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SYSTEM ARCHITECTURE OF THE ONBOARD AIRCRAFT IDENTIFICATION TAG (AIT) SYSTEM

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TITLE:

SYSTEM ARCHITECTURE OF THE ONBOARD AIRCRAFT IDENTIFICATION TAG (AIT) SYSTEM

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Abstract:

The implementation of the Aircraft Identification Tag (AIT) concept promises high benefit for safety and security of the air transportation. AIT embeds a digital signature into the voice, which is transmitted over the standard air ground voice communication channel. The digital signature is realised by embedding a unnoticeable watermark into the analogue voice.

This note describes ideas for technical solutions for the implementation of the AIT concept in the aircraft cockpit without modifications to existing equipment.

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Summary

Controller-pilot voice communication for the Air Traffic Control (ATC) in the continental regions relies on analogue DSB-AM (Double-Side-Band Amplitude Modulation) technology. For oceanic communication the HF (High Frequency) band is used. This technology is known for its poor voice quality and to be highly sensitive for any kind of noise on the transmission path. On these shared broadcast channels one air traffic controller and multiple pilots communicate. The pilots have to identify themselves with their call-sign. In addition to the low channel quality, imperfections in human speaking and understanding may hamper unambiguous identification of the originator of an aircraft message. The AIT system proposes a technique for an automatic identification of the originator of the voice message without any human's intervention. AIT addresses safety and security aspects of the conventional air-ground VHF voice communication.

The AIT technique uses standard audio watermark algorithms, as used for example for intellectual property rights for digital audio and video. These watermarks are embedded in the voice signal such that the watermark is not noticeable. An implemented prototype demonstrator based on spread spectrum technology shows very high robustness with a very low error rate. At the moment a R&D study at the EEC in cooperation with Graz University of Technology tries to increase the watermark capacity to allow payload data rates of about 100 bits per second. Then payload data could for example be extended to the identification of the originator (signature) and a position report, or any other digital data.

The first aim of the AIT architecture is to work automatically without any human intervention. Second, AIT shall be compatible with the existing transmitter and receiver equipment in the aircraft and on ground. Especially in the aircraft AIT should act as an add-on device to the existing certified equipment. Ideally AIT is built into a pilot headset and pin-compatible to existing headsets. In this case the current aircraft equipment (Tx, Rx) remains unchanged and only the headset including AIT will need security proof or certification.

This note handles some basic ideas to realise this challenge without supplementary connections between AIT architecture and the aircraft system.

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1 Introduction

The basic AIT system is described by Hering [1]. The speech duration is considered arbitrary. The duration of the watermark is to about 800 ms. Therefore it was decided to implement the watermark only at the beginning of the transmission. In Figure 1 the principal timing relation between voice signal, watermark and the Push-To-Talk (PTT) signal is given. The PTT-button is pressed by the speaker for the entire period of the transmission. For technical reasons (non linear transmission start), the watermark signal will be slightly delayed (~100 ms) to the PTT signal start.

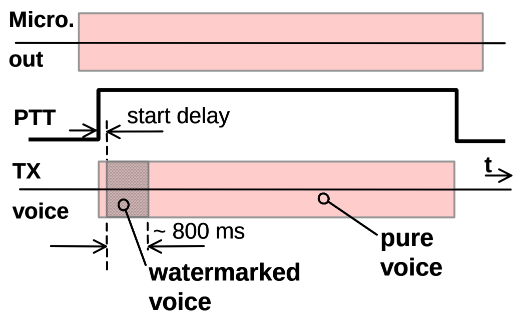

Figure 1: AIT timing

Table 1 shows results for the mean duration of the controller to pilot voice communication from a EUROCONTROL Experimental Centre study of H. Hering [2]. Due to the equivalent phraseology structure for the pilot to controller voice communication, the presented speech duration times for these cases will be similar to these presented here.

	general	utt. without AC call-sign	utt. AC call-sign only
duration (s)	5.0	2.7	1.9

Table 1: Mean duration of spoken controller utterances

The availability of the payload data in the ground system within less than one second was chosen in a deliberate manner. In case of the shortest utterance duration - the call-sign was the only message - the mean duration of such a message is still longer as the watermark requires.

For inserting the payload data, the AIT system requires information on the payload data and PTT switch information. This note points out some innovative solutions to reduce interactions between AIT and aircraft transceiver system.

2 AIT Onboard System

2.1 Overview

Figure 2 shows the principal implementation of the AIT system in a cockpit. There are separate AIT watermark embedding systems for pilot and co-pilot. Both AIT systems are identical and working independently. The selection of the voice signal transmitted is selected in a multiplexer based on several distributed, seat related PTT switch information. To interconnect these multiple PTT switches with the AIT system (to get the signal triggering) the onboard AIT would require special interconnection with the aircraft transceiver system. Such an additional interconnection would be safety critical and very expensive. This note presents innovative solutions for an AIT system to use the standard aircraft connectivity for pilot headset as specified by ARINC [3], only.

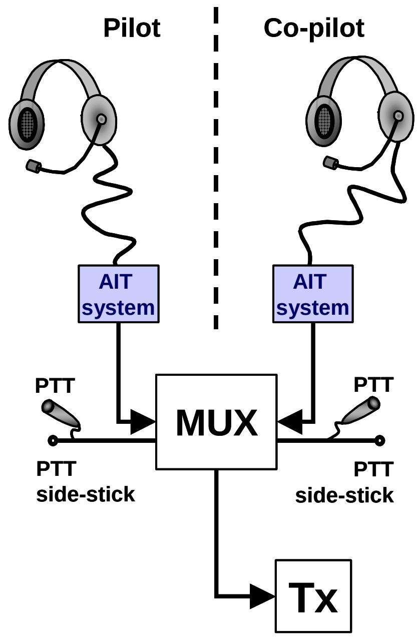

Figure 2: AIT in the cockpit

Each microphone in the cockpit has its own independent AIT system. The internal AIT system architecture is shown in Figure 3. It consists of an AIT base unit and an AIT data module.

The AIT base unit consists mainly of the DSP (Digital Signal Processor) module required for watermark embedding. The architecture of this module is dependent of the used DSP. The software algorithms for the DSP are currently subject of research at the EEC.

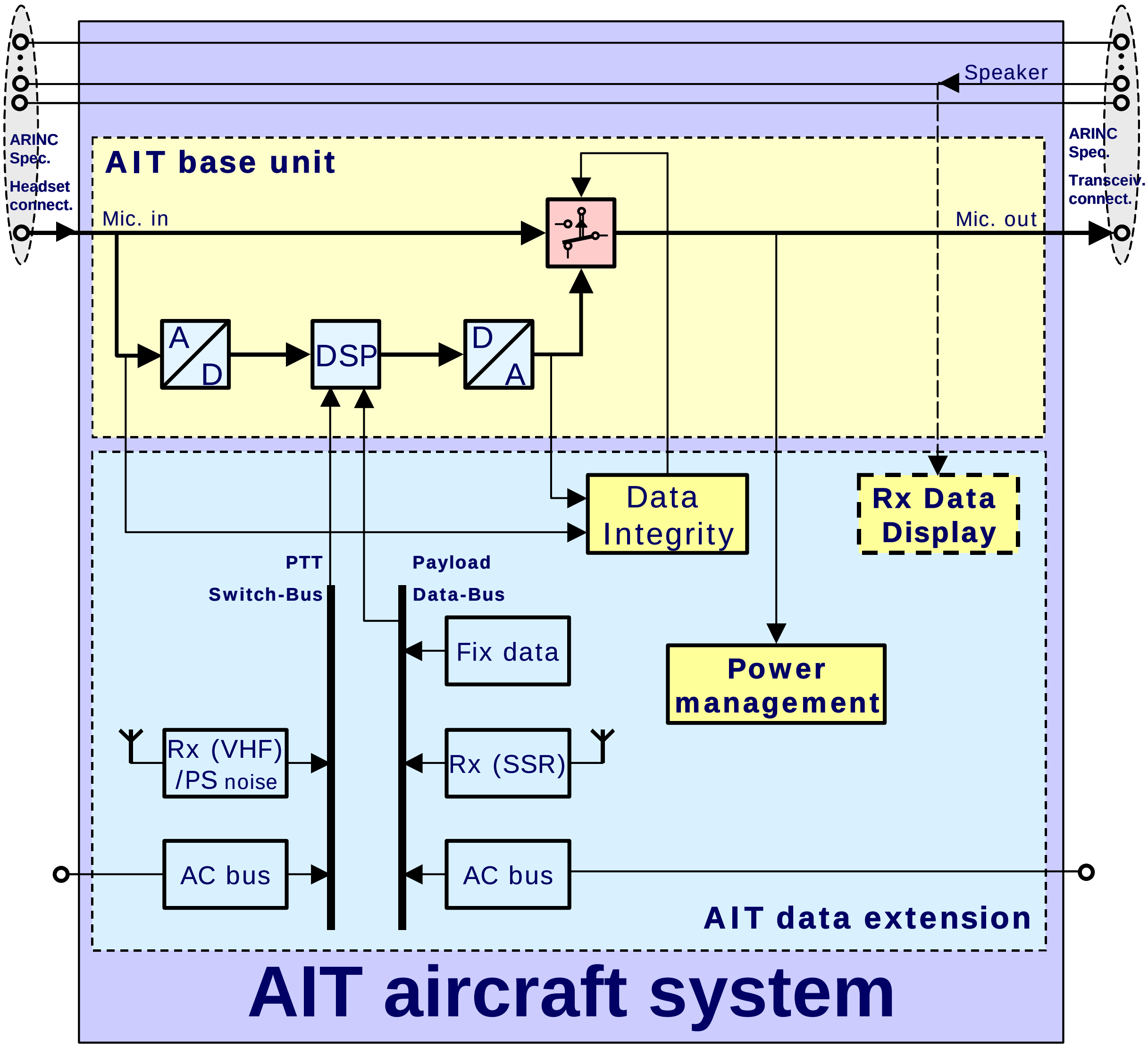

Figure 3: AIT System architecture for the aircraft

The AIT data extension represents the technology level and can be developed in parallel to research for the base unit. The aim of the data extension is to provide to the base unit the required information about PTT switch status, payload data and to manage power consumption. Optional it may have a Rx Data Display module (extraction and display) to show watermarks from the receiver channel of the aircraft.

The AIT system should be pin-compatible to the current pilot headset connector. If the compatibility incorporates the electrical specifications for pilot headsets, a simplified procedure for the certification issue may be possible.

The AIT system requires following inputs from the aircraft:

- Analogue voice signal from the microphone (on this connection the AIT system has to be provided microphone power to the connected microphone).
- PTT switch status information
- Payload data
- Power (furnished by the aircraft via the microphone connection)

The AIT system has the following output signal:

- Analogue voice signal with the embedded watermark. (This signal-line provides the power for the AIT and the connected microphone, too)

Only the analogue voice signal from the microphone is treated by the AIT system and after embedding of the watermark fed to the transmitter as analogue voice. The delay caused by the digital treatment of the voice signal is estimated to about 60 ms. All other connections to the headset are bypassing the AIT system. The ‘ground’ signal is bypassing too, but used from AIT as electrical signal reference. PTT switch status should be captured wireless from aircraft’s own VHF radiation. Payload data (identification) may be stored fix in the AIT system, or as well captured wireless.

A size optimised AIT system can be integrated in a headset or realised as a small in-between cable device with male-female connectors for use with an existing headset. In long term the AIT system could be incorporated into new developments for aircraft communication systems.

2.2 AIT Base Unit

The AIT base unit receives the speech frequency signal from the connected microphone. Pre-amplification may be required if it is not included in the microphone. In an analogue-to-digital converter this signal is digitalised, then treated by the DSP (Digital Signal Processor) module and converted back to analogue again in a digital-to-analogue converter. In this analogue form (including the watermark already) it is feed to the transmitter via the standard headset connector. The processing time for this chain (A/D, DSP, D/A) is estimated to approximately 60 ms. With optimisation and specific hardware about 30ms are reachable. This process runs permanently to avoid time shifts between watermarked and non-watermarked signal. The embedding of the watermark is triggered by the start of the PTT switch signal. After embedding, the DSP holds the overall delay time of the AIT system constant.

Triggered by the PTT switch signal, the DSP embeds the watermark with the data provided by the payload data bus. In case the PTT switch signal ends earlier as the embedding process of the watermark, embedding will be aborted. As the watermark signal is incomplete, payload data decoding at the receiver side will fail.

In collaboration with the Graz University of Technology research is executed at the EEC to increase and optimise payload data capacity of the AIT system. The research results and their implementation are independent of the used DSP hardware.

For certification issues it is probable that the AIT base unit needs an automatic bypass function of the watermark embedding process if any significant discrepancies are detected by the data integrity module.

The payload data and the PTT switch information are provided to the AIT base system by the AIT data extension module, which is described in the next section.

2.3 AIT Data Extension

The AIT data extension gathers information and data required for the AIT system. Some of the information and data is not available through the headset connector. There are several distributed PTT switches in the cockpit, used by the different pilots (see Figure 2). Retrieving the concatenated PTT switch information at the aircraft VHF communication system would be possible. But a supplementary access to an aircraft equipment could put in question an AIT system success, as such a connection requires changes in the aircraft cabling. Therewith associated are more costly certification procedures for the changes and the extended certification of the AIT system. Similar problems may arise if it is required to use special payload data which is available in internal aircraft bus systems only. Nevertheless Figure 3 indicates this option with aircraft bus connections for the payload data and the PTT switch information. In a later time developments of new aircraft communication equipment (transceiver) may have built in AIT facilities, then direct access to the aircraft-bus system can be a valid option.

To overcome these problems, it is proposed to use the idea of wireless capturing of existing active aircraft radio transmissions or their unwished side effects inside the aircraft to collect the required information. In this case as well the watermark start-up delay (Figure 1) can be omitted.

2.3.1 PTT Switch capturing

In standard operation the PTT switch triggers the aircraft's VHF transmitter to start transmitting modulated energy. A broadband VHF receiver (covering ATC VHF frequencies) in the AIT data extension could detect this transmission and transform it into a secondary PTT switch signal for the AIT system.

Assuming spherical radiation, the received signal energy E_{RX} of an electro-magnetic transmission highly depends on the distance d between transmitter and receiver:

$$\boxed{E_{RX} = \sim f(1/d^2)}$$

This strong dependency on the distance guarantees, that a simple threshold would safely eliminate receptions not originating from the own aircraft. In practice the own aircraft VHF antenna is in a near distance unlike the closest transmitting VHF antenna of another safe separated aircraft. The minimum vertical separation between aircrafts is 1000 feet which makes the received signal of the own antenna approximately 400 times stronger.

Another feasible way, could be the capturing of the PTT switch information by noise signal analysis on the aircraft signal lines. The VHF aircraft transmission is high energetic and may so leave noise finger prints in the form of VHF frequency noise on the aircraft power distribution or other connections of the communication-system. AIT signal lines for the headset could be overlaid with such noise caused by the aircraft VHF transmission. This may allow to generate a secondary PTT switch signal for the AIT system.

2.3.2 Payload Data

Any small amount of digital data can be transmitted by the AIT system as payload data. Payload data in the generic sense may be any kind of useful information for the receiver, for example identification, position report and so on. In this note, payload data representing a digital signature will be discussed, only.

A digital signature allows an automatic identification of the originator of a message at the receiver side. In case of general avionics the tail-number could be used and burnt into the AIT data extension by the system integrator. For commercial aircrafts their 24 bit unique aircraft-identifier could be burned in as data. Until now these 24 bit aircraft-identifiers are not widely used or known by the ATC authorities. Today, ATC is using the company generated flight identification (i.e. AFR 2356), but has no knowledge about the physical aircraft (aircraft type known for performance) executing the flight. So, currently these 24 bit aircraft-identifiers may not be a good solution in every case. With the larger use of 'Mode S' radars and the ADS-B technology this may change in the future. These technologies use the 24 bit aircraft-identifier.

In the meanwhile, the SSR (Secondary Surveillance Radar) code could be used for the identification of the aircraft. The onboard SSR transponder answers to an on ground interrogation with the identification or the actual flight level. This identifier is assigned by ATC authorities for identification of the flight. But it is not permanent and might even change during a flight. Permanent capturing of the onboard SSR replies, decoding and buffering as up-to-date payload data could be a solution. This concept could be extended to any digital data (e.g. ADS data, …) sent actively from the aircraft. Capturing dynamically modified data for payload will increase the security barrier of the AIT signature against fake communication.

The physical conditions for capturing the SSR aircraft replies will be similar to those described in the chapter 'PTT switch capturing'.

Filtering the SSR identifier from the power or signal lines for AIT may be much more difficult as data has to be extracted. In case of the PTT switch the occurence of the transmission was of interest, only.

2.3.3 Data Integrity Module

For the certification issue the AIT system permanently has to monitor the integrity of the output signal with reference to the input signal. The data integrity module has to be independent from the normal process of the system. If some discrepancy is detected, the 'data integrity' module has to switched to a mode without watermarking technique.

2.3.4 Power Management Module

Current pilot headsets require power supply for the headset microphone. This power is provided by the aircraft transmitter equipment via the headset connector. The available power is small. Due to the decreasing power consumption of modern low-power DSPs, it might be possible that the available power from the actual aircraft connection can supply both the AIT system and the connected microphone. An intelligent power management would decrease the maximum power requirements by for example the accumulation of energy during times where no watermark is embedded.

2.3.5 RX Data Display Module

The data display module extracts from the received analogue speech (for the headset speaker) the embedded AIT data and displays it. This module is optional. It gives sense only, if the AIT payload data is in clear text (e.g. sector identification, flight identification, tail number) and not coded (e.g. SSR code, Mode-S identifier).

3 Conclusion

The implementation of AIT would bring benefit for safety and security of air transportation. This note point out technical solutions to solve potential problems of the implementation of AIT in the aircraft.

It requires long time to implement new concepts in the aircraft. To speed up the research and development of the AIT concept, independent tasks should be done in parallel. The development of a hardware platform is independent from the research on the watermark algorithm. This note points out ideas for technical solutions to realise the AIT concept for the cockpit.

References

[1] H. Hering, M. Hagmueller, G. Kubin, 2003, Safety and security increase for Air Traffic Management through unnoticeable watermark Aircraft Identification Tag transmitted with the VHF voice communications, Proceedings of 22nd DASC conference, Indianapolis, USA

[2] H. Hering, 2001, Technical Analysis of ATC Controller to Pilot Voice Communication with Regard to Automatic Speech Recognition Systems, Eurocontrol Experimental Centre, Brétigny, France

[3] ARINC, 2003, Airborne VHF Communication Transceiver, ARINC Characteristic 716-11, Aeronautical Radio Inc., Annapolis, USA