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SIMULATION OF THE AIR TRAFFIC CONTROL RADAR BEACON SYSTEM (SOAR) WITH APPLICATION TO A DISCRETE ADDRESS BEACON SYSTEM. VOLUME I. TEXT

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Transportation Systems Center
Cambridge, Massachusetts

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Volume I: Text

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Mary Jane Miner

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16. Abstract

This report describes a computer simulation of the Air Traffic Control Radar Beacon System (ATCRBS). Operating on real air traffic data and actual characteristics of the relevant ground interrogators, the FORTRAN program re-enacts system operation in a pulse-by-pulse manner. The level of detail thus incorporated into the program structure enables a computer-generated representation of the air traffic controller's display to be produced. The versatility of the simulation model is further evidenced by the incorporation of program modifications which also make possible investigation of the Discrete Address Beacon System (DABS). These program modifications permit examination and evaluation of the effectiveness of DABS interrogations in an ATCRBS environment. Results of simulation of DABS operation in a 1980 interrogator environment are furnished in this document.

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PREFACE

The work described in this report was performed at the Transportation Systems Center (TSC) in support of the continuing effort of the Federal Aviation Administration (FAA) to improve the performance of the Air Traffic Control Radar Beacon System (ATCRBS) and to develop a Discrete Address Beacon System (DABS). Mr. Kleiman is Chief of the Beacon Systems Projects Office in the Aeronautical Programs Division at TSC, and Ms. Miner is an applied mathematician with the Information Sciences Division.

The authors are especially grateful to the following FAA personnel for their technical advice and enthusiastic support of the development and application of TSC's ATCRBS simulation program: Joseph Herrmann, Martin Natchipolsky, Kenneth Wise, Donald Asker, Richard Bowers, Thurman Duncan, Donald Jenkins, and Gerald Markey. The guidance of Sylvan Karlin, FAA project manager for the DABS investigations, and the DABS task coordination and technical information provided by William Harman of the MIT (Massachusetts Institute of Technology) Lincoln Laboratory are very much appreciated.

The computer services provided by the Boston Data Center of Control Data Corporation, particularly through the efforts of James Crook, have proven indispensable throughout development and application of the simulation program.

Paul Manning of TSC's Beacon Systems Projects Office has made many suggestions and supplied numerous technical explanations that have helped make the report more cohesive.

Finally, the authors are deeply indebted to Leon Tritter, technical writer with the Raytheon Service Company, whose services have been invaluable throughout the development of this report. Leon's outstanding ability to comprehend quickly and to express the content of numerous technical briefings, his careful attention to detail, and his devotion to the project have resulted in the logical flow of information set forth on the pages that follow.

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1. INTRODUCTION

The Transportation Systems Center (TSC) has been involved since July 1970 in an effort to improve the performance and operation of the Air Traffic Control Radar Beacon System (ATCRBS) in support of the Federal Aviation Administration (FAA). Both the present Second Generation Air Traffic Control System and the semiautomated Third Generation System now being implemented by the FAA depend primarily on the ATCRBS to provide information for air traffic controllers about the position and identification of transponder-equipped aircraft. The ATCRBS makes possible automatic reporting and display of aircraft altitude and identity for either the en route [National Airspace System (NAS)] or terminal [Automated Radar Terminal System (ARTS)] portion of the Third Generation ATC System. This automatic reporting capability is essential for the efficient operation of the Third Generation System, whose objective is to provide safer and faster ATC services despite increasing air traffic density. (Since many descriptions of the ATCRBS, its problems, and potential solutions to those problems have appeared in the literature, a system description is not included in this document. Readers unfamiliar with the operation of the ATCRBS are encouraged to read the article by Ashley* and to consult the extensive bibliography contained therein for supplementary background material.)

One of TSC's initial contributions to the solution of problems encountered in the daily operation of ATCRBS consisted of the design and implementation of a computer Simulation of the Air Traffic Control Radar Beacon System (SOAR), which was conceived as a means of analyzing system problems and testing solutions to them. The power of SOAR was quickly recognized, however, to encompass

*Ashley et al., "System Capability of Air Traffic Control Radar Beacon System," Appendix E-5, Report of Department of Transportation Air Traffic Control Advisory Committee, Vol. 2, Appendixes, December 1969.

not only the present and improved beacon systems, but also the proposed Discrete Address Beacon System (DABS) that would evolve from ATCRBS. As a result, TSC was asked in 1972 to modify SOAR for investigation of several phenomena of interest to the FAA and to the MIT Lincoln Laboratory in the development of DABS.

This publication documents SOAR and its application to the investigation of DABS as noted in the following brief summary:

a. Section 2 contains a general description of SOAR and its logical flow.

b. Section 3 presents in detail the transponder model originally developed for SOAR.

c. Section 4 discusses the DABS investigations undertaken, the simulation modifications involved, and the numerical results achieved.

d. Section 5 states the conclusions of the investigations.

e. Appendix A contains a technical development of the transponder reply rate limit control model.

f. Appendices B and C contain listings of the computer programs used to obtain numerical results for the investigation of two DABS phenomena.

g. Appendix D provides definitions of parameters used in tables B-1 and C-1.

2. DESCRIPTION OF SOAR

2.1 GENERAL BACKGROUND

The Transportation Systems Center (TSC) has conceived, designed, and implemented a simulation model, SOAR, which deals with situations similar to those experienced in real time by the ATCRBS. The model accepts simulated inputs analogous to real-time air traffic situations and ground interrogator environments, and, after processing them through the simulation system components, provides outputs which are determined by the various inputs. The outputs thus obtained contain data which, on analysis and interpretation, suggest the means for solving problems which are inherent in the ATCRBS and which are introduced into the model as parametric inputs. The computer program for SOAR is written in FORTRAN [CDC (Control Data Corporation) 6600 Extended FORTRAN, Version 3.0], which provides for flexibility, detail, and convenience.

2.2 BASIC OPERATION OF SOAR

a. The simulation model is designed to investigate conditions consistent with actual conditions at a typical ATCRBS site. Thus, the simulation model considers operations involving many interrogators and transponders within a given area (e.g., the terminal area), a number of different types of antennas, ground receiver equipment, target processors, and actual aircraft and interrogator characteristics. The operations, which include transmissions and replies from the numerous interrogators and transponders respectively, all occur within an interval of time known as a simulation cycle. This cycle represents the length of time between successive interrogations from the interrogator of interest, the interrogator to which all transponder replies are assumed to return. For a typical case, in which an interrogator transmits pulses to a transponder at a rate of 400 interrogations per second, a simulation cycle is equivalent to an interrogation repetition period of 2.5 milliseconds.

b. Operation of the simulation model is based on the following factors:

(1) Restriction of all transmissions and replies from interrogators and transponders to the time interval within the simulation cycle

(2) Simultaneous incrementing of antenna rotation for each interrogator at the beginning of each simulation cycle

(3) Selection of one of the interrogators as the interrogator of interest, i.e., the one which records on its display the effects of transponder replies to its own interrogation as well as transponder replies elicited by other interrogators

(4) Storage and final tabulation of data from the displays caused by interrogations and replies from all the other interrogators and all the transponders.

c. At the beginning of a simulation cycle, all the antennas at the respective interrogators are rotated by an incremental amount from their previous position. From this point in time until the end of the simulation cycle, all aircraft and interrogators remain motionless. During the interval, interrogation pulses are sent out from the interrogator of interest and from the other interrogators (as determined by program logic), and transponder replies are indicated on the display of the interrogator of interest. (Only indications on the display of the interrogator of interest are considered.) The replies from the respective transponders are valid only for the interrogations sent out by the interrogator of interest. Nevertheless, transponder replies and suppressions caused by all other interrogators in the area of concern are also tabulated and ordered in a manner suitable for evaluation. (The latter transponder replies are valid for the interrogators which triggered them. With respect to the interrogator of interest, however, they constitute spurious replies which cause beacon interference.)

2.3 BLOCK DIAGRAM DISCUSSION OF SOAR

2.3.1 General Structure

The simulation model functions in accordance with the event sequence indicated in the block diagram of figure 2-1. Except for the establishment of initial conditions and the operations inherent to the input, all the other operations involved in the simulation are performed within the simulation cycle interval (defined in paragraph 2.2.a). Initial conditions are established, inputs are applied to the simulation model, and the events constituting the simulation cycle are sequenced as described in the following paragraphs.

2.3.2 Input

The input portion of the simulation model has initial conditions read in as program data, typical of which are the following:

a. Characteristics of all ground interrogators

b. Characteristics of horizontal and vertical radiation patterns of directional and omnidirectional antennas

c. Position and attitude of all aircraft as functions of time

d. Transponder parameters

e. Defruiter gate length

f. Target detection criteria

g. Display characteristics.

Data and signal inputs are processed through the simulation system components to provide the outputs related to the OUTPUT block of figure 2-1.

2.3.3 State Update

The state update operation begins the simulation cycle. At the beginning of a simulation run, the input data referred to in paragraph 2.3.2 provide the initial conditions on which the first simulation cycle loop operation (figure 2-1) is based. On completion of the first loop operation, coincident with completion of

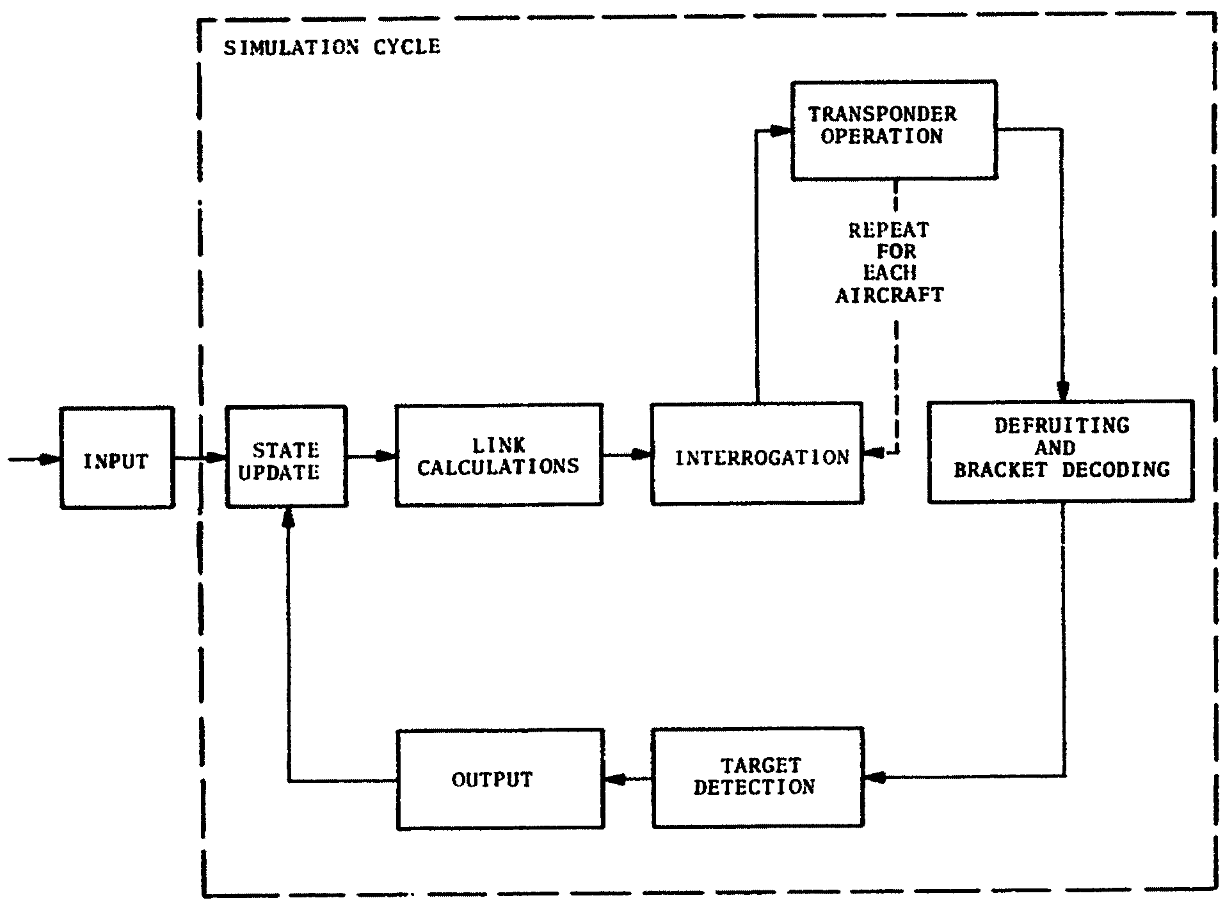

Figure 2-1. General Simulation Flow

the first simulation cycle, the output portion of the loop feeds back information to the state update portion, causing the succeeding simulation cycle to be initiated. Successive loop operations follow until the simulation run is completed. During the state update interval, at the beginning of a simulation cycle, a time counter is incremented. In addition, the pointing directions of all interrogator antennas are incremented, and the position and attitude of each aircraft are updated in accordance with the specified flight profile of the aircraft. Each interrogator antenna, which has been initially set to an arbitrary azimuth angle, is rotated by an increment according to its rotation rate. The state of each aircraft can be kept as it was for the initial input, or it can be modified at an arbitrarily selected number of updating times. The motion of an aircraft in a few milliseconds will not materially affect the system output of the simulation model. Therefore, instead of providing an update at every simulation cycle, and hence at every sweep, the simulation model user can choose an update interval equal to an integral number of sweeps. [A sweep refers to an interrogation repetition period. Therefore, for a moderate number of updates, say 20, and for an interrogation repetition frequency of 400 interrogations per second (or 2.5-millisecond interrogation repetition period), the update interval will be 50 milliseconds. This interval will not greatly affect the changing position and attitude of the aircraft. At the same time, relaxing of the updating frequency requirement helps to save computer processing time for the simulation run.]

2.3.4 Link Calculations

a. The next step in the processing of inputs to the simulation model involves determination of the parameters which describe the propagation of pulses between ground-site interrogators and aircraft transponders. The following parameters are computed in this portion of the processing:

(1) Signal propagation time between each interrogator and each aircraft

(2) Power attenuation of interrogator pulses (P_1 and P_3) due to the vertical radiation pattern of the interrogator antenna

(3) Attenuation of SLS (side-lobe suppression) pulses (P_2) due to the radiation pattern of the omnidirectional antenna

(4) Attenuation of all pulses due to free space loss and to the radiation pattern of the aircraft antenna.

b. The link calculation function can be bypassed under the following conditions:

(1) The state of an aircraft is not updated for one or more sweeps.

(2) The effect of interrogator pulse attenuation due to horizontal rotation of the interrogator directional antenna (during the non-updated sweep period) is accounted for in a subsequent part of the simulation program.

The following discussion provides additional data on these criteria.

c. During a non-updated sweep interval, the elevation angle of the interrogator directional antenna will remain fixed, and the aircraft transponder will stay fixed with respect to both the ground and its position in the previous simulation cycle. Therefore, the strength of signal contributed to the transponder by the interrogator beacon antennas, omnidirectional and directional, is constant for the conditions stated.

d. If only the above parameters were involved, the link calculation portion of the simulation program could be bypassed from the state update to the interrogation section of the program without further consideration of other parameters. However, during every sweep the interrogator directional antenna rotates in a horizontal plane. The directional signals transmitted to the transponder are therefore attenuated with change in position between the transponder and the center line of the transmitted directional beam.

e. Even with this antenna rotation parameter, the link calculation function can still be bypassed, for a non-updated sweep interval, from the state update to the interrogation section. This can be done by computing, for every sweep, the attenuation of the P_1 - P_3 pulses due to the horizontal radiation pattern of the rotating antenna. The computation will be accomplished in the interrogation portion of the simulation program.

2.3.5 Interrogation

a. The interrogation process consists of determining the time and mode of all interrogations that occur during the present simulation cycle, and the time of arrival and power of each interrogation pulse at each transponder. This process is performed serially with the transponder operation process to minimize storage of interrogation data. Thus, the effect of all interrogators on one transponder is computed, and the resulting transponder replies are stored. (The number of replies is considerably fewer than the number of interrogation pulses received.) The time of arrival and power of interrogation pulses at each of the other aircraft are then computed in sequence.

b. The determination of time of arrival of interrogation pulses is a complex process because of the many combinations of pulses that may fall into a particular simulation cycle. In the interrogation portion of the program, time of interrogation is defined as the time of transmission of a P_3 pulse. Time of arrival at a transponder is therefore the time of transmission plus propagation time. Any pulse transmitted by an interrogator during the present simulation cycle is assumed to arrive at a transponder between the time it is transmitted and 25 microseconds before the end of the next simulation cycle. Thus, an interrogation near the end of the present simulation cycle still has sufficient time to reach an aircraft more than two hundred nautical miles away. The response of such an aircraft is processed during the next simulation cycle, since uplink pulse arrival times (and corresponding pulse powers) which occur within the 25-microsecond interval before the end of the present simulation cycle are saved.

c. Any interrogation whose individual pulses occur before and after the time at which pulses are saved for the next simulation cycle is fully accounted for. It is this feature which involves significant complexity in the interrogation section of SOAR. As shown in figure 2-2, three uplink pulses can arrive at a transponder in such a way that they fall into separate simulation cycles. Furthermore, two interrogations from a site with a higher interrogation rate than that of the interrogator of interest may arrive during a single simulation cycle, while no interrogations may arrive during the cycle from a site with a lower rate. The number of interrogation pulses even further complicates the process, since the use of improved SLS, normal SLS, or no SLS can result in the detection of the following interrogation sets: (P_1, P_3), (P_1, P_2, P_3), (P_2), (P_1, P_2), (no pulse).

d. After time of arrival and power of all received interrogation pulses are determined for a transponder, the downlink pulse power that would be received by both directional and omnidirectional (for the receiver SLS option) antennas at the interrogator of interest is computed and stored. Uplink pulses are ordered chronologically, and the transponder operation portion of SOAR begins its operation.

2.3.6 Transponder Operation

2.3.6.1 Transponder Inputs. As the generated interrogation pulses enter the simulated transponder, they are processed in a manner which, with appropriate choice of transponder parameters, will satisfy the U.S. National Standard.* The following parameters, discussed in paragraph 2.3.5 with respect to the interrogation section of the program, form the basic inputs to the transponder:

a. Number of pulses, an alphanumeric representation of pulses arriving at the transponder during the present simulation cycle

*U.S. National Standard for the IFF Mark X (SIF) Air Traffic Control Radar Beacon System (ATCRBS) Characteristics, Order No. 1010.51A.

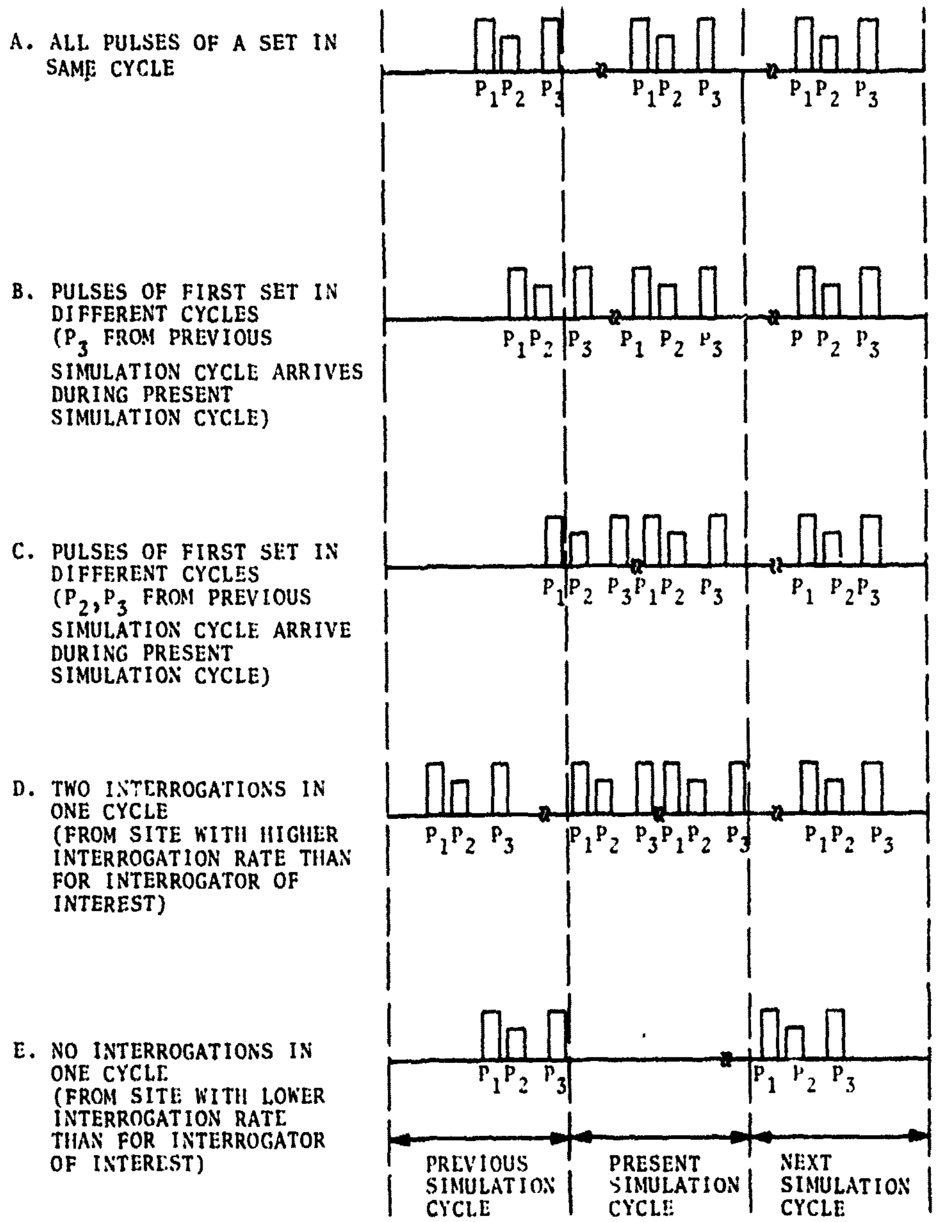

Figure 2-2. Possible Interrogation Arrival Times

b. Time of arrival of each of the pulses referred to in item a, expressed as the number of seconds from the zero reference start time of the simulation

c. Power in the pulses expressed in dB with respect to a one-milliwatt reference. (These parameters are also discussed in greater detail in paragraph 3.5 of Section 3.)

2.3.6.2 Characteristics. Transponder dead time after a reply and suppression time after a valid P_1-P_2 pair can be specified independently for each transponder. Desensitization occurs on receipt of every pulse (echo suppression) and when reply rate or suppression rate exceeds a specified level. (Additional details are provided in Section 3 on transponder dead time, suppression time, decoding, and desensitization.) Although the transponder model is designed nominally to reply to either mode A or mode C interrogations, it can be modified to reply to any combination of modes.

2.3.6.3 Types of Decoding. Two types of transponder decoding circuits can be selected:

a. Active, or Gate Type, Decoder. This decoder, on receipt of any pulse, waits for a potential P_3 pulse to be detected by the transponder receiver. When a P_3 pulse is properly detected, the decoder circuit triggers a coder which, in turn, provides coded pulses to the transponder transmitter for transmission of replies to the ground-site receiver. If, at an anticipated time after receipt of the initial pulse, a P_3 pulse is not detected, the decoder looks for another potential P_1 pulse. When a random single noise pulse or P_2 pulse is detected, the active decoder hangs up for 21 microseconds looking for a P_3 pulse, after which it looks for a potential P_1 pulse.

b. Passive, or Delay-Line, Decoder. This decoder looks for P_1-P_2 or P_1-P_3 pairs, and processes the first such pair detected. The passive decoder receives serially a set of pulses (P_1-P_2 or P_1-P_3 pulse-pairs), which are applied simultaneously as inputs to a delay line and an AND gate. One pulse of the pulse-pair enters the delay line (and the AND gate) and experiences a delay corresponding to the time separation between the two pulses of the pulse-pair. This delayed pulse is then transferred from the delay line as one input to the AND gate. At a later time corresponding to the same time separation mentioned above, the second pulse of the pulse-pair is applied to the delay line and to the AND gate. The AND gate therefore receives both inputs to it at the same instant, and coincidence is established. With coincidence, the AND gate provides an output which triggers the transponder to reply to the ground-site interrogator. (A single noise pulse will not establish coincidence at the inputs of an AND gate. Since the pulse-pair criterion is not met, the decoder will not provide an output.)

2.3.7 Defruiting and Bracket Decoding

a. Before the reply pulses generated by the SOAR transponder are processed further (i.e., in the elapsed time between the start of the present simulation cycle and the arrival of each reply pulse), they are ordered chronologically. Each reply pulse is then passed to the defruiter section. A reply pulse is considered valid (not fruit) if, within a certain tolerance, it arrives with the same elapsed time, and hence, with the same range, as another pulse on the previous sweep of the same mode. Otherwise, it is eliminated as fruit from further processing if the defruiter switch is on. The defruiter tolerance (also aperture or gate) can be specified arbitrarily by the user; one microsecond is a normal tolerance for most defruiters. Modes 1, 2, A, and C are all processed by the SOAR defruiter.

b. The model contains a fruit counter which registers all replies regarded as fruit by the interrogator/receiver of interest. The defruiter can be switched on or off, but, whether on or off, it permits transponder reply pulses to be routed through it to drive the fruit counter. The distinguishing feature between the switching states is that when the defruiter is switched off, all the reply pulses must be processed. When the defruiter is switched on, it removes the fruit pulses from further processing, and passes them on to the fruit counter. The fruit counter also includes the pulses consisting of the first hit on each mode for a valid target. The fruit pulse count divided by two provides the number of fruit brackets.

c. When the defruiter action is completed, those pulses that remain enter the bracket decoder. Any pair, or bracket, separated by 20.3 microseconds ($\pm$0.1 microsecond) is treated as a valid reply (whether or not it comes from a valid target). This reply is used to compute a reply range for subsequent processing and output. (The reply range is the speed of light multiplied by one-half the elapsed time between main interrogation and receipt of the first framing pulse. Transponder delay time, approximately three microseconds, is subtracted from the round-trip time.) Since the bracket decoder begins with the first pulse of the chronologically ordered reply time array, the reply range array is formed automatically by the bracket decoder in order of increasing range. Overlapping brackets are decoded as proper targets, since there is no pulse width, signal phase, or information pulse to cause garble. Potential garble situations and instances of pulse-train interleaving can be flagged, however, by checking the relative positions of adjacent bracket pulses.

2.3.8 Target Detection

Up to three target detectors may be selected to process the beacon reply data generated by the bracket decoder. The target detectors include those portions of the Common Digitizer (CD), ARTS (Automated Radar Terminal System) III, and TPX-42 responsible for beacon target declaration, but not for tracking. Any combination, including all three, of the target detectors may be chosen to operate on the same video information, thus allowing for a direct comparison among them.

2.3.8.1 Common Digitizer (CD)

a. During any simulation cycle, the CD processes replies only if a mode A interrogation was transmitted to begin the cycle; otherwise, CD processing is bypassed for that sweep. If CD processing is initiated, antenna azimuth is converted to azimuth change pulses (ACPs - 4096 per revolution), and reply range is truncated to 0.25 - nautical-mile accuracy. (A range-accuracy flag is also set to allow 0.125-nautical-mile accuracy in the final indication of target range.)

b. An array of 1024 computer words, each of which represents a quarter-nautical-mile range (range bin), contains the history of replies received from 0 to 256 nautical miles away. Although actual CD hardware records only the past eleven mode A sweeps, SOAR's simulated CD can record an arbitrary number of sweeps. This number of sweeps is referred to as the length of a sliding window. Each time a reply is received, the computer word corresponding to the range bin of the reply is shifted left one place, and a 1 is entered in the rightmost bit position; information to the left of the eleventh bit (from the right) in the CD, or an arbitrary bit in SOAR, is shifted out of the sliding window and is lost. For each range bin in which no reply is received during a mode A sweep, an identical shift occurs, but a 0 is entered in the rightmost bit position. Thus, a 1 in the sliding window indicates a hit, while a 0 represents a miss.

c. When the number of hits in a particular sliding window equals a leading edge threshold, T_L, selected by the user, then a leading edge flag is set (if it was not set previously) to indicate the start of a potential target in the range bin in question. Antenna azimuth (in ACPs) is also stored when the leading edge flag is set, i.e., when leading edge is declared; this azimuth is referred to as azimuth at target start. If an update of a range bin results in a number of hits, in the sliding window, which equals or exceeds T_L, and if the leading edge flag was set on some previous sweep, no further action is taken immediately; such a range bin is said to contain a potential target in process.

d. When a range bin update causes the number of hits in a sliding window to be equal to or less than a trailing edge threshold, T_T, also selected by the user, no further action is taken unless the leading edge flag is set. If the flag is set, the azimuth at target stop is stored, and a target is declared. The leading edge flag for that range bin is immediately reset to zero, and the target's center azimuth is computed.

e. As a result of the target detection operation described above, a target report is printed in the SOAR standard tabular output. The report includes:

(1) Range

(2) Start azimuth

(3) Stop azimuth

(4) Center azimuth.

2.3.8.2 TPX-42

a. During every simulation cycle, the TPX-42 processes replies regardless of the mode of interrogation that was transmitted to begin the cycle. If TPX-42 processing is initiated, antenna azimuth is converted to azimuth change pulses, and the number of replies (bracket pairs) received during the current sweep checked. Whenever the number of replies on a given sweep exceeds 20, the TPX-42 processes only the first 20 replies received. Reply range is truncated to 1/32-nautical-mile accuracy.

b. Instead of using 1024 fixed range bins, as in the CD, the TPX-42 employs floating range bins, which associate new replies with in-process targets by comparing the range of each new reply with the range of the most recent reply in each target register. This process avoids the problem of range splitting that occurs in the CD, because in the CD the range of each new reply is compared only with the range of the reply received at the time of declaration of leading edge.

c. Replies received during the present simulation cycle are stored in a reply array which is merged with an array of in-process target registers (maximum of 20 targets). Separate pointers are maintained for the number of the target register (old target register) being updated by new reply information and the update register into which the new information is inserted. Once an element of the reply array or an old target register has been processed, the appropriate pointer is incremented to avoid further reference to the processed data.

d. Like the CD, the TPX-42 employs a sliding window detector whose length, both in the simulation and in the actual hardware, is variable. A nominal window length of 8 is generally used. As in the CD, a 1 is entered in the window if a hit is encountered, and a 0 if a miss occurs. These processes are referred to as hit-update and miss-update respectively.

e. When TPX-42 processing begins, the old target registers are blank. A reply arriving during the present simulation cycle is inserted into the reply array, which is then compared with the array of old target registers. Since no old targets yet exist, all new replies are used to hit-update the old target registers, and thus the replies become new targets. The reply range and antenna azimuth are recorded for each new target, the window count is set to 1, and the leading edge flag is initialized to 0.

f. On subsequent simulation cycles, elements of the reply array are compared, one by one, with the old target registers. If no replies are received during a simulation cycle, then all old targets are miss-updated; values for old target range, azimuth, leading edge flag, and confidence count are transferred to new update registers in the in-process array, and a revised window count is stored similarly.

g. If both old targets and new replies exist during a simulation cycle, then the two arrays are compared, beginning with the first element in each. Both arrays are arranged in descending order of range. If the first reply range is greater (within a tolerance) than the first old target register, then it is assumed no old target can correlate in range with the new reply. The new reply is thus considered a new target (as described above) and is hit-updated and stored after the last old target in the in-process array. The reply array pointer is moved to the next closest reply, which is then compared with the same old-target register for which no correlation was found.

h. When, on the other hand, the reply range is less (within a tolerance) than the old target register range in question, then it is assumed no reply can correlate in range with the old target. The old target register is thus miss-updated as described above and stored in the next available update position in the in-process array. The old target pointer is moved to the next old target register, which is then compared with the same reply for which no correlation was found.

i. If the reply range equals (within a tolerance) the range stored in the old target register in question, then the reply is assumed to correlate with the old target register, which is hit-updated. Range of the reply and old-target leading edge flag, azimuth, confidence count, and window count are transferred to new update registers in the in-process array. Then both the reply array pointer and old target pointer are moved to the next element in their respective arrays.

j. After any hit-update, the interrogation mode for the present simulation cycle is checked. If the hit is in response to a mode A interrogation, then the confidence counter is incremented. When a target trailing edge is eventually found, a target is declared only if the confidence count exceeds some prescribed number, nominally 4.

k. Hit-updates are always followed by a test for leading-edge detection similar to that performed in the CD. Nominally, two hits out of eight are required to set the leading-edge flag. Miss updates are followed by a test for the trailing edge criterion, usually one hit in the sliding window. If trailing edge is detected and the leading edge flag is set, then a target is declared if the confidence count has been satisfied. Detection of trailing edge before the leading edge flag is set results in elimination of the old target from the in-process array.

l. When a target is declared, its center azimuth is computed from the azimuths recorded at the time of detection of leading and trailing edges. Target range is the range of the last recorded hit. The target report printed in the SOAR standard tabular output includes:

(1) Range

(2) Start azimuth

(3) Stop azimuth

(4) Center azimuth

(5) Confidence check value.

2.3.8.3 ARTS III

a. The ARTS III beacon target processor involves a more complex detection algorithm than that of the CD or TPX-42. SOAR limits the number of replies processed by the ARTS III to the first 30 received. If the mode of interrogation transmitted to begin a simulation cycle was other than mode A or mode C, the number of replies for that cycle is set to zero, and processing continues. At the start of ARTS III processing, antenna azimuth is converted to azimuth change pulses, and reply range is truncated to 1/16-nautical-mile accuracy.

b. ARTS III processing is similar to that of the TPX-42 in that a reply array is merged with an in-process target array. The ARTS III, however, merges the reply array with an array of old target registers, and stores the result in a separate array of new target registers. Both old and new target-register arrays are limited to 45 elements. Unlike the TPX-42, all arrays are kept in ascending order of range.

c. Rather than using a sliding window algorithm,the ARTS III employs an expanding window technique that requires the maintenance of several counters. A hit counter records the number of hits in all potential target sequences. A miss counter, which is zeroed after the receipt of any hit in a sequence, contains the number of consecutive misses. The sweep counter indicates the number of the current sweep since processing of the target in question began. Finally, a sum counter accumulates the sum of all sweep numbers on which hits occur. In addition to these counters, the in-process arrays contain a range register and a leading edge flag for each in-process target.

d. As with TPX-42 processing, the ARTS III begins with blank in-process arrays. All replies on the first sweep thus result in hit-updates that cause new targets to be processed. In this case, the hit-update consists of recording reply range, setting the hit, sweep, and sum counters to 1, and setting the miss counter and leading edge flag to 0 in the new-target array. Upon completion of the hit-update process for all replies, the new-target registers are transferred to the old-target array for subsequent processing.

e. Once in-process targets have been established, any simulation cycle in which no replies are received results in a miss-update for all in-process targets. This process involves incrementing the sweep and miss counters, and retaining prior values of the range register, hit counter, sum counter, and leading-edge flag for all targets.

f. When both replies and old targets are to be processed by the ARTS III, then, if the difference between the old target register range and the reply range is more than 1/16 nautical mile, a new target register is begun, and processing continues with the next reply. If a reply correlates (within 1/16 nautical mile) with an old target, a hit-update is performed, and the next reply and old target are examined. A reply range which exceeds old target range by 1/16 nautical mile results in miss-updating the old target in question and repeating the correlation process with the next old target in the array. This correlation process is identical to that of the TPX-42, except that the ARTS III arrays are processed beginning with the closest reply.

g. After a hit-update, the reply range for the target in question is recorded, the hit and sweep counters are incremented, the sum counter is increased by the value of the sweep counter, and the miss counter is reset. The counters are checked to determine if the leading-edge flag should be set, i.e., when a specified number (IHY3P3) of hits, nominally three, occurs before another specified number (IMY3P3) of consecutive misses, nominally two. Unlike the TPX-42, the ARTS III can issue a target report after a hit-update if the sweep counter exceeds a specified number (IRNGR3), nominally 31, that indicates a ring-around target. In such a case, the end of the target is assumed to occur immediately, a message indicating the target as a segment of a ring-around target is printed, and the in-process registers for that target are eliminated.

h. After a miss-update, target registers are checked to determine several conditions. If a specified number (IMY4P3) of consecutive misses, nominally four, is detected but the leading-edge flag is not set, the old target in question is discarded as interference. If the leading-edge flag is set, however, and the miss criterion (IMY4P3) for trailing edge detection is met, further checks for target validity are made. To be valid, a target's sweep counter must equal a minimum value or run length (IRMRP3), nominally 21, while its hit counter must meet a minimum hit criterion (IHY4P3), nominally seven. If the run length criterion is not met, processing continues; however, failure to satisfy the minimum hit requirement results in elimination of the target from the in-process array.

i. When a valid target is declared, the number of hits is also compared with a target quality criterion (ITQYR3), nominally 14. If met, this criterion results in the printing of a message indicating strong confidence in the computed azimuth of the target; otherwise, only the basic target report data are printed. The target report printed in the SOAR standard tabular output includes:

(1) Range

(2) Center azimuth

(3) Sweep counter

(4) Hit counter

(5) Sum counter

(6) Target quality message.

2.3.9 Output

a. After printing all input parameters at the start of program execution (table 2-1), SOAR provides a sweep-by-sweep account of the broadband target information, in addition to the selected target processor reports discussed above, as part of its standard tabular output (table 2-2). This broadband information consists of one printed line per sweep (simulation cycle) containing present time in seconds, antenna azimuth in degrees, interrogation mode, and range, in nautical miles, of all replies received during that sweep. Reply range is printed at a distance to the right of the interrogation mode proportional to the value of the range. The routine that determines the print position of a reply uses the input parameter RMAX as a scale factor. Thus, a simulation run that specifies RMAX = 60. will print 60-nautical-mile replies at the right side of a page, 30-nautical-mile replies in the middle, and 1-nautical-mile replies immediately after the interrogation mode. This feature is performed by over-writing all replies received during a sweep on the same line; thus, closely spaced replies may appear over-written, or garbled.

b. SOAR also tabulates several items of information which are printed at the conclusion of each scan. These items include the following:

(1) Running target counts for all three target processors

(2) Fruit count for each scan by mode of interrogation

(3) Average, maximum, and minimum fruit per scan to date

(4) Average, maximum, and minimum interrogation, reply, uplink SLS, and suppression rates for each aircraft

(5) Reply and suppression probabilities for each aircraft.

c. The pulse-by-pulse capability of SOAR enables it to drive a set of subprograms that produce a computer-generated representation of an air traffic controller's display (figure 2-3). The graphics software consists of FORTRAN and SC4020 plotter routines. Input to the graphics software includes time between frames. Thus, one can record either a full scan by specifying the scan time as

TABLE 2-1. SIMULATION INPUT PARAMETERS*

INT. NO.	ROTATION RATE (RPM)	PRF (INT/SEC)	INITIAL INT. AZIMUTH (DEG)	P1 POWER (WATTS)	LAT. (DMS)	LONG. (DMS) (WEST)	SITE ELEV. (FT)	ANT. HT. (FT)	START TIME (USEC)	P2 POWER WRT. P1 (DB)	MODE INTERLACE	DIR. ANT. GAIN (DB)	IISLS SWITCH (1 ON, 0 OFF)
1	15.07	400.	0.	700.	39.52.32.	74.14. 1.	0.	20.	0.	-00.0	[illegible]	20.	0
2	15.09	390.	127.	500.	40.38.11.	73.46. 3.	12.	33.	1695.	-15.0	AACAACAACAAC	21.	1
3	14.96	380.	133.	500.	40.41.43.	74.10.22.	0.	51.	2238.	-15.0	AACAACAACAAC	21.	1
4	12.01	350.	24.	500.	41.56.19.	73.41. 2.	173.	24.	2007.	-15.0	AACAACAACAAC	21.	1
5	15.00	370.	144.	500.	41.16. 3.	75.59.34.	250.	74.	1050.	000.0	333233323332	19.	0
6	20.00	275.	320.	500.	39. 7.46.	75.27.50.	20.	16.	1220.	000.0	333233323332	17.	0
7	15.04	200.	64.	500.	38.54. 0.	77. 0. 0.	214.	14.	2752.	-00.0	[illegible]	21.	0
8	15.07	280.	292.	500.	38.49.16.	77. 1.36.	284.	50.	757.	-15.0	333233323332	14.	0
9	6.03	350.	316.	1000.	38.50.53.	76.59.13.	284.	46.	2555.	000.0	333233323332	19.	0
10	6.07	350.	245.	1000.	38.50.53.	76.59.13.	190.	22.	26.	-00.0	333233323332	19.	0
11	14.94	400.	150.	500.	38.51.42.	77. 2. 2.	11.	27.	805.	-15.0	AACAACAACAAC	21.	1
12	10.06	294.	355.	500.	38. 9. 0.	76.25. 0.	30.	30.	567.	000.0	333233323332	19.	0
13	15.06	250.	15[illegible]	500.	3[illegible].10. 0.	76.40. 0.	24.	25.	167.	-15.0	333233323332	21.	0
14	14.97	375.	286.	500.	39.18.44.	76.41. 3.	157.	40.	1907.	-15.0	AACAACAACAAC	21.	1
15	15.06	353.	113.	500.	38.17.24.	76.24.29.	70.	29.	2507.	000.0	333233323332	21.	0
16	6.04	350.	270.	500.	[illegible]	[illegible]	[illegible]	80.	2425.	-15.0	AAAAAAAAAAAA	21.	1
17	6.92	360.	102.	1000.	38.17.10.	76.25.50.	66.	33.	103.	000.0	333233323332	20.	0
18	4.99	370.	97.	1000.	39. 6.59.	76.43.39.	297.	68.	1695.	-15.0	333233323332	21.	0
19	15.01	385.	45.	500.	38.48.44.	76.54. 2.	271.	55.	1481.	-15.0	[illegible]	21.	1
20	14.94	450.	318.	500.	39.28. 0.	76.10. 0.	50.	30.	937.	-15.0	333233323332	19.	0
21	5.03	241.	284.	1000.	42. 2. 0.	76. 3.13.	164.	46.	3021.	-15.0	333233323332	21.	0
22	12.07	292.	3.	500.	42.11.40.	73.33.21.	299.	39.	2107.	-00.0	333233323332	21.	0
23	14.84	300.	60.	500.	41.39.44.	76.31.23.	123.	27.	3040.	-15.0	AAAZAAAZAAAZ	21.	1
24	14.07	300.	296.	500.	42. 8.52.	76.54.30.	163.	15.	997.	000.0	333233323332	17.	0
25	5.03	350.	180.	1000.	42.23.21.	76.38.11.	60.	35.	1347.	-15.0	[illegible]	21.	1
26	4.96	370.	89.	1000.	42.16. 0.	71.53. 0.	1004.	30.	49.	-00.0	333233323332	21.	0
27	14.93	395.	86.	700.	42.21.41.	71. 0.37.	19.	30.	1261.	-15.0	AACAACAACAAC	21.	1
28	6.00	450.	335.	1000.	42.38.20.	71.14. 0.	133.	50.	615.	-15.0	333233323332	21.	0
29	14.01	2[illegible]5.	330.	500.	43. 5. 4.	70.40. 2.	83.	7.	615.	000.0	333233323332	21.	0
30	10.07	300.	205.	400.	40. 1.40.	74.21. 3.	90.	17.	404.	000.0	333233323332	17.	0
31	15.00	300.	120.	500.	40. 1. 0.	76.36. 1.	133.	52.	150.	-00.0	333233323332	21.	0
32	12.00	343.	324.	500.	[illegible]	[illegible].35. 2.	[illegible]	45.	1723.	-15.0	AAAAAAAAAAAA	21.	1
33	14.97	350.	265.	500.	39.27.25.	74.34.45.	76.	40.	1164.	-15.0	AACAACAACAAC	21.	1
34	5.02	360.	309.	1000.	39.35.19.	74.41.56.	119.	85.	210.	-15.0	AAAAAAAAAAAA	21.	1
35	13.06	380.	32[illegible].	500.	39.27.10.	74.35.32.	73.	28.	253.	-15.0	AAAAAAAAAAAA	21.	1
36	9.04	287.	133.	500.	40.44.13.	73.25. 9.	50.	30.	357.	-15.0	333233323332	19.	0
37	14.07	275.	142.	900.	44.30.54.	73.27.52.	223.	30.	1299.	-00.0	333233323332	20.	0
38	14.97	343.	34.	200.	41. 3.40.	73.42.55.	200.	41.	1147.	-15.0	AAAAAAAAAAAA	21.	1
39	6.07	350.	286.	1000.	42.38.16.	77.39.14.	2027.	45.	701.	-15.0	AAAAAAAAAAAA	21.	1

*Definitions of parameters related to above data are contained in Appendix D.

TABLE 2-1. SIMULATION INPUT PARAMETERS (CONT'D)

40	15.09	350.	50.	500.	43. 0.44.	78. 0.20.	400.	25.	1082.	-15.0	AACAACAACAAC	21.	1
41	5.95	355.	18.	1000.	40.39.45.	73.46.48.	18.	99.	1490.	-15.0	AAAAAAAAAAAA	21.	1
42	5.01	360.	6.	1000.	43. 9. 6.	75.37. 4.	445.	50.	303.	-00.0	333233323332	28.	0
43	9.91	370.	169.	500.	40.52. 0.	73.22.10.	50.	40.	1011.	-15.0	AAAAAAAAAAAA	19.	0
44	15.07	300.	46.	500.	42.44.44.	73.47.56.	370.	51.	1030.	-15.0	AACAACAACAAC	21.	1
45	14.90	390.	201.	500.	43. 7.14.	77.39.55.	542.	31.	915.	-15.0	AACAACAACAAC	21.	1
46	15.07	390.	5.	500.	43.13.41.	75.29.27.	374.	41.	1003.	-15.0	AACAACAACAAC	21.	1
47	15.05	395.	350.	500.	42.56.26.	78.44.11.	711.	37.	1132.	-15.0	AACAACAACAAC	21.	1
48	14.95	400.	194.	500.	42.12.30.	75.50.45.	1581.	57.	303.	-15.0	AAACAAACAAAC	21.	1
49	10.07	400.	234.	500.	43.40.24.	74.29.50.	50.	36.	1500.	-15.0	AAAAAAAAAAAA	21.	0
50	6.04	410.	232.	1000.	44. 2.11.	75.44.25.	670.	73.	1855.	-00.0	333233323332	20.	0
51	4.90	267.	118.	1000.	40.12.10.	75. 8.35.	369.	16.	490.	-00.0	333233323332	20.	0
52	14.94	300.	206.	500.	40.12.10.	75. 8.35.	369.	17.	3194.	-00.0	333233323332	17.	0
53	14.97	350.	267.	500.	41.20. 9.	75.43.10.	1037.	47.	2356.	-15.0	AAAAAAAAAAAA	21.	1
54	4.98	360.	245.	1000.	41.21.25.	76.17.36.	2500.	68.	2582.	-15.0	AAAAAAAAAAAA	21.	1
55	4.94	365.	154.	1000.	40. 0. 5.	74.59.14.	9.	33.	2235.	-15.0	AAAAAAAAAAAA	21.	1
56	5.97	370.	197.	800.	40.48.30.	77.52.40.	1200.	40.	2423.	-15.0	333233323332	23.	0
57	14.91	390.	228.	500.	40.13.24.	74.52.39.	494.	59.	1208.	-15.0	AAAAAAAAAAAA	21.	1
58	6.09	370.	2.	1000.	41.27.30.	71.26.30.	119.	32.	646.	-00.0	333233323332	23.	0
59	15.00	308.	314.	500.	41.30. 8.	71.24.40.	10.	58.	1781.	-15.0	AACAACAACAAC	21.	1
60	5.02	239.	326.	1000.	44.46.54.	73. 3.58.	1304.	36.	1620.	-15.0	333233323332	21.	0
61	5.97	340.	344.	1000.	44.29. 3.	73. 8.57.	337.	45.	483.	-15.0	AAAAAAAAAAAA	21.	1
62	4.97	281.	139.	1000.	37. 8. 2.	76.57. 4.	9.	99.	1827.	-15.0	AAA2AAA2AAA2	21.	1
63	6.09	250.	100.	1000.	36.49.46.	76. 2.20.	20.	50.	2831.	-00.0	333233323332	28.	0
64	5.03	267.	245.	1000.	38.30. 0.	77.10. 0.	12.	20.	1420.	-00.0	333233323332	25.	0
65	15.09	275.	179.	500.	37. 5. 7.	76.21.35.	13.	18.	686.	-00.0	333233323332	20.	0
66	15.07	300.	81.	500.	36.56.14.	76.17.33.	15.	9.	954.	-00.0	333233323332	17.	0
67	14.96	380.	347.	500.	38.57.24.	77.27.50.	295.	37.	871.	-15.0	AACAACAACAAC	21.	1
68	15.00	390.	91.	500.	37.30.19.	77.19.28.	157.	35.	2026.	-15.0	AAAAAAAAAAAA	21.	1
69	15.09	395.	318.	500.	36.53.44.	76.11.37.	75.	55.	1262.	-15.0	AACAACAACAAC	21.	1
70	5.09	380.	100.	1000.	37.31. 2.	78.10.38.	4226.	48.	8130.	-15.0	333233323332	21.	0
71	14.96	400.	197.	500.	40.29.53.	80.14.40.	1243.	38.	1605.	-15.0	AACAACAACAAC	21.	1
72	5.02	398.	232.	1000.	40.23.56.	80. 9.26.	1354.	54.	8008.	-15.0	AAAAAAAAAAAA	21.	1

STIME,SENSTV(I),REDUNS,RMU,RMX,KRSLS,RSLVL 0.0 -80.0 45.0 1.0 1.0 0 12.0
IAPNDR,BAC,ERPTT(I),DELAY,TSNZMX(I),TRRL(I),DESDIF,DEADT(I),SUPPT(I)
0 0.0 54.0 3.0 -77.0 1200.0 5.0 35.0 35.0
IRCREP(I),IRCSLS(I),RALCO,IRADYP,IRASWCH 0 0 0.00 1 1
TOF,PT 4.0 12.0
INPUT,DFRATE 1 1.0
IDD,IMC,ITI,ITT,BIAS,IC 0 11 6 2 1.00
KBRTS3,INY3P3,INY3P8,INY4R3,IRNBR3,ITQYR3,IRMRP3,INY4R3 0 3 9 4 31 14 21 7
KTPX42,IUMLX,ITLX,ITTX,ICONFK 0 8 2 1 4
ISMAX 0

TABLE 2-2. STANDARD TABULAR OUTPUT

```
    *          ARTS 3       SWEEP COUNTER =   22          TARGET RANGE   =  3.6250 NAUTICAL MILES
   * *         TARGET       HIT   COUNTER =   18          CENTER AZIMUTH = 271.4979 DEGREES
  *****        REPORT       SUMH  COUNTER =  171           *** STRONG TARGET AZIMUTH CONFIDENCE ***

   x x         TPX-42       TARGET RANGE    =  3.6250 NAUTICAL MILES       CONFIDENCE CHECK = 12
    x          TARGET       CENTER AZIMUTH = 271.4941 DEG (3089 ACPS)
   x x         REPORT       START  AZIMUTH = 268.9453 DEG (3060 ACPS)      STOP AZIMUTH = 274.1309 DEG (3119 ACPS)

  *****        COMMON       RANGE BIN              15     (  3.6875 NAUTICAL MILES )
  *   *        DIGITIZER    TARGET STARTS AT     3059     ( 268.8574    DEGREES     )
  *   *        TARGET       CENTER MARK   AT     3088     ( 271.4062    DEGREES     )
  *****        REPORT       TARGET STOPS  AT     3118     ( 274.0430    DEGREES     )
491.960 296.582 A     4.2
491.962 296.807 A     4.2
491.965 297.032 C     4.2
491.967 297.256 A     4.2
491.970 297.481 A     4.2
491.972 297.706 C     4.2
491.975 297.931 A     4.2
491.977 298.155 A     4.2
491.980 298.380 C     4.2
491.982 298.605 A     4.2
491.985 298.829 A     4.2
491.987 299.054 C     4.2
491.990 299.279 A     4.2
491.992 299.503 A     4.2
491.995 299.728 C     4.2
491.997 299.953 A     4.2
492.000 300.177 A     4.2
492.002 300.402 C     4.2
492.005 300.627 A     4.2
    *          ARTS 3       SWEEP COUNTER =   23          TARGET RANGE   =  4.1875 NAUTICAL MILES
   * *         TARGET       HIT   COUNTER =   19          CENTER AZIMUTH = 298.5438 DEGREES
  *****        REPORT       SUMH  COUNTER =  190           *** STRONG TARGET AZIMUTH CONFIDENCE ***

   x x         TPX-42       TARGET RANGE    =  4.1875 NAUTICAL MILES       CONFIDENCE CHECK = 13
    x          TARGET       CENTER AZIMUTH = 298.5645 DEG (3397 ACPS)
   x x         REPORT       START  AZIMUTH = 295.9277 DEG (3367 ACPS)      STOP AZIMUTH = 301.2891 DEG (3428 ACPS)

  *****        COMMON       RANGE BIN              17     (  4.1875 NAUTICAL MILES )
  *   *        DIGITIZER    TARGET STARTS AT     3366     ( 295.8398    DEGREES     )
  *   *        TARGET       CENTER MARK   AT     3396     ( 298.4766    DEGREES     )
  *****        REPORT       TARGET STOPS  AT     3427     ( 301.2012    DEGREES     )
CD TARGET COUNT FOR SCAN NO.  5 IS      3.
ARTS-3 VALID TARGET COUNT FOR SCAN NO.  5 IS      3.          RING AROUND TARGET COUNT IS      0.
TPX-42 TARGET COUNT FOR SCAN NO.  5 IS      3.
FRUIT COUNT FOR SCAN NO.  5 IS      12.        (FRUIT BY  MODE.  A -      6.  C -      6.  1 -      0.  2 -      0.)
AVERAGE FRUIT PER SCAN OVER  5 SCANS IS      10.    MAXIMUM IS      12     MINIMUM IS      4.
AVERAGE RATE OF INTERROGATION PER SECOND OVER  5 SCANS IS     4.444.    MAXIMUM IS    320.000.   MINIMUM IS     0.000.
AVERAGE RATE OF REPLY          PER SECOND OVER  5 SCANS IS     4.444.    MAXIMUM IS    320.000.   MINIMUM IS     0.000.
AVERAGE RATE OF UPLINK SLS   PER SECOND OVER  5 SCANS IS   105.706.    MAXIMUM IS    400.000.   MINIMUM IS     0.000.
AVERAGE RATE OF SUPPRESSION PER SECOND OVER  5 SCANS IS   105.706.    MAXIMUM IS    400.000.   MINIMUM IS     0.000.

REPLY PROBABILITY = 1.000      SUPPRESSION PROBABILITY = 1.000
```

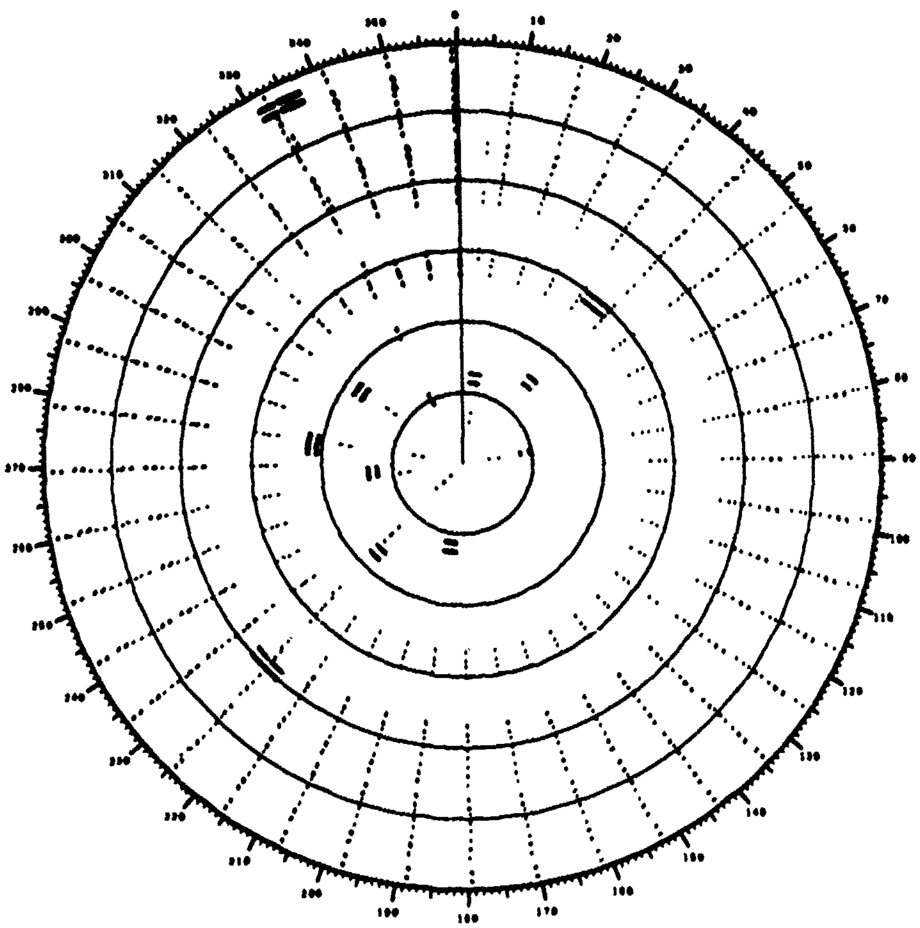

Figure 2-3. Example of Computer-Generated Air Traffic Controller's Display

the time between frames, or a real-time movie by specifying 1/24 second between frames. (TSC has produced such a movie for the Atlanta terminal area using a CDC6600 computer and a Calcomp 890 CRT plotter.)

3. DETAILED DESCRIPTION OF THE TRANSPONDER MODEL

3.1 TRANSPONDER REPLY/PRIMARY RADAR ECHO SIGNAL COMPARISON

The transponder, which plays a significant role in the radar beacon system, is the basis of the distinction between the primary radar system and the radar beacon system. Specifically, the airborne transponder, when triggered by pulses from a ground-based interrogator, returns to the ground-based interrogator a reply in the form of pulses of energy content dependent on the transponder's power capability. On the other hand, when a primary radar system transmits from its ground site a pulse to the aircraft target, the target reflects the pulse, and returns it to the primary radar system receiver as a relatively weak echo whose energy content is dependent on the physical properties which determine the radar cross section of the target. For the modes of excitation of the respective ground receivers described, a decided advantage is realized for the transponder type of reply over the echo signal return. In addition to the power capability advantage evidenced by transponder performance over the echo return, the transponder is equipped to send back coded replies which will identify the target and also provide information as to its altitude This feature is unique to the radar beacon system and to the transponder capability. By contrast, the primary radar system would require external operations to accomplish these functions (e.g., identification of an aircraft target by controller instructions for the aircraft to perform identifying maneuvers). Separation of the signal reflection function from the signal source (i.e., use of an airborne transponder-type reply rather than a signal reflected from an aircraft body) provides two additional advantages:

a. It eliminates clutter existing when the echo signal is returned to the primary radar receiver. (Clutter results from the ground effects of reflection of radiated energy from local and distant terrain, and masks legitimate aircraft echoes.)

b. It minimizes the potential for missed signals when the target is a small-sized aircraft. In this case, since the echo signal energy is related to target size, the returned signal strength could be of insufficient strength to be received by the primary radar receiver. A transponder, once triggered, sends back a signal whose strength is determined by the transponder's relatively strong power transmission capability, and, therefore, is independent of the target size.

3.2 TRANSPONDER FEATURES

The following text considers certain features which characterize transponder operation, including decoding, dead time, echo suppression, side-lobe suppression, hangup, desensitization, and reply rate limit control. A brief summary of basic transponder operation is also included to serve as background where required for the specific topics mentioned.

3.2.1 Summary of Transponder Operation

When a ground interrogator, as part of the ATCRBS, transmits a pair of coded interrogation pulses toward an aircraft target, a transponder contained in the aircraft is triggered by the pulse-pair to transmit a coded reply which is received by the interrogator of interest. The transponder receives triggering inputs and decodes them, and then codes and transmits replies with identification and altitude information which is received by the interrogator of interest.

3.2.2 Transponder Dead Time

When a transponder receives a valid interrogation, there is a delay of three microseconds between receipt of the P_3 pulse (the second pulse of the interrogator-transmitted pulse-pair) and transmission of the first pulse of the transponder reply. The transponder is so designed that, on completion of the reply pulse train, the transponder does not reply again for a period at least as long as the duration of a reply pulse train, and in some cases extending to 125 microseconds after transmission of the last transponder reply pulse. This period of inhibition is known as transponder dead time.

3.2.3 Side-Lobe Suppression Time

a. Side-lobe suppression time is a function of a P_2 pulse transmitted from the ground-based interrogator in conjunction with the transmission of the regular P_1-P_3 interrogation pulse-pair. Adoption of the side-lobe suppression feature stems from the need to suppress transponder triggering by the minor lobes of the transmitted beam. The following brief discussion describes the circumstances relating to development of the side-lobe suppression feature and to resulting side-lobe suppression time.

b. The transmitted interrogator signal radiation pattern contains, in addition to a main beam, a number of contiguous minor lobes. It is possible for these lobes, if sufficiently strong, to exceed the minimum threshold for triggering the transponder. Related effects of the following type can result from this form of transponder triggering.

(1) Broadened Targets. When a transponder is within range of the minor lobes of the directional antenna main beam, the minor lobes trigger the transponder and elicit replies which are received by the interrogator and indicated on the interrogator receiver display. The indications are very close to those representing replies to the main beam. The resulting display indication is a pattern much wider than would be obtained from a reply to the four-degree beamwidth of the directional antenna main beam. Broadening of the beamwidth affects the resolution of the target azimuth indication. In addition, it can also obscure a reply from a second aircraft transponder close to and at the same range as the first aircraft transponder.

(2) Ring Around. Broadening of the target on the interrogator receiver display will be increased if the aircraft

transponder remains within minor-lobe range for a longer period. As the aircraft transponder approaches the interrogator site, it can come within range of the minor lobes for a period encompassing the complete rotation of the interrogator directional antenna. In such a case, the transponder replies due to the minor lobes will be shown on the display throughout the rotation, and the indication on the display will be extended to a complete circle, or ring-around pattern.

(3) Multiple Targets. A transponder triggered by the minor lobe of a beam from a rotating directional antenna will cause a target reply pattern to be indicated on the interrogator receiver display. The aircraft transponder in its travel can leave the minor-lobe range and enter a null response space created by the vertical lobing characteristic of the interrogator directional antenna. At this time, the target display will be interrupted, because the transmitted beam power is insufficient to trigger the transponder. As the transponder continues in flight, it enters within the range of the main beam of the interrogator transmission. This again causes triggering of the transponder. The transponder reply to this triggering causes another target pattern to appear on the interrogator receiver display. Only one target has been triggered, but it appears as two targets on the display because of the vertical lobing of the directional antenna and the transmission of minor lobes together with the main beam. Also, the interrogator directional antenna wave pattern is the same for reception of signals as it is for transmission. If the antenna is within range of transmission from the aircraft transponder, the minor-lobe portion of the antenna can intercept the transponder transmission, and the interrogator receiver will indicate a target pattern on the receiver display. Therefor, when the aircraft transponder is triggered by an interfering interrogator station, it is possible for the interrogator

of interest to receive fruit because of the minor-lobe characteristic of its directional antenna.

c. Elimination of these degrading effects is accomplished by use of the side-lobe-suppression (SLS) feature, in which an additional pulse (P_2) is transmitted between the P_1 and P_3 pulse-pair. The P_2 pulse, transmitted separately by the interrogator transmitter on an omnidirectional antenna, is greater in power than the maximum side lobe. A transponder circuit compares the magnitudes of the P_1 and P_2 signals to determine whether the interrogation is in the main beam of the interrogator directional antenna. If the difference between P_1 and P_2 exceeds 9dB (P_1 greater than P_2), the transponder is not suppressed. If, however, the magnitude of P_2 is equal to or greater than P_1, the transponder becomes inhibited for a suppression time of 35 microseconds. The P_3 pulse, which arrives at the omnidirectional antenna of the transponder within this 35-microsecond suppression interval, is therefore rejected by the transponder. Since the transponder receiver has not received both pulses of the time-coded P_1-P_3 pulse pair, the transponder is not triggered. Thus, during the suppressed time interval, a side-lobe interrogation has been inhibited. This inhibiting function ensures that the transponder will be triggered only by the four-degree-wide main beam of the P_1 pulse.

Note: For magnitudes of P_2 between P_1 and 9dB below P_1, there is an area of uncertainty as to whether or not the transponder will reply to the interrogation. This tolerance range is permitted by the standards of ICAO (International Civil Aviation Organization) Annex 10. Reduction of this area of uncertainty, which in turn is a function of transponder capability, would provide the ground controller with more predictable transponder operation.

d. According to the U.S. National Standard, the suppression time period must be able to be reinitiated for the full 35-microsecond duration within two microseconds after the end of any suppression period. The simulation model transponder will not reinitiate suppression before a suppression time interval has elapsed, but will provide suppression time intervals after initial application of a P_2 pulse.

e. The SLS system described in paragraph c does not adequately provide for suppression of radar beacon replies to reflected interrogator main-beam signals. These replies cause erroneous indications of aircraft transponder location on the interrogator receiver display, and must be rejected in favor of replies from direct-line interrogations from the ground site transmitter's main beam. Rejection of the replies to reflected main-beam interrogations is accomplished by use of a modified, or improved, SLS system. This system uses to advantage the fact that reflected transmissions (from buildings, hangars, towers, and fences) are delayed in arrival due to longer path lengths to the aircraft.

(1) In the normal operation of the unmodified SLS system, a P_1 side lobe has sufficient amplitude to exceed the receiving threshold of the aircraft transponder receiver. This condition provides the initial P_1 pulse of a P_1-P_2 SLS pulse-pair at the transponder. The P_2 pulse, equal to or greater than the maximum side lobe of P_1, completes the SLS pulse-pair requirement, and causes a 35-microsecond suppression interval at the transponder. Any pulse arriving at the transponder within the suppression period (but after P_2) is rejected by the transponder. Therefore, if the main beam of the transmitted P_1 pulse strikes a reflecting surface, and, after reflection, arrives at the transponder within the dead-time period of the transponder, but more than two microseconds later than the P_1 side lobe, the reflected main-beam P_1 pulse is rejected.

(2) The conditions described in (1) are applicable for a P_1 side-lobe pulse which exceeds the receiving threshold of the transponder receiver. If the amplitude of the P_1 side lobe transmitted from the interrogator directional antenna is less than the receiving threshold, the P_1 side lobe is not detected by the transponder. The requirement for transponder detection of a P_1-P_2 pulse-pair is not met, and the transponder is not suppressed. Therefore, the reflected main-beam P_1 pulse and

the succeeding P_3 pulse provide a delayed pulse-pair interrogation to which the transponder replies. This reply, because of the increase in the time of arrival at the ground site receiver, represents an erroneous range which is greater than the true range of the transponder.

(3) The improved SLS system enables the P_1 side-lobe transmission to equal or exceed the transponder receiving threshold level. This is accomplished at the interrogator site by transmitting the P_1 signal from the ground site omnidirectional antenna as well as from the interrogator directional antenna. With this method of operation, the P_1 side-lobe amplitude is increased sufficiently to be detected by the transponder, and the P_2 pulse is the same as before, but still equal to or greater than the maximum side lobe. The transponder is now suppressed in the manner described in (1), and the reflected P_1-P_3 pulse-pair arrives during the suppression time and does not elicit a reply.

3.2.4 Decoding

a. The transponder passes the received pulses through its decoder, which determines the nature of the interrogation request and controls the type of coded replies to be sent back to the ground receiver. The active type of decoder exercises a hangup, or waiting, feature. That is, when it first receives a P_1 pulse, it waits for a second pulse which it can interpret as the second of a valid pulse-pair. This second, or P_3, pulse, together with the initial P_1 pulse, causes a reply to be coded by the transponder's coder and to be sent back to the ground receiver. (A P_2 pulse would also be interpreted as part of a valid P_1-P_2 pulse-pair, as signaling for initiation of a suppression time interval.)

b. The active decoder treats any first incoming pulse as a P_1 pulse, and then waits a proper time interval to interpret the next pulse as a valid P_3 (or P_2) pulse. If the first two-microsecond interval passes without a pulse (P_2), then it waits for an eight-microsecond interval beyond the P_1 pulse to interpret a mode A (identification) pulse-pair. If this time interval does not register a pulse-pair, it waits for a 21-microsecond interval beyond the P_1 pulse to interpret a mode C (altitude) information pulse-pair. If this mode is not detected, then the procedure is repeated on receipt of another pulse.

c. In keeping with this discussion, suppose that, instead of a P_1 pulse, a noise pulse is first detected by the decoder. The noise pulse will be presumed to be a P_1 pulse. Assume now that a valid P_1 pulse does arrive at the detector, but that this occurs at a time which does not correspond to a coded time interval (e.g., three microseconds after the noise pulse). In this case, even if a valid P_1-P_2 or P_1-P_3 pulse-pair arrives at the decoder after the initial noise pulse, it will fail to provide proper time spacing for the decoder to interpret this as a valid pulse-pair. For the 21-microsecond interval referred to above, there will be no response to these inputs, and the valid P_1-P_3 (or P_1-P_2) pulse-pair will have been lost because of noise interference.

d. The passive decoder performs on the basis of receiving pulse-pairs and determining that the first pair detected constitutes a P_1-P_3 interrogation pair or a P_1-P_2 suppression pair. The basic delay-line action associated with the passive decoder is described in paragraph 2.3.6.3b.

3.2.5 Desensitization

a. The transponder circuitry provides for reduction of receiver sensitivity when interrogation pulses are applied to the receiver input. This desensitizing action reduces the possibility of interference from echoes following reception of the interrogation signals. (The echoes referred to here correspond to late multiple arrivals of the interrogation pulses, and to reflections from ground or ground-based structures close to the interrogator.) Figure 3-1 illustrates the concept of an echo pulse following an interrogation pulse.

Figure 3-1. Echo Pulses

Figure 3-2 indicates the time function of response patterns for the interrogation pulses. The solid curve represents dB response plotted with respect to time for transponder receiver signal inputs of varying strengths. The minimum triggering level of -71dBm is shown from t = 0 to t = 1, at which time an interrogation pulse causes the receiver to be desensitized to approximately -57dBm.

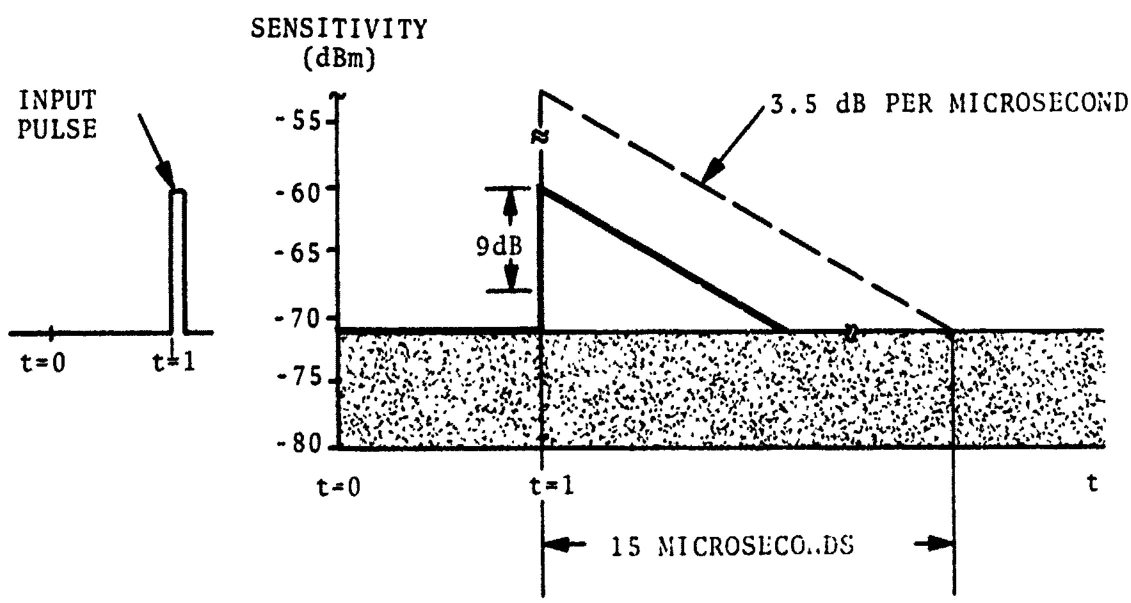

Figure 3-2. Desensitization and Recovery Characteristics

Note: According to figure 3-2, at t = 1 the receiver sensitivity has decreased by an amount corresponding to the power of the input pulse, in this case 14dB. The U.S. National Standard (DOT-FAA Order No. 1010.51A) specifies that an input pulse more than 0.7 microsecond in duration must cause a receiver to desensitize by an amount within 9dB of the power of the input signal. With respect to figure 3-2, the peak value of receiver desensitization can occur within the 9dB region indicated in the figure. The user of the simulation model provides an initial value, nominally 5dB, as the difference between the power of the input signal and the peak receiver desensitization just prior to beginning of the recovery period.)

The receiver then begins to recover its sensitivity toward -71dBm immediately following the interrogation pulse. The recovery is linear in nature. It attains a sensitivity within three dB of the minimum triggering level in a time interval no greater than 15 microseconds after the desensitizing pulse has been received. The linear rate of recovery occurs at an average rate not greater than 3.5dB per microsecond and within a period not greater than 15 microseconds. The maximum values are shown in the dotted portion of the curve in figure 3-2, with the recovery rate along the negative slope, and with the maximum allowable time along the t axis.

b. A second type of desensitization occurs when the transponder reply rate exceeds a certain limit. This limit can be arbitrarily set to any rate between 500 and 2000 interrogations per second. (The limit in the simulation model reply rate limit control circuit is nominally 1200 interrogations per second.) When once set, however, any interrogation rate exceeding the limit will desensitize the transponder. (This type of desensitization is covered in detail in Appendix A.)

3.3 TRANSPONDER MODEL SIMULATION AS PART OF SOAR PROGRAM

The program for transponder simulation is in fact a part of the overall program for SOAR. (The entry and exit for the transponder program are designated as statements 1203 and 7 respectively of the SOAR program, and are referred to and commented on in the tabular summary of table 3-4.) The following description of the overall simulation program for SOAR is equally applicable for the transponder when the scope of the functions mentioned is narrowed to the transponder alone.

3.4 BRIEF DESCRIPTION OF THE SOAR SIMULATION PROGRAM

The computer program for the SOAR model provides input data, operational instructions, and outputs involved in the simulation of actual air traffic conditions at air terminals or at en route sites. Processing of the input data and performance of the instructions furnish computer outputs which make possible analysis, interpretation, evaluation, and ultimate decision-making on the basis of the computer input/output relationships. The basic presentation on data handling and computation is contained in paragraph 2.2. The parameters and instructions which form the program for problem solution are presented in the following paragraphs.

3.5 TRANSPONDER INPUTS

Three basic inputs are applied to the transponder. These are tabulated and described in table 3-1. Additional pertinent information relative to the inputs is given below.

a. NPULS. This variable integer changes for each simulation cycle because of variations in other system parameters, such as antenna variations.

b. TXPNDR (I). This variable, a time characteristic of the pulse variable, represents an array in which subscript I can vary from 1 to NPULS. The time is expressed in seconds, and is referenced with respect to the zero start time of the simulation.

TABLE 3-1. TRANSPONDER INPUT PARAMETERS*

Input	Description
NPULS	Number of pulses entering the transponder during the present simulation cycle
TXPNDR (I)	Time of arrival of the I^{th} pulse at the antenna end of the aircraft transponder
PXPNDR (I)	Power (dBm) of the I^{th} pulse at the antenna end of the transmission line between aircraft antenna and transponder

*Program parameters for inputs, outputs, and intermediate functions are expressed in mnemonic form.

c. PXPNDR (I).

(1) The third variable of the input group relates to power in the pulses transmitted from the ground site interrogator to the aircraft transponder. Each value of PXPNDR(I) represents the power in the interrogator pulse (dB with respect to 1 milliwatt reference) for the I^{th} pulse reaching the antenna end of the transmission line between the aircraft antenna and the transponder.

(2) The energy content of the pulse is also characterized with respect to transponder receiver sensitivity, in terms of the minimum triggering level (MTL) of the transponder receiver. The nominal MTL is -71dBm (71dB below the 1- milliwatt reference level), but levels within the range -69dBm to -77dBm are considered acceptable. (These requirements assume a 3-dB loss in the transmission line from the aircraft antenna to the transponder receiver input, and aircraft antenna performance equivalent to that of a quarter-wave antenna.) The transponder receiver must operate satisfactorily for signal inputs which vary in amplitude range between the MTL and 50dB above the MTL of the particular transponder receiver being considered. (Stronger signal inputs may saturate the transponder receiver and degrade its operation; this is an acceptable condition provided the specification has been met within the above-mentioned input signal amplitude range.)

3.6 TRANSPONDER OUTPUTS

The outputs from the transponder are indicated by the simulation program parameters IREPLY and REPLY(J).

a. IREPLY. This variable integer indicates the number of reply pulses (i.e., the sum of all F_1 and F_2 framing pulses) transmitted by the transponder during the present simulation cycle. Since a transponder reply consists of a frame bracket, or F_1-F_2 framing puls-pair, the number of replies to the interrogator of interest is equal to half the value of the variable IREPLY. The value of variable IREPLY changes for each simulation cycle in accordance with input parameter changes, which, in turn, are caused by variations in system component parameters at the beginning of each simulation cycle.

b. REPLY(J)

(1) This parameter represents the time of the J^{th} reply of an array in which subscript J can vary from 1 to IREPLY. The total time involved in the computation of this variable by the program occurs between the following bounding times:

(a) The time of transmission of P_3 of the interrogation pulse-pair that began the present simulation cycle

(b) The time of arrival of the J^{th} reply pulse at the ground site receiver.

(2) The time required for a reply to reach the interrogator of interest is determined by use of equation 3-1. The parameters related to REPLY(J) are described in table 3-2.

REPLY(J) = TXPNDR(I) + DELAY + PROPTM (1,L) - TRANP3 (3-1)

(3) Solution of equation 3-1 provides the arrival time, at the ground receiver, of the first reply pulse F_1. Arrival time of the second reply pulse (F_2) is determined by use of equation 3-2. In the use of these equations, the subscript J, which is initially 1, is incremented as the number of reply pulses increases.

REPLY (J+1) = REPLY (J) + 20.3 E-06 (3-2)

The Fortran E-notation 20.3E-06 represents a 20.3-microsecond spacing between transponder reply framing pulses F_1 and F_2, within which coded pulses are inserted to

TABLE 3-2. PARAMETERS RELATED TO COMPUTATION OF REPLY (J)

Parameter	Description
TXPNDR(I)	Time of arrival of the I^{th} pulse at the antenna end of the aircraft transponder. In this case, the pulse is equivalent to the P_3 pulse of the interrogation transmitted to the transponder. (Refer also to paragraph 3.5b.)
DELAY	User-specified parameter, given at the beginning of the program. (This parameter is defined and applied by the user of the imulation in accordance with his arbitrarily assigned conditions. In actual practice, however, the U.S. National Standard specifies a transponder reply delay as 3.0 ± 0.5 microseconds between the leading edge of the interrogation P_3 pulse and the leading edge of the first pulse of the reply.)
PROPTM(1,L)	Time of propagation between a particular interrogator and the L^{th} aircraft. The interrogator is identified by the first number within the parentheses. In the mnemonic shown, the number 1 indicates that the propagation is to the interrogator of interest.
TRANP3	Time at which the P_3 pulse from the interrogator of interest was transmitted at the ground site. This time is given with reference to zero start time of the simulation.

constitute coded transponder replies to the ground site transmitted interrogations. (Insertion of coded pulses between framing pulses F_1 and F_2 relates to aircraft transponders in actual use. The simulation model transponder reply function does not require definition of any specific reply code; hence, it makes use of the framing, or bracketing, pulses only.)

3.7 TRANSPONDER PROGRAM LISTING DETAILS

3.7.1 Program Content

The remaining paragraphs of Section 3 cover that portion of the simulation model computer program relating to transponder operation. Together with the descriptive information on transponder input and output parameters contained in paragraphs 3.5 and 3.6 respectively, this section provides the programmed steps through which the transponder functions are realized. The inputs to the transponder in the simulation model approximate those detected in actual transponder operation.

3.7.2 Transponder Functions Covered in Program

The following functions are covered in the program listing for the transponder. (The program listing for transponder operation is contained in table 3-5.)

3.7.2.1 Desensitization

a. When input pulses are received at the transponder, the transponder receiver undergoes desensitization in accordance with either of the following operational purposes:

Echo suppression

Reply rate limit control.

b. In the first approach to desensitization, a pulse received at the transponder antenna causes the transponder receiver sensitivity to be reduced by an amount within 9dB of the desensitizing signal. (According to the U.S. National Standard, DOT/FAA

Order No. 1010.51A, the desensitization must not exceed the value, in dB, of the desensitizing pulse.) This action prevents the transponder receiver from being influenced by echo interference signals. The desensitization can be caused by a pulse from an interrogation pair, or by a pulse from a suppression pair, or even by a noise pulse. In every case, however, desensitization is followed by a recovery period during which the receiver sensitivity is restored in the manner described in paragraph 3.2.5.

c. In the second method of receiver desensitization, an incoming interrogation or suppression pulse-pair is detected by a reply limit control circuit in the transponder receiver. When the pulse-pair is properly decoded, a reply is generated from the transponder, and, at the same time, the supply voltage to the IF stages of the transponder receiver is reduced. The latter action decreases the sensitivity of the transponder receiver. After desensitization, the receiver sensitivity is recovered exponentially in a manner described in detail in Appendix A. (Refer also to paragraph 2.3.6.3 for a discussion of the decoding action with respect to the passive decoder portion of the transponder receiver.)

d. Implementation of the sensitivity reduction feature by reply rate limit control occurs when the transponder reply rate exceeds a rate established in the reply rate limit control circuit. Although the control circuit and the simulation model permit limit control adjustments to values between 500 and 2000 replies per second, the simulation model uses a nominal reply rate limit of 1200 replies per second. The sensitivity reduction for a reply rate exceeding the reply rate limit by more than 50 percent (e.g., 1800 replies per second for the simulation model) must be at least 30dB.

e. The following text presents the equations which form the quantitative determination of transponder sensitivity for both echo suppression and reply rate limit control.

(1) Transponder Receiver Sensitivity [TSNSTV(JAC)]. The dynamic transponder receiver sensitivity takes into account the effects of desensitization due to echo sup-

pression and to reply rate limiting. It also includes the maximum sensitivity of the transponder receiver, as noted in equation 3-3.

TSNSTV(JAC) = TSNSMX(JAC) + TDSNEC(JAC) + TDSNRL(JAC) (3-3)

The maximum transponder receiver sensitivity TSNSMX(JAC) corresponds to the MTL (minimum triggering level) of the transponder receiver, and has a nominal value of -71dBm in the simulation model. The desensitizations (in dB) due to echo suppression [TDSNEC(JAC)] and to reply rate limiting [TDSNRL(JAC)] are positive quantities which are added to TSNSMX(JAC) to provide the dynamic sensitivity of the transponder receiver.

(2) Desensitization Due to Echo Suppression [TDSNEC (JAC)]. This time-varying parameter corresponds to the sensitivity variations indicated by the negative-slope line in figure 3-2 of paragraph 3.2.5. Its value is determined by the relationship of parameters in equation 3-4.

TDSNEC(JAC) = TDESEC(JAC) - 3.5E+06* (TXPNDR(I) - TTDSEC(JAC)) (3-4)

At the time when the last desensitizing pulse is applied to the transponder and just before sensitivity recovery begins, the echo suppression parameter TDSNEC(JAC) has its maximum desensitizing value, and is identical to TDESEC(JAC) (see table 3-3). Recovery then begins, and proceeds at the rate of 3.5dB per microsecond. The time of interest for computation of TDSNEC(JAC) is the difference between the time of desensitization for the last pulse which caused desensitization to occur [TTDSEC (JAC)] and the time of arrival of the current pulse of interest [TXPNDR(I)].

(3) Peak Desensitization Due to Echo Suppression [TDESEC(JAC)]. (The following statement applies to an I pulse or to a J pulse. The illustrative equation 3-5 will refer to the I pulse.) This para-

meter expresses the difference between the power in the most recent pulse received by the transponder [PXPNDR(I)] and the desensitization difference (DESDIF) which the transponder experiences, in accordance with the specification in the U.S. National Standard, DOT/FAA Order No. 1010.51A, on receipt of an input pulse. This mandatory reduction in receiver sensitivity is discussed in the Note of paragraph 3.2.5. Since the computation is done with the transponder receiver maximum sensitivity [TSNSMX(JAC)] as zero reference, this value is also subtracted from PXPNDR(I). The relationship is shown in equation 3-5.

TDESEC(JAC) = PXPNDR(I) - DESDIF-TSNSMX(JAC) (3-5)

(4) Desensitization Due to Reply Rate Limiting [TDSNRL(JAC)]. This contribution to desensitization in the equation for total receiver dynamic sensitivity [TSNSTV(JAC)] is given by equation 3-6:

```
TDSNRL(JAC) = 60*ALOG10(12./ (12.-(12.-TDESRL(JAC))*
  EXP((TTDSRL(JAC) - TXPNDR(I))/ALTAUR(JAC)))        (3-6)
```

The basis for this equation is the equation for the total change in the minimum detectable signal S_R (in dB) due to the reply rate limit control:

$$S_R = 60 \log_{10} [V_o/V_{(t)}] \qquad (3\text{-}7)$$

(See Section III, SUMMARY, of Appendix A.)

Comparison of equations 3-6 and 3-7 shows that:

S_R corresponds to TDSNRL(JAC);

V_o corresponds to 12; and

$V_{(t)}$ corresponds to the denominator in equation 3-6.

$V_{(t)}$ also corresponds to equation (2) of Appendix A. The correspondence is indicated in the equations reproduced below for comparison:

From Appendix A, equation (2),

$$V_{(t)} = V_o - \left[V_o - V(t_D^+)\right] e^{-(t-t_D)/\tau T_R}$$

From equations 3-6 and 3-7 of Section 3,

$V_{(t)}$ = (12.-(12.-TDESRL(JAC))* EXP((TTDSRL(JAC)
- TXPNDR(I))/ALTAUR(JAC)))

3.7.2.2 Decoding. In the decoding process, the time separation between input pulses is interpreted. For example, if the transponder recognizes two input pulses separated by a two-microsecond spacing, it will interpret them as a P_1-P_2 suppression pulse-pair. Similarly, if two pulses received by the transponder are separated by 8 microseconds or by 21 microseconds, the transponder will decode them as a corresponding mode A or mode C (P_1-P_3 pulse-pair) interrogation. (Only mode A and mode C decoders are incorporated in the current transponder.)

3.7.2.3 Inhibition. The transponder program listing includes statements which determine that certain intervals of time represent either suppression (SLS) or interrogation dead time. In the first case, the information will be related to the fact that a P_2 pulse preceded immediately before the time space being investigated. In the latter case, the dead time in question will have immediately followed the P_3 pulse of an interrogation.

3.7.3 Transponder Program Listing Parameters

Parameters used in the transponder program listing are expressed as mnemonics, and are referenced and defined in table 3-3.

3.7.4 Transponder Program Listing

a. A listing of the transponder portion of the simulation program is preceded by a flow chart of the simulation routines (figure 3-3) and by a tabular summary of the program statements (table 3-4). The combination of flow chart and summary clarifies the steps of the program, and also serves as a guide to the step sequence in the actual program listing of table 3-5.

b. The flow chart provides a program step sequence which furnishes a quick insight into the overall simulation function of the transponder. The functional blocks have numbers associated with them; these numbers correspond to the identically numbered statements, in the simulation program, to which the block functions are applicable.

c. The tabular summary expands upon and clarified the simulation program step sequence which determines transponder operation. The Statement Content column (table 3-4) reproduces the program statements in text form. The Comments column explains the basis on which the statements are made, interprets the statements, and references previous material relevant to the particular statements.

TABLE 3-3. TRANSPONDER PROGRAM LISTING PARAMETERS

Parameter	Description
ALTAUR (JAC)*	This parameter represents a combined-form time constant $\alpha\tau_R$. The time constant is part of an equation which determines the exponential recovery of voltage in a reply rate limit control circuit just after desensitization. For additional information on determination of this exponential recovery and the contribution of this exponential recovery and the contribution of time constant $\alpha\tau_R$, refer to the discussion in Appendix A (Transponder Reply Rate Limited Control Model for ATCRBS Simulation), and particularly to equation (2) of that discussion.
DEADT (JAC)	An input parameter representing the time interval during which the transponder will not reply to any other interrogation. This time interval, which can last from 0 to 125 microseconds, begins on completion of a transponder reply to a proper interrogation. Therefore, when referencing the dead time period to the P_3 pulse of the interrogation, the following times must be added:

*In this case, and wherever else it occurs in table 3-3, the parenthesized expression JAC signifies that the mnemonic with which JAC is associated applies to an array of aircraft (and their transponders), of which the Jth aircraft is the aircraft of interest. (Also refer, in table 3-3, to the definition of JAC.)

TABLE 3-3. TRANSPONDER PROGRAM LISTING PARAMETERS (CONT'D)

Parameter	Description
DEADT (JAC) (Cont.)	3 microseconds - time delay, from reception of the P_3 pulse by the transponder to beginning of the transponder reply 20.3 microseconds - reply time, from leading edge of framing pulse F_1 to leading edge of framing pulse F_2 0.45 microsecond - width of framing pulse F_2 4.35 microseconds - time interval following a framing pulse F_2, reserved for application of an SPI (special position identification) or IDENT pulse initiated by a pilot.
DELAY	A parameter related to computation of REPLY (J). (See table 3-2.)
DESDIF	Desensitization difference. This parameter contributes to the degree of desensitization which a transponder receiver undergoes on receipt of a pulse more than 0.7 microsecond in duration. It is expressed as the difference between the power of the input pulse and the peak desensitization caused by the input signal. The allowable variation in this difference is between 0 and 9dB. A nominal difference of 5dB from the input pulse power is used in the simulation model program. For additional information on this topic, refer to paragraph 3.2.5 and figure 3-2.
HFTAUR (JAC)	This parameter equals 1/2 τ_R. It is used in the computation of TDESRL (supply voltage to the transponder receiver IF amplifiers just

TABLE 3-3. TRANSPONDER PROGRAM LISTING PARAMETERS (CONT'D)

Parameter	Description
HFTAUR (JAC) (Cont.)	after the most recent desensitization) under conditions where the reduction in voltage, ΔV, is an exponentially varying quantity. [Refer to Appendix A and the discussion relative to equations (1) and (7).]
IREPLY	A variable integer which indicates the number of reply pulses (sum of all F_1 and F_2 framing pulses) transmitted by the transponder during the present simulation cycle. (See paragraph 3.6a.)
IRLREP (JAC)	A parameter which indicates whether a transponder reply rate limit control circuit is activated by an interrogation. The reply rate limit control circuit is activated when the parameter equals 1, and not activated when the parameter equals 0.
IRLSLS (JAC)	A parameter which indicates whether a transponder reply rate limit control circuit is activated by suppressions. The reply rate limit control circuit is activated when the parameter equals 1, and not activated when the parameter equals 0. If both IRLREP (JAC) and IRLSLS (JAC) equal 1, both interrogation and suppression pairs cause reply rate limit action.
JAC	J^{th} aircraft. An interrogator of interest interrogates one aircraft transponder at a time. For the first aircraft transponder interrogated, JAC = 1; for the second, JAC = JAC + 1, and for the third, JAC = JAC + 1. This type of designation occurs for successive interrogations until JAC = NACRFT, the maximum number of aircraft appearing during the present simulation cycle.

TABLE 3-3. TRANSPONDER PROGRAM LISTING PARAMETERS (CONT'D)

Parameter	Description
KNTINT (JAC)	A parameter which indicates a running count of transponder replies
KNTSLS (JAC)	A parameter which indicates a running count of suppressions
KRSLS	Receiver side-lobe suppression switch. The switch is off when the parameter equals 0, and on when the parameter equals 1.
NPULS	Transponder input parameter. (See table 3-1.)
PROPTM (1,L)	Parameter related to computation of REPLY (J). (See table 3-2.)
PXPNDR (I)	Transponder input parameter. (See table 3-1.)
PXPSAV (JAC)	This parameter represents the power in an uplink pulse (arriving at the J^{th} aircraft) which is saved for future insertion as the first value of the next PXPNDR (I) array.
REDSNS	Reduced sensitivity, arbitrarily introduced in the program. It is the number of dB by which the initial sensitivity of the transponder received has been reduced due to STC (sensitivity time control) action, and it can vary from 0 to 50dB. (The nominal value for use in the simulation model is 45dB.)
REPLY (J)	Transponder output parameter. (See paragraph 3.6b.)
REPTIM	This parameter indicates the reply time for a reply pulse from the J^{th} aircraft. The time required for the reply to reach the interrogator of interest is determined by the following parameters:

TABLE 3-3. TRANSPONDER PROGRAM LISTING PARAMETERS (CONT'D)

Parameter	Description
REPTIM (Cont.)	TXPNDR (J) - time of arrival of the J^{th} pulse at the antenna end of the transponder.
	DELAY - Transponder reply delay between leading edge of the J^{th} pulse and the leading edge of the first pulse of the reply
	PROPTM (1,JAC) - Time of propagation between interrogator of interest and the J^{th} aircraft
	TRANP3 - Time at which the J^{th} pulse (in this case equivalent to a P_3 pulse) was transmitted at the ground site. This time is referenced to the zero start time of the simulation.
	[Note: REPTIM as used in the program listing (table 3-5) is interchangeable with REPLY (J), equation 3-1 of paragraph 3.6b. REPTIM is calculated in the program listing as in statement 1345. This value is then used in the program by replacing REPLY (J) with REPTIM whenever reply time would again have to be computed (e.g., step ATCRBS 1334 in table 3-5). This procedure saves computer time by limiting determination of reply time to a single computer operation.]
RMAX	Maximum range in nmi indicated on the ground receiver display
RMIN	Minimum range in nmi indicated on the ground receiver display

TABLE 3-3. TRANSPONDER PROGRAM LISTING PARAMETERS (CONT'D)

Parameter	Description
RRLCO	Reply rate limit cutoff. At this value (in dB) the transponder sensitivity is near maximum. If the contribution to desensitization [TDSNRL (JAC)] is less than or equal to RRLCO, that value of TDSNRL (JAC) can be used as sufficiently accurate for the determination of the receiver sensitivity [TSNSTV (JAC)]. Otherwise, TDSNRL (JAC) is computed in accordance with equation 3-6. During periods of low activity, i.e., when inputs are low and the receiver sensitivity in the vicinity of RRLCO is within 3dB of maximum sensitivity, use of RRLCO as a criterion makes possible the saving of computer time. This is so because, with this approximation, it is unnecessary for the computer to go through the computation of TDSNRL (JAC) for exact determination of TSNSTV (JAC) (total sensitivity of the J^{th} aircraft transponder receiver).
RSLVL	Receiver side-lobe suppression level setting at the ground receiver. This setting contributes to determination of a potential side-lobe reply at the ground receiver. If, when the receiver side-lobe suppression switch KRSLS is on, the level RSLVL plus the power of the reply pulse received on the onmidirectional antenna [TPOWOM (JAC)] equals or exceeds the power of the reply pulse received on the directional antenna [TPOWER (JAC)], the reply pulse is rejected.
SENSTV (1)	Maximum ground receiver sensitivity. This is analogous to TSNSMX (JAC), the MTL (minimum triggering level) of the transponder receiver.

TABLE 3-3. TRANSPONDER PROGRAM LISTING PARAMETERS (CONT'D)

Parameter	Description
SENSTV (2)	Dynamic (time-varying) sensitivity of the ground receiver. This is analogous to TSNSTV (JAC), the transponder receiver sensitivity.
SUPPT (JAC)	Suppression time. This is a constant, which is provided as an initial input to the program.
TDESEC (JAC)	Total desensitization due to echo suppression when the last pulse was received by the transponder receiver of the J^{th} aircraft
TDESRL (JAC)	Value of supply voltage to the IF amplifier stages just after the last (or most recent) reply rate desensitization
TDSNEC (JAC)	Contribution (in dB) of echo suppression to the desensitization of the transponder receiver of the J^{th} aircraft. Since this parameter contributes to a reduction in sensitivity of the transponder receiver, its value must be positive (A negative value would signify an increase in the transponder receiver sensitivity. This condition is prevented from occurring.
TDSNRL (JAC)	This parameter contributes to the desensitization of the transponder receiver in the same manner as described for the parameter TSDNEC (JAC). In this case, however, the contribution to desensitization is due to reply rate limiting.
TMAX	Time between transmission of a pulse from the interrogator of interest to an aircraft transponder at the maximum range, and reception of the reply from the transponder at the ground site receiver. This time is computed in the input of the simulation program.

TABLE 3-3. TRANSPONDER PROGRAM LISTING PARAMETERS (CONT'D)

Parameter	Description
TMIN	Time between transmission of a pulse from the interrogator of interest to an aircraft transponder at the minimum range, and reception of the reply from the transponder at the ground site receiver. This time is computed in the input of the simulation program.
TPOWER (JAC)	Transponder power received on directional antenna by the ground receiver
TPOWOM (JAC)	Transponder power received on omnidirectional antenna by ground receiver
TRANP3	Parameter related to computation of REPLY(J). (See table 3-2.)
TSNSMX (JAC)	Maximum sensitivity for transponder receiver of the J^{th} aircraft. This parameter, which corresponds to the MTL (minimum triggering level) of the receiver, is fixed for a particular transponder, but can vary for different transponders in other aircraft.
TSNSTV (JAC)	Dynamic (time-varying) sensitivity of the transponder receiver. This is analogous to SENSTV (2), the ground receiver sensitivity.
TTDSEC (JAC)	Time of desensitization for the last pulse which caused desensitization to occur
TTDSRL (JAC)	Time of last desensitization for reply rate limit circuit (i.e., the last P_1-P_2 or P_1-P_3 action causing desensitization). This can also be stated as the time of arrival of the P_2 or P_3 pulse of the pulse-pairs mentioned above.
TXPNDR (I)	See definition in table 3-2.
TXPSAV (JAC)	This parameter represents the time of arrival of an uplink pulse (arriving at the J^{th} aircraft)

TABLE 3-3. TRANSPONDER PROGRAM LISTING PARAMETERS (CONT'D)

Parameter	Description
TXPSAV (JAC) (Cont.)	which is saved for future insertion as the first value of the next TXPNDR (J) array. (See table 3-2 for definition of TXPNDR.)
XIN	Input to a log routine used in determining XLOG
XLOG	Log to the base 10 of the computed range to the aircraft in question. The range is computed in the elapsed time of the reply from a transmission to the interrogator of interest. (The reply need not have been caused by an interrogation pulse-pair from the interrogator of interest.)

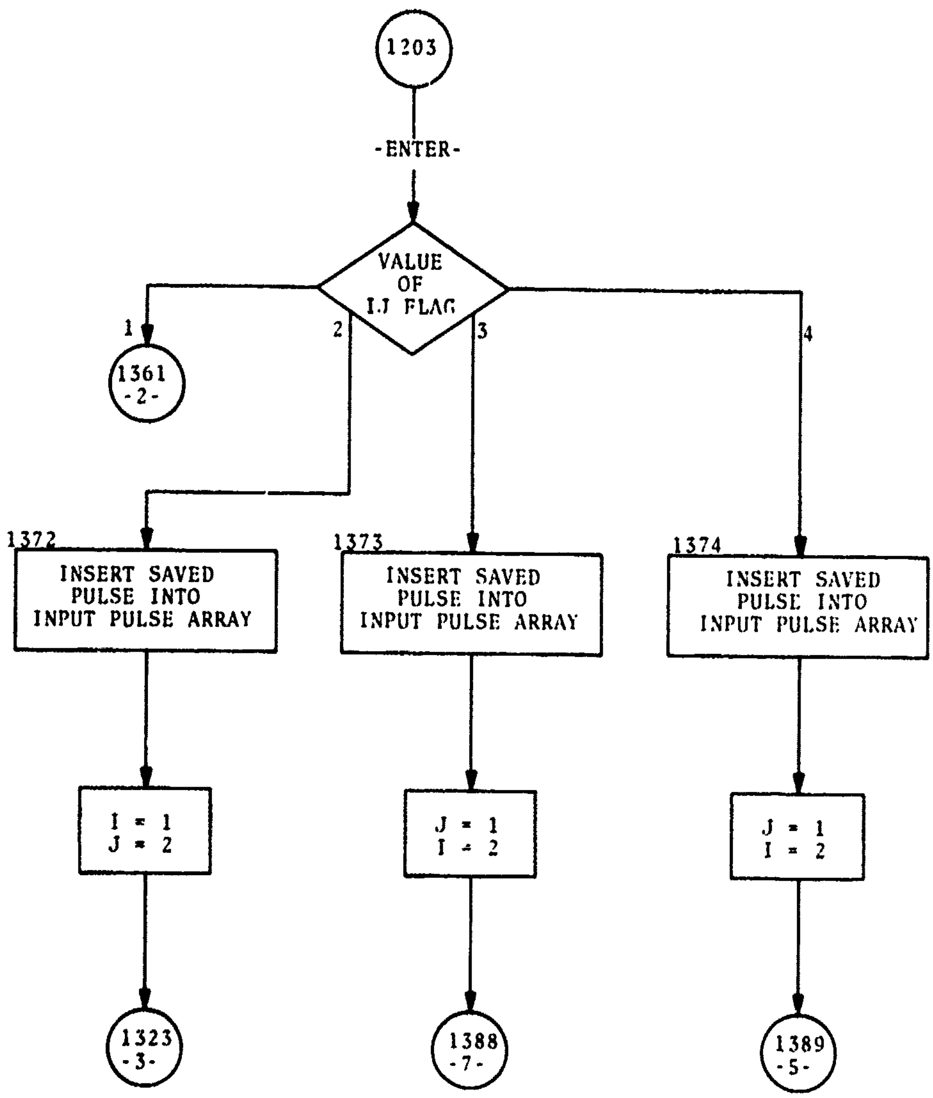

Figure 3-3. Flow Chart of ATCRBS Transponder Simulation Routine (Sheet 1 of 7)

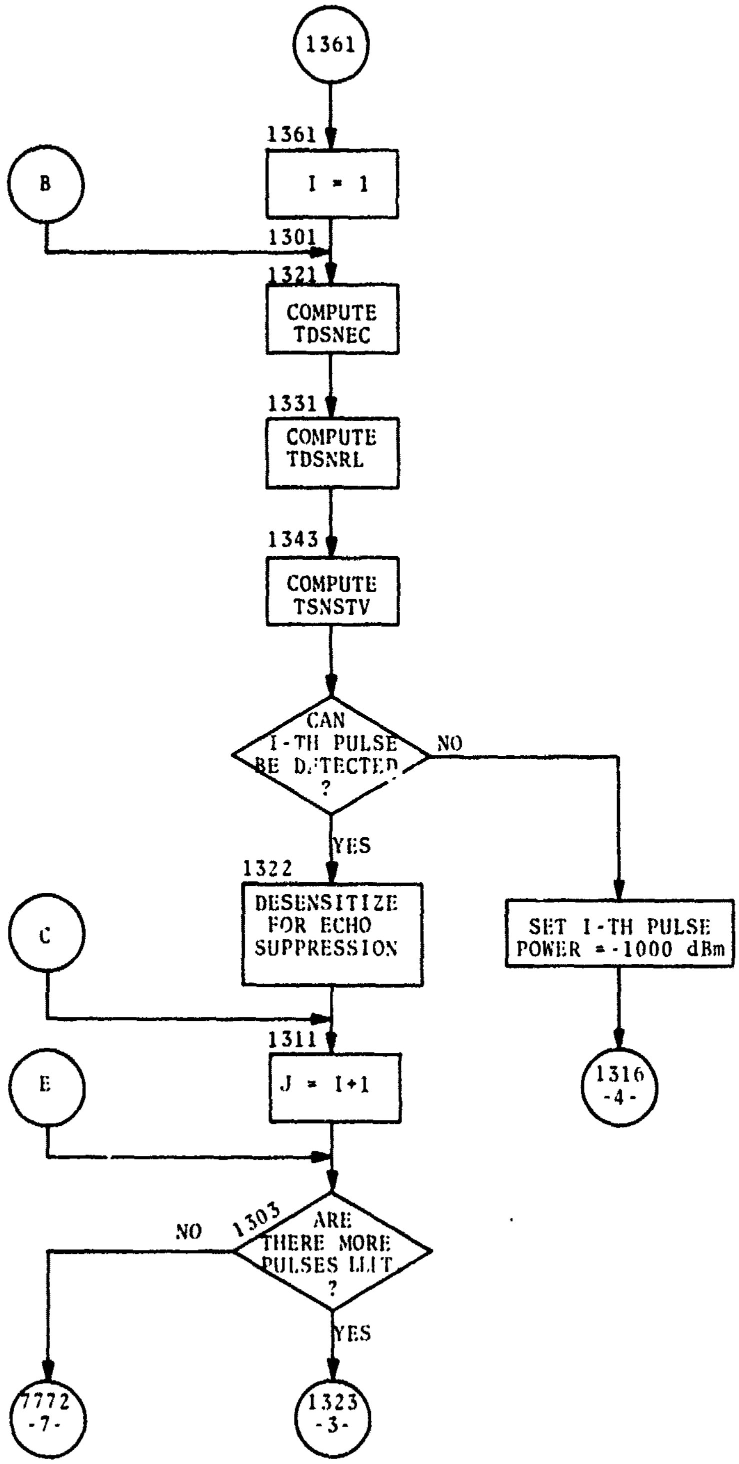

Figure 3-3. Flow Chart of ATCRBS Transponder Simulation Routine (Sheet 2 of 7)

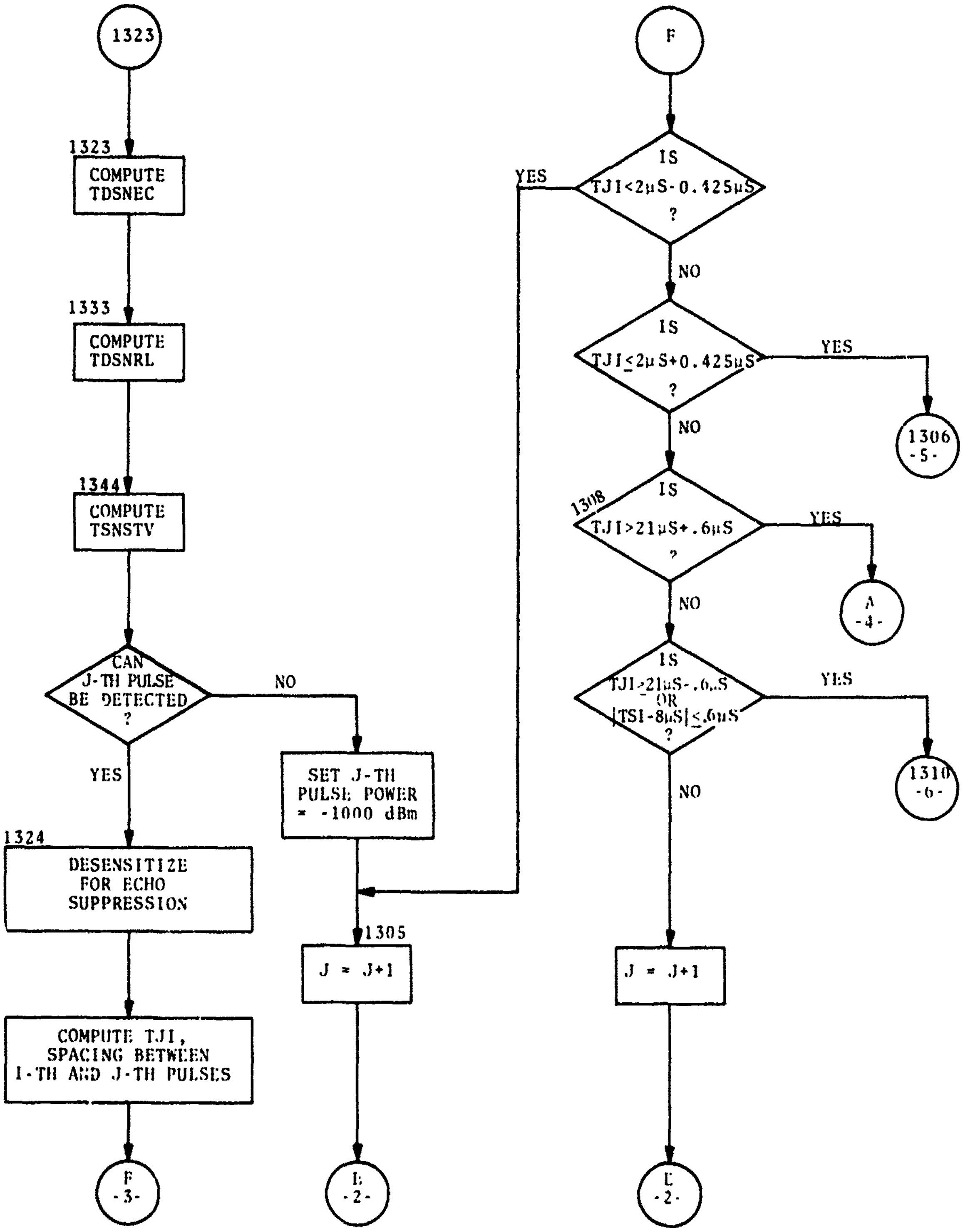

Figure 3-3. Flow Chart of ATCRBS Transponder Simulation Routine (Sheet 3 of 7)

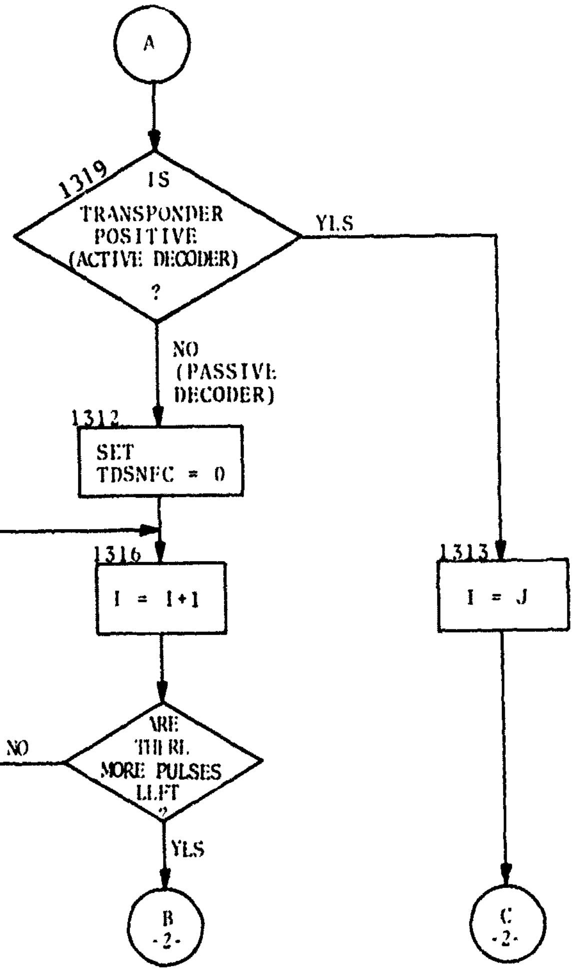

Figure 3-3. Flow Chart of ATCRBS Transponder Simulation Routine (Sheet 4 of 7)

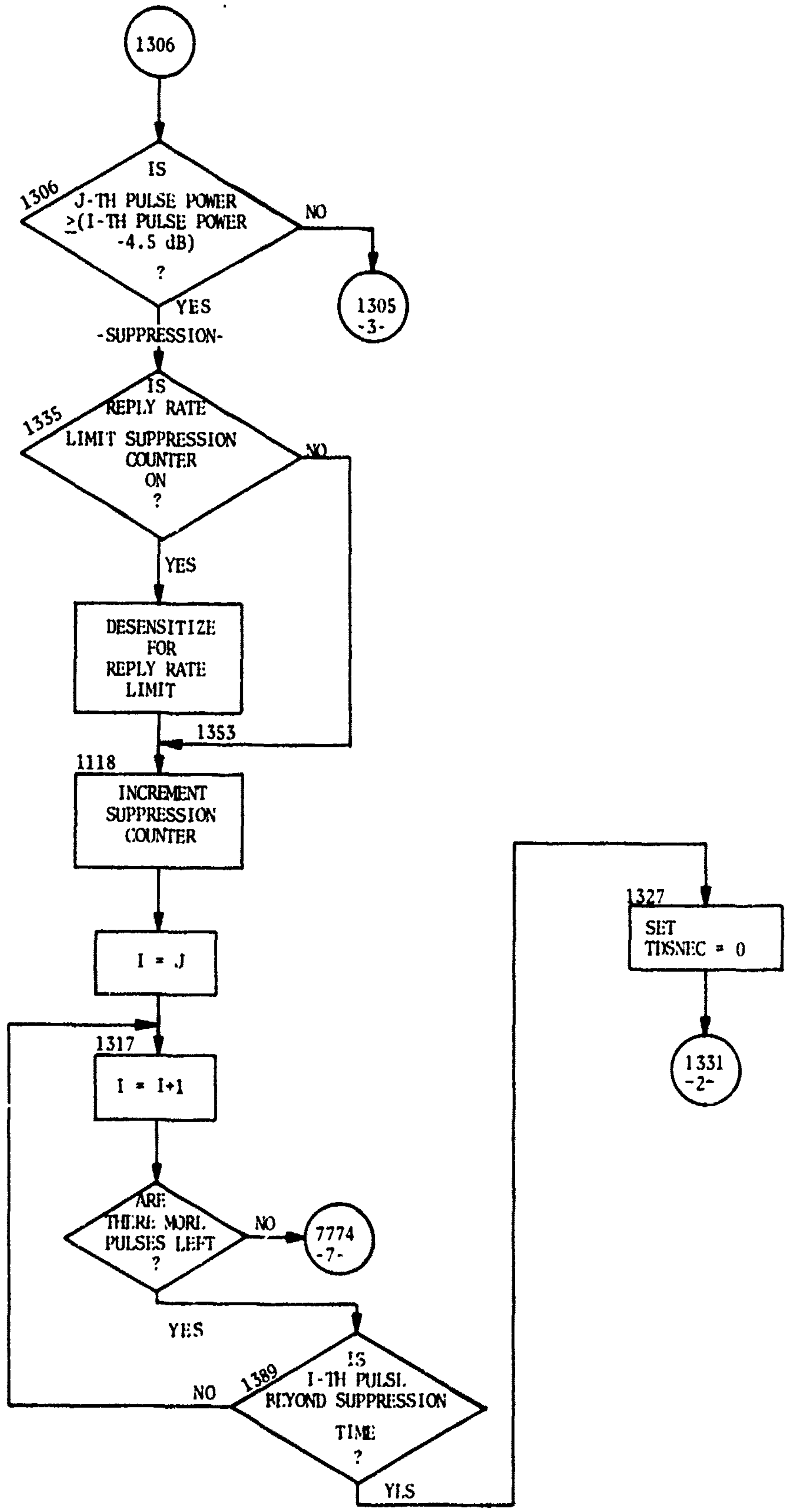

Figure 3-3. Flow Chart of ATCRBS Transponder Simulation Routine (Sheet 5 of 7)

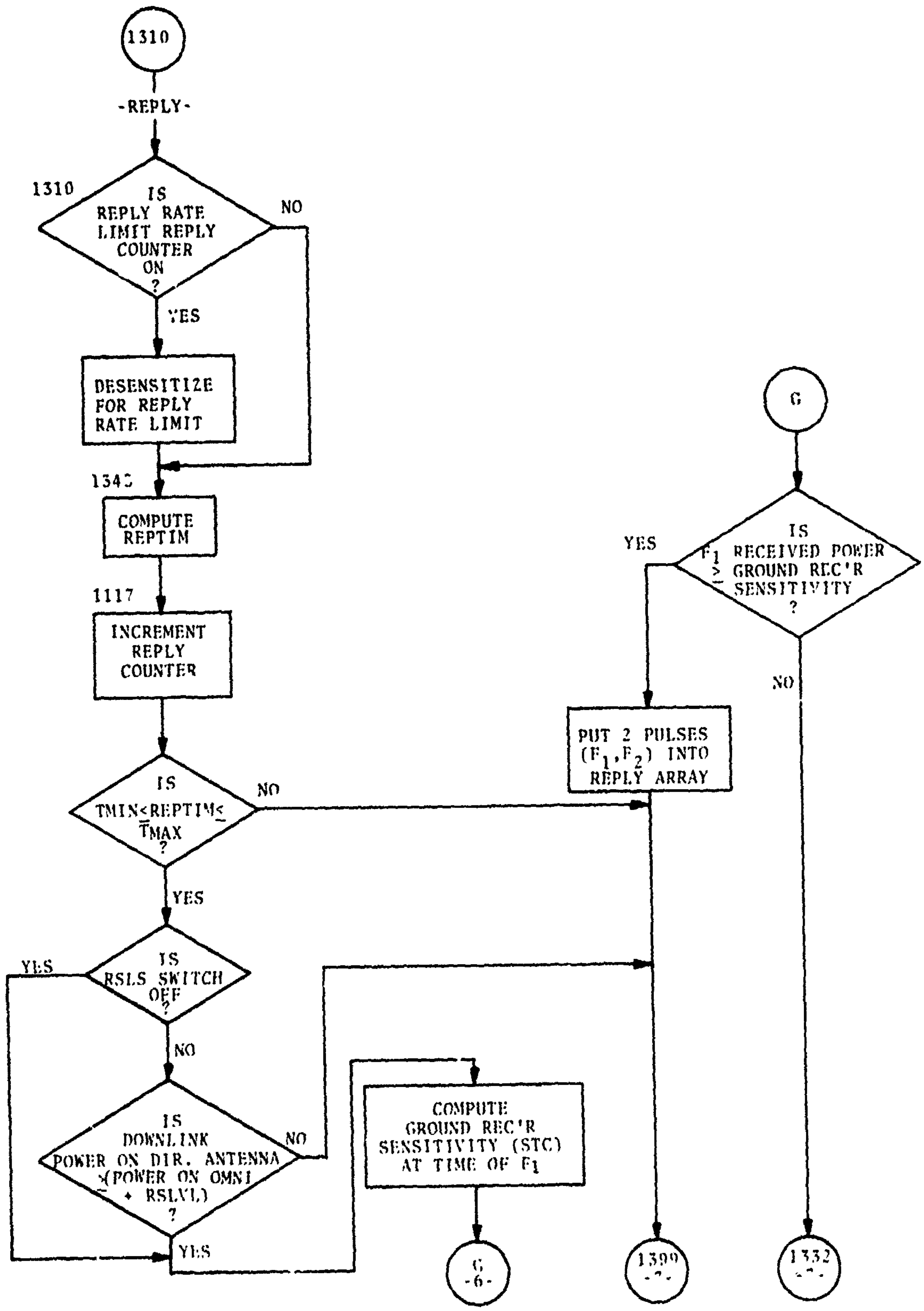

Figure 3-3. Flow Chart of ATCRBS Transponder Simulation Routine (Sheet 6 of 7)

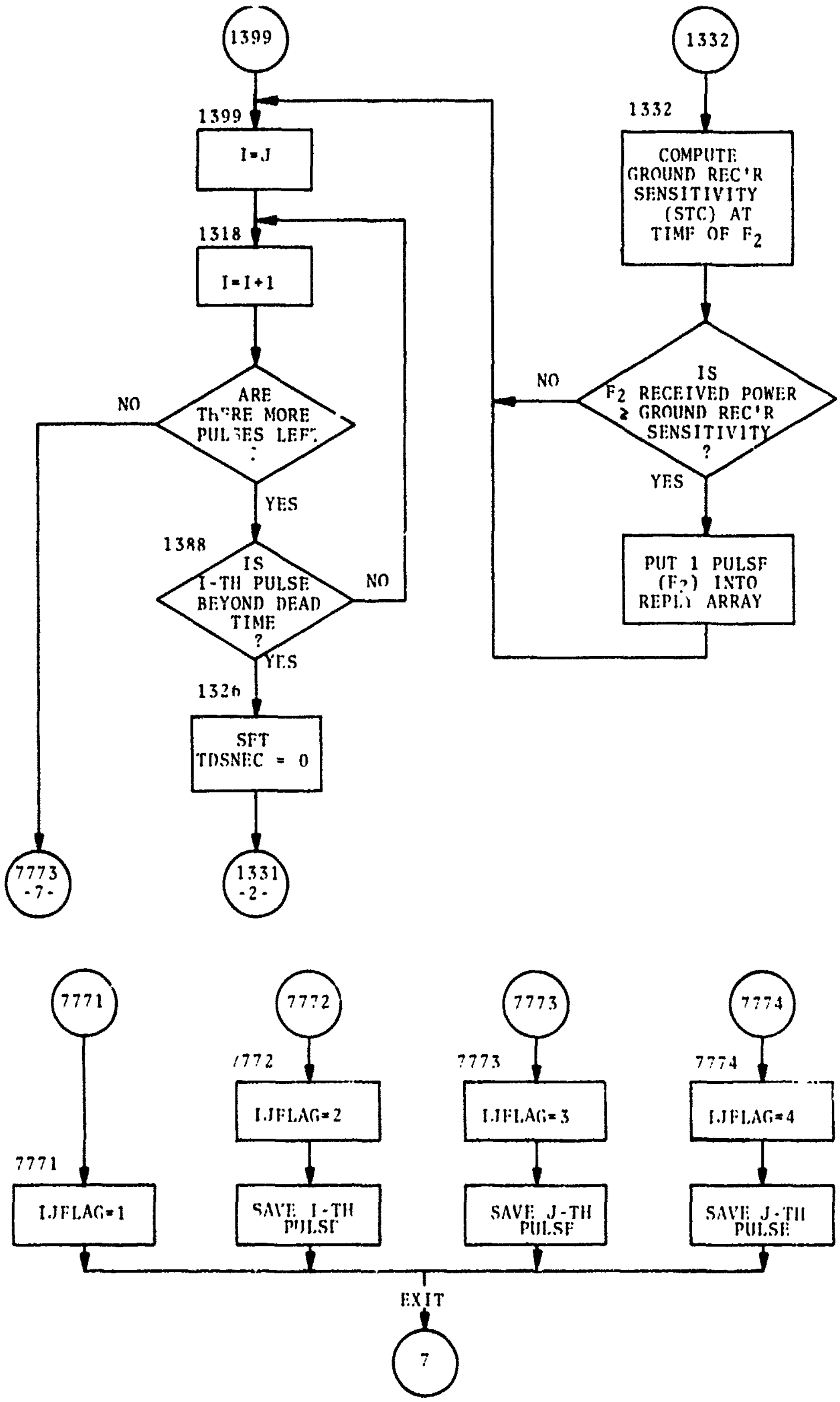

Figure 3-3. Flow Chart of ATCRBS Transponder Simulation Routine (Sheet 7 of 7)

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING

Statement	Statement Content	Comments
1203* (-1-)	Examine the setting of IJFLAG(JAC), and go to the appropriate statement according to the setting of IJFLAG(JAC).	The transponder portion of the program listing is entered with statement 1203. The program is set up so that IJFLAG(JAC) is initially set to equal 1. Therefore, in accordance with the interpretation of statement 1203, the program is continued with statement 1361. When the program reaches a statement in which IJFLAG(JAC) is set equal to 2, 3, or 4, the corresponding statement 1372, 1373, or 1374 will be implemented.
1372 (-1-) 1373 (-1-) 1374 (-1-)	These statements are called for by the respective values of IJFLAG(JAC).	The three statements are similar in nature, and are arrived at when the parameter IJFLAG(JAC) has the values 2, 3, and 4 respectively. They initiate a group of statements which bring saved (stored) pulses up from their stored position in the program. The procedure for bringing up these

*1. The sequence of statement numbers conforms with that in the program listing of table 3-5.

2. The parenthesized number identifies the numbered sheet of figure 3-3 on which the correspondingly numbered functional block is located.

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
		saved pulses is identical for each statement, so only statement 1372 and the succeeding related steps are presented in the next statements.
1372 (-1-)	Increment NPULS by 1.	This increases the I array elements by 1.
	Let NP1 equal NPULS + 1 NP2 equal NPULS + 2	
	Perform the next three statements of the program [steps ATCRBS 1228, 1229, and 1230 (statement 1382)] for values of IJK from 2 through NPULS.	This group of statements of the DO loop has the effect of bringing the last value of the original array down one element to the last element of the new array referred to in statement 1372. On continuation of the DO loop, the next-to-last value of the original array is also brought down one element, placing it just above the last value of the new array. This operation continues through the DO loop sequence until the first pulse of the original array is in the second element of the new array. The first element of the new array can now accommodate the insertion of the saved pulse.

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
1382 1384 1386	These statements are the last (and included) statements of the DO loop for shifting pulses from one array to another and positioning them in the manner described.	
	Bring the saved pulse to the new array to the space available for it.	TXPSAV(JAC) is substituted in TXPNDR(1), and PXPSAV(JAC) is substituted in PXPNDR(1).
	Let I=1 J=2	
	Go to statement 1323.	The J^{th} pulse is analyzed, and the loop is repeated.
1361 (-2-)	Provide an input (I) pulse.	At this point, continue with statement 1321, which calls for computation of desensitization of the transponder receiver due to echo suppression.
1321 (-2-)	If the current contribution to desensitization due to echo suppression [TDSNEC(JAC)] is less than or equal to 0, go to statement 1331.	If TDSNEC(JAC) is positive, refer to the next statement in the Statement Content column. Note that if, for any reason, TDSNEC(JAC) is less than 0, the time elapsed from the initiation of the desensitizing pulse has already exceeded

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
1321 (-2-) (Cont.)		the full recovery time of the sensitivity control circuit. This is indicated graphically in figure 3-2 of paragraph 3.2.5, where TDSNEC(JAC) corresponds to the time-varying contribution to desensitization above the -71dB minimum triggering level (maximum receiver sensitivity), which serves as 0dB reference. The negative-slope line represents the rate of recovery in sensitivity. TDSNEC(JAC) will therefore decrease toward 0 reference (-71dB) along the negative-slope line. A negative value of TDSNEC(JAC) would mean a return to a receiver sensitivity greater than the maximum sensitivity of the receiver (i.e., an extension of the negative-slope line into the sectioned area of figure 3-2). This is not allowed, and so, if TDSNEC(JAC) is less than 0, set TDSNEC(JAC) equal to 0 and proceed to statement 1331.

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
	Compute TDSNEC(JAC) in accordance with the program listing equation of step ATCRBS 1261.	The equation states that TDSNEC(JAC) is equal to the difference between items a and b below: a. TDESEC(JAC) - see table 3-3 for definition. b. No. of dB related to receiver sensitivity recovery. This is equal to the product of the rate of recovery (3.5dB per microsecond) and the time interval, in microseconds, from TTDSEC(JAC) to TXPNDR(I). (See table 3-3 for definitions of the time parameters.)
1331 (-2-)	If the contribution to desensitization due to reply rate limiting is less than or equal to the reply rate limit cutoff, go to statement 1343. Otherwise, go to the following statement. If the contribution to desensitization is greater than the reply rate	This test is made primarily to minimize computer processing time in the reply rate limit circuit model during periods when reply rate limit action is unnecessary. (Refer also to definition of RRLCO in table 3-3.)

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
	limit cutoff, compute TDSNRL(JAC), and continue with statement 1343.	
1343 (-2-)	Compute the present sensitivity TSNSTV (JAC).	Statement 1343 is the equation for the present sensitivity, taking into account the desensitization due to echo suppression and reply rate limiting. These factors represent attenuation in the transponder receiver. They cause variations from the maximum receiver sensitivity TSNSMX(JAC), which is also included in the computation of the total sensitivity.
		After computation of the total sensitivity, refer to the next statement in the Statement Content column to check the power in the input pulse.
	If the power in the input pulse [PXPNDR(I)] is greater than or equal (in dB) to transponder sensitivity TSNSTV(JAC), go to statement 1322.	If the power content exceeds TSNSTV (JAC), the input pulse is strong enough to be detected. The test is now made, by the routine that begins with statement 1322, to determine that the pulse has been detected. If the power in the pulse is such that the receiver

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
		threshold is not reached, the program replaces the PXPNDR(I) value with a large negative value to remove the possibility of marginal operation, and a new pulse (I=I+1) is inserted by implementing statement 1316 as the next statement in the program sequence.
1316 (-4-)	Increment the I^{th} pulse by 1.	Before continuing further, the program must determine whether incrementing the last I^{th} pulse has caused the value NPULS to be exceeded. If the new value for I has indeed exceeded NPULS, then all the (I) pulses entering the transponder during the present simulation cycle have been accounted for by the program. In this case, proceed to statement 7771. If, on the other hand, there are still pulses left in the present simulation cycle (i.e., I is less than or equal to NPULS), refer to the next statement in the Statement Content column.

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
	If I is less than or equal to NPULS (there are still pulses left in the present simulation cycle to be considered by the program), return to statement 1321 and repeat, for the incremented I, the computations for desensitization due to echo suppression and reply rate limiting, sensitivity, and pulse power.	Each time an I^{th} pulse power is insufficient to enable detection in the transponder receiver, a new pulse will be introduced into the program, and the loop statements will be repeated, starting with statement 1321 and including statements 1331 and 1343. The program will continue beyond the loop when the I^{th} pulse power is such that it can be detected, and the program will continue with statement 1322.
1322 (-2-)	Compute TDESEC(JAC) for echo suppression, and continue with the next statement.	At this point, the computation for TDESEC(JAC) is performed. This parameter is one of those included in determination of TDSNEC(JAC). The computation for TDESEC(JAC) is in compliance with the specification in U.S. National Standard DOT/FAA Order 1010.51A. This specification requires that, on receipt of a pulse longer than 0.7 microsecond, the receiver sensitivity shall be reduced to a level varying from 0 to 9dB below the level of the desensitizing signal.

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
	If TDESEC(JAC) is less than 0, set TDESEC(JAC) equal to 0, and continue with the next statement.	a. This conditional statement relative to TDESEC(JAC) is quite similar to the statement with respect to TDSNEC(JAC) when its computed value is less than 0. (Refer to the second conditional statement after statement 1321.) The comments for that statement are applicable here on substitution of TDESEC(JAC) for TDSNEC(JAC). b. The parameters TDESEC(JAC) and TDSNEC(JAC) are related; specifically, TDSNEC(JAC), a dynamic parameter which varies with time, is a function of TDESEC(JAC), which represents a peak value of desensitization due to echo suppression caused by the last pulse received by the transponder receiver. Actually, TDSNEC(JAC) and TDESEC(JAC) are identical at a point just before recovery of receiver sensitivity has begun.
	If TDESEC(JAC) is equal to or greater than 0, replace the value of TDSNEC (JAC) with TDESEC(JAC); replace the	In this case, the pulse has just been received, and TDSNEC(JAC) is identical to TDESEC(JAC). By replacing

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
	value of TTDSEC(JAC) with TXPNDR(I); and proceed to statement 1311.	TTDSEC(JAC) with TXPNDR(I), the effect of recovery of receiver sensitivity has been removed from consideration at this initial state.
1311 (-2-)	Set J=I+1, and proceed to statement 1303.	This statement is the first of a group of statements which perform the same functions for the J^{th} pulse as were performed for the I^{th} pulse by a previous group of statements. Statement 1303 and the included Note provide specific references with respect to the previous group of statements.
1303 (-2-)	If the value of the J^{th} pulse (corresponding to I+1) is greater than NPULS, go to statement 7772.	By this statement the program determines whether the last J^{th} pulse exceeds the value NPULS. If the new value of J does exceed NPULS, then all the J pulses entering the transponder during the present simulation cycle have been accounted for by the program. In this case, proceed to statement 7772. If, however, there are still pulses left in the present simulation cycle (i.e., J is less than or equal to NPULS), refer

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
		to the Note below, and then continue with the next statement in the Statement Content column.

Note: The next series of statements, from step ATCRBS 1278 through ATCRBS 1292, repeats the procedure already described for the sequence of statements 1321 to 1311 (corresponding to steps ATCRBS 1260 through ATCRBS 1275). The present group of statements determines for the J^{th} pulse, just as was done for the I^{th} pulse, the amount of desensitization for echo suppression and reply rate limiting, the present sensitivity, and the ability of the J^{th} pulse to be detected by the transponder receiver (i.e., power of the pulse at the transponder receiver antenna).

Statement	Statement Content	Comments
	Assign a parameter designation TJI to represent the spacing in time between the I^{th} (a potential P_1) and the J^{th} (a potential P_2 or P_3) pulses of the interrogation (or suppression) pulse-pair.	
	Examine the spacing in time between the I^{th} and J^{th} pulses from the interrogator.	
	If the time spacing between the pulses (TJI) is less than 1.575 microseconds, go to statement 1305.	A time interval of less than 1.575 microseconds (2 microseconds minus a 0.425-microsecond tolerance) precludes the possibility of a P_1-P_2 suppression

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
		pulse-pair. Therefore, the transponder does not accept this as a valid pair, and searches for the next potential (P_2 or P_3) pulse, beginning with statement 1305.
	If the time spacing between pulses I and J is less than or equal to 2.425 microseconds, go to statement 1306. Otherwise, go to statement 1308.	Because the program has arrived at the present statement, the time spacing in the previous statement must be interpreted as being at least 1.575 microseconds. Therefore, the present statement in effect places the time spacing within the range of 1.575 to 2.425 microseconds (i.e., 2 microseconds ± 0.425 microsecond tolerance). This represents a valid P_1-P_2 suppression pulse-pair, depending on the relative amplitudes of the P_1 and P_2 pulses. If this stipulation is not met, the next step will involve checking for a potential mode A (8-microsecond spacing) or mode C (21-microsecond spacing) P_1-P_3 pulse-pair.

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
1308 (-3-)	If the interval spacing between the I^{th} and J^{th} pulses is greater than 21.6 microseconds, go to statement 1319.	The interval spacing of 21.6 microseconds represents a mode C P_1-P_3 pulse-pair (21-microseconds plus 0.6 microsecond tolerance). If the spacing between the two pulses is greater than the maximum allowable time of 21.6 microseconds, the program proceeds to check whether the transponder decoder is active or passive. If the interval spacing is less than 21.6 microseconds, the program determines whether the spacing is 21 microseconds (±0.6 microsecond tolerance), or 8 microseconds (±0.6 microsecond tolerance), or neither in the next statement in the Statement Content column.
	If TJI is greater than or equal to 20.4 microseconds, or if the absolute value of the difference between TJI and 8 microseconds is less than or equal to 0.6 microsecond (the permissible tolerance), go to statement 1310.	Reaching this statement from statement 1308 indicates that TJI is not greater than 21.6 microseconds. Therefore, the present statement establishes a time interval of 21 microseconds ±0.6 microsecond tolerance.

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
		Alternatively, the statement relative to the 8-microsecond spacing indicates an acceptable range of 7.4 microseconds to 8.6 microseconds for a valid mode A interrogation pair. If the interval spacing falls outside the limits indicated, proceed to the next statement in the Statement Content column.
	If the interval spacing falls outside the acceptable limits noted in the above statement, insert a new J pulse. Return to statement 1303, and check for remaining potential P_2 or P_3 pulses. If no pulses remain, go to statement 7772. If there are pulses remaining, continue with desensitization and sensitivity computations, using statements 1323, 1333, and 1344 in the sequence.	
1310 (-6-)	This statement indicates whether the reply rate limit control circuit (counter) is activated, or on. If the counter is off [IRLREP(JAC)	

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
	equals 0], go to statement 1345. Otherwise, go to the next statement	
	If [IRLREP(JAC)] equals 1, compute the desensitization for the reply rate limit.	Refer to equation (2) of Appendix A.
	If the computed value for the supply voltage (VT) after desensitization is greater than or equal to 8.5 volts, go to statement 1341.	
	If the computer value is between 6.0 and 8.5 volts, go to statement 1340.	
	If neither of the above conditions prevails [i.e., if (VT) is less than 6.0 volts], compute TDESRL(JAC) according to the equation of step ATCRBS 1304.	This equation for voltage just after desensitization corresponds to equation (1) of Appendix A, except that ΔV is modified in accordance with equation (7). In this case, the value for constant k is 1.800.
	If the computed value for TDESRL(JAC) is less than 3, set TDESRL(JAC) equal to 3, and proceed to statement 1342.	As indicated in figure A-1 of Appendix A, the maximum desensitization due to reply rate limit control corresponds to a supply voltage (VT) of 3 volts. Therefore, any value of (VT) less than

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
		3 volts is not considered in the computation for transponder receiver sensitivity due to reply rate limit control. (Also see step 4 in the Summary of Appendix A.)
1340	Compute TDESRL(JAC) for (VT) between 6.0 and 8.5 volts. If the computed value for TDESRL is less than 3, set TDESRL equal to 3 and continue with statement 1342.	The comments for the two previous statements apply here. The equation for computing TDESRL(JAC) is of the same form as previously described, except that the constant k in the equation for ΔV [equation (7) of Appendix A] is now 1.288.
1341	Compute TDESRL(JAC) for (VT) between 8.5 and 12.0 volts. If the computed value for TDESRL is less than 3, set TDESRL(JAC) equal to 3, and continue with statement 1342.	The comments for statement 1340 are applicable for this statement. In the solution for TDESRL(JAC) in this case, ΔV is computed with constant k equal to 0.760.

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
1342	Insert the time of arrival of the J^{th} pulse at the transponder [TXPNDR(J)] as the new value replacing the time of arrival of the P_2 or P_3 pulse of the last P_1-P_2 of P_1-P_3 pair causing desensitization [TTDSRL(JAC)].	In the expression TXPNDR(J), J represents a potential P_2 or P_3 pulse.
	Compute the total desensitization due to reply rate limiting [TDSNRL(JAC)], using the value for TDESRL(JAC) as determined in statement 1341.	
1345 (-6-)	Compute the reply time for the J^{th} pulse from the transponder to the ground receiver of the interrogator of interest in accordance with the equation for REPTIM.	

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
1117	Increment the running count of the transponder reply counter by 1.	
(-6-)	Determine whether the reply time is outside the limits TMAX and TMIN for maximum and minimum ground receiver ranges, respectively. If the reply time is greater than TMAX or less than TMIN, go to statement 1399.	
	Check for the state of the receiver side-lobe-suppression switch KRSLS, and compare the transponder powers received by the ground receiver on the directional and omnidirectional antennas [TPOWER(JAC) and TPOWOM (JAC)] respectively. If the side-lobe-suppression switch is on (KRSLS=1), and if the signal strength TPOWER(JAC) is greater than the signal strength	

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
	TPOWOM(JAC) plus the ground receiver side-lobe-suppression level setting, go to statement 1399.	
	If the side-lobe-suppression switch is off (KRSLS=0), or TPOWER(JAC) is greater than or equal to the sum of TPOWOM(JAC) and the receiver side-lobe-suppression level setting at the receiver, compute the sensitivity of the ground receiver at the time of the first reply pulse (F_1 framing pulse) from the transponder.	The computation in this statement is related to the reduction in gain at the ground receiver due to STC (sensitivity time control) action in the receiver. [See Notes below for reference to STC, SENSTV(1), and SENSTV(2).]

Notes:

1. The STC computation consists of a number of statements identified in the program listing as steps ATCRBS 1323 through ATCRBS 1330. The dynamic, or time varying, sensitivity [SENSTV(2)] of the ground receiver is defined by the equation of step ATCRBS 1329. The next statement (ATCRBS 1330) provides that if the computed dynamic sensitivity SENSTV(2) exceeds the maximum sensitivity of the ground receiver SENSTV(1), then SENSTV(1) is to be substituted for SENSTV(2).

2. The ground receiver dynamic sensitivity, related to ground receiver STC, is computed in the transponder program listing, an action which saves computer time and storage space. The reason for this is that with the maximum ground receiver

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
	sensitivity SENSTV(1) known and instantaneous ground receiver (dynamic) sensitivity SENSTV(2) computed, it is possible to determine which reply pulses will not come back to the ground receiver. These reply pulses will not be transmitted by the transpor er, and the time involved in these transmissions will be saved. In addition, the reply array will not be filled with reply pulses which will not be received by the ground receiver, and therefore storage space will be saved.	
	If the power of the F_1 reply arriving at the ground receiver [TPOWER(JAC)] is less than the dynamic sensitivity [SENSTV(2)] of the receiver, go to statement 1332.	In this case, the F_1 pulse is too weak to be detected by the ground receiver. When this has been determined, the statement 1332 examines the F_2 (framing pulse) reply, which may or may not be detected, depending on the rate of sensitivity recovery in the receiver after the F_1 pulse.
	If TPOWER(JAC) is greater than SENSTV(2), insert two reply pulses (F_1 and F_2) into the reply array.	
	If the sum of the reply pulses (IREPLY) is equal to or greater than 201, go to statement 1398.	Since a simulation cycle is permitted a maximum of 200 reply pulses, a value of IREPLY greater than 200 causes a diagnostic to be brought to the programmer's attention by a computer printout

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
		and by the computer stopping on completion of the printout. The printout, which states the condition, is generated in statement 1398, and is provided in the format indicated by statement 1397.
	If IREPLY remains less than 201 on insertion of an F_1-F_2 pulse-pair into the reply array, assign the value REPTIM to the next-to-last reply pulse [REPLY (IREPLY-1)]. Then the time for the last reply pulse [REPLY (IREPLY)] is 20.3 microseconds greater. On assignment of these values in the reply array, go to statement 1399.	
1332 (-7-)	Compute STC for the second reply pulse (F_2) of the F_1-F_2 pulse-pair.	Statement 1332 is the first step in a sequence of steps (ATCRBS 1337 through ATCRBS 1344) which accomplish the STC computation on receipt of the F_2 pulse. In this case, as was the case in the previous STC computation for the F_1 pulse, if the computed dynamic

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
		sensitivity SENSTV(2) is greater than the maximum receiver sensitivity SENSTV(1), then SENSTV(1) replaces SENSTV(2).
	If the power of the F_2 reply pulse arriving at the ground receiver [TPOWER(JAC)] is less than the dynamic sensitivity of the ground receiver [SENSTV(2)], go to statement 1399.	
	If TPOWER(JAC) for F_2 is greater than SENSTV(2), insert one pulse (F_2) into the reply array, making the sum of the reply pulses IREPLY greater by 1.	
	Examine IREPLY after insertion of the additional reply pulse. If the new value of IREPLY is equal to or greater than 201, go to statement 1398.	Refer back to the fifth statement preceding this one, and to the accompanying comment. An identical condition is considered for insertion of an F_1-F_2 pulse-pair into the reply array.
	For the new value of IREPLY, substitute a new reply time by adding 20.3 microseconds to the reply time	

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
	of the last pulse, and go to statement 1399.	
1399 (-7-)	Substitute J for I.	This statement causes the I^{th} value in the TXPNDR and PXPNDR array to have the same value (i.e., the same pulse) as the J^{th} value.
1318 (-7-)	Increment I by 1.	
	Compare the new value of I with the total number of pulses in the I array (NPULS). If this value is greater than NPULS, go to statement 7773.	This comparison may provide a value of I less than or equal to NPULS, indicating that there are still pulses remaining to be processed. When this is so, the spacing between pulses is evaluated, as in statement 1388.
1388 (-7-)	If the time spacing between a subsequent pulse I and the P3 pulse causing interrogation is less than or equal to the dead time period, go to statement 1318.	During the dead time period there will be no reply from the transponder. The program calls for insertion of a new input pulse in accordance with statement 1318, and for continuation of the loop between statements 1318 and 1388 until the I^{th} pulse is beyond the dead time. When this occurs, the program continues with statement 1326.

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
1326 (-7-)	Set TDSNEC(JAC) equal to 0, and go to statement 1331.	See Note below.
Note:	This statement initiates a loop operation, beginning with statement 1331, in which computations are made for desensitization due to echo suppression and reply rate limiting, sensitivity of the transponder, detection of interrogation or suppression pairs by the transponder receiver, and determination of mode A or mode C interrogation or suppression time intervals. This loop is followed until, at one of certain points, it is determined that all of the input pulses (NPULS) have been used, or until the program returns to statement 1326, at which point the loop is once more performed, but with new I and J parameters.	
1398	Provide a printout in accordance with the format of statement 1397.	
1397	The format for printout is presented in this statement.	The format directive is to provide space for 25 alphanumeric characters, and to print on top of a new page the following: IREPLY GREATER THAN 200.
	The printout is followed by a command to stop the computer program.	
1306 (-5-)	Compare the strengths of the J^{th} (P_2) pulse and the I^{th} (P_1) pulse. If the J^{th} pulse is equal to or greater than the I^{th} pulse minus 4.5dB, go to	This statement has been reached because, in accordance with steps ATCRBS 1294 and ATCRBS 1295, it has been determined that the pulse-pair being examined is a

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
	statement 1335. Otherwise, go to statement 1305.	suppression pair. If the J^{th} pulse is acutally greater than or equal to the I^{th} pulse (minus 4.5dB), suppression occurs. If not, the next pulse (potentially P_3) is examined (statement 1305).
1319 (-4-)	If IXPNDR is positive, go to statement 1313. Otherwise, go to statement 1312.	A positive value for IXPNDR signifies an active decoder for the transponder. If the value is 0 or negative, a passive decoder is indicated.
1312 (-4-)	Set TDSNEC(JAC) equal to 0.	This statement nullifies the contribution to transponder sensitivity due to the action of the echo suppression circuit. The next step takes the program back to statement 1316. A new input pulse is inserted into the program, and the desensitization and sensitivity computations are repeated with the new parameters.
1313 (-4-)	Substitute J for I. Go to statement 1311.	The J^{th} pulse is now compared with the I^{th} pulse to determine whether the pair of pulses constitutes a suppression

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
		pair, mode A, mode C, or none. The usual routine is first covered, namely, to ensure that there are pulses still left in the present simulation cycle, and to compute desensitization, sensitivity, and power.
1335 (-5-)	This statement determines whether or not the transponder reply rate limit control circuit counts suppressions. If it does, then IRLSLS(JAC) equals 1, and the suppression counter is on. In this case, refer to the Note below for the next sequence of steps. If, on the other hand, the counter is off [IRLSLS(JAC) equals 0], continue with statement 1118.	
Note:	The sequence of steps from ATCRBS 1366 through ATCRBS 1378 in the program computes the desensitization for the reply rate limit suppression counter in the "on" condition. The routine is identical to the computation of desensitization as contained in steps ATCRBS 1301 through ATCRBS 1313, except that TXPNDR(J) refers to a P_2 pulse in the present case, rather than to a P_3 pulse. The latter steps are included, and commented on, in this table between statements 1310 and 1345.	

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
1118 (-5-)	Increment the suppression counter [KNTSLS(JAC)] by 1.	
	Substitute J for I.	
1317 (-5-)	Increment I by 1, and examine the value of I with respect to NPULS.	
	If the value of I is greater than NPULS, go to statement 7774. Otherwise, go to statement 1389.	When I is less than or equal to NPULS, there are still input pulses left in the present simulation cycle.
1389 (-5-)	If the I^{th} pulse is within the suppression time, return to statement 1317, i.e., increment I by 1, check that there are still pulses left, and continue until the I^{th} pulse is beyond the suppression time. At this time go to statement 1327.	
1327 (-5-)	Set TDSNEC(JAC) equal to 0.	This nullifies the contribution to transponder sensitivity due to the action of the echo suppression circuit.
	Go to statement 1331.	The loop is once more repeated with the new input parameters.

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
7771 (-7-)	IJFLAG(JAC) is set equal to 1.	Statement 7771 is reached when the program has run out of input pulses within the present simulation cycle and is seeking the next potential P_1 pulse.
	Go to statement 7.	This is the exit statement for the transponder portion of the simulation program, enabling the computer to continue on with the rest of the program. It is also the last statement of a DO loop which begins with the DO statement of step ATCRBS 633 (e.g., step ATCRBS 633 of table B-1 in Appendix B). The DO loop causes replies from all other transponders in addition to those from the transponder of interest to be accounted for in the present simulation cycle.
7772 (-7-)	IJFLAG(JAC) is set equal to 2.	Statement 7772 is reached when the program has run out of input pulses within the present simulation cycle and is seeking the next potential P_2 or P_3 pulse that might associate with the P_1 pulse (I^{th} pulse) already detected.

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
	Save the I^{th} pulse [the time of arrival TXPNDR(I) and power in the pulse PXPNDR(I) at the transponder antenna].	This statement ensures that a pulse-pair will not be lost because of the occurrence of a P_2 or P_3 pulse in the succeeding simulation cycle.
	Go to statement 7.	Refer to the GO TO statement comments following statement 7771.
7773 (-7-)	IJFLAG(JAC) is set equal to 3.	Statement 7773 is reached when the program has run out of input pulses within the present simulation cycle and is seeking the next potential P_1 pulse beyond the dead time following the last interrogation.
	Save the J^{th} pulse.	This statement ensures that a pulse will not be detected if a dead time falls into a succeeding simulation cycle.
	Go to statement 7.	Refer to the GO TO statement comments following statement 7771.
7774 (-7-)	IJFLAG(JAC) is set equal to 4.	Statement 7774 is reached when the program has run out of input pulses within the present simulation cycle and is seeking a P_1 pulse beyond the suppression time following the last P_1-P_2 suppression pair.

TABLE 3-4. TABULAR SUMMARY OF TRANSPONDER PROGRAM LISTING (CONT'D)

Statement	Statement Content	Comments
	Save the J^{th} pulse.	This statement ensures that a pulse will not be detected if a suppression time falls into a succeeding simulation cycle.
	Go to statement 7.	Refer to the GO TO statement comments following statement 7771.

TABLE 3-5. TRANSPONDER PROGRAM LISTING

```
1203  GO TO (1361,1372,1373,1374),IJFLAG(JAC)
1372  NPULS=NPULS+1
      NP1=NPULS+1
      NP2=NPULS+2
      DO 1382 IJK=2,NPULS
      TXPNDR(NP2-IJK)=TXPNDR(NP1-IJK)
1382  PXPNDR(NP2-IJK)=PXPNDR(NP1-IJK)
      TXPNDR(1)=TXPSAV(JAC)
      PXPNDR(1)=PXPSAV(JAC)
      I=1
      J=2
      GO TO 1323
1373  NPULS=NPULS+1
      NP1=NPULS+1
      NP2=NPULS+2
      DO 1384  IJK=2,NPULS
      TXPNDR(NP2-IJK)=TXPNDR(NP1-IJK)
1384  PXPNDR(NP2-IJK)=PXPNDR(NP1-IJK)
      TXPNDR(1)=TXPSAV(JAC)
      PXPNDR(1)=PXPSAV(JAC)
      J=1
      I=2
      GO TO 1388
1374  NPULS=NPULS+1
      NP1=NPULS+1
      NP2=NPULS+2
      DO 1386 IJK=2,NPULS
      TXPNDR(NP2-IJK)=TXPNDR(NP1-IJK)
1386  PXPNDR(NP2-IJK)=PXPNDR(NP1-IJK)
      TXPNDR(1)=TXPSAV(JAC)
      PXPNDR(1)=PXPSAV(JAC)
      J=1
      I=2
      GO TO 1389
1361  I=1
1301  CONTINUE
1321  IF (TDSNEC(JAC).LE.0.) GO TO 1331
      TDSNEC(JAC)=TDESEC(JAC)-3.5E+06*(TXPNDR(I)-TTDSEC(JAC))
      IF (TDSNEC(JAC).LT.0.) TDSNEC(JAC)=0.
1331  IF (TDSNRL(JAC).LE.RRLCO) GO TO 1343
      TDSNRL(JAC)=60.*ALOG10(12./(12.-(12.-TDESRL(JAC))*EXP((TTDSRL(JAC)
     1-TXPNDR(I))/ALTAUR(JAC))))
1343  TSNSTV(JAC)=TSNSMX(JAC)+TDSNEC(JAC)+TDSNRL(JAC)
      IF (PXPNDR(I).GE.TSNSTV(JAC)) GO TO 1322
      PXPNDR(I)=-1000.
1316  I=I+1
      IF (I.GT.NPULS) GO TO 7771
      GO TO 1301
1322  TDESEC(JAC)=PXPNDR(I)-DESUR-TSNSMX(JAC)
      IF (TDESEC(JAC).LT.0.) TDESEC(JAC)=0.
      TDSNEC(JAC)=TDESEC(JAC)
      TTDSEC(JAC)=TXPNDR(I)
1311  J=I+1
1303  IF (J.GT.NPULS) GO TO 7772
1323  IF (TDSNEC(JAC).LE.0.) GO TO 1333
      TDSNEC(JAC)=TDESEC(JAC)-3.5E+06*(TXPNDR(J)-TTDSEC(JAC))
      IF (TDSNEC(JAC).LT.0.) TDSNEC(JAC)=0.
1333  IF (TDSNRL(JAC).LE.RRLCO) GO TO 1344
      TDSNRL(JAC)=60.*ALOG10(12./(12.-(12.-TDESRL(JAC))*EXP((TTDSRL(JAC)
     1-TXPNDR(J))/ALTAUR(JAC))))
1344  TSNSTV(JAC)=TSNSMX(JAC)+TDSNEC(JAC)+TDSNRL(JAC)
      IF (PXPNDR(J).GE.TSNSTV(JAC)) GO TO 1324
      PXPNDR(J)=-1000.
1305  J=J+1
```

TABLE 3-5. TRANSPONDER PROGRAM LISTING (CONT'D)

```
      GO TO 1303
1324  TDESEC(JAC)=PXPNDR(J)-DESDIF-TSNSMX(JAC)
      IF (TDESEC(JAC).LT.0.) TDESEC(JAC)=0.
      TDSNEC(JAC)=TDESEC(JAC)
      TTOSEC(JAC)=TXPNDR(J)
      TJI=TXPNDR(J)-TXPNDR(I)
      IF (TJI.LT.1.575E-06) GO TO 1305
      IF (TJI.LE.2.425E-06) GO TO 1306
1308  IF (TJI.GT.21.6E-06) GO TO 1319
      IF ((TJI.GE.20.4E-06).OR.(ABS(TJI-8.E-06).LE.0.6E-06)) GO TO 1310
      J=J+1
      GO TO 1303
1319  IF (IRLREP(JAC).EQ.0) GO TO 1345
      VT=12.-(12.-TDESRL(JAC))*EXP((TTOSRL(JAC)-TXPNDR(J))/ALTAUR(JAC))
      IF (VT.GE.8.5) GO TO 1341
      IF (VT.GE.6.0) GO TO 1340
      TDESRL(JAC)=VT-1.800*EXP((TTOSRL(JAC)-TXPNDR(J))/HFTAUR(JAC))
      IF (TDESRL(JAC).LT.3.) TDESRL(JAC)=3.
      GO TO 1342
1340  TDESRL(JAC)=VT-1.288*EXP((TTOSRL(JAC)-TXPNDR(J))/HFTAUR(JAC))
      IF (TDESRL(JAC).LT.3.) TDESRL(JAC)=3.
      GO TO 1342
1341  TDESRL(JAC)=VT-0.760*EXP((TTOSRL(JAC)-TXPNDR(J))/HFTAUR(JAC))
      IF (TDESRL(JAC).LT.3.) TDESRL(JAC)=3.
1342  TTOSRL(JAC)=TXPNDR(J)
      TDSNRL(JAC)=60.*ALOG10(12./TDESRL(JAC))
 1345 REPTIM=TXPNDR(J)+DELAY+PROPTM(1,JAC)-TRANP3
1117  KNTINT(JAC)=KNTINT(JAC)+1
      IF ((REPTIM.GT.TMAX).OR.(REPTIM.LT.TMIN)) GO TO 1399
      IF((KRSLG.GT.0).AND.(TPOWER(JAC).LT.(TPOWOM(JAC)+RSLVL))) GO TO 13
     1399
      XIN=(REPTIM-DELAY)/12.36E-06
      XTEST=(XIN.AND.00007777777777777777B).OR.17170000000000000000B
      SUBSCR=XTEST*1000.
      L=SUBSCR
      XLOG=Y(L)+(Y(L+1)-Y(L))*(SUBSCR-FLOAT(L))+XL2*FLOAT(SHIFT(XIN,-48)
     1-975)
      SENSTV(2)=SENSTV(1)+REDSNS-20.*XLOG
      IF (SENSTV(2).LT.SENSTV(1)) SENSTV(2)=SENSTV(1)
      IF (TPOWER(JAC).LT.SENSTV(2)) GO TO 1332
      IREPLY=IREPLY+2
      IF (IREPLY.GE.201) GO TO 1398
      REPLY(IREPLY-1)=REPTIM
      REPLY(IREPLY)=REPLY(IREPLY-1)+20.3E-06
      GO TO 1399
1332  XIN=(REPTIM+20.3E-06-DELAY)/12.36E-06
      XTEST=(XIN.AND.00007777777777777777B).OR.17170000000000000000B
      SUBSCR=XTEST*1000.
      L=SUBSCR
      XLOG=Y(L)+(Y(L+1)-Y(L))*(SUBSCR-FLOAT(L))+XL2*FLOAT(SHIFT(XIN,-48)
     1-975)
      SENSTV(2)=SENSTV(1)+REDSNS-20.*XLOG
      IF (SENSTV(2).LT.SENSTV(1)) SENSTV(2)=SENSTV(1)
      IF (TPOWER(JAC).LT.SENSTV(2)) GO TO 1399
      IREPLY=IREPLY+1
      IF (IREPLY.GE.201) GO TO 1398
      REPLY(IREPLY)=REPTIM+20.3E-06
1399  I=J
1318  I=I+1
      IF (I.GT.NPULS) GO TO 7773
1388  IF ((TXPNDR(I)-TXPNDR(J)).LE.DEADT(JAC)) GO TO 1318
1326  TDSNEC(JAC)=0.
      GO TO 1331
 1398 PRINT 1397
 1397 FORMAT (25H1IREPLY GREATER THAN 200.
      STOP
```

TABLE 3-5. TRANSPONDER PROGRAM LISTING (CONT'D)

```
1306  IF (PXPNOR(J).GE.(PXPNDR(I)-4.5)) GO TO 1335                  ATCRBS
      GO TO 1305                                                    ATCRBS
1319  IF (IXPNOR) 1312,1312,1313                                    ATCRBS
1312  TDSNEC(JAC)=0.                                                ATCRBS
      GO TO 1316                                                    ATCRBS
1313  I=J                                                           ATCRBS
      GO TO 1311                                                    ATCRBS
1335  IF (IRLSLS(JAC).EQ.0) GO TO 1353                              ATCRBS
      VT=12.-(12.-TDESRL(JAC))*EXP((TTDSRL(JAC)-TXPNOR(J))/ALTAUR(JAC))  ATCRBS
      IF (VT.GE.8.5) GO TO 1351                                     ATCRBS
      IF (VT.GE.6.0) GO TO 1350                                     ATCRBS
      TDESRL(JAC)=VT-1.800*EXP((TTDSRL(JAC)-TXPNDR(J))/HFTAUR(JAC))  ATCRBS
      IF (TDESRL(JAC).LT.3.) TDESRL(JAC)=3.                         ATCRBS
      GO TO 1352                                                    ATCRBS
1350  TDESRL(JAC)=VT-1.288*EXP((TTDSRL(JAC)-TXPNDR(J))/HFTAUR(JAC))  ATCRBS
      IF (TDESRL(JAC).LT.3.) TDESRL(JAC)=3.                         ATCRBS
      GO TO 1352                                                    ATCRBS
1351  TDFSRL(JAC)=VT-0.760*EXP((TTDSRL(JAC)-TXPNDR(J))/HFTAUR(JAC))  ATCRBS
      IF (TDFSRL(JAC).LT.3.) TDESRL(JAC)=3.                         ATCRBS
1352  TTDSRL(JAC)=TXPNDR(J)                                         ATCRBS
      TDSNRL(JAC)=60.*ALOG10(12./TDESRL(JAC))                       ATCRBS
1353  CONTINUE                                                      ATCRBS
1118  KNTSLS(JAC)=KNTSLS(JAC)+1                                     ATCRBS
      I=J                                                           ATCRBS
1317  I=I+1                                                         ATCRBS
      IF (I.GT.NPULS) GO TO 7774                                    ATCRBS
 1389 IF((TXPNOR(I)-TXPNDR(J)).LE.SUPP?(JAC)) GO TO 1317            ATCRBS
1327  TDSNEC(JAC)=0.                                                ATCRBS
      GO TO 1331                                                    ATCRBS
7771  IJFLAG(JAC)=1                                                 ATCRBS
      GO TO 7                                                       ATCRBS
7772  IJFLAG(JAC)=2                                                 ATCRBS
      TXPSAV(JAC)=TXPNDR(I)                                         ATCRBS
      PXPSAV(JAC)=PXPNDR(I)                                         ATCRBS
      GO TO 7                                                       ATCRBS
7773  IJFLAG(JAC)=3                                                 ATCRBS
      TXPSAV(JAC)=TXPNDR(J)                                         ATCRBS
      PXPSAV(JAC)=PXPNDR(J)                                         ATCRBS
      GO TO 7                                                       ATCRBS
7774  IJFLAG(JAC)=4                                                 ATCRBS
      TXPSAV(JAC)=TXPNDR(J)                                         ATCRBS
      PXPSAV(JAC)=PXPNDP(J)                                         ATCRBS
      GO TO 7                                                       ATCRBS
7770  IJFLAG(JAC)=1                                                 ATCRBS
7     CONTINUE                                                      ATCRBS
```

4. DABS INVESTIGATIONS

4.1 OBJECTIVES

4.1.1 General

The objectives of the DABS investigations performed by TSC took into account that the transition from ATCRBS to DABS will be a gradual one (over a period of years) and that, until the change-over is final, there must be compatibility between the DABS and ATCRBS modes of operation. Because of this, it is still possible for ATCRBS interrogations to cause uplink interference to the DABS (and also for DABS interrogations to interfere with ATCRBS transponders), depending on the transponder state at the time of the transmissions. Three areas of interest were covered. Two of them related to the following specific tasks:

a. Task A: Effects of lengthening suppression time

b. Task B: Second-miss statistics.

The third objective was to evaluate the ATCRBS simulation model functional validity in the course of performance of Tasks A and B. This evaluation will demonstrate the capabilities of the model, identify limitations, and establish agreement with calculations related to Tasks A and B.

4.1.2 Task A - Effects of Increasing Suppression Time

a. Over a given period of simulation time in which interrogation and suppression pairs are transmitted from a ground site, an aircraft transponder will provide a number of replies, depending on the transponder parameters such as MTL (minimum triggering level) and SLS (side-lobe suppression) time; on the number of valid interrogations from the ground site within beamwidths of varying extent; and on the number of suppression pairs, which inhibit transponder replies for the length of the suppression period.

b. The effect of suppression time on the number of replies that a transponder would deliver with a given number of interrogation inputs within a given beamwidth was determined by comparing reply ratios for different lengths of suppression time. The reply ratio was expressed as a percentage of the total number of interrogations to which the transponder replied. With all other parameters except suppression time the same, the comparison was made between the reply ratios for the respective conditions of suppression time. This basic comparison was made for reply ratios involving varying interrogation inputs as well as varying suppression time, so that a set of values could be plotted as a curve of relative reply ratios for varying suppression times.

4.1.2.1 Reply Ratio Input Parameters. The information needed for determination of the effects of lengthened transponder suppression times was obtained for three categories of interrogator transmission. The nature of the categories was reflected in the definitions of reply ratios calculated for a number of events occurring over a given simulation time.

a. RRC - Beam Center Reply Ratio. This calculation relates N_{RC}, the number of replies from the transponder, to N_{IC}, the number of valid interrogations from the interrogator of interest, and is limited to those interrogations from the beam center, within plus or minus 1.25 degrees of the boresight axis. The reply ratio is expressed as

$$RRC = \frac{N_{RC}}{N_{IC}} .$$

b. RRF - Full-Beam Reply Ratio. The reply ratio in this case concerns the number of replies, N_{RF}, with respect to N_{IF}, the number of valid interrogations from the interrogator of interest within the full azimuth beamwidth. The relationship is expressed as

$$RRF = \frac{N_{RF}}{N_{IF}} .$$

c. RRE - Whole Environment Reply Ratio. This relationship includes replies to interrogations from all other sources in the environment as well as to those from the interrogator of interest. The reply ratio is then

$$RRE = \frac{N_{RE}}{N_{IE}}, \text{ where}$$

N_{IE} = number of valid interrogations from all sources in the environment

N_{RE} = total number of replies.

The above categories of interrogator transmission were considered for three aircraft positions, at each of which positions nine transponders were assigned. These transponders had different suppression times and MTLs, and were paired off for comparison purposes; i.e., one of the pair had a given reference suppression time of 35 microseconds, and the other had a greater suppression time (50 microseconds or 100 microseconds). The reply ratio data for these transponder pairs were tabulated, and then plotted as follows:

RRC, 50 microseconds versus RRC, 35 microseconds

RRC, 100 microseconds versus RRC, 35 microseconds

RRF, 50 microseconds versus RRF, 35 microseconds

RRF, 100 microseconds versus RRF, 35 microseconds

RRE, 50 microseconds versus RRE, 35 microseconds

RRE, 100 microseconds versus RRE, 35 microseconds.

(The method followed to obtain these points and tabulation and plotting of the results are discussed in paragraphs 4.2.1 and 4.3.1).

4.1.2.2 Supplementary Data for Selected Transponders. In addition to the data already collected for the 27 transponders, supplementary data were required of two of them. The objective of the latter effort was to determine average values for a selected number of parameters, and to indicate graphically the cumulative power distribution of transponder input signals for varying MTLs and for specific but different suppression times (35 microseconds and 100 microseconds).

(Discussion of the supplementary data for the two special transponders, tabulation of data, and plotting of power distribution data in the form of power histograms are covered in paragraphs 4.2.1 and 4.3.1.)

4.1.3 Task B - Second-Miss Statistics

4.1.3.1 Objective of Task B. This task provided the investigative procedure for determining the difference between the probabilities of first and second misses with DABS interrogations and with DABS transponders in assigned aircraft. The criteria for this investigation are noted in paragraphs a through g below and in paragraph 4.1.3.2. The method by which the simulation was performed, the results of the investigation based on the criteria and the simulation performance, and references to tabular and graphical information on the second-miss probabilities are also included in paragraphs 4.2.2 and 4.3.2.

a. The aircraft and DABS interrogator assignments are noted below. Transponder characteristics for the DABS transponders in this investigation are given in table 4-1.

b. Three transponders were considered in this task, one each for aircraft located in the vicinities of Philadelphia (Transponder X), Trenton (Transponder Y), and New York (Transponder Z), as indicated in figure 4-1.

c. The DABS interrogator of interest was located at the Philadelphia International Airport.

d. Transponder X was 10,000 feet above ground level, and Transponders Y and Z were 40,000 feet above ground level. The latitude and longitude for the three aircraft were identified at the positions indicated in figure 4-1.

e. The simulation was carried out in an ATCRBS 1980 environment. (The projection into the 1980 period is equated with the assumed present-day existence of 72 interrogators within a circular

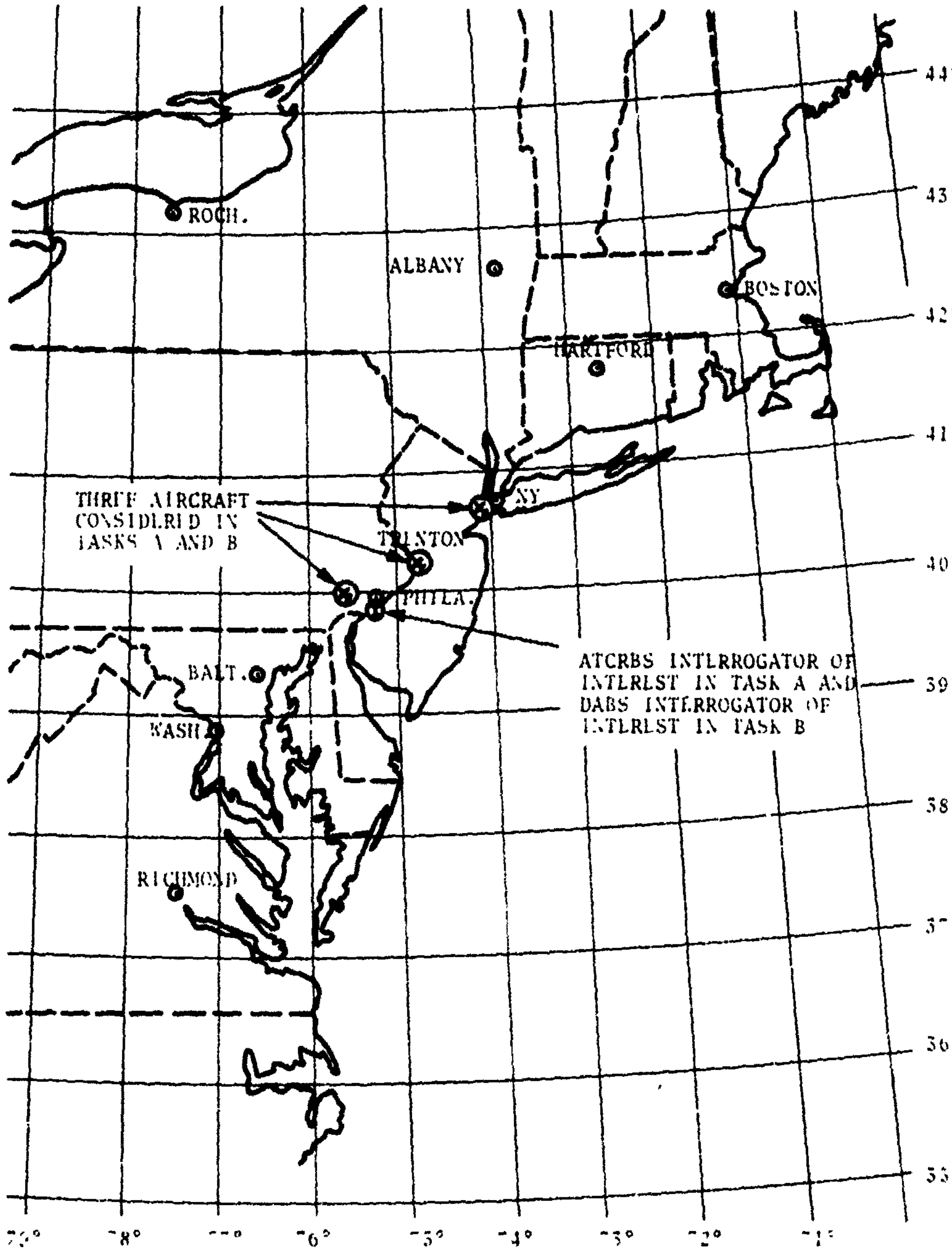

Figure 4-1. Locations of Aircraft and Interrogators of Interest in Region of Simulation

area of 250-mile radius, and with the division of the total number of interrogators into a mix between the FAA and the military. However, despite the equality between the projected and existing interrogator sites, the 1980 period environment is expected to develop to a higher functional level. This is so because, whereas many of the existing interrogators are not at present in full-time use, the 1980 environment is envisioned as one in which all 72 interrogators will operate at all times. Also, the SLS capability does not project appreciably beyond the present capability for the 1980 environment. The FAA is expected to extend this function to most of its equipment, but the military adaptation of this feature will materialize at a slower pace.)

f. Fixed parameters for the DABS investigation Task B included ATCRBS mode A and mode C capability, passive type of decoding, and an inoperative reply rate limit control.

g. The dead time, suppression time, and MTL used for the respective transponders are given in table 4-1.

TABLE 4-1. TASK B TRANSPONDER CHARACTERISTICS

Transponder	Location	Dead Time (Microseconds)	Suppression Time (Microseconds)	MTL (dBm)
X	Philadelphia	35	35	-69
Y	Trenton	35	35	-77
Z	New York	35	35	-77

4.1.3.2 Definitions of Hit/Miss with Respect to DABS

a. Interrogations. Determination of probabilities of first and second misses of DABS interrogations initiated in the simulation model depends upon the definition as to what constitutes a hit (resulting in a transponder reply) and a miss (resulting in failure to reply).

(1) The definition is based on the format of a DABS uplink signal as shown in figure 4-2.

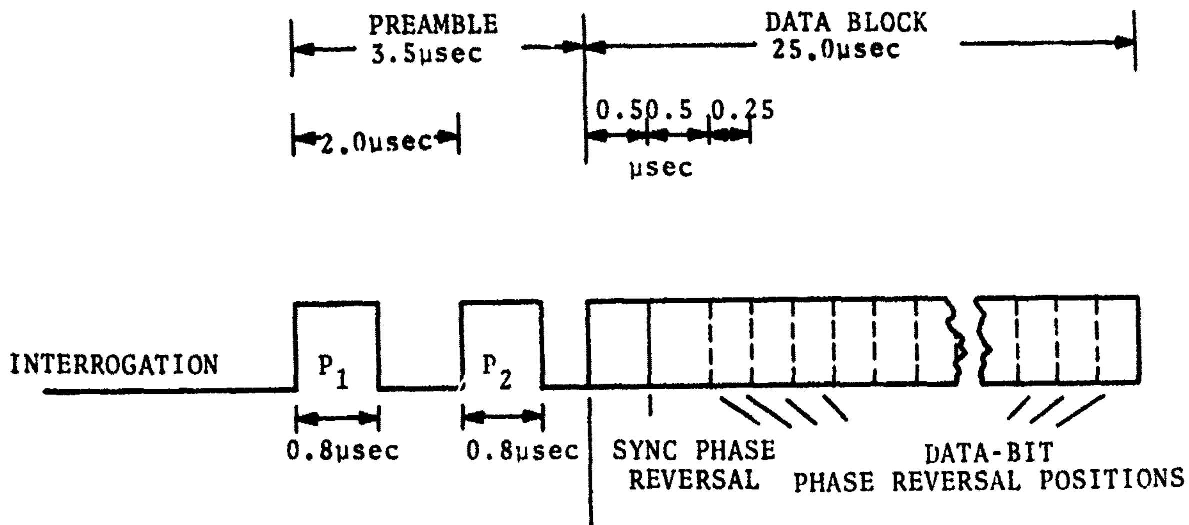

Figure 4-2. DABS Uplink Signal Format

In actual field operation, decoding of the DABS uplink interrogation is accomplished by decoding the preamble in a manner similar to ATCRBS uplink decoding, and by demodulating the differential phase-shift-keyed modulation type message. For simulation model operation, however, the preamble is treated the same as noted above, but the message is treated as purely a bracketed 25-microsecond period occurring in the interval from 3.5 to 28.5 microseconds after the start of the first preamble pulse.

(2) The following cases identify misses, and are valid for DABS interrogations which begin arriving at time t'. They are equally valid for ATCRBS interrogations which fit the indicated pulse power criteria and the time of arrival at the DABS transponder. The validity of including ATCRBS considerations in this investigation is substantiated by the compatibility feature of the DABS transponder with the ATCRBS function in mode A and mode C.

b. Miss Criteria

(1) Transponder in reply state at t' or in reply state at t' plus two microseconds

(2) DABS received power is less than DMTL for either of the preamble pulses

(3) Any ATCRBS pulse with power greater than or equal to DABS power occurring in the interval (t' plus 3.5 microseconds) to (t' plus 28.5 microseconds), where

t' = time at which the DABS interrogation begins arriving

Reply state = time between the beginning of pulse P_3 of a decoded ATCRBS interrogation and the end of the last reply pulse

DMTL = Dynamic or time-varying MTL which accounts for any instantaneous desensitization. (Refer also to paragraph 3.2.5 and figure 3-2 of Section 3.)

(Note: The absence of all the above conditions constitutes a hit.)

4.2 METHODS USED FOR DATA GATHERING AND PROGRAM MODIFICATIONS

This section describes the procedures followed in producing the simulation runs for DABS investigation Tasks A and B, and the modifications applied to the ATCRBS program listing to provide adaptability to DABS mode performance by the simulation model.

4.2.1 Description of Data Runs for Task A

Two runs were made for determining reply ratios. Fixed parameters common to all transponders for both runs included a dead time of 35 microseconds, mode A and mode C capability, reply rate limit circuit in the off condition, and passive type of decoding. Steps performed distinctly for the individual runs are outlined below.

4.2.1.1 Run Number 1 of Task A

a. Procedure for Run Number 1. The first step in gathering data for the first run was to initialize the simulation. In this procedure, random initial conditions were selected for antenna rotations, sweep phases, and mode interlace phases. These random parameters, which were selected by a random-number generator, were uniformly distributed over their ranges, and were chosen to be independent of all other parameters.

b. Data Gathering.

(1) Three aircraft, located respectively in the vicinity of Philadelphia, Trenton, and New York, were chosen for this run. The aircraft were at an altitude of 40,000 feet above ground level, and were identified at degrees latitude and longitude as shown in figure 4-1.

(2) Each aircraft position had nine transponders. The transponders were divided into groups of three with respect to the MTL and suppression time characteristics. Specifically, in each group of three transponders, one had a suppression time of 35 microseconds; the second, 50 microseconds; and the third, 100 microseconds. As for the MTLs, one group of transponders had receivers with an MTL of -77dBm; the second group's receiver MTL was -71dBm; and the receivers of the third group had an MTL of -69dBm.

(3) The interrogator of interest was located at the Philadelphia International Airport in an environment representing the 1980 period. (Refer to figure 4-1 for location of the airport, and to paragraph 4.1.3.1e for additional comment on the 1980 environment.)

(4) Two transponders of the 27 mentioned (paragraph 4.1.2.2) were singled out for additional data gathering, and were identified as Transponders A and B. Transponder A, located in the Philadelphia aircraft, had an MTL of -69dBm and a suppression time of 35 microseconds. Transponder B was located in the New York aircraft, and had an MTL of -77dBm and a suppression time of 100 microseconds.

(5) Common data were gathered for all 27 transponders. These data consisted of RRC, RRF, and RRE. The following additional data were gathered for Transponders A and B:

Average valid interrogation arrival rate

Average reply rate

Average valid SLS arrival rate

Average suppression rate

Average single-P_2 arrival rate.

4.2.1.2 Run Number 2 of Task A. The second run, which applied only to Transponders A and B, was performed similarly to the first run with respect to employment of the same interrogator of interest and interrogator environment, initialization, and five-minute period of data gathering. The data gathered included RRC, RRF, and RRE, and also the special data for Transponders A and B referred to in paragraph (5) above.

4.2.2 Simulation Procedure for Task B

The simulation was carried out for a number of starts selected to cause approximately 50 random second misses to occur. Each simulation was initialized and then stabilized for one simulation cycle, after which the first DABS interrogation was transmitted to each transponder. The hit/miss status was determined. If a hit occurred, the event was counted, and no further data were taken on that transponder until after the next start. If a miss occurred, the following sequence of steps was adopted:

a. The event was counted.

b. The hit/miss status was determined for a second DABS interrogation at time τ later, with τ values between 1 and 10 milliseconds in 5-microsecond steps.

c. The hit/miss status was determined at time τ' later, where τ' is a random variable, uniformly distributed over the interval 1 to 10 milliseconds.

After these computations were completed, the simulation was restarted, with re-initialization of input conditions completely independent of any previous history.

4.2.3 Task A Program Listing Modifications

The program listing for Task A includes ATCRBS simulation program modifications which make both the DABS and ATCRBS simulation modes compatible. The flow-chart presentation of these modifications (figure 4-3) contains DO loops (outer and inner loops) which permit SLS and interrogation pulse-pairs and random single pulses to be detected, analyzed, identified, and recorded. The blocks in the inner and outer loops follow the same functional sequence except for those blocks which terminate the respective loops. (This feature is discussed in greater detail below.) In the following discussion statement numbers, ATCRBS step numbers, and DABS step numbers refer to designations in figure 4-3 and also to corresponding designations in the program listing for Task A of Appendix B.

4.2.3.1 Initial Steps of DABS Modification. As noted in step ATCRBS 1191 of figure 4-3 and of the Task A program listing, the number of pulses (NPULS) in the present simulation cycle interval is first determined. If only one pulse exists (NPULS=1), it is tested for detection by the simulation model transponder. If this pulse can not be detected, transponder operation is then initiated in the program by going to statement 1203 of the Task A program listing. (The transponder portion of the Task A program is basically the same, except for a few minor changes, as the ATCRBS transponder program described in detail in table 3-4 of Section 3.) If, however, NPULS can be detected (statement 8101, the first pulse from the input array of the next simulation cycle is entered into the simulation model, and is compared with the detected NPULS of the previous input array to determine whether an interrogation pulse-pair, an SLS pulse-pair, or a random single P_2 pulse has resulted. If the number of remaining pulses in the input array of the present simulation cycle is greater than one, the program continues with a series of DO loops which compare the pulses two at a time to determine their composition. The overall approach for these final determinations is initiated in accordance with the sequence of steps a through d in paragraph 4.2.3.2.

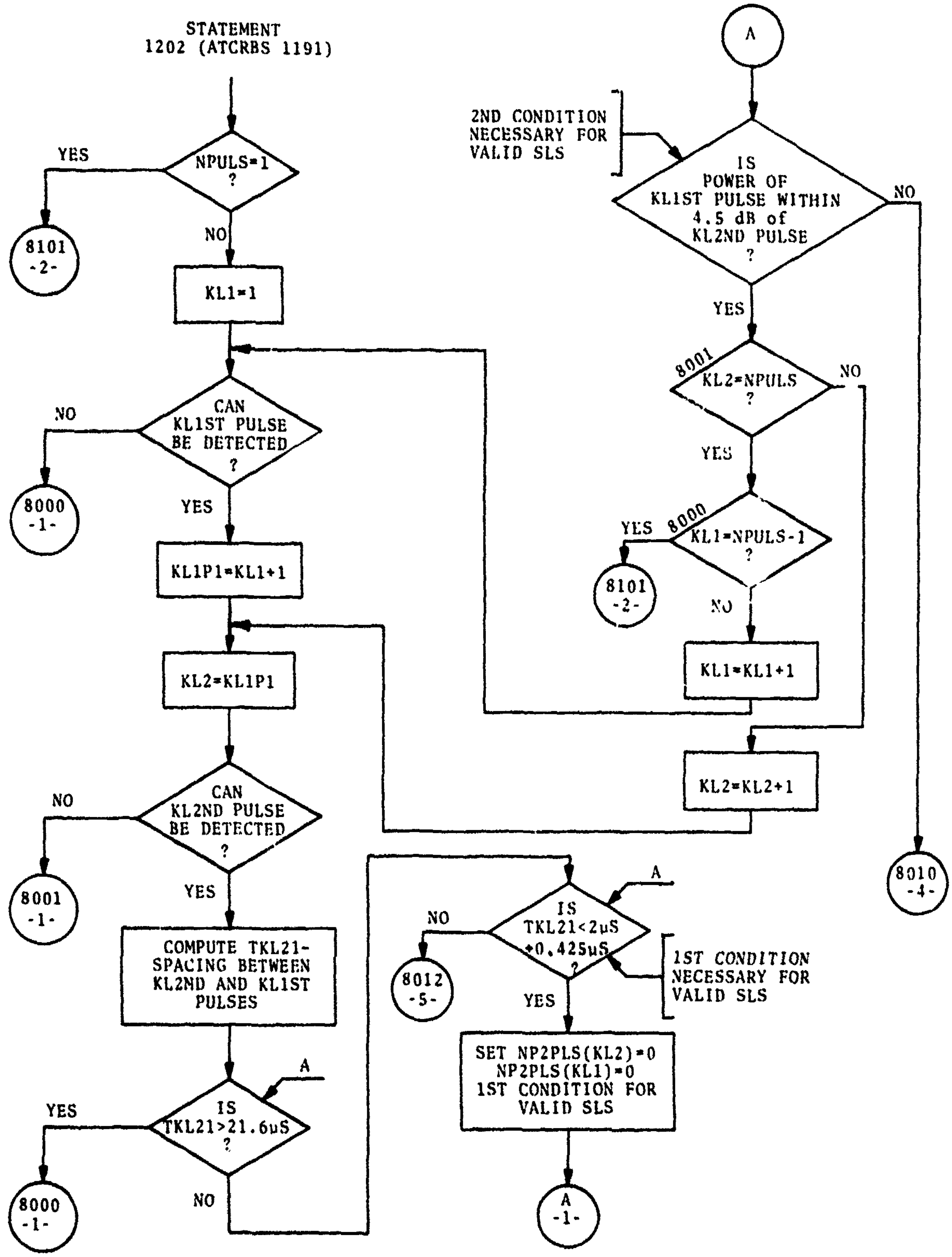

Figure 4-3. Flow Chart of ATCRBS Simulation Program Modifications Incidental to Performance of Task A (Sheet 1 of 8)

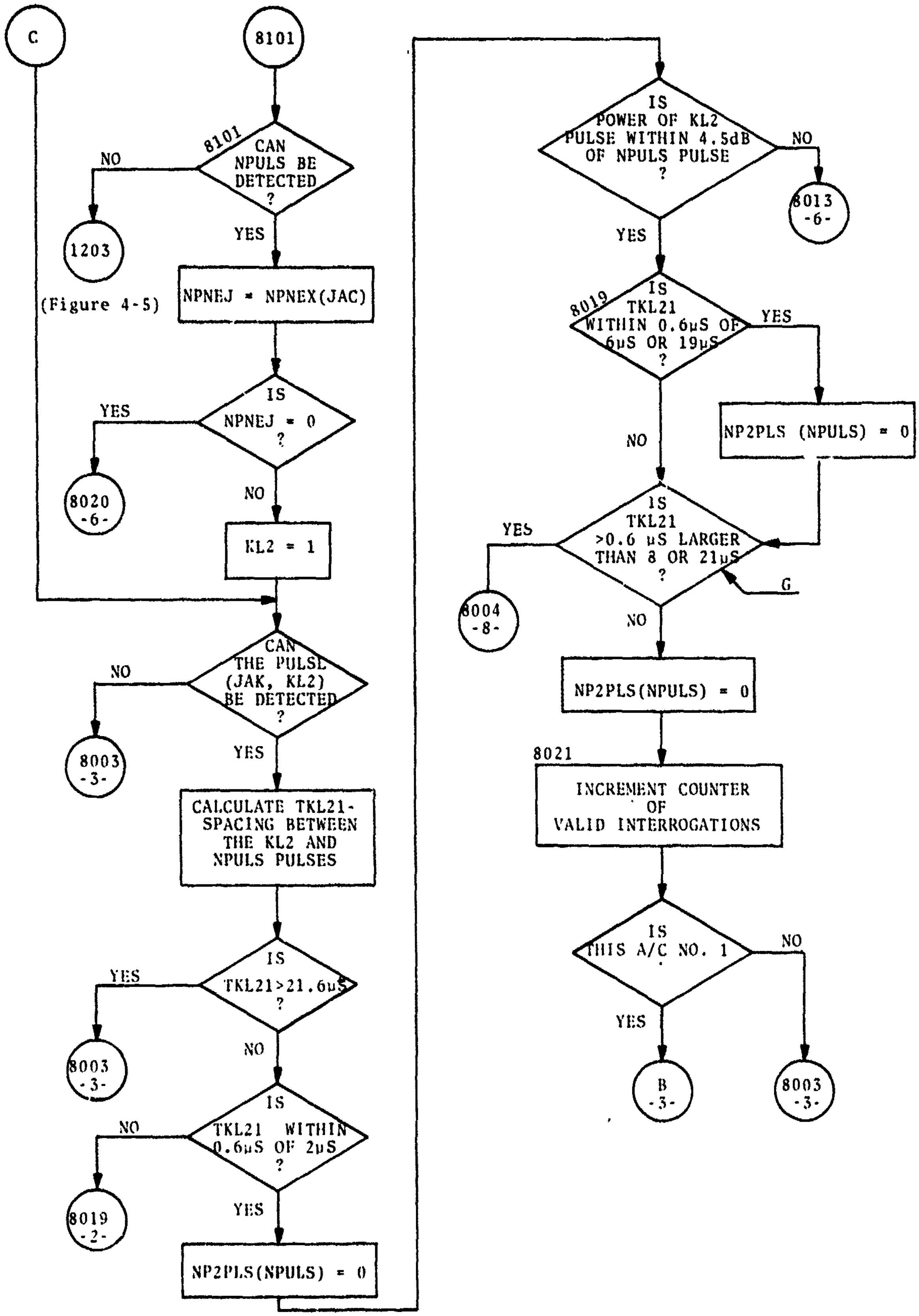

Figure 4-3. Flow Chart of ATCRBS Simulation Program Modifications Incidental to Performance of Task A (Sheet 2 of 8)

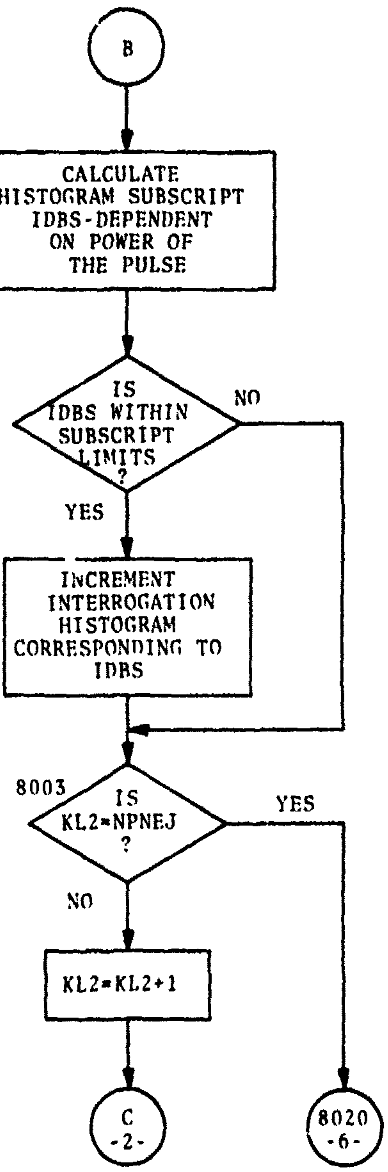

Figure 4-3. Flow Chart of ATCRBS Simulation Program Modifications Incidental to Performance of Task A (Sheet 3 of 8)

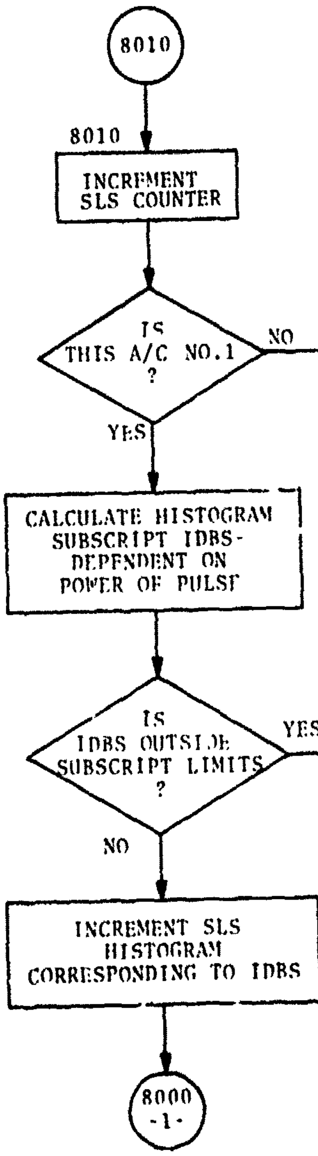

Figure 4-3. Flow Chart of ATCRBS Simulation Program Modifications Incidental to Performance of Task A (Sheet 4 of 8)

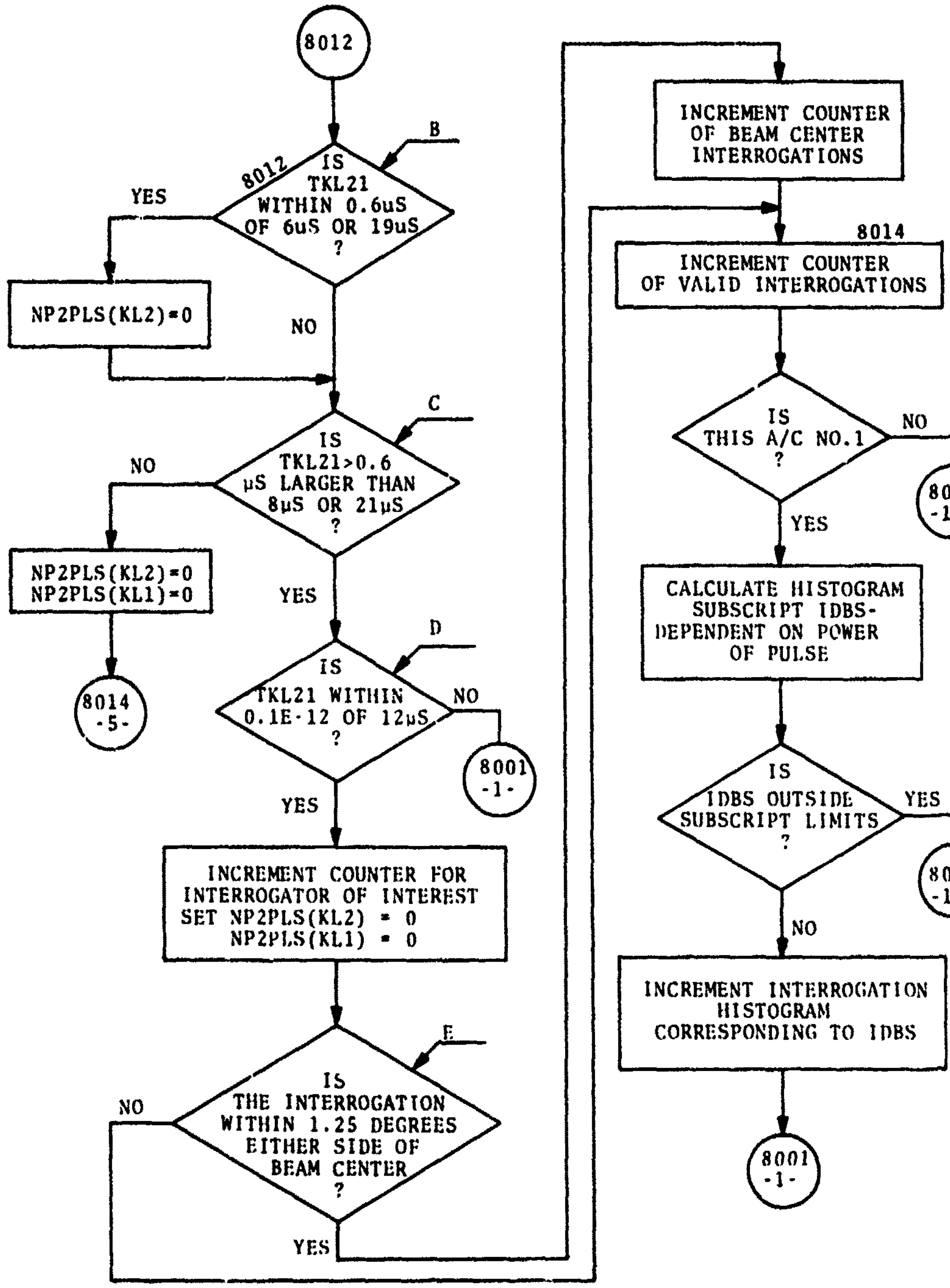

Figure 4-3. Flow Chart of ATCRBS Simulation Program Modifications Incidental to Performance of Task A (Sheet 5 of 8)

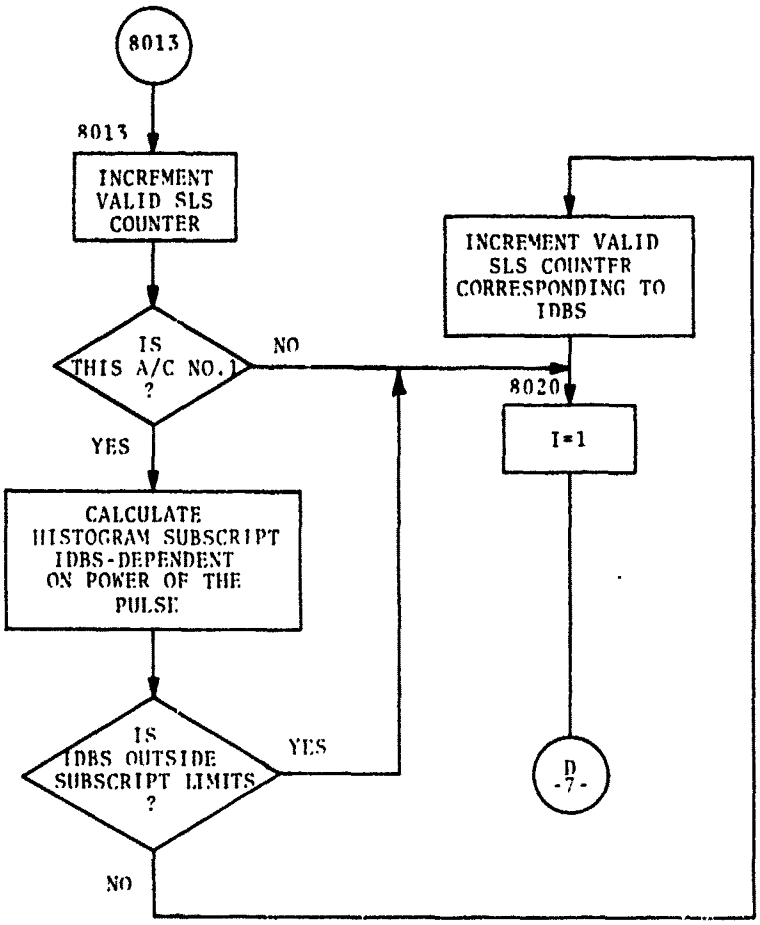

Figure 4-3. Flow Chart of ATCRBS Simulation Program Modifications Incidental to Performance of Task A (Sheet 6 of 8)

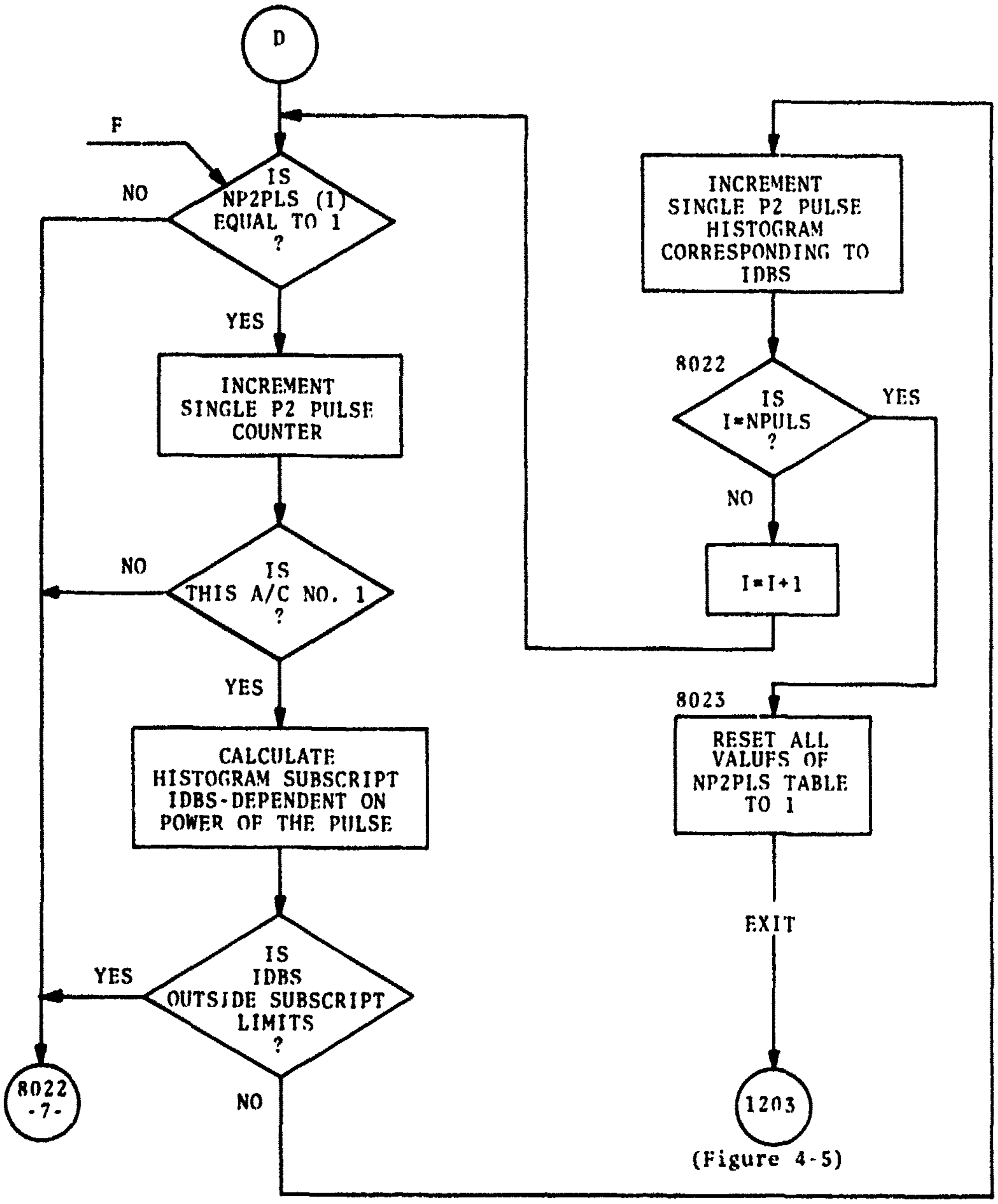

Figure 4-3. Flow Chart of ATCRBS Simulation Program Modifications Incidental to Performance of Task A (Sheet 7 of 8)

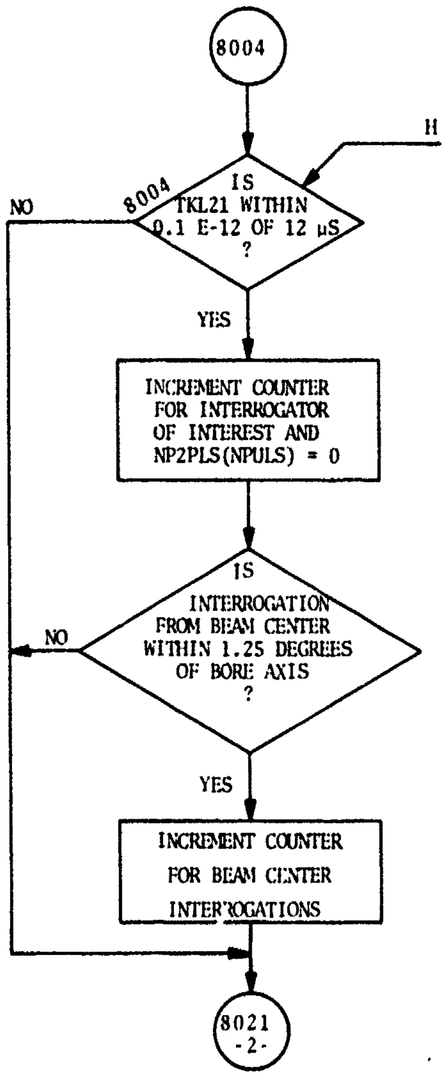

Figure 4-3. Flow Chart of ATCRBS Simulation Program Modifications Incidental to Performance of Task A
(Sheet 8 of 8)

4.2.3.2 Introduction to DO Loops. All the DO loops shown in figure 4-3 are begun by a number of basic procedures designed to establish the pairs of pulses (KL_1 - KL_2 and NPULS - KL_2) which are investigated as to their time spacing, power relationships, and ultimate disposition. These introductory steps lead to decision statements, or blocks, which distinguish the different flow-chart paths according to whether interrogation pulse-pairs, SLS pulse-pairs, or single pulses have been supplied to the transponder. The following discussion relates primarily to the KL_1 - KL_2 inputs (figure 4-3) and to the flow paths to which the input conditions lead. The NPULS - KL_2 conditions arrived at in the decision-making process are mentioned at present for continuity of discussion. The latter conditions are investigated further following the complete discussion of the KL_1 - KL_2 conditions. Statements a through d below are common to the determination of the flow-chart paths for interrogation pulse-pairs, SLS pulse-pairs, or random single P_2 pulses respectively. The specific paths to which these statements lead are examined in paragraphs 4.2.3.3 and 4.2.3.4.

a. If it is determined that a number of pulses remains in the input array of the present simulation cycle, KL_1 is designated to represent the first of these input pulses arriving at the transponder, and is checked as to whether it can be detected by the transponder. (If it is not detected, refer to statement d below. Otherwise, proceed directly with statement b.)

b. If KL_1 is detected by the transponder, the next pulse is entered by incrementing KL_1 by one and then transferring it to the KL_2 designation. This second pulse KL_2 is also checked to determine that it can be detected. (If it cannot be detected, refer to statement d below. Otherwise, proceed directly with statement c.)

c. With both KL_1 and KL_2 established as having been detected by the transponder, the time interval between the two pulses is computed.

(Note: For the condition the KL_1 and KL_2 have been detected and the command for computation of the time spacing between them has been initiated, the flow chart branches off in paths corresponding to the categories into which the pulse arrivals fall.)

d. If the KL_1 pulse cannot be detected, it is checked, in statement 8000, to determine whether it represents the next-to-last pulse of the input array. If so, the next pulse NPULS is introduced, and it also is checked as to whether it can be detected by the transponder. If NPULS cannot be detected, there are no more pulses in the input array for the present simulation cycle, and transponder operation is initiated by program statement 1203. If NPULS can be detected, it becomes the first pulse entered in the transponder with respect to the pulses from the input array of the next simulation cycle. The pulse KL_2 of this new simulation cycle is entered on the fact that a number of pulses is available from the input array of the second simulation cycle, and the time spacing is then computed between NPULS and the KL_2 pulse.

4.2.3.3 Interrogation DO Loop. This DO loop provides the step sequence for determining whether pulse arrivals from the present simulation cycle input array constitute ATCRBS interrogations or DABS interrogations, and also for recognizing the existence of a random single P_2 pulse. The time spacing between incoming pulses is determined to be not greater than 21.6 microseconds. Also, for the interrogation path, the absolute value of the difference between the pulse spacing and 2 microseconds is greater than 0.425 microsecond, as indicated in decision block A of figure 4-3. An extended analysis of the actual input content is presented in a through f below.

a. With the time spacing between the pulses KL_2 and KL_1 initially determined, a further inspection is made (in the block B) as to whether the time separation between the pulses is either 6 microseconds or 19 microseconds (plus or minus 0.6 microsecond tolerance). If either of these conditions is met, then a valid P_2 is established as available in a P_1 - P_2 - P_3 pulse group and, therefore, a random single P_2 pulse is precluded at this point in the program.

b. For the same condition that a P_1 - P_2 - P_3 group is identified, the decision block C can satisfy only the YES criterion; i.e., a valid DABS P_1 - P_3 interrogation pulse-pair exists in the grouping of pulses being considered. The program now continues with a determination, through decision block D, as to whether the detected pulse-pair constitutes a part of the total environment, or of an interrogator transmission beam within plus or minus 1.25 degrees from the beam center, or of the full azimuth beamwidth of 4.5 degrees. (These determinations are related to the calculations for reply ratios RRE, RRC, and RRF, defined and discussed in paragraph 4.1.2.1.)

c. The decision block D indicates the existence of a DABS interrogation by establishing that the pulse spacing differs from 12 microseconds by an extremely small time tolerance (0.1 picosecond). The value of 12 microseconds was chosen to distinguish a DABS interrogation from an ATCRBS interrogation in the overall environment.

(1) If the pulse spacing is different from 8 or 21 microseconds (decision block C) and also not equal to 12 microseconds (decision block D), the pulse-pair is not considered to be a valid interrogation either from the interrogator of interest or from any other interrogator in the environment. The DO loop is re-initiated with statement 8001 and performed and repeated until the last pulse in the array is used.

(2) If the pulse spacing (decision block D) is equal to 12 microseconds (plus or minus one picosecond), then the pulse-pair is considered to be a valid DABS interrogation. The counter for the interrogator of interest is incremented, and a further check on the pulse-pair is made in decision block E. The latter check distinguishes a DABS center beam radiation (within 1.25 degrees of the boresight axis) from a full-beam radiation. If the condition with respect to block E is verified, then the received pulse-pair qualifies for use in the calculation for RRC. The beam-center interrogation counter and the valid interrogation

counter are both incremented. The latter counter is the same one incremented when an ATCRBS interrogation pulse-pair was detected. The succeeding steps for determining the type of aircraft transponder and for inclusion of an associated histogram are considered for the remaining pulses in the array in accordance with the DO loop steps described in the following paragraphs d and e, but relative to the DABS interrogation.

(3) If, with respect to decision block E, the interrogation does not satisfy the beam-center classification, then it qualifies as the interrogation to be used in the calculation for RRF. The valid interrogation counter is incremented, and the loop steps are continued as was done for the previous two DABS interrogations.

d. If the pulse spacing in the decision block B is neither 6 nor 19 microseconds (plus or minus 0.6 microsecond tolerance), then, according to decision block C, the spacing is inspected as to whether the transponder has received a valid ATCRBS interrogation or a valid DABS interrogation (or neither). If the pulse spacing is 8 or 21 microseconds (plus or minus 0.6 microsecond), an ATCRBS interrogation pulse-pair has been detected. The valid interrogation counter is now incremented, and the transponder under consideration is checked as to whether it is either Transponder A or Transponder B. If the transponder is either of these two, a histogram is provided for valid interrogation arrivals at the transponder for different settings of the transponder sensitivity, as indicated for the total histograms of figures 4-13, 4-16, 4-19, and 4-22. The summations of the values for the incremented interrogation histograms are obtained by successive operations of the DO loop containing the steps already covered and including the decision blocks marked A, B, and C. The loop operations are repeated for all the pulses in the input array through NPULS, after which the next simulation cycle is considered.

e. If the aircraft transponder of interest is neither Transponder A nor Transponder B, the DO loop is re-initiated (in statement 8001) with a check as to whether the most recent KL_2 pulse considered was the last one (NPULS) of the array. The loop is processed further, depending on the result of the check, in accordance with the sequence of steps beginning with statement 8001 of figure 4-3. The loop operation is repeated until the last pulse of the array is reached, and the flow-chart path traveled depends on the types of input pulses from the array.

f. If the pulse spacing (in decision block C) differs from 8 or 21 microseconds (plus or minus 0.6 microsecond), the transponder has detected a DABS interrogation pulse-pair. The subsequent determination of the type of DABS interrogation for which the pulse-pair qualifies is made in the same manner described in paragraphs 4.2.3.3b and 4.2.3.3.c.

4.2.3.4 SLS DO Loop

a. The SLS DO loop path is reached when it is shown in the flow-chart that the time spacing between pulses KL_1 and KL_2 has an absolute value within 0.425 microsecond of 2 microseconds. This condition is necessary, but not sufficient, for establishing that the transponder has detected a valid SLS pulse-pair.

b. The second condition to be validated is indicated in the decision block which determines whether the power in pulse KL_2 is at least 4.5dB greater than the power in pulse KL_1. If not, the transponder has not detected an SLS pulse-pair. The KL_2 pulse is then checked as to whether it was the last pulse of the input array of the present simulation cycle. If not, a new pulse is inserted as input to the inner SLS DO loop, and the cycle is repeated for computation of the KL_1 - KL_2 interval time spacing and relative powers. This loop operation is continued until the last KL_2 pulse (NPULS) of the input array has been considered.

c. If, on the other hand, KL_2 was identified as the last pulse (NPULS), then input pulse KL_1 is checked as to whether, at the same time, KL_1 was the next-to-last pulse (NPULS minus one). If not, the KL_1 pulse is incremented by one and the outer SLS DO loop is re-initiated. This cycle is repeated with new values of

KL_1 from the input array until KL_1 does, in fact, become the next-to-last pulse in the input array.

d. With the conditions stated in c, and with the last KL_2 pulse removed from the present input array, KL_1 is the only remaining pulse in the input array of the present simulation cycle. As such, it becomes the equivalent of NPULS = 1, and is checked for detection by the transponder (statement 8101 of figure 4-3). If it is not detected, transponder action begins with statement 1203 of the DABS program. If, however, it is detected by the transponder, it is compared with the first input pulse from the next input array (KL_2 = 1 in this case). This constitutes the first detected pulse-pair of the second simulation cycle.

e. If the second condition for a valid SLS pulse-pair is met, i.e., KL_2 is at least 4.5dB greater than KL_1, the SLS counter is incremented by one, and the (simulated) aircraft transponder is checked to determine if it is either Transponder A or B. If the transponder is indeed Transponder A or B, the detection of the SLS pulse-pair by this transponder is indicated as part of a histogram readout. The histogram data are provided for the respective histogram subscripts in the range of receiver sensitivities at which the transponder is operating. These histogram subscripts correspond to the power levels marked on the abscissas of figures 4-14, 4-17, 4-20, and 4-23. In the case described, the cycle for Transponder A or B is repeated, beginning once more with statement 8000. This statement initiates the repetitive sequence of steps (already described in paragraphs 4.2.3.1, 4.2.3.2, 4.2.3.3, and part of 4.2.3.4) which provide the following possibilities as to the nature of pulses or pulse-pairs in the present or succeeding simulation cycles:

(1) There are no pulses remaining in the present simulation cycle, and transponder action is begun.

(2) The last pulse of the present simulation cycle array has been detected, and it is compared with the first input pulse of the next array.

(3) Pulse-pairs are detected and their spacing and power relationship are determined.

(4) On the basis of the findings in (3), the input pulses are analyzed as ATCRBS or DABS interrogations, SLS pulse-pairs, or single random P_2 pulses.

The sequence of steps is repeated until the last pulse-pair of the present simulation cycle has been considered.

4.2.3.5 Second Simulation Cycle. The discussion in paragraphs 4.2.3.1 through 4.2.3.4 on program modifications for DABS adaptation has dealt primarily with DO loops encountered during the first simulation cycle of operation. For continuity of the discussion, means were also provided for entering the next simulation cycle and for introducing a new set of inputs from the input array of the new simulation cycle. The following text continues with a similar consideration of the new array to determine the nature of the inputs arriving at the transponder of interest. Although some of the following remarks overlap statements already made during the first simulation cycle analysis (e.g., relative to entering the second simulation cycle), they are included here to suggest completeness to the steps involved in the second simulation cycle.

4.2.3.6 Single P_2 Pulse DO Loop. Statement 8101 of the program listing indicates whether a single pulse (NPULS) from the previous simulation cycle is detected for comparison with the first pulse of the next input array. If the NPULS of the previous simulation cycle cannot be detected, it is no longer considered relative to the new simulation cycle, and transponder operation is begun with statement 1203 of the modified program. If the NPULS can be detected but no pulses are available in the new array, a DO loop is initiated (statement 8020) for an index (I) array, beginning with I = 1 and ending with I = NPULS, to check whether the pulse investigated equals 1. If the separate pulse, in this case NPULS of the previous simulation, is equal to 1, then it constitutes a single P_2 pulse. The single-P_2 pulse counter is now incremented, and the transponder of interest is checked to determine whether it is either a Transponder A or a Transponder B (i.e., a/c no. 1). This information, relative to the single P_2 pulse detected by the transponder of interest, is recorded as part of a histogram of arrivals of single P_2 pulses for given values of transponder receiver sensitivity. The values for points on the histogram are related to the power in the pulses, and the points are plotted for particular operating receiver sensitivities as indicated on the abscissas of the curves in figures 4-15, 4-18, 4-21, and 4-24. The process is repeated for the histogram plots through the last pulse (NPULS) of the new array, after which all values of the NP2PLS table are reset to 1 and the transponder operation is begun with step 1203 of the modified program.

4.2.3.7 <u>DO Loops for Pulse-Pair Comparisons in Second Simulation Cycle</u>. When it is determined that the NPULS from the previous simulation cycle is detected (statement 8101), and also that the next simulation cycle array has inputs available for comparison (NPNEJ is greater than 0), NPULS is compared with the first input from the new array. This comparison is the first step of a DO loop which starts with the block $KL_2 = 1$ and extends through statement 8003 of the program listing. The decisions made and actions taken for the newly introduced pulse-pairs in this DO loop are similar to those made and taken for the corresponding pulse-pair KL_1 - KL_2 of the previous simulation cycle (paragraph 4.2.3.2). The following additional comments are pertinent to the second simulation cycle and supplementary to the information provided for the previous simulation cycle.

a. If NPULS of the previous simulation cycle is detected (statement 8101) but the input pulse KL_2 from the new array cannot be detected, then the array is tested for additional available pulses (statement 8003). If KL_2 was the last pulse (NPNEJ), then NPULS is determined to be a single P_2 pulse (statement 8020 and affirmative to decision block F). The single P_2 pulse counter is incremented, and the sequence of events following the incrementing is performed in accordance with the sequence described in paragraph 4.2.3.6. If the KL_2 pulse now being considered is not the last pulse in the array, another KL_2 pulse is entered, and a new decision is made as to whether it can be detected. This loop sequence is repeated until KL_2 equals NPNEJ, the last pulse in the array.

b. If both NPULS and KL_2 are detected and the spacing between them is greater than 21.6 microseconds, then the possibility that KL_2 represents a single P_2 pulse is once more explored by going to statements 8003 and 8020, and to the subsequent steps already described in paragraph 4.2.3.6.

c. If both NPULS and KL_2 are detected and the spacing between them is equal to 2 microseconds (plus or minus 0.6 microsecond), this precludes the possibility that the last pulse of the previous simulation cycle (NPULS) was a single P_2 pulse; actually, the 2-microsecond spacing between NPULS and KL_2 represents the first of two necessary conditions for acceptance by the transponder of a valid P_1 - P_2 SLS pulse-pair. In addition to the 2-microsecond spacing, the second necessary condition is ascertained, namely, that the power in pulse $P_2(KL_2)$ is at least 4.5dB greater than the power in P_1 (NPULS). With these conditions met, the valid SLS counter is incremented, after which the transponder of interest is checked as to whether it is either Transponder A or Transponder B. If the latter condition is true, the succeeding steps are followed for recording the pulse-pair arrival data as part of the histograms in the manner described in paragraph 4.2.3.6. The process is continued in the loop sequence until the last pulse (NPULS) of the array has been reached. The values in the NP2PLS table are all reset to 1, and transponder operation is initiated with statement 1203 of the program listing.

d. If the transponder of interest is neither Transponder A nor Transponder B, the P_2 pulse of the pulse-pair is checked to see if it is the last pulse (NPULS) of the array. If it is, then all the values of the NP2PLS table are reset to 1, and transponder operation begins with statement 1203 of the program listing. Otherwise, additional pulses are compared with NPULS of the previous simulation cycle, and the cycle of operations is repeated until the last pulse (NPULS) of the present array has been checked.

e. If only the first condition for detection of an SLS pulse-pair (2-microsecond spacing) is met, then statement 8019 must be answered NO and decision block G must be answered YES, in effect establishing a DABS interrogation (P_1 - P_2 pulse-pair in the preamble of the DABS interrogation). The valid interrogations counter is incremented, and the sequence of steps is continued as in paragraph 4.2.3.6 for determination of the transponder of interest as Transponder A or Transponder B, and for recording interrogation arrivals in the associated histograms.

f. If both NPULS and KL_2 are detected and the pulse spacing is less than 21.6 microseconds but either greater than 2.6 microseconds or less than 1.4 microseconds, the pulse-pair is tested to determine if the spacing is either 6 or 19 microseconds (plus or minus 0.6 microsecond). If it is either of these, then a single P_2 pulse is precluded. A P_1 - P_2 - P_3 pulse group must be present, in which the P_2 pulse is matched to the P_1 pulse (P_1 - P_2 equals 2 microseconds) and to the P_3 pulse (P_2 - P_3 is either 6 microseconds or 19 microseconds). Decision block G in this case must be considered affirmatively, since the absolute value of the difference between the pulse spacing and 8 or 21 microseconds is greater than 0.6 microsecond. Therefore, statement 8004 having been reached, the condition prevails for investigating the existence of a DABS interrogation. The procedure at this point is similar to that discussed in paragraph 4.2.3.3c.

g. If, with NPULS and KL_2 detected, and the pulse spacing as in f, it is determined in statement 8019 that the pulse spacing is also neither 6 nor 19 microseconds (plus or minus 0.6 microsecond), further investigation through decision block G determines whether the pulse spacing is 8 or 21 microseconds (plus or minus 0.6 microsecond). If so, an ATCRBS interrogation has been detected. The sequence of steps in the DO loop is then repeated for all the pulses in the array, including valid interrogation counter incrementing, establishing the specific transponder of interest, and recording of data for the associated histogram. Otherwise, a DABS interrogation is established, and the sequence of steps discussed in f above is again followed, beginning with statement 8004 of the program listing.

4.2.4 Task B Program Listing Modifications

The simulation program for Task B provides the simulator with the means for accomplishing the procedures described in paragraph 4.2.2. Actual performance of Task B is made possible by application of the complete Task B simulation program contained in Appendix C. The program was set up according to the approach presented in the main flow chart of figure 4-4 and the auxiliary flow charts of figures 4-5 and 4-6. (Figure 4-4 is presented together with the text of paragraph 4.2.4.2, and figures 4-5 and 4-6 are included as part of paragraph 4.2.4.3.) The following discussion describes the flow charts as a basic sequence of steps in the simulation procedure for determining the probability of second misses; it also analyzes the relationships of the addenda of figures 4-5 and 4-6 to the basic operational procedures indicated in figure 4-4.

4.2.4.1 Brief Description of DABS Second-Miss Program. The program is begun with an initializing process which provides the conditions under which a series of DABS interrogations is to be transmitted to each of three assigned aircraft transponders. These first conditions, which define the initialization, refer to selection of random initial positions for the rotating antennas, and the initial setting of sweep phases and mode interlace phases. The uplink transmissions, which originate from a DABS interrogator located at the Philadelphia International Airport, are radiated for interception (and potential replies), under the given conditions, by each of three transponders in aircraft located at Philadelphia, Trenton, and New York respectively. Determination of whether these transmissions result in hits (replies from the transponders) or misses (failure to reply) with respect to the transponders under consideration constitutes the greater part of the program and the flow charts. When the determination is made, it is then possible to calculate the number of hits, the number of first misses, the number of second misses, and the probability of second misses with respect to first misses for different magnitudes in the initialization.

a. Parameters Related to Input Variables

(1) Two types of variable input data are used in determining the probability of second misses: uniformly incremented variables, and randomly selected variables. The former are related to the number of second misses occurring at regularly incremented five-microsecond intervals for an investigation extending through 10 milliseconds. The random variables have to do with interrogator transmissions uplinked at random times, but evenly distributed within the same 10-millisecond period. (These uniform and random time intervals refer to τ and τ' of paragraphs 4.2.2, 4.3.2a, and 4.3.2b.) Parameters used in the flow chart of figure 4-4 and related to the input variables are listed in table 4-2.

TABLE 4-2. LIST OF PARAMETERS RELATED TO INPUT VARIABLES

Parameter	Remarks
DBHIT	A counter which records the number of DABS hits. (For the meaning of a hit as used here, refer to the listing of miss criteria in paragraph 4.1.3.2, and note that the absence of all these miss criteria constitutes a hit.)
DBMIS1	A counter of first misses. Recording a miss on this counter is related to the setting of a flag MISSFL, described in table 4-3. This flag is initially set equal to zero. If, with MISSFL=0, a DABS interrogation is missed by a transponder, the DBMIS1 counter is incremented by 1, and the flag MISSFL is set equal to 1. With MISSFL=1, the next DABS interrogation miss becomes a second miss, causing a second-miss counter DBMIS2 to be incremented by 1.
DBMIS2(ITAU)	A subscripted counter used to count the number of second misses for each uniformly incremented five-microsecond interval within the 10-millisecond period.

TABLE 4-2. LIST OF PARAMETERS RELATED TO INPUT VARIABLES (CONT'D)

Parameter	Remarks
ILOOP	A counter expressing the number of simulation starts in a range of N starts. This counter number is used to calculate first-miss probabilities.
PDABSM	Power contained in a DABS interrogation occurring at time TDABSM. This variable is predetermined, and is specifically assigned for each aircraft position.
RANMS2	A counter which records the number of random second misses. This counter causes the program to stop when it reaches a count of 50.
TDABSM	Time at which a first DABS interrogation miss occurs. This variable is predetermined, and is specifically assigned for each aircraft position.

(2) The random conditions referred to in (1) above are valid for a particular simulation start in the group of N starts. A new set of conditions is initiated for each succeeding start until 50 random second misses have been counted. The initial conditions are inserted as inputs to the program by a random number generator, which provides random inputs over a predefined interval.

(3) In addition to the random inputs provided by the random number generator, the parameters relating to the transponder under consideration are also reset to initial values. In this way the transponder operation will be relevant only to the newly inserted inputs, and independent of any past history which may have influenced the state of the transponder. The parameters to be reset and their initial settings are indicated in paragraph 4.2.4.1b.

(4) The probability of DABS second misses in an environment including ATCRBS interrogations is determined in the simulation model by the effect on DABS interrogations inserted into an array of ATCRBS pulses. The simulation program is initially performed until a first DABS miss is encountered, following which a 10-millisecond interval is examined for possible DABS second misses within that interval. A counter ICK is used to indicate the number of consecutive 2.5-millisecond simulation cycles executed for accumulation of ATCRBS pulses into the array referred to above. (When ICK equals 4, the array content represents an accumulation of ATCRBS pulses over the 10-milliseconds period.) The first in the series of second DABS interrogations is inserted into the array one millisecond after detection of the first miss, and the transponder operation determines whether a hit or (second) miss has been achieved. The result of this action is recorded, the previous second DABS interrogation is removed, and a new second DABS interrogation is inserted (5 microseconds after the previous second DABS interrogation) into the array for a similar determination of a second miss or a hit. This operation is repeated at 5-microsecond increments for the period extending through the entire 10 milliseconds. In addition, a random DABS interrogation is inserted into the array, and determination is made as to whether a hit or a second miss was achieved. The random DABS second miss is recorded, and the search for a new first miss is begun with new initial conditions. This procedure continues until 50 random DABS second misses have been recorded.

(5) Additional initial settings are required for a number of flags. The parameters used to identify them are defined in table 4-3, and the actual settings are indicated in paragraph 4.2.4.1b.

TABLE 4-3. LIST OF FLAGS

Flag	Remarks
IRNTFL	Random tau flag
M1STFL	This flag is initially set to 1. When a statement in the program inquires whether M1STFL equals 1, an affirmative answer indicates that the loop containing this inquiry is being passed through for the first time.
MISSFL	First miss flag which, by its setting (0 or 1) indicates whether or not to anticipate a second miss when the next miss occurs.
MIS2FL	Second-miss flag.

b. Initial Settings - The initial settings associated with the parameters of paragraph 4.2.4.1a serve as references for the simulator in its calculations of hits and first and second misses on the basis of the given random input conditions. The parameters, with their initial settings, are contained in the first three blocks of figure 4-4 under the general heading, "Initialization". A compact presentation of the parameters is also provided in table 4-4, together with a brief definition and initial setting for each parameter. The tabular arrangement follows the arrangement of the parameters in the blocks of figure 4-4. This ensures separation of fixed parameters from parameters involved in loop operation, and also presents as a group the transponder parameters which must be reset prior to a simulation start.

(Note: For expanded definitions of the transponder parameters, refer to table 3-3 of Section 3. Also, note that when additional parameters are considered in procedures subsequent to initialization, they are defined in the text for that part of the program in which they are used.)

TABLE 4-4. INITIAL SETTINGS FOR PARAMETERS IN SECOND-MISS PROGRAM LISTING

Parameter	Description	Initial Setting
DABS Parameters (Counters, Time of Occurrence, Power)		
DBHIT	Counter, records number of DABS hits	DBHIT = 0
DBMIS1	Counter, records number of first misses	DBMIS1 = 0
DBMIS2	Counter, records number of second misses	DMBIS2 = 0
ILOOP	Counter, records number of attempted DABS interrogations	ILOOP = 0
PDABSM	Power in DABS interrogation miss	PDABSM...*
RANMS2	Counter, records number of random second misses	RANMS2 = 0
TDABSM	Time of occurrence of DABS interrogation miss	TDABSM...*

*Predetermined. Changes with each aircraft.

	Transponder Parameters	
TDESEC(I)	Total desensitization due to echo suppression when last pulse was received by transponder receiver of the I^{th} aircraft	TDESEC(I) = 0
TDESRL(I)	Supply voltage to IF amplifier stages just after last (or most recent) reply rate desensitization	TDESRL(I) = 0
TDSNEC(I)	Contribution in dB of echo suppression to desensitization of transponder receiver of I^{th} aircraft	TDSNEC(I) = 0

TABLE 4-4. INITIAL SETTINGS FOR PARAMETERS IN SECOND-MISS PROGRAM LISTING (CONT'D)

Parameter	Description	Initial Setting
TDSNRL(I)	Contribution in dB of reply rate limiting to desensitization of transponder receiver of I^{th} aircraft	TDSNRL(I) = 0
TSNSTV(I)	Dynamic (time varying) sensitivity of transponder receiver	TSNSTV(I) = TSNSMX(I)*
TTDSEC(I)	Desensitization time for last pulse causing desensitization to occur	TTDSEC(I) = -1.E+50
TTDSRL(I)	Time of last desensitization for reply rate limit circuit	TTDSRL(I) = -1.E+50

*TSNSMX(I) is defined as maximum sensitivity for transponder receiver of the I^{th} aircraft.

Flag and Counter Parameters		
ICK	Counter, related to investigation of possible DABS second misses when DABS interrogations are inserted into an array of ATCRBS pulses. The counter indicates the number of consecutive 2.5-millisecond simulation cycles executed for accumulation of the ATCRBS pulses into the array	ICK = 0
IRNTFL	Random tau flag	IRNTFL = 0
M1STFL	First-pass indicator	M1STFL = 1
MIS2FL	Second-miss flag	MIS2FL = 0
MISSFL	First-miss flag	MISSFL = 0

4.2.4.2 Flow-Chart Analysis of DABS Second-Miss Program

a. The flow chart of figure 4-4 represents a block-type condensation of the Task B program for achieving first and second misses, and for calculating and comparing their respective probabilities of occurrence.

b. Analysis of the flow chart is accomplished in the following sequential procedure. In one instance, where the intent is to maintain overall continuity in the simulation process, one block embraces a set of functions (e.g., block 19, which covers state update, link calculations, and interrogation). In the other cases, the command and decision blocks are covered in detail sufficient to demonstrate the means for achieving the goals mentioned in paragraph a above.

c. In the following steps references are made to block numbers and statement numbers. These references are interchangeable. For example, decision block 49 in the flow chart also applies to statement 49 (or step SECMS 124) in the Task B program of Appendix C. The sole reservation in this relationship is block 19, which is a conglomerate of procedures beginning with statement 19 (step ATCRBS 347) of the Task B program and ending with step ATCRBS 1190 of the program.

d. The following steps provide the basic procedure. Additional comment is also included to provide supplementary background not contained in the mere statement of the steps.

(1) Perform the initialization steps in accordance with the data provided in paragraph 4.2.4.1b.

(2) Perform the steps in block 19 by starting with step ATCRBS 340 of the Task B program and going through the sequence of steps ending with step ATCRBS 1190. Completion of this sequence will satisfy the input processing requirements of the following functional blocks in figure 2-1 of Section 2:

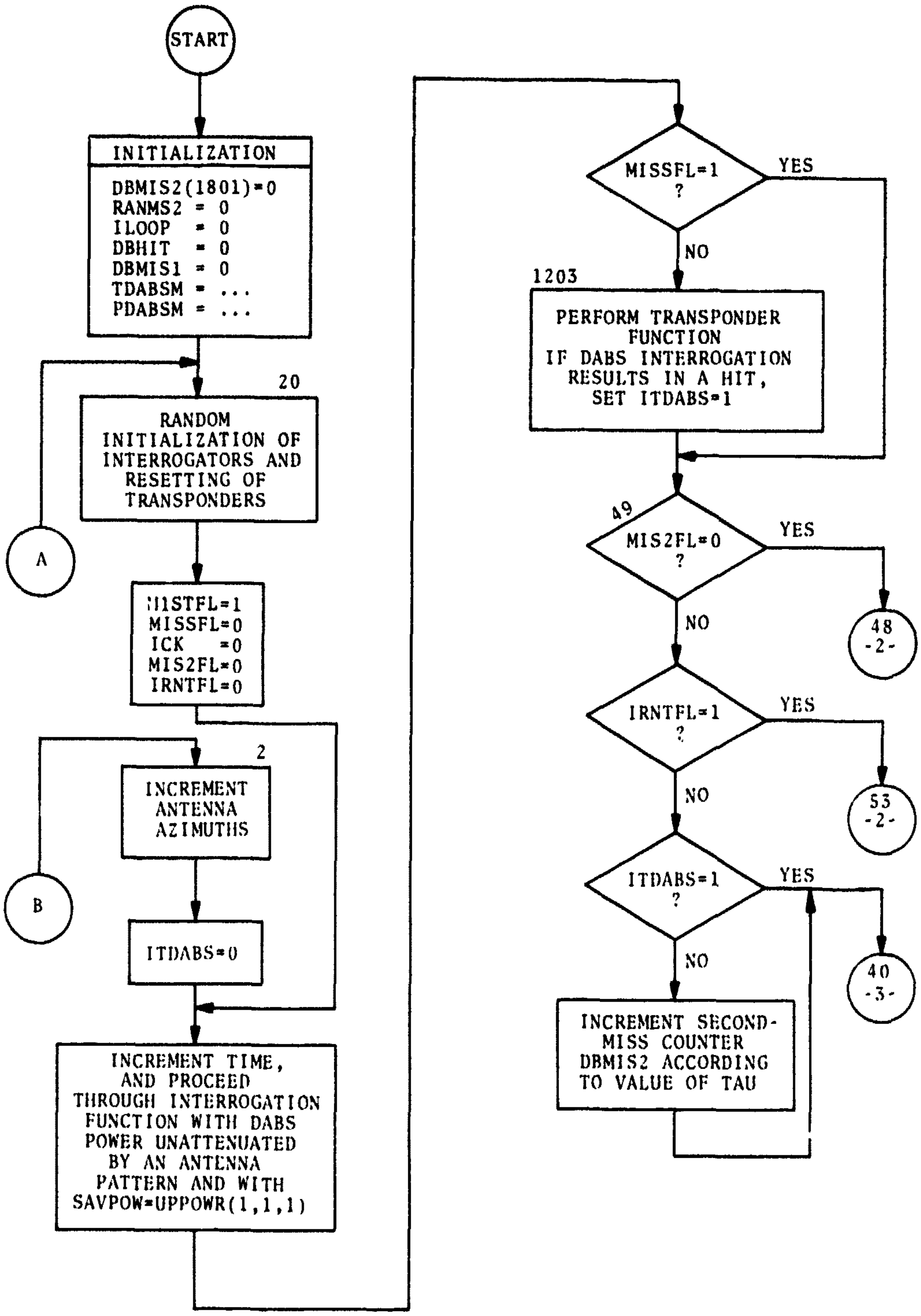

Figure 4-4. Flow-Chart Presentation of Task B Simulation Program (Sheet 1 of 3)

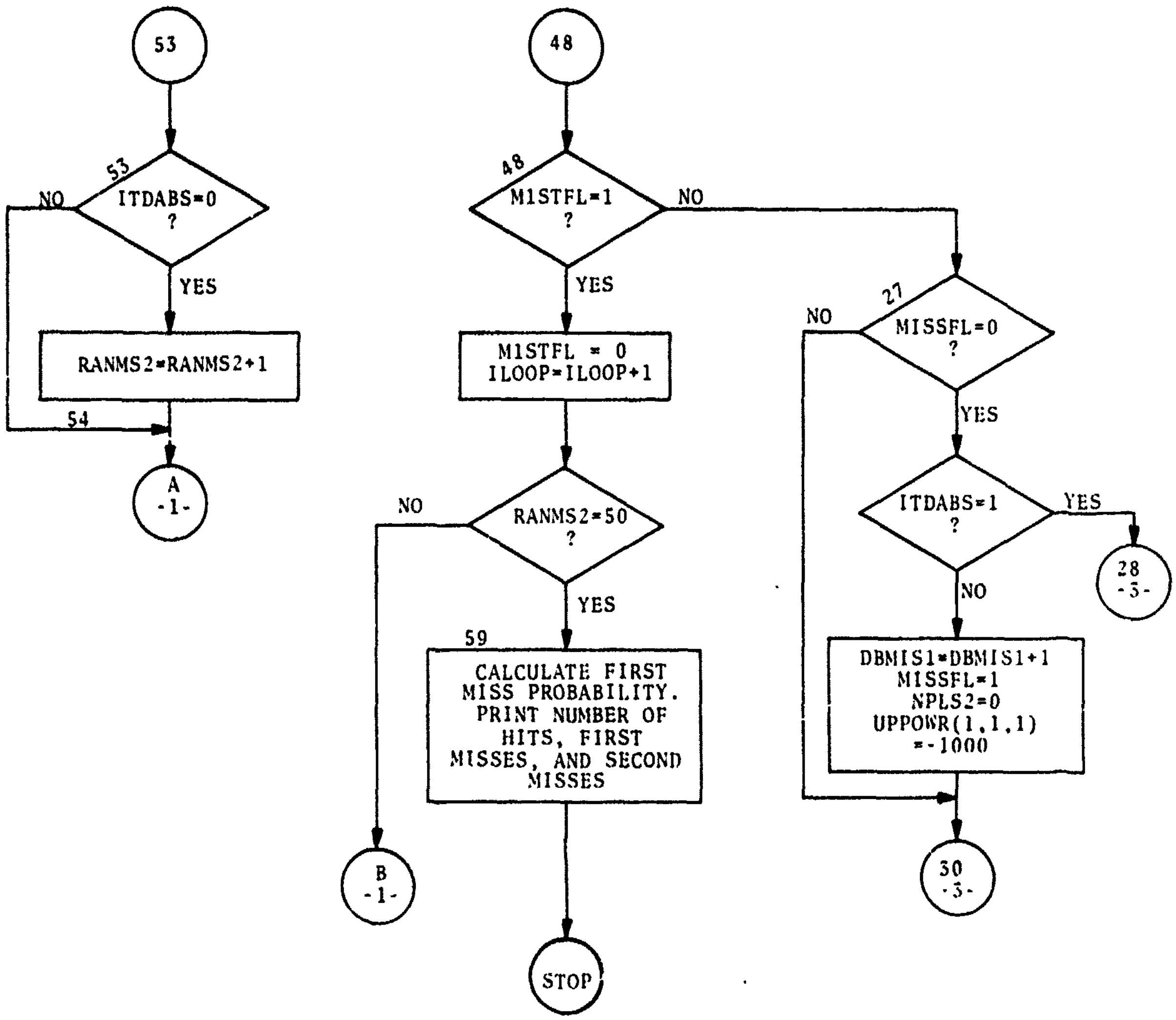

Figure 4-4. Flow-Chart Presentation of Task B Simulation Program (Sheet 2 of 3)

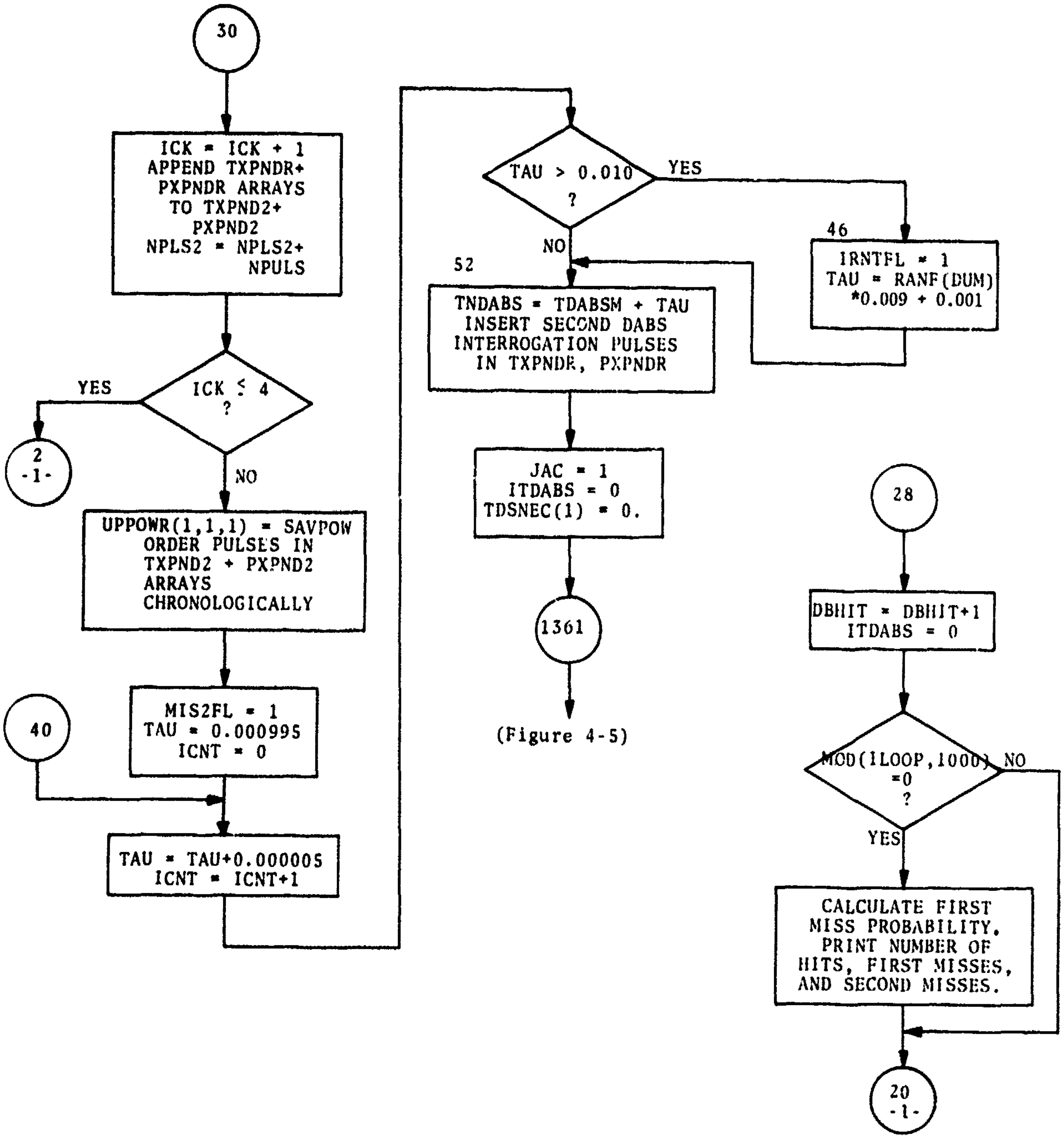

Figure 4-4. Flow-Chart Presentation of Task B Simulation Program (Sheet 3 of 3)

o State update

o Link calculations

o Interrogation.

Block 19 functions as part of either of two loops, depending on whether the loop return terminates at block 20 or at block 2. Choice of a particular loop for a repeat operation depends on the return path of the most recently traversed loop, and is based on the following analysis with respect to the type of miss encountered and the next steps to be taken:

(a) If the return path is to block 20, then a second random miss was achieved. A return to block 20 calls for re-initialization with a new set of interrogation and transponder conditions, and a repeat of block 19 with the new parameters as inputs.

(b) If, instead, the return path is to block 2, then a first miss has been achieved, but the fiftieth random second-miss has not yet been reached. In this case, increment the antenna azimuth setting, set the ITDABS flag, which represents a hit flag, to 0, and repeat the block 19 set of steps for the new parameters.

(3) On completion of the steps in block 19, check the MISSFL flag for a change in setting from its initial 0 setting. If it equals 1, i.e., a miss has occurred, investigate statement 49 as to the status of the second-miss flag MIS2FL. If MIS2FL is still equal to 0, then a second miss did not occur. At this point, determine whether the set of checks being made represents the first time through the program after initialization of a new set of parameters. This condition prevails when the MISTFL flag equals 1 (statement 48), the same as the initial setting. Set MISTFL to 0 to preclude the possibility of once more passing through a first-time condition. (The only time that this condition can be repeated

is a first-time situation after another simulation start and a new initialization of random data.)

(4) Increment loop counter ILOOP by 1 to record the latest number of simulation starts. This counter is incremented after each simulation start until N starts have been made, at which time 50 random second misses have occurred. When this is the case (RANMS2 = 50), the first miss probability is calculated, using N as one of the factors in the calculation. The hits and first and second misses are printed out, and the simulation program stops. When RANMS2 is determined to be less than 50, return to block 2, increment the antenna azimuth, set the hit flag ITDABS equal to 0, and repeat the sequence of steps beginning with block 19 and continuing until RANMS2 equals 50.

(5) If, in step (3), the MISSFL flag indication remains the same as its initial setting, i.e., MISSFL = 0, then a miss did not occur. In this case, follow the MISSFL indication with the DABS transponder operation, beginning with statement 1203 (step DABS 104 of the Task B program listing) and continuing through statement 7 (step ATCRBS 1410). The transponder portion of the program listing determines whether the conditions were proper for a hit to have taken place. If a DABS interrogation results in a hit, set the flag ITDABS equal to 1. Continue with statement 49, check for a second miss, and complete steps (3) and (4) for the conditions stated therein.

(6) Decision block 49 can show, as alternative to the condition of step (3), a change in the MIS2FL flag from the initial 0 setting to a setting of 1, in which case a second miss has been achieved. Following this indication, a random DABS interrogation can be arbitrarily introduced. If, at this point, a random DABS interrogation has not been transmitted, and if the hit flag ITDABS referred to in step (5) does not indicate a hit during transponder operation (i.e., ITDABS remains equal to 0), then

increment the second-miss counter DBMIS2 for the five-microsecond period related to the second miss considered in statement 49, and proceed to step (7). If, however, transponder operation has indicated a hit by a change in ITDABS from 0 to 1, then bypass the incrementing of DBMIS2 and proceed directly to step (7).

(7) Increment τ by five microseconds, and also increment the counter of the time intervals considered by 1 (ICNT=ICNT+1). If τ has attained a value greater than 10 milliseconds, set the random τ flag IRNTFL equal to 1, and choose a random τ, after which set a time for a new DABS interrogation (TNDABS). Insert pulses of a second DABS interrogation into a new array of pulses going to the transponder. Set the number of the first aircraft considered (JAC) equal to 1, reset the hit flag ITDABS equal to 0, set TDSNEC (I) equal to 0, and proceed to statement 1361 of the program listing for modified DABS transponder operation (figure 4-5).

(8) Arrival of a random DABS interrogation is verified when the decision block following block 49 indicates a random τ flag (IRNTFL) value of 1. The next determination involves block 53, which distinguishes a hit (ITDABS = 1) from a miss (ITDABS = 0). In the former case, the next step is to return to block 20 for re-initialization of a new set of random inputs and resetting of transponder parameters. If the latter case prevails, the random second-miss counter RANMS2 is incremented by 1 and the procedure of block 20 is implemented as stated above.

(9) In step (3), the M1STFL flag was assumed to equal 1, implying a first pass through the DABS second-miss program. If, alternatively, the existing situation has precluded a second miss (statement 49, MIS2FL = 0) and the DABS second-miss program has been traversed more than one time (statement 48, M1STFL = 0), then statement 27 is

examined for the status of the miss flag MISSFL. If the miss flag equals 1, then, according to statement 30, increment the check and control counter ICK by 1. Store the number of pulses in the new array TXPND2 into the storage area NPLS2. Check counter ICK for a count less than or equal to 4. If the count is as stated, the program causes consecutive 2.5-millisecond simulation cycles to be executed (beginning at block 2) until the ICK count equals 4. This count represents an accumulation, over a period of 10 milliseconds, of ATCRBS pulses into an array into which DABS interrogations are inserted for determination of DABS first and second misses. When the ICK count is greater than 4, substitute the saved pulse SAVPOW for the uplink pulse UPPOWR(1,1,1). [The subscripts (1,1,1) refer to the first interrogator, first aircraft, and first pulse (P_1) of the P_1 - P_3 interrogation.] Order the pulses in the transponder arrays TXPND2 and PXPND2 chronologically. Set the second-miss flag MIS2FL equal to 1. Provide an initial value of τ to equal .000995, and set the internal counter ICNT equal to 0, and continue with step (7).

(10) If the condition in step (9) is altered so that the first-miss flag MISSFL referred to in statement 27 equals 0, then determine the status of hit flag ITDABS. If the hit flag has a value of 0, then no hit was involved, and, since MISSFL equals 0, there have been no misses yet, and the present miss is a first miss. Therefore, increment the first-miss counter DBMIS1 by 1. Set the first-miss flag MISSFL equal to 1, the storage counter NPLS2 equal to 0, and the uplink pulse power UPPOWR(1,1,1) equal to -1000. From this point, follow the same procedure in the portion of step (9) which starts with statement 30.

(11) If the hit flag ITDABS in the decision block after statement 27 equals 1, then, in accordance with statement 28, increment the DABS hit counter DBHIT by 1, and reset the hit flag ITDABS to 0. Check the value of MOD(ILOOP,) 1000). If it equals 1, return to block 20 for the next

simulation start and re-initialization with a new set of random inputs. If MOD(ILOOP,1000) equals 0, calculate the first-miss probability, and print the number of first and second misses. After this, return to block 20 for the next simulation start and re-initialization with a new set of random inputs.

4.2.4.3 Modifications to ATCRBS Transponder - The flow chart of figure 4-5 and the addenda of figure 4-6 provide the necessary changes to the ATCRBS transponder program to adapt it for DABS operation. The combined information in these figures establishes the criteria for resetting the hit counter ITDABS to 1 (indicating a hit according to the 1203 block of figure 4-4), or for leaving ITDABS at the original value of 0 (indicating a miss).

a. Flow Chart of Modified Transponder. Figure 4-5 shows a flow chart of a modified ATCRBS transponder program which makes it compatible with DABS operation. Changes from the ATCRBS transponder routine of figure 3-3 are initiated in figure 4-5 by three addendum blocks, each of which is labeled SECOND MISS STATISTICS followed by the appropriate ADDENDUM A, or ADDENDUM B, or ADDENDUM C. These addendum blocks serve effectively as inserts to the original flow chart of figure 3-3 to permit the transponder to accept DABS interrogations. The addendum blocks encompass sets of steps which are shown in flow-chart form for the respective addenda of figure 4-6.

b. Analysis of Modified ATCRBS Transponder. The modified transponder capability is expanded by the addenda of figure 4-6. These are discussed in turn below.

(1) Addendum A.

(a) The two incoming pulses I and J are checked for a valid DABS interrogation pulse-pair by noting their time spacing (2 microseconds plus or minus 0.1 picosecond) and their relative powers. If the pulses do not qualify as a valid DABS pulse-pair, they are checked for 2-microsecond spacing with

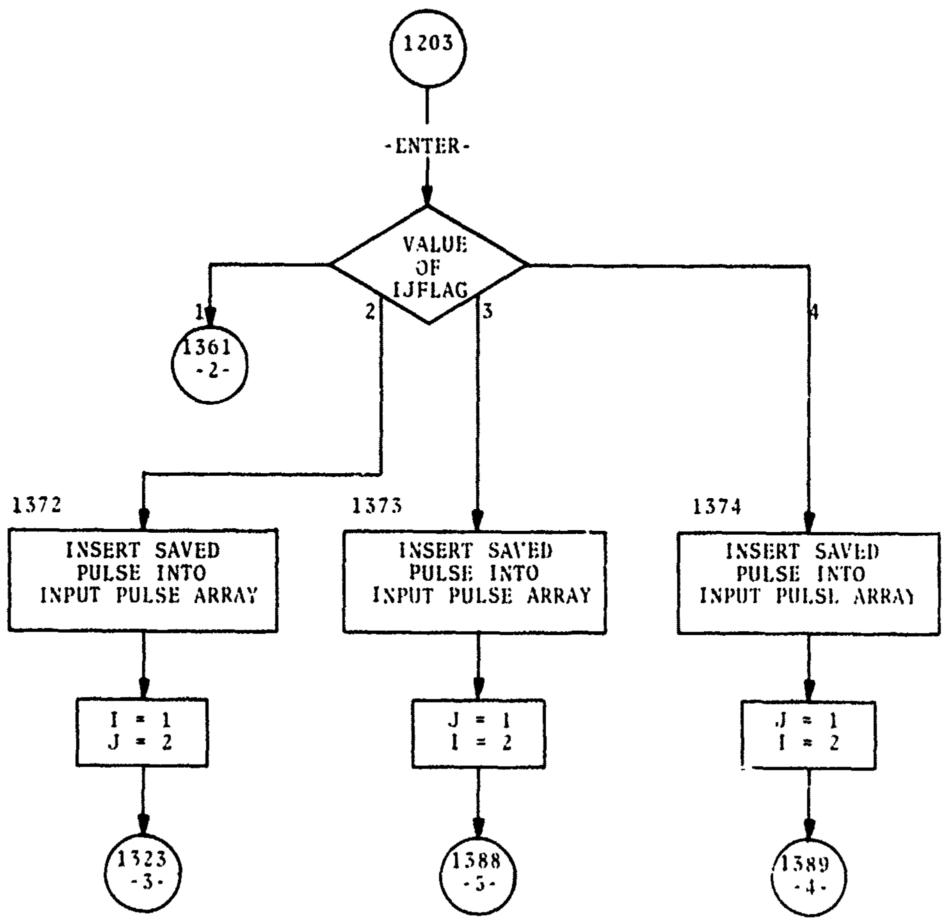

Figure 4-5. Flow Chart of ATCRBS Transponder Program Modifications to Provide DABS Operation Capability (Sheet 1 of 6)

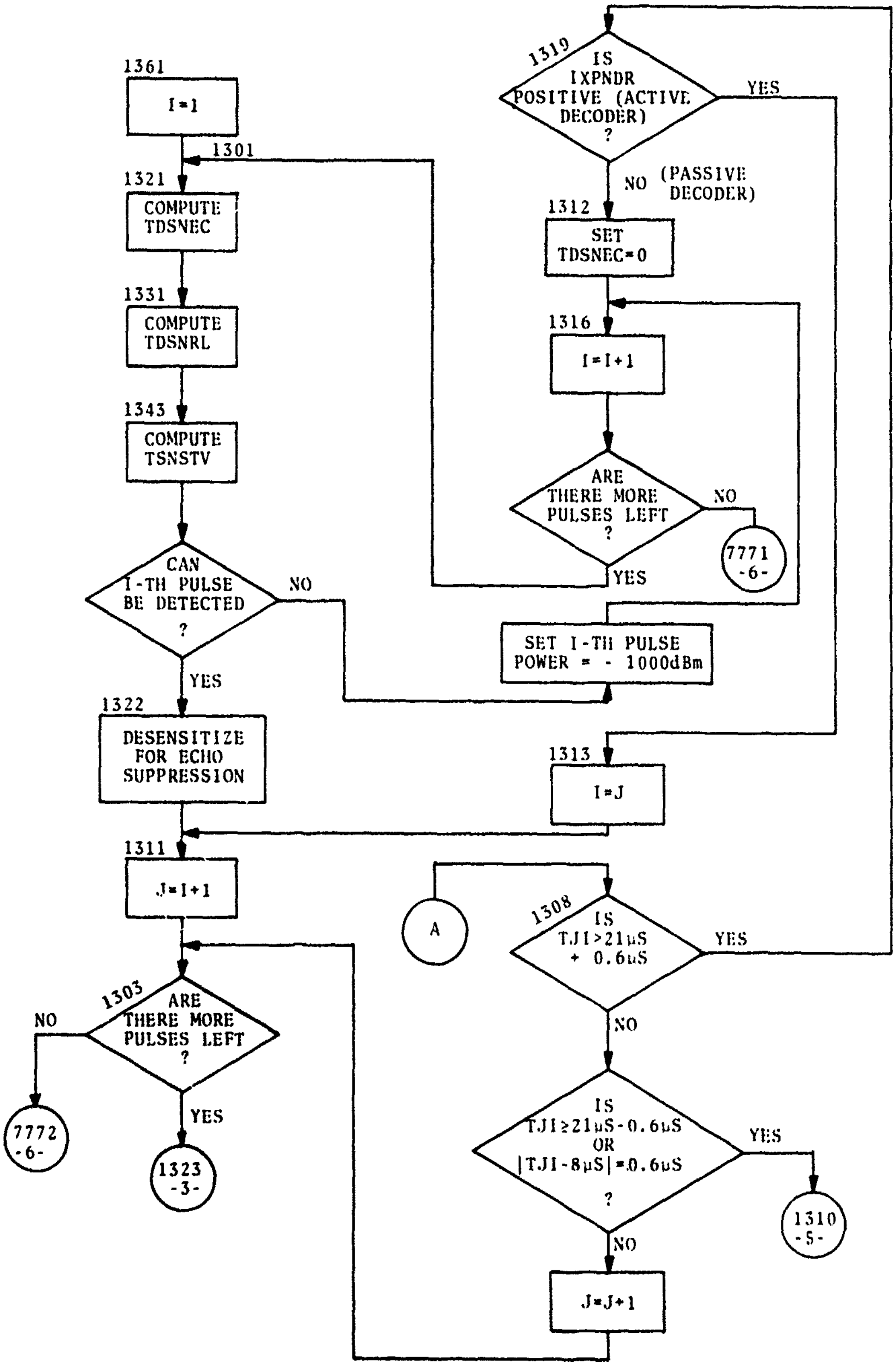

Figure 4-5. Flow Chart of ATCRBS Transponder Program Modifications to Provide DABS Operation Capability (Sheet 2 of 6)

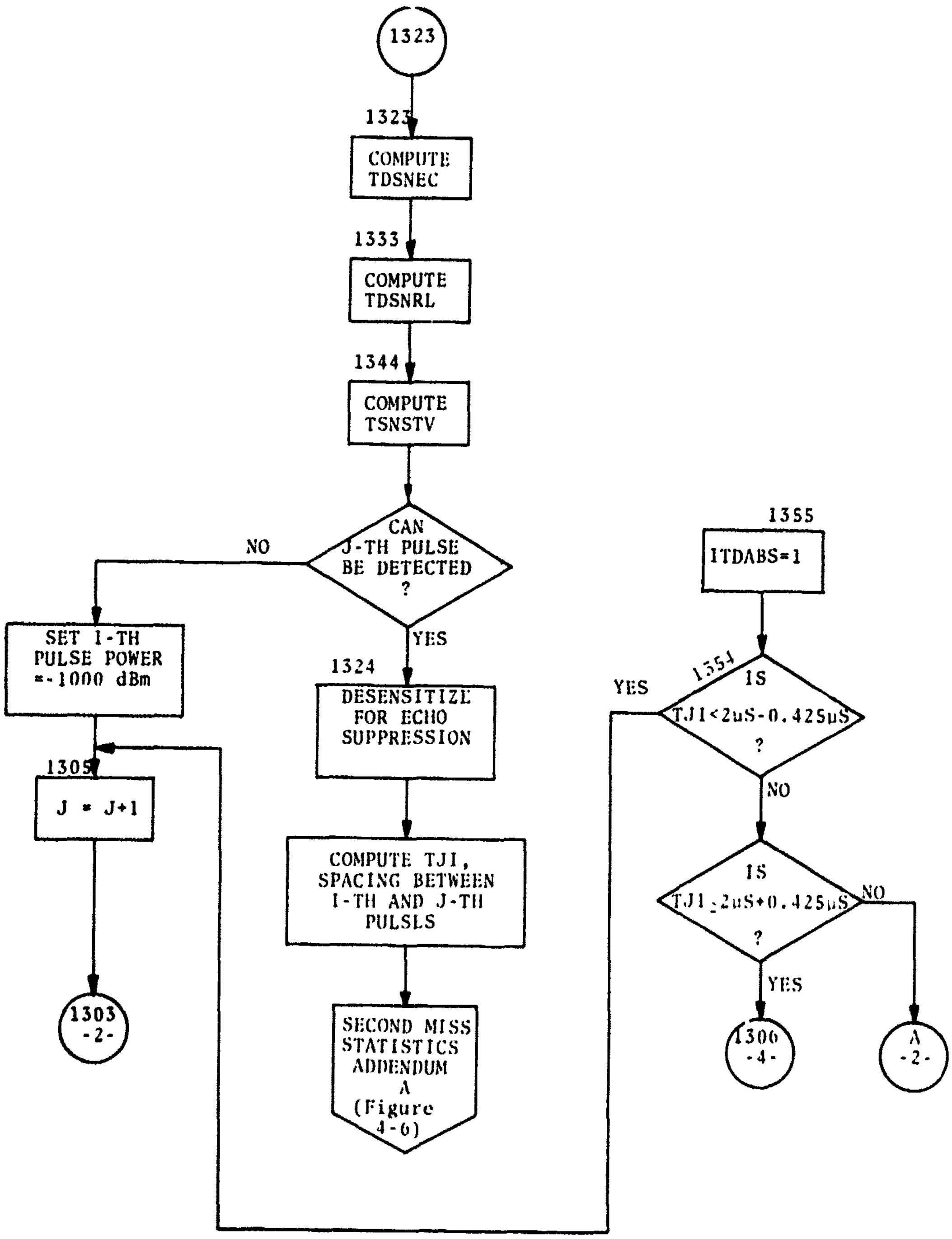

Figure 4-5. Flow Chart of ATCRBS Transponder Program Modifications to Provide DABS Operation Capability (Sheet 3 of 6)

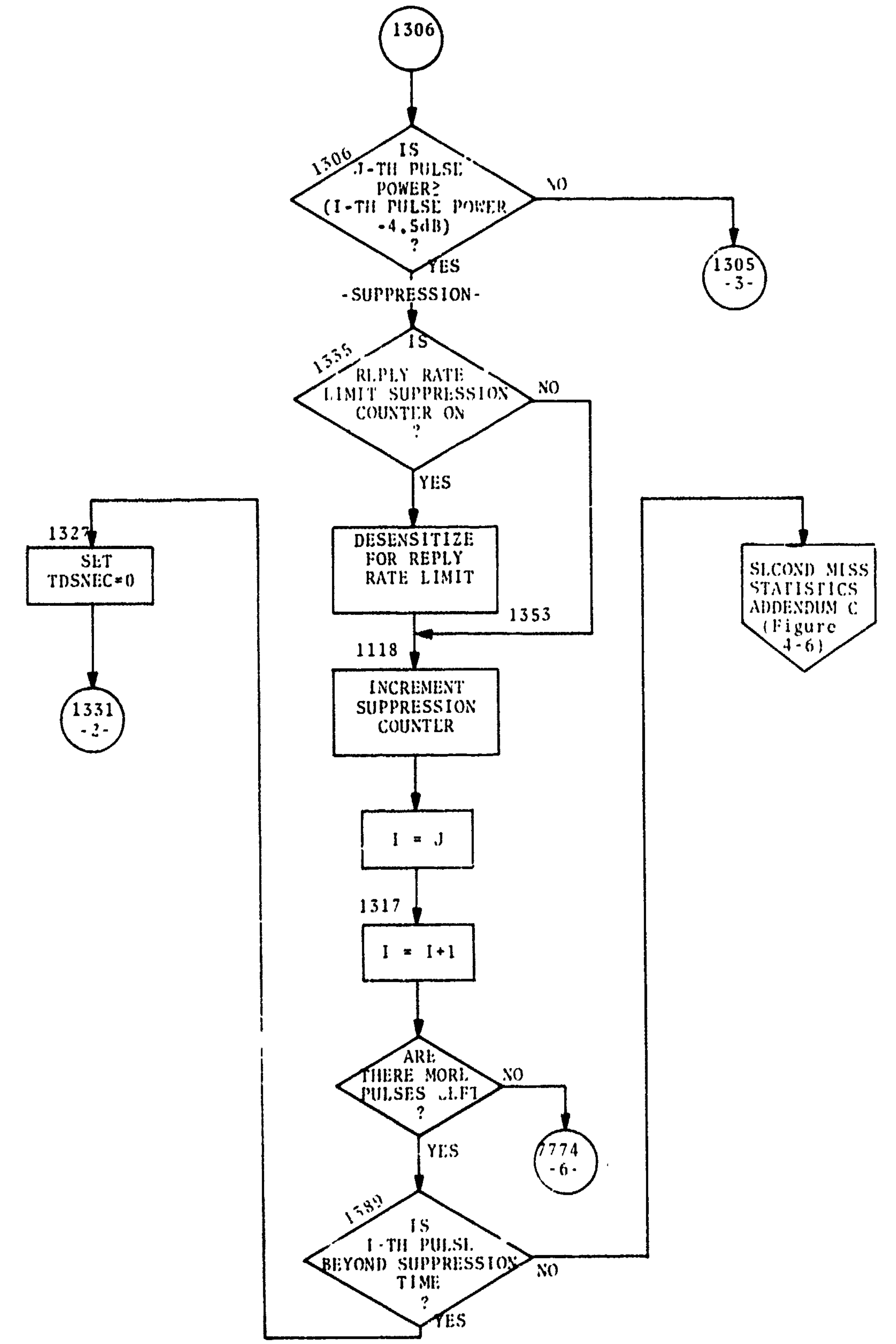

Figure 4-5. Flow Chart of ATCRBS Transponder Program Modifications to Provide DABS Operation Capability (Sheet 4 of 6)

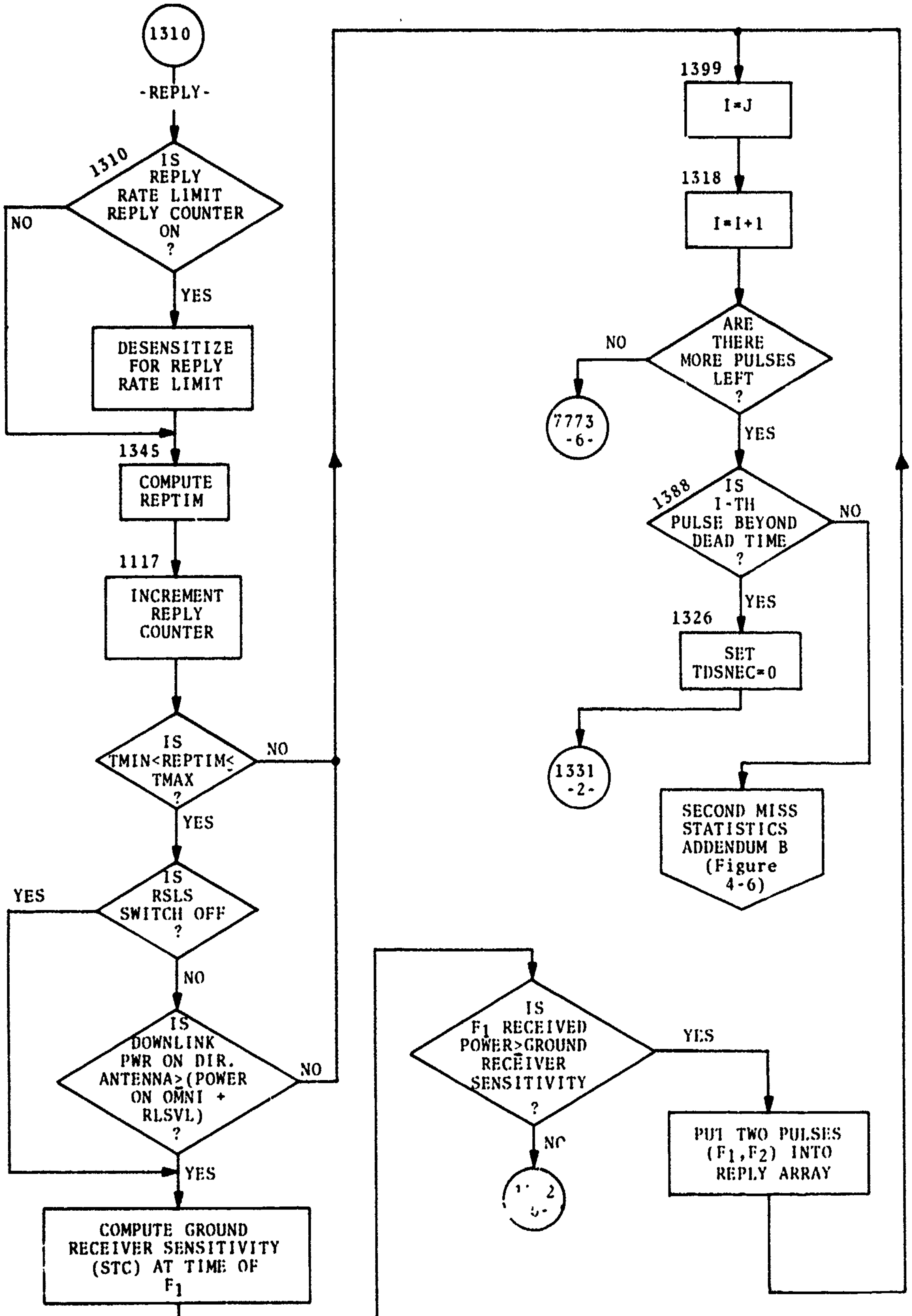

Figure 4-5. Flow Chart of ATCRBS Transponder Program Modifications to Provide DABS Operation Capability (Sheet 5 of 6)

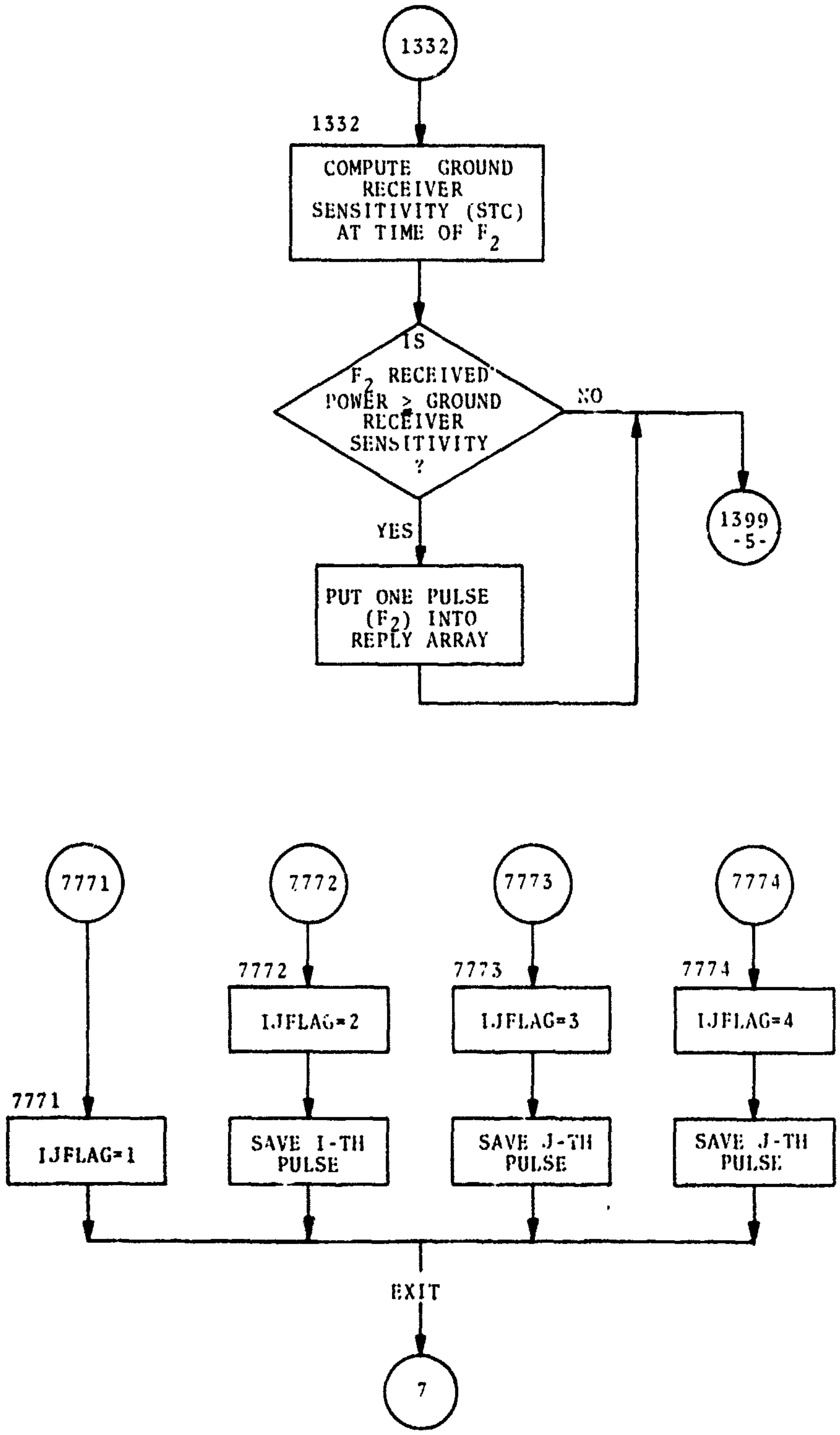

Figure 4-5. Flow Chart of ATCRBS Transponder Program Modifications to Provide DABS Operation Capability (Sheet 6 of 6)

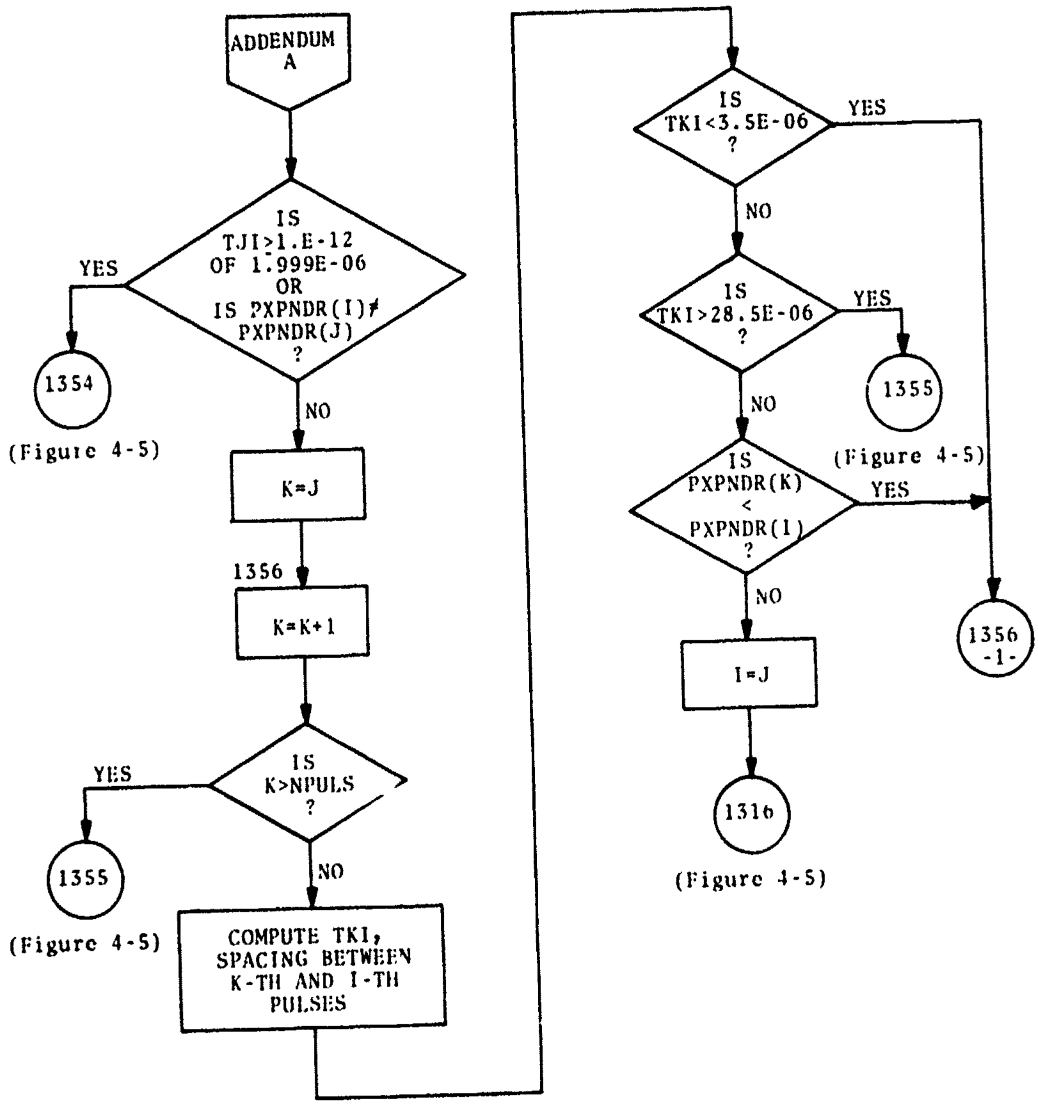

Figure 4-6. Flow Chart of Addenda to Modified ATCRBS Transponder Program (Sheet 1 of 5)

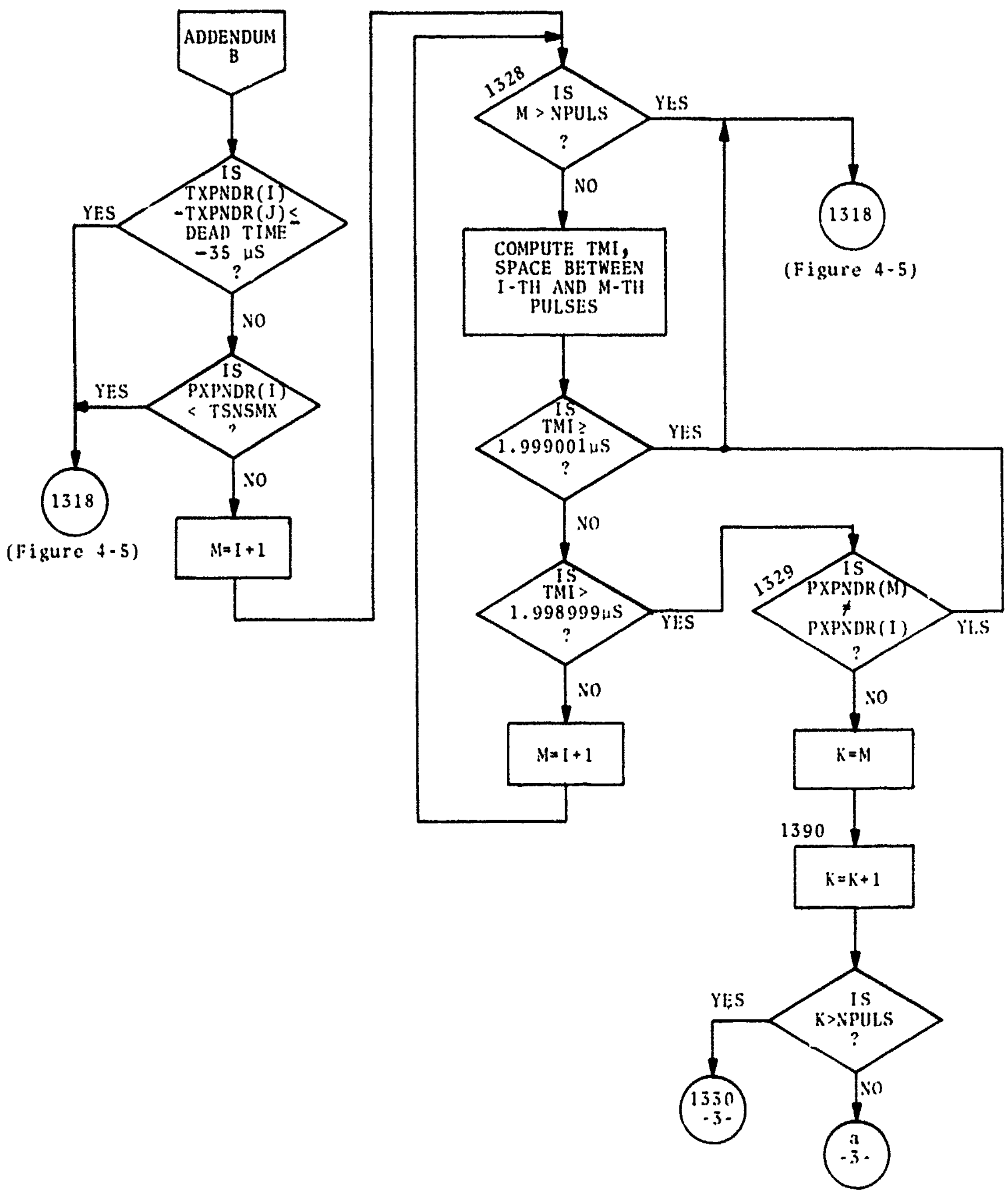

Figure 4-6. Flow Chart of Addenda to Modified ATCRBS Transponder Program (Sheet 2 of 5)

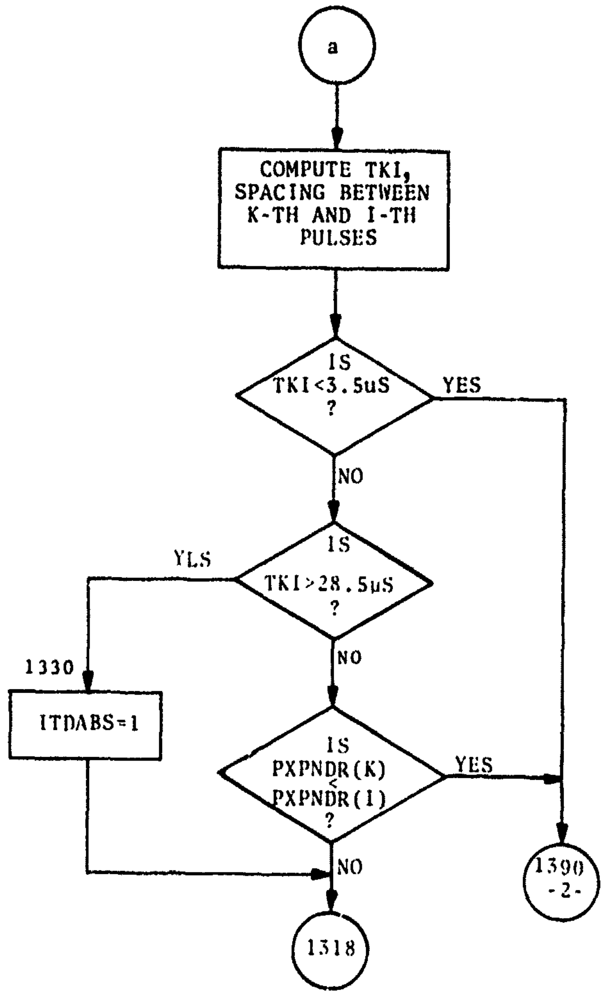

Figure 4-6. Flow Chart of Addenda to Modified ATCRBS Transponder Program (Sheet 3 of 5)

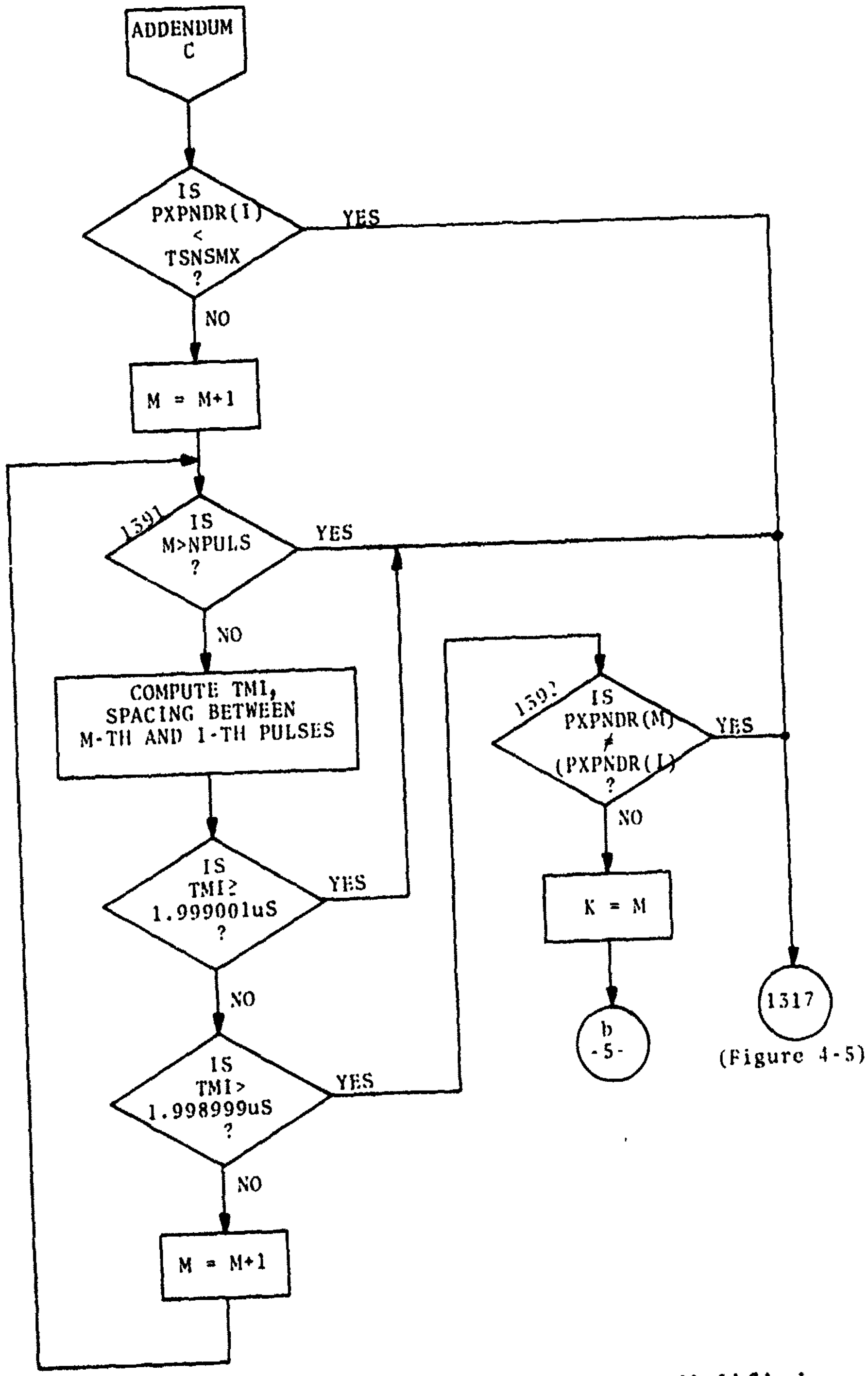

Figure 4-6. Flow Chart of Addenda to Modified ATCRBS Transponder Program (Sheet 4 of 5)

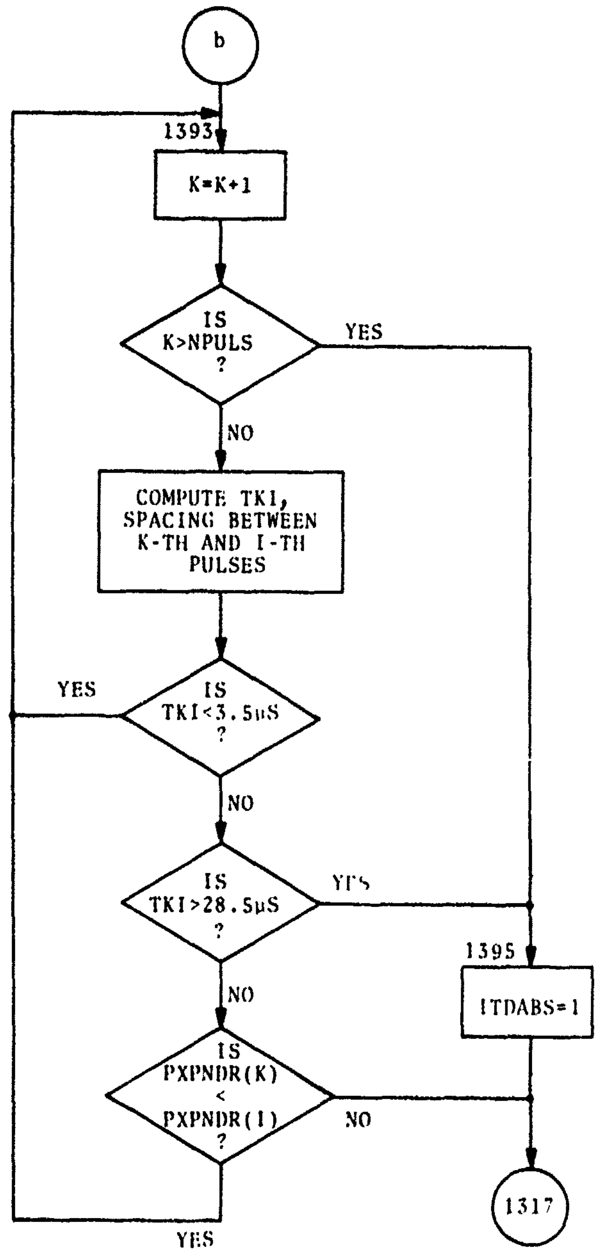

Figure 4-6. Flow Chart of Addenda to Modified ATCRBS Transponder Program (Sheet 5 of 5)

ATCRBS tolerances (2 microseconds plus or minus 0.425 microsecond), after which the normal sequences already described for the ATCRBS transponder routine are performed (e.g., the discussion of sequences beginning with statements 1306 and 1308 of figures 3-3 and 4-5 is identical to that of table 3-4 described for the ATCRBS transponder program). The flow-chart sequence in figure 4-5 is then followed until addendum C is reached.

(b) If a DABS interrogation has been established, i.e., the JI spacing is within 0.1 picosecond and the J^{th} pulse power equals the I^{th} pulse power, then additional pulses are examined to determine whether the DABS interrogation constitutes a hit or a miss. This determination is related to the possibility that the additional incoming pulses can interfere with the DABS interrogation and prevent a reply from the transponder to the DABS interrogation. The J^{th} parameter used in determining the validity of a DABS pulse-pair is now assigned a parameter value K, and a check is made as to whether additional pulses exist in the pulse array. (This is done by incrementing K by 1 and noting whether K is greater than NPULS, the last pulse in the array.) If no additional pulse exists (K is greater than NPULS), then there was no interference with the DABS pulse-pair, and a hit is recorded by the hit counter ITDABS, as indicated by statement 1355, figure 4-5.

(c) If the additional pulse is less than NPULS, then it is examined (figure 4-6) to determine whether the pulse falls before, within, or after the 25-microsecond interval following the DABS preamble. If the K^{th} pulse is less than 3.5 microseconds from the I^{th} pulse, then the K^{th} pulse has occurred during a gap in the DABS interrogation format. Another pulse is then examined, and the check is repeated.

(d) If the K^{th} pulse is greater than 28.5 microseconds from the I^{th} pulse, it falls outside and beyond the 25-microsecond data interval of the DABS uplink signal. This constitutes a hit (no interference to the DABS signal), and is so recorded in the hit counter ITDABS.

(e) If the K^{th} pulse is between 3.5 and 28.5 microseconds beyond the time of the I^{th} pulse, then the K^{th} pulse lies within the 25-microsecond data interval of the DABS uplink signal. The relative powers of the K^{th} and I^{th} pulses are now checked. If the K^{th} pulse power is less than the I^{th} pulse power, the K^{th} pulse did not interfere, and a new pulse is examined for its effect on the DABS interrogation.

(f) When the incoming K^{th} pulse is within the 25-microsecond interval and the K^{th} pulse power exceeds or equals the I^{th} pulse power, this constitutes ATCRBS interference and a resulting DABS miss. A new pair of pulses is then examined, starting with an I^{th} pulse which is assigned the J^{th} pulse value. The sequence is then continued with statement 1316 of figure 4-5, and new pulse-pairs are examined according to the transponder functions indicated in figure 4-5 subsequent to statement 1316.

(2) Addendum B

(a) This addendum checks for arrival of DABS interrogations at the transponder within a dead-time interval caused by ATCRBS interrogations. The ATCRBS dead-time period encompasses three definable areas of time coverage:

- A 3-microsecond delay after interception by the transponder of the P_3 pulse of the ATCRBS interrogation
- A 20.3 microsecond interval for transponder reply to the ATCRBS interrogation

- A 35-microsecond dead-time following the transponder reply.

The DABS interrogation is permitted to register as a hit in the event that it arrives at the transponder in the final 35-microsecond interval of the ATCRBS dead-time period. Note, however, that the DABS interrogation still has to be examined, with respect to potential interference within the 25-microsecond data interval of the DABS uplink signal, as to whether the DABS interrogation will ultimately be recorded as a hit or whether it will be a miss. If the DABS interrogation arrives during the 3-microsecond delay time or during the transponder reply time, it will not be permitted to register as a hit.

(b) Other than the checks referred to in (a), the steps in addendum B follow closely the steps in addendum A, with the additional distinction that the concern in addendum B is for M^{th} and I^{th} pulses.

(3) Addendum C.

Addendum C checks within the suppression time to determine a hit for a DABS interrogation. A DABS interrogation is allowed for the total duration of the suppression time; i.e., a DABS interrogation within this interval is permitted to register as a hit provided the same test for the DABS 25-microsecond interval is performed as was described in the discussion of paragraph (2) (a) above. The remaining checks for this addendum are basically similar to the previous addenda except for statement numbers which revert back to portions of transponder action already discussed in table 3-4 with respect to referred statements on the blocks of figure 3-3.

4.3 NUMERICAL AND GRAPHICAL RESULTS

4.3.1 Outputs for Task A

4.3.1.1 Run Numbers 1 and 2. Results of the data gathering described in paragraph 4.2.1.1b for the two runs of Task A are contained in tables 4-5 through 4-9, and in graphic form in figures 4-7 through 4-24. Output information relating to the 27 transponders in the three aircraft is provided for run number 1 in tables 4-5 through 4-8 and also in figures 4-7 through 4-12. Supplementary data for Transponders A and B are provided as part of run number 1, but are included in table 4-9 as a basis of comparison with corresponding data for run number 2, also included in table 4-9. (Transponders A and B correspond to transponders designated as a/c 1 and a/c 27 respectively in tables 4-5 through 4-8.) The results of data-taking and of graphic evaluation of power histograms for run number 2 are shown respectively in table 4-9 and in figures 4-13 through 4-24.

4.3.1.2 Reply Ratio Comparisons for Different Suppression Times (Run Number 1). Figures 4-7 through 4-12 each contain nine data points relating reply ratios to transponders with different suppression times, and tables 4-6, 4-7, and 4-8 provide the data on which these figures are based. Correspondence between table 4-6 and figures 4-7 and 4-8, relating to RRC, is typical of the correspondence in the other two categories - table 4-7 with figures 4-9 and 4-10 for RRF, and table 4-8 with figures 4-11 and 4-12 for RRE. Therefore, the following explanation of the reply ratio relationship for the first group (RRC) will apply to all three categories.

a. Any of the nine data points in figure 4-7 represents two transponders on the same aircraft differing only in suppression time. In this case, the difference is between the 35-microsecond reference and the 50-microsecond suppression time.

b. The data for these points are obtained from the nine columns in the data group of table 4-6(a). The a/c numbers in the first and third rows of table 4-6(a) represent aircraft transponders which, in turn, are identified in table 4-5 with respect

TABLE 4-5. IDENTIFICATION OF AIRCRAFT TRANSPONDERS

a/c (Aircraft) No.	Location	Suppression Time (Microseconds)	MTL [TSNSMX(JAC)] (dBm)
1	Philadelphia	35	-69
2	Philadelphia	50	-69
3	Philadelphia	100	-69
4	Philadelphia	35	-71
5	Philadelphia	50	-71
6	Philadelphia	100	-71
7	Philadelphia	35	-77
8	Philadelphia	50	-77
9	Philadelphia	100	-77
10	Trenton	35	-69
11	Trenton	50	-69
12	Trenton	100	-69
13	Trenton	35	-71
14	Trenton	50	-71
15	Trenton	100	-71
16	Trenton	35	-77

TABLE 4-5. IDENTIFICATION OF AIRCRAFT TRANSPONDERS (CONT'D)

a/c (Aircraft) No.	Location	Suppression Time (Microseconds)	MTL[TSNSMX(JAC)] (dBm)
17	Trenton	50	-77
18	Trenton	100	-77
19	New York	35	-69
20	New York	50	-69
21	New York	100	-69
22	New York	35	-71
23	New York	50	-71
24	New York	100	-71
25	New York	35	-77
26	New York	50	-77
27	New York	100	-77

TABLE 4-6. REPLY RATIO DATA FOR RRC (BEAM CENTER REPLY RATIO)

a/c	2	5	8	11	14	17	20	23	26
RRC 50 μs	96.8	97.3	94.1	96.4	96.3	92.3	93.1	93.0	86.0
a/c	1	4	7	10	13	16	19	22	25
RRC 35 μs	96.8	97.3	94.1	94.1	96.3	93.3	95.1	95.0	89.4

(a) Comparative RRC Values (Percent) for Transponder Suppression Times = 50 and 35 Microseconds

a/c	3	6	9	12	15	18	21	24	27
RRC 100 μs	95.2	95.7	91.1	93.5	93.4	86.1	86.4	86.4	78.3
a/c	1	4	7	10	13	16	19	22	25
RRC 35 μs	96.8	97.3	94.1	96.4	96.3	93.3	95.1	95.0	89.4

(b) Comparative RRC Values (Percent) for Transponder Suppression Times = 100 and 35 Microseconds

TABLE 4-7. REPLY RATIO DATA FOR RRF (FULL BEAM REPLY RATIO)

a/c	2	5	8	11	14	17	20	23	26
RRF 50 μs	96.9	97.2	93.5	96.4	96.3	91.8	93.2	93.1	85.7
a/c	1	4	7	10	13	16	19	22	25
RRF 35 μs	96 9	97.2	93.5	96.4	96.3	92.8	95.3	95.1	89.1

(a) Comparative RRF Values (Percent) for Transponder Suppression Times = 50 and 35 Microseconds

a/c	3	6	9	12	15	18	21	24	27
RRF 100 μs	95.4	95.7	90.5	93.4	93.3	85.4	86.7	86.4	78.1
a/c	1	4	7	10	13	16	19	22	25
RRF 35 μs	96.9	97.2	93.5	96.4	06.3	92.8	95.3	95.1	89.1

(b) Comparative RRF Values (Percent) for Transponder Suppression Times = 100 and 35 Microseconds

TABLE 4-8. REPLY RATIO DATA FOR RRE (WHOLE ENVIRONMENT REPLY RATIO)

a/c	2	5	8	11	14	17	20	23	26
RRE 50 µs	95.3	94.6	88.3	97.1	95.8	82.7	91.0	91.0	80.0
a/c	1	4	7	10	13	16	19	22	25
RRE 35 µs	96.1	95.4	89.1	97.7	96.3	84.5	92.7	92.7	81.8

(a) Comparative RRE Values (Percent) for Transponder Suppression Times = 50 and 35 Microseconds

a/c	3	6	9	12	15	18	21	24	27
RRE 100 µs	91.8	90.9	84.6	95.5	94.2	70.3	87.1	86.9	74.8
a/c	1	4	7	10	13	16	19	22	25
RRE 35 µs	96.1	95.4	89.1	97.7	96.3	84.5	92.7	92.7	81.8

(b) Comparative RRE Values (Percent) for Transponder Suppression Times = 100 and 35 Microseconds

TABLE 4-9. DATA FOR TRANSPONDER A AND TRANSPONDER B PARAMETERS WITH SEPARATE INITIALIZATION OF INPUT CONDITIONS FOR RUNS 1 AND 2

		RRC	RRF	RRE	Average Valid Inter-rogation Rate*	Average Reply Rate*	Average Valid SLS Rate*	Average Suppres-sion Rate*	Average Single P_2 Rate*
TRANSPONDER	Run 1	0.9683	0.9696	0.961	94.430	90.735	751.411	731.410	32
A	Run 2	0.9550	0.9598	0.955	94.887	90.608	751.184	736.474	27
TRANSPONDER	Run 1	0.783455	0.781170	0.748	234.600	182.311	1804.301	1511.150	1354
B	Run 2	0.8161	0.8260	0.698	245.477	171.403	1810.866	1516.230	1356

*Rate is expressed in units/sec.

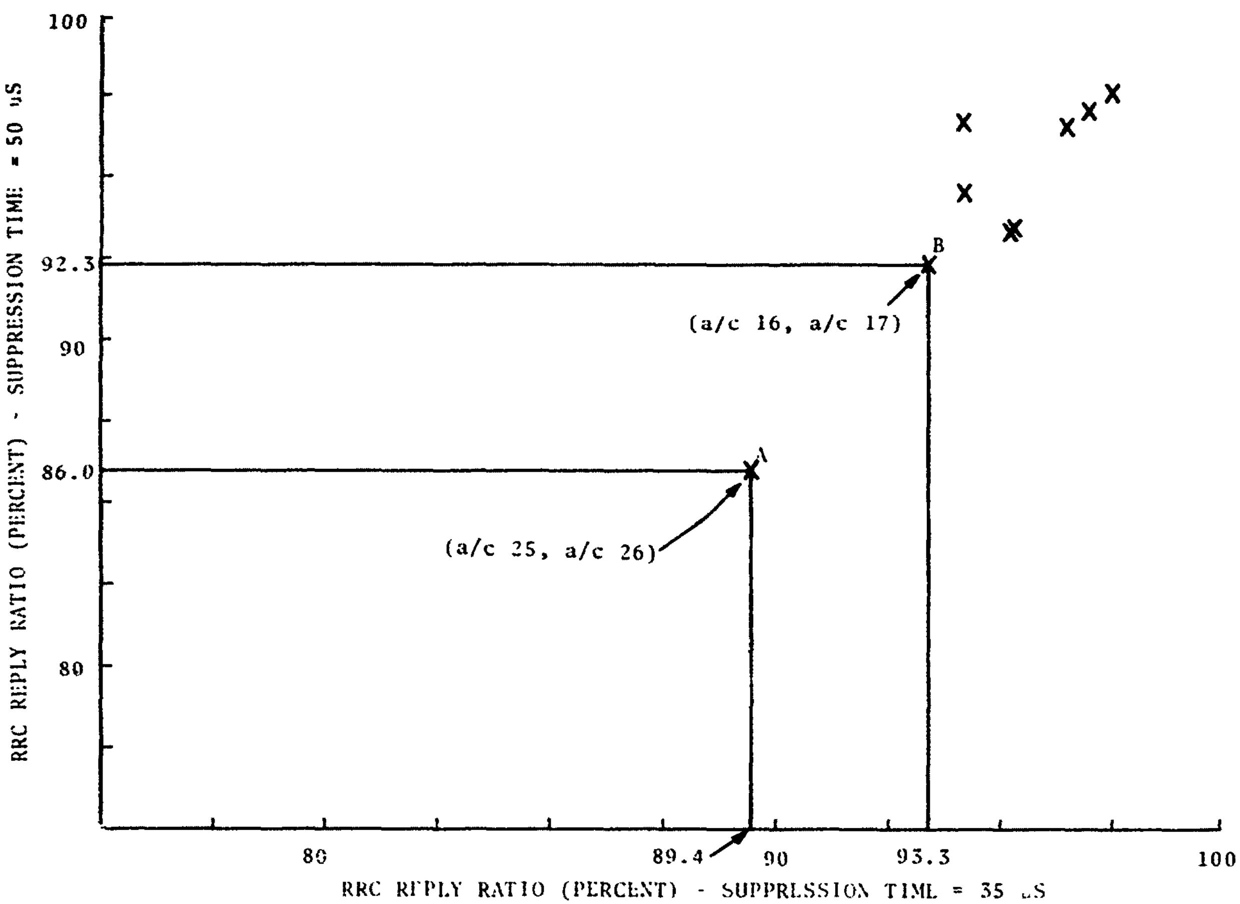

Figure 4-7. Relative Reply Ratios (Percent) for Mode RRC and Suppression Times of 50 and 35 Microseconds

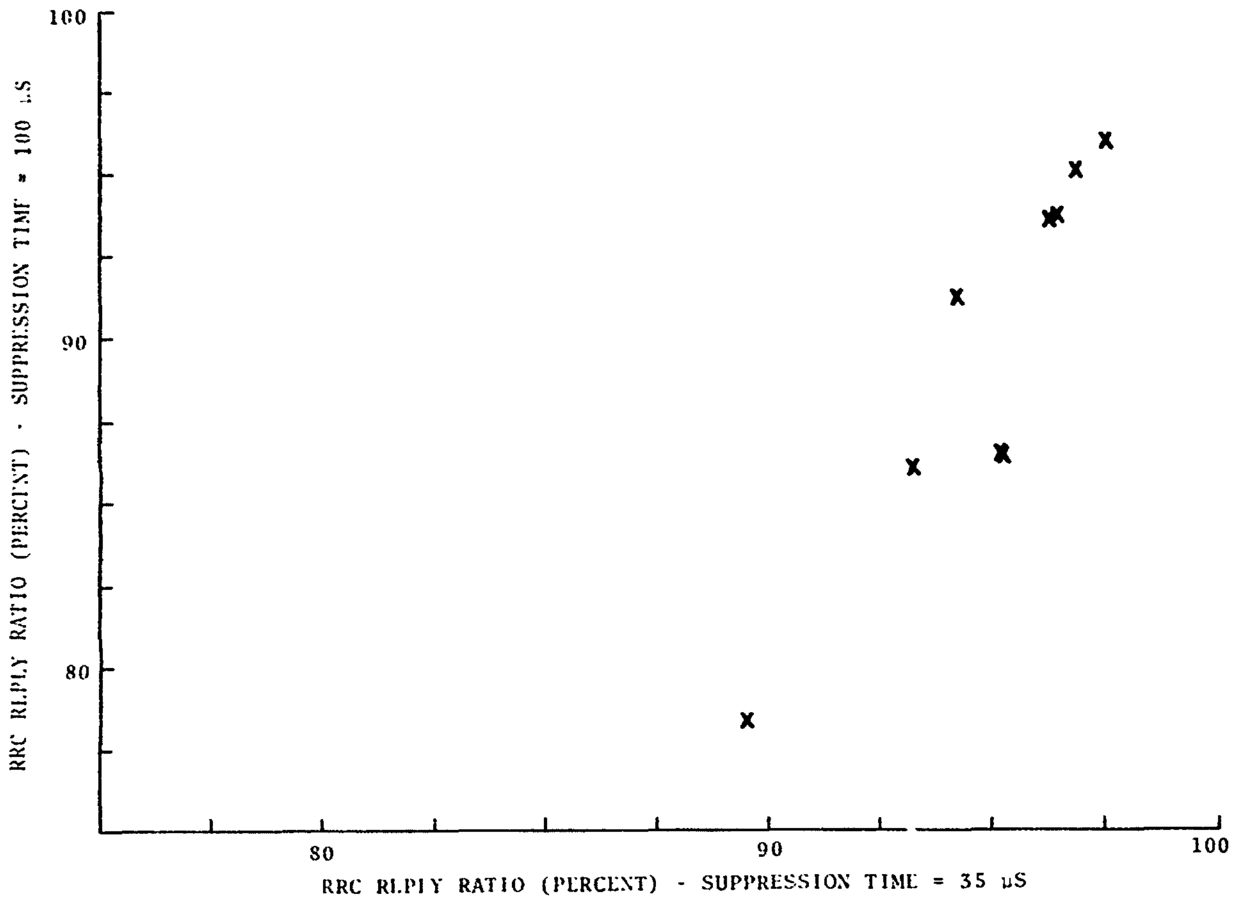

Figure 4-8. Relative Reply Ratios (Percent) for Mode RRC and Suppression Times of 100 and 35 Microseconds

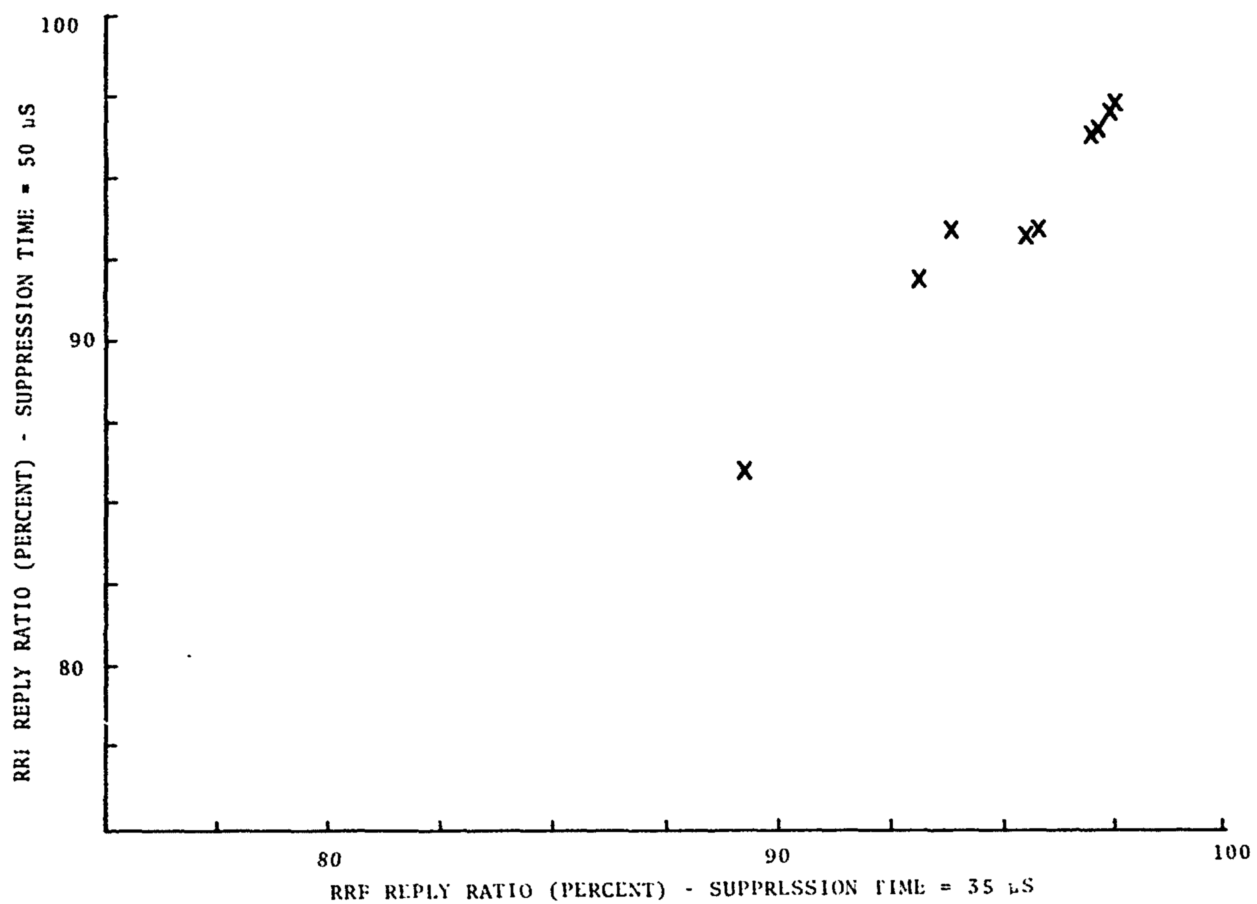

Figure 4-9. Relative Reply Ratios (Percent) for Mode RRF and Suppression Times of 50 and 35 Microseconds

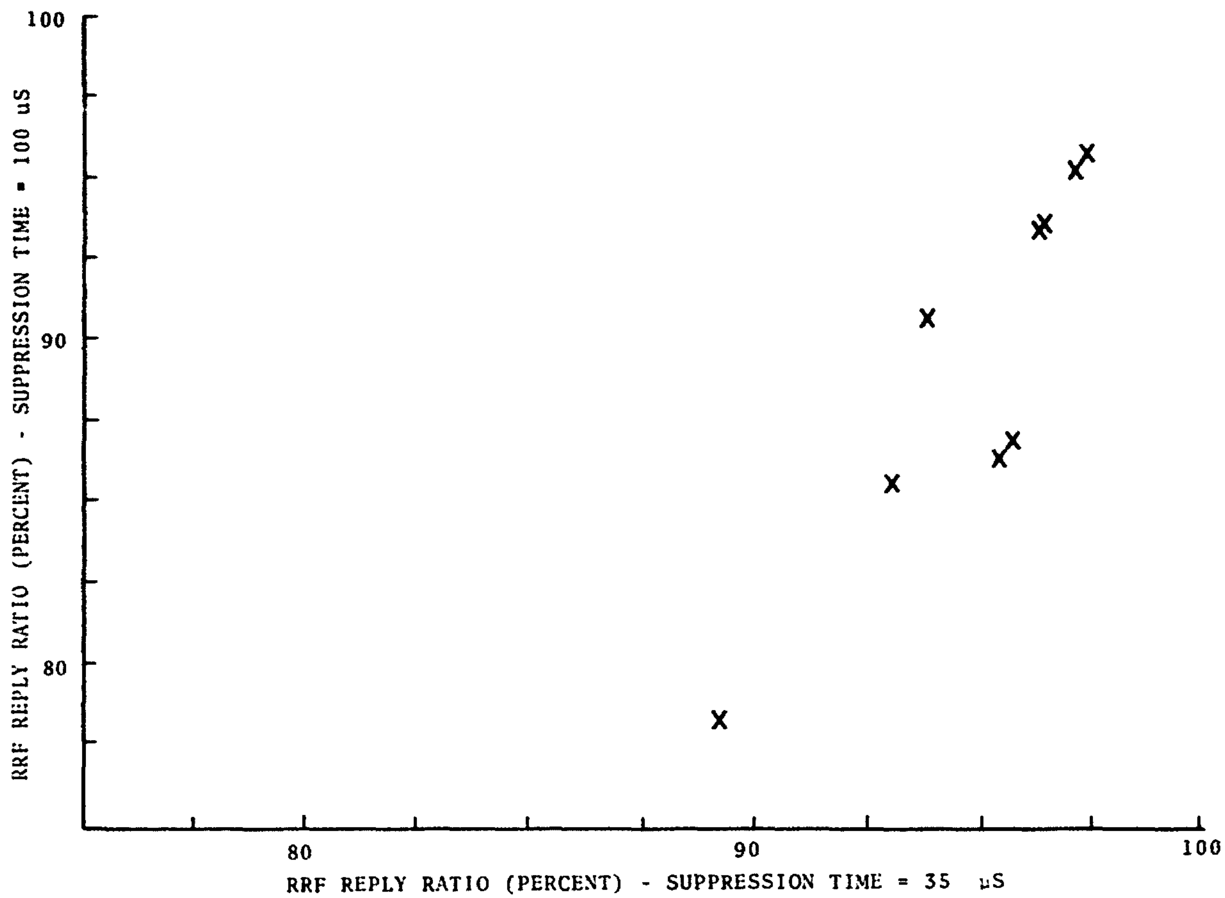

Figure 4-10. Relative Reply Ratios (Percent) for Mode RRF and Suppression Times of 100 and 35 Microseconds

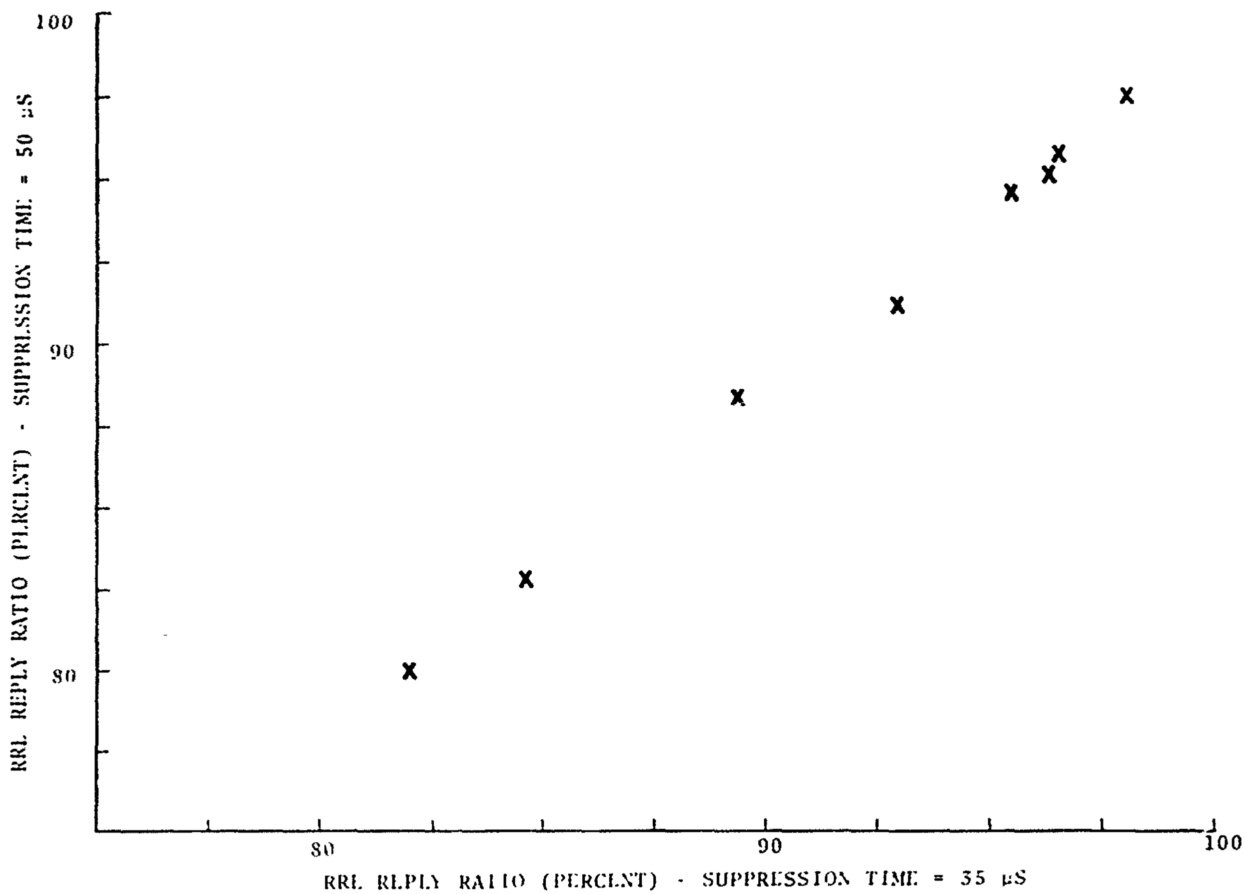

Figure 4-11. Relative Reply Ratios (Percent) for Mode RRE and Suppression Times of 50 and 35 Microseconds

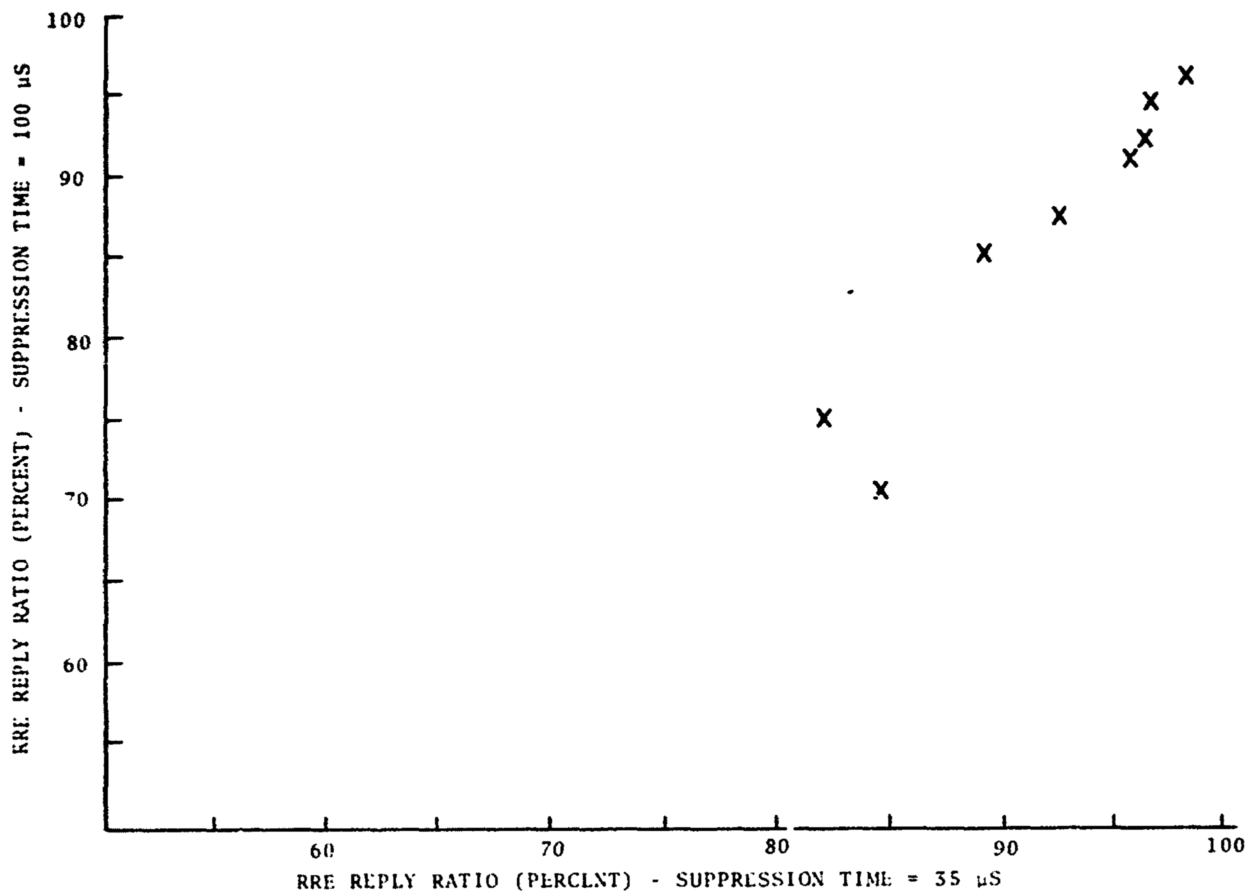

Figure 4-12. Relative Reply Ratios (Percent) for Mode RRE and Suppression Times of 100 and 35 Microseconds

to a/c (aircraft) number, location, suppression time, and MTL, also expressed as TSNSMX(JAC), the maximum transponder receiver sensitivity for the J^{th} aircraft. Thus, in figure 4-7, the reply ratios at point A correspond to the relative number of replies, in percent, from transponders a/c 25 and a/c 26 of the New York aircraft with MTLs of -77 dBm. Similarly, point B indicates a reply ratio correspondence with respect to transponders a/c 16 and a/c 17 of the Trenton aircraft with MTLs of -77 dBm.

c. The procedure of paragraph b is duplicated for aircraft transponders still in the RRC mode, but whose suppression times are now 35 and 100 microseconds respectively. The graphic presentation for the relative reply ratios for the new combination of suppression times is shown in figure 4-8, and the reply ratio data used for the graphic plots are obtained from table 4-6(b).

4.3.1.3 Supplementary Data for Transponders A and B

a. Run number 1 of Task A also provided data relative to the additional requirements for Transponders A and B listed in paragraph 4.2.1.1b(5). These data are included in table 4-9 together with data obtained for corresponding parameters in a second run for Transponders A and B only. The latter run was made following a re-initialization of input conditions for the simulation model.

b. Runs numbers 1 and 2 of Task A also furnished the power histograms for Transponders A and B. These histograms are indicated in figures 4-13 through 4-18 for signals arriving at the transponder receiver at power levels between -70 dBm and -40 dBm, and in figures 4-19 through 4-24 for signals arriving at the transponder receiver at power levels between -100 dBm and -40 dBm. (The reason for using a dual set of power level ranges in figures 4-13 through 4-24 is given in the Note following d below.)

c. The basic histogram for each figure provides the percentage of valid uplink arrivals which the transponder receiver will detect at a power level within the given power level range. The percentage of arrivals varies as indicated in the histogram for

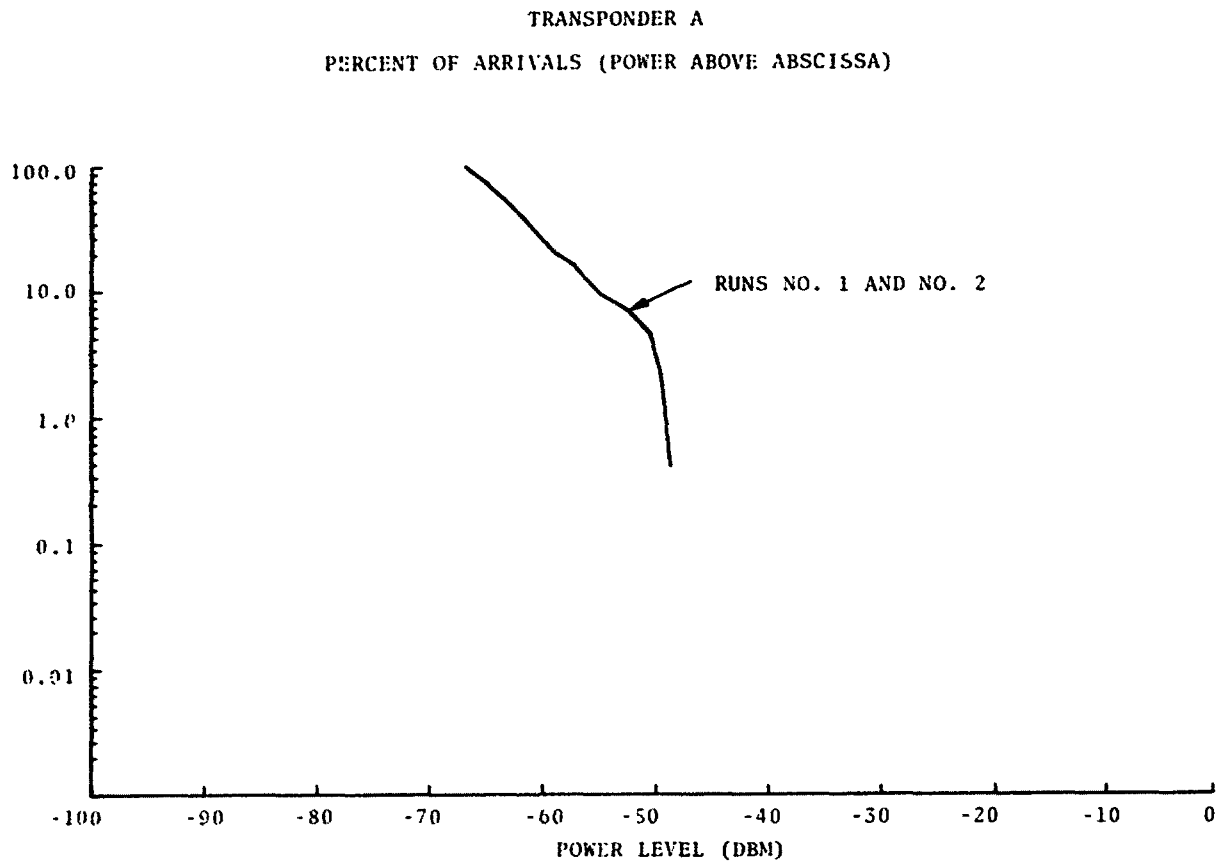

Figure 4-13. Power Distribution of Interrogations for Transponder MTL Range -70 dBm to -40 dBm (Transponder A)

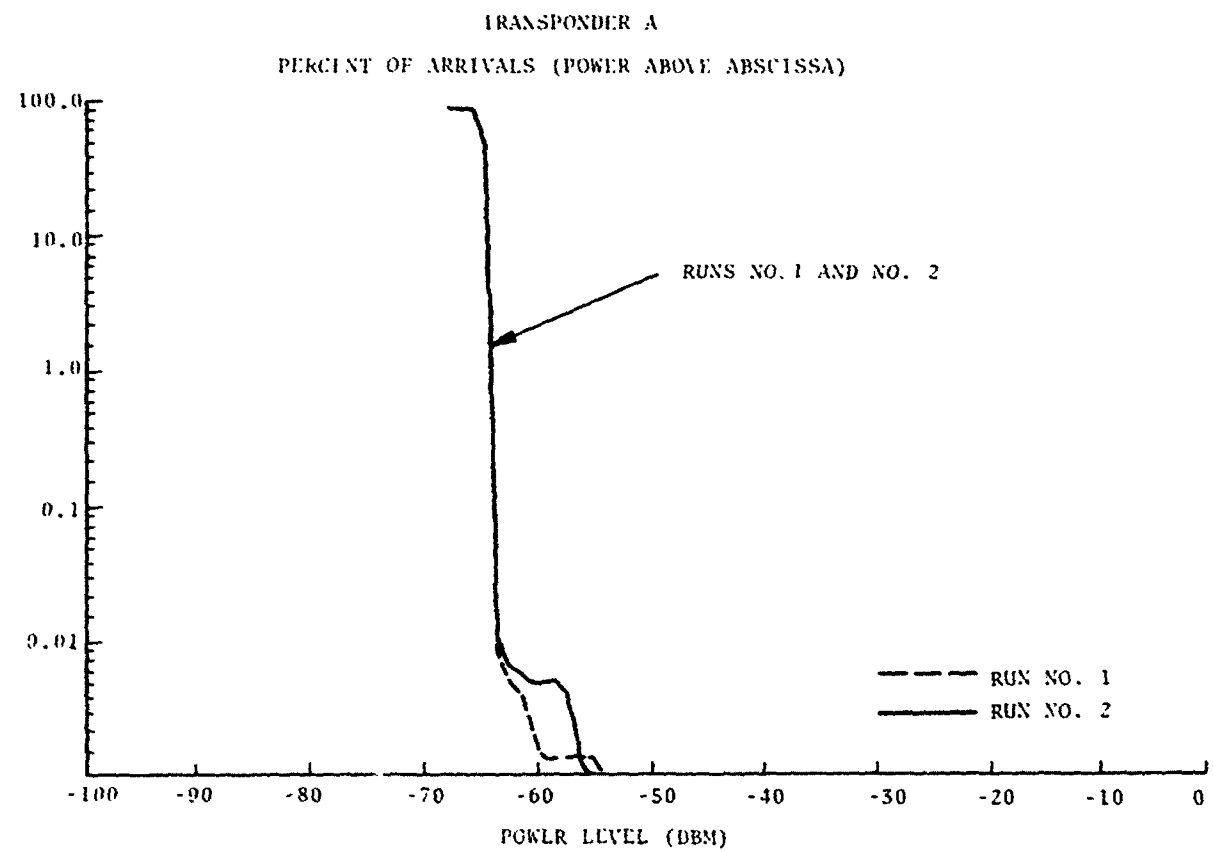

Figure 4-14. Power Distribution of SLS for Transponder MTL Range -70 dBm to -40 dBm (Transponder A)

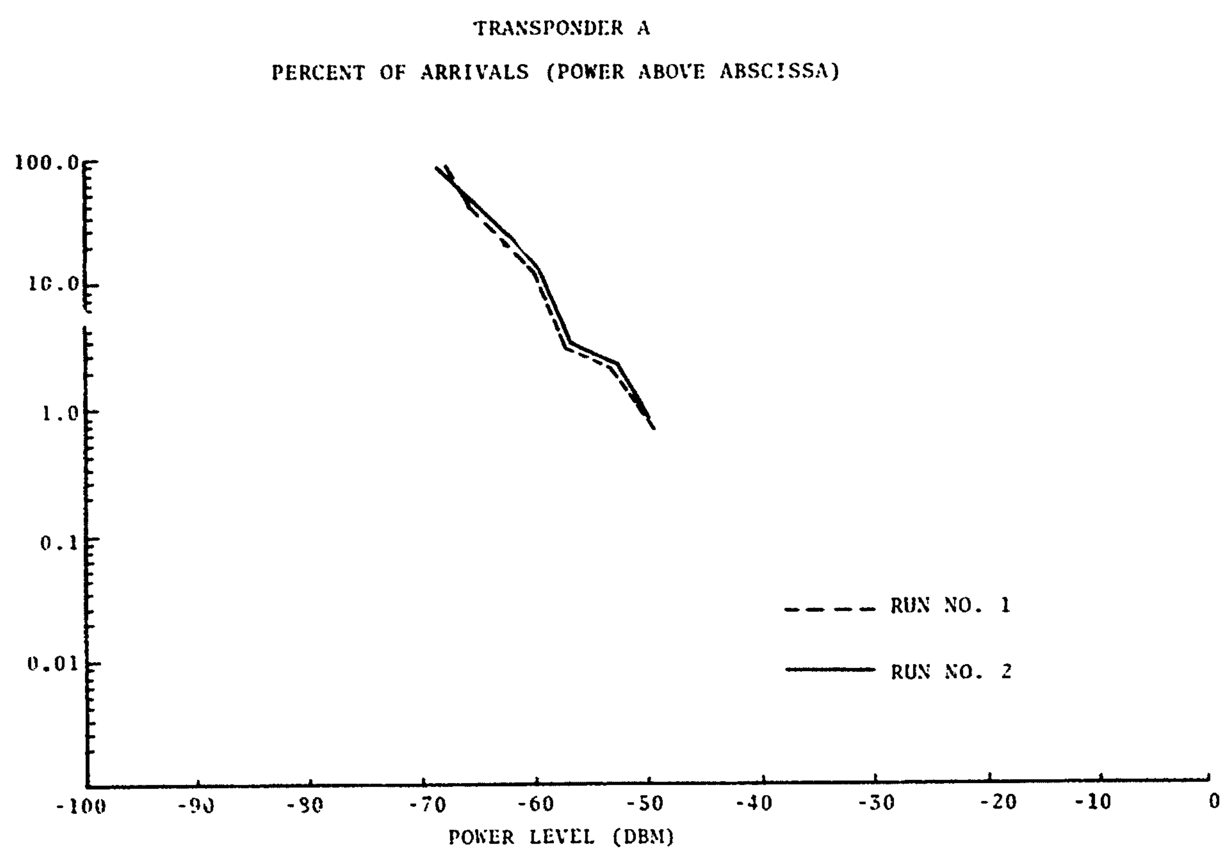

Figure 4-15. Power Distribution of Single P_2 Pulses for Transponder MTL Range -70 dBm to -40 dBm (Transponder A)

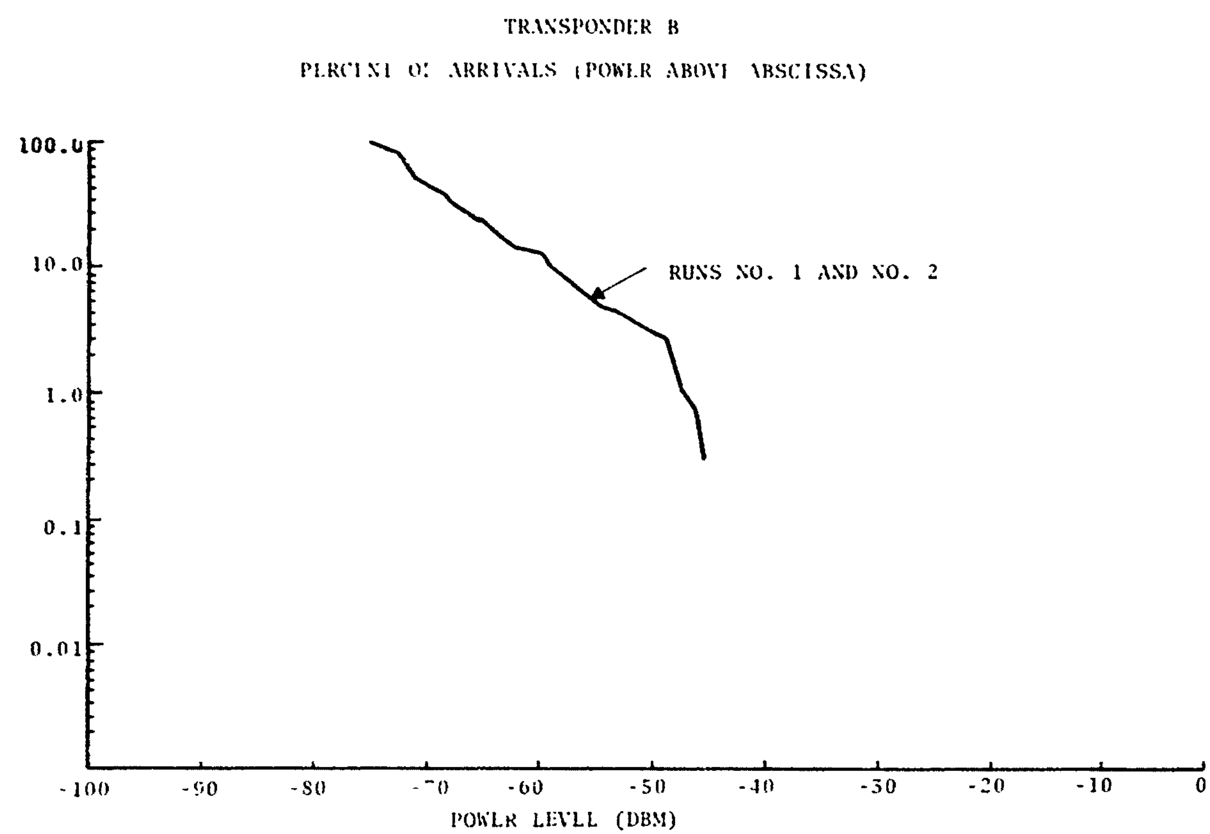

Figure 4-16. Power Distribution of Interrogations for Transponder MTL Range -70 dBm to -40 dBm (Transponder B)

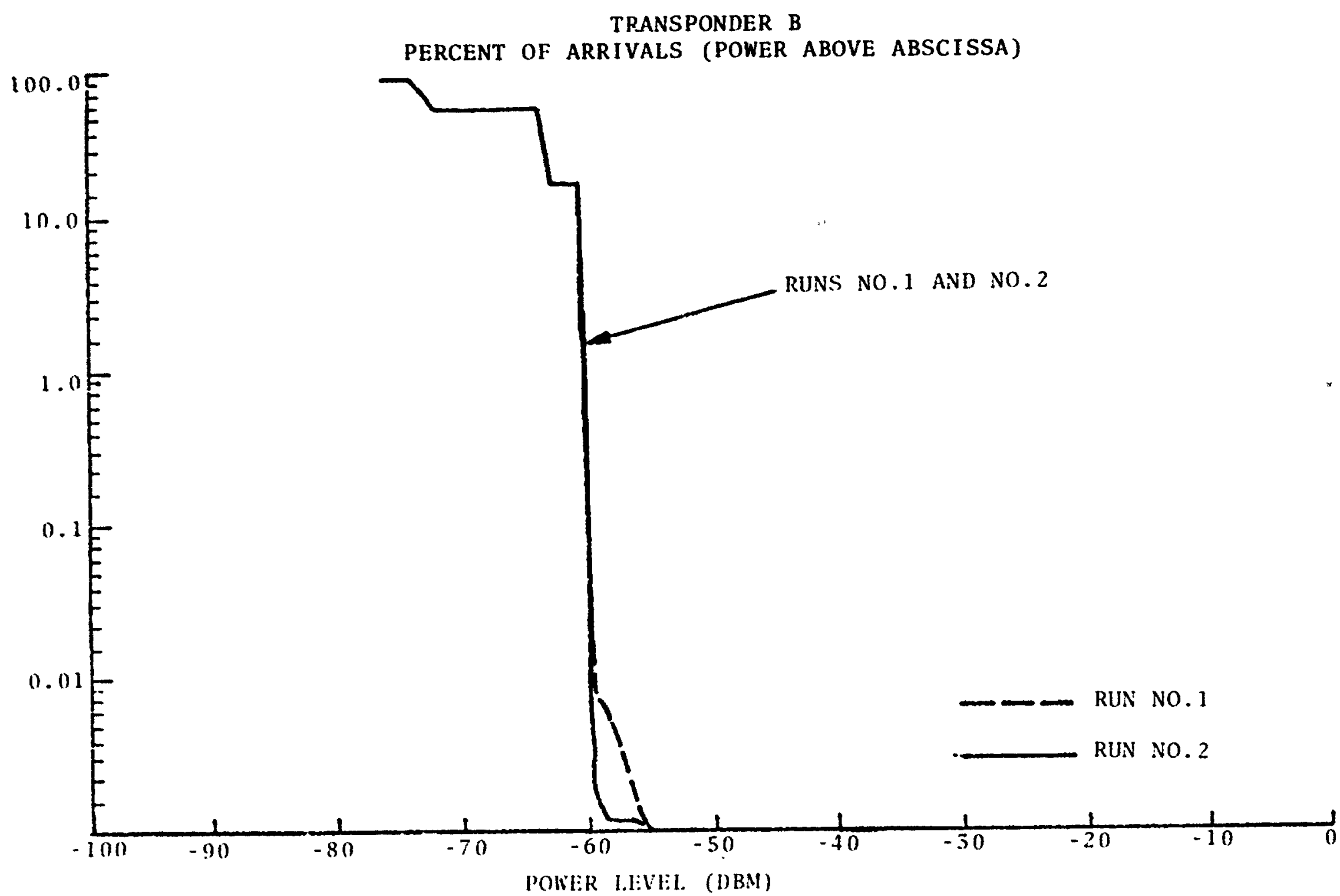

Figure 4-17. Power Distribution of SLS for Transponder MTL Range -70 dBm to -40 dBm (Transponder B)

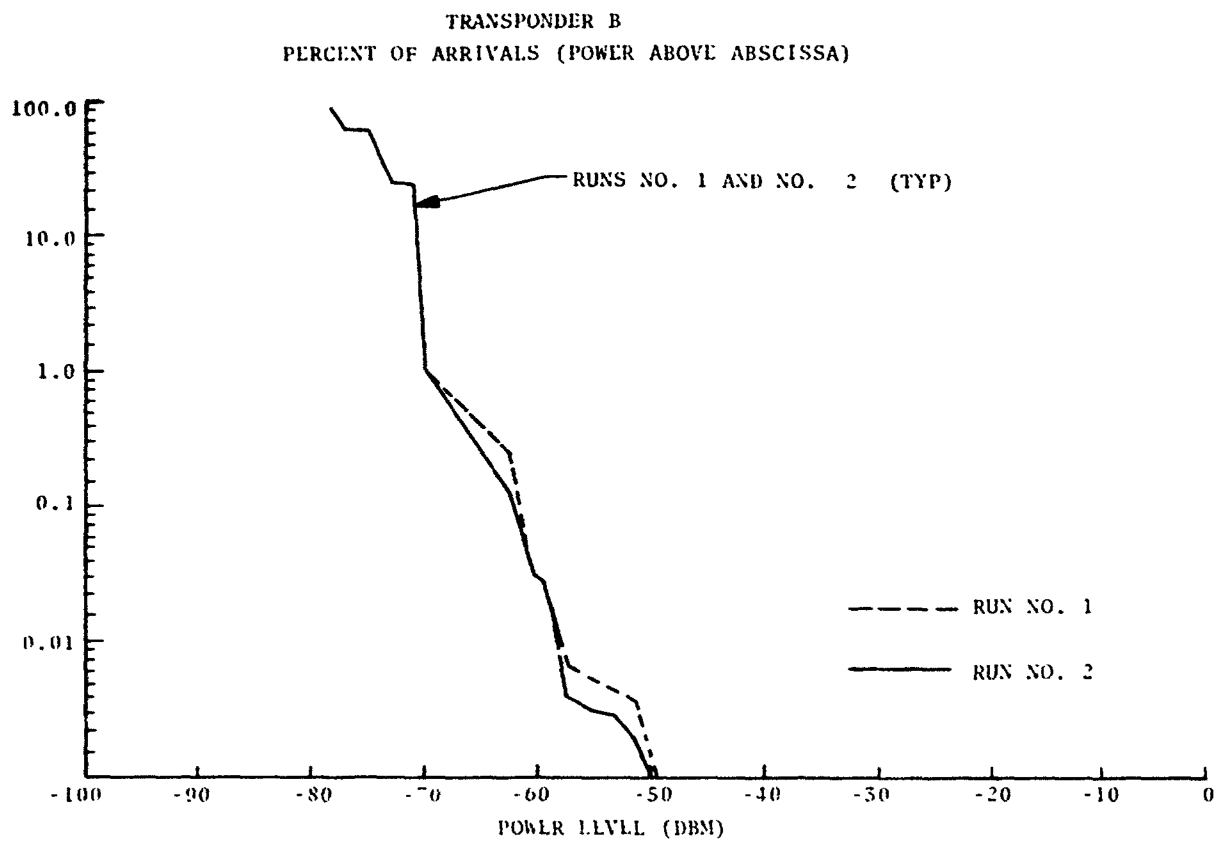

Figure 4-18. Power Distribution of Single P_2 Pulses for Transponder MTL Range -77 dBm to -40 dBm (Transponder B)

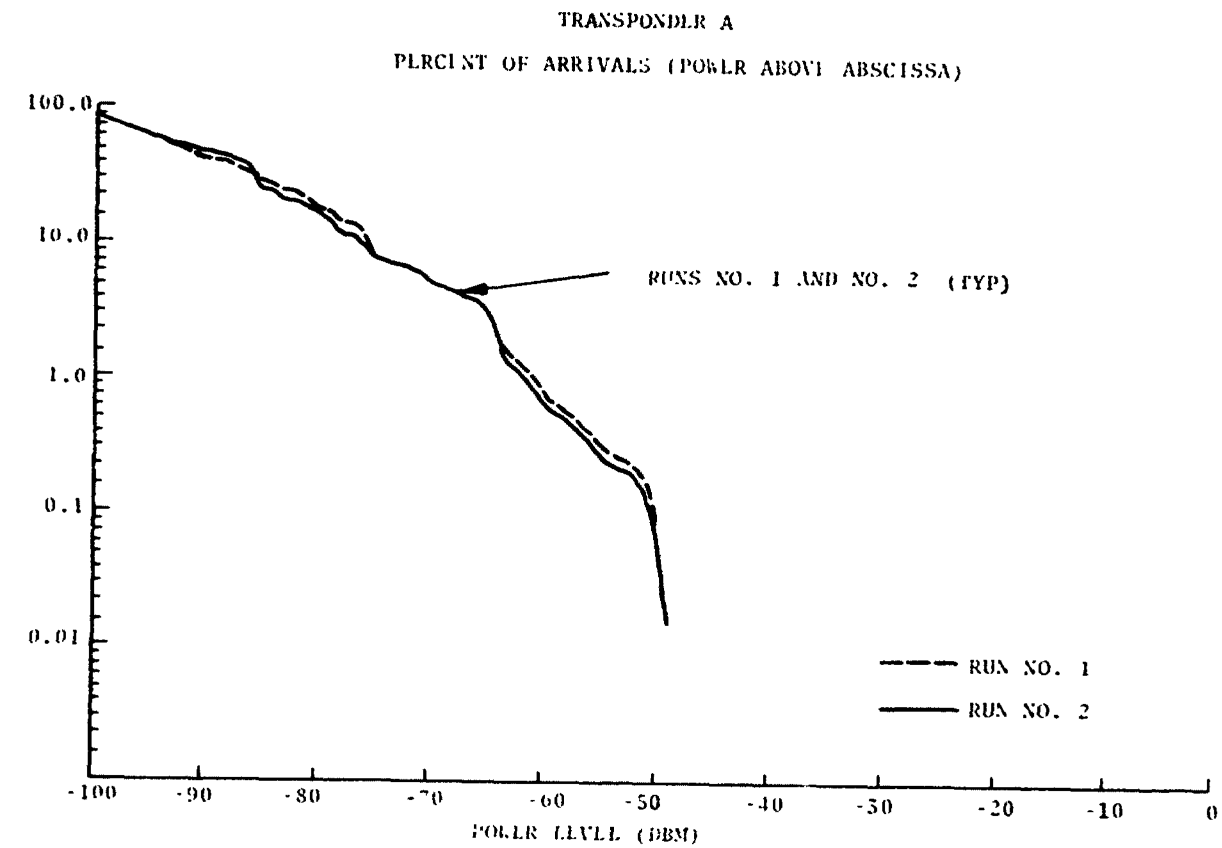

Figure 4-19. Power Distribution of Interrogations for Transponder MTL Range -100 dBm to -40 dBm (Transponder A)

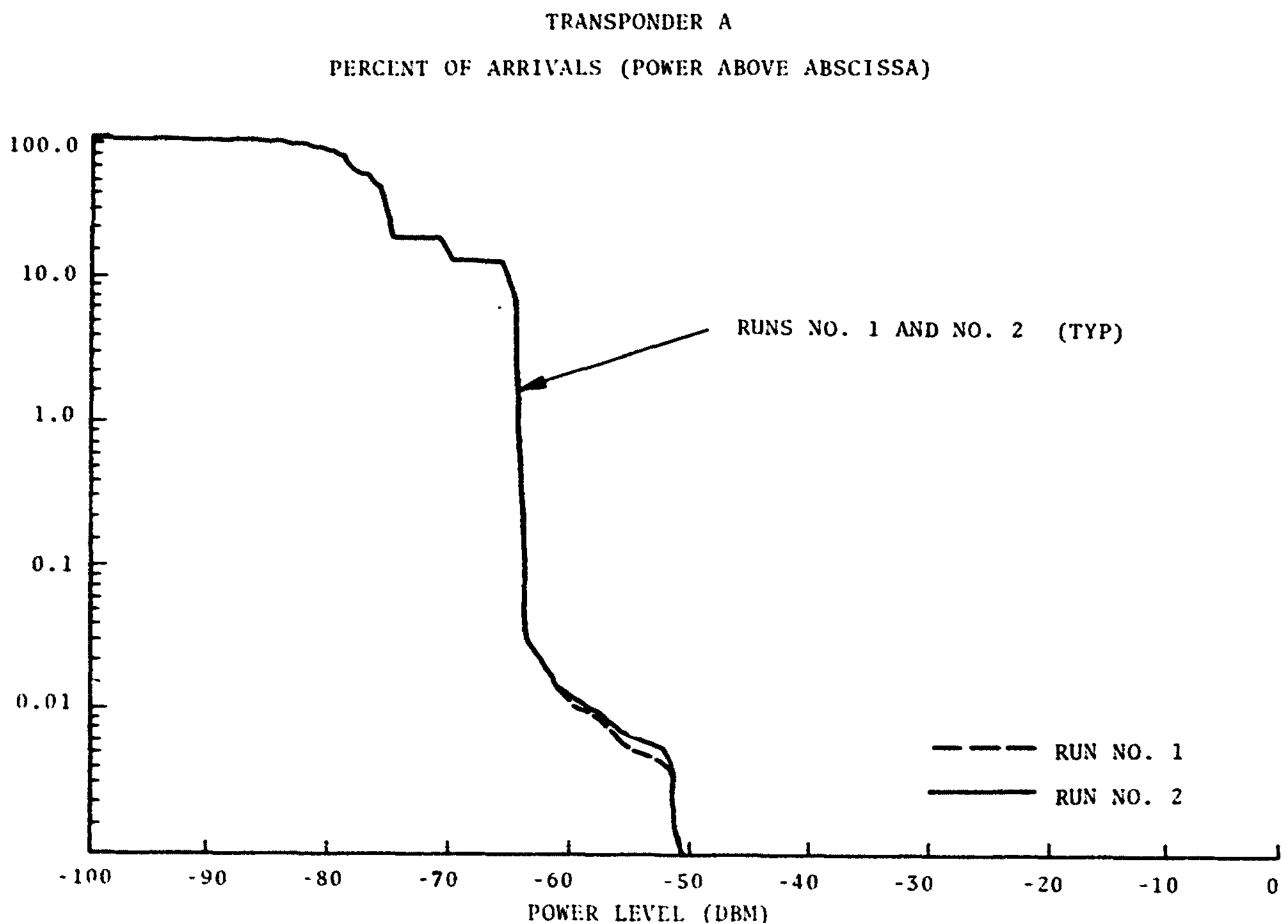

Figure 4-20. Power Distribution of SLS for Transponder MTL Range -100 dBm to -40 dBm (Transponder A)

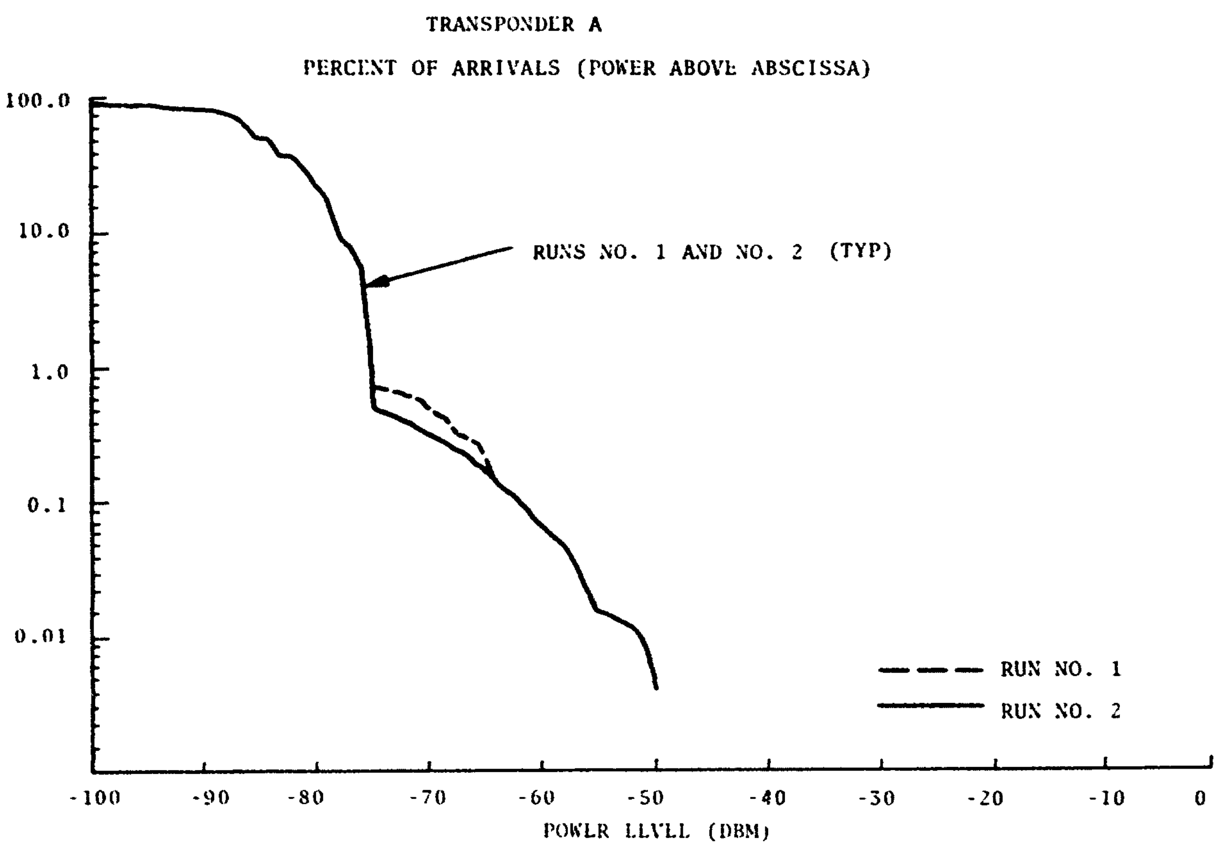

Figure 4-21. Power Distribution of Single P_2 Pulses for Transponder MTL Range -100 dBm to -40 dBm (Transponder A)

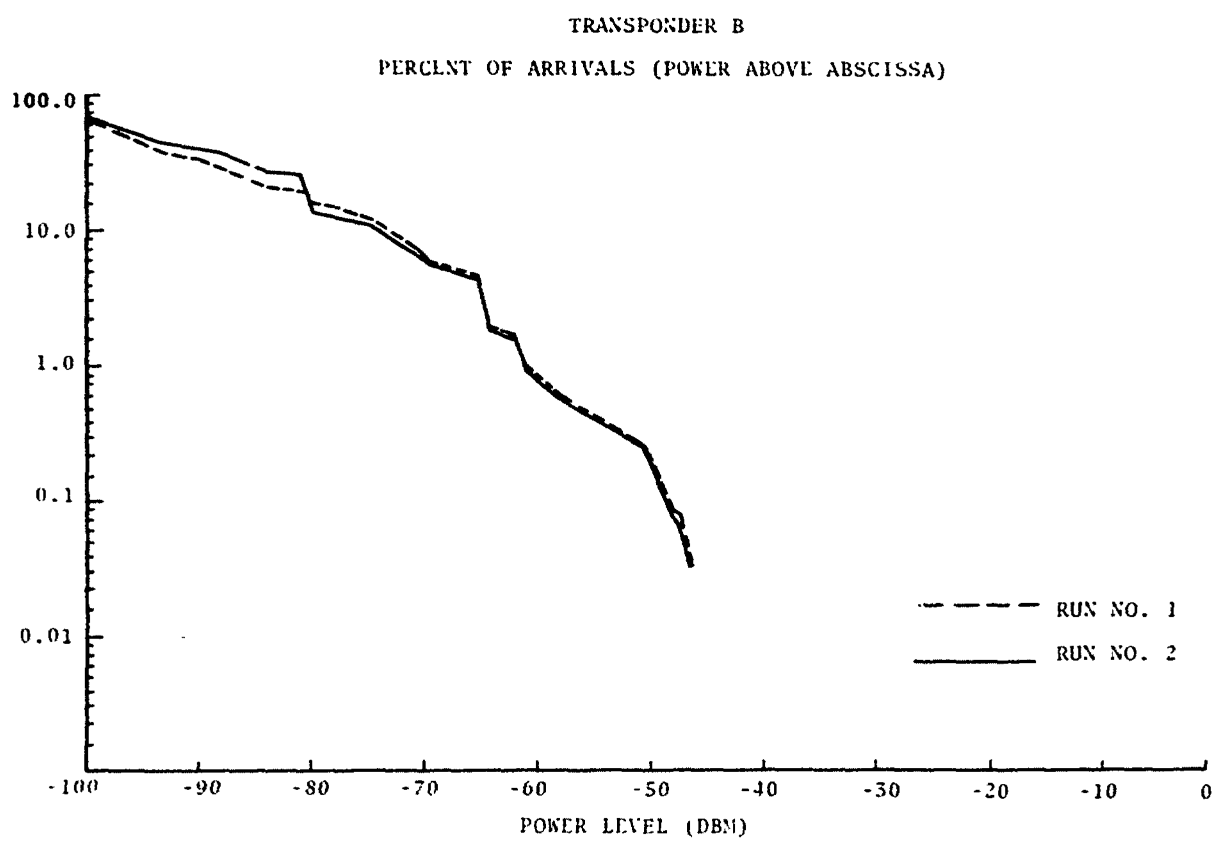

Figure 4-22. Power Distribution of Interrogations for Transponder MTL Range -100 dBm to -40 dBm (Transponder B)

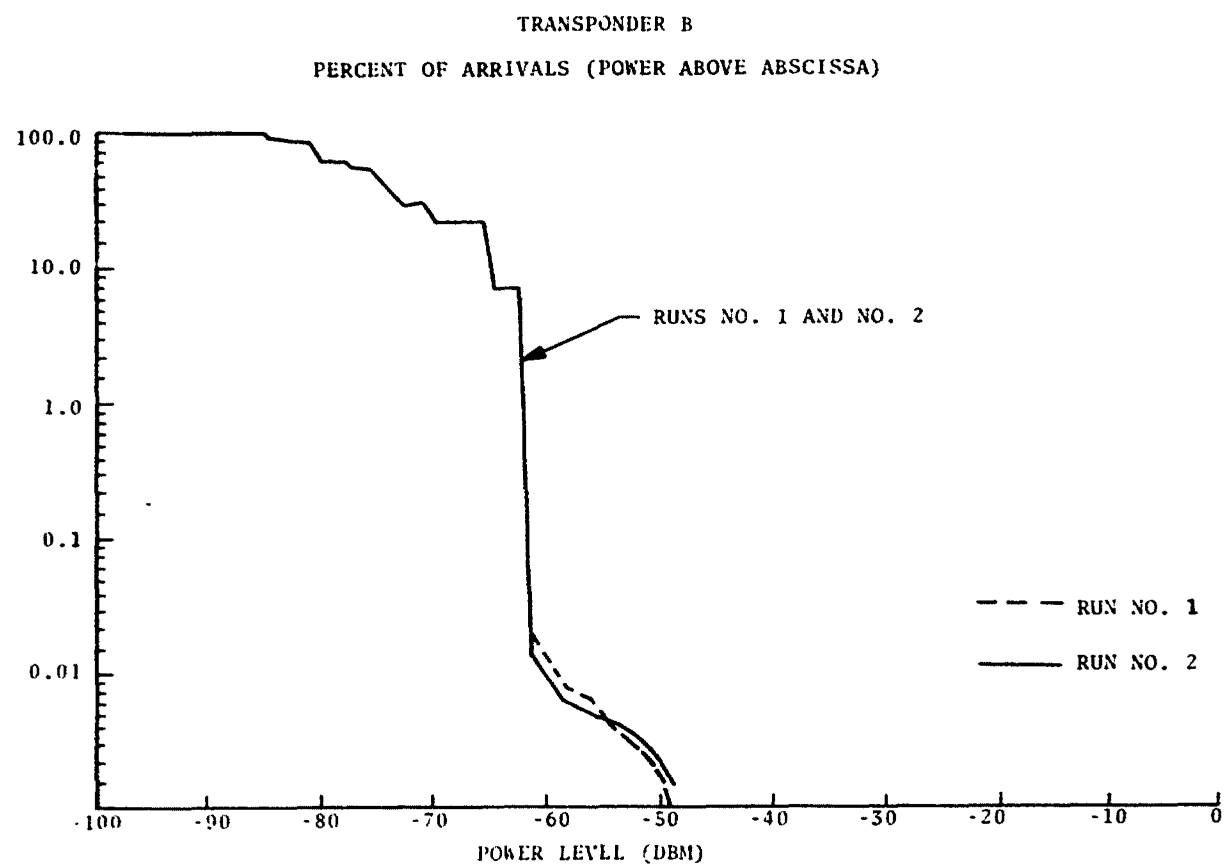

Figure 4-23. Power Distribution of SLS for Transponder MTL Range -100 dBm to -40 dBm (Transponder B)

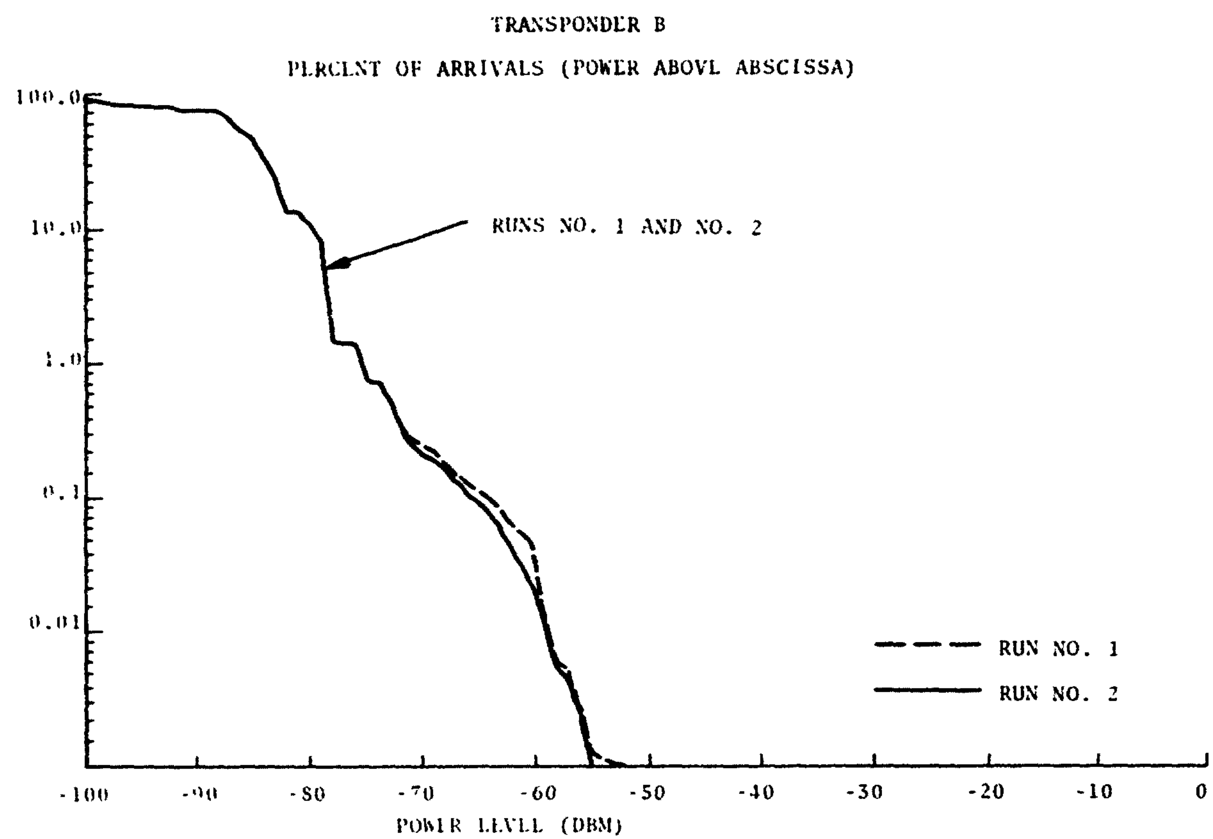

Figure 4-24. Power Distribution of Single P_2 Pulses for Transponder MTL Range -100 dBm to -40 dBm (Transponder B)

values of power levels (dBm) on the abscissa. Each transponder is monitored for the following arrivals:

(1) Percentage of valid interrogation arrivals

(2) Percentage of valid SLS arrivals

(3) Percentage of single P_2 pulse arrivals.

d. Each figure has two curves, which represent runs 1 and 2 respectively. In two instances (figures 4-13 and 4-16) an appearance of only one curve signifies that the results of the respective runs are so close as to make the two curves essentially coincident. Where differences in the runs are distinguishable, those portions of run number 1 which can be identified as distinct are designated run number 1 (e.g., dashed lines in figures 4-14, 4-15, and 4-17 through 4-24).

(Note: The simulation model is programmed so that the MTL for the simulated transponder receiver is nominally between -69 dBm and -77 dBm. With this MTL range existent, the histograms for figures 4-13 through 4-18 were processed for interrogation, SLS, and single P_2 pulse arrivals. However, the requirements for the DABS investigation were extended to include an MTL range from -100 dBm to -40 dBm. The simulation model program was therefore modified to permit investigation of power distribution for transponder MTLs up to -100 dBm. The resulting histograms of figures 4-19 through 4-24 were obtained with these extended ranges for the same criteria of pulse arrivals as noted above.)

4.3.2 Outputs for Task B

a. First- and second-miss probabilities for Transponders X, Y, and Z are given in table 4-10. The random time indicated in the table corresponds to random time τ' mentioned in paragraph 4.2.2.

TABLE 4-10. MISS PROBABILITIES FOR TRANSPONDERS X, Y, AND Z

Transponder	P (First Miss)	P(Second Miss/First Miss)*
X (Philadelphia)	0.015	0.017
Y (Trenton)	0.026	0.026
Z (New York)	0.058	0.061

*For random times between DABS interrogations

b. The second-miss probability is also provided in figures 4-25, 4-26, and 4-27 for Transponders X, Y, and Z respectively. The probability is expressed as a percentage of second misses relative to first misses for time τ from 1 to 10 milliseconds at 50-microsecond increments.

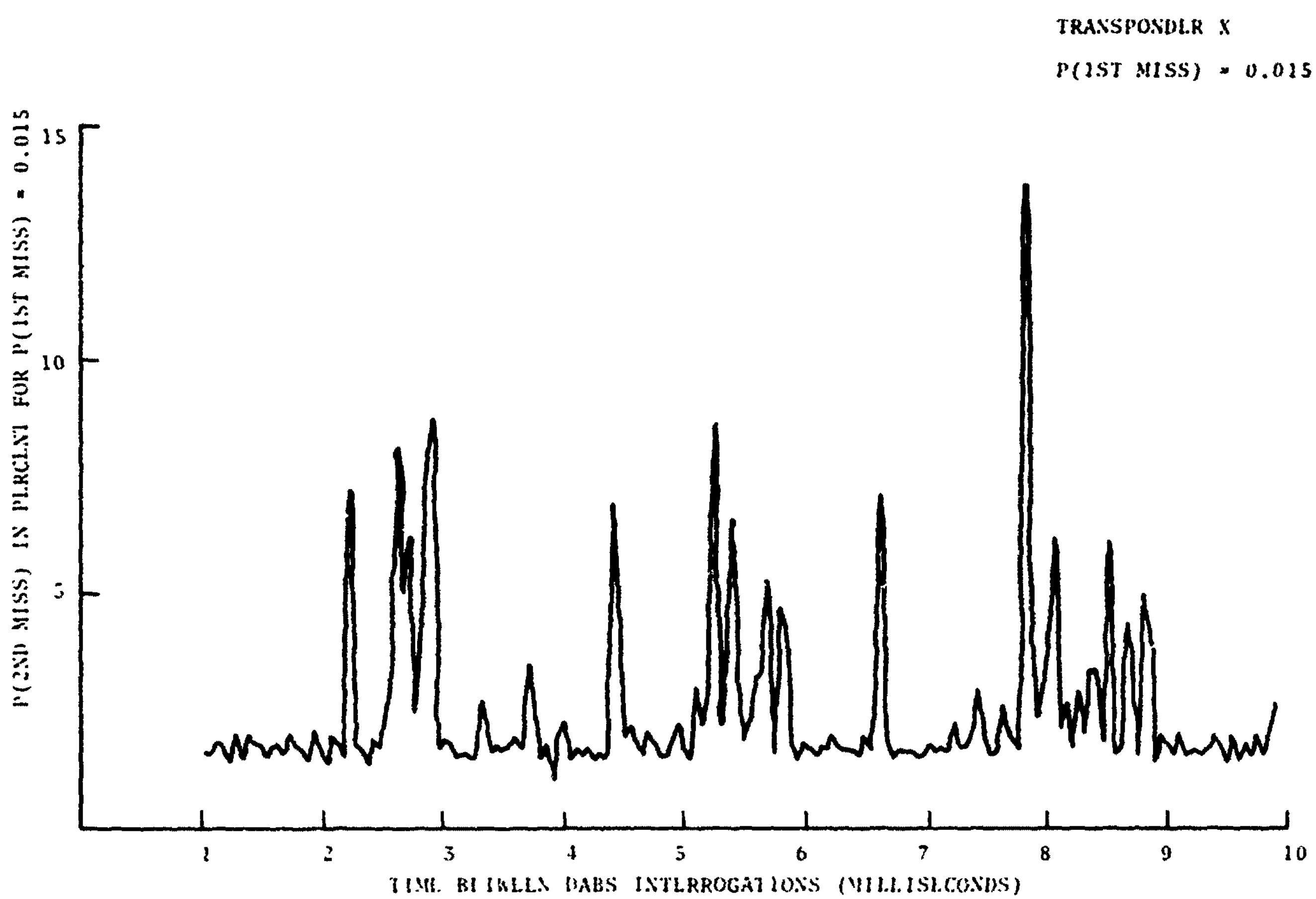

Figure 4-25. Second-Miss Probabilities for Transponder X (Philadelphia)

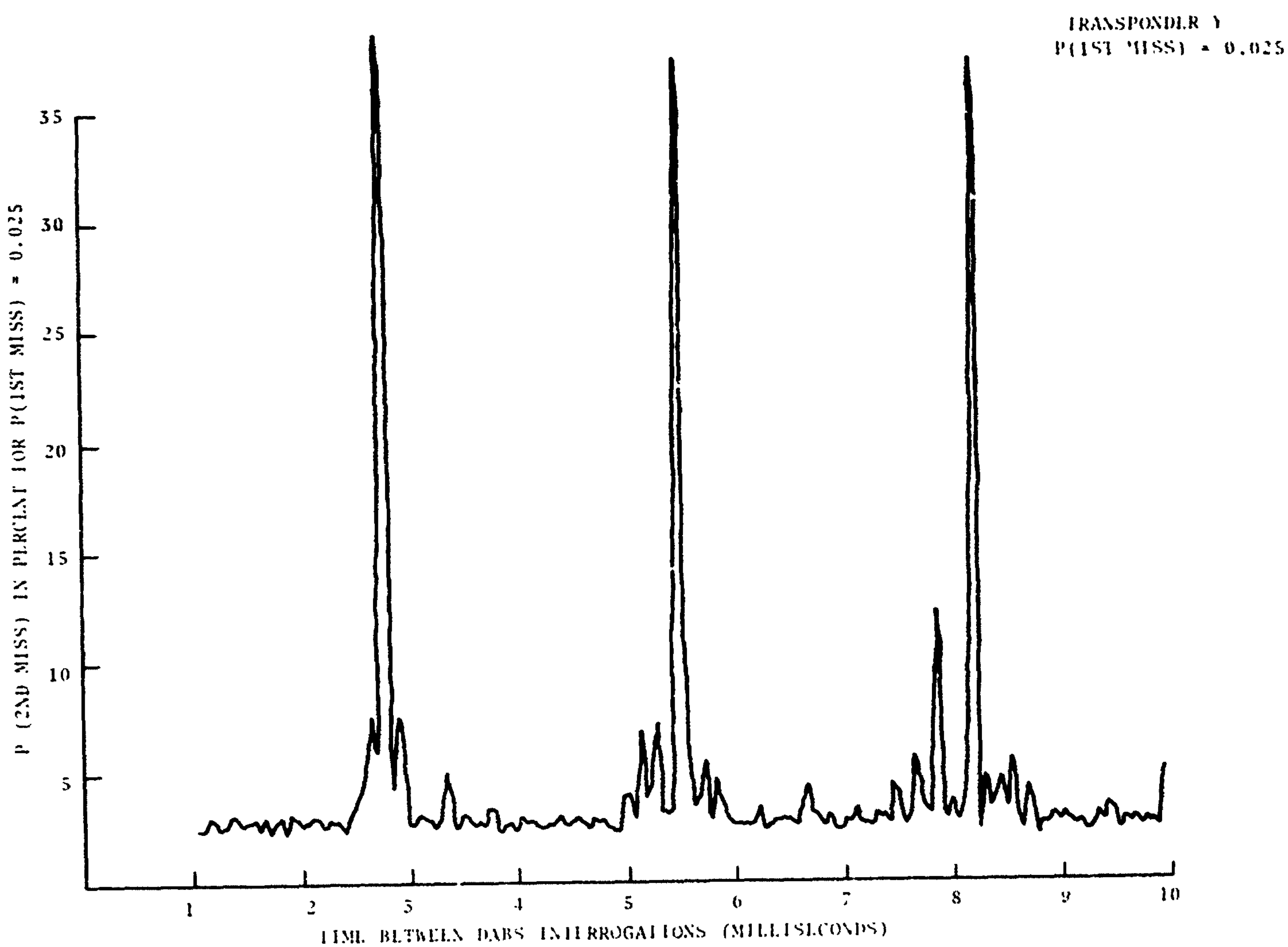

Figure 4-26. Second-Miss Probabilities for Transponder Y (Trenton)

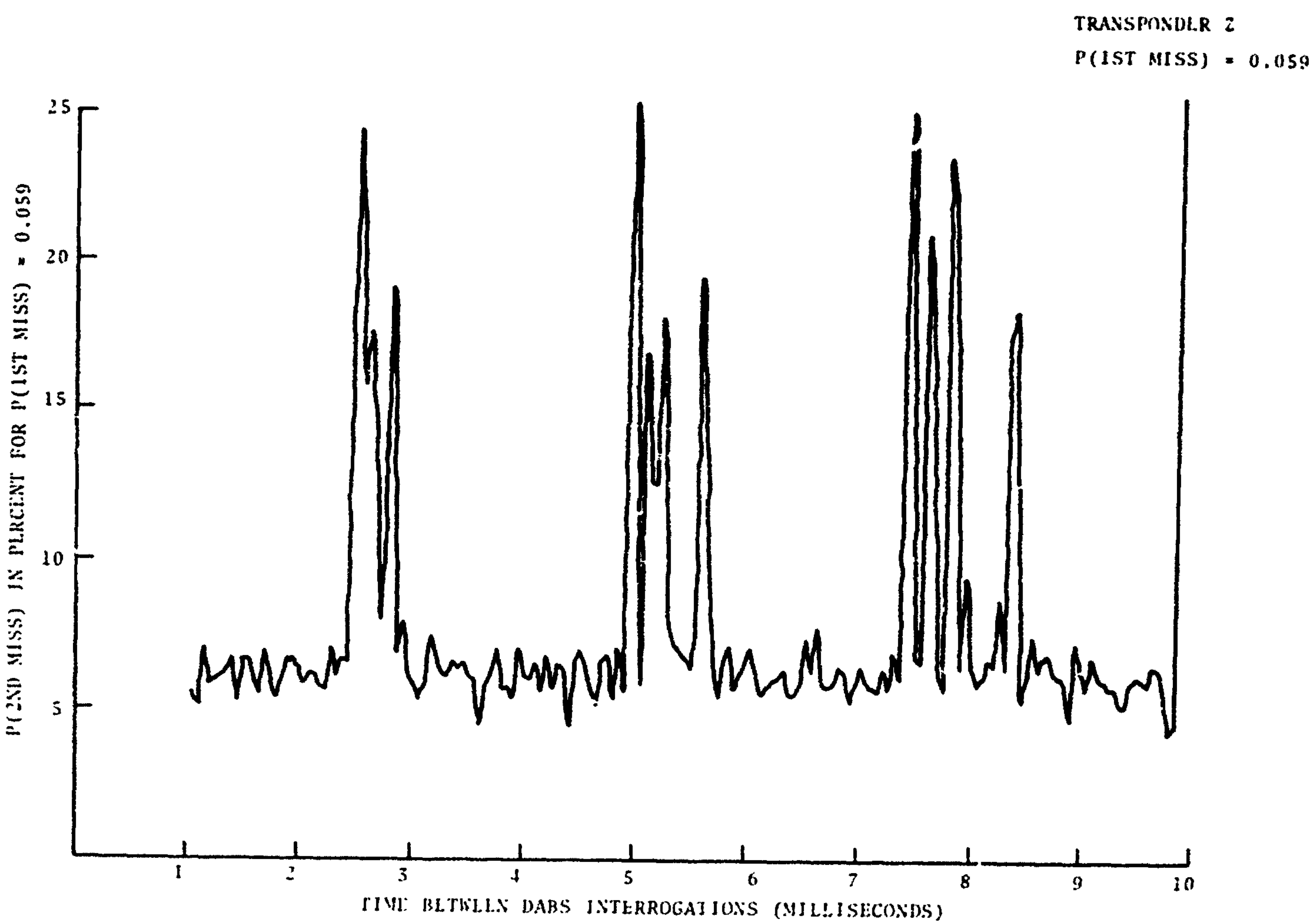

Figure 4-27. Second-Miss Probabilities for Transponder Z (New York)

5. CONCLUSIONS

The environmental data generated in the course of simulation runs for the tasks described in Section 4 validate the realism of the simulation. Interrogation rates, suppression rates, and reply ratios obtained by simulation correlate well, within allowable measurement errors, with flight test data recorded recently by M.I.T.'s Lincoln Laboratory* and by MITRE Corporation.** Simulation data pertaining to system performance using non-standard transponders with extended (50-microsecond and 100-microsecond) suppression times reflect the reduced reply ratios in a manner that one would expect.

The probability of occurrence of DABS misses was found to be sufficiently low to render ATCRBS interference nearly inconsequential. In fact, it was difficult to find an aircraft position and altitude at which, even with maximum transponder sensitivity, the probability of a DABS miss exceeded the six percent probability experienced in the vicinity of New York City. Those DABS interrogation periods that resulted in relatively high probabilities of a second DABS miss are merely the periods of nearby ATCRBS interrogators whose transmissions continued to interfere synchronously with DABS interrogations once the first miss was experienced. In this case, DABS interrogation scheduling, like current assignment of ATCRBS interrogation repetition frequencies, will minimize this synchronous interference phenomenon by a judicious choice of the DABS interrogation period or by use of a randomly jittered period. The fact that second-miss probabilities approximate the low first-miss probabilities (both for a random DABS interrogation period and for most of the interrogation periods plotted in figures 4-25

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*Quarterly Technical Summary, QTS 1 January - 30 March 1974, FAA DABS Report FAA-RD-74-85, Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, Massachusetts, pp 22-23, 1 April 1974.

**S.R. Jones, "Evaluation of ATCRBS Performance in an Interference Environment," MITRE Technical Report MTR 6239, Washington, D.C., 1 August 1972.

through 4-27) should facilitate the scheduling of DABS interrogations. Moreover, potential increases in beacon interference due to the growth of air traffic in the years ahead will be offset by the following developments:

- o Continuation of ATCRBS power reduction by the FAA and the Military
- o Future consolidation and control of military interrogator sites
- o Development of more reliable transponders
- o Implementation of ATCRBS improvements.