



ICAO

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**THE FOURTH MEETING OF MODE S DOWNLINKED
AIRCRAFT PARAMETERS WORKING GROUP
(MODE S DAPs WG/4)**

Video Teleconference, 29 – 31 March 2021

Agenda Item 3: Sharing of State's implementation on Mode S and related issues

ANALYSIS OF INCORRECT RA CODE ON MODE S RADAR

(Presented by China)

SUMMARY

This information paper presents the incorrect RA code of Mode S radar that results in the wrong RA warning in the ATM automation system, and shares the result of investigation and analysis.

1. INTRODUCTION

1.1 In 2020, the ATC department of Beijing Capital International Airport reported several RA warnings prompted by the ATM automation system, which the aircraft did not generate TCAS warning after verifying with the crew. (see Appendix 1. background). To solve this problem, we analyzed the raw data of Mode S radar, came to a conclusion, and gave some suggestions.

2. DISCUSSION

Investigation and analysis.

2.1 In 2020, the ATC department reported four incorrect RA information output by Thales radar (RSM 970s DP13.05) of Beijing Capital International Airport. We analyzed the raw radar data of these four incorrect RA warnings through a dedicated radar data analysis tool, and found two anomalies:

- The Cat048 / item 260 does not start with "30" (hexadecimal) and all data are invalid, as shown in figure 1. (see Appendix 2. basic principles)
- The radar data of Cat048 / item 250 BDS 6,0 is the same as Cat048 / item 260 BDS3,0 in all four RA warning events, as shown in figure 2.

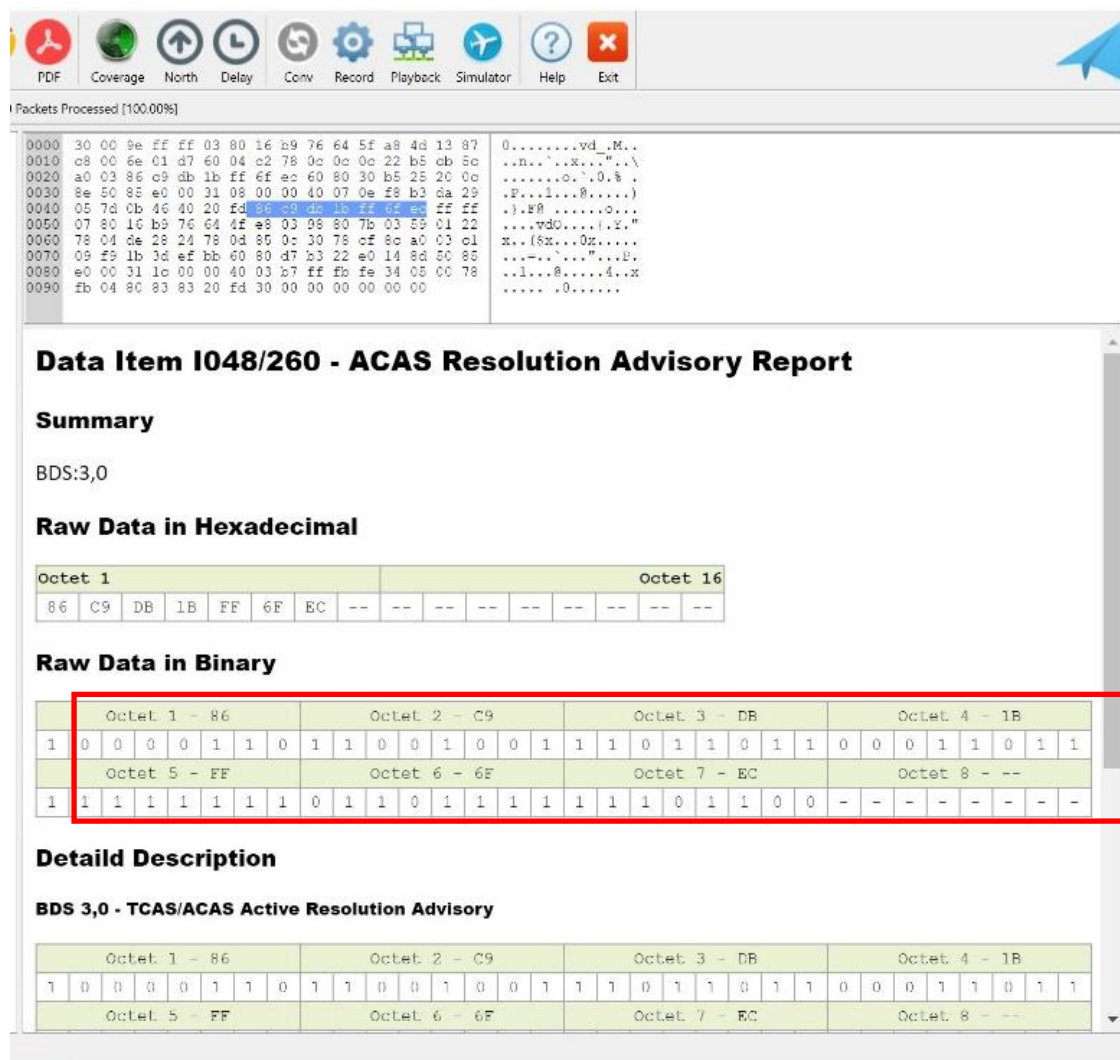


Figure 1. Incorrect first byte data of Asterix Cat048/ item 260.

2.2 When the type of BDS data interrogated by the Mode S radar is inconsistent with the type of BDS data sent by the aircraft transponder at the same time, we call this phenomenon "BDS swap". BDS swap may occur in all BDS data. After analysis, the data of Cat048 / item 250 BDS 6,0 is the same as Cat048 /item 260 BDS3,0 in four incorrect RA warning events, which means that BDS swap occurs.

2.3 The four events all occurred in the approach area with heavy air traffic, and aircraft in some of the area might be interrogated by seven radars at the same time, this may result in "BDS swap" as follows.

2.4 The transponder receives two interrogations sent by different radars almost at the same time (for example, one radar requests BDS3,0 and the other request BDS6,0). The transponder will only reply to one request, and the two radars will receive the same reply. This reply is the correct reply to one of the radars, but it is the wrong reply to the other one. The more intensive deployment of Mode S radar, the more probability of BDS swap might have happened.

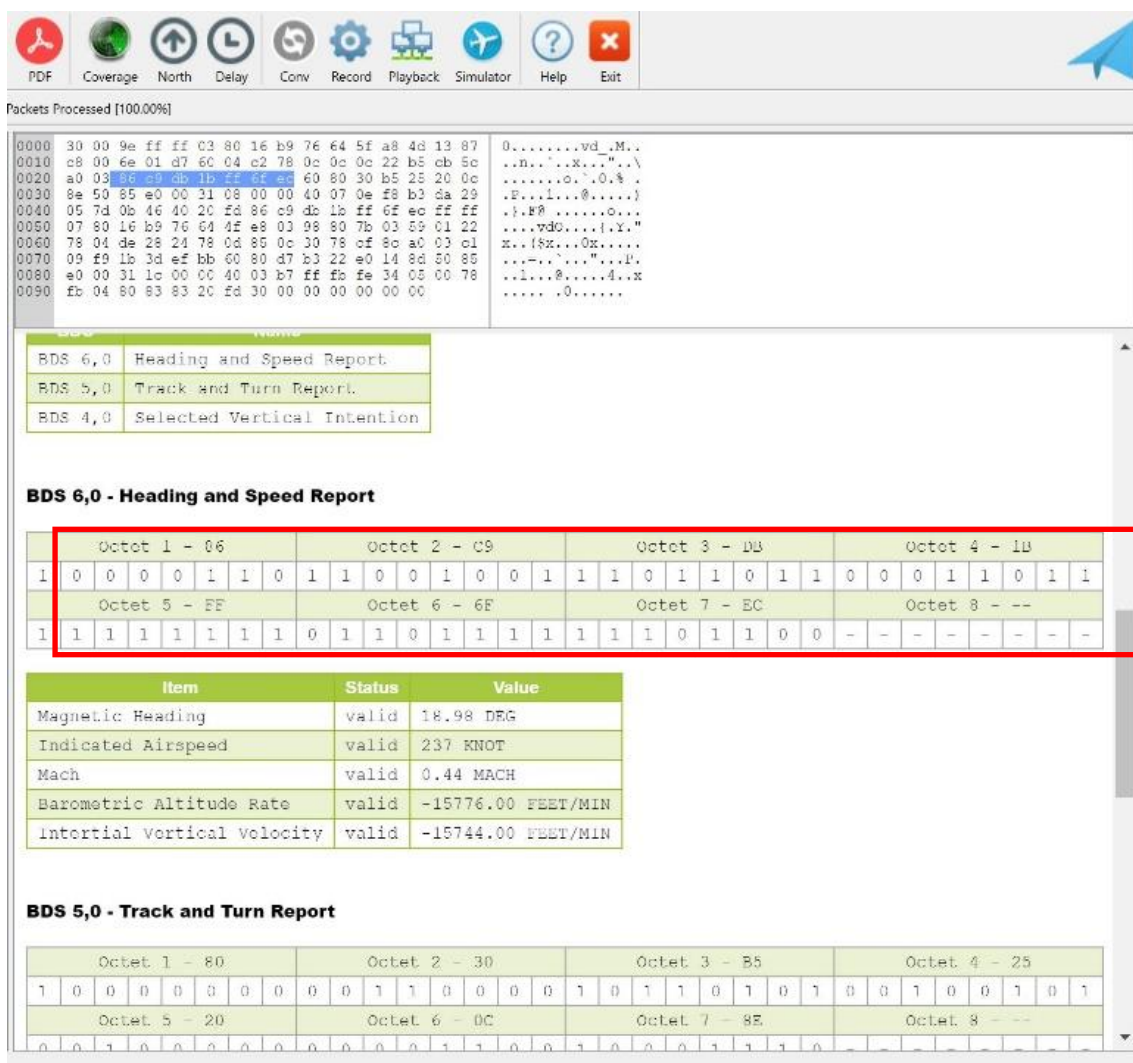


Figure 2. The data of BDS 3,0 and BDS 6,0 are the same

2.5 After analysis, the reason caused of the four incorrect RA warnings is that the aircraft transponder received both BDS3,0 and BDS 6,0 information requests from different Mode S radars almost at the same time, and only replied BDS6,0 information. Since the radar only checks whether the received information code is correct or not, it does not judge whether the replied information is comply with the requested information or not, this results in the radar outputs wrong RA information to the ATM automation system.

Proposed improvement measures.

2.6 Short term solution in radar improvement: The new type Mode S radar (Thales radar RSM970s DP16.01) in Beijing Daxing International Airport has been able to process the incorrect data after BDS swap, it checks the data flag bits of BDS10, 20, and 30, and checks the consistency of UF / DF.

- It rejects BDS contents (BDS 1,0; 2,0 and 3,0) in case of flag bits error.
- It rejects data of BDS content or replies in case of difference between UF and DF.

This solution relies on the judgment of the radar on the request and reply, and it cannot guarantee 100% of eliminating the BDS swap issue.

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2.7 Medium and long term solutions:

At present, in the Mode S downlink reply DF20 / 21, the aircraft transponder uses the "AP" field for coding as the verification.

The "Overlay" function is introduced in the fifth edition of Volume IV of ICAO document annex 10. In the downlink reply DF20 / 21, the DP (data parity) field is introduced to replace the AP field to check the BDS register number, to solve the problem of BDS swap from the source.

To realize the "overlay control" function, both the aircraft transponder and radar need to be upgraded at the same time.

20	10100	FS:3	DR:5	UM:6	AC:13	MB:56	AP:24 Comm-B, altitude reply (see Note 5)
							DP:24	
21	10101	FS:3	DR:5	UM:6	ID:13	MB:56	AP:24 Comm-B, identify reply (see Note 5)
							DP:24	

Figure 3. The structure of DF20 / 21

Some suggestion.

2.8 When BDS3,0 is added to the radar request list, it is necessary to evaluate whether the radar can identify and handle BDS swap problems, to avoid anomalies to the ATM automation system.

2.9 It is suggested to upgrade the earlier version of Mode S radar to solve the problem of BDS swap.

2.10 The display of ACAS Resolution Advisory Report in ATM automation system can be turn on or turn off by user, and it is not recommended by IFATCA. The user is suggested to do the relevant safety evaluation and training before applying this function. Moreover, it is recommended to develop corresponding procedures in case of anomalies of ACAS RA display in ATM automation system.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

- a) note the information contained in this paper, and
- b) discuss any relevant matter as appropriate.

Appendix 1. BACKGROUND

1.1 Enhanced Mode S radar usually outputs BDS 4,0 / 5,0 / 6,0 data to the ATM automation system as default. The acquisition of other BDS data (except ELS) can be added to the radar interrogation list by the requirements of the ATC department.

1.2 The aircraft transponder notifies the Mode S radar of interrogating and extract the RA information through the AICB mode by changing DR filed to 2, 3, 6, and 7 in downlink reply (DF4, 5, 20 ,and 21).

1.3 Because it is difficult to verify the timeliness and effectiveness of the RA data in AICB mode, the radar technicians add BDS3,0 to the interrogation list of Thales Mode S radar (RSM970s DP13.05) of Beijing Capital International Airport to acquire real-time RA information of the aircraft for testing purposes.

Appendix 2. BASIC PRINCIPLES

2.1 RA information (BDS 3,0) is included in the MB field of the Mode S downlink reply DF20 / 21, as shown in figure 1. Bits 33-41, the first byte of the MB field (we call it “flag bits”) indicate the MB filed is BDS3,0 and the other bits in the field are RA information.

2.2 Also, there are no flag bits at the beginning of the MB field of BDS4,0 / 5,0 / 6,0, as shown in figure 2.

Note.— Structure of MB for an RA report:

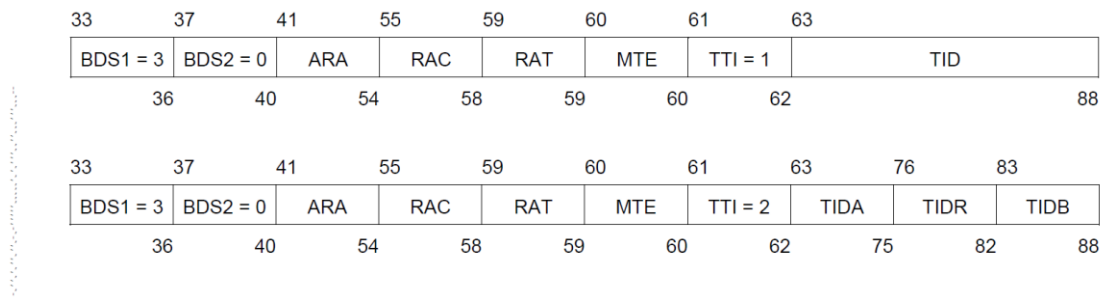


Figure1. BDS3,0 structure.

Table A-2-80. BDS code 5,0 — Track and turn report

MB FIELD		
1	STATUS	PURPOSE: To provide track and turn data to the ground systems. 1) If the value of the parameter from any source exceeds the range allowable in the register definition, the maximum allowable value in the correct positive or negative sense shall be used instead. <i>Note.— This requires active intervention by the GFM.</i> 2) The data entered into the register shall, whenever possible, be derived from the sources that are controlling the aircraft. 3) If any parameter is not available on the aircraft, all bits corresponding to that parameter shall be actively set to ZERO by the GFM. 4) The LSB of all fields shall be obtained by rounding. <i>Note 1 — Two's complement coding is used for all signed fields as specified in §A.2.2.2.</i> <i>Note 2 — Additional implementation guidelines are provided in §D.2.4.5.</i>
2	SIGN 1 = Left Wing Down	
3	MSB = 45°	
4		
5		
6	ROLL ANGLE	
7		
8	Range = [-90, +90]°	
9		
10		
11	LSB = 45/256°	
12	STATUS	
13	SIGN 1 = West (e.g. 315 = -45°)	
14	MSB = 90°	
15		
16		
17	TRUE TRACK ANGLE	
18		
19	Range = [-180, +180]°	
20		
21		
22		
23	LSB = 90/512°	
24	STATUS	
25	MSB = 1 024 kt	
26		
27		
28	GROUND SPEED	
29		
30	Range = [0, 2 046] kt	
31		
32		
33		
34	LSB = 1 024/512 kt	
35	STATUS	
36	SIGN 1 = Minus	
37	MSB = 8°/s	
38		
39		
40	TRACK ANGLE RATE	
41	Range = [-16, +16]°/s	
42		
43		
44		
45	LSB = 8/256°/s	
46	STATUS	
47	MSB = 1 024 kt	
48		
49		
50	TRUE AIRSPEED	
51		
52	Range = [0, 2 046] kt	
53		
54		
55		
56	LSB = 2 kt	

Figure 2. BDS5,0 structure.

2.3 The Mode S radar output data of ASTERIX Cat048 /item 260 RA information, which corresponds to BDS3,0 data sent by aircraft transponder, the beginning must be 0011 0000 (hexadecimal 3,0). If the Cat048 /item 260 RA information does not start with 30 (hexadecimal), it is invalid data.

2.4 when the aircraft has no ACAS RA information, the normal data should be 30 00 00 00 00 00 00, as shown in figure 3.

0000 30 01 f7 ff ff 03 80 16 b9 55 a2 0b a8 7b fb 9e 0.....U...{..

0010 27 0f 07 01 b4 60 04 b4 78 0f 33 0d 30 f8 e3 6c !.....x.3.0..1

0020 60 03 98 da 5d 22 be 7f cd 60 80 72 df 2e 3f fc ".j".....r.?

0030 b2 50 91 60 00 30 a4 00 00 40 00 d3 d6 3a d2 33 .P..0...@.....3

0040 06 9a 2e 5b 40 20 fd 30 00 00 00 00 00 00 ff ff[.0.....

0050 03 80 16 b9 55 a2 00 a8 5e dd 9b bd 0e 2a 01 d7U.....*

0060 60 04 ba 78 0c b6 bd 50 75 db 2c a0 03 96 aa 33P.....3

0070 20 ff bf ff 60 ff d2 a5 2b a0 04 a8 50 8b 88 00+.....P...

0080 31 1c 00 00 40 04 e0 e4 f0 d9 0c 06 25 29 a7 40 1...@.....%):@

0090 20 fd 30 00 00 00 00 00 ff df 03 80 16 b9 55 .0.....U

00a0 a2 0a a8 3d 57 9d af 0e 89 00 98 60 02 c1 7b c9 ...=W.....f.

00b0 de 44 44 c6 3c d6 86 00 25 eb 94 e9 1e 03 b5 17 .DD.<...3.....

Octet 1	Octet 16
30 00 00 00 00 00 00 --	-- -- -- -- -- -- --

Raw Data in Binary

Octet 1 - 30	Octet 2 - 00	Octet 3 - 00	Octet 4 - 00
0 0 1 1 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
Octet 5 - 00	Octet 6 - 00	Octet 7 - 00	Octet 8 - --
0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	- - - - - - -

Detailed Description

BDS 3,0 - TCAS/ACAS Active Resolution Advisory

Octet 1 - 30	Octet 2 - 00	Octet 3 - 00	Octet 4 - 00
0 0 1 1 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
Octet 5 - 00	Octet 6 - 00	Octet 7 - 00	Octet 8 - --
0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	

Figure3. the normal BDS3,0 data of no ACAS RA information.