RTCA Special Committee 209 / EUROCAE WG49

ATCRBS / Mode S Transponder MOPS Maintenance

Joint Meeting #11

RTCA Headquarters, Washington, DC

8 – 10 September 2010

Potential Changes to RTCA DO181 & EUROCAE ED 73 As a result of the EASA Sponsored Study into Mode S Signal-In-Space and the Impact on Airborne Transponders

Kevin Hallworth

EASA

SUMMARY

This Working Paper is a 'follow on' to the presentation given by Dr.-Ing Jochan Bredemeyer at the last Joint SC 209/WG 49 meeting (Meeting 10) held in Malakoff, Paris on 28-29 June 2010.

The Working Paper contains the conclusions of the study and highlights the areas where EUROCAE ED 73C may require amendment.

1. Introduction

A study was commissioned by the European Aviation Safety Agency (EASA, Tender EASA.2009.OP.20) to investigate the Mode S Signal-In-Space and the impact on airborne transponders and a report was produced which documents the results

The main task of this study was to measure and analyse the actual signal-in-space as it exists in several parts of the European airspace with respect to radar and transponder performance. A new measurement receiver was developed for this purpose that allows a detailed investigation of signals transmitted by conventional SSR facilities, TCAS (Traffic Alert and Collision Avoidance System) equipped aircraft and ground-based multilateration systems. This receiver was installed in a special mission flight inspection aircraft, operated by FCS Flight Calibration Services GmbH. This recorded interrogation signals during various FCS measurement campaigns, totalling more than 100 flight hours.

As a result of the analysis, a number of recommendations for improvements of the Mode S specifications (ICAO Annex 10 and ED-73C) are suggested. These recommendations are aimed at ensuring that a transponder that successfully passed all ED-73C test cases and complies with the standards will actually work correctly in the Mode S operational environment.

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.

- Transponder reply rates required in the current operational environment are well below the minimum reply rate capabilities specified in the standards.

- Non-diversity transponder installations with only one antenna (as applicable for most General Aviation aircraft), mounted below the fuselage, pose no significant problem for radar detection or TCAS communication.

- Some TCAS units perform interrogations that are not compliant with ICAO Annex 10 and ED-73C.

- There are some discrepancies between ICAO Annex 10 and ED-73C that need to be resolved.

This working paper only addresses the suggested changes to EUROCAE ED 73C.

2. Potential Changes to EUROCAE ED 73C (and RTCA DO 181D)

2.1. Amplitude Drop Issue – Phase Reversal Detection

Like ICAO Annex 10, the current ED-73C also seems to assume a phase reversal with a drop in amplitude during phase reversal: It describes in section §5.5.8.1 a test method for protocol checks stating:

"... a simple diode detector is adequate for manual determination of the location of phase reversals in a 0 dBm signal..."

and later:

"The phase transitions within P6 will cause amplitude modulation that can be easily observed"

Since existing interrogators apply different methods for phase reversal (hard keying with strong amplitude drop or I/Q blending with little to no amplitude drop), the standards should reflect this and not make any assumptions on modulation technology. Furthermore, this might be misleading, since it unintentionally suggests an inadequate method for using the amplitude for demodulation instead of the phase.

2.2 Side Lobe Suppression Criteria

There is a clear contradiction between the side lobe suppression criteria as given in ICAO Annex 10 and ED-73C (see section §3.8 & §5.4.4): While ICAO Annex 10 states that no reply shall occur when P5 > P6 + 0 dB (upper threshold) and always reply when P5 < P6 - 9 dB (lower threshold), ED-73C specifies these limits to be 3 dB (upper) and -21 dB (lower). Also, the required transponder reply behaviour in the range between lower and upper threshold is not defined.

The report recommends the following changes:

1. Change ICAO Annex 10 and ED-73C to use the same thresholds.

2. Specify expected behaviour of transponder between lower and upper threshold values, e.g. gradual reduction of reply rate. Note: the safest option would be to state that an interrogator cannot rely to any reply above the lower threshold.

2.3 Transponder Test Equipment

Commercially available transponder test equipment generate ideal signals which may considerably differ from real signals-in-space. Only a few real interrogators radiate phase transitions comparable to those test sets. However, the interoperability between approved

transponders, complying with the MOPS, and existing radars must be sufficiently ensured. Therefore, it is proposed to introduce new transponder test equipment capabilities to synthesize multipath propagation effects and blending phase modulation, as stated in section §3.1.2.4. In case of a strong SLS effect overlaying the SPR at the beam boundary there might be an additional error contribution to the TOA determination and to the subsequent reply delay. The "Mode S Reply Delay and Jitter" limits specified in section §3.72 of ED-73C may be exceeded, so their actual values should be measured under dedicated SLS test conditions. This may be extended to certain multipath-affected signal conditions. In general, the MOPS should determine one or more worst-case interrogations, e.g., out of the variety given by this study, which is still suitable to elicit a reply. Those reference signals should then be generated by a suitable transponder test equipment. All discrepancies between ICAO Annex 10 and ED-73, as stated above, should be resolved.

3. Action

The meeting is invited to review the working paper and decide if any changes are required to existing documentation.