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DEVELOPMENT AND MODERNIZATION PRINCIPLES OF AIRCRAFT DIGITAL GROUND/AIR COMMUNICATIONS ARCHITECTURE

ПРИНЦИПЫ РАЗРАБОТКИ И МОДЕРНИЗАЦИИ АРХИТЕКТУРЫ ЦИФРОВОЙ НАЗЕМНО-ВОЗДУШНОЙ СВЯЗИ САМОЛЕТОВ

ӘУЕ КЕМЕЛЕРІНІҢ САНДЫҚ ЖЕР-ӘУЕ БАЙЛАНЫСЫНЫҢ АРХИТЕКТУРАСЫН ӘЗІРЛЕУ ЖӘНЕ ЖАҢҒЫРТУ ПРИНЦИПТЕРІ

Abstract. In this paper are analyses the types and development principles of aircraft air/ground communication architecture, which is used for acquiring, conditioning and processing all required aircraft parameters, collected from the aircraft and data, receives on low and high speed ARINC 429 buses. The paper also considers the possibility of receiving and sending data via ARINC 618 buses.

On the example of modern aircraft such as the Boeing 777 and Boeing 787, the functionality of air/ground communication, built on the basis of a data communication management system (DCMS) and the principles of modernizing the airborne radio communication system, are investigated.

This paper also explores the capabilities of the Data Communications Management System (DCMS) system architecture and interfaces for interfacing with other existing aircraft systems to send reports/queries on the uplink or downlink.

Keywords: Aircraft, datalink, communication, interface, uplink request, downlink request.

Аннотация. В этой статье анализируются типы и принципы архитектуры воздушно-наземной связи самолета, которая используется для сбора и обработки всех необходимых параметров самолета, собранных с самолета и данных, полученных по низкоскоростным и высокоскоростным шинам ARINC 429 данных. В работе также расматриваются возможности приема и отправления данных по шинам ARINC 618.

На примере современных самолетов типа Boeing 777 и Boeing 787 исследуются функциональные возможности воздушной/наземной связи, построенной на основе системы управления передачей данных (DCMS-Data communication management system) и принципы модернизации системы бортовой радиосвязи.

В данной работе исследуются также возможности системной архитектуры системы управления передачей данных (DCMS) и интерфейсов, обеспечивающих взаимосвязь с другими существующими системами на воздушных судах для отправки отчетов/запросов по восходящей линии связи или нисходящей линии связи.

Ключевые слова: Самолет, канал передачи данных, связь, интерфейс, запрос восходящей линии связи, запрос нисходящей линии связи.

Аңдатпа. Бұл мақалада ұшақтан жиналған барлық қажетті ұшақ параметрлерін және төмен және жоғары жылдамдықты ARINC 429 деректер автобустары арқылы алынған деректерді жинау және өңдеу үшін пайдаланылатын әуе кемесінің әуе-жер байланысы архитектурасының түрлері мен принциптері талданады. Қағаз сонымен қатар ARINC 618 шинлары арқылы деректерді қабылдау және жіберу мүмкіндігін қарастырады.

Boeing 777 және Boeing 787 сияқты заманауи ұшақтардың мысалында мәліметтерді басқару жүйесі (DCMS-Data коммуникациясын басқару жүйесі) және әуедегі радиобайланысты жаңғырту қағидаттары негізінде құрастырылған әуе/жер үсті байланысының функционалдығы. жүйесі зерттеледі.

Бұл жұмыс сонымен қатар деректер байланысын басқару жүйесінің (DCMS) архитектурасының мүмкіндіктерін және жоғары немесе төмен сілтеме бойынша есептерді/сұрауларды жіберу үшін ұшақтағы басқа бар жүйелермен өзара жұмыс істеуге арналған интерфейстерді зерттейді.

Түйін сөздер: Ұшақ, деректер сілтемесі, байланыс, интерфейс, жоғары сілтеме сұрауы, төмен сілтеме сұрауы.

Introduction: As aircraft began to be equipped with digital avionics in the 1970's, a system was developed to exchange air-ground data messages between aircraft and airline operations centers.

It was initially used to report aircraft movement, then to allow on-board systems, pilots and cabin crew to communicate with the airlines' ground systems, and now, with the Air Traffic Control (ATC) centers.

The current datalink environment consists of VHF, HF and Satellite packet-mode data services and Gate-link.

The datalink service providers provide mobile wireless data communications to aircraft around the world. It is partitioned into VHF and HF (depends on provider and a/c type), which aircraft may access in more than160 countries and SATELLITE, which provides worldwide coverage through Inmarsat's or Iridium geosynchronous satellites [1].

Nowadays, through datalink functions possible the transfer of flight plan and maintenance data between the airplane and the ground service providers (GSP).

In this article is shown the architecture of digital air/ground communications in other words the data communication management system based on the aircrafts B787 and B777 [2-5].

The purpose of this article is to define the functionality capabilities of air/ground communications based on the data communication management system (DCMS) that is used on modern B777 or B787 aircraft.

The Data Communication Management System (DCMS) is an integrated system that provides data link message exchanges with the ground ACARS station, using VHF (including VDL Mode 2 when suitable ground stations are available), HF data link and SATCOM media.

As shown in below Figure 1, the communication management system architecture includes the following components: Satellite Data Unit, VHF Transceivers, Radio Tuning Panel, Maintenance Access Terminal, Flight Compartment Printer, AIMS Cabinet, Display Select Panel, MFD, CDU, Data communication management function (DCMF) and Flight deck communication function (FDCF).

The data communication management system (DCMS) controls analog and digital data communication in many different formats. The DCMS is an integrated system that provides data link message, exchanges with the ground ACARS station, using VHF (including VDL Mode 2 when suitable ground stations are available), HF data link and SATCOM media [6-9].

The DCMS divides operation into these two functions:

a. Data communication management function (DCMF)
b. Flight deck communication function (FDCF).

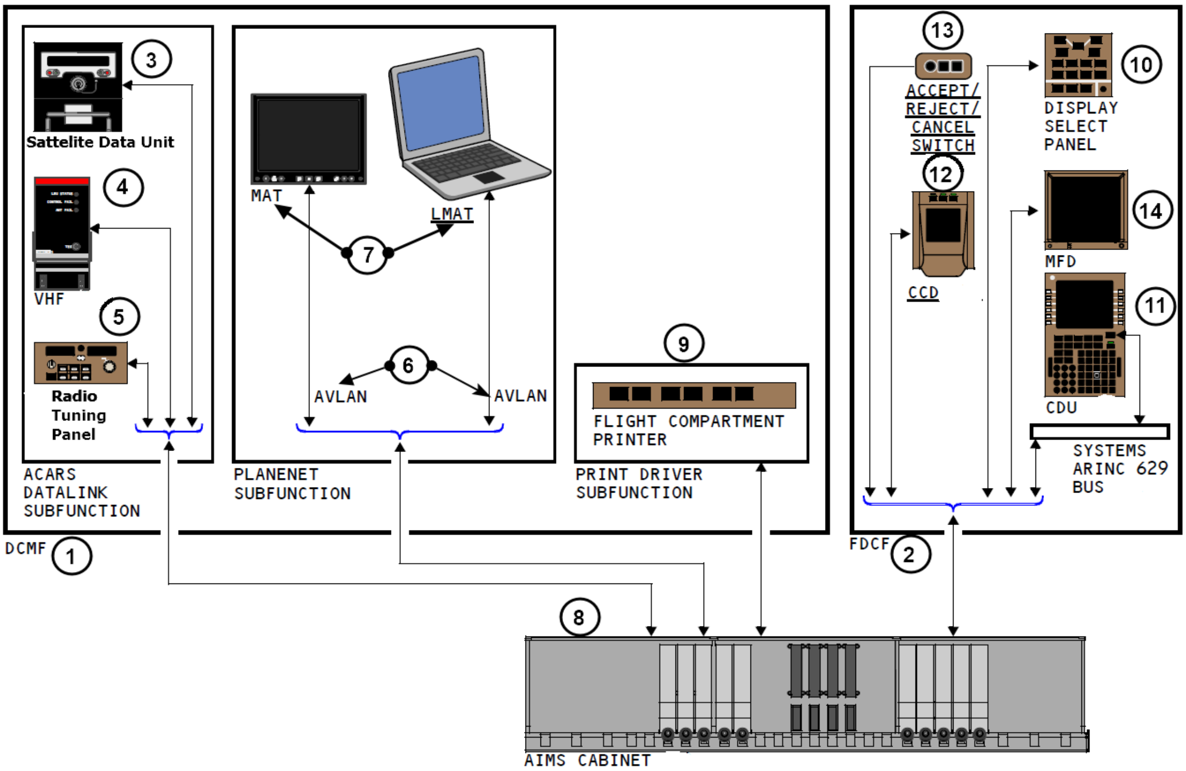

Figure 1. Architecture of data communication management system (DCMFS).

1. The DCMF controls the aircraft communications addressing and reporting system (ACARS) interface with:

a. The flight deck printer

b. The avionics local area network (AVLAN)

2. The flight deck communication function (FDCF) displays show on a multifunction display (MFD). The FDCF receives messages from the airline ground station and sends them to the primary display system (PDS) to show on the MFD. The flight crew can also send messages to the airline ground station.

3. The satellite communications (SATCOM) system uses ground stations and satellites to transmit and receive data and voice messages. SATCOM gives higher quality data and voice message signals for passengers and crew for longer distances than VHF/HF communication systems.

4. The very high frequency (VHF) communication system permits voice and data communication over line-of-sight distances. It permits communication between airplanes or between ground stations and airplanes.

5. The radio tuning panel (RTP) selects the modes of operation, and selects the active and standby frequencies for each communication radio.

The datalink subfunction connects to these components of other systems:

- The satellite communications (SATCOM)
- VHF communication transceivers
- Radio tuning panels (RTPs).

The DCMF uses the data key line to do a key of the VHF communication transceiver. When the DCMF does a key of the transceiver, the DCMF sends the downlink message to the VHF communication transceiver [10].

The DCMF uses the voice/data select to set the VHF communication transceiver to the data signal mode. At power-up the DCMF sets the center VHF communication transceiver to the data signal mode. If the center VHF communication transceiver has a failure, then it chooses the SATCOM for data transmissions.

If SATCOM has a failure, the DCMF selects the right VHF communication transceiver for data transmissions since there are installed 3 e.a VHF Transceivers.

6. The AVLAN is also known as the PlaneNet sub-function that controls the data exchange between the DCMF and the components on the AVLAN.

The DCMF supplies the protocols and controls data for ACARS datalink subfunction and avionics local area network.

The datalink subfunction controls the transfer of flight plan and maintenance data between the airplane and the ground service provider (GSP).

The PlaneNet interface subfunction that shown in Figure 1 controls the data exchange between the DCMF and the components on the AVLAN.

7. The AVLAN includes these components:

- Maintenance access terminal (MAT)
- Laptop maintenance access terminal (LMAT).

8. The airplane information management system (AIMS) cabinet collects and calculates large quantities of data. The AIMS use this data for different integrated avionics systems and MAT, LMAT is necessary for connection to AIMS cabinets [11].

9. The printer can print an 8.5-inch page. The printer resolution is 300 dots per inch. You can load a full paper roll of 125 linear feet into the printer. The printer uses the U.S. standard 8.5-inch roll or the A4 European Air standard paper.

The print driver subfunction controls all print requests for the DCMS. This subfunction sends data from the DCMS to the flight compartment printer and sends print job status and fault data back to the DCMS.

The Flight deck communication function (FDCF) provides the interface between the flight crew and the DCMS (Figure 2). These components that shown in Figure 1 are used to make inputs to the FDCF:

- Display select panel (DSP)
- Multi-function display (MFD)
- Control display units (CDU)
- Cursor control devices (CCD)
- Accept/reject/cancel switches.

10. The Display select panel (DSP) controls which display unit shows the Multi-function display (MFD).

The DSP is also used to select the Flight deck communication function (FDCF) main menu display.

11. The CDUs are used to enter text into the FDCF displays.

After text and/or numerics have been entered in the CDU scratch pad, the Cursor control devices (CCD) select switch is used to enter it to the FDCF display.

12. The Cursor control devices (CCD) are also used to set menu items, buttons, and text boxes on the FDCF displays.

13. The accept/reject/cancel switches are used to accept, reject, or cancel datalink messages that are displayed on the FDCF displays.

14. Via the Flight deck communication function (FDCF) Menu’s the Crew can send the following requests and downlink reports through the multi-function displays (MFD) as shown in **Figure 2:**

1. **Altitude request** - The flight crew can make altitude requests.
2. **Route request** - The flight crew can make route requests.
3. **Speed request** - The flight crew can make speed requests.
4. **Clearance Request Display** - The flight crew can request clearances.

5. **When Can We Expect Display** - The flight crew can request schedule information about altitude, speed and route changes.

6. **Voice Contact Request Display** - The flight crew can request voice contact with the ATC.

7. **Logon/Status Display** - The flight crew uses to connect to the ATC.

8. **Emergency Report Display** - The flight crew can report an emergency.

9. **ATC Requested Reports** - The ATC can request reports from the flight crew.

10. **Position Report Display** - The flight crew can report position information.

11. **Free Text Message Display** - The flight crew can use this display to make free text messages and send them to the ATC.

Figure 2. Flight deck communication function (FDCF) MFD ATC MENU.

Moreover, the crew can send additional information to the airline and the following downlink requests through the multi-function displays (MFD) COMPANY menu as shown in **Figure 3**.

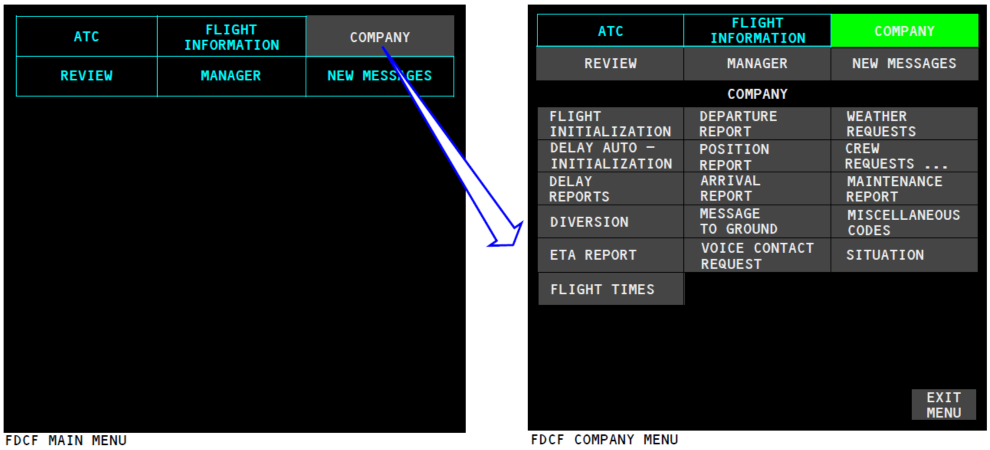

Figure 3. Flight deck communication function (FDCF) MFD COMPANY MENU.

1. **Delay Reports** - The flight crew uses the delay reports to tell the airline of a departure, takeoff or enroute delay.
2. **Diversion Display** - The flight crew uses the diversion report display to tell the airline the ETA at the diversion destination.
3. **Estimated Time of Arrival Report Display** - The flight crew uses the estimated time of arrival display to tell the airline the planned ETA at the destination airport.
4. **Flight Times Display** - The flight crew uses the flight times display to show the OUT, OFF, ON, and IN times. This shows the fuel on board and boarded fuel for the current and previous flights
5. **Departure Report Display** - The flight crew uses the departure report display to send information that shows on the flight times display and additional information that relates to a departure.
6. **Position Report Display** - The flight crew uses the position report display to send this information:
    - Position information
    - Current position
    - Flight level
    - Next position
7. **Arrival Report Display** - The flight crew uses the arrival report display to send information that shows on the flight times display and additional information that relates to an arrival.
8. **Weather Requests Display** - The flight crew uses the weather request display to request weather information from the airline host or ground service provider.
9. **Maintenance Report Display** - The flight crew uses the maintenance report display to enter codes and/or free text about maintenance problems for transmissions to the ground.
10. **Situation Display** - The flight crew uses the situation display to tell the ground station of an emergency situation.

In order to activate datalink function airline should consider an agreement with datalink service provider (DSP) most known DSP's are ARINC and SITA in order to run the datalink communication will be required some software's [10].

The software's should be uploaded to the airplane information management system (AIMS) cabinet and depends on airline requirement the software can be customized as per airline requirements or uploaded default software that will specify the downlink reports related to the aircrafts systems.

In addition, in order to set up ground infrastructure the airlines should procure the ground servers in order to be able to accept downlink reports or free text messages, it can be cloud server or physical hardware servers [11].

By taking into account all above mentioned we can say that nowadays the availability of datalink communication is very important for the airlines to monitor and control their fleet by receiving of necessary information related to Maintenance condition, Planning purposes and reliability reports that allow to take preventive action to keep the fleet in airworthiness condition.

Methods of research and analysis.

The research has been done based on following manuals:

1. Training Manual for B777 Ref: COM-2OF2-1799528
2. Application requirements document for ACMS Ref: ARD-COL0053OPRTR
3. Datalink User Manual SITA Ref: 02/VL.UG-ACS-001(1)
4. Operational use of datalink Ref: STL 945.3173/04

Analysis of results of investigations and experimental simulation.

Data link services provide communications that are intended to support more efficient air traffic management and increase airspace capacity. In addition, in airspace where procedural separation is being applied, the data link services improve communications, surveillance and route conformance monitoring to support operational capabilities.

Datalink communication improves communication capabilities by reducing voice channel congestion and enabling the use of transmission related to automation [1,7-9].

Conclusion. The results of the conducted studies showed that depending on the specific implementation of Data communication management system (DCMS), other advantages associated with DCMS include [10,11]:

a) Providing Data communication management function (DCMF) in airspace where it was notpreviously available.

b) Allowing the flight crew to print messages.

c) Allowing messages to be stored and reviewed as needed.

d) Reducing flight crew-input errors by allowing the loading of information from specific uplink messages, such as route clearances or frequency change instructions, into other aircraft systems, such as the FMS or radios.

e) Allowing the flight crew to request complex route clearances, which the controller can respond to without having to manually enter a long string of coordinates.

f) Reducing flight crew workload by supporting automatically transmitted reports when a specific event occurs, such as crossing a waypoint and the loading of clearance information directly into the flight management system.

g) Reducing controller workload by providing automatic flight plan updates when specific downlink messages (and responses to some uplink messages) are received.

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