Final Project Report

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Abstract

The document finalizes and shortly describes work that was done within the project SESAR 9.21. The document describes all major activities, outcomes and recommendations of the project for the future use.

Three mitigation techniques were identified and evaluated within the project. Simulation and measurement results indicated that the selected mitigation techniques can improve reception (in comparison to the baseline receiver as defined in DO-260B/ED102A) of the messages up to 20% in highly congested areas.

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Intellectual Property Rights (foreground)

This deliverable consists of SJU foreground.

Publishable Summary

The ADS-B link is one of the enablers that are envisioned for the future ATM airborne and ground applications. Data broadcasted by ADS-B are used for situational awareness on board or on the ground by applications such as ATSA – AIRB, SURF, ITP, ASPA-FIM.

To reach required performance of the current 1090 MHz link (as defined in DO260B/ED102A) is considered to be a potential issue in highly congested areas. This is due to level of interference which decreases the probability of message decoding. The decrease of probability of message decoding will have impact on use of the current and future ATM applications.

The 09.21 project aimed at defining and developing the mitigations techniques that would on one hand have no impact on the link definition and on the other hand would allow to increase performance of the link in terms of range and probability of decoding of the ADS-B messages.

The project ran in following phases:

- **REQUIREMENTS COLLECTION:** Requirements of the new applications and growth of interference in the future due to mandate on use of ADS-B were analyzed. The analysis showed that there is a need for mitigation for use of the link in extremely congested areas.
- **MITIGATION TECHNIQUES SELECTION:** In the second project phase, the team proceeded with identification and assessment of mitigation techniques that could improve reception of the ADS-B messages even in the high interference environment. Their employment shall enable utilization of the link for current and envisioned applications for the short- and mid-term use.

  The selection of the mitigation techniques was based on discussions with representatives of the project 15.01.06. This project was focusing on the environmental issues on 1090 MHz frequency band.

The mitigation techniques evaluated during project are:

  - Enhanced Bit and Confidence Declaration (EBCD), The technique improves bit & confidence declaration algorithm exploiting pre-generated lookup tables
  - Blind Beamforming (BB). The technique aims to separate overlapping surveillance messages prior to a conventional decoder by processing the data received by an antenna array
  - Sectorized Antennas (SA). The technique exploits a spatial diversity through the use of multiple directive antenna beams, followed by multiple receivers.

- **MITIGATION TECHNIQUES VERIFICATION:** Verification of the mitigation techniques were provided by simulations and laboratory tests of the receiver with implemented mitigation techniques. The verification was based on the standard DO260B/ED102A tests and additional tests that raised from nature of the mitigation techniques.

  Even the project plan was to select, develop and evaluate one mitigation technique, during project execution was decided to work on three the most promising techniques. The decision was based on comparison done during task 003("Operation of the current ADS-B in future RF environment") where we found that some techniques are costly for implementation across all aircraft categories and some techniques can benefit to current aircraft without significant changes in hardware and software.

Current performance analysis	T9.21-001 Assessment of the current 1090 MHz ADS-B transmission technique
	T9.21-002 Consolidation of the requirements of the future ADS-B applications

Definition and modeling of the proposed solution	T9.21-003 Description of the proposed techniques and selection of a solution
	T9.21-004 Specification of the selected solution
	T9.21-005 Airborne ADS-B model creation
	T9.21-006 Impact assessment on the aircraft

T9.21-007 Simulation	T9.21-007.1 Model simulation
	T9.21-007.2 Simulation results evaluation

T.9.21-008 Lab prototyping	T9.21.-008.1 Lab prototype design
	T9.21.-008.2 Lab tests evaluation and assesment

Figure 1: Project Structure as described in Project Initiation Report

Use of any of the three proposed mitigation techniques was proved to be feasible and they might be implemented into the real product. Decision on which one to implement shall be taken in line with the expectations of user on cost-benefit ratio. The simulation results and laboratory tests on mock-up indicated that blind beamforming outperforms sectorized antennas and enhanced bit & confidence declaration techniques. EBCD only impacts the unit, as it only requires software update. No significant hardware modification is expected for this technique. As a consequence this technique is applicable for retrofit by updating the software contained in the unit. BB technique using an existing TCAS antenna composed of multiple antenna elements (existing TCAS installed on SA aircraft use antennas which are composed of 4 unidirectional antenna elements) has a quite low impact on aircraft installation. It only requires an update of the unit, as the wiring is already present and the antenna elements allow performing mitigation with use of blind beamforming technique. SA technique requires modifications only impacting the TCAS unit itself. Both hardware and software modifications are needed. As these solutions do not need installation modification, they seem adapted for retrofit installation, no interface modifications are needed.

The results of the project were deemed as positive. The results indicated that mitigation techniques can improve reception (in comparison to the baseline receiver as defined in DO-260B/ED102A) of the messages up to 20% in highly congested areas. Another fact is that mitigation techniques can be implemented not only airborne side but potentially on the ground side as well.

It can be concluded that mitigation techniques as proposed by the project can partially solve the issues of the ADS-B on 1090 MHz frequency and enable use of the current link by applications without changes of the link in short- and mid-term period.

The results of the project were presented to the ICAO ASP (April 2014) and ASP-TSG (January 2014) standardization groups. Apart from receiving a positive feedback, project results were deemed as potential material for future standardization.

Results of project 9.21 are further utilized within project SESAR 9.22 “Mid and Full ADS-B Capability – Research”.

The project team was composed from Honeywell as a main provider of the surveillance technology and Airbus that is leading aircraft manufacturer.

Final Project Report

Contribution to the Roadmap

The results of the project contribute to various OI, where ADS-B is the main enabler. The contribution can be seen as direct or indirect for the current and future surveillance airborne applications. Also, the techniques developed in the project contribute to all categories of future ACAS-X (Xa, Xo, Xu and Xp).

EN Code	EN Title	Activities, Contributions
A/C-25	Airborne Traffic Situational Awareness to support surface operations (ATSA-SURF), including reception (ADS-B in), processing and display	Assessment of the performance of current link to support application
A/C-26	Airborne Traffic Situational Awareness to support in flight operations (ATSA-AIRB), including reception (ADS-B in), processing and display	Assessment of the performance of current link to support application
A/C-27	Airborne Traffic Situational Awareness to support enhanced Visual Separation on Approach (ATSA-VSA), including reception (ADS-B in), processing and display	Assessment of the performance of current link to support application
A/C-28	Airborne Traffic Situational Awareness to support In-Trail Procedure (ATSA-ITP), including reception (ADS-B in), processing and display	Assessment of the performance of current link to support application
A/C-29	Onboard conflict detection and resolution to support ASAS self-separation	Assessment of the performance of current link to support application
A/C-59	New ADS-B solution to increase the capacity of data broadcasted	Investigation of a way to keep performance of the link to support future applications without need for radical changes. The project contributes to the SESAR 9.22 where new link need is under investigation
CTE-S2c	ADS-B 1090 in/out (260A+) to support initial separation (step 4)	Improvements of the reception side of the link to achieve higher integrity
CTE-S3	New ADS-B link	Assessment of the link performance, improvements on the reception side to allow the increase of capacity of data broadcasted

Project Achievements

The main project achievement was the development and testing of a new approach for ADS-B signal reception to increase probability of the message detection in highly congested areas. Proposed solutions do not have any impact on the link as defined in DO-260B/ED102A, i.e. the solutions are backward compatible.

Project demonstrated a potential way forward for extension of service life of current 1090 MHz ADS-B link without changes on the waveform. Also, mitigation techniques increase integrity of the reception and decoding of the broadcasted messages in the highly congested areas.

Project Deliverables

Nine deliverables were delivered to the SJU during project execution- the ninth being this final report. All deliverables were accepted with positive feedback and only minor comments appeared during gate discussions. Three mitigation techniques for 1090 MHz ADS-B were evaluated to support use of the link for the short- and mid-term use. Short descriptions of all deliverables and their outputs are provided below.

Del. code	Deliverable Name	Description
D01	ADS-B transmission technique assessment	The document provided an overview and assessment of ADS-B surveillance performance. Key interference mechanisms were identified and prioritized with examples from real measurements. Simulation results characterizing ADS-B surveillance performance in high density traffic environment were presented. A brief discussion of multi-path issues, which are especially present during surface operations, was also presented. A surveillance performance metric used was discussed as well.
D02	Requirements on the future ADS-B from application point of view	For current and future ADS-B applications, the document listed key performance requirements such as an update interval and detection range. For the requirements collection of SESAR Step 1 applications (e.g. ATSA-SURF, ATSA-AIRB, ATSA-VSA and ATSA-ITP), the data and performance requirements were taken from standardization documents. The document addressed performance requirements for candidate applications for SESAR Step 2 deployment and some more advanced Airborne Separation Assistance System (ASAS) applications (in the scope of SESAR Step 3) were also considered. Requirements had not yet been established for a significant number of ADS-B applications that time and for these applications assumptions have been established, based on engineer judgment.
D03	Techniques comparison and solution selection	The document described promising solutions for mitigating current ADS-B 1090 MHz link performance issues. Evaluation of the methods took into account various criteria. The methods were divided into two main groups according to whether they showed an impact on the ADS-B OUT or ADS-B IN side of the link or not. The methods that required changes on the ADS-B OUT side (power management, media access control protocol) lead to extra cost for final users and thus were excluded in line with SJU recommendations. For further investigation, methods that affected only the ADS-B IN side were preferred. Three mitigation techniques (enhanced bit and confidence declaration, sectorized antennas and blind beamforming) were selected for further investigation due to: • Low impact on avionics

		• No impact on backward compatibility
D04	Preliminary specification of the selected solution for the future 1090MHz ADS-B	This document described functional and performance requirements for an improved ADS-B receiver as presented in deliverable D03, where multiple levels of ADS-B receiver improvement were presented as sufficient solutions. These methods covered both lower and higher interference mitigation efficiency, which has low impact on avionics and no impact on backward compatibility. Sample architectures/implementations that satisfy the performance improvement levels were provided.
D05	Airborne ADS-B Model	D05 described the ADS-B model which was used in the next phase of the project (deliverable D07) to evaluate mitigation techniques presented in the previous stages of the project (deliverable D03 and D04). The model comprised all parts of transmission chain, including transmitters, channel, antenna and receiver (including both analogue and digital part). All modules of ADS-B model enabled to capture the characteristics of ADS-B receivers, both of a standard receiver or and of receiver with the proposed 9.21 improvements. The model functionality was validated by number of tests as described in the DO-260B/ED102A.
D06	Impact assessment on the aircraft	The document concluded that all three solutions (proposed improved receivers) can be either mandatory or optional for airlines. However, in order to gain the attention of the airline benefits have to be clearly demonstrated (the solution can be necessary for some future applications, for flying in certain airspaces e.g. surface movement or high density traffic operations). Concrete impact on aircraft installations is as follows. The simulation results and laboratory tests on mock-up indicated that blind beamforming outperforms sectorized antennas and enhanced bit & confidence declaration techniques. EBCD only impacts the unit, as it only requires software update. No significant hardware modification is expected for this technique. As a consequence this technique is applicable for retrofit by updating the software contained in the unit. BB technique using an existing TCAS antenna composed of multiple antenna elements (existing TCAS installed on SA aircraft use antennas which are composed of 4 unidirectional antenna elements) has a quite low impact on aircraft installation. It only requires an update of the unit, as the wiring is already present and the antenna elements allow performing mitigation with use of blind beamforming technique. SA technique requires modifications only impacting the TCAS unit itself. Both hardware and software modifications are needed. As these solutions do not need installation modification, they seem adapted for retrofit installation, no interface modifications are needed.
D07	Simulation of solutions for future 1090MHz ADS-B	The document featured simulation results of the selected promising mitigation techniques. The performance of these techniques was compared to the standard receiver, using the

		simulation model described in the deliverable D05. From the simulation results, following conclusions can be drawn: • Sectorized antennas technique outperforms baseline receiver and receiver with EBCD implemented. The performance of this technique is antenna pattern dependent. • Receiver with enhanced bit and confidence declaration technique performs better than baseline receiver. However, it requires significant memory for look-up table. The performance of the technique is proportional to the fidelity of pre-generated lookup table. • Blind beamforming technique outperforms all other investigated techniques. This technique is however computationally demanding.
D08	Laboratory prototype design, evaluation and assessment	This document provided design details and performance evaluation of the laboratory prototype incorporating the selected mitigation techniques. The performance of these techniques was compared to the standard receiver that was implemented according to DO-260B / Appendix I. All measurement results basically corresponded with simulation results. There were only slight differences related to implementation matters. Even though the measurement results served for evaluation and comparison of selected techniques, the overall assessment and determination of the most suitable technique was not provided within this document. This is due to the fact that it is necessary to understand and consider the requirements of the environment, the cost, certification process and feasibility of the techniques. From the implementation process and measurement results, following conclusions can be drawn: • All measurement results basically correspond with simulation results. • All three mitigation techniques are feasible and might be implemented into the real product.

More detailed project results are available to other SESAR projects under conditions as stated in the MFA.

Impact on Standardization Bodies

The results of the project were presented to the ICAO ASP (April 2014) and ASP-TSG (January 2014) standardization groups. Apart from receiving a positive feedback, project results were deemed as potential material for future standardization.

Further coordination of standardization bodies is planned to continue both as member's internal follow up of SESAR 9.21 project and additionally as part of 9.22 activities.

Project Recommendation

The project recommendations are as follows:

- To consider the mitigation techniques within project SESAR 9.22 for the evaluation of the 1090 MHz link for the long-term use.
- To consider to standardize mitigation techniques in the future ADS-B standards, i.e. DO260/ED102.
- To consider results of the project by other SESAR projects, such as 9.14, 9.22, 9.47, etc., where ADS-B is enabling technology.

References

[1] 9.21 D01, ADS-B Transmission Technique Assessment, SESAR Project 9.21 deliverable, 2011.

[2] 9.21 D02 Requirements on the future ADS-B from application point of view, SESAR Project 9.21 deliverable, 2011.

[3] 9.21 D03, Techniques Comparison and Solution Selection, SESAR Project 9.21 deliverable, 2011.

[4] 9.21 D04, Preliminary Specification of the Selected Solution for the Future 1090MHz ADS B, SESAR Project 9.21 deliverable, 2012.

[5] 9.21 D05, Airborne ADS-B Model, SESAR Project 9.21 deliverable, 2012.

[6] 9.21 D06, Impact assessment on the aircraft, SESAR Project 9.21 deliverable, 2012.

[7] 9.21 D07, Simulation of Solutions for Future 1090 MHz ADS-B, SESAR Project 9.21 deliverable, 2013.

[8] 9.21 D08, Laboratory prototype design, evaluation and assessment, SESAR Project 9.21 deliverable, 2014.

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