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Navigation and Surveillance Sub-group (CNS SG/24) of
APANPIRG**

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Agenda Item 6: Surveillance

6.2 Other surveillance related issues

LOCKOUT OVERRIDE OPERATION TO AVOID IC(II) ¹CODE COLLISION

(Presented by Incheon international airport corporation/Republic of Korea²)

SUMMARY

This information paper presents the information about the Mode-S radar configuration to avoid IC code collision with adjacent radars and the performance evaluation result about it. As the result, lockout override of probability 1/2 could be a good solution for the radar having the problem to acquire the new aircraft address in the Mode-S IC code collision region.

1. Introduction

1.1 Acquiring the aircraft address (ICAO 24 bit address) by Mode-S radar is the first step to detect new target. Without acquiring the aircraft addresses, Mode-S radar can't make the selective interrogation. It could end up failing to detect new inbound aircraft within the coverage of the Mode-S radar if the radar fails to acquire aircraft address.

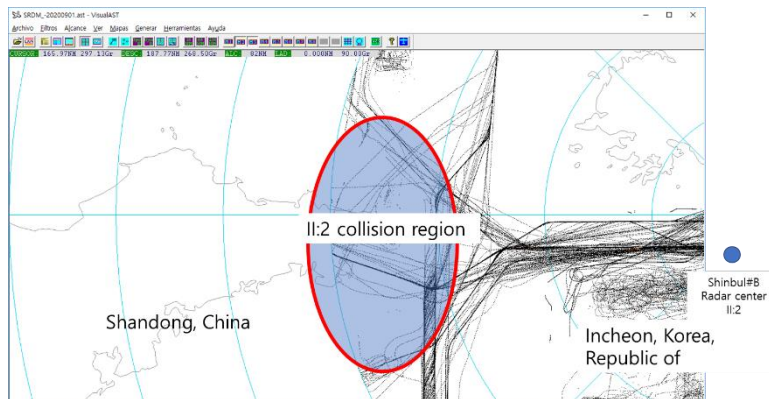
1.2 Since Korea republic of, China and Japan are upgrading their classic SSRs to Mode-S, it will become very difficult to operate all the Mode S without any IC code collision. This paper presents Mode-S lockout override configuration method that could possibly alternative solution to overcome the IC code collision. In this paper, Incheon airport, ROK conducted a radar survey about lockout override configuration.

2. Mode-S IC collision

Incheon airport has two Mode-S radar and one SSR radar. Shinbul#B radar (II:2 code) has Mode-S IC code collision allegedly against the unknown Chinese Mode-S radar at the Shandong peninsula airspace.

¹ IC = II(16) + SI(64) , (IC, Interrogation code), II(Interrogation Identifier), SI(surveillance Identifier)

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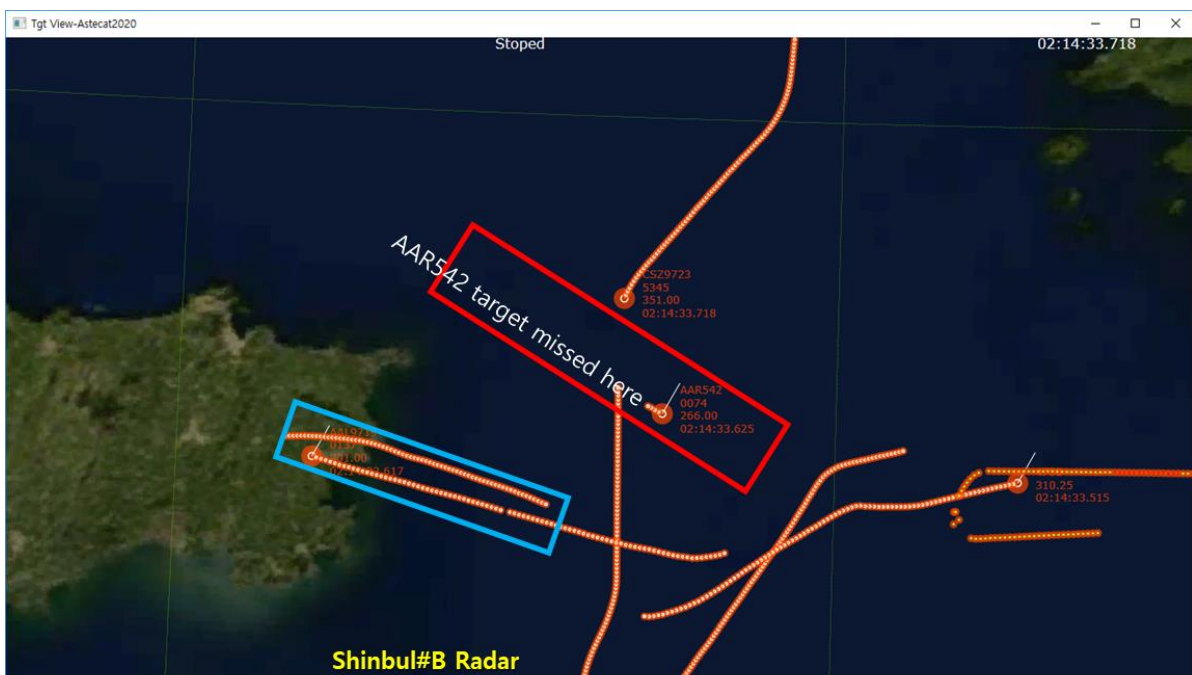


<Picture#1: the location information about the II:2 collision region (2020.9.1) >

Within the region, detection of inbound aircrafts is limited depending on the heading of the aircraft. Some aircrafts are detected very normally but the other aircrafts are not detected until the aircraft has freed from the lockout status of the unknown Chinese radar with II:2 code. Because the success or failure of the aircraft detection is varied even within the region, an ATC controller is blinded only over some aircrafts selectively. It could be a risk for the ATM.



< Picture#2 Left: Wangsan (II:1) Radar detection, Right: Shinbul#B(II:2) Radar detection >



< Picture#3 Inbound detection miss: AAR542, Outbound detection success: AAL9719 >

Incheon airport has two Mode-S radars, which are located at the airport and has similar Mode-S detection coverage. The distance between two Mode-S radar is only about 6NM. When you refer to the picture#2, the detection situation is very different between two radars. Especially, AAR542 flew toward east. Shinbul#B missed about 80 Scans of AAR542 targets, but Wangsan didn't miss it.

It could be interpreted as the following, the aircraft address of AAR542 is succeed to be acquired by II:1 but fail to be acquired by II:2. So, it is very reasonable to think that there is II:2 collision in the region. Repeatedly, the coverage of II:2 and II:1 is almost same (200NM).

At the same time, AAL9719 detection by Shinbul#B radar is same with detection by Wangsan. AAL9719 flew toward the west. AAL9719 is normally detected by both radars. Picture#3 shows that IC code collision makes the continuous blind over inbound target to Shinbul#B within the IC collision region. Intermittent miss on the one flight is NOT observed within the IC collision region. We can conclude that IC collision makes continuous miss for inbound target. The significant implication about the Mode-S IC collision is that the detection results are different between inbound and outbound flights in the IC collision region. Based on the Mode-S lockout mechanism, this phenomenon can be explained as the following.

<Explanation about inbound detection miss case>

- Shinbul#B Radar cannot newly acquire the aircraft address of AAR542 by using II:2 because AAR542 already locked out by the unknown II:2 radar.
- Shinbul#B Radar does not have a lockout list for AAR542. Mode-S radar (Shinbul#B) cannot perform selective interrogation.

3. Countermeasure to avoid Mode-S IC collision

<The use of classic Mode-A, C interrogation>

Easiest way to overcome the Mode-S IC collision is to change MIP (Mode interlace pattern) to add classic Mode-A, Mode-C.

By mixing classic Mode-A, C, UF11 and Selective interrogation at the MIP configuration of the radar, minimum detections of targets could be guaranteed.

Pros & Cons of adding Classic Mode-A, C interrogation in the Mode-S radar

Pros

1. In the IC collision region, even if mode-S detections fail, but Mode-A, C detection could work normally. Mode-A,C interrogation does not need radar IC.

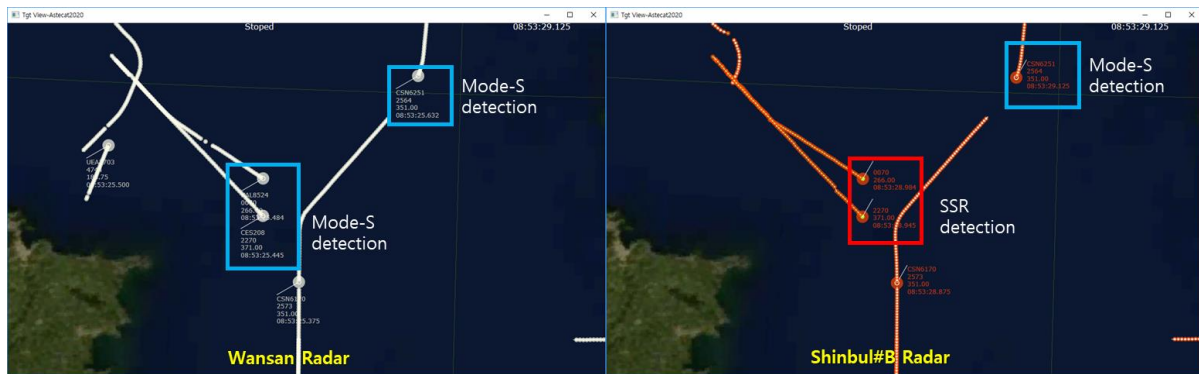
Cons

1. Acquiring the aircraft ID(Callsign) and other Mode-S information is not possible in the IC collision region because in that region, Mode-A, C communication only works.

2. To add classic Mode-A, C interrogation in the MIP configuration, the selective interrogation slot must be reduced. That means less receiving of Comm-B data block such as ACAS RA report, turn track angle report and selective altitude report. But this thing is not significant.

3. The reply/interrogation rate (Mode-S PRF) is little bit increased and at the same time, a radio frequency congestion rate does

4. There is very little possibility to see the increasement of the MSSR reflection target from Mode-A, C interrogation. Mode-S interrogation is more optimized to reduce the MSSR reflection target.



< Picture#4 The use of classic Mode A, C interrogation in the IC collision region >

The following is the explanation about picture#4. KAL5825 and CES208 is inbound flights from China. The detection type of KAL5825 and CES208 is Mode-S at Wangsan radar and SSR at Shinbul#B radar. At picture#3, AAR542 is detection-missed about 80 scans by Shinbul#B. At picture#4, KAL5825 and CES208 is not detection-missed, but detected as SSR type after changing MIP of Shinbul#B radar. Picture#4 shows that mixing classic Mode-A, C with Mode-S interrogation could be an alternative solution to fix IC collision between radars. This does not mean “mixed Mode” at Mode-S MIP but just mean to add additionally classic Mode-A, C slot in a Radar MIP.

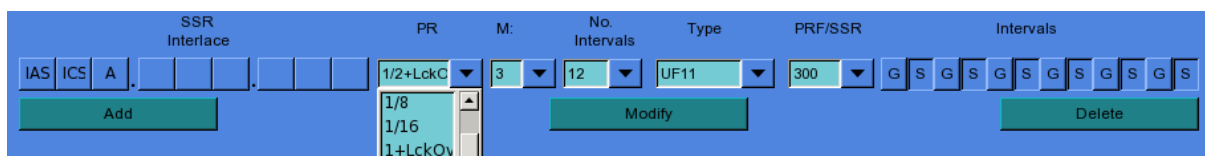
<The use of lockout override with probability of 1/2>

		<i>Field</i>	<i>Reference</i>
1	6	UF uplink format	3.1.2.3.2.1.1
10	14	PR probability of reply	3.1.2.5.2.1.1
17	33	IC interrogator code	3.1.2.5.2.1.2
5	9	CL code label	3.1.2.5.2.1.3
13	16	spare — 16 bits	
32	56	AP address/parity	3.1.2.3.2.1.3

< Picture#6 Mode-S Only all-call interrogation, UF11 frame structure >

- PR: probability of reply (4 bit)
- 0 signifies reply with probability of 1
- 1 signifies reply with probability of 1/2
- 2 signifies reply with probability of 1/4
- 3 signifies reply with probability of 1/8
- 4 signifies reply with probability of 1/16
- 5~15 : refer to the ICAO annex 10 vol 4 documents

<List#1 PR field at UF 11 frame >

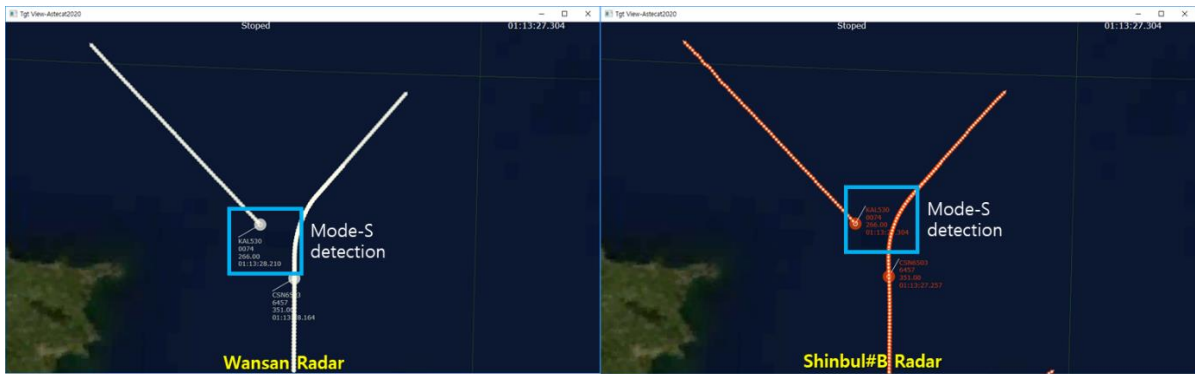


< Picture#7 Configuration screenshot for lockout override of probability 1/2 (Indra systems™) >

Lockout override³

In order to allow a Mode-S radar to operate without co-ordination with its neighbor radars, the Mode S protocols allow the Mode-S radar to force a transponder to reply to all-calls (UF11 interrogation), regardless of the current lockout status to that interrogating IC. It is called lockout override. In addition, in order to avoid garbling problem, it is recommended that lockout override is applied with “a Probability of Reply” value of less than 1.

From 10. Sept.2020, Shinbul#B radar at Incheon airport had been configured to use lockout override with PR 1/2. After adapting lockout override, target detection situation in the IC collision region becomes to the normal. Mode -S data block acquired normally. Our engineers are trying to find the weakness of lockout override operation. But what we see are the merits of lockout override because by using it, detection for inbound aircrafts in the IC collision region is turning to the normal.



< Picture#7 Inbound detection with lockout override of PR 1/2 >

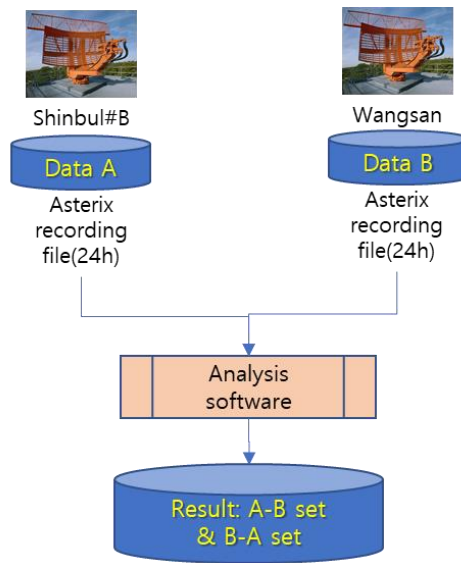
3. Analysis method about Mode-S IC collision

The merits of Mode-S radar are the selective communication with aircrafts and a lockout mechanism to reduce transponder replies. But for the lockout function, each radar must have a unique ID (Mode-S IC) and each aircraft also have the aircraft address (ICAO 24 bit address). If lockout mechanism goes wrong with unknown fault, the transponder of an aircraft could miss reply from the Mode-S radar presumably because it erroneously thinks it was already locked out by that radar.

As the analysis purpose, finding silently undetected targets is very difficult. Lockout situation could be different depending on the heading of the aircraft. Manual watch-over the detection screen are time-taking jobs, even with little reliability to find undetected target. So, the Incheon airport developed analysis software to find a undetected MSSR target.

The analysis software named as “Astecat frametest” designed to compare the two of Asterix recordings of different radars to find undetected targets. The software works as the following.

³ Referred from Eurocontrol document “Principles of Mode S Operation and interrogator codes”, 2003.3.18, V2.3



< Picture#8 The framework to find the undetected target through the analysis software >

```
Pseudo code to find Data set "A-B"  
Data Set A : {Target list of Wangsan Radar detection }  
Data Set B : { Target list of Shinbul#B Radar detection }  
  
for (int i = 0; i < CountOfA; i++)  
{  
    Target getA = A_DataSet.GetAt(i);  
    int isOnTheSameScan;  
    int isMatchedTarget=0;  
    for (int j = 0 ; j < CountOfB ; j++)  
    {  
        Target getB = B_DataSet.GetAt(j);  
  
        isOnTheSameScan=CheckTimeDifference(getA,getB);  
  
        if(isOnTheSameScan)  
        {  
            isMatchedTarget=ComparePositionAndCallsign(getA,getB);  
            if(isMatchedTarget)  
                break;  
        }  
    }  
    if(isMatchedTarget==0)  
        SaveTarget(getA ); // Save Data set of "A-B" logical operation  
}
```

< Picture#9 Pseudo code of “A-B” logical operation >

The software “*Astecat frametest*” designed to distinguish and find the different data set between Target A and B. While doing the investigation to find undetected targets, an engineer can do A-B or B-A operation and by reviewing the result they can easily find undetected targets.

5. Discussion

Now many SSR radars are upgrading into Mode-S radars. Mode-S IC collision between Mode-S radars now becomes into the new normal. To overcome IC collision, adding classic Mode A, C interrogation slot in the MIP configuration could be one solution with some dis-advantage. Incheon airport is testing “Lockout Override with PR 1/2”. Current test result show that still there is no reason not to use Lockout override in the IC collision condition. No side-effect of lockout override configuration is not observed. Incheon airport wants to hear various opinions about it. If there is any information about it, we want to share and hear it.

To find the undetected target, manual analysis method is not effective. So, Incheon airport developed minus (difference) logical operation software for Asterix recording files. This kind of systematic approach to solve the problem would be always welcomed by all relative shareholders.
