



ICAO

*International Civil Aviation Organization***Seventh Meeting of the Surveillance Implementation  
Coordination Group (SURICG/7)**

Video Teleconference, 24 – 27 May 2022

**Agenda Item 7:** Report on surveillance ground system and avionics performance monitoring and improvement in compliance

## **AN ANOMALY OF MODE A/C ONLY TRANSPONDER REPLY TO MODE S INTERROGATION**

(Presented by China)

### **SUMMARY**

This paper introduces a case where an aircraft equipped with the Mode A/C only transponder generates false targets in response to Mode S radar interrogation, analyzes the causation of the phenomenon in combination with the relevant ICAO Annex 10 specifications, and provides some suggestions for Mode S radar manufacturers and aircraft maintenance engineers.

## **1. INTRODUCTION**

1.1 In recent years, the world's civil aviation industry is developing rapidly. The volume of aircrafts equipped with mode S transponders keep growing, but there are some aircrafts still using Mode A/C only transponders, especially the old non-upgraded commercial aircrafts, military aircrafts or training aircrafts.

1.2 In accordance with ICAO Annex10 Volume IV standards and recommendations (in particular with the suppression function of P1-P2 pulse pairs), the Mode A/C only transponders shall not respond to Mode S interrogation. However, the abnormal response of the Mode A/C only transponders to the Mode S interrogation occurs sometimes.

## **2. ABNORMAL RESPONSE PHENOMENON**

2.1 In January 2022, an abnormal response of a Mode A/C only transponder to a Mode S interrogation occurred in the airspace of Chengdu, China (false targets appeared). As shown in Figure 1, the characteristics of false targets are as follows.

- a) The false target and the true target have the same azimuth with respect to the radar, and the distance to the radar was greater than 100 NM. The distance between the targets was slightly less than 10NM (the false target was closer to the radar), and remained stable for a certain period.
- b) The Code A of the false and the true target were both 6666, and their Code C were respectively 226 and 719 (FL).

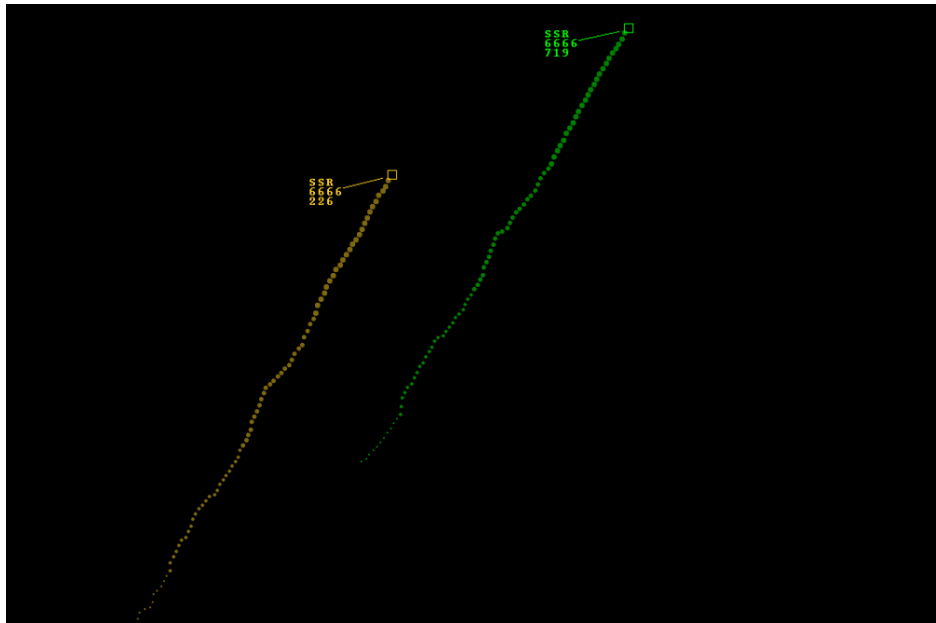


Figure 1. True and false targets generated by the replies of the Mode A/C only transponder's response to Mode S interrogation

### 3. MEASUREMENT and ANALYSIS

3.1 The Mode S radar generally uses Mode S only All-Call (UF11) and Mode A/C only All-Call (short P4) interrogation in the All-Call period (Figure 2). This operation is very efficient, because it separately and effectively interrogates Mode S transponders and Mode A/C only transponders in the air space while minimizing unnecessary interrogations and replies.

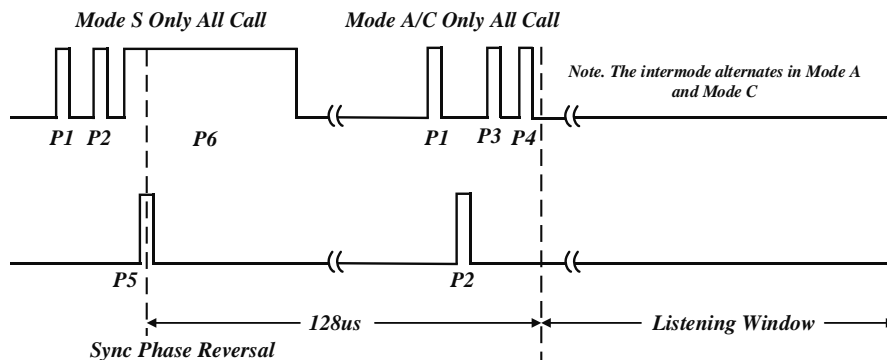


Figure 2. Mode S Only All-Call (UF11) and Mode A/C Only All-Call (Short P4) Interrogation

3.2 According to 3.1.1.7.4 SUPPRESSION in "ICAO Annex10 Volume IV", when the P1-P2 pulse pairs are received (the amplitude of the P2 pulse is equal to or greater than P1, and the spaced time is in  $2 \pm 0.15\mu s$ ), the Mode A/C transponder will trigger Suppression mechanism ( $35 \pm 10\mu s$ ) to prevent Mode A/C transponders from responding to SSR sidelobe interrogations and Mode S radar interrogations. In fact, this function failed in this case.

3.3 The above assumption was verified by the measurement of the Mode S radar interrogation pulse with the oscilloscope, it can be observed that the amplitude of the P6 pulse has a large discontinuous gap (exactly  $8\mu s$  after the pulse P1 of the UF11), as shown in Figure 3. In this case, the Mode A/C transponder accepted the UF11 as a Mode A interrogation and generated a Mode A reply falsely when the suppression function failed (Note: The Mode C reply will not be triggered because the

interval of P1-P2-P6 pulses is 19.75us for any UF11). The following Mode A/C only All-Call (short P4) interrogation triggered the Mode A/C only transponder to reply Mode A or C respectively. In the Mode S only All-Call period, the Mode A/C only transponder could reply with Mode A+A or Mode A+C when it received a low level Mode S All-Call interrogation, then the radar would generate 2 targets, one of which is of course a false target. As shown in Figure 4, the time interval between the 8us after pulse P1 of the UF11(Mode S only All-Call) and pulse P3 of Mode A/C only All-Call is about 120us, which match with the range between the true and false targets, slightly less than 10NM.

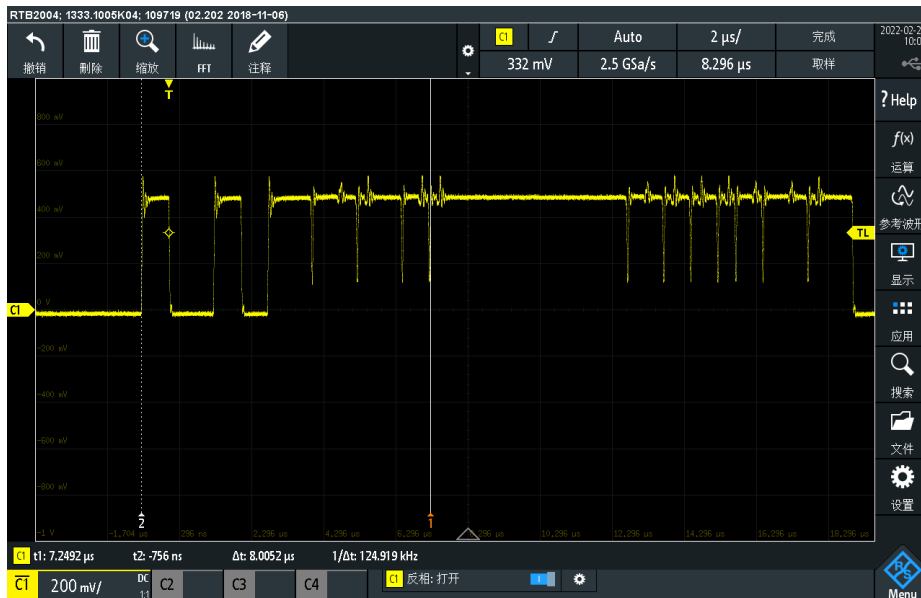


Figure 3. The measured pulse waveform of Mode S only all call (UF11)

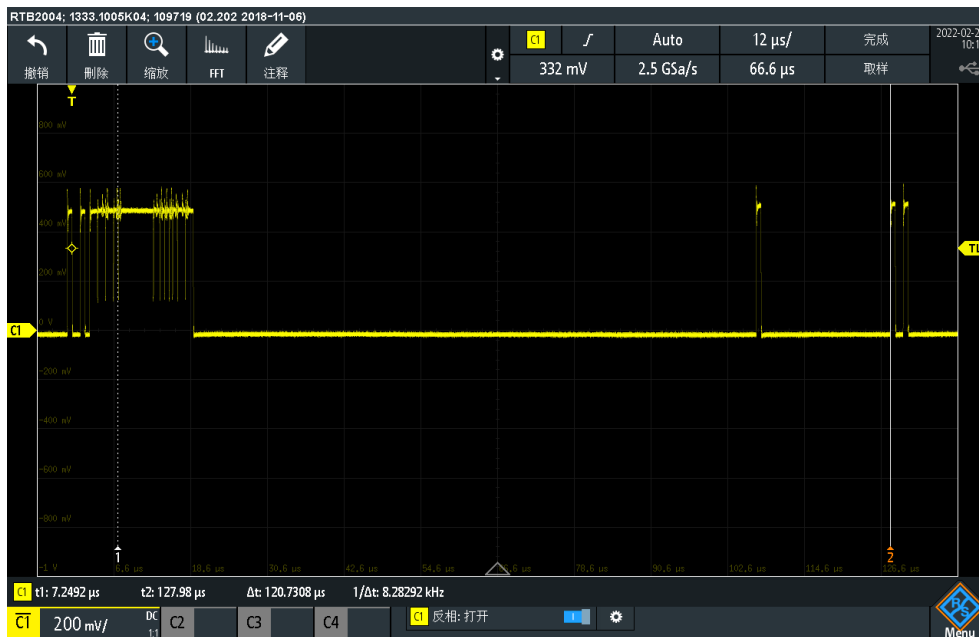


Figure 4. The measured pulse waveform of Mode S only All-Call (UF11) + Mode A/C only All-Call (short P4)

3.4 The case in figure 1, the Mode A/C only transponder responded to the Mode S MSSR UF11 + Mode C-only ALL-CALL (short P4) interrogation with the Mode A and C replies falsely. The

Mode S radar decoded the received signal according to the Mode C, and generated true and false altitudes (when the A code is erroneously decoded into the C code). The specific procedure is:  $A=6666=A_1A_2A_4B_1B_2B_4C_1C_2C_4D_1D_2D_4=011011011011$ . When it was falsely decoded into C code,  $C=D_2D_4A_1A_2A_4B_1B_2B_4C_1C_2C_4=11011011011$ , and the corresponding altitude was 71900ft obtained by referring to the table. So the altitude of the false target is 719FL, and the altitude of the true target is 226FL.

**4. RESOLUTION and RECOMMENDATION**

4.1 In addition to the suppression failure, the reason for the false target is also due to the amplitude depression around 8us after the pulse P1 of the UF11 (the amplitude depression could be judged as a potential P3 pulse leading edge by the transponder).

The position of the amplitude depression can be changed by modifying the corresponding UF11 IC data segment parameters (Figure 5 and Figure 6), and eliminate the false targets finally. However, it is not a sufficiently good method, because the parameters IC (II or SI code) are assigned by the CAAC ATMB. There always a radar would be assigned with the parameters same as this case, and may cause the same problem.

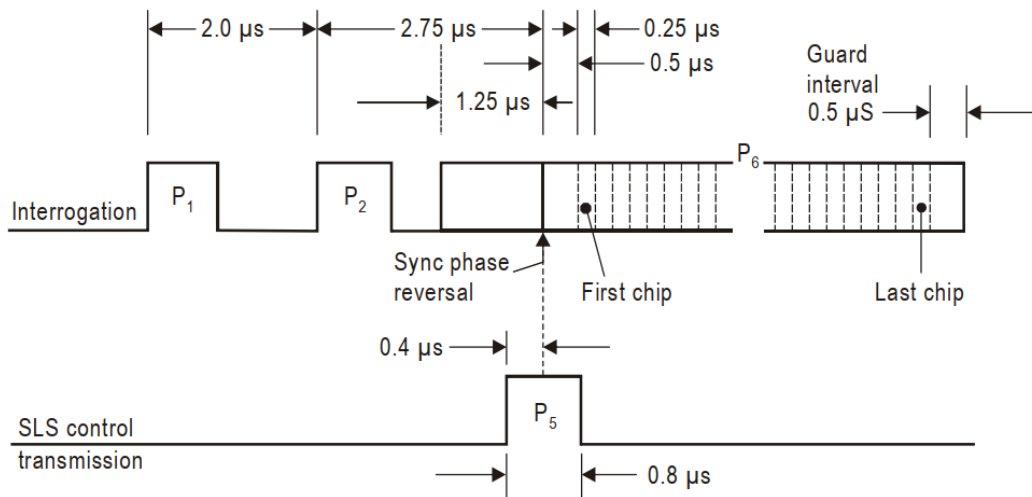


Figure 5. The pulse waveform of Mode S only All-Call (UF11)

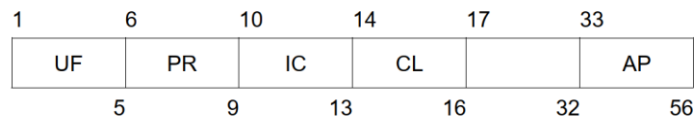


Figure 6. the uplink format of Mode S only All-Call (UF11)

4.2 It is mentioned in 3.1.2.1.4.2.1 Phase reversal duration in "ICAO Annex10 Volume IV": The phase reversal can be generated by using different methods. This includes hard keying with strong amplitude drop and rapid phase reversal or other techniques with little or no amplitude drop, but with frequency shift during the phase reversal and slow phase reversal (80ns). To avoid the ghost target abnormal phenomenon, it is recommended to avoid the severe amplitude fading during the phase reversal interval.

4.3 On the transponder side, it is recommended that the aircraft maintenance personnel regularly test the Mode A/C-only transponder to ensure the effectiveness of the 3.1.1.7.4 SUPPRESSION function in "*ICAO Annex10 Volume IV*".

**5. ACTION BY THE MEETING**

5.1 The meeting is invited to:

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

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