Evaluation of a Low-Cost ADS-B Receiver as a Tool for Investigating Air-Ground Propagation

Junichi Naganawa, Hiromi Miyazaki

Electronic Navigation Research Institute (ENRI),

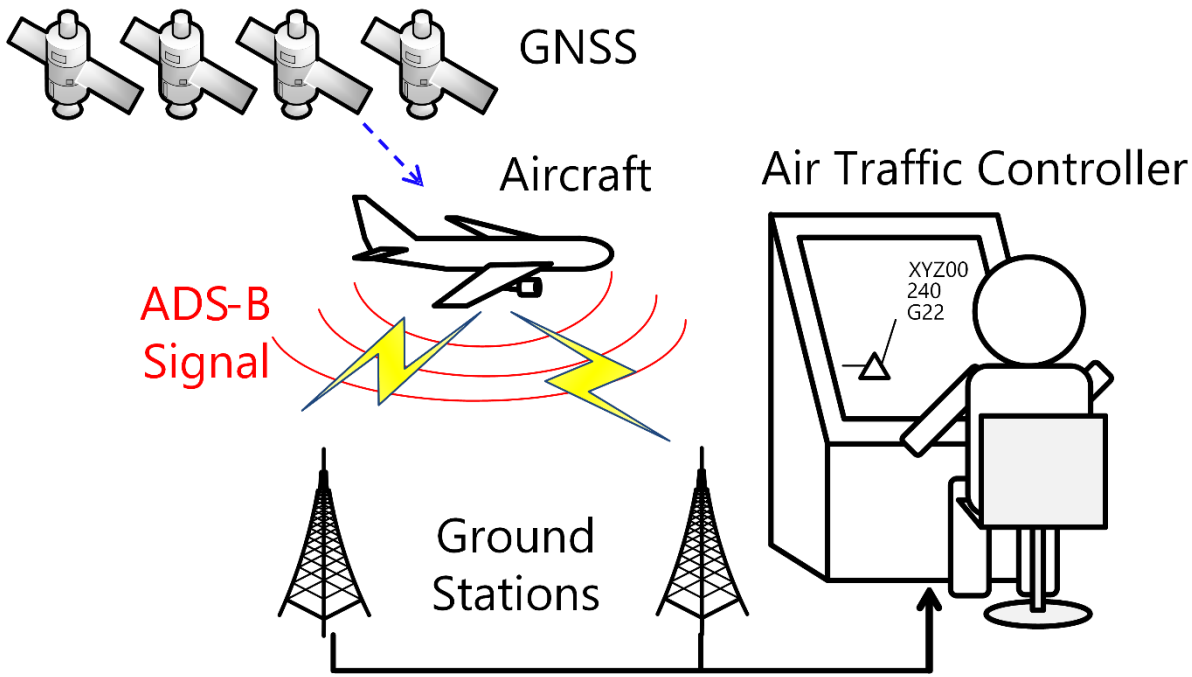
Tokyo, Japan,

URSI GASS 2020

Introduction

ADS-B is a new means of aeronautical surveillance.

Aircraft periodically sends the signal called *squitter*, which contains airborne position, velocity, and identification.

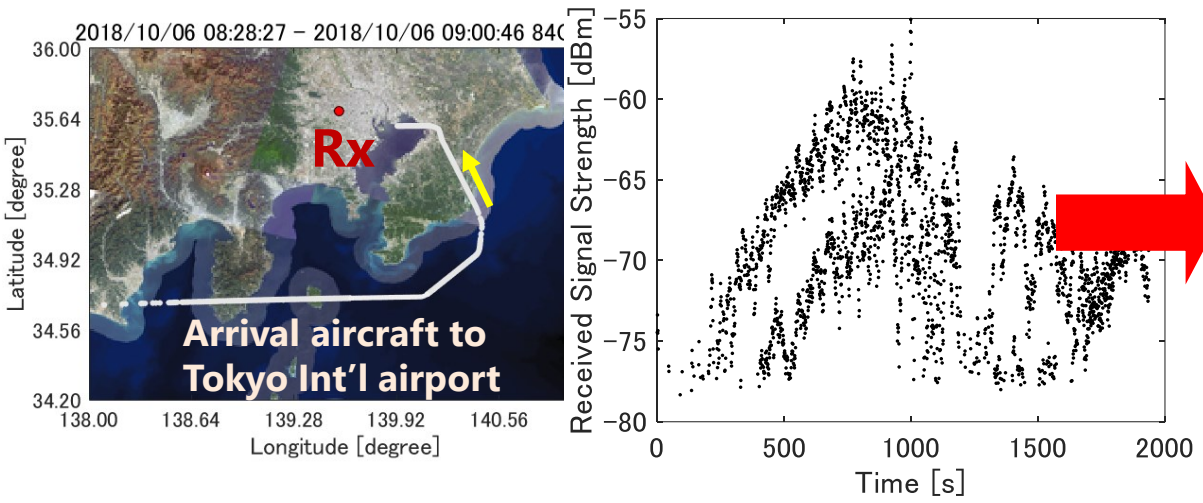


Introduction

ADS-B allows us to get massive aeronautical data easily.

We have been proposing measurement of opportunistic ADS-B signals as a propagation research methodology.

Example data



What we can do with the ADS-B signal:

- Model verification [6]
- Statistical modeling [7]

[6] J. Naganawa, et al,``Measurements of Opportunistic Aircraft Signals and Verification of a Propagation Prediction Tool in Mountainous Region," Proc. 14th Eur. Conf. Antennas Propag (EuCAP),Mar 2020.

[7] J. Naganawa and H. Miyazaki, ``Opportunistic-Target-Measurement-Based Narrowband Statistical Modeling of Civil Aviation Surveillance Signal at 1090 MHz,'' *IEEE Trans. Antennas & Propag.*, Vol. 68, No. 3, Mar 2020.

Purpose of this work

Performance of a low-cost commercial receiver as a measurement tool was evaluated, aiming at making propagation research more affordable.

Performance measures

- The accuracy of RSS (received signal strength)
- The number of signals (measure of reception performance)

Receiver under test (RUT)

- Radarcape (→)

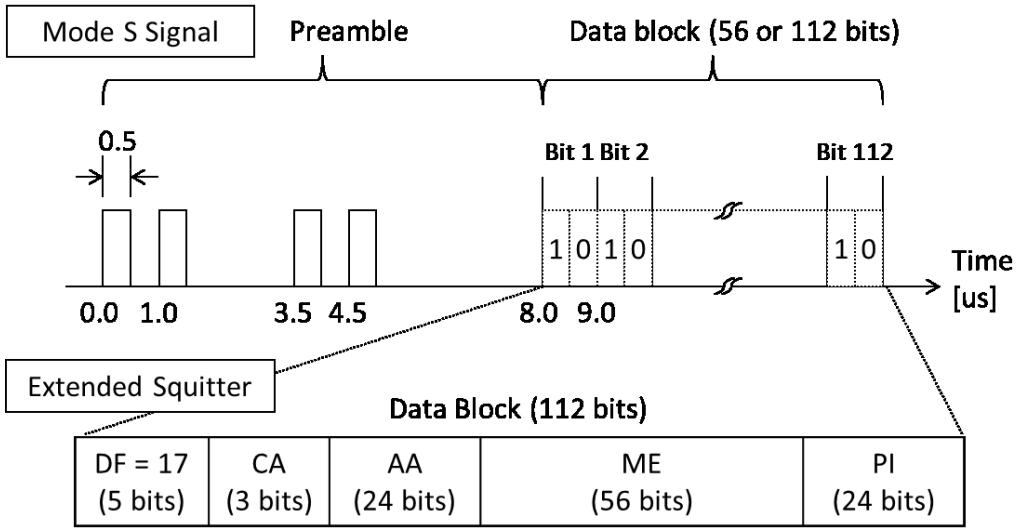
Reference receiver

- In-house receiver developed by USRP

Measurement

ADS-B Introduction

Specification	
Frequency	1090 MHz
Modulation	Pulse Position Modulation
Pulse width	0.5 usec
Frame length	112 bit



DF: Downlink Format
CA: Capability
AA: Address Announced
ME: Message, Extended Squitter
PI: Parity/Interrogator Identifier

Useful information

- Aircraft address (Mode S Address)
- Position (latitude, longitude, altitude)
- Velocity, call signs, .etc

Transmission rate

- Position, Velocity: 2 transmissions / sec

Receivers

Receivers under test (RUT)

- Radarcape
  with a record PC

Reference receiver

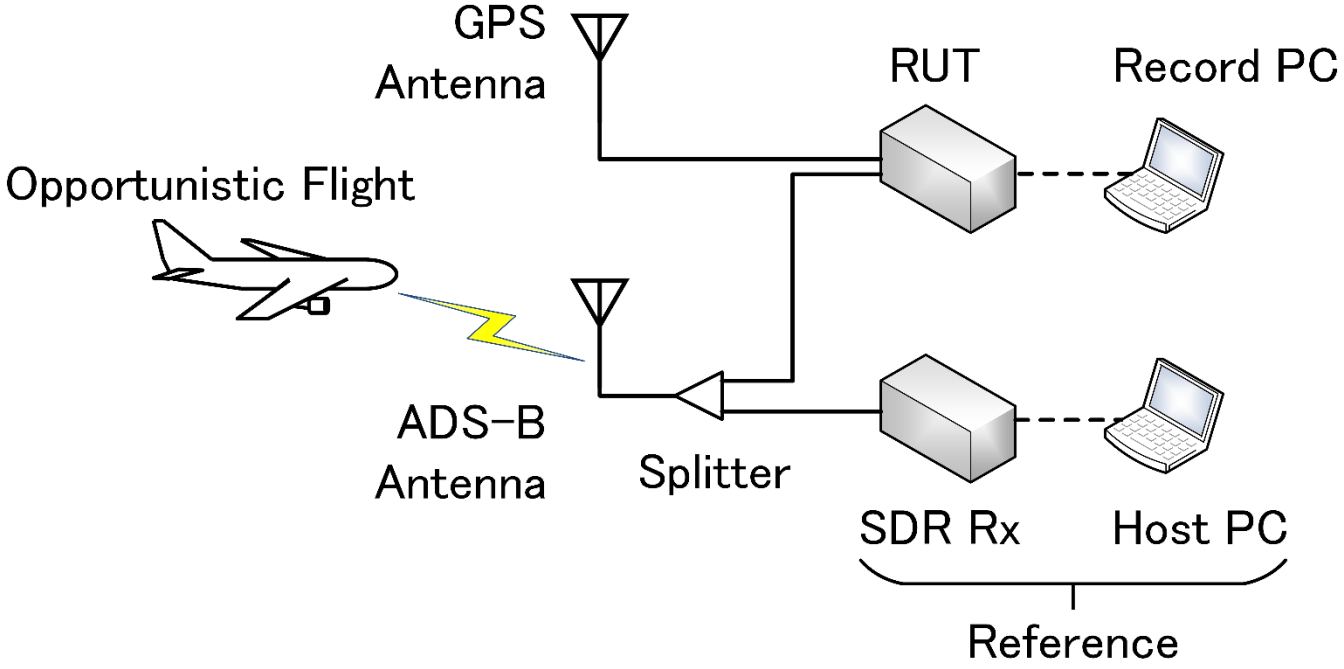
- In-house receiver developed by USRP 2901
  with a host PC, Rb oscillator (SRS FS 725), and MATLAB.

USRP

SRS FS 725

Host PC (left) Record PC (right)

Setup



ADS-B Antenna

- The ADS-B antenna connected to RUT and the reference via a splitter
- The detection threshold of -80 dBm for the reference
- Measurement period of 90 minute
- TCP packet recorded by the record PC
- The host PC recorded the RF signal and demodulated/decoded the signal offline

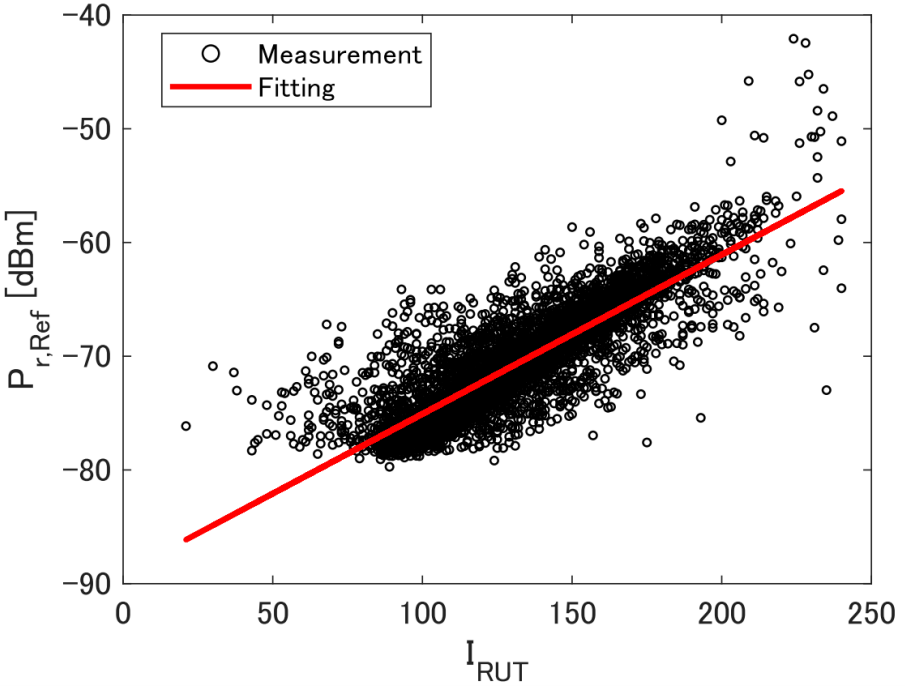
Preprocessing: dBm conversion

One-byte RSS value of RUT (integer) was converted to dBm:

$$P_{r,\mathrm{RUT}} = a \cdot I_{r,\mathrm{RUT}} + b.$$

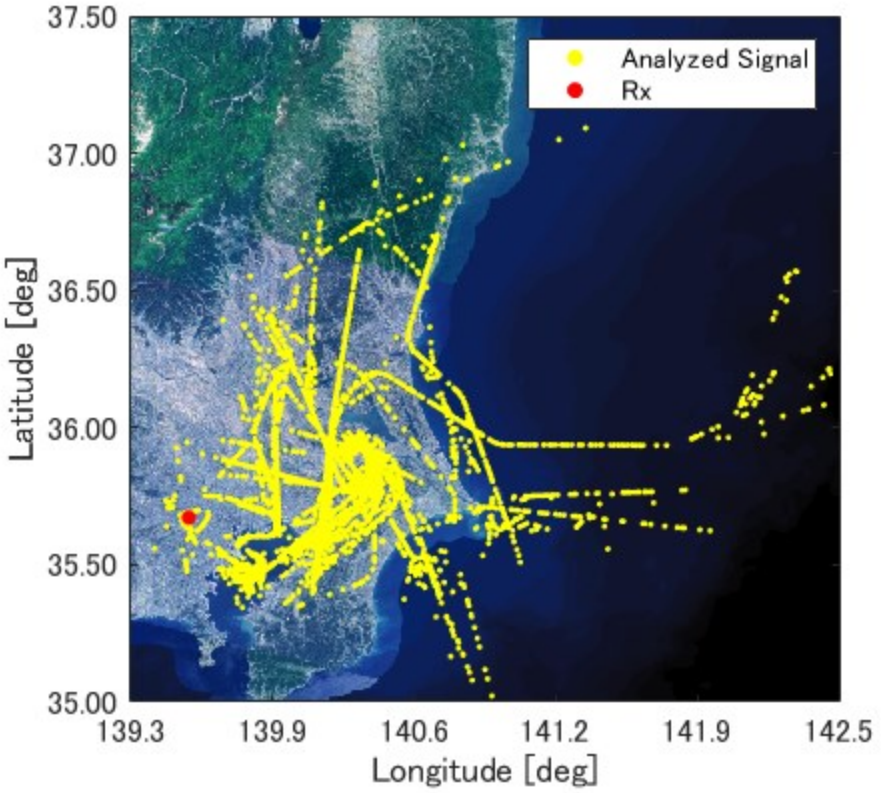
- $I_{r,RUT}$: the integer RSS, $P_{r,RUT}$: RSS in dBm, a, b: coefficients

- The coefficients were obtained by the least-square fiting using the RSS measurement result by the reference receiver, $P_{r,Ref}$



Measured signal

5823 signals were obtained



The map data is obtained from https://maps.gsi.go.jp/development/ichiran.html, accessed on 20 January 2020.
Data source: Landsat8 Image (GSI, TSIC, GEO Grid/AIST), Landsat8 Image (courtesy of the U.S. Geological Survey), Bathymetric chart: GEBCO.

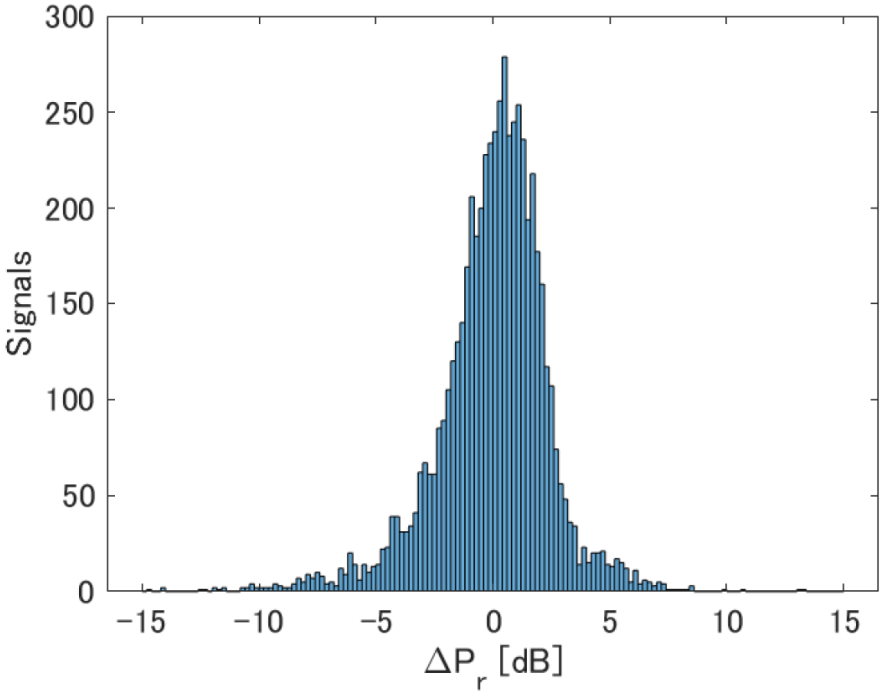
Evaluation

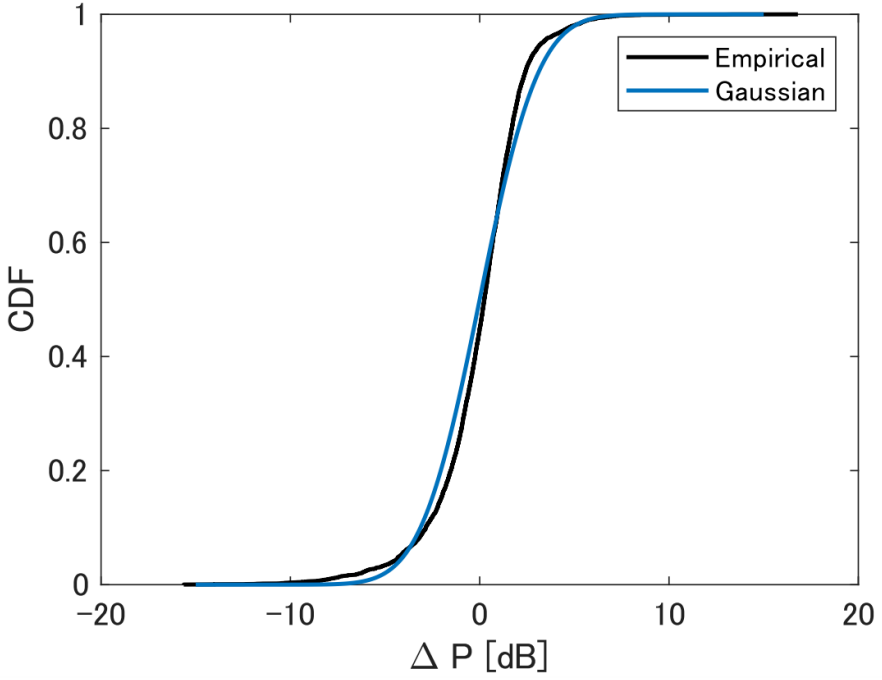
RSS measurement accuracy

Accuracy measure: dB difference in RSS:

$$\Delta P_r = P_{r,\mathrm{RUT}} - P_{r,\mathrm{Ref}}.$$

- Mean 0.0 dB
- Standard deviation 2.44 dB





RSS measurement accuracy

Interpretation:

- Mean 0.0 dB

  … Large-scale effect such as path loss can be measured after collecting much sample.

- Standard deviation 2.44 dB

  … Instantaneous effects such as fading might be difficult to be measured.

  … Terrain shadowing could be measurable (but perhaps as a signal loss).

Reception performance

Reception performance measure:
the number of correctly decoded ADS-B signals

- RUT: $N_{RUT} = 19{,}912$
- Reference receiver $N_{Ref} = 114{,}370$

- Degraded performance is due to co-channel interference
- This is the limitation in sampling interval in propagation measurement

Bench-test

Bench-test Purpose & Setup

Bench-test provides result supporting the evaluation:

- Verification of the dBm conversion
- Use of the in-house receiver as the reference
- The reason of the degraded reception performance

Setup:

- Instead of the ADS-B antenna, an ADS-B signal generator implemented by USRP was used
- Signals of constant power and constant rate (20 signal per sec) were generated and measured

Bench-test result (1)

Verification of the dBm conversion

- The integer RSS: $I_{r,RUT}$ = 135.87

  → After conversion, $P_{r,RUT} = -70.06$ dBm

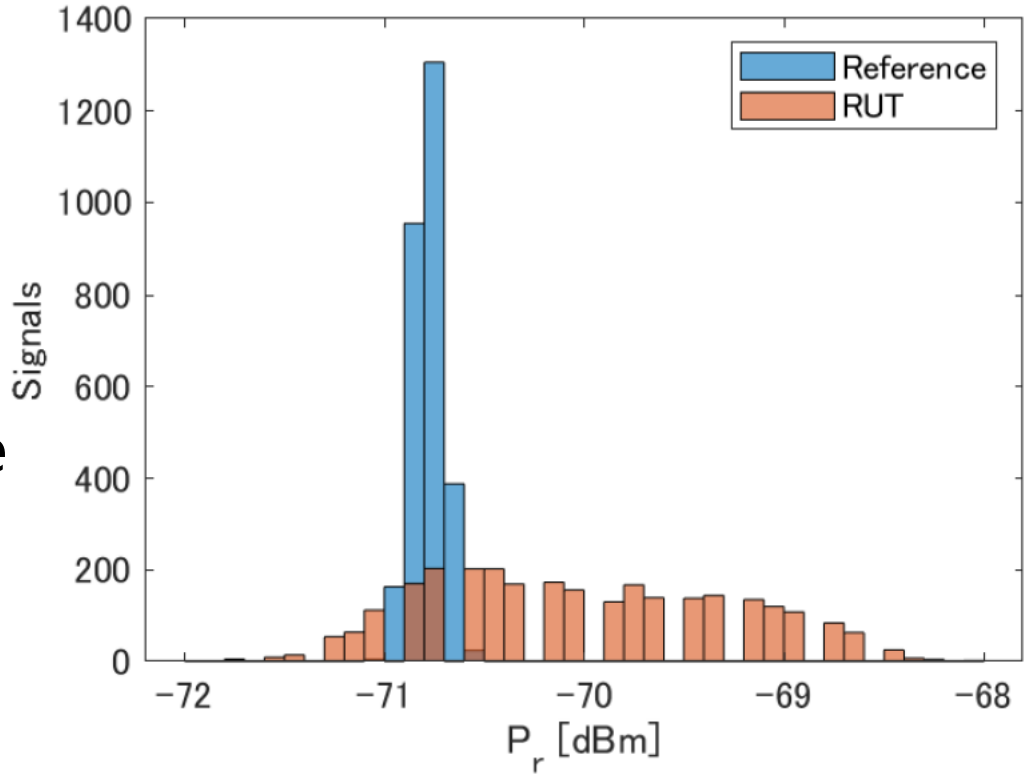
- The RSS by reference receiver: $P_{r,Ref} = -70.78$ dBm
- Acceptable agreement was obtained

Bench-test result (2)

Use of the in-house receiver as the reference

- The standard deviation
  RUT: 1.49 dB
  Reference: 0.0761 dB

- Stable RSS measure-ment by the reference justifies its use as a reference



Bench-test result (3)

The reason of the degraded reception performance

- the number of correctly decoded ADS-B signals (10min)

	Bench Test (10 min)	Real Environment (90 min)
RUT	2,728	19,912
Reference	2,838	11,4370

Degraded

- No degradation was observed in the bench-test
- Reason of the performance degradation in the real environment
  1. Multipath … unlikely with an open-air channel and an antenna of a sharp-cut off pattern
  2. Co-channel interference

Conclusion

Performance of a ADS-B lowcost commercial receiver as a measurement tool was evaluated, aiming at making propagation research more affordable.

- The difference in RSS was non-biased but had a spread with a standard deviation of 2.44 dB.
  … This may limits the application into path loss or terrain shadowing.
- The degradation of reception performance was also observed in the actual environment, which limits the sampling interval.

Future work:

- Different models of low-cost receivers will be evaluated, e.g. USB dongle type.

This work was supported by the Japan Society for the Promotion of Science (JSPS) KAKENHI under Grant 17K14688.