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CF-18 AN/ALQ-126B–MG 13 IIP INTERFACE TO THE DREO ELECTRONIC WARFARE ENGAGEMENT SIMULATION FACILITY

by

James Loo and Serge Labeaume

DEFENCE RESEARCH ESTABLISHMENT OTTAWA

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ABSTRACT

This document describes the integration of the AN/ALQ-126B jammer and the MG-13 IIP air intercept radar into the DREO Electronic Warfare Engagement Simulation Facility. The test configuration enables the jammer performance to be evaluated in an open-loop hardware-in-the-loop mode. The jamming waveforms from the AN/ALQ-126B can be observed and their effect on the MG-13's performance can be monitored. Some recommendations for improving the simulator design are also made.

RÉSUMÉ

Ce document décrit l'intégration du système de brouillage électronique AN/ALQ-126B et du radar d'interception MG-13 IIP au Simulateur de Combat de Guerre Electronique du CRDO. La configuration des essais de l'équipement en boucle ouverte permet d'évaluer les performances du brouilleur. Les signaux émis par le brouilleur AN/ALQ-126B ainsi que leurs effets sur le MG-13 peuvent être observés sur écran. De plus, quelques recommendations visant l'amélioration du simulateur sont fournies.

EXECUTIVE SUMMARY

The AN/ALQ-126B is the radar jammer carried aboard the CF-18 fighter aircraft to jam non-coherent pulsed radars. The jammer is software programmable and capable of generating a variety of radar countermeasures signals. To evaluate the effectiveness of radar jammers and jamming techniques, the Defence Research Establishment Ottawa (DREO) has developed the Electronic Warfare Engagement Simulation Facility (EWESF).

This report describes fundamental concepts of electronic countermeasures (ECM) effectiveness evaluation, the EWESF layout, the AN/ALQ-126B radar jammer, and the jammer interface to the EWESF to jam the MG-13 IIP air intercept radar. Some of the advantages and disadvantages of the configuration are discussed. This is an interim task report documenting work performed under Director Avionics Simulators and Photography (DASP) tasking 159 to investigate the basic operation and performance of the AN/ALQ-126B jammer and to study the effectiveness of jamming techniques against different radar systems.

This facility serves as a test bed for operating the jammer and testing its responses on different types of experimental radars. The test configuration is also useful for the CF-18 Integrated Support Station (ISS) project where open-loop jamming tests using new ECM techniques may be performed as they are developed. These concepts may also be applicable for evaluation of the RAMSES naval jammer which is used aboard the Canadian Patrol Frigate.

This report also discusses some limitations of the present test configuration and discusses several modifications to improve the performance and user-friendliness of the EWESF. These options include upgrading the scenario control computers and software, upgrading the tracking radar from the MG-13 configuration, and adding a continuous target angle motion capability.

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LIST OF ABBREVIATIONS

AC	alternating current
AFEWES	Air Force Electronic Warfare Environment Simulator
AM	amplitude modulation
CADJ	counter anti-deception jamming
CF	Canadian Forces
COSRO	conical scan on receive only
CW	continuous wave
DASP	Director Avionics Simulators and Photography
DREO	Defence Research Establishment Ottawa
ECM	electronic countermeasures
EW	electronic warfare
EWESF	Electronic Warfare Engagement Simulation Facility
GTRS	Generic Threat Radar Simulator
HOJ	home on jam
ISS	integrated support station
LORO	lobe on receive only
LOS	line of sight
PRF	pulse repetition frequency
PRI	pulse repetition interval
PWM	pulse width modulator
RF	*radio frequency*
TTL	transistor-transistor-logic
UDF	user data file

1.0 INTRODUCTION

1.1 Background

The AN/ALQ-126B jammer is used by the CF-18 fighter jet to provide self-protection jamming against non-coherent pulsed radar guided weapons systems. The jammer is carried on board the CF-18 and provides an automatic response to jam enemy radars when the jammer detects a threat radar signal. The jamming responses to each threat radar are software programmable. The AN/ALQ-126B jammer is capable of generating a wide variety of countermeasures techniques and an experimental facility is required to test and assess the fundamental effectiveness of these jamming techniques. The Directorate of Avionics Simulators and Photography (DASP) tasked the Defence Research Establishment Ottawa (DREO) under tasking DASP 157 to study the AN/ALQ-126B and to investigate the fundamental effectiveness of the jamming techniques.

Electronic countermeasures (ECM) technique effectiveness testing can be performed using a variety of methods. For optimum realistic simulation, flight trials of the CF-18 against actual or simulator mock-ups of enemy radars are required. In a full flight trial, the CF-18 carries the AN/ALQ-126B jammer and radiates jamming signals against actual radars. The effect of jamming on the radar can be closely monitored and ECM effectiveness may be quantified by calculating missile flyout trajectories and assessing miss distances. Ideally, the flight is repeated using improved ECM techniques each time until an optimum technique is found. Another method of ECM evaluation consists of testing a jammer in a hardware-in-the-loop configuration in which the jammer is integrated into a radar guided weapons simulator. A computer calculates simulation parameters and generates radar signals which are representative of those actually experienced by the jammer in an engagement. The jammer receives these radar signals and emits a jamming signal as a response. The jamming signal is processed by the radar simulator and the degradation in the weapon system performance is assessed by monitoring any missile or artillery trajectories. Digital modelling is another simulation technique in which the performance of the jammer, radar, and weapon system are entirely represented in software and the engagement is mathematically modelled [Ref. 1].

Each of these ECM evaluation techniques has its advantages and disadvantages. Flight trials provide the highest level of realism but are expensive to perform. In order to scientifically evaluate jamming effectiveness, the victim radar must be fully instrumented and the effect of the ECM on the radar signal processing must be studied. Hardware-in-the-loop simulations test the jammer by stimulating it with representative threat signals and then using the actual jammer responses to degrade the threat radar. These simulations can be useful provided that the simulator has been validated and is well designed to perform real-time simulations. Digital simulations provide the greatest flexibility for modelling different types of countermeasures and radars, however, digital simulations lack the realism of using actual jamming equipment. Digital simulations are useful for research purposes, such as modelling complex engagement scenarios. EW scenarios can be modelled from high level down to the engineering emulation level. Software development costs can be high and the models require validation. All these types of simulations play roles in the ECM effectiveness testing process.

The Radar Countermeasures Section of the Electronic Warfare Division of DREO has been developing an anechoic chamber based hardware-in-the-loop simulator for evaluating ECM effectiveness. The objective of the Electronic Warfare Engagement Simulation Facility (EWESF) is to test jammers in a real-time, real-frequency, and real-power hardware-in-the-loop configuration in an anechoic chamber. The EWESF was originally designed with the goal of achieving a closed-loop simulation capability. In a closed-loop simulation, target and jamming signals are processed by a victim radar and influence the overall performance of the weapons system. In electronic warfare (EW) research, closed-loop simulation requires the calculation of miss distances for a simulated weapon system. A study [Ref. 2] was performed on the EWESF configuration and it was concluded that the EWESF laboratory could not meet the original objective of testing jammers in a closed-loop configuration. The processing requirements and simulation fidelity for real-time closed-loop missile trajectory calculation, and miss distances could not be met with the existing equipment. The EWESF uses an anechoic chamber to simulate and radiate radar signals and it was concluded that the existing EWESF design could not simulate target motion in angle. The EWESF can, however, serve as a simulation testbed for testing range deception jamming techniques and to investigate the basic interactions between a jamming signal and the victim radar's signal processing.

1.2 Objective and Document Organization

This technical note describes the simulation facility, the AN/ALQ-126B jammer, the radar testbed, and interface of the jammer to the simulation facility. It also describes the capabilities of the EWESF and the types of ECM tests that can be performed. Limitations in the existing EWESF design are identified and some improvements are presented.

The first section of this report discusses the simulator, the second section discusses the AN/ALQ-126B jammer, the third section discusses the MG-13 air intercept radar, and the fourth section discusses the interface in the testbed design. A discussion on different EWESF simulation aspects is presented and some proposals for simulator improvements are also made.

2.0 ELECTRONIC WARFARE ENGAGEMENT SIMULATION FACILITY

2.1 Functions

The EWESF simulates the electromagnetic environment of a radar-guided weapons engagement. The simulation facility is designed to test on-board jamming equipment in a hardware-in-the-loop configuration incorporating free-space signal radiation through an anechoic chamber. In this type of configuration, a radar jammer is stimulated by threat radar signals and the jammer responds with actual jamming waveforms. The target echo is combined with the jamming waveform and transmitted through the anechoic chamber. The signals received by the threat radar should be representative of those in an actual engagement. One of the main objectives of employing an actual radar is to observe and monitor its electrical and dynamic response. The radar can be fully instrumented to monitor actual jamming and target signals. Fig. 1 illustrates a design of a fully closed-loop hardware-in-the-loop simulator.

The EWESF tests equipment in an open-loop mode as depicted in Fig. 2. An engagement scenario is generated at RF level and presented to a threat radar. The reactions of the latter are recorded, but they are not fed back to influence the execution of the scenario. The target motion is predefined and is not affected by the countermeasures under test.

2.2 Basic Configuration

The EWESF uses an anechoic chamber to implement free space transmission of radar skin return and jamming signals. A transmit antenna, consisting of a single standard gain pyramidal horn located in the middle of one end of the anechoic chamber, radiates the simulated radar skin return and the jammer generated countermeasures signal. The radar antenna unit, which operates in receive mode only, is located at the opposite end of the chamber. The radar signal processing circuitry is located outside the anechoic chamber.

3.0 AN/ALQ-126B JAMMER

3.1 System Introduction

The AN/ALQ-126B is a non-coherent pulsed radar jammer carried aboard the CF-18 fighter aircraft to provide self protection against radar guided weapons. The unit is manufactured by Lockheed Sanders and is also carried aboard United States Navy A-6, A-7 and F-14 combat aircraft. The jammer is primarily designed to jam target-tracking radars and the jamming response for each threat is highly software programmable. The jammer employs two main types of countermeasures techniques: range techniques, which are used to deceive the range tracking loops of threat radars,

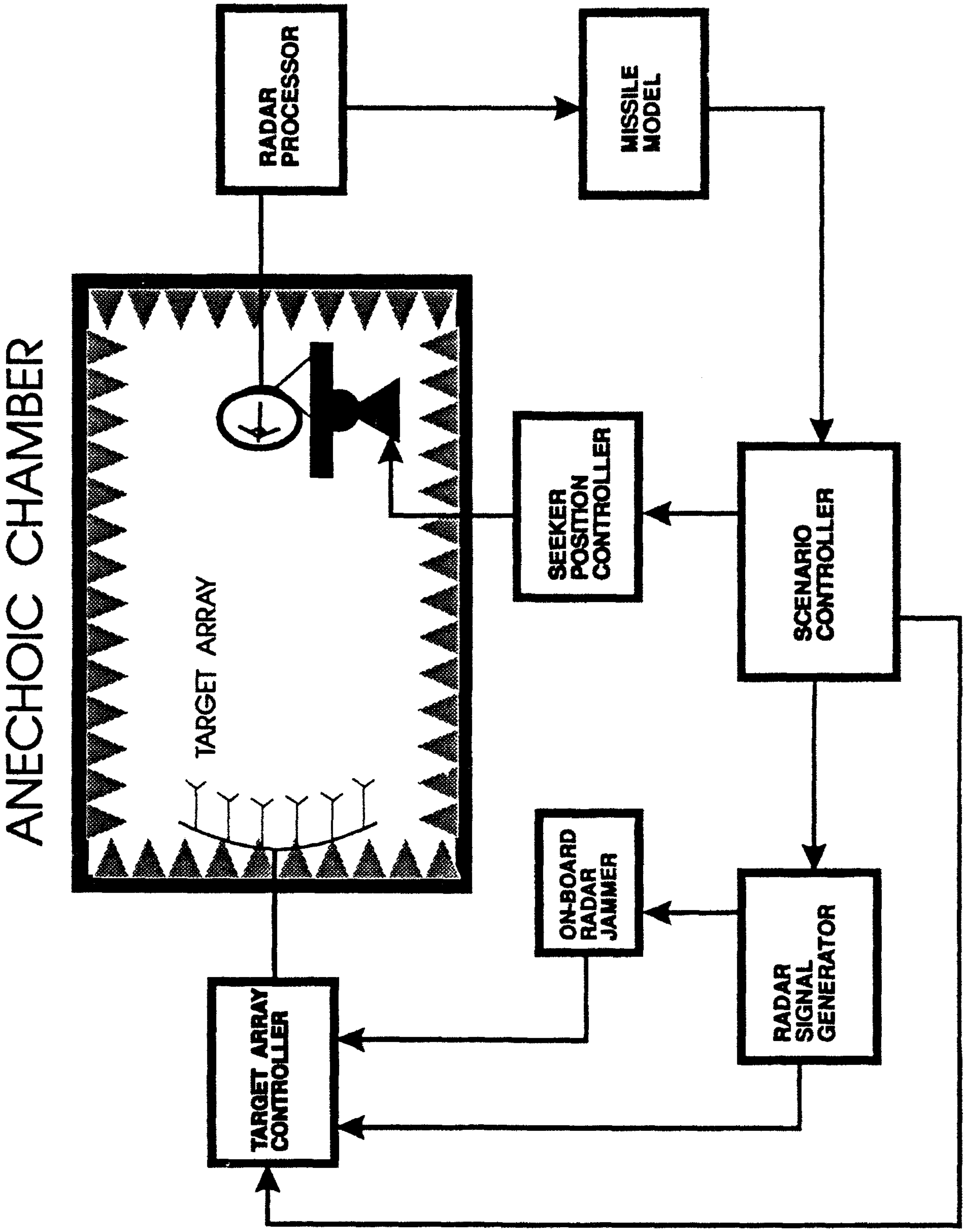

Fig. 1 Layout of a fully closed-loop hardware-in-the-loop simulator

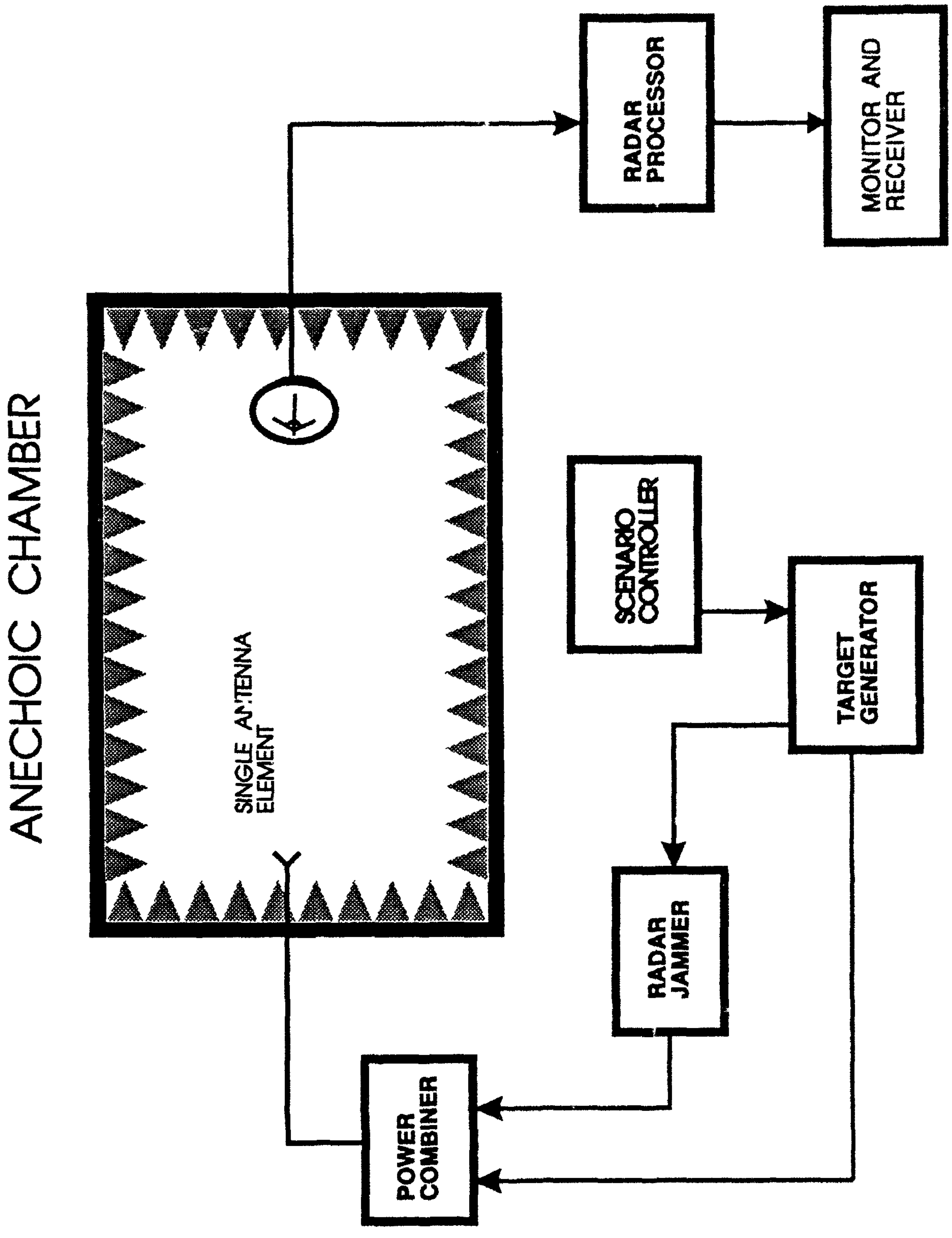

Fig. 2 Layout of EWESF open-loop simulator

and angle techniques, which are used against the angle tracking loops.

The AN/ALQ-126B is highly software programmable and can generate a variety of jamming techniques. It can operate in a pulse transponder or a pulse repeater mode against each threat radar. The jamming technique which is used depends on the threat's priority, available jamming power, and the trackability of the radar signal. To test the jammer in an open-loop hardware-in-the-loop configuration, a radar signal is fed into the input receiver and the jamming output signal is injected into the victim radar.

Fig. 3 illustrates the microwave layout and system design of the jammer.

3.2 Jammer Testing Configuration

Fig. 4 is an illustration of the AN/ALQ-126B jammer interface to the EWESF. The jammer receives a radar signal from the MG-13 signal generation circuitry and radiates a jamming signal which is combined with the skin return and transmitted in the anechoic chamber. The creation and generation of jamming techniques for the AN/ALQ-126B is performed using an Intel minicomputer system. A hot bench supplies 115 Volts AC and 400 Hz power to the AN/ALQ-126B. The jammer's response to the input can be monitored on the system display test fixture which displays the threats being jammed, their relative priorities, and the mode of the jamming technique. The jammer's range jamming techniques are monitored using a crystal detector to detect the video envelope of the range jamming technique. The resulting signals are displayed on an oscilloscope and the frequency content of the jamming signal is displayed on a spectrum analyzer.

4.0 MG-13 IIP AIR INTERCEPT RADAR

4.1 System Description

The EWESF can use two radars for experiments: the Generic Threat Radar System [Ref. 3] and the MG-13 IIP radar. The MG-13 IIP radar will be described in this note. The MG-13 IIP radar was built by Hughes Aircraft Company and provided air intercept functions (target search, acquire, and track) for the CF101B VooDoo fighter jet. The radar is no longer in service in the Canadian Forces, having been phased out in the early 1980's.

The radar can operate in a frequency agile mode in the 8500 - 9250 MHz RF range. The pulse repetition frequency (PRF) is 416 Hz for 1.0 μs pulse width and it is 910 Hz for 0.5 μs pulse width signals. The radar operates in a pulse repetition interval (PRI) jittered mode with 70 μs jitter and uses lobe-on-receive-only (LORO) processing for angle tracking. It can operate at four separate LORO frequencies: 89, 122, 145, and 185 Hz. The radar transmits 250 kW peak power [Ref. 4].

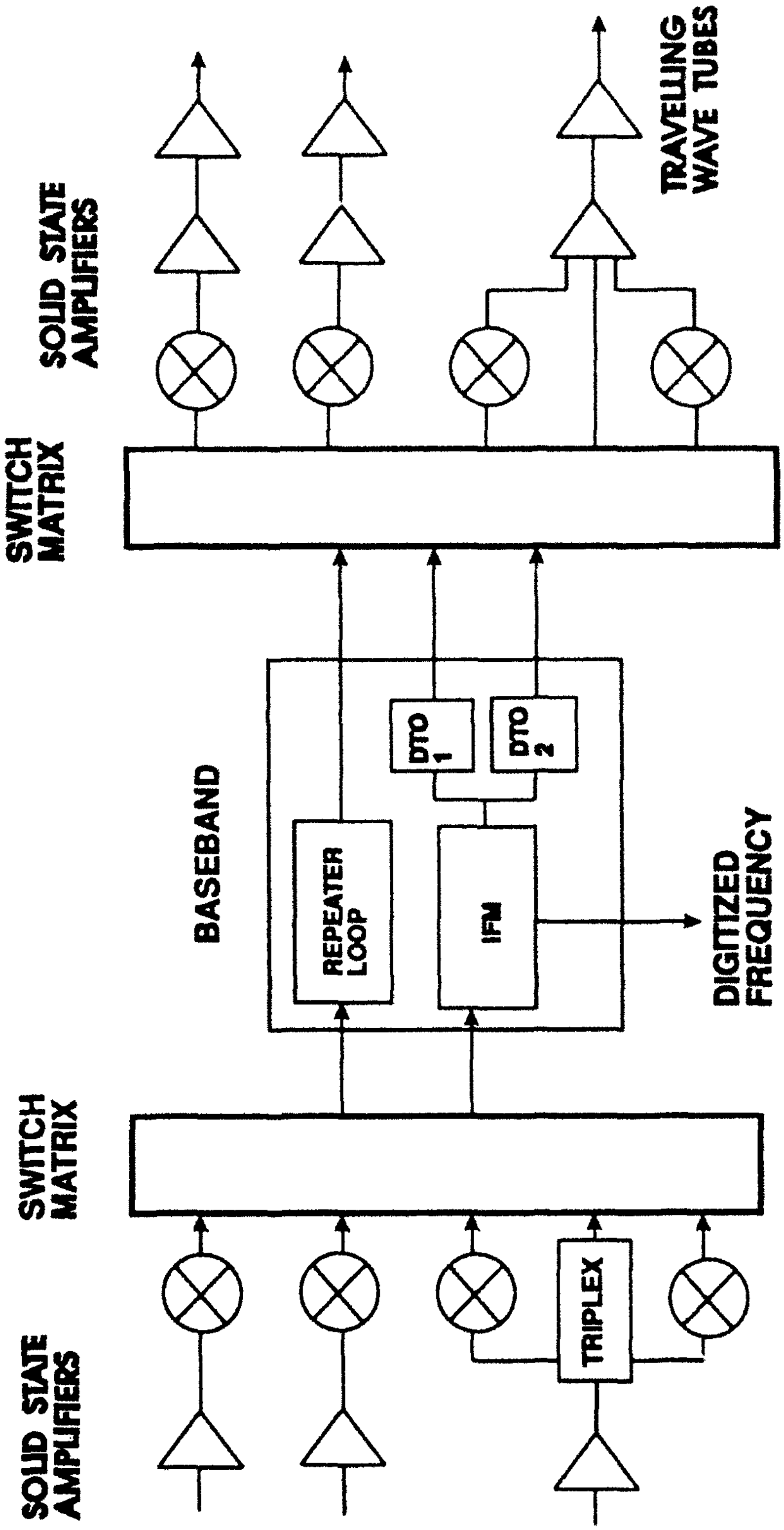

Fig. 3 Layout and Design of AN/ALQ-126B Jammer

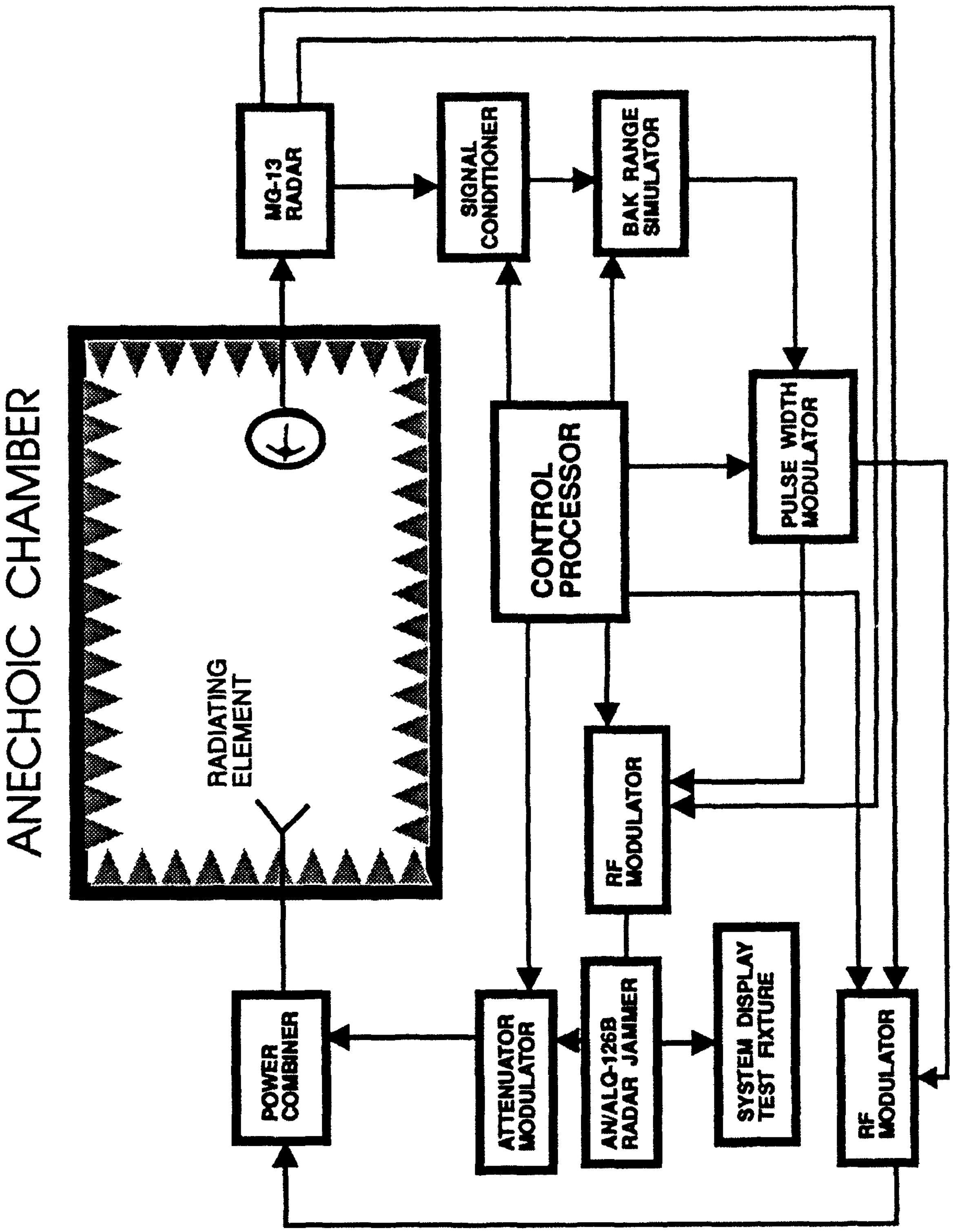

Fig. 4 Illustration of AN/ALQ-126B jammer interface to EWESF

The MG-13 operator has a B-scan display which provides the target's location in azimuth and range. The navigator-operator identifies targets and manually positions a range gate over the selected target.

The radar tracks targets and provides steering information for the pilot to fly a collision course to intercept the target. The MG-13 mission computer incorporates information provided by the radar and aircraft mounted gyroscopes to calculate an intercept course. When the aircraft approaches within weapons range of the target, ballistic ammunition such as bullets and unguided missiles are fired against the target. The radar did not provide a target illumination function for radar guided weapons.

The MG-13 tracking can be deceived if a jammer causes a breaklock or if the jammer introduces sufficient confusion pulses to make discrimination of the target difficult. Some counter-countermeasures features have been incorporated into the system. The MG-13 possesses a home on jam (HOJ) mode which can be activitated by the operator if noise jamming is detected and the target cannot be tracked in range. When HOJ mode is entered, target range tracking is disabled and the radar only angle tracks. When the radar enters burnthrough range, the operator disables HOJ and re-establishes range track on the target. The MG-13 possesses a counter anti-deception jamming (CADJ) mode in which the range gate can be biased to track the leading or trailing edge of a chaff cloud. This feature prevents the MG-13 from locking onto the centroid of chaff clouds and losing the target.

5.0 SYSTEM INTEGRATION

5.1 System Interface Configuration

The MG-13 installed in the EWESF is a stripped down version of the CF101B configuration. The radar does not transmit radar energy into the anechoic chamber but only operates in receive mode. The radar transmitter power is dissipated in a dummy load. In order to generate the MG-13 radar signal, a sample of the MG-13 magnetron CW RF frequency, 30 MHz below the carrier, is sampled and mixed with a stable 30 MHz reference CW signal, which regenerates the original radar carrier frequency. The CW signal then serves as the RF source for the radar signal generator.

A radar high voltage transmit trigger is generated by the MG-13 and fed to the simulator for timing purposes. The trigger is first conditioned to a transistor-transistor-logic (TTL) level which serves as an input to a radar range simulation unit, the BAK PX-219-P. The BAK range simulator delays the train of radar transmit triggers to simulate propagation delay in space. The delay can be controlled dynamically to simulate target motion in range. The target's acceleration is computer controlled. Since the AN/ALQ-126B jammer is carried on board the target, the range delay corresponding to propagation from the threat radar to the target jammer is the same as that from the jammer to the radar. The same range delay applies to both.

The range delayed trigger pulse modulates one of the CW channels to produce a pulsed RF radar signal. A computer calculates the skin return power level in real-time and attenuates the pulsed RF according to path loss and scintillation effects. The resulting RF signal is fed to a power combiner.

Another sample of the CW signal is fed into a different RF modulator, then to the AN/ALQ-126B input, as the threat radar signal. The same range delayed trigger will pulse modulate the CW, but the RF level is attenuated based on a one way propagation loss calculation. The AN/ALQ-126B then receives the real power, real frequency, and real-time radar signal. The jammer output is attenuated by a third RF modulator to account for the other one way propagation loss.

The jammer signal is extracted from the monitor output on the AN/ALQ-126B hot bench facility. The signal is fed into the equipment rack patch panel where it is attenuated, combined with the skin return signal and then radiated into the anechoic chamber. The magnitude of the jamming signal is dynamically set by computer controlled variable attenuators.

The MG-13 threat radar receiver receives a combined skin return and jamming signal from the single target antenna. Fig. 5 is a photograph of the MG-13 radar antenna in the EWESF. It is required to attenuate the power level of the skin return pulses to account for the effectiveness of J/S levels as an experimental parameter. Fig. 4 contains further details of the signal flow in the EWESF.

5.2 Computer Control of Scenario

A PDP 11/84 minicomputer controls the signal levels of the simulation. The MG-13 radar signals are simulated by generating an actual pulse delay due to propagation time and are attenuated to simulate path losses due to range propagation. The computer provides the RF modulators and Radar Range Simulators with the necessary control information to synthesize a target which moves along a pre-defined flight profile. The computer program is written in Pascal and uses PDP 11 macro language to implement lower level functions.

Target range simulation is performed by a range modulator (BAK PX-219-P) which is manually or computer controlled. The following formula for range R is implemented in hardware:

$$R = R_0 + K_v t V_0 + K_a t^2 A_0$$

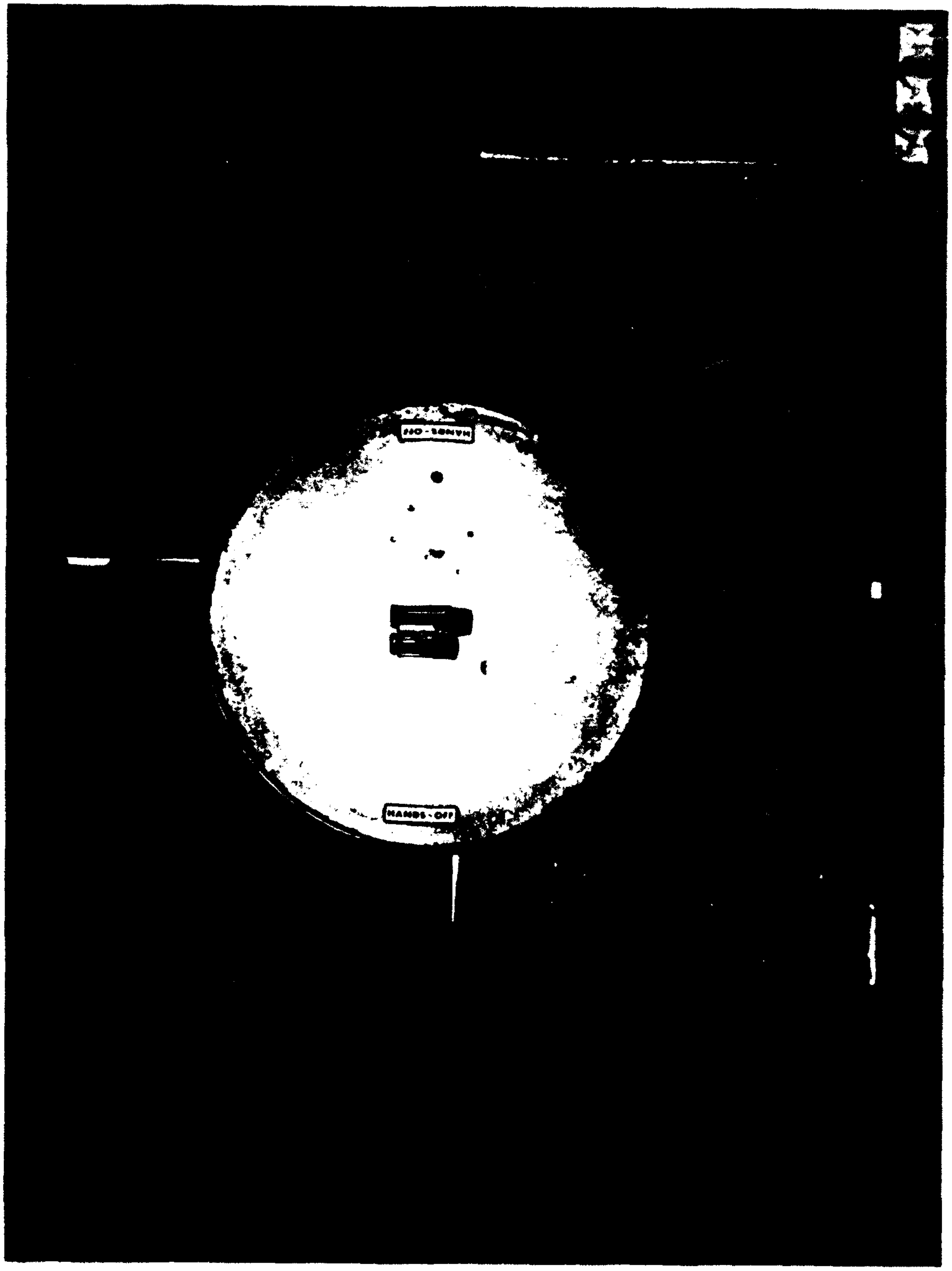

Fig. 5 Photograph of MG-13 IIP radar antenna in EWESF

The BAK unit requires the target's initial range (R_0), initial velocity (V_0), and initial acceleration (A_0). The values K_v and K_a are velocity and acceleration constants and t denotes simulation time. When the initial parameters are input to the BAK, it becomes a stand-alone unit that uses the MG-13 radar transmit trigger as a clock for its internal counters. The BAK unit introduces a time delay to account for round-trip signal propagation. The parameters cannot be dynamically changed apart from the acceleration.

The amplitude modulation due to range is performed under computer control. The Antekna modulators serve as computer controlled variable attenuators. The attenuation level is computed by the scenario controller which implements the radar equation to generate the required power levels at the threat radar.

The width of the RF pulse is controlled by either the BAK range units or by a Pulse Width Modulator (PWM) inserted between the BAK and RF modulators. The BAK unit has two possible pulse widths: 0.2 μs and 2.5 μs, and the PWM can generate pulse widths in the 0.1 - 6.0 μs range. The PWM is also under computer control. Since the target is confined to move in a radial direction relative to the radar, the computer control contribution is limited. The computer exercises dynamic control over the attenuation levels of the skin return and the jamming return. There is no tangential motion of the target relative to the threat radar so target angular motion need not be simulated.

5.3 Operating Procedure

The radar is initially put into a search mode and the MG-13 sweeps from left to right to detect a target. When a target is detected, the operator then manually positions a range gate over the target return. The azimuth motion is controlled by a lateral motion of a joystick, while elevation motion is controlled by adjusting a thumbwheel. The range gate is engaged by depressing the joystick trigger, and controlled by a vertical motion of the joystick. Once the joystick trigger is released, the MG-13 proceeds to acquire and track the designated target. The operator may observe target returns and jamming on the A-scope display. If the range gate loses track of the target or tracks a false jamming pulse and is then dumped, the operator must manually re-acquire the target. Fig. 6 shows the radar and the radar operator's instrumentation.

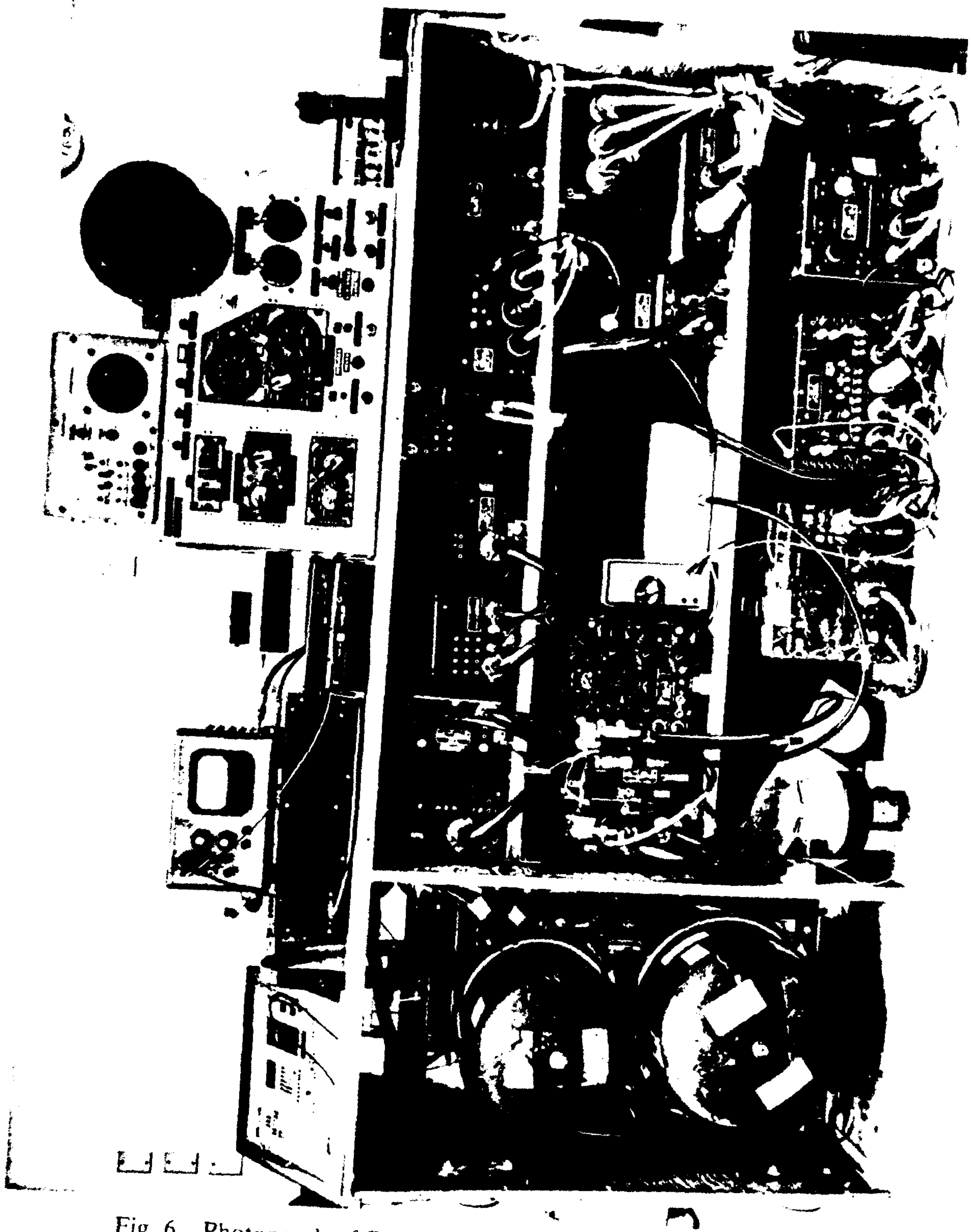

Fig. 6 Photograph of Radar and Operator Instrumentation

6.0 CONCLUSION AND DISCUSSION

This report described the DREO EWESF and its interface with the AN/ALQ-126B jammer and the MG-13 IIP air intercept radar. The simulator is an open-loop hardware-in-the-loop design and it serves as a testbed for performing experiments on the fundamental effectiveness of electronic countermeasures techniques against selected victim test radars.

Different types of open-loop experiments can be conducted in the EWESF. These include: examining the basic properties of range jamming parameters, examining jamming power requirements to deceive a radar, and studying the limits of jamming parameters which are effective. Angle tracking jamming techniques may also be tested with this facility, but a different type of test radar would be required. For example, inverse gain jamming can be tested but only against conical scan or conical scan on receive only (COSRO) radars. In these applications, a variation in the line of sight is not necessary to introduce angle tracking errors. Jamming techniques which require a variation in the line of sight to be effective can not be evaluated in this facility due to the lack of target angular motion simulation capability.

The simulator can also serve as a useful training and analysis tool for the jammer technique development process. When an ECM analyst or jammer operator designs a new jamming technique, the technique can be quickly tested in the EWESF to assess its generic effectiveness. The radar in the EWESF may not be representative of the the desired victim radar and the jamming degradation may not be quantifiable but the simulator provides a means to examine the ECM signal. The EWESF can be a useful tool for generating and observing ECM techniques in preparation of actual CF-18 ECM flight trials. Flight trials provide the actual research environment for assessing technique effectivness and observations made during these trials can be first observed in a laboratory environment. Flight ranges at Eglin Air Force Base can be used to calculate missile flyouts and assess ECM effectiveness. The threat radars against which the aircraft flies must be well instrumented to perform a thorough scientific assessment of technique effectiveness. The facility can be used to supplement the functions of the CF-18 AIR ISS and its objective of generating and performing basic testing on the CF-18 jammer's user data files as they are developed.

If laboratory-generated missile miss distances are required, a closed-loop missile flyout model is required to quantitively assess radar countermeasures effectiveness. This is best performed at a simulation facility such as the Air Force Electronic Warfare Environment Simulator (AFEWES) or Radio Frequency Simulation System (RFSS). These facilities have validated and instrumented hardware-in-the-loop simulators where jamming techniques can be repeated and their effects closely monitored. Repetitive simulation runs using different parameters can be performed to optimize ECM techniques.

7.0 EWESF ENHANCEMENTS

The present simulator configuration is limited to performing the open-loop ECM tests described in this report. The simulator's performance and ease of use is limited and several modifications can be performed to enhance its capability. However, it is unlikely that the EWESF will be upgraded to achieve a real-time closed-loop simulation capability which can be used to quantify ECM techniques and generate weapon miss distances. This option is expensive and it is more cost effective to use foreign simulation facilities such as AFEWES or RFSS.

Possible upgrades for the EWESF are discussed below:

Replacement Computers: The current PDP 11/84 target control computer has limited processing speed and will be unable to meet higher simulator control input/output requirements. The computers are being replaced by microcomputers. The computer can also digitize radar and jammer parameters in time for subsequent processing during data analysis. A higher performance processor would enable the usage of a real-time missile model to compute missile flyout trajectories. Closing the loop would still require real-time processing capability for synchronization with hardware input/output.

Replacement Software: The present simulation software structure does not provide flexibility for expansion. The control software is written in PDP 11 Pascal with lower level routines written in PDP 11 macro. The software is being re-written in a more input/output oriented language such as the C computer language.

Replacement Radar: the radars usable in the EWESF are presently limited to those in DREO inventory. The Generic Threat Radar Simulator (GTRS), can also be used in the EWESF. The GTRS possesses a monopulse antenna and its receiver uses a type of scan with compensation processing. To further investigate the basic jamming capabilities of the AN/ALQ-126B, different types of radar angle tracking designs such as: conical scan, track-while-scan, two and three channel monopulse systems should be tested against the AN/ALQ-126B . However, the successful jamming of these radars requires combination of ECM and aircraft maneuvers.

Target Angular Motion: if a longer term objective of improving the ECM simulation capability at DREO is required, the EWESF could be designed to perform limited closed-loop simulations in which realistic target angular motion can be simulated. Since the target and jammer are radiated from a single source and the radar antenna is fixed, the present EWESF configuration is only suitable for evaluating range jamming techniques and cannot stress the threat radar angle tracking loops. The EWESF does not currently have target angular motion capability to represent radar line-of-sight variations in the tangential direction. If angle tracking must be tested in a technique, target angular motion is required. This can be achieved through use of a multiple axis motion pedestal to position and support the threat radar or through some type of mechanism to move the target in angle. The target motion can also be simulated in angle by using an antenna array system [Ref. 5] to change the apparent location of a target, or by using a mechanical positioner to move a single RF source. Several of these issues are discussed in [Ref. 2]. The EWESF is being upgraded to possess a continuous target motion capability using a horizontal positioner with two target antennas.

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(U) This report describes the integration of the AN/ALQ-126B jammer and the MG-13 IIP air intercept radar into the DREO Electronic Warfare Engagement Simulation Facility. The test configuration enables the jammer to be evaluated in an open-loop hardware-in-the-loop mode. The jamming wavefors from the AN/ALQ-126B can be observed and their effect on the MG-13's performance can be monitored. Some recommendations for improving the simulator design are also made.

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AN/ALQ-126B
ELECTRONIC COUNTERMEASURES
ELECTRONIC COUNTERMEASURES TESTING
ELECTRONIC WARFARE
ELECTRONIC WARFARE SIMULATION
HARDWARE-IN-THE-LOOP SIMULATION
MG-13
OPEN-LOOP TESTING