Research & Development of VDL Mode 3 System

VDL Research Group
Aeronautical Systems Division

Independent Administrative Institution
Electronic Navigation Research Institute

ENRI

Presentation Overview

1. Electronic Navigation Research Institute (ENRI)
2. VDL Mode 3 Research Activities in ENRI
3. VDL Mode 3 Test System
4. Tests and Evaluation
   - Radio interference tests
   - Preliminary communication tests
   - Preliminary evaluation for voice quality
   - Flight tests
   - Voice quality tests by PESQ tool

Electronic Navigation Research Institute

Mission

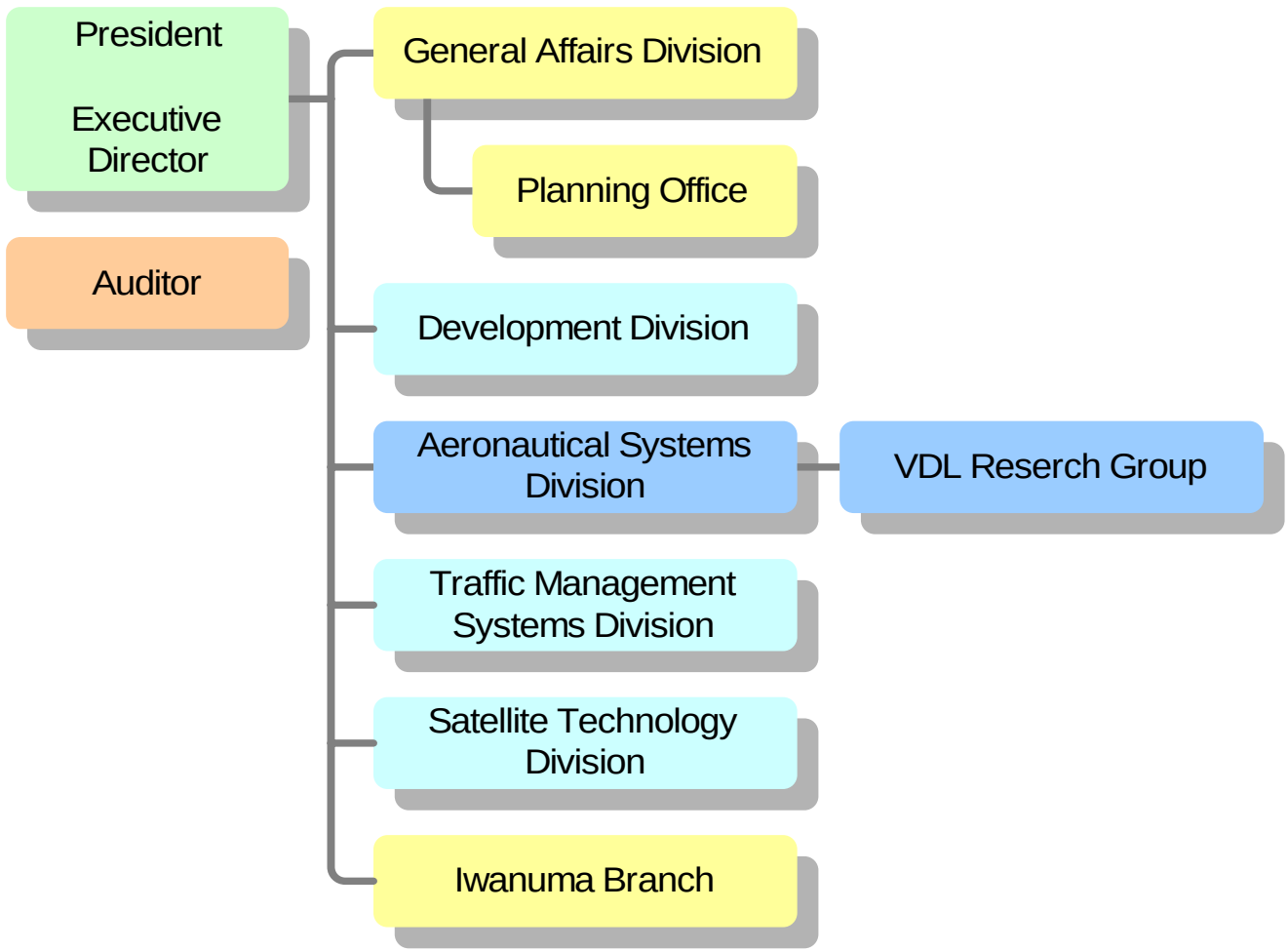
To carry out research and development in order to ensure safe and efficient transport systems as the leading institute of electronic navigation in Japan

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



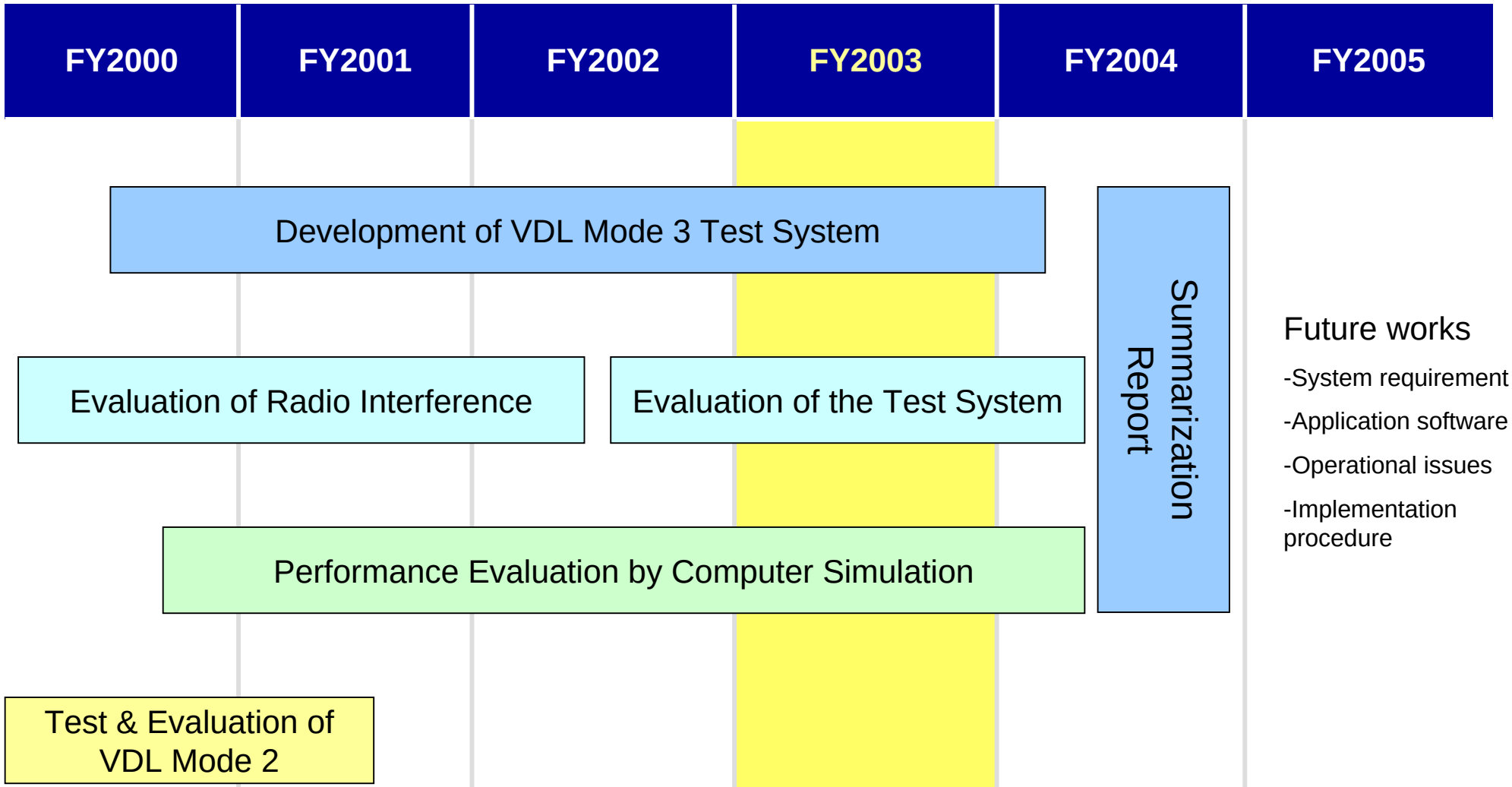
Overview of VDL Mode 3 R&D Activities

1. Objectives
   - Development and evaluation of VDL Mode 3 system compliant with ICAO SARPs
   - Study and consideration on possible operational issues to implement VDL Mode 3 system in Japanese airspace
2. Duration of Research and Development Activity
   - 2000-2004 (based on fiscal year in Japan)

Overview of VDL Mode 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 Mode 3 R&D Activities



Overall Plan for VDL Mode 3 Tests & Evaluation

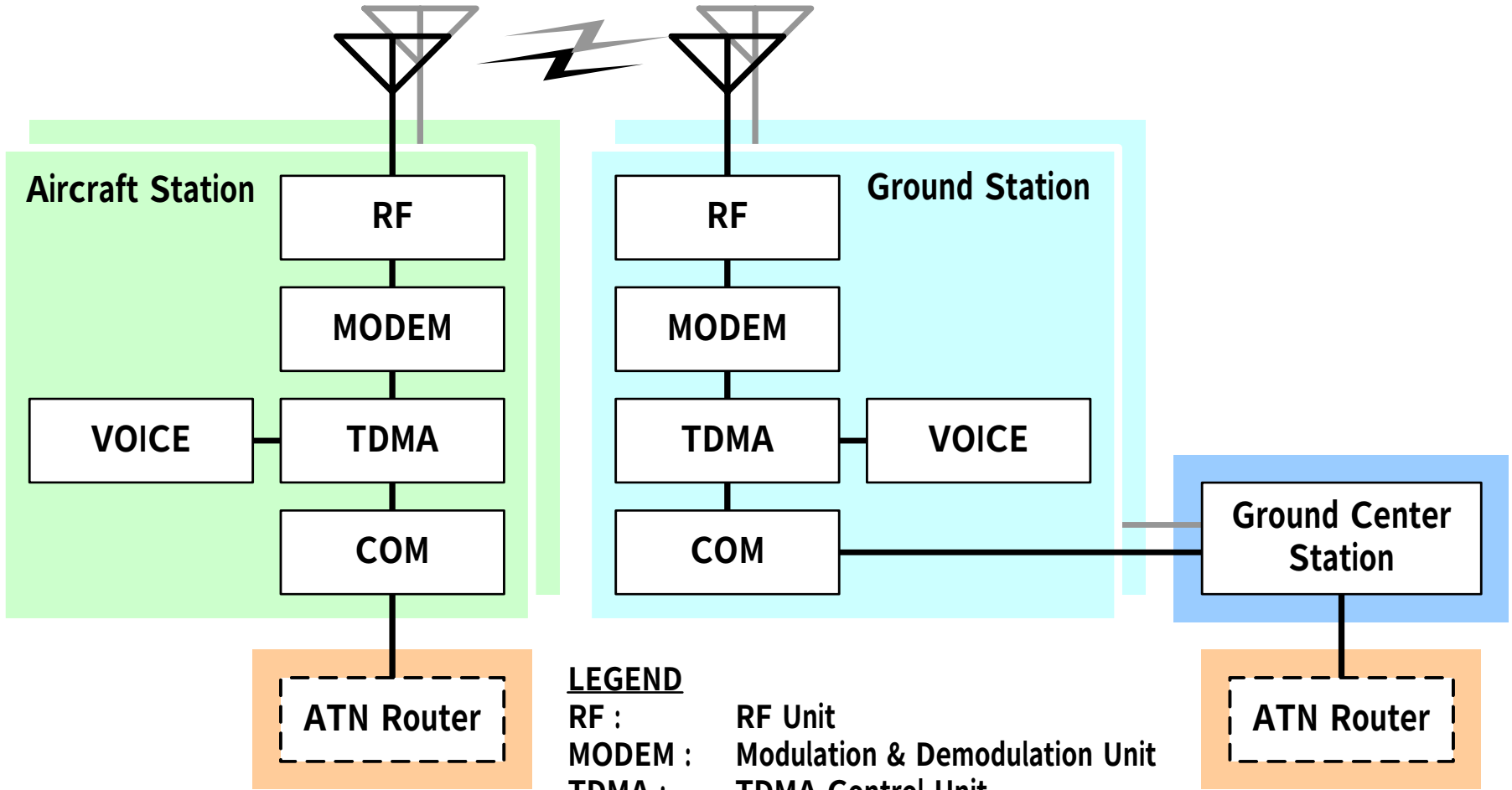
Major Event	FY2000	FY2001	FY2002	FY2003	FY2004
Evaluation for Vocoder Selection	**x** SEP-NOV				
Radio Interference Test		**x** OCT	**x** SEP		
Evaluation for Data Communication			**x** FEB	**x** DEC	**x** SEP
Evaluation for Voice Communication			**x** FEB	**x** SEP	**x** SEP
Flight Test				**x** **x** **x** APR SEP MAR	**x** SEP
ATN Connection Test					**x** **x** APR SEP

x: done / **x**: plan

Major Specifications of VDL Mode 3 Test System

Subject	Test System Specifications
General	Compliant with ICAO SARPs & Manual
Tx Power	15w (=42dBm)
Tx/Rx Frequency	118.000 – 136.975MHz in Laboratory Test 136.900 and 136.925MHz in Flight Test
System Configuration	2V2D and 3V1D
Minimum Receiving Sensitivity	-103.2dBm (at BER=10^{-3} before FEC; measured value)
The Number of Equipment	Ground/Air Station : Two sets each Ground Center Station : One set

Configuration of Test Equipment



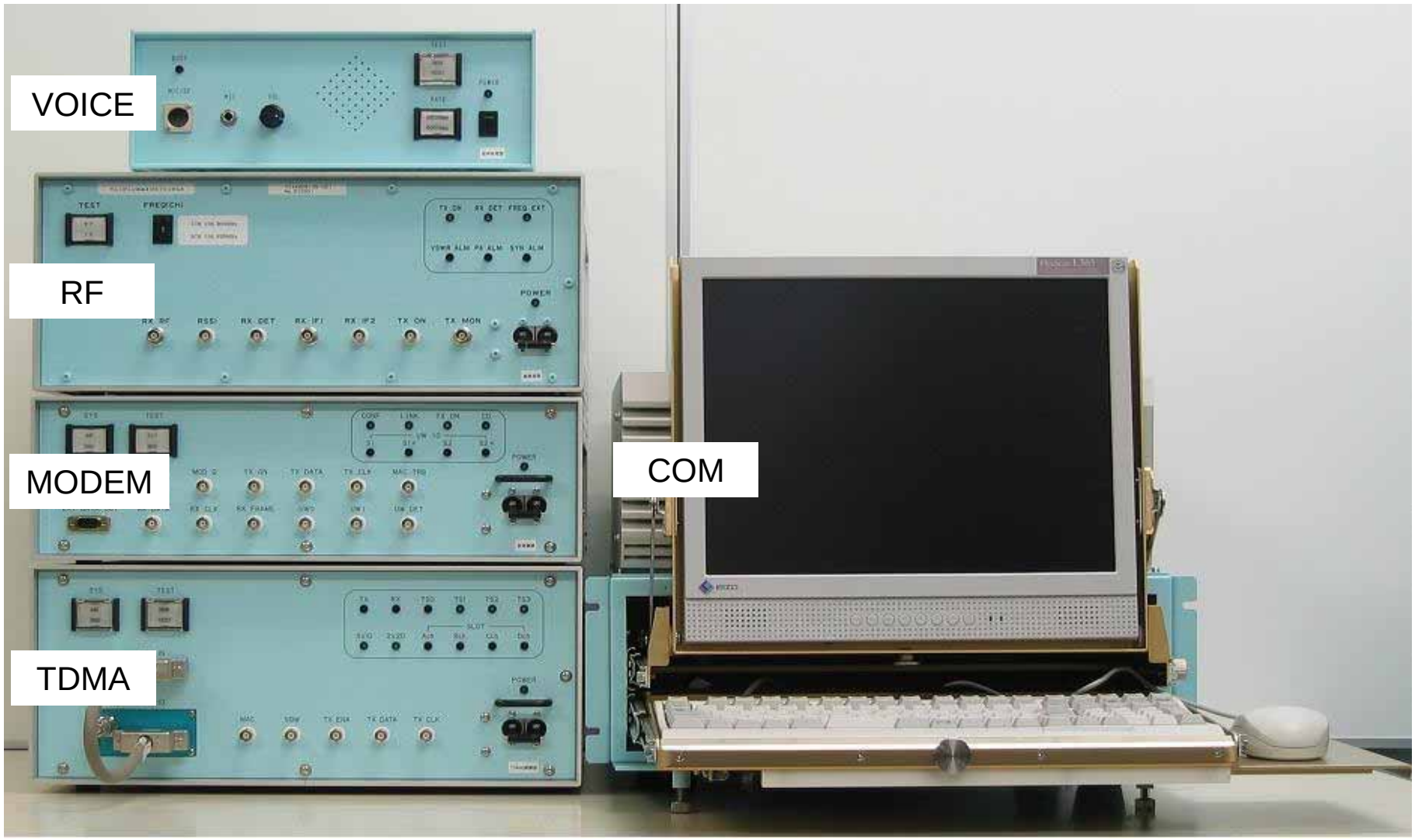
Additional Function for Testing

1. Monitor and Storage of Received Data Status
   - For each M burst and V/D burst received
   - MODEM unit detects and calculates;
     - Average received power : -45 to –115dBm (0.5dB step)
     - Minimum received power : the same as above
     - SQP value : 0 to 15 (DSP and software defined)
     - Average phase error : 0 to 22.5deg (0.1deg step)
   - TDMA Control unit detects and calculates;
     - The number of bits corrected by Golay code
       0 to 3, FF (FF indicates uncorrectable)
     - The number of bytes corrected by RS code
       0 to 5, FF (FF indicates uncorrectable)

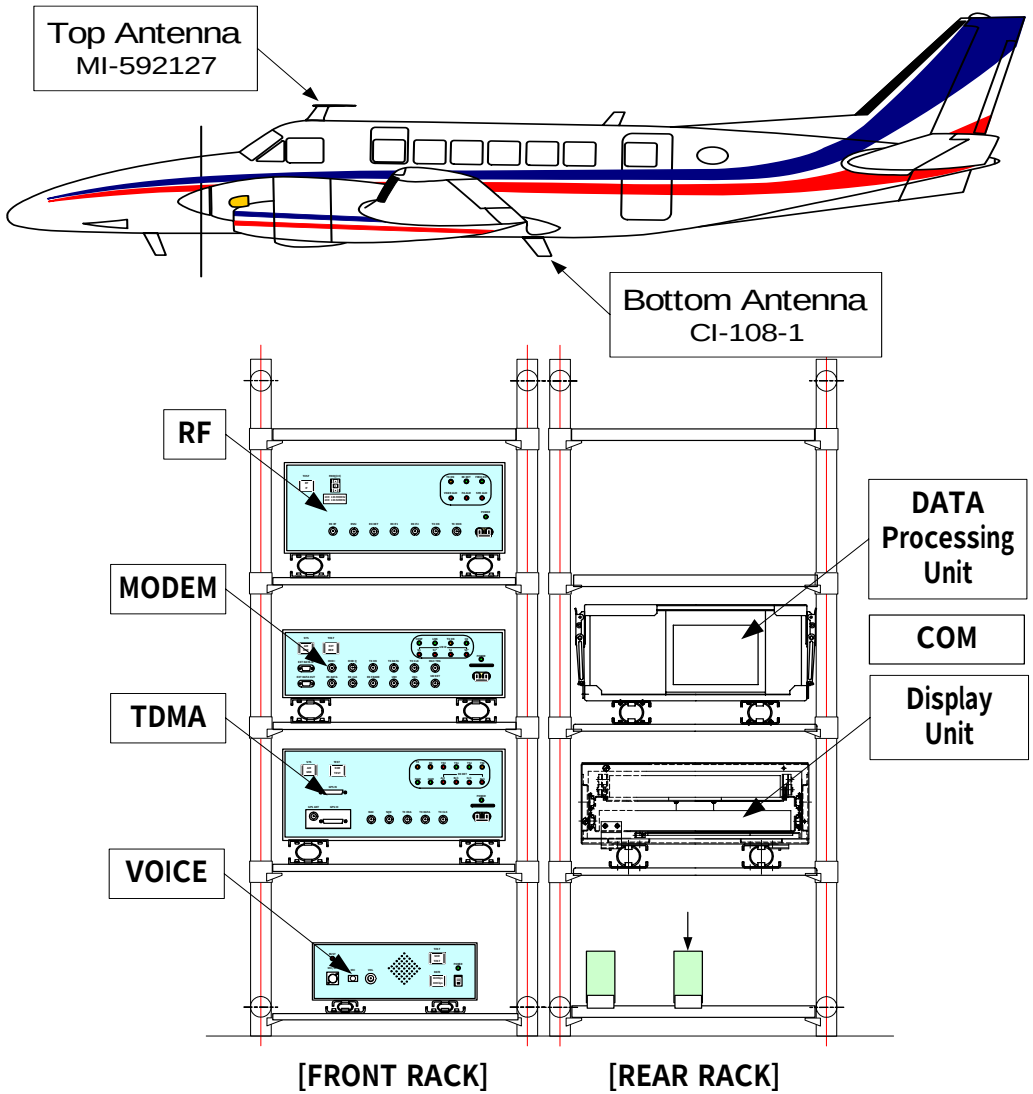
Additional Function for Testing (cont.)

2. Data Communication Based on Predefined Scenario
   - Any data length : 62 to 930bytes
   - Any transfer priority : 0 to 3
   - Any transfer interval (0.1sec step)
3. Graphical Display of Received Data Status
   - Real time monitoring
   - Avg & Min received power, SQP value, Avg phase error
4. Visual Display of In-flight Aircraft Position
   - Current position displayed on the map
   - Azimuth and distance from selected ground station

External View of Test Equipment

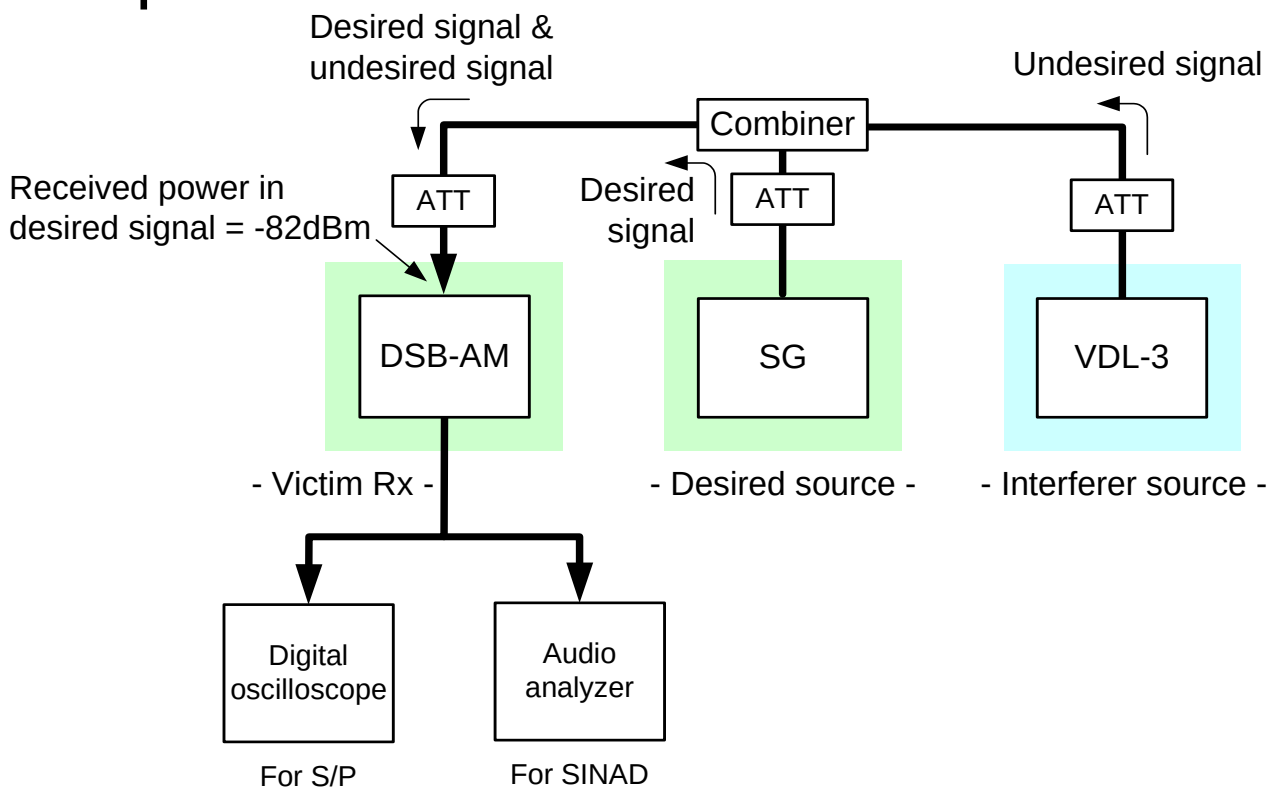


Test Equipment (Aircraft Station)

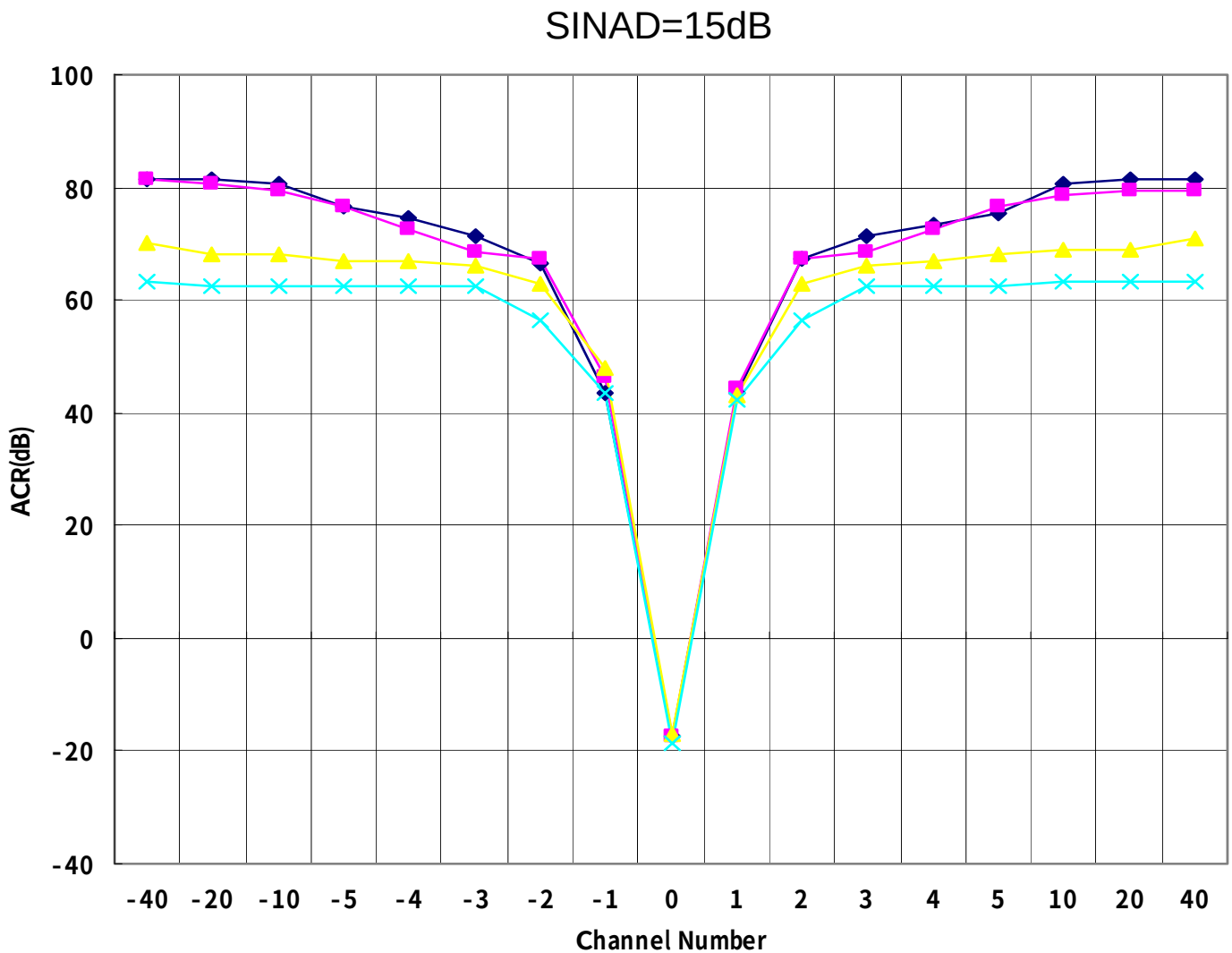


Radio Interference Tests for DSB-AM

1. Test Items
   a) SINAD, S/P test
   b) MOS evaluation by pilots and controllers
2. Test Setup

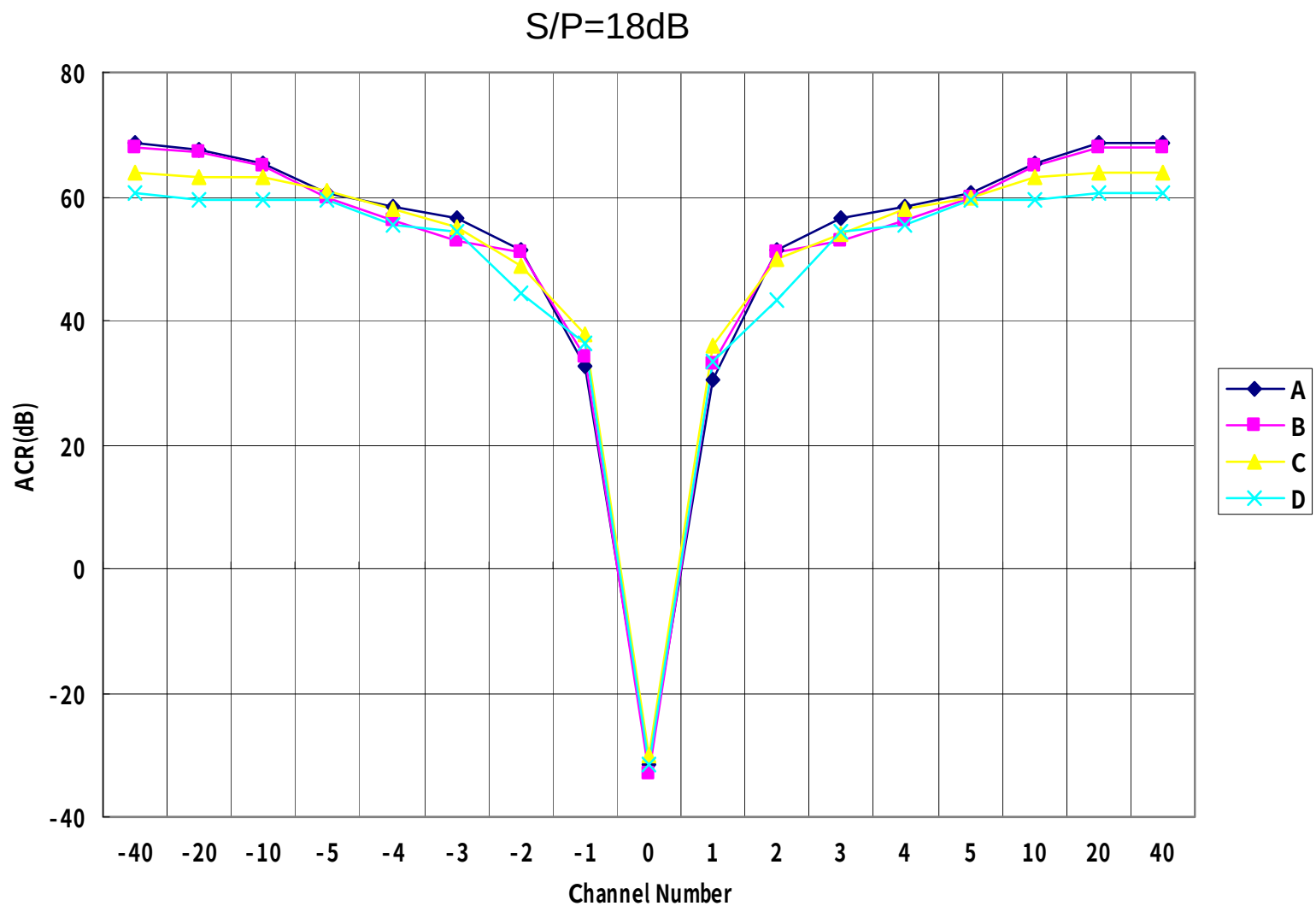


Test Results - SINAD -

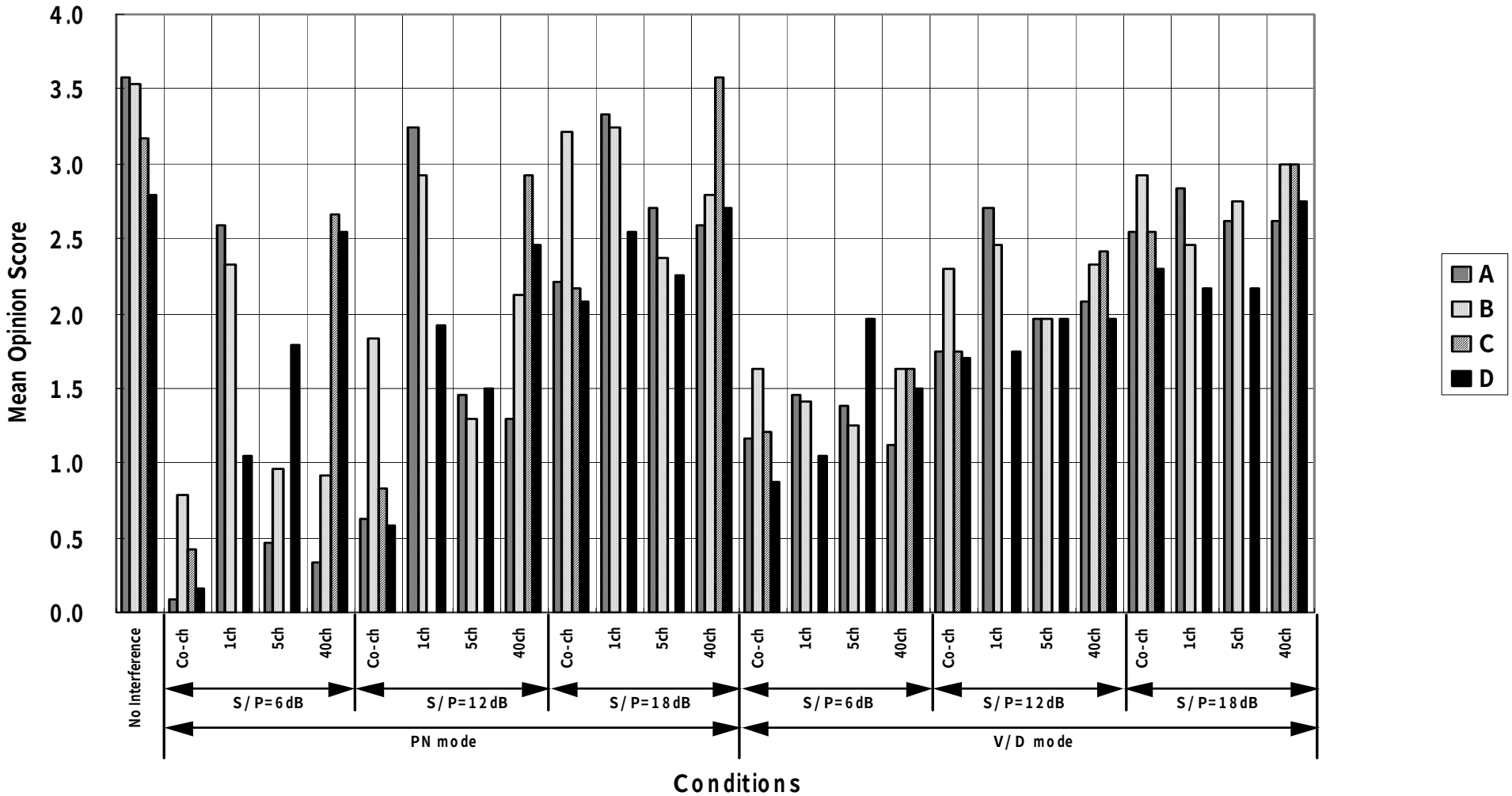


A – D indicate four type of DSB-AM airborne transceivers.

Test Results – S/P –

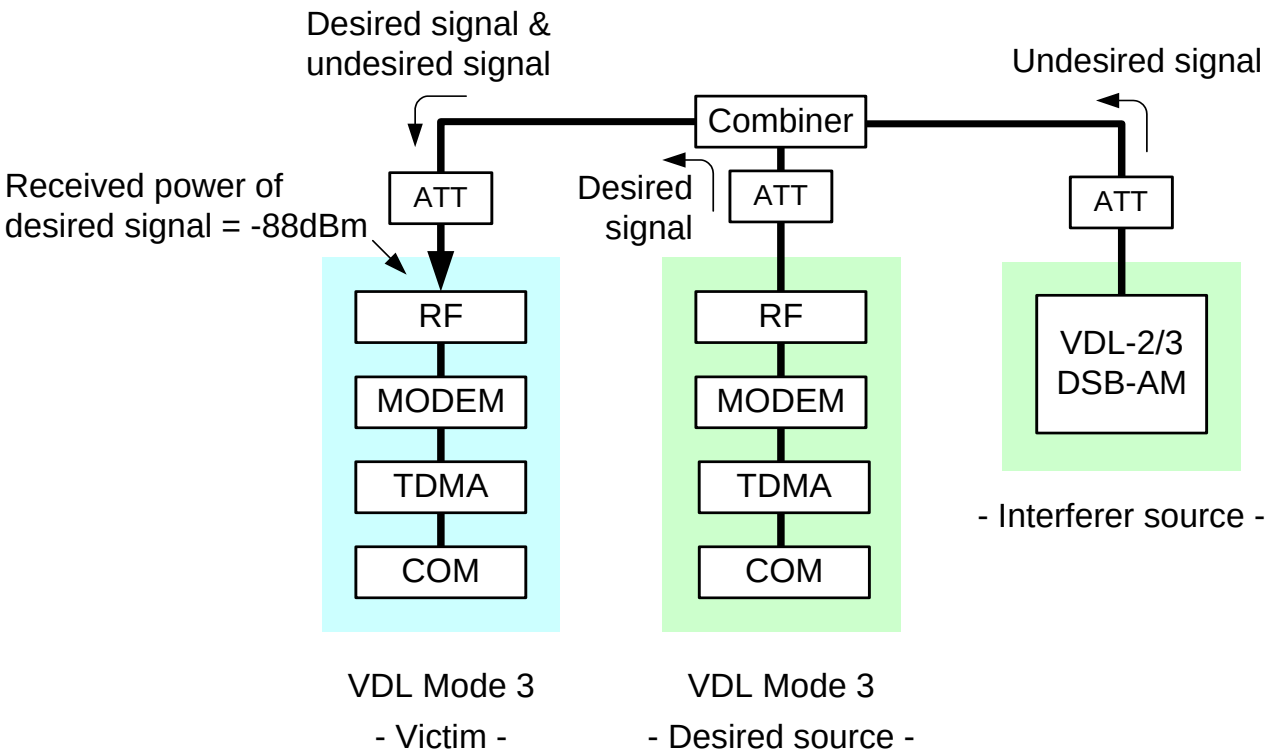


Test Results – MOS evaluation -

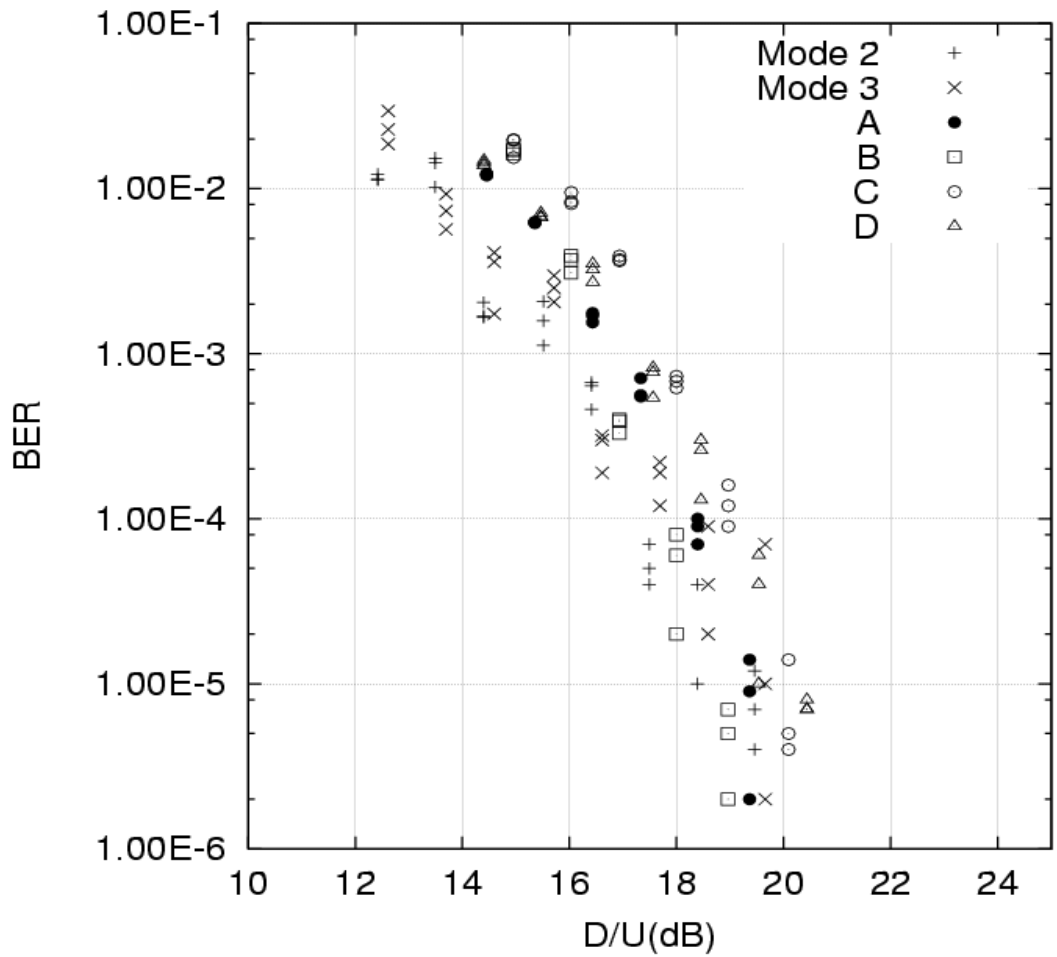


Radio Interference Tests for VDL Mode 3

1. Test Items
   a) BER under interference on co-channel
   b) Adjacent Channel Rejection (ACR)
2. Test Setup

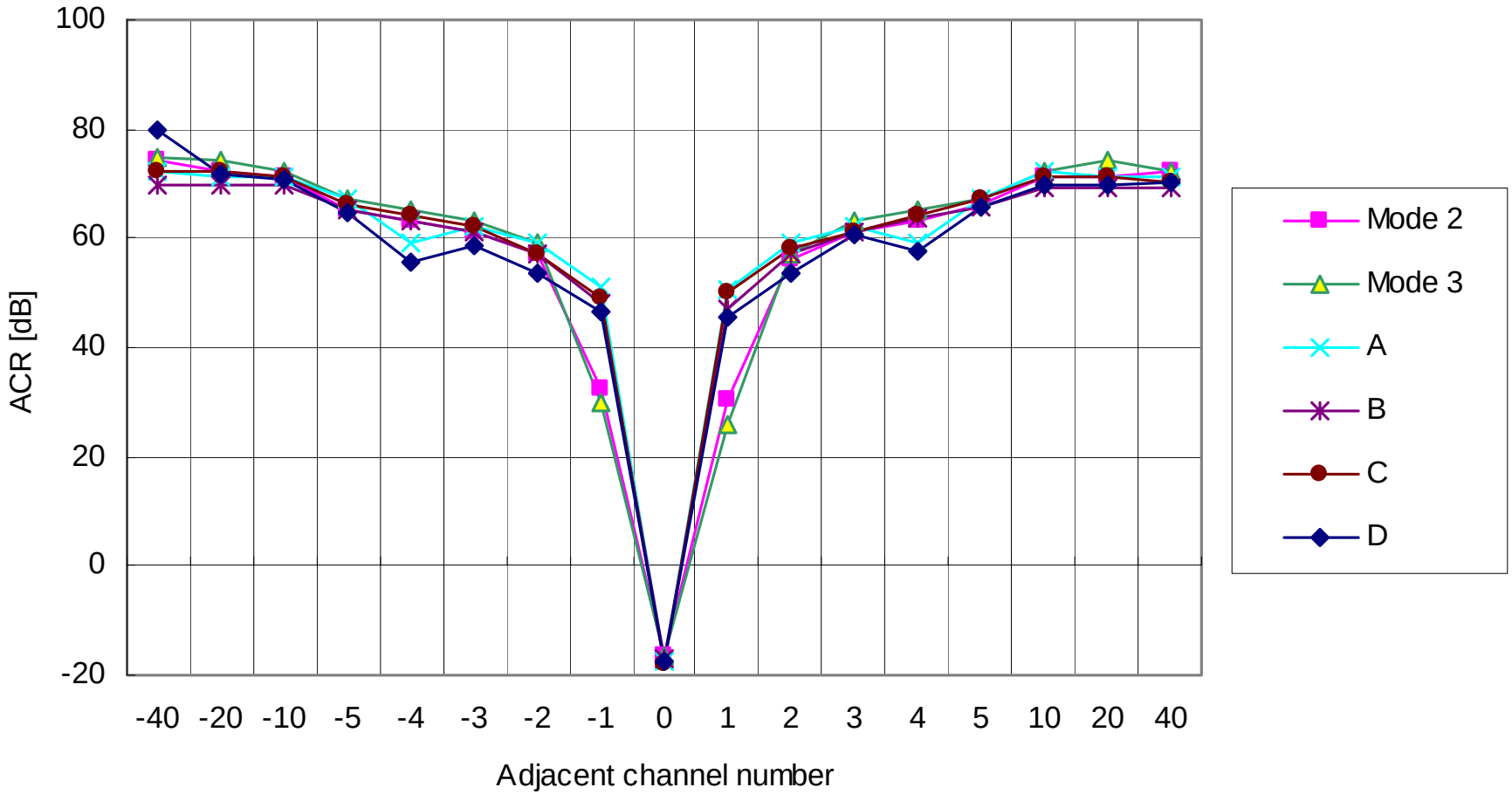


Test Results
- BER Under Interference on co-channel -

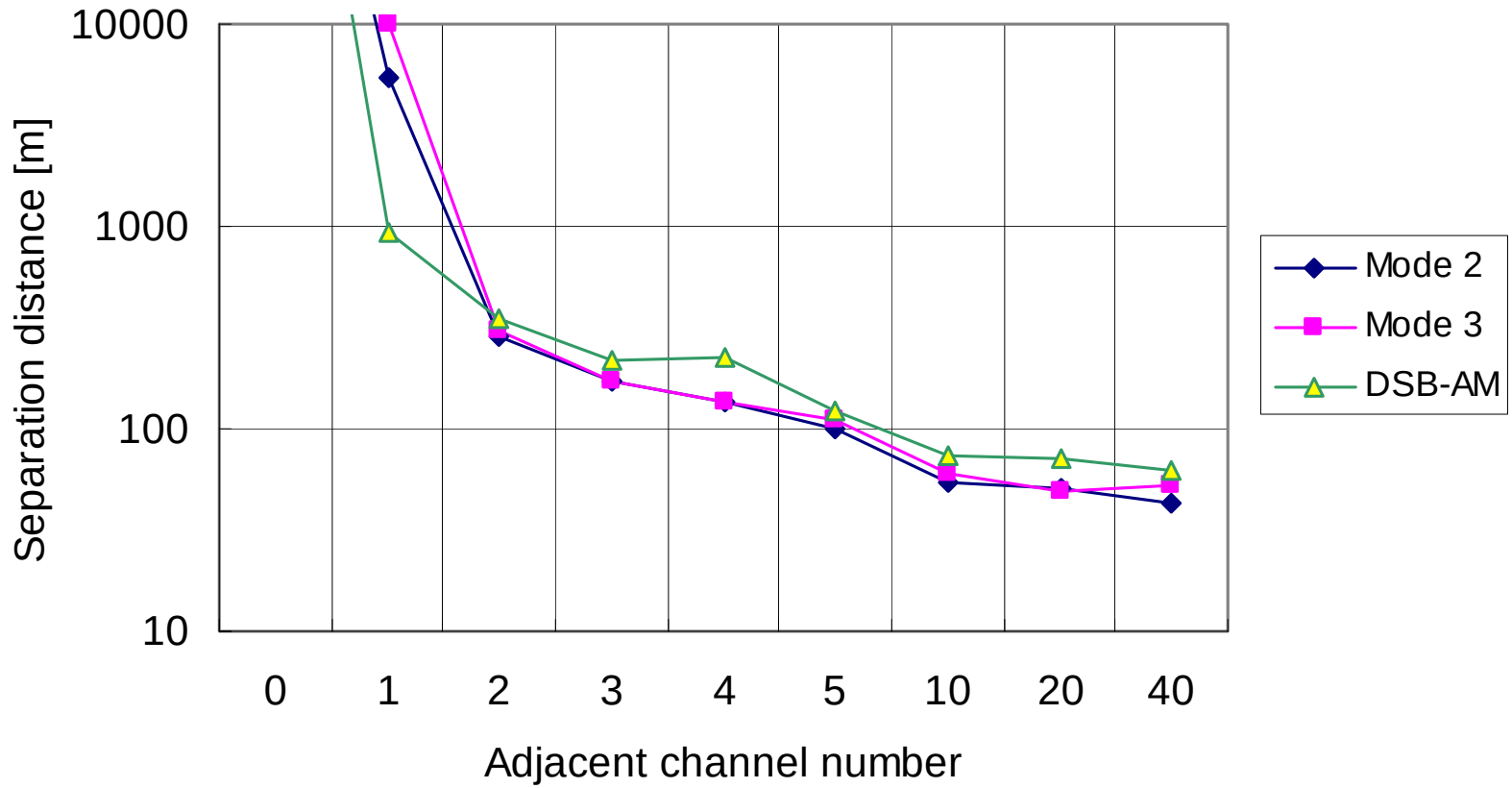


A – D indicate four type of DSB-AM airborne transceivers

Test Results
- Adjacent Channel Rejection -

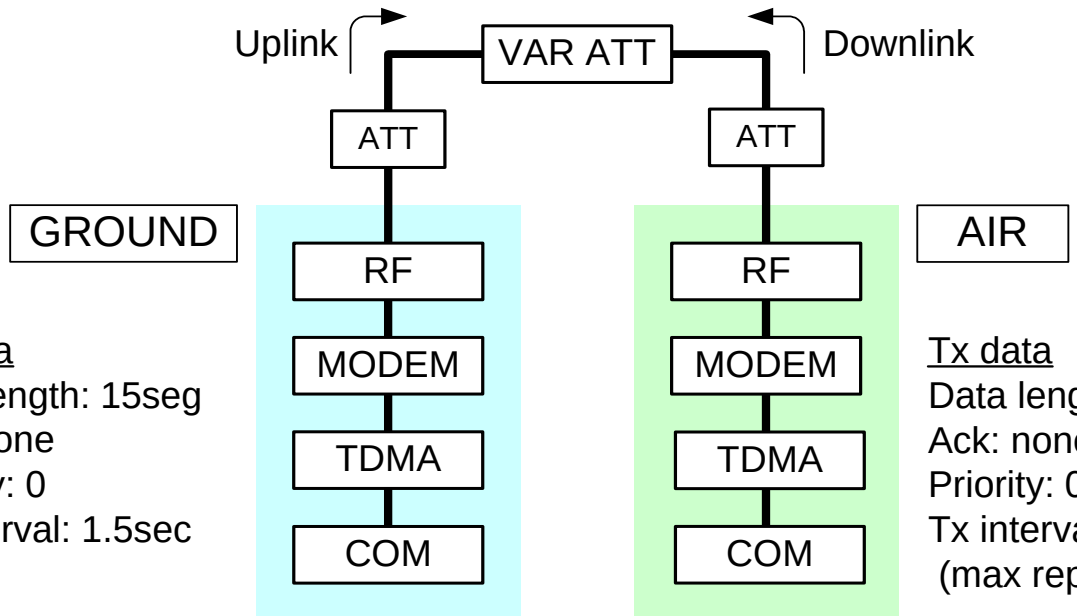


Test Results
- Isolation converted into separation distance -



Preliminary Communication Tests (1)

1. Test Items; a) Received Power vs.BER
   b) BER vs. Transfer Delay & Throughput
2. Test Setup



RF : RF Unit

MODEM : MODEM Unit

TDMA : TDMA Control Unit

COM : Communication Control Unit

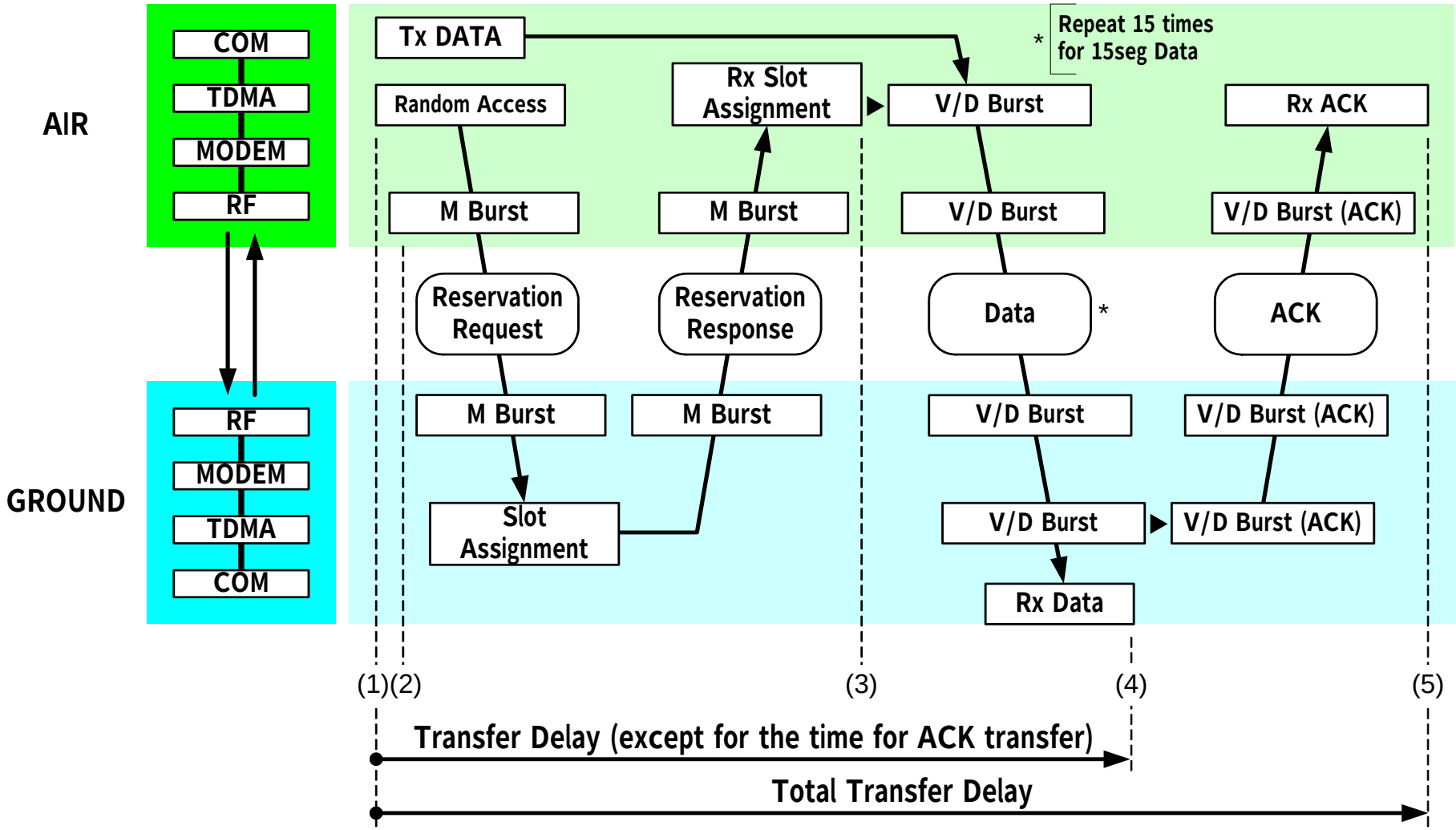
Tx data
Data length: 15seg
Ack: none
Priority: 0
Tx interval: 1.5sec

Tx data
Data length: 1or15seg
Ack: none
Priority: 0
Tx interval: 0
(max repeated)

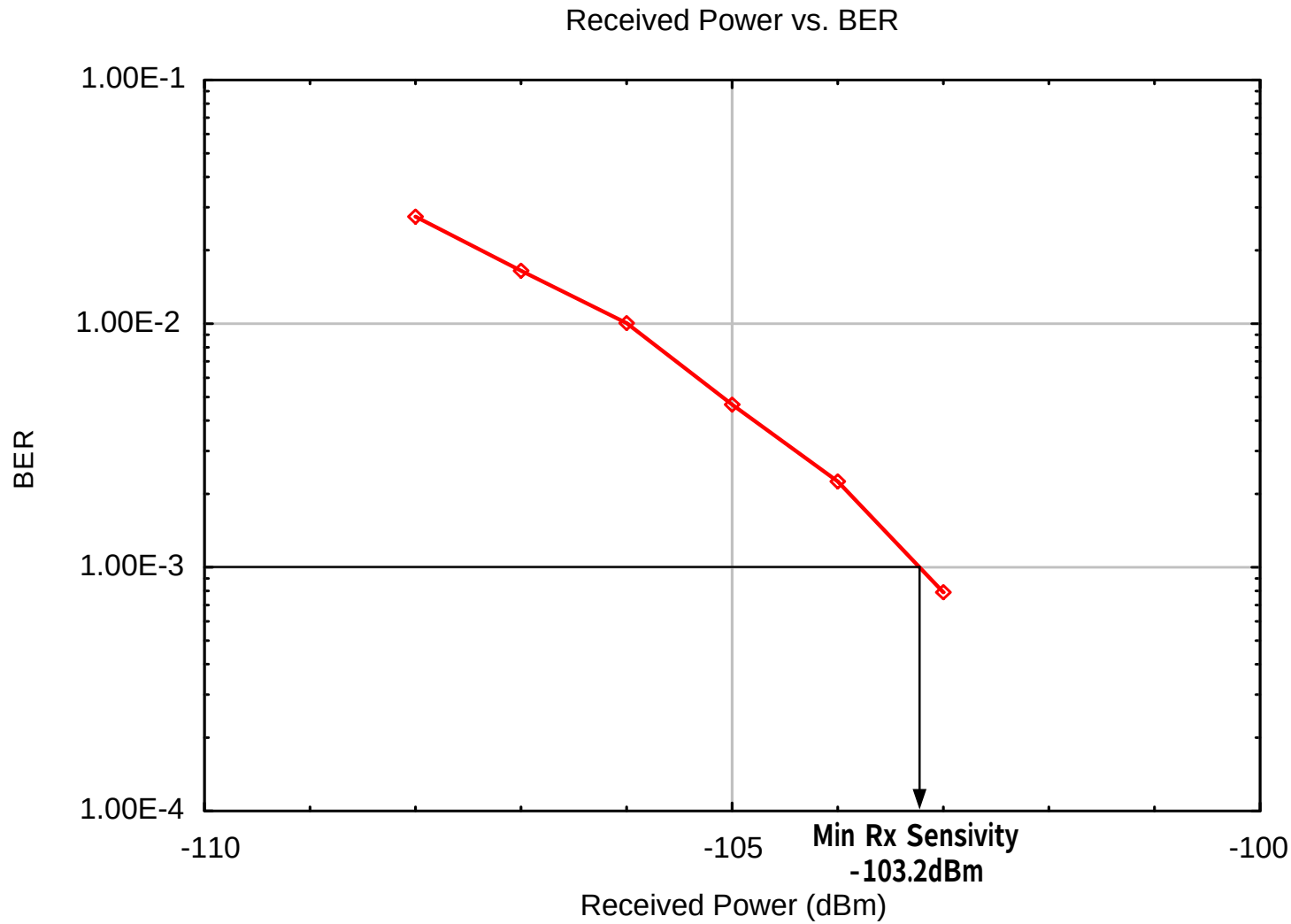
1seg : 62byte data

15seg : 930byte data

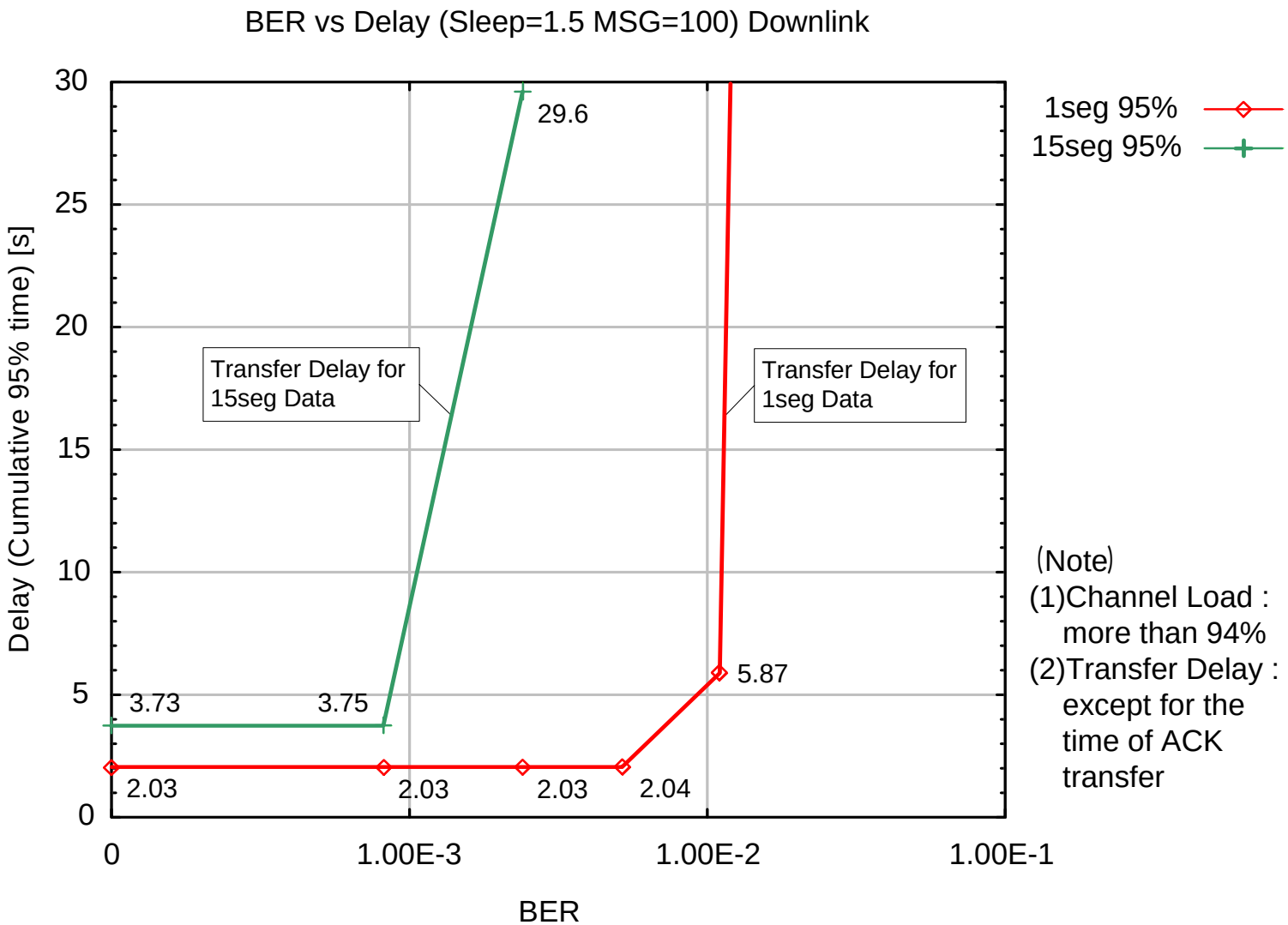
Definition for Transfer Delay in the Test



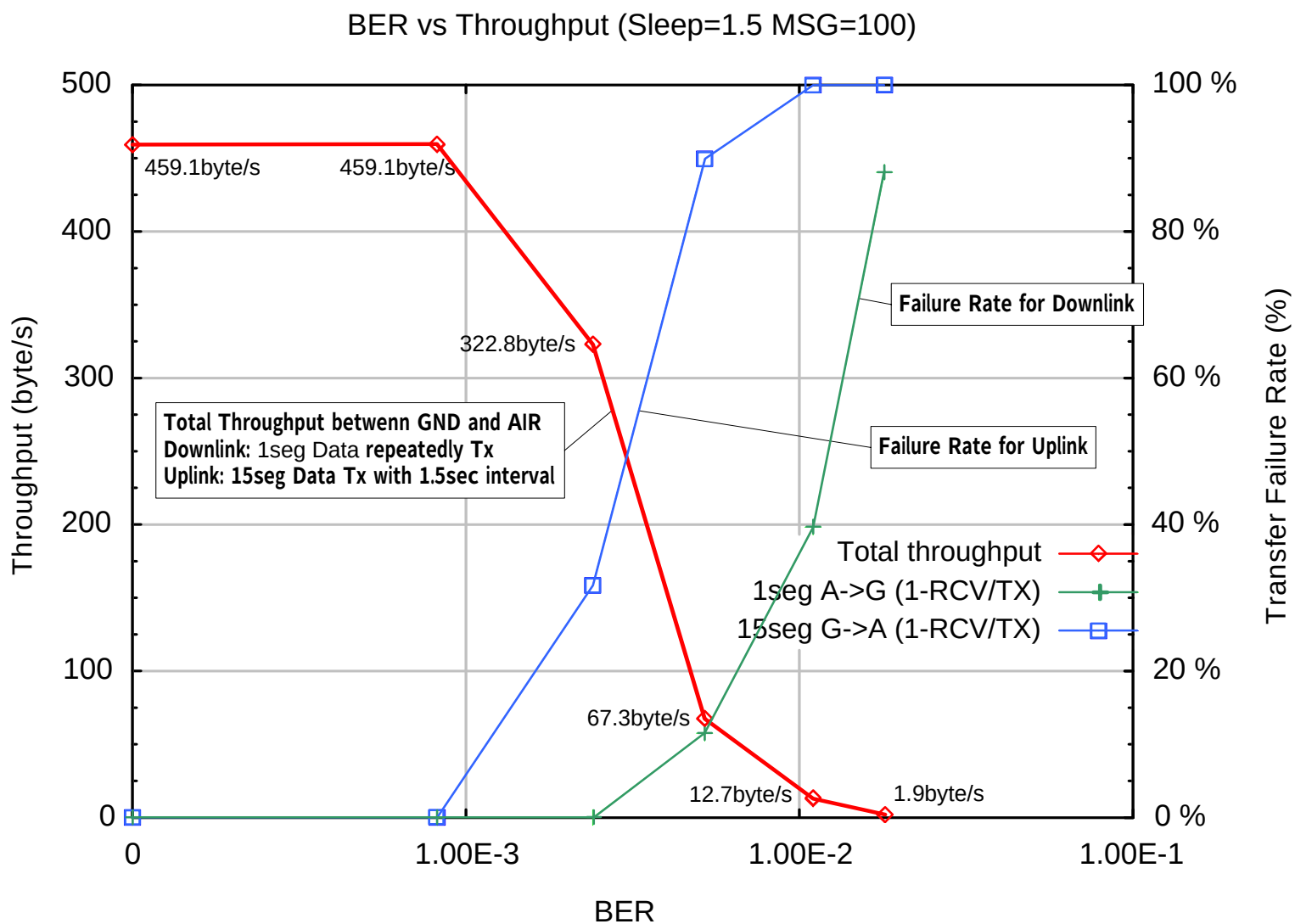
Test Results - Received Power vs.BER –



Test Results - BER vs.Transfer Delay –

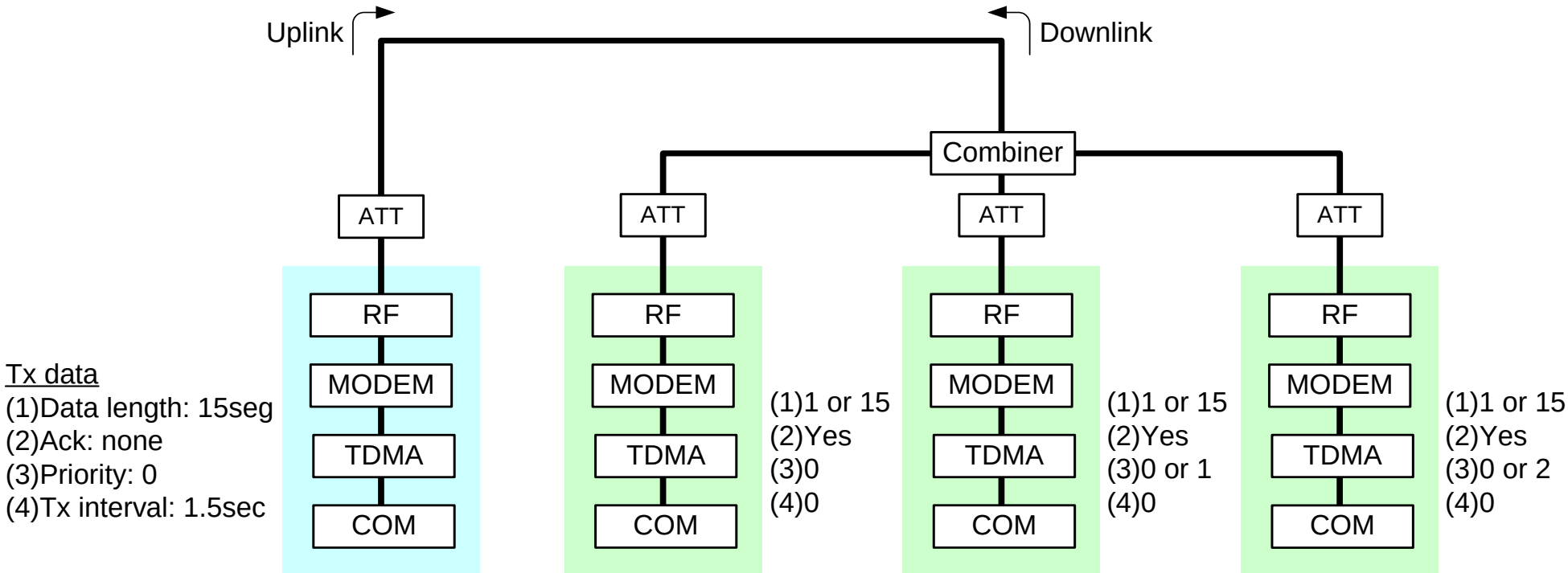


Test Results – BER vs.Throughput –



Preliminary Communication Test (2)

1. Test Items; Transfer Delay for Data with Different Priorities
2. Test Setup



Test Scenarios
- Transfer Delay for Data with Different Priorities -

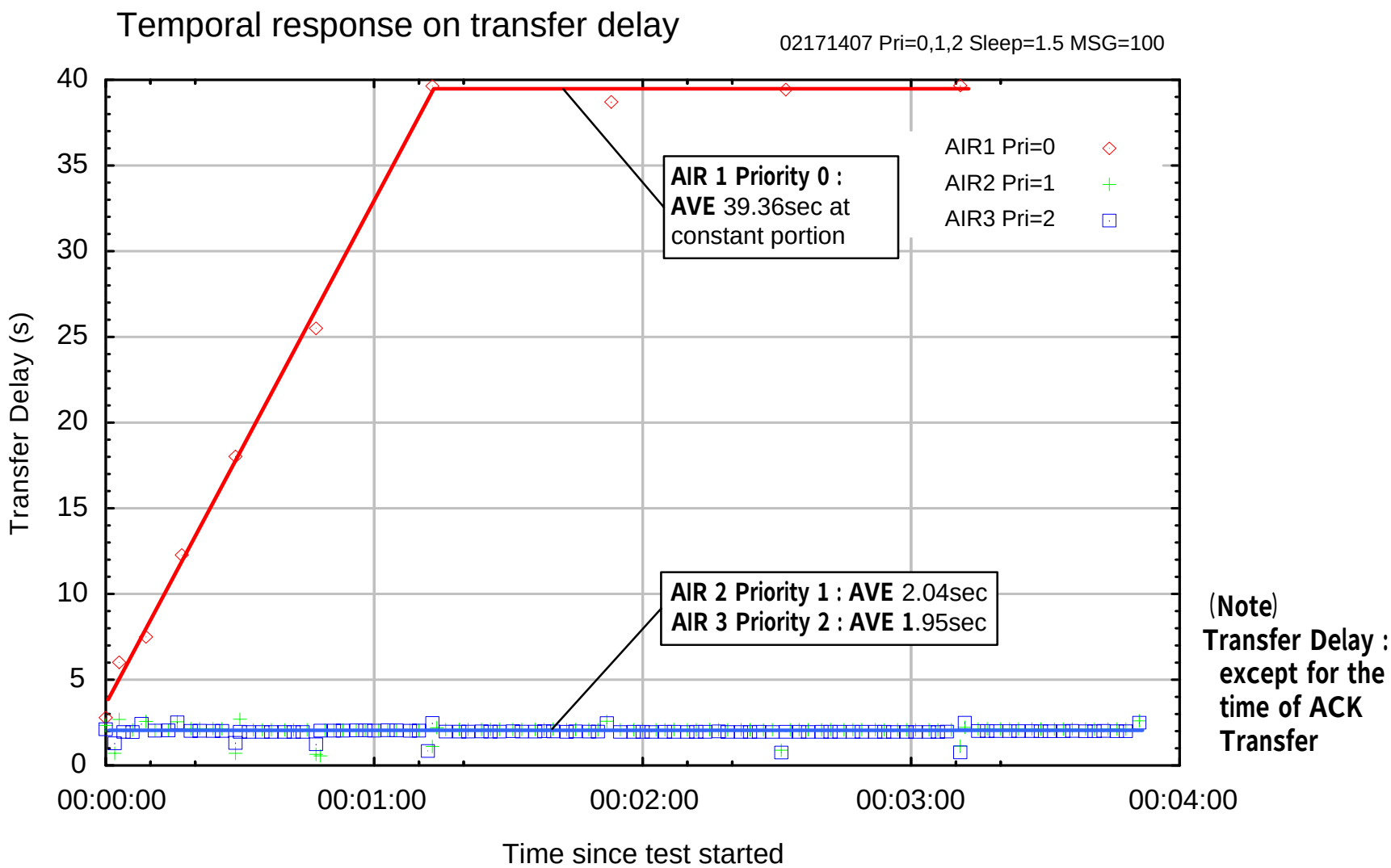
Scenario	Data Length	Tx Interval for Uplink	Priority for AIR 1	Priority for AIR 2	Priority for AIR 3
1	1seg	1.0sec	0 (low)	0 (low)	0 (low)
6	1seg (62bytes)	1.0	0 (low)	1 (mid)	2 (high)
7		1.5	0	1	2
8		2.0	0	1	2
9		2.5	0	1	2
10		3.0	0	1	2
16	15seg (930bytes)	1.0	0	1	2
17		1.5	0	1	2
18		2.0	0	1	2
19		2.5	0	1	2
20		3.0	0	1	2

Test Results
- Transfer Delay for Data with Different Priorities -

Scenario No.	Downlink Data Length	Channel Load	Total Transfer Delay (sec) 95th percentile time		
			AIR 1	AIR 2	AIR 3
1	1seg	95.0%	4.74	4.72	4.72
6	1seg (62bytes)	93.2%	39.79	2.50	2.47
7		93.9%	39.79	2.78	2.80
8		92.3%	29.22	2.83	2.78
9		88.7%	9.89	2.85	2.84
10		83.8%	5.75	2.93	2.87
16	15seg (930bytes)	97.7%	300.16*	7.98	5.75
17		97.6%	300.88*	7.97	5.75
18		97.7%	233.49*	8.01	5.75
19		97.5%	240.86*	7.95	5.75
20		97.7%	240.84*	7.94	5.75

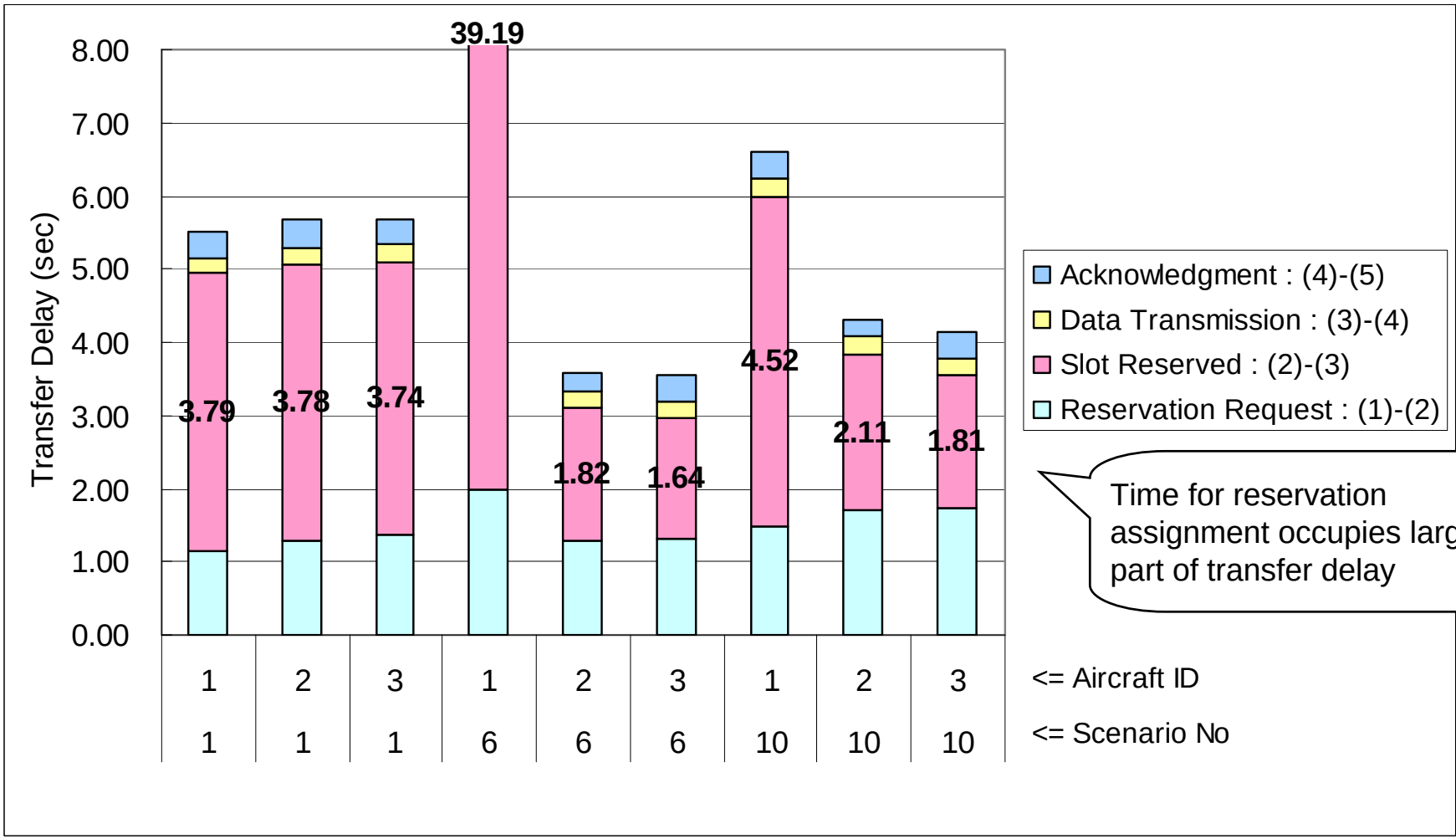
*The values equal to the maximum one among multiple acquired data because the number of the data was less than 10.

Test Results
- Transfer Delay for Data with Different Priorities -



Test Results
- Transfer Delay for Different Priority Data –

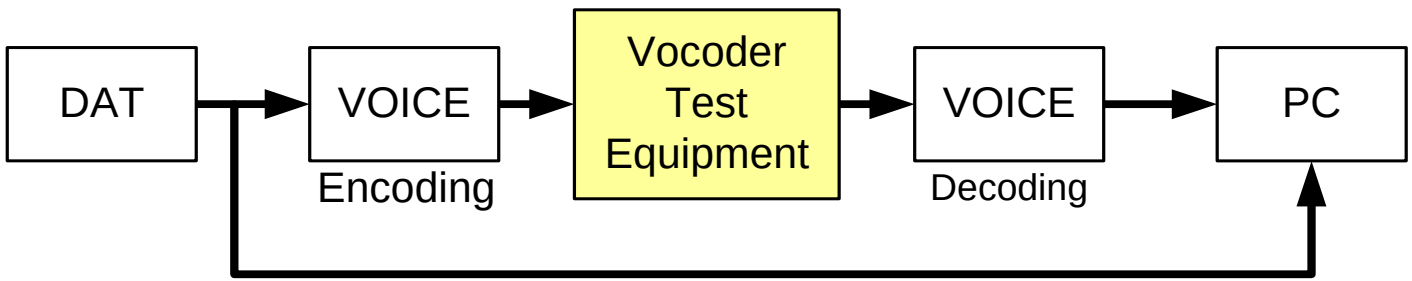
For each transmission section (refer to slide #27)



Preliminary Evaluation for Voice Quality (1)

1. Test Items; a) Processing delay in Vocoder
   b) Voice Quality with a Voice Frame Lost
2. Test Setup

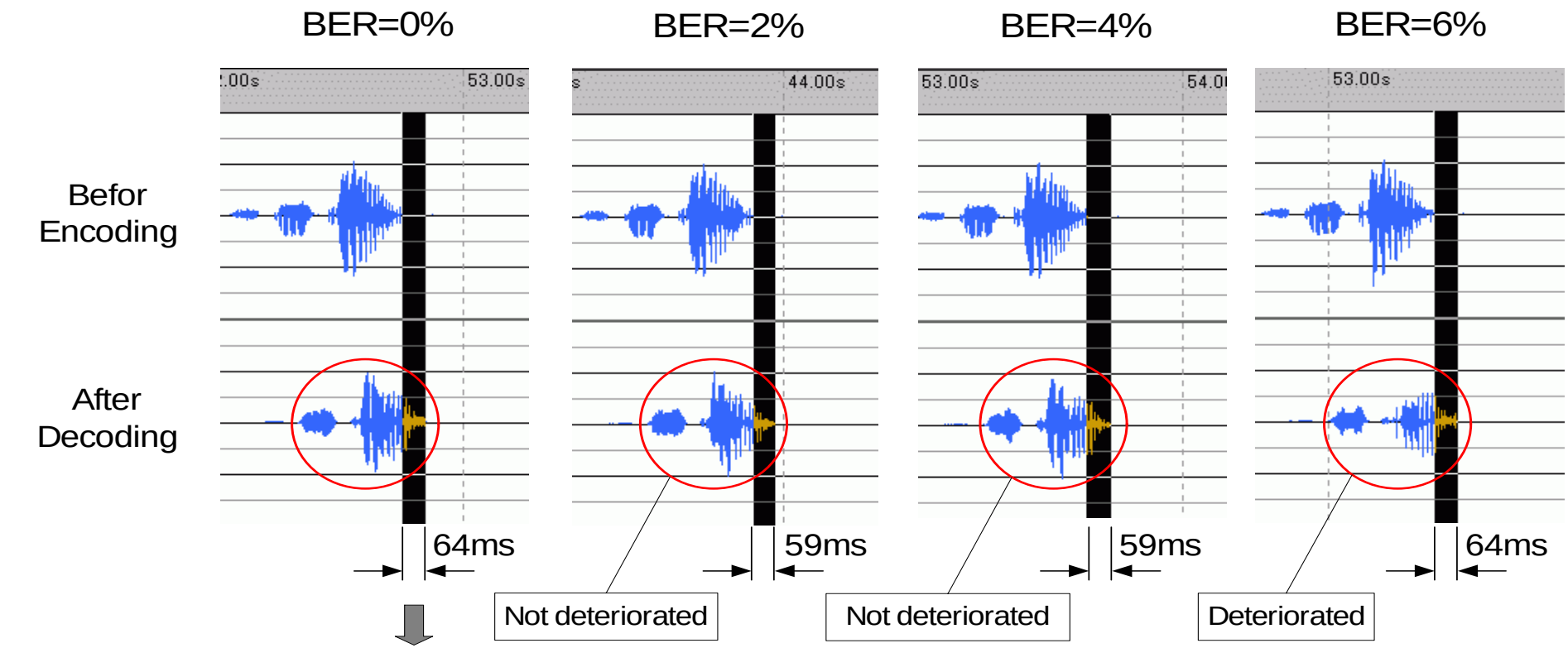
Bit error：0～7％
Lost voice frame：1 per 1 to 8 frame
（1 voice frame : 20ms period）

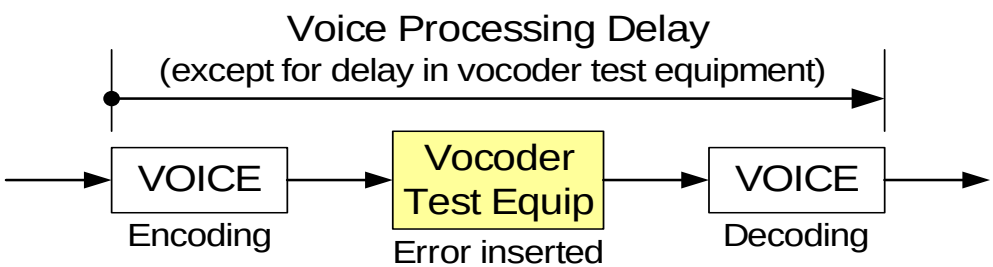


VOICE : Voice processing equipment with Vocoder

Vocoder itself has the capability to correct error of up to 4%

Voice Processing Delay for Vocoder





Preliminary Evaluation for Voice Quality (2)

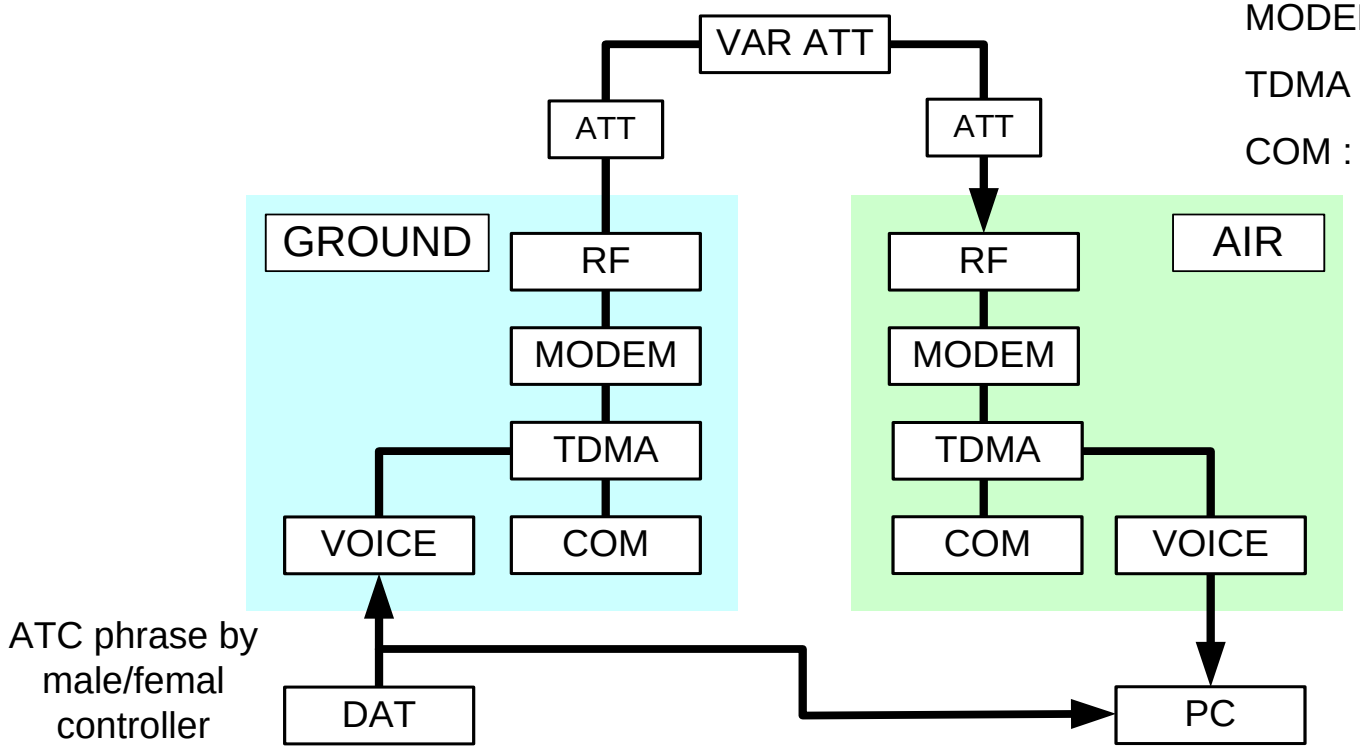
1. Test Items; a) System Transfer Delay (End to End
   b) Receiving Level vs.Transfer Delay
2. Test Setup

RF : RF Unit

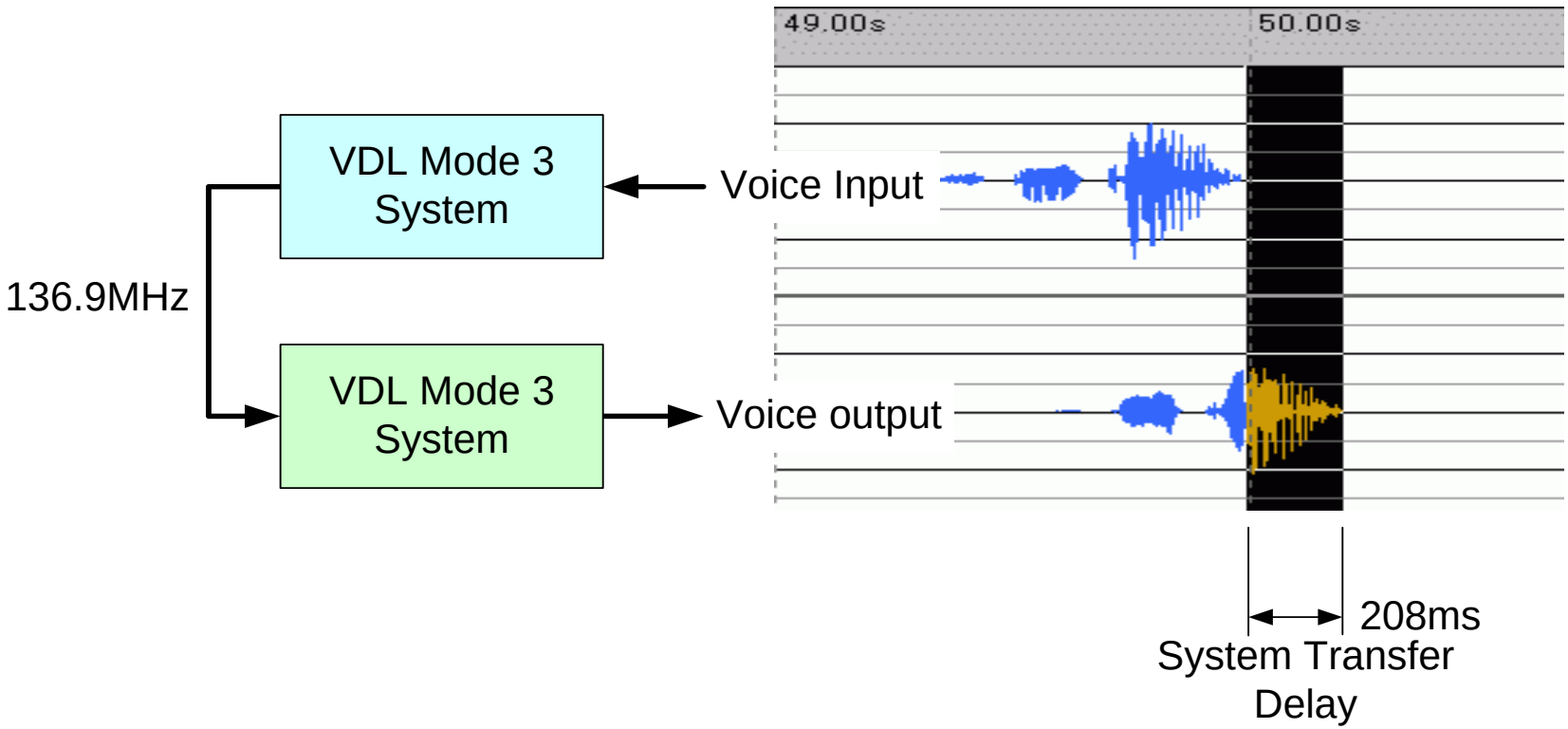
MODEM : MODEM Unit

TDMA : TDMA Control Unit

COM : Communication Control Unit



Test Result – System Transfer Delay –



Specifications on system transfer delay in ICAO Manual Doc 9805

- 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

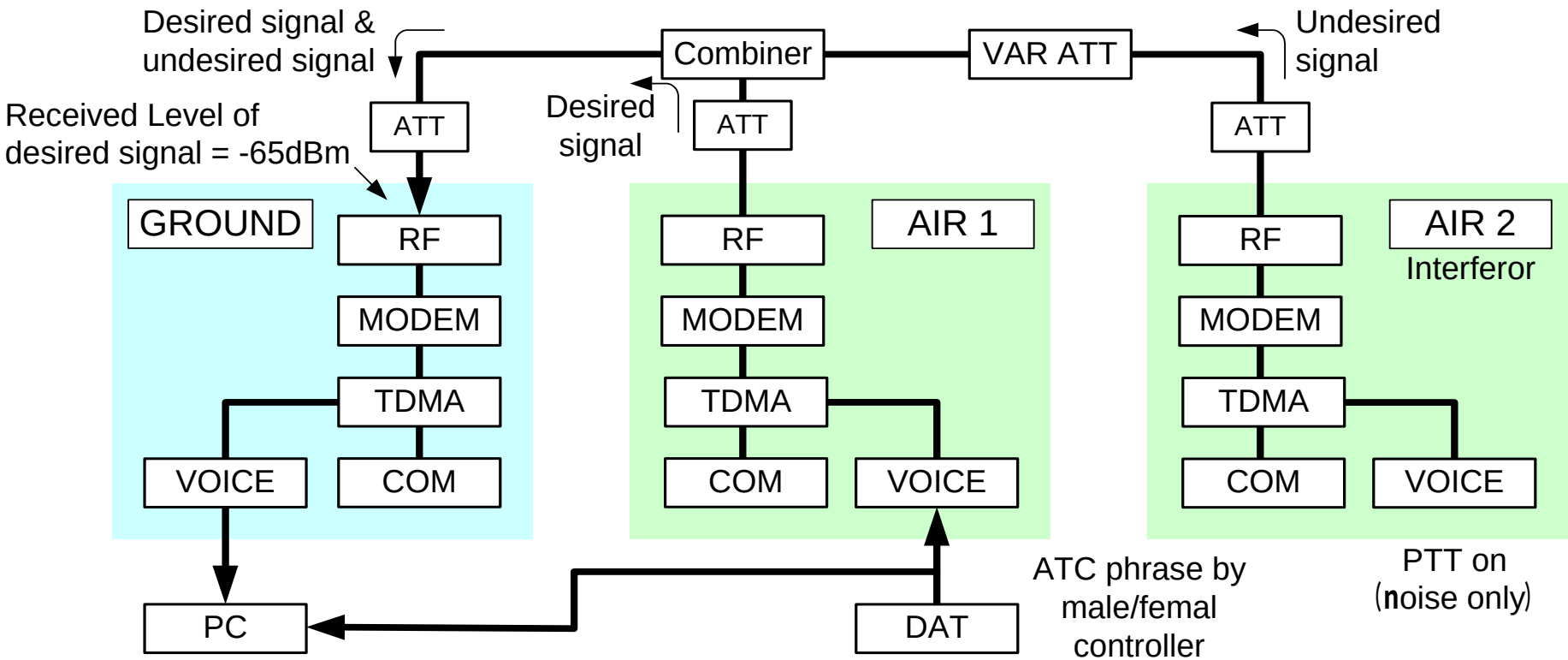
Received Level (BER) vs. Transfer Delay & Voice Quality

Received Power	BER	Delay	Quality of Received Voice
-103dBm	8.6E-04	214ms	Clearly audible
-104dBm	2.1E-03	208ms	Clearly audible
-105dBm	5.4E-03	208ms	Very little degradation recognized
-106dBm	1.0E-02	208ms	Degradation recognized but voice message was understandable
-107dBm	1.8E-02	208ms	Partially silent but voice message was understandable
-108dBm	2.8E-02	208ms	Difficult to understand as voice message was significantly interrupted
-109dBm	4.1E-02	--*	Not understandable due to many no sound portions
-110dBm	5.8E-02	--*	Almost no sound

*Immesurable

Preliminary Evaluation for Voice Quality (3)

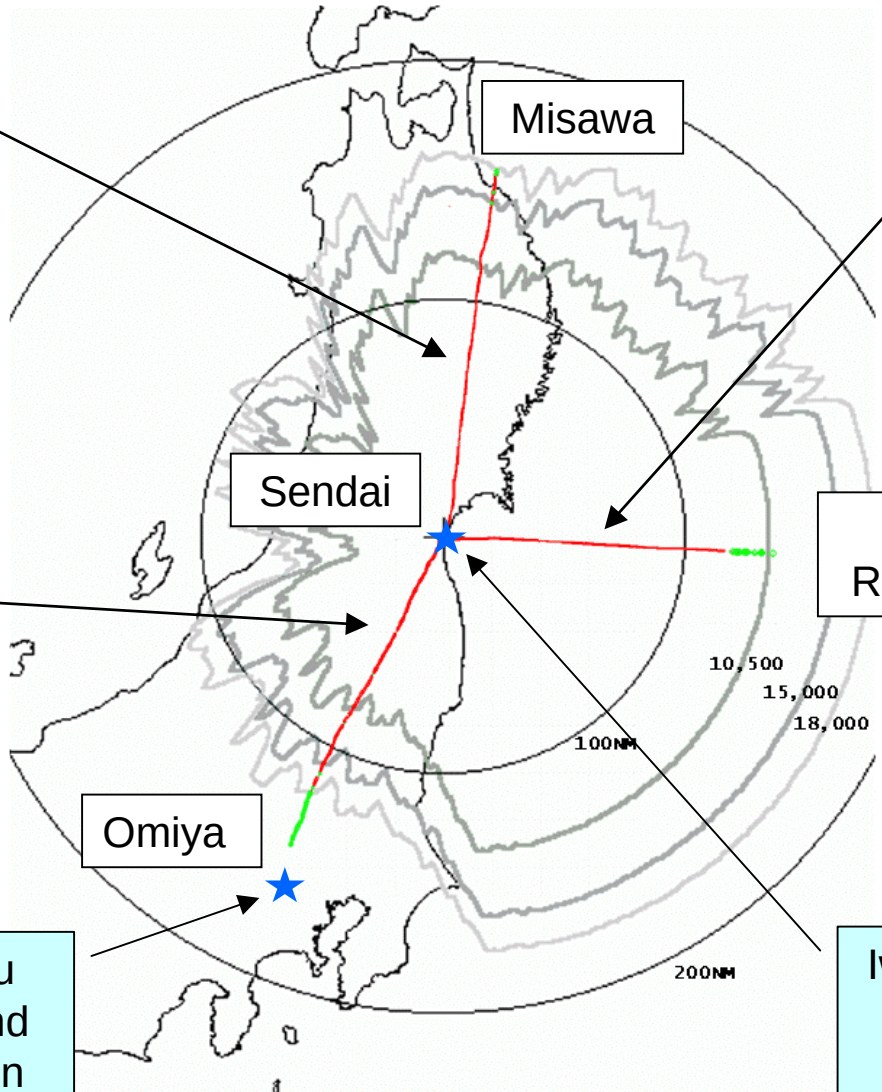
1. Test Item; a) Voice Quality under Radio Interference
2. Test Setup



Received Voice under 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

Flight Tests - Trajectory of the Aircraft –



Flight Path-2

Sendai<=>Misawa

FL150/10,000feet

Flight Path-3

Sendai<=>R100/150NM

10,500feet

Flight Path-1

Sendai<=>Omiya

FL180

No frame error

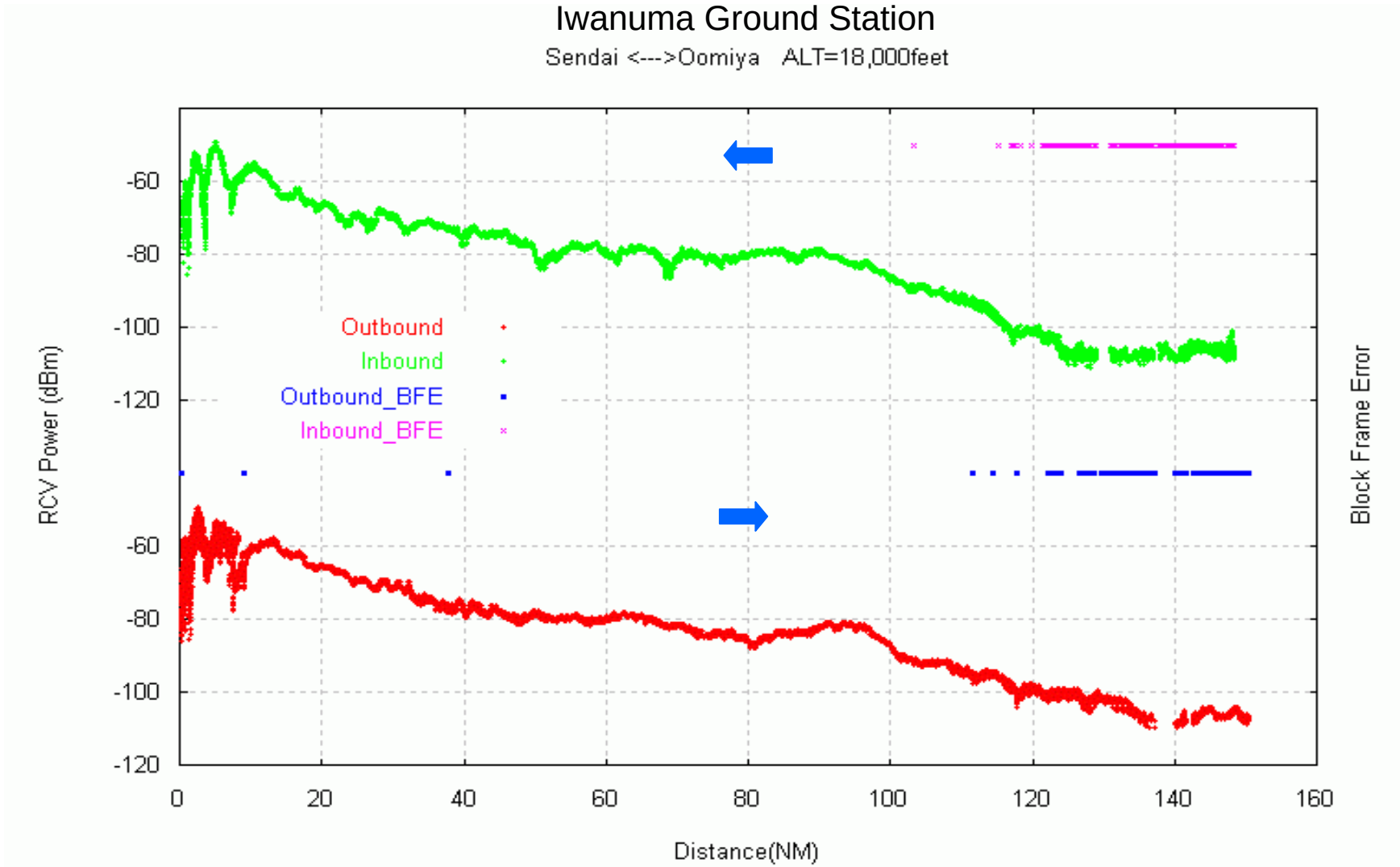
Frame error

Radio horizon from Iwanuma Station

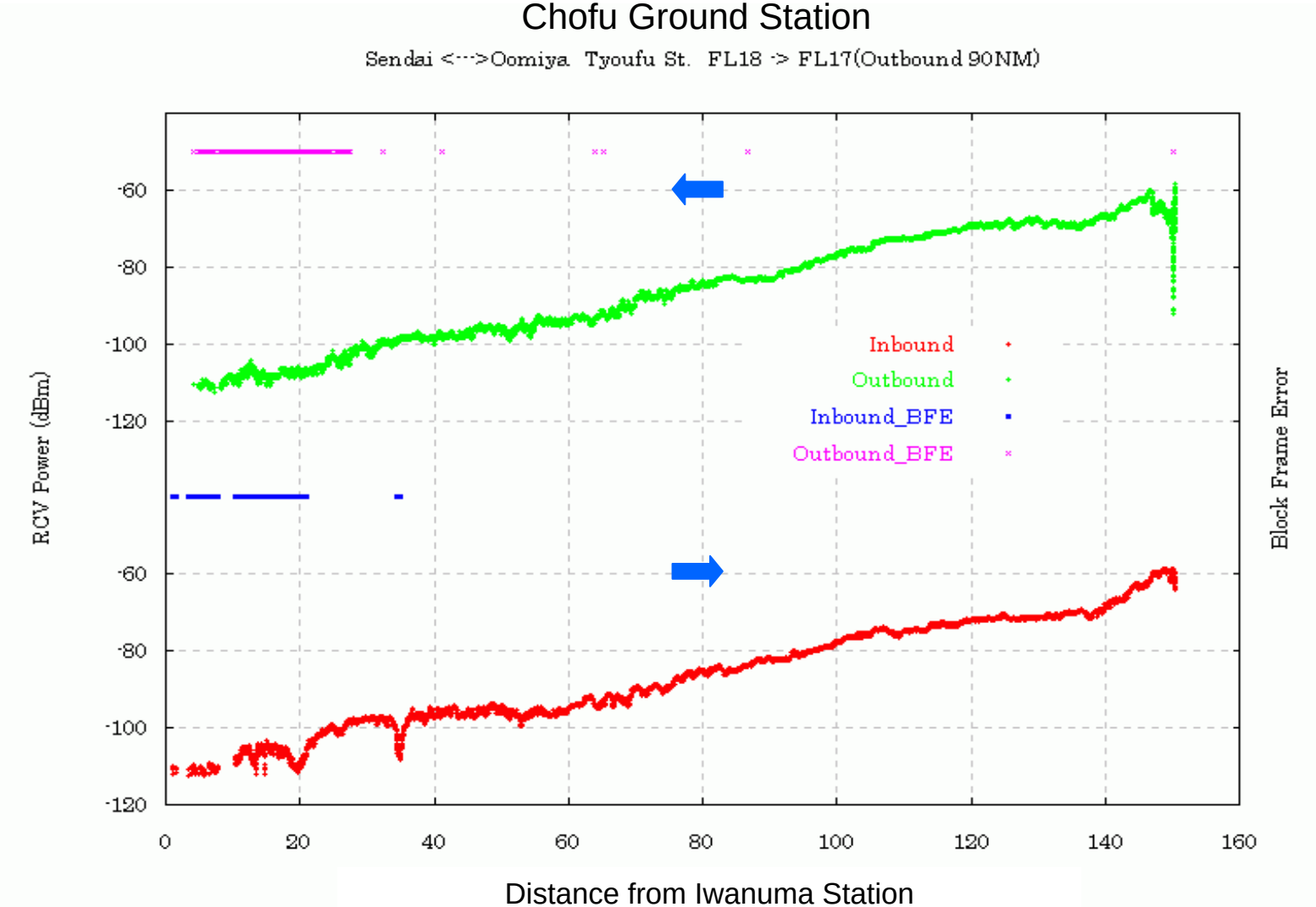
Chofu Ground Station

Iwanuma Ground Station

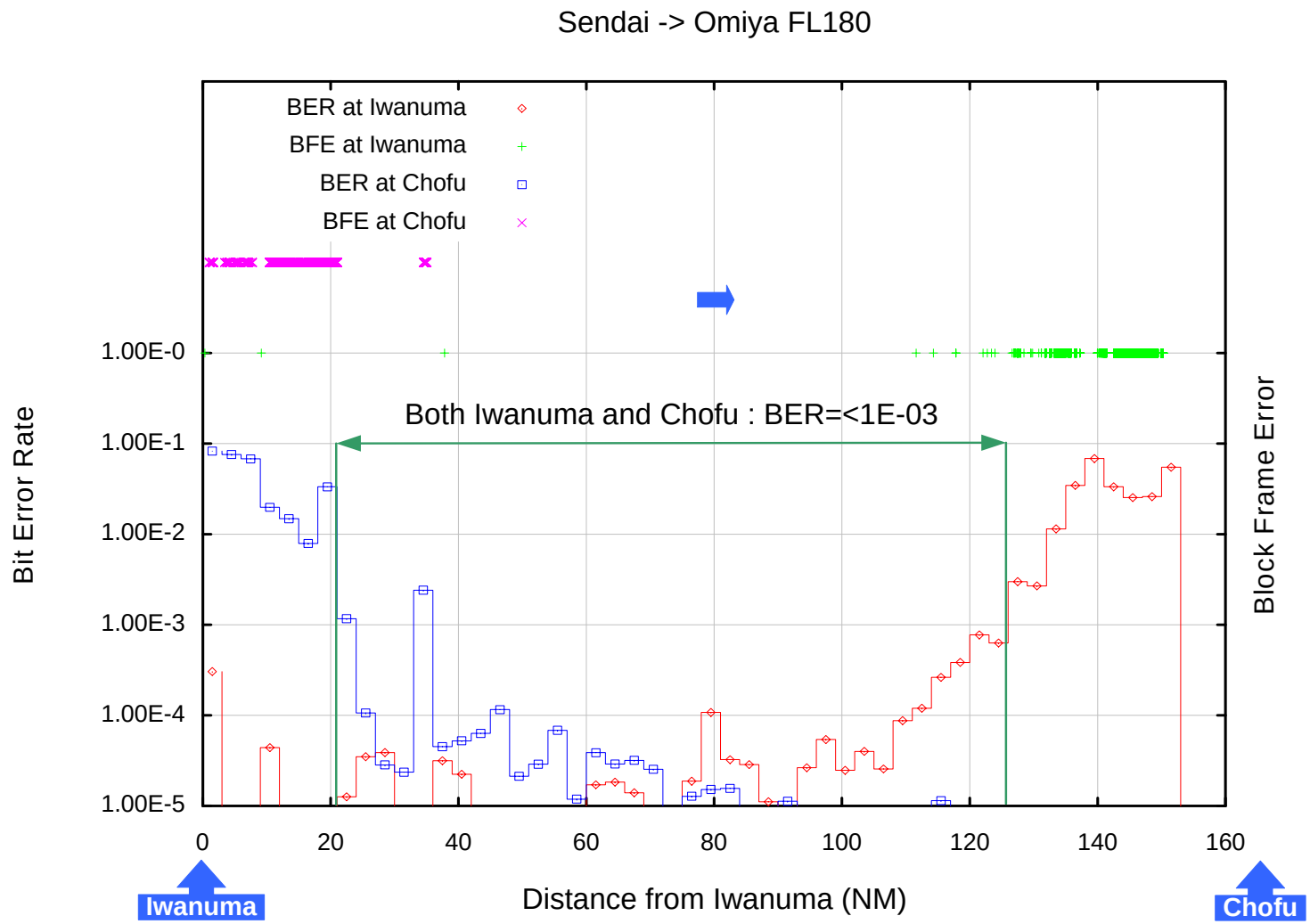
Test Results
– Received Power at Iwanuma in Flight Path-1 –



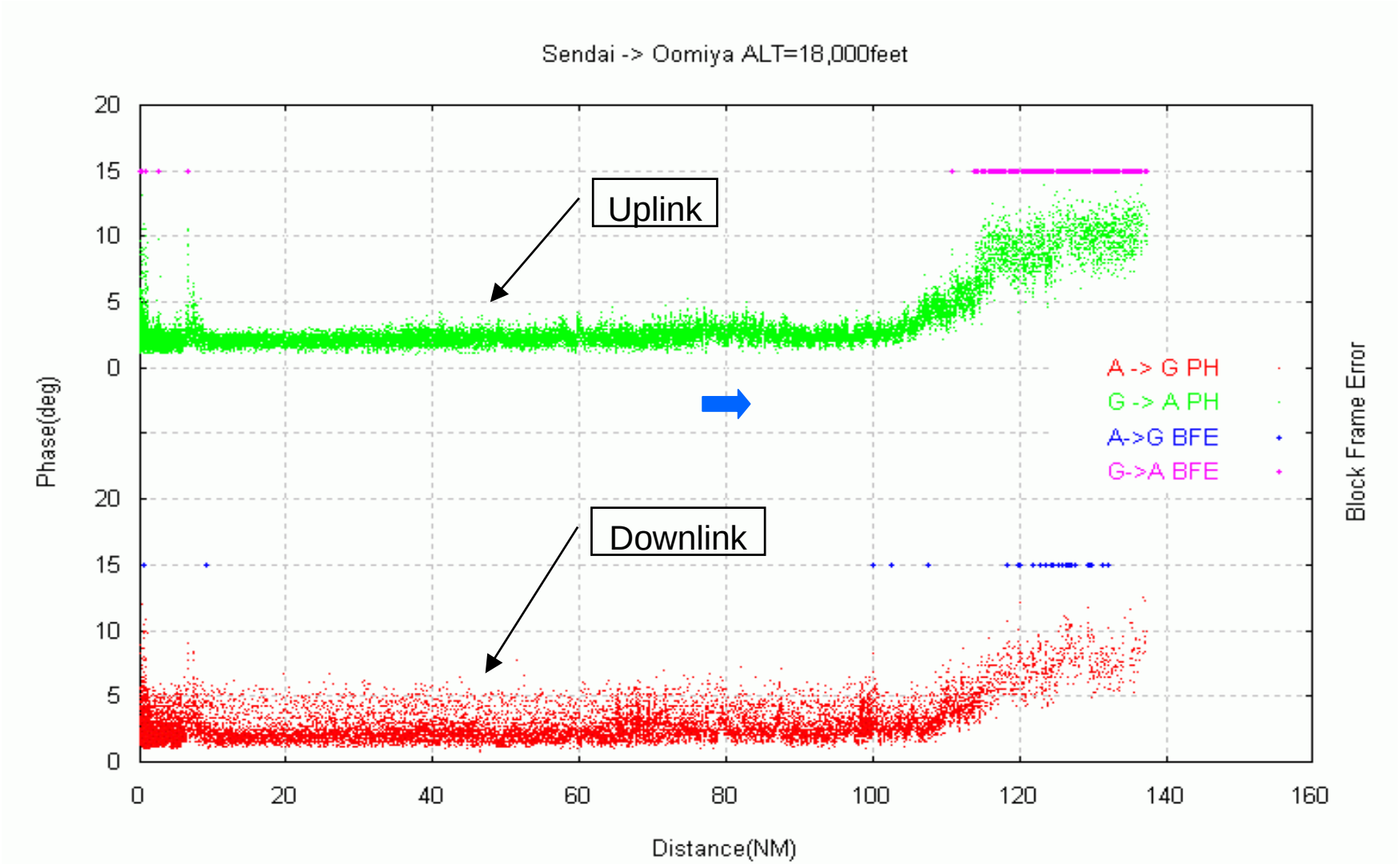
Test Results
– Received Level at Chofu in Flight Path-1 –



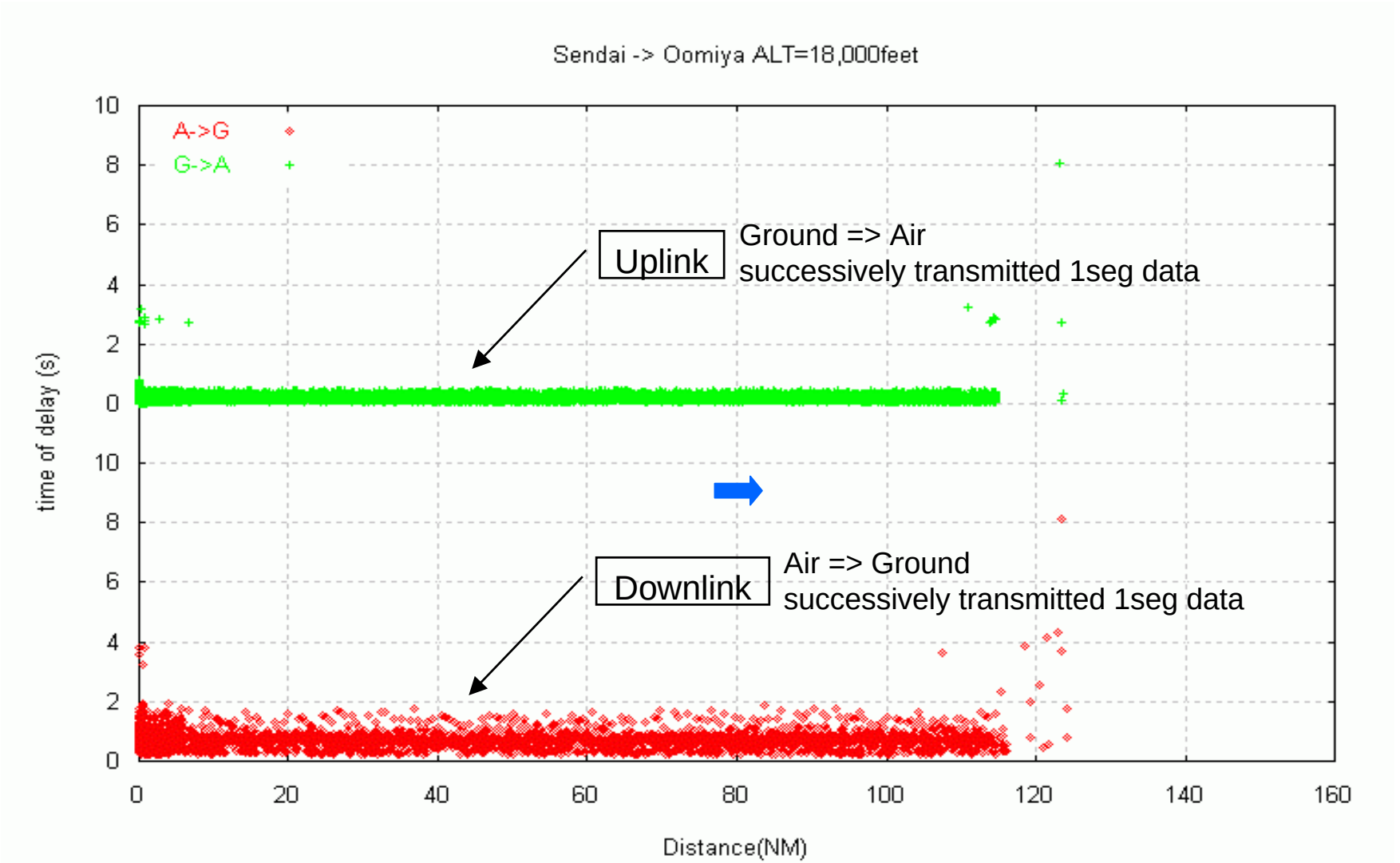
Test Results
– BER Characteristic in Flight Path-1 –



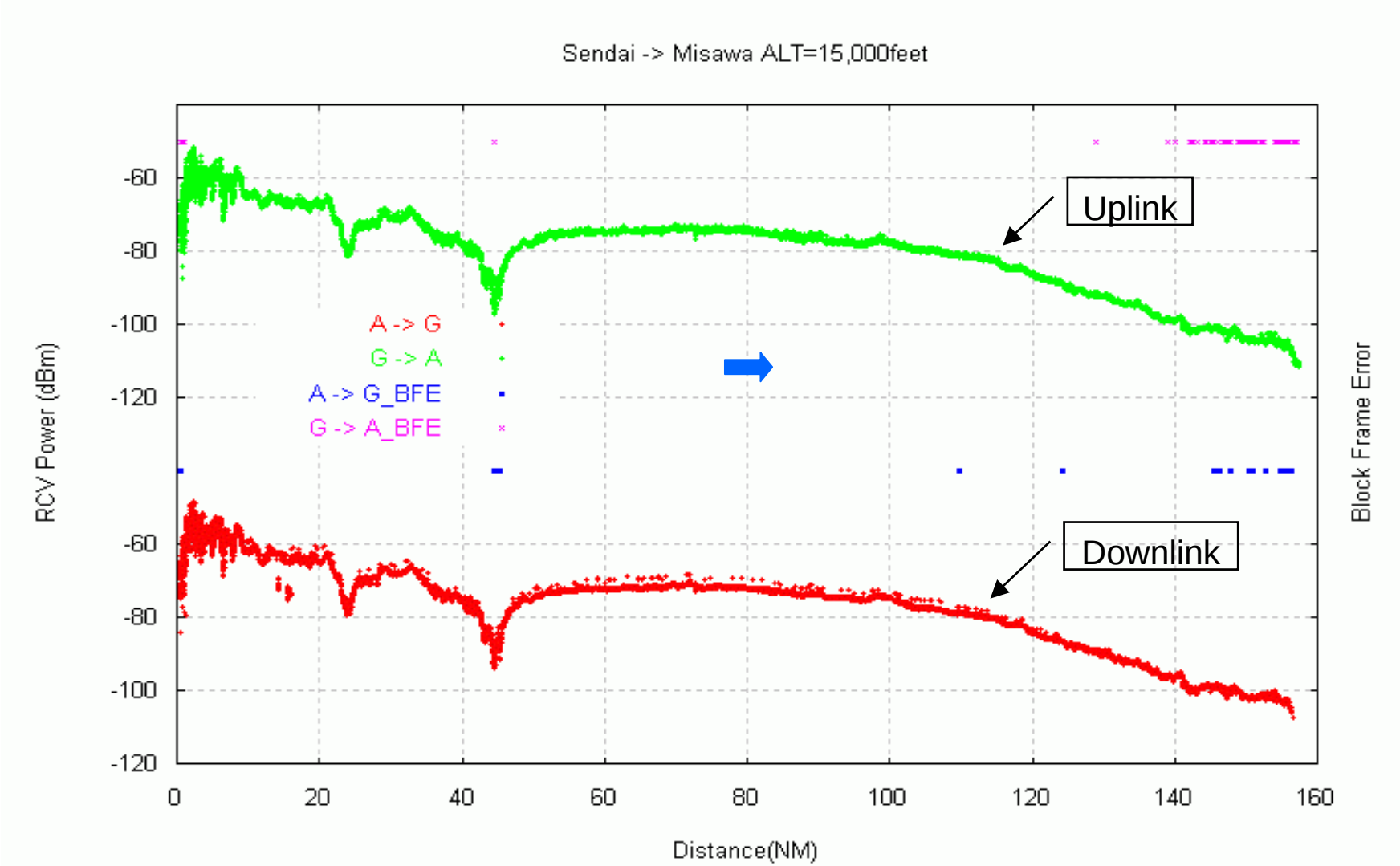
Test Results
– Phase Error in Flight Path-1 –



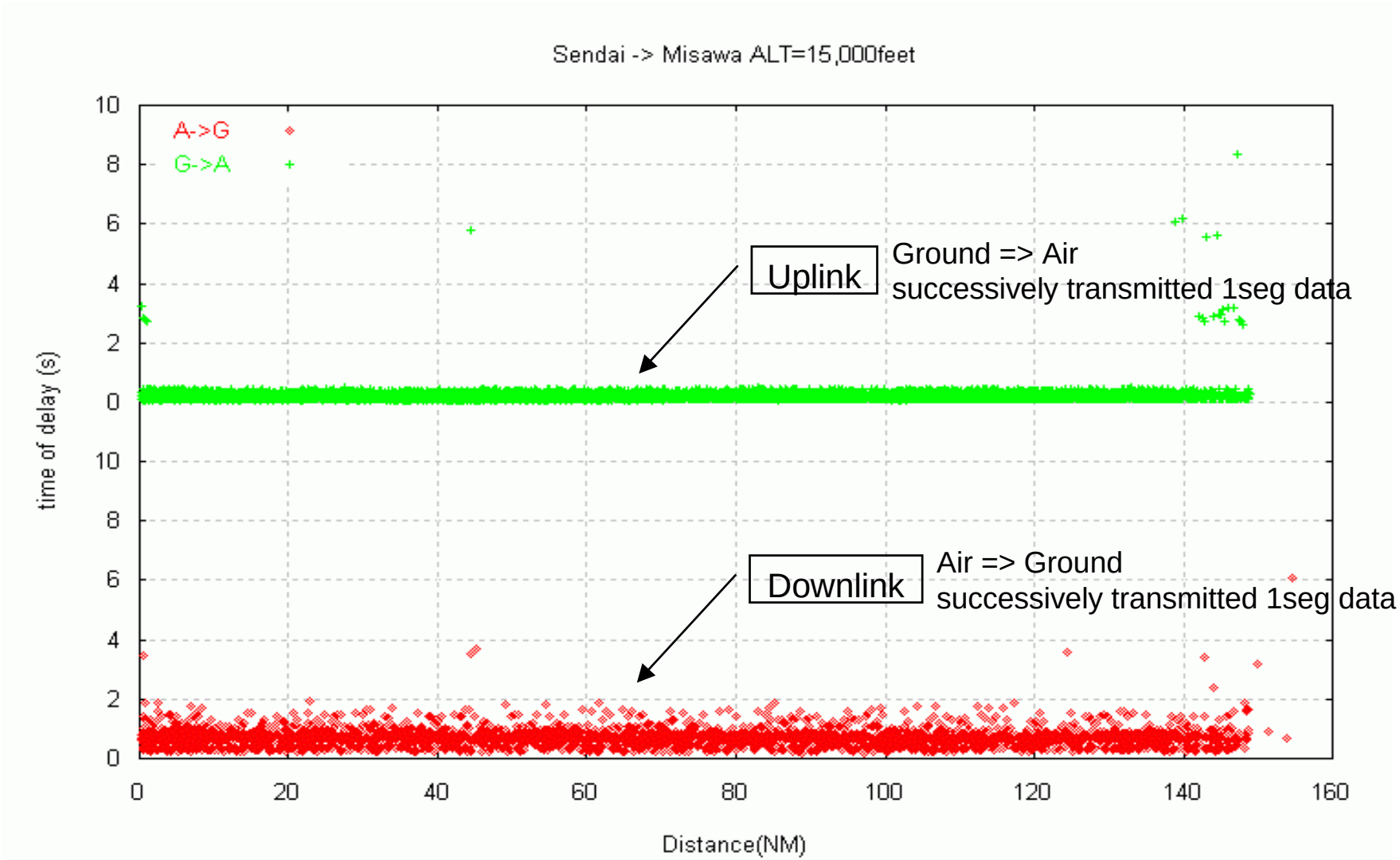
Test Results
– Transfer Delay in Flight Path-1 –



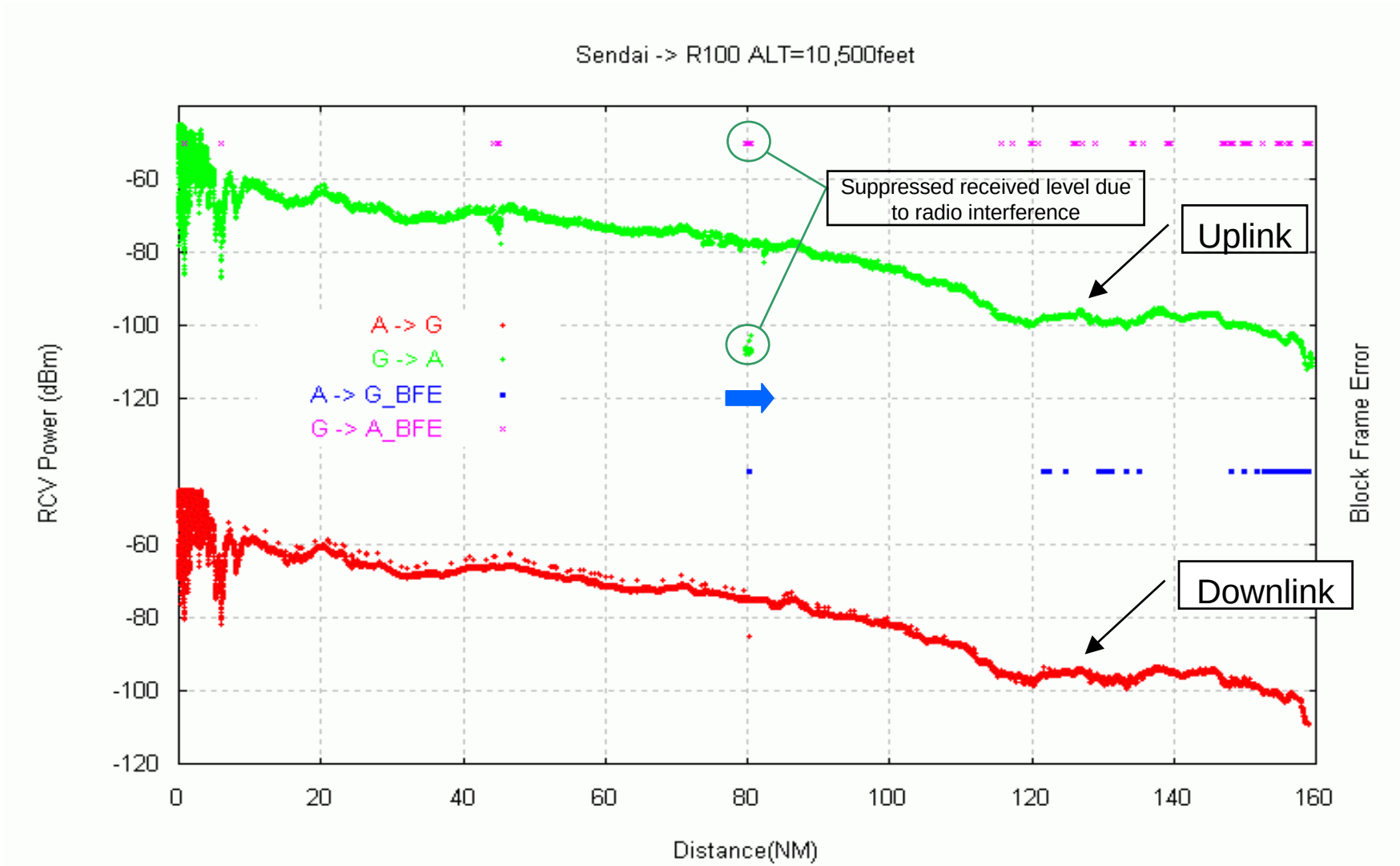
Test Results
– Received Level in Flight Path-2 –



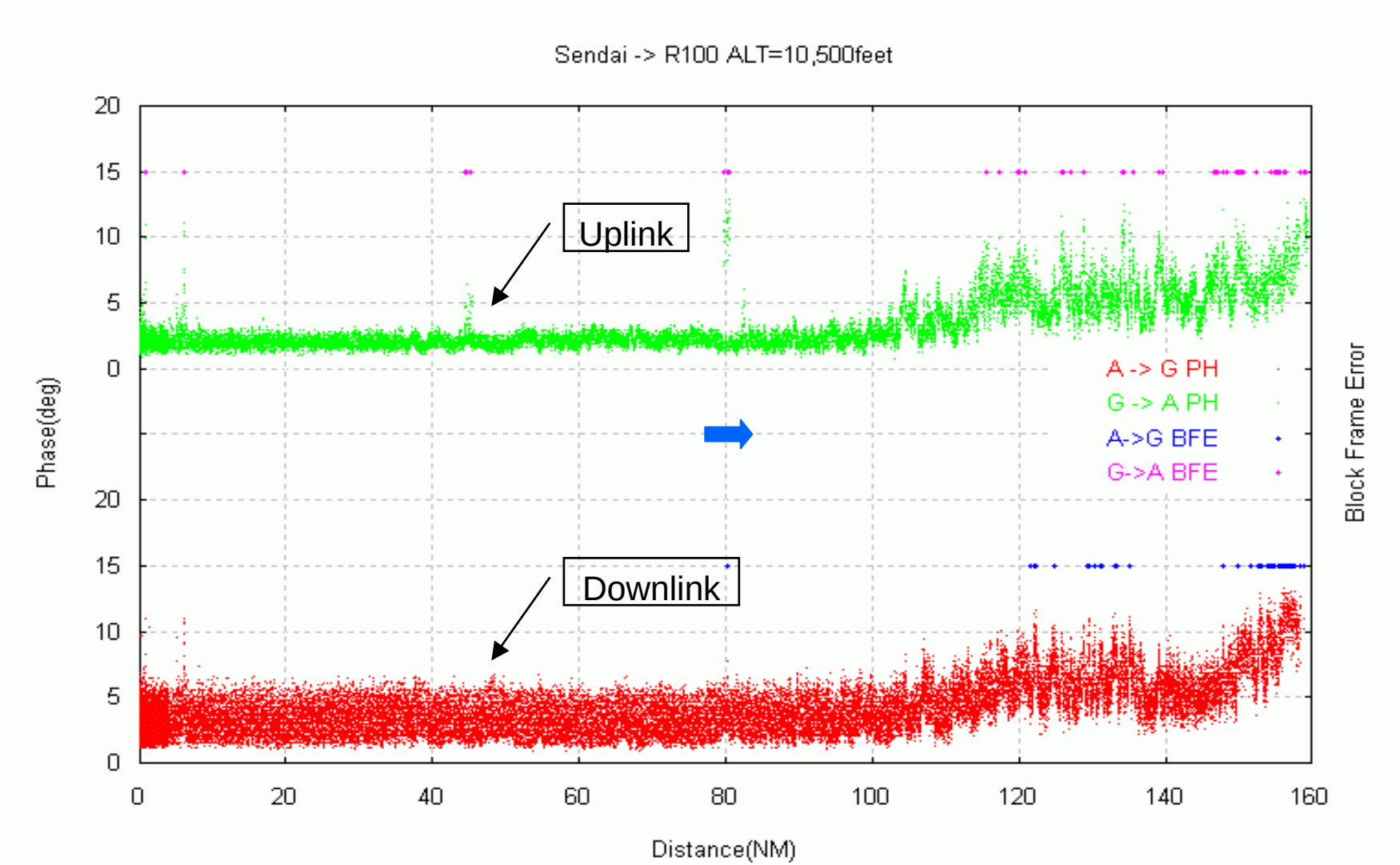
Test Results
– Transfer Delay in Flight Path-2 –



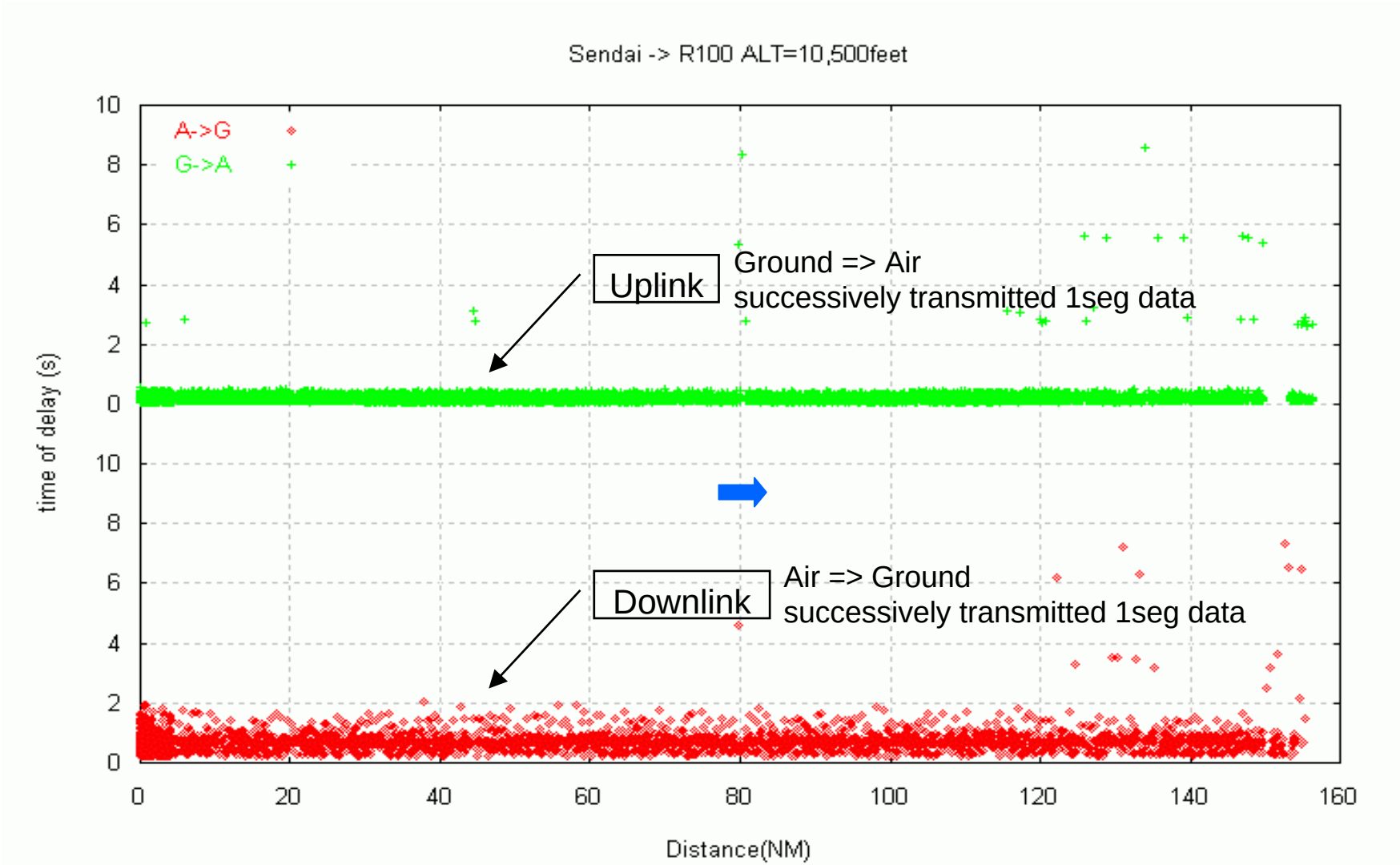
Test Results
– Received Level in Flight Path-3 –



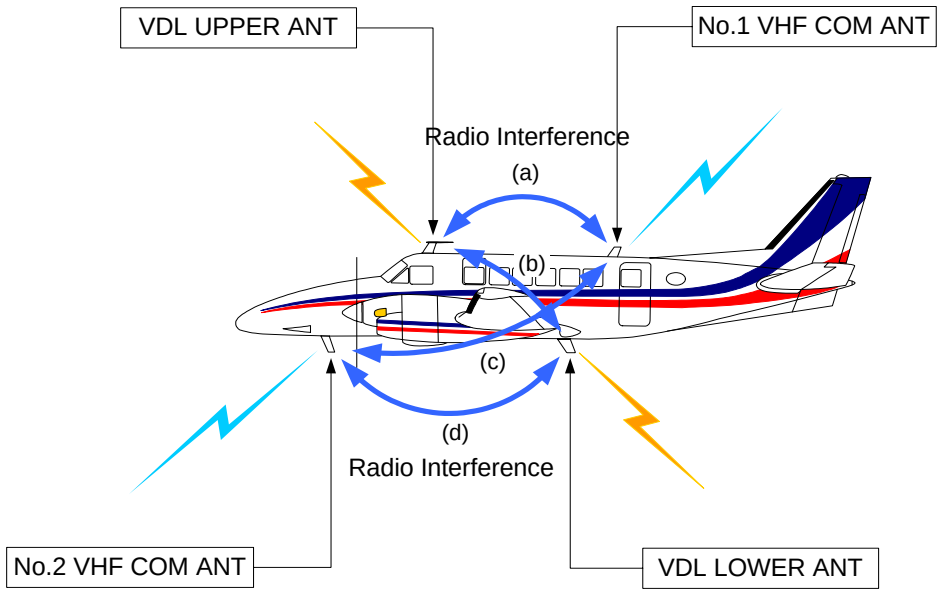
Test Results
– Phase Error in Flight Path-3 –

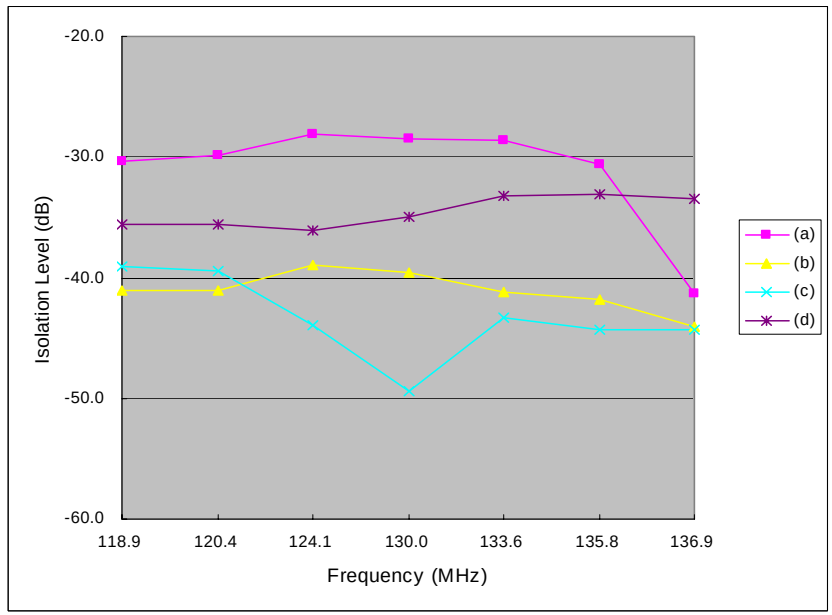


Test Results
– Transfer Delay in Flight Path-3 –



ANT Isolation Level between DSB-AM and VDL Mode 3



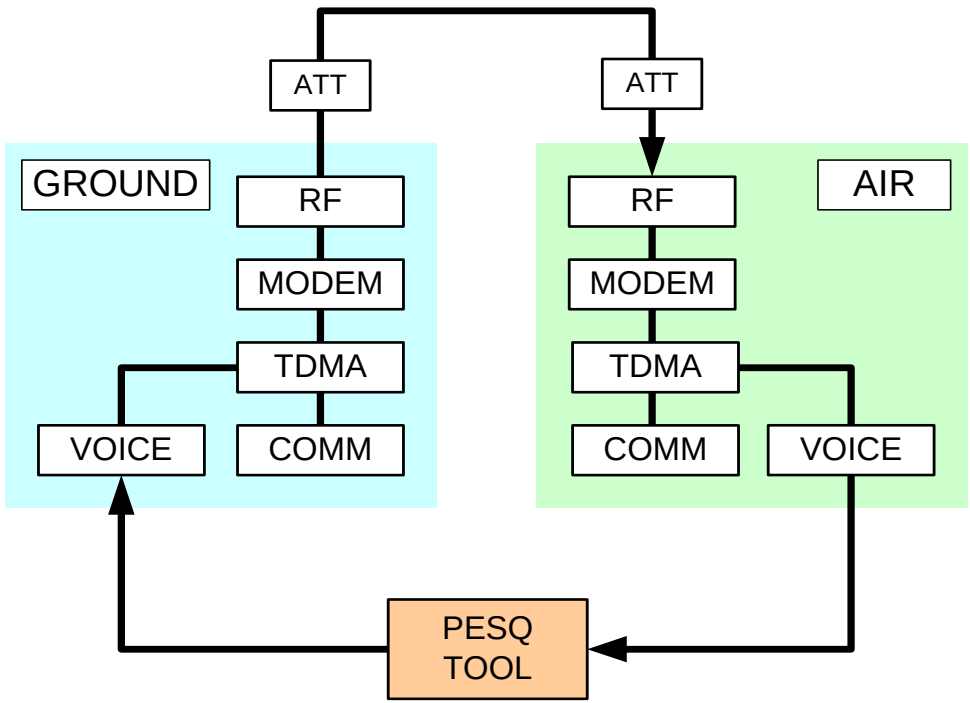


	VDL ANT	DSB-AM ANT	118.9MHz	120.4MHz	124.1MHz	130.0MHz	133.6MHz	135.8MHz	136.9MHz
			Tokyo ACC Tohoku	Sendai Approach	Tokyo ACC Kanto North	--	Tokyo ACC Kanto East	Johon-zan AEIS	VDL
(a)	UPPER	No.1(Upper)	-30.4	-29.9	-28.2	-28.5	-28.7	-30.7	-41.3
(b)	UPPER	No.2(Lower)	-41.1	-41.1	-39.0	-39.6	-41.2	-41.8	-44.1
(c)	LOWER	No.1(Upper)	-39.1	-39.5	-43.9	-49.4	-43.4	-44.3	-44.4
(d)	LOWER	No.2(Lower)	-35.6	-35.6	-36.1	-35.0	-33.3	-33.1	-33.4

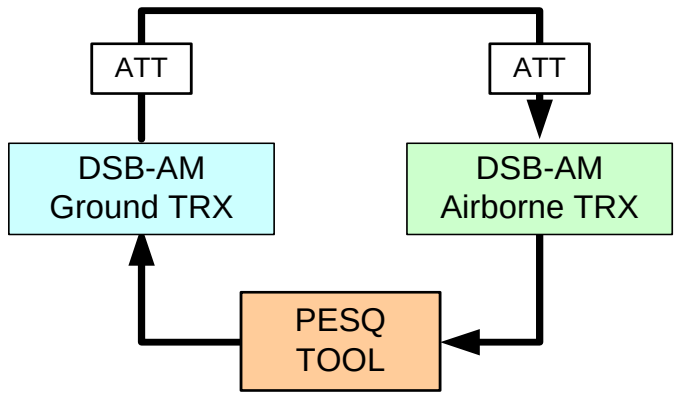
ANT Isolation between DSB-AM and VDL Mode 3

Voice Quality Tests by PESQ Tool

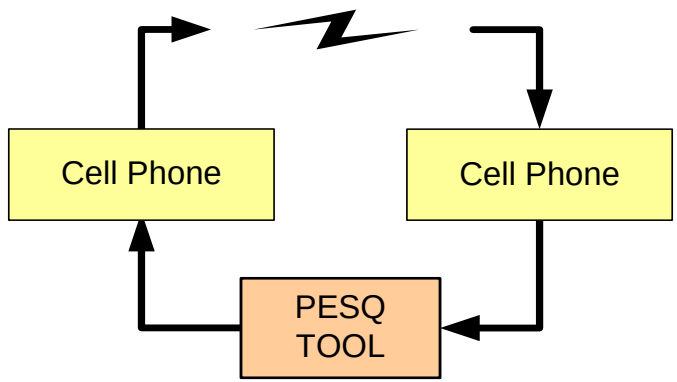
1. Test Setup



Evaluation for VDL Mode 3 System



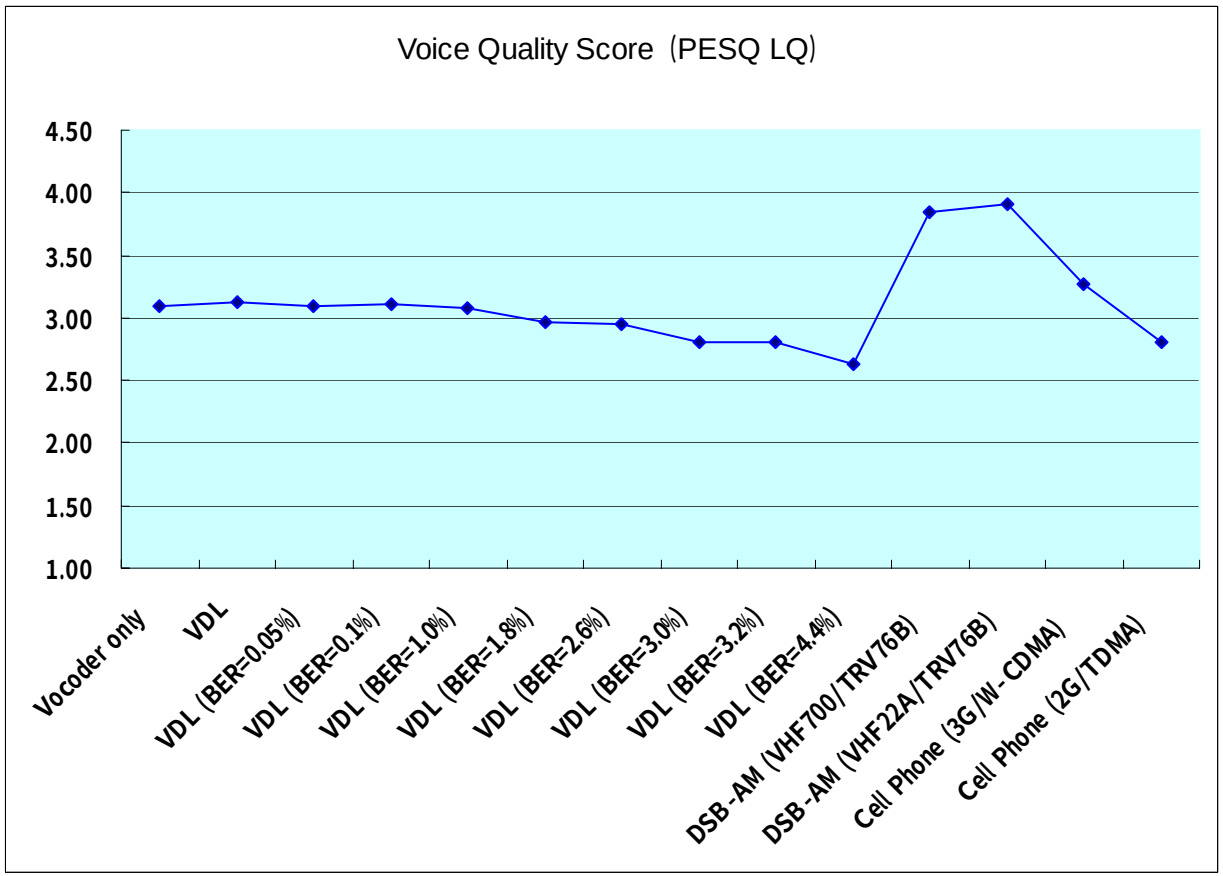
Evaluation for DSB-AM TRX



Evaluation for Cell Phone

PESQ Tool : Agilent VQT J1981A
PESQ : Perceptual Evaluation of Speech Quality
(ITU-T standard P.862)

Test Results for Voice Quality
- Standard Voice –



Device/Condition	Score
Vocoder only	3.09
VDL	3.12
VDL (BER=0.05%)	3.09
VDL (BER=0.1%)	3.11
VDL (BER=1.0%)	3.08
VDL (BER=1.8%)	2.97
VDL (BER=2.6%)	2.95
VDL (BER=3.0%)	2.80
VDL (BER=3.2%)	2.80
VDL (BER=4.4%)	2.63
DSB-AM (VHF700/TRV76B)	3.84
DSB-AM (VHF22A/TRV76B)	3.91
Cell Phone (3G/W-CDMA)	3.27
Cell Phone (2G/TDMA)	2.81

Evaluated voice were prepared by Agilent

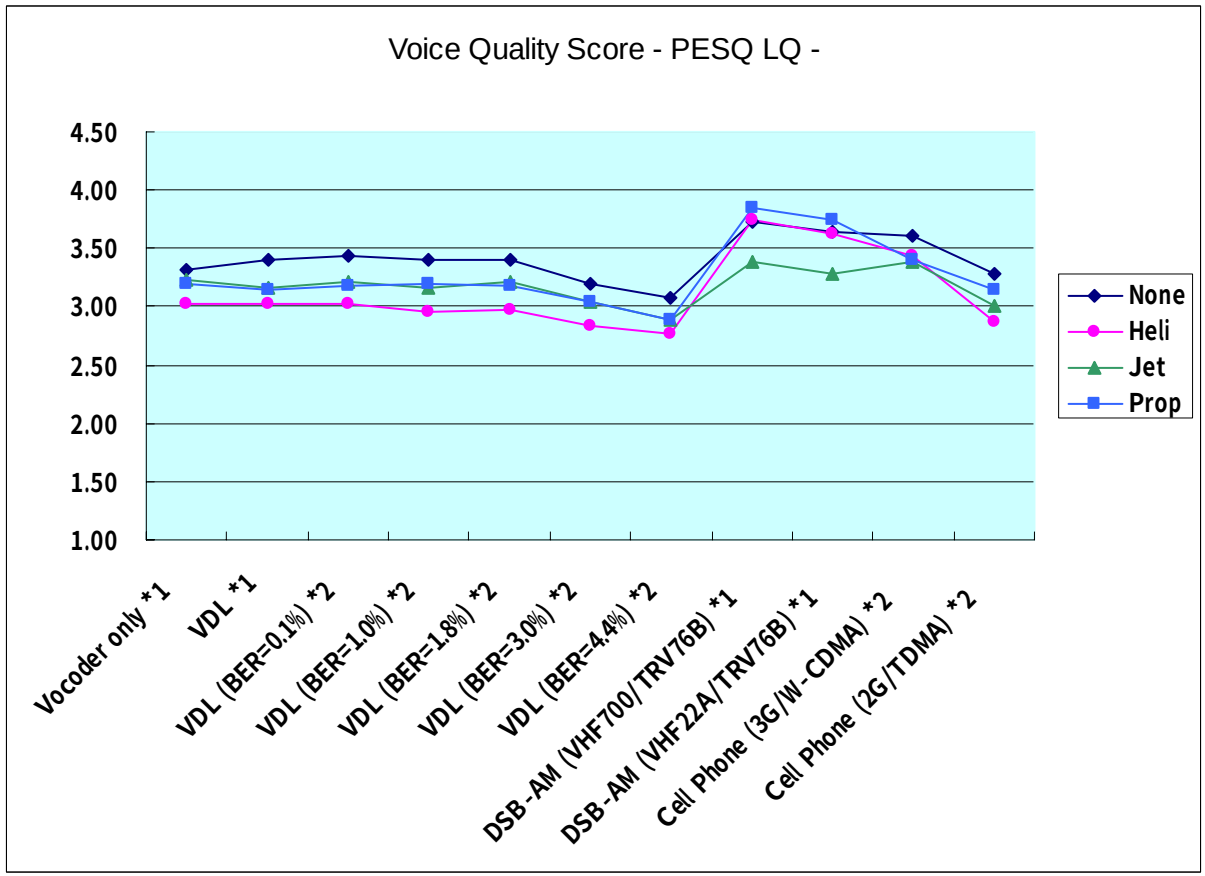
Six Americans (three male/female each)

Six Japanese (three male/female each)

Scores are the values of PESQ LQ

LQ : Listening Quality

Test Results for Voice Quality
- ATC Phrase by Controllers –



Device/Condition	Background Noise			
	None	Heli	Jet	Prop
Vocoder only *1	3.31	3.02	3.23	3.19
VDL *1	3.41	3.02	3.17	3.15
VDL (BER=0.1%) *2	3.44	3.02	3.22	3.18
VDL (BER=1.0%) *2	3.40	2.96	3.17	3.20
VDL (BER=1.8%) *2	3.40	2.98	3.21	3.18
VDL (BER=3.0%) *2	3.20	2.84	3.04	3.04
VDL (BER=4.4%) *2	3.08	2.77	2.89	2.89
DSB-AM (VHF700/TRV76B) *1	3.73	3.74	3.39	3.84
DSB-AM (VHF22A/TRV76B) *1	3.64	3.63	3.29	3.75
Cell Phone (3G/W-CDMA) *2	3.61	3.43	3.38	3.41
Cell Phone (2G/TDMA) *2	3.28	2.87	3.01	3.15

Evaluated voice were prepared by ENRI

*1 Four Japanese ATC Controllers (two male/female each)

*2 Two Japanese ATC Controllers (one male/female each)

Scores are the values of PESQ LQ

LQ : Listening Quality

The End

Thank you !!