Lecture 10

- Project
- Exam
- Spread spectrum techniques

Project

- Study one existing or proposed link
  - If choosing a standard, also choose an application example.
- Write a description of it, including
  - Technical details on speed, modulation, equalisation, antennas etc.
  - Link budget, both numerical and graphical
    - » Use well motivated assumptions where no data can be found.
  - 2-4 pages.
- Deadline:
- Format: pdf
- Email: ajn@eit.lth.se, mark subject EITN75 report
- Reports will be run through Urkund.

Ideas

- Sattellite links, such as Sattelite TV, INMARSAT, GPS, Irridium,
- Space probes such as Mars probes, including rovers, New Horizons (Pluto), Pioneer, Voyager, Cassini etc.
- DAB-radio, Terrestial digital TV,
- Domestic system: *GSM, 4G, 5G*, Blutetooth, Bluetooth LE, WiFi, *LORA*, WiMax,
- Medical applications: MICS, Bluetoth LE
- *Submarine communication*

Exam

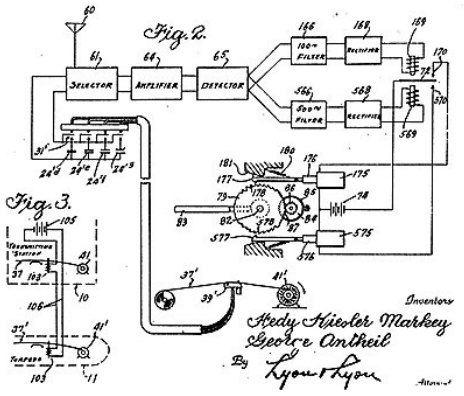
- First time the course is given
  - No old exams exists!
- Will provide typical questions.

Spread spectrum

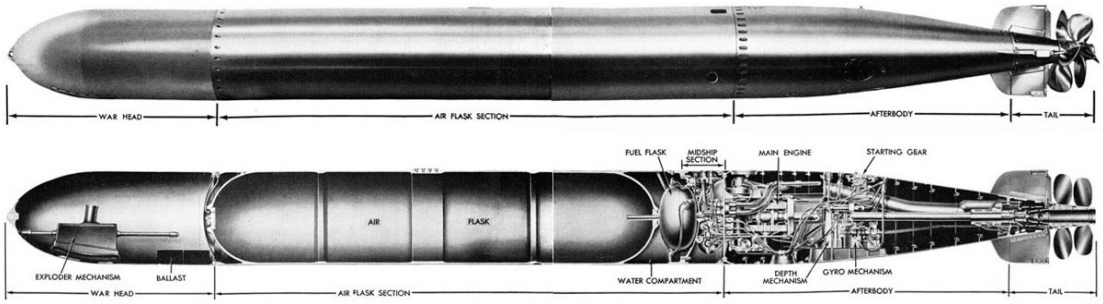
- Generic name of different methods of increasing the bandwidth of a transmitted signal.
  - Frequency hoppping
  - Direct sequence spread spectrum

Frequency Hopping spread spectrum

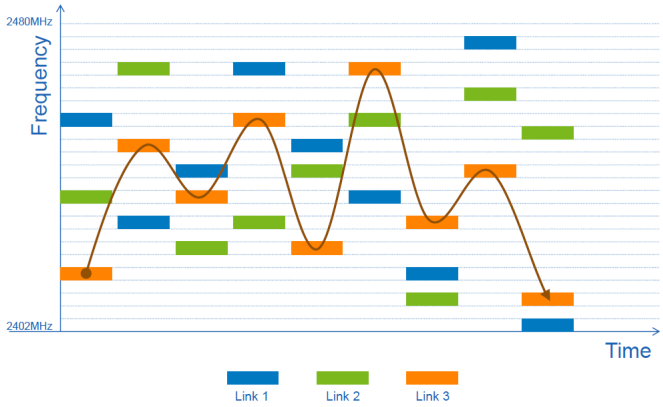
- Initially developed as an anti-jamming method
  - Hedy Lamarr, 1941
- Now used by many systems, such as Bluetooth.



Torpedo

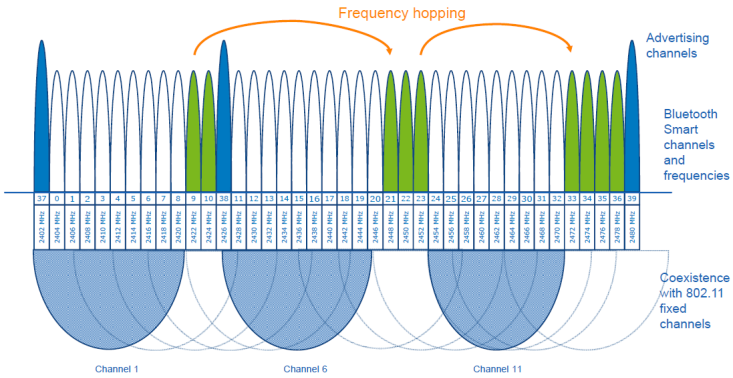


Bluetooth



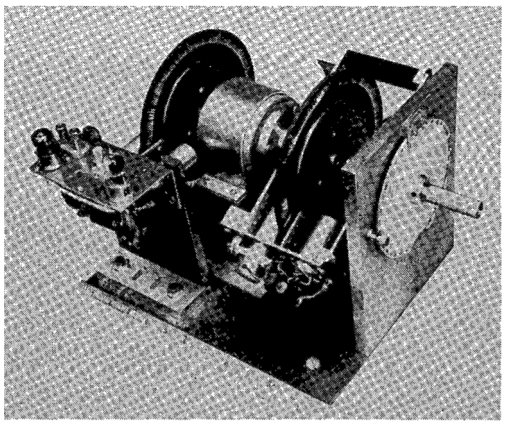
http://microchipdeveloper.com/wireless:ble-link-layer-channels

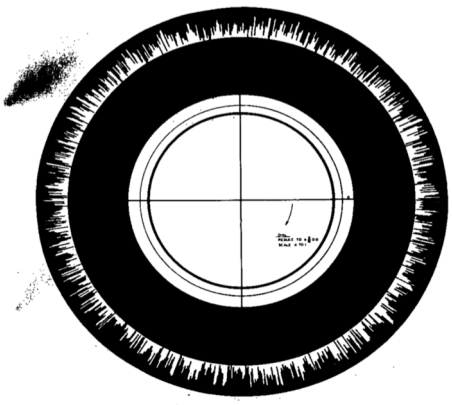
Adaptive frequency hopping



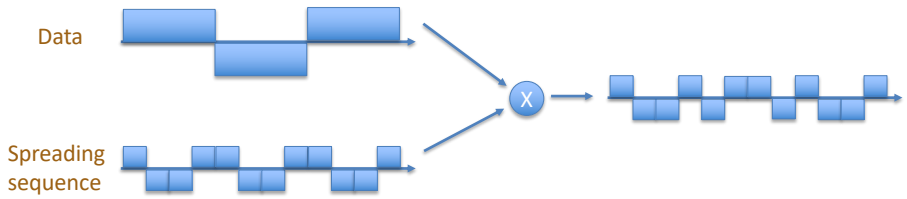
Direct sequence spread spectrum

- First experiments were analog



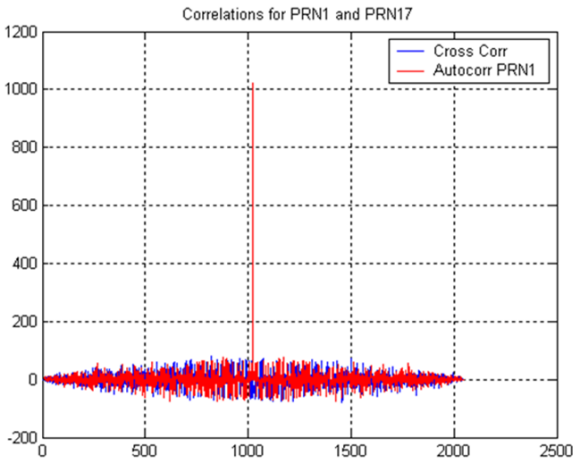


Direct sequence spread spectrum



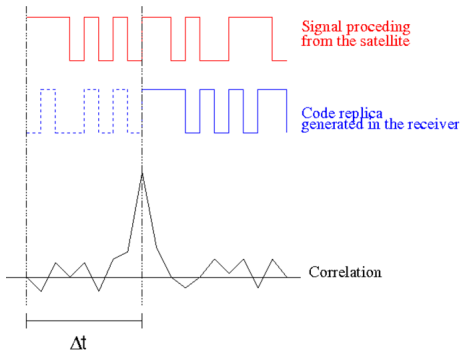
Correlation of sequencies

- Correlation of GPS sequencies
- Chip length = 1023

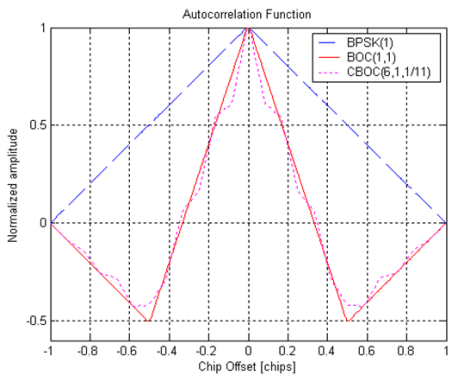


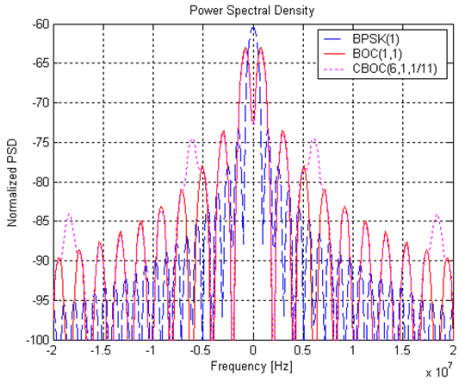
http://www.navipedia.net/index.php/Correlators

Sliding correlator



Influence of modulation





http://www.navipedia.net/index.php/Correlators

UWB

Defined as either

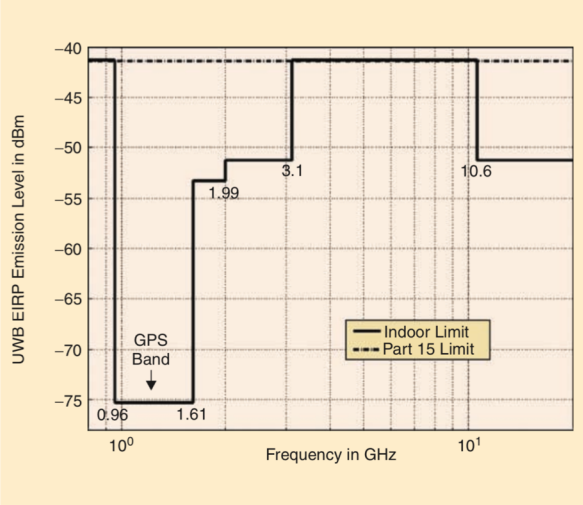
- A technology (Typically impulse radio)

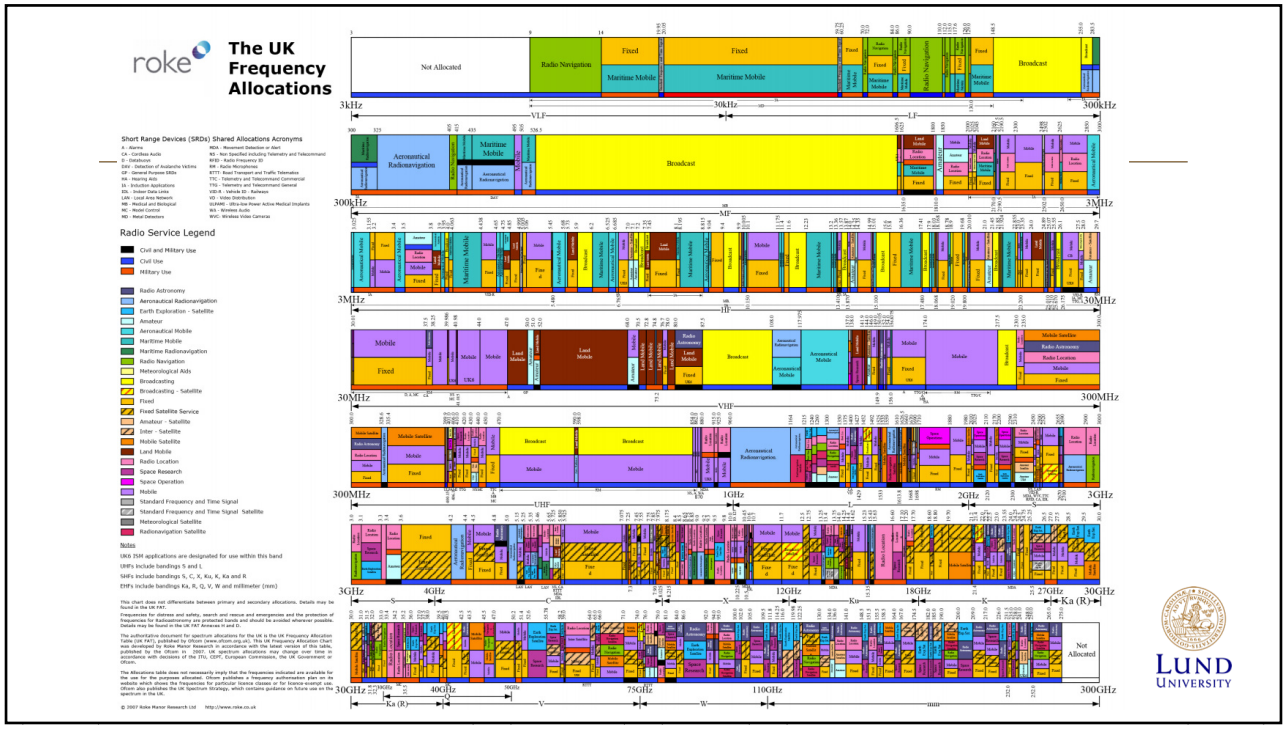
or

- A system that takes up a certain bandwidth, typically ”large”
  - >50 MHz
  - >500 MHz
  - >20% of centre frequency

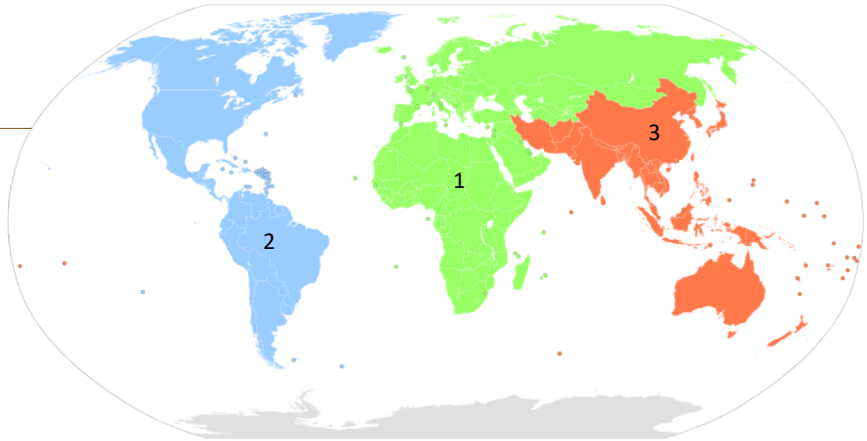
- Often used for the frequency allocation of 3.1 GHz to 10.6 GHz.

UWB Spectrum mask (old)





ITU Regions



- Region 1: Europe, Middle East, Africa, the former Soviet Union, including Siberia; and Mongolia;
- Region 2: North and South America and Pacific (East of the International Date Line);
- Region 3: Asia, Australia and the Pacific Rim (West of the International Date Line).

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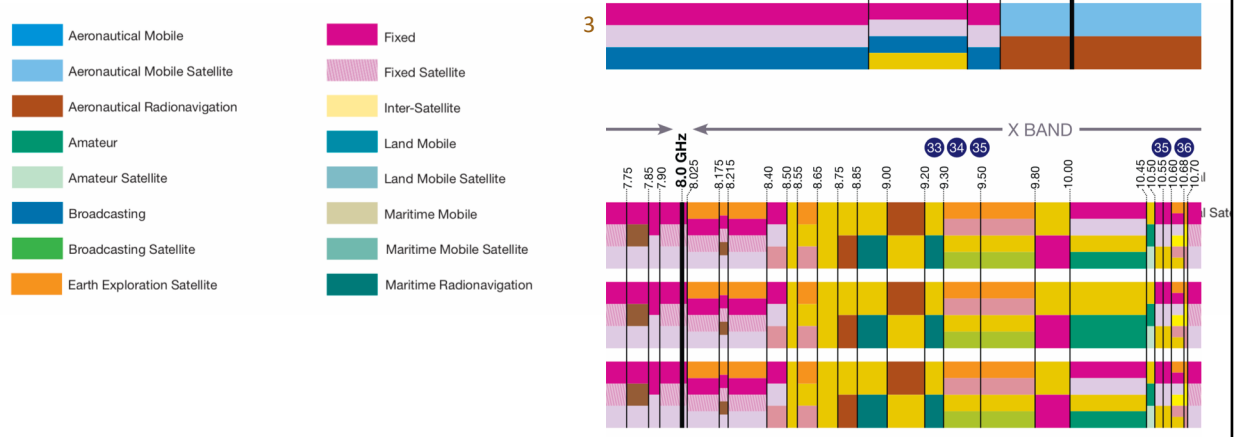
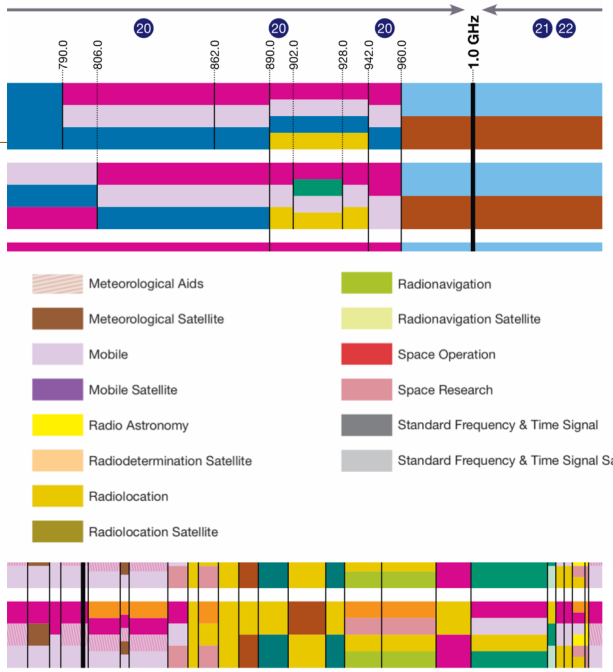
Global allocations



- Aeronautical Mobile
- Aeronautical Mobile Satellite
- Aeronautical Radionavigation
- Amateur
- Amateur Satellite
- Broadcasting
- Broadcasting Satellite
- Earth Exploration Satellite
- Fixed
- Fixed Satellite
- Inter-Satellite
- Land Mobile
- Land Mobile Satellite
- Maritime Mobile
- Maritime Mobile Satellite
- Maritime Radionavigation

https://info.tek.com/rs/tektronix/images/spectrum-allocations-posterLR.pdf

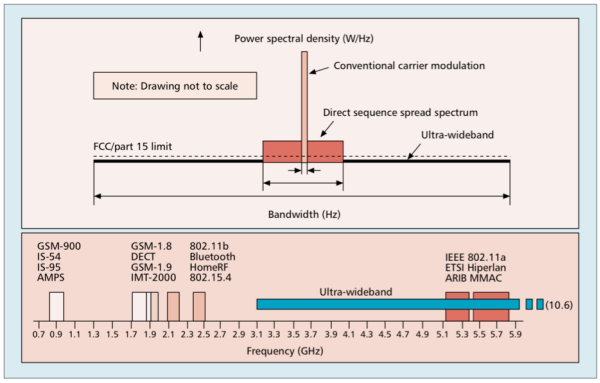
Global allocations



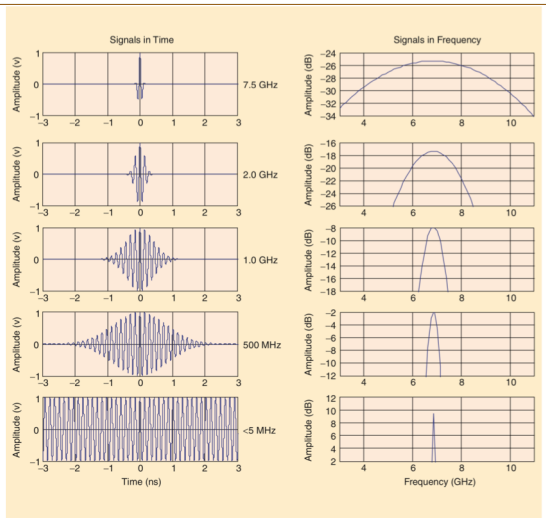
- Aeronautical Mobile
- Aeronautical Mobile Satellite
- Aeronautical Radionavigation
- Amateur
- Amateur Satellite
- Broadcasting
- Broadcasting Satellite
- Earth Exploration Satellite
- Fixed
- Fixed Satellite
- Inter-Satellite
- Land Mobile
- Land Mobile Satellite
- Maritime Mobile
- Maritime Mobile Satellite
- Maritime Radionavigation
- Meteorological Aids
- Meteorological Satellite
- Mobile
- Mobile Satellite
- Radio Astronomy
- Radiodetermination Satellite
- Radiolocation
- Radiolocation Satellite
- Radionavigation
- Radionavigation Satellite
- Space Operation
- Space Research
- Standard Frequency & Time Signal
- Standard Frequency & Time Signal Satel

https://info.tek.com/rs/tektronix/images/spectrum-allocations-posterLR.pdf

Spread-spectrum vs. UWB

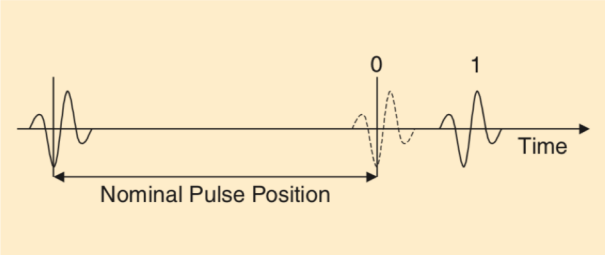


Signal bandwidth

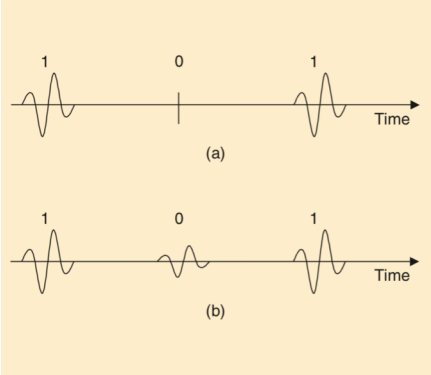


Ultra-Wideband Wireless Systems, Aiello and Rogerson, IEEE Microwave Magazine

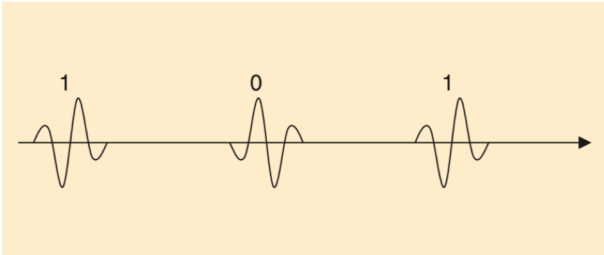
Pulse Position Modulation (PPM)



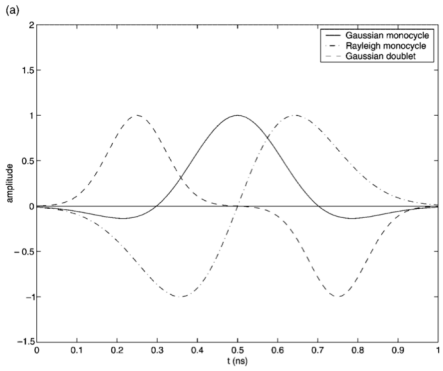
Pulse Amplitude Modulation (PAM)



Bi-phase Modulation



Different types of monocycles



Ultra-wideband wireless communications Weihua Zhuang, Xuemin (Sherman) Shen and Qi Bi

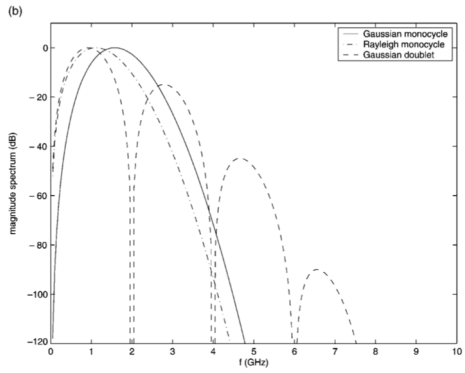


Table I. The 10-dB bandwidth and center frequency of the monocycles.

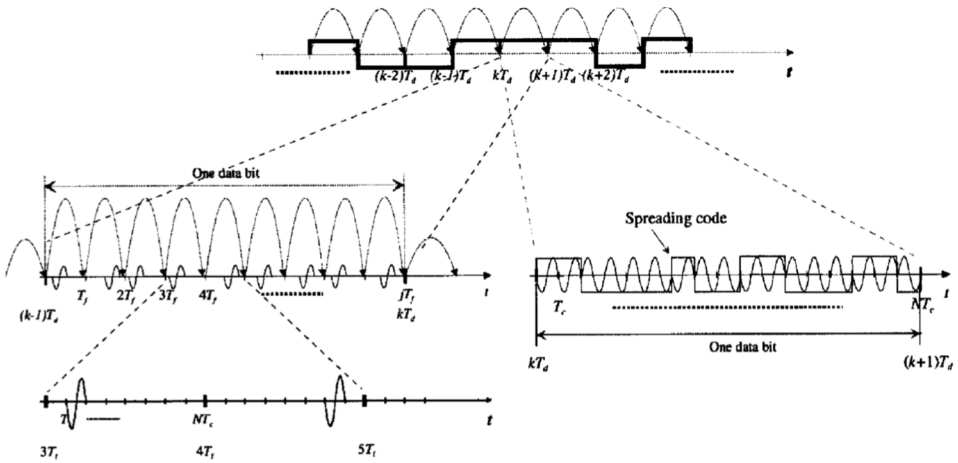
Monocycle	$B_{10\,\mathrm{dB}}$	f_c
Gaussian	$1.11/T_p$	$1.61/T_p$
Rayleigh	$1.11/T_p$	$1.16/T_p$
Gaussian doublet	$0.83/T_p$	$0.94/T_p$

Modulation examples

- Time-hopping Spread Spectrum (TH-SS) PPM
- $x(t) = \sqrt{E_p}\sum_{n=1}^{\infty}\sum_{j=0}^{N_s-1} p\left[\left(t - nT_d - jT_f - (c_t)T_c - \delta d_n\right)\right]$

- Time-hopping Spread Spectrum (TH-SS) PAM
- $x(t) = \sqrt{E_p}\sum_{n=1}^{\infty}\sum_{j=0}^{N_s-1} p\left(t - nT_d - jT_f - (c_t)_j T_c\right)d_n$

- T_d *the bit interval*
- T_f *the nominal pulse repetition interval*
- T_c *chip interval*
- d_n *is the data sequence.*
- *Details in W. Shuang et. Al.*



Time-hopping Spread Spectrum PAM

Direct sequence Spread Spectrum PAM

Hämäläinen M, et al. On the UWB system coexistence with GSM 900, UMTS/WCDMA and GPS

Correlator reciever

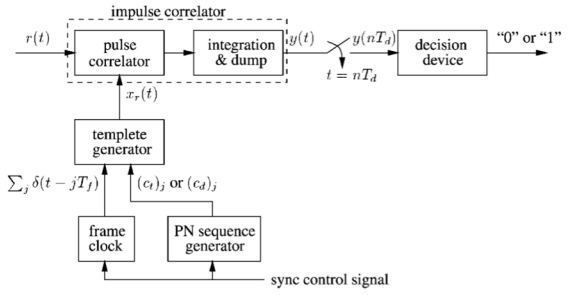


Figure 3. Block diagram of the correlator receiver.

Rake reciever

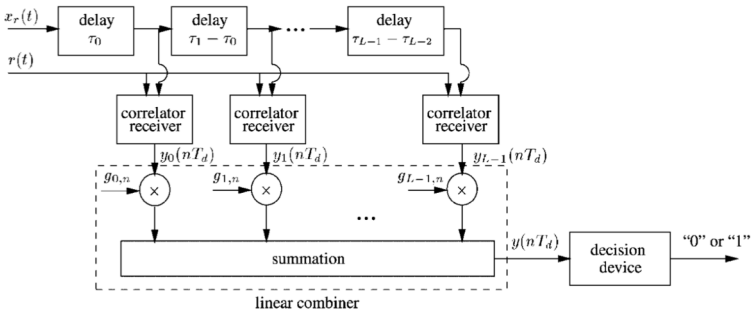


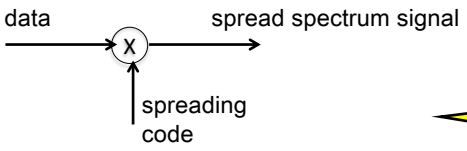
Fig. 4. Block diagram of the rake receiver.

WIDE-BAND CODE-DIVISION MULTIPLE ACCESS (WCDMA)

WCDMA
Some parameters

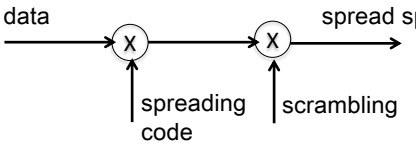
Carrier spacing	5 MHz
Chip rate	3.84 Mchips/sec
Uplink spreading factor	4 to 256
Downlink spreading factor	4 to 512

WCDMA
Direct-Sequence CDMA



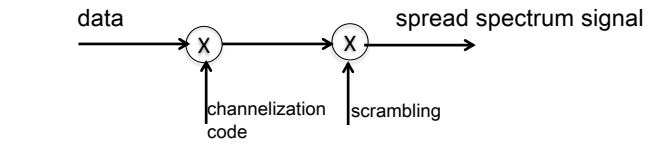
Users/channels are separated by different codes.

In WCDMA we do this a bit different:



The total spreading is a combination of spreading and scrambling.

WCDMA
Channelization and scrambling

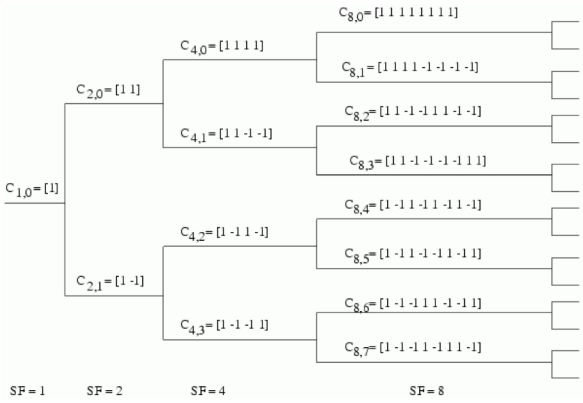


The different channelization/spreading codes are orthogonal and have different spreading factors between 4 and 512.

Scrambling makes the total spreading (spreading + scrambling) unique between different sources.

WCDMA
Orthogonal Variable Spreading Factor

The OVSF codes used for variable rate spreading can be viewed as a code tree.

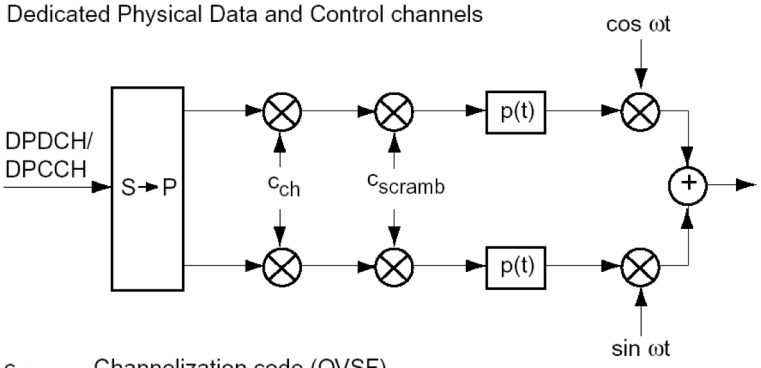


We can create several orthogonal channels by picking spreading codes from different branches of the tree.

WCDMA Downlink

Downlink Spreading and Modulation

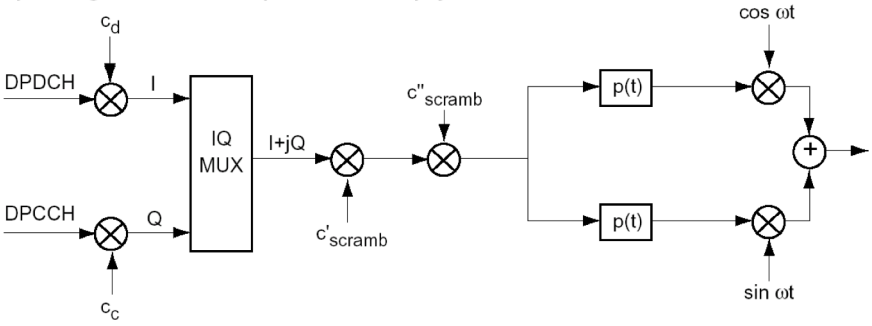
Dedicated Physical Data and Control channels



c_{ch}	Channelization code (OVSF)
c_{scramb}	Scrambling code (10 ms) 2^{18}-1 Gold code (40 960 chips)
p(t)	Root-raised cosine pulse shaping roll off 0.22
OVSF:	Orthogonal Variable Spreading Factor

WCDMA Uplink

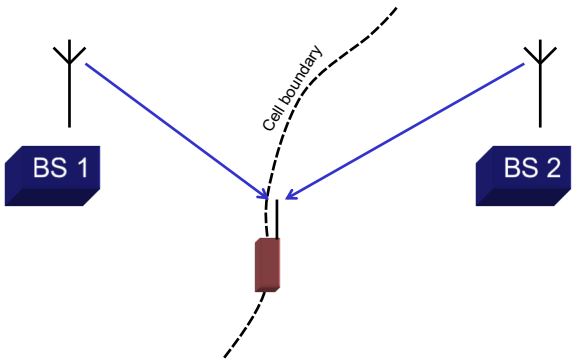
Spreading/modulation for uplink dedicated physical channels



c_c, c_d	Channelization codes (OVSF)
c'_{scramb}	Primary scrambling code (256 chips) VL-KASAMI code (2 codes)
c''_{scramb}	Secondary scrambling code (10 ms optional) 2^{41}-1 Gold code (40 960 chips)
p(t)	Root-raised cosine pulse shaping, roll-off 0.22

WCDMA
Soft handover

Since all base stations used the same frequency band, a terminal close to the cell boundary can receive “the same” signal from more than one base station and increase the quality of the received signal.



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Random notes

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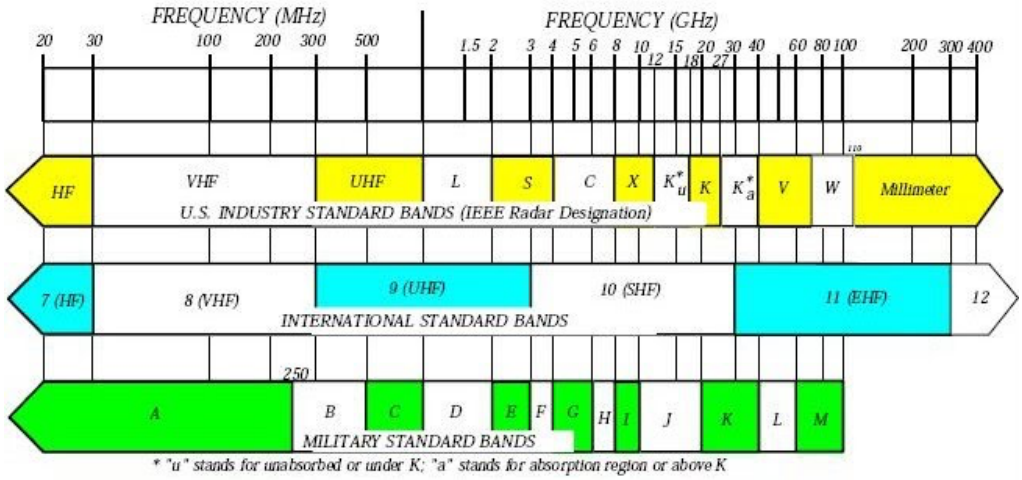
Radio band names are not unique!



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Not a block diagram…

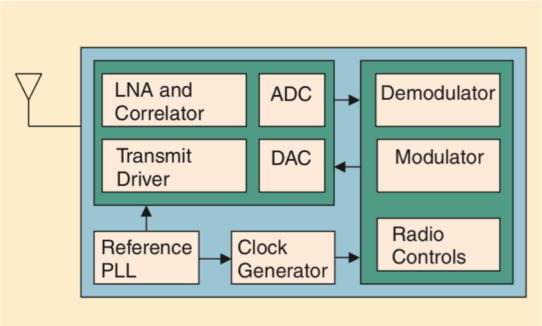

Figure 9. *Multiband transceiver's block diagram.*

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