Final Project Report

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Abstract

Project 9.44 aimed at investigating the technical and business feasibility, and at identifying solutions of new on-board flexible radio architectures and equipment which could support several or the totality of the future and legacy airborne radio communication elements.

Prototypes of the candidate flexible radio equipment solutions were developed for demonstration of the feasibility of key technological items and proof of the overall concepts

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Intellectual Property Rights (foreground)

This deliverable consists of SJU foreground.

Acronyms

Acronym	Definition
AEEC	Airlines Electronic Engineering Committee
AeroMACS	Aeronautical Mobile Airport Communications System
API	Application Programming Interface
ATM	Air Traffic Management
AU	Antenna Unit
CNS	Communication, Navigation, Surveillance
EMI	Electromagnetic Interference
HF	High Frequency
HPA	High Power Amplifier
IMA	Integrated Modular Avionics
LDACS	L-band Digital Aeronautical Communication System
LNA	Low Noise Amplifier
NRC	Non-Recurring Costs
PA	Power Amplifier
RF	Radio Frequency
RU	Radio Unit
SBB	Swift Broad Band
SDR	Software Defined Radio
TRL	Technology Readiness Level
VDL	VHF Data Link
VHF	Very High Frequency

1 Project Overview

The SESAR Project 9.44 “Flexible Communication Avionics” aimed at investigating the technical and business feasibility, and at identifying solutions of new on-board flexible radio architectures and equipment which could support several or the totality of the future and legacy airborne radio communication elements; prototypes of the candidate flexible radio equipment solutions were developed for demonstration of the feasibility of key technological items and proof of the overall concepts.

1.1 Project progress and contribution to the Master Plan

The SESAR P09.44 flexible radio architecture concepts have been verified through the development of prototypes and laboratory testing, completed by some transverse studies.

A first developed prototype (from Honeywell) consisted in a generic radio software computing platform able to run simultaneously two radios software in interoperation with remotely distributed RF front ends. This prototype was verified and demonstrated by running simultaneously on this platform a VHF radio software, and an Inmarsat SBB radio software. The prototype also supported dynamic reconfiguration of the radio software on the platform and a Radio Resource Manager was developed to demonstrate the capability to change dynamically one radio software by another during a simulated flight, as a function of some contextual conditions. The prototype radio software computing platform was tested in combination with a prototype Antenna Unit functionally representative of the RF Front End equipment

The second developed prototype -from Finmeccanica Airborne & Space Systems Division (Selex)- is a “behavioural” demonstrator, aiming at showing the possibility of decoupling different RF front-ends from arrays of digital signal processing stages. It also consisted in a generic radio software computing platform able to run simultaneously two radios software in interoperation with remotely distributed RF front ends. This second prototype was verified by running simultaneously on this platform an HF radio software, and an AeroMACS radio software. The demonstration aimed at evaluating effectiveness of the distributed SDR architectural concept with respect to the expected characteristics of modularity, re-configurability and, fault tolerance with graceful degradation. The verification exercised concentrated on providing evidences on the capability of the demonstrator to operate multiple radios simultaneously and to dynamically modify its configuration, following a failure affecting one or more modules, based on a predefined logic.

Transverse studies aimed at assessing the benefits and some potential technical and industrial difficulties of the flexible communication avionics architecture, notably security and certification aspects, and potential impacts on the industrial and business models for the supply of avionics radios.

The project worked on new technologies that should allow easing evolution and transition of the Aircraft radios toward future communication technologies. The flexible communication radios technologies can be considered as an indirect enabler for other SESAR technical Enablers and OI Steps being linked to the technological enabler CTE-C02g

Code	Name	Project contribution	Maturity at project start	Maturity at project end
CTE-C02g	Air to Air functionality of New A/G radios	The project allowed to identify promising potential benefits that could be obtained with flexible airborne radio architectures,	N/A	TRL-4

		demonstrated the feasibility of key technological items and gave proof of the overall concepts.		

Potential impacted OIs : AOM-0304-C, AUO-0505, CM-0704, CNS-0001-C, IS-0406

The SESAR P09.44 delivered the SESAR Solution "Flexible Communication Avionics".

1.2 Project achievements

The SESAR P09.44 project obtained the following results:

- During P09.44 Phase 1:
  - Statement of requirements applicable to Airborne communication Systems in the future
  - Reporting on prospective technologies and concepts, and study and assessment of new candidate architectures for short/medium term evolutions and for longer term future global optimisation of the radio systems on Mainline and Regional Aircraft.
  - Selection of the most promising options and preferred future architectures for the communication systems on mainline and regional Aircraft
- During P09.44, Phase 2:
  - Two different prototypes of flexible radio platforms hosting multiple waveforms have been developed.
  - Laboratory tests of these prototypes have been completed
  - General studies have been performed to investigate potential issues that could arise with the use of flexible radio architectures. Associated deliverables are listed in the next section.

P09.44 heavily contributed to Airbus and Finmeccanica Aircraft Division (Alenia) studies, roadmaps and strategic plans regarding the evolution to the Aircraft radio systems, and was key for the decision to commit further effort within the Clean Sky 2 programme, where the flexible radio architectures is a central topic of important Work Packages.

1.3 Project Deliverables

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

Reference	Title	Description
D10	SESAR P09.44 Phase 1 Executable Summary	The purpose of this document is to create a summary of the Phase 1 of SESAR P09.44. This document includes selected data from internal restricted deliverables D01-Requirements, D02-Technology, D03 – Architecture for Mainliner A/C, D04-Architecture for Regional A/C and D05&D06-Prototypes definition. The textual (word document) version of this executable summary is available for SESAR Members only. A power point presentation of this Executable Summary has been made for dissemination to non-SESAR members

D12	Report on the current status of research and Development in the SDR field	This document reports on a survey of the current state of the art and of the existing studies in the field of Software Define Radios and on the possible applications of Software Defined Radio technologies for the development of civil aeronautical communication systems.
D14	Report on the possible industrial models for the development of SDR-based Aeronautical radios	This report aims at identifying different business models for the development of SDR-based Aeronautical radios and at assessing them through a list of selected criteria. Advantages and drawbacks of each industrial scenario are identified, and discussed.
D15	Initial proposal for a technical aeronautical SDR standard	This document explores the need and potential directions to start standardisation activities in the domain of airborne Software Defined Radios architectures and Systems.
D16	Draft elements for SDR development and certification guidance	This document elaborates regulatory, certification, or process recommendations that could be made for the development of SDR-based aeronautical radios. It aims at providing draft avionics SDR development and certification guidance material.
D17	Draft elements for SDR development and security guidance	This document considers the additional security risks introduced by the use of SDR technologies for the airborne radio communications equipment, and assesses the need for specific counter-measures and/or particular security assurance processes that could become applicable with the development of such radios
D21	SESAR P09.44 Phase 2 Conclusion report	This document is the overall conclusive report on the Phase 2 of the SESAR 9.44 project. It Reminds the main architectural principles under study in SESAR 9.44 for the design of avionics radios in the future; it explains the benefits that could be expected from the adoption of the SESAR 9.44 flexible radio concepts; it discusses on potential open points, difficulties, and trade-off that may remain to assess; it provides the main outcomes from the SESAR 9.44 prototypes development and tests, and from the transverse studies; and finally, it concludes on the perspectives for future implementation of flexible avionics radios on Aircraft, and on the proposed way forward. The document also includes, in its appendix, an executive summary of all SESAR 9.44 Phase 2 activities
D29	SESAR P09.44 WA1 Final Report	This document is the conclusion report on the Phase 2 - Working Area 1 of the SESAR 9.44 project. - the Honeywell activities in the SESAR 9.44 project. It provides general description of the Flexible Communication Architecture and approach to the prototype development adopted by Honeywell team. It also provides generic results from the verification exercise executed on the Flexible Communication Demonstrator. In order to

		introduce and promote the project to wider SESAR community, a graphical leaflet and a video were created and are incorporated in the deliverable.
D39	SESAR P09.44 WA2 Demonstration test report	This document is the Verification report from Phase 2 Working Area 2 of the SESAR 9.44 project, relevant to the Selex ES / Alenia Flexible Communications Avionics demonstrator. It describes the results of verification exercises and how they have been conducted.

1.4 Contribution to Standardisation

Considerations on the Flexible Communication Avionics standardization framework have concluded that there are a number of technical elements for which there might be a need or an interest for standardization. These are:

- the digital interface between the computing platform hosting generic baseband radio software and the RF front-ends
- the software interface (API) between the radio software (waveform applications) and the generic baseband radio software computing platforms
- A possible centralized management interface with the Flexible Communication Avionics to command and control the dynamic reconfigurations of the radios
- the digital interface between the radio and the voice/audio peripherals
- the interface between the avionics radios and the avionics routers
- the packaging (Fit and form) for generic baseband radio software computing platform and RF Front Ends

These potential standards would have to be conducted by AEEC.

The project however considered that it was premature to launch standardisation activities, due to the following aspects:

- The need for standards is pending the resolution of some identified open points, difficulties and trade-off, which include notably interrogations on the business model and work share which should be applied for the procurement and supply of the components of the Flexible Communication Avionics architectures.
- Even if standardisation at AEEC of flexible avionics radio technologies is felt to be desirable at some stage, standardisation might also be counterproductive in that, when a standard will exist, it may impose one unique solution, and restrain innovations that could otherwise be spontaneously and individually proposed by suppliers
- It is generally desirable to delay the production of such AEEC standards until a first candidate Aircraft program, and use case, have been identified for a first implementation of the standards, which may not be the case.

Other reasons can be that:

- Future Communication Systems (LDACS, Satcom Class A, AeroMACS) will come in the long term
- Near term new communication systems (Satcom SBB Safety, Iridium next) are already being standardized as separate equipment, with no particular modularity being exhibited.

- CNS radio integration is a long term study item.

1.5 Project Conclusion and Recommendations

One primary conclusion of P09.44 is that the proposed concept of distributed Software Defined Radios architectures has the potential to bring many benefits at Aircraft level, among which:

- Lower Product Recurring Cost, due to a reduced number of hardware parts, software reuseability, and greater independence from the variable quality and behaviour of analog components
- Lower Supplier NRC, because the Suppliers can implement and verify new communication products (e.g. new protocols) more easily (software development and debug) , and can reduce the prototyping time (and so the time-to-market)
- Lower aircraft production costs, because the conventional mechanical RF structures (high-quality connectors, waveguide, coaxial wires and brackets) which are numerous, expensive, and installation effort consuming can be replaced by less constraining digital buses
- Weight savings – on the wiring, due to replacement of RF coaxial cables by thinner, lighter, and bundled digital cables
- Weight savings – at equipment level, with the simplification of the analog radio stages (HPA, LNA,…) placed closer to the antenna, and the factorisation of the baseband parts into a smaller number of shared computing platforms hosting and running multiple radio software.
- Reduction of Interference Issues, because long RF coaxial cables (which have EMI radiation and susceptibility issues) are replaced by digital buses
- Design Flexibility, Upgradability, Reusability, Reconfigurability, as a number of radios functions are implemented with software
- Improved Reliability, because “software cannot break”, and thanks to reconfiguration possibilities

The prototypes development and testing allowed collecting positive evidences on:

- The interest and feasibility of distributed Software Defined Radios architectures
- The capacity to exploit software defined radio technologies, in order to achieve the required multifunctional capabilities and ease growth capability for future radio services
- The flexibility of use, i.e. the capability to reconfigure the available hardware and software resources, so as to provide different radio services, while optimizing the number of required hardware elements
- The capacity of these architectures to support the implementation of both legacy (HF, VHF, …) and new generation (AeroMACS, INMARSAT SBB, …) radio technologies
- The feasibility to implement radios that can be dynamically reconfigured during a flight following a failure or as a way to adapt the Aircraft communication capabilities to the communication services effectively available at the present moment of the flight.

However, some key points remain to be considered on the path to concept viability. In particular:

- The appropriateness of installing remote RF Front End units close to (or within) the antenna, in regard to all the associated installation constraints, notably on accessibility/maintainability, heat dissipation issues, impacts of tough environmental conditions on reliability, aircraft power distribution, and certification constraints.
- The most appropriate repartition of the radio digital signal processing components over the Radio and the Antenna Units, with pros and cons identified for the different alternatives

- The fact that new or future communications systems (e.g. AeroMACS, IRIDIUM-next, INMARSAT SBB) have to or can beneficially rely on proprietary hardware chipsets, which can move them away from architectural concepts assuming the use of software waveforms running on generic hardware SDR platforms
- Concerns that have been raised on the likely high costs of the certification of multi-waveforms, reconfigurable radio units.
- The interest and feasibility of a convergence between software radio platforms and IMA platforms.
- The potential impacts of such distributed flexible radio architectures on the business model currently established for the procurement of radio by Airframers and Airlines from Avionics Suppliers
- Finding a first opportunity for introduction of such flexible distributed radio architectures, in a context where new aircraft development programs and future communication systems developments are placed in the long term..

So, while the Flexible Communication Avionics concept is considered technically feasible and promising, further studies and verifications must be done before envisaging implementation and certification of such distributed software defined radio architectures on Aircraft.

The proposed way forward is to focus future initiatives on the development and resolution of the points summarised above. These should comprise:

- project(s) to study further, experiment (with TRL-6 prototypes) and validate the concept of using remote Antenna Units installed close to or within the antennas, to address questions on Installation and accessibility/maintainability, Heat dissipation, Reliability, Power distribution, Lightning effects survival and Certification constraints for these units. Ideally, the prototyping activities done in this scope should allow reaching a next phase for SDR architecture maturity, by going further in the level of integration of the prototypes on Aircraft, particularly at the level of the Antenna Unit integration, but also at the level of the Radio Unit by implementation of interfaces with other aircraft systems (e.g. A429 buses), and verification of the whole prototyped radio subsystems through integration with the other aircraft systems, on an aircraft or on a fully representative aircraft environment test rig.
- project(s) to study further and experiment the interest and feasibility of a possible convergence in between IMA platforms development and flexible distributed radio architectures. Convergence of baseband processing units and IMA future developments is assessed to be a potential additional contributor to the benefits, but requires more detailed and collaborative work between IMA and radio specialists, to confirm or infirm the business and technical feasibility, and to establish scenario for a possible SDR-IMA platforms convergence time line, which could be a driver for starting standardisation activities.
- A study aiming at identifying the possible near to medium terms opportunities that may appear for a first introduction of the flexible distributed radio architecture concepts on an Aircraft program.
- Finally, it will be necessary at some stage to create an appropriate forum for avionics Suppliers and Airframers to discuss if a consensus can be reached on a common and global (standardized) approach for implementation of future generation of aircraft radio systems, based on the flexible distributed architecture concepts studied in SESAR P9.44. This forum will certainly be within AEEC scope. It is unclear today however if such forum will be/should be created at the initiative of the Suppliers or of an Airframer, and at which term it should be initiated. Progress on the three first above initiatives, coupled with individual or common airframer-supplier workshops, should eventually lead to decisions on this point.

The following additional topics could be considered in projects set up to explore longer term opportunities:

- The project identified opportunities and associated promising benefits for future cross CNS domains integration of C, N, and S base band processing functions. This opens the door to further initiatives, to progress the study a step further, e.g. to address feasibility of integrating/communalizing CNS radio waveforms, front ends and antennas.

- Study of Wide-band Antenna Units and antennas

In SESAR 2020, the following SESAR Solutions could be enabled by this technological flexible radio solution:

- CNS environment evolution
- CNS avionics integration
- FCI Terrestrial Data Link
- Future Satellite Communications Data link
- FCI Network Technologies incl. voice solution and military interfacing
- Development of new services similar to FIS-B to support ADS-B solutions for General Aviation
- Completion of AeroMACS development.
- GBAS
- Multi Constellation / Multi Frequency (MC/MF) GNSS
- Alternative Position, Navigation and Timing (A-PNT)
- Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations
- ACAS for Commercial Air Transport specific operations

2 References

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[2] European ATM Master Plan

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[7] P9.44.-D06: Project 9.44 Phase 2 Work and Costs proposal, 00.02.01, 28/02/2012

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[10] P9.44.-D23: D1.1: System requirements review [SRR v1], 00.01.01, 19/02/2013

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[13] P9.44.-D24: D1.2: System Design review [SRR v2 ADR v1 TR v1], 00.01.00, 03/01/2014

[14] P9.44.-D14: D3.4: Report on the possible industrial models for the development of SDR-based Aeronautical radios, 00.01.00, 17/01/2014

[15] P9.44.-D17: D3.7: draft elements for SDR development and security guidance, 00.01.00, 17/01/2014

[16] P9.44.-D32: D2.1: Report on Selex demonstrator Requirements and Design, 00.01.00, 19/05/2014

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[18] P9.44.-D16: D3.6: draft elements for SDR development and certification guidance, 00.02.00 12/01/2015

[19] P9.44.-D25: D1.3: Prototype v1 CDR [SRR v3 ADR v2], 00.01.00, 31/03/2015

[20] P9.44.-D36: D2.5: Report on demonstrator Simulation Environment definition, 00.01.00, 12/05/2015

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[22] P9.44.-D27: D1.5: System Requirements Report [SRRv4], 00.03.00, 31/05/2016)

[23] P9.44.-D33: D2.2: Updated Report on Selex Demonstrator Design, 00.01.00, 10/02/2016

[24] P9.44.-D41: D1.11:Radio resources management Architecture definition report, 00.02.00, 23/05/2016)

[25] P9.44.-D40: D1.9:Antenna Unit Architecture definition report, 00.01.00, 25/05/2016

[26] P9.44.-D28: D1.5: Architecture Definition Report [ADRv3], 00.01.00, 15/06/2016

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[31] P9.44.-D39: D2.8: Demonstration test report, 00.01.00, 18/07/2016

[32] ATM Master Plan / Integrated Roadmap - dataset 15

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