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SOME CHARACTERISTICS OF A PROPOSED CONICAL-SCAN RADAR HOMING EQUIPMENT FOR THE SKYLARK MISSILE

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SOME CHARACTERISTICS OF A PROPOSED CONICAL-SCAN RADAR HOMING EQUIPMENT FOR THE SKYLARK MISSILE

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Problem No. R05-29

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ABSTRACT

A discussion is given of a conical-scan radar homing equipment for application to the Skylark Missile. Theoretical range calculations are presented for a passive homing system showing that with an SNB target at 30 miles range to a ground control radar (type SP-1M) it is possible to track the target with the missile-borne radar homing system at a conservative 6-mile range.

PROBLEM STATUS

This is an interim report on this problem; work is continuing.

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SOME CHARACTERISTICS OF A PROPOSED CONICAL-SCAN RADAR HOMING EQUIPMENT FOR THE SKYLARK MISSILE

INTRODUCTION

The preliminary planning for the Skylark program has been described in an NRL letter to the Bureau of Aeronautics.* In accordance with this program, Appendix II is presented as a study of both the amplitude and the phase simultaneous lobe comparison systems as suitable radar homing equipments. As a result of this study (Appendix II) and in view of the time objective set forth, it was recommended that scanning-type radar homing equipment utilizing standard r-f and receiver components be utilized.

OBJECTIVES

The discussion in this report is confined to a proposed alternate passive seeker for the Skylark (KAQ-1 missile). The objectives of the development program for this system are the attainment of a passive homing test flight by 1 June 1948, with a possible increase in homing range over that predicted for the present AN/APN-23 active radar target seeker.

CONICAL SCANNING SYSTEM

This report presents a brief description of a proposed alternate target seeker. The investigations were preliminary in character and threefold in nature i.e.; (a) maximum diameter of antenna dish and estimated maximum space required for mechanism to rotate the dish and control the antenna position, (b) circuit details and weight estimates and, (c) theoretical calculations to determine the maximum possible tracking range at various target-to-ground radar ranges.

ANTENNA DESIGN

The preliminary investigations for the design of the antenna indicate that the antenna dish may be a maximum of approximately 9" in diameter (this corresponds to a beamwidth of 33° with a gain of 27). The antenna design investigation indicated that it was possible to spin the dish at 10,000 rpm with the dish offset at such an angle as to provide a lobe crossover point at 3 db down (one-way). Considerations of the tactical problem indicate that the antenna must be capable of a minimum of 30° lead angle in any direction from the

* NRL Conf ltr. C-1100-414A/47(ten), to BuAer, 6 May 1947, "Record of Consultative Services; Report on Conference of 30 April 1947."

forward heading of the missile. It is estimated that the entire antenna and scanning assembly including gimbals and servo motors can be designed to weigh less than 30 pounds total.

CIRCUIT DETAILS AND WEIGHT ESTIMATES

The physical configuration of this alternate target seeker will be such as to make it interchangeable (insofar as installation) with the active seeker AN/APN-23, which is proposed for the Lark missile.

Below are listed estimated weights and tube complements for the various circuits of the receiver. The estimates are based upon the use of miniature type tubes and are subject to weight reductions if the use of sub-miniature tubes is found practicable. The block diagram of a typical receiver is shown in Figure 1.

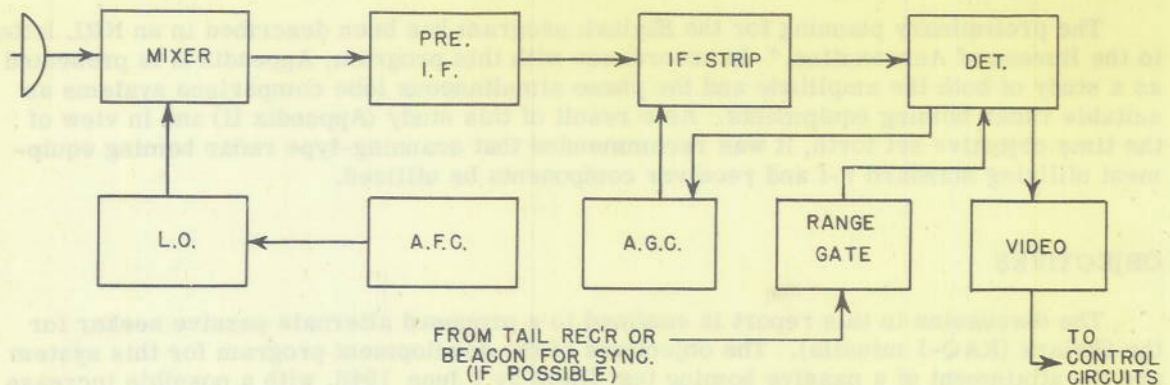


Figure 1

| Component | Estimated Weight | Tubes |
|------------------------------------------|------------------|-----------------|
| Local Oscillator | 3 lb | 1 |
| Preamplifier | 2 lb | 2 |
| I-F amplifier | 3 lb | 6 |
| Video Detector | 2 lb | 3 |
| Automatic Frequency Control | 3 lb | 4 |
| Automatic Gain Control | 2 lb | 2 to 3 |
| Gate Circuit to remove transmitter pulse | <u>3 lb</u> | _____ |
| TOTAL | 18 lb | 19 tubes |

In the above letter to BuAer a number of criteria have been proposed for consideration in this survey. Although these criteria have not been considered completely, the following comments are appropriate at this time.

- (a) **Maximum Range.** The maximum homing range of this passive target seeker is based on the use of the existing SP-1M radar for target illumination. Theoretical range calculations show that with an SNB target to SP-1M radar range of 30 miles, it is possible to track the target with the missile-borne radar homing system at a conservative range of 6 miles. (See range curves in Appendix I.)

- (b) Availability of system equipment. The receiver to be used is one of standard design with an I-F bandwidth of 1.5 mc/sec. A number of each of such I-F strips are available using the 6AK5 type tube. The local oscillator, mixer, gate circuit and video must be developed but can be patterned after existing standard circuits.
- (c) Bandwidth requirements. The servo bandwidth requirements of the overall guidance loop will be reported separately by another group. The susceptibility to jamming and extraneous noise is a problem common with that of all S-band radars during this past war. The best available designs will be incorporated into this system.
- (d) Target Discrimination. This system shall be designed so that it may discriminate among targets separated 200 yards nominally in radar range. This figure is based on the characteristics of the SP-1M radar. The angle discrimination is a function of beamwidth which is rather wide as compared to tracking radars. It appears that the system will not be optimum design with reference to angle discrimination.

THEORETICAL CALCULATIONS OF RANGE

In order to determine the approximate capabilities of the system, several calculations were performed to determine the power received at the target and at the missile as reflected from the target. These calculations and the plot of the range curves are presented as Appendix I. The range curves indicate that with a target-to-ground radar range of 30 miles, it will be possible to begin tracking with the homing system at about a 6-mile range. A number of conservative assumptions were made when calculating this figure. Under conditions of a more optimistic assumption it appears possible to begin tracking the target at a 12-mile missile-to-target range.

ACKNOWLEDGMENT

The authors are grateful to Mr. J. W. Titus for his investigations of the mechanical characteristics of the Antenna assembly. The helpful comments and criticisms of Mr. A. S. Locke, Mr. P. Waterman and Mr. H. L. Flowers are deeply appreciated.

* * *

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APPENDIX I

Passive Homing System Calculations

Note: Numerical values of the various parameters involved in the equations used for the following calculations were obtained from the characteristics listed in Appendix II.

THE GENERAL EQUATION

Figure 2 illustrates the relationship and meaning of many of the terms used.

POWER REFLECTED FROM A TARGET TO MISSILE

$$P_m = \left(\frac{P_p G_o A_t}{4\pi R^2} \right) \left(\frac{A_r}{4\pi R_m^2} \right) \quad (1)$$

Power Reflected = (Pwr Rec'd by Target) (Fraction of Pwr Rec'd at R_m)

Where:

- P_m = power reflected to missile from target at a range R_m
- P_p = peak-power of radar transmitter
- G_o = power-gain of radar's ant.
- A_t = effective area of the target
- A_r = effective area of rec'g ant. at R_m
- R = range from radar to target
- R_m = range from target to missile ant.

$$\text{Power Rec'd by 3-sq-meter Target} = \left(\frac{P_p G_o A_t}{4\pi R^2} \right) \quad (2)$$

$$G_o = 0.6 \left(\frac{\pi D}{\lambda} \right)^2$$

$$\begin{cases} D = 96'' = 244 \text{ cm} \\ \lambda = 10.7 \text{ cm} \end{cases}$$

$$G_o = 0.6 \left[\frac{(3.14)(244)}{10.7} \right]^2$$
$$= 3.06 \times 10^3$$

$$A_t = 3 \text{ sq m} = 3.6 \text{ sq yds}$$

$$P_p = 8.00 \times 10^5$$

$$\left(\frac{P_p G_o A_t}{4\pi} \right) \frac{1}{R^2} = \left[\frac{(8 \times 10^5)(3.06 \times 10^3)(3.6)}{12.56} \right] \frac{1}{R^2}$$
$$= \frac{7.02 \times 10^8}{R^2} \quad (3)$$

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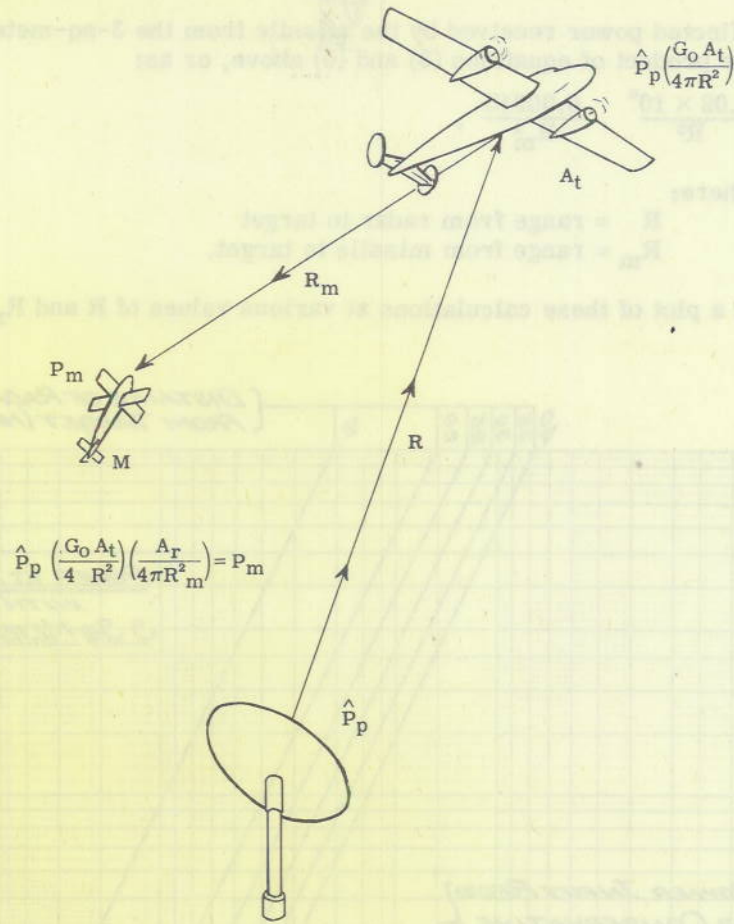


Fig. 2 - Power Distribution for a Passive Homing System

FRACTION OF TARGET-REFLECTED POWER RECEIVED BY THE MISSILE

$$\text{Fraction} = \left(\frac{A_r}{4\pi} \right) \frac{1}{R_m^2} \tag{4}$$

$$A_r = 0.7 \left(\frac{\pi D}{4} \right)^2$$

$$\left\{ \begin{array}{l} D = 9'' = 0.25 \text{ yds} \\ A_r = 0.7 \left[\frac{(3.14)(0.25)}{4} \right]^2 \end{array} \right.$$

$$= 0.027 \text{ sq yds}$$

$$\begin{aligned} \left(\frac{A_r}{4\pi} \right) \frac{1}{R_m^2} &= \left(\frac{0.027}{12.56} \right) \frac{1}{R_m^2} \\ &= \frac{0.00215}{R_m^2} \end{aligned} \tag{5}$$

Finally, reflected power received by the missile from the 3-sq-meter target may be calculated as the product of equations (3) and (5) above, or as:

$$\frac{7.02 \times 10^8}{R^2} \cdot \frac{0.00215}{R_m^2}$$

where:

- R = range from radar to target
- R_m = range from missile to target.

Figure 3 is a plot of these calculations at various values of R and R_m.

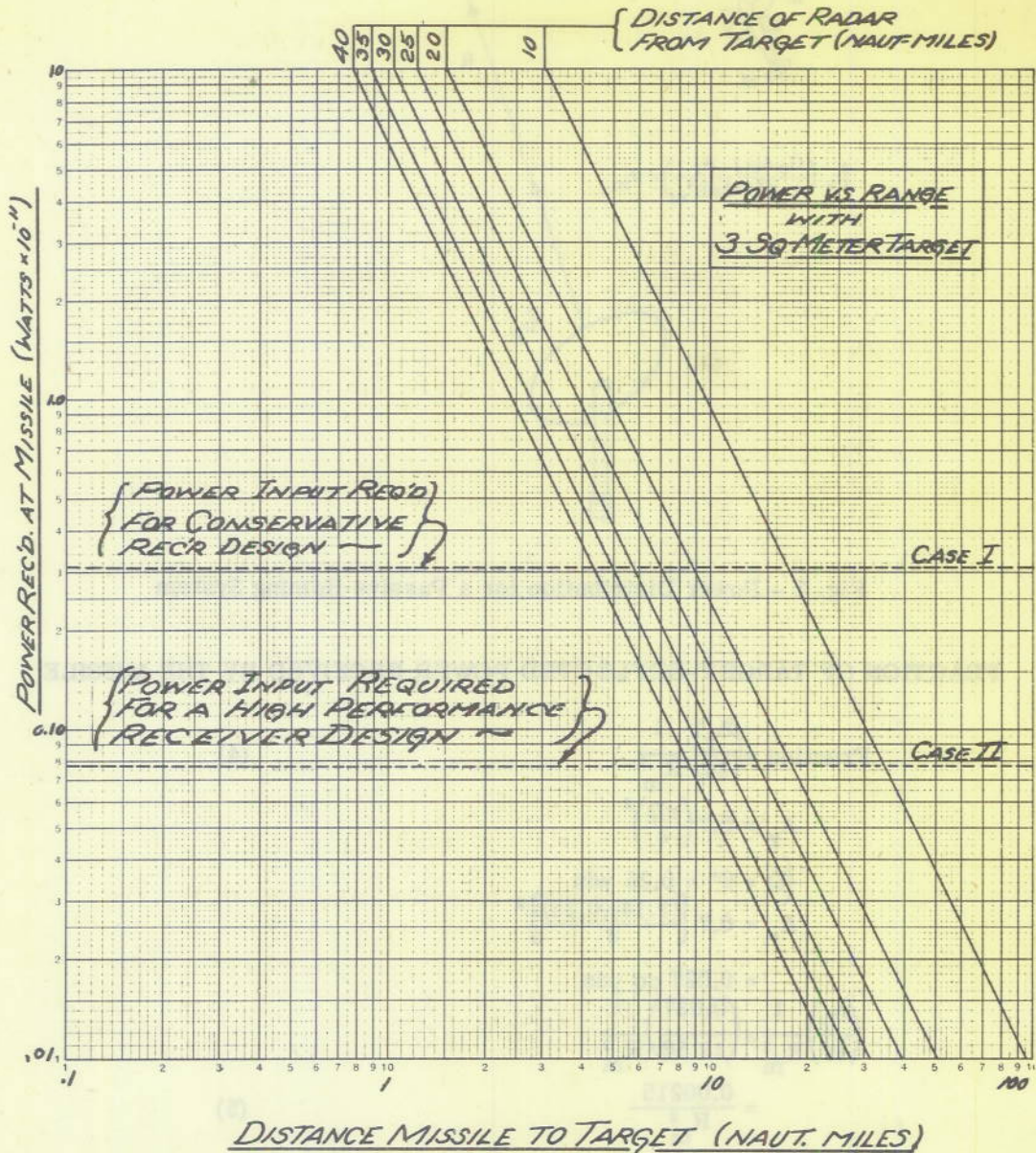


Fig. 3 - Passive Homing System

MAXIMUM RADAR TRACKING RANGE FOR A 3-SQ-METER TARGET

$$r_{\max} = \sqrt[4]{\frac{P_t G_r G_t A_t (\lambda)^2 X\%}{(4\pi)^3 P_n}} \quad (6)$$

where: $P_t = 8 \times 10^5$ watts
 $A_t = 3$ sq m
 $X\% = 80\%$
 $G_r = G_t = 3.06 \times 10^3$
 $\lambda = 10.7$ cm
 $P_n = 4.95 \times 10^{-13}$

$$r_{\max} = \sqrt[4]{\frac{(8 \times 10^5)(9.36 \times 10^6)(3)(1 \times 10^{-2})(0.8)}{(4\pi)^3 4.95 \times 10^{-13}}}$$

= 11.60×10^4 meters
 = 126,200 yds
 = 63.1 naut. miles

Power Rec'd by 10-sq-meter Target = $\left(\frac{P_p G_o A_t}{4\pi R^2}\right)$ (7)

where: $A_t = 10$ sq m = 11.45 sq yds

$$\left(\frac{P_p G_o A_t}{4\pi R^2}\right) = \left[\frac{(8 \times 10^5)(3.06 \times 10^3)(11.45)}{12.56}\right] \frac{1}{R^2}$$

$$= \frac{22.3 \times 10^8}{R^2} \quad (8)$$

Finally, reflected power received by the missile from the 10-sq-meter target may be calculated as the product of equations (8) and (5) above, or as:

$$\frac{22.3 \times 10^8}{R^2} \cdot \frac{0.00215}{R_m^2}$$

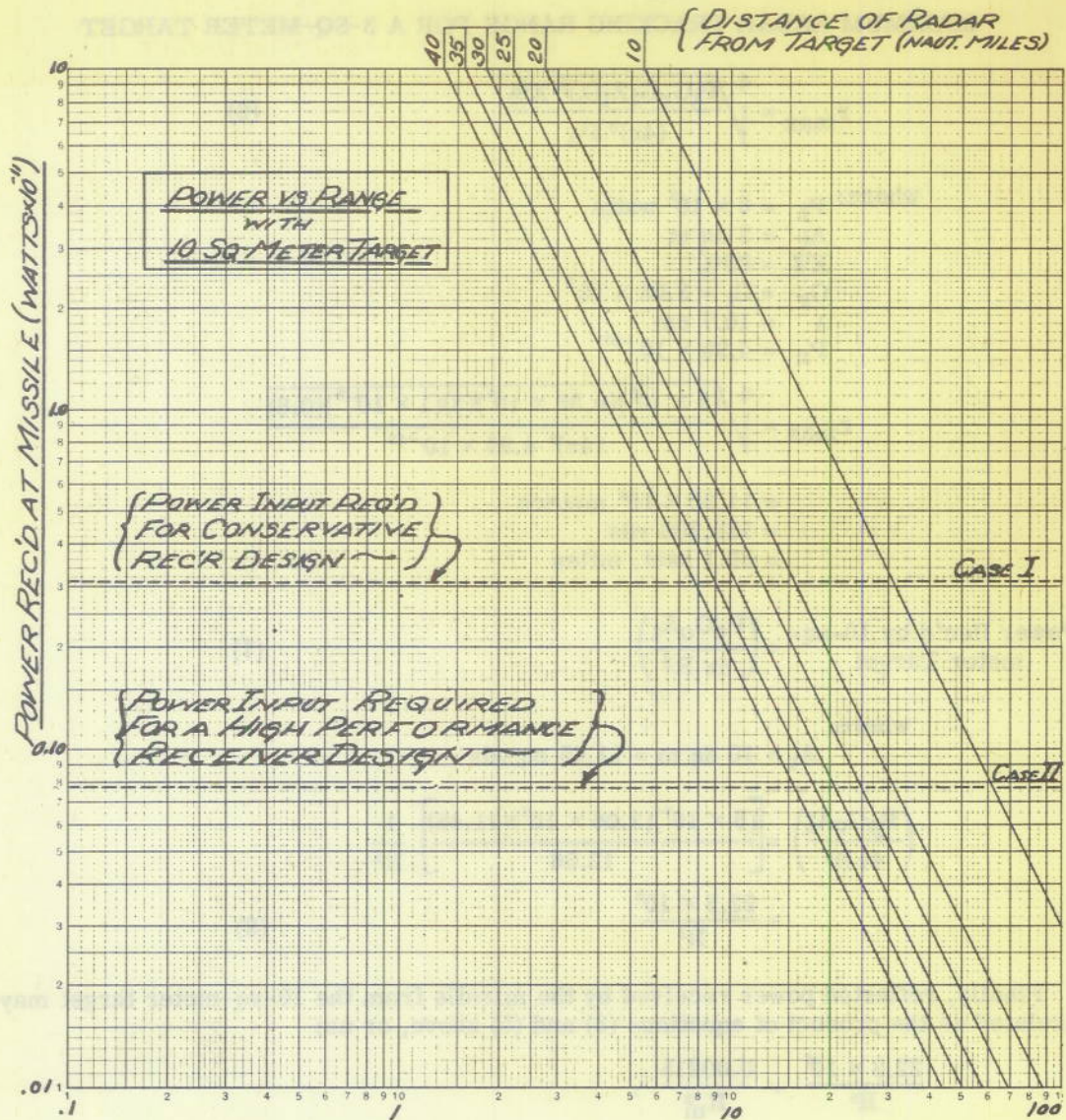
where:
 R = range from radar to target
 R_m = range from missile to target.

Figure 4 is a plot of these calculations at various values of R and R_m .

MAXIMUM RADAR TRACKING RANGE FOR A 10-SQ-METER TARGET

$$r_{\max} = \sqrt[4]{\frac{P_t G_r G_t A_t (\lambda)^2 X\%}{(4\pi)^3 P_n}}$$

where:
 $P_t = 8 \times 10^5$ watts
 $A_t = 10$ sq m
 $X\% = 80\%$
 $G_r = G_t = 3.06 \times 10^3$
 $\lambda = 10.7$ cm
 $P_n = 4.95 \times 10^{-13}$



DISTANCE MISSILE TO TARGET (NAUT. MILES)

Fig. 4 - Passive Homing System

$$r_{\max} = \sqrt[4]{\frac{(8 \times 10^5)(9.36 \times 10^6)(10)(1 \times 10^{-2})(0.8)}{(4\pi)^3 4.95 \times 10^{-13}}}$$

$$= 15.8 \times 10^4 \text{ meters}$$

$$= 173,000 \text{ yds}$$

$$= 86.5 \text{ naut. miles}$$

CALCULATION OF FACTORS USED IN THE
 "MAXIMUM RADAR RANGE EQUATION" FOR SP-IM RADAR

$$G_r = G_t = 0.6 \left(\frac{\pi D}{\lambda} \right)^2$$

$$\begin{cases} D = 96'' = 244 \text{ cm} \\ \lambda = 10.7 \text{ cm} \end{cases}$$

$$\begin{aligned} G_t &= 0.6 \left[\frac{(3.14)(244)}{10.7} \right]^2 \\ &= 3.06 \times 10^3 \end{aligned}$$

$$\begin{cases} P_n = \overline{NF} K T \Delta f \\ \overline{NF} = 20 \text{ db} = 100 \\ K = 1.37 \times 10^{-23} \\ \Delta f = 1.2/\delta = 1.2 \times 10^6 \\ \delta = 1 \times 10^{-6} \text{ pulse width} \\ T = 300 \\ P_n = (100)(1.37 \times 10^{-23})(300)(1.2 \times 10^6) \\ = 4.95 \times 10^{-13} \end{cases}$$

CASE I

MISSILE RECEIVER MINIMUM POWER REQUIRED—CONSERVATIVE P_n

$$(1) \quad \overline{NF} = \frac{P_n}{K T \Delta f} \quad \text{or} \quad P_n = \overline{NF} (K T \Delta f)$$

\overline{NF} = Noise Figure of the receiver
 $K T \Delta f$ = Noise Pwr at Input

Assumptions:

- 18 db typical receiver \overline{NF}
- 6 db tracking factor
- 3 db lobe cross-over factor
- 27 db total $\overline{NF} = 502$ power ratio.

$$\begin{aligned} K &= 1.37 \times 10^{-23} \\ T &= 300 \\ \Delta f &= 1.5/\delta \\ \delta &= 1 \times 10^{-6} \text{ sec. pulse} \end{aligned}$$

From (1)

$$\begin{aligned} P_n &= \overline{NF} (K T \Delta f) \\ &= (502)(1.37 \times 10^{-23})(300)(1.5/1 \times 10^{-6}) \\ &= 30.8 \times 10^{-13} \text{ watts} \\ &= -115 \text{ dbm} \end{aligned}$$

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CASE II

MISSILE RECEIVER MINIMUM POWER REQUIRED—OPTIMISTIC

15 db typical receiver \overline{NF}
 3 db tracking factor
3 db lobe cross-over factor

21 db total $\overline{NF} = 126$ power ratio.

$$\begin{aligned} P_n &= \overline{NF} (K T \Delta f) \\ &= (126)(1.37 \times 10^{-23})(300)(1.5/1 \times 10^{-6}) \\ &= 7.75 \times 10^{-13} \text{ watts} \\ &= -109 \text{ db m} \end{aligned}$$

MISSILE ANTENNA

$$\text{Beam Angle} \cong \frac{70\lambda}{D}$$

$$\begin{cases} \lambda = 10.7 \text{ cm} \\ D = 9'' = 22.8 \text{ cm} \end{cases}$$

$$\begin{aligned} \text{B. A.} &= \frac{(70)(10.7)}{22.8} \\ &= 32.8^\circ \end{aligned}$$

$$\begin{aligned} \text{Gain of Ant. } G_r &= 0.6 \left(\frac{\pi D}{\lambda} \right)^2 \\ &= 0.6 \left[\frac{(3.14)(22.8)}{10.7} \right]^2 \\ &= 27 \end{aligned}$$

ANALYSIS OF FIGURES 3 AND 4

A brief justification for the upper and lower power limits for the receiver, shown as horizontal dotted-lines, follows from the calculations shown on pages 9 and 10. The difference is due to the various values of \overline{NF} and Tracking-Factor used in each case.

| | | | | | |
|---------------|-------------|--------------------------|----------------|-------------|--------------------------|
| <u>CASE I</u> | 18 db | receiver \overline{NF} | <u>CASE II</u> | 15 db | receiver \overline{NF} |
| | 6 db | Tracking-Factor | | 3 db | Tracking-Factor |
| | <u>3 db</u> | lobe cross-over | | <u>3 db</u> | lobe cross-over |
| | 27 db | Total | | 21 db | Total |

Therefore, it is reasonable to believe that the completed receiver would lie between these limits.

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APPENDIX II

Study of the Limitations of Radar Homing Equipment for
Possible Application to the Skylark Program

ABSTRACT OF APPENDIX II

This appendix describes a survey conducted to evaluate the application of either the amplitude (TAB) or the phase (Meteor) simultaneous lobe comparison systems as suitable radar homing equipments for the Skylark missile. Because of the requirements for producing a completed system within approximately eight months it was concluded that neither amplitude nor phase simultaneous lobe comparison would be suitable. It was therefore recommended that a scanning type homing radar equipment be adapted for the Skylark.

INTRODUCTION

During the Skylark conference of 30 April 1947, it was decided that both Fairchild and NRL would initiate a study of the limitations of various radar homing equipments having possible applications to the Skylark missile. The study at NRL was to be devoted to a comparison of the TAB and Meteor simultaneous lobe comparison systems as passive radar homing devices operating at S-band frequency. The Fairchild study was to be devoted to scanning-type radar homing systems. It was agreed that on September 18, 1947 the study of the various radar homing systems would be evaluated and a selection would be made of one system for development for Skylark.

The survey in this appendix examines possible methods of obtaining radar information for "homing" on the basis of restrictions imposed by the Skylark missile and the assumed target. The proposed missile path used is the constant true bearing course.

MISSILE AND TARGET CHARACTERISTICS

In this study of the radar homing problem the following characteristics of the missile and the target have been assumed:

Characteristics of Target

| | |
|---------------------|-------------------------------------|
| Assumed Target | Equivalent to SNB (3 square meters) |
| Target Velocity | 300 mph |
| Altitude of Target | 25,000 ft |
| Manuevers of Target | 3g |

Characteristics of the Missile

| | |
|-------------------------------|------------------|
| Configuration, spacing etc... | The Lark Missile |
| Velocity | Mach No. 0.85 |

Characteristics of Radar Homing Equipment

| | |
|--------------------|--------------|
| Frequency | S-Band |
| Type of Homing | Passive type |
| Maximum Lead angle | 30° |

Characteristics of SP-1M Radar

| | |
|--------------------------------------|----------------------------|
| Ground Radar | SP-1M (as modified by NRL) |
| Frequency | S-Band |
| Peak Power | 800 kw |
| Pulse width | 1 microsecond |
| Pulse repetition freq. | 576 cps |
| Scanning rate | 24 cps |
| Antenna diameter | 8 ft |
| Cross-over (down) | 1.4 db 1 way |
| Approximately 100 percent modulation | 3° from cross-over |
| Train and elevation servo bandwidth | below 1/2 cycle |
| Range gates automatic | ± 10 yards accuracy |

CRITERIA FOR SELECTION OF HOMING SYSTEM

Criteria in the following order of importance were decided upon as a basis for comparison of various homing systems:

a) Maximum Range

Curves shall be plotted of radar range to target vs maximum homing range using established standard target and method outlined. Fairchild report E-272* used as basis for comparison.

b) Availability of System Equipment

Under this item shall be listed the stage of research upon design of or status of manufacture of such systems or components of systems being compared.

c) Bandwidth requirements

This will involve a study of the bandwidth requirements of the overall guidance loop and the internal loop of airframe control in the absence of guiding signals. The terminal trajectory will determine these requirements in part, and the outputs of the homing receiver may be a determining factor for the type of trajectory. Susceptibility to jamming and extraneous noise will be considered.

d) Economics

Under this item will be considered:

- 1) the complexity of ground equipment, the time required to accomplish construction, and maintenance difficulties;

* C. D. Perrine, Jr., "Proposed KAQ-1 alternate guidance system," Fairchild Report E-272, March 27, 1947

- 2) complexity of airborne equipment-weight, space, servo power requirements, electrical power requirements, efficiency of operation, ease of installation, ease of design, etc; and
- 3) system stability, including requirement to adjust and trim for operation.
- e) Transition to homing

Particular reference to test rather than tactical conditions will be observed in this consideration.

- f) Target discrimination

Both angular and range discrimination and derivatives of each shall be considered.

- g) Detonation

The ability of the homing system to detonate the missile within 50 feet of the target will be considered.

EVALUATION OF THE TAB (AMPLITUDE) SIMULTANEOUS LOBE COMPARISON SYSTEM

The theory of operation and design of the TAB system was studied in an effort to determine the possibility of adapting the present NRL X-band system to S-Band, and, secondly, to investigate the possible problems which may be encountered in the development of such a system for passive radar homing. It was concluded that the system could be converted for S-Band use, but to adapt the system to such a missile as the Skylark presented many difficult problems. The major problem to be encountered in such a development is that of antenna design. Since the maximum diameter of the missile is 11 inches, the receiving antenna in the missile is limited to 9.25 inches or less. In the amplitude-comparison system it is required that the four horns, or dipoles, be placed together as a point source located at the focal point of a parabolic or lens antenna. In accordance with completed investigations, it was concluded that because of the relatively large area of the horns with respect to the small area of the dish, (particularly in view of the use of S-band frequencies), such an antenna arrangement would introduce a certain amount of r-f phase change along with the amplitude change.

To illustrate this theory, a reflecting system for light rays will be discussed.† If a mathematically perfect paraboloid is conceived with a geometrical point light source having a spherical radiation distribution, the source being exactly at the focus of the reflector, the resultant reflected light energy would be in the form of a beam of the same diameter as the original reflector at all points, consisting of precisely parallel light rays, and would continue to infinity. This theoretical concept is far from the practical result, however, but is most nearly approximated as focal length and diameter of mirror is increased, and the source of light frequency is increased.

It can be determined from the above that with respect to electronic application with r-f propagation, the theoretical paraboloid would establish a plane of constant phase front.

† Ward Harrison and Phelps Meeker, "Some elements in the design of lighting reflectors of specular or essentially specular materials"

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But, in this case where the focal length is short, the source of energy (area of the feed horns) is about 60 percent of the size of the antenna aperture, there would exist a non-uniform r-f phase front across the face of the resulting antenna system resulting in an r-f phase change along with the amplitude change. In accordance with NRL and Bell Telephone Laboratory Reports,† it may be concluded that a system can be developed under the foregoing conditions (phase with amplitude). Such a combination system may result in a loss in angle sensitivity and will possess an appreciably high amplitude first reverse lobe with attending ambiguity. It is not considered desirable to recommend such a system for the present Skylark program. Continuing studies and developments are necessary to determine the associated problems and limitation of possible application as a tracking system.

Some consideration has been given to a wave guide filled with material having a high dielectric constant to reduce the feed area, but it was concluded that the use of such a technique was a problem of long development having questionable end results.

It was therefore concluded that a pure amplitude comparison system at S-band frequency was not immediately practical for the Skylark application.

EVALUATION OF THE METEOR (PHASE) SIMULTANEOUS LOBE COMPARISON SYSTEM

In order to discuss the problems of developing an S-band phase-type simultaneous lobe comparison system as a radar homing system for Skylark missile, it is necessary first to describe the theory of operation of this system. The present Meteor system requires a receiver utilizing two channels for each plane. One local oscillator feeds two balanced mixers. The antennas are spaced a known distance apart. The r-f phase of the signals arriving at the antennas vary, depending on the relative positions of the target and the antennas. The changing phase is compared in a sensitive phase detector following the i-f amplifiers. The output voltage is therefore proportional to the phase difference between the two antennas of each plane. As the receiver is driven to phase balance (null output from the phase detector), the coupled shaft of the servomechanism will rotate at a velocity proportional to the rotation of the tracking line.

Because the antennas are separated and are fixed to the missile, a special device is necessary to remove the motion of the missile from the system. In this system, development work is leading toward either a single sideband modulator or a goniometer at 30 mc/sec. In the actual system, either two single sideband modulators or two goniometers are necessary to introduce the angular velocity of the missile into the receiver and also to balance out of the receiver the motion of the missile.

Since this system still requires the development of the goniometer and several new circuits, it was concluded that it would be impossible to develop this system for the Skylark and still maintain the required time schedule. It was therefore concluded that the phase comparison system could not be recommended for use on the Skylark.

† J. B. Trevor, Jr. and A. E. Hastings, "Analysis and specifications of simultaneous lobing system TAB," NRL Report No. R-2554, July 1, 1945.

H. L. Gerwin, "Design and development of antennas and r-f components for simultaneous lobing radar," NRL Report No. R-3042, January 3, 1947.

H. T. Budenbom, "Preliminary studies on alternate systems and components for monopulse angle tracking," Bell Telephone Lab. Case 26500-4, MM 46-2730-38, July 8, 1946.

H. T. Budenbom, "Low power cw comparison of alternate systems for monopulse tracking," Bell Telephone Laboratories, MM 46-2730-43, September 6, 1946.

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COMPARISON OF TAB (AMPLITUDE) AND METEOR (PHASE)
SIMULTANEOUS LOBE COMPARISON SYSTEMS

During the studies undertaken, many points of design were considered in order to compare the advantages and disadvantages of the two (amplitude and phase) simultaneous lobe comparison systems. The major advantages and disadvantages of these systems as determined by the present study for possible application to the Skylark missile for radar homing are listed below:

AMPLITUDE SYSTEM

Advantages

- (a) The system provides two types of information:
1. present position
 2. rate of change of tracking line.

Disadvantages

- (a) To retain pure amplitude comparison at S-band frequencies, the present system requires an antenna of large aperture which is impossible to obtain because of the limited space in the Skylark missile.

PHASE SYSTEM

Advantages

- (a) The system allows the use of four fixed receiving elements which can be easily installed on the Skylark missiles.
- (b) Rate of change of tracking line.

Disadvantages

- (a) Because this system uses fixed antennas, a special device (as yet not completely developed) is necessary to remove the motion of the missile from the receiving system.
- (b) No readily available present position.

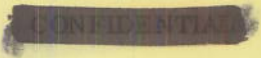
In view of the conclusions reached in the foregoing comparisons, it was deemed necessary to study the sequential lobe comparison systems (conical scan) in order to evaluate the advantages and disadvantages of the scanning system and to compare them with the conclusions reached in the simultaneous system study.

The high-speed electronic lobing system using r-f switch tubes was studied for possible application to S-band. Investigation indicated that the system would have several advantages, but it was concluded that S-band r-f switch tubes would not be available in sufficient time to meet the required schedule.

On the basis of the studies described in this appendix the following conclusions and recommendations are made:

CONCLUSIONS

Because of the requirement to produce working radar homing equipment within eight months, it is concluded that neither the amplitude nor phase types of simultaneous lobe comparison systems can be adapted for the Skylark within this time.



RECOMMENDATIONS

It is recommended that a scanning-type radar homing equipment utilizing standard r-f and receiver components be adapted for the Skylark.

It is recognized that, depending upon configuration and size of guided missiles in future studies, advantages of fixed antennas and/or reduction of moving parts may accrue to the favor of simultaneous lobe comparison and electronically scanned radar homing equipments. It is therefore recommended that, when the workload of the Division permits, a fundamental, mathematical and theoretical study be initiated to determine the advantages of each of these equipments for use with radar homing systems. If, from this study, sufficient advantages should accrue in favor of one or more of the systems, it is recommended that suitable work projects be set up to prove the theoretical analysis.

PHASE SYSTEM

Disadvantages

Advantages

- (a) Because this system uses fixed antennas, a special device (as yet not completely developed) is necessary to remove the motion of the missile from the receiving system.
- (b) No readily available present position.

- (a) The system allows the use of low band receiving elements which can be readily installed on the Skylark.
- (b) Rate of change of tracking line.

In view of the conclusions reached in the foregoing paragraphs, it was deemed desirable to study the essential lobe comparison system (control room) in order to evaluate the advantages and disadvantages of the scanning system and to compare them with the conclusions reached in the simultaneous system study.

The high speed electronic lobe system using r-f switch tubes was studied for possible application to 5-band. Investigation indicated that the system would have several advantages, but it was concluded that 5-band r-f switch tubes would not be available in sufficient time to meet the required schedule.

On the basis of the studies described in this report the following conclusions and recommendations are made:

CONCLUSIONS

Because of the requirement to produce working radar homing equipment within eight months, it is concluded that neither the simultaneous nor phase type of simultaneous lobe comparison systems can be adapted for the Skylark within this time.