THE DISCRETE ADDRESS BEACON SYSTEM DATA LINK

John L. Leeper and James C. Anderson
M.I.T./Lincoln Laboratory
Lexington, Massachusetts

Abstract

The Discrete Address Beacon System (DABS) is a surveillance and communication system for air traffic control. DABS is under development as an evolutionary replacement for the FAA's existing Air Traffic Control Radar Beacon System (ATCRBS) to enhance surveillance and provide a digital data communication capability. Each DABS aircraft recognizes and responds with a unique code (its discrete address), thus permitting data link messages to and from a particular aircraft to be accommodated integrally with the surveillance interrogations and replies. The FAA is currently testing a set of data link applications which will provide aviation services for the initial field implementation of DABS. Link formats, ground interfaces, and systems to support a set of data link applications are also being evaluated for inclusion in the DABS field implementation.

The initial data link services include ATC coordination messages and ground-to-air dissemination of weather and aviation related information. Uplink ATC messages include Minimum Safe Altitude Warning (MSAW) Alerts, Altitude Assignment Clearance Confirmation messages, and Takeoff Clearance Confirmation messages. These messages provide the pilot with a supplementary visual confirmation of voice communications. The services also include the capability for the pilot to request weather products derived from National Weather Service (NWS) information. The weather products include surface observations, terminal forecasts, winds aloft, pilot reports, hazardous weather advisories and digitized weather radar information. Real-time surface measurements from the Enhanced Terminal Information Service (ETIS) are also included. The ETIS is a flight advisory service which provides the pilot information to assist in conducting safe approaches to (or departures from) an airport. It includes information normally provided by the current Automated Terminal Information Service (ATIS) plus additional data such as weather alerts which pertain to the airport of interest.

A DABS data link avionics system has been developed for the purpose of demonstrating and evaluating the initial services. It consists of an airborne microprocessor system with a variety of peripherals and interfaces. The microprocessor communicates with the ground-based equipment via a DABS transponder. Data link information included in the uplink interrogations is processed in the airborne microprocessor and then displayed to the pilot. The display device is a time-shared weather radar indicator with a 256 x 256 bit color graphics capability. Other peripherals include a printer, pilot keyboard, altitude alerter, and a multi-function annunciator capable of speech output.

The Discrete Address Beacon System (DABS)

The Federal Aviation Administration is currently developing the Discrete Address Beacon System (DABS) as an evolutionary replacement for the existing Air Traffic Control Radar Beacon System (ATCRBS). Like ATCRBS, DABS provides the range, azimuth, altitude and identity information required for air traffic control surveillance. The fundamental difference between ATCRBS and DABS is the selective interrogation of aircraft transponders by DABS. Each DABS aircraft transponder recognizes and responds with its unique code and ignores interrogations directed to other aircraft. This discrete addressing feature avoids the surveillance saturation which can occur with ATCRBS when replies are generated by all transponders within the sensor mainbeam.

In addition to the improved surveillance accuracy and reliability, DABS provides an integral two-way data link between the DABS sensor and all DABS transponder equipped aircraft in view of the sensor. The discrete address of the sensor interrogations and transponder replies provide the identification required for digital communications, and the interrogation/reply formats contain coding space to include messages.

DABS interrogations and replies consist of 56 or 112 bits, which include the 24-bit discrete address of the transponder. The 56-bit formats are designed for surveillance. DABS data link transactions utilize the 112-bit formats shown in Fig. 1. The normal data link format includes a link control field, a surveillance data field, a standard message field, and a combined address/parity field. Since the normal data link format includes a surveillance data field, it is used in place of, rather than in addition to, a surveillance interrogation and/or reply. The message field of the normal data link format is used for tactical message applications, and other messages where the message content can be encoded in the 56-bit field. Uplink interrogations using the normal data link format are referred to as Comm-A interrogations, and downlink replies in the normal data link format are Comm-B replies.

LINK CONTROL FIELD 16 BITS	SURVEILLANCE DATA FIELD 16 BITS	STANDARD MESSAGE FIELD 56 BITS	ADDRESS/PARITY FIELD 24 BITS

a) Normal Data Link Format

LINK CONTROL FIELD 8 BITS	EXTENDED LENGTH MESSAGE FIELD 80 BITS	ADDRESS/PARITY FIELD 24 BITS

b) Extended Length Message Format

Fig. 1. DABS Data Link Formats

The extended length message (ELM) format utilizes a reduced link control field, eliminates the surveillance data field and provides an 80-bit message field. This format is used for the efficient transmission of long data link messages. Up to sixteen extended length messages can be transmitted, either uplink or downlink, and acknowledged with a single downlink or uplink as appropriate. The acknowledgment indicates which, if any, of the message segments were not received or were received in error. The missing segments are then retransmitted until the transaction is complete. The ELM format is a data link format and is not used for surveillance.

The address parity/field of all DABS formats includes a 24-bit discrete address overlayed with a 24-bit parity field. Errors occurring in the reception of an interrogation or reply alter the decoded address. If this occurs in an uplink interrogation, the transponder rejects the interrogation and does not reply. For reply errors, the sensor performs a limited amount of error correction since the expected address is known. This error correction resolves many error patterns that span no more than 24 bits, which occurs when interference is caused by a single simultaneously-received ATCRBS reply.

DABS data link integrity is assured by the use of technical acknowledgments and error detection. If interrogation errors are detected by the transponder, a reply is not transmitted, and the sensor repeats the message. For a downlink message, the sensor acknowledges the receipt of a message in the following interrogation. If a sensor acknowledgment is not received by the transponder, the message is repeated at the opportunity. This combination of error detection and technical acknowledgment assures the sender that the message has been received correctly before the transaction is considered complete.

DABS Data Link Applications

The FAA is currently testing an initial set of data link applications which can provide aviation services in the same time-frame as the DABS sensor implementation, i.e., the mid-1980's. Development testing of these initial applications is being conducted at the DABS Experimental Facility at M.I.T. Lincoln Laboratory. Formal test and evaluation will begin at the National Aviation Facilities Experimental Center (NAFEC) in late 1979.

The introduction of data link services is visualized as an evolutionary process. The data link applications outlined below are the candidates for the initial DABS data link implementation, and include ATC coordination messages, ground-to-air data dissemination, and terminal information services. Additional services will be tested as the necessary ground support systems become available.

A basic application of the DABS data link is the delivery of ATC messages to DABS data link equipped aircraft. ATC messages are highly structured messages which often require rapid delivery to the aircraft. ATC data link applications utilize the Comm-A format since the message information can be encoded in a single interrogation and delivered on a priority basis. The three ATC coordination messages to be tested at NAFEC are summarized below.

Minimum Safe Altitude Warning (MSAW) Alerts

In all ARTS-III terminals, the approach controller is provided a visual warning and an aural alarm when tracked Mode-C equipped aircraft are projected to violate site dependent low altitude criteria programmed into the ARTS-III processors. This information is relayed to the flight crew by the controller over the current voice link. The DABS data link extends the MSAW alert utility by sending the same alert to DABS data link equipped aircraft. This can reduce the delay between detection and warning transmittal, and possibly provide the pilot more time to react.

The DABS data link MSAW message is delivered to the aircraft during each antenna scan, as long as the MSAW alert is active. When the MSAW alert is dropped, a Clear-MSAW message is delivered to the aircraft to clear the alert from the cockpit display.

Altitude Assignment Clearance Confirmation

The Altitude Assignment Clearance Confirmation is an uplink message to the cockpit of the altitude to which the enroute controller has cleared the aircraft. The message provides the pilot with a visual confirmation of the standard voice clearance. The message is triggered by the controller keyboard input of the assigned altitude. The keyboard entry is used as standard procedure to enter the assigned altitude into the aircraft data block on the controller's display. Past occurrances of misunderstanding of an altitude clearance are minimized by the visual confirmation transmitted over the DABS data link.

Takeoff Clearance Confirmation

As with the Altitude Assignment Confirmation, the Takeoff Clearance Confirmation provides the pilot with a visual confirmation of the standard voice clearance. The takeoff clearance confirmation allows the flight crew to easily confirm that the clearance exists, and minimizes the possibility of misunderstanding between the crew and the controller.

Weather Information

Routine weather information available on the ground is currently delivered to the cockpit by voice communications from controllers and flight service station personnel. With the establishment of an automated weather data base, much of this information can be provided over the DABS data link. The near-term candidate weather services are provided on a request basis to avoid cluttering the data link display with unnecessary information. Providing this information via the DABS data link makes the information readily available to the pilot and potentially reduces the human workload of the ground system.

The initial weather products to be evaluated as DABS data link applications are:

1. Hourly Surface Observations
2. Terminal Forecasts
3. Pilot Reports
4. Winds Aloft Forecasts
5. Hazardous Weather Advisories
6. Digitized Weather Radar Summaries

The ELM format is used for the uplink delivery of all weather messages, using six-bit truncated ASCII coding for the alphanumeric information. Downlink pilot requests for weather information are encoded in normal data link downlink (Comm-B) format.

Enhanced Terminal Information Services (ETIS)

Terminal area information is currently provided by recorded voice messages from the Automated Terminal Information Service (ATIS). Updates to the recorded messages are provided by the controller as necessary. With the introduction of automated weather systems, much of this information can be automatically delivered to the cockpit over the DABS data link.

In support of the data link applications program, the Transportation Systems Center, Cambridge, Massachusetts has developed a concept for providing terminal area information to aircraft utilizing the DABS digital data link. The Enhanced Terminal Information Services (ETIS) is a flight advisory service which provides information to assist the pilot in conducting a safe approach to or departure from an airport. It includes the information currently provided by ATIS, plus other data such as weather alerts which pertain to the airport of interest.

The basic ETIS data link message provide a report of the local weather and airport conditions, similar to ATIS messages. This information is automatically updated by ETIS change notices as conditions change. If the aircraft is on final approach and conditions warrant, visibility and wind information are delivered. Wind shear alerts are also automatically transmitted to DABS data link equipped aircraft.

Tactical ETIS messages, such as the wind shear alerts and the final approach messages, are delivered to the aircraft as priority messages encoded in Comm-A interrogations. The basic ETIS messages and change notices are encoded as alphanumeric text messages and are delivered as extended length messages.

Automatic Traffic Advisory and Resolution Service (ATARS)

ATARS is a ground-based collision avoidance system based upon the earlier concept of Intermittent Positive Control. It utilizes surveillance data from DABS, formulates traffic and resolution advisories, and delivers the advisories via the DABS data link. While ATARS is being tested independent of the above data link applications, the airborne d[illegible] link system described later is designed to acc[illegible]e ATARS as an integral part of the system.

DABS Data Link Ground Environment

Figure 2 shows a simplified block diagram of the DABS data link ground environment to be used in the NAFEC testing. In addition to providing surveillance information, the DABS sensor operates as a store-and-forward communication relay to and from DABS data link aircraft. ATC messages are passed to the sensor from the ATC automation computers, and other data link messages are generated by the data link Applications Processor (AP). The AP processes downlink information requests, performs the necessary information retrieval, and formulates the uplink messages in the appropriate DABS formats.

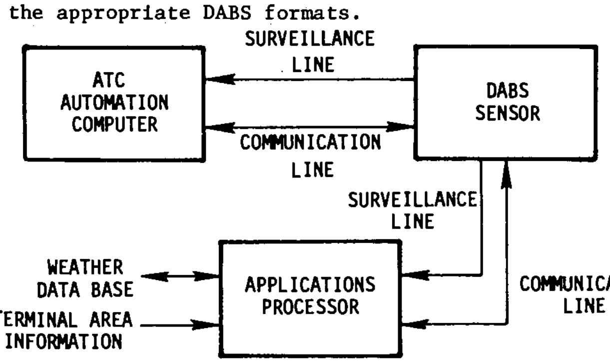

Fig. 2. Simplified DABS Data Link Ground System

The information source for the requested weather products is the flight services weather data base located at MITRE/METREK in McLean, Virginia. This data base is used in the Pilot Self Briefing (PSB) program, and a modified PSB retrieval program developed by the Transportation Systems Center provides the weather messages to the AP. In an operational system this information would be retrieved from a fully automated weather data base serving a wide variety of users.

Terminal area information will be provided from a local processing system at NAFEC. This system collects the required weather information, wind shear alerts, and keyboard inputs necessary to complete the ETIS reports. Updates on the inputs are provided to the ETIS processor in the AP. The surveillance input to the AP provides the ETIS processor with the aircraft position information required for the triggering of the final approach messages.

Airborne Display System

A DABS data link avionics system, called the Airborne Intelligent Display (AID), has been developed for the purpose of demonstrating and evaluating the initial and future services. The AID consists of an airborne microprocessor system with a variety of peripherals and interfaces (refer to Fig. 3). The AID is not aimed at any specific segment of the aviation community (e.g., general aviation or commercial), but rather is a tool to aid in the evaluation of the initial data link applications. Maximum flexibility of the data link avionics is provided by the DABS data link formats so that individual users can select from a variety of display options appropriate to the service and price range desired.

The AID's microprocessor is a bus-oriented design (S-100 Bus) and uses a Z-80 CPU system. The computer system uses 32 kilobytes (KB) of RAM for temporary data storage, 16 KB of Erasable Programmable ROM (EPROM) for monitor program storage, and 32 KB of EPROM for bulk storage of look-up tables. The memory available in the AID is, of course, far more than would be needed for an operational system. The large amount of available memory allows a high degree of system flexibility.

The microprocessor communicates with the ground-based equipment via a DABS transponder. The transponder is equipped with two digital interfaces: the Standard Message Interface (SMI) and Extended Length Message (ELM) interface. The SMI provides a "party line" type of serial data connection, and a number of devices can be attached to the SMI, although the microprocessor is the only device shown attached in Fig. 3. The SMI operates at a 1 MHz data rate. The ELM interface is a medium-speed (12 to 14.5 KHz) serial interface which is used when a large amount of information is to be uplinked (or downlinked). The ELM interface is not connected to any other equipment.

Data link information included in the uplink interrogations is decoded in the airborne microprocessor and then displayed to the pilot on a high visibility CRT unit. The CRT is a color weather radar indicator with minor modifications, and is capable of producing white, green, red, aqua, yellow, and magenta graphics or characters. The ability of a single centralized display to perform multiple functions is demonstrated, because both data link and weather radar information can be displayed.

The CRT unit provides timing signals to the optional weather radar transceiver unit and to the AID's video RAM system. Video data is sent from the radar transceiver and the AID to the CRT unit. The display mode is selected by two bits which are sent to the CRT under microprocessor control. The four possible display modes are:

1. weather radar data only
2. weather radar data OR'ed with data link
3. data link only
4. blank screen

When the microprocessor is powered down or disconnected, the CRT displays weather radar data (mode #1) as a default condition, assuming that the aircraft is equipped with a weather radar transceiver unit. If the pilot wishes, he or she can normally look at weather radar data and be alerted only when there is a data link message which has been uplinked. In this mode of operation (mode #2) the words "MESSAGE PENDING" will appear on the CRT and overwrite, but not interfere with, the weather radar data. If a priority message is uplinked, the data link system automatically takes over the CRT to display the information (mode #3). This mode can also be selected by the pilot as a normal operation mode, if desired. Finally, the microprocessor can blank the CRT screen, when necessary, to prevent invalid or changing data from being displayed. This mode (mode #4) is required because the video RAM must be accessed both by the computer and by the CRT display, causing memory contention. To prevent this memory contention from displaying extraneous "hash" on the CRT, the computer simply blanks the CRT, changes the required memory locations in the video RAM, and then unblanks the CRT. The entire process typically takes less than .1 second, depending upon how much video RAM data must be changed.

The 24 KB video RAM itself is organized as 256 bits by 256 bits by 3 memory banks, one bank controlling each of the CRT guns (red, green, and blue). Characters are generated via graphics software, so that the character set and size are completely under program control. The character size normally used for data link information allows 13 lines of 32 characters to be displayed. Character color is selected by writing data into one or more video RAM memory banks simultaneously. Because of this feature, all characters can be produced in the same amount of time regardless of the character's color, which can cut processor time required to produce a given display by as much as a factor of three.

The overall AID operation is controlled from a four-position selector switch mounted on the cockpit control panel. The positions are labeled:

1. WX RADAR only
2. WX RADAR/DATA LINK
3. DATA LINK
4. TEST

In the first position, power to the microprocessor is turned off, and the weather radar system and DABS transponder can operate as though no microprocessor system existed. In the second position, only weather radar data is displayed unless a data link message is pending. In this selector switch position the display is actually shared by data link and the weather radar, as described earlier. When the third switch setting is used, the CRT is displays only data link information. The fourth selector switch position is presently used to allow access to built-in test and diagnostic programs which reside in the computer's read-only memory. In the future, programs could be added which would

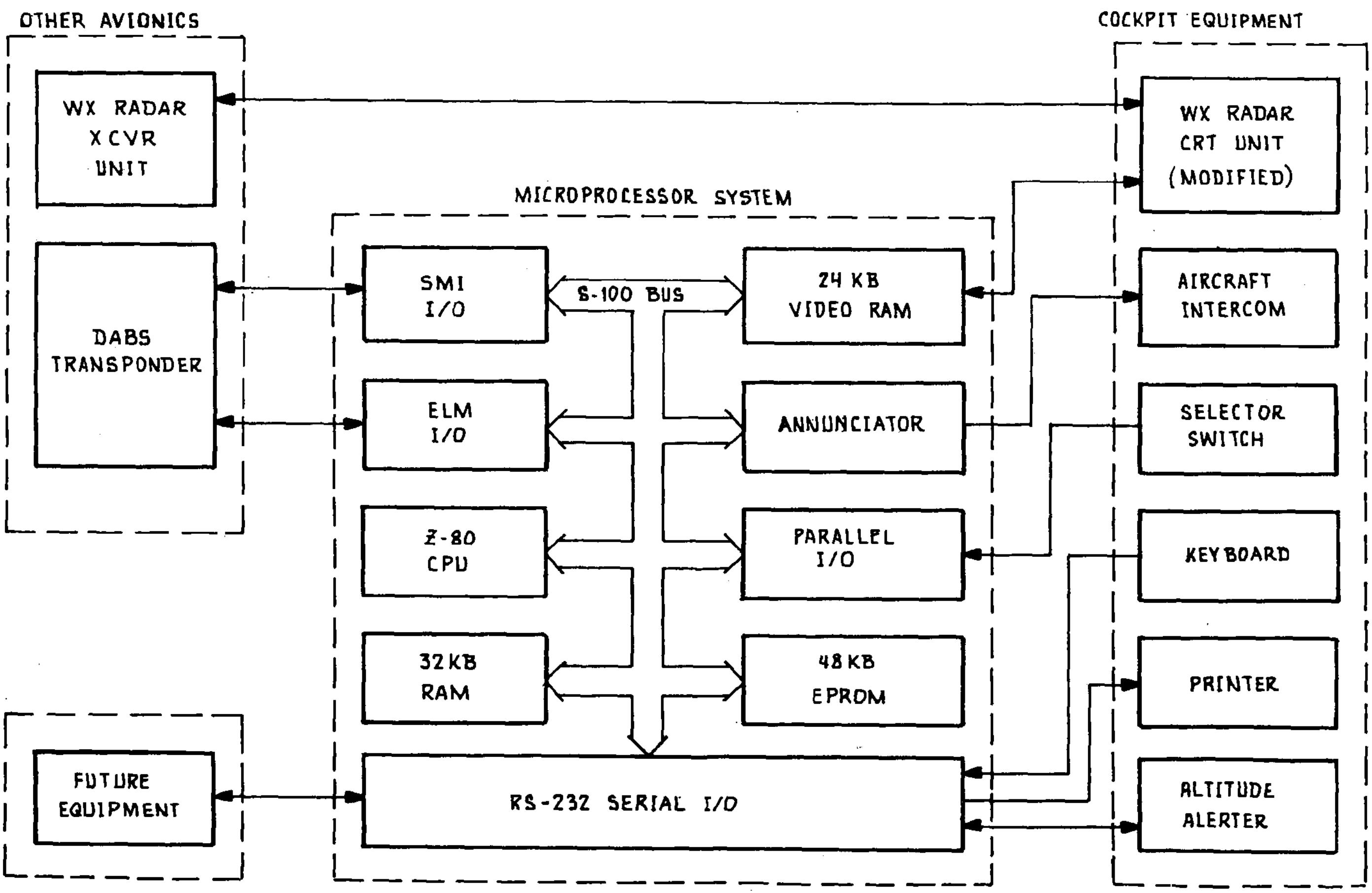

FIG. 3. AIRBORNE INTELLIGENT DISPLAY (AID)

allow the pilot to use the computer as a calculator, run navigation programs, etc., although these features are not part of the immediate objectives of the project.

An annunciator system which is capable of speech output is used to alert the pilot when messages have been received via the DABS data link. The annunciator, which feeds into the aircraft intercom system, is also capable of producing audible alarms under program control. The speech data is encoded using CVSD (Continuously-Variable Slope Delta) modulation, since LSI chips for this purpose are available from a number of manufacturers. The speech is encoded at a rate of 2 KB per second. This speech data is then stored in 16 KB of EPROM in the bulk storage (look-up table) portion of the microprocessor's memory. When a word is to be spoken by the annunciator, the microprocessor transfers the appropriate data from memory to an output port, where it is buffered in a 4 KB external RAM. When all the required data has been transferred to the external RAM, the processor issues a command which causes the annunciator system to take data from this RAM and feed it into a CVSD decoder which produces the speech output. The processor, meanwhile, is free to do other tasks and is interrupted when the speech output is complete. Tone outputs are accomplished in similar fashion, except that small programs are used to generate the required data for output, as opposed to storing the entire repetitive pattern in a ROM. The current pre-stored vocabulary consists of the following words: acknowledge, alert, altitude, clearance, high, low, message, pending, takeoff, and windshear. The verbal messages to be constructed from this vocabulary consist of: altitude clearance, low altitude alert, takeoff clearance, windshear alert, altitude high, altitude low, and message pending. When required, the word "acknowledge" can preceed a spoken message, thereby asking for a pilot response, e.g., "acknowledge altitude clearance".

Pilot data entries are made on a calculator-type alphanumeric keyboard. The keyboard is small and light-weight so that it can be strapped to the pilot's knee, mounted on the yoke (steering column), or mounted on the cockpit control panel. Special function keys allow the pilot to edit data, enter multiple downlink requests, send data to a printer, clear the display, and so on.

A cockpit printer is used to obtain hard copy of alphanumeric information. For example, weather information requested by the pilot can be sent to the printer to be preserved for future reference. Certain message types can be routed directly to the printer, if desired, without being displayed on the CRT. This demonstrates the use of distributed displays, as opposed to using only the CRT for display purposes.

Another peripheral which demonstrates the distribution of display responsibilities is the Altitude Alerter unit. The pilot normally enters a desired altitude into the alerter, and this information is automatically compared with the aircraft altimeter reading. The system alerts the pilot when the selected altitude has been achieved, and again if the altitude varies from the selected setting. Rather than having the pilot select the altitude value, the alerter can optionally be loaded by the processor with the altitude which has been uplinked in the altitude assignment clearance confirmation message.

A number of interface options are available for the addition of future equipment. RS-232 serial I/O lines as well as TTL parallel I/O lines are generally used. Additionally, lines are available so that external devices can generate CPU interrupts when necessary.

The microprocessor system resides in a shock mounted standard 2-ATR enclosure (15 x 19.5 x 7.5 inches), and the power supplies are mounted in a separate but similar enclosure. No attempts were made to minimize physical volume of this experimental AID system, and a mass-produced version of such a system would occupy considerably less volume. Adequate cooling is provided in each enclosure so that the AID can operate over a broad temperature range. Additionally, temperature switches are provided in each of the two enclosures so that the AID automatically turns its power off if the base plate temperature exceeds 80°C (176°F). Inexpensive temperature recorders (heat-sensitive paper) are placed throughout the system so that problem areas can be located in the event of a thermal failure.

Summary

The DABS data link provides the capability for two-way data communication between the ground and DABS data link equipped aircraft. The FAA is currently testing a set of initial applications which can be implemented in the same time-frame as the DABS sensor application.

A digital avionics system has been developed for the purpose of demonstrating and evaluating the initial services.

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