THE DISCRETE ADDRESS BEACON SYSTEM (DABS)

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Introduction

The requirement for additional automation in the air traffic control process has placed new emphasis on the need for high quality surveillance data and for a ground-to-aircraft data link. The ATCRBS beacon system has proven a valuable complement to radar because it provides the ground controller with position, identity, and altitude data that is not contaminated by ground and weather clutter. However, the growing number of beacon-equipped aircraft and ground interrogators and the inherent self-interference limitations of the ATCRBS beacon system have motivated the need for a more reliable and flexible beacon system. In 1969 the Air Traffic Control Advisory Committee recommended the development of such an improved system which they named the Discrete Address Beacon System (DABS), incorporating both surveillance and a data link. Since 1971, M.I.T. Lincoln Laboratory, under the sponsorship of the FAA, has been investigating various DABS design options.

Because the widespread implementation of any new beacon system will be expected to take place over a long period of time (10 to 15 years), one very important consideration in the design of DABS was to maintain complete compatibility with ATCRBS. The DABS interrogator must therefore be designed to operate with both DABS and ATCRBS transponders, and the DABS transponder must be capable of responding to both DABS and ATCRBS interrogators. Two other basic design factors were (1) to provide a data link capability adequate to meet all the foreseeable ATC needs, and (2) provide a version of the system at a cost which would be acceptable to the general aviation pilot. A crucial issue was to ascertain if a system meeting these requirements could be designed with a very high reliability when it is operating in the ATCRBS channel interference environment.

Description of DABS

DABS, as its name implies, is a system with the ability to discretely address any particular aircraft and to elicit a response from it and not from its neighbors. In this manner, interference on the channel will be reduced and overlapping returns from closely-spaced aircraft will be eliminated. In addition, since DABS will be a new generation of equipment (Fig. 1),it can exploit improved coding and digital processing technology to achieve added flexibility and reliability. To reduce the interference in the channel, DABS will use monopulse direction-finding techniques, which will enable a single interrogation and response to update a surveillance track on an aircraft.

The ability of a ground site to uniquely address a specified aircraft permits the use of DABS as a data link to pass digital messages from the ground facility to and from an aircraft. The availability of such a data link for routine ATC messages will leave the VHF voice channel free for special situations and back-up. In DABS, a ground site will interrogate an aircraft only as often as it needs to refresh the surveillance file or deliver a message. This adaptive technique, plus the more effective use of system netting and the use of redundant coverage from nearby sites, offers an attractive possibility for achieving high system capacity, reliability, and accuracy.

Function of DABS in ATC

The ATC process involves three basic functions: surveillance, control, and

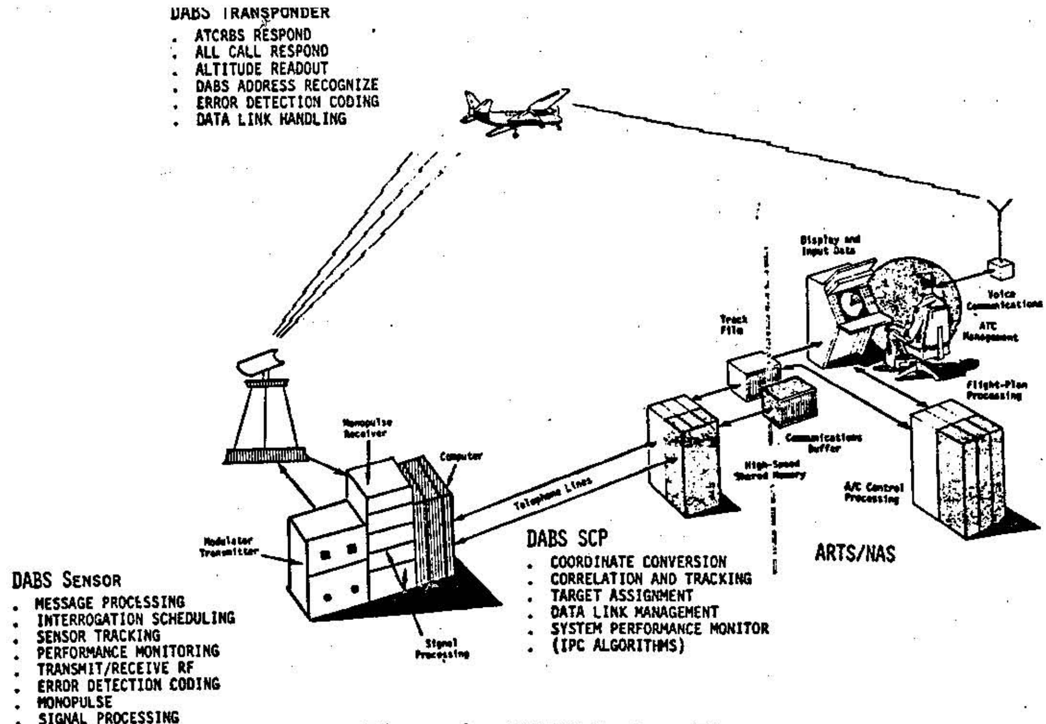

Figure 1. DABS System Elements.

communication. In today's system, one or more radars or beacons are used to provide surveillance data to a control facility where a team of controllers edit the data and assist the computer to initiate and maintain tracks. The air traffic controller makes decisions based on flight plans plus the observed surveillance data and communicates to aircraft by VHF voice radio.

With additional automation, the role of the controller will change in three important ways. First, he will be relieved of the role of assisting in the surveillance function. This is the basis of one DABS requirement, i.e., a much more reliable surveillance function providing uninterrupted continuity of tracking. Second, the controller will be relieved of the task of communicating all control messages. Here is the second need to be met by DABS, i.e., to provide a two-way digital data channel for the computer to communicate directly with the aircraft unless the controller chooses to intervene. Third, and what in effect drives the other two changes, the controller must be gradually withdrawn from making most control decisions personally. Instead, they will be made by computer and the controller will manage by exception.

While it is conceptually possible to improve ATCRBS and provide a separate channel for a data link, the integrated system (DABS) offers both operational and economic advantages. Because DABS has the capability to service many thousands of aircraft. a ground site can reach any aircraft in its region without channel switching. In addition, the identity code which is needed for surveillance is also used in the discrete address communication function, and this results in economic advantages. Some of the comparative performance differences are shown in Fig. 2.

In the future automated system, all aircraft (both IFR and VFR) will be able to receive conflict advisories and collision avoidance commands based upon DABS capabilities, completely automatically, without controller involvement. DABS is currently being developed to support two forms of conflict detection; Intermittent Positive Control (IPC) which is ground based and centralized; and Synchro-DABS which is a form of airborne CAS.

In IPC, a computer calculates potential conflicts, and issues avoidance instructions via the DABS digital data channel to uncontrolled (VFR) aircraft. In addition, it provides a separation assurance back-up for all traffic, including IFR, in case of ATC system failure. IPC provides this service to a DABS-equipped aircraft, warning it of all traffic in its vicinity, whether that traffic is DABS- or only ATCRBS-equipped.

Synchro-DABS is a mode of DABS operation wherein each DABS ground site schedules its interrogations so as to synchronize the reply times of the aircraft transponder.

	ATCRBS and VHF Voice	DABS
Surveillance Accuracy (1 σ) at 20 miles	400 x 400 ft	200 x 200 ft
Interrogations used for surveillance update	20	1 or 2
Communication capacity	Voice limited (~5 a/c per controller per min)	$>10^4$ 100-bit msg per 4 sec
Max. IFR a/c handled per controller	~ 7	~ 14 (with IPC)
ATC service for VFR a/c	optional (as time permits)	continuous

Figure 2. Comparative Performance

Then, each aircraft, by listening to the replies of all its neighbors, can determine range, and from successive replies the range rate. This, along with a simple airborne directional antenna, permits the equipped aircraft to compute its own avoidance maneuvers. Synchro-DABS would be effective with other DABS-equipped aircraft only, not against ATCRBS-equipped aircraft.

Data Link Considerations

To efficiently time-share a single interrogator with the many hundreds of airplanes that might be within its coverage zone, it is necessary to be able to complete a ground-air interrogation and response in a relatively short period of time. However, this requirement can be met relatively easily since the surveillance accuracy, which calls for a position determination with an uncertainty less than a few hundred feet, dictates the use of a channel bandwidth of greater than one MHz. This bandwidth is adequate to accomplish all of the surveillance and data link functions, even when it is time-shared among several thousand aircraft. The adaptive interrogation mode permits long messages to be segmented and/or sent in an extended digital burst which is limited only by the characteristics of the airborne data storage and display. In the very high density traffic areas, a ground interrogator with an agile electronic array antenna can easily handle the projected demands of several thousand aircraft.

Since DABS will be used for both surveillance and communications, it must be extremely reliable. In addition to the obvious back-up components at an interrogator site, the netting of sensors and the effective utilization of contiguous sites with overlapping coverage is indicated. This mode of operation should also minimize the effects of aircraft antenna shielding since an antenna is rarely shielded simultaneously from several ground sites.

Elements of the DABS Surveillance and Communication System

1. Transponders

Three types of DABS transponders are envisioned. Two of these will be principally for use by general aviation and the third type primarily by the air carrier. All three types are identical in their surveillance and synchro-DABS functions but differ in their data link capability (see Fig. 3). The lowest cost transponder will provide the surveillance function plus uplink for IPC and downlink for pilot acknowledgment. The next level of transponder would include the above functions plus a nominal uplink and downlink message capability. This, when interfaced to cockpit input-output devices, in addition to IPC, will provide a complete two-way digital communication capability. This transponder will serve all the ATC data communication needs of VFR and IFR flights, including messages relating to voice frequency settings, separations, merging, altitude changes, turn directions, air traffic advisories, altimeter settings, and IPC. The long-message capability transponder is expected to be used principally by air carriers and will permit complete change of flight plan, more extensive pilot reporting

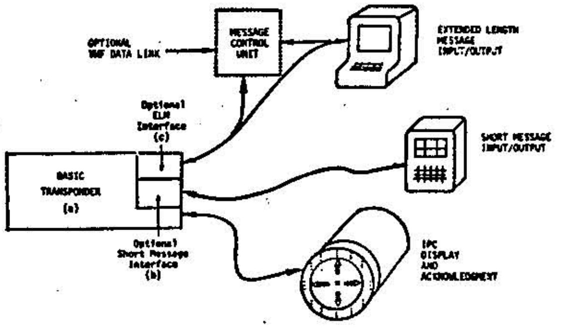

Figure 3. DABS Avionics

on weather, and transmission to the cockpit while in flight of pertinent notices to airmen, such as those that deal with the status of airways facilities, runway obstructions, etc.

2. Ground-Air-Ground Link

a) Uplink Formats: Each DABS interrogation (on 1030 MHz) begins with a pair of pulses spaced 2.0 μsec, followed by appropriate synch and initializing waveforms. The pulse pair prevents random triggering of ATCRBS transponders by simulating an ATCRBS sidelobe suppression. Following this preamble is a multibit format with DPSK modulation at a 3.2 megabit/sec rate. Each interrogation is composed of three segments: a link control segment, a message segment, and an address/coding overlay segment. The 24-address bits are planned to allow each aircraft its own unique identity. Using appropriate error-detection coding for the channel, 24 parity bits are overlayed on the address. In the transponder, decoding an error-free transmission removes the parity bits and leaves the address. In each case, the link control field indicates the nature of the uplink transmission and the type of reply expected. A surveillance interrogation is processed completely internal to the transponder, an IPC message goes via direct connection tr the IPC display, data link messages pas? through a buffer to the communications interface, etc. In each case, a reply, generated within the transponder, is returned within several microseconds.

b) Downlink Formats: Downlink transmissions (on 1090 MHz) use a redundant form of PAM at an information rate of 1.6 megabit/sec. The formats also contain three fields: a 24-bit address field, a link control field, and a variable-length message field.

3. The DABS Sensor

Several types of DABS sensors, each performing similar functions will be designed to match the various traffic and terrain conditions. Some DABS installations may utilize monopulse feeds operating with the reflector of the primary radar. It is further visualized that some DABS sensors will be initially deployed in a nearly stand-alone mode while others will be integrated into a network.

In the software of a general-purpose computer, sweep-to-sweep reply processing is done, followed by track correlation, smoothing, and prediction. Up- and downlink message processing, altitude correction, and interrogation scheduling are based upon sensor track file contents. The sensor computer accomplishes all interfaces with the control facilities. In addition, the computer monitors sensor performance to detect malfunctions. A typical ATC control facility would be serviced by and control the use of several sensors. Sensors can serve more than one control facility, and by using this multisensor network each aircraft can be reached (for surveillance and communication) by more than one sensor. In case of a failure at a control facility, each sensor can continue to serve other facilities and to perform IPC autonomously in the area normally under control of the failed control facility.

At a control center a computer assigns sensors to tracks, routes data link messages, checks for proper acknowledgments, and monitors performance of the entire surveillance and communication system. In the event of failure, the computer at the center reassigns areas and tracks, reroutes messages, and alerts maintenance personnel to the kind of failure which has occurred.

Current Status

Preliminary designs for the ground interrogator and airborne transponder have been established and experimental equipment is now under test. By the end of this year, specifications will be prepared for the FAA that will permit the procurement of prototype equipment for installation at NAFEC for further evaluation. This NAFEC installation will eventually include three sites to evaluate experimentally the data netting and track handover problem. Procurement of production equipment could start in three to four years, with an initial operation capability possible in 1979 at several major terminal areas.