AWGN
FREEBAND

Adaptive DSP Algorithms for UMTS:

Adaptive Receive Filtering in FDD UMTS

Adaptive Wireless Networking (AWGN)

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Outline

- Adaptive Wireless Networking (AWgN) Project
  - Objective
  - Definition of adaptivity
- Adaptive Receive Filtering in a FDD UMTS Handset
  - Purpose of receive filtering
  - Variation of interference conditions
  - Receive filtering in analog and digital domain
  - Adaptive digital receive filter architecture
- Conclusions and Future Work

Part I

Adaptive Wireless Networking (AWgN) Project

Adaptive Wireless Networking (AWgN) Project

Objective:

Develop methods and techniques for engineering highly adaptable and efficient base stations and terminals for 3G/4G wireless networking

Two activities:

- Mapping DSP Algorithms to a Reconfigurable Architecture (CADTES)
- Adaptive DSP Algorithms for UMTS (SaS)

Definition of Adaptivity

Adaptivity on three levels:

- Standards level adaptivity
  - Support multiple wireless communication standards
- Algorithm-selection level adaptivity
  - Select the algorithm that is used to implement a DSP function
- Algorithm-parameter level adaptivity
  - Change the parameters of an algorithm that implements a DSP function

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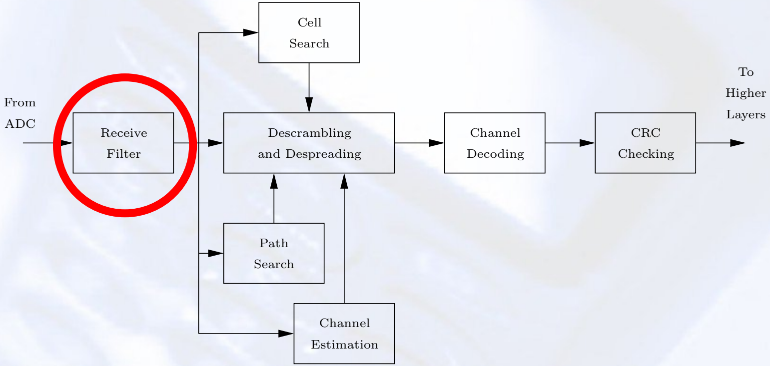
Part II

Adaptive Receive Filtering in a FDD UMTS Handset

FDD UMTS Handset Receiver DSP Functions



Purpose of Receive Filtering (I)

Two purposes:

1. Achieve aggregate raised cosine response combined with base station transmit filter
2. Provide sufficient attenuation in the adjacent channels to suppress adjacent channel interference (ACI)

In FDD UMTS ACI is caused by other base stations in the neighborhood of a handset transmitting on adjacent carrier frequencies

Purpose of Receive Filtering (II)

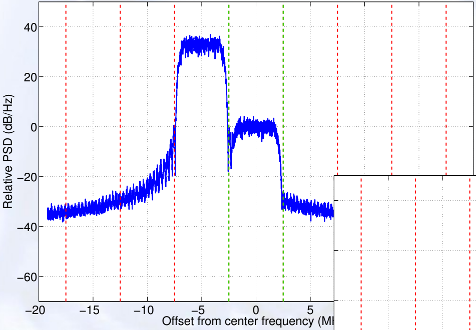
Freq. band (MHz)	2110.3 - 2124.9	2124.9 - 2139.7	2139.7 - 2149.7	2149.7 - 2159.7	2159.7 - 2169.7
Operator	Vodafone	KPN	Orange	Telfort	T-Mobile
Carriers	3	3	2	2	2

Table: UMTS downlink spectrum assignment in the Netherlands

The amount of ACI can vary because of:

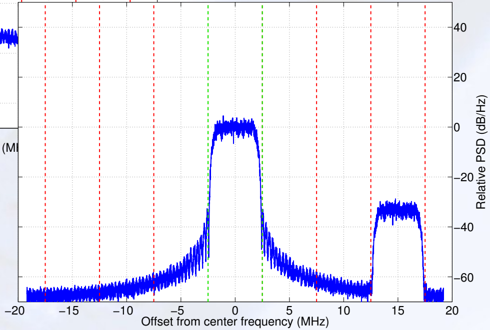
1. Adjacent carrier frequencies not being in use
2. Relative difference in distance between handset and wanted base station and handset and unwanted interfering base station(s)

Adjacent Channel Interference Conditions



Bad

Good (relatively)



Position in the Signal Processing Chain

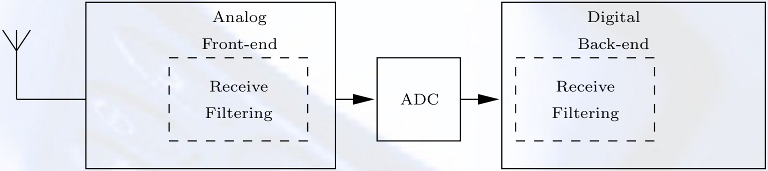


Figure: Position of receive filtering in the signal processing chain

Tradeoff between amount of receive filtering performed in the analog front-end and in the digital back-end

Receive Filtering in Analog Front-End

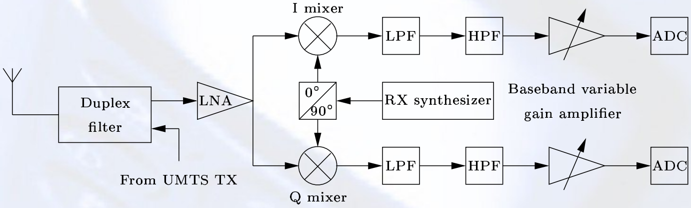


Figure: Homodyne receiver architecture

- UMTS handset receivers will generally use a homodyne receiver architecture
- All receive filtering will therefore have to be performed in analog or digital baseband

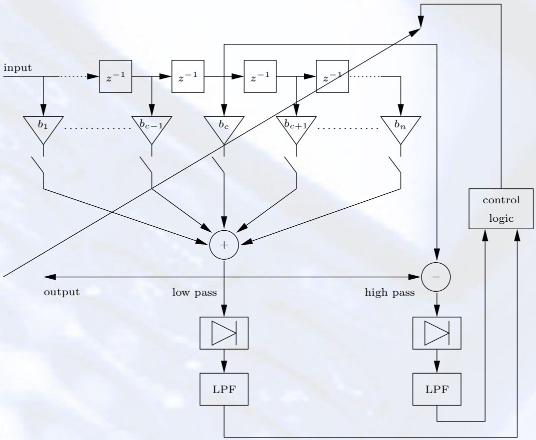
Adaptive Digital Receive Filtering

Adaptive FIR receive filter architecture:

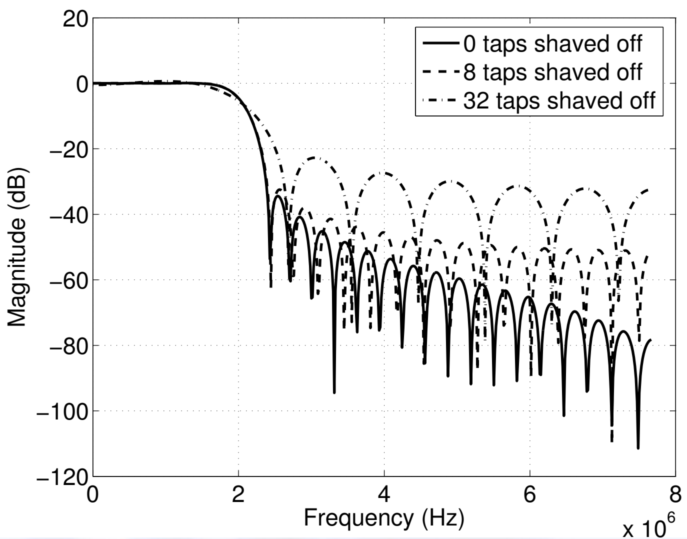
- Developed by Veljanovski et al. [1] for a Time Division Duplex (TDD) UMTS handset
- Signal powers in pass and stop band are measured
- The stop band attenuation of the FIR filter is adjusted to the measured adjacent channel interference by shaving off or adding filter taps

This architecture can also be used in FDD UMTS handsets

Adaptive FIR Receive Filter Architecture [1]



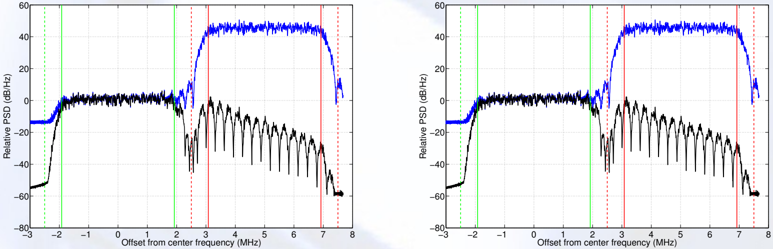
Adaptive Filter Attenuation



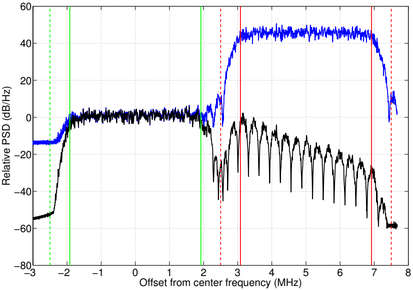
Practicality

- Adaptive receive filtering adds a control overhead of eight multiplications per filtered sample (depending on control implementation)
- So on average more than eight FIR filter taps should be shaved off
- To make this possible a large part of the receive filtering will have to be performed in the digital baseband
- This increases the demands on the dynamic range of the VGAs and ADCs in the analog front-end
- Recent developments in $\Sigma\Delta$ ADC technology, however, allow this

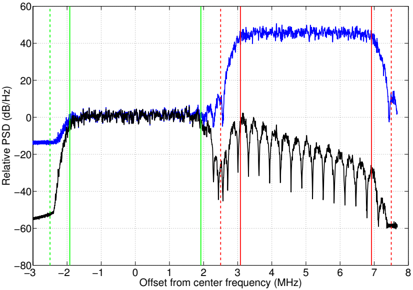
Example



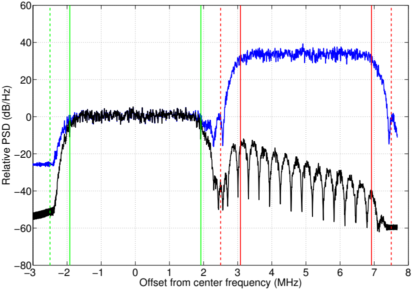
- Left fixed 49 tap filter; Right adaptive 49 tap filter
- Wanted channel and strong interfering signal in adjacent channel on the right
- Power of interfering signal is reduced in steps
- Received signal before receive filtering in blue
- Received signal after receive filtering in black

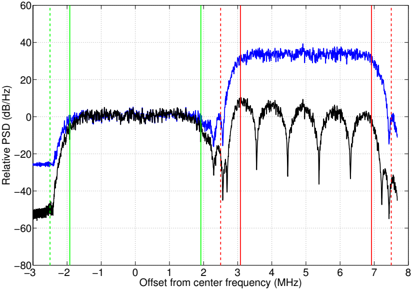


Fixed
wanted channel BER 0 for 10^7 bits



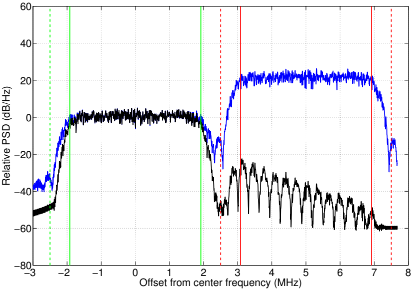
Adaptive 0 taps shaved off
wanted channel BER 0 for 10^7 bits

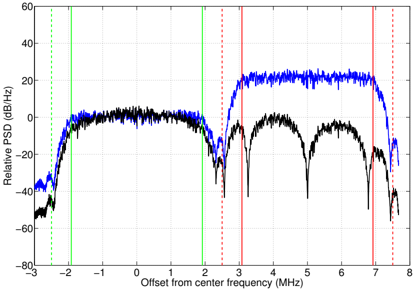




Fixed
wanted channel BER 0 for 10^7 bits

Adaptive ≈32 taps shaved off
wanted channel BER 0 for 10^7 bits





Fixed
wanted channel BER 0 for 10^7 bits

Adaptive ≈40 taps shaved off
wanted channel BER 0 for 10^7 bits

Part III

Conclusions and Future Work

Conclusions (I)

- Three levels of adaptivity can be distinguished in wireless communication systems:
  - Standards level
  - Algorithm-selection level
  - Algorithm-parameter level

Conclusions (II)

- Based on the required number of operations an adaptive digital receive filter can be computationally more efficient than a fixed length FIR receive filter under certain interference conditions
- This is, however, only the case in receivers where a large part of the receive filtering is performed in the digital baseband

Future Work

- Study the effect of shaving off taps of the FIR receive filter on the inter symbol interference and the receivers bit error rate performance
- Get estimates of the actual costs of analog and digital receive filter implementations to better study the tradeoffs
- Obtain coverage simulations or measurements of two UMTS networks transmitting on adjacent channels to get an idea about the ACI conditions in practice

Questions?

References (I)

[1] R. Veljanovski, J. Singh, and M. Faulkner.
A proposed reconfigurable digital filter for a mobile station receiver.
In *Proceedings of GLOBECOM '02*, pages 524–528, November 2002.