Physical Layer Specification of the L-band Digital Aeronautical Communications System (L-DACS1)

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Overview

- System Characteristics
- Deployment Concepts
- Physical Layer Specification
  - System Parameters
  - FL/RL Frame Types
  - Framing Structure
- Receiver Design
  - Channel Estimation
- Simulation Results
- Conclusions

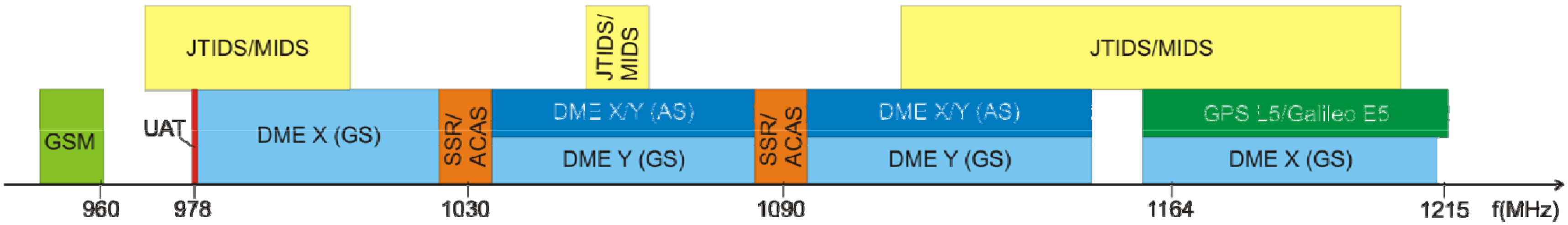
System Characteristics

- L-DACS1 is the broadband candidate for future L-band areonautical communication system
  - Based on B-AMC in combination with P34 and WiMAX features
- A/G communication system providing various ATS and AOC services
- Optimized for data communications; voice communications optional
- Cellular structure with L-DACS1 ground station as central unit controlling multiple aircraft (target operational range: 200 nm)
- Designed to meet requirements of future aeronautical communication system (according to COCR)

- L-DACS1 is based on Orthogonal Frequency Division Multiplexing (OFDM)
- Forward and Reverse Link (FL/RL) separated by Frequency Division Duplex (FDD)

Deployment Options

- Current L-band usage



- Inlay system between adjacent DME channels
  - FL: 985.5 – 1008.5 MHz
  - RL: 1048.5 – 1171.5 MHz
  - No new channel assignments required
  - Strong interference from other L-band systems
- Non-inlay system in free spectrum
  - Requires new channel assignments
- Mixed approach

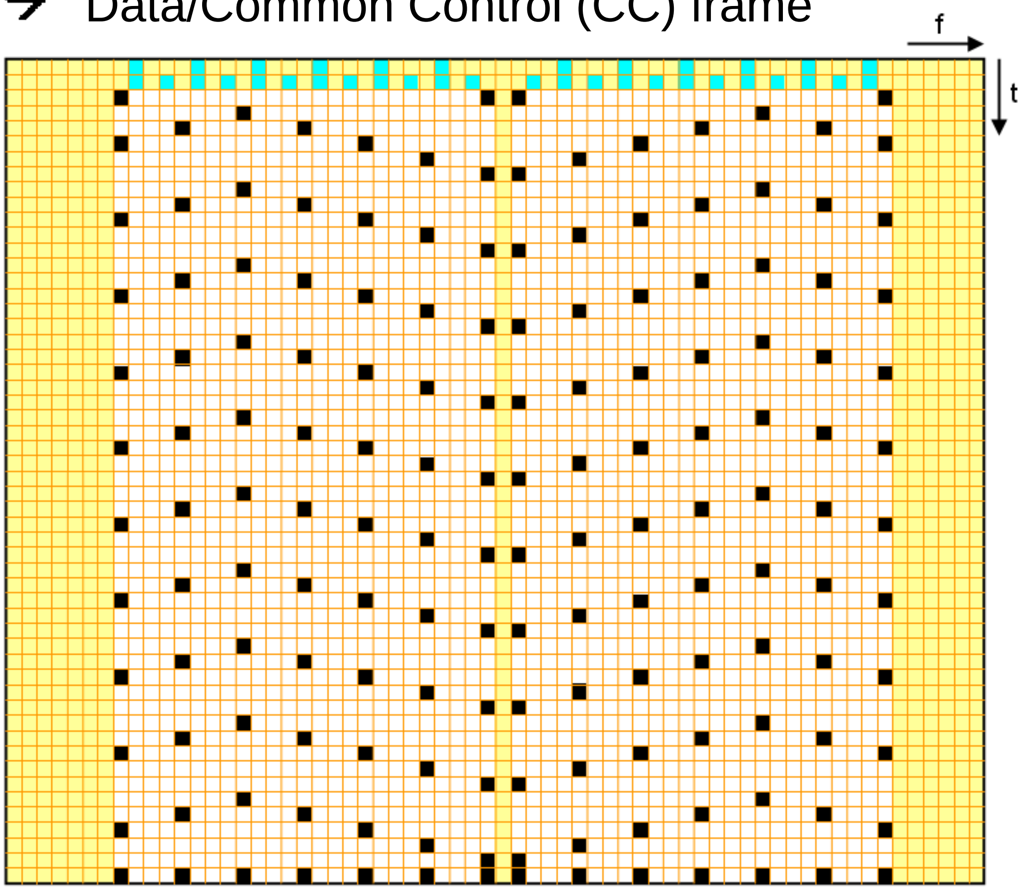
Physical Layer Specification
L-DACS1 Parameters

- FL: pure OFDM, continuous transmission
  - Broadcast and addressed user and control data
- RL: OFDMA-TDMA bursts assigned to different users
  - Duty cycle per user can be minimized to keep interference towards onboard L-band systems at a minimum
- OFDM parameters:

Parameter	**Value**
Effective bandwidth (FL or RL)	498.05 kHz
Sub-carrier spacing	9.765625 kHz
Used sub-carriers	50
FFT length	64
OFDM symbol duration	102.4 μs
Cyclic prefix (guard + windowing time)	17.6 μs = 4.8 μs + 12.8 μs
Total OFDM symbol duration	120 μs

Physical Layer Specification
Forward Link Frames

- Data/Common Control (CC) frame

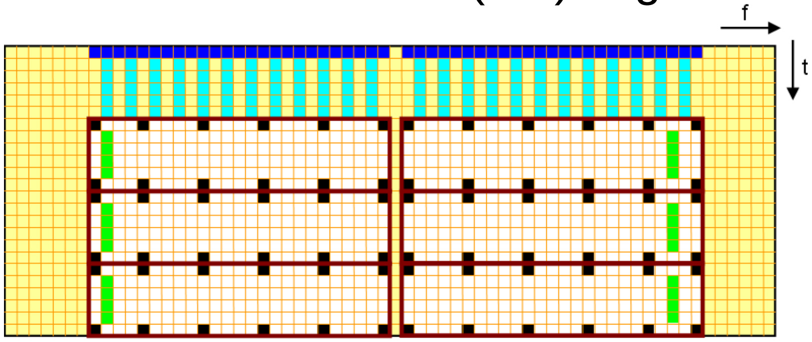


- **Sync symbols** for time and frequency synchronisation
- **Pilot symbols** for channel estimation
- **Guard sub-carriers**

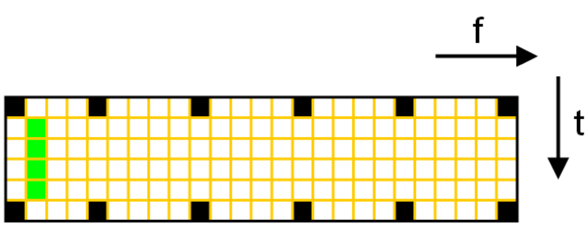
- Duration: 6.48 ms
- Total data capacity:
  - 2442 symbols

Physical Layer Specification
Reverse Link Frames

- Tiles and segments to realize multiple-access via OFDMA-TDMA
- Dedicated control (DC) segment



- One tile of the data segment

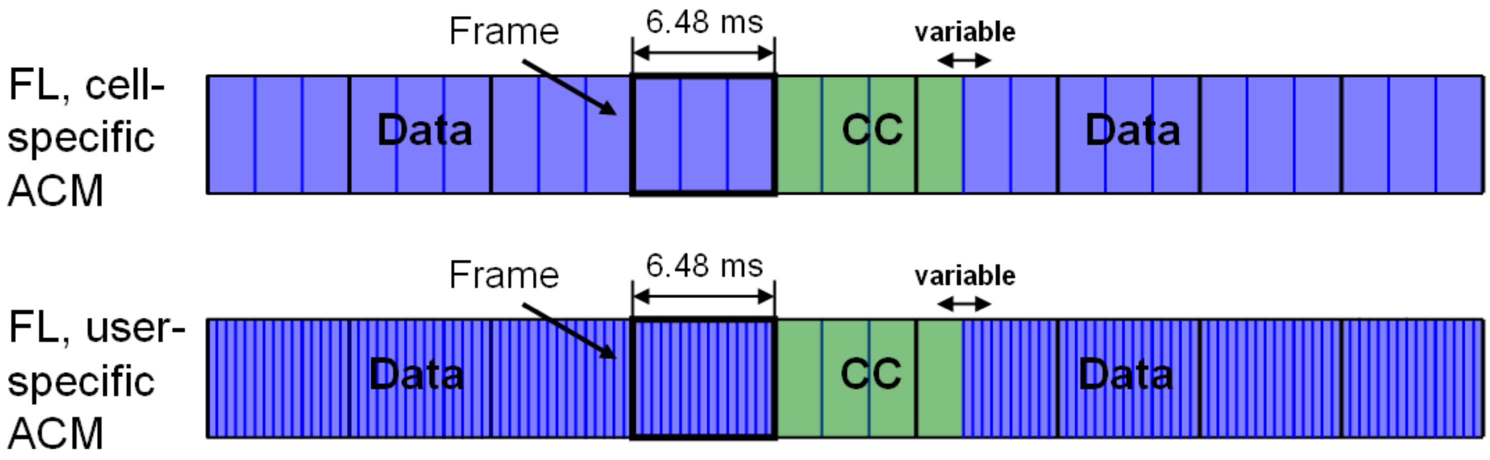


- **AGC preamble**
- **Sync symbols** for time and frequency synchronisation
- **Pilot symbols** for channel estimation
- **Guard sub-carriers**
- **PAPR** symbols

- Capacity per tile:
  - 134 symbols

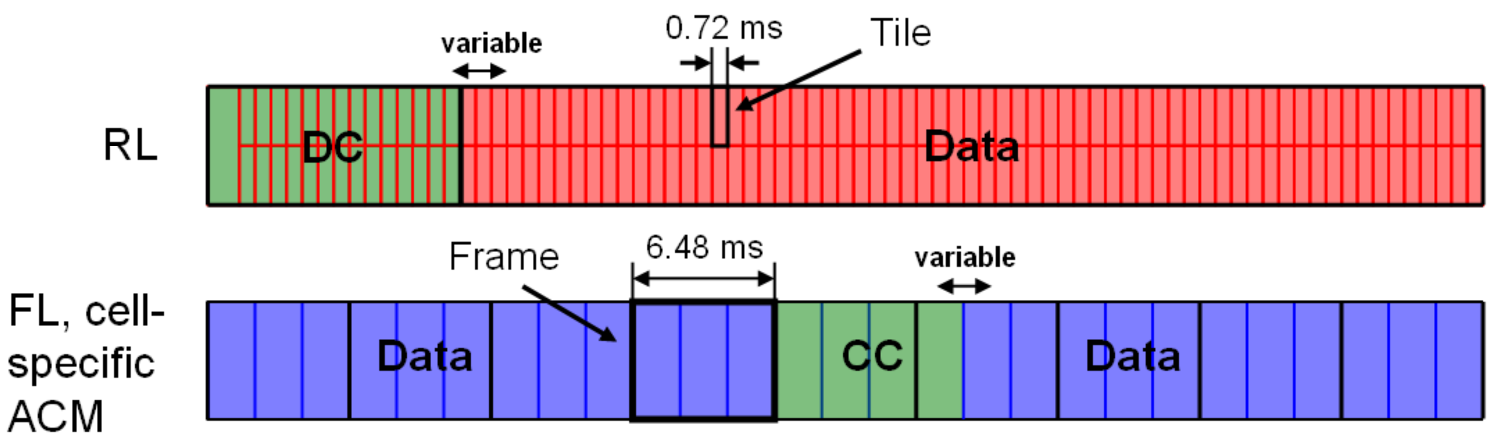
Physical Layer Specification
Multi-Frame Structure (FL)

- 9 CC/Data frames form one multi-frame
- 3 or 15 Data PHY-PDUs mapped onto one frame (depending on ACM mode)
- Variable length of CC frame, carries 1-12 CC PHY-PDUs



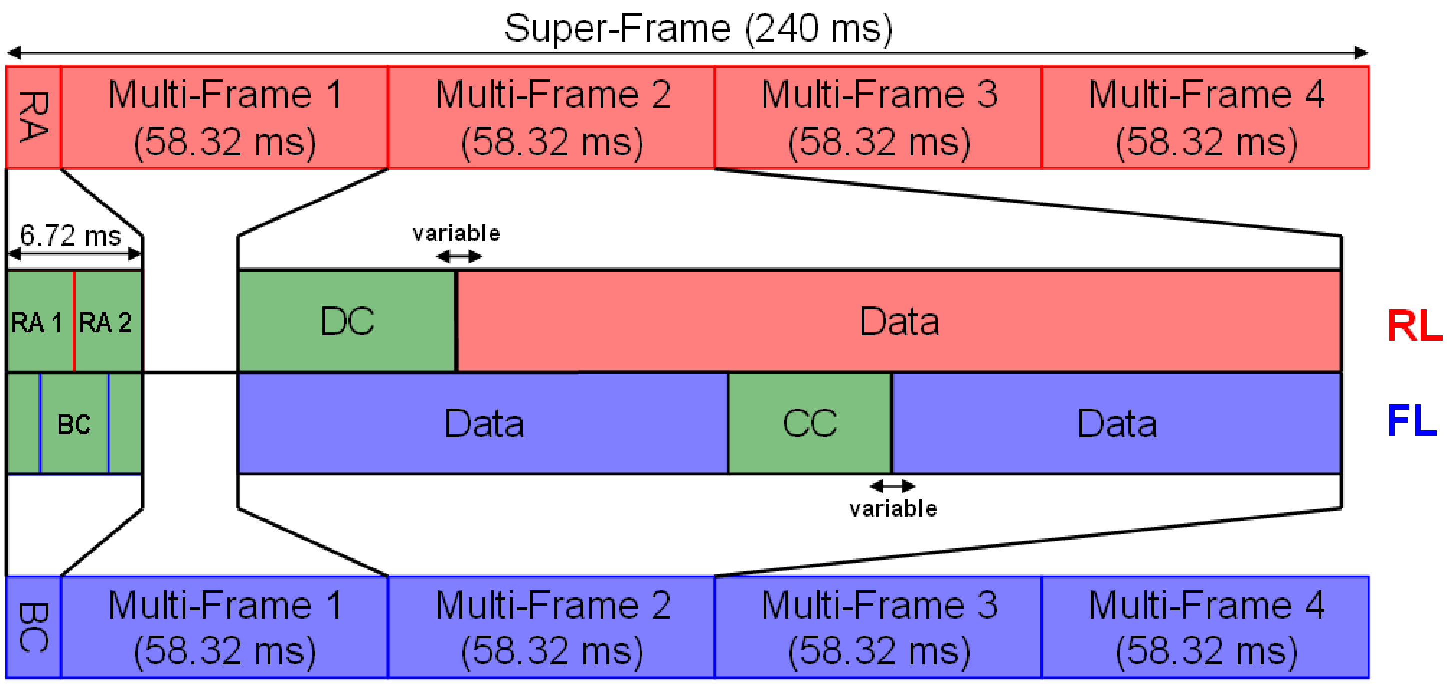
Physical Layer Specification
Multi-Frame Structure (RL)

- Variable length of DC segment
  - Maximum length: 52 tiles
- Remainder filled with data segment
- FL and RL synchronized to beginning of multi-frame
- Time shift between RL DC segment and FL CC segment
  - Requests sent in the DC segment can be answered in the CC PHY-PDU of the same multi-frame



Physical Layer Specification
Super-Frame Structure

- Four multi-frames form one super-frame
- Broadcast (BC) frame in FL for broadcast cell information
- Two random access (RA) opportunities in RL for net entry



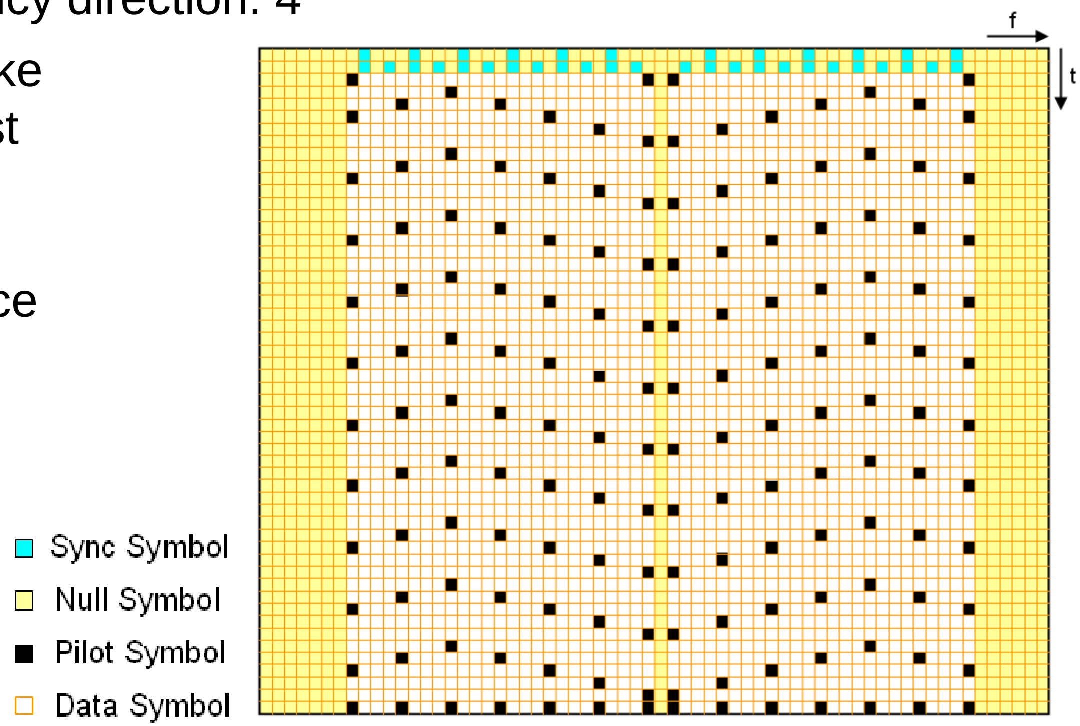
Physical Layer Specification
Coding and Modulation

- Concatenated convolutional and Reed-Solomon code to achieve interference robustness
- Adaptive Coding and Modulation (ACM)
  - User-specific ACM: Different coding and modulation scheme for each user (in FL and RL)
  - Cell-specific ACM: Same coding and modulation scheme is used in entire cell (announced in FL BC channel)
  - 8 different coding and modulation schemes

- FL data rates: (2 CC PHY-PDUs, 25 Data PHY-PDUs per MF)
  - 303.3 to 1373.3 kbit/s
- RL data rates: (DC segment contains 20 tiles)
  - 220.3 to 1038.4 kbit/s

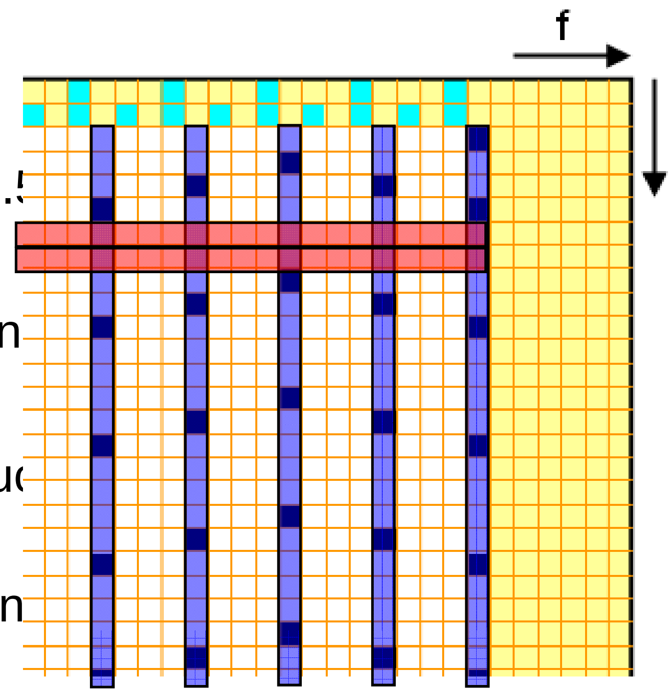
Receiver Design
Channel Estimation

- Pilot pattern (FL):
  - Distance in time direction: 5
  - Distance in frequency direction: 4
- No regular pattern to make channel estimation robust towards interference (only a few pilot symbols affected when interference occurs)



Receiver Design
Channel Estimation

- Linear interpolation
  - 1st step: interpolation in time direction
  - 2nd step: frequency direction
- Improvements:
  - Pilot boosting
    - Higher power on pilot tones (+2.5
  - Pilot erasure setting
    - Pilot tones affected by interferen
  - Pilot reconstruction
    - Erased pilot tones are reconstruc
      tones on the s arrier
  - Pulse blanking in ti Rx sign

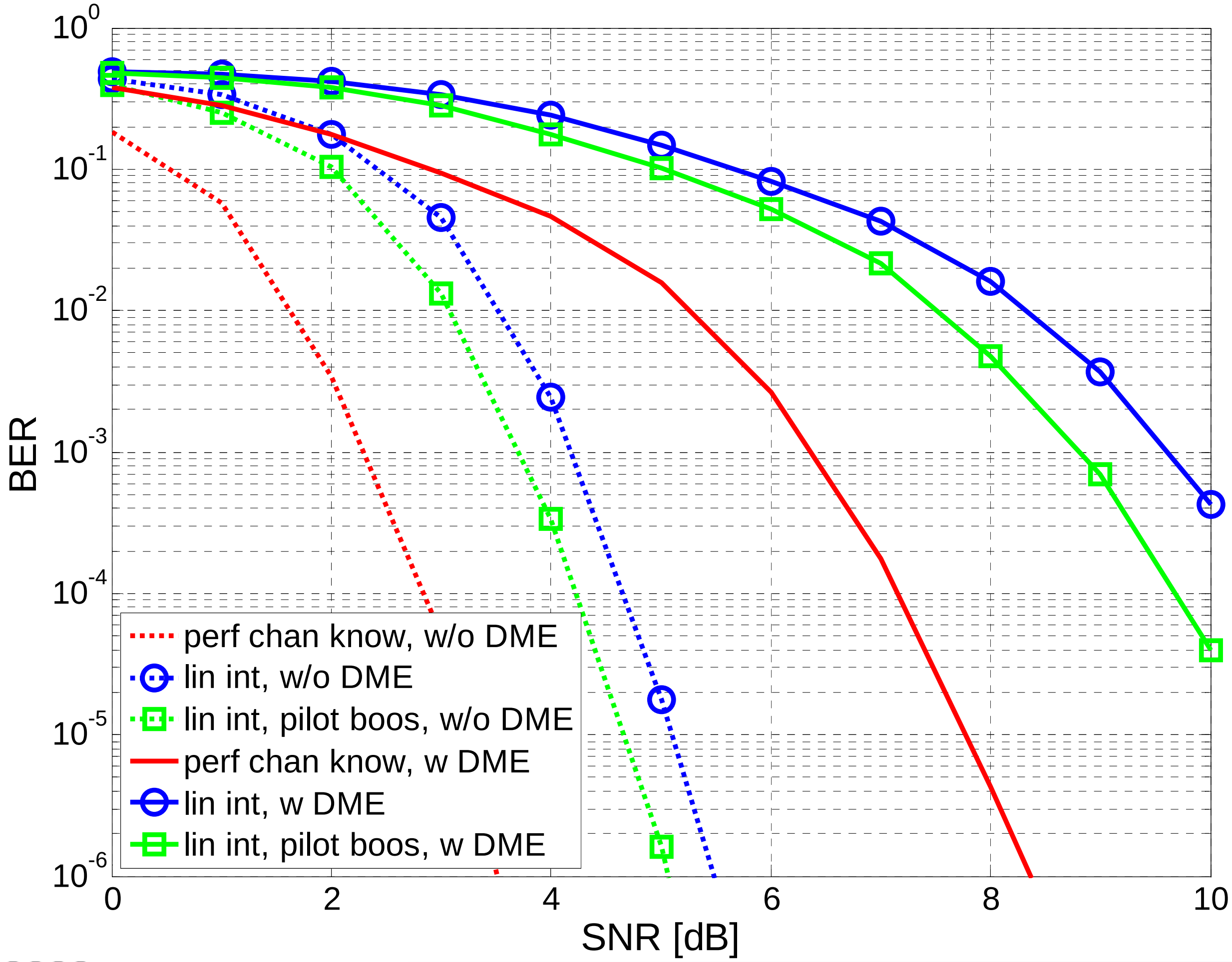


Simulation Results
Simulation Parameters

- QPSK and convolutional code, rate ½
  - No Reed-Solomon code
- En-route channel model:
  - 1.25 kHz Doppler shift
  - Strong line-of-sight path
  - Two delayed paths
- Interference scenario (FL):

Station	Frequency	Interference power at victim Rx input	Pulse rate
TACAN	995 MHz	-67.9 dBm	3600 ppps
OFDM	995.5 MHz		
TACAN	996 MHz	-74.0 dBm	3600 ppps
TACAN	996 MHz	-90.3 dBm	3600 ppps

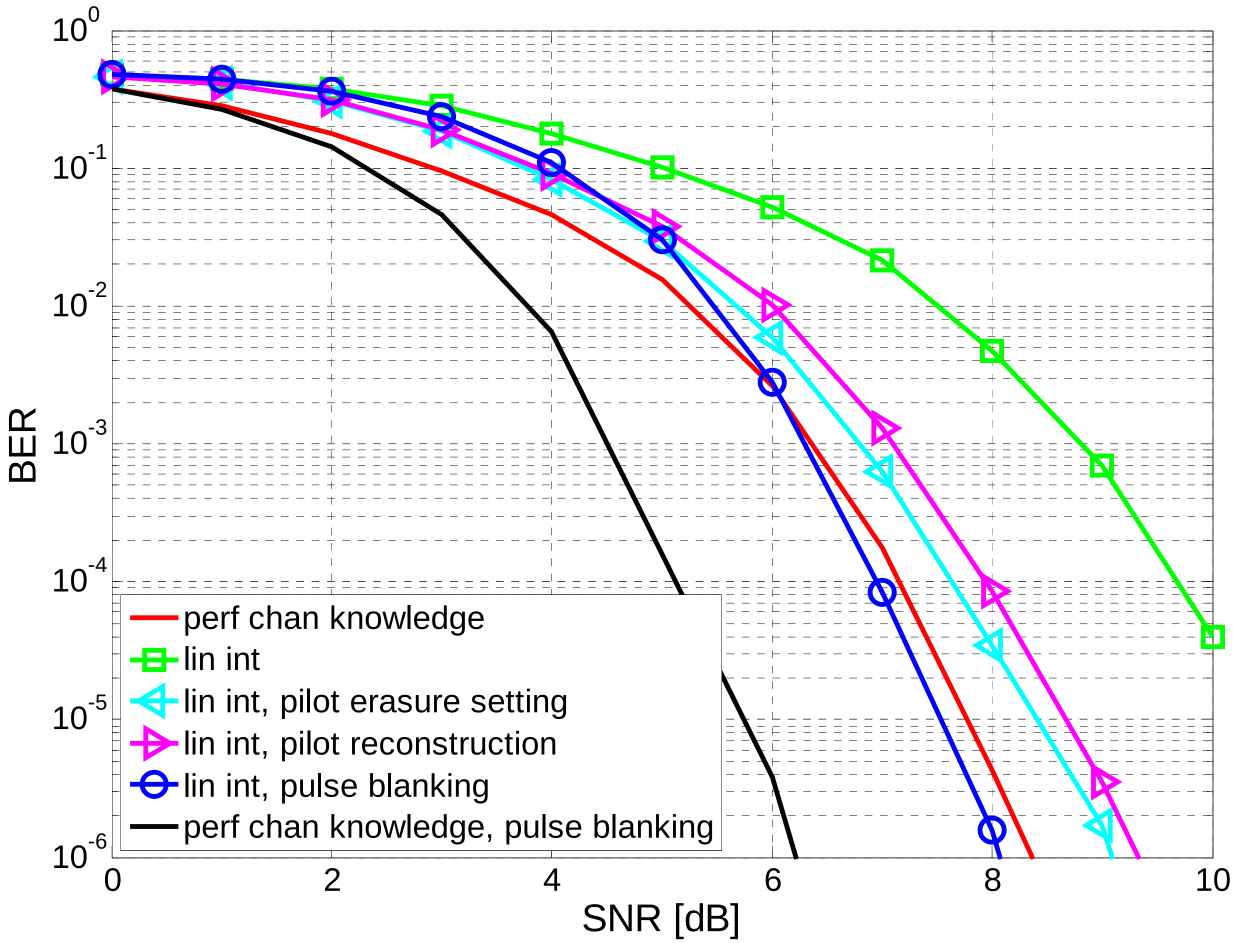
Simulation Results
Pilot Boosting



- Linear interpolation w/o pilot boosting
- Lin. interpolation w/ pilot boosting

- Improvements with pilot boosting
- Gap to perfect channel estimation remains

Simulation Results
Improved Channel Estimation



- Improvements by:
- Pilot reconstruction
  - Not as good as expected
- Pilot ersure setting
  - Gap to perfect CE reduced to 0.4 dB!
- Better results with pulse blanking
  - Gap to perfect CE with pulse blanking due to ICI

Conclusions

- L-DACS1 is broadband candidate for future A/G communication system
- Physical layer design:
  - Flexible design to enable inlay and non-inlay deployment
  - Flexible framing structure allows for adapting transmission of control and user data to current requirements
- Receiver design:
  - Pilot pattern chosen to make channel estimation robust towards interference
  - Good results for pilot-aided linear interpolation in the interference-free case
  - With interference, improvements with pilot boosting and pilot erasure setting
  - Performance of perfect channel estimation almost reached