# Research & Development of VDL Mode 3 Test System

VDL Research Group
Aeronautical Systems Division

Independent Administrative Institution
Electronic Navigation Research Institute

# Presentation Overview

1. Electronic Navigation Research Institute
2. VDL Mode 3 Research Activities in ENRI
3. Feature of VDL Mode 3 System
4. VDL Mode 3 Test System
5. Tests and Evaluation

# Electronic Navigation Research Institute

http://www.enri.go.jp

## Mission

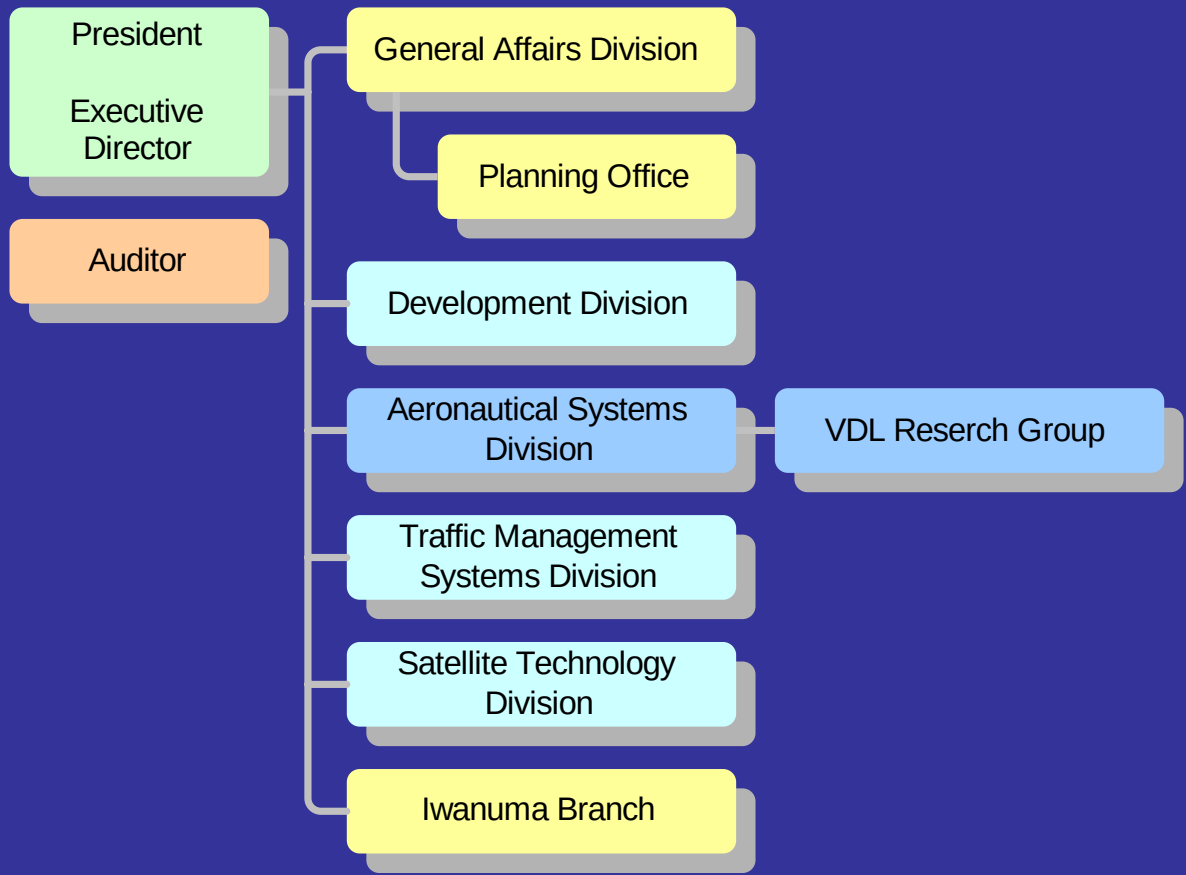
To carry out research and development in order to ensure safe and efficient transport systems as the leading institute of electronic navigation in Japan

## Number of Personnel

as of April 2003

| | |
|---|---|
| President | 1 |
| Executive Director | 1 |
| Auditor | 1 |
| Part-Time Auditor | 1 |
| Office Staff | 16 |
| Research Staff | 48 |
| Total | 68 |

## Organization



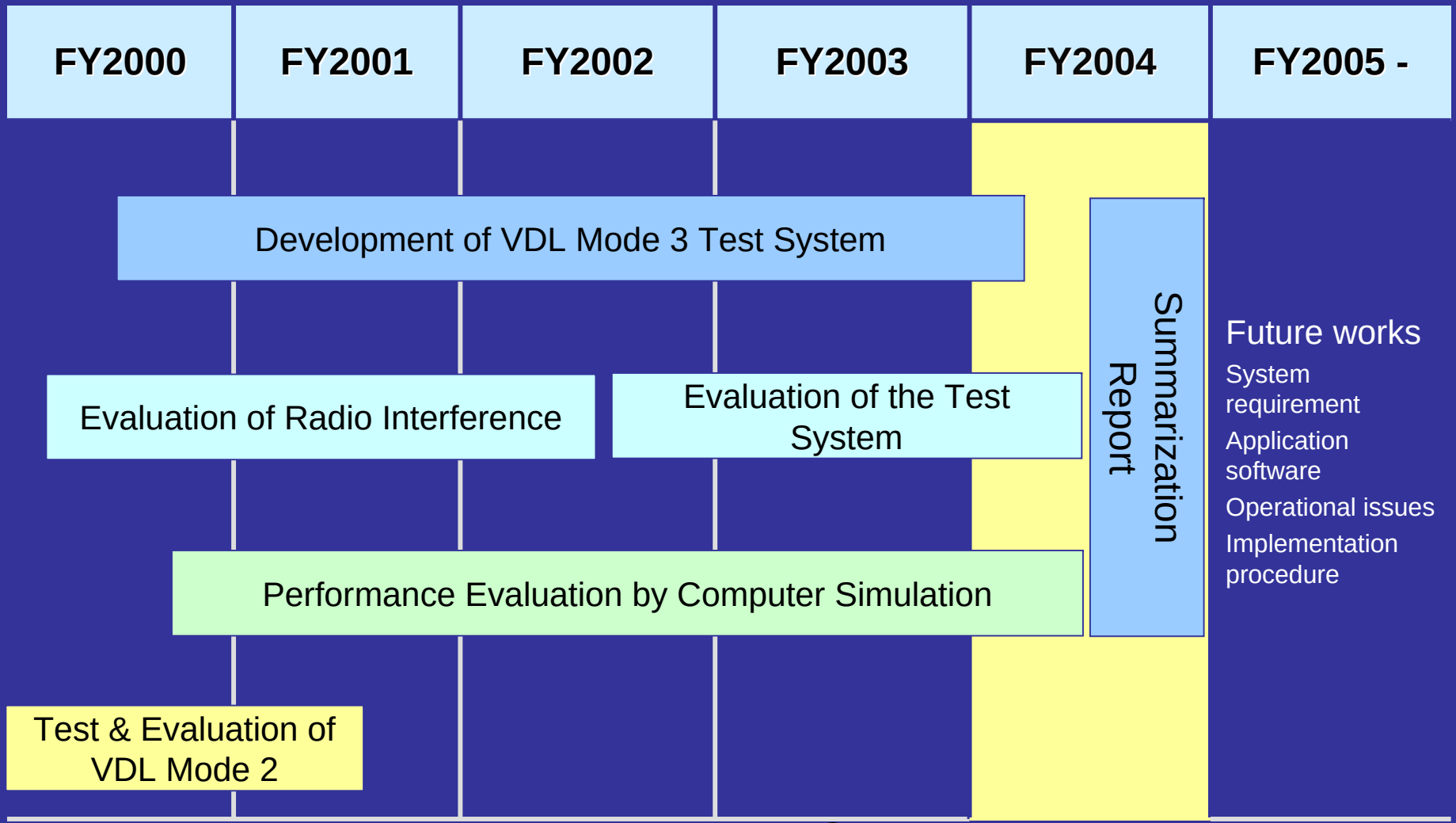
# Overview of VDL-3 R&D Activities

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, TBD)

# Overview of VDL-3 R&D Activities (cont.)

3. Detail Activities
   - Development of VDL Mode 3 test system
   - Evaluation of the test system
     - Radio interference
     - Communication performance
     - Voice quality
     - ATN connection (compatibility with ATN)
   - Computer simulation
     - VDL Mode 3 performance under various traffic models

# Overall Plan for VDL-3 R&D Activities



# Overall Plan for VDL-3 Tests & Evaluation

| Major Event | FY2000 | FY2001 | FY2002 | FY2003 | FY2004 |
|---|---|---|---|---|---|
| Vocoder Evaluation | X SEP-NOV | | | | |
| Radio Interference Test | | X OCT | X SEP | X DEC | X SEP |
| Evaluation for Data Communication | | | X FEB | X DEC | X NOV X JAN |
| Evaluation for Voice Communication | | | X FEB | X SEP | X NOV X JAN |
| Flight Test | | | | X APR X SEP X MAR | X SEP |
| ATN Connection Test | | | | X MAR | X JUN X NOV |
| Interoperability Test | | | | | X JUL |

# Research Activities in FY2004

- Improvement of VDL-3 Test System
- ATN Connection Test
- Interoperability Test (FAA NEXCOM System)
- Overall Evaluation of Test System
- Co-site Radio Interference Test
- Controller Evaluation (Voice & Data)
- Study of Diversity Site Group Operation
- Summarization of Report to JCAB

# VHF Digital Link (VDL)

| | VDL Mode 2 | VDL Mode 3 | VDL Mode 4 |
|---|---|---|---|
| Application | Data<br>AOC・ATC | Voice/Data<br>ATC | Surveillance<br>ADS-B |
| Modulation | D8PSK | D8PSK | GFSK |
| Media Access | CSMA | TDMA | STDMA |
| Rate | 31.5 kbps | 31.5 kbps | 19.2 kbps |
| ICAO SARPs | 1997 | 2001 | 2001 |

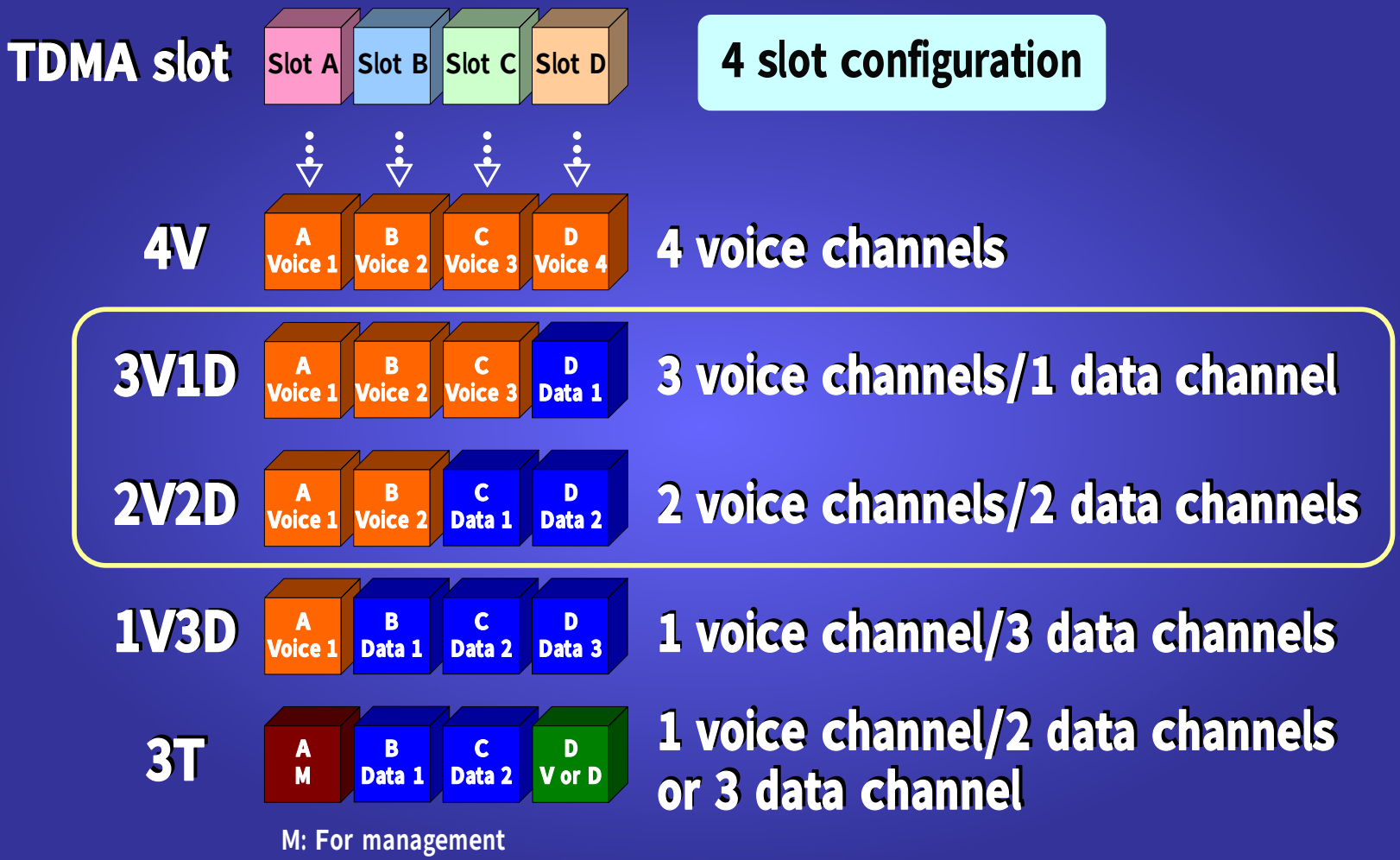
# VDL-3 Key Features (for Voice)

- Anti Blocking
  - First come, first served
  - Resolution for stepped-on transmission
- Controller Override
  - Controller can preempt ongoing aircraft transmission
- Next Channel Uplink
  - Uplink of next frequency
- Urgent Downlink Request
  - Pilot can inform controller of necessity of urgent voice transmission by downlink data message

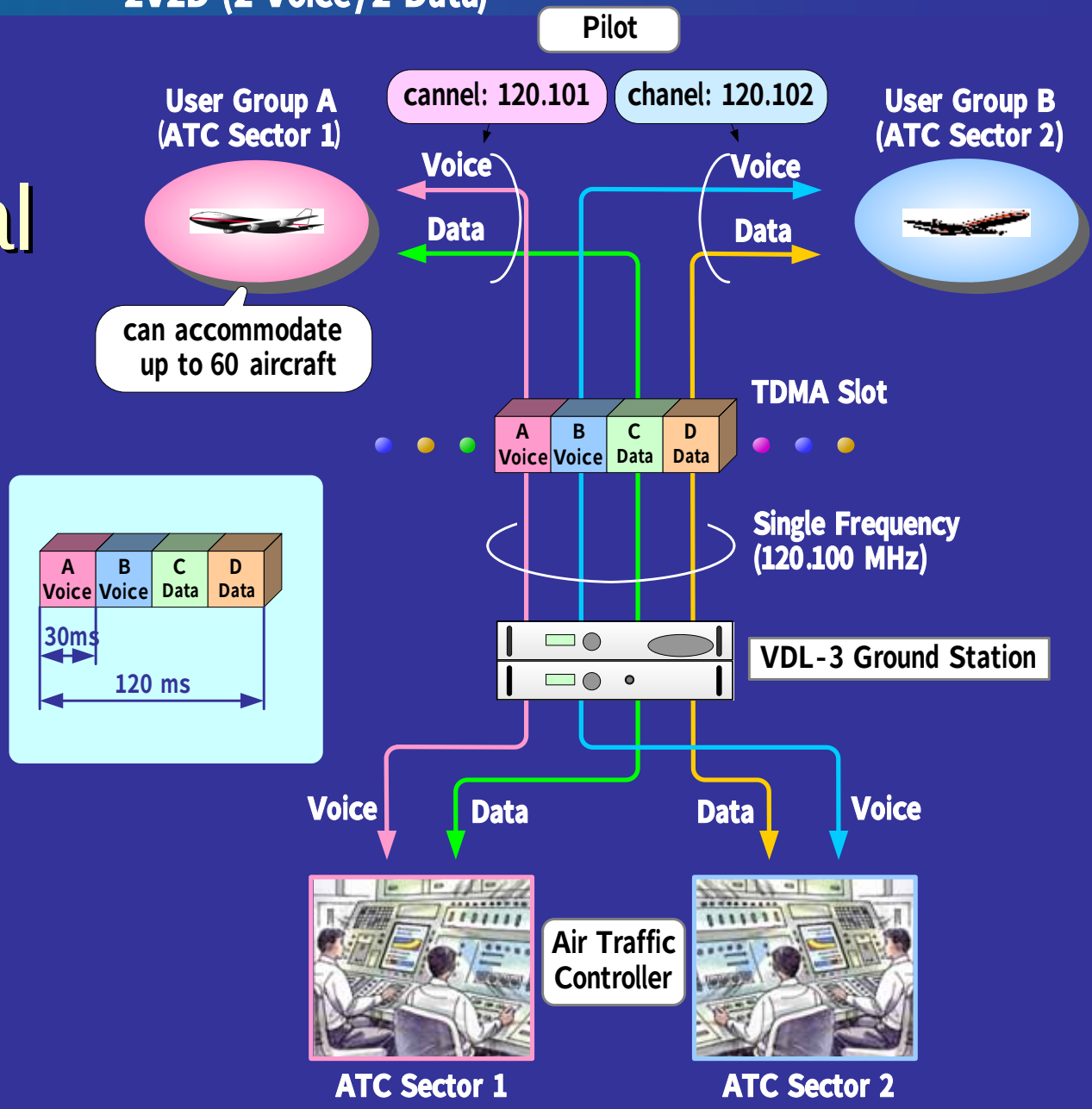
# VDL-3 Key Features (for Data)

- Priority control for data transmission
  - Supports up to four priority of data
- Slot allocation based on reservation request
  - Avoids simultaneous data transmission
- Secures received data by FEC
  - Up to 5 byte error in received data can be corrected by Reed Solomon Code, RS(72,62)

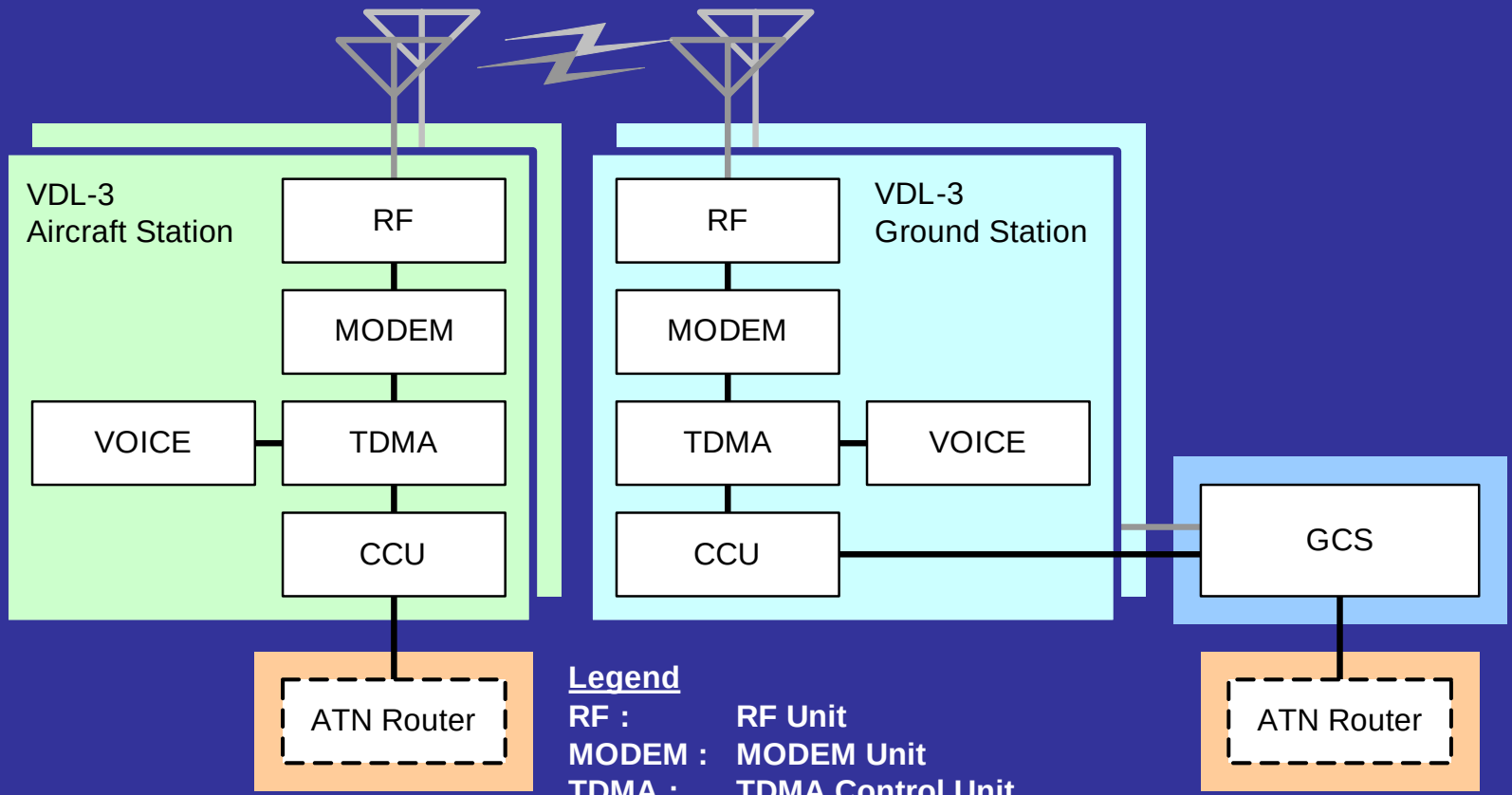
# VDL-3 System Configuration



# VDL-3 Operational Concept



# ENRI VDL-3 Test System




**Legend**

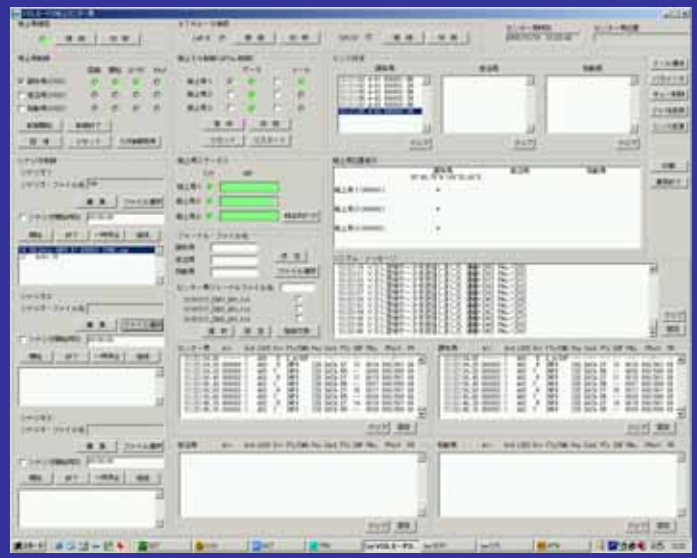
| | |
|---|---|
| **RF :** | **RF Unit** |
| **MODEM :** | **MODEM Unit** |
| **TDMA :** | **TDMA Control Unit** |
| **CCU :** | **Communication Control Unit** |
| **VOICE :** | **Voice Processing Unit** |
| **GCS:** | **Ground Center Station** |

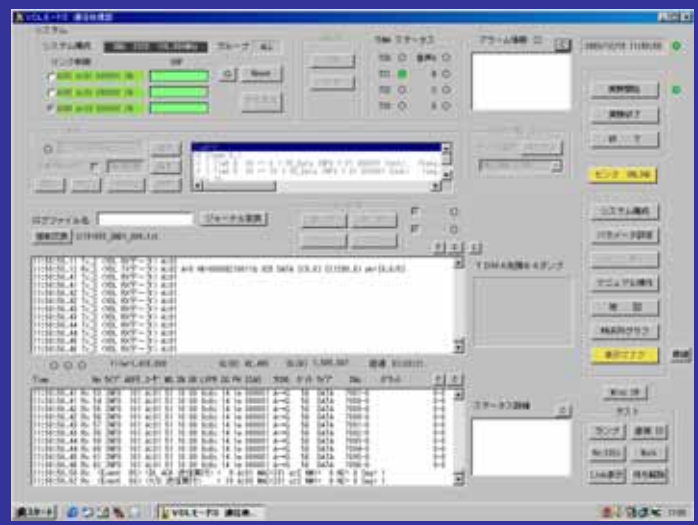
# Major Specifications

| Subject | Specifications |
|---|---|
| General | Compliant with ICAO SARPs and<br>VDL-3 Manual (Doc 9805) |
| TX Power | 15 w (42 dBm) |
| TX/RX Frequency | Lab Test：118～136.975MHz （25kHz step）<br>Flight Test：136.900 / 136.925MHz |
| System Configuration | 2V2D： Two Voice / Two Data<br>3V1D： Three Voice / One Data |
| Min. Receiving Sensitivity | -103.2 dBm (at BER=$10^{-3}$ before FEC) |
| Number of Equipment | Ground/Aircraft Station : Two sets each<br>Ground Center Station : One set |

# 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

# Tests and Evaluation of VDL-3 Test System

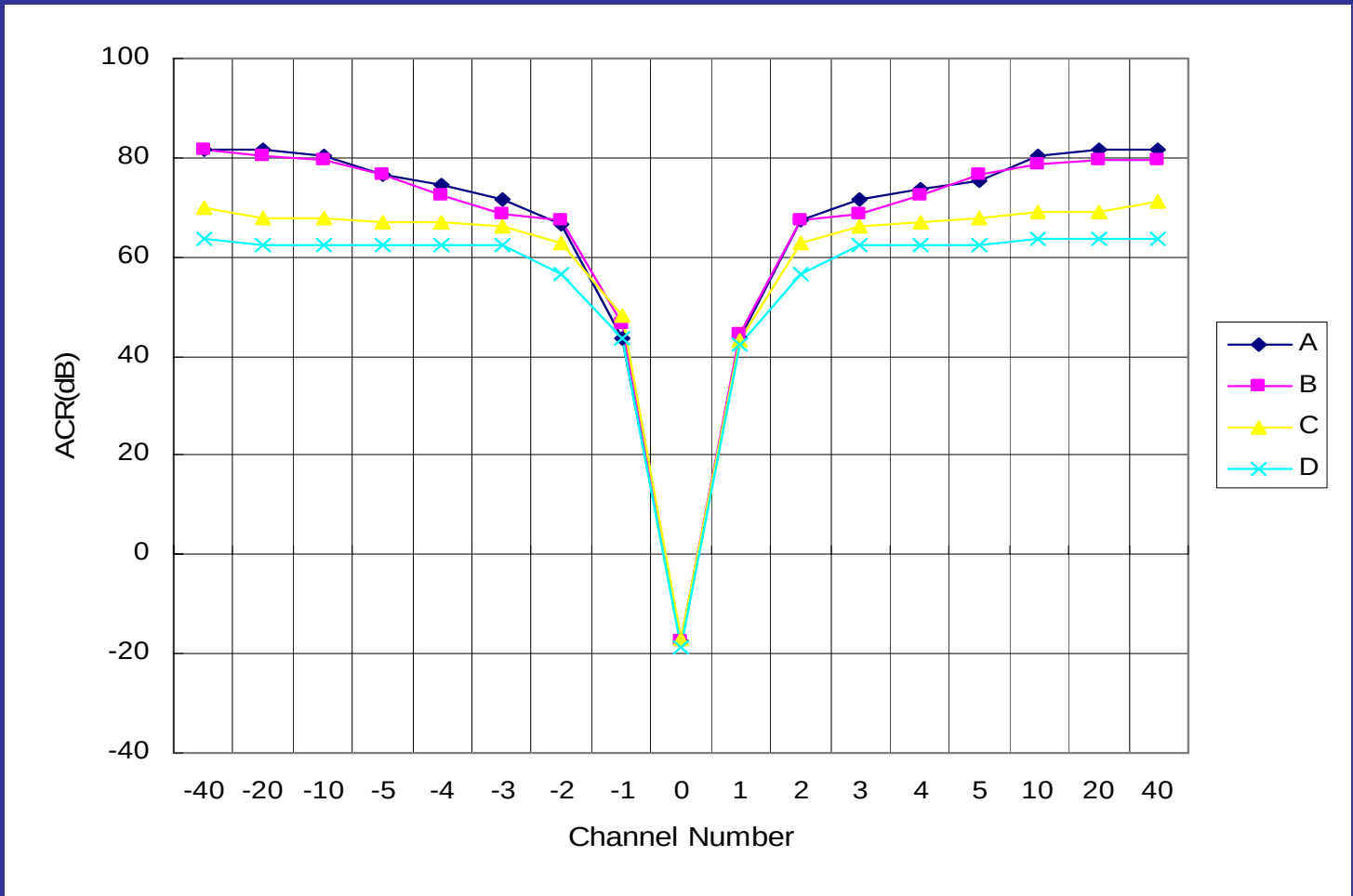
- Radio Interference Test
- Laboratory Test for Data Transfer
- Laboratory Test for Voice Quality
- Flight Test
- Lab Test for Co-site Radio Interference

# Lab Test for Radio Interference

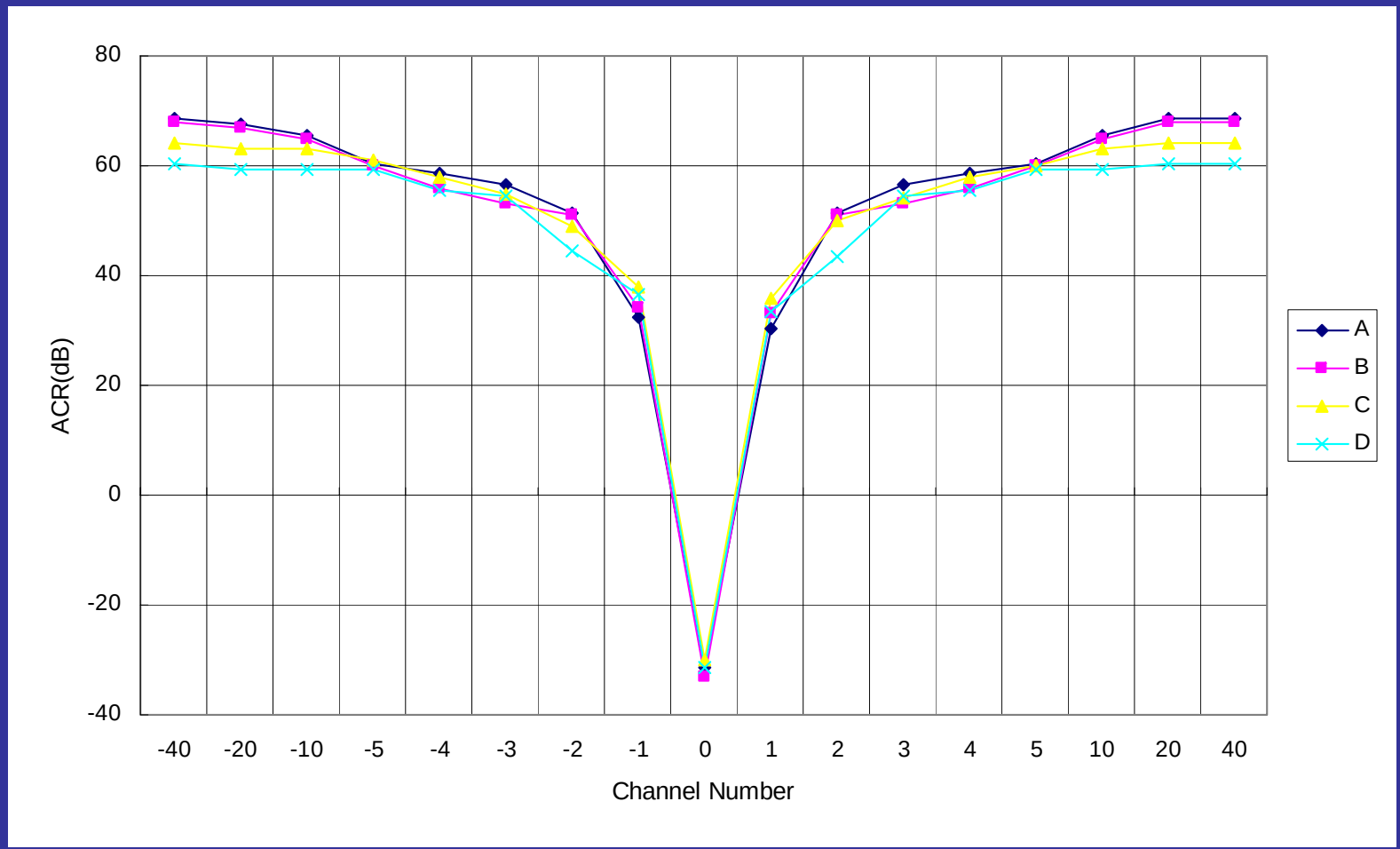
## Test Items

- Interference from VDL-3 to DSB-AM
  - SINAD
  - S/P Ratio
  - Test Results were submitted to ACP WGB/12
- Interference from DSB-AM to VDL-3
  - Bit Error Rate (BER)
  - Adjacent Channel Rejection (ACR)
  - Test Results were submitted to ACP WGB/14

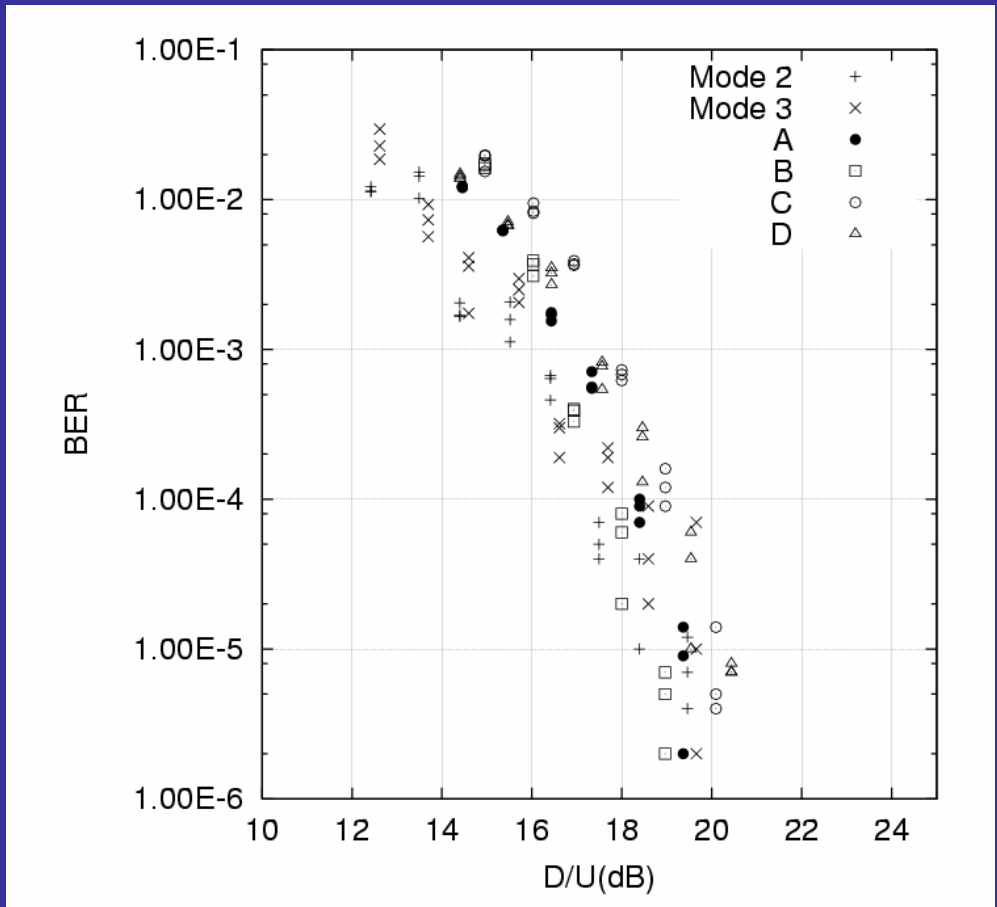
# ACR Characteristic : SINAD=15dB



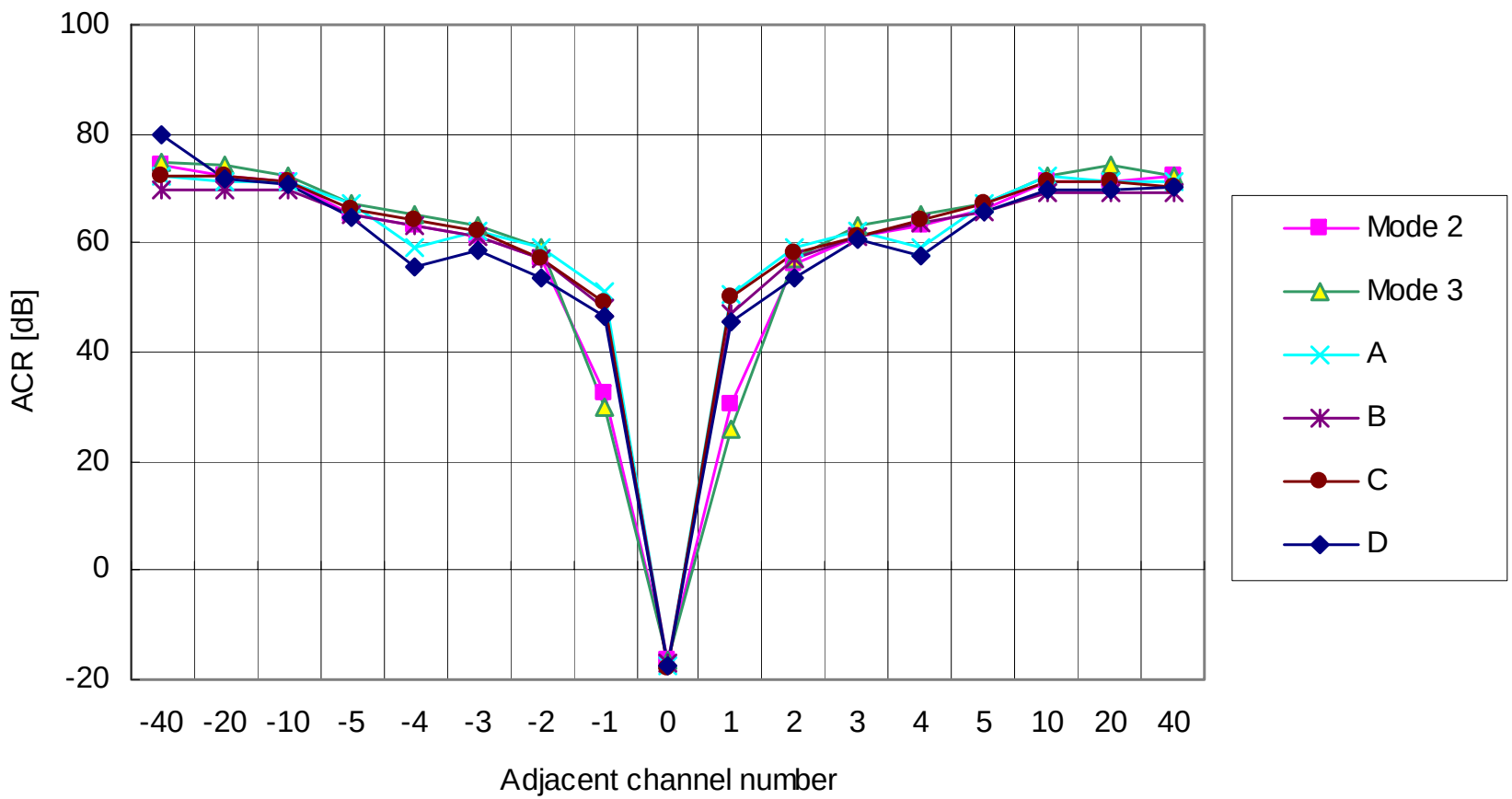
# ACR Characteristic : S/P=18dB



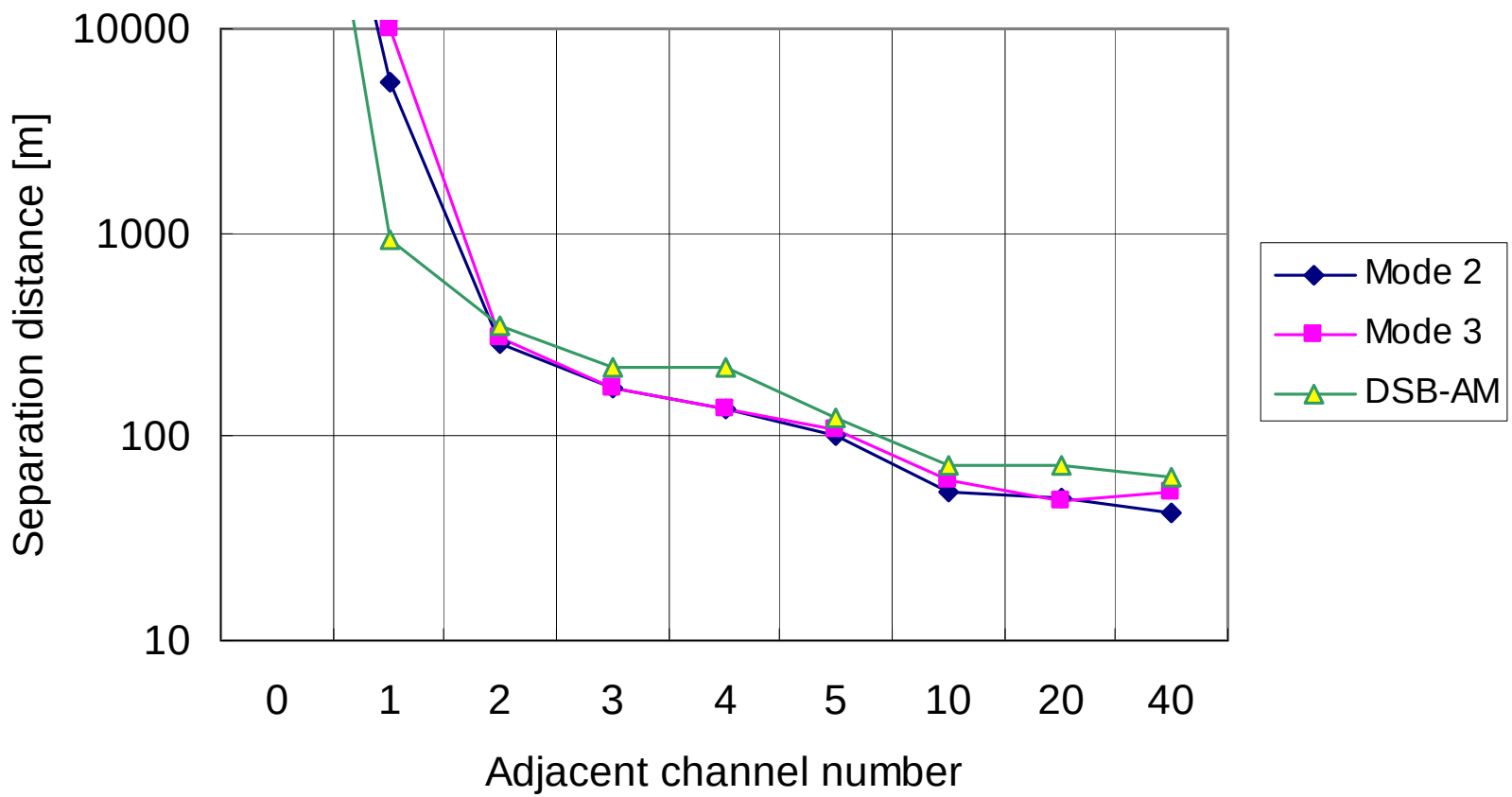
# D/U Ratio vs. BER Characteristic



# ACR Characteristic: BER=1x10$^{-3}$



# Required Separation Distance



# Laboratory Test for Data Transfer

## Test Items

- Received Level vs. Bit Error Rate (BER)
- BER vs. Transfer Delay
- BER vs. Throughput
- Transfer Delay vs. Traffic Load
- Transfer Delay with Different Data Priorities

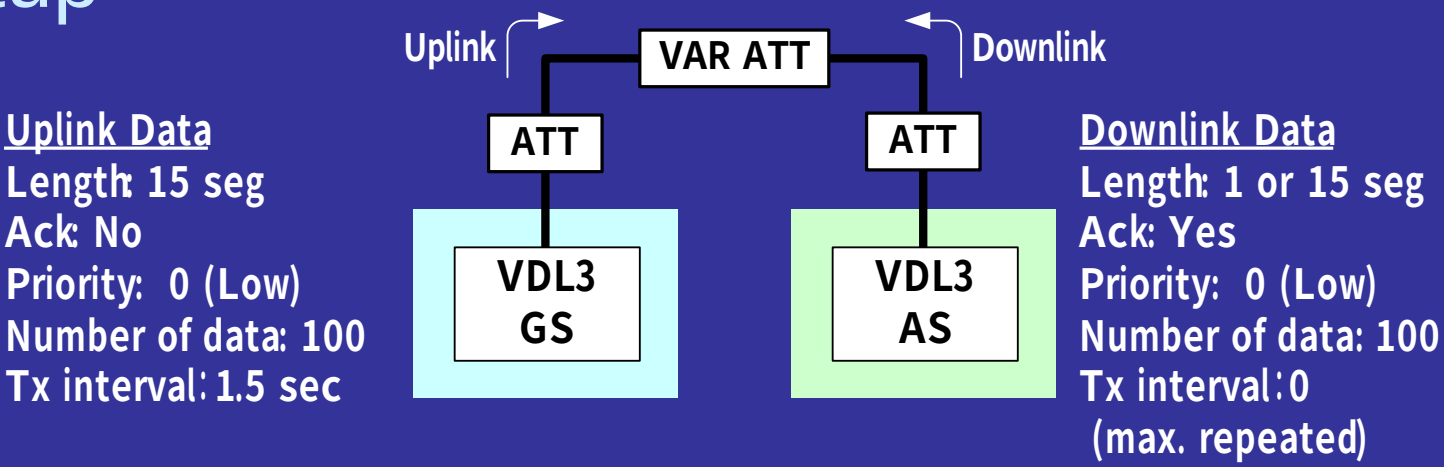
# Lab Test for Data Transfer (1)

## Test Items

(a) Received Level vs. BER

(b) BER vs. Transfer Delay & Throughput

## Test Setup

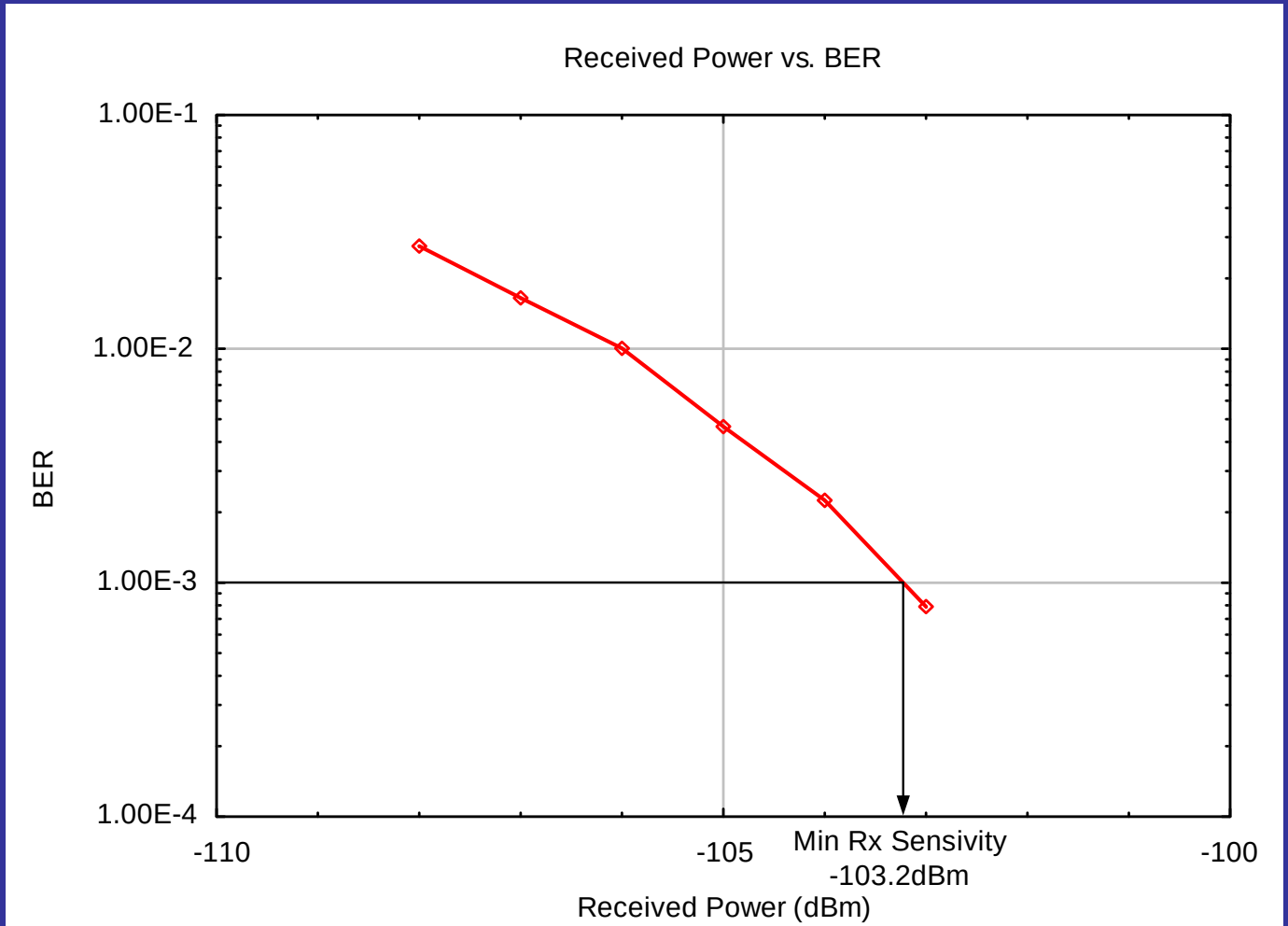



**Uplink Data**
Length: 15 seg
Ack: No
Priority: 0 (Low)
Number of data: 100
Tx interval: 1.5 sec

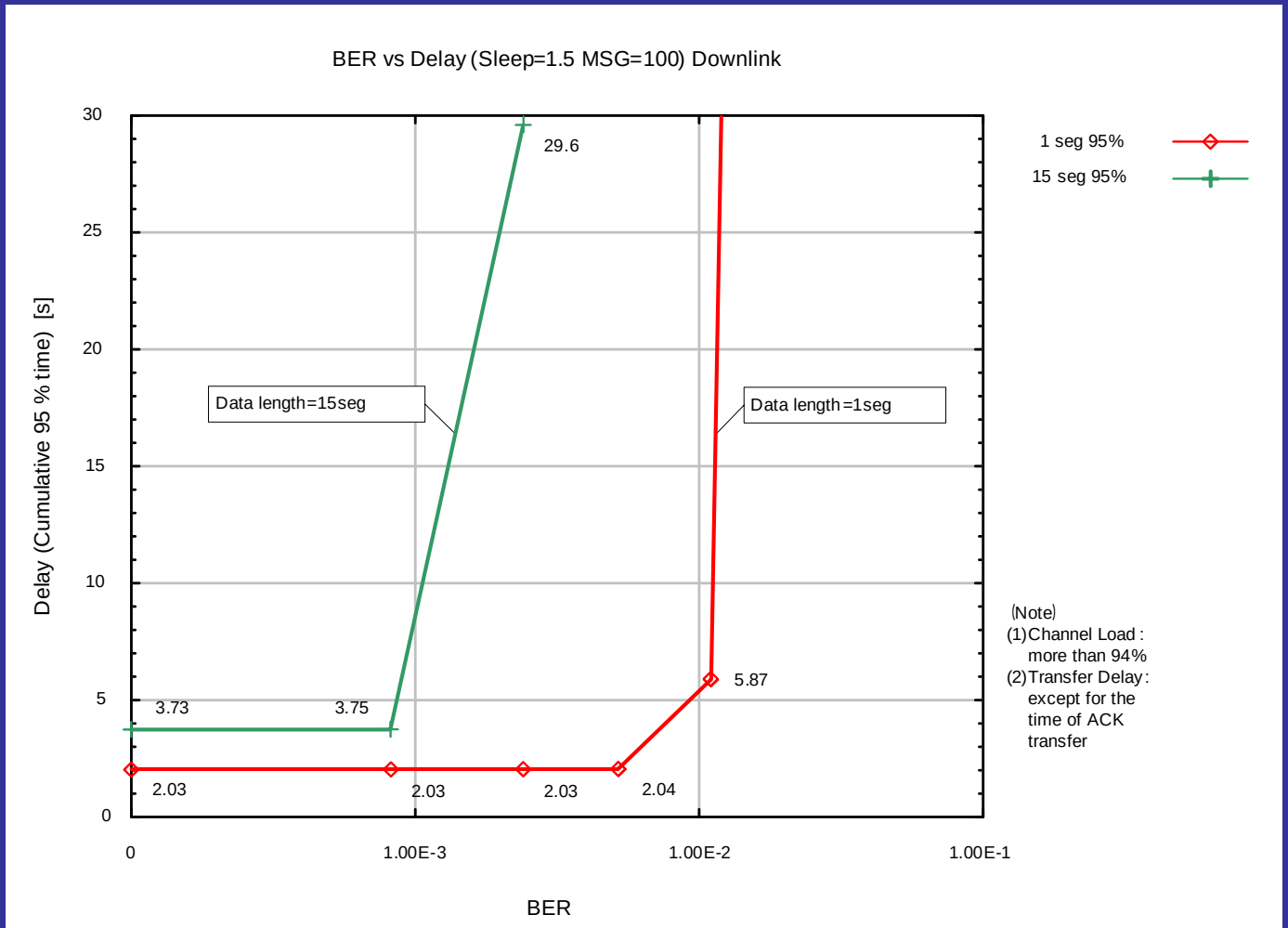
**Downlink Data**
Length: 1 or 15 seg
Ack: Yes
Priority: 0 (Low)
Number of data: 100
Tx interval: 0
(max. repeated)

1 seg (segment) is equivalent to 1 data burst of TDMA slot
1 seg => 62 byte
15 seg => 930 byte
GS: Ground Station / AS: Aircraft Station

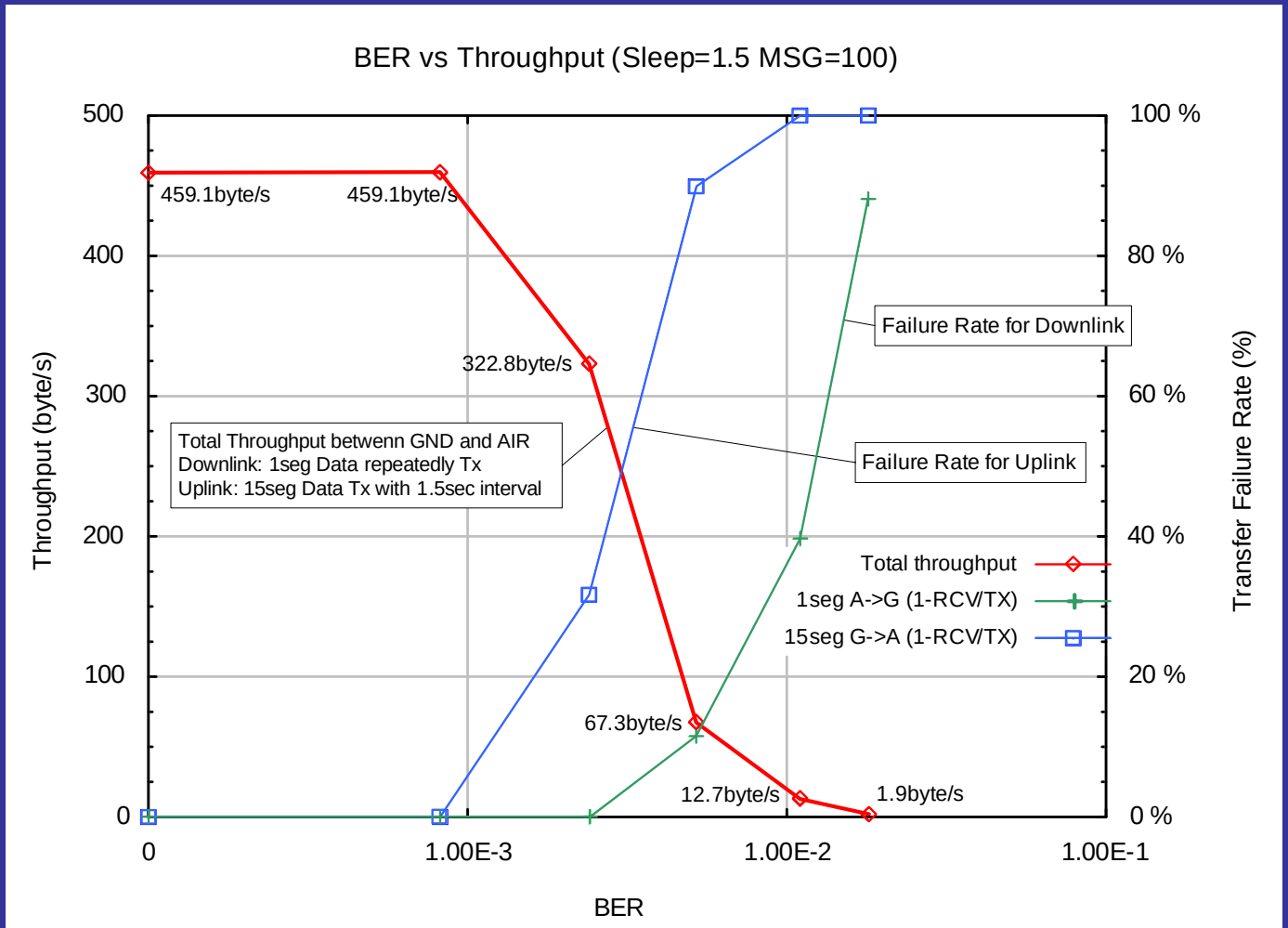
# Received Level vs. BER



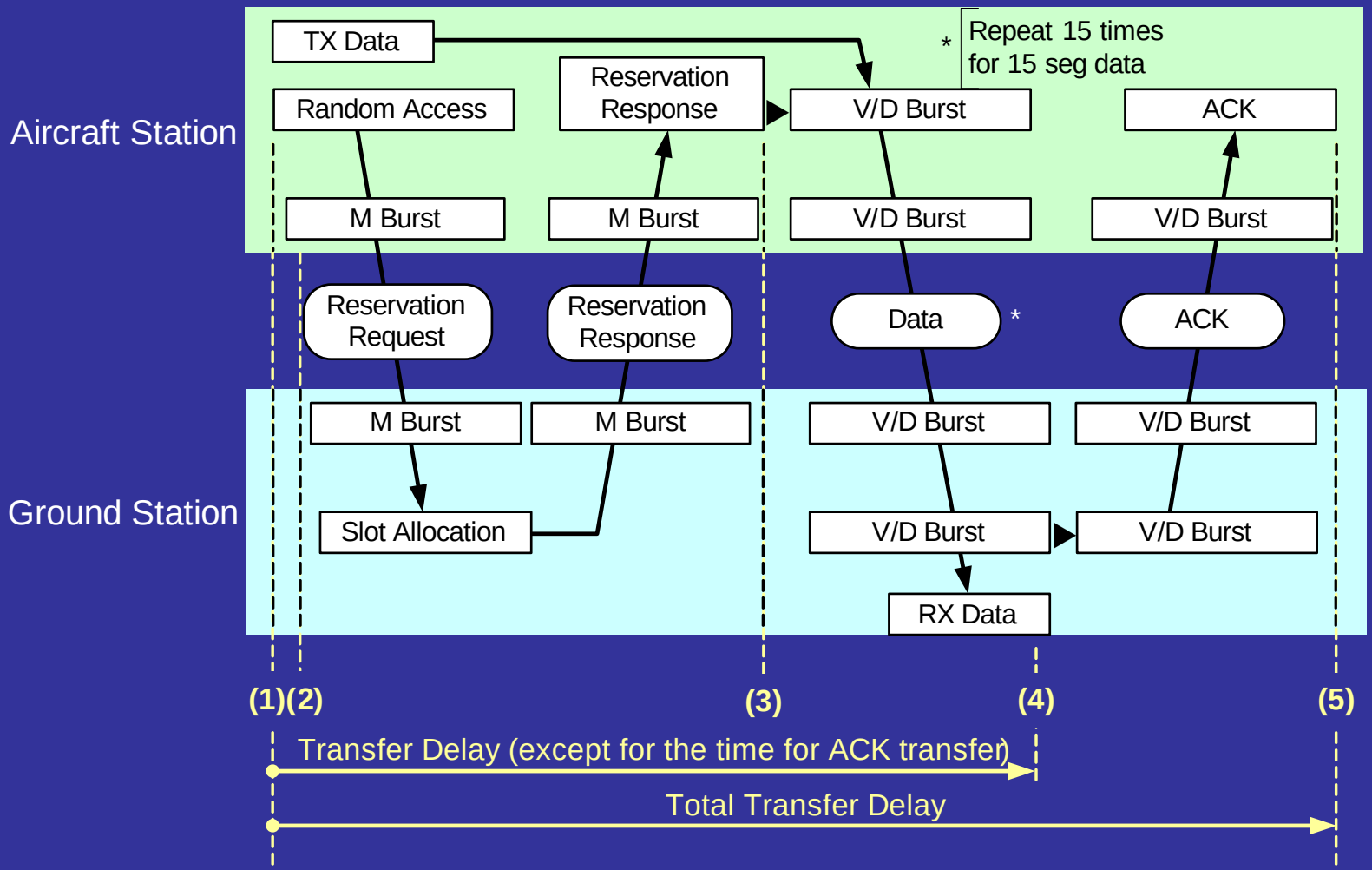
# BER vs. Transfer Delay



# BER vs. Throughput



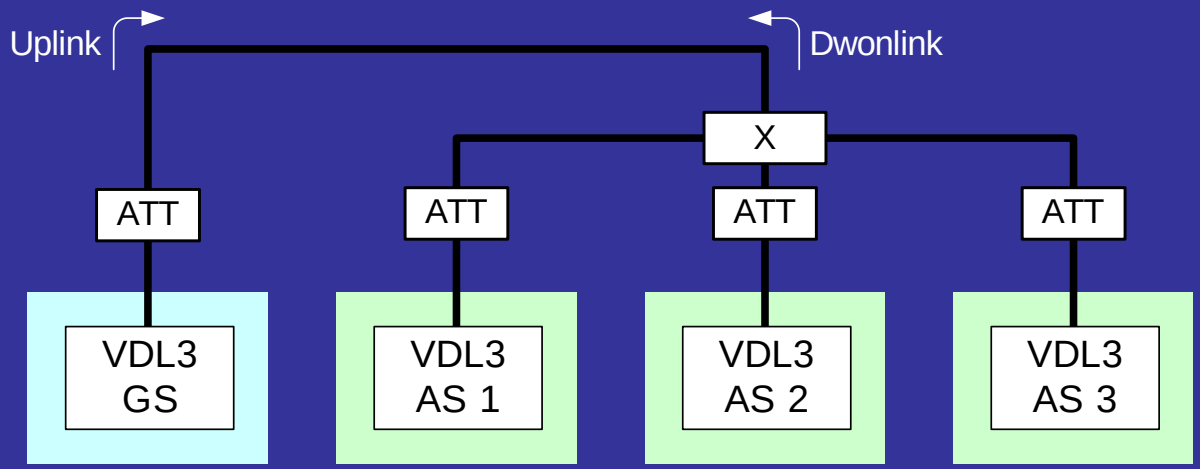
# Definition for Transfer Delay



# Lab Test for Data Transfer (2)

**Test Items** (a) Transfer Delay vs. Traffic Load
(b) Transfer Delay with Different Data Priorities

**Test Setup**




TX Data
(1)Length: 15seg
(2)ACK: No
(3)Priority: 0(Low)
(4)Number of data : 100
(5)TX interval :
1～3sec(0.5step)

(1)1 or 15
(2)Yes
(3)0(Low)
(4)100
(5)0

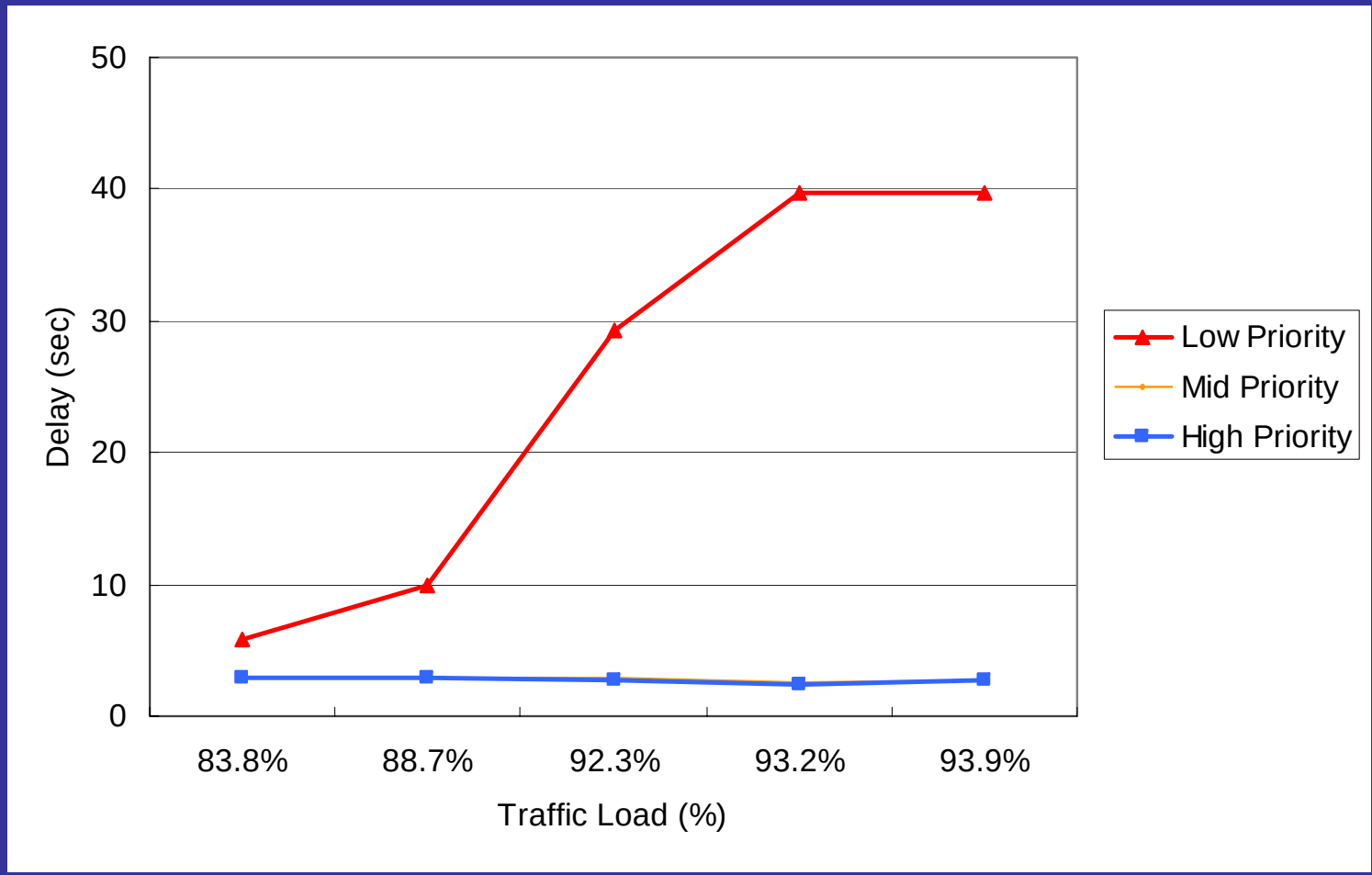
(1)1 or 15
(2)Yes
(3)0(Low) or 1(Mid)
(4)100
(5)0

(1)1 or 15
(2)Yes
(3)0(Low) or 1(High)
(4)100
(5)0

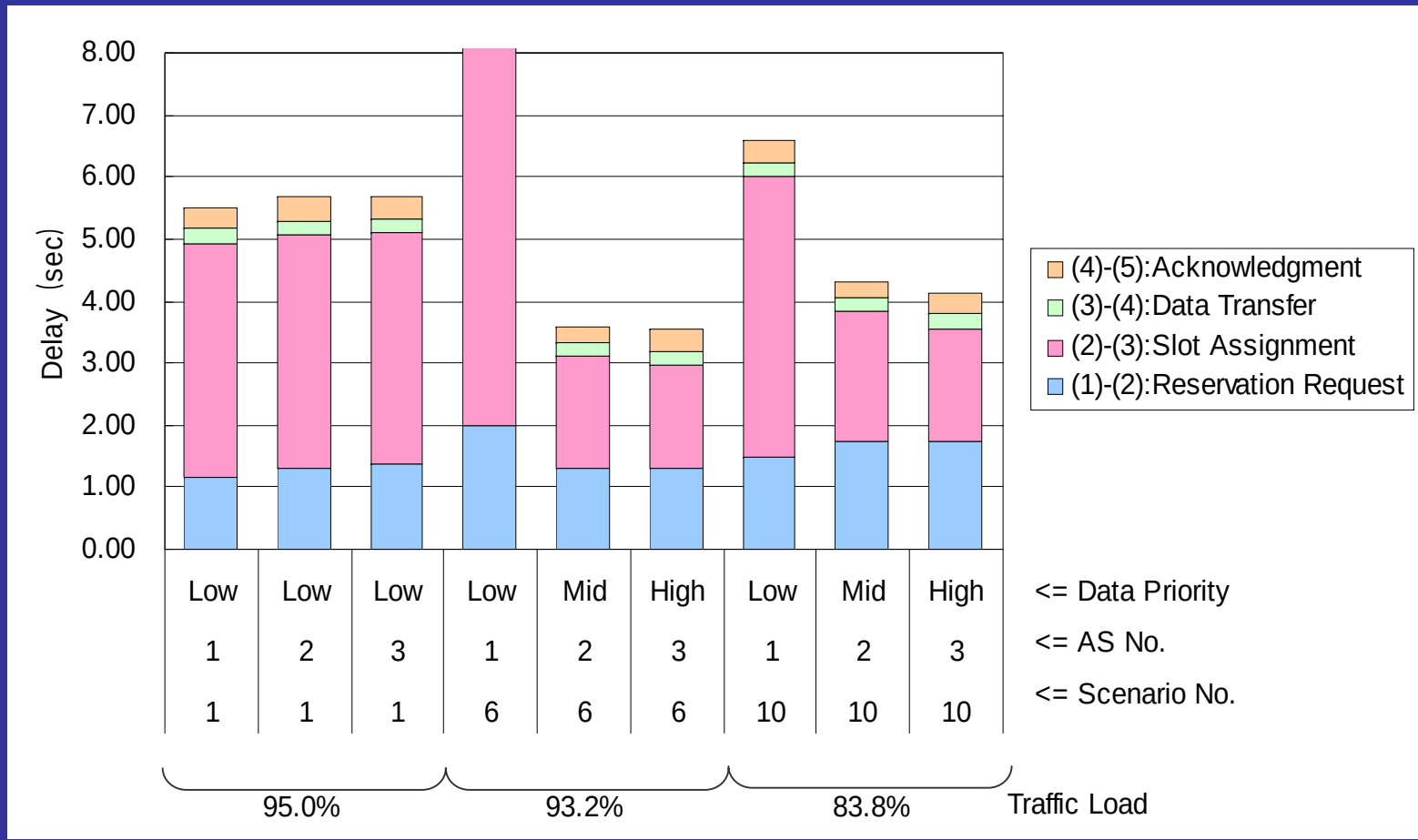
# Test Scenarios for Data Transfer Tests (2)

| Scenario | Data Length | TX Interval for Uplink | Priority for AS 1 | Priority for AS 2 | Priority for AS 3 |
|---|---|---|---|---|---|
| 1 | 1 seg | 1.0 sec | 0 (Low) | 0 (Low) | 0 (Low) |
| 6 | 1 seg (62 bytes) | 1.0 | 0 (Low) | 1 (Mid) | 2 (High) |
| 7 | | 1.5 | 0 | 1 | 2 |
| 8 | | 2.0 | 0 | 1 | 2 |
| 9 | | 2.5 | 0 | 1 | 2 |
| 10 | | 3.0 | 0 | 1 | 2 |
| 16 | 15 seg (930 bytes) | 1.0 | 0 | 1 | 2 |
| 17 | | 1.5 | 0 | 1 | 2 |
| 18 | | 2.0 | 0 | 1 | 2 |
| 19 | | 2.5 | 0 | 1 | 2 |
| 20 | | 3.0 | 0 | 1 | 2 |

# Traffic Load vs. Transfer Delay



# Transfer Delay with Different Data Priorities

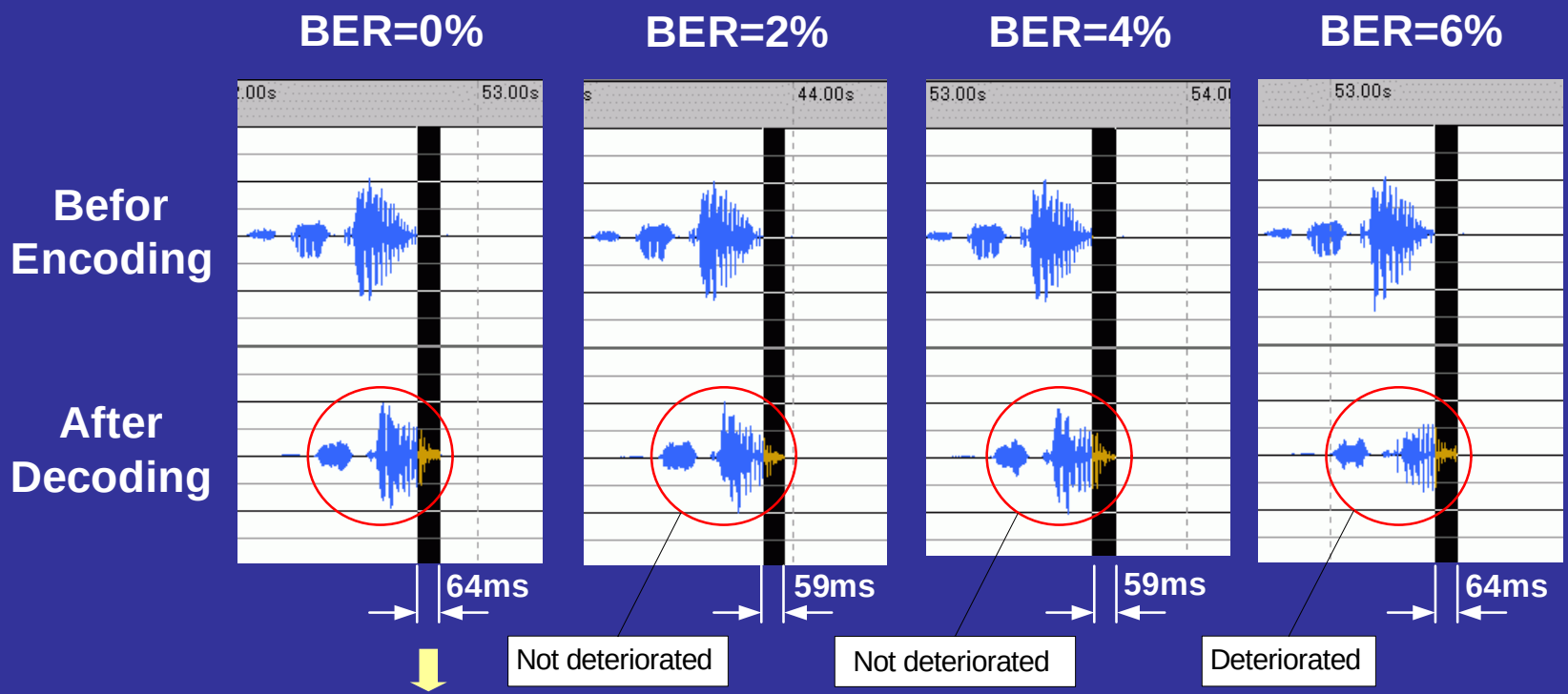


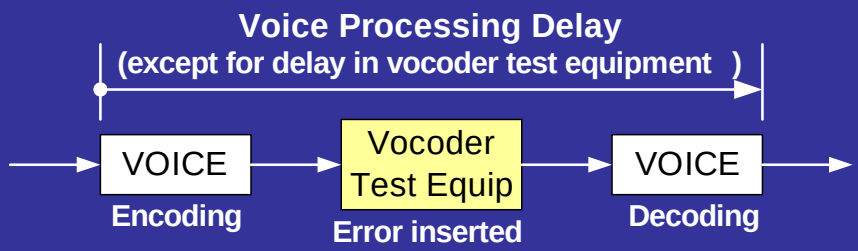
# Laboratory Test for Voice Quality

## Test Items

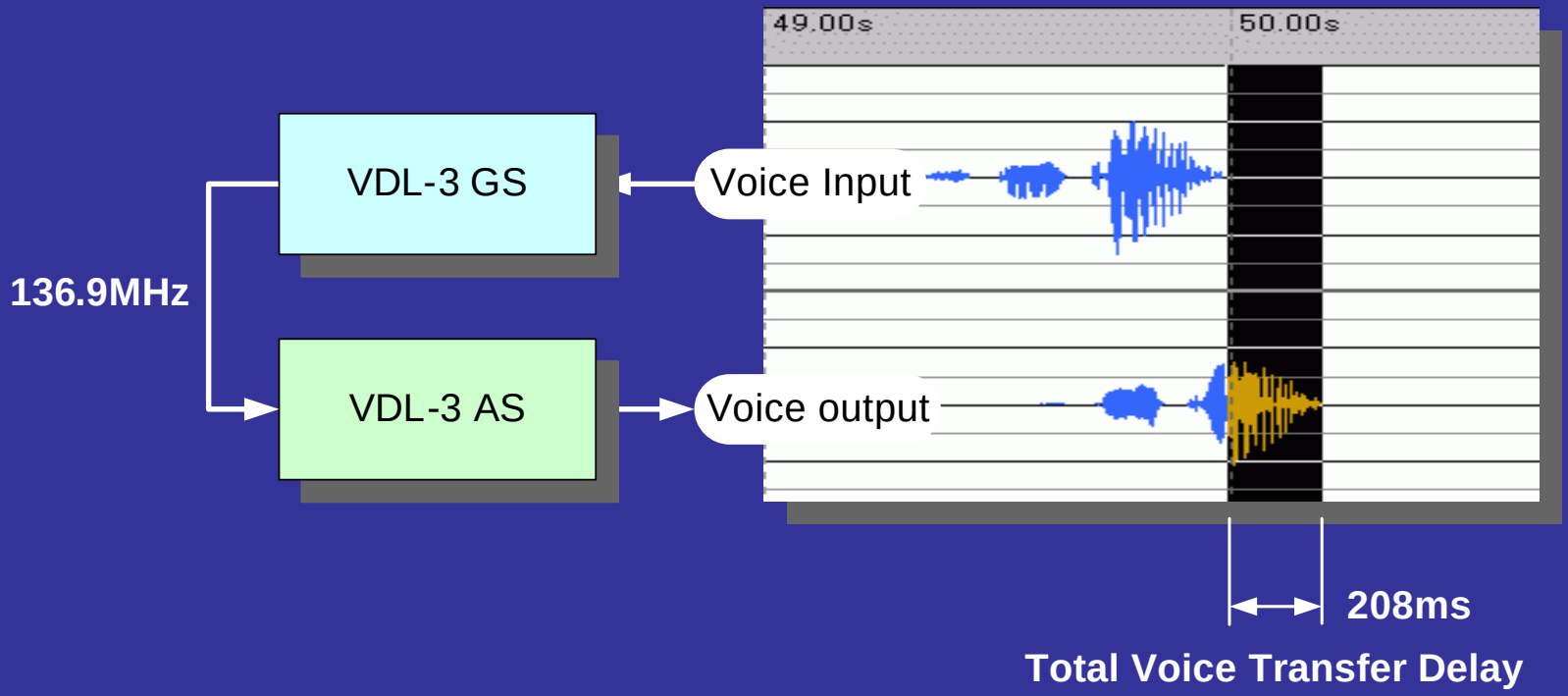
- Vocoder Processing Delay
- Total Transfer Delay (end to end)
- Voice Quality with Radio Interference
- Voice Quality by PESQ Tool

# Vocoder Processing Delay



# Total Voice Transfer Delay (end to end)




Specifications on system transfer delay in ICAO Manual Doc9805

- Transmit delay =< 175ms : Delay from voice input to RF transmission
- Receive delay =< 40ms : Delay from RF reception to voice output
- End-to-end voice delay = max 250ms : Total transfer delay

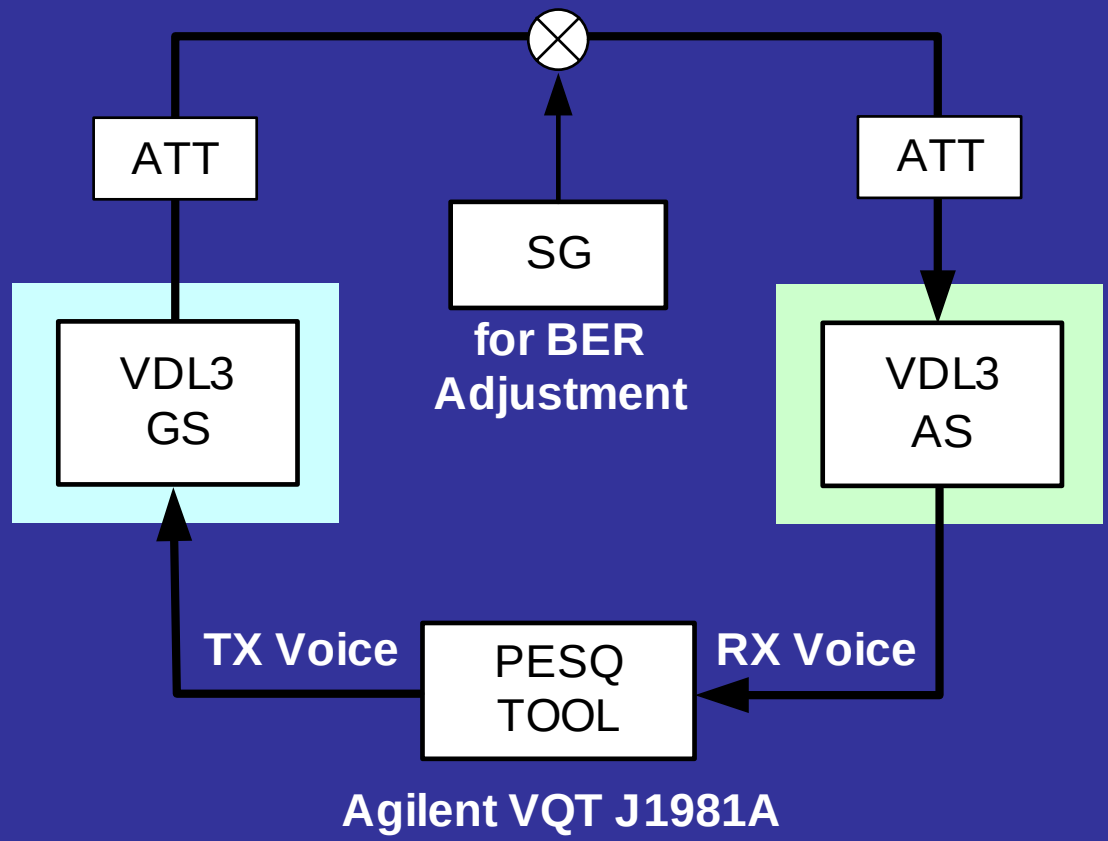
# Voice Quality with Radio Interference

| D/U | BER | Quality of Received Voice |
|---|---|---|
| 10dB | 6.0E-02 | Very little audio output (close to “step on” situation) |
| 11dB | 4.7E-02 | A very little part of voice message understandable |
| 12dB | 4.6E-02 | Considerable part understandable |
| 13dB | 3.1E-02 | Interference recognized but voice message was understandable, in particular bass is partly unclear |
| 14dB | 1.7E-02 | Interference obviously recognized but voice message was understandable |
| 15dB | 4.5E-03 | Some interference recognized |
| 16dB | 2.0E-03 | No interference identified |

# Voice Quality by PESQ Tool

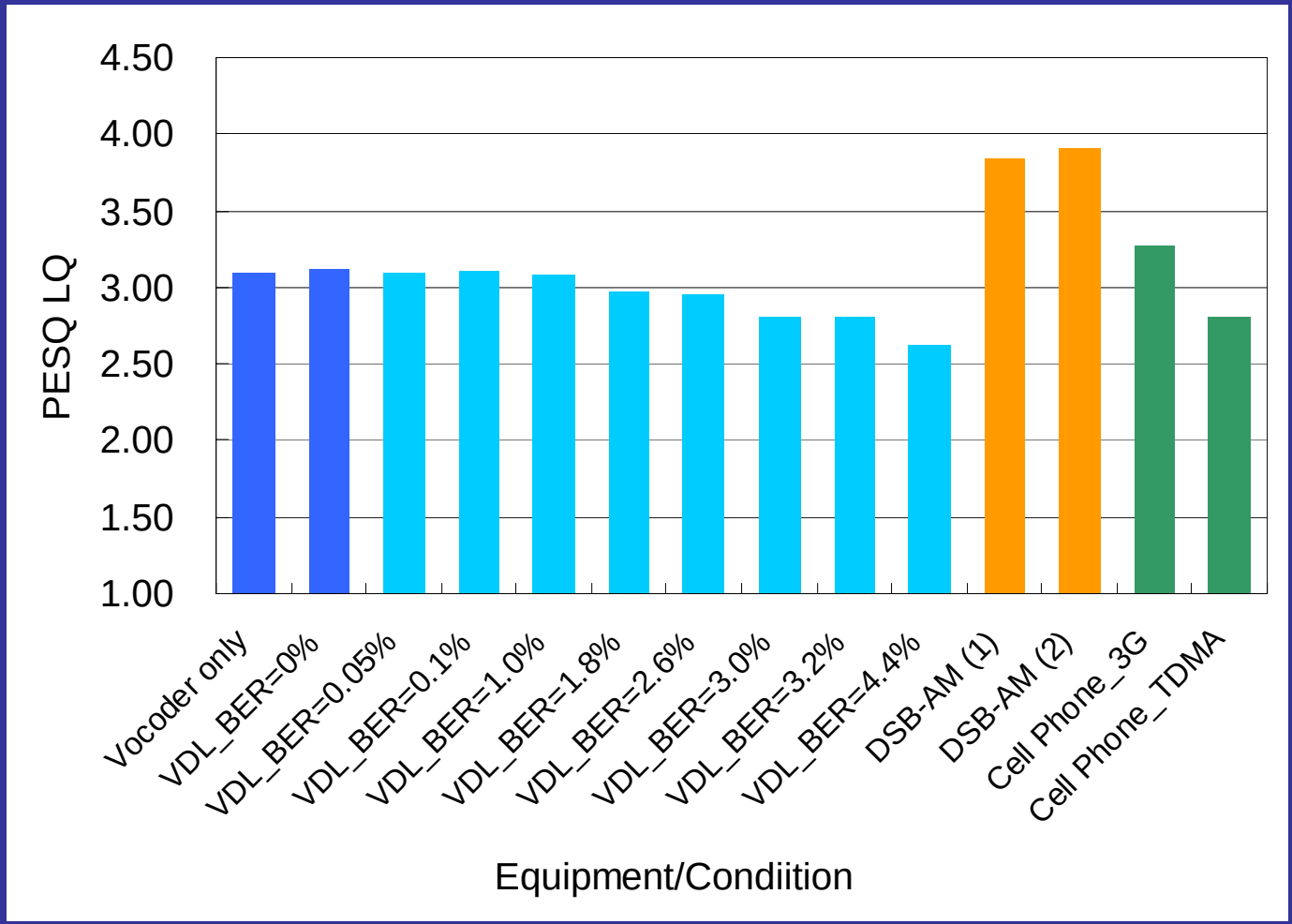
## Test Setup

**Reference Voice**
**(1) Prepared by Agilent**
**(2) ATC Phrase**
**by Japanese Controller**

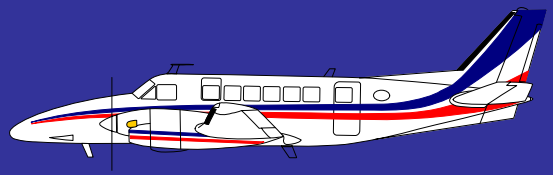


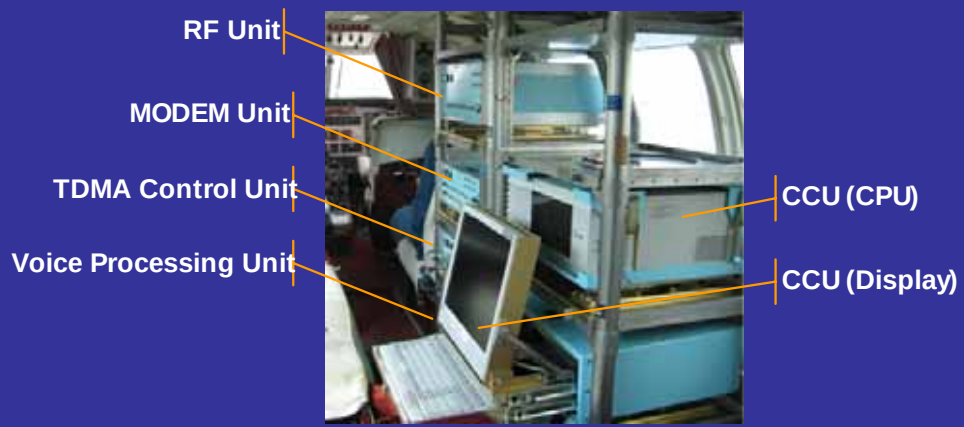

PESQ: Perceptual Evaluation of Speech Quality
ITU-T Recommendation P.862

# Voice Quality by PESQ Tool

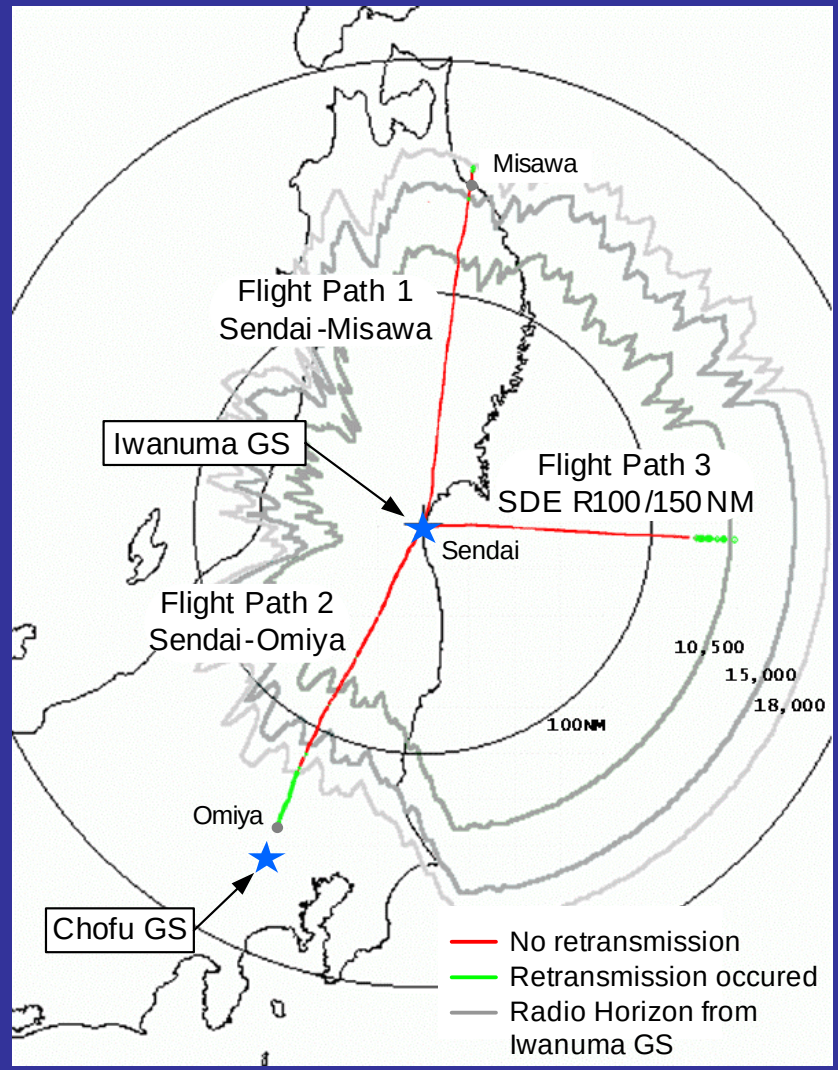


# Flight Test






**Aircraft Station**




Flight Path

# Flight Test - Received Level