DAB

Software Receiver Implementation

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Task

Goal: Implementation of a real-time DAB receiver as SDR

SDR

Software Defined Radio → (almost) all signal processing in software

DAB

Digital Audio Broadcasting → digital radio technology standardized by ETSI

Real-time

Process data as fast as it arrives → 2 MSPS or 16 MB/s

Software Defined Radio

Idea

Digitize the signal and do all the signal processing in (high level, architecture independent) software.

Strengths

- Flexibility
- Reusable code, fast development cycle
- Cognitive radio: Adapts itself dynamically to RF environment $\longrightarrow$ better spectral and power efficiency

Weaknesses

- Limited sample rate and dynamic range of ADCs and DACs $\longrightarrow$ analog front end needed for filtering
- Resource usage, energy consumption, cost

Digital Audio Broadcasting (DAB) Specification

Modes

Four modes for different frequency ranges and RF characteristics

- Presentation: Mode I (Code: All Modes)

DAB Mode I OFDM signal

- Frames with 76 OFDM symbols (1 pilot, 75 data)
- Null symbols (energy zero) to separate frames
- 1536 subcarriers à 1 kHz & central carrier zero → 1.537 MHz
- D-QPSK modulation for each subcarrier
- Cyclic prefix: 504 samples → SFN with max. TX distance 74 km

Upper Layers

- Punctured convolutional coding
- Energy dispersal, Time interleaving
- MPEG 2 audio coding

GNU Radio

Overview

- Open source framework for real-time software radios
- Provides many common building blocks: FFT, FIR & IIR filters, mathematical operations, AGC, modulation & demodulation, . . .

Flow Graph Concept

- Programmer creates a directed graph for sample flow
- Signal processing blocks are written in C++ and wired together in Python

Signal Processing Block

- `work()` function receives a number of samples from scheduler
- Block processes as many samples as possible and returns the number of consumed and produced samples

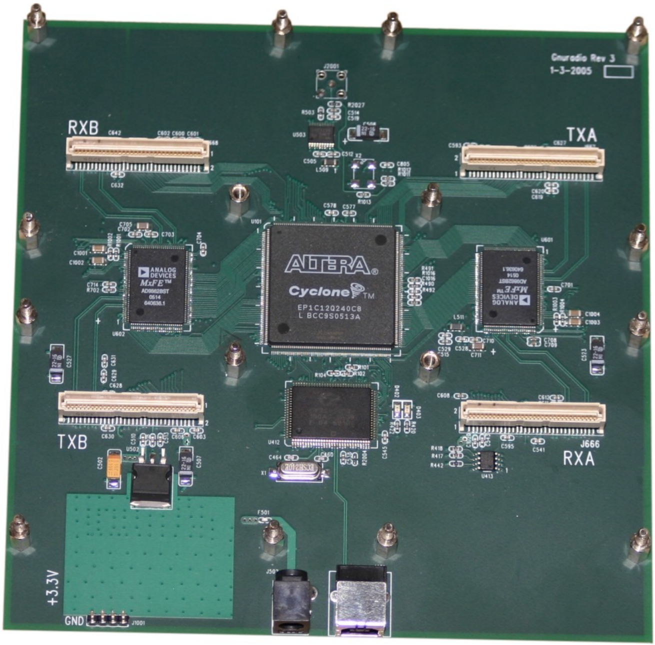
Universal Software Radio Peripheral (USRP)

Hardware

- Interface between computer and antenna is needed
- Most commonly used with GNU Radio: USRP

USRP

- Two AD9862 Mixed Signal Front-End Processors
  - 4 DACs with sampling rate 128 MSPS $\rightarrow$ 2 I/Q TX channels
  - 4 ADCs with sampling rate 64 MSPS $\rightarrow$ 2 I/Q RX channels
- Altera Cyclone FPGA for conversion to/from baseband, decimation/interpolation, multiplexing and buffering
- Cypress FX2 USB 2.0 interface
- Daughterboards according to selected frequency range



(Source: http://ettus.com)

OFDM I – Synchronisation

Time Synchronisation

- Frame start detection must be accurate, as the other blocks depend on it
- Can easily be done by looking at the energy of the signal (Null symbols)
- Implemented with moving sum, inverter and peak detector

Frequency Synchronisation

- Small subcarrier spacing $\rightarrow$ accurate synchronisation needed
- Fine frequency synchronisation (offsets $<$ subcarrier spacing)
    - compare cyclic prefix to end of the symbol $\rightarrow$ fine frequency offset can be estimated from the phase offset
- Coarse frequency synchronisation (offsets $>$ subcarrier spacing)
    - done after fine frequency synchronisation and after FFT
    - simply shift signal in the frequency domain $\rightarrow$ very efficient

OFDM II – Demodulation

Demodulation

- Besides time and frequency synchronisation, demodulation is rather straightforward
- Sampler: Remove cyclic prefix, pack each OFDM symbol in a vector
- FFT
- Calculate phase difference (undo the D in D-QPSK)
- Magnitude equalization (only needed for soft bits, as the information is only in the phase)
- Undo frequency interleaving: Mix symbols according to sequence specified in DAB standard
- I and Q components contain independent bits $\rightarrow$ simply check if $\Re(x) > 0$ and $\Im(x) > 0$

Test Setup

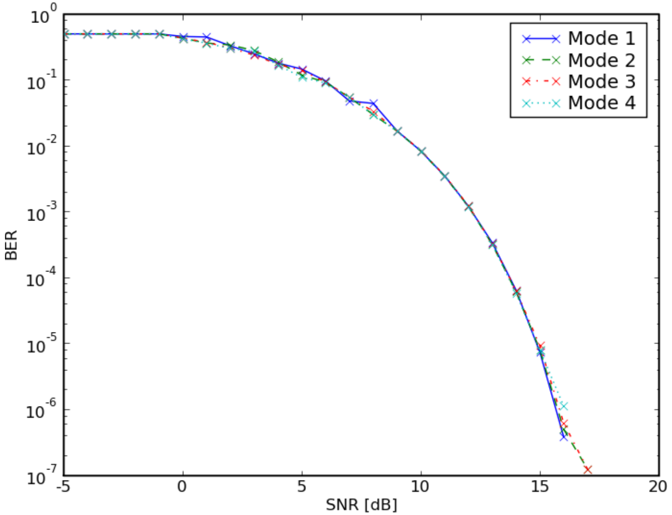
Simulation Cycle

- Generate random bytes
- Modulation
- Channel-model distorts OFDM signal
- Demodulation
- Calculate BER from original and received bytes

Channel Model

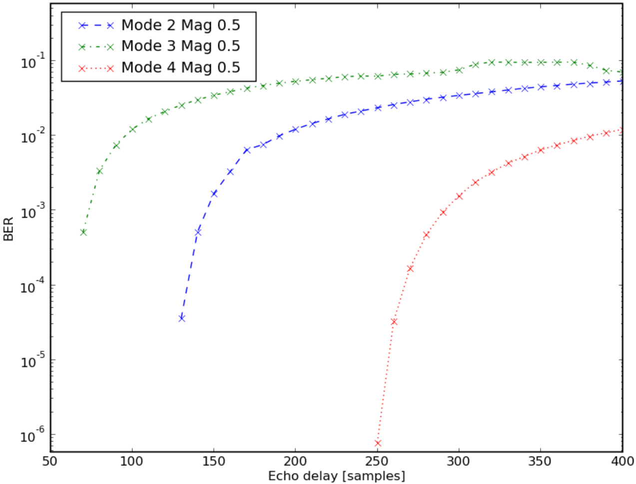
- Sampling frequency offset modeled by fractional interpolator
- Multipath propagation modeled with FIR filter
- Frequency offset (signal source + multiplication block)
- AWGN (noise source + adder block)

Results – SNR



Mode 1
Mode 2
Mode 3
Mode 4
BER
SNR [dB]
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
-5
0
5
10
15
20

Results – Effects of Multipath Propagation



DAB Mode	1	2	3	4
Cyclic Prefix Length	504	126	63	252

Conclusions

Conclusions

- Real-time processing is possible
- FIBs successfully decoded
- No audio yet

Challenges

- Very efficient algorithms and programming needed
- Many signal processing papers are written from a primarily mathematical perspective

Advantages

- Same code for simulation and actual receiver
- Open source code of existing blocks helps understand algorithms
- Existing code can sometimes be adapted for new purposes
- GNU Radio: Large and enthusiastic community

Questions?

Thank you for your attention.