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SESAR 2020 PJ.14-W2-84d - Phase Overlay for ADS-B - Contextual Note - TRL6

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INTEGRATED COMMUNICATION, NAVIGATION AND SURVEILLANCE SYSTEMS

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Abstract

This TRL6 Contextual Note provides the SESAR2020 Solution PJ.14-W2-84d description for industrialization consideration. This Solution addresses Phase Overlay technology for ADS-B and Mode S features.

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1 Purpose

Currently, the ADS-B technology is one of the main sources of aviation surveillance, and its relevance is reflected in the CNS Roadmap[1], where included as future surveillance backbone. Therefore, any new feature added to this system will improve the performance of the system, what could lead to benefits in other areas such as safety and airspace capacity.

In the last RTCA and EUROCAE DO-181F/ED-73F and DO260C/ED-102B standard documents, a new optional feature was included for the ADS-B: **Phase Overlay**. This new technology consists in overlapping a phase modulation (8PSK) on top of the current waveform modulated in amplitude (PPM) in order to transmit more data, increasing from 112 to 448 raw bits (effectively, from 54 to 204). This extension can be used for different applications, from transmitting new types of data (such as weather information), add cybersecurity layers (ADS-B technology is currently not protected and its service can be degraded by spoofing or eavesdropping attacks) or reduce the 1090MHz frequency congestion (diminishing the transmission rate sending the same amount of data in less messages). In addition, as the new modulation does not affect the original one, backwards compatibility is ensured.

The objective of the SESAR2020 PJ.14-W2-84d Technological Solution is to verify the well-functioning of this feature at technology level targeting TRL6 maturity level and validate its concept for its future application development and later deployment. For this purpose, the technical goal of this Solution is to evolve the enablers **A/C-48b (*Air broadcast of aircraft data – ADS-B Out – compliant with new DO-260C/ED-102B standard*)** and **CTE-S03c (*New ADS-B stations for future ADS-B applications*)**, thus enabling the following and unique Performance Operational Improvement: **POI-0060-SUR (*Phase Overlay for ADS-B*)**.

[1] SESAR2020 D2.1.200 PJ.14-W2-76 CNS Evolution Roadmap and Strategy, Ed.00.04.05, November 2021

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2 Improvements in Air Traffic Management (ATM)

SESAR2020 Technological Solution PJ.14-W2-84d refers to the validation of the Phase Overlay concept for ADS-B and Mode S features at technological level to achieve a TRL6 maturity level at the end of the SESAR2020 Wave-2. The Phase Overlay feature consists in a phase modulation (8PSK) message added on top of the current amplitude-modulated (PPM) ADS-B squitter, what results in an increase of the transmitted data bits, raising them from 112 to 448 bits (effectively, from 54 to 204). This data extension can be used for several applications such as the transmission of more information (such as weather), cybersecurity applications or potential reduction of the spectrum congestion (gathering the information of 4 different messages into only one). In addition, this technology covers all phases of flight: Surface, Terminal Manoeuvring Area and En-Route.

This new ADS-B feature can bring many benefits to the ATM community depending on the application decided for this technology. Using the potential applications mentioned in last paragraph as reference:

- The transmission of new types of information, like weather data, could provide pilots and ATCOs more situational awareness, allowing them to make better choices during the flight.
- The introduction of cybersecurity layers (such as an encrypted digital signature) could allow the ATM community to guarantee the integrity and authentication of the ADS-B messages sent by a real aircraft and mitigate potential attacks like spoofing, eavesdropping or data modification.
- With a change in the normative and a world common agreement to change the ADS-B message transmission rate, it could be possible to send the information of almost four different current ADS-B messages in just one Phase Overlay ADS-B squitter. This could allow to reduce the frequency spectrum congestion, a real problem that is causing to reach aircraft capacity limits in locations with a high traffic density like Germany.

Although section 3.1.2 of the TS/IRS[2] document limits the potential application of Phase Overlay ADS-B to the TMA, this technology is applicable in all the flight phases, just like the current versions of ADS-B. Besides, if implemented (both in air and ground segments), its benefits would be immediate. In case the cybersecurity layers were introduced, military aircraft would be capable to mask their public information; on the other hand, the use of the extended data for weather purposes could allow ATCOs to know more about the situation and decide better routes for the aircraft. As seen, several members from the ATM community can benefit from the Phase Overlay ADS-B technology implementation.

[2] Check reference in 12

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3 Operational Improvement Steps (OIs) & Enablers

SESAR2020 PJ.14-W2-84d Technological Solution covers the following enablers:

Enabler ID	Enabler Title	Enabler coverage	Dataset
A/C-48b	Air broadcast of aircraft data (ADS-B Out) compliant with new ED-102B / DO-260C standard	Full	22
CTE-S03c	New ADS-B station for future ADS-B applications	Full	22

Table 1. SESAR2020 PJ.14-W2-84d enablers list

These enablers support the following OI steps:

POI Code	POI Title	Dataset
POI-0060-SUR	Phase Overlay for ADS-B	22

Table 2. SESAR2020 PJ.14-W2-84d OI steps list

Lastly, the only link this Solution has with other SESAR Solution is the PJ.14-04-03 Solution, *New use and evolution of Cooperative and Non-Cooperative Surveillance*. The PJ.14-W2-84d Solution is the continuity of the PJ.14-04-03 Solution, located within the Wave-1, where TRL4 maturity level was achieved. Therefore, this link is just for traceability between SESAR2020 waves.

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4 Background and validation process

Phase Overlay technology is an ADS-B feature proposed for the first time in the ICAO Technical Group in June 2008. Under SESAR1 program, the first feasibility studies for Phase Overlay were conducted, achieving TRL2 maturity level. Nevertheless, the standardization of this technology did not start until 2016 in the frame of the Combined Surveillance Committee group.

Later, during SESAR2020 Wave 1 and using the draft standard documents DO-260C / ED-102B, a prototype system, composed by a transmitter developed by Thales and a receiver developed by Indra, implemented the Phase Overlay concept and was tested under laboratory conditions through the Test & Result technique, achieving TRL4. These tests, executed in both Indra's and Thales' premises in Madrid and Paris, respectively, checked the physical and logical characteristics of the Phase Overlay technology using a cabled transmission, reaching successful results.

Afterwards, under SESAR2020 Wave 2 program, PJ.14-W2-84d Solution focused on the improvement of the Phase Overlay prototype system in order to achieve TRL6. The first step was to update the system, so it complied with the recently published standard documents. Once the system was in line with the normative, two different exercises were defined within this Solution in order to check if it was capable of achieving TRL6:

- A laboratory test, where the integration of the system was carried out. This one was a replica of the exercise executed to achieve TRL4, but updated with the requirements from the standard documents. This test was located in Indra's premises in Torrejón de Ardoz (Madrid, Spain) with the participation of Thales, Indra and Enaire.

- Once the laboratory test was passed, a new test under real environment conditions was executed. This test consisted in several flights with a helicopter, where the Thales' transmitter was installed on, while the Indra's receiver was located in different locations (max. distance between prototypes: 50NM) in order to study the functioning of the Phase Overlay concept under real circumstances and with opportunity traffic. This test was executed near Saintes (Bordeaux, France) with the participation of Thales and Indra.

In summary, the results for TRL6 in this Wave 2 Solution were successful.

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5 Results and performance achievements

The main result and finding from this Solution are the demonstration of the feasibility of the Phase Overlay concept at technology level. The results obtained during the last exercise (under real environment conditions) are very optimistic for this ADS-B feature.

In summary, the findings found out during the overall validation exercises are:

- The system behaved as expected both from the transponder and receiver side, with the data received being the same as the transmitted originally. This is in line with requirements specified in normative documents ED-102B / DO-260C.
- The system maintains the backwards compatibility with current ADS-B versions (0, 1 & 2).
- The phase modulation does not affect the frequency spectrum of the current ADS-B versions and does not interfere with the rest of transmissions near the 1090MHz frequency.
- The Forward Error Correction (FEC) methods perform well (although recommendations are raised for future tests that could be executed in the new SESAR projects).

All these results come from the integration of the Thales' transmitter and the Indra's receiver. These prototypes obtained almost 99% of Phase Overlay messages during the laboratory exercise and 90% of them throughout the real environment test. Nevertheless, these values must be considered as qualitative, not quantitative, as they depend on the performances of prototypes that will be improved in the future. These values should be considered as the baseline to define the Phase Overlay performance figures, which will be carried out by EUROCAE and RTCA standardization bodies hand in hand with the development of the final products by manufacturers

Therefore, Phase Overlay technology can be considered as a potential tool for several applications such as cybersecurity, specialized data transmission or frequency spectrum reduction.

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6 Recommendations and Additional activities

Phase Overlay is a very promising technology. Nevertheless, as it is yet defined as optional in the last versions of normative documents, its applications have not been considered, being the only one the transmission of more detailed data (such as latitude and longitude, with more accuracy) or the retransmission of information (Mode A code, emergency status, etc.). For this reason, Phase Overlay is a technology ready to be deployed, but its applications are not definitive.

This Solution proposes and recommends the creation of new SESAR projects in the future dedicated to study the potential operational applications of Phase Overlay, such as cybersecurity (due to the interest of stakeholders to “anonymize” the ADS-B messages), the introduction of new contents into the new data available that could be beneficial for both controllers and ANSPs or the reduction of the 1090MHz frequency congestion with the redistribution of the current data transmitted by ADS-B. To achieve that, the execution of flight tests will be needed to validate these applications operationally.

The only recommendation for the future deployment of the Phase Overlay technology is that both airlines and ANSP must be aligned, as the introduction of a new phase modulation requires both sides to change their transmitters and receivers. The deployment rate can be very low, but depending on the chosen application, it can vary and provide benefits for certain stakeholders.

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7 Actors impacted by the SESAR Solution

As stated in the CBAT[3], the potential actors/stakeholders impacted/concerned by the deployment of a Phase Overlay technology are the followings according to the different potential applications:

- **Cybersecurity:** ANSPs, airspace users (both civil and military), military ground and manufacturers. The introduction of security layers in ADS-B will allow the authentication of the messages, ensuring the integrity of the aircraft and mitigating potential spoofing or eavesdropping attacks that could affect the ATM network, degrading the surveillance service.

- **Transmission of new data:** ANSPs and airspace users (excluding general aviation VFR). The introduction of weather data can provide them more situational awareness and let them decide, with detailed information, the best route to avoid hazardous situations or optimize the fuel consumption flying in optimal flight levels.

- **Reduction of frequency spectrum congestion:** ANSPs, all airspace users, network managers. The congestion of the 1030/1090 MHz frequency can lead to situation where the system performance does not comply with the safety requirements required for specific separation minima, what leads to restrictions to access the airspace, potentially provoking delays and cancellation in flights. Therefore, a reduction of the usage of this resource also reduces the probability of that situation to take place.

[3] Check reference in 12

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8 Impact on Aircraft System

As stated before, the inclusion of a new modulation on top of the current one obliges airspace users to change their transponders or update their software. In relation to the rest of specifications, they do not affect to the rest of aircraft components such as avionics or external antennas.

Nevertheless, this necessity can be met at the end of the lifespan of the current ADS-B transponders, introducing in a smooth way the new capacities of ADS-B version 3. This deployment is possible within an environment where all the ADS-B versions co-exist thanks to the backwards compatibility of the Phase Overlay technology.

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9 Impact on Ground Systems

Like its air counterpart, the inclusion of a new modulation on top of the current one obliges ANSPs to change their ADS-B ground stations or update their software.

Nevertheless, this necessity can be met at the end of the lifespan of the current ADS-B ground stations, introducing in a smooth way the new capacities of ADS-B version 3. This deployment is possible within an environment where all the ADS-B versions co-exist thanks to the backwards compatibility of the Phase Overlay technology.

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10 Regulatory Framework Considerations

With the last published normative documents (ED-102B / DO-260C) there is no impact on the SES and EASA regulatory frameworks, as Phase Overlay already lands under the scope of those documents. In this Solution three potential scenarios were considered regarding the potential state of this technology (optional or mandatory) for the future, as stated in section 3.5.2 of CBAT:

- **Scenario #1:** The use of Phase Overlay is **optional**. This scenario is the most likely in the foreseeable future since the current standards contemplate the coexistence of PPM and Phase Overlay modulations. In this situation, no action from SES or EASA is expected since this technology will be introduced smoothly through system upgrades or installation of new ground stations / transponders that already implement it.

- **Scenario #2:** The use of Phase Overlay is **mandatory**. This scenario could be feasible in the future. For this situation to happen, SES and EASA would need to oblige ANSPs and airspace users to update all their systems (both transponders and ground stations).

- **Scenario #3:** The use of Phase Overlay is **optional** in the short term, but becomes **mandatory** in the future. This situation is similar to the current one, where the deployment of ADS-B version 2 (the one compliant with ED-102A / DO-260B) has not been yet completed (there is still a 10% of airlines and ANSPs that have not transitioned yet). Nevertheless, due to the optional state of Phase Overlay in the normative and the current economic framework due to the impact of COVID-19, the deployment of this feature could be delayed. Therefore, in the short term, no action from the SES or EASA is needed, but in the future, like ADS-B version 2, they will have to choose the appropriate deployment method.

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11 Standardization Framework Considerations

Phase Overlay technology has gone under different descriptions from its original one in June 2008 until the last one defined in ED-102B / DO-260C. The results of this Solution are a valuable input for standardization bodies: RTCA and EUROCAE.

As stated in previous sections, Phase Overlay is considered as an ***optional*** feature for ADS-B in the normative at its current versions (ED-102B / DO-260C), and due to this, its data is not related to any application. Therefore, once the final application for Phase Overlay is decided (e.g., cybersecurity), standardization bodies will have to update the normative by amendments or new versions to reflect the changes in the data. In order to know the final application, cooperation between standardization bodies and the rest of airspace users, manufacturers and R&D programs will be required.

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12 Solution Data pack

The Data pack for this Solution includes the following documents:

- **Final TS/IRS:** *SESAR 2020 PJ.14-W2-84d – Phase Overlay for ADS-B – Final TS/IRS – TRL6* (D12.4.120, Ed.00.01.01, June 2022). This document provides the technical specifications and interface requirement specifications for the Phase Overlay technology based on the ED-102B / DO-260C regulations. It was used as reference for the validation of the Phase Overlay concept throughout the SESAR2020 PJ.14-W2-84d Solution.
- **TVALR:** *SESAR 2020 PJ.14-W2-84d – Phase Overlay for ADS-B – TVALR – TRL6* (D12.4.400, Ed.00.01.01, June 2022). This document provides the results obtained from the SESAR2020 PJ.14-W2-84d Validation Exercises for Phase Overlay technology, along with conclusions and recommendations regarding this ADS-B feature.
- **CBAT:** *SESAR 2020 PJ.14-W2-84d – Phase Overlay for ADS-B – Technical Cost Benefit Analysis (CBAT) for TRL6* (D12.4.500, Ed.00.01.02, September 2022). This document explores and sets up all the technological benefits and costs related to Phase Overlay technology.

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