CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT (CAASD)

Investigating an Interoperable Multi-Band A/G Aeronautical Communications Standard

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Introduction

History

- Future Communications Study (FCS), a joint study performed by FAA and EUROCONTROL to identify “a Future Globally Interoperable Communications System”
- Variety of digital communication technologies were investigated for their capability to supply data communication in the L-band (960 – 1024 MHz)

Motivation

- WRC-07 to make 112 – 117.975 MHz for Aeronautical Mobile Communication that follows ICAO standard
- FAA’s desire to maintain operations in VHF band for aeronautical A/G communications
- FCS roadmap alludes to far-term planning for flexible voice communications – including networked voice capabilities in VHF band

As a result, MITRE:

- Selected B-AMC since it was one of leading technology candidate from FCS
- Investigated feasibility of implementing **Broadband Aeronautical Mobile Communications (B-AMC)** in VHF band
- Determined potential of B-AMC in supporting networked voice communications

B-AMC Features

Broadband Aeronautical Mobile Communication (B-AMC) system

- **System Architecture**
  - **OFDM = Orthogonal Frequency-Division Multiplexing**
    - **Multiple subcarriers w/ QPSK or other modulation**
      - ✓ **Spectrally efficient**
      - ✓ **Multipath resistance**
      - ✗ **Non-constant envelope reduces power efficiency**
  - **Frequency Division Duplex (FDD)**
    - Information are sent on dedicated Forward (FL) or Reverse Link (RL) channel pair
    - Frequencies are separated by at least 5% of the nominal RF frequency (e.g., Using 136 MHz as nominal frequency, requires a 6-7 MHz separation)

- **Other parameters**

– **Band of Operation**	**L-band (960 – 1024 MHz)**
– **Multiple Access**	**Frequency Division Duplex (FDD)**
– **Size of FFT (total num. of subcarriers)**	$N_C = 64$
– **Channel Bandwidth**	**667 kHz**
– **Symbols per Data Frame**	$N_S = 54$
– **Subcarrier spacing (data only)**	$\Delta f = 10.416$ kHz = (500 kHz / 48)
– **Symbol Duration (w/ Guard)**	$T_{OG} = 120$ µs

Translating to a Different Frequency

"How are things different?"

- **Different RF environments**
  - **Different distortions to overcome**
    - Doppler effects
    - Multipath spreads
  - **Coexistence with other systems**

- **Different frequency resources available**
  - **Finite spectrum; so availability of sufficient spectral resources depends on capacity needs and frequency re-use factor**

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RF Environment

- **Environmental noise can limit range**
  - L-band has negligible environmental noise, while VHF has LARGE noise factor
- **Path loss is greater at L-band than VHF**
  - Loss (dB) ~ 20 Log (frequency)
  - Ex. L-band: 20 Log (1024 MHz) = <u>60dB</u>; compared with

    VHF: 20 Log (137 MHz) = <u>43dB</u>
- **Ultimately, these effects largely cancel out each other**

	L-Band (1024 MHz)	**VHF** (137 MHz)
Enviornmental Noise	Little ✔	20 dB ✖
Path Loss (free space)	144.02 dB ✖	126.55 dB ✔
Margin	9.91 dB	10.05 dB
Tx Power	10 watts	14.5 watts (avg.)

Similar in values. Therefore, attributes differences <u>even out</u>

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RF Environment (cont.)

- **Coexistence with other systems**
  - **L-band: DMEs**

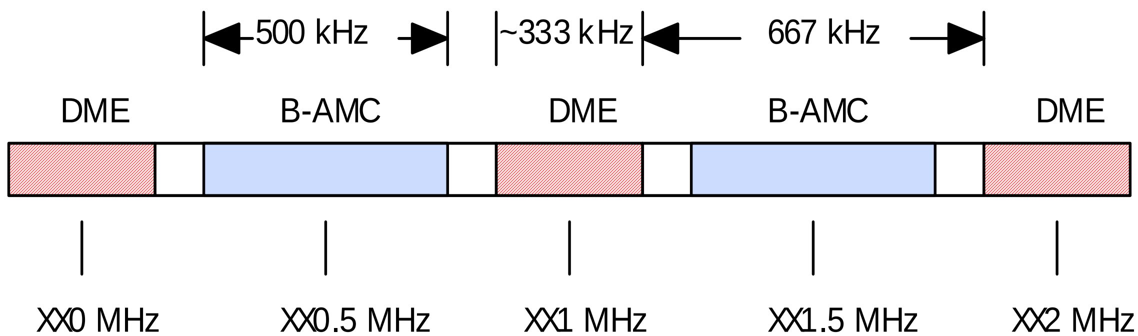
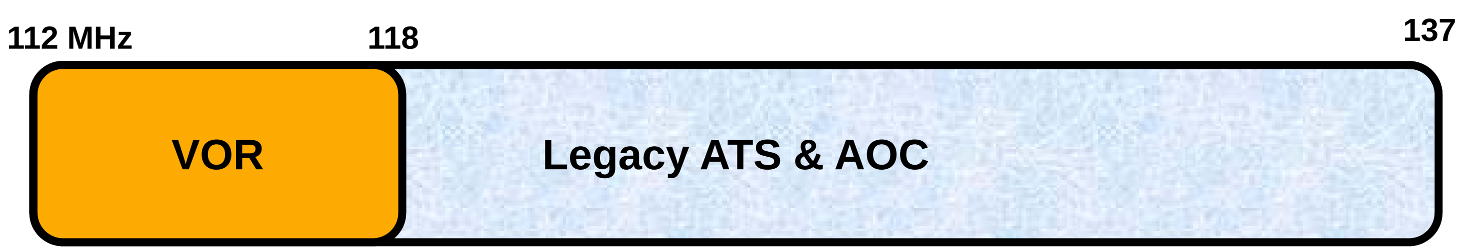


Figure: L-band Channel Plan

  - **VHF band: VORs, Legacy ATS & AOC**



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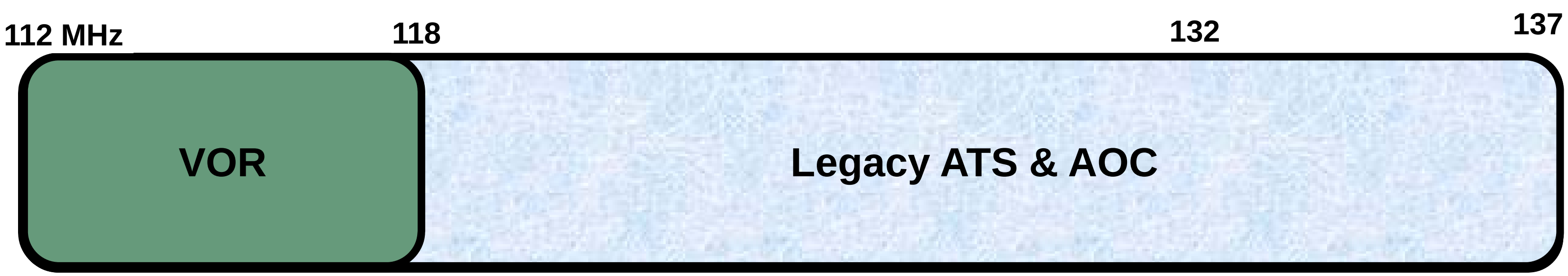
Available VHF Resources

- **Systems currently in VHF band**
  - Air Traffic Services (ATS) and Airline Operational Communications (AOC)
  - VHF Omnidirectional Range (VOR)
  - VDL-2 (data communications)
- **Obtaining available resources for transition to B-AMC in VHF band**
  - Divest or retune fractions of VORs
  - Repack ATS portion of the VHF spectrum
    - Shown to be feasible based on simulations



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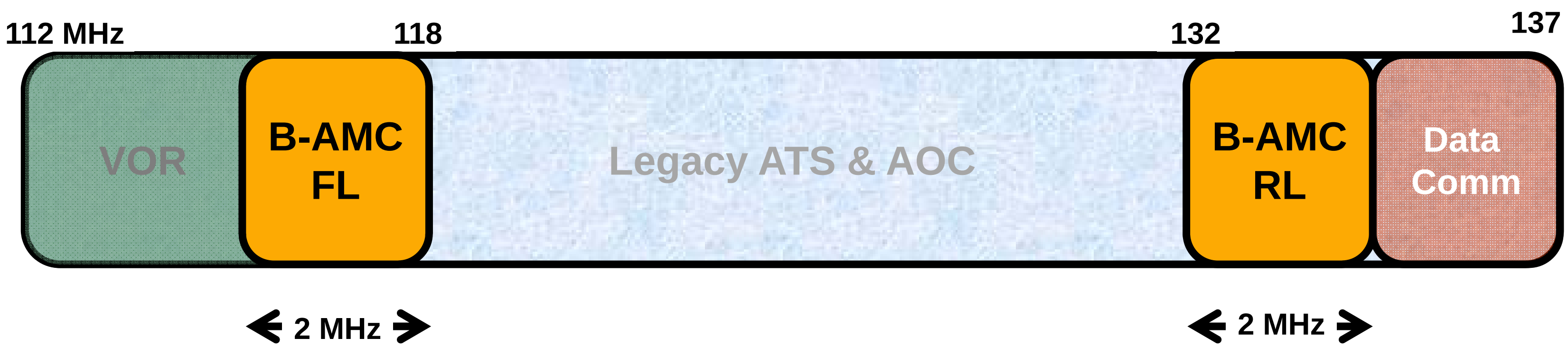
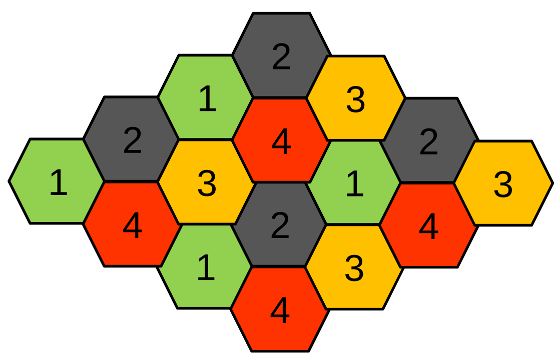
Frequency Planning



- **To maximize usage of a limited amount of spectrum**
  - **4-cell frequency reuse pattern is the minimum number of cells required to**
    - Avoid cochannel interference
    - Maximize bandwidth



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Fitting into VHF band

- **A 4-cell reuse pattern requires 4 unique frequencies per FL and RL**
- **Channel Bandwidth in VHF becomes 500 kHz = 2 MHz / 4 channels per FL (or RL)**
  - **Which is 75% of L-Band's Channel Bandwidth (667 kHz)**

- **Parameter adjustments to accommodate the reduced Channel Bandwidth in VHF:**
  - **Reduce subcarriers spacing by a factor of 0.25, while preserving B-AMC's structure (e.g., same number of subcarriers)**

Parameters	L-Band	VHF
Subcarrier Spacing	10.416 kHz	7.813 kHz
Channel Bandwidth	667 kHz	500 kHz
Occupied Bandwidth	500 kHz	375 kHz
Symbol Duration	120 µs	160 µs
Channel Data Rates	711 kbps	533 kbps

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VHF B-AMC Voice Capacity

Analysis of Digital Voice over B-AMC

As reference case, used:

- **AMBE-ATC-10 Codec (4.8 kbps)**
- **20 ms voice frames**
- **IPv4/UDP/RTP**
- **No compression techniques**

Modulation	Data Rates	# Voice Channels per Cell	Busy Channel(s)*
BPSK	151 kbps	8	0.53
QPSK	302 kbps	16	0.27
16-QAM	605 kbps	32	0.13
64-QAM	907 kbps	48	0.09

* Based on traffic analysis of current systems

Summary

- B-AMC is very similar to the L-DACS1 system that operates in a FDD configuration and utilizes OFDM modulation
- MITRE postulated how B-AMC might fit into the VHF band
- B-AMC could offer a common communication platform which caters to different frequency bands, thereby enabling interoperability between U.S. and Europe
- Possible next step
  - Investigate feasibility of implementing other systems in the VHF band such as L-DACS2

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THANK YOU

Any Questions?

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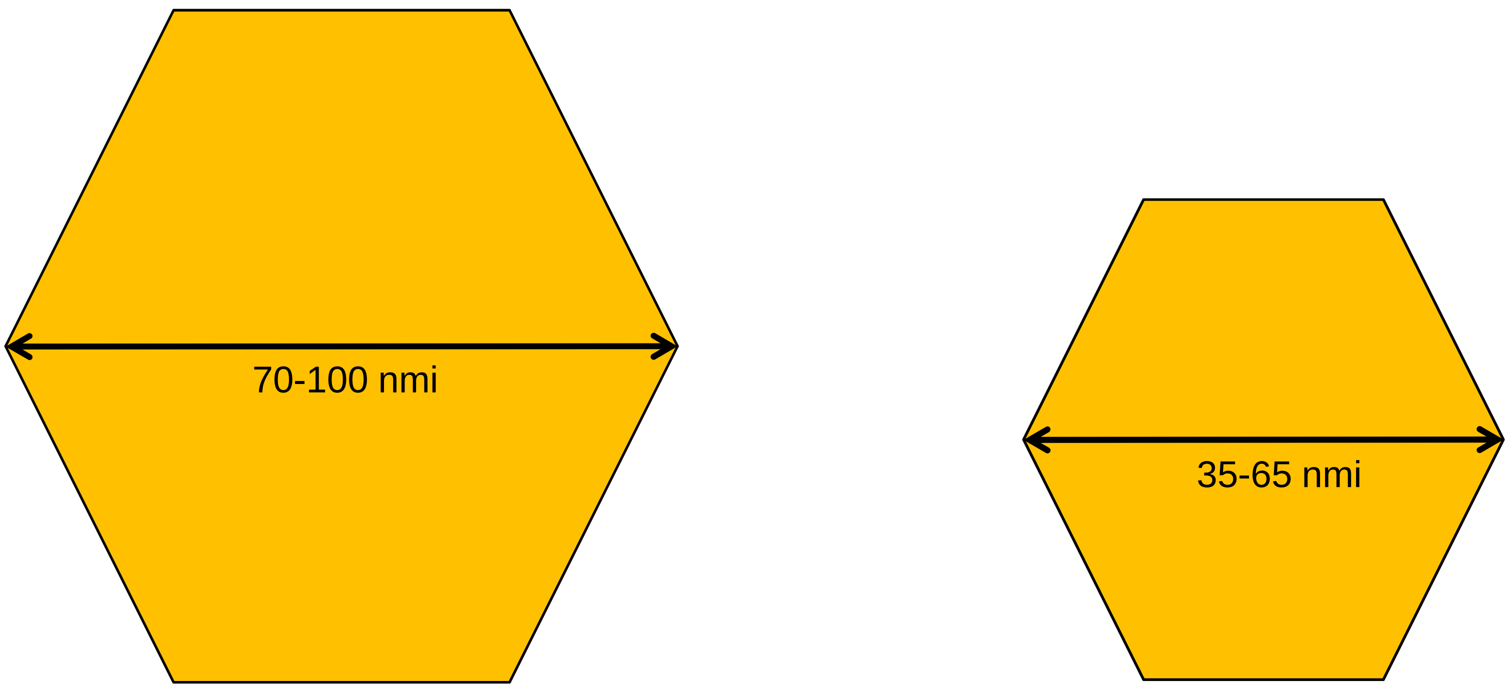

En Route Environment
24,000 - 45,000 ft.

Terminal Environment
6,000 - 18,000 ft.

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