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ADDRESS REPLY TO
DIRECTOR, NAVAL RESEARCH LABORATORY
WASHINGTON 25, D. C.

AND REFER TO:
C-3940-18A/54 bws

NAVAL RESEARCH LABORATORY
WASHINGTON 25, D. C.

for PEACE OF MIND - BUY SAVINGS BONDS

CONFIDENTIAL

18 January 1954

Subj: Calculation of Maximum Intercept Ranges of A Crystal Video Intercept Receiver Against Airborne Radars

1. It is assumed that the intercept receiver antenna consists of 6 helical-beam elements equally spaced about a cylinder or similar reflector as shown in Figure 1. All six elements are assumed to feed video preamplifiers whose outputs are combined to provide a signal relatively independent of azimuth angle.

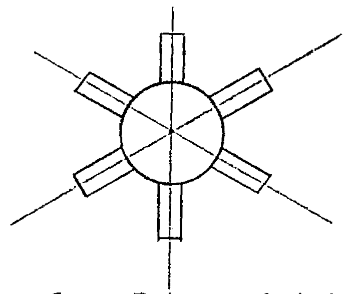

Figure 1. Intercept Antenna

(Azimuth Plane)

2. Each of these elements is circularly polarized and is assumed to have a half-power beamwidth of 45 degrees. From "Antennas" by J. D. Kraus (page 21) this element has a power gain of about 14, i.e.

$$G = 14 \quad (11.5 \text{ db}) \qquad (1)$$

The effective gain for either vertically or horizontally polarized signals is

$$G_e = 7 \quad (8.5 \text{ db}) \qquad (2)$$

3. The effective receiver sensitivity, for a discernible signal, is assumed to be

$$P_r = -45 \text{ dbm} \qquad (3)$$

This amount of power would be required to produce a detectible signal if only one antenna and crystal detector were connected to the receiver input terminals. Since six antenna elements and preamplifiers are used, the noise power at the receiver input is 6 times (7.8 db) as much as would be present with one antenna element. Thus, the effective receiver sensitivity is

$$P_{r6} = -45 + 7.8 \qquad (4)$$

$$= -37.2 \text{ dbm}$$

$$= 1.9 \times 10^{-7} \text{ watt}$$

Encl (1) to
NRL Ltr-File C-3940-18A/54

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4. The effective absorbing area, A_e, of an antenna is related to its power gain as follows:

$$A_e = \frac{G_e \lambda^2}{4\pi} \qquad (5)$$

For each of the helical beam antenna elements then, from equations (2) and (5),

$$A_e = \frac{7\lambda^2}{4\pi}, \qquad (6)$$

where A_e is in square meters if λ is in meters.

5. The incident power density required by the intercept system, using 6 antennas elements is

$$S_r = \frac{P_{r6}}{A_e} = \frac{1.9 \times 10^{-7}}{7\lambda^2} \times 4\pi \qquad (7)$$

$$S_r = \frac{3.41 \times 10^{-7}}{\lambda^2} \text{ watts per sq. meter}$$

6. The power density in free space due to a radar transmitter is given by

$$S = \frac{P_t G_t}{4\pi D^2} \text{ watts per sq. meter} \qquad (8)$$

where P_t = radar peak power in watts

G_t = radar antenna power gain

D = distance from radar in meters

Equating (7) and (8) by setting $S_r = S$ allows one to solve for the maximum free-space intercept range:

$$D^2 = \frac{P_t G_t}{4\pi S_r} \qquad (9)$$

or

$$D = \sqrt{\frac{P_t G_t \lambda^2}{4.28 \times 10^{-6}}} \text{ meters} \qquad (10)$$

7. Equation (10) was used to calculate the free space ranges, D_0, given in Table 1 [redacted] ranges D_1, D_2, and D_3 were found from propagation curves and are de[redacted]ned by the value of D_0 for each example. It should be noted that [redacted]lues of D_1, D_2, and D_3 depend upon the various assumptions

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made in choosing values of P_r and G_e as well as upon the radar characteristics. Also, for the case where the airborne radar is closing with respect to the intercept vessel, the signal will fade in and out for some time after first intercept because of the interference effect produced by the direct and reflected waves at the receiving antenna.

TABLE 1 - MAXIMUM INTERCEPT RANGES AGAINST AIRBORNE RADARS (Receiving Antenna Height = 12 feet)

					MAXIMUM RANGE, NAUTICAL MILES		
RADAR	FREQ. Mc.	POWER KW.	ANTENNA Power Gain	D_o FREE SPACE RANGE	D_1 AIRCRAFT AT 1000 Ft	D_2 AIRCRAFT at 5000 ft	D_3 AIRCRAFT at 10,000 ft
APS-44	9375	1000	1000	270	42	89	123
APS-33	"	70	1200	78	40	77	77
APS-19	"	40	1200	59	39	58	58
APS-15	"	40	200	24	23	23	24
APS-20	2880	1000	1000	830	43	90	124
LOW-POWER	3000	40	100	53	36	52	53
Note: RADAR HORIZON DISTANCES ⟶					43	92	127

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DEPARTMENT OF THE NAVY
BUREAU OF AERONAUTICS
WASHINGTON 25 D. C.

Aer-EL-91

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010965
13 October 1949

From: Chief, Bureau of Aeronautics
To: Director, Naval Research Laboratory
Anacostia, D. C.
Attention: Program Records Office

Subject: Development of Wide Open Airborne Direction Finding System in Microwave Frequencies.

Enclosure: (A) Project Details.

1. It is requested that a countermeasures project be established at the Naval Research Laboratory (NRL) in accordance with the enclosure and the following information:

 a. Project Title: Development of a Wide Open Airborne Direction Finding System for Countermeasures Intercept in the microwave frequencies.

 b. Bureau of Aeronautics (BuAer) Project No. NRL-EL-9A-358.

 c. Estimated Dates of Completion: Short range portion 1 May 1951, Long range portion 1 October 1954.

2. The following additional information is supplied:

 a. Necessary equipment is to be supplied by NRL.

 b. No aircraft are required for this development.

 c. BuAer Cognizant Engineer is Mr. H. B. Pickett, Code EL-91, Telephone REpublic 7400, Extension 3146.

 d. Precedence: It is requested that a precedence be established for this project which will permit completion on or about the estimated completion dates.

3. It is requested that the cost of this project be chargeable to: Allotment E, Bureau Control No. 40659, Expenditure Account No. 46846.

CC: With Encl.
Addressee (15)
CNO (Op-413C)
CNO (Op-341D)
ONR
BuShips (810)
NAMSU

[redacted]

By Direction

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PROJECT DETAILS
FOR
DEVELOPMENT OF WIDE OPEN AIRBORNE DIRECTION FINDING SYSTEM IN MICROWAVE FREQUENCIES

1. In order to provide D.F. equipment capable of providing bearing information on signals of short duration and scattered in frequency throughout the microwave ranges, it is necessary to provide D.F. equipment which is wide open to signals over a broad band and which will provide azimuth indication of the direction of arrival of these signals without necessity for scanning a directional antenna in azimuth. The object of this problem is to provide techniques for construction of Airborne equipment of this type and to construct flyable breadboard models for test; to analyze the capabilities and deficiencies of various types of circuits and components adaptable to this type of signal presentation and to finally arrive at a suitable solution for producing equipment fulfilling military requirements for broad band D.F. equipment with high probability of intercept and near instantaneous D.F. on short duration signals.

2. <u>Short Range Project</u>: Under the short range project a system will be constructed suitable for test in naval aircraft and utilizing techniques which are available or can be made available with minimum research and development. The Crystal Video type of receiving equipment is suggested, using low-drag broad band antennas. Sensitivity and bandwidth should be as great as the state of the art permits. The equipment should be capable of providing at least broad indication of received frequencies.

3. <u>Long Range Project</u>: The object of this portion of the project is to work for improvement of techniques and components to eventually provide a complete system incorporating increased bandwidth, increased sensitivity, improved bearing accuracy, simultaneous indication of frequency and bearing of all signals within the pass band. Methods of indication and analysis of signals shall also be considered with the object of integrating such indication and analysis into an overall system.

4. The laboratory shall coordinate this work with other research and development work in the field and maintain familiarity with all work of other government agencies and private activities which may be applicable to this project.

5. Complete reports containing all pertinent information concerning the developments shall be prepared upon completion of each phase of the project. Ten (10) copies of these reports shall be furnished the Bureau of Aeronautics (Attention: EL-91).

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ENCLOSURE (A)

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