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Tactical Electronics Simulation Test System : Feasibility Assessment Briefing CDRL A003, B002

University of Central Florida Institute for Simulation and Training

INSTITUTE FOR SIMULATION AND TRAINING

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TACTICAL ELECTRONICS SIMULATION TEST SYSTEM

Feasibility Assessment Briefing
CDRL A003, B002

APRIL 12, 1991

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Division of Sponsored Research

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<u>INSTITUTE FOR SIMULATION AND TRAINING (IST)</u>
BACKGROUND

• <u>Defense Science Board 1982</u> Cited need for better DoD use of simulation and training technologies.

• <u>Dr. Hermann's Report 1983</u> Recommended establishment of a Center of Excellence for simulation and training. Suggested Orlando as the location. Strongly urged a university affiliation. Report concurred in by Joint Logistics Commanders.

• <u>State of Florida Chartered IST</u> in April 1985

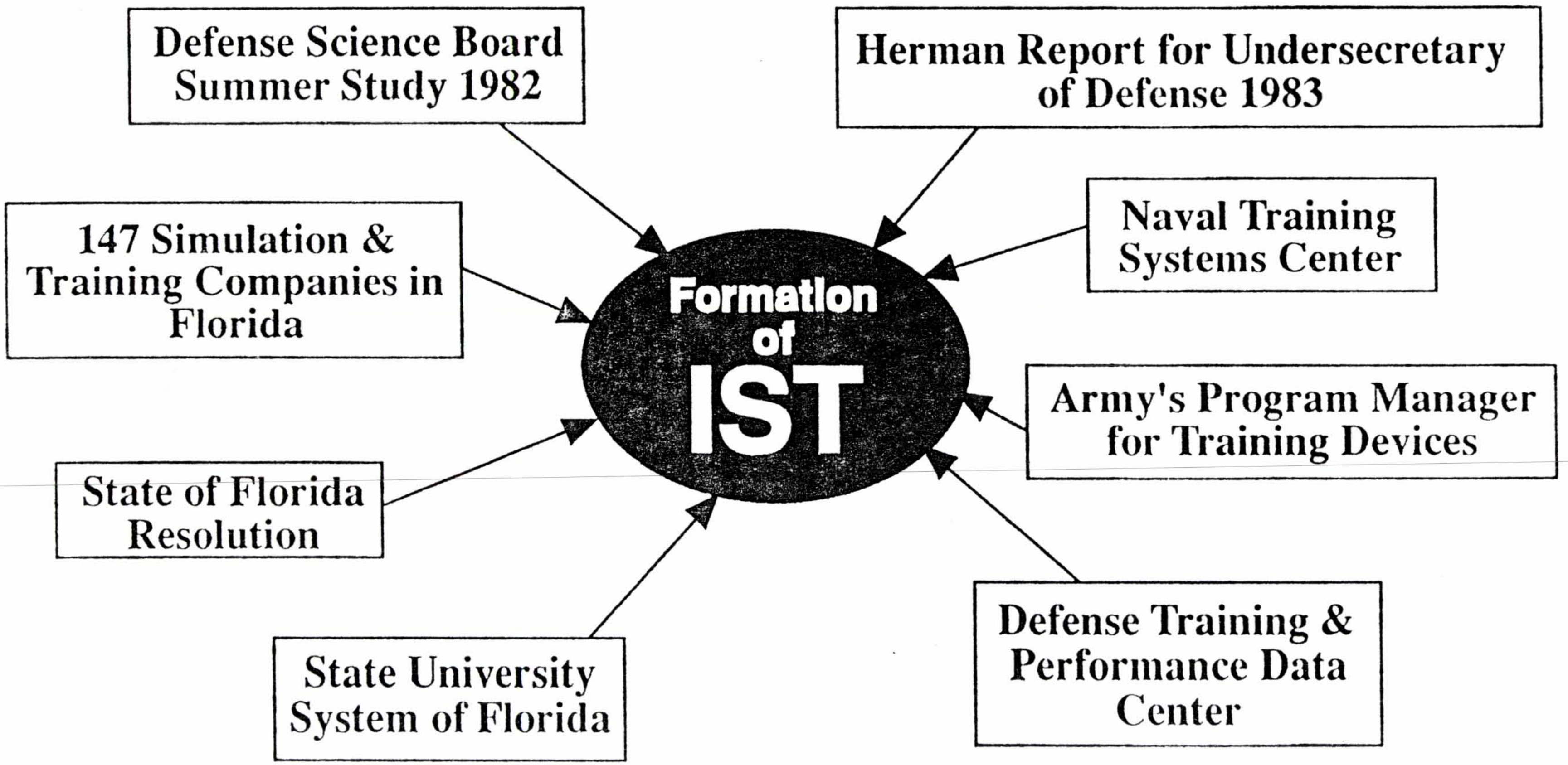
- University of Central Florida selected over 9 other universities
- UCF one of only five universities with sponsored chair in Computer Science
- UCF only major university to offer Advanced Degree in Simulation
- UCF has strong Computer Science and Electrical Engineering Departments

    - UCF Computer Team:
        - Second Place in International Competition 1986
        - Fifth Place in International Competition 1991

• <u>IST can draw on vast resources</u> in International Training Community

- 40 years of Government research and procurement experience at NTSC, PM TRADE
- 147 Simulation and Training companies in Orlando area
- Colleges, universities, and institutes world wide

Factors which have led to the formation of IST and the Center of Excellence in Simulation and Training



INSTITUTE FOR SIMULATION AND TRAINING

An Institute dedicated to the following purposes:

- Advance the State of the Art in Simulation and Training
- Make Simulation and Training more affordable and effective
- Transfer technology to the Simulation and Training Community
- Provide an Environment for Simulation and Training Education

APPROACH

- Conduct interdisciplinary research in S&T
  - Engineering
  - Computer Science
  - Human Factors
  - Instructional Systems
- Conduct seminars and workshops
- Support graduate programs in S&T

ROLES OF IST WITHIN CENTER OF EXCELLENCE

- DIMINISH TECHNOLOGY RISK TO GOVERNMENT AND INDUSTRY
  - Wash technical risk out of emerging programs
  - Numerous contractual vehicles with various agencies

- DEVELOP SIMULATION STANDARDS, PROTOCOLS, AND GUIDELINES
  - Enables simulator interoperability
  - Major research effort in networking standards

- PERFORM VARIOUS HONEST BROKER TASKS
  - Sponsor symposiums and conferences
  - Assess simulator equipment and training methodologies
  - Provide objective perspective on critical issues

IST CHARACTERISTICS

- FOCAL POINT FOR TRAINING AND SIMULATION RESEARCH
  - Exec. Director Co-Chairs Center of Excellence Committee (NTSC, PM TRADE, TPCD, ASD)
  - Conducts collaborative and contracted research for government and industry
  - Broad range of working agreements with other universities Carnegie-Mellon, GTRI, Univ. of Iowa, Etc.

- TAILORS RESEARCH TEAM TO TASK
  - Uses small internal staff, expertise, with campus faculty
  - Broad use of graduate and undergraduate students

- NOT-FOR-PROFIT INSTITUTE
  - Subsidized by State of Florida
  - Low overheads assessed to contracts

INDUSTRIAL ADVISORY BOARD
PURPOSE

The Industrial Advisory Board consists of senior representatives, normally Vice-Presidents and Chief Executive Officers, from twenty simulation and training corporations. They meet with the Institute's management once every six months, are briefed on current research projects, and provide valuable advice and guidance to the IST Executive Director to better enable him in directing IST to perform its chartered mission.

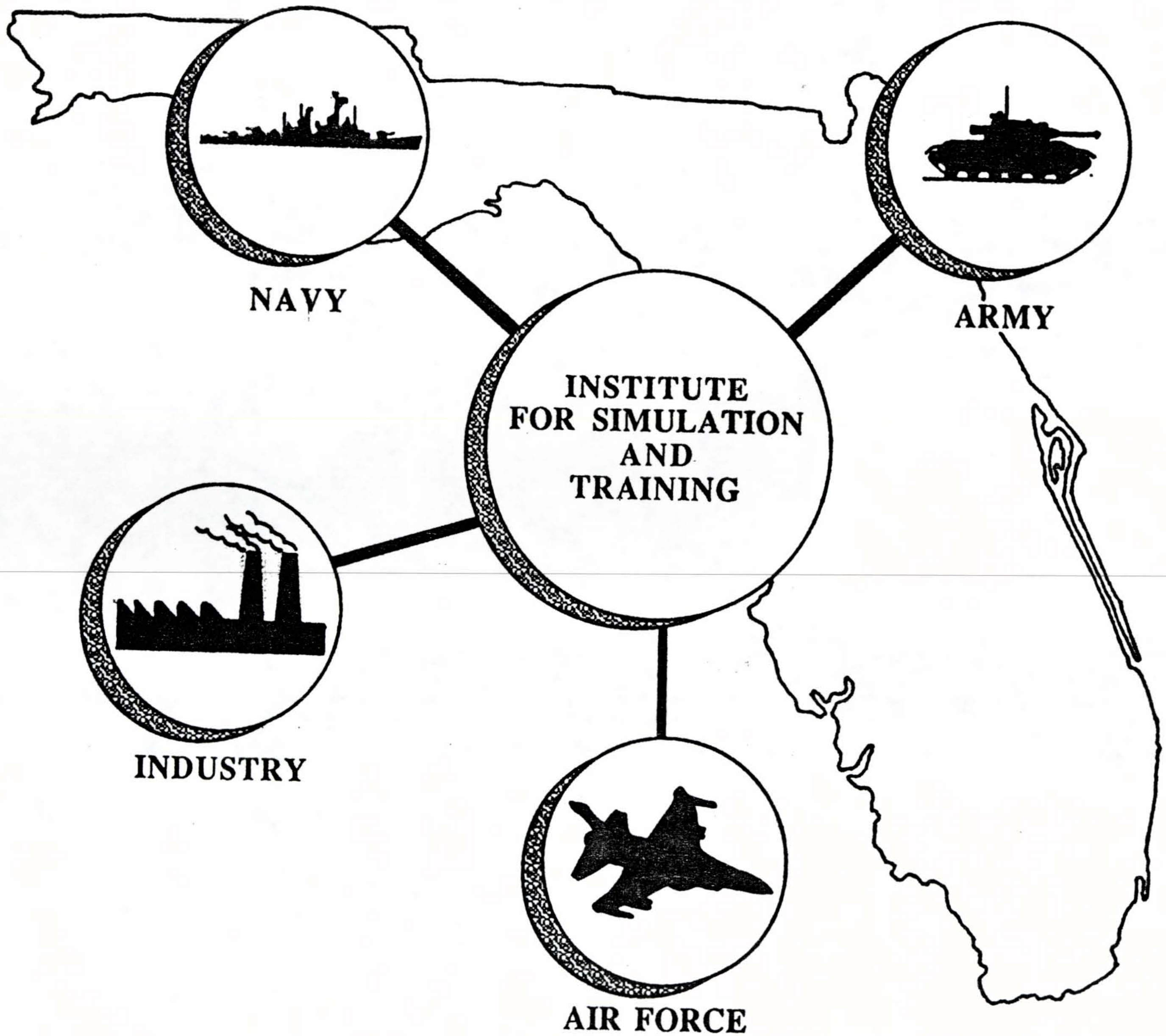
Various government agencies, such as NTSC, PM TRADE, ASD and TPDC usually send senior representatives to attend meetings and briefings involving this advisory body. Senior faculty and administrators from the University of Central Florida are also in attendance.

0182-1647

INDUSTRIAL ADVISORY BOARD

- Burtek
- CAE-Link
- Encore Computer
- ECC International
- Evans & Sutherland
- G. E. Aerospace
- Grumman Electronics
- Harris
- Hughes Simulation Systems
- Loral Defense Systems
- McDonnell Douglas
- Perceptronics
- Reflectone
- Star Mountain
- Systems & Simulation
- Westinghouse Electric

PROPOSED CHAIRS



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SIMULATION AND TRAINING STUDIES AND REPORTS
Typical Projects

- Networking Standards for Simulations have been developed by IST under sponsorship by PM TRADE & DARPA

- Technology Assessments for PM TRADE investment strategy are being developed at IST.

- Evaluation of NTSC's ASTAR training system development software has been completed by IST

- Mission rehearsal technology assessment for USAF SIMSPO has been completed by IST.

- Florida High Technology/Industry Council research Studies continue at IST.

- Selective collaborative research with industry (e.g. TSI, McDonnell Douglas, IBM, Florida Power, Westinghouse) is on-going at IST

IST CONTRIBUTIONS TO SIMULATION AND MODELING

- IST knows how to interface dissimilar systems through its networking laboratory. (Successfully networked a SIMNET M-1 Tank Trainer with a Low-Cost Aviation Trainer-F16 ASAT)

- IST can populate a battlefield with entries through its networking and computer generated forces models.

- IST can allow for flexible entity behavior and a flexible human interface through its computer generated forces model.

- IST can portray the simulation through its visual laboratory.

- IST can capture human and vehicle performance data in real time for analysis.

- IST can validate single vehicle simulation models dynamics systems.

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IST DISCRIMINATORS

Institute functions as a business entity

- Responsive to customer
- Capable of multi-disciplinary efforts
- Understands the problem

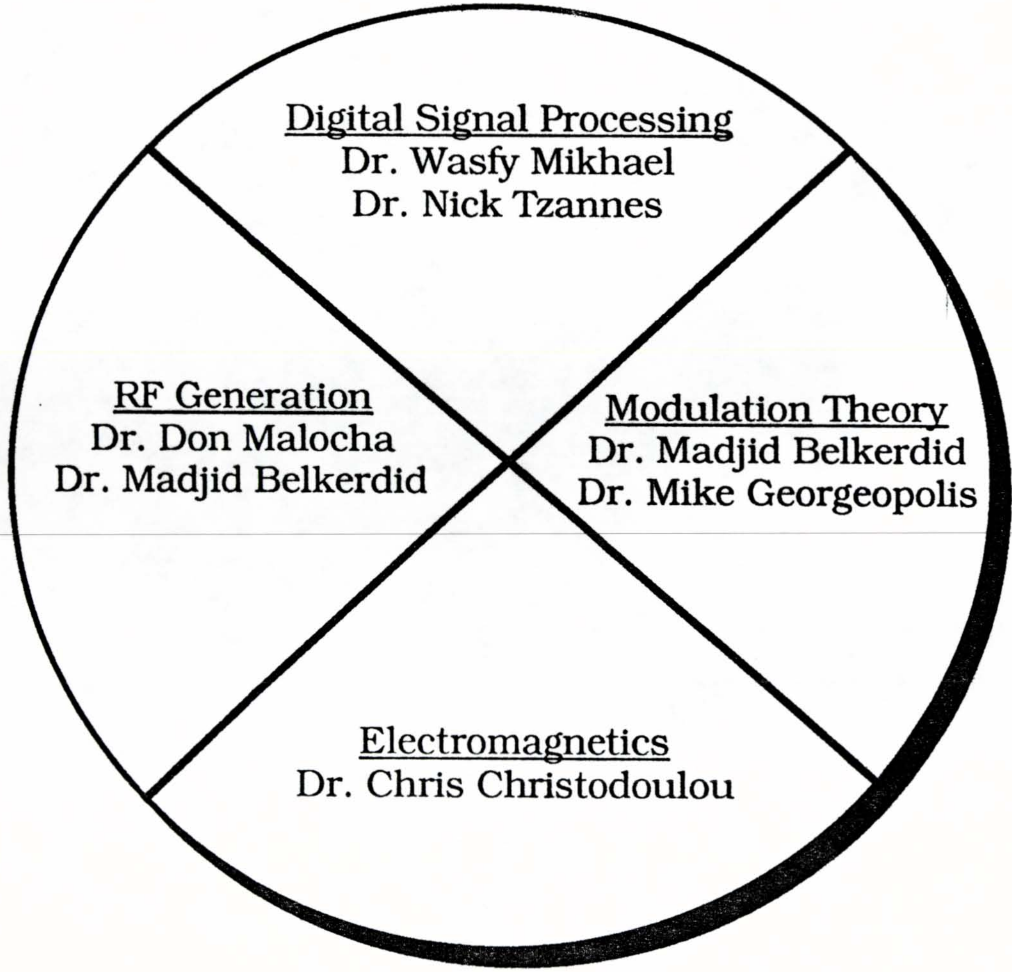
IST addresses research with results oriented approach

- Reflected in literature, proposals
- No ivory tower types in management positions

Sensitivity to programmatic, political issues

- Able to help acquisition activity with their customer
- Projects structured to fit budget constraints
- Able to speak and report in customers language

TESTS
REQUIRED ELECTRICAL ENGINEERING DISCIPLINES



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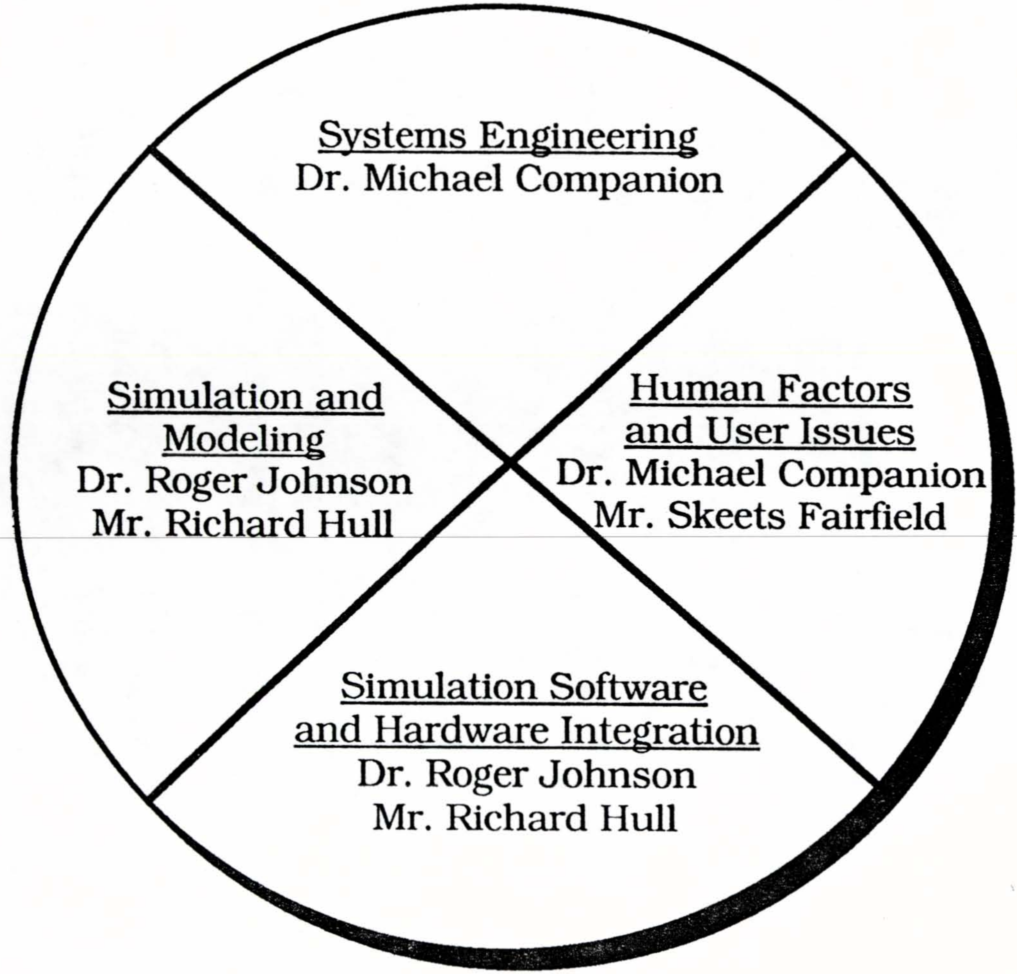
TESTS
REQUIRED SIMULATION DISCIPLINES



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UCF TESTS TALENT

NAME	DEGREE/INSTITUTION/DATE	REMARKS
Dr. Michael Companion	Ph.D. Engineering Psychology/ Man-Machine Systems New Mexico State University, 1978	Principal Investigator, Technical Lead, IST Manager, General Research, 8 Years Industry Experience
Dr. Wasfy Mikhael	Ph.D. Electrical Engineering Concordia University Canada, 1973	Principal Investigator, Research Lead, EE Tenured Professor, UCF 12 Years Industry Consulting Experience NRL Consultant, 1991
Dr. Roger Johnson	Ph.D. Electrical Engineering UCLA, 1966	TESTS Simulation Lead, IST 14 Years Industry Experience Design/Development Engineer Senior Program Manager 4600 Flight Hours In 21 Aircraft Types
Dr. Nicholas Tzannes	Ph.D. Electrical Engineering Johns Hopkins, 1966	Chairman, UCF EE Department Author, 14 EE Books 32 Years Industry Cousultant 28 Years EE Teaching Experience

0192-1729

UCF TESTS TALENT (CON'D)

NAME	DEGREE/INSTITUTION/DATE	REMARKS
Dr. Christos Christodoulou	Ph.D. Electrical Engineering North Carolina State 1985	Experience as Researcher, NASA Langley 5 Years Research/Teaching experience at NC State Antennas, Microwave Theory, EM
Dr. Donald Malocha	Ph.D. Electrical Engineering University of Illinois, 1977	Over 12 Years Experience as Industry Consultant 50 Professional Articles, 3 Patents Granted 3 Patents Filed, 2 Copyrights 1990 Florida IEEE Outstanding Service Award 1989 Florida Governors Award Outstanding Contribution 1988 Florida IEEE Outstanding Educator Award
Dr. Madjid Belkerdid	Ph.D. Electrical Engineering University of Central Florida, 1984	Expertise In RF Communications, Signal Modulation Theory Established UCF RF Laboratory Developed Several EE Courses 12 Years Industry Consulting 10 Years EE Teaching Experience Author Of 4 EE Textbooks

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LONG TERM GOAL

Enhance U.S. Economic Competitiveness

- Transfer Military Simulation & Training Technology
- Develop New Low-Cost Technology
- Improve Primary/Secondary Education
  - Primarily Math/Science
- Improve Factory Training
- Improve Vocational Training/Re-training

TESTS General Description
Program Objective

TESTS is a NAVAIRTESTCEN program to develop a prototype simulation based test tool for developmental test and evaluation of installed NGIFF avionics equipment on aircraft and ground based IFF platforms in an anechoic chamber or shielded hangar environment.

- OBJECTIVES:
  - Provide a test tool to evaluate NGIFF performance to the maximum extent possible in a controlled environment in order to maximize data collection and test repeatability, while minimizing test flight hour costs
  - Support vulnerability analysis testing
  - Enable problems to localized so that they can be fixed during the test activity
  - Provide an operational test and evaluation capability

TESTS
CONSTRAINTS ON A SIMULATION MODEL

A simulation environment can become impractical if it is unbounded. The constraints for the simulation environment should be determined based on application requirements. For the present effort several constraints are identifiable.

- The simulation environment should be scenario driven.
- The simulation test environments should parallel operational test environments to the extent feasible.
- The simulation environment should be able to operate either integrated with existing facilities or stand alone.
- The simulation environment should provide for easy transition between test phases, i.e., developmental T&E operational T&E.
- The simulation environment should be compatible with existing facilities.
- The simulation environment should make maximum use existing hardware and software/simulation capabilities.

TESTS
PROJECT OBJECTIVES

1) to determine existing baseline capabilities at NAVTRASYSCEN and NAVAIRTESTCEN applicable to the development of a tactical electronics simulation/stimulation model;

2) to determine the requirements and constraints for development of a tactical electronics simulation/stimulation model;

3) to assess the simulation technical risk issues;

4) to develop a conceptual design for TESTS

5) to conduct a feasibility assessment to ascertain that MK XV IFF TESTS can be developed, that it can achieve test objectives, and that it represents a cost-effective solution and;

6) to develop a research plan for development of TESTS

TESTS TECHNICAL TASKS

TASK 1: Conduct an Analysis of Mark XV IFF Test Objectives
TASK 2: Conduct a Survey of Existing Facilities
TASK 3: Assess the Hardware Interface Requirements for TESTS
TASK 4: Assess the Software Interface Requirements for TESTS
TASK 5: Examine Identified Technical Risk Issues Which Could Impact the Feasibility of TESTS
TASK 6: Examine the User Interface Requirements for TESTS
TASK 7: Review the MK XV Performance Criteria
TASK 8: Conduct a Feasibility Assessment to Integrate the Findings of TASKS 1 - 7
TASK 9: Compare the Available and Required Scenario Capabilites for TESTS
TASK 10: Develop a Conceptual Simulation Model Approach
TASK 11: Conduct Preliminary Studies to Refine the TESTS Design

TASK 1: ANALYSIS OF TEMP OBJECTIVES
TECHNICAL APPROACH

Task Definition:
Analysis of the MK XV Test and Evaluation Master Plan (TEMP) objectives was conducted to identify the performance requirements of TESTS.

Technical Approach:
Based upon review of

MK XV TEMP,
Navy inputs to the MK XV Combined Test Force
NAVAIRTESTCEN TEMP and IFF Test Procedures Briefing

The focus of this analysis was five primary simulation TEMP objectives identified for TESTS by the NAVAIRTESTCEN. These primary TEMP objectives for TESTS include:

Probability of Correct ID
Anti-Jam
System Capacity/Interrogation Volume
Code Validation
Split Targets

Other TEMP objectives were evaluated to determine which could benefit from TESTS as a spin-off from the capability required to meet the primary simulation objectives.

TASK 1: ANALYSIS OF MK XV TEMP OBJECTIVES
FINDINGS - SUMMARY

Findings: In addition to the five simulation objectives specified for TESTS, there are approximately a dozen other objectives that might be augmented by TESTS.

The list of objectives which could benefit from TESTS are:

Primary Simulation TEMP Objectives

- Probability of Correct ID
- Code Validation
- System Capacity/ Interrogation Volume
- Anti-Jam Capabilities
- Split Targets

Other TEMP Objectives

- Diversity Performance
- Range Resolution
- Range Accuracy
- Azimuth Accuracy
- FRUIT Rate
- Interop./Compatibility
- Maximum Range
- Minimum Range
- Azimuth Resolution
- Multipath
- Anti-Spoof
- Electromagnetic Compat.

TASK 1: ANALYSIS OF MK XV TEMP OBJECTIVES
FINDINGS - SUMMARY

- All primary and most secondary objectives should be met with a high degree of fidelity.
- These secondary objectives can be accomplished without imposing additional requirements on the design.
- The secondary objectives benefit from TESTS by extending the scope of conditions that can be tested and the increased number of repeatable data points.
- The critical issues related to the TEMP objectives are:
  - multiple platforms
  - K-15
  - system test (i.e., coupled versus uncoupled test)
- The TEMP objectives with the greatest risk are:
  System Capacity/Interrogation Volume - generation of large numbers of valid platform simulations are the most demanding technical and cost factors

TASK 1: ANALYSIS OF TEMP OBJECTIVES
ASSESSMENT OF TESTS FIDELITY

% RATING	DEFINITION
100	Perfect emulation of the real world
90	Sufficient to fully meet specification requirements
70-80	One or two minor deficiencies which may reduce the total scope of test capability, but still meet other aspects at a high level of fidelity.
60-70	General overall reduction in capability, but sufficient to conduct selected tests
40-50	Some capability in selected areas, but major weaknesses
0	No capability

TASK 1: ANALYSIS OF TEMP OBJECTIVES
PROBABILITY OF CORRECT ID

Definition: The system single scan and multiple scan probability of Friend Identification and Probability of Enemy Acceptance.

Issues:

a) Normally requires a dense environment.

b) Must be conducted for embedded MK XII modes and MK XV formats both individually and in interlaced presentations.

c) Effects of split targets, multipath, and false detection

Discussion: The probability of correct ID is affected by the target data processors algorithm used to predict the target location. Any algorithm will have to tradeoff location accuracy, azimuth resolution and probability of friend declaration and enemy acceptance. Probability of correct ID then becomes a part or subset of the system capacity evaluation.

Estimated Fidelity: It is estimated that the fidelity of testing this TEMP objective will be 90 %.

TASK 1: ANALYSIS OF TEMP OBJECTIVES
ANTI-JAM CAPABILITIES

Definition: The amount of performance degradation under various Electronic Counter Measures (ECM) environments.

Issues:

a) Threat systems include: airborne jammers (Big Crow/Little Crow jammer aircraft), heliborne jammers, ground based jammers.

b) Interacts with all other performance parameters.

Discussion: There is a need to investigate the immunity of the receiver from hostile ECM signals. This will be a function of the processing gain, the ECM signals, other multiple channels, system dynamic range, and the receiver sensitivity. The ability to meet this objective will be determined by cost and TESTS configuration.

Estimated Fidelity: Test fidelity for this objective is dependent upon TESTS configuration. In the stand alone benign configuration the test fidelity is 0 %. In the stand alone configuration with external jamming subsystem, fidelity will range from 70 - 90 % depending upon the capabilities of the selected jamming system.

TASK 1: ANALYSIS OF TEMP OBJECTIVES
SYSTEM CAPACITY/INTERROGATION VOLUME

Definition: The ability to identify friendly targets and adequately locate them in range/azimuth to correlate/associate with the primary sensor in an environment of increasing interrogation rates.

Issues:

a) The severity of signal overlapping to degrade system

b) The number of overlapping signals to degrade the system

c) System performance with overlapped waveforms

d) In-beam: effects of overlapped waveforms, including FRUIT rate.

e) Number of platforms required in real time simulation.

TASK 1: ANALYSIS OF TEMP OBJECTIVES
SYSTEM CAPACITY/INTERROGATION VOLUME

Discussion:	This is going to be the most difficult item to fully simulate since it is a function of all parameters and a function of how the parameters interact. Simulation of large numbers of platforms in high fidelity and real time appears to be the major technical driver and cost for TESTS. The proposed approach minimizes, though it does not eliminate, the technical risk and cost to accomplish this objective.
Estimated Fidelity:	It is estimated that the fidelity of testing this TEMP objective will be 90 %. When tested in support of other objectives, the fidelity will be determined by the objective with the lowest fidelity level.

TASK 1: ANALYSIS OF TEMP OBJECTIVES
CODE VALIDATION

Definition: Percentage of proper code validations per interrogation, a ratio of times the interrogator correctly decodes the reply over the number of interrogations during the dwell on a target transponder.

Issues:

Interrogator Tests -

a) Probability of friend rejection

b) Probability of enemy acceptance

c) Effects of split targets, multipath, and false detection

Transponder Tests -

d) Garbling and synchronization of received signals

e) Code information reliability

TASK 1: ANALYSIS OF TEMP OBJECTIVES
CODE VALIDATION

Discussion: The probability of correct ID is affected by the target data processors algorithm used to predict the target location. Any algorithm will have to tradeoff location accuracy, azimuth resolution and probability of friend declaration and enemy acceptance. Code validation then becomes a part or subset of the system capacity evaluation. This is going to be a function of the number of signals, fading, multipath, etc. Ultimately, it will depend upon the simulation accuracy in software and/or hardware of the code generation.

Estimated Fidelity: It is estimated that the fidelity of testing this TEMP objective will be 90 %.

TASK 1: ANALYSIS OF TEMP OBJECTIVES
SPLIT TARGETS

Definition: Percentage of targets declared as multiple targets per scan.

Issues:

a) The conditions creating target splits.

b) Effects of split targets during detection on code validation and probability of correct ID.

c) Effects of multipath and false detections.

d) Probability of friend rejection.

e) Probability of enemy acceptance.

Discussion: This is the percentage of transponder responses per interrogation interval which appear to originate from two or more azimuths. The primary measurement is in a benign environment. It must be assessed in conjunction with other position characteristics including target correlation, range accuracy and resolution, azimuth accuracy and resolution, and beam sharpening.

Estimated Fidelity: It is estimated that the fidelity of testing this TEMP objective will be 90 %.

TASK 1 ANALYSIS OF TEMP OBJECTIVES
DIVERSITY PERFORMANCE

Definition: The capability of the transponder algorithms to determine through which antenna the reply should be sent. The reply is sent through the antenna receiving the strongest and/or first interrogation pulse.

Issues:

a) The performance of the MK XV must be evaluated in various interrogator - transponder geometries.

b) Must be evaluated in conjunction with tests for maximum range, range resolution, minimum range, multipath and azimuth resolution.

Discussion: The transponder diversity decision is compared to the calculated decision based on aircraft pitch, roll, heading and platform location. Hence, the limiting factor on this objective is the platform position resolution in SWEG.

Estimated Fidelity: It is estimated that the fidelity of testing this TEMP objective will be 90 %. It is possible that SWEG limitations or platform specificity may reduce fidelity to 70-80 %, but this can not be determined at this time.

TASK 1 ANALYSIS OF TEMP OBJECTIVES
MAXIMUM RANGE

Definition: The maximum range in nautical miles at which consistent ID is lost.

Issues:

a) The maximum range for each combination of variables without a potential false max range created by hitting the line-of-sight limit.

b) Maximum range must be equal to or greater than the platform's primary sensor capabilities.

Discussion: This will be a function of environmental conditions, ECM, processing gain, sensitivity, multiple channels, and jamming. Antenna gain, pattern and channels need to be considered. TESTS is projected to incorporate the factors required to test this objective.

Estimated Fidelity: It is estimated that the fidelity of testing this TEMP objective will be 90 %.

TASK 1 ANALYSIS OF TEMP OBJECTIVES
RANGE RESOLUTION

Definition:	The minimum range separation of two targets where they are still distinguishable.
Issues:	a) Range separation is measured in feet.
	b) Baseline established in a benign environment.
Discussion:	This objective will be a function of the environment, processing gain, and sensitivity. Antenna resolution and timing accuracy are very important. A limiting factor on this objective is the positional resolution in SWEG.
Estimated Fidelity:	It is estimated that the fidelity of testing this TEMP objective will be 90 %. It is possible that SWEG limitations may reduce fidelity to 70-80 %, but this can not be determined at this time.

TASK 1 ANALYSIS OF TEMP OBJECTIVES
MINIMUM RANGE

Definition: The minimum range at which consistent ID is lost.

Issues:

a) The minimum range for each combination of variables in a benign or jamming environment.

Discussion: This objective will be a function of the environment, ECM, processing gain, sensitivity, system dynamic range, and jammers. This objective will push the TESTS signal delay/time to reply specification. TESTS should be able to reply to an interrogation as fast or faster than in the real world.

Estimated Fidelity: It is estimated that the fidelity of testing this TEMP objective will be 90 %.

TASK 1 ANALYSIS OF TEMP OBJECTIVES
RANGE ACCURACY

Definition: Accuracy of target range over entire range of system.

Issues: a) Target range measured in feet.

Discussion: This is the magnitude of error in the interrogator's estimation of the transponder's slant range. This should be a function of the processing gain and processing/transmission delays. Timing accuracy within TESTS will be very important for this objective. Must be assessed in conjunction with other position characteristics including target correlation, range resolution, azimuth accuracy and resolution, and beam sharpening. A limiting factor on this objective is the positional resolution in SWEG.

Estimated Fidelity: It is estimated that the fidelity of testing this TEMP objective will be 90 %. It is possible that SWEG limitations may reduce fidelity to 70-80 %, but this can not be determined at this time.

TASK 1 ANALYSIS OF TEMP OBJECTIVES
AZIMUTH RESOLUTION

Definition: The minimum azimuth separation of two distinguishable targets.

Issues:

a) Measured in feet and expressed as a percentage of the host systems antenna beam width.

b) Determine the azimuth resolution in a benign environment.

c) Due to the potential impact of propagation effects, the most critical test case is a near land scenario.

TASK 1 ANALYSIS OF TEMP OBJECTIVES
AZIMUTH RESOLUTION

Discussion: Must be assessed in conjunction with other position characteristics including target correlation, range accuracy and resolution, azimuth accuracy and beam sharpening. This is primarily driven by the geometry of the relationship between the Interrogator and the Transponder platforms and the fidelity selected in the subsystems (i.e., resolutions of antenna pattern, propagation effects, etc.) of the simulator. The limiting factor on this objective is the positional resolution in SWEG.

Estimated Fidelity: It is estimated that the fidelity of testing this TEMP objective will be 90 %. It is possible that SWEG limitations may reduce fidelity to 70-80 %, but this can not be determined at this time.

TASK 1 ANALYSIS OF TEMP OBJECTIVES
AZIMUTH ACCURACY

Definition: Evaluate accuracy of IFF reported target azimuth over the entire system range.

Issues: a) Target azimuthal position measured in feet. Flight test assessment is limited by truth data accuracy at short range, whereas simulation testing can extend this assessment over the entire range of the system.

Discussion: Must be assessed in conjunction with other position characteristics including target correlation, range accuracy and resolution, azimuth resolution and beam sharpening. The limiting factor on this objective is the positional resolution in SWEG.

Estimated Fidelity: It is estimated that the fidelity of testing this TEMP objective will be 90 %. It is possible that SWEG limitations may reduce fidelity to 70-80 %, but this can not be determined at this time.

TASK 1: ANALYSIS OF TEMP OBJECTIVES
MULTIPATH

Definition: Evaluate the impacts to system performance as a result of multipath effects.

Issues:

a) Altitude combinations for Interrogators and Transponders

b) Over land, over water and combined effects.

c) Atmospheric reflections

d) Comparison of system performance in non-multipath conditions with multipath conditions.

TASK 1: ANALYSIS OF TEMP OBJECTIVES
MULTIPATH

Discussions: This is going to be a function of any type of multipath and fading problems. The multipath looks very much like another channel; therefore, it can be handled via superposition. The inclusion of multipath and other propagation effects will be one of the major contributions of TESTS and the primary feature which distinguishes it from a black box test set.

Estimated Fidelity: It is estimated that the fidelity of testing this TEMP objective will be 90 %. Multipath fidelity is a selectable tradeoff with system capacity.

TASK 1 ANALYSIS OF TEMP OBJECTIVES
FRUIT RATE

Definition: Replies received by an interrogator which were intended for another interrogator.

Issues:

a) System performance degradation in a dense, non-ECM environment.

b) Effects of FRUIT on other parameters

Discussion: FRUIT is the result of the omnidirectional characteristics of the transponder which leads to the reception of replies meant for other interrogators. This objective is directed toward the embedded MK XII within the MK XV. The large number of simulated valid replies required for this objective is a primary design issue for TESTS.

Estimated Fidelity: It is estimated that the fidelity of testing this TEMP objective will be 90 %.

TASK 1 ANALYSIS OF TEMP OBJECTIVES

ANTI-SPOOF

Definition:	Resistance to exploitation of spoofing.
Issues:	The resistance to spoofing by calculating probability of enemy acceptance in the presence of a spoofer.
Discussion:	This TEMP objective is similar to anti-jam. The configuration of TESTS will provide the capability to accommodate spoofing. The development of spoofing capability is a government responsibility and TESTS will be designed to accommodate that capability as available. TESTS itself could be used to simulate a spoofer which could be used to exercise this feature.
Estimated Fidelity:	Dependent upon government capability. Current assets for anti-spoof limit fidelity of this test to 70 - 80 %. However, new planned anti-spoof capabilities mentioned during site visits at NAVAIRTESTCEN suggest that this fidelity level could approach 90 % when the new capability becomes available.

TASK 1 ANALYSIS OF TEMP OBJECTIVES
CRYPTO

Definition:	The adequacy of the crypto components for maintaining system integrity and crypto stability and accuracy.
Issues:	a) TOD synchronization b) Cryptographic processing capacity and timing compatibility
Discussion:	While the impact of the crypto unit on other TEMP objectives must be considered, the specific assessment of the crypto objective is a "black box" test that can not be addressed by TESTS. However, the simulation of the crypto and its timing features is a challenging design feature.
Estimated Fidelity:	Not applicable to testing with TESTS

TASK 1 ANALYSIS OF TEMP OBJECTIVES
INTEROPERABILITY AND COMPATIBILITY

Definition: The ability of the MK XV IFF system to operate within the civil ATC, current military IFF systems, and the NIS.

Issues:

a) Embedded MK XII IFF vs. current US and NATO, civil ATC and military IFF systems

b) Integral Mode S vs. emerging civil ATC Mode S system, MK XV IFF (both radar Mode and TDF) vs. NIS as developed by participating countries.

Discussion: TESTS could be used directly to assess compatibility and interoperability with other related systems. TESTS could aid in assessing this TEMP objective, but should not be the primary test method for this objective.

Estimated Fidelity: It is estimated that the fidelity of testing this TEMP objective will be 90 %. This could be reduced dependent upon the interface characteristics of other systems but the impact should be minor.

TASK 1· ANALYSIS OF TEMP OBJECTIVES
ELECTROMAGNETIC COMPATIBILITY

Definition: The ability to operate simultaneously with other systems within the platform without degradation due to Electromagnetic Interference (EMI).

Issues:

a) Compatibility - Verify the compatibility of the MK XV IFF as installed and operated within the host platform without presenting an unacceptable interference to or receiving and unacceptable interference from any system within the environment.

b) Determine the ability of the MK XV system to operate at the inter element, inter platform and intra platform levels

c) Aircraft carrier suitability - evaluate the suitability of MK XV IFF to the environments encountered by aircraft carrier-based platforms.

TASK 1 ANALYSIS OF TEMP OBJECTIVES
ELECTROMAGNETIC COMPATIBILITY

Discussion: This is a problem due to the fact that the MK XV will not be in an isolated environment but rather running in an environment where there are other communications systems with many signals and signal levels in the immediate vicinity of the receiver. TESTS could be used to exercise the system under test. TESTS should not be the primary test method, but could augment the test procedure.

Estimated Fidelity: Not directly applicable (see discussion), but should be at least 60 - 70 %.

TASK 1 ANALYSIS OF TEMP OBJECTIVES
CONCLUSIONS - 1

- Of the five primary TEMP objectives that TESTS was formulated to address, it appears that all can be technically met.
- System capacity/interrogation volume drive the TESTS design because of the number of platforms required.
- The ability to meet the anti-jam objective will require additional capability in a stand alone configuration, however, off-the-shelf systems are available which provide that capability.
- While it is not possible to achieve 100% fidelity, i.e., perfect emulation of the real world and all its variations, in the TESTS design, it appears that all primary TEMP objectives for TESTS can be achieved with high levels of fidelity.

TASK 1 ANALYSIS OF TEMP OBJECTIVES
CONCLUSION - 2

In addition:

- TESTS should be able to augment test and evaluation of a broad range of secondary TEMP objectives. The basic capability required for these secondary objectives is a subset of the parameters which must be included in TESTS to achieve acceptable levels of fidelity on the primary TESTS TEMP objectives.

The key is selective levels of fidelity.

- Selective fidelity emphasizes choosing the lowest level of fidelity which provides realistic test conditions and appropriate system performance impact.

- Different levels of fidelity may be selected for every factor in the design, i.e., high levels of fidelity are chosen for critical factors and lower levels of fidelity are chosen for those factors which impose little impact on system performance.

TASK 2: SURVEY OF EXISTING FACILITIES
DEFINITION AND APPROACH

Task Definition: Review existing capabilities at NAVAIRTESTCEN, NAVTRASYSCEN and other government/contractor facilities to determine applicability and compatibility of current hardware and software resources with TESTS.

Technical Approach: On site visits were conducted at NAVAIRTESTCEN, NAVTRASYSCEN, NRL, NESEA, Kirtland AFB, and Bendix. The on site visits included tours and briefings by government personnel covering current capabilites and procedures. Approximately 20 laboratory tours and briefings were received during this task.

TASK 2 SURVEY OF EXISTING FACILITIES
FINDINGS - NAVTRASYSCEN

- They have a software configuration management system which could be used for TESTS
- Secured laboratories are accessible as necessary for later stages of TESTS development
- Can provide Ada development guidance based on recent successful development efforts
- Based on recent experience recommended CASE tools from MARK V Systems for TESTS software development
- Can provide access to NAVTRASYSCEN developed Electronic Warfare Database which provides a valuable source of emitter data. Incorporates the Naval Emitter Reference File (NERF) and Naval Warfare Tactical Database (NWTDB).

TASK 2 SURVEY OF EXISTING FACILITIES
FINDINGS - NAVAIRTESTCEN ACETEF

EWISTL

- Provides initial baseline threat simulation/ stimulation of EW systems which can be used with TESTS
- Contains ETEWES (Enhanced Tactical Electronic Warfare Environment Simulator) hardware for generation of friendly RWR signals and WAVETEK MEWES hardware for generation of red signals
- Can not generate valid spread spectrum signals suitable for TESTS

EMEGS

- EMEGS currently owns an expandable version of the CAL Tactical Signal Simulator (TASS). This is a compact, multi-purpose, electronic combat environment simulator which could provide a threat environment for TESTS in a stand alone (non-ACETEF) configuration.
    - simple search radars to complex multi-mode radars on moving platforms
    - up to 16 simultaneous complex emitters
    - 0.5 to 18 GHz band
    - simulates three-dimensional platform in motion in real time

TASK 2 SURVEY OF EXISTING FACILITIES
FINDINGS - NAVAIRTESTCEN ACETEF

CNIL

- Will provide the primary interface for TESTS into ACETEF
- Planned hardware procurements for CNIL may include equipment which could be used to calibrate TESTS thereby reducing duplication of hardware.

OCC

- Provides SWEG

TASK 2 SURVEY OF EXISTING FACILITIES
FINDINGS - OTHER NAVAIRTESTCEN LABORATORIES

IFF Data Center

- Computer resources include Vax Mini mainframes with SUN workstations
- Data formats and protocols for IFF Data Center will determine structure for TESTS data capture
- Human Computer Interface guidelines developed for the data center will be used as guidance

ATLAS

- Provides the capability to develop antenna pattern data from aircraft in flight which can be utilized in TESTS V&V
- Has three dimensional empirical antenna pattern data on many platforms which can be used as a data source for TESTS
- Has smooth surface multipath model which may be useful as a reference baseline

NIFFTE

- Has MK XII IFF hardware that could be used to evaluate and demonstrate early versions of TESTS

CTR

- Source of flight test data for TESTS V&V

TASK 2: SURVEY OF EXISTING FACILITIES
BENDIX CORPORATION

- Under AF contract MK XV, Bendix built 10 sets of subsystem elements of test equipment to be used for MK XV checkout and calibration (using modified ADM equipment designs)... One set was assembled before contract termination.

- Subsystems for transponder and/or interrogator test sets were mounted on mobile carts and consisted of -

  (A) Digital interface drawer
  (B) Density signal generator drawer (2 channels)
  (C) D-Band RF drawer
  (D) Radar Mode RF drawer
  (E) COMSEC drawer
  (F) Power supply

TASK 2 SURVEY OF EXISTING FACILITIES
FINDINGS - OTHER RESOURCES

<u>ELECTROMAGNETIC COMPATIBILITY ANALYSIS CENTER</u>

- ECAC-TTP, Release 3: ECM program with "Terrain Integrated Rough Earth Model"

<u>ROME DEVELOPMENT CENTER</u>

- GEMACS: Antenna pattern and near field effects

<u>MARK V SYSTEMS</u>

- Objectmaker: CASE software development environment
- C Language Module: C autocode generation
- Ada Language Module: Ada autocode generation

<u>OTHER PROGRAMS</u>

- BOSS
- STRIPES
- INAC-3

TASK 2 SURVEY OF EXISTING FACILITIES
CONCLUSIONS

- The survey identified a number of existing resources which will reduce technical risk and cost in the development of TESTS.
- These resources could offer benefits in almost all aspects of TESTS.

TESTS ITEM	POTENTIAL % COST REDUCTION USING EXISTING CAPABILITY
SIMULATION	30%
SIGNAL GENERATION	30%
SCENARIO CONTROL	90%
TACTICAL ENVIRONMENT	90%
CALIBRATION	90%
SOFTWARE DEVELOPMENT	50%
RESEARCH	60%

TASK 3 HARDWARE INTERFACE ASSESSMENT
DEFINITION AND APPROACH

Task Definition: An initial assessment and definition of the hardware interface to integrate/interface TESTS to ACETEF and other existing resources. Also determine development environment for TESTS.

Technical Approach: Analysis of data gathered during survey and interface specifications.

TASK 3 HARDWARE INTERFACE ASSESSMENT

Hardware Interface Requirements for TESTS

Findings and Conclusions:

The hardware interface with ACETEF is straight forward. Current hardware uses industry standard interfaces.

Current RF generation equipment at NAVAIRTESTCEN does not support RF generation of spread spectrum signals. This capability will be developed as part of TESTS. However, jammer capabilities within EWISTL and EMEGS can be easily interfaced to TESTS.

The hardware development platform selected for TESTS is a federated (i.e., multiple, networked computers) configuration based on SUN workstations with Skycomputer accelerator modules. This platform is compatible with existing computer resources at NAVAIRTESTCEN and provides a cost-effective flexible and easily expandable configuration.

TASK 4 SOFTWARE INTERFACE ASSESSMENT
DEFINITION AND APPROACH

Task Definition: Assess the software interface to integrate/interface TESTS to ACETEF and other facilities. Also develop a recommendation for the TESTS software development environment.

Technical Approach: Review of data gathered during survey and review of applicable interface documents. Discussions were also conducted with NAVAIRTESTCEN and NAVTRASYSCEN software personnel to solicit inputs to determine requirements.

TASK 4 SOFTWARE INTERFACE ASSESSMENT
Software Interface Requirements for TESTS

Findings and Conclusions:

Format for TESTS data capture will be dictated by IFF Data Center

SWEG/ACETEF protocols are straight forward and do not pose design drivers.

Current software in ACETEF and related facilities are a mixture of FORTRAN, C and Ada. The trend is toward Ada and C as new programs are developed or existing programs are updated.

TASK 5: TECHNICAL ISSUES ASSESSMENT
DEFINITION AND APPROACH

Task Definition: Assessment of technical risk issues identified by government personnel related to the development of TESTS. Also, technical objectives for TESTS were examined.

Technical Approach: Analysis of data gathered during site surveys, analysis of technical specifications for MK XV, discussions with key government personnel, analytic studies using BOSS and custom computer analysis programs, literature reviews, and consideration of ways to minimize or eliminate issue through the conceptual design of TESTS. Six technical briefings by government personnel were recieved in support of this task.

TASK 5 TECHNICAL RISK ISSUES
OVERVIEW

ASSESSMENT OF TECHNICAL ISSUES

- IST/EE team conducted an in depth assessment of the technical requirements for TESTS.
- The EE Department took the lead in examining technical risk issues regarding signal processing requirements for TESTS and the potential for modeling various propagation effects.
- IST took the lead in the development of the TESTS conceptual design and the procedures that will be followed during TESTS development and implementation.
- A joint effort between the two groups was pursued in the analysis of signal simulation approaches and the development of signal generation concepts.

TASK 5 TECHNICAL RISK ISSUES
OVERVIEW 2

Ten Specific Technical Risk Issues

- MK XV Time Dependent Formats
- Rapidly Changing Masking Functions
- COMSEC Validity Interval
- MK XV IFF Radar Mode
- RF Generation of Spread Spectrum Signals
- RF Generation of Multiple Spread Spectrum Signals
- Simulation of Multipath Propagation Effects
- Reception of Processing of Time Dependent Formats
- Near Field Effects
- Modeling of Antenna Pattern Effects

TASK 5 TECHNICAL RISK ISSUES
MK XV TIME DEPENDENT FORMATS

Problem Definition.

- The use of time dependent modulation formats in a communications system can be thought of as using modulation systems whose parameters vary with time.

Method of Investigation.

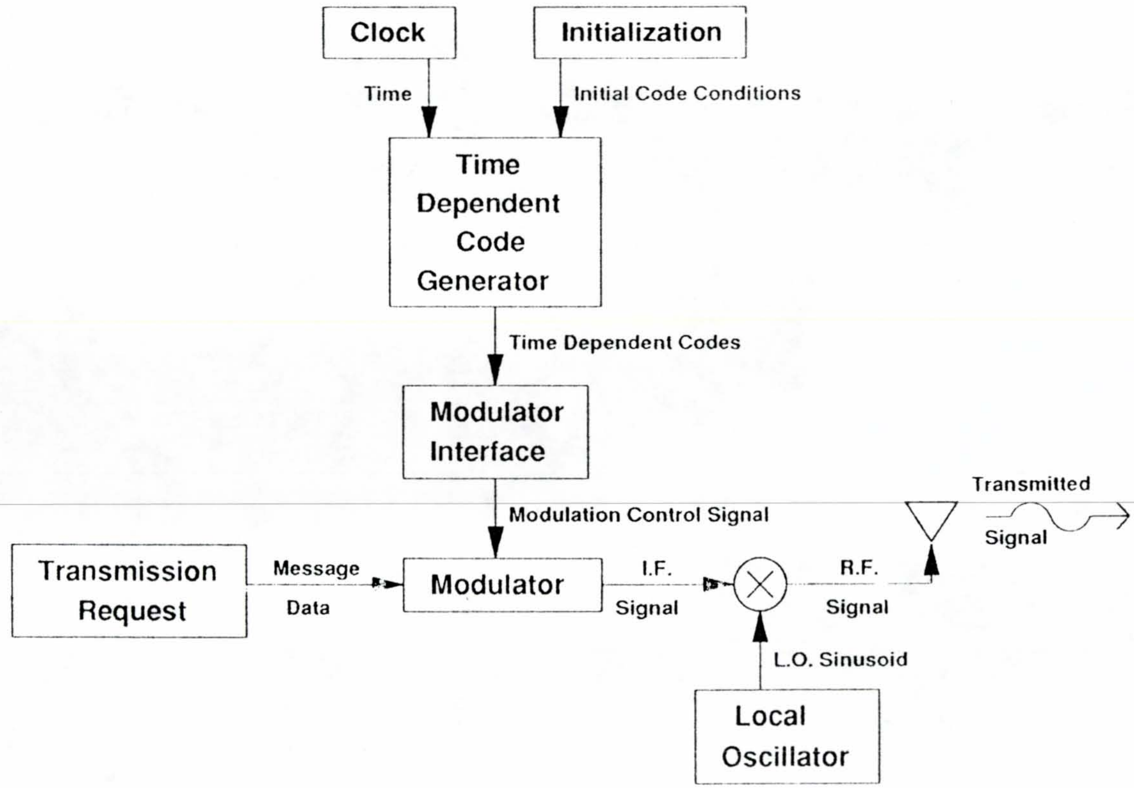
- Analysis tools were applied to various modulation schemes for spread spectrum applications.

TASK 5 TECHNICAL RISK ISSUES
MK XV TIME DEPENDENT FORMATS (cont.)

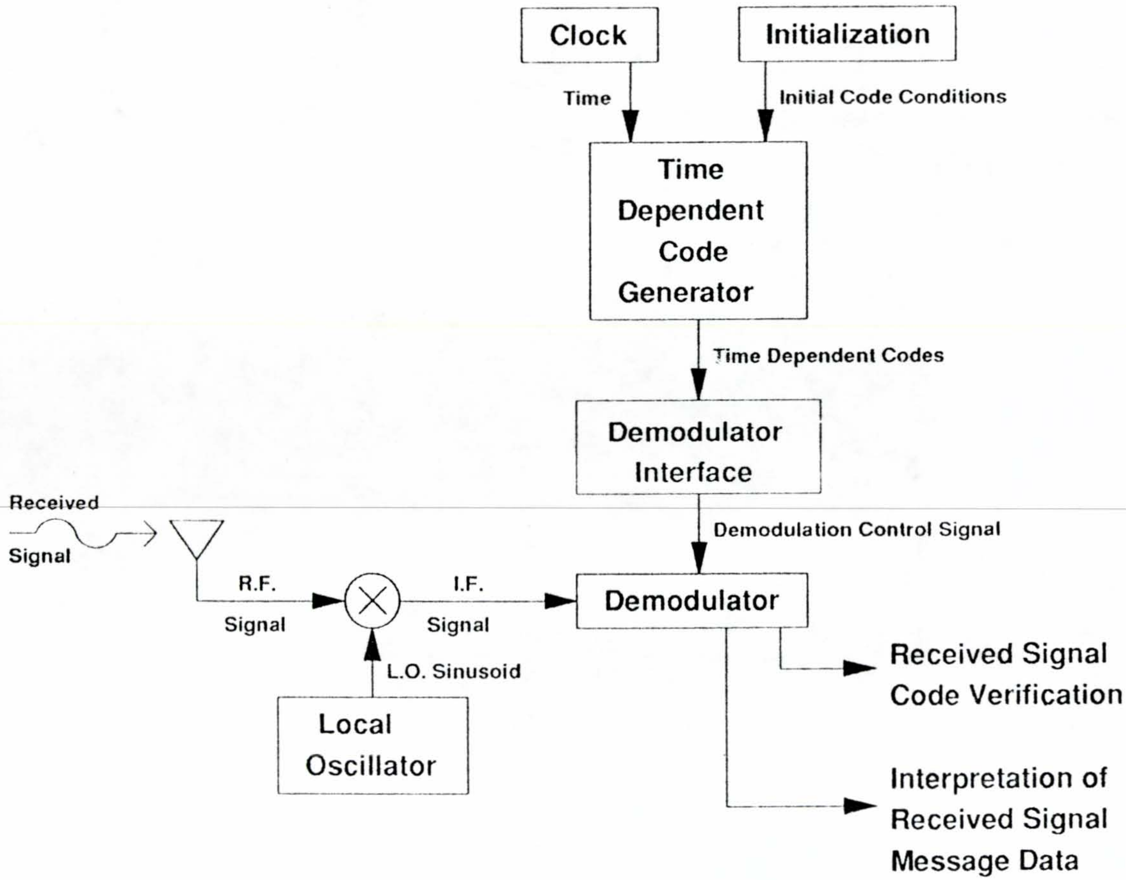
Findings.

- The modulation generates signals in time as a function of both the time varying message data and the time dependent modulation control signal.
- The time dependent control signal is generated through the interpretation of time dependent code sequences which are, in turn, generated from a time dependent code generator.
- These fixed field, random (but known) PN sequences or formats are made time dependent.
- Synchronization depends on the fact that the time dependent code generator of each transmitter and receiver is using code generation algorithms that are known to the cooperating communication systems.

TASK 5 TECHNICAL RISK ISSUES
BLOCK DIAGRAM OF TRANSMITTER EMPLOYING TDMF



TASK 5 TECHNICAL RISK ISSUES
BLOCK DIAGRAM OF RECEIVER EMPLOYING TDMF



TASK 5 TECHNICAL RISK ISSUES
MK XV TIME DEPENDENT FORMATS (cont.)

Conclusions.

- The simulator computer can synthesize a fixed field of PN sequences and transmit it to the SUT, as well as other friendly emitters.
- The spreading or despreading process is therefore controlled by masking (in real-time) the coefficients of the primitive polynomial with the PN sequence.
- This method of simulator implementation would provide early testing of SUT's without the necessity of using the KI-15 equipment.

TASK 5 TECHNICAL RISK ISSUES
RAPIDLY CHANGING MASKING FUNCTIONS

Problem Definition.

- Masking functions are used in the the MK XV IFF System. It is implemented by merging two binary fields (using basic instruction set commands).

Method of Investigation.

- The technique of using masking functions is common to digital logic instruction. Methods were surveyed to select appropriate techniques to apply.

TASK 5 TECHNICAL RISK ISSUES
RAPIDLY CHANGING MASKING FUNCTIONS (cont.)

Findings.

- The spreading sequence is particularized by taking the complement of an "EXCLUSIVE OR" command, bit by bit, across the field of PN control sequences and the field of coefficients of the primitive polynomials for each change in time.
- This masking operation is fast enough to implement changing masking functions every millisecond if necessary.

TASK 5 TECHNICAL RISK ISSUES
RAPIDLY CHANGING MASKING FUNCTIONS (cont.)

Conclusions.

- Time dependent masking will be implemented in the simulator tool.
- Use and synchronization is compatible to the mechanization described for the TDF discussion.
- Use of the Bendix waveform generation equipment would use masking techniques (already implemented) for conditioning the waveform through all of the IFF MODES of operation.

TASK 5 TECHNICAL RISK ISSUES
COMSEC VALIDITY INTERVAL

Problem Definition.

- The COMSEC validity interval changes at a rapid rate in the MK XV/K-15 system.
- MK XV system performance is totally dependent upon the validity of the COMSEC interval.
- COMSEC validity interval is not synchronized between TESTS and the SUT.
- System errors would be a function of the timing desynchronization.

TASK 5 TECHNICAL RISK ISSUES
COMSEC VALIDITY INTERVAL

Method of Investigation.

- Examination of specification documents, briefings and discussions with personnel from the Naval Research Laboratory (NRL) and NAVAIRTESTCEN.
- Analysis of the data within the context of the TESTS design.

Findings.

- Driving both TESTS and the SUT from the same time source will ensure proper synchronization.

Conclusions.

- The synchronization requirements for the COMSEC interval in TESTS can be achieved by linking both TESTS and the K-15 of the SUT to a common source.
- Close coordination with the NSA to select the most acceptable and technically feasible approach.

TASK 5 TECHNICAL RISK ISSUES
MK XV IFF RADAR MODE

Problem Definition.

- The simulation tool will be required to stimulate radar mode transponders only.
- The differences in the MK XV IFF RMFE waveform processing must be analyzed and related to the requirements for the Interrogator Simulator Tool.

Method of Investigation.

- The particulars of the IFF RMFE specifications were analyzed with respect to differences in waveform format, generation, and modulation.

TASK 5 TECHNICAL RISK ISSUES
MK XV IFF RADAR MODE (cont.)

Findings.

- The modulation/carrier frequency for the IFF RMFE are at X and S-Band vs L-Band for the other IFF modes.
- The waveform format and processing functions is different than the format used in the L-Band modulation protocols.
- A separate processing channel must be used to satisfy the RMFE Interrogator Simulator Tool (IST) requirement.

TASK 5 TECHNICAL RISK ISSUES
MK XV IFF RADAR MODE (cont.)

Conclusions.

- Implementation of IFF-RMFE is accomplished by modeling the RMFE channel to satisfy the processing protocol.
- To provide for carrier frequency modulation at X-Band and S-Band.
- Use of the Bendix Test equipment RMFE waveform and modulation equipment would dramatically shorten this task.

TASK 5 TECHNICAL RISK ISSUES
RF GENERATION OF SPREAD SPECTRUM SIGNALS

Problem Definition.

- The MK XV IFF system utilizes spread spectrum signals to enhance communication performance and security.
- Spread spectrum signals severely limit the waveform manipulation.
- Enormous processing requirements are associated with performing convolutions and correlations on large data sets in real time.

TASK 5 TECHNICAL RISK ISSUES
RF GENERATION OF SPREAD SPECTRUM SIGNALS

Method of Investigation.

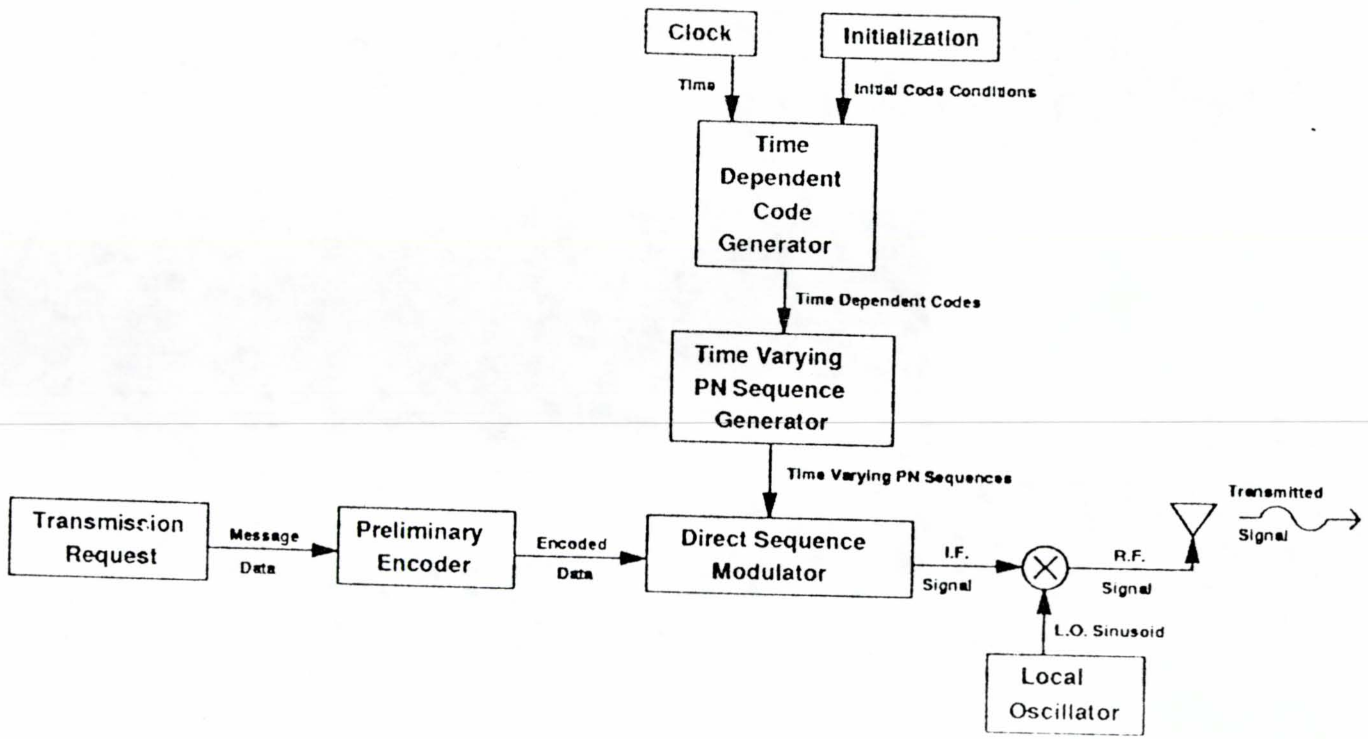
- The two major techniques investigated were Direct Sequence (DS) and Frequency Hopping (FH).
- The impact of utilizing Time Dependent Formats in a spread spectrum communication system was studied.
- These studies provide the mathematical basis for understanding and modeling spread spectrum communication signals.

TASK 5 TECHNICAL RISK ISSUES
RF GENERATION OF SPREAD SPECTRUM SIGNALS

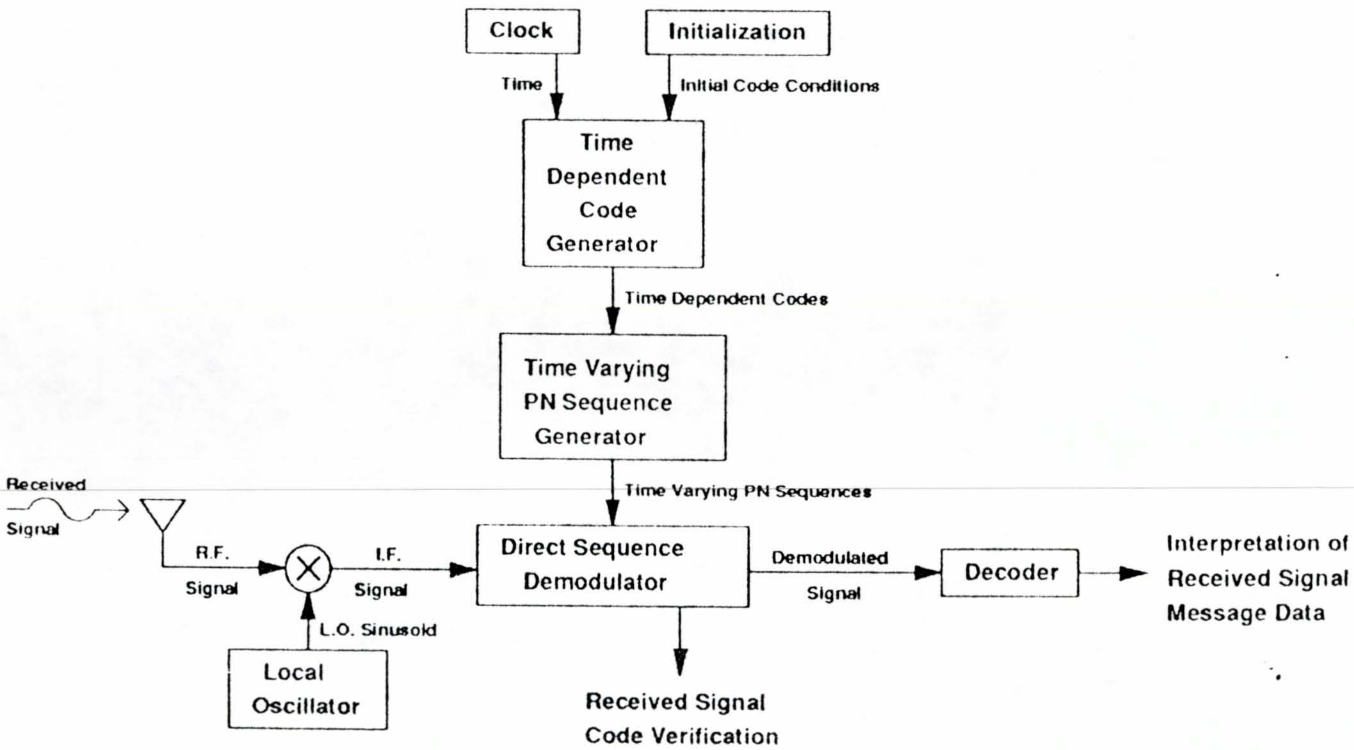
Findings.

- Spreading information in the frequency domain inherently requires shrinking of pulse widths, called chips, in the time domain.
- The high chip rates associated with spread spectrum signals of interest would require enormous processing speeds.
- Computer simulation of real time spread spectrum systems will typically require giga-flop processing speeds, while hardware implementations require less than 100 MHz clock rates.

TASK 5 TECHNICAL RISK ISSUES
TRANSMITTER FOR A DIRECT SEQUENCE SPREAD SPECTRUM



TASK 5 TECHNICAL RISK ISSUES
RECEIVER FOR A DIRECT SEQUENCE SPREAD SPECTRUM



TASK 5 TECHNICAL RISK ISSUES
RF GENERATION OF SPREAD SPECTRUM SIGNALS

Conclusions.

- The recommended implementation of a TESTS system requires the use of hardware components to perform the actual spreading and despreading operations.
- The TESTS host computer will manipulate IFF messages at baseband information levels, and communicate such information to the TESTS hardware signal generation devices.

TASK 5 TECHNICAL RISK ISSUES
RF GENERATION OF MULTIPLE SPREAD SPECTRUM SIGNALS

Problem Definition.

- MK XV TEMP Objectives require the testing of the IFF system in realistic scenarios many additional transponders and interrogators will be operating simultaneously.
- Interrogation rates on the order of several thousand per second.
- Reply rates on the order of 30 thousand per second.
- These rates stress the computational capacity of the TESTS host computer.
- Require that multiple RF signal generators be incorporated in order to realistically simulate a high density signal environment.

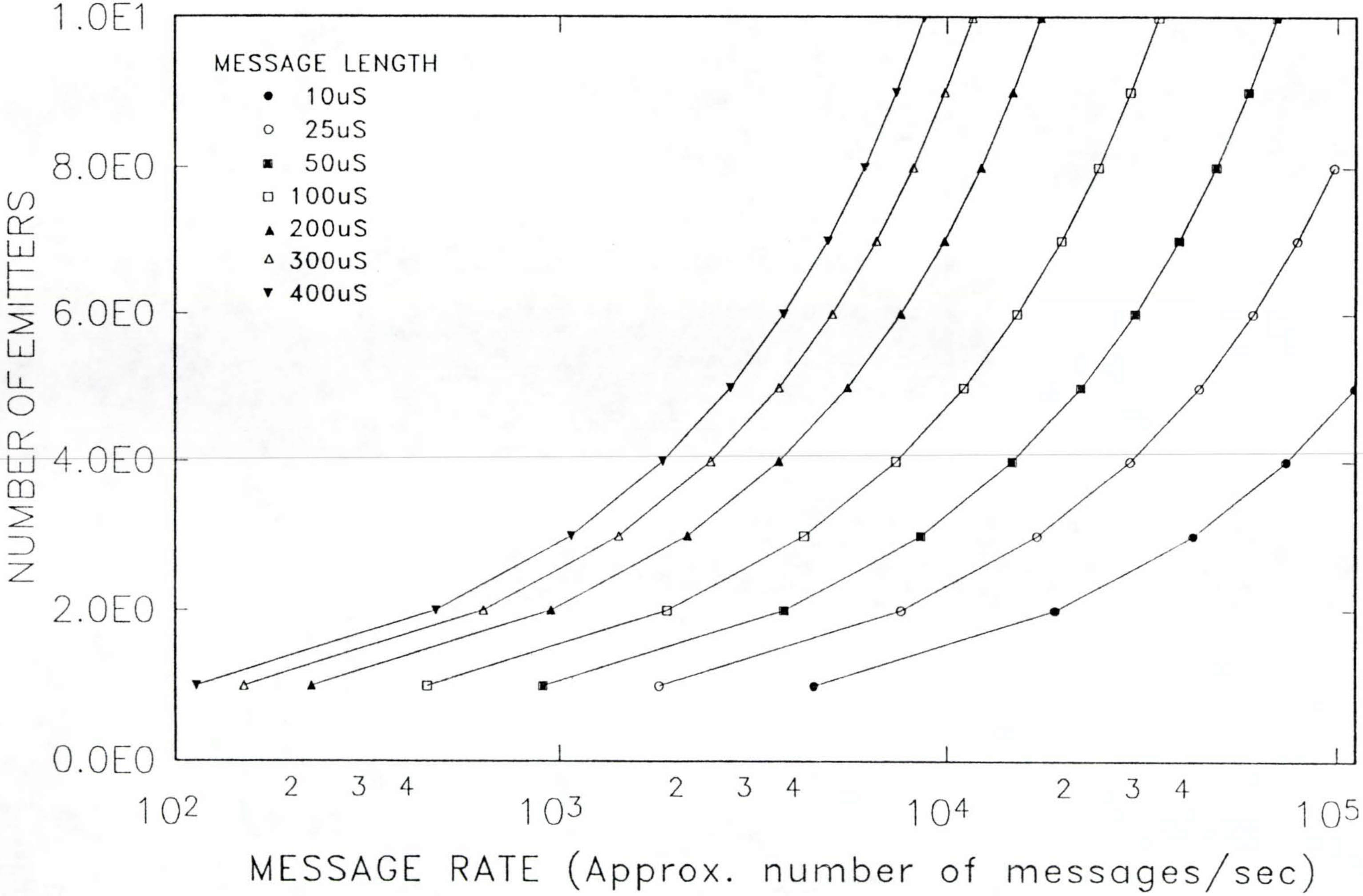
TASK 5 TECHNICAL RISK ISSUES
RF GENERATION OF MULTIPLE SPREAD SPECTRUM SIGNALS

Method of Investigation.

- Programmable signal generators can be used that will allow time division multiplexing of IFF messages that do not overlap in time.
- Messages which overlap in time will be transmitted over multiple independent emitters.
- A computer analysis was performed to determine the probability of message overlap.

TASK 5 TECHNICAL RISK ISSUES

NUMBER OF RF TRANSMITTERS REQUIRED (99.9% CONF.)



TASK 5 TECHNICAL RISK ISSUES
RF GENERATION OF MULTIPLE SPREAD SPECTRUM SIGNALS

1.0 CALCULATION OF THE NUMBER OF NEEDED EMITTERS FOR A GIVEN MESSAGE RATE

For a message rate of n signals per second and a signal length of p microseconds, the probability of exactly k signals (or k - 1 overlaps) present at any given time is given by the binomial distribution

$$p(k) = \frac{n!}{k!(n-k)!} p^k q^{n-k}$$

where q = 1 - p. The probability of k or fewer signals at a given time is the sum

$$\sum_{i=0}^{k} \frac{n!}{i!(n-i)!} p^i q^{n-i}$$

For a given value of k, the sum is a function of the message rate n. Determining the value of n that makes the sum equal to 0.999 thus indicates that k signal generators will create the necessary number of overlapping signals 99.9% of the time for that message rate. Since the sum is an increasing function of n, a binary search for the correct n may be used. The following program uses this method to find the value of n for several values of k for each of several message lengths.

TASK 5 TECHNICAL RISK ISSUES
RF GENERATION OF MULTIPLE SPREAD SPECTRUM SIGNALS

TABLE 3-2

EXAMPLES OF THE NUMBER OF TESTS EMITTERS
REQUIRED FOR MK XII AND MK XV MESSAGES

	MESSAGE TYPE	APPROXIMATE MESSAGE LENGTH	MESSAGE RATE	# OF EMITTERS REQUIRED
(U)	MK XII MODE 3A INTERROGATION	10 u sec	5000/sec	1
(U)	MK XII MODE C INTERROGATION	25 u sec	5000/sec	2
(U)	MK XII MODE 4 INTERROGATION	75 u sec	5000/sec	2
(S)	MK XV INTERROGATION	(classified)	5000/sec	
(U)	MK XII MODE 3A REPLY	25 u sec	30000/sec	4
(U)	MK XII MODE C REPLY	25 u sec	30000/sec	4
(U)	MK XII MODE 4 REPLY	5 u sec	30000/sec	2
(S)	MK XV REPLY	(classified)	30000/sec	

TASK 5 TECHNICAL RISK ISSUES
RF GENERATION OF MULTIPLE SPREAD SPECTRUM SIGNALS

Findings.

- The program was written to search on the number of overlapping messages, as an independent variable in order to determine the message rate (which could be either reply rate or interrogation rate) required to achieve a fixed cumulative probability (99.9 %).

Conclusions.

- These results indicate that a finite and feasible number of RF signal generators (approximately 2 to 10) can be used in the recommended TESTS approach to achieve the signal density environments required by the proposed test scenarios.

TASK 5 TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

Problem Definition.

- Multipath propagation effects are caused by the interference of a reflected electromagnetic waveform with the primary, direct path waveform at the receiver.
- The interference at the receiver may be either constructive, or destructive, and depends upon the gain, phase, frequency shift, and time delay.
- Depend upon many parameters such as the geometry of the transmitting and receiving platforms, the electromagnetic properties of the reflecting surface, and the type and complexity of the intervening terrain.

TASK 5 TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

Method of Investigation.

- The investigation followed two major divisions: Sea Surface Reflections, and Near Land and Irregular Terrain Reflections.
- Mathematical equations and computer models were readily found to describe many of the effects in question.
- A quick look computer analysis was performed to determine the multipath propagation delay times associated with an ideal reflected path relative to the direct path.

TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

Findings:

1 Technical Approach and State-of-the Art Available Models

- The presence of hills, buildings, sea, lakes, etc. near a radiating antenna affect the radiation mechanism by introducing the following phenomena :
- Reflection or Scattering
- Diffraction Phenomena
- Refraction Effects (ducting , ray bending, etc)

The two main categories of Multipath problems are due to :

- Sea Surface Reflection
- Near Land and Irregular Terrain.

TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

Findings:

2 Sea Surface Reflection

Balanis' model can be used which covers:

- Receiver and transmitter antenna heights.
- Path lenth and divergence.
- Receiver and transmitter antenna beamwidths and polarization states.
- Frequency .
- Ground-to-air cases.
- Air-to-ground cases.
- Air-to-air cases.
- This formulation is well documented and valid provided the sea surface is smooth. It does not consider any other sea states due to various wind conditions.

Findings:

3 Summary of Balanis' approach

Let the total E_θ component from a vertical dipole be given by :

$$E_\theta = \frac{j\eta k I_o e^{-jkr}}{4\pi r} sin\theta \left[e^{-jkhcos\theta} + DR_v e^{-jkhcos\theta}\right] \quad (1)$$

where D is the divergence factor that takes into account the spreading (weakening) of energy from a curved surface given by:

$$D \approx \left[1 + 2\frac{h_1^{'} h_2^{'}}{adtan_\psi^3}\right]^{-1/2} \quad (2)$$

and :

- $h_1^{'}$ = height of the source point above the earth
- $h_2^{'}$ = height of observation point above the earth
- d = range between the source and the observation point
- a = radius of the earth . (4/3 radius of earth is used)
- ψ = reflection angle with respect to the tangent at the point of reflection.
- R_v = reflection coefficient for vertical polarization

Findings:

Also :

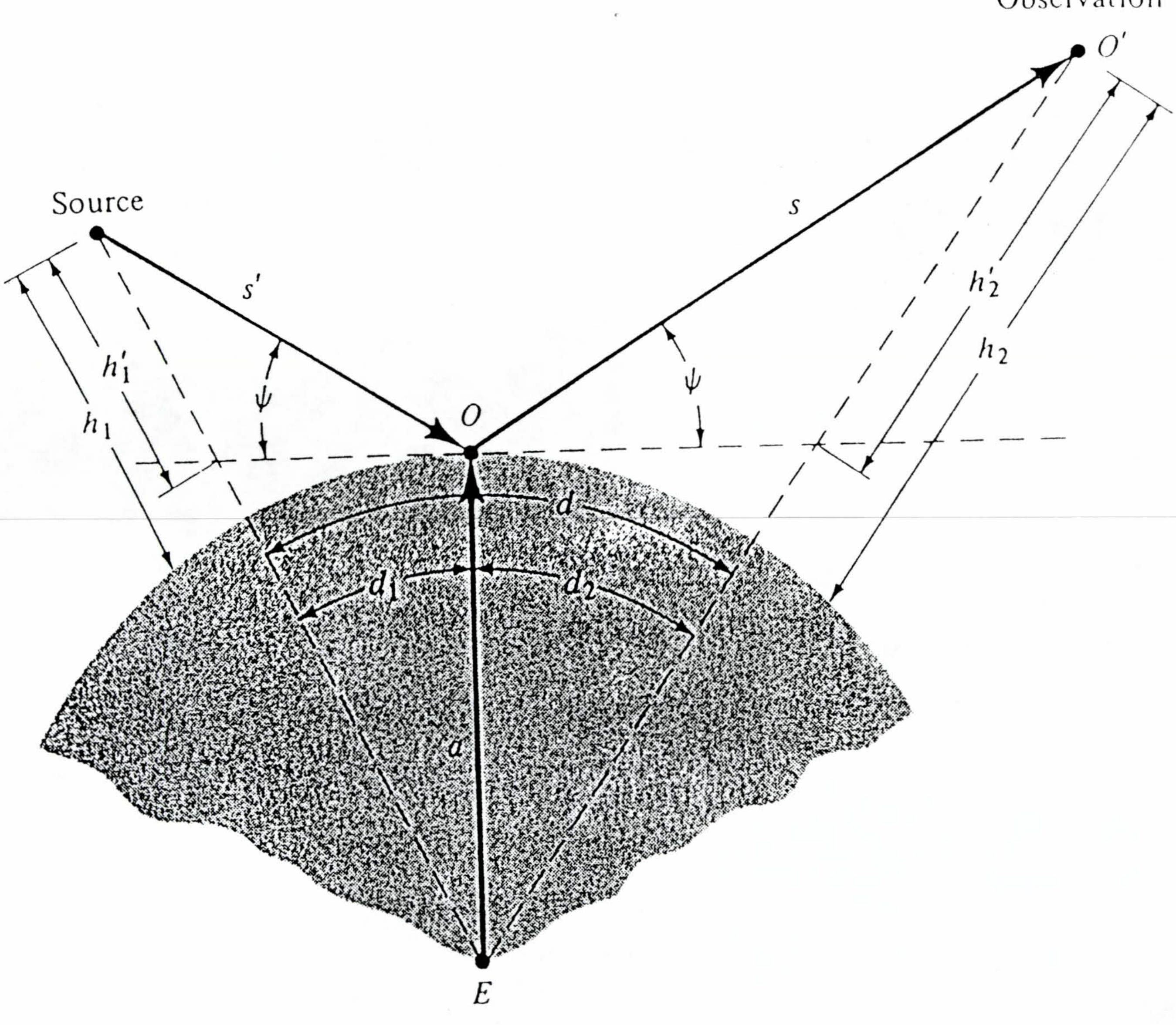
$$s' \approx \frac{h_1'}{sin\psi} \tag{3}$$

and

$$s \approx \frac{h_2'}{sin\psi} \tag{4}$$

- In a real life situation, one will have to replace the pattern of the vertical dipole by the pattern of the antenna placed on a specific platform.

TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS



TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

<u>Findings</u>:

- This model does not consider any other sea states or wind conditions.
- This formulation can still be used for other rough surfaces provided the geometry satisfies the Rayleigh criterion :

$$h = \frac{\lambda}{8 sin\psi} \tag{5}$$

where: h = maximum height of waves
λ = wavelength
ψ = grazing angle.

TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

Findings:

4 Near Land and Irregular Terrain

- Normally, irregular multipath propagation exist in hilly terrain, but it can also be found in any populated areas where obstacles, such as, buildings, trees, etc. are present.
- For a pulsed communication system the delays of the reflected or diffracted pulses can pose a serious system degradation.
- The system performance depends on the pulse width and the amplitude of the reflected (diffracted) pulses and the distance of separation between the receiver and transmitter.
- If the reflected signal is substantially smaller than the direct-path signal it is suppressed. On the other hand,if the reflected signal is larger then is locked onto instead of the direct-path signal.
- For this project, it is important that we develop a model that predicts the frequency of occurrence of multipath propagation of certain delay and amplitude.
- Various models have been developed for different terrains, heights above these terrains, frequency of operation, range, and pulsewidth of transmitted signals.

TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

Findings:

5 Model 1-Multipath for Pulse signals

- In this model, the probability of occurrence of multipath propagation of pulse signals over irregular terrain at VHF and UHF are determined. In free space the available power received by an antenna is given by :

$$P_{r,o} = P_t(G_t/4\pi R^2)A_e \tag{6}$$

where :

$$A_e = G_r\lambda^2/4\pi \tag{7}$$
$$G = \eta D \tag{8}$$

Under the assumption of a smooth plane earth and at near grazing propagation the power received is :

$$P_{r,p} = P_t G_t G_r (h_t h_r/R2)^2 \tag{9}$$

where:

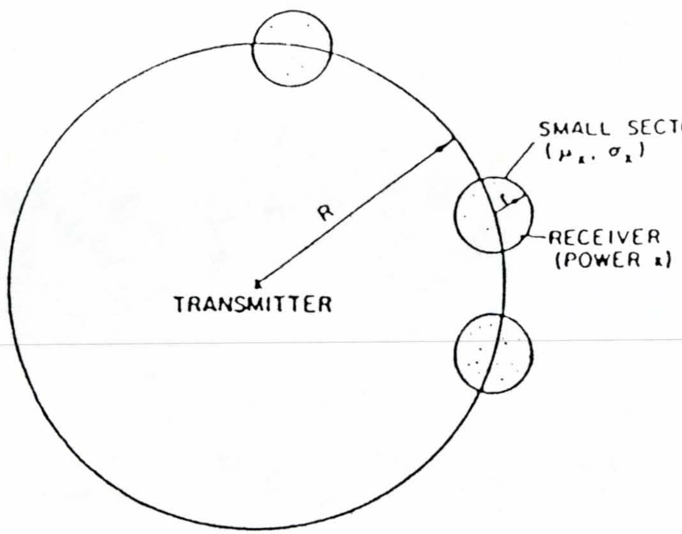
TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

Findings:

- P_t = transmitted power
- G_t = gain of transmitting antenna
- G_r = gain of receiving antenna
- R = transmitter-receiver distance of separation
- A_e = effective aperture of antenna
- η = antenna efficiency
- h_t = height of transmitting antenna
- h_r = height of receiving antenna
- In practical situations, the assumption of a smooth earth isnot valid and additional losses occur that must be accounted for.

TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

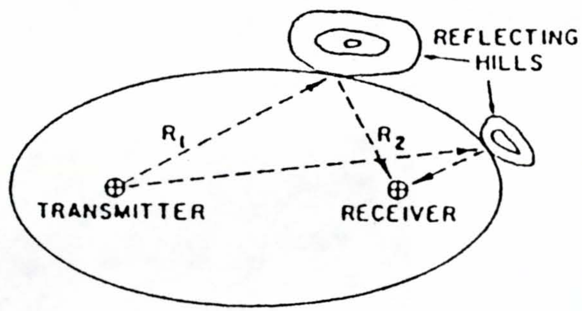
Findings:



Transmitter and receiver locations.

TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

Findings:



Multipath propagation of constant delay.

TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

Findings:

- For "Irregular" terrain, Egli gives a statistically derived expression for the median received power at frequencies above 40 MHz as :

$$P_{r,50} = P_t G_t G_r (h_t h_r / R2)^2 (40/f)^2 \qquad (10)$$

  for a $h_r > 9 meters$.

- This equation gives a measure of the power that will be received from a direct ray.
  For a reflected path R is replaced by $(R_1 + R_2)$.

- The locus of points for which the total path length $R_1 + R_2$ traveled by a reflected wave is constant. A reflected pulse of certain delay is generated by all terrain features that exist sufficiently close to the perimeter of the ellipse.

TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

Findings:

6 ECAC Model

Developed by the Electromagnetic Compatibility Analysis Center in Annapolis .

It can handle the line-of-sight, Diffraction, and Tropospheric modes of propagation over an irregular terrain.

We propose to use the Integrated Rough Earth Model (TIREM) and (MIXPATH). This code covers :

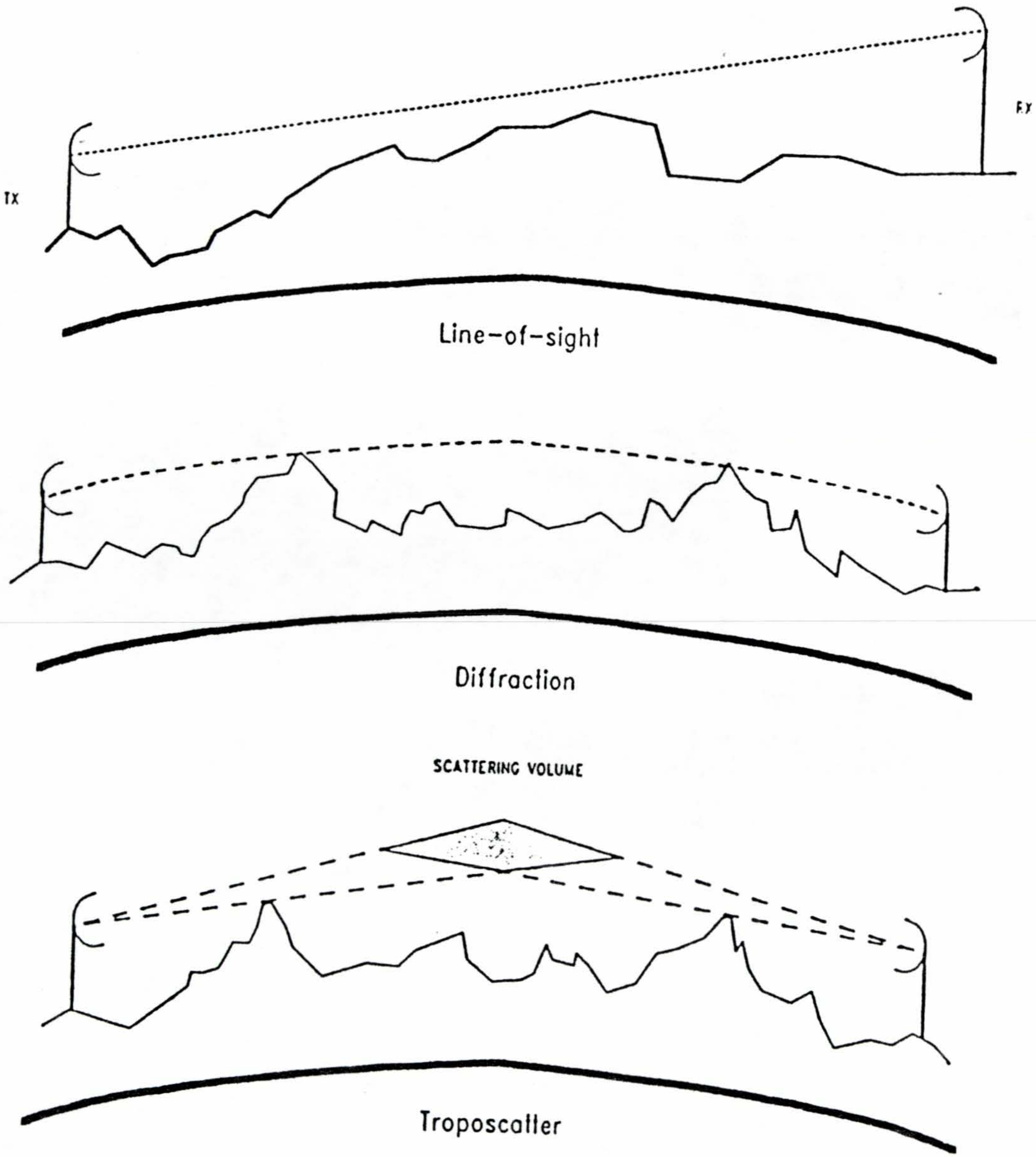
- Most multipath effects between 20 MHz and 20 GHz.
- Distance and elevation profiles
- Geographic coordinates (Latitude ad Longitude) of the transmitter and receiver.
- Environmental parameters of the terrain (permittivity, conductivity, etc.)

TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

Findings:

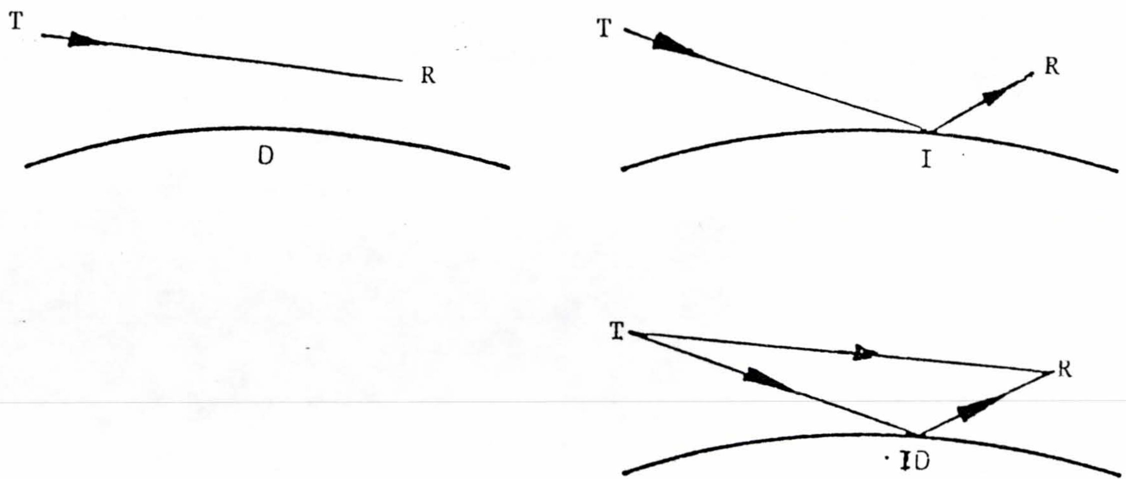
- Antenna heights, their frequncy, and polarization
- Antenna gains and transmitter power.
- Topographic profiles between the transmitter and the receiver. Terrain topography can be obtained from the Defense Mapping Agency DMA for many locations or the user can imput any terrain profile of his own.
- Degree of reliability of the propagation between a transmitter and a receiver.
- This model, however, does not consider pulse signals and their dispersion through the atmosphere.
- It is also restricted to a number of specific types of antennas. That means that an antenna radiation pattern that includes all platform effects should be entered in this code to simulate real life signals.

TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS



TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

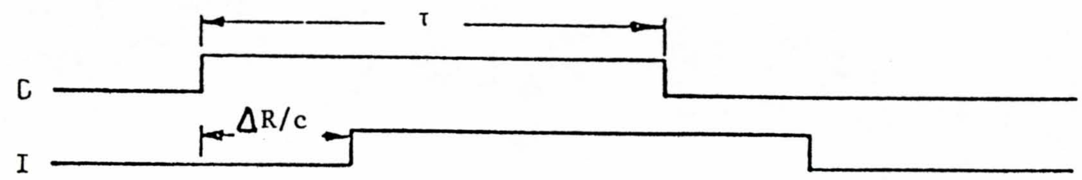
Findings:



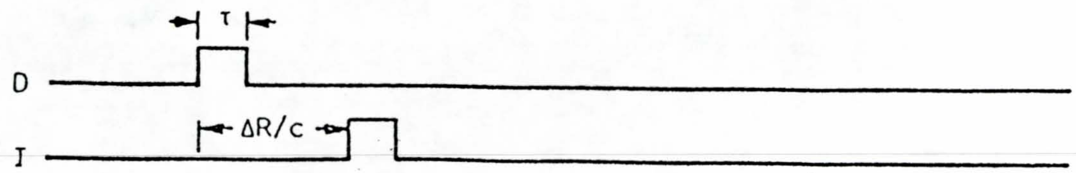
Possible radar paths over a reflecting surface

TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

Findings:



(a) $\tau >> \Delta R/c$



(b) $\tau < \Delta R/c$

Time relationships of multipath received pulses for long and short pulse lengths.

TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

Findings:

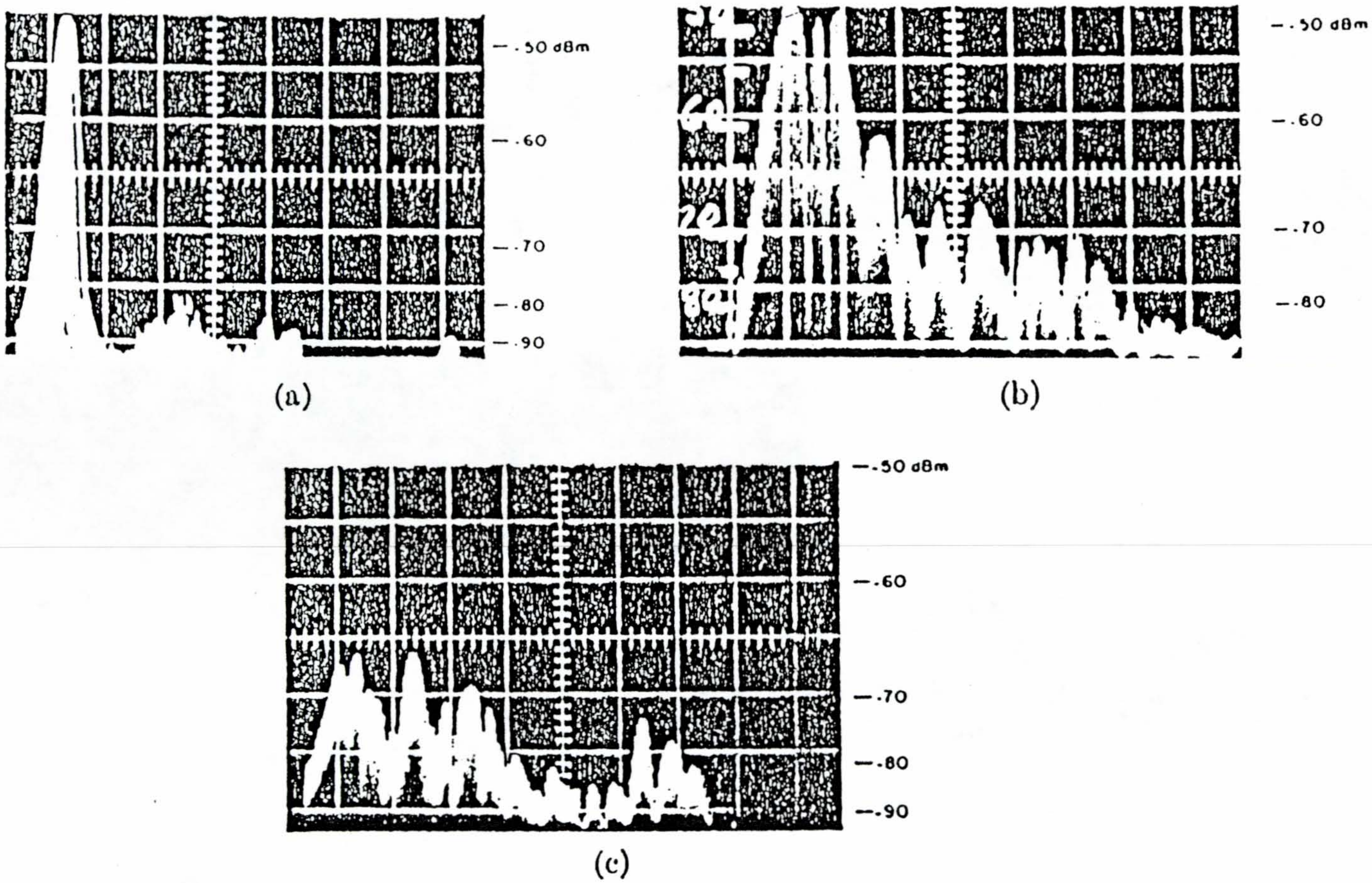


Fig.5. Typical oscilloscope displays of a pulse received over a line-of-sight path and over paths in hilly terrain; pulsewidth: ~5 μs, horizontal: 10 μs/div. (a) Line-of-sight reception at 40 km. (b) Non-line-of-sight reception at 10 km. (c) Non-line-of-sight reception at 20 km.

TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

Findings:

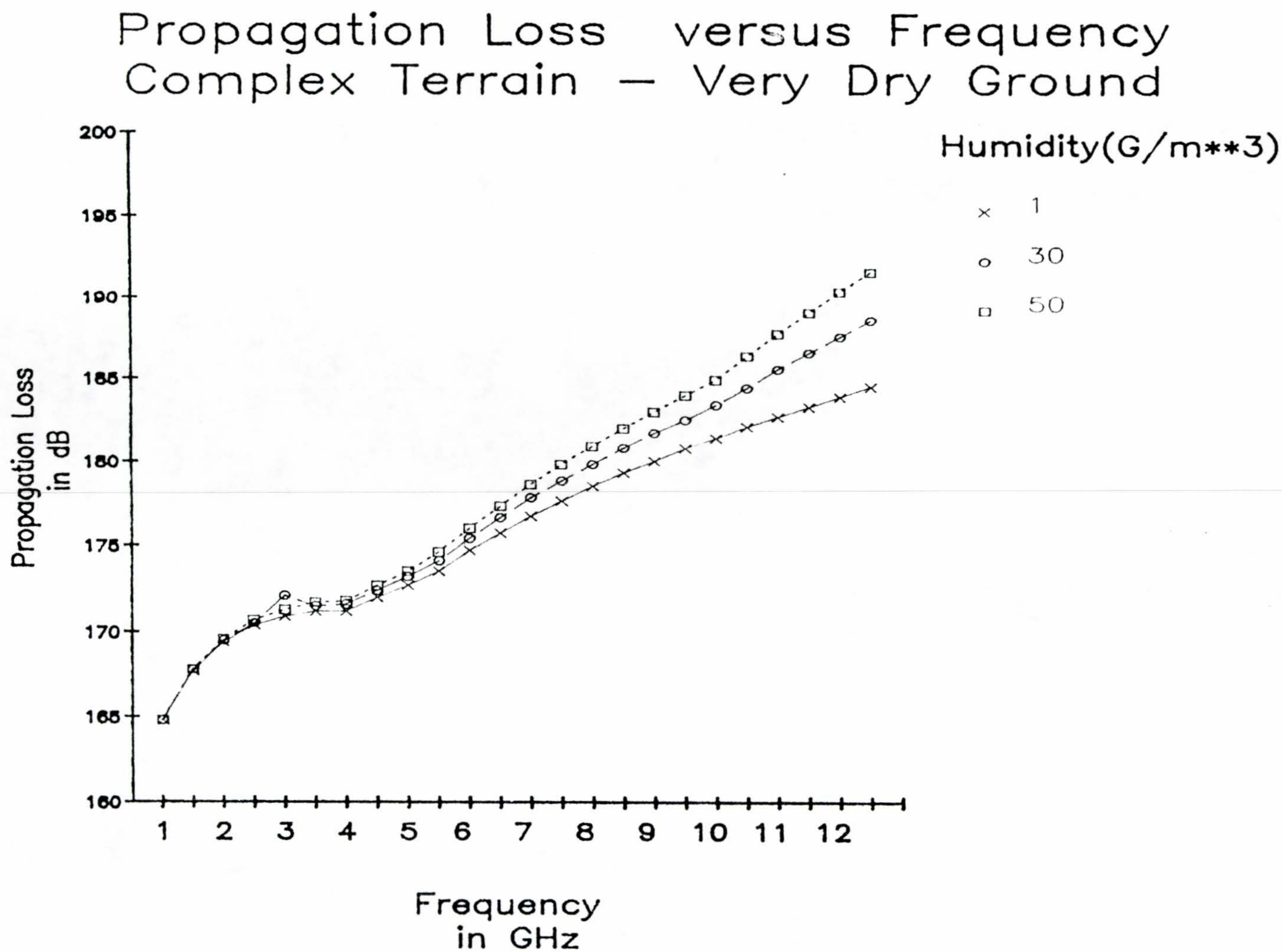
7 Proposed Testing and Verification

Basically, our work can be validated though :

- In flight measurements at NATC or elsewhere.
- Comparison with available Published experimental data.
- Laboratory experiments for some simple cases.

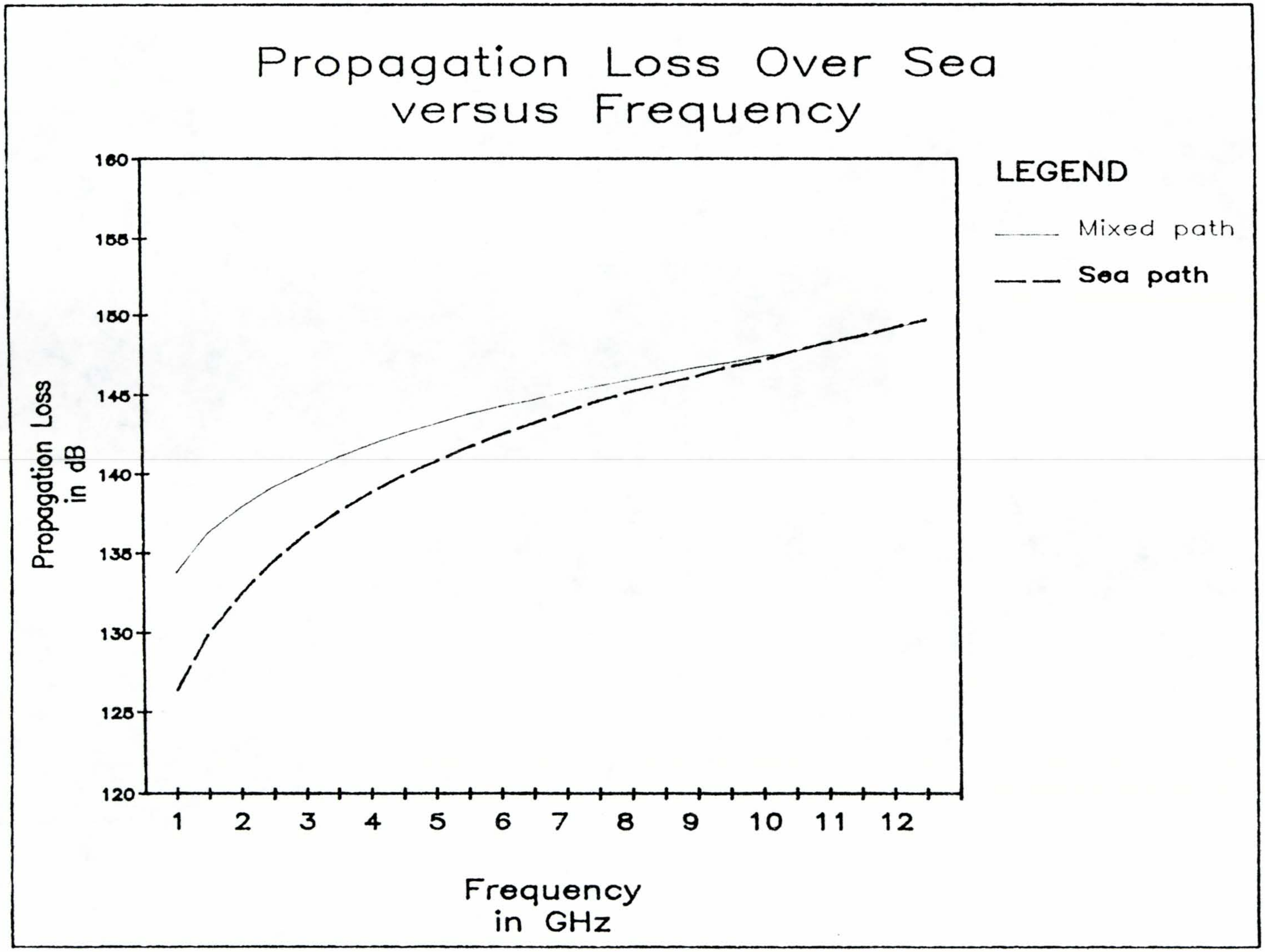
TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

Findings:



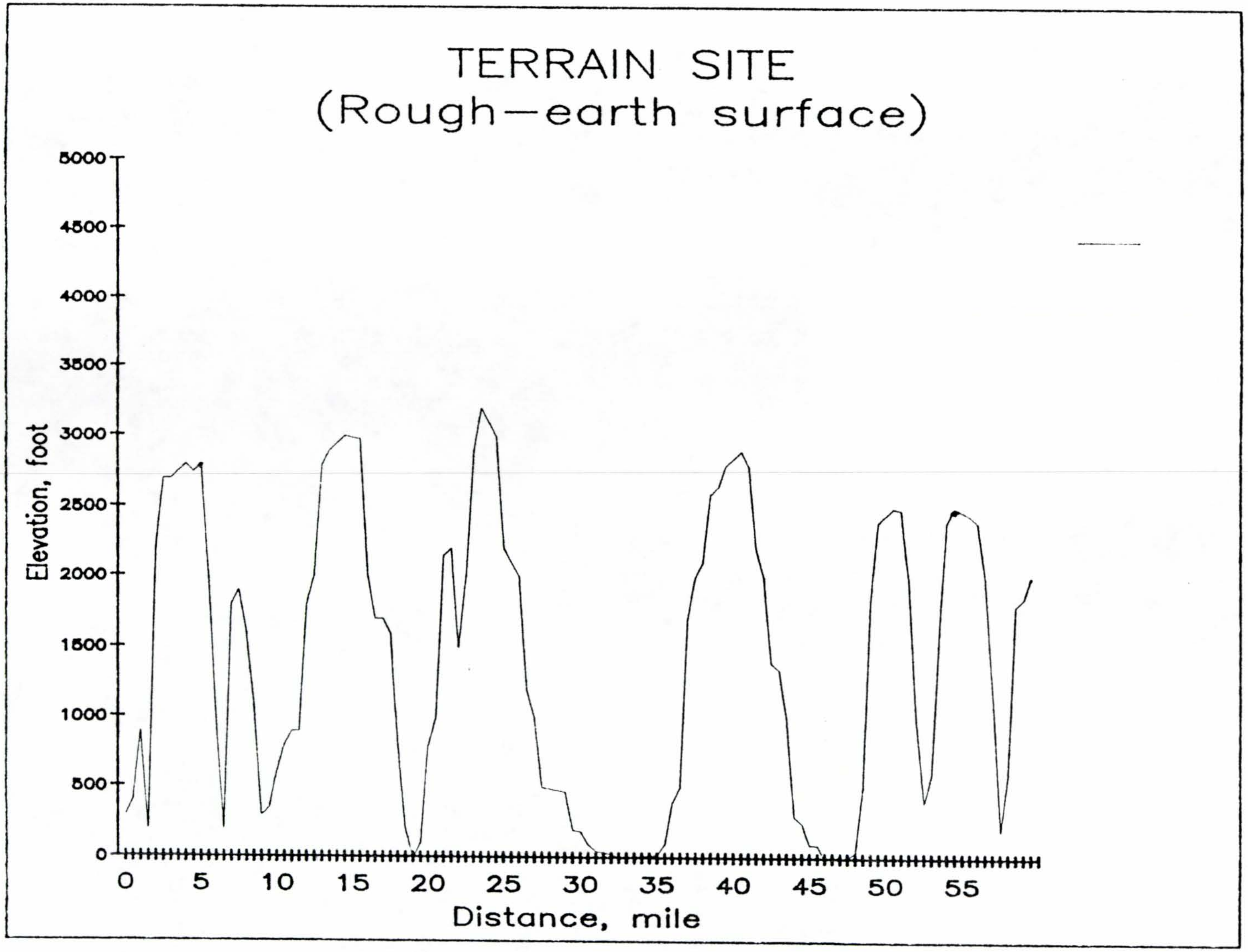
TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

Findings:



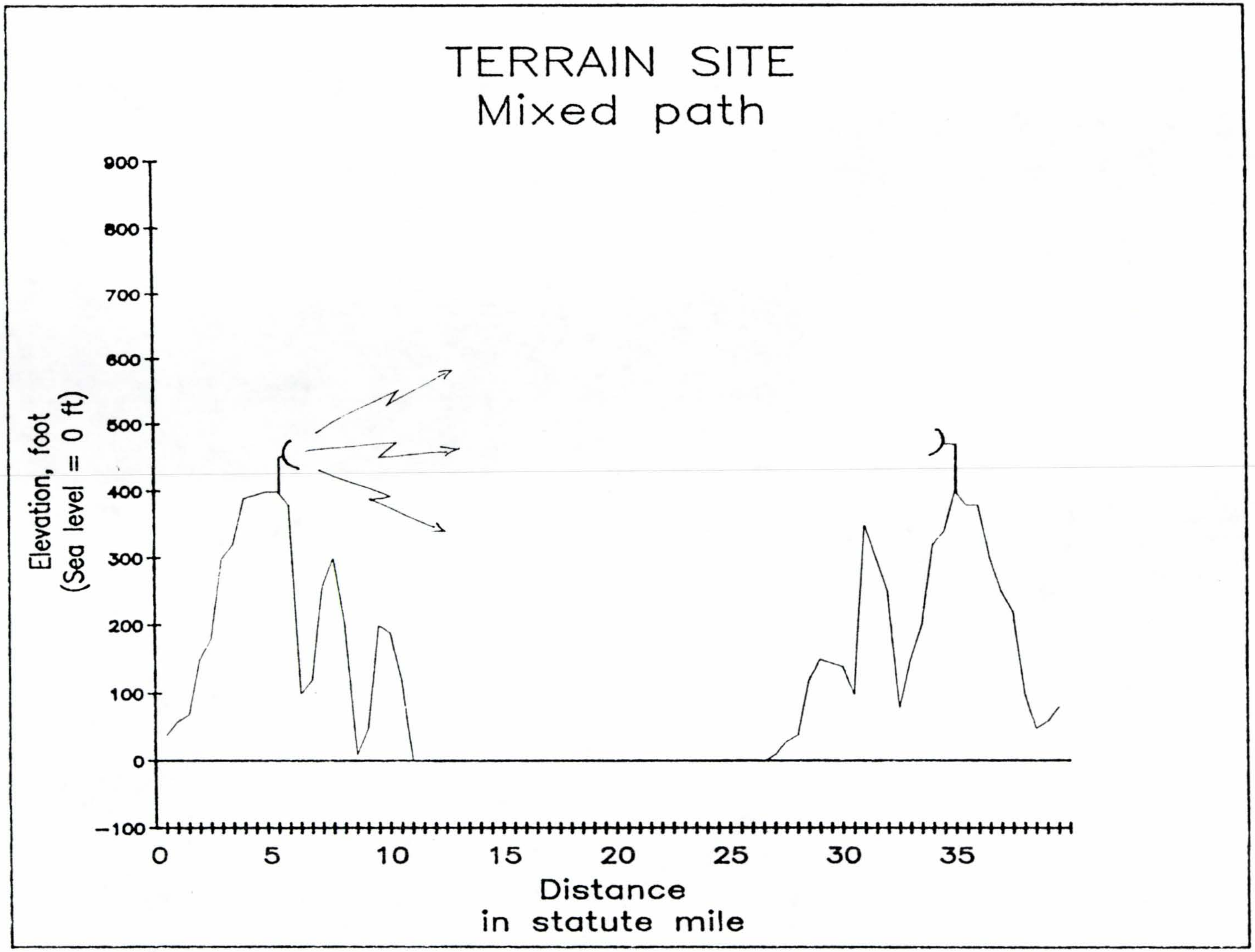
TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

Findings:



TASK 5: TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

Findings:



TASK 5 TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

- An analysis of multipath delay times as a function of source/receiver altitudes and distance was conducted.

  Source altitudes 5,000, 20,000 and 40,000 ft
  Receiver altitudes 5,000 - 40,000 ft

- This data was used in the determination of the number of independent emitters required for TESTS.

TASK 5 TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

2.0 CALCULATION OF MULTIPATH TIME DELAY

Each signal transmitted by a sender may travel by two paths - one signal traveling directly between the platforms and the other undergoing a reflection off the earth. The signal traveling directly between the platforms arrives first and the reflected signal arrives a short time later.

The time difference between the direct and reflected signals is shown in Figure C-1.

$$\frac{d-r_1-r_2}{c}$$

where c is the speed of light and d is given by

$$d=\sqrt{(R_E+h_1)^2+(R_E+h_2)^2-2(R_E+h_1)(R_E+h_2)\cos\theta}$$

d is known from radar and thus the above equation may be solved for θ. From the law of sines, r_1 and r_2 are given by

$$\frac{r_1}{\sin\theta_1}=\frac{R_E+h_1}{\sin(\alpha_1+90)}$$

and

$$\frac{r_2}{\sin\theta_2}=\frac{R_E+h_2}{\sin(\alpha_2+90)}$$

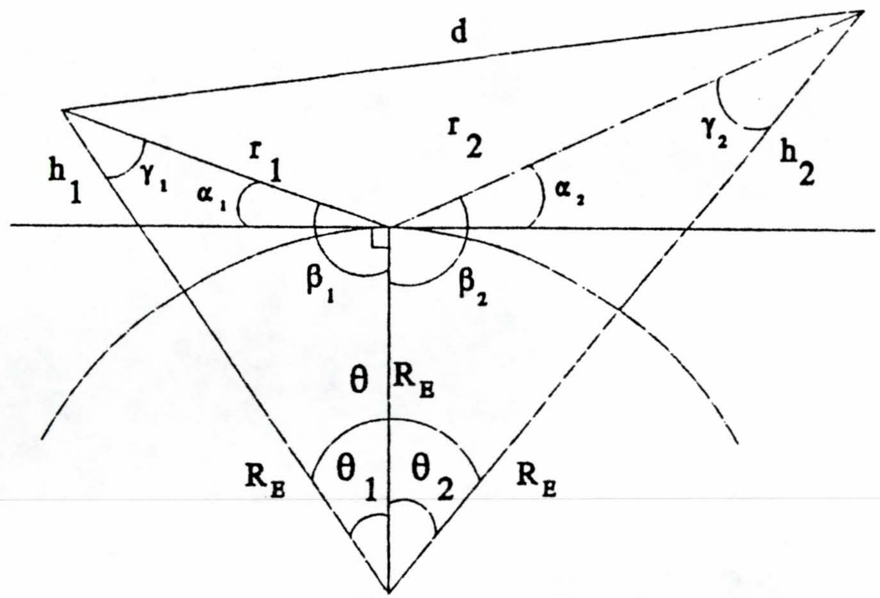


Figure C-1. Multipath Geometry for Reflections from a Spherical Surface

TASK 5 TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

The angles, as shown in Figure C-2, are found by writing

$$\gamma - \tan^{-1}\left(\frac{b}{a}\right) - \tan^{-1}\left(\frac{R_E \sin\theta}{R_E(1-\cos\theta)+h}\right)$$

which gives the expressions

$$\alpha_1 - 90 - \theta_1 - \tan^{-1}\left(\frac{R_E \sin\theta_1}{R_E(1-\cos\theta_1)+h_1}\right)$$

and

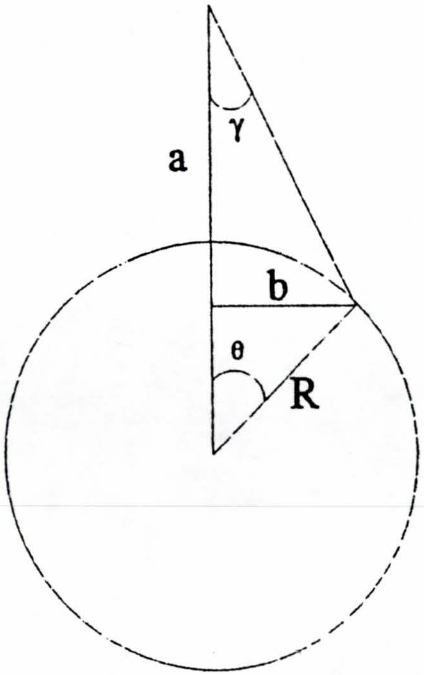
$$\alpha_2 - 90 - \theta_2 - \tan^{-1}\left(\frac{R_E \sin\theta_2}{R_E(1-\cos\theta_2)+h_2}\right)$$

For reflection, $a_1 = a_2$ and thus setting $\theta_2 = \theta - \theta_1$ gives

$$\theta_1 + \tan^{-1}\left(\frac{R_E \sin\theta_1}{R_E(1-\cos\theta_1)+h_1}\right) - \theta - \theta_1 + \tan^{-1}\left(\frac{R_E \sin(\theta-\theta_1)}{R_E(1-\cos(\theta-\theta_1))+h_2}\right)$$

To find θ_1, the value of θ_1 is incremented in small steps until the left and right hand sides of the last equation are equal to within a given tolerance. The other angles may then be determined and used to find r_1 and r_2 and hence the time difference

TASK 5 TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

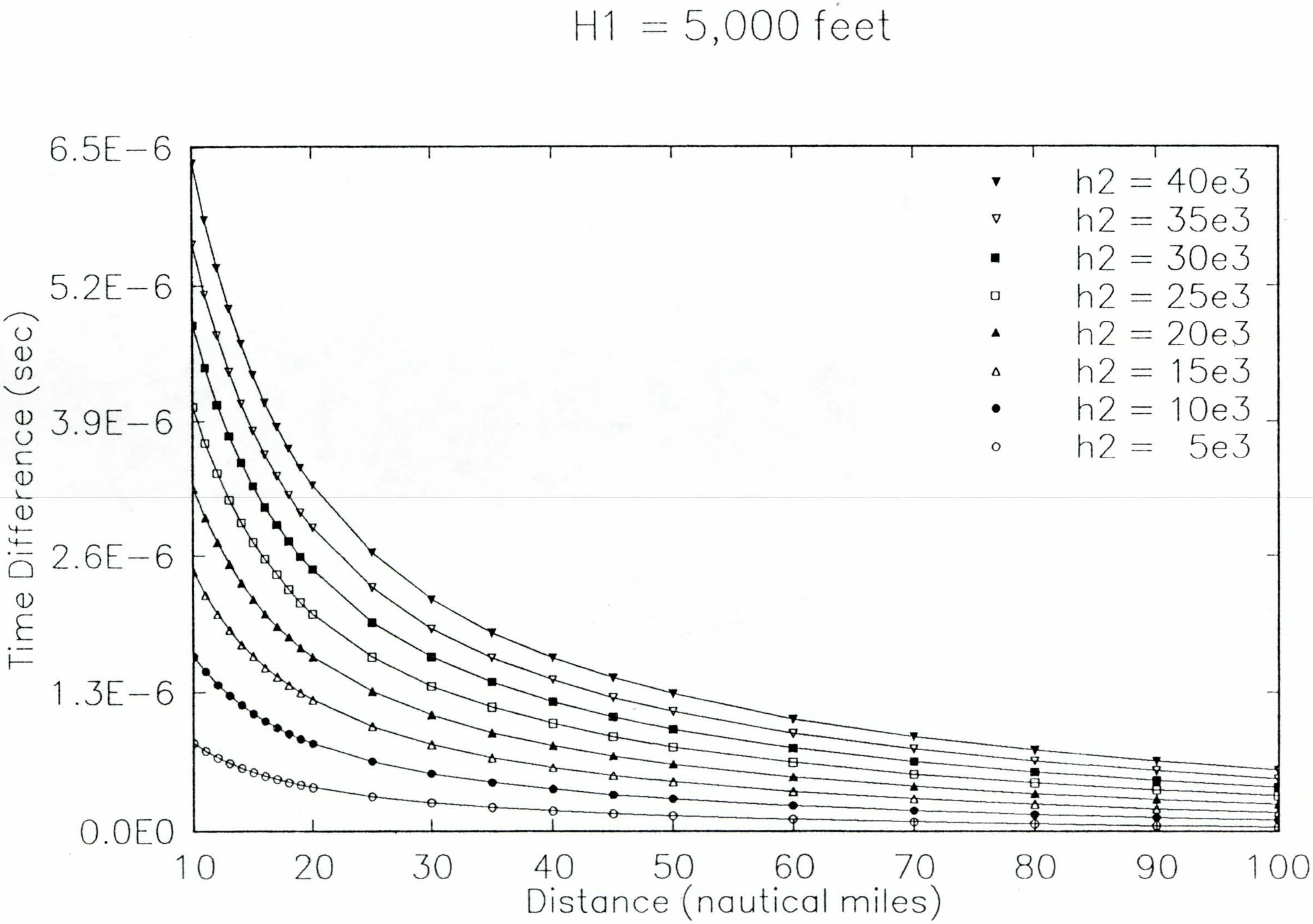


$$b = R \sin\theta$$

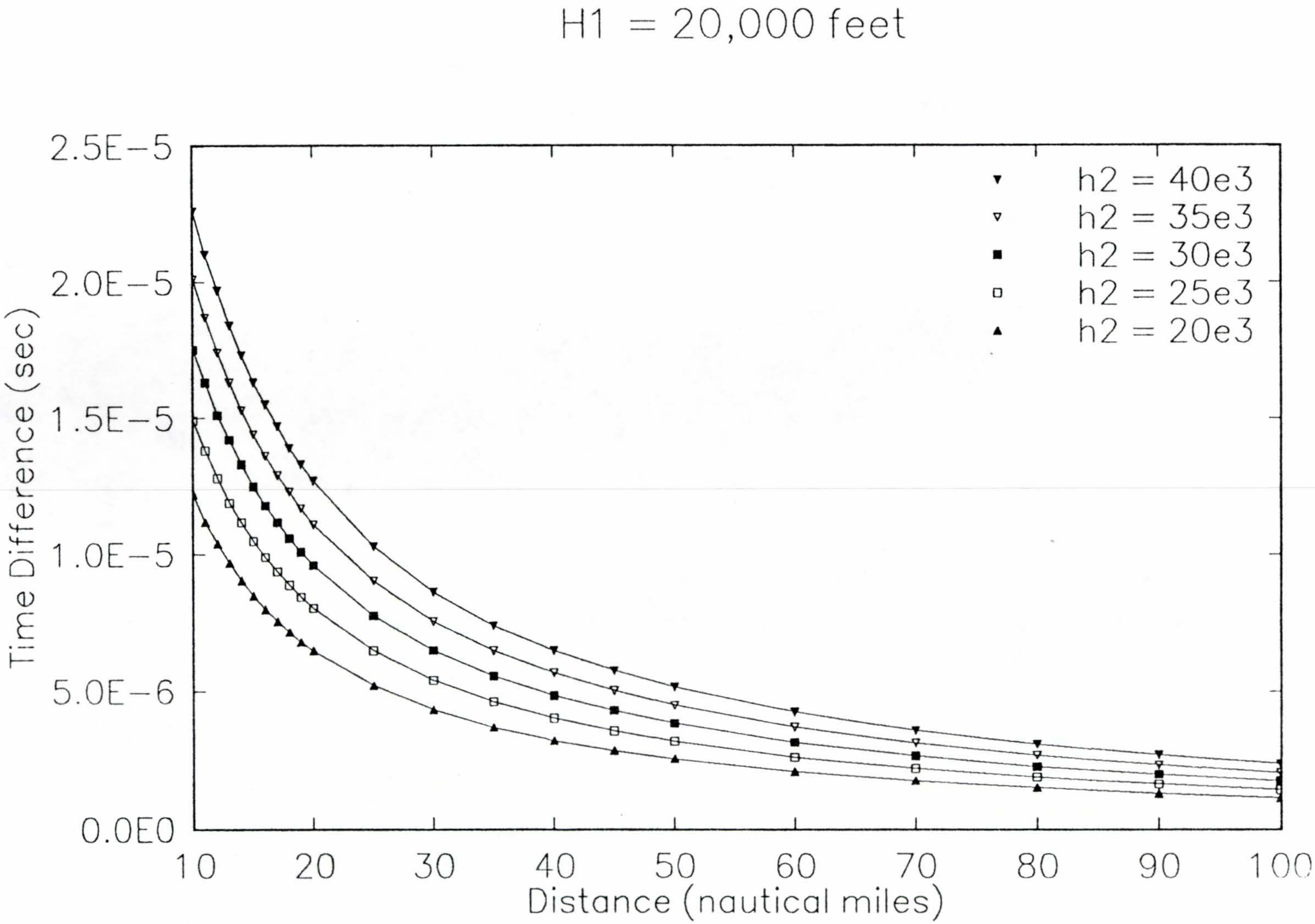
$$a = (R+h) - R \cos\theta$$

Figure C-2. Multipath Geometry - Gamma Components

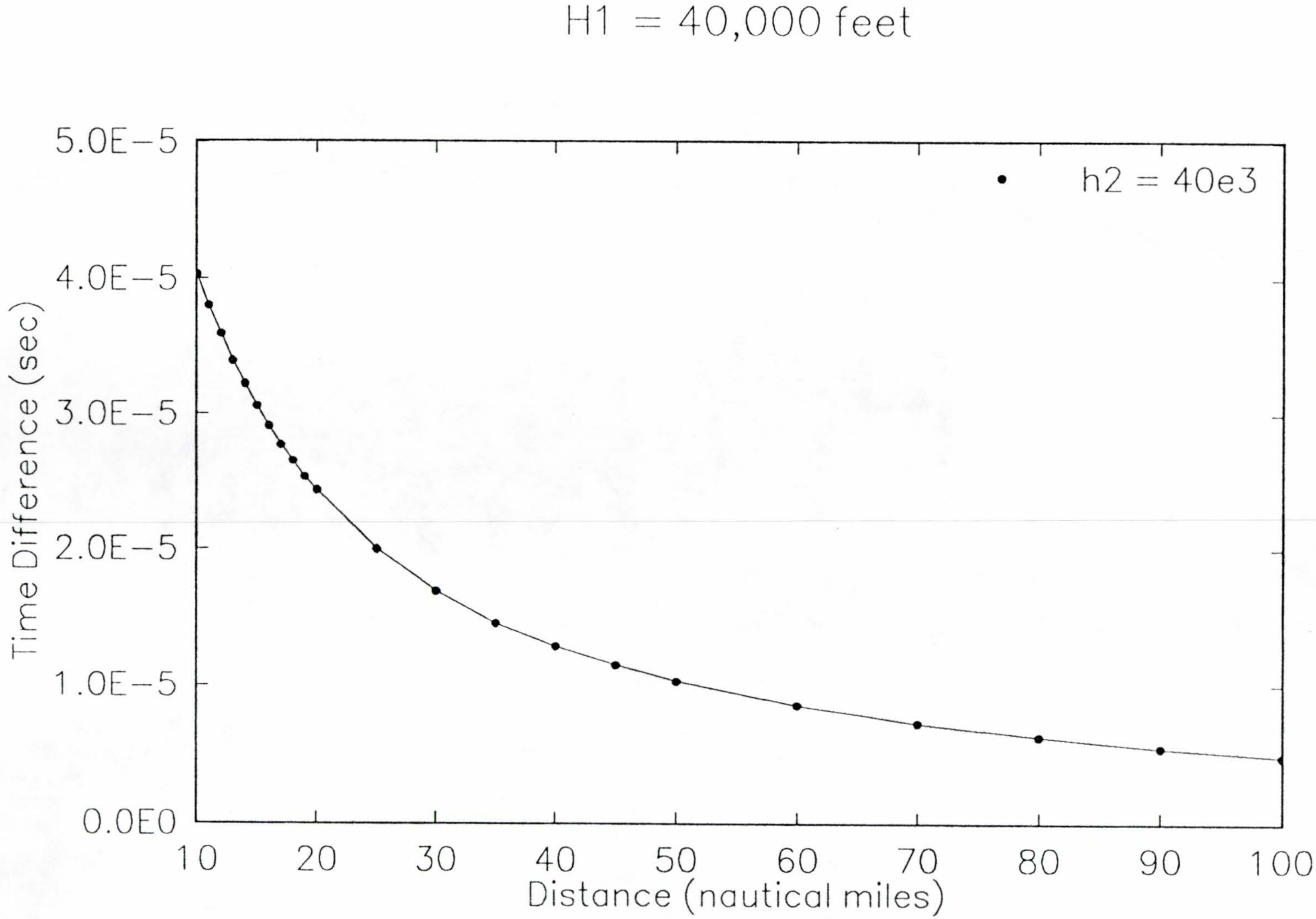
TASK 5 TECHNICAL RISK ISSUES
MULTIPATH DELAY TIMES H1 = 5K FT.



TASK 5 TECHNICAL RISK ISSUES
MULTIPATH DELAY TIMES H1 = 20K FT.



TASK 5 TECHNICAL RISK ISSUES
MULTIPATH DELAY TIMES H1 = 40K FT.



TASK 5 TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

Findings.

- The requirement to solve the equations describing the multipath effects in real time for multiple platforms can be achieved.
- The requirement to superimpose the reflected signals with the direct signals at the RF receiver of the Platform Under Test (PUT) can be achieved.

TASK 5 TECHNICAL RISK ISSUES
SIMULATION OF MULTIPATH PROPAGATION EFFECTS

Conclusions.

- To alleviate TESTS host computer processing loads, and to provide accurate, credible superpositioning of direct and reflected path signals, the recommended TESTS concept uses separate, parallel hardware channels (split from a common signal/message input).
- A separate set of programmable time delay, gain and phase distorters will be provided in hardware to represent the indirect signal.
- TESTS software components will compute the equations and algorithms for the multipath effects to determine the appropriate gain, phase, and time delays to transmit to the hardware distortion devices.

TASK 5 TECHNICAL RISK ISSUES
RECEPTION AND PROCESSING TIME DEPENDENT FORMATS

Problem Definition.

- A description of the reception and processing of TDFs is sought. Identification of the processes and timing considerations are needed to relate the TDF issues.

Method of Investigation.

- The receiver processes are analyzed to relate the sensitivities of the TDF's to fidelity of the data capture.

TASK 5 TECHNICAL RISK ISSUES
RECEPTION AND PROCESSING TIME DEPENDENT FORMATS

Findings.

- The reciprocal process of demodulation, decode and identification inversely follows the waveform generation. It was found that the PN sequence mask must be synchronized to the received waveform in order to despread the spread spectrum signal and recover the data correctly. Timing was found to be extremely sensitive to correct data capture.

Conclusions.

- The implementation of the Bendix Test equipment, namely, the receiver subsystem, has already mechanized the demodulation and decode processes. Using this subsystem along with the synchronized PN sequences (TDF) that are centrally generated by the simulator computer, could make the implementation of the simulator tool much easier.

TASK 5 TECHNICAL RISK ISSUES
NEAR FIELD EFFECTS

Problem Definition.

- The near field effects of an antenna relate to the modification of the radiation pattern by the close proximity of various objects or other antenna to the transmitter.

Method of Investigation.

- Various models are used, namely, "New-Air", INAC-3, GEMACS, and STRIPES, to analyze the near field effects of interrogator geometries, antennae placements (diversity systems), and to give antenna pattern functional relationships for a range of IFF platforms.

TASK 5: TECHNICAL RISK ISSUES
NEAR FIELD EFFECTS

Findings: This problem can be divided into the following parts (tasks) :

- **Antenna Effects** (Near-field and far-field)
  The presence of a ground plane changes the radiation patterns of the antenna and its gain by introducing vertical lobing. That means that the signal transmitted by the system will have some nulls in some directions. These direction must be determined.

- **Platform Effects** (Near-field and far-field)
  The radiation patterns of an antenna is dependent on the geometry of the platform (ship, plane, ground surveillance system, etc.) and the location of the antenna on a specific platform. The proximity of the antenna to various objects on a platform changes the near field pattern as well as the far-field patterns. Any nulls or depolarization changes introduced by the specific platform should be accurately predicted and accounted for in any communication link.

- **Coupling Effects** (near-field)
  In a diversity system more than one antenna will be used. The effects of interaction between the two antennas or more should be known. Both maximum and minimum power transmitted from the antennas are related to their degree of coupling. The amount of coupling and its effects on input impedance of the antennas are important for the correct calibration of the system.

TASK 5: TECHNICAL RISK ISSUES
NEAR FIELD EFFECTS

Findings:

state-of-the art models :

- **NEC-Basic Scattering Code**
  High Frequency
  Based on the Uniform Theory of Diffraction
  It can handle various platform Geometries
- **New Air**
  High Frequency
  Based on the Geometrical Theory of Diffraction
  It can handle aircraft platforms (If antenna is placed on fuselage)
- **INAC-3**
  Low Frequencies
  Based on the method of momemts
  It can handle ship and aircraft geometries

TASK 5: TECHNICAL RISK ISSUES
NEAR FIELD EFFECTS

Findings:

- **GEMAGS**
  Most Frequencies of Interest
  Hybrid method (GTD and Method of Moments)
  Good for all geometries and all frequencies
  Can find the coupling between antennas.

- **STRIPES**
  Most Frequncies of Interest
  Transmission Line Method -It requires a mesh generation (could be a frequency limitation)
  It can be applied to various platform geometries.

TASK 5 TECHNICAL RISK ISSUES
NEAR FIELD EFFECTS

Findings.

- "New-Air" Code can be used to find near field patterns of antenna mounted on aircraft or missiles.
- GEMACS is a hybrid method. It combines both the Geometrical Optics (GO) approach and the method of moments.
- STRIPES is based on the transmission line method and is not intrinsically limited in frequency.

TASK 5: TECHNICAL RISK ISSUES
NEAR FIELD EFFECTS

Findings: **Coupling Among Antennas**

- The degree of coupling between two or more antennas depends on:
  - the type of antennas under test
  - their location on the platform
  - their proximity to various conducting objects
  - their frequency of operation ,and
  - the polarization of the transmitted and received waves.
- This problem could be quite complex and it will require further research once the information on the antennas and their arrangement are known.
- GEMACS can solve for the coupling between some antennas on a given platform
- We propose to include this option into the model that will be developed to handle the 3-D radiation patterns and platform effects.
- Coupling is important for the calibration of the system (gain info).

TASK 5: TECHNICAL RISK ISSUES
NEAR FIELD EFFECTS

Findings:

Testing and Verification

- **Far-field and near field patterns.**
  Will be verified by comparing our data against published theoretical and experimental data, as well as, data provided by NATC.

- **Coupling**
  It can be verified , partially, by using expreimental techniques, such as, lab measurements and in-flight measurements. Prior to the verification of this part the platform effects and 3-D patterns should be verified.

TASK 5 TECHNICAL RISK ISSUES
NEAR FIELD EFFECTS

Conclusion.

The state-of-the-art software programs have been examined to access their value. The ranges and functionality have been determined to be appropriate to the needed fidelity and to model the near field antenna patterns required for TESTS.

TASK 5 TECHNICAL RISK ISSUES
MODELING OF ANTENNA EFFECTS

Definition.

- Computer Models are necessary to relate the parameter of "antenna gain" to all aspects (azimuth and pitch angle) of the various platforms under study.

Method of Investigation.

- The "New-Air", INAC-3, GEMACS, and Stripes models will be used to generate 3-D antenna pattern (antenna gain) by computer simulation.

TASK 5: TECHNICAL RISK ISSUES
MODELING OF ANTENNA PATTERN EFFECTS

Findings: This problem can be divided into the following parts (tasks) :

- **Antenna Effects** (Near-field and far-field)
  The presence of a ground plane changes the radiation patterns of the antenna and its gain by introducing vertical lobing. That means that the signal transmitted by the system will have some nulls in some directions. These direction must be determined.

- **Platform Effects** (Near-field and far-field)
  The radiation patterns of an antenna is dependent on the geometry of the platform (ship, plane, ground surveillance system, etc.) and the location of the antenna on a specific platform. The proximity of the antenna to various objects on a platform changes the near field pattern as well as the far-field patterns. Any nulls or depolarization changes introduced by the specific platform should be accurately predicted and accounted for in any communication link.

- **3-Dimensional Patterns** (far-field)
  Complete azimuthal and elevation plane patterns are critical since received and transmitted signals propagate in any direction. The ability to predict the radiation patterns in any plane cut will determine the gain, power and sensitivity needs of the receiver and transmitter.

TASK 5: TECHNICAL RISK ISSUES
MODELING OF ANTENNA PATTERN EFFECTS

Findings:

state-of-the art models :

- **NEC-Basic Scattering Code**
  High Frequency
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TASK 5: TECHNICAL RISK ISSUES
MODELING OF ANTENNA PATTERN EFFECTS

Findings:

- **GEMAGS**
  Most Frequencies of Interest
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  Can find the coupling between antennas.
- **STRIPES**
  Most Frequncies of Interest
  Transmission Line Method -It requires a mesh generation (could be a frequency limitation)
  It can be applied to various platform geometries.

TASK 5: TECHNICAL RISK ISSUES
MODELING OF ANTENNA PATTERN EFFECTS

Findings:

Three-Dimensional Patterns

- Currently, flight measurements at NATC and other facilities can yield complete azimuthal plane patterns and partial elevation patterns.
- The limitation on the elevation pattern is due to flight dynamics. This limitation can be very critical in a real life situation since interrogations and responses can be transmitted or received in any direction and angle.
- The capability of having a three-dimensional radiation pattern will :
  - greatly enhance the confidence and reliability level of a communication link .
  - save a lot of time and money by reducing the number of flight measurements.
- Once the surface currents are known from the models described earlier one can derive the three dimensional patterns. (examples : GEMACS, STRIPES).

TASK 5: TECHNICAL RISK ISSUES
MODELING OF ANTENNA PATTERN EFFECTS

Findings:

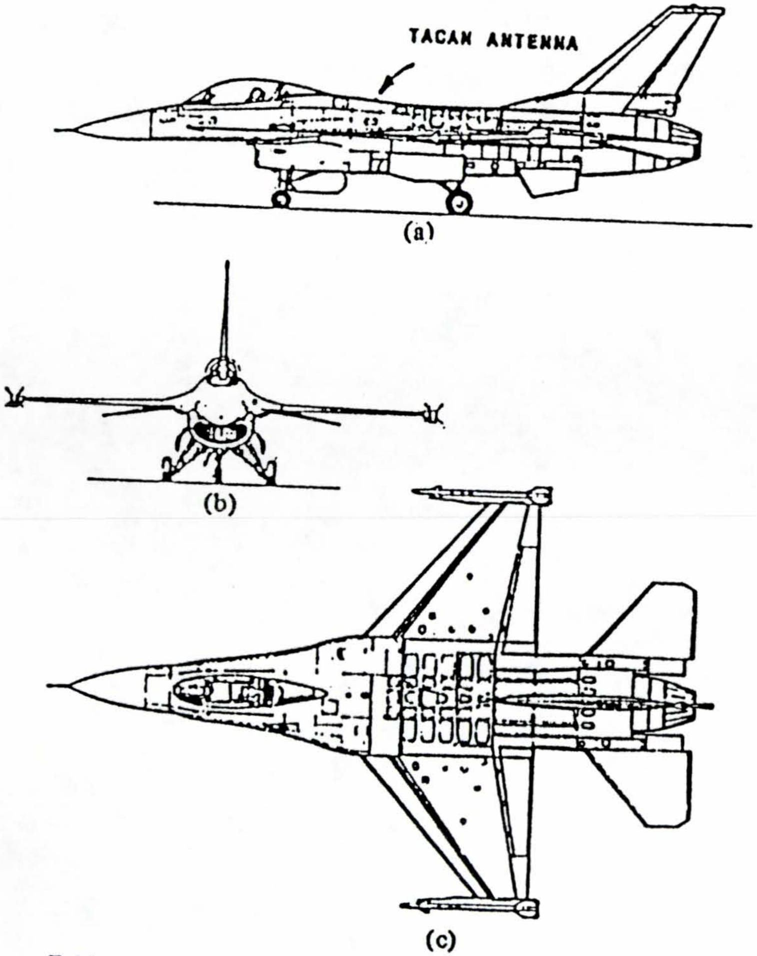
Testing and Verification

- **Far-field and near field patterns.**
  Will be verified by comparing our data against published theoretical and experimental data, as well as, data provided by NATC.

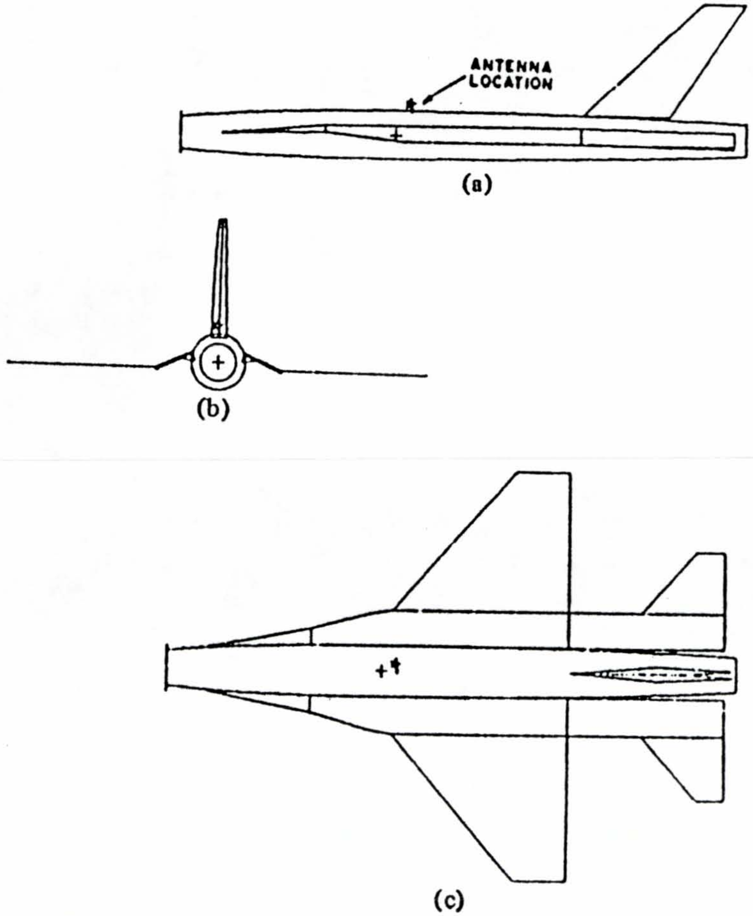
- **3-D plots**
  Can be verified by comparing our results with available in flight measurements from NATC. Some additional in-flight measurements may be required for further verification of this part.

TASK 5: TECHNICAL RISK ISSUES
MODELING OF ANTENNA PATTERN EFFECTS

Findings:



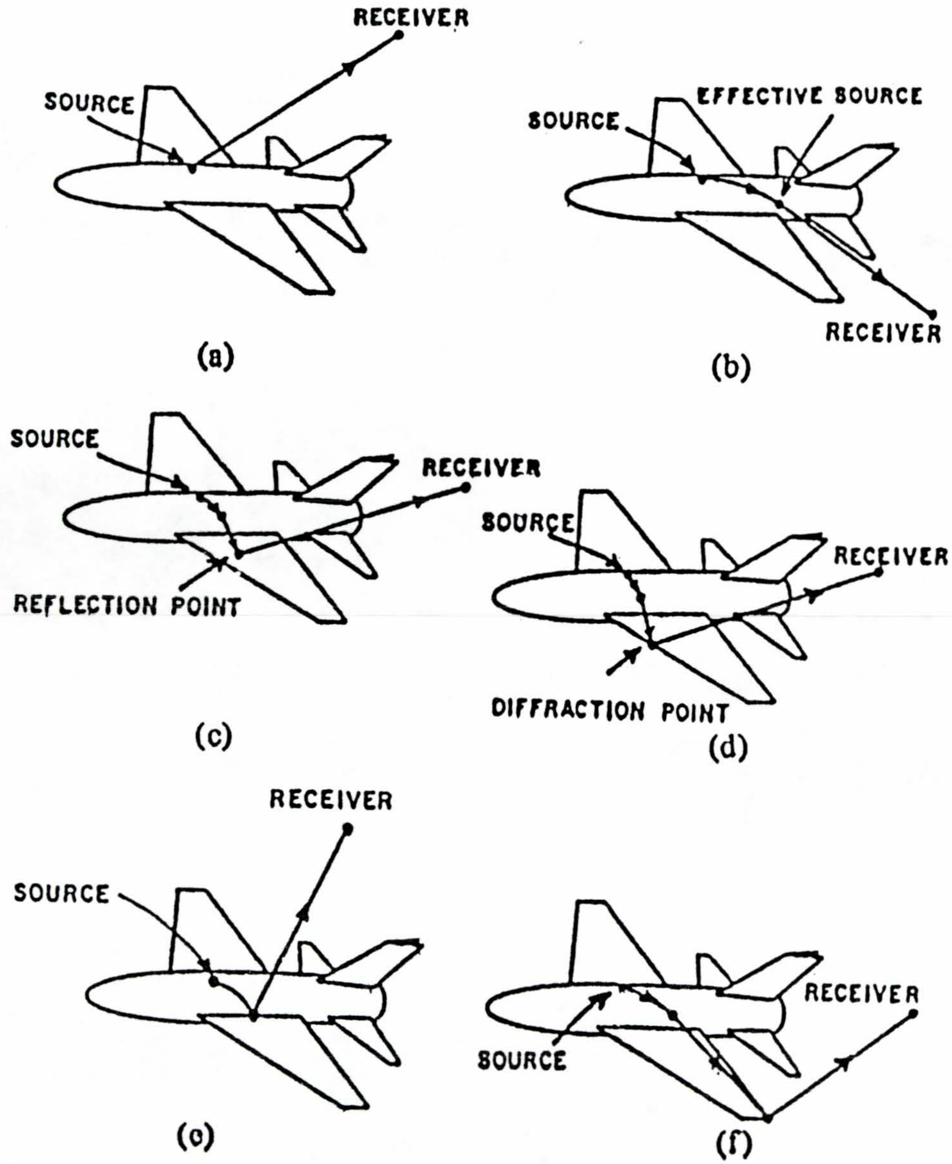
F-16 fighter aircraft. (a) Side view. (b) Front view. (c) Top view.



Computer simulated model of an F-16 fighter aircraft. (a) Side view (b) Front view. (c) Top view.

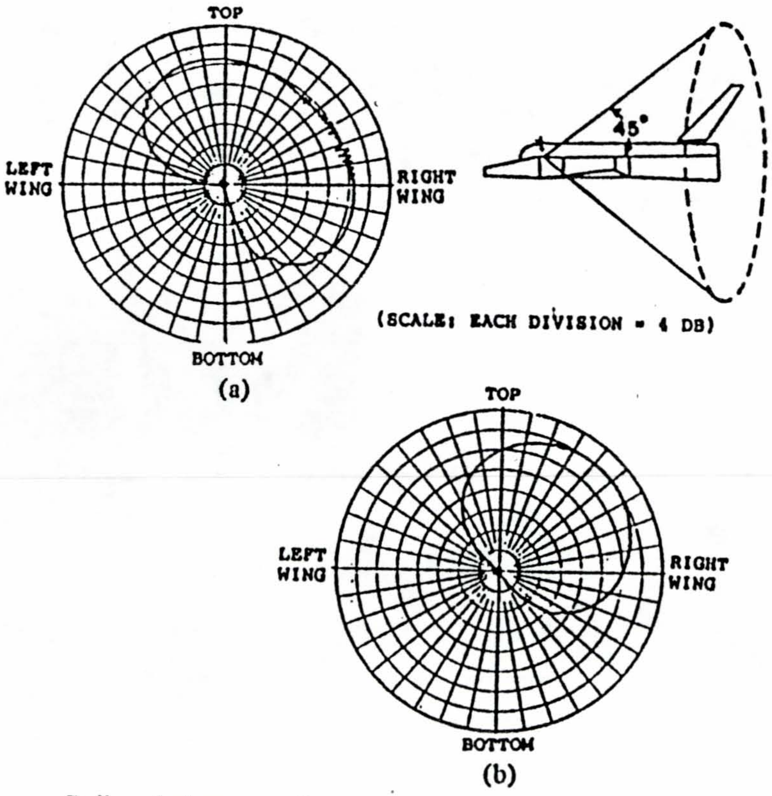
TASK 5: TECHNICAL RISK ISSUES
MODELING OF ANTENNA PATTERN EFFECTS

Findings:



TASK 5: TECHNICAL RISK ISSUES
MODELING OF ANTENNA PATTERN EFFECTS

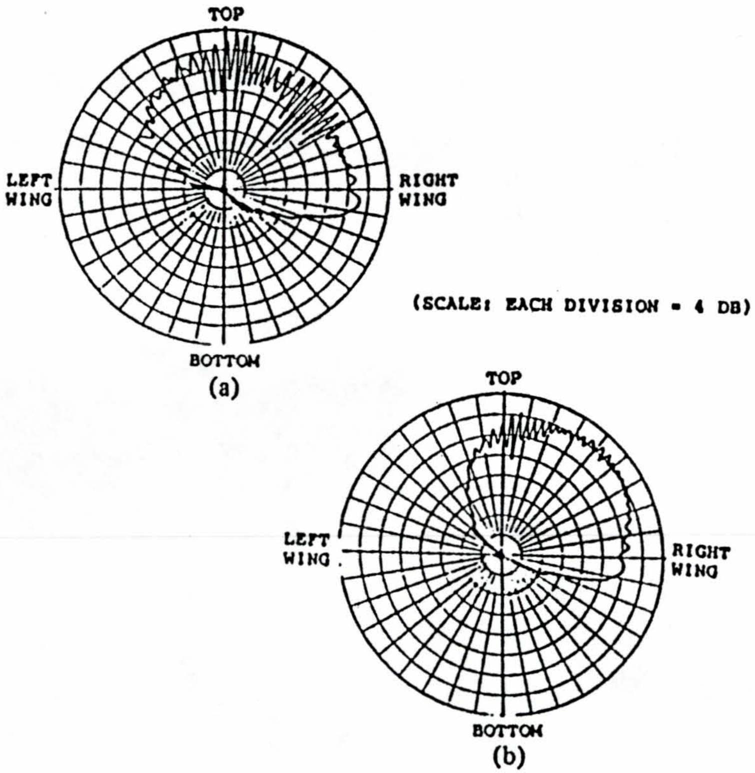
Findings:



Roll conical patterns ($\theta_p = 45°$) for a crossed-slot antenna mounted on the top of a space shuttle orbiter when the payload bay doors are *closed*. (a) E_ϕ. (b) E_θ.

TASK 5: TECHNICAL RISK ISSUES
MODELING OF ANTENNA PATTERN EFFECTS

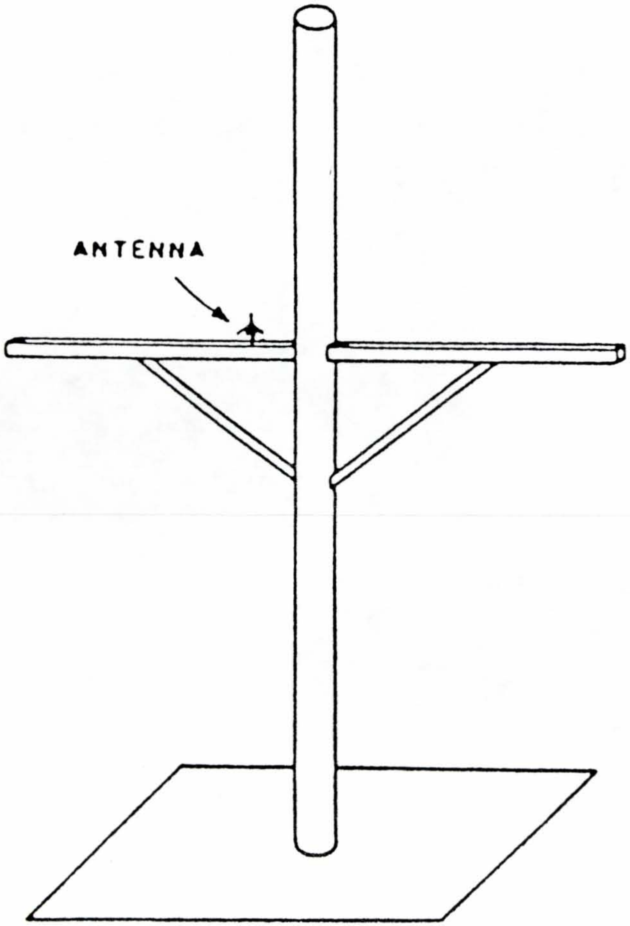
Findings:



Roll conical patterns ($\theta_p = 45°$) for a crossed-slot antenna mounted on the top of a space shuttle orbiter when the payload bay doors are *open*. (a) E_ϕ. (b) E_θ.

TASK 5: TECHNICAL RISK ISSUES
MODELING OF ANTENNA PATTERN EFFECTS

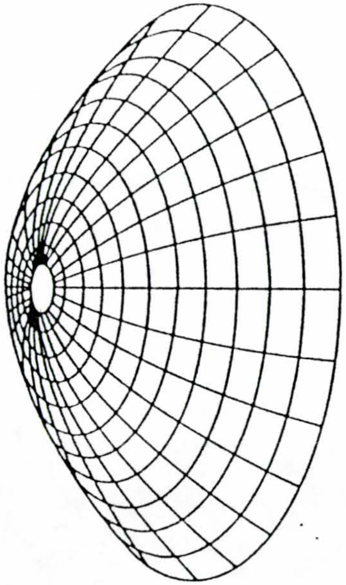
Findings:



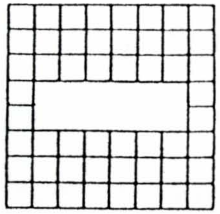
Example of an antenna in a typical shipboard environment.

TASK 5: TECHNICAL RISK ISSUES
MODELING OF ANTENNA PATTERN EFFECTS

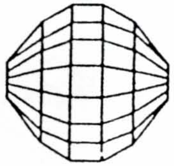
Findings:



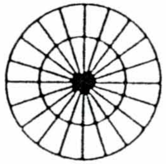
Parabolic reflector



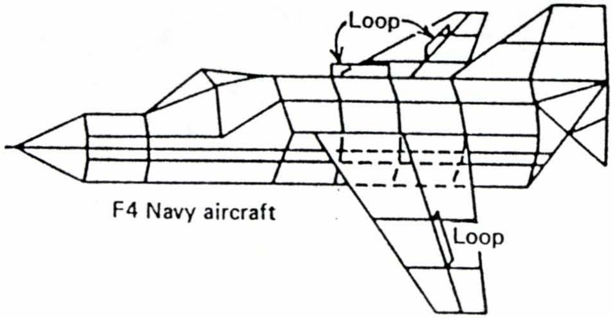
Slot in flat plate



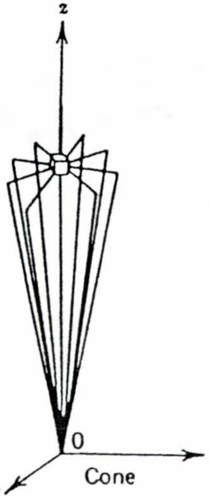
Sphere



Circular disk



F4 Navy aircraft

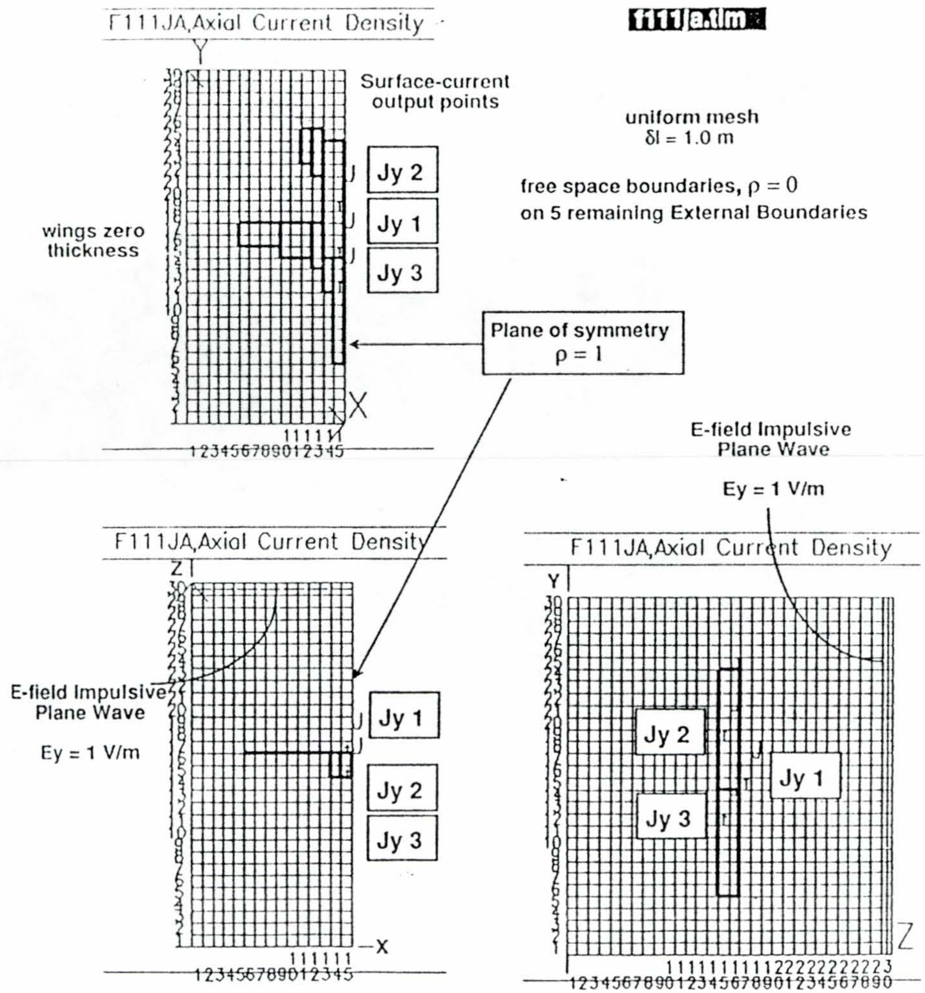


Cone

TASK 5: TECHNICAL RISK ISSUES
MODELING OF ANTENNA PATTERN EFFECTS

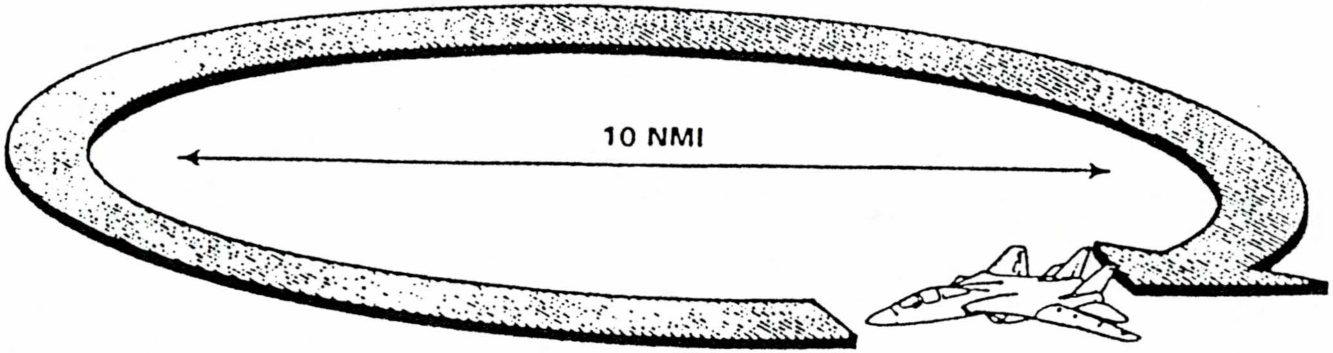
Findings:

TLM model of an F111 aircraft illuminated by an E-field plane wave along the fuselage to predict axial current densities J_A

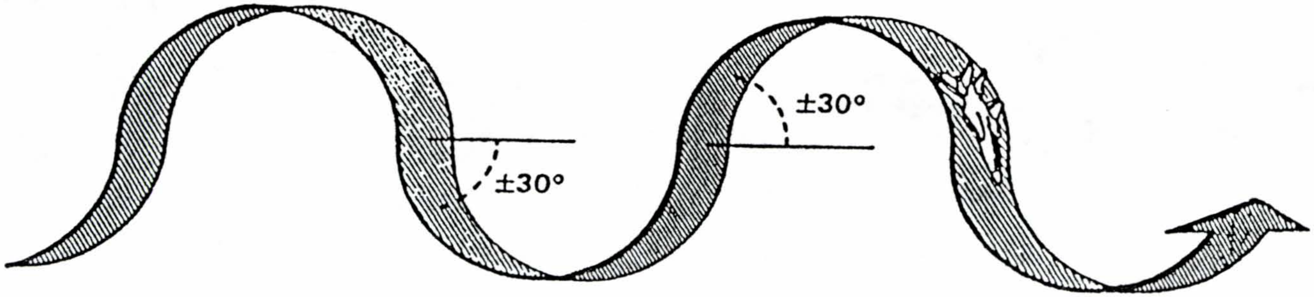


TASK 5: TECHNICAL RISK ISSUES
MODELING OF ANTENNA PATTERN EFFECTS

Findings:



Orbit Turn



Porpoise

TASK 5 TECHNICAL RISK ISSUES
MODELING OF ANTENNA PATTERN EFFECTS

Findings.

- The near field and far field patterns can be incorporated in terms of power, gain, directivity, phase and polarization.
- The angular resolution needed to accurately model the antenna gain is one degree in both azimuth and pitch. Since the computation time of this parameter must be kept minimal, a table look-up file will be used to implement the antenna gain factor into the real-time computer algorithm.

Conclusion.

- The need and unique ability of simulation modeling to easily generate three dimensional antenna patterns is critical to TESTS.

TASK 5 TECHNICAL RISK ISSUES
OTHER CRITICAL REQUIREMENTS ISSUES

In addition to the ten technical risk issues identified by the Navy, IST identified a number of additional technical issues that needed to be examined during the Feasibility Assessment. This issues include:

- Propagation Effects
- Validation and Verification
- Simulation of Real Time Response
- Simulation of Multiple Interrogators and Transponders
- Secure Transmission Modes
- TESTS Hardware/Software Allocation

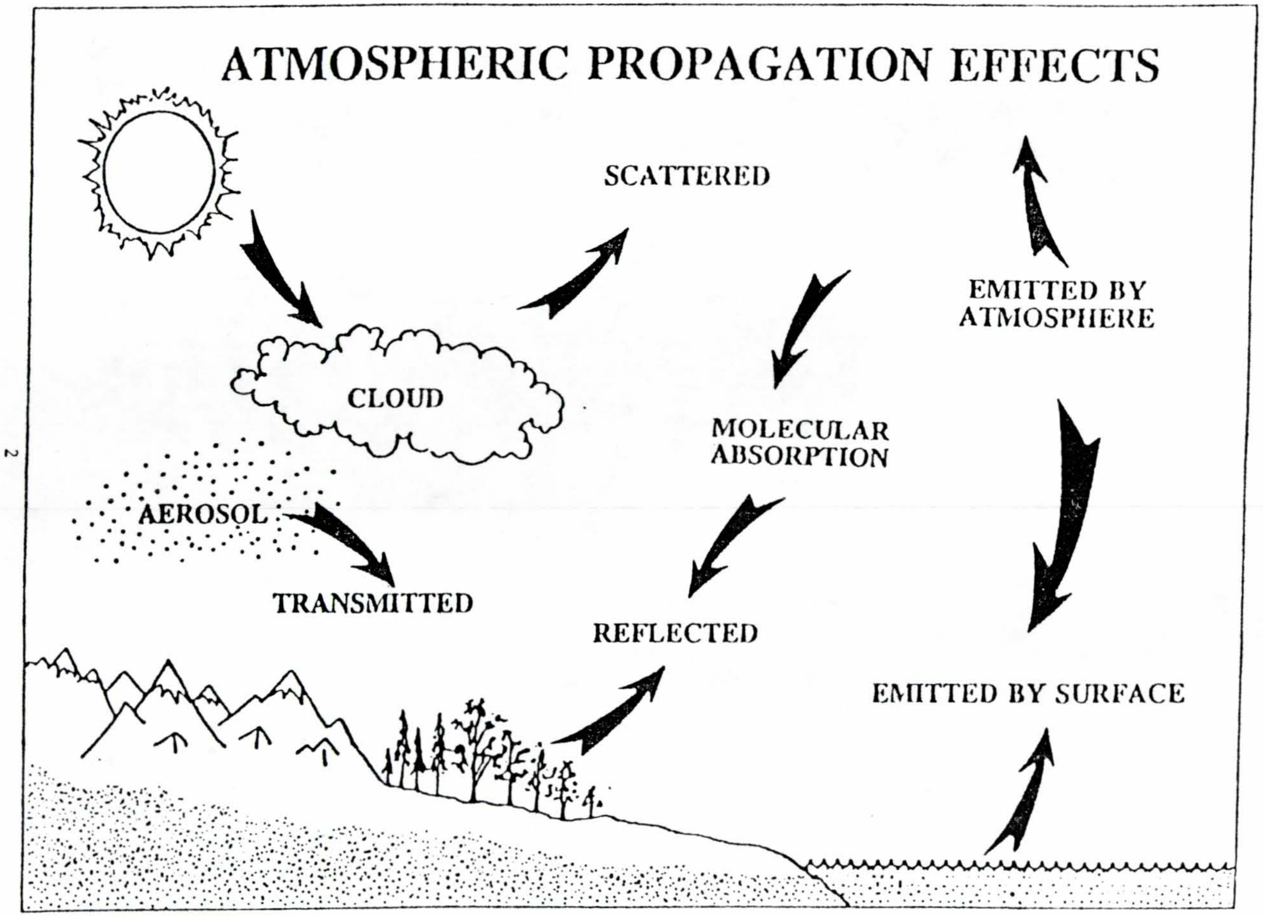
TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES
PROPAGATION EFFECTS

STATEMENT OF THE PROBLEM

Major propagation factors that can affect the behaviour of the electromagnetic wave

* Atmospheric Absorption
* Tropospheric/Ionospheric Scintillation
* Ducting
* Multipath Fading
* Dust and Sand
* Depolarization

TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES
PROPAGATION EFFECTS



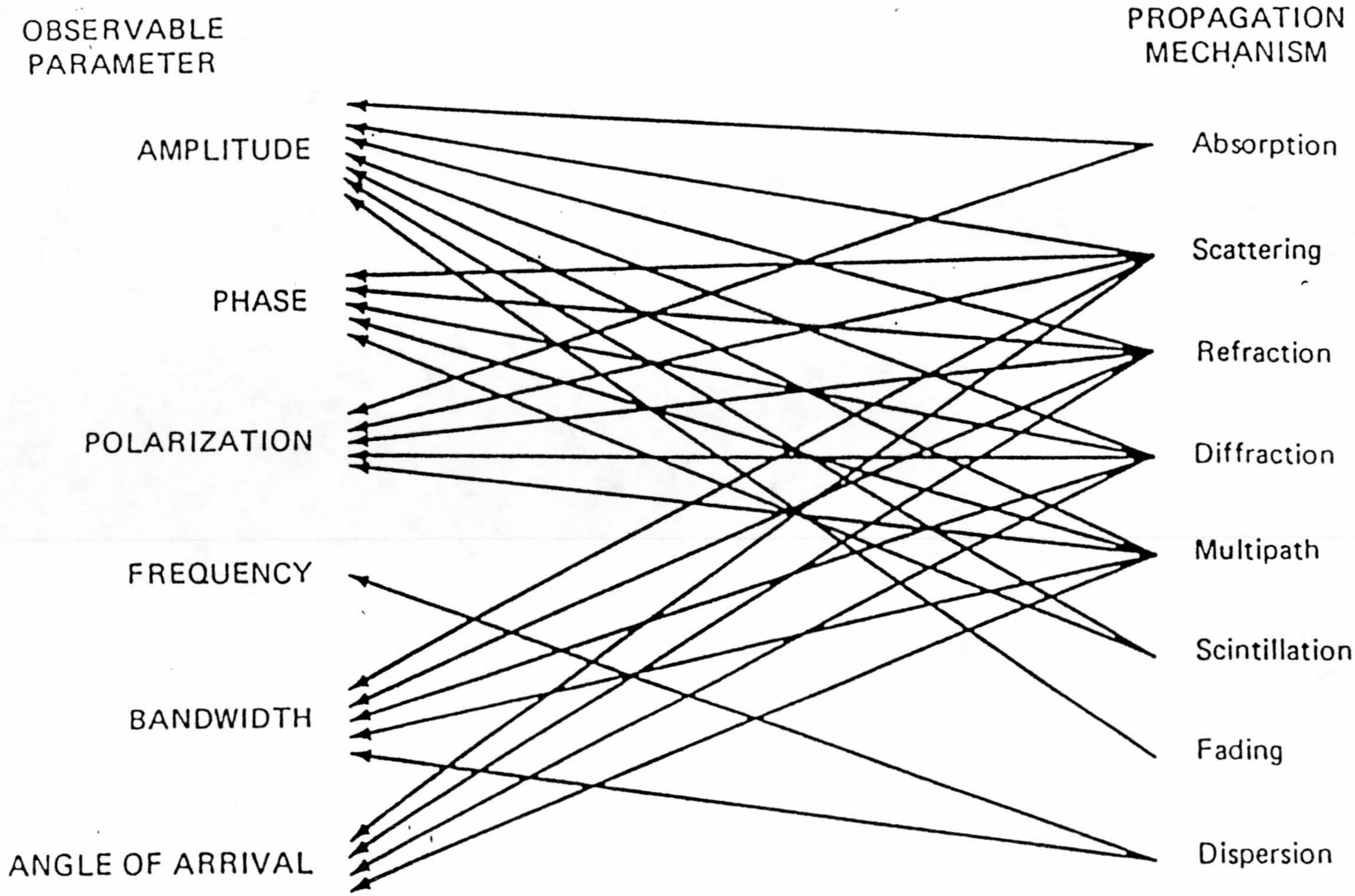
TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES
PROPAGATION EFFECTS

Parameters that can be observed or measured

* Amplitude
* Phase
* Polarization
* Frequency
* Bandwidth
* Angle of arrival

TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES

PROPAGATION EFFECTS



TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES
PROPAGATION EFFECTS

ATMOSPHERIC ATTENUATION

The presence of rain, fog, cloud, hail, ice or snow in the propagation path can modify the transmitted signal and cause major impairments to the communication system as a whole. Rain drops absorb and scatter the electromagnetic wave, resulting in signal attenuation. Hail, ice and snow play a minor role in producing attenuation of the signal as compared to rain, clouds and fog.

The attenuation of a wave propagating in a volume of rain of extent L in the direction of propagation is expressed as

$$A = \int_0^L \alpha \, dx \qquad 1$$

For a plane wave of transmitted power P_t incident on a volume of uniformly distributed spherical water drops, of radius r, extending over a length L, the received power P_r is

$$P_r = e^{-kL} \qquad 2$$

where k is the attenuation coefficient for the rain volume in units of reciprocal length.

The attenuation of the wave, is given by

$$A = 10\log_{10}\frac{P_t}{P_r} \qquad db \tag{3}$$

using (1),

$$A = 4.343\, kL \qquad db \tag{4}$$

The attenuation coefficient is expressed as

$$k = \rho\, Q_t \tag{5}$$

where ρ is the drop density, i.e. the number of drops per unit volume and Q_t is the attenuation cross section. Q_t is a function of the drop radius, r, the wavelength λ, of the wave and the complex refractive index of the water drop, m. That is,

$$Q_t(r,\lambda,m) = Q_s + Q_a \tag{6}$$

Q_s is the scattering cross section and Q_a is the absorbtion cross section.
In gereral the attenuation coefficient can be expressed as

$$k = \int Q_t(r,\lambda,m)\, n(r)\, dr \qquad 7$$

where n(r) is the drop size distribution.
The specific attenuation in db/km is

$$\alpha = 4.343 \int Q_r(r,\lambda,m)\, n(r)\, dr \qquad 8$$

The above result demonstrates the dependance of rain attenuation on drop size, drop size distribution, rain rate and attenuation cross section. The first three parameters are characteristics of the rain structure only. It is through the attenuation cross section that the frequency and temperature dependance of rain attenuation is determined. All of the parameters exhibit time and spatial variations which are random in nature and hence predictions of rain attenuations must depend on statistical methods of analyses.

TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES

PROPAGATION EFFECTS

The distribution of rain drop size as a function of the rain rate and type of storm activity can be represented by an exponential of the form

$$n(r) = N_0 e^{-br} = N_0 e^{-cR^{-d}} dr \qquad 9$$

where R is the rain rate in mm/h and r is the drop radius. N_0, b,c and d are emperical constants determined from measured distributions.

The specific attenuation can now be expressed as

$$\alpha = 4.343 N_0 \int Q_t(r, \lambda, m)\, e^{-br} dr \quad db/km \qquad 10$$

The total rain attenuation over a given path L is then given by

$$A = 4.343 \int_0^L \left[N_0 \int Q_t e^{-br} dr \right] dx \quad db \qquad 11$$

The specific attenuation produced on the wave path can be approximated by

$$\alpha = aR^b \qquad db/km \qquad 12$$

where a and b are frequency and temperature dependent constants.

TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES
PROPAGATION EFFECTS

MODELS FOR RAIN ATTENUATION PREDICTION

Almost all prediction models use surface measured rain rate as the statistical varible and assume the aR^b relationship to determine the rain attenuation. The prediction models can be expressed in the form

$$A(db) = aR^b L(R) \qquad 13$$

where L(R) is an effective path length parameter.

RICE-HOLMBERG MODEL

This model constructs a rain rate distribution by assuming that the rain structure can be divided into two types - thunderstorm rain and all other rain. The sum of these two modes produces the total distribution.

DUTTON-DOUGHERTY MODEL

This model is based on meteorological consideration of the proagation path. It provides atmospheric attenuation, i.e. gaseous, cloud and rain attenuation. The model has been updated to provide a more flexible procedure for general use.

TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES
PROPAGATION EFFECTS

CCIR RAIN ATTENUATION MODEL

This model determines an annual attenuation distribution at a specified location from an average year rain rate distribution. It employs three separate methods for maritime climates, continental climates and tropical climates.

EREPS: SOFTWARE PACKAGE

This software package from the Naval Ocean Systems Center can simulate and predict the effect of water vapor absorption and diffraction on the performance of a radar system.

RESEARCH

The above models can acheive 80% of our objectives. Further research will be conducted to expand the capability of these models and to introduce more detailed effects of the scattering and depolarization.

TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES
PROPAGATION EFFECTS

TROPOSPHERIC/IONOSPHERIC SCINTILLATION

Scintillation, the rapid fluctuation of the signal parameters caused by time-dependent irregularities in the path of the wave. The amplitude, phase, polarization and angle of arrival of the wave are affected by scintillations. Scintillation effects are produced in the troposphere and in the ionosphere, however, the mechanisms and characteristics for each differ.

Ionospheric scintillations, produced by electron density fluctuations approximately 200-400 km in altitude, are prevalent in the equatorial regions and high latitude locations. A detailed analytical procedure to predict the ionospheric scintillations is difficult to attain. Approximate solutions of the wave propagation model for a volume of random refractive index irregularities for specialized conditions are available.

Tropospheric scintillation is produced by refractive index fluctuations in the first few kilometers of altitude and is caused by high humidity gradients. The effects are dependent on the seasons and vary with the local climate. The troposphere can,as a first approximation, be considered as being horizontally stratified with refractive index of the thin layers changing with altitude.

TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES
PROPAGATION EFFECTS

AVAILABLE MODELS

Ionospheric Scintillation

Born Approximation	Weak scintillation produced by a thin region or a single dominant irregularity
Rytov Approximation	Weak scintillation and a thick irregularity region
Single Thin Phase Screen	Strong scintillation and a thin layer
Markov Approximation	Strong scintillation and a thick layer

TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES
PROPAGATION EFFECTS

Tropospheric Scintillation

EREPS: REFRACTIVE EFFECTS PREDICTION SYSTEM

Developed by the Naval Ocean Systems Center Tropospheric Branch, Ocean and Atmospheric Sciences Division. This package can accurately predict the propagation effects of refraction and tropospheric scatter.

CCIR TROPOSPHERIC SCINTILLATION MODEL

ECAC SOFTWARE PACKAGE

TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES
PROPAGATION EFFECTS

RESEARCH

The above mentioned models can acheive about 70% of our objectives. Further research is needed to arrive at more detailed models especially for the S and X bands.

PROPOSED TESTING AND VERIFICATION

Results obtained will be compared with measured data available in the literature.

TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES
PROPAGATION EFFECTS

ATMOSPHERIC DUCTING

* The propagation of electromagnetic waves is affected by the earth's surface and its atmosphere.

* Ducting can occur when

  The temperature of the sea or land surface is appreciably less than that of the air - temperature inversion

  The upper air is exceptionally warm and dry in comparison with the air at the surface

  Due to the movement of warm dry air from land over cooler bodies of water.

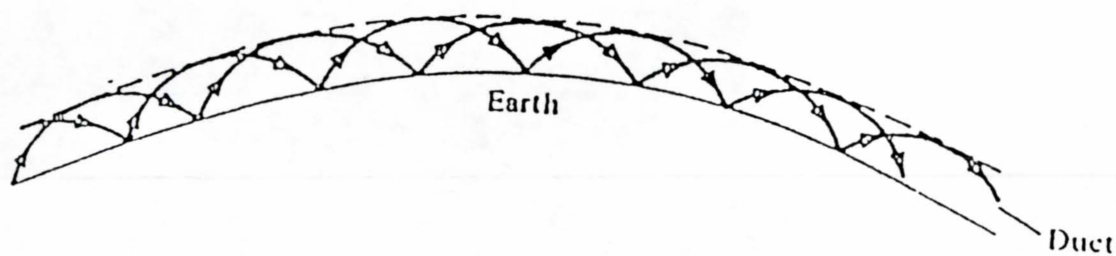
TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES
PROPAGATION EFFECTS

* When propagating within a duct, the waves are bent or refracted.

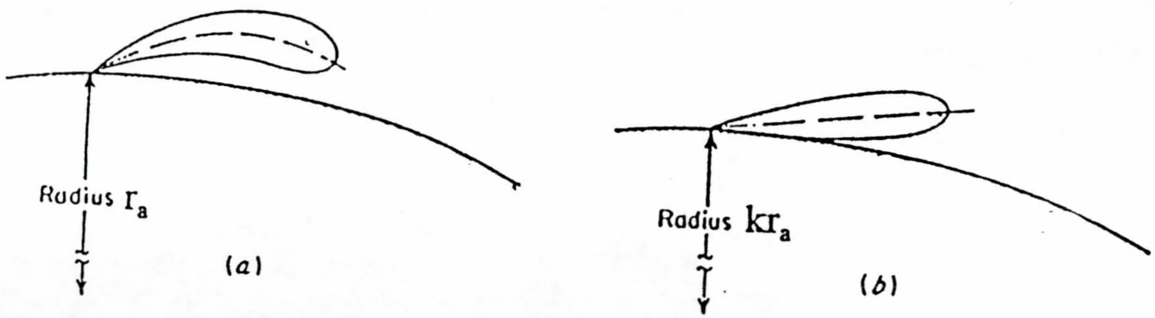
* The extension of the radar range results in a reduction of coverage in other directions.

* The regions of reduced coverage are called radar holes.

TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES
PROPAGATION EFFECTS



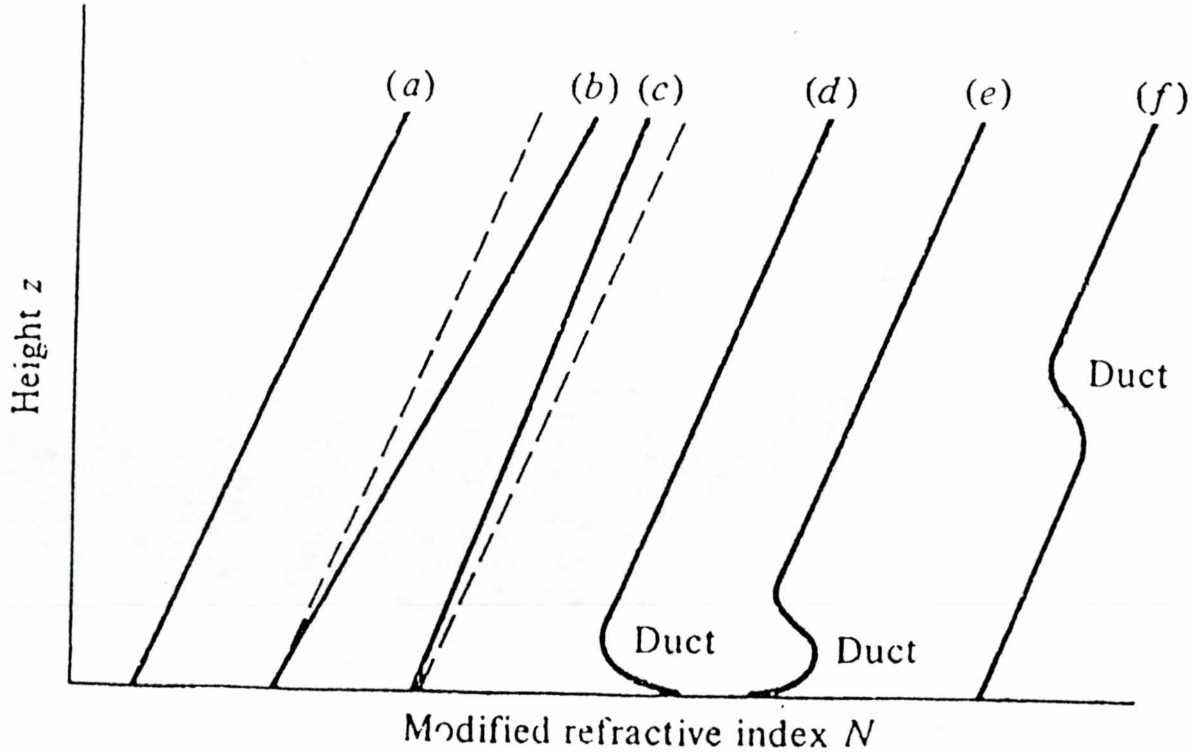
TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES
PROPAGATION EFFECTS



(a) Bending of antenna beam due to refraction by the earth's atmosphere; (b) shape of beam in quivalent-earth representation with radius Kr_a

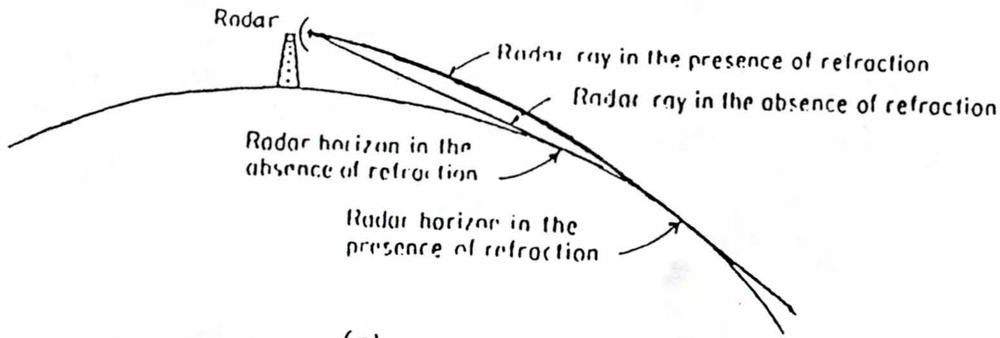
TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES

PROPAGATION EFFECTS

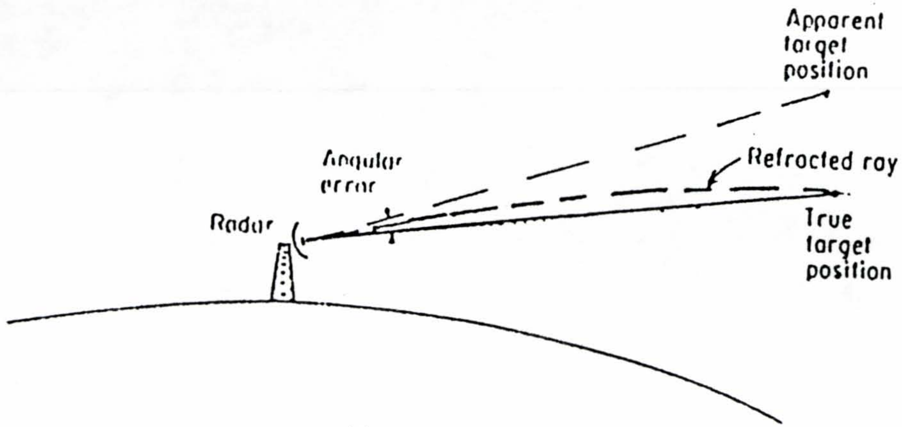


Modified index of refraction profiles; (a) standard atmosphere; (b) substandard refraction; (c) profile for superrefraction; (d) profile for surface duct; (e) profile for nearsurface duct; and (f) profile for elevated duct.

TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES
PROPAGATION EFFECTS



(a)



(b)

TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES
PROPAGATION EFFECTS

The variation of refraction with height can be modeled in a linear or exponential form. At microwave frequencies, the linear model is used:

$$N = (n-1)\,10^6 = 77.6\frac{P}{T} + 3.373 \times 10^5\,\frac{e}{T^2} \qquad 14$$

where P = barometric pressure, mbar (1mm = 1.3332 mbar)
e = partial pressure of water vapor, mbar

T = absolute temperature, K
N = the refractivity, the "scale up" index of refraction.

The index of refraction of the earth's surface is 1.0003 and in a standard atmosphere, the index decreases at the rate of about 4E-10 m^{-1} of height.

For purposes of computation, the atmospheric refraction is accounted for by a factor k. This factor k when multiplied by the actual radius r_a of the earth will yield the effective radius $r_e = k\,r_a$, and the actual atmosphere is replaced by a homogeneous atmosphere in which the waves will travel in straight lines rather than curved lines as shown in Figure 4. The value for k can then be written as

$$k = \frac{1}{1 + r_a\left(\frac{dn}{dh}\right)} \qquad 15$$

dn/dh = rate of change of the earth's atmospheric refractive index n with altitude h above the earth's surface. Usually dn/dh < 0.
r_a = actual radius of the earth.

TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES
PROPAGATION EFFECTS

The standard refraction is used when the index of refraction decreases uniformly with altitude in such a manner that k = 3/4.

The horizontal distance from the radar at a height h is calculated as

$$d = \sqrt{2kr_a h}$$

for k = 3/4

$$d = \sqrt{2h(ft)} \qquad statue miles$$
$$d = 1.23\sqrt{h(ft)} \quad nautical miles$$
$$d = 130\sqrt{h(km)} \quad km$$

The use of r_e in the linear model implies that n decreases linearly with height. However, for the height above 1 km the experimental results are in disagreement with the linear model. A more accurate model is one in which the refractivity varies exponentially with height

$$N = N_s \exp(-C_e(h_t - h_r))$$

where N_s = refractivity at the surface of the earth
h_t = altitude of the target

h_r = altitude of the radar
$C_e = \ln(N_s/N_1)$ = constant depending on N_s and N_1, the refractivity at an altitude of 1 km.

TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES

PROPAGATION EFFECTS

A simplified model of propagation in the atmospheric ducts gives the maximum wavelength that can be propagated in a surface duct as

$$\lambda_{max} = 2.5\left(-\frac{\Delta n}{\Delta h}\right)^{\frac{1}{2}} d^{\frac{3}{2}}$$

where d = depth of the surface duct
Δh = altitude above the ground
λ_{max}, d, Δh have the same units.

For $\Delta n/\Delta h$ = - 1.57E-7 m^{-1} at the X band, λ = 3 cm and d must be greater than 10m. In the S band, λ = 10 cm and d must be greater than 22m.

TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES
PROPAGATION EFFECTS

RESEARCH

The available models can acheive 30% of our objectives. Extensive research is required in this area to cover all aspects of the effects of ducting.

PROPOSED VERIFICATION AND TESTING

The results obtained from models generated will be compared with available measured data.

TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES
PROPAGATION EFFECTS

AVAILABLE MODELS

ECAC Software Package

EREPS: Engineer's Refractive Effects Prediction System

This model can simulate the effects of surface-based ducting.

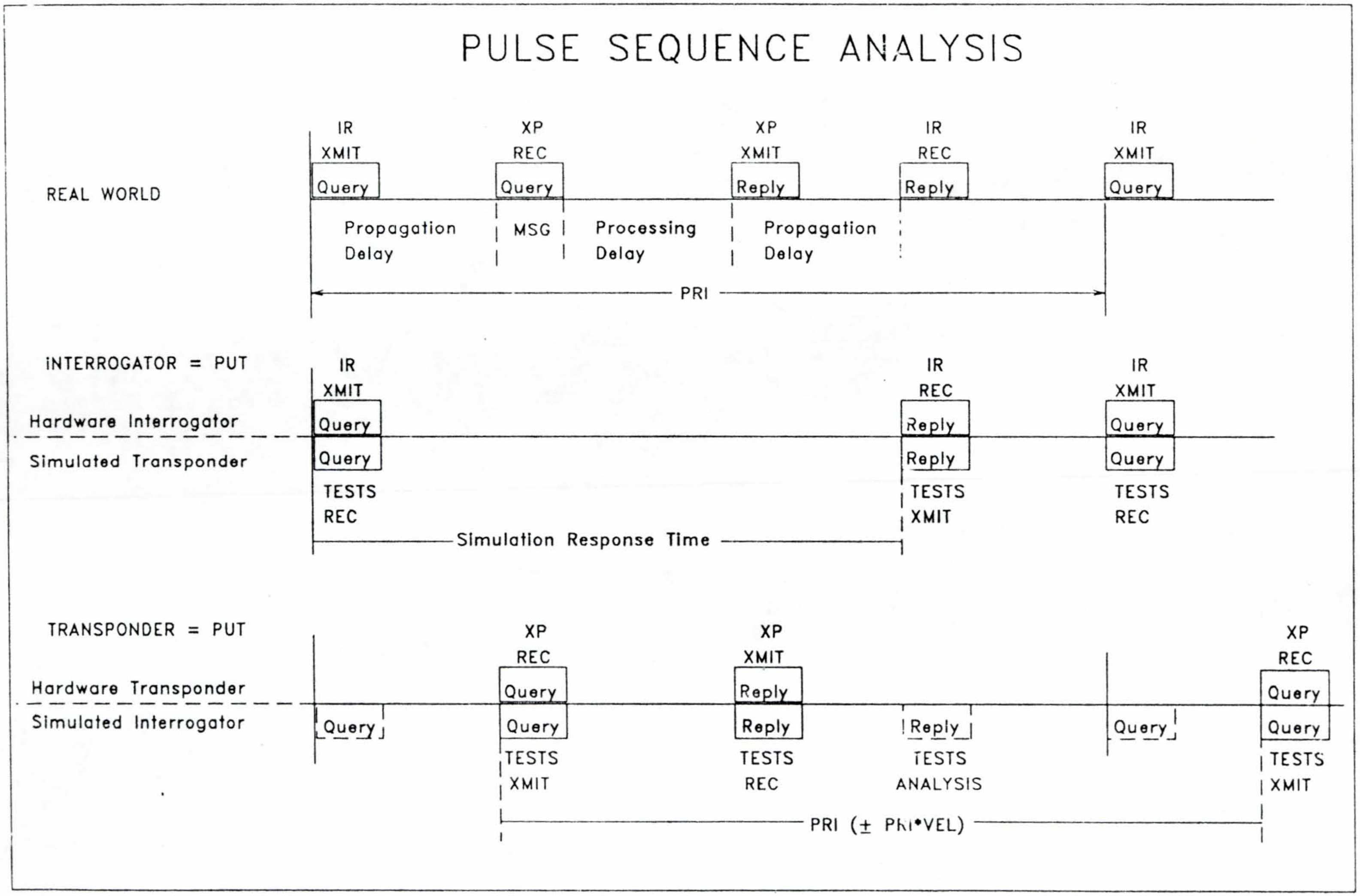
TASK 5 TECHNICAL RISK ISSUES
VALIDATION AND VERIFICATION

- Subsystem element software models will be verified at the element level with respect to other analysis and existing flight data.
  - Antenna Patterns
  - Propagation Effect Levels, etc.
- Simulator system will be verified and calibrated using scenarios (collected data) of existing flight information.
- Validation and Verification of TESTS will not require any unique data, i.e., data requirements will be compatible with those needed for other analyses associated with the development of the NGIFF.
- Where new flight test data is required, it will identified early in the project so that it can be "piggy-backed" on other normal flight test activities, thereby minimizing flight test and cost impact.

TASK 5 TECHNICAL RISK ISSUES
SIMULATION OF REAL-TIME RESPONSE

- Figure presents a quick look analysis of the pulse sequences required to stimulate or respond to actual IFF equipment in real-time for either MK XII or MK XV.
- Figure further illustrates how this pulse pattern could be simulated by TESTS, where the SUT may be either an interrogator or a transponder.
- If the SUT is an interrogator, the required response time depends upon the round trip propagation delays, the message lengths and the transponder processing delay. For a worst case condition at zero range, the TESTS simulator response time would have to be equal to that of an actual transponder.
- If the SUT is a transponder, the PRI of the simulated interrogator is the critical factor, and for a moderately high Interrogation Rate of 500 / sec, the PRI yields a much less stringent response time requirement on the order of 2000 micro-seconds.

TASK 5 TECHNICAL RISK ISSUES
SIMULATION OF REAL-TIME RESPONSE



TASK 5 TECHNICAL RISK ISSUES
SIMULATION OF REAL TIME RESPONSE

PROCESSING DELAY TIMES FOR DIFFERENT TRANSPONDERS/MODES

		PROCESSING DELAY
MK XII	SIF MODES	3 MICROSECONDS
MK XII	MODE 4	(CLASSIFIED)
MK XV	(ALL)	(CLASSIFIED)

TASK 5 TECHNICAL RISK ISSUES
SIMULATION OF MULTIPLE TRANSPONDERS & INTERROGATOR

- MK XV TEMP Objectives require the testing of the System Under Test in realistic scenarios where many additional transponders and interrogators will be operating simultaneously.
- As the number of IFF messages is increased (reply rate, or interrogation rate), the probability of message overlap at the receiver of the SUT likewise increases.
- A parametric analysis was performed to determine the maximum number of message overlaps that occur within a cumulative probability of 99.9%.
- TESTS must be able to provide at least the same number of independent emitters (n) as the number of simultaneous overlapping signals that we wish to simulate.
- Somewhere between 2 and 10 independent RF signal emitters will be sufficient to achieve the signal density environments required.

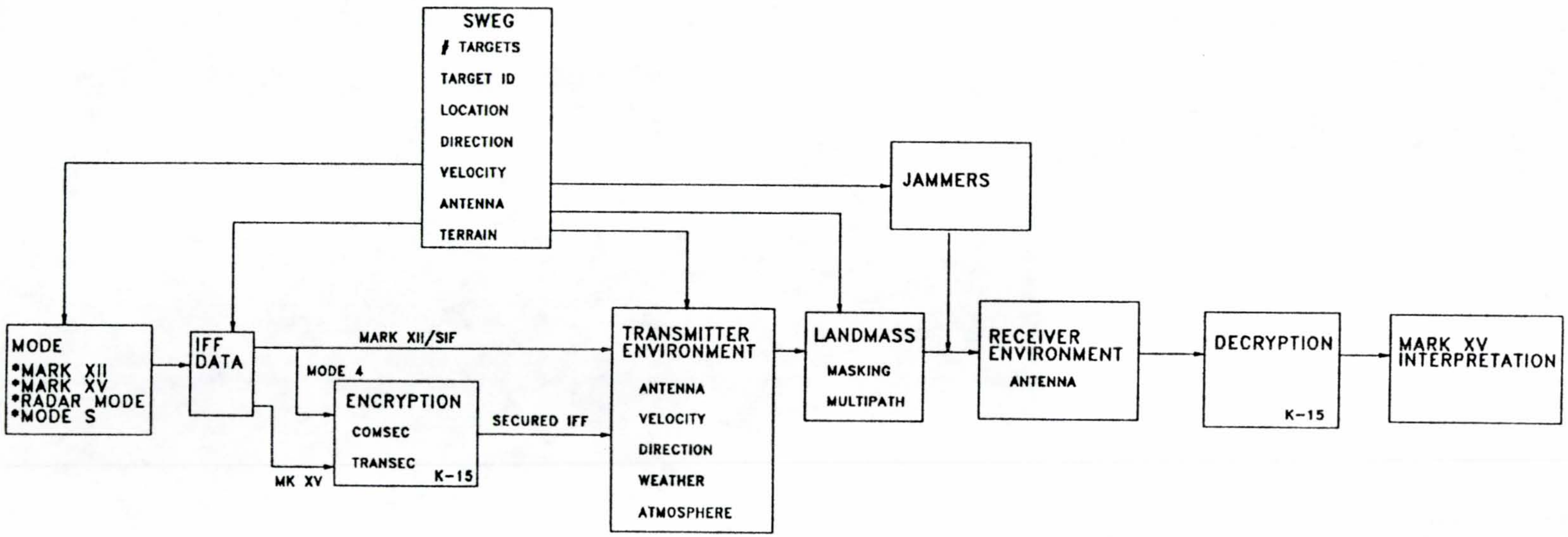
TASK 5 TECHNICAL RISK ISSUES
SECURE TRANSMISSION MODES

- MK XII Mode 4 utilizes the security codes generated by KIT/KIR equipment to provide secure and encrypted IFF transmissions.
- Embedded MK XII Mode 4, and all MK XV transmission modes utilize the COMSEC / TRANSEC codes generated by the KI-15 equipment to provide secure and encrypted IFF transmissions.
- The NSA has indicated that they would make available the interface (pin-out) information for the K-15 as they have for the KIT/KIR.
- In order to test encrypted modes, when interfacing with an actual transponder or interrogator as the SUT, the TESTS tool will have to perform the complementary encryption / decryption functions.

TASK 5 TECHNICAL RISK ISSUES
HARDWARE/SOFTWARE ALLOCATION

- The most critical design decision of the TESTS concept is the division between hardware and software functions.
- Impacts the requirements for TESTS host computer processing speeds, and the data transfer rate between the TESTS processor and the TESTS hardware signal generators.
- Theoretically, the interface or transition boundary between software and hardware can occur anywhere along this continuum.
- The task is to determine the optimum tradeoff in terms of cost and performance.
- Overriding these factors is technical feasibility and risk.
- The four concepts examined for TESTS varied along this continuum from primarily software to primarily hardware.

TASK 5: OTHER CRITICAL REQUIREMENTS ISSUES
HARDWARE/SOFTWARE ALLOCATION



TASK 6: USER INTERFACE REQUIREMENTS
DEFINITION AND APPROACH

Task Definition: An assessment of the user interface to access and control the TESTS simulation model environment.

Technical Approach: Interviews with NAVAIRTESTCEN personnel to determine potential end users, review of SWEG and ACETEF interface documents, review of TESTS conceptual design, review of Draft Navy inputs to the IFF Combined Test Force, and examinination of relevant user interface design guidelines.

TASK 6 USER INTERFACE REQUIREMENTS

Findings and Conclusions:

Two existing capabilities at NAVAIRTESTCEN will impact the user interface for TESTS; SWEG and interface standards for the IFF Data Center. New TESTS user interface requirements will be designed to maximize compatibility.

Because TESTS might eventually be extended to aid Operational T&E, there may be two very different user populations.

Because of the possibility of multiple user populations and multiple data entry routines (SWEG and TESTS specific) the need for a user interface "shell" will be examined.

TASK 7: REVIEW OF PERFORMANCE CRITERIA
DEFINITION AND APPROACH

Task Definition: Assessment of the performance criteria necessary to validate the performance of TESTS against MK XV, and identify design drivers for TESTS.

Technical Approach: Review and analysis of MK XV specifications and discussions with NAVAIRTESTCEN and NRL personnel. Several technical briefings by government personnel were received which contributed to this task.

TASK 7 REVIEW OF MK XV PERFORMANCE CRITERIA

Findings and Conclusions:

The primary design driver is the number of platforms/ emitters. However, this factor can not be addressed in isolation because it interacts with and is modified by a variety of other factors including duty cycle, field-of-view of the primary sensor, etc. These confounding factors are also very complex, e.g., field-of-view of the primary sensor is affected by scan rate, rate of change of platform orientation and range.

The second design driver is the requirements for timing accuracy, both in pulse width and COMSEC/TRANSEC intervals The ability to handle this requirement has a large impact on TESTS performance.

TASK 8: FEASIBILITY ASSESSMENT
DEFINITION AND APPROACH

Task Definition: The feasibility assessment involved the integration and analysis of the findings of Tasks 1-7. This analysis identified design studies required to examine technical issues, which were conducted under Task 11.

Technical Approach: Individual analysis of specific technical areas, small group meetings to discuss integrate technical analysis and design concepts, and large group meetings to exchange and discuss general issues. Discussions were also held with NAVAIRTESTCEN personnel.

TASK 8 FEASIBILITY ASSESSMENT

Findings and Conclusions:

A directed and systematic research plan will be required to define the parameters necessary to implement channel effects in TESTS. The necessary data does not exist in the available literature. However, there does not appear to be any reason that this data can not be generated.

A hybrid hardware/software approach is required for TESTS. To meet performance requirements a higher degree of functionality will need to be implemented in hardware than originally hoped for.

Current state-of-the-art hardware components can be used to meet both signal generation requirements and interface requirements.

TASK 9: SCENARIO ASSESSMENT
DEFINITION AND APPROACH

Task Definition: Examine current approaches to scenario development at NAVAIRTESTCEN and scenario capabilities within SWEG.

Technical Approach: Briefings by NAVAIRTESTCEN personnel were received on SWEG and procedures for developing IFF test scenarios in the IFF Data Center. The data in the MK XV TEMP and Draft U.S. Navy inputs to the Combined Test Force were reexamined.

TASK 9 SCENARIO ASSESSMENT

Findings and Conclusions:

The IFF Data Center has standardized procedures for generating test scearios, which can be customized as needed. These custom scenarios are used instead of a fixed data base of canned scenarios.

SWEG currently only has capabilities for generating air-to-air scenarios. Capability to conduct air-to-ground scenarios is a planned improvement over the next several years. Will eventually have four scenarios (environments) which should meet the basic needs of TESTS. A number of additional features, which will enhance the scenario flexibility within SWEG, are planned.

TASK 10: CONCEPTUAL DESIGN
DEFINITION AND APPROACH

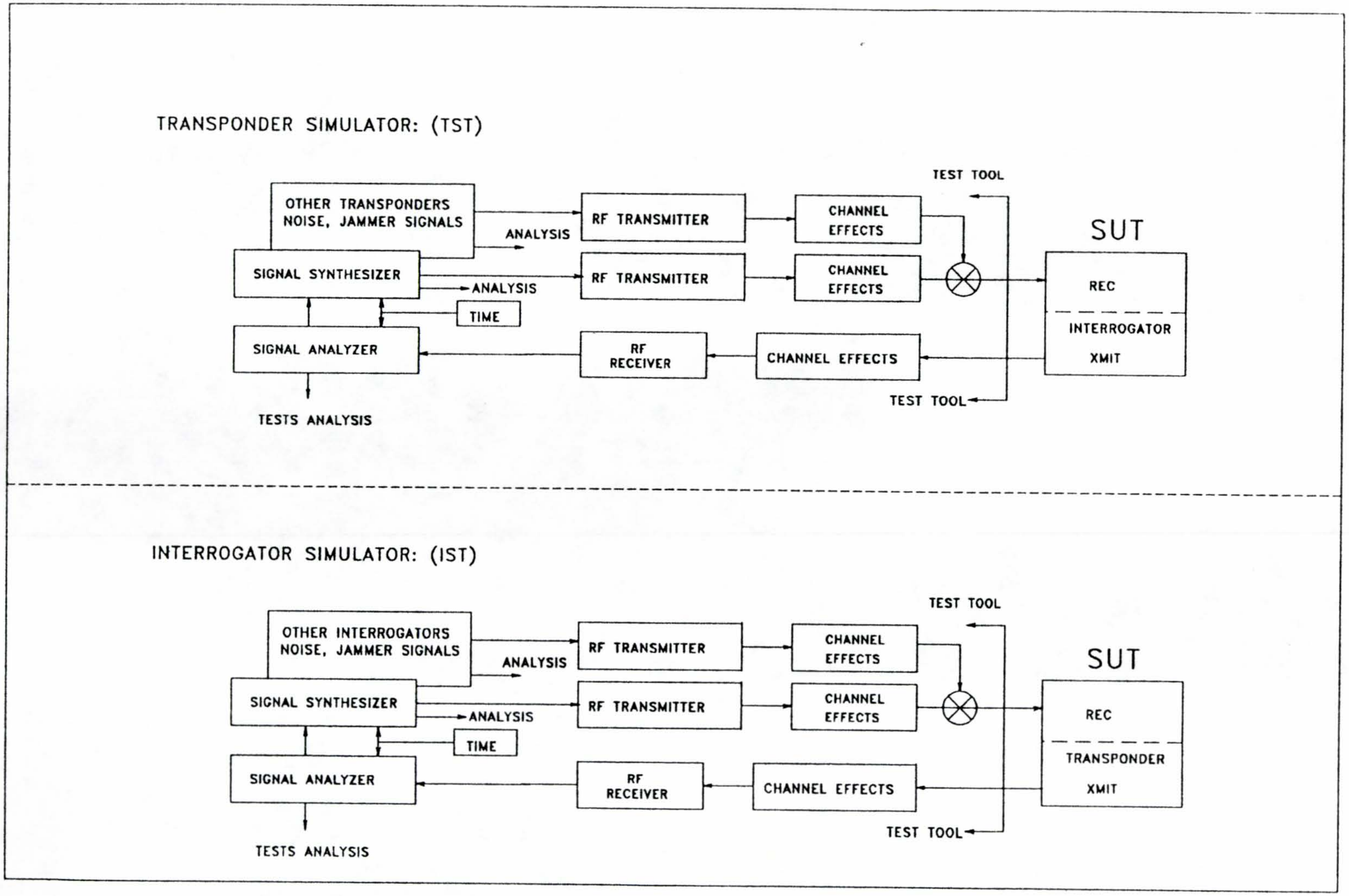
Task Definition: Develop a conceptual design of TESTS. This conceptual design will examine both simulation and stimulation components of TESTS and determine the optimal tradeoff between software and hardware implementation aspects of TESTS.

Technical Approach: Systems approach design process supported by design analyses. Several different approaches were examined with the recommended approach selected and refined as a subteam effort by simulation and signal generation experts from IST and EE.

Four generic TESTS concept approaches were examined:

- Concept A - Sampled Data Interface (software intensive)
- Concept B - Pulse Level Interface to Hardware
- Concept C - Message Level Interface to Hardware
- Concept D - Hardware Intensive Design

TASK 10: CONCEPTUAL DESIGN
TESTS FUNCTION FLOW



TASK 10 CONCEPTUAL DESIGN
TESTS FUNCTIONAL FLOW OVERVIEW

- The SUT may be either an actual interrogator or transponder mounted on its aircraft platform inside the shielded hangar or anechoic chamber.
- The TESTS tool will then provide a realistic simulation of the external environment as seen at this interface via combination of hardware and software components as required.

TASK 10 CONCEPTUAL DESIGN
TESTS FUNCTIONAL FLOW

Functional blocks of the TESTS communications loop consist of:

- Signal Synthesis - Determination of the scenario appropriate baseband IFF challenge or reply; includes additional interrogators, and transponders, as well as possible jammers of various types.
- RF Transmitter - The TESTS RF Transmitter must be able to create and modulate the uplink and downlink RF carrier frequencies to the desired waveforms of the MK XII signals or MK XV spread spectrum signals, and transmit them to the SUT.

TASK 10 CONCEPTUAL DESIGN
TESTS FUNCTIONAL FLOW

Functional blocks of the TESTS communications loop consist of:

- Channel Effects - Channel effects will be calculated in software by the TESTS tool based on time and scenario dependent conditions which affect the electromagnetic transmission, propagation, and reception of the IFF signal waveforms. Channel effects include:
  - Antenna pattern gains
  - Aircraft and platform masking
  - Electromagnetic propagation time delays
  - Multipath propagation effects
  - Atmospheric absorption, refraction, diffraction
  - Relative polarization phenomenon
  - Frequency dispersion and doppler shift

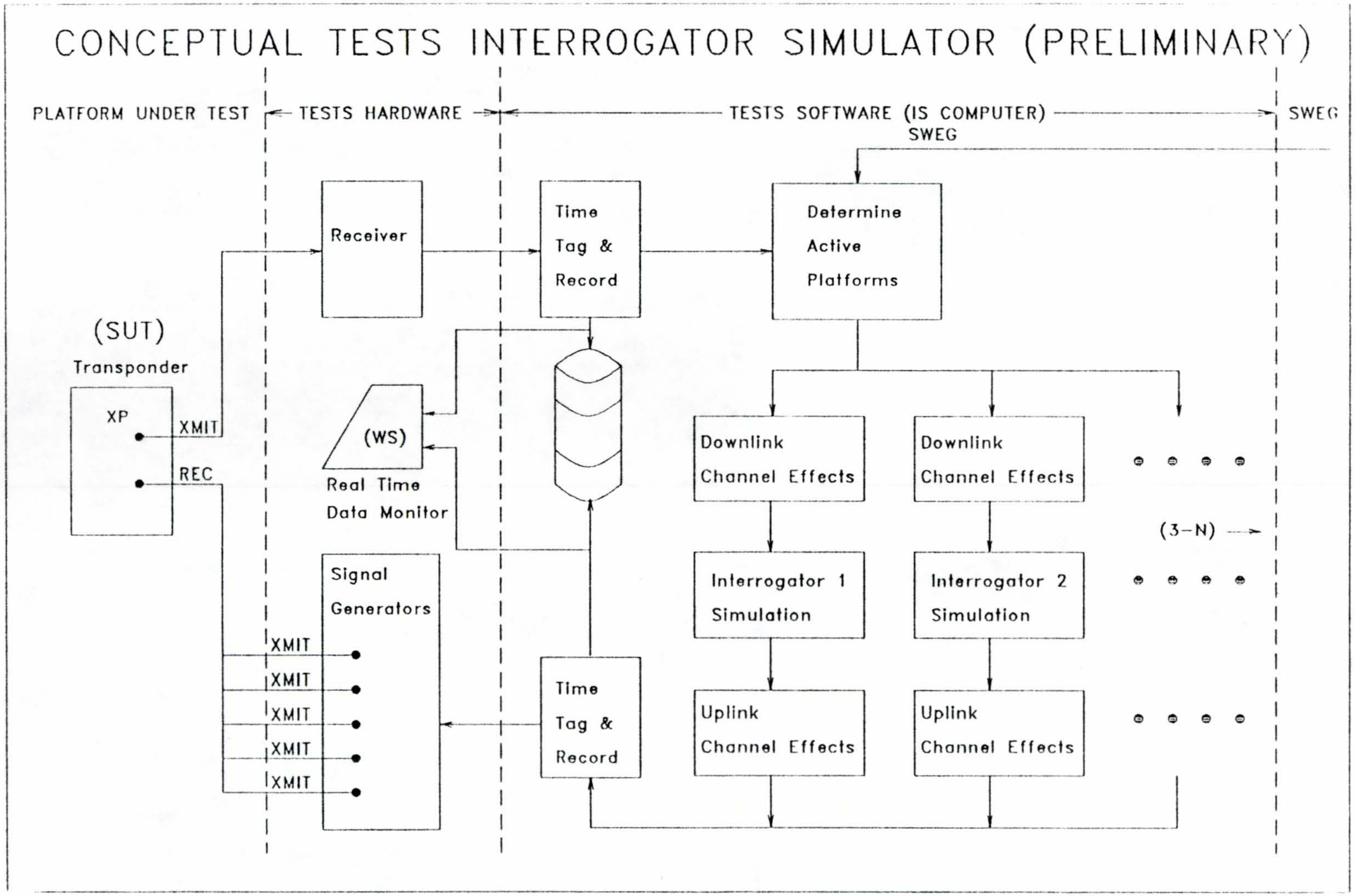
TASK 10 CONCEPTUAL DESIGN
TESTS FUNCTIONAL FLOW

Functional blocks of the TESTS communications loop consist of:

- RF Receiver - The TESTS RF Receiver must be able to receive and demodulate the MK XII and MK XV IFF signals transmitted by the SUT at RF carrier frequencies, to an appropriate baseband format.

- Signal Analyzer - The TESTS Signal Analyzer will extract message mode and information data from IFF signals received from the SUT, and will analyze the signals for desired performance characteristics. Analyzer will also time tag and output signals generated by TESTS to data collection devices.

TASK 10: CONCEPTUAL DESIGN
TESTS GENERIC CONCEPTUAL INTERROGATOR



TASK 10 CONCEPTUAL DESIGN
GENERIC INTERROGATOR SIMULATOR

- Interrogator Simulator Computer - Starting with the SWEG initializations/platforms/emitters are identified by their respective position, velocity, attitude and emitter description; these are downloaded to the IS Computer. Positions, velocities and attitudes of these emitters with respect to the SUT will identify the interrogators and modes necessary to stimulate the SUT.

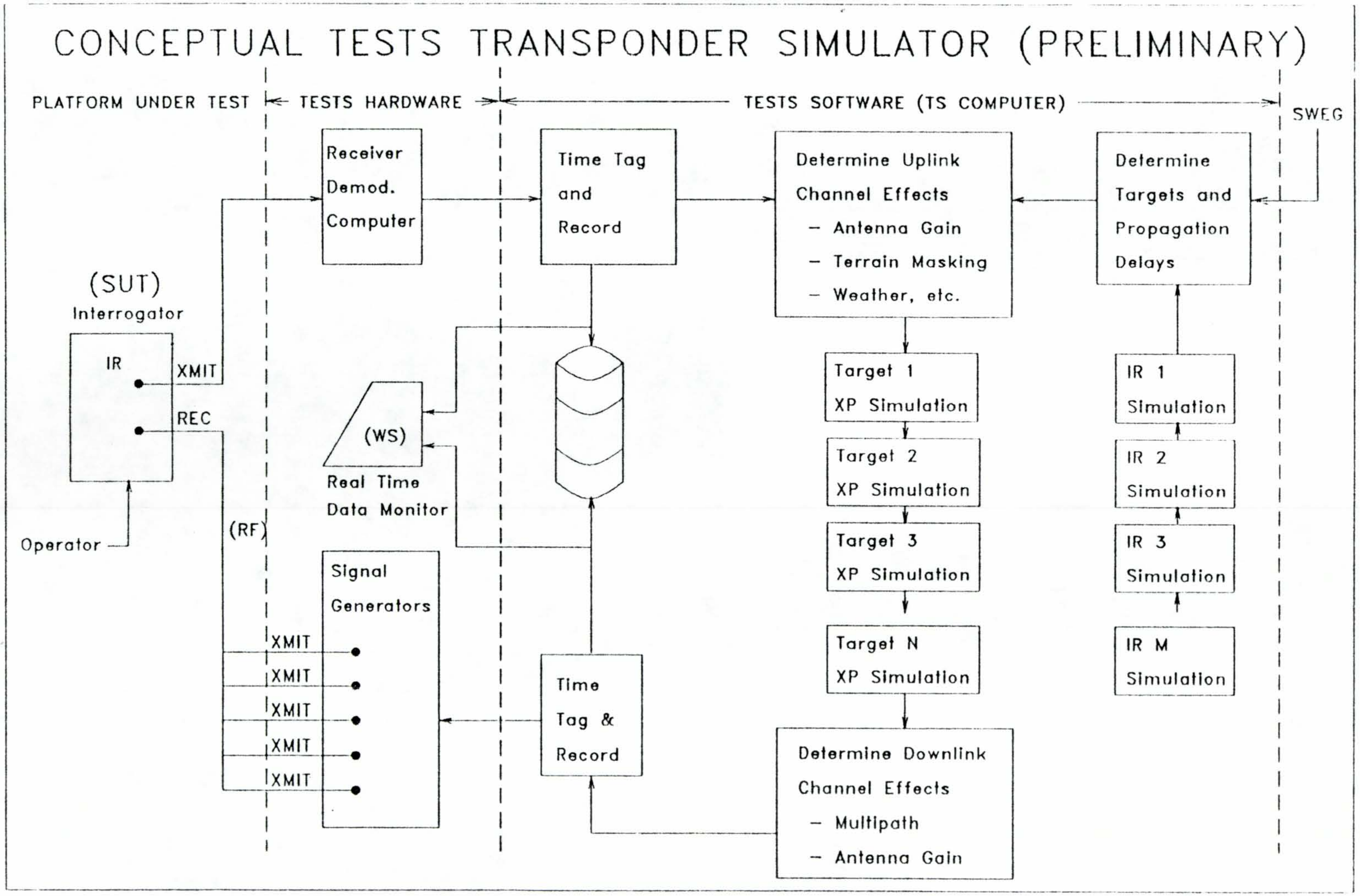
- Uplink and Downlink Channel Effects - These channel effects are computed or table driven by the IS to condition the transponder reply (attenuation, phase shift, time delay, frequency shift)

- Interrogator Simulators - The interrogators are identified in the computer and generate the proper waveform message for the given mode with the proper ID to identify its platform.

TASK 10 CONCEPTUAL DESIGN
GENERIC INTERROGATOR SIMULATOR

- Signal Generators - These interrogator signals/waveforms are sent to the signal generators (time tagged and recorded for analysis) where they are modulated at the carrier frequency,
- System Under Test (SUT) - The SUT receives the RF output of the signal generator hardware (multiple signal generators to accommodate overlapping or multipath signals) of the identified interrogators stimulating the SUT.
- Tests Receiver - The reply is received by the TESTS receiver (hardware) where it is demodulated, decoded, time tagged, recorded and matched up to the interrogator platforms/emitters to complete the loop.
- Real Time Data Monitor - A real time monitor (WS) is shown to monitor and control the simulation.

TASK 10: CONCEPTUAL DESIGN
TESTS GENERIC CONCEPTUAL TRANSPONDER



TASK 10 CONCEPTUAL DESIGN
GENERIC TRANSPONDER SIMULATOR

- System Under Test (SUT) - The operator initiates the interrogator of the SUT through the operator workstation, and sends the interrogator RF signal to the simulator receiver.

- Transponder Simulator Receiver - The TS receiver (hardware) demodulates, decodes, and discriminates desired targets. The timing of the response to the SUT interrogators is critical in the TS Configuration. The response time must conform to the timing threshold/specification of the SUT.

- Real Time Data Monitor - The real time data monitor provides the quick look analysis visibility and controls the simulation progress.

TASK 10 CONCEPTUAL DESIGN
GENERIC TRANSPONDER SIMULATOR

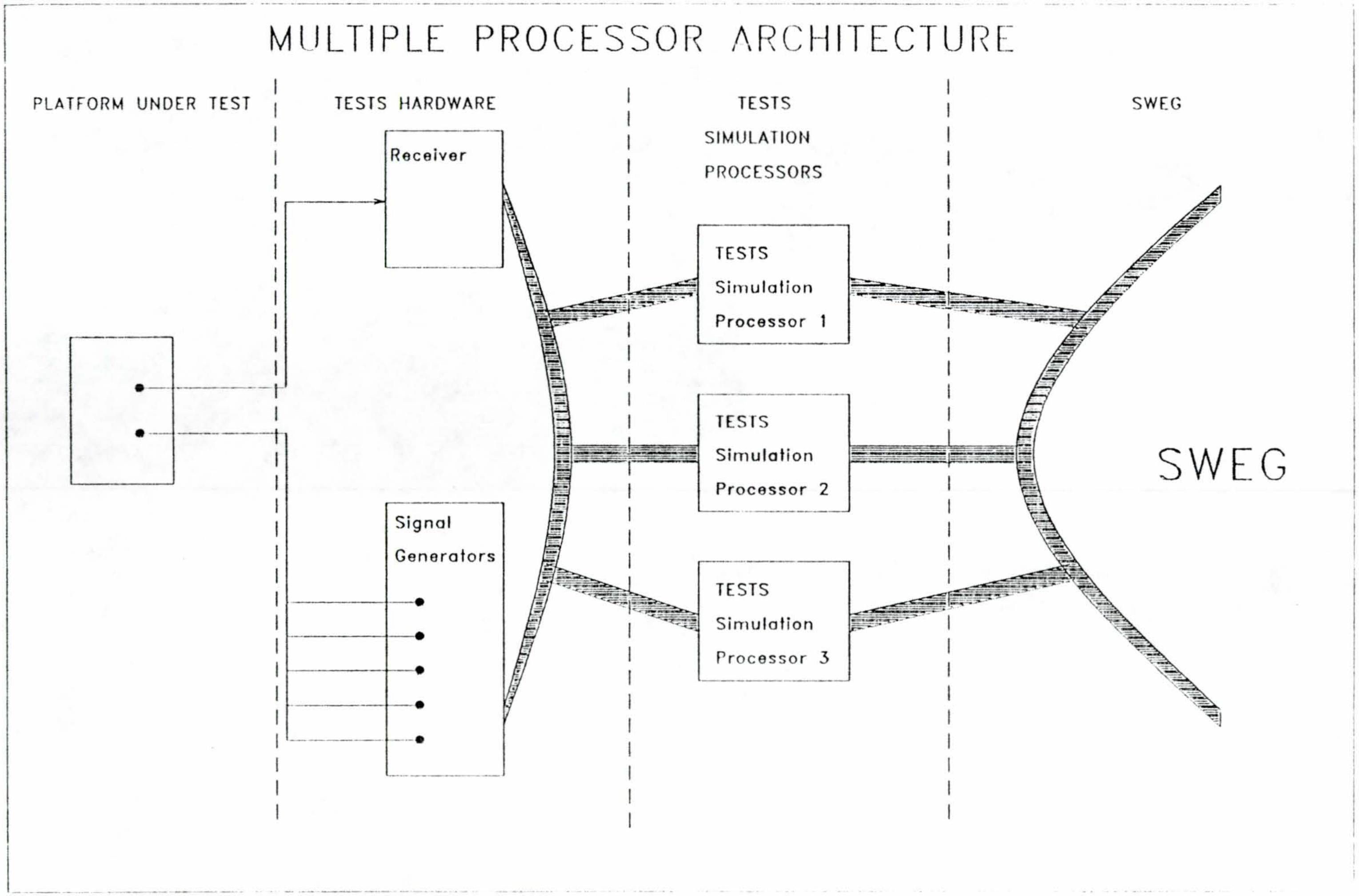
- Transponder Simulator Computer - The target set of transponders is identified by the scenerio set up using SWEG for the test and downloaded to the TS computer.

- Propagation and Channel Effects - The TS computer will use the computed relative positions and velocities of the targets with respect to the position of the SUT (main and sidelobe interrogation) to generate the propagation delays and environmental modification parameters for the Uplink communication RF signal.

- Transponder Simulator - The transponder transmitter(XP) for the target set takes the transponder waveform reply formats to control the signal generators RF transmissions back to the SUT.

- Signal Generators - These interrogator signals/ waveforms are sent to the signal generators (time tagged and recorded for analysis) where they are modulated at the carrier frequency.

TASK 10: CONCEPTUAL DESIGN
TESTS SIMULATOR ENVIRONMENT

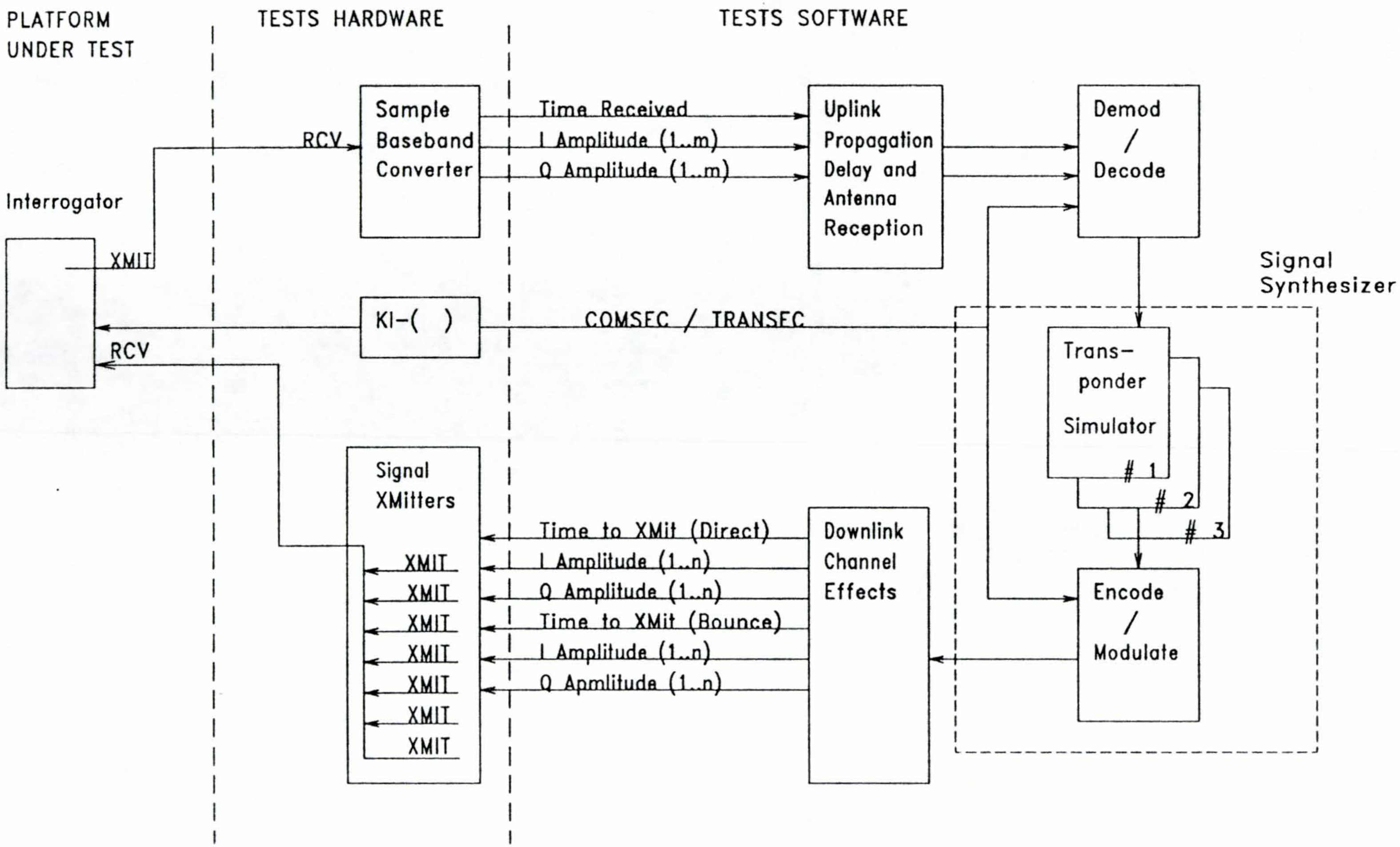


TASK 10 CONCEPTUAL DESIGN
CONCEPT A - SAMPLED DATA INTERFACE

- This approach consists of sampling or slicing a signal in time so as to represent a signal numerically by a sequence of numbers. This approach is a software intensive implementation of TESTS.
- Primary advantage is the ability to conveniently apply digital techniques to required signal processing operations.
- Sampled Data Interface approach focuses on software in order to capitalize on the advantages of this approach in terms of versatility and direct signal programmability.

TASK 10: CONCEPTUAL DESIGN
CONCEPT A

Sampled Data Interface



TASK 10: CONCEPTUAL DESIGN A
FUNCTIONAL BLOCK DESCRIPTIONS

PLATFORM UNDER TEST:

<u>INTERROGATOR</u>

FUNCTIONAL DESCRIPTION:
SYSTEM UNDER TEST (SUT) INSTALLED IN AN AIRCRAFT IN AN ANECHOIC CHAMBER OR SHIELDED HANGAR.

BLOCK INPUTS:
INTERROGATION REQUESTS FROM PLATFORM, KI-() COMSEC AND TRANSEC CODING INFORMATION, RF REPLY WAVEFORMS.

BLOCK OUTPUTS:
RF INTERROGATION WAVEFORMS.

INTERNAL OPERATIONS:
USES COMSEC/TRANSEC CODING INFORMATION TO GENERATE INTERROGATION WAVEFORMS IN RESPONSE TO PLATFORM INTERROGATION REQUESTS. USES COMSEC/TRANSEC CODING INFORMATION TO INTERPRET RF REPLY WAVEFORMS.

TASK 10: CONCEPTUAL DESIGN A
FUNCTIONAL BLOCK DESCRIPTIONS

PLATFORM UNDER TEST:

TRANSPONDER

FUNCTIONAL DESCRIPTION:
SYSTEM UNDER TEST (SUT) INSTALLED IN AN AIRCRAFT IN AN ANECHOIC CHAMBER OR SHIELDED HANGAR.

BLOCK INPUTS:
RF INTERROGATION WAVEFORMS, KI-()
COMSEC AND TRANSEC CODING INFORMATION.

BLOCK OUTPUTS:
RF REPLY WAVEFORMS.

INTERNAL OPERATIONS:
USES COMSEC/TRANSEC CODING INFORMATION TO INTERPRET INTERROGATION WAVEFORMS AND GENERATE, WHEN APPROPRIATE, REPLY WAVEFORMS.

TASK 10: CONCEPTUAL DESIGN A
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS HARDWARE:

SAMPLE BASEBAND CONVERTER

FUNCTIONAL DESCRIPTION:
DETECTS RF IFF SIGNALS FROM SUT, CONVERTING THEM TO AN I/Q PROTOCOL TIME SAMPLED DATA FORMAT.

BLOCK INPUTS:
SUT IFF SYSTEM OUTPUT WAVEFORMS.

BLOCK OUTPUTS:
TIME SAMPLED I/Q PROTOCOL DATA RF SIGNAL DESCRIPTION.

INTERNAL OPERATIONS:
QUADRATURE DEMODULATION FOLLOWED BY DUAL LOW PASS FILTERING AND HIGH SPEED A/D CONVERSION.

TASK 10: CONCEPTUAL DESIGN A
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS HARDWARE:

SIGNAL TRANSMITTER

FUNCTIONAL DESCRIPTION:
CONVERTS SOFTWARE GENERATED I/Q PROTOCOL TIME SAMPLED DATA SIGNALS INTO RF SUT STIMULUS SIGNALS.

BLOCK INPUTS:
TIME SAMPLED I/Q PROTOCOL DATA RF SIGNAL DESCRIPTIONS.

BLOCK OUTPUTS:
RF SUT STIMULUS SIGNALS.

INTERNAL OPERATIONS:
DUAL HIGH SPEED D/A CONVERSION FOLLOWED BY QUADRATURE MODULATION TO RF CARRIER. COMBINES SIGNALS INTO A SINGLE COMPLEX WAVEFORM.

TASK 10: CONCEPTUAL DESIGN A
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS HARDWARE:

KI-()

FUNCTIONAL DESCRIPTION:
CRYPTO UNIT WHICH INTERACTS WITH MK XV OR NAVY ADVANCED IFF SUBSYSTEM TO PROVIDE COMSEC/TRANSEC INFORMATION TO IFF SUBSYSTEM AND TESTS HOST PROCESSOR.

BLOCK INPUTS:
TIME OF DAY INFORMATION AND KEY CODES.

BLOCK OUTPUTS:
COMSEC/TRANSEC INFORMATION VIA SHIELDED CABLE.

INTERNAL OPERATIONS:
ACTUAL INTERNAL OPERATION IS CLASSIFIED AND MAY BE REPLACED IN SOME TEST CASES WITH AN UNCLASSIFIED SUBSTITUTE.

TASK 10: CONCEPTUAL DESIGN A
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS SOFTWARE:

UPLINK PROPAGATION DELAY AND ANTENNA RECEPTION

FUNCTIONAL DESCRIPTION:

APPLIES PROPAGATION DELAY TO I/Q SAMPLED DATA FORMAT SUT RF SIGNAL DESCRIPTIONS, AND PASSES OR REJECTS SIGNAL BASED ON WHETHER THE SIGNAL WAS IN THE ANTENNA RECEIVING LOBE.

BLOCK INPUTS:

I/Q SAMPLED DATA FORMAT DESCRIPTIONS OF SUT RF SIGNALS.

BLOCK OUTPUTS:

I/Q SAMPLED DATA FORMAT SIGNAL DESCRIPTIONS ADJUSTED FOR PROPAGATION DELAY.

INTERNAL OPERATIONS:

COMPUTATIONAL APPLICATION OF CHANNEL EFFECTS VIA I/Q MODEL PROTOCOLS DETAILED IN ANNEX A. AFTER ADDING PROPAGATION DELAY, THE SIGNAL IS PASSED IF IT WAS IN THE ANTENNA'S RECEPTION LOBE OR REJECTED IF IT WAS NOT VALIDLY RECEIVED.

TASK 10: CONCEPTUAL DESIGN A
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS SOFTWARE:

<u>DEMOD</u> / <u>DECODE</u>

FUNCTIONAL DESCRIPTION:
DEMODULATION, DESPREADING AND/OR DECRYPTION OF I/Q SAMPLED DATA FORMAT SIGNALS INTO IFF MESSAGE TYPES, MODES AND CONTENTS.

BLOCK INPUTS:
I/Q SAMPLED DATA FORMAT SIGNAL DESCRIPTIONS ADJUSTED FOR CHANNEL EFFECTS; COMSEC/TRANSEC INFORMATION.

BLOCK OUTPUTS:
IFF MESSAGE TYPES, MODES AND CONTENT.

INTERNAL OPERATIONS:
APPLIES APPROPRIATE DEMODULATION, DESPREADING AND/OR DECRYPTION PROCESSES THROUGH I/Q MODEL PROTOCOLS AS DESCRIBED IN ANNEX A.

TASK 10: CONCEPTUAL DESIGN A
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS SOFTWARE:

TRANSPONDER SIMULATOR

FUNCTIONAL DESCRIPTION:
INVOKES TESTS INTERROGATIONS OR REPLIES APPROPRIATE TO THE TEST FUNCTION AND TIME DEPENDENT SCENARIO CONDITIONS.

BLOCK INPUTS:
IFF MESSAGE TYPES, MODES AND CONTENT.

BLOCK OUTPUTS:
NEW IFF MESSAGE TYPES, MODES AND CONTENT.

INTERNAL OPERATIONS:
FOLLOWS TEST SCENARIO TO SIMULATE INDIVIDUAL IFF PLATFORMS.

TASK 10: CONCEPTUAL DESIGN A
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS SOFTWARE:

<u>ENCODE / MODULATE</u>

FUNCTIONAL DESCRIPTION:
MODULATION, SPREADING AND/OR ENCRYPTION OF NEW IFF MESSAGE TYPES, MODES AND CONTENT INTO I/Q SAMPLED DATA FORMAT SIGNALS.

BLOCK INPUTS:
NEW IFF MESSAGE TYPES, MODES AND CONTENT; COMSEC/TRANSEC INFORMATION.

BLOCK OUTPUTS:
I/Q SAMPLED DATA FORMAT SIGNAL DESCRIPTIONS.

INTERNAL OPERATIONS:
APPLIES APPROPRIATE MODULATION, SPREADING AND/OR ENCRYPTION PROCESSES THROUGH I/Q MODEL PROTOCOLS AS DESCRIBED IN ANNEX A.

TASK 10: CONCEPTUAL DESIGN A
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS SOFTWARE:

<u>DOWNLINK CHANNEL EFFECTS</u>

FUNCTIONAL DESCRIPTION:
APPLIES CHANNEL EFFECTS TO I/Q SAMPLED DATA FORMAT SUT RF SIGNAL DESCRIPTIONS.

BLOCK INPUTS:
I/Q SAMPLED DATA FORMAT SIGNAL DESCRIPTIONS.

BLOCK OUTPUTS:
I/Q SAMPLED DATA FORMAT SIGNAL DESCRIPTIONS ADJUSTED FOR CHANNEL EFFECTS.

INTERNAL OPERATIONS:
COMPUTATIONAL APPLICATION OF CHANNEL EFFECTS VIA I/Q MODEL PROTOCOLS DETAILED IN ANNEX A.

TASK 10 CONCEPTUAL DESIGN
CONCEPT A - TECHNICAL ANALYSIS

- The I/Q protocol represents an attempt to alleviate the high computational requirements associated with the Sampled Data Interface approach.
- Direct data sampling of radio frequency (RF) signals requires sampling or time slicing rates in excess of twice the carrier frequency.
- I/Q protocol time sampling requires a sampling rate equal to the RF bandwidth and not twice the RF or IF carrier frequency.
- I/Q protocol sampling is clearly and by far the most feasible protocol for data sampling in the Sampled Data Interface approach.

TASK 10 CONCEPTUAL DESIGN
CONCEPT A - TECHNICAL ANALYSIS

- The I/Q protocol standard Sampled Data Interface concept represents a versatile adaptable solution to the TESTS RF signal detection, simulation and generation requirements.
- In practice, this solution is difficult to realize due to computational and data transfer considerations.
- Example calculates the amount of data, in bits, which must be considered when applying the I/Q protocol Sampled Data Interface concept to a MK XII Mode 3A reply.

TASK 10 CONCEPTUAL DESIGN
CONCEPT A - DATA RATE REQUIREMENTS

EXAMPLE - CONCEPT A - MK XII MODE 3A REPLY REQUIRES :

50 MHZ SAMPLING FREQUENCY (DUE TO BANDPASS FILTER)

LONGEST MESSAGE LENGTH = 25.1 USEC

NUMBER OF SAMPLES = (50 MHZ) (25.1 USEC) = 1255 SAMPLES / MESSAGE

TESTS TRANSMIT MESSAGE FORMAT :

TIME TO XMIT	(DIRECT)	= 32 BITS	
I AMPLITUDE	(DIRECT)	= 10,040 BITS	(1255 SAMPLES X 8 BITS)
Q AMPLITUDE	(DIRECT)	= 10,040 BITS	
TIME TO XMIT	(BOUNCE)	= 32 BITS	
I AMPLITUDE	(BOUNCE)	= 10,040 BITS	(1255 SAMPLES X 8 BITS)
Q AMPLITUDE	(BOUNCE)	= 10,040 BITS	
	TOTAL	= 40,224 BITS / MESSAGE	

TASK 10 CONCEPTUAL DESIGN
CONCEPT A - TECHNICAL ANALYSIS

- This approach allows for simple TESTS transmit and receive hardware to be used.
- However, it requires enormous real time digital signal processing and data transfer rates to be performed by TESTS software components executing in the host computer.
- At the most complicated scenarios, in terms of number of targets, multipath effects, etc., the computational requirements effectively exceed the capability of a supercomputer.

TASK 10 CONCEPTUAL DESIGN
CONCEPT B - PULSE LEVEL INTERFACE

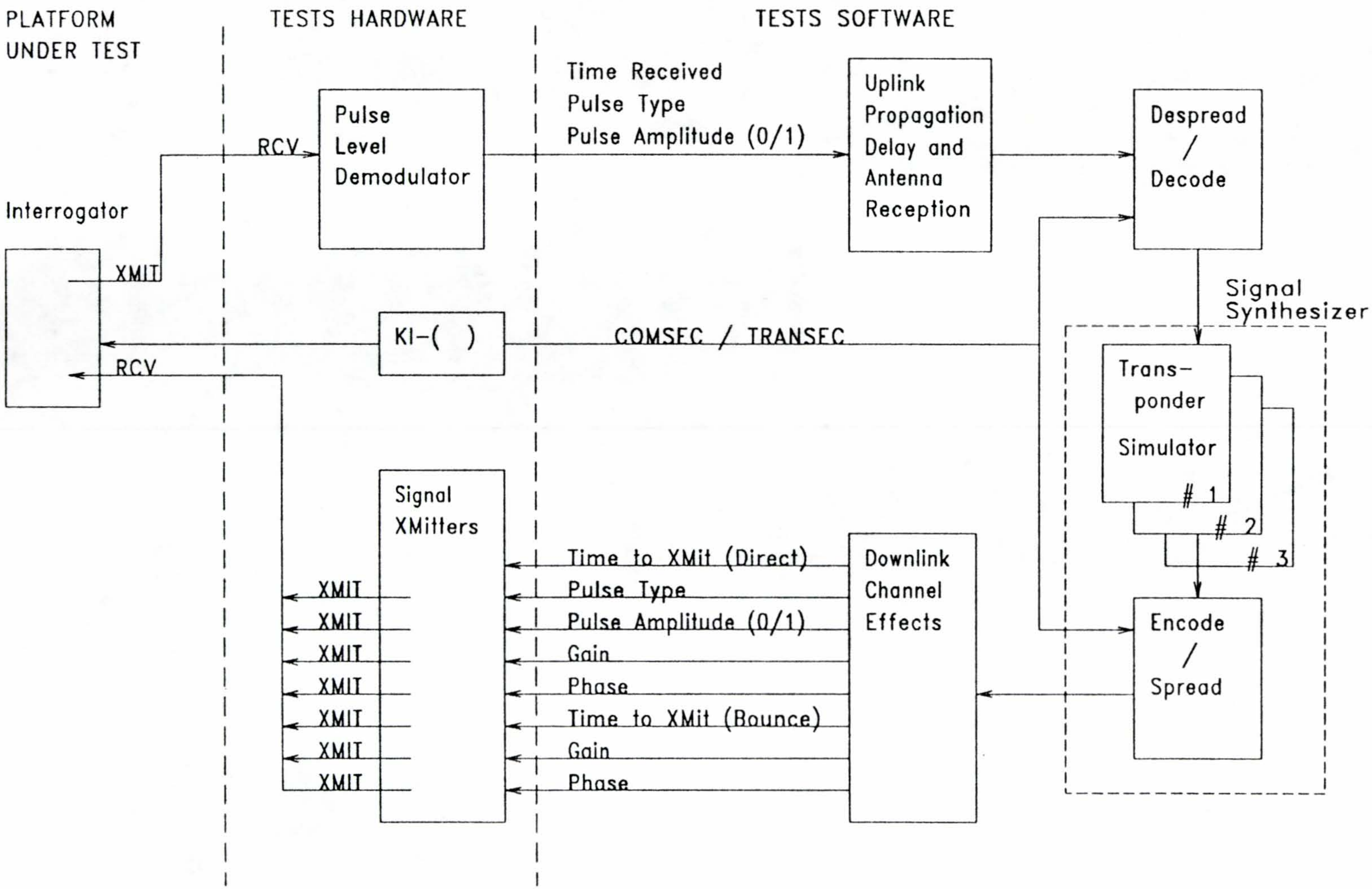
The Pulse Level Interface concept approaches signal reception, processing and generation by applying pulse level decomposition and modeling to RF signals.

This design approach shifts a moderate portion of the processing requirements to hardware in order to reduce the data rate requirements across the software/hardware interface.

Concept B gains computational advantage over Concept A by modeling RF signals through predetermined characteristic pulses or predetermined modulated data symbol shapes as defined in MK XII or MK XV specifications.

TASK 10: CONCEPTUAL DESIGN
CONCEPT B

Pulse Level Interface



TASK 10: CONCEPTUAL DESIGN B
FUNCTIONAL BLOCK DESCRIPTIONS

PLATFORM UNDER TEST:

INTERROGATOR

FUNCTIONAL DESCRIPTION:
SYSTEM UNDER TEST (SUT) INSTALLED IN AN AIRCRAFT IN AN ANECHOIC CHAMBER OR SHIELDED HANGAR.

BLOCK INPUTS:
INTERROGATION REQUESTS FROM PLATFORM, KI-() COMSEC AND TRANSEC CODING INFORMATION, RF REPLY WAVEFORMS.

BLOCK OUTPUTS:
RF INTERROGATION WAVEFORMS.

INTERNAL OPERATIONS:
USES COMSEC/TRANSEC CODING INFORMATION TO GENERATE INTERROGATION WAVEFORMS IN RESPONSE TO PLATFORM INTERROGATION REQUESTS. USES COMSEC/TRANSEC CODING INFORMATION TO INTERPRET RF REPLY WAVEFORMS.

TASK 10: CONCEPTUAL DESIGN B
FUNCTIONAL BLOCK DESCRIPTIONS

PLATFORM UNDER TEST:

TRANSPONDER

FUNCTIONAL DESCRIPTION:
SYSTEM UNDER TEST (SUT) INSTALLED IN AN AIRCRAFT IN AN ANECHOIC CHAMBER OR SHIELDED HANGAR.

BLOCK INPUTS:
RF INTERROGATION WAVEFORMS, KI-()
COMSEC AND TRANSEC CODING INFORMATION.

BLOCK OUTPUTS:
RF REPLY WAVEFORMS.

INTERNAL OPERATIONS:
USES COMSEC/TRANSEC CODING INFORMATION TO INTERPRET INTERROGATION WAVEFORMS AND GENERATE, WHEN APPROPRIATE, REPLY WAVEFORMS.

TASK 10: CONCEPTUAL DESIGN B
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS HARDWARE:

PULSE LEVEL DEMODULATOR

FUNCTIONAL DESCRIPTION:
DETECTS RF IFF SIGNALS FROM SUT, CONVERTING THEM TO A PULSE LEVEL DATA FORMAT.

BLOCK INPUTS:
SUT IFF SYSTEM OUTPUT RF WAVEFORMS.

BLOCK OUTPUTS:
PULSE LEVEL DATA FORMAT RF SIGNAL DESCRIPTION, I.E., STREAM OF PULSES (CHIPS) FORMATED BY TIME RECEIVED, TYPE OF PULSE AS CHARACTERIZED BY MODE OR FORMAT SPECIFICATIONS, AND AMPLITUDE.

INTERNAL OPERATIONS:
DATA SYMBOL SHAPE RECOGNITION ACCORDING TO VARIOUS IFF MODES AND FORMATS AND DEMODULATION TO THE PULSE OR CHIP LEVEL AS APPROPRIATE TO THE MK XII OR MK XV.

TASK 10: CONCEPTUAL DESIGN B
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS HARDWARE:

SIGNAL TRANSMITTER

FUNCTIONAL DESCRIPTION:
CONVERTS SOFTWARE GENERATED PULSE LEVEL DATA FORMAT SIGNALS INTO RF SUT STIMULUS SIGNALS.

BLOCK INPUTS:
PULSE LEVEL DATA FORMAT RF SIGNAL DESCRIPTIONS.

BLOCK OUTPUTS:
RF SUT STIMULUS SIGNALS.

INTERNAL OPERATIONS:
DATA SYMBOL LEVEL MODULATION FROM PULSES (CHIPS) TO RF CARRIER.

TASK 10: CONCEPTUAL DESIGN B
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS HARDWARE:

KI-()

FUNCTIONAL DESCRIPTION:
CRYPTO UNIT WHICH INTERACTS WITH MK XV OR NAVY ADVANCED IFF SUBSYSTEM TO PROVIDE COMSEC/TRANSEC INFORMATION TO IFF SUBSYSTEM AND TESTS HOST PROCESSOR.

BLOCK INPUTS:
TIME OF DAY INFORMATION AND KEY CODES.

BLOCK OUTPUTS:
COMSEC/TRANSEC INFORMATION VIA SHIELDED CABLE.

INTERNAL OPERATIONS:
ACTUAL INTERNAL OPERATION IS CLASSIFIED AND MAY BE REPLACED IN SOME TEST CASES WITH AN UNCLASSIFIED SUBSTITUTE.

TASK 10: CONCEPTUAL DESIGN B
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS SOFTWARE:

<u>UPLINK PROPAGATION DELAY AND ANTENNA RECEPTION</u>

FUNCTIONAL DESCRIPTION:
APPLIES PROPAGATION DELAY TO PULSE LEVEL DATA FORMAT SUT RF SIGNAL DESCRIPTIONS. PASSES PULSE LEVEL DATA WHEN RECEIVED IN ANTENNA RECEPTION LOBE, REJECTS OTHERWISE.

BLOCK INPUTS:
PULSE LEVEL DATA FORMAT DESCRIPTIONS OF SUT RF SIGNALS.

BLOCK OUTPUTS:
PULSE LEVEL DATA FORMAT SIGNAL DESCRIPTIONS ADJUSTED FOR CHANNEL EFFECTS.

INTERNAL OPERATIONS:
COMPUTATIONAL APPLICATION OF PROPAGATION DELAY VIA PULSE LEVEL DATA FORMAT DESCRIPTIONS AND DECIDES WHETHER TO PASS THE DATA BASED ON WHETHER THE SIGNAL WAS LOCATED IN THE ANTENNA'S RECEPTION LOBE.

TASK 10: CONCEPTUAL DESIGN B
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS SOFTWARE:

DESPREAD / DECODE

FUNCTIONAL DESCRIPTION:
DEMODULATION, DESPREADING AND/OR DECRYPTION OF PULSE LEVEL DATA FORMAT SIGNALS INTO IFF MESSAGE TYPES, MODES AND CONTENTS.

BLOCK INPUTS:
PULSE LEVEL DATA FORMAT SIGNAL DESCRIPTIONS ADJUSTED FOR CHANNEL EFFECTS; COMSEC/TRANSEC INFORMATION.

BLOCK OUTPUTS:
IFF MESSAGE TYPES, MODES AND CONTENT.

INTERNAL OPERATIONS:
APPLIES APPROPRIATE (REMAINING) DEMODULATION, DESPREADING AND/OR DECRYPTION PROCESSES THROUGH PULSE LEVEL DATA FORMAT MODEL.

TASK 10: CONCEPTUAL DESIGN B
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS SOFTWARE:

TRANSPONDER SIMULATOR

FUNCTIONAL DESCRIPTION:
INVOKES TESTS INTERROGATIONS OR REPLIES APPROPRIATE TO THE TEST FUNCTION AND TIME DEPENDENT SCENARIO CONDITIONS.

BLOCK INPUTS:
IFF MESSAGE TYPES, MODES AND CONTENT.

BLOCK OUTPUTS:
NEW IFF MESSAGE TYPES, MODES AND CONTENT.

INTERNAL OPERATIONS:
FOLLOWS TEST SCENARIO TO SIMULATE INDIVIDUAL IFF PLATFORMS.

TASK 10: CONCEPTUAL DESIGN B
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS SOFTWARE:

ENCODE / SPREAD

FUNCTIONAL DESCRIPTION:
MODULATION, SPREADING AND/OR ENCRYPTION OF NEW IFF MESSAGE TYPES, MODES AND CONTENT INTO PULSE LEVEL DATA FORMAT SIGNALS.

BLOCK INPUTS:
NEW IFF MESSAGE TYPES, MODES AND CONTENT; COMSEC/TRANSEC INFORMATION.

BLOCK OUTPUTS:
PULSE LEVEL DATA FORMAT SIGNAL DESCRIPTIONS.

INTERNAL OPERATIONS:
APPLIES APPROPRIATE MODULATION TO PULSE LEVEL, SPREADING AND/OR ENCRYPTION PROCESSES THROUGH PULSE LEVEL DATA MODEL.

TASK 10: CONCEPTUAL DESIGN B
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS SOFTWARE:

<u>DOWNLINK CHANNEL EFFECTS</u>

FUNCTIONAL DESCRIPTION:
APPLIES CHANNEL EFFECTS TO PULSE LEVEL DATA FORMAT SUT RF SIGNAL DESCRIPTIONS.

BLOCK INPUTS:
PULSE LEVEL DATA FORMAT SIGNAL DESCRIPTIONS.

BLOCK OUTPUTS:
PULSE LEVEL DATA FORMAT SIGNAL DESCRIPTIONS ADJUSTED FOR CHANNEL EFFECTS.

INTERNAL OPERATIONS:
COMPUTATIONAL APPLICATION OF CHANNEL EFFECTS VIA PULSE LEVEL DATA MODEL.

TASK 10 CONCEPTUAL DESIGN
CONCEPT B - TECHNICAL ANALYSIS

- The Pulse Level Interface concept may be described in more detail by comparing the functions of various Concept B components to their corresponding Concept A components.
- Concept B hardware is designed to expect waveforms with predetermined modulation data formats such as MK XII and MK XV interrogation formats.
- A pulse sequence description consists of a starting time, a pulse type (i.e., MK XII Reply, MK XII Query, MK XII Mode 4 Reply, etc.) and a pulse amplitude (0/1 or f-mark / f-space).
- TESTS software in turn sends pulse sequence descriptions to the TESTS hardware signal transmitters, queued to be transmitted at specific times.

TASK 10 CONCEPTUAL DESIGN
CONCEPT B - TECHNICAL ANALYSIS

- The pulse type, amplitude (0/1), gain, phase, and possibly frequency, information must be sent for each pulse of the direct path message.
- The Concept B signal transmitters would be equipped to accept such full fidelity pulse sequence descriptions from TESTS software and convert them into equal fidelity RF replies.
- Channel effects are thus computed in software, but applied in hardware via the programmable gain, phase, frequency and time delay settings associated with each pulse.
- The difference is that Concept B software is geared to the processing of RF pulse sequence signal descriptions which save enormously on computational and data transfer requirements.

TASK 10 CONCEPTUAL DESIGN
CONCEPT B - DATA RATE REQUIREMENTS

EXAMPLE - CONCEPT B - MK XII MODE 3A REPLY REQUIRES :

LONGEST MESSAGE LENGTH = 15 PULSES

TESTS TRANSMIT MESSAGE FORMAT :

TIME TO XMIT	(DIRECT)	=	32 BITS
PULSE TYPE	(DIRECT)	=	15 BITS
PULSE AMPLITUDE	(DIRECT)	=	1 BITS
PULSE GAIN	(DIRECT)	=	8 BITS
PULSE PHASE	(DIRECT)	=	8 BITS
TIME TO XMIT	(BOUNCE)	=	32 BITS
PULSE GAIN	(BOUNCE)	=	8 BITS
PULSE PHASE	(BOUNCE)	=	8 BITS

112 BITS / PULSE

X 15

TOTAL = 1680 BITS / MESSAGE

TASK 10 CONCEPTUAL DESIGN
CONCEPT B - TECHNCIAL ANALYSIS

- The result is that a modeling requirement of over forty thousand bits of information in Concept A is reduced to less than two thousand bits of information in Concept B.
- Concept B yields a significant computational and data transfer advantage over Concept A.
- Concept B, however, still requires computation and data transfer rates that become difficult to implement as the pulse shapes used to characterize signals become small.
- This order of reduction can not be achieved for spread spectrum signals of the type used by MK XV.
- While MK XII signals are compatible with state-of-the-art computing resources, Mark XV signals under this design concept still exceed the capability of a supercomputer.
- This concept is that it does not work for spread spectrum signals in a hostile, i.e., jamming, or noisy environment.

TASK 10 CONCEPTUAL DESIGN
CONCEPT C - MESSAGE LEVEL INTERFACE

The Message Level Interface represents a logical step in the evolution of the TESTS concepts which alleviates the data transfer and computational requirements of the TESTS software by at least an order of magnitude over the Pulse Level Interface concept. It reallocates a larger portion of the processing to hardware.

Concept C most closely approximates the recommended TESTS concept. Concept C allows for versatility in terms of signal modeling to accommodate environmental effects and signal superposition.

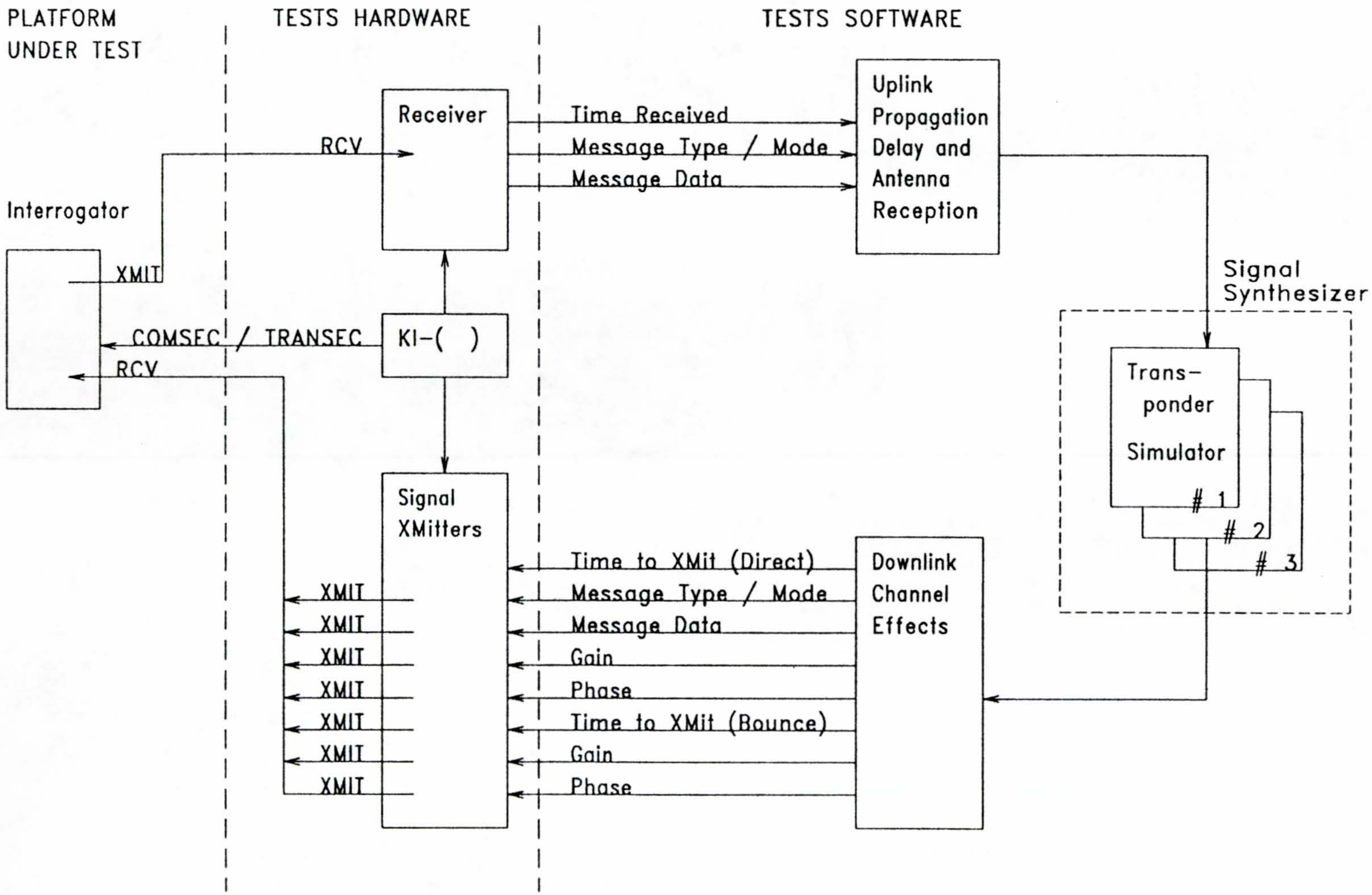
TASK 10 CONCEPTUAL DESIGN
CONCEPT C - MESSAGE LEVEL INTERFACE

The Message Level Interface represents a logical step in the evolution of the TESTS concepts which alleviates the data transfer and computational requirements of the TESTS software by at least an order of magnitude over the Pulse Level Interface concept. It reallocates a larger portion of the processing to hardware.

Concept C most closely approximates the recommended TESTS concept. Concept C allows for versatility in terms of signal modeling to accommodate environmental effects and signal superposition.

TASK 10: CONCEPTUAL DESIGN
CONCEPT C

Message Level Interface



TASK 10: CONCEPTUAL DESIGN C
FUNCTIONAL BLOCK DESCRIPTIONS

PLATFORM UNDER TEST:

<u>INTERROGATOR</u>

FUNCTIONAL DESCRIPTION:
SYSTEM UNDER TEST (SUT) INSTALLED IN AN AIRCRAFT IN AN ANECHOIC CHAMBER OR SHIELDED HANGAR.

BLOCK INPUTS:
INTERROGATION REQUESTS FROM PLATFORM, KI-() COMSEC AND TRANSEC CODING INFORMATION, RF REPLY WAVEFORMS.

BLOCK OUTPUTS:
RF INTERROGATION WAVEFORMS, THREAT ID INFORMATION.

INTERNAL OPERATIONS:
USES COMSEC/TRANSEC CODING INFORMATION TO GENERATE INTERROGATION WAVEFORMS IN RESPONSE TO PLATFORM INTERROGATION REQUESTS. USES COMSEC/TRANSEC CODING INFORMATION TO INTERPRET RF REPLY WAVEFORMS.

TASK 10: CONCEPTUAL DESIGN C
FUNCTIONAL BLOCK DESCRIPTIONS

PLATFORM UNDER TEST:

TRANSPONDER

FUNCTIONAL DESCRIPTION:
SYSTEM UNDER TEST (SUT) INSTALLED IN AN AIRCRAFT IN AN ANECHOIC CHAMBER OR SHIELDED HANGAR.

BLOCK INPUTS:
RF INTERROGATION WAVEFORMS, KI-()
COMSEC AND TRANSEC INFORMATION.

BLOCK OUTPUTS:
RF REPLY WAVEFORMS.

INTERNAL OPERATIONS:
USES COMSEC/TRANSEC CODING INFORMATION TO INTERPRET INTERROGATION WAVEFORMS AND GENERATE, WHEN APPROPRIATE, REPLY WAVEFORMS.

TASK 10: CONCEPTUAL DESIGN C
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS HARDWARE:

<u>SIGNAL RECEIVER</u>

FUNCTIONAL DESCRIPTION:
DETECTS RF IFF SIGNALS FROM SUT, CONVERTING THEM TO A MESSAGE LEVEL DATA FORMAT.

BLOCK INPUTS:
SUT IFF SYSTEM OUTPUT WAVEFORMS; COMSEC/TRANSEC INFORMATION.

BLOCK OUTPUTS:
MESSAGE LEVEL DATA FORMAT RF SIGNAL DESCRIPTION.

INTERNAL OPERATIONS:
DEMODULATION INCLUDING DESPREADING, DECODING AND/OR DECRYPTION AND MESSAGE LEVEL SIGNAL RECOGNITION.

TASK 10: CONCEPTUAL DESIGN C
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS HARDWARE:

<u>SIGNAL TRANSMITTER</u>

FUNCTIONAL DESCRIPTION:
CONVERTS SOFTWARE GENERATED MESSAGE LEVEL DATA FORMAT SIGNALS INTO RF SUT STIMULUS SIGNALS.

BLOCK INPUTS:
MESSAGE LEVEL DATA FORMAT RF SIGNAL DESCRIPTIONS; COMSEC/TRANSEC INFORMATION.

BLOCK OUTPUTS:
RF SUT STIMULUS SIGNALS.

INTERNAL OPERATIONS:
MESSAGE LEVEL MODULATION INCLUDING SPREADING, ENCODING AND/OR ENCRYPTION, AND MODIFICATION FOR CHANNEL EFFECTS BY ADJUSTING GAIN, PHASE, DELAY AND FREQUENCY SHIFT OF GENERATED SIGNAL.

TASK 10: CONCEPTUAL DESIGN C
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS HARDWARE:

KI-()

FUNCTIONAL DESCRIPTION:
CRYPTO UNIT WHICH INTERACTS WITH MK XV OR NAVY ADVANCED IFF SUBSYSTEM TO PROVIDE COMSEC/TRANSEC INFORMATION TO IFF SUBSYSTEM AND TESTS HOST PROCESSOR.

BLOCK INPUTS:
TIME OF DAY INFORMATION AND KEY CODES.

BLOCK OUTPUTS:
COMSEC/TRANSEC CODES VIA SHIELDED CABLE.

INTERNAL OPERATIONS:
ACTUAL INTERNAL OPERATION IS CLASSIFIED AND MAY BE REPLACED IN SOME TEST CASES WITH AN UNCLASSIFIED SUBSTITUTE.

TASK 10: CONCEPTUAL DESIGN C
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS SOFTWARE:

UPLINK PROPAGATION DELAY AND ANTENNA RECEPTION

FUNCTIONAL DESCRIPTION:
COMPUTES PROPAGATION DELAY TO MESSAGE LEVEL DATA SUT RF SIGNAL DESCRIPTIONS. PASSES DATA IF IT WAS RECEIVED IN THE ANTENNA'S RECEPTION LOBE.

BLOCK INPUTS:
MESSAGE LEVEL DATA FORMAT DESCRIPTIONS OF SUT RF SIGNALS.

BLOCK OUTPUTS:
MESSAGE LEVEL DATA FORMAT SIGNAL DESCRIPTIONS MODIFIED FOR PROPAGATION DELAY.

INTERNAL OPERATIONS:
ADDITION OF PROPAGATION DELAY VIA MESSAGE LEVEL DATA FORMAT DESCRIPTIONS COMPUTED FOR DIRECT AND REFLECTED SIGNALS. REJECTS DATA IF IT WAS NOT RECEIVED IN THE ANTENNA'S RECEPTION LOBE.

TASK 10: CONCEPTUAL DESIGN C
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS SOFTWARE:

TRANSPONDER SIMULATOR

FUNCTIONAL DESCRIPTION:
INVOKES TESTS INTERROGATIONS OR REPLIES APPROPRIATE TO THE TEST FUNCTION AND TIME DEPENDENT SCENARIO CONDITIONS.

BLOCK INPUTS:
IFF MESSAGE TYPES, MODES AND CONTENT.

BLOCK OUTPUTS:
NEW IFF MESSAGE TYPES, MODES AND CONTENT.

INTERNAL OPERATIONS:
FOLLOWS TEST SCENARIO TO SIMULATE INDIVIDUAL IFF PLATFORMS.

TASK 10: CONCEPTUAL DESIGN C
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS SOFTWARE:

DOWNLINK CHANNEL EFFECTS

FUNCTIONAL DESCRIPTION:
COMPUTES CHANNEL EFFECTS TO MESSAGE LEVEL DATA FORMAT.

BLOCK INPUTS:
MESSAGE LEVEL DATA FORMAT SIGNAL DESCRIPTIONS.

BLOCK OUTPUTS:
MESSAGE LEVEL DATA FORMAT SIGNAL DESCRIPTIONS ADJUSTED FOR CHANNEL EFFECTS.

INTERNAL OPERATIONS:
ADDITION OF CHANNEL EFFECTS VIA MESSAGE LEVEL DATA MODEL.

TASK 10 CONCEPTUAL DESIGN
CONCEPT C - TECHNICAL ANALYSIS

- The message level format significantly alleviates computational and data transfer requirements for TESTS software.
- This reduction can be achieved for both encrypted and spread spectrum signals.
- A direct result of emphasizing TESTS hardware with respect to TESTS software in the conditioning of RF stimulus signals.

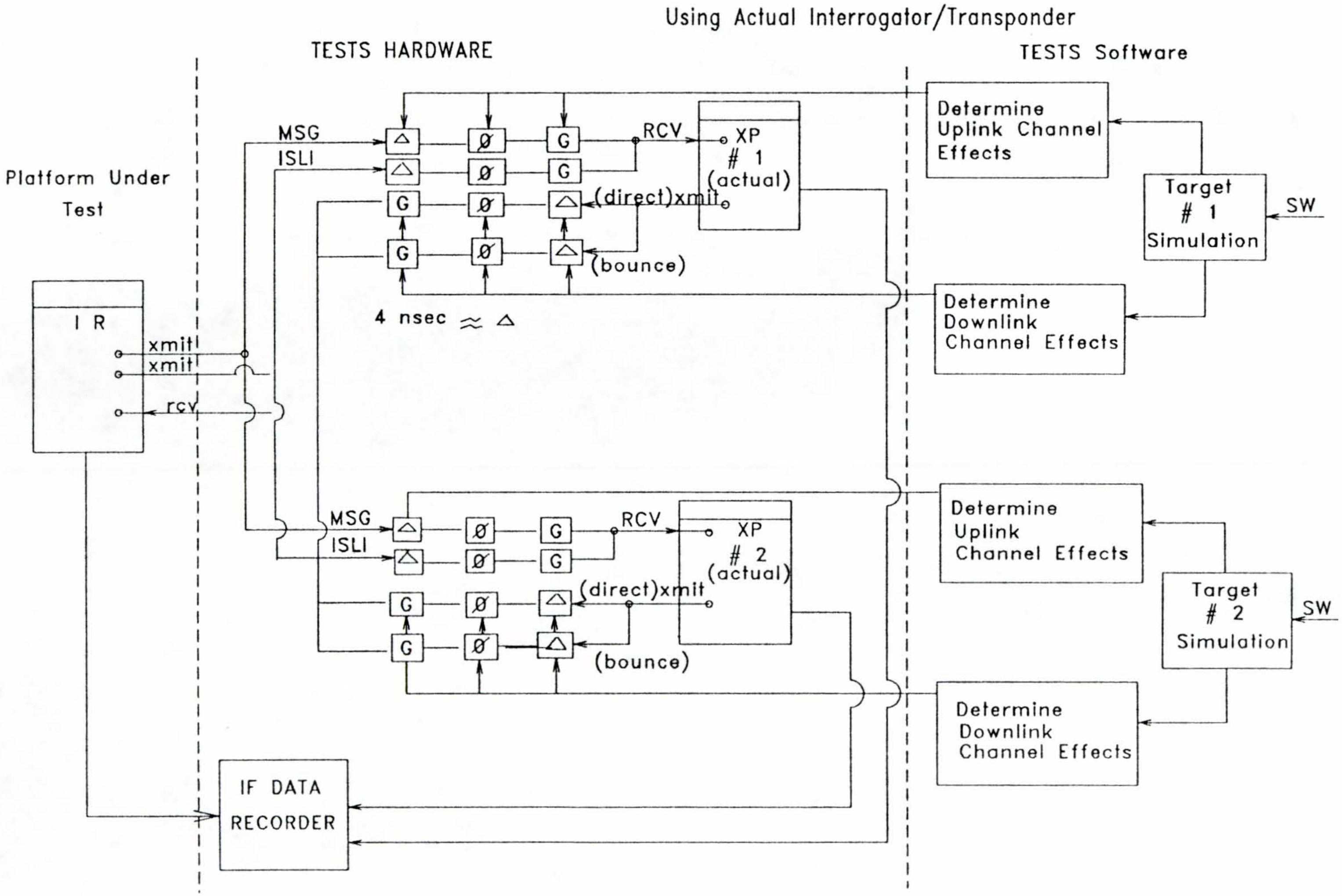
TASK 10 CONCEPTUAL DESIGN
CONCEPT D - HARDWARE INTENSIVE DESIGN CONCEPT

Figure 3-12 illustrates the last design concept, the Hardware Intensive Design Concept.

Concept D represents the extreme in the evolution of the TESTS approach which employs a minimal amount of software signal processing.

This approach assumes actual and complementary IFF equipment will be used to stimulate the SUT. Hence, the vast majority of the signal manipulation work in Concept D is done in TESTS hardware.

TASK 10: CONCEPTUAL DESIGN
CONCEPT D
Hardware Intensive Design



TASK 10: CONCEPTUAL DESIGN D
FUNCTIONAL BLOCK DESCRIPTIONS

PLATFORM UNDER TEST:

<u>INTERROGATOR</u>

FUNCTIONAL DESCRIPTION:
SYSTEM UNDER TEST (SUT) INSTALLED IN AN AIRCRAFT IN AN ANECHOIC CHAMBER OR SHIELDED HANGAR.

BLOCK INPUTS:
INTERROGATION REQUESTS FROM PLATFORM, KI-() COMSEC AND TRANSEC CODING INFORMATION, RF REPLY WAVEFORMS.

BLOCK OUTPUTS:
RF INTERROGATION WAVEFORMS, THREAT ID INFORMATION.

INTERNAL OPERATIONS:
USES COMSEC/TRANSEC CODING INFORMATION TO GENERATE INTERROGATION WAVEFORMS IN RESPONSE TO PLATFORM INTERROGATION REQUESTS.

TASK 10: CONCEPTUAL DESIGN D
FUNCTIONAL BLOCK DESCRIPTIONS

PLATFORM UNDER TEST:

TRANSPONDER

FUNCTIONAL DESCRIPTION:
SYSTEM UNDER TEST (SUT) INSTALLED IN AN AIRCRAFT IN AN ANECHOIC CHAMBER OR SHIELDED HANGAR.

BLOCK INPUTS:
RF INTERROGATION WAVEFORMS; KI-() COMSEC AND TRANSEC CODING INFORMATION.

BLOCK OUTPUTS:
RF REPLY WAVEFORMS.

INTERNAL OPERATIONS:
USES COMSEC/TRANSEC CODING INFORMATION TO INTERPRET INTERROGATION AND GENERATE REPLY WAVEFORMS WHEN APPROPRIATE.

TASK 10: CONCEPTUAL DESIGN D
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS HARDWARE:

<u>TRANSPONDERS</u>

FUNCTIONAL DESCRIPTION:
AUTHENTIC IFF TRANSPONDER TO REPLY TO SUT INTERROGATOR.

BLOCK INPUTS:
IFF INTERROGATION WAVEFORMS PERTURBED BY RF ENVIRONMENTAL SIMULATION HARDWARE; COMSEC/TRANSEC INFORMATION.

BLOCK OUTPUTS:
IFF REPLY WAVEFORMS.

INTERNAL OPERATIONS:
INTERPRETS AND REPLIES TO INTERROGATIONS.

TASK 10: CONCEPTUAL DESIGN D
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS HARDWARE:

INTERROGATORS

FUNCTIONAL DESCRIPTION:
AUTHENTIC IFF INTERROGATORS TO QUERY SUT TRANSPONDER FOR THE CASE OF TRANSPONDER PUT.

BLOCK INPUTS:
INTERROGATION REQUESTS; COMSEC/TRANSEC INFORMATION; REPLY WAVEFORMS PERTURBED BY RF ENVIRONMENTAL SIMULATION HARDWARE.

BLOCK OUTPUTS:
IFF INTERROGATION WAVEFORMS; THREAT ID INFORMATION.

INTERNAL OPERATIONS:
GENERATES INTERROGATION WAVEFORMS UPON REQUEST AND INTERPRETS REPLIES.

TASK 10: CONCEPTUAL DESIGN D
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS HARDWARE:

<u>IF DATA RECORDER</u>

FUNCTIONAL DESCRIPTION:
RECORDS IF SIGNAL EXCHANGE BETWEEN SUT AND TESTS HARDWARE. RECORDS THE TRANSMITTED IF FROM THE INTERROGATOR AND TRANSPONDER.

BLOCK INPUTS:
SUT IF WAVEFORMS; TESTS HARDWARE IF WAVEFORMS.

BLOCK OUTPUTS:
RECORD OF IF SIGNAL EXCHANGE FOR FUTURE ANALYSIS.

INTERNAL OPERATIONS:
CONVENIENT DEMODULATION AND DATA RECORDING FUNCTIONS ARE IMPLEMENTED.

TASK 10: CONCEPTUAL DESIGN D
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS HARDWARE:

<u>PROGRAMMABLE TIME DELAY, PHASE, GAIN AND FREQUENCY BLOCKS</u>

FUNCTIONAL DESCRIPTIONS:
IMPLEMENTATION OF CHANNEL EFFECTS ON RF SIGNALS.

BLOCK INPUTS:
CONTROL SIGNALS ORIGINATING IN SOFTWARE.

BLOCK OUTPUTS:
PERTURBATIONS ON RF SIGNALS.

INTERNAL OPERATIONS:
PROGRAMMABLE TIME DELAY WOULD RESPOND TO PREDETERMINED CONTROL SIGNALS WITH PREDETERMINED AMOUNTS OF UNIFORM GROUP DELAY. PROGRAMMABLE PHASE AND GAIN BLOCKS WOULD SIMILARLY APPLY VARIABLE LEVELS OF CARRIER PHASE AND SIGNAL ATTENUATION.

TASK 10: CONCEPTUAL DESIGN D
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS SOFTWARE:

<u>CHANNEL EFFECTS</u>

FUNCTIONAL DESCRIPTION:
APPLIES CHANNEL EFFECTS CONTROL SIGNALS TO PROGRAMMABLE TIME DELAY, PHASE AND GAIN BLOCKS.

BLOCK INPUTS:
SIMULATION SCENARIO ENVIRONMENT INFORMATION.

BLOCK OUTPUTS:
CONTROL SIGNALS FOR PROGRAMMABLE TIME DELAY, PHASE AND GAIN BLOCKS.

INTERNAL OPERATIONS:
ADDITION OF CHANNEL EFFECTS VIA MESSAGE LEVEL DATA FORMAT DESCRIPTIONS.

TASK 10: CONCEPTUAL DESIGN D
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS SOFTWARE:

TARGET SIMULATION

FUNCTIONAL DESCRIPTION:
KEEPS TRACK OF SCENARIO ENVIRONMENT INFORMATION SO AS TO UPDATE CHANNEL EFFECTS CONTROL BLOCKS.

BLOCK INPUTS:
TIME DEPENDENT SIMULATION INFORMATION.

BLOCK OUTPUTS:
SIMULATION SCENARIO ENVIRONMENT INFORMATION.

INTERNAL OPERATIONS:
FOLLOWS TEST SCENARIO TO UPDATE INDIVIDUAL IFF CHANNEL EFFECTS CONTROL BOXES.

TASK 10 CONCEPTUAL DESIGN
CONCEPT D - TECHNICAL ANALYSIS

- No message information is communicated between software and hardware.
- Authentic transponders which reside completely in hardware are used to stimulate the platform under test.
- The Concept D configuration provides for two sets of programmable time delay lines. This allows for interrogator sidelobe suppression pulses to be simulated on the uplink and multiple path propagation to be simulated for the downlink.
- This approach has the fewest software to hardware interface requirements of all approaches investigated.

TASK 10 CONCEPTUAL DESIGN
CONCEPT D - TECHNICAL ANALYSIS

- This concept has several disadvantages.
  - First and foremost, it is difficult to expand this configuration to simulate test scenarios which require more than a few interrogators and transponders.
  - Secondly, Concept D requires a great deal of hardware equipment including the availability of authentic interrogators and transponders for each platform in the test scenario.

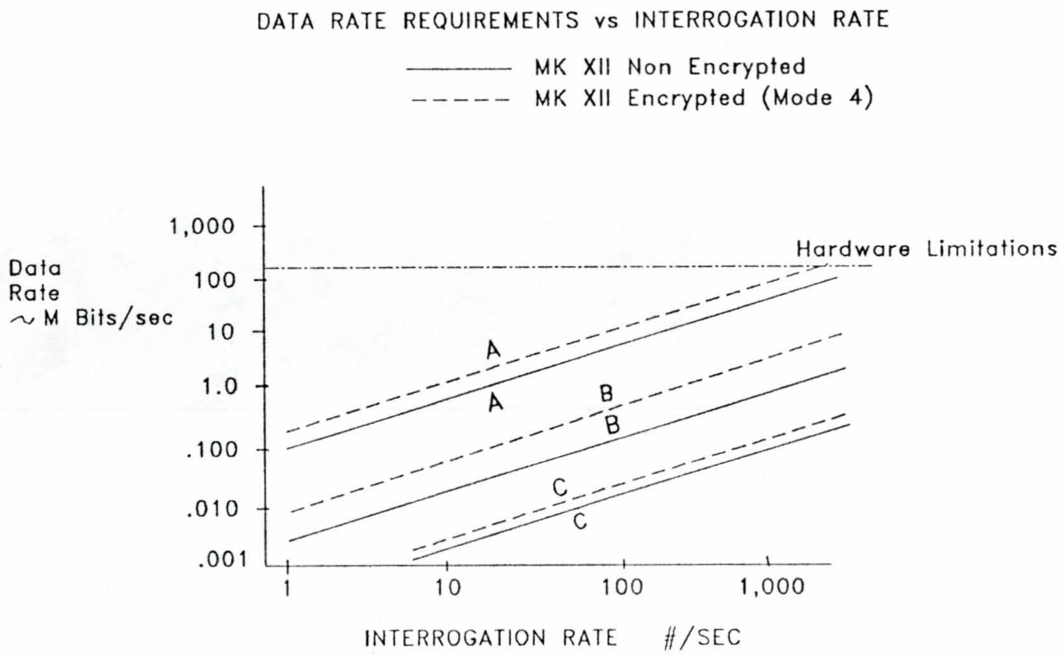
TASK 10: CONCEPTUAL DESIGN
FINDINGS: SUMMARY ON CONCEPTS A-D

- Concepts A and B can not be effectively achieved because of excessive data rates. Generation of MK XV spread spectrum signals for even a moderate number of platforms with multipath would require a supercomputer and an extremely fast communication network.

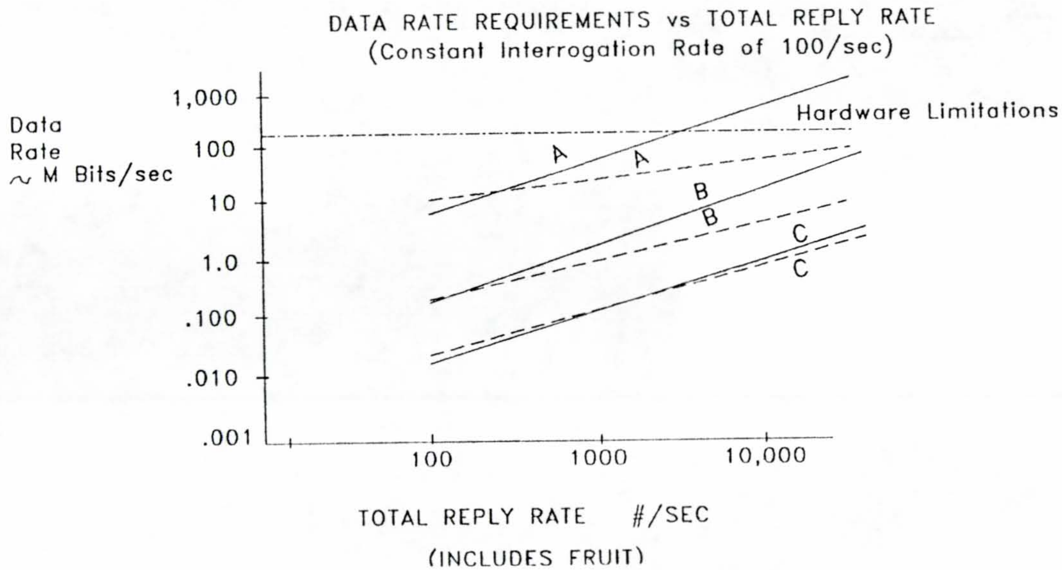
- Concept D is not cost effective. It is overly complex in that a separate hardware system for each platform is necessary.

- Concept C using a message level interface is achievable both technically and in terms of cost. Data rates are within the limits of state-of-the-art computers and network speed, and the dynamic introduction of channel effects. The parsing of functionality between hardware and software assigns time critical functions to hardware, which will enable TESTS to meet its real time requirements.

TASK 10: CONCEPTUAL DESIGN
DATA RATE COMPARISON FOR MK XII



TASK 10: CONCEPTUAL DESIGN
DATA RATE COMPARISON FOR MK XII



TASK 10: CONCEPTUAL DESIGN
DATA RATE COMPARISON FOR MK XV

TASK 10 CONCEPTUAL DESIGN
RECOMMENDED TESTS CONCEPT APPROACH

An approach utilizing the Message Level Interface coupled with the modular channel effects hardware devices

- Receiver - Able to recognize each of the possible IFF signal types and modes, and to demodulate, decode, and despread the signal to determine message data content.
- KI-() - Real or simulated encryption device that provides the COMSEC/TRANSEC sequences to the TESTS Receiver, TESTS Signal Generators, and Platform Under Test.
- TESTS Signal Generators (XMIT) - Receives a complete message in binary (baseband) format from the TESTS host computer, and constructs the desired IFF message modulated at RF frequency for transmission over hardware channels to the Platform Under Test.

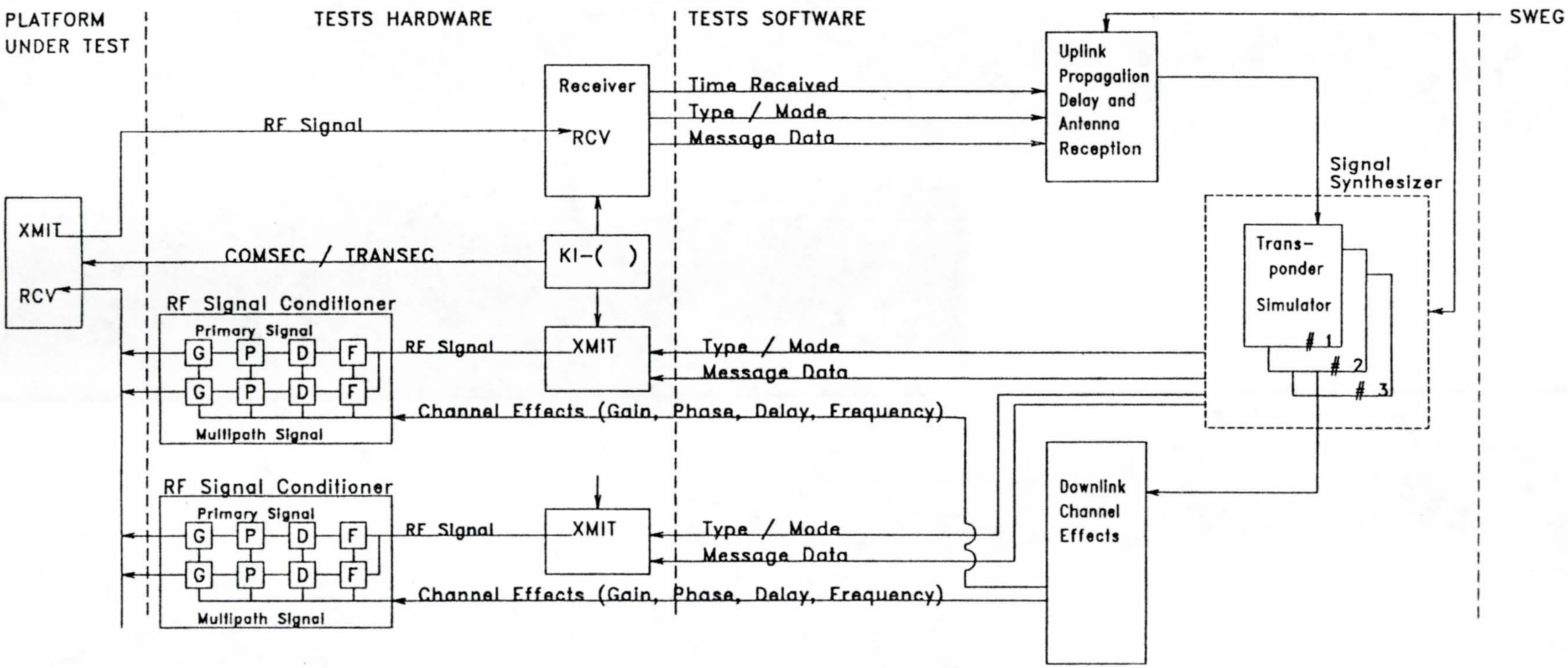
TASK 10 CONCEPTUAL DESIGN
RECOMMENDED TESTS CONCEPT (cont.)

- RF Signal Conditioner (G-P-D-F) - Special purpose hardware devices that can be used to dynamically introduce channel effects in the generated IFF signals. They contain programmable Gain (G), Phase (P), Time Delay (D), and Frequency Shift (F) devices that can be directly controlled from the TESTS host computer.

- Platform Under Test (PUT) - This represents the RF transmit and receive hardware lines of the actual IFF equipment on the Platform Under Test.

TASK 10: CONCEPTUAL DESIGN
TESTS RECOMMENDED CONCEPT

RECOMMENDED APPROACH – Modular Hardware / Message Level Interface



TASK 10: CONCEPTUAL DESIGN - RECOMMENDED
FUNCTIONAL BLOCK DESCRIPTIONS

PLATFORM UNDER TEST:

INTERROGATOR

FUNCTIONAL DESCRIPTION:
SYSTEM UNDER TEST (SUT) INSTALLED IN AN AIRCRAFT IN AN ANECHOIC CHAMBER OR SHIELDED HANGAR.

BLOCK INPUTS:
INTERROGATION REQUESTS FROM PLATFORM, KI-() COMSEC AND TRANSEC CODING INFORMATION, RF REPLY WAVEFORMS.

BLOCK OUTPUTS:
RF INTERROGATION WAVEFORMS, THREAT ID INFORMATION.

INTERNAL OPERATIONS:
USES COMSEC/TRANSEC CODING INFORMATION TO GENERATE INTERROGATION WAVEFORMS IN RESPONSE TO PLATFORM INTERROGATION REQUESTS. USES COMSEC/TRANSEC CODING INFORMATION TO INTERPRET RF REPLY WAVEFORMS.

TASK 10: CONCEPTUAL DESIGN - RECOMMENDED
FUNCTIONAL BLOCK DESCRIPTIONS

PLATFORM UNDER TEST:

TRANSPONDER

FUNCTIONAL DESCRIPTION:
SYSTEM UNDER TEST (SUT) INSTALLED IN AN AIRCRAFT IN AN ANECHOIC CHAMBER OR SHIELDED HANGAR.

BLOCK INPUTS:
RF INTERROGATION WAVEFORMS, KI-()
COMSEC AND TRANSEC INFORMATION.

BLOCK OUTPUTS:
RF REPLY WAVEFORMS.

INTERNAL OPERATIONS:
USES COMSEC/TRANSEC CODING INFORMATION TO INTERPRET INTERROGATION WAVEFORMS AND GENERATE, WHEN APPROPRIATE, REPLY WAVEFORMS.

TASK 10: CONCEPTUAL DESIGN - RECOMMENDED
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS HARDWARE:

SIGNAL RECEIVER

FUNCTIONAL DESCRIPTION:
DETECTS RF IFF SIGNALS FROM SUT, CONVERTING THEM TO A MESSAGE LEVEL DATA FORMAT.

BLOCK INPUTS:
SUT IFF SYSTEM OUTPUT WAVEFORMS; COMSEC/TRANSEC INFORMATION.

BLOCK OUTPUTS:
MESSAGE LEVEL DATA FORMAT RF SIGNAL DESCRIPTION.

INTERNAL OPERATIONS:
MESSAGE LEVEL SIGNAL RECOGNITION AND DEMODULATION INCLUDING DESPREADING, DECODING AND/OR DECRYPTION.

TASK 10: CONCEPTUAL DESIGN - RECOMMENDED
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS HARDWARE:

SIGNAL TRANSMITTER

FUNCTIONAL DESCRIPTION:
CONVERTS SOFTWARE GENERATED MESSAGE LEVEL DATA FORMAT SIGNALS INTO RF SUT STIMULUS SIGNALS.

BLOCK INPUTS:
MESSAGE LEVEL DATA FORMAT RF SIGNAL DESCRIPTIONS; COMSEC/TRANSEC INFORMATION.

BLOCK OUTPUTS:
RF SUT STIMULUS SIGNALS.

INTERNAL OPERATIONS:
MESSAGE LEVEL MODULATION INCLUDING SPREADING, ENCODING AND/OR ENCRYPTION.

TASK 10: CONCEPTUAL DESIGN - RECOMMENDED
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS HARDWARE:

KI-()

FUNCTIONAL DESCRIPTION:
CRYPTO UNIT WHICH INTERACTS WITH MK XV OR NAVY ADVANCED IFF SUBSYSTEM TO PROVIDE COMSEC/TRANSEC INFORMATION TO IFF SUBSYSTEM AND TESTS HOST PROCESSOR.

BLOCK INPUTS:
TIME OF DAY INFORMATION AND KEY CODES.

BLOCK OUTPUTS:
COMSEC/TRANSEC CODES VIA SHIELDED CABLE.

INTERNAL OPERATIONS:
ACTUAL INTERNAL OPERATION IS CLASSIFIED AND MAY BE REPLACED IN SOME TEST CASES WITH AN UNCLASSIFIED SUBSTITUTE.

TASK 10: CONCEPTUAL DESIGN - RECOMMENDED
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS HARDWARE:

RF SIGNAL CONDITIONER

FUNCTIONAL DESCRIPTIONS:
IMPLEMENTATION OF CHANNEL EFFECTS ON RF SIGNALS.

BLOCK INPUTS:
CONTROL SIGNALS ORIGINATING IN SOFTWARE.

BLOCK OUTPUTS:
PERTURBATIONS ON RF SIGNALS.

INTERNAL OPERATIONS:
PROGRAMMABLE TIME DELAY WOULD RESPOND TO PREDETERMINED CONTROL SIGNALS WITH PREDETERMINED AMOUNTS OF UNIFORM GROUP DELAY. PROGRAMMABLE PHASE AND GAIN BLOCKS WOULD SIMILARLY APPLY VARIABLE LEVELS OF CARRIER PHASE AND SIGNAL ATTENUATION.

TASK 10: CONCEPTUAL DESIGN - RECOMMENDED
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS SOFTWARE:

UPLINK PROPAGATION DELAY AND ANTENNA RECEPTION

FUNCTIONAL DESCRIPTION:
COMPUTES PROPAGATION DELAY TO MESSAGE LEVEL DATA FORMAT SUT RF SIGNAL DESCRIPTIONS AND PASSES DATA IF IT WAS RECEIVED IN THE ANTENNA'S RECEPTION LOBE.

BLOCK INPUTS:
MESSAGE LEVEL DATA FORMAT DESCRIPTIONS OF SUT RF SIGNALS.

BLOCK OUTPUTS:
MESSAGE LEVEL DATA FORMAT SIGNAL DESCRIPTIONS MODIFIED FOR PROPAGATION DELAY.

INTERNAL OPERATIONS:
ADDITION OF PROPAGATION DELAY VIA MESSAGE LEVEL DATA FORMAT DESCRIPTIONS COMPUTED FOR DIRECT AND REFLECTED SIGNALS. REJECTS DATA IF IT WAS NOT RECEIVED IN THE ANTENNA'S RECEPTION LOBE.

TASK 10: CONCEPTUAL DESIGN - RECOMMENDED
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS SOFTWARE:

<u>TRANSPONDER SIMULATOR</u>

FUNCTIONAL DESCRIPTION:
INVOKES TESTS INTERROGATIONS OR REPLIES APPROPRIATE TO THE TEST FUNCTION AND TIME DEPENDENT SCENARIO CONDITIONS.

BLOCK INPUTS:
IFF MESSAGE TYPES, MODES AND CONTENT.

BLOCK OUTPUTS:
NEW IFF MESSAGE TYPES, MODES AND CONTENT.

INTERNAL OPERATIONS:
FOLLOWS TEST SCENARIO TO SIMULATE INDIVIDUAL IFF PLATFORMS.

TASK 10: CONCEPTUAL DESIGN - RECOMMENDED
FUNCTIONAL BLOCK DESCRIPTIONS

TESTS SOFTWARE:

DOWNLINK CHANNEL EFFECTS

FUNCTIONAL DESCRIPTION:
COMPUTES CHANNEL EFFECTS TO MESSAGE LEVEL DATA FORMAT.

BLOCK INPUTS:
SIMULATION SCENARIO ENVIRONMENT INFORMATION.

BLOCK OUTPUTS:
CONTROL SIGNALS FOR PROGRAMMABLE TIME DELAY, PHASE AND GAIN BLOCKS.

INTERNAL OPERATIONS:
ADDITION OF CHANNEL EFFECTS VIA MESSAGE LEVEL DATA FORMAT DESCRIPTIONS.

TASK 10 CONCEPTUAL DESIGN
RECOMMENDED TECHNICAL ANALYSIS 1

- A number of separate signal generators may be easily added to increase the reply rate or Interrogation rate capacity of the TESTS system.
- The programmable gain, phase, time delay, and frequency distortion devices are special purpose hardware devices that can be built separately, and used in a modular fashion to introduce channel effects in the generated signals.
- Each channel effects box would contain at least two sets of separately programmable signal distortion devices, in order to simulate at least one indirect bounce path for multipath effects.
- This approach is the opinion of the IST/UCF team that it is both cost-effective and technologically achievable.

TASK 10: CONCEPTUAL DESIGN
FINDINGS: RECOMMENDED APPROACH

- The recommended design permits TESTS to be implemented in either a coupled or uncoupled test mode; preferences for both configurations have been expressed. Final selection of configuration will be determined during detail design of TESTS. It is likely to be driven by cost.

- The recommended design eliminates many potential problems with generation of multiple spread spectrum signals. By using a number of independent RF generators for multiple platforms and multipath, it effectively sums RF signals in the same manner as the real world. There is no requirement for computationally attempting to generate parallel spread spectrum signals.

TASK 10: CONCEPTUAL DESIGN
SIGNAL GENERATION OPTIONS - SUMMARY

The signal generation approach is more hardware intensive than the original objective because of the spread spectrum requirement.

Three major options to address the signal generation requirements of TESTS are being examined.

1. Simulation + custom hardware
   - requires extensive laboratory capabilities for hardware development which is expensive
   - can be accomplished through the integration of off-the-shelf components, plus one custom design component (RF signal conditioner to insert channel effects)

2. Simulation + modified Hewlett Packard FASS (Fast Agile Signal Simulator) + channel effects

3. Simulation + Bendix Test Hardware + channel effects
   Bendix hardware could be used for signal processing (receive or decode), signal generation or both

Options 1 and 3 are currently the preferred approaches. Final selection will be made during detail design effort.

TASK 10 SIGNAL GENERATION
HP OPTION (HARDWARE IMPLEMENTATION)

- Signal Simulator (FASS - HP 8791 Model 10)
  - 10 - 2000 MHz
  - AM and FM up to 40 MHZ BW
  - Control Carrier Frequency and Modulation
  - Non-Dynamic RF Signal Conditioning (Memory limited for large messages)
- Would need to be modified to meet TESTS requirements
- Since core capability exists, it provides some reduction in technical risk
- Expensive $ 250K/ System, multiple would be required

TASK 10 SIGNAL GENERATION
BENDIX HARDWARE OPTION

- Subsystems for transponder and/or interrogator test sets were mounted on mobile carts and consisted of -

  (A) Digital interface drawer
  (B) Density signal generator drawer (2 channels)
  (C) D-Band RF drawer
  (D) Radar Mode RF drawer
  (E) COMSEC drawer
  (F) Power supply

- Selected subsystems could be effectively used for "simulator tool" implementation - (Under recommended concept) -

  (A) Digital interface drawer (All "modes" of waveform generation and a receiver capability) — 1 Ea
  (B) Density signal generator (2 independent channels, each) — 5* Ea
  (C) Power supply drawer — 1 Ea

  * Capable of generating 10 simultaneous modulated RF signals under computer control

TASK 10 SIGNAL GENERATION
BENDIX HARDWARE OPTION

- IST evaluation of equipment found:
  - Standard IFF modes implemented with provision for outside additional waveforms (488 Bus)
  - Hardware modularized within each drawer, with easy access to interconnections for hardware modifications or additions (such as inputs for channel effects)
  - Flexibility for outside computer control of critical elements and/or for timing synchronization
  - Receiver demodulation and decode capability already implemented
  - Additional evaluation necessary to determine if one simulator tool could serve as both interrogator tool and transponder tool (carrier frequency and message formats different)

TASK 10 SIGNAL GENERATION
CUSTOM HARDWARE OPTION

REQUIREMENTS

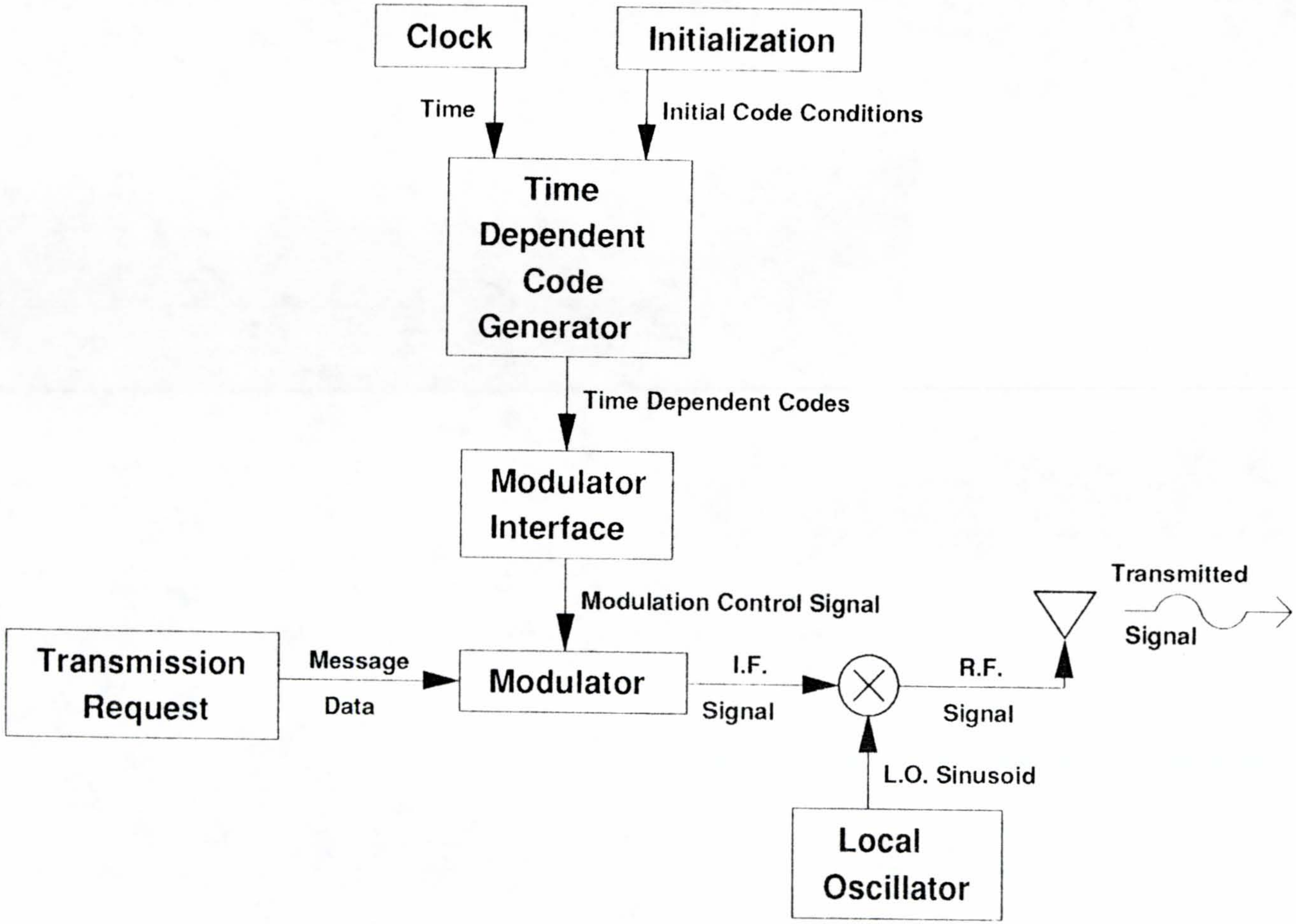
- Real Time
- Modular
    - Software Modeling
    - Hardware Design
- Cost Effective
- Act as Test Tool and Simulator

TASK 10 SIGNAL GENERATION
CUSTOM HARDWARE OPTION

- Signal Generator System
  - Message generation
  - Code generation
  - Encryption
  - Modulation
- Signal Conditioner System
  - Deterministic signal modification
    - Amplitude
    - Delay
    - Frequency
    - Dispersion
- Demodulation-Detector System
  - De-modulate signal
  - De-encrypt signal
  - Decode signal
  - Message detection-reply

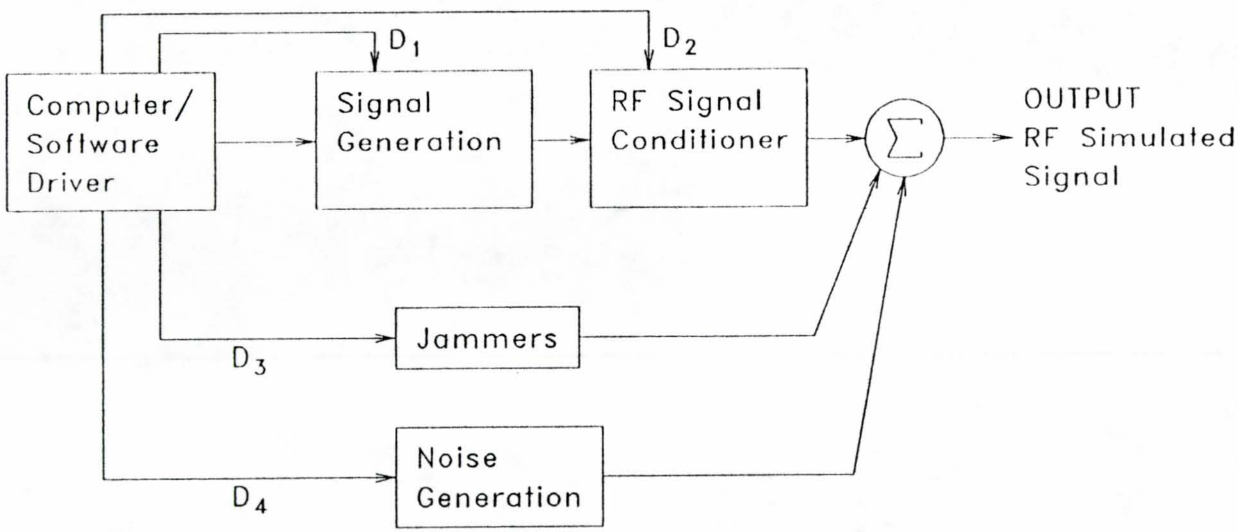
TASK 10 SIGNAL GENERATION
CUSTOM HARDWARE OPTION

GENERALIZED TRANSMITTER



TASK 10 SIGNAL GENERATION
CUSTOM HARDWARE OPTION

SIGNAL GENERATION



TASK 10 SIGNAL GENERATION

CUSTOM HARDWARE OPTION

SIGNAL GENERATOR SYSTEM

- Computer Models/Simulation Driver
- Computer Controller
- Digital Drivers to Hardware
- Hardware
  - Message generators
  - Code generators
  - Encryption
  - Modulators
  - Carrier insertion

TASK 10 SIGNAL GENERATION
CUSTOM HARDWARE OPTION

RF SIGNAL CONDITIONER

OBJECTIVES

Generate a Signal Conditioner Sub System to

- Dynamically modify RF signal to simulate environmental effects
- Simulate distant, stationary or moving interrogators in real time
- Meet TEMP objectives of multi-platform and variable environment

TASK 10 SIGNAL GENERATION
CUSTOM HARDWARE OPTION

APPROACH

- Amplitude
  - Function of distance
  - Function of environment
- Phase (Delay)
  - Function of distance
  - Function of environment
- Frequency Offset
  - Doppler
  - Tuning
- Amplitude dispersion
  - Frequency dependent amplitude response
- Phase dispersion
  - Frequency dependent delay response

TASK 10 SIGNAL GENERATION
CUSTOM HARDWARE OPTION

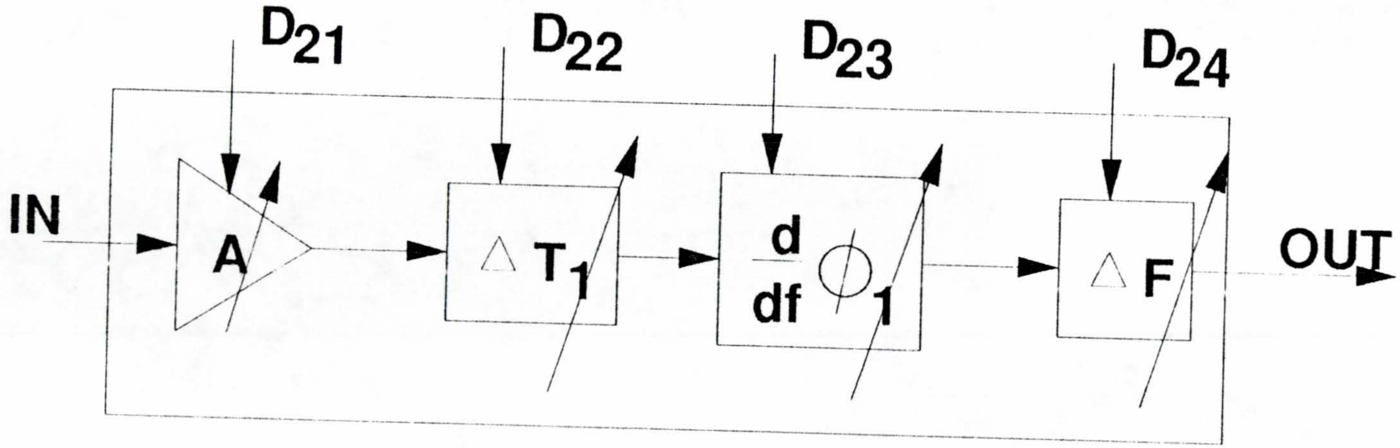
APPROACH

- RF Hardware
    - Frequency consistent with bandwidth and availability
    - RS 232 or equivalent, addressable
    - Fast response times
    - Model driven
    - Computer controlled

TASK 10 SIGNAL GENERATION
CUSTOM HARDWARE OPTION

APPROACH

- RF Signal Conditioner Block Diagram



- Digital Control
- Analog Processing
  - Serial convolution of passive elements
  - Non-linear effect through mixing and filtering

TASK 10 SIGNAL GENERATION
CUSTOM HARDWARE OPTION

VARIABLE PARAMETER IMPLEMENTATION

- Amplitude
  - Programmable Amplifiers or Attenuators
  - Issues
    - Accuracy
    - Speed
    - Dynamic Range
    - Cost
- Phase (Delay)
  - Programmable Delay Lines
  - Issues
    - Maximum delay
    - Incremental delay
    - Accuracy
    - Speed
    - Dynamic Range
    - Cost

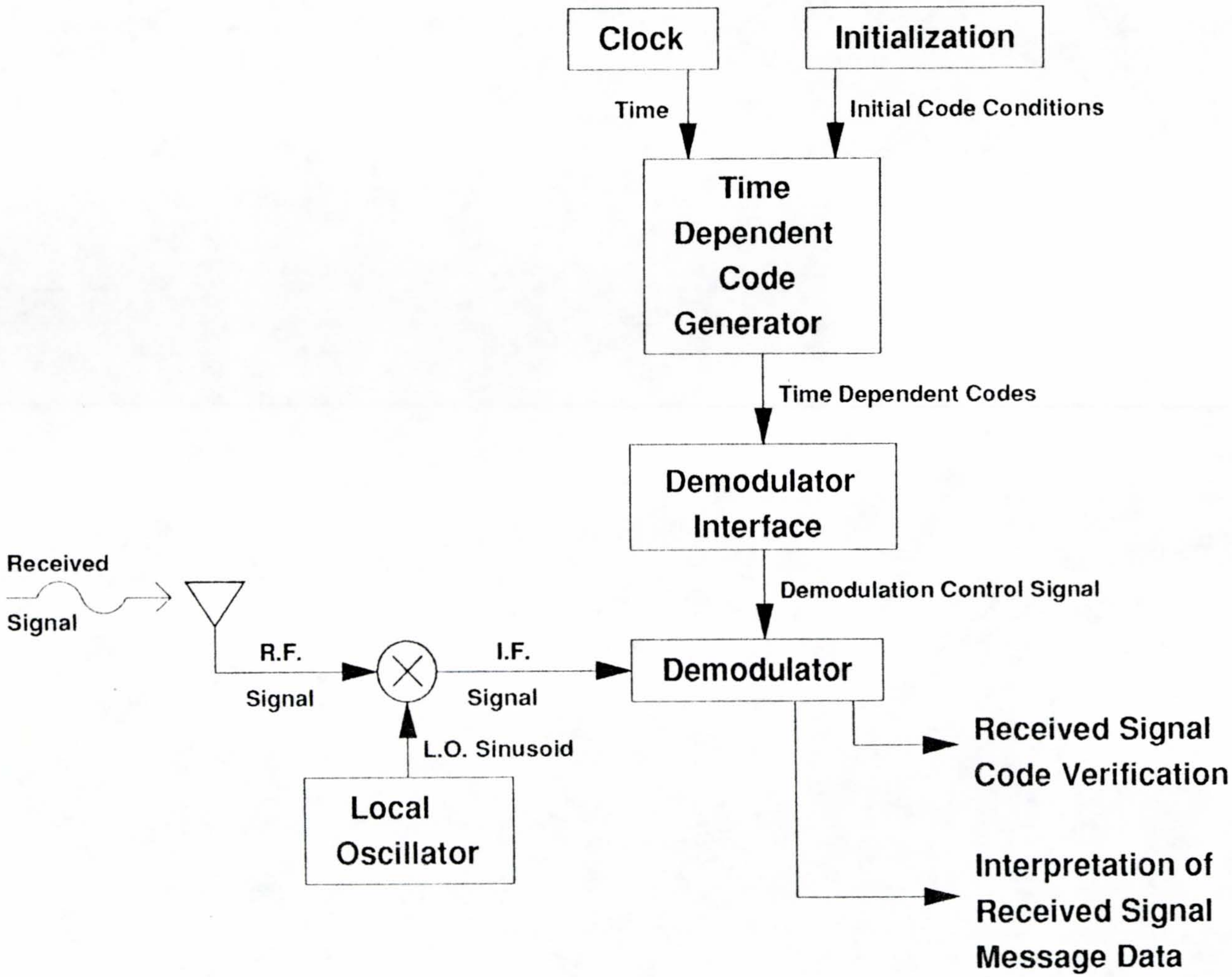
TASK 10 SIGNAL GENERATION
CUSTOM HARDWARE OPTION

VARIABLE PARAMETER IMPLEMENTATION

- Frequency Offset
  - Programmable Frequency Shifts
  - Issues
    - Image Responses
    - Accuracy
    - Speed
    - Dynamic Range
    - Linearity
    - Cost
- Dispersion
  - Programmable Amplitude and Phase Dispersion
  - Issues
    - Maximum dispersion necessary
    - Accuracy
    - Speed
    - Dynamic Range
    - Cost

TASK 10 SIGNAL GENERATION
CUSTOM HARDWARE OPTION

GENERALIZED RECEIVER



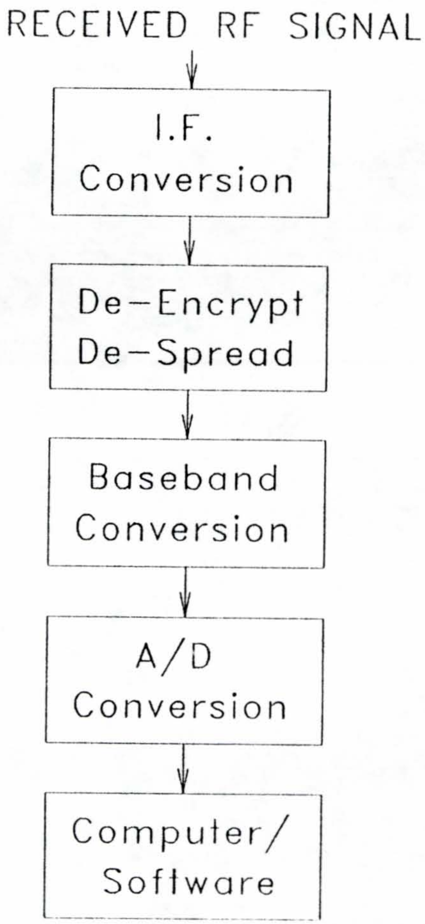
TASK 10 SIGNAL GENERATION
CUSTOM HARDWARE OPTION

DEMODULATOR SYSTEM

- Hardware
  - Carrier Extraction
  - De-spread/Decode
  - De-encrypt
  - De-modulate/Correlate
  - Basband Detector
- Computer
  - Data Analysis
  - Message Decision
  - Reply Decision

TASK 10 SIGNAL GENERATION
CUSTOM HARDWARE OPTION

SIGNAL DEMODULATION



TASK 10 CONCEPTUAL DESIGN
TESTS PROTOTYPE BUILD PLAN

An evolving Prototype Build Plan will be adopted for TESTS.

Provides a low risk, high confidence, and low cost approach to the design, purchase, fabrication, and integration of the hardware and software components of the TESTS system.

Number of incremental builds which provide

- increasing capability and diversity in the number of platforms and signals to be generated, and simultaneously

- increasing fidelity in the environmental and channel propagation effects to be simulated by TESTS.

Allows early closed loop testing and validation of the TESTS system with existing IFF systems such as the MK XII, and provides a low risk transition to more advanced IFF systems utilizing spread spectrum signals.

TASK 10: CONCEPTUAL DESIGN

PROTOTYPE BUILD PLAN

	PLATFORM							SIGNALS					Dynamics		
Prototype	F-18 (XP)	F-15 (IR)	F-15 (XP)	Hawk (IR)	Ship (IR)	Radar Mode (X-IR)	Radar Mode (S-IR)	Mk XII (Clear)	Mk XII (Mode 4)	Mk XV	Mode S	Stationary	Moving	SWEG	
1.0	X							X				X			
1.1	X	X						X				X	X		
1.2	X	X						X	X			X	X		
2.0	X							X	X	X		X	X		
2.1	X	X						X	X	X		X	X		
2.2	X	X	X					X	X	X		X	X	X	
3.0	X	X	X	X	X			X	X	X		X	X	X	
3.1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	

TASK 10: CONCEPTUAL DESIGN
PROTOTYPE BUILD PLAN

	Emitters		Terrain Data			Multipath		Antenna			Propogation				
Prototype	Single	Multiple	4/3 Rad Earth	DMA Topography	Roughness	Single Reflection	Stochastic	Free Space	Platform Masking	Coupling	Standard Atmos.	Weather	Dust / Clouds	Ducting	
1.0	X		X			X		X			X				
1.1	X		X			X		X			X				
1.2	X	X	X			X		X			X	X			
2.0	X	X	X			X		X	X		X	X			
2.1	X	X	X			X		X	X		X	X	X		
2.2	X	X	X	X		X		X	X		X	X	X		
3.0	X	X	X	X	X	X	X	X	X	X	X	X	X		
3.1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	

TASK 10 CONCEPTUAL DESIGN
ACETEF INTEGRATION AND INTERFACE

TESTS will integrate into the expanding capabilities of ACETEF, initially to provide Development Testing of the NGIFF system, and eventually to provide full Operational Testing of IFF systems as part of the CNIL.

It is anticipated that TESTS will be employed in at least four different configurations:

1) as a stand alone benign test tool to provide IFF testing on aircraft in the shielded hangar,

2) as a stand alone test tool integrated with additional equipment such as the Tactical Agile Signal Simulator (TASS), used to provide an ECM/jamming environment,

3) integrated in CNIL with CNIL operating independently ofACETEF, or

4) in a fully integrated ACETEF testing environment utilizing several assets at once to test aircraft systems in the anechoic chamber.

TASK 10 CONCEPTUAL DESIGN
SWEG INTERFACE

SWEG provides a standard format for the shared memory interface between the various components of ACETEF, and defines the protocol for interactions between components.

The software components of TESTS will interface to the SWEG shared memory for required scenario simulation data, such as platform positions, attitudes, velocities, terrain elevation data, antenna pattern directional attenuations, antenna scan rates, etc.

TESTS will utilize or upgrade existing ACETEF simulation models whenever possible, and will conform to the ACETEF established conventions for scenario preparation, initialization, execution, shutdown, and post processing phases of operation.

In the CNIL integrated configuration TESTS may require a second interface to the shared memory to meet real time processing requirements for multipath calculations.

The need for this second access to shared memory will depend upon the final architecture for the CNIL.

TASK 10 CONCEPTUAL DESIGN
SWEG TERRAIN DATA BASE

Utilizes standard DMA data.

The resolution of the data base is determined by available memory.

The SWEG terrain data base can accept the finest resolution of DMA data available.

While DMA data is not of infinite resolution, it is sufficient to achieve a moderately high level of fidelity.

Hence, it does not appear that the SWEG terrain data base resolution will impose any severe limitation on the development or utility of TESTS.

The most critical technical terrain data base issue is the real time calculation of platform inter-visibility.

TASK 10 CONCEPTUAL DESIGN
SWEG SCENARIO UPDATE RATES

Simulation assets of SWEG may either be event driven or updated periodically.

The update period for certain platform parameters such as positions (latitude, longitude, altitude) and attitudes (pitch, roll, yaw), is critical to the fidelity requirements of TESTS.

A preliminary analysis indicates that approximately 1.0 degrees of angular motion, and 50.0 feet of relative translational motion can be tolerated per simulation update cycle. Assuming average aircraft angular rates of 30.0 degrees per second, or less, and average closing velocities of 1500 feet per second or less, a simulation update rate of 30 times per second should be adequate for TESTS.

TASK 10 CONCEPTUAL DESIGN
SOFTWARE DEVELOPMENT APPROACH

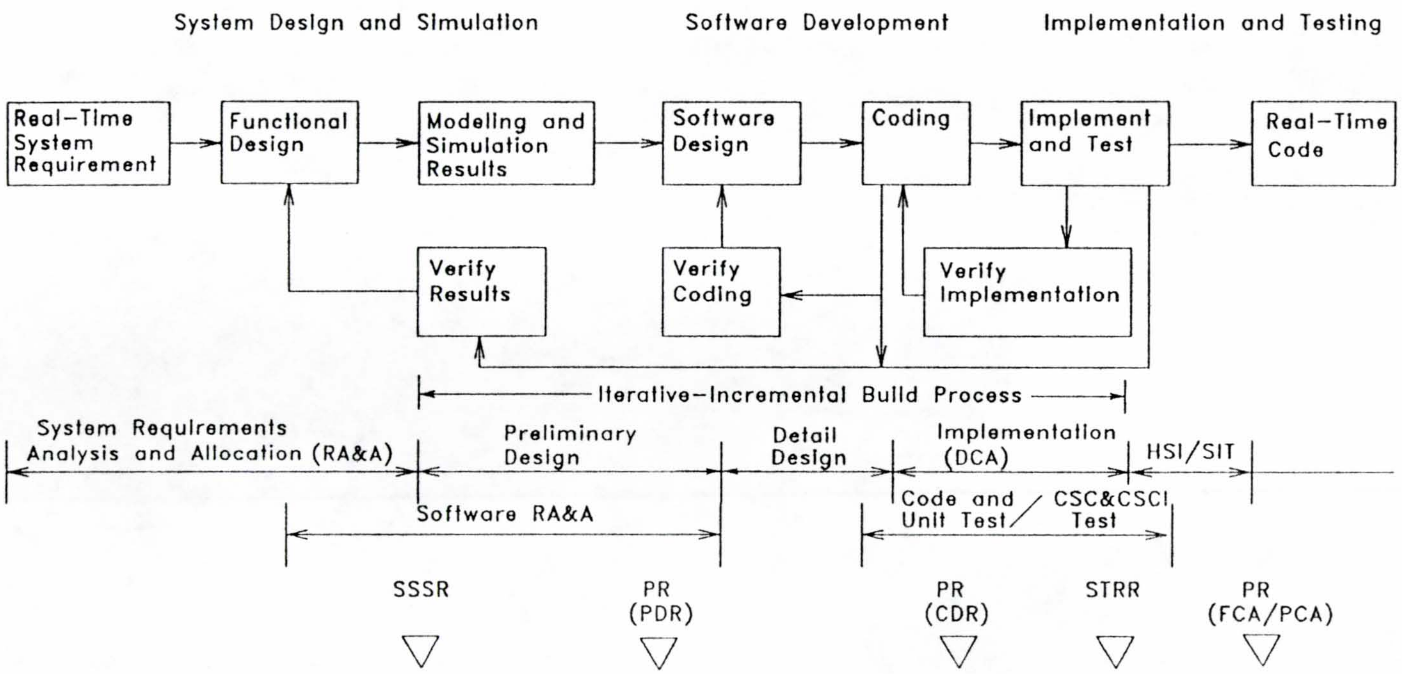
TESTS project will utilize a tailored MIL-STD-2167A software development approach.

A tailored approach to DoD software development standards is proposed to accommodate the prototyping approach to the TESTS development, accommodate the research aspects of TESTS and maintain the cost effectiveness of the TESTS concept.

The term prototype as used herein refers to an instance of a software version that does not exhibit all properties of the final system as defined in DoD-HDBK-287. It is an intermediate stage to the development of the final product.

TASK 10: CONCEPTUAL DESIGN
SOFTWARE DEVELOPMENT APPROACH

OVERVIEW OF DEVELOPMENT PROCESS:

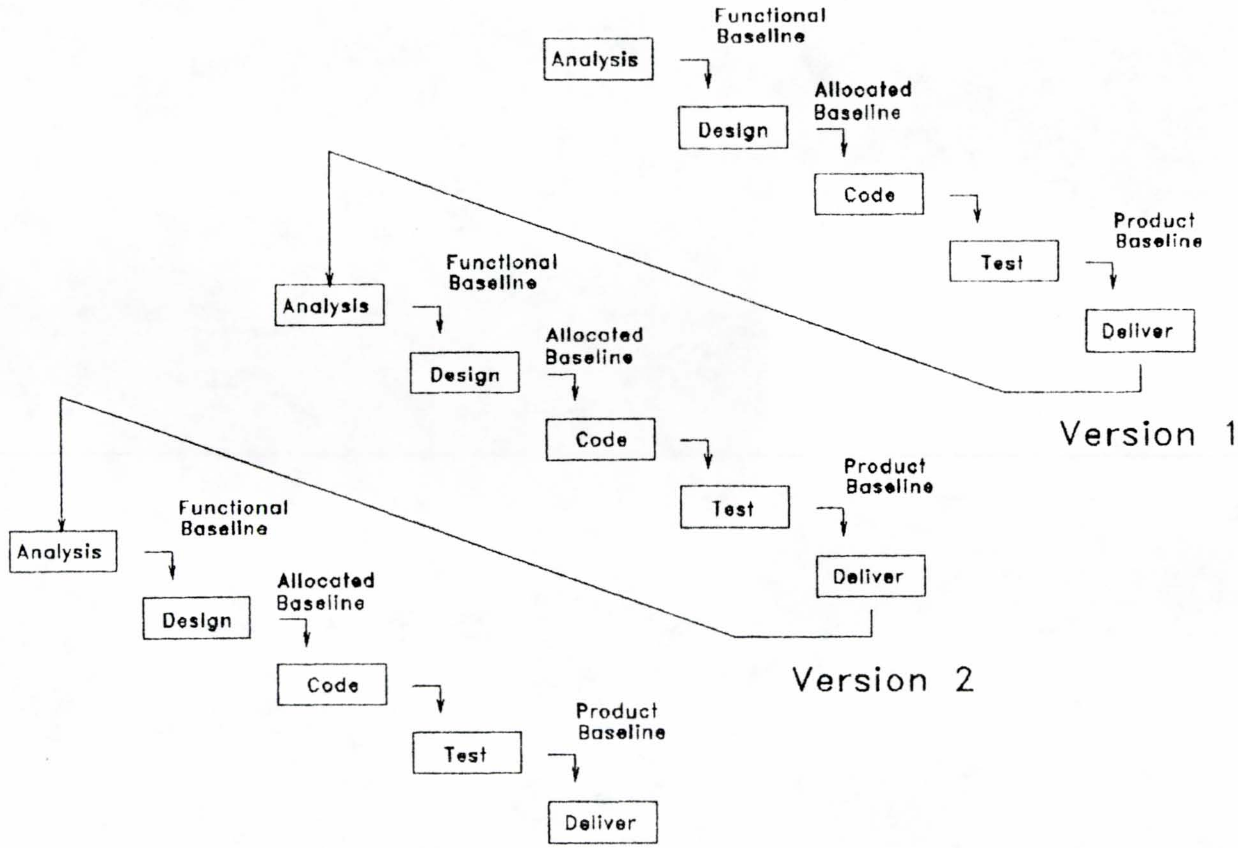


Notes on Tailoring:

1. 2167A and 1521B call out 9 major reviews as minimum plus potentially separate HW-SW PDRs/CDRs: Schedule above shows 5 reviews but assumes the PDR, CDR, & FCA/PCA could be replaced by a Progress Review (PR)
2. 2167A calls out 17 Data Items and 490A implies A, B and C specs. A potential plan for SW Development would be to combine the SSS (Aspec) and the PIDS/CIDS (B/C) and the SSDD into the Functional Description (FD), DI-E-30104B, with a contractor defined RTM.

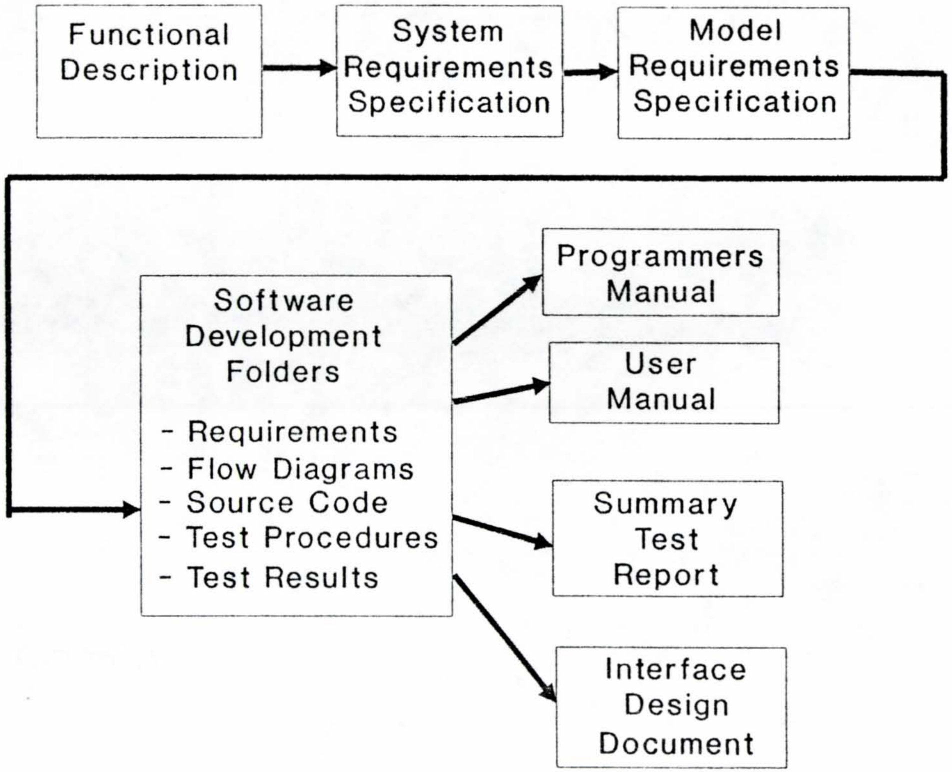
TASK 10: CONCEPTUAL DESIGN
SOFTWARE DEVELOPMENT APPROACH

PROTOTYPING APPROACH:



TASK 10: CONCEPTUAL DESIGN
SOFTWARE DEVELOPMENT APPROACH

SOFTWARE DOCUMENTATION DEVELOPMENT:



TASK 10 CONCEPTUAL DESIGN
TESTS - SUMMARY

There are four major functional blocks within TESTS

Simulator Component
In the signal generation operation, the TESTS simulator component generates IFF messages, calculates propagation effects, etc., in software and formats the simulation commands to the stimulation component. In the receiving operation, the simulator component decodes the received signal and passes it to the data capture facility.

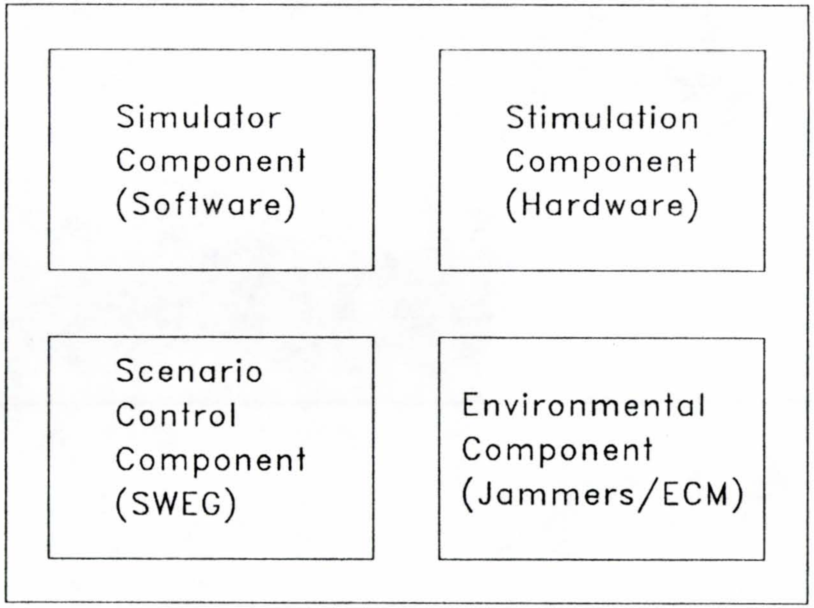
Stimulation Component
The stimulation component is the hardware RF generator portion of TESTS. It includes both the signal generation hardware and the signal distortion, i.e., channel effects, hardware. This component translates the message level simulation command into the appropriate signal signature(s), both data and characteristics, required to stimulate the SUT. On the receiving side, it demodulates the SUT signal and transforms the received signal into a format interpretable by the simulator module.

TASK 10 CONCEPTUAL DESIGN
TESTS - SUMMARY

Scenario Control Component
The primary scenario control component for TESTS is SWEG. SWEG provides all of the operational information concerning platforms, and environmental data and terrain data required for multipath and other propagation effects determinations. This component also initializes the appropriate test conditions and provides the interface to other facilities, e.g., CNIL, ACETEF. SWEG will be augmented by a TESTS specific scenario control subcomponent if it is determined that all parameters required for TESTS can not be obtained from SWEG.

Environmental Component
The environmental component provides the jammer/ECM environment for TESTS. This component will be provided by external resources. TESTS will provide the appropriate interface to integrate this capability. Depending upon the TESTS configuration, this capability may be provided by ACETEF through EWISTL or other off-the-shelf hardware.

TASK 10: CONCEPTUAL DESIGN
TESTS SUMMARY



TASK 11: TESTS REFINEMENT STUDIES

Task Definition: As necessary, conduct preliminary research efforts focusing on technical issues required to assess TESTS feasibility, and develop and refine the TESTS conceptual design.

Technical Approach: Develop computer analyses to evaluate tradeoffs between design parameters, e.g., data rate requirements as a function of design concept, or IFF Mode.

Findings:

Completed analyses or ongoing include:

- Processing data rates for MK XII and MK XV
- Number of RF channels based on probability of overlapping signals
- Multipath delay times for selected altitude combinations
- Methods for modeling spread spectrum signals
- Propagation effects

SUMMARY AND CONCLUSIONS

- The Navy's active support and cooperation ensured that the feasibility assessment was both comprehensive and thorough.
- The essential conclusion is that TESTS will enable the Navy to address the five primary simulation TEMP objectives identified for simulation and achieve accurate test results with high levels of confidence.
- Additionally, the project team is confident that TESTS can greatly improve the statistical confidence and accomplishment of a number of other TEMP objectives.
- The recommended conceptual design presented in this document optimizes the TESTS to achieve identified TEMP objectives for the NGIFF system utilizing a spread spectrum format, as well as the current MK XII system.
- The concepts proposed herein for the TESTS represent a significant, yet practical, advancement in the state-of-the-art simulation environment for DT&E and OT&E testing of both current and proposed IFF systems.
- A systematic research and development effort is required to realize the potential of the TESTS conceptual design.