Evaluation Results of Multilateration at Narita International Airport

Hiromi Miyazaki, Tadashi Koga, Eisuke Ueda, Izumi Yamada, Yasuyuki Kakubari and Shiro Nihei
Electronic Navigation Research Institute (E-mail: hiro@enri.go.jp)

ABSTRACT

The multilateration (MLAT) is a new surveillance system which has been introduced for air traffic control in recent years. This paper describes evaluation results of performance tests for MLAT conducted at Narita international airport (Narita airport) for airport surface surveillance. Increasing aviation demand has brought expansions of major airports. As a result, the airport layout and operations have become more complex. In order to ensure safe and smooth operations in this situation, an essential requirement will be the provision to air traffic controllers of accurate and highly reliable surveillance information. And this requirement needs introducing advanced surveillance system, such as MLAT. MLAT detects signals from SSR transponder (Secondary Surveillance Radar), and measures a target position by the TDOA technique (Time Difference of Arrival). To achieve high performance in MLAT, an appropriate antenna allocation is the most important. In the evaluation tests, performance degradation by signal interference occurred at a terminal area especially. This paper points out a typical problem caused by an inappropriate antenna installation. In addition, this paper proposes an idea for improvement to mitigate the performance degradation. The results of evaluation tests indicated that the idea for improvement is effective to resolve the problem.

1. INTRODUCTION

Narita airport is a main airport for international flight in Japan. There are two runways and two terminals in this airport. In addition, layouts of terminal areas are the most complex in Japanese airports. And also, Narita airport is now under construction for extending B runway and adding a new taxiway. As a result, traffic volume will increase, and then the ground control will become more complex. Therefore, it is decided to introduce the new MLAT system for surface surveillance at Narita airport, in order to support air traffic controllers for ground control.

Air traffic controllers now use a conventional Surface Movement Radar (SMR) for ground control. However, the SMR has some problems such as performance degradation in specific conditions. On the other hand, MLAT is capable of resolving the problems. Therefore, it is expected that surface surveillance system can achieve advanced functions and higher performance by operating MLAT in combination with SMR.

To achieve high performance in MLAT, an appropriate antenna allocation fitted with the airport layout is very important. Especially, performance verification is highly required in an area where many constructions exist, such as a terminal area.

From this reason, Electric Navigation Research Institute conducted evaluation tests of MLAT at Narita airport using an evaluation system. Main purposes of the evaluation are to verify performances of MLAT, and to fix the appropriate antenna allocation based on the test results.

This paper describes an overview of MLAT firstly. Next, a problem which led to performance degradation in the initial tests is pointed out. Then, an idea for improvement to resolve the problem is proposed. And finally, evaluation results applied the idea for improvement is indicated.

2. Overview of MLAT

Figure 1 shows a conceptual figure of MLAT positioning. MLAT detects SSR “squitter” signals from aircraft transponder, and measures a target position by using TDOA technique. This means, the time differences of arrival among ground Receiver Units (RUs) are transformed to the distance differences between the aircraft and RUs. Then the target position is fixed as the intersection of the two hyperbolic lines.

Figure 1 Conceptual figure of MLAT positioning
Main advantages of MLAT are as follows; indication of identification information on radar screen, no performance degradation in bad weather condition, complementally surveillance to SMR blind area, and no necessity for additional equipment to aircraft.

Position accuracy of MLAT mainly depends on precision of signal detection time and positional relation among the aircraft and RUs. That is GDOP (Geometrical Dilution of Precision). A positional relation becomes fine in a situation that RUs surround the aircraft. Precise time synchronization among RUs is also important, because MLAT measures a target position by TDOA.

On the other hand, a main cause of performance degradation is signal corruption by multipath. It is highly required to avoid this cause, because the multipath leads to undetected signal or false detection. From the above facts, it is important to fix an antenna allocation and antenna positions appropriately, based on the airport layout and the signal environment.

3. Evaluation tests

Figure 2 represents system architecture of the evaluation system. The evaluation system consists of 26 RUs, 2 Reference Transmitters (RefTs), and a Central Processing Station (CPS). The RU detects SSR signal and transfers the signal information to the CPS with detection time. The RefT transmits squitters for time synchronization among RUs and monitoring of the whole system. The CPS calculates a target position from the signal information and tracks the target. Figure 3 represents an antenna allocation of the evaluation system with an evaluation area. The evaluation area was divided into 5 specific areas to analyse each performance in detail, because performance depends on the antenna allocation strongly. Evaluation items are position accuracy and detection rate. European standard (2) is used as a performance requirement. Table 1 shows requirement values for position accuracy and detection rate. Kinematic GPS data is used as reference point to calculate position accuracy. The tests were conducted by using a test van equipping a transponder, because it is efficient to collect data for large evaluation areas. Figure 4 shows a picture of the test van. A test using a flight inspection aircraft was also conducted.

3.1 Problem confirmed in initial tests

Performance degradation occurred at some spots in the initial tests. Figure 5 represents occurrence spots of the performance degradation. The main cause was that some signals was not detected at RUs which should detect the signals. Multipath signal by constructions occurs frequently at a terminal area which has complex layout. To resolve this problem, it is typically effective to set a RU antenna on high place.

![Figure 2 System architecture of the evaluation system](image1)

![Figure 3 Antenna allocation and Evaluation area](image2)

![Table 1 Requirement values in the evaluation test](image3)

![Figure 4 Picture of the test van](image4)

![Figure 5 Occurrence spots of performance degradation](image5)
However, setting the antenna on high place requires a robust pole. Then, it may be difficult constitutionally to install the robust pole on a top of a terminal building. And also, it may be difficult from cost-effective relationship, because the robust pole basically brings huge installation cost.

Figure 6 shows an example picture of constitutional difficulty. On the other hand, redundancy allocation by adding RUs may achieve performance upgrade. However, it also brings negative effect, such as load growth of CPS by more complicated process and inaccurate position measurement by increasing RU combination. To summarize this problem, it is difficult to set RU antennas on an ideal place at a terminal area which has complex layout. That is, there are restrictions for setting RU antennas on high place and adding RUs to the system for the redundancy.

3.2 Idea for resolving the problem

To resolve the problem above-mentioned, it is effective to set RU antennas on existing high place which has fine line-of-sight to wide area of whole airport. This means that a typical existing high place in airport is a top of Air Traffic control (ATC) tower. This idea has some advantages, such as no necessity for a robust pole, no necessity for additional RUs, better resistance to multipath, and formation of better GDOP. Actually, a new RU antenna was installed in a top of apron control tower in the evaluation test. The apron control tower is located next to the ATC control tower. Figure 7 shows a picture and location of towers.

Figure 6 Example pictures for constitutional difficulty

And figure 8 shows pictures of line-of-sight to each area from the apron control tower.

3.3 Test results applying the idea

3.3.1 Runway/Taxiway areas

Figure 9 represents performance values of tests applying the idea at each runway/taxiway areas as well as the test track. A red dot means a measured track by MLAT. A blue dot means a track by Kinematic GPS. Fine MLAT tracks were taken to all areas. It was confirmed that the performance at runway/taxiway areas satisfy the performance requirement.

3.3.2 Terminal areas

Figure 10 and Figure 11 represent performance values of tests applying the idea with the tracks at 1st and 2nd terminal, as well as results of the initial tests. It was confirmed that performance values at most terminal areas satisfy the performance values. And also, performance upgrade was achieved by applying the idea at stands occurring performance degradation. Figure 12 represents a comparison for occurrence spots of performance degradation between before and after applying the idea. As the figure shows, test results indicated that the idea is effective to resolve the problem. However, performance values at some stands have not yet satisfied the performance requirement. For these stands, it is expected to improve the performance by installing more RUs on the top of ATC tower.
Figure 9 Performance values of tests applying the idea at each runway/taxiway areas

(a) Test applying the idea

(b) Initial test

Figure 10 Performance values at 1st Terminal area
Figure 11 Performance values at 2nd Terminal area

- (a) Test applying the idea
  - Accuracy: 7.1m, Detection: 100%
  - Accuracy: 6.6m, Detection: 100%
  - Accuracy: 9.5m, Detection: 100%
  - Accuracy: 10m, Detection: 80.9%
  - Accuracy: 6.6m, Detection: 100%
  - Accuracy: 6.8m, Detection: 100%

- (b) Initial test
  - Accuracy: 7.7m, Detection: 100%
  - Accuracy: 226m, Detection: 96.9%
  - Accuracy: 108m, Detection: 100%
  - Accuracy: 32m, Detection: 100%
  - Accuracy: 43m, Detection: 97.6%
  - Accuracy: 10m, Detection: 98.7%

Figure 12 Comparison for occurrence spots of performance degradation

- (a) After applying the idea
  - RU: 27 units
  - RefT: 2 units
  - Performance Degradation

- (b) Before applying the idea
  - RU: 26 units
  - RefT: 2 units
  - Performance Degradation
4. Test by flight inspection aircraft

A test using a flight inspection aircraft was conducted to runway/taxiway areas. Figure 13 shows a picture of the flight inspection aircraft. Figure 14 shows performance values at each runway/taxiway areas with tracks. Performance values at each area did not satisfy the performance requirement. And also, all values were worse than each value in the van test.

It is considered that a cause of the performance degradation is difference of signal environment. The test using the flight inspection aircraft was conducted in operational hours, but the test using the van was conducted in midnight hours after ending an operation. There are much SSR signals in operation hours, because there is a lot of flying or moving aircraft around or on the airport. In addition, surrounding aircraft is also treated as a construction which generates multipath signals. These situations lead to negative impact to the signal environment.

On the other hand, for the flight inspection aircraft, there is a difference in the antenna positions between the transponder and the reference GPS. This difference affects position accuracy as a bias error.

5. Conclusion

It was confirmed in the evaluation tests that performance values of MLAT at Narita airport satisfied the performance requirement to almost evaluation areas. However, performance values at some stands of the terminal area have not yet satisfied the requirement. Performance degradation occurred frequently at a terminal area having complex layout, because there are restrictions to setting an antenna on ideal place. For this problem, the test results indicated that our idea for improvement is effective to upgrade performance, without increase in cost. Furthermore, it was confirmed by the tests that performance of MLAT in operation hours is worse than midnight hours. In addition, it is expected to achieve better performance by installing more RUs on the top of ATC tower.

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Reference