Research & Development of VDL Mode 3 System

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Independent Administrative Institution
Electronic Navigation Research Institute

IFATSEA Tokyo Assembly 8 – 12 NOV 2004
Presentation Overview

1. Features of VDLM3 System
2. VDL Mode 3 (VDLM3) Research & Development Activities in ENRI
3. ENRI VDLM3 Test System
4. FAA-JCAB VDLM3/ATN Interoperability Testing
## VHF Digital Link (VDL)

<table>
<thead>
<tr>
<th></th>
<th>VDL Mode 2</th>
<th>VDL Mode 3</th>
<th>VDL Mode 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Application</strong></td>
<td>Data</td>
<td>Voice/Data</td>
<td>Surveillance</td>
</tr>
<tr>
<td></td>
<td>AOC, ATC</td>
<td>ATC</td>
<td>ADS-B</td>
</tr>
<tr>
<td><strong>Modulation</strong></td>
<td>D8PSK</td>
<td>D8PSK</td>
<td>GFSK</td>
</tr>
<tr>
<td><strong>Media Access</strong></td>
<td>CSMA</td>
<td>TDMA</td>
<td>STDMA</td>
</tr>
<tr>
<td><strong>Bit Rate</strong></td>
<td>31.5 kbps</td>
<td>31.5 kbps</td>
<td>19.2 kbps</td>
</tr>
<tr>
<td><strong>ICAO SARPs</strong></td>
<td>1997</td>
<td>2001</td>
<td>2001</td>
</tr>
</tbody>
</table>

- VDL: VHF Digital Link
- Mode 2: Application: Data, Modulation: D8PSK, Media Access: CSMA, Bit Rate: 31.5 kbps, ICAO SARPs: 1997

**ICAO SARPs:**
- 1997: Mode 2
- 2001: Mode 3, Mode 4
VDLM3 System Configuration
VDLM3
Operational Concept
VDLM3 Radio Tuning Panel

- Radio Tuning Panel developed by Gables for:
  - Rockwell Collins  VHF-2100
  - Honeywell      RTA-50D

Gables G7424 Radio Tuning Panel
VDLM3 Key Features (for Voice)

- **Anti Blocking**
  - Resolution for stepped-on transmission

- **Controller Override**
  - Controller can preempt ongoing pilot transmission

- **Next Channel Uplink**
  - Uplink of next frequency

- **Urgent Downlink Request**
  - Pilot can notify controller of his urgent downlink voice request
VDLM3 Key Features (for Data)

- **Priority control for data transmission**
  - Supports up to four types of priority

- **Slot allocation based on reservation request**
  - Avoids simultaneous data transmission

- **Secures received data by FEC\(^*1\)**
  - Reed Solomon (72,62) code
  - correction of up to 5 bytes error in received data

FEC\(^*1\) : Forward Error Correction
VDLM3 R&D Activities in ENRI

1. Objectives
   ■ Development and evaluation of VDL Mode 3 test system compliant with ICAO SARPs
   ■ Study and consideration on possible operational issues to implement VDL Mode 3 system in Japanese airspace

2. Duration
   ■ 2000-2004 (based on fiscal year in Japan)
   ■ 2005-2009 (additional research activities)
VDL-3 R&D Activities in ENRI (cont.)

3. Detail Activities

- Development of VDL Mode 3 test system
- Evaluation of the test system
  - Impact of radio interference
  - Voice and data communication performance
  - ATN connection (compatibility with ATN)
  - Interoperability with FAA VDLM3 system
- Computer simulation (OPNET)
  - VDL Mode 3 performance under various traffic models
Overall Plan for VDL-3 R&D Activities

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<tbody>
<tr>
<td>Development of VDL Mode 3 Test System</td>
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<tr>
<td>Evaluation of Radio Interference</td>
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<tr>
<td>Performance Evaluation by Computer Simulation</td>
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<tr>
<td>Evaluation of the Test System</td>
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<td>Summarization Report</td>
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Future works:
- System requirement
- Application software
- Operational issues
- Implementation procedure

Test & Evaluation of VDL Mode 2
### Overall Plan for VDLM3 Tests & Evaluation

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<tbody>
<tr>
<td>Vocoder Evaluation</td>
<td></td>
<td>xSEP-NOV</td>
<td></td>
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<tr>
<td>Radio Interference Test</td>
<td></td>
<td>xOCT</td>
<td>xSEP</td>
<td>xDEC</td>
<td>xNOV</td>
</tr>
<tr>
<td>Evaluation for Data Communication</td>
<td></td>
<td></td>
<td>xFEB</td>
<td>xDEC</td>
<td>xNOV Jan</td>
</tr>
<tr>
<td>Evaluation for Voice Communication</td>
<td></td>
<td>xFEB</td>
<td>xSEP</td>
<td></td>
<td>xAUG xJAN</td>
</tr>
<tr>
<td>Flight Test</td>
<td></td>
<td></td>
<td></td>
<td>xApr xSep xMar</td>
<td>xNOV</td>
</tr>
<tr>
<td>ATN Connection Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>xMAR xJUN</td>
</tr>
<tr>
<td>Interoperability Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>xJUL</td>
</tr>
</tbody>
</table>
Research Activities in FY2004

- Improvement of VDLM3 Test System
- ATN Connection Test
- Interoperability Test with FAA VDLM3 System
- Overall Evaluation of Test System
- Radio Interference Test
- Controller Evaluation (Voice & Data)
- Study of Diversity Site Group Operation
- Summarization of Report to JCAB HQ
Future Plan for R&D Activities (TBD)

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<tr>
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<tbody>
<tr>
<td>Improvement of VDLM3 Test System for Diversity Site Group Operation and Other Functions</td>
<td></td>
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<tr>
<td>Development of IP Subnetwork Function</td>
<td></td>
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<tr>
<td>Development of Security Function</td>
<td></td>
<td></td>
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<tr>
<td>Development of Network Management Function</td>
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<tr>
<td>Development of ATS Datalink Application</td>
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Evaluation of End-to-end Air/Ground Communications

Operational Evaluation
ENRI VDL LM 3 Test System

Legend
RF : RF Unit
MODEM : MODEM Unit
TDMA : TDMA Control Unit
CCU : Communication Control Unit
VOICE : Voice Processing Unit
GCS: Ground Center Station
## Major Specifications

<table>
<thead>
<tr>
<th>Subject</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General</strong></td>
<td>Compliant with ICAO SARPs and VDLM3 Manual (Doc 9805)</td>
</tr>
<tr>
<td><strong>TX Power</strong></td>
<td>15 w (42 dBm)</td>
</tr>
<tr>
<td><strong>TX/RX Frequency</strong></td>
<td>Lab Test :118〜136.975MHz (25kHz step)</td>
</tr>
<tr>
<td></td>
<td>Flight Test :136.900 / 136.925MHz</td>
</tr>
<tr>
<td><strong>System Configuration</strong></td>
<td>2V2D : Two Voice / Two Data</td>
</tr>
<tr>
<td></td>
<td>3V1D : Three Voice / One Data</td>
</tr>
<tr>
<td><strong>Min. Receiving Sensitivity</strong></td>
<td>-103.2 dBm (at BER=10^-3 before FEC)</td>
</tr>
<tr>
<td><strong>Number of Equipment</strong></td>
<td>Ground/Aircraft Station : Two sets each</td>
</tr>
<tr>
<td></td>
<td>Ground Center Station : One set</td>
</tr>
</tbody>
</table>
Additional Functions

- Simple Link Monitor
- Graphical Display
- Received Data Status Log
- Predefined Scenario  
  (for data performance test)
- Aircraft Position Display

Upper: GCS main display
Lower: CCU main display
External View of Test Equipment

VOICE
RF
MODEM
TDMA
CCU

equipment onboard
Tests and Evaluation of VDLM3 Test System

- Radio Interference Test
- Laboratory Test for Data Transfer
- Laboratory Test for Voice Quality
- Flight Test
- Lab Test for Co-site Radio Interference
- Interoperability Testing with FAA System
FAA-JCAB VDL Mode 3 / ATN Interoperability Testing
FAA NEXCOM Program

- FAA’s program to modernize and improve VHF air/ground communications in the U.S. national airspace system (NAS)

- VDLM3 features
  - Enhancement of channel capacity
  - Reduction of future frequency spectrum congestion
  - Improvement in security
  - Voice and data (CPDLC) operations
NEXCOM System
Outline of Interoperability Test

- Date: 26-30 July 2004
- Place: Electronic Navigation Research Institute (ENRI), Tokyo
- Participants:
  - FAA Headquarters / FAA Technical Center / BCI / CIE Engineering
  - JCAB / ENRI / NEC / OKI
Objectives of Interoperability Test

- To examine interoperability between FAA and ENRI VDLM3/ATN systems.
- To identify the technical maturity of international standards for VDLM3/ATN.
  - ICAO VDLM3 SARPs and Manual (Doc 9805)
  - ICAO ATN SARPs and Manual (Doc 9705)
  - RTCA DO-224A MASPS for VDL
  - RTCA DO-271B MOPS for Aircraft VDLM3 TRX
## Test Schedule

<table>
<thead>
<tr>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Briefing &amp; Discussions</strong></td>
<td><strong>FAA(G) ↔ ENRI(A)</strong> Voice Test</td>
<td><strong>FAA(G) ↔ ENRI(A)</strong> Voice Test</td>
<td><strong>FAA(G) ↔ ENRI(A)</strong> Additional Voice Test</td>
</tr>
<tr>
<td></td>
<td>• Basic Voice</td>
<td>• In Timing State 2</td>
<td><strong>Summarization &amp; Discussions</strong></td>
</tr>
<tr>
<td></td>
<td>• Enhanced Voice</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Next Channel Uplink</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ENRI(G) ↔ FAA(A)</strong> Voice Test</td>
<td><strong>FAA(G) ↔ ENRI(A)</strong> ATN Data Test</td>
<td><strong>ENRI(G) ↔ FAA(A)</strong> ATN Data Test</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Basic Voice</td>
<td></td>
<td><strong>Voice Quality Test</strong></td>
</tr>
<tr>
<td></td>
<td>• Enhanced Voice</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Next Channel Uplink</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>FAA(A) ↔ ENRI(A)</strong> Voice Test</td>
<td></td>
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<td></td>
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</tbody>
</table>

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Electronic Navigation Research Institute
Equipment Tested (FAA Ground)
## Equipment Tested (FAA Ground)

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Vendor</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-mode Digital Radio TX</td>
<td>ITT</td>
<td>MDR</td>
</tr>
<tr>
<td>Multi-mode Digital Radio RX</td>
<td>ITT</td>
<td>VDLM3, DSB-AM (25k/8.33k)</td>
</tr>
<tr>
<td>Real Time Platform (RTPF)</td>
<td>CIE</td>
<td></td>
</tr>
<tr>
<td>- Octal T1 Module (OTM)</td>
<td>CIE</td>
<td></td>
</tr>
<tr>
<td>- Voice Channel Module (VCM)</td>
<td>CIE</td>
<td>Four modules</td>
</tr>
<tr>
<td>Radio Interface Unit (RIU)</td>
<td>BCI</td>
<td></td>
</tr>
<tr>
<td>Link Monitor Tool / PXI Radio</td>
<td>Veridian</td>
<td>For monitoring</td>
</tr>
<tr>
<td>Ground Network Interface (GNI)</td>
<td>BCI</td>
<td>Installed on one laptop PC</td>
</tr>
<tr>
<td>ATN A/G Router</td>
<td>BCI</td>
<td></td>
</tr>
</tbody>
</table>
### Equipment Tested (FAA Air)

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Vendor</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDL Mode 3 Avionics アビオニクス</td>
<td>Avidyne</td>
<td>Prototype for General Aviation</td>
</tr>
<tr>
<td>Airborne Network Interface (ANI)</td>
<td>BCI</td>
<td>Installed on one laptop PC</td>
</tr>
<tr>
<td>ATN Airborne (A/B) Router</td>
<td>BCI</td>
<td></td>
</tr>
</tbody>
</table>

**IFATSEA Tokyo Assembly 8 – 12 NOV 2004**
Equipment Tested (ENRI Ground/Air)
## Equipment Tested (ENRI Ground/Air)

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Vendor</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDLM3 Test System</td>
<td>NEC</td>
<td>Same configuration for Ground and Aircraft Station</td>
</tr>
<tr>
<td>- RF Unit</td>
<td>NEC</td>
<td>RF Unit</td>
</tr>
<tr>
<td>- Modulation/Demodulation Unit</td>
<td>NEC</td>
<td>MODEM Unit</td>
</tr>
<tr>
<td>- TDMA Control Unit</td>
<td>NEC</td>
<td>TDMA Unit</td>
</tr>
<tr>
<td>- Communication Control Unit</td>
<td>NEC</td>
<td>COMM Unit</td>
</tr>
<tr>
<td>- Voice Processing Unit</td>
<td>NEC</td>
<td>VOICE Unit</td>
</tr>
<tr>
<td>- Ground Center Station</td>
<td>NEC</td>
<td>GCS</td>
</tr>
<tr>
<td>ATN A/G Router</td>
<td>OKI</td>
<td>Two sets</td>
</tr>
</tbody>
</table>
Test Items for Voice Communication

- Validate Basic Voice Communication
  - Digital Voice Quality
  - Stuck Microphone Resolution
  - Controller Override
  - Anti-blocking
  - Truncated Voice in Timing State 2

- Validate Enhanced Voice Communication
  - Urgent Downlink Request
  - Next Channel Uplink
Test Setup for Voice Test (1)

- ENRI GND ⇔ FAA AIR
Test Setup for Voice Test (2)

- ENRI GND/AIR ↔ FAA AIR
Test Setup for Voice Test (3)

- ENRI GND/GND ⇔ FAA AIR
Test Setup for Voice Test (4)

- FAA GND ⇔ ENRI AIR
Test Setup for Voice Test (5)

- FAA GND ⇔ ENRI AIR/AIR
Test Setup for Voice Test (6)

- FAA GND/ENRI GND ↔ ENRI AIR
Test Setup for Voice Test (7)

- ENRI GND/AIR ↔ FAA AIR
Test Items for ATN Data Transfer

- Route Initiation
- Route Termination
- Echo Request/Response between ATN Routers
- Echo Request to Unknown Destination Address
- Circuit Failure at Airborne side
## Protocol Stacks

<table>
<thead>
<tr>
<th>ENRI BIS</th>
<th>ENRI GNI/ANI</th>
<th>VDLM3 Radio</th>
<th>VDLM3 Radio</th>
<th>FAA GNI/ANI</th>
<th>FAA BIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ES-IS, IDRDP</td>
<td>CLNP</td>
<td>ISO8208 mobile SNDCF</td>
<td>ISO8208 PLP</td>
<td>LAPB</td>
<td>LAPB</td>
</tr>
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<td></td>
<td></td>
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<td></td>
<td>Physical</td>
<td>Physical</td>
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<td></td>
<td>TCP/IP</td>
<td>TCP/IP</td>
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<td></td>
<td>MAC</td>
<td>MAC</td>
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<td></td>
<td>DLS/LME</td>
<td>ISO8208 PLP</td>
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<td>Physical</td>
<td>Physical</td>
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<td></td>
<td></td>
<td></td>
<td>Physical</td>
<td>TCP/IP</td>
</tr>
</tbody>
</table>
Test Setup for ATN Data Test (1)

- Preliminary Test using Public Internet
Test Setup for ATN Data Test (2)

- FAA GND ⇔ ENRI AIR

ATN Data Test
System Configuration: 2V2D
Frequency: 136.301 MHz
Test Setup for ATN Data Test (3)

- ENRI GND ⇔ FAA AIR

![Diagram of the test setup](Diagram.png)

- ATN Data Test
  - System Configuration: 2V2D
  - Frequency: 136.901 MHz
Test Result

- **Voice Communication Test**
  - Basic Voice Operation
  - Enhanced Voice Operation

- **ATN Data Test**
  - Basic Connectivity

Interoperability was validated
Discrepancies between two systems

Some discrepancies emerged during the test caused by:

- mis-implementation
- variation in implementation
- specifications for the experimental purposes
- lack of clarity of ICAO VDLM3 Manual (Doc 9805)
- lack of clarity of ICAO ATN Manual (Doc 9705)
Report of the Test Result

- ICAO Aeronautical Communications Panel
  - WGC/8 in Munich 20-24 Sep 2004
  - WGB/17&M/9 in Montreal 20 Oct-2 Nov 2004
  - WGN/4 in New Orleans 10-19 Nov 2004

- RTCA Special Committee 172*
  - 51\textsuperscript{st} meeting in Washington, DC 21-22 Sep 2004

SC-172*: Future Air-Ground Communications in the VHF Aeronautical Data Band (118-137 MHz)
Future Testing Plan

- Further VDLM3/ATN interoperability tests will be planned in the future.
  - Voice communications in various combinations of VDLM3 Timing State 1/2/3
  - Data communications between ground and multiple aircraft stations
  - ATN data test for other sub-network protocols
  - Full end-to-end test of CPDLC/CM applications
Thank You for Listening!

Any Questions?