Aircraft Identification Tag Study – Equipment And Implementation Scenarios
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Abstract
The EUROCONTROL Experimental Centre (EEC) developed an innovative concept called Aircraft Identification Tag (AIT), which aims at:

- Reducing voice communication errors by allowing the controller to visually identify the aircraft that is currently using the voice channel.
- Improving the security of controller-pilot voice communications by allowing authentication of received voice communications.

In July 2006, EUROCONTROL launched an Initial Feasibility Study on the AIT concept to provide EUROCONTROL with enough information to decide and give orientations for a full feasibility analysis of the AIT concept. The study was conducted by SOFREAVIA with FREQUENTIS and ROCKWELL COLLINS FRANCE. It has proposed an initial Operational Concept [A-D1], developed implementation scenarios, described expected benefits and provided initial cost estimates for the most promising AIT applications.

This paper summarizes the findings of the second deliverable of this Initial Feasibility Study – AIT Equipment and Implementation Scenarios [A-D2].

First, it establishes a relationship between the AIT operational concept and the enabling in-band technologies. Then it presents the most promising AIT applications and provides an overview of a technical AIT communication system explaining its functions and interfaces. It captures system parameters based on existing AIT prototypes, makes proposals about future possible system improvements and identifies data items exchanged between AIT end systems.

Further, this paper focuses on representative existing airborne and ground voice and ATM systems, identifying possible platforms for implementing the additional functions required for AIT operation, together with associated interfaces. An important finding of this analysis was that an airborne AIT technical system could be implemented - at least for some AIT applications - in the form of an additional “AIT box” between the pilot’s headset and the headset plug, without modifications of existing avionics components and wiring. A similar “stand-alone” solution was identified for the ground voice communication system.
architecture, where the required AIT functions would be provided in the form of stand-alone units with limited modifications of existing Voice Communications Systems (VCS). Combined together, these two solutions could be used for an early deployment of AIT. In the long-term, AIT components could be fully integrated within avionics and ground systems’ components.

Independent of the selected airborne or VCS solution, the preferred solution for displaying the AIT data to the controller is the controller’s operational HMI. In some cases, a “stand alone” AIT HMI could be envisaged – e.g. within the VCS Operator Position (OP). Two options have been identified for interfacing the VCS with the local ATM system; one using a single centralized interface and another one based on multiple direct interfaces between each OP and its associated controller position within the local ATM system.

Finally, the paper describes several deployment scenarios that aim to provide operational improvements in an incremental way, starting with the least demanding operational application based on the “stand-alone” airborne and ground solutions, and ending with the most advanced security-oriented application that would be optimally provided within a fully integrated scenario. Several issues related to the technical AIT implementation have been highlighted that will have to be studied in the following work.

In-band Communications Options

All operational AIT applications described in this paper rely upon a common capability of transmitting a limited amount of digital information (e.g. aircraft call sign) - the AIT message - embedded within each voice message on the VHF voice channel.

The EUROCONTROL Experimental Centre (EEC) developed a prototype AIT system that is based on digital speech watermarking technology [RD-1]. Some supplementary solutions have been developed by the industry [RD-2], using e.g. an in-band narrowband modem instead of watermarking.

The AIT Operational Concept (OC) developed in the course of the Initial Feasibility Study is not restricted to the watermarking solution – it generally applies to any in-band technology (or mixture of technologies) capable of providing the required transmission capabilities. However, the rest of this paper assumes the usage of AIT watermarking technology.

AIT Applications

In the course of developing an AIT OC, several candidate applications proposed in [RD-4] have been evaluated. Finally, three most promising AIT applications have been retained:

- OC1 - Identification of transmitting aircraft on the controller HMI
- OC2 - Uplink of ATC identification
- OC3 - Authentication of voice communications

With OC1, the aircraft identity (flight call-sign and ICAO 24-bit aircraft address) is supplied to the ground AIT system in the received AIT message. These data must be forwarded to the local ATC system and displayed on the controller’s HMI within nearly real-time constraints.

Application OC2 aims at increasing voice system’s robustness against non-malicious attackers by comparing the ATC Domain Identifier received within an uplink AIT message against a list of legal Domain Identifiers entered into AIT avionics. OC2 check result is presented to the flight crew as a visual or aural signal.

Application OC3 consists in the uplink and downlink transmissions of secured digital signatures embedded within a voice message. The receiving AIT system extracts the secured digital signatures to verify the authenticity of a received voice messages. OC3 check result is presented to the flight crew/controller as a visual or aural signal.

Several other possible applications such as using AIT for channel equalization and audio bandwidth extension or position reporting via AIT apparently require further R&D work and have been deemed immature in the context of the AIT Initial Feasibility Study.

AIT Communications System

Being an in-band technology, AIT communications system is entirely implemented
within the audio frequency baseband, so it does not require any modification to existing ATC voice radios. Both airborne and ground AIT sub-systems include two new functional blocks [RD-3], so called AIT Base Unit (ABU) and AIT Data Unit (ADU). Figure 1 shows these AIT blocks together with their interfaces to external data systems (A4/G4), local Voice Communications System – VCS (A1/G1) and the radio part of the VCS (A2/G2). Internal interfaces between ABU/ADU (A3/G3) and time reference interfaces (TA/TG) that are required in support of OC2 and OC3 are indicated as well.

Figure 1: AIT Communications System

An ABU requires a Digital Signal Processor (DSP) and basically performs tasks associated with the physical layer of a communications system. A transmitting ABU accepts an incoming voice stream from the local VCS over an A1/G1 interface, performs voice analogue to digital conversion and framing and implements a specific algorithm to embed AIT data received from the local ADU over an A3/G3 interface into the voice stream. Finally, it converts the digital voice with embedded watermark data back to the analogue signal and forwards this signal over A2/G2 interface towards the local ATC transmitter. When the PTT key is pressed, the ATC transmitter sends the embedded AIT message together with voice over an air-ground radio interface (RF) towards the ATC receiver. The receiving ABU accepts analogue voice that was received via an ATC receiver over A2/G2, searches for the AIT frame boundaries and synchronizes to the received message. Received voice is directly passed to its recipient, while AIT data are extracted and sent over A3/G3 towards the local ADU.

The ADU handles payload data that are exchanged via AIT messages. Transmitting ADU receives user data items over an external interface (A4/G4), composes an AIT message, adds some data items and parity bits and passes the message to the transmitting ABU. The receiving ADU performs operations that are “symmetrical” to that of the transmitting ADU.

Table 1 provides an overview of data exchanged over AIT system interfaces (details of these interfaces are yet to be defined) shown in Figure 1.

<table>
<thead>
<tr>
<th>IF</th>
<th>Items Exchanged</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>User’s voice</td>
</tr>
<tr>
<td>A2</td>
<td>User’s voice containing AIT data items, error coding/parity &amp; synchronization bits</td>
</tr>
<tr>
<td>A3</td>
<td>AIT data items, error coding/parity bits</td>
</tr>
<tr>
<td>A4</td>
<td>User data items</td>
</tr>
<tr>
<td>G1</td>
<td>User’s voice</td>
</tr>
<tr>
<td>G2</td>
<td>User’s voice containing AIT data items, error coding/parity &amp; synchronization bits</td>
</tr>
<tr>
<td>G3</td>
<td>AIT data items, error coding/parity bits</td>
</tr>
<tr>
<td>G4</td>
<td>User data items</td>
</tr>
<tr>
<td>TA</td>
<td>UTC date and time</td>
</tr>
<tr>
<td>TG</td>
<td>UTC date and time</td>
</tr>
<tr>
<td>RF</td>
<td>RF modulated voice with AIT data items, error coding/parity &amp; synchronization bits</td>
</tr>
</tbody>
</table>

Table 2 provides basic parameters of the existing prototype AIT system with estimates of required performance for an operational AIT system. Further development and optimization (e.g. combination of several in-band technologies) will thus be needed to achieve target performance goals. Also, detailed acceptance criteria for the readability of the AIT in-band signal will have to be developed to guarantee safe operation of the voice system once AIT has been implemented.
Table 2: AIT System Performance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>AIT Prototype</th>
<th>AIT OP System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess voice delay (ms)</td>
<td>30…60</td>
<td>≤20</td>
</tr>
<tr>
<td>AIT frame duration (s)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>AIT user data rate (bps)</td>
<td>≤36</td>
<td>≥100</td>
</tr>
</tbody>
</table>

Airborne Architecture Options

In order to identify options for implementing an airborne AIT sub-system, an analysis of existing airborne voice architectures has been performed for large transport aircraft, and General Aviation (GA) aircraft with basic or advanced avionics.

The analysis has shown that VHF radio, Radio Control Panel (RCP) and Audio Control Panel (ACP) appear in all architectures. RCP gives the flight crew control (frequency and data mode selection) of all VHF/HF radio communication systems, but is not directly involved with voice processing. ACP is used for selecting the desired radio system both for transmission and reception and adjusting audio levels. In some architectures ACP are connected to the Audio Management Units (AMU) or Radio Interface Units (RIU) that handle voice streams and provide interfaces to VHF radios. As these components do not exist in some GA architectures, the ACP may also directly communicate with the radio equipment. Dependent on the aircraft type, pilot’s voice accessories (headset, microphones, oxygen mask, loudspeakers) may be attached either to the ACP or to the AMU.

The analysis has also shown that the DSP platforms that are required for the AIT ABU implementation are available in some VHF radios and some AMU/RIU units. This has led to the two basic options for an airborne AIT implementation described in the following sections.

“Headset” Solution

With that solution which would allow for an early implementation of an initial AIT package (OC1 application), the airborne ABUs/ADUs are implemented (Figure 2) within separate boxes inserted between the headsets and the cockpit jacks. As entire AIT processing is done within each box, the rest of the audio system (VHF radio, ACP, AMU/RIU) remains unchanged. AIT-specific data (e.g. Flight ID) must be pre-loaded prior to the flight into airborne ADU by using some loading device via interface A4 or a specific HMI on the box. For other applications, the “AIT box” would have to provide a kind of aural or visual signal to indicate the outcome of the ATC facility identification/message authentication to the pilot.

Figure 2: “Headset” Solution

“Integrated” Solution

With an “integrated” solution, airborne ADU/ABU are integrated within either the VHF radio or the AMU/RIU unit, being a part of the software of these units and using their existing DSP platforms. This solution is envisioned as part of advanced AIT implementation packages and would support all kinds of operational applications (OC1, OC2 and OC3).

AIT-specific data (Flight ID, ICAO address) are derived from the Communications Management Unit (CMU) by implementing a “new” interface A4. The date and time reference required for OC2 and OC3 are derived from an on-board GNSS source. An interface to the loading device is still required for entering the ATC domain identifier and security keys into AIT avionics. It may be possible to use Electronic Flight Bag (EFB) for that purpose.

OC2 and OC3 signals for the pilot require an additional AIT Human Machine Interface (HMI). EFB can be used for that purpose too. Figure 3 shows the case where ABU/ADU are implemented within the VHF radio. The situation with an
implementation within the AMU/RIU is very similar.

In theory, the ground AIT system could be completely contained within the VCS, but the AIT operational concept [A-D1] has clearly indicated that an optimum implementation of applications OC1 and OC3 requires modifications of the CWPs within the ATC system.

An existing VCS architecture comprises ground ATC radios (RX, TX), radio interfaces (RIF), core switch (SW) and the operator position (OP) that is in most cases associated with the corresponding CWP. AIT-capable VCS architecture additionally comprises multiple receiving (AR) and transmitting (AT) ADU/ABU units, as well as a central “AIT Server” unit.

The AIT server is aware of the actual configuration of each OP of the VCS and is able to associate the AIT message with the VHF channel used at a particular OP. If several ground receivers are involved with reception on the particular channel, the AIT server is aware of both the channel and the “channel leg” over which the message was received. Required configuration data are collected from VCS OPs over an internal interface S1.

The AIT server provides data interfaces (G4) to all external AR units. Each AR unit submits decoded content of received AIT messages and/or the outcome of message authentication to the AIT server over G4 interface either directly, or by using existing data channels within the VCS. In some cases (analogue lines between VCS and remote radio sites) external modems may be required, as shown in Figure 4. The AIT server itself is configured over a local interface C1.

The detailed analysis has shown that the preferred position for a transmitting ABU/ADU (AT) unit is the OP (Figure 4). In such a case, AT unit would be able to serve multiple channel legs, communicating with the AIT server over a local interface G4. In some cases (e.g. if voice compression is used across the “voice net”) an AT unit may still have to be deployed at the “VCS periphery”, close to the AR unit. In such a case an AIT Server would forward OC2/OC3 applications data over an interface G4 to the “proper” remote transmitting AT unit.
**VCS - ATC System Interconnection Options**

OC1 data (aircraft identity) and OC3 data (outcome of the security check) should be presented to the controller, preferably on the CWP (e.g. by highlighting transmitting aircraft). Moreover, a particular CWP should only display AIT data that are relevant for that CWP, dependent on the VCS OP configuration of voice channels for the corresponding ATC sector. Several options for interconnecting the VCS with the local ATC system have been identified in [A-D2].

Assuming the first option, the AIT server sends these data to the VCS OPs. Each OP is aware of its own voice channel configuration and forwards only “its own” AIT data over a local interface S5 to its associated CWP where they are correlated with the flight data and presented to the controller. OP is supporting the display of AIT data on the CWP by providing (over S5) real-time channel activity status of all active voice channels configured at that OP.

With another option (dashed lines in Figure 4), AIT server within the VCS architecture itself performs association of AIT messages with the relevant OPs/CWPs and forwards received AIT data for all CWPs over a single concentrated interface S3 to another “ATC AIT server” that must be implemented within the ATC system. This server in turn distributes the messages to the relevant CWPs over a local interface S4.

In some cases (e.g. small airports) no CWP exists. In such a case AIT server forwards received AIT data over an interface S2 to a local AIT HMI where they are displayed to the controller (the straightforward way - shown in Figure 4 - is to integrate such local AIT HMI within the VCS OP).

**Deployment Scenarios**

AIT operational concept [A-D1] sees for a successive deployment of AIT applications based on “operational packages”. The “Initial AIT package” (IAP) aims at deploying single OC1 application within a relatively short time-frame to bring early operational safety benefits. IAP should be followed by the “First advanced AIT package” (AA1) that comprises both OC1 and OC2. Finally, the AIT deployment would be completed with “Second advanced AIT package” (AA2) that effectively replaces OC2 by OC3 after an overlapping phase where both OC2 and OC3 would co-exist.

The preferred airborne solution for the IAP deployment is retrofit based on the previously described “headset solution”. Forward-fit based on an “integrated solution” is not a realistic option for IAP, but – assuming the availability of adequate DSP platforms within avionics - is the preferred solution for AA1 and AA2 packages. It works with all kinds of pilot’s voice accessories (not limited to headsets) and is better adapted to OC2 and OC3 applications than the “headset solution”. The “headset solution” could be still applicable to GA and part of the transport aviation that does not yet implement advanced avionics with suitable DSPs at the time of AA1 introduction.

Ground AIT components required for IAP – AIT server, AR units – may be initially deployed as stand-alone equipment that interfaces to existing VCS components – RIF, SW and OP. However, even in this early deployment phase some modifications of existing VCS and ATC system components are required (as indicated in the previous section). AA1 package requires additional components (AT, local time source) to be added to existing components. These could also be deployed as stand-alone components, but the preferred way for AA1 and AA2 is forward-fit of new VCS installations for AIT, based on integrating AIT components within emerging VCS platforms with suitable DSPs: SW, RIF or OP. In all cases the AIT data should preferably be exported from the VCS OP towards the CWP of the ATC system via local interface (S5).

**Identified Technical Issues**

Several issues have been identified related to the technical AIT implementation that will have to be studied in the following work.

Existing prototype AIT system should be further developed. In particular, the AIT system capability to provide required capacity and performance at the boundary of the voice service volume as well as robustness of an AIT signal embedded in the particular audio stream to other overlapping audio streams with or without AIT signals should be confirmed. The details of interaction between an AIT system, HF voice
system and SELCAL decoder should be studied as well.

An appropriate method for entering the AIT parameters (security keys, list of valid ATC Domain identifiers, Flight ID, ICAO address) and date/time information into avionics, as well as an interface for signaling the outcome of OC2/OC3 security check to the pilot are required as well.

Within the ground architecture, system performance (e.g. latency when displaying AIT data), degraded modes of operation, recording and replay of AIT data, as well as selecting the best solution for interfacing the VCS with the ATC system will require further investigations.

For prototyping purposes, a detailed specification of all AIT functional blocks and their interfaces should be produced.

Conclusions

The AIT OC developed in the course of the AIT Initial Feasibility Study generally applies to any in-band technology. The future work may need to consider a combination of AIT watermarking technology and other in-band technologies (e.g. in-band modem) to meet operational requirements developed in [A-D1]. Such a combined solution could provide more capacity, being implemented within the same DSP platform (ABU) that is used for the AIT system alone.

Two realistic options have been identified for an airborne implementation of AIT packages:

- “Headset option” – AIT implementation within an “AIT box” between the pilot’s headset and the headset plug
- “Integrated option” - AIT implementation within the VHF radio or AMU

Both options apply to large transport aircraft and GA aircraft with basic or advanced avionics. The headset solution is particularly applicable for an early deployment of the OC1, while integrated solutions are preferred for OC2 and OC3.

On the ground side, the “stand-alone” VCS option requires only limited changes of VCS OP and would allow for an early implementation of OC1. Applications OC2 and OC3 require adding additional components to the existing AIT components. The preferred way for OC2 and OC3 is requiring the forward-fit for new VCS installations, based on integrating AIT components within emerging VCS platforms.

In all cases, displaying the AIT data on the CWP remains the preferred choice, but the optimum method for interfacing the VCS AIT sub-system with the ATC system is to be further investigated.

References


Biographies

Miodrag SAJATOVIC received his MSEE from the Electrotechnical Faculty of the University of Zagreb, Croatia in 1976. He has successfully participated in international aeronautics research activities where his focus was on communications and operational concepts (F-VHF, MA-AFAS). His special expertise lies in radio communications, in particular VHF and he holds a patent for secure VHF communication.

Dieter EIER is the Director of Product Management for FREQUENTIS USA. Mr. Eier has 16 years experience in engineering analysis and product strategy in communications systems for mission critical applications. He was instrumental in the
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Thierry VIRION, Master in Telecommunications (ENST, 1994), graduated in Economics (University of Paris XI, 1995) had been involved in R&D activities on the ATN and in the development of ATC systems before joining Sofréavia in 2003. He has since been involved in various CNS/ATM projects, including R&D, audits, Master Plans and on-site technical assistance activities for the operational transition of ATC centres.

Horst HERING, Dipl. Ing. in communication techniques (Ulm -1970); Graduated in human factors (Univ. Paris 5 - 1999) and in psychosociological aspects of stress (Univ. Paris 5 - 2001). German ATC authority (1970 -1986). Since 1986 at the EUROCONROL experimental centre working in different R&D projects like satellite communication, controller workload recording, project leader speech recognition and synthesis, new technologies and concepts for CWP, HMI’s and ATM.

Frederic DAVIERE, Master in Aeronautics (SUPAERO, 1997), since 2000 at Rockwell Collins France. Experience in Flight Management Systems and avionics platform integration. He is familiar with the requirements for CNS/ATM. He acquired this expertise when he was expatriated for Rockwell Collins in 2004/2005 to participate to the development of the Flight2 advanced avionics system. Prior to this experience, he participated to the certification of Airbus embedded network.

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