Drahtlose Breitbandkommunikation - Synchronisation

Humboldt-Universität zu Berlin, Institut für Informatik,

IHP, Leibniz Institut für innovative Mikroelektronik, Frankfurt (Oder)

Vorlesung Drahtlose Breitbandkommunikationssysteme

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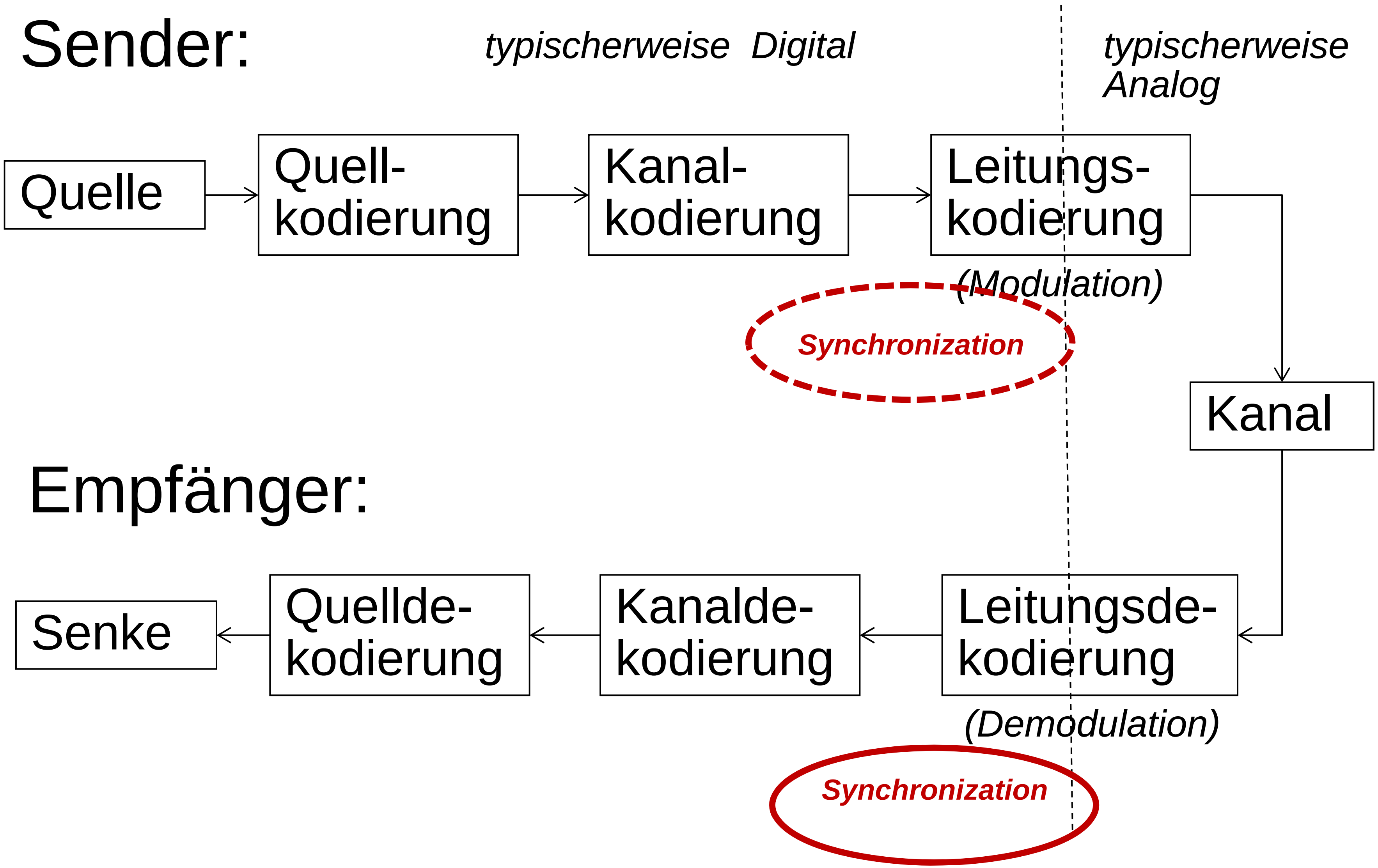
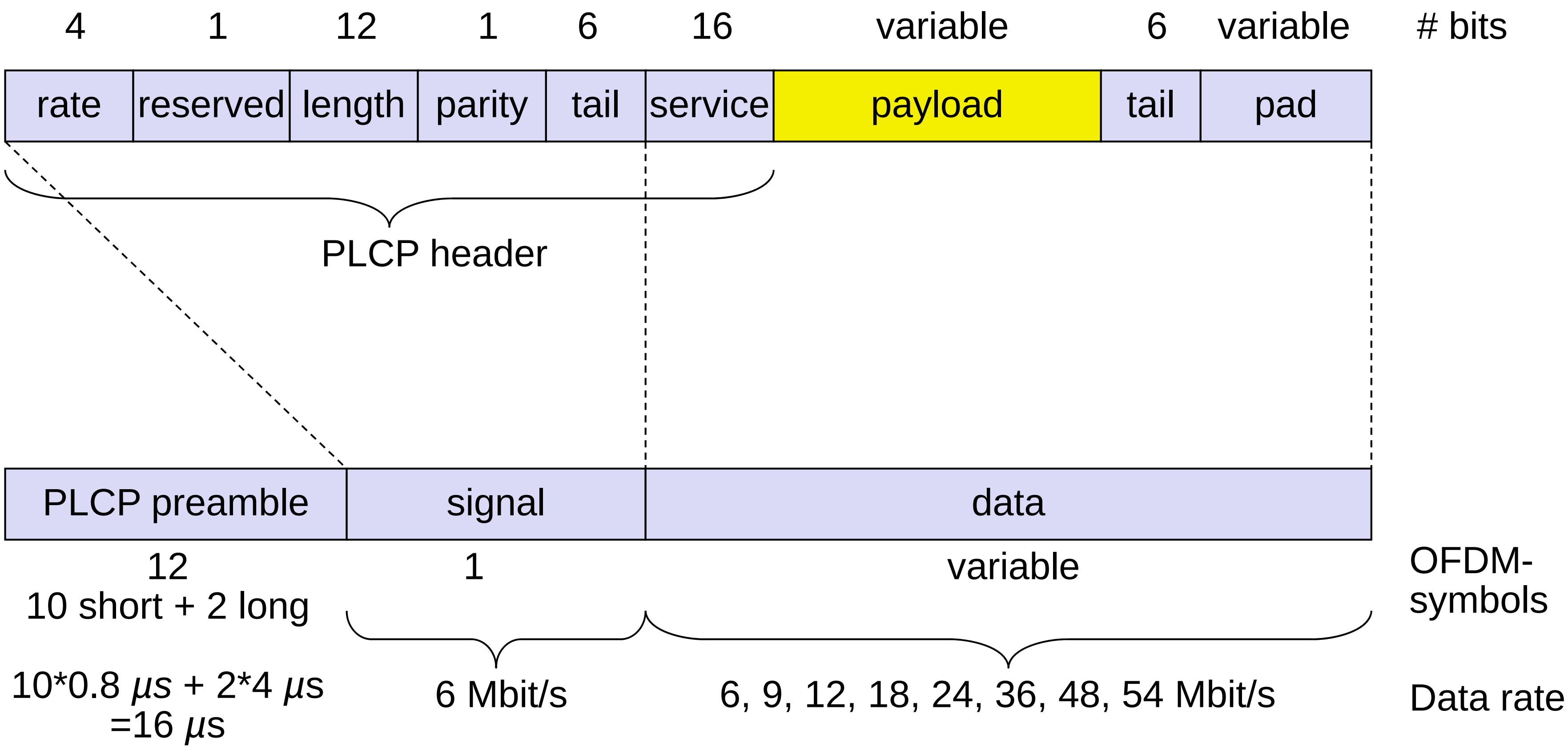
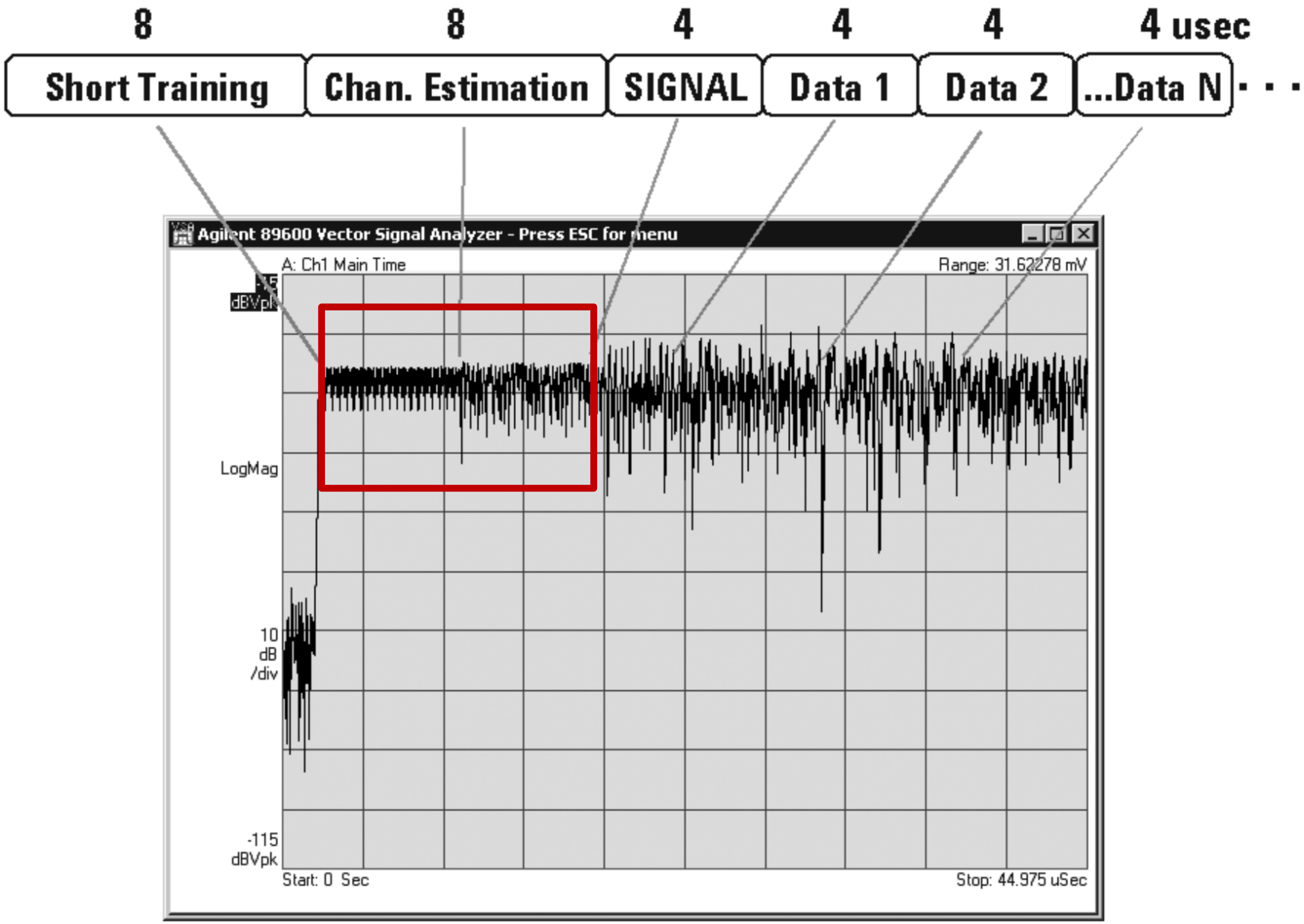

Sender:
typischerweise Digital
typischerweise Analog
Quelle
Quell-kodierung
Kanal-kodierung
Leitungs-kodierung
(Modulation)
Synchronization
Kanal
Empfänger:
Senke
Quellde-kodierung
Kanalde-kodierung
Leitungsde-kodierung
(Demodulation)
Synchronization

IEEE 802.11a – PHY Frame Format

One OFDM-Symbol: 0.8 µs (guard interval) + 3.2 µs (data) = 4 µs

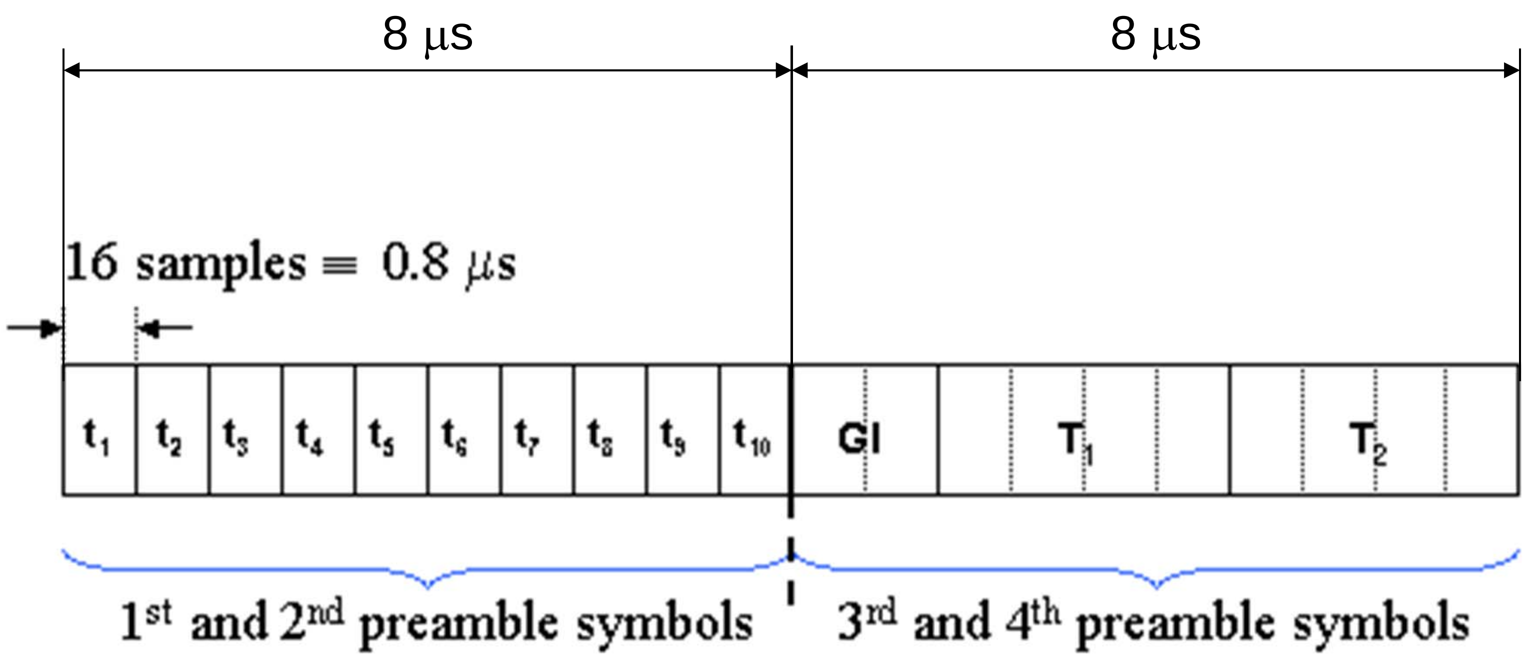


Recorded OFDM Data Frame



Source: http://cp.literature.agilent.com/litweb/pdf/5988-9440EN.pdf

IEEE802.11a Preamble structure:

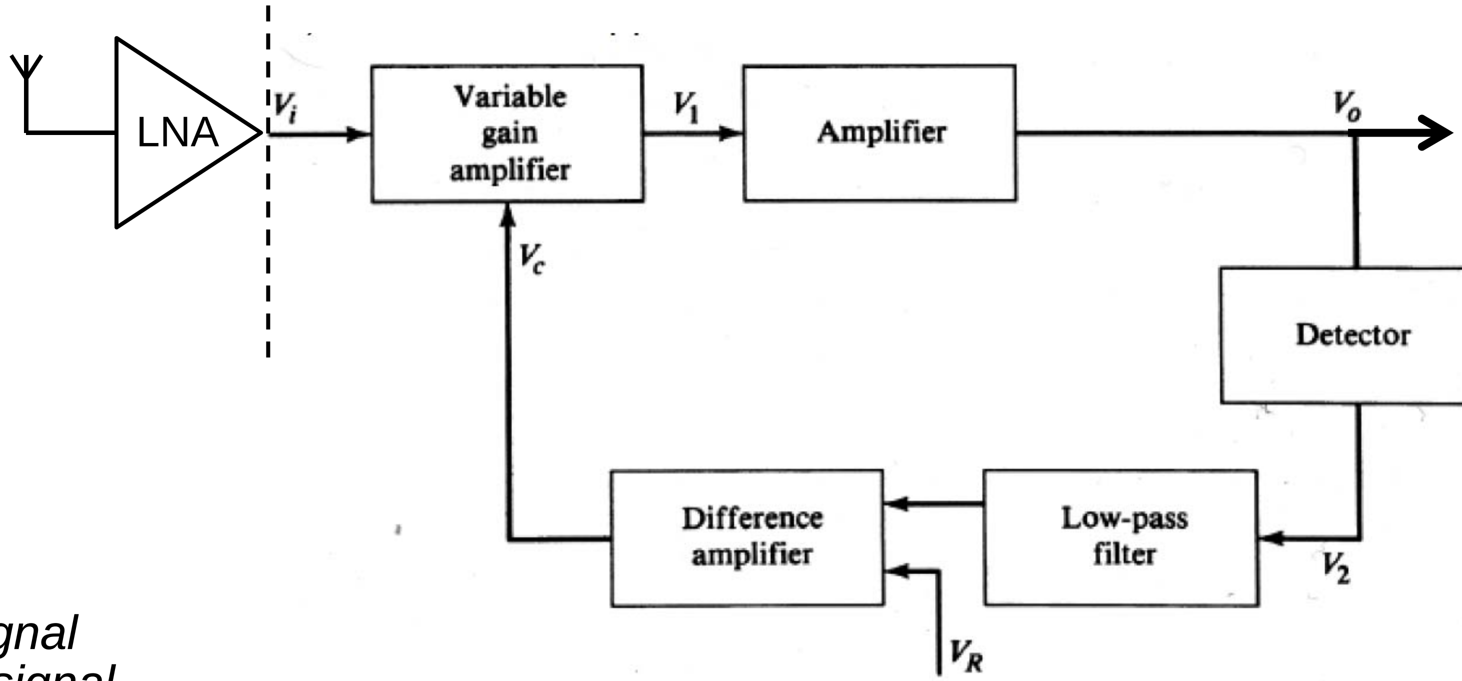


Main Synchronization Steps

1) Frame detection (coarse timing estimation).
    - Settling of Automatic Gain Control (AGC)
    - Auto-correlation (short preamble symbols)
2) Carrier frequency offset estimation and correction.
3) Determination of the symbol timing (fine timing estimation).
    - Cross-correlation (long preamble symbols)
4) Extraction of the reference channel estimation.
5) Data reordering -> Signal Field decoding -> Data decoding

Automatic Gain Control (AGC)-Operation

- An AGC is used in the receive path of the analog frontend to normalize the signal level
- The AGC control signal (V_c) should settle (stabilize) during the short preamble

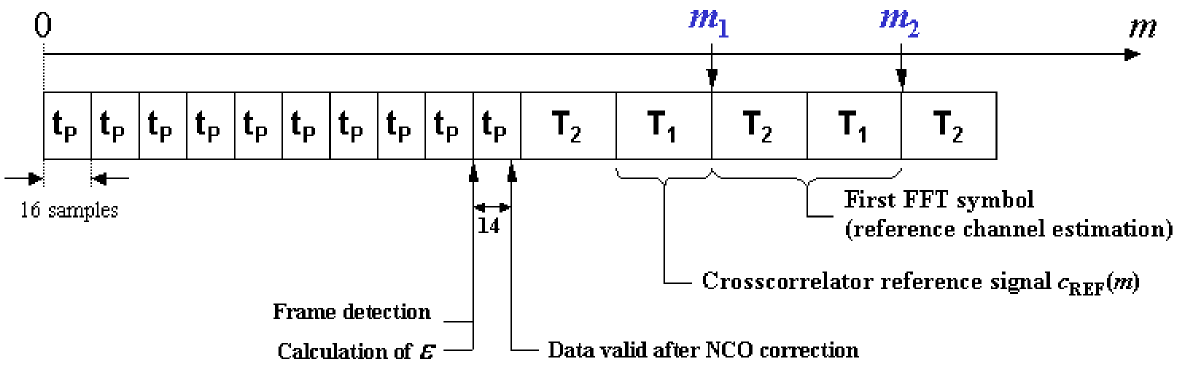


AGC Block Diagram

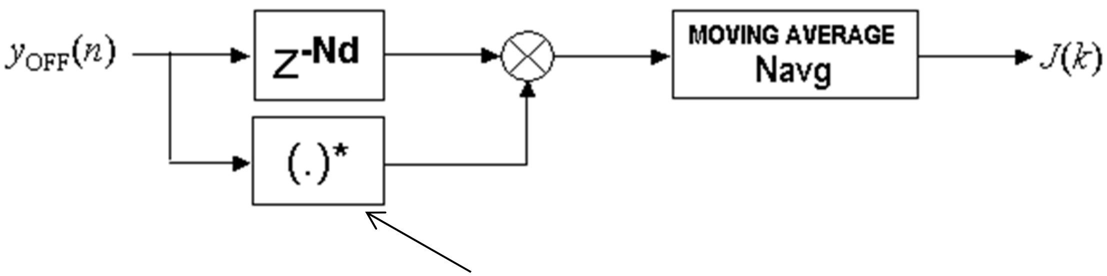
V_i – Input signal
V_o – Output signal
V_c – Control signal
V_R – Reference signal

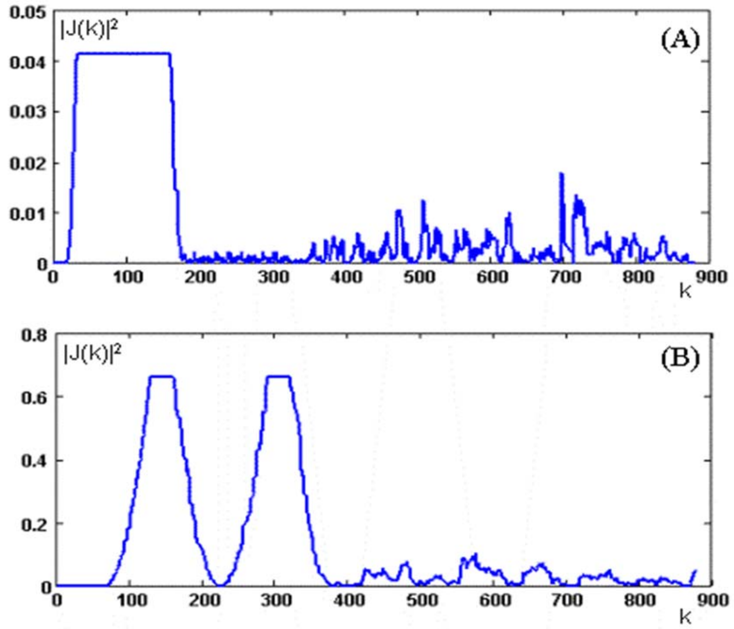
Source: Iulian Rosu, http://www.qsl.net/va3iul/

IEEE802.11a Preamble structure:



General autocorrelator architecture:



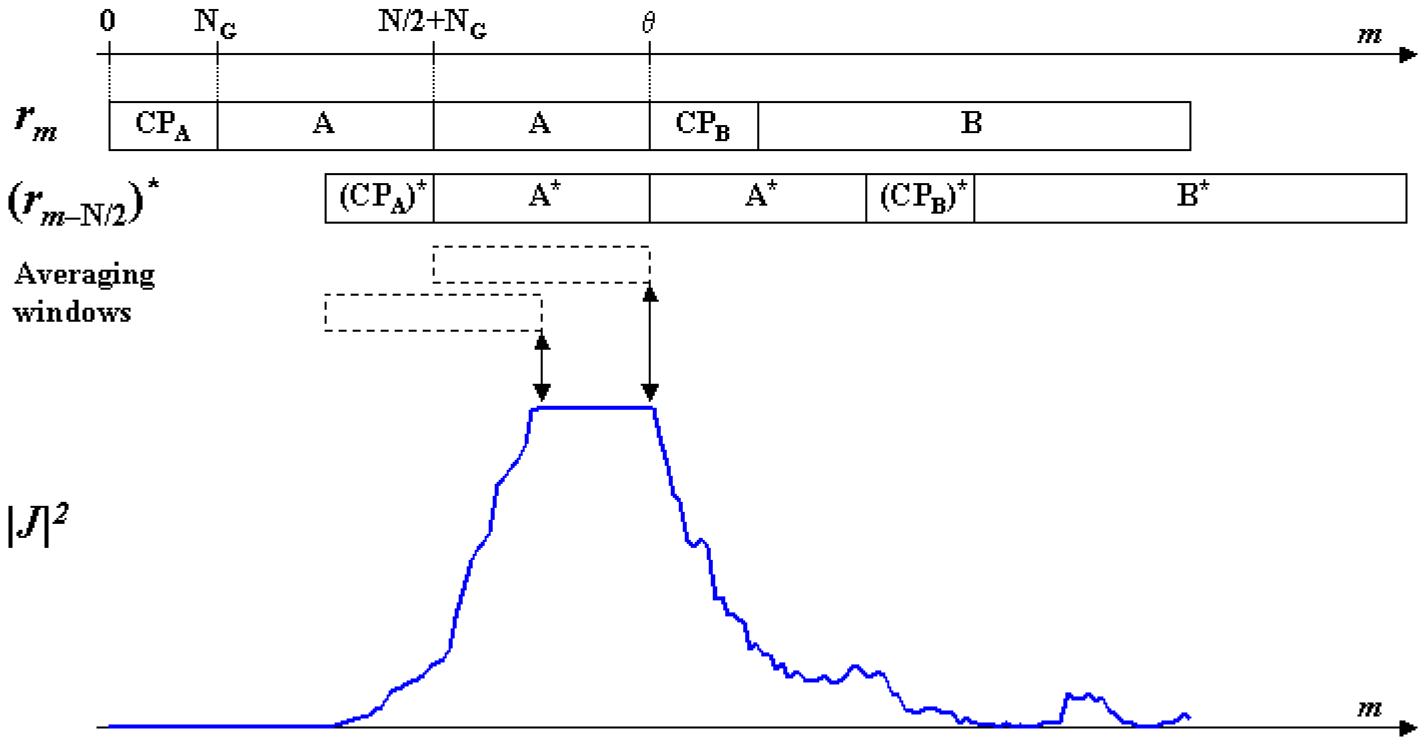


Autocorrelation applied to the IEEE 802.11a preambles:
(A) Nd=16, Navg=16
(B) Nd=64, Navg=64

Source: Alfonso Troya Ph.D.

Detailed Timing of Autocorrelator

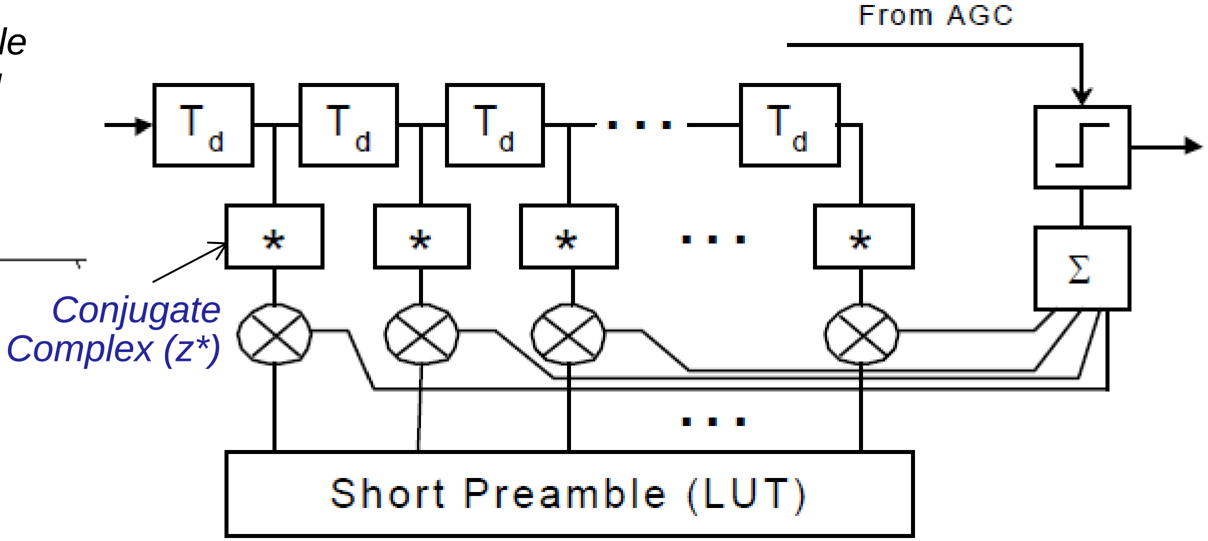
- Coarse Timing estimation based on Autocorrelation



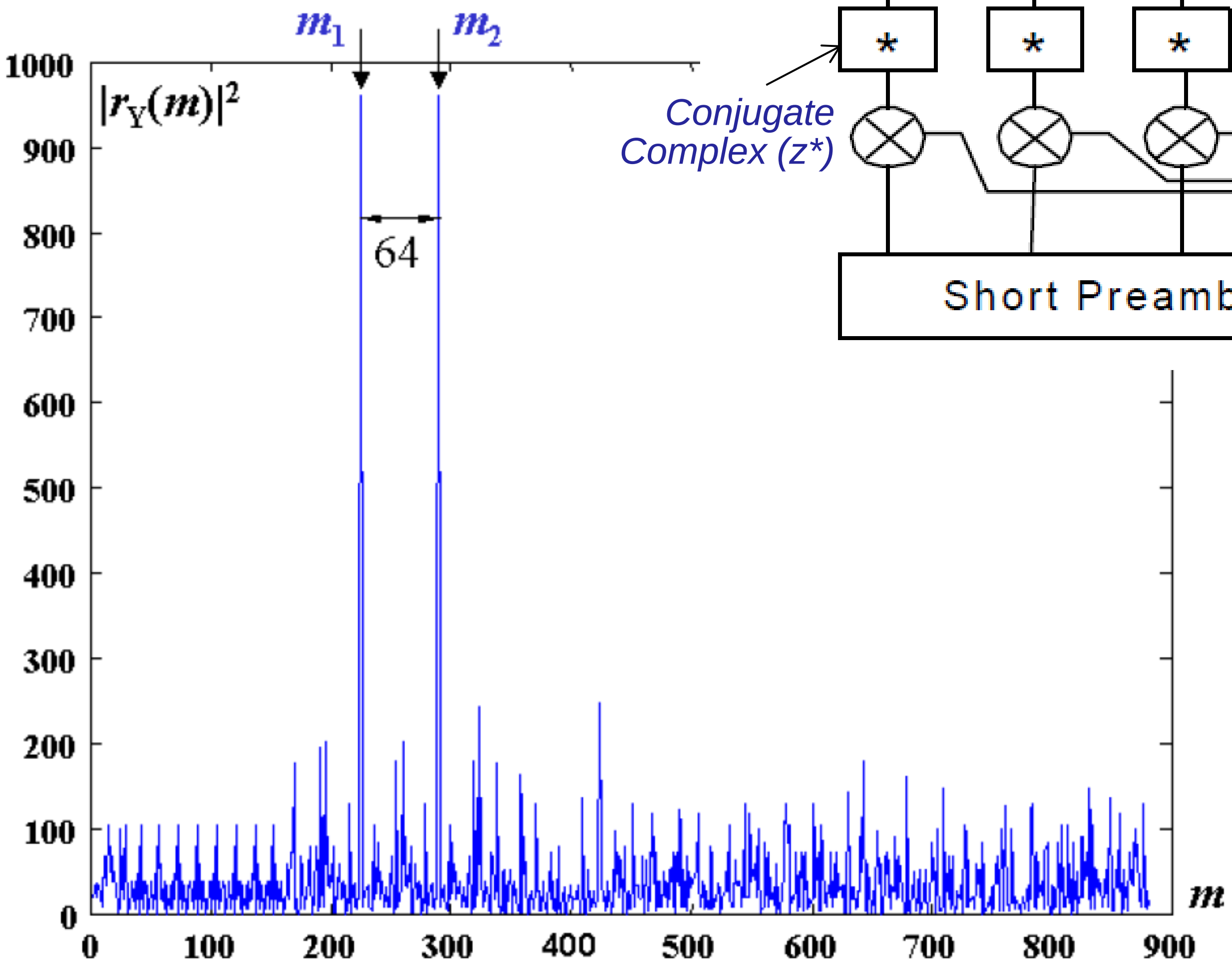
Source: Alfonso Troya Ph.D.

Fine Timing Estimation using Long Preamble

- *Cross-correlation on long preamble symbols is used for symbol timing estimation.*



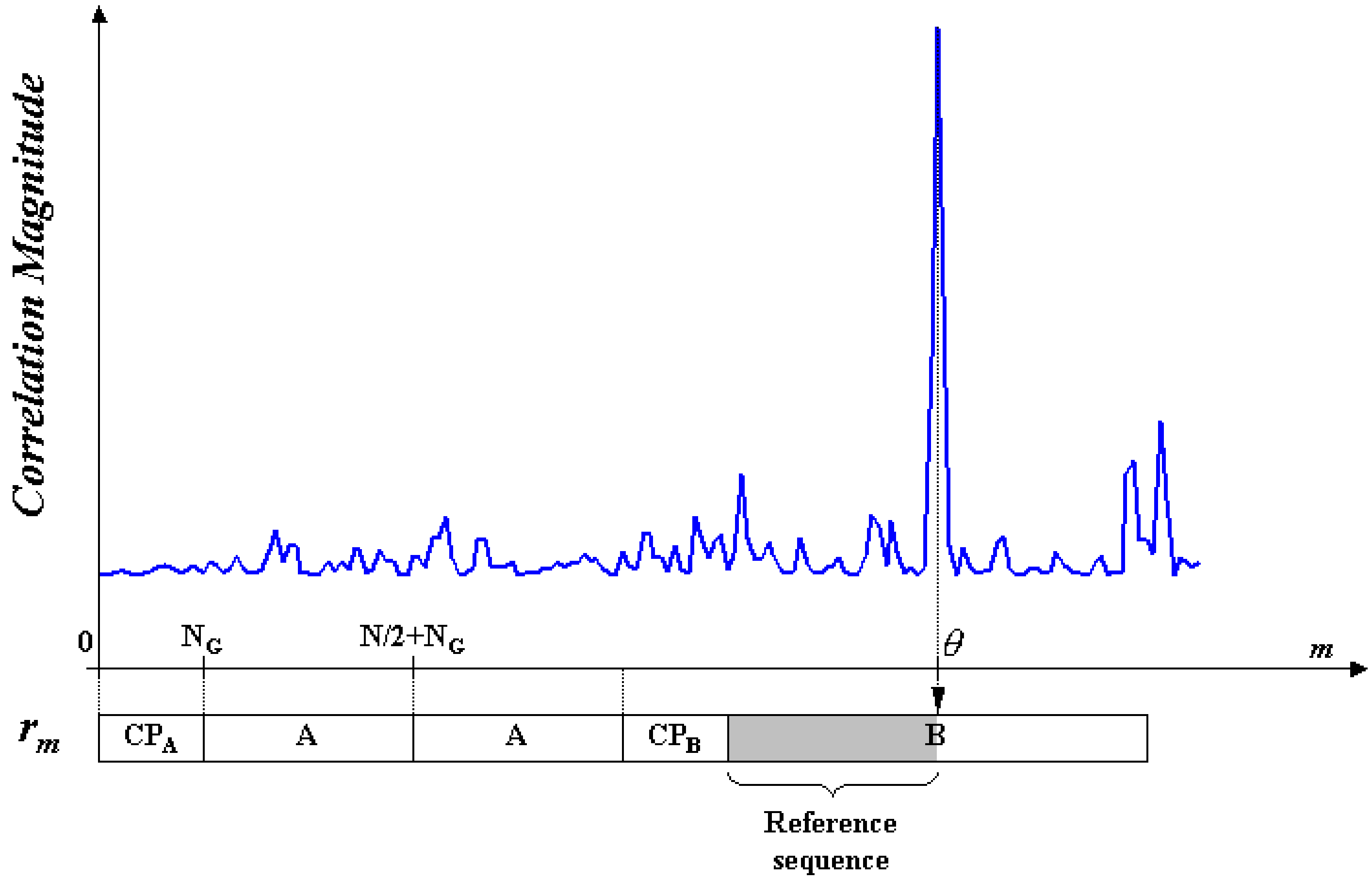
Source: E225C – Lecture 16



Source: Alfonso Troya Ph.D.

Detailed Timing of Crosscorrelator

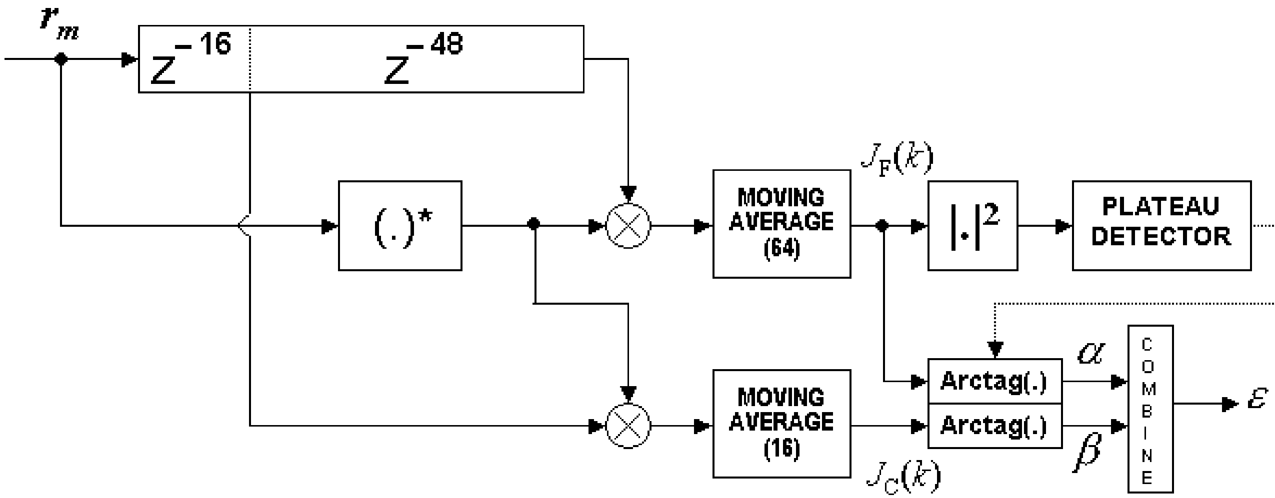
- Results for the fine timing estimator based on the crosscorrelation with the long preamble symbol:



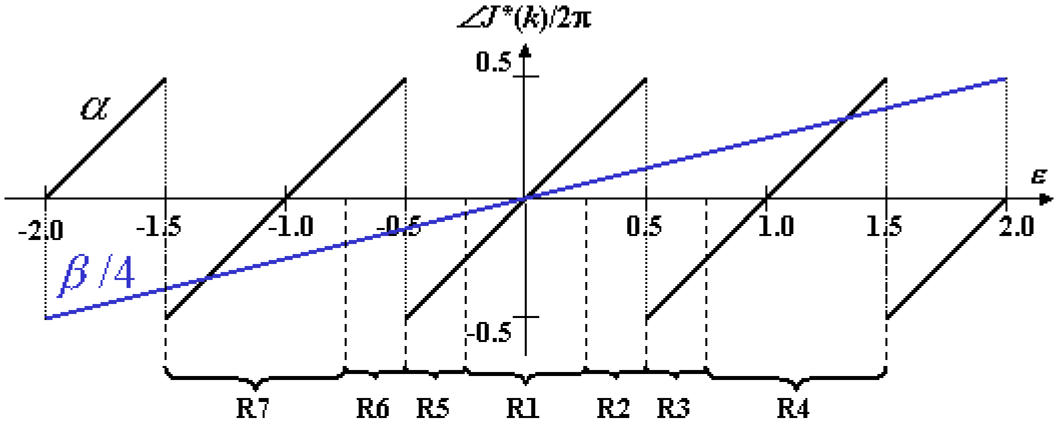
Source: Alfonso Troya Ph.D.

Frequency Offset Estimation

Frequency offset estimator using autocorrelation:



Relationship between normalized phase of J*(k) and actual frequency offset:



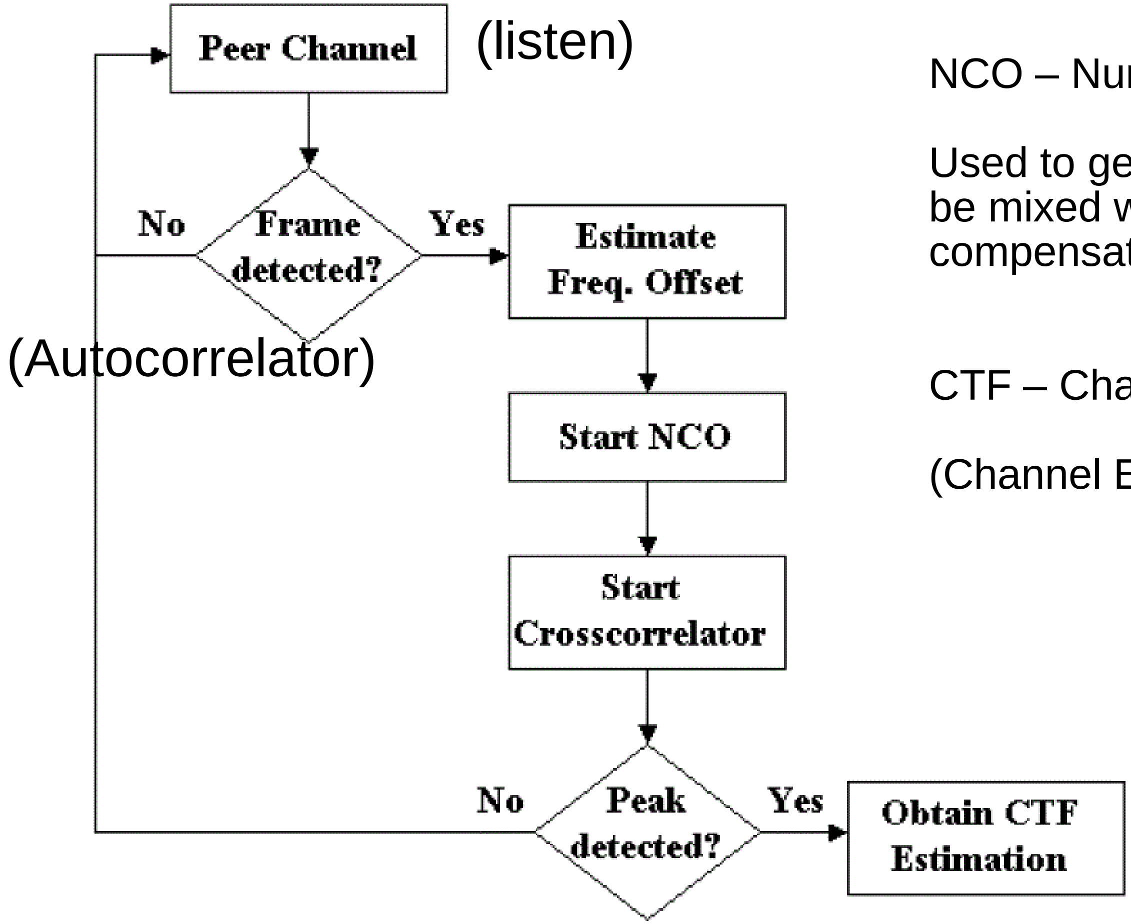
α – fine frequency offset
[-0.5, +0.5]

β – coarse frequency offset
[-2, +2]

Source: Alfonso Troya Ph.D.

Synchronizer General Operation

Flowchart with the different operations carried out at the Synchronizer.



NCO – Numerically Controlled Oszillator

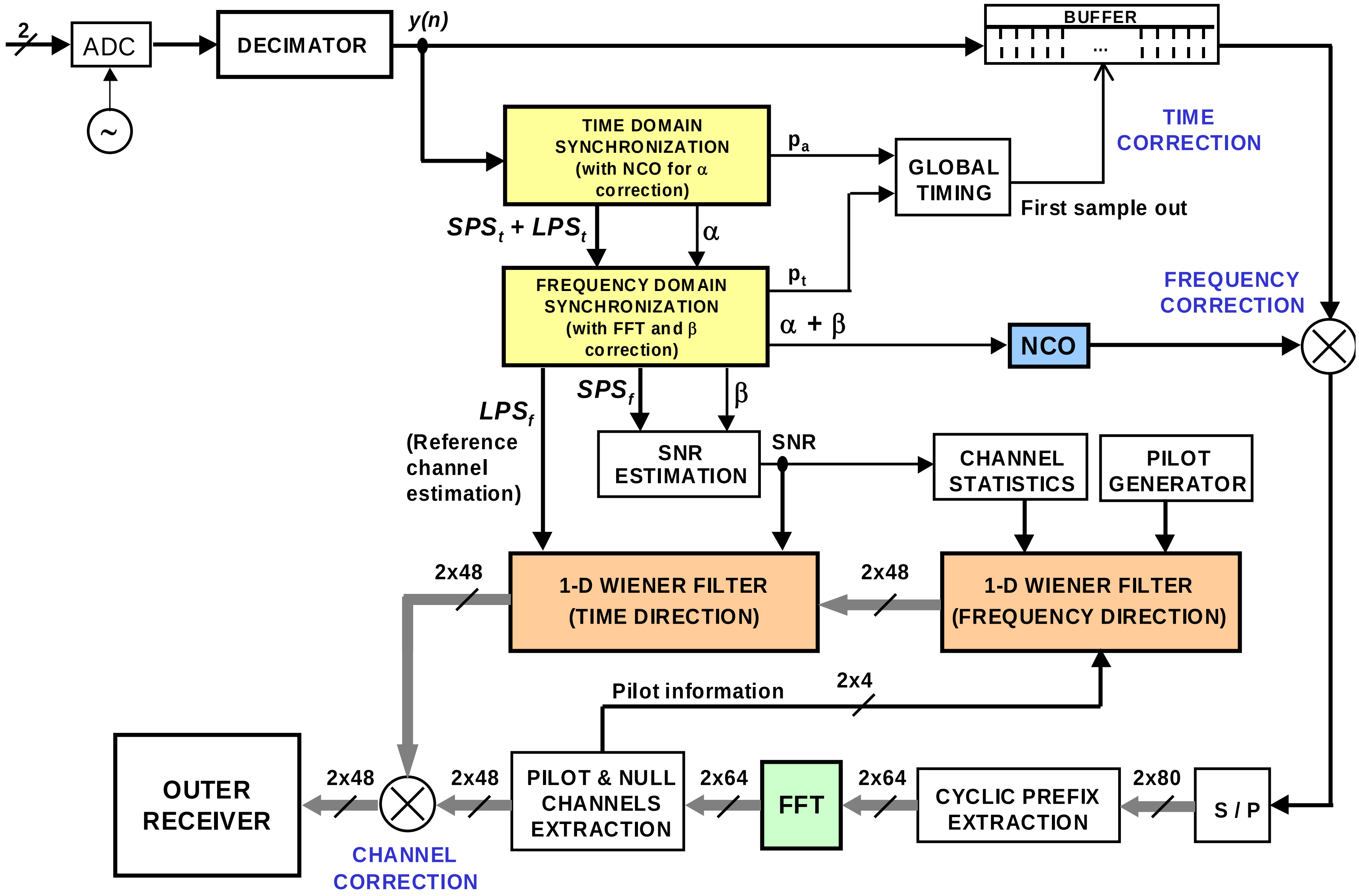
Used to generate low frequenzy sin waves to be mixed with signal for frequncy offset compensation

CTF – Channel Transfer Function

(Channel Estmation)

Source: Alfonso Troya, Ph.D.

Architecture of synchronisation and channel estimation blocks for the IEEE 802.11a Standard



Processing Requirements IEEE802.11a TX & RX

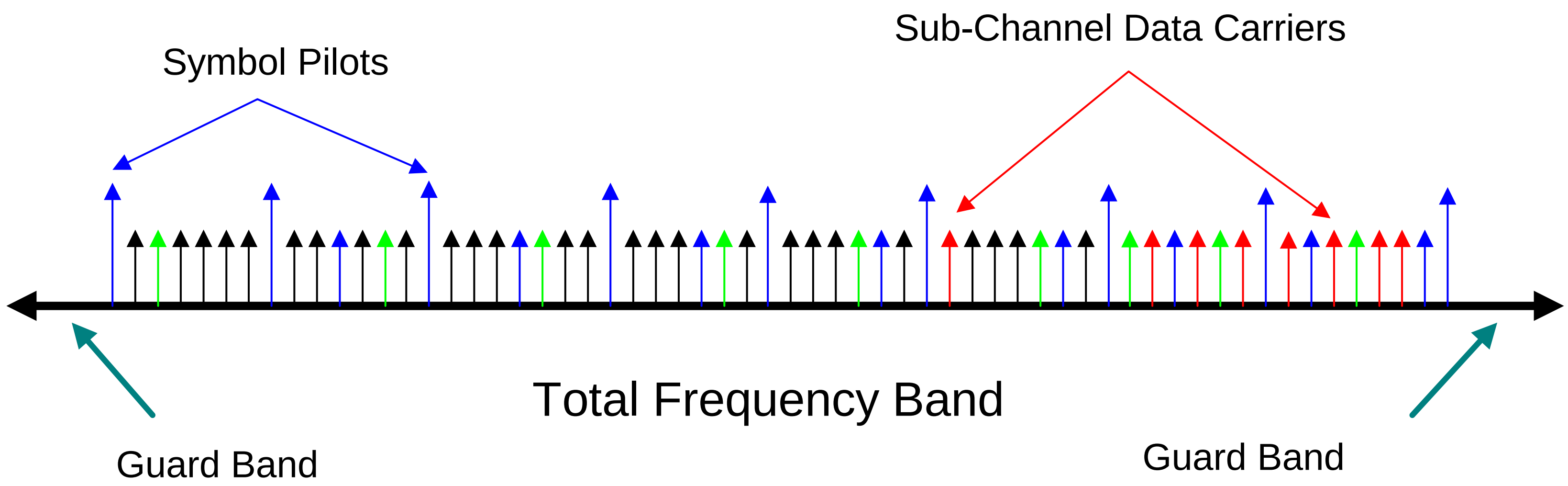
Approximate gatecount of IEEE802.11n Transmitter and Receiver.

Transceiver Block	Gatecount
Synchronizer	334000
Demodulator	800
Deinterleaver	10000
Channel Equalizer	351000
Viterbi Decoder	20000
FCS (Frame Check Sequence)	35000
UCM (Unit Control Module)	30000
Encoder	20000
Modulator	1600
IFFT/FFT	30000

Source: VIJAYANT BHATNAGAR, M.Sc., New Jersey, 2008.

OFDMA:

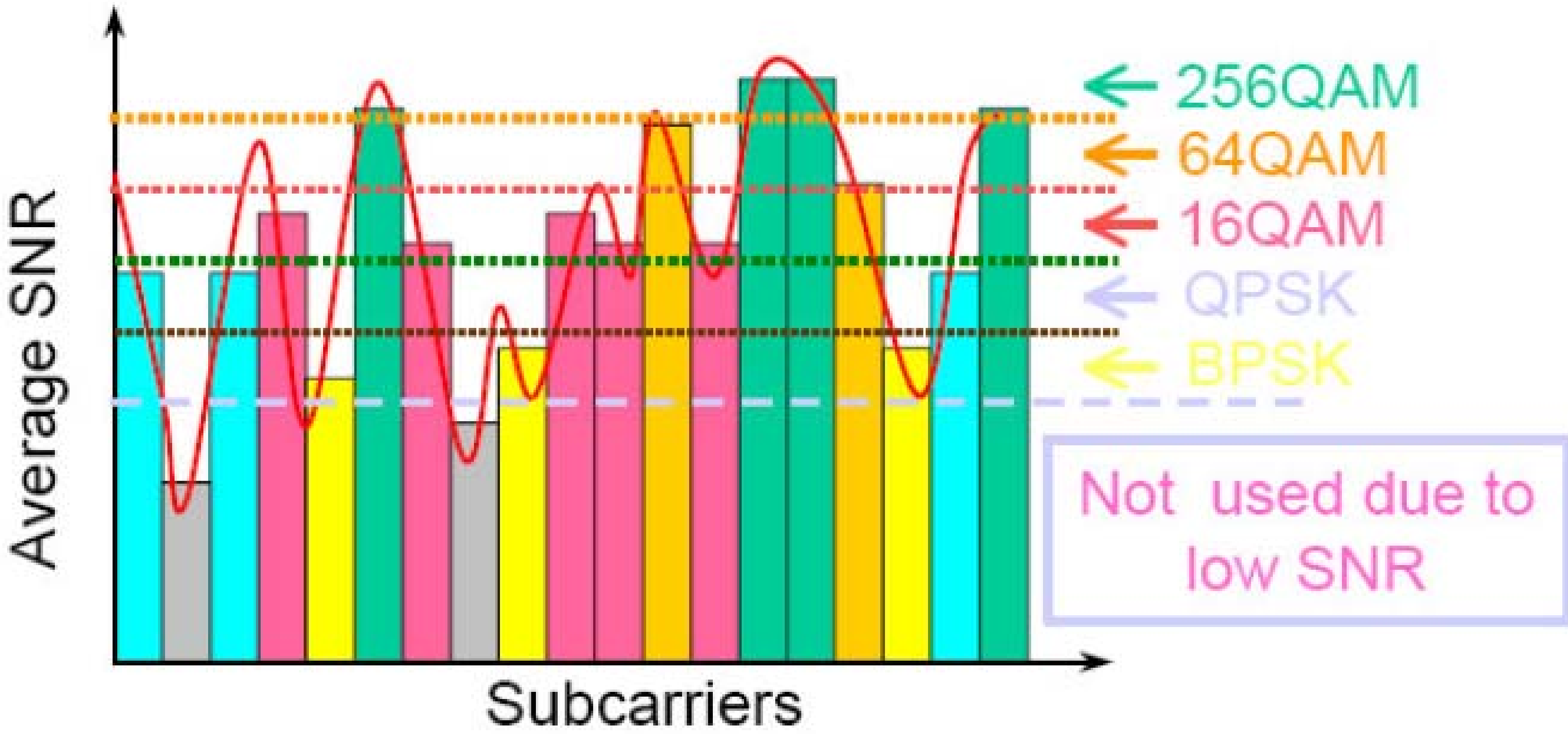
1. Strictly speaking OFDMA is not a modulation but an acces scheme
2. It is used e.g. in LTE
3. Every user has a certain number of subcarriers allocated
4. Downlink is very efficient
5. Uplink is very difficult (therefore, not used for uplink!)



Source: E. Sofer and Y. Segal, Doc. IEEE802.22-05-0005r1, Jan. 2005

Adaptive Modulation:

1. Special version of OFDM where, depending on the SNR-level, the modulation scheme for every subcarrier is adapted optimally
2. High SNR -> High modulation scheme (i.e. 64 QAM)
3. Low SNR -> low modulation scheme (i.e. BPSK) or subcarrier not used
4. Advantage: Optimal use of channel
5. Disadvantage: Signaling overhead
   (Receiver needs to know modulation scheme for each subcarrier.



Source: M. Essam Khedr, “Adaptive Modulation in OFDM“, Fall 2007

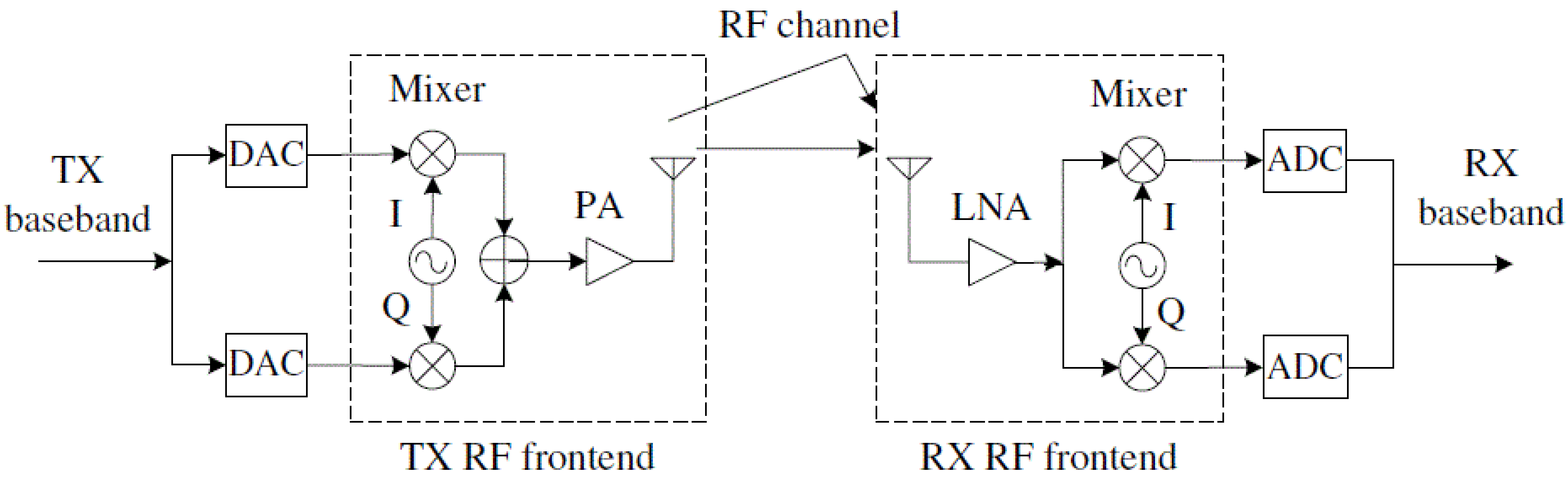
Hardware Impairmants

Main Hardware Impairments

Hardware impairments can be modeled as part of the channel:

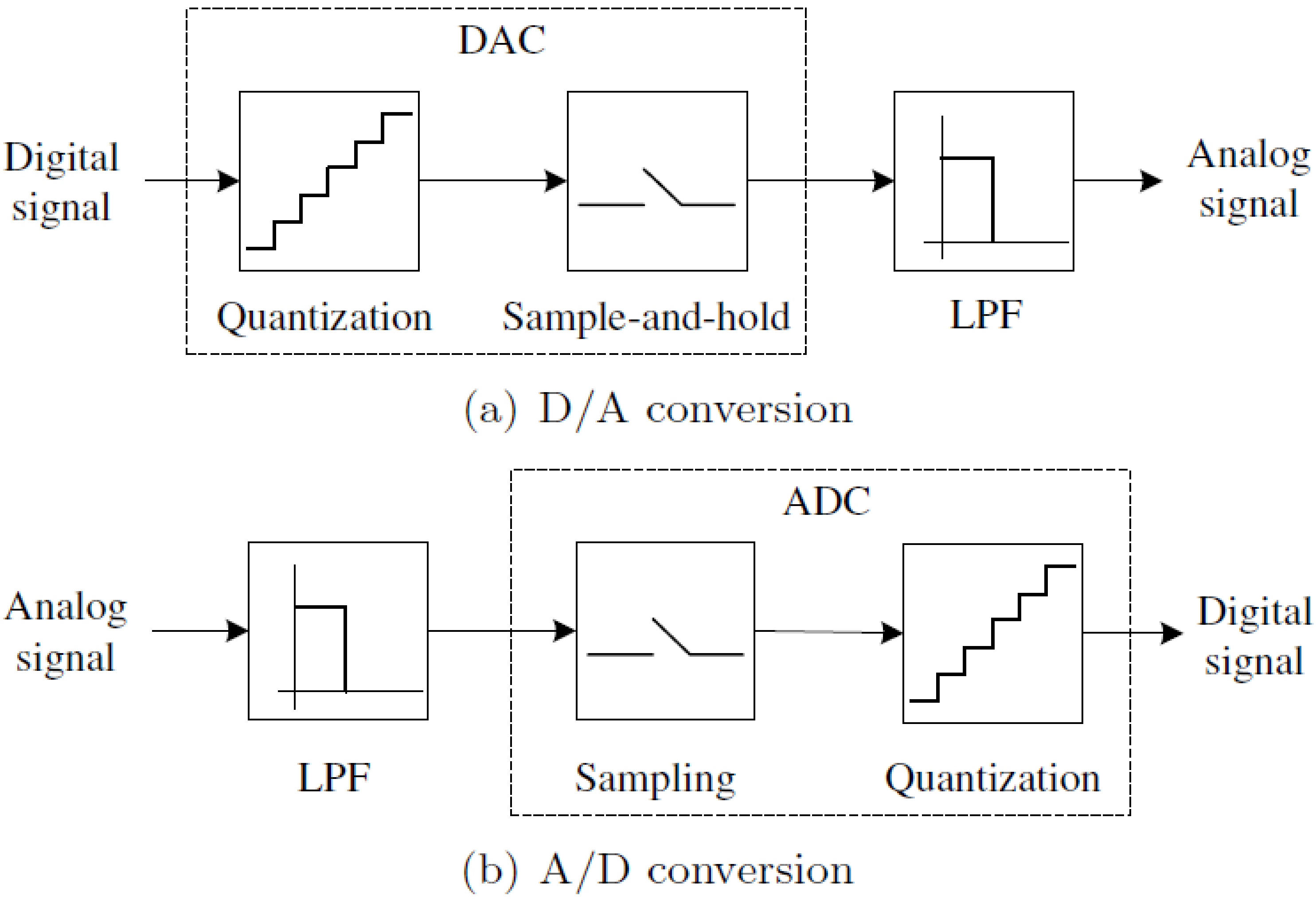
- Power amplifier non-linearity
- Phase-noise
- Frequency offset between transmitter and receiver
- Phase offset
- Data converter resolution and non-linearity
- I/Q mismatch (phase, amplitude)
- Receiver (LNA) noise-figure

RF-Transceiver & Hardware Impairments



Source: http://alexandria.tue.nl/extra2/200811734.pdf

ADC & DAC - Quantisation



Source: http://alexandria.tue.nl/extra2/200811734.pdf

Multiplexing

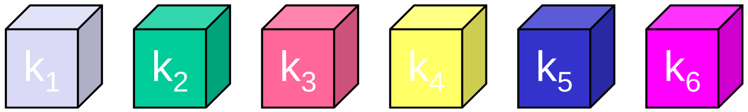
Multiplexing

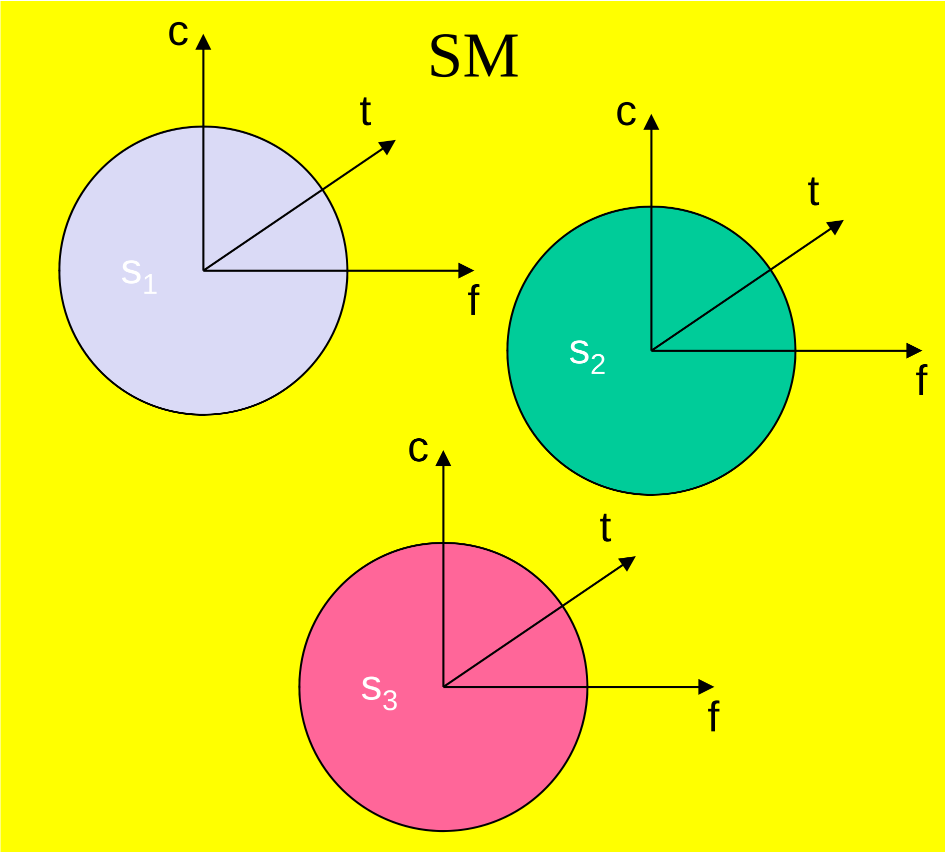
- **Goal:**
  multiple use
  of a shared medium

- Multiplexing in 4 dimensions
  - space (s_i)
  - time (t)
  - frequency (f)
  - code (c)

- Important:
  guard spaces needed!

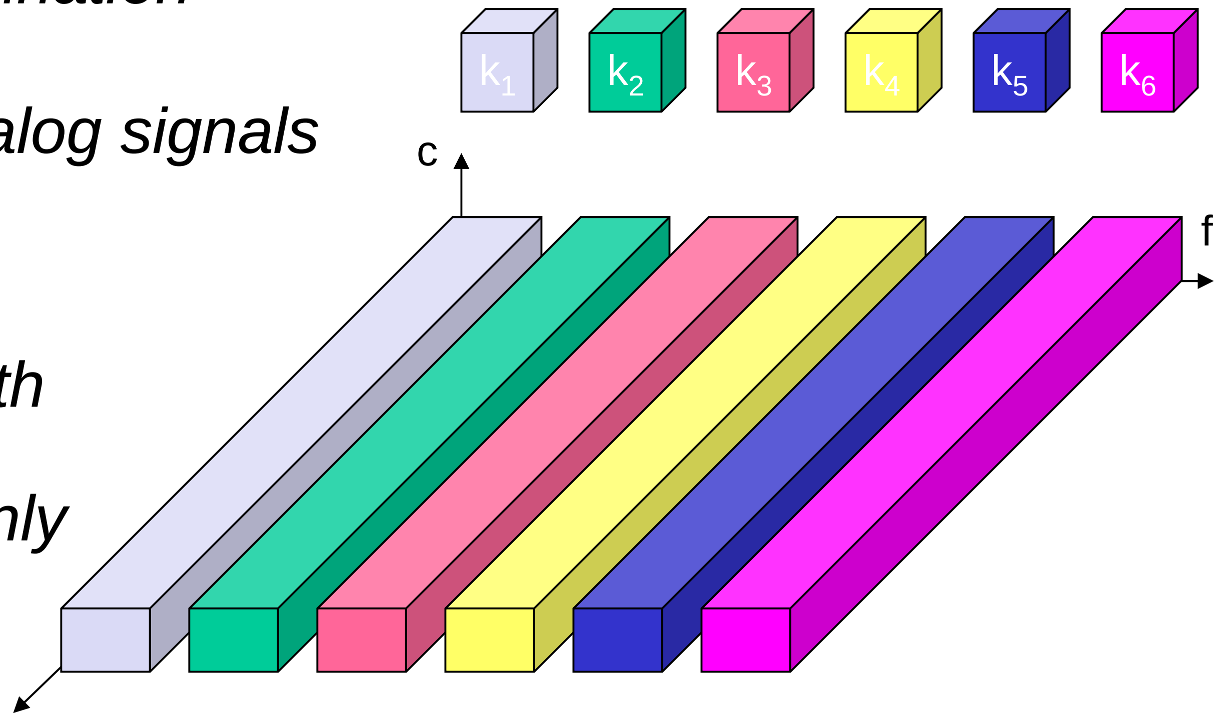
channels k_i





Frequency multiplex

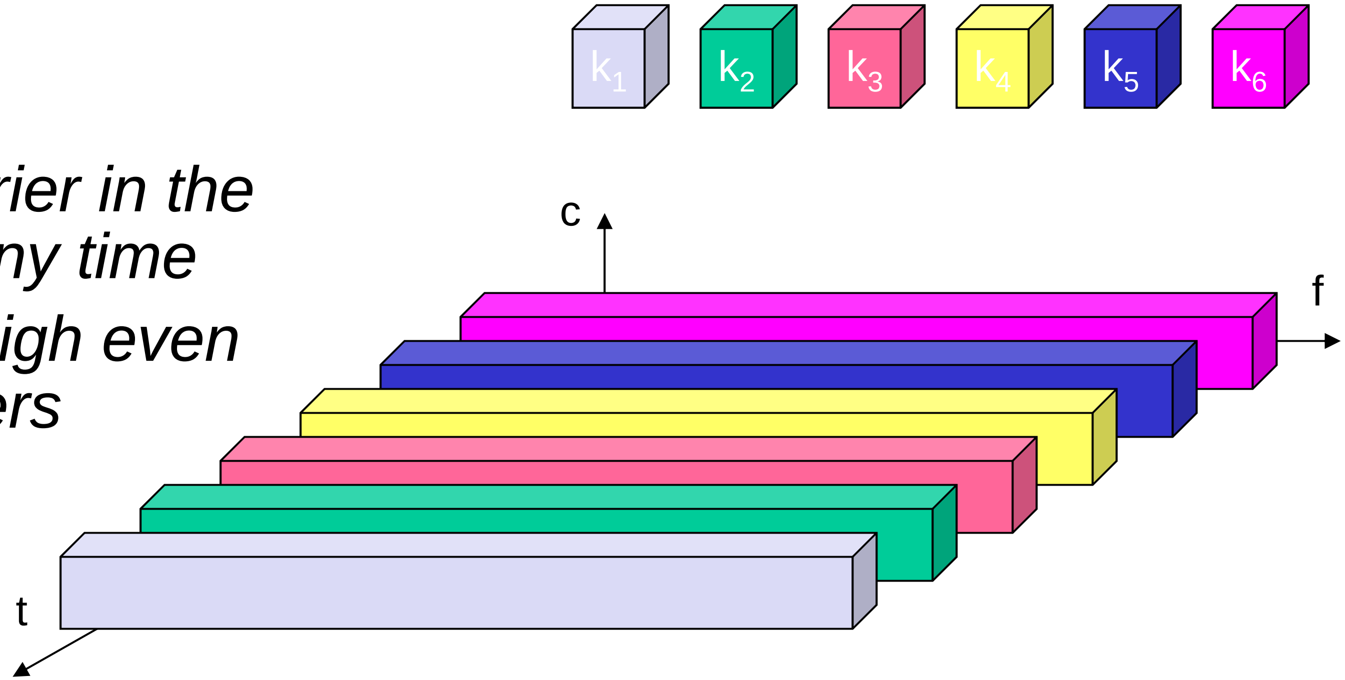
- Separation of the whole spectrum into smaller frequency bands
- A channel gets a certain band of the spectrum for the whole time
- Advantages:
  - *no dynamic coordination necessary*
  - *works also for analog signals*
- Disadvantages:
  - *waste of bandwidth if the traffic is distributed unevenly*
  - *inflexible*
  - *guard spaces*



Time multiplex

- A channel gets the whole spectrum for a certain amount of time

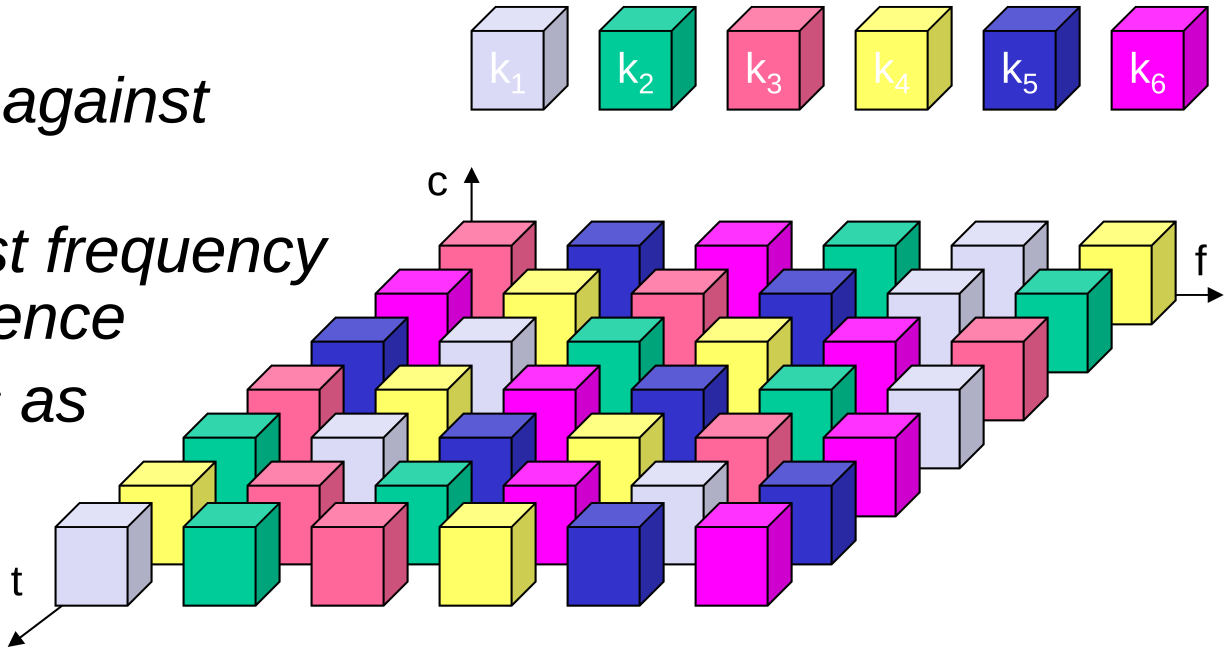
- Advantages:
  - *only one carrier in the medium at any time*
  - *throughput high even for many users*



- Disadvantages:
  - *precise synchronization necessary*
  - *Time for synchronization wasted in each time-slot*

Time and frequency multiplex

- Combination of both methods
- A channel gets a certain frequency band for a certain amount of time
- Example: GSM, Bluetooth (frequency-hopping)
- Advantages:
  - *better protection against tapping*
  - *protection against frequency selective interference*
  - *higher data rates as compared to code multiplex*
- Disadvantages:
  - *precise coordination required*



Code multiplex

- Each channel has a unique code
- All channels use the same spectrum at the same time
- Advantages:
  - *bandwidth efficient*
  - *no coordination and synchronization necessary (parallel transmission)*
  - *good protection against interference and tapping*
- Disadvantages:
  - *lower user data rates*
  - *more complex signal regeneration*
- Implemented using spread spectrum technology