

A-1551

**FINAL TECHNICAL REPORT**

**95 GHz COBRA LEADING EDGE ANTENNA SYSTEM**

**EES/GIT PROJECT A-1551**

**Prepared for**

**UNITED STATES ARMY**

**FRANKFORD ARSENAL**

**PHILADELPHIA, PA. 19137**

**UNDER**

**CONTRACT DAAA25-73-C-0648**

**by**

**D. G. Bodnar and R. M. Goodman, Jr.**

**15 April 1974**

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Engineering Experiment Station

**GEORGIA INSTITUTE OF TECHNOLOGY**

Atlanta, Georgia

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## ABSTRACT

An antenna concept has been developed and a conceptual design performed for a 95 GHz antenna system to be located in a modified stub-wing of an AH-1G Cobra helicopter. The antenna system consists of three antennas: two 18-inch diameter geodesic lenses and one 9-inch diameter Cassegrain reflector. One lens is placed in each stub-wing and each lens scans a  $0.5^\circ$  beam ( $2^\circ$  beam in the non-scan plane) over a  $60^\circ$  sector from dead ahead. These lenses provide search coverage over a  $120^\circ$  sector. Target tracking and identification is achieved by a conically scanned Cassegrain antenna located in one of the wings. Using off-the-shelf receiver and transmitter components, the proposed system should provide detection and tracking out to 12 to 18 km. The existing stub-wing must be approximately doubled in size in order to accommodate the antennas. This wing modification will not significantly alter the aircraft performance since the stub-wing is not an aerodynamic lifting surface.

## ACKNOWLEDGEMENTS

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## I. INTRODUCTION

### A. Purpose of Study

The objective of the study performed under this contract was to develop an antenna concept and to perform a conceptual design for a 95 GHz antenna system which could be located in a modified stub-wing of an AH-1G Cobra helicopter. This antenna system, when combined with an appropriate radar, should provide target detection, acquisition, tracking and identification out to 12 to 18 km. Targets of interest include tanks, tracked vehicles, trucks, jeeps, and personnel. The antenna location was selected by Frankford Arsenal after considering a number of alternative locations. The nose of the helicopter is, of course, a desirable location for the antenna. However, future plans call for using the nose for weapons and other sensors, thus, this location will not be available for the radar antenna. Other antenna locations considered by Frankford Arsenal included mounting arrays conformal to the nose of the helicopter, mounting the antenna in the shroud around the engine drive shaft above the pilot, mounting in a pod which would be located either under one of the wings or between the skids, and mounting in the stub-wing. An initial look at mounting the antenna conformal with the nose or locating a phased array in the leading edge indicated that the cost and development risks would be high for a millimeter antenna. Mounting in the shroud area did not afford sufficient room for packaging a practical scanning antenna. Mounting the antenna in a canister and placing the canister on one of the stub-wings would reduce the fire power of the aircraft, and so, was deemed unsatisfactory. Mounting under the belly of the helicopter between the skids presents a serious clearance problem when the aircraft makes a hard landing. In addition, the landing struts block the antenna's view. Hence, this location was ruled out. The stub-wing location was selected as the best location for the following reasons.

- (1) Sufficient room is available, with some wing modification, for mounting an antenna in the wing.
- (2) This location will not reduce the fire power of the aircraft.
- (3) Changing this wing will not drastically alter the aerodynamic performance of the vehicle.



A geodesic lens was selected as the candidate antenna for study because of its excellent wide-angle scan capabilities and because it was felt that such an antenna could be developed at millimeter frequencies without great risk. Initially three frequencies were selected for examination, namely 35 GHz, 70 GHz, and 95 GHz. These frequencies were selected because atmospheric windows exist at these frequencies, and because of the availability of components at the frequencies. The majority of the emphasis in the program was placed at 95 GHz by Frankford Arsenal because of the improved resolution for a fixed antenna size that can be obtained at 95 GHz over the other frequencies, and because backscatter measurements indicated improved performance at 95 GHz over 70 GHz.

#### B. Background

Operation of small aircraft in the battlefield environment of a mid-intensity conflict places a set of requirements on the electromagnetic sensors which generally cannot be satisfied by equipment in the Army's inventory at this time. The aircraft will most likely fly in a nap-of-the-earth mode to reduce the possibility of detection by enemy tanks and track mounted weapons. Weather conditions encountered in the mid-intensity type conflict vary widely. Daily conditions vary from clear skies to heavy overcast of nimbo-stratus clouds and from fog to heavy rains of 25 mm/hr. In addition, the need exists to operate at night with no light as well as in daylight periods of full sun intensity. It currently appears that increased capability is needed by the aircraft in order that it can survive as well as conquer the opposition by improved fire power.

The study reported in the following sections has been directed toward the determination of antenna apertures which can be used to direct electromagnetic energy at the battlefield and have the best potential for assisting in locating and identifying targets. In addition, a location on the aircraft must be selected which does not interfere with other sensors and is of a configuration which does not reveal the presence of another sensor.

A number of operational parameters must be chosen in order to establish a set of base-line requirements for the total sensor requirements which in turn influence the antenna aperture of the sensor. In this sense, not all parameters

of the system have been considered or studied, but only those which have influence on the aperture. A system study for a scout type of helicopter was performed by the Sensor Systems Division of Georgia Tech using internal funds. This study was undertaken in order to establish the technical requirements of a 95 GHz radar system needed to perform the scout mission. The study resulted from a request for a 95 GHz radar concept for a scout helicopter from Col. Wayne B. Davis of the Office of Chief of Research and Development, Department of the Army. The results of this radar system study were presented to Col. Davis in an informal report entitled "A Millimeter Radar Concept for Helicopter Application" by Bodnar, Reedy, Dyer, and Goodman dated January 1974. A good deal of this study also applies to the Cobra helicopter, and hence, helps establish the feasibility of a 95 GHz radar for the Cobra.

In view of the requirements for adverse weather and night operation, it appears that IR and optical wavelengths are less desirable than millimeter or centimeter wavelength radiation. Since a small, lightweight system is preferred, millimeter wavelengths appear a better choice than centimeter wavelengths. The availability of hardware and developed components and an examination of atmospheric transmission properties leads one to consider only 35, 70, or 95 GHz as potential operating frequencies. Systems operating at 70 GHz are less desirable since it has been shown [1,2] that there is an adverse effect caused by rain attenuation and backscattering at 70 GHz as compared to either 35 or 95 GHz.

In application to the fire-control weapon use, it will be desirable that the antenna perform a true area search over an azimuth sector of  $\pm 60$  degrees from dead-ahead and over a range sector from 1500 meters to 18,000 meters. In addition, when a particular target has been identified, it will be required to track this target in a range sector from 6,000 meters to 1,000 meters for the purpose of munition delivery. It is desired to have a small enough azimuth beamwidth that targets separated under standard deployment procedures can be resolved by the radar. For example, a beam one degree wide will illuminate a section 17.4 meters wide at 1000 meters range and 314 meters wide at 18,000 meters range. This is about the maximum beamwidth that could be used in the anticipated mid-intensity conflict.

The range resolution of a radar is controlled by the pulse length of the transmitted energy. For example, during a nap-of-the-earth flight, a 100 ns

pulse will illuminate a 15 meter strip on the ground. The radar prf will establish the number of pulses that hit an illuminated area per second if the antenna is stationary. The number of pulses required to illuminate a target to insure a sufficiently low false alarm rate must be combined with how often this information must be up-dated in order to determine the prf. Thus the scan rate of the radiated beam must be determined from aircraft speed, false alarm rate, azimuth beamwidth, pulse length, and prf.

During the short range weapon delivery operation, tracking of the target is required for accurate delivery of the munition. One of the major assets of small aircraft and helicopters is the extreme maneuverability of the ship. However, the wide range of aircraft attitudes places an extreme burden on the stabilization and pointing of the radar antenna. For example, the nose down attitude of the Cobra changes as a function of speed. Climb angles of  $27^\circ$ , descent angles of  $40^\circ$ , and turn angles of  $30^\circ$  are encountered in extreme maneuvers. In addition, an azimuth yaw of  $5^\circ$  at a cyclic rate of  $1/6$  Hz and a pitch variation of  $5^\circ$  at  $1/6$  Hz are observed in the Cobra helicopter.

The following sections present the results of a conceptual design study of a millimeter antenna system of an AH-1G Cobra Helicopter that is capable, when integrated with an appropriate radar, of achieving target location, identification, and tracking for munition delivery in a mid-intensity battlefield environment.

## II. CANDIDATE ANTENNA CONCEPTS

The antenna work performed during this study was oriented toward the use of millimeter geodesic lens antennas in or on the stub wings of the AH-1G Cobra helicopter. A preliminary study was made of other types of antennas such as waveguide, stripline arrays, and phased arrays. The cost and/or development risk associated with these alternate antennas was deemed unreasonably high. Hence, an antenna type which had the potential of providing the desired performance at millimeter frequencies with low risk was selected by Frankford Arsenal for this study.

The basic type of antenna considered is a geodesic Luneberg lens. The geodesic Luneberg lens is a waveguide analog of a planar slice through a three-dimensional Luneberg lens [3]. The geodesic Luneberg lens has the property that a point-source feed on its periphery is transformed into a line source diametrically opposite the feed point. Thus the geodesic lens provides collimation of energy in one plane. Collimation of energy in the other plane can be obtained, for example, through the use of a parabolic cylinder fed by the line source output of the geodesic lens. Geodesic lenses are excellent scanning antennas even at millimeter wavelengths. Geodesic lenses have been built at Georgia Tech for X-band to V-band (70 GHz) [4,5,6]. They are very broadband devices that typically operate over an entire waveguide band. Thus they are compatible with Doppler signal processing and frequency agile transmitters.

A line drawing of the AH-1G Cobra helicopter is shown in Figure 1. The stub-wings are located on both sides of the helicopter behind the pilot's seat. The dimensions of a stub-wing are given in Figure 2. The wing is composed of three I beams that are perpendicular to the fuselage center line and which are covered by an airfoil. Each wing may be detached as a unit from the aircraft fuselage. The stub-wing is used as an attachment point for weapons and is not an aerodynamic lifting surface.

The decision to try to utilize the leading-edge location for the antennas was reached by Frankford Arsenal after considering a number of alternate

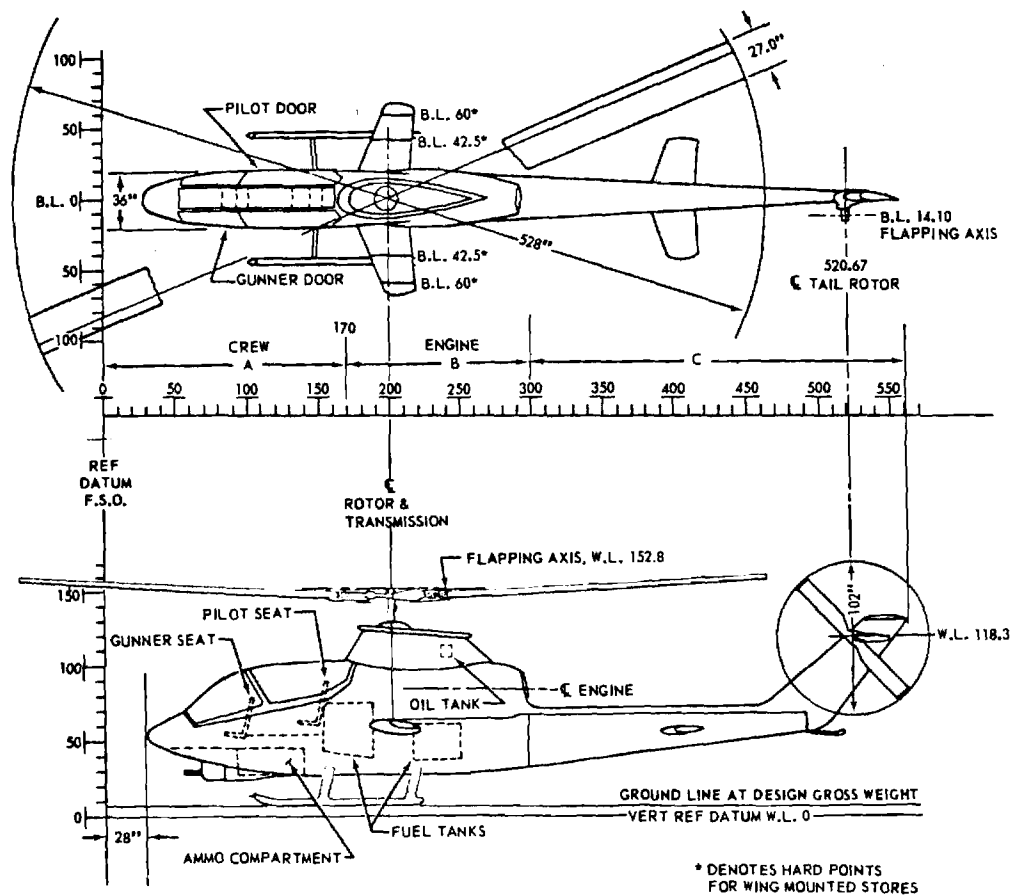


Figure 1. The AH-1G Cobra helicopter.\*

\*Figure taken from Department of the Army Technical Manual TM 55-1520-221-10, 19 June 1971, p. 12-3.

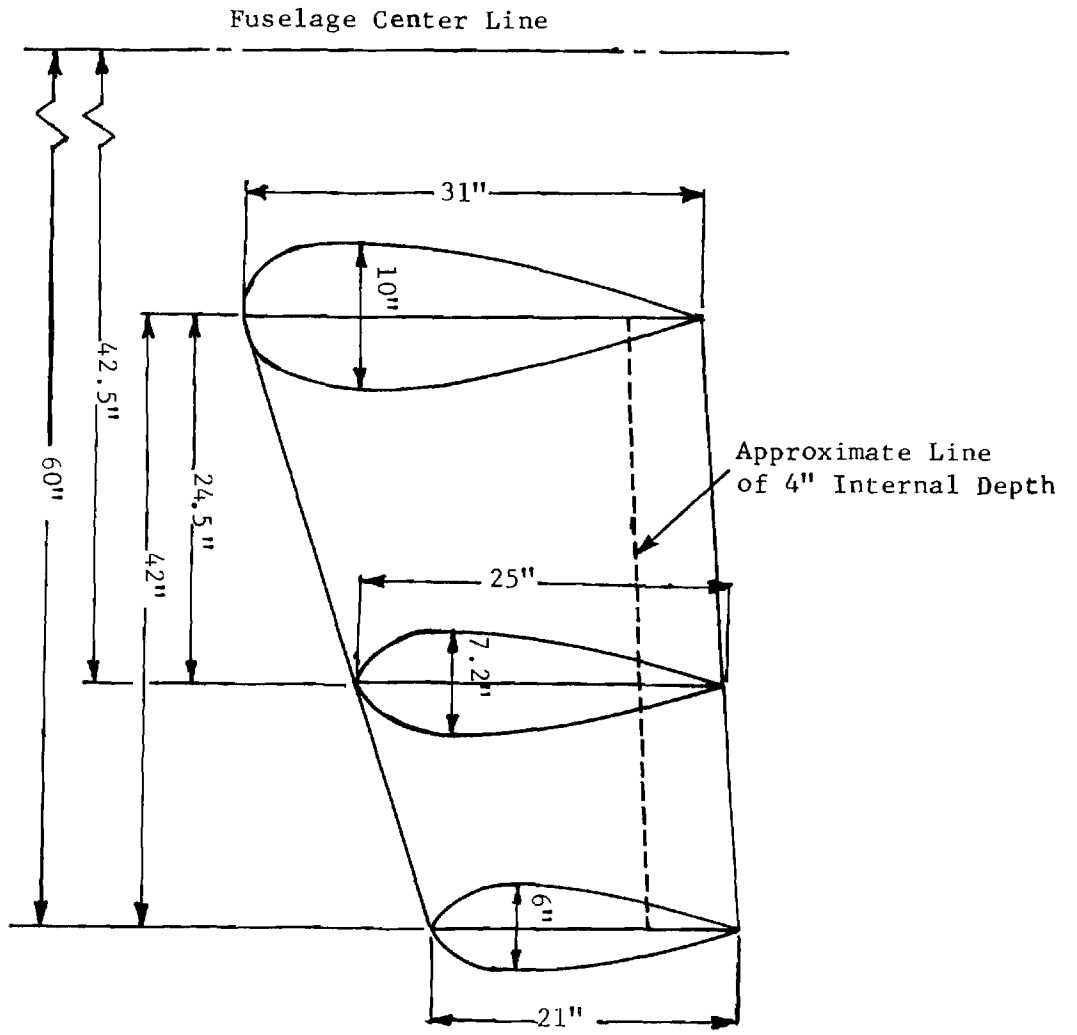


Figure 2. Approximate dimensions of AH-1G stub-wing.

locations. Some of the advantages of the leading edge location are (1) space is available in the wings for the antennas, (2) fire power is not compromised, and (3) only a small drag increase is expected by the resulting wing modification. The stub-wings on the attack helicopter are actually beams on which weapon stores are hung. An airfoil is placed around the beams to streamline their shape. They are not aerodynamic lifting surfaces, however, and so modifying their shape will not drastically affect aircraft performance.

Two antennas, one in each wing, will be required for the target detection mode using the leading-edge location due to the optical blockage produced by the fuselage. Each geodesic lens will scan a  $60^{\circ}$  sector on its side of the vehicle from dead ahead. It would of course be desirable for these antennas to provide both the sector search as well as the tracking function. A track-while-scan mode was considered for the antennas but was eliminated since an insufficient number of pulses is returned from the target to permit Doppler processing. It is believed that the Doppler signature will be very important in identifying targets and should be retained via an alternate approach.

Another approach for dual mode operation is to stop the scanner and look at the desired target for a short period of time and then resume scanning. The time required to stop (or start) an electromechanical scanner is on the order of 1/2 second. Thus the sector search will be off for an appreciable portion of time using this approach. Hence, this approach for dual mode operation is not recommended.

The approach finally selected involves the use of three antennas. The two geodesic lenses previously discussed are used for target detection only. A third antenna provides the tracking function. Some of the candidate antenna concepts that were considered in the process of arriving at the above recommended geometry are discussed in the next sections. Some of the characteristics desired by Frankford Arsenal for this antenna are listed in Table I.

A beamwidth of  $1^{\circ}$  or less is desirable in azimuth for adequate target resolution and a  $2^{\circ}$  beamwidth in elevation (possible with some shaping) should provide adequate ground coverage in the search mode. Range performance calculations, assuming off-the-shelf components, indicates that a  $0.5^{\circ}$  azimuth beamwidth is required to achieve detection ranges in the order 12 to 18 km as

Table I

Antenna Performance Characteristics Desired  
for the AH-1G Leading Edge Antenna System

Parameter	Nominal Value
Az BW	1° maximum
Az Coverage (Scan sector)	120° total
EI Coverage	15-20° total
EI BW	2° plus shaping
Power	20 kw
Bandwidth	1 to 2 GHz
Frequency	35, 70, or 95 GHz
Scan rate	6-10 per sec
Pulse Length	50 n sec
prf	4 kHz
Dual Polarization	Desirable
Az and EI tracking	Dead ahead only
Tracking Accuracy	1.2 mrad
Track While Scan	Desirable



desired. Thus the antenna must produce a  $0.5^\circ$  by  $2^\circ$  beam in the search mode. A  $\text{csc}^2 \theta$  pattern should be used beyond  $2^\circ$  to achieve proper ground coverage.

#### A. Large Aperture Approach

The aperture size in both the E- and H-planes is determined both by the available size for packaging the antenna and by the resolution requirements. The maximum size of the Cobra wing is roughly 10 inches high and 31 inches deep (front-to-back) as seen from Figure 2. However, the major portion of the wing is much smaller than this. The largest folded geodesic lens, non-gimbaled, which could be fitted into this envelope is about 15 to 25 inches in diameter.

The relationship between beamwidth, aperture size, and frequency was examined and is presented in Figure 3. A cosine shaped aperture distribution raised to the first power produces -23 dB sidelobes [7] while the cosine squared distribution produces -32 dB sidelobes. This range of sidelobe levels brackets those expected from the final antenna.

From Figure 3 it can be seen that the desired  $0.5^\circ$  search beamwidth in azimuth requires an aperture of 50 inches at 35 GHz, 26 inches at 70 GHz and 18 inches at 95 GHz. The aperture required to produce a  $2^\circ$  beam is one fourth the corresponding values for the  $0.5^\circ$  beam. Operation at 95 GHz permits a smaller antenna for a fixed resolution than does operation at lower frequencies. However, the antenna is still large physically due to the narrowness of the beam that must be produced.

If the aperture is sufficiently large, the desired tracking resolution can be obtained from the antenna beam directly. A typical approximation is to use the 3 dB beamwidth as the resolution capability of the beam. From an extrapolation of Figure 3, it can be seen that an aperture length of 370, 190, and 135 inches is needed at 35, 70, and 95 GHz, respectively, in order to achieve a 1.2 mrad ( $0.069^\circ$ ) beamwidth. Geodesic lenses in this size range obviously cannot be packaged in the stub-wings. Hence, a technique other than the brute-force method of increasing the aperture size must be used to achieve the desired tracking accuracy. An alternate approach is to use a lens in each wing as an interferometer pair. This approach is considered next.

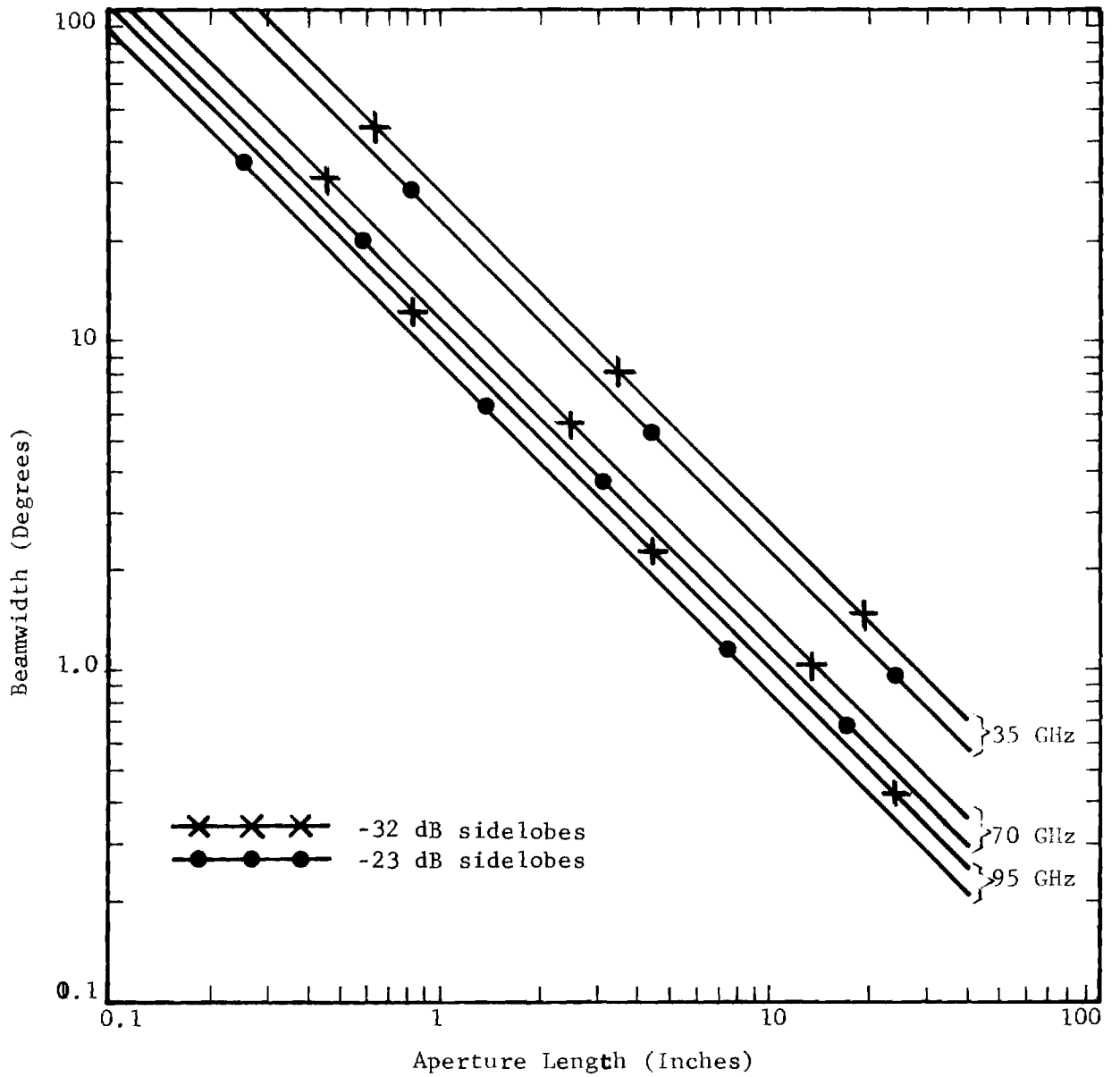


Figure 3. Beamwidth versus aperture length at millimeter frequencies for two different sidelobe levels.

## B. Antenna Patterns Produced by Two Antennas Located in the Stub-Wings

An analysis was made of the interferometer effects produced by two antennas (for example, geodesic lenses) located in the stub-wings of the Cobra helicopter. The objective of the study was to determine how much, if any, azimuth beam sharpening could be obtained using the two antennas together. The antennas were modeled as two line sources each of length  $D$  and displaced by a distance  $L$  as shown in Figure 4. The total pattern will be represented by  $E(\theta)$ , the array factor by  $AF(\theta)$ , and the element pattern by  $E_e(\theta)$ . Thus

$$E(\theta) = E_e(\theta) AF(\theta) \quad (1)$$

Assume that Aperture 1 has a complex amplitude  $A_1$  while Aperture 2 has a complex amplitude  $A_2$ . Then

$$AF(\theta) = A_1 e^{-jk\frac{L}{2} \sin \theta} + A_2 e^{+jk\frac{L}{2} \sin \theta}$$

Assume a symmetric phase difference of  $\phi$  between the two elements, and that they have equal amplitudes, chosen to be 0.5 for convenience. Then

$$|A_1| = |A_2| = \frac{1}{2} \quad ,$$

$$\angle A_1 = -\frac{\phi}{2} \quad , \text{ and}$$

$$\angle A_2 = +\frac{\phi}{2} \quad .$$

Thus

$$AF(\theta) = \frac{1}{2} e^{-j(k\frac{L}{2} \sin \theta + \frac{\phi}{2})} + \frac{1}{2} e^{j(k\frac{L}{2} \sin \theta + \frac{\phi}{2})} \quad ,$$

or

$$AF(\theta) = \cos \Psi \quad . \quad (2)$$

where

$$\Psi = k\frac{L}{2} \sin \theta + \frac{\phi}{2} = \pi \left( \frac{L}{\lambda} \right) \sin \theta + \frac{\phi}{2} \quad . \quad (3)$$

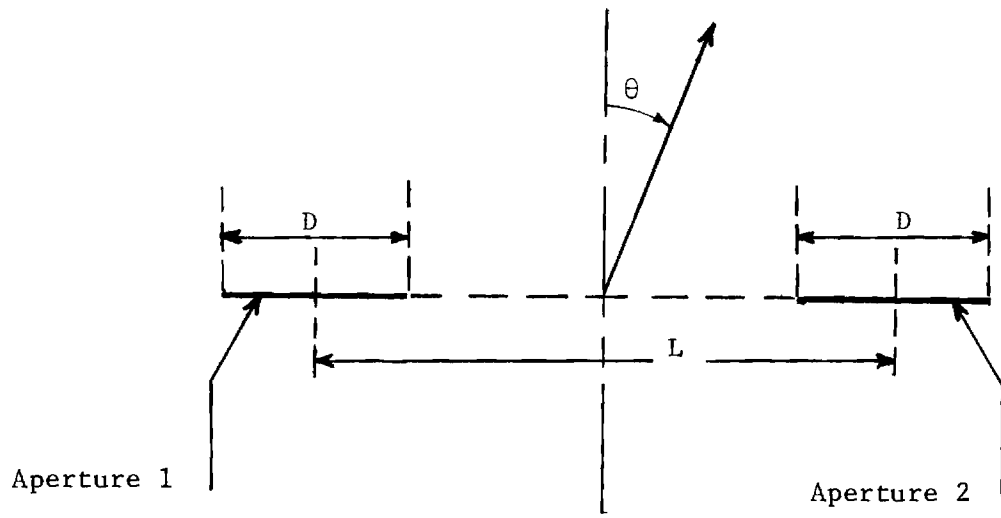


Figure 4. Two displaced, identical antennas.

For ease of computation a simple far field pattern was assumed for the geodesic lens, namely

$$E_e(\theta) = \left[ \frac{\sin\left(\frac{u}{n}\right)}{\left(\frac{u}{n}\right)} \right]^n \quad (4)$$

where  $n = 1, 2, 3, \dots$  and  $u = \pi(D/\lambda) \sin \theta$ . For  $n = 1$  the pattern (4) is produced by a uniformly illuminated line source for which the sidelobe level is -13.2 dB, and the beamwidth is  $50.8^\circ D/\lambda$ . For  $n = 2$  the pattern (4) is produced by a triangular distribution on the line source for which the sidelobe level is -26.4 dB and beamwidth is  $73.4^\circ D/\lambda$ .

Patterns were calculated for the following set of parameters:

Lens diameter	$D = 25''$
Lens spacing	$L = 40'', 60'', 80''$
Wavelength	$\lambda = 0.347''$ (35 GHz), $0.124''$ (95 GHz)
Phase difference	$\varphi = 0^\circ$
Aperture taper	$n = 2$ (triangular)

These six patterns are shown in Figures 5-10. A triangular aperture distribution was chosen since it gave reasonable, i.e. -26.4 dB, sidelobes. Note from the figures that the array factor samples the element pattern as expected. Note also that the first interferometer lobe is very high, and is independent of frequency. The level of the first interferometer lobe is tabulated in Table II.

The lenses must be separated by about 70 to 80 inches since the Cobra is 36 inches wide at the wings and the lenses are 25 inches in diameter. Thus, although the main beam of the pattern has been narrowed by using the two antennas as an interferometer, the amplitude of adjacent interferometer lobes are so close to that of the main beam (only about 1 dB down) that it would be impossible to distinguish which lobe was on the target in a tactical situation.

The level of the interferometer lobes can be reduced by decreasing the taper on the aperture since this narrows the main beam. The sidelobe level

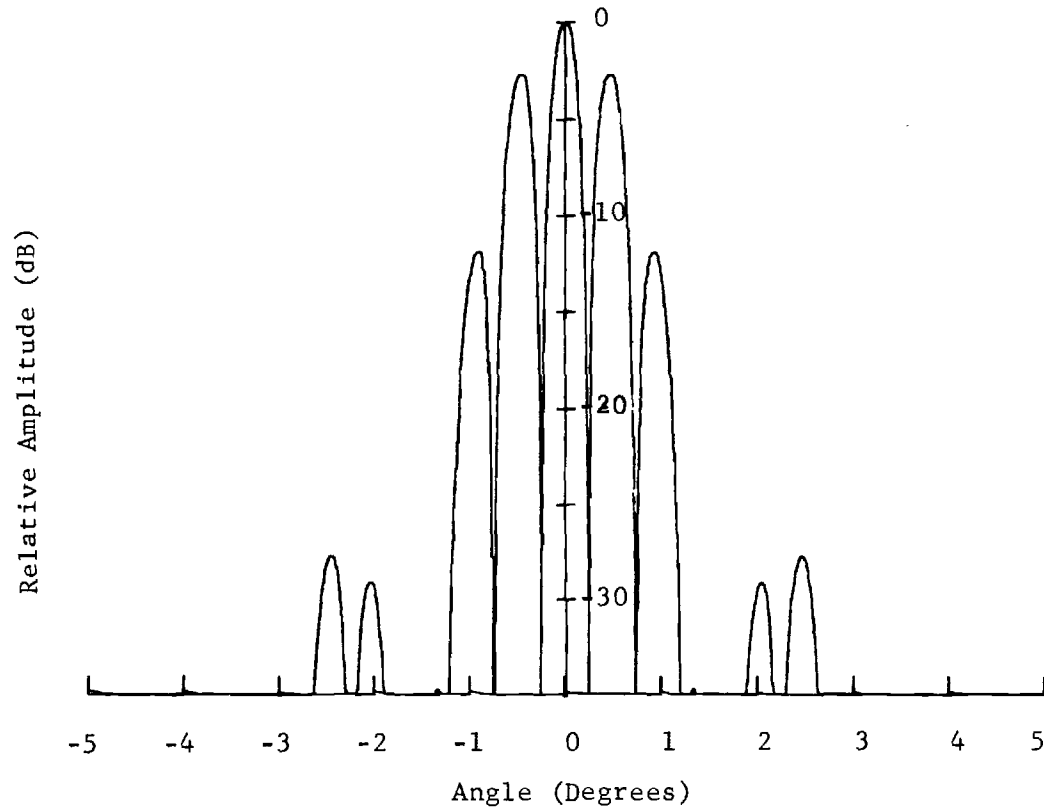


Figure 5. Pattern produced by two line source antennas with  $D = 25$  inches,  $L = 40$  inches,  $n = 2$ , and  $f = 35$  GHz.

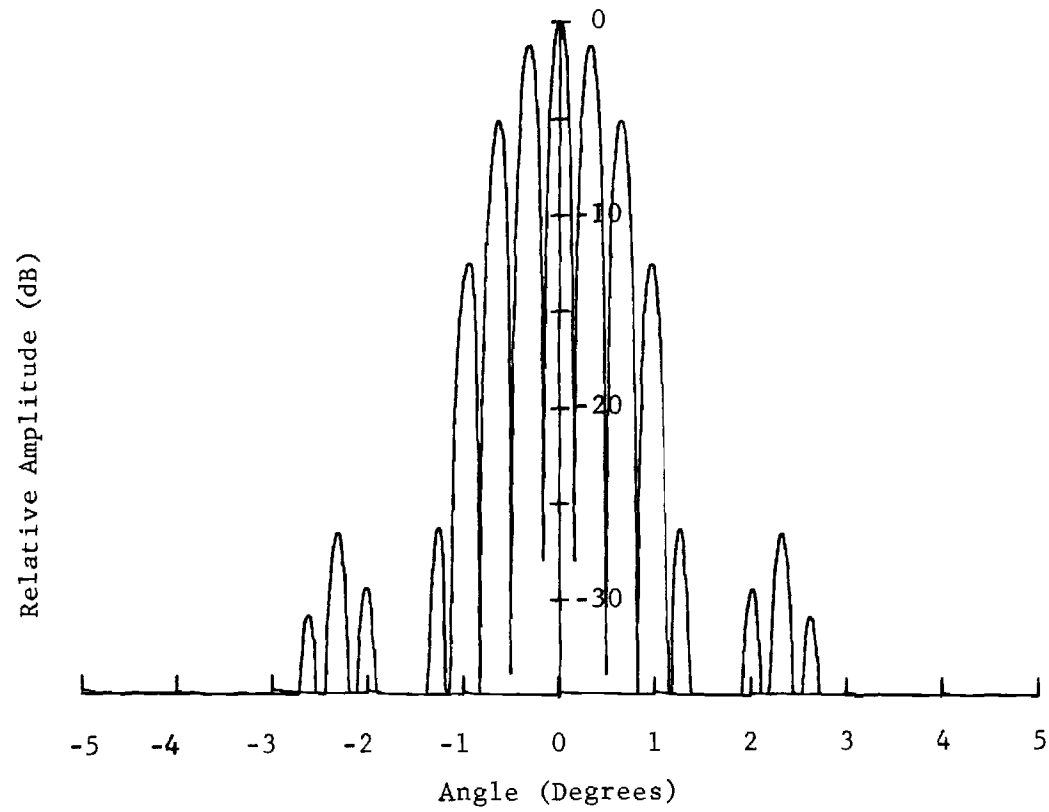


Figure 6. Pattern produced by two line source antennas with  $D = 25$  inches,  $L = 60$  inches,  $n = 2$ , and  $f = 35$  GHz.

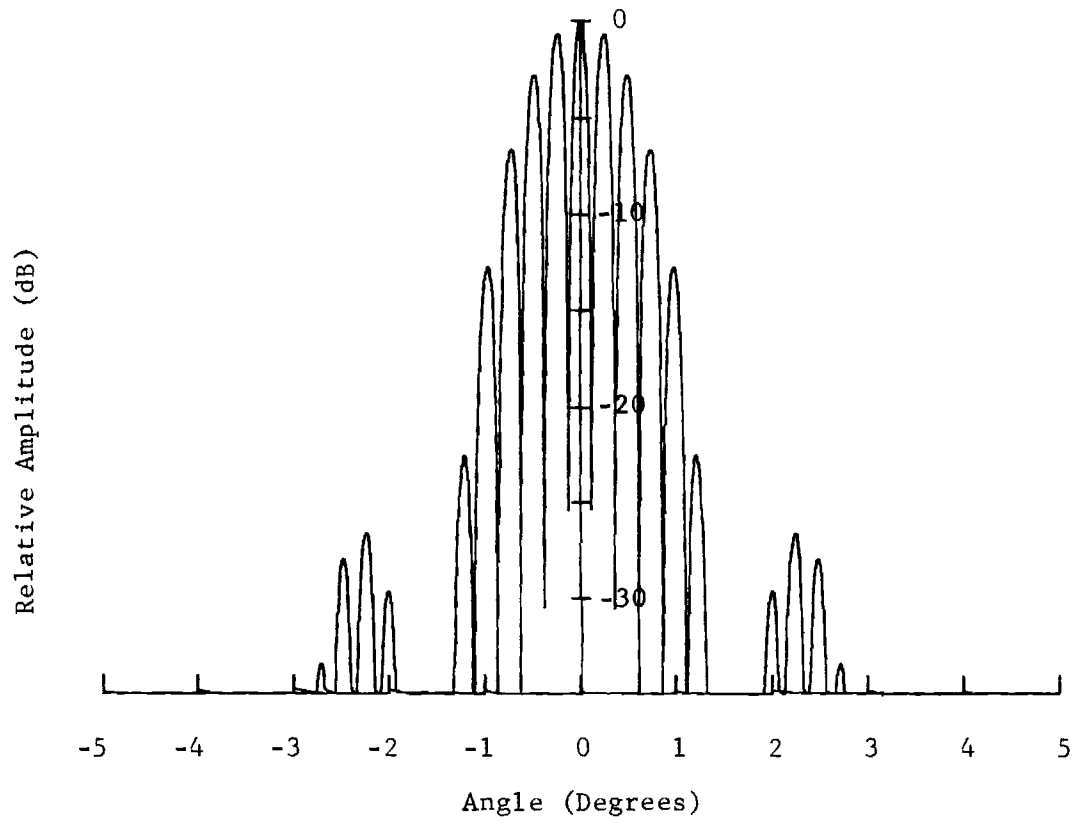


Figure 7. Pattern produced by two line source antennas with  $D = 25$  inches,  $L = 80$  inches,  $n = 2$ , and  $f = 35$  GHz.



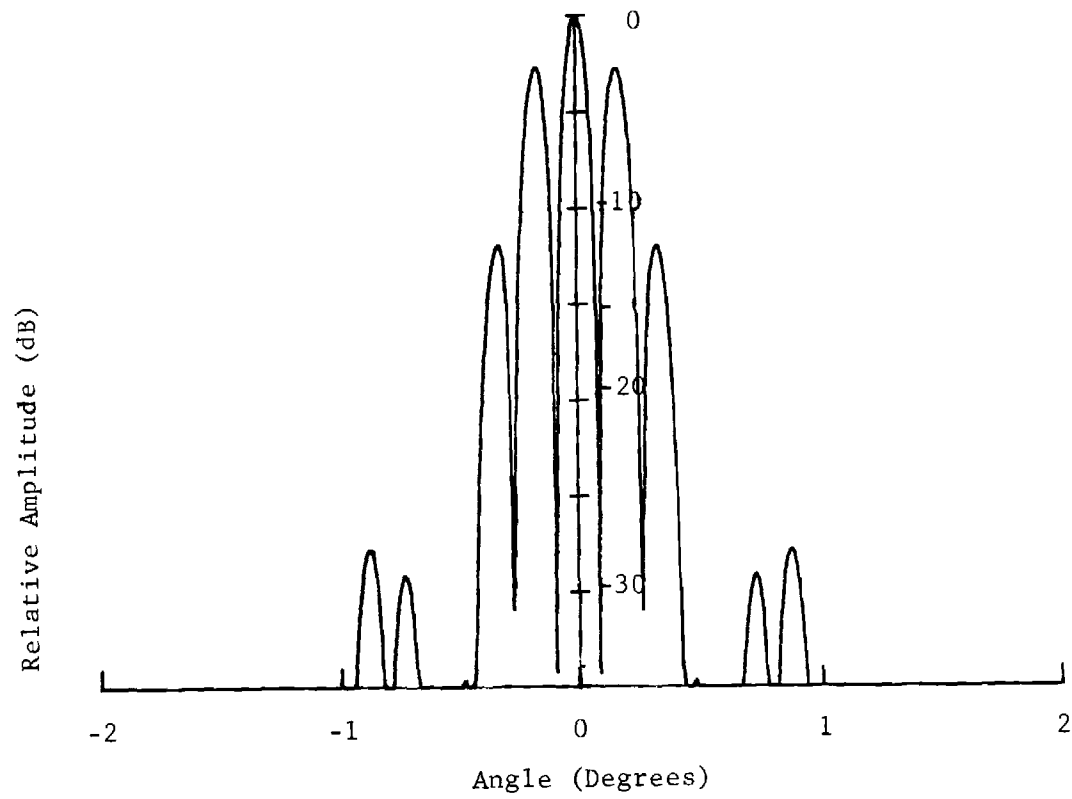


Figure 8. Pattern produced by two line source antennas with  $D = 25$  inches,  $L = 40$  inches,  $n = 2$ , and  $f = 95$  GHz.

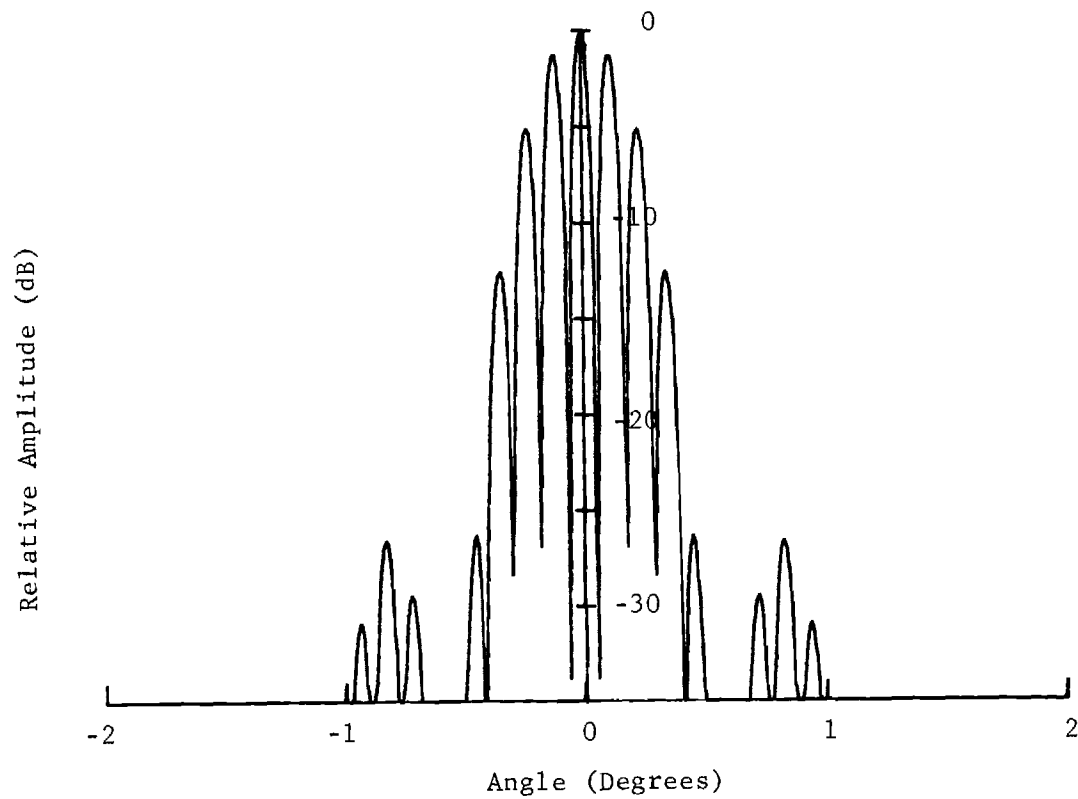


Figure 9. Pattern produced by two line source antennas with  $D = 25$  inches,  $L = 60$  inches,  $n = 2$ , and  $f = 95$  GHz.

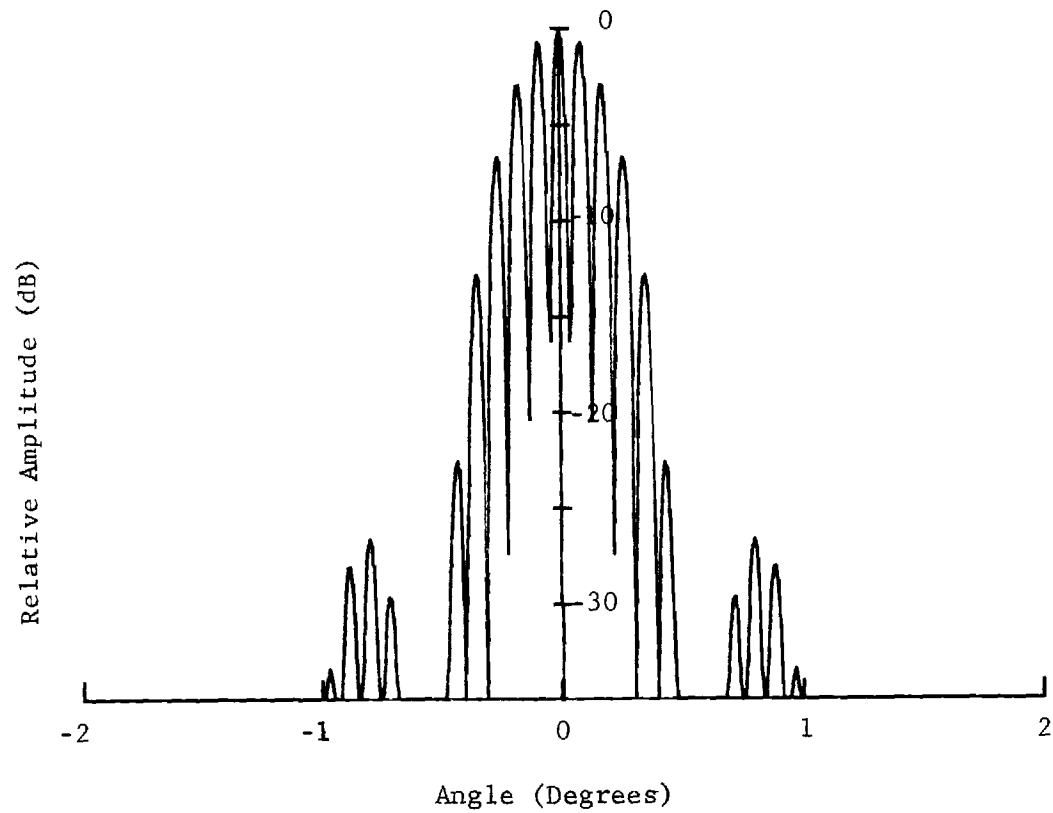


Figure 10. Pattern produced by two line source antennas with  $D = 25$  inches,  $L = 80$  inches,  $n = 2$ , and  $f = 95$  GHz.

Table II

Interferometer Lobe Level Versus Separation

L (inches)	First Interferometer Lobe Level (n=2)
40	-2.7 dB
60	-1.2 dB
80	-0.7 dB

of the element pattern is increased, however, by doing this. Calculations for an 80-inch lens spacing and a uniformly illuminated ( $N=1$ ) aperture showed that the interferometer lobes are only 2 dB below the main beam. Again, the interferometer lobe levels are independent of frequency. Hence, the interferometer lobes are unacceptably high even with a uniformly illuminated aperture.

From the preceding analysis it is concluded that use of a lens in each wing as an interferometer pair will not perform satisfactorily for the leading-edge geometry, since the amplitudes of adjacent interferometer lobes are so close to that of the main beam that it would be impossible to distinguish which lobe was on the target.

### C. Monopulse and Conical Scan

Two-plane monopulse tracking was examined for the leading-edge antenna. One concept was to provide a dual mode feed for each geodesic lens for azimuth-plane monopulse and to stack two lenses one above the other to provide elevation-plane monopulse. Such an antenna is conceptually capable of providing dual-plane monopulse; however, an examination of the phase tracking requirements precludes its use at millimeter frequencies. The phase difference between receiver channels must be maintained to within  $25^\circ$  or better for reasonably

proper performance according to Page [8]. Maintaining such tight phase tracking through the lenses, the ring switches and the connecting waveguide of the stacked lens approach would be difficult at 95 GHz, especially while scanning. In addition, it appears that off-the-shelf receiver components at 95 GHz cannot currently provide the required phase stability. Thus dual plane monopulse using stacked geodesic lenses was ruled out. Monopulse could be incorporated in a separate tracking antenna such as the Cassegrain reflector proposed as the result of this study. However, the increased system complexity will still be present since three receivers are typically required for monopulse.

Conical scanning, on the other hand, can be implemented with off-the-shelf receiver components. In addition, its receiver circuitry is considerably simpler than that in monopulse and in many instances the tracking performance of conical scan is as good as that of monopulse. Hence, conical scan is the recommended tracking technique at the present time. As receiver components improve and if ECM conditions require a change, the tracking antenna could be converted over to monopulse at a later date. A rotating subreflector is recommended for producing the conical scan. Such an approach permits a small motor to be used since the mass of the subreflector will be low, and eliminates the need for a rotary joint at the feed.

### III. RECOMMENDED ANTENNA GEOMETRY

The results of the preceding sections indicate that the optimum antenna configuration for the 95 GHz modified stub-wing installation consists of three antennas. One geodesic lens will be placed in each wing as shown in Figure 11. Each lens provides  $60^\circ$  of search coverage from dead ahead for a total of  $120^\circ$  search coverage for the antenna system. Data from the two antennas will be combined for presentation on a single display. This will allow the operator to designate (sequentially) targets of interest with a single-cursor system. The conical scan tracking antenna will then be automatically positioned on the designated target and commence automatic tracking independent of helicopter motion. Doppler signature data will be extracted from the track signal to aid in target identification. The tracking information will also be used to cue other sensors and/or for weapons delivery.

The plan view shown in Figure 11 depicts two possible geodesic lens locations. The lower installation depicts the lens attached in front of the present stub-wing of the AH-1G. The upper installation depicts a lens built inside of the present wing. The size of the wing was increased for both installations in order to maintain the same lift to drag ratio as exists in the present wing. The size of the wing is roughly the same for either installation. It should be noted that the stub wings of the Cobra are not aerodynamic lifting surfaces but merely weapon store racks.

The lenses will probably be gimballed to compensate for aircraft motion. Figure 12 shows the wing size for  $\pm 15^\circ$  stabilization in both pitch and roll. The height of the wing appears thicker in Figure 12 than it actually is since it is a front view with the aircraft horizontal and so appears larger in this frontal projection.

Some of the pertinent characteristics of the recommended antenna systems are summarized in Table III. Each 18-inch diameter geodesic lens is connected by parallel plates to a line source feed horn. This horn illuminates a 33-inch long cylindrical reflector that is 4.5 inches high. About 3 inches of the cylinder height is parabolic in shape to produce the non-scan plane main beam while the remaining 1.5 inches is used for beam shaping for short range ground coverage.

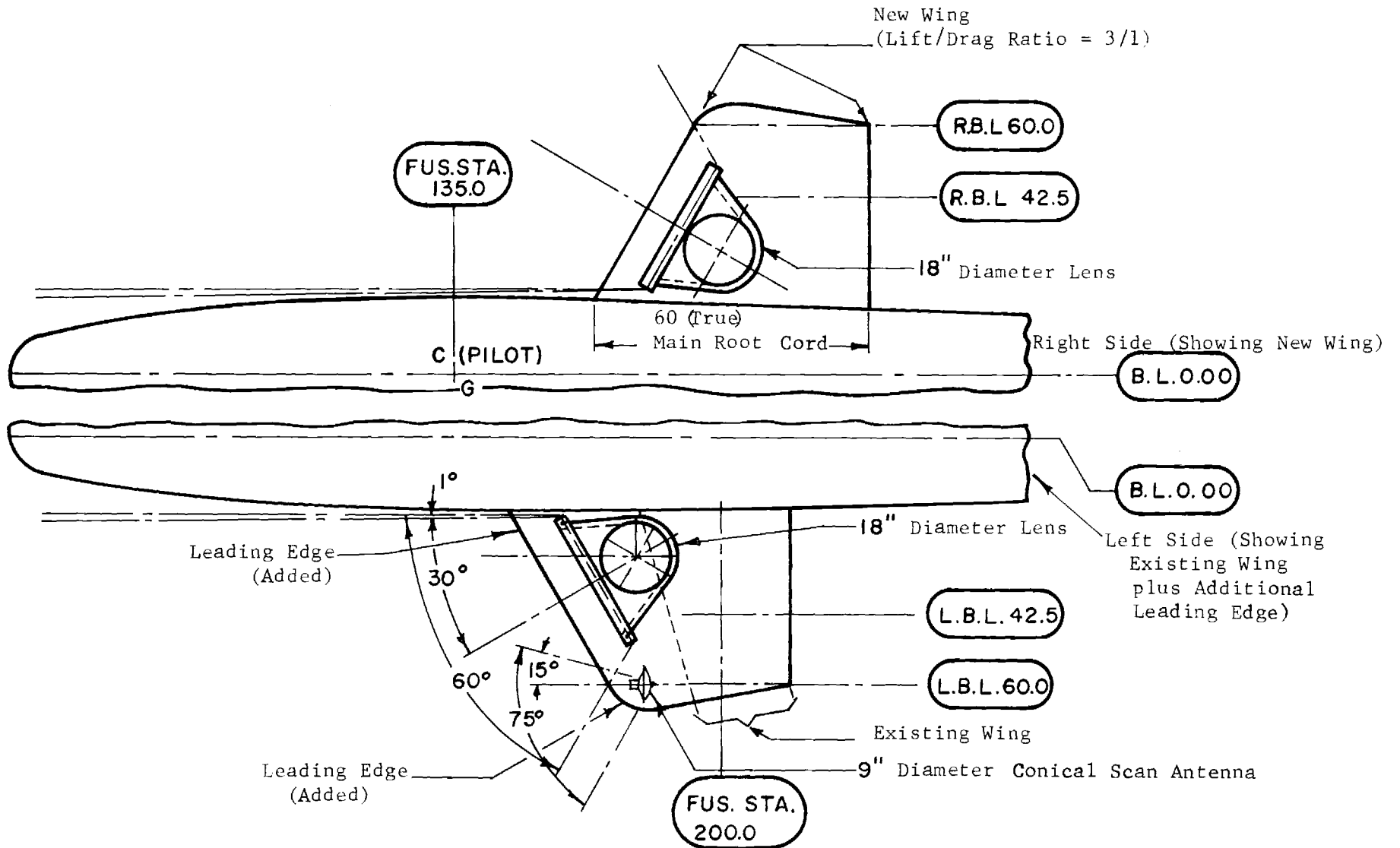


Figure 11. Plan view of stub-wing antenna installation.

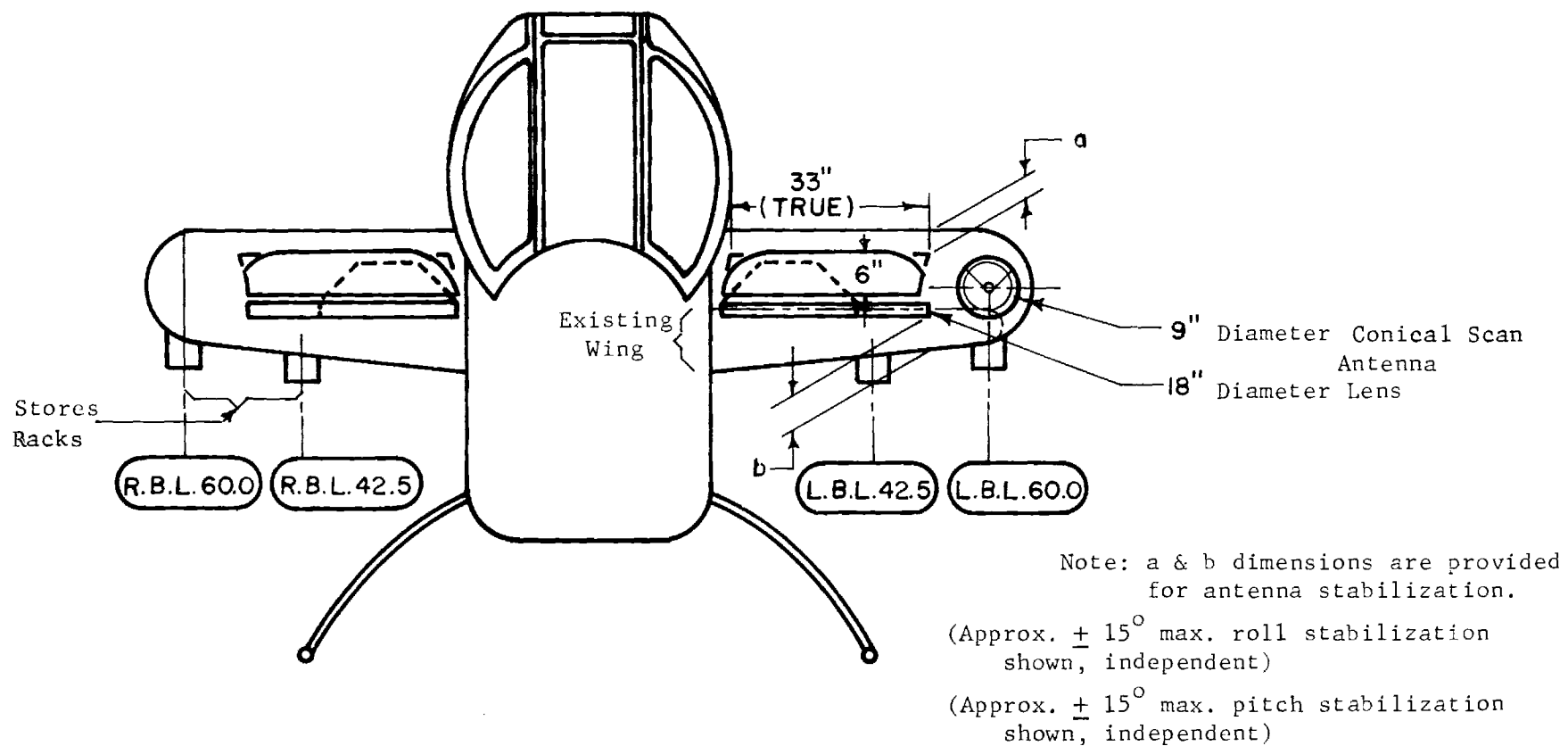


Figure 12. Front view looking aft of stub-wing antenna installation.



Table III

Summary of Characteristics of Recommended  
95 GHz Leading Edge Antenna System For the AH-1G Cobra Helicopter

Parameter	Value
<u>Geodesic Lenses (2 each)</u>	
Frequency	95 GHz $\pm$ 2 GHz
Beamwidth (half power)	0.5 <sup>o</sup> Az
	2.0 <sup>o</sup> El plus $\text{csc}^2$ shaping
Scan Sector	$\pm$ 30 <sup>o</sup>
Sidelobe level	-23 dB wrt main beam
Gain	42 dB
Scan rate	10 scans per second
Power handling	8 kW
<u>Conical Scanning Cassegrain Antenna (1 each)</u>	
Frequency	95 GHz $\pm$ 2 GHz
Beamwidth	1.0 <sup>o</sup> pencil beam
Gain	42 dB
Crossover	-1.5 dB $\pm$ 0.5 dB wrt beam peak
Scan rate	26 rps
Power handling	8 kW

#### IV. CONCLUSIONS

The findings of the leading edge antenna study for the AH-1G helicopter performed by Georgia Tech under Contract DAAA25-73-C-0648 were reported in the preceding sections. A conceptual design has been obtained for a practical antenna system which can be located in a modified stub-wing of the attack helicopter. The antenna system consists of two 18-inch diameter geodesic lenses and one 9-inch diameter Cassegrain reflector. One lens is placed in each stub wing and each lens scans a  $60^{\circ}$  sector from dead ahead. Thus,  $120^{\circ}$  of search coverage is obtained. Target tracking and identification are achieved through the conically scanned Cassegrain antenna located in one of the wings. Since the receiver, transmitter, as well as all other system components are available at 95 GHz, it appears entirely feasible to proceed with the design of a 95 GHz radar for the attack helicopter.

It is recommended that the development of an advanced 95 GHz radar system be undertaken on the basis of the antenna design concepts presented in the preceding sections. It is further recommended that this development be accomplished in four major phases:

- I. Antenna Development Program
- II. Integrated System Configuration Study and Component Design Validation Program
- III. Hardware Feasibility Demonstration
- IV. Brassboard/Prototype Development

An outline of these four recommended phases is given below. It is anticipated that an orderly development program, such as one comprising the above would result in a quality radar sensor at minimum risk. The insertion of a low cost, near term, feasibility demonstration radar (Phase III) into the program will provide the Army with a relatively efficient checkpoint to use for an in-depth assessment of the potential of such a new sensor. In addition, this phase will allow for an optimum opportunity for the input of management and technical direction to the development program. A key output of Phase IV will be the detailed technical and management data needed to guide the procurement and production of this system.

Since the antenna subsystem of the radar is a very critical item in determining the radar performance, it is recommended that the antenna be built and tested early in the program (i.e. Phase I). The recommended four phase development program is as follows:

Phase I. Antenna Development Program

Objective: Build and test the two geodesic lenses and one conical scanning antenna specified by Georgia Tech under Contract DAAA25-73-C-0648.

Tasks to be Accomplished: Perform a detailed design, build, test, and deliver the above three antennas. This effort will validate the predictions of performance of the antennas which are very critical items in establishing radar performance.

Phase II. Integrated System Configuration Study

Objective: Define, in detail, the configuration of a 95 GHz radar sensor for use on a scout and/or attack helicopter which is based on the geodesic lens/conscan antenna concept developed by Georgia Tech on Contract DAAA25-73-C-0648.

Tasks to be Accomplished: Examination of the operational requirements, system performance characteristics, detailed subsystem design, clutter reduction techniques, and other signal processing requirements. The results of the detailed examinations above will be merged into a comprehensive system design plan, including specific engineering specifications and design data.

Phase III. Hardware Feasibility Demonstration

Objective: Design, build, and field evaluate a breadboard of the radar system specified in Phase II.

Tasks to be Accomplished: Design and build a breadboard radar operating at 95 GHz which comprises a complete antenna, transmitter, and receiver systems. It will include limited signal processing and simple displays; however, it will be designed to allow the acquisition of calibrated engineering and performance data. A series of ground and flight tests will be undertaken. The resulting data will be analyzed and recommendations (including engineering specifications) will be made for the development of a complete prototype (brassboard) system. The Phase I antennas will be used in this phase.

Phase IV. Brassboard/Prototype Development

Objective: Design, build, and flight test the brassboard radar system recommended in Phase III. The goal is to provide all necessary technical data for use in the specification and procurement of a service approved radar sensor.

Tasks to be Accomplished: Design and build a complete radar including full signal processing and sophisticated displays. Integrate into aircraft, including mating to other sensors, etc. Develop complete test program plan. Support the Army in the performance of comprehensive flight test program. Prepare complete data (software) package. Provide the Army with detailed test analysis, and performance results. Provide the Army with assistance in the preparation of procurement specifications, etc.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) An antenna concept has been developed and a conceptual design performed for a 95 GHz antenna system to be located in a modified stub-wing of an AH-1G Cobra helicopter. The antenna system consists of three antennas: two 18-inch diameter geodesic lenses and one 9-inch diameter Cassegrain reflector. One lens is placed in each stub-wing and each lens scans a 0.5° beam (2° beam in the non-scan plane) over a 60° sector from dead ahead. These lenses provide search coverage over a 120° sector. Target tracking and identification is achieved		

by a conically scanned Cassegrain antenna located in one of the wings. Using off-the-shelf receiver and transmitter components, the proposed system should provide detection and tracking out to 12 to 18 km. The existing stub-wing must be approximately doubled in size in order to accommodate the antennas. This wing modification will not significantly alter the aircraft performance since the stub-wing is not an aerodynamic lifting surface.