NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

IMPROVING THE LAMPS MK III
SH-60B HF COMMUNICATION SYSTEM

by

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September, 1991

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UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No 0704-0188

1a REPORT SECURITY CLASSIFICATION	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY 2b DECLASSIFICATION/DOWNGRADING SCHEDULE	3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited
4 PERFORMING ORGANIZATION REPORT NUMBER(S)	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION: Naval Postgraduate School 6b OFFICE SYMBOL (If applicable): AS	7a NAME OF MONITORING ORGANIZATION Naval Postgraduate School
6c. ADDRESS (City, State, and ZIP Code) Monterey, CA 93943-5000	7b ADDRESS (City, State, and ZIP Code) Monterey, CA 93943-5000
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO / PROJECT NO / TASK NO / WORK UNIT ACCESSION NO

11 TITLE (Include Security Classification) IMPROVING THE LAMPS MK III SH-60B HF COMMUNICATION SYSTEM

12. PERSONAL AUTHOR(S)
ADAMS, Frederick C., Jr.

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Master's Thesis	FROM ____ TO ____	1991 September	64

16 SUPPLEMENTARY NOTATION The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the US Government.

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	SH-60B Helicopter; LAMPS MK III, HF Communications; OTH Communications

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

This thesis examines the over-the-horizon (OTH) communications capability of the SH-60B Seahawk. The LAMPS Mk III communications system incorporates a high frequency (HF) radio in its design to provide reliable two-way voice communications at extended ranges for use during operations that require the helicopter to be below the ship's radio horizon. In addition, the HF radio system is necessary to provide communications with non-LAMPS equipped naval forces and commercial shipping and to provide long-range, sea-air rescue capabilities.

Topics addressed with respect to the OTH communications capability of the SH-60B Seahawk are the basics of HF propagation theory, a chronology of events concerning the SH-60B's current HF communication system and an analysis of issues.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a NAME OF RESPONSIBLE INDIVIDUAL BOGER, Dan C.	22b TELEPHONE (Include Area Code): 408-646-2607 22c OFFICE SYMBOL: AS/Bo

DD Form 1473, JUN 86 Previous editions are obsolete SECURITY CLASSIFICATION OF THIS PAGE

S/N 0102-LF-014-6603 UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

DD Form 1473, JUN 86 (Reverse)

SECURITY CLASSIFICATION OF THIS PAGE

Improving The LAMPS MK III SH-60B HF Communication System

by

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Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN TELECOMMUNICATIONS SYSTEMS MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
September 1991

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ABSTRACT

This thesis examines the over-the-horizon (OTH) communications capability of the SH-60B Seahawk. The LAMPS Mk III communications system incorporates a high frequency (HF) radio in its design to provide reliable two-way voice communications at extended ranges for use during operations that require the helicopter to be below the ship's radio horizon. In addition, the HF radio system is necessary to provide communications with non-LAMPS equipped naval forces and commercial shipping and to provide long-range, sea-air rescue capabilities.

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I. INTRODUCTION

A. BACKGROUND

The SH-60B LAMPS Mk III helicopter program is a combination of computer technology in the helicopter and in the shipboard environment and the latest in versatile helicopter design. The Department of the Navy's initial procurement strategy for the LAMPS Mk III program illustrates this unique design combination. To be effective, the system was going to have to be an integrated air-ship system. Therefore, the Navy established the first LAMPS Mk III project office within the Naval Material Command in the mid-1970's. The Ship/Air System Integration Program Office was able to draw expertise and assistance from the Naval Air (NavAir) Systems Command, the Naval Sea (NavSea) Systems Command and the Naval Electronics Systems Command. This surface and air community organization would be able to access nearly all of the Navy's laboratories and test facilities necessary to implement this unique weapon system in the fleet. Later, when testing was well underway and major airframe funding was necessary, the program office was transferred to NavAir, but the program manager was dual-hatted within both NavAir and NavSea as Project Manager Air/Project Manager Sea 266 (PMA/PMS 266). Also, the Navy only selected senior officers as program managers for this project who were well versed in both the aviation and surface warfare communities. In 1974, International Business Machines (IBM) Federal Systems Division was selected as the primary contractor for the program due to its modern computers and avionics. In 1977, there were fly-off tests of competitive airframes from Boeing Aircraft and United Technologies Sikorsky Aircraft. In September, 1977, Sikorsky Aircraft was selected as one of the subcontractors and they were responsible for supplying the LAMPS Mk III airframe. Also, General Electric was selected to supply a navalized version of the T-700 engine (T700-GE-401) and Canada's DAF/INDAL Corporation was selected for the shipboard recovery, assist, securing and traversing (RAST) haul-down system. [Ref. 1: p. 94]

LAMPS is the acronym for Light Airborne Multi-Purpose System. The SH-60B Seahawk is deployed on modern United States naval cruisers, destroyers and frigates and is an extension of the ship's electronics and weapons systems. The SH-60B Seahawk is designed to provide an airborne platform capable of locating, actively pursuing and destroying seaborne threats. Its primary mission is anti-submarine warfare (ASW) and the major secondary mission is anti-ship surveillance and targeting (ASST). Other secondary missions include search and rescue (SAR), medical evacuation (MEDEVAC), communications relay (COMREL), vertical replenishment (VERTREP) and naval gunfire support (NGFS).

B. PURPOSE

The purpose of this thesis is to examine the over-the-horizon (OTH) communications capability of the SH-60B Seahawk. The LAMPS Mk III communications system incorporates a high frequency (HF) radio in its design to provide reliable two-way voice communications at extended ranges for use during operations that require the helicopter to be below the radio horizon with respect to the ship. In addition, the HF radio system is necessary to provide communications with non-LAMPS equipped naval forces and commercial shipping and to provide long-range, sea-air rescue capabilities. The SH-60B Seahawk currently operates the AN/ARC-174A(V)2 HF radio with a horizontal dipole long-wire antenna. This thesis will illustrate that the HF communication system on the SH-60B helicopter appeared to have problems from its development and will recommend the need for updating and/or replacing the HF radio and antenna.

Topics included in this discussion of the OTH communications capability of the SH-60B Seahawk include the basics of HF propagation theory, a chronology of events concerning the SH-60B's current HF communication system and an analysis of issues.

C. SCOPE

This thesis is designed to clearly illustrate basic HF propagation theory, the SH-60B's operating area within the HF spectrum, the apparent problems of the current HF radio and antenna system and analyze issues to rectify the current HF communication system.

Using a combination of naval reports and findings, this thesis will illustrate the apparent problems and then analyze issues that could be investigated with further dedicated study. However, the solution to these problems cannot be solved in an easy manner. Instead, the solution lies somewhere between theory and practical thinking. Any money spent solving the SH-60B Seahawk's HF problems must produce a sizeable return in order to justify the significant financial outlay during these tight budget years. As stated, there is no easy solution, only the ever-present reality of whether the end justify the means.

II. BASIC HF PROPAGATION THEORY

A. INTRODUCTION

High frequency (HF) radio is characterized by radio frequency transmission between 3 and 30 Mhz. HF propagation consists of a groundwave and a skywave component. The groundwave follows the surface of the earth and can provide useful communications up to about 400 miles, particularly over water, in the lower part of the band. Skywave propagation, on the other hand, permits reliable communication for distances up to 4000 miles. Figure 1 illustrates these two components of HF propagation [Ref. 2: p. 11].

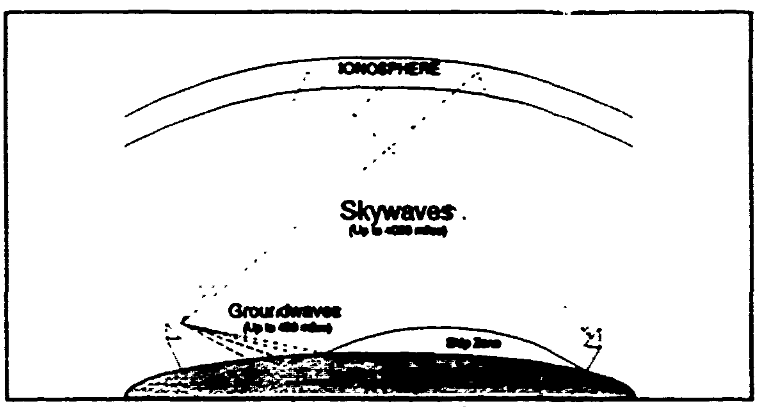


Figure 1. HF Propagation Components

The SH-60B Seahawk, under its present standard operating procedures, rarely would operate beyond 200 miles from its battlegroup. Even though the groundwave component can transmit up to 400 miles, the SH-60B with its current HF radio and antenna system would have to operate using both the groundwave and skywave component to communicate with other naval forces.

B. IONOSPHERE

The ionosphere is an ionized region in the upper atmosphere that consists of the following four layers:

- D region
- E layer
- F_1 layer
- F_2 layer

The D region is not always present, but when it does exist, it is only during the daylight hours. It is the lowest of the four layers. When it does exists, it occupies an area between 30 and 55 miles above the earth and is heavily absorptive. The E layer also occurs only during the daylight hours and exists between 55 and 85 miles above the earth. It is most dense directly under the sun and depends directly on the sun's ultraviolet radiation. The layer disappears shortly after sunset. The F_1 layer is also a daylight phenomenon that exists between 85 and 150 miles above the earth. It is similar to the E layer and at sunset, the F_1 layer rises and merges with the next higher layer, the F_2 layer. The F_2 layer exists both day and night between 90 and 150 miles (night) and 150 and 180 miles (day) above the earth. Variations in height are due to solar heat. The electron density increases and neutral atmospheric components decrease with altitude. The frequency depends on the amount of bending or reflection experienced by a signal in the ionized layers. Higher frequency signals bend to a lesser degree than lower frequency signals. Therefore, lower frequency signals penetrate farther into the ionosphere. The following important natural phenomena also affect the ionosphere:

- Sunspots
- Magnetic storms
- Sudden ionospheric disturbances (SID)
- Sporadic E (layer)

The lower end of the HF spectrum is more closely associated with the groundwave component, whereas, the higher end of the spectrum is associated with the skywave component. In general, the skywave signal is less stable than the groundwave due to the changeable state of the ionosphere. [Ref. 3: p. 129]

C. GROUNDWAVE PROPAGATION

The groundwave consists of a surface wave which follows the contour of the earth and is bounded by the earth and the ionosphere. Groundwave propagation is a very stable form of communication and is not affected by daily or seasonal ionospheric changes as is the skywave. Usually, groundwave propagation uses the low frequencies of the HF spectrum, so the groundwave provides a limited bandwidth and would require a long antenna. But in reality, long antenna lengths are not practical, so shorter antennas are substituted, limiting the efficiency of the antenna. [Ref. 2:p. 9]

D. HF COMMUNICATION FREQUENCIES

A compromise must be established where the frequency is low enough to permit the signal to be returned to the earth but high enough so that all the useful energy is not absorbed enroute to the receiving station [Ref. 4:p. 15]. The HF communication frame of reference is the usable frequency band with an upper limit defined as the maximum usable frequency (MUF) and a lower limit defined as the lowest usable frequency (LUF). Both of these frequencies depend on the number of free electrons which vary from hour to hour, day to day and season to season. Sunrise increases both the MUF and the LUF due to the sun's production of free electrons.

E. POLARIZATION

Groundwave transmission is widely used at the low to medium frequencies. Because the electric lines of force are perpendicular to the ground, vertical polarization is necessary for groundwave transmission, since propagating waves can travel a considerable distance along the earth's surface with minimum attenuation. Horizontal polarization is restricted at these frequencies because the electric lines are parallel to and touch the earth, causing excessive attenuation due to absorption at lower frequencies. At higher frequencies, both horizontal and vertical polarization can be used for successful skywave transmission. Horizontally polarized antennas do have certain advantages and are preferred at higher frequencies. Figure 2 illustrates these two types of polarization [Ref. 5:p. 95].

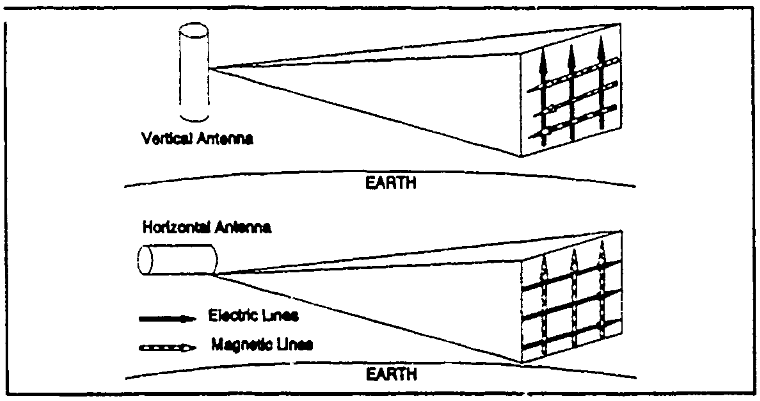


Figure 2. Polarization

F. COMPUTER SIMULATION

Several computer programs are available to predict propagation via the ionosphere but Advance Prophet, distributed by the Naval Ocean Systems Center [Ref. 6], is used for demonstration purposes in this thesis. The Advanced Prophet program was used in a scenario where the SH-60B helicopter and a typical naval ship were approximately 120 miles apart located in the middle of the Pacific Ocean. This scenario is meant to illustrate the features of the Advanced Prophet program and will be used in further evaluate the SH-60B's HF communication performance. Figure 3 gives the area coverage of both platforms. Figure 4 illustrates the groundwave range as a function of frequency. Given the limited parameters of the SH-60B helicopter, notice the small range. Figure 5 illustrates groundwave range as a function of power. And finally, Figure 6 illustrates how optimum frequency shifts during the course of the day.

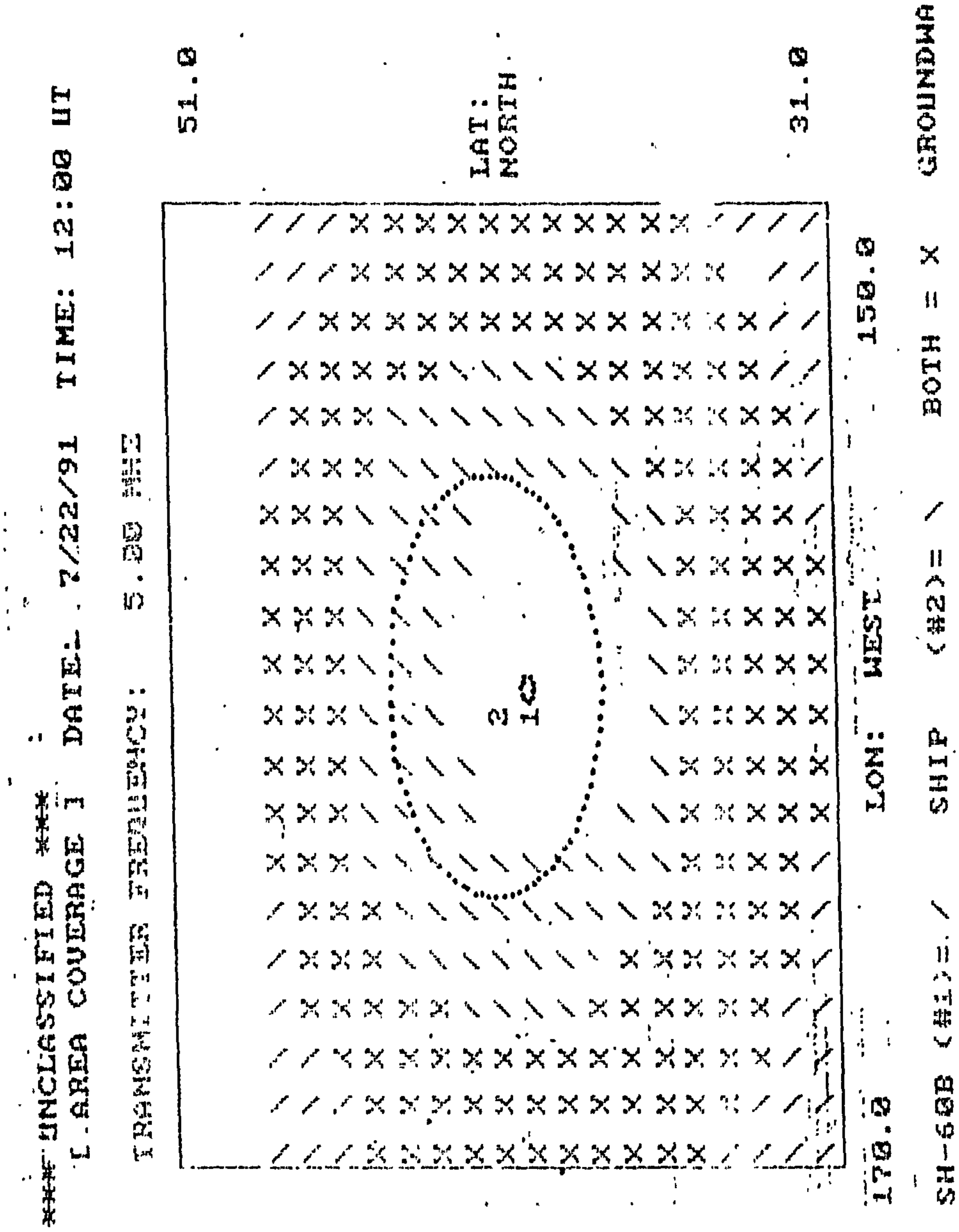


Figure 3. Advanced Prophet Area Coverage.

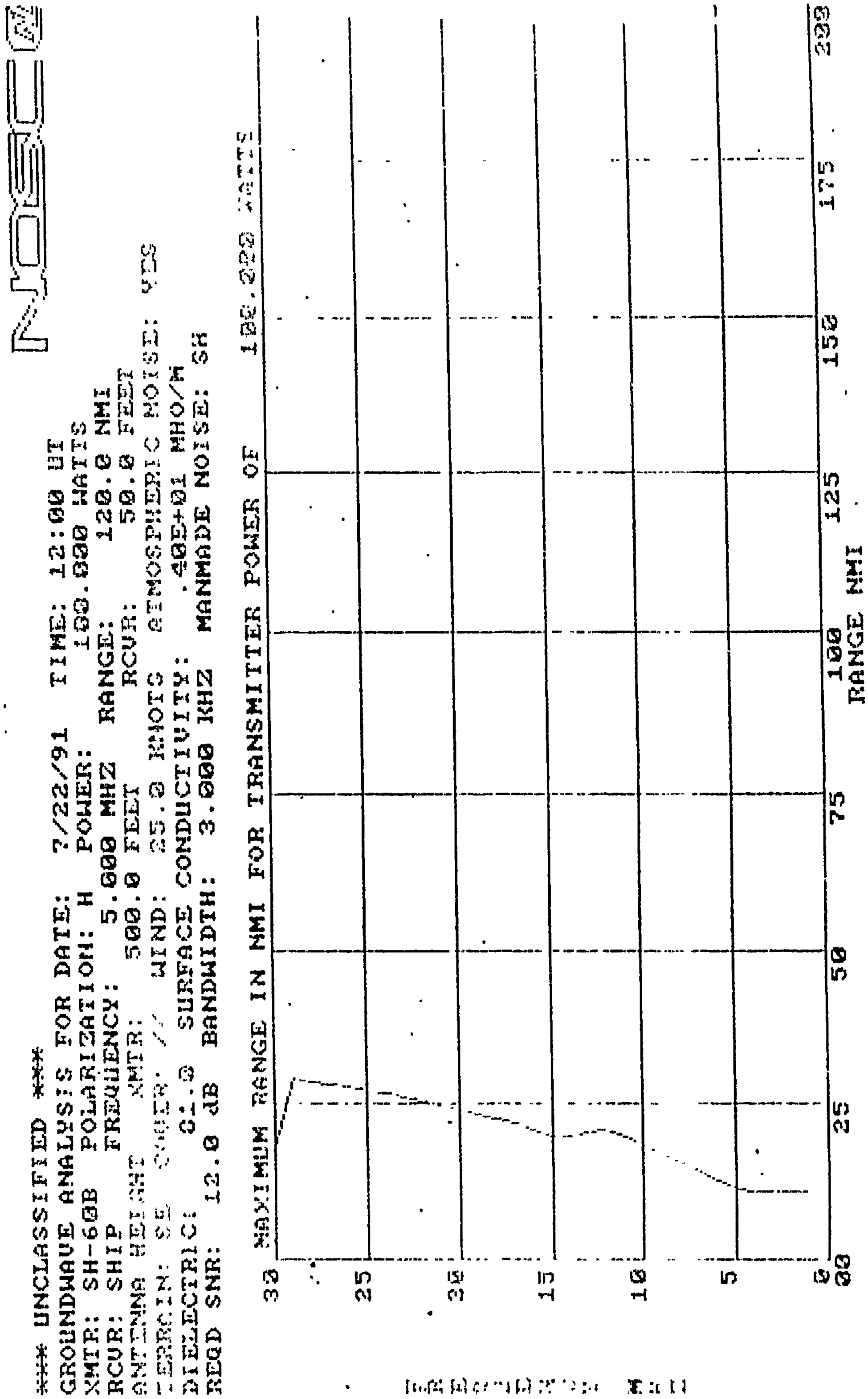


Figure 4. Groundwave Range vs. Frequency.

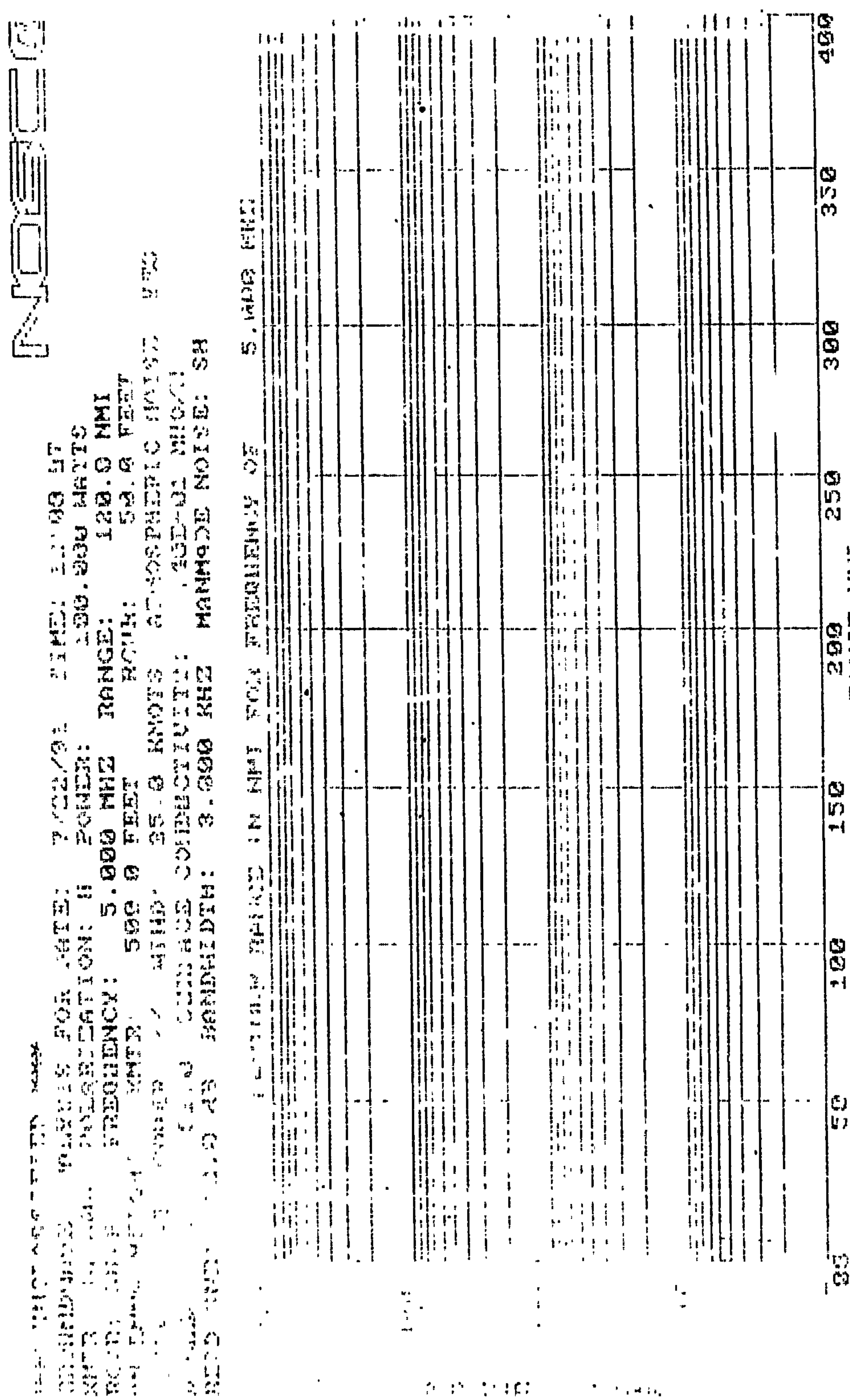


Figure 5. Groundwave Range vs. Power.

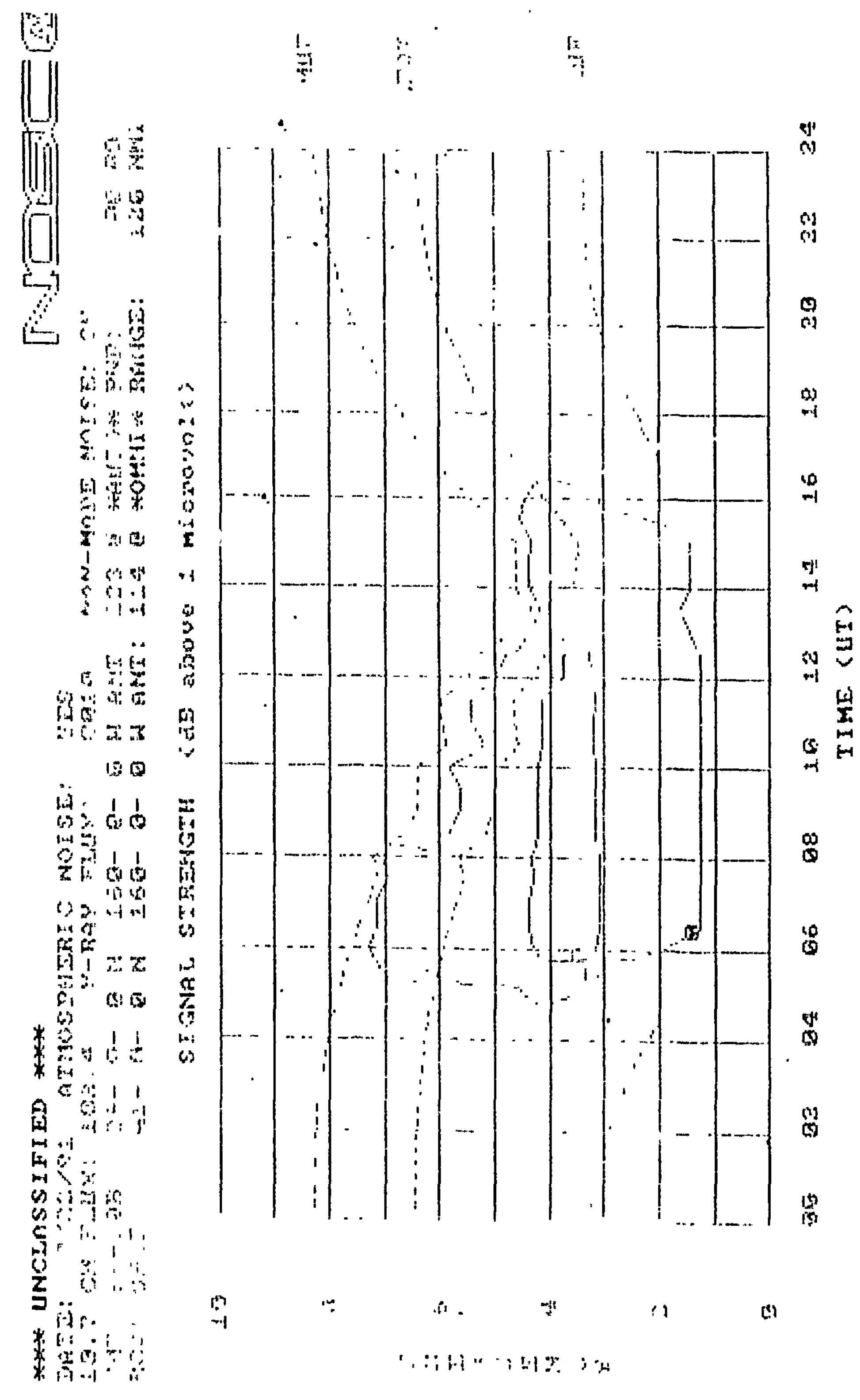


Figure 6. Frequency vs. Time of Day.

III. HISTORICAL EVENTS

A. INTRODUCTION

With the contract awarded to IBM for the LAMPS Mk III program, the Navy embarked on an ambitious research development test and evaluation (RDT&E) program. The first LAMPS Mk III test and evaluation plan was scheduled for six years of RDT&E, which avoided the major problem of trying to rush a system into the fleet, thereby setting the program up for failure before it was completed [Ref. 1: p. 94]. The Navy backed this long-term procurement strategy, incurring significant costs in a test ship (the USS McInerney [FFG-8]), five prototype YSH-60Bs, a land-based test site at Patuxent River, Maryland, a large system integration facility at Fleet Combat Direction System Support Activity, Dam Neck, Virginia, RAST test platform at the Naval Air Engineering Center (NAEC) and extensive facilities at contractor plants and Navy laboratories.

After all the usual bench testing, the LAMPS Mk III program reached full ship/air systems integration via a digital data link in the laboratory before the first aircraft ever flew. The first of five YSH-60B prototypes (BuAer number 161169) flew on December 12, 1979. Operating at the land-based test site at Patuxent River, Maryland, the five YSH-60B prototypes logged thousands of hours of developmental and operational testing. Later, operating with the LAMPS Mk III test ship, they made more than 1,000 shipboard landings. The testing progressed at an orderly routine of fly-fix-fly pace that allowed time to meet all test goals. As a result of all the time and testing, the final operational tests proved so outstanding that the system almost literally sold itself at the final Department of Defense Systems Acquisition Review Council briefings and congressional hearings. In the end, the Deputy Chief of Naval Operations for surface warfare (DCNO) paid almost a billion dollars of RDT&E to prove the system, as well as the cost of the ship systems, while the Deputy Chief of Naval Operations for Air Warfare absorbed all helicopter and airborne electronics and avionics costs. [Ref. 1: p. 94]

B. HF TESTING

1. Patuxent River Testing

Each specification of a new system is contained within the contract. It is the responsibility of the contractor and subcontractors to comply with each of the specifications. In the case of the LAMPS Mk III program, the specification concerning the HF system was contained in AS-4200D, Amendment No. 2, System Specification for LAMPS Mk III Ship/Air Weapon System, of 15 Apr 1981, paragraph 3.2.1.5.1.1.2. During the Patuxent River testing, the following test results were contained in the Naval Air Test Center Deficiency Report No. RW-92A:

> Design errors in the SH-60B helicopter high frequency radio antenna system are causing marginal to poor HF operational performance across the entire 2 - 30 MHz frequency range. The results of communication checks made on several frequencies during a recent test flight are shown in Table [1] and are typical of the poor operational performance results which can be expected with the existing antenna system. Numerous design errors collectively contributing to the poor performance of the HF system were identified during the NPE-III shore-based tests and are listed in Table [2]. The HF radio system as installed in the LAMPS Mk III air vehicle is necessary to provide communications with non-LAMPS equipped Naval Forces, to provide over-the-horizon communications with the LAMPS homeship for weapons release authorizations and to provide long-range, sea-air and direction finding navigation steering capabilities. Effective and adequate HF performance to satisfy these requirements is not attainable due to the improper antenna design [Ref. 7: p. 1].

The report went on further to state that the contractor was responsible for correction and the recommendation was for the contractor to investigate and take corrective action as soon as practicable.

2. Contractors Meeting

On March 2, 1982, a meeting was held at the Naval Air Test Center, Patuxent River, Maryland, to discuss the HF antenna problems on the SH-60B Seahawk. The meeting was attended by representatives from Naval Air Test Center (NATC), Naval Air Command (NAC), Naval Air (NAVAIR) Systems

TABLE 1
SH-60B TYPICAL HF RADIO TEST PERFORMANCE

Frequency	Communication Quality
13.974 MHz	Readable with considerable difficulty/Fair signals
10.258 MHz	Readable with considerable difficulty/Fair signals
7.645 MHz	Barely readable/Weak signals
6.835 MHz	Barely readable/Weak signals
4.007 MHz	No contact
2.128 MHz	No Contact
NOTES: Aircraft altitude: 1,600 ft above MSL Aircraft range (from ground station): 31 nautical miles	

Command, IBM, Rockwell-Collins and Sikorsky Aircraft. NATC considered the antenna performance so poor that it would not be useable in the LAMPS Mk III mission. The discussion concluded that the present long wire system, shown in Figures 7 and 8 [Ref. 8], cannot be corrected with only minor modifications. Three new approaches were considered to be feasible:

- Route the long wire under the fuselage aft of the tail wheel, then forward above the sonobuoy launcher to provide a length of at least 19 feet. This would require no rework of the equipment installation.

TABLE 2
SH-60B HF ANTENNA DESIGN ERRORS

Design Error: Poor bonding and shielding of HF antenna/coupler components causing EMI with other systems. Recommended Solution: Ensure proper bonding and shielding practices are implemented.
Design Error: Improper HF antenna wire routing causing cancellation of transmitted radio frequency signal. Recommended Solution: Reroute antenna wire to eliminate parallel lengths in vicinity of aft starboard ESM antenna.
Design Error: Improper aircraft skin penetration by antenna wire causing detrimental capacitive coupling of signal to aircraft skin. Recommended Solution: Antenna wire should exit at 90 degree angle to aircraft skin for 12-15 inches prior to running parallel to surfaces.
Design Error: Improper use of metal standoffs to support antenna wire causing undesired coupling of signal to aircraft skin ground plane. Recommended Solution: Antenna wire support standoffs should be made from an insulating material to decouple antenna from aircraft.
Design Error: Insufficient number of antenna wire standoffs causing long spans of wire (exceeding 5 feet) which flex in-flight causing rotor modulation of signal. Recommended Solution: Maximum spacing of antenna wire standoffs should not exceed 3-4 feet to minimize wire flexing during flight.
Design Error: Insufficient spacing of antenna wire from tail boom (within 6 inches) which results in decreased isolation and detrimental coupling of signal to metal surfaces. Recommended Solution: Antenna wire support standoffs should be 12-15 inches in length and located to maximize antenna wire spacing from aircraft skin.

TABLE 2
SH-60B HF ANTENNA DESIGN ERRORS (CONTINUED)

Design Error: HF antenna wire located too close (within 2-3 inches) of upper UHF blade antenna causing unacceptable levels of EMI to the UHF radio system. Recommended Solution: Relocate either the HF antenna or the upper UHF antenna to minimize or eliminate the capacity coupling effects between the two antenna.

- Use the Rockwell-Collins 437R-2 tuned HF monopole antenna in a left hand version of the U.S. Army's Blackhawk helicopter installation as shown in Figure 9 [Ref. 8]. This would require a different coupler mount, preferably relocating the equipment to the left side.

- Use the Rockwell-Collins 437R-2 tuned HF monopole antenna in approximately the same location as the U.S. Army's Blackhawk helicopter on the right side of the aircraft, then route the wire directly up to the existing stand-offs to the rear of the ECS outlet [Ref. 9: p. 3].

The planned action was for IBM, as the prime contractor, to investigate all the approaches and propose plans for a test installation to NAVAIR. Sikorsky Aircraft was asked to support the investigation by specifically investigating the following:

- The feasibility of the long wire routing and the possibility of making a test installation by bonding the standoffs to the airframe. This would be a one-flight installation with safety straps in case of loosening of the standoffs.

- To provide temperature data for the area aft of the starboard engine exhaust.

- The possibility of mounting a nylon standoff in place of an existing metal standoff to determine the effect of exhaust temperature. [Ref. 9: p. 2]

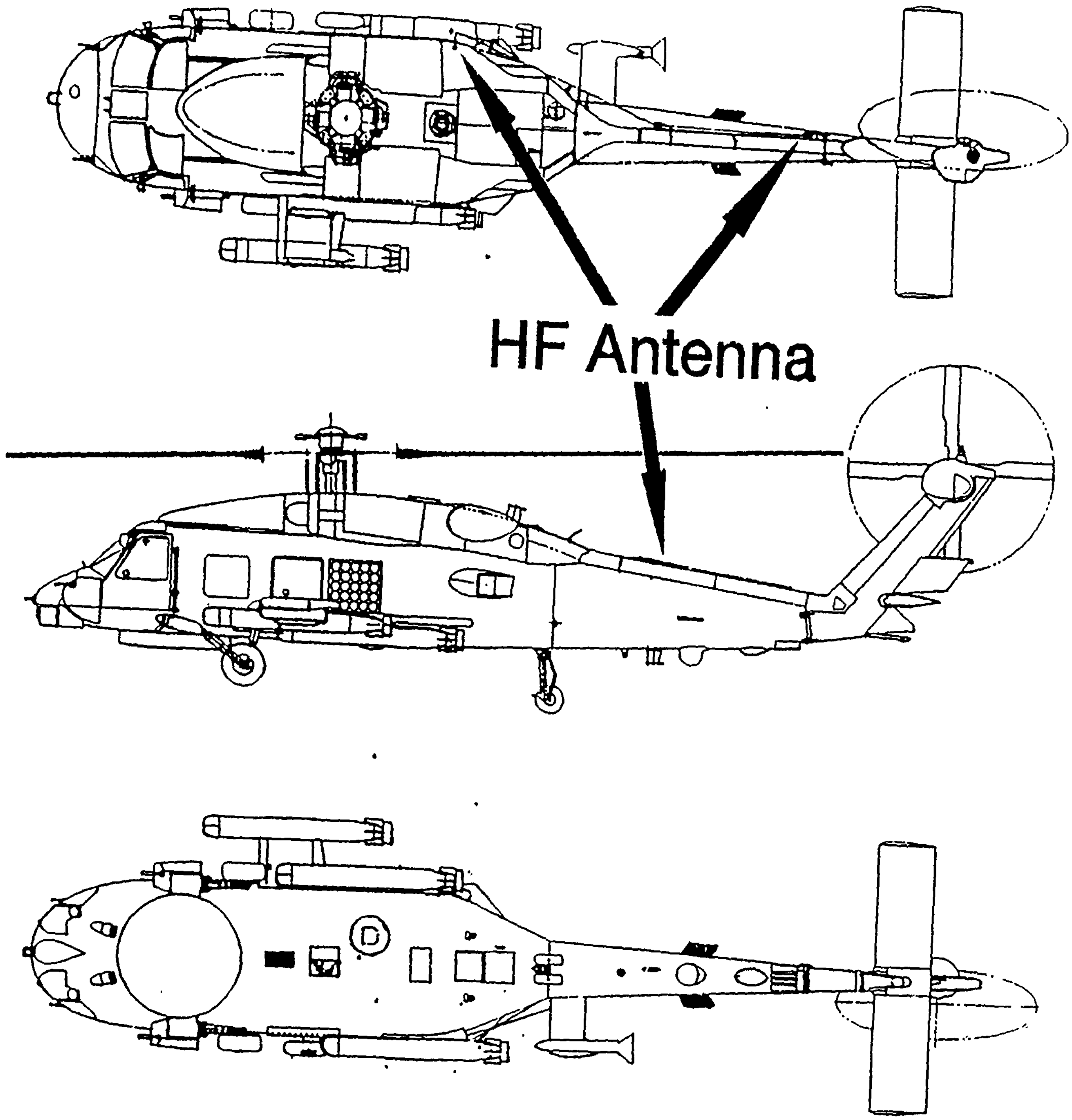


Figure 7. SH-60B Configuration

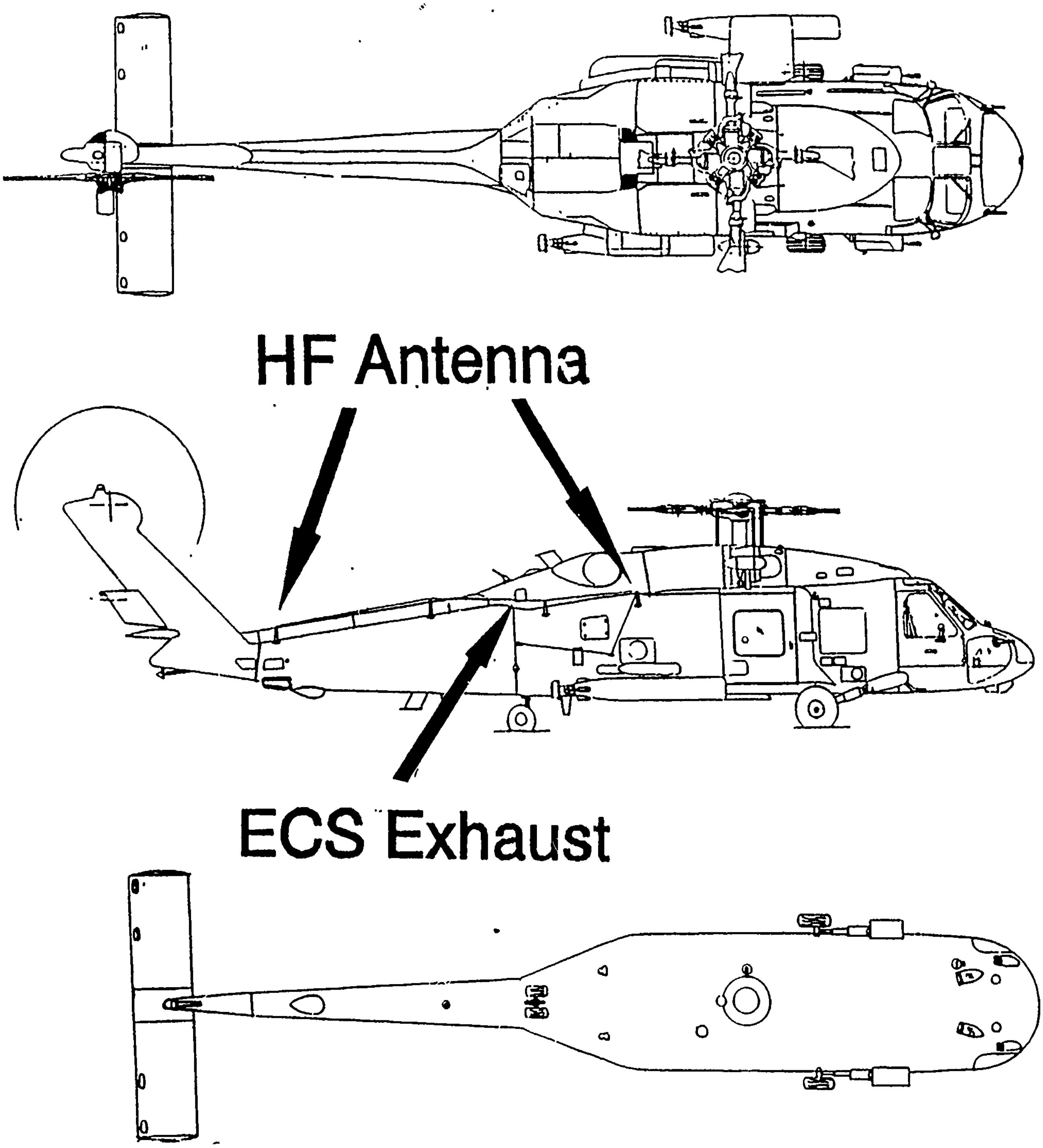


Figure 8. SH-60F - Same HF Antenna As SH-60B

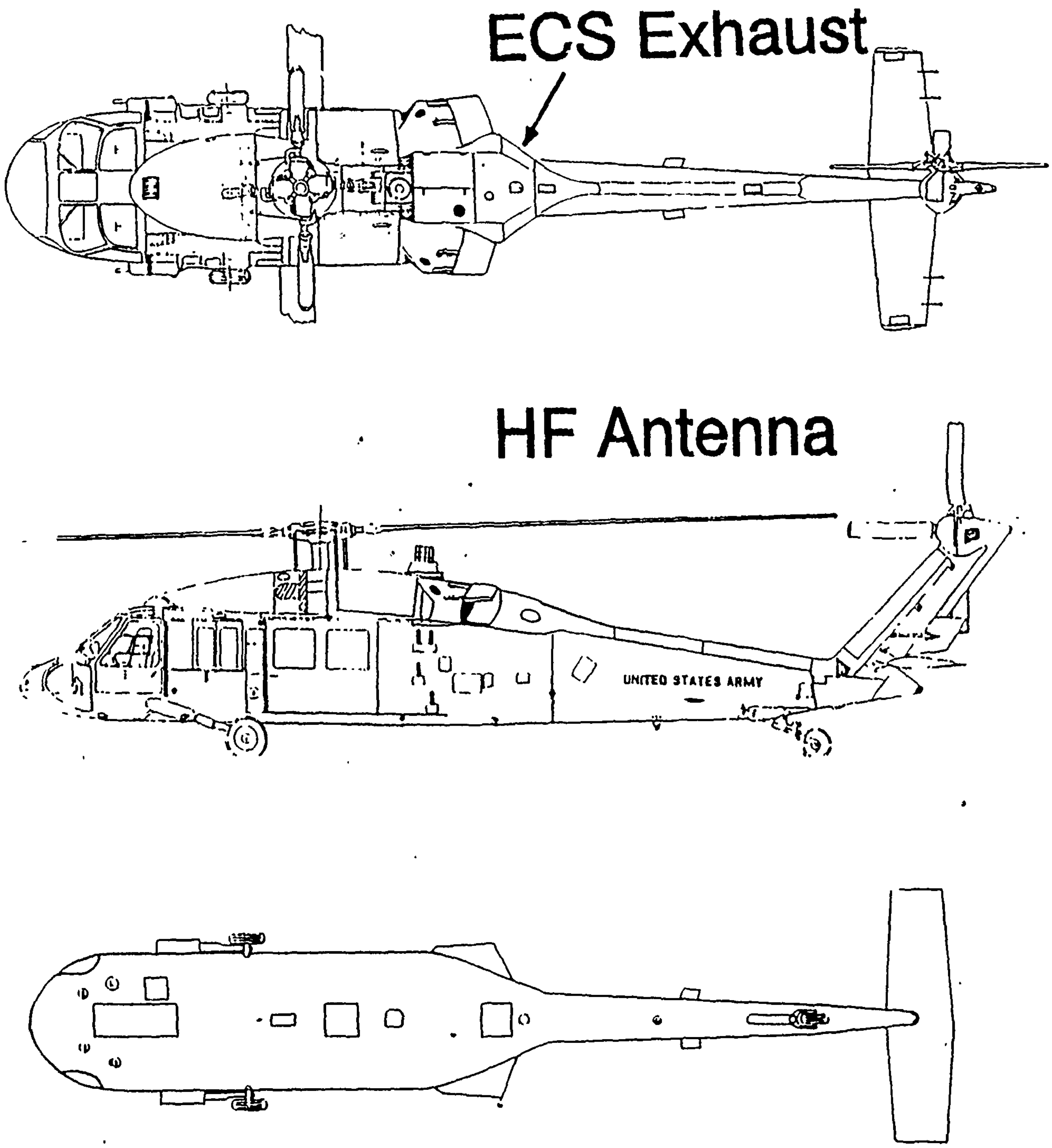


Figure 9. U.S. Army UH-60 Configuration

3. Evaluation of the Rockwell-Collins 437R-2 Antenna

After the March 2, 1982 contractor's meeting, in September, 1982, a prototype Rockwell-Collins 437R-2 tuned HF monopole and short-wire antenna system was installed on SH-60B, BuNo 161172, at Sikorsky Aircraft. The following chronology occurred for the antenna test and evaluation:

- October 12, 1982 - SH-60B, BuNo 161172, arrived at NATC, Patuxent River, Maryland.
- November 8, 1982 - Work request issued to NATC.
- December 21, 1982 - Final test plan issued.
- January 4, 1983 - Torpedo interference/ground tests commenced.
- January 5, 1983 - Maximum range communications test flight completed.
- January 10, 1983 - Prototype HF antenna system from SH-60B, BuNo 161172, and original design long-wire antenna reinstalled prior to aircraft transfer to HSL-41, North Island, California.
- February 9-16, 1983 - Flight tests conducted with original design long-wire HF antenna on SH-60B, BuNo 161173, to establish baseline database.
- February 25, 1983 - Ordnance compatibility contributory test report received.
- March 3-9, 1983 - Prototype HF antenna system installed on SH-60B, BuNo 161173, by NATC personnel.
- March 14 - April 4, 1983 - Flight test period for prototype HF antenna system installed on SH-60B, BuNo 161173.
- June 9, 1983 - SH-60B HF antenna evaluation contributory test report received.
- August 31, 1983 - Data reduction completed.
- January 27, 1984 - Final report issued. [Ref. 10: p. 4]

The evaluation consisted of tests to determine if the antenna design met functional installation and safety-of-flight criteria and to characterize HF communications system performance. A photograph of the Rockwell-Collins 437R-2 tuned HF monopole antenna is shown in Figure 10 [Ref. 11].

a. *Ground Tests*

In the ground test phase, the Rockwell-Collins 437R-2 tuned HF monopole antenna system performed better than the existing system at the lower frequencies, but not as well at the higher frequencies. Also, poor AM-6798/ARC-174(V) antenna coupler tuning performance in the 9.5 to 14.0 MHz frequency range caused marginal to nonexistent HF operational capability which degrades the capabilities of both the equipment and the aircraft.

The physical compatibility of the prototype HF antenna with the deployment of MK-46 torpedoes from the starboard pylon of the SH-60B helicopter was determined during ground tests. It was determined that it was possible for the retaining strap of the torpedo air stabilizer to hit the HF antenna system. Upon initial release of the MK-46 torpedo, the retaining strap unwinds and passes within approximately 6 inches of the fuel dump pipe. This would place the strap in direct line with the vertical section of the short-wire antenna. The second possible contact could occur after the

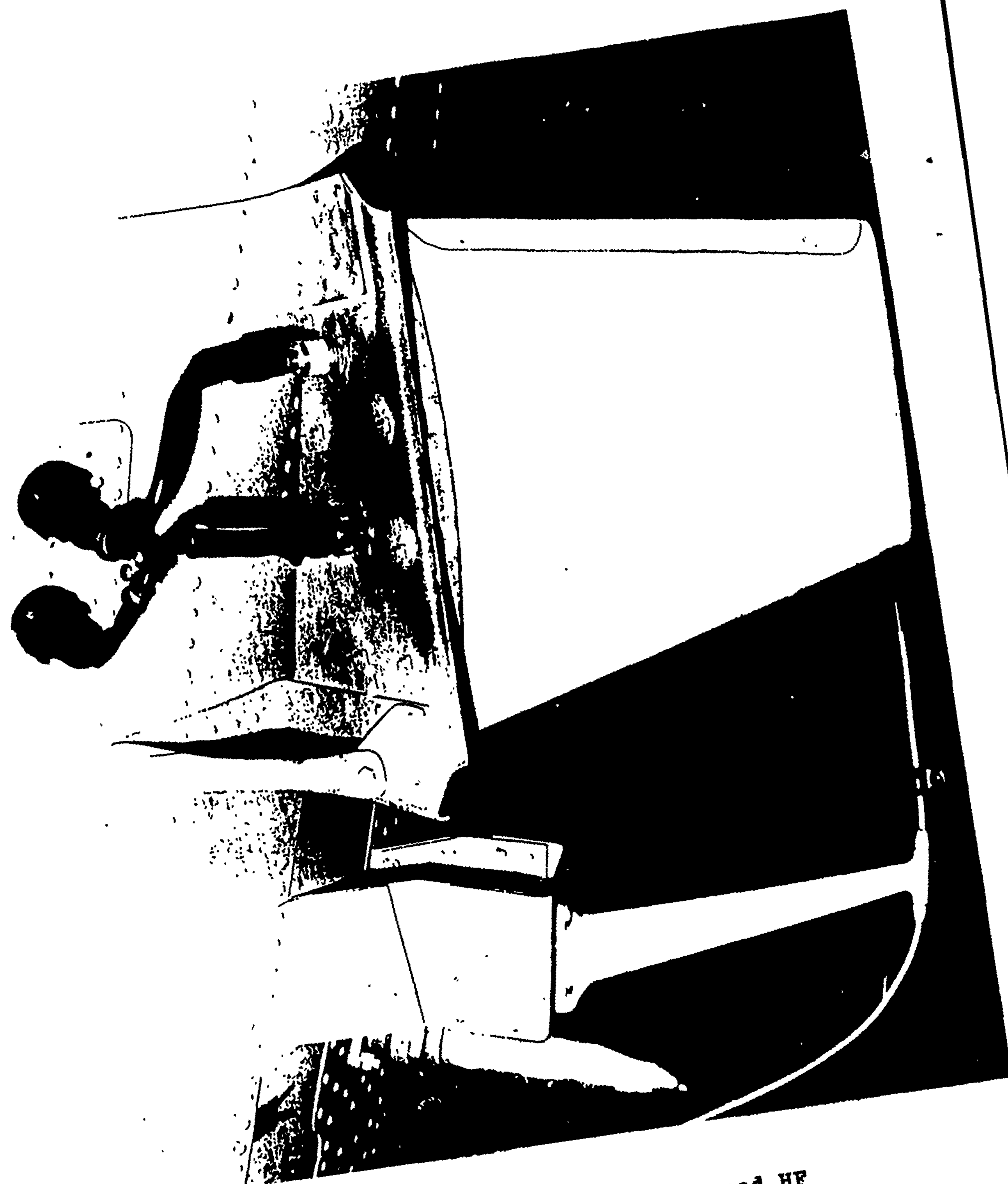


Figure 10. Rockwell-Collins 437R-2 Tuned HF Monopole Antenna

air stabilizer has been pulled from the parapack container and immediately before the static line break link separates. The parapack cover, the retaining strap and other associated parts are thrown into the MAD, fuel dump and the lower HF antenna system areas. The possible damage to the monopole blade should be limited to paint scrapes and minor cuts. The short wire, however, could be severed rendering the HF system inoperative. The failure of the short wire at practically any point along its path could allow the wire to pull through the standoffs and become entangled in the rotor systems.

b. Flight Tests

The antenna radiation patterns of the HF antenna systems were measured at frequencies of 2.130, 4.040, 7.645, 13.974, 18.100 and 26.835 MHz. The HF antenna radiation patterns of both the horizontal and vertical polarization are shown in Appendix A. The patterns for the existing antenna and the 437R-2 antenna system, at corresponding frequency and polarization, have been overlaid for relative comparison between antenna systems. If there were any effects from skywaves or surface waves, no determination could be made from the test and evaluation. All flights were flown using the same flight profile so any effect that this may have should have been consistent throughout the patterns. Comparison between the prototype Rockwell-Collins 437R-2 tuned HF monopole and short-wire antenna system and the existing long-wire HF antenna shows the former provided a more omnidirectional antenna radiation pattern and greater gains at each frequency except 13.974 MHz. The poor performance at 13.974 MHz was caused by inefficient coupler tuning in the 437R-2 system in that area of the HF band.

The conclusions from the flight tests were, with the exception of the 13.974 MHz frequency, the Rockwell-Collins 437R-2 tuned HF monopole and short-wire antenna system provided greater, more omnidirectional gains than the existing HF long-wire system. And the HF voice communication check flight revealed that, at 7.645 MHz, the probability of a HF skywave was the greatest. At this frequency, the Rockwell-Collins 437R-2 tuned HF monopole and short-wire antenna system provided effective communications at extended ranges and altitudes from 50 to 5,000 feet AGL (above ground level).

c. Reliability and Maintainability

The mechanical reliability of the prototype HF antenna system was monitored closely following the completion of flight tests In the 21-week period between April 4 and August 3, 1983, three monopole blade structural failures occurred as a result of accidental contact. All these failures occurred while the SH-60B helicopter was undergoing routine maintenance in a controlled test and evaluation environment. This configuration of HF antenna, deployed in a shipboard environment where the majority of maintenance procedures are conducted in a confined aircraft hangar area, would result in a significant number of monopole blade failures due to accidental contact. And because of the shipboard environment, the prototype HF antenna system configuration is not suitable for installation on the SH-60B helicopter. The operational suitability of the HF radio system would be affected by the poor mechanical reliability and susceptibility to damage of the Rockwell-Collins 437R-2 tuned HF monopole antenna. The end result of the NATC report was recommending that the Rockwell-Collins 437R-2 tuned HF monopole antenna system not be installed on the SH-60B helicopter because of the numerous reliability issues but not due to the performance of the antenna system.

C. THE PERIOD AFTER 1984

Since the testing and evaluation of the Rockwell-Collins 437R-2 tuned HF monopole and short-wire antenna system in 1983, there has been minimal effort to effect a change in the existing HF long-wire antenna configuration. Besides safety-of-flight items that were needed to prevent the breaking of the long-wire antenna itself, neither the prime contractor, IBM, nor Sikorsky Aircraft have orchestrated changes in the current HF antenna system. In the following chapter, an analysis of issues will be investigated in which to greatly enhance the multi-task mission of the LAMPS Mk III SH-60B helicopter.

IV. ANALYSIS OF ISSUES

A. INTRODUCTION

This chapter will focus on analyzing some of the issues concerning the improvement of the HF communications system on the SH-60B helicopter. These issues will deal with improving the current radio and analyzing different HF antenna configurations to allow the SH-60B helicopter to achieve better HF communication ranges.

B. IMPROVING THE RADIO

The current radio installed in the SH-60B, the AN/ARC-174 HF radio, features 1970's technology. In the interest of improving the entire HF communication system, this radio should be updated.

Collins Defense Communications, a subsidiary of Rockwell International Corporation (commonly referred to as Rockwell-Collins), is the manufacturer of the AN/ARC-174 HF radio. Making use of new communication technology, they have developed a new generation of HF radio, the AN/ARC-217(V) Lightweight Tactical Airborne Radio. The AN/ARC-217(V) HF radio provides a 175 watt power output compared to the 100 watt output of the current AN/ARC-174 HF radio. The physical design of the AN/ARC-217(V) is compatible to the AN/ARC-174 HF radio so that physical replacement would not be a problem.

Figures 11 and 12 [Ref. 6] were obtained using Advanced Prophet and illustrate that increasing the power output of the HF radio greatly increases the area coverage of the HF signal.

Another feature which is not available on the AN/ARC-174 HF radio but is on the AN/ARC-217(V) HF radio is automatic link establishment (ALE). This allows the HF radio to scan the HF band between 2.0 and 29.9 MHz and select the best frequency at that time and slave the HF receiver to that frequency to establish communications. The ALE essentially "sounds" the ionosphere and uses the time of day to find the best usable frequency.

One of the unique design features of the AN/ARC-217(V) radio is that the system units are interconnected by lightweight fiber optic cable in a ring configuration. The current AN/ARC-174 HF radio uses coaxial cable to interconnect the radio components. The concept of replacing copper cable with fiber optic cable is currently being investigated in the SAFENET II program as a way to reduce topside weight in naval vessels [Ref. 12]. That program also addresses the survivability issue and how fiber optic cable systems perform under the rigors of combat and damage. This is a modern issue in the design of aircraft because there is always a need to reduce total gross weight without losing effectiveness. A complete assessment of the fiber optic cable concept needs to be completed so that this new technology can be designed into new aircraft and helicopters.

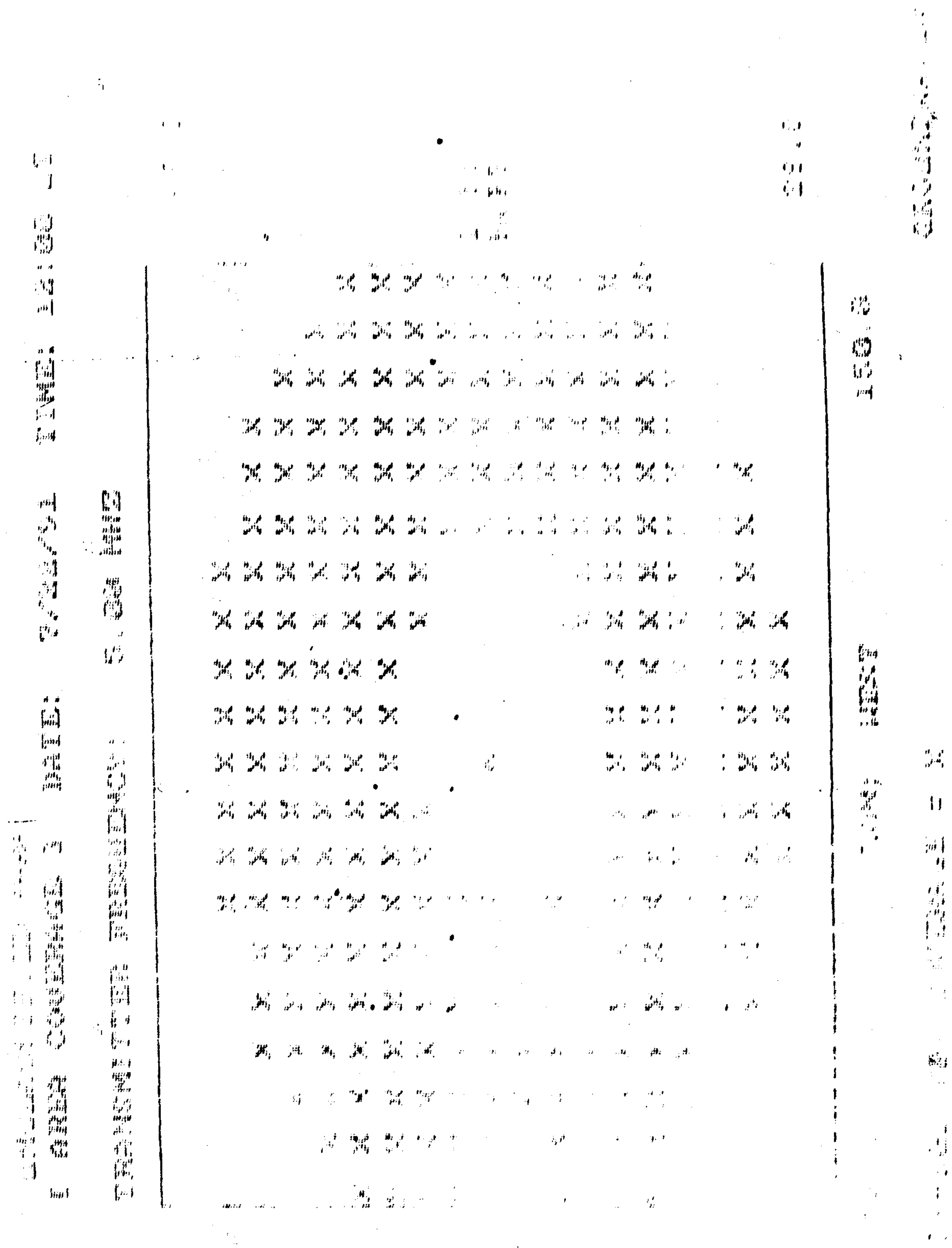


Figure 11. AN/ARC-174 HF Coverage With 100 Watt Output

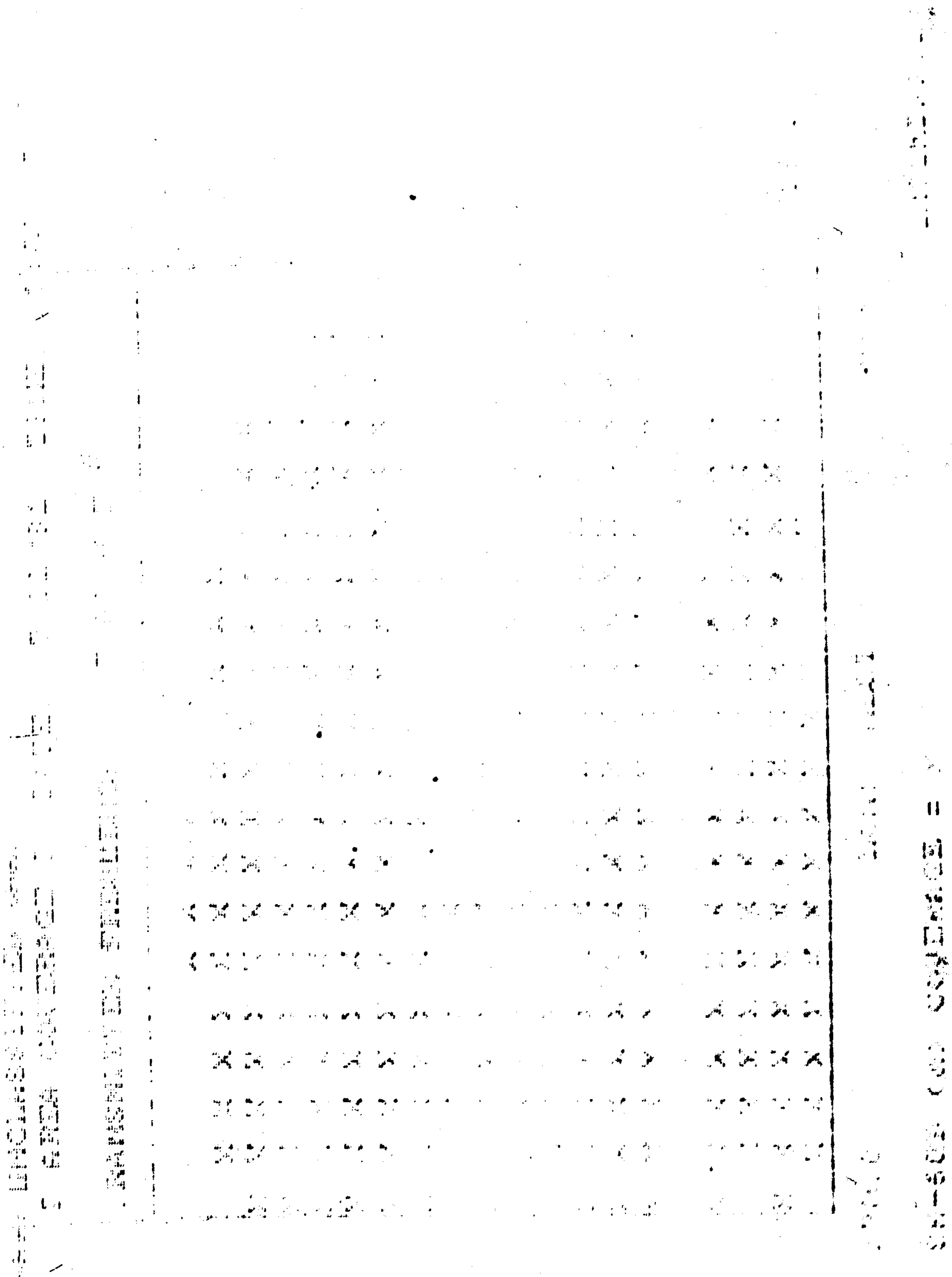


Figure 12. AN/ARC-217 HF Coverage With 175 Watt Output

C. ANTENNA CONFIGURATIONS

1. Introduction

At issue is the current HF long-wire antenna configuration on the SH-60B. The AN/ARC-174 HF radio was a sound choice for the aircraft at the time and the HF long-wire antenna configuration was of an acceptable design until it came to the test phase of the development. The following sections will look at earlier testing on another airframe, other research and then different HF antenna alternatives that would improve the HF radio system on the SH-60B.

2. Previous Testing and Research

On June 9, 1975, the Naval Air Test Center issued a final report on an evaluation of the AN/ARC-174 HF radio and two different HF antenna configurations on the SH-3H helicopter. The SH-3H helicopter is a larger aircraft than the SH-60B helicopter. The first result was the determination that the AN/ARC-174 HF radio set was suitable for military applications in helicopters. The other results involved the two different HF antenna configurations. Figures 13, 14, 15 and 16 show the different HF antenna configurations and how they were attached and adapted to the SH-3H for testing [Ref. 12:p. 33]. One notable difference between the two aircraft is that on the SH-3H, the HF antennas are mounted on the left side of the aircraft whereas on the SH-60B helicopter, the HF antenna is mounted on the right side of the

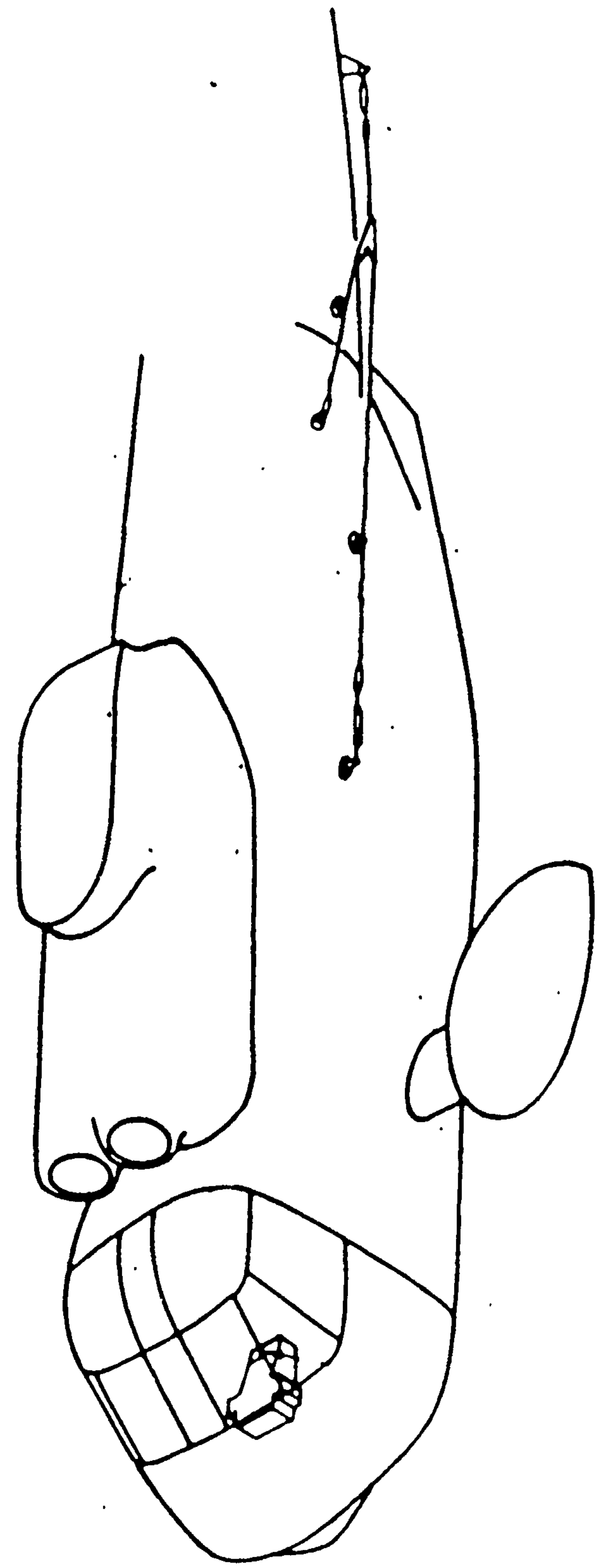


Figure 13. HF Long-Wire Antenna on the SH-3H

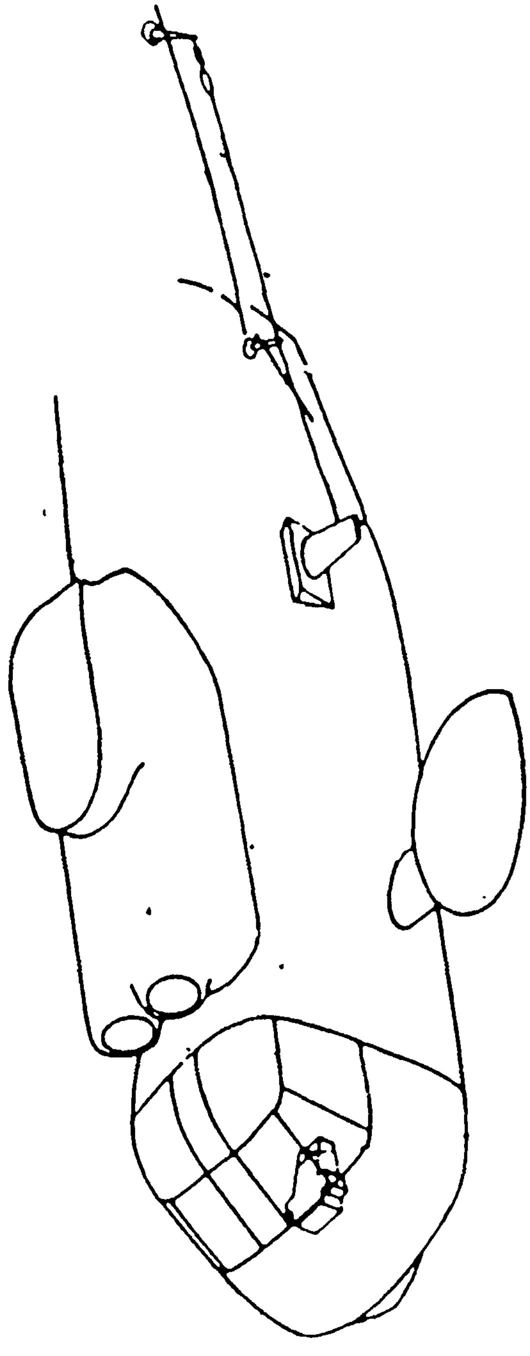


Figure 14. 437R-2 Monopole Antenna on SH-3H

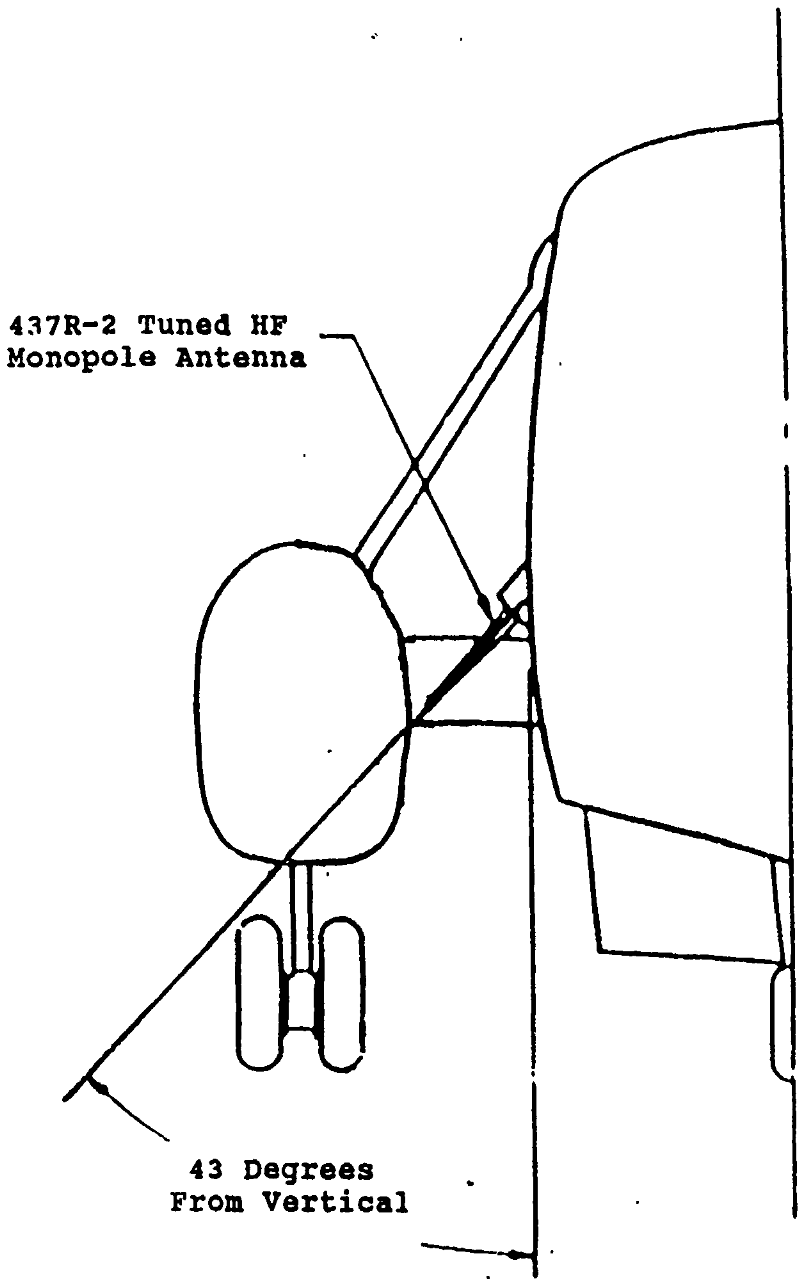


Figure 15. Rear View 437R-2 Monopole Antenna on SH-3H

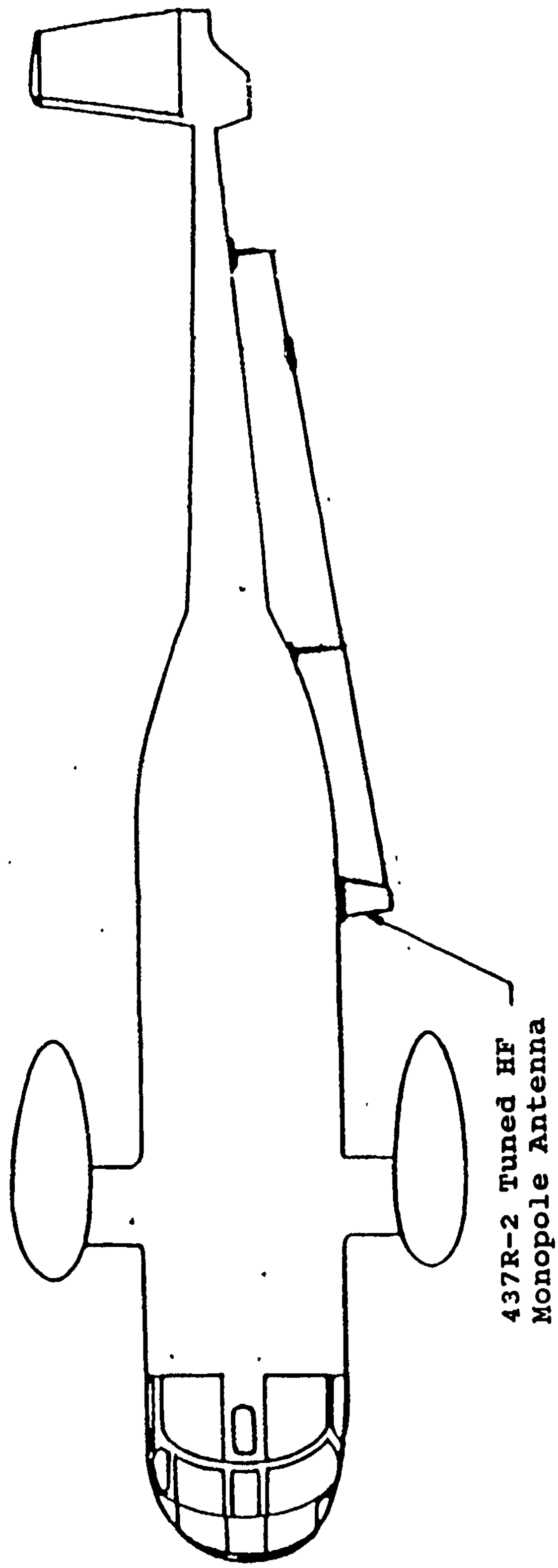


Figure 16. Top View of 437R-2 Monopole Antenna on SH-3H

aircraft because the tail section is folded to the left to be placed into the ship's hangar. The 437R-2 Tuned HF Monopole and short-wire antenna on the SH-3H helicopter is mounted at a 43 degree angle from the side of the aircraft. In the test involving SH-60B helicopter, the antenna was mounted perpendicular to the aircraft side. The study included a recommendation that the 437R-2 Monopole Antenna Assembly could be used on new installations in smaller helicopters where antenna real estate is at a premium [Ref. 13:p. 25]. This is clearly the case for the SH-60B helicopter.

A master's thesis from the Naval Postgraduate School examined optimizing the HF antenna for the Coast Guard's version of the H-60 helicopter [Ref. 4]. A unique aspect of the study was that it used Numerical Electromagnetic Code (NEC) which is a FORTRAN computer program used to analyze the electromagnetic response of metal structures. Antennas may be modeled and analyzed using NEC. The study analyzed the original long-wire antenna configuration and the Collins 437R-2 HF monopole antenna. When the SH-60B model was run at frequencies below 13 MHz with the original long-wire antenna, NEC was unable to model the electromagnetic responses. To solve the problem the long-wire antenna was moved further away from the aircraft skin and this provided accurate results. This concurs with the recommendation from the contractor's meeting held in March 1982 [Ref. 9] about manufacturing the antenna wire standoffs so that the antenna wire would be farther from the aircraft skin. A conclusion in the thesis was that from a computer modeling standpoint, the Collins 437R-2 Tuned HF monopole antenna wound enhance HF performance on the SH-60B helicopter. [Ref. 4: pp. 25-57]

3. Types of Antenna

Foreign allied governments have chosen Sikorsky Aircraft as the prime contractor for their variants of the H-60 helicopter design. The basic outward appearances of the H-60 helicopters are the same but the internal configurations and choice of avionics are different due to the distinctive missions required by the foreign nations. One foreign nation chose to use the Rockwell-Collins 437R-2 Tuned HF monopole antenna mounted similarly to the way that it was mounted on the SH-3H helicopter (at a 43 degree angle as opposed to vertical) and were pleased with the results. [Ref. 4:p. 26]

The typical test plan for evaluating HF radio and antenna performance was to fly the helicopter outbound from the communication range facility at an altitude of 100 feet and at designated HF frequencies, record the distance at which two way communication was lost [Ref. 14]. These results are contained in Table [3] [Ref. 14: p. I-3]. These HF flight results show a marked improvement over the Naval Air Test Center testing described in a previous chapter of the 437R-2 Tuned HF monopole antenna mounted in the vertical position. Results were obtained at lower frequencies of 3.2810 MHz and

9.0015 MHz whereas in the NATC testing, there was no contact at 2.128 MHz and 4.007 MHz.

TABLE 3
FOREIGN H-60 HF FLIGHT RESULTS

HF Frequency	Range
3.2810 MHz	20 - 25 miles
9.0015 MHz	35 - 40 miles
9.0115 MHz	55 - 60 miles
24.7510 MHz	30 miles

4. Loop Antenna

The final antenna design to be discussed is the loop antenna design, sometimes referred to as the "towel bar antenna." This HF antenna is currently in use on the VH-60D helicopter which is used by the President of the United States. This antenna design is illustrated in Figures 17 and 18 [Ref. 8]. The idea behind this antenna design is that the tubular antenna medium would provide more surface area to transmit and receive and would lower the impedance. This solid one-piece aluminum constructed tube is installed approximately 8 to 10 inches from the aircraft skin by end of the aluminum tube, at nonmetallic standoffs. At each the first and last standoff, there is a metal rod that connects the aluminum antenna tube to the metal base of the

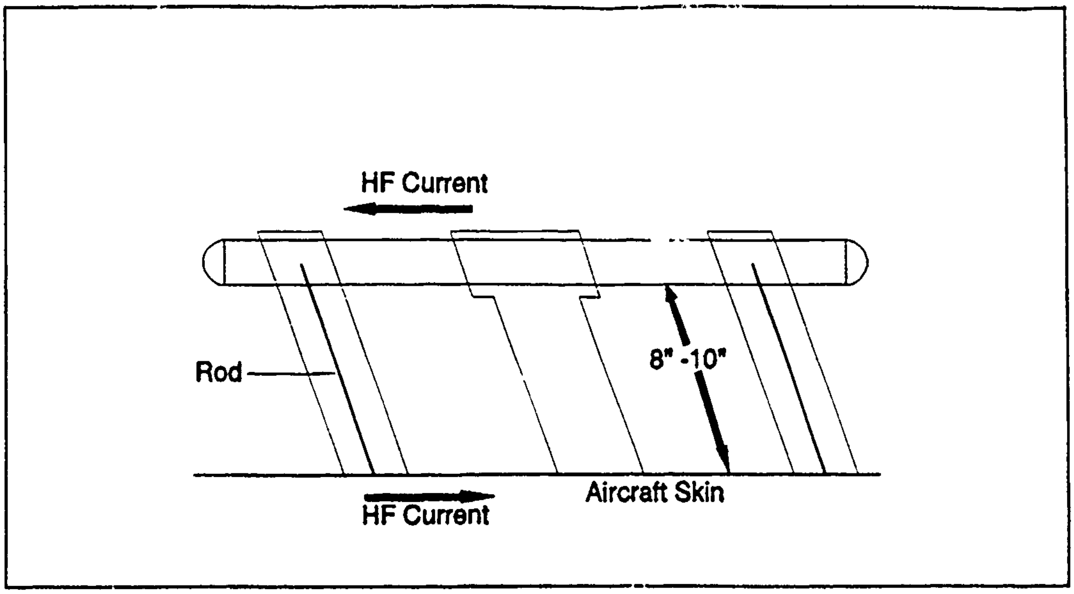


Figure 17. Loop Antenna Design

standoff which is in contact with the metal skin of the aircraft. This essentially uses the aircraft skin as the second half of the loop antenna. No test results were available to evaluate this HF antenna design but from a safety point of view, this HF antenna design would prevent the possibility of the long-wire antenna breaking and flying up into the rotor system. This was the concern of the Naval Air Test Center during their tests of the 437R-2 Tuned HF monopole and short-wire antenna system [Ref. 10]. The rigid aluminum design of the loop antenna would prevent potential aircraft damage.

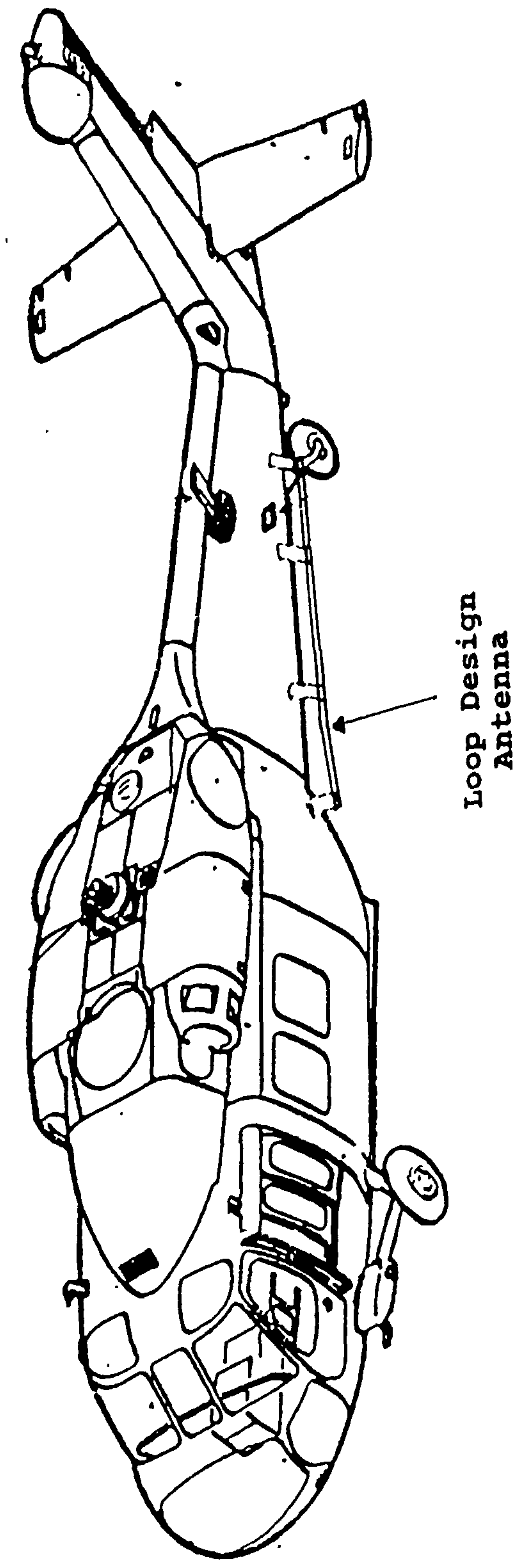


Figure 18. VH-60D Helicopter

V. CONCLUSIONS

A. RECOMMENDATIONS

In analyzing the issues involved in improving the HF communication capabilities of the SH-60B, there is no easy solution to improving the current HF antenna system on the SH-60B Seahawk. From a theoretical and not a practical point of view, the HF communications capabilities on the SH-60B can be solved with plenty of time, research and money. But from a practical standpoint, would the outlay of financial and research resources in this time of Department of Defense budget reductions vastly improve the current mission and capabilities of the SH-60B helicopter? Probably to the point that the HF communication system would be the primary form of voice communication for the SH-60B helicopter.

With the advent of new technology and in the interest of maximum safety, the loop antenna design holds the most merit for improving the HF capabilities of the SH-60B helicopter. Its rigid aluminum "towel bar" design would have to be installed on the right side of the aircraft (opposite of the VH-60D) to accommodate the folding tail pylon. And the danger of the current HF long-wire antenna wire breaking and interfering with the rotor systems would be alleviated.

The Rockwell-Collins 437R-2 Tuned HF monopole and short-wire antenna have proven track records for performance. But on the SH-60B helicopter where real estate is at a premium for placing aircraft antennas, the placement of the Rockwell-Collins 437R-2 Tuned HF monopole and short-wire antenna would have to be researched so that all antennas on the tail pylon of the SH-60B helicopter could be accommodated and perform up to their capabilities. As shown in the foreign H-60 helicopter research and in the SH-3H helicopter, the placement of the Rockwell-Collins 437R-2 Tuned HF monopole antenna would be better at an angle of approximately 45 degrees with the side of the aircraft as opposed to vertical as tested by the Naval Air Test Center. Any upgrading to the HF communications system would probably have to be coupled into future block design improvements to the SH-60B helicopter and not just a single improvement due to the financial impracticality of such an upgrade.

B. ADDITIONAL RESEARCH

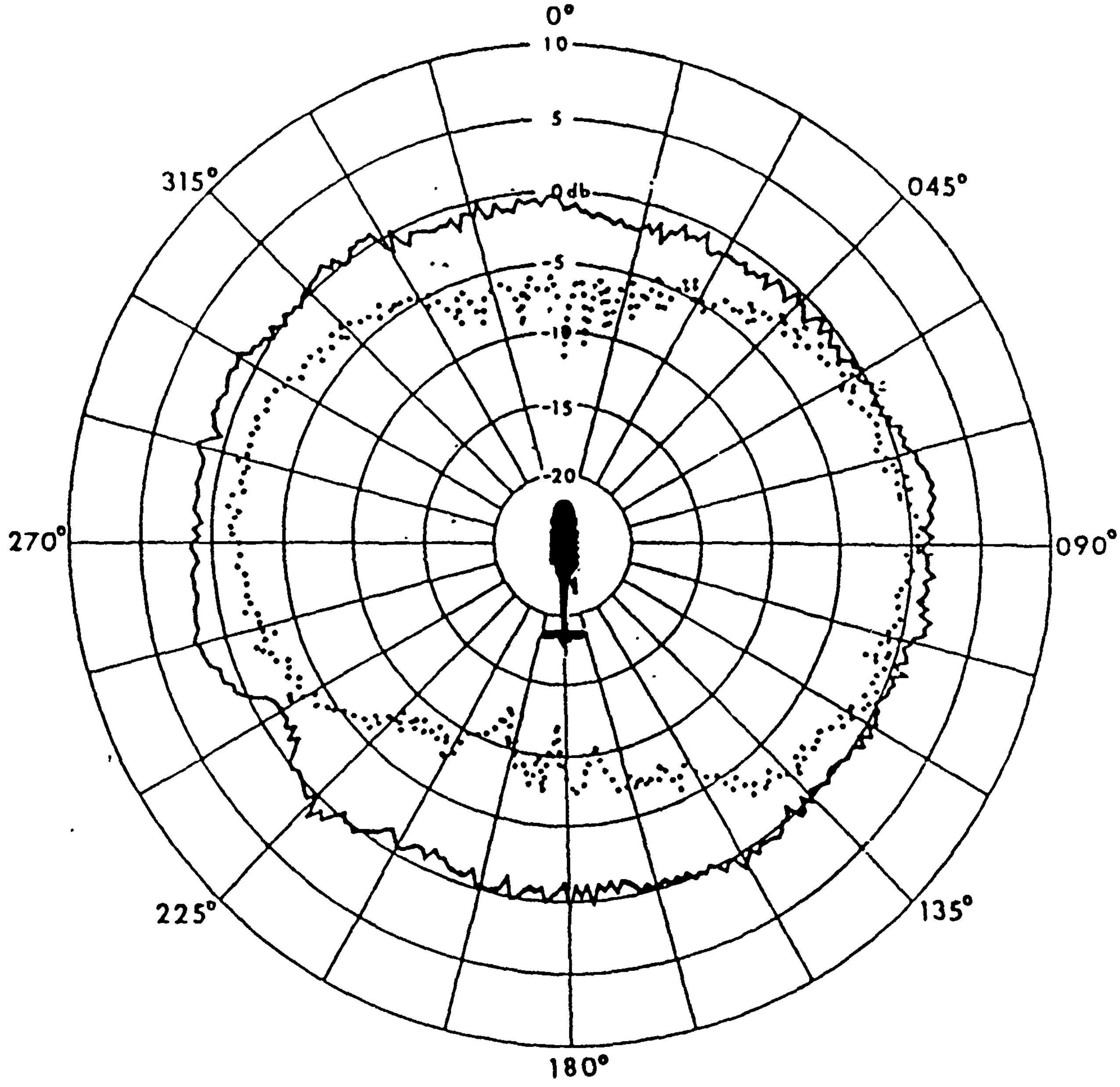
Further studies and research need to done to fully evaluate each of the recommendations for improving the HF communications capability of the SH-60B helicopter. Probably the first study that should be done is a cost analysis of whether it is practical to explore HF communications improvement in the SH-60B helicopter. By using computer modeling such as NEC and computer programs as Advanced

Prophet, proposed HF antenna designs can be initially evaluated for performance.

C. SUMMARY

The SH-60B helicopter and all its multi-tasked missions are the primary long distance antisubmarine warfare and over-the-horizon targeting vehicle for U. S. Naval cruisers, destroyers and frigates. This helicopter must be improved in order to keep up with the ever changing complexity of our naval mission.

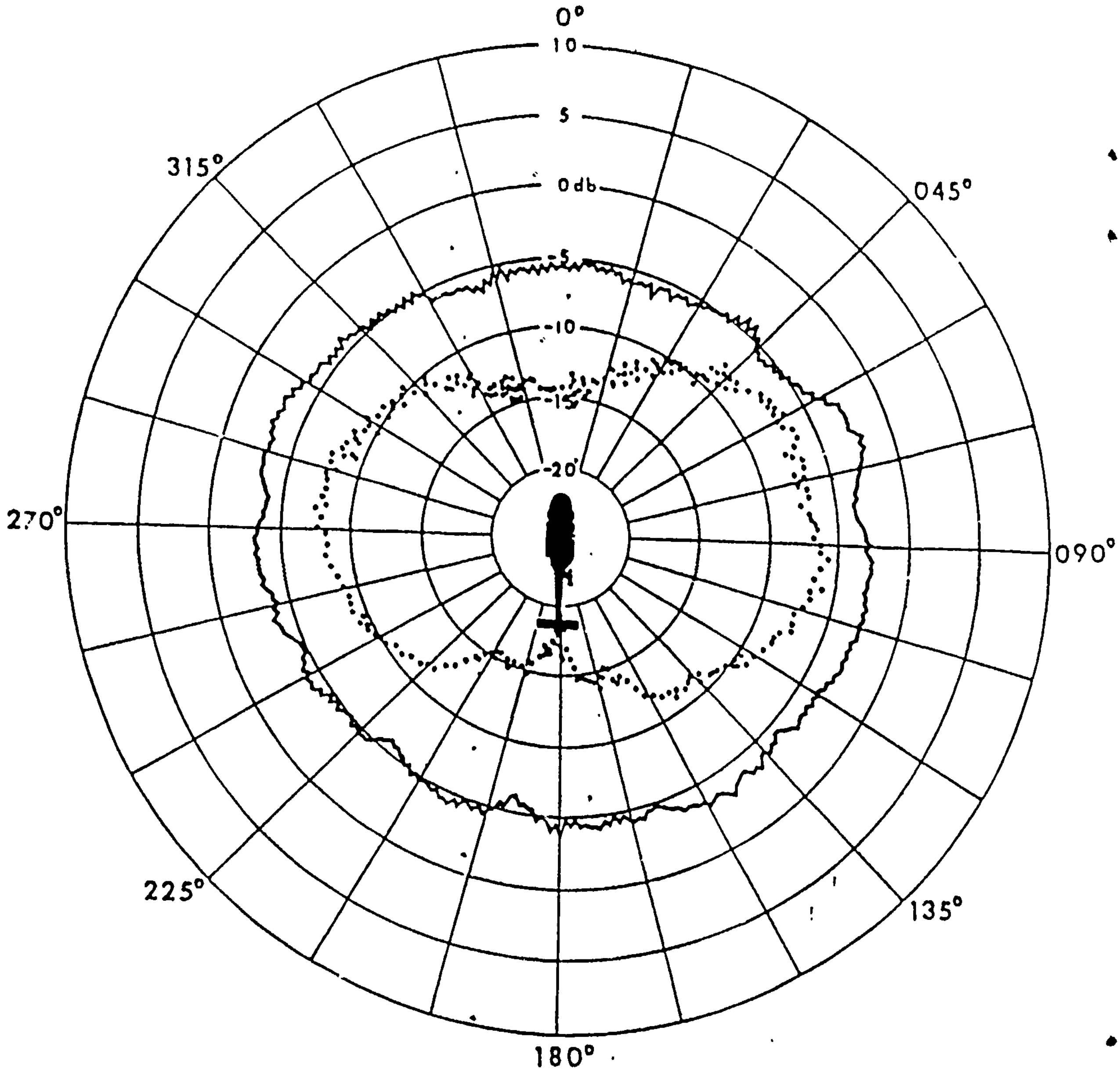
APPENDIX A. HF RADIATION PATTERNS [Ref. 10]



FREQUENCY: 7.645 MHz
POLARIZATION: HORIZONTAL
ALTITUDE: 200 FT

SCALE: GAIN PLOTTED IN dB RELATIVE TO ISOTROPIC (0 dB = 10 dBI) VERSUS AZIMUTH ANGLE

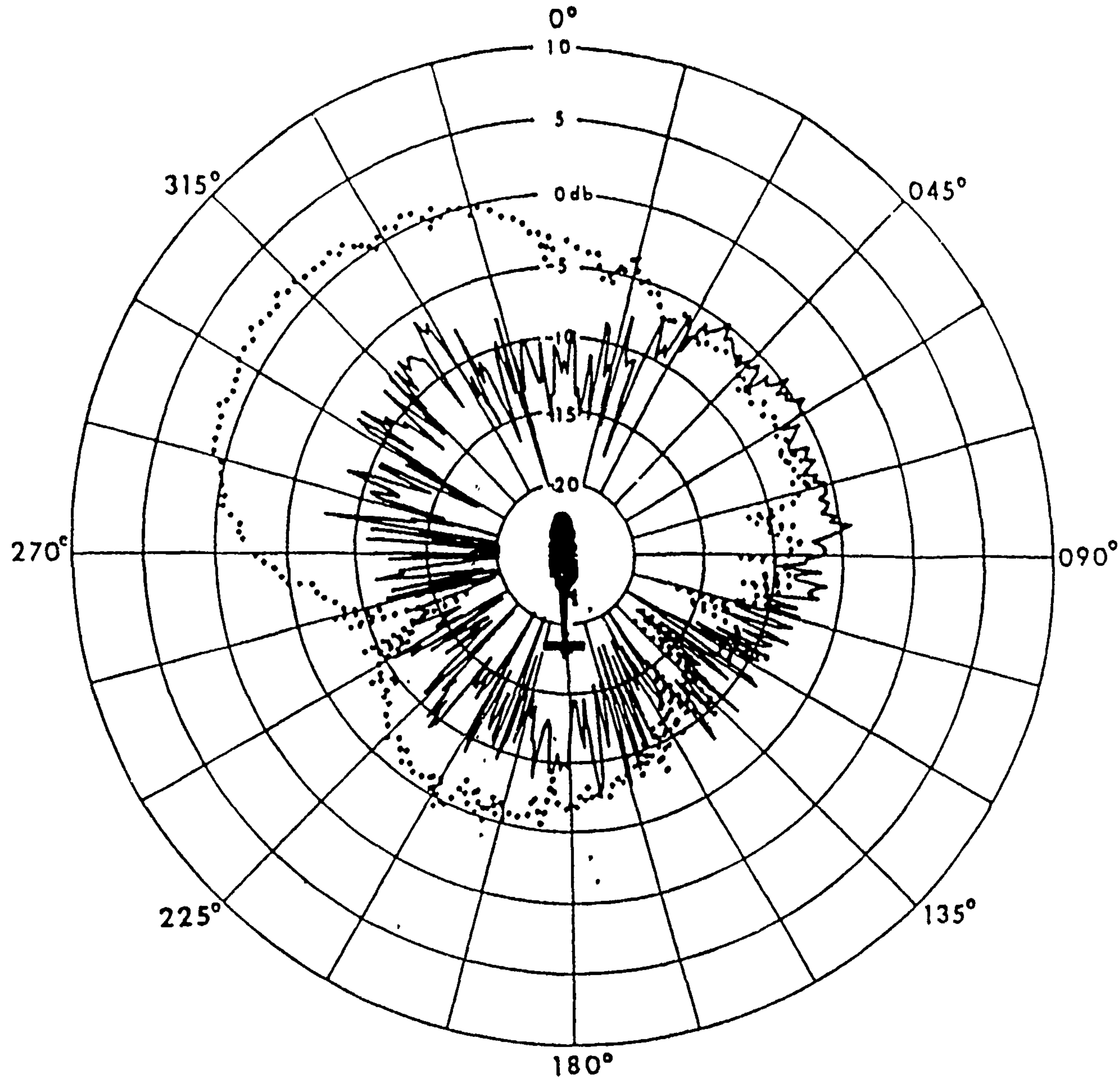
• • • • EXISTING SYSTEM
——— 437R-2



FREQUENCY: 7.645 MHz
POLARIZATION: VERTICAL
ALTITUDE: 200 FT

SCALE: GAIN PLOTTED IN dB RELATIVE TO ISOTROPIC (0 dB = -15 dBi) VERSUS AZIMUTH ANGLE

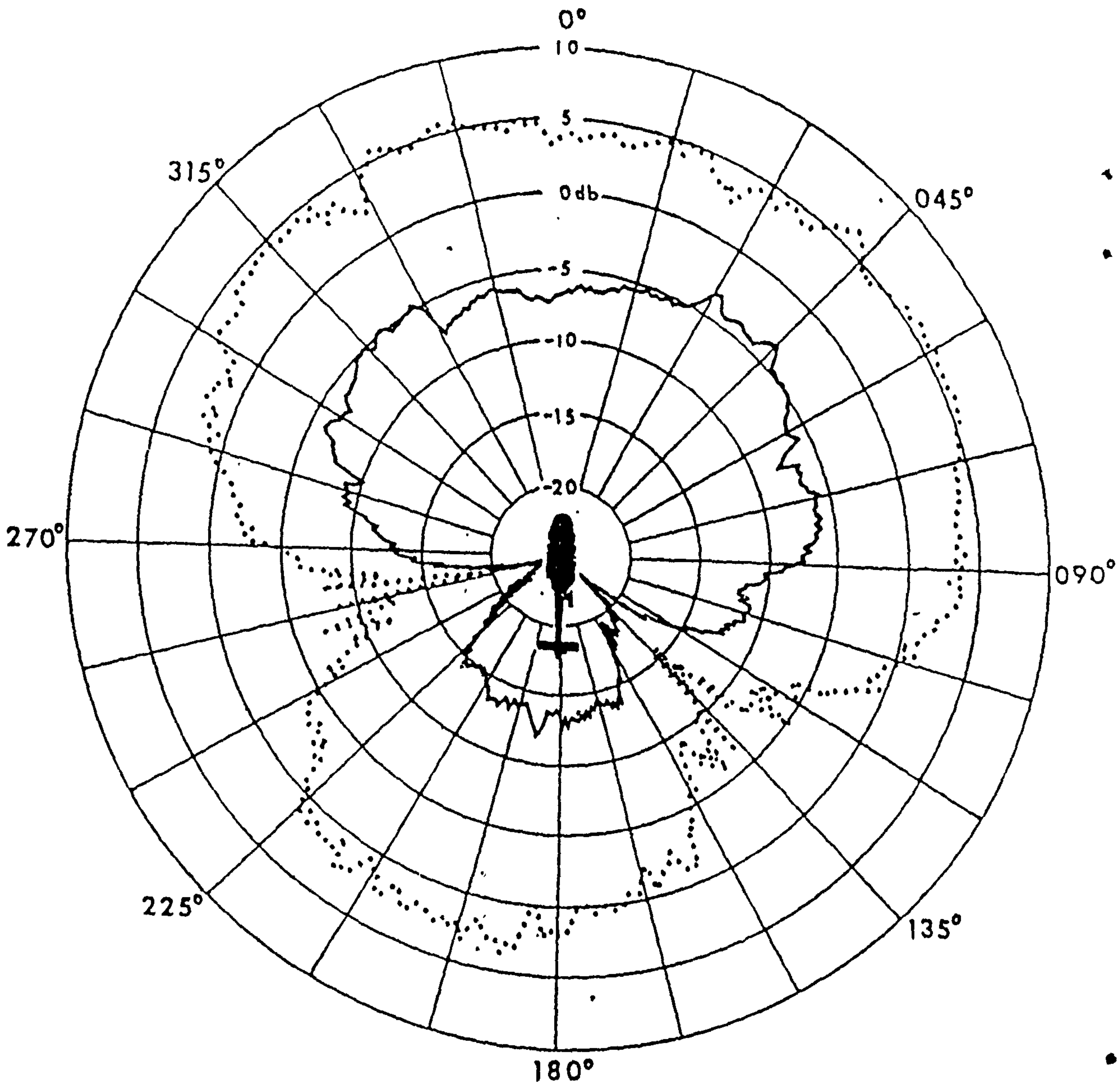
•••• EXISTING SYSTEM
—— 437R-2



FREQUENCY: 13.974 MHz
POLARIZATION: HORIZONTAL
ALTITUDE: 200 FT

SCALE: GAIN PLOTTED IN dB RELATIVE TO ISOTROPIC (0 dB = 0 dBI) VERSUS AZIMUTH ANGLE

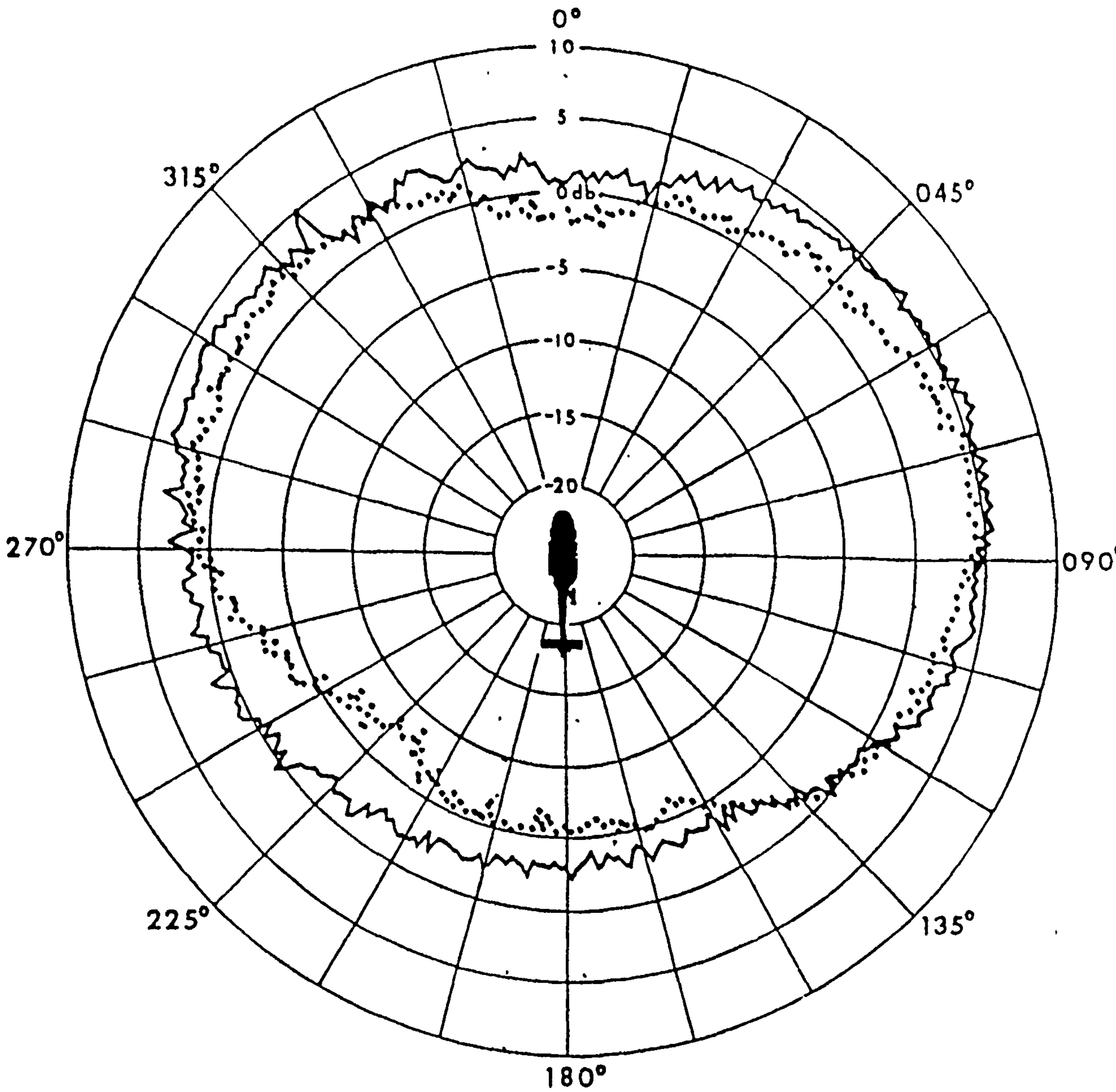
•••• EXISTING SYSTEM
——— 437R-2



FREQUENCY: 13.974 MHz
POLARIZATION: VERTICAL
ALTITUDE: 200 FT

SCALE: GAIN PLOTTED IN dB RELATIVE TO ISOTROPIC (0 dB = -15 dBI) VERSUS AZIMUTH ANGLE

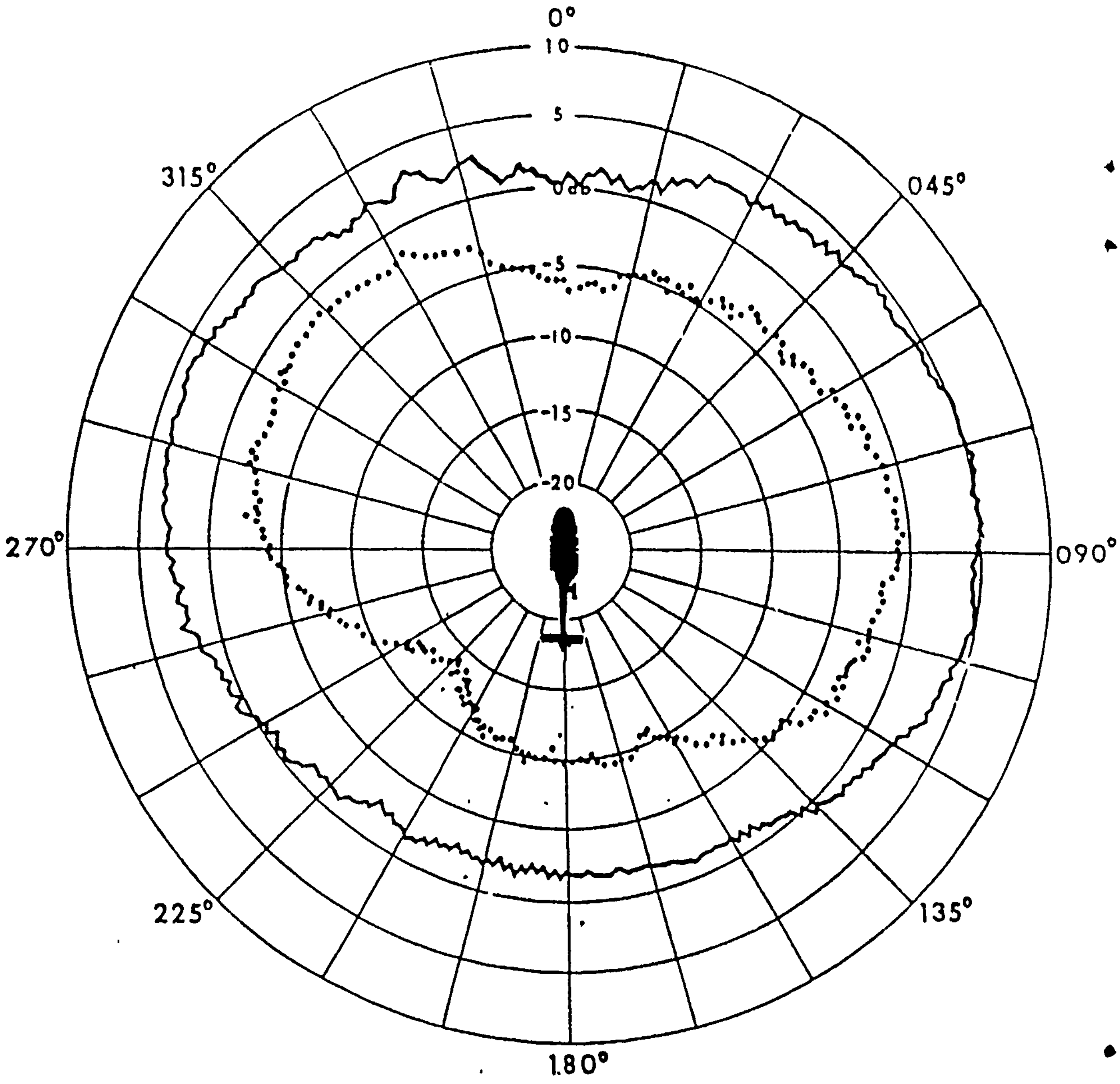
• • • • EXISTING SYSTEM
—— 437R-2



FREQUENCY: 18.1 MHz
POLARIZATION: HORIZONTAL
ALTITUDE: 200 FT

SCALE: GAIN PLOTTED IN dB RELATIVE TO ISOTROPIC (0 dB = 0 dBI) VERSUS AZIMUTH ANGLE

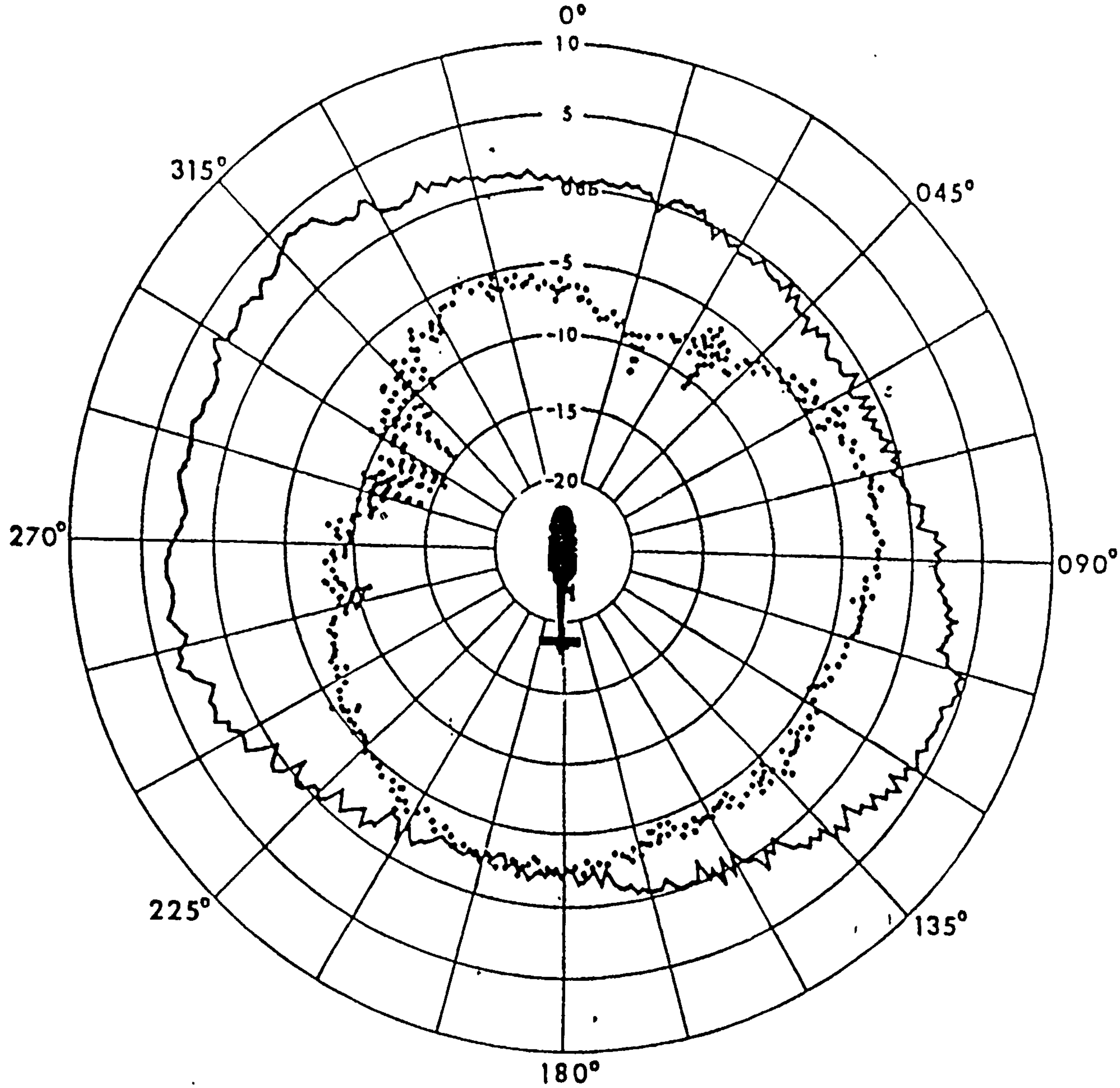
•••• EXISTING SYSTEM
—— 437R-2



FREQUENCY: 18.1 MHz
POLARIZATION: VERTICAL
ALTITUDE: 200 FT

SCALE: GAIN PLOTTED IN dB RELATIVE TO ISOTROPIC (0 dB = 0 dBi) VERSUS AZIMUTH ANGLE

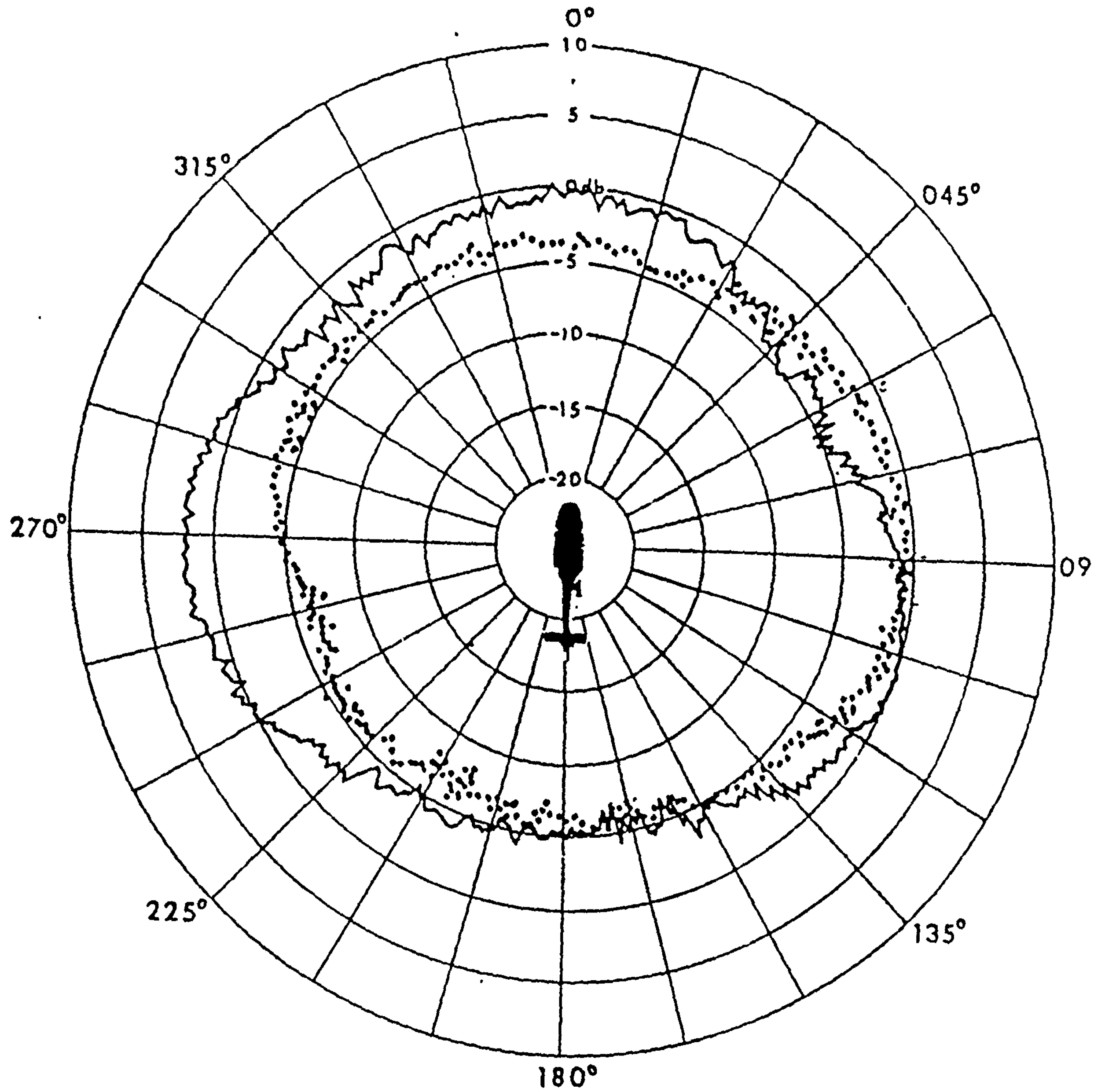
• • • • EXISTING SYSTEM
——— 437R-2



FREQUENCY: 26.835 MHz
POLARIZATION: HORIZONTAL
ALTITUDE: 200 FT

SCALE: GAIN PLOTTED IN dB RELATIVE TO ISOTROPIC (0 dB = 0 dBi) VERSUS AZIMUTH ANGLE

• • • • EXISTING SYSTEM
—— 437R-2



FREQUENCY: 26.835 MHz
POLARIZATION: VERTICAL
ALTITUDE: 200 FT

SCALE: GAIN PLOTTED IN dB RELATIVE TO ISOTROPIC (0 dB = -15 dBI) VERSUS AZIMUTH ANGLE

•••• EXISTING SYSTEM
—— 437R-2

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