RTCA Special Committee 209 / EUROCAE WG49

ATCRBS / Mode S Transponder MOPS Maintenance

Joint Meeting #12

EUROCAE, Malakoff
15 – 19 November 2010

1030 DPSK Modulation Clarification

In Response to Action Item 11-03

Revision 1

Eric Potier
EUROCONTROL

SUMMARY

This WP proposes different modifications of the transponder MOPS to clarify the issue reported in section 2.1 of WP11-14 (misleading interpretation of the use of a diode detector) and to clarify that transponders shall be able to reply to interrogations generated by the different phase modulators currently used by the Mode S interrogators.

1 Introduction

A problem of interoperability has been detected between a Mode S transponder and a Mode S interrogator.

Different investigations have been done to understand the reasons. During these investigations it has been noticed that the phase reversal within the Mode S interrogations can be generated using different methods. Each method has different impacts on the Mode S signal generated.

In addition a study was commissioned by the European Aviation Safety Agency (EASA) to investigate the Mode S Signal-In-Space and the impact on airborne transponders and a report was produced which documents the results. Some of the major findings of this study were:

- Most radar stations surveyed apply a phase modulation technique (I/Q modulation) that is not simulated by existing test equipment.
- The duration of Mode S phase reversals may exceed the maximum of 80 ns due to a number of effects (e.g., P5 side lobe suppression, multipath propagation). Existing test equipment cannot simulate such slow phase reversals.
- Some TCAS units perform interrogations that are not compliant with ICAO Annex 10 and ED-73C.
- Transponder test equipment generate ideal signals with quick phase transition which may considerably differ from real Signals-in-Space.

Some of these findings were reported by EASA in Working Paper SC209-WP11-14.

This Working Paper proposes different modifications of the transponder MOPS to clarify the issue reported in section 2.1 of SC209-WP11-14 (misleading interpretation of the use of a diode detector) and to clarify that transponders shall be able to reply to interrogations generated by the different phase modulators currently used by the Mode S interrogators.

2 Proposed modifications

2.1 First level of clarification

This level consists in adding notes to make clear that different types of modulators could be used to generate the phase reversal and that a diode detector can only be used for test purpose.

2.1.11.1 Interrogation Carrier Frequency {ED-73C, §1.6.2}
The carrier frequency of received interrogations is:
a. 1030 ±0.2 MHz from ATCRBS interrogators.
b. 1030 ±0.01 MHz from Mode S interrogators.

Note: *The 1030 MHZ transmitter can generate phase reversal using different methods. This includes hard keying with strong amplitude drop and rapid phase reversal or IQ modulation with little or no amplitude drop but with a frequency shift of several MHz during the phase reversal.* ← *THIS Note to be accepted*

2.1.11.4.3 Phase Reversals {ED-73C, §1.6.4 d}

The first phase reversal within P6 is the sync phase reversal. The midpoint of each following data phase reversal can occur only at a time 0.25 N ±0.02 microsecond (where N is larger than or equal to 2) after the sync phase reversal.

Note: *The 1030 MHZ transmitter can generate phase reversal using different methods. This includes hard keying with strong amplitude drop and rapid phase reversal or IQ modulation with little or no amplitude drop but with frequency shift during the phase reversal and slow phase reversal (80ns).* ← *THIS Note to be accepted*

2.4.2.1 Receiver Characteristics (§2.2.2) {ED-73C, §5.4.1.2}

Equipment Required:

ATC Test Set with P4 Capability (TIC T-50-3A/4B, or equivalent) and with slow phase reversal time capability using IQ modulator for step 9.

Measurement Procedure:

With the equipment connected as shown in Figure 2-24, interrogate the transponder with a standard Mode A interrogation and follow Steps l through 4 below.

…

2.5.4.1 Procedure #1: Error Protection

…

Equipment Required:

Test set capable of generating Mode S interrogations at a 0-dBm power level.

DPSK modulation detector ~~(a simple diode detector is adequate for manual determination of the location of phase reversals in a 0-dBm signal).~~

A simple diode detector for manual determination of the location of phase reversals when the Mode S signal test generator is using hard keying with amplitude drop.

Note: *Such method is only possible for test purpose as some transmitters can generate the phase reversal using IQ modulator with little or no amplitude drop.*

Wide-band oscilloscope (HP1710B, or equivalent).

…

When the Mode S signal generator uses a hard keying method to generate phase reversal resulting in amplitude drop the following method can be used to verify the Test Set Error Protection circuit.

Verification of Test Set Error Protection Circuits

Connect the diode detector and oscilloscope to the RF output of the test set and generate a signal strong enough to register on the oscilloscope. Synchronize with the test set interrogation rate and observe the shape of the resulting P6 pulse. The phase transitions within P6 will cause amplitude modulation that can be easily observed.

The following combinations of texts and interrogation addresses AA will result in AP as shown:

UF=4, all fields = 0, AA = CO 51 F6 hex : AP = all ZEROs.
UF=4, all fields = 0, AA = 3F AB F2 hex : AP = AA AA AA hex.
UF=20, all fields = 0, AA = AC C5 55 hex : AP = all ZEROs.
UF=20, all fields = 0, AA = 53 3F 51 hex : AP = AA AA AA hex.

2.2 Second level- proposal for additional requirement

A theoretical analysis of transmitter using an IQ modulator shows that such transmitter will generate the phase reversal using the maximum time allowed by ICAO i.e., 80ns.

Measurements made for the EASA study confirmed that some phase reversal durations are measured at about 80ns. The measurements can even show longer phase reversal durations at the receiver side.

In addition to the clarifications proposed in section 2.1 above, the following modifications could be added to explicitly require the correct interrogation decoding with long phase reversal duration.

2.2.2.1 Interrogation Tolerances {ED-73C, §3.2.1}
Paragraph §2.1.11 and its subparagraphs define a number of deviations allowed in the interrogation values. The transponder **shall** be tolerant to all such deviations within the ranges specified in §2.1.11.

In particular the transponder shall be tolerant to the different types of phase modulators used to generate the phase modulation and accept phase reversal of a duration of 80ns.

Note: *The 1030 MHZ transmitter can generate phase reversal using different methods. This includes hard keying with strong amplitude drop and rapid phase reversal or IQ modulation with little or no amplitude drop but with frequency shift during the phase reversal and slow phase reversal (80ns).* ← *THIS Note to be accepted*

Note: *The transponder can not make any assumption on the type of modulation technology used and therefore cannot rely on the specificities of the signal during the phase reversal to detect a phase reversal.* ← *THIS Note to be accepted*

2.4.2.1 Receiver Characteristics (§2.2.2) {ED-73C 5.4.1.2}
Equipment Required:
ATC Test Set with P4 Capability (TIC T-50-3A/4B, or equivalent) and with slow phase reversal time capability using IQ modulator for step 9.

Measurement Procedure:
With the equipment connected as shown in Figure 2-24, interrogate the transponder with a standard Mode A interrogation and follow Steps l through 4 below.
…
Step 1 Sensitivity Variation with Frequency (§2.2.2.2)
..
Step 2 Sensitivity (§2.2.2.4 a and e)
…
Step 3 ATCRBS and ATCRBS/Mode S All-Call Dynamic Range (§2.2.2.4.f)
…

Step 4 Bandwidth (§2.2.2.3)
…
Step 5 ATCRBS and ATCRBS/Mode S All-Call Low-Level Reply Ratio (§2.2.2.4.d)
…
Step 6 Mode S (§2.2.2.4.b)
…
Step 7 Mode S Dynamic Range (§2.2.2.4.c)
…
Step 8 Mode S Low-Level Reply Ratio (§2.2.2.4.d)
…
Step 9 Mode S slow phase reversal duration (§2.2.2.1)

Note: *This step requires the use of test equipment having the capabilities to generate phase reversal using an IQ or similar modulator generating phase reversals in 80ns or more.*

Repeat Step 6 with phase reversal duration of 80ns or more.

3 Test bench issue

During the study commissioned by EASA to investigate the Mode S Signal-In-Space, the following phase reversal duration were measured on 3 types of test bench:

- Type 1: 28 to 57ns
- Type 2: 38 to 57ns
- Type 3: 10 to 38ns

The two main transponder Test bench manufacturers have been contacted. They have confirmed that, in general, their basic test benches use Type 1 modulator. However one company has an IFF test bench (IFF-45TS) that uses Type 2 modulator (IQ modulator) for which it might be possible to investigate the generation of the phase reversal in about 80ns.

4 Action

The meeting is invited to review the proposed modifications and to decide which modifications must be inserted in the transponder MOPS.