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Effects of the Joint Tactical Information Distribution System (JTIDS) on FAA L-Band Systems

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16. Abstract

The compatibility of a military Joint Tactical Information Distribution System (JTIDS) and the Federal Aviation Administration (FAA) L-band systems was investigated. The L-band systems tested were the ground and airborne components of the Air Traffic Control Radar Beacon System (ATCRBS), the airborne component of the Mode S system, and the ground and airborne components of the Tactical Air Navigation System (TACAN), and the Distance Measuring Equipment (DME). FAA criteria were established for each L-band system tested. Application of these criteria to the data collected resulted in establishing maximum JTIDS input levels for the L-band systems tested (with the exception of the airborne component of the TACAN/DME). The FAA criteria for the TACAN/DME airborne components were not met for several units tested.

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1. INTRODUCTION.

1.1. PURPOSE.

The purpose of this report is to document the effect of the Joint Tactical Information Distribution System (JTIDS) on the Federal Aviation Administration (FAA) L-band systems. The L-band encompasses frequencies from 960 to 1215 megahertz (MHz). The FAA L-band systems are the Air Traffic Control Radar Beacon System (ATCRBS), the Mode S System, the Traffic Alert and Collision Avoidance System (TCAS), the Tactical Air Navigation System (TACAN), and the Distance Measuring Equipment (DME). The JTIDS configuration tested used a 100/50 timeslot duty factor. This is the timeslot duty factor that Department of Defense (DOD) requested to be used on an unrestricted, uncoordinated basis.

1.2. BACKGROUND.

The DOD is presently authorized to operate JTIDS according to the provisions contained in Interdepartmental Radio Advisory Committee (IRAC) document 21167/1-1.14.10. The Stage 4 frequency allocation for time division multiple access (TDMA) JTIDS to operate in the 960 to 1215 MHz frequency band was granted December 6, 1979. The IRAC document essentially allows JTIDS to operate using a maximum timeslot duty factor of 40/20 and to employ transmitters that produce 200 watts Effective Isotropically Radiated Power (EIRP). The 40/20 timeslot duty factor notation specifies that the total JTIDS community will not transmit in more than 40 percent of the total available timeslots for single or multiple nets. Contributions from a single user will not exceed 20 percent.

The DOD made the JTIDS allocation request in 1975, and the request identified the 40/20 JTIDS requirement. The Office of Telecommunication Policy (OTP) (Executive Order 11556) was responsible for reviewing Federal Telecommunication Systems for frequency availability and electromagnetic compatibility (EMC). This review is normally carried out by the Spectrum Planning Subcommittee (SPS) of the IRAC. However, due to the concerns of the FAA as to JTIDS operating in this band and the complexity of the JTIDS problem, the review was conducted by OTP with the assistance of the affected federal agencies. A JTIDS steering committee was formed to plan a course of action to resolve the JTIDS spectrum support problem. The committee consisted of members from the FAA, DOD, Federal Communications Commission (FCC), and the Department of Commerce Office of Telecommunications (OT).

The JTIDS steering committee identified two tasks for the JTIDS review process. The first task was a joint study by OT and DOD Electromagnetic Compatibility and Analysis Center (ECAC) to determine the feasibility of satisfying JTIDS requirements in bands other than the 960-1215 MHz band. This study identified four other bands that had the potential to accommodate JTIDS. If JTIDS was found to be compatible with the present, firmly planned systems in the 960-1215 MHz band, then this would be assessed as the number one candidate band.

The second task, started at the same time as the band study, consisted of measurements and analysis programs to determine the actual and predicted compatibility of JTIDS with existing and firmly planned systems designed to operate in the 960-1215 MHz band. A joint working group (SPS WG-1) was organized by the steering committee

to conduct this task. The SPS WG-1 was composed of representatives from DOD, FAA, OT, FCC, ECAC, Aeronautical Radio Incorporated Research Corporation (ARINC), and Radio Technical Commission for Aeronautics (RTCA). The SPG WG-1 was initially chaired by FAA and then later by OT. It was tasked to determine the type of bench and flight test measurements required to evaluate the electromagnetic compatibility of JTIDS with the air traffic control (ATC) system. The working group was also responsible for directing the measurement programs and organizing the measurement data processing for subsequent evaluation. During this test program, JTIDS net characteristics were simulated using a single terminal (single net). This terminal normally transmitted in 40 percent of the available timeslots to meet DOD stated requirements. During bench tests, typically, half of the transmissions were high powered, which simulated a nearby relay aircraft, and half were low powered, which represented distant elements of the JTIDS network. The low-level signals represent the remaining JTIDS community located within a few miles of the ATC system element under test. During flight tests, transmissions in all 40 percent of the timeslots were high powered.

The results of the measurement program are documented in OT Report 78-140. The general conclusions of that report are:

1. "The test and analysis efforts show that the Phase I JTIDS signals have either no effect or only minimal operational effects on current designs of existing and firmly planned ATC systems. These effects occur when the ATC systems are receiving desired signals that are at or near their performance limits (near threshold) while simultaneously receiving very strong JTIDS signals.

2. "If recognized flight-separations requirements are observed, the mobility of airborne airborne JTIDS terminals makes the probability of experiencing these minimal operational effects very low. However, care must be taken to assure that ground-based JTIDS terminals are sited to keep JTIDS signal levels below those that affect ATC system performance.

3. "When JTIDS terminals and ATC equipments are collocated on airborne platforms, the DOD should assure that isolation between avionics is provided to maintain required ATC system performance.

4. "The present level of JTIDS/ATC system electromagnetic compatibility can be continued in the future provided current design features and operating conditions are maintained. This implies that compatibility-related features of JTIDS (e.g., waveform structure, time-slot duty factor, etc.) will not change, and that modifications to or new models of ATC systems will continue to incorporate features that promote compatibility."

The OT report, an FCC review, and a public hearing resulted in the United States (U.S.) Allocation Table Change (Footnote U.S. 224). The JTIDS is allowed to operate in the 960-1215 MHz band on a noninterfering basis in accordance with the provisions of the IRAC document, 21167/1-1.14.10, (in essence, an uncoordinated 40/20 JTIDS operation).

In the ensuing years, 1979 through 1982, DOD continued JTIDS testing and modeling to further explore the capabilities of JTIDS. During this same timeframe, JTIDS testing was conducted in the European area. As a result of this testing, a 40/20 JTIDS operation was approved in most North Atlantic Treaty Organization (NATO) nations.

In 1982, the United States Navy (USN) filed for a JTIDS allocation but specified a pulse distribution scheme different from that approved and authorized by the FCC. The USN distribution scheme was labled "Distributed Time Division Multiple Access (DTDMA) JTIDS."

National Telecommunications and Information Administration (NTIA) requested DOD to submit a consolidated spectrum support package for both TDMA and DTDMA. During this same timeframe, the USN was granted Stage Three approval for DTDMA JTIDS (September 30, 1982).

In 1983, DOD established a Tri-Service group to assess future JTIDS requirements of all military services for operation in the continental United States and a Tri-Nation group to access all JTIDS requirements for NATO operation in the European area. The activities of both these groups identified the individual services and intra-service JTIDS requirements for both continental U.S. and NATO operations. These new JTIDS requirements exceeded those originally requested and presently authorized 40/20 JTIDS timeslot duty factor.

The DOD briefed the SPS WG-1 as to these new JTIDS requirements. The SPS WG-1 agreed to initiate a test program funded by DOD to determine the effects of the expanded JTIDS requirements on the present, firmly planned systems of the 960-1215 MHz band. The SPS WG-1 formed a Test Plan Group (TPG) to identify and document the tests required to assess the effects of the expanded JTIDS on the other 960-1215 MHz systems. The TPG consisted of members from DOD, FAA, and NTIA. The actual JTIDS testing was started in September of 1983.

Testing of the JTIDS effects on the ATCRBS, the airborne Mode S System, and the ground TACAN/DME beacons was conducted at the FAA Technical Center in Atlantic City, New Jersey; and testing of the JTIDS effects on the airborne TACAN/DME equipments was conducted at the Illinois Institute of Technology Research Institute (IITRI) laboratories in Annapolis, Maryland.

The stated DOD JTIDS frequency allocation requirements as of late 1983 were as follows:

1. 100/50 - Unrestricted and uncoordinated wide band and single frequency 969 MHz.

    a. Two nets TDMA (Army/Air Force).

    b. Dual Metachannel (Navy/Marine Corps).

    c. DTDMA and TDMA combination with up to four simultaneous transmissions/time-slot (joint).

2. 200/50 - Coordinated general exercise; will accept restrictions as dictated by test program.

    a. Five nets TDMA (Army/Air Force).

    b. Five Metachannel DTDMA (Navy/Marine Corps).

c. DTDMA and TDMA combination with up to 10 simultaneous transmissions per timeslot (joint).

3. 400/50 - coordinated special exercise; will accept restrictions as dictated by test program.

a. Ten nets TDMA (Army/Air Force).

b. Ten Metachannel DTDMA (Navy/Marine Corps).

c. DTDMA/TDMA combination with up to 20 simultaneous transmissions per timeslot (joint).

The DOD JTIDS requirement has expanded from the 1975 view of a TDMA system deployed principally on Air Force E-3A's with limited ground command and control systems to a 1984 perspective of TDMA and DTDMA with the deployment expanded to Navy E-2s and Air Force and Navy fighter planes and ground deployment expanded to support Army JTIDS applications.

The 1984-85 JTIDS effects testing was devoted to the ground and airborne components of the ATCRBS, the airborne components of the MODE S, and the airborne components of the TACAN/DME.

On October 16, 1985, the Secretary of the Navy directed the Navy to cancel the DTDMA program and procure the TDMA JTIDS system for Navy operations. The cancellation was precipitated by the decision that the technical risks associated with the development of the DTDMA system would not allow Navy JTIDS deployment as required by DOD. All testing as to the effects of the DTDMA JTIDS was eliminated from the test program.

The 1986 JTIDS testing was devoted to the ground components of the TACAN/DME system and the airborne components of the TACAN/DME system.

1.3. JTIDS DESCRIPTION.

The JTIDS is a secure, frequency-hopping communication system designed to operate in the 960 to 1215 MHz band. The system operates in end-to-end timeslots where each timeslot is 7.812 milliseconds (ms) in duration (128 timeslots per second). The actual JTIDS transmission occupies 1.6512 ms of each timeslot. All JTIDS pulses are 6.4 microseconds (μs) wide. The JTIDS pulses per timeslot are 258 for a normal timeslot and 444 for a packed timeslot (Pack 2 double pulse or Pack 4).

JTIDS transmits on frequencies that are uniformly spaced (3 MHz) and selected from within three frequency sub-bands (969-1008 MHz, 1053-1065 MHz, and 1113-1206 MHz). The transmit frequency of each JTIDS pulse is randomly selected from the allowable transmit frequencies.

JTIDS has the capability of operating multiple independent nets in the same geographic area. The capability of more than one JTIDS terminal transmitting in the same timeslot in the same net also exists in the JTIDS.

1.4 TEST PROGRAM.

The Phase I portion of the test program was designed to focus on the 100/50 uncoordinated JTIDS requirements with some limited 200/50 testing. The Phase II portion was to focus on the 200/50 and 400/50 general and special JTIDS exercises.

At DOD's request, NTIA, with the coordination of SPS WG-1, drafted a risk accessment report accessing the potential EMC risks of a JTIDS-procurement decision. The risk accessment completion date was May 1987, to satisfy DOD's timetable at that time.

The test program has had several revisions due to changes in DOD's use of JTIDS. Initially, DOD proposed a test series of parametric variations of JTIDS input to the ATC systems under test. The FAA, in order to maintain a viable test program, requested that DOD provide an operational deployment of JTIDS terminals for the 100/50 training requirements for each JTIDS service user (Air Force, Navy, Army, joint Air Force/Army). The DOD responded to the FAA and developed the requested scenarios. The actual transmissions between all terminals were identified, and these scenarios were used as input to the ATC systems under test to assess the impact of 100/50 JTIDS on the ATC system.

The Air Force training scenario tested used TDMA JTIDS pulses, standard packed timeslots (double pulse 258 pulses/timeslot), dual net; and no simultaneous JTIDS tranmissions. The Navy scenario used DTDMA JTIDS waveforms. The Army scenario used additional aspects of JTIDS. It used TDMA JTIDS pulses, some packed time-slots (Pack 2 double pulse 444 pulses/timeslot), multinet, and multiple simultaneous transmissions. The joint scenario (Air Force/Army) used TDMA JTIDS pulses and combinations of the separate Air Force and Army scenarios.

All of the TACAN/DME airborne interrogators (12) in this program were tested using the TDMA Air Force scenario, the DTDMA Navy scenario, and the TDMA Army scenario. Subsequently, the DTDMA program was cancelled. DOD then developed the Navy test scenario using the TDMA JTIDS waveforms.

For expediency, the test program identified 4 of the 12 airborne TACAN/DME units to be tested using the TDMA joint scenario and the TDMA Navy scenario. The four units identified were the poorest performers in the presence of JTIDS when tested against the Air Force and Army scenarios.

The test plan, written by the test plan subworking group and approved by the SPS WG-1 relative to JTIDS effects on TACAN/DME airborne interrogators, used the previous JTIDS test program as a precedent. The previous program collected interrogator data that were eventually used in an operational analysis. This test program identified a similar approach; the objective being to use the data in operational analysis. In essence, an operational analysis correlates the change in an interrogator's performance due to JTIDS into a change in range where the interrogator is operating with a ground beacon. The operational analysis is then a combination uplink and downlink aspect of the performance of the TACAN/DME interrogator with and without JTIDS present. This approach has not be approved by the FAA for use in developing compatibility criteria.

Part way through the TACAN/DME interrogator test program, the FAA with the support of RTCA representatives presented criteria for assessing the effects of JTIDS on TACAN/DME interrogators. The intent was to provide bench-test criteria for JTIDS similar to the criteria in the TSOs for the allowable change in receiver sensitivity in the presence of random pulses. The criteria for JTIDS are (1) an allowable 3-decibel (dB) change in interrogator acquisition sensitivity for outside the service, and (2) an unchanged acquisition sensitivity within the service volume. As of this writing, the DOD intends to perform an operational analysis on all TACAN/DME interrogators that fail to meet the FAA criteria in the presence of JTIDS.

The FAA requested, and DOD agreed to test the operational scenarios which DOD would develop based on planned usage. Thus, the test program employed a combination of JTIDS operational scenarios and JTIDS parametric variations to be used in testing all ground ATC systems (ATCRBS and TACAN/DME beacons). The operational scenarios identified for ground ATC testing were the Navy and Army scenarios and parametric variations of multipulse combinations of multinet, simultaneous transmissions, and normal and packed timeslots.

As of this writing, the Army has announced they do not intend to use the Class II JTIDS terminals and will instead use a terminal identified as Class 2M. The Army scenario tested in this test program was predicated on the capabilities of a Class II JTIDS terminal. The similarity or difference between the Class II and Class 2M terminal is not known by this writer at this time.

2. JTIDS/ATCRBS GROUND SYSTEM.

2.1. DESCRIPTION OF EQUIPMENT.

The ATCRBS is designed with the primary function of surveillance of cooperative aircraft for air traffic control purposes. The system requires transponders aboard aircraft and the use of ground interrogator equipment to determine aircraft position. Aircraft identity and altitude are determined by the transponder reply to the ground interrogations.

The ATCRBS is a cooperative system and consists of a ground-based rotating directional antenna system, air traffic control beacon interrogator receiver (ATCBI-5), receiver, sensor receiver and processor (SRAP), and active aircraft transponders.

The ground-based interrogations are radio frequency (RF) pulse groups transmitted by the ground equipment on 1030 MHz to interrogate all aircraft within the area of coverage. Upon interrogation, the aircraft transponder transmits a coded reply pulse train back to the ground station at a frequency of 1090 MHz. Depending on the pulse spacing of the interrogation pulse groups (mode 3A, 8 μs; mode C, 21 μs), the aircraft reply contains the aircraft identity selected by the pilot (mode 3A) or the aircraft altitude automatically selected from an onboard barometric altimeter (mode C). The ground-based equipment can then automatically decode the information and determine the aircraft range, azimuth, identity, and altitude.

Figure 2-1 is a block diagram of the receiver portion of the ATCBI-5/SRAP. The ATCBI-5 is the interrogator/receiver portion of the ATCRBS. The interrogator provides periodic beacon sync triggers (time zero triggers) and corresponding periodic interrogations. These interrogations are time-shared between mode 3A and mode C. The interrogators are normally operated in a one-to-one mode interlace pattern where the interrogation pattern is mode 3A, C, 3A, C, etc.

The receiver accepts 1090 MHz replies from the directional antenna and passes these replies through a mixer, intermediate frequency (IF) amplifier, several video amplifiers, a band-pass filter, a quantizer, and then output via a limiter/driver. A sensitivity time control (STC) is applied to the IF amplifier to desensitize the receiver for a fixed amount (generally 30 dB) at zero range and then allows the receiver to recover at the rate of space attenuation (6 dB/double the range). This STC function prevents saturation of the IF amplifier from close-in aircraft replies.

The output pulses of the ATCBI-5 receiver are passed through a defruiter (interference blanker MX8757/UPX). The defruiter's function is to allow only replies that are synchronous with the interrogation to pass on to the processors. Elimination of nonsynchronous replies is achieved by delaying all the pulses by one pulse repetition frequency (PRF) interval and then comparing them with those in the next PRF interval of the same mode (mode 3A, mode C). The pulses that are not coincident in each period are eliminated.

The SRAP consists of two distinct units, the radar data acquisition subsystem (RDAS) and the beacon data acquisition subsystem (BDAS).

The function of RDAS is to detect and transfer aircraft target and weather data derived from search radar video returns. The BDAS provides detection and transfer of aircraft target data derived from beacon transponder replies supplied from the output of the defruiter. The BDAS also correlates and merges radar and beacon target report data and outputs the target report data and weather data (1) to the Automated Radar Terminal System (ARTS) IIIA input/output processors (IOP), and (2) to an ATC display.

Associated with each ATCBI-5 equipment is a beacon test target generator (TTG). The TTG is a controlled source of 1090 MHz aircraft-like replies to interrogations from the ATCBI-5 interrogator. The TTG is actually triggered from beacon sync; and the reply code, range, azimuth, and number of replies per aircraft are controlled by front panel controls. For this test program, the TTG was configured to generate 16 targets, all at the same range and reply code and uniformly distributed in azimuth through 360°. The TTG was used in this program as the source of desired targets.

2.2 TEST DESIGN.

All testing was conducted at the ATCBI-5 site of the FAA Technical Center. Testing was conducted jointly by FAA Technical Center project personnel and DOD support personnel.

The ATCBI-5 and SRAP systems were checked before testing to ascertain that they were operating within the appropriate specifications. Tests were then conducted to determine the effect of a defined extraneous pulse environment (EPE) and, then, the effect of the EPE and various JTIDS configurations on the performance of the ATCBI-5/SRAP configuration. Figure 2-2 is a block diagram of the basic test configuration.

The EPE source consisted of an ATCRBS 1090 MHz fruit source, a Mode S 1090 MHz fruit source, and a 1094 MHz source of TACAN/DME replies.

The ATCRBS and Mode S fruit sources were designed and fabricated at the FAA Technical Center in support of previous EMC test programs.

The ATCRBS fruit generator is capable of generating fruit rates from 0 to 80,000 replies per second in 20 replies-per-second increments. The fruit generator is capable of randomly generating eight different ATCRBS reply codes. The ATCRBS codes are 0737, 7024, 1231, 0541, 7030, 0647, 0567, and 3022. Selection of desired fruit rate is via keyboard entry.

The Mode S fruit generator is capable of generating fruit rates from 0 to 2000 replies per second in 4 replies-per-second increments. Selection of the percentage of long replies (112 ms) and short replies (56 ms) and the percentage mixture of selected codes are programmable features. Desired fruit rate is via keyboard entry.

For both fruit generators, the time and amplitude distributions of the fruit replies are selected according to a program derived from measurements in the Los Angeles Basin. Amplitude distributions vary from -47 to -77 dB referenced to 1 milliwatt (dBm). Time distributions are appropriate for the fruit rate selected.

The output of these generators is appropriately modulated for ATCRBS and Mode S. A separate variable L-Band RF generator is used for each fruit generator. The source of TACAN/DME replies is a standard TACAN/DME beacon simulator. The simulator is adjustable to any of the 1-MHz spaced TACAN/DME pulse-pairs-per-second (ppps), and the RF output level is adjustable from -110 dBm up to -10 dBm. The desired target source is the beacon test target generator discussed in 2.1. The block labeled JTIDS is the JTIDS source required to generate the required pulses for the JTIDS scenario tested. The SRAP IIIA block that outputs to the IOP and display is physically in a display area along with the IOPs and displays located about 1 mile from the ATCRBS facility. The TTG, the EPE, the JTIDS, the ATCBI-5 equipment, the defruiter, and the other SRAP are all physically located in the ATCRBS building. The EPE rates were determined from model studies of the Los Angeles Basin and supplied in a letter from FAA Headquarters to the JTIDS test program. The rates were 17,983 ATCRBS fruit replies per second, 52 Mode S fruit replies per second, and a 240 ppps TACAN/DME signal at a frequency of 1094 MHz and an input power level of -50 dBm. Testing of the ATCBI-5 is concerned only with the effects of JTIDS on the ATCBI-5 receiver. Therefore, during all tests, the ATCBI-5 high voltage is disabled such that no transmissions are emitted. For testing, the EPE, the TTG, and the JTIDS source are input to the ATCBI-5 directional antenna port. The JTIDS source is operated in the normal frequency-hopping mode, and the ATCBI-5 and TTG operate in their normal mode.

The number of quantized pulses out of the ATCBI-5 receiver and the number of quantized pulses, lead edge pulses (total and desired), and monitor decodes in the SRAP are recorded from the SRAP located at the ATCRBS facility. The target report range azimuth, identity and altitude code, and the garble indicators for mode 3A and C reports, along with the number of replies per target report, are recorded at the operational SRAP located with the IOP and displays.

Table 2-1 contains the JTIDS snapshot variations that were tested with the ATCRBS ground system. The table shows that single, double, four, and ten net configurations were tested. Standard (258 pulses/timeslot) and packed (444 pulses/timeslot) configurations, as well as contention, were tested.

2.3. METHOD OF APPROACH.

The data collection block diagram for the ATCBI-5/SRAP effects test is shown in figure 2-3. The desired target source is the beacon TTG, and the 1090 MHz EPE source is the ATCRBS and Mode S fruit generators and the TACAN/DME beacon simulator.

For the effects test, the desired target source is triggered with normal beacon system triggers, and the JTIDS operates in a 100/50 configuration in its normal random frequency-hopping mode. The desired signal source is configured to produce 16 ATCRBS target reports per antenna scan. (See figure 2-4). The "X" and the dark portion indicate that JTIDS is turned on only during the time when the test set is generating desired replies. Note also, during one of the 16 target reports, JTIDS is not turned on. This NO JTIDS target report is used as a monitor target to insure the beacon system integrity during the test period.

The counters at the ATCBI-5 receiver and the SRAP, along with the output of the operational SRAP, are recorded and analyzed to determine the integrity of the 16 test targets from the conditions of JTIDS ON and JTIDS OFF.

For each test condition, data are collected for 100 antenna scans; the counters sample for 1 second. The mean, standard deviation, and the minimum and maximum count of each counter are recorded for each 100-scan data run. Figure 2-5 is a sample data sheet of the mean counts for the receiver quantizer, the SRAP quantizer, and the lead edge. The -120 JTIDS level is the NO JTIDS case, and the JTIDS levels are as shown. The JTIDS levels are for the foreground level which is 50 percent of the 100/50 JTIDS. The other 50 percent JTIDS pulses were held at a -50 dBm level.

The output of the SRAP is recorded and analyzed as to the integrity of the 16 test reports for the conditions of JTIDS ON and JTIDS OFF.

2.4. DATA RESULTS.

The FAA criterion for judging the effects of JTIDS on the ATCRBS focuses on the change in lead edge count attributed to JTIDS. Table 2-2 contains the mean and standard deviation lead edge count in pulses per second for the JTIDS OFF case (-120) and the mean lead edge count for JTIDS levels of -40 to -10 for the twelve JTIDS 100/50 scenarios tested. The table shows generally no significant increase in the lead edge count for JTIDS levels below -25 dBm. Correspondingly, the lead edge counts increase for JTIDS levels of -20 dBm and stronger.

2.5. DATA ANALYSIS.

The FAA criterion for judging the effects of JTIDS states that the isolation between a JTIDS source and a ground ATCRBS must prevent an increase of less than one standard deviation above the mean JTIDS OFF lead edge pulse count. The lead edge count is selected since any output from the processor lead edge circuit is considered by the rest of the system to be a valid ATCRBS pulse. All pulses output from the lead edge circuit are standardized as to width and amplitude. Any increase in lead edge count during a JTIDS test condition indicates that JTIDS has introduced into the processor an increase in the number of pulses perceived by the processor as valid ATCRBS pulses. The effect of this increase in JTIDS-caused lead edge pulses is seen as a decrease in the target report blip scan and the validity and quality counts.

The data in table 2-2 are for a lead edge count per second. Note from figure 2-4 that JTIDS is turned on 15 times per antenna scan. The antenna scan is 4.72 seconds. Therefore, for this test configuration, JTIDS is turned on 15 JTIDS/4.72 = 3.177 times per second. The lead edge count per second for each JTIDS level shown in table 2-2 is caused by 3.2 JTIDS exposures per second.

The data in table 2-3 have been adjusted to show the effect of each JTIDS 100/50 scenario on the lead edge count. Table 2-3 shows (for each 100/50 JTIDS scenario tested) the mean and grouped standard deviation for the two NO JTIDS tests; the FAA criterion of the NO JTIDS mean-plus-one standard deviation count; the modified JTIDS lead edge count for -15, -20, and several -25 dBm JTIDS levels; and the JTIDS level required to pass the FAA criterion. Table 2-3 shows that for snapshot 400 test, the FAA criterion is a lead edge count of 4514.4 pulses per second. The -20 dBm JTIDS level just fails the FAA criterion; therefore, a -25 dBm level is required to pass the criterion.

Figures 2-6 and 2-7 are graphs of the lead edge counts for NO JTIDS and JTIDS levels that pass and fail the FAA criterion. The data for each figure were collected on different days; and the desired signal level for figure 2-7 data was set slightly higher (less than 1 db). This increased desired signal level accounts for the higher lead edge counts of figure 2-7. The difference between NO JTIDS and JTIDS is unaffected by the different desired signal levels. Figure 2-6 is for JTIDS snapshots 400, 401, 402, 404, 406, 408, and 410, while figure 2-7 is for JTIDS snapshot 403, 405, 407, 409, and 411. The -120 annotation on the bars are for the NO JTIDS data samples. The annotations -15 through -25 are the respective JTIDS levels. The figures simply show how close the various 100/50 JTIDS levels are to the FAA criterion.

Figures 2-6 and 2-7 show that 100/50 JTIDS snapshots 400, 405, and 406 fail the FAA criterion at a JTIDS level of -20 dBm. All other 100/50 JTIDS snapshots tested pass the FAA criterion at the -20 dBm JTIDS level. Snapshots 400 and 405 just fail the criterion at the -20 dBm JTIDS level while snapshot 406 fails the criterion by a larger margin. It is worth noting that snapshot 406 is a Navy JTIDS scenario using all airborne JTIDS terminals.

It seems reasonable to take into account the transitory nature of an airborne JTIDS operation and make a judgment from the data that a JTIDS 100/50 operation must maintain a separation distance to allow no greater than a -20 dBm JTIDS level to appear at the input to the ATCRBS receiver.

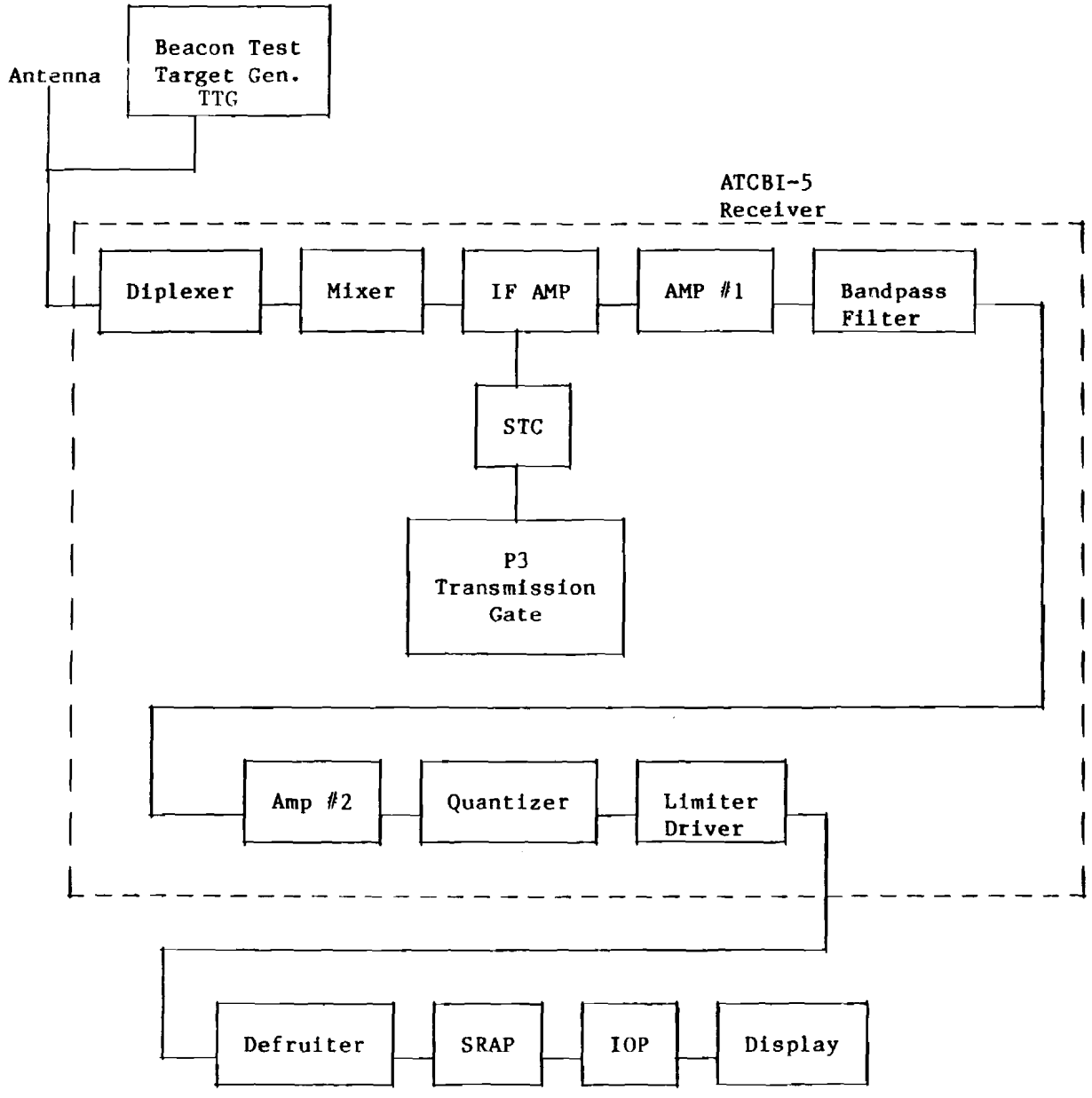


FIGURE 2-1. ATCRBS RECEIVING SYSTEM

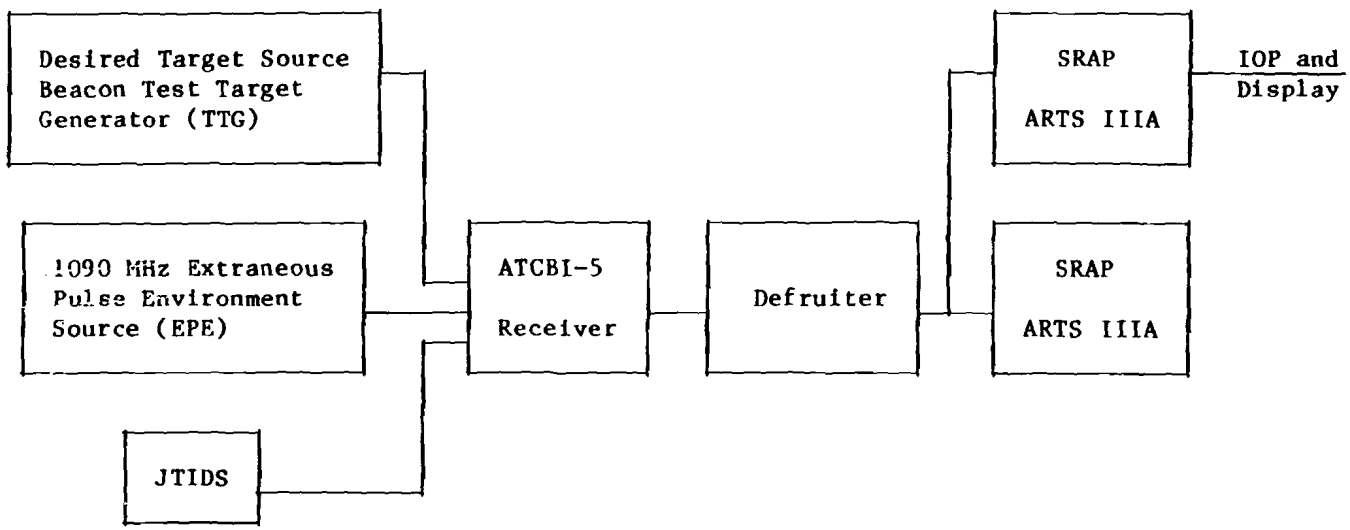


FIGURE 2-2. JTIDS/ATCRBS BASIC TEST CONFIGURATION

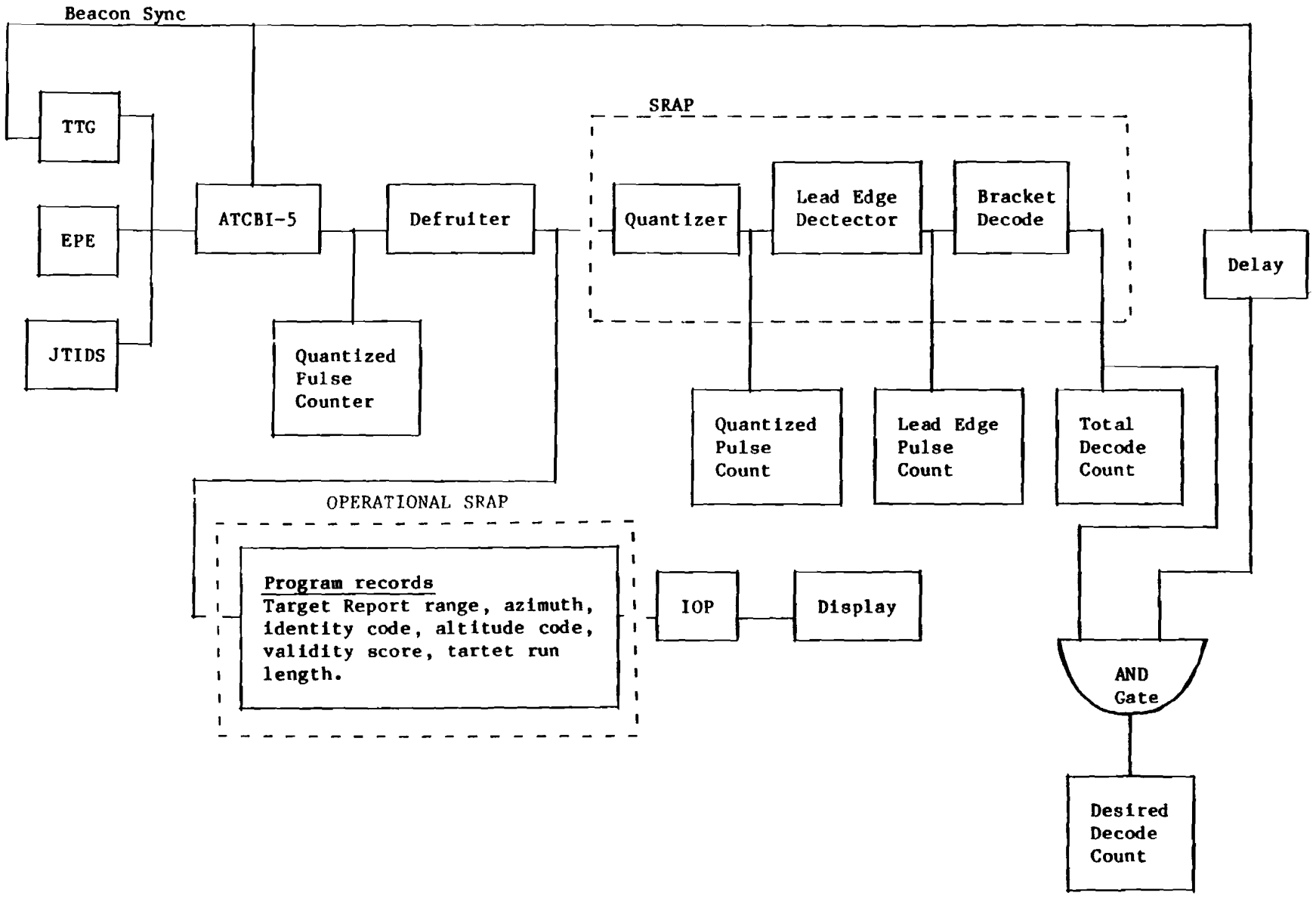


FIGURE 2-3. DATA COLLECTION BLOCK DIAGRAM

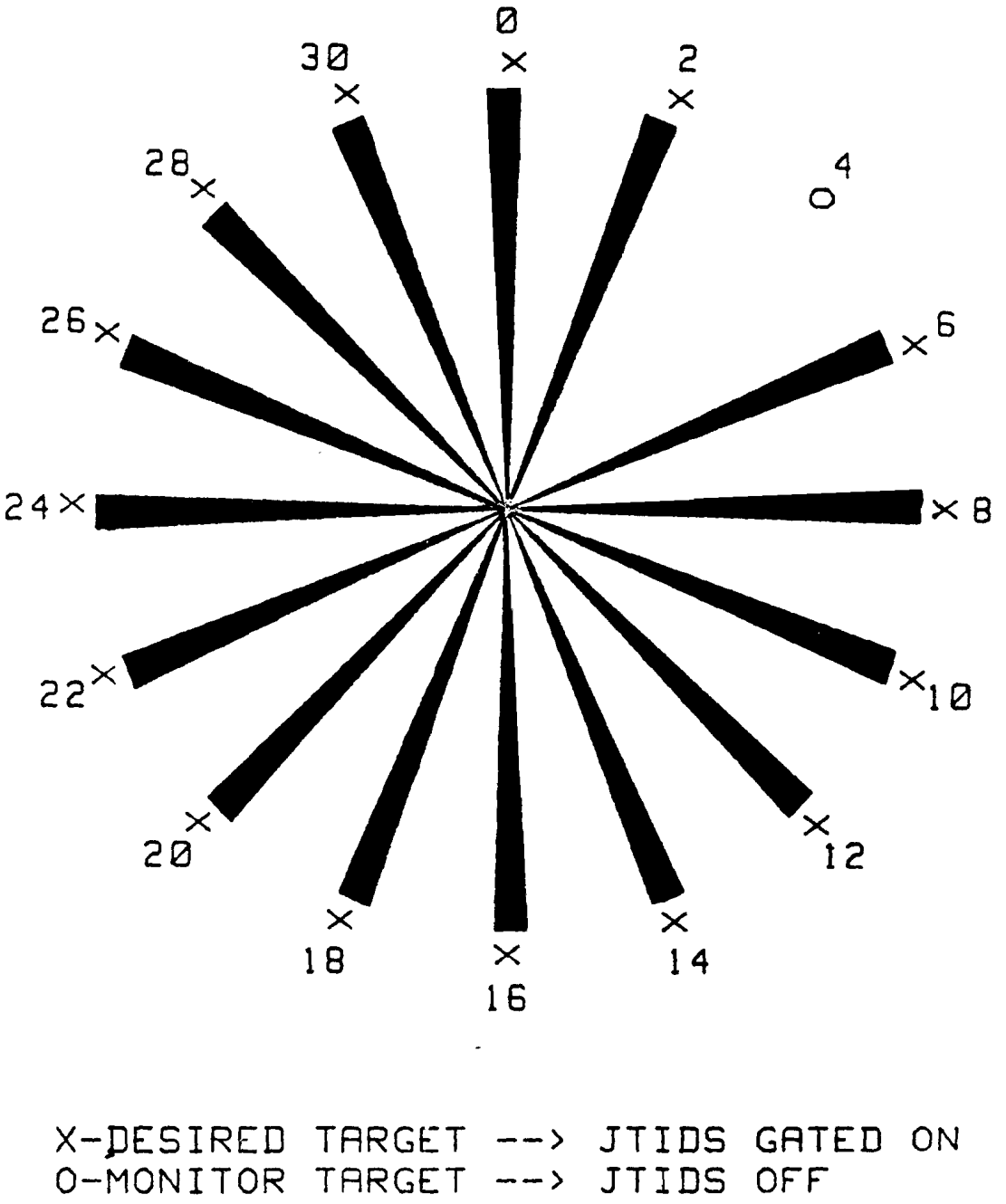


FIGURE 2-4. TEST TARGET DISPLAY

Mean OF THE FOLLOWING COUNTS

LEGEND
A=RECEIVER QUANTIZER PULSES
B=SRAP QUANTIZER PULSES
C=LEAD EDGE PULSES

DESIRED SIGNAL LEVEL=-80DBM

START TIME	STOP TIME	JTIDS LEVEL	A	B	C
183550	183744	-120	29407.44	4314.0076162	4458.8892044
183801	183955	-40	29309.16	4265.559747	4402.1779524
184012	184206	-35	29440.72	4323.7245974	4467.4306776
184223	184417	-30	29413.4	4306.340553	4436.6241856
184434	184628	-25	29666.58	4343.3137578	4485.7935882
184645	184839	-20	30340.5	4471.088169	4614.3997556
184856	185050	-15	31446.72	4668.6416762	4814.6490194
185107	185301	-10	33441.98	5094.443529	5267.6220756
185319	185512	-120	29380.56	4300.7904164	4436.903765

FIGURE 2-5. SAMPLE COUNTER DATA SHEET

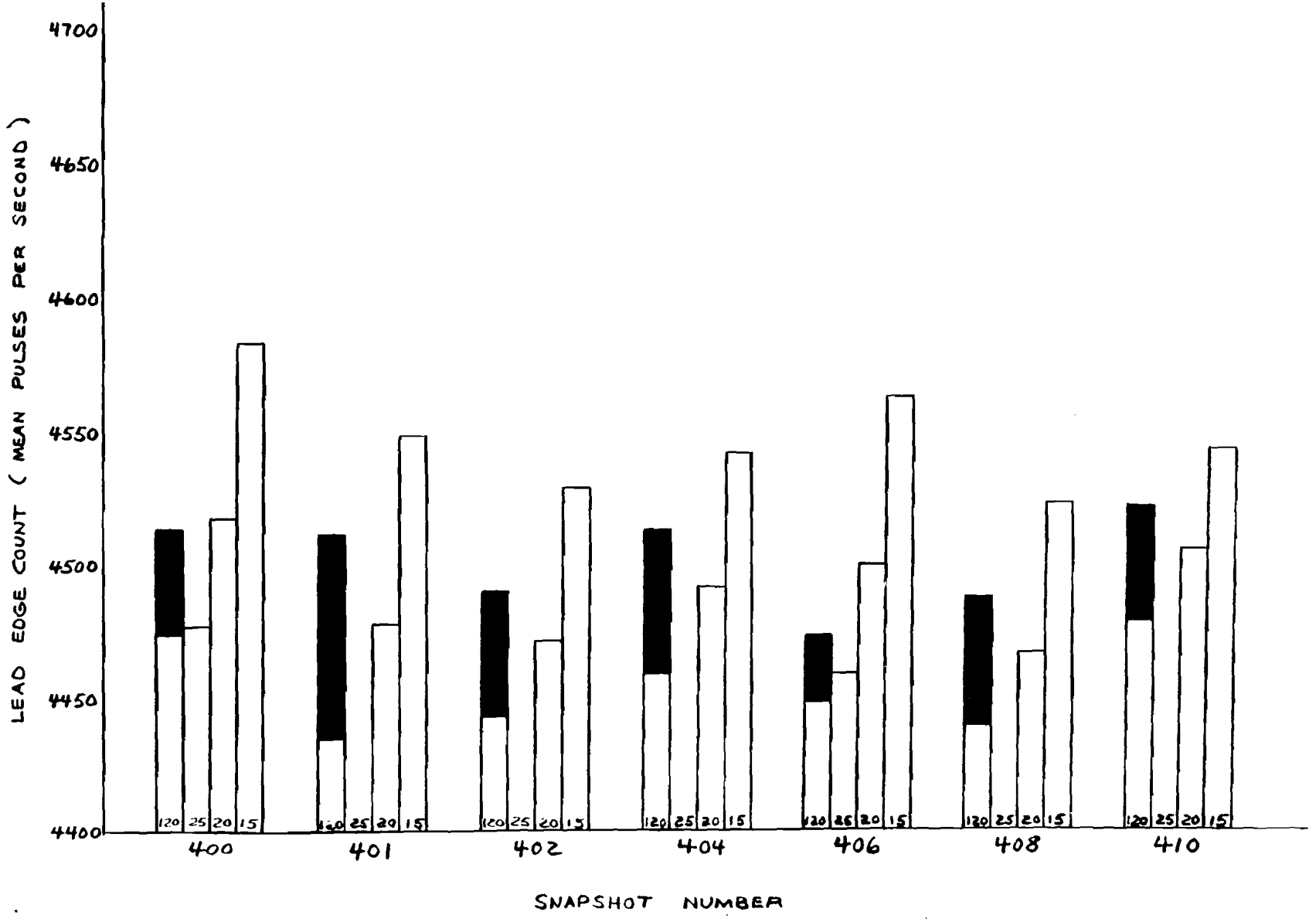


FIGURE 2-6. MEAN LEAD EDGE COUNT PLOT - DAY 1

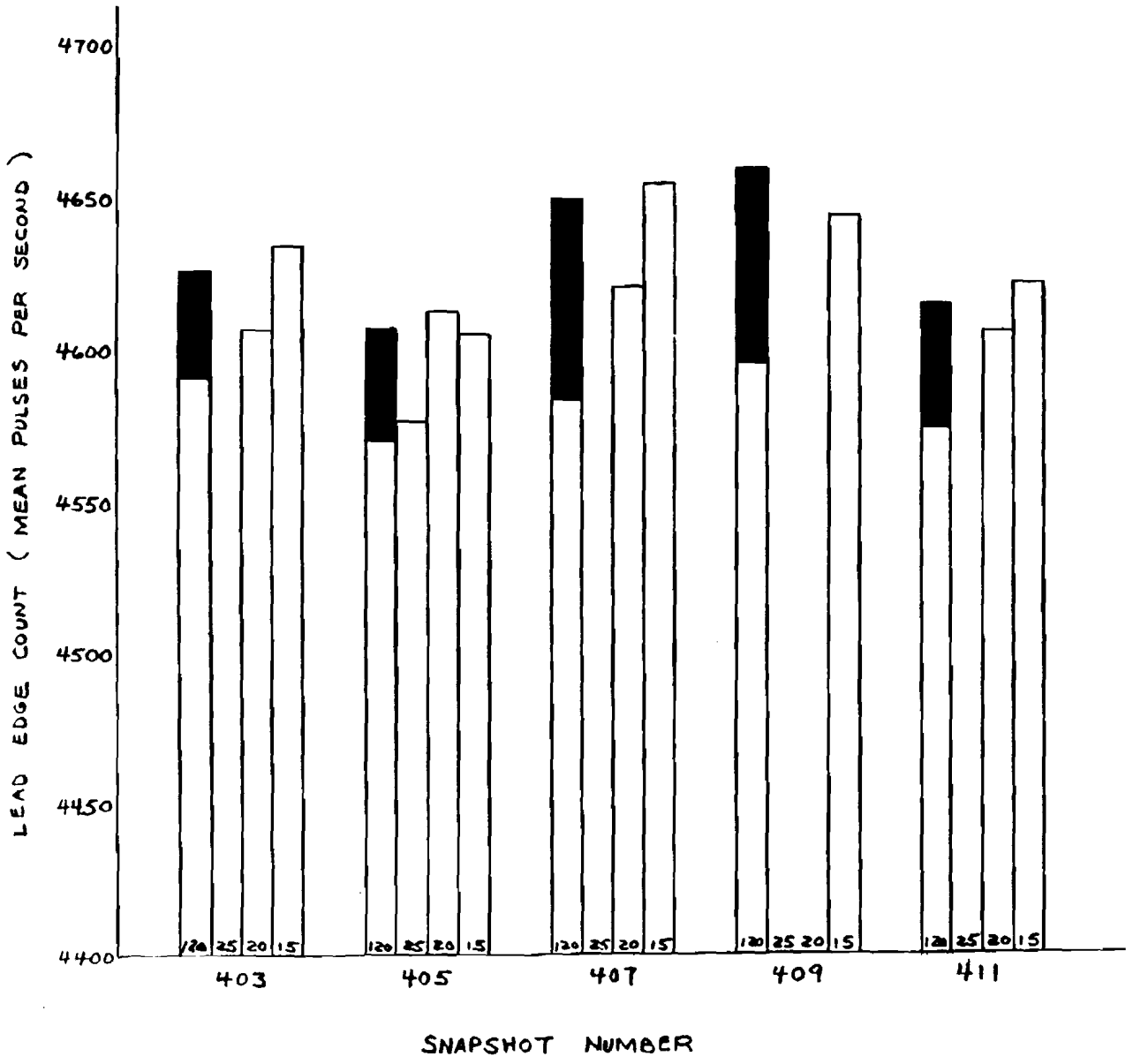


FIGURE 2-7. MEAN LEAD EDGE COUNT PLOT - DAY 2

TABLE 2-1. JTIDS SNAPSHOT AND ENVIRONMENT VARIATIONS/ATCRBS

Snapshot Number	Comments
400	Single-net, 258-pulse time slots, no contention
401	Single-net, 444-pulse time slots, no contention
402	Single-net, 258-pulse time slots, two-user contention in every time slot
403	Single-net, 258-pulse time slots, four-user contention in every time slot
404	Double-net (100% overlap), 258-pulse time slots, no contention
405	Four-net (100% overlap), 258-pulse time slots, no contention
406	Navy beacon snapshot, some contention, two-net
407	Army beacon snapshot, ten-net, contention (maximum four transmissions same time) slot on same net, 444-pulse time slot extensively used
408	Single-net, 444-pulse time slots, two-user contention in every time slot
409	Single-net, 444-pulse time slots, four-user contention in every time slot
410	Double-net (100% overlap), 444-pulse time slots, no contention
411	Four-net (100% overlap), 444-pulse time slots, no contention

TABLE 2-2. LEAD EDGE COUNT IN PULSES PER SECOND

Snapshot Number	-120 Mean	-120 S.D.	-40 Mean	-35 Mean	-30 Mean	-25 Mean	-20 Mean	-15 Mean	-10 Mean	-120 Mean	-120 S.D.
400	4472	29.89	4422	4431	4481	4486	4615	4824	5245	4476	48.67
401	4455	71.96	4445	4425	4421	4494	4573	4796	5155	4416	79.15
402	4444	28.14	4426	4442	4428	4492	4535	4719	4975	4442	59.75
403	4563	47.0	4555	4618	4574	4625	4643	4730	4686	4619	13.02
404	4451	48.19	4475	4442	4461	4444	4561	4727	4994	4467	58.60
405	4595	39.99	4564	4615	4581	4592	4704	4684	4613	4545	35.26
406	4459	18.69	4402	4467	4437	4486	4614	4815	5268	4437	50.64
407	4604	62.31	4566	4611	4561	4561	4702	4810	4793	4561	69.66
408	4447	58.45	4450	4446	4444	4455	4530	4709	4987	4431	38.22
409	4558	54.32	4575	4544	4565	4668	4655	4750	4676	4632	72.60
410	4490	28.50	4451	4454	4465	4438	4567	4686	4931	4468	54.41
411	4595	46.31	4541	4589	4587	4602	4674	4727	4691	4551	35.53

TABLE 2-3. LEAD EDGE COUNT MODIFIED

Snapshot Number	-120 JTIDS			Modified JTIDS Mean			JTIDS Level to Pass Criteria
	Mean	Grouped S.D.	Mean +1 S.D.	-25 dBm	-20 dBm	-15 dBm	
400	4474	40.4	4514.4	4477	4518	4583	-25
401	4435	75.6	4510.6		4478	4548	-20
402	4443	46.7	4489.7		4471	4529	-20
403	4591	34.5	4625.5		4607	4634	-20
404	4459	53.6	4512.6		4491	4542	-20
405	4570	37.7	4607.7	4576	4612	4605	-25
406	4448	25.3	4473.3	4459	4500	4563	-25
407	4583	66.1	4649.1		4620	4654	-20
408	4439	49.4	4488.4		4467	4523	-20
409	4595	64.1	4659.1			4643	<-15
410	4479	43.4	4522.4		4506	4544	-20
411	4573	41.2	4614.2		4605	4621	-20

3. JTIDS/ATCRBS-MODE S TRANSPONDERS.

3.1. DESCRIPTION OF EQUIPMENT.

The ATCRBS and Mode S transponders are the airborne portion of the ATCRBS and Mode S systems. The transponders receive on 1030 MHz and transmit on 1090 MHz. The ATCRBS transponders respond to pulse amplitude modulated (PAM) pulses at spacings of 8 μs (mode 3A) and 21 μs (mode C) as shown in the upper portion of figure 3-1. The Mode S transponder responds to two different types of interrogations as shown in the middle and lower sections of figure 3-1. The ATCRBS/Mode S All Call interrogations are PAM pulses while the Mode S Roll Call interrogations are two PAM pulses followed by a burst of differential phase shift keyed (DPSK) pulses.

The ATCRBS and Mode S 1090 MHz replies are shown in figure 3-2. The ATCRBS transponder replies are PAM pulses labeled "ATCRBS reply" in figure 3-2. The Mode S transponder replies to ATCRBS interrogations (mode 3A or mode C) the same as an ATCRBS transponder, and replies to ATCRBS/Mode S All Call or Roll Call interrogations with a four-bit PAM field and a burst of pulse position modulated (PPM) pulses as shown in the lower portion of figure 3-2.

Figure 3-3 is a general block diagram representing a Mode S transponder. Ground interrogations are received via the top and bottom antennas. The interrogations are fed through the preselectors and are amplified and conditioned by the log IF amplifier which provides two outputs (RF and log video). The log video is passed to the video processor and then to the decoder. The RF output is fed to the DPSK demodulator through a diversity switch that selects the upper or lower antenna inputs for further processing. The selected antenna (upper or lower) is communicated through the decoder back to the pin diode driver so that the transponders transmitter is connected to the selected antenna during the transmit cycle. The DPSK demodulator converts the differential phase shift information (0° to 180° relative) contained in the 60 MHz carrier into a digital output signal that contains the phase modulation information. The video processor converts incoming video signals into digital pulses for processing. Noise and side lobe suppression thresholding and reply rate limiting are performed by the video processor. The decoder eliminates narrow and wide pulses and determines which type interrogation (see figure 3-1) is present. The type of interrogation determined by the decoder is then communicated to the encoder such that a proper response is provided (figure 3-2).

An ATCRBS transponder uses a single antenna input and does not require a DPSK demodulator. Thus, an ATCRBS transponder would consist of the duplexer, preselector, mixer, IF amplifier, decoder, encoder, and modulator/transmitter (see figure 3-3).

3.2 TEST DESIGN.

An analysis report, SPS-WGI-84-1, titled, "Effects of JTIDS on 1030 and 1090 MHz ATC Avionics" concluded that "Based on an interference threshold equal to minimum sensitivity, JTIDS signals will not affect the operation of an ATCRBS transponder, a Mode S transponder, or a TCAS receiver under worst-case JTIDS-equipped aircraft to ATC receiver-equipped aircraft signal coupling conditions."

In other words for a maximum JTIDS level present at an airborne ATC receiver from an airborne JTIDS source, the analysis determined the JTIDS level to be below the minimum sensitivity of the ATCRBS and Mode S transponders and the TCAS equipment.

The JTIDS test plan committee validated this analysis technique by conducting limited tests on a selected ATCRBS and Mode S transponder. The selected ATCRBS transponder was a Narco AT-5A, and the selected Mode S transponder was a Bendix TRU-2A.

All testing was conducted at the FAA Technical Center using the mobile transponder performance analyzer (MTPA) developed by the Technical Center. Figure 3-4 is a basic block diagram of the test configuration. The JTIDS source is set to the 50/50 configuration. The 50/50 indicates that only 50 percent of the timeslots are used and that these 50 percent are all foreground pulses. The foreground-only pulses were used since the RF level of the JTIDS background pulses would be significantly below the receiver sensitivity of the units being tested. The MTPA generates the appropriate interrogations shown in figure 3-1 and processes the appropriate transponder responses shown in figure 3-2. The MTPA is designed to measure all characteristics of a transponder as specified in the International Civil Aviation Organization (ICAO) and U.S. National Standards. The appropriate tests selected for JTIDS effects were receiver sensitivity and unsolicited replies. The receiver sensitivity is simply the ratio of desired replies to desired interrogations as a function of desired signal level, and the unsolicited reply is the number of ATCRBS or Mode S replies generated by the transponder with the JTIDS source as the only transponder input.

The receiver sensitivity and unsolicited replies are recorded with and without JTIDS. The JTIDS levels are varied from -35 to -16 dBm for the ATCRBS transponder and from -35 to -6 dBm for the Mode S transponder.

3-3. METHOD OF APPROACH.

Figure 3-5 shows the test configuration for the JTIDS/ATCRBS-Mode S transponder tests. The JTIDS simulator is set to produce a 50/50 timeslot duty factor. The 50/50 indicates that 50 percent of the available timeslots are being transmitted and that all of the timeslots are foreground signals. The RF level of the JTIDS simulator output is controlled via the 10 dB and 1 dB step attenuators. The JTIDS simulator is coupled into the transponder under test via several circulators and a 10 dB directional coupler. The MTPA is shown within the dashed lines. Under program control from the PDP 11/34, the modulation control sets up the proper interrogation format. This modulator output is combined with the 1030 MHz RF generator to provide the required RF interrogations to the transponder under test. The RF interrogations are passed through a circulator, combined with the JTIDS simulator in the 10 dB coupler, and input to the antenna jack of the transponder under test. The 1090 MHz reply from the transponder under test is received by the RF receiver, demodulated, detected, and passed via the reply processor to the data record function of the PDP 11/34. The PDP 11/34 sets up the accept gate timing to record and store the required replay characteristics.

For the ATCRBS transponder tests, the test sequence was to conduct the receiver sensitivity and unsolicited reply tests for the NO JTIDS case, then the -35 to -30 dBm JTIDS case, then a NO JTIDS case, then the -29 to -25 dBm JTIDS case, and continue this sequence up to a -16 dBm JTIDS level. Figure 3-6 is a data sample of the NO JTIDS receiver sensitivity (labeled ATCRBS Dynamic Reply Test-1) and the

unsolicited reply test (labeled Unsolicited Reply Test-II). The first column of test I is the RF interrogation power at the antenna input to the transponder. The power is varied in 3 dB steps from -21 to -90 dBm. For each RF interrogation level, the transponder is interrogated 100 times. The percent reply (column 2) is the average reply efficiency. Thus, as can be seen from figure 3-6, the transponder replied with 100-percent reply efficiency for interrogation levels of -21 to -72 dBm. Also, note that for test II, there are no unsolicited replies in the NO JTIDS case. The columns labeled delay (mean) and delay (range) are the measured transponder delays from the mode decode time to the first framing pulse of the transponders reply. This parameter is specified as 3 $\pm$ .5 users. These data are not used in the analysis of the effects of JTIDS on the transponders. Figure 3-7 is a data sample of tests I and II for the same ATCRBS transponder with a -19 dBm JTIDS signal injected into the transponder. Note the reduction from the NO JTIDS case in the percent replies and that, in this case, JTIDS causes the transponder to create 52 ATCRBS responses in the 60-second measurement time. Data sheets similar to figures 3-6 and 3-7 were collected for each JTIDS level tested.

The sequence of tests are the same for the Mode S transponder tests. In the Mode S case, however, there are three interrogation formats that a Mode S transponder can reply to. The interrogation formats are shown in figure 3-1. The data for the Mode S transponder require three reply efficiency tests in addition to the unsolicited reply tests.

3.4. DATA RESULTS.

The data results for the ATCRBS and Mode S transponder tested are shown in tables 3-1 and 3-2, respectively. In order to make the data presentation less bulky, the SPS WG-1 developed a method of compressing the data. As seen from the data sample sheets of figures 3-6 and 3-7, the percent replies remain fairly constant until the minimum triggering level (MTL) of the transponder is attained and then the percent replies remain at zero. For clearer presentation, the reply efficiency points above the MTL were averaged for each JTIDS and NO JTIDS test. The data in tables 3-1 and 3-2 are these average percent reply results. Note from table 3-1 that for the ATCRBS transponder tested, the reply efficiency remains below the NO JTIDS, 100-percent figure for JTIDS levels of -29 dBm and above. The JTIDS levels of -20 dBm and above generate unsolicited replies from the ATCRBS transponder tested. For the Mode S transponder (table 3-2) tested, the reply efficiency remains below 100 percent for JTIDS levels of -19 dBm and above for ATCRBS interrogations; -20 dBm and above for the ATCRBS/Mode S All Call interrogations; and -17 dBm and above for the Mode S Roll Call interrogations. The JTIDS levels of -17 dBm and above generate unsolicited replies from the Mode S transponder tested.

3.5. DATA ANALYSIS.

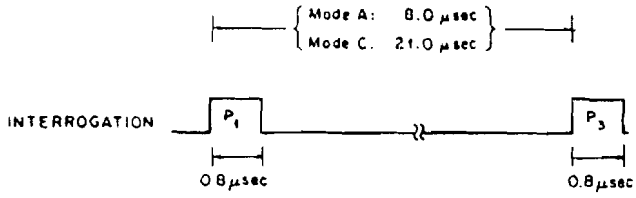
The FAA criteria for judging the effect of JTIDS on ATCRBS and Mode S transponders state that (1) JTIDS shall cause no change in reply efficiency for interrogation signals at MTL and above, and (2) JTIDS shall not solicit replies from a transponder. Table 3-3 shows the delta reply efficiency for all JTIDS levels tested for both the ATCRBS and Mode S transponder. The delta reply efficiencies of table 3-3 were obtained by subtracting the average percent replies shown in tables 3-1 and 3-2 from the 100-percent NO JTIDS value. Table 3-3 also shows the unsolicited replies for both transponders tested.

The table shows that for the ATCRBS transponder tested, the FAA criteria are met if JTIDS is not allowed to be any greater than -30 dBm, as seen at the antenna port of the transponder. The table also shows that for the Mode S transponder tested, the FAA criteria are met if the JTIDS level remains below -20 dBm, as seen at the antenna port of the transponder. The maximum JTIDS level coupled in an air-to-air configuration from two aircraft flying at 1000-foot vertical separation is -36 dBm at the antenna port of the transponder. This -36 dBm coupled level has been calculated and verified in several flight tests. The -30 dBm JTIDS level that passes the FAA criteria can never be attained from a 200-watt EIRP JTIDS terminal via air-to-air mode with both aircraft maintaining the minimum ATC vertical separation of 1000 feet.

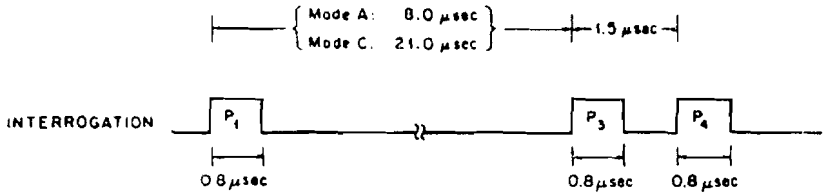
There should be concern, however, that the JTIDS levels that fail the FAA criteria would be present at the input to a transponder on the same aircraft as the JTIDS source. The DOD should be required to demonstrate that the co-site airborne configurations do not cause JTIDS levels in excess of -30 dBm to be present at the antenna port of the onboard ATC transponder.

Figure 3-8 is a plot of the delta reply efficiency for both the ATCRBS and Mode S transponders tested as a function of JTIDS level. The graph simply demonstrates that the ATCRBS transponder tested is more susceptible to JTIDS than the Mode S transponder tested. The plot also demonstrates the rate at which the reply efficiency degrades as the JTIDS level is increased.

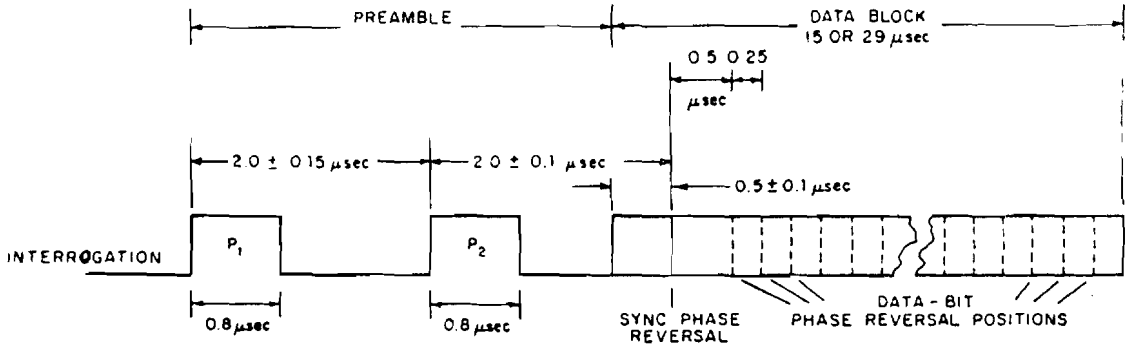
The data collected validate the SPS-WGI-84-1 analysis report. The conclusion is that for the worst case of air-to-air coupling at standard altitude separations, the JTIDS level is several db below the sensitivities of ATCRBS and Mode S transponders and TCAS receivers.



ATCRBS (Mode A, Mode C) Interrogation

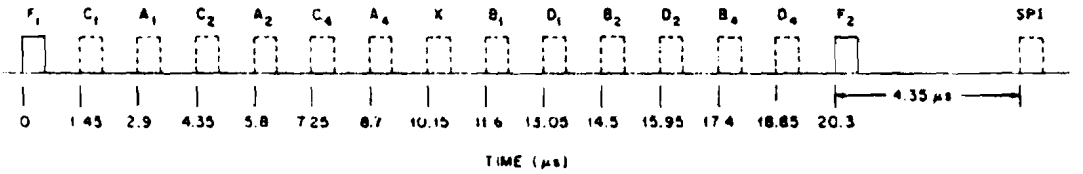


ATCRBS/Mode S All Call Interrogation



Mode S Roll Call Interrogation

FIGURE 3-1. ATCRBS - MODE S INTERROGATION FORMATS



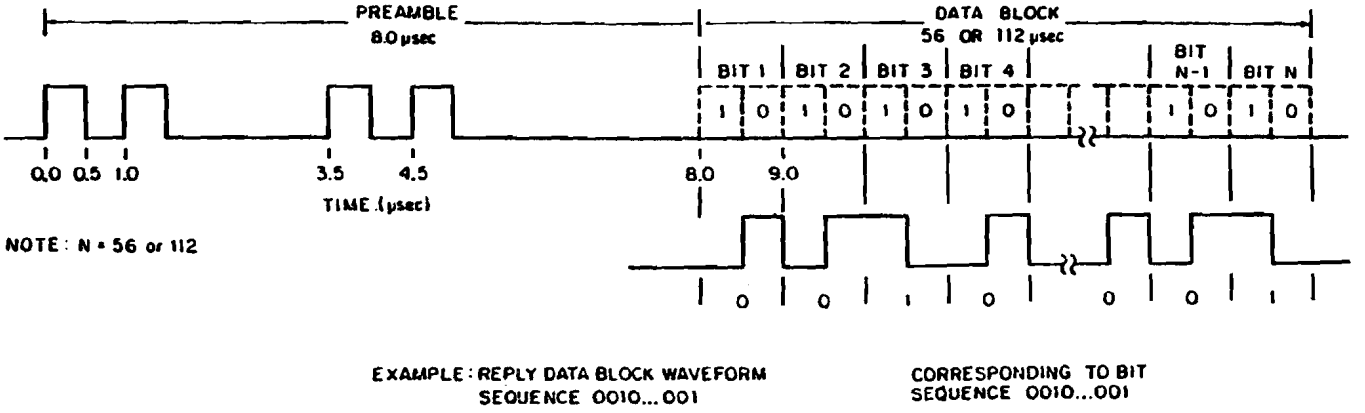


FIGURE 3-2. ATCRBS - MODE S REPLY FORMATS

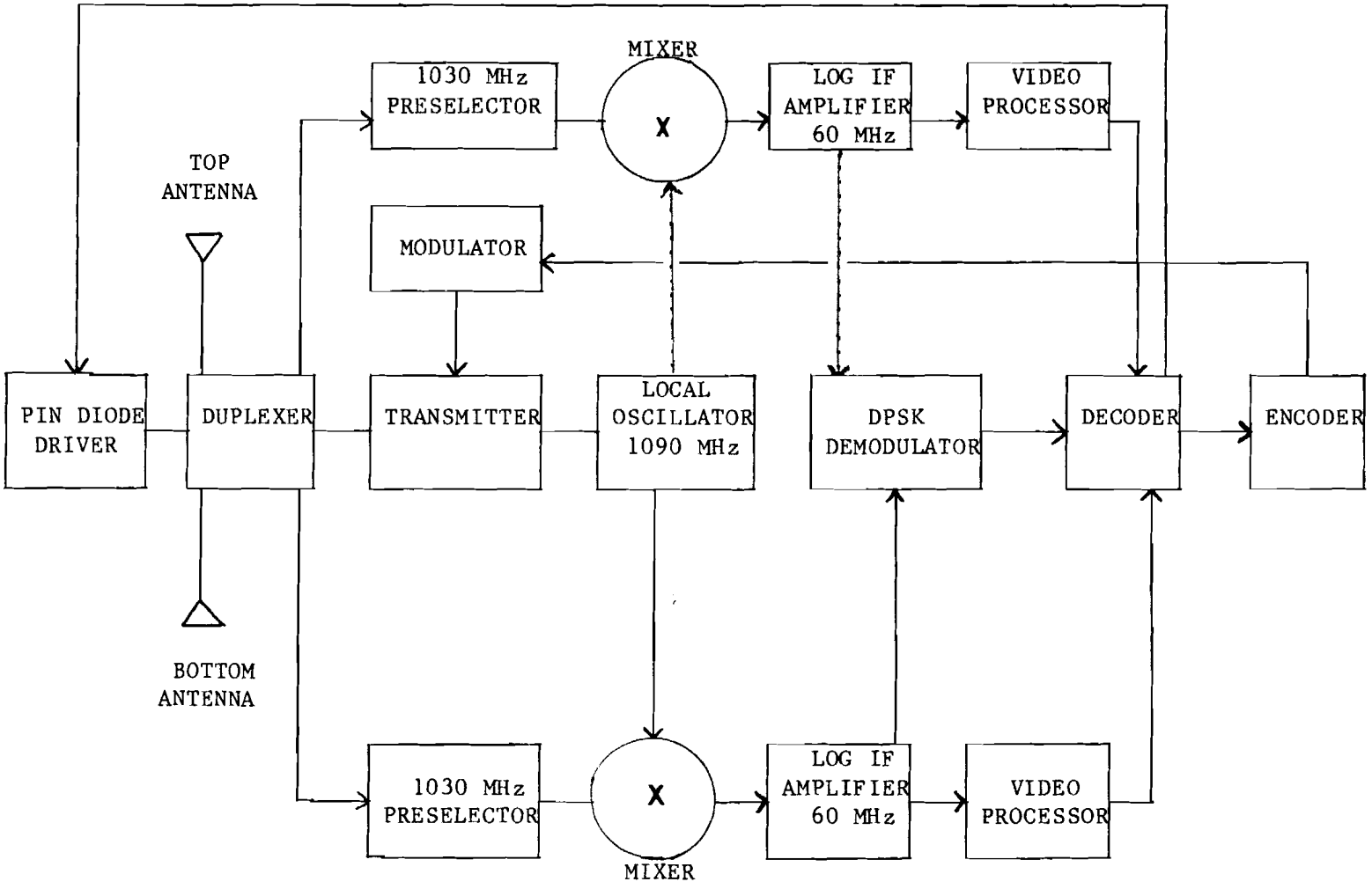


FIGURE 3-3. GENERAL BLOCK DIAGRAM - MODE S TRANSPONDER

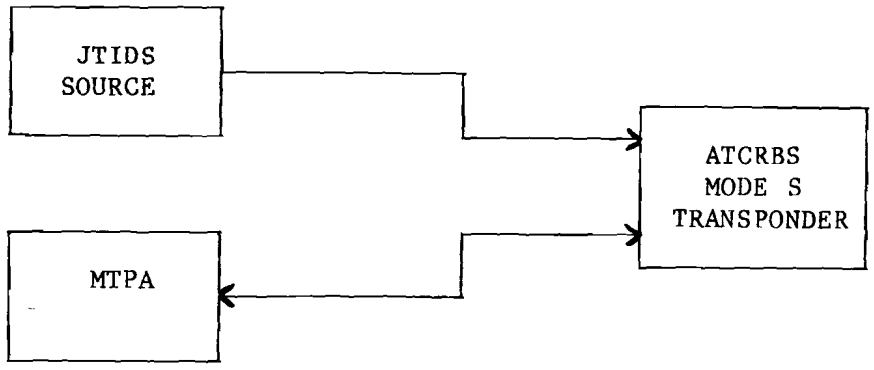


FIGURE 3-4. BASIC TEST CONFIGURATION JTIDS/ATCRBS - MODE S TRANSPONDER

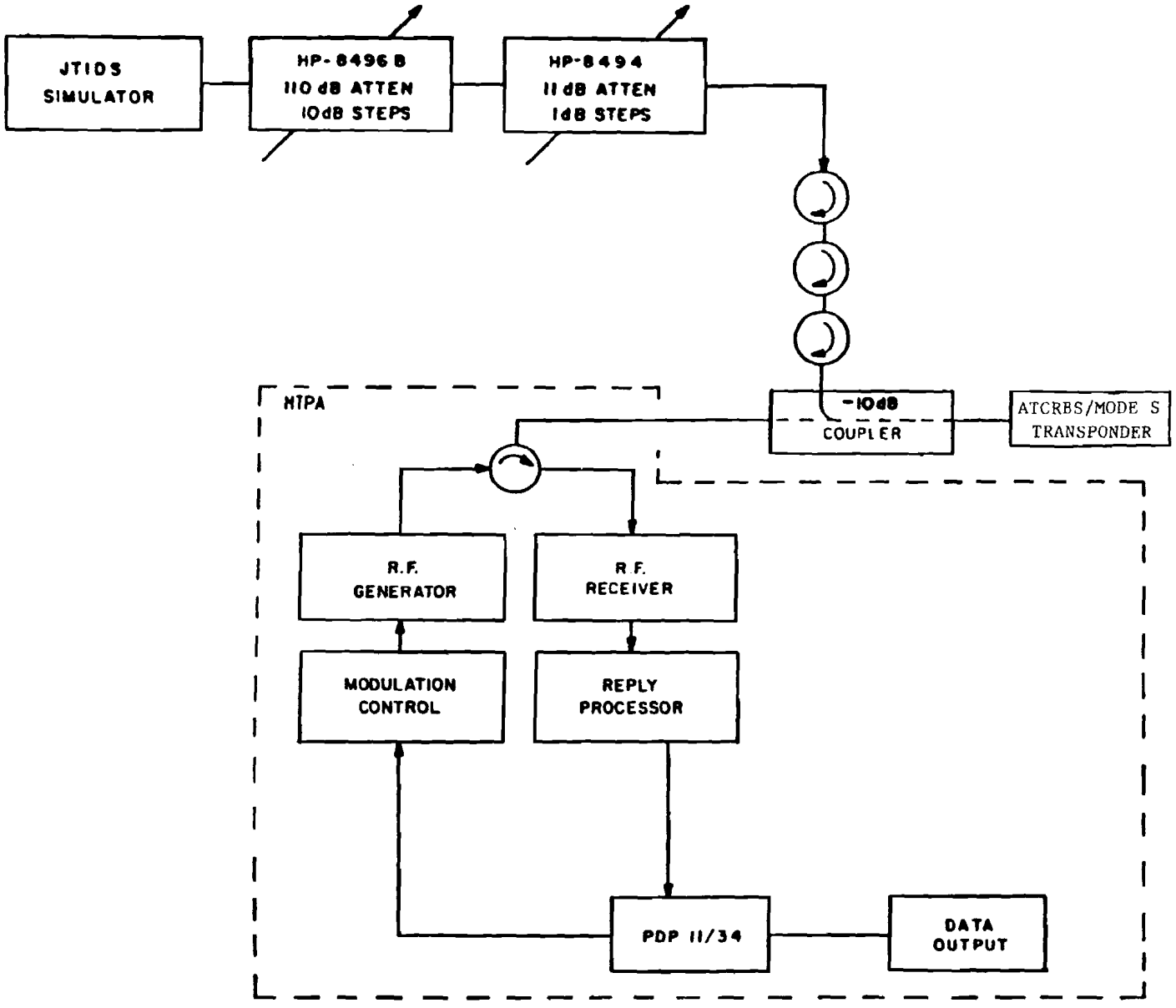


FIGURE 3-5. TEST CONFIGURATION - JTIDS/ATCRBS - MODE S TRANSPONDER

AT5A S/N 79CP7 NO JTIDS
ATCRBS DYNANIC REPLY TEST - I

POWER (-DB)	% REPLY	DELAY(MEAN) (USEC)	DELAY(RANGE) (USEC)
21	100.0	2.83	2.83 - 2.85
24	100.0	2.83	2.83 - 2.85
27	100.0	2.83	2.83 - 2.85
30	100.0	2.83	2.83 - 2.88
33	100.0	2.85	2.85 - 2.88
36	100.0	2.85	2.85 - 2.88
39	100.0	2.85	2.85 - 2.88
42	100.0	2.85	2.85 - 2.90
45	100.0	2.85	2.85 - 2.90
48	100.0	2.88	2.85 - 2.90
51	100.0	2.88	2.88 - 2.90
54	100.0	2.88	2.88 - 2.90
57	100.0	2.90	2.88 - 2.92
60	100.0	2.90	2.90 - 2.95
63	100.0	2.92	2.90 - 2.98
66	100.0	2.95	2.95 - 3.00
69	100.0	3.00	2.95 - 3.05
72	100.0	3.10	3.00 - 3.43
75	0.0		
78	0.0		
81	0.0		
84	0.0		
87	0.0		
90	0.0		

AT5A S/N 79CP7 NO JTIDS
UNSOLICITED REPLY TEST - II

0 REPLIES RECEIVED IN THE LAST 60 SECONDS

0 ATCRBS REPLIES
0 MODE S REPLIES

FIGURE 3-6. DATA SAMPLE - NO JTIDS

AT5A S/N 79CP7 JTIDS HOPPING @ -19DBM 50/50 N@-6(DBC
ATCRBS DYNAMIC RANGE TEST - 1

POWER (-DB)	% REPLY	DELAY(MEAN) (USEC)	DELAY(RANGE) (USEC)
21	90.0	2.83	2.58 - 2.85
24	92.0	2.83	2.60 - 2.88
27	93.0	2.83	2.55 - 2.88
30	93.0	2.83	2.60 - 2.88
33	94.0	2.85	2.58 - 2.88
36	95.0	2.85	2.55 - 2.88
39	94.0	2.85	2.58 - 2.88
42	95.0	2.85	2.67 - 2.90
45	93.0	2.85	2.58 - 2.90
48	94.0	2.88	2.63 - 2.90
51	89.0	2.88	2.63 - 2.92
54	92.0	2.88	2.55 - 2.92
57	90.0	2.88	2.58 - 2.92
60	92.0	2.92	2.65 - 2.95
63	90.0	2.92	2.60 - 2.98
66	89.0	2.98	2.55 - 3.03
69	92.0	3.00	2.65 - 3.15
72	84.0	3.12	2.65 - 3.40
75	0.0		
78	0.0		
81	0.0		
84	0.0		
87	0.0		
90	0.0		

AT5A S/N 79CP7 JTIDS HOPPING @ -19DBM 50/50 N@-6(DBC
UNSOLICITED REPLY TEST - 11

52 REPLIES RECEIVED IN THE LAST 60 SECONDS

52 ATCRBS REPLIES
0 MODE S REPLIES

FIGURE 3-7. DATA SAMPLE -19 dBm JTIDS

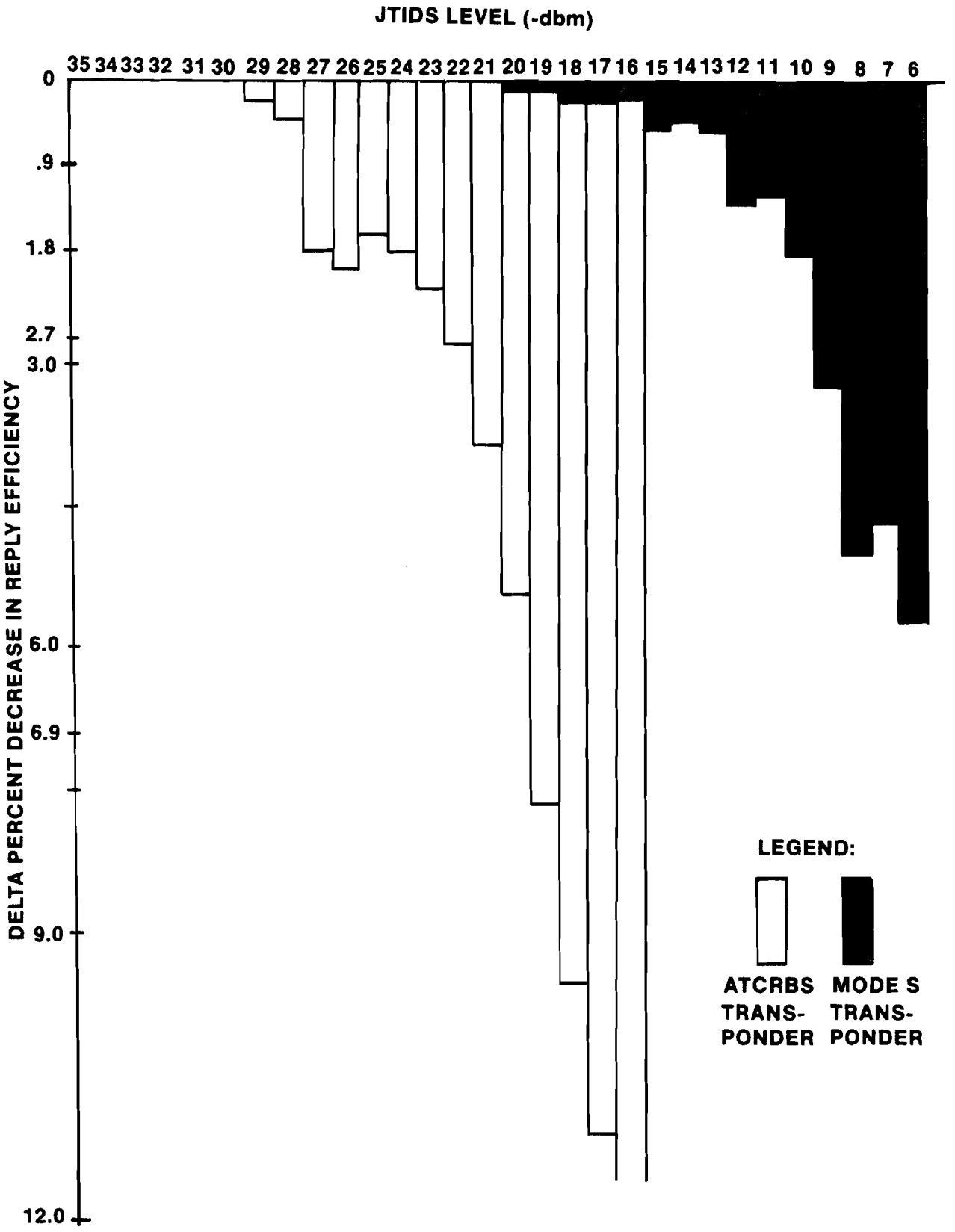


FIGURE 3-8. DELTA REPLY EFFICIENCY VS JTIDS LEVEL

TABLE 3-1. AT 5A ATCRBS TRANSPONDER DATA RESULTS

JTIDS 50/50 -60 dBc

	Average Number of Replies -21 to MTL dBm	
JTIDS Level	ATCRBS Interrogations	Unsolicited Replies per 60 Seconds
-16	87.3	508
-17	88.9	257
-18	90.5	138
-19	92.4	52
-20	94.6	15
-21	96.2	0
-22	97.2	0
-23	97.8	0
-24	98.2	0
-25	98.4	0
-26	98.0	0
-27	98.2	0
-28	99.6	0
-29	99.8	0
-30	100.0	0
-31	100.0	0
-32	100.0	0
-33	100.0	0
-34	100.0	0
-35	100.0	0
-120	100.0	0

TABLE 3-2. TRU 2A MODE S TRANSPONDER DATA RESULTS

JTIDS 50/50 -60 dBc

JTIDS Level	Average Number of Replies -21 to MTL dBm			Unsolicited Replies per 60 Seconds
	ATCRBS Int.	ATCRBS/Mode S All Call Int.	Mode S Roll Call Int.	
-6	94.4	94.3	94.0	9185
-7	96.9	95.4	94.9	7602
-8	96.8	95.0	97.0	6235
-9	97.6	96.8	96.8	4645
-10	98.3	98.2	98.2	2986
-11	98.6	98.8	98.4	1713
-12	99.4	98.7	99.0	806
-13	99.2	99.5	99.2	279
-14	99.6	99.6	99.6	95
-15	99.7	99.5	99.6	23
-16	99.8	99.8	99.8	38
-17	99.8	99.8	99.8	27
-18	99.8	99.8	100.0	26
-19	99.9	99.9	100.0	24
-20	100.0	99.9	100.0	5
-21	100.0	100.0	100.0	0
-22	100.0	100.0	100.0	0
-23	100.0	100.0	100.0	0
-24	100.0	100.0	100.0	0
-25	100.0	100.0	100.0	0
-26	100.0	100.0	100.0	0
-27	100.0	100.0	100.0	0
-28	100.0	100.0	100.0	0
-29	100.0	100.0	100.0	0
-30	100.0	100.0	100.0	0
-31	100.0	100.0	100.0	0
-32	100.0	100.0	100.0	0
-33	100.0	100.0	100.0	0
-34	100.0	100.0	100.0	0
-35	100.0	100.0	100.0	0
-120	100.0	100.0	100.0	0

TABLE 3-3. DELTA REPLY EFFICIENCY AND UNSOLICITED REPLIES

ATCRBS and Mode S Transponder

JTIDS LEVEL (-DBM)	ATCRBS INTERROGATOR		MODE S INTERROGATOR			
	DELTA REPLY EFFICIENCY	UNSOLICITED REPLIES	DELTA REPLY EFFICIENCY			UNSOLICITED REPLIES
	ATCRBS INTERROGATOR		ATCRBS INTERROGATOR	ATCRBS/MODE S ALL CALL INTER.	MODE S ROLL CALL INTER.	
6			5.6	5.7	6.0	9185.0
7			3.1	4.6	5.1	7602.0
8			3.2	5.0	3.0	6235.0
9			2.4	3.2	3.2	4645.0
10			1.7	1.8	1.8	2986.0
11			1.4	1.2	1.6	1713.0
12			0.6	1.3	1.0	806.0
13			0.8	0.5	0.8	279.0
14			0.4	0.4	0.4	95.0
15			0.3	0.5	0.4	23.0
16	12.7	508.0	0.2	0.2	0.2	38.0
17	11.1	257.0	0.2	0.2	0.2	27.0
18	9.5	138.0	0.2	0.2	0.0	26.0
19	7.6	52.0	0.1	0.1	0.0	24.0
20	5.4	15.0	0.0	0.1	0.0	5.0
21	3.8	0.0	0.0	0.0	0.0	0.0
22	2.8	0.0	0.0	0.0	0.0	0.0
23	2.2	0.0	0.0	0.0	0.0	0.0
24	1.8	0.0	0.0	0.0	0.0	0.0
25	1.6	0.0	0.0	0.0	0.0	0.0
26	2.0	0.0	0.0	0.0	0.0	0.0
27	1.8	0.0	0.0	0.0	0.0	0.0
28	0.4	0.0	0.0	0.0	0.0	0.0
29	0.2	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	0.0
32	0.0	0.0	0.0	0.0	0.0	0.0
33	0.0	0.0	0.0	0.0	0.0	0.0
34	0.0	0.0	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0	0.0	0.0

4. JTIDS/TACAN-DME GROUND SYSTEMS.

4.1 DESCRIPTION OF EQUIPMENT.

The DME system, operating in the 960-1215 MHz band, is the internationally accepted means of determining the slant range between an aircraft and a known ground location. In the U.S., the DME is usually integrated with the very high frequency (VHF) omnidirectional radio range (VOR) in a single VOR/DME installation. TACAN can also be integrated with VOR in a single VORTAC installation. VOR is the international system operating on 50 kilohertz (kHz) channels in the 108-117.95 MHz band to provide aircraft with the bearing information to a known ground location. TACAN is a U.S. and NATO military navigation system that incorporates the international DME function with a bearing determination system. It also operates in the 960-1215 MHz band. The TACAN/DME operation requires an interrogator in the aircraft and a transponder (beacon) on the ground. The TACAN interrogator makes a bearing and a range determination based on reference signals transmitted by the ground station. The DME interrogator determines only the slant range with respect to the ground station. Slant range is obtained by interrogating the transponder which receives and decodes each interrogation (a pulse pair with proper spacing) and then transmits a reply (also a pulse pair with proper spacing). The interrogator receives the reply and determines the distance, based on the time between transmission of the interrogation and the reception of the reply (minus the transponder's fixed time delay).

TACAN and DME frequencies are designated on aeronautical charts by channel numbers 1-126. TACAN channels are paired with VOR or instrument landing systems (ILS) localizer frequencies in the 108-118 MHz band. This pairing arrangement facilitates the employment of a VOR in conjunction with a TACAN/DME transponder to provide a VORTAC facility to transmit simultaneous azimuth and range information to civil aircraft. TACAN channels 17-59 and 70-126 are designated for use in the National Airspace System (NAS). Most of these TACAN channels are used by the FAA to provide air navigation services. TACAN channels 1-16 and 60-69 are designated for military services' tactical use and are not used in the NAS. Figure 4-1 is a frequency assignment chart for the TACAN/DME frequencies. TACAN/ DME channels designated X mode use a pulse pair spacing of 12 ms for both the ground-to-air (G/A) and the air-to-ground (A/G) frequencies. TACAN/DME channels designated Y mode use a G/A pulse pair spacing of 30 ms and an A/G pulse pair spacing of 36 ms. The chart shows the planned W and Z modes with corresponding G/A and A/G frequencies and pulse pair spacings.

4.1.1. Second Generation VORTAC.

Figure 4-2 is a block diagram of the receive and coder/decoder portion of the TACAN section of the Second Generation VORTAC (SGV). The interrogation pulse pairs at the correct RF are received from the TACAN or DME antenna and pass through directional coupler, lowpass filter, and preselector to the input of the preamplifier mixer. The directional coupler following the antenna couples interrogation/test signals from the monitor into the preamplifier-mixer via the lowpass filter. It also provides transmitted signals to the monitor detectors and to the modulation controller. The output of the preselector is amplified and mixed with a local oscillator signal from the frequency synthesizer to produce a 63 MHz IF signal. The 63 MHz output of the preamplifier mixer is routed to the receiver IF section. The first IF amplifier is a log amplifier that detects and amplifies

input signals to produce a wideband output (3.5 MHz), which provides an accurate logarithmic response to each received interrogation. The log video output of the first IF amplifier is supplied to the video processor. A second output of the first IF amplifier is supplied to the second IF amplifier where the signal is mixed to produce a second IF signal of 8.75 MHz. This signal is detected in a narrow-band Ferris discriminator to produce a gating video output signal which is also supplied to the video processor. The second IF amplifier also contains an adjusted automatic gain reduction (AGR) circuit to control the gain of the first IF amplifier. The AGR responds to traffic overload and continuous wave (CW) rejection, and is only activated when this occurs. The video processor references all timing and system delays to the 6 dB point on the first pulse of a pulse pair. The video processor also includes echo suppression circuits in which an echo suppression gate is generated upon decoding a high-amplitude pulse pair. The signal amplitude threshold, at which echo decoding occurs, and the gate width are set at the system console. The effect of this gate is to raise the decoding threshold so that received echoes from the originally received pulse pair are not decoded during the duration of the echo suppression gate. In the coder/decoder, counters are used to generate the system time delay and the reply pulse spacing. The azimuth reference bursts and the identity pulses are generated in the coder/decoder. The north and auxiliary azimuth reference bursts are generated in time relationship with the 15 hertz (Hz) and 135 Hz triggers received from the antenna. The identity code is generated in the TACAN monitor and is synchronized (by a signal from the VOR monitor) with the transmitted VOR identity code. The identity keying envelope is applied to the coder/decoder counter circuits which generate the 1350 Hz pulse pairs and equalization pulses. Ident keying is given top priority over other system functions. Monitor measurements of reply efficiency, squitter rate, and receiver sensitivity are reduced to zero during ident, and are thus ignored by the monitor. The coder/decoder circuits also contain a squitter generator. This circuit uses a counter to control the distribution and repetition rate of the squitter. Counter techniques maintain the transmitter pulse repetition rate due to decoded-pulse-pairs plus squitter to be kept at the required 2700 ppps rate. The replies and squitter are added, with the proper priority to the azimuth reference bursts and the identity code signals, to form the modulation pulse train. The modulation pulse train from the coder/decoder is then supplied to the modulation controller circuits which shape the modulation signal and control the RF drive signal to the intermediate power amplifier.

4.2 TEST DESIGN.

All testing was conducted at the FAA Technical Center. The SGV tests were conducted at the Technical Center's SGV facility and the Cardion™ DME tests were conducted in the Technical Center's EMC laboratory. Testing was conducted jointly by Technical Center and IITRI personnel.

The SGV and Cardion equipments were checked before and monitored during testing to ascertain that the equipments were operating within the appropriate specifications. The SGV and DME receivers were tuned to channel 122X for all JTIDS tests. Two on-channel DME loads were used. A DME load of 2174 ppps (where all interrogations were below the echo suppression gate threshold) and a 1500 ppps rate (where half the interrogations enabled the echo suppression gate and the other half were below the threshold of the echo suppression gate), the threshold of the echo suppression

gate was set at -70 dBm. The operating frequency, the on-channel DME loads, and the echo suppression gate threshold were all specified in the approved test plans. Tests were then conducted to determine the effect of a defined off-channel DME load EPE and various JTIDS configurations on various level-desired interrogations to the TACAN/DME equipment under test.

Figure 4-3 is a block diagram of the basic test configuration. The desired signal source is a standard TACAN/DME beacon simulator. The simulator is tuned to the receiver frequency of the TACAN/DME unit under test. The interrogation rate of the simulator is manually set to 200 DME interrogations per second for all tests. The RF output level of the desired signal source is varied by a computer controlled variable attenuator on the output of the simulator. The on-channel DME load is another standard TACAN/DME beacon simulator. This simulator is also tuned to the receiver frequency of the system under test. The rate is manually set to a rate of 2174 or 1500 interrogations per second as dictated by the test. The RF output is manually adjusted to -60 dBm. The random amplitude modulator (RAM), under manual switch control, then either (1) attenuates (by 20 dB) the 2174 interrogations per second such that they are all below the -70 dBm threshold of the echo suppression gate, or (2) attenuates half of the 1500 interrogations per second such that 750 are at -80 dBm and the other 750 are unattenuated and thus are at -60 dBm. The off- channel DME source, or EPE, was designed and built by IITRI personnel. The EPE provides a specific number of interrogations and pulse spacings at delta frequencies of 1 through 5 MHz in 1 MHz increments. The block labeled JTIDS is the JTIDS sources required to generate the required pulses for the JTIDS scenarios tested.

For all tests, the desired signal source at the input to the receiver is stepped through levels of -104 to -50 dBm. The effect of JTIDS ON and JTIDS OFF is recorded for each desired signal source level. The data recorded are the reply efficiency and reply delay of the desired signal source, the number of echo suppression gates, and total decode output created by all inputs to the receiver under test and the TACAN AGR voltage. Also recorded are the JTIDS level commanded and the JTIDS level and number of timeslots generated. Table 4-1 contains the JTIDS snapshot numbers and descriptions of the JTIDS variations tested.

4.3 METHOD OF APPROACH.

The data collection block diagram for the SGV and Cardion tests is shown in figure 4-4. The desired signal source, the JTIDS, and the ON and OFF tuned DME environment are all input to the system under test, via a directional coupler placed in the transmit/receive antenna line. The system under test is operated into a dummy load such that no external signals from the antenna can enter the system. The voltmeter for the AGR voltage and the counters for the echo suppression gates, the valid decodes, and the reply efficiency count are also shown in the figure 4-4. For the desired signal reply efficiency, the video of the desired signal source is delayed the same as the normal system delay in the TACAN/DME system (50 μs). The output of the delayed desired signal video is ANDed with the output of the coder/decoder. The output of the AND gate is the desired replies. The ratio counter with inputs of number of interrogations (desired signal video) and the gated desired replies provide a reply efficiency count which, in effect, is desired replies divided by desired interrogations.

Two basic test sequences were employed: operational scenarios (snapshots 406-Navy, 407-Army) and some single-net scenarios (snapshots 401 through 405 and 408 through 411). For operational scenarios of each desired signal level, the EPE was

interleaved with the JTIDS ON and JTIDS OFF conditions; whereas, for the single-net scenarios, the EPE was always ON for both JTIDS ON and JTIDS OFF conditions.

Figure 4-5 is a sample data sheet for the operational scenarios. The first six lines describe the test conditions. Note that "#" indicates EPE ON. The data sheet shows the JTIDS level; the # for EPE on; the desired signal level; the mean numbers for reply efficiency, reply delay, echo gates, squitter voltage, AGR; and the total decode count mean. The second JTIDS-level column and the JTIDS count mean were a version of a JTIDS monitor scheme that measured the actual JTIDS level and the timeslot duty count of the input to the system under test. These data are not used in any data analysis. The last two columns (monitor reply efficiency and reply delay) were not used during these tests. For a desired signal level of -94 dBm, JTIDS level -45 with EPE ON (#) shows a reply efficiency of 72.3 percent, and for the same condition with EPE OFF, the reply efficiency is 75.4 percent. The JTIDS OFF (-120) reply efficiency for these conditions is 74.0 and 79.0, respectively. For this report, data will be presented for the EPE ON condition only.

4.4. DATA RESULTS.

The FAA criterion for judging the effects of JTIDS is focused on the change in reply efficiency attributed to JTIDS. The criterion identifies a desired signal level of -92 dBm for TACAN and -88 dBm for DMEs. Table 4-2 contains (for the SGV) JTIDS ON and JTIDS OFF, reply efficiency for the two JTIDS foreground levels tested (-36 and -45 dBm), and the two DME loads tested (2174 Ram, 0 percent and 1500 Ram, 50 percent) for the 12 JTIDS 100/50 scenarios tested. Table 4-3 contains corresponding data for the Cardion DME. The table reflects that some JTIDS scenarios were tested several times. All data in the tables were used in judging the effects of JTIDS. The tables show a maximum decrease in reply efficiency attributed to JTIDS of 4.6 percent on the SGV and 7.9 percent on the Cardion DME.

4.5 DATA ANALYSIS.

The FAA criterion for judging the effects of JTIDS on the ground Tacan/DME units is as follows:

> For operation of JTIDS in the vicinity of the ground TACAN/DME units, the FAA criterion is that the change in reply efficiency caused by a duty factor of 100/50 JTIDS (-60 decibels below carrier (dBc) noise floor) on the flat portion of the beacon performance curve cannot be appreciably different from that caused by the operation of JTIDS at the 40/20 duty factor. The acceptable change in reply efficiency is defined as a need to operate the JTIDS signal source so that it will not cause a reduction in the reply efficiency of TACAN/DME to the point that it falls below a nominal 75 percent under any condition of operation.
>
> For testing purposes, the conditions of a fully loaded beacon (with the echo suppression circuits disabled) and a desired signal level of -92 dBm for TACANs and -88 dBm for DMEs are the specified conditions present when evaluating the effects of JTIDS. The criterion indicates that under these conditions JTIDS must not cause the reply efficiency to go below a nominal 75-percent reply efficiency.

Figure 4-6 is a plot for the SGV of the JTIDS OFF and JTIDS ON reply efficiency for each JTIDS scenario tested. The desired signal level and the DME load is as indicated in the FAA criterion (-92 dBm, 2174 ppps Ram 0 percent). Figure 4-6 shows similiar data for the Cardion DME where the desired signal level is -88 dBm as indicated by the criterion. For each scenario, the top horizontal bar is the JTIDS OFF reply efficiency and the bottom horizontal bar is the JTIDS ON reply efficiency. The solid horizontal line at 75-percent reply efficiency is the FAA criterion. The dashed line at 70-percent reply efficiency is the U.S. National Standard specified reply efficiency that the FAA guarantees to provide from a ground TACAN/DME station to an airborne interrogation. Figures 4-6 and 4-7 show that for all scenarios tested, JTIDS (in all cases) caused a decrease in reply efficiency. None of the scenarios tested fail the FAA criterion of 75-percent reply efficiency. Note the JTIDS OFF reply efficiency is higher for the Cardion DME (figure 4-7) than for the SGV (figure 4-6). The lower reply efficiency of the SGV is caused by the north and auxiliary gates required to generate azimuth information. The north and auxiliary blanking gates create additional receiver dead time and, thus, less available receiver time. The DME ground equipments do not generate azimuth; therefore, the additional dead time is not created.

It is important to note that although the JTIDS scenarios tested cause a maximum decrease in reply efficiency of less than 5 percent at the SGV, this 5 percent is 50 percent of the margin between the NO JTIDS case and the U.S. National Standard reply efficiency of 70 percent.

Figures 4-8 and 4-9 show the effects of the DME loads and JTIDS on the reply efficiency for the SGV and the Cardion DME, respectively. (Note from figure 4-8 (SGV), the combination of DME load with the echo suppression circuit being triggered by the load (Ram 50 percent) and JTIDS, the reply efficiency is within 1 to 2 percent of the U.S. National Standard of 70 percent.) The point of both figures 4-8 and 4-9 is that the DME loadings on the SGV and Cardion systems use up a fair portion of the margin above the 70-percent reply efficiency. Thus, although the 100/50 JTIDS tested does not violate the FAA criterion; caution must be exercised in the uncoordinate use of JTIDS 100/50. It can be expected in some areas of the country that the margin above the 70-percent reply efficiency may not be large enough to accommodate 100/50 JTIDS operation. The controlling factor under all circumstances is that JTIDS operation should not be allowed to degrade the TACAN/ DME below the operationally acceptable level.

As noted earlier, all 12 JTIDS scenarios were tested at JTIDS foreground levels of -36 and -45 dBm, and all scenarios tested show a decrease in reply efficiency caused by JTIDS. Table 4-4 shows the effect on reply efficiency of one JTIDS snapshot (400) at JTIDS foreground levels of -33, -36, -39, -42, -45, -50, and -60 dBm. The table contains data for both the SGV and the Cardion DME. Figure 4-10 is a plot of the data from table 4-4. The plot shows that, for all JTIDS levels tested, the effect of JTIDS on the reply efficiency is essentially the same. The JTIDS level that causes no effect on the reply efficiency has not been determined. This level is important since a ground JTIDS terminal operating at 100/50 must be sited such as to cause no decrease in reply efficiency. The airborne JTIDS terminals being transitory, in nature, would in most cases be allowed to operate uncoordinated 100/50. The FAA is presently in discussion with DOD to have the JTIDS airborne terminals configured to contain hardware/firmware to limit operations to 40/20 in those areas where 100/50 causes unacceptable degradation to NAS systems; e.g., in those areas where the NO JTIDS reply efficiency is at or below 75 percent.

Tacan/DME

	Military	Civil	Military		Civil	Military	Civil	Military		Civil
Channel	1X-16X	17X [Even Channels 18W-56W] 59X	60X-63X	64Y-69Y	70Y [All Channels 80Z-119Z] 126Y	1Y-16Y	17Y [All Channels 17Z-55Z] 59Y	60Y-63Y	64X-69X	70X-126X
G/A (MHz)	962-977	962 [979-1017] 1020	1021-1024	1025-1030	1031 [1041-1080] 1087	1088-1103	1104 [1104-1142] 1146	1047-1150	1051-1156	1157-1213
Pulse Pair Spacing (usec)	12	12 [24] 12	12	30	30 [15] 30	30	30 [15] 30	30	12	12
A/G (MHz)	1025-1040	1041 [1042-1080] 1083	1084-1087	1088-1093	1094 [1104-1143] 1150	1025-1040	1041 [1041-1079] 1083	1084-1087	1088-1093	1094-1150
Non Precision Pulse Pair Spacing (usec)	12	12 [24] 12	12	36	36 [21] 36	36	36 [21] 36	36	12	12
Precision Pulse Pair Spacing (usec)	-	- [30] -	12	42	42 [27] 42	42	42 [27] 42	42	-	-

NOTE: Channels X and Y — Use All Channels
Channels 80Z to 119Z — Use All Channels Between 80 and 119 Inclusive
Channels 18W to 56W — Use Even Channels Only Between 18 and 56 Inclusive
Channels 17Z to 55Z — Use All Channels Between 17 and 55 Inclusive
Even Channels X and Y from 18X, 18Y to 56X, 56Y reserved for ILS

FIGURE 4-1. FREQUENCY ASSIGNMENT CHART

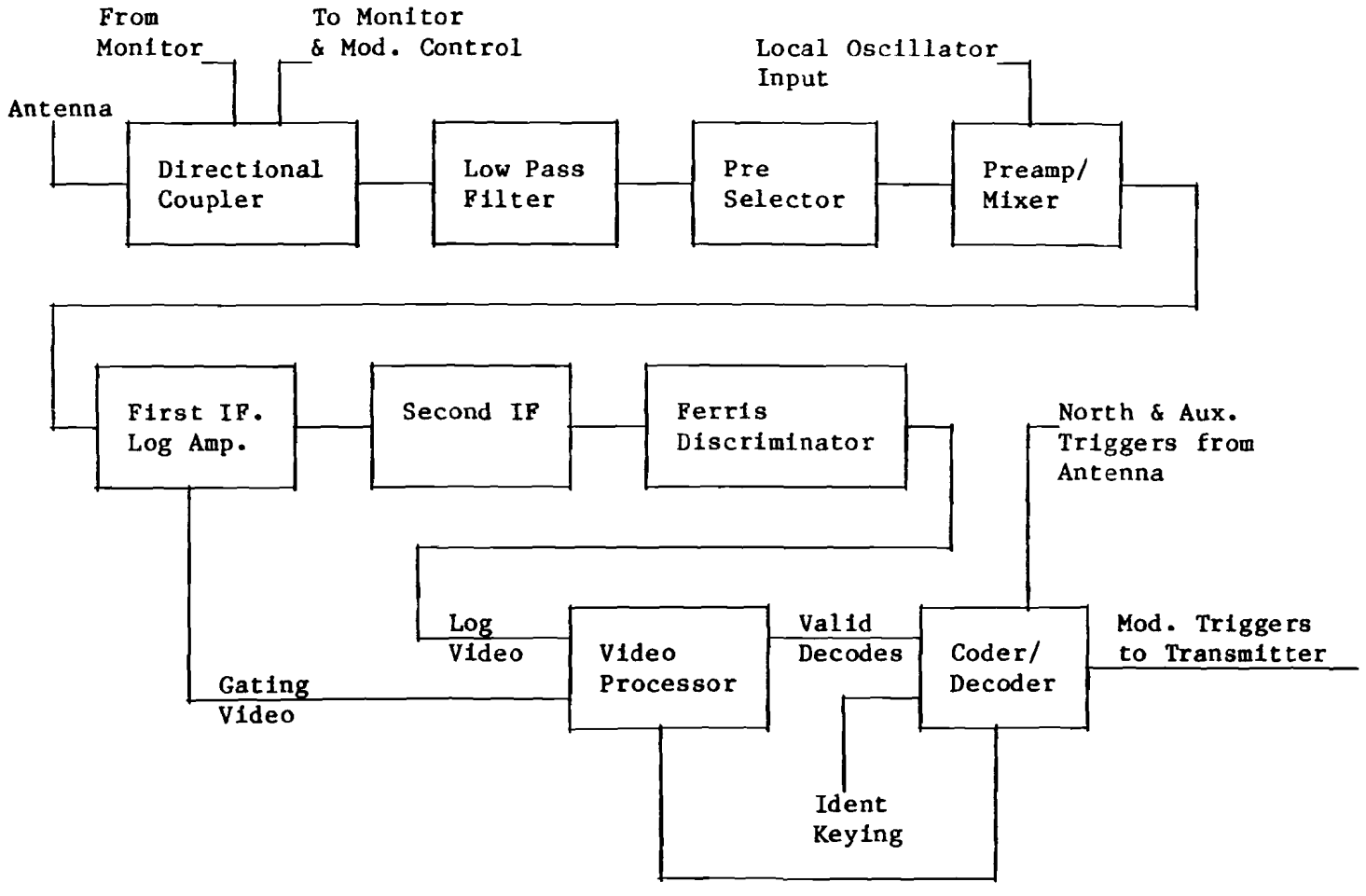


FIGURE 4-2. SECOND GENERATION VORTAC TACAN RECEIVE AND CODER/DECODER FUNCTION

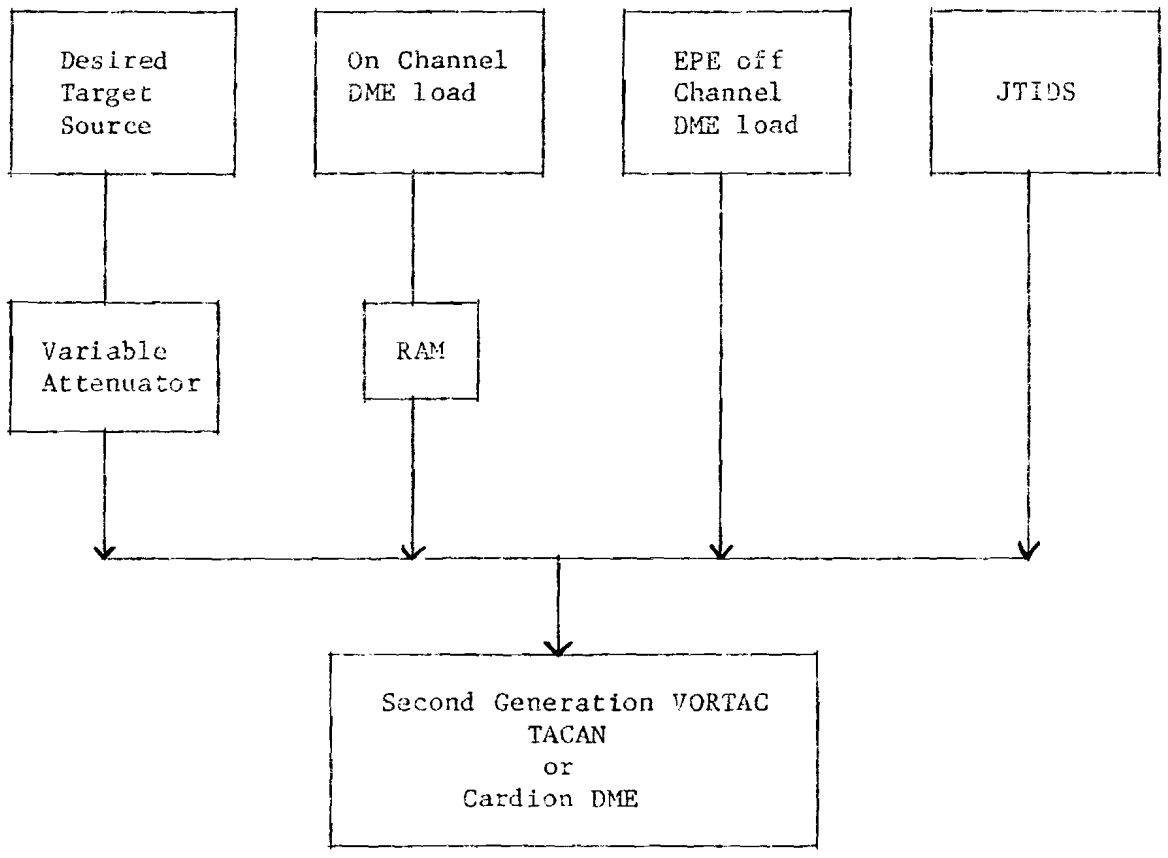


FIGURE 4-3. BASIC TEST CONFIGURATION TACAN/DME GROUND EQUIPMENT

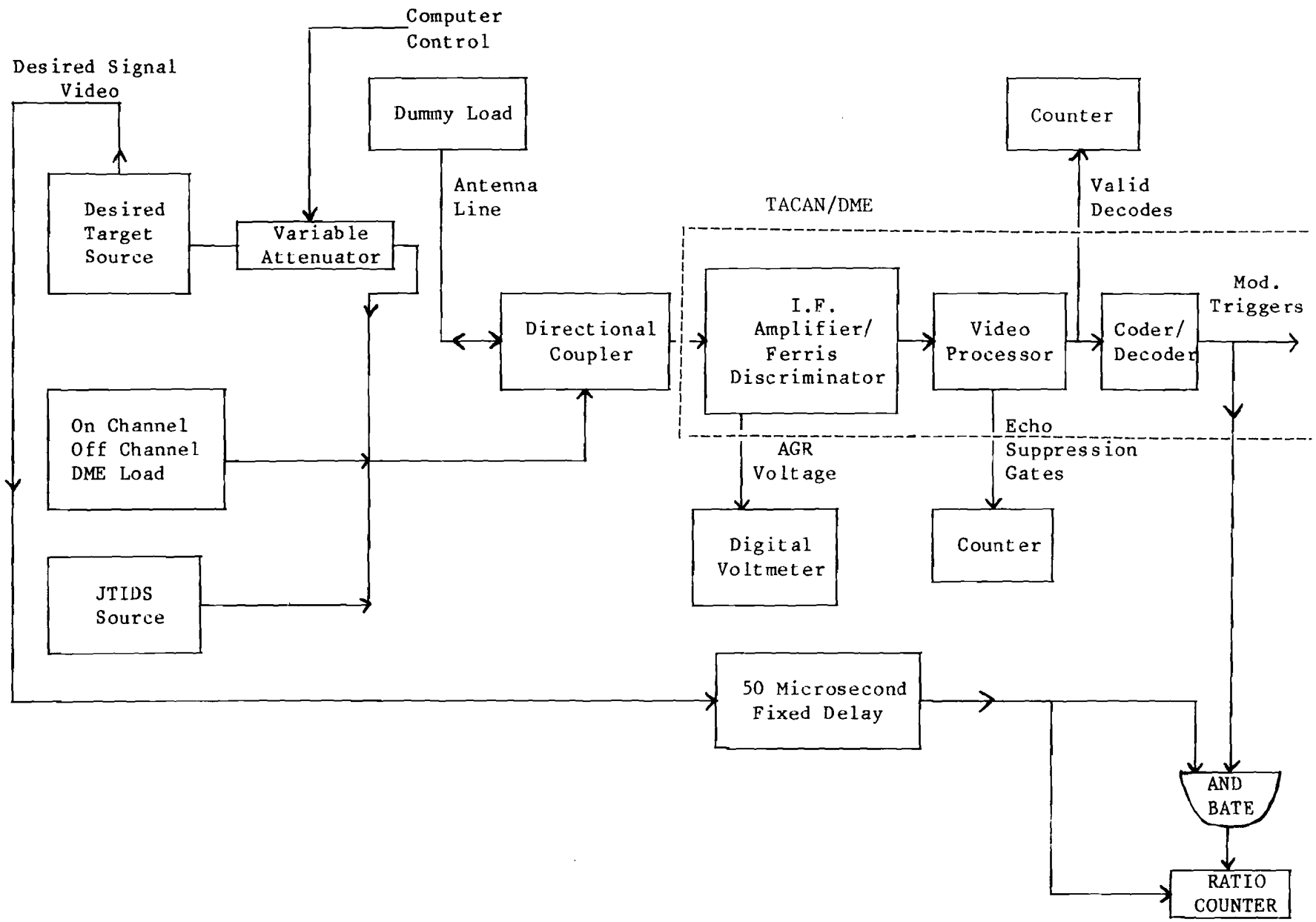


FIGURE 4-4. DATA COLLECTION JTIDS/TACAN DME GROUND EQUIPMENT

SROSEQ130 BEACON TEST DATA EPE INTERLEAVED(#=ON) JTIDS SNAPSHOT# 407
BEACON TESTED: SGV SN64 BEACON LOCATION:FAA TECH CENTER
BEACON TYPE:TACAN,CHANNEL:122X,INTERROGATION RATE:200PPPS
BEACON LOAD:1500 PPPS@-70dBm,RAM SET TO 50% HIGH
JTIDS:TDMA ARMY 100/50
COMMENT: ECHO SUPPRESSION GATE 150uSEC & -70dBm 07-OCT-86 13:44:53

JTIDS LEVEL	DES. LEVEL	BEACON REPLY EFF	ECHO REPLY DELAY	ECHO GATES MEAN	SQUIT VOLT MEAN	DECODE COUNT MEAN	JTIDS LEVEL	JTIDS COUNT MEAN	MONITOR REPLY EFF	MONITOR REPLY DELAY
-120	#-100	0.370	50.39	698	0.143	1645	-85	0		
-120	-100	0.375	50.38	690	0.143	1626	-85	0		
-45	# -98	0.539	50.09	727	0.143	1693	-35	64		
-45	-98	0.568	50.49	716	0.143	1665	-35	63		
-120	# -98	0.564	50.13	697	0.143	1695	-85	0		
-120	-98	0.591	50.03	692	0.143	1664	-85	0		
-45	# -97	0.626	50.34	731	0.143	1709	-36	64		
-45	-97	0.655	50.03	719	0.143	1688	-36	62		
-120	# -97	0.647	50.01	685	0.143	1710	-85	0		
-120	-97	0.685	50.00	685	0.143	1677	-85	0		
-45	# -96	0.679	49.87	722	0.144	1718	-35	64		
-45	-96	0.724	49.90	713	0.143	1686	-36	63		
-120	# -96	0.717	50.04	692	0.144	1713	-85	0		
-120	-96	0.739	49.69	697	0.143	1706	-85	0		
-120	-96	-0.761	49.90	684	0.143	1694	-85	0		
-45	# -95	0.717	50.01	723	0.143	1719	-35	63		
-45	-95	0.740	49.96	718	0.143	1697	-36	64		
-45	-95	-0.742	49.79	730	0.143	1706	-35	63		
-45	-95	-0.757	49.93	724	0.143	1706	-36	64		
-120	# -95	0.723	49.88	688	0.143	1713	-85	0		
-120	-95	0.770	49.77	688	0.143	1700	-85	0		
-45	# -94	0.723	49.69	728	0.143	1725	-35	64		
-45	-94	0.754	49.34	718	0.143	1698	-36	64		
-120	# -94	0.740	49.87	688	0.143	1715	-85	0		
-120	-94	0.790	49.44	692	0.143	1701	-85	0		
-45	# -93	0.714	49.62	730	0.143	1728	-36	62		
-45	# -93	-0.710	49.42	720	0.143	1717	-35	64		
-45	# -93	-0.728	49.66	727	0.143	1722	-36	62		
-45	-93	0.773	49.41	714	0.143	1697	-36	63		
-120	# -93	0.753	49.68	689	0.143	1718	-85	0		
-120	-93	0.785	49.66	691	0.143	1693	-85	0		
-120	-93	-0.794	49.45	694	0.143	1709	-85	0		
-45	# -92	0.734	49.57	717	0.143	1717	-35	64		
-45	-92	0.777	49.38	713	0.143	1697	-35	64		
-120	# -92	0.763	49.66	691	0.143	1722	-85	0		
-120	-92	0.785	49.36	695	0.143	1704	-85	0		
-45	# -91	0.743	49.64	731	0.143	1740	-35	65		
-45	-91	0.772	49.47	722	0.143	1699	-35	62		
-120	# -91	0.750	49.44	697	0.143	1724	-85	0		
-120	-91	0.792	49.22	698	0.143	1707	-85	0		
-45	# -90	0.742	49.35	722	0.143	1725	-35	64		
-45	-90	0.770	49.53	718	0.143	1713	-35	64		
-120	# -90	0.749	49.46	694	0.143	1722	-85	0		
-120	# -90	-0.755	49.56	693	0.143	1730	-85	0		
-120	# -90	-0.764	49.65	699	0.143	1721	-85	0		

FIGURE 4-5. SAMPLE DATA SHEET FOR SGV/JTIDS OPERATIONAL SCENARIO

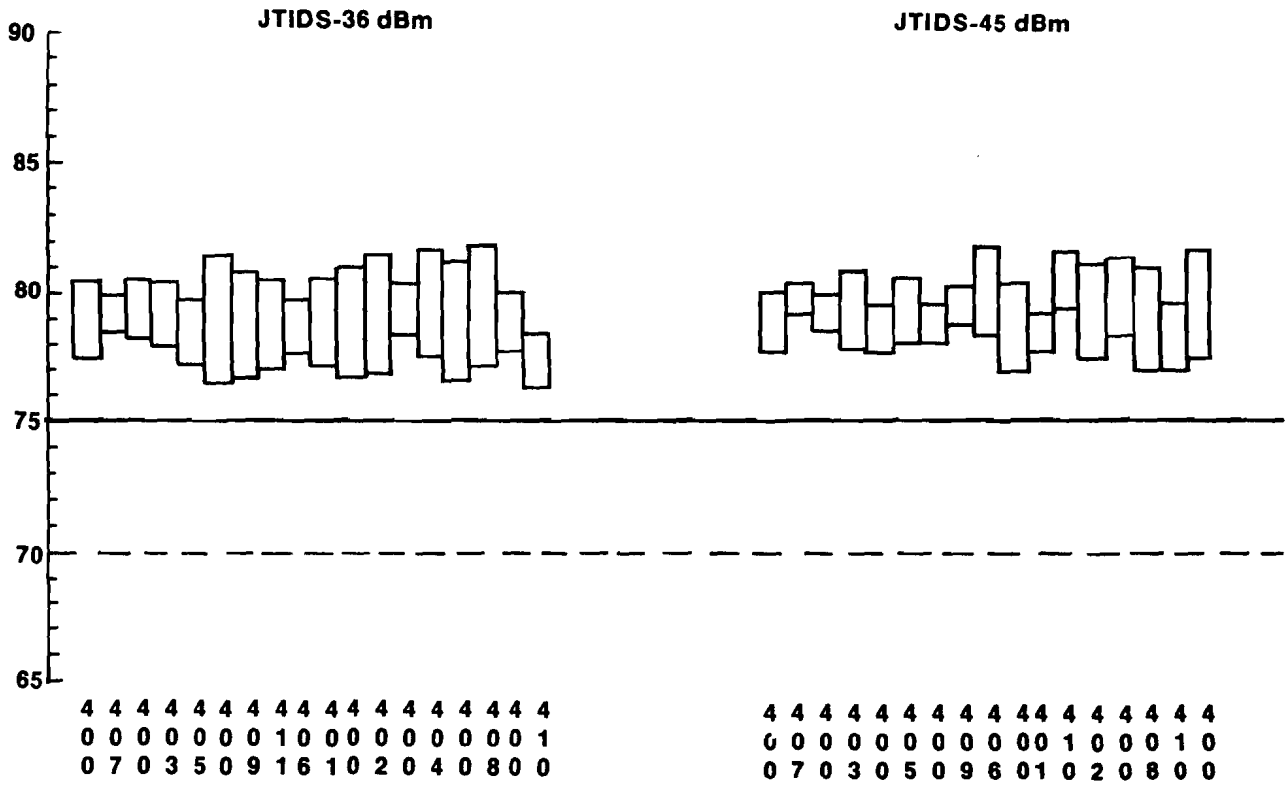


FIGURE 4-6. -92 dBm SGV DME LOAD 2174 PPPS RAM 0 PERCENT

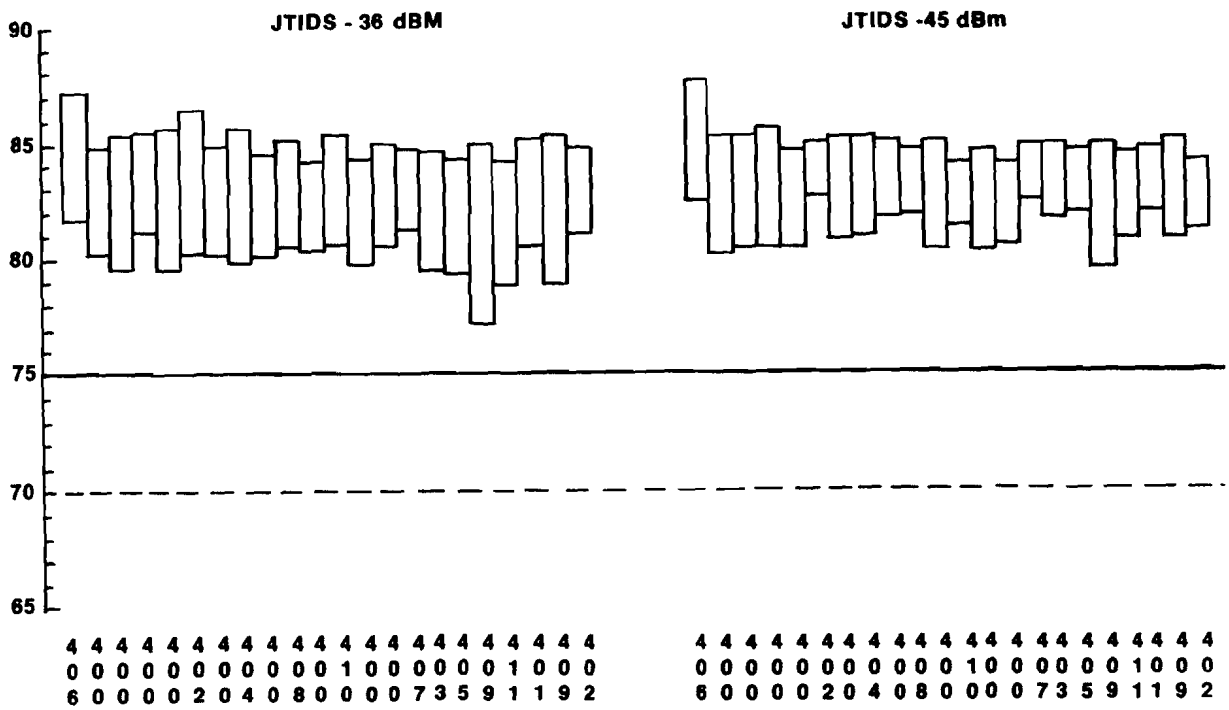


FIGURE 4-7. -88 dBm CARDION DME LOAD 2174 PPPS RAM 0 PERCENT

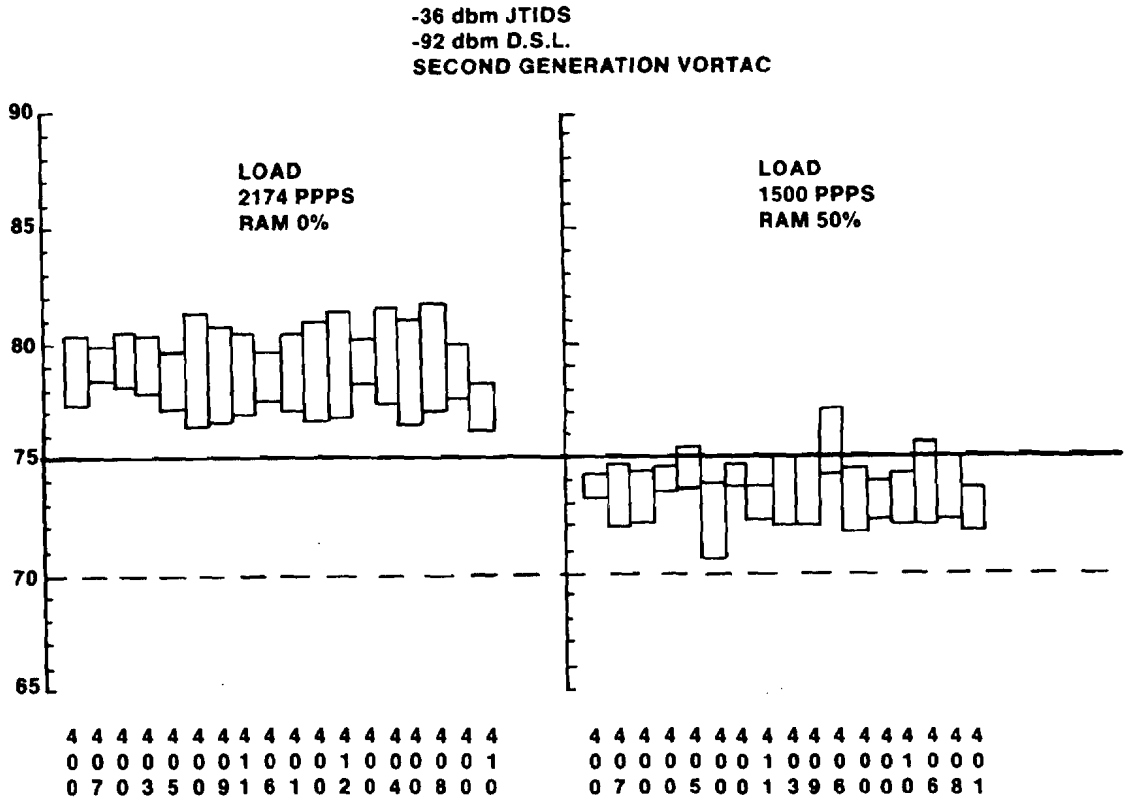


FIGURE 4-8. EFFECT OF JTIDS AT VARIOUS DME LOADS (SGV)

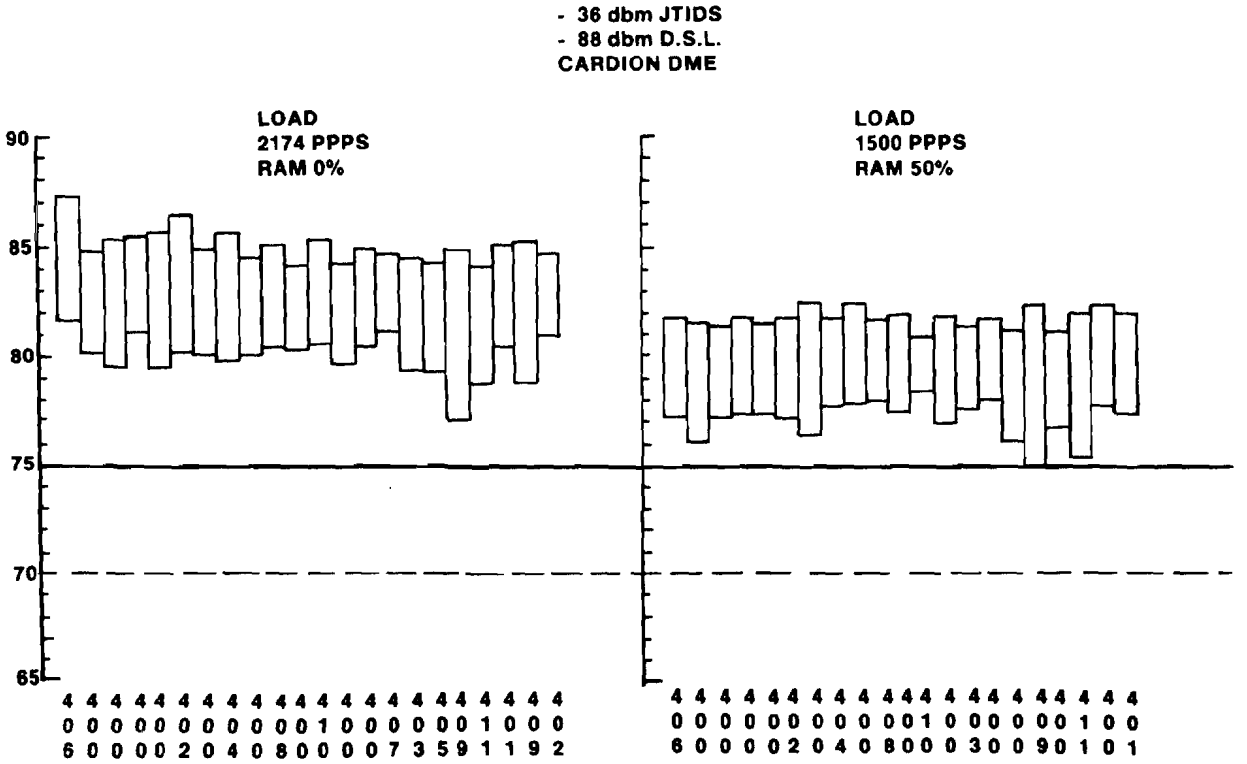


FIGURE 4-9. EFFECT OF JTIDS AT VARIOUS DME LOADS (CARDION DME)

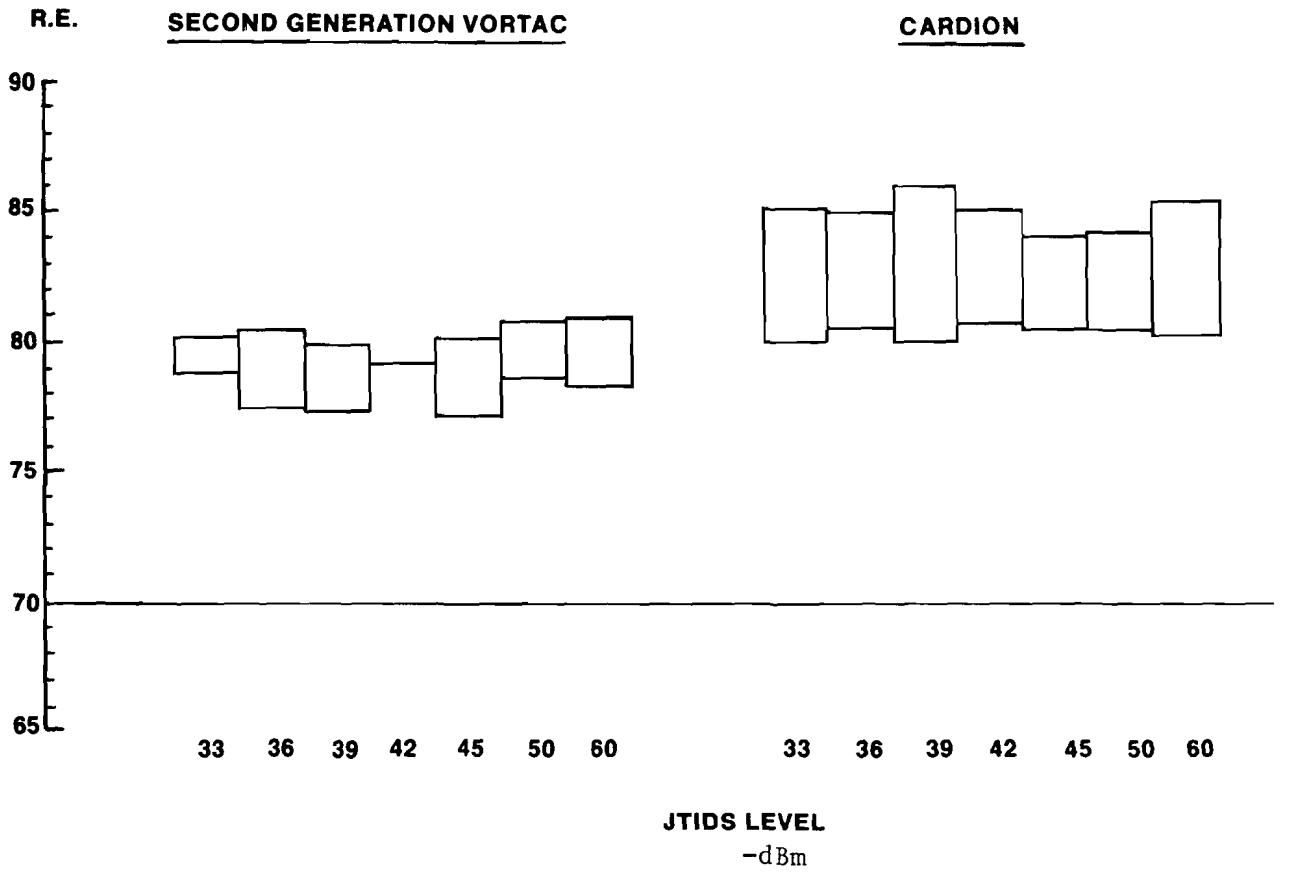


FIGURE 4-10. EFFECT OF JTIDS AT VARIOUS JTIDS LEVELS

TABLE 4-1. JTIDS SNAPSHOT AND ENVIRONMENT VARIATIONS/TACAN DME BEACONS

Snapshot Number	Comments
400	Single-net, 258-pulse time slots, no contention
401	Single-net, 444-pulse time slots, no contention
402	Single-net, 258-pulse time slots, two-user contention in every time slot
403	Single-net, 258-pulse time slots, four-user contention in every time slot
404	Double-net (100% overlap), 258-pulse time slots, no contention
405	Four-net (100% overlap), 258-pulse time slots, no contention
406	Navy beacon snapshot, some contention, two-net
407	Army beacon snapshot, ten-net, contention (maximum four transmissions same time) slot on same net, 444-pulse time slot extensively used
408	Single-net, 444-pulse time slots, two-user contention in every time slot
409	Single-net, 444-pulse time slots, four-user contention in every time slot
410	Double-net (100% overlap), 444-pulse time slots, no contention
411	Four-net (100% overlap), 444-pulse time slots, no contention

TABLE 4-2. EFFECT OF JTIDS SCENARIOS ON SECOND GENERATION VORTAC

SECOND GENERATION VORTAC
-92 dBm Desired Signal Level

	-36 dBm JTIDS			-45 dBm JTIDS		
Snapshot	JTIDS-OFF RE	JTIDS-ON RE	DELTA RE	JTIDS-OFF RE	JTIDS-ON RE	DELTA RE
			Load 2174 RAM 0 Percent			
400	80.4	77.4	-3.0	80.1	77.7	-2.4
407	79.9	78.5	-1.4	80.4	79.2	-1.2
400	80.5	78.2	-2.3	80.0	78.6	-1.4
403	80.4	77.9	-2.5	80.9	77.9	-3.0
400	-	-	-	79.6	77.8	-1.8
405	79.7	77.2	-2.5	80.7	78.1	-2.6
400	81.4	76.5	-4.9	79.6	78.1	-1.5
409	80.8	76.6	-4.2	80.4	76.8	-3.6
411	80.5	77.0	-3.5	-	-	-
406	79.7	77.6	-2.1	81.9	78.5	-3.4
400	-	-	-	80.5	77.0	-3.5
401	80.5	77.2	-3.3	79.3	77.8	-1.5
400	81.0	76.7	-4.3	81.7	79.5	-2.2
402	81.5	76.9	-4.6	81.2	77.6	-3.6
400	80.3	78.4	-1.9	81.5	78.4	-3.1
404	81.6	77.5	-4.1	-	-	-
400	81.2	76.6	-4.6	-	-	-
408	81.8	77.2	-4.6	81.1	77.2	-3.9
400	80.1	77.7	-2.4	-	-	-
410	78.4	76.4	-2.0	79.7	77.1	-2.6
400	-	-	-	79.7	77.6	-2.1
			Load 1500 RAM 50 PERCENT			
400	74.5	73.4	-1.1	75.9	71.8	-4.1
407	74.9	72.2	-2.7	76.3	73.4	-2.9
400	74.6	72.4	-2.2	73.8	71.8	-2.0
403	75.1	72.3	-2.8	73.8	72.6	-1.2
400	74.7	73.7	-1.0	75.1	72.4	-2.7
405	75.6	73.8	-1.8	75.7	71.9	-3.8
400	74.1	70.8	-3.3	74.3	72.2	-2.1
409	75.4	72.3	-3.1	76.1	73.0	-3.1
400	74.9	74.0	-0.9	75.0	73.3	-1.7
411	74.0	72.5	-1.5	76.3	72.8	-3.5
406	77.4	74.5	-2.9	75.1	71.9	-3.2
400	74.8	72.0	-2.8	74.9	73.5	-1.4
402	-	-	-	75.1	74.2	-0.9
400	74.3	72.6	-1.7	75.1	73.5	-1.6
410	74.6	72.4	-2.2	-	-	-
404	-	-	-	75.1	72.5	-2.6
400	-	-	-	75.7	72.5	-3.2
408	75.5	72.7	-2.8	75.0	71.8	-3.2
400	-	-	-	75.2	73.1	-2.1
406	76.0	72.4	-3.6	75.3	72.8	-2.5
400	-	-	-	73.7	71.5	-2.2
401	74.0	72.1	-1.9	73.4	71.7	-1.7

TABLE 4-3. EFFECT OF JTIDS SCENARIOS ON CARDION DME

CARDION DME
-88 dBm Desired Signal Level

	-36 dBm JTIDS			-45 dBm JTIDS		
Snapshot	JTIDS-OFF RE	JTIDS-ON RE	DELTA RE	JTIDS-OFF RE	JTIDS-ON RE	DELTA RE
			Load 2174 RAM 0 Percent			
406	87.2	81.7	-5.5	87.7	82.5	-5.2
400	84.8	80.1	-4.7	85.3	80.1	-5.2
400	85.4	79.5	-5.9	85.3	80.4	-4.2
400	85.5	81.1	-4.4	85.7	80.4	-5.3
400	85.7	79.5	-6.2	84.7	80.4	-4.3
402	86.5	80.2	-6.3	85.0	82.7	-2.3
400	84.9	80.1	-4.8	85.3	80.8	-4.5
404	85.7	79.8	-5.9	85.3	80.9	-4.4
400	84.5	80.1	-4.4	85.1	81.7	-3.4
408	85.1	80.5	-4.6	84.7	81.9	-2.8
400	84.7	80.3	-4.4	85.1	80.3	-4.8
410	85.4	80.6	-4.8	84.1	81.3	-2.8
400	84.4	79.7	-4.7	84.7	80.2	-4.5
400	85.0	80.5	-4.5	84.1	80.5	-3.6
407	84.7	81.2	-3.5	85.0	82.5	-2.5
403	84.6	79.4	-5.2	85.0	81.6	-3.4
405	84.3	79.3	-5.0	84.7	81.9	-2.8
409	85.0	77.1	-7.9	85.0	79.4	-5.6
411	84.2	78.8	-5.4	84.5	80.7	-3.8
401	85.2	80.5	-4.7	84.8	81.9	-2.9
409	85.3	78.9	-6.4	85.2	80.7	-4.5
402	84.8	81.0	-3.8	84.2	81.1	-3.1
			Load 1500 RAM 50 PERCENT			
406	81.8	77.3	-4.5	80.8	77.8	-3.0
400	81.4	76.1	-5.3	82.0	79.0	-3.0
400	81.3	77.2	-4.1	82.6	77.9	-4.7
400	81.8	77.4	-4.4	81.3	78.5	-2.8
400	81.5	77.4	-4.1	80.6	77.6	-3.0
402	81.1	77.2	-3.9	81.0	78.1	-2.9
400	82.5	76.4	-6.1	81.9	76.3	-5.6
404	81.8	77.8	-4.0	81.2	78.9	-2.3
400	82.5	77.9	-4.6	80.6	78.0	-2.6
408	81.7	78.0	-3.7	81.7	78.2	-3.5
400	82.0	77.5	-4.5	81.2	78.1	-3.1
410	81.0	78.4	-2.6	80.7	78.9	-1.8
400	81.8	76.9	-4.9	80.5	78.3	-2.2
403	81.4	77.6	-3.8	81.3	79.3	-2.0
400	81.7	78.0	-3.7	82.5	78.2	-4.3
400	81.2	76.2	-5.0	82.0	78.7	-3.3
409	82.4	75.1	-7.3	82.1	76.9	-5.2
400	81.2	76.8	-4.4	81.8	78.2	-3.6
411	82.0	75.4	-6.6	80.7	78.1	-2.6
400	82.4	77.8	-4.6	82.2	79.0	-3.2
401	82.0	77.4	-4.6	81.3	77.7	-3.6

TABLE 4-4. SNAPSHOT 400 JTIDS EFFECT ON SGV AND CARDION AT VARIOUS JTIDS LEVELS

SECOND GENERATION VORTAC

Channel 122X
Snapshot 400
Beacon Load 2174 PPPS
RAM 0 Percent
EPE ON

Desired Signal Level -92 dBm

JTIDS LEVEL (-dBm)							
33	36	39	42	45	50	60	
80.2	80.4	79.9	79.1	80.1	80.8	81.0	JTIDS-OFF R.E.
78.8	77.4	77.3	79.0	77.7	78.6	78.3	JTIDS-ON R.E.
-1.4	-3.0	-2.6	-0.1	-2.4	-2.2	-2.7	DELTA R.E.

CARDION

Channel 122X
Snapshot 400
Beacon Load 2174 PPPS
RAM 0 %
EPE ON

Desired Signal Level -88 dBm

JTIDS LEVEL (-dBm)							
33	36	39	42	45	50	60	
85.1	85.0	86.0	85.1	84.1	84.2	85.5	JTIDS-OFF R.E.
80.0	80.5	80.0	80.7	80.5	80.5	80.3	JTIDS-ON R.E.
-5.1	-4.5	-6.0	-4.4	-3.6	-3.7	-5.2	DELTA R.E.

5. JTIDS/TACAN-DME INTERROGATORS.

5.1. DESCRIPTION OF EQUIPMENT.

The TACAN/DME interrogators are the airborne portion of the navigation system. The DME interrogates the ground TACAN/DME systems and recognizes and converts the replies from the ground into distance from the ground station. The receiver frequencies of the TACAN interrogators are 962 through 1213 MHz and the DME interrogators are 978 through 1213 MHz.

All of the interrogators tested can be represented in the receiver function as shown in figure 5-1. Once the interrogator is tuned to a particular ground beacon, all the transmitted pulses from the beacon pass from the antenna to the decoder input via the IF and video amplifiers. Properly spaced pulses (12 μs, X mode and 30 μs, Y mode) cause a decoder output. The decoder output is ANDed with the video amplifier output to provide an automatic gain control (AGC) for the IF amplifier. The AGC controls the gain of the IF amplifier such as to produce uniform amplitude pulses at the output of the video amplifier. In some interrogators, the decoder output also produces a dead-time gate to inhibit the output of the decoder for some fixed time after each decode. The dead-time gate serves to reduce the possibility of synchronizing the DME to reflection path signals (echoes). The decoder output is passed on for processing and finally to the DME display. The processing determines which of the decodes are synchronized with the interrogator's transmitter and converts the elapsed time, from transmit to synchronous decode, to nautical miles from the ground beacon.

5.2. TEST DESIGN.

All testing was conducted at the IITRI Laboratories in Annapolis, Maryland. The TACAN/DME interrogators were checked before testing to be certain that the equipments were operating within the appropriate specifications. Tests were then conducted to determine the effect of a defined EPE, and then to determine the effect of the EPE and various JTIDS configurations on the performance of the TACAN/DME interrogators.

The performance parameter of interest is acquisition stable operating point (ASOP). ASOP is generally defined as the minimum signal level that permits a TACAN/DME interrogator to acquire lock within 5 seconds, in five out of five trials. Due to design differences in interrogators, the acquisition test time was increased from 5 to 20 seconds for several interrogators tested.

Table 5-1 is a list of the interrogators proposed by RTCA and NTIA for testing. The first nine units are conventional DMEs; the 10th, 11th, and 12th units are scanning DMEs. The 13th unit is a commercial TACAN, while the 14th and 15th units are military TACANS.

After the checkout of specifications, each interrogator is tested to determine the effects of JTIDS when the interrogator is tuned to three different signal types. The signal types, 1000 and 2700 ppps from a DME ground station and 2700 ppps from a TACAN station, all exist in the environment. The objective of this first JTIDS test is to determine at which of the three TACAN/DME environments the interrogator

is most susceptible to JTIDS. Once the worst-case environment is determined for each interrogator, this environment is used for all future JTIDS tests.

The three JTIDS foreground levels used in this test program are -36, -42, and -48 dBm. These levels represent the worst-case signal level coupled to an aircraft from a JTIDS-equipped aircraft with EIRP of 200 watts where the aircraft are at a 1000-foot vertical separation. The different levels are experienced with respect to aircraft antenna configuration (i.e., both aircraft, bottom-mounted antennas; one aircraft, top- mounted; one aircraft, bottom-mounted antennas; etc.).

Figure 5-2 is a block diagram of the basic test configuration. The EPE includes adjacent and co-channel pulses that are transmitted by other TACAN/DME beacons and interrogators. The JTIDS source generates the required pulses for the JTIDS scenario tested. The TACAN/DME environment simulator is standard avionics test equipment used to test TACAN/DME interrogators. The simulator is, in reality, a ground TACAN/DME beacon. The simulator can be switch-configured to be a DME or TACAN beacon. The number of pulses can be adjusted from 0 to 9000 ppps. The reply efficiency of the simulator can be adjusted such that the simulator returns a percentage of interrogations as replies. The reply efficiency can be adjusted from 0 to 100 percent. The RF level of the replies to the interrogations is adjustable from 0 to -100 dBm. The unit under test is 1 of the 15 interrogators in table 5-1. The DME indicator is a visual indication that the DME interrogator has locked onto the reply from the TACAN/DME environment simulator.

All interrogators tested were tuned to either channel 32X or 59Y. Channel 32X tunes the interrogator receiver to 993 MHz. The 993 MHz frequency is one of the JTIDS transmit frequencies and is in the middle of the JTIDS lower-operating frequency band of 969 to 1008 MHz. Channel 59Y tunes the interrogator receiver to 1146 MHz. The 1146 MHz frequency is one of the JTIDS transmit frequencies and is in the middle of the JTIDS upper-operating frequency band of 1113 to 1206 MHz. For all interrogators tested, the effect of JTIDS at channel 32X was greater or the same as the effect at 59Y. The data in this report present only the channel 32X results.

The FAA criteria are that ASOP degradation due to JTIDS interference should be no greater than 3 dB outside the service volume and degradation due to JTIDS inside the service volume is 0. The criteria also identify a JTIDS level of -36 dBm and acknowledges a reduction of this level to -42 dBm if certain JTIDS terminal safeguards and a JTIDS ground-monitoring capability are provided.

The signal level received at the fringes of the low-level service volume (18,000 feet and below) is -79 dBm, and at the high service volume is -84.5 dBm. Table 5-2 contains the listing of the interrogators tested that use the low-level and high-level service volume minimum sensitivity.

The essence of the criteria is that outside the service volume JTIDS may cause a 2 dB-degradation not to exceed a 3 dB-degradation but in no case can JTIDS cause a low-level service volume interrogator to degrade below -79 dBm or a high-level service volume interrogator to degrade below -84.5 dBm. These criteria are applied where the interrogator is receiving a 70-percent reply efficiency.

5.3. METHOD OF APPROACH.

The data collection block diagram for the JTIDS/TACAN-DME interrogator tests is shown in figure 5-3. The RF levels of the EPE, the TACAN/DME environment simulator, and the JTIDS source are under program control via the RF interface unit. The average power meter monitors the average power of the JTIDS source while the spectrum analyzer checks the RF spectrum of the JTIDS source and the TACAN/DME environment simulator. The interrogator's range and bearing information, the interrogation and reply counter data, and the automatic gain control voltage from the digital voltmeter are all stored via general purpose interface buss (GPIB) by the 4052 co controller on magnetic tape. The digital interface unit sets the attenuators in the radio frequency interference unit (RFIU) and thus controls the RF output of the JTIDS, EPE, and the TACAN/DME environment simulator. These attenuator settings are converted to RF output level in -dBm and stored on the same magnetic tape as the other data. Thus, the ASOP data for all test conditions are stored on tape.

The ASOP test establishes the minimum beacon signal level that allows the interrogator to lock up five out of five trials in 5 seconds, and to remain locked up for 60 seconds. The beacon identification (ID) is disabled during the ASOP tests so that the normal, twice-a-minute occurrence of ID does not prevent the interrogator from locking up on one of the five ASOP trials. Once the unit has acquired lockup five out of five times, the ID is turned on and the unit is required to track for 60 seconds.

The test starts out with a low desired signal level, and the acquisition and tracking tests are executed. If the unit fails either test, the desired signal level is increased by 1 dB. This process is repeated until the ASOP signal level is established.

The basic test consists of three JTIDS OFF (NJ) ASOP tests interleaved with two JTIDS ON (J) ASOP tests. The sequence of the basic test is as follows:

NJ J NJ J NJ

The NJ results are checked to see that the minimum and maximum values do not vary by more than 1 dB. If the variation is greater than 1 dB, the same test sequence is repeated with the first sequence results retained. If the second test results still show more than a 1-dB spread in the JTIDS OFF data, the tests are terminated and the reason for the unstable NJ results is investigated.

If after the second test sequence, the NJ spread is found to be not greater than 1 dB, then the first test sequence results are deleted and replaced with the second test sequence results.

After deletion/replacement of test results or if the first test sequence results are within the prescribed 1 dB, a check is then made to determine if the JTIDS ON result is greater than 1 dB. If it is, three additional JTIDS ON tests and one additional JTIDS OFF test will be performed. No further checks are performed, and the data are stored for future analysis. The sequence of tests will appear as follows:

Sequence one or sequence two after replacement					Additional JTIDS ON tests			
NJ	J	NJ	J	NJ	J	J	J	NJ

Figure 5-4 is a sample data sheet of the results of the effect of JTIDS scenarios on the ASOP of TACAN/DME interrogators. The top portion of figure 5-4 shows the effect of the Navy scenario on the Bendix DMA-37A DME, while the lower portion of the figure shows the effect of the joint (Air Force/Army) scenario on the King KN-63 DME. The JTIDS foregrounds used for the interrogator tests were determined by the JTIDS platform configurations. Thus, as figure 5-4 indicates, the JTIDS levels were different for each scenario. To establish a common reference, the -36 dBm JTIDS level was included in all scenario tests.

Figure 5-4 shows that for the Navy scenario at a -36 dBm JTIDS level there were two JTIDS ON ASOPs recorded (N=2) and there were three JTIDS OFF ASOPs recorded (N=3). The minimum and maximum JTIDS ON ASOP levels were -87 and -88 dBm, respectively, while the minimum and maximum JTIDS OFF ASOP levels were the same at a -88 dBm level. The figure also shows that for the joint scenario there were five JTIDS ON ASOPs recorded (N=5) and there were four JTIDS-OFF ASOPs recorded (N-4). The minimum and maximum JTIDS ON ASOP levels were -69 and -75 dBm, respectively, while the minimum and maximum JTIDS OFF ASOP levels were -80 and -81 dBm, respectively. The (mean dBm) columns are simply the arithmetic mean of the two, three, four, or five ASOP levels recorded while the (Diff dB) column is the dB difference in the JTIDS OFF or JTIDS ON ASOP levels recorded.

The JTIDS OFF N=3 with a JTIDS ON of N=2 indicates that only test sequence one (NJ, J, NJ, J, NJ) was required since the JTIDS OFF AND JTIDS ON ASOPs were both within one dB. The JTIDS OFF of N=4 with a JTIDS ON of N=5 indicates that test sequence one (NJ, J, NJ, J, NJ) and test sequence two (J, J, J, NJ) were both required since the JTIDS ON ASOPs recorded during test sequence one were not within 1 dB.

It is important to keep in mind that each ASOP level recorded is the result of five successful sequential acquisition attempts and a 60-second lock-on period at the ASOP signal level recorded. Thus, a minimum ASOP level is just as valid as a maximum ASOP level. For this report, the effect of JTIDS is from the most sensitive JTIDS OFF ASOP recorded to the minimum JTIDS ON ASOP recorded.

5.4. DATA RESULTS.

Table 5-3 contains the minimum and maximum ASOPs for the JTIDS OFF (NJ) and JTIDS ON (J) levels that are pertinent to the FAA criteria. The JTIDS levels identified in the criteria are -36 and -42 dBm. The Army and joint scenarios were tested at JTIDS levels of -36, -39, -45, and -51; and -36, -38, -44, and -50, respectively. To apply the criteria, the JTIDS levels of -39 (Army) and -38 (joint) were used since -42 dBm JTIDS level results were not collected.

The table shows no data for the DME 40, DME 451, and 860 E3, and KN 65A for the Air Force scenario. The DME 40 and 860 E3 showed less than a 2-db degradation with a -36 dBm JTIDS; and by committee decision, these data were not disseminated as data for record. Data for the DME 451 and KN 65A were collected and later declared invalid by IITRI engineers after reviewing the initial checkout data. Appendix A contains a letter explaining the realignments and manufacturer modifications performed on several of the interrogators after the JTIDS effect data were collected. Note that these decisions were made by IITRI personnel and communicated to the committee after the changes had been accomplished.

Under the Army scenario, the original DME 451 and KN 65A no longer exist. The KTU 709 was modified after the Air Force scenario tests but before starting the Army scenario test. Thus, the original KTU 709 was not available for Army scenario tests.

The table shows that with both the Navy and Joint scenarios only four interrogators were tested. The decision to test a limited number of interrogators was requested by DOD due to the limited test time remaining for the Navy and Joint scenarios. The units selected by the committee were the two general aviation, one commercial, and one scanning interrogator that were most susceptible to JTIDS from the Air Force and Army scenario results.

One unit, not mentioned in the letter (appendix A) was also realigned. That unit was the KN 63. The essence of this realignment was an error in the manufacturer's manual as to the adjustment for the interrogator's power supply. This adjustment was made on the test KN 63 after several JTIDS scenarios had been tested. All the data for the KN 63 were retaken, and the data in table 5-3 for the KN 63 (for all four JTIDS scenarios) are after this realignment.

5.5 DATA ANALYSIS.

Figures 5-5 through 5-12 are plots of the data contained in table 5-3. Figures 5-5 and 5-6 are the Air Force scenario results, figures 5-7 and 5-8 are the Army scenario results, figures 5-9 and 5-10 are the Navy scenario results, and figures 5-11 and 5-12 are the joint (Army/Air Force) scenario results. The horizontal dashed line on the figures is the FAA 3-dB criteria line. The numbers at the bottom of each vertical bar are the minimum JTIDS ON (J) ASOP levels for the appropriate interrogator as recorded in table 5-3. The zero axis is the maximum JTIDS OFF (NJ) ASOP level for the appropriate interrogator as recorded in table 5-3. The legend indicates which unit under test interrogator is associated with the horizontal axis numbers. The solid bars are the interrogators that are identified as low altitude units and cannot be degraded below -79 dBm. The hashed bars are the interrogators that are identified as high altitude units and cannot be degraded below 84.5 dBm. For example, looking at figure 5-5 and table 5-3, one notes that this figure is for the Air Force scenario with a JTIDS level of -36 dBm. For unit under test number one (DME 1077B), the NJ maximum ASOP from table 5-3 is -91 dBm and the minimum J-36 ASOP level is -85 dBm. The difference between -91 dBm and -85 dBm is 6 dB. The vertical bar in figure 5-5 graphically indicates this 6-dB ASOP degradation caused by the -36 dB 100/50 JTIDS Air Force scenario. The -85 dBm number at the bottom of the bar is simply the J-36 minimum ASOP level recorded. The solid bar for unit under test number one indicates that this unit cannot be degraded below -79 dBm. The graphic shows this unit fails the 3-dB criteria.

By scanning figure 5-5, note that of the 10 interrogators tested against the -36 dBm Air Force scenario, 7 of the interrogators failed the 3-dB criteria. Two of the seven interrogators (low altitude units 6 and 7) also failed the -79 dBm threshold.

Two other units that just pass the 3-dB criterion (high altitude unit number 3 and low altitude unit number 4) fail the -84.5 and -79 dBm criteria. Thus, of the 10 interrogators tested only 1 unit passes the FAA criteria at the -36 dBm JTIDS level.

Figure 5-6 is the same scenario as figure 5-5 except the JTIDS foreground level has been reduced 6 dB from -36 to -42 dBm. This figure shows that four units (1, 6, 9, 11) failed the 3-dB criteria and one of these units (low altitude unit number 6) also failed the -79 dBm threshold.

Figures 5-7 and 5-8, which are for the ARMY scenario, show six units failed the 3-dB criteria at -36 dBm JTIDS and five units failed the 3-dB criteria at -39 dBm JTIDS. The magnitude of the failure is much greater from the Army scenario than the Air Force scenario. The other figures (figure 5-9 through 5-12) show that at least 50 percent of the units tested with the Navy and joint scenario also fail the -3 dB criteria.

The totality of the data shows the failure rate caused by 100/50 JTIDS of the delta 3 dB and -79 dBm threshold criteria is excessive. The conclusion is obvious. The FAA criteria as stated and the data presented from this test program indicate that the effect of JTIDS on TACAN/DME interrogators is excessive and 100/50 JTIDS uncoordinated operations should not be considered by the FAA.

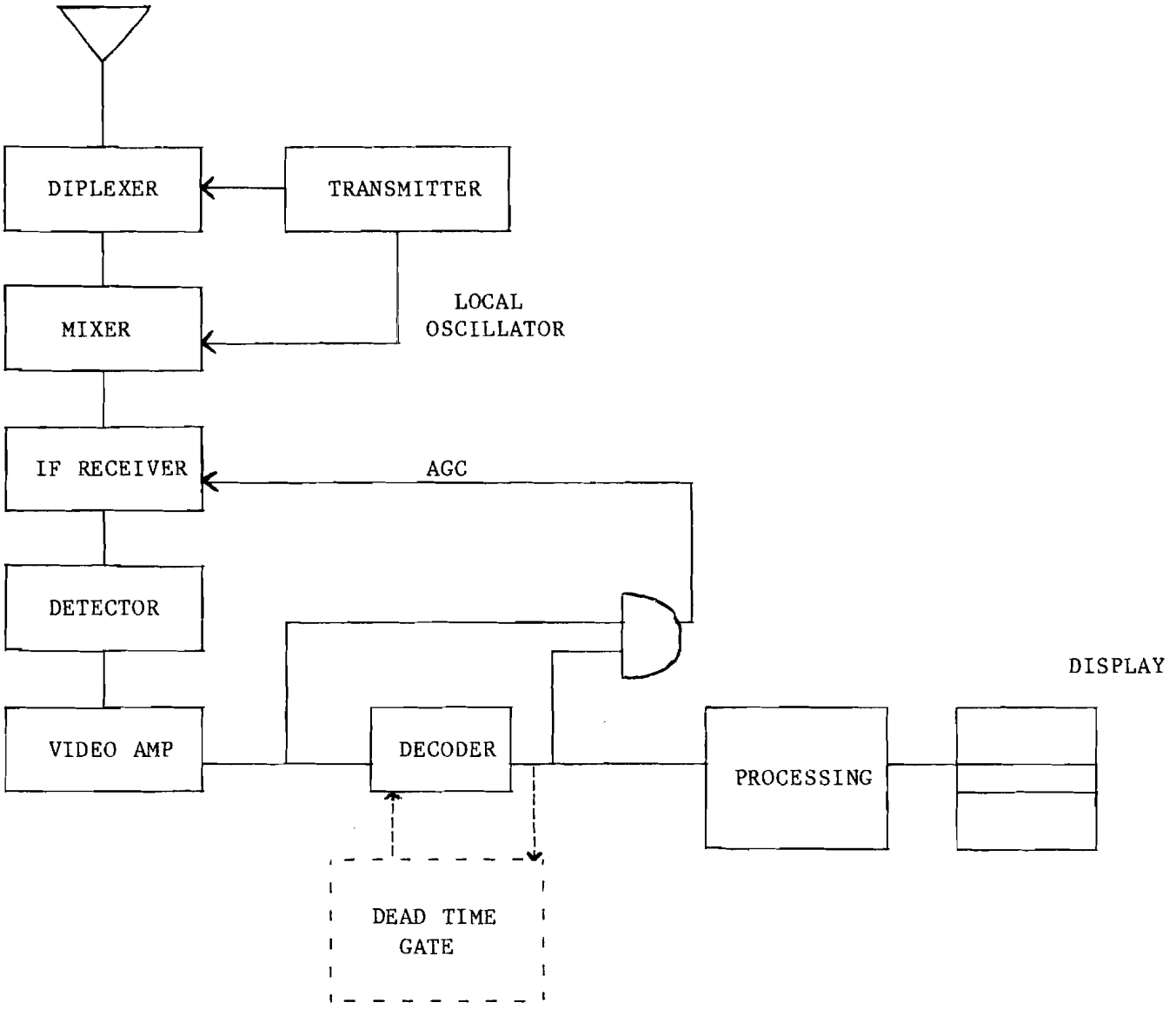


FIGURE 5-1. TACAN/DME RECEIVER

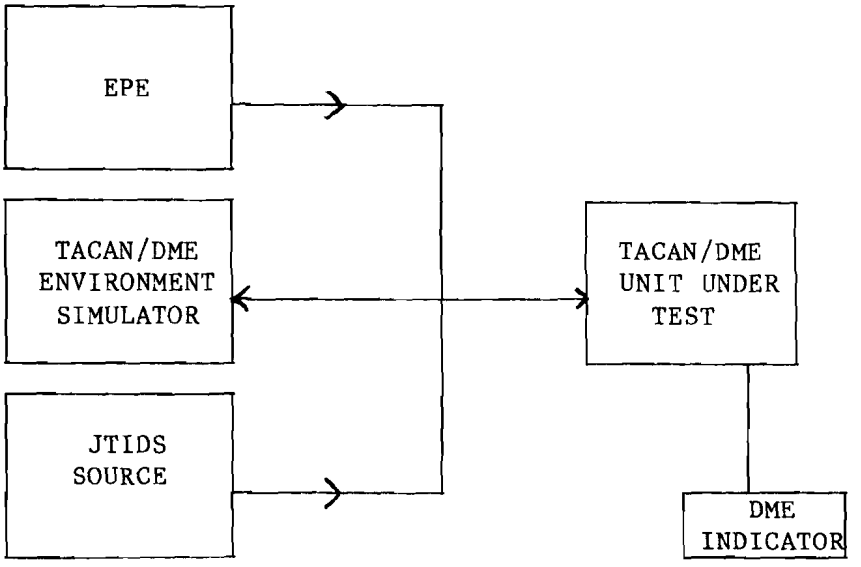


FIGURE 5-2. BASIC TEST CONFIGURATION FOR TACAN/DME INTERROGATOR TESTS

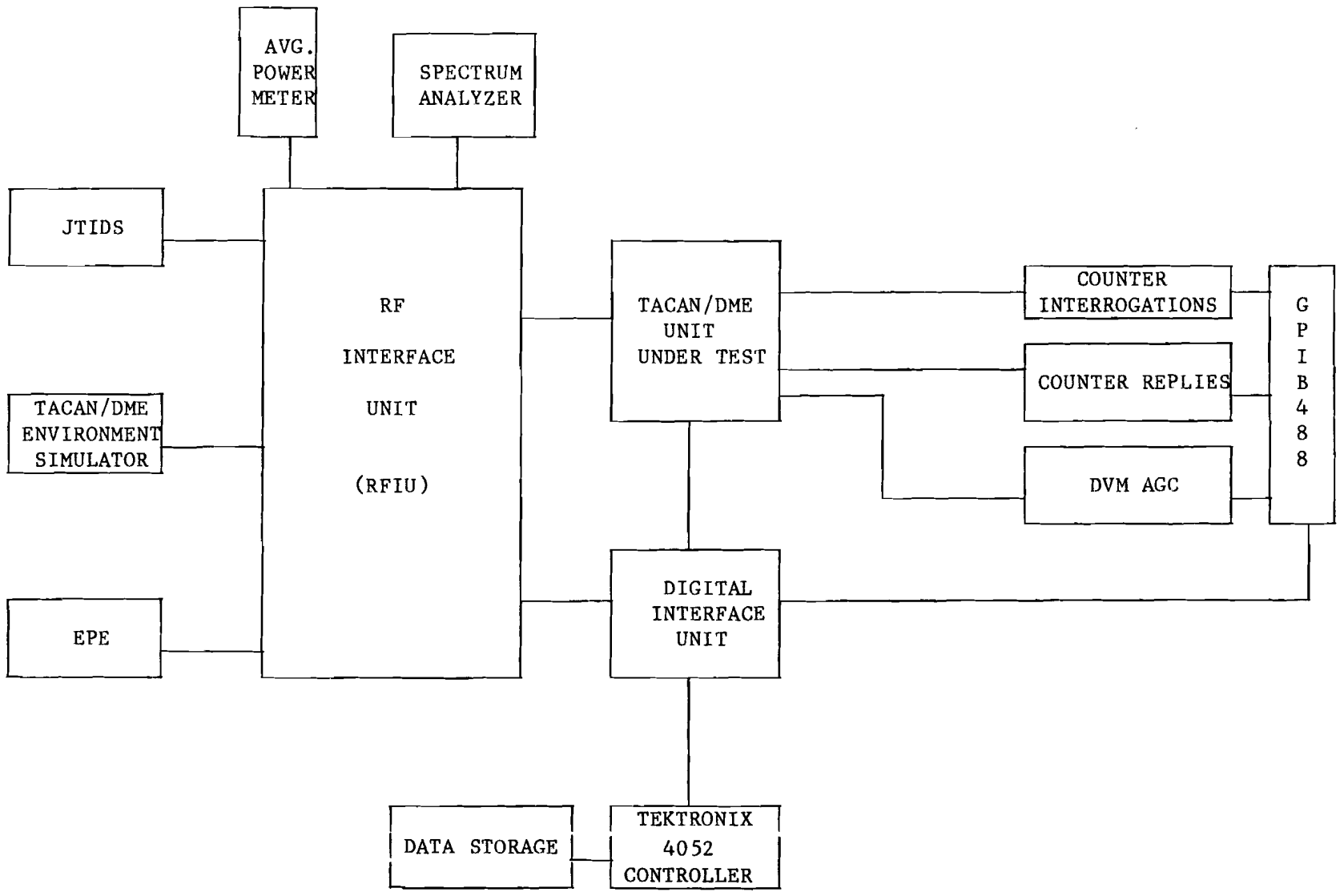


FIGURE 5-3. FUNCTIONAL BLOCK DIAGRAM TACAN/DME INTERROGATOR TESTS

NAVY
DMA-37A
EFFECTS
CHANNEL 32X

100/50
S/N 1215
ASOP (range)

Desired Signal: TACAN 2700 ppps 70% BRE
EPE Status: ON
Test Site: ECAC
Test Date: 16-JUL-86 13:13:5

JTIDS-On Data						JTIDS-Off Data					
JTIDS Level (dBm)	ASOP Mean (dBm)	ASOP Min (dBm)	ASOP Max (dBm)	Diff (dB)	N	JTIDS Off (dBm)	ASOP Mean (dBm)	ASOP Min (dBm)	ASOP Max (dBm)	Diff (dB)	N
-36	-87.5	-87	-88	1	2	-120	-88.0	-88	-88	0	3
-42	-87.0	-87	-87	0	2	-120	-87.3	-87	-88	1	3
-47	-87.5	-87	-88	1	2	-120	-87.7	-87	-88	1	3
-50	-87.5	-87	-88	1	2	-120	-87.7	-87	-88	1	3

JOINT
KN-63
EFFECTS
CHANNEL 32X

100/50
S/N 5054
ASOP (range)

Desired Signal: TACAN 2700 ppps 70% BRE
EPE Status: ON
Test Site: ECAC
Test Date: 13-AUG-86 13:42:2

JTIDS-On Data						JTIDS-Off Data					
JTIDS Level (dBm)	ASOP Mean (dBm)	ASOP Min (dBm)	ASOP Max (dBm)	Diff (dB)	N	JTIDS Off (dBm)	ASOP Mean (dBm)	ASOP Min (dBm)	ASOP Max (dBm)	Diff (dB)	N
-36	-71.8	-69	-75	6	5	-120	-80.5	-80	-81	1	4
-38	-71.5	-71	-72	1	2	-120	-79.7	-79	-80	1	3
-44	-73.4	-72	-75	3	5	-120	-80.5	-80	-81	1	4
-50	-75.2	-74	-76	2	5	-120	-81.0	-80	-82	2	4
-53	-76.6	-74	-78	4	5	-120	-80.5	-80	-81	1	4
-56	-78.2	-76	-79	3	5	-120	-80.0	-79	-81	2	4

FIGURE 5-4. DATA SAMPLE OF FINAL ASOP DATA RESULTS FOR JTIDS/TACAN DME INTERROGATORS

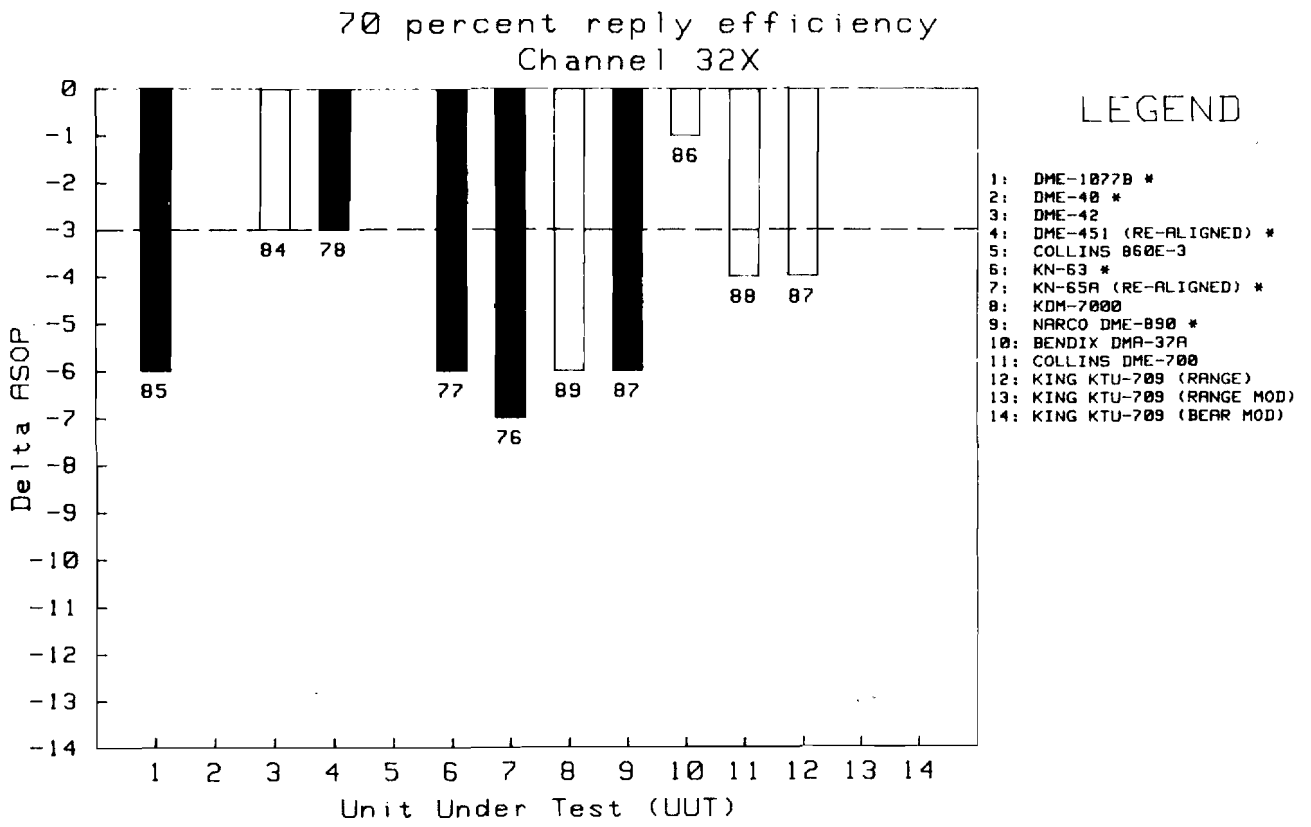


FIGURE 5-5. DELTA ASOP, AIR FORCE 100/50, -36 dBm JTIDS

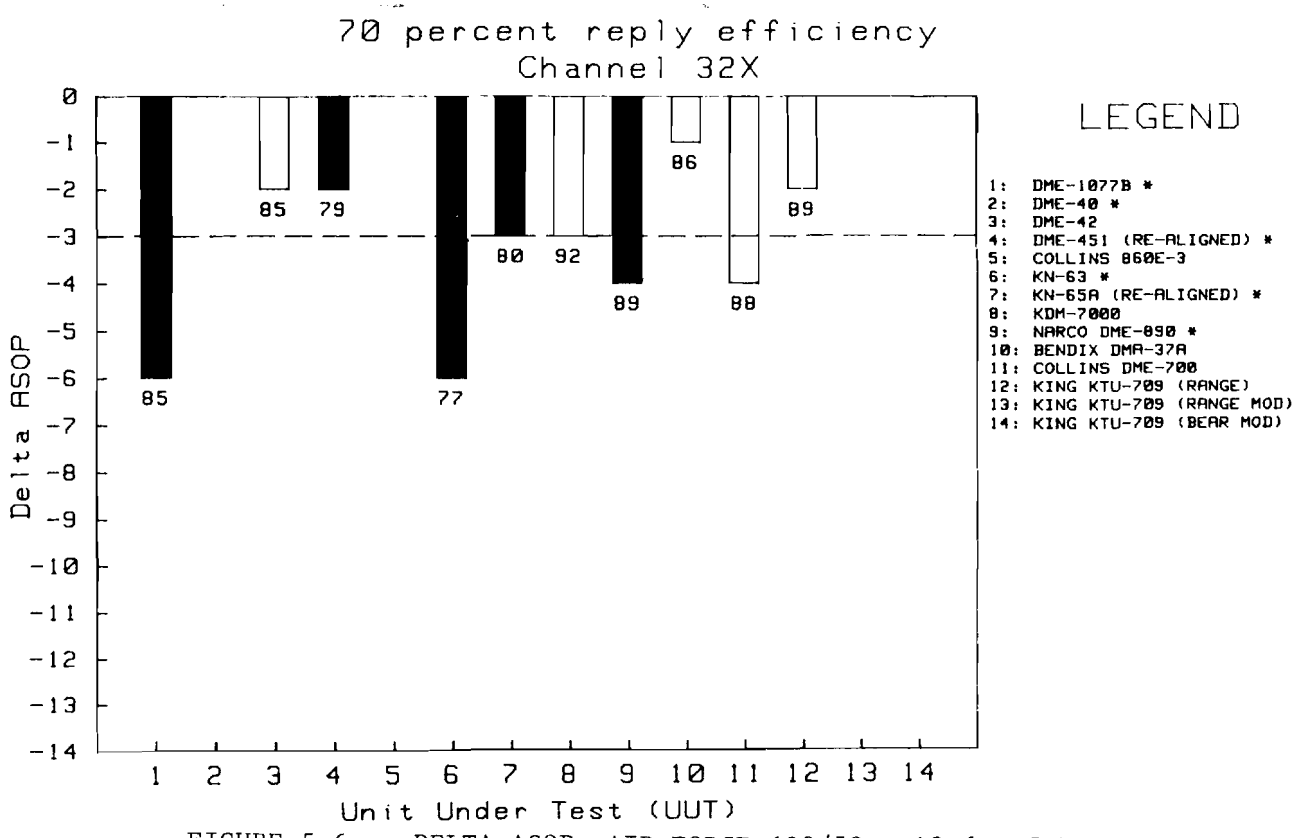


FIGURE 5-6. DELTA ASOP, AIR FORCE 100/50, -42 dBm JTIDS

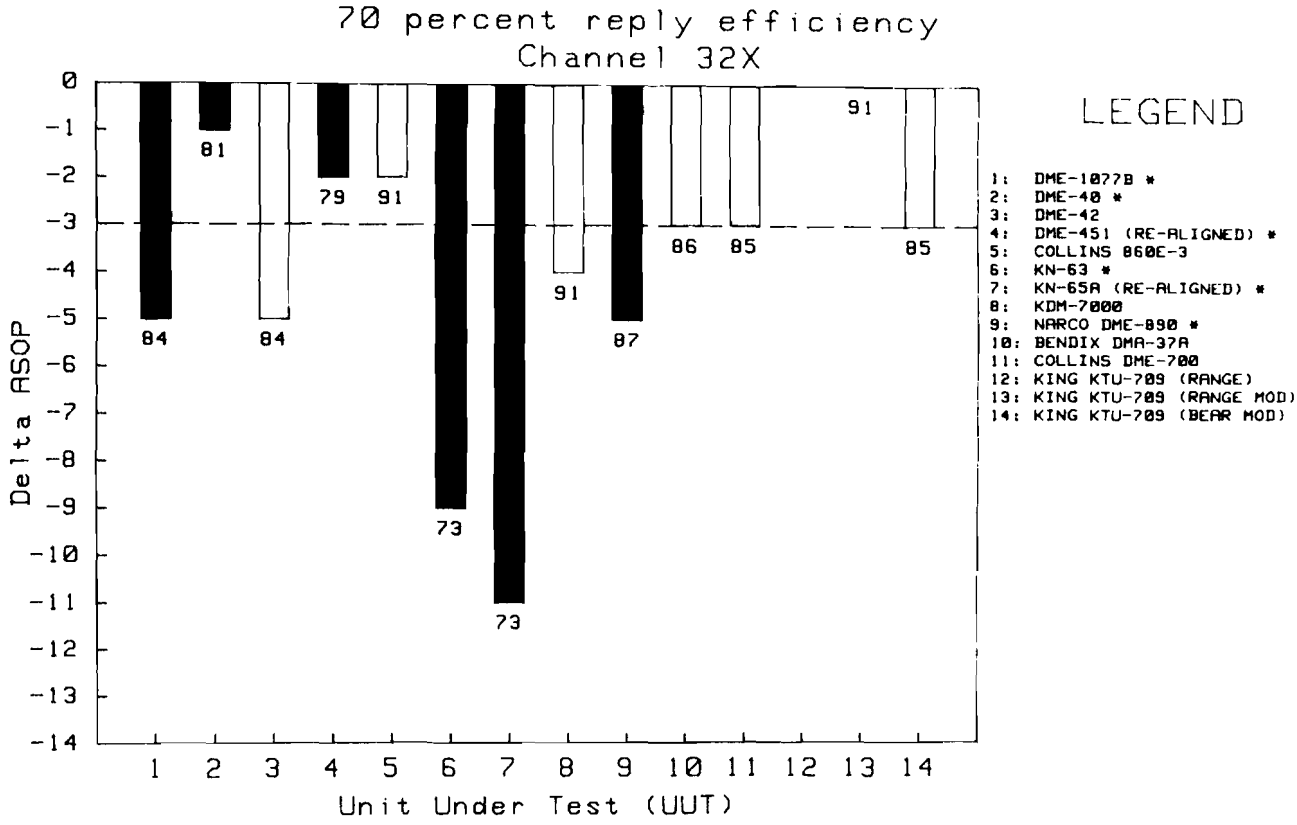


FIGURE 5-7. DELTA ASOP, ARMY 100/50, -36 dBm JTIDS

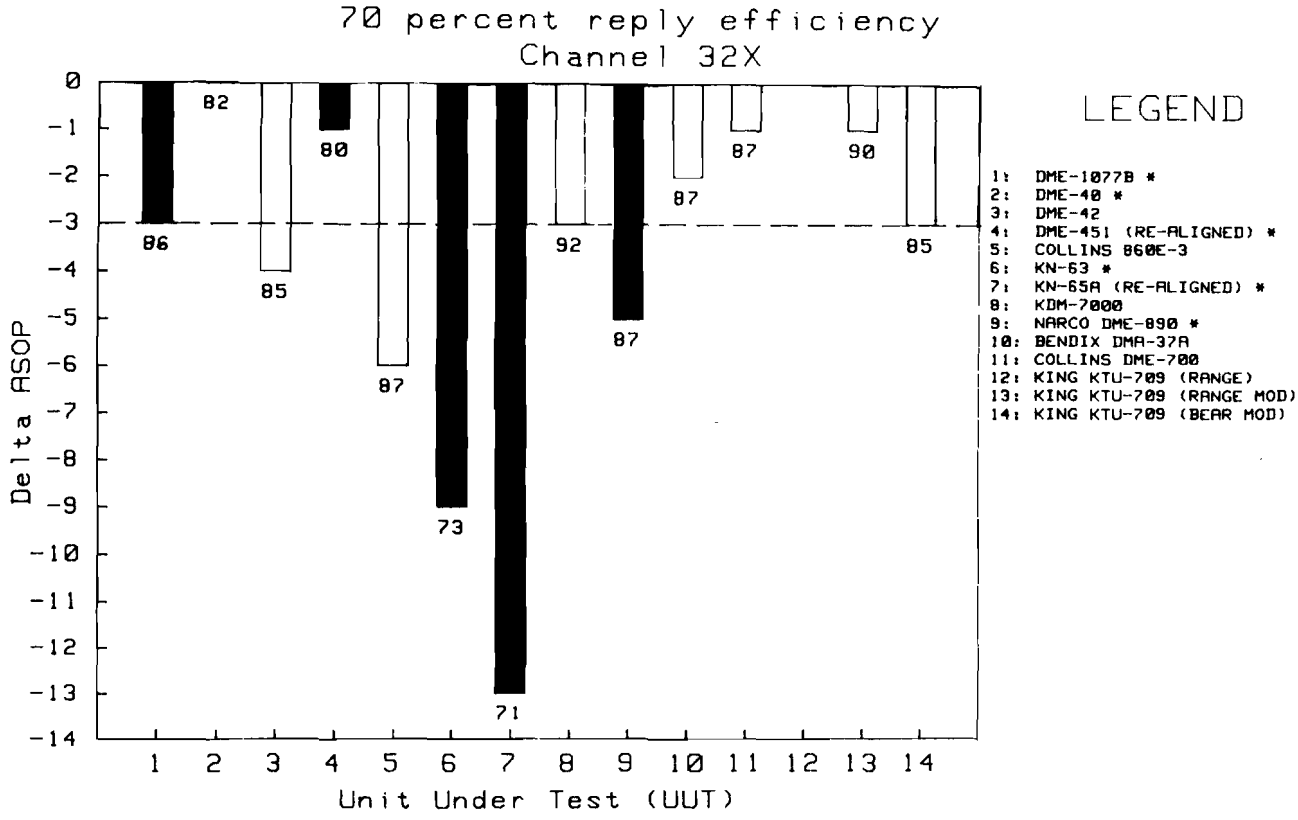


FIGURE 5-8. DELTA ASOP, ARMY 100/50, -39 dBm JTIDS

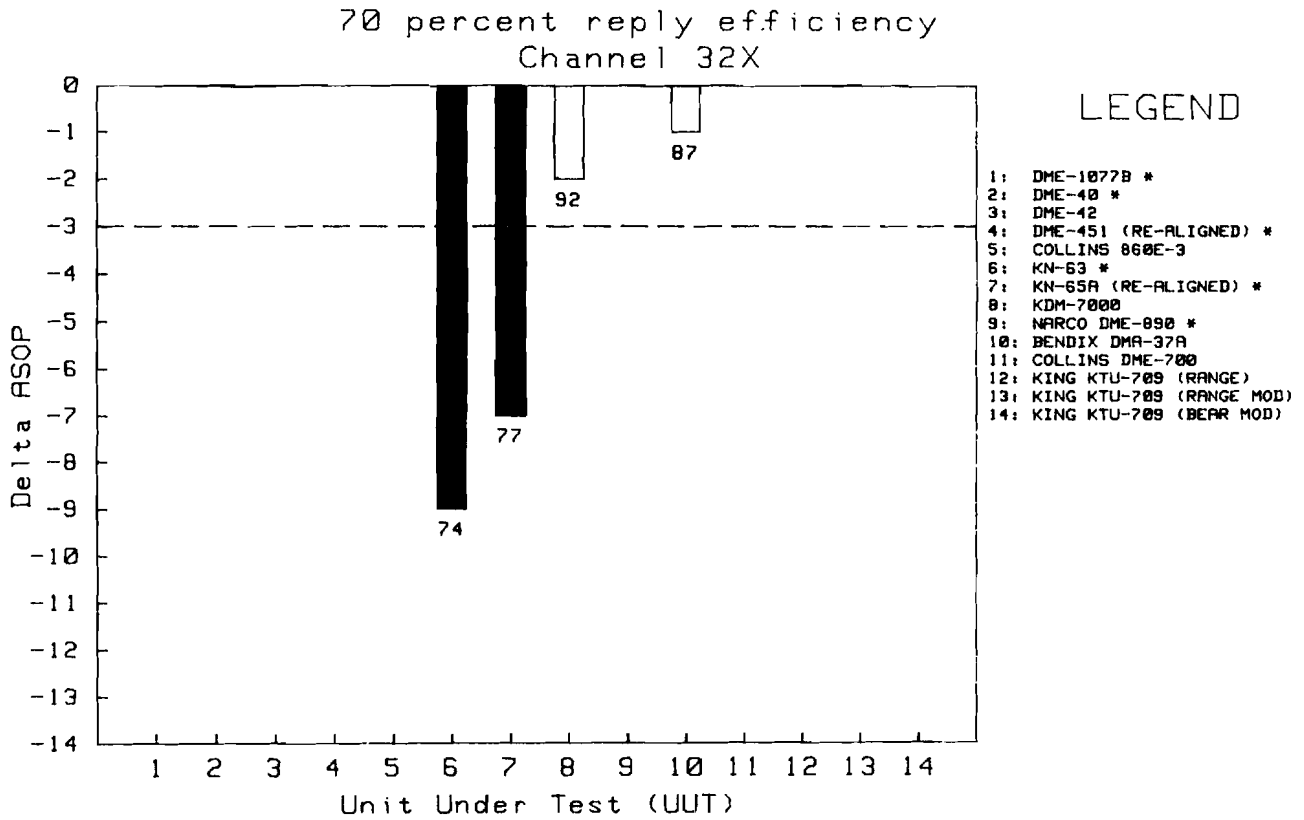


FIGURE 5-9. DELTA ASOP, NAVY 100/50, -36 dBm JTIDS

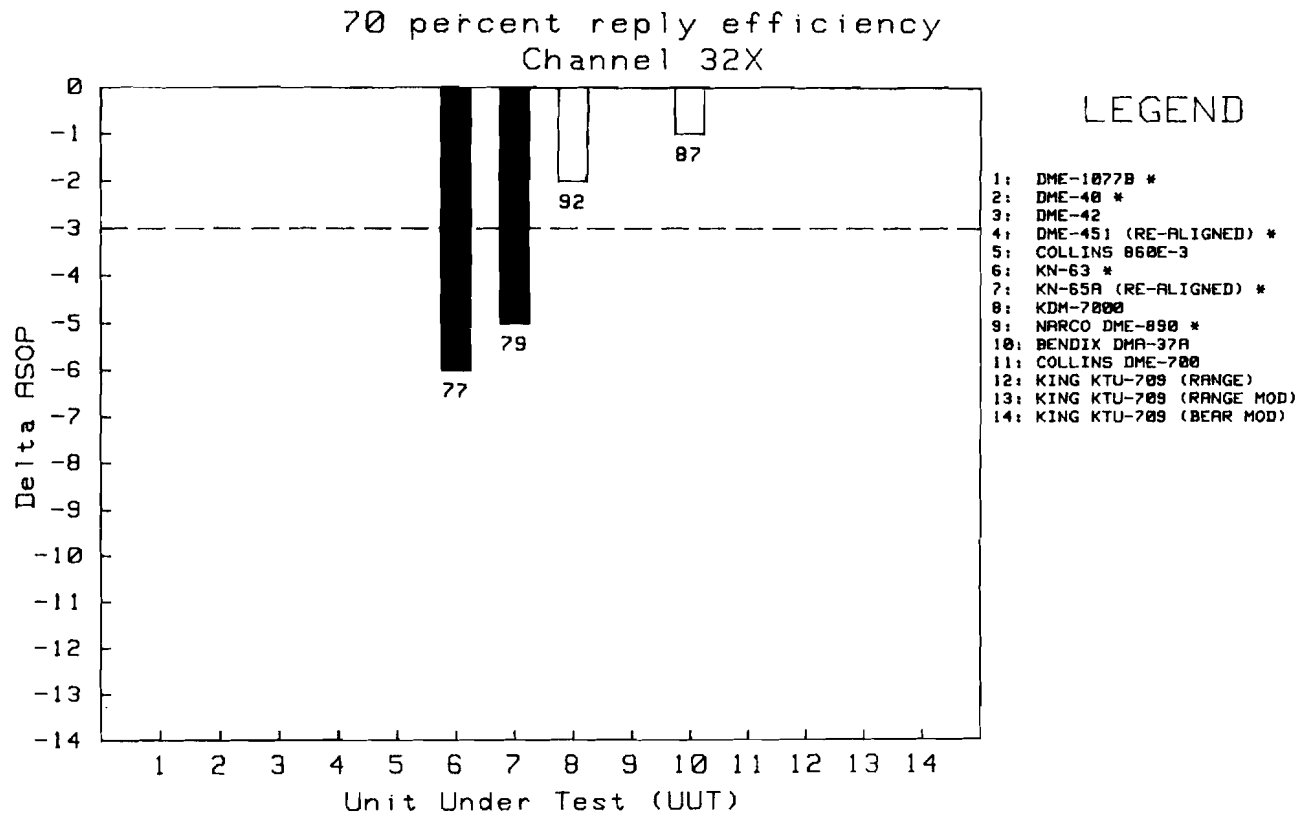


FIGURE 5-10. DELTA ASOP, NAVY 100/50, -42 dBm JTIDS

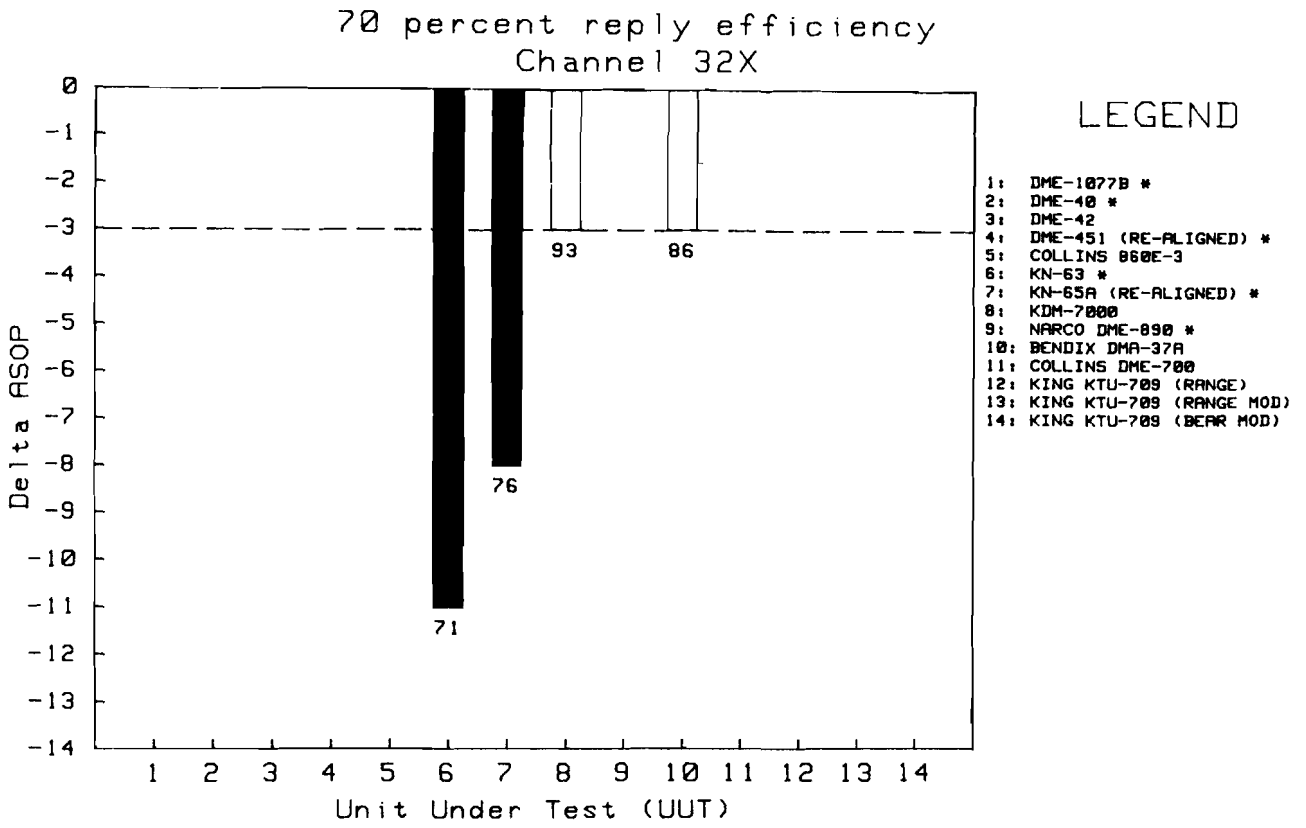


FIGURE 5-11. DELTA ASOP, JOINT 100/50, -36 dBm JTIDS

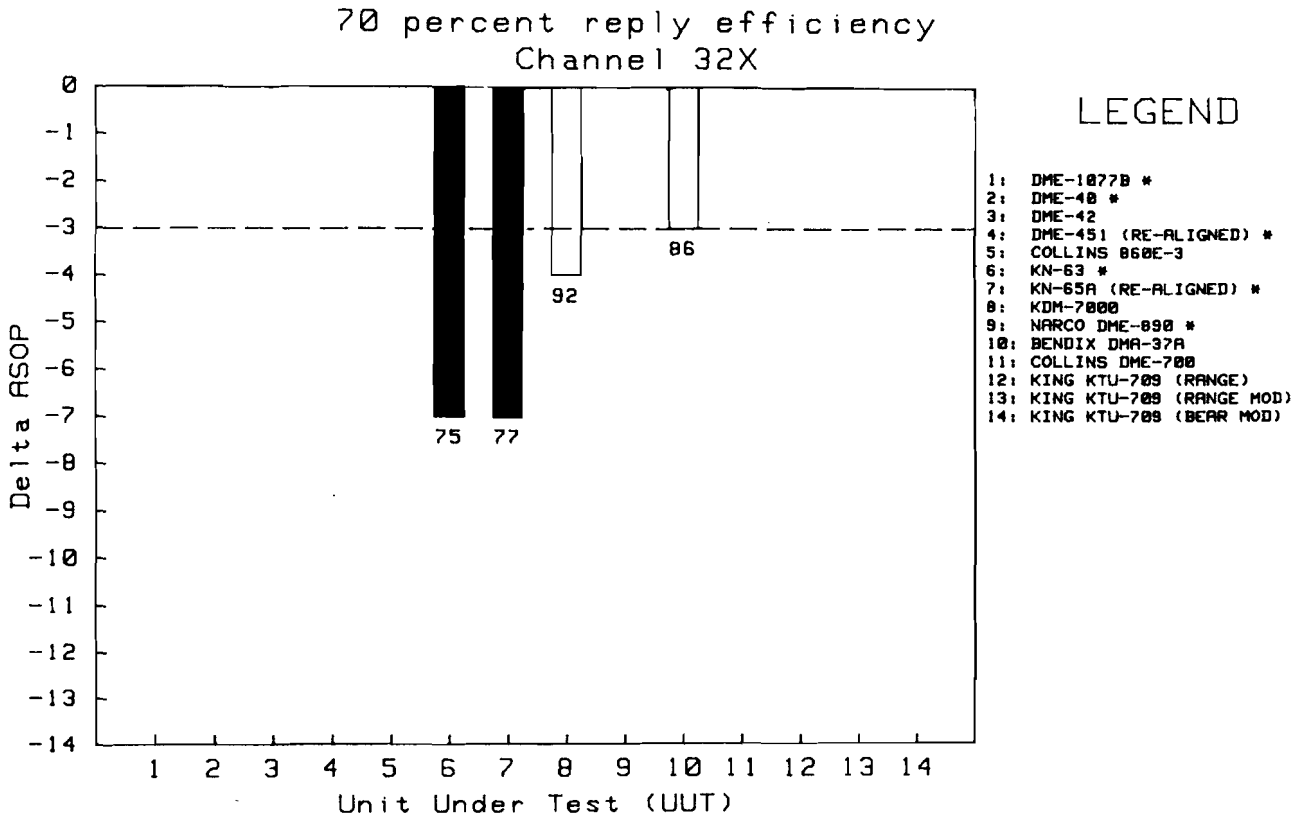


FIGURE 5-12. DELTA ASOP, JOINT 100/50, -39 dBm JTIDS

TABLE 5-1. PROPOSED TACAN/DME INTERROGATORS FOR JTIDS TESTS

Proposed TACAN/DME Interrogators For JTIDS Tests	
Cessna 1077B	Bendix DMA37A
Collins DME 40	Bendix DMS44A
Collins DME 42	Collins DME700
Collins DME 451	King KTU-709 (Commercial TACAN)
Collins 860E3	AN/ARN118 (Military TACAN)
King KN62	AN/ARN84 (Military TACAN)
King KN65A	King KDM7000
NARCO 890	

TABLE 5-2. LISTING OF HIGH AND LOW SERVICE VOLUME TACAN/DME INTERROGATORS

High-Level Service Volume (-84.5 DBM)	
Collins DME 42	Collins DME 700
Collins 860E3	King KTU-709
King KDM 7000	AN/ARN 118
Bendix DMA 37A	AN/ARN 84
Bendix DMS 44A	

Low-Level Service Volume (-79 DBM)	
Cessna 1077B	King KN 63
Collins DME 40	King KN65A
Collins DME 451	NARCO 890

TABLE 5-3. MINIMUM/MAXIMUM ASOP FOR JTIDS/TACAN DME INTERROGATORS

EQUIPMENT DESCRIPTION	AIR FORCE						ARMY						NAVY						JOINT					
	NJ		J-36		J-42		NJ		J-36		J-39		NJ		J-36		J-42		NJ		J-36		J-39	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
DME 1077B	90	91	85	87	85	88	88	89	84	85	86	86												
DME 40	--	--	--	--	--	--	--	--	--	--	--	--												
DME 42	86	87	84	85	85	86	87	89	84	85	85	86												
DME 451	--	--	--	--	--	--	--	--	--	--	--	--												
DME 451 (REALIGNED)	80	81	78	79	79	80	80	81	79	79	80	80												
860E-3	--	--	--	--	--	--	90	93	91	91	87	92												
KN 63	81	83	77	77	77	77	79	82	73	74	73	74	78	83	74	78	77	78	80	82	71	75	75	76
KN 65A	--	--	--	--	--	--	--	--	--	--	--	--												
KN 65A (REALIGNED)	83	83	76	77	80	81	82	84	73	75	71	77	83	84	77	78	79	82	83	84	76	80	77	81
KDM 7000	94	95	89	89	92	92	94	95	91	92	92	92	93	94	92	93	92	93	96	96	93	93	92	94
DME 890	91	93	87	89	89	89	91	92	87	87	87	88												
DME 37A	86	87	86	86	86	87	88	89	86	86	87	88	87	88	87	88	87	87	87	89	86	88	86	88
DME 700	90	92	88	89	88	89	87	88	85	87	87	88												
KTU-709 RANGE	90	91	87	88	89	89	--	--	--	--	--	--												
KTU-709 RANGE (MOD)							90	91	91	91	90	91												
KTU-709 BEAR. (MOD)							87	88	85	86	85	86												

6. SUMMARY OF RESULTS.

The ATCRBS and TACAN/DME ground systems were tested using scenarios with various capabilities of the class 2 Joint Tactical Information Distribution System (JTIDS) terminal. Single, double, and 10-net configurations using standard and packed timeslots with various percentages of contention were tested. The TACAN/DME airborne systems were tested using four separate operational scenarios (Air Force, Navy, Army, Joint (Air Force/Army). The ATCRBS/Mode S airborne systems were tested using a single, 50-percent foreground JTIDS source.

The test data collected to determine the effects of 100/50 timeslot, -60 decibels below carrier (dBc) noise floor JTIDS on the FAA L-band systems indicated the following:

1. The FAA criterion for the ATCRBS ground system is satisfied provided the JTIDS 50-percent foreground user does not exceed -20 dBm input level to the ATCRBS receiver.

2. The FAA criteria for the ATCRBS/Mode S transponder is satisfied for a 200-watt effective radiated power JTIDS terminal-equipped aircraft maintaining a 1000-foot vertical separation from other ATC aircraft. Data indicate a concern for co-site JTIDS/ATCRBS/Mode S installations, as the JTIDS input level must remain below -30 dBm to the ATCRBS/Mode S receiver to pass the FAA criteria.

3. The results of this report validate the SPS WG-1 84-1 analysis report. The analysis report shows that JTIDS signal levels will be below the minimum sensitivity of ATCRBS/Mode S transponders and TCAS receivers under worst-case signal coupling conditions between JTIDS- and ATC-equipped aircraft.

4. The FAA criterion for TACAN/DME ground systems is satisfied for JTIDS levels up to -36 dBm where the TACAN/DME system maintains a quiescent 80-percent reply efficiency. The data also show that where a TACAN/DME ground system is handling a large DME load (reply efficiency at or below 75 percent), JTIDS fails the FAA criterion for all JTIDS levels tested.

5. The FAA criteria for TACAN/DME airborne units is not satisfied. At the worst-case signal coupling condition, seven of the ten TACAN/DME units tested fail the FAA criteria when using the Air Force JTIDS operational scenario.

DJA/J. Smithmyer

FAA Technical Center 13 August 1986

ATTN: George Hartranft - Test Director

SUBJECT: Interrogator Modification/Realignment/Repair Information

1. In response to a request from the Data Review Committee, information on the alignment, repair, and modification of the various DME interrogators being used in the JTIDS test program is being provided. The purpose of this letter is to summarize the history of that work. Four topics are addressed in this letter: a) the status of the Bendix/King DMS-44A, b) other interrogators that were modified by the manufacturer, c) interrogators that were realigned by the manufacturer and d) a brief summary of other interrogator repairs.

2. The Bendix/King DMS-44A.

a. The 44A was a new design when initially identified by RTCA for this test program. Parts of the maintenance manual are still not available. Initial testing, at ECAC in the absence of JTIDS signals, revealed that some range measurement data was being lost due to the processing of the three channel data in a shared processor. As a result of technical interchange discussions with Bendix engineers, Bendix requested the 44A to be returned to Bendix on two different occasions for software and hardware modifications. After the most recent modifications (March 1986), the 44A failed the TSO C66a tests, which it had previously passed. Upon contacting Bendix/King representatives, it was discovered that many of the modifications which had been discussed verbally, had not been incorporated and the interim software modifications which were installed were not complete.

b. It was during this time frame that a representative of King Radio took over responsibility for the 44A. His investigations into the 44A problems have lead him to undertake a substantial effort on redesigning the unit. The 44A is not planned to be released by King in a form which passes TSO until December 1986, whereupon we can return our 44A to King for modification. Therefore, it is impractical to include it in the Phase I test program. Recommend, the 44A be tested in the initial part of the Phase II program along with the two military interrogators.

3. Other modified interrogators.

a. Two other interrogators have been modified by the manufacturer as a result of not meeting their advertised specifications. They are the King KDM-7000 and KTU-709. The KDM-7000 was found to not conform to ARINC 568, paragraph 4.18.2, "Performance Degradation." This is a test of receiver sensitivity in the presence of on channel, off-code pulses. After technical discussions, King Radio modified the KDM 7000 in February 1985. They immediately incorporated the modificaion in their production line and published a Service Aid in April 1986 (see Attachment 1).

b. The King KTU-709 was found to not conform to RTCA DO-151A, paragraph 2.9.c, which prescribes the required sensitivity in the presence of on-channel, off-code pulses. Preliminary manual mechanisms tests revealed that an earlier King modification to the CW AGC circuit was creating a problem. Technical discussions were held with King representatives and they decided to modify the KTU-709 in January 1986. The modifications have been instituted in the production line and a service bulletin is expected to be published later this year.

4. Realigned interrogators.

a. A careful examination of the checkout data uncovered the fact that the Collins DME-451 was not meeting its specifications. When the checkout was initially performed, the marginal performance on the breaklock specification of TSO C66a, Section 2.9, receiver sensitivity, was considered and a decision was made to continue testing the unit. Upon reexamination of the data and technical discussions with Collins engineers, the decision was made by Collins that the unit was not operating properly and the 451 was sent back to Collins for realignment in May 1986. After realignment, the unit passed the specification and it was retested.

b. The King KN-65A, S/N 20174, was discovered to have an unusual AGC response, as compared to other KN-65As (see Attachment 2). After technical discussions with King Radio, they requested the unit to be sent back for realignment in January 1986. The anomalous AGC alignment was corrected by King Radio and the unit was retested.

5. A brief summary of interrogator repairs.

a. King KN-63, grounding problem

b. King KTU-709, bearing indicator

c. Narco 890, VCO control

d. King KDM-7000, several repairs

e. Collins 860 E3, several repairs

f. Cessna 1077B, power supply

g. Collins DME-40, distance indicator

h. To summarize the repair situation, we do some of the repairs ourself and sometimes we send the units to the manufacturer. Considering the long period of time these interrogators are operating during the tests, this is to be expected.

6. This letter provides the initial documentation of the current DME interrogator modification/realignment/repair situation. A briefing is being developed to provide the engineering details of the modifications and realignments.

Jack Smithmyer
Manager
JTIDS

2 Attachments
1. KDM-7000 Service Aid, 10 Apr 86
2. KN-65A AGC Response Curves