B-AMC
Detailed Project Results

Prepared by B-AMC Consortium

Presented by Michael Schnell

Overview

- Introduction
  - Project scope
  - Deployment Options
- B-AMC System Description
  - From B-VHF to B-AMC
  - System Parameters
- B-AMC Interference Assessment
  - Impact on L-Band Systems (UAT, SSR, DME)
- B-AMC Performance Assessment
  - Performance in L-Band Interference (DME, JTIDS/MIDS)
- B-AMC System Deployment
- Conclusions

Introduction

- Project Scope
  - Design a B-VHF like system for L-band use (B-AMC)
  - Conclusion if B-AMC can be successfully operated in L-band

- ECTL L-Band Deployment Options
  - Option 1: Deployment between DME channels without any frequency planning
    Study result: Not feasible assuming worst-case conditions
  - Option 2: Deployment between DME channels with frequency planning for B-AMC
    Study result: Possible option even under worst-case conditions
  - Option 3: Deployment in “green” spectrum
    Preferred option for A/A mode, not required for A/G mode

B-AMC System Description

- From B-VHF to B-AMC
  - B-VHF as baseline for
    - B-AMC functional scope
    - B-AMC physical layer
    - B-AMC protocol
  - B-AMC functional scope
    - B-AMC supports data link and (optionally) voice communications
    - B-AMC covers all A/G ATS and AOC services
    - B-AMC supports A/G multi-link and multi-service communications
    - B-AMC extends B-VHF functional scope (not further discussed)
      - Complete A/A connectivity (A/A mode)
      - High-speed point-to-point links (OPR areas)

B-AMC System Description

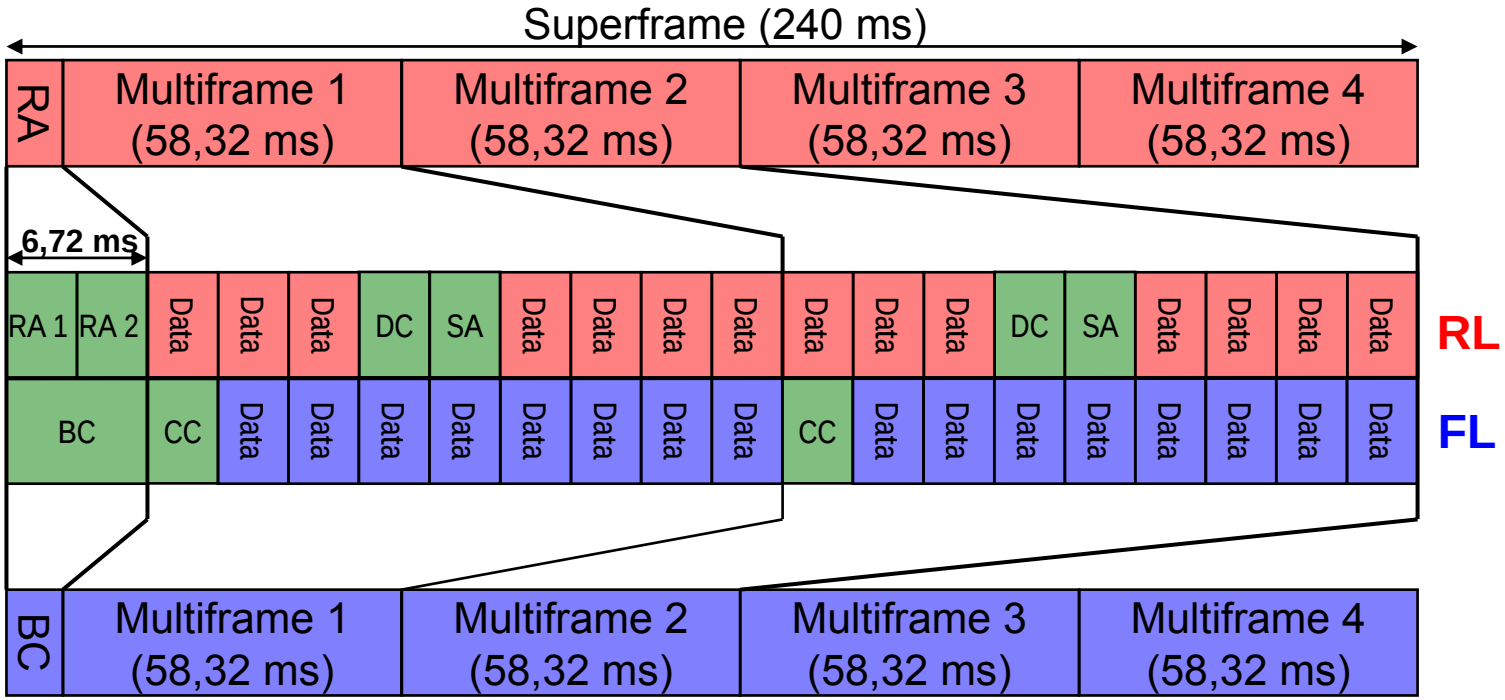
- From B-VHF to B-AMC
  - B-AMC physical layer adjustments
    - Duplex scheme changed from TDD to FDD
    - Forward link access changed from MC-CDMA to OFDM(A)
    - Reverse link remains OFDM(A), additional TDMA component
    - OFDM parameters adapted to L-band use
  - B-AMC protocol adjustments
    - Re-designed framing structure (FDD, OFDM parameters)
    - Physical layer adjustments allow improved DLL design
      - Dedicated MAC RL opportunities to reduce latency/delays
      - Highly flexible DLL ensures optimal trade-off between user capacity and latency/delays

B-AMC System Description

- System Parameters
  - Channel bandwidth: $B = 500$ kHz
  - Length of FFT: $N_c = 64$
  - Used sub-carriers: $N_{c,used} = 48$
  - Number of cancellation carriers: $N_{cc} = 2x2$
    - Side-lobe suppression
  - Sub-carrier spacing (500/48 kHz): $\Delta f = 10.416$ kHz
  - OFDM symbol duration with guard: $T_{og} = 120$ µs
  - OFDM symbol duration w/o guard: $T_o = 96$ µs
  - Overall guard time duration: $T_g = 24$ µs
    - RC-window (roll-off 0.1) for side-lobe suppression (12 µs)
    - Large remaining guard interval (12 µs)
  - OFDM symbols per data frame: $N_s = 54$

B-AMC System Description

- Framing Structure



B-AMC System Description

- Achievable Data Rate per B-AMC Cell

Conv. code	R_{CC} = 1/2		R_{CC} = 2/3		R_{CC} = 3/4		R_{CC} = 1	
RS code	0.9	1	0.9	1	0.9	1	0.9	1
QPSK	272.16 kbit/s	302.4 kbit/s	362.88 kbit/s	403.2 kbit/s	408.24 kbit/s	453.6 kbit/s		
8-PSK		453.6 kbit/s		604.8 kbit/s		680.4 kbit/s		
16-QAM		604.8 kbit/s		809.4 kbit/s		907.2 kbit/s		
64-QAM		907.2 kbit/s		1209.6 kbit/s		1360.8 kbit/s		

- Strong/medium interference
- Weak interference, bad channel
- Weak interference, medium channel
- Weak interference, good channel

B-AMC Interference Assessment

- Characterised L-band TX, RX, and Antennas
- Characterised B-AMC RX and TX in A/G Mode
  - RX: Interference mechanisms clarified
  - TX: Spectrum mask proposed – OFDM side-lobes, IMD3 products and broadband noise considered
- Interference Towards B-AMC RX
  - Assessed as part of B-AMC performance investigations
- Interference From B-AMC TX
  - Assessed as min. required frequency/distance spacing (FD)
  - Based on calculated Frequency Dependent Rejection (FDR)

B-AMC Interference Assessment

- Airborne Co-site Interference Analysis
  - Airborne B-AMC RX is jammed by any co-located L-band TX
  - Mitigation techniques proposed
    - No airborne DME TX in B-AMC FL frequency range (985-1009 MHz)
    - Low duty-cycle of co-site interferers and strong FEC applied on FL allow for satisfactory operation of airborne B-AMC RX
  - Airborne B-AMC TX would jam any co-located L-band RX
  - Mitigation techniques proposed
    - Airborne B-AMC TX should operate with low duty-cycle
    - Usage of suppression bus recommended

B-AMC Interference Assessment

- Interference from B-AMC TX
  - Conservative assessment, no RF filtering after B-AMC TX and within front-ends of the victim L-band receivers
  - DME RX at 600 m distance requires Δf = 1.5…2 MHz
  - Airborne and ground SSR RX operate well at 600 m distance
  - Airborne aircraft does not impact GSM/UMTS ground RX
  - Airborne UAT RX at 600 m distance requires RF pre-filtering, e.g. duplexer as proposed by UAT implementation manual
  - Interference from ground B-AMC TX towards other ground RX is uncritical
- Interference towards B-AMC RX
  - B-AMC performance assessment

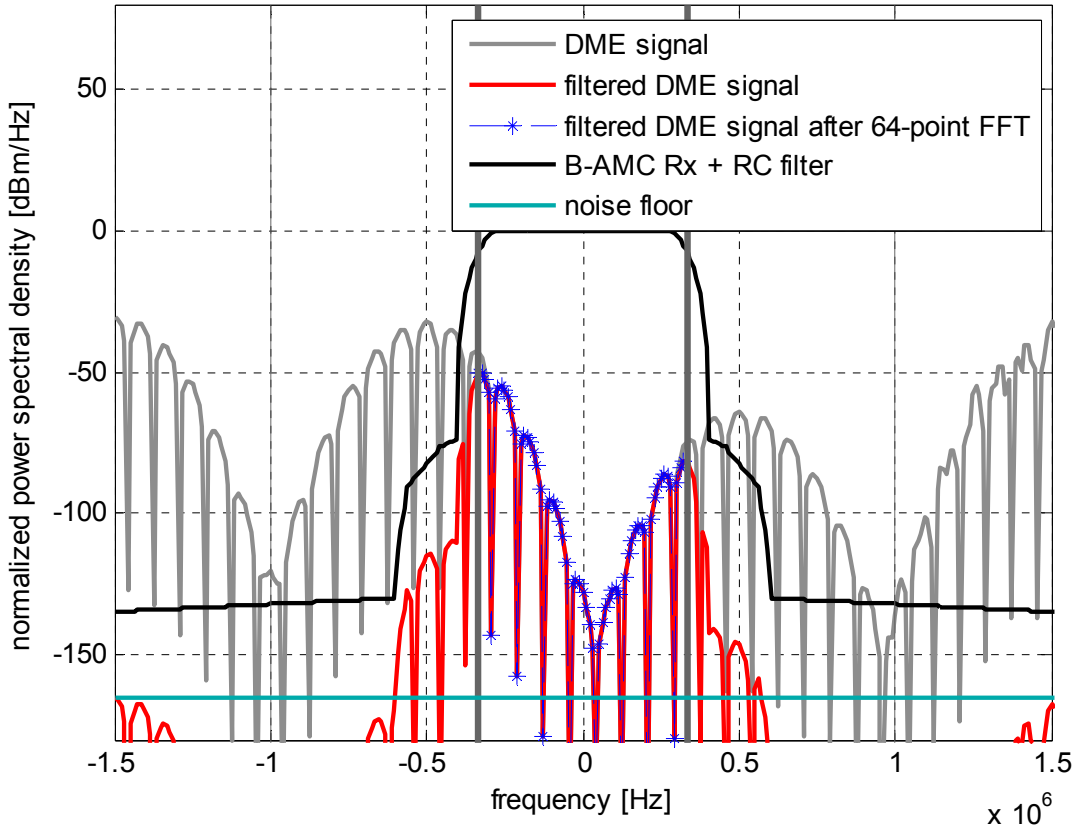
B-AMC Physical Layer Assessment

B-AMC Performance Assessment

- Channel Modeling
  - En-route channel model
  - Take-off/landing channel model
  - Parking channel model
- Interference Modeling
  - Worst case DME interference with frequency planning
    - Worst case European region (Paris CDG, highest DME density)
    - Frequency planning: Choose “best” B-AMC channel
    - All DME transmitters (GS, A/C) within radio horizon considered
    - Worst case duty cycle and realistic power distribution applied
  - Worst case JTIDS/MIDS interference
    - Fully-loaded system considered (max. number of supported A/C)
    - Realistic power distribution applied

B-AMC Performance Assessment

- Interference Modeling – DME, FL, En-route
  - Without frequency planning – interference at Rx



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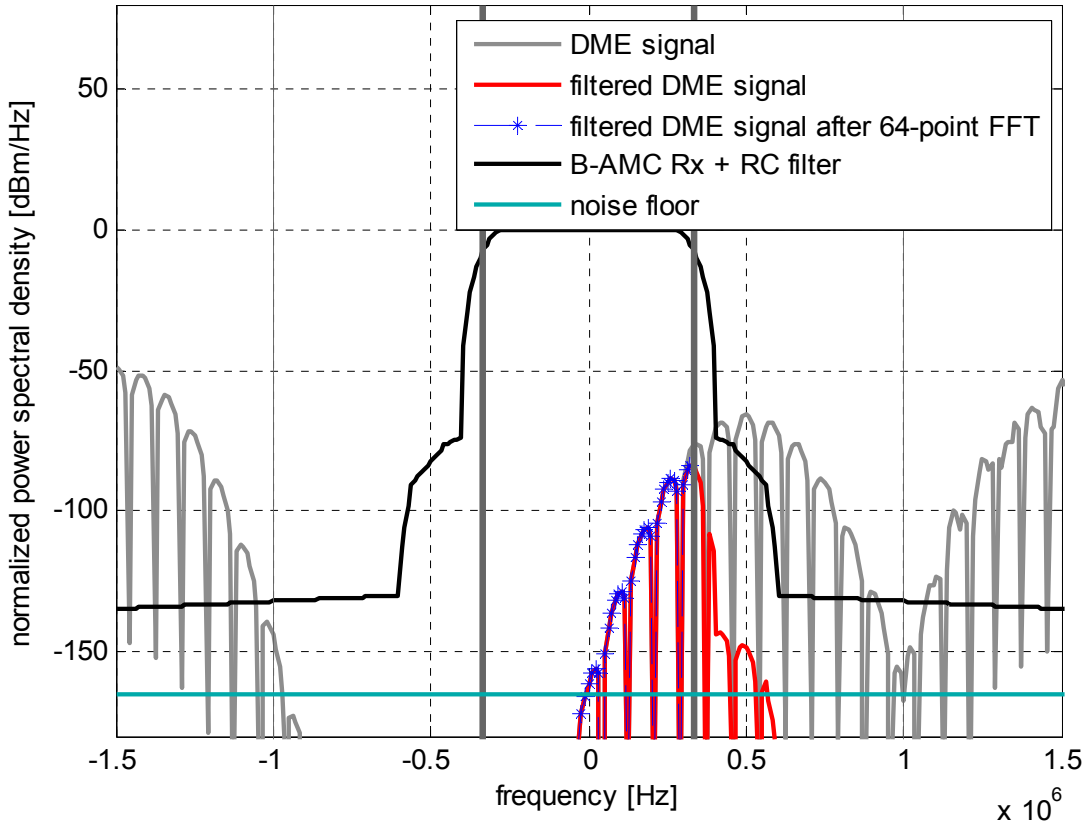
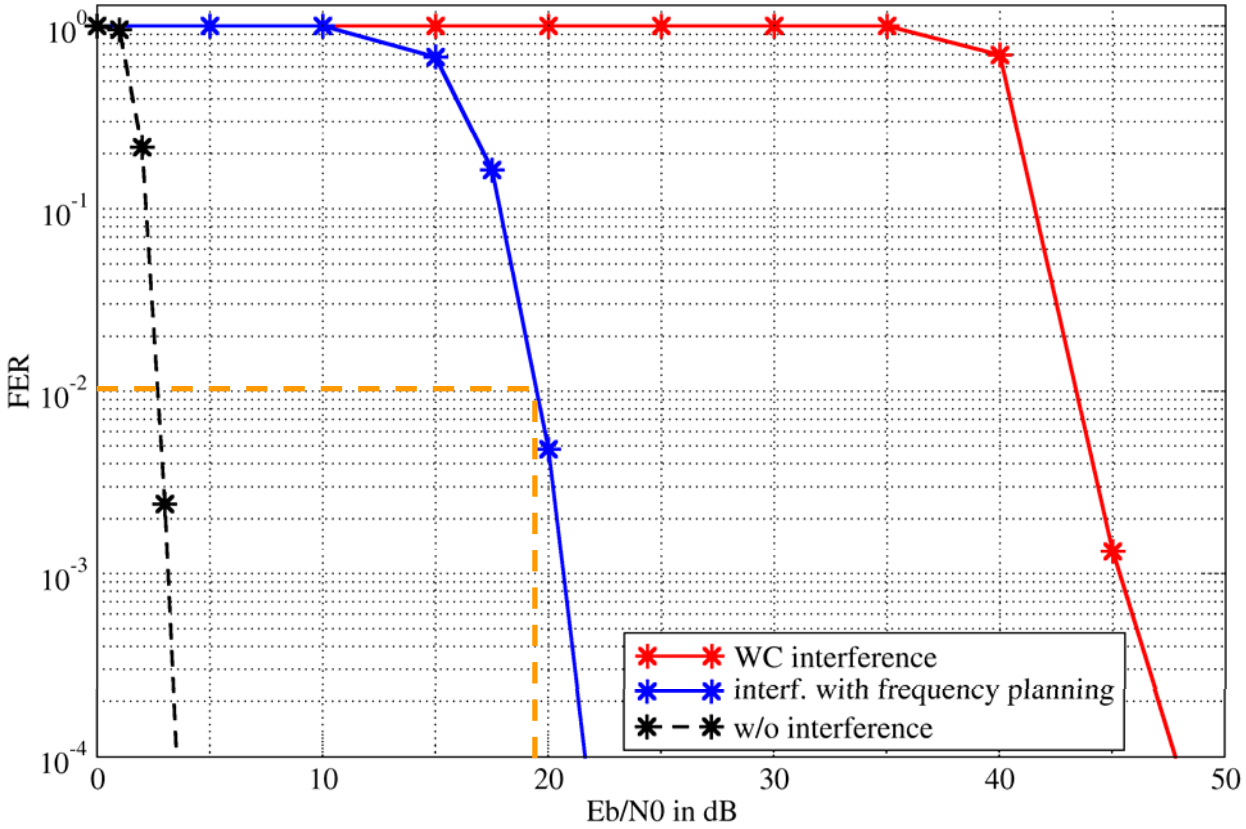


B-AMC Performance Assessment

- Simulation Results – DME, FL, En-route
  - FER vs. SNR, CC & RS coding without erasure decoding



B-AMC Performance Assessment

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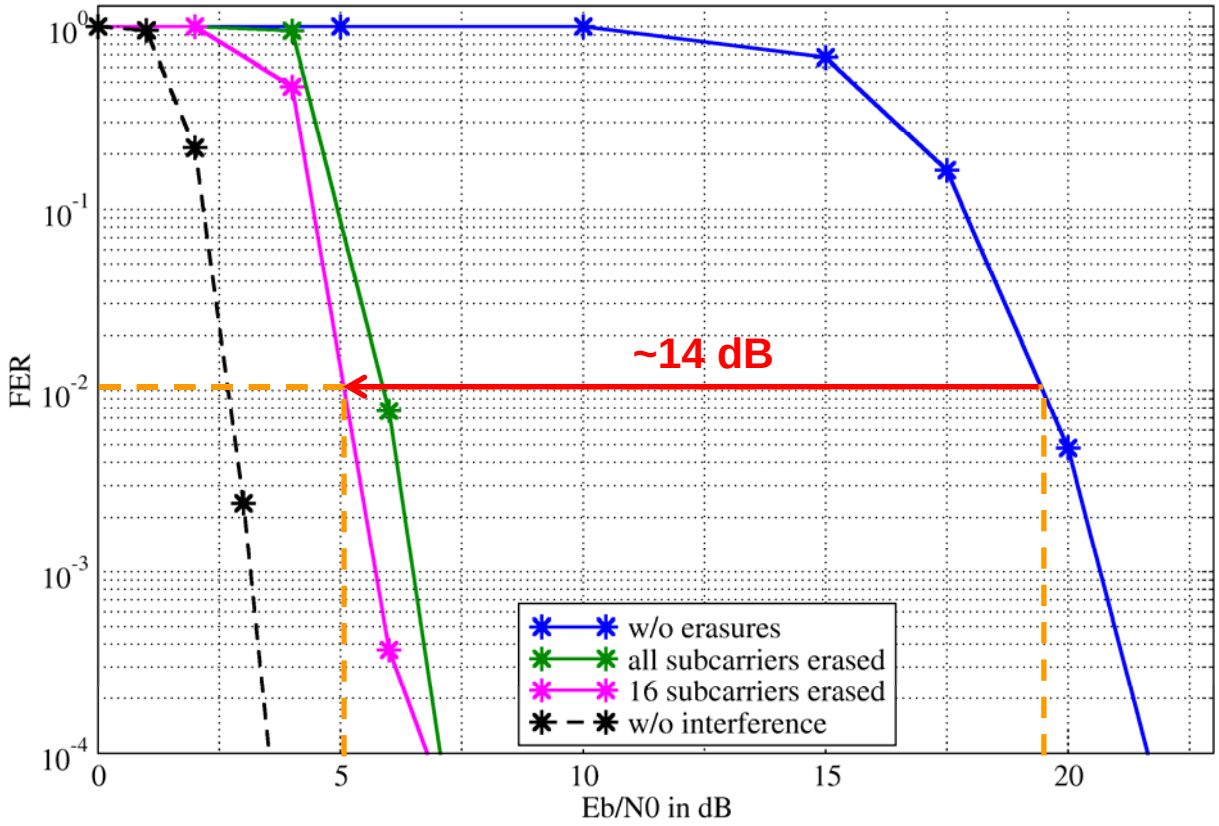
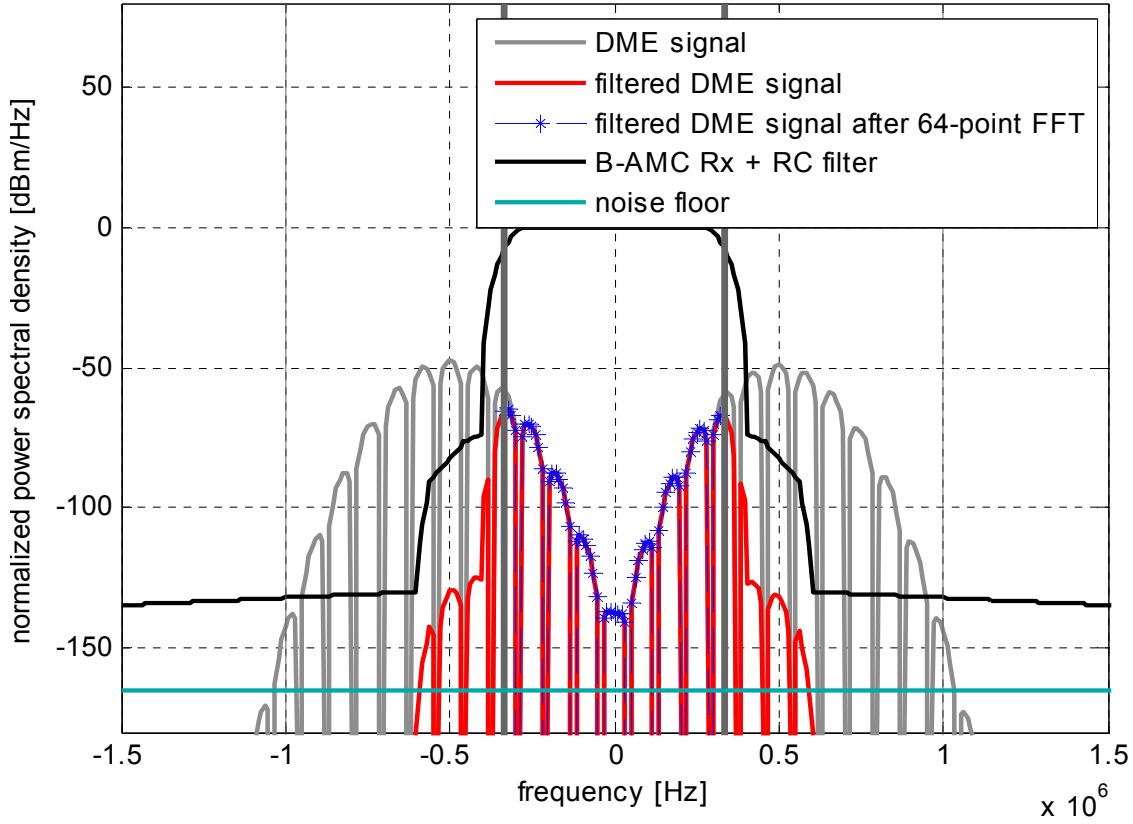


B-AMC Performance Assessment

- Interference Modeling – DME, RL, En-route
  - With frequency planning – interference at Rx



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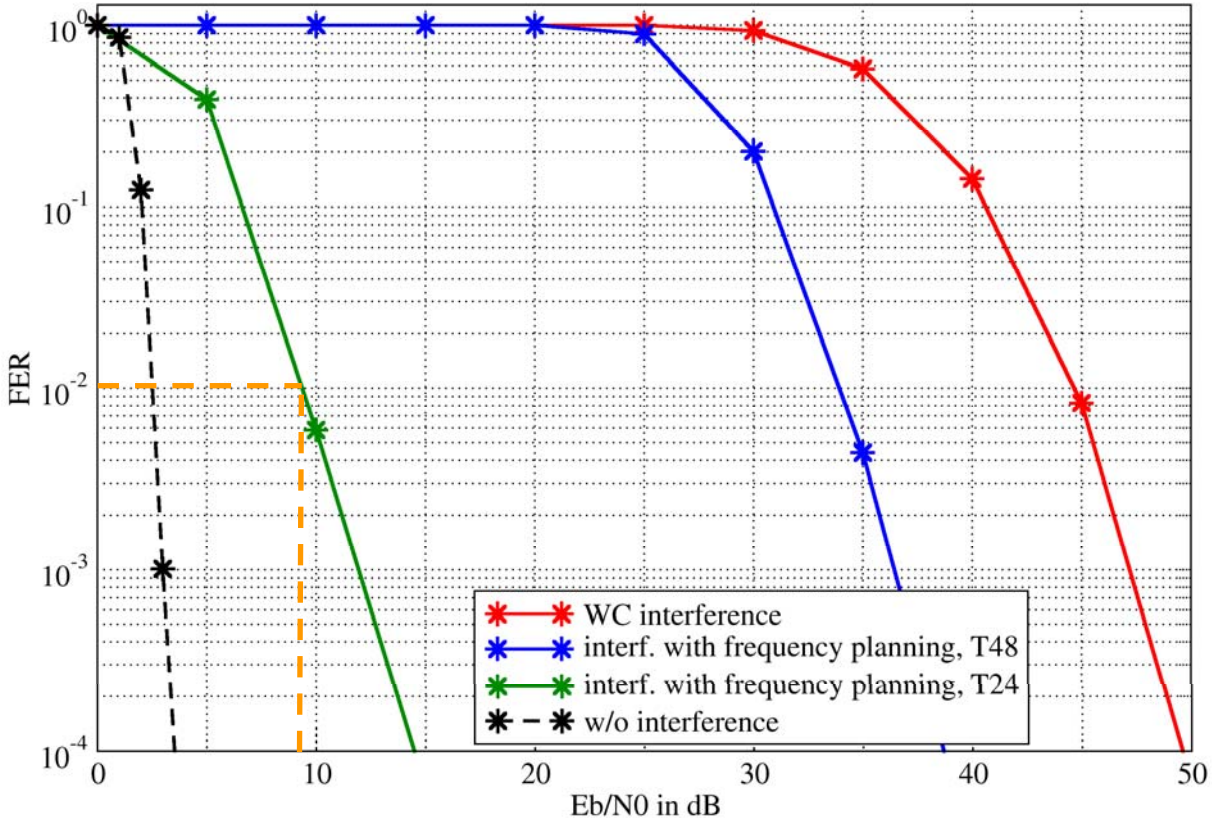
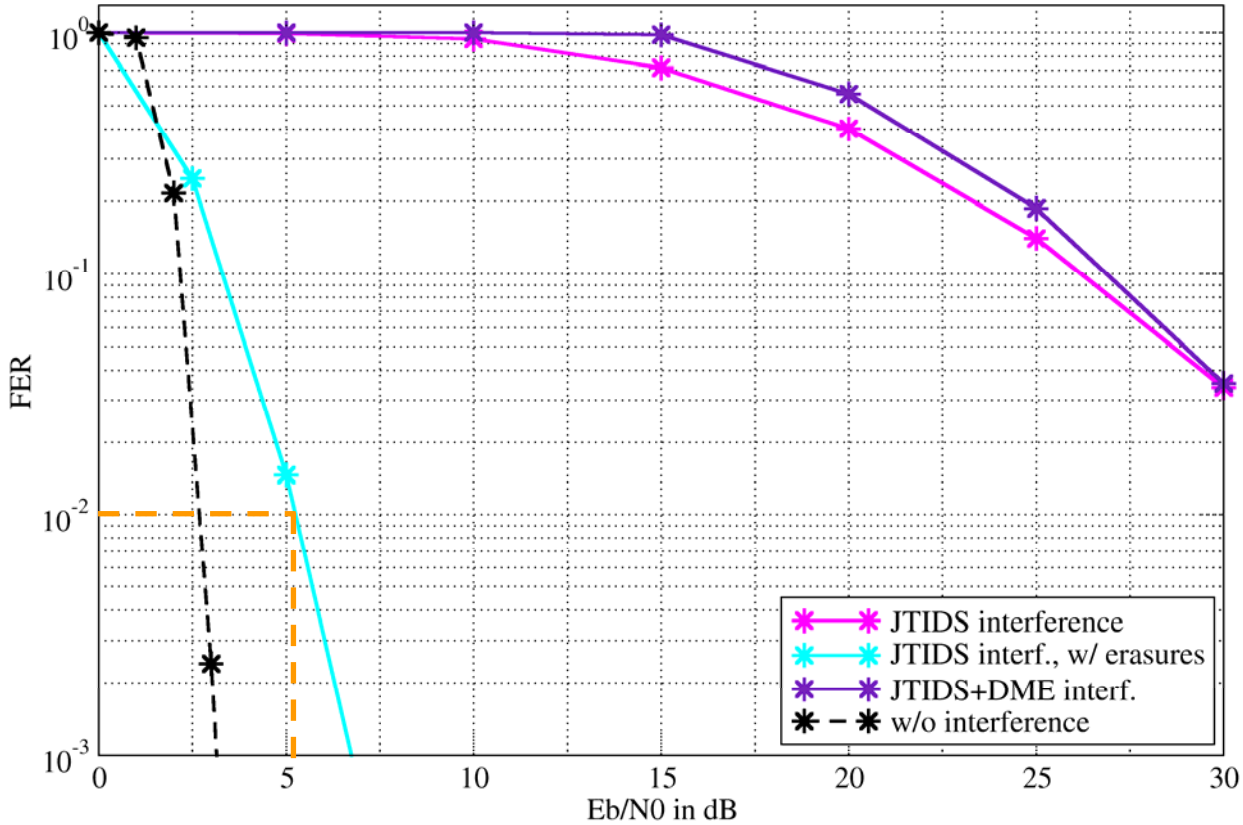


B-AMC Performance Assessment

- Simulation Results – DME & JTIDS/MIDS, FL, En-route
  - FER vs. SNR, CC & RS coding without/with erasure decoding



B-AMC Protocol Assessment

B-AMC Performance Assessment

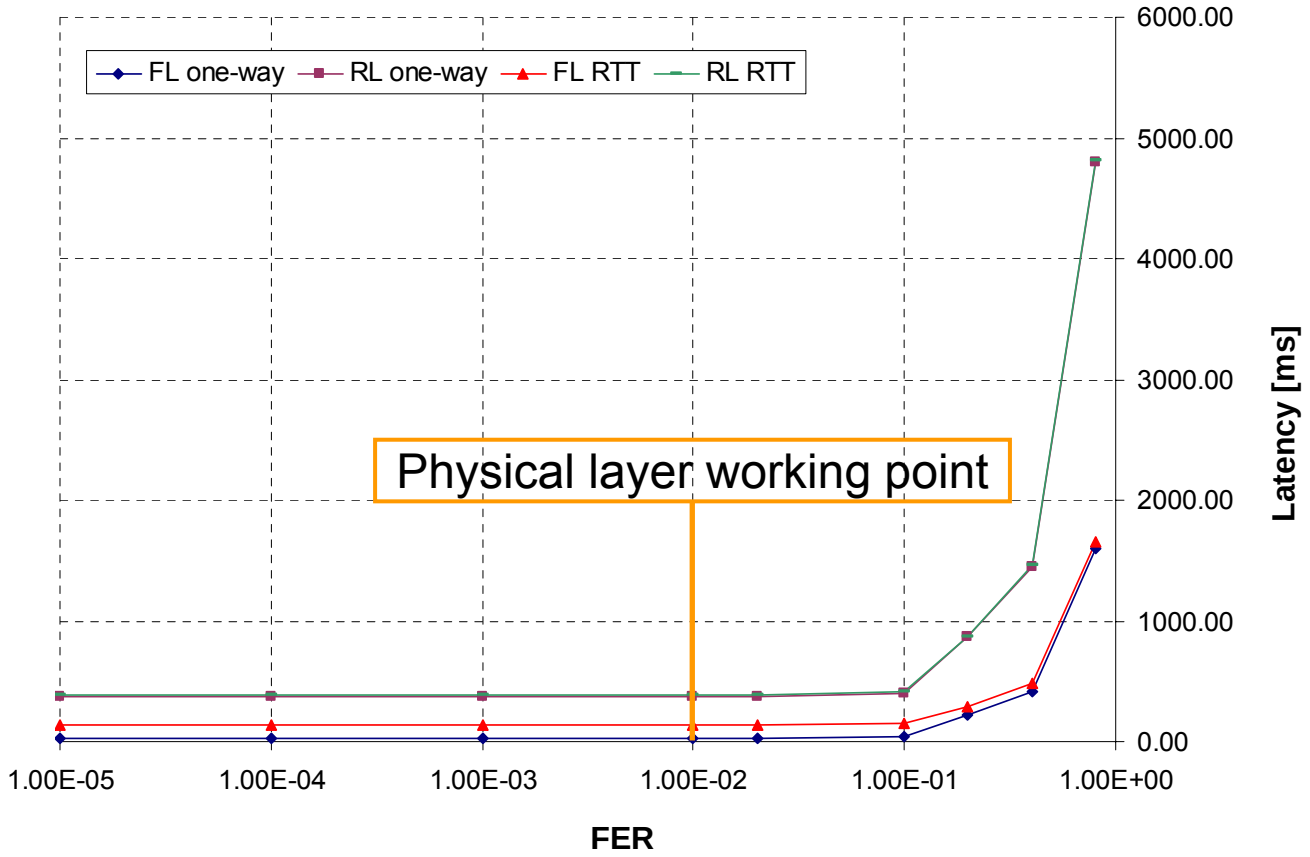
- Simulation Scenarios
  - Traffic requirements based on COCR

Scenario	PIAC	Capacity Requirement (kbps)							
		ATS Only, with A-EXEC		ATS + AOC, with A-EXEC		ATS Only, without A-EXEC		ATS + AOC, without A-EXEC	
		FL	RL	FL	RL	FL	RL	FL	RL
APT Surface	264	-	-	-	-	30	30	150	30
APT Zone	26	-	-	-	-	3	10	3	15
TMA Small	44	30	30	30	30	30	30	30	30
TMA Large	53	30	30	30	30	30	30	30	30
ENR Small	45	30	30	150	30	30	30	80	30
ENR Medium	62	30	30	150	30	30	30	100	30
ENR Large	204	30	40	300	40	30	40	200	40
ENR Super Large	522	40	50	500	50	40	50	500	50

Scenarios not simulated

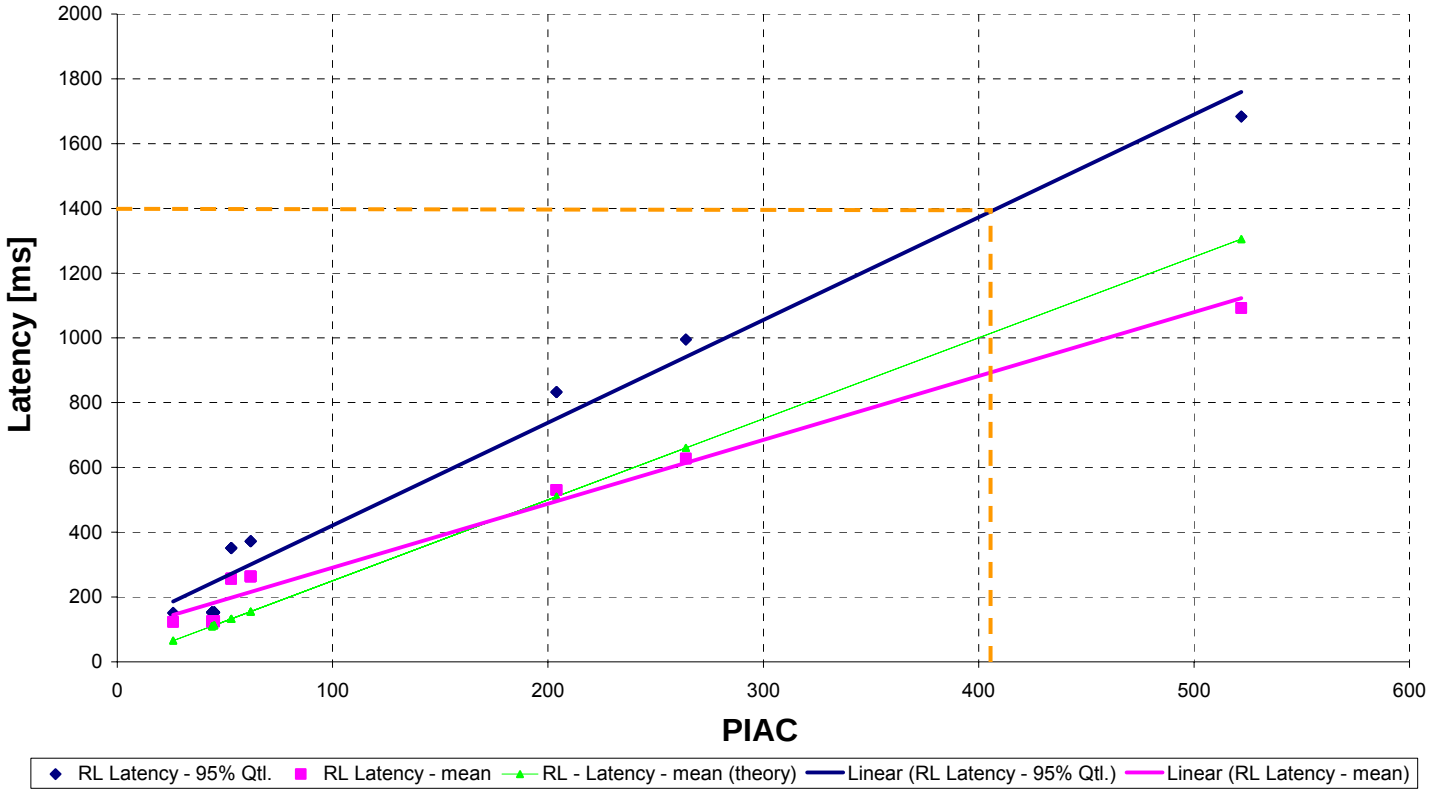
B-AMC Performance Assessment

- Simulation Results – Latency vs. FER
  - ENR Medium / ATS & AOC with A-EXEC



B-AMC Performance Assessment

- Simulation Results – Latency vs. PIAC (RL)



B-AMC Performance Assessment

- Summary of Protocol Simulation Results

Scenario	ATS Only, with A-EXEC		ATS + AOC, with A-EXEC		ATS Only, without A-EXEC		ATS + AOC, without A-EXEC	
	FL	RL	FL	RL	FL	RL	FL	RL
APT Surface								
APT Zone								
TMA Small								
TMA Large								
ENR Small								
ENR Medium								
ENR Large								
ENR Super Large								

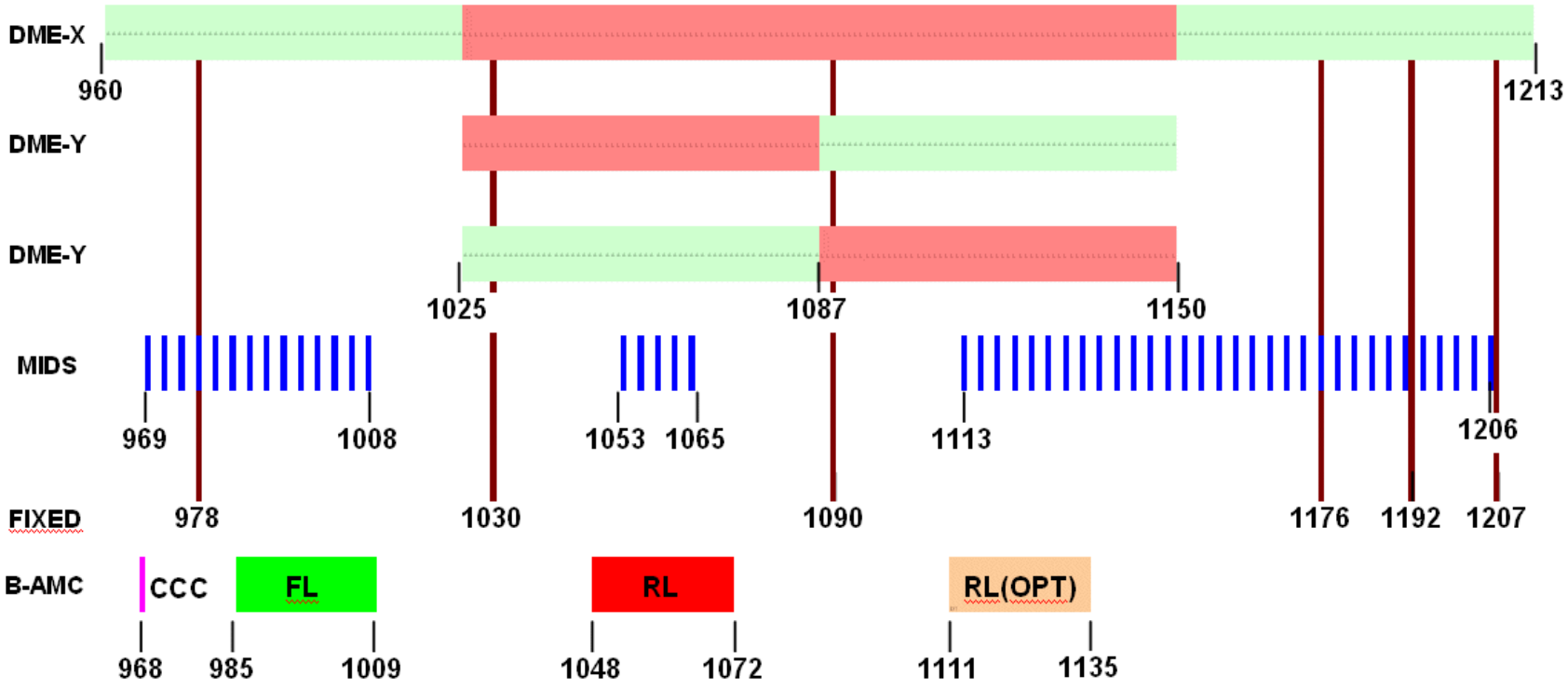
Latency
Continuity
Integrity

Fulfilled | Not fulfilled | Not simulated

- Priority handling (to be investigated)

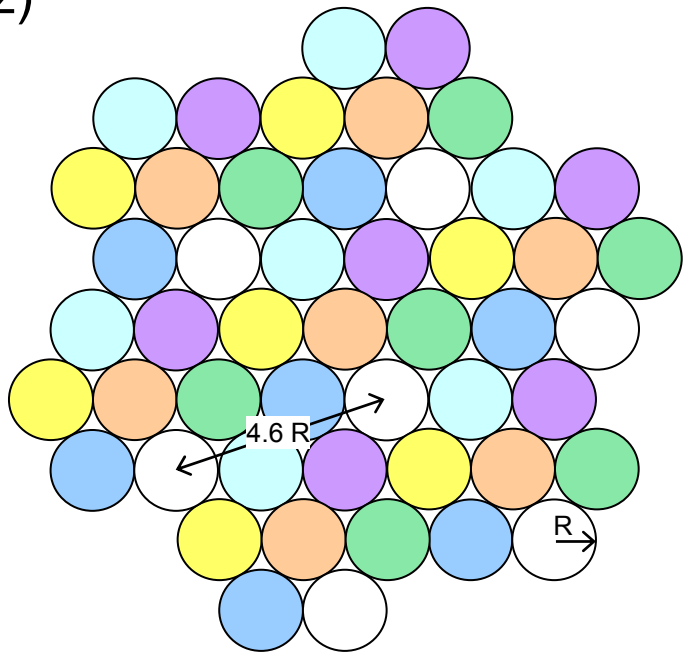
B-AMC System Deployment

- L-band Usage by B-AMC



B-AMC System Deployment

- Foreseen Frequency Ranges
  - Forward link: 985-1009 MHz
    - Large guard bands towards UAT and SSR
  - Reverse link: 1048-1072 MHz
    (optionally: 1111-1135 MHz)
    - Large guard bands towards SSR
- Frequency Re-use
  - Minimum cluster size: 3
  - Chosen cluster size: 7
  - Required cell distance: 4.6 R



Conclusions

- ECTL Option 2 is a Possible Strategy
- Interference Assessment for Option 2 (B-AMC TX)
  - Conservative assessment, no RF filtering after B-AMC TX and within front-ends of the victim L-band receivers
  - DME RX at 600 m distance requires Δf = 1.5…2 MHz
  - Airborne and ground SSR RX operate well at 600 m distance
  - Airborne aircraft does not impact GSM/UMTS ground RX
  - Airborne UAT RX at 600 m distance requires RF pre-filtering, e.g. duplexer as proposed by UAT implementation manual
  - Interference from ground B-AMC TX towards other ground RX is uncritical

Conclusions

- Performance Assessment for Option 2 (B-AMC RX)
  - B-AMC physical layer guarantees (average) FER < 10^{-2} with TX power less than +39 dBm (en-route, 200 nm)
  - B-AMC protocol fulfills all requirements (except ENR SL)
- B-AMC Copes With Worst-Case Interference in L-band
  - Worst-case DME interference
  - Worst-case JTIDS/MIDS interference
  - Critical: Worst-case DME and worst-case JTIDS/MIDS
  - Countermeasure: Interference-adjusted erasure decoding
- B-AMC as "Inlay" L-Band System ("Spectrum for Free")
- B-AMC in Green Spectrum: Much Higher Capacity

Further Work

- B-AMC Implementation Issues
  - Impact of real channel estimation
  - Impact of real synchronization
  - Filtering (baseband, IF, RF)
  - Amplifier (HPA)
- Further Improvements on PHY and Protocol
  - Interference adjusted decoding
  - Priority handling
- B-AMC Prototype Development
  - PHY and protocol
  - RF front-end
- Laboratory Interference Testing