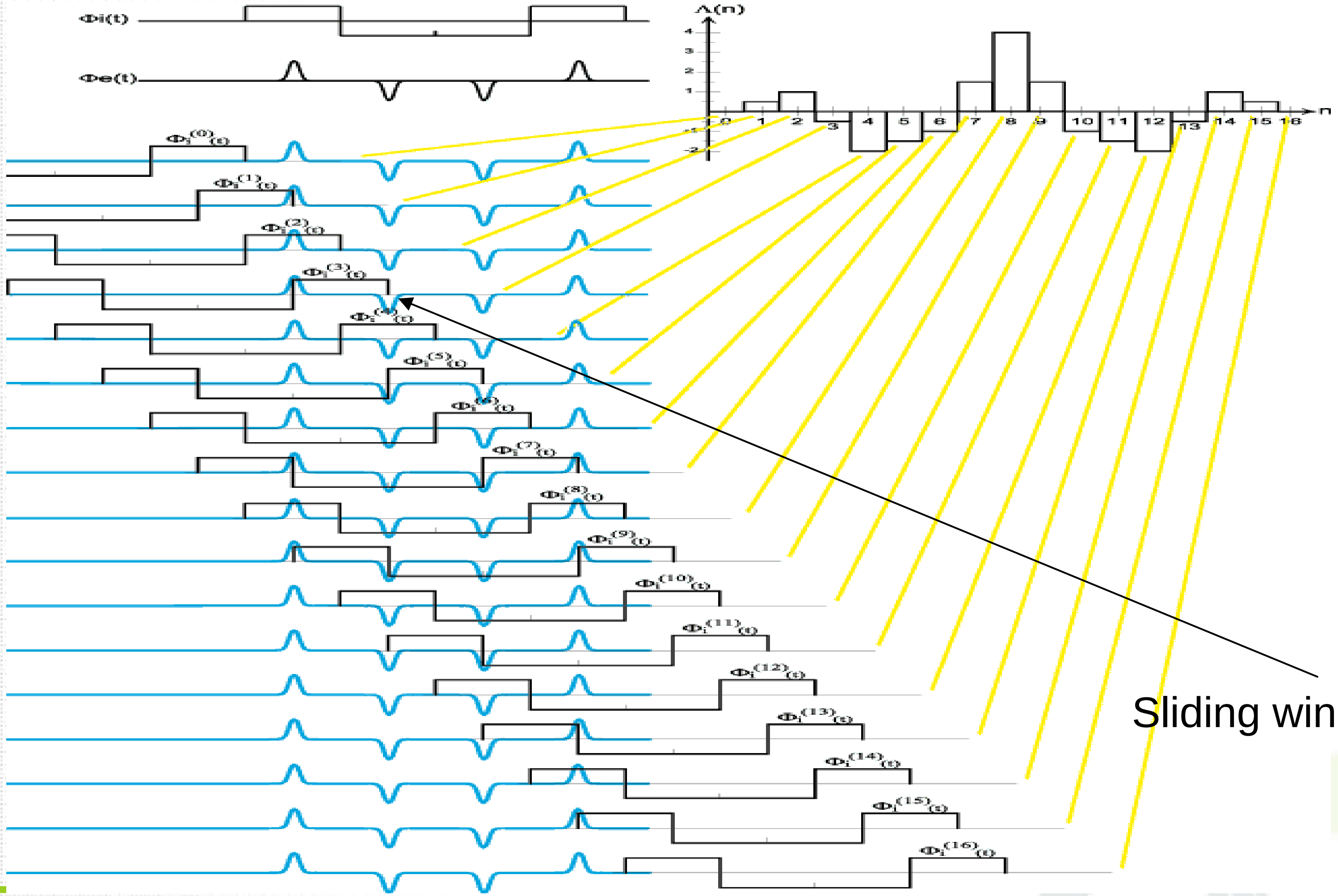
UWB Correlation Process



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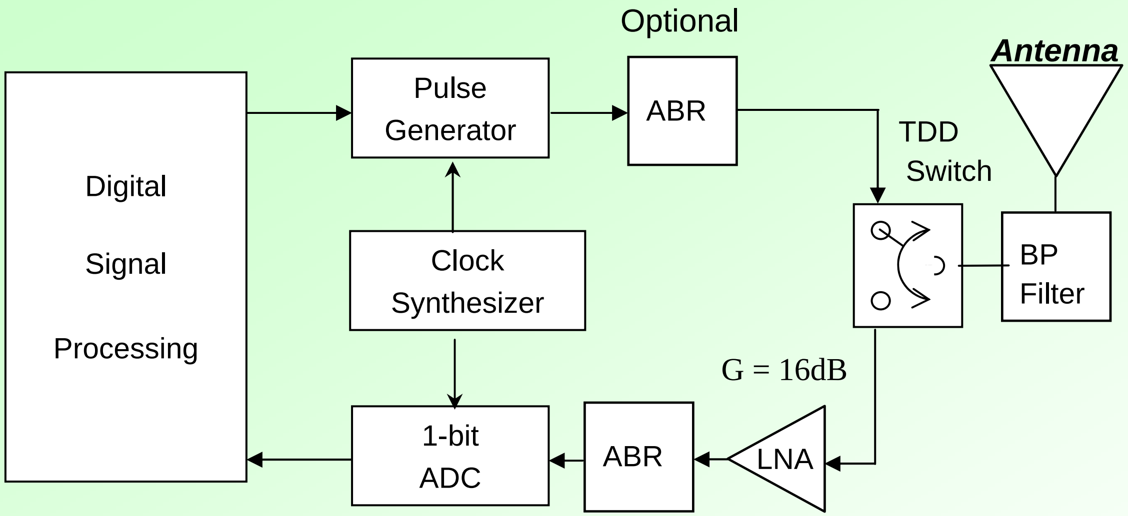
Other Alternatives



- ✓ Digital Correlator
- ✓ 20 GHz Sampling
- ✓ 1 bit ADC
- ✓ Reconfigurable pulse pattern on correlation
- ✓ Rake receiver for multipath energy recovery

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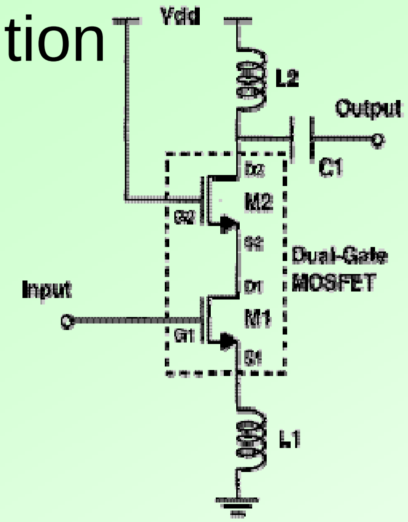
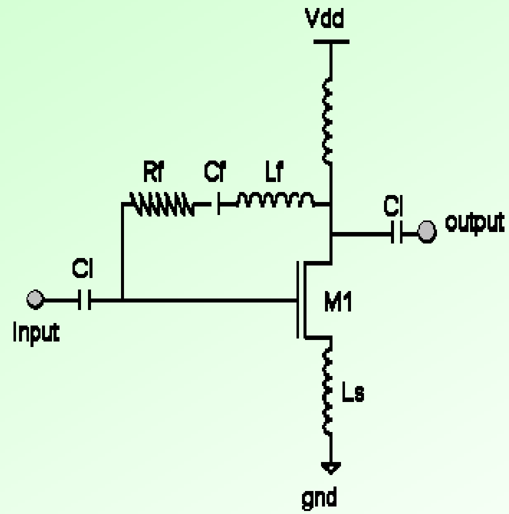
LNAs

CMOS Solution



Narrowband Shaeffer Architecture



Wideband Feedback Architecture

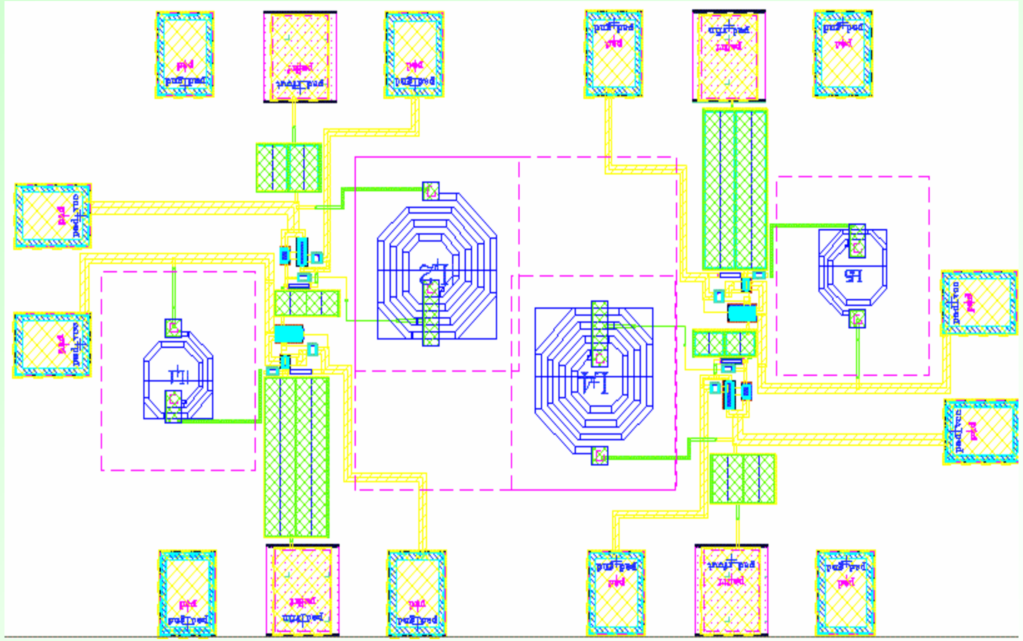
Objectives:

- ✓ Gain ~ 15 dB
- ✓ Ultra wideband input-output matching
- ✓ Noise Figures < 4 dB

LNAs (II)

SiGe-Bipolar Solution

Wideband Darlington Architecture

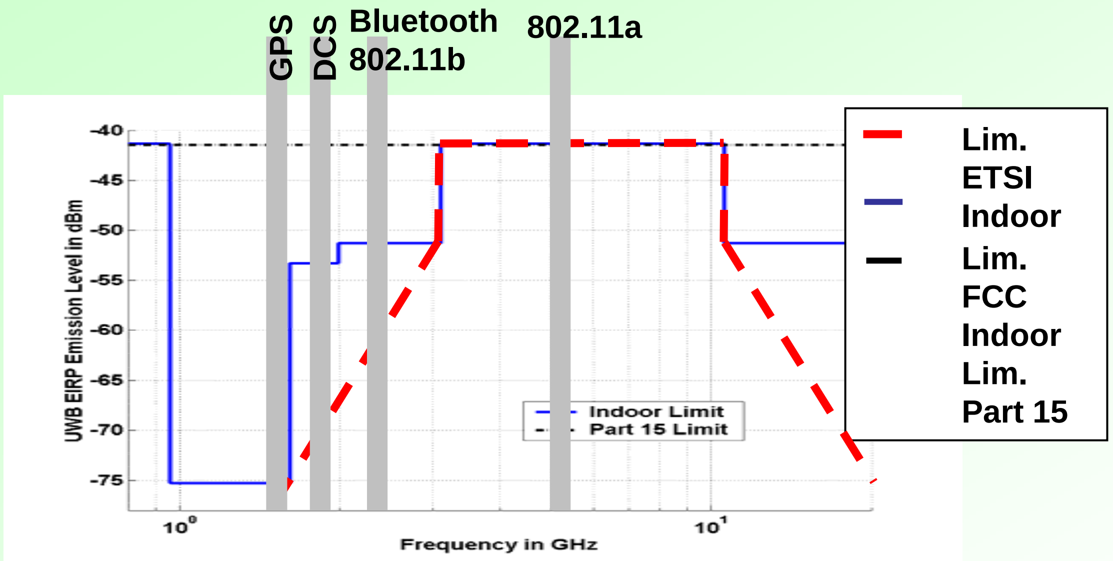


Objectives:

- ✓ Gain ~ 22 dB
- ✓ Ultra wideband input-output matching (3-10 GHz)
- ✓ Figuras de ruido ~ 4 dB

Filtering

To avoid overcrowded bands and/or carry with regulatory limits



Tx filter → Band pass filter

✓GPS band protection (weak signals)

Rx filter → Band pass and Notch filter

✓WLAN band rejection

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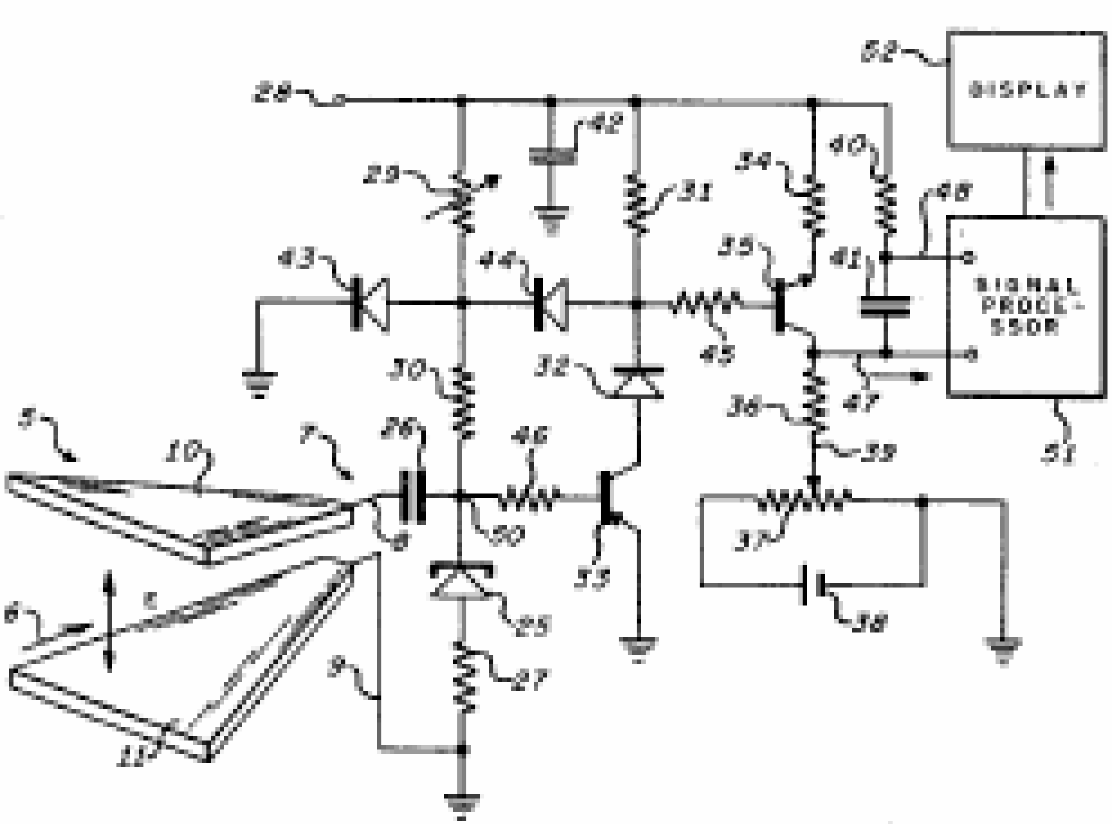
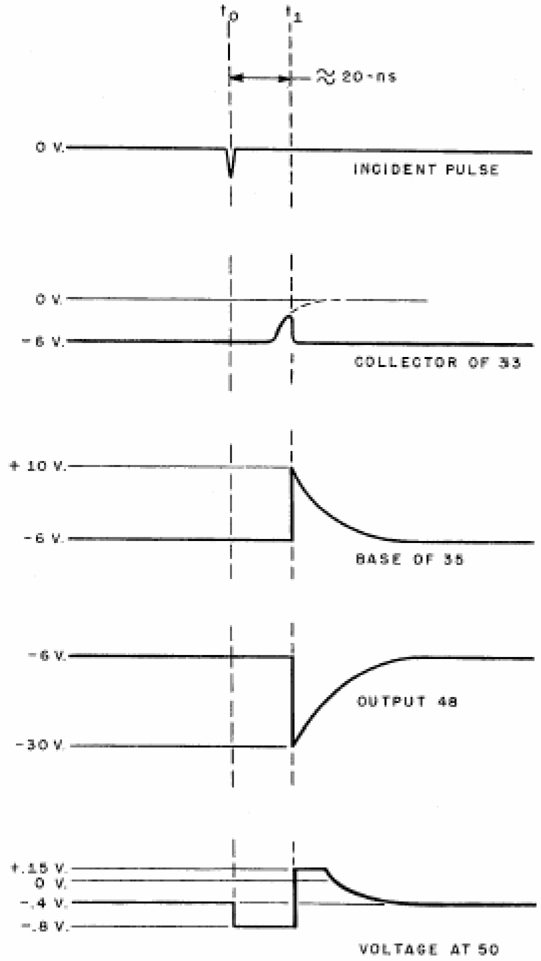
Threshold Reception

Tunnel Diode Threshold detector





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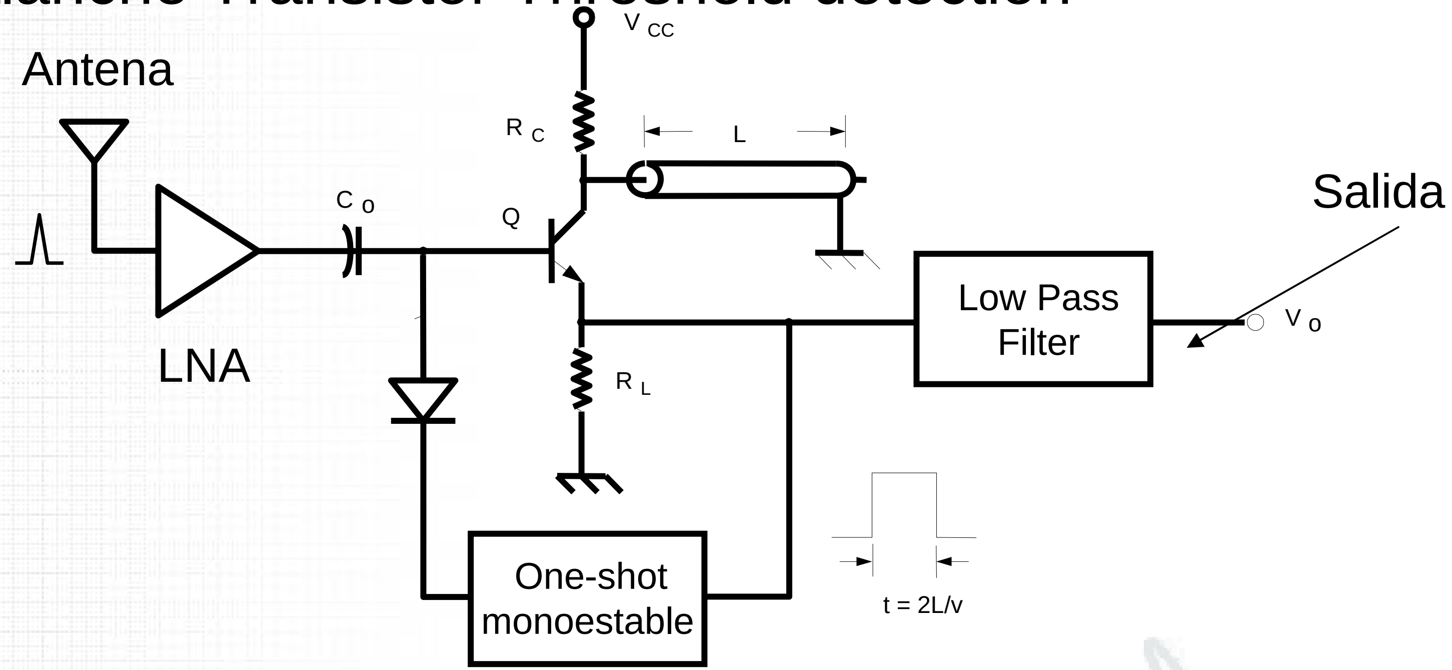
Threshold Reception (II)

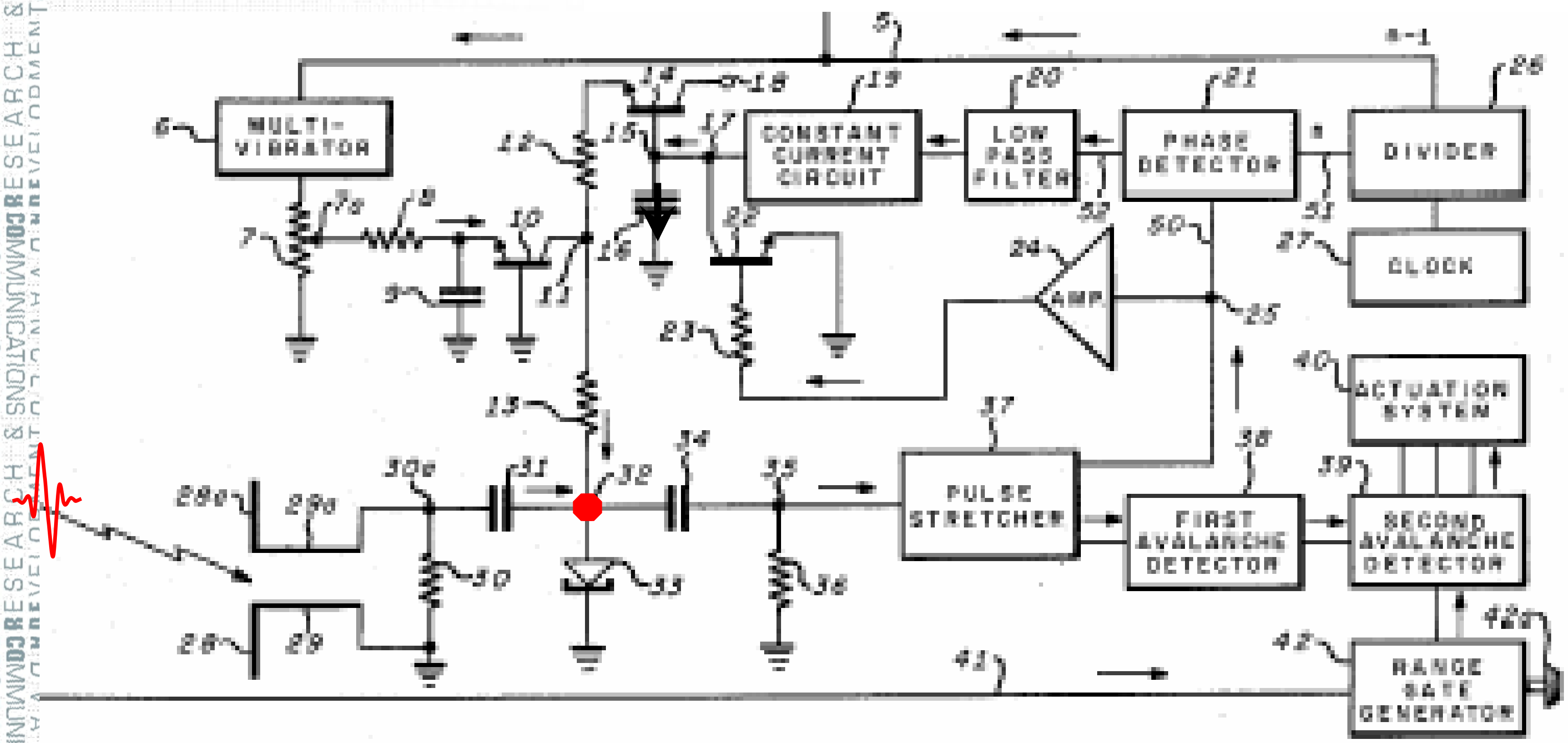
Avalanche Transistor Threshold detection



The transistor is polarized to work on the avalanche region

Incoming signals → Pulse generated → The delay line works as Pulse Stretcher

Super Regenerative Receiver



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Correlators

Analog Correlators

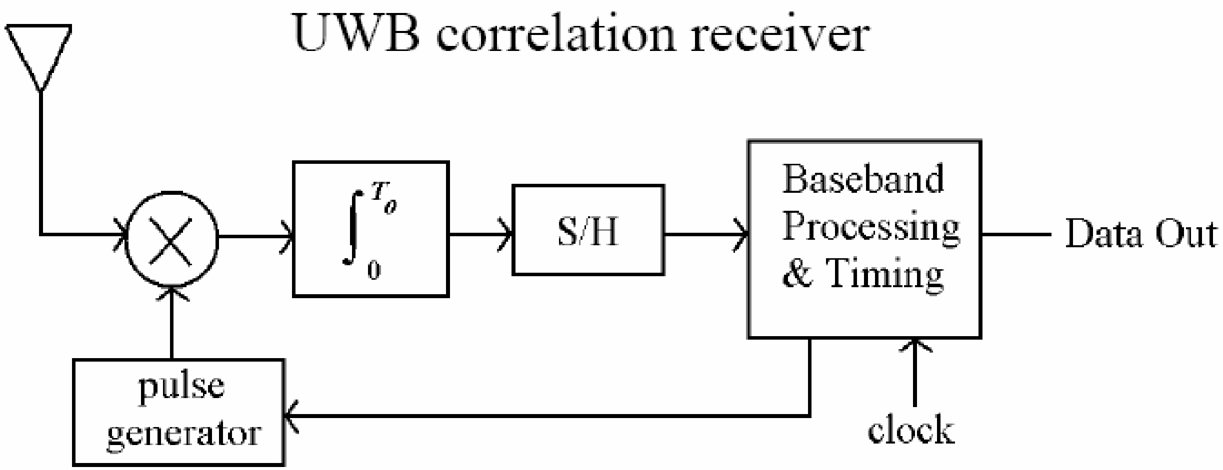
- Multiply (mixer) the incoming signal with a template waveform stored at the receiver side → Matched filter
- Critical point → Sinchronization between the received pulse and the template
- Analog integrator (energy addition)

Digital Correlators

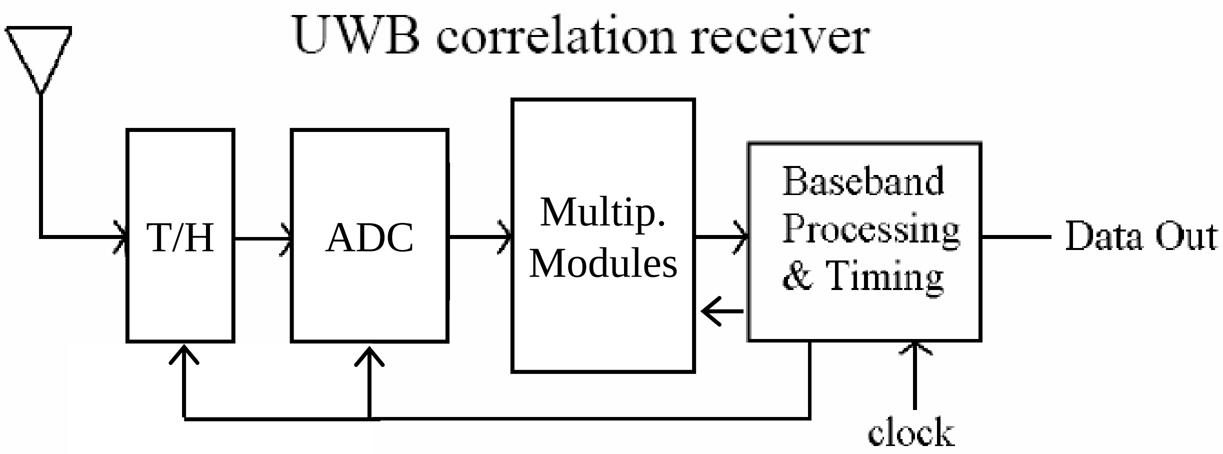
- Sampling of the incoming signal
- Digital multiplication of the template and the samples
  - Sliding window multiplication → + perfor., expens.
  - Static multiplication → - performance, cheaper

Correlators (II)

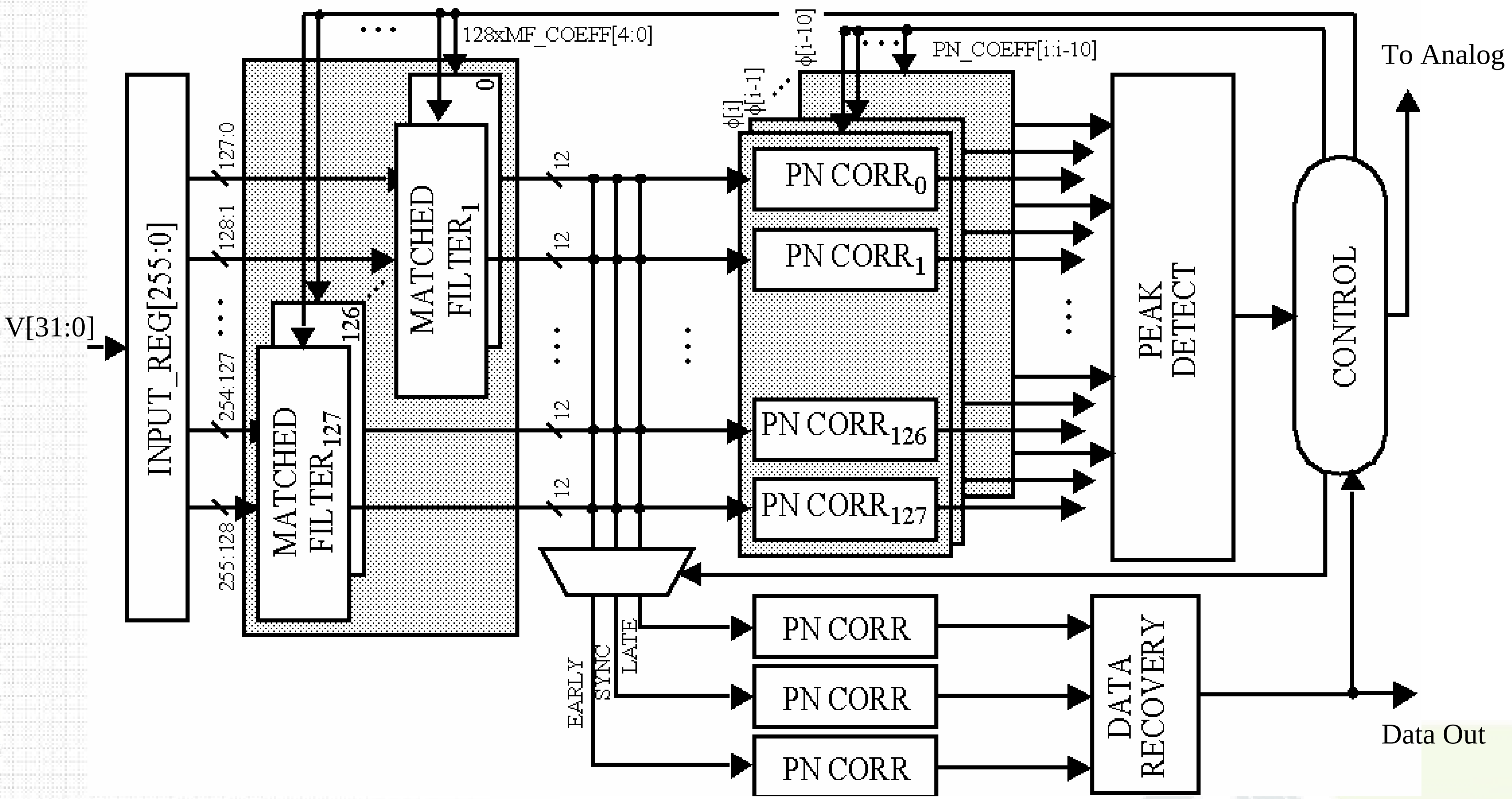
Analog



Digital



Digital Correlation Implementation



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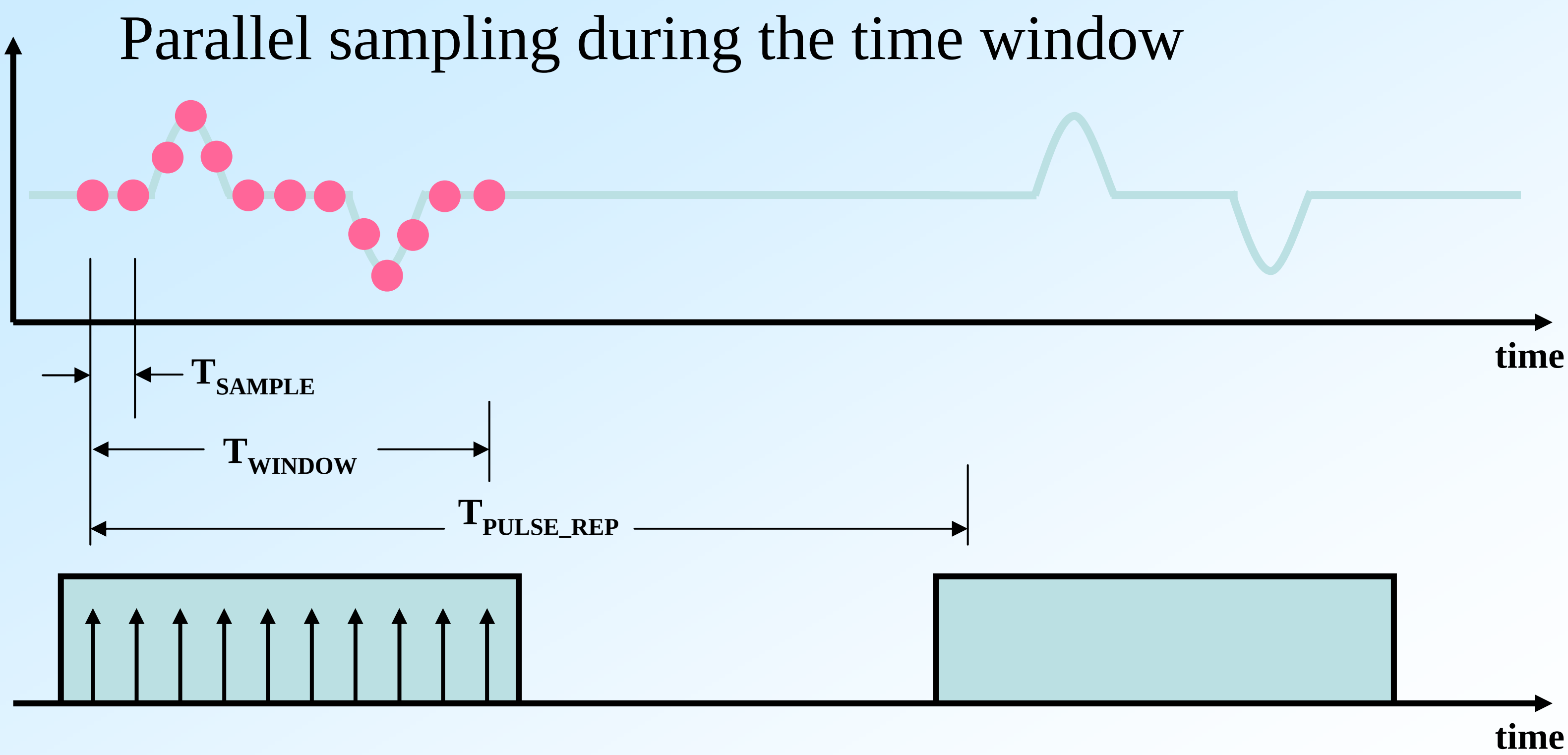
Álvaro Álvarez Vázquez

Digital Correlation Implementation (II)



Three different time scales:

T_{SAMPLE} (<ns) T_{WINDOW} (~10's ns) T_{PULSE_REP} (~100's ns)

Digital Correlation Implementation (UCAN)

Matche

– D

• Multi gurable (to match

• High

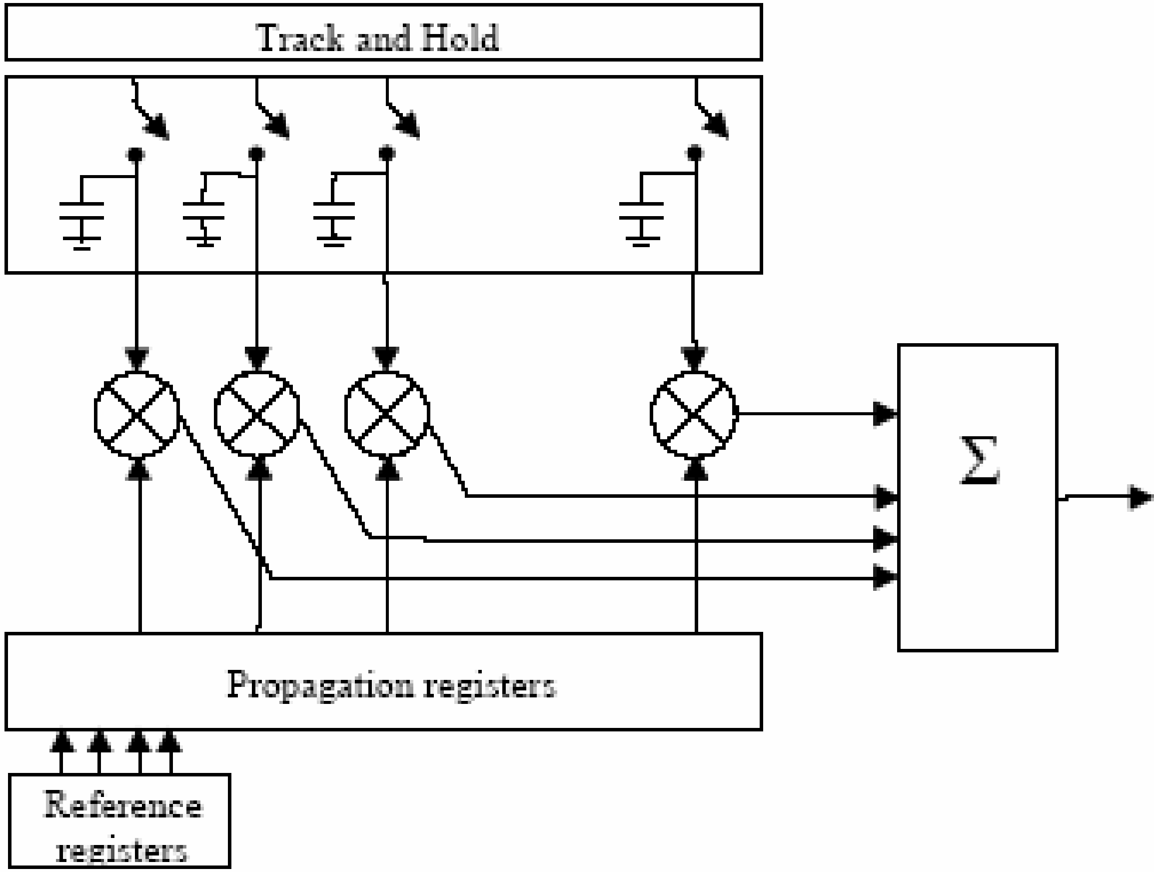
– old units.

Alte pling) and

cor

– A

• DC o



RAKE Receiver

UWB signals has got up to 30 different multipath components → Take benefit from multipath energy → RAKE

- The multipath energy can be combined making use of a RAKE receiver → System improvement
- Every path provides a small portion of energy. It is difficult to estimate the bin weight for each path.
  - Every path has a different amplitude/distortion
  - Combine 30 different components might be difficult
- Simpler alternatives to make use of the multipath energy?
  - Non-coherent receivers

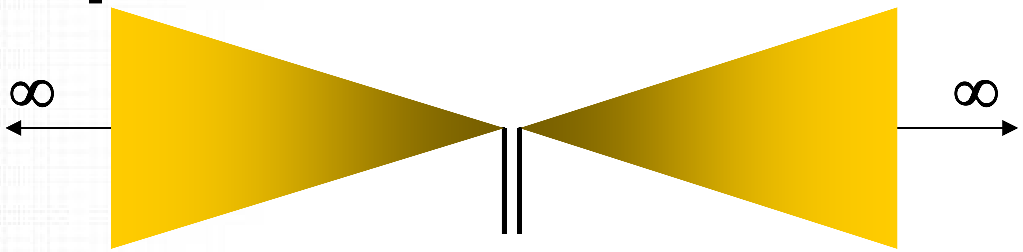
UWB Antennas

The antenna is the component in charge of the radiation of the radio-electrical signals, and with UWB signals must carry out the following properties:

- Large bandwidth (several GHz)
- Must be able to radiate short impulse type signals (ps range), without distortion and ringing
- The operative bandwidth is directly related to the matching within this band (this is → $|S11|_{dB} < -10$ dB)
- The final objective is to obtain the smaller antenna (printed antennas are the challenge) for massive applications and commercial integration

UWB Antennas (II)

"*If the shape of an antenna could be specified entirely by angles, the antenna performance would be independent of frequency*" [1,2]



Strictly, the structure must have infinite dimensions in order to carry out with this condition

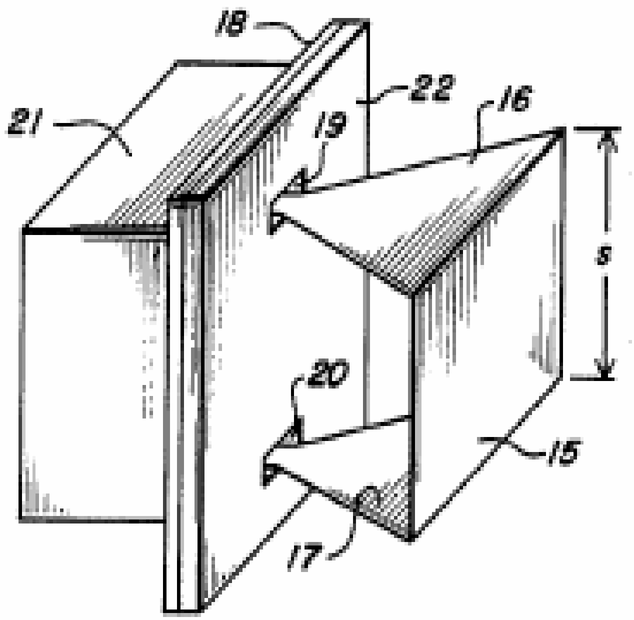
If the antenna has limited size, a frequency dependency s established and the bandwidth is limited

[1] J. D. Dyson, "The Equiangular Spiral Antenna," *IRE Transactions on Antennas and Propagation*, vol. 7, pp. 181-187, 1959.

[2] V. H. Rumsey, "Frequency Independent Antennas," in *Proc. IRE National Convention*, New York, NY, USA, 1957.

Large Current Radiator

Large Current Radiator

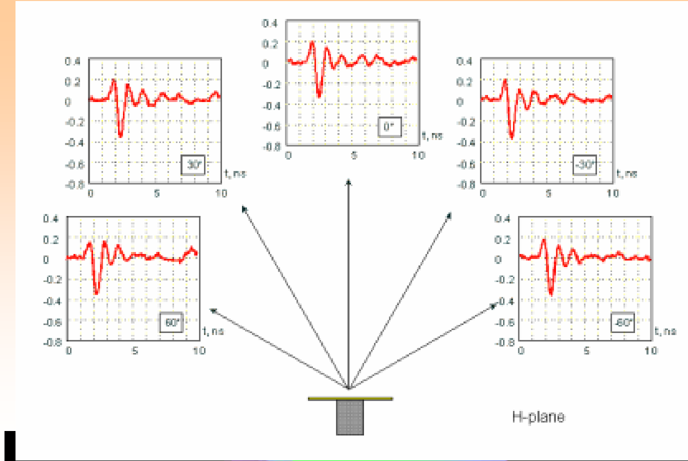


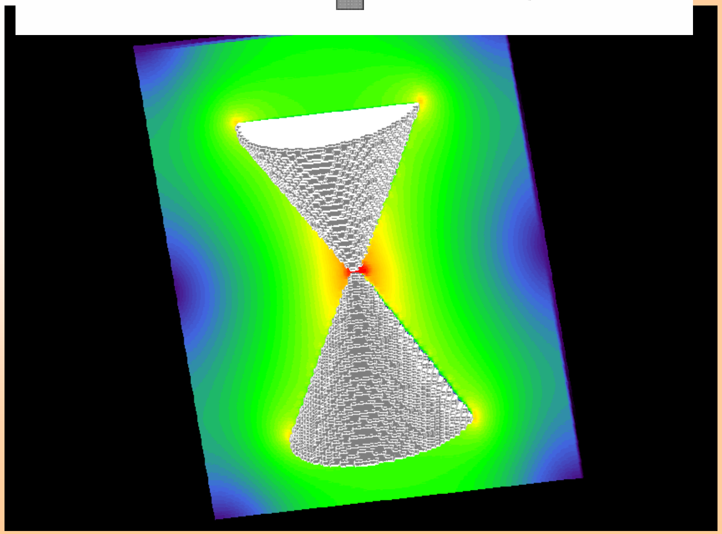
Hartmuth Patent – US4,506,267

Based on the electrical excitation by the current through the structure

Biconical Antenna

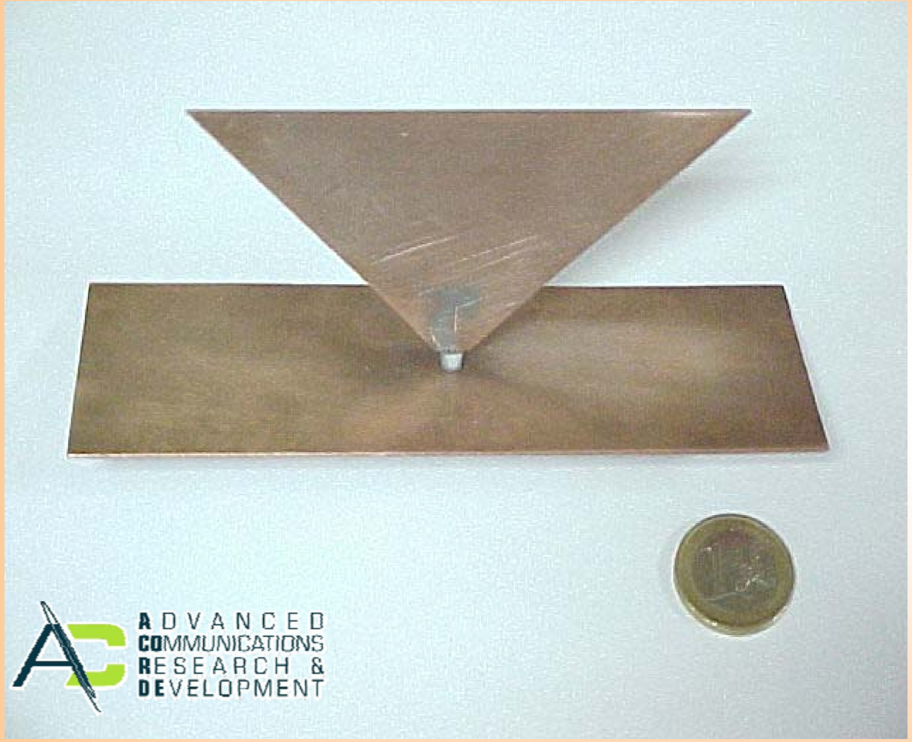
Biconical Antenna

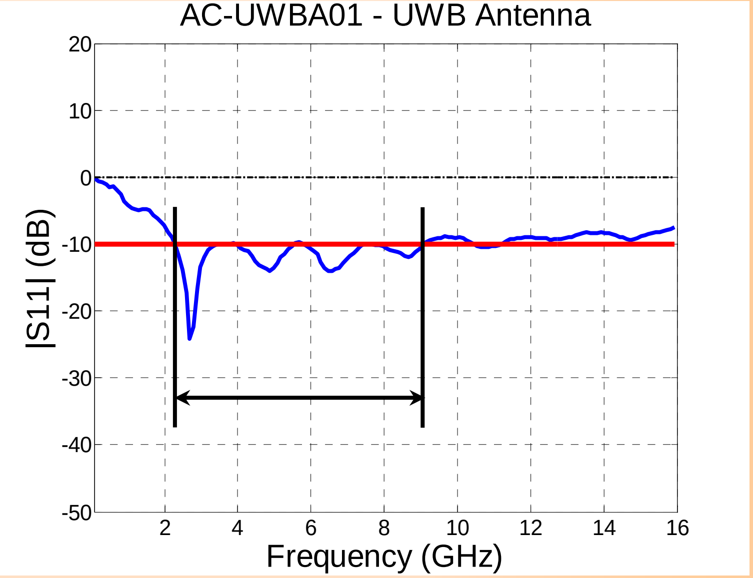




Trapezoidal Antenna

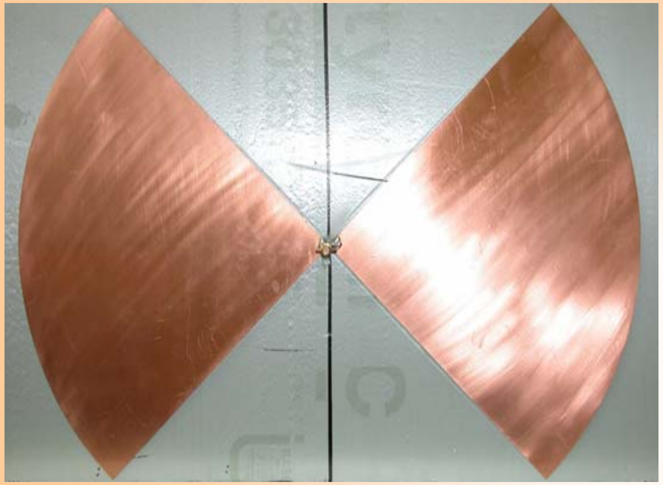
Trapezoidal Antenna





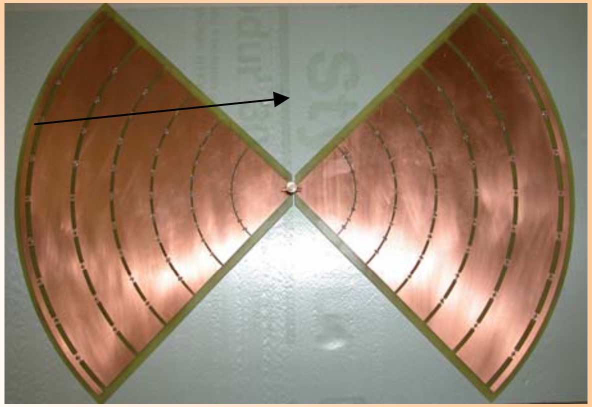
Bowtie Antennas

Bowtie o Brown Woodward Antennas

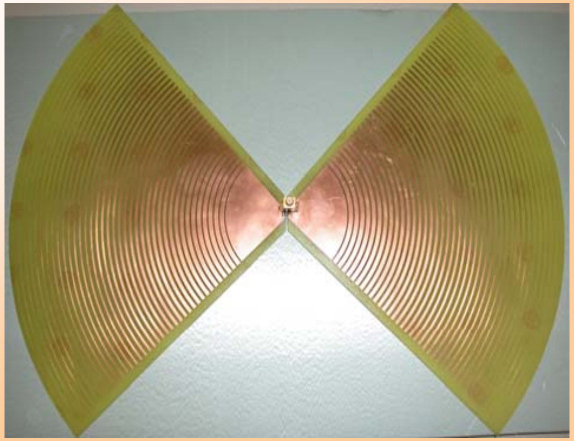


Bow-tie printed antenna

Resistively loaded antenna



Capacitive loaded antenna



Pictures and data from:

LCM LINZ CENTER OF COMPETENCE IN MECHATRONICS

Institute for Communication and Information Engineering
University of Linz

Spiral Antennas

Logaritmic-Spiral or Equiangular-Spiral Antennas

Logarithmic spiral antenna

Substrate:	FR4
Thickness:	1.55 mm
Copper thickn.:	35 µm
Dielectric cnst.:	4.7
δ:	$\pi/2$
Maximal dim.:	270 mm and 420 mm

Very broadband antennas with input impedance around 60 Ohms.

Pictures and data from:

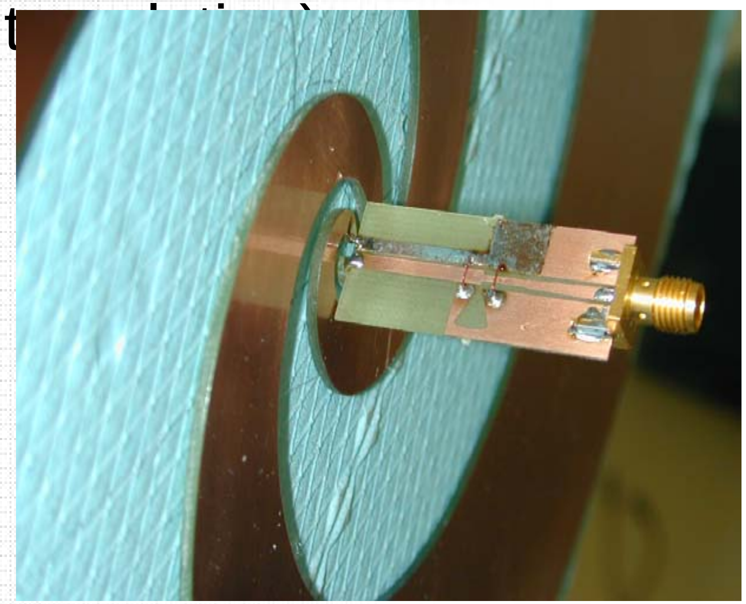
LCM LINZ CENTER OF COMPETENCE IN MECHATRONICS

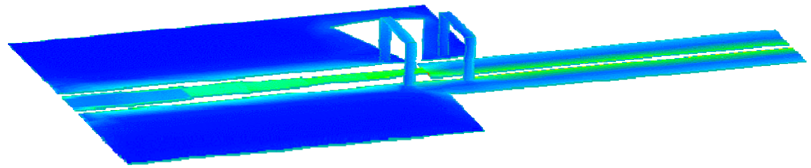
Institute for Communication and Information Engineering
University of Linz

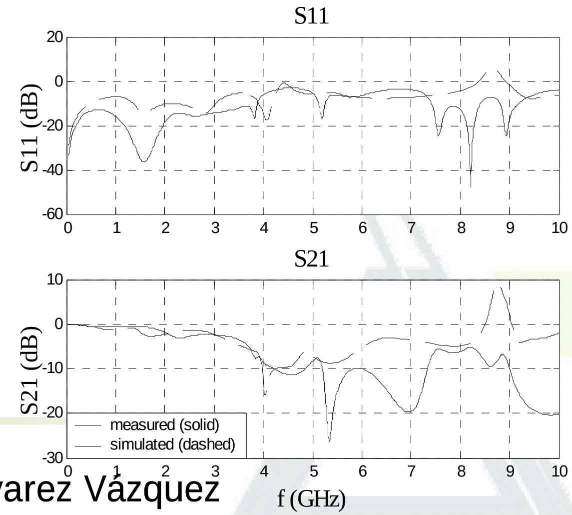
Planar Antennas: Risks and Benefits

The hardest issue of working with planar antennas, is the feeding connection, this is the link between the radio front-end and the radiating element by itself.

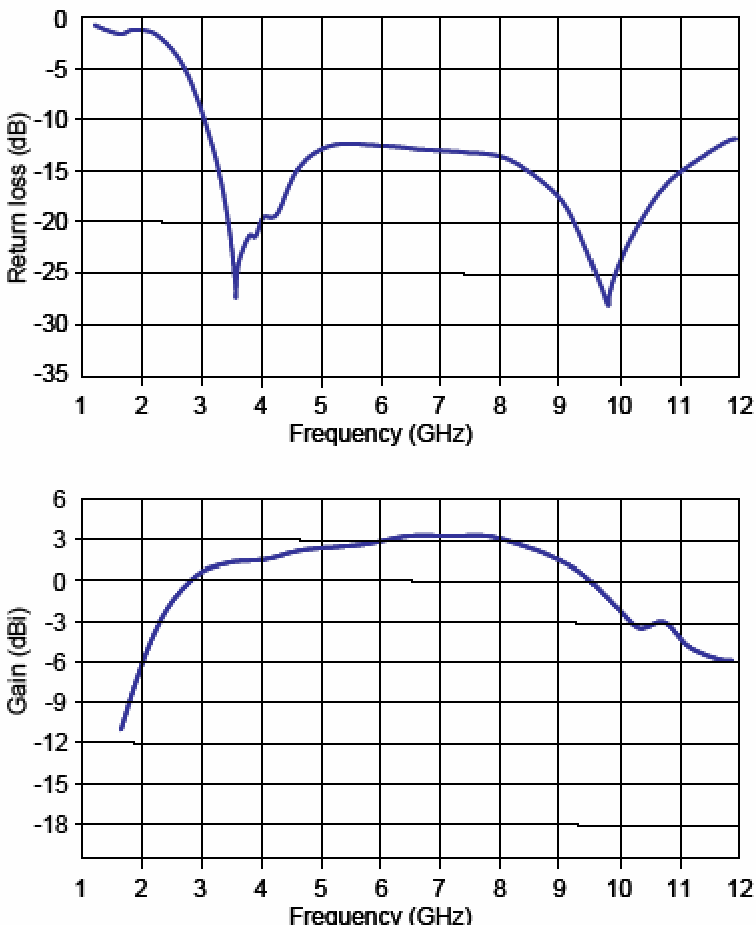
In order to feed this antennas, sometimes is required to employ a wideband balun (unbalanced to balanced translation).







UWB antennas need not be complex or expensive as shown in the example on the right (suggested by Prof. Jack Lang, constructed and measured by Dr. Hans Schantz). Although US cents are shown, discs similar in size (19 mm diameter and 0.7 mm thickness) such as the Euro 2-cent piece may also be employed. (Of course, the Euro dipole design would be a four-cent solution). The diameter affects the lower bandwidth frequency, while the thickness and gap spacing between the two elements affects the match.



For a more complete analysis please see: H. G. Schantz, **"Planar Elliptical Element Ultra-Wideband Dipole Antennas,"** Proceedings of the 2002 IEEE APS/URS Conference, San Antonio, TX, 16-21 June 2002.

Variations on this theme are in Patent Application "Ultra Wideband Antenna" PCT/GB2003 /005070 filed Nov. 2003. [You can use the variations, if the patent issues, for non-commercial and academic work, providing that any IPR is acknowledged and any changes or improvements are reported back to Artimi Ltd under Reasonable and Non-Discriminatory, Zero-royalty (RAND-Z) terms.]

Localization with UWB

- Wideband signals allow a very precise time resolution → Ranging and localization also very precise
- Example:

$$BW = 1\ GHz \rightarrow \tau = 1\ ns \rightarrow \Delta d = 30\ cm$$

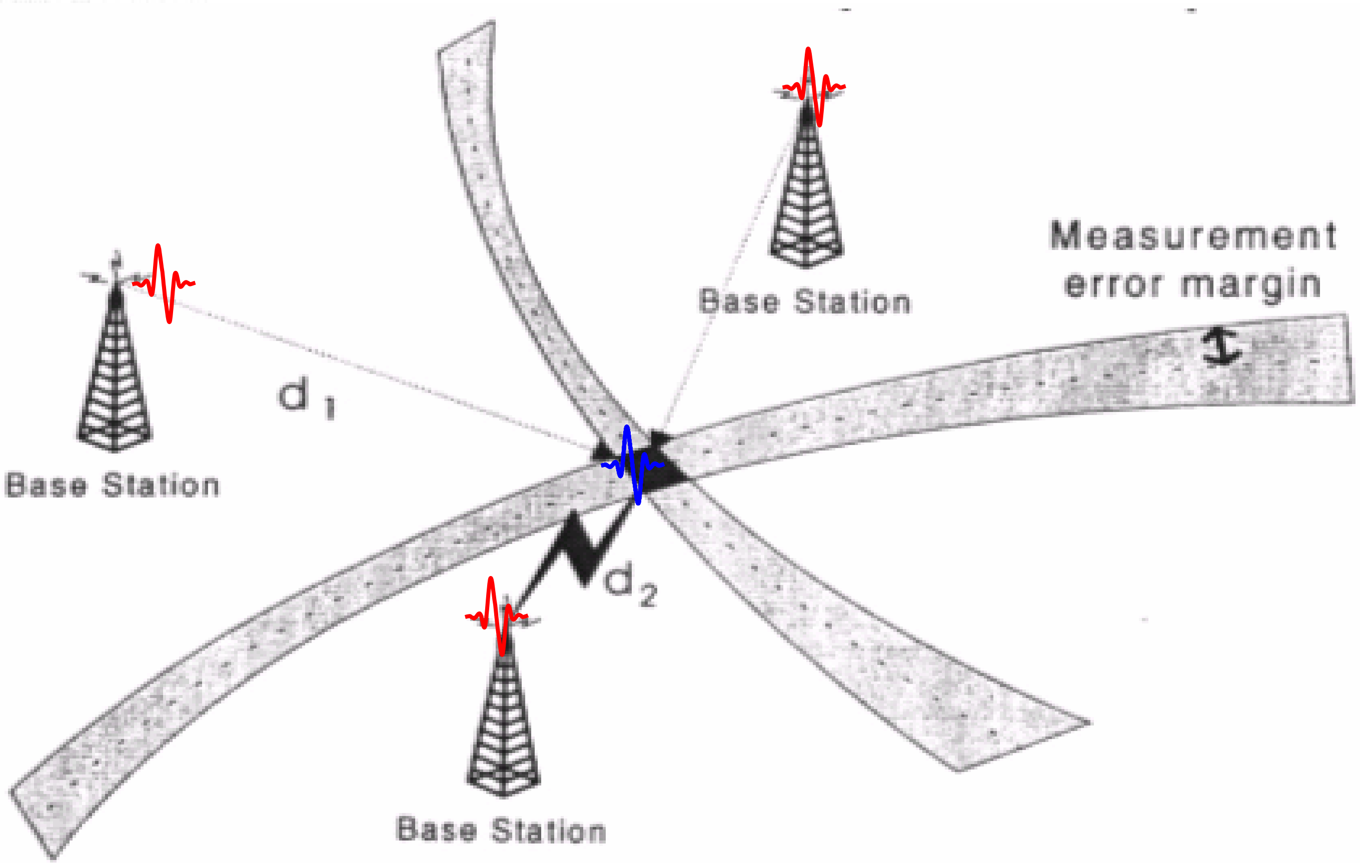
- The transmission of low power impulses makes harder the signal detection process (low power due to regulation)
  - ✓ Low duty cicle signals
  - ✓ Complex receiver architectures
- Is required to know the global position of at leats 4 devices to establish the absolute position of the full UWB network

Localization Technique

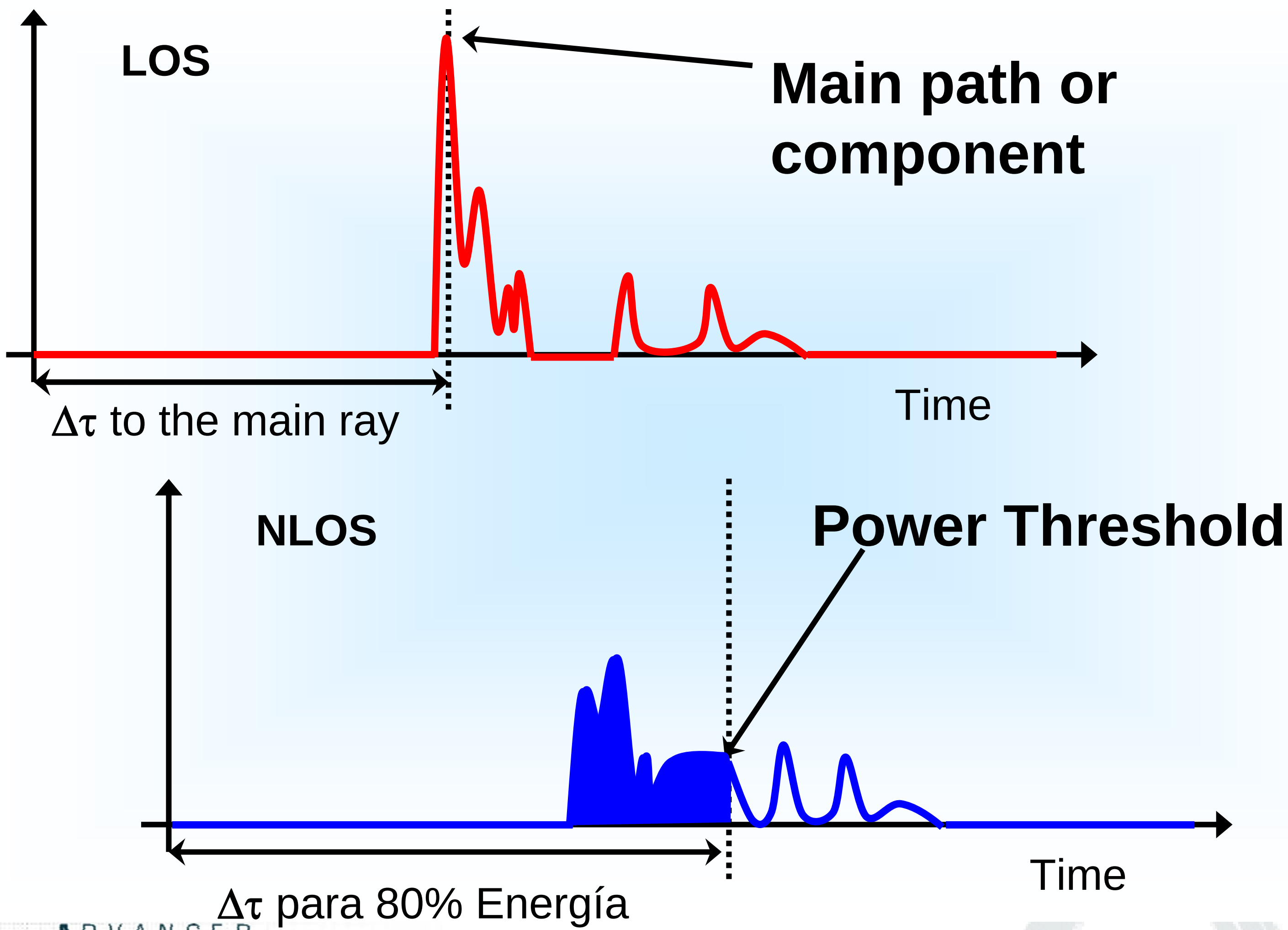
Triangulation:

- N references are required to achieve the N-a order relative position
- Is required to have the absolute postion of 4 references to achieve the global position of one device
- Maximum likehood algorithm has been deployed to estimate the device position, making use of:
  - ✓ Arrival time of the main ray (LOS)
  - ✓ Energy/Power threshold
- The most precise methodology is based on the time estimation of the main ray on LOS cases

Triangulation

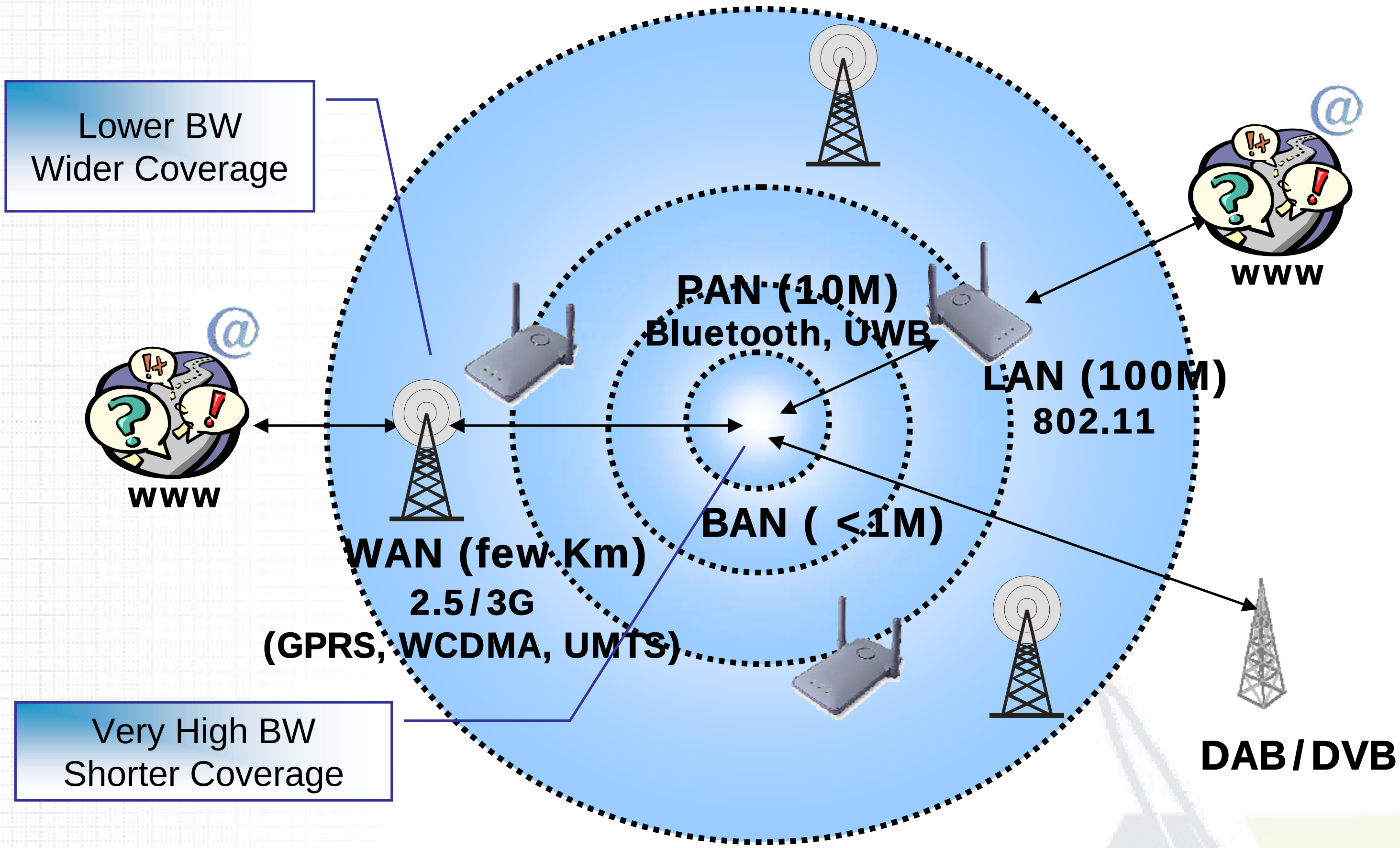


Triangulation (II)



Applications

UWB Application Scenarios



Concentric Spheres of Interconnected Wireless Networks

Source: Intel Research & Development

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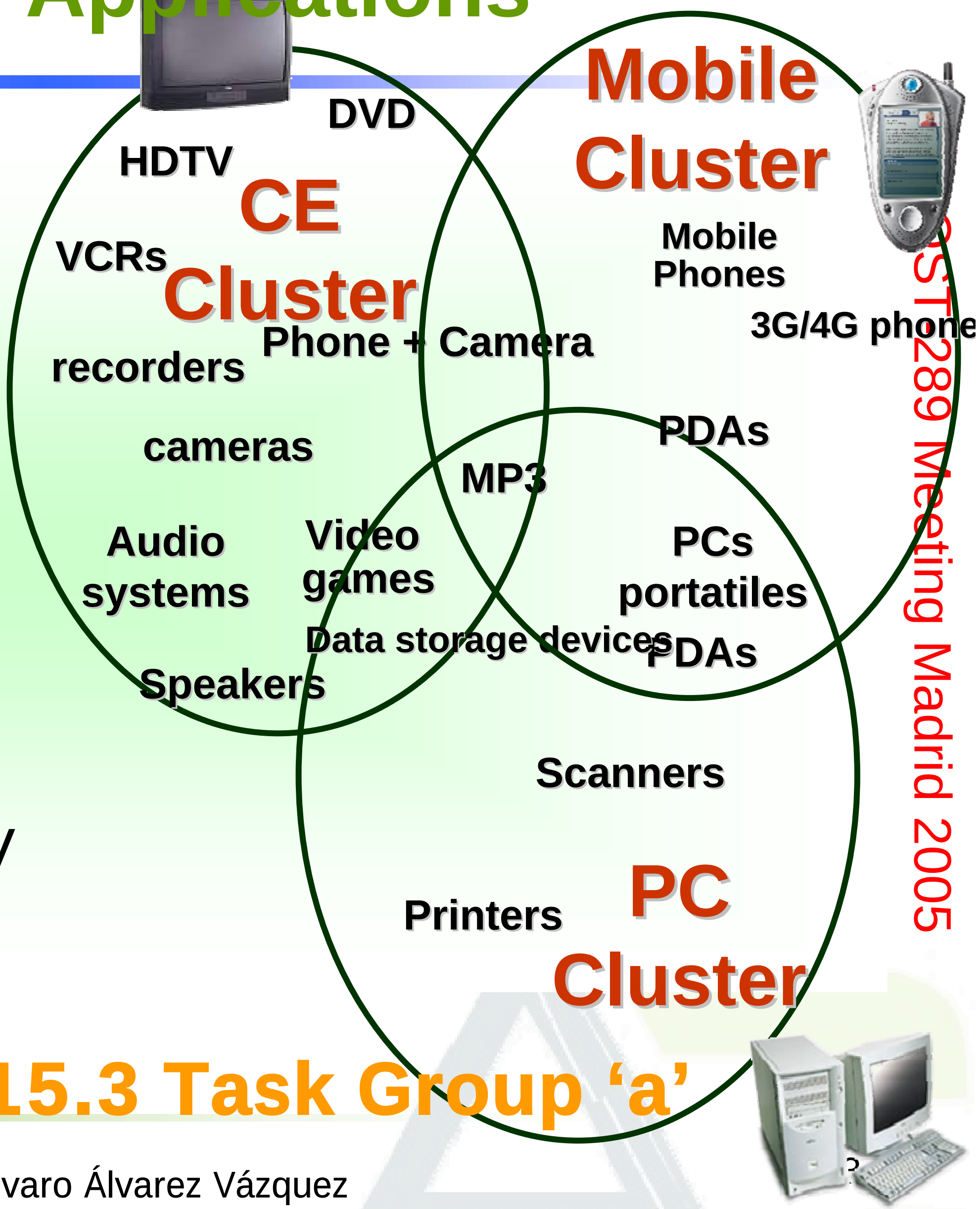
Other UWB Applications

Communications for:

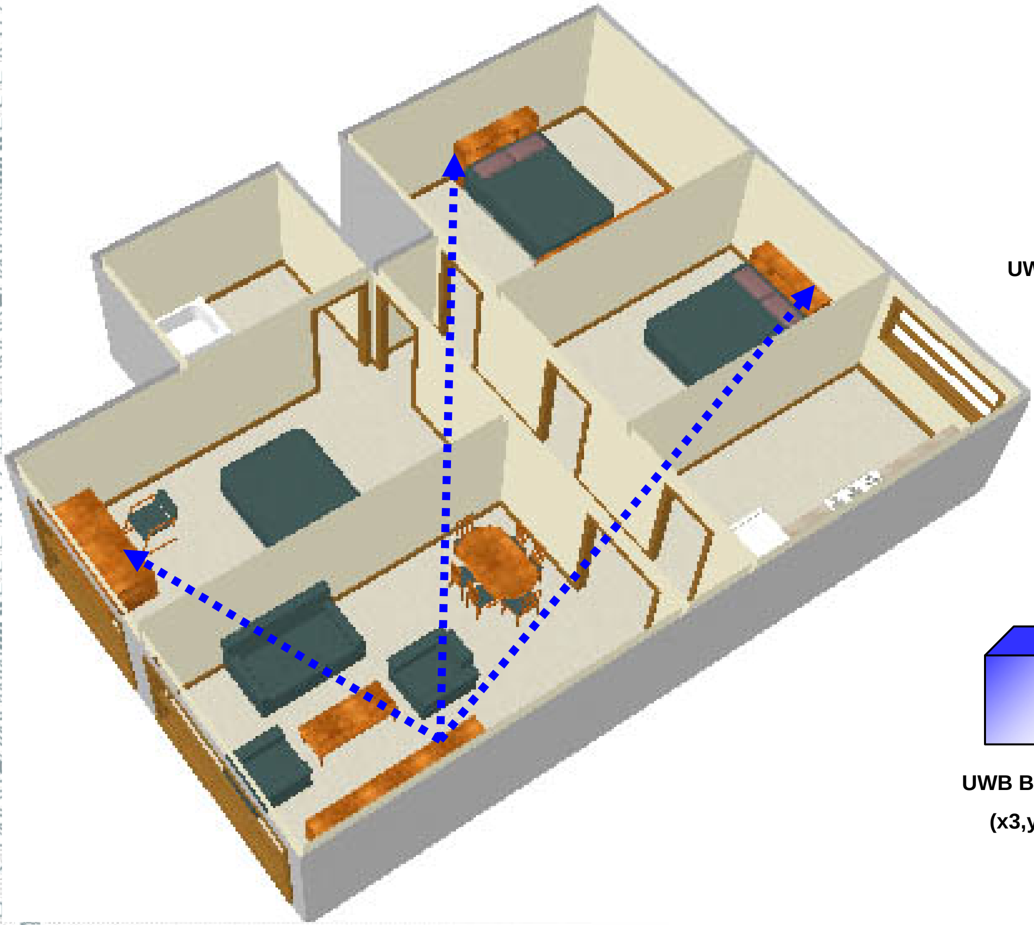
PCs and laptops
- Scanners and Printers
- Storage Devices
- Ad-hoc networking

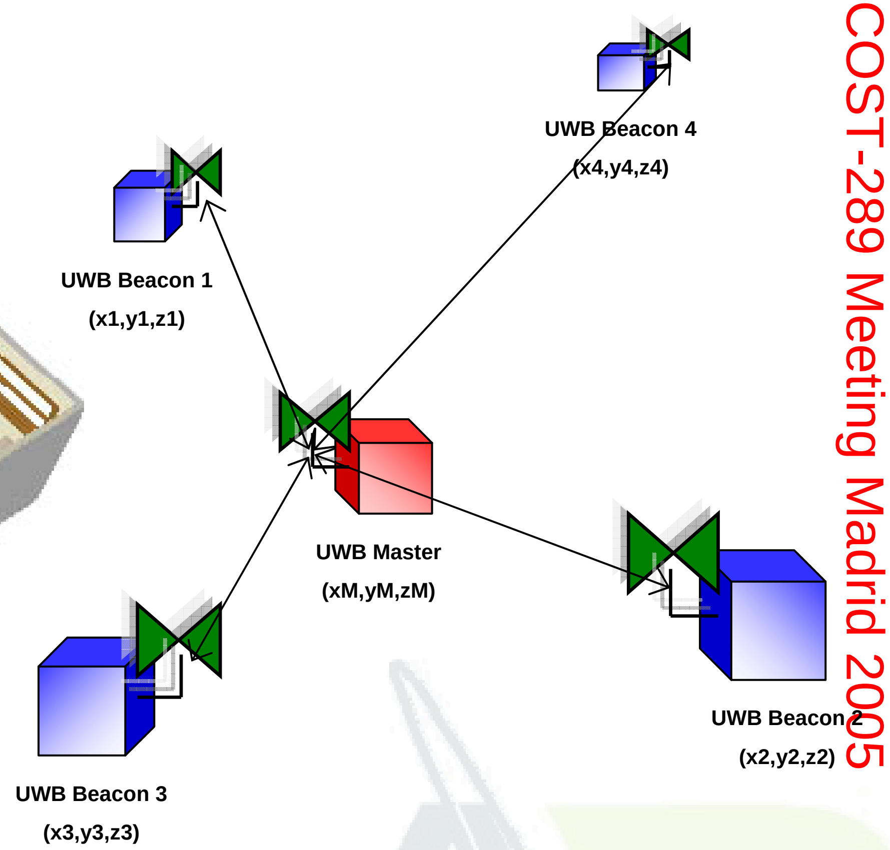
Mobiles
- Multimedia File transfer
- Personal Connectivity

Electronics
- Cameras, DVD, HDTV



UWB Home Applications - Localization





Trough Wall Imaging

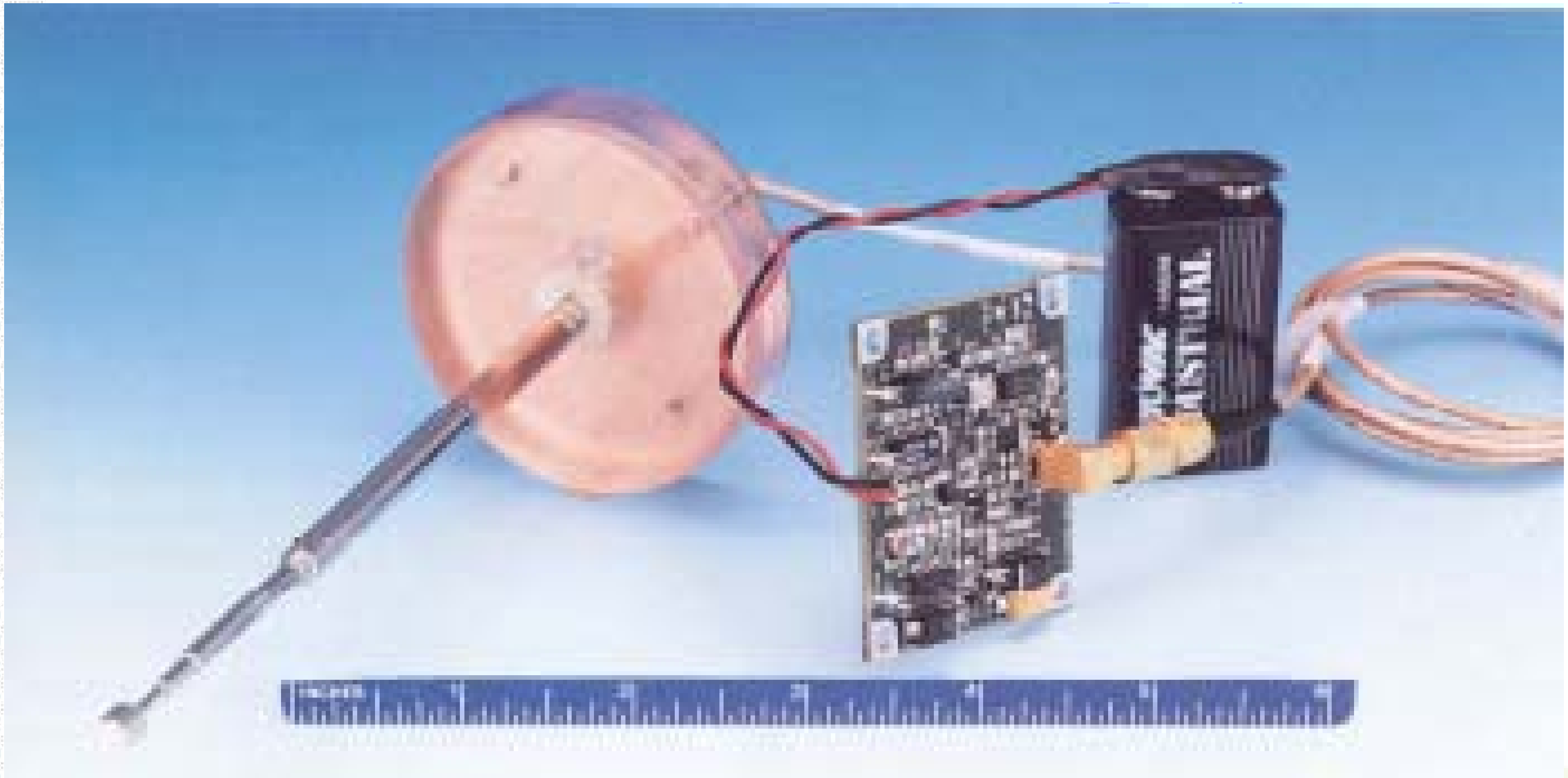
Micropower Impulse Radar

- Features
  - Single Board Impulse Radar
  - Connects to any antenna
  - 100ps wide impulse
  - 1-meter sweep range (or specify)
  - Range controlled receive gain
  - Low bandwidth output - will work with sound card for data acquisition
  - Single 5V supply
  - Low cost SiGe technology
  - Meets FCC UWB mask with proper antenna

Micropower Impulse Radar

- Applications
  - Imaging
  - Rangefinding
  - Tank Levels
  - Electromagnetics research
  - Biomedical research
  - Materials evaluation

Micropower Impulse Radar



TIME 200 pS/DIV

Transmit Pulse
(rev. c)

AMPLIFIER

Block diagram

Research Interests

Open Issues

- Mainly focused on the receiver design
  - Synchronization
  - Energy detection / Correlation
  - Signal Post-Processing
  - Coherent vs. Non-coherent approach
- But also on system design
  - UWB Signals and Modulation options
  - Multi-user techniques

MANY THANKS FOR YOUR KINDLY ATTENTION

ANY QUESTION??