Final Project Report

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Abstract

Project 9.22 evaluated the need and viability for a 1090 MHz Automatic Dependent Surveillance - Broadcast (ADS-B) link technology evolution to fulfil ADS-B requirements of current and future Air Traffic Management (ATM) applications. The main motivation for this project was the concern that current 1090 MHz ADS-B link performance might not be sufficient to accommodate air traffic growth and related ATM services in the future. A phase modulation of 1090 MHz Extended Squitter (ES) was identified as promising ADS-B evolution. The selected technology was assessed by simulations and laboratory measurements. An overall evaluation of the phase modulation was summarized together with the necessary steps to enable standardization of the technology and its operational use. Moreover, the impact of proposed solution both on aircraft and ground systems was analysed as well.

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Acronyms

Acronym	Definition
ADS-B	Automatic Dependent Surveillance - Broadcast
ASAS	Airborne Separation Assistance System
ASP	Aeronautical Surveillance Panel
ASWG	Aeronautical Surveillance Working Group
ATM	Air Traffic Management
ES	Extended Squitter
ICAO	International Civil Aviation Organisation
OI	Operational Improvements
SESAR	Single European Sky ATM Research Programme
TRL	Technology Readiness Level
TSG	Technical Sub-Group

1 Project Overview

Project 9.22 evaluated the need and viability for the 1090 MHz ADS-B (Automatic Dependent Surveillance - Broadcast) link technology evolution to fulfil ADS-B requirements of current and future ATM (Air Traffic Management) applications. The main objective was to provide research resulting in requirements of next generation of ADS-B OUT datalink service to support future ATM services and applications. The current 1090 MHz ADS-B link was assessed and a phase modulation of 1090 MHz ES (Extended Squitter) technique (Phase Overlay) was identified as promising ADS-B evolution.

1.1 Project progress and contribution to the Master Plan

The project execution comprised of two phases:

- Phase 1 (2012-2014) focused on assessment of current ADS-B link and identification of possible ADS-B evolutions. The main steps were:
    - Gathering of requirements on ADS-B 1090 MHz link from application's perspective including new data and needs envisioned by other SESAR (Single European Sky ATM Research Programme) projects. It was concluded that an increase of overall broadcast rate of ADS-B messages (up to about 8.07 messages per second) is expected in the future (assuming the current ADS-B 1090 MHz link technology).
    - Determining whether the current ADS-B 1090 MHz technology as defined in DO-260B/ED-102A standard and complemented by SESAR 9.21 mitigations is able to accommodate the ATM needs at the 2025 horizon. It was concluded that the expected increase of broadcast rate will cause a degradation of airborne surveillance performance in the future horizon (2025 timeframe).
    - Identification of promising ADS-B evolution, namely, a phase modulation of 1090 MHz ES (Phase Overlay).
- Phase 2 (2014-2016) focused on assessment of phase modulation technique:
    - Assessment of Phase Overlay via simulations.
    - Development and assessment of a laboratory prototype incorporating Phase Overlay decoder.
    - Overall results evaluation and impact analysis of the Phase Overlay technology both on aircraft and ground.

The results of the project contribute to various OI (Operational Improvements) Steps and Enablers ([2], Dataset 15 [4]), where ADS-B technology is the main enabler. The project contributes both in direct and indirect way to the current and particularly to the future surveillance airborne applications and related SESAR solutions [5] (Enhanced ground controller situational awareness in all weather conditions, ASAS (Airborne Separation Assistance System) spacing applications ‘remain behind’ and ‘merge behind’, ADS-B surveillance of aircraft in flight and on the surface, Meteorological information exchange).

The following table presents relevant OI Steps and Enablers. AUO-0505 and A/C-48b have been identified beyond the Dataset 15 [4]. Moreover, A/C-30a has been assessed as more relevant to 09.22 project than A/C-30b stated in [4].

Code	Name	Project contribution	Maturity at project start	Maturity at project end
AUO-0505	Improved Air safety using data exchange via e.g. ADS-B for Wake Turbulence	Investigation of the link evolution allowing transmission of additional data without increasing the bandwidth and without increasing	V2	V2

	prediction	the link congestion		
A/C-30a	Onboard prediction of wake turbulences based on aircraft data exchange	Investigation of a link evolution allowing transmission of additional data without increasing the bandwidth and without increasing the link congestion	TRL4	TRL6
A/C-48b	Air broadcast of aircraft data (ADS-B OUT) compliant with new DO260C standard	Investigation of a link evolution allowing transmission of additional data without increasing the bandwidth and without increasing the link congestion	TRL2	TRL2
A/C-59	New ADS-B solution to increase the capacity of data broadcasted	Investigation of a link evolution allowing transmission of additional data without increasing the bandwidth and without increasing the link congestion	TRL3	TRL4
CTE-S03c	New ADS-B station for future ADS-B applications	Investigation of a backward compatible link evolution allowing transmission of additional data without increasing the bandwidth and without increasing the link congestion	TRL3	TRL4

1.2 Project achievements

The project addressed the following targets:

- Summarization of current and identification of future (envisioned by other SESAR projects, currently absent from ADS-B standard definitions) requirements on data to be broadcasted by ADS-B. A set of future requirements of additional data to be broadcasted with size of about hundreds of bits was identified in [6] and [8].
- The current 1090 MHz ADS-B link and its performance were assessed from the 2025 timeframe's perspective. A future degradation of airborne surveillance performance caused in consequence of expected increased broadcast rate of ADS-B messages was identified [7].
- Promising backward compatible link evolution technique (Phase Overlay) was identified [7]. The Phase Overlay creates additional information bandwidth for additional data (204 additional data bits per one Mode S ES message) without increasing the ES broadcast rate. Moreover, Phase Overlay is backward compatible with current 1090 MHz systems.
- The Phase Overlay technology was assessed by simulations [9] and laboratory measurements [10]. An overall evaluation of the Phase Overlay was summarized together with the necessary steps to enable standardization of the technology and its operational use [11]. The impact of Phase Overlay both on aircraft and ground systems was analysed [12].

The general outcome of the project is the identification and assessment of mitigation plan in case of future 1090 MHz link overload to support future ATM services and applications.

1.3 Project Deliverables

The following table presents the relevant deliverables that have been produced by the project.

Reference	Title	Description
D02	Assessment of the current ADS-B link and its evolution	The document provides assessment of ADS-B link (simulation results characterizing ADS-B surveillance performance in current and future environment) as predicted by an analytical model (considering future ADS-B requirements identified in D01, [6]). It also provides an evaluation of several promising mitigation techniques that should extend the life of the link including a phase modulation of 1090 MHz ES (Phase Overlay).
D03	Air to Air and Air to Ground Requirements Refinement	The deliverable describes the future ADS-B applications which will be developed in the coming years. In order to be implemented, they will need additional ADS-B parameters currently absent from ADS-B standard definitions. These additional data have been described in this document and are derived to requirements with associated performance values. These requirements are rough estimations of the expected performances.
D04	Modeling and simulation – ADS-B Evolution	This document provides description of a simulation model used for evaluation of the selected ADS-B evolution, which is a phase modulation of 1090 MHz ES. This document also provides simulation results and assessment of the selected ADS-B evolution.
D05	ADS-B Evolution Mock-up	The deliverable provides design details and performance evaluation of the laboratory prototype incorporating the Phase Overlay decoder.
D08	Results Evaluation	This document provides an overall evaluation of 1090 MHz link and selected link evolution. It provides a summary of the different results obtained as well as some remaining points that need to be further investigated before moving to operational use of the Phase Overlay technology.
D09	Impact Analysis of the technology on Aircraft/Ground	This document describes the impact of Phase Overlay on the aircraft and on the ADS-B ground systems, and highlights interoperability and backward compatibility issues.

1.4 Contribution to Standardisation

The results of the project were presented to several standardization working groups:

- ICAO (International Civil Aviation Organization) ASP (Aeronautical Surveillance Panel) TSG (Technical Subgroup): January 2015, [13].

- ICAO ASWG (Aeronautical Surveillance Working Group) TSG: January 2016, [14].

The Phase Overlay technique and relevant development status have been presented by several organizations to the ICAO TSG to be reviewed and considered in the future ADS-B standards, i.e. DO-260/ED-102. Project 9.22 addressed some activities (assessment of Phase Overlay performance and feasibility) related to the Phase Overlay technique preceding the own standardization process. A movement to an operational use of the Phase Overlay technology may be expected in the future. Nevertheless, currently there is no tangible need (e.g. application) driving the technology standardization and deployment of its operational use.

1.5 Project Conclusion and Recommendations

All objectives of project 9.22 were achieved. Project 9.22 assessed the current 1090 MHz ADS-B link and its performance from the 2025 timeframe's perspective considering a set of current and foreseen future requirements on data to be broadcasted by ADS-B.

A phase modulation of 1090 MHz ES technique (Phase Overlay) was identified and proposed as a promising link evolution. Phase Overlay technique was assessed by simulations. The technical feasibility was demonstrated by implementation of the Phase Overlay decoder into laboratory prototype. Performance of Phase Overlay decoder was assessed by laboratory measurements.

Both simulation and measurement results have indicated that Phase Overlay is a promising technique creating additional information bandwidth for additional data without increasing the ES broadcast rate. Moreover, the Phase Overlay is backward compatible with current pulse position modulation used for ADS-B messages (there is no impact on current aircraft's equipment functionality).

The project recommendations are as follows:

- Consider the Phase Overlay technique for the future ADS-B link evolution as it allows transmission of additional data that are foreseen to be required by future ATM applications.
- Address the remaining development and verification of Phase Overlay.
- Incorporate Phase Overlay into the future ADS-B standards, i.e. DO-260C/ED-102B or their subsequent versions.
- Monitor Enablers and OI Steps following ICAO Block upgrades where ADS-B is planned as a key technology. Requirements on the technology will be taken into account in SESAR 2020 timeframe activities.

2 References

[1] SESAR Programme Management Plan, Edition 03.00.01

[2] European ATM Master Plan

[3] Multilateral Framework Agreement ("MFA") signed between the SJU, EUROCONTROL and its 15 selected members on August 11, 2009, amended on 14 June 2010, 19 October 2010 and 2 July 2012

[4] Integrated Roadmap version DS15, 08/02/2016

[5] SESAR Solutions Catalogue, First Edition, 2016

[6] P09.22, Air to Air and Air to Ground Requirements, D01, Edition 00.00.02, 01/07/2014

[7] P09.22, Assessment of the current ADS-B link and its evolution, D02, Edition 00.02.00, 05/11/2014

[8] P09.22, Air to Air and Air to Ground Requirements Refinement, D03, Edition 00.00.03, 31/07/2015

[9] P09.22, Modeling and simulation – ADS-B Evolution, D04, Edition 00.01.00, 17/03/2015

[10] P09.22, ADS-B Evolution Mock-up, D05, Edition 00.00.03, 14/12/2015

[11] P09.22, Results Evaluation, D08, Edition 00.01.00, 31/05/2016

[12] P09.22, Impact Analysis of the technology on Aircraft/Ground, D09, Edition 00.01.00, 14/06/2016

[13] ICAO ASP TSG WP18-35 – Honeywell Activity is SESAR, January 2015

[14] ICAO ASWG TSG WP02-25 – Enhanced Mode S Reception Techniques Update, January 2016

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