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Introduction to existing ultra wideband (UWB) technologies

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"The best way to predict the future is to invent it."

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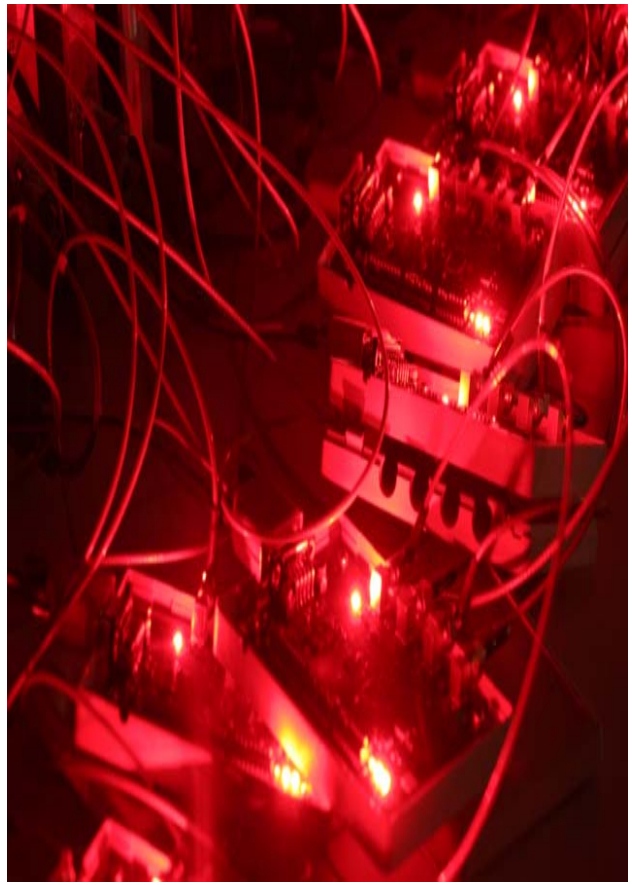
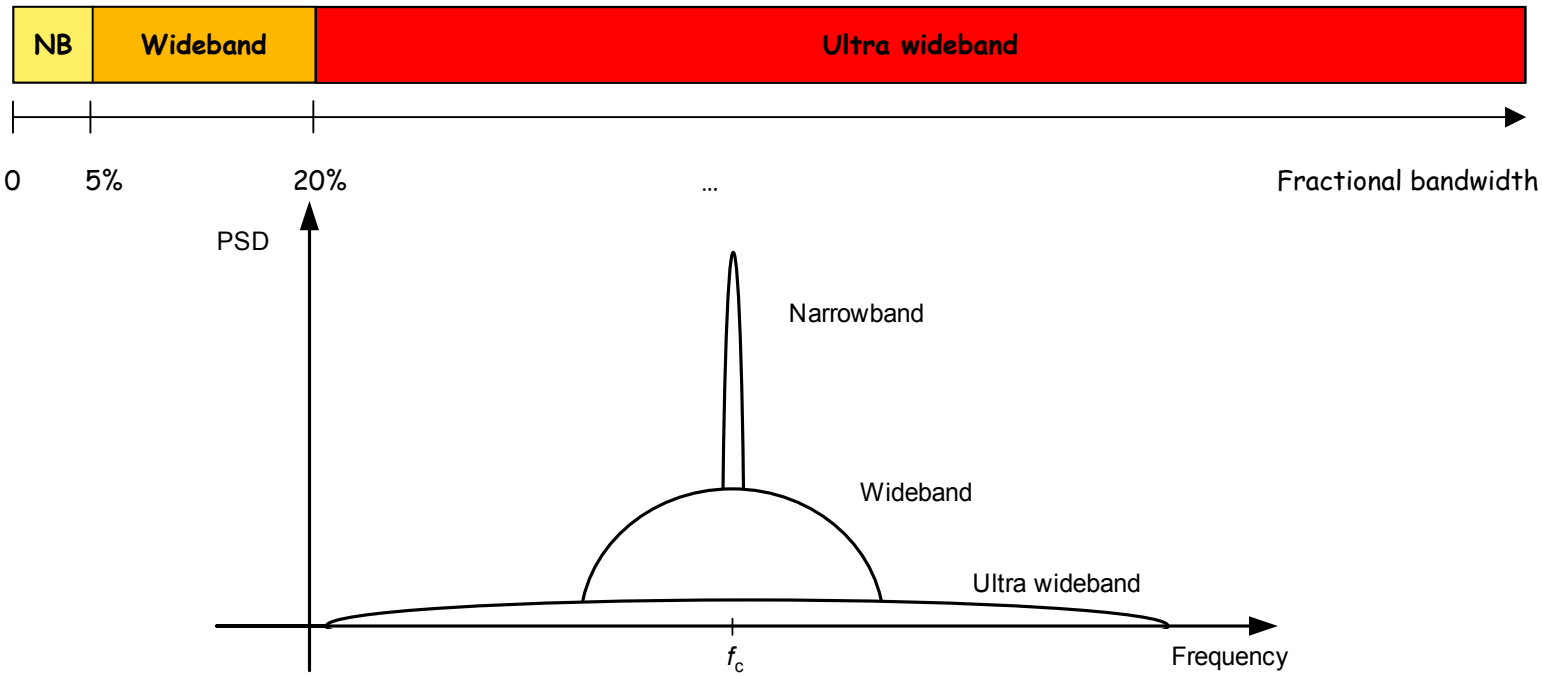


Control boards of UWB transmitters that CWC have

What is UWB?

- Signal is defined as an ultra wideband if
  - -10 dB fractional bandwidth $B_f > 20\%$ or
  - signal bandwidth $B > 500$ MHz
    - cf. $B_{GSM} = 200$ kHz, $B_{UMTS} = 3.8$ MHz, $B_{802.11a} = 16.6$ MHz, $B_{GPS} = 20$ MHz

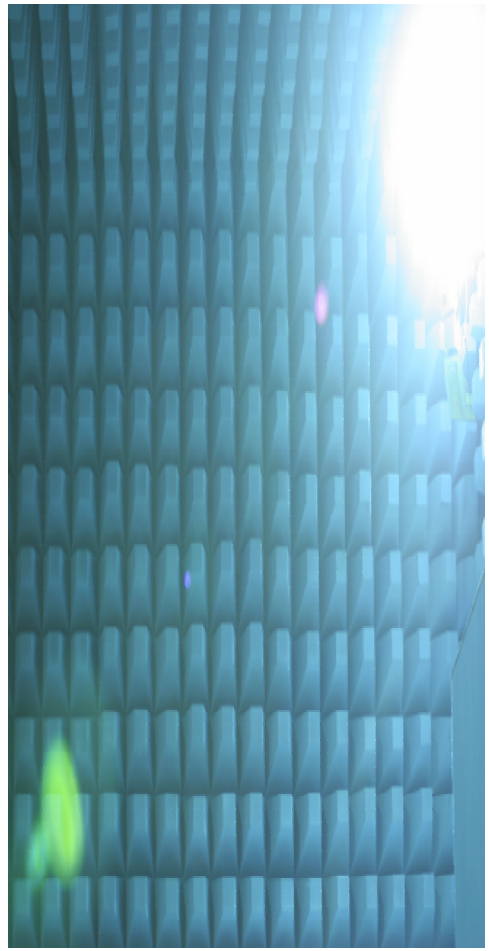
$$B_f = 2\frac{f_H - f_L}{f_H + f_L}$$



Regulation and standardization

Regulation and standardization

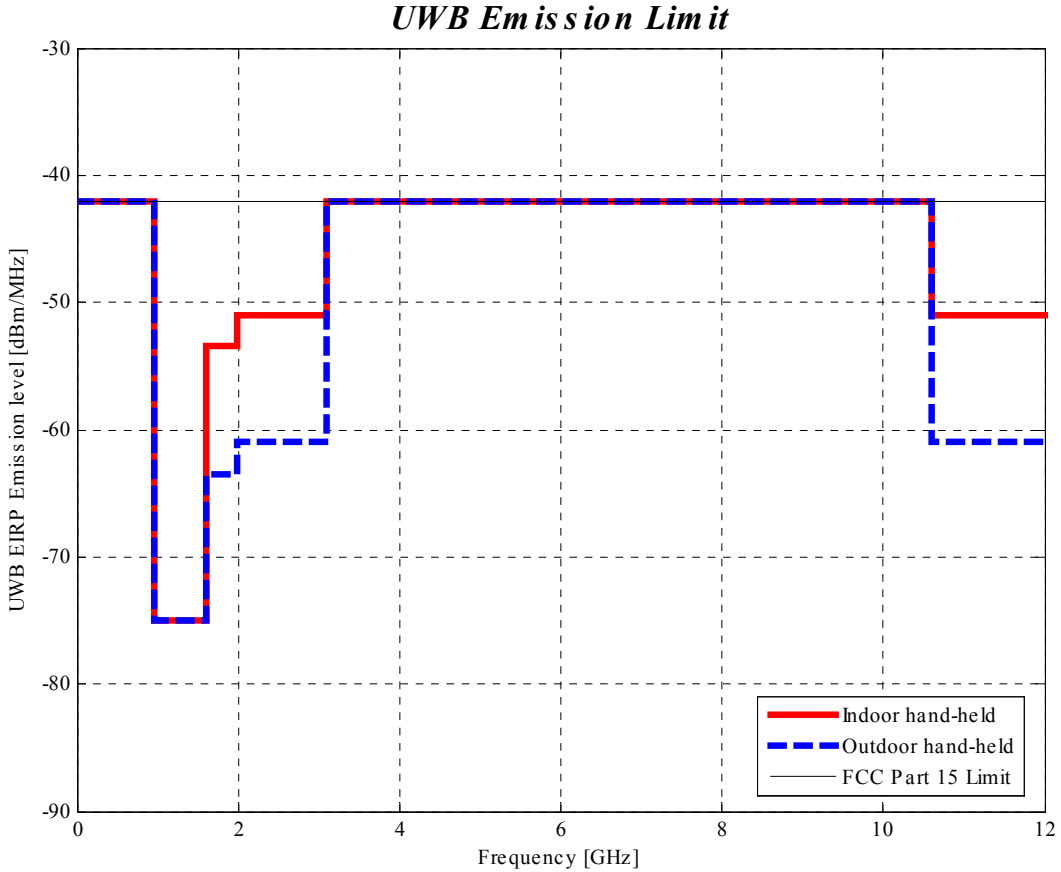
- Federal Communication Commission (FCC), USA
  - *Notice of Inquire*, 1998
  - *Notice of Proposed Rule Making*, 2000
  - ***The First Report and Order, 2002***
  - *Memorandum Opinion and Further Notice of Proposed Rule Making, 2003*
  - *The Second Report and Order and Second Memorandum Opinion and Order*, 2004



Anechoic chamber at Univ. of Oulu

Regulation and standardization

- Output of the FCC work
  - definition for UWB
  - radiation limits and spectrum masks
  - unlicensed use of UWB was accepted
  - use on board, in airplane, fixed outdoors devices and toys are forbidden



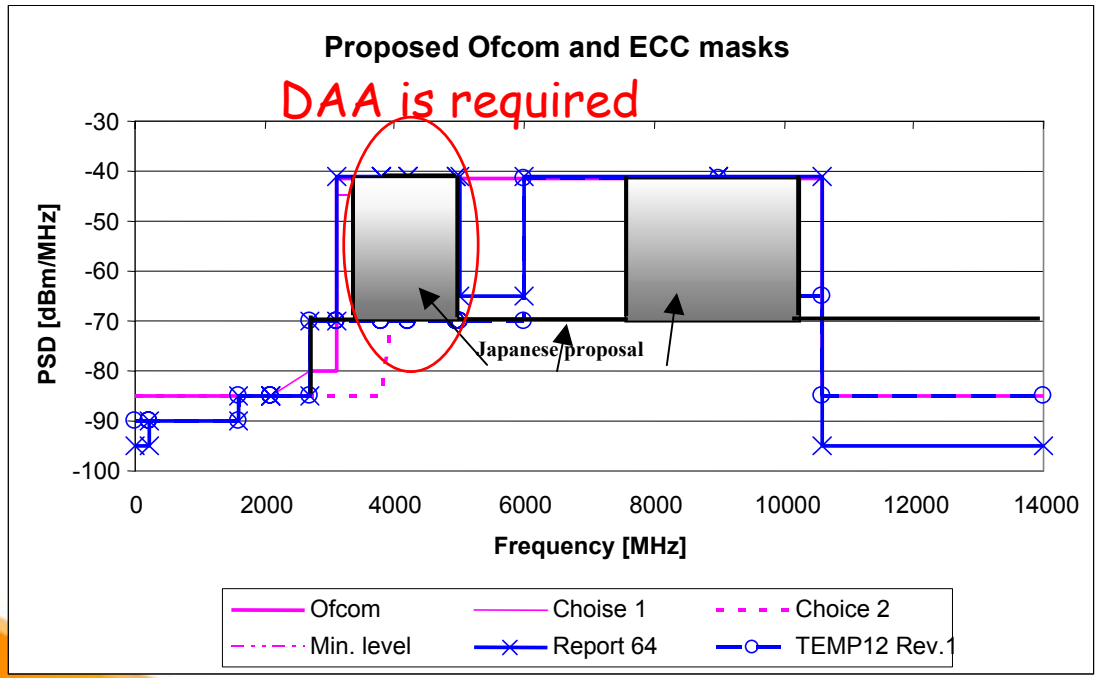
In addition

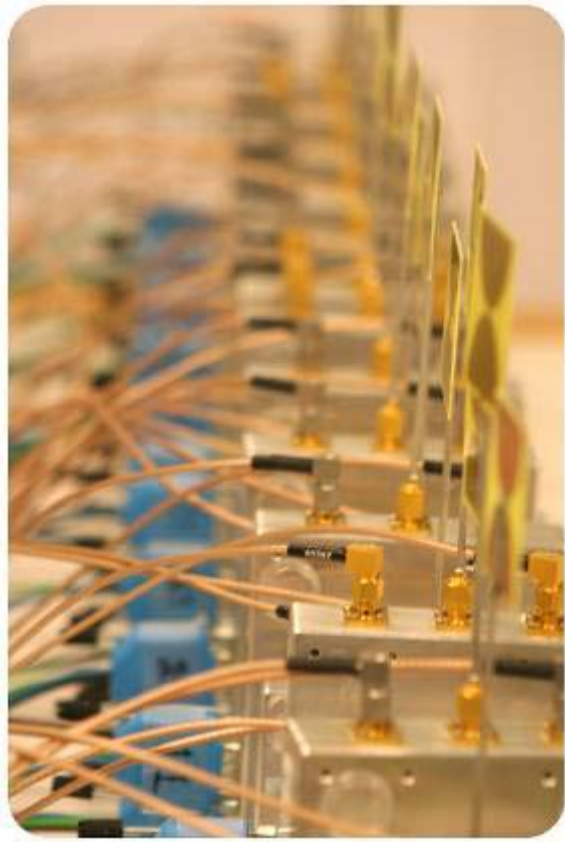
- through material radars, $f < 960$ MHz
- 22 – 29 GHz is reserved for vehicular radars

with the same upper radiation limit.

Regulation and standardization

- In Europe and Japan, the goal is to finalize UWB regulation process during March 2006
  - more stringent mask might be adopted with some interference mitigation mechanism
    - detection and avoid (DAA)
    - low duty cycle





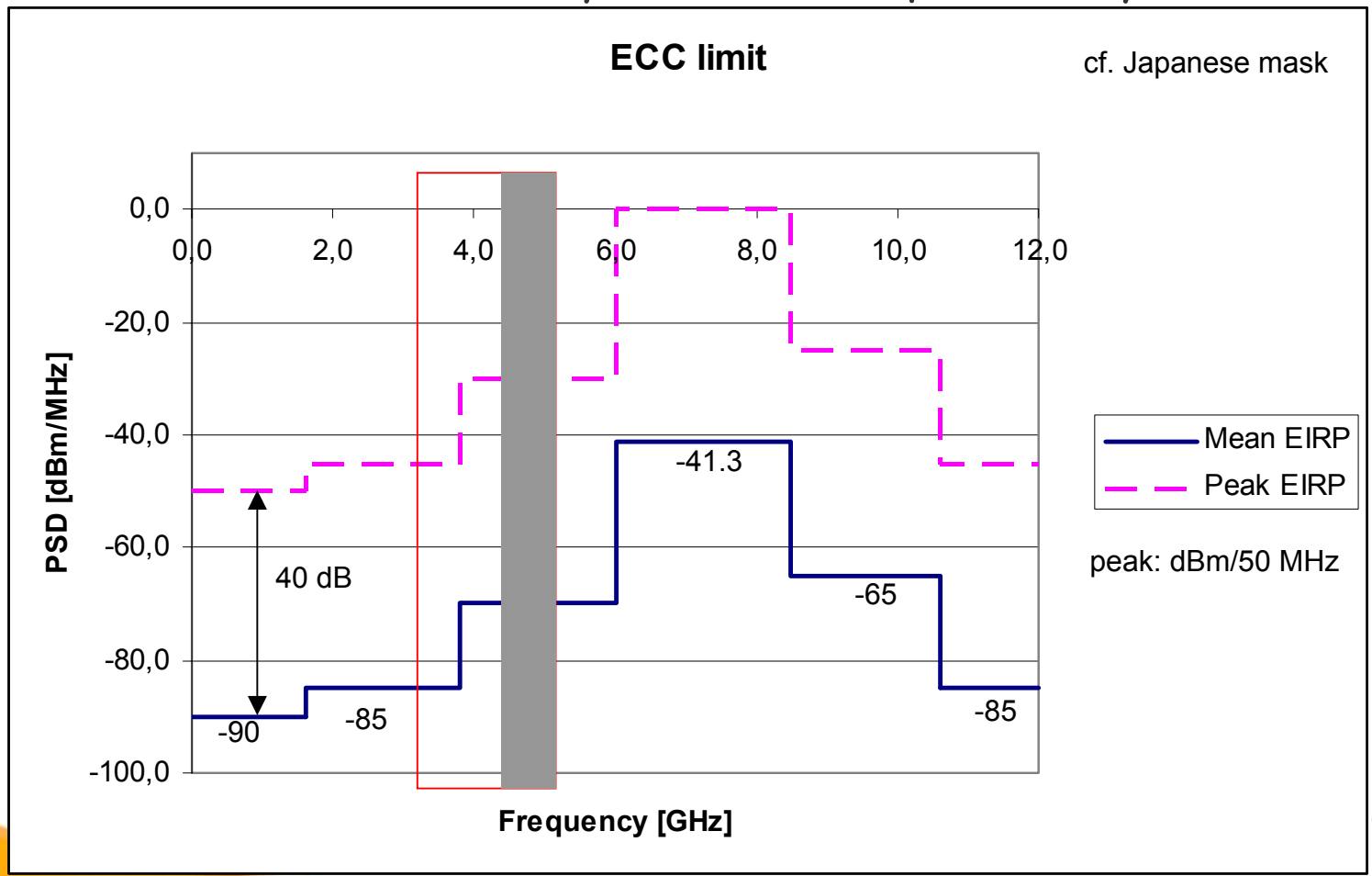
UWB transmitters by CWC

Regulation and standardization

- European Communications Committee (ECC) released a decision about the UWB regulation on 24th March, 2006
  - enters into force on 24 March 2006
  - implementation of the Decision, 1 October 2006
- ECC's decision is applicable to radio technologies having a bandwidth wider than 50 MHz
- It is intended for communications; measurements; location; imaging; surveillance and medical applications
  - primarily for indoor use
  - unlicensed use
- Within a frequency band of 6 – 8.5 GHz UWB transmission without any mitigation techniques is allowed using the maximum PSD of -41.3 dBm/MHz.

A detection and avoid, or a low duty cycle interference mitigation method are proposed for a frequency band of 3.1 – 4.8 GHz

- Since there is no interference mitigation requirement available for the frequency band of 3.1 – 4.8 GHz, the proposal considers allowing the use of band between **4.2 – 4.8 GHz** without any mitigation technique until 2010/2012
- Comments before 29 May 2006 are requested by the ECC



Regulation and *standardization*

- At the end of 2001, IEEE launched a working group **IEEE802.15.3a** to define a new physical layer technology for *high data rate* short range applications
  - range: ~10's of meters
  - based on UWB technology
  - two proposals remain in the final vote
    - DS-UWB
      - Belkin, Freescale, Motorola, Pulse-LINK, Time Domain, etc.
    - Multiband-OFDM
      - Alereon, Intel, Nokia, Philips, Sony, Staccato Communications, Texas Instruments, STMicroelectronics, etc.
  - IEEE802.15.3a was not able to make a decision and no standard proposal was made (it requires 75% of the votes)
  - WiMedia has been selected as a common radio platform for wireless Bluetooth
- As the industry organizations dedicated to productization in both camps, the work of IEEE802.15.3a was withdrawn on Jan 2006 without any standard
  - markets will select the winning technology!

- IEEE802.15.4a: WPAN **Low Rate** Alternative PHY
  - The principle interests are
    - providing communications and high precision ranging & location capability (1 meter accuracy and better)
    - high aggregate throughput and ultra low power
    - adding scalability to data rates, longer range, and lower power consumption and cost
  - started on 2002 and the work is currently ongoing

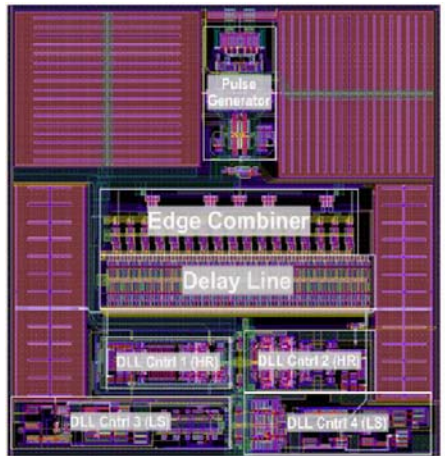
- Both UWB related 802.15 study groups defined channel models for UWB research

- Ecma International supports multiband-OFDM approach in its own standard proposal (ECMA-368 standard)
  - at the moment, it is valid only in the USA

Competing technologies

- Typically, conventional radio systems are (super)heterodyne systems, in which baseband signal is sent using higher frequencies

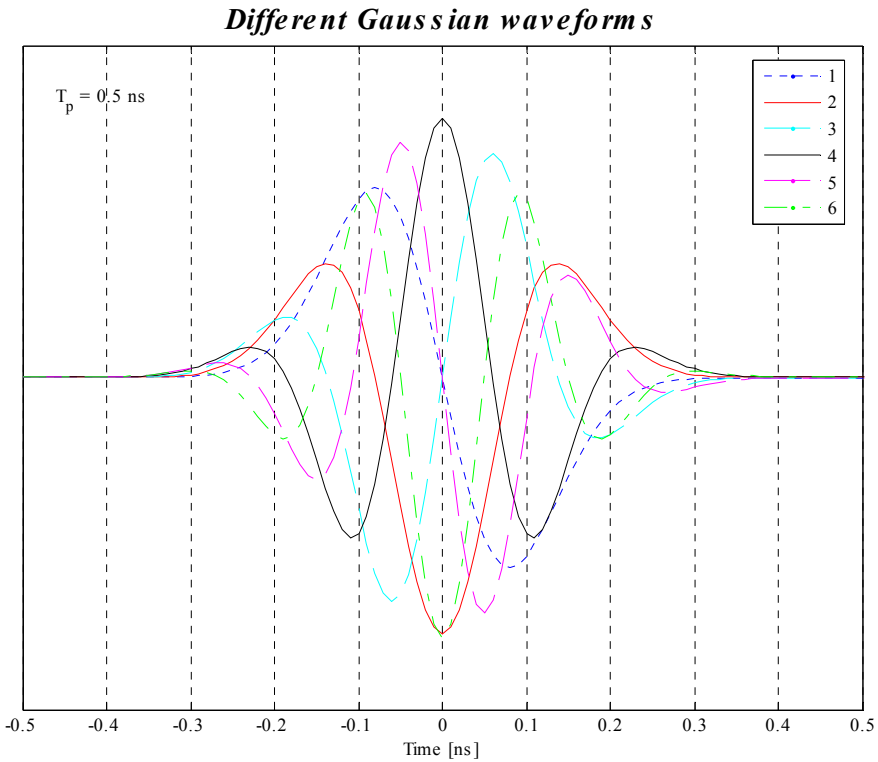
- Singleband UWB
  - "*Impulse radio*"
  - Baseband signal
  - Low average transmitted power
  - Low peak-to-average power ratio (3 dB)
  - Low or medium data rates
    - **Time-hopping UWB (TH-UWB)**
      - short pulses
      - user separation with TDMA
      - discontinuous transmission
        - » low duty cycle (ON/OFF ratio)
    - **Direct sequence UWB (DS-UWB)**
      - short pulses
      - high duty cycle
      - radar type approach
      - user separation with CDMA

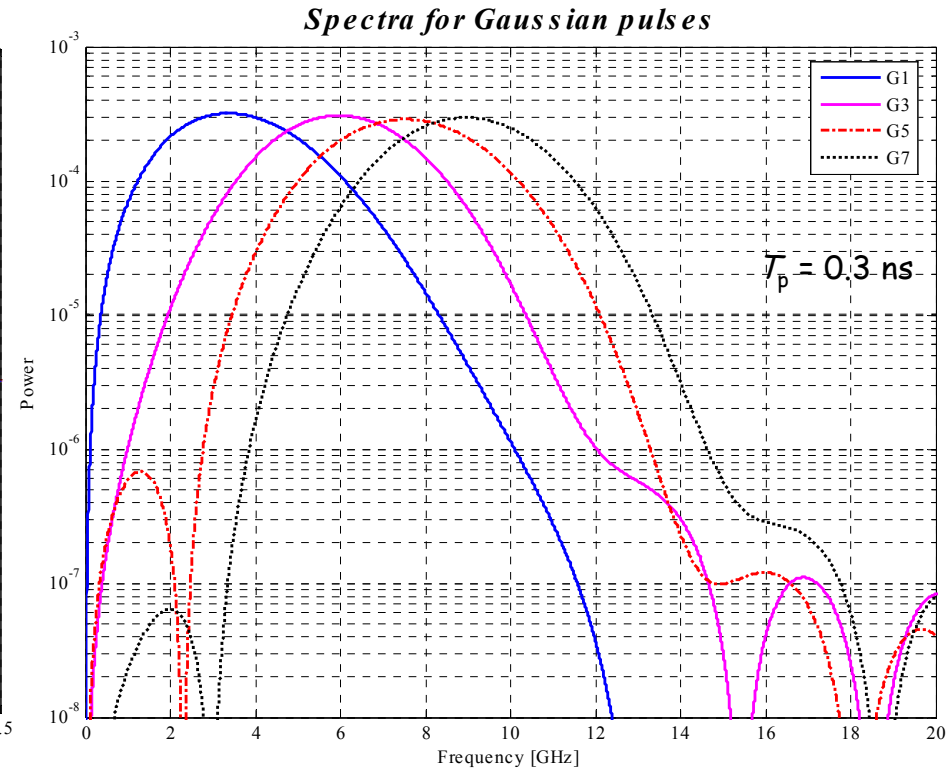


Singleband UWB transmitter chip designed in CWC (0.35 μm CMOS, area 0.5 mm^2).

Competing technologies: singleband

- Pulse waveforms are typically based on
  - Gaussian pulse set or Hermitean pulse set





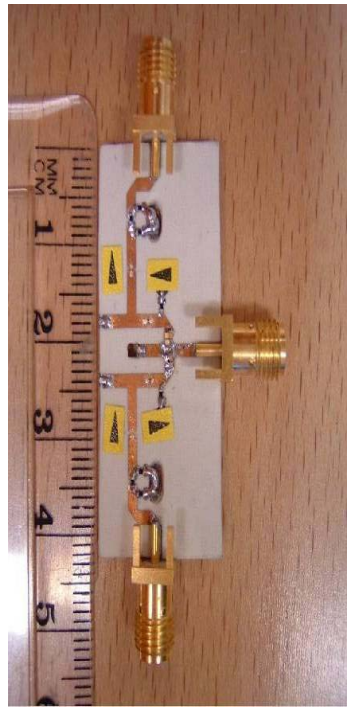
  - pulse shape and pulse width defines the occupied frequency band

Competing technologies: singleband

- Modulation methods:
  - pulse position
  - pulse amplitude
  - pulse shape
  - on-off keying
  - bit position
- *M*-ary modulation is possible
- Perfect for low data rate applications having accurate positioning requirements.
- IEEE802.15.3a standard proposal supports data rates 28, 55, 110, 220, 500, 660 and 1320 Mbps
  - DS-UWB
- A choice for IEEE802.15.4a standard (low data rate with accurate positioning)
  - R_d ~10's to 100's of kHz

Competing technologies: multiband

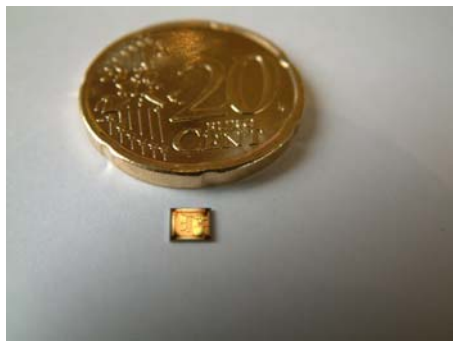
- Multiband UWB
  - Carrier signal
  - High data rate
    - Multiband-OFDM
      - WLAN type approach
      - OFDM, like used in IEEE802.11a, WiMax (IEEE802.16a) and DVB
      - continuous transmission using 128 sub-carriers per band
        - » B = 528 MHz
  - to be used in wireless USB
    - providing 480 Mbps
  - a common radio platform for high speed Bluetooth



UWB pulse generator by CWC

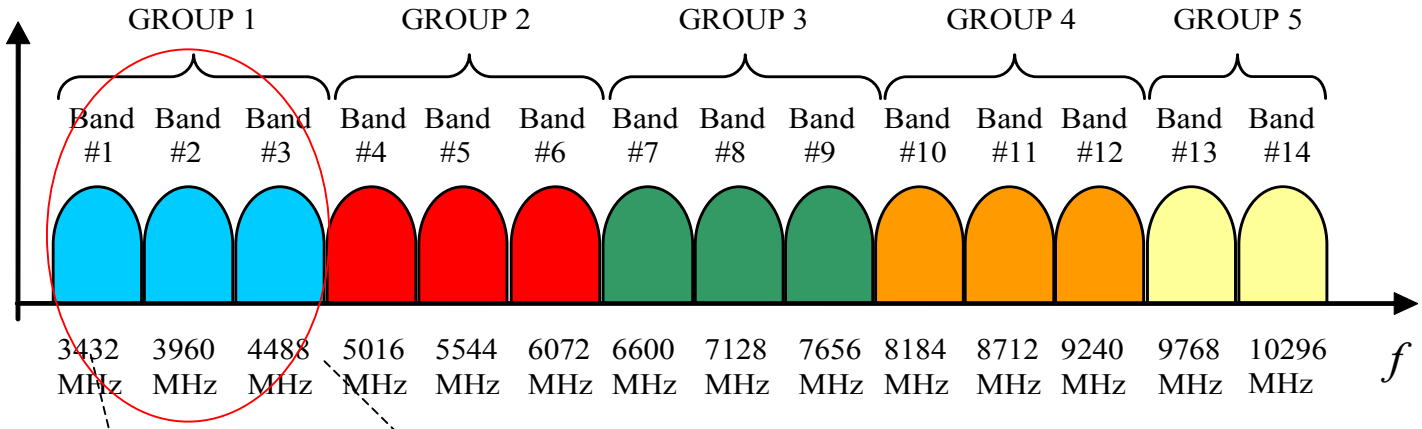
Competing technologies: multiband

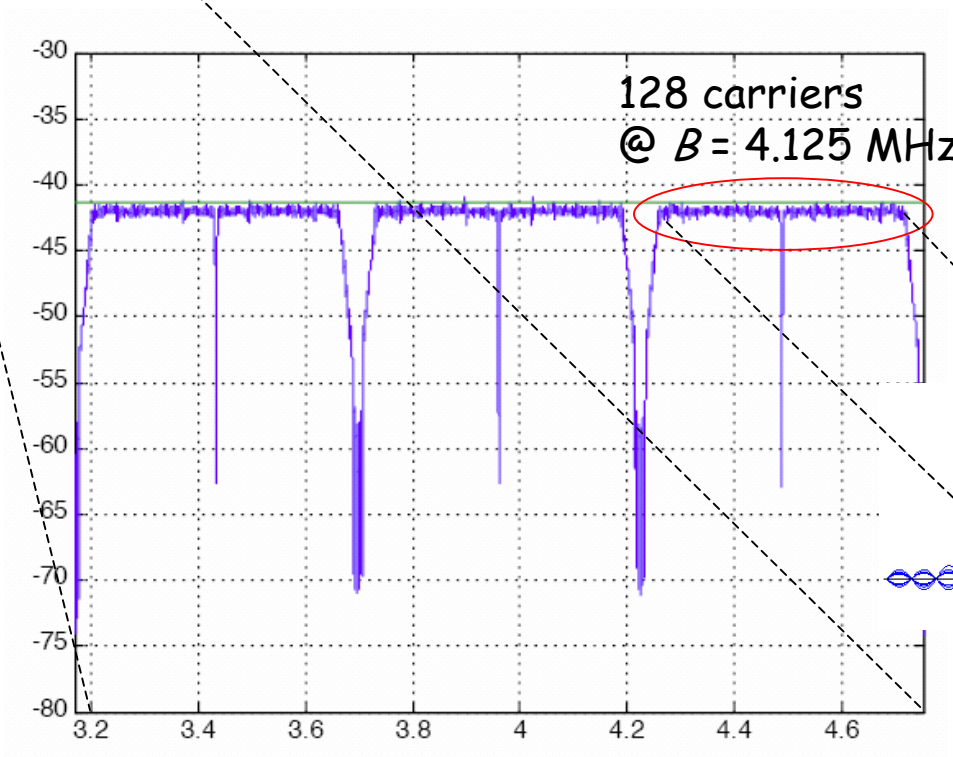
- Multicarrier modulation results in straight forward scheme to manipulate signal spectra
- High data rate applications
- Positioning accuracy is poorer than in singleband approach due to it's narrower bandwidth
- 14 overlapping OFDM channels, each having B = 528 MHz
- Industrial standard (Ecma) supports data rates 53.3, 80, 106.7, 160, 200, 320, 400 and 480 Mb/s
- Ultimate goal is set to R_d > 1 GHz



Noncoherent singleband UWB transceiver chip designed by CWC

Competing technologies: multiband

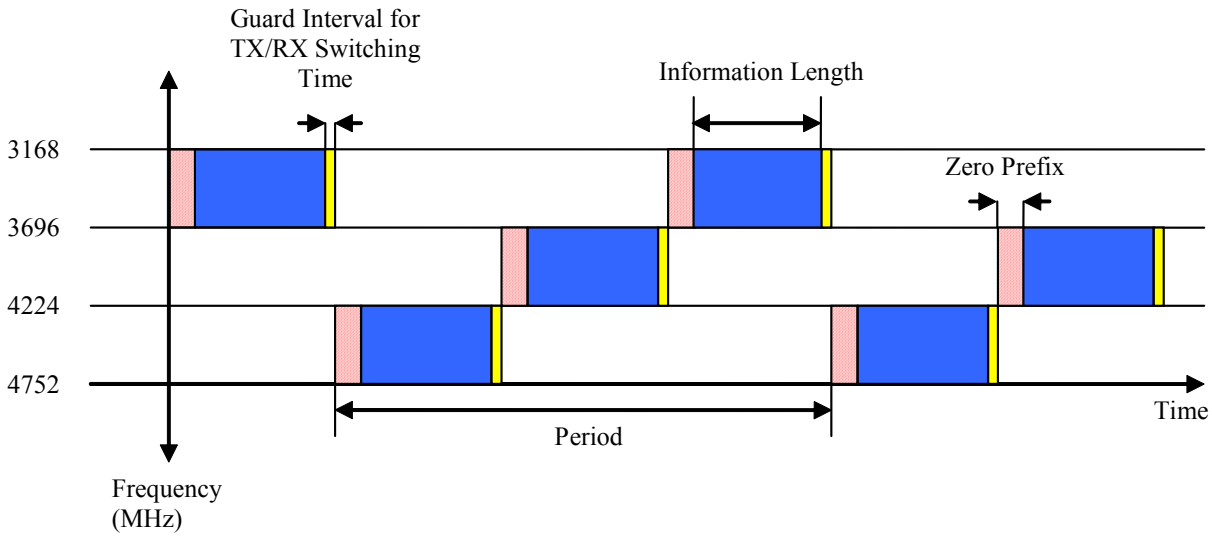




Group 1 is mandatory for all MB-OFDM systems

Depending on the spectrum regulations, some subcarriers can be suppressed

- FFI: Fixed frequency interleaving
- TFI: Time frequency interleaving



- Modulation
  - QPSK: quaternary phase shift keying
    - antipodal
    - group of 2 bits
  - DCM: dual carrier modulation
    - orthogonal
    - group of 4 bits mapped to two different 16-point constellation separated by 50 tones

Competing technologies: minority alternatives

Other possibilities

- Chirp modulation
  - using fast frequency chirps
  - used in (through material) radars
- UWB-FM
  - low and medium data rates
  - low modulation index FSK followed by high modulation index FM
  - user separation with different sub-carrier frequencies, i.e., FDMA
- Transmitted reference
  - two pulses: one for channel estimation and the other for modulated data
  - equivalent performance can be achieved with noncoherent bit position modulation

UWB Applications

Communications

- Wireless-USB
- High speed Bluetooth
- WLANs
- Short range communication links
- *Ad hoc* networks
- Data & voice & control links

Radar

- Ground penetrating radars
- Through-wall radars
- Imaging and ranging
- Buried victim rescue
- Landmine detection

Intelligent Sensors

- Collision avoidance, proximity and altitude sensors
- Telemetry
- Motion detection
- RF tags
- Fluid level monitoring
- Reverse driving and parking aids
- Intelligent Airbags
- Intelligent Transport System

Others

- Geolocation
- Wireless door openers
- Medical applications

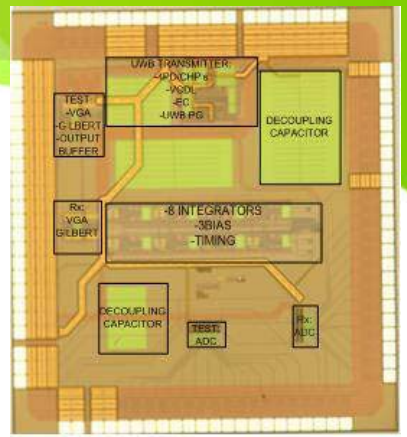
- For high data rates: IEEE802.15.3a
  - high speed wireless personal area networks
  - based on two proposals: DS-UWB and MB-OFDM-UWB
  - no agreement which one will be selected => the work of 15.3a SG was stopped on Jan 2006 => market will decide the surviving technology

=> Only a global standard would result in great success

- For low data rates: IEEE802.15.4a
  - communications and high precision ranging/location
  - standardization process is ongoing

=> Also proprietary solutions are needed

Positioning



Noncoherent TX/RX chip
area 9 mm^2

- Carrier-less transmission
  - inexpensive CMOS technology can be used
  - low data rate
- UWB localizers are suitable for indoor environment where GPS cannot be used
- Large bandwidth of UWB signal -> high resolution
- Relative distances between localizers are defined by measuring propagation times of the pulse sequences (ToA)
- *Ad hoc* network structure will improve the accuracy
  - more calculation points

Summary

- UWB is coming but the use is allowed only in the USA at the moment
  - B_f > 20% or B > 500 MHz
  - radiation masks for different applications
- Regulatory decisions in Europe and Japan are expected soon
  - an European proposal has been released
    - tighter than the FCC's radiation mask
- Different technologies to generate UWB signal are available
- Technology is suitable for different kinds of applications
  - low and high data rates
  - accurate positioning