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Aeronautical Communications Panel Working Group B and F Meeting
Navigation Systems Panel Spectrum Sub-Group Meeting

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Agenda Item 7: Further Developments on VDL Modes 3 and 4 Frequency Assignment Planning Criteria

Report of VDL Mode 3 Voice Quality Tests with Radio Interference

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SUMMARY

The Electronic Navigation Research Institute (ENRI) has carried out a series of radio interference tests between DSB-AM and VDL Mode 3, and submitted working papers to ACP WG-B/12, 14 and 16 to report those tests results. Since those tests were primary intended to develop VDL Frequency Assignment Planning Criteria, ENRI investigated impact of radio interference on physical layer characteristics such as bit error rate (BER) or signal to pulse ratio. However voice quality should be the most important element for voice communications especially for air traffic control services. Therefore ENRI carried out additional radio interference tests between DSB-AM and VDL Mode 3 to examine impact on voice quality using a voice quality tester (VQT). This paper outlines the test results.

1 Introduction

The Electronic Navigation Research Institute (ENRI) has ever carried out a series of radio interference tests and reported those tests results to ACP WG-B as follows.

- Radio interference test from VDL Mode 3 to DSB-AM in 2001 > WGB/12-WP8
- Radio interference test from DSB-AM to VDL Mode 3 in 2002 > WGB/14-WP5

- Co-site radio interference test between DSB-AM and VDL Mode 3 in 2003 > WGB/16-WP12

Since these tests were primary intended to develop VDL Frequency Assignment Planning Criteria, ENRI investigated impact of radio interference on physical layer such as bit error rate (BER) for VDL Mode 3 (VDL-M3) or signal to pulse ratio (S/P) for DSB-AM on the basis of discussions at ACP WGB meeting. BER for VDL-M3 and S/P for DSB-AM were measured as indexes representing voice quality with undesired radio signal interfered. However voice quality should be the most important element for voice communications especially for air traffic control services.

Consequently ENRI conducted voice quality test with co-channel and adjacent channel radio interference between DSB-AM and VDL-M3 by the use of a voice quality tester (VQT). The VQT is capable of evaluating voice quality objectively through some evaluation methods as follows.

- Perceptual Evaluation of Speech Quality (PESQ)   ITU-T R.862
- Perceptual Analysis Measurement System (PAMS)
- Perceptual Speech Quality Measurement (PSQM)   ITU-T R.861

Of these methods above, PESQ is widely used to evaluate voice quality for VoIP (Voice over IP). PESQ-LQ (Listening Quality) provides a good predictor of MOS (Mean Opinion Score) score. PESQ-LQ score range is from 1 to 4.5; 4.5 being excellent quality. Therefore ENRI used PESQ-LQ method for the voice quality test.

This paper describes the test procedures and the results.

2 Test Setup

Figure 1 shows the test setup for the voice quality test with co-channel or adjacent channel interference. Agilent VQT J-1981A was used with the following 12 voice phrases supplied with the VQT.

- Three English phrases of a male American
- Three English phrases of a female American
- Three Japanese phrases of a male Japanese
- Three Japanese phrases of a female Japanese

The desired signal source was set to produce a signal level of -85 dBm for airborne receiver and -94 dBm for ground receiver at victim receiver input that were based on definitions described in section 2 of VDL Frequency Assignment Planning Criteria (see table 1). Radio frequency of desired signal was set to 136.0 MHz. Characteristic of desired and undesired signals were set to as shown in table 2. Undesired signal level was described in section 3.1 and 4.1.

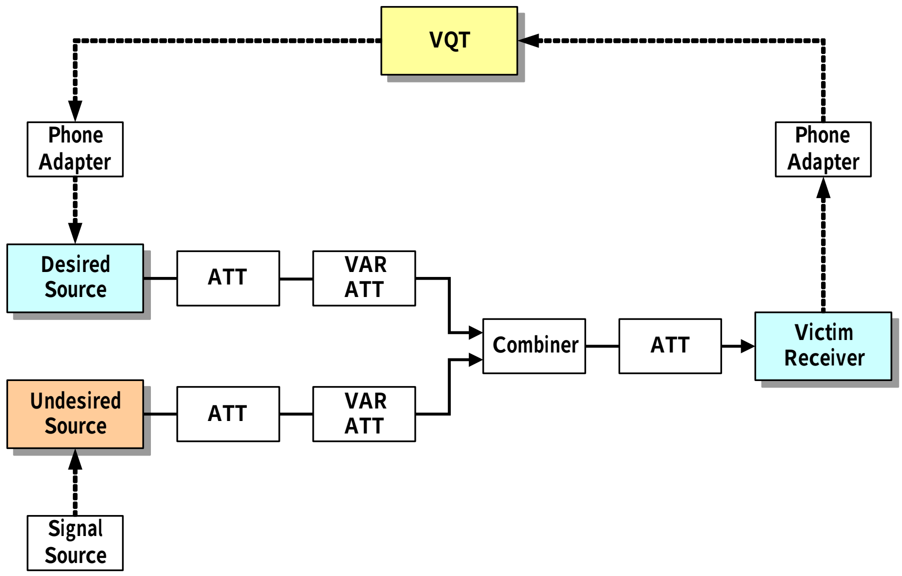

Figure 1 Test Setup

Table 1 Precondition and Setting

Parameter	DSB-AM	VDL-M3	
	Airborne	Airborne	Ground
TRASMITTER			
Output power	44 dBm (25 W)	44 dBm (25 W)	44 dBm (25 W)
Feeder loss	-3 dB	-3 dB	-3 dB
Antenna gain	0 dB	0 dB	2 dB
EIRP	41 dBm (12.5 W)	41 dBm (12.5 W)	43 dBm (20 W)
RECEIVER			
Minimum signal at receiver antenna	-82 dBm	-82 dBm	-93 dBm
Feeder loss	-3 dB	-3 dB	-3 dB
Antenna gain	0 dB	0 dB	2 dB
Minimum signal at receiver input	-85 dBm	-85 dBm	-94 dBm

Table 2 Characteristics of Desired/Undesired Signals

Parameter	DSB-AM	VDL-M3 AIR	VDL-M3 GND
Equipment	SG (Rohde&Shwarz SMIQ 02B)	ENRI VDL-M3 Airborne TX	ENRI VDL-M3 Ground TX
Channel load for desired source	Voice phrase with 90% peak modulation	1 time slot (1 voice burst with voice phrase)	
Channel load for undesired source	1 kHz tone with 90 % modulation	1 time slot (1 voice burst with PN pattern)	

3 Co-channel Interference Test

3.1 Test Procedure

Co-channel interference test was conducted in the equipment combinations shown in table 3. D/U* ratio variable range varied according to the voice quality score in each equipment combination. When the voice quality score reached approximately normal score without any radio interference, the D/U was upper limit. On the other hand, when the score was degraded considerably, the D/U was lower limit. Voice quality score for each voice phrase was obtained by calculating average score after same test was repeated five times.

Note.—The D/U is received power ratio (dB) between the desired and undesired signal at the victim receiver input.

Table 3 Equipment Combinations

	Desired Source	Victim Receiver	Undesired Source
1	VDL-M3 AIR	VDL-M3 GND	DSB-AM
2	VDL-M3 GND	VDL-M3 AIR	DSB-AM
3	VDL-M3 AIR	VDL-M3 GND	VDL-M3 AIR
4	VDL-M3 GND	VDL-M3 AIR	VDL-M3 AIR
5	DSB-AM	DSB-AM	VDL-M3 AIR

Note.—GND stands for ground station and AIR stands for aircraft station.

3.2 Test Result

Figure 2 and 3 are the graph showing VDL-M3 GND and AIR voice quality against D/U with DSB-AM interfered on the same frequency (136.0 MHz) respectively. The bar graph represents PESQ-LQ scores (voice quality) of male and female voice and the line graph represents average score. These test results show that VDL-M3 voice quality was nearly unaffected by DSB-AM undesired signal when the D/U was 15 dB or more and lower D/U had a greater impact on female voice.

Figure 4 and 5 represent VDL-M3 GND and AIR voice quality against D/U with VDL-M3 interfered on the same frequency (136.0 MHz) respectively. These test results show that VDL-M3 voice quality are nearly unaffected by VDL-M3 undesired signal when the D/U was 14 dB or more and also lower D/U had a greater impact on female voice.

Figure 6 shows DSB-AM voice quality against D/U with VDL-M3 interfered on the same frequency (136.0 MHz). According to this test result, DSB-AM voice quality was affected when the D/U was 30 dB. This shows that DSB-AM voice signal is vulnerable to radio interference and analog voice signals transmitted by amplitude modulation are directly affected by radio interference. With signal level decreasing, DSB-AM voice quality received is getting worse (see figure 7). Therefore, when received level is low, analog voice quality is significantly affected by radio interference. While digital voice signals transmitted by VDL-M3 are unaffected directly by received level and radio interference, because according to our previous test result, the vocoder can correct up to four percent of bit error in the voice frame received.

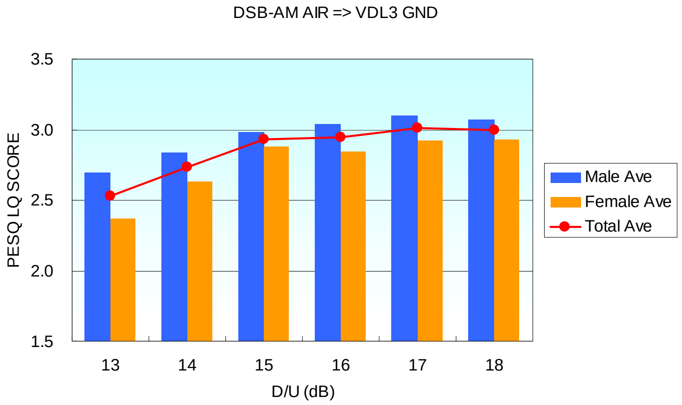

Figure 2 Voice Quality of VDL-M3 GND with DSB-AM interfered

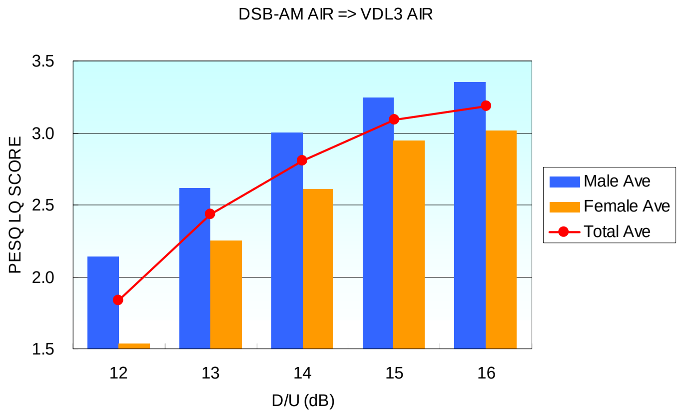

Figure 3 Voice Quality of VDL-M3 AIR with DSB-AM interfered

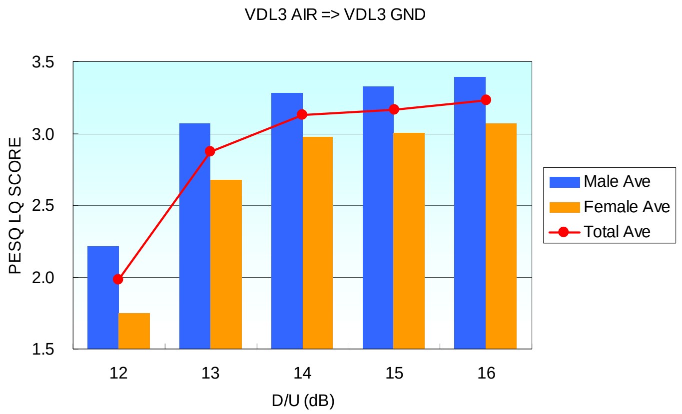

Figure 4 Voice Quality of VDL-M3 GND with VDL-M3 interfered

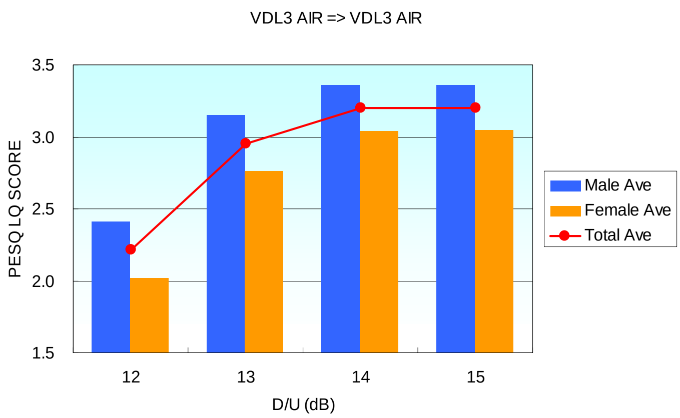

Figure 5 Voice Quality of VDL-M3 AIR with VDL-M3 interfered

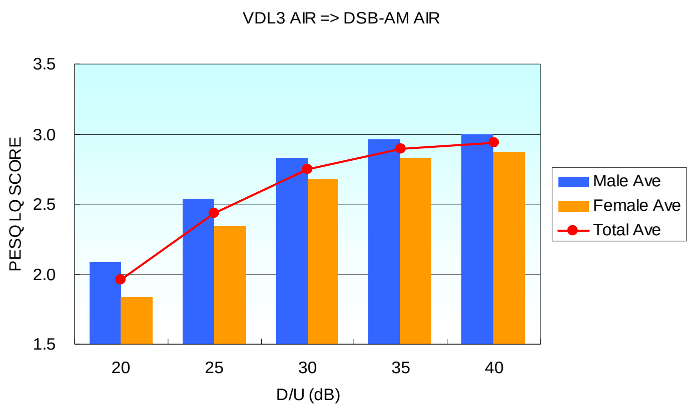

Figure 6 Voice Quality of DSB-AM AIR with VDL-M3 interfered

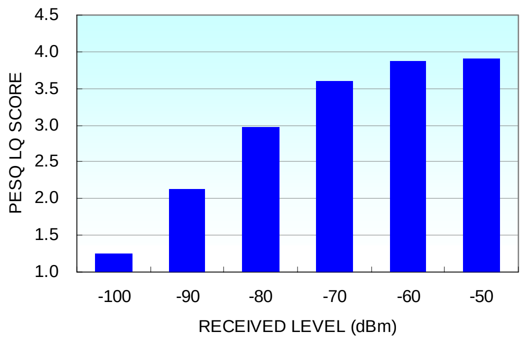

Figure 7 DSB-AM Voice Quality Score against Received Level

4 <u>Adjacent Channel Interference Test</u>

4.1 Test Procedure

Adjacent channel interference test was conducted in the equipment combinations shown in table 4. Undesired signal level was set to the value calculated on the assumption that distance between an interfering transmitter and a victim receiver was 600 m (2,000 feet) (see figure 8).

First, the test was made when the undesired signal source was tuned to the first adjacent channel (plus/minus 25 kHz of desired signal frequency that was 136.0 MHz). If the voice quality score was unable to be obtained due to heavy interference, the test was skipped. Then adjacent channel number was increased with 25 kHz step and the test was repeated. When the voice quality score reached approximately normal score without any interference, the test ended. Voice quality score for each voice phrase was obtained by calculating average score after same test was repeated five times.

Table 4 Equipment Combinations

	Desired Source	Victim Receiver	Undesired Source
1	VDL-M3 GND	VDL-M3 AIR	DSB-AM AIR
2	VDL-M3 GND	VDL-M3 AIR	VDL-M3 AIR
3	DSB-AM	DSB-AM AIR	VDL-M3 AIR

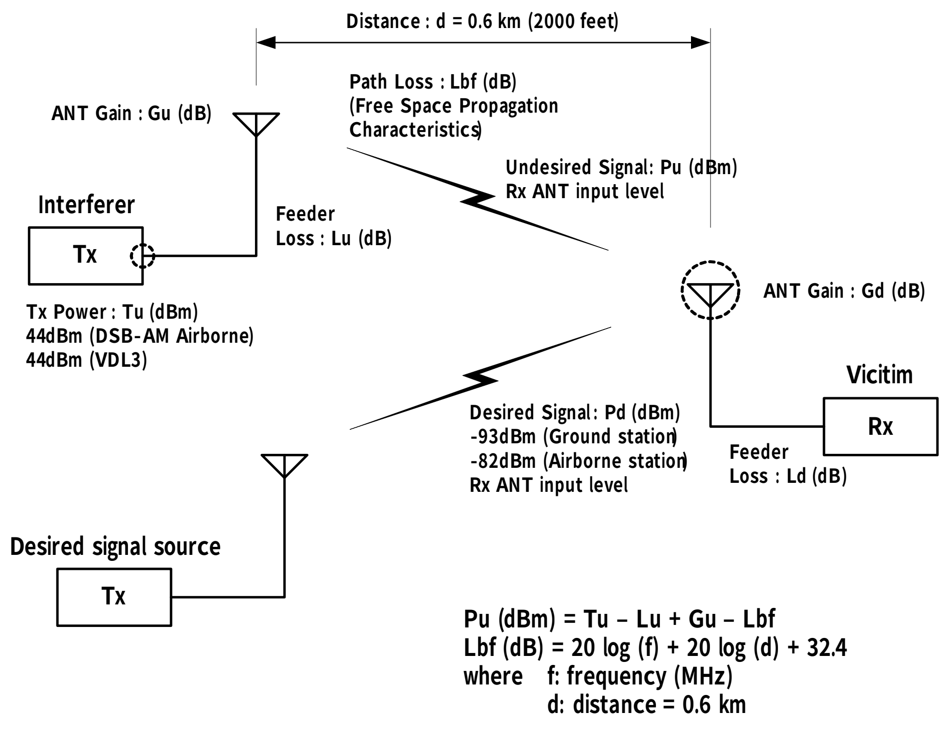

Figure 8 Interference Model

4.2 Test Result

Figure 9 is the graph showing VDL-M3 AIR voice quality against with radio interference from VDL-M3. The bar graph represents PESQ-LQ scores (voice quality) of male and female voice and the line graph represents average score. This test result shows that VDL-M3 voice quality was nearly unaffected by undesired VDL-M3 signal on the first adjacent channel. This test result indicates that the first adjacent channel can be used if two VDL-M3 stations are apart at a distance of 2000 feet or more.

Figure 10 and 11 show DSB-AM AIR voice quality with radio interference from VDL-M3 and vice versa. In the first case, DSB-AM voice quality score at the first adjacent channel could not be obtained due to heavy interference. The test results show that DSB-AM voice signals at minimum level (-85 dBm) were vulnerable than VDL-M3 voice signals at the same level as well as the result of co-channel radio interference test.

Compared with the PESQ-LQ scores between male and female voice signals, female voice scores were much less than those of male voice. It appears that high tone of voice is a little susceptible to interference.

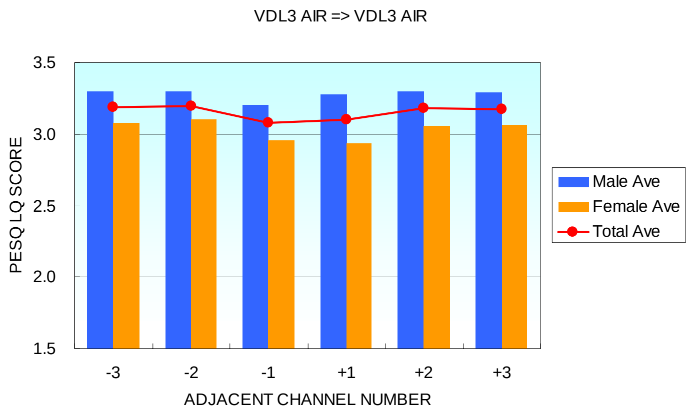

Figure 9 Voice Quality of VDL-M3 AIR with VDL-M3 Interfered

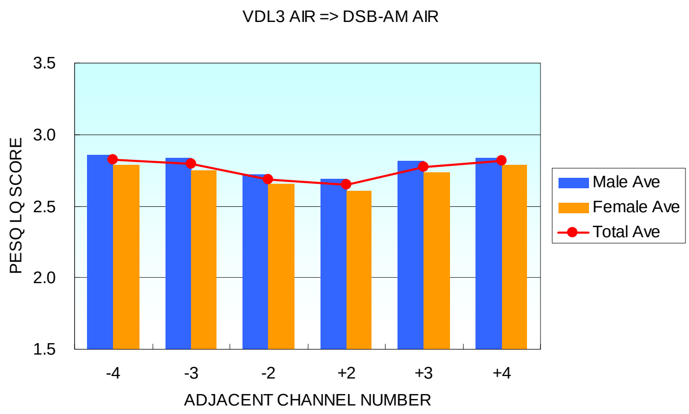

Figure 10 Voice Quality of DSB-AM AIR with VDL-M3 Interfered

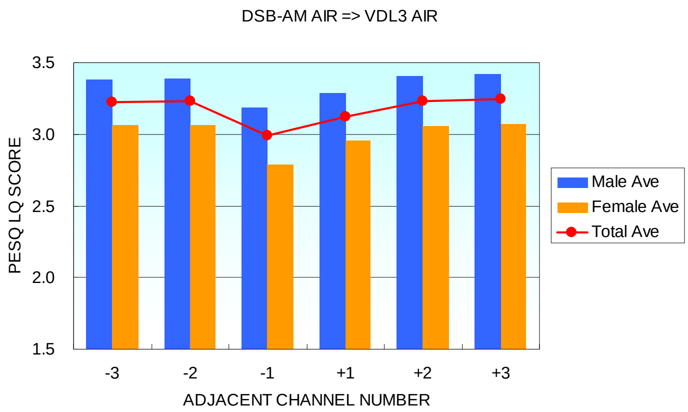

Figure 11 Voice Quality of VDL-M3 AIR with DSB-AM Interfered

5 Conclusions

ENRI carried out additional radio interference test between DSB-AM and VDL-M3 to examine voice quality. This test results indicate that voice quality (PESQ-LQ) score is effective as an index to show impact of radio interference, and that DSB-AM voice signal is susceptible to radio interference in particular at low signal level, while VDL-M3 digital voice signal is more robust.