NTIA REPORT 80-53

FOR INFORMATION

EVALUATION OF DISCRETE ADDRESS BEACON SYSTEM (DABS) EMC

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U.S. DEPARTMENT OF COMMERCE • National Telecommunications and Information Administration

NTIA REPORT 80-53

EVALUATION OF DISCRETE ADDRESS BEACOM SYSTEM (DABS) EMC

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GLOSSARY

AIMS	- Air Traffic Control Radar Beacon System, Identification, Friend or Foe, Mark XII System.
Antenna Beam Dwell	- The period of time (nominally 40 msec) that a ground sensor antenna mainbeam illuminates an aircraft during an antenna rotation.
Antenna Monopulse	- Antenna direction finding technique employed by DABS ground sensors to obtain target azimuth information on single replies.
ARIES	- Aircraft Reply and Interference Environmental Simulator.
ARTCC	- Air Route Traffic Control Center.
ARTS	- Automated Radar Terminal System.
ATCRBS	- Air Traffic Control Radar Beacon System.
ATCRBS/DABS All-Call Interrogations	- Periodic DABS ground sensor interrogations that perform the function of interrogating ATCRBS transponder equipped aircraft and acquiring a track on DABS transponder equipped aircraft not yet on the DABS sensors target list.
BCAS	- Beacon Collision Avoidance System.
Blip/Scan	- The percentage ratio of the number of times a track was detected (Blip) to number of times the target could have been detected (Scan).
Common Digitizer	- Video portion of ATCRBS ground sensor receiver that performs digital data processing on beacon and radar inputs from either FAA or Air Force equipments.
CDTI	- Cockpit Display Traffic Information.
DABS	- Discrete Address Beacon System.
DABS Roll-Call Interrogation	- Scheduled DABS ground sensor transmissions to DABS transponder equipped aircraft in the antenna beam for which a track has already been established.
DABSEF	- Discrete Address Beacon System Experimental Facility, experimental DABS ground sensor and

associated instrumentation used to evaluate DABS design concepts.

DME - Distance Measuring Equipment, provides distance information by time of round-trip transmission of pulses between airborne interrogator and ground transponder.

DPSK - Differential Phase Shift Keyed modulation that DABS uses on the uplink.

ELM - Extended Length Message, transmitted from a DABS ground sensor or transponder as a sequence of up to sixteen message segments, in close succession with no intervening replies or interrogations. Used to efficiently transfer large quantities of data.

False Brackets - A DABS reply or a combination of interfering pulses that is incorrectly decoded by an ATCRBS reply processor as a string of overlapping ATCRBS reply brackets.

False Targets - The decision by the ATCRBS or DABS ground sensor that a target is present when no target is actually present.

Fruit - Asynchronous aircraft transponder replies, at a victim ground sensor, due to other ground sensor interrogations.

ICAO - International Civil Aviation Organization, "specialized Agency" of the United Nations system, whose mission is to achieve broad international agreement in aviation regulatory and technical areas.

Improved SLS - Improved Sidelobe Suppression, has the same function as unimproved SLS, but effectively operates over greater ranges.

MLS/DME - (Microwave Landing System)/(Distance Measuring Equipment), a precision landing approach system that provides a pilot with aircraft height above the runway, slant range to touch down, and range rate information out to 30 nmi. The system consists of a scanning-beam azimuth and elevations system operating in the 5 GHz band and a precision DME operating in the 960-1215 MHz band.

Multipath	- The coupling of energy from a transmitter to a receiver by an indirect path such as surface reflections, as opposed to the direct path between the transmitter and receiver.
nmi	- nautical miles.
PPM	- Pulse Position Modulation, type of signal modulation that DABS uses on the downlink.
PRF	- Pulse Repetition Frequency.
Round Reliability	- Ratio of valid replies received at the ground sensor from a specific transponder to the number of valid interrogations transmitted by that ground sensor to the specific transponder.
RPM	- Revolutions Per Minute.
SLS	- Sidelobe Suppression, a technique that prevents airborne transponders from replying to ground sensor antenna sidelobe or reflected (multipath) mainbeam interrogations.
Synch Phase Reversal	- Used in the Differential Phase Shift Key (DPSK) uplink transmissions from the DABS ground sensor to synchronize aircraft transponders receivers, in order that data block bit phase information can be detected at the correct time interval.
TACAN	- Tactical Air Navigation, A system that provides range and azimuth to a known ground location by combining DME with a multilobe omnirange subsystem, the latter providing azimuth information.
TRACON	- Terminal Radar Control Facility that serves all airports within a delegated terminal airspace area.
Transponder Suppressions	- A period of time during which an aircraft transponder is unavailable for replying to any interrogations.

ABSTRACT

The FAA is currently developing the Discrete Address Beacon System (DABS) as an evolutionary upgrading of the Air Traffic Control Radar Beacon System (ATCRBS). Questions have been raised regarding the Electromagnetic Compatibility (EMC) of ATCRBS and DABS because of their common channel usage. The committee on Science and Technology, U.S. House of Representatives, requested that the National Telecommunications and Information Administration (NTIA) review DABS as a radio telecommunication system giving particular attention to potential interference problems.

The EMC of DABS with operational and firmly planned systems in the 960-1215 MHz band was investigated. This was accomplished by evaluating FAA theoretical calculation, measurement, and simulation results, and performing an independent analysis through theoretical calculations and computer simulations.

It was concluded that replacing FAA ATCRBS ground sensors with DABS sensors, operating according to FAA specified scenarios, will not reduce the performance of the remaining ATCRBS sensors or the DABS sensors. The compatibility of DABS with TACAN/DME, MLS/DME, and BCAS is operationally and technically manageable. The compatibility of the ATCRBS IFF Mark XII System (AIMS) and DABS is being addressed in a joint FAA and DoD EMC study.

KEY WORDS

Discrete Address Beacon System (DABS)
Air Traffic Control Radar Beacon System (ATCRBS)
Electromagnetic Compatibility (EMC)
Transponder Suppression
Fruit

SECTION 1

INTRODUCTION

BACKGROUND

The National Telecommunications and Information Administration (NTIA) is responsible for managing the radio spectrum allocated to the U.S. Federal Government. Part of NTIA's responsibility is to: "...establish policies concerning spectrum assignment, allocation and use, and provide the various Departments and agencies with guidance to assure that their conduct of telecommunications activities is consistent with these policies" [Department of Commerce, 1978]. In support of these requirements, the guidance provided by NTIA with the assistance of the Interdepartment Radio Advisory Committee (IRAC) encompasses the areas of: utilizing spectrum, identifying existing and/or potential Electromagnetic Compatibility (EMC) problems between systems of various departments and agencies, providing recommendations for resolving any compatibility conflicts, and recommending changes to improve spectrum management procedures.

Several EMC issues between DABS and ATCRBS were brought to the attention of the Committee on Science and Technology (House of Representatives). As a result of these issues, the Committee report (96-54) which accompanied the FAA appropriations (bill H.R. 2277), for research and development, requested that FAA divert $100,000 to support an NTIA review of the Discrete Address Beacon System (DABS), giving particular attention to potential interference problems. An interagency agreement between FAA and NTIA to perform this EMC study was signed on February 15, 1980.

The study contains a detailed EMC investigation of DABS with operational and firmly planned systems in the 960-1215 MHz band. The 960-1215 MHz band is allocated to the Aeronautical Radionavigation Service on a primary basis both nationally and internationally. The 960-1215 MHz band is presently being used by the TACAN/DME, ATCRBS, and military ATCRBS IFF Mark XII System (AIMS). Three new systems planned for operation in the 960-1215 MHz band include FAA's Beacon Collision Avoidance System (BCAS) and the Microwave Landing System/DME (MLS/DME), and DoD's Joint Tactical Information Distribution System (JTIDS).

DABS is being developed by the Federal Aviation Administration (FAA) as the next generation evolutionary replacement for the Air Traffic Control Radar Beacon System (ATCRBS), the current primary means of air traffic surveillance. DABS is a combined secondary surveillance radar (beacon) and integral ground-air-ground data link communication system designed to meet the projected growth of air traffic requirements for surveillance and communications. The DABS will provide surveillance of DABS and ATCRBS transponder-equipped aircraft and two-way digital communications with aircraft equipped with DABS transponders. The principal feature of the system is that each DABS transponder-equipped aircraft can be uniquely addressed by the DABS ground sensor. Therefore, surveillance and data link messages can be directed to individual aircraft. By proper timing of these interrogations, replies from closely-spaced aircraft can be received without mutual interference to the DABS ground sensor. DABS ground sensor interrogations of transponders are transmitted on 1030 MHz and aircraft transponder replies are received on 1090 MHz.

OBJECTIVE

The objective of this study was to determine the EMC of DABS with operational and firmly planned systems in the 960-1215 MHz band, and if spectrum support should be granted based on the EMC of DABS.

APPROACH

In order to accomplish the objective of this investigation, the following actions were taken:

1. Review and evaluate the Government Master File (GMF), NTIA spectrum services application file, and available reports pertaining to the design, technical characteristics, and potential interference associated with DABS and other systems (present and future) in the 960-1215 MHz band.

2. Evaluate issues presented to the committee on Science and Technology (House of Representatives) regarding ATCRBS/DABS EMC.

3. Observe and evaluate ATCRBS/DABS EMC tests at the FAA Technical Center.

4. Evaluate Lincoln Laboratory analytical investigations and Electromagnetic Compatibility Analysis Center (ECAC) simulations performed for FAA.

5. Perform an independent evaluation of DABS/ATCRBS EMC using analytical and computer simulation methods.

6. Monitor the joint Department of Defense (DoD) and FAA investigation of EMC between DABS and AIMS.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

GENERAL

This section contains a summary of the conclusions and recommendations resulting from a detailed investigation into the Electromagnetic Compatibility (EMC) of DABS with present and firmly planned systems that will operate in the 960-1215 MHz frequency band. The conclusions and recommendations are based on the DABS system characteristics given in Appendix B. Any changes to the DABS system specifications or data capacity as given in Appendix B may result in changes in the findings of this investigation.

NTIA conducted a detailed EMC study consisting of: (1) evaluating the results of FAA ATCRBS/DABS EMC investigations, (2) monitoring the ongoing joint FAA and DoD DABS/AIMS investigation and (3) performing an independent analytical computer analysis of DABS EMC with present and firmly planned systems in the 960-1215 MHz band. This led to the following conclusions which are discussed in detail in Section 3.

GENERAL CONCLUSIONS

1. Replacing a percentage of the FAA ATCRBS ground sensors with DABS sensors will not reduce the performance of the remaining ATCRBS sensors. This conclusion is valid for DABS channel occupancies that do not exceed those associated with the worst-case FAA specified data link scenarios used in the analysis. The simulations and calculations considered that 11 percent of the aircraft in the 1982 Los Angeles environment Basin Standard Traffic Model will be provided extended data link service (average of 10 interrogations per target per antenna rotation) and the remainder of the aircraft population standard data link service (average of 2.5 interrogations per target per antenna rotation). The air traffic densities in the 1982 Los Angeles Basin Standard Traffic Model are not likely to occur in the Los Angeles basin until approximately 1990.

2. DABS should perform the surveillance of DABS aircraft better than the present ATCRBS would in future interference environments and should perform surveillance of ATCRBS equipped aircraft at least as well as ATCRBS.

3. The compatibility of DABS with TACAN/DME, MLS/DME, and BCAS is operationally and technically manageable. The EMC between DABS and AIMS is being investigated in a joint FAA/DoD study. Potential interference interactions between DABS and some AIMS equipment nomenclatures have been identified. Technical and operational solutions to these potential interactions are being investigated by the joint study group.

4. The EMC analysis presented to the Committee on Science and Technology (House of Representatives) by a member of the aviation community predicted a more serious interference effect on ATCRBS than FAA because invalid assumptions were made in the calculations regarding

DABS technical characteristics and FAA specified deployment scenarios. This analysis was also based on computed worst-case DABS uplink suppression and downlink fruit rate peaks that assumed unrealistically high aircraft bunching in the DABS antenna beam.

The above general conclusions were based on the following specific conclusions:

SPECIFIC CONCLUSIONS

1. FAA calculated average interference levels to ATCRBS from a single DABS sensor are pessimistic. However, the calculations indicate that a single DABS sensor will not degrade ATCRBS performance in future air traffic environments.

2. The FAA and NTIA simulation results indicated that replacing one or more ATCRBS ground sensors with DABS sensors in the 1982 Los Angeles environment will not reduce ATCRBS performance from that which existed before DABS deployment.

3. FAA flight tests have demonstrated that the average uplink suppression rate for the majority of airspace around a sensor will be reduced when the DABS sensor replaces an ATCRBS sensor that employs improved sidelobe suppression. Bench tests have indicated that fruit in a multiple DABS and ATCRBS ground sensor environment will not noticeably affect ATCRBS performance. The uplink/downlink tests demonstrated that an ATCRBS ground sensor's surveillance performance (target detection and code validation) of an ATCRBS aircraft, that is being continually interrogated by a single DABS sensor at full capacity, will not be noticeably degraded.

4. Comparison testing by Lincoln Laboratory in 1976-1977 indicated that the ATCRBS mode of DABS performed the surveillance function better than the existing ATCRBS. However, the data does not address the performance during multiple overlaps (more than two) that may occur in future synchronous garble environments. Since the DABS sensor uses monopulse and more sophisticated processing capability, the DABS sensor in the ATCRBS mode should perform the surveillance function at least as well as the present ATCRBS in multiple overlap interference environments. It should also be noted that as DABS transponders replace ATCRBS transponders, the synchronous garble situation improves for the ATCRBS mode of DABS. The DABS surveillance mode should perform surveillance of DABS aircraft better than the present ATCRBS would in interference environments of the future.

5. Lincoln Laboratory simulations and calculations indicate that the data link performance goal for undetected error probability will be achieved in the presence of ATCRBS interference. Analysis of FAA tests indicates that the basic Automatic Traffic Advisory and Resolution Service (ATARS) advisory and command rates assumed by FAA for the 1982 Los Angeles scenario should not significantly affect DABS mode of DABS surveillance in the presence of ATCRBS/DABS interference. The effect of the long messages on DABS surveillance for data link loading that

exceeds this ATARS requirement is not addressed in this NTIA report. However, it is understood that potential interference problems to DABS are manageable because data link loading beyond basic ATARS could be limited if surveillance were found to be significantly affected.

6. Since DABS has a wider receiver and emission bandwidth than the present ATCRBS, additional guardband frequencies between the TACAN/DME channels and DABS operation frequencies may be required. The ongoing FAA studies will determine the necessary guardband frequencies for compatible operations between TACAN/DME and DABS.

7. The design of MLS/DME is expected to include provisions to insure compatibility with DABS.

8. Previous EMC testing between prototype DABS equipment and JTIDS demonstrated that the two systems can operate compatibly in the same environment. Additional testing should be performed with an operational DABS to confirm the results of these tests.

RECOMMENDATIONS

1. Spectrum support should be granted for DABS operations, providing the results of the AIMS/DABS EMC study does not identify any serious EMC problems.

2. FAA should design future Air Traffic Control systems (e.g. MLS/DME) to be compatible with other systems in the 960-1215 MHz band.

3. The results of the following current investigations should be made available to NTIA to assure that appropriate spectrum management changes, if necessary, are made: (a) the DABS/AIMS EMC measurements and simulations, (b) the study to determine the necessary guardband frequencies between TACAN/DME and DABS, (c) the measurements of DABS differential phase shift keying (DPSK) uplink performance in the presence of ATCRBS interference.

4. EMC testing between an operational DABS and JTIDS should be performed to confirm the two systems are compatible.

5. If data link loading significantly greater than the basic ATARS requirement is planned, additional investigations should be conducted. These investigations should determine the level (if any) that data link loading degrades the DABS mode of DABS surveillance.

SECTION 3

DABS EMC ANALYSIS

INTRODUCTION

This section discusses the evaluation of DABS EMC with operational and firmly planned systems in the 960-1215 MHz band including ATCRBS, AIMS, BCAS, TACAN/DME, and JTIDS. In addition, other EMC issues raised by Mr. Litchford (Litchford Electronics, Inc.) were investigated. The interaction between DABS and AIMS is being investigated by the DoD in cooperation with FAA. The results of this investigation will be available in 1981.

SYSTEM DESCRIPTIONS

A general description of the ATCRBS and DABS is given in this subsection. A more detailed description of DABS is given in Appendix B.

DABS Description

The Discrete Address Beacon System (DABS) is a cooperative surveillance and communications system for air traffic control. It employs ground-based sensors (interrogators) and airborne transponders. Ground-to-air and air-to-ground data link communications are accommodated integrally with the surveillance interrogations and replies. DABS has been designed as an evolutionary replacement for the current Air Traffic Control Radar Beacon System (ATCRBS) to provide the enhanced surveillance and communication capability required for air traffic control in the 1980's and 1990's. Operational compatibility with ATCRBS has been emphasized to permit an extended, economical transition.

A principal feature of DABS is that each aircraft is assigned a unique address code. With this unique code, interrogations can be directed to a particular aircraft, and replies are unambiguously identified. Interference is minimized because a sensor can limit its interrogations to targets of interest. In addition, through the proper timing of interrogations, replies from closely-spaced aircraft can be received without mutual interference. The unique address in each interrogation and reply also permits the inclusion of data link messages to or from a particular aircraft. DABS uses the same frequencies for interrogations and replies as ATCRBS (1030 and 1090 MHz, respectively). The DABS interrogation is transmitted using differential phase shift keying (DPSK) at a 4 Mbps rate, and comprises 56 or 112 bits including the 24 bit discrete address. The reply also comprises 56 or 112 bits including address, and is transmitted at a 1 Mbps rate using binary pulse-position modulation. Coding is used on both interrogations and replies to protect against errors.

The DABS sensor provides surveillance of all aircraft equipped with either DABS or ATCRBS, plus data link service to DABS aircraft. In addition, it correlates beacon replies with radar target reports from a collocated radar. The DABS sensor transmits surveillance data to, and exchanges messages with, the Terminal Radar Control (TRACON) and Air Route Traffic Control Centers (ARTCC) via low-rate digital circuits. The DABS sensor communicates directly with adjacent

DABS sensors to hand off targets and to provide surveillance and communication backup in the event of momentary link failures. DABS sensors may include an Automatic Traffic Advisory and Resolution Service (ATARS) function which provides automatic traffic advisory service and conflict resolution service to DABS-equipped aircraft via the ground-air data link.

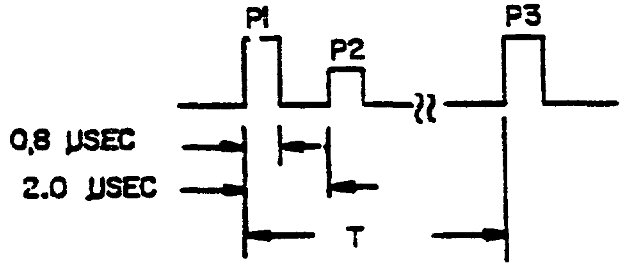
The three basic DABS data link transmission types include surveillance, Normal Communications, and Extended Communications. The 56 bit surveillance interrogations and replies are used when there is little or no data to be transferred. The surveillance interrogation includes transponder control data and 16 bits for general purpose data transfer. Normal Communications consist of Comm-A interrogations and Comm-B replies. These longer 112 bit transmissions include all of the control and surveillance fields of the surveillance transmissions and, in addition, are each capable of transferring up to 56 bits of general purpose data. Extended length messages (ELMs) are used in Extended Communications and consist of strings of Comm-C's or Comm-D's transmitted in close succession without need for intervening replies or interrogations. All surveillance data is omitted from these formats, thereby providing a total of 80 general purpose data bits. Extended length messages provide an efficient means for transferring larger quantities of data. The improved efficiency results both from the greater number of data bits and the fact that one reply is not required for each transmission.

ATCRBS Description

The ATCRBS is the principal source of aircraft position information in today's air traffic control system. The ATCRBS consists of a ground sensor that interrogates transponder-equipped aircraft on 1030 MHz, and aircraft transponders that reply on 1090 MHz. The position of the ground sensor rotating antenna and the elapsed time between the interrogation and receipt of the transponder reply provide aircraft azimuth and range information. The ATCRBS interrogates aircraft with a pair of 0.8 microsecond pulses (P1,P3) as shown in Figure 3-1. The spacing, T, between the P1 and P3 pulses denotes the information (mode) being requested from the aircraft.

The aircraft transponder replies consist of up to 15 pulses as shown in Figure 3-2. The first pulse F1 and last pulse F2, referred to as bracket or framing pulses, define the beginning and end of the data pulse train. Thirteen data pulse positions are included between the bracket pulses. The combinations of pulses that occur in these positions, except the X position, provide the information content of the reply signal. To prevent transmitting overlapping reply codes, the transponder is inhibited from replying to any further interrogations for an interval of time. This interval of time is 35 to 125 microseconds for military systems and 35 $\pm$10 microseconds for civilian units.

All FAA ATCRBS ground sensors and some military systems employ sidelobe suppression (SLS). The function of SLS is to prevent aircraft transponders from responding to ground sensor antenna sidelobe interrogations. Systems that employ SLS include a P2 pulse 2 microseconds after the P1 pulse of the interrogation signal as shown in Figure 3-3. An aircraft in the 9 dB beamwidth of the directional antenna, as shown in Figure 3-3, receives the P1 pulse at a higher level relative to P2 than when the aircraft is in the sidelobe region of the



MODE	T
1	3 μsec
2	5
3/A	8
B	17
C	21
D	25

Figure 3-1. ATCRBS Interrogation Format

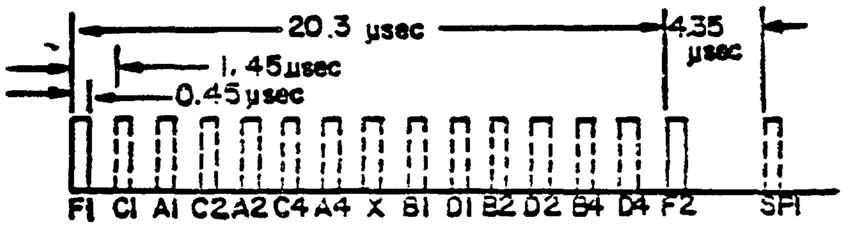


Figure 3-2. ATCRBS Aircraft Transponder Reply Format

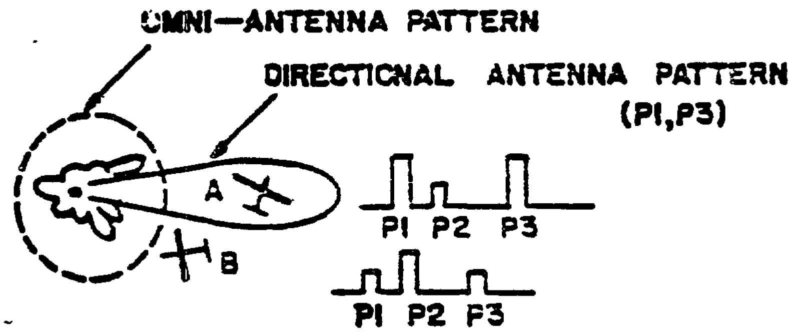


Figure 3-3. ATCRBS Interrogator Sidelobe Suppression

directional antenna. The level of the P1 pulse radiated by the directional antenna and the P2 pulse radiated by the omni antenna are compared by circuits in the transponder to determine if the interrogation was from the mainbeam or sidelobe region of the interrogator directional antenna. The transponder is inhibited from replying to antenna sidelobe interrogations. To prevent responses to later arriving replicas of the interrogation, due to mainbeam reflection, the transponder is inhibited for a total 35 $\pm$10 microseconds.

Most operational FAA terminal ATCRBS employ an improved version of SLS called ISLS. The function of the SLS improvement feature is to eliminate false targets caused by transponder replies to off-axis reflections of antenna mainbeam interrogations. For systems that employ SLS, the 35 $\pm$10 microseconds suppression of transponders after each SLS request is sufficient to prevent transponders at close ranges from replying to delayed mainbeam reflected interrogations. However, the P1 pulse amplitude transmitted from the sidelobe region of the directional antenna pattern is often of insufficient level to be recognized by transponders at long ranges. To increase the probability or extend the range that P1 pulse amplitudes are recognized by transponders, a fraction of the P1 pulse energy in ISLS systems is radiated from the omni antenna.

ATCRBS/DABS EMC

DABS Effect on ATCRBS

FAA has investigated the impact of DABS on ATCRBS performance through analytical, simulation, and measurement investigations. This subsection discusses the evaluation of these investigations and additional analysis performed by NTIA.

FAA Analytical Investigations

The ATCRBS/DABS EMC analysis report (Welch, 1978) addresses analytically EMC questions that were raised in response to the publication of the proposed DABS National Standard in the March 1978 Federal Register. The report presents the assumptions, models, and system operational characteristics used to analytically assess the potential interference effects of DABS on ATCRBS. The report also provided a guide for subsequent simulations and tests that were used to verify the report's theoretical predictions. The main conclusion of the report is that the effects of DABS interrogations and replies on ATCRBS ground sensors and transponders are predictable, and that DABS suppressions of ATCRBS transponders and the fruit resulting from interrogations by DABS sensors will not degrade the surveillance ability of existing ATCRBS sensors. The report further concludes that DABS deployment will reduce the interference to ATCRBS ground sensors.

The data and analysis presented in the Welch report were evaluated by NTIA and the following conclusions were formed:

1. The equations and calculated results presented in the report for the defined DABS operational and deployment scenarios, indicate that the <u>average</u> uplink suppression and downlink fruit rates in a <u>multiple</u> DABS ground sensor environment will not degrade the surveillance ability of existing ATCRBS sensors. However, the report does not address the

frequency and magnitude of worst-case uplink suppression and downlink fruit rate peaks in a multiple DABS ground sensor environment. These analysis details are difficult to describe in simple equations and are best addressed through simulation.

2. The peak or average suppression and downlink fruit rates in a single DABS ground sensor environment will not degrade ATCRBS performance.

3. The DABS interference level to ATCRBS can be operationally managed in the field, if necessary, by distributing the data link load among multiple DABS sensors, careful scheduling of ATCRBS ground sensor replacements with DABS, and limiting low priority data link service.

The following paragraphs discuss NTIA's evaluation of the assumptions, equations, and calculated results that are presented in the report and the resulting conclusions presented above.

Downlink Fruit Calculations. The fruit rate prediction equations that are presented in the report (see Equation C-1 through C-4 in Appendix C) account for the effects of the ATCRBS ground sensor directional antenna characteristics and receiver threshold, and the traffic distribution around the location of a particular ATCRBS ground sensor. The equations do not account for the gain time control characteristics (GTC) of ATCRBS ground sensor processors. The GTC circuit automatically decreases receiver sensitivity as a function of time relative to each interrogation. The gain time control characteristics of an en route ATCRBS ground sensor with a common digitizer processor is shown in Figure 3-4 and for a terminal ATCRBS ground sensor with an ARTS-III processor in Figure 3-5. It is evident from the terminal ATCRBS ground sensor GTC characteristics in Figure 3-5 that the receiver is effectively turned-off 80 percent of the time and is desensitized by more than 10 dB at all times. This reduces the average received fruit rate over an antenna rotation considerably. Therefore, the equations predict a higher DABS reply rate (fruit) than actually would be received by an ATCRBS ground sensor with GTC.

The percent of DABS fruit that is received by an ATCRBS ground sensor was calculated in the Welch report for sensors at New York, Philadelphia, and Los Angeles. The calculation for Los Angeles accounted for future high air traffic densities. In all cases, the calculations indicated that less than one tenth of the total transponder generated fruit would be received above the sensitivity threshold by an ATCRBS ground sensor. An effective antenna sidelobe gain of -12.5 dBi (assuming uniform aircraft distribution in area) was used in the report calculations. This value was checked by applying Equation C-4 to ATCRBS ground beacon antenna pattern measurements (Pratt, 1976) obtained in the field with NTIA's Radio Spectrum Measurement System (RSMS) van. Effective antenna sidelobe gain values were obtained which agree within 1 dB of the -12.5 dBi Welch report value. The Welch report calculations used a receiver threshold (referenced to the antenna output) of -74 dBm. This threshold appears to be too high. The FAA ATCRBS ground sensor used in the report calculations have a receiver sensitivity of -86 dBm and a cable loss of 4 dB. Therefore, the system has a receiver sensitivity, referenced to the antenna output, of -82 dBm. However, the reduction in received fruit due to receiver GTC characteristics was not accounted

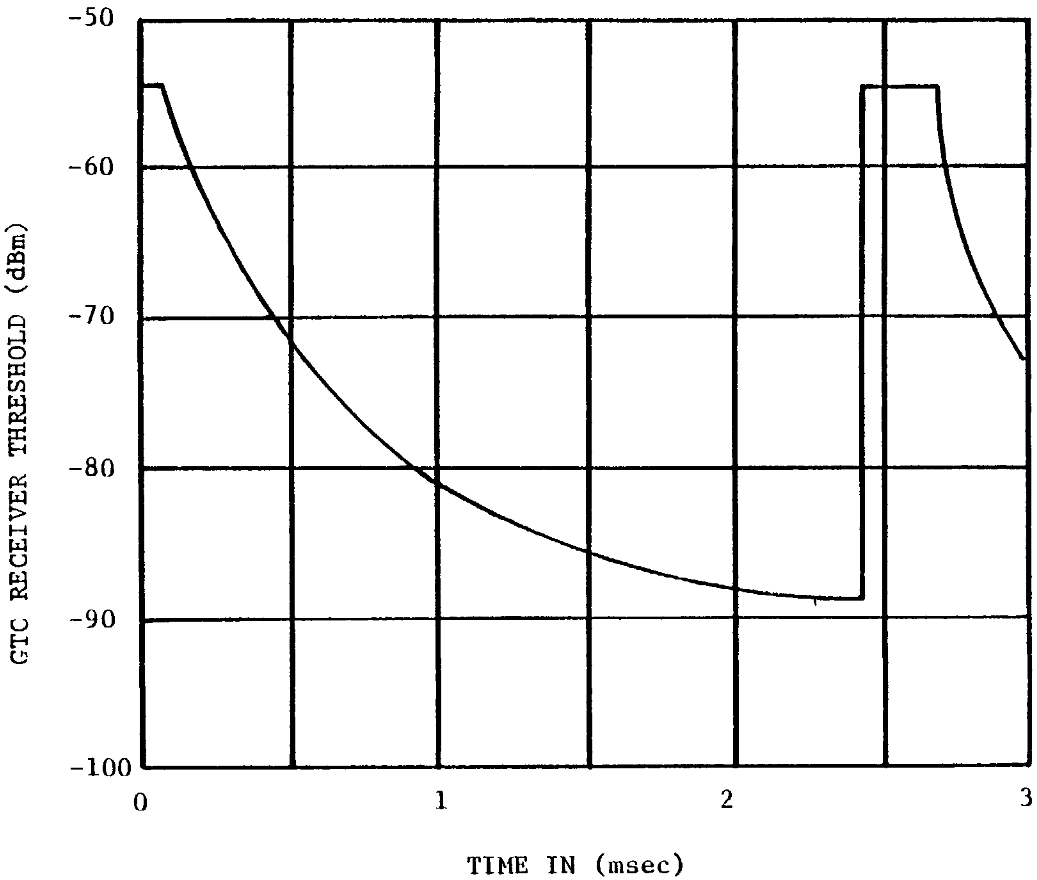


Figure 3-4. Gain Time Control Characteristics of En Route ATCRBS

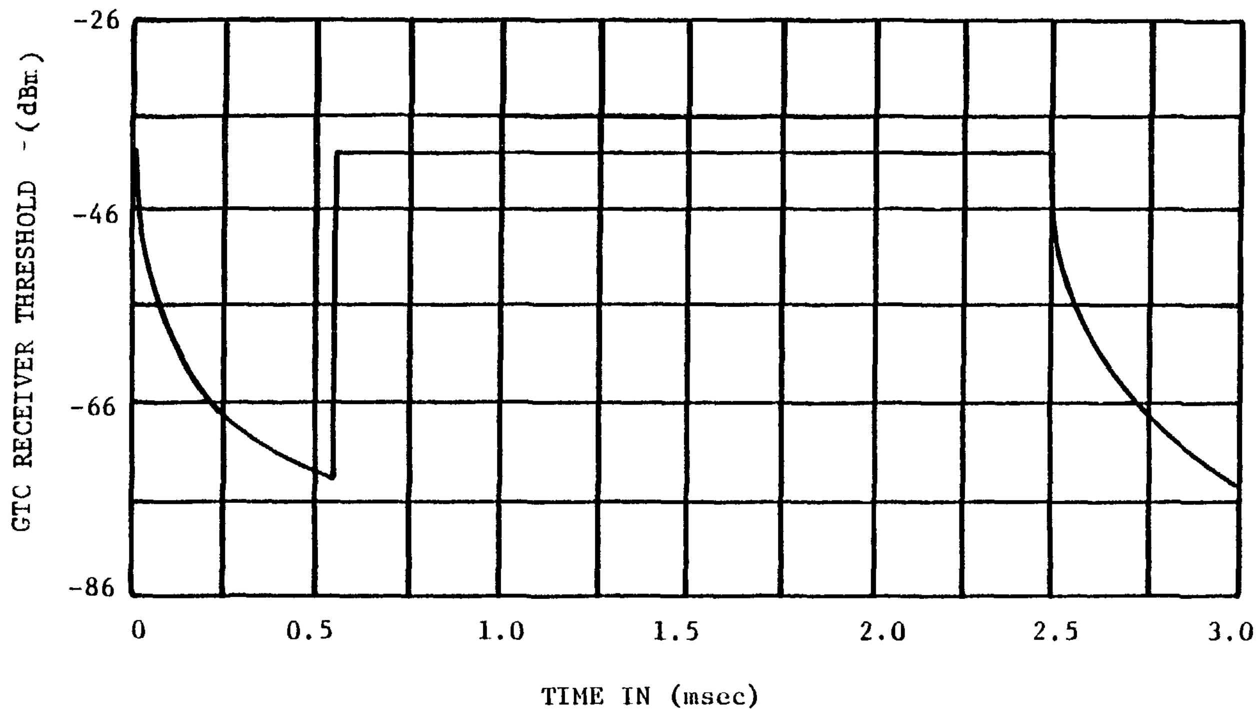


Figure 3-5. Gain Time Control Characteristics of Terminal ATCRBS

for in the calculations. As pointed out earlier, the GTC desensitizes ATCRBS receivers at terminal sites by more than 10 dB at all times. This results in the ATCRBS terminal ground sensor having an effective receiver sensitivity level above -72 dBm. Therefore, the Welch report calculations result in a slightly pessimistic estimate of DABS fruit interference effects.

The percent of total fruit generated by DABS transponders that an ATCRBS en route ground sensor would receive was not computed in the report. Measurements and calculations by NTIA in a recent study (Pratt, 1976) in the Los Angeles area indicated that the San Pedro en route ATCRBS sensor would receive more than 10 percent of the fruit generated in its coverage area (see Figure 3-6). The curve indicates that less than 10 percent of the fruit generated by transponders at 370 km (200 nmi) (peripheral of coverage area) is received, but that over 10 percent of the fruit generated at 278 km (150 nmi) or less from the site is received. Since the greatest aircraft density is less than 278 km (150 nmi) from the site, the percentage of fruit received by the San Pedro en route ATCRBS ground sensor is much greater than 10 percent.

It is difficult to determine the exact future data link demand on DABS. However, the data link load scenario used in the FAA calculations was estimated from the distribution of aircraft types (General Aviation, Air Carrier, and Military) predicted by the 1982 and 1995 air traffic models, and a recently completed study of DABS data link loading by Mitre Corporation.

A copy of the table in the Welch report that summarizes ATCRBS and DABS fruit rate comparison calculations is given in TABLE 3-1. It was assumed for the DABS fruit calculation that one-half of the 400 aircraft environment was DABS transponder-equipped, and that 22 percent of the DABS transponder aircraft receive extended data link service. The probability of a desired ATCRBS reply being overlapped by a fruit reply was computed by taking the product of the fruit rate and overlap window (sum of desired and fruit reply lengths). The Welch report considered the probability of incorrectly decoding a desired ATCRBS reply to be 1.0 if it is overlapped by a DABS reply, and 0.32 if it is overlapped by an ATCRBS reply. The calculations indicate that the probability of an ATCRBS reply loss is 0.03 percent greater for the ATCRBS interrogator (0.22 percent) than for the DABS interrogator (0.19 percent). The assumptions and calculations appear to be valid for the hypothesized scenario.

The Welch report (see TABLE 3-2) also computed the probability of ATCRBS reply loss due to a single DABS sensor for the 1982 and 1995 Los Angeles model with all aircraft DABS transponder-equipped. A probability of ATCRBS reply loss of 0.60 percent was obtained for 1982 and 0.80 percent for 1995. A 0.22 percent probability of ATCRBS reply loss was obtained for 1982 and 0.37 percent for 1995 when NTIA repeated these calculations for an ATCRBS sensor. Therefore, these calculations indicate that the probability of an ATCRBS reply loss is slightly greater for the DABS interrogator than the ATCRBS interrogator.

The fact that these results contradict the calculation results shown in TABLE 3-1, which indicated that the DABS interrogator would cause a lower ATCRBS reply loss probability, illustrates the dependence of the calculation results on the air traffic scenario. However, both sets of calculations indicate that the probability of ATCRBS reply loss due to a single ATCRBS or DABS sensor is insignificant.

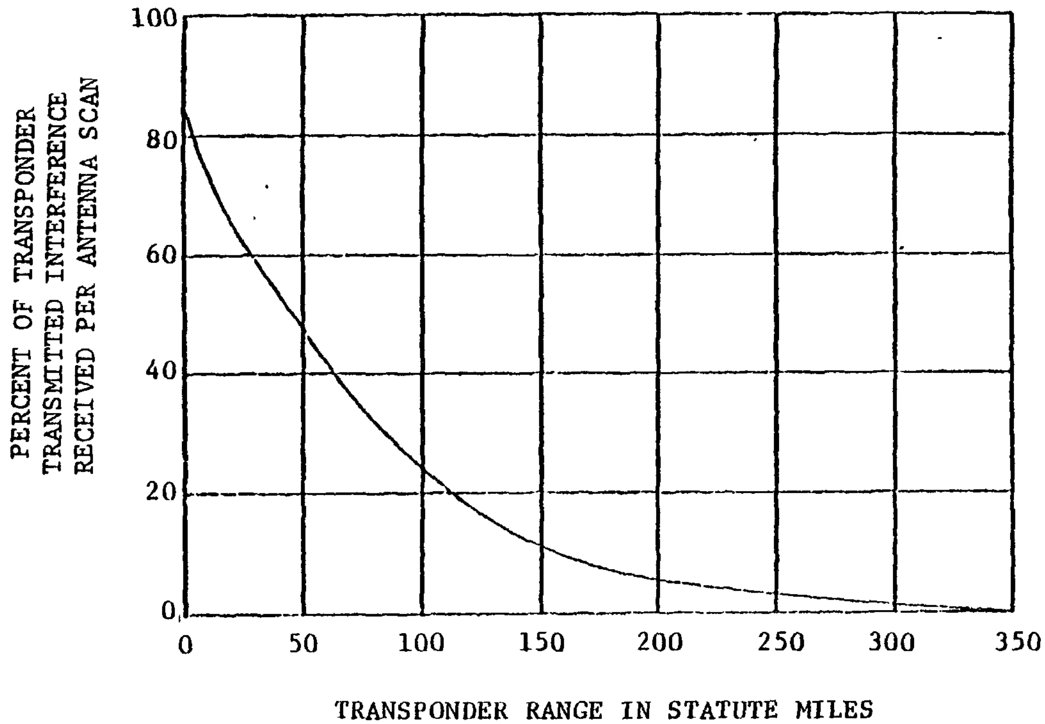


Figure 3-6. Percent of Transponder Transmitted Interference Received by San Pedro Hill ATCRBS Per Antenna Scan as a Function of Transponder Range

TABLE 3-1

ATCRBS AND DABS FRUIT RATE COMPARISON

(from Welch, 1980)

TRANSPONDER POPULATION	ATCRBS CASE		DABS CASE
ATCRBS Transponders	400		200
DABS Transponders	-		200
% Standard Datalink	-		78%
% High Option Datalink	-		22%
FRUIT GENERATED BY ATCRBS REPLIES	**ATCRBS CASE**		**DABS CASE**
Run Length	16		6
Replies/Scan	6400		1200
Replies/Sec	1600		300
Fruit/Sec (Received by Victim)	160		30
Probability of Overlap (42 μsec Window)	0.672%		0.126%
Probability of Reply Loss (0.32/ Overlap)	0.215%		0.040%
FRUIT GENERATED BY DABS REPLIES	**SURVEILLANCE**	**COMM-B**	**COMM-D**
Transponders	200	200	44
Replies/Transponder/Scan	2	0.5	2
Replies/Scan	400	100	88
Replies/Sec	100	25	22
Fruit/Sec (Received by Victim)	10	2.5	2.2
ATCRBS Overlap Window (μsec)	64+21=85	120+21=141	120+21=141
Prob Reply Loss (Prob Overlap)	0.084%	0.035%	0.032%
OVERALL PROBABILITY OF REPLY LOSS	**ATCRBS CASE**	**DABS CASE**	
	0.22%	0.19%	

TABLE 3-2

DABS INTERFERENCE TO ATCRBS

(from Welch, 1980)

Model	1982	1995
Total A/C in Model	735	1700
% DABS Equipped	100%	100%
A/C in Mainbeam Range of Victim ATCRBS Sensor	535	700
A/C Interrogated by Busiest DABS Sensor[1]	400	700
Fraction of A/C with High-Option CDTI & Datalink [2]	0.11	0.22
DABS Interrogation Rate[3]	365/sec	799/sec
% Suppressed Time for Victim with Range < 1 NMI[4]	2.33%	4.27%
% Suppressed Time for Victim with Range > 5 NMI[5]	0.71%	0.75%
Reply Rate of All Targets in Range of Mainbeam[6]	499/sec	663/sec
DABS Fruit Rate Above MTL of ATCRBS Sensor[7]	50/sec	66/sec
Probability of ATCRBS Reply Loss Due to DABS Replies[8]	0.60%	0.80%

NOTES:
1. Assumes adjacent Sensor Failure
2. Remainer Have Mid- and Low-Option Service
3. Reinterrogation Rate is 10%
4. SLS is Used; All Transmissions are detected by ATCRBS Transponder; ATCRBS Interrog. Rate = 150 sec; Xponder Supp. Time = 45 μsec
5. Only Mainbeam DABS Interrogations are Detected; All SLS Pulses are Detected Within Improved SLS Range (20 to 50 nmi)
6. Each Target Gets Dual Surveillance and Single Data Coverage; Link Failures Divide Equally Between up & Downlink
7. Fixed Threshold at -79 dBm (S.T.C. would further reduce the Fruit Rate); BCAS Squitters Locked Out
8. ATCRBS Receiver Blanked for 120 μsec on Receipt of DABS Preambles; No ATCRBS or All-Call Fruit included

The Welch report also presents equations to show that the average fruit rate due to a multiple DABS ground sensor environment would be considerably less than for the same number of ATCRBS ground sensors. This result is not unexpected because ATCRBS fruit is proportional to the product of transponder-equipped aircraft and ATCRBS interrogators, while DABS fruit is less dependent on the number of DABS interrogators. This is because each DABS transponder on the Roll-Call list receives data link interrogations from only one DABS sensor, and surveillance interrogations from no more than two DABS sensors. In the ATCRBS case, all transponder-equipped aircraft are interrogated that are within range of the interrogator.

<u>Uplink Suppression Calculations.</u> The uplink suppression equation (see Equation C-5 in Appendix C) presented in the report for a single DABS sensor will give pessimistic results. This is because the (1+D) factor in the equation indicates that every aircraft will receive separate surveillance and data link interrogations. However, separate surveillance interrogations to DABS aircraft receiving data link service will not be required. This is because surveillance is accomplished in each data link interrogation. A modified form of Equation C-5 that accounts for this factor is given by

$$N_{ss} = \frac{N_T}{T}(1+R)(D+1-F_H-F_L) = \frac{N_T}{T}(1+R)(9F_H+1.5F_L+1) \qquad (3-1)$$

where

N_{ss} = Uplink suppression rate, in suppression/s

N_T = Number of DABS transponders served by the sensor

R = Average reinterrogation rate of DABS ground sensor

T = Antenna rotation period of DABS ground sensor

D = Average number of data link interrogations required per aircraft

F_H = Fraction of DABS aircraft population requiring extended data link service

F_L = Fraction of DABS aircraft population requiring standard data link service

Numerical evaluation of Equations 3-1 and C-5 for the 1982 Los Angeles data link scenario indicates that Equation C-5 predicts 20 percent higher average suppression rates.

Equations (see Equations C-8 and C-9 in Appendix C) are presented in the report for predicting uplink suppression rates in a multiple DABS ground sensor environment. Equation C-8 predicts the uplink suppression rate when the victim ATCRBS transponder is well outside of the effective sidelobe range of all sensors, but within the SLS range of all sensors. Equation C-9 gives the suppression rate received by an ATCRBS transponder which is within the effective sidelobe range of one DABS sensor, and within the SLS range of all sensors. These equations give slightly pessimistic results because the number of transponders in the scenario (N) would not receive surveillance and data link interrogations from all DABS ground sensors as the equations indicate. FAA has indicated that the traffic load will be distributed among multiple DABS ground sensors that have overlapping coverage areas. Normally, a DABS transponder-equipped aircraft will receive surveillance interrogations from two DABS sensors and data link interrogations from one DABS sensor. However, surveillance and data link transmissions are combined into one message for aircraft receiving data link service. Equations C-8 and C-9 were rederived taking these factors into account. The new version of equation C-8 is given by

$$S = \left[\frac{N_T(1+R)}{T}\right]\left[1+\frac{(N_D-1)(1.5B)}{360}\right]\left[2+(F_H+F_L)(D-2)\right]+400N_A+150N_D \qquad (3\text{-}2)$$

and equation C-9 by

$$S = \left[\frac{N_T(1+R)}{T}\right]\left[\frac{1.5B}{360}\right]\left[2+(F_H+F_L)(D-2)\right]+400N_A+150N_D \qquad (3\text{-}3)$$

where

S = Average DABS surveillance interrogation rate

N_A = Number of ATCRBS sensors in the scenario

N_D = Number of DABS sensors in the scenario

N_T = Number of DABS transponders in the scenario

R = Average DABS reinterrogation rate

B = Antenna Beamwidth

T = Antenna Rotation Period

The numerical results given by Equations 3-2 and 3-3 were compared with those obtained from Equations C-8 and C-9 for the 1982 Los Angeles environment. The DABS discrete interrogation term of Equation C-8 and C-9 (from Welch report) predicted approximately twice the suppression rate predicted by the corresponding terms of Equations 3-2 and 3-3. However the total suppression rate predicted by Equations C-8 and C-9 were only slightly greater than that predicted by Equations 3-2 and 3-3, because the terms used to compute the ATCRBS SLS and DABS All-Call suppression rates have the greatest effect on the numerical results and are identical for both sets of equations.

As discussed earlier, Equations C-2, C-3, and C-4 were used in the Welch report to compute the effective antenna sidelobe range that an ATCRBS ground sensor would receive DABS transponder replies. These equations were also used in the Welch report to compute the effective DABS ground sensor antenna sidelobe range that ATCRBS transponders can receive DABS discrete interrogations or DABS All-Call SLS transmissions. The report computed an effective antenna sidelobe range of 5.9 km (3.2 nmi) to 8.3 km (4.5 nmi). based on an antenna effective sidelobe level of -12.5 dBi. It is evident that this level exceeds the effective sidelobe level of the DABS experimental antenna referenced in the report. However, the operational DABS antenna is a 5-foot open array antenna and the experimental DABS antenna a reflector type antenna. For this reason, the effective antenna sidelobe level of the DABS operational antenna was computed using Equations C-3 and C-4. The calculations indicated that the effective antenna sidelobe level of the DABS operational antenna is less than the experimental antenna. Therefore, the effective antenna sidelobe range of the DABS suppressions should be less than 9.2 km (5 nmi) and the calculation in the FAA report give slightly more pessimistic results.

TABLE 3-2 includes the results of uplink suppression calculations that appeared in the Welch report. The calculations predict that the rate of DABS discrete interrogations at an ATCRBS transponder for the 1982 air traffic scenario is 365/s, and 799/s for the 1995 scenario. These results were checked using Equations C-5 and C-7. The average percent of time that a transponder within the antenna sidelobe range of the DABS interrogator, is suppressed was computed to be 2.33 percent for 1982 and 4.27 percent for 1995. The average percent of transponder suppression was 0.71 percent (1982) and 0.75 percent (1995) for the case in which the transponder aircraft is sufficiently far from the DABS interrogator to only detect mainbeam interrogations.

The percent of time that a transponder is suppressed was computed in the Welch report by taking the product of the suppression rate and the time that a transponder remains suppressed (see Equation C-11). An equation that more closely predicts the percent of time, P5, that a transponder is unavailable to reply to ATCRBS interrogations is given by

$$P_S = N_S \times (T_S + T_I) \quad (3\text{-}4)$$

where

N_S = Suppression rate, suppressions per second

T_S = Time that transponder remains in suppression, in seconds

T_I = The average time between the P1 and P3 pulses of ATCRBS 3/A and C mode interrogations, assuming a 1:1 interlace.

The numerical value of T_I is 14.5 microseconds and the nominal ATCRBS transponder suppression time, T_S, is 35 microseconds. Therefore, T_I+T_S in Equation 3-4 is 49.5 microseconds. Since the Welch report computes percent transponder suppression using a transponder suppression time of 45 microseconds, the numerical results closely approximate that which would be obtained by using Equation 3-4. Therefore, the transponder reply probability calculations in the Welch report give correct results.

The NTIA Uplink Program A was used to verify that Equations 3-4 and C-11 are valid for the complex DABS interrogation signal format. The program includes the capability to simulate the effect of All-Call, Roll-Call, and extended length message (ELM) transmission, from one or more DABS sensors, on ATCRBS transponder suppression. A description of the program is given in Appendix A. The program simulation results indicated that Equation 3-4 and C-11 can be used to estimate the average percentage of time that an ATCRBS transponder would be in suppression due to DABS interrogations.

Concern has been expressed by the EMC community about the effect of high peak DABS uplink suppression rates on ATCRBS performance. These peaks are associated with aircraft bunching in the DABS antenna beams, and the transmission of extended length messages (ELMs). The Welch report addresses the peak ATCRBS transponder suppression due to a single DABS interrogator operating at full capacity. A worst-case approach is to consider the short-term interrogation rate peak specified for DABS operating at full capacity, because these rates are greater than the peak interrogation rates specified for longer periods. A maximum ATCRBS transponder suppression of 12.6 percent was computed in the Welch report. NTIA calculations using the peak interrogation rate specified in the March 6 proposed DABS National Standard indicated a maximum suppression of 11.88 percent. Simulations and measurements have indicated this level of transponder suppression will not degrade ATCRBS performance. The percent transponder suppression time during an ELM transmission burst from a single DABS interrogator is approximately 70 percent. However, this high suppression level is not relevant because an ELM burst is not of sufficient length to cause consecutive ATCRBS transponder reply losses.

In summary, the equations in the Welch report predict worst-case peak and average interference effects of a single DABS ground sensor on ATCRBS performance. The calculated results indicate that the uplink suppressions from a single DABS sensor, and fruit from multiple DABS sensors, will not degrade performance.

FAA Simulations

FAA tasked ECAC to investigate the impact of the DABS operation on ATCRBS performance. The analysis was conducted as a simulation (Keech, 1979) using the ATCRBS/DABS/AIMS Performance Prediction Model (Crawford, 1980). The planned deployment of DABS (up to four sites) in the Los Angeles area and FAA specified operational scenarios were accounted for in the simulation. The air traffic environment consisted of the 1982 standard Los Angeles air traffic model (Hildenberger, 1973). The performance of ATCRBS was examined at the Los Alamitos and Long Beach sites with and without DABS deployment.

The report concluded that the performance of ATCRBS at both the Los Alamitos and Long Beach site will be relatively unaffected by DABS deployment, and that the average suppression rate at ATCRBS transponders will not exceed the level that existed before DABS deployment. The Keech report noted that there were regions where the suppression rate exceeded the level which existed before DABS deployment, but that this did not degrade the ability of the ATCRBS sensor to detect and validate targets. Although NTIA does not agree with all numerical results presented in the report, there is agreement with the above conclusions. The following paragraphs in this subsection discusses NTIA's evaluation of the simulation.

Los Alamitos Site. The simulated performance of the ATCRBS sensor at Los Alamitos, in terms of transponder reply probability and percentage of overlapped desired replies, that appears in the Keech report is shown in TABLE 3-3 and 3-4. The percentage (0.04) of desired replies overlapped by ATCRBS fruit, shown in column 7 of TABLE 3-3, appears low for the ATCRBS fruit rates shown in column 2. Calculations that take into account the Los Alamitos ATCRBS antenna coupling and receiver gain time control (GTC) characteristics indicates a greater percentage of reply overlap due to ATCRBS fruit.

The possible error in the computed probability of a transponder reply overlap does not invalidate the ATCRBS and DABS fruit rates shown in TABLE 3-3. Column 2 of the table indicates that the ATCRBS fruit rate decreased when DABS was deployed and that the added DABS fruit (columns 3 and 4) was insignificant. TABLE 3-3 also indicates that DABS deployment resulted in a slight improvement in average ATCRBS transponder reply probability. Since the DABS deployment resulted in an insignificant increase in DABS fruit and no decrease in transponder reply probability, it can be concluded that DABS will not decrease Los Alamitos ATCRBS performance.

Long Beach Site. The results of the computer runs to determine the impact of DABS on the Long Beach ATCRBS ground sensor performance are shown in TABLE 3-5 and 3-6. The data in TABLE 3-6 indicates that there is less than 1 percent reduction in both target detection probability and code validation with DABS deployment.

The fruit and suppression rates indicated in TABLE 3-5 appear to be realistic, based on calculation using Equations C-1 and C-9. The average target detection and code validation probabilities indicated in TABLE 3-6 were compared with those obtained from ARTS-III precessor bench tests at FAA's Technical Center (FAA Technical Center). The comparison indicated that the simulation predicts slightly greater ATCRBS degradation (with or without DABS deployment) than the bench tests, even though the transponder reply probabilities and ATCRBS/DABS fruit rates were lower in the simulation.

Spatial and Temporal Peaking. To verify that a simulation run of one antenna rotation is sufficient to achieve a useful level of accuracy, three statistically independent simulation runs were conducted with Long Beach as the victim. Two 6-scan simulations were also conducted to investigate the validity of ATCRBS performance predictions that are based on 3-scan simulations. The data indicated that the ATCRBS ground sensor performance parameters do not appreciably change from rotation-to-rotation of the antenna. This result seems reasonable when one considers that the performance parameters (target detection, code validation, transponder suppression) are averaged over all targets for one antenna rotation.

TABLE 3-3

TRANSPONDER PERFORMANCE AT LOS ALAMITOS

(from Keech, 1979)

SCENARIO (a)	AVERAGE NO. OF ATCRBS INTERROGATIONS ARRIVING AT EACH A/C PER SECOND	AVERAGE NUMBER OF DABS ALL-CALL INTERROGATIONS ARRIVING AT EACH A/C PER SECOND	AVERAGE NUMBER OF DABS ROLL-CALL INTERROGATIONS ARRIVING AT EACH A/C PER SECOND	AVERAGE NUMBER OF EFFECTIVE SUPPRESSIONS ARRIVING AT EACH A/C PER SECOND[b]	AVERAGE PROBABILITY OF REPLY
1	395	--	--	1048	93.9
2	385	0.31	0.25	722	94.8
3	385	0.31	0.77	847	94.8
4	390	0.15	0.56	969	94.5

[a] Scenario 1 (ATCRBS Baseline)
Scenario 2 (DABS Surveillance)
Scenario 3 (DABS Surveillance, plus Data Link)
Scenario 4 (DABS Surveillance, plus Data Link with CDTI)

[b] Includes ATCRBS SL suppressions, DABS SL suppressions, misaddressed DABS interrogations and DABS all-calls when "locked-out".

TABLE 3-4

INTERROGATOR PERFORMANCE AT LOS ALAMITOS

(from Keech, 1979)

SCENARIO (a)	ATCRBS FRUIT PER SECOND	DABS ALL-CALL FRUIT PER SECOND	DABS ROLL-CALL FRUIT PER SECOND	% OF DESIRED REPLIES OVERLAPPED BY DABS ALL-CALL FRUIT	% OF DESIRED REPLIES OVERLAPPED BY DABS ROLL-CALL FRUIT	% OF DESIRED REPLIES OVERLAPPED BY ATCRBS FRUIT
1	4558	--	--	--	--	0.04
2	4510	7.5	2.2	0.01	0.02	0.04
3	4505	7.5	1.5	0.06	0.02	0.04
4	4522	3.7	3.0	0.01	0.03	0.04

[a] Scenario 1 (ATCRBS Baseline)
Scenario 2 (DABS Surveillance)
Scenario 3 (DABS Surveillance, plus Data Link)
Scenario 4 (DABS Surveillance, plus Data Link with CDTI)

TABLE 3-5

TRANSPONDER PERFORMANCE AT LONG BEACH
(from Keech, 1979)

SCENARIO[a]	AVERAGE NO. OF ATCRBS INTERROGATIONS ARRIVING AT EACH A/C PER SECOND	AVERAGE NUMBER OF DABS ALL-CALL INTERROGATIONS ARRIVING AT EACH A/C PER SECOND	AVERAGE NUMBER OF DABS ROLL-CALL INTERROGATIONS ARRIVING AT EACH A/C PER SECOND	AVERAGE NUMBER OF EFFECTIVE SUPPRESSIONS ARRIVING AT EACH A/C PER SECOND	AVERAGE PROBABILITY OF REPLY
1	324	--	--	759	95.8
2	312	0.71	0.43	596	96.4
3	312	0.71	0.67	610	96.4
4	312	0.73	1.28	705	95.9

[a] Scenario 1 (ATCRBS Baseline)
Scenario 2 (DABS Surveillance)
Scenario 3 (DABS Surveillance, plus Data Link)
Scenario 4 (DABS Surveillance, plus Data Link with CDTI)

TABLE 3-6

INTERROGATOR PERFORMANCE AT LONG BEACH
(from Keech, 1979)

SCENARIO[a]	P(DETECTION)	P(VAL-A)[b]	P(VAL-C)[b]	ATCRBS FRUIT PER SECOND	DABS ALL-CALL, FRUIT PER SECOND	DABS ROLL-CALL FRUIT PER SECOND
1	96.4	80.8	72.7	10830	-	-
2	96.4	80.7	72.3	10480	11.1	10.5
3	96.4	80.7	72.3	10491	11.1	18.0
4	96.6	80.6	71.8	10427	10.8	37.4

a Scenario 1 (ATCRBS Baseline)
Scenario 2 (DABS Surveillance)
Scenario 3 (DABS Surveillance, plus Data Link)
Scenario 4 (DABS Surveillance, plus Data Link with CDTI)

b Probability of mode validation given that the A/C was detected.

The simulation effort also included investigating the average dead time of transponders in 9.26 km (5 nmi) squares in the Los Angeles area with Long Beach as the victim. The largest average percentage of transponder dead time that occurred for a single antenna rotation with DABS sensors operating at their maximum data link scenarios was 10 percent. The largest average that occurred before DABS ground sensor deployment was only 4 percent.

The Long Beach ATCRBS ground sensor detection performance of 30 aircraft was also investigated at three locations of expected maximum suppression and interrogation rates. The three locations included regions 16.7 km (9 nmi) south of Long Beach, and within the antenna sidelobe regions of the Burbank and Los Angeles DABS sensor sites. The suppression rate at most aircraft approximately doubled with DABS deployment. However, the target detection performance (missed detections and code validations) by the Long Beach ATCRBS ground sensor was not noticeably reduced.

It should be pointed out that the suppression and interrogation rates simulated for aircraft in the high suppression and interrogation regions would be exceeded for particular antenna beam orientations of the DABS sensor. For example, it is unlikely that the one-to-three antenna rotation simulation runs resulted in the aircraft being simultaneously illuminated by more than one DABS sensor antenna beam. However, simultaneous antenna beam illumination does not occur frequently enough to be of concern.

The Los Angeles air traffic model used in the simulation includes only aircraft within 111 km (60 nmi) of the Los Angeles airport (LAX). It is evident from the 1995 Los Angeles model, which includes aircraft at distance beyond 111 km from LAX, that the aircraft density decreases rapidly beyond 111 km from LAX. In addition, most of the planned DABS sensor deployments are relatively close to the Los Angeles airport and have a maximum coverage range of 111 km. This leads one to intuitively believe that not accounting for aircraft farther than 111 km from LAX will not affect the simulation results.

In summary, the simulation results in the Keech report indicate that replacing FAA ATCRBS ground sensors with DABS ground sensors, that operate in the 1982 Los Angeles Basin Standard Traffic Model environment according to FAA specified scenarios, will not reduce ATCRBS performance from that which existed before DABS deployment. The suppression of transponders is the predominant DABS-to-ATCRBS interference mechanism. The deployment of DABS can cause transponder suppression peaks to increase in some regions of the coverage areas, however, the transponder suppression increase for the 1 to 3 antenna rotation simulations was not sufficient to cause noticeable degradation in ATCRBS performance.

NTIA Simulations

Two computer programs were written to evaluate the level of DABS interference to ATCRBS in a future Los Angeles environment, and assess FAA ATCRBS/DABS EMC investigation results. The first program counts the number of DABS interrogations at an ATCRBS transponder, and the second program the number of downlink fruit replies at an ATCRBS ground sensor antenna output, during antenna beam dwell periods. A detailed description of these programs is given in

Appendix A. The computer analysis results are discussed in the following subsections.

Uplink Analysis. The uplink program simulates and counts the number of DABS transmissions that a transponder would receive, at a specified location in a future Los Angeles environment, during antenna beam dwell periods. The program employs the 1982 Los Angeles Basin Standard Traffic Model (Cohen, 1973) for aircraft location statistics and assumes that all aircraft in the air traffic model are DABS transponder-equipped. This is a worst-case condition because the level of DABS interrogations and replies increase according to the number of DABS targets. The total ground sensor environment consists of the Long Beach, Los Angeles, Burbank, and Ontario sites. Deployment of DABS and ATCRBS ground sensors at these sites was simulated and their effect on ATCRBS transponder suppression compared. The FAA specified operational scenario for this DABS sensor deployment plan was used in the simulation. This included the distribution of traffic load (primary and secondary area of responsibility) among the four DABS ground sensors, and the level of DABS data link service provided to each type of aircraft.

The fifteen computer runs that were made with the uplink model are summarized in TABLE 3-7. The coordinates, in nmi relative to the Los Alamitos site that DABS transmissions were counted is indicated in column 2 and 3. The fourth column indicates if DABS or ATCRBS sensors were deployed, and column 4 the particular Los Angeles air traffic model snapshot that was used for the run. The last column provides comments on the location that DABS transmissions were counted. The first three computer runs were conducted to count the number of DABS transmissions at expected worst-case locations. They included locations where the maximum number of aircraft occurred in the antenna beam and within the sidelobe range of the DABS sensors. The Long Beach and Ontario DABS sensors were chosen for these runs because they had the highest level of air traffic load and aircraft bunching in their antenna beam. Run four through six involved conducting the runs with three different Los Angeles standard air traffic model snapshots for the worst-case locations identified in runs one through three. Run seven was conducted with ATCRBS ground sensors deployed at the Long Beach, Los Angeles, Burbank, and Ontario sites to obtain baseline and comparison data. Computer runs eight through fifteen were conducted at the locations in the Los Angeles area indicated in Figure 3-7.

Computer run one and three resulted in the highest level of DABS transmissions at an ATCRBS transponder. TABLE 3-8 indicates the program output statistics for run one. The data indicates the number of antenna beam dwell periods in which a specific number and type of DABS transmissions would be received by an ATCRBS aircraft. Columns two, three, and four gives the number of antenna beam dwells that Comm-A, Comm-C, and surveillance interrogations respectively, were received for the number indicated in column one. The last column gives the number of antenna beam dwells that a specific number of total suppressions (indicated in column one) were received by the ATCRBS aircraft. The cumulative probability distribution of this data is shown in Figure 3-8. The curve gives the percentage of antenna beam dwells that the number of received suppressions exceeded the abscissa value. The data points on this curve were used to compute the cumulative probability distribution of ATCRBS transponder suppressions shown in Figure 3-9. The curve gives the percentage of antenna beam

TABLE 3-7

INPUT DATA AND PARAMETERS FOR UPLINK MODEL B COMPUTER RUNS

RUN NO.	X COORDINATE OF ATCRBS A/C (nmi)	Y COORDINATE OF ATCRBS A/C (nmi.)	GROUND SENSOR ENVIRONMENT	SNAPSHOT OF LOS ANGELES TRAFFIC MODEL	COMMENTS
1	30.10	15.16	DABS	45304	A/C IN ONTARIO'S AB & SLR
2	0.86	20.94	DABS	45304	A/C IN LONGBEACH AB & OUTSIDE SLR
3	-4.39	4.77	DABS	45304	A/C IN LONGBEACH AB & SLR
4	-4.39	4.77	DABS	45604	A/C IN LONGBEACH AB & SLR
5	-4.39	4.77	DABS	45904	A/C IN LONGBEACH AB & SLR
6	-4.39	4.77	DABS	46204	A/C IN LONGBEACH AB & SLR
7	-4.39	4.77	ATCRBS	45304	RUN 3 WITH ATCRBS ENVIRON.
8	14.14	14.14	DABS	45304	LOCATION SHOWN IN FIGURE 3-7
9	28.28	28.28	DABS	45304	LOCATION SHOWN IN FIGURE 3-7
10	14.14	-14.14	DABS	45304	LOCATION SHOWN IN FIGURE 3-7
11	28.28	-28.28	DABS	45304	LOCATION SHOWN IN FIGURE 3-7
12	-14.14	-14.14	DABS	45304	LOCATION SHOWN IN FIGURE 3-7
13	-28.28	-28.28	DABS	45304	LOCATION SHOWN IN FIGURE 3-7
14	-14.14	14.14	DABS	45304	LOCATION SHOWN IN FIGURE 3-7
15	-28.28	28.28	DABS	45304	LOCATION SHOWN IN FIGURE 3-7

NOTE: A/C = ATCRBS TRANSPONDER EQUIPPED AIRCRAFT
(X,Y) = COORDINATES OF AIRCRAFT RELATIVE TO LOS ALAMITOS SITE
AB = ANTENNA BEAM
SLR = SIDELOBE RANGE

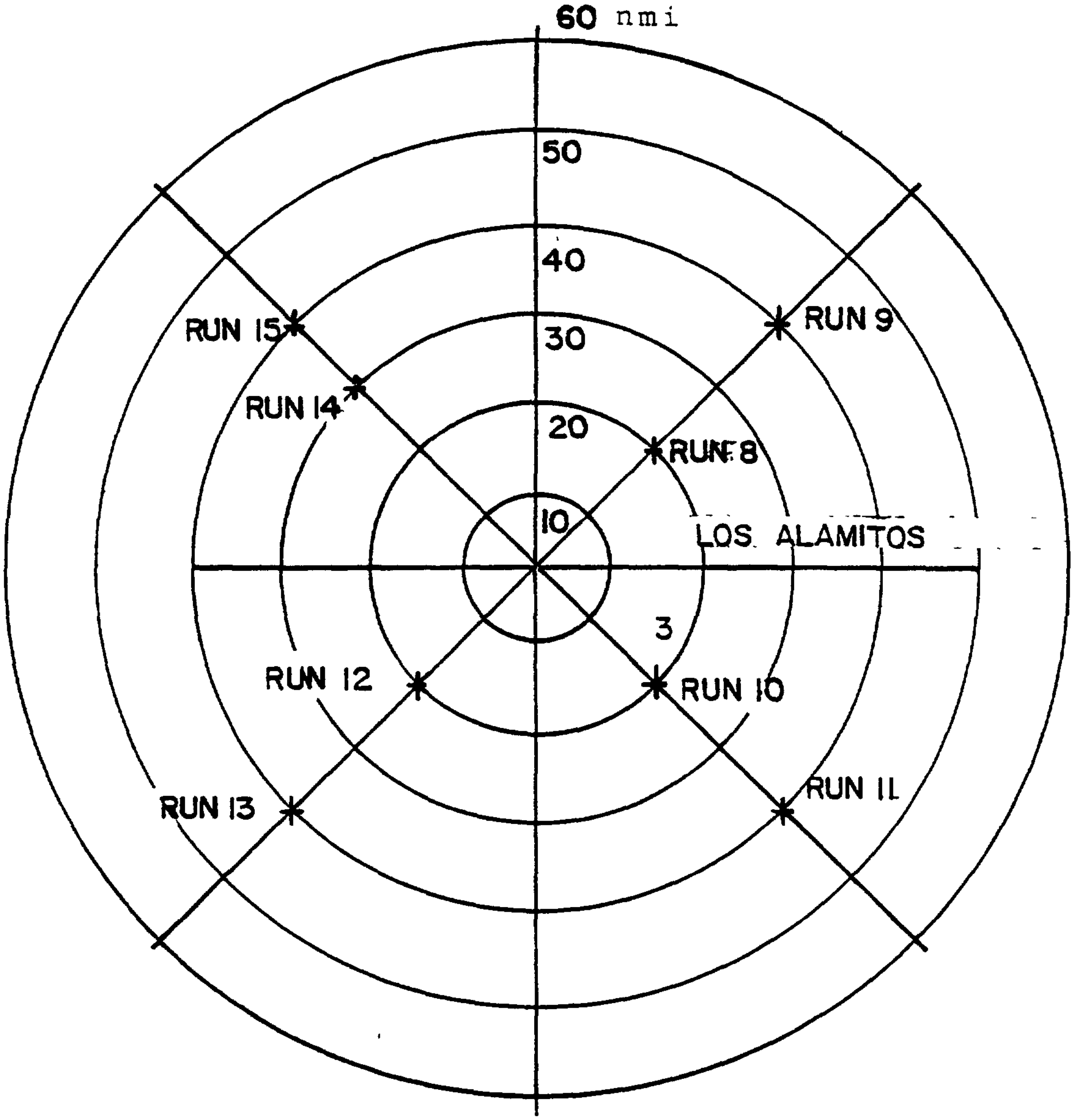


Figure 3-7. Location of ATCRBS Aircraft for Computer Runs 8 through 15.

TABLE 3-8

UPLINK PROGRAM B OUTPUT STATISTICS GIVING NUMBER OF ATCRBS TRANSPONDER SUPPRESSIONS DUE TO DABS GROUND SENSOR INTERROGATIONS (RUN NO. 1)

NO. OF DABS UPLINK SUPPRESSIONS	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF COMM - A SUPPRESSIONS INDICATED IN COL. 1 OCCURRED	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF COMM - C SUPPRESSIONS INDICATED IN COL. 1 OCCURRED	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF SURV. SUPPRESSIONS INDICATED IN COL. 1 OCCURRED	ATCRBS ANTENNA BEAM DWELLS THAT TOTAL NO. OF SUPPRESSIONS INDICATED IN COL. 1 OCCURRED
0	14157	417753	0	0
1	120426	0	490191	0
2	116617	0	9744	0
3	90939	3773	65	0
4	53547	7577	0	0
5	29654	7733	0	0
6	18492	7633	0	0
7	12681	7370	0	0
8	9137	7731	0	104007
9	6812	7632	0	104891
10	0	0	0	82840
11	5522	7854	0	48650
12	4463	7761	0	27506
13	3509	7739	0	18383
14	2758	4083	0	14055
15	2403	482	0	11721
16	1795	580	0	10814
17	1386	617	0	5700
18	985	579	0	9608
19	707	517	0	9496

NOTE: COL.=COLUMN
NO.=NUMBER
SURV.=SURVEILLANCE

TABLE 3-8 Continued

UPLINK PROGRAM B OUTPUT STATISTICS GIVING NUMBER OF ATCRBS TRANSPONDER SUPPRESSIONS DUE TO DABS GROUND SENSOR INTERROGATIONS (RUN NO. 1)

NO. OF DABS UPLINK SUP-PRESSIONS	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF COMM - A SUPPRESSIONS INDICATED IN COL. 1 OCCURRED	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF COMM - C SUPPRESSIONS INDICATED IN COL. 1 OCCURRED	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF SURV. SUPPRESSIONS INDICATED IN COL. 1 OCCURRED	ATCRBS ANTENNA BEAM DWELLS THAT TOTAL NO. OF SUPPRESSIONS INDICATED IN COL. 1 OCCURRED
20	460	480	0	8992
21	0	0	0	7582
22	401	414	0	6118
23	358	323	0	4470
24	363	302	0	3528
25	342	245	0	2809
26	353	179	0	2331
27	328	146	0	2124
28	281	92	0	1439
29	271	70	0	1479
30	231	58	0	1297
31	183	37	0	1164
32	0	0	0	1010
33	130	47	0	926
34	110	35	0	722
35	77	31	0	705
36	40	19	0	625
37	28	23	0	571
38	23	17	0	500
39	16	9	0	331

NOTE: COL.=COLUMN
NO.=NUMBER
SURV.=SURVEILLANCE

TABLE 3-8 Continued

UPLINK PROGRAM B OUTPUT STATISTICS GIVING NUMBER OF ATCRBS TRANSPONDER SUPPRESSIONS DUE TO DABS GROUND SENSOR INTERROGATIONS (RUN NO. 1)

NO. OF DABS UPLINK SUPPRESSIONS	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF COMM - A SUPPRESSIONS INDICATED IN COL. 1 OCCURRED	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF COMM - C SUPPRESSIONS INDICATED IN COL. 1 OCCURRED	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF SURV. SUPPRESSIONS INDICATED IN COL. 1 OCCURRED	ATCRBS ANTENNA BEAM DWELLS THAT TOTAL NO. OF SUPPRESSIONS INDICATED IN COL. 1 OCCURRED
40	0	9	0	350
41	6	11	0	341
42	1	14	0	281
43	0	0	0	267
44	3	1	0	272
45	0	0	0	223
46	0	5	0	205
47	0	4	0	173
48	0	6	0	165
49	0	2	0	167
50	0	4	0	126
51	0	0	0	111
52	0	0	0	112
53	0	0	0	103
54	0	6	0	68
55	0	2	0	74
56	0	0	0	76
57	0	2	0	78
58	0	0	0	46
59	0	0	0	42

NOTE: COL.=COLUMN
NO.=NUMBER
SURV.=SURVEILLANCE

TABLE 3-8 Continued

UPLINK PROGRAM B OUTPUT STATISTICS GIVING NUMBER OF ATCRBS TRANSPONDER SUPPRESSIONS DUE TO DABS GROUND SENSOR INTERROGATIONS (RUN NO. 1)

NO. OF DABS UPLINK SUPPRESSIONS	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF COMM - A SUPPRESSIONS INDICATED IN COL. 1 OCCURRED	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF COMM - C SUPPRESSIONS INDICATED IN COL. 1 OCCURRED	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF SURV. SUPPRESSIONS INDICATED IN COL. 1 OCCURRED	ATCRBS ANTENNA BEAM DWELLS THAT TOTAL NO. OF SUPPRESSIONS INDICATED IN COL. 1 OCCURRED
60	0	0	0	40
61	0	0	0	33
62	0	0	0	30
63	0	0	0	34
64	0	0	0	16
65	0	0	0	20
66	0	0	0	15
67	0	0	0	10
68	0	0	0	10
69	0	0	0	11
70	0	0	0	12
71	0	0	0	7
72	0	0	0	5
73	0	0	0	3
74	0	0	0	11
75	0	0	0	2
76	0	0	0	1
77	0	0	0	0
78	0	0	0	2
79	0	0	0	5

NOTE: COL.=COLUMN
NO.=NUMBER
SURV.=SURVEILLANCE

TABLE 3-8 Continued

UPLINK PROGRAM B OUTPUT STATISTICS GIVING NUMBER OF ATCRBS TRANSPONDER SUPPRESSIONS DUE TO DABS GROUND SENSOR INTERROGATIONS (RUN NO. 1)

NO. OF DABS UPLINK SUPPRESSIONS	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF COMM - A SUPPRESSIONS INDICATED IN COL. 1 OCCURRED	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF COMM - C SUPPRESSIONS INDICATED IN COL. 1 OCCURRED	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF SURV. SUPPRESSIONS INDICATED IN COL. 1 OCCURRED	ATCRBS ANTENNA BEAM DWELLS THAT TOTAL NO. OF SUPPRESSIONS INDICATED IN COL. 1 OCCURRED
80	0	0	0	0
81	0	0	0	4
82	0	0	0	3
83	0	0	0	2
84	0	0	0	0
85	0	0	0	0
86	0	0	0	1
87	0	0	0	0
88	0	0	0	0
89	0	0	0	0
90	0	0	0	2
91	0	0	0	0
92	0	0	0	0
93	0	0	0	0
94	0	0	0	0
95	0	0	0	0
96	0	0	0	0
97	0	0	0	0
98	0	0	0	0
99	0	0	0	0

NOTE: COL.=COLUMN
NO.=NUMBER
SURV.=SURVEILLANCE

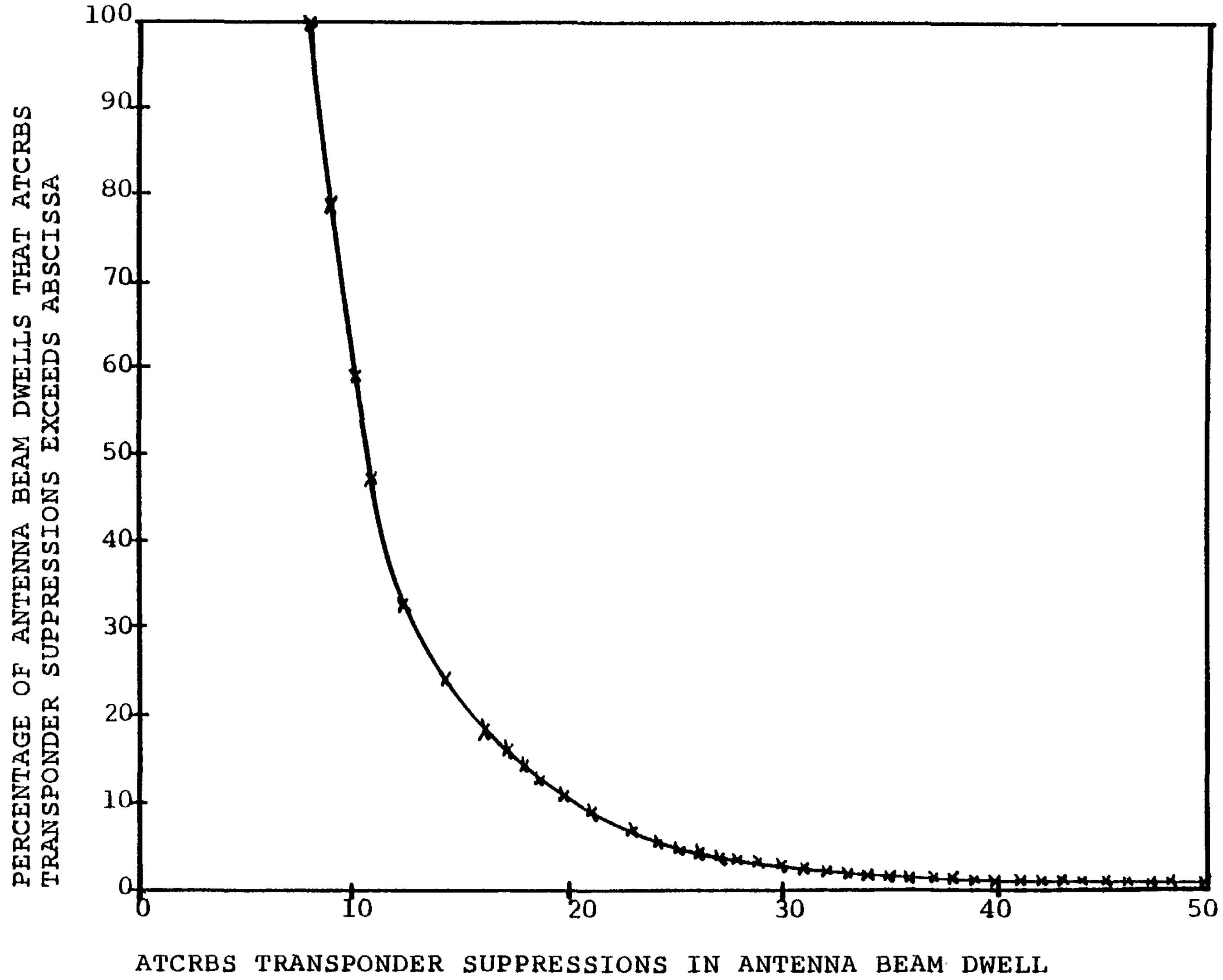


Figure 3-8. Cumulative Probability Distribution of ATCRBS Transponder Suppressions (Computer Run 1)

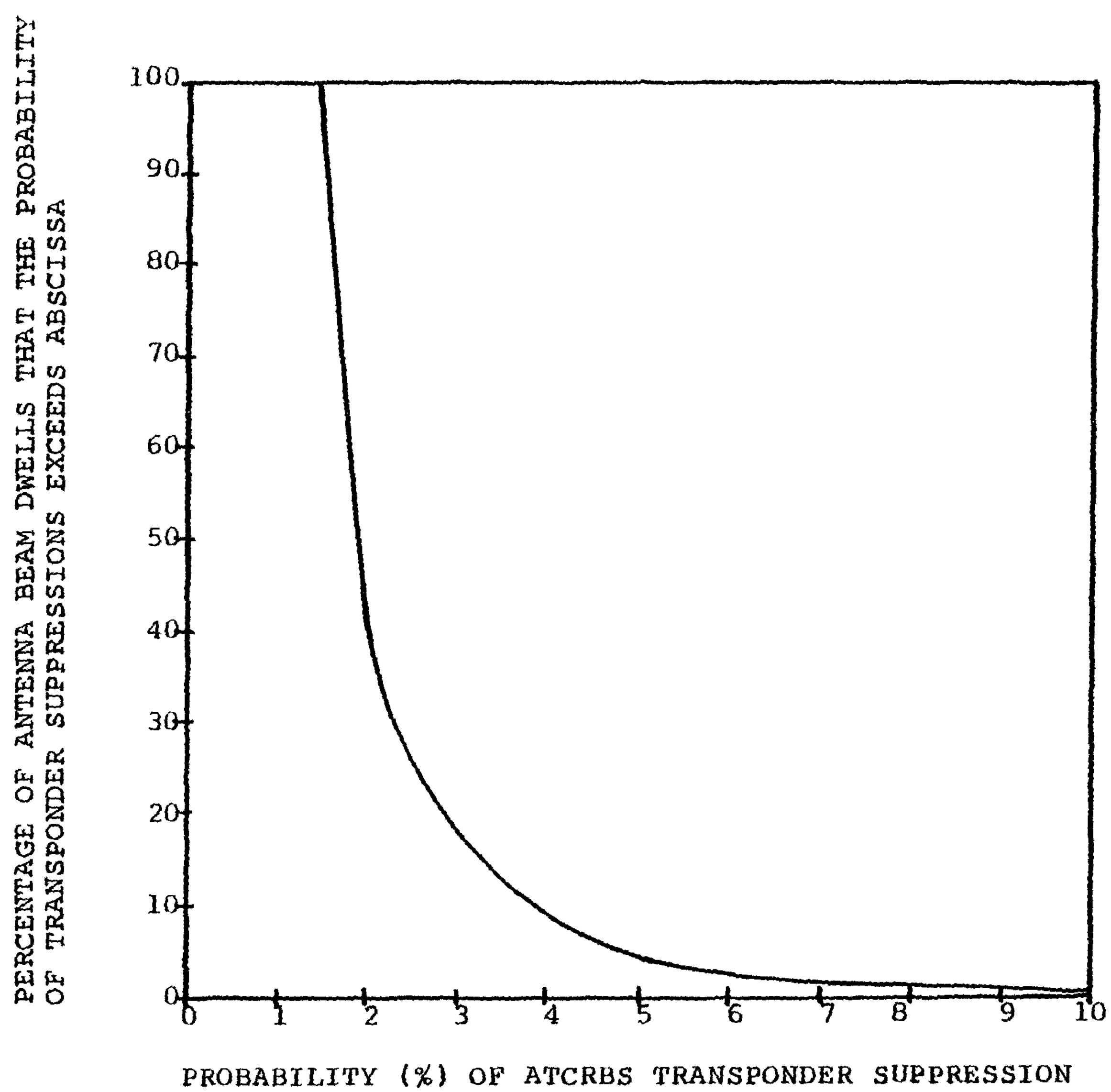


Figure 3-9. Cumulative Probability Distribution of Percent ATCRBS Transponder Suppression (Computer Run 1)

dwells in which the average percent ATCRBS transponder suppression exceeded the abscissa value. Less than 5 percent of the antenna beam dwells had greater than 5 percent ATCRBS transponder suppression. The ATCRBS transponder suppression had an average value of approximately 1.6 percent. The average suppression level for the ATCRBS only environment runs, which assumed an improved SLS range of 46.3 km (25 nmi), was 4.6 percent. Thus, the simulations indicate that replacing the FAA ATCRBS ground sensor, at the Long Beach, Los Angeles, Burbank, and Ontario sites, with DABS ground sensors will result in an ATCRBS transponder suppression improvement of 3.0 percent.

The ECAC simulation results (see TABLE 3-3 and 3-5) indicated an over all ATCRBS transponder suppression improvement of 0.1 to 1.0 percent, depending on the particular DABS ground sensor deployment scenario. The average suppression for transponders located at worst-case locations increased 6 percent for DABS deployment. Therefore, the ECAC simulated impact of DABS on ATCRBS transponder suppression is slightly more pessimistic than NTIA simulation results. The fact that the simulation results do not agree exactly can be attributed to the following differences between the two models.

1. The ECAC model considers the victim to be a DABS transponder while the NTIA model considers the victim to be an ATCRBS transponder.

2. The ECAC model considers the average transponder suppression per antenna rotation over all aircraft while the NTIA model considers the average transponder suppression per antenna beam dwell period for one aircraft at a specific worst-case location.

3. The percentage of DABS ground sensors considered operational and the site location of the victim ATCRBS ground sensor were not exactly the same for both simulations.

4. The ECAC simulation included all ATCRBS ground sensor within 926 km (500 nmi) radius of Los Angeles, while the NTIA simulations included only the four FAA sites specified for DABS sensor replacement.

5. A worst-case approximation was used in the NTIA simulation to compute the number of transmissions required for CDTI data link service.

Although slightly different simulation results were obtained by ECAC and NTIA, both indicated that DABS will not reduce ATCRBS performance.

The NTIA uplink simulation results are based on 500,000 antenna beam dwell samples. This results in the simulations including approximately 3333 single DABS sensor antenna beam illuminations of the ATCRBS transponder, and 22 instances of simultaneous antenna beam illumination by two DABS sensors. The number of samples required to account for three or four simultaneous DABS sensor antenna beam illuminations was found to require excessive computer time. However, these events occur so infrequently that they will not have a significant effect on the results. Thus, a sufficient number of antenna beam dwell samples were taken to statistically characterize DABS uplink interference.

<u>Downlink Analysis.</u> The downlink program simulates and counts the number of

DABS replies that the Los Alamitos ATCRBS ground sensor would receive over its antenna beam dwell periods. The program uses the 1982 Los Angeles Basin Standard Traffic Model data and FAA specified DABS operational scenarios. The program assumes that all aircraft are DABS transponder-equipped. The DABS ground sensors are deployed at Long Beach, Los Angeles, Burbank, and Ontario. The total environment includes only these sites.

Two computer runs were made. They included one run with the antenna sidelobe range (SLR) of the Los Alamitos ATCRBS ground sensor set at 29.6 km (16 nmi), and the other run at 48 km (26 nmi). TABLE 3-9 indicates the program output statistics for the 29.6 km SLR run and TABLE 3-10 for the 48 km SLR run. The tables indicate the number of Los Alamitos antenna beam dwells in which a specific number and type of DABS reply was received by the Los Alamitos ATCRBS sensor. Columns two and three give the number of antenna beam dwells that the short and long DABS replies received equaled the number indicated in column one. The last column indicates the number of antenna beam dwells in which the total (long plus short) replies indicated in column one were received. It is evident from the table that the number of received long DABS replies is insignificant compared to short replies. The cumulative probability distribution was computed from the data in the last columns of TABLE 3-9 and 3-10 and are shown in Figure 3-10 and 3-11 respectively. The curves give the percentage of antenna beam dwells that the number of received DABS replies exceeded the abscissa values. The data points on this curve were used to compute the cumulative probability distribution of percent ATCRBS reply losses shown in Figure 3-12 and 3-13. The curves give the percentage of antenna beam dwells that the percentage of loss ATCRBS replies exceeded the abscissa value. The loss of ATCRBS replies had a median value of 0.5 percent for the 29.6 km SLR run (see Figure 3-12) and 3.5 percent for the 48 km SLR run (see Figure 3-13). Less than 5 percent of the antenna beam dwells had an ATCRBS reply loss greater than 6 percent for the 29.6 km SLR run, and greater than 11 percent for the 48 km SLR run.

It should be pointed out that these results are pessimistic because the receiver gain time control (GTC) characteristics of the ATCRBS ground sensor were not accounted for in the program. Calculations and NTIA measurements (Pratt, 1976) indicated that the Los Alamitos ATCRBS ground sensor has an effective antenna sidelobe range of approximately 29.6 km. Therefore, the 29.6 km SLR run more closely estimates the number of replies received by the Los Alamitos ATCRBS sensor than the 48 km SLR runs.

The average DABS fruit rate for the 29.6 km SLR runs was 165 fruit/s. This value is approximately 3 times the 48 fruit/s value obtained in the worst-case scenario ECAC simulation runs (see TABLE 3-6). The higher value of average DABS fruit rate obtained in the NTIA simulations is mainly attributed to the fact that the NTIA model does not account for the GTC receiver characteristics of the ATCRBS ground sensor. The results of both the NTIA and ECAC simulations indicate that the average level of DABS fruit is not great enough to significantly reduce ATCRBS performance.

In summary, the NTIA simulations indicated that operating DABS in the 1982 Los Angeles Basin Standard Traffic Model environment according to FAA specified scenarios will not reduce ATCRBS performance. The average percentage of ATCRBS transponder suppression, and probability of ATCRBS reply loss, estimated by the

TABLE 3-9

DOWN LINK PROGRAM OUTPUT STATISTICS
GIVING NUMBER OF DABS TRANSPONDER
REPLIES RECEIVED BY ATCRBS GROUND
SENSOR WITH 16 N.Mi. ANTENNA SIDELOBE RANGE

NO. OF DABS REPLIES	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF SHORT REPLIES INDICATED IN COL. 1 WERE RECEIVED	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF LONG REPLIES INDICATED IN COL. 1 WERE RECEIVED	ATCRBS ANTENNA BEAM DWELLS THAT TOTAL NO. OF REPLIES INDICATED IN COL. 1 WERE RECEIVED
0	539631	999339	539292
1	4848	171	4940
2	8307	183	8373
3	11873	153	11962
4	15269	89	15310
5	19499	42	19517
6	24086	19	24091
7	30082	3	30072
8	39919	0	39916
9	82442	0	82427
10	21513	1	21530
11	2148	0	2166
12	28461	0	28465
13	45515	0	45490
14	53161	0	53157
15	4703	0	4716
16	5362	0	5375
17	6074	0	6080
18	6692	0	6698
19	6814	0	6821
20	5482	0	5483
21	8485	0	8486
22	9564	0	9560
23	7790	0	7792
24	1521	0	1523
25	1380	0	1381
26	2482	0	2484
27	2250	0	2253
28	1515	0	1516
29	387	1	387
30	386	0	386
31	511	0	510
32	353	0	354

NOTE: COL. = COLUMN
NO. = NUMBER

TABLE 3-9 (Continued)

DOWN LINK PROGRAM OUTPUT STATISTICS
GIVING NUMBER OF DABS TRANSPONDER
REPLIES RECEIVED BY AN ATCRBS GROUND
SENSOR WITH 16 N.MI. ANTENNA SIDELOBE RANGE

No. of DABS Replies	ATCRBS Antenna Beams Dwells that No. of Short Replies indicated In Column 1 were Received	ATCRBS Antenna Beam Dwells that No. of Long Replies indicated In Column 1 were Received	ATCRBS Antenna Beam Dwells that Total No. of Replies indicat-ed In Column 1 were Received
33	326	0	329
34	311	0	311
35	348	0	348
36	314	0	314
37	151	0	151
38	0	0	0
39	0	0	0
40	0	0	0
41	0	0	0
42	0	0	0
43	0	0	0
44	0	0	0
45	0	0	0
46	0	0	0
47	0	0	0
48	0	0	0
49	0	0	0
50	0	0	0
51	0	0	0
52	0	0	0
53	0	0	0
54	0	0	0
55	0	0	0
56	0	0	0
57	0	0	0
58	0	0	0
59	0	0	0
60	0	0	0
61	0	0	0
62	0	0	0
63	0	0	0
64	0	0	0
65	0	0	0

Note: CoL. = Column
No. = Number

TABLE 3-10

DOWN LINK PROGRAM OUTPUT STATISTICS GIVING NUMBER OF DABS TRANSPONDER REPLIES RECEIVED BY ATCRBS GROUND SENSOR WITH 23 N. MI. ANTENNA SIDELOBE RANGE

NO. OF DABS REPLIES	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF SHORT REPLIES INDICATED IN COL. 1 WERE RECEIVED	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF LONG REPLIES INDICATED IN COL.1 WERE RECEIVED	ATCRBS ANTENNA BEAM DWELLS THAT TOTAL NO. OF REPLIES INDICATED IN COL. 1 WERE RECEIVED
0	330012	996062	328789
1	7337	1110	7667
2	10313	1105	10597
3	12635	942	12916
4	14015	999	14158
5	15817	209	15879
6	17308	57	17313
7	19327	12	19303
8	21477	2	21464
9	23542	1	23510
10	25971	1	25975
11	11542	0	1615
12	30432	0	30372
13	36261	0	36168
14	51211	0	51120
15	53564	0	53496
16	18492	0	18578
17	21762	0	21836
18	27585	0	27592
19	46328	0	46224
20	38491	0	38499
21	8042	0	8148
22	9437	0	9529
23	9077	0	9138
24	9647	0	9658
25	9623	0	9636
26	9232	0	9233
27	10504	0	10485
28	10597	0	10605
29	10482	0	10476
30	9344	0	9350
31	9863	0	9862
32	12233	0	12232

Note: CoL. = Column
No. = Number

TABLE 3-10 (Continued)

DOWN LINK PROGRAM OUTPUT STATISTICS GIVING NUMBER OF DABS TRANSPONDER REPLIES RECIEVED BY ATCRBS GROUND SENSOR WITH 23 N. MI, ANTENNA SIDELOBE RANGE

NO. OF DABS REPLIES	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF SHORT REPLIES INDICATED IN COL. 1 WERE RECEIVED	ATCRBS ANTENNA BEAM DWELLS THAT NO. OF LONG REPLIES INDICATED IN COL. 1 WERE RECEIVED	ATCRBS ANTENNA BEAM DWELLS THAT TOTAL NO. OF REPLIES INDICATED IN COL. 1 WERE RECEIVED
33	12314	0	12316
34	11491	0	11480
35	6643	0	6647
36	3184	0	3212
37	3246	0	3269
38	3550	0	3554
39	3221	0	3230
40	1864	0	1875
41	1288	0	1296
42	1171	0	1183
43	1126	0	1124
44	1118	0	1112
45	1086	0	1086
46	1016	0	1016
47	990	0	997
48	1024	0	1024
49	907	0	909
50	849	0	851
51	801	0	801
52	664	0	664
53	539	0	541
54	285	0	286
55	69	0	71
56	0	0	1
57	0	0	0
58	0	0	0
59	0	0	0
60	0	0	0
61	0	0	0
62	0	0	0
63	0	0	0
64	0	0	0
65	0	0	0

Note: CoL. = Column
No. = Number

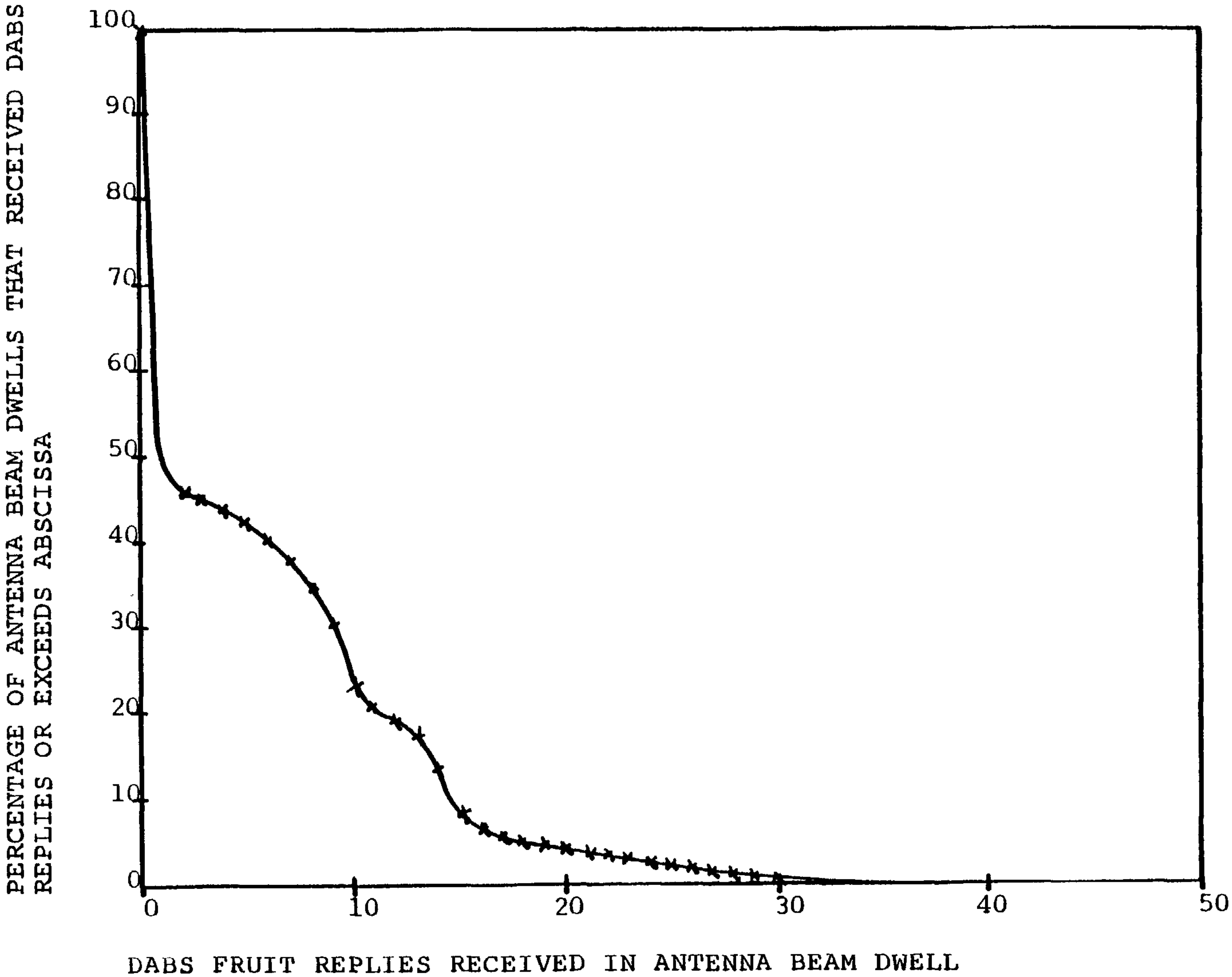


Figure 3-10. Cumulative Probability Distribution of Short Dabs Fruit Replies Received by ATCRBS Sensor (Antenna Sidelobe Range 16 nmi)

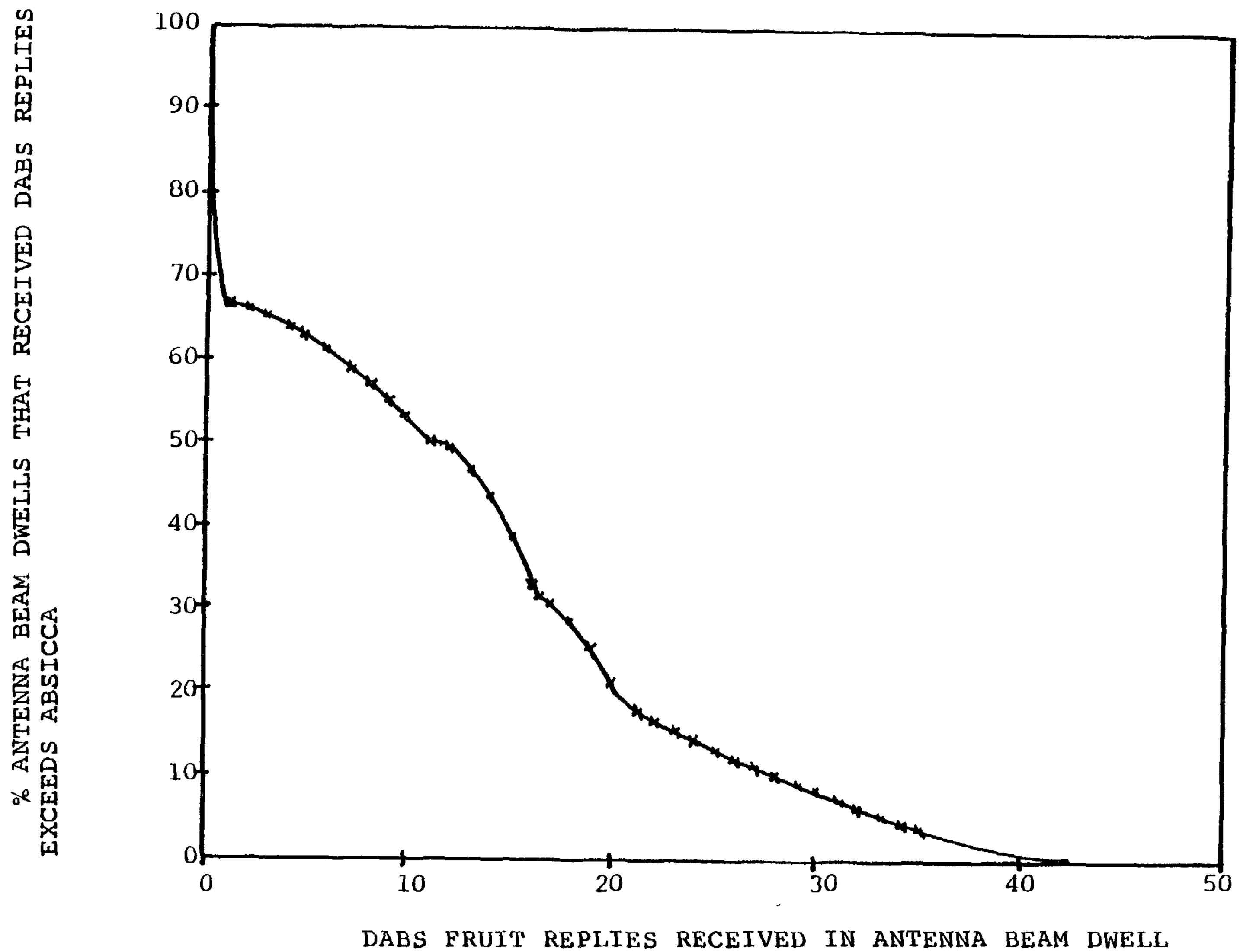


Figure 3-11. Cumulative Probability Distribution of Short DABS Fruit Replies Received by ATCRBS Sensor (Antenna Sidelobe Range: 23 nmi)

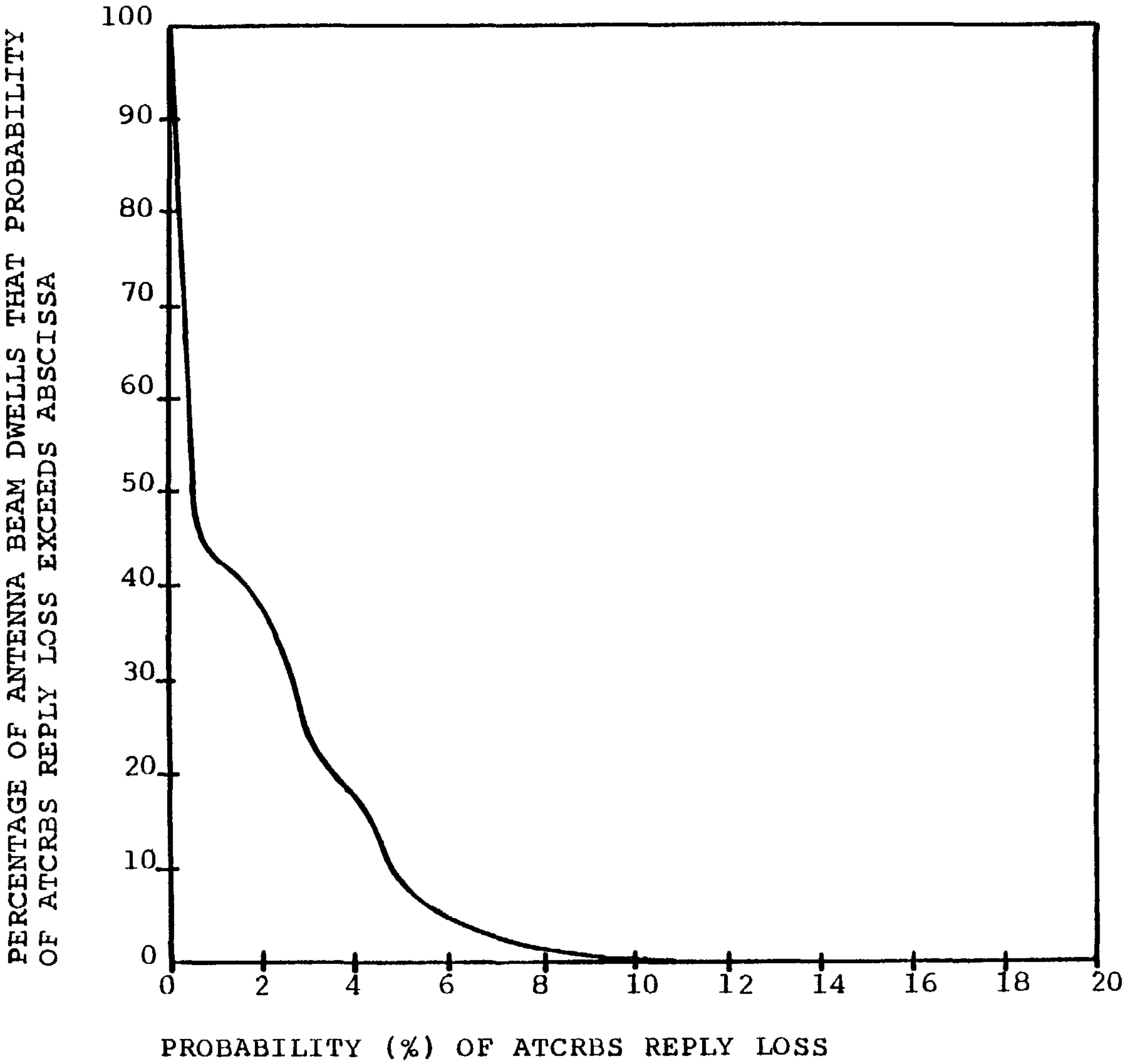


Figure 3-12. Cumulative Probability Distribution of ATCRBS Reply Loss (ATCRBS Sensor Antenna Sidelobe Range 16 nmi)

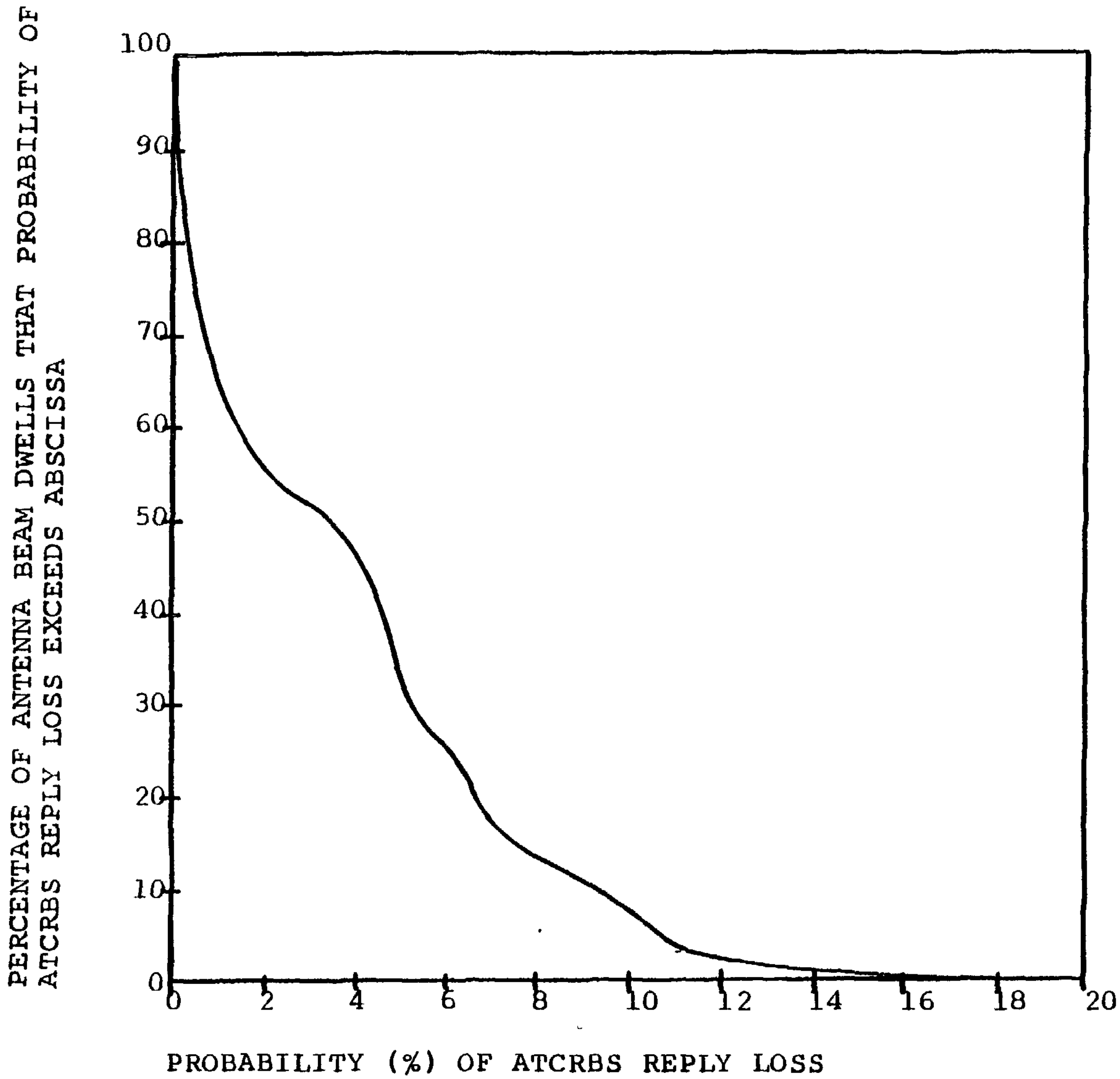


Figure 3-13. Cumulative Probability Distribution of ATCRBS Reply Loss (ATCRBS Sensor Antenna Sidelobe Range 23 nmi)

simulations are similar to that predicted by the theoretical calculations in the Welch report and ECAC simulation results in the Keech report.

FAA Measurements

FAA conducted tests at FAA Technical Center to investigate the impact of DABS on ATCRBS performance. The planning of these tests was coordinated with NTIA, and portions of the tests were observed by NTIA. The purpose of the test effort was to verify the predictions and conclusions resulting from the Lincoln Laboratory theoretical analysis (Welch, 1978), by quanitatively determining the effect of DABS transmissions on ATCRBS performance. An additional objective of the tests included determining the necessary corrective action if a compatibility problem should be found.

The three basic types of tests conducted at FAA Technical Center and their purpose are listed below;

1. Live flight tests to determine DABS uplink suppression effects on aircraft transponders.

2. Bench tests to determine DABS downlink fruit effects on ATCRBS ground sensor performance.

3. Uplink/downlink open system tests to determine the combined DABS uplink suppression and downlink fruit interference effects on ATCRBS performance.

The following subsections discuss NTIA's evaluation of these test results.

Flight Tests. A FAA interim report (Mahnken, 1979) includes the results of uplink flight tests conducted at FAA Technical Center. The uplink suppression tests consisted of counting and recording the number of suppressions (P1 and P2 pulse pairs) at an aircraft flying on a 55.5 km (30 nmi) radial relative to the DABS site, for several different ATCRBS and DABS ground sensor configurations. One set of tests was conducted while the three ATCRBS ground sensors were operating in their normal mode of operation, and another set with one ATCRBS ground sensor replaced with a DABS ground sensor. Measurements were made with the DABS operating at a 500 per second Roll-Call interrogation rate in one subset of the tests, and a 1000 per second rate in another subset.

The measured suppression rate as a function of distance from the DABS site for the "1000" Roll-Call DABS interrogation case is shown in Figure 3-14, and for the ATCRBS-only case in Figure 3-15. These curves were extracted from the FAA Technical Center interim measurement report. In the DABS "1000" case, the average suppression level exceeds the ATCRBS-only ground sensor case by an insignificant amount (1.5 percent) out to a range of 5.5 km (3 nmi), and was considerably less for distances greater than 5.5 km.

It is not unexpected that the DABS caused a lower suppression rate at distances greater than 5.5 km from the DABS sensor because the ATCRBS it replaced employed "Improved SLS." The SLS suppressions transmitted from this type of ATCRBS ground sensors have a range of 37-91 km (20-50 nmi) while the Roll-Call

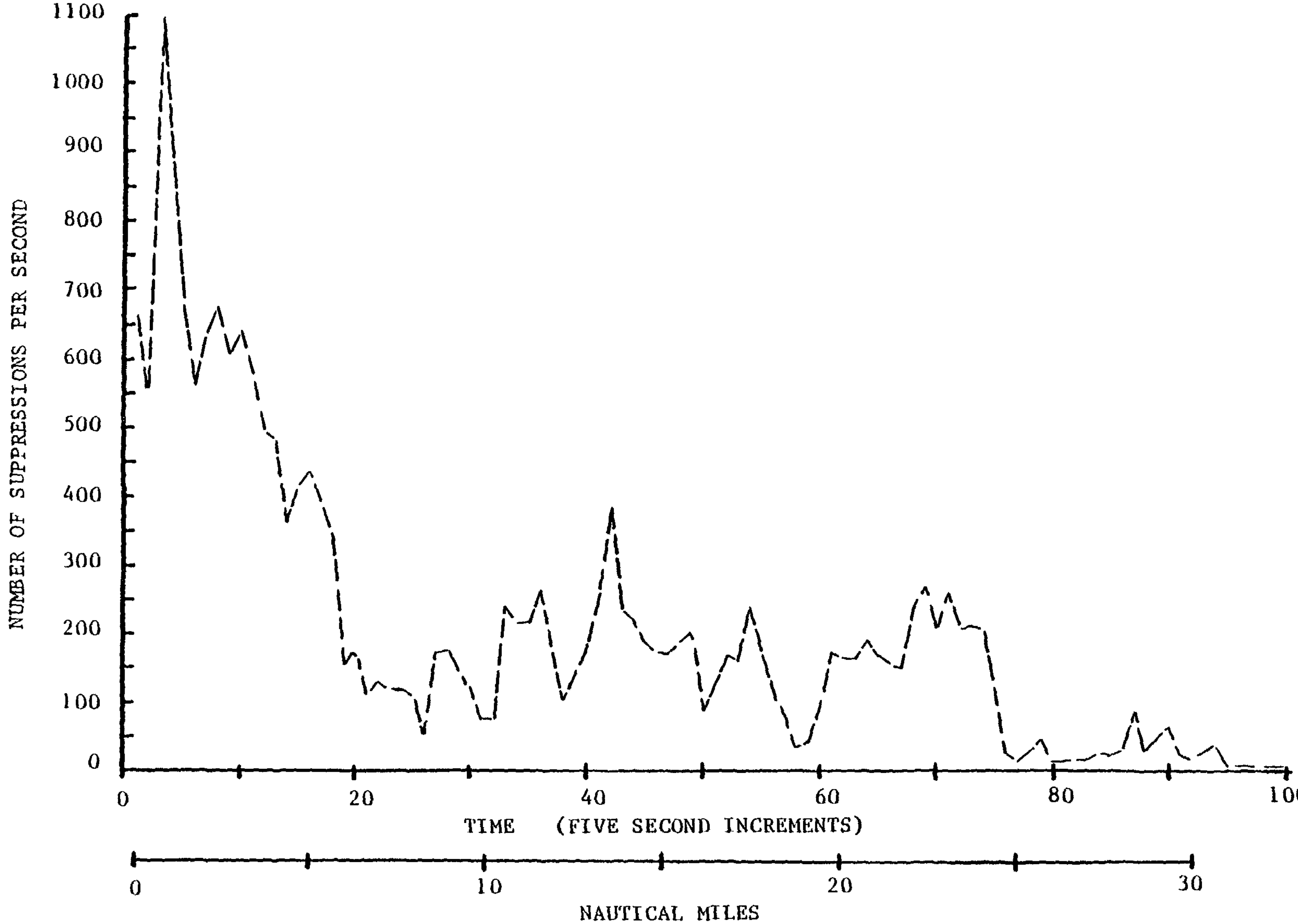


Figure 3-14. Run 9 - Suppression Rates Using the DABS "1000" Configuration
(June 12, Test Flight from Mahnken, 1979)

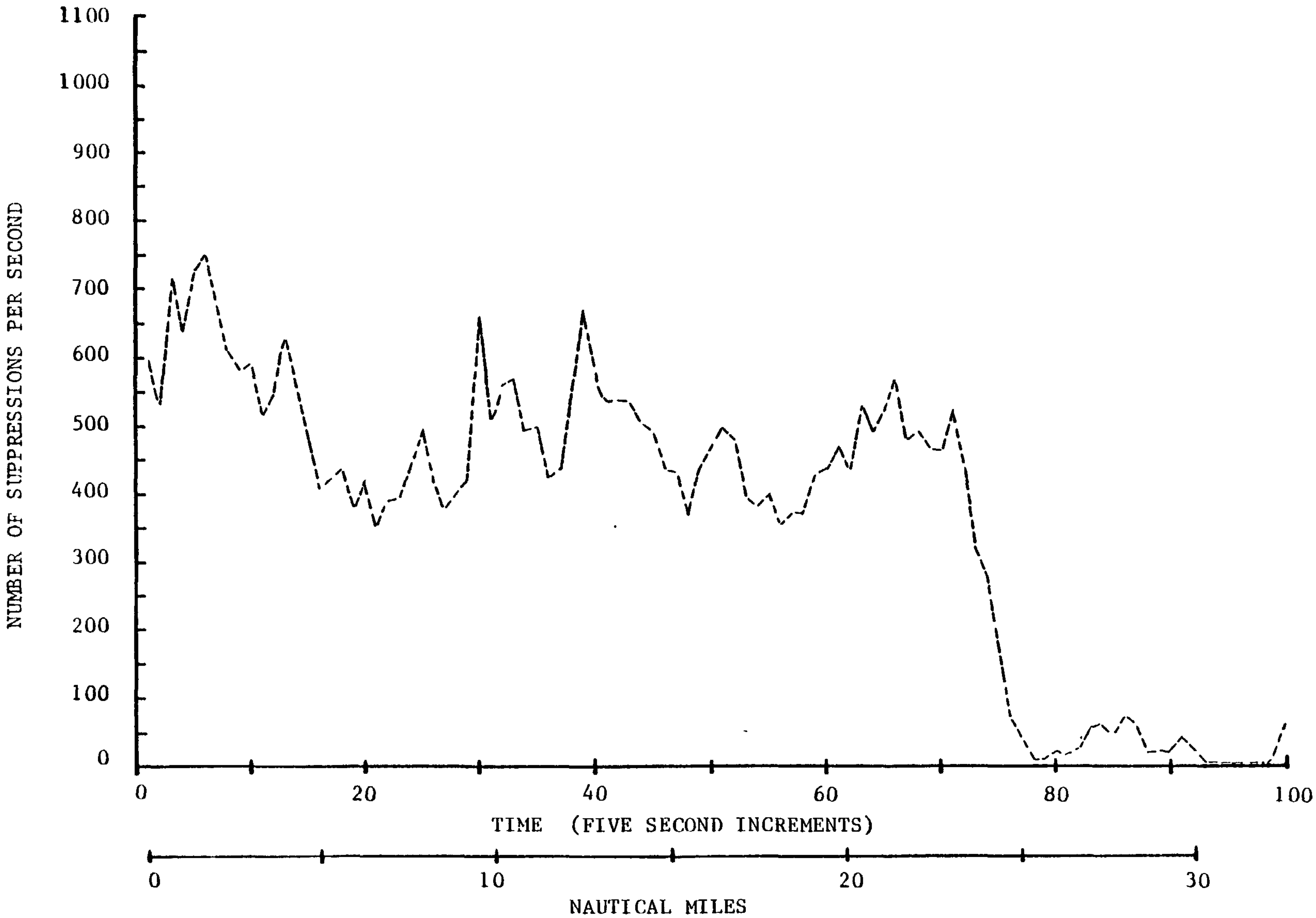


Figure 3-15. Run 8 - Suppression Rates Using the "ATCRBS" Configuration (June 12, Test Flight from Mahnken, 1979)

interrogations radiated from the DABS directional antenna sidelobes only have a range of 5.5-9.3 km (3-5 nmi). If the ATCRBS sensor that the DABS sensor replaced employed only non-improved SLS, a less dramatic reduction of the suppression rate would have resulted. The "ATCRBS only" curve in Figure 3-15 would have decreased at approximately 5.5-9.3 km like that indicated by the DABS "1000" curve. Therefore, the particular suppression reductions illustrated in Figures 3-14 and 3-15 can only be realized for cases in which the DABS sensor replaces ATCRBS sensors that employ improved SLS.

ATCRBS/DABS All-Call suppressions were not included in the DABS ground sensor transmissions. These suppression will have ranges of 37-91 km for those DABS sensors that employ improved SLS. However, since DABS sensors transmit ATCRBS/DABS All-Call interrogations at only a nominal rate of 150 per second, its effect on the test results would be insignificant.

A 100-watt peak pulse power was used for the DABS ground sensor in the tests. FAA has specified that DABS Roll-Call interrogations will be transmitted at 100 watts, and Roll-Call reinterrogation at 800 watts. The fact that the 100 watt DABS transmitter power used in the tests is less than the Roll-Call reinterrogations power of 800 watts does not invalidate the test results because the DABS Roll-Call reinterrogation rate is only approximately one-tenth the Roll-Call interrogation rate.

The measured DABS suppression rate curves shown in Figure 3-14 and 3-15 represent the average suppression rate over approximately one DABS antenna rotation period (4.72 seconds). This was accomplished by taking the average of 40 one-eighth record samples or an average of five seconds of data. A single DABS sensor can transmit Roll-Call interrogations at a rate greater than that used in the tests (1000 interrogations/s) for shorter periods of time than one antenna rotation. However, the proposed DABS national standard indicates that the 1000 interrogation/s test rate is close to the maximum rate (1165 interrogations/s) that a DABS sensor is capable of sustaining over one antenna rotation.

The suppression rate curve in Figure 3-14 for the DABS "1000" case confirms Lincoln Laboratory theoretical predictions (Welch, 1978), that Roll-Call interrogations radiated on the DABS directional antenna sidelobes will not be detected by transponders beyond 5.5-9.3 km. The tests also confirmed that the average Roll-Call suppressions per antenna rotation outside the sidelobe region of a DABS sensor is less than that within the sidelobe region, by the amount predicted by Equation C-6.

Bench Tests. The bench tests were designed to determine the ATCRBS processor susceptibility to DABS fruit interference. They consisted of measuring the performance of the ATCRBS reply processors for various ATCRBS/DABS fruit rate combinations and transponder reply probabilities. Target and fruit replies from two generators were injected into the processor input in the same manner that they would have been received from the receiver quantizer of either an ATCRBI-4 or ATCBI-5 interrogator/receiver unit. The ATCRBS performance parameters measured included percent target detection, code validation, target splits per antenna rotation, and false alarms per antenna rotation.

The reply processors that were tested at FAA Technical Center are listed below:

1. ARTS-III

2. ARTS-II

3. ARTS-IIIA (Sensor Receiver & Processor)

4. AN/FYQ-47 (Common Digitizer)

5. AN/TPX-42A

The FAA Technical Center interim report (Mahnken, 1979) included partial results of the bench tests on the ARTS-III and partial test results on the ARTS-II and AN/TPX-42 processors. The interim report indicates that the ARTS-III was tested at average DABS fruit rates up to 1000 fruit/s and the AN/TPX-42A at rates up to 400 fruit/s. Calculations indicate that the average DABS fruit rate per antenna rotation should not exceed 75 fruit/s and that short term peak rates will not exceed 380 fruit/s through 1995. The bench test measurements indicated that DABS fruit rates of 400 fruit/s will not affect ARTS-III and TPX-42 processor performance. Therefore, the performance of these processors will not be degraded by either average or short term peak DABS fruit rates.

All bench tests have been completed; however, the final test reports have not been officially released. It is not anticipated that the forthcoming bench test results on the ARTS-II, ARTS-IIIA, AN/FYQ-47, and AN/TPX-42A will indicate performance degradation for operational DABS fruit levels.

It is not unexpected that the DABS fruit rates in the bench tests did not degrade ATCRBS processor performance. Calculations (Welch, 1978) indicate that DABS fruit effects on ATCRBS performance are insignificant and relatively small compared to suppressions.

Uplink/Downlink Tests. The uplink/downlink tests were performed by FAA to satisfy a request from NTIA to simultaneously measure the combined effect of DABS uplink suppressions and downlink fruit on ATCRBS performance. It was also requested that this test be conducted with typical scheduled (non-periodic) Roll-Call interrogation scenarios.

The test involved pointing the DABS ground sensor antenna beam at a tower mounted transponder while the ATCRBS victims ground sensor detection and code validation performance was measured. The DABS sensor continually transmitted Roll-Call interrogation message preambles at an average rate of approximately 3231 interrogations/s per antenna beam dwell. This rate exceeds the maximum interrogation specified (2400 interrogations/s) in the proposed DABS National Standard for a DABS sensor antenna beam dwell period. The DABS transmissions were scheduled in time to simulate typical Roll-Call interrogation scenarios. Three scenarios were run. The first scenario was with DABS off to establish baseline comparison data. The second and third scenarios runs included DABS transmitting with two different Roll-Call schedules over antenna beam dwell periods. These Roll-Call schedules were continually repeated for every antenna beam dwell period.

The DABS sensor caused approximately a 11 percent reduction in ATCRBS transponder round reliability for both scenarios. This resulted in approximately one out of ten lost replies at the victim ATCRBS ground sensor. The 11 percent reduction in ATCRBS round reliability due to the DABS sensor transmission rate of 3231 interrogations/s is approximately the value predicted by Lincoln Laboratory theoretical calculations and Equation 3-4. This reduction in round reliability did not cause a noticeable reduction in the percent of target detections and code validations. Modern ATCRBS processor can tolerate the measured 11 percent reduction in round reliability observed in the tests without noticeable degredation, because of the large number of replies (16-20) received from each target in its sliding window detector. The number of hits (replies) required to declare a target and validate codes is relatively small compared to this number. This fact is also evident from the FAA Technical Center bench test measurements and binomial probability calculations.

The "DABS" test runs with two different Roll-Call schedules resulted in approximately the same percentage reduction in round reliability. This indicates that the number of unique Roll-Call scheduled tranmissions in the test was sufficient, and that the result of the tests are not dependent on the particular timing sequences of the Roll-Call schedule.

It was necessary to transmit only the preamble of the DABS Roll-Call interrogations in the test in order not to exceed the maximun duty cycle of the DABS tramsmitter power supply. However, not transmitting the full Roll-Call message did not result in less impact on ATCRBS performance because the preample (P1,P2 Pulses) is the portion of the transmission that causes transponder suppression.

In summary, the uplink tests demonstrated that the average uplink suppression rate for the majority of airspace will be less when DABS sensors replace ATCRBS sensors that employ improved SLS. The bench tests indicated that fruit in a multiple DABS ground sensor environment will not noticeably affect ATCRBS performance, and that DABS fruit is relatively insignificant compared to uplink suppression effects. The uplink/downlink tests indicated that the combination of uplink suppressions from a single DABS sensor and downlink fruit levels for a multiple DABS sensor environment will not reduce ATCRBS performance. Since the DABS sensor in the uplink/downlink tets continually suppressed the ATCRBS transponder 11 percent of the time, and this level exceeds the average suppression levels that will exist in a multiple DABS sensor environments of the future, the tests indicate that DABS multisensor deployment should not reduce overall ATCRBS performance.

Summary of DABS Effects on ATCRBS

Investigations by FAA and NTIA have indicated that replacing FAA ATCRBS ground sensors with DABS ground sensors will not significantly reduce ATCRBS performance from that which existed before deployment of DABS. Short term peak DABS interference levels (uplink suppression rates) will exceed levels that exist in an ATCRBS only ground sensor environment. However, the DABS interference peaks are small in duration, magnitude, and frequency of occurrence, and do not have an impact on over all ATCRBS performance. The FAA and NTIA simulations of ATCRBS performance are based on the 1982 Los Angeles Basin Standard Trafffic Model with DABS technical characteristics and the DABS operational deployment scenarios defined by FAA. However, the air traffic densities used in the 1982 Los Angeles Basin Standard Traffic Model will not likely occur in the Los Angeles basin until approximately 1990. Lincoln Laboratory (Harman, 1979) measured air traffic densities in the 1976 Los Angeles Basin and compared them with those used in the Los Angeles Basin Standard Traffic Model. The results indicated that the measured aircraft density was one-fifth the density in the model. The air traffic density in 1995 may exceed those used in the 1982 model. However, a study by Mitre Corporation for the 1995 Los Angeles environment indicated that with an increased number of DABS ground sensor deployments, the peak aircraft density in the DABS antenna beam would be maintained at the 1982 model level. The average level of DABS interference to ATCRBS per antenna rotation would increase for the 1995 scenario; however, the uplink interference level from each DABS sensor during the critical ATCRBS ground sensor antenna beam illumination of the target would not exceed 1982 model levels.

ATCRBS Effect on DABS

DABS Surveillance Performance of ATCRBS Equipped Aircraft

Near DABS sensor sites, aircraft with ATCRBS transponders will not be served by the DABS mode of DABS, but will be served by the ATCRBS mode of DABS. Therefore, the performance of the ATCRBS mode of DABS is important to ATCRBS equipped aircraft.

During the last half of 1976 and early 1977, Lincoln Laboratory measurements compared the performance of the ATCRBS with the ATCRBS mode of DABS. Measurements were made at Boston, Washington, D.C., Philadelphia, Los Angeles, Salt Lake City, and Las Vegas using a Transportable Measurements Facility (TMF). In each case, simultaneous measurements were made at a nearby operational ATCRBS site. These results are reported in a Lincoln Laboratory report (Wells, 1977). Results of that report from an interference standpoint are summarized and discussed in this subsection.

TABLES 3-11 thru 3-16 summarize the results of important parameters during comparative testing of present ATCRBS and ATCRBS Mode of DABS. TABLE 3-11 is a comparison of Blip/Scan ratio (measured probability of target detection per antenna rotation) for the operational ATCRBS and the ATCRBS mode of DABS at the six sites mentioned previously. The results are presented in two categories:

- "All" Tracks refers to reports from all the qualified tracks including crossing tracks.

- "Crossing" Tracks refers to reports from qualified tracks when they were crossing other tracks (i.e., within 2 nmi in range and 1 beamwidth in azimuth).

TABLE 3-11 shows the ATCRBS mode of DABS to have the better Blip/Scan ratio at each site in both categories.

TABLE 3-12 shows the percent of reports transmitted by the sensor that did not have an altitude update in the scan (antenna rotation). This statistic is referred to as Old Altitude. With the exception of the Las Vegas "All" tracks case, the ATCRBS mode of DABS had the better "Old Altitude" performance at each site in both categories. ATCRBS mode of DABS also had better performance averaged over all sites in both categories.

TABLE 3-13 shows the percent of reports which did not have a code update during the current scan (antenna rotation). This statistic is referred to as Old Code. For each site and for both track categories, the ATCRBS mode of DABS performance was better than the present ATCRBS (i.e., the percent Old Code was smaller).

TABLE 3-14 gives the number of "Two Tracks on One Aircraft" expressed as a fraction of the total numbers of qualified tracks. For the average over all sites the DABS was significantly better at preventing double tracks than the present ATCRBS. For one site, Los Angeles, the present ATCRBS was slightly better than the ATCRBS mode of DABS.

TABLE 3-15 gives the number of times two aircraft are on one track as a fraction of the total number of qualified tracks. For the average over all sites the "Two Aircraft on One Track" performance of the ATCRBS mode of the DABS was significantly better than present ATCRBS. Also, at all six sites the ATCRBS mode of DABS was equal to or better than the present ATCRBS in this category.

TABLE 3-16 compares the azimuth error standard deviation for the present ATCRBS with the ATCRBS mode of DABS. The azimuth error standard deviation was better for the ATCRBS mode of DABS at each site.

TABLE 3-11

MEASURED PROBABILITY OF DETECTION PER ANTENNA ROTATION

	PRESENT ATCRBS ALL	PRESENT ATCRBS CROSSING	ATCRBS MODE OF DABS ALL	ATCRBS MODE OF DABS CROSSING
BOSTON	97.8%	91.5%	98.6%	100. %
WASHINGTON, D.C.	96.0%	92.0%	97.3%	96.4%
PHILADELPHIA	91.9%	78.3%	99.4%	98.6%
LOS ANGELES	91.7%	84.7%	96.7%	94.7%
SALT LAKE CITY	93.0%	75.4%	98.0%	95.0%
LAS VEGAS	94.3%	85.5%	98.5%	95.2%
AVERAGE OVER ALL SITES	94.6%	86.9%	98.0%	96.6%

TABLE 3-12

PERCENT OF REPORTS WITH NO ALTITUDE UPDATE

	PRESENT ATCRBS ALL	PRESENT ATCRBS CROSSING	ATCRBS MODE OF DABS ALL	ATCRBS MODE OF DABS CROSSING
BOSTON	0.6%	4.1%	0.4%	0.0%
WASHINGTON, D.C.	3.0%	9.5%	1.6%	3.0%
PHILADELPHIA	3.8%	6.3%	1.3%	2.4%
LOS ANGELES	4.2%	9.5%	1.4%	3.0%
SALT LAKE CITY	3.3%	12.2%	0.8%	8.8%
LAS VEGAS	1.2%	8.7%	1.6%	4.0%
AVERAGE OVER ALL SITES	2.7%	8.3%	1.4%	3.0%

TABLE 3-13

PERCENT OF REPORTS WITH NO CODE UPDATE

	PRESENT ATCRBS ALL	PRESENT ATCRBS CROSSING	ATCRBS MODE OF DABS ALL	ATCRBS MODE OF DABS CROSSING
BOSTON	0.7%	5.2%	0.1%	0.0%
WASHINGTON, D.C.	1.2%	5.9%	1.1%	4.0%
PHILADELPHIA	2.6%	11.7%	0.4%	2.0%
LOS ANGELES	2.4%	6.8%	0.8%	2.1%
SALT LAKE CITY	1.0%	7.1%	0.8%	7.0%
LAS VEGAS	0.8%	8.2%	0.3%	3.0%
AVERAGE OVER ALL SITES	1.4%	7.4%	0.7%	3.0%

TABLE 3-14

NUMBER OF DOUBLE TRACKS ON A SINGLE AIRCRAFT EXPRESSED AS A FRACTION OF QUALIFIED TRACKS

	PRESENT ATCRBS	ATCRBS MODE OF DABS
BOSTON	0.0816	0.0178
WASHINGTON	0.0446	0.
PHILADELPHIA	0.0690	0.0126
LOS ANGELES	0.0135	0.0141
SALT LAKE CITY	0.0435	0.
LAS VEGAS	0.	0.
AVERAGE OVER ALL SITES	0.0415	0.0051

TABLE 3-15

NUMBER OF TIMES TWO AIRCRAFT ARE ON ONE TRACK EXPRESSED AS A FRACTION OF QUALIFIED TRACKS

	PRESENT ATCRBS	ATCRBS MODE OF DABS
BOSTON	0.	0.
WASHINGTON	0.0191	0.0034
PHILADELPHIA	0.0345	0.0063
LOS ANGELES	0.0811	0.0211
SALT LAKE CITY	0.	0.
LAS VEGAS	0.0313	0.
AVERAGE OVER ALL SITES	0.0280	0.0045

TABLE 3-16

STANDARD DERIVATION OF THE AZIMUTH ERROR IN DEGREES

	PRESENT ATCRBS	ATCRBS MODE OF DABS
BOSTON	0.196	0.036
WASHINGTON	0.148	0.043
PHILADELPHIA	0.191	0.036
LOS ANGELES	0.143	0.059
SALT LAKE CITY	0.236	0.033
LAS VEGAS	0.129	0.036
AVERAGE OVER ALL SITES	0.16	0.04

The TMF data described above (Wells, 1977) is the best available data comparing the present ATCRBS to the ATCRBS mode of DABS in an interference environment. These results show that the ATCRBS mode of DABS performed better in the interference environments of 1976-1977. The only exceptions were for "ALL" tracks altitude update at Las Vegas, and for two tracks on one aircraft at Los Angeles where the present ATCRBS was slightly better than the ATCRBS mode of DABS. However, results are not available for the environments of the future. The ATCRBS mode of DABS sensor uses monopulse and possesses more sophisticated processing capability than the present ATCRBS. This permits only 4 interrogations within a beam dwell as compared with 16 interrogations within a beam dwell for ATCRBS. The question then becomes whether synchronous garble would be much less of a problem in 1995 for the present ATCRBS than the ATCRBS mode of DABS due to a garble condition lasting for only a fraction of a present ATCRBS beam dwell.

Assuming the speed of two aircraft in garbling position to be 533 knots (614 mph), the relative velocity could be 545 meters (1800 feet) per second. The approximate duration of the present ATCRBS beam dwell is .040 seconds therefore, the distance between these aircraft will have increased by 22 meters (72 feet) during the beam dwell time. Even if the sensor and the two aircraft are all in a line, this will imply a shift in the two waveforms of only 144 nanoseconds. Since the width of an ATCRBS pulse is 450 nanoseconds, the garbling condition will typically exist for the entire beam dwell. The present ATCRBS beam dwell and the DABS beam dwell last approximately the same time; therefore, the duration of the garbling condition should be about the same for both.

Therefore, the extra number of interrogations does not appear to be a significant advantage where synchronous garble is concerned.

In summary, comparison testing by Lincoln Laboratory in 1976-1977 indicated that the ATCRBS mode of DABS performed the surveillance function better than the existing ATCRBS. However, it is not known to what extent the data reflects the performance due to multiple overlaps (more than two) that may occur in synchronous garble environments of the future. Since the DABS sensor uses monopulse and more sophisticated processing capability, the DABS sensor in the ATCRBS mode should perform the surveillance function at least as well as the present ATCRBS would in multiple overlap interference environments. It should also be noted that as DABS transponders replace ATCRBS transponders, the synchronous garble situation improves for the ATCRBS mode of DABS.

DABS Surveillance Performance of DABS Equipped Aircraft

DABS Uplink (Delivery) Reliability. A source of data on DABS uplink waveform performance in interference is the link performance experiments performed in 1976 near Brea, CA. TABLE 3-17 is a summary of the Brea tests reproduced from a quarterly report (Lincoln Laboratory, 1977). The 1976 time frame of these tests precludes direct use of the downlink portion of this data since traffic densities of the future are expected to be much greater. However, the ATCRBS interference environment may be somewhat realistic for the uplink for some time into the future since this interference is not directly dependent on traffic density; it is dependent on the number of ATCRBS sensors.

TABLE 3-17

SUMMARY OF LINK PERFORMANCE FOR BREA, CALIFORNIA, DABS/TMF FLIGHT EXPERIMENTS NUMBERED 8053, 8057, 8059, AND 8100 (from Lincoln Lab., 1977)

Experiment	Replies per Interrogation	Correct Decode Given Reply Received	Correct Replies per Interrogation	Error Correction Contribution to Decoding	Correctable Messages not Decoded	Reports per Scan
8053 Circle Flight	0.932	0.996	0.924	0.0030	0.003	0.974
8057 LA to San Diego	0.885	0.991	0.877	0.026	0	0.966
8059 San Diego to LA	0.865	0.982	0.849	0.046	0.002	0.936
8100 Low-Altitude Loop West of Brea	0.850	0.970	0.82	0.06	0.004	0.95
Weighted Average	0.917	0.988	0.881	0.026	0.002	0.96

The Brea, CA experiments were conducted in an environment which consisted of all ATCRBS sensors, the only DABS sensor being the test unit. Nevertheless, the uplink data is still valid for more general sensor environments, since FAA planned substitution of DABS sensors for ATCRBS sensors will reduce the average uplink interference due to surveillance coverage. This reduction is due to the the lower All-Call rate and the use of the mainbeam (in lieu of the sidelobes) to transmit the P2 suppression pulses in the Roll-Call mode. Since the mainbeam has a narrow beamwidth, the average interference will be lower. As can be seen from TABLE 3-17, the average probability of a reply generated by the transponder is 0.917.

<u>DABS Probability of Detection.</u> As is discussed in the section on DABS Uplink (Delivery) reliability, the average probability of a reply (RR) to a DABS interrogation being generated by the DABS transponder was .92 in the Brea tests. This value will be used for this analysis, though it must be noted that the Brea tests involved a transponder built to the old DABS standard. A FAA Technical Center report (Holtz, 1980) gives a value for RR of .92 for ATCRBS targets of opportunity interrogated by a DABS sensor. The tests were performed in the FAA Technical Center area in 1979. DABS sensor bench tests conducted by the FAA Technical Center are also described. Figures 3-16 and 3-17, reproduced from the report, show probability of detection (Pd) as a function of fruit rate for specific values of RR. Note that the set of curves plotted for RR = .93 is close to the value RR = .92 obtained from the Brea data and the FAA Technical Center data. Figure 3-16 indicates that the performance of a DABS sensor detecting a DABS equipped aircraft in heavy DABS fruit is equal to or better than that of the same sensor detecting an ATCRBS equipped aircraft in heavy ATCRBS fruit. Note that the Probability of Detection for conflicting tracks begins to degrade more rapidly at heavy fruit rates for the ATCRBS mode than for the DABS mode. Also note that the degradation in the Probability of Detection in both clear air tracks and conflicting tracks is about an order of magnitude less for the DABS mode than the ATCRBS mode as the RR drops from 0.93 to 0.70.

Figure 3-17 shows results of FAA Technical Center tests to determine if system performance varied as a function of the mixture of target type and fruit rate. The FAA Technical Center concluded that, "The plots indicate that Pd for DABS targets was not significantly affected by the addition of ATCRBS fruit and was independent of the target flight pattern". Although this seems like a reasonable observation, it should be pointed out that criteria for acceptable probability of detection or round trip reliability are not available. It should also be noted that the DABS mode had a better probability of detection of clear air (straight non-conflicting) targets than the ATCRBS mode of DABS in heavy fruit.

<u>Effect of Synchronous Garble on DABS Round Reliability.</u> The DABS baseline test and evaluation report (Holtz, 1980) identifies a major problem encountered in testing of the DABS sensor using the AIRES simulator. Three simulated aircraft in the basic 42 aircraft scenario flew parallel flight routes approximately 40 nmi south of the sensor. These targets were 1.0 nmi apart. When these targets were DABS aircraft and first appeared in the scenario, the All-Call replies were not decoded by the DABS sensor because the replies overlapped and garbled each other. During some runs the garbling continued

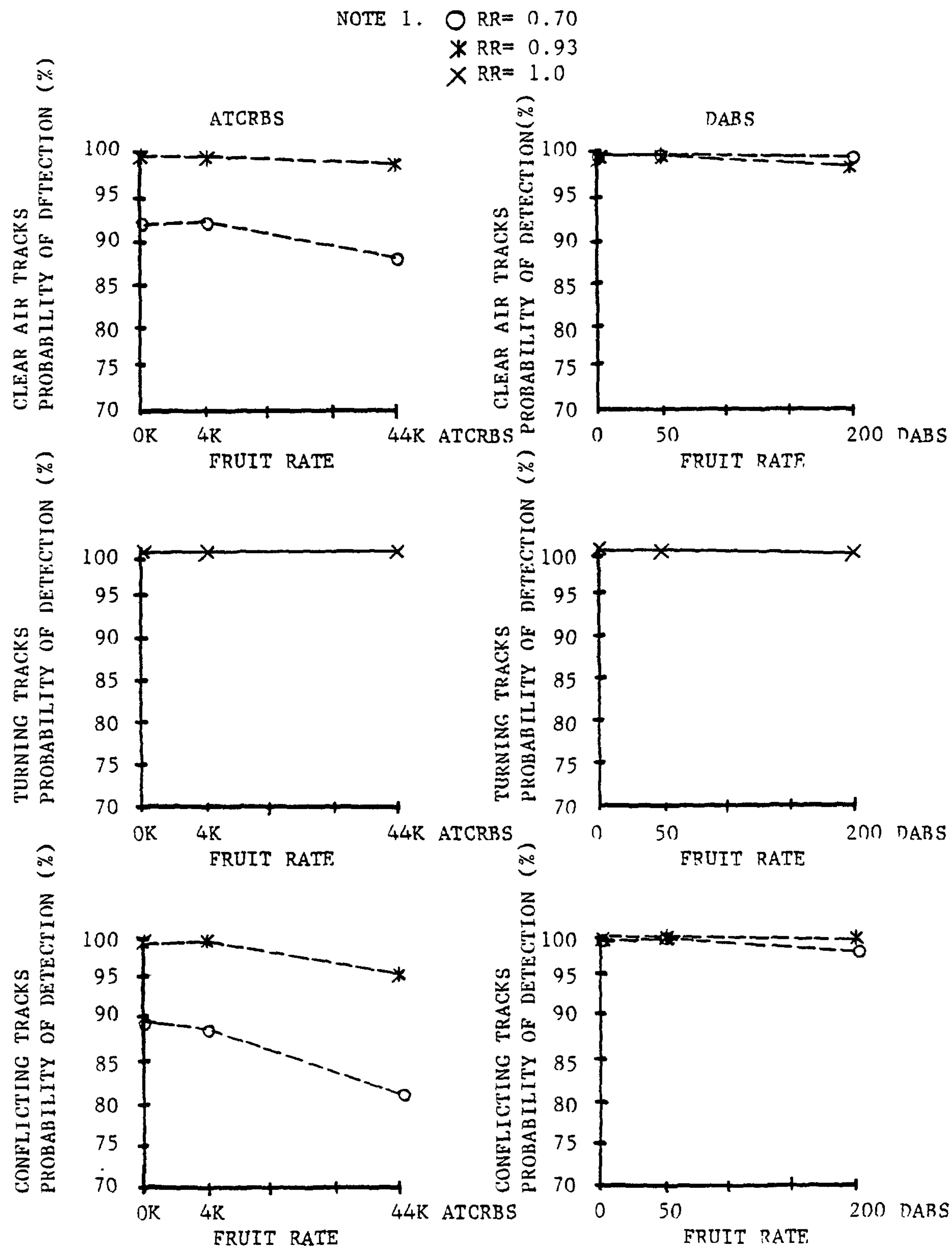


Figure 3-16. Probability of Detection (from Holtz, 1980)

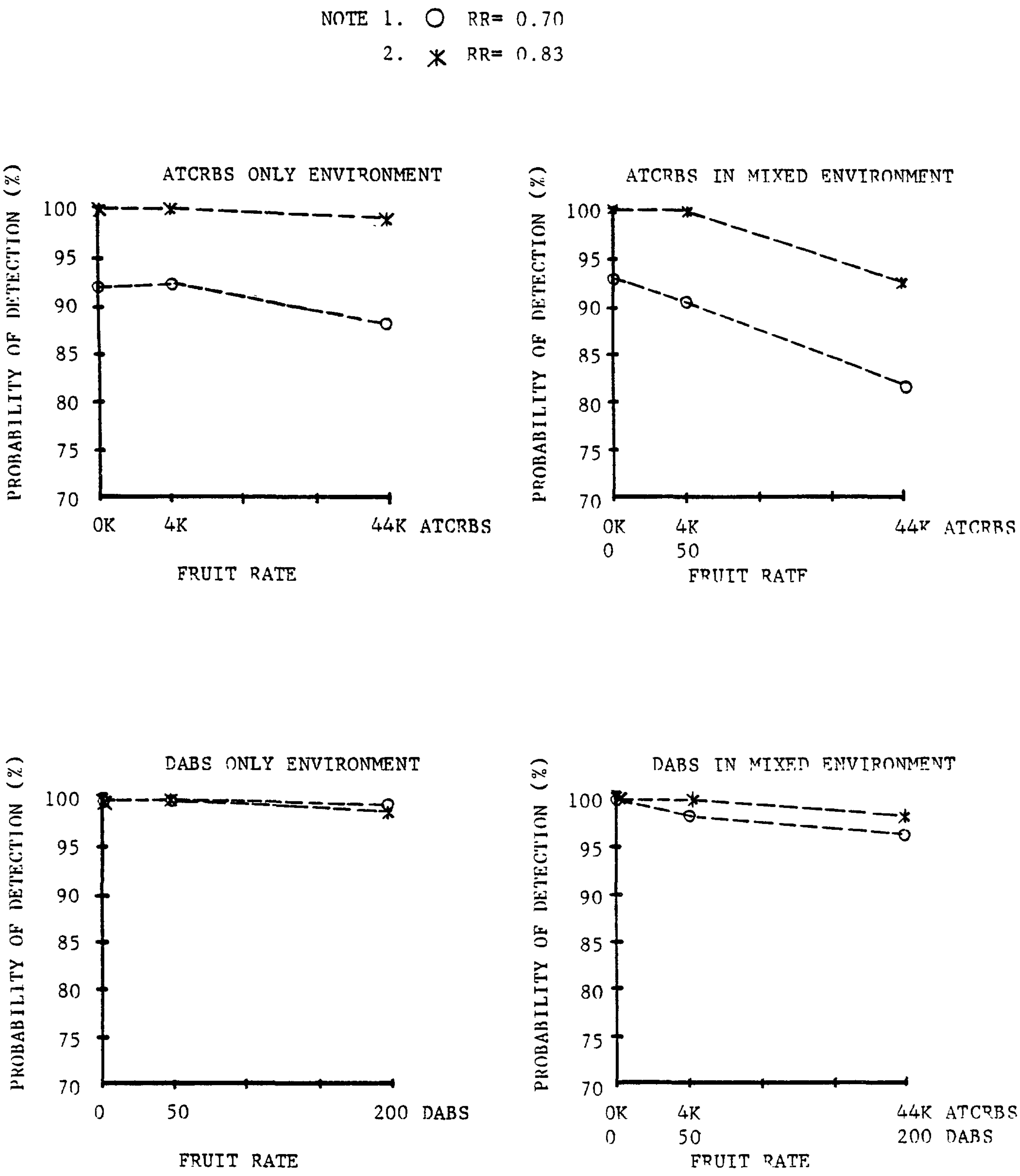


Figure 3-17. Probability of Detection of Clear Air Targets for ATCRBS/DABS Targets in ATCRBS only and ATCRBS and DABS Mixed Fruit Environments (from Holtz, 1980)

during the entire 100 scans and the probability of detection for these targets was significantly below the expected value. However, it should be noted that the aircraft maintained a constant relative position to each other for the entire 100 scans and that this is not a typical operational scenario. A possible solution to this problem has been incorporated into the new March 6, 1980 version of the DABS standard. This solution consists of having the sensor assign a specific reply probability to the DABS transponders. This method is known as stochastic acquisition.

Stochastic acquisition should help in the case of synchronous garbling of a DABS transponder by either DABS or ATCRBS transponders. The following is a brief functional description of stochastic acquisition as applied to a typical surveillance situation. If the DABS reply processor senses that a DABS All-Call (PPM) reply is in a garble situation, then it will establish what is known as a "trial track". Although the identity of this DABS aircraft will not be known, the range and approximate azimuth will be determined from the time at which the garbled signal was received. On the next scan (antenna rotation), this unknown aircraft will be interrogated during the normal Roll-Call schedule, since the range is known. The format to be used in the interrogation is the DABS-only All-Call. Since the DABS-only All-Call does not elicit a response from an ATCRBS transponder, ATCRBS replies will be eliminated as a source of synchronous garbling of the DABS transponder reply. Meanwhile the DABS-only All-Call will cause the DABS transponders to reply with a probability of 1/2, thus reducing the amount of garbling of DABS transponder replies by other DABS transponder replies. As the mutually garbling DABS transponders are identified, they will be placed in the surveillance file and locked out to DABS-only All-Calls (as well as DABS/ATCRBS All-Calls). This will further reduce the severity of the mutual garbling. Within a few scans the last of the previously garbled DABS aircraft will be placed in the surveillance file. Note also that the ATCRBS replies will be relieved of synchronous garbling by DABS replies. This is a benefit of the DABS/ATCRBS All-Call Lockout.

Garbling of a DABS transponder reply by a single strong ATCRBS reply, which can result in bit decision errors spanning no more than 24 bits, should result in a correctable error pattern, since this is a design feature of the DABS.

In summary, the DABS mode of DABS surveillance performance in interference was addressed in flight data taken near Brea, CA, (Lincoln Laboratory, 1977). This provides uplink data in the DABS mode, and a key parameter needed to interpret recent FAA Technical Center bench tests. The FAA Technical Center tests (Holtz, 1980) show the relative performance of the ATCRBS mode of DABS and DABS mode of DABS in simulated environments. The data indicates the DABS mode performed detection of aircraft equal to or better than the ATCRBS mode of DABS in heavy fruit. Moreover, the DABS mode is less susceptible to synchronous garble than either the ATCRBS mode of DABS or the present ATCRBS system. Therefore, the DABS mode design should perform surveillance better in interference environments of the future than the present ATCRBS.

<u>DABS Data Link Performance in Interference</u>

<u>DABS Uplink Undetected Error Probability.</u> A responsibility of DABS will be the delivery of collision avoidance and other traffic control commands to

aircraft. DABS uses an error detecting coding scheme to transmit and validate the command in a single uplink transmission. The probability of an undetected message error, P(UDME), is therefore an important measure of DABS performance, and it was necessary to determine the effect of interference on P(UDME). A design goal was to allow a probability of undetected message error of no more than ten to the minus seven (Barrows, 1975). Undetected errors fall into two categories:

- acceptance of erroneous messages
- acceptance of misdirected messages

"Technical" acknowledgement of the correct receipt of an uplink message is achieved by the receipt of the correct reply at the correct time by the ground sensor. This is necessary so that the sensor can retransmit the message if necessary. However, the aircraft may still have received the correct message even without receipt of the acknowledgement by the ground sensor, hence, the term technical acknowledgement.

The DABS Functional Description (Orlando and Drouilhet, 1980) gives an Undetected Error Rate of less than ten to the minus seven for the data link (uplink), which is consistent with the system design goal. The question of the undetected error rate has been investigated extensively by Lincoln Laboratory and the results published in a report entitled DABS Uplink Coding (Barrows, 1975).

TABLE 3-18 is excerpted from that report. It gives the results of a simulation. The report points out that all but two entries in the table are less than ten to the minus six. But, the report goes on to point out that the A Posteriori (conditional) probabilities are to be multiplied by the A Priori probabilities, which reduces each result by at least two orders of magnitude. Thus, in all cases the probability of undetected message error, due to ATCRBS interference, is less than ten to the minus seven.

The simulation mentioned in the preceding paragraph does not include the case of Acceptance of Misdirected Messages. But as the author points out, because of the two to the twenty-four possible number of addresses, this A Posteriori event will occur approximately one time in two to the twenty-four. So the probability of Acceptance of Misdirected Messages also is expected to meet the design goal of ten to the minus seven.

<u>DABS Data Link Delivery Reliability.</u> The performance of the communications (data) link is addressed in a FAA Technical Center Report (Holtz, 1980). Testing consisted of communication between the Comm-A/B driver (executing in a spare DABS computer) and an aircraft reply and interference environmental simulator (ARIES). The uplink message format was Comm-A (112 bits long) and the downlink message format was Comm-B (112 bits long). Extended length message (ELM) testing was not conducted since the ARIES simulator does not have ELM capability and ELM equipped transponders were not available (it is understood that the most important data link functions are not dependent on ELM capability.) All tests were run with a 0.95 "beacon R/R" (transponder reply reliability). The basic results stated by the FAA Technical Center were as follows:

TABLE 3-18

A POSTERIORI PROBABILITY OF UNDETECTED MESSAGE ERROR
(from Barrows, 1975)

Mode Pairs M, M		Pr(UDME | M, M') 5-bit burst	Pr(UDME | M, M') 4-bit burst
P_2	P_2	0	0
	P_1P_2	1.17×10^{-6}	0
	P_1P_3 Mode 2	0	0
	P_1P_3 Mode 3/A	0	0
	P_1P_3 Mode C	0	0
	$P_1P_2P_3$ Mode 2	1.85×10^{-7}	0
	$P_1P_2P_3$ Mode 3/A	4.49×10^{-7}	0
	$P_1P_2P_3$ Mode C	6.78×10^{-7}	0
P_1P_2	P_1P_2	5.91×10^{-7}	0
	P_1P_3 Mode 2	5.48×10^{-7}	0
	P_1P_3 Mode 3/A	5.74×10^{-7}	0
	P_1P_3 Mode C	1.06×10^{-6}	0
	$P_1P_2P_3$ Mode 2	3.08×10^{-7}	3.65×10^{-9}
	$P_1P_2P_3$ Mode 3/A	6.49×10^{-7}	4.25×10^{-7}
	$P_1P_2P_3$ Mode C	8.11×10^{-7}	4.72×10^{-10}
P_1P_3 Mode 2	P_1P_3 Mode 2	5.34×10^{-8}	0
	P_1P_3 Mode 3/A	1.67×10^{-8}	0
	P_1P_3 Mode C	2.33×10^{-9}	0
	$P_1P_2P_3$ Mode 2	8.53×10^{-8}	1.59×10^{-8}
	$P_1P_2P_3$ Mode 3/A	1.82×10^{-7}	8.81×10^{-9}
	$P_1P_2P_3$ Mode C	3.27×10^{-7}	0
P_1P_3 Mode 3/A	P_1P_3 Mode 3/A	1.57×10^{-8}	0
	P_1P_3 Mode C	8.56×10^{-9}	1.4×10^{-8}
	$P_1P_2P_3$ Mode 2	1.19×10^{-7}	1.96×10^{-9}
	$P_1P_2P_3$ Mode 3/A	2.08×10^{-7}	2.32×10^{-9}
	$P_1P_2P_3$ Mode C	3.21×10^{-7}	1.06×10^{-8}
P_1P_3 Mode C	P_1P_3 Mode C	3.78×10^{-9}	0
	$P_1P_2P_3$ Mode 2	1.98×10^{-7}	7.89×10^{-10}
	$P_1P_2P_3$ Mode 3/A	4.36×10^{-7}	2.11×10^{-9}
	$P_1P_2P_3$ Mode C	6.51×10^{-7}	1.03×10^{-8}
$P_1P_2P_3$ Mode 2	$P_1P_2P_3$ Mode 2	6.08×10^{-8}	2.0×10^{-8}
	$P_1P_2P_3$ Mode 3/A	7.64×10^{-8}	5.79×10^{-8}
	$P_1P_2P_3$ Mode C	2.80×10^{-7}	6.06×10^{-9}
$P_1P_2P_3$ Mode 3/A	$P_1P_2P_3$ Mode 3/A	3.0×10^{-7}	1.20×10^{-7}
	$P_1P_2P_3$ Mode C	5.64×10^{-7}	2.34×10^{-7}
$P_1P_2P_3$ Mode C	$P_1P_2P_3$ Mode C	7.22×10^{-7}	3.87×10^{-9}

All Comm-A and Comm-B messages were delivered during the basic 42 aircraft scenario testing. In 10 percent of the cases for which three transactions per aircraft were attempted in a single scan, a second scan was required to complete the transaction. The basic conclusion stated that the DABS system test and evaluation showed a highly reliable air-ground communications link.

Based on the baseline tests conducted at FAA Technical Center, it appears that the basic ATARS advisory and command rates assumed by FAA (Welch, 1978) for the 1982 Los Angeles scenario will not significantly affect DABS mode of DABS surveillance in ATCRBS/DABS interference. Although unmanageable interference problems to DABS due to data link are not anticipated, further testing is desired for the following reasons. The FAA Technical Center baseline testing was not conducted with the primary objective of determining the effect of interference to DABS. DABS uplink reliability was included as a parameter in the FAA Technical Center baseline testing, but was not actually included in the testing. The effect of using full data capacity on DABS mode surveillance with the longer Comm-A and Comm-B messages was not measured.

AIMS/DABS EMC

The military ATCRBS IFF MARK XII SYSTEM (AIMS) is a secure identification system which consists of a surveillance capability (known as Mark X) similar to the civil ATCRBS and a secure mode of operation (known as Mode 4). The system interrogates on 1030 MHz and replies on 1090 MHz.

DABS Effect on AIMS

The effect of DABS on AIMS performance is being investigated in a joint FAA/DoD study at the Bendix Corporation, Naval Research Laboratory (NRL), and FAA Technical Center. The results of the study at the Bendix Corporation and FAA Technical Center indicated that DABS will not significantly reduce the performance of the AIMS equipment nomenclatures tested. NRL has identified potential interference interactions between DABS and some of the AIMS equipment nomenclatures they tested. Technical and operational solutions to these potential interactions are being investigated by the joint study group.

AIMS Effect on DABS

The military services employ AIMS interrogators for Identification Friend or Foe (IFF) at defense ground sites, on aircraft, and onboard ships. However, the number of IFF interrogations and replies relative to ATCRBS is extremely low. This is due to the fact that there are fewer IFF equipments than ATCRBS in the U.S. environment and the fact that IFF interrogations for each equipment occur less frequently than that for ATCRBS. Since this study has indicated that DABS can operate effectively in high ATCRBS interference environments, IFF operations should not degrade DABS performance.

BCAS/DABS EMC

The Active-BCAS is an airborne system that will provide collision avoidance service against any other aircraft equipped with an ATCRBS transponder (containing an altitude encoder) or a future DABS transponder. Active-BCAS will provide this service in airspace outside the Air Traffic Control (ATC) radar surveillance coverage as well as some portions of en route and terminal airspace. Active-BCAS is not intended to operate in high density airspace and will be either turned-off or interrogation rate limited in these areas. Active-BCAS is an initial element of a full capability BCAS being developed by FAA. The full capability BCAS will be designed to operate in all airspace. FAA is primarily developing BCAS for civil aviation; however, it may also be deployed on military aircraft. BCAS operates on the 1030 and 1090 MHz frequencies.

DABS Effect on BCAS

DABS can potentially affect BCAS performance in two ways. First, DABS 1030 MHz interrogations can reduce the probability of ATCRBS and DABS transponders replying to Active-BCAS interrogations and second, transponder replies to DABS interrogation (fruit) can garble desired BCAS replies. FAA studies performed by Lincoln Laboratory (Harman, 1979) have indicated that Active-BCAS will have to be shut-off due to its own self-induced synchronous garble interference before ATCRBS interference has an impact on its performance. Since FAA simulations performed by ECAC (Keech, 1979) indicate that replacement of ATCRBS sensors with DABS sensors will result in less overall interference levels, BCAS performance should not be degraded by DABS.

BCAS Effect on DABS

The effects of Active-BCAS on DABS performance in the Los Angeles 1982 environment was analyzed by ECAC (Theberge, 1978). The effect of BCAS on a hypothetical DABS ground beacon located at the Los Angeles Airport was predicted with all 29 Federal Aviation Administration (FAA) sites in the area operating as DABS ground sensors. The analysis indicated that deploying Active-BCAS would not significantly reduce DABS performance. In addition, an interrogation limiting function is being included in the Active-BCAS design to insure that the total Active-BCAS avionics environment does not reduce transponder reply probability by more than 2 percent.

The probability of the DABS sensor incorrectly interpreting BCAS elicited DABS transponder replies as valid replies to its own interrogations was not addressed in the ECAC study. However, this interference effect should be insignificant for the following reason. The DABS ground beacon schedules a "listening" period to receive a reply to its discrete interrogations. Replies with incorrect addresses or replies outside the "listening" period are rejected. In addition, DABS transponder replies to BCAS interrogations use different formats than replies to DABS ground beacon interrogations. Using this knowledge, DABS ground beacons should be able to discriminate against BCAS elicited replies.

The Active-BCAS design includes a 1030 MHz data link (using a DABS Comm-A signal format) between the BCAS aircraft and the Radar Beacon Transponder (RBX) installed at ATCRBS ground beacon sites. When the ground beacon is a DABS, the data link will be provided by the DABS Comm-A (1030 MHz) interrogation and Comm-B (1090 MHz) reply data link. Therefore, the BCAS air-to-ground data link should be compatible with the DABS ground sensors by design.

(TACAN/DME)/DABS EMC

There are 126 channels available for TACAN/DME Mode X and Y operations in the 962-1215 MHz frequency band. The TACAN only channels (used by the military) include assignments on the DABS 1030 MHz and 1090 MHz operational frequencies. The TACAN consists of an airborne interrogator and ground transponder which provides an aircraft pilot with slant range and bearing to selected ground beacons.

DABS Effect on TACAN/DME

A detailed analysis of the possible effects of the then proposed downlink transmission on TACAN was performed (Harman, 1979). The report concluded that TACAN X-Mode performance, with 5 percent of the TACAN aircraft in search mode and 95 percent in track mode, is unaffected by DABS on all channels except 64X through 68X where there was a reduction in beacon reply efficiency. Channels 64X through 68X are used exclusively by the military and are allocated on a secondary basis and therefore must accept the predicted interference. Results for Y-Mode operation will be similar.

Interference to the TACAN/DME uplink will now be addressed. A potential mode of interference to the TACAN interrogator receiver would be the 4 Mbits/s Differential Phase Shift Keying (DPSK) data blocks at 1030 MHz and the 1 M bits/s Pulse Position Modulation (PPM) data blocks at 1090 MHz which are part of the DABS mode interrogations and replies respectively. There is a possibility that a DPSK or PPM signal at these data rates could cause false decodes and possibly false acquisition of range lock. An ECAC report (Wingard, 1975) analyzes test data dealing with the effect of provisional DABS formats on TACAN/DME performance. Data and results in the report are extrapolated from tests using a DABS signal simulator and representative TACAN/DME equipments. The report concludes that the ability of the TACAN interrogator to acquire azimuth lock is unaffected by DABS signals. Based on previous tests and analysis, acquisition of azimuth lock was assumed to be the most susceptible interrogator function.

The ECAC studies cited indicate that DABS interference to TACAN/DME is manageable. The existing guardbands to protect TACAN/DME from ATCRBS interference may not be adequate for DABS, because DABS has a wider emission spectrum, more complex signal modulation, and different channel occupancy characteristics than ATCRBS. FAA is conducting an investigation to determine the necessary guardbands in light of current knowledge of DABS characteristics and operations.

TACAN/DME Effect on DABS

In practice, new TACAN/DME assignments are not made within 3 MHz of either 1030 or 1090 MHz within the CONUS. Apparently, this is adequate to prevent significant interference from TACAN/DME to ATCRBS. However, the DABS transponder receivers have a wider selectivity than present ATCRBS ground sensor and transponder receivers. For example, a comparison of ICAO Aeronautical Telecommunications Annex 10 with the engineering requirements for the DABS reply processor indicates that the TACAN X-Mode downlink channel at 1094 MHz is allocated on a primary basis and will fall within the 8 MHz, 3 dB bandwidth of the DABS reply processor. The probability of the longer DABS interrogation or replies being overlapped by a TACAN/DME pulse is greater than for ATCRBS.

The above factors demonstrate the need to perform a study to determine the required guardbands to protect DABS from TACAN/DME interference. FAA is conducting such investigations.

(MLS/DME)/DABS EMC

The Microwave Landing System (MLS/DME) is intended to replace the existing instrument landing system (ILS) and to serve as the primary domestic and foreign landing guidance system. The MLS/DME consists of a scanning-azimuth and elevation antenna beam in the band 5030-5090 MHz and precision distance-measuring equipment operating in the 960-1215 MHz band. The precision DME range will be used out to approximately 9 km (5 nmi) with the scanning-beam elevation information to compute height above the runway. In addition, the MLS/DME system will provide slant range to touchdown and range-rate information out to approximately 37 km (20 nmi).

(MLS/DME)/DABS Interactions

The MLS/DME program has not matured to the point where a specific design has been selected. FAA is currently considering various channeling schemes to provide the required 200 precision DME channels. It is likely that the channels will be provided through assignment or sharing of existing TACAN/DME X-Mode channels, and multiplexing between the Y and Z channels.

FAA is currently investigating the guardband frequencies required to preclude interference between the MLS/DME and other systems, including DABS, operating on 1030 MHz and 1090 MHz.

JTIDS/DABS EMC

The JTIDS is an advanced information distribution system that provides communication, navigation and identification (CNI) capabilities in an integrated form for application to military tactical and air defense operations. Additionally, the system will be capable of accomplishing relative Aeronautical Radionavigation, location, and identification. The TACAN and IFF functions may also be included as an integral capability within the JTIDS terminals. JTIDS design objectives have been to develop a system that can operate compatibly with the operational and firmly planned ATC systems. The wideband mode of the JTIDS operates with spread-spectrum modulation in the 960-1215 MHz band, except in the region of 1030 MHz and 1090 MHz. The system can also operate in a narrowband frequency mode with a 3.5 MHz bandwidth centered at a carrier frequency of 969 MHz. The JTIDS provides the DoD with an integrated communication, navigation, and identification function.

DABS Effect on JTIDS

The JTIDS EMC study (Mayher, 1978) included an analysis of JTIDS susceptibility to ATCRBS interference. The analysis considered worst-case interference levels from ATCRBS transponders and ground interrogators, and concluded that JTIDS is not susceptible to ATCRBS interference. Simulations (Keech, 1979) indicate that average transponder suppression and fruit rates do not increase due to DABS deployment. Therefore, even though JTIDS is permitted on a non-interference basis, performance should not be degraded by average DABS interference levels.

JTIDS Effect on DABS

An interagency EMC analysis of JTIDS in the 960-1215 MHz band (Mayher, 1978) included a study of JTIDS interference effects on DABS equipment. The pertinent conclusions from the report are given below.

The following conclusions are based on flight-test measurements on prototype DABS equipment in the presence of JTIDS equipment supplemented by theoretical analysis and ATCRBS bench-test measurements. These findings apply to DABS equipment with specifications similar to the units tested.

1. The DABS flight-test measurements and analysis indicate that a JTIDS aircraft at minimum ATC operational altitude separation from a DABS aircraft, or near a DABS interrogator, would not affect DABS performance.

2. The above conclusion also applies to an environment containing multiple DABS transponders, DABS interrogators, and JTIDS terminals. Increases in the number of DABS equipments would not make the DABS more susceptible to JTIDS signals.

Since the measurements and analysis were performed on prototype equipment, NTIA has required further evaluation and analysis, including additional testing when operational DABS equipment is available.

ADDITIONAL EMC ISSUES

A letter was received on August 7, 1979, from the Honorable Thomas R. Harkin (Chairman of the U.S. House Subcommittee on Transportation, Aviation, and Communications) requesting that the technical ATCRBS/DABS EMC issues raised by Mr. Litchford be assessed and evaluated. The evaluation indicated a number of reasons why Mr. Litchford arrived at different conclusions from FAA regarding ATCRBS/DABS EMC.

The main reason that Mr. Litchford formed a different conclusion from FAA regarding ATCRBS and DABS EMC is the assumptions used in his calculations. These assumptions are not consistent with DABS technical characteristics and FAA specified deployment scenarios (Welch, 1978). ATCRBS/DABS compatibility is dependent upon the air traffic scenarios, DABS technical characteristics, and DABS planned deployment scenarios. These factors greatly affect the amount of DABS data link loading and, consequently, the level of ATCRBS transponder suppressions and downlink fruit caused by DABS. The FAA calculations are presented in the ATCRBS/DABS EMC analysis report (Welch, 1978) and those of Mr. Litchford in his May 23, 1978 letter response to FAA's proposed U.S. National Aviation Standard for the Discrete Address Beacon System.

The differences between the assumptions used in Mr. Litchford's and FAA's calculations are discussed below:

1. Mr. Litchford assumed that 50 percent of the aircraft in the 1995 Los Angeles environment will require high-option CDTI service, while FAA calculations indicate that the maximum number of aircraft requiring CDTI will not exceed 22 percent.

2. Mr. Litchford assumed that a maximum of 20 aircraft positions will be displayed for CDTI, while FAA assumes that an average of 12 targets will be displayed for high option CDTI.

3. Mr. Litchford's peak interference calculations considered 20 aircraft in the DABS antenna mainbeam while FAA's average calculations effectively considered an average of 7 aircraft in the antenna beam over each antenna rotation.

4. Mr. Litchford assumed that aircraft will receive Roll-Call interrogations from the DABS antenna sidelobes out to 20 nmi; however, FAA calculations and measurements indicate they will not be received beyond 5 nmi.

5. Mr. Litchford assumed that a DABS transponder replies to every DABS interrogation, while FAA calculations indicate that on the average only 2.5 replies are associated with a burst of ELM uplink messages for high option CDTI service.

6. Mr. Litchford assumed that one uplink message is required for each target displayed on the CDTI while FAA calculations indicated that two targets can be handled by one message.

The density of aircraft in the antenna mainbeam (item 3 above) was greater than FAA's calculation because it was assumed that the whole Los Angeles area traffic load would be handled by one DABS ground sensor. However, FAA plans to distribute the load among at least four DABS sensors. In addition, the data link capacity limitations of a single DABS sensor was not accounted for in Mr. Litchford's calculation. The DABS technical characteristics, including data link capacity, are listed in the March 6, 1980 DABS National Standard. The specific DABS deployment scenarios for Los Angeles do not appear in the Standard, but they seem to be realistic.

There is also disagreement because of the type calculations used to analyze ATCRBS/DABS EMC. Mr. Litchford relied mostly on worst-case peak ATCRBS transponder suppression and downlink fruit rate calculations while FAA considered both peak and average calculations. Peak DABS interference effects are an important factor to consider in the EMC analysis, but one has to ask what the impact of these peak rates are on ATCRBS ground sensor performance. The ATCRBS/DABS EMC analysis has indicated that deployment of DABS will result in greater uplink suppression peaks in some regions of the sensor coverage area. However, these interference peaks have a negligible over all interference effect on ATCRBS performance.

Mr. Litchford also expressed concern about the DABS transponder being locked-out to ATCRBS ground sensor interrogations. Mr. Litchford stated that this function would deny vital air traffic information to ATCRBS ground sensors. This is no longer an EMC issue because FAA has eliminated this feature of DABS. Originally, FAA considered locking-out DABS transponders to ATCRBS ground sensor interrogations if the DABS aircraft was in airspace that the ATCRBS ground interrogator had no interest. However, the use of airborne interrogators by the military has prevented the practical implementation of this technique.

In summary, a worst-case peak interference effect on ATCRBS was computed which is more severe than that indicated by FAA specified DABS technical characteristics and operational deployment scenarios. The analysis has indicated that DABS interference peaks will exceed that for an ATCRBS-only environment, but the peaks will not noticeably degrade ATCRBS performance. Mr. Litchford's concern about the DABS transponder lock-out to ATCRBS interrogations is no longer relevant because FAA has decided not to employ this technique.

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APPENDIX A

NTIA COMPUTER ANALYSIS PROGRAMS

INTRODUCTION

This Appendix describes four computer programs that were written by NTIA to assess FAA EMC measurement and simulation results, and independently evaluate DABS interference effects on ATCRBS. Two of the programs simulate 1030 MHz uplink DABS interference effects on ATCRBS and a third program, DABS 1090 MHz downlink DABS interfence effects. A fourth program was used to extract data from the 1982 Los Angeles Basin Standard Traffic Model and create an input data file for Uplink Program B and the Downlink Program. All four computer programs were written in Fortran IV.

The programs account for the most basic operational characteristics of the systems involved and were designed to provide raw data for further analysis. For example, the DABS Roll-Call scheduling associated with Uplink Program A does not take into account processing overhead limitations. In addition, Uplink Program B and the Downlink Program do not account for reply rate limiting in the ATCRBS transponder or sensitivity time control characteristics of ATCRBS ground beacon receivers. However, the simplifications used in the programs either results in more pessimistic interference prediction or provides the data necessary to evaluate the second order interference effect not considered by the programs.

UPLINK PROGRAM A

General Description

Uplink Program A was written to determine if the product of the average DABS interrogation rate and ATCRBS transponder suppression time (see Equation C-11) does in fact give the percent ATCRBS transponder suppression, as proposed by FAA, for DABS All-Call and Roll-Call scheduled interrogations. The program was also written to determine if DABS Roll-Call scheduled interrogations would result in a different number of consecutive ATCRBS transponder losses than periodic interrogations.

The program computes ATCRBS transponder suppression rates that occur due to simultaneous antenna beam illumination by multiple ground sensors. The program is a discrete event orientated simulation. The program assumes that aircraft are continuously within the antenna sidelobe range of up to three ATCRBS sensors and in the mainbeam of a combination of ATCRBS and DABS sensors. One of the ATCRBS sensors is considered the victim. During each interrogation and reply period of the victim, an All-Call followed by an ELM burst followed by a Roll-Call schedule occurs. The program does not permit reinterrogation. Each interrogation is for a new aircraft whose distance is randomly generated. This distance is generated in a manner which implies aircraft are uniformly distributed in area. Statistics are collected on an antenna beam dwell basis for both total and consecutive transponder suppressions. The program output consists of a table which gives the number of ATCRBS antenna beam dwells in which a specific number of reply losses and consecutive reply losses of the ATCRBS transponder occurred. A simplified flow diagram of the program is given in Figure A-1.

The derivation of the equation used by the program to generate random ranges of aircraft is given below. The dummy and the simulated variable are related by

$$p_x(x)\ dx = p_r(r)\ dr \tag{A-1}$$

where $p_x(x)$ is the density of a uniformly distributed dummy variable x, and r is the distance from the center of the circle to an aircraft of uniform spatial distribution within the circle of radius R_{max}.

$$p_r(r) = [p_x(x)] \left|\frac{dx}{dr}\right| \tag{A-2}$$

Substituting for the density and derivative and integrating, get

$$P_R(R) = \int_o^R \left(\frac{1}{x_{max}}\right)(Kr) \tag{A-3}$$

where

$$P_R(R) \triangleq \int_o^R p_r(r)\ dr \tag{A-4}$$

The result of integrating (A-4) is

$$P_R(R) = \frac{KR^2}{2x_{max}} \tag{A-5}$$

By definition

$$P_R(R_{max}) \triangleq 1 \tag{A-6}$$

From (A-5) and (A-6)

$$1 = \frac{K\ R^2_{max}}{2\ x_{max}} \tag{A-7}$$

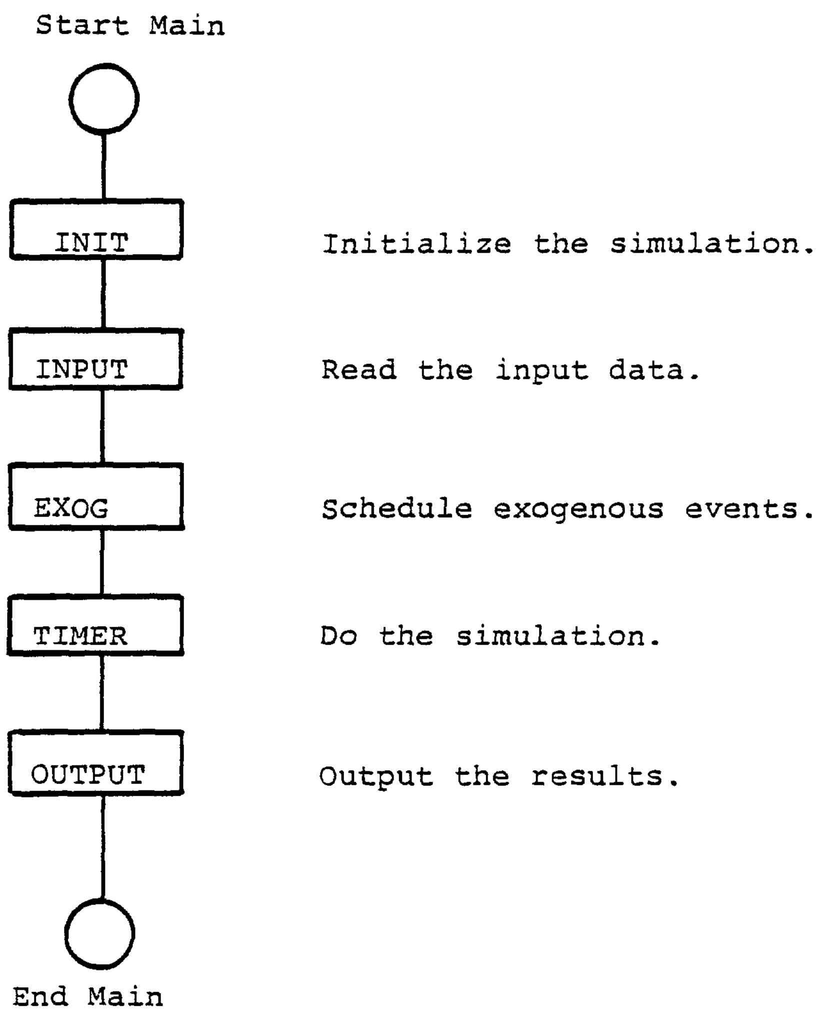

Figure A-1a. Simplified Flow Diagram of Uplink Model A

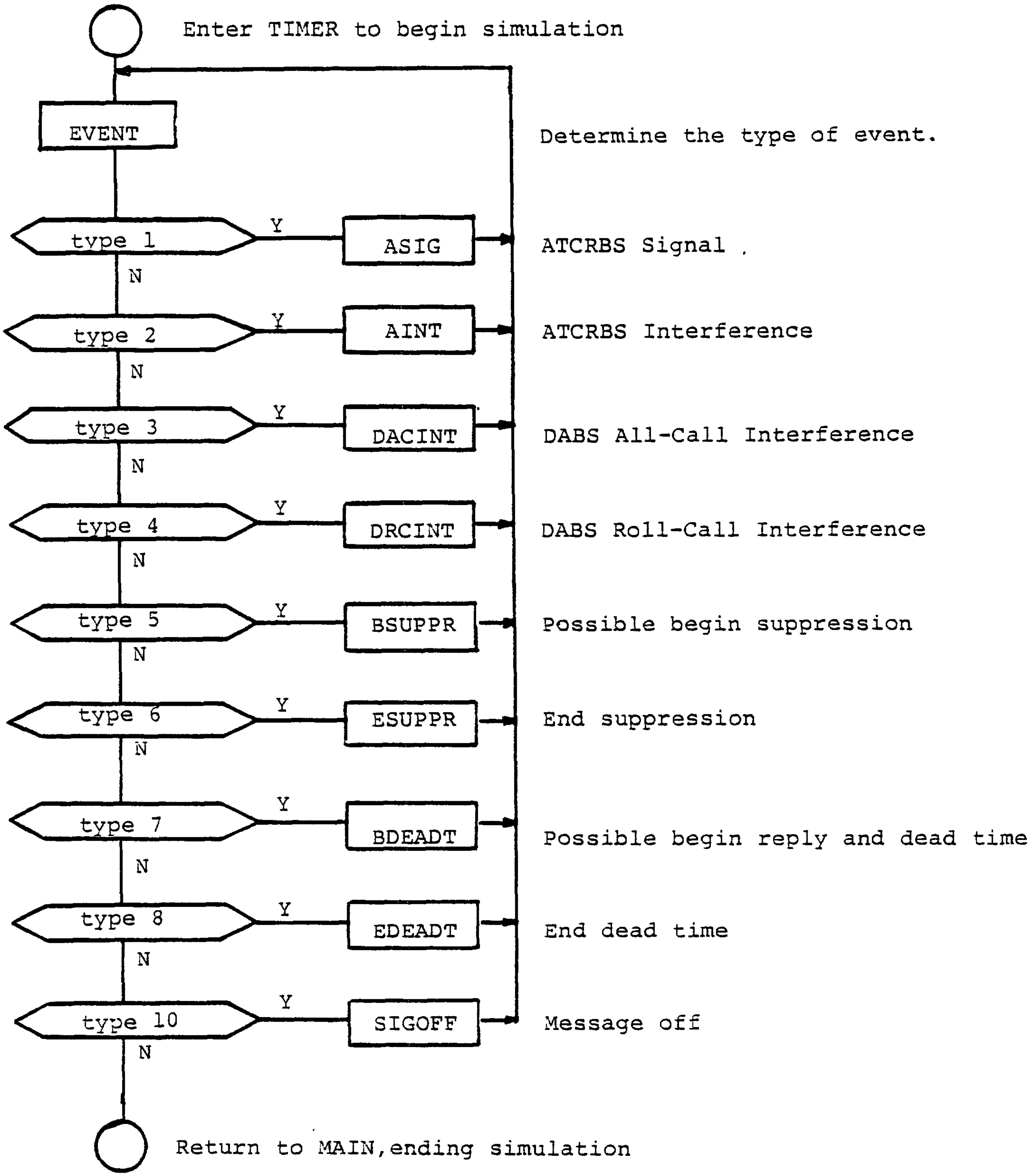

Figure A-1b. Simplified Flow Diagram of Uplink Model A

Rearranging (A-7) get

$$\frac{K}{2\ x_{max}} = \frac{1}{R^2_{max}} \qquad \text{(A-8)}$$

Substituting (A-8) into (A-5), obtains

$$P_R(R) = \frac{R^2}{R^2_{max}} \qquad \text{(A-9)}$$

But,

$$P_x(X) = P_R(R) \qquad \text{(A-10)}$$

So, substituting (A-9) into (A-10) obtains

$$P_X(X) = \frac{R^2}{R^2_{max}} \qquad \text{(A-11)}$$

Rearranging (A-11)

$$R^2 = R^2_{max}\ P_X(X) \qquad \text{(A-12)}$$

Taking the square root of both sides of (A-12)

$$R = R_{max}\ [P_X(X)]^{\frac{1}{2}} \qquad \text{(A-13)}$$

where R_{max} = 60 nmi and P_X is generated randomly between 0,1.

UPLINK PROGRAM B

General Description

The second uplink program simulates and counts the number of DABS Roll-Call suppressions and All-Call interrogations that an ATCRBS transponder would receive, at a specified location in a future Los Angeles environment, during ATCRBS antenna beam dwell periods. The program employs the 1982 Los Angeles Basin Standard Traffic Model (Cohen, 1973) data and FAA specified DABS ground sensor deployment scenarios (Welch, 1978). The FAA specified DABS ground sensor deployment scenario taken into account includes:

1. The distribution of aircraft population that receive various options of DABS data-link service.

2. The number of DABS uplink transmissions required to provide a given level of data-link service.

3. The distribution of traffic load (primary and secondary areas of responsibility) amoung the four DABS ground sensors in the Los Angeles area, as shown in Figure A-2 and TABLE A-1.

4. The specific location of the four DABS ground sensors in the Los Angeles basin, as shown in Figure A-2.

The four DABS ground sensor locations include the Long Beach, Los Angeles, Burbank, and Ontario airports.

The program employs Monte Carlo sampling techniques to randomly select DABS ground sensor antenna beam orientations. Each data sample is generated by randomly selecting the antenna beam pointing directions of the four DABS ground sensors and counting the number of DABS transmissions that an ATCRBS aircraft would receive over an ATCRBS antenna beam dwell period. The transmissions from a given DABS ground sensor are included in the count only if the aircraft is located in its antenna beam or within its antenna sidelobe range. The number of transmissions that an ATCRBS transponder receives from a DABS sensor, which satisfies one of the above two conditions, is determined by the number of aircraft in its antenna beam and the level of data link that each aircraft requires.

Data input and parameter selection options for the program includes:

1. Selection of data from one of four snapshots of the 1982 Los Angeles Basin Standard Traffic Model.

2. Selection of the ATCRBS transponder location in the Los Angeles basin.

3. Specification of the DABS antenna sidelobe range associated with Roll-Call interrogations.

4. Designation of the four ground sensor sites as either DABS or ATCRBS equipped.

The ATCRBS transponder location selection option allows the program user to determine the number of DABS Roll-Call suppressions and All-Call interrogations that an ATCRBS transponder would receive at any location in the Los Angeles environment. The last input option allows the program user to determine if replacing the four FAA designated ATCRBS sensors with DABS sensors results in an increase or decrease in ATCRBS transponder reply probability.

The program output consists of a table which gives the number of ATCRBS sensor antenna beam dwell periods in which a specific number and type of DABS transmissions was received. The table includes statistics on the number of Surveillance, Comm-A, Comm-C, and All-Call DABS transmissions received by the ATCRBS transponder.

TABLE A-1

DABS GROUND SENSOR AREAS OF RESPONSIBILITY

DABS SITE	SURVEILLANCE AND DATA LINK AREA	SURVEILLANCE ONLY AREA
BURBANK	A	D
LAX-4	B	A
LONG BEACH	C	B
ONTARIO	D	C

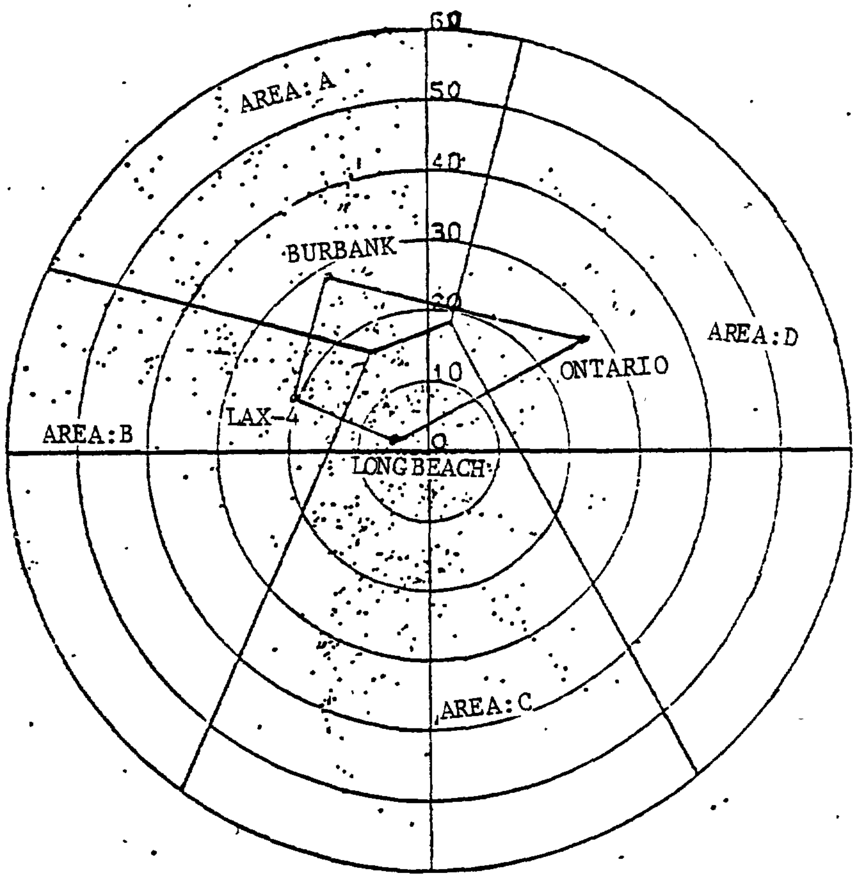

Figure A-2. DABS Ground Sensor Areas of Responsibility

Detailed Description

A flow diagram of Uplink Program B is shown in Figure A-3. Basically, the program consists of three nested Do Loops. The outer most Do Loop selects the antenna beam dwell sample. The next inner nested Do Loop selects individual DABS sensor antenna beam orientations and determines if the ATCRBS aircraft is in the antenna mainbeam or sidelobe range of the sensor. If the ATCRBS aircraft is within the DABS sensor antenna mainbeam or sidelobe range, the program determines the number of DABS aircraft in its antenna beam for the primary and secondary areas of responsibility. The innermost Do Loop computes the number of transmissions received by the ATCRBS aircraft from a given DABS ground sensor. It performs this task by determining the level of data link service that each aircraft in the antenna beam requires. One of three aircraft data link services is randomly selected according to the aircraft types and population distribution shown in TABLE A-2. The aircraft population is considered to consist of 89 percent single engine general aviation and military aircraft. These aircraft were randomly divided into the first two data link services shown in column one of TABLE A-2. Eleven percent of the aircraft population consisted of air carrier and multi-engine general aviation (GA) aircraft, and received the highest level of data link service. The equations used to compute the number of surveillance (N_S), Comm-A (N_A), and Comm-C (N_C) transmissions associated with each level of data link service is shown in the last column of TABLE A-2. These equations were defined by FAA to realistically represent the data-link operation of DABS.

The manner in which the variables T_M, T_H, and P in these equations were generated differs slightly from that used by the FAA simulation. The technique used to generate these random variables was adopted to simplify the simulation program and results in slightly higher levels of DABS interference to ATCRBS than predicted by FAA's simulation. The manner in which the random variables were generated is described in the following paragraphs.

The variables T_M and T_H represent the number of targets displayed to a pilot for Mid-Option and High-Option Cockpit Displayed Traffic Information (CDTI), respectively. The variables were generated randomly, assuming them to be uniformly distributed with possible values of (0,1,...,6) for T_M and (0,1,...,20) for T_H. The random variable T_H takes into account the results of a study (Boeing, 1977) which estimated that the maximum target capacity of CDTI would not exceed 19.

The variable P in the equations (see TABLE A-2) used to compute the number of Comm-A transmissions (N_A) is a random variable of a Poisson distribution and defined by the equation:

$$\text{PROBABILITY}(P=K) = \frac{M^k e^{-M}}{K!} \qquad \text{(A-14)}$$

where

M = the mean of the Poisson distribution

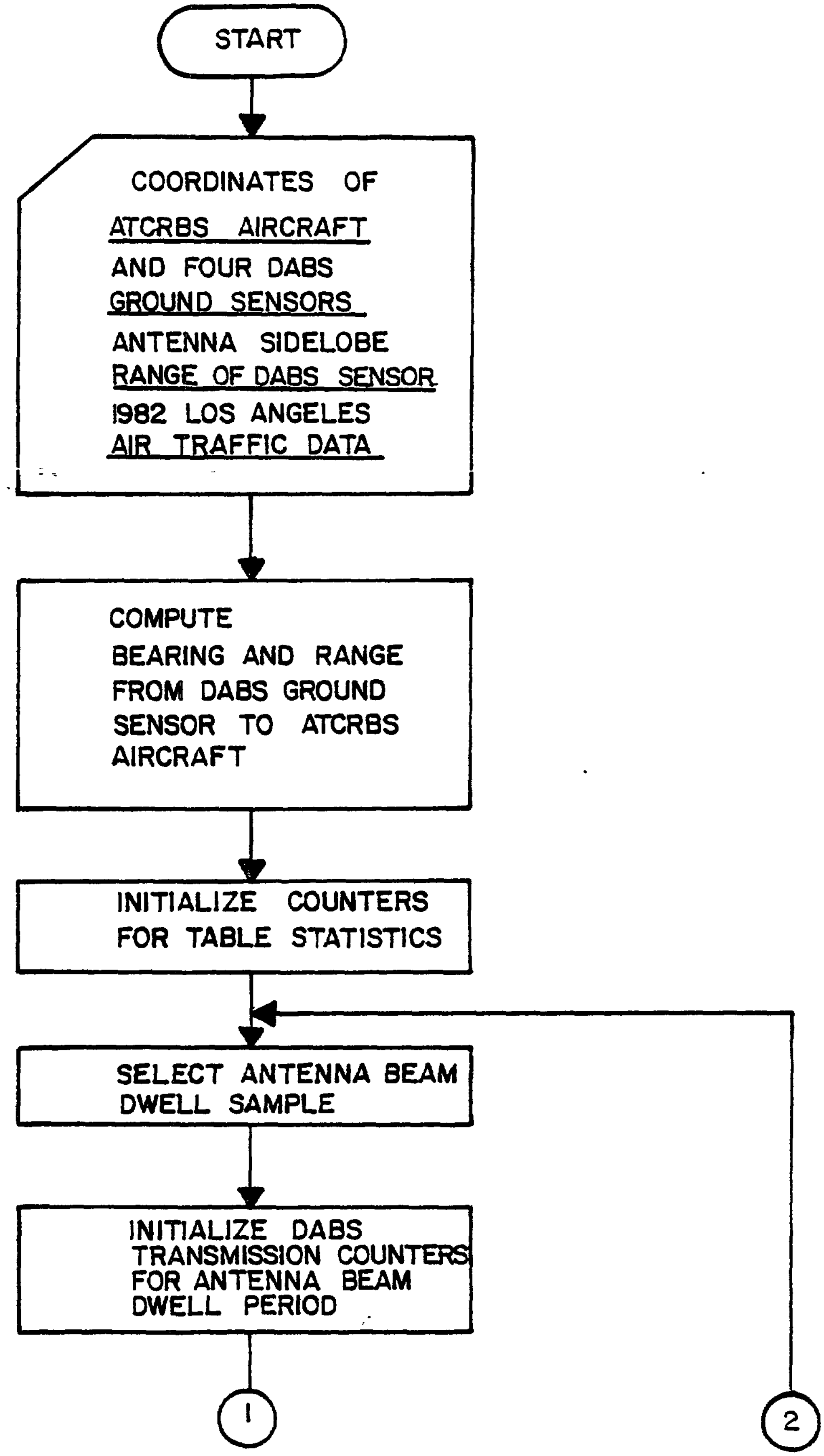

Figure A-3a. Flow Diagram of Uplink Computer Model B

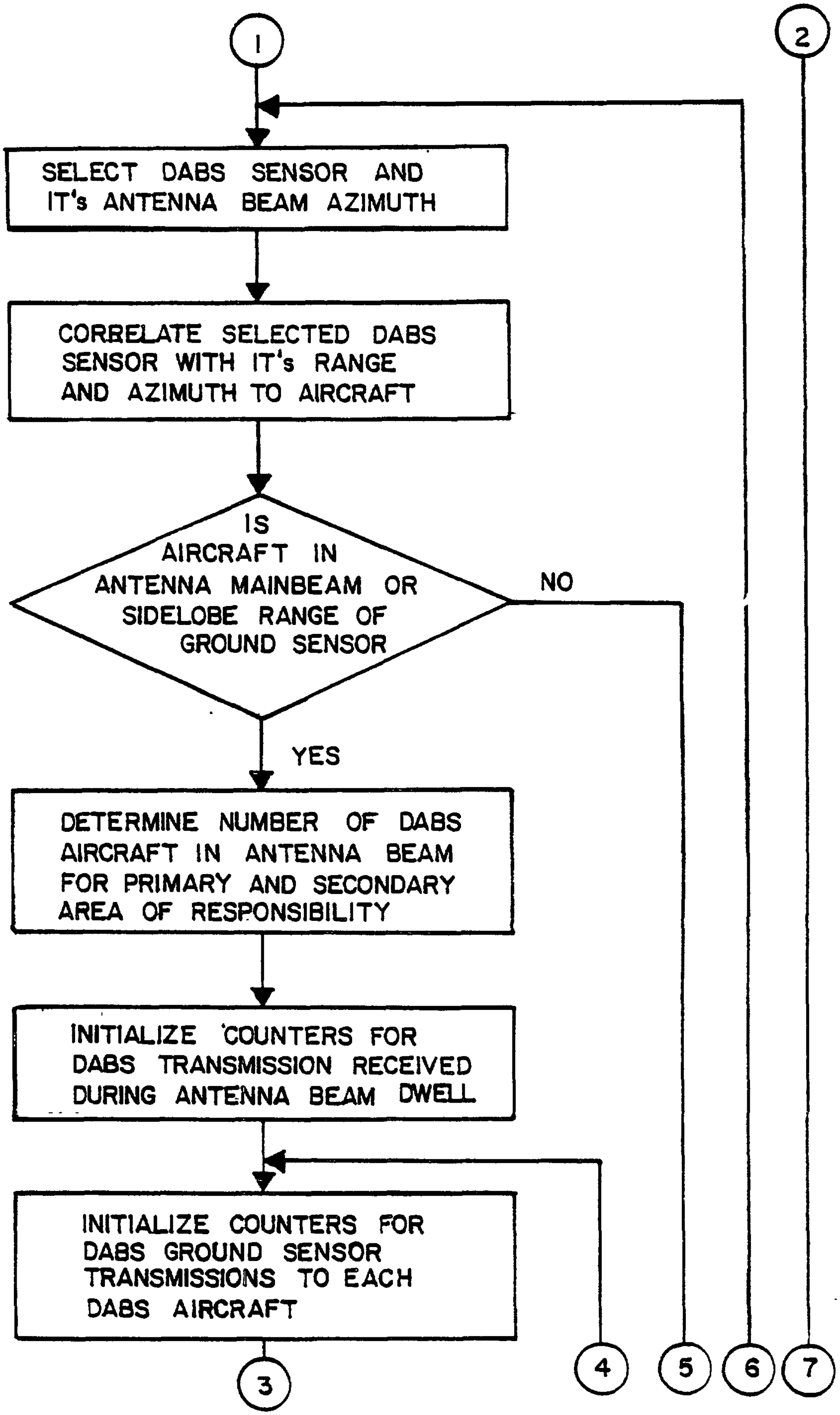

Figure A-3b. Flow Diagram of Uplink Computer Model B

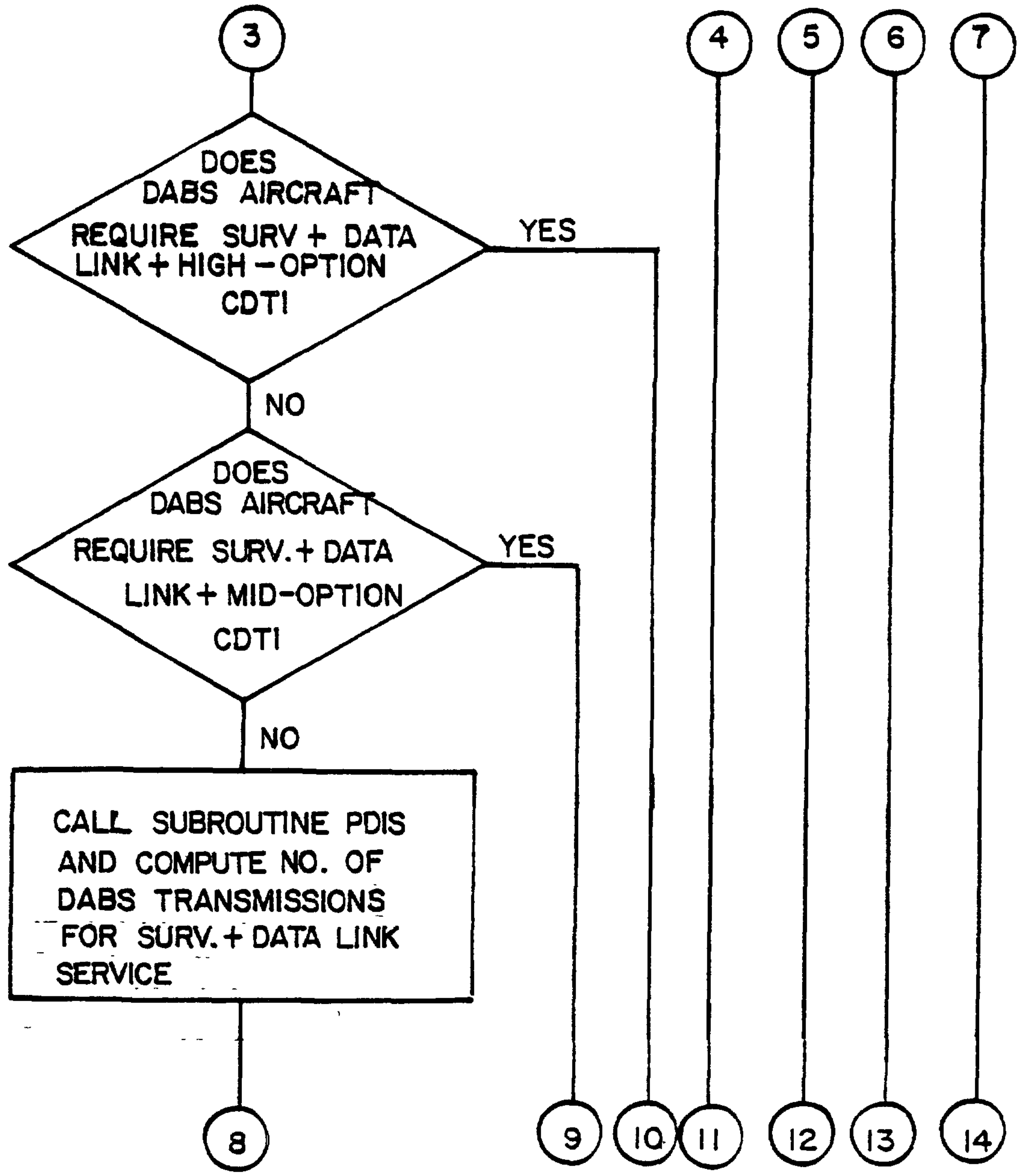

Figure A-3c. Flow Diagram of Uplink Computer Model B

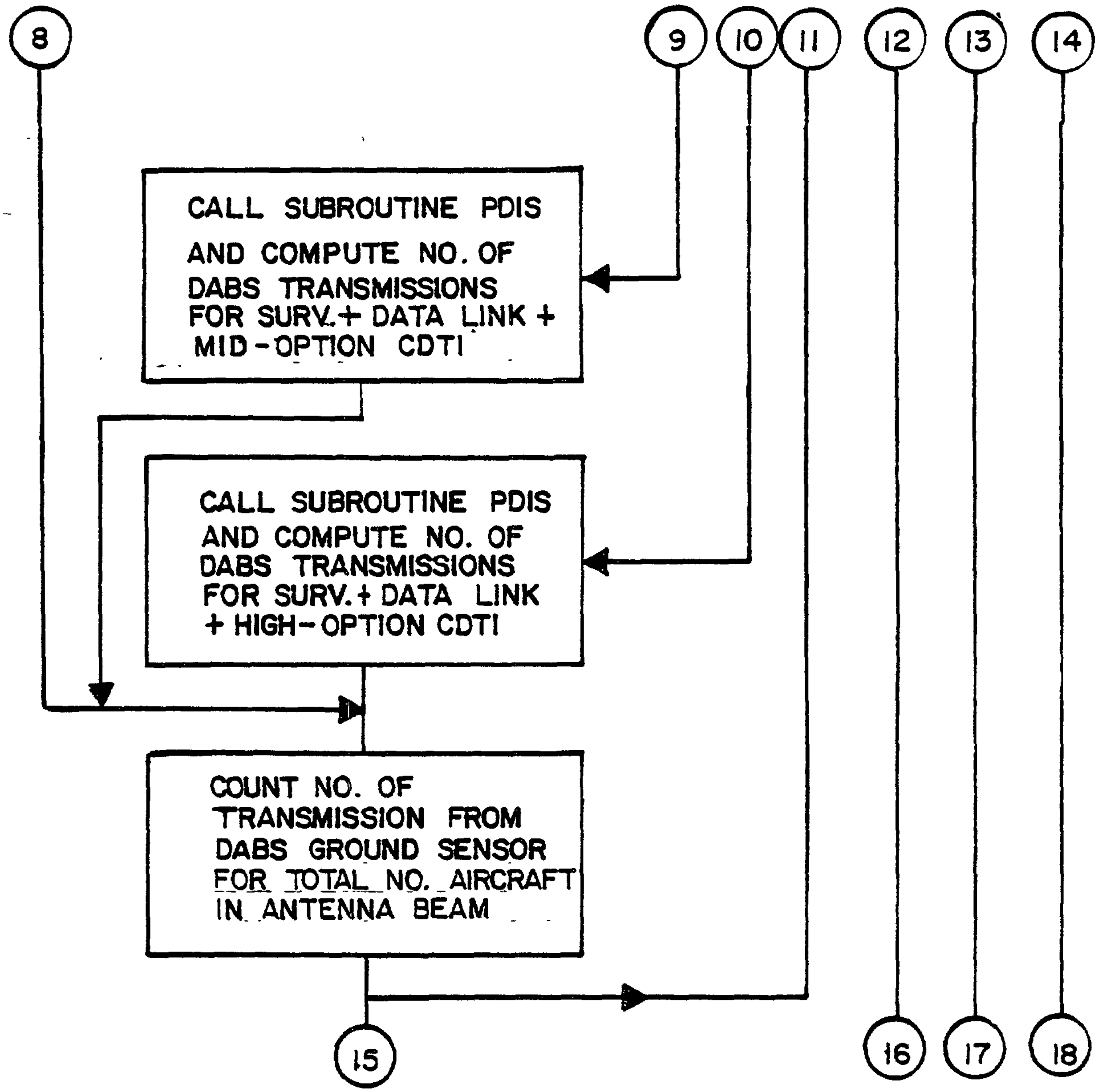

Figure A-3d. Flow Diagram of Uplink Computer Model B

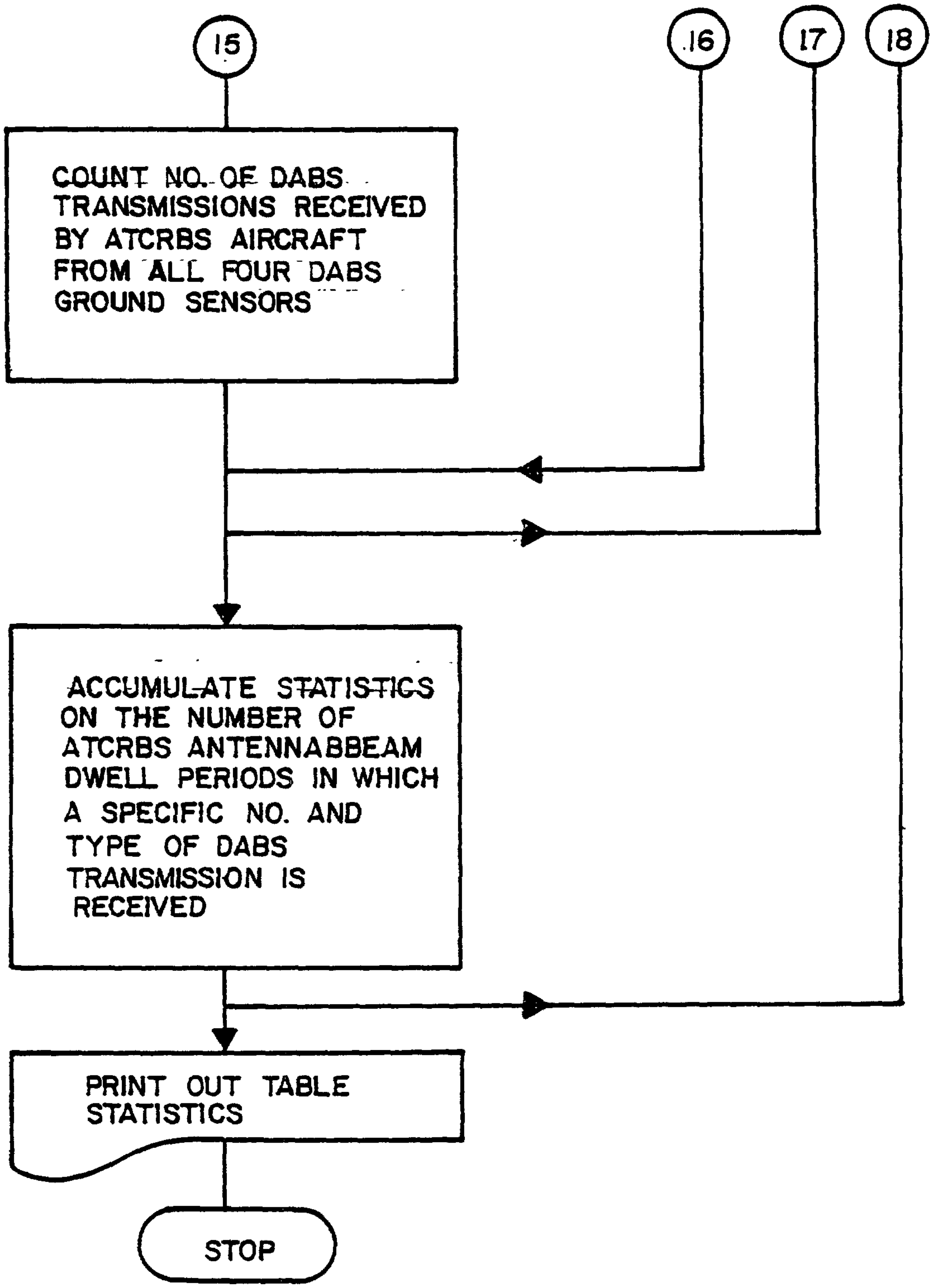

Figure A-3e. Flow diagram of Uplink Computer Model B

TABLE A-2

DETERMINATION OF THE NUMBER OF DABS GROUND SENSOR TRANSMISSION TO A PARTICULAR TYPE OF DABS AIRCRAFT

SERVICE REQUIRED	TYPE OF AIRCRAFT	PERCENT TYPE OF AIRCRAFT IN TOTAL POPULATION	NUMBER AND TYPE OF DABS TRANSMISSIONS
SURVEILLANCE, DATA LINK	SINGLE ENGINE GENERAL AVIATION, MILITARY	44.5	$N_S=0$ $N_A=1+P$ $N_C=0$
SURVEILANCE DATA LINK MID-OPTION CDTI	SINGLE ENGINE GENERAL AVIATION, MILITARY	44.5	$N_S = \begin{cases} 1 & N_A=0 \\ 0 & N_A>0 \end{cases}$ $N_A = (T_M/2)+P$ $N_C = 0$
SURVEILANCE DATA LINK HIGH OPTION CDTI	AIR CARRIER, MULTI-ENGINE GENERAL AVIATION	11.0	$N_S = \begin{cases} 1 & N_A=0 \\ 0 & N_A>0 \end{cases}$ $N_A = P$ $N_C=(T_H/2)+2.5$

NOTE; CDTI= COCKPIT DISPLAY TRAFFIC INFORMATION

N_S= NUMBER OF SURVEILANCE INTERROGATIONS

N_A= NUMBER OF COMM-A INTERROGATIONS

N_C= NUMBER OF COMM-C INTERROGATIONS

P= RANDOM VARIABLE OF POISSON DISTRIBUTION

T_M= NO. OF MID-OPTION CDTI TARGETS DISPLAYED UNIFORMLY DISTRIBUTED RANDOM VARIABLE WITH POSSIBLE VALUES (0,1,2,...,6)

T_H= NO. OF HIGH-OPTION CDTI TARGETS DISPLAYED, UNIFORMLY DISTRIBUTED RANDOM VARIABLE WITH POSSIBLE VALUES (0,1,2,...,20)

K = integer value (K = 0,1,2,...)

The mean of the Poisson distribution M was set to the following values for particular types of aircraft.

$$M = \begin{matrix} 1.0 \text{ for air carrier and multi-engine GA} \\ 0.7 \text{ for military and single-engine GA} \end{matrix} \qquad (A-15)$$

The maximum integer value of K was set at 7 for M = 1.0 and at 5 for M = 0.7.

The main program calls the subroutine PDIS, as shown in Figure A-3C of the flow diagram, to generate the random variable P. The random variable P is generated by the subroutine by the following procedure:

1. Evaluate Equation A-14 for K = 0,1,2... and let these values equal Q_0, Q_1, Q_2..., respectively.

2. Generate a random number R, uniformly distributed between 0 and 1.

3. If $R < Q_0$, set P = 0 and return to main program. If $R > Q_0$, proceed to below test.

4. If $R < (Q_0 + Q_1)$, set P = 1 and return to main program. If $R > (Q_0 + Q_1)$, proceed to next test.

This procedure is continued until the test condition is satisfied or the maximum integer value of K is one less than the value P is allowed to have. For example, if P is not allowed to have an integer value greater than seven, the last comparison test would involve $R < (Q_0 + Q_1 + ... + Q_6)$. If this condition is not satisfied, P would be set equal to seven.

DOWNLINK PROGRAM

General Description

The downlink program simulates and counts the number of DABS replies that the Los Alamitos ATCRBS ground sensor would receive over its antenna beam dwell period. The program employs the 1982 Los Angeles Basin Standard Model Traffic data and the FAA specified ground sensor deployment scenarios described in the previous section .

The program uses Monte Carlo sampling techniques to randomly select the antenna beam orientation of the victim ATCRBS DABS sensors. One data sample consists of counting the number of DABS replies received by the ATCRBS sensor for a given set of antenna beam orientations. Counts of both long and short DABS replies are maintained. The replies are associated with ATCRBS/DABS All-Call and surveillance interrogations, and the long replies with Comm-A and Comm-C interrogations. Eighty percent of the aircraft population is considered to receive Roll-Call interrogations and 20 percent All-Call interrogations. A 10 percent Roll-Call reinterrogation rate is also assumed.

The program tests to determine if DABS ground sensor antenna beams intersects the ATCRBS ground sensor antenna beam. If an antenna beam intersection occurs, the DABS ground sensors area of responsibility that the antenna beam intersection lies in is determined. If the antenna beam intersection lies in the area of responsibility of the same DABS whose antenna beam intersects the ATCRBS ground sensor antenna beam, the number of aircraft in the antenna beam intersection area is determined. The number of DABS interrogations that these aircraft receive from the DABS sensor and resulting number of replies the ATCRBS ground sensor received is determined.

The program also tests to determine if the DABS ground sensor antenna beam intersects the sidelobe region of the ATCRBS ground sensor. If this intersection occurs, the number of aircraft in the intersection area and the DABS All-Call replies received by ATCRBS ground sensor due to DABS All-Call interrogation of these aircraft are computed.

Data input and parameter selection options for the program include selection of data from one of four snapshots of the 1982 Los Angeles Basin Standard Traffic Model data, and the antenna sidelobe range of the victim ATCRBS ground sensor. The program output consists of a table which gives the number of ATCRBS sensor antenna beam dwell periods in which a specific number of short and long replies are received.

Detailed Description

A flow diagram of the Downlink Program is shown in Figure A-4. The program basically consists of three nested Do Loops. The outermost Do Loop selects the ATCRBS ground sensor antenna beam pointing direction and antenna sample. The next inner nested Do Loop selects individual DABS sensor antenna beam pointing directions. A vector analysis technique is used to determine if the antenna beams intersect. If the antenna beams intersect, the area of the antenna beam intersection is computed using the following equation:

$$AMB = \frac{R_A B_A \; R_D B_D}{\sin \gamma} \qquad \text{(A-16)}$$

where

R_A = Distance from ATCRBS ground sensor to antenna beam intersection

B_A = Antenna beamwidth of ATCRBS ground sensor

R_D = Distance from DABS ground sensor to antenna beam intersection

B_D = Antenna beamwidth of DABS ground sensor

γ = Angle between DABS and ATCRBS antenna beams

The program then identifies the DABS sensor that has primary responsibility

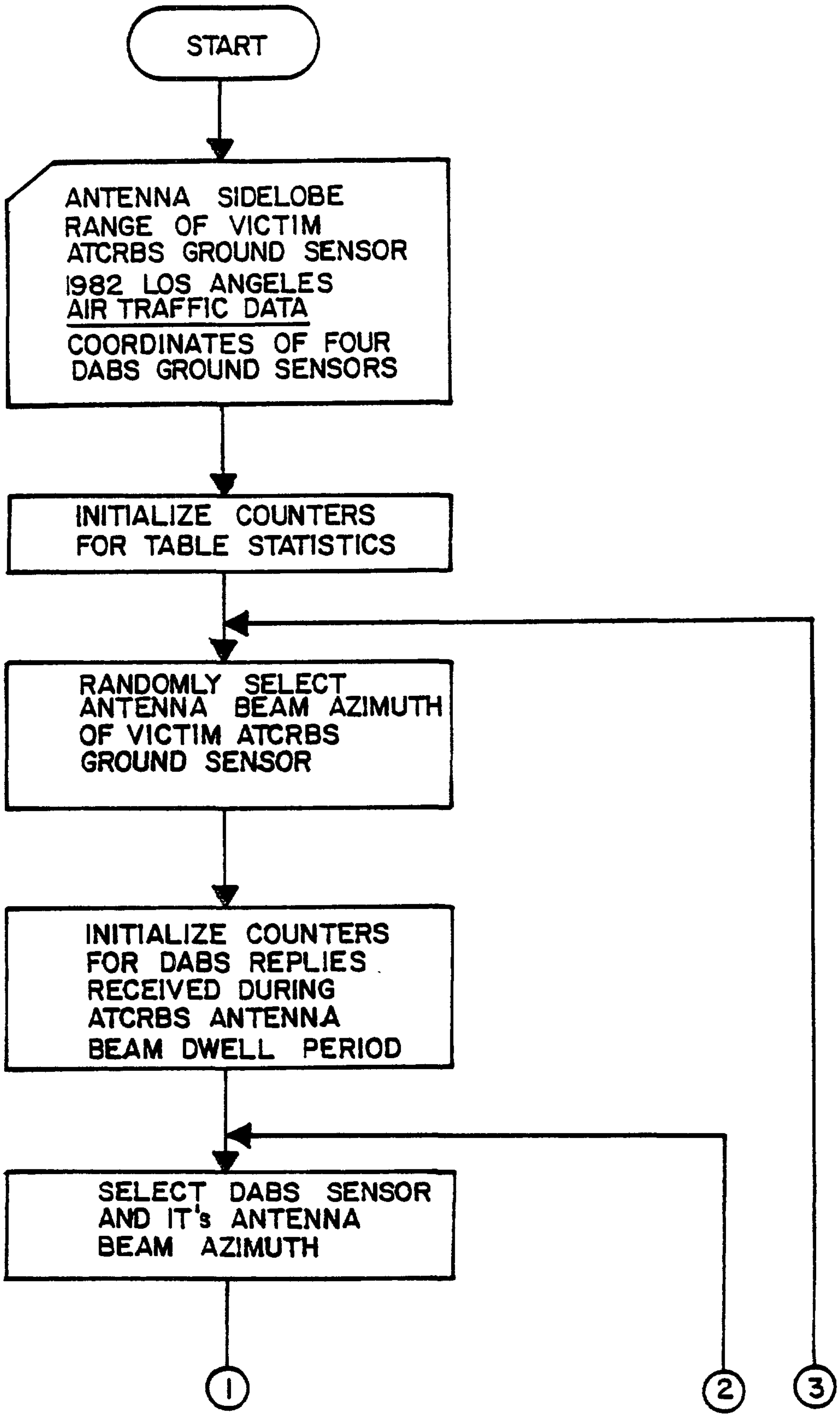

Figure A-4a. Flow Diagram of Downlink Computer Model

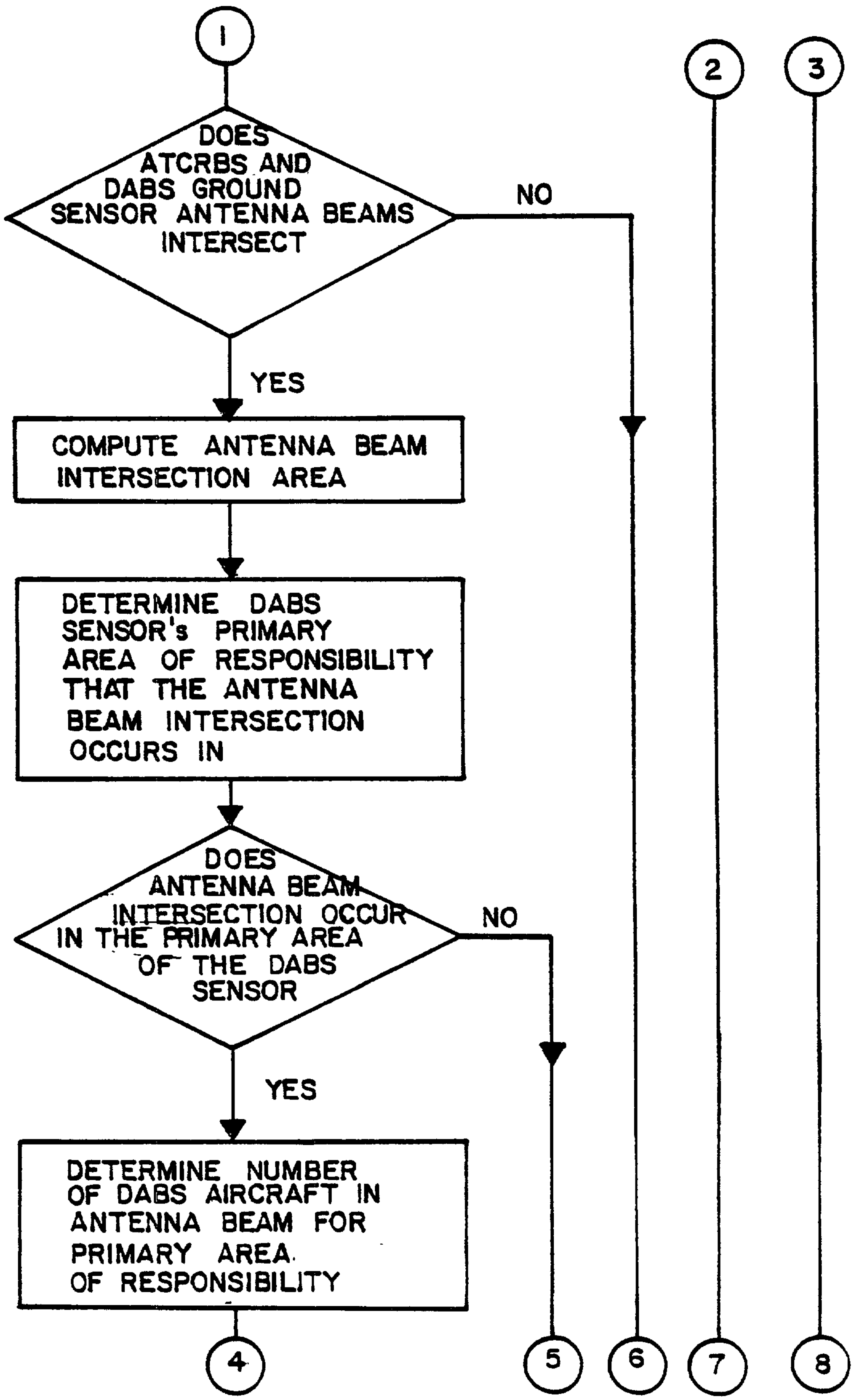

Figure A-4b. Flow Diagram of Downlink Computer Model

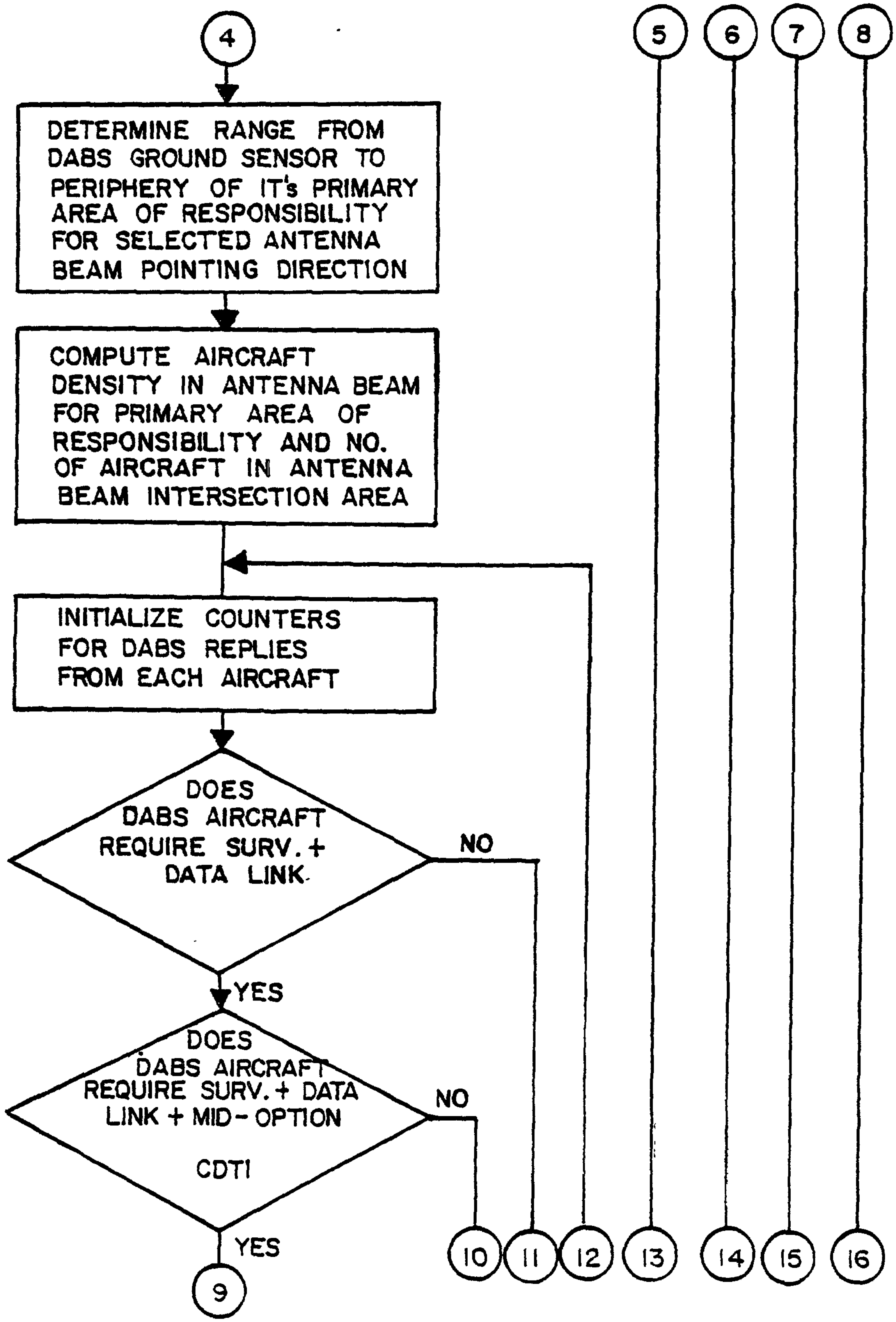

Figure A-4c. Flow Diagram of Downlink Computer Model

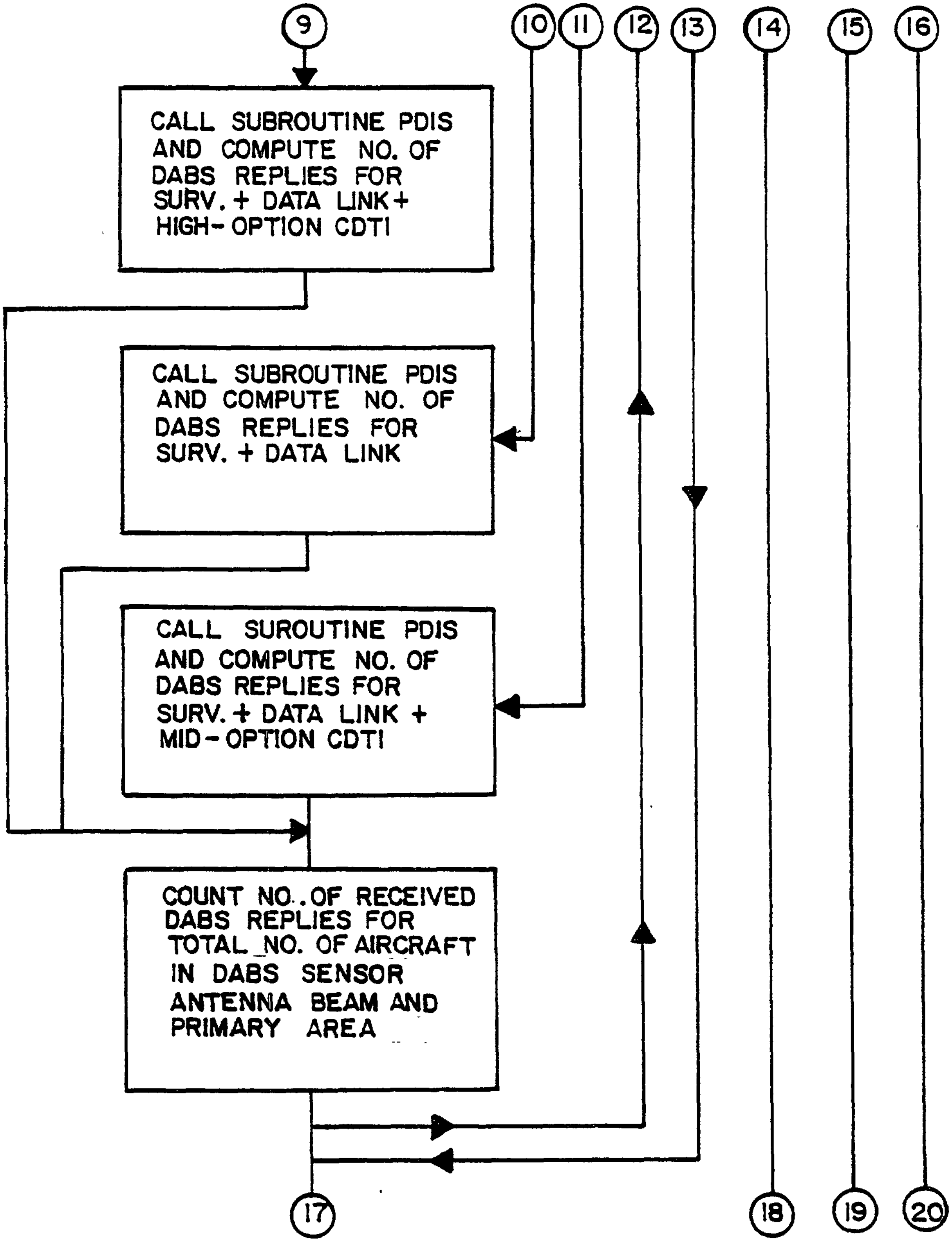

Figure A-4d. Flow Diagram of Downlink Computer Model

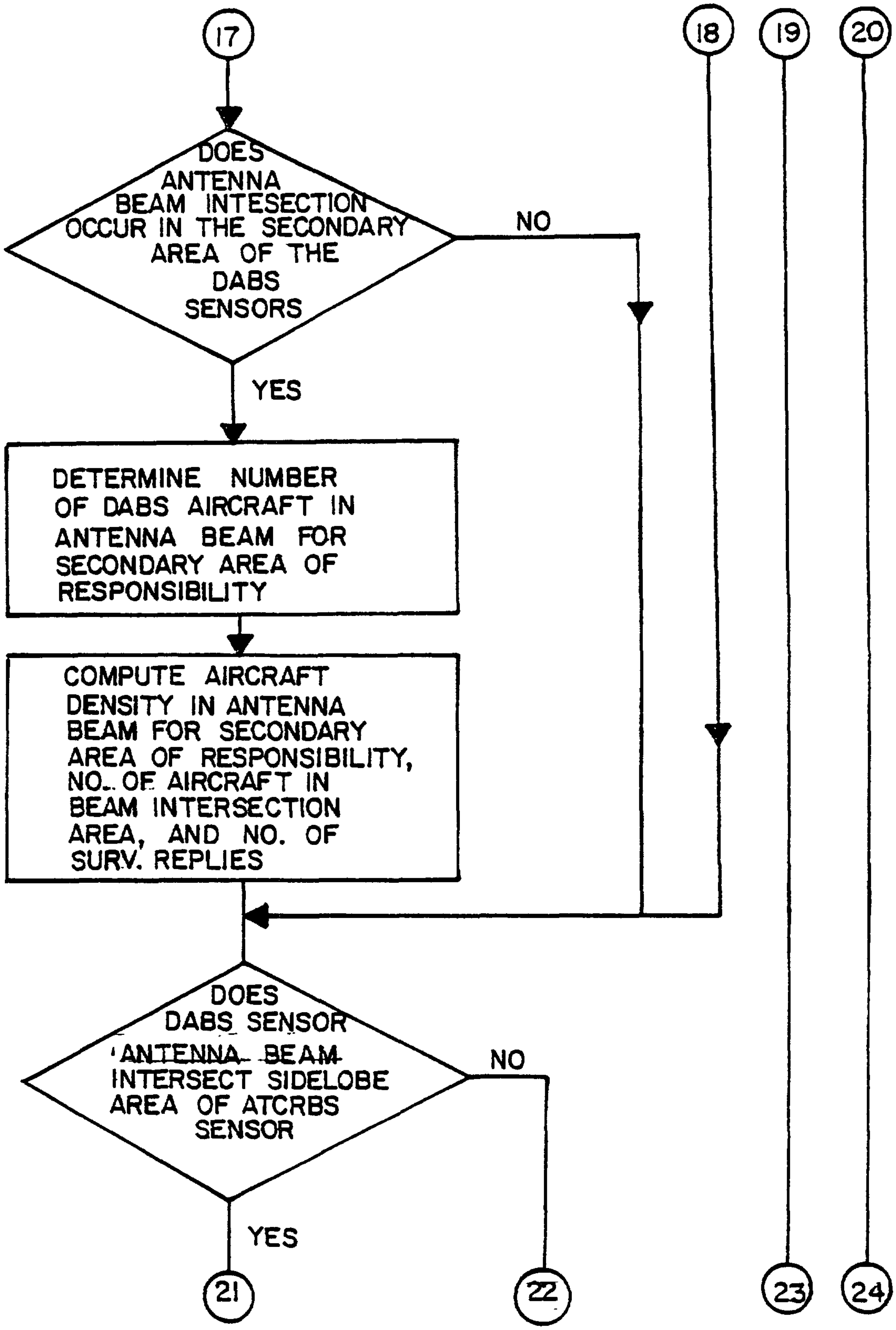

Figure A-4e. Flow Diagram of Downlink Computer Model

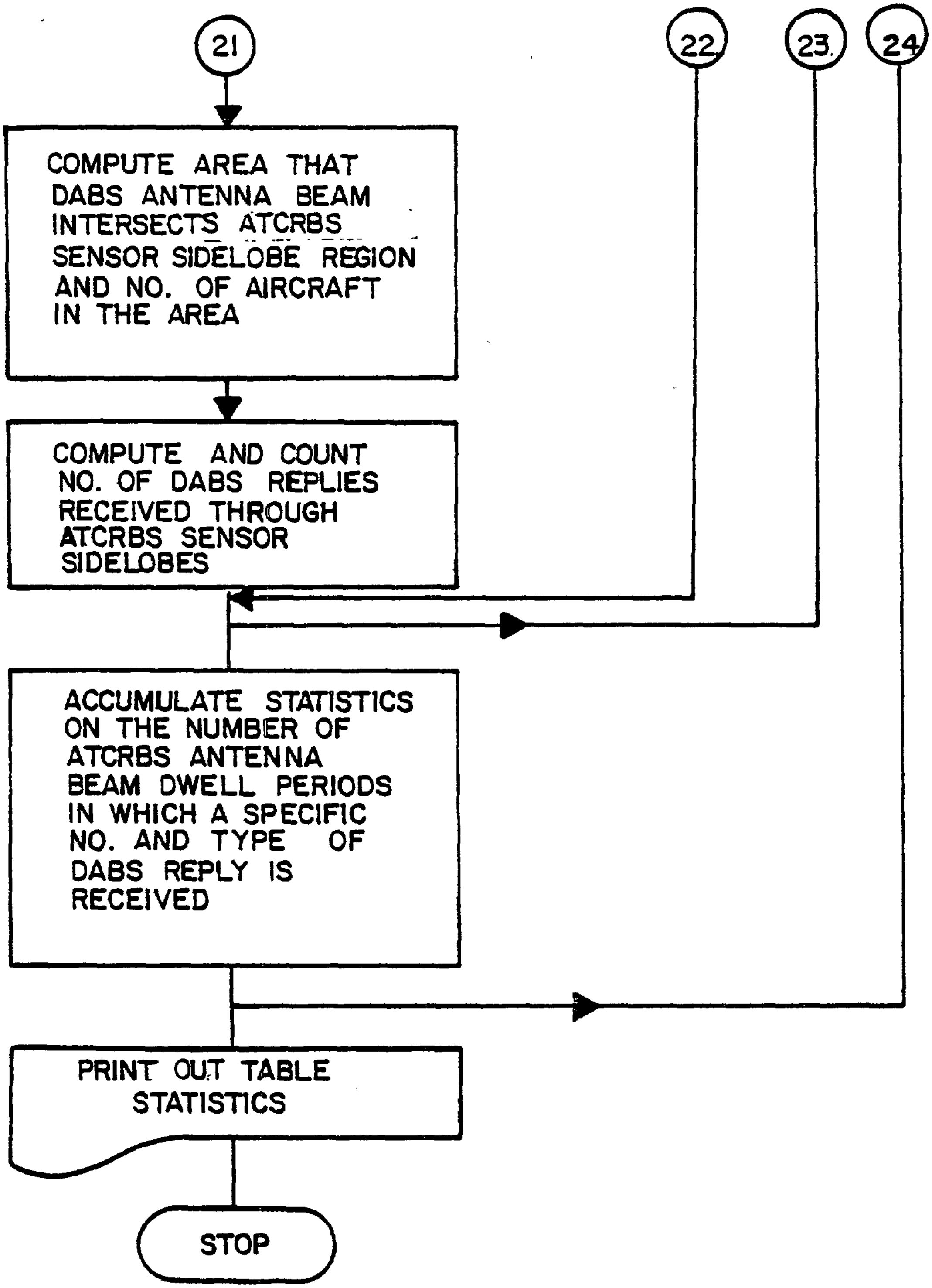

Figure A-4f. Flow Diagram of Downlink Computer Model for the area in which the beam intersection occurs. The program accomplishes this by computing the distance between each DABS ground sensor and the antenna beam intersection point, and selecting the DABS ground sensor that is closest. If the antenna beam intersection occurs in the primary area of the DABS sensor that is being considered in this pass through the Do Loop, the number of aircraft in the antenna beam intersection area is computed. The number of aircraft in the area is the final index of the next nested Do Loop (see Figure A-4c) which computes the number of DABS replies the ATCRBS ground sensor receives due to DABS interrogations of the aircraft in the antenna beam intersection area. The procedures used to determine the types of aircraft and the number of interrogations each receives is essentially the same as those described for Uplink Program B. The number of replies associated with each interrogation was then computed.

After exiting from the innermost nested Do Loop, the program determines if the antenna beam intersection occurred in the secondary area of responsibility for the DABS sensor (see Figure A-4e). If this condition is satisfied, the number of replies associated with the DABS surveillance interrogations is computed.

The program next determines if the DABS sensor antenna beam intersects the antenna sidelobe region of the ATCRBS sensor. If this condition is satisfied, the area that the DABS antenna beam intersects the ATCRBS sidelobe region is computed (see Figure A-4f) using the following equation:

$$ASL = 2R_S B_D (SLR) \, SIN(B_D - 90.) \qquad (A\text{-}17)$$

where

R = Distance between ATCRBS and DABS ground sensor

B_D = Antenna beamwidth of DABS ground sensor

SLR = Antenna sidelobe range of ATCRBS ground sensor

The program then multiplies this area by the density of aircraft in this region to obtain the number of aircraft. Finally the number of replies that the ATCRBS ground sensor receives from these aircraft are computed.

DATA REDUCTION PROGRAM

The Data Reduction program was used to reduce data from the 1982 Los Angeles Basin Standard Traffic Model tapes into input files for Uplink Program B and the Downlink Program. The Data Reduction Program divides the 360 degree coverage region of each DABS sensor into 150 antenna beamwidth (2.4 degree) sectors. The number of aircraft in the portion of the antenna beam sectors included in the DABS sensor's coverage area of responsibility was counted. This aircraft count was conducted for both the DABS ground sensor's primary (data link and surveillance coverage) and secondary (surveillance only coverage) areas of responsibility. Figure A-2 indicates the primary area of responsibility associated with each DABS sensor and TABLE A-1 lists the primary and secondary areas of responsibility interpreted by the program for each DABS sensor.

Aircraft counts were entered into a 150 (no. of 2.4 degree antenna beamwidth in 360 degree) by eight (4 DABS sensors X 2 areas of responsibility) array file for each of the four Los Angeles air traffic snapshots. These data arrays were used as input file options for Uplink Program B and the Downlink program. The four 1982 Los Angeles Basin Standard Traffic Model snapshots that were considered included 45304, 45604, 45904, and 46204. These numbers indicate the time of the snapshot in seconds from midnight Pacific Daylight Time.

APPENDIX B

DABS FUNCTIONAL DESCRIPTION

INTRODUCTION

This Appendix contains Chapter 1 and 2 of the FAA report entitled "DABS Functional Description" (Orlando, 1980). The DABS description is presented for reader convenience and to provide an understanding of the ATCRBS-DABS interference interactions.

CHAPTER 1

OVERVIEW AND SUMMARY

INTRODUCTION

The Discrete Address Beacon System (DABS) is a combined secondary surveillance radar (beacon) and ground-air-ground data link system capable of providing the aircraft surveillance and communications necessary to support ATC automation in the dense traffic environments expected in the future. It is capable of common-channel interoperation with the current ATC beacon system*, and thus may be implemented at low user cost over an extended ATCRBS-to-DABS transition period. In supporting ATC automation, DABS will provide the surveillance and communication performance required by the Automatic Traffic Advisory and Resolution Service (ATARS), the reliable communications needed to support data link services, and the capability of operating with a terminal or enroute, radar digitizer-equipped, ATC surveillance radar. When operating in conjunction with such a surveillance radar a DABS sensor will use the radar returns either to reinforce beacon tracks, or in cases of transponder failure, to provide tracked radar targets.

The need to support ATARS substantially increases the requirements for ATC surveillance and communication. Today, ATC is primarily concerned with controlled, or IFR, aircraft. ATARS will provide automatic, ground-based, conflict resolution advisories to mode-C equipped VFR and IFR aircraft, and ATC backup separation service to IFR aircraft. To support ATARS, all aircraft in the airspace served, VFR as well as IFR, must be provided with accurate, continuous surveillance, and reliable, minimum delay, digital, communications. In order to meet this requirement at en route facilities, DABS sensors operate with back-to-back beacon antennas to provide twice the beacon data rate available from a standard antenna.

A central DABS design requirement was assurance that the system could be implemented in an evolutionary manner. By the time deployment of DABS begins, approximately 1983, there will be on the order of 200,000 aircraft equipped with ATCRBS transponders, and approximately 500 ground-based interrogators. DABS is designed to operate in this environment, and in a way which will permit the gradual, economic, transition to an all-DABS operation.

The capability for such a transition has been achieved by providing a high degree of compatibility between DABS and ATCRBS. DABS uses the same interrogation and reply frequencies as ATCRBS, and the signal formats have been chosen to permit substantial commonality in hardware. This degree of compatibility permits an economic and smooth transition, in which (a) DABS interrogators will provide surveillance of ATCRBS-equipped aircraft, and (b) DABS transponders will reply to ATCRBS interrogators.

Thus DABS equipment, both on the ground and in aircraft, can be introduced gradually and continue to interoperate with existing systems during an extended transition phase.

THE DABS CONCEPT

The fundamental difference between DABS and ATCRBS is the manner of addressing aircraft, or selecting which aircraft will respond to an interrogation. In ATCRBS, the selection is spatial, i.e, aircraft within the mainbeam of the interrogator respond. As the beam sweeps around, all angles are interrogated, and all aircraft within line-of-sight of the antenna respond. In DABS, as implied by its name, each aircraft is assigned a unique address code. Selection of which aircraft is to respond to an interrogation is accomplished by including the aircraft's address code in the interrogation. Each such interrogation is thus directed to a particular aircraft. Narrow-beam antennas will continue to be used, but primarily for minimizing interference between sites and as an aid in the determination of aircraft azimuth.

Two major advantages accrue from the use of discrete address for surveillance. First, an interrogator is now able to limit its interrogation to only those targets for which it has surveillance responsibility, rather than to continuously interrogate all targets within line-of-sight. This prevents surveillance system saturation caused by all transponders responding to all interrogators within line-of-sight. Secondly, appropriate timing of interrogations ensures that the responses from aircraft do not overlap, eliminating the mutual interference which results from the overlapping of replies from closely spaced aircraft (so-called synchronous garble).

In addition to the improved surveillance capability, the use of the discrete address in interrogations and replies permits the inclusion of messages to or from a particular aircraft, thereby providing the basis for a ground-air and air-ground digital data link.

DABS ELEMENTS

As illustrated in Fig. 1-1, DABS is comprised of the sensors, transponders, and the signals-in-space which form the link between them. DABS provides surveillance and ground-air-ground communication service to air traffic control facilities including en route (ARTCC), terminal (TRACON and TRACAB), and the unmanned, sensor based, Automatic Traffic Advisory and Resolution Service (ATARS).

DABS' primary function is to provide these survellance and communication services in support of air traffic control. However, by proper timing of the interrogations to all DABS-equipped aircraft, suitably equipped aircraft may utilize the DABS replies from other nearby aircraft to perform onboard proximity and conflict detection. This air-to-air mode is termed Synchro-DABS (Ref. 2).

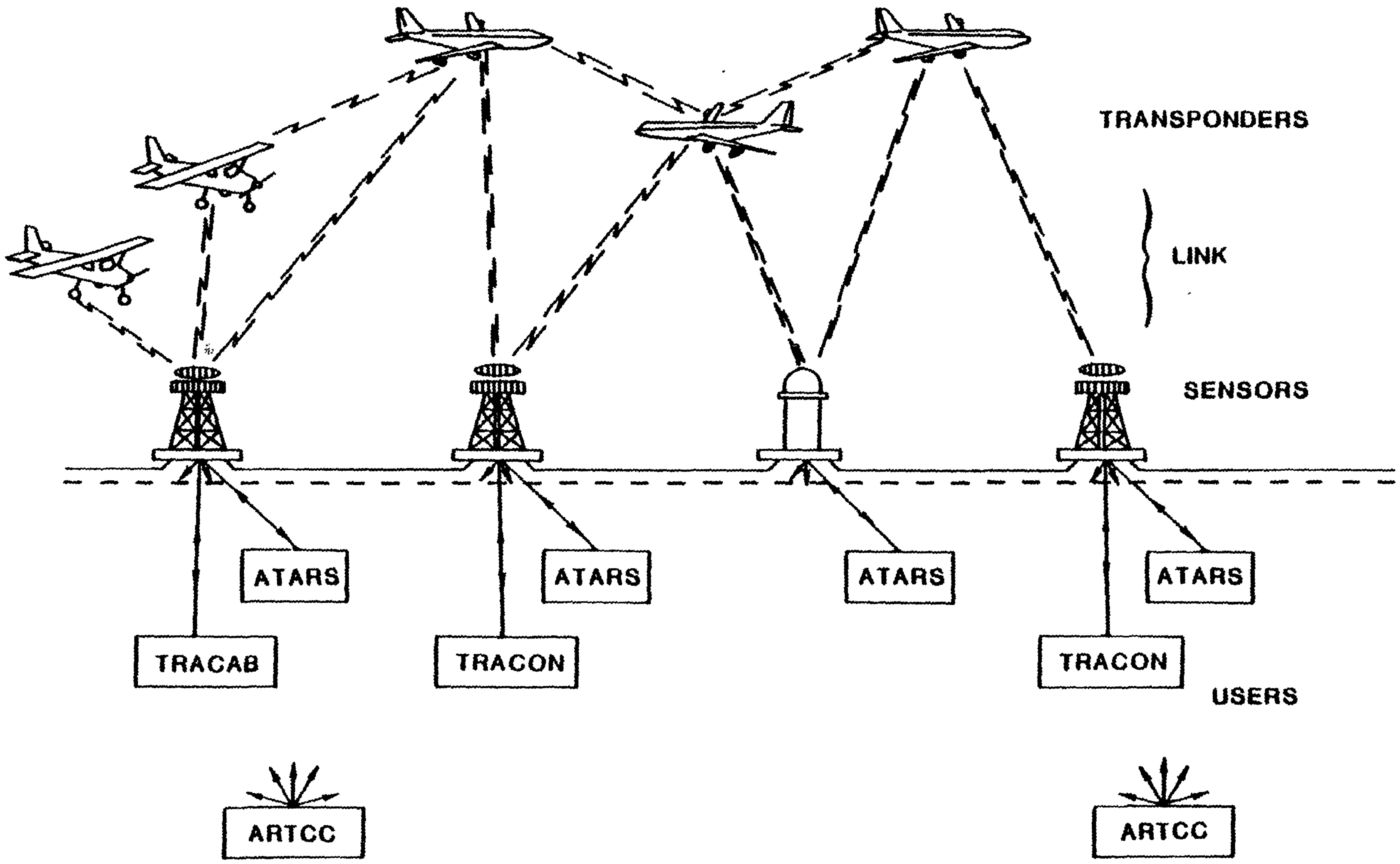

Fig. 1-1. DABS Elements.

The DABS link employs signal formats used for ATCRBS, and adds to these the signal waveforms and message formats necessary to acquire DABS-equipped targets, and for discretely-addressed surveillance and data-link interrogations and replies. The principal characteristics of the DABS signals are as follows:

Interrogation -

Frequency: 1030 MHz
Modulation: Differential Phase-Shift Keying (DPSK)
Data Rate: 4 Mbps

Reply -

Frequency: 1090 MHz
Modulation: Pulse Position (PPM)
Data Rate: 1 Mbps

Interrogation and Reply -

Data block: 56-bit or 112-bit
Parity check code (included in data block): 24-bit

A more complete summary of the DABS signal formats is contained in Chapter 2.

The DABS sensor provides surveillance of ATCRBS-and DABS-equipped aircraft, and operates as a store and forward communication relay for data-link communication between aircraft and ATC facilities. In addition, the sensor accepts digitized radar target reports from a collocated radar and combines these with the beacon reports into a composite surveillance output stream. When beacon and radar reports occur on the same target, the radar report is suppressed and the beacon report tagged as radar-reinforced. Radar-only output reports are provided on targets that are not beacon equipped.

To discretely interrogate DABS-equipped aircraft, the sensor maintains a file of the identity and approximate position of all such aircraft within its defined area of coverage.

Each sensor's operation is controlled by a prestored map defining its coverage volume, which may be different in normal operation and in the event of various system failures, e.g., the failure of an adjacent sensor.

In a netted configuration, each sensor may communicate directly with adjacent sensors via ground lines to hand-off targets as they pass from the region of one sensor's coverage to that of an adjacent sensor. In addition, in regions of overlapping coverage, this intersensor communication (in those cases where ground lines are installed) may be used to assist in the reaquisition of a lost target.

In general, each sensor can provide surveillance and communication services to several ATC facilities, i.e., all those whose areas of control responsibility overlap the coverage area of the sensor. The interface between the sensor and each control facility comprises a one-way circuit for the transmission of surveillance data, both radar and beacon, and a two-way circuit for the interchange of data-link messages. The latter is also used to transmit reports of ATARS activity to the ATC facility, and various status and control messages between the sensor and the ATC facility.

The DABS transponder includes all of the functions of an ATCRBS transponder, and adds to these the ability to decode DABS interrogations and to format and transmit the appropriate replies. For data link, the transponder functions primarily as a modem. On receipt of a ground-to-air transmission, it verifies the correctness of the received message using the error-detecting code. Once verified, the transponder transfers the message contents to one or more external devices. For air-to-ground messages, the transponder accepts the message contents from an external input device, and formats and encodes the data for transmission as part of the reply to a subsequent interrogation.

DABS SURVEILLANCE

The principal features of DABS surveillance are as follows:

Unique address
All-call acquisition
All-call lockout
Range-ordered roll-call interrogation
Adaptive reinterrogation
Monopulse direction-finding
Positive handoff
Multisensor Coverage

Each DABS-equipped aircraft has a permanently assigned unique 24-bit address. This 24-bit address will be included in all discretely-addressed interrogations to that aircraft, and in all DABS replies from that aircraft.

The DABS sensor range-orders interrogations to DABS-equipped aircraft in such a way that the replies do not overlap. The use of monopulse direction finding on the reply permits the sensor to provide surveillance of DABS-equipped aircraft, generally within a single interrogation/reply cycle per rotation (scan) of the interrogator antenna. If a reply to the interrogation is not received, or is received but not successfully decoded, the interrogator has the capability of reinterrogating (several times if necessary) the aircraft during the time the aircraft is in the antenna beam.

In order to be discretely interrogated, an aircraft must be on the sensor's roll-call file, i.e., the sensor must know its address and approximate position. To acquire targets not yet on any sensor's roll-call file, each sensor transmits all-call interrogations. A DABS-equipped aircraft will respond to such an interrogation with its unique address, and be added to the sensor's roll-call file.

Once on the sensor's roll-call file, the DABS-equipped aircraft may be locked-out from replying to subsequent DABS all-call interrogations. This lockout condition is under positive control of the DABS sensor and is transmitted to the DABS transponder as part of the DABS discrete interrogation. The use of DABS lock-out eliminates unnecessary all-call replies and therefore minimizes interference (particularly all-call synchronous gable) on the air-to-ground channel.

While DABS lock-out can minimize synchronous garble on acquisition, it cannot eliminate it completely nor is it effective in the case where a DABS sensor resumes operation after a period of inactivity and must therefore acquire many DABS aircraft simultaneously. These latter cases are handled by a feature called "the stochastic acquisition mode". In this mode, the DABS sensor interrogates garbling aircraft with a special all-call interrogation that instructs them to reply with a specified less-than-unity reply probability. The resulting reduced reply rate means that some all-call replies will be received ungarbled and these aircraft will thus be acquired. Once an aircraft is acquired it is locked out and hence no longer interferes with the all-call replies from the remaining unacquired aircraft. The process is repeated until all aircraft are acquired.

The use of DABS lockout to minimize interference on all-call replies means that provision must be made to hand off the DABS address to an adjacent site in areas of multisensor coverage. In a netted configuration, DABS aircraft are handed off to an adjacent sensor via direct sensor-to-sensor transmission of the aircraft's address and position. Provision has also been made for the case where DABS sensors have overlapping coverage but do not have ground-to-ground communications links. The principal alternatives are:

Cooperative Unlocking. This alternative requires that each site selectively unlock aircraft at surveillance boundaries in order to allow them to be acquired by the adjacent sensor's normal all-call interrogations.

Site Addressed Lockout. The DABS transponder can be selectively and independently locked out to special all-call interrogations originating from up to 15 different sensor sites. Adjacent sites using different site address numbers are completely unaffected by the other sites' lockout activity and hence can perform acquisition and lockout in a completely autonomous manner.

Lockout Override. A special all-call interrogation can be used that instructs the DABS transponder to ignore any previous lockout instructions. The resulting all-call garble is handled by the stochastic acquisition mode. While offering reduced performance compared to the other alternatives, the approach provides a means for sensors with overlapping coverage to operate with no site-to-site coordination. Hence it may be useful for operation across national boundaries or for mobile military interrogators.

If for any reason an aircraft ceases to receive discretely-addressed interrogations for a period of approximately 16 seconds (corresponding to a few interrogator scans), any existing lockout will lapse so that the aircraft may be reacquired by normal DABS acquisition.

In regions of airspace visible to more than one DABS sensor, each DABS target will generally be simultaneously on the roll-call of at least two sensors to provide continuity of surveillance and data-link service in the event of a link or sensor failure.

ATCRBS MODE OF DABS

The DABS sensor provides surveillance of ATCRBS targets with quality better than that of presently operating equipment. This is important because of the high density of ATCRBS-equipped targets which will be experienced during the early years of the ATCRBS-to-DABS transition.

The principal characteristics of ATCRBS surveillance provided by a DABS sensor are:

Reduced interrogation rate,
Monopulse direction finding,
Improved reply degarbling,
False target identification.

The use of monopulse direction finding on ATCRBS replies permits operation at a reduced ATCRBS interrogation rate, nominally four interrogations in the 3-dB antenna beamwidth. This reduction in ATCRBS interrogation rate causes an immediate and significant reduction in the ATCRBS interference environment at the time when an ATCRBS sensor is replaced by a DABS sensor.

Improved reply processing is used to minimize the effects of mainbeam and sidelobe interference. A major element of this is the use of pulse-by-pulse monopulse data to help decode overlapping replies.

A major current problem in ATCRBS is the appearance of false targets due to reflection from large objects such as buildings, or hillsides. The DABS sensor is programmed to identify and flag such false targets using both target reply parameters (e.g., mode-A code) and the pre-stored geometry of principal reflecting surfaces.

In side-by-side experimental measurements comparing the performance of the ATCRBS mode of DABS with currently operational ATCRBS equipment, it has been shown that the new system provides improvements in range and azimuth accuracies by about 5:1, as well as significant improvement in target report reliability (Ref. 3).

DABS DATA LINK

DABS provides both ground-to-air and air-to-ground data link capability. Air-to ground messages may be either pilot-initiated, e.g., a request for a clearance change or for weather information, or ground-initiated, e.g., to read out onboard instrumentation.

The critical nature of many of the messages to be carried by DABS requires a high degree of message integrity; it must be known both at the transponder and at the sensor that a message has been received correctly before the transaction can be considered complete. The required message integrity is ensured by providing for error detection, and technical acknowledgment.

Error-detecting codes are used on both interrogations and replies to essentially eliminate the acceptance of a message containing an error. When the presence of an (uncorrectable)* error is detected, the whole transmission is rejected. Technical acknowledgment of the correct receipt of an uplink message is achieved by the receipt of a correct reply at the proper time. Technical acknowledgment for a downlink message is provided by an acknowledgment included in a subsequent interrogation. If an error had been detected, no acknowledgment would be received and the message would be repeated.

The three main classes of messages accommodated by DABS are:

Surveillance data,
Standard message,
Extended-length message.

Surveillance Data

Surveillance data may be included in each normal DABS interrogation and reply (with the exception of the special extended length message and all-call formats). Normally, in a reply this includes an altitude report identical to the ATCRBS mode-C report. However, either the ground or the pilot may initiate the inclusion of the ATCRBS mode-A code in place of the altitude report, e.g., to indicate an emergency condition. In an interrogation, this may include a command to lockout the transponder to all-call interrogations.

Standard Message

Most DABS data-link transmissions will be handled as one 56-bit standard message included as part of a 112-bit interrogation or reply; e.g., an ATARS transmission. These transmissions may include surveillance data in addition to the data-link message, and thus will generally be used in place of, rather than in addition to, a surveillance interrogation and/or reply.

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*The sensor can correct certain types of error occurring in replies. Since the transponder has no error-correction capability, an interrogation is only accepted when it is free of error.

In order to prevent interference between DABS replies from different aircraft, the control field of each interrogation specifies the length of the associated reply. Thus when a long reply is needed the interrogator knows in advance and schedules the proper time the reply should be received and allows enough time to receive the long replies. When an aircraft-initiated air-to-ground data-link message is to be sent, a bit is set in the control field of a reply which requests the interrogator to schedule a long reply in response to a subsequent interrogation. The long reply, containing the data-link message, is then transmitted when directed by the interrogator.

Extended Length Message

Each standard message must be acknowledged before the transmission of the next one. In order to provide for the more efficient transmission of longer messages, an extended-length message (ELM) capability is incorporated. Using this, a sequence of up to sixteen 80-bit message segments (within 112-bit transmissions) can be transmitted, either ground-to-air or air-to-ground and acknowledged with a single reply or interrogation. This acknowledgment indicates which, if any, of the message segments were not received (or received in error), so that only those need be retransmitted.

Extended-length messages do not contain the surveillance data and thus cannot substitute for a surveillance interrogation and/or reply. As in the case of the air-to-ground standard message, the transponder must request permission to transmit an air-to-ground ELM, and then does so under interrogator control.

Multisite Operation

The data link protocol for the standard ground-to-air message operates correctly in areas of overlapping sensor coverage without any requirements for site-to-site coordination. This permits the autonomous delivery of time-critical tactical messages under any circumstances. The other protocols, e.g., the air-to-ground standard and the extended length messages, require that only one sensor at a time exercise these protocols for a particular aircraft in order to avoid message loss or error.

SURVEILLANCE MANAGEMENT

DABS limits its surveillance to targets of interest, i.e., to those within a defined coverage volume. This contrasts with ATCRBS in which all targets within line-of-sight are interrogated. Control of the DABS sensor's surveillance and communications functions is based upon a prestored map which defines the action of the sensor for the regions of airspace within its visibility.

For an isolated sensor (one for which there are no other DABS sensors with continuous or overlapping coverage), the surveillance management functions are quite simple. They consist of defining the regions of airspace in which:

(a) the sensor provides surveillance and data-link service, and
(b) the sensor locks out DABS-equipped aircraft from responding to all-call interrogations.

As DABS sensors become deployed, multiple coverage will exist at higher altitudes. DABS includes a network management function to control the operation of the DABS sensors in this environment. Adjacent sensors will normally be netted and hence will communicate directly with each other, both to handoff targets as they cross surveillance boundaries, and to assist one another in maintaining continuity of surveillance and data-link service. Non-netted sensors will coordinate their surveillance activities using one of the alternatives previously described. Data link coordination is effected through the use of multisite coordination features incorporated in the DABS transponder.

As in the isolated sensor case, the basis for network management is a map prestored at each sensor which defines its reponsibilities for targets in each region of airspace. Not only does this map define the actions of the sensor itself, it also designates which adjacent sensors provide coverage of the same region of airspace and defines the location of coverage boundaries. Netted sensors refer to this map to determine which adjacent sensor can give it assistance in maintaining track on a given target, and when a sensor should initiate a handoff of the target to another sensor. Non-netted sensors use the map to determine when to use the transponder multisite coordination features for downlink or ELM transactions as well as to determine when to initiate periodic DABS unlocking to enable acquisition by an adjacent sensor.

Multiple sensor coverage is exploited in DABS to assure a continuity of both surveillance and data-link service. Where such multiple coverage is available, a target is always maintained simultaneously on roll-call of at least two sensors, thereby providing instantaneous backup in the event of the failure of one sensor/aircraft link. If for some reason a netted sensor loses contact with an aircraft, it calls on the adjacent tracking sensor for assistance in reacquiring the target.

In order to preclude possible ambiguities which can occur when two sensors simultaneously have an aircraft on their roll, a single sensor is normally designated primary in each region of airspace. The special functions which are the responsibility of the primary sensor are:

(a) readout of air-to-ground data-link messages,
(b) synchronous interrogation,
(c) lockout to DABS all-calls,
(d) ELM transactions.

The determination of which DABS sensor is to act as primary for a particular aircraft is made by the air traffic control facility which has control responsibility for the aircraft. This is done to ensure that air initiated data link messages are read out by the sensor connected to the controlling ATC facility. For uncontrolled aircraft, the DABS sensors make the assignment themselves, based on coverage map information.

DABS/ATC INTERFACE

The DABS/ATC interface is particularly simple in the case of an isolated DABS sensor interacting with a single control facility, e.g., a sensor at an airport interconnected only with the local TRACON. In this situation the sensor provides surveillance data to the TRACON, and operates as a relay point for data-link messages between aircraft and ATC.

In general, however, each sensor is capable of providing surveillance and communication service for more than one facility, and in turn each control facility may receive data from more than one sensor. This capability of greater connectivity permits control facilities to take advantage of multiple coverage to maintain surveillance and data-link service in the event of an equipment or link failure at a particular sensor. Surveillance boundaries between adjacent sensors are determined primarily by coverage geometry; these will not be the same as the control boundaries between adjacent ATC facilities, which are determined by air traffic flow patterns.

In general, a control facility will use the data from only one sensor to maintain its track on a particular aircraft. For an en route facility, data on the same aircraft may be available from another sensor as an instantaneous backup. Typically the data from the sensor designated as primary would be used, as presumably this sensor would have best coverage in a particular region of airspace. The control facility may use any sensor which has an aircraft in its track file for the transmission of standard ground-to-air data-link messages to that aircraft. In the case of a particularly urgent message, more than one sensor can be used simultaneously for ground-to-air message delivery to minimize the possibility of any delay in its reception.

OTHER INTERFACES

The DABS sensor will interface with other external devices and facilities. These include:

Data Link. In general, the data link processes will use the DABS sensor as a communications modem and will therefore use the same communications interface employed by the ATC facilities.

MTD/SRAP. Digitized radar data will be input to the DABS sensor via a special input port designated for this purpose. Provision is made to interface with either the Moving Target Detector (MTD) or the Sensor Receiver and Processor (SRAP).

Military Air Defense Command. A special configuration of back-to-back DABS sensor will operate at joint use sites. This configuration will include interfaces to military equipment to permit the coordination of beacon surveillance and secure IFF modes of operation. A special surveillance output interface is included to provide the military ATC facility with data in the proper format.

SYSTEM PERFORMANCE SUMMARY

Surveillance -

Capacity	- 250, 400 or 700 aircraft per sensor
Sigma-azimuth	- 0.06 deg., ± 0.033° bias
Sigma-range	- 50 feet, ± 150 feet bias
Data update interval	- 4 seconds (terminal sensor beacon data)
	- 5 seconds (enroute sensor)
	- 10 seconds (en route sensor primary radar data)

Data Link -

Capacity	All identified ATC messages require a few percent of available capacity.
Delivery Reliability	> 0.99 in 4 seconds for short tactical messages
Undetected error rate	$< 10^{-7}$

System Reliability -

Multiple coverage.
Automatic monitoring and network reconfiguration.
Automatic substitution of redundant sensor components without loss of database in case of failure.
Remote maintenance monitor.

The available interrogation time is sufficient to permit a sensor to maintain discrete-address surveillance of more than 1000 aircraft. This is considerably in excess of the maximum expected target load. A typical sensor would be sized with the processing capability or track file storage to accommodate a much smaller number, e.g., 400 targets.

The achievable range measurement accuracy is dominated primarily by transponder turn-around time uncertainty.

CHAPTER 2

THE DABS LINK

SIGNAL WAVEFORMS

There are five signal types used by DABS for surveillance of ATCRBS-and DABS-equipped aircraft, and data-link communication with DABS-equipped aircraft. These are:

(a) The ATCRBS/DABS all-call interrogation, used for surveillance of ATCRBS-equipped aircraft and acquisition of DABS-equipped aircraft not already on a sensor's roll-call.

(b) The ATCRBS-only all-call interrogation, used for surveillance of ATCRBS equipped aircraft in conjunction with the DABS-only all-call. It does not elicit a response from DABS equipped aircraft.

(c) The ATCRBS reply, used by ATCRBS transponders in replying to ATCRBS and ATCRBS/DABS all-call interrogations and by DABS transponders in replying to ATCRBS interrogators.

(d) The DABS interrogation, used for roll-call surveillance and data-link communication to DABS-equipped aircraft. It is also used for the DABS-only all-call interrogation format needed for the stochastic acquisition mode, site addressed lockout and lockout override functions.

(e) The DABS reply, used by DABS transponders in response to DABS interrogations and ATCRBS/DABS all-call interrogations and DABS-only all-call interrogations.

To maximize hardware compatibility between DABS and ATCRBS, DABS interrogations and replies use the same frequencies as are used for ATCRBS interrogations and replies, i.e., 1030 and 1090 MHz, respectively.

The characteristics of these signal types are summarized in the following paragraphs, together with the most common DABS data block formats. A more detailed description of the DABS interrogations and replies is presented in the DABS National Standard.

ATCRBS/DABS and ATCRBS-Only All-Call Interrogations

The ATCRBS/DABS and ATCRBS-only all-call interrogations are similar to the corresponding ATCRBS interrogations as defined in the United States National Standard for ATCRBS (Ref. 5) but with an additional pulse P4 following P3

(Fig. 2-1). A P-4 pulse width of 1.6 μsec defines the ATCRBS/DABS all-call interrogation, while a P-4 pulse width of 0.8 μsec defines the ATCRBS-only all-call interrogation.

An ATCRBS transponder is unaffected by the presence of the P4 pulse. It will respond with a normal ATCRBS reply. A DABS transponder will recognize the interrogation as a DABS all-call or ATCRBS-only all-call and transmit a DABS reply containing its discrete address to the former and not respond to the latter.

As in ATCRBS, DABS interrogator sidelobe suppression (SLS or ISLS) is accomplished by the transmission of a control pulse P2 on an SLS control pattern (usually omni-directional in azimuth). If this pulse is received by either an ATCRBS or DABS transponder at an amplitude exceeding that of the P1 pulse of the interrogation, the transponder will not reply.

ATCRBS Reply

The ATCRBS reply signal characteristics are as defined in the United States National Standard for ATCRBS. The signal format is depicted in Fig. 2.2.

DABS Interrogation

The DABS interrogation is formed by three pulses, P_1, P_2 and P_6 as illustrated in Fig. 2-3.

Pulses P_1 and P_2 form the preamble and are spaced 2 μs apart. An ATCRBS transponder which receives this interrogation will interpret the pair as an ATCRBS sidelobe suppression command and will remain in suppression (35 ± 10 μsec) during the remainder of the DABS interrogation. Without such suppression, the subsequent DABS P_6 pulse would, with high probability, trigger the ATCRBS transponder, causing a spurious reply.

The P_6 pulse of the DABS interrogation is either 16.25 or 30.25 μs long and contains the data in the form of DPSK (Differential Phase Shift Keying) modulation at a 4 Mbps rate. A phase reversal of the rf carrier at the beginning of a bit interval represents a binary one while the absence of such reversal denotes a binary zero.

The 4 Mbps rate permits transmission of 112-bit messages within the minimum available ATCRBS suppression interval. DPSK provides superior interference immunity, increased fade margin, and greater multipath immunity than pulse amplitude modulation (PAM). These advantages are realized at a small increment in transponder cost.

Transmit sidelobe suppression is accomplished by the transmission of a control pulse (P5) on an SLS control pattern. If the control pulse amplitude received by the transponder exceeds the amplitude of the interrogation, the sync phase reversal will be obscured and the interrogation will be rejected. With discrete address interrogations, transmit SLS is not required to prevent

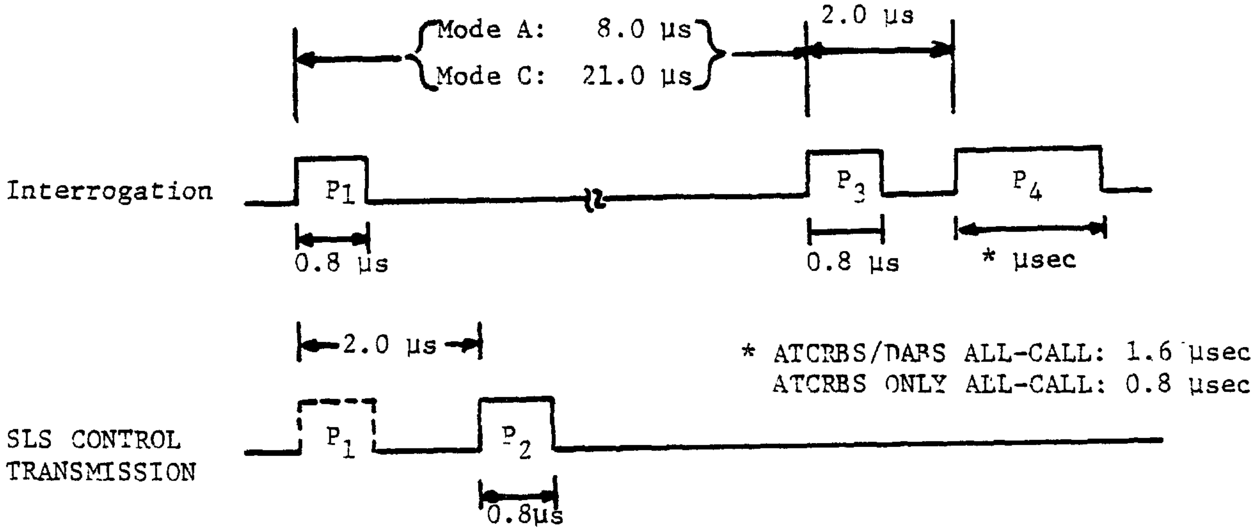

Fig.2-1. ATCRBS/DABS All-Call Interrogation.

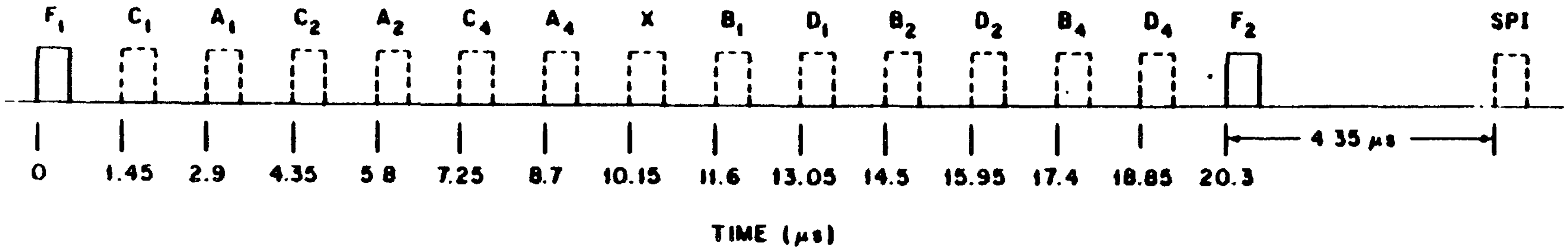

Fig. 2-2. ATCRBS Reply.

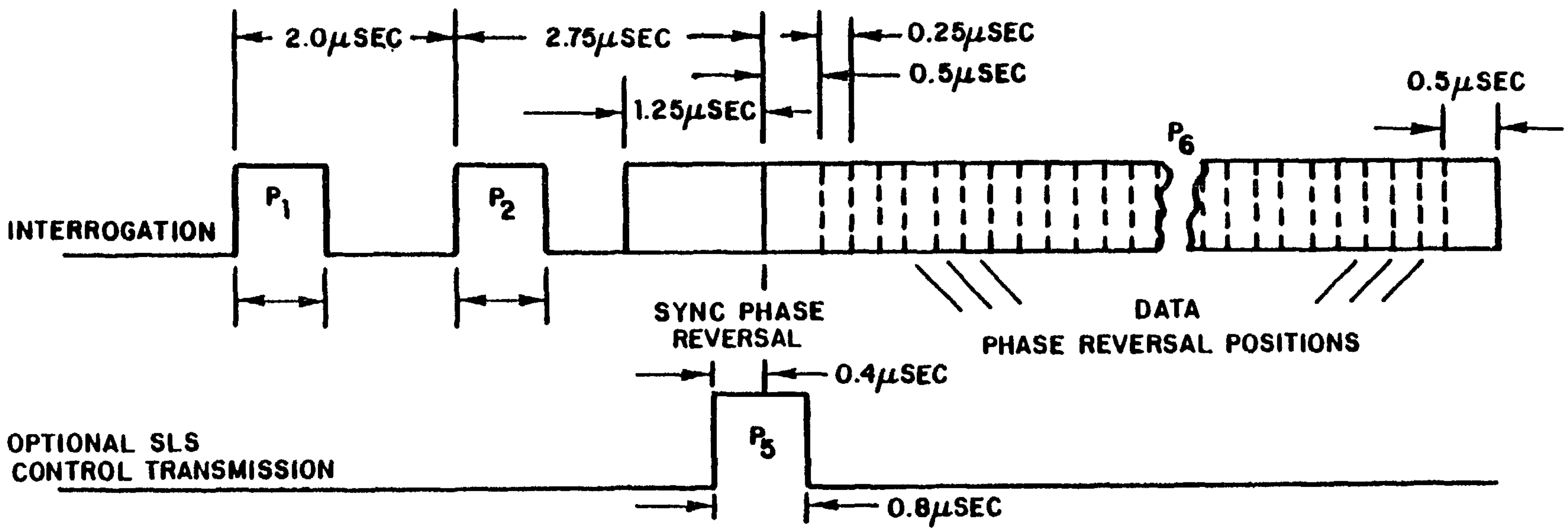

Fig. 2-3. DABS Interrogation.

sidelobe replies, as in general an aircraft will be interrogated only when in the mainbeam of the interrogator antenna. However, transmit SLS on discretely-addressed interrogations minimizes the probability of an aircraft erroneously accepting an interrogation directed to another aircraft; most such interrogations will be received through an interrogator antenna sidelobe, and thus will be rejected by the transponder without decoding.

DABS Reply Waveform

A DABS reply consists of a preamble and a data block containing 56 or 112 pulses. The signal format is depicted in Fig. 2-4.

The preamble consists of a series of four 0.5 μs pulses. The data block begins 8.0 μs after the leading edge of the first preamble pulse. Binary data are transmitted at a 1 Mbps data rate using pulse position modulation (PPM) as follows: in the 1.0 μs interval corresponding to each data bit, a 0.5 μs pulse is transmitted in the first half of the interval if the data bit is a 1, and in the second half of the interval if the data bit is a 0.

Transponder cost considerations limited the choice of reply signal formats to ones which could be generated by the proven, low-cost, pulsed-cavity oscillator transmitters currently used in ATCRBS transponders. Within that constraint, the reply format has been designed to achieve reliable air-to-ground operation in the presence of heavy ATCRBS interference.

The four-pulse preamble is designed to be easily distinguished from ATCRBS replies. It can be reliably recognized and used as a source of reply timing in the presence of one overlapping ATCRBS reply, while at the same time resulting in a low rate of false alarms arising from multiple ATCRBS replies.

The choice of PPM for the data modulation permits reliable bit detection in the presence of ATCRBS interference. In addition, PPM results in a constant number of pulses in each reply, assuring sufficient energy for an accurate monopulse estimate.

Operation at 1 Mbps, in combination with the use of the 24-bit parity check coding described below, further enhances downlink reliability by permitting the correction of any error pattern which can result from a single ATCRBS reply interfering with the desired DABS reply.

DABS SIGNAL CONTENT

The information transmitted in DABS interrogations and replies is contained in data blocks which can carry either 56 or 112 bits of information. The interrogation data block is formed by the sequence of (DPSK) phase reversals within P_6, while the reply data block is represented by the pulse position modulation of the DABS reply waveform.

Information within each data block is encoded in fields, each field existing for a dedicated purpose. All data blocks contain at least two essential fields, the format descriptor and the address/parity field. The

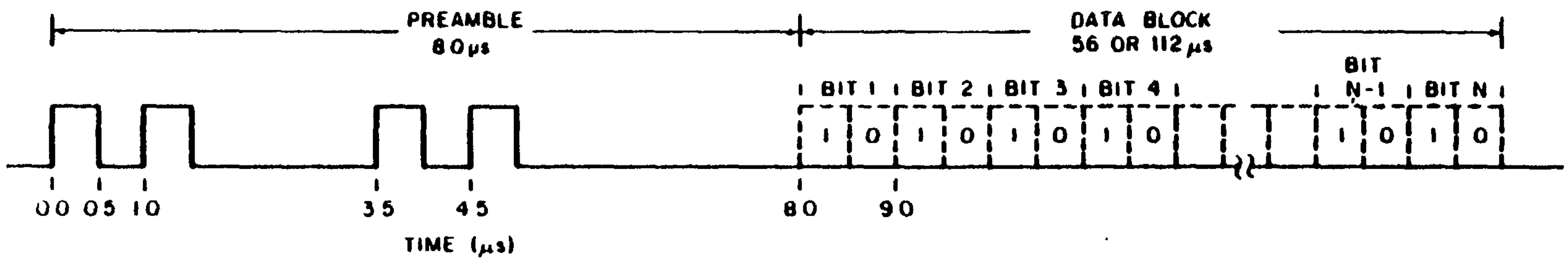

Fig. 2-4. DABS Reply.

5-bit format descriptor is transmitted at the beginning of each data block while the address/parity field is transmitted at the end. For different purposes and missions of the DABS system, 25 different formats can be used; 12 are presently defined. Format information is summarized in figs. 2-5 and 2-6 as well as Table 2-1. For details see the DABS National Standard.

The 24-bit address/parity field contains the aircraft's 24-bit unique address code overlayed on (summed bit-by-bit modulo 2 with) 24 parity check bits generated on the preceding part of the transmission, as illustrated in Fig. 2-7.

An error occurring anywhere in the reception of an interrogation or a reply will modify the decoded address. On the uplink, the transponder will not accept the message and will not reply, as the interrogation does not appear to be addressed to it. On the downlink, the interrogator will recognize that an error has occured, since the reply does not contain the expected address. Because the interrogator knows the address of the transponder replying to a discrete interrogation, the interrogator can perform a limited amount of error-correction. The code parameters have been selected to permit the correction of many error patterns which span no more than 24 bits. In particular, most bursts of errors caused by interference from a simultaneously-received ATCRBS reply can be corrected.

Format No.	UF	
0	(0 0000)(AQ:1)(BI:26)(AP:24).	Short Special Surveillance
1	(0 0001)—————27—————(AP:24)	
2	(0 0010)(EP:8)———19—————(AP:24).	Short Synchr. Surveillance
3	(0 0011)—————27—————(AP:24)	
4	(0 0100)(PC:3)(RR:5)(DI:3)(SD:16)(AP:24).	Surveillance, Altitude
5	(0 0101)(PC:3)(RR:5)(DI:3)(SD:16)(AP:24).	Surveillance, Identity
6	(0 0110)—————27—————(AP:24).	Ground-Air Coordination
7	(0 0111)—————27—————(AP:24)	
8	(0 1000)—————27—————(AP:24)	
9	(0 1001)—————27—————(AP:24)	
10	(0 1010)—————27—————(AP:24)	
11	(0 1011)(PR:4)(II:4)(--19 one's--)(AP:24).	DABS-Only All-Call
12	(0 1100)—————27—————(AP:24)	
13	(0 1101)—————27—————(AP:24)	
14	(0 1110)—————27—————(AP:24)	
15	(0 1111)—————27—————(AP:24)	
16	(1 0000)(AQ:1)(BI:26)(MU:56)(AP:24). .	Long Special Surveillance
17	(1 0001)—————83———————(AP:24)	
18	(1 0010)(EP:8)———19—————(MS:56)(AP:24). .	Long Synchr. Surveillance
19	(1 0011)—————83———————(AP:24)	
20	(1 0100)(PC:3)(RR:5)(DI:3)(SD:16)(MA:56)(AP:24). .	Comm-A, Altitude
21	(1 0101)(PC:3)(RR:5)(DI:3)(SD:16)(MA:56)(AP:24). .	Comm-A, Identity
22	(1 0110)—————83———————(AP:24). .	Ground-Air Coordination
23	(1 0111)—————83———————(AP:24)	
24	(11)(RC:2)(NC:4)(MC:80)(AP:24). .	Comm-C (ELM)

Notes: (1) (XX:M) denotes a field designated "XX" which is assigned M bits,
(2) ---N--- denotes free coding space with N available bits,
(3) UF (Uplink Format) codes 24 through 31 are reserved for Comm-C transmissions. The leading bits of these codes are always "11"; the remaining bits vary with the content of the RC and NC fields.

Fig. 2-5. Summary of DABS Uplink Formats.

Format No.	DF	
0	(0 0000)(AQ:1)(BR:13)(AC:13)(AP:24)	. . . . . Short Special Surveillance
1	(0 0001)——27——(AP:24)	
2	(0 0010)(EP:8)——6——(AC:13)(AP:24)	. . . . . Short Synchr. Surveillance
3	(0 0011)——27——(AP:24)	
4	(0 0100)(FS:3)(DR:5)(UM:6)(AC:13)(AP:24)	. . . . . Surveillance, Altitude
5	(0 0101)(FS:3)(DR:5)(UM:6)(ID:13)(AP:24)	. . . . . Surveillance, Identity
6	(0 0110)——27——(AP:24)	. . . . . Not Used
7	(0 0111)——27——(AP:24)	
8	(0 1000)——27——(AP:24)	
9	(0 1001)——27——(AP:24)	
10	(0 1010)——27——(AP:24)	
11	(0 1011)(CA:3)(AA:24)(PI:24)	. . . . . All-Call Reply
12	(0 1100)——27——(AP:24)	
13	(0 1101)——27——(AP:24)	
14	(0 1110)——27——(AP:24)	
15	(0 1111)——27——(AP:24)	
16	(1 0000)(AQ:1)(BR:13)(AC:13)(SC:56)(AP:24)	. .Long Special Surveillance
17	(1 0001)——83——(AP:24)	
18	(1 0010)(EP:8)——6——(AC:13)(MT:56)(AP:24)	. .Long Synchr. Surveillance
19	(1 0011)——83——(AP:24)	
20	(1 0100)(FS:3)(DR:5)(UM:6)(AC:13)(MB:56)(AP:24)	. .Comm-B, Altitude
21	(1 0101)(FS:3)(DR:5)(UM:6)(ID:13)(MB:56)(AP:24)	. .Comm-B, Identity
22	(1 0110)——83——(AP:24)	. .Not Used
23	(1 0111)——83——(AP:24)	
24	(11)—1—(KE:1)(ND:4)(MD:80)(AP:24)	. .Comm-D (ELM)

Notes: (1) (XX:M) denotes a field designated "XX" which is assigned M bits,
(2) —N— denotes free coding space with N available bits,
(3) DF (Downlink Format) codes 24 through 31 are reserved for Comm-D transmissions. The leading bits of these codes are always "11"; the remaining bits vary with the content of the KE and ND fields.

Fig. 2-6. Summary of DABS Downlink Formats.

TABLE 2-1

DABS FIELD DESCRIPTIONS

Code	Field Name		Downlink (D)/Uplink (U) Meaning
AA	Address Announced	D	Aircrf. identification in All-Call reply
AC	Altitude Code	D	equivalent to aircraft Mode-C code
AP	Address/Parity	U/D	error detection field
AQ	Acquisition	U/D	part of BCAS protocol
BR	BCAS Reply Data	D	special data for BCAS
CA	Capability	D	aircraft report of system capability
DF	Downlink Format	D	downlink descriptor
DI	Data Identification	U	describes content of SD field
DR	Downlink Request	D	aircraft requests permission to send data
EP	Epoch	U/D	synchro-DABS time indicator
FS	Flight Status	D	aircraft's situation report
ID	Identification	D	equivalent to ATCRBS identity number
II	Interrogator Identification	U	site number for multisite features
KE	Control, ELM	D	part of Extended Length Message protocol
MA	Message, Comm-A	U	message to aircraft
MB	Message, Comm-B	D	message from aircraft
MC	Message, Comm-C	U	long message segment to aircraft
MD	Message, Comm-D	D	long message segment from aircraft
MS	Message, Synchro-DABS	D	uplink synchro DABS message
MT	Message, Synchro-DABS	D	downlink synchro DABS message
MU	Message, Uplink	U	message without surveillance function
MS	Message, Synchro-DABS	D	uplink synchro DABS message
MT	Message, Synchro-DABS	D	downlink synchro DABS message
MU	Message, Uplink	U	message without surveillance function (BCAS etc.)
NC	Number, C-segment	U	part of ELM protocol
ND	Number, D-segment	D	part of ELM protocol
PC	Protocol	U	operating commands for the transponder
PI	Parity/Interr.Identifier	D	reports source of interrogation
PR	Probability of Reply	U	used in stochastic acquisition mode
RC	Reply Control	U	part of ELM protocol
RR	Reply Request	U	commands details of reply
SC	Special Communication	D	BCAS report
SD	Special Designator	U	control codes to transponder
UF	Uplink Format	U	format descriptor
UM	Utility Message	D	short message from aircraft

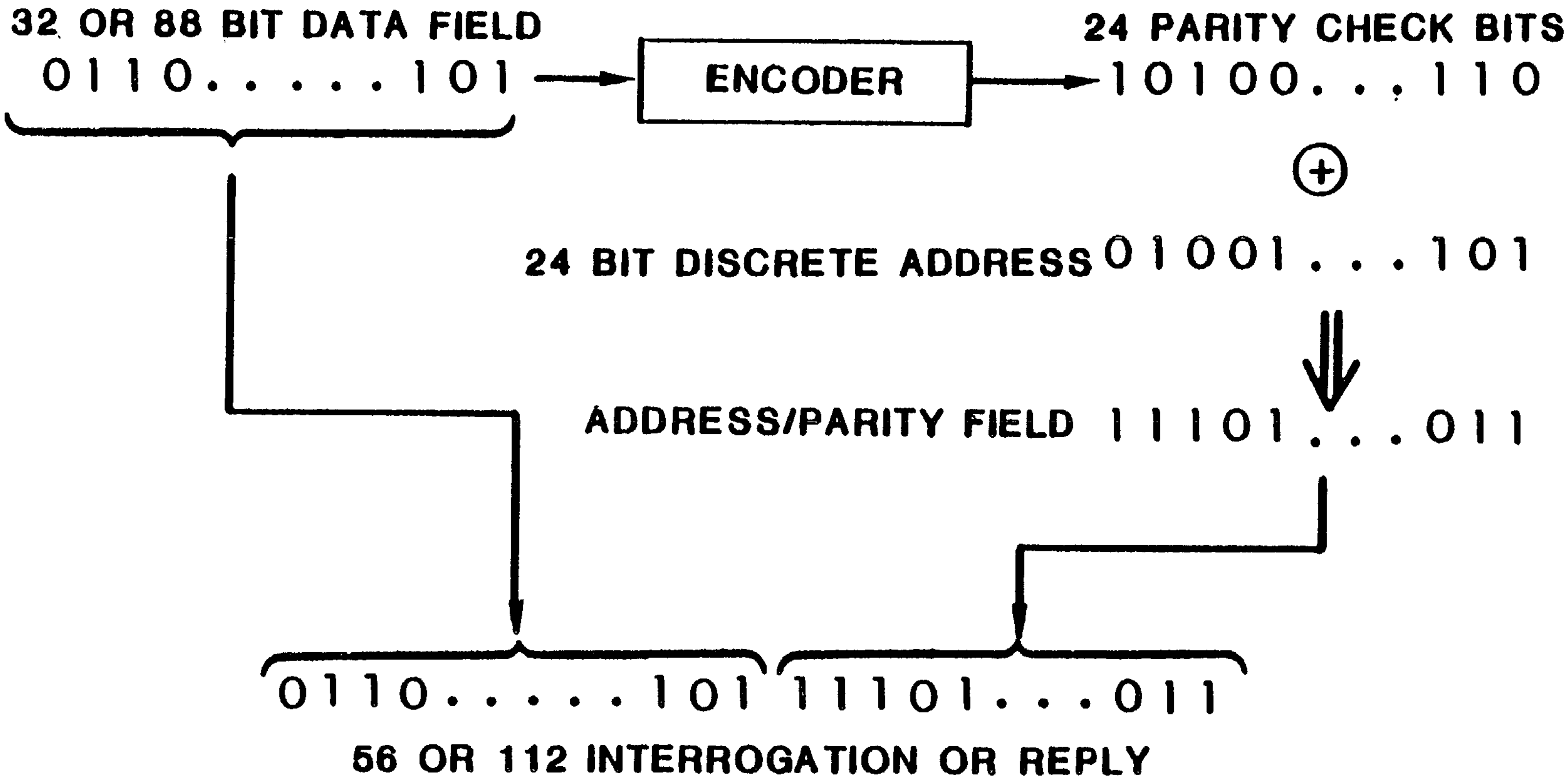

Fig. 2-7. Address/Parity Field Generation.

APPENDIX C

INTERFERENCE PREDICTION EQUATIONS

INTRODUCTION

This Appendix gives the basic equations that were presented in the ATCRBS/DABS EMC analysis report (Welch, 1978).

FRUIT EQUATIONS

The equation presented in the Welch report to compute the percent of environmental DABS replies (fruit) that is received by an ATCRBS ground sensor is given below:

$$\frac{F_r}{F_t} = \eta_m + (1-\eta_m) \times \frac{N(R_s)}{N} \qquad \text{(C-1)}$$

where

F_t = Total DABS transponder reply (fruit) rate is the environment, in replies/sec.

F_r = Received DABS reply (fruit) rate at an ATCRBS ground sensor, in replies/sec.

η_m = Fraction of 360 degrees coverage in which ATCRBS ground sensor antenna beam can receive fruit, (2 x 3dB beamwidth/360 degrees)

N = Total number of DABS aircraft within line-of-sight

$N(R_s)$ = Number of DABS transponder equipped aircraft within range R_s of the ATCRBS ground sensor's antenna sidelobe range, in nmi.

The value $N(R_s)$ in Equation C-1 is evaluated for a particular ATCRBS ground sensor site from aircraft traffic distribution curves.

The effective antenna sidelobe range R_s, assuming free space propagation loss is computed from the equation

$$R_s = \frac{\lambda}{4\pi} \sqrt{\frac{P_t G_t G_e}{T_R}} \qquad \text{(C-2)}$$

where

λ = Wavelength of frequency in nmi

P_t = Transmitter power of DABS transponder (nominally 500 watts)

G_t = Antenna gain of DABS transponder (nominally 1)

T_R = Receiver threshold of ATCRBS ground sensor, in watts

G_e = Effective sidelobe level of ATCRBS ground sensor antenna.

The effective sidelobe gain, G_e, of the ATCRBS ground sensor is defined in the Welch report as the gain of an omni antenna (omni in azimuth) that would result in receiving the same number of fruit replies as the sidelobe region of the actual antenna. The effective antenna sidelobe gain, G_e, is given by the equation

$$G = \left[\frac{1}{2\pi-\Theta_M} \int_{2\pi-\Theta_M} \sqrt{G(\Theta)}\, d\Theta\right]^2 \qquad \text{(C-3)}$$

for aircraft uniformly distributed in range, and by the equation

$$G = \frac{1}{2\pi-\Theta_M} \int_{2\pi-\Theta_M} G(\Theta)\, d\Theta \qquad \text{(C-4)}$$

for aircraft uniformly distributed area. $G(\Theta)$ in Equations C-3 and C-4 represent the sidelobe gain of the actual antenna as a function of azimuth Θ. The integration limits $2\pi - \Theta_M$ indicates that the integrals are evaluated over the entire antenna pattern except the mainbeam.

SUPPRESSION EQUATIONS

The ATCRBS/DABS EMC analysis report (Welch, 1978) presents equations for predicting DABS uplink suppression effects on ATCRBS transponder reply probability.

Discrete DABS interrogations include a preamble pulse pair (P1, P2) to suppress ATCRBS transponders and prevent them from replying. The Welch report states that the suppression rate, due to these interrogations, at an ATCRBS transponder within the effective sidelobe range of the DABS ground sensor is

$$N_{ss} = N_T/T\ (1+R)(1+D) \qquad \text{(C-5)}$$

where

N_T = Number of DABS transponders served by the sensor

R = Average reinterrogation rate of DABS ground sensor

T = Antenna rotation period of DABS ground sensor

D = Average number of data link interrogations required per aircraft

If the ATCRBS transponder is outside the effective sidelobe range of the DABS ground sensor, the suppressions associated with the discrete interrogation are only detected when the mainbeam illuminates the ATCRBS transponders. The suppression rate for this case is given by

$$N_{SM} = 1.5B/360\ N_{SS} \qquad \text{(C-6)}$$

where B is the 3 dB antenna beamwidth of the DABS sensor.

ATCRBS transponders in the DABS sensor antenna mainbeam are interrogated at a nominal All-Call rate of 150/s. DABS ground sensors will employ either sidelobe suppression (SLS) or improved sidelobe suppression (ISLS). ATCRBS transponders within the range of SLS or ISLS will receive a suppression rate of approximately 150 suppressions/sec over the entire antenna rotation. As pointed out in the ATCRBS description section of this report, ISLS is effective over a greater range than SLS. The range of SLS is the same as the effective sidelobe range of the directional antenna. The equations for suppression and interrogation rates, due to the combination of All-Call and discrete interrogations, at various ranges is given by :

$$N_S = \begin{cases} N_{SS} + 150 & \text{for } R_A < R_S \\ 1.5B/360\ N_{SS} + 150 & \text{for } R_S < R_A < R_I \\ 1.5B/360(N_{SS} + 150) & \text{for } R_I < R_A \end{cases} \qquad \text{(C-7)}$$

where

R_A = Range of ATCRBS transponder

R_S = Effective sidelobe range of DABS ground sensor directional antenna

R_I = Effective range of ISLS

This equation gives the average suppression/interrogation rate at an ATCRBS transponder due to a single DABS ground sensor. The Welch report also derives the equations for calculating suppression rates in a mixed DABS and ATCRBS environment involving multiple sensors. Two scenarios were considered. The equation below gives the suppression rate at an ATCRBS transponder that is outside the effective sidelobe range of all DABS and ATCRBS sensors, but within the SLS range of all ATCRBS and DABS sensors.

$$N_{ST} = \begin{pmatrix}\text{ATCRBS}\\ \text{SLS RATE}\end{pmatrix} + \begin{pmatrix}\text{DABS}\\ \text{SLS RATE}\end{pmatrix} + \begin{pmatrix}\text{DABS SURVEILLANCE}\\ \text{INTERROGATION RATE}\end{pmatrix} + \begin{pmatrix}\text{DABS DATALINK}\\ \text{INTERROGATION RATE}\end{pmatrix}$$

$$= 400N_A + 150N_D + \frac{N_T}{T}(1+R)\left(\frac{1.5B}{360}\right)N_D + \frac{N_T}{T}(1+R)\left(\frac{1.5B}{360}\right)D \qquad \text{(C-8)}$$

where

N_A = Number of ATCRBS sensors in the scenario

N_D = Number of DABS sensors in the scenario

N_T = Number of DABS transponders in the scenario

R = Average DABS reinterrogation rate

B = Antenna beamwidth

T = Antenna rotation period

D = Average number of data link interrogations required per aircraft

The total suppression rate at an ATCRBS transponder within the discrete interrogation sidelobe (effective sidelobe) range of one DABS sensor, and within the SLS range of all ATCRBS and DABS sensors was derived in the FAA report as

$$N_{ST} = \begin{pmatrix}\text{ATCRBS}\\ \text{SLS RATE}\end{pmatrix} + \begin{pmatrix}\text{DABS}\\ \text{SLS RATE}\end{pmatrix} + \begin{pmatrix}\text{DABS SURVEILLANCE}\\ \text{INTERROGATION RATE}\end{pmatrix} + \begin{pmatrix}\text{DABS DATALINK}\\ \text{INTERROGATION RATES}\end{pmatrix}$$

$$= 400\,N_A + 150N_D + \frac{N_T}{T}(1+R)\left[1+\frac{1.5B}{360}(N_D-1)\right] + \frac{N_T}{T}(1+R)\left(\frac{D}{N_D}\right)\left[1+\left(\frac{1.5B}{360}\right)(N_D-1)\right] \qquad \text{(C-9)}$$

The average number of data link interrogations required per aircraft, D, in Equations C-5, C-8 and C-9 greatly affect the computed suppression rates. The FAA defined air traffic scenario used to compute D is given by

$$D = 10F_H + 2.5F_L \qquad \text{(C-10)}$$

where

F_H = Fraction of DABS aircraft population requiring extended data link service

F_L = Fraction of DABS aircraft population requiring standard data link service

The factors 10 and 2.5 in Equation C-10 are based on the estimate that extended data link service requires an average of 10 interrogations per target per antenna rotation and standard data link service 2.5.

The percent of time that a transponder is in suppression was computed in the report using the equation

$$P_S = N_S \times T_S \qquad \text{(C-11)}$$

where

N_S = Suppression rate, suppressions per second

T_S = Time that transponder remains in suppression, in seconds.

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Abstract (Continued)

It was concluded that replacing FAA ATCRBS ground sensors with DABS sensors, operating according to FAA specified scenarios, will not reduce the performance of the remaining ATCRBS sensors or the DABS sensors. The compatibility of DABS with TACAN/DME, MLS/DME, and BCAS is operationally and technically manageable. The compatibility of the ATCRBS IFF Mark XII System (AIMS) and DABS is being addressed in a joint FAA and DoD EMC study.