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AERONAUTICAL COMMUNICATIONS PANEL (ACP)

WG-B 16th MEETING

Tokyo, 28th January－6th February 2004

Agenda Item g：discussion of potential new WG-B agenda item on radio frequency interference

Co-site radio interference between DSB-AM and VDL Mode 3

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Summary

The Electronic Navigation Research Institute (ENRI) has carried out a series of tests for radio interference between VDL Mode 3 and DSB-AM. In those tests, we evaluated an impact on off-channel interference on the victim receivers. However, significant co-site radio interference between DSB-AM and VDL Mode 3 installed on our small aircraft was observed during the first flight test for VDL Mode 3 test equipment, even though the difference in frequency between an interfering transmitter and a victim receiver was 10 MHz or wider. Therefore ENRI measured transmitter-to-receiver isolation level on the aircraft and evaluated the impact on the interference in the laboratory. This paper reports the test method and the results.

1. Introduction

The Electronic Navigation Research Institute (ENRI) has carried out a series of tests for radio interference from VDL Mode 3 into DSB-AM in 2001 and from DSB-AM into VDL Mode 3 in 2002. Two working papers describing both test results were submitted to ICAO AMCP (now ACP) WG-B/12 and WG-B/14 to develop VDL Frequency Planning Assignment Criteria. In those tests, we evaluated the impact on radio interference on the victim receivers with interfering signal frequency varied in range of plus or minus 40 channels (1 MHz) centering around desired signal frequency.

However, significant co-site radio interference between DSB-AM and VDL Mode 3 installed on the ENRI's small aircraft was observed during our first flight test for VDL Mode 3 test equipment in April 2003, even though the difference in frequency between an interfering transmitter and a victim receiver was 10 MHz or wider. Therefore ENRI measured transmitter-to-receiver isolation level between DSB-AM airborne transceiver and VDL Mode 3 test equipment on our experimental aircraft and then conducted some tests in the laboratory to evaluate the impact on co-site radio interference between them.

This paper describes the test method and the results.

Please refer to VDL Mode 4 Airborne Architecture Study (VM4AAS) prepared by Eurocontrol for more information on co-site interference between DSB-AM, VDL Mode 2 and Mode 4.

2. Unexpected Interference in the Flight Test

During our first flight test for VDL Mode 3 test equipment in April 2003, we encountered unexpected radio interference between DSB-AM and VDL Mode 3. It made an impact as follows.

a) VDL Mode 3 transmission signal degraded DSB-AM receiving voice quality with burst noise reduplicated. As a level of DSB-AM receiving signal was lower, voice quality became worse.

b) DSB-AM transmission signal caused receiving level suppression to VDL Mode 3 receiver and degraded bit error rate (BER) of received data.

Figure 1 shows an example of radio interference during the flight test. The upper graph presents a receiving power characteristic at the VDL Mode 3 aircraft station when 62-byte-length data was successively transferred from the ground station. The lower graph presents the same characteristic at the ground station when the same data was transmitted from air to ground. The aircraft was flying over the sea heading for Sendai airport at constant altitude 10,500 feet. Radio interference from DSB-AM into VDL Mode 3 occurred at A, B and C on the upper graph in the Figure 1, suppressing received level of VDL Mode 3. In particular suppression level was nearly 20 dB at C and the receiver failed to receive data, because the BER exceeded the correctable limit. However, receiving level at the ground station was not affected at all as shown in the lower graph.

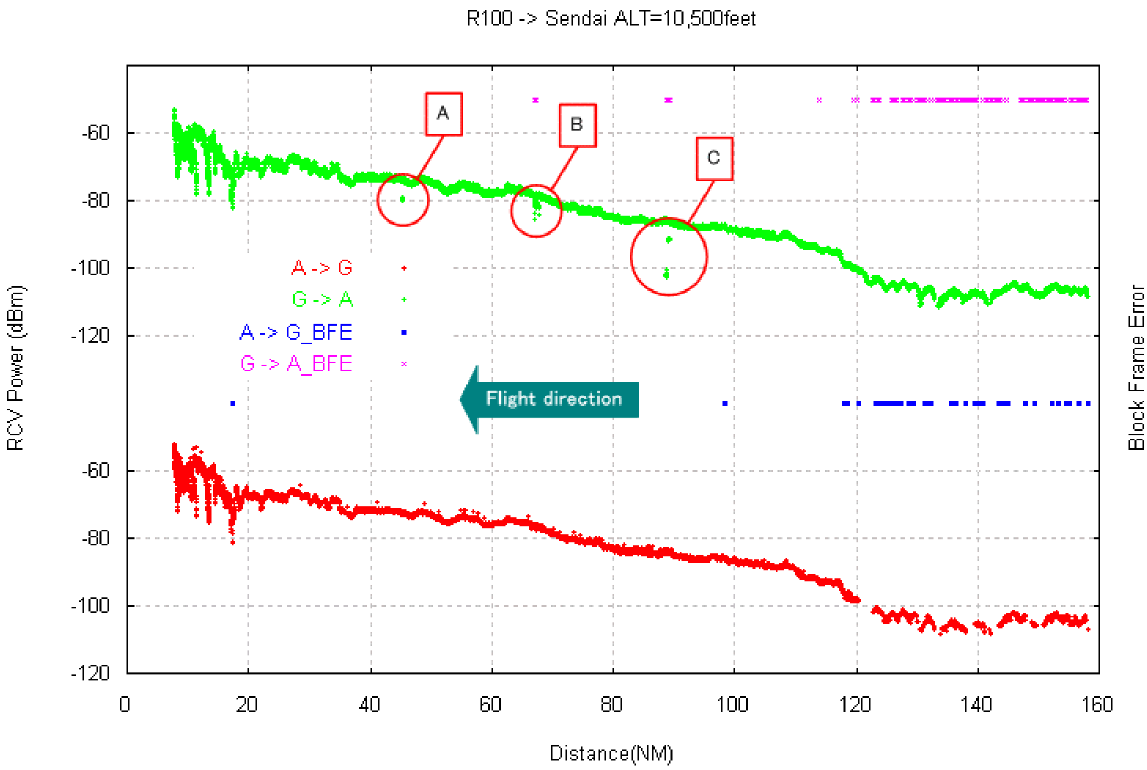


Figure 1 Interference Example

3. Transmitter-to-Receiver Isolation on the Experimental Aircraft

After the flight test, we measured transmitter-to-receiver isolation between DSB-AM airborne transceiver and VDL Mode 3 test equipment on the ENRI's small aircraft. The aircraft, Beechcraft B99, has two antennas for VDL at top-front and bottom-after, and another two VHF antennas for DSB-AM. During the flight test for VDL Mode 3, bottom-after antenna is usually used for VDL Mode 3 and top-after for DSB-AM. Dimensions of the aircraft are shown in Table 1 and Figure 2 presents the antenna layout.

The isolation level was measured with a network analyzer, Advantest R3767CH, connected with each antenna port when the aircraft was on the ground. Measured frequencies were 118.9, 120.4, 124.1, 130.0, 133.6, 135.8 and 136.9 MHz. Most of them are those assigned for ATC voice communications during the flight test. 136.9 MHz is one of two frequencies assigned for VDL Mode 3 test equipment.

Table 2 shows measurement results of the transmitter-to-receiver isolation. The isolation levels are 28.2 dB minimum and 36.1 dB maximum for same side antennas, 39.0 dB minimum and 49.4 dB maximum for opposite side antennas. However the isolation levels in particular for bottom-to-bottom are supposed to be less than actual levels, because the measurement was inevitably affected by reflected wave from the ground.

Table 1　Dimensions of the Aircraft

Registration No.	JA8801
Model	Beechcraft B99
Length	13.58 m
Width	13.98 m
Height	4.38 m
Max. Weight	4,944 kg
Engine	PT6A-28/680shp x 2

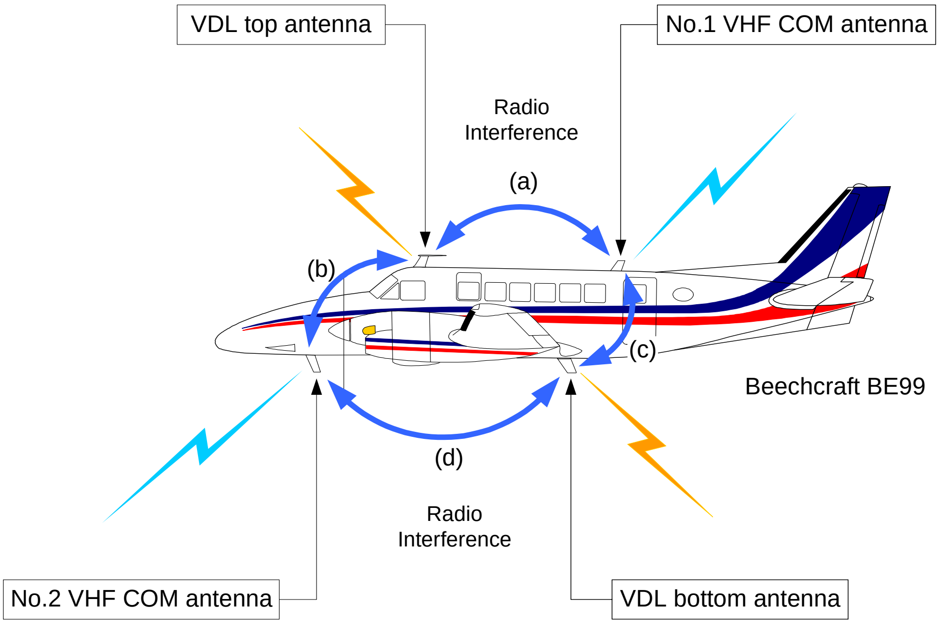


Figure 2　Antenna Layout

Table 2　Transmitter-to-Receiver Isolation (dB)

	VDL ANT	DSB-AM ANT	118.9MHz	120.4MHz	124.1MHz	130.0MHz	133.6MHz	135.8MHz	136.9MHz
			TokyoACC Tohoku	Sendai Approach	TokyoACC Kanto N	-	TokyoACC Kanto E	Johon-zan AEIS	VDL-3
(a)	top	No.1(top)	-30.4	-29.9	-28.2	-28.5	-28.7	-30.7	-41.3
(b)	top	No.2(bottom)	-41.1	-41.1	-39.0	-39.6	-41.2	-41.8	-44.1
(c)	bottom	No.1(top)	-39.1	-39.5	-43.9	-49.4	-43.4	-44.3	-44.4
(d)	bottom	No.2(bottom)	-35.6	-35.6	-36.1	-35.0	-33.3	-33.1	-33.4

4. Impact on Radio Interference on the DSB-AM Receiver

We evaluated in the laboratory S+N/N, SINAD and S/P ratio of DSB-AM received voice signals in the presence of VDL Mode 3 transmission signal interfering. Interfering signal frequency was 136.9 MHz and DSB-AM reception frequencies were 118.9, 120.4, 124.1, 130.0, 133.6 and 135.8 MHz at which transmitter-to-receiver isolation levels were measured. In these tests, Rockwell Collins VHF-22A for general aviation aircraft was used as a victim receiver, and VDL Mode 3 test equipment was used as an undesired signal source. Desired signal source was a standard signal generator. Levels of desired signal at receiver input were -70 to -85 dBm and levels of interfering signal were -2.4 or +8.6 dBm based on the transmitter-to-receiver isolation measured. Figure 3 shows the test setup for this evaluation.

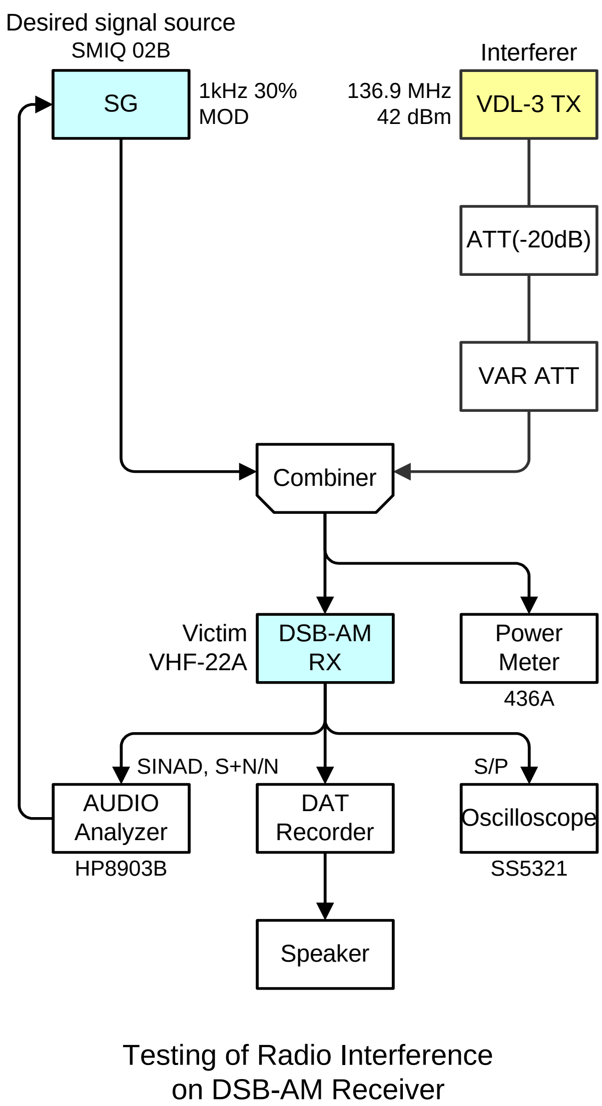


Figure 3 Test Setup

4.1 Testing Parameters

4.1.1 Interferer transmitter (undesired signal source)

Parameter	Setting
Equipment	VDL Mode 3 test equipment (transmitter)
Frequency	136.9 MHz
Input level at victim RX	-2.4 dBm (42-44.4 dBm) and +8.6 dBm (42-33.4 dBm)
Channel load	one timeslot (V/D burst successively transmitted)

4.1.2 Victim receiver

Parameter	Setting
Equipment	DSB-AM airborne receiver VHF-22A
Frequencies	118.9, 120.4, 124.1, 130.0, 133.6 and 135.8 MHz
Input levels of desired signal	-70, -76, -82 and -85 dBm
Measurement items	S+N/N, SINAD and S/P

4.1.3 Desired signal source

Parameter	Setting
Equipment	Signal generator, SMIQ 02B
Frequency	118.9, 120.4, 124.1, 130.0, 133.6 and 135.8 MHz
Modulation	1kHz 30%

4.2 Test Result

a) S+N/N

Figure 4 shows S+N/N test result when desired signal level was -85 dBm. Compared to the test result without interference, S+N/N with interference from VDL Mode 3 bottom antenna to DSB-AM top antenna (opposite side antennas) dropped by 8 to 10 dB, but rather constant over different desired frequency. Meanwhile, S+N/N with interference from VDL Mode 3 bottom antenna to DSB-AM bottom antenna (same side antennas) dropped by 14 to 20 dB. A greater impact was observed in lower frequency.

Table 3 in the attachment of this paper shows all S+N/N test results. Upper table in the Table 3 shows the test result without interference, middle one with bottom-to-top interference and lower one with bottom-to-bottom interference.

b) SINAD

Figure 5 shows SINAD test result when desired signal level was -85 dBm. It shows similar tendency to S+N/N test result. Table 4 in the attachment shows all SINAD test results.

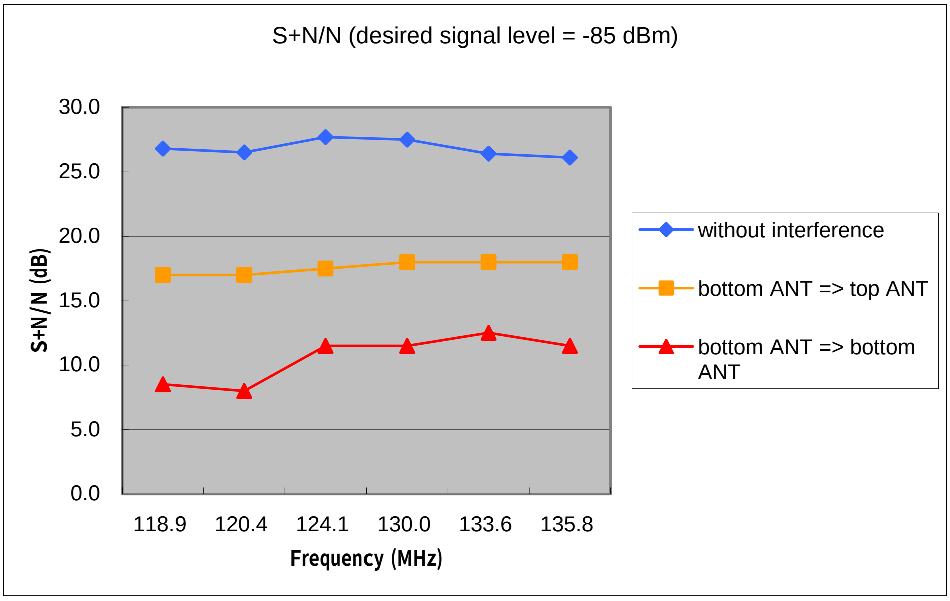


Figure 4 Test Result - S+N/N

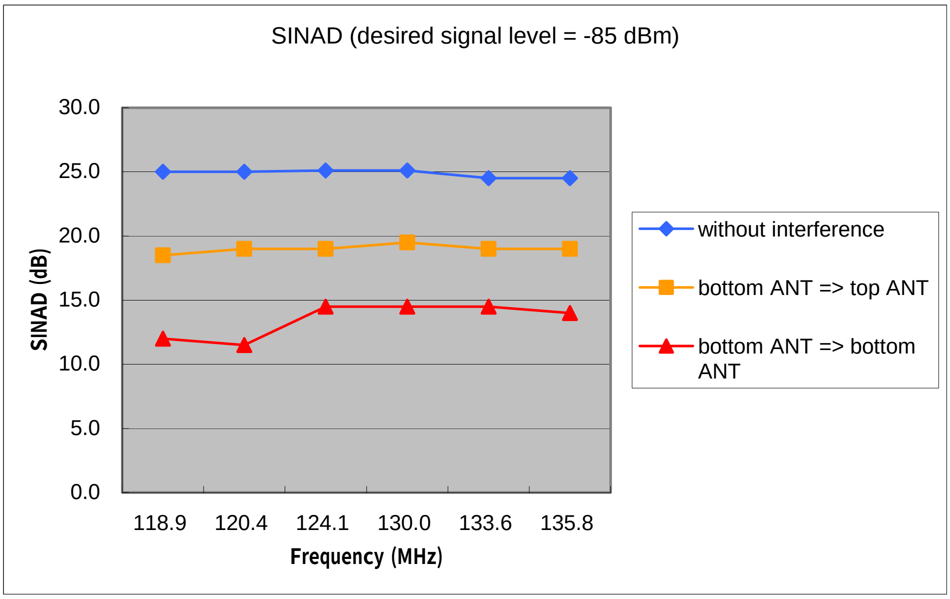


Figure 5 Test Result – SINAD

c) S/P ratio

Figure 6 shows S/P test result when desired signal level was -70 and -85 dBm. VDL Frequency Planning Assignment Criteria requires the S/P ratio in protection parameters for DSB-AM receiver to be more than 18 dB for VDL Mode 3 interference. S/P ratio measured satisfied the requirement only when desired signal level was -70 dBm with interference for opposite side antennas.

Figure 7 shows an example of received voice with bottom-to-bottom interference. When desired signal level was -82 dBm, it took effort to listen received voice due to burst noise caused by VDL transmission signal. Table 5 in the attachment shows all S/P test results.

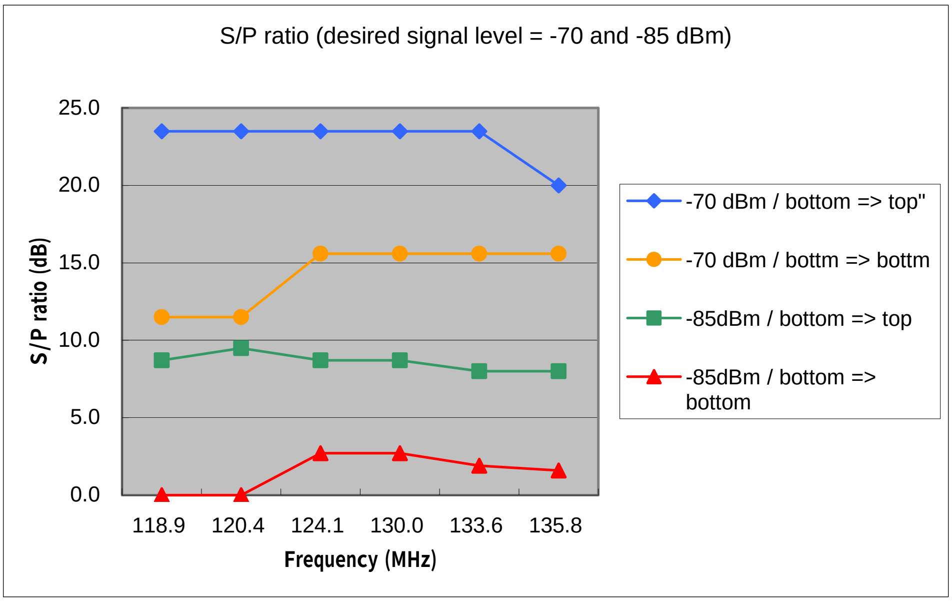


Figure 6 Test Result – S/P ratio

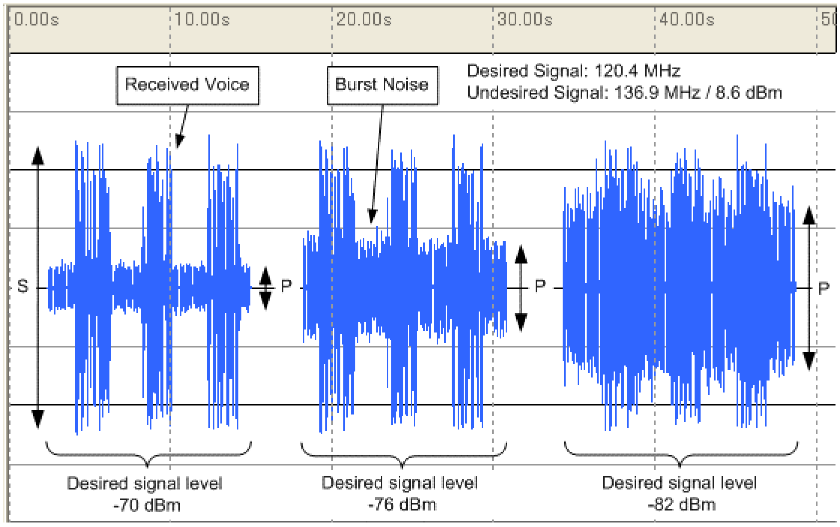
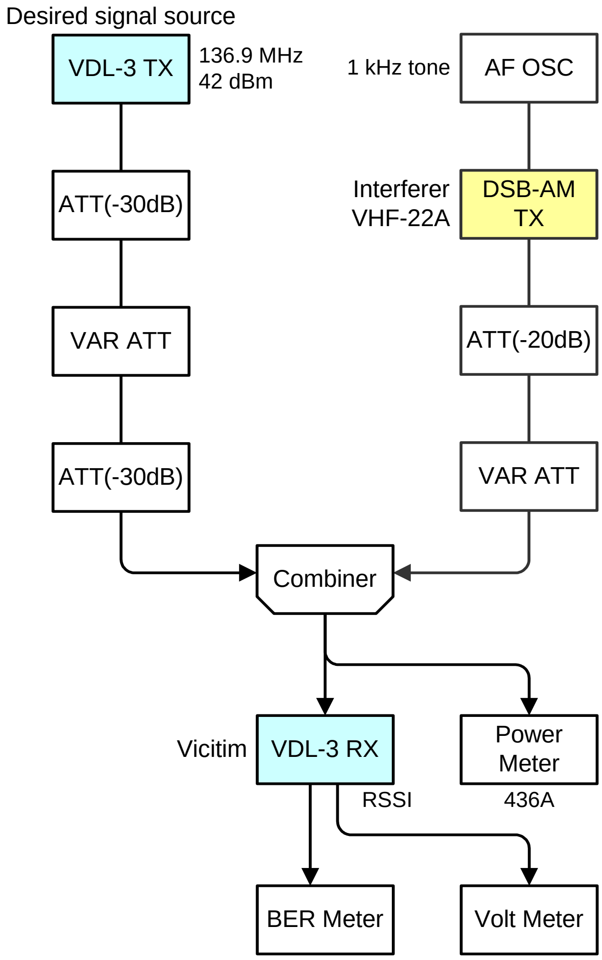


Figure 7 Voice Received with Interference (for example)

5. Impact on Radio Interference on the VDL-3 Receiver

We then evaluated in the laboratory how much the interference from DSB-AM airborne transmitter affected the BER and suppressed the desired signal level of VDL Mode 3 receiver. VDL Mode 3 reception frequency was set to 136.9 MHz and DSB-AM transmission frequencies were set to 118.9, 120.4, 124.1, 130.0, 133.6 and 135.8 MHz at which transmitter-to-receiver isolation were measured. In these tests, the VDL Mode 3 test equipment which ENRI has developed was used as a victim receiver and desired signal source. DSB-AM transmitter as a interferer was Rockwell Collins VHF-22A.

Levels of desired signal at receiver input were -55 to -95 dBm and levels of interfering signal were -6.4 to +9.9 dBm based on the transmitter-to-receiver isolation measured on the experimental aircraft. Figure 8 shows test setup for this evaluation.



Testing of Radio Interference
on VDL Mode 3 Receiver

Figure 8 Test Setup

5.1 Testing Parameters

5.1.1 Interferer transmitter

Parameter	Setting
Equipment	DSB-AM airborne transmitter
Frequencies	118.9, 120.4, 124.1, 130.0, 133.6 and 135.8 MHz
Input level at victim RX	various levels depending on the antenna isolation levels

5.1.2 Victim receiver

Parameter	Setting
Equipment	VDL Mode 3 test equipment (receiver)
Frequency	136.9 MHz
Input levels of desired signal	-55, -65, -75, -85 and -95 dBm
Measurement item	BER and Suppressed level of desired signal

5.2 Test Result

a) BER

Table 6 in the attachment shows the BER measured with interference from DSB-AM transmitter into VDL Mode 3 receiver. The BER became deteriorated with the desired signal level decreasing and DSB-AM frequency becoming closer to VDL frequency. When desired signal level was -95 dBm and undesired frequency was 124.1 MHz or higher, any BER for opposite side antennas did not meet the requirement, BER=$1x10^{-3}$ which was stipulated by SARPs as the specified error rate for VDL Mode 3. When desired signal level was -75 dBm and undesired frequency was 135.8 MHz, BER for same side antennas exceeded the specified error rate.

b) Suppressed level of desired signal

Table 7 shows test result to evaluate how much desired signal level of VDL Mode 3 receiver was suppressed by interference from DSB-AM transmitter. As DSB-AM frequency came closer to VDL frequency, the suppression level increased. By contraries, as desired signal level became lower, suppression level decreased. It might come from that victim receiver processes the undesired signal leaking into the receiver as its desired signal. Its effect becomes significant as desired signal level is lower.

6. Consideration

This co-site radio interference was considered to result from desensitization, not from off-channel interference. Off-channel interference is caused by adjacent channel power (ACP) emitted from interfering transmitter, while the desensitization is caused by a transmission signal much stronger than desired signal level. The strong signal leaking into a victim receiver could saturate the receiver front-end circuit and suppresse the receiver sensitivity.

According to the test results especially in a combination of the same side antennas, it is recognized that co-site radio interference between DSB-AM and VDL Mode3 on the same aircraft poses a significant problem on those radio’s operation.

After VDL Mode 3 implementation, we expect that VDL Mode 3 system will be used for ATC voice and data communications, DSB-AM will remain to be used for AOC analog voice communications and VDL Mode 2 continues to be used for AOC data communications. Therefore co-site interference between DSB-AM and VDL Mode 3 as reported in this paper could be occurred on the same aircraft.

However we estimate that actual impact on co-site radio interference between DSB-AM and VDL Mode 3 could be more moderate than that our test results reported here. The reason is that undesired signal levels at victim receiver input were determined on the basis of transmitter-to-receiver isolation level measured. The actual isolation level might be lower than that measured in the test because the isolation measurement here was conducted when the aircraft was on the ground.

Actually, our pilots did not make any complaint about DSB-AM VHF voice communications during the flight test unless making use of bottom-to-bottom antennas combination.

7. Possible Solution

From the technical standpoint, the measures to mitigate co-site radio interference on the same aircraft can be listed as follows.

a) To reduce interfering transmission power.
b) To restrict DSB-AM transmission (may be for AOC only) when VDL Mode 3 receiver is receiving digital voice or data.
c) To restrict VDL Mode 3 transmission when DSB-AM receiver is receiving analog voice signal.
d) To secure large frequency separation between DSB-AM and VDL Mode 3, especially if VDL frequency should be assigned to upper part of aeronautical VHF communications band, then interfering signal into receiver could be mitigated by appropriate filter.
e) To increase the transmitter-to-receiver isolation level on the same aircraft.

a) is unfeasible because lower transmission power invites narrower coverage. b) and c) are very effective for the resolution of co-site interference, but they are also unfeasible because DSB-AM transmission must be waited for a long time in congested airspace where ATC communications take place at frequent and random intervals, and current DSB-AM transceivers must be modified. And VDL Mode 3 transmission can not wait because ATC communications requires quick response after receiving air traffic clearances or instructions from air traffic controllers. d) is difficult to implement during transition period from the current DSB-AM, to new VDL Mode 3 because of welter frequency assignment. And d) is not decisive measures to mitigate the desensitization caused by co-site interference.

The remaining item is only e). Simple and easy way to mitigate co-site interference is operation in top-front and bottom-after antenna combination, or top-after and bottom-front antenna combination. However this method even can not completely eliminate the impact on the interference, just ease it.

8. Conclusion

The meeting is invited to,

a) note the test results of co-site radio interference between DSB-AM and VDL Mode 3 on the small aircraft.
b) note that further thorough evaluation for the desensitization caused by co-site interference with commercially available VDL Mode 3 radios are needed for VDL Mode 3 implementation. And then
c) consider appropriate measures to mitigate the interference.

Table 3　Test Result of S+N/N

Interferer: VDL Mode 3 transmitter 136.9MHz

S+N/N

DSB-AM RX Performance without Interference

Desired signal (dBm)	S+N/N (dB)					
	118.9 MHz	120.4 MHz	124.1 MHz	130.0 MHz	133.6 MHz	135.8 MHz
-70.0	40.5	41.0	41.3	41.7	40.9	40.3
-76.0	35.7	35.7	36.4	36.5	35.5	35.1
-82.0	29.5	29.5	30.5	30.6	29.4	29.4
-85.0	26.8	26.5	27.7	27.5	26.4	26.1

Radio Interference from VDL Mode 3 TX into DSB-AM RX

VDL-3 Bottom ANT => DSB AM Top ANT

In band Undesired signal level	Desired signal (dBm)	S+N/N (dB)					
		118.9 MHz	120.4 MHz	124.1 MHz	130.0 MHz	133.6 MHz	135.8 MHz
-2.4	-70.0	32.0	32.0	32.5	32.7	33.0	31.5
	-76.0	26.0	26.0	26.5	26.8	27.0	26.5
	-82.0	20.0	20.5	21.0	21.5	21.0	21.0
	-85.0	17.0	17.0	17.5	18.0	18.0	18.0

Radio Interference from VDL Mode 3 TX into DSB-AM RX

VDL-3 Bottom ANT => DSB AM Bottom ANT

In band Undesired signal level	Desired signal (dBm)	S+N/N (dB)					
		118.9 MHz	120.4 MHz	124.1 MHz	130.0 MHz	133.6 MHz	135.8 MHz
8.6	-70.0	22.5	22.0	26.5	27.0	26.7	21.0
	-76.0	16.0	16.5	20.5	21.5	21.5	18.5
	-82.0	10.5	10.5	14.5	15.0	15.0	14.0
	-85.0	8.5	8.0	11.5	11.5	12.5	11.5

Attachment

Table 4 Test Result of SINAD

Interferer: VDL Mode 3 transmitter 136.9MHz

SINAD

DSB-AM RX Performance without Interference

Desired signal (dBm)	SINAD (dB)					
	118.9 MHz	120.4 MHz	124.1 MHz	130.0 MHz	133.6 MHz	135.8 MHz
-70.0	25.2	25.2	25.0	25.0	25.2	25.3
-76.0	26.3	26.4	26.2	26.2	26.3	26.3
-82.0	25.8	25.8	26.0	26.0	25.6	25.6
-85.0	25.0	25.0	25.1	25.1	24.5	24.5

Radio Interference from VDL Mode 3 TX into DSB-AM RX

VDL-3 Bottom ANT => DSB AM Top ANT

In band Undesired signal level	Desired signal (dBm)	SINAD (dB)					
		118.9 MHz	120.4 MHz	124.1 MHz	130.0 MHz	133.6 MHz	135.8 MHz
-2.4	-70.0	25.0	24.5	24.5	24.5	24.5	24.5
	-76.0	24.0	24.0	24.5	24.5	24.5	24.0
	-82.0	21.0	21.0	21.5	21.5	21.5	21.0
	-85.0	18.5	19.0	19.0	19.5	19.0	19.0

Radio Interference from VDL Mode 3 TX into DSB-AM RX

VDL-3 Bottom ANT => DSB AM Bottom ANT

In band Undesired signal level	Desired signal (dBm)	SINAD (dB)					
		118.9 MHz	120.4 MHz	124.1 MHz	130.0 MHz	133.6 MHz	135.8 MHz
8.6	-70.0	21.5	21.5	23.0	23.5	23.5	21.5
	-76.0	17.5	17.5	21.0	21.5	21.0	19.5
	-82.0	13.5	13.0	16.5	17.0	17.0	16.0
	-85.0	12.0	11.5	14.5	14.5	14.5	14.0

Table 5 Test Result of S/P

Interferer: VDL Mode 3 transmitter 136.9MHz

S/P

Radio Interference from VDL Mode 3 TX into DSB-AM RX <S/P>

VDL-3 Bottom ANT => DSB AM Top ANT

In band Undesired signal level	Desired signal (dBm)	S/P (dB)					
		118.9 MHz	120.4 MHz	124.1 MHz	130.0 MHz	133.6 MHz	135.8 MHz
-2.4	-70.0	23.5	23.5	23.5	23.5	23.5	20.0
	-76.0	17.5	17.5	17.5	17.5	17.5	15.6
	-82.0	11.5	11.5	11.5	11.5	11.5	11.5
	-85.0	8.7	9.5	8.7	8.7	8.0	8.0

Radio Interference from VDL Mode 3 TX into DSB-AM RX <S/P>

VDL-3 Bottom ANT => DSB AM Bottom ANT

In band Undesired signal level	Desired signal (dBm)	S/P (dB)					
		118.9 MHz	120.4 MHz	124.1 MHz	130.0 MHz	133.6 MHz	135.8 MHz
8.6	-70.0	11.5	11.5	15.6	15.6	15.6	15.6
	-76.0	8.0	6.6	11.5	10.5	9.5	10.5
	-82.0	3.5	1.2	4.9	4.4	4.9	4.4
	-85.0	0.0	0.0	2.7	2.7	1.9	1.6

Table 6 Test Result of BER

Victim: VDL Mode 3 receiver 136.9MHz

BER

Radio Interference from DSB-AM TX into VDL Mode 3 RX

DSB AM Top ANT => VDL-3 Bottom ANT

Desired signal (dBm)	Undesired Frequency	BER					
		118.9 MHz	120.4 MHz	124.1 MHz	130.0 MHz	133.6 MHz	135.8 MHz
	In band signal level	3.9	3.5	-0.9	-6.4	-0.4	-1.3
-55.0		-	-	-	-	-	-
-65.0		-	-	-	-	-	-
-75.0		-	-	-	-	-	-
-85.0		-	-	-	1.57E-03	1.00E-06	1.24E-04
-95.0		-	-	1.39E-03	x	1.54E-02	5.20E-02

-: error free x: incapable measurement

Radio Interference from DSB-AM TX into VDL Mode 3 RX

DSB AM Bottom ANT => VDL-3 Bottom ANT

Desired signal (dBm)	Undesired Frequency	BER					
		118.9 MHz	120.4 MHz	124.1 MHz	130.0 MHz	133.6 MHz	135.8 MHz
	In band signal level	7.4	7.4	6.9	8.0	9.7	9.9
-55.0		-	-	-	-	-	-
-65.0		-	-	-	-	-	-
-75.0		-	-	-	-	7.80E-05	2.64E-02
-85.0		-	-	-	2.82E-04	4.51E-02	x
-95.0		1.00E-06	2.00E-06	5.08E-02	x	x	x

-: error free x: incapable measurement

Attachment

Table 7 Test Result of Suppressed Level of Desired Signal

Victim: VDL Mode 3 receiver 136.9MHz

LEVEL

Radio Interference from DSB-AM TX into VDL Mode 3 RX

DSB AM Top ANT => VDL-3 Bottom ANT

Desired signal (dBm)	Undesired Frequency	Suppressed Level of Desired Signal (dB)					
		118.9 MHz	120.4 MHz	124.1 MHz	130.0 MHz	133.6 MHz	135.8 MHz
	In band signal level	3.9	3.5	-0.9	-6.4	-0.4	-1.3
-55.0		0.13	0.13	0	1.06	8.05	8.45
-65.0		0.26	0.13	0	1.06	7.92	8.05
-75.0		0	0.13	0	1.06	7.66	7.39
-85.0		0.13	0.26	0	1.06	7.53	4.49
-95.0		0.26	0.13	0	1.19	8.32	-3.3

Radio Interference from DSB-AM TX into VDL Mode 3 RX

DSB AM Bottom ANT => VDL-3 Bottom ANT

Desired signal (dBm)	Undesired Frequency	Suppressed Level of Desired Signal (dB)					
		118.9 MHz	120.4 MHz	124.1 MHz	130.0 MHz	133.6 MHz	135.8 MHz
	In band signal level	7.4	7.4	6.9	8.0	9.7	9.9
-55.0		0.40	0.40	0.13	13.2	21.12	21.12
-65.0		0.53	0.53	0.13	13.2	20.73	19.54
-75.0		0.4	0.53	0	12.94	20.46	14.65
-85.0		0.4	0.53	0.26	12.67	19.94	6.07
-95.0		0.53	0.53	0.26	13.33	14.23	-3.56