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JTIDS Electromagnetic Compatibility in the 960-1215 MHz Band

By

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13. ABSTRACT (Maximum 200 words)

The Joint Tactical Information Distribution System (JTIDS) operates in the 960-1215 MHz frequency band. This band is allocated world-wide on a primary basis for aeronautical radio navigation. JTIDS was designed to be electromagnetically compatible with the Air Traffic Control systems that operate in this band. Over the past 15 years, extensive bench tests, flight tests, and analyses were conducted to assess the electromagnetic compatibility (EMC) of JTIDS in the 960-1215 MHz band. This report summarizes the results and conclusions of these efforts, presents some supporting data and provides specific guidance for the operation of JTIDS within the National Air Space. Guidance and recommendations are also provided to assist in the definition and scope of a JTIDS EMC test and analysis effort.

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TABLE OF CONTENTS

SECTION **PAGE**

SECTION **PAGE**

LIST OF ILLUSTRATIONS

FIGURE **PAGE**

LIST OF TABLES

TABLE **PAGE**

SECTION 1

INTRODUCTION

1.1 JTIDS PROGRAM BACKGROUND

The Joint Tactical Information Distribution System (JTIDS) provides totally integrated communications, navigation, and identification (ICNI) capabilities. This system operates in the 960-1215 megahertz (MHz) band, which is allocated on a primary basis worldwide for the aeronautical radionavigation service. JTIDS was specifically designed to be electro-magnetically compatible with radionavigation systems in that frequency band. JTIDS employs spread spectrum modulation (frequency hopping and direct sequence modulation) techniques that promote electromagnetic compatibility (EMC). It hops on 51 uniformly spaced carriers in three subbands from 969 to 1206 MHz. Some JTIDS terminals have an integrated Tactical Air Navigation (TACAN) capability.

Currently there are two general classes of JTIDS terminals. Both classes of terminals have the same emission requirements. JTIDS Class 1 terminals are used in large-scale airborne and surface command and control systems. JTIDS Class 1 terminals are out of production and are installed in all United States and NATO E-3 airborne warning and control systems and in the Adaptable Surface Interface Terminal (ASIT) which are deployed throughout the world. Each rack mounted Class 1 terminal weighs about 400 pounds (181 kg) and occupies a volume of 6.5 ft^3 (0.18 m^3). The Class 1 terminal can transmit at 200 watts (W) or 1000 W. JTIDS Class 2 terminals are intended for use in small mobile command and control (C^2) elements and non-command and control elements, such as weapons systems. Class 2 terminals are in the low rate initial production (LRIP) phase. The Class 2 terminal occupies a volume of 1.56 ft^3 (0.05 m^3), weighs 125 pounds (56.7 kg) and transmits at 200 W.

The JTIDS Class 2H terminal is a Class 2 terminal with a high power capability. The Class 2H terminal is in currently in full scale development (FSD) and LRIP. Higher power is accomplished by the addition of a separate high power amplifier group (HPAG). The HPAG can transmit at 200 W or 1000 W and occupies a volume of 1.5 ft^3 (0.04 m^3) and weighs 88 pounds (39.9 kg). The Class 2H terminal is intended for use in ship, large airborne and surface C^2 elements.

The JTIDS Class 2M terminal for the Army is a ground-based terminal which is tailored for ground-to-ground communications. The JTIDS Class 2M terminal is currently in FSD. Each Class 2M terminal weighs 87 pounds (39.5 kg) and occupies a volume of 1.5 ft^3 (0.04 m^3). Class 2M terminals transmit at 200 W or 42 W.

France, Germany, Italy, Spain, and the United States are cooperatively developing a more compact JTIDS terminal, known as the Multifunctional Information Distribution System (MIDS) Low-Volume (LV) terminal or Class 2 LV terminal. This terminal will implement the requirements of NATO Standardization Agreement (STANAG) 4175, which is based on the JTIDS Class 2 terminal specification. The FSD contract is expected to be released in March 1992.

The expected volume of the MIDS LV terminal is 0.6 ft^3 (0.017 m^3), and its specified weight is 66 pounds (30 kg). These are 65 and 47 percent reductions, respectively, from the Class 2 terminal. The platforms on which the Terminal will be installed include the F/A-18, Rafale, German Tornados, and European Fighter Aircraft (EFA) fighter aircraft, French and Italian ground C^2 sites, and French ships.

1.2 JTIDS ALLOCATION STATUS

1.2.1 United States

The Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA) share responsibility for spectrum management in the United States The FCC, in accordance with the Communications Act of 1934, regulates the spectrum for all users other than those within the federal government. Figure 1-1 graphically shows this. The NTIA, a Department of Commerce (DOC) agency, accomplishes this function for federal systems. The Interdepartment Radio Advisory Committee (IRAC) assists the NTIA in their assigning of frequencies to United States government radio stations, and in developing and executing policies, programs, procedures, and technical criteria pertaining to the allocation, management, and use of the spectrum. The IRAC is composed of members from throughout the government, including representatives from the military services. These agencies provide direct representation from all affected spectrum users.

The Spectrum Planning Subcommittee (SPS) of the IRAC performs reviews of many systems at the national level for the civil authorities. These reviews are conducted to provide an appraisal of the current and future needs of the various radio services and make recommendations to the IRAC for changes in the Table of Frequency Allocations. These reviews are based in part on 1) the optimum placement of radio services with a view to the most effective use of the spectrum, 2) the anticipated needs of users in the future, 3) new developments, 4) new techniques, 5) new services, 6) the promotion of EMC. JTIDS is one of the systems under review. However, the NTIA retains the final decision on spectrum support for JTIDS.

Because the Federal Aviation Administration (FAA) had concerns with the implementation of JTIDS, the NTIA established SPS Working Group-1 (SPS WG-1) within the present structure of the SPS. Figure 1-2 shows the relationship of the agencies involved in JTIDS spectrum support. The SPS WG-1 is composed of four working groups

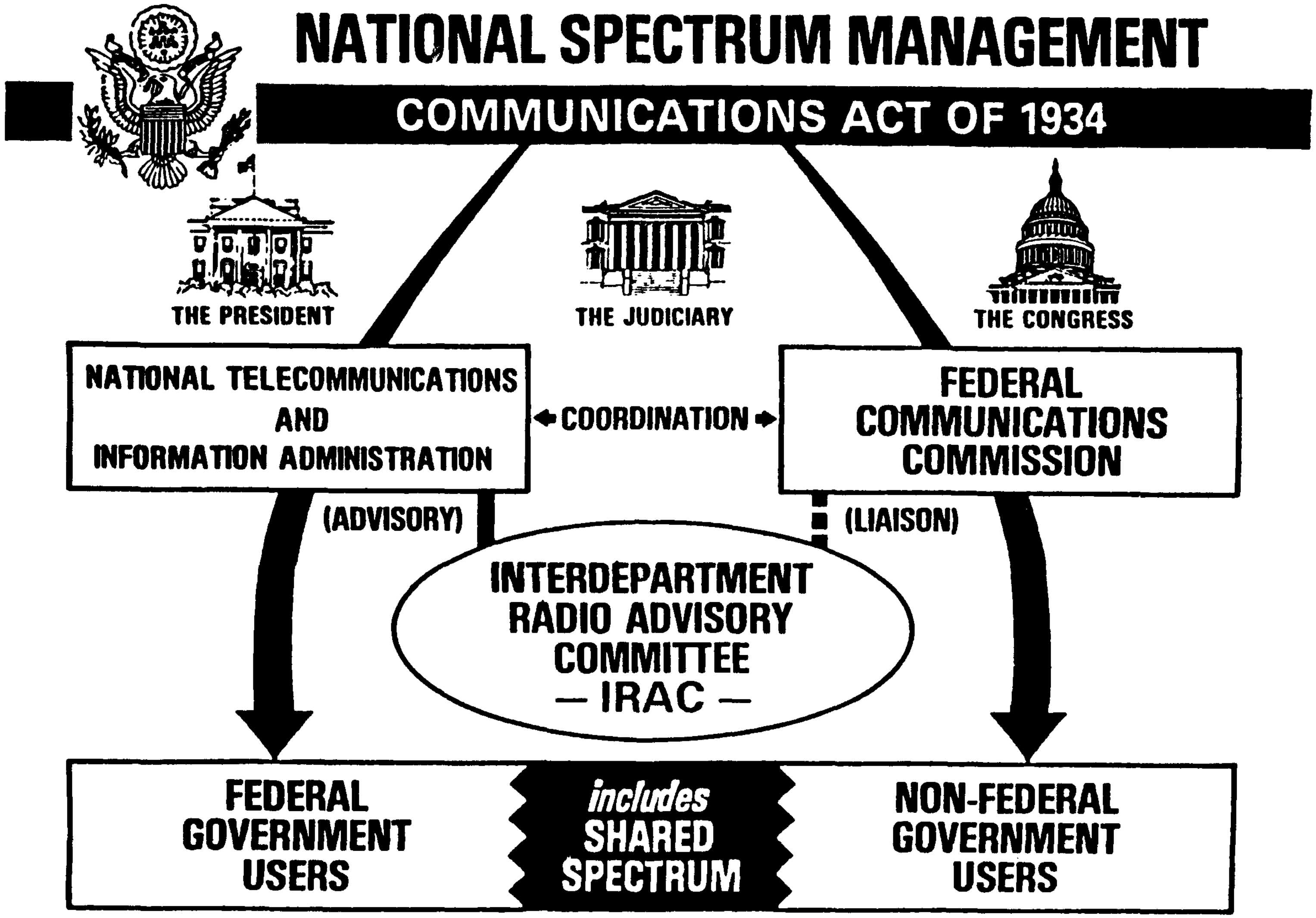

Figure 1-1. Spectrum Support Authority in the United States

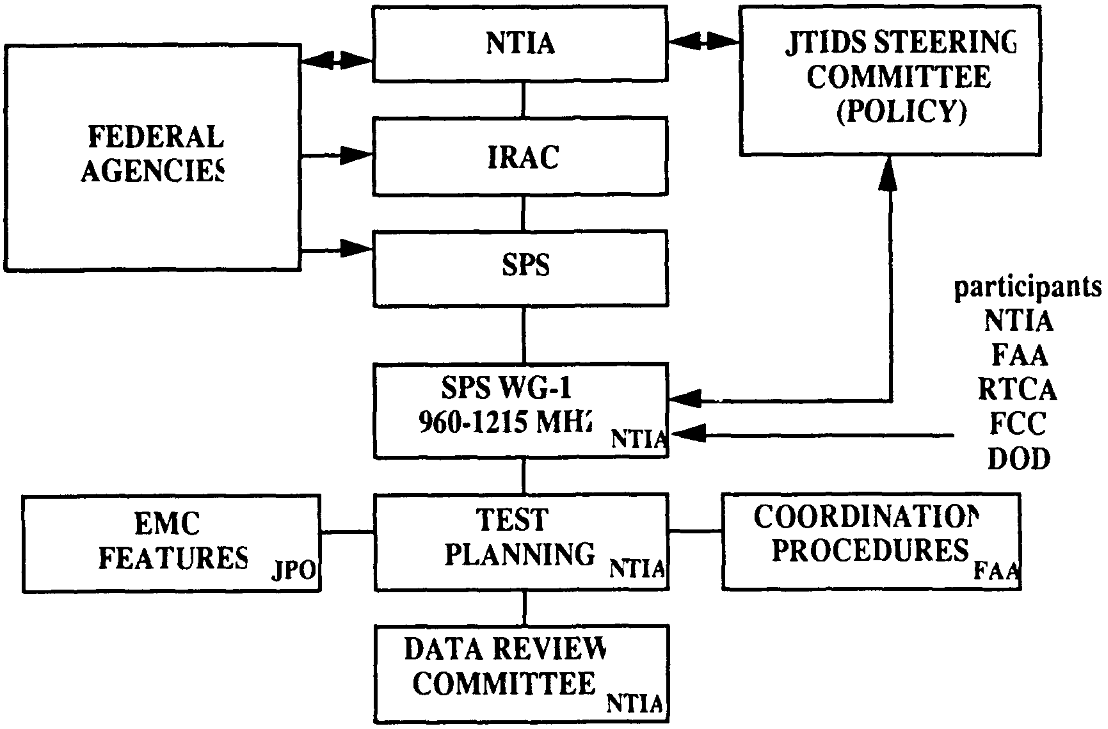

Figure 1-2. JTIDS Spectrum Support in the United States

where users of 960-1215 MHz band discuss their concerns and gather information to evaluate the potential for JTIDS interference. The Test Planning Sub Working Group (TPSWG) writes all the test plans, oversees the collection of data and analyzes and evaluates data and analysis. The Data Review Committee (DRC) assists the TPSWG in the preparation of reports, and reviews the data for correctness. The EMC Features Sub Working Group (EFSWG) reviews JTIDS terminal hardware for compliance with the allocation restrictions. The Coordination Procedures Sub Working Group (CPSWG) establishes the methods of controlling JTIDS day-to-day operations.

1.2.1.1 40/20 TSDF

A JTIDS EMC Test and Evaluation (T&E) program was conducted during 1976 and 1977 and an extensive report was developed (reference 1). As a result of reviews by the NTIA and the FCC, an operational frequency allocation in the 960-1215 MHz band was approved for JTIDS terminals to operate at a time slot duty factor (TSDF) of 40/20[a] using standard 258-pulse messages. Certification for spectrum support for the JTIDS waveform was granted on 6 December 1979 on the condition that harmful interference[b] will not be caused to the Aeronautical Radionavigation Service. The spectrum support provisions for JTIDS are contained in IRAC Document 21167 (reference 3 and appendix A). The United States Table of Frequency Allocations was amended by footnote US224, which authorized the use of government systems utilizing spread spectrum techniques for terrestrial communication, navigation, and identification to operate in the 960-1215 MHz band.

In addition to limiting a single terminal's transmissions to 20 percent of the time slots, the 40/20 TSDF allocation stipulates that the Terminal output power be limited to a nominal 200 W, no more than one assigned transmitter in any time slot, and individual terminals are prohibited from transmitting in adjacent time slots. In addition, the Terminal must monitor its transmissions and inhibit transmission if 1) the frequency hopping mode fails to distribute the JTIDS spectrum uniformly across the band, 2) the radiated pulse varies from the specified width of 6.4 microseconds ± 5 percent, 3) the energy radiated within ± 7 MHz of 1030 and 1090 MHz exceeds a level of 60 dB below the peak of JTIDS spectrum as measured in a 300 kHz bandwidth. Terminal emissions are monitored by hardware and software EMC features built into the JTIDS terminal.

New JTIDS terminal types cannot operate under the 40/20 allocation until NTIA certifies that the new Terminal design is in compliance with the allocation. This is accomplished by a demonstration of the Terminal hardware EMC features and operational controls.

The Class 1 terminal was granted spectrum support certification in December 1982. Certification of the Class 1 terminal allows this particular terminal type to be operated in accordance with the 40/20 TSDF frequency allocation. The Class 2 terminal was granted spectrum support certification in August 1989. The 2H terminal was demonstrated to the NTIA for operation under the 40/20 TSDF allocation in March 1991. The 2M terminal will be demonstrated to NTIA in the 2nd or 3rd quarter of 1992.

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[a] The 40/20 time slot duty factor notation specifies that the total JTIDS community will not transmit in more than 40 percent of the total time slots using standard 258-pulse messages [maximum of 615 time slots(158,670 pulses) each 12-second period] and that contributions from a single user will not exceed 20 percent [maximum of 308 time slots (79,464 pulses) each 12-second period].

[b] Harmful interference is defined in reference 2, Chapter 6, Definitions and Particulars of Assignments, as "Interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radio communication service operating in accordance with these regulations. (RR)"

1.2.1.2 100/50 TSDF

The DOD determined that the current 40/20 TSDF allocation was insufficient to support projected daily routine training exercises. In September 1984, the NTIA agreed to plans for evaluating an expanded allocation request for 100/50 TSDF[a]. The requested 100/50 TSDF allocation includes all the JTIDS capabilities and operating modes (see section 2 for details on the JTIDS capabilities).

To assist NTIA in rendering their decision on the requested 100/50 allocation, a 100/50 TSDF T&E program was established. The 100/50 T&E program is addressing the capabilities not covered during the 40/20 TSDF program, such as multinet operation, contention access and 444-pulse messages. The DOD has stated that they require a 100/50 TSDF allocation by June 1992, and the T&E program is structured to provide most of the needed data by June 1992. Section 1-3 expands on the activities performed during the 40/20 and 100/50 T&E programs.

1.2.2 North Atlantic Treaty Organization (NATO)

Each individual nation is responsible for granting an allocation for JTIDS operations within their country. Guest forces are required to comply with the host country's JTIDS allocation.

JTIDS testing began in the United Kingdom (U.K.) in January 1980 and continued until January 1984. Testing in the Federal Republic of Germany started in September 1981 and was completed in December 1982. These efforts and United States test data supported a JTIDS spectrum support request for a 40/20 TSDF allocation in NATO countries. Spectrum support requests for NATO-operated JTIDS were evaluated by the committee for European Airspace Coordination (CEAC), Working Group on Communication and Aeronautical Navigation Aids (COMNAV). The Shape Technical Center (STC) analyzed the supporting data. In October 1982, COMNAV recommended that the nations consider acceptance of a 40/20 TSDF allocation with the same constraints as the United States allocation, applicable only to E-3 and ground based terminals using Class 1 terminals.

In 1984 COMNAV recommended that the nations consider expanding the JTIDS allocations to allow 100/50 TSDF operations for NATO E-3 and ground based terminals. The suggested expansion did not permit any increase in JTIDS capabilities just an increase in the transmitted TSDF. The United Kingdom, Belgium, Denmark, France, Germany, Greece, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain and

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[a] The 100/50 time slot duty factor notation specifies that the total JTIDS community will not transmit in more than 100 percent of the total time slots using standard 258-pulse messages [maximum of 1536 time slots (396,288 pulses) each 12-second period] and that contributions from a single user will not exceed 50 percent [maximum of 768 time slots (198,144 pulses) each 12-second period].

Turkey amended their JTIDS allocations to permit 100/50 TSDF operations. The specific restrictions relating to JTIDS operations vary among countries.

As a result of MIDS LV terminal development, many nations are conducting a T&E program to support the anticipated needed expansion of their JTIDS allocation. The U.K., Germany, Italy and France have initiated efforts in defining the scope of their test efforts. Through the Multination Ad Hoc MIDS/JTIDS Spectrum Support Working Group (MNWG), the United States lends technical assistance and provides United States test data to countries that participate. The MNWG was formed to provide an open informal forum to discuss issues that concern JTIDS testing, network management and Air Traffic Control (ATC) system developments. The MNWG does not report to any organization and participation is on a voluntary basis. Appendix B contains the charter of the MNWG.

1.3 JTIDS TEST AND EVALUATION PROGRAM SUMMARY

1.3.1 40/20 TSDF Program

In response to the DOD's request for a JTIDS frequency allocation, an EMC Test and Evaluation Program was conducted between August 1976 and March 1977. The testing was performed in cooperation with the DOD, FAA and Department of Commerce Office of Telecommunications (now NTIA). The investigation required approximately 1500 hours of bench tests, 1000 hours of flight tests and over eight man years of analysis. Table 1-1 lists the equipment tested. Bench tests were conducted at a TSDF of 40/20 percent and flight tests were conducted at a TSDF of 40/40 percent. The detail results of the 40/20 T&E program are presented in section 5.

The following are the general conclusions stated verbatim in the final test report (reference 1).

1. The test and analysis efforts show that 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-separation requirements are observed, the mobility of airborne JTIDS terminals makes the probability of experiencing these minimum 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.

Table 1-1. ATC Systems Investigated During the 40/20 TSDF T&E Program

ATC System	System Component	Receive Frequency (MHz)	Primary Type of Investigation
TACAN/DME (X and Y Modes)	5 Ground Beacon Types	1025-1150	Bench and Flight Tests[a]
	11 Interrogator Types	962-1024 & 1151-1213	
ATCRBS	1 en route and Terminal Beacon Type	1090	Bench Tests
	14 Transponder Types	1030	
ATCRBS Monopulse	Beacon	1090	Flight Tests
	Transponder	1030	
DABS[b]	Beacon	1090	Flight Tests
	Transponder	1030	
BCAS[c] (passive)	BCAS Receiver	1030/1090	Flight Tests
BCAS (active)	BCAS Receiver ATCRBS Transponder DABS Transponder	1090	d
MLS/DME	Ground Beacon	1025-1150	Flight Tests
	Interrogator	962-1024 & 1151-1213	

[a] only X Mode was flight tested
[b] now called Mode S
[c] now called Traffic Collision Avoidance System (TCAS)
[d] no fully configured BCAS was tested. Active mode BCAS results were extrapolated from DABS and ATCRBS transponder measurements.

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) will not change, and that modifications to or new models of ATC systems will continue to incorporate features that promote compatibility.

Additional Considerations

1. TACAN/Distance Measuring Equipment (DME) beacons can operate in the presence of JTIDS signals due largely to their ability to reject signals that do not have certain pulse-pair-spacing. This ability to reject what appears to the TACAN/DME receiver as single-pulse interference is the result of design considerations that were incorporated prior to the advent of JTIDS.

2. Narrowband JTIDS operations (single channel 969 MHz) require approximately 9 MHz of separation for compatible operation with the ATC system. Based on these measurements, narrowband operation with the carrier at 969 MHz should provide sufficient frequency separation to preclude interference to all of the ATC elements used in the common civil ATC system. However, this may not allow simultaneous operation of TACAN in most of the military portions of the TACAN band.

1.3.2 100/50 TSDF Program

The 100/50 TSDF T&E Program is divided into two phases. Phase 1 commenced in 1984 and was completed in May 1987 with the publication of the Risk Assessment Document (reference 4). The Phase 1 program primary investigated specific JTIDS scenarios. These JTIDS scenarios are explained in section 4.2.2.1. The results are presented in section 6. Phase 2 began in May 1987 and is scheduled for completion in December 1994. The Phase 2 program so far has investigated JTIDS parametric variations on TACAN/DME interrogators. These parametric variations are discussed in section 4.2.2.2 and the results are also presented in section 6. The program was divided into two parts so that DOD could obtain an early assessment of the likelihood of obtaining spectrum support certification for JTIDS uncoordinated operations at 100/50 TSDF.

1.3.2.1 Phase 1

The Risk Assessment was needed for the initial stages of a Class 2 terminal production decision. The Phase 1 effort was limited in scope and did not address all the JTIDS capabilities. 444-pulse messages and up to four simultaneous transmissions in a time slot were tested. The ATC systems investigated during Phase 1 are shown in table 1-2

Table 1-2. ATC Systems Investigated In Phase 1 100/50 TSDF T&E Program

ATC System	System Component	Receiver Frequency (MHz)	System Status	Type of Investigation
TACAN/DME-N	12 Interrogator Types	962-1213	Operational	Bench Tests
	2 Beacon Types	1025-1150		
DME/P	Interrogator	962-1213	Firmly Planned	Analysis
	Transponder	1025-1150		
ATCRBS	Interrogator	1090	Operational	Bench Tests
	Transponder	1030		Analysis/Bench Tests
Mode S	Interrogator	1090	Firmly Planned	Analysis
	Transponder	1030		Analysis/Bench Tests
TCAS	Interrogator	1030/1090	Firmly Planned	Analysis

In instances where testing could not be accomplished because of unavailability of equipment, an analysis was performed.

The following conclusions are based on the 100/50 JTIDS environment measurements and analyses that were accomplished as part of the Phase 1 EMC T&E program and are taken verbatim from reference 4.

1. Based on the Phase 1 test and analysis results to date, there do not seem to be effects on any of the ATC systems that would cause the 100/50 expanded spectrum support certification to be denied. Potential risk areas exist because of such things as the lack of TACAN/DME interrogator JTIDS-environment variations test data, DME/P interrogator and beacon test data, Mode S sensor test data, TCAS test data and the Y Mode DME beacon test data.

2. If recognized flight separation requirements are observed, the mobility of airborne JTIDS terminals makes the probability of ATC equipment experiencing operational effects very low. However, care must be taken to assure that surface-based JTIDS terminals are sited to keep signal levels weaker than those that affect ATC system performance.

3. For JTIDS terminals and ATC equipment collocated on airborne platforms, DOD must develop plans to assure that proper EMC techniques (antenna isolation may not be adequate on all platforms) are implemented so that the required ATC system performance can be maintained.

1.3.2.2 Phase 2

The Phase 2 T&E Program is evaluating all the JTIDS capabilities (see section 2), including up to ten simultaneous transmissions in a time slot. ATC equipments that were analyzed during Phase 1 will be tested to confirm the analysis. So far only the TACAN/DME interrogators have been tested in Phase 2. Figure 1-3 shows the schedule of the testing to be performed.

The detailed results of the 100/50 T&E Program are contained in section 6.

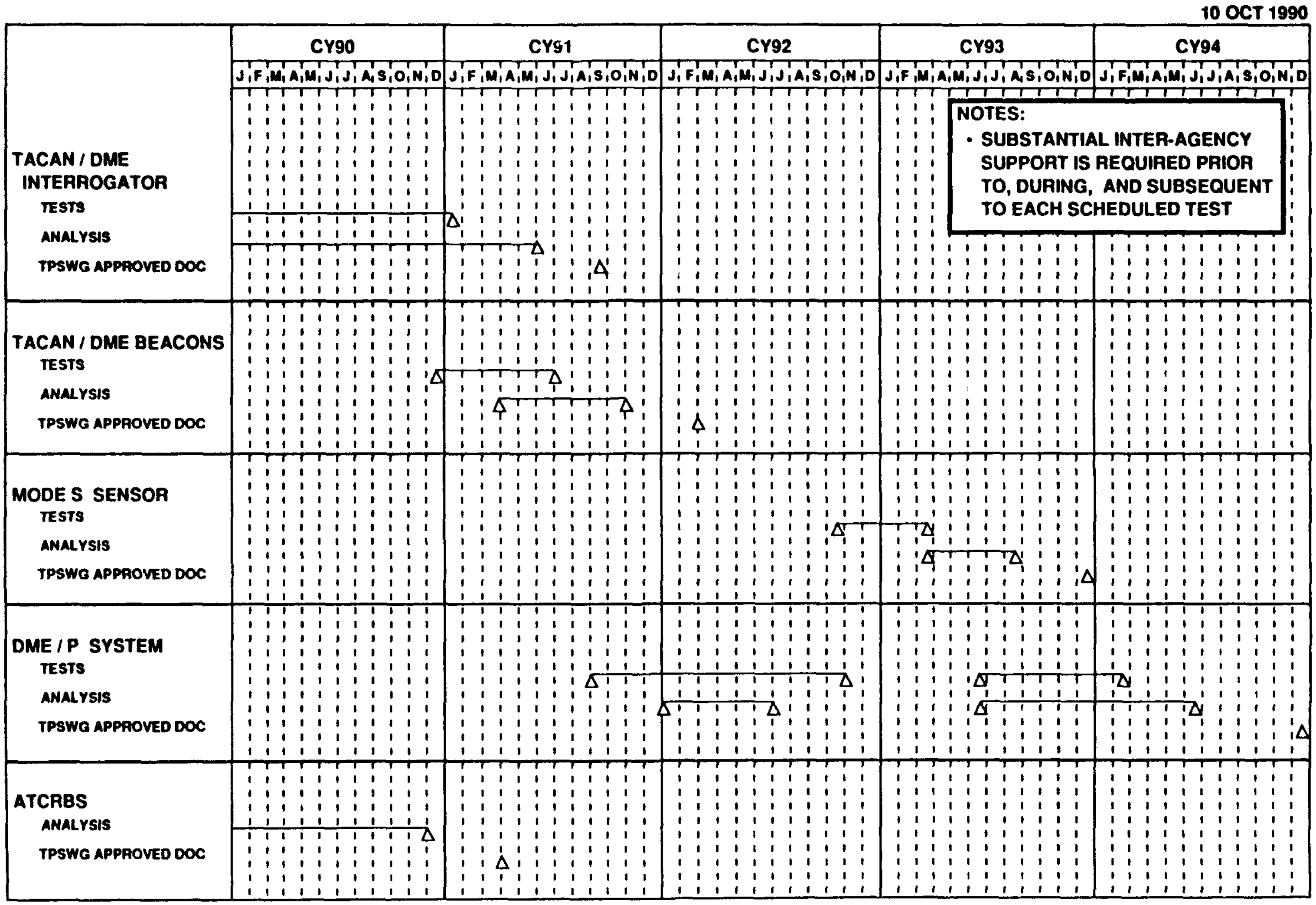


Figure 1-3. United States 100/50 TSDF Test and Evaluation Program Schedule

SECTION 2

DESCRIPTION OF JTIDS EQUIPMENT

2.1 SYSTEM DESCRIPTION AND CAPABILITIES

2.1.1 General

JTIDS is an advanced information distribution system that provides secure integrated, communications, navigation, and identification (ICNI) capabilities for application to military tactical operations. JTIDS can be employed in most types of aircraft and in major airborne and surface command-and-control facilities such as ships and shelters.

JTIDS employs a time division multiple access (TDMA) technique. The system has two navigation features: the TACAN function and an integral position-location capability within a common reference grid. JTIDS also has the capability, through the secure dissemination of position information, to provide velocity and identity data on both friendly and hostile force elements. In addition, the system has the capability to interconnect scattered sources of surveillance, such as support and intelligence information sources, weapons controllers, weapon systems, and tactical commanders. It is designed to provide selectable levels of connectivity among these sources, so the tactical commander can structure or restructure available forces on a continuing real-time basis as the combat situation evolves. A list of key JTIDS characteristics is presented in table 2-1.

2.1.2 JTIDS Timing

JTIDS operates on the principle of time sharing the same randomly hopped frequencies with other subscribers within the information distribution net. To accomplish this, a time period called an epoch is established in which time slots are repeated every 12.8 minutes. The epoch is divided into 64 individual, 12 second time frames. Each time frame is divided into 1536 time slots, each 7.8125 milliseconds (ms) in duration, thus providing 128 time slots per second for the transmission or reception of data (figure 2-1).

Table 2-1. Key JTIDS Characteristics

Time Slot Duration	7.8125 ms (128 per second)
Transmitter On-Time per slot	0.4608 ms, 1.6512 ms and 2.8416 ms[a]
Pulse Width	6.4 µs ± 5% at 90% amplitude points
Space between Pulses	6.6 µs
Pulses per Slot	72, 258 and 444[a]
Pulse Modulation	5 megabit CPSM[b]
Data Rate	28.8 kb/s minimum with error detection coding 238.08 kb/s maximum without error detection coding
Carrier Frequency Bands	Hopped pulse-to-pulse 969-1008, 1053-1065 and 1113-1206 MHz
Transmitter Power	200 Watts (nominal)[c]

[a] Transmitter on-time per time slot and pulses per time slot change for different message structures.

[b] Continuous phase shift modulation

[c] The Class 2M Terminal can operate in a low power mode of 42 watts. The Class 1 and the Class 2H Terminals are capable of transmitting 1000 watts in the high power mode. This high power capability can only be used in exercise and combat EMC feature override modes.

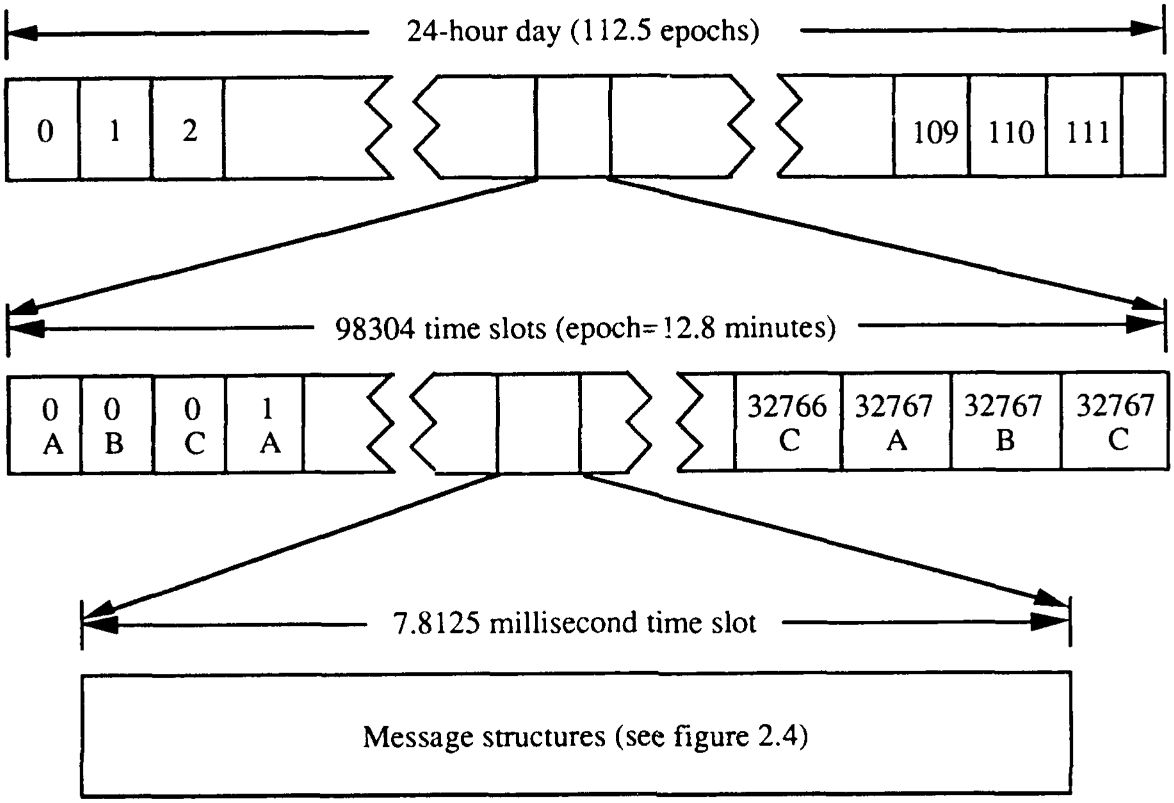


Figure 2-1. JTIDS Time Slot Structure

2.1.3 JTIDS Frequency Waveform

JTIDS is designed to minimize its effect on other systems within the 960-1215 MHz frequency band. The basic JTIDS pulse has a duration of 6.4 microseconds (µs) at the 90 percent amplitude points. Each pulse conveys five bits of data. The five bits of each pulse are represented by a 32-chip cyclic code shift keying pattern obtained from cyclic permutations of a fixed 32-bit pattern. In the secure modes of operation, the resulting 32-chip sequence is encrypted. The resulting encrypted or non-encrypted pattern of each pulse is then continuous phase shift modulated (CPSM) at a 5 megabit-per-second (Mbps). See figure 2-2

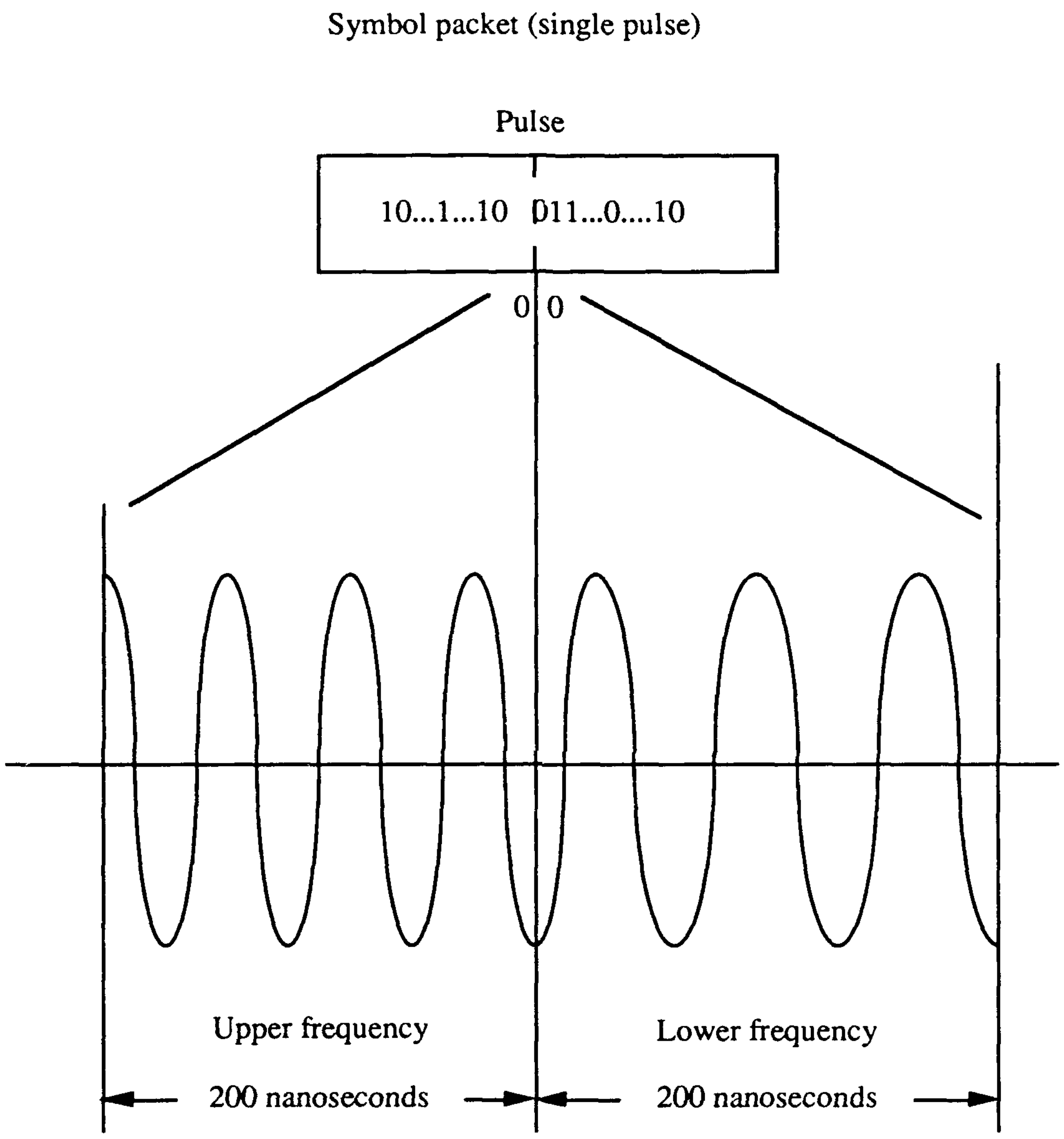


Figure 2-2. JTIDS Pulse Structure

The pulse width is limited to minimize the effects on TACAN/DME receivers that could be sensitive to long single pulses. Use of CPSM confines the spectrum and limits the number of TACAN/DME channels that can potentially be affected by a single JTIDS pulse. In ordinary biphase modulation, a discrete phase change of 180 degrees occurs at bit transition times in the modulating sequence. CPSM [also referred to as minimum frequency shift keying (MFSK)] provides a signal with a constantly varying phase difference relative to an unmodulated carrier. By eliminating the discontinuity inherent in biphase modulation at bit transitions, the frequency separation between the first nulls in the power density spectrum is reduced by 25 percent, and causes the spectrum to fall off as a function of frequency at a rate of 12 decibels (dB) per octave, as compared to 6 dB per octave for biphase modulation.

The CPSM spectrum of each JTIDS pulse is further improved by filtering. The result is a radiated spectrum which when referenced to the spectrum peak occurring at the carrier frequency, the spectrum level is 10 dB below the peak at 3 MHz from the carrier, 23 dB below the peak at 5 MHz from the carrier, 55 dB below the peak at 13 MHz from the carrier, and 60 dB below the peak at and beyond 15 MHz from the carrier. Between 5 MHz and 13 MHz, the spectrum falls off at a rate of approximately 24 dB per octave. Within ±7 MHz of 1030 and 1090 MHz, the level referenced to the carrier frequency is monitored and maintained at least 60 dB below the peak. Figure 2-3 shows a reproduction of a spectrum analyzer display (resolution bandwidth equals 300 kHz) of the JTIDS carrier at 969 MHz. This measured spectrum is representative of all the JTIDS carriers.

2.1.4 JTIDS Message Structures

The number of pulses transmitted during each time slot depends on the message structure that is being used. A JTIDS terminal can transmit 72, 258, or 444 pulses per time slot. The five JTIDS message structures are defined in the following paragraphs, and are illustrated in figure 2-4.

2.1.4.1 Round Trip Timing Messages

Round trip timing (RTT) messages are required by the terminal synchronization process. An RTT message is either an interrogation, which requests time-of-arrival information, or a reply. RTT interrogations and replies each consist of 72 pulses. The reply is transmitted in the same time slot as the interrogation. For this message structure, the interrogation and reply transmitters each have an on-time per time slot of 0.4608 ms.

2.1.4.2 Standard Double-Pulse Messages

The standard double-pulse message structure contains 258 pulses. Without error detection coding, there are 465 information bits per time slot which is equal to 59.52 kilobits per second (kb/s) at a TSDF of 100 percent. With error detection coding, there are 225 information bits per time slot which is equal to 28.8 kb/s at a TSDF of 100 percent. To enhance communication reliability, the same information is transmitted on two adjacent pulses. The pulses containing identical information are transmitted on different carrier frequencies because all adjacent pulses are frequency separated. For this message

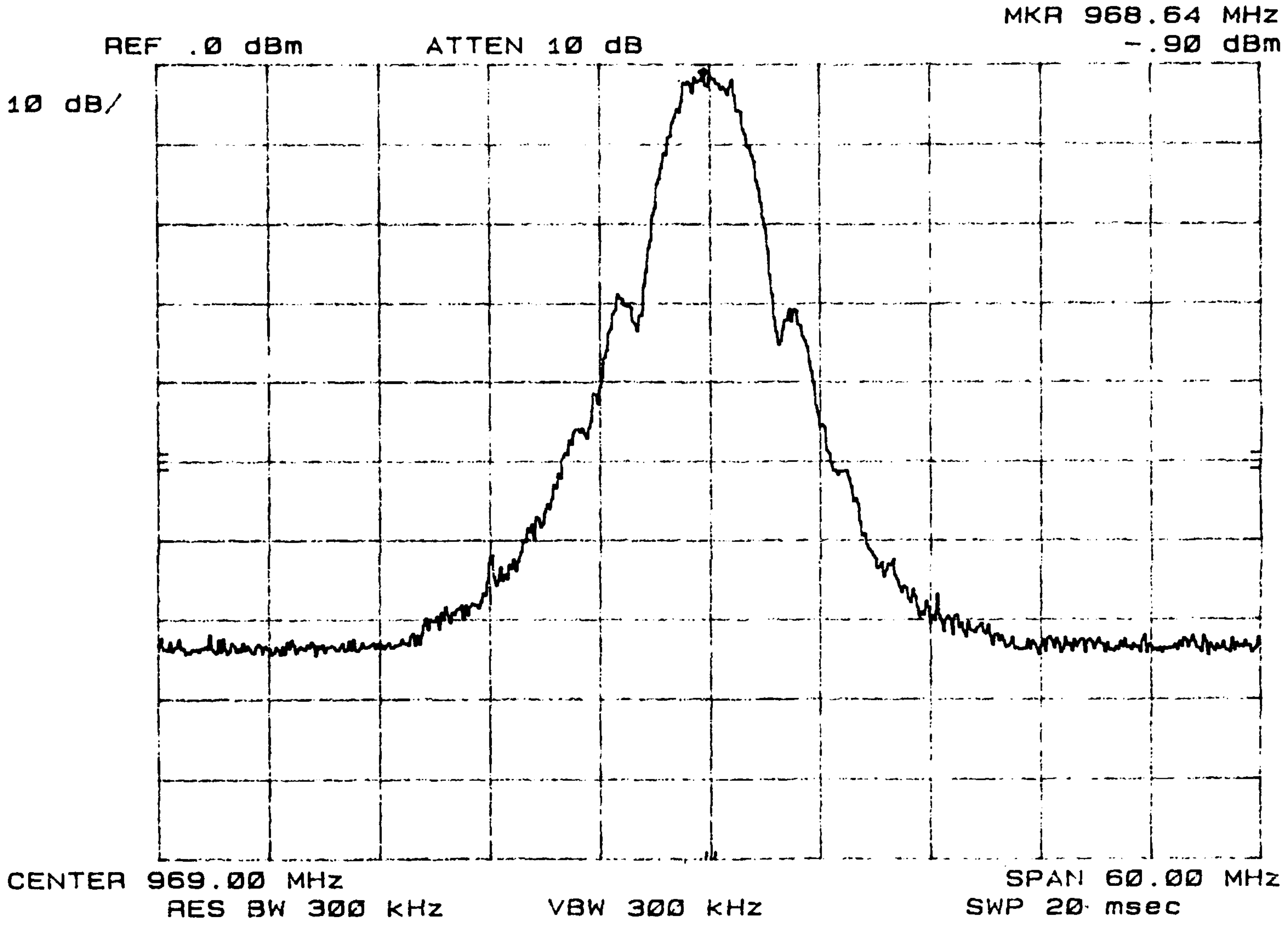
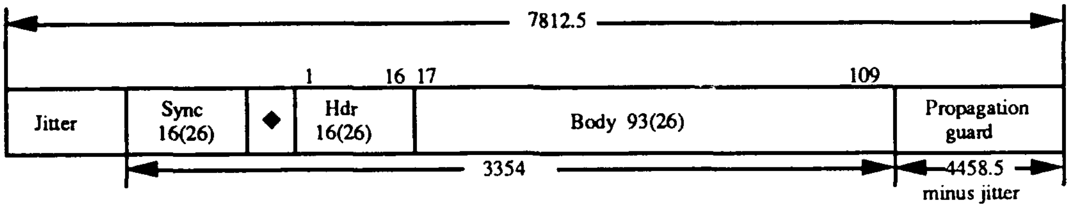
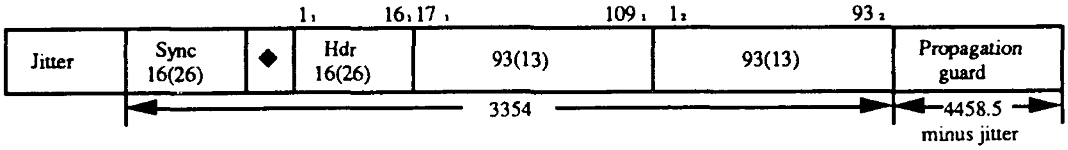


Figure 2-3. The Spectrum of a Single JTIDS Pulse

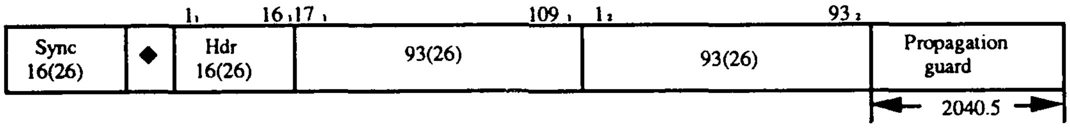
A. Standard Double Pulse



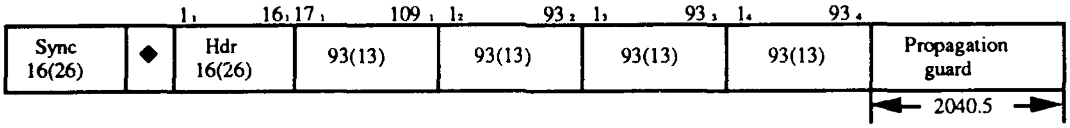
B. Packed-2 Single Pulse



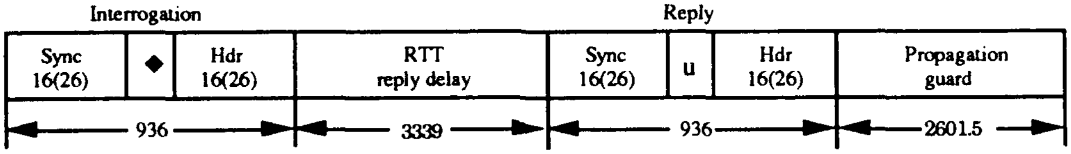
C. Packed-2 Double Pulse



D. Packed-4 Single Pulse



E Round trip timing interrogation and reply



Notes:
1. All timing values are in microseconds
2. Notation 16(26) = 16 x 26 microsecond symbol packets
   Notation 93(13) = 93 x 13 microsecond symbol packets
   Notation 93(26) = 93 x 26 microsecond symbol packets
3. All 26 microsecond symbol packets are double pulse
4. ◆ denotes time refinement symbol packets -- 4(26)

Figure 2-4. JTIDS Message Structures

structure, the transmitter on-time per time slot is 1.6512 ms. The start of the message (first pulse in time slot) is pseudorandomly varied to provide additional anti-jam protection.

2.1.4.3 Packed-2 Single-Pulse Messages

The Packed-2 single-pulse message structure is similar to the standard double-pulse message structure in that it also contains 258 pulses per time slot. However, this structure contains twice as much information as the standard double-pulse waveform, because the redundancy is removed and adjacent pulses are used to transmit different information. Without error detection coding, there are 930 information bits per time slot which is equal to 119.04 kb/s at a TSDF of 100 percent. With error detection coding, there are 450 information bits per time slot which is equal to 57.6 kb/s at a TSDF of 100 percent. The transmitter on-time per time slot is the same as for the standard double-pulse waveform.

2.1.4.4 Packed-2 Double-Pulse Messages

The Packed-2 double-pulse message structure contains 444 pulses. This message structure contains the same amount of message information as the Packed-2 single-pulse waveform, but because it employs the double-pulse technique to increase transmission reliability, it contains 444 pulses per time slot. The transmitter on-time per time slot is 2.8416 ms.

2.1.4.5 Packed-4 Single-Pulse Messages

The Packed-4 single-pulse message structure is similar to the Packed-2 double-pulse waveform in that it also contains 444 pulses. However, this structure contains twice as much information as the Packed-2 double-pulse waveform because the redundancy is removed. Without error detection coding, there are 1860 information bits per time slot which is equal to 238.08 kb/s at a TSDF of 100 percent. With error detection coding, there are 900 information bits per time slot, which is equal to 115.2 kb/s at a TSDF of 100 percent. The transmitter on-time per time slot is the same as for the Packed-2 double-pulse message structure.

2.1.5 Carrier Frequency Selection

JTIDS terminals are capable of wideband and narrowband modes of operation. In the narrowband mode, all pulses are transmitted on the single carrier frequency of 969 MHz. In the wideband mode, each consecutive JTIDS pulse is transmitted on a different carrier frequency. Possible pulse carrier frequencies are uniformly spaced and selected from within three subbands: 969 to 1008 MHz, 1053 to 1065 MHz, and 1113 to 1206 MHz, inclusive. The excluded regions provide spectral splatter protection to the 1030 MHz and 1090 MHz frequencies, which are used for identification purposes in the ATC system.

The frequency hopping algorithm ensures that each JTIDS carrier frequency is equally likely to be selected. However, the minimum frequency separation between adjacent pulses is tightly controlled to reduce the likelihood that JTIDS pulses would be decoded by TACAN/DME equipment. The selection of transmission frequencies is a part of an encryption process. To an observer who does not possess the appropriate cryptovariable, the sequence of JTIDS transmission frequencies appears as a random sequence with no discernable pattern. This prevents the enemy from eavesdropping and/or jamming the transmission. Figure 2-5 depicts the total wideband JTIDS spectrum taken over a time period long enough to include all transmitting frequencies.

2.1.6 Multinet Operation

As was described earlier, the frequency of the JTIDS transmission is changed from pulse to pulse. This frequency hopping technique also provides for simultaneous non-interfering JTIDS data distribution. Each time-frequency hopping pattern is referred to as a "net". More than one terminal may transmit in a single time slot without discernible mutual-interference, given that each of the transmitting terminals is on a different net. This type of transmission is referred to as multinet operation. JTIDS terminals can select any one of 128 different nets (limited by an 8-bit word) for their transmissions or reception and can change nets on a time slot by time slot basis.

2.1.7 JTIDS Transmit Access Modes

The JTIDS terminal provides different access modes for use in distributing the desired information. The access modes define which JTIDS terminals can transmit in specific time slots. The following access modes can be employed.

2.1.7.1 Dedicated Access

In this access mode, specific time slots are assigned to specific users on a one-to-one basis. Typically, each user is assigned a periodic sequence of time slots. The number of slots assigned depends on the user's needs in terms of the amount of data to be transmitted and the required response time. Any slots assigned to a user that are not needed are not used for transmission.

2.1.7.2 Contention Access

In the contention access mode, a pool of time slots is shared by a number of users. Each user independently and randomly selects a time slot from the pool when that user has information to transmit. The number of time slots in which the user transmits depends on the amount of information to be transmitted and the required response time. It is possible that two or more terminals will select the same time slot, resulting in multiple transmissions in that slot. In the event that overlapping transmissions arrive at a JTIDS terminal, only the first message detected will be received. Even though conflicts

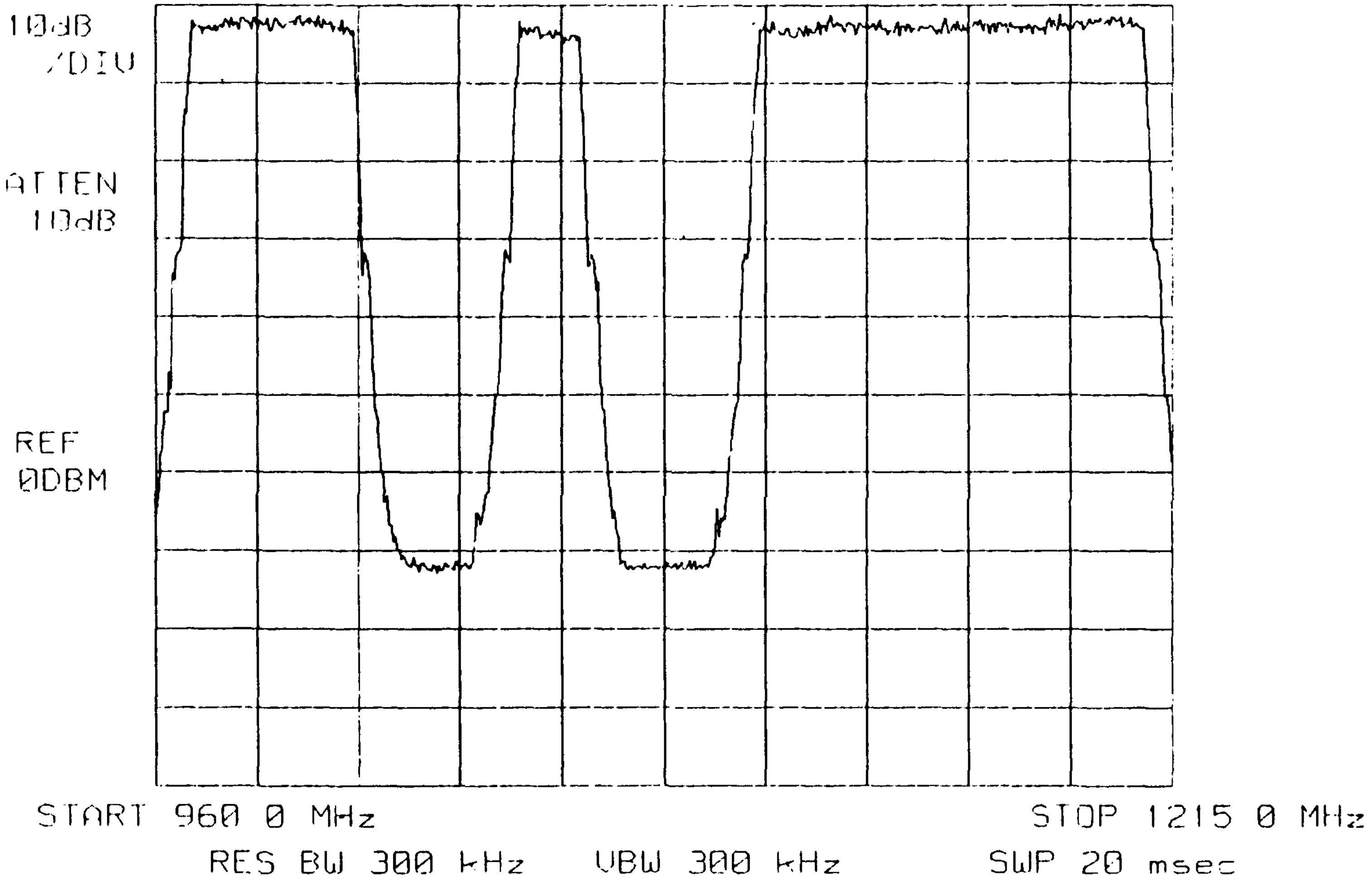


Figure 2-5. JTIDS Full Band Spectrum in the Frequency Hopping Mode

like this can occur, each transmitter will get his message through with a probability that is a function of the number of other users in the pool, and their spatial distribution from each JTIDS receiver.

2.1.7.3 Time Slot Reallocation

Time Slot Reallocation (TSR) is an adaptive means of allocating the system's resources on an as needed basis. The TSR mode provides for the assignment of a pool of time slots to a community of users. Two modes of TSR are available. In Mode A, the pool is allocated for use by a slowly varying number of terminals whose net loading requirements are changing. Each terminal transmits its net loading requirements not more than two times per 12 second frame. By monitoring the requirements of the other terminals, the time slot allocation algorithm within the terminal calculates the unique group of time slots it will use for transmission. The terminals can change their requirements as needed and thus transmit in a different number of time slots.

In Mode B of TSR, the pool is allocated for use by a slowly varying number of terminals whose net loading requirements are known and not changing. The pool is allocated on different nets associated with various participation groups. Terminals in a particular participation group will each have a particular net loading requirement. When a user wishes to join a participation group, he will command the JTIDS terminal to the appropriate net number, and the time slot reallocation algorithm will calculate which time slots, within the net, will be used for transmissions. In both modes of TSR, unless an electronic counter measures (ECM) environment exists, there will not be more than one transmission in a time slot.

2.1.7.4 Paired Slot Relay

In this relay approach, a block of time slots, designated as receiving time slots, are paired with another time slot block of the same size for retransmission. A terminal can relay on a conditional or unconditional basis. In the conditional relay mode, the terminal only relays when there is no other designated relay with better coverage (e.g., higher altitude) than itself. In the unconditional mode, the terminal relays all messages that are received in the time slots designated for receiving messages to relay. In either mode when a resulting retransmission time slot is assigned to more than one terminal, multiple transmissions can occur in the time slot.

2.1.7.5 Repromulgation Relay

In this relay approach designed for ground to ground links, the user originating the message (258 pulses or 444 pulses) designates the number of times the message is to be relayed and donates to relaying terminals the sequence of time slots to be used in the relay process. On receiving a message, the receiving terminal will retransmit the message unless the desired number of retransmissions has been reached. At each retransmission of the message, a random amount of jitter (i.e., 0, 10, 20, 30, 40, 50, 60, or 70 μs delay) is included. This is to preclude interference at a receiving terminal from two or more relaying terminals in a close geographic distribution. JTIDS messages will overlap in time when they arrive at the receiver, but the JTIDS receiver would only detect the first message received. The originating user can transmit messages in every third time slot.

2.1.7.6 Enhanced Repromulgation Relay

Enhanced repromulgation relaying is similar to repromulgation relaying including the 0 to 70 μs jitter delay. It also employs an additional 256 μs delay at each subsequent relay. This additional time delay enables the originating terminal to transmit in every second time slot without interfering with nearby terminals.

2.1.8 Terminal EMC Controls

To comply with the conditions delineated in the JTIDS frequency allocation, JTIDS terminals incorporate hardware and software controls called EMC features. The EMC features monitor terminal emissions and will inhibit further transmissions if the following measured parameters are exceeded: 1) the terminal fails to distribute the transmitted carrier frequencies uniformly across the band, 2) the pulse width exceeds 6.4 μs ±5 percent at the 90 percent amplitude level, 3) the transmitted emissions in the 1030 ± 7 MHz or 1090 ± 7 MHz notches exceed a level of -60 dBc relative to the peak transmitted power level as measured in a 300 kHz bandwidth.

There are three levels of EMC protection called full EMC protect, exercise override and combat override. The full EMC protect mode is the default mode. When in the full EMC protect mode, in addition to the three hardware monitors listed above, the terminal also monitors its TSDF and prohibits all terminal operating modes and message structures not allowed under the JTIDS allocation. High power (1 Kw) operation is not permitted in the full protect EMC mode.

In the exercise override EMC mode, only the three hardware features are active. The full use of terminal capabilities are permitted in exercise override. This allows testing of certain terminal parameters and allows special training exercises to be conducted.

In the combat override EMC protect mode, all the EMC features are disabled. The terminal will not inhibit transmissions.

2.2 JTIDS PARAMETERS CRITICAL TO EMC

Statements in this section are taken verbatim from reference 4.

The EMC of JTIDS signals with the ATC equipment is dependent upon the number of pulses coupled into the ATC receivers. The number of JTIDS pulses that are transmitted in an area is limited by the available TSDF. JTIDS was specifically designed to be compatible with ATC equipment in the 960-1215 MHz band. The pulse width, pulse timing, and frequency selection algorithm were chosen to reduce the number of decodes generated by JTIDS signals in the TACAN/DME equipment. Additionally, JTIDS does not operate on frequencies near the 1030 MHz and 1090 MHz ATC equipment. The JTIDS terminal includes EMC features that are specified in reference 2.

The JTIDS pulse width is limited to 6.4 μs to prevent single pulse decodes in TACAN/DME equipment that are susceptible to long pulses. The pulse separation and frequency selection algorithm minimize the probability of an ATC receiver decode.

Multinet and contention operations reduce the effectiveness of the frequency selection algorithm as an EMC protection feature. This is because pulses on the same frequency from different nets can sometimes be close in time and produce decodes in TACAN/DME equipment. In the contention case, if terminals are spaced to produce pulse pairings that are within the decode window, decodes can occur. The rate at which decodes could occur is dependent upon the number and location of terminals transmitting in the same time slots.

To maximize compatibility with 1030/1090 MHz ATC equipment, JTIDS does not transmit on frequencies within 21 MHz to 22 MHz of either 1030 MHz or 1090 MHz. Because of transmitter noise and/or spurious emissions in these notches, some potential for noncompatible situations exists. The key to reducing these problems is making sure that the noise floor and spurious emissions are as weak as possible. The JTIDS specification requires radiated energy to be at least 60 decibels (dB) weaker than the peak carrier level (dBc), as measured in a 300 kHz bandwidth on all frequencies that are at and beyond 15 MHz from the JTIDS carrier frequency.

Another parameter critical to JTIDS EMC with ATC equipment is the JTIDS signal level received at the input to the ATC equipment. This signal level is dependent upon JTIDS output power, antenna gain, cable losses, and equipment separation distances.

SECTION 3

DESCRIPTION OF ATC SYSTEMS

The information in this section contains statements verbatim from reference 3.

3.1 TACAN/DME/N

3.1.1 General

The conventional Distance Measuring Equipment (DME/N) system is the internationally accepted means for determining the slant range between an aircraft and a fixed ground station. The system requires an interrogator in the aircraft and a transponder (beacon) on the ground. Coded pulse pairs are used to identify interrogations from the aircraft and replies from the beacon. Slant range is determined in the aircraft by measuring the elapsed time between the transmission of an interrogation and the reception of the corresponding reply from the transponder and adjusting the elapsed time for the transponder's time delay. The DME/N pulse spacings are shown in table 3-1. Frequencies used for the DME/N system are spaced in 1 MHz increments throughout the 962 to 1213 MHz band (reference 5).

Table 3-1. TACAN/DME-N Pulse Spacings

Mode	Air-to-Ground Interrogation (μs)	Ground-to-Air Reply (μs)
X	12	12
Y	36	30

The Tactical Air Navigation (TACAN) system, a US/NATO military navigation system, incorporates the standard international DME/N function with a bearing determination function on the same radio frequency (RF) carrier. Bearing from an aircraft to a TACAN beacon is determined by measuring the time-position of a reference burst within the amplitude modulated sinusoidal envelope of a pulse train emitted by the beacon. The beacon employs an antenna with a cardioid radiation pattern that rotates at a rate of 15 Hz. Each rotation of this antenna appears as an amplitude-modulated sine wave at a point in space occupied by an aircraft. When the antenna pattern mainbeam points due east, a reference signal (designated the north reference burst) is transmitted. Depending on the location of the aircraft, this reference signal will appear at the phase (or position) within the sinusoid indicative of the bearing of the aircraft from true north. The accuracy of the bearing measurement is enhanced by superimposing an additional 135 Hz sine wave on the rotating cardioid pattern. Auxiliary reference bursts are transmitted every 40°of antenna rotation for phase comparison with the observed 135 Hz sine wave to provide a vernier bearing measurement with an accuracy of ± 3 degrees.

The beacon also transmits an identification (ID) signal in international Morse code. These beacon ID signals are transmitted automatically at intervals separated by approximately 35 seconds. These transmissions replace all reply pulses that would normally occur during that time.

3.1.2 Airborne Interrogator

Commercial TACAN/DME Interrogators. Commercial units are interrogators used in air carrier aircraft that operate throughout the FAA defined service volumes at altitudes up to 45,000 feet. Generally, interrogators intended for commercial aviation usage meet more stringent performance standards. As a result, commercial aviation interrogators tend to have more sensitive receivers than general aviation interrogators.

Military TACAN Interrogators. Interrogators used in military aircraft operate throughout the FAA defined service volumes at altitudes up to 45,000 feet. The military interrogators also tend to have more sensitive receivers than general aviation interrogators.

General Aviation DME Interrogators. General aviation units are typical of interrogators used in private aircraft that generally operate throughout the FAA defined terminal and low en route service volumes at altitudes up to 18,000 feet.

3.1.3 Ground Beacons

The TACAN beacons operate at a constant duty cycle, transmitting 3600 pulse pairs per second (ppps). These 3600 pulse pairs consist of 2700 pairs, both interrogation-elicited and self-generated, and 900 reference-burst pairs. If a TACAN beacon is not receiving any interrogations, a mechanism within the receiver triggers all of the 2700 pulse pairs required. If a TACAN beacon is replying to 1000 interrogation pulse pairs to provide distance information, the receiver generates an additional 1700 replies. The bearing information is contained in the pulse-amplitude modulation of 15 Hz and 135 Hz that is imposed on the transmitted pulse pairs by a cardioid antenna pattern.

The operation of a DME beacon differs slightly from that of a TACAN beacon. If the number of interrogation-generated replies is less than 1000 per second, a constant reply rate of 1000 per second is maintained. This consists of only interrogation-generated and self-generated replies (squitter), since no reference bursts are transmitted. When the number of interrogation-generated replies exceeds 1000 per second, the number of self-generated replies is essentially zero and the total reply rate equals the interrogation-generated rate. Thereafter, the reply rate will increase in accordance with the interrogation rate until the maximum reply count of 2700 per second is reached. DME beacons do not have any pulse-amplitude modulation imposed on the pulse-pair transmission since they do not provide bearing information.

3.2 DISTANCE MEASURING EQUIPMENT/PRECISION (DME/P)

3.2.1 General

The DME/P system has been approved internationally for implementation with the Microwave Landing System (MLS). MLS is the firmly planned replacement guidance system for the existing Instrument Landing System (ILS). DME/P is designed to operate as a DME/N system when user aircraft are farther than 7 to 8 nautical miles (nmi) from the ground beacon and to provide precision range measurements (to aircraft within 7 to 8 nmi) throughout the approach and landing or takeoff phases of flight. Improved range measurement is obtained by making use of a fast-rise-time pulse and by measuring the time of arrival of the pulse using the 5 to 30 percent portion of the leading edge. Using this area of the leading edge provides for a more accurate pulse time-of-arrival measurement with a lower risk that the pulse will be corrupted by multipath signals.

The DME/P system makes use of the same frequencies as DME/N, but uses different interrogation pulse spacings as shown in table 3-2.

Table 3-2. Pulse Pair Coding for DME/P

Channel	Operating Mode	Interrogator pulse Pair Spacing (μs)	Beacon Pulse Pair Spacing (μs)
X	IA	12	12
	FA	18	12
Y	IA	36	30
	FA	42	30
W	IA	24	24
	FA	30	24
Z	IA	21	15
	FA	27	15

3.2.2 DME/P Ground Beacon

The DME/P ground beacon replies to initial approach (IA) and final approach (FA) interrogations. Initial approach replies are transmitted from a ground beacon when an aircraft interrogates the beacon from farther than 7 to 8 nmi. In the initial approach mode, the DME/P beacon performs the same as a DME/N beacon. Final approach replies are transmitted from the beacon when the aircraft is closer than 7 to 8 nmi from the beacon. The FA mode interrogation and reply pulses have faster rise times than the DME/N reply pulses.

The DME/P ground beacon must provide high integrity replies to aircraft that are in critical approach and landing maneuvers. A monitoring system ensures the quality of the replies. The monitoring system interrogates the beacon at a rate of 40 Hz measuring primary and secondary parameters. If any of the primary parameters are out of tolerance, it could lead to a hazardous flight situation. If any of the secondary parameters are out of tolerance, only maintenance action is required. If a primary parameter is out of tolerance, the beacon is shutdown or redundant circuits are activated. If a secondary parameter is out of tolerance, the beacon indicates that maintenance is needed.

3.2.3 DME/P Airborne Interrogator

The DME/P airborne interrogator transmits IA and FA mode interrogations to a ground beacon. The interrogator derives range readouts by measuring the time delay between the transmission of interrogations and the receipt of replies. When calculating time delay in the IA mode, pulses are thresholded at the 50 percent level. This is the same threshold level as used by DME/N interrogators. In the FA mode, the pulses are thresholded at approximately the 30 percent amplitude point. Thresholding pulses at a lower amplitude reduces range errors caused by pulse shape distortion. A major cause of pulse shape distortion is when multipath pulses are received along with the desired signal. By using the lower threshold level, the distance information from the FA mode is accurate to within 100 feet.

3.3 AIR TRAFFIC CONTROL RADAR BEACON SYSTEMS (ATCRBS)

3.3.1 General

ATCRBS [also known as Secondary Surveillance Radar (SSR)] is a cooperative system consisting of ground-based interrogators and airborne transponders. The interrogator transmits in several different interrogation modes to elicit aircraft identification and altitude responses in the form of pulse-coded replies from the aircraft transponders. The ground interrogator system then receives and decodes the transponder replies.

3.3.2 ATCRBS Ground Interrogator System

The ATCRBS Ground Interrogator System consists of the Receiver/Transmitter System, and either the en route Processing System or the Terminal Processing System. The interrogator system has a rotating, vertically polarized, directional antenna that has a narrow horizontal beamwidth and a fan-shaped vertical beamwidth. The relative bearing from the beacon to the aircraft is determined from the direction in which the mainbeam of the interrogator antenna is pointing when the transponder reply is received. Aircraft range is determined by the elapsed time between transmission of the interrogation pulses and the receipt of the transponder reply. All ATCRBS interrogators transmit on 1030 MHz and receive on 1090 MHz.

The ATCRBS receiver filters, detects, and quantizes the transponder replies for input to the processing equipment. The Terminal Processing System includes various defruiters, limiters, data storage circuits, a video processor, and software to determine and present aircraft identity, altitude, and ground speed information to ATC personnel. The functions of the en route and Terminal Processing Systems are similar.

3.3.3 ATCRBS Airborne Transponder

When a transponder receives a valid interrogation, it will reply with either its identity code or its altitude, depending on the interrogation mode received. The pilot can indicate emergencies and communication failures by setting the transponder to reply with specific codes.

There are two classes of transponders that differ mainly in RF power output to provide for aircraft ceiling altitude differences. However, all transponders are required to have the same receiver sensitivity, which is normally referred to as the minimum triggering level (MTL).

3.4 MODE S SYSTEM

3.4.1 General

Mode S is a computer controlled, cooperative surveillance and communication system for air traffic control. It was originally known as the Discrete Address Beacon System (DABS), and is the firmly planned replacement system for ATCRBS. It employs ground-based sensors (interrogators) and airborne transponders. Each Mode S equipped aircraft is assigned a unique address code. Selection of the aircraft to respond to an interrogation is accomplished by including the aircraft address code in the interrogation. Each such interrogation is thus directed at a particular aircraft. An antenna incorporating monopulse technology is used for the Mode S sensor. Interrogation of a particular aircraft is restricted to the mainbeam dwell interval. The Mode S system is fully compatible with ATCRBS.

3.4.2 Mode S Ground Interrogator (Sensor) System

The Mode S Ground Interrogator System includes the Mode S Receiver/Transmitter System and, like ATCRBS, either an en route Processing System or a Terminal Processing System.

Two major advantages accrue from the use of discrete addresses for surveillance. First, a Mode S interrogator is able to limit its interrogations to only those targets for which it has surveillance responsibility, rather than continuously interrogating all targets within line-of-sight, as is done by the ATCRBS interrogator. This approach prevents surveillance system saturation which can occur when all transponders respond to all interrogators within line-of-sight (LOS). Secondly, appropriate timing of interrogations ensures that the responses from aircraft do not overlap. thus eliminating the mutual interference that results from the overlapping of replies from closely spaced aircraft (termed synchronous garble).

The Mode S links include the signals used for ATCRBS and adds to these the signal waveforms and message formats for servicing Mode S equipped targets. An ATCRBS/Mode S All-Call Interrogation (at 1030 MHz) is used to acquire aircraft not already on a sensor's roll call. An All-Call interrogation includes the ATCRBS type interrogation with an added pulse. Recognition of this added pulse elicits a Mode S All-Call reply from the Mode S transponder instead of an ATCRBS reply (ATCRBS transponders would reply as usual). The regular Mode S (roll call) interrogation has a preamble that is used to suppress ATCRBS transponders. This preamble is followed by a data block. The roll call interrogation is addressed to a single Mode S equipped aircraft that is already on the sensor's roll call list.

3.4.3 Mode S Airborne Transponder

The avionics components of Mode S are the transponder and the associated data link message display and input devices. The Mode S transponder has all of the functions of an ATCRBS transponder and adds to these the ability to decode Mode S interrogations, and to format and transmit the appropriate replies. In particular, the RF units of the receiver, transmitter, and modulator are essentially identical to the corresponding ATCRBS units. Also, the performance characteristics of a Mode S transponder are similar to those of an ATCRBS transponder designed for the same class of service. In fact, when operating in the ATCRBS mode (receiving and replying to ATCRBS interrogations), the Mode S transponder must conform to all requirements of the relevant ATCRBS transponder Technical Standard Order (TSO, reference 6).

3.5 TRAFFIC ALERT AND COLLISION AVOIDANCE SYSTEM (TCAS)

TCAS has been designed to provide a backup separation assurance service for the existing conventional air traffic control system. The operation of TCAS is not dependent upon ground-based systems and does not produce unwanted alarms of encounters for which the collision risk does not warrant escape maneuvers.

The TCAS equipment in the aircraft uses 1030 MHz to interrogate air traffic control (ATCRBS and Mode S) transponders on aircraft in its vicinity, and listens for transponder replies on 1090 MHz. By computer analysis of these replies, the airborne TCAS equipment determines which aircraft represent potential collision threats, and provides appropriate display indications (or advisories) to the flight crew to assure minimum acceptable separation.

TCAS employs Mode C only All-Call interrogations when interrogating/tracking ATCRBS transponders, and Mode S waveforms when interrogating/tracking aircraft equipped with Mode S transponders. If the intruder aircraft is equipped with a TCAS unit, the two units communicate resolution advisories using the 1030/1090 MHz Mode S data link.

TCAS has the capability to communicate with the ground-based air traffic control system when a ground-based Mode S sensor equipped with the necessary complementary features has been installed.

The MTL for Mode C and Mode S signals is nominally -74 dBm (decibels referenced to a milliwatt) and the TCAS surveillance range is 14 nmi. For further information on TCAS units, see reference 7.

SECTION 4

EMC TEST AND EVALUATION PROGRAM SIGNAL ENVIRONMENTS

4.1 Description of ATC Extraneous Pulse Environments

The information in this section was taken verbatim from reference 4.

The Extraneous Pulse Environment (EPE) consists of pulses from equipment that are operating in the National Airspace System (NAS). The EPE is used to immerse the unit under test (UUT) in a representative operating environment, thereby ensuring that the tests account for any interaction that may occur between the EPE and JTIDS pulses. Only the EPE used during the 100/50 TSDF tests are described.

In the case of the TACAN/DME interrogator tests, the EPE is comprised of pulses (ppps) from adjacent channel beacons providing service to other aircraft (table 4-1). For the TACAN/DME beacon tests, the EPE is made up of aircraft replies to adjacent channel beacons (table 4-2). Finally, the ATCRBS ground interrogator tests utilized an EPE representing both the ATCRBS and Mode S replies to other ATCRBS/Mode S interrogators and replies of aircraft to an off-frequency DME beacon (table 4-3). An EPE was not used for the limited testing of the ATCRBS and Mode S transponders. The pulse environment for the DME/P is shown in table 4-4 (reference 8). The Mode S environment is a hypothesized peak Los Angeles (LA) Basin air traffic environment (reference 9). For the TACAN/DME environment, existing and planned FAA channel assignment procedures were applied to an LA Basin siting scenario (reference 10) to produce high density EPEs.

Table 4-1. TACAN/DME-N Interrogator EPE

Relative Frequency (MHz)	Pulse Type	Pulse Spacing (μs) X Mode	 Y Mode	Pulse Rate (ppps)	Signal Level (dBm)
+1	DME/P	12	30	1373	-75
+1	DME/P	12	30	700	-78
+3	DME/P	12	30	1373	-90
+3	DME/P	12	30	1373	-97

Table 4-2. TACAN/DME-N Beacon EPE

Relative Frequency (MHz)	Pulse Type	Pulse Spacing (μs) X Mode	Pulse Spacing (μs) Y Mode	Pulse Rate (ppps)	Signal Level (dBm)
+1	DME/P	12	36	288	-104 to-109
+1	DME/P	36[a]	12[a]	2320	-64 to-98
+3	DME/N	12	36	1800	-76 to -104
+3	DME/P	12	36	2512	-52 to -109
+3	DME/P	36[a]	12[a]	1616	-58 to -98

[a] These are off code pulse spacings.

[b] Actual levels used are presented in reference 11.

Table 4-3. ATCRBS Interrogator EPE

Frequency (MHz)	Pulse Type	Rate per Second	Amplitude
1090	ATCRBS replies	17,983	Variable[a]
1090	Mode S replies	52	Variable[b]
1094	DME Pulse Pairs	240	-50 dBm

[a] See reference 12, page 3-8.

[b] See reference 12, page 3-10.

Table 4-4. DME/P Pulse Environment

Frequency Offset	Pulse Rate	Amplitude	Code[a]
-2 MHz	3240 ppps	-51 dBm	Same
-1 MHz	3240 ppps	-71 dBm	Same
0 MHz	3240 ppps	-71 dBm	Different
+1 MHz	3240 ppps	-71 dBm	Same
+2 MHz	3240 ppps	-51 dBm	Same

[a] As compared to the desired signal.

4.2 DESCRIPTION OF JTIDS ENVIRONMENTS

Bench tests, field tests and flight tests were performed during both the 40/20 and 100/50 TSDF T&E Programs. JTIDS terminals and JTIDS simulators were used to generate the JTIDS signals. The JTIDS simulators use actual JTIDS hardware and provide JTIDS signals which meet all the spectrum and time slot structure requirements.

4.2.1 40/20 TSDF JTIDS Environments

Because DOD only requested a TSDF of 40/20 on a single net, and the use of dedicated access using 258-pulse time slots, the majority of testing was accomplished at this level.

The bench tests were largely conducted at 40/20 TSDF. Limited data was also taken at TSDFs of 100/100, 100/50, 100/25, 40/40, 40/10 and 40/1 in order to determine the effect of JTIDS TSDF on equipment susceptibility.

The 40/20 TSDF environment consisted of two JTIDS transmitters called a foreground and background transmitter. A foreground transmitter had its received transmitted power at relatively high levels (e.g., -36 dBm to -50 dBm). The background signals were typically transmitted 20 dB below the foreground signal level to simulate the reduced received power of JTIDS signals transmitted 5 to 10 nmi away from an ATC receiver. In all instances there were no transmissions in adjacent time slots.

Flight tests were conducted using an FAA flight inspection sabre liner, Model 80 and a USAF flight-inspection C-140 Jetstar. The C-140 Jetstar was equipped with a JTIDS simulator operating at a TSDF of 40/40.

4.2.2 100/50 TSDF JTIDS Environments

More elaborate JTIDS environments were tested during the 100/50 TSDF T&E Program than those tested for in the 40/20 TSDF T&E Program. Simultaneous transmissions on multiple nets and 444-pulse time slots were tested. The effect of the JTIDS pulse arrival spacing at the ATC receiver was also investigated.

The 100/50 TSDF JTIDS signal environment is represented by JTIDS snapshots. A snapshot is a representation of the RF environment due to the presence of JTIDS terminals as seen by the ATC equipment under test. A snapshot captures the most stressful interval during a JTIDS dynamic training scenario.

Scenarios were developed by the JTIDS Joint Program Office (JPO) which represented the use of JTIDS in routine day-to-day training exercises. The scenarios should not be construed as the United States' concept of operation for JTIDS. Platforms that were viable candidates for JTIDS were given time slot assignments in an attempt to lend some operational significance to the scenarios, and to ensure that the electromagnetic environment would be stressed. The scenarios modeled both JTIDS and ATC aircraft motion and the propagation effects (timing and amplitude changes) of pulses arriving at the ATC receiver, and the varying amount and type of JTIDS transmissions. The most stressful (worst case) interval of this dynamic scenario was determined and the parameters representing this interval were used to initialize the JTIDS signal sources used for testing.

JTIDS scenario snapshots were used to test the ATC equipments in the Phase 1 100/50 T&E program. Phase 2 testing involved parametric variation testing. This was accomplished by defining a generic JTIDS snapshot from which the JTIDS parameters and relative timing was varied. Parametric testing allows a thorough evaluation of the effects that specific JTIDS capabilities have on ATC equipment. The information in the following sections contain statements verbatim from references 4 and 13.

4.2.2.1 Phase 1 Snapshots

The scenarios developed by the JPO identified JTIDS platforms, platform motion, geographic layout and the JTIDS net structure including individual JTIDS terminal time slot assignments.

An ATC receiver was placed in each scenario near the user or group of users that transmitted at a 50 percent TSDF rate. This information was analyzed to determine the received JTIDS RF environment seen by the ATC equipment. The conditions occurring during the most stressful interval of time were fixed and developed into a snapshot. Summaries of the scenarios are included in table 4-5. In order to predict the JTIDS signal environment at the ATC receiver, the snapshot development took into account the location and motion of JTIDS terminals, the location and motion of the ATC receiver, antenna patterns, JTIDS transmitter power, cable and insertion losses, propagation loss (50 percent time availability), time delay and the frequency hopping JTIDS carrier frequencies.

The signal levels from each JTIDS terminal were calculated at the input to the ATC receiver using the IF-77 electromagnetic wave propagation model (reference 14).

Table 4-5. JTIDS 100/50 TSDF Training Scenario Summary

Military Training Service	Surface Based Terminals	Airborne Terminals	Highest TSDF User (50 %)	Predicted Foreground Levels[a] (dBm)	Foreground (dBm)	Ring 1 (dBm)	Ring 2 (dBm)
Air Force	2 Command & Reporting Centers	1 E-3A 16 F-15s	E-3A	-42[b]	-36 -42 -48	-66	-78
Army	7 Garrison Areas 3 Relay Areas 3 Training Areas	None	Garrison Area Group	-45	-36 -39 -45 -51	-60	-72
Navy	1 Aircraft Carrier	1 E-2C 4 F-14s	E-2C	-47	-36 -42 -47 -50	-68	-77
Joint	5 Garrison Areas 4 Relay Areas 3 Training Areas	1 E-3A 4 F-15s	Garrison Area Group	-44	-36 -38 -44 -50	-60	-66

[a] The 50 percent time availability IF-77 propagation model data were used to predict these levels.

[b] The final predicted levels were 1 dB stronger for the Air Force scenario and 1 dB weaker for the Joint Scenario. The revised IF-77 propagation model predicted these levels after most of the the testing had been accomplished.

To simplify the JTIDS snapshot, the varying amplitude levels from the numerous JTIDS pulses were quantized into three fixed levels. These are designated as foreground, Ring 1 and Ring 2. The amplitude of the pulses for the three levels are shown in table 4-5 The foreground consisted of 50 percent TSDF, Ring 1 contained 30 percent TSDF and Ring 2 is composed of 20 percent TSDF. The snapshot information is then used in the computer program to (exercise/drive) the JTIDS signal sources. Figure 4-1 shows the scenario for the Air Force use of JTIDS.

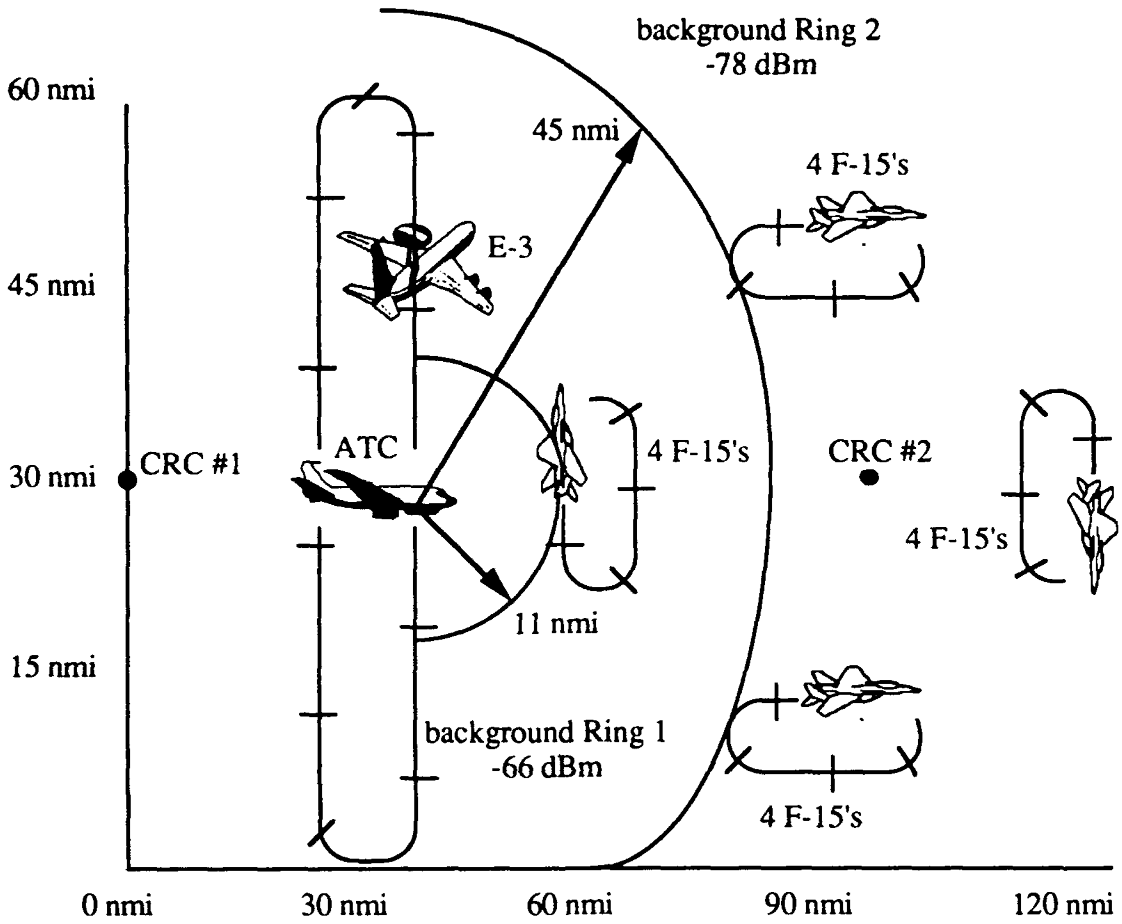


Figure 4-1. Air Force Routine Training Scenario at 100/50 TSDF

4.2.2.1.1 TACAN/DME Interrogator Snapshots

Snapshots based on the four service (Air Force, Navy, Army and Joint) scenarios were developed. These snapshots investigated multinet, contention, 258-and 444-pulse time slots. A maximum of four simultaneous transmissions in a time slot were tested. Figure 4-2 is an example of three snapshots. Figure 4-2a is the basic 100/50 TSDF snapshot with 50 percent TSDF foreground, 30 percent TSDF Ring 1, and 20 percent TSDF Ring 2 users, all transmitting 258-pulse time slots. Figure 4-2b shows the same configuration when all users transmit 444-pulse time slots. Because the maximum number of pulses allowed to transmit in a 12-second interval is fixed at 396,288 (footnote on page 5) no transmissions are permitted in 650 time slots of the total 1536 time slots in an epoch. Figure 4-2c shows a 2-user multinet configuration with 100 percent overlap.

Foreground 50 % TSDF 768 time slots (TS)	Ring 1 30 % TSDF 460 TS	Ring 2 20 % TSDF 308 TS	1536 TS/12 sec

a. 258-pulse time slot 100/50 TSDF snapshot

Foreground 50 % TSDF 446 TS ■	Ring 1 30 % TSDF 262 TS ■	Ring 2 20 % TSDF 178 TS ■	650 empty time slots	1536 TS/12 sec

b. 444-pulse time slot 100/50 TSDF snapshot

■ denotes 444-pulse time slot

0	Foreground 25% TSDF 384 TS	Ring 1 15 % TSDF 230 TS	Ring 2 10 % TSDF 154 TS	768 empty time slots	1536 TS/12 sec
1	Foreground 25% TSDF 384 TS	Ring 1 15 % TSDF 230 TS	Ring 2 10 % TSDF 154 TS	768 empty time slots	1536 TS/12 sec

c. two user mulitnet 258-pulse time slot 100/50 TSDF snapshot

Figure 4-2. 100/50 TSDF Snapshots

A limited set of parametric data was collected to have a more comprehensive set of data. These were developed to investigate different geometric distributions of the JTIDS platforms and to investigate different time slot assignments. The variations included changing the TSDF in Ring 1, the percent of net overlap, and the Ring 1 signal level.

Additional information on the JTIDS scenarios and snapshots can be found in references 15, 16, 17, 18, and 19.

4.2.2.1.1.1 Geographic Area Snapshots

To answer the question "What is the area that bounds a single JTIDS 100/50 TSDF exercise?" or, alternately, "How close can a JTIDS 100/50 TSDF exercise approach an existing 100/50 TSDF exercise before the effects of the intruding exercise is observed?", a geographic area investigation was conducted.

The Phase 1 approach was to investigate how close a single 200 percent TSDF point source could approach an ATC receiver that was located within a 100/50 TSDF JTIDS operation. The Air Force and Army scenario snapshots were slightly modified to include a 200 percent TSDF point source. A 200 percent TSDF point source was used instead of a 100 percent TSDF point source to provide worst case conservative results. The received signal strength of the 200 percent TSDF point source was increased in 3 dB steps until the TACAN/DME interrogators sensitivity was effected.

4.2.2.1.2 TACAN/DME Beacon Snapshots

Two types of JTIDS environments were developed for beacon testing. The first type, referred to as beacon snapshot intervals, was developed from Navy and Army 100/50 TSDF training scenarios. The second environment type, referred to as JTIDS environment variations, was developed to test the effects of specific JTIDS parameters on TACAN/DME beacon receivers.

The beacon snapshot intervals were developed from the Navy and Army interrogator snapshot intervals by modifying certain terminal platform designations and locations, and the relative position of the ATC receiver. These modifications were made to maximize the effects of the JTIDS environment on a ground-based beacon receiver. The JTIDS net structure was kept the same for the beacon snapshot intervals as for the interrogator snapshot intervals.

The beacon environment variations were developed to produce a specific time-of-arrival condition at the beacon. These environment variation snapshots were composed of six JTIDS terminals (two foreground, two Ring 1 and two Ring 2). Within the foreground and each Ring, the JTIDS terminals of a pair were separated by 2 nmi. This represents a propagation delay of 12 μs. The pulse spacing for a desired TACAN/DME interrogator on X mode is 12 μs. Thus, when testing of multinet or contention time slots, JTIDS pulses have been purposely arranged to arrive at the beacon with the proper spacing to produce a decode. The received signal levels for the three-level quantized environment variations were: -33 to -60 dBm for the foreground, -60 dBm for Ring 1 and -75 dBm for Ring 2.

Detailed information on the beacon snapshot intervals and the beacon environment variations can be found in references 20 and 21.

4.2.2.1.3 ATCRBS Interrogator Snapshots

The JTIDS environment variations investigated during the ATCRBS interrogator testing represent 23 separate JTIDS network configurations. These configurations represent variations of the basic 100/50 TSDF environment and they are very similar to the two beacon snapshot intervals plus the environment variations used for the beacon tests. One configuration represents a variation of a 100/100 TSDF environment, eight represent variations of a 200/50 TSDF environment, and two represent variations of a 400/50 TSDF environment.

To cover pulse time-of-arrival conditions, two terminals were located to represent a close background environment called Ring 1, and the two remaining terminals were located at a more distant location to represent Ring 2. Within the foreground and each ring, the JTIDS terminals of a pair were assumed to be separated by 3.3 nmi. This separation represents a propagation delay of 20.3 μs, which is the framing pulse spacing of an ATCRBS reply. Thus, when testing multinet or contention time slots, JTIDS pulses have been purposely arranged to arrive at the interrogator with the proper spacing to produce a decode. Although the JTIDS terminals were placed in two rings for signal timing considerations, all the background terminals (Ring 1 and Ring 2) were set to produce the same power level at the ATCRBS interrogator (i.e.,-50 dBm).

The TSDF assigned to each ring was fixed for each of the 100/50 TSDF JTIDS environment variation snapshots. Fifty percent of the time slots were allocated to the foreground, 30 percent to Ring 1 and 20 percent to Ring 2. JTIDS signal levels used during the testing were in accordance with the ATCRBS test plan (reference 22). Additional information for the ATCRBS interrogator snapshots can be found in reference 12.

4.2.2.1.4 1030/1090 MHz Avionics JTIDS Environment

The JTIDS signal environment for all the 1030/1090 MHz avionics tests consisted of a single net operating on 50 percent of the available time slots with a 258-pulse time slot format. This 50/50 TSDF test was all that was required since JTIDS background signals weaker than -50 dBm cannot get into the receiver of the transponders. This had been determined during the ATCRBS interrogator testing. The peak power of the JTIDS signal at the receiver port of the avionics transponder was varied in 1 dB steps from -35 dBm to a power level where the effects of JTIDS signals were clearly established. Additional information regarding the JTIDS signal environments used during the 1030/1090 MHz avionics testing can be found in reference 23.

4.2.2.2 100/50 TSDF Phase 2 Snapshots

Presently to date, only TACAN/DME interrogator testing is complete. Phase 2 testing involved numerous snapshots representing a multitude of JTIDS variations and environment variations. The details are described in the following sections.

4.2.2.2.1 Generic Snapshot

The generic snapshot consists of a total of a 50 percent JTIDS transmitter in the foreground, a total of 30 percent in Ring 1 and a total of 20 percent in Ring 2. The foreground represents the JTIDS terminals that have been positioned as close to the DME interrogator as possible under normal ATC control procedures governing aircraft flight. Depending on the particular JTIDS training operation, the foreground could represent for example, an E-3A, an F-15, an F-14 or various ground-based terminals from any of the military services.

The signal level that was used to represent the foreground was based on worst case ATC distance separations and worst case JTIDS signal coupling into the DME interrogator receiver (takes into account all antenna gains, line losses and peak JTIDS transmitter power). Because of the various parameters, the worst case received signal level depends on the JTIDS platform employed. This signal level has been previously calculated to be in the range of -42 to -45 dBm (airborne JTIDS terminals produce -42 dBm and ground JTIDS terminals produce -45 dBm). During the Phase 2 testing, the number of foreground signals that were tested depended largely on the test objective. A foreground signal level of -42 dBm was always tested. Normally, a set of data using a foreground signal range of -36 to -45 dBm was collected in 3 dB steps. However, occasionally a foreground signal range of -36 to -51 dBm was used to bracket possible future applications of JTIDS.

Using 30 percent TSDF in Ring 1 is intended to represent the combined duty factor of all the JTIDS background terminals that will produce a received signal level at the DME interrogator stronger than -66 dBm. For the purpose of the test, Ring 1 is placed at a relative distance from the DME interrogator of approximately 5 nmi and produces a received signal level at the DME of -60 dBm.

Since the total JTIDS TSDF is 100 percent, a 20 percent TSDF is assigned to Ring 2. Ring 2 is intended to represent the combined duty factor of all the JTIDS terminals that produce a received signal level weaker than -66 dBm. For the purpose of the test, Ring 2 is placed at a relative distance from the DME interrogator of approximately 20 nmi and it produces a received signal level at the DME of -72 dBm.

In addition to the values used to specify the generic snapshot, it is also necessary to specify the net numbers and the relative time-of-arrival of the pulses from each time slot at the DME interrogator before a snapshot can be tested. These parameters are what was varied to investigate JTIDS effects on TACAN/DME interrogators.

4.2.2.2.2 JTIDS Environment Variations

One hundred fifty-three (153) snapshots were tested during the Phase 2 effort. Early in the testing it was discovered that whenever a snapshot was modified to only change the number of pulses in a JTIDS time slot to either 258 or 444 (keeping the total number of pulses equivalent to 100/50 TSDF), the results were approximately the same. Based on this result, to reduce the scope of the parametric testing, subsequent testing was performed primarily with 444-pulse time slots.

The contention parameters that are responsible for producing additional effects when compared to multinet were investigated. The primary parameter is referred to as the delta time-of-arrival between the pulses from two time slots in contention. Snapshots varied the relative pulse arrival offset time from 6 to 18 μs in 1 μs steps. This was done to investigate the effect of contention on the 12 μs X mode decoder. Also, several snapshots investigated the effect of varying the number of contention time slot pulses that were assigned a fixed offset of 20 μs. This was done to investigate the effect of dispersing the JTIDS terminals throughout the test area as opposed to concentrating them in the worst possible location.

Snapshots were developed to investigate the distribution of contention and multinet time slots. foreground to foreground overlap, Ring 1 to Ring 1 overlap, Ring 2 to 2 overlap, foreground to Ring 1 and Ring 2 overlap, and Ring 1 to Ring 2 overlap were investigated. Varying proportions of overlap were investigated.

Snapshots were developed to investigate the effect of increasing the number of simultaneous JTIDS transmissions in a time slot from two to ten.

4.2.2.2.3 Army Snapshot

To answer a specific question regarding the Army use of JTIDS, an updated Army scenario of two snapshots was developed. This snapshot employed 22 JTIDS terminals and made extensive use of enhanced repromulgation relay. The two snapshots investigated contention effects in which 1/8 and 1/4 of the contention time slot pulses were assumed to arrive at the interrogator with a 12 μs decoder spacing.

4.2.2.2.4 Geographic Area Snapshot

Additional geographic area tests were conducted to investigate the effects of contention in the 200 percent TSDF geographic area point source. In Phase 1, the geographic area source consisted of non-overlapping time slots. The Phase 2 snapshot consisted of two users in contention, with 1/8 of the overlapping time slot pulses spaced 12 μs apart.

SECTION 5

40/20 TSDF DATA AND ANALYSES

Certain statements are taken verbatim from reference 1. The data and conclusions stated in this section are summarized from reference 1. This data is applicable to JTIDS transmitting in the normal power mode of 200 watts.

5.1 TACAN/DME INTERROGATIONS AND BEACONS

5.1.1 Data

5.1.1.1 Beacons

A summary of the measured TACAN/DME beacon performance is presented in table 5-1. This data applies to beacons operating at 70 percent reply efficiency with JTIDS signals present at 40/20 TSDF. It is shown that for JTIDS aircraft 1000 feet above the beacon, the received signal level varies as a function of lateral distance from the beacon. This variation encompasses signal levels of -40 dBm when JTIDS is above the beacon to -60 dBm when the JTIDS terminal is 5 nmi from the beacon. At a constant JTIDS received signal level of -50 dBm, the observed JTIDS effects had a variability that bounded the effects due to -40 dBm and -60 dBm JTIDS received signals. Based on this it was decided to use a -50 dBm JTIDS received signal level as the signal level where JTIDS effects would be evaluated.

Table 5-1 shows the effect of JTIDS on beacon performance as a function of beacon load. In addition to the beacon EPE, which is undesired interrogators from other TACAN/DME beacons in the vicinity, the beacon load is also input to the beacon under test. The beacon load refers to other valid interrogators from aircraft using the beacon under test which are not of interest. Full beacon load means all other beacon interrogators are being received at a signal level above the retriggerable blanking gate (RTBG). This is a worst case condition. The 50/50 load is when only 50 percent of the interrogations are above the RTBG level.

For ground based JTIDS transmitters, the required distance separation from a TACAN/DME beacon is shown in table 5-2 for various received signal levels. These values were calculated based on the specific JTIDS and beacon antenna system parameters and characteristics considered in the 40/20 T&E program.

Table 5-1. Summary of the Decrease in TACAN/DME Beacon Reply Efficiency for 40/20 TSDF JTIDS Signals

GROUND BEACON	en route (Wilcox 596B)			Terminal (Aerocom 5350A)			Terminal (Cardion 8974)		
JTIDS Signal Level (dBm)	-40	-50	-60	-40	-50	-60	-40	-50	-60
Maximum Reduction for all loads (%)	2.1	1.5	a	4.29	4.5	2.96	3.6	2.87	1.5
Maximum Reduction for 50/50 loads (%)	a	a	a	3.78	3.0	2.31	2.5	1.9	a
[a] No measurable effect									

Table 5-2. Typical Required Distance Separation Between a TACAN or DME Ground Beacon and a JTIDS Ground Terminal To Ensure that the Given JTIDS Signal Level is not Exceeded

	Distance Separation in Nautical Miles					
	TACAN			DME		
JTIDS Antenna Height (feet)	JTIDS @ -40 dBm	JTIDS @ -50 dBm	JTIDS @ -60 dBm	JTIDS @ -40 dBm	JTIDS @ -50 dBm	JTIDS @ -60 dBm
35	1.4	3.75	5.9	1.09	3.59	6.25
100	1.25	4.8	8.9	1.06	4.09	9.53

5.1.1.2 Interrogators

Tables 5-3, 5-4 and 5-5 show the interrogator beacon coupled acquisition sensitivity [ASOP (see section 6.1.1.1.1.3 for discussion on data types)] of the 11 TACAN/DME interrogators tested for the three types of ground-based service. Also shown in the tables is the change in TACAN/DME acquisition sensitivity in the presence of a JTIDS at 40/20 TSDF for signal levels of -36 dBm and -42 dBm. Considering the system variability of the ground based beacons and interrogators, and the variability of propagation phenomena, the maximum change in acquisition sensitivity of 1.7 dB with JTIDS present may not be detected in an operational environment.

Table 5-3. Interrogator Acquisition Sensitivity For TACAN Beacon Service

Interrogator Equipment	ASOP without JTIDS (dBm)	Decrease in Acquisition Sensitivity for JTIDS 20 % TSDF	
		JTIDS Signal Level	
		-42 dBm	-36 dBm
KDM-7000	-89.1	0	0.2
KN-60C	-75.1	0.5	0.5
KN-65	-79.1	0	0
DME-190	-76.1	0	0
DME-195	-76.1	0	0
860E-2	-88.3	0.3	0.3
860E-3	-86.9	0.5	0.5
860E-5	-86.7	0	0
UDI-4	-73.0	0	0
AN/ARN-118	-89.1/-90.5[a]	no data	0/0
Siera Test Set	-89.1	0.5	0.5

[a] Acquisition sensitivity of range/bearing

Table 5-4. Interrogator Acquisition for DME En Route Beacon

Interrogator Equipment	ASOP without JTIDS (dBm)	Decrease in Acquisition Sensitivity for JTIDS 20 % TSDF	
		JTIDS Signal Level	
		-42 dBm	-36 dBm
KDM-7000	-92.5	1.3	1.7
KN-60C	-77.8	0.9	0.9
KN-65	-83.0	0	0
DME-190	-79.8	0.2	0.2
DME-195	-80.0	0	0
860E-2	-89.5	0.5	0.5
860E-3	-90.2	0.8	0.8
860E-5	-87.3	0	0
UDI-4	-77	0	0
AN/ARN-118	-92.0	no data	0
Siera Test Set	-92.0	1.1	1.3

Table 5-5. Interrogator Acquisition Sensitivity for DME Terminal Beacon Service

Interrogator Equipment	ASOP without JTIDS (dBm)	Decrease in Acquisition Sensitivity for JTIDS 20 % TSDF	
		JTIDS Signal Level	
		-42 dBm	-36 dBm
KDM-7000	-94.5	1.5	1.5
KN-60C	-80.7	0	0
KN-65	-86.0	0.3	0
DME-190	-84.6	0	0
DME-195	-84.8	0	0
860E-2	-89.5	0	0
860E-3	-92.5	0	0
860E-5	-93.0	0	0.5
UDI-4	-79.8	0.2	0.2
AN/ARN-118	-95.5	no data	0.4
Siera Test Set	-94.0	0.5	0

5.1.2 Conclusions

The following conclusions were derived from data obtained from bench tests and confirmed by flight tests.

1. Measurements show that JTIDS signals did not cause false range, bearing or velocity indications, or affect the quality of the identification tone.

2. When JTIDS signals are coupled into the TACAN/DME system, the operational effect is to reduce the interrogator acquisition range by a few nautical miles (maximum of 7 nmi). This will occur only when the interrogator is attempting to acquire the TACAN/DME signal at the service limits of the interrogator while a JTIDS aircraft is either near the TACAN/DME ground beacon or at a minimum ATC separation distance from the interrogator. Analyses indicate that this low-probability event produces range-acquisition changes that are less than the normal TACAN/DME system variability observed during the test program.

3. When the JTIDS signal is coupled from a ground terminal to an interrogator-equipped aircraft, the maximum potential change in service range is only a few thousand feet, and can occur only if the aircraft is within 1000 feet of the ground terminal during acquisition.

4. JTIDS ground-based units require site engineering to ensure that JTIDS signals do not affect the performance of TACAN/DME beacon receivers. The separation distances required will vary according to particular terrain conditions, but will be on the order of 3 to 5 nmi for line-of-sight conditions.

5. If JTIDS ground terminals are properly sited, these results indicate that JTIDS operations will produce no harmful operational effects in the TACAN/DME system.

5.2 ATCRBS

5.2.1 Data

5.2.1.1 Transponders

Prior to ATCRBS transponder bench testing, all transponders were checked to insure that they were within the specification set forth in FAA Order 1010.51A, "United States National Aviation Standard for the IFF Mark X (SIF)/Air Traffic Control Radar Beacon System Characteristics". Using the National Standard specifications as a performance threshold reference, the minimum triggering level (MTL), Side Lobe Suppression (SLS), and echo-suppression characteristics of sixteen different transponders were measured with and without JTIDS signals present. It was noted during these bench tests that a

JTIDS signal with -20 dBm peak pulse power and 40/20 time-slot duty factor in the double-pulse mode (258-pulse in a time slot) has no discernible effect on transponder MTL, SLS, and echo-suppression characteristics. This result was the same whether or not the notch filters were installed at the JTIDS transmitter output.

The Class 1 terminal built by Hughes Aircraft Company and tested in the 40/20 T&E Program, includes a notch filter at the output of the terminal. This notch filter provides additional attenuation at 1030 MHz and 1090 MHz frequencies. During bench testing, the notch filters could be bypassed thus providing no external filtering of the transmitted JTIDS signals. The notch filters were installed to mitigate collocation effects between JTIDS and ATC avionics.

5.2.1.2 Interrogators

The bench-test measurements on the terminal beacon system ATCBI-4 involved counting the detected targets, fruit, and transponder replies at various combinations of JTIDS and transponder signal levels, and combinations of defruiter and notch-filter employment. Fruit is normally defined as received nonsynchronous beacon replies due to other beacon interrogations; however, the definition here has been expanded to include reception of any spurious replies not associated with the target. The highest JTIDS signal levels that had no observable effects on ATCBI-4 performance parameters are given in table 5-6. The top row indicates the four combinations of notch-filter and defruiter employment and the first column indicates the ATCBI parameters measured. The defruiter is used to filter out reply signals which are not synchronous to the transmissions of the interrogator. The next to last row of the table indicates the highest JTIDS signal levels that had no effect on any of the three parameters measured.

During the JTIDS bench-test measurements, the gain time control (GTC) circuit in the beacon receiver was disconnected so that its effect would not influence the count of lost targets and lost replies attributable to JTIDS. The GTC function automatically desensitizes the receiver. It was determined that more than 10 dB of desensitization is introduced 100 percent of the time. This has the effect of increasing the JTIDS signal level necessary to affect beacon performance. Since the GTC circuit is always used operationally, the strongest JTIDS signals that would have no effect are 10 dB greater than the maximum JTIDS bench test signal that did not affect ATCRBS ground interrogator performance. The resulting maximum JTIDS signal levels that would not affect performance with GTC employed are indicated in the bottom row of table 5-6.

Based on the transponder effect data, and given that the defruiter of the interrogator will be operational, a JTIDS signal level of -20 dBm is acceptable at the input to an interrogator receiver. It was determined that a JTIDS equipped aircraft observing the FAA flight separation rules would result in signal levels coupled to a ground interrogator, which are less than or equal to the highest JTIDS signal level that had no effect on ATCRBS ground beacon performance (-20 dBm).

Table 5-6. Maximum JTIDS Signal Levels Which Have No Effect On Terminal ATCBI-4 Performance Parameters

Notch Filter Defruiter	In On	In Off	Out On	Out Off
Performance Parameters				
Target Detection	-10 dBm	-20 dBm	-30 dBm	-40 dBm
Fruit Count	0 dBm	-20 dBm	-20 dBm	-40 dBm
Transponder Replied (Target Hits)	-10 dBm	0 dBm	-30 dBm	-30 dBm
Any One of Three Parameters	-10 dBm	-20 dBm	-30 dBm	-40 dBm
Adjusted Bench Test Signal for GTC	0 dBm	-10 dBm	-20 dBm	-30 dBm

For the case of ground based JTIDS transmitters, table 5-7 delineates the required separation distances from a ground based ATCRBS interrogator beacon.

Table 5-7. Minimum Separation Distance Between JTIDS Ground Installations and Terminal ATCRBS Ground Beacon (Notch Filters Out, Defruiter On, and -20 dBm JTIDS Signal Level

JTIDS Antenna Height (feet)	ATCRBS Antenna Height (feet)	Distance Separation (yards)
6	30	111.4
10	30	141.7
30	30	172.2
100	30	303.8
6	85	162.0
10	85	202.5
30	85	263.3
100	85	486.1

5.2.2 Conclusions

The following conclusions were derived from data obtained from bench tests.

1. For predicted JTIDS coupling levels that correspond to minimum operational ATC distance separations, none of the transponders tested were susceptible to JTIDS, with or without the JTIDS notch filters.

2. At minimum ATC operational separation distances, ATCRBS en route interrogators and terminal interrogators with defruiters on are not susceptible to JTIDS, with or without the JTIDS notch filters.

3 When a JTIDS transmitter and an ATCRBS transponder are installed in the same aircraft, engineering may be required to assure adequate isolation between the two equipments.

4. JTIDS ground-based units should be site engineered to ensure that maximum JTIDS signal levels do not affect the performance of the ATCRBS ground interrogator. The required separation distances will vary depending on particular terrain conditions and JTIDS/ATCRBS antenna height combinations, but they are estimated to be approximately 100 to 500 yards for line-of-sight conditions for a JTIDS terminal near an ATCRBS ground facility.

5.3 DABS

5.3.1 Data

The Discrete Address Beacon System (DABS) flight tests involved the use of prototype DABS transponders and a DABS interrogator at the MIT/Lincoln Laboratory DABS experimental facility.

5.3.1.1 Transponders

The JTIDS signal level coupled between a JTIDS terminal and a DABS equipped aircraft with an approximate 1000 foot altitude difference was investigated in flight tests. A DABS transponder equipped aircraft was flown at a 1240-1440 foot differential slant range in tandem formation above a JTIDS aircraft. To maximize JTIDS-to-DABS coupling, the JTIDS transmitter was connected to the top-mounted antenna. The DABS ground interrogator transmitter power was reduced to 100 watts to simulate the operation of a transponder at a maximum range of 200 nmi. The JTIDS transmitted at a 40/40 TSDF. Notch filters were not used at the output of the JTIDS terminal at 1030 MHz or 1090 MHz. The results of the tests indicated no degradation to the performance of DABS all-call replies or track quality due to JTIDS.

5.3.1.2 Interrogators

The effect of the JTIDS airborne signal on a DABS ground interrogator was evaluated in the DABS flight tests. The JTIDS aircraft was flown on an inbound radial directly over the DABS ground interrogator at a 3000 foot altitude. Simultaneously, a DABS transponder-equipped aircraft was flown outbound on the same radial. In addition, the replies from a calibration DABS transponder mounted on a water tower 5.5 nmi from the DABS interrogator was monitored. The calibration transponder output power was attenuated to simulate effective ranges of 71 and 200 nmi. JTIDS transmitted at a 40/40 TSDF. DABS monopulse direction finding performance was also evaluated. The test results showed that DABS reply probabilities, monopulse characteristics, and track qualities were unaffected by JTIDS signals.

Because DABS ground interrogators are no more susceptible to JTIDS transmissions than the ATCRBS ground interrogators, the required separation distances between DABS and JTIDS should be the same as those from ATCRBS interrogators.

5.3.2 Conclusions

The following conclusions are based on flight-test measurements on prototype DABS equipment in the presence of JTIDS equipment without notch filters, supplemented by theoretical analysis and ATCRBS bench-test measurements. These findings apply to DABS equipment with specifications similar to the units tested. [DABS has been replaced by Mode S.]

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

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

3. Flight tests indicated that DABS performance would not be affected even if JTIDS transmitters without notch filters and DABS transponders were installed on the same aircraft, and both antennas were mounted on the bottom of the same aircraft.

5.4 BCAS

5.4.1 Data

The JTIDS effect on the Beacon Collision Avoidance System (BCAS) ability to track ATCRBS ground beacons was investigated. Analyses were performed and confirmed by flight tests. The flight tests were conducted at 1000 foot minimum separation distances. The flight tests indicated no effect on the ability of BCAS to either acquire or track the ground beacon station.

The ability of BCAS to decode ATCRBS transponder replies in a JTIDS signal environment was investigated. Flight tests were conducted with a separation distance between JTIDS and BCAS of 1000 feet. BCAS was able to track other aircraft during the test with no discernible reduction in its accuracy. An increased fruit level was noted but no other effect was observed.

5.4.2 Conclusions

The following conclusions are based on flight-test measurements and theoretical analysis using passive BCAS feasibility equipment. They are applicable to BCAS equipment with similar technical characteristics.

1. The BCAS flight-test measurements show that a JTIDS aircraft separated by the minimum ATC operational altitude from a BCAS aircraft would not affect BCAS performance. The theoretical analysis indicated that JTIDS coupling levels at the minimum BCAS aircraft-to-aircraft operational separation distance would not affect BCAS/ATCRBS transponder reply efficiency, and would provide only a negligible contribution to fruit on 1090 MHz in congested terminal areas.

2. Active mode BCAS equipment was not available. Based on measurements of the passive mode and ATCRBS transponders, and on analysis, JTIDS would not affect BCAS performance in the active mode.

3. Collocating a JTIDS transmitter and a BCAS interrogator aboard the same aircraft may require engineering to assure adequate isolation between the two equipments.

5.5 MLS/DME

5.5.1 Data

The Microwave Landing System (MLS) will utilize a precision DME (DME/P) for its range function. The ground based DME/P transponder will be collocated with the MLS equipment. Only prototype DME/P equipment was evaluated because the final design had not been selected yet.

5.5.1.1 Avionics

Static and dynamic flight tests were conducted. The static flight test consisted of parking an aircraft equipped with MLS/DME (DME/P) avionics on a taxiway adjacent to the main runway and flying the JTIDS aircraft at 1000 feet altitude down the runway. This resulted in maximum JTIDS signal level coupling.

The dynamic flight tests involved an MLS/DME equipped aircraft making 2000 foot altitude passes over the runway with the JTIDS aircraft at 1000 foot lower altitude in a trail position.

For both the static and dynamic flight tests, JTIDS had no measurable effects on the MLS/DME avionics.

5.5.1.2 Ground Transponders

Both static and dynamic flight tests involved the worst case JTIDS signal level coupling situation in which a JTIDS aircraft flies directly over a MLS/DME ground transponder at 1000 feet altitude. No JTIDS effect on the ground beacon reply efficiency for either the static or dynamic portion of the flight tests was observed.

5.5.2 Conclusions

The following conclusions are based on flight tests of experimental MLS/DME equipment, supplemented with theoretical analysis. The MLS/DME equipment tested consisted of a terminal ground beacon and an airborne interrogator, both modified to tentative MLS/DME specifications. The following results are indicative of the electromagnetic compatibility to be expected if this type of MLS/DME design is operationally implemented.

1. All measured operational conditions show that JTIDS would not affect MLS/DME performance. However, no measured data is available concerning the performance of collocated JTIDS terminals and MLS/DME equipment.

2. The effect of collocating an MLS/DME interrogator and a JTIDS terminal aboard the same aircraft requires evaluation with representative operational equipment. This collocation should be engineered to preclude interference in the interrogator receiver.

3. When operationally representative equipment is available, an evaluation should be made to determine if a minimum separation distance is required between the ground beacon receiver and a JTIDS-equipped aircraft on the glide slope.

SECTION 6

100/500 TSDF DATA AND ANALYSES

The data and analyses presented in this section contains statements taken verbatim from references 4 and 13. Specific conclusions are identified by bold type.

6.1 TACAN/DME/N INTERROGATORS AND BEACONS

6.1.1 Interrogators

The EMC T&E Program assumed that the following worst case events occurred at the same time so the results are very conservative, and there is no need for any additional margin to be used. These simultaneous conditions include the foreground JTIDS terminal TSDF being at a constant 50 percent, the DME unit being in search, the DME and JTIDS units being at the minimum ATC separation distance, the JTIDS equipped aircraft maintaining the maximum coupling position, both platforms traveling at approximately the same velocity, the DME equipped aircraft being at its maximum service range, the desired signal level being in an unfavorable propagation fade condition (95 percent time availability), the desired beacon being loaded with traffic, and the DME and JTIDS antenna gains and cable losses being at the most conservative values.

In addition, some of the JTIDS parameters tested assumed operationally unrealistic conditions. For example, significant foreground or background overlap conditions are very unlikely because JTIDS networks are designed with minimal time slot overlap; however, they were tested to evaluate the JTIDS parameters that effect EMC. Also, many of the test conditions investigated assumed a worst case JTIDS pulse spacing of 12 μs. In many of the test cases it is physically impossible to realize 12 μs spacings.

The interrogator testing was conducted in the following manner. The desired signal type was selected based on which type made the unit under test (UUT) more susceptible to JTIDS signals. There are three types of desired signals which TACAN/DME system uses, these are: a TACAN beacon signal operating at a squitter rate (pulse pairs per second) of 2700, a DME beacon signal at a squitter rate of 2700 and a DME beacon signal at a squitter rate of 1000. Each UUT was tested to determine which desired signal would be used. The JTIDS RF signals and the desired signal along with the EPE was input to the UUT. The EPE (see section 4) is designed to represent the undesired on channel or adjacent channel TACAN/DME pulses that could be detected by the UUT.

The reply efficiency of the beacon simulator (which supplies the desired signal) was adjusted to provide a 70 percent BRE. Reply efficiency is the ratio of the number of replies provided by the TACAN/DME beacon that are in response to the desired TACAN/DME interrogations divided by the number of interrogations. A 70 percent reply efficiency is the minimum specified amount that will be provided by TACAN/DME beacons. Consequently, using a value of 70 percent is conservative since the operational reply efficiency will actually be higher than that value. A higher reply efficiency will generally permit the TACAN/DME to operate better in the presence of pulsed interference. The desired signal was also set to operate in either X mode or Y mode. It was determined that Y mode operation experienced no greater effects than X mode operation and consequently most of the testing was done in X mode.

6.1.1.1 Performance Measurement

In the T&E Programs, two types of TACAN/DME interrogator performance parameters were measured. These are Acquisition Stable Operating Point (ASOP) and Time To Acquire (TTA).

In the 40/20 T&E Program ASOP data was collected. In the 100/50 TSDF T&E Program, ASOP and TTA data were collected. As will be explained later, because TTA data provides a better indication of the operational effect of JTIDS signals than that provided by ASOP data, TTA data is primarily used to establish whether the effects of JTIDS environments will provide harmful interference in the TACAN/DME interrogators.

The ASOP and the TTA point measurements are used to determine the ability of each interrogator to acquire and track a desired signal. ASOP is a sensitivity test that determines the minimum desired signal level (DSL) needed at the interrogator to obtain repetitive acquisition and tracking performance for that test condition. For each ASOP, the interrogator is required to complete five consecutive acquisitions with the beacon identification (ID) tone off, each within a certain time period, and track the acquired signal continuously for 60 seconds with the ID tone on following the last acquisition. Therefore, if the unit acquired lock four times out of five at a desired level of -90 dBm and five times out of five at a level of -89 dBm (and the unit tracked for 60 seconds), ASOP is defined as -89 dBm.

For each interrogator tested a specific ASOP acquisition time limit (AATL) was established. The AATL value is the amount of time in which the interrogator must achieve lock. The time limit was increased from five seconds until repeatable performance could be achieved. For conventional interrogators, acquisition was established when the unit acquired a single desired channel. For the scanning units, acquisition was not considered complete until all five foreground channels had acquired the desired signal. The AATL values in the Phase 1 and Phase 2 efforts are shown in table 6-1. The values used in the Phase 2 effort differ from those established during the Phase 1 effort. It was determined that the Phase 1 AATL values in some cases were incorrect. They were too short a time for the units to achieve stable operation.

Table 6-1. TACAN/DME Interrogator ASOP Acquisition Time Limits (AATL)

Type	Nomenclature	Phase 1 AATL (seconds)	Phase 2 AATL (seconds)
DME Interrogator	DME890	5	10
	DME1077B	10	10
	KN 63	5	15
	DME-451	10	25
	DME-40	5	10
	KN 65A	20	20
	DME-42	5	10
	KDM 7000	5	5
	DME-860E-3	5	10
	DME-44A	-	45
	DMA-37A	10	15
	DME-700	5	15
TACAN Interrogator	KTU 709 (R)	10	30
	KTU 709 (B)	20	10

In the TTA tests, the performance data that is recorded on TACAN/DME units is the time it takes to acquire and read out the range that is programmed in the desired signal generator. The TTA tests were performed with the beacon ID tone off. However, the breaklock point was established with the beacon ID tone on. The breaklock point is the strongest signal level at which the unit cannot track the beacon signal for 60 seconds.

During the TTA test, the desired signal level is varied in 1 dB steps from a very weak level at which the DME will not acquire to a strong level at which the DME will acquire almost immediately. At each desired signal level, the DME is forced to search (unlock condition) for the desired signal 20 times (10 times in Phase 1). At the end of each search cycle, the amount of time needed to acquire the desired signal is recorded. If 120 seconds elapse before the DME can acquire lock, a miss is recorded for that trial. After the 20 trials are completed or if 5 misses are recorded, the desired signal is increased 1 dB and the 20 trials are repeated. The TTA data array is processed to determine the weakest desired signal level at which the unit can acquire on each of the 20 trials. This level is referred to as the principal TTA (PTTA) level and it is indicative of the receiver sensitivity.

During the early parts of the Phase 2 effort, it was established (reference 24) that the ASOP data could be analytically derived from the TTA data set. After the ASOP/TTA relationship was verified, ASOP test data was no longer collected in Phase 2.

When compared to ASOP data, TTA data provides a much better estimate of the acquisition signal level at which the pilot will observe the interrogator acquiring lock . When the aircraft is at some large distance from the desired beacon, the pilot will tune the TACAN/DME interrogator to the beacon channel. After the DME acquires the beacon signal and provides a range readout, the pilot does not rechannel the unit four more times to see if the signal is valid. TTA data represents the situation in which the pilot, after tuning to the station, experiences a time delay (for example, 15 seconds) before the DME can provide a range readout.

The TTA approach that was used in Phase 1 is very similar to the Phase 2 TTA approach. The major difference was the Phase 1 TTA only collected 10 samples per data point and the Phase 2 TTA collected 20 samples. In the Risk Assessment Report (reference 3) analysis of the Phase 1 test data, more weight was given to the TTA results over the ASOP results because of the increased stability and operational significance of the TTA data.

6.1.1.1.1 Phase 1

During the collection of this data, the bearing and distance measuring accuracies were never affected by the presence of JTIDS signal environments. What was affected was the time to acquire the desired signal, or in the case of ASOP measurements, the interrogator required a stronger desired signal to acquire lock within the AATL time limit. Also, the effects from JTIDS signals were independent of whether or not the EPE was present.

6.1.1.1.1.1 ASOP Data

Summarized ASOP data on 12 civilian TACAN/DME interrogators selected for testing are contained in table 6-2. The interrogators were grouped by type (DME or TACAN), overall design (single channel or multichannel) and usage (general aviation or commercial aviation) so that the data for comparable units could be shown together. The table primarily presents the 70 percent BRE ASOP data for Channel 32X with the EPE ON. The only exception to this is that the Channel 59Y data are also shown for the KTU 709. This was done because the KTU 709 showed the most effect in Y mode. On all the other units, the 59Y data showed no worse of an effect than the 32X data so it was not necessary to include the 59Y data in this summary.

Each unit was tested using the desired beacon signal for which the unit experienced the most effect. This signal type is shown in column two and the remaining columns contain data that were taken using this signal type. The columns labeled NJ (NO JTIDS) contain the ASOP signal level when JTIDS signals were not present. Because of the way that the amplitude modulated TACAN signals were measured, the TACAN levels were adjusted by -3.4 dB (e.g., -92 dBm became -95.4 dBm) so that they could be compared with the DME signal levels. The remaining columns contain the change in ASOP (JTIDS ON - JTIDS OFF) at the various JTIDS foreground signal levels for the Air Force, Army, Navy and Joint Snapshots. The asterisks at various points in the columns indicate that there was some improvement with JTIDS signals present. The dashes in the columns indicate that the units were not available to take data for those snapshots. These units required modification or did not meet specification and had to be realigned. The reasons for the realignments and modifications are contained in reference 15. Since the SPS WG-1 approved limited testing for the Navy and Joint scenarios, only the KN 63, KN 65A, KDM 7000, and DMA-37A were tested with these snapshots.

6.1.1.1.1.2 TTA Data

Summarized TTA data on the TACAN/DME interrogators are contained in table 6-3 The same format is used in table 6-2 and table 6-3 so the information and explanations already provided for table 6-2 also apply to table 6-3. Again, all of the data are for 70 percent BRE 32X except the KTU 709 59Y data are also included. The asterisks and dashes have the same meaning as in table 6-2. A "NO" code means that TTA data could not be obtained from this unit.

The "NP" code means that the interrogator had a PTTA change (between JTIDS off and JTIDS on) of 2 dB or less, or the JTIDS on PTTA was weaker than the minimum signal level at the edge of the standard service volume (SSV). The SSV is the area in which the FFA guarantees a minimum signal strength from a TACAN/DME beacon. In the low altitude general aviation SSV, the signal strength is -79 dBm. In the high altitude commercial aviation SSV, the signal strength is -84.5 dBm. The values are based on a 95 percent availability basis.

6.1.1.1.1.3 ASOP and TTA Range Change Analyses

To relate the change in interrogator sensitivity to change in acquisition range, an operational analysis is performed. Each supporting operational analysis package contains a background on operational analysis and an overview of the operational analysis technique, which includes a detailed description of the four major analysis stages in the program and examples of how the analysis results are presented. references 25, 26, 27, and 28 respectively are TACAN/DME interrogator operational analysis packets on the Air Force, Army, Navy, and Joint 100/50 TSDF Snapshots. Additional details on the operational analysis of these units are contained in the ECAC archives.

The analyses determine the range at which ASOP and TTA acquisitions would occur for the JTIDS OFF and JTIDS ON conditions. Because the TACAN/DME equipment operate in a closed loop system, the characteristics of the ground beacon and each interrogator must be used to determine the service range of the interrogator. The units were analyzed using the Second Generation VORTAC (SGV), en route TACAN beacon, and the Cardion en route and Terminal DME beacons. The determination of service range involves relating the interrogator signal level at the beacon to the beacon signal level at

Table 6-2. Summarized ASOP Data, 70 Percent BRE, EPE on

interrogator unit	signal type channel	Air Force				Army					Navy					Joint				
		(-dBm)	(delta dB)			(-dBm)	(delta dB)				(-dBm)	(delta dB)				(-dBm)	(delta dB)			
		NJ[a]	-48	-42	-36	NJ[a]	-51	-45	-39	-36	NJ[a]	-50	-47	-42	-36	NJ[a]	-50	-44	-38	-36
DME 890	DME 2700 32X	91.9	1.4	2.9	3.5	91.4	3.9	3.4	3.9	4.4										
DME 1077B	DME 2700 32X	90.4	2.9	3.4	4.2	88.8	2.8	3.2	2.8	4.3										
KN 63	TAC 2700 32X	85.5	1.6	5.1	5.1	84.3	4.4	5.4	7.1	7.4	84.5	2.8	3.6	3.6	5.5	84.5	3.5	4.1	5.6	7.1
DME-451	TAC 2700 32X	77.2	*	*	*	-	-	-	-											
DME-451 realigned	DME 2700 32X	80.6	1.1	1.1	2.1	80.4	0.9	0.2	0.4	1.4										
DME-40	TAC 2700 32X	85.7	*	*	*	84.9	0	0.5	*	0.5										
KN65A	DME 2700 32X	81.1	0.9	0.6	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KN65A realigned	DME 1000 32X	83.0	1.0	2.5	6.5	82.8	0.3	3.8	8.4	8.4	83.1	0.6	1.1	2.5	5.6	83.3	0.8	1.8	4.1	5.7
DME-42	TAC 2700 32X	90.0	0.6	1.1	2.1	91.4	2.0	1.0	2.5	3.5										
KDM 7000	DME 2700 32X	94.7	0.7	2.7	5.7	94.6	1.6	2.6	2.6	3.1	93.9	0.9	0.9	1.4	1.4	96.0	1.5	2.5	3.0	3.0
DME-860E-3	TAC 2700 32X	93.9	0.5	0.5	1.0	95.3	*	2.3	1.5	0.9										
DMA-37A	TAC 2700 32X	89.8	0.9	*	0.4	92.3	1.9	2.4	1.4	2.9	91.1	0.2	0.2	0.7	0.2	91.3	0.9	0.9	0.7	0.7
DME-700	TAC 2700 32X	94.6	2.2	2.7	2.7	90.9	1.0	0	0	1.3										
KTU 709 range	TAC 2700 32X	93.8	1.9	1.4	2.9	-	-	-	-	-										
	59Y	97.1	3.2	6.7	9.7	-	-	-	-	-										
KTU 709 modified range	TAC 2700 32X	94.5	0.1	*	0.1	94.2	0.3	0.8	0.3	*										
	59Y	96.2	*	*	0.8	95.7	*	0.3	0.8	0.8										
KTU 709 modified bearing	TAC 2700 32X	92.1	1.7	2.2	2.7	90.7	1.3	1.3	1.8	1.8										
	59Y	93.0	2.6	3.1	3.1	92.2	1.8	1.8	2.3	2.8										

[a] TACAN no JTIDS values adjusted (weakened) by 3.4 dB.

* improvement with JTIDS signals present.

\- unit not available to collect data.

Table 6-3. Summarized TTA Data, 70 Percent BRE, EPE on

interrogator unit	signal type channel	Air Force (-dBm)	Air Force (delta dB)			Army (-dBm)	Army (delta dB)				Navy (-dBm)	Navy (delta dB)				Joint (-dBm)	Joint (delta dB)			
		NJ[a]	-48	-42	-36	NJ[a]	-51	-45	-39	-36	NJ[a]	-50	-47	-42	-36	NJ[a]	-50	-44	-38	-36
DME 890	DME 2700 32X	92	1	2	3	93	2	2	3	4										
DME 1077B	DME 2700 32X	92	3	3	4	91	0	3	2	2										
KN 63	TAC 2700 32X	87.4	2	2	3	86.4	1	1	2	2	87.4	1	2	2	2	87.4	3	2	4	5
DME-451	TAC 2700 32X	NP	NP	NP	NP	-	-	-	-	-										
DME-451 realigned	DME 2700 32X	83	0	0	1	NP	NP	NP	NP	NP										
DME-40	TAC 2700 32X	NP	NP	NP	NP	NP	NP	NP	NP	NP										
KN65A	DME 2700 32X	NP	NP	NP	NP	-	-	-	-	-										
KN65A realigned	DME 1000 32X	84	0	1	2	84	0	0	4	4	84	0	*	0	2	84	0	0	1	1
DME-42	TAC 2700 32X	91.4	0	1	2	93.4	0	1	2	2										
KDM 7000	DME 2700 32X	96	1	2	2	96	0	2	2	2	95	1	1	1	2	97	2	2	2	2
DME-860E-3	TAC 2700 32X	NP	NP	NP	NP	NP	NP	NP	NP	NP										
DMA-37A	TAC 2700 32X	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
DME-700	TAC 2700 32X	98.4	0	0	0	97.4	0	*	1	1										
KTU 709 range	TAC 2700 32X	96.4	2	2	2	-	-	-	-	-										
	59Y	97.4	2	2	5	-	-	-	-	-										
KTU 709 modified range	TAC 2700 32X	NP	NP	NP	NP	NP	NP	NP	NP	NP										
	59Y	NP	NP	NP	NP	NP	NP	NP	NP	NP										
KTU 709 modified bearing	TAC 2700 32X	92.4	2	2	3	91.4	1	1.3	1	1										
	59Y	93.4	3	3	4	92.4	2	2	3	3										

[a] TACAN no JTIDS values adjusted (weakened) by 3.4 dB.

* improvement with JTIDS signals present.

\- unit not available to collect data.

NO - TTA data could not be collected on this unit. NP - unit passed dB selection criteria.

the interrogator. In the referenced reports, the service range of each interrogator was calculated, as a function of altitude, using the operational analysis method that is described in the 1978 OT report (reference 1).

The ranges at which acquisition would occur for the various test and altitude conditions are contained in the referenced operational analysis packets. These range values are plotted along with the service volume boundaries in the referenced documents. These portrayals of the range data provide further insight into the operational significance of any JTIDS signal effects on the operation of a TACAN/DME interrogator. For example, the en route beacon operational range analyses of the KN 63 (5.4 dB delta) and KN 65A (3.8 dB delta) ASOP results for the predicted JTIDS foreground signal levels for the Air Force and Army scenarios show that the maximum change in range at an altitude of 25,000 feet was 17.9 nmi for the KN 63 and 14.1 nmi for the KN 65A. These were for the 50 percent time availability (TA, see reference 29) desired signal levels and the 95 percent TA values were smaller. Both of these range changes occurred well outside of the SSV range (130 nmi) for this altitude. The acquisition distance for the KN 63 with JTIDS signals present was 146.3 nmi and for the KN 65A it was 144.9 nmi.

6.1.1.1.1.4 Geographic Area

The Phase 1 approach was to investigate how close a single 200 percent TSDF point source could approach a TACAN/DME interrogator that was located within a 100/50 TSDF JTIDS operation. The results are analyzed in reference 30 and the data supports a geographic area definition that corresponds to a maximum JTIDS received signal level of -78 dBm from a distant 200 percent TSDF point source. **This result is interpreted as an adjacent 200 percent TSDF JTIDS operation to an existing 100/50 TSDF JTIDS exercise must be separated in distance by approximately 45 nmi.**

6.1.1.1.2 Phase 2

The data collected during the Phase 2 effort has not been evaluated by the SPS WG-1. The conclusions stated here are based on a DOD assessment of the data.

6.1.1.1.2.1 Geographic Area

The approach was to collect a full set of TTA JTIDS effects data on the four worst performing TACAN/DME interrogators without the geographic area source present. The geographic area source was then turned on and varied from -72 dBm to -90 dBm in 3 dB steps. The additional effect due to the geographic area source was noted.

The data was evaluated by identifying the geographic area (200 percent TSDF point source) signal level which caused an additional 2 dB change PTTA. The geographic area signal level was then decreased by 3 dB (the previous no effect value) to identify the strongest point source signal level that does not produce an additional effect on TACAN/DME interrogator performance.

A 2 dB change in sensitivity was selected to establish that an effect had occurred because the data shows that the normal variable of the TACAN/DME sensitivity fluctuates by at least 1 dB.

Based on this approach, the geographic area data indicates that the geographic area corresponds to a JTIDS received signal level of -81 dBm. **This result is interpreted as an adjacent 200 percent TSDF operation must be separated from a 100/50 TSDF JTIDS exercise by approximately 65 nmi.**

6.1.1.1.2.2 Conclusions

The following results are based on TTA data for a 70 percent BRE with the EPE on. The data is summarized for a worst case JTIDS received signal level of -36 dBm or the strongest predicted JTIDS foreground signal levels.

1. The accuracy of the TACAN/DME interrogators was never affected by the presence of JTIDS signal environments.

2. Whenever a snapshot was modified to change only the number of pulses in a JTIDS time slot to either 258 or 444 (keeping the total number equivalent to 100/50 TSDF), the effect on the TACAN/DME interrogators was the same. **Therefore, there should not be any operational restrictions on the usage of either 258-pulse or 444-pulse time slots.**

3. Under worst case conditions with 12 µs pulse spacing arrival times, the usage of multinet did not affect the operation of the TACAN/DME interrogators. This result is based on the worst case time slot overlap foreground/foreground, ring 1/ring 1 and ring 2/ring 2 and is independent of the number of simultaneous overlapping nets. The testing included the effect of up to ten simultaneous transmissions, and the results indicate that there was a slight decrease in the effect as the number of simultaneous transmissions increased above two. This is because the total number of transmitted pulses is fixed at 396,288 (100 percent TSDF). In a two net configuration, the maximum number of TACAN/DME pulses are overlapped. As the net usage is increased, more JTIDS pulses transmit in a time slot thus increasing the time slots in which no JTIDS pulses are transmitted. As the number of transmitters increase, the amount of TACAN/DME pulses overlapped decreases. Therefore, the results can be extended to the use of an unlimited number of simultaneous nets. Consequently, **there should not be any operational restrictions on the use of multinet regardless of the number of simultaneous pulse transmissions from the various nets.**

4. The effects of contention are dependent on the type of time slot overlap, and the number of contention time slot pulses that have a propagation delay difference that is within the TACAN/DME decoder window. The number of time slots in contention can be stated as a percent of the total time slots. If all the time slots are in contention then this is called 100 percent time slot contention. If all the pulses within the time slots are in contention and the pulse pair time of arrival spacing is 12 μs, then this is referred to 100 percent time slot pulses in contention. As a consequence of the random time slot pulse jitter (see section 2.1.7.5), 7/8 of the time slots which are in contention will have pulse spacings which are not 12 μs. Therefore, 1/8 of the time slot pulses will have 12 μs a spacing. Under unrealistically worst case conditions involving foreground to foreground contention, the results indicate that 1/4 of the contention time slot pulses can have a propagation delay within the decoder window without affecting TACAN/DME interrogator performance. This result was based on 100 percent of the time slot pulses being in contention. It is expected that if fewer time slot pulses are in contention, the proportion can be higher than 1/4, however, this dependency was not investigated.

Similarly, any JTIDS operational requirement, such as repromulgation relay that produces an equivalent proportion of contention time slot pulses within the decoder aperture that is less than 1/4, will not operationally effect the TACAN/DME interrogators. The usage of repromulgation relay is bounded by this result. Therefore, 100 percent of the time slots can produce repromulgation relay pulses. Consequently, **there should not be any restrictions on the operational use of contention access or repromulgation relay.**

6.1.2 Beacons

6.1.2.1 Description of Data

JTIDS EMC tests were performed on an SGV beacon and a Cardion DME beacon (references 20 and 21). The beacon data packages contain a description of the six performance parameters that were measured. The measured performance parameters include the primary performance parameter of beacon reply efficiency and five secondary performance parameters which were used in the interpretation of the BRE. These secondary parameters are beacon reply delay, echo suppression gate count, valid decode count, automatic gain reduction (AGR) voltage, and monitor status. The data packages describe the various combinations of desired signal parameters, JTIDS signal parameters, EPE status (ON or OFF), and beacon load types for which data was collected. Also included is a description of the test setup, the data collection approach, and the test data.

The beacon load represents the effects of an environment of cochannel interrogations, other than those from the desired interrogator, that are competing for range replies from the beacon under test. The parameters used for the beacon load are shown in table 6-4. The table indicates the threshold setting of the retriggerable blanking gate (RTBG).

Table 6-4. Beacon Load Parameters

Pulse Rate Received at Beacon	Load Level at Beacon with RTBG Set @ -70 dBm
1500 ppps	50% @ -60 dBm 50% @ -80 dBm
2174 ppps	100% @ -80 dBm

6.1.2.2 Summary of Test Data Results

The test data summary is based solely on BRE. Beacon reply delay, monitor status and AGR voltage were not affected over the range of JTIDS signal conditions tested. The JTIDS signal effects on the remaining two secondary parameters (echo suppression gate count and valid decode count) were consistent with the JTIDS effects on the BRE.

6.1.2.2.1 SGV TACAN Beacon

6.1.2.2.1.1 Effect of Different JTIDS Scenarios

The 100/50 TSDF results on the SGV beacon were independent of the snapshot tested. That is, the SGV experienced the same effect regardless of whether JTIDS was transmitting any of the various 100/50 training scenarios or any variations of these scenarios including the amount of 444-pulse or 258-pulse time slots, the amount of contention, and the amount of net overlap.

6.1.2.2.1.2 Effect of EPE and Beacon Load

With JTIDS OFF, the effect of the EPE was to reduce the beacon sensitivity by 1 dB and to reduce the BRE by approximately 5 percent. Also with JTIDS OFF, the beacon load (table 6-4) of 2174 ppps all low load produced a 1 dB increase in sensitivity and a 5 percent BRE increase over the 1500 ppps 50 percent high load data.

6.1.2.2.1.3 Effect of Varying JTIDS Signal Level

Varying the JTIDS foreground signal level over the range of the measurements (from -33 dBm to -60 dBm) did not make an appreciable change in the JTIDS signal effects on the performance characteristics of the beacon. The change in beacon sensitivity with JTIDS signals present was less than 1 dB and the reduction in BRE was generally from 2 to 3 percent. Table 6-5 summarizes the minimum BRE values observed during the tests. The change in BRE due to JTIDS signals was the same whether the beacon load was 2174 ppps or 1500 ppps or whether the EPE was ON or OFF.

Table 6-5. Minimum BRE for SGV TACAN Beacon Operating with a Desired Signal Level of -92 dBm with JTIDS Present

Minimum BRE (%)	Beacon Load (ppps)	EPE
76.4	2174 all low	on
79.4	2174 all low	off
70.8	1500 high	on
74.8	1500 high	off

6.1.2.2.2 Cardion DME Beacon

6.1.2.2.2.1 Effect of Different JTIDS Scenarios

The test data collected on the Cardion beacon indicates for desired signal levels stronger than -90 dBm, the effects were independent of the snapshot tested. That is, the Cardion experienced the same effect regardless of whether JTIDS was transmitting any of the 100/50 TSDF training scenarios, or any variations of the scenarios including the amount of 444-pulse or 258-pulse time slots, the amount of contention, and the amount of net overlap. For desired signal levels weaker than -90 dBm, there was a slight dependency on the amount of foreground-to-foreground overlap, but the effects were independent of whether 444-pulse or 258-pulse time slots were used, and whether the background time slot pulse overlap was the result of multinet or contention conditions.

6.1.2.2.2.2 Effect of EPE and Beacon Load

With JTIDS OFF, the effect of the EPE was to reduce the beacon sensitivity by 0.5 dB and to reduce the BRE by approximately 2 percent. Also with JTIDS OFF, the beacon load of 2174 ppps all low load produced an increase in sensitivity that was less than 0.5 dB and a 3 to 4 percent BRE increase over the 1500 ppps 50 percent high beacon load data.

6.1.2.2.2.3 Effect of Varying JTIDS Signal Level

The effect of JTIDS on the Cardion DME beacon did not change greatly as the JTIDS foreground signal level was varied over the range of the measurements (from -33 dBm to -60 dBm). The change in sensitivity with JTIDS signals present was less than 1 dB and the reduction in BRE was generally from 3 to 6 percent. Table 6-6 summarizes the minimum BRE observed during the tests. The change in BRE due to JTIDS was the same whether the beacon load was 2174 ppps or 1500 ppps or whether the EPE was ON or OFF.

Table 6-6. Minimum BRE for Cardion DME Beacon Operating with a Desired Signal Level of -88 dBm with JTIDS Present

Minimum BRE (%)	Beacon Load (ppps)	EPE
77.1	2174 all low	on
79.8	2174 all low	off
74.2	1500 high	on
77.1	1500 high	off

6.1.2.3 Evaluation of Results

The Cardion and SGV BRE bench test data was used to calculate the acquisition range of several DME interrogators. This is referred to as an operational analysis (references 31 and 32). The operational analysis was used to convert the BRE performance curve, with JTIDS signals present, into a reduction in acquisition range that could be experienced by DME interrogator equipped aircraft. The beacon operational analysis was conducted using four DME interrogators (KN 63, KN 65A, DME-451 and KDM 7000) and a variety of aircraft altitudes (1000 to 45,000 feet). These four interrogators were selected because they represent a wide range of acquisition signal levels.

6.1.2.3.1 SGV TACAN Beacon

An operational analysis was only performed on a typical 100/50 JTIDS scenario consisting of 258-pulse time slots with no overlap because all JTIDS 100/50 TSDF snapshots tested on the SGV produced the same effect. **The results indicate that the maximum**

change in acquisition range will be less than 0.2 nmi for JTIDS signal levels of -33 dBm or weaker. This change in range is significantly less than the 10 nmi change that was considered acceptable in reference 1. The small change in acquisition range is due to the fact that the reduction in beacon sensitivity for the SGV is less than 1 dB with JTIDS signals present.

6.1.2.3.2 Cardion DME Beacon

An operational analysis was performed on snapshots 400 and 409 corresponding to a typical JTIDS exercise and a worst case, JTIDS exercise respectively. **The analysis indicates that for JTIDS foreground signal levels of -33 dBm or weaker, snapshot 400 will produce less than a 2 nmi change in range, and snapshot 409 will produce less than a 3 nmi change in range.** These range changes are well within the 10 nmi change that was considered acceptable in reference 1. These range changes were primarily based on the DME-451 for an en route beacon at an altitude of 18,000 feet. For all other conditions and for all other DME interrogators, the distance changes were less than 1.0 nmi. The reason for the small change in acquisition range is that the reduction in beacon sensitivity for the Cardion is less than 1 dB with JTIDS signals present.

6.1.2.4 Application of Results to Airborne and Ground-Based JTIDS Terminals

The SGV and Cardion operational analyses indicate that for the JTIDS foreground signal levels tested, the effective change in acquisition range will not operationally affect the performance of the TACAN/DME system. **For collocating ground-based JTIDS terminals in the vicinity of the SGV or Cardion beacons, JTIDS signal levels of -33 and -36 dBm[a] correspond to distance separations of approximately 0.4 to 0.6 nmi, respectively. For the case of an airborne JTIDS terminal, the JTIDS signal levels of -33 and -36 dBm correspond to aircraft altitudes of less than 1000 feet. Since 1000 feet is the minimum flight altitude, no special minimum air-to-ground separation is needed for airborne JTIDS terminals.**

6.1.2.5 Data Limitation

Data was only collected on the X mode of operation for both the SGV and Cardion beacons. The Y mode of operation was not tested. The Y mode is expected to be used in the FAA terminal areas and not for en route applications. Therefore, Y mode data was not planned to be collected on the SGV, which is primarily an en route facility. However, Y mode data was planned to be collected on the Cardion beacon, which is designated as both an en route and a terminal beacon. Although Y mode data was not taken on the

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[a] Both values are used because -33 dBm data was not taken on snapshot #409.

Cardion beacon, limited exploratory data was collected on the Cardion receiver circuitry. This data indicates that JTIDS pulses do not get into the pulse pair decoder and therefore, JTIDS pulses will not decode in either the X or the Y mode of operation. Therefore, the risk of an additional effect during Y mode operations is very small. The mechanism data was analyzed in reference 33 and it concluded that Y mode testing of the Cardion DME beacon is not necessary.

6.2 ATCRBS

6.2.1 ATCBI-5 Interrogator

JTIDS EMC tests were performed on the ATCBI-5 interrogator system (reference 12). The interrogator data package contains a description of the ten performance parameters that were measured. The ten performance parameters included the leading edge pulse count, percent detection/code verification, receiver quantized pulses, sensor receiver and processor (SRAP) quantized pulses, total bracket decodes, desired bracket decodes, monitor bracket decodes, quality score, Mode 3/A validity and Mode C validity.

The performance parameters were measured for various combinations of the desired reply signal parameters, the JTIDS signal environment, and the EPE. Reference 12 contains an overview of the test program, a description of the ATCBI-5 system, and descriptions of the test setups, test variables, performance measures, and test procedures. The portions of the ATCRBS ground system that were tested consisted of the ATCBI-5, the MX-8757/UPX defruiter, the SRAP, and the automated radar terminal system (ARTS) IIIA processor.

6.2.1.1 Summary of Test Data Results

The JTIDS 100/50 TSDF environment effects on the ATCBI-5 system were independent of the snapshot tested. That is, the system experienced the same effect regardless of which of the JTIDS 100/50 training scenarios were used or which of the variations to these scenarios, including the amount of 444-pulse or 258-pulse time slots, the amount of contention and the amount of net overlap. Also the 100/50 test results indicate that the background JTIDS signals do not affect the performance of the ATCRBS receiver. In addition, preliminary exploratory data collected on the ATCBI-5 receiver circuitry clearly show that -50 dBm JTIDS signals do not get into the receiver. Therefore, all JTIDS background signals at or weaker than -50 dBm will not affect the operation of the ATCRBS interrogator.

The effects test data showed no effect on any of the performance parameters when JTIDS signals entered the receiver at levels equal to or weaker than -30 dBm. When JTIDS signals entered the receiver at levels between -25 dBm and -20 dBm, there was an increase in the number of pulses detected at the output of the receiver quantizer, while the remaining nine parameters were basically not affected. At JTIDS signal levels of -15 dBm or stronger, changes in all performance measures except the monitor bracket decode count were noted. The detailed test results can be found in section 3 and appendix E of reference 12.

6.2.1.2 Evaluation of Results

The data was analyzed using both a spectrum sharing criterion provided by the FAA (change in leading edge pulse count), and an analysis of the conditions (percent detection/code verification data) that must exist in order for JTIDS signals to affect the ATC display.

FAA Criterion

The FAA criterion for the electromagnetic compatibility of JTIDS environments with the ground ATCRBS equipment is that sufficient separation/isolation must exist to prevent an increase of more than one standard deviation above the mean JTIDS OFF leading edge pulse count. The mean and standard deviation used in this evaluation are based on the five, ten second leading edge pulse counts that were taken before and after each JTIDS environment was tested. The test data indicate that this requirement can be met by maintaining separation/isolation between the systems to keep the JTIDS foreground signal level from exceeding -20 dBm at the ATCRBS interrogator receiver directional antenna port.

Percent Detection/Code Verification Display Analysis

The ARTS IIIA tracking software requires target range, azimuth, altitude and identity code information to track a target. A change in percent detection/code verification reflects a change in these ARTS IIIA inputs. A reduction in percent detection/code verification translates into a reduction in the number of correct target presentations. The test data indicate that there is no effect on percent detection/code verification from JTIDS signals at or weaker than -20 dBm.

6.2.1.3 Application of Results to Airborne and Ground-Based JTIDS Terminals

The ATCRBS interrogator percent detection/code verification display analysis and the application of the FAA criterion indicate that for JTIDS foreground signal levels equal to or weaker than -20 dBm, the performance of the ATCRBS interrogator will not be operationally affected. The -20 dBm JTIDS signal level can be translated into distance separations between the ATCRBS and JTIDS antennas.

Airborne JTIDS Terminals

A -20 dBm JTIDS received signal level at an ATCRBS interrogator receiver directional antenna port has been shown not to be operationally attainable from JTIDS airborne terminals (reference 1).

Ground-Based JTIDS Terminals

JTIDS ground-based units should be site engineered to ensure that JTIDS signal levels do not exceed -20 dBm at the ATCRBS interrogator receiver directional antenna port. **The required separation distances will vary depending on specific terrain conditions and JTIDS/ATCRBS interrogator antenna height combinations, but they are estimated to be approximately 100 to 500 yards for line-of-sight conditions.**

6.2.1.4 Data Limitation

The analysis of the potential ATC display effects was based on inputs to the ARTS IIIA tracking software. If ATC display tests had been accomplished, it is possible that a stronger JTIDS signal level threshold could have been established before effects would be noted on the ATC display.

6.2.2 1030/1090 MHz Avionics

Analyses were accomplished on the ATCRBS transponders, Mode S transponders, and the TCAS avionics to determine the likelihood that JTIDS signals would have operational effects on these equipment. The analyses are based on Frequency Dependent Rejection (FDR) and presented in reference 7. FDR represents the total rejection provided by the ATC receiver selectivity with respect to the JTIDS emission spectral bandwidth, and the relative frequency separation between the ATC receiver tuned frequency and the closest JTIDS carrier frequency.

EMC testing was performed on a representative sample of 1030 MHz ATC avionics to confirm the FDR analyses. This test effort was documented in reference 23.

6.2.2.1 Description of Supporting Documentation

Reference 7 documents the analyses. It explains FDR and presents FDR analyses for ATCRBS and Mode S transponders and TCAS units. It compares the results of the FDR analyses to the data collected during the 1976-1977 40/20 TSDF EMC test program. The document states that JTIDS signals from non-cosite JTIDS terminals will not affect the performance of the ATC avionics because the FDR analysis indicated that the JTIDS aircraft-to-aircraft coupled signal level would not exceed the Minimum Triggering Level (MTL).

Reference 23 explains why only a limited amount of testing was necessary on ATCRBS and Mode S transponders. It describes the test setups involved, the test variables, and the performance measures, and presents the JTIDS effects, modified spectrum and pulsed CW data. It documents the FDR analysis performed using the measured data. This analysis predicts the JTIDS signal levels that could have an effect on the ATC equipment. The results of the analysis in reference 23 are compared to the JTIDS effects test data.

6.2.2.2 Summary of Results

6.2.2.2.1 Predicted Effects

The FDR analysis was accomplished using measured MTL and selectivity data on the AT-5A and TRU-2A. The measured MTL, minimum FDR and predicted JTIDS level needed to exceed MTL are presented in table 6-7. The analysis assumes that JTIDS signals weaker than MTL will not produce an effect. The analysis predicts that JTIDS signals weaker than -29.8 and -26.2 dBm will not exceed the MTL of the AT-5A and TRU-2A transponders, respectively.

Table 6-7. Summary of ATCRBS/MODE S Transponder Testing and Analysis Results

	ATCRBS AT-5A	Mode S TRU-2A
Receiver MTL	-84.0 dBm[a]	-78.9 dBm
Minimum FDR	54.2 dB	51.8 dB
Predicted JTIDS Level Needed to Exceed MTL	-29.8 dBm	-26.2 dBm
Measured JTIDS Level Needed to Change Reply Efficiency or Unsolicited Replies	-28.0 dBm	-20.0 dBm
[a] The AT-5A receiver is tuned to 1032 MHz		

6.2.2.2.2 Measured Effects

The data required to validate these predictions are the JTIDS effects' data collected with the JTIDS signal source transmitting in the frequency hopping mode with the JTIDS wideband noise floor in the 1030 MHz notch set to -60 dBc. One set of JTIDS effects' data was analyzed for each transponder. Each set of data was analyzed to determine the weakest JTIDS signal level that produced any change in either MTL, reply efficiency, or unsolicited replies. The measured JTIDS levels needed to produce a change in reply efficiency or unsolicited replies are presented in the bottom row of table 6-7. The data indicate that JTIDS signals with amplitudes weaker than -28 and -20 dBm had no effect on the AT-5A and TRU-2A transponders, respectively.

6.2.2.3 Evaluation of Results

The predicted and measured levels are within 1.8 dB and 6-2 dB for the AT-5A and the TRU-2A, respectively. Since the levels predicted to produce effects are weaker than the levels that were actually measured, the analysis predictions are on the conservative side.

The testing and analysis documented in reference 23 demonstrates that the FDR analysis is a valid method of predicting the effects of JTIDS signals on ATCRBS/Mode S transponders and TCAS units. The analysis technique documented in reference 7 pertained to ATCRBS, Mode S, and TCAS avionics. Since the analysis was validated with the ATCRBS and Mode S test data, the use of the FDR technique to evaluate TCAS is appropriate.

The FDR analyses in reference 7 indicate that the strongest JTIDS signals received from off-board JTIDS terminals are at least 7 dB weaker than the MTL of the ATCRBS/ Mode S transponders and the TCAS units. **The FDR analyses and the measured data indicate that there will be no effects on ATC avionics from JTIDS off-board signals. This indicates that the FAA compatibility criteria of no unsolicited replies and no change in percent replies for interrogations from -21 dBm to -69 dBm desired signal levels will be met when the 1000 foot ATC flight separation distance is observed.**

6.3 MODE S SENSOR

The question of JTIDS compatibility with the Mode S sensor was addressed by analysis techniques as Mode S hardware was not available for testing in the Phase 1 program.

6.3.1 Analysis Approach

The effects of a JTIDS 100/50 TSDF on the Mode S sensor were predicted using twc separate approaches. The first approach is based upon previous JTIDS measurements/ analysis (reference 1) performed on the Mode S sensor (then called DABS), and on recent JTIDS measurements performed on the ATCRBS interrogator receiver (reference 12). The Mode S sensor measurements were conducted with a JTIDS TSDF of 40/40 and the ATCRBS interrogator measurements were conducted with a JTIDS TSDF of 100/50.

The results are based in part on the prediction that the ATCRBS interrogator receiver is more susceptible to JTIDS signals than the proposed Mode S sensor receiver.

The second approach complements the first by focusing on the Mode S monopulse method of azimuth estimation for ATCRBS transponder equipped aircraft. Azimuth estimation accuracy is thought to be the most vulnerable aspect of the Mode S surveillance processing in that each transponder is interrogated 4 to 6 times per mainbeam dwell in contrast to the nominal run length of 20 for ATCRBS. The performance measure used for this analysis is the root mean square (RMS) error in Mode S monopulse azimuth estimates (reference 34 and 35). To represent a "worst case" condition, it was assumed that a desired ATCRBS reply was received at the Mode S sensor receiver at the minimum triggering level of -79 dBm. The RMS error in azimuth estimates was computed with the effects of receiver noise only, receiver noise plus JTIDS, and with receiver noise, JTIDS, and ATCRBS/Mode S system self-interference in an LA Basin environment.

6.3.2 Discussion of Previous Measurements of JTIDS Effects on Mode S and ATCRBS Equipment

The test data collected in reference 1 indicated that for a JTIDS TSDF of 40/20, JTIDS signal levels of -20 dBm will not affect the operation of the ATCRBS interrogator. The -20 dBm level was determined to be equivalent to a 1000 foot altitude separation between the JTIDS terminal and the ATCRBS interrogator.

Reference 1 also documented flight test measurements that were performed with a 40/40 TSDF JTIDS signal on prototype Mode S equipment. The flight tests indicated that a JTIDS aircraft passing directly over the Mode S sensor at 3000 feet would not affect Mode S performance. The sensor was tested in both the Mode S mode and the ATCRBS mode. The results indicated that the azimuth and range accuracy tolerances for the system were not exceeded with JTIDS signals present. Reply probabilities, monopulse characteristics and track qualities were also not affected by JTIDS signals.

The flight test could not be conducted with the JTIDS aircraft at a 1000 foot altitude due to noise abatement procedure requirements. However, theoretical analysis indicates that Mode S performance would not be affected by a JTIDS aircraft passing over a Mode S ground sensor at a 1000 foot altitude. This result was based on the assumption that the susceptibility of the Mode S interrogator to JTIDS signals is equal to or less than that of the ATCRBS interrogator. The rationale for this assumption is the downlink Mode S transponder reply format has been designed to achieve reliable air-to-ground operations in the presence of heavy ATCRBS interference.

Recent test results reported in reference 12 indicate that for a JTIDS TSDF of 100/50, a JTIDS signal level of -20 dBm will not affect the operation of the ATCRBS interrogator.

For the conditions tested, it was shown that JTIDS background terminal signals equal to or weaker than -50 dBm are not detected by the interrogator receiver. Therefore, using the same analysis approach and assumptions made in reference 1, it can be concluded that a single JTIDS-equipped aircraft transmitting a 50 percent TSDF will not affect the operation of the Mode S sensor at an altitude separation of 1000 feet. This would apply to any JTIDS scenario with a 50 percent TSDF foreground as long as the JTIDS background signals are no stronger than -50 dBm.

6.3.3 Effect of JTIDS Signals on Mode S Monopulse Accuracy

6.3.3.1 RMS Azimuth Error with Receiver Noise and with JTIDS

RMS azimuth error estimates for a received desired signal of -79 dBm were calculated with just receiver noise and with JTIDS signals received at -20 dBm (at the Mode S sensor receiver RF port) plus receiver noise. The RMS azimuth error with just receiver noise is 0.046 degrees and the RMS azimuth error with JTIDS plus receiver noise is 0.056 degrees. Reference 1 indicates that when a JTIDS foreground user overflys a Mode S sensor at an altitude of 1000 feet, the peak received power at the Mode S sensor receiver is less than -20 dBm. Therefore, the RMS azimuth error, with a 50 percent JTIDS foreground terminal present at -20 dBm, will not exceed the accuracy requirement of 0.1 degrees RMS (reference 36).

6.3.3.2 Monopulse Performance in the Los Angeles Basin

To put the results of this analysis into an operational perspective, the RMS azimuth estimation error with JTIDS operating was computed for aircraft in a simulated environment with other ATCRBS and Mode S signals present as self-interference. The simulation results were predicted using the DABS/ATCRBS/AIMS performance prediction model in a hypothesized peak LA Basin air traffic environment (references 9 and 37).

By examining the detailed reply history of each transponder, it was found that one target did not reply to two of the six mainbeam interrogations. None of the four replies from this aircraft were garbled by fruit. This is as expected for the predicted mainbeam ATCRBS fruit rate of 528 per second. The target was located 9.5 nmi from the LAX-4 Mode S sensor at a relative bearing of 141^{o} and at an altitude of 565 feet above ground level (AGL). The received signal level at the Mode S sensor from that transponder was -48 dBm. Assuming that an airborne foreground JTIDS terminal is overflying at an altitude of 1000 feet AGL, and that the received power at the RF front end is -20 dBm, the RMS azimuth estimation error is negligible (0.002 degrees). That is, the signal-to-noise ratio (S/N) is equal to 38.9 dB for the 3.4 pulses overlapped by JTIDS and 46.5 dB for the 28.6 pulses not overlapped. For a worst-case desired signal condition, where the received signal is at -79 dBm, the RMS azimuth error is equal to 0.068^{o}, which is well below the peak specified value.

It should be noted that in the actual Mode S sensor implementation, all azimuth samples that exceed the reference azimuth by a specified amount are discarded. This is similar to the outlier window approach used in the DME/P receiver. Because an accurate simulation of the monopulse outlier window was beyond the scope of this analysis, it was assumed that all errors contribute to the final azimuth estimate. This approach should result in the prediction of a larger error than is expected to occur.

6.3.4 Evaluation of Results

The analysis results demonstrate that for a JTIDS TSDF of 100/50, the JTIDS foreground signal level received by the Mode S sensor must be stronger than -20 dBm to affect Mode S sensor performance.

Airborne JTIDS Terminals

A -20 dBm JTIDS received signal level at a Mode S interrogator receiver directional antenna port has been shown not to be operationally attainable from JTIDS airborne terminals (reference 1).

Ground-Based JTIDS Terminals

JTIDS ground-based units should be site engineered to ensure that JTIDS signal levels do not exceed -20 dBm at the Mode S interrogator receiver directional antenna port. **The required separation distances will vary depending on specific terrain conditions and JTIDS/Mode S sensor antenna height combinations, but they are estimated to be approximately 100 to 500 yards for line-of-sight conditions.**

6.4 TCAS

The analysis of JTIDS and TCAS compatibility was addressed in section 6.2.2. The analyses is based on FDR and is presented in references 7, 23, and 38. ECAC updated the EMC analysis (reference 38) between JTIDS transmitters and TCAS 1090 MHz avionics because of changes to the receiver selectivity specified in the Minimum Operational Performance Standards (reference 39) and the availability of updated TCAS receiver selectivity, MTL, and antenna gain measurements. The EMC between JTIDS transmitters and TCAS 1030 MHz receivers, however, was not reevaluated because the specifications pertaining to the TCAS 1030 MHz receiver have not changed. This effort is documented in reference 38 and the following is take from this report.

The effective received JTIDS signal level, as would be measured in the intermediate frequency (IF) bandwidth of the TCAS 1090 MHz receiver, was calculated based on the signal level at the antenna port of the TCAS receiver and the FDR associated with the

JTIDS emission spectrum and the TCAS receiver selectivity. The calculation was performed twice, once based on the measured JTIDS and TCAS system characteristics and once based on the specified system characteristics. The maximum JTIDS signal level at the antenna port of the TCAS receiver was calculated assuming that a JTIDS equipped aircraft and a TCAS equipped aircraft were positioned at the minimum ATC separation distance. The FDR was calculated using the JTIDS emission spectrum and the TCAS receiver selectivity. The FDR was then subtracted from the maximum JTIDS signal level received at the antenna port in order to determine the effective received signal level in the IF bandwidth. The effective received JTIDS signal level in the IF bandwidth was then compared with the MTL of the TCAS 1090 MHz receiver. The analysis was based on the assumption (established in reference 7, confirmed through testing, and then documented in reference 23) that if the effective received JTIDS signal level, in the IF bandwidth, is weaker than the receiver MTL, there is no potential for operational effects on the receiver from the JTIDS emissions. Table 6-8 presents the results of the analysis.

Table 6-8. Summary of JTIDS/TCAS EMC Analysis

Analysis Parameters	Specified Emission Spectrum, Receiver MTL and Receiver Selectivity	Measured Emission Spectrum, Receiver MTL and Receiver Selectivity
Maximum JTIDS Signal Level at RF Input of TCAS Receiver	-34.5 dBm	-35.5 dBm
Minimum FDR	52.9 dB	54.9 dB
Received JTIDS Level in the IF Bandwidth	-87.4 dBm	-90.4 dBm
MTL	-78.0 dBm	-79.0 dBm
Margin of Protection	9.4 dB	11.4 dB

It is concluded that under normal ATC aircraft-to-aircraft encounters, signals from airborne JTIDS transmitters will not affect the performance of off-board TCAS 1030 MHz or 1090 MHz receivers. No assessment was made of the effect of collocating JTIDS terminals with 1030 MHz and 1090 MHz avionics or of the effect of JTIDS equipped aircraft flying in formation with TCAS equipped aircraft.

6.5 DME/P

The analysis of JTIDS compatibility with the DME/P system required the use of a computer model because hardware was not available for testing. Consistent with this approach, a DME/P simulator that was developed for the FAA was exercised on two separate JTIDS scenarios. The first of these was basically the Air Force 100/50 TACAN/DME interrogator scenario with all of the ring 2 pulses moved to ring 1, while the second was the Army 100/50 TACAN/DME interrogator scenario. Both of these scenarios are described in section 5.2.1. Each of these JTIDS environments was then combined with the DME/P extraneous pulse environment shown in table 6-9 (reference 40) to construct a composite DME/JTIDS pulse environment for use in the simulations.

Table 6-9. DME/P Pulse Environment

Frequency Offset	Pulse Rate (ppps)	Amplitude (dBm)	Code
-2 MHz	3240	-51	on
-1 MHz	3240	-71	on
0 MHz	3240	-71	off
+1 MHz	3240	-71	on
+2 MHz	3240	-51	on

The simulation results were compared to three proposed criterion of acceptable performance that are based on the International Civil Aviation Organization (ICAO) total system (up and down links combined) limits for Control Motion Noise (CMN) garble, Path Following Error (PFE) garble, and minimum system efficiency. These were:

1. The CMN error component induced by the DME/JTIDS extraneous environment shall not exceed 20 feet (0.95 probability),

2. The PFE error component induced by the DME/JTIDS extraneous environment shall not exceed 20 feet (0.95 probability), and

3. The system efficiency shall not fall below 66 percent (assuming 100 percent ground transponder reply efficiency and 100 percent receiver processor efficiency) in the presence of the DME/JTIDS extraneous pulse environment and receiver noise. This 66 percent limit allows the ICAO minimum system efficiency of 50 percent to be met when the ground transponder reply efficiency is 80 percent and the receiver processor efficiency is 95 percent.

The simulation results indicate that the previously described JTIDS environments can be accommodated within the ICAO prescribed limits when predicted EPEs are considered. As such, it is the FAA position that no further analysis of the JTIDS effect on DME/P is required. This position is based on the fact that the simulator outputs show the effects to be within the acceptable limits. The FAA foresees no compatibility problem between the two systems, as long as the effects measured during hardware testing are less than or equal to those specified in 1, 2, and 3 above.

6.6 KOREA TEST RESULTS

A JTIDS Class 1 ASIT terminal is installed at Osan Air Base (AB), Korea. To support routine day-to-day operational training requirements, JTIDS will need to utilize a 100/50 TSDF. The Korea Ministry of Communications requested that JTIDS be demonstrated to be compatible with the existing ATC equipment at Osan AB. This would include flight test measurements with ATC check aircraft and over-the-air bench tests with an ASIT and an E-3A transmitting JTIDS. Over a period of three weeks in March 1988, representatives from the JPO and the Electromagnetic Compatibility Analysis Center (ECAC) performed the necessary tests.

The various ATC receivers and their corresponding distance separation from the ASIT terminal are as follows: An AN/GRN-20B TACAN beacon (4200 feet), an AN/TRN-41 portable TACAN beacon (4200 feet), an AN/TPX-42 IFF interrogator (5200 feet) and an AN/TPX-49A range and azimuth beacon monitor (RABM) (2300 feet). The TACAN beacon separation distances are significantly less than the 3 to 5 nmi separation distances recommended from the 40/20 TSDF T&E Program (reference 1). The 3 to 5 nmi distance is based on a JTIDS received signal level of -50 dBm at the TACAN/DME beacon. The recent 100/50 TSDF Phase 1 tests indicate that JTIDS signals as strong as -33 dBm do not harmfully effect the operation of the SGV and Cardion DME Beacons. However, to verify that these results could be applied to any beacon, testing was conducted.

The following information is based on the results documented in the final test report (reference 41). The general conclusion was:

During the Korea tests, the ASIT was required to radiate a 50 percent TSDF from 0700 to 2000 hours for 18 consecutive days. Throughout the test period, no electromagnetic interference (EMI) reports were filed on any airborne or ground-based IFF or TACAN system at Osan AB.

6.6.1 AN/GRN-20B TACAN Beacon Bench Tests

1. The JTIDS ASIT signal level measured at the input to the beacon receiver was -40 dBm when the ASIT was transmitting in the 200 watt mode and -34 dBm when the ASIT was transmitting in the 1000 watt mode.

2. The E-3A JTIDS transmitted a power level of 1000 watts and continuously flew in a 24 nmi by 40 nmi oval pattern over the beacon. The JTIDS equipped E-3A signal level measured at the input to the beacon receiver varied between -55 dBm and -60 dBm.

3. The operation of the beacon monitor and the operation of the beacon automatic gain reduction circuitry were not affected by JTIDS signals. Only the beacon reply efficiency was affected by JTIDS signals.

4. The maximum reduction in beacon receiver sensitivity of 1.7 dB occurred when the ASIT was transmitting a 50 percent TSDF in either power mode.

5. The maximum reduction of 11 percent in beacon reply efficiency occurred when the ASIT was transmitting a power level of 1000 watts at 50 percent TSDF. This is illustrated in figure 6-1. For an ASIT transmitter at 50 percent TSDF, in the 200 watt mode, the maximum reduction in beacon reply efficiency was 7 percent. This is illustrated in figures 6-2 and 6-3.

6. When both the ASIT and the E-3A were configured to transmit a 50 percent TSDF (100 percent TSDF total), the additional effect from the E-3A was negligible (see table 6-10).

6.6.2 AN/GRN-20B TACAN Beacon Flight Tests

1. A flight check aircraft flew a radial check on the beacon at 25,000 feet, while the ASIT was transmitting in the 200 watt mode at 50 percent TSDF and the E-3A was transmitting in the 1000 watt mode at 50 percent TSDF. The maximum change in the acquisition range of the flight check aircraft with JTIDS signals present was 3.4 nmi. This was well within the normal variability of the acquisition range (151.1 nmi to 160.4 nmi) when JTIDS signals were not present.

2. A flight check aircraft flew an orbit check on the beacon at an altitude of 7000 feet and a distance of 7 nmi while the ASIT was transmitting in the 200 watt mode at 50 percent TSDF. There was no discernible difference in the orbit check data with JTIDS signals present as compared to when JTIDS signals were not present.

Table 6-10. Summary of AN/GRN-20B BRE During E-3 Flight Tests ASIT at 200 watts, E-3 at 1000 watts

desired level (dBm)	JTIDS off BRE (%)	JTIDS ASIT only BRE (%)	JTIDS ASIT and E-3 BRE (%) (E-3 range in nmi, radial in degrees from beacon)				
			set 1	set 2	set 3	set 4	set 5
-96	64.0	56.5	52.7 (45/114)[a]	57.4 (9/248)	57.0 (32/82)	55.8 (29/82)	56.9 (51/108)
-95	68.9	61.3	59.8 (54/105)	61.3 (13/234)	62.0 (22/82)	60.3 (20/82)	61.8 (53/95)
-94	74.1	64.7	64.8 (53/95)	66.4 (21/209)	66.9 (17/82)	65.3 (12/80)	66.0 (47/85)
-93	77.3	69.2	69.2 (47/85)	69.8 (23/174)	69.7 (8/80)	69.1 (8/79)	69.2 (39/82)
-92	79.6	71.8	71.6 (39/83)	69.3 (23/157)	71.3 (43/117)	71.5 (1/17)	70.2 (30/86)
-91	79.4	72.2	(31/83)	71.0 (31/129)	71.9 (49/111)	71.8 (10/243)	71.5 (11/86)
-90	79.5	72.8	73.1 (20/81)	73.1 (44/114)	72.3 (54/99)	72.2 (18/214)	73.0 (5/77)
-88	80.7	74.8	73.9 (14/81)	73.3 (52/100)	74.4 (50/80)	73.0 (26/142)	73.9 (3/253)
-86	79.3	75.1	74.5 (1/54)	73.7 (48/89)	73.7 (43/83)	74.1 (37/120)	73.6 (16/181)

[a] E-3 was 45 nmi from the beacon on 114° radial

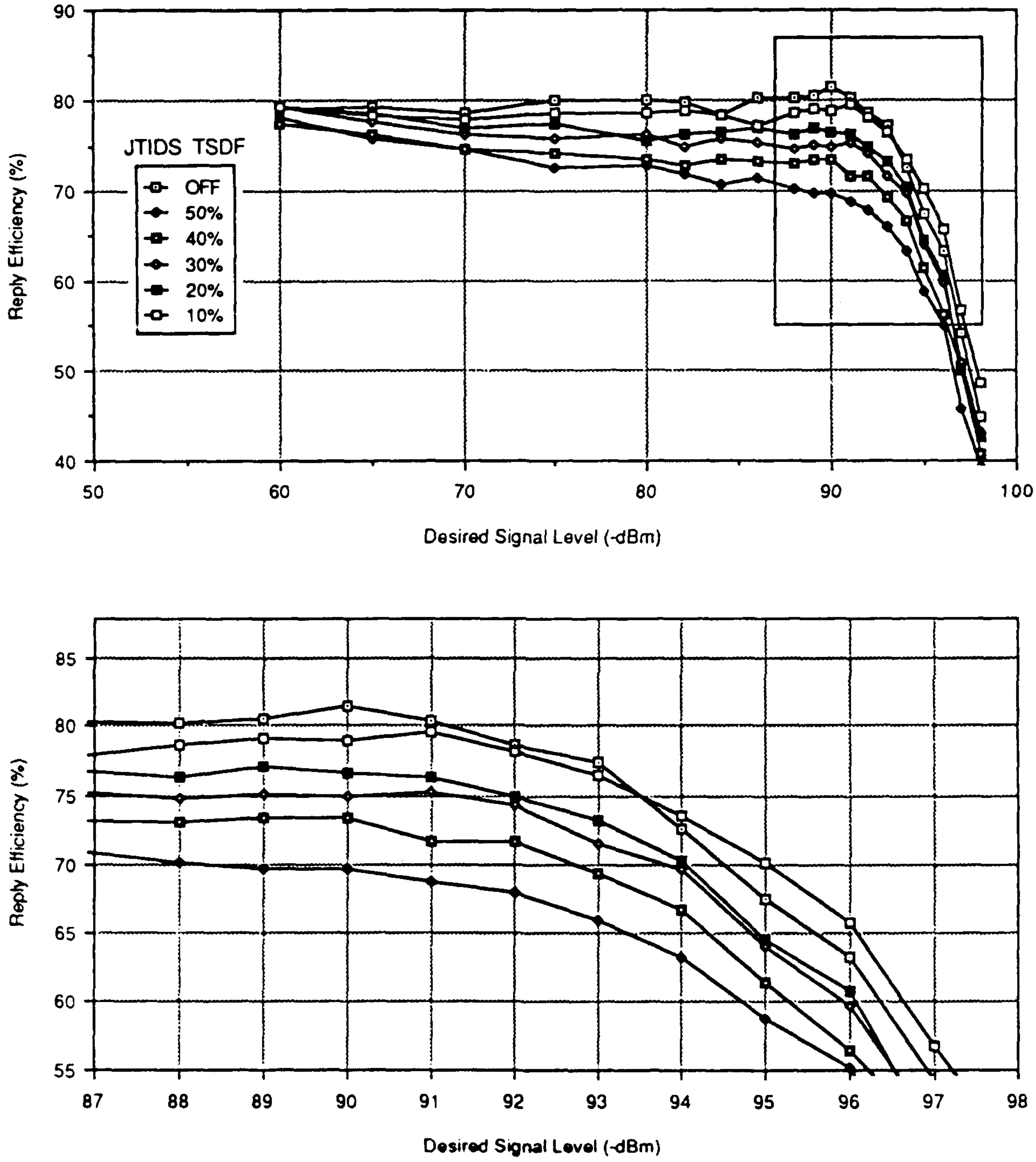
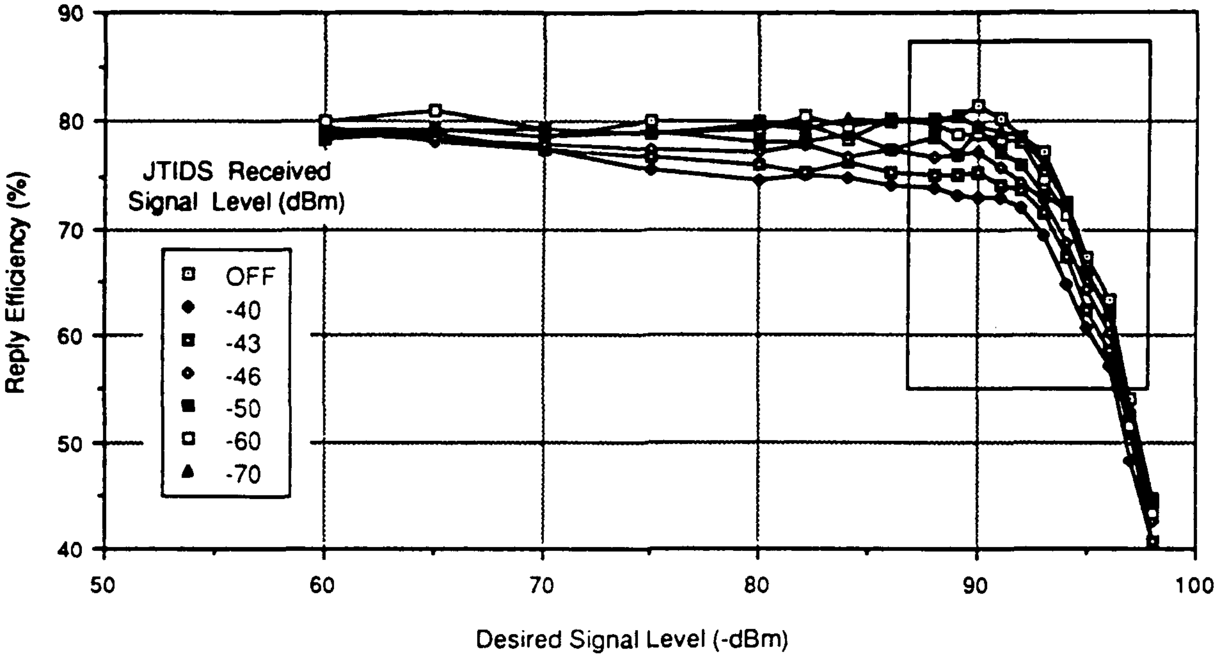


Figure 6-1. AN/GRN-20B TACAN Beacon Test Results, Osan AB Korea, Channel 94X. JTIDS 1000 watts, TSDF Varied. Received JTIDS Signal Level -34 dBm.



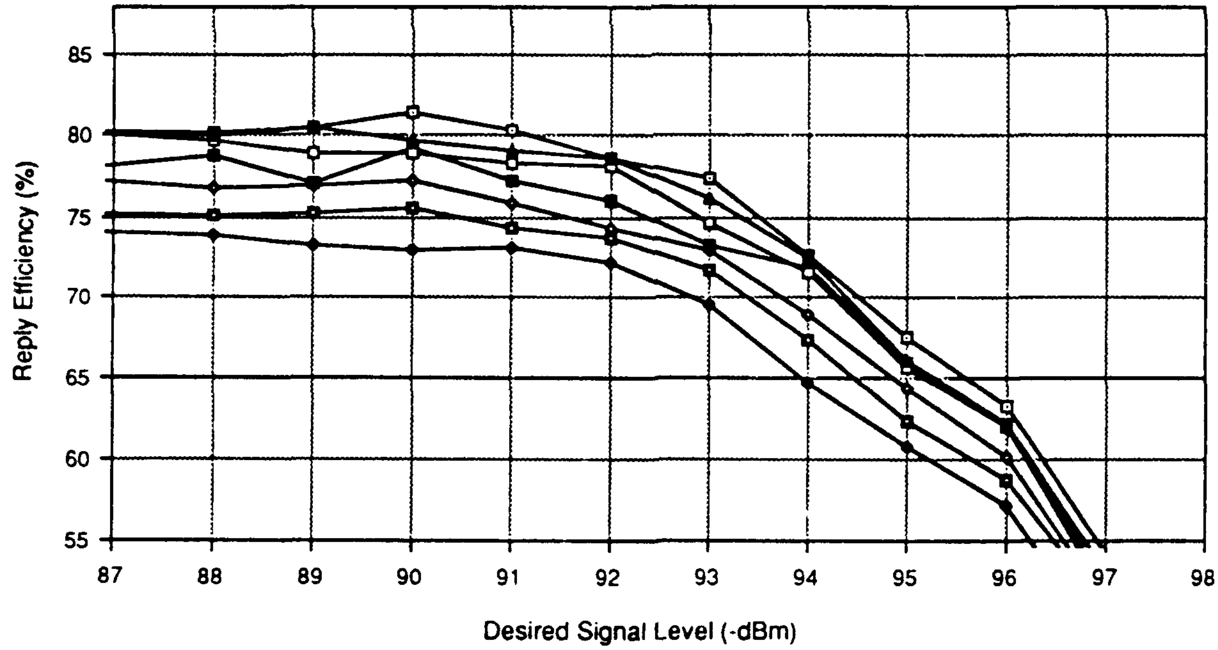


Figure 6-2. AN/GRN-20B TACAN Beacon Test Results, Osan AB Korea, Channel 94X. JTIDS TSDF 50 percent at 200 watts. Received JTIDS Signal Level Varied.

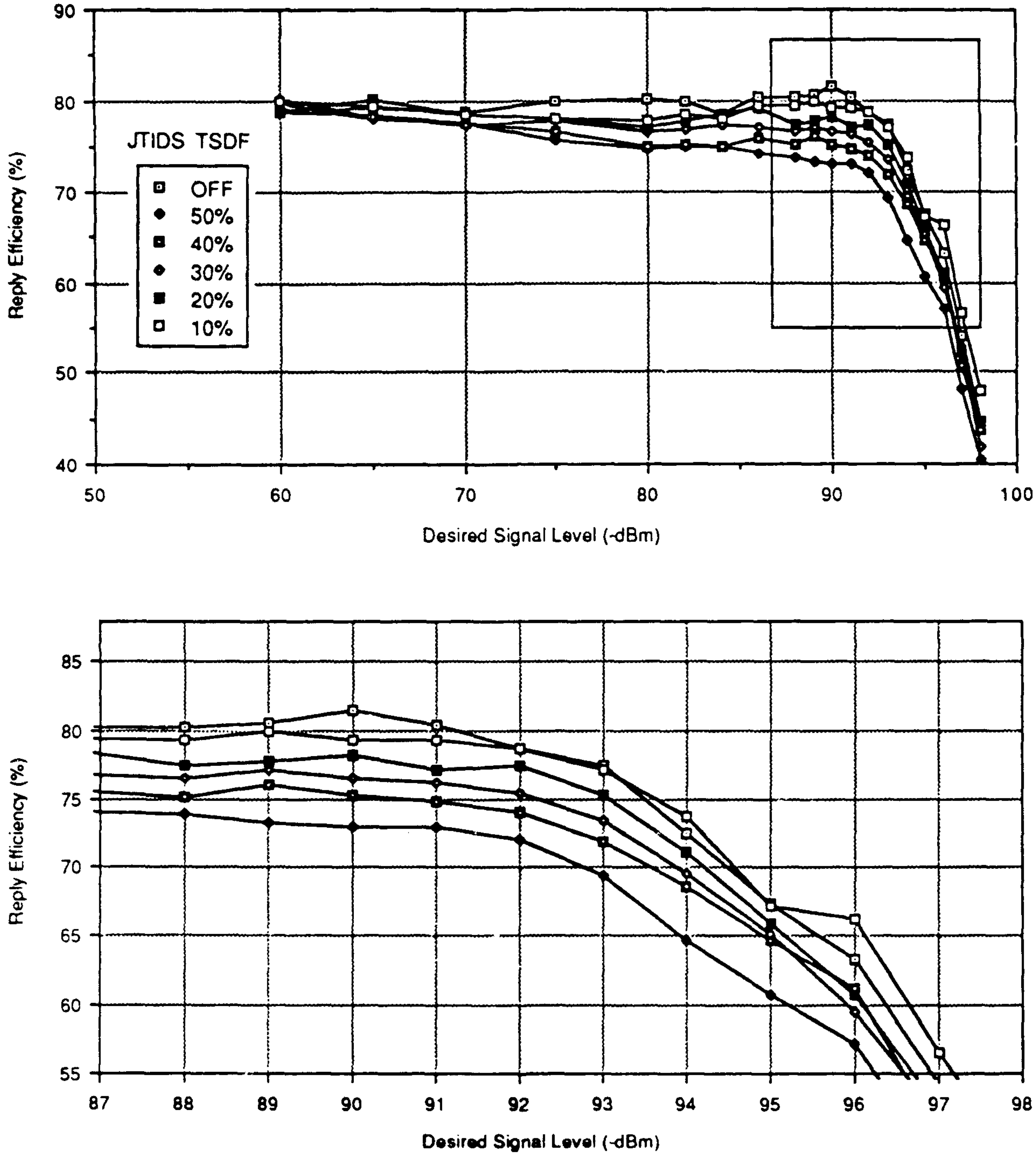


Figure 6-3. AN/GRN-20B TACAN Beacon Test Results, Osan AB Korea, Channel 94X. JTIDS 200 watts, TSDF Varied. Received JTIDS Signal Level at -40 dBm.

6.6.3 AN/TRN-41 TACAN Beacon Bench Tests

1. The JTIDS ASIT signal level measured at the input to the beacon receiver was -40 dBm when the ASIT was transmitting in the 200 watt mode and -34 dBm when the ASIT was transmitting in the 1000 watt mode.

2. The operation of the beacon monitor was not affected by JTIDS signals. Only the beacon reply efficiency was affected when JTIDS signals were present.

3. The maximum reduction in beacon receiver sensitivity of 2.3 dB occurred when the ASIT was transmitting in the 1000 watt mode at 50 percent TSDF. When the ASIT was transmitting in the 200 watt mode at 50 percent TSDF, the reduction in beacon receiver sensitivity was 1.8 dB.

4. The maximum reduction of 9 percent in beacon reply efficiency occurred when the ASIT was transmitting in the 1000 watt mode at 50 percent TSDF. When the ASIT was transmitting in the 200 watt mode, the maximum reduction in beacon reply efficiency was 5 percent. Figures 6-4 through 6-6 illustrate the effect of varying the JTIDS TSDF and JTIDS received signal level on beacon reply efficiency.

6.6.4 AN/TPX-42 IFF Interrogator Tests

The JTIDS ASIT signal level measured at the input to the IFF interrogator receiver was -28 dBm when the ASIT was transmitting in the 200 watt mode and -22 dBm when the ASIT was transmitting in the 1000 watt mode. Previous testing on IFF interrogators has indicated that JTIDS signals do not affect the performance of the IFF interrogator if the signal level at the receiver input is -20 dBm or weaker. Since the JTIDS signal level received by the IFF interrogator was weaker than -20 dBm, no additional operational tests were performed.

6.6.5 AN/TPX-49A Range and Azimuth Beacon Monitor Tests

1. The JTIDS ASIT signal measured at the input to the AN/TPX-49A receiver was -42 dBm when the ASIT was transmitting in the 200 watt mode and -37 dBm when the ASIT was transmitting in the 1000 watt mode.

2. The ASIT signal was not detectable in the AN/TPX-49A video.

6.6.6 Conclusions

Based on an analysis of the measured and predicted flight check aircraft acquisition range data, it is concluded that the utilization of worst case JTIDS TSDF (50 percent) and worst case JTIDS transmitter power level (1000 watts) did not operationally affect the two TACAN beacons at Osan AB, Korea.

Based on an analysis of the bench test data, it is concluded that the utilization of worst case JTIDS TSDF (50 percent) and worst case JTIDS transmitter power level (1000 watts), did not operationally affect the IFF interrogator and the range and azimuth beacon monitor at Osan AB, Korea.

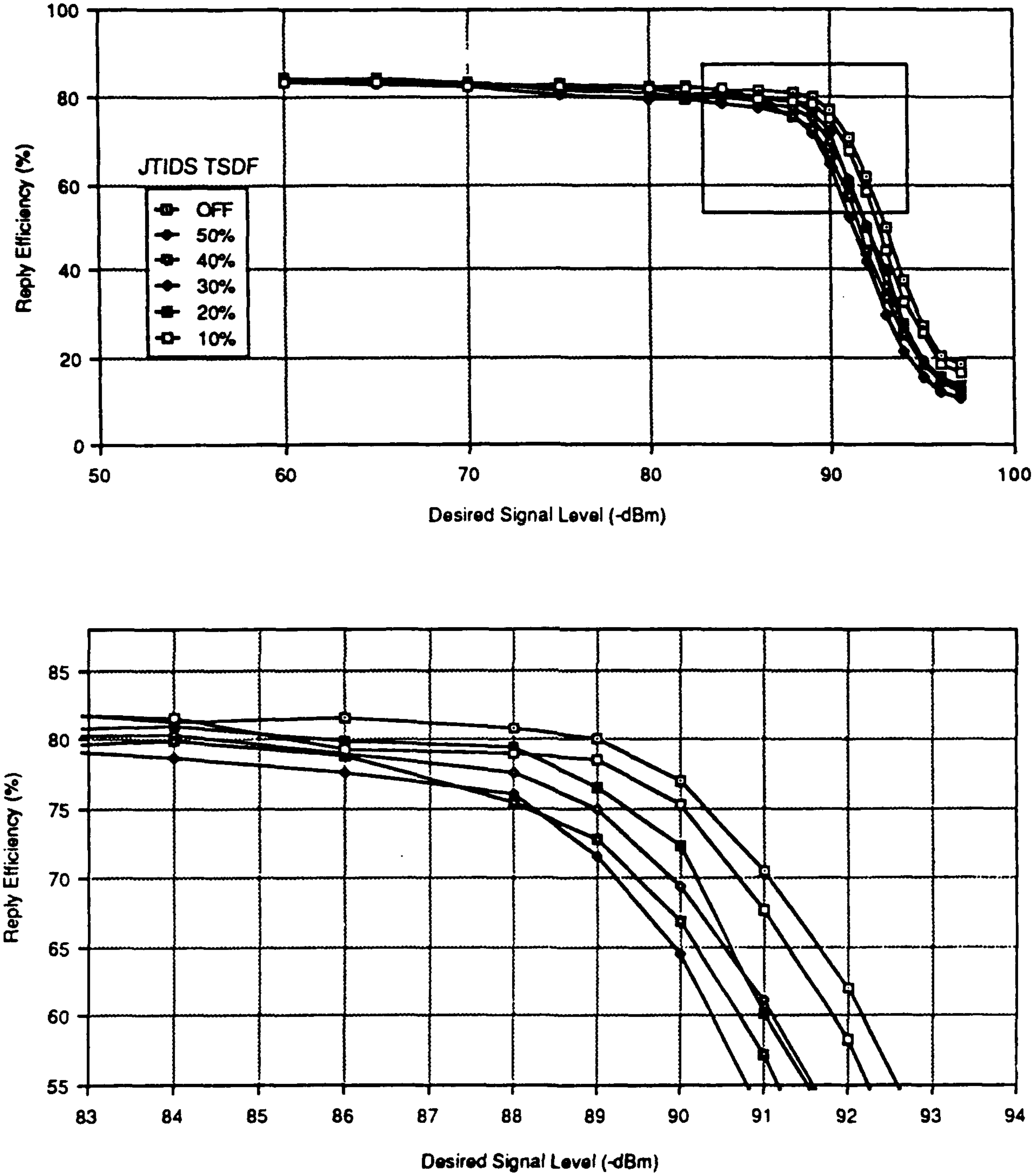


Figure 6-4. AN/TRN-41 TACAN Beacon Test Results, Osan AB, Korea, Channel 96X. JTIDS 200 watts, TSDF Varied. Received JTIDS Signal Level -40 dBm.

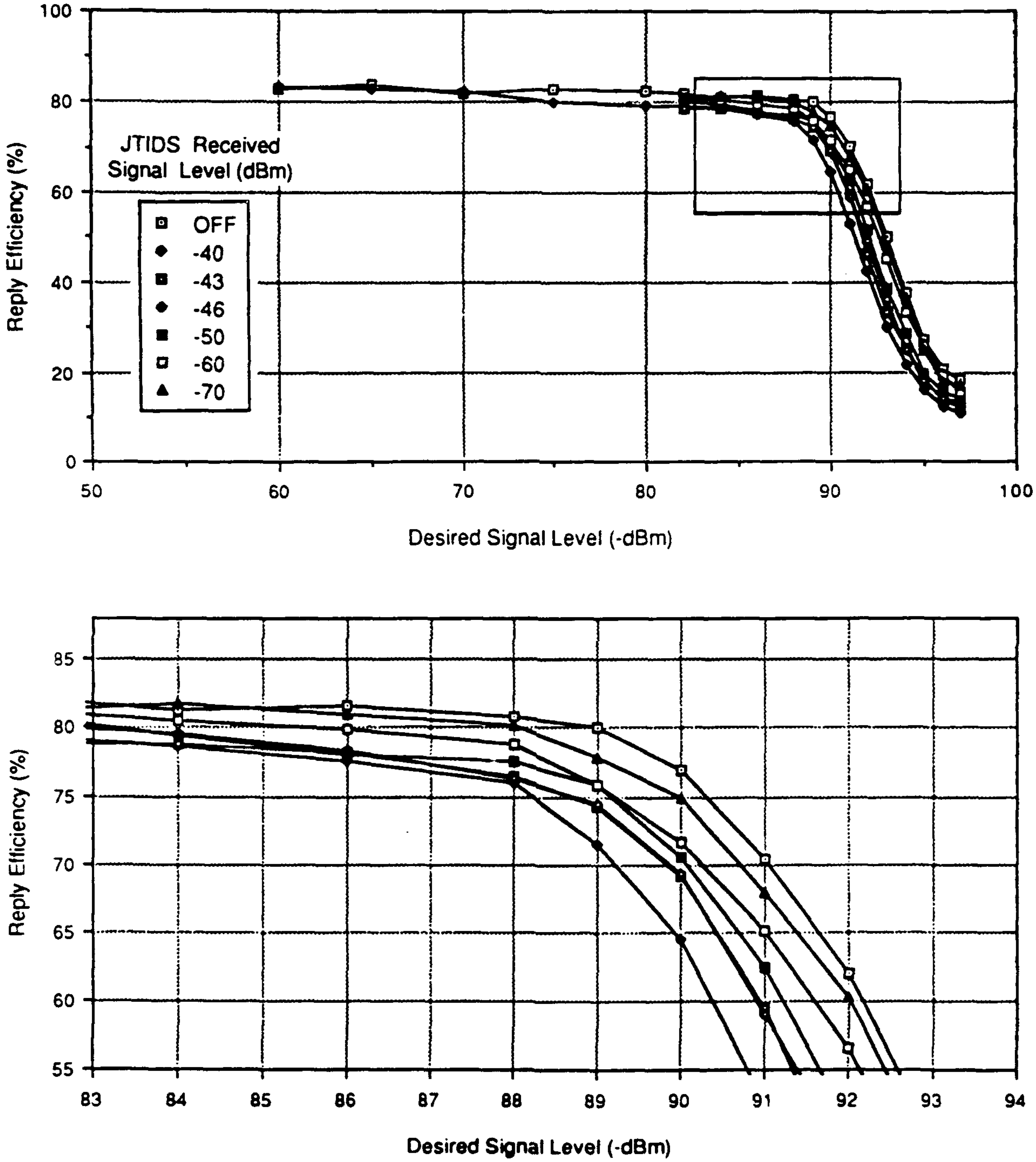
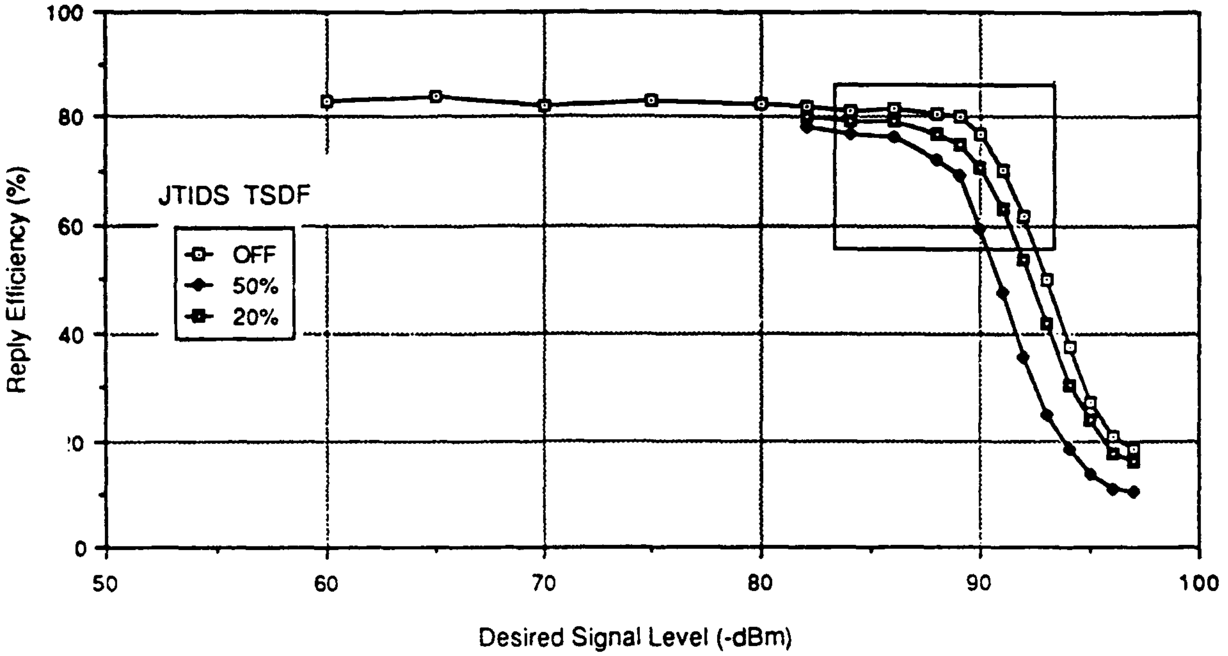


Figure 6-5. AN/TRN-41 TACAN Beacon Test Results, Osan AB, Korea, Channel 96X. JTIDS TSDF 50 percent at 200 watts. Received JTIDS Signal Level Varied.



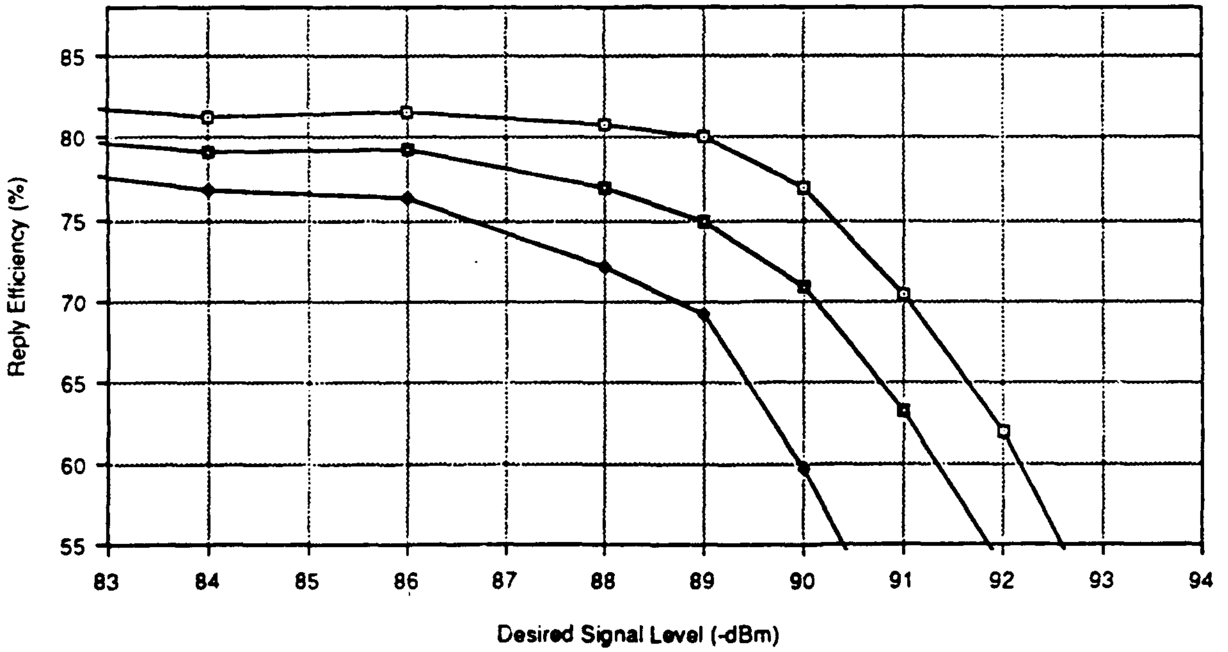


Figure 6-6. AN/TRN-41 TACAN Beacon Test Results, Osan AB, Korea, Channel 96X. JTIDS 1000 watts, TSDF Varied. Received JTIDS Signal Level at -34 dBm.

SECTION 7

GUIDANCE FOR JTIDS OPERATIONS IN NON-JTIDS ALLOCATED COUNTRIES

The 960-1215 MHz band is allocated world-wide on a primary basis for the use of aeronautical radio navigation services. ATC systems designed to operate in this band must meet the performance requirements contained in "International Standards, Recommended Practices and Procedures for Air Navigation Services, Aeronautical Telecommunications annex 10 to the Convention on International Civil Aviation", International Civil Aviation Organization (ICAO). These systems are designed to operate in a pulsed interference environment. As a result, ATC systems world-wide are expected to experience relatively the same effects due to JTIDS, regardless of manufacture. This situation promotes the sharing of EMC test and analysis information among countries. However, because many different types of hardware designs are used for ATC equipment, it is possible that different implementations of the same ATC function (e.g., two different DME interrogators) will react differently to JTIDS.

The United States' JTIDS T&E programs were conducted quite conservatively. The tested electromagnetic environments are so severe that they are almost physically unrealizable. If these situations were to occur they would certainly be transitory. Nevertheless, these situations were tested to identify the expected absolute upper bounds (worst case) of JTIDS effects on ATC systems. Also, the JTIDS networks constructed for these tests are not operationally realistic in that numerous multiple transmissions in a time slot and the excessively high TSDF assigned to single users are seldom if ever realized.

The United States' T&E program and data have served as the benchmark for the European JTIDS test community and spectrum management authorities. Limited testing has also been accomplished by the United Kingdom and Germany.

Additional testing of JTIDS should be limited to confirmation and validation of the existing data. The most likely candidates for testing are those units which employ a particular design or claim to perform to different specifications than those ATC equipment previously tested.

Countries that are involved in the MIDS program (e.g., France and Italy) are currently defining their need for a JTIDS EMC evaluation program. These countries are being assisted by the MNWG. The organization of their programs are outlined in section 7-2. This is the recommended approach for establishing a JTIDS EMC evaluation effort.

7.1 SPECIFIC GUIDANCE FOR JTIDS OPERATIONS IN THE NATIONAL AIR SPACE

The following list of guidelines for the operation of JTIDS to preclude interference to the ATC systems operating in the 960-1215 MHz band are compiled from the results of the United States T&E programs. These recommendations are summarized in table 7-1. Most of the supporting data has been presented or summarized in this report. For the most part, these results are from the 100/50 TSDF effort.

Table 7-1. Recommended JTIDS to ATC Equipment Siting Guidelines

ATC Equipment	Maximum JTIDS Signal Level at ATC Receiver	Separation Distance
TACAN/DME		
Interrogators	-42 dBm	1000 feet
Beacons	-33 dBm	0.4 nmi
ATCRBS		
Interrogators	-20 dBm	100 to 500 yards
Transponders	-21 dBm	1000 feet
Mode S		
Interrogators	-20 dBm	100 to 500 yards
Transponders	-21 dBm	1000 feet
TCAS		1000 feet

7.1.1 Recommended JTIDS Operations

1. The time slot duty factor should be limited to 100/50 percent, on a pulse rate equivalent basis, for routine operations. The total JTIDS community should not transmit in more than 100 percent of the time slots using 258-pulse messages in more than 1536 time slots resulting in a maximum 396,288 pulses. A single JTIDS terminal should not transmit in more than 50 percent of the time slots using 258-pulse messages in more than 768 time slots resulting in a maximum 198,144 pulses.

2. There should not be any operational restrictions on the usage of either 72-pulse, 258-pulse or 444-pulse message structures.

3. There should not be any operational restrictions on the use of multinet regardless of the number of simultaneous pulse transmissions from the various nets.

4. There should not be any operational restrictions on the use of contention access or repromulgation relay.

5. The Terminal output power should be limited to 200 watts nominal at the input to the JTIDS antenna. Terminal output power of 1000 watts can be used during precoordinated exercises in designated areas which are site engineered to ensure that the received JTIDS power level does not exceed that of a normal 200 watt exercise.

7.1.2 TACAN/DME

Independent 100/50 TSDF JTIDS exercises should be separated by a distance of at least 65 nmi. This distance should be measured from the foreground user (typically the highest TSDF user) to the nearest JTIDS terminal of the adjacent exercise. This will preclude effects on TACAN/DME equipment from an adjacent 100/50 TSDF exercise.

7.1.2.1 Interrogators

There should not be any special air-to-air separation distances (other than the normal 1000 feet flight separation rules) between JTIDS equipped aircraft and other TACAN/DME equipped aircraft.

7.1.2.2 Beacons

Site engineering should be accomplished when cositing ground-based JTIDS terminals in the vicinity of the TACAN/DME beacons to ensure that the received JTIDS signal level at the beacon receiver port does not exceed -33 dBm. A JTIDS signal level of -33 dBm corresponds to distance separation of approximately 0.4 nmi. For the case of an airborne JTIDS terminal, a JTIDS signal level of -33 dBm corresponds to aircraft altitudes of less than 1000 feet. Since 1000 feet is the minimum flight altitude, no special minimum air-to-ground separation is needed for airborne JTIDS terminals.

7.1.2.3 DME/P

The JTIDS environments considered in this report (Air Force and Army scenarios, section 5.2.1) can be accommodated within the ICAO prescribed limits when predicted (those considered in table 6-9) EPEs are considered.

7.1.3 ATCRBS

7.1.3.1 Interrogators

For JTIDS foreground signal levels equal to or weaker than -20 dBm, the performance of the ATCRBS interrogator will not be operationally affected.

A -20 dBm JTIDS received signal level at an ATCRBS interrogator receiver directional antenna port has been shown to be operationally unattainable from JTIDS airborne terminals; therefore, no special air-to-ground separation distances are required between JTIDS-equipped aircraft and ground based ATCRBS interrogators.

Site engineering should be accomplished when cositing ground-based JTIDS terminals in the vicinity of ATCRBS interrogators to ensure that the received JTIDS signal level at the ATCRBS interrogator receiver port does not exceed -20 dBm. The required separation distances between ground based JTIDS terminals and ATCRBS interrogators will vary depending on specific terrain conditions and JTIDS/ATCRBS interrogator antenna height combinations, but they are estimated to be approximately 100 to 500 yards for line-of-sight conditions.

7.1.3.2 1030/1090 MHz Avionics

The frequency dependent rejection analyses and the measured data indicate that there are no effects on 1030/1090 MHz avionics (Mode S and ATCRBS transponders and TCAS avionics) from JTIDS off-board signals. This indicates that the FAA compatibility criteria of no unsolicited replies and no change in percent replies for interrogations from 21 dBm to -69 dBm desired signal levels will be met when the 1000 foot ATC flight separation distance is observed.

7.1.4 Mode S

For a JTIDS TSDF of 100/50, the JTIDS foreground signal level received by the Mode S sensor must be stronger than -20 dBm to affect Mode S sensor performance.

A -20 dBm JTIDS received signal level at a Mode S interrogator receiver directional antenna port has been shown to be operationally unattainable from JTIDS airborne terminals; therefore no special air-to-ground separation distances are required between JTIDS-equipped aircraft and ground based Mode S sensors.

JTIDS ground-based units should be site engineered to ensure that JTIDS signal levels do not exceed -20 dBm at the Mode S interrogator receiver directional antenna port. The required separation distances will vary depending on specific terrain conditions and JTIDS/Mode S sensor antenna height combinations, but they are estimated to be approximately 100 to 500 yards for line-of-sight conditions.

7.1.5 TCAS

Under normal ATC aircraft-to-aircraft separation distances, signals from airborne JTIDS transmitters will not affect the performance of off-board TCAS 1030 MHz or 1090 MHz receivers; therefore, no special air-to-air distance separation is required.

7.2 JTIDS EMC TEST AND EVALUATION PROGRAM STRUCTURE

The complexity of a JTIDS EMC T&E program is directly related to the amount of testing that is to be performed. Bench and/or flight tests require special test equipment and signal sources that are unique to JTIDS and ATC systems. Before the decision is made to invest time, money, and effort in testing, a thorough determination of the data required to support a frequency allocation decision should be made. The military should identify its requirements for JTIDS operations as early as possible. These will change over time as the military becomes more knowledgeable about JTIDS and this should be acknowledged by the participating agencies. The requirements should be separately identified as routine day-to-day JTIDS capabilities, under which the majority of the JTIDS exercises will fall, and special training exercises which will occasionally require the use of higher TSDFs and a greater percentage of multiple time slot transmission capabilities (such as a joint service training exercise). The civil aviation authorities (CAA) should understand JTIDS and identify the type and amount of data needed for them to endorse a JTIDS frequency allocation. They should identify the ATC systems of interest and determine the performance parameters to be monitored. Both the military and the CAA must agree on the criteria that will be used to judge the effects of JTIDS on the ATC systems.

The test and evaluation program can be separated into three distinct phases. Phase 1 should encompass those tasks identified in the preceding paragraph. In addition, the structure of the national test and evaluation program should be identified. This would be similar to the functions performed by the United States' SPS WG-1 and its subgroups (see section 1.2.1).

Phase 2 would be to perform an analysis and evaluation of existing JTIDS and ATC EMC data. This data is available through the MNWG. The analysis should identify if the particular ATC equipments of interest are covered by the existing documentation.

Phase 3 of the T & E program would be to perform analyses of ATC systems for which insufficient data exists. Some limited testing could be performed to 1) validate and confirm the analyses, and 2) establish the performance of unique ATC systems or those with different designs than have been previously tested. This phase should address all the questions of the requested JTIDS capabilities.

7.2.1 EMC Test Program Considerations

The three most important considerations in establishing an EMC test and evaluation program are, 1) cooperation between the civil aviation authorities and the JTIDS military procuring authority, 2) the testing of properly operating ATC equipments, 3) the use of a valid JTIDS transmitter or signal source.

The JTIDS military procuring authority and the civil aviation authorities should form a close working relationship. A system for defining the JTIDS parameters to be tested and the ATC performance parameters to be monitored should be established, understood and agreed to. Agreement on these issues should be reached prior to any testing or analysis.

If testing is required, the type and amount of testing should be known. Bench testing allows a thorough investigation of the system but generally yields conservative (worst case) results. Flight tests are time consuming and expensive and are generally bounded by bench test results.

The ATC systems to be tested should be proven to meet all applicable specifications. Pre- and post-JTIDS effects checkout tests should be performed to ensure that a stable ATC unit was tested.

The test agency should verify that signal sources used to generate the desired environments exhibit the proper spectral characteristics. ATC equipments can be exercised with commercial simulators. For example, the bench testing of TACAN/DME interrogators is accomplished with the use of a TACAN/DME beacon simulator which supplies the desired signals. A separate extraneous pulse generator supplies the undesired background ATC environments.

The JTIDS signals should be representative of those present in the environment. Field and flight tests could be performed with actual JTIDS terminals. Bench tests and field tests could be performed with a JTIDS signal source. The advantage of a JTIDS signal source is that it can substitute for many JTIDS transmitters and it permits the easy manipulation of the JTIDS network structure.

7.2.2 JTIDS Simulator

The JTIDS signals used for the conduct of the 100/50 TSDF tests in the United States were generated by an enhanced TDMA Signal Source (ETSS). The ETSS uses JTIDS synthesizer and emulates a JTIDS terminal. The time slot structure, pulse characteristics, and spectrum characteristics are identical to those of a JTIDS terminal. The ETSS is capable of generating any combination of 258-pulse, 444-pulse, multinet, contention, RTT, and relay time slot structures with up to 10 simultaneous transmissions in a time slot. More than ten simultaneous transmissions in a time slot can be performed with the addition of more signal source units (SSUs).

The ETSS permits a large degree of flexibility in the types of JTIDS environments to be tested. Static and dynamic testing can be accommodated. Special pulse timing environments can be created to investigate specific EMC conditions, or to investigate the mechanisms of the effects of JTIDS signals.

The ETSS is composed of three major components: the system controller, the scenario controller, and up to ten signal source units. The system controller is an HP9836 desktop computer. It is used to transfer the JTIDS scenario data to the scenario controller. The scenario controller is a special purpose multiprocessor containing multiple single board computers and associated I/O circuitry that is used to control the SSUs. It schedules the various types of time slot message structures so that a specific JTIDS environment can be simulated.

The SSU consists of a pulse controller and a transmitter. The pulse controller performs all the tasks necessary to format each JTIDS pulse and the pulse timing within the slot. The transmitter generates the RF JTIDS pulse. The outputs of each transmitter can be individually attenuated. The transmitter outputs are combined along with the desired test signal (e.g., TACAN/DME interrogation), and an EPE or loading signals and input to the unit under test (UUT). An additional transmitter output is provided as a monitor port to check the spectrum levels of the transmitted JTIDS signals. Figure 7-1 demonstrates the ETSS configuration for up to five simultaneous transmissions in a time slot.

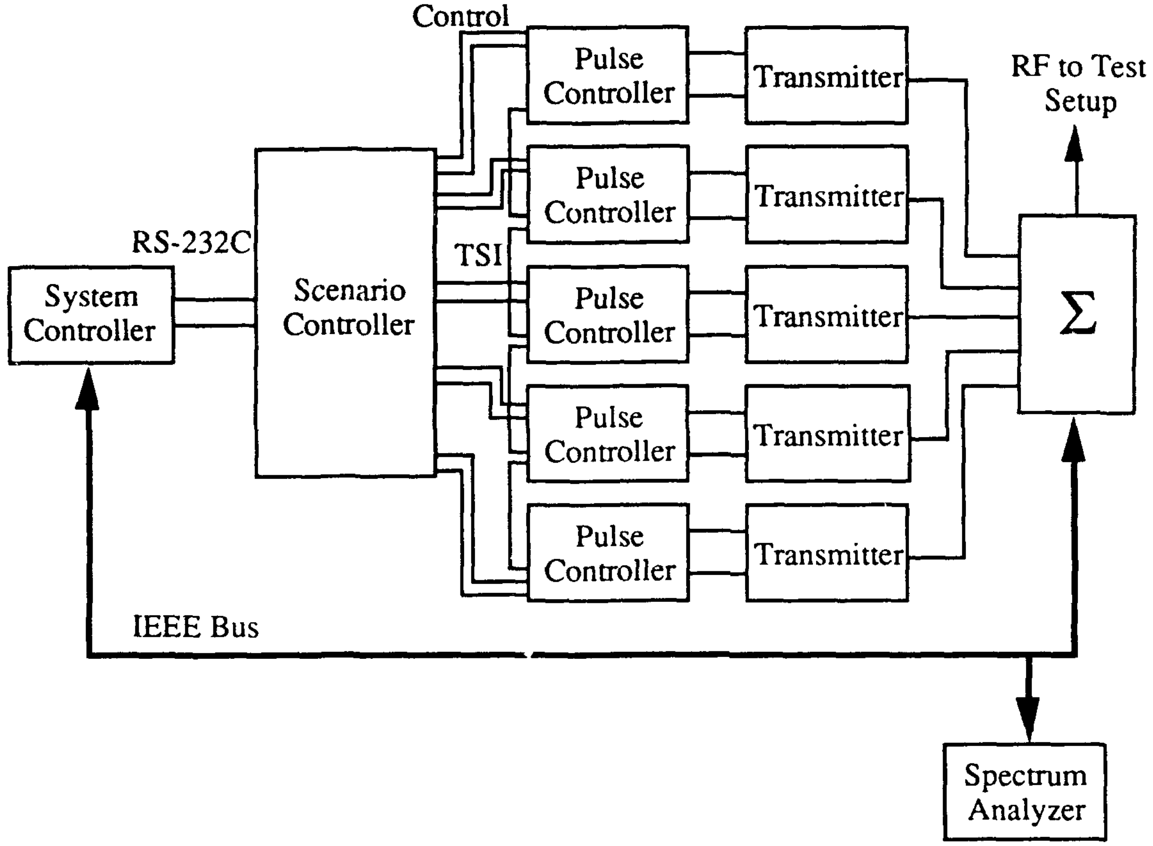


Figure 7-1. JTIDS Enhanced TDMA Signal Source

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APPENDIX A

United States JTIDS Frequency Allocation

UNITED STATES DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Washington, D.C. 20230

Doc. 21167/1-1.14.10
FAS ADM790260
SPS-4280/1-1.14.10

December 6, 1979

Col. Jerome J. Banaszak
U.S. Air Force
Frequency Management Office
Washington, D. C. 20330

Dear Col. Banaszak:

The system review of your agency's Joint Tactical Information Distribution System (JTIDS) Phase I has been completed by the Spectrum Planning Subcommittee (SPS). The results of that review are enclosed.

This Office concurs with the recommendations of the SPS. This concurrence is given with the understanding that the information on JTIDS system parameters and their effect on civilian DME interrogators and on an ATCRBS transponder will be published and released to the civilian community by mid January 1980, that the information on JTIDS system parameters and their effect on the remaining ATC system elements be provided as soon as possible, and that the other actions specified by the SPS will be accomplished in a timely manner.

Sincerely,

Leo A. Buss
Director
Spectrum Plans and Policies

Enclosures

cc: IRAC w/Atch
FAS w/Ltr to DSPP
SPS w/Ltr to DSPP

UNITED STATES DEPARTMENT OF COMMERCE
National Telecommunications and
Information Administration
Washington, D.C. 20230

SPS-4213/2-1.14.10
Ref: SPS-3339
SPS-3538/2
SPS-4195

DATE: November 30, 1979

TO: Director, Spectrum Plans and Policies

SUBJECT: System Review - Air Force Joint Tactical Information Distribution System (JTIDS) Phase 1 (TDMA) - Stage 4

The Spectrum Planning Subcommittee (SPS) has reviewed the JTIDS Phase 1, which is a time division multiple access system, as described in attachment 1 (SPS-3339 as modified by SPS-4195) under the provisions of Part 8.3 of the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management.

The SPS noted that:

1. This system has an essential wartime mission.

2. The air traffic control systems which FAA operates in the 960-1215 MHz band will come under the purview of DOD during time of war.

3. When JTIDS is operated in the narrowband mode on 969 MHz, JTIDS may interfere with the military TACAN operations between 960 and 977 MHz.

4. The OTP and now NTIA has had the subject system under review in accordance with Part 8.3 of the Manual. This review involved extensive bench and flight tests to ascertain EMC with existing and firmly planned systems in the 960-1215 MHz band. The reports on these tests have been provided to IRAC/SPS.

5. The information on this system and the NTIA preliminary assessment has been coordinated with the SPS 960-1215 MHz Working Group.

6. The FCC, upon the request of OTP, agreed to modify the National Table of Frequency Allocations to include a footnote that would accommodate spread spectrum systems such as JTIDS on a non-interference basis.

7. Restrictions have been placed on the use of the 960-1215 MHz band by JTIDS. These restrictions were delineated in a letter from NTIA to DOD dated May 23, 1978 and encompass operational controls, siting and collocation procedures, changes in design parameters, additional data on JTIDS characteristics and the non-interference status of JTIDS. These constraints are intended to insure compatible operations between JTIDS and the operational and firmly planned systems designated for this band.

The SPS considered the NTIA preliminary assessment of this system contained in attachment 2 (SPS-3538/2). This assessment was coordinated with the SPS 960-1215 MHz Working Group.

The SPS recommends that spectrum support be granted on a non-interference basis for the JTIDS Phase 1 (TDMA) subject to the following.

OPERATIONAL CONTROLS

A. Transmissions be inhibited if:

   1. The frequency-hopping mode fails to distribute the JTIDS spectrum uniformly across the band;

   2. The radiated pulse varies from the specified width of 6.4 microseconds ±5%;

   3. The energy radiated within ± 7 MHz of 1030 and 1090 MHz exceeds a level of 60 dB below the peak of the JTIDS spectrum as measured in a 300 kHz bandwidth; and

   4. The time slot duty factor exceeds a 20 percent duty factor for any single user or a 40 percent composite duty factor for all JTIDS emitters in a geographic area.

B. Transmitter power be limited to a nominal 200 W at the terminal output.

C. Time slot allocation techniques will be available for the class 2 terminal that can assign more than one transmitter to radiate in any time slot. This time slot allocation technique be inhibited both automatically and by associated administrative procedures when the full EMC controls are in effect.

D. An individual terminal be inhibited from transmitting in an adjacent time slot when full EMC controls are in effect.

E. Exceptions to the above operational controls be limited to experimental, test and exercise operations and be coordinated with FAS on a case by case basis.

F. DOD document and report to NTIA when any overrides to the above operational constraints are utilize or when the terminal transmission is inhibited by any of the above operational controls.

G. DOD periodically verify that the hardware which implements the operational controls given above is properly functioning.

SITING AND COLLOCATION PROCEDURES

H. DOD participate in developing geographic separation distances between terrestrial JTIDS terminals (fixed, land mobile, portable shipborne, or transportable) and ground-based ATC systems. (The separation distances will be developed in the SPS using the guidelines and technical criteria contained in OT Report 78-140.)

I. Engineering efforts be established by DOD to address the EMC aspects of collocating JTIDS and ATC equipment on the same aircraft.

DESIGN CHANGES

J. Changes in the JTIDS design, including changes in EMC controls, or planned operational deployment that have a potential to affect compatibility or deployments that are different than those considered during the EMC evaluation, be reassessed by SPS to assure compatibility.

DATA ON JTIDS CHARACTERISTICS

K. Information concerning JTIDS system parameters and their effect on ATC system elements be provided to NTIA via the

SPS. The information includes but is not necessarily limited to the following:

1. Those JTIDS characteristics that should be considered by the civil aviation community and FAA in designing ATC equipment for minimum susceptibility, (e.g., the number of pulses in a TACAN/DME channel); and

2. Information on the mechanisms by which JTIDS signals produce changes in performance of ATC system elements (e.g., reduced beacon reply efficiency, change in interrogator acquisition sensitivity).

FUTURE ATC SYSTEMS

L. Since tests and analysis for the firmly planned systems of DABS, BCAS and MLS/DME were not performed with operational equipment, their system design may change prior to introduction into this band. Continued coordination should therefore be maintained between DOD, FAA and NTIA to ensure potential EMC problems do not develop. In addition, further evaluation and analysis, including additional testing, will be required when operational equipment is available.

It is further recommended that DOD coordinate internally the narrowband mode of operation to assure the military TACAN system is not subjected to harmful interference.

William Gamble
Chairman, SPS

APPENDIX B

MULTINATIONAL AD HOC MIDS/JTIDS SPECTRUM SUPPORT WORKING GROUP CHARTER

JTIDS/MIDS MULTINATIONAL AD HOC SPECTRUM SUPPORT WORKING GROUP

OBJECTIVE:

The primary purpose of this group is to assist in and address the many issues dealing with International Spectrum Support for JTIDS/MIDS.

MEMBERSHIP:

1. Membership shall consist of civil and military delegations from countries interested in JTIDS/MIDS development and deployment. The exact composition of each delegation in the working group shall be left to the discretion of the member nation. The maximum number of participants at any specific meeting may be limited by host nation facilities, member nation travel budgets, participant consensus at a prior meeting or unanimous agreement of delegation heads.

2. A steering committee shall be formed which would consist of a representative from each member nation and the chairman. The steering committee shall establish the scope of activities of the working group.

FUNCTIONS:

1. Exchange of JTIDS EMC test plans and results. Each nation is encouraged to submit JTIDS EMC test plans, results, and related documentation for use by member nations as possible inputs to their internal frequency approval organizations. All documents are still subject to originating nation release procedures.

2. Recommendations for testing. Each nation may review JTIDS EMC test plans being developed by another nation and, if desired, make recommendations to test methodology or equipment under test so that the results may be more useful to their frequency support process. These recommendations will be reviewed by the nation conducting the test for possible implementation and cost sharing.

3. Support for JTIDS/MIDS Equipment. The Working Group is encouraged to search for, recommend, and disseminate information on the best use of the JTIDS EMC test plans and test results to provide spectrum support for JTIDS/MIDS equipment such as the MIDS Low-Volume terminal.

ADMINISTRATIVE CONSIDERATIONS:

1. Meeting locations and dates will be determined by consensus of the working group. Special considerations will be required due to the group's size. Should a change in meeting location become necessary, the chairman will be responsible for identifying and coordinating a new meeting location.

2. Travel and lodging costs for the members will be funded by each member's nation.

revised 15 October 1990

GLOSSARY

ARTS - Automated radar terminal system. The portion of the ATCRBS interrogator receiver system that is responsible for generating target reports and target tracks. It receives quantized video and mode triggers from the interrogator receiver and provides target report and tracking information to the display software.

ASOP - Acquisition stable operating point. The weakest beacon signal level that an interrogator can acquire within a specified time limit (usually five seconds), five out of five consecutive trials with the identification (ID) tone off, and then can remain in track for 60 seconds with the ID tone on.

ATCRBS - Air traffic control radar beacon system. An ATC system consisting of ground-based interrogators and airborne transponders. The interrogator can transmit in several different modes to obtain aircraft identification and/or pressure altitude responses. The ground interrogator then receives and decodes the transponder replies. All ATCRBS interrogators transmit on 1030 MHz and receive on 1090 MHz. All ATCRBS transponders transmit on 1090 MHz and receive on 1030 MHz.

ATC System - Air traffic control system. The national system that is used to provide information to aircraft and to air traffic controllers to enable them to provide safe separation distances between aircraft that are en route or within the terminal areas.

BRE - Beacon reply efficiency. The percentage ratio of the number of replies transmitted by a beacon transponder over the number of valid interrogations.

Breaklock point - The strongest beacon signal level at which an interrogator will not track a beacon signal for 60 seconds with the ID tone on.

Class 1 terminal - A JTIDS terminal developed for use in large airborne and surface command and control elements. The Class 1 terminal uses IJMS and has a nominal output power of 200 watts or 1000 watts.

Class 2 terminal - A JTIDS terminal developed for use in fighter aircraft and small mobile command and control elements. The Class 2 terminal uses TADIL J and has a nominal output power of 200 watts. Some Class 2 terminals will also have the capability to use IJMS.

Class 2H terminal - A JTIDS Class 2 terminal equipped with a High Power Amplifier Group (HPAG) for use in large airborne and surface command and control elements. The Class 2H terminal uses TADIL J and has a nominal output power of 200 watts or 1000 watts. Some Class 2H terminals will also have the capability to use IJMS.

Class 2M terminal - A JTIDS terminal developed for Army ground mobile applications. The Class 2M is a single LRU version of the Class 2 terminal without TACAN or voice capability. The Class 2M terminal uses IJMS and TADIL J and has a nominal output power of 42 watts or 200 watts.

CMN - Control motion noise. That portion of the DME/P equipment error which could affect aircraft attitude angles and cause control wheel and column motion during coupled flight, but which does not cause aircraft displacement from the desired flight path.

Contention - A term used to denote multiple JTIDS transmission that use the same frequency hopping pattern in the same time slot.

Contention access - A JTIDS transmit access mode in which a group of JTIDS users is assigned a pool of time slots to satisfy their transmission requirements. Time is divided into access intervals. A user may transmit only once per access interval. Users randomly select their transmit time slots from the pool.

Coordinated operation - A military operation using JTIDS equipment that is subject to prior coordination with national regulatory agencies because one or more aspects of the national JTIDS frequency clearance/certification of spectrum support must be exceeded to satisfy operational requirements.

Cull criteria - A conservative value or threshold used to determine if test results indicate little or no effect on the performance of the unit. If the cull criteria is exceeded, additional testing is often needed to accurately quantify the effect.

Dedicated access - A JTIDS transmit access mode in which each JTIDS terminal is assigned time slots for its exclusive use in a given net. This mode is used to specify no more than one terminal transmission per time slot per net.

Defruiter - A portion of the ATCRBS/IFF/SSR interrogator system that is used to filter out reply signals which are not synchronous to the transmissions of the interrogator.

DFR - Data-for-record. All EMC data, as determined by the SPS WG 1 Test Planning Subworking Group, that are used to evaluate the performance of ATC systems operating in national environments that may include JTIDS signals.

DME - Distance measuring equipment. An ATC system operating in the 960-1215 MHz band. DME is the internationally accepted means of determining the slant range between an aircraft and a known ground station.

DME/N - Designation for the conventional (narrowband) DME system. This designation is used to distinguish it from the precision DME system.

DME/P - Precision distance measuring equipment. This system provides a higher accuracy range measurement through the use of a wider bandwidth and faster rise time signal. The system is to be used with the Microwave Landing System (MLS).

EMC - Electromagnetic compatibility. This condition which prevails when equipment is performing its individually designed function in a common electromagnetic environment without causing or suffering unacceptable degradation due to unintentional electromagnetic interference.

EMC features - The hardware and software controls in a JTIDS terminal that are used to detect terminal faults that affect the JTIDS time/frequency waveform.

EMC maintenance testing - EMC testing of ATC equipment to assure that JTIDS continues to be compatible with future ATC systems.

Enhanced repromulgation relay - A JTIDS relay technique identical to repromulgation relay except that an additional time delay is used on subsequent retransmissions. Use of the additional time delay enables the originating terminal to donate fewer (compared to repromulgation relay) assigned time slots for retransmission of the message thus increasing the message throughput from the originating terminal.

EPE - Extraneous pulse environment. The undesired background environment at an ATC receiver. The EPE represents all undesired signals seen by the ATC receiver except JTIDS signals. The TACAN/DME EPE consists of on-channel off-code and adjacent-channel on-code DME/N and DME/P type pulses.

Epoch - A 12.8-minute interval consisting of 98,304 time slots.

Equivalent TSDF - The pulse transmission rate that is equivalent to the same number of pulses that would be transmitted if each time slot contained 258 pulses. The equivalent TSDF of 100/50 is 33,024 pulses per second for the JTIDS community and 16,512 pulses per second for a single terminal when averaged over a 12-second frame. The term "equivalent TSDF" should be used whenever operations include 444 pulse time slots or multiple transmissions in a time slot.

FDR - Frequency dependent rejection. The rejection provided by a receiver because of the bandwidth difference between the receiver and transmitter and by the tuned frequency of the receiver with respect to the transmitter.

Foreground level - The strongest received JTIDS signal level at an ATC receiver during a JTIDS operation.

Frame - A 12-second subdivision of an epoch. The frame is the basis for the Calculation of TSDF. A frame contains 1536 time slots.

Frequency allocation - An entry in the Table of Frequency Allocations of a given frequency band for the purpose of its use by one or more radio communications services.

Frequency assignment - An authorization given by the responsible administration for a transmitter (radio station) to use radio frequencies or frequency channels under specified conditions.

Frequency clearance - Governs the use of frequencies or radio frequency channels for a radio system to operate and provide a specified class of service.

Fruit - Extraneous pulses detected by an ATCRBS/IFF/SSR interrogator or Mode S sensor receiver. This term is sometimes used interchangeably with the term TACAN/DME extraneous pulse environment.

General exercise - A military exercise that exceeds the criteria for a routine training operation. The JTIDS TSDF of a general exercise is approximately 200/50.

Geographic area - A physical area within which a JTIDS operation cannot exceed the frequency clearance/spectrum support certification limits. For example, it is the area within radius "R" which does not exceed a TSDF of 100 percent when the radius "R" is drawn around each JTIDS terminal.

Harmful interference - Interference that endangers the functioning of a radio navigation service or other safety service or seriously degrades, obstructs or repeatedly interrupts a radio communication service operating in accordance with ITU regulations.

IFF - Identification friend or foe. A military system functionally interoperable with ATCRBS/SSR.

IJMS - Interim JTIDS Message Specification. The JTIDS message specification that was primarily developed for E-3A operations.

IPF - Interference protection feature. An alternate term for EMC features.

JTIDS net - One of the 128 unique pseudorandom sequences used to determine the time, phase, and frequency parameter for JTIDS transmissions.

JTIDS Pulse - A 6.4 microsecond wide (measured at 90 percent amplitude points) burst of energy containing continuous phase shift modulation (CPSM). The CPSM is modulated with one of 32 possible sequences generated by cyclic code shift keying (CCSK). The 32 chip sequence represents a five bit data symbol. The pulse also contains 5 additional chips in the leading edge of trailing edge for control of soft turn-on and turn-off. The interpulse period for JTIDS pulses is 6.6 microseconds.

Link 16 - A formal message standard that was developed for NATO JTIDS operations. It is essentially the same as TADIL J.

LRU - Line replaceable unit. A subassembly of a JTIDS terminal that can be removed and replaced at the JTIDS platform.

Mechanisms test - A technique used to determine why a receiver does or does not respond to a specific type of signal. A specific type of test that is used to determine how JTIDS signals affect an ATC receiver.

Message structure - The organization of JTIDS pulses within a time slot to provide for different information capacities and performance levels. The terminal can transmit 72, 258, or 444 JTIDS pulses in a time slot.

MIDS - Multifunction information distribution system. An advanced information distribution system that provides navigation, communication and identification capabilities in an integrated form for application in air, land and maritime tactical operations. STANAG 4175 defines the minimum electric and physical system characteristics required for interoperability, electronic countermeasures resistance, security, and electromagnetic compatibility.

MIDS LV terminal - A small terminal being developed for applications with severe space constraints. The MIDS LV terminal meets STANAG 4175 requirements, uses IJMS and Link 16, and has a nominal output power of 200 watts. An external 1000 watt amplifier can be connected to the MIDS LV terminal.

Mode S - A surveillance and communication system for air traffic control. Mode S is an ATCRBS system employing ground-based sensors (interrogators) and airborne transponders. Each Mode S-equipped aircraft is assigned a unique address code. The ground-based sensors are able to solicit replies from selected aircraft in the environment thus reducing the amount of pulses being generated.

MOPS - Minimum operational performance standards. Documents written by the Radio Technical Commission for Aeronautics (RTCA) that recommend system characteristics to assure satisfactory equipment performance under all normally encountered conditions. For example, RTCA/DO-151A and DO-189 are two documents written for airborne DMEs. The MOPS are normally coordinated with the appropriate European Organization for Civil Aviation Electronics (EUROCAE) working group.

MTL - Minimum triggering level. The weakest ATCRBS/IFF/SSR interrogator signal level to which an ATCRBS/IFF/SSR transponder will reply 90 percent of the time.

MTPA - Mobile transponder performance analyzer. A test set used by the FAA to evaluate the performance of ATCRBS and Mode S transponders.

Multiple nets - A term used to denote multiple JTIDS transmissions in a time slot, each using a different frequency hopping pattern.

Needline - An information distribution link that must have direct or indirect connectivity.

Network management - The process of selecting appropriate terminal parameters for member terminals, assigning time slots to each terminal to provide for its transmission and reception requirements and assuring that all terminals are initialized in a compatible manner so that a JTIDS communication network is realized.

NIB - Noninterference Basis. A radio system that is authorized to be operated on a noninterference basis shall not cause harmful interference to or claim protection from other radio services to which the frequency band is allocated.

Nominal - The typical value measured over a sample size. The measured value may be at variance with the specified value. In general, the measured value will approximate, but will not necessarily be identical to, the specified value.

OFR - Off-frequency rejection. The rejection provided by a receiver due to the difference in the tuned frequency of the receiver with respect to the tuned frequency of the transmitter.

OTR - On-tune rejection. The rejection provided by the receiver selectivity characteristics with respect to a transmitter that is tuned to the same frequency.

Pack 2 double-pulse message - A JTIDS message structure composed of 444 pulses. This message structure contains the same amount of information as the Pack 2 single pulse message but information transfer reliability is enhanced by retransmitting each bit of information on the adjacent pulse.

Pack 2 single-pulse message - A standard message structure composed of 258 pulses. This message structure transmits twice as much information as the standard double-pulse message because each bit of information is transmitted only once.

Pack 4 single-pulse message - A message structure composed of 444 pulses. This message structure holds twice as much information as the Pack 2 double-pulse message and four times as much as the standard double-pulse message because each bit of information is transmitted only once.

Parametric testing - A test method in which parameters such as the percentage of multinet and/or contention transmissions are varied to assess their effect on ATC equipment.

PFE - Path following error. That portion of the DME/P system error which could cause aircraft displacement from the desired flight path.

Precoordinated operation - A military operation that remains within the JTIDS frequency clearance limits so that additional coordination with regulatory agencies is not required. (Also referred to as an uncoordinated operation.)

PTTA - Principal time-to-acquire. The weakest TACAN/DME beacon signal level at which an interrogator can consistently acquire lock within 120 seconds.

Pulse density - See TSDF and equivalent TSDF definitions.

Recurrence rate - A parameter that indicates the spacing between time slots in a block of periodically spaced slots, specified as an integer R, where 2^R is the number of time slots per epoch in the block.

Relay - Retransmission of a message at a fixed number of time slots after its initial reception.

Repromulgation relay - A JTIDS relay technique which includes random jitter and is used to extend information flow beyond line-of-sight distances. A terminal receiving a repromulgation relay message retransmits it in a later time slot donated by the originating terminal, unless the terminal received the identical message earlier or unless the specified number of retransmissions has been satisfied.

Routine Training - A precoordinated JTIDS training operation that is conducted on a daily basis. The TSDF of routine operations and training is usually at 100/50 or less.

RTBG - Retriggerable blanking gate. A circuit in a TACAN beacon designed to prevent the generation of replies to multipath signals that develop from airborne interrogations. The RTBG circuit is activated when a valid interrogation signal level exceeds the established threshold (e.g., -70 dBm). During the time that the RTBG circuit is activated, an interrogation can be decoded if it exceeds the threshold value. This interrogation would retrigger the RTBG circuit.

RTT message - Round trip timing message. Messages required for terminal synchronization. An RTT message is either an interrogation which requests time-of-arrival information or a reply. RTT interrogations and replies each contain 72 pulses. A reply message is transmitted in the same time slot as the requesting interrogation.

Scenario - A representative use of military equipment in a training operation or a simulated wartime exercise.

Snapshot - The 60-second time period taken from an operational scenario which causes the highest pulse density to be detected by an ATC receiver.

Special exercise - A military operation that exceeds the criteria for a general exercise. The JTIDS TSDF of a special operations and training exercise is approximately 400/50.

Spectrum support certification - The certification by the national regulatory administrations that a given type of electronic equipment can be operated in a given frequency band to provide a specified class of service. (Synonymous with frequency clearance.)

SPS WG-1 - Spectrum Planning Subcommittee Working Group One. A working group of the United States Spectrum Planning Subcommittee (SPS) which the National Telecommunications and Information Administration (NTIA) established to evaluate all systems that operate in the 960-1215 MHz band. The NTIA reviews federal systems for frequency supportability and electromagnetic compatibility.

SSR - Secondary surveillance radar. An air traffic control system similar to ATCRBS.

Standard double-pulse-message - A message structure composed of 258 pulses. Information transfer reliability is enhanced by retransmitting each bit of information on the adjacent pulse.

STC - Sensitivity time control. A circuit in an ATCRBS/IFF/SSR interrogator receiver that can gradually increase the gain of the receiver after an interrogation. This circuit prevents receiver saturation from close-in targets.

Symbol packet - A single element containing either one (single-pulse symbol packet) or two (double-pulse symbol packet) 6.4 microseconds pulses. The single-pulse packet (13 microseconds) consists of a 6.4 microsecond pulse followed by a 6.6 microsecond interval of off time. The double-pulse packet (26 microseconds) consists of two 6.4 microsecond pulses, each followed by 6.6 microsecond intervals of off time.

TACAN - Tactical air navigation. A worldwide navigation system that incorporates the standard international DME function with a bearing determination capability on a single RF carrier in the 960-1215 MHz band.

TADIL J - Tactical Digital Information Link J. A formal message standard that was developed for multiservice JTIDS operations.

TCAS - Traffic alert and collision avoidance system. TCAS airborne equipment interrogates ATCRBS/Mode S transponder equipped aircraft in its vicinity to determine which aircraft represent potential collision threats and provides appropriate display indications (or advisories) to the flight crew to ensure aircraft separation. TCAS units transmit interrogations on 1030 MHz and receive replies on 1090 MHz.

Time slot - A 7.8125 millisecond time interval during which JTIDS messages may be transmitted or received.

Time slot block - A collection of time slots spaced uniformly in time. A block is defined by an indexing time slot number (0 to 32,767), a time slot set (A, B, or C), and a recurrence rate (0 to 15).

TSDF - Time slot duty factor. A two term parameter that specifies the number of pulse transmissions allowed for a community of JTIDS terminals during each 12-second frame. The first term is a percentage indicator of the number of transmissions allowed for the total community. The second percentage term indicates the limit for a single terminal. The 100/50 TSDF notation specifies that the total community is limited to a pulse density of 396,288 transmitted JTIDS pulses in a 12 second frame and a single terminal is limited to 198,144. The TSDF is always stated in terms of 258 pulses per time slot. Therefore, the total number of pulses can be derived for a 100/50 TSDF by considering the 100 percent for the total community as

$$100\%\ (\text{TSDF}) = \frac{258\ \text{pulses}}{\text{time slot}} \times \frac{1536\ \text{time slots}}{\text{12-second frame}} = 396{,}288\ \text{pulses/12-second frame}$$

Using this total, the maximum percentage of time slots that is available to the JTIDS community for a 100/50 TSDF if all terminals are programmed for Pack 4 single-pulse messages can be derived by:

$$\text{Pack 4 time slot limitation} = \frac{396288\ \text{pulses}}{\frac{444\ \text{pulses}}{\text{time slot}} \times \frac{1536\ \text{time slots}}{\text{12-second frame}}} = 58\%$$

TSO- Technical standard order. An FAA document which states the general requirements and minimum performance standards needed for all parts and equipment used on civil aircraft. For example, TSO-C66a and TSO-C66b are two standards written specifically for airborne DMEs.

TTA- Time-to-acquire. The time required for a TACAN/DME interrogator to acquire a beacon signal at a particular desired signal level with the ID tone off. Breaklock data is taken with the ID tone on during the TTA test.

Uncoordinated operation - See Precoordinated operation definition.