Investigation of DME Multipath Propagation

Mitsuhiro Maruhashi
Flight Inspector
Japan Civil Aviation Bureau
Tokoname-City, Aichi, Japan
Fax: +81 569 381350
E-mail: maruhashi-m46ce@mlit.go.jp

ABSTRACT

DME unlocks were observed in the specific quadrant of a VOR/DME station which was under its special flight inspection. The cause of these unlocks were DME multipath propagation by the influence of an airport terminal building. Although some in-flight inspection can be omitted by adopting the result of radio wave propagation simulation which uses high-precision terrain database, we found that these could not perfectly simulate terrain and buildings, and could not accurately capture multipath propagation. In this report, we describe the cause of DME multipath propagation and the RF capture technology which is used at identify the cause its self. By using AFIS, Flight Inspectors are able to realize that the signal disturbances are caused by multipath propagation, on the other hand, it is highly difficult to identify the cause of that multipath unless using RF signal capture technology to analyze the entire signals.

DME/DME navigation is expected as a short-term response of APNT (Alternate Position Navigation and Timing), the use of DMEs are possible to continue the safe and efficient aircraft operations in case of the loss of GNSS. Therefore, identifying the multipath propagation which affects the DME signals is a significant issue.

INTRODUCTION

GNSS is widely used in RNAV, but sometimes it cannot be used due to interference or jamming. Construction and implementation of the alternative positioning method, which is called APNT (Alternate Position Navigation and Timing), is one of the issues at ICAO to maintain safety and efficiency of aircraft control in case of GNSS signal loss. It is being studied that DME/DME positioning is applied to RNP air routes navigation and standardization has started in EUROCAE WG-107. DME ground facilities require ability called "integrity" which informs anomaly to pilots in case that the ground facilities provide undesired position information. Multipath propagation is one of the integrity threats, and it is an urgent issue to clarify the mechanism of its occurrence.

In January to February 2021 a special flight inspection was conducted due to the renewal of the VOR / DME located at Chubu Centrair International Airport in Japan. At that time, DME unlocks were observed in the specific quadrant. The cause was multipath propagation by the terminal building. The RF capture technology that used to identify its cause may help clarify the mechanism of multipath generation.

This paper describes the case of DME unlocks and the RF capture technology.

SUMMARY OF CASE

Location of Chubu VOR/DME

Chubu VOR/DME is located at Chubu Centrair International Airport, Japan. Figure 1 shows a map of Japan, and Figure 2 shows an aerial view of Chubu Centrair International Airport.

Figure 1. Map of JAPAN

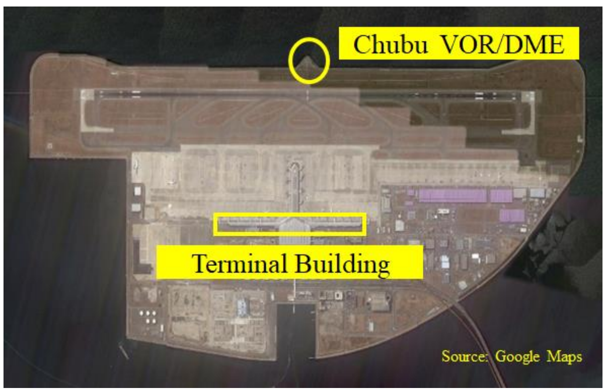

Figure 2. Chubu Centrair International Airport

About the Case

DME unlocks were observed in the west side of orbit flight when the VOR/DME ground facility was renewed. Figure 3 shows the flight route of 15NM and 40NM orbit. The red lines show the part of DME unlocks.

DME unlocks were observed in the following areas.

・Orbit 15NM R240-R310 (5,500ft)

・Orbit 40NM R210-R250 (7,000ft)

R250-R290 (5,000ft)

R290-R350 (7,000ft)

All components including transmitter-receiver, antenna, cables, connectors, configured its DME ground station were inspected by specialists. However, no defect was found.

The Ministry of Internal Affairs and Communications investigated radio interference, but it was not detected. The past periodic flight inspection was satisfactory and no change has been made in the obstacle buildings around its DME ground station after that.

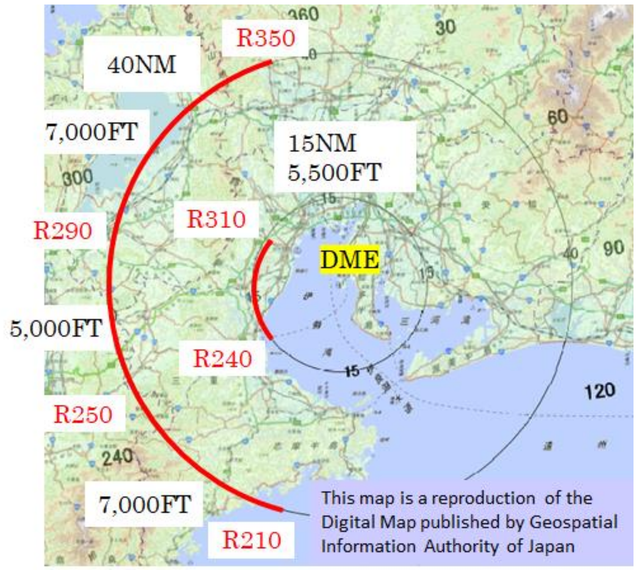

Figure 3. Flight Route

The Cause

As a result of the subsequent investigation, it was found that DME unlocks occurred because the reflected radio wave from the terminal building became stronger due to the change of the DME antenna specifications after the renewal.

Figure 4 shows the estimated reflection area that reflected by the terminal building. This area was approximately matched in the west quadrant where DME unlocks were observed.

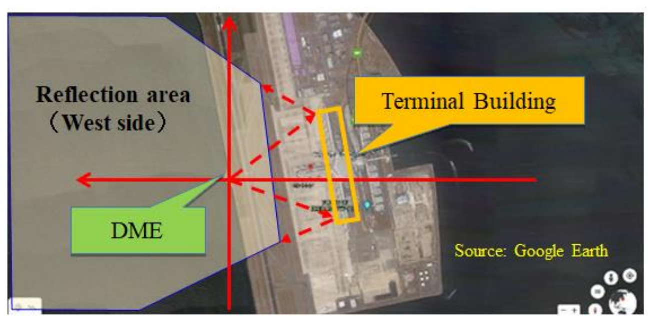

Figure 4. Estimated Reflection Area

The radiation peak angle of DME antenna had changed from 4.7 degrees to 2.8 degrees after the renewal of its DME ground station. Figure 5. shows the comparison chart of the DME Antenna Radiation Pattern before and after. The radiation RF level around 0 to 1.4 degrees, which is directly reflected by the terminal building, became stronger after the renewal. In addition, the radiation RF level (around 0 to -11 degrees), which is reflected on the ground and then reflected on the terminal building, also became stronger after the renewal. As a result, DME unlocks occurred.

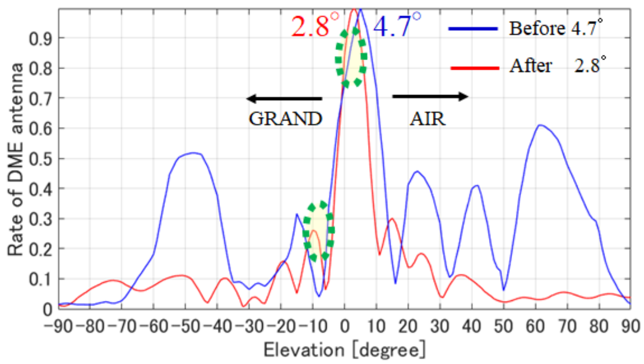

Figure 5. Comparison Chart of The DME Antenna Radiation Pattern

INVESTIGATION

Analysis

Figure 6 shows the flight inspection data of 15NM orbit flight after DME renewal. The magenta line shows the DME signal strength, and the blue line shows the DME range err. DME unlocks were observed between R240 and R310 and also, the signal strength was disturbed over a wide range.

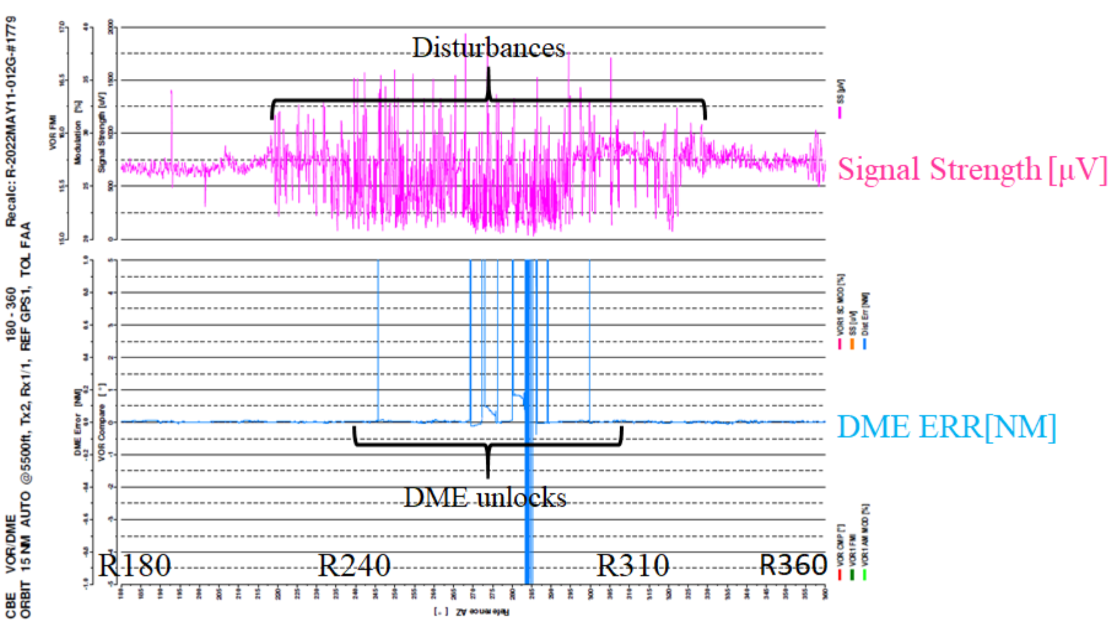

Figure 6. After DME Renewal

Figure 7 shows the flight inspection data of 15NM orbit flight before DME renewal. The DME range was satisfactory, but there were some disturbances in the signal strength.

This means that DME unlocks were observed only after DME renewal. On the other hand, the disturbances in signal strength were found both before and after.

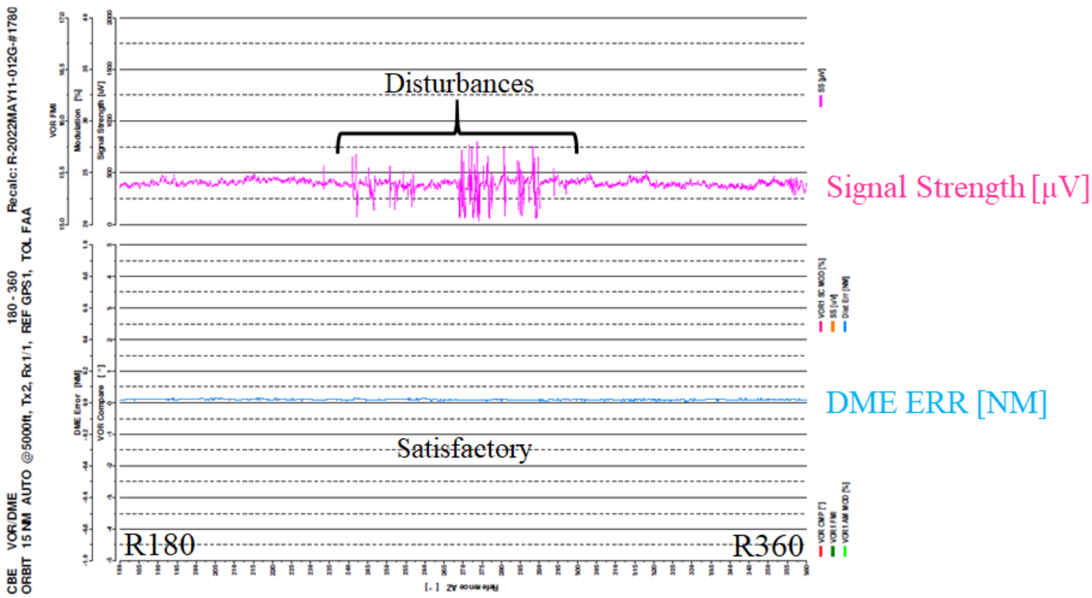

Figure 7. Before DME Renewal

Investigation of Flight

RF capture device was equipped on the aircraft and investigation of flight of 15NM orbit was conducted. As a feature of RF capture technology, this device can record an RF signal in the fields and the recorded data can be taken out. Then, they can be reproduced in factories or laboratories. Cessna's CJ4 was used for the flight inspection aircraft as well as a Collins Co., Ltd. model DME-4000 was used as a receiver.

Figure 8. Aircraft and Equipment

DME Reply Signal

Figure 9 shows the flow of RF data's reproduction. By selecting the RF recording data on the control PC and pressing the play button, the RF capture outputs the RF signal. This signal can be analyzed by the DME pulse Analyzer.

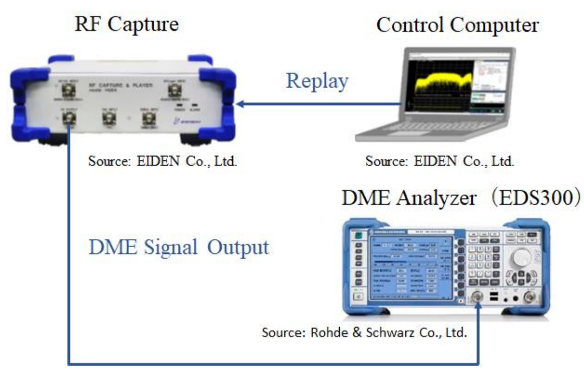

Figure 9. RF Signal Reproduction Flow

Figure 10 shows the analysis result by the DME pulse analyzer of RF signal recorded during investigation flight. It was observed that multipath was mixed between the 12μsec direct pulse pair. The multipath was received with an intensity of about 80% of the direct pulse pair, and the reply signal could not be identified on the aircraft under this condition. From this analysis, it was found that the DME signal was strongly reflected by something, which caused DME unlocks. The multipath had a delay of 6 to 7μsec from the direct pulse pair. This delay is equivalent to 1,800 to 2,100 m in distance conversion.

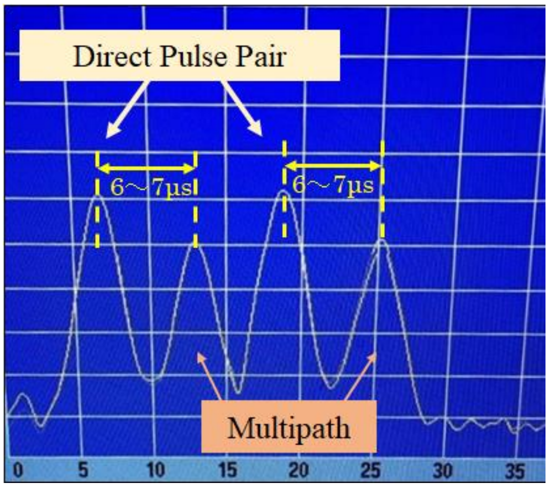

Figure 10. DME Reply Signal

Fig11 shows that the distance between the DME and the terminal building is about 1,000m, which means the round-trip distance is about 2,000m. As this number matched the conversion distance of 6 to 7μsec, it was highly possible that the terminal building was the cause of multipath.

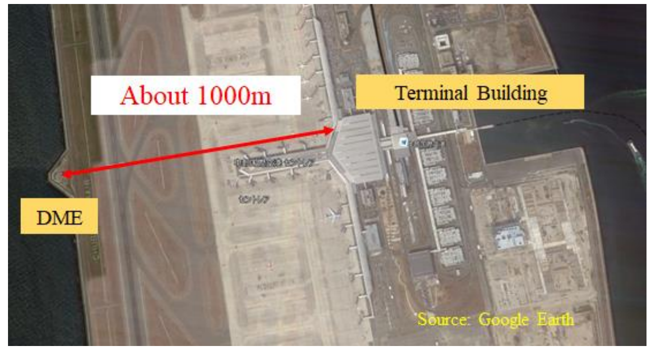

Figure 11. Distance between DME ground station and terminal building

DME Antenna Replacement

Because there was a high possibility of multipath by the terminal building, DME antenna was replaced with the one which has suppressed the radiation pattern on the east side of the DME ground station. As a method of suppressing the radiation pattern, Metallic (copper) foil tape was attached to the inside of the radome to make the radiation pattern "Cardioid". Figure 12 shows the flight inspection data of 15NM orbit after the antenna replacement. The signal strength remained some disturbed, but the DME range result was satisfactory. From this result, it was confirmed that the multipath propagation reflected by the terminal building was the cause of DME unlocks.

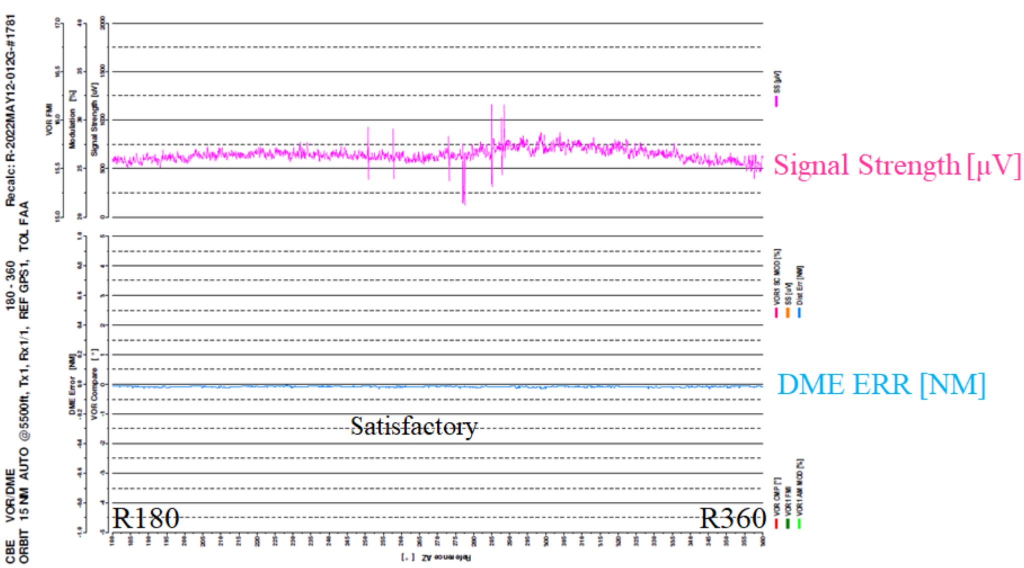

Figure 12. After DME Antenna Replacement

Since the radiation pattern in the east side was suppressed, it was necessary to inspect the performance in that side. Figure 13 shows flight inspection data of 15NM orbit in the east side. The signal strength was about half of that before the antenna replacement, but the DME range was satisfactory.

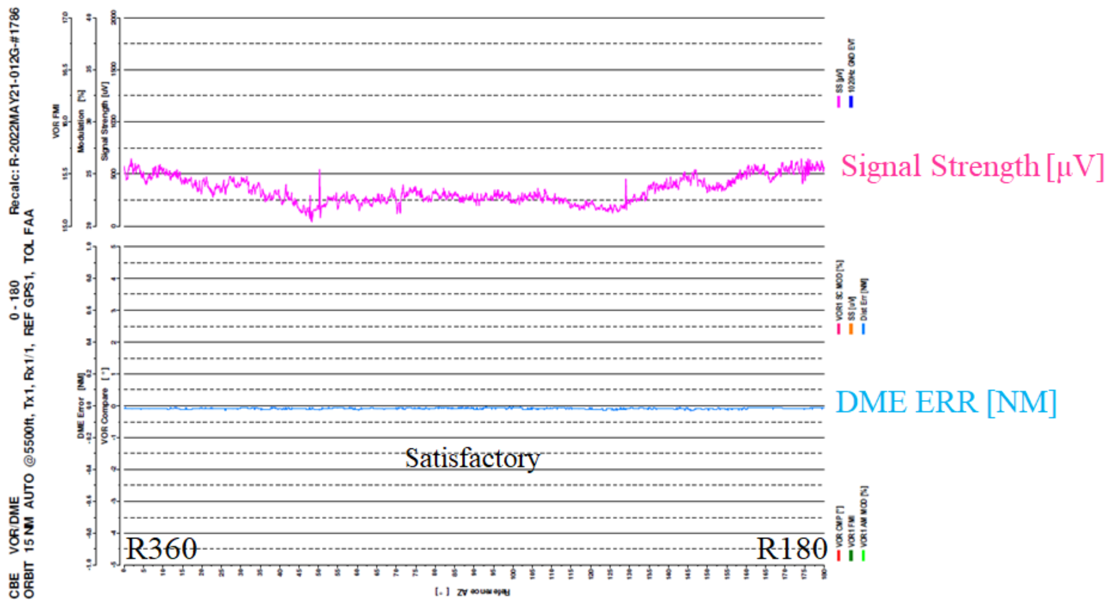

Figure 13. East Side of Orbit Flight

CONCLUSIONS

At present, the DME antenna is being operated with the one that raises the radiation peak angle from 2.8 to 4.8 degrees as well as that suppresses radiation pattern in the east side. Since the influence of multipath differs greatly depending on the antenna specifications, it is important to check the difference in the antenna specifications prior to commissioning and special flight inspection.

The RF capture device is effective in identifying the cause of multipath propagation. So, it can be an important device for future flight inspection operations. JCAB plans to introduce the RF capture device as a standard equipment for new flight inspection system in 2022.

Although some in-flight inspections can be omitted by adopting the result of radio wave propagation simulation, which uses a high-precision terrain database, we found that these could not perfectly simulate terrain and buildings and also could not accurately capture multipath propagation. Therefore, it is important to inspect by flying actually.

ACKNOWLEDGMENTS

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