The Summary of the Flight Inspection Data Management system

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BIOGRAPHY

Shunsuke Fujita was born in Tokyo in 1983. He studied radio engineering at the Aeronautical Safety College and assigned to several airport offices as an engineering specialist for Air Traffic Control. Since 2012, he has been working at Flight Inspection Division as a Flight Inspector.

ABSTRACT

Japan Civil Aviation Bureau (JCAB) is developing a Flight Inspection Data Management system (FIDM) which accumulates enormous electronic data extracted from Automatic Flight Inspection System (AFIS) as a "BIG DATA" in order to promote more effective use of those data. The outputted data from AFIS includes aircraft position, attitude and other information (using satellite number etc...) in addition to the status of radio waves emitted from radio navigation aids such as VOR, DME and TACAN. FIDM accumulates flight inspection data and environmental data (e.g. AIP, e-TOD and topographic data) into each airspace box which is created by dividing Japanese airspace three-dimensionally. Above the "BIG DATA" is intended to be used for an improvement of efficiency of the operation of Flight Inspection and of the designing flight procedures or even for various research institutes.

INTRODUCTION

Recently, the number of international passengers visiting Japan has increased by 40% compared to five years ago with the growth of foreign tourists. It is expected that foreign airliners flying into Japan will increase more due to the Tokyo Olympics and Paralympic games held in 2020. In order to deal with those demands, we intend to utilize the flight inspection data which have been acquired to reduce our mission flights by using this new system. JCAB is currently planning to introduce FIDM for that purpose and proceeding with its detail design.

At the moment, flight inspection data (including plenty of signals from radio navigation aids and aircraft position, attitude etc.) are saved individually, but FIDM is going to manage and store these data as "BIG DATA". Herewith, it will be possible to operate flight inspection more efficiently and be able to provide flight inspection data to relevant organizations.

In this paper, the summary and main functions of FIDM are described.

SUMMARY OF FIDM

FIDM structure

FIDM is composed of an operation processing unit, a data management unit, a web server, laptop computers and a network. All flight inspection data are stored in the data management unit, and calculated by the operation processing unit. Since use while on a business trip is assumed, those functions will be available from remote locations by using a laptop computer with VPN connection. In addition, external organizations such as flight procedure designers can use FIDM functions through a web server. It will also be possible to provide flight inspection data to external organizations as necessary.

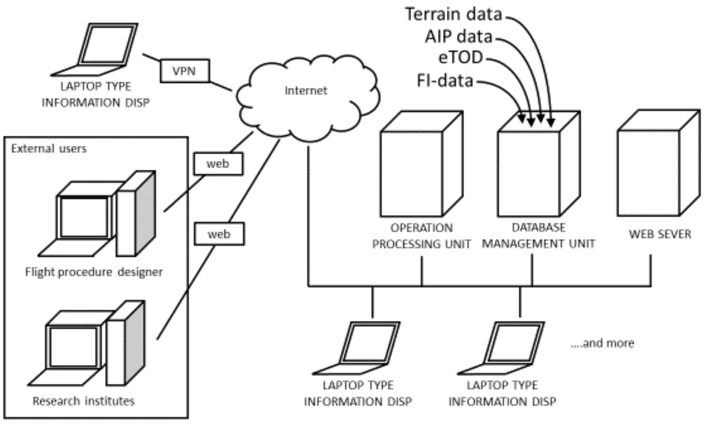

Fig 1. FIDM structure

In FIDM, the result of each functions are displayed on the following basic display configuration. A part from flight inspection data, various data are displayed either 2-dimensionaly or 3-dimensionaly depending on user's purposes. Next, each data used in this display will be explained.

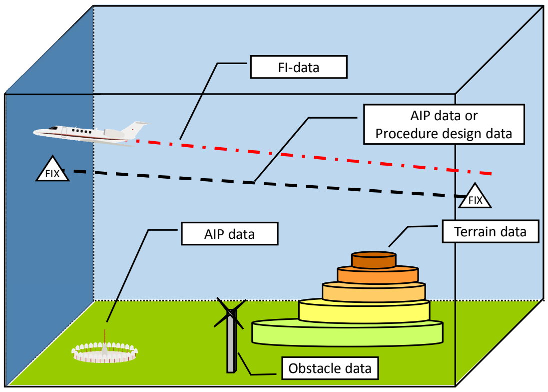

Fig 2. The data used for display in FIDM

・Flight inspection data

The data outputted from AFIS in CSV format. With acquisition of the new flight inspection system introduced between 2016 and 2018, it became possible to output those data easily during mission flight. They are outputted on 10 Hz, and we refer to each data as a slot. One slot contains signals exceeding 100 items such as signal conditions from radio navigation aids and aircraft attitude information.

- GPS information: Latitude /Longitude /Time /Number of Satellites /etc.
- Aircraft information: Altitude /Speed /Heading /Pitch /Roll /Yaw /etc.
- Signals from ground navigation facilities: Deviation/Signal strength/modulation /etc.

These data are outputted in a specific format, converted to csv format by a dedicated converter called FANTAx, and used as flight inspection data.

Table 1. Sample of flight inspection data

	eqmAHRS:: MagHeading	eqmAHRS:: Pitch	eqmDME1:: DMECh1Distance	eqmDME1:: DMECh1Freq	eqmDME1:: DMECh1Ident	eqmDME1:: DMECh1SS_dBm
TIMESLOT	(Double)	(Double)	(Double)	(Double)	(Text)	(Double)
61075	261.6833	1.082793	14.1875	116.65	HCE	-51.2537
61076	261.6888	1.082016	14.18424	116.65		-51.237
61077	261.6998	1.110974	14.17969	116.65	HCE	-51.2273
61078	261.6943	1.16312	14.17643	116.65		-51.2268
61079	261.6833	1.22557	14.16862	116.65	HCE	-51.2264
61080	261.6779	1.283056	14.16406	116.65		-51.2259

・AIP data

AIP data provided from Japan Aeronautical Information Service Center (Japan AISC) on AIXM 4.5 format. In FIDM, this data is registered by AIRAC 28-day cycle, and it is used as a database of radio navigation aids position and RNAV routes in coverage simulation and RNAV analysis functions. At present, AIP data is provided on the AIXM 4.5 format only. However, since it will be shifted to the AIXM 5.1 format in the future, we will prepare the way to import AIXM 5.1 format.

・Terrain data

5 m / 10 m mesh terrain data provided from Geospatial Information Authority of Japan on Digital Elevation Model (DEM). DEM contains elevation data and is used as environmental information for coverage simulation and RNAV analysis functions.

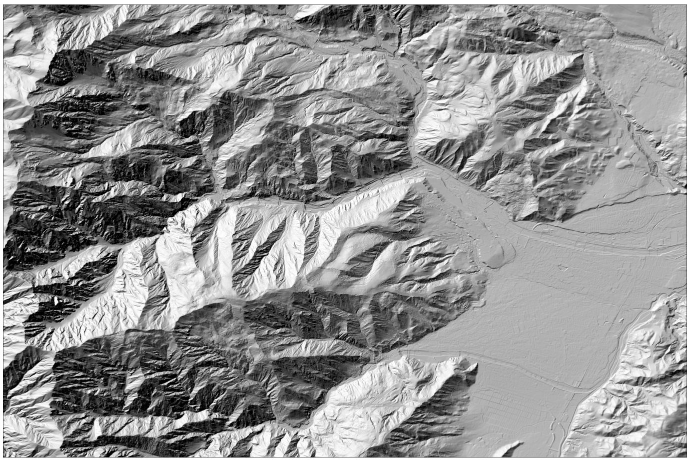

Fig 3. DEM data at Nagano prefecture in japan

・Obstacle data

Obstacle data provided by Japan AISC as eTOD (electric Terrain and Obstacle Data). This data contains obstacle information exceeding 12,000 points in Japan and is used as environmental information together with terrain data.

・Flight procedure design data

Flight procedure design data created by the flight procedure designer. By using this data, it is possible to analyze the flight procedures which have not been published yet, for the coverage simulation and RNAV analysis functions.

The way of accumulate flight inspection data

Our operation of flight inspection is based on business trips to inspect multiple radio navigation aids installed around the destination. The flight inspection data acquired during mission flights has already been started accumulating, we are planning to acquire those data while even on a navigation flight as well. Particularly, for coverage simulations described later, flight inspection data obtained at long distances from radio navigation aids will be beneficial. This is because the data acquired at a distance greater than a normal orbit radius (15 NM) can correct the coverage simulation over a wider range. All of these data is stored in FIDM and are registered in the database in an appropriate storage method to realize each function to be described later. Next, this storage method will be described.

Airspace box
Flight inspection data is stored in a box called "air space box" which divided sky above japan into a specific size.

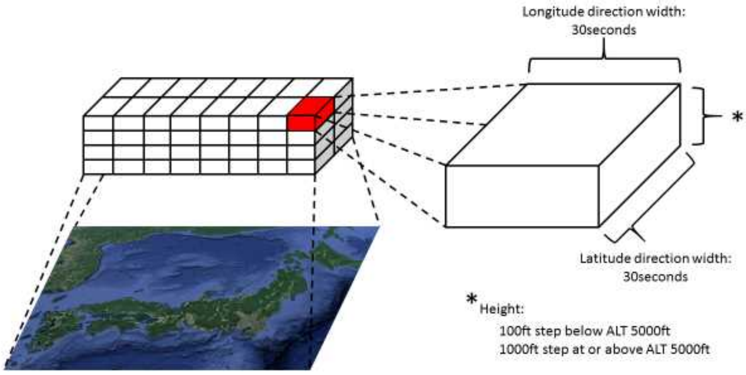

Fig 4. Airspace box

Airspace box size: 30 seconds × 30 seconds × height *
*100ft step below 5,000ft
1,000ft step at or above 5,000ft

All of flight inspection data outputted on 10 Hz is stored in the air space box arranged at the same position using position information contained in the slot. Multiple slots acquired during the same flight are stored in one airspace box, and unified to the average and treat as one slot.
The reason for adopting the concept of this airspace box is reduction of calculation load for the hardware. For example, flight inspection data is outputted on 10 Hz, flying at 240kt means, the slot is outputted every about 12 m. To carry out the coverage simulation, very high specification hardware is required to calculate all the slots every 12 m, which raises concern about increasing in manufacturing cost. For this reason, we adopted a method called "airspace box" to reduce the cost. By storing a group of slots into one air space box and averaging them, it is possible to reduce load for the hardware.
However, in adopting this method, it was necessary to determine an appropriate size of the air space box. In particular, when coverage simulation and RNAV analysis are performed, the analysis resolution is influenced by the size of the air space box. Therefore, we determined the size from the resolution required for the coverage simulation. The situation when we need the minimum resolution is 25NM coverage orbit which is carried out at the time of a commissioning inspection, and the airspace box size is set with 1 degree of the outer circumference of this orbit as minimum resolution. Therefore, the airspace box width is set to 25 NM × 2 × pi × 1/360 = 0.44 NM ≈ 30 seconds.

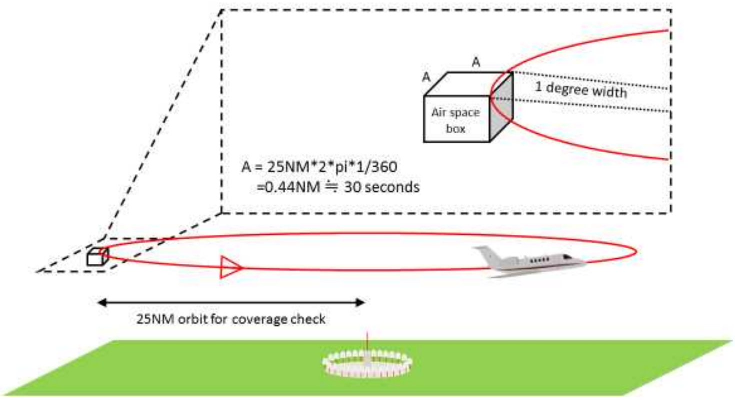

Fig 5. Reason for Airspace box size

For height of this box, we decided to divide it into two sizes at alt 5,000 ft. This is because the altitude unit in the flight procedure design in Japan is 100ft step below alt 5,000ft and 1,000ft step at or above alt 5,000ft.

MAIN FUNCTONS

Next, the main functions implemented in FIDM are described.

Coverage simulation

The purpose of the coverage simulation is "improving clarification and precision of its simulated coverage". Since Japan is a mountainous country, signals from VOR, DME and TACAN have a direct influence by those mountains and hard to reach to far distance. Under these circumstances, the radio wave reception status can be bad over some mountains, so sometimes new flight procedures become unable to be set because of the result of its flight inspection. In this case, a re-inspection flight has to be performed to search for a good area where radio wave reception status is within the allowable value. However by using FIDM’s coverage simulation function, it will be possible to improve the flight inspection efficiency by reducing the re-inspection flight by forecasting the simulated coverage.

This function consists of two steps. The first step is to calculate the theoretical coverage, the second one is to correct the theoretical coverage with flight inspection data acquired as the measured value, and improve the coverage range accuracy. Thus this simulation is calculated with the airspace box as the minimum unit.
Although general coverage simulation is based on various radio propagation theory, there is some differences between theoretical value and measured value depending on the geographical feature of japan in many cases. For this reason, we decided to make our coverage simulation by finding the coverage modeling calculation formula from the stored flight inspection data and perform corrected coverage simulation with the latest flight inspection data. With this corrected coverage simulation, its accuracy will be improved. On the other hand, if the flight inspection data is insufficient, it cannot be corrected completely and remains portion of theoretical coverage simulation, making it impossible to derive an accurate simulation. Therefore, it is important that the amount of flight inspection data is stored in FIDM sufficiently for this function.

However, in order to make corrections based on our flight inspection data, they must be acquired in an appropriate environment. Because it is known that the signal strength is varied depending on aircraft attitude, especially change of L-band signals such as DME / TACAN are more noticeable. Therefore, by using the pitch and roll information included in flight inspection data, only the data acquired in the following aircraft attitude is used for correction.

・PITCH ± 2.0 °
・ROLL ± 3.0 °

The reason why we set these values is that aircraft’s attitude at climbing / descending make signal strength become unstable, so we use flight inspection data on the level flight only where pitch stabilizes. However, pitch is constantly changing to maintain aircraft’s altitude even at a level flight, and we confirmed its pitch during the level flight ranges within ± 2.0 ° at maximum from past flight inspection. Therefore, we decided that the set value was to be ± 2.0 °. On the other hand, concerning the set value of roll, since our flight inspection data have been acquired up to radius of 10 NM at orbit flight, we decided the set value for roll was to be ± 3.0 °. This set value is the roll when flying 10NM orbit at 240kt. Those flight inspection data obtained in aircraft attitude that does not meet above conditions are not used in coverage simulation function.

Next, the outline of the correction process are explained.

In Fig 6, to perform modeling calculation using have been acquired flight inspection data and perform coverage simulation without correction. The maximum altitude of coverage is FL 450 which is our aircraft’s maximum operation altitude, and horizontal covering area is a line of minimum signal strength (VOR: -114dBw / m2 DME: -89dBw / m2 TACAN: -89dBw / m2).

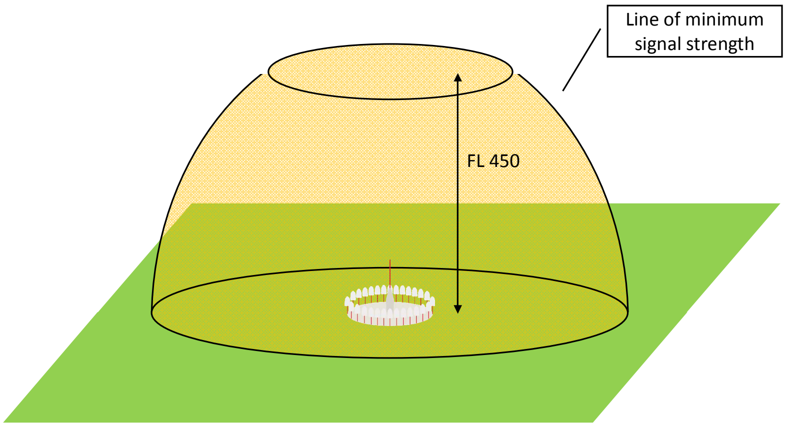

Fig 6. Coverage simulation with modeling calculation only

The result of the theoretical coverage simulation with modeling calculation formula is corrected by acquired flight inspection data. In this case, correction is performed 1degree in units. By using an orbit data, omnidirectional correction becomes available. Fortunately, since we have obtained orbit data for each radio navigation aids at commissioning or periodic inspection already, so it is possible to correct omnidirectionally for all radio navigation aids controlled by JCAB.
Correction is performed by comparing the theoretical value at the same point of the obtained flight inspection data and enlarging / reducing the coverage by the rate of change. Fig. 7 shows an image when the coverage is reduced because the signal strength in flight inspection data was lower than the theoretical value.

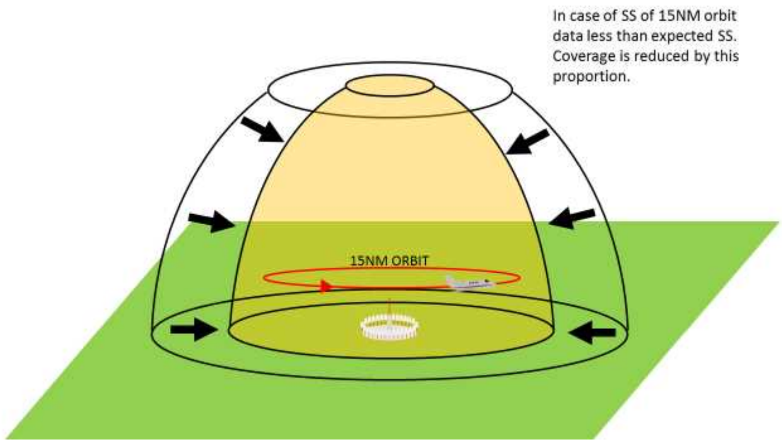

Fig 7. In case of coverage reduced

Fig 8 shows that the area assumed to be blind area from the terrain data, if it is determined that radio wave can be received from the cause of the radio wave diffraction, the coverage is assumed to be unaffected by terrain and the blind area is reduced.

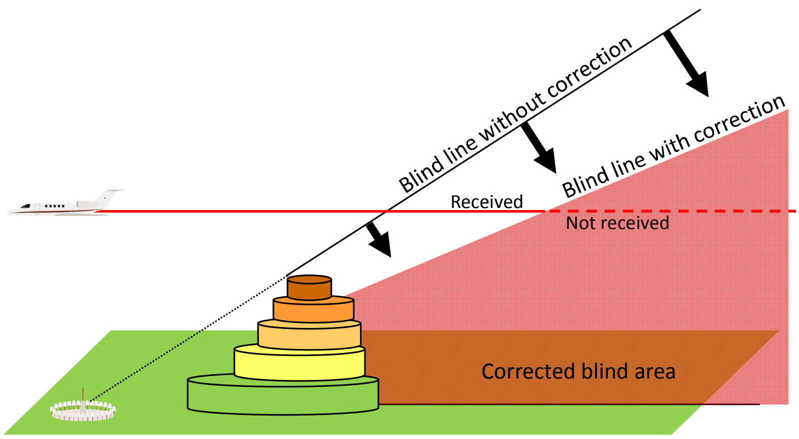

Fig 8. In case of blind area reduced

Above all, the coverage simulation is always performed with the latest data which is stored at every time when flight inspection flight is done.

RNAV analysis

This function is a RNAV analysis tool applying the above coverage simulation function. In Japan, it is common to set multiple RNAV routes within a narrow airspace and even if there are existing RNAV routes in the vicinity, all the new RNAV routes are subject to be inspected.

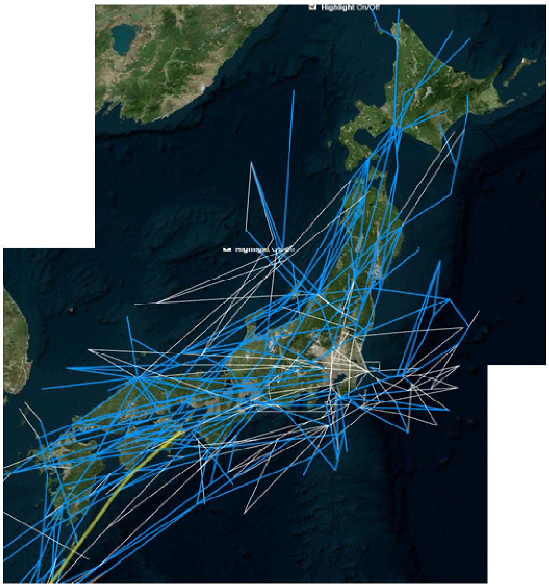

Fig 9. RNAV5 in JAPAN (Total 4600NM over)

Therefore, by conducting RNAV analysis using coverage simulation of multiple radio navigation aids, omission of partial inspection of RNAV routes are considered. However, it is needless to say that actual flight is absolutely necessary in cases when there is a doubt in the coverage simulation results or a areas where new RNAV routes are set for the first time.
In order to omit the partial actual flight for an inspection, it is important to analyze always using the coverage simulation corrected by the latest flight inspection data. By having a function to extract flight inspection data of optionally set date, it is possible to perform correction with only the latest flight inspection data without using an old one.

In the RNAV analysis, the RNAV routes created based on AIXM 4.5 or the flight procedure design file are analyzed, and DMEs list that can be received on the routes and result of critical DME / DME GAP sections are displayed together with the terrain data. Then, the list is outputted on specific format for AFIS and mounted in AFIS. It is possible to conduct flight inspection with tuned DMEs based on the result in the RNAV simulation.

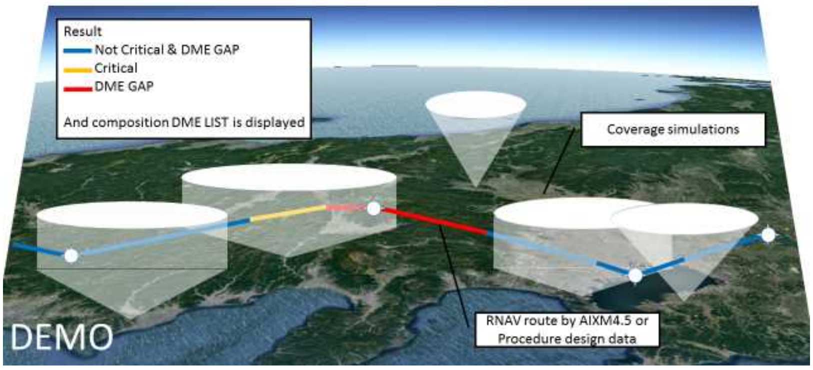

Fig 10. RNAV analysis image

Visualization of relationship between terrain and radio wave

Disturbance of signal conditions are often caused by terrain, the influence is remarkable especially in Japan as there are many mountains. In order to grasp the relationship between terrain and radio wave conditions easily, we visualize the relationship between them by displaying received signal on track contained in the flight inspection data with the terrain data inputted in FIDM. To check this relationship in advance by the flight procedure designer with the data providing function shown below make it possible to prevent from setting a new flight procedure within an airspace which has poor radio wave conditions.
Fig 11 shows relationship between VOR ERR and terrain. By displaying multiple signals from flight inspection data, you can see that a specific mountain has some influence on radio wave. By confirming this indication at the time of designing a new flight procedure, it will be easy to distinguish between areas where the radio wave condition is good and bad. It will help flight procedure designer with setting appropriate new flight procedure.

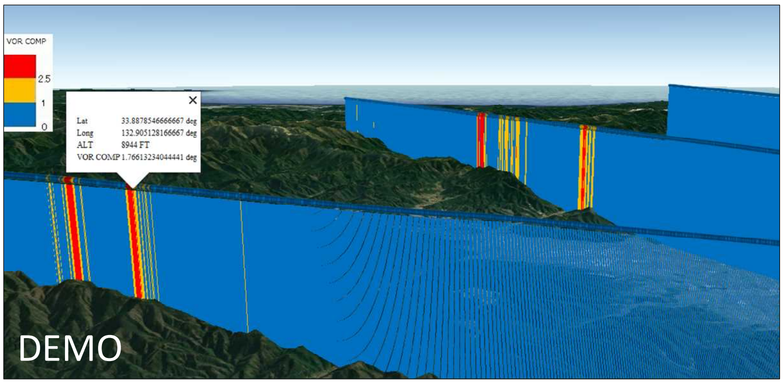

Fig 11. Relationship between terrain and radio wave

Data providing

This is a function that external organizations such as flight procedure designers and research institutions can use each FIDM's functions from the remote location connected with web. Especially, a flight procedure designer will be able to design new procedures within a good radio wave condition area by using the result of the coverage simulation. It is expected that the necessity of re-inspection due to the poor reception condition decreases and it would be possible to set new procedures by minimum flight inspection.

CONCLUSION

If sufficient flight inspection data were stored in the FIDM and the RNAV analysis function operates sufficiently, it is assumed that newly published RNAV 5 routes set during the past 2 years could have been set by flying about 1,500 NM instead of 4,470 NM in 2016 and as well as about 700 NM instead of 1,300 NM in 2017. In addition, the number of flight inspection flights to set a new flight procedure will be reduced by referring the signal condition from the result of the coverage simulation. However, in order to realize the improvement of an efficiency of flight inspection by utilizing the FIDM, the following items are necessary.

・To secure enough flight inspection data amount.
・To determine an appropriate modeling calculation formula for coverage simulation.
・To validate for the coverage simulation result.

As for the amount of our flight inspection data, in addition to these already collected over the past two years, we need to collect them continuously while proceeding with manufacturing of the FIDM, so it will not be perfect at the completion of the FIDM manufacture, but a certain amount of these data will be secured. In particular, it is necessary to sufficiently consider the characteristic change of the signal strength due to the environment such as mountainous areas and sea. As a validation check, it is necessary to compare several corrected coverage simulation results with the data acquired in the actual flight, and confirm that the correction is adequately reflected.
This confirmation work should be started immediately after completion of the manufacturing, but since JCAB is developing this kind of system for the first time, there still is some concerns of what kind of result there will be. However, the proper

correction is extremely important for the FIDM, and we would like to find an appropriate solution and make the flight inspection more efficient, no matter what problem comes out.