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Research activities for investigating on-board electromagnetic compatibility issues in current radio environments

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Overview

Research background

On-board electromagnetic compatibility (EMC) issues in current radio environments.

IPL measurement results

Case study of IPL characteristics of aircrafts such as BK117-C2, KingAir 350, DHC8-Q400, ERJ170-100.

Conclusions

Interference path loss (IPL)

IPL is a one of parameters that stands for aircraft's tolerance to electromagnetic interference (EMI).

Estimation of EMI tolerance

Estimation of EMI tolerance due to the Sub-6 band 5G devices on-board.

On-board EMC issues in current radio environments

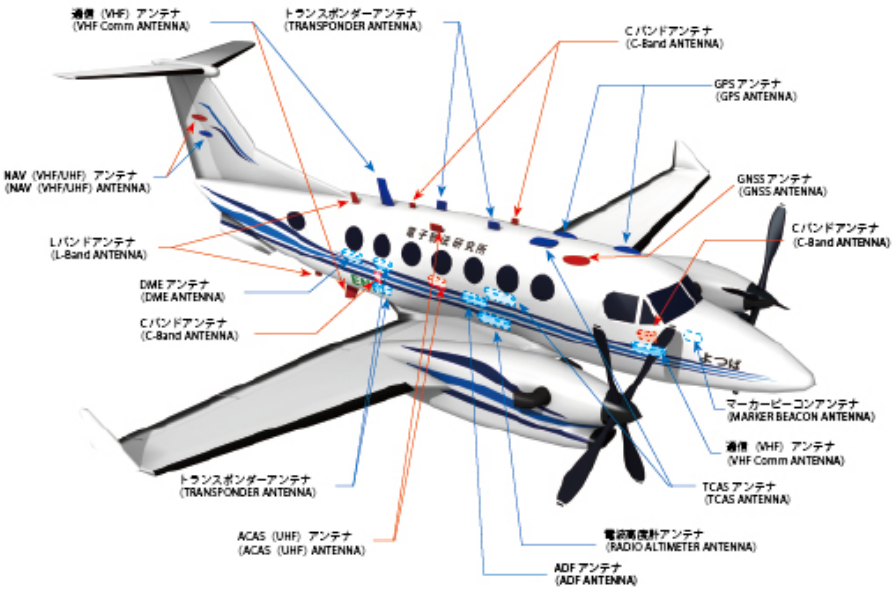
Various radio wave use of portable electronics devices (PEDs)

- As the use of PEDs on aircraft increases, it is becoming necessary to evaluate the electromagnetic interference (EMI) tolerance of various avionics.
- RTCA DO-307B/EUROCAE ED-239A describe the aircraft design recommendations that lead to aircraft tolerance to both intentional RF transmission sand spurious RF emissions from PEDs.
- The avionics subject to the evaluation of EMI due to the PEDs are not satellite-based systems, except for GNSS and SATCOM, but required to evaluate very low levels of interference power due to the proximity of the interfering systems to the avionics antennas.
- The current DO-307B/ED-239A was published in June 2022. The main changes are to address EMI issues with radio altimeters (RAs) due to the introduction of C-band (Sub-6 band) 5G mobile systems in the United States.
- As a national research institute in Japan, ENRI has been working on EMI issues due to PEDs including GNSS. In this presentation, we will discuss the EMI issue of RAs as a new topics.

Interference path loss (IPL)

IPL between avionics and electronics devices inside cabin

- IPL stands for the path loss between the antenna of the electronics antenna and the avionics receiving port.
- Target IPL of avionics systems such as the VHF, NAV, ILS, ATC, TCAS, GNSS are determined. In addition, the IPL target value of RAs are added on DO-307B/ED-239A.



（EIRP of interference source）-IPL
>Interference threshold power
Possibility of EMI

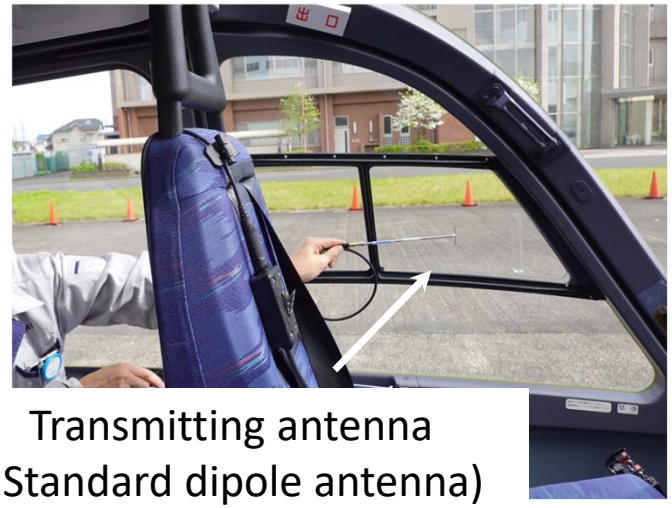
Receiver Aggregate Susceptibility Threshold PSD (dBm/MHz)

Receiver	Power spectral density (dBm/MHz)
GNSS L1	-183
GNSS L5	-180
RA	-167 or -179

Overview of IPL measurement

Conditions

- Measurement frequency band:
  - 3,500 MHz-4,700 MHz (Radio altimeter band and adjacent frequency band)
- Transmitting antenna: Standard dipole antenna
- Transmitting antenna polarization: three orthogonal axis
- Measurement dynamic range: Approximately 120 dB

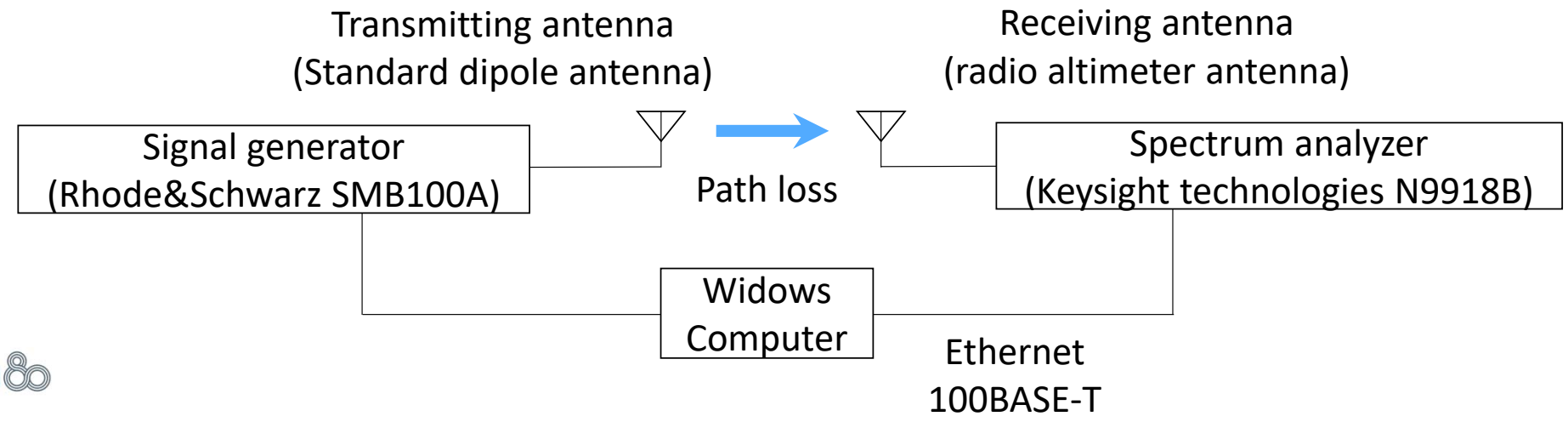


Transmitting antenna
(Standard dipole antenna)

Measurement set-up

IPL measurement set-up

- The path loss between the transmitting antenna and the receiving antenna are measured using the signal generator and spectrum analyzer.
- IPL measurements are carried out based on the procedure described in DO-307B/ED-239A - Aircraft Design and Certification for Portable Electronic Device (PED).
- The cable loss, transmitting antenna return loss are calibrated at IPL calculation.



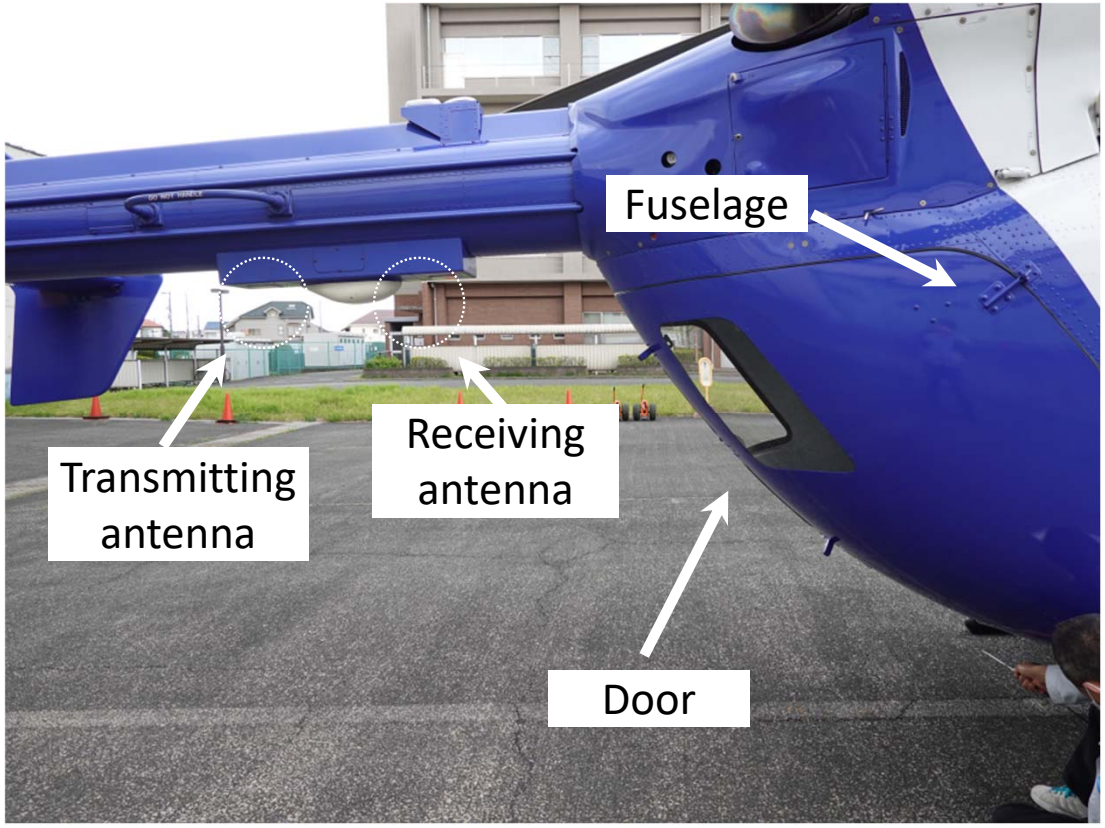
BK117-C2

Kawasaki
BK117-C2

measured Jul. 2020

BK117-C2: Radio altimeter antenna

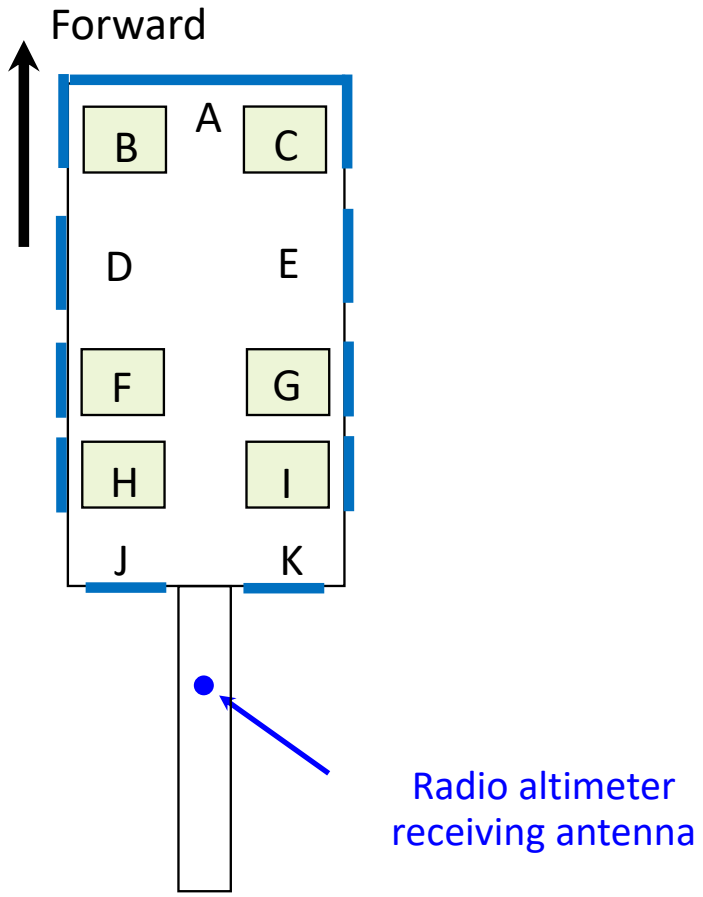
Location of transmitting and receiving antenna of radio altimeter



BK117-C2: Measurement results

No	Transmitting antenna location	IPL minimum (dB)	IPL median (dB)
A	Cockpit (center)	72.1	85.1
B	Cockpit (left seat)	70.8	85.0
C	Cockpit (right seat)	71.4	86.0
D	Left window (2nd row)	70.5	82.8
E	Right window (2nd row)	71.3	83.4
F	Left window (3rd row)	66.9	79.2
G	Right window (3rd row)	65.5	77.1
H	Left window (4th row)	59.5	75.3
I	Right window (4th row)	61.5	73.7
J	Left rear window	51.6	66.1
K	Right rear window	49.2	64.4
	Inside total	49.2	79.5

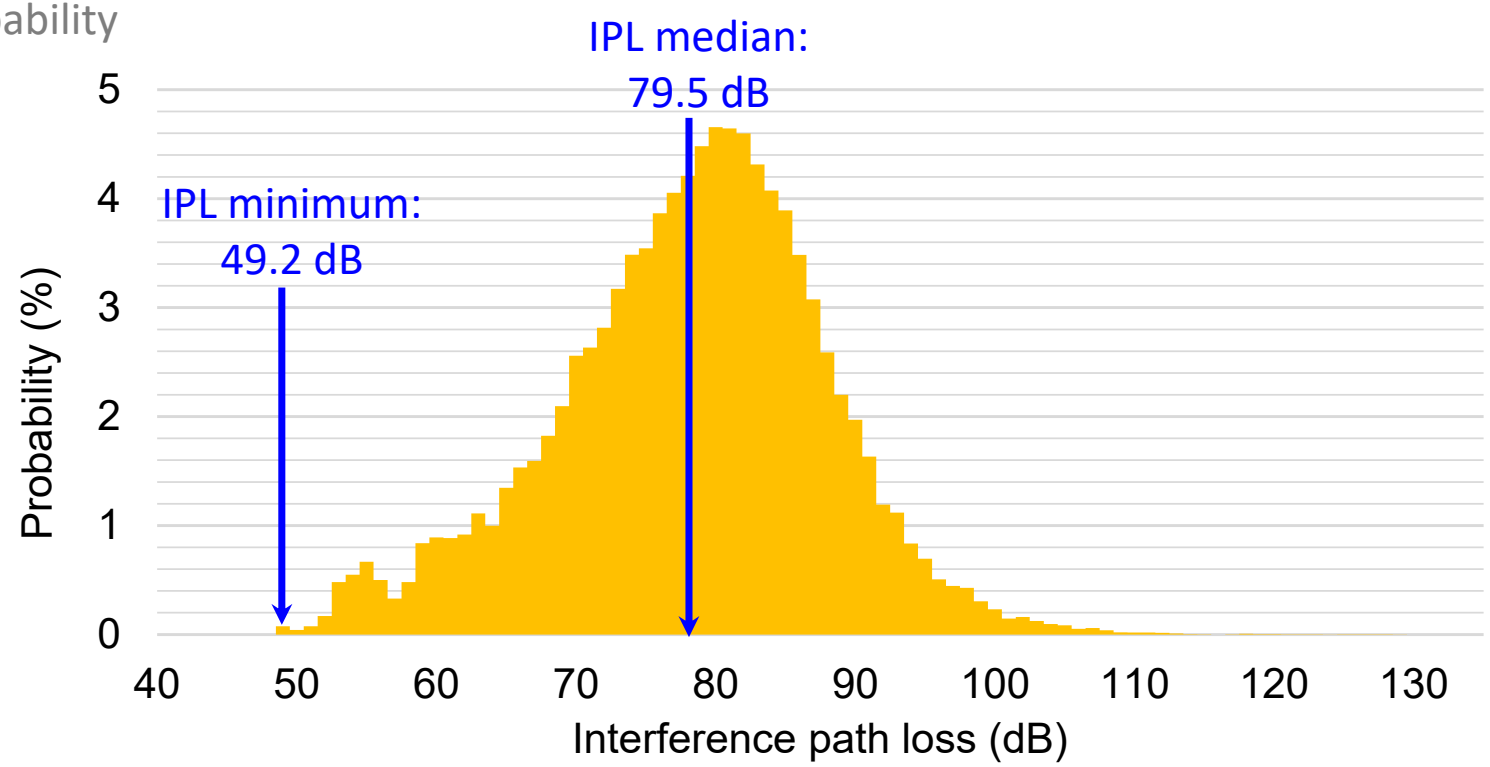
Inside cabin: 11 locations



The minimum IPL values is 49.2 dB, obtained at line-of-sight condition with the RA antenna.

BK117-C2: Measurement results

IPL probability



Total measurement data 290,763 points: 11 (transmitting antenna location) x 801 (Frequency domain) x 11 (time domain) x 3 (transmitting antenna axis)

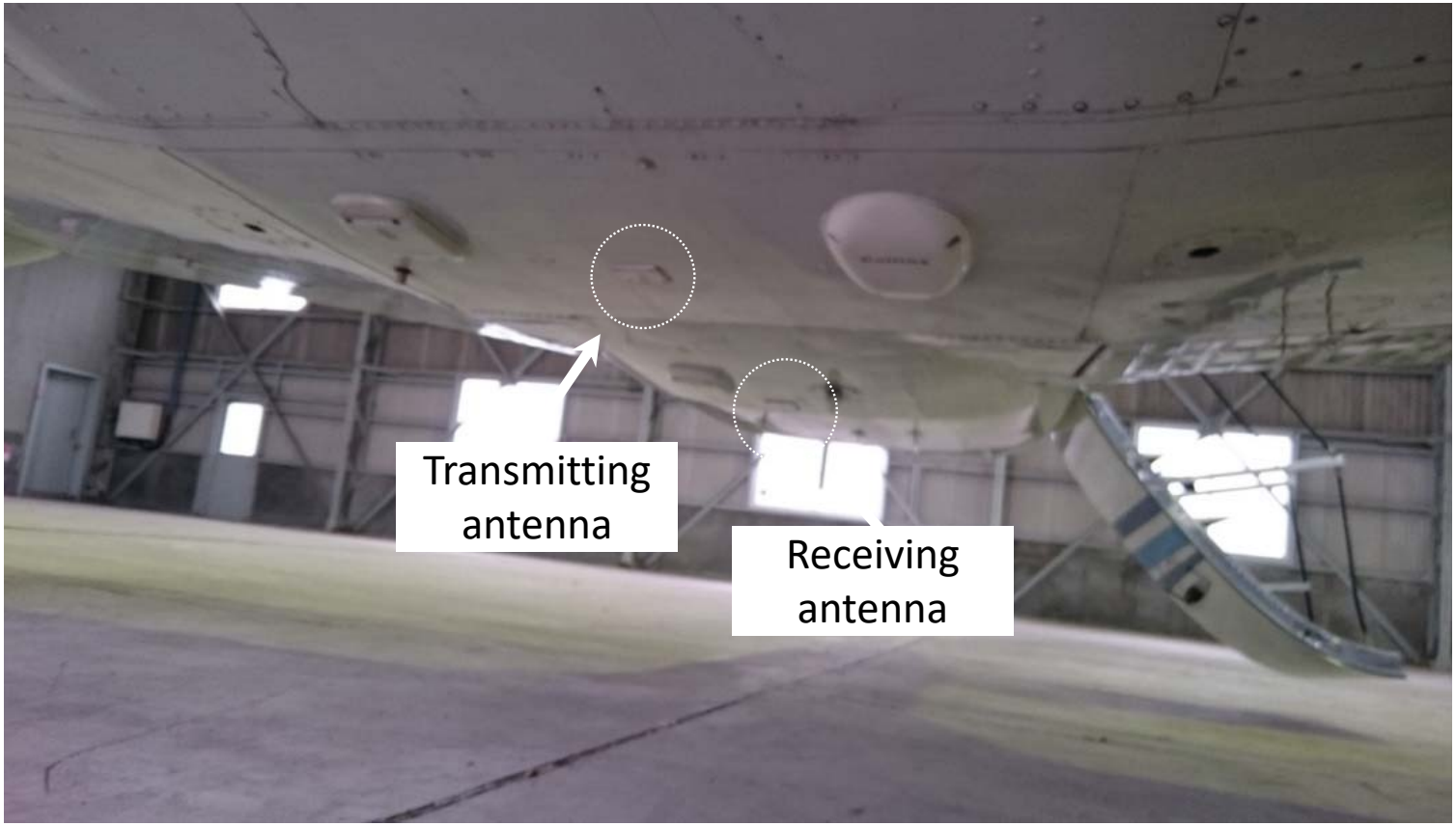
B300

Beechcraft
B300
(KingAir 350)

measured Nov. 2020

B300: Radio altimeter antenna

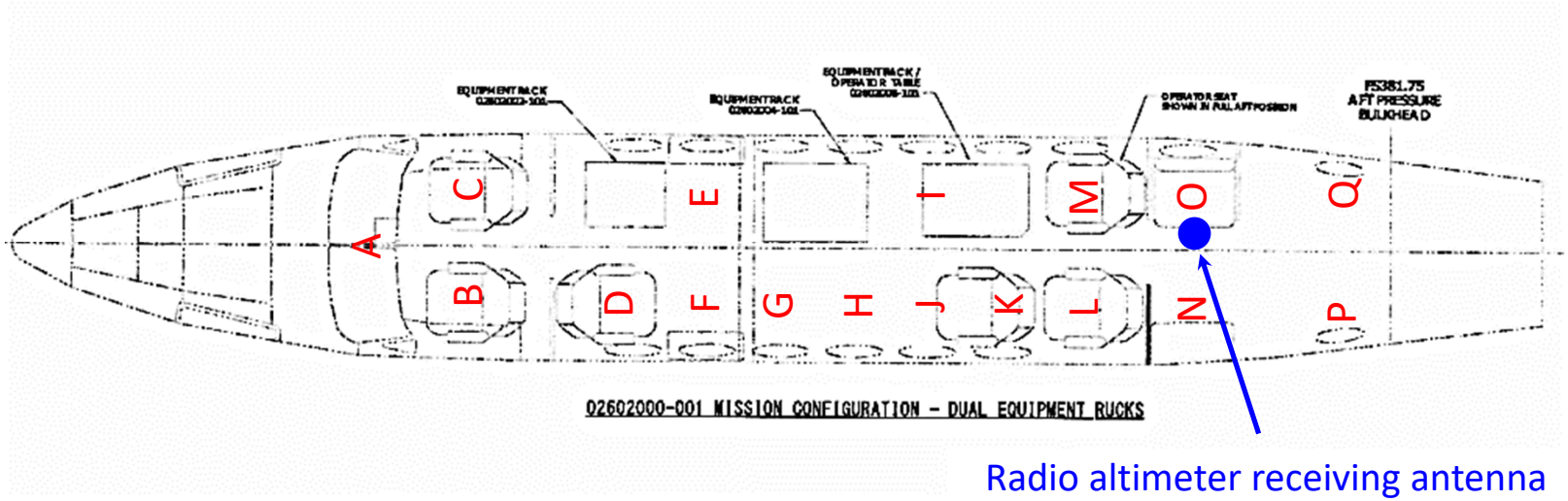
Location of transmitting and receiving antenna of radio altimeter



B300: Location of transmitting antenna and results

Location of transmitting antenna inside cabin

- Assuming the Sub-6 band 5G devices, the number of transmitting antenna locations are 17 points.



The minimum IPL values is 67.5 dB.

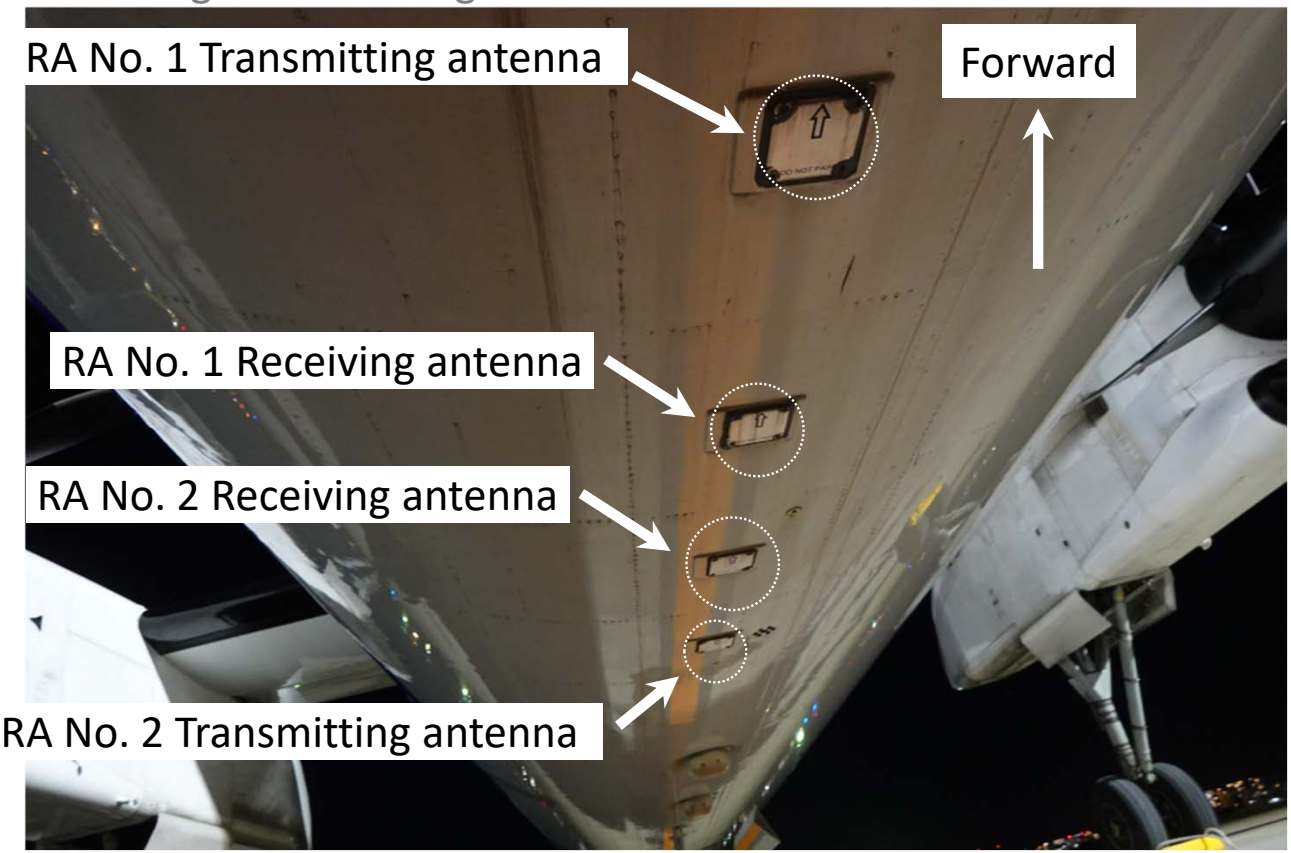
DHC8-Q400

Bombardier DHC-8-402

measured Aug. 2022

DHC8-Q400: Radio altimeter antenna

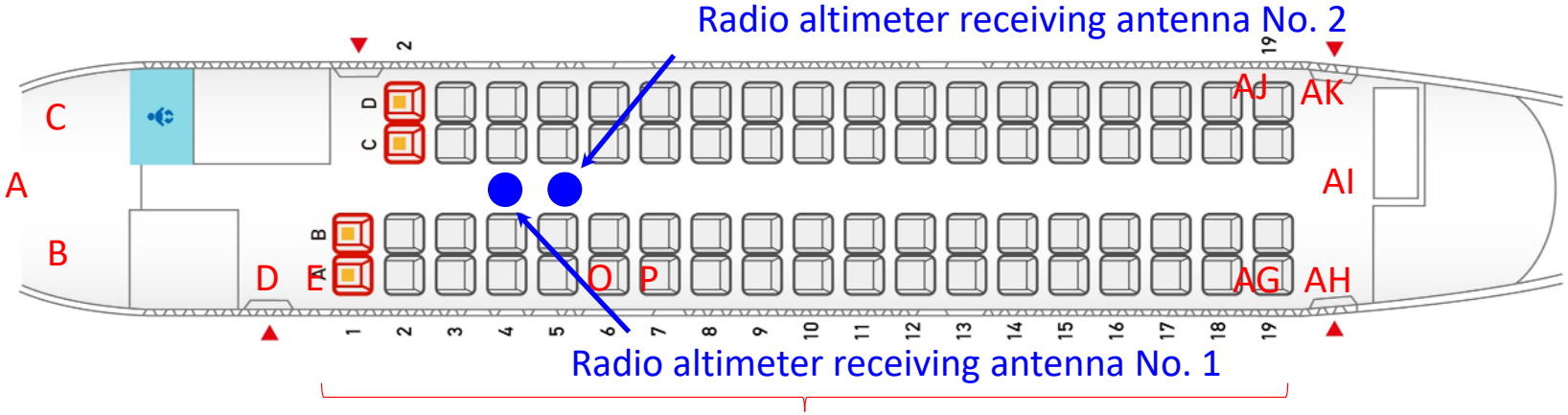
Location of transmitting and receiving antenna of radio altimeter



DHC8-Q400: Location of transmitting antenna and results

Location of transmitting antenna inside cabin

- Inside the cabin, there are 37 transmitting antenna locations. Common locations for these antennas include every window, the cockpit, and the rear door.
- The minimum IPLs for RA No. 1 and RA No. 2, recorded at 69.2 and 68.7 dB, are observed at locations P (12th window) and O (11th window), respectively.



The minimum IPL values for RA No. 1 and No. 2 are 69.2 dB and 68.7 dB, respectively.

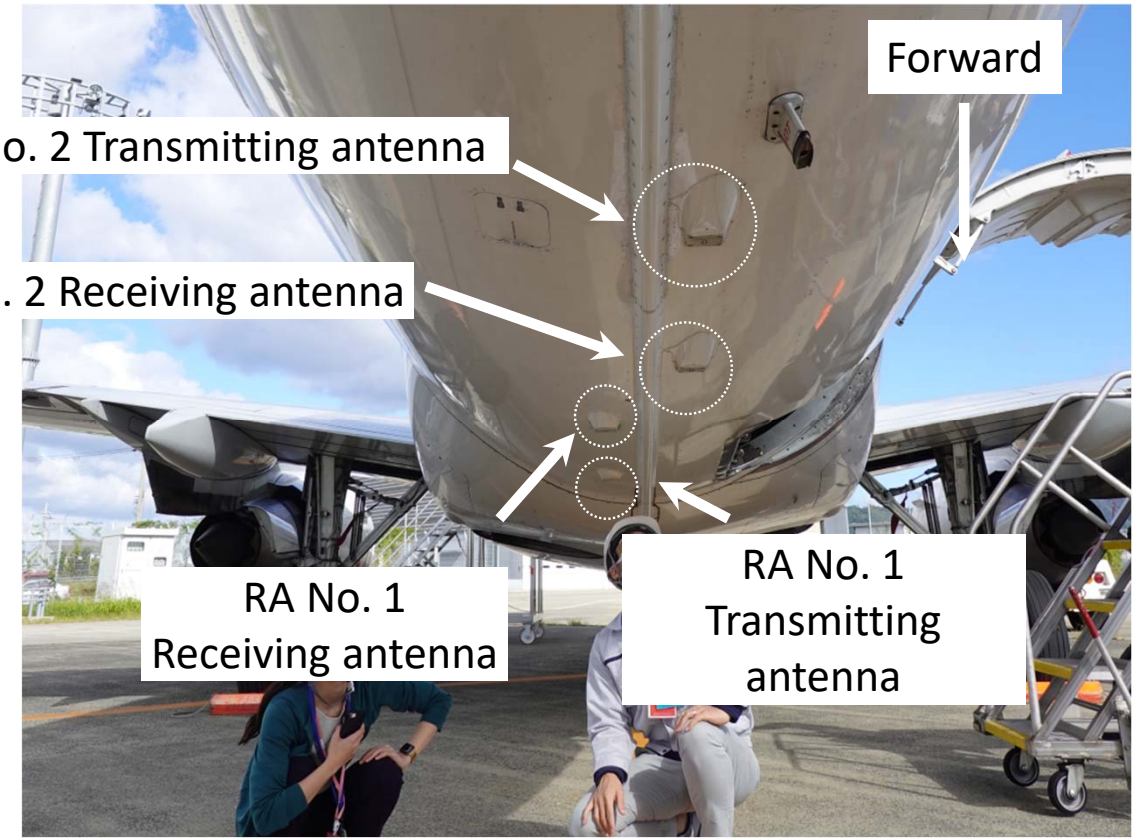
E170

Embraer ERJ170-100

measured Oct. 2022

E170: Radio altimeter antenna

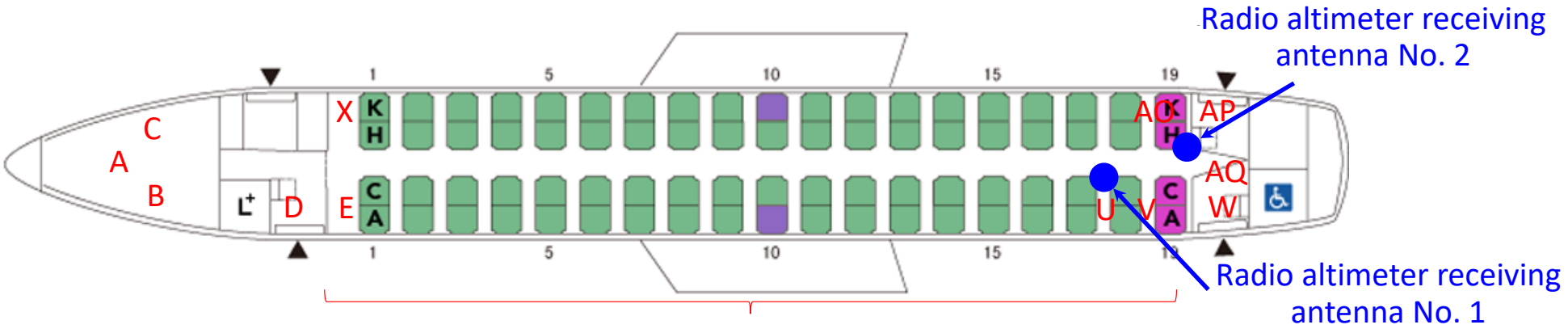
Location of transmitting and receiving antenna of radio altimeter



E170: Location of transmitting antenna and results

Location of transmitting antenna inside cabin

- The cabin contains 43 transmitting antenna locations. The RA antennas are not located centrally on the fuselage: antennas for RA No. 1 lean to the left, while those for RA No. 2 lean to the right.
- The lowest IPLs for RA No. 1 and RA No. 2, at 70.9 dB and 79.0 dB are observed at location U (17th window, left side) and location AO (18th window, right side), respectively.



The minimum IPL values for RA No. 1 and No. 2 are 70.9 dB and 79.0 dB, respectively.

Discussions

Estimation of EMI occurrence

In-band EMI estimation: non-intentional radiated (NIRA) emissions

Comparison of IPL target values described in DO-307B

- The measured IPL values are compared with the IPL target values described in the DO-307B (Appendix C, Table C-5) of NIRA conditions. The target IPL values are selected based on the RA usage category and the number of seats.
- Helicopters have a lower minimum IPL value of around 50 dB, leaving a margin of around 5 dB. On the other hand, fixed-wing aircraft have a minimum IPL value of around 70 dB, leaving a margin of more than 20 dB.

Aircraft/parameters	Target IPL values (dB) in DO-307B	Measured minimum IPL（dB）	Margin (dB)
BK117C-2	44 (Category 3, small aircraft)	49.2	5.2
B300	44 (Category 2, small aircraft)	67.5	23.5
DHC8-Q400	46 (Category 2, large aircraft)	68.7	22.7
E170	46 (Category 2, large aircraft)	70.9	24.9

For the in-band EMI, helicopters have the lowest margin, but there is still positive margin.

Out-band EMI estimation: intentional radiated (IRA) emissions

Comparison of IPL target values described in DO-307B

- The measured IPL values are compared with the IPL target values described in the DO-307B (Appendix D, Table D-1) of IRA conditions.
- The margin for helicopters and the fixed-wing aircraft are approximately -60 dB and -40 dB, respectively, which is a significant negative margin. This is because the target IPL is based on the RA, which is the most susceptible to interference, and the margin may increase if the interference characteristics of the actual RA installed.

Aircraft/parameters	Target IPL values (dB) in DO-307B	Measured minimum IPL（dB）	Margin (dB)
BK117C-2	106 (Category 3, small aircraft)	49.2	-56.8
B300	106 (Category 2, small aircraft)	67.5	-38.5
DHC8-Q400	106 (Category 2, large aircraft)	68.7	-37.3
E170	106 (Category 2, large aircraft)	70.9	-35.1

The target IPL value of DO-307B is based on the US frequency conditions with a 200 MHz guard band. In Japan, where there is a 100 MHz guard band, conditions are more susceptible to interference, because of this, a larger margin is may required than those of described in DO-307B.

Conclusions

Investigation of on-board EMC issues in current radio environments

Regarding on-board EMC issues, in addition to existing systems such as GNSS, new interference concerns have arisen with the expansion of radio wave use, such as Sub-6 band 5G mobile communications systems.

As an example, this presentation introduced an evaluation of the EMI assessment of RAs due to on-board Sub-6 band 5G devices, which is newly introduced in DO-307B/ED-239A.

For the aircrafts measured in this presentation, while the interference margin for in-band interference was positive, for RAs without Sub-6 5G retrofit modification, the margin for out-of-band interference is significantly negative.

Future works

- Evaluations will be conducted using target IPLs based on the specific radio altimeters installed on each aircraft, rather than the generic target IPL values described in DO-307B.

Thank You

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