(2)

~~TOP SECRET~~ [redacted]

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

C-3940-18/54 bws

NAVAL RESEARCH LABORATORY
WASHINGTON 25, D. C.

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19 January 1954

From: Code 3945A, Naval Research Laboratory
To: Code 842, Bureau of Ships

Subj: Calculation of Maximum Intercept Ranges of A Crystal Video Intercept Receiver Against Airborne Radars, dated 18 January 1954

Encl: (1) Two copies of subject memo, C-3940-18A/54

Ref: (a) Conference on 7 January 1954 at NRL with W. Dix, J. March, R. Owens and [redacted] participating

1. Enclosure (1) is forwarded for your information. This information was requested in reference (a).

[redacted]
Code 3945A

HANDLE VIA BYEMAN-TALENT-KEYHOLE-[illegible] CONTROL SYSTEMS JOINTLY

This memo may be downgraded to Unclassified when the enclosure has been removed.

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HANDLE VIA BYEMAN CONTROL SYSTEM ONLY

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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 pre-amplifiers whose outputs are combined to provide a signal relatively independent of azimuth angle.

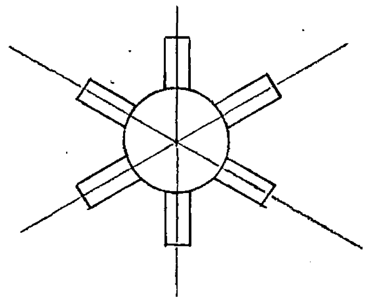

Figure 1. Intercept Antenna
(Azimuth Plane)

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

$$P_r = -45 + 7.8 \qquad (4)$$

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

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

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4. The effective abs[redacted]rea, 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),

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

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

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

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

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

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

where $P_t \doteq$ radar peak power in watts

$G_t \doteq$ radar antenna power gain

$D \doteq$ distance from radar in meters

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

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

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

7. Equation (10) was used to calculate the free space ranges, D_o, given in Table 1. The ranges D_1, D_2, and D_3 were found from propagation curves and are determined by the value of D_o for each example. It should be noted that the values 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)

RADAR	FREQ. Mc.	POWER KW.	ANTENNA Power Gain	D_o FREE SPACE RANGE	MAXIMUM RANGE, NAUTICAL MILES: 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