AD-768 330

DETECTION PERFORMANCE OF THE AN/TPN-19 PAR (PRECISION APPROACH RADAR)

Vincent C. Vannicola

Rome Air Development Center
Griffiss Air Force Base, New York

August 1973

AD-768330

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER RADC-TR-72-238 | 2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* DETECTION PERFORMANCE OF THE AN/TPN-19 PAR	5. TYPE OF REPORT & PERIOD COVERED In-House Report 6. PERFORMING ORG. REPORT NUMBER RADC-TR-72-238
7. AUTHOR(s) Vincent C. Vannicola	8. CONTRACT OR GRANT NUMBER(s) N/A
9. PERFORMING ORGANIZATION NAME AND ADDRESS Rome Air Development Center (OCTS) Griffiss Air Force Base, New York 13441	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 404L0004
11. CONTROLLING OFFICE NAME AND ADDRESS Rome Air Development Center (OCTS) Griffiss Air Force Base, New York 13441	12. REPORT DATE August 1973 13. NUMBER OF PAGES ~~114~~ 120
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)* Same	15. SECURITY CLASS. *(of this report)* UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

Same

18. SUPPLEMENTARY NOTES

None

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Radar
Detection Probability
Moving Target Indication
Diversity

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The purpose of this report is to determine the receiver operating characteristics of the AN/TPN-19 PAR Air Force radar in some of its operating modes. The scan mode and the coherent MTI (Moving Target Indicator) mode will be considered for the case when the received target signal is corrupted by white Gaussian noise only. The MTI loss (the increase in signal-to-noise ratio required for the same detection performance when switching from the scan mode to the MTI mode) is also determined and discussed. Methods for

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

20. improving the MTI performance are given and evaluated.

DETECTION PERFORMANCE OF THE AN/TPN-19 PAR

Vincent C. Vannicola

FOREWORD

This report describes the detailed solution of a difficult theoretical problem which is directly related to an Air Force radar system currently in development. The system is the AN/TPN-19 Landing Control Central and more specifically, the *P*recision *A*pproach *R*adar (PAR) for that system. The research was accomplished under Job Order 404L0004.

It has been known for many years that when a typical radar is operated in an anti-clutter or *M*oving *T*arget *I*ndicator (MTI) mode, its detection performance drops with respect to that obtained in a normal scan mode for the same radar. Even though the existence of this loss in detection performance was known, the closed-form theoretical solution and precise quantitative effects have not been carried out or published to date.

The main body of this report is a very careful delineation of the problem and the development of a rigorous closed-form solution which yields quantitative results. This method can be adapted to provide quantitative results for numerous other radar problems.

This report has been reviewed by the RADC Information Office (OI) and is releasable to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved.

Approved:

ARTHUR J. FROHLICH
Chief, Techniques Branch
Surveillance and Control Division

Approved: William T. Pope

WILLIAM T. POPE
Assistant Chief
Surveillance & Control Division

FOR THE COMMANDER:

CARLO P. CROCETTI
Chief, Plans Office

ABSTRACT

The purpose of this report is to determine the receiver operating characteristics of the AN/TPN-19 PAR Air Force radar in some of its operating modes. The scan mode and the coherent MTI (*M*oving *T*arget *I*ndicator) mode will be considered for the case when the received target signal is corrupted by white Gaussian noise only. The MTI loss (the increase in signal-to-noise ratio required for the same detection performance when switching from the scan mode to the MTI mode) is also determined and discussed. Methods for improving the MTI performance are given and evaluated.

ACKNOWLEDGEMENT

The author is indebted to the following individuals for contributions to this report: Clarence F. Silfer and Franklin C. Bradley who provided an in-depth understanding of the system and the problems involved; and Sgt. Eugene Bromley for writing the programs used in obtaining the data contained herein.

TABLE OF CONTENTS

LIST OF FIGURES

Appendix A:

INTRODUCTION

The TPN-19 PAR has primarily three modes of operation: a scan mode employing post detection integration, a coherent MTI, and a non-coherent MTI mode both of which use a non-recursive 2-pulse delay digital canceller. The modes differ to the extent the received signal is processed. This report will cover the performance of the scan and coherent MTI mode when the signal is corrupted by thermal noise only. The signal-to-noise ratio that is required for various detection probabilities will be determined.

The radar scans the coverage with a raster, transmitting six pulses per beam position. Each beam overlaps in coverage with adjacent beams so that the target may be detected in one or more of these beams during a single scan.

The probability that a target is detected is equal to the probability that the received signal crosses a set threshold in at least one of the beams, adjacent or otherwise. This detection criteria applies to all three modes of operation.

For the scan mode all six pulses per beam position, each three at an independent center frequency, are received through separately tuned receivers, square law detected, and integrated. The sum of these six pulses represents a variable which is tested against a threshold and accepted or rejected as a target.

For the coherent MTI mode, six pulses are transmitted per beam position, each three at an independent center frequency. These are received through two receiver channels each tuned to the appropriate center frequency. Each group of three received pulses are video detected, i.e., down converted to zero IF, passed through a three-pulse canceller, gated, and then made positive by squaring or taking its absolute value. These outputs of the two receiver channels are added and this sum is tested against the threshold. The adjacent beam operates in like manner except the PRF of the six pulses is different and the center frequencies are also different. The different PRF has the effect of avoiding blind speeds since the target will always appear in the visible portion of the spectrum in at least one of the beams. The additional independent frequencies provide the system with diversity gain.

When the second raster scan takes place, the PRF and frequency occur at alternate beam positions. The scanning cycle is then considered complete.

In this report the performance of the scan mode and the coherent MTI mode are each evaluated and a comparison is made as to their relative performance. Also evaluated herein is the performance of the MTI mode if the received signal were to be video detected in both the in-phase and the quadrature-phase channel, i.e., "$I^2 + Q^2$." (Note: The present AN/TPN-19 PAR processes the in-phase channel only: "I Only").

We shall first evaluate the scan mode.

SCAN MODE

When the system is operating in the scan mode, three pulses are received at each of two independent frequencies. These six pulses are each square law detected and video integrated. The target is assumed to be a Swerling Case I* at any one frequency. Thus each beam position gives a total of six square law detected signals containing two independent Rayleigh samples. The probability density function of the output variable, Y, and the probability of detection is derived in Appendix A.

We assume that the target is located anywhere within a beam with uniform probability and that the beams overlap as shown in Figure 1. We determine a composite[1] detection probability by first determining the conditional probability of detecting the target in either of the beams at some particular target location. Next we average the detection probability throughout all locations within the coverage. This can be done very effectively by determining the detection probability at each of ten (10) points within the triangle of symmetrical coverage shown in Figure 1 and averaging the results.

---

*A Swerling Case I target has a slow fluctuating Rayleigh distributed return.

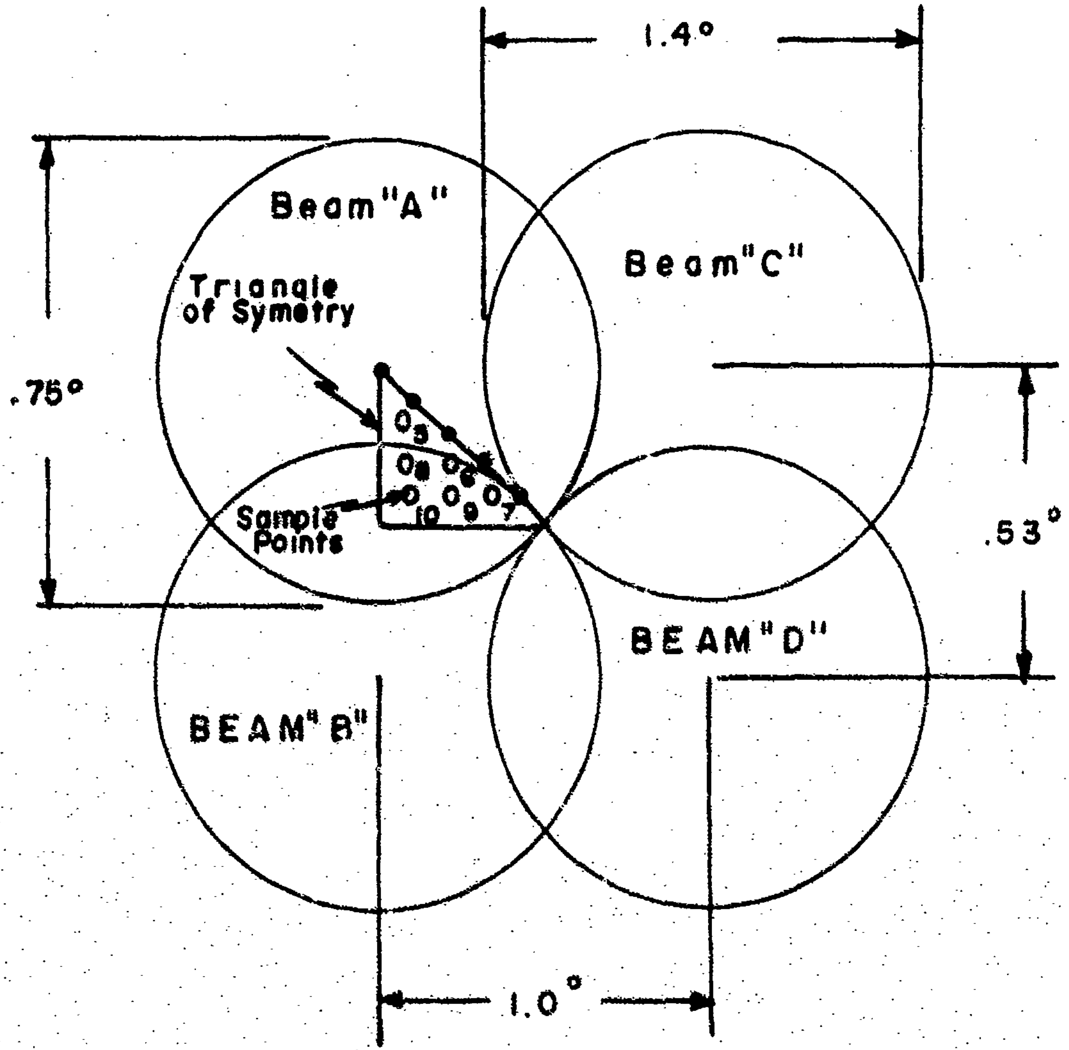

Figure 1. Relative Beam Positions of PAR

Since the output variable, Y, is dependent on beam position, L, and target location, ϕ, we denote the conditional detection probability, i.e., that the output variable Y crossed the threshold γ of beam L by $P_{DL|\phi,H_1}(Y>\gamma|\phi,H_1)$.* Note that velocity dependence does not apply for the scan mode.

The probability that a target is detected in at least one of the K beams, i.e., either in beam A, or B, or C, etc., or any combination thereof is

$$P_{D|\phi,H_1} = 1-[1-P_{DA|\phi,H_1}(Y>\gamma|\phi,H_1)]\,[1-P_{DB|\phi,H_1}(Y>\gamma|\phi,H_1)]\ldots$$

$$\ldots[1-P_{DL_K|\phi,H}(Y>\gamma|\phi,H_1)] \qquad (1)$$

provided that the return signal from each beam is independent.

---

*The symbol H_1 refers to hypothesis 1, i.e., the target is present. Likewise H_0 refers to the target is not present.

Averaging over the scan triangular sector

$$P_D = \frac{1}{10} \sum_{j=1}^{10} P_D | \phi_j \qquad (2)$$

where the pdf of target location is assumed to be discretely uniformly distributed.

COMPUTER RESULTS FOR SCAN MODE

In computing the position and beam dependent probabilities of detection the amplitude weighting factors GA(i), GB(i), . . . and GL(i) for position i and beam A, B, . . . and L, respectively, were provided by the contractor, Raytheon and are shown listed in Table I. In the scan mode beams E, F, G, and H are redundant in space coverage but occur one-half second later. Equation (2) was computed for the values of false alarm and signal-to-noise ratio in dB as indicated. Several beam combinations are shown. The values are given in Tables II through IV. The detection probability for the target located at the center of beam "A" and "A and/or E" is shown in Tables V and VI respectively.

COHERENT MTI MODE

In order to keep the terminology simple in the derivations of the probability density functions for the different receiver models to be evaluated, beam center values and velocity dependent target signals will be used. The situation will be generalized for position, velocity, and beam averaging later in the report.

VELOCITY DEPENDENT SIGNAL ON BEAM CENTER

The received signal is assumed to be a Swerling Case I waveform with the further condition that a random bit correlated phase is present from pulse to pulse in any three pulse bursts. The phase is modulated by the target radial velocity. The signal is corrupted by white Gaussian noise with power spectral density $N_0/2$.

For a single pulse the RF received signal may be written[1].

$$H_1: r(t) = v \sqrt{\frac{2}{T}}\ \text{rect}\left\{\frac{t}{T}\right\} \cos\ [w_0 + w_d)\ t + \theta] + w(t) \qquad (3\text{-A})$$

when a target is present, i.e., hypothesis H_1 holds, and

$$H_0: r(t) = w(t) \qquad (3\text{-B})$$

when there is no target present.

We know that for a Swerling Case I target the amplitude v in Equation (3) has a Rayleigh distribution and the phase θ has a uniform distribution. The function

$$\sqrt{\frac{2}{T}}\ \text{rect}\ \left\{\frac{t}{T}\right\} \qquad (3)$$

corresponds to the waveform envelope and is normalized so that the energy in the received signal is v^2. The quantities w_0 and w_d represent the RF center frequency and the doppler frequency, respectively, and the function $w(t)$ is white Gaussian noise present in the receiver.

After the received signal is sufficiently amplified above the noise level of subsequent stages it is eventually down converted (see Figure 2) by the following normalized operation.

$$r_0 = \int_{-\frac{\tau}{2}}^{\frac{\tau}{2}} r(t)\sqrt{\frac{2}{\tau}} \cos w_0 t\,dt \qquad (4\text{-A})$$

giving

$$H_1: \quad r_0 = v \cos\theta + n_0 : w_d\,\tau << 1 \qquad (4\text{-B})$$

$$H_0: \quad r_0 = n_0$$

It can be shown[2] that when v is Rayleigh with $E\,[\,v^2\,] = 2\sigma_s^2$ and when the noise $\|\,w(t)\,|$ is Rayleigh with $E\,[\,|w^2|\,] = N_0$ then $v \cos\theta$ is Gaussian with variance σ_s^2 and n_0 is Gaussian with variance $N_0/2$. Since $w(t)$ is a narrow band white Gaussian process with power spectral density $N_0/2$, the envelope $|\,w(t)\,|$ is Rayleigh with $E\,[\,|w^2\,|\,] = N_0$.

It also can be shown that the preceding pulse takes on the form

$$r_{-1} = v \cos(-w_d T + \theta) + n_{-T} \qquad (4\text{-C})$$

and the preceding pulse

$$r_1 = v \cos(w_d T + \theta) + n_T \qquad (4\text{-D})$$

The variables n_{-T}, n_0, n_T are each independent.

When each variable r_i occurring at time it is fed through the three-pulse canceller having an impulse response

$$h(\tau) = -\delta(\tau + T) + 2\delta(\tau) - \delta(\tau - T) \qquad (4)$$

then the resulting variable at the output of the canceller at the time the last variable t_1 is feeding the input can be written

$$\begin{aligned} H_1&: r = 4 \sin^2\left(\frac{w_d T}{2}\right) v \cos\theta - n_{-T} + 2n_0 - n_T \\ H_0&: r = -n_{-T} + 2n_0 - n_{+T} \end{aligned} \qquad (5)$$

where the noise terms may be grouped into a single term, n, with variance $3N_0$ and the variance of the signal at the output of the canceller is $16 \sin^4 (w_d T/2)\,\sigma_s^2$. Both these terms are zero mean Gaussian random variables.

In the system under analysis the output of the canceller is gated on during the interpulse period immediately following the third input pulse. Therefore the observed variable under each hypothesis is zero mean Gaussian with pdf as follows

$$p_{r|w_d,H_1}(R\,|\,\Omega_d, H_1) = \frac{1}{\sqrt{2\pi}\,\sigma_1} \exp\left(-\frac{R^2}{2\sigma_1^2}\right) \qquad (6\text{-A})$$

$$p_{r|H_0}(R\,|\,H_0) = \frac{1}{\sqrt{2\pi}\,\sigma_0} \exp\left(-\frac{R^2}{2\sigma_0^2}\right) \qquad (6\text{-B})$$

where

$$\sigma_1^2 = 16 \sin^4 \left(\frac{w_d T}{2}\right) \sigma_s^2 + 3N_0$$

$$\sigma_0^2 = 3N_0$$

and σ_s^2 is the mean square signal returned from the target scatterer in one Gaussian channel, ($v \cos \theta$). This channel will also be referred to as the "I Only" channel, as shown in Figure 2.

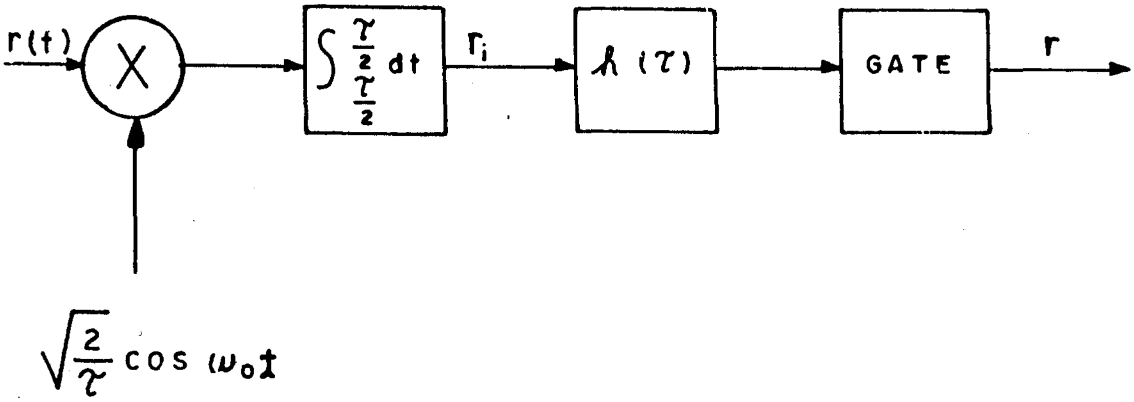

Figure 2. "I Only" Receive Channel

The canceller output of each frequency diverse channel has identical probability density function and is independent of any other channel. Two different interpulse periods are each shared by each group of two frequency diverse channels.

The channel shown in Figure 2 is the basic coherent correlator followed by a gated MTI three-pulse canceller. The output variable, r, may be combined with the output variables, r, of other channels in several ways, each giving different levels of performance as will be shown later. Four different configurations for combining the variables, r, are shown in Figures 3-A through 3-D.

Figures 3-A and 3-B show "I Only" processing of two frequency independent MTI channels, 3-A representing envelope detection and 3-B representing square law detection of the Gaussian variables, r, from the output of the three-pulse canceller. Each configuration represents six received pulses, three for I_1 and three for I_2, respectively, at a particular interpulse interval, T_A.

Figures 3-C and 3-D show I and Q processing of the two frequency independent MTI channels in the same manner as in Figures 3-A and 3-B.

After applying the test statistics, ℓ_A, to a threshold and thereafter to a scope, a second statistic, ℓ_E, processed in an identical fashion from two other MTI channels having different independent frequencies and a different interpulse interval, T_E, is also thresholded 0.5 seconds later. This second statistic accounts for six more received pulses so that a total of twelve pulses are processed before the sequence repeats itself. A target at beam center will be indicated at the scope if either ℓ_A or ℓ_E or both are above the threshold. (See Figure 4.)

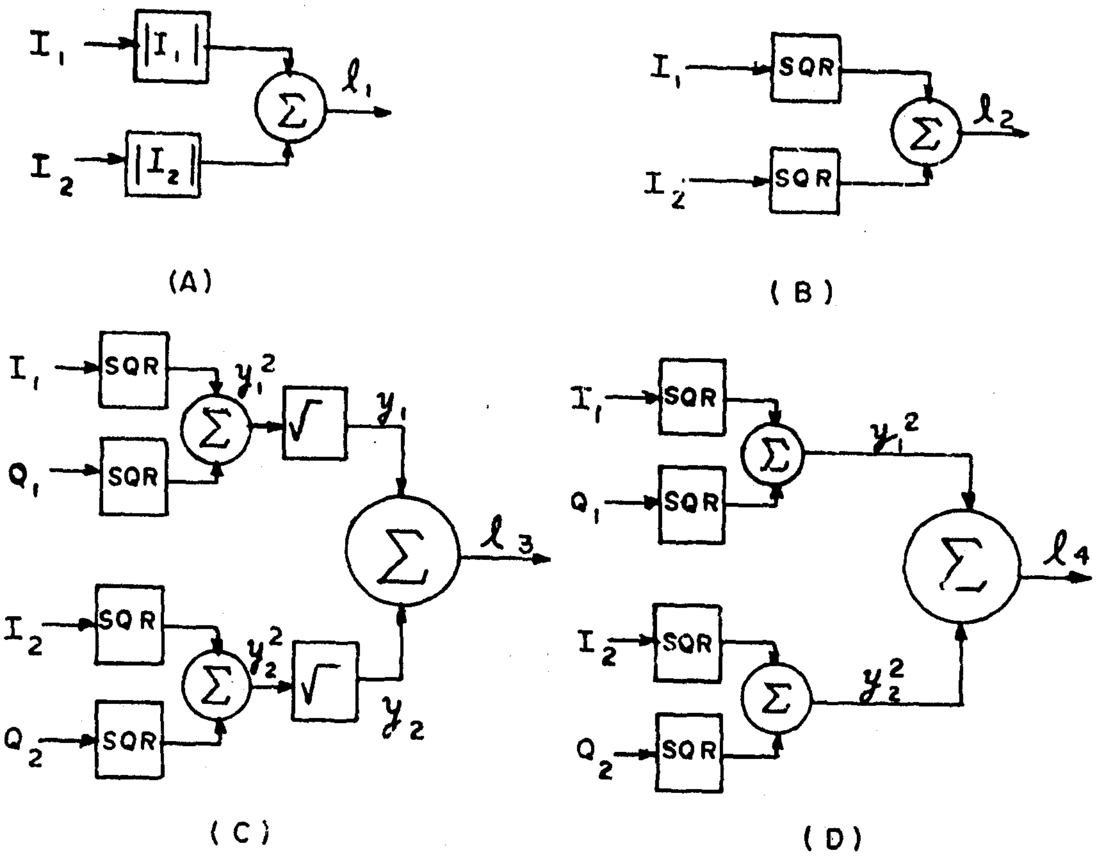

Figure 3. Four Receiver Models

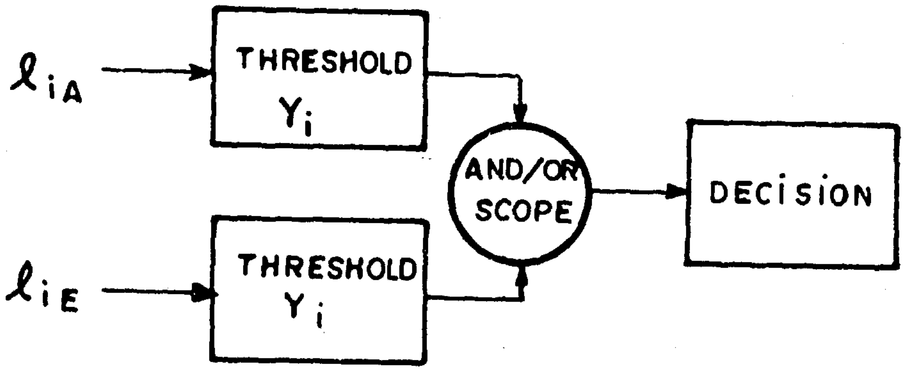

Figure 4. Combination Of Dual Channels

Figure 4. Combination of Dual Channels

DERIVATION OF SIGNAL-TO-NOISE FOR GIVEN PROBABILITY OF DETECTION

Let us start the derivation with the probability density function of the gated output from the canceller, equation 6. After performing the transformations appropriate for the block diagrams of Figure 3, we have the probability density function of ℓ_i, (the details of this analysis are found in Appendix B) is

$$P_{\ell_1 | \omega_d, H_1}(\ell_1 | \Omega_d, H_1) = \frac{2}{\sqrt{\pi}\,\sigma_1} \exp\left\{- \frac{1^2}{4\sigma_1^2}\right\} \left[1 - \operatorname{erfc}\left\{\frac{\ell_1}{2\sigma 1}\right\}\right] \tag{7-A}$$

$$P_{\ell_2 | \omega_d, H_1}(\ell_2 | \Omega_d, H_1) = \frac{1}{2\sigma_1^2} \exp\left\{- \frac{\ell_2}{2\sigma_1^2}\right\} \tag{7-B}$$

$$P_{\ell_3 | \omega_d, H_1}(\ell_3 | \Omega_d, H_1) = \frac{\ell_3}{2\sigma_1^2} \exp\left\{- \frac{\ell_3^2}{2\sigma_1^2}\right\} + \frac{\sqrt{\pi}}{2\sigma_1} \exp\left\{- \frac{\ell_3^2}{4\sigma_1^2}\right\}$$

$$\left(\frac{\ell_3^2}{2\sigma_1^2} - 1\right) \operatorname{erf}\left\{\frac{\ell_3}{2\sigma 1}\right\} \tag{7-C}$$

$$P_{\ell_4 | \omega_d, H_1}(\ell_4 | \Omega_d, H_1) = \frac{\ell_4}{4\sigma_1^4} \exp\left\{- \frac{\ell_4}{2\sigma_1^2}\right\} \tag{7-D}$$

with signal present. When the signal is not present

$$P_{\ell_i | H_o}(\ell_i | H_o) = P_{\ell_i | \omega_d, H_1}(\ell_i | \Omega_d, H_1) \Big|_{\sigma_1 = \sigma_0} \tag{8}$$

Equation (8) was written in this form to save space since it is identical to Equation (7) except that σ_0 is substituted for σ_1.

As is well known the probability of false alarm is derived[1] by the following

$$P_{F_i} = \int_{\gamma_i}^{\infty} P_{\ell_i | H_o}(\ell_i | H_o)\, d\ell_i \tag{9}$$

EXAMPLE: THRESHOLD COMPUTATION:

For each of the four cases we set $P_{F_{A,E}}$ equal to 5×10^{-7} in order to obtain a false alarm probability at the scope of 10^{-6}. From Figure 4 we see that at the scope

$$P_F = P_{F_A} + P_{F_E} - P_{F_A} P_{F_E} \cong 2P_{F_A} \tag{10}$$

when

$$0 < P_{F_A} = P_{F_E} << 1$$

Evaluating the integral in (9) for each of the four cases, substituting for σ_0, and setting the P_{F_i} equal to 5×10^{-7}, for example, we have

$$2 \operatorname{erfc}\left\{\frac{\gamma_1}{2\sqrt{3N_o}}\right\} \cong 5 \times 10^{-7} \qquad \text{(11-A)}$$

$$\exp\left\{-\frac{\gamma_2}{6N_o}\right\} = 5 \times 10^{-7} \qquad \text{(11-B)}$$

$$\exp\left\{-\frac{\gamma_3^2}{12N_o}\right\}\left[\sqrt{\pi}\frac{\gamma_3}{2\sqrt{3N_o}} \operatorname{erf}\left\{\frac{\gamma_3}{2\sqrt{3N_o}}\right\} + \exp\left\{-\frac{\gamma_3^2}{12N_o}\right\}\right] = 5 \times 10^{-7} \qquad \text{(11-C)}$$

$$\left(\frac{\gamma_4}{6N_o} + 1\right)\exp\left\{-\frac{\gamma_4}{6N_o}\right\} = 5 \times 10^{-7} \qquad \text{(11-D)}$$

Solving for the various thresholds γ_i we have

$$\gamma_1 = 7.30\sqrt{3N_o} \qquad \text{(12-A)}$$

$$\gamma_2 = 29 \times 3N_o \qquad \text{(12-B)}$$

$$\gamma_3 = 8.1\sqrt{3N_o} \qquad \text{(12-C)}$$

$$\gamma_4 = 35 \times 3N_o \qquad \text{(12-D)}$$

Returning to our discussion we may use these threshold values and the probability density function of Equation (7) to evaluate the probability of detection of each of the models in Figure 3 through the integral.

$$P_i(\ell_{iA} > \gamma_i | \omega_d, H_1) = \int_{\gamma_i}^{\infty} p_{\ell_{iA}|\omega_d, H_1}(\ell_{iA} | \Omega_d, H_1)\, d\ell_{iA} \qquad \text{(13)}$$

where the subscript A denotes the particular choice of interpulse period T_A or T_E of which the variance σ_1^2 is a function.

Evaluating this integral for each one of the cases in Figure 3 we have

$$P_1(\ell_{1A} > \gamma_1 | \omega_d, H_1) = 1 - \operatorname{erf}^2\left\{\frac{\gamma_1}{2\sigma_1}\right\} \qquad \text{(14-A)}$$

$$P_2(\ell_{2A} > \gamma_2 | \omega_d, H_1) = \exp\left\{-\frac{\gamma_2}{2\sigma_1^2}\right\} \qquad \text{(14-B)}$$

$$P_3(\ell_{3A} > \gamma_3 | \omega_d, H_1) = \exp\left\{-\frac{\gamma_3^2}{4\sigma_1^2}\right\}\left[\sqrt{\pi}\frac{\gamma_3}{2\sigma_1} \operatorname{erf}\left\{\frac{\gamma_3}{2\sigma_1}\right\} + \exp\left\{-\frac{\gamma_3^2}{4\sigma_1^2}\right\}\right] \qquad \text{(14-C)}$$

$$P_4(\ell_{4A} > \gamma_4 | \omega_d, H_1) = \left(\frac{\gamma_4}{2\sigma_1^2} + 1\right)\exp\left\{-\frac{\gamma_4}{2\sigma_1^2}\right\} \qquad \text{(14-D)}$$

Equation (14) is the probability that the signal, derived from the six received pulses of period T_A and present at the output of the network shown in Figure 3 (or the input to the A port of Figure 4), exceeds the threshold for a particular target radial velocity associated with ω_d. When the six pulses having period T_E are also applied to the and/or circuit of Figure 4 the overall probability of detection for all twelve pulses and for a particular ω_d is

$$P_{D_i} | \omega_d = P_i([\ell_{iA} > \gamma] \cup [\ell_{iE} > \gamma_i] | \omega_d, H_1) \tag{15}$$

$$= P_i(\ell_{iA} > \gamma_i | \omega_d, H_1) + P_i(\ell_{iE} > \gamma_i | \omega_d, H_1) - P_i([\ell_{iA} > \gamma_i] \cap [\ell_{iE} > \gamma_i] | \omega_d, H_1)$$

Since the events $\ell_{iA} > \gamma_i$ and $\ell_{iE} > \gamma_i$ are independent the last term in (15) can be written as the product of their probabilities.

The average detection probability may be computed by integrating out the dependency on ω_d

$$P_{D_i} = \int_{\Omega_d} P_i[\ell_{iA} > \gamma_i] \cup [\ell_{iE} > \gamma_i] | \omega_d, H_1) P_{\omega_d | H_1}(\omega_d | H_1)\, d_{\omega_d} \tag{16}$$

Where $P_{\omega_d | H_1}(\omega_d | H_1)$ is the probability density function of the doppler frequency ω_d and integration is over the range of ω_d.

COMPOSITE DETECTION PROBABILITY OVER POSITION AND VELOCITY

Thus far we have derived the expressions for the conditional probability of detection when the target is located in the center of beam A and E. In this special case, beam E is spatially coincident with A but occurs one-half second later. The detection probability given in Equation (15) is conditional on target velocity and beam center. The detection probability of Equation (16) is composite over target velocity and is conditional only on beam center. These expressions may be applied to any receiver case of Figure 3 by assigning the appropriate index, *i*, to the subscripts in Equation (15) and (16) and making the proper substitution from Equation (14).

We shall now make the detection problem even more conditional by introducing multiple antenna beams, each having its own position L along with its own PRF, T_k. We also may assume that the target is located at a common but random position, ϕ, within the beams' coverage. Now defining a detection as constituting a hit in one or more of K beams we have for the conditional detection probability of a particular receiver case

$$P[(\ell_A > \gamma) \cup (\ell_B > \gamma) \cup \ldots (\ell_{LK} > \gamma) | \phi, \omega_d, H_1] =$$

$$1 - [1 - P(\ell_A > \gamma | \phi, \omega_d, H_1)][1 - P(\ell_B > \gamma | \phi, \omega_d, H_1)] \ldots [1 - P(\ell_{LK} > \gamma | \phi, \omega_d, H_1)] \tag{17}$$

That is, a detection is made if the target is detected in beam A or beam B or . . . beam LK, or any combination thereof.

The subscript "*i*" for the receiver case has been omitted. It is assumed that the signal and noise received from each beam A, B, C, . . . LK is uncorrelated and therefore independent.

The composite probability of detection for all K beam positions is therefore obtained by averaging Equation (17) with respect to ϕ and ω_d.

$$P_D \Big|_{\text{K Beams}} = \int_\phi \int_\Omega P[(\ell_A > \gamma) \cup (\ell_B > \gamma) \cup \ldots (\ell_{LK} > \gamma) | \phi, \omega_d | H_1] P(\phi, \omega_d | H_1)\, d_\phi d_{\omega_d} \tag{18}$$

Since the target position, ϕ, within the beams is independent of velocity, ω_d, we may write

$$P(\phi, \omega_d | H_1) = P(\phi | H_1)\, P(\omega_d | H_1).$$

Equation (18) is the average probability of detection for the coherent MTI mode. The averaging is over the spatial coverage and over the target velocity. This equation also considers a detection when the processed signal crosses the threshold in beam A or beam B or, . . . beam LK, or any combination thereof.

COMPUTER RESULTS

The expressions given above were programmed on the computer. The program was written to accommodate any number of beams A, B, C . . . LK each of which may have assigned a particular PRF interval, $T_A, T_B, T_C \ldots T_{LK}$. An example of four beams and their relative locations is shown in Figure 1 (provided by the contractor). A triangle of symmetry by which the entire coverage can be represented is also shown. The target is assumed to be located anywhere within this triangle (and therefore anywhere within the coverage) with uniform probability. To facilitate the computation, the target location was given a uniform discrete probability density function at ten equally spaced points within the triangle.

$$P(\phi | H_1) = \frac{1}{10} \sum_{j=1}^{10} \delta(\phi - \phi_j) \tag{19}$$

For the same reason the velocity is also assumed to have a uniform discrete distribution

$$P(\omega_d | H_1) = \frac{1}{10} \sum_{l=1}^{10} \delta(\omega_d - \omega_{dl}) \tag{20}$$

Each of the density functions on the right side of Equation (17) are evaluated first giving

Beam A:

$$P(\ell_A > \gamma | \phi, \omega_{dl}, H_1) =$$

$$P(\ell > \gamma | \omega_{dl}, H_1) \Bigg|_{\substack{T = T_A \\ \sigma_s^2/A = 10 - \frac{GA(j)}{10} \sigma_s^2}} = P_{Djl/A}$$

Beam B:

$$P(\ell_B > \gamma | \phi_j, \omega_{dl}, H_1) =$$

$$P(\ell > \gamma | \omega_{dl}, H_1) \Bigg|_{\substack{T = T_B \\ \sigma_s^2/B = 10 - \frac{GB(j)}{10} \sigma_s^2}} = P_{Djl/B}$$

⋮

Beam L:

$$P(\ell_L > \gamma | \phi_j, \omega_{dl}, H_1) =$$

$$P(\ell > \gamma | \omega_{dl}, H_1) \Bigg|_{\substack{T = T_L \\ \sigma_s^2/L = 10 - \frac{GL(j)}{10} \sigma_s^2}} = P_{Djl/L} \tag{21}$$

The middle part of equation (21) is taken from Equation (14) where $\sigma_s{}^2{}_j$ A, the target amplitude, is substituted for $\sigma_s{}^2$ in the definition for $\sigma_1{}^2$, following Equation (6-B). GA(j) is the two-way antenna gain (beam center gain equals unity) for the A beam target located at the j point in the triangular coverage sector. Values used for GL(j) were provided by the contractor, Raytheon, and are shown listed in Table I.

From Equation (21) one can see that for each value of P_{DijLk} the variance under H_1, $\sigma_1{}^2$, (as defined under equation (6) and appearing in equation (14) for detection probability) is dependent on *beam position, PRF, Target location,* and *velocity. Beam Position* and *PRF* dependence is lumped together through Equation (17) which is repeated here in modified form.

$$P_{Dij}\,(\text{All K Beams}) = 1 - (1 - P_{DijA})\,(1 - P_{DijB}) \ldots . (1 - P_{DijLK}) \tag{22}$$

Target Location is averaged out by performing the integration indicated in Equation (18) with respect to ϕ.

$$P_{Di}\ (\text{K Beams}) = \frac{1}{10} \sum_{=1}^{10} P_{Dij}\ (\text{K Beams}) \tag{23}$$

Finally, *Velocity Dependence* is averaged out by a similar integration on P_{Di}.

$$P_D\,(\text{K Beams}) = \frac{1}{10} \sum P_{Di}\ (\text{K Beams}) \tag{24}$$

The values used for the antenna beam -- target location two-way gain, GL(j), are given in Table I for the four beams shown in Figure 1. The values for target velocity used to compute the doppler frequency, ω_{di}, range from 105 knots to 195 knots in 10 knot intervals. This is considered a typical velocity range for a landing radar and spans at least one spectral PRF interval. Therefore, averaging over a larger velocity range would give the same result.

Tables VII through XVI give the probability of detection, Equation (23), for different values of target signal-to-noise ratios (referenced to target on beam center) and at different target velocities. Also given is the detection probability averaged over velocity, Equation (24). False alarm probability is 10^{-5}. Two PRFs were assumed and are indicated by T_1 and T_2. The beam-target location characteristics used are as follows for each designated beam.

BEAM	TWO-WAY GAIN		PRF
A	GA(j)	$t = 0$	T_1
B	GB(j)		T_2
C	GC(j)		T_2
D	GD(j)		T_1
E	GA(j)	t = 1/2 seconds	T_2
F	GB(j)		T_1
G	GC(j)		T_1
H	GD(j)		T_2

As indicated Tables VII through XVI include detection over the two, four, and eight strongest beams. They also include all four receiver cases analyzed with the following respective thresholds for a probability of false alarm of 10^{-5} per beam position

$$\gamma_1 = 6.46\sqrt{3N_o}$$

$$\gamma_2 = 23.0 \times 3N_o$$

$$\gamma_3 = 7.32\sqrt{3N_o}$$

$$\gamma_4 = 28.4 \times 3N_o$$

The values for ω_{di} corresponding to target radial velocities between 100 and 200 knots were obtained from the relation

$$\begin{aligned}\omega_{di} &= 4\pi\, v f_o/C \\ &= 194\, v_k\end{aligned}$$

where v is target velocity, C is the velocity of light, f_o is the carrier frequency, 9.01 GHz and v_k is target velocity in knots (nautical miles per hour).

Since the storage time of the scope is not known, the anlaysis was not carried out for more than 1 second, i.e., one complete round of looks, 2 scans.

Tables XVII through XX give the probability of detection for the target located at the center of beams A and E. The other beams are not considered for on-center performance in computing the data in Tables XVII through XX.

Tables XIX and XX are presented in a different format than the preceding tables. At the top of each group of data a signal-to-noise ratio is given as a direct power ratio (not in dB) followed by the receiver case being considered. The false alarm probability which appears on each page of data is the overall value for the two beams A&E, i.e., for one beam P_F is 5×10^{-7}. The first column of values represent the target velocity in knots; the second and third column of values denote the detection probabilities in Beam A and Beam E respectively, Equation (14); the fourth column denotes probability in either of the two beams, Equation (15); and the average probability at the bottom of each group of data denotes averaging only over velocity, Equation (16).

As expected, for I and Q processing a marked improvement is obtained as compared for I processing only with all probabilities of detection analyzed. The improvement is brought about by integration gain and diversity gain when going from the independent channels of "I Only" to twice as many independent channels of I and Q each. The improvement in the required signal-to-noise ratio for the particular average detection probability can be seen by comparing case 1 or 2 with case 3 or 4 of the tables. This is in general agreement with the literature[3, 4] for video integration of the two independent pulses versus video integration of four independent pulses. (Note that one video detected pulse must consist of two independent Gaussian components.)

As expected[5] the tables also show a slight improvement for square law detection, 2 and 4, compared to envelope detection, 1 and 3.

CONCLUSIONS

Tables XXI and XXII summarize the results of this analysis.

The values of S/N for a single beam center (unity weighting) obtained by Ward[6] using Barton[7] differed slightly from those obtained using Appendix A of this report. This difference is maintained after averaging the detection probability over all ten points of the coverage triangle in Beam A and/or Beam B. These values are shown in Table XXI.

In Table XXII it can be seen that failure to average the detection probability over velocity or beam coverage results in optimistic values for signal-to-noise ratio. For example, there is approximately a 4.0 dB difference between the MTI values obtained by Ward using an average velocity and those computed herein for Beams A and/or B, (AUB) (A union B). There is also a difference of about 2.0 dB in signal-to-noise ratio for beams AUE, on center as compared to target position averaging but in this case a similar difference is realized in the scan mode and so the MTI loss is unchanged.

The last set of conditions in Table XXII represent the most likely situation. Here the target is observed in two of the beams (AUB) during the first scan and again (EUF) during the second scan. Probability of detection has been averaged over beam coverage and over velocity. The MTI loss for false alarm probability of 10^{-5} per beam and overall detection probability of 75% is 8.0 dB for I^2 only MTI and 4.9 dB for $I^2 + Q^2$ MTI.

REFERENCES

1. H.L. VanTrees, *Detection, Estimation, and Modulation Theory,* New York, John Wiley and Sons, Inc., 1968, Section 4.4.2.

2. W.B. Davenport, Jr. and W.L. Root, *Random Signals and Noise,* New York, McGraw-Hill, 1958, pp 158-161.

3. F.E. Nathanson, *Radar Design Principles,* New York, McGraw-Hill, 1969, pp 81, 82.

4. P. Swerling, "Probability of Detection for Fluctuating Targets," *IRE Trans. Information Theory,* Vol IT-6, No. 4, pp 269-308, April 1960.

5. J.V. DiFranco and W.L. Rubin, *Radar Detection,* Englewood Cliffs, N.J., Prentice-Hall, Inc., 1968, pp 342, 343, 376.

6. H.R. Ward, "Maximum Range of the AN/TPN-19 PAR Scan Mode," Raytheon Memo No. HRW-172-B, EM-71-0516, 21 July 1971, Revised 30 August 1971.

7. D.K. Barton, "Simple Procedures for Radar Detection Calculations," *IEEE Trans. Aerospace and Electronic Systems,* Vol AES-5, No. 5, pp 837-846, September 1969.

```
                    TABLE  I
   ANTENNA BEAM -- TARGET LOCATION TWO WAY GAIN (DB)
-------------------------------------------------------------
   GA(1)=.08       GB(1)=10.66    GC(1)=10.80    GD(1)=21.00
   GA(2)=00.74     GB(2)= 8.26    GC(2)= 8.40    GD(2)=16.00
   GA(3)= 2.40     GB(3)= 6.90    GC(3)= 6.80    GD(3)=11.30
   GA(4)= 4.66     GB(4)= 6.02    GC(4)= 6.00    GD(4)= 7.20
   GA(5)= 0.46     GB(5)= 7.94    GC(5)=11.00    GD(5)=18.40
   GA(6)= 1.62     GB(6)= 6.12    GC(6)= 9.20    GD(6)=13.50
   GA(7)= 3.46     GB(7)= 4.96    GC(7)= 8.00    GD(7)= 9.50
   GA(8)= 1.20     GB(8)= 4.78    GC(8)=11.80    GD(8)=16.40
   GA(9)= 2.70     GB(9)= 4.24    GC(9)=10.10    GD(9)=11.80
  GA(10)= 2.30    GB(10)= 3.84   GC(10)=12.80   GD(10)=14.40
-------------------------------------------------------------
```

TABLE II

DETECTION PROBABILITY FOR SCAN MODE

Beam Number A

N = 3   M = 2

False Alarm Probability

S/N RATIO	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
	16.45	19.55	22.53	25.41	28.22
2.10	0.2208	0.1331	0.0810	0.0499	0.0310
2.20	0.2282	0.1390	0.0854	0.0531	0.0333
2.30	0.2358	0.1450	0.0900	0.0565	0.0358
2.40	0.2435	0.1513	0.0948	0.0600	0.0383
2.50	0.2514	0.1577	0.0997	0.0637	0.0410
2.60	0.2593	0.1642	0.1048	0.0676	0.0439
2.70	0.2674	0.1710	0.1101	0.0716	0.0469
2.80	0.2757	0.1779	0.1156	0.0758	0.0501
2.90	0.2840	0.1849	0.1212	0.0802	0.0534
3.00	0.2925	0.1922	0.1270	0.0847	0.0569
3.10	0.3010	0.1996	0.1331	0.0895	0.0606
3.20	0.3097	0.2071	0.1393	0.0944	0.0644
3.30	0.3185	0.2148	0.1456	0.0995	0.0684
3.40	0.3274	0.2227	0.1522	0.1048	0.0726
3.50	0.3363	0.2307	0.1589	0.1103	0.0770
3.60	0.3454	0.2389	0.1659	0.1160	0.0816
3.70	0.3545	0.2472	0.1730	0.1218	0.0863
3.80	0.3637	0.2556	0.1802	0.1279	0.0912
3.90	0.3730	0.2642	0.1877	0.1341	0.0964
4.00	0.3823	0.2729	0.1953	0.1406	0.1017
4.10	0.3917	0.2817	0.2031	0.1472	0.1072
4.20	0.4011	0.2906	0.2110	0.1540	0.1129
4.30	0.4106	0.2997	0.2191	0.1610	0.1188
4.40	0.4201	0.3088	0.2274	0.1682	0.1249
4.50	0.4296	0.3181	0.2358	0.1756	0.1312
4.60	0.4392	0.3274	0.2444	0.1831	0.1377
4.70	0.4488	0.3369	0.2531	0.1909	0.1444
4.80	0.4584	0.3464	0.2619	0.1988	0.1513
4.90	0.4680	0.3560	0.2709	0.2068	0.1584
5.00	0.4776	0.3656	0.2800	0.2151	0.1656
5.10	0.4872	0.3754	0.2892	0.2235	0.1731
5.20	0.4968	0.3852	0.2985	0.2320	0.1807
5.30	0.5064	0.3950	0.3080	0.2407	0.1886
5.40	0.5159	0.4049	0.3175	0.2496	0.1966
5.50	0.5254	0.4148	0.3272	0.2586	0.2047
5.60	0.5349	0.4247	0.3369	0.2677	0.2131
5.70	0.5444	0.4347	0.3467	0.2770	0.2216
5.80	0.5538	0.4447	0.3566	0.2863	0.2303
5.90	0.5631	0.4547	0.3665	0.2958	0.2391

TABLE II (Continued)

DETECTION PROBABILITY FOR SCAN MODE

Beam Number A

N = 3, M = 2

False Alarm Probability

S/N Ratio	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
6.00	0.5724	0.4647	0.3766	0.3055	0.2481
6.10	0.5816	0.4746	0.3866	0.3152	0.2572
6.20	0.5908	0.4846	0.3967	0.3250	0.2665
6.30	0.5999	0.4946	0.4069	0.3349	0.2758
6.40	0.6089	0.5045	0.4171	0.3449	0.2854
6.50	0.6178	0.5144	0.4273	0.3549	0.2950
6.60	0.6266	0.5242	0.4375	0.3651	0.3047
6.70	0.6354	0.5341	0.4477	0.3753	0.3146
6.80	0.6441	0.5438	0.4579	0.3855	0.3246
6.90	0.6526	0.5535	0.4681	0.3958	0.3346
7.00	0.6611	0.5632	0.4784	0.4061	0.3447
7.10	0.6694	0.5728	0.4885	0.4165	0.3549
7.20	0.6777	0.5823	0.4987	0.4268	0.3652
7.30	0.6858	0.5917	0.5088	0.4372	0.3755
7.40	0.6939	0.6010	0.5189	0.4476	0.3859
7.50	0.7018	0.6103	0.5290	0.4580	0.3963
7.60	0.7096	0.6195	0.5390	0.4684	0.4067
7.70	0.7172	0.6285	0.5489	0.4787	0.4172
7.80	0.7248	0.6375	0.5588	0.4891	0.4277
7.90	0.7322	0.6464	0.5686	0.4994	0.4382
8.00	0.7395	0.6551	0.5783	0.5097	0.4487
8.10	0.7467	0.6638	0.5879	0.5199	0.4592
8.20	0.7538	0.6723	0.5975	0.5301	0.4697
8.30	0.7607	0.6807	0.6069	0.5402	0.4802
8.40	0.7675	0.6890	0.6163	0.5502	0.4907
8.50	0.7741	0.6972	0.6255	0.5602	0.5011
8.60	0.7807	0.7053	0.6347	0.5701	0.5114
8.70	0.7871	0.7132	0.6437	0.5800	0.5218
8.80	0.7933	0.7210	0.6527	0.5897	0.5320
8.90	0.7995	0.7286	0.6615	0.5993	0.5422
9.00	0.8055	0.7361	0.6702	0.6089	0.5524
9.10	0.8114	0.7435	0.6788	0.6183	0.5624
9.20	0.8171	0.7508	0.6872	0.6277	0.5724
9.30	0.8227	0.7579	0.6955	0.6369	0.5823
9.40	0.8282	0.7649	0.7037	0.6460	0.5921
9.50	0.8336	0.7717	0.7118	0.6550	0.6018
9.60	0.8388	0.7784	0.7197	0.6639	0.6114
9.70	0.8439	0.7850	0.7275	0.6727	0.6209
9.80	0.8489	0.7914	0.7351	0.6813	0.6303
9.90	0.8538	0.7977	0.7426	0.6898	0.6396

TABLE II (Continued)

DETECTION PROBABILITY FOR SCAN MODE

Beam Number A

N = 3   M = 2

False Alarm Probability

S/N Ratio	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
10.00	0.8565	0.8039	0.7500	0.6981	0.6487
10.10	0.8631	0.8099	0.7572	0.7064	0.6578
10.20	0.8676	0.8158	0.7643	0.7144	0.6667
10.30	0.8720	0.8215	0.7712	0.7224	0.6755
10.40	0.8762	0.8271	0.7780	0.7302	0.6841
10.50	0.8804	0.8326	0.7847	0.7379	0.6926
10.60	0.8844	0.8379	0.7912	0.7454	0.7010
10.70	0.8883	0.8431	0.7975	0.7527	0.7092
10.80	0.8921	0.8482	0.8038	0.7600	0.7173
10.90	0.8958	0.8531	0.8098	0.7671	0.7253
11.00	0.8994	0.8580	0.8158	0.7740	0.7331
11.10	0.9029	0.8626	0.8216	0.7808	0.7407
11.20	0.9063	0.8672	0.8272	0.7874	0.7482
11.30	0.9096	0.8717	0.8328	0.7939	0.7556
11.40	0.9128	0.8760	0.8381	0.8003	0.7628
11.50	0.9159	0.8802	0.8434	0.8065	0.7699
11.60	0.9189	0.8843	0.8485	0.8125	0.7768
11.70	0.9218	0.8882	0.8535	0.8184	0.7835
11.80	0.9246	0.8921	0.8583	0.8242	0.7902
11.90	0.9273	0.8958	0.8631	0.8299	0.7966
12.00	0.9300	0.8995	0.8676	0.8353	0.8030

TABLE III

DETECTION PROBABILITY FOR SCAN MODE

Beam Numbers A and B

N = 3 M = 2

False Alarm Probability

S/N Ratio	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
	16.45	19.55	22.53	25.41	28.22
2.10	0.2543	0.1468	0.0865	0.0521	0.0319
2.20	0.2631	0.1535	0.0913	0.0555	0.0343
2.30	0.2720	0.1604	0.0964	0.0591	0.0369
2.40	0.2811	0.1675	0.1016	0.0629	0.0396
2.50	0.2903	0.1746	0.1070	0.0668	0.0424
2.60	0.2997	0.1823	0.1127	0.0710	0.0454
2.70	0.3093	0.1900	0.1185	0.0753	0.0486
2.80	0.3190	0.1979	0.1246	0.0798	0.0519
2.90	0.3289	0.2061	0.1309	0.0846	0.0554
3.00	0.3389	0.2144	0.1374	0.0895	0.0591
3.10	0.3491	0.2230	0.1441	0.0947	0.0630
3.20	0.3594	0.2317	0.1511	0.1000	0.0671
3.30	0.3698	0.2407	0.1582	0.1056	0.0714
3.40	0.3803	0.2498	0.1656	0.1114	0.0759
3.50	0.3909	0.2592	0.1733	0.1174	0.0806
3.60	0.4017	0.2687	0.1811	0.1237	0.0855
3.70	0.4125	0.2784	0.1892	0.1302	0.0906
3.80	0.4234	0.2883	0.1975	0.1369	0.0959
3.90	0.4344	0.2983	0.2060	0.1438	0.1015
4.00	0.4454	0.3086	0.2147	0.1510	0.1072
4.10	0.4565	0.3190	0.2236	0.1584	0.1132
4.20	0.4677	0.3295	0.2328	0.1660	0.1195
4.30	0.4789	0.3402	0.2421	0.1739	0.1260
4.40	0.4901	0.3510	0.2517	0.1820	0.1327
4.50	0.5014	0.3620	0.2615	0.1903	0.1396
4.60	0.5127	0.3731	0.2714	0.1989	0.1468
4.70	0.5239	0.3843	0.2816	0.2076	0.1542
4.80	0.5352	0.3956	0.2919	0.2166	0.1619
4.90	0.5464	0.4070	0.3024	0.2259	0.1698
5.00	0.5576	0.4184	0.3131	0.2353	0.1779

TABLE III (Continued)

DETECTION PROBABILITY FOR SCAN MODE

Beam Numbers A and B

N = 3   M = 2

False Alarm Probability

S/N Ratio	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
5.10	0.5688	0.4300	0.3239	0.2450	0.1863
5.20	0.5800	0.4416	0.3349	0.2548	0.1949
5.30	0.5910	0.4533	0.3460	0.2649	0.2037
5.40	0.6021	0.4650	0.3573	0.2752	0.2128
5.50	0.6130	0.4768	0.3687	0.2856	0.2221
5.60	0.6239	0.4886	0.3802	0.2963	0.2316
5.70	0.6346	0.5004	0.3918	0.3071	0.2414
5.80	0.6453	0.5122	0.4036	0.3181	0.2513
5.90	0.6558	0.5240	0.4154	0.3292	0.2615
6.00	0.6663	0.5358	0.4273	0.3405	0.2719
6.10	0.6766	0.5476	0.4392	0.3520	0.2824
6.20	0.6868	0.5593	0.4513	0.3635	0.2932
6.30	0.6968	0.5709	0.4633	0.3752	0.3041
6.40	0.7067	0.5825	0.4754	0.3871	0.3152
6.50	0.7165	0.5941	0.4875	0.3990	0.3265
6.60	0.7261	0.6055	0.4997	0.4110	0.3380
6.70	0.7355	0.6169	0.5118	0.4231	0.3495
6.80	0.7447	0.6281	0.5239	0.4353	0.3613
6.90	0.7538	0.6393	0.5360	0.4475	0.3731
7.00	0.7627	0.6503	0.5481	0.4598	0.3851
7.10	0.7714	0.6612	0.5601	0.4721	0.3971
7.20	0.7800	0.6720	0.5720	0.4844	0.4093
7.30	0.7883	0.6826	0.5839	0.4967	0.4215
7.40	0.7965	0.6930	0.5957	0.5091	0.4339
7.50	0.8044	0.7034	0.6074	0.5214	0.4462
7.60	0.8122	0.7135	0.6190	0.5337	0.4587
7.70	0.8198	0.7234	0.6305	0.5459	0.4711
7.80	0.8271	0.7332	0.6419	0.5582	0.4836
7.90	0.8343	0.7428	0.6531	0.5703	0.4961
8.00	0.8412	0.7522	0.6642	0.5824	0.5086
8.10	0.8480	0.7615	0.6751	0.5944	0.5210
8.20	0.8546	0.7705	0.6859	0.6063	0.5335
8.30	0.8609	0.7793	0.6966	0.6181	0.5459
8.40	0.8671	0.7879	0.7070	0.6297	0.5582
8.50	0.8731	0.7963	0.7173	0.6413	0.5705
8.60	0.8788	0.8045	0.7274	0.6527	0.5827
8.70	0.8844	0.8125	0.7373	0.6639	0.5948
8.80	0.8898	0.8202	0.7470	0.6750	0.6069
8.90	0.8950	0.8278	0.7565	0.6860	0.6188

TABLE III (Continued)

DETECTION PROBABILITY FOR SCAN MODE

Beam Numbers A and B

N = 3   M = 2

	False Alarm Probability				
S/N Ratio	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
9.00	0.9000	0.8351	0.7658	0.6968	0.6306
9.10	0.9048	0.8422	0.7748	0.7073	0.6422
9.20	0.9095	0.8491	0.7837	0.7177	0.6537
9.30	0.9139	0.8558	0.7924	0.7280	0.6651
9.40	0.9182	0.8623	0.8008	0.7380	0.6763
9.50	0.9224	0.8686	0.8090	0.7478	0.6873
9.60	0.9263	0.8746	0.8170	0.7574	0.6981
9.70	0.9301	0.8805	0.8248	0.7668	0.7088
9.80	0.9338	0.8861	0.8323	0.7759	0.7193
9.90	0.9372	0.8916	0.8396	0.7849	0.7296
10.00	0.9406	0.8968	0.8467	0.7936	0.7396
10.10	0.9438	0.9019	0.8536	0.8021	0.7495
10.20	0.9468	0.9067	0.8602	0.8103	0.7591
10.30	0.9497	0.9114	0.8667	0.8184	0.7685
10.40	0.9525	0.9159	0.8729	0.8262	0.7777
10.50	0.9551	0.9202	0.8789	0.8338	0.7867
10.60	0.9576	0.9243	0.8847	0.8411	0.7955
10.70	0.9600	0.9283	0.8902	0.8482	0.8040
10.80	0.9623	0.9321	0.8956	0.8551	0.8123
10.90	0.9645	0.9357	0.9008	0.8618	0.8203
11.00	0.9666	0.9392	0.9057	0.8682	0.8281
11.10	0.9685	0.9425	0.9105	0.8745	0.8357
11.20	0.9704	0.9456	0.9151	0.8805	0.8430
11.30	0.9721	0.9486	0.9195	0.8862	0.8502
11.40	0.9738	0.9515	0.9237	0.8918	0.8570
11.50	0.9754	0.9542	0.9277	0.8972	0.8637
11.60	0.9769	0.9568	0.9316	0.9023	0.8701
11.70	0.9783	0.9593	0.9352	0.9073	0.8763
11.80	0.9796	0.9617	0.9388	0.9120	0.8823
11.90	0.9809	0.9639	0.9421	0.9166	0.8880
12.00	0.9821	0.9660	0.9453	0.9209	0.8936

TABLE IV

DETECTION PROBABILITY FOR SCAN MODE

Beam Numbers A, B, E, and F

N = 3 M = 2

False Alarm Probability

S/N Ratio	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
S/N RATIO	16.45	19.55	22.53	25.41	28.22
2.10	0.4371	0.2676	0.1630	0.1002	0.0622
2.20	0.4498	0.2787	0.1716	0.1065	0.0668
2.30	0.4626	0.2900	0.1805	0.1132	0.0716
2.40	0.4755	0.3016	0.1897	0.1201	0.0766
2.50	0.4885	0.3134	0.1992	0.1273	0.0820
2.60	0.5015	0.3254	0.2090	0.1348	0.0876
2.70	0.5146	0.3377	0.2190	0.1427	0.0934
2.80	0.5277	0.3501	0.2294	0.1508	0.0997
2.90	0.5408	0.3628	0.2401	0.1593	0.1063
3.00	0.5539	0.3757	0.2511	0.1681	0.1131
3.10	0.5670	0.3887	0.2623	0.1772	0.1202
3.20	0.5801	0.4019	0.2739	0.1866	0.1276
3.30	0.5931	0.4153	0.2857	0.1963	0.1354
3.40	0.6061	0.4288	0.2977	0.2064	0.1435
3.50	0.6190	0.4424	0.3100	0.2168	0.1519
3.60	0.6318	0.4561	0.3226	0.2274	0.1606
3.70	0.6445	0.4699	0.3354	0.2384	0.1697
3.80	0.6571	0.4838	0.3484	0.2497	0.1791
3.90	0.6696	0.4977	0.3616	0.2613	0.1888
4.00	0.6819	0.5117	0.3751	0.2732	0.1988
4.10	0.6940	0.5257	0.3887	0.2853	0.2092
4.20	0.7060	0.5397	0.4024	0.2977	0.2199
4.30	0.7177	0.5537	0.4163	0.3104	0.2309
4.40	0.7293	0.5676	0.4304	0.3233	0.2423
4.50	0.7407	0.5815	0.4446	0.3365	0.2539
4.60	0.7518	0.5953	0.4588	0.3499	0.2658
4.70	0.7627	0.6091	0.4732	0.3635	0.2781
4.80	0.7733	0.6227	0.4876	0.3773	0.2906
4.90	0.7837	0.6362	0.5020	0.3913	0.3033
5.00	0.7939	0.6496	0.5165	0.4054	0.3164

TABLE IV (Continued)

DETECTION PROBABILITY FOR SCAN MODE

Beam Numbers A, B, E, and F

N = 3 M = 2

	False Alarm Probability				
S/N Ratio	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
5.10	0.8038	0.6628	0.5310	0.4197	0.3297
5.20	0.8134	0.6759	0.5455	0.4341	0.3432
5.30	0.8227	0.6887	0.5599	0.4487	0.3569
5.40	0.8317	0.7014	0.5743	0.4633	0.3709
5.50	0.8405	0.7138	0.5886	0.4780	0.3850
5.60	0.8490	0.7260	0.6029	0.4928	0.3994
5.70	0.8572	0.7380	0.6170	0.5076	0.4138
5.80	0.8651	0.7497	0.6310	0.5224	0.4284
5.90	0.8727	0.7612	0.6448	0.5372	0.4432
6.00	0.8800	0.7724	0.6585	0.5519	0.4580
6.10	0.8870	0.7833	0.6720	0.5667	0.4729
6.20	0.8937	0.7939	0.6853	0.5813	0.4879
6.30	0.9002	0.8042	0.6984	0.5959	0.5029
6.40	0.9063	0.8142	0.7112	0.6103	0.5179
6.50	0.9122	0.8239	0.7238	0.6247	0.5329
6.60	0.9178	0.8333	0.7362	0.6388	0.5479
6.70	0.9232	0.8424	0.7482	0.6529	0.5629
6.80	0.9283	0.8511	0.7600	0.6667	0.5778
6.90	0.9331	0.8595	0.7715	0.6803	0.5926
7.00	0.9377	0.8676	0.7827	0.6937	0.6072
7.10	0.9420	0.8754	0.7936	0.7069	0.6218
7.20	0.9461	0.8829	0.8042	0.7198	0.6362
7.30	0.9500	0.8901	0.8145	0.7324	0.6504
7.40	0.9536	0.8969	0.8244	0.7448	0.6645
7.50	0.9570	0.9034	0.8340	0.7569	0.6783
7.60	0.9603	0.9097	0.8432	0.7686	0.6919
7.70	0.9633	0.9156	0.8521	0.7801	0.7052
7.80	0.9661	0.9212	0.8607	0.7912	0.7183
7.90	0.9688	0.9266	0.8690	0.8021	0.7312

TABLE IV (Continued)

DETECTION PROBABILITY FOR SCAN MODE

Beam Numbers A, B, E, and F

N = 3 M = 2

	False Alarm Probability				
S/N Ratio	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
8.00	0.9713	0.9317	0.8769	0.8125	0.7437
8.10	0.9736	0.9365	0.8844	0.8227	0.7560
8.20	0.9757	0.9410	0.8917	0.8325	0.7679
8.30	0.9778	0.9453	0.8986	0.8419	0.7795
8.40	0.9796	0.9493	0.9052	0.8510	0.7908
8.50	0.9814	0.9531	0.9114	0.8598	0.8017
8.60	0.9830	0.9567	0.9174	0.8682	0.8123
8.70	0.9845	0.9600	0.9231	0.8762	0.8226
8.80	0.9858	0.9631	0.9284	0.8839	0.8325
8.90	0.9871	0.9661	0.9335	0.8913	0.8421
9.00	0.9883	0.9688	0.9383	0.8983	0.8512
9.10	0.9893	0.9714	0.9428	0.9050	0.8601
9.20	0.9903	0.9737	0.9471	0.9114	0.8685
9.30	0.9912	0.9759	0.9511	0.9174	0.8767
9.40	0.9921	0.9780	0.9548	0.9231	0.8844
9.50	0.9928	0.9799	0.9583	0.9286	0.8918
9.60	0.9935	0.9816	0.9616	0.9337	0.8989
9.70	0.9942	0.9833	0.9647	0.9385	0.9056
9.80	0.9947	0.9848	0.9676	0.9431	0.9120
9.90	0.9953	0.9862	0.9703	0.9474	0.9181
10.00	0.9957	0.9874	0.9728	0.9514	0.9238
10.10	0.9962	0.9886	0.9751	0.9552	0.9293
10.20	0.9966	0.9897	0.9772	0.9587	0.9344
10.30	0.9969	0.9906	0.979	0.9620	0.9393
10.40	0.9972	0.9915	0.9810	0.9651	0.9438
10.50	0.9975	0.9924	0.9827	0.9680	0.9481
10.60	0.9978	0.9931	0.9843	0.9707	0.9521
10.70	FY				

TABLE V

DETECTION PROBABILITY FOR SCAN MODE

Beam Number A

N = 3 M = 2 Center (No Beam Averaging)

	False Alarm Probability				
S/N Ratio	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
	16.45	19.55	22.53	25.41	28.22
2.10	0.3813	0.2646	0.1822	0.1252	0.0858
2.20	0.3914	0.2740	0.1904	0.1319	0.0911
2.30	0.4015	0.2835	0.1987	0.1389	0.0968
2.40	0.4116	0.2932	0.2073	0.1460	0.1026
2.50	0.4218	0.3030	0.2160	0.1535	0.1087
2.60	0.4320	0.3129	0.2249	0.1611	0.1151
2.70	0.4422	0.3230	0.2340	0.1689	0.1216
2.80	0.4525	0.3331	0.2433	0.1770	0.1284
2.90	0.4628	0.3433	0.2527	0.1853	0.1355
3.00	0.4730	0.3536	0.2623	0.1938	0.1428
3.10	0.4833	0.3641	0.2720	0.2025	0.1503
3.20	0.4936	0.3745	0.2819	0.2114	0.1580
3.30	0.5038	0.3851	0.2920	0.2205	0.1660
3.40	0.5140	0.3957	0.3021	0.2298	0.1742
3.50	0.5242	0.4063	0.3124	0.2393	0.1826
3.60	0.5343	0.4170	0.3228	0.2489	0.1912
3.70	0.5443	0.4277	0.3333	0.2587	0.2001
3.80	0.5544	0.4384	0.3439	0.2687	0.2091
3.90	0.5643	0.4491	0.3546	0.2788	0.2184
4.00	0.5742	0.4598	0.3654	0.2890	0.2278
4.10	0.5840	0.4706	0.3762	0.2994	0.2374
4.20	0.5937	0.4813	0.3871	0.3099	0.2472
4.30	0.6033	0.4919	0.3980	0.3205	0.2572
4.40	0.6129	0.5026	0.4090	0.3313	0.2674
4.50	0.6223	0.5132	0.4199	0.3421	0.2776
4.60	0.6316	0.5238	0.4310	0.3530	0.2881
4.70	0.6409	0.5343	0.4420	0.3640	0.2986
4.80	0.6500	0.5447	0.4530	0.3750	0.3093
4.90	0.6590	0.5551	0.4640	0.3861	0.3201
5.00	0.6678	0.5653	0.4750	0.3973	0.3310

TABLE V (Continued)

DETECTION PROBABILITY FOR SCAN MODE

Beam Number A

N = 3   M = 2   Center (No Beam Averaging)

S/N Ratio	False Alarm Probability 10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
5.10	0.6766	0.5756	0.4860	0.4085	0.3420
5.20	0.6852	0.5857	0.4969	0.4197	0.3531
5.30	0.6937	0.5957	0.5078	0.4309	0.3643
5.40	0.7021	0.6056	0.5186	0.4421	0.3755
5.50	0.7103	0.6154	0.5294	0.4533	0.3868
5.60	0.7184	0.6251	0.5401	0.4646	0.3981
5.70	0.7263	0.6347	0.5507	0.4757	0.4094
5.80	0.7341	0.6441	0.5613	0.4869	0.4208
5.90	0.7418	0.6534	0.5717	0.4980	0.4322
6.00	0.7493	0.6626	0.5821	0.5090	0.4435
6.10	0.7566	0.6717	0.5923	0.5200	0.4549
6.20	0.7638	0.6806	0.6025	0.5310	0.4663
6.30	0.7709	0.6894	0.6123	0.5418	0.4776
6.40	0.7778	0.6980	0.6224	0.5526	0.4888
6.50	0.7846	0.7065	0.6322	0.5633	0.5001
6.60	0.7912	0.7148	0.6418	0.5738	0.5112
6.70	0.7977	0.7230	0.6513	0.5843	0.5223
6.80	0.8040	0.7310	0.6607	0.5947	0.5334
6.90	0.8102	0.7389	0.6699	0.6049	0.5443
7.00	0.8162	0.7466	0.6798	0.6150	0.5552
7.10	0.8221	0.7542	0.6880	0.6250	0.5659
7.20	0.8278	0.7616	0.6967	0.6349	0.5766
7.30	0.8334	0.7689	0.7054	0.6446	0.5871
7.40	0.8389	0.7760	0.7138	0.6542	0.5976
7.50	0.8442	0.7829	0.7222	0.6636	0.6079
7.60	0.8494	0.7897	0.7303	0.6729	0.6180
7.70	0.8544	0.7963	0.7383	0.6820	0.6281
7.80	0.8593	0.8028	0.7461	0.6910	0.6380
7.90	0.8641	0.8091	0.7538	0.6998	0.6478
8.00	0.8687	0.8152	0.7613	0.7085	0.6574

TABLE V (Continued)

DETECTION PROBABILITY FOR SCAN MODE

Beam Number A

N = 3   M = 2

Center (No Beam Averaging)

	False Alarm Probability				
S/N Ratio	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
8.10	0.8732	0.8212	0.7687	0.7170	0.6668
8.20	0.8776	0.8271	0.7759	0.7253	0.6761
8.30	0.8819	0.8328	0.7829	0.7335	0.6853
8.40	0.8860	0.8384	0.7897	0.7415	0.6943
8.50	0.8900	0.8438	0.7964	0.7493	0.7031
8.60	0.8939	0.8490	0.8030	0.7570	0.7118
8.70	0.8977	0.8541	0.8093	0.7645	0.7203
8.80	0.9013	0.8591	0.8156	0.7718	0.7286
8.90	0.9049	0.8640	0.8216	0.7790	0.7367
9.00	0.9083	0.8687	0.8275	0.7860	0.7447
9.10	0.9116	0.8732	0.8333	0.7929	0.7525
9.20	0.9148	0.8777	0.8388	0.7995	0.7602
9.30	0.9180	0.8820	0.8443	0.8060	0.7677
9.40	0.9210	0.8861	0.8496	0.8124	0.7750
9.50	0.9239	0.8902	0.8547	0.8185	0.7821
9.60	0.9267	0.8941	0.8597	0.8246	0.7891
9.70	0.9295	0.8979	0.8646	0.8304	0.7959
9.80	0.9321	0.9016	0.8693	0.8361	0.8025
9.90	0.9347	0.9052	0.8739	0.8417	0.8090
10.00	0.9371	0.9086	0.8783	0.8471	0.8153
10.10	0.9395	0.9120	0.8827	0.8523	0.8214
10.20	0.9418	0.9152	0.8868	0.8574	0.8274
10.30	0.9440	0.9184	0.8909	0.8624	0.8332
10.40	0.9462	0.9214	0.8948	0.8672	0.8388
10.50	0.9483	0.9243	0.8986	0.8719	0.8443
10.60	0.9503	0.9272	0.9023	0.8764	0.8497
10.70	0.9522	0.9299	0.9059	0.8808	0.8549
10.80	0.9540	0.9326	0.9094	0.8851	0.8599
10.90	0.9558	0.9351	0.9127	0.8892	0.8648
11.00	0.9576	0.9376	0.9159	0.8932	0.8696
11.10	0.9592	0.9400	0.9191	0.8971	0.8742
11.20	0.9608	0.9423	0.9221	0.9008	0.8787
11.30	0.9624	0.9445	0.9250	0.9045	0.8830
11.40	0.9639	0.9467	0.9279	0.9080	0.8872
11.50	0.9653	0.9487	0.9306	0.9114	0.8913
11.60	0.9667	0.9507	0.9332	0.9147	0.8953
11.70	0.9680	0.9526	0.9358	0.9179	0.8991
11.80	0.9693	0.9545	0.9382	0.9210	0.9028
11.90	0.9705	0.9563	0.9406	0.9239	0.9064
12.00	0.9717	0.9580	0.9429	0.9268	0.9099

TABLE VI

DETECTION PROBABILITY FOR SCAN MODE

Beam Numbers A and E

N = 3   M = 2   Center (No Beam Averaging)

	False Alarm Probability				
S/N Ratio	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
	16.45	19.55	22.53	25.41	28.22
2.10	0.6172	0.4592	0.3313	0.2347	0.1641
2.20	0.6296	0.4729	0.3445	0.2464	0.1740
2.30	0.6417	0.4867	0.3580	0.2584	0.1842
2.40	0.6538	0.5004	0.3716	0.2708	0.1947
2.50	0.6657	0.5142	0.3853	0.2834	0.2056
2.60	0.6774	0.5279	0.3992	0.2962	0.2169
2.70	0.6889	0.5416	0.4132	0.3094	0.2285
2.80	0.7002	0.5552	0.4274	0.3227	0.2404
2.90	0.7114	0.5688	0.4415	0.3363	0.2526
3.00	0.7223	0.5822	0.4558	0.3501	0.2651
3.10	0.7330	0.5956	0.4701	0.3640	0.2780
3.20	0.7435	0.6088	0.4844	0.3781	0.2911
3.30	0.7538	0.6219	0.4987	0.3924	0.3044
3.40	0.7638	0.6348	0.5130	0.4068	0.3180
3.50	0.7736	0.6475	0.5272	0.4213	0.3319
3.60	0.7831	0.6601	0.5414	0.4358	0.3459
3.70	0.7924	0.6724	0.5555	0.4505	0.3601
3.80	0.8014	0.6846	0.5696	0.4651	0.3745
3.90	0.8102	0.6965	0.5835	0.4798	0.3891
4.00	0.8187	0.7082	0.5972	0.4945	0.4037
4.10	0.8269	0.7197	0.6108	0.5092	0.4155
4.20	0.8349	0.7309	0.6243	0.5238	0.4334
4.30	0.8427	0.7419	0.6376	0.5383	0.4483
4.40	0.8501	0.7526	0.6507	0.5528	0.4632
4.50	0.8573	0.7630	0.6635	0.5672	0.4782
4.60	0.8643	0.7732	0.6762	0.5814	0.4932
4.70	0.8710	0.7831	0.6886	0.5955	0.5081
4.80	0.8775	0.7927	0.7008	0.6094	0.5230
4.90	0.8837	0.8020	0.7127	0.6232	0.5378
5.00	0.8897	0.8111	0.7244	0.6367	0.5525

TABLE VI (Continued)

DETECTION PROBABILITY FOR SCAN MODE

Beam Numbers A and E

N = 3   M = 2   Center (No Beam Averaging)

	False Alarm Probability				
S/N Ratio	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
5.10	0.8954	0.8198	0.7358	0.6501	0.5671
5.20	0.9009	0.8283	0.7469	0.6632	0.5815
5.30	0.9062	0.8365	0.7577	0.6761	0.5959
5.40	0.9112	0.8444	0.7683	0.6888	0.6100
5.50	0.9161	0.8521	0.7785	0.7012	0.6239
5.60	0.9207	0.8594	0.7885	0.7133	0.6377
5.70	0.9251	0.8665	0.7981	0.7251	0.6512
5.80	0.9293	0.8733	0.8075	0.7367	0.6645
5.90	0.9333	0.8799	0.8166	0.7480	0.6776
6.00	0.9371	0.8862	0.8253	0.7590	0.6904
6.10	0.9408	0.8922	0.8338	0.7696	0.7029
6.20	0.9442	0.8980	0.8420	0.7800	0.7151
6.30	0.9475	0.9035	0.8498	0.7901	0.7271
6.40	0.9506	0.9088	0.8574	0.7998	0.7387
6.50	0.9536	0.9139	0.8647	0.8093	0.7501
6.60	0.9564	0.9187	0.8717	0.8184	0.7611
6.70	0.9591	0.9233	0.8784	0.8272	0.7718
6.80	0.9616	0.9277	0.8849	0.8357	0.7823
6.90	0.9640	0.9318	0.8911	0.8439	0.7924
7.00	0.9662	0.9358	0.8970	0.8518	0.8021
7.10	0.9684	0.9396	0.9026	0.8594	0.8116
7.20	0.9704	0.9432	0.9080	0.8667	0.8207
7.30	0.9723	0.9466	0.9132	0.8737	0.8295
7.40	0.9740	0.9498	0.9181	0.8804	0.8380
7.50	0.9757	0.9529	0.9228	0.8868	0.8462
7.60	0.9773	0.9558	0.9273	0.8930	0.8541
7.70	0.9788	0.9585	0.9315	0.8989	0.8617
7.80	0.9802	0.9611	0.9356	0.9045	0.8690
7.90	0.9815	0.9636	0.9394	0.9099	0.8759
8.00	0.9828	0.9659	0.9430	0.9150	0.8826
8.10	0.9839	0.9680	0.9465	0.9199	0.8890

TABLE VI (Continued)

DETECTION PROBABILITY FOR SCAN MODE

Beam Numbers A and E

N = 3 M = 2 Center (No Beam Averaging)

S/N Ratio	False Alarm Probability 10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
8.20	0.9850	0.9701	0.9498	0.9246	0.8951
8.30	0.9860	0.9720	0.9529	0.9290	0.9010
8.40	0.9870	0.9739	0.9558	0.9332	0.9065
8.50	0.9879	0.9756	0.9586	0.9372	0.9118
8.60	0.9887	0.9772	0.9612	0.9410	0.9169
8.70	0.9895	0.9787	0.9636	0.9445	0.9217
8.80	0.9903	0.9802	0.9660	0.9479	0.9263
8.90	0.9909	0.9815	0.9682	0.9512	0.9307
9.00	0.9916	0.9827	0.9702	0.9542	0.9348
9.10	0.9922	0.9839	0.9722	0.9571	0.9388
9.20	0.9927	0.9850	0.9740	0.9598	0.9425
9.30	0.9933	0.9861	0.9758	0.9624	0.9460
9.40	0.9938	0.9870	0.9774	0.9648	0.9494
9.50	0.9942	0.9879	0.9789	0.9671	0.9525
9.60	0.9946	0.9888	0.9803	0.9692	0.9555
9.70	0.9950	0.9896	0.9817	0.9712	0.9583
9.80	0.9954	0.9903	0.9829	0.9731	0.9610
9.90	0.9957	0.9910	0.9841	0.9749	0.9635
10.00	0.9960	0.9917	0.9852	0.9766	0.9659
10.10	0.9963	0.9923	0.9862	0.9782	0.9681
10.20	0.9966	0.9928	0.9872	0.9797	0.9702
10.30	0.9969	0.9933	0.9881	0.9811	0.9722
10.40	0.9971	0.9938	0.9889	0.9824	0.9740
10.50	0.9973	0.9943	0.9897	0.9836	0.9758
10.60	0.9975	0.9947	0.9905	0.9847	0.9774
10.70	0.9977	0.9951	0.9911	0.9858	0.9789
10.80	0.9979	0.9955	0.9918	0.9868	0.9804
10.90	0.9980	0.9958	0.9924	0.9877	0.9817
11.00	0.9982	0.9961	0.9929	0.9886	0.9830
11.10	0.9983	0.9964	0.9935	0.9894	0.9842
11.20	0.9985	0.9967	0.9939	0.9902	0.9853
11.30	0.9986	0.9969	0.9944	0.9909	0.9863
11.40	0.9987	0.9972	0.9948	0.9915	0.9873
11.50	0.9988	0.9974	0.9952	0.9921	0.9882
11.60	0.9989	0.9976	0.9955	0.9927	0.9890
11.70	0.9990	0.9978	0.9959	0.9933	0.9898
11.80	0.9991	0.9979	0.9962	0.9938	0.9906
11.90	0.9991	0.9981	0.9965	0.9942	0.9912
12.00	0.9992	0.9982	0.9967	0.9946	0.9919

TABLE VII

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B $T_1 = 1/4010$ $T_2 = 1/2645$

$P_F = 10^{-5}$

FOR RECEIVER CASE 1

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.000	0.001	0.002	0.006	0.021	0.062
115.	0.000	0.001	0.004	0.012	0.036	0.088	0.176
125.	0.001	0.004	0.013	0.037	0.090	0.180	0.302
135.	0.001	0.003	0.010	0.031	0.078	0.161	0.279
145.	0.000	0.001	0.002	0.006	0.020	0.053	0.120
155.	0.000	0.000	0.000	0.001	0.005	0.018	0.051
165.	0.001	0.002	0.008	0.025	0.067	0.147	0.266
175.	0.004	0.013	0.040	0.098	0.196	0.328	0.475
185.	0.010	0.032	0.082	0.172	0.299	0.444	0.586
195.	0.014	0.042	0.101	0.202	0.340	0.496	0.647
AVE =	0.003	0.010	0.026	0.059	0.114	0.194	0.296

	14.	16.	18.	20.	22.	24.
105.	0.153	0.303	0.492	0.675	0.816	0.906
115.	0.298	0.438	0.579	0.706	0.810	0.888
125.	0.441	0.577	0.696	0.790	0.859	0.907
135.	0.416	0.554	0.676	0.775	0.848	0.900
145.	0.223	0.356	0.502	0.644	0.766	0.861
155.	0.124	0.250	0.419	0.608	0.756	0.866
165.	0.409	0.553	0.680	0.780	0.853	0.903
175.	0.613	0.728	0.815	0.878	0.920	0.949
185.	0.707	0.801	0.871	0.920	0.953	0.974
195.	0.775	0.870	0.931	0.966	0.984	0.993
AVE =	0.416	0.543	0.666	0.773	0.857	0.915

TABLE VII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B $T_1 = 1/4010$ $T_2 = 1/2545$

$P_F = 10^{-5}$

FOR RECEIVER CASE 2

VELOCITY	S/N RATIO (DB) 0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.000	0.001	0.002	0.008	0.027	0.079
115.	0.000	0.001	0.005	0.016	0.046	0.107	0.206
125.	0.001	0.005	0.017	0.047	0.110	0.211	0.341
135.	0.001	0.004	0.014	0.040	0.096	0.190	0.316
145.	0.000	0.001	0.002	0.008	0.025	0.067	0.144
155.	0.000	0.000	0.001	0.002	0.007	0.023	0.065
165.	0.001	0.003	0.010	0.032	0.083	0.175	0.305
175.	0.005	0.017	0.051	0.119	0.230	0.370	0.517
185.	0.014	0.041	0.101	0.203	0.339	0.487	0.625
195.	0.018	0.053	0.124	0.237	0.384	0.541	0.688
AVE =	0.004	0.013	0.032	0.071	0.133	0.220	0.329

	14.	16.	18.	20.	22.	24.
105.	0.186	0.353	0.547	0.722	0.848	0.924
115.	0.336	0.480	0.618	0.739	0.836	0.906
125.	0.482	0.615	0.727	0.813	0.876	0.919
135.	0.457	0.593	0.709	0.800	0.866	0.912
145.	0.258	0.397	0.544	0.682	0.797	0.883
155.	0.152	0.292	0.471	0.649	0.794	0.891
165.	0.452	0.594	0.713	0.805	0.870	0.916
175.	0.651	0.758	0.837	0.893	0.931	0.955
185.	0.739	0.825	0.887	0.931	0.960	0.979
195.	0.807	0.891	0.944	0.973	0.988	0.995
AVE =	0.452	0.580	0.700	0.801	0.877	0.928

TABLE VII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B $T_1 = 1/4010$ $T_2 = 1/2645$

$P_F = 10^{-5}$

FOR RECEIVER CASE 3

	S/N RATIO (DB)												
VELOCITY	0.	2.	4.	6.	8.	10.	12.	14.	16.	18.	20.	22.	24.
105.	0.000	0.000	0.001	0.004	0.015	0.053	0.155	0.349	0.595	0.805	0.928	0.979	0.995
115.	0.001	0.002	0.009	0.032	0.091	0.207	0.372	0.556	0.722	0.847	0.928	0.972	0.991
125.	0.002	0.009	0.033	0.095	0.212	0.379	0.562	0.724	0.843	0.919	0.961	0.982	0.992
135.	0.002	0.007	0.027	0.080	0.187	0.347	0.530	0.698	0.825	0.908	0.956	0.980	0.991
145.	0.000	0.001	0.004	0.015	0.050	0.132	0.271	0.449	0.632	0.786	0.895	0.958	0.986
155.	0.000	0.000	0.001	0.003	0.013	0.045	0.128	0.288	0.511	0.730	0.883	0.960	0.989
165.	0.001	0.005	0.020	0.064	0.165	0.328	0.524	0.704	0.837	0.918	0.962	0.983	0.993
175.	0.010	0.034	0.101	0.231	0.415	0.609	0.771	0.879	0.942	0.973	0.988	0.995	0.998
185.	0.027	0.083	0.199	0.374	0.570	0.741	0.861	0.932	0.969	0.987	0.995	0.998	1.000
195.	0.036	0.105	0.238	0.426	0.626	0.794	0.905	0.964	0.989	0.997	0.999	1.000	1.000
AVE =	0.008	0.025	0.063	0.132	0.234	0.363	0.508	0.654	0.787	0.887	0.950	0.981	0.993

TABLE VII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B T_1 = 1/4010 T_2 = 1/2645

P_F = 10^{-5}

FOR RECEIVER CASE 4

S/N RATIO (DB)

VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.000	0.001	0.004	0.018	0.063	0.181
115.	0.001	0.003	0.011	0.038	0.106	0.232	0.405
125.	0.003	0.011	0.039	0.110	0.238	0.411	0.594
135.	0.002	0.009	0.032	0.093	0.211	0.379	0.563
145.	0.000	0.001	0.005	0.019	0.060	0.151	0.299
155.	0.000	0.000	0.001	0.004	0.015	0.054	0.149
165.	0.002	0.006	0.024	0.076	0.188	0.361	0.559
175.	0.012	0.041	0.118	0.259	0.450	0.643	0.795
185.	0.032	0.097	0.225	0.408	0.605	0.768	0.878
195.	0.043	0.122	0.267	0.462	0.660	0.819	0.920
AVE =	0.010	0.029	0.072	0.147	0.255	0.388	0.534

	14.	16.	18.	20.	22.	24.
105.	0.389	0.638	0.835	0.941	0.983	0.996
115.	0.589	0.748	0.866	0.939	0.977	0.993
125.	0.750	0.861	0.929	0.967	0.985	0.994
135.	0.725	0.845	0.920	0.962	0.983	0.993
145.	0.483	0.663	0.810	0.910	0.965	0.989
155.	0.323	0.551	0.764	0.903	0.968	0.991
165.	0.733	0.856	0.929	0.968	0.986	0.994
175.	0.894	0.950	0.978	0.990	0.996	0.998
185.	0.942	0.974	0.990	0.996	0.999	1.000
195.	0.971	0.991	0.998	1.000	1.000	1.000
AVE =	0.680	0.808	0.902	0.958	0.984	0.995

TABLE VIII

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B $T_1 = 1/2645$ $T_2 = 1/4010$

$P_F = 10^{-5}$

FOR RECEIVER CASE 1

S/N RATIO (DB)

VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.000	0.002	0.006	0.020	0.055	0.128
115.	0.004	0.012	0.037	0.092	0.187	0.318	0.464
125.	0.013	0.039	0.095	0.192	0.323	0.470	0.609
135.	0.010	0.032	0.082	0.172	0.298	0.444	0.585
145.	0.002	0.006	0.020	0.055	0.126	0.238	0.378
155.	0.000	0.000	0.000	0.001	0.005	0.016	0.047
165.	0.000	0.000	0.001	0.002	0.008	0.025	0.064
175.	0.000	0.001	0.004	0.013	0.039	0.093	0.183
185.	0.001	0.003	0.011	0.032	0.079	0.164	0.286
195.	0.002	0.007	0.023	0.068	0.165	0.323	0.515
AVE =	0.003	0.010	0.027	0.063	0.125	0.214	0.326

	14.	16.	18.	20.	22.	24.
105.	0.246	0.402	0.571	0.724	0.840	0.916
115.	0.604	0.721	0.810	0.875	0.919	0.949
125.	0.725	0.813	0.876	0.919	0.948	0.967
135.	0.706	0.799	0.867	0.913	0.944	0.964
145.	0.524	0.655	0.761	0.840	0.896	0.935
155.	0.117	0.241	0.410	0.594	0.752	0.865
165.	0.138	0.248	0.383	0.523	0.650	0.755
175.	0.307	0.446	0.582	0.699	0.792	0.861
185.	0.435	0.592	0.734	0.844	0.918	0.960
195.	0.696	0.831	0.915	0.960	0.982	0.992
AVE =	0.450	0.575	0.691	0.789	0.864	0.916

TABLE VIII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B $T_1 = 1/2645$ $T_2 = 1/4010$

$P_F = 10^{-5}$

FOR RECEIVER CASE 2

S/N RATIO (DB)

VELOCITY	0.	2.	4.	6.	8.	10.	12.	14.	16.	18.	20.	22.	24.
105.	0.000	0.001	0.002	0.008	0.025	0.069	0.154	0.286	0.449	0.618	0.762	0.867	0.932
115.	0.005	0.016	0.047	0.113	0.220	0.359	0.507	0.642	0.751	0.832	0.890	0.930	0.956
125.	0.017	0.049	0.116	0.225	0.365	0.513	0.646	0.754	0.835	0.891	0.930	0.955	0.971
135.	0.014	0.041	0.101	0.203	0.339	0.487	0.624	0.737	0.822	0.883	0.924	0.951	0.969
145.	0.002	0.008	0.026	0.069	0.152	0.275	0.421	0.565	0.690	0.788	0.859	0.909	0.944
155.	0.000	0.000	0.000	0.002	0.006	0.020	0.060	0.143	0.283	0.462	0.644	0.791	0.889
165.	0.000	0.000	0.001	0.003	0.010	0.031	0.080	0.165	0.284	0.424	0.562	0.684	0.783
175.	0.000	0.001	0.005	0.017	0.049	0.113	0.215	0.346	0.487	0.619	0.730	0.816	0.877
185.	0.001	0.004	0.014	0.040	0.097	0.193	0.326	0.480	0.635	.770	0.870	0.933	0.968
195.	0.002	0.009	0.030	0.086	0.201	0.374	0.570	0.741	0.861	0.932	0.969	0.986	0.994
AVE =	0.004	0.013	0.034	0.077	0.146	0.243	0.360	0.486	0.610	0.722	0.814	0.882	0.928

TABLE VIII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B $T_1 = 1/2645$ $T_2 = 1/4010$

$P_F = 10^{-5}$

FOR RECEIVER CASE 3

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.004	0.015	0.050	0.137	0.292
115.	0.009	0.032	0.094	0.219	0.400	0.596	0.761
125.	0.033	0.098	0.226	0.408	0.603	0.766	0.876
135.	0.027	0.082	0.198	0.373	0.570	0.741	0.860
145.	0.004	0.015	0.051	0.138	0.289	0.482	0.670
155.	0.000	0.000	0.001	0.003	0.011	0.040	0.118
165.	0.000	0.000	0.001	0.005	0.020	0.063	0.156
175.	0.001	0.002	0.010	0.034	0.098	0.217	0.385
185.	0.002	0.007	0.027	0.080	0.189	0.352	0.544
195.	0.004	0.016	0.059	0.170	0.373	0.622	0.825
AVE =	0.008	0.025	0.067	0.145	0.260	0.402	0.549

	14.	16.	18.	20.	22.	24.
105.	0.498	0.704	0.859	0.946	0.983	0.996
115.	0.873	0.938	0.972	0.988	0.995	0.998
125.	0.940	0.973	0.988	0.995	0.998	0.999
135.	0.931	0.969	0.986	0.994	0.998	0.999
145.	0.813	0.905	0.955	0.980	0.992	0.997
155.	0.274	0.497	0.722	0.880	0.959	0.989
165.	0.306	0.487	0.661	0.800	0.893	0.948
175.	0.568	0.729	0.847	0.921	0.962	0.983
185.	0.727	0.866	0.948	0.983	0.996	0.997
195.	0.937	0.982	0.996	0.999	1.000	1.000
AVE =	0.687	0.805	0.893	0.949	0.978	0.991

TABLE VIII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B $T_1 = 1/2645$ $T_2 = 1/4010$

$P_F = 10^{-5}$

FOR RECEIVER CASE 4

VELOCITY	S/N RATIO (DB) 0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.065	0.018	0.060	0.158	0.325
115.	0.011	0.038	0.110	0.247	0.435	0.630	0.786
125.	0.040	0.114	0.254	0.443	0.637	0.791	0.892
135.	0.032	0.095	0.224	0.408	0.604	0.767	0.878
145.	0.005	0.018	0.061	0.158	0.321	0.518	0.700
155.	0.000	0.000	0.001	0.003	0.014	0.048	0.138
165.	0.000	0.000	0.002	0.006	0.024	0.074	0.178
175.	0.001	0.003	0.012	0.041	0.113	0.243	0.418
185.	0.002	0.009	0.032	0.074	0.213	0.384	0.578
195.	0.005	0.020	0.070	0.197	0.415	0.664	0.8[illegible]
AVE =	0.010	0.030	0.077	0.162	0.283	0.428	0.574

	14.	16.	18.	20.	22.	24.
105.	0.537	0.737	0.880	0.956	0.987	0.997
115.	0.889	0.947	0.976	0.990	0.996	0.998
125.	0.948	0.977	0.990	0.996	0.998	0.999
135.	0.941	0.973	0.988	0.995	0.998	0.999
145.	0.835	0.917	0.962	0.983	0.993	0.997
155.	0.308	0.539	0.756	0.900	0.967	0.991
165.	0.336	0.520	0.690	0.821	0.906	0.955
175.	0.600	0.754	0.864	0.931	0.968	0.996
185.	0.756	0.885	0.957	0.987	0.997	0.999
195.	0.950	0.986	0.997	0.999	1.000	1.000
AVE =	0.710	0.824	0.906	0.956	0.981	0.992

TABLE IX

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E $T_1 = 1/4010$ $T_2 = 1/2645$

$P_F = 10^{-5}$

FOR RECEIVER CASE 1

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.002	0.007	0.024	0.068	0.161
115.	0.004	0.012	0.037	0.092	0.187	0.318	0.464
125.	0.013	0.039	0.095	0.192	0.323	0.470	0.609
135.	0.010	0.032	0.082	0.172	0.298	0.444	0.585
145.	0.002	0.006	0.020	0.055	0.126	0.238	0.378
155.	0.000	0.000	0.001	0.003	0.009	0.030	0.087
165.	0.001	0.002	0.008	0.025	0.067	0.147	0.266
175.	0.004	0.013	0.040	0.098	0.196	0.328	0.475
185.	0.011	0.032	0.082	0.172	0.299	0.446	0.589
195.	0.015	0.044	0.109	0.222	0.380	0.557	0.718
AVE =	0.006	0.018	0.048	0.104	0.191	0.305	0.433

	14.	16.	18.	20.	22.	24.
105.	0.310	0.495	0.674	0.813	0.904	0.954
115.	0.604	0.721	0.812	0.878	0.925	0.956
125.	0.725	0.813	0.876	0.919	0.948	0.967
135.	0.706	0.799	0.867	0.913	0.944	0.964
145.	0.524	0.656	0.764	0.845	0.904	0.944
155.	0.200	0.369	0.561	0.732	0.854	0.927
165.	0.409	0.553	0.680	0.780	0.853	0.904
175.	0.613	0.728	0.815	0.878	0.920	0.949
185.	0.713	0.812	0.885	0.935	0.966	0.983
195.	0.840	0.917	0.961	0.982	0.992	0.997
AVE =	0.564	0.687	0.790	0.868	0.921	0.955

TABLE IX (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E $T_1 = 1/4010$ $T_2 = 1/2645$

$P_F = 10^{-5}$

FOR RECEIVER CASE 2

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.003	0.009	0.030	0.085	0.194
115.	0.005	0.016	0.047	0.113	0.220	0.359	0.507
125.	0.017	0.049	0.116	0.225	0.365	0.513	0.646
135.	0.014	0.041	0.101	0.203	0.339	0.487	0.624
145.	0.002	0.008	0.026	0.069	0.152	0.275	0.421
155.	0.000	0.000	0.001	0.003	0.012	0.039	0.109
165.	0.001	0.003	0.010	0.032	0.083	0.175	0.305
175.	0.005	0.017	0.051	0.119	0.230	0.370	0.517
185.	0.014	0.041	0.101	0.204	0.340	0.489	0.628
195.	0.019	0.056	0.133	0.261	0.429	0.607	0.759
AVE =	0.008	0.023	0.059	0.124	0.220	0.340	0.471

	14.	16.	18.	20.	22.	24.
105.	0.359	0.549	0.720	0.845	0.922	0.964
115.	0.642	0.752	0.835	0.894	0.936	0.963
125.	0.754	0.835	0.891	0.930	0.955	0.971
135.	0.737	0.822	0.883	0.924	0.951	0.969
145.	0.566	0.692	0.791	0.865	0.918	0.953
155.	0.239	0.422	0.614	0.773	0.880	0.942
165.	0.452	0.594	0.713	0.805	0.871	0.916
175.	0.651	0.758	0.837	0.893	0.931	0.955
185.	0.746	0.837	0.902	0.946	0.973	0.987
195.	0.867	0.933	0.969	0.986	0.994	0.998
AVE =	0.601	0.719	0.816	0.886	0.933	0.962

TABLE IX (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E $T_1 = 1/4010$ $T_2 = 1/2645$

$P_F = 10^{-5}$

FOR RECEIVER CASE 3

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.004	0.017	0.059	0.166	0.356
115.	0.009	0.032	0.094	0.219	0.400	0.596	0.761
125.	0.033	0.098	0.226	0.408	0.603	0.766	0.876
135.	0.027	0.082	0.158	0.373	0.570	0.741	0.860
145.	0.004	0.015	0.051	0.138	0.289	0.482	0.670
155.	0.000	0.000	0.001	0.006	0.022	0.077	0.209
165.	0.001	0.005	0.020	0.064	0.165	0.328	0.524
175.	0.010	0.034	0.101	0.231	0.415	0.609	0.771
185.	0.027	0.083	0.199	0.374	0.571	0.742	0.863
195.	0.038	0.110	0.253	0.459	0.675	0.843	0.939
AVE =	0.015	0.046	0.115	0.229	0.377	0.535	0.683

	14.	16.	18.	20.	22.	24.
105.	0.591	0.794	0.918	0.974	0.993	0.998
115.	0.873	0.939	0.972	0.989	0.996	0.999
125.	0.940	0.973	0.988	0.995	0.998	0.999
135.	0.931	0.969	0.986	0.994	0.998	0.999
145.	0.814	0.905	0.956	0.981	0.993	0.998
155.	0.426	0.665	0.847	0.945	0.984	0.996
165.	0.704	0.837	0.918	0.962	0.983	0.993
175.	0.879	0.942	0.973	0.988	0.995	0.998
185.	0.935	0.973	0.990	0.997	0.999	1.000
195.	0.981	0.995	0.999	1.000	1.000	1.000
AVE =	0.807	0.899	0.955	0.983	0.994	0.998

TABLE IX (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E $T_1 = 1/4010$ $T_2 = 1/2645$

$P_F = 10^{-5}$

FOR RECEIVER CASE 4

	S/N RATIO (DB)												
VELOCITY	0.	2.	4.	6.	8.	10.	12.	14.	16.	18.	20.	22.	24.
105.	0.000	0.001	0.005	0.021	0.071	0.191	0.394	0.631	0.822	0.933	0.980	0.995	0.999
115.	0.011	0.038	0.110	0.247	0.435	0.630	0.786	0.889	0.947	0.977	0.991	0.996	0.999
125.	0.040	0.114	0.254	0.443	0.637	0.791	0.892	0.948	0.977	0.990	0.996	0.998	0.999
135.	0.032	0.096	0.224	0.408	0.604	0.767	0.878	0.941	0.973	0.988	0.995	0.998	0.999
145.	0.005	0.018	0.061	0.158	0.321	0.518	0.700	0.835	0.918	0.963	0.985	0.994	0.998
155.	0.000	0.001	0.002	0.007	0.027	0.091	0.239	0.467	0.703	0.871	0.956	0.988	0.997
165.	0.002	0.006	0.024	0.076	0.188	0.361	0.559	0.733	0.856	0.929	0.968	0.986	0.994
175.	0.012	0.041	0.118	0.259	0.450	0.643	0.795	0.894	0.950	0.978	0.990	0.996	0.998
185.	0.032	0.097	0.225	0.408	0.605	0.769	0.880	0.945	0.977	0.992	0.998	0.999	1.000
195.	0.045	0.128	0.284	0.498	0.710	0.866	0.950	0.985	0.996	0.999	1.000	1.000	1.000
AVE =	0.018	0.054	0.131	0.253	0.405	0.563	0.707	0.827	0.912	0.962	0.986	0.995	0.998

TABLE X

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, E and F $T_1 = 1/4010$ $T_2 = 1/2645$

$P_F = 10^{-5}$

FOR RECEIVER CASE 1

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.002	0.008	0.025	0.074	0.181
115.	0.004	0.013	0.041	0.103	0.218	0.381	0.564
125.	0.014	0.042	0.107	0.223	0.388	0.571	0.733
135.	0.011	0.035	0.092	0.199	0.356	0.539	0.707
145.	0.002	0.007	0.022	0.061	0.144	0.280	0.456
155.	0.000	0.000	0.001	0.003	0.010	0.033	0.095
165.	0.001	0.002	0.008	0.027	0.074	0.168	0.315
175.	0.004	0.015	0.044	0.110	0.228	0.394	0.577
185.	0.011	0.035	0.092	0.199	0.357	0.540	0.710
195.	0.016	0.048	0.122	0.257	0.448	0.657	0.827
AVE =	0.006	0.020	0.053	0.119	0.225	0.364	0.517

	14.	16.	18.	20.	22.	24.
105.	0.358	0.579	0.778	0.907	0.969	0.992
115.	0.728	0.849	0.924	0.965	0.985	0.995
125.	0.852	0.925	0.965	0.984	0.993	0.997
135.	0.834	0.915	0.960	0.982	0.992	0.997
145.	0.636	0.784	0.886	0.946	0.977	0.991
155.	0.225	0.426	0.652	0.833	0.937	0.981
165.	0.495	0.670	0.809	0.900	0.952	0.978
175.	0.738	0.855	0.927	0.966	0.985	0.993
185.	0.839	0.922	0.967	0.988	0.996	0.999
195.	0.930	0.977	0.994	0.999	1.000	1.000
AVE =	0.664	0.790	0.886	0.947	0.979	0.992

TABLE X (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, E and F $T_1 = 1/4010$ $T_2 = 1/2645$

$P_F = 10^{-5}$

FOR RECEIVER CASE 2

S/N RATIO (DB)

VELOCITY	0.	2.	4.	6.	8.	10.	12.
15.	0.000	0.001	0.003	0.010	0.033	0.094	0.219
15.	0.005	0.017	0.052	0.127	0.257	0.431	0.615
12.	0.018	0.054	0.131	0.263	0.439	0.621	0.773
13.	0.015	0.045	0.114	0.236	0.406	0.590	0.750
145	0.002	0.008	0.028	0.077	0.174	0.325	0.508
155	0.000	0.000	0.001	0.004	0.013	0.042	0.120
165	0.001	0.003	0.011	0.035	0.093	0.202	0.363
175.	0.006	0.019	0.055	0.135	0.269	0.445	0.627
185.	0.015	0.045	0.114	0.237	0.407	0.592	0.753
195.	0.021	0.061	0.150	0.303	0.506	0.711	0.864
AVE =	0.008	0.025	0.066	0.143	0.260	0.405	0.559

	14.	16.	18.	20.	22.	24.
105.	0.415	0.639	0.823	0.931	0.979	0.994
115.	0.769	0.876	0.939	0.973	0.989	0.996
125.	0.876	0.940	0.972	0.988	0.995	0.998
135.	0.863	0.932	0.968	0.986	0.994	0.997
145.	0.684	0.819	0.908	0.957	0.982	0.994
155.	0.271	0.487	0.709	0.871	0.955	0.987
165.	0.547	0.716	0.841	0.919	0.962	0.983
175.	0.778	0.881	0.942	0.973	0.988	0.995
185.	0.868	0.938	0.975	0.991	0.997	0.999
195.	0.949	0.984	0.996	0.999	1.000	1.000
AVE =	0.702	0.821	0.907	0.959	0.984	0.994

TABLE X (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, E and F T_1 = 1/4010 T_2 = 1/2645

$P_F = 10^{-5}$

FOR RECEIVER CASE 3

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.005	0.018	0.064	0.181	0.397
115.	0.009	0.034	0.103	0.245	0.460	0.688	0.859
125.	0.035	0.107	0.253	0.469	0.696	0.864	0.952
135.	0.028	0.089	0.221	0.427	0.658	0.840	0.941
145.	0.004	0.016	0.055	0.151	0.327	0.557	0.768
155.	0.000	0.000	0.002	0.006	0.024	0.082	0.228
165.	0.001	0.005	0.021	0.069	0.182	0.373	0.605
175.	0.010	0.037	0.110	0.259	0.477	0.703	0.868
185.	0.029	0.089	0.221	0.428	0.659	0.841	0.943
195.	0.040	0.120	0.283	0.522	0.763	0.919	0.982
AVE =	0.016	0.050	0.127	0.260	0.431	0.605	0.754

	14.	16.	18.	20.	22.	24.
105.	0.664	0.873	0.969	0.995	1.000	1.000
115.	0.950	0.986	0.997	0.999	1.000	1.000
125.	0.986	0.997	0.999	1.000	1.000	1.000
135.	0.983	0.996	0.999	1.000	1.000	1.000
145.	0.905	0.969	0.992	0.998	1.000	1.000
155.	0.474	0.742	0.917	0.984	0.998	1.000
165.	0.804	0.924	0.976	0.994	0.999	1.000
175.	0.954	0.987	0.997	0.999	1.000	1.000
185.	0.984	0.996	0.999	1.000	1.000	1.000
195.	0.997	1.000	1.000	1.000	1.000	1.000
AVE =	0.870	0.947	0.985	0.997	1.000	1.000

TABLE X (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, E and F $T_1 = 1/4010$ $T_2 = 1/2645$

$P_F = 10^{-5}$

FOR RECEIVER CASE 4

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.002	0.006	0.022	0.076	0.209	0.441
115.	0.011	0.041	0.120	0.277	0.500	0.724	0.881
125.	0.043	0.125	0.285	0.510	0.732	0.886	0.961
135.	0.034	0.105	0.250	0.468	0.696	0.864	0.953
145.	0.005	0.019	0.065	0.175	0.364	0.597	0.799
155.	0.000	0.001	0.002	0.007	0.029	0.098	0.262
165.	0.002	0.007	0.026	0.082	0.208	0.412	0.645
175.	0.012	0.044	0.129	0.292	0.518	0.738	0.889
185.	0.034	0.105	0.251	0.468	0.697	0.866	0.954
195.	0.048	0.140	0.319	0.566	0.798	0.936	0.987
AVE =	0.019	0.059	0.145	0.287	0.462	0.633	0.777

	14.	16.	18.	20.	22.	24.
105.	0.708	0.898	0.977	0.997	1.000	1.000
115.	0.960	0.989	0.997	1.000	1.000	1.000
125.	0.989	0.998	0.999	1.000	1.000	1.000
135.	0.987	0.997	0.999	1.000	1.000	1.000
145.	0.922	0.976	0.994	0.999	1.000	1.000
155.	0.521	0.781	0.936	0.988	0.999	1.000
165.	0.832	0.938	0.982	0.995	0.999	1.000
175.	0.963	0.990	0.998	1.000	1.000	1.000
185.	0.988	0.997	1.000	1.000	1.000	1.000
195.	0.998	1.000	1.000	1.000	1.000	1.000
AVE =	0.887	0.956	0.988	0.998	1.000	1.000

TABLE XI

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, [illegible], F, G and H

T_1 = 1/4010 T_2 = 1/2643

$P_F = 10^{-5}$

FOR RECEIVER CASE [illegible]

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.002	0.008	0.026	0.076	0.186
115.	0.004	0.014	0.041	0.106	0.226	0.401	0.602
125.	0.014	0.043	0.110	0.232	0.409	0.609	0.783
135.	0.012	0.036	0.094	0.206	0.374	0.574	0.756
145.	0.002	0.007	0.022	0.062	0.148	0.293	0.484
155.	0.000	0.000	0.001	0.003	0.010	0.034	0.097
165.	0.001	0.003	0.009	0.028	0.076	0.174	0.330
175.	0.004	0.015	0.045	0.113	0.237	0.415	0.616
185.	0.012	0.036	0.094	0.206	0.375	0.576	0.759
195.	0.016	0.049	0.125	0.266	0.471	0.694	0.867
AVE =	0.007	0.020	0.054	0.123	0.235	0.385	0.548

	14.	16.	18.	20.	22.	24.
105.	0.372	0.607	0.815	0.938	0.985	0.997
115.	0.778	0.897	0.960	0.987	0.997	0.999
125.	0.900	0.961	0.987	0.996	0.999	1.000
135.	0.884	0.953	0.984	0.995	0.999	1.000
145.	0.680	0.835	0.930	0.975	0.993	0.998
155.	0.231	0.442	0.682	0.868	0.962	0.992
165.	0.526	0.717	0.859	0.941	0.979	0.994
175.	0.788	0.903	0.962	0.988	0.996	0.999
185.	0.888	0.958	0.987	0.997	0.999	1.000
195.	0.958	0.991	0.998	1.000	1.000	1.000
AVE =	0.701	0.826	0.917	0.969	0.991	0.99X

TABLE XI (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, C, D, E, F, G and H

$T_1 = 1/4010$ $T_2 = 1/2645$

$P_F = 10^{-5}$

FOR RECEIVER CASE 2

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.003	0.010	0.033	0.096	0.226
115.	0.005	0.018	0.053	0.131	0.258	0.456	0.656
125.	0.018	0.055	0.135	0.274	0.464	0.663	0.823
135.	0.015	0.046	0.117	0.245	0.428	0.629	0.799
145.	0.002	0.009	0.028	0.078	0.180	0.341	0.540
155.	0.000	0.000	0.001	0.004	0.013	0.043	0.122
165.	0.001	0.003	0.011	0.036	0.095	0.209	0.381
175.	0.006	0.019	0.057	0.139	0.280	0.470	0.669
185.	0.015	0.046	0.117	0.246	0.429	0.631	0.802
195.	0.021	0.062	0.154	0.314	0.532	0.750	0.901
AVE =	0.008	0.026	0.067	0.148	0.272	0.429	0.592

	14.	16.	18.	20.	22.	24.
105.	0.432	0.670	0.859	0.958	0.991	0.999
115.	0.819	0.921	0.971	0.991	0.998	1.000
125.	0.923	0.971	0.991	0.997	0.999	1.000
135.	0.909	0.966	0.989	0.997	0.999	1.000
145.	0.730	0.869	0.947	0.983	0.995	0.999
155.	0.278	0.506	0.742	0.904	0.975	0.995
165.	0.583	0.764	0.889	0.956	0.985	0.996
175.	0.828	0.925	0.972	0.991	0.998	0.999
185.	0.914	0.970	0.992	0.998	1.000	1.000
195.	0.972	0.994	0.999	1.000	1.000	1.000
AVE =	0.739	0.856	0.935	0.977	0.994	0.999

TABLE XI (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, C, D, E, F, G and H

$T_1 = 1/4010$ $T_2 = 1/2645$

$P_F = 10^{-5}$

FOR RECEIVER CASE 3

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.005	0.018	0.065	0.184	0.407
115.	0.009	0.034	0.104	0.251	0.476	0.718	0.892
125.	0.036	0.108	0.259	0.486	0.727	0.896	0.973
135.	0.029	0.091	0.225	0.442	0.687	0.874	0.964
145.	0.004	0.016	0.056	0.154	0.336	0.579	0.802
155.	0.000	0.001	0.002	0.006	0.024	0.083	0.232
165.	0.001	0.006	0.021	0.070	0.186	0.385	0.631
175.	0.010	0.037	0.112	0.265	0.494	0.734	0.900
185.	0.029	0.091	0.226	0.442	0.688	0.875	0.965
195.	0.041	0.122	0.290	0.540	0.792	0.944	0.992
AVE =	0.016	0.051	0.130	0.268	0.447	0.627	0.776

	14.	16.	18.	20.	22.	24.
105.	0.687	0.899	0.983	0.999	1.000	1.000
115.	0.971	0.994	0.999	1.000	1.000	1.000
125.	0.995	0.999	1.000	1.000	1.000	1.000
135.	0.993	0.999	1.000	1.000	1.000	1.000
145.	0.934	0.985	0.998	1.000	1.000	1.000
155.	0.486	0.765	0.940	0.992	0.999	1.000
165.	0.838	0.950	0.989	0.998	1.000	1.000
175.	0.974	0.995	0.999	1.000	1.000	1.000
185.	0.994	0.999	1.000	1.000	1.000	1.000
195.	0.999	1.000	1.000	1.000	1.000	1.000
AVE =	0.887	0.959	0.991	0.999	1.000	1.000

TABLE XI (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, C, D, E, F, G and H

T_1 = 1/4010 T_2 = 1/2645

P_F = [illegible]

FOR RECEIVER CASE 4

VELOCITY	S/N RATIO (DB) 0.	2.	4.	6.	8.	10.	12.
105.	0.001	0.002	0.006	0.023	0.077	0.213	0.452
115.	0.011	0.041	0.122	0.284	0.519	0.756	0.913
125.	0.043	0.127	0.292	0.529	0.764	0.917	0.979
135.	0.035	0.106	0.256	0.484	0.726	0.897	0.973
145.	0.005	0.020	0.066	0.178	0.375	0.622	0.833
155.	0.000	0.001	0.002	0.008	0.029	0.099	0.266
165.	0.002	0.007	0.026	0.083	0.213	0.425	0.673
175.	0.013	0.045	0.131	0.299	0.537	0.771	0.920
185.	0.035	0.107	0.257	0.485	0.727	0.898	0.974
195.	0.049	0.142	0.327	0.586	0.828	0.958	0.995
AVE =	0.019	0.060	0.148	0.296	0.480	0.656	0.798

	14.	16.	18.	20.	22.	24.
105.	0.731	0.922	0.989	0.999	1.000	1.000
115.	0.978	0.996	0.999	1.000	1.000	1.000
125.	0.996	0.999	1.000	1.000	1.000	1.000
135.	0.995	0.999	1.000	1.000	1.000	1.000
145.	0.949	0.989	0.998	1.000	1.000	1.000
155.	0.534	0.805	0.956	0.995	1.000	1.000
165.	0.866	0.962	0.992	0.999	1.000	1.000
175.	0.980	0.997	1.000	1.000	1.000	1.000
185.	0.995	0.999	1.000	1.000	1.000	1.000
195.	1.000	1.000	1.000	1.000	1.000	1.000
AVE =	0.902	0.967	0.993	0.999	1.000	1.000

TABLE XII

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 1

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.004	0.013	0.037	0.090	0.180
115.	0.000	0.000	0.001	0.003	0.011	0.033	0.081
125.	0.000	0.000	0.000	0.001	0.004	0.014	0.043
135.	0.001	0.003	0.009	0.028	0.074	0.159	0.282
145.	0.006	0.019	0.053	0.122	0.232	0.371	0.517
155.	0.013	0.039	0.096	0.194	0.326	0.473	0.611
165.	0.012	0.036	0.089	0.183	0.312	0.459	0.599
175.	0.004	0.013	0.039	0.097	0.194	0.327	0.473
185.	0.000	0.001	0.004	0.015	0.043	0.104	0.206
195.	0.000	0.000	0.000	0.001	0.002	0.006	0.021
AVE =	0.004	0.011	0.030	0.066	0.124	0.203	0.301

	14.	16.	18.	20.	22.	24.
105.	0.302	0.441	0.577	0.696	0.789	0.859
115.	0.166	0.285	0.423	0.561	0.685	0.786
125.	0.115	0.247	0.429	0.620	0.777	0.883
135.	0.428	0.573	0.702	0.805	0.881	0.933
145.	0.649	0.756	0.836	0.892	0.930	0.955
155.	0.726	0.814	0.877	0.920	0.948	0.967
165.	0.717	0.807	0.872	0.917	0.946	0.966
175.	0.611	0.727	0.815	0.877	0.920	0.949
185.	0.342	0.491	0.632	0.752	0.845	0.911
195.	0.064	0.157	0.310	0.501	0.684	0.823
AVE =	0.412	0.530	0.647	0.754	0.841	0.903

TABLE XII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 2

VELOCITY	S/N RATIO (DB) 0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.005	0.017	0.047	0.110	0.211
115.	0.000	0.000	0.001	0.004	0.014	0.042	0.100
125.	0.000	0.000	0.000	0.001	0.005	0.018	0.056
135.	0.001	0.003	0.012	0.036	0.092	0.189	0.322
145.	0.007	0.024	0.066	0.147	0.268	0.413	0.559
155.	0.017	0.050	0.118	0.227	0.368	0.515	0.649
165.	0.015	0.045	0.109	0.215	0.353	0.501	0.637
175.	0.005	0.017	0.050	0.118	0.228	0.368	0.516
185.	0.000	0.002	0.006	0.019	0.055	0.127	0.241
195.	0.000	0.000	0.000	0.001	0.002	0.008	0.028
AVE =	0.005	0.014	0.037	0.079	0.143	0.229	0.332

	14.	16.	18.	20.	22.	24.
105.	0.341	0.482	0.615	0.727	0.813	0.876
115.	0.195	0.323	0.464	0.600	0.717	0.811
125.	0.143	0.293	0.484	0.671	0.814	0.905
135.	0.471	0.614	0.735	0.830	0.899	0.945
145.	0.685	0.784	0.856	0.906	0.939	0.961
155.	0.756	0.836	0.892	0.930	0.955	0.971
165.	0.747	0.830	0.888	0.927	0.953	0.970
175.	0.649	0.757	0.836	0.892	0.930	0.955
185.	0.384	0.534	0.670	0.783	0.868	0.926
195.	0.081	0.191	0.360	0.556	0.730	0.854
AVE =	0.445	0.564	0.680	0.782	0.862	0.917

TABLE XII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 4

	S/N RATIO (DB)												
VELOCITY	0.	2.	4.	6.	8.	10.	12.	14.	16.	18.	20.	22.	24.
105.	0.001	0.003	0.011	0.039	0.110	0.238	0.411	0.594	0.750	0.861	0.929	0.967	0.985
115.	0.000	0.001	0.002	0.009	0.034	0.097	0.217	0.387	0.571	0.732	0.850	0.926	0.968
125.	0.000	0.000	0.001	0.003	0.011	0.041	0.130	0.311	0.558	0.781	0.916	0.975	0.994
135.	0.002	0.007	0.028	0.086	0.206	0.385	0.583	0.753	0.871	0.941	0.977	0.992	0.998
145.	0.017	0.058	0.152	0.312	0.508	0.693	0.830	0.914	0.960	0.982	0.992	0.997	0.999
155.	0.041	0.116	0.256	0.447	0.640	0.793	0.893	0.949	0.977	0.990	0.996	0.998	0.999
165.	0.036	0.106	0.240	0.428	0.623	0.781	0.886	0.945	0.975	0.989	0.996	0.998	0.999
175.	0.011	0.041	0.116	0.257	0.448	0.640	0.794	0.893	0.949	0.977	0.990	0.996	0.998
185.	0.001	0.003	0.013	0.046	0.127	0.274	0.468	0.660	0.810	0.908	0.961	0.986	0.996
195.	0.000	0.000	0.000	0.001	0.005	0.018	0.065	0.185	0.397	0.647	0.842	0.945	0.985
AVE =	0.011	0.034	0.082	0.163	0.271	0.396	0.528	0.659	0.782	0.881	0.945	0.978	0.992

TABLE XII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 3

	S/N RATIO (DB)											
VELOCITY	0.	2.	4.	6.	8.	10.	12.	14.	16.	18.	20.	22.	24.
105.	0.001	0.002	0.009	0.033	0.095	0.212	0.379	0.562	0.724	0.843	0.919	0.961	0.982
115.	0.000	0.001	0.002	0.008	0.028	0.083	0.193	0.355	0.538	0.705	0.832	0.914	0.961
125.	0.000	0.000	0.001	0.002	0.009	0.034	0.110	0.274	0.514	0.746	0.898	0.968	0.992
135.	0.001	0.006	0.023	0.073	0.181	0.351	0.548	0.725	0.853	0.931	0.972	0.990	0.997
145.	0.014	0.048	0.132	0.281	0.473	0.661	0.808	0.901	0.953	0.979	0.991	0.996	0.998
155.	0.034	0.100	0.228	0.411	0.606	0.768	0.878	0.941	0.973	0.988	0.995	0.998	0.999
165.	0.030	0.091	0.213	0.393	0.589	0.755	0.870	0.936	0.971	0.987	0.995	0.998	0.999
175.	0.009	0.034	0.100	0.229	0.412	0.607	0.769	0.878	0.941	0.973	0.988	0.995	0.998
185.	0.001	0.003	0.011	0.038	0.110	0.245	0.432	0.627	0.786	0.893	0.954	0.983	0.995
195.	0.000	0.000	0.000	0.001	0.004	0.015	0.054	0.159	0.356	0.605	0.813	0.932	0.980
AVE =	0.009	0.028	0.072	0.147	0.251	0.373	0.504	0.636	0.761	0.865	0.936	0.974	0.990

TABLE XIII

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

$T_1 = 1/4950$ $T_2 = 1/3268$

$P_F = 10^{-5}$

FOR RECEIVER CASE 1

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.004	0.013	0.039	0.095	0.192	0.323	0.470
115.	0.001	0.003	0.011	0.034	0.085	0.177	0.305
125.	0.000	0.000	0.001	0.005	0.016	0.046	0.111
135.	0.000	0.000	0.001	0.003	0.010	0.030	0.079
145.	0.000	0.002	0.006	0.019	0.051	0.115	0.217
155.	0.001	0.004	0.013	0.038	0.092	0.182	0.304
165.	0.001	0.003	0.012	0.035	0.085	0.172	0.292
175.	0.000	0.001	0.004	0.013	0.038	0.092	0.182
185.	0.000	0.000	0.000	0.001	0.005	0.016	0.048
195.	0.000	0.000	0.001	0.004	0.014	0.040	0.098
AVE =	0.001	0.003	0.009	0.025	0.059	0.119	0.211

	14.	16.	18.	20.	22.	24.
105.	0.609	0.725	0.813	0.876	0.919	0.948
115.	0.451	0.591	0.711	0.803	0.869	0.915
125.	0.219	0.367	0.533	0.689	0.814	0.899
135.	0.173	0.318	0.496	0.672	0.811	0.902
145.	0.347	0.487	0.619	0.731	0.820	0.886
155.	0.444	0.580	0.698	0.791	0.860	0.908
165.	0.430	0.567	0.687	0.783	0.854	0.904
175.	0.305	0.444	0.581	0.700	0.795	0.867
185.	0.118	0.242	0.413	0.598	0.758	0.870
195.	0.198	0.335	0.490	0.641	0.769	0.865
AVE =	0.329	0.465	0.604	0.728	0.827	0.896

TABLE XIII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

$T_1 = 1/4950$ $T_2 = 1/3268$

$P_F = 10^{-5}$

FOR RECEIVER CASE 2

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.005	0.017	0.049	0.116	0.225	0.365	0.513
115.	0.001	0.004	0.014	0.043	0.105	0.209	0.345
125.	0.000	0.000	0.002	0.006	0.021	0.058	0.135
135.	0.000	0.000	0.001	0.004	0.013	0.038	0.098
145.	0.001	0.002	0.007	0.024	0.064	0.139	0.251
155.	0.001	0.005	0.017	0.048	0.112	0.213	0.343
165.	0.001	0.004	0.015	0.044	0.104	0.202	0.330
175.	0.000	0.001	0.005	0.017	0.048	0.112	0.213
185.	0.000	0.000	0.001	0.002	0.006	0.021	0.061
195.	0.000	0.000	0.001	0.005	0.018	0.051	0.120
AVE =	0.001	0.004	0.011	0.031	0.071	0.141	0.241

	14.	16.	18.	20.	22.	24.
105.	0.646	0.754	0.835	0.891	0.930	0.955
115.	0.493	0.630	0.742	0.826	0.885	0.926
125.	0.257	0.413	0.580	0.730	0.843	0.917
135.	0.206	0.365	0.548	0.717	0.843	0.921
145.	0.387	0.527	0.655	0.761	0.842	0.901
155.	0.485	0.617	0.729	0.814	0.876	0.919
165.	0.471	0.605	0.719	0.807	0.871	0.916
175.	0.344	0.485	0.613	0.731	0.819	0.885
185.	0.145	0.284	0.465	0.649	0.797	0.894
195.	0.232	0.378	0.535	0.681	0.801	0.887
AVE =	0.367	0.506	0.643	0.761	0.851	0.912

TABLE XIII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

T_1 = 1/4950 T_2 = 1/3268

$P_F = 10^{-5}$

FOR RECEIVER CASE 3

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.009	0.033	0.098	0.225	0.408	0.663	0.766
115.	0.002	0.008	0.028	0.086	0.205	0.382	0.578
125.	0.000	0.001	0.003	0.012	0.041	0.116	0.258
135.	0.000	0.000	0.002	0.007	0.024	0.076	0.190
145.	0.001	0.004	0.014	0.048	0.126	0.262	0.439
155.	0.002	0.009	0.034	0.096	0.215	0.382	0.565
165.	0.002	0.008	0.030	0.088	0.201	0.365	0.548
175.	0.001	0.002	0.010	0.034	0.096	0.215	0.383
185.	0.000	0.000	0.001	0.003	0.012	0.042	0.120
195.	0.000	0.001	0.002	0.010	0.035	0.102	0.233
AVE =	0.002	0.007	0.022	0.061	0.136	0.255	0.408

	14.	16.	18.	20.	22.	24.
105.	0.876	0.940	0.973	0.988	0.995	0.998
115.	0.747	0.865	0.934	0.970	0.987	0.994
125.	0.456	0.663	0.829	0.930	0.977	0.994
135.	0.376	0.604	0.803	0.924	0.977	0.994
145.	0.619	0.768	0.873	0.938	0.973	0.989
155.	0.726	0.845	0.920	0.962	0.983	0.993
165.	0.713	0.836	0.914	0.959	0.981	0.992
175.	0.566	0.727	0.846	0.922	0.964	0.986
185.	0.275	0.497	0.723	0.882	0.961	0.989
195.	0.419	0.619	0.788	0.901	0.962	0.988
AVE =	0.577	0.736	0.860	0.937	0.976	0.992

TABLE XIII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and B

$T_1 = 1/4950$ $T_2 = 1/3268$

$P_F = 10^{-5}$

FOR RECEIVER CASE 4

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.011	0.040	0.114	0.253	0.443	0.636	0.791
115.	0.002	0.009	0.034	0.101	0.231	0.417	0.613
125.	0.000	0.001	0.004	0.014	0.049	0.135	0.289
135.	0.000	0.001	0.002	0.008	0.029	0.089	0.216
145.	0.001	0.005	0.017	0.057	0.145	0.291	0.472
155.	0.003	0.012	0.040	0.111	0.240	0.415	0.597
165.	0.003	0.010	0.036	0.102	0.226	0.397	0.580
175.	0.001	0.003	0.012	0.040	0.112	0.241	0.415
185.	0.000	0.000	0.001	0.004	0.014	0.050	0.140
195.	0.000	0.001	0.003	0.012	0.042	0.119	0.261
AVE =	0.002	0.008	0.026	0.070	0.153	0.279	0.437

	14.	16.	18.	20.	22.	24.
105.	0.892	0.948	0.977	0.990	0.996	0.998
115.	0.774	0.881	0.943	0.974	0.989	0.995
125.	0.493	0.697	0.853	0.942	0.982	0.995
135.	0.414	0.643	0.831	0.938	0.982	0.996
145.	0.649	0.791	0.888	0.946	0.977	0.991
155.	0.752	0.862	0.930	0.967	0.985	0.994
165.	0.739	0.854	0.925	0.965	0.984	0.993
175.	0.598	0.753	0.864	0.932	0.970	0.988
185.	0.308	0.538	0.758	0.902	0.969	0.992
195.	0.455	0.653	0.813	0.916	0.969	0.991
AVE =	0.607	0.762	0.878	0.947	0.980	0.993

TABLE XIV

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 1

	S/N RATIO (DB)												
VELOCITY	0.	2.	4.	6.	8.	10.	12.	14.	16.	18.	20.	22.	24.
105.	0.004	0.013	0.039	0.095	0.192	0.323	0.470	0.609	0.725	0.813	0.876	0.919	0.948
115.	0.001	0.003	0.011	0.034	0.085	0.177	0.305	0.451	0.591	0.711	0.803	0.870	0.916
125.	0.000	0.000	0.002	0.005	0.018	0.054	0.133	0.267	0.444	0.627	0.779	0.882	0.942
135.	0.001	0.003	0.009	0.029	0.075	0.161	0.287	0.440	0.596	0.734	0.841	0.914	0.957
145.	0.006	0.019	0.053	0.122	0.232	0.371	0.517	0.649	0.757	0.836	0.893	0.931	0.957
155.	0.013	0.039	0.096	0.194	0.326	0.473	0.611	0.726	0.814	0.877	0.920	0.948	0.967
165.	0.012	0.036	0.089	0.183	0.312	0.459	0.599	0.717	0.807	0.872	0.917	0.946	0.966
175.	0.004	0.013	0.039	0.097	0.194	0.327	0.473	0.612	0.727	0.815	0.878	0.921	0.950
185.	0.000	0.001	0.004	0.015	0.044	0.106	0.211	0.353	0.514	0.668	0.795	0.885	0.941
195.	0.000	0.000	0.001	0.004	0.014	0.042	0.105	0.216	0.371	0.547	0.710	0.833	0.913
AVE =	0.004	0.013	0.034	0.078	0.149	0.249	0.371	0.504	0.635	0.750	0.841	0.905	0.946

TABLE XIV (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 2

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.005	0.017	0.049	0.116	0.225	0.365	0.513
115.	0.001	0.004	0.014	0.043	0.105	0.209	0.345
125.	0.000	0.001	0.002	0.007	0.024	0.068	0.162
135.	0.001	0.003	0.012	0.037	0.093	0.191	0.328
145.	0.007	0.024	0.066	0.147	0.268	0.413	0.559
155.	0.017	0.050	0.118	0.227	0.368	0.515	0.649
165.	0.015	0.045	0.109	0.215	0.353	0.501	0.637
175.	0.005	0.017	0.050	0.118	0.228	0.368	0.516
185.	0.000	0.002	0.006	0.019	0.055	0.129	0.246
195.	0.000	0.000	0.001	0.005	0.018	0.053	0.128
AVE =	0.005	0.016	0.043	0.094	0.174	0.281	0.408

	14.	16.	18.	20.	22.	24.
105.	0.646	0.754	0.835	0.891	0.930	0.955
115.	0.493	0.630	0.742	0.826	0.886	0.927
125.	0.312	0.497	0.676	0.814	0.904	0.954
135.	0.485	0.639	0.770	0.866	0.929	0.966
145.	0.685	0.784	0.856	0.906	0.940	0.963
155.	0.756	0.836	0.892	0.930	0.955	0.971
165.	0.747	0.830	0.888	0.927	0.953	0.970
175.	0.649	0.757	0.837	0.893	0.931	0.957
185.	0.398	0.560	0.708	0.826	0.905	0.953
195.	0.254	0.420	0.597	0.750	0.862	0.930
AVE =	0.543	0.671	0.780	0.863	0.920	0.955

TABLE XIV (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 3

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.009	0.033	0.098	0.225	0.408	0.603	0.766
115.	0.002	0.008	0.028	0.086	0.205	0.382	0.578
125.	0.000	0.001	0.003	0.013	0.046	0.134	0.303
135.	0.002	0.006	0.023	0.073	0.182	0.353	0.555
145.	0.014	0.048	0.132	0.281	0.473	0.661	0.808
155.	0.034	0.100	0.228	0.411	0.606	0.768	0.878
165.	0.030	0.091	0.213	0.393	0.589	0.755	0.870
175.	0.009	0.034	0.100	0.229	0.412	0.607	0.769
185.	0.001	0.003	0.011	0.038	0.111	0.248	0.439
195.	0.000	0.001	0.002	0.010	0.036	0.106	0.246
AVE =	0.010	0.032	0.084	0.176	0.307	0.462	0.621

	14.	16.	18.	20.	22.	24.
105.	0.876	0.940	0.973	0.988	0.995	0.998
115.	0.747	0.865	0.934	0.970	0.987	0.995
125.	0.530	0.746	0.891	0.963	0.990	0.998
135.	0.737	0.869	0.945	0.981	0.994	0.999
145.	0.901	0.953	0.979	0.991	0.996	0.999
155.	0.941	0.973	0.988	0.995	0.998	0.999
165.	0.936	0.971	0.987	0.995	0.998	0.999
175.	0.878	0.941	0.973	0.988	0.995	0.998
185.	0.641	0.806	0.913	0.968	0.990	0.997
195.	0.449	0.665	0.835	0.935	0.979	0.994
AVE =	0.764	0.873	0.942	0.977	0.992	0.998

TABLE XIV (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 4

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.011	0.040	0.114	0.253	0.443	0.636	0.791
115.	0.002	0.009	0.034	0.101	0.231	0.417	0.613
125.	0.000	0.001	0.004	0.016	0.055	0.156	0.338
135.	0.002	0.007	0.028	0.086	0.207	0.388	0.590
145.	0.017	0.058	0.152	0.312	0.508	0.693	0.830
155.	0.041	0.116	0.256	0.447	0.640	0.793	0.893
165.	0.036	0.106	0.240	0.428	0.623	0.781	0.886
175.	0.011	0.041	0.116	0.257	0.448	0.640	0.794
185.	0.001	0.003	0.013	0.046	0.128	0.277	0.476
195.	0.000	0.001	0.003	0.012	0.043	0.124	0.276
AVE =	0.012	0.038	0.096	0.196	0.333	0.490	0.649

	14.	16.	18.	20.	22.	24.
105.	0.892	0.948	0.977	0.990	0.996	0.998
115.	0.774	0.881	0.943	0.974	0.989	0.996
125.	0.571	0.778	0.909	0.971	0.992	0.998
135.	0.756	0.887	0.955	0.985	0.996	0.999
145.	0.914	0.960	0.982	0.993	0.997	0.999
155.	0.949	0.977	0.990	0.996	0.998	0.999
165.	0.945	0.975	0.989	0.996	0.998	0.999
175.	0.893	0.949	0.977	0.990	0.996	0.998
185.	0.675	0.831	0.927	0.974	0.998	0.998
195.	0.487	0.700	0.859	0.947	0.984	0.996
AVE =	0.787	0.889	0.951	0.981	0.994	0.998

TABLE XV

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, E and F

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 1

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.004	0.014	0.042	0.107	0.223	0.387	0.570
115.	0.001	0.003	0.012	0.037	0.096	0.205	0.364
125.	0.000	0.001	0.002	0.006	0.020	0.059	0.149
135.	0.001	0.003	0.010	0.031	0.083	0.185	0.341
145.	0.006	0.020	0.058	0.139	0.272	0.447	0.628
155.	0.014	0.043	0.108	0.226	0.391	0.574	0.736
165.	0.013	0.039	0.100	0.212	0.374	0.557	0.722
175.	0.004	0.014	0.043	0.109	0.226	0.391	0.574
185.	0.000	0.001	0.005	0.016	0.048	0.119	0.246
195.	0.000	0.000	0.001	0.005	0.015	0.046	0.118
AVE =	0.004	0.014	0.038	0.089	0.175	0.297	0.445

	14.		18.	20.	22.	24.
105.	0.733	0.852	.925	0.965	0.984	0.993
115.	0.547	0.714	0.839	0.918	0.961	0.983
125.	0.308	0.520	0.729	0.879	0.957	0.987
135.	0.530	0.712	0.851	0.936	0.977	0.993
145.	0.777	0.880	0.941	0.973	0.988	0.995
155.	0.854	0.926	0.965	0.985	0.993	0.997
165.	0.844	0.921	0.963	0.983	0.993	0.997
175.	0.736	0.854	0.926	0.966	0.985	0.994
185.	0.422	0.616	0.785	0.901	0.962	0.988
195.	0.249	0.438	0.646	0.819	0.925	0.975
AVE =	0.600	0.743	0.857	0.932	0.973	0.990

TABLE XV (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, E and F

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 2

VELOCITY	S/N RATIO (DB) 0.	2.	4.	6.	8.	10.	12.
105.	0.005	0.018	0.054	0.131	0.263	0.438	0.621
115.	0.001	0.004	0.015	0.047	0.118	0.243	0.414
125.	0.000	0.001	0.002	0.008	0.025	0.075	0.182
135.	0.001	0.004	0.013	0.040	0.104	0.221	0.391
145.	0.008	0.026	0.073	0.168	0.317	0.499	0.675
155.	0.018	0.055	0.133	0.266	0.442	0.624	0.776
165.	0.017	0.050	0.123	0.251	0.424	0.608	0.763
175	0.005	0.019	0.055	0.134	0.267	0.443	0.625
185.	0.001	0.002	0.006	0.021	0.061	0.146	0.289
195.	0.000	0.001	0.002	0.006	0.020	0.059	0.145
AVE =	0.006	0.018	0.048	0.107	0.204	0.336	0.488

	14.	16.	18.	20.	22.	24.
105.	0.773	0.878	0.940	0.972	0.988	0.995
115.	0.598	0.756	0.867	0.934	0.970	0.987
125.	0.360	0.581	0.779	0.908	0.969	0.992
135.	0.583	0.757	0.881	0.952	0.984	0.995
145.	0.813	0.903	0.950	0.979	0.991	0.996
155.	0.880	0.941	0.973	0.988	0.995	0.998
165.	0.872	0.936	0.971	0.987	0.994	0.998
175.	0.776	0.880	0.941	0.973	0.988	0.995
185.	0.475	0.668	0.825	0.984	0.973	0.992
195.	0.294	0.495	0.700	0.856	0.945	0.983
AVE =	0.643	0.780	0.883	0.947	0.980	0.993

TABLE XV (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, E and F

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 3

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.010	0.035	0.107	0.252	0.469	0.696	0.864
115.	0.002	0.008	0.030	0.093	0.228	0.438	0.668
125.	0.000	0.001	0.004	0.014	0.049	0.146	0.337
135.	0.002	0.006	0.025	0.079	0.202	0.403	0.639
145.	0.015	0.052	0.145	0.317	0.545	0.759	0.900
155.	0.036	0.108	0.256	0.473	0.699	0.866	0.953
165.	0.032	0.099	0.238	0.450	0.680	0.854	0.947
175.	0.010	0.036	0.109	0.257	0.474	0.700	0.866
185.	0.001	0.003	0.011	0.041	0.121	0.278	0.504
195.	0.000	0.001	0.003	0.011	0.038	0.115	0.274
AVE =	0.011	0.035	0.093	0.199	0.351	0.525	0.695

	14.	16.	18.	20.	22.	24.
105.	0.952	0.986	0.997	0.999	1.000	1.000
115.	0.846	0.944	0.984	0.996	0.999	1.000
125.	0.598	0.828	0.952	0.992	0.999	1.000
135.	0.833	0.944	0.987	0.998	1.000	1.000
145.	0.967	0.991	0.998	1.000	1.000	1.000
155.	0.987	0.997	0.999	1.000	1.000	1.000
165.	0.985	0.996	0.999	1.000	1.000	1.000
175.	0.953	0.987	0.997	0.999	1.000	1.000
185.	0.734	0.895	0.971	0.994	0.999	1.000
195.	0.511	0.752	0.913	0.980	0.997	1.000
AVE =	0.837	0.932	0.980	0.996	0.999	1.000

TABLE XV (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, E and F

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 4

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.012	0.043	0.124	0.285	0.510	0.732	0.886
115.	0.003	0.010	0.036	0.110	0.259	0.478	0.705
125.	0.000	0.001	0.004	0.017	0.059	0.170	0.378
135.	0.002	0.008	0.030	0.093	0.230	0.443	0.679
145.	0.018	0.062	0.168	0.353	0.586	0.791	0.918
155.	0.043	0.127	0.288	0.514	0.735	0.888	0.962
165.	0.039	0.116	0.269	0.491	0.716	0.877	0.958
175.	0.012	0.044	0.127	0.289	0.515	0.736	0.888
185.	0.001	0.004	0.014	0.049	0.140	0.312	0.546
195.	0.000	0.001	0.003	0.013	0.046	0.135	0.309
AVE =	0.013	0.041	0.106	0.221	0.380	0.556	0.723

	14.	16.	18.	20.	22.	24.
105.	0.961	0.989	0.998	0.999	1.000	1.000
115.	0.870	0.955	0.987	0.997	0.999	1.000
125.	0.643	0.859	0.964	0.994	0.999	1.000
135.	0.860	0.956	0.990	0.998	1.000	1.000
145.	0.974	0.993	0.999	1.000	1.000	1.000
155.	0.990	0.998	1.000	1.000	1.000	1.000
165.	0.988	0.997	0.999	1.000	1.000	1.000
175.	0.962	0.990	0.998	1.000	1.000	1.000
185.	0.769	0.914	0.978	0.996	1.000	1.000
195.	0.555	0.788	0.931	0.986	0.998	1.000
AVE =	0.857	0.944	0.984	0.997	1.000	1.000

TABLE XVI

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, C, D, E, F, G and H

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 1

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.004	0.014	0.043	0.110	0.232	0.409	0.609
115.	0.001	0.004	0.012	0.038	0.098	0.212	0.383
125.	0.000	0.001	0.002	0.006	0.020	0.060	0.153
135.	0.001	0.003	0.010	0.032	0.085	0.191	0.358
145.	0.006	0.021	0.060	0.143	0.284	0.474	0.671
155.	0.015	0.044	0.111	0.234	0.412	0.612	0.786
165.	0.013	0.040	0.103	0.220	0.394	0.594	0.772
175.	0.004	0.015	0.044	0.112	0.235	0.413	0.613
185.	0.001	0.001	0.005	0.017	0.049	0.123	0.255
195.	0.000	0.001	0.001	0.005	0.016	0.047	0.121
AVE =	0.005	0.014	0.039	0.092	0.183	0.314	0.472

	14.	16.	18.	20.	22.	24.
105.	0.783	0.900	0.961	0.987	0.996	0.999
115.	0.583	0.763	0.888	0.956	0.985	0.996
125.	0.319	0.545	0.766	0.913	0.977	0.996
135.	0.563	0.758	0.[illegible]5	0.966	0.992	0.998
145.	0.828	0.925	0.972	0.991	0.998	0.999
155.	0.901	0.962	0.987	0.996	0.999	1.000
165.	0.893	0.958	0.986	0.996	0.999	1.000
175.	0.786	0.902	0.962	0.987	0.996	0.999
185.	0.445	0.656	0.831	0.938	0.983	0.997
195.	0.258	0.468	0.683	0.860	0.955	0.990
AVE =	0.636	0.783	0.893	0.959	0.988	0.997

TABLE XVI (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, C, D, E, F, G and H

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 2

VELOCITY	S/N RATIO (DB)						
	0.	2.	4.	6.	8.	10.	12.
105.	0.005	0.018	0.055	0.135	0.274	0.463	0.663
115.	0.001	0.005	0.016	0.048	0.121	0.252	0.437
125.	0.000	0.001	0.002	0.008	0.026	0.076	0.187
135.	0.001	0.004	0.013	0.041	0.106	0.229	0.411
145.	0.008	0.027	0.075	0.174	0.332	0.530	0.721
155.	0.019	0.056	0.137	0.277	0.467	0.666	0.826
165.	0.017	0.051	0.127	0.261	0.448	0.648	0.813
175.	0.006	0.019	0.056	0.137	0.278	0.468	0.667
185.	0.001	0.002	0.006	[illegible]	0.062	0.150	0.301
195.	0.000	0.001	0.002	0.006	0.020	0.060	0.149
AVE =	0.006	0.018	0.049	0.111	0.213	0.354	0.517

	14.	16.	18.	20.	22.	24.
105.	0.823	0.923	0.971	0.991	0.997	0.999
115.	0.638	0.806	0.913	0.967	0.990	0.997
125.	0.374	0.609	0.817	0.939	0.985	0.997
135.	0.620	0.804	0.922	0.977	0.995	0.999
145.	0.863	0.943	0.980	0.994	0.998	1.000
155.	0.924	0.972	0.991	0.998	0.999	1.000
165.	0.917	0.969	0.990	0.997	0.999	1.000
175.	0.826	0.924	0.972	0.991	0.998	0.999
185.	0.502	0.710	0.869	0.956	0.989	0.998
195.	0.306	0.521	0.739	0.895	0.970	0.994
AVE =	0.679	0.818	0.917	0.970	0.992	0.998

TABLE XVI (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, C, D, E, F, G and H

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 3

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.010	0.036	0.108	0.256	0.485	0.726	0.896
115.	0.002	0.008	0.031	0.095	0.234	0.453	0.697
125.	0.000	0.001	0.004	0.014	0.050	0.148	0.345
135.	0.002	0.007	0.025	0.059	0.206	0.416	0.666
145.	0.015	0.053	0.148	0.326	0.567	0.793	0.930
155.	0.037	0.110	0.262	0.490	0.730	0.898	0.973
165.	0.033	0.100	0.244	0.466	0.710	0.887	0.969
175.	0.010	0.037	0.111	0.263	0.491	0.731	0.899
185.	0.001	0.003	0.012	0.042	0.123	0.285	0.523
195.	0.000	0.001	0.003	0.011	0.039	0.117	0.281
AVE =	0.011	0.036	0.095	0.204	0.363	0.545	0.718

	14.	16.	18.	20.	22.	24.
105.	0.973	0.995	0.999	1.000	1.000	1.000
115.	0.880	0.967	0.993	0.999	1.000	1.000
125.	0.618	0.856	0.971	0.997	1.000	1.000
135.	0.867	0.966	0.995	1.000	1.000	1.000
145.	0.983	0.997	1.000	1.000	1.000	1.000
155.	0.995	0.999	1.000	1.000	1.000	1.000
165.	0.994	0.999	1.000	1.000	1.000	1.000
175.	0.973	0.995	0.999	1.000	1.000	1.000
185.	0.765	0.924	0.985	0.998	1.000	1.000
195.	0.528	0.782	0.939	0.991	0.999	1.000
AVE =	0.858	0.948	0.988	0.998	1.000	1.000

TABLE XVI (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A, B, C, D, E, F, G and H

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 4

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.012	0.043	0.126	0.292	0.528	0.764	0.916
115.	0.003	0.010	0.037	0.111	0.265	0.495	0.736
125.	0.000	0.001	0.004	0.017	0.060	0.173	0.387
135.	0.002	0.008	0.030	0.095	0.235	0.458	0.707
145.	0.019	0.063	0.171	0.364	0.610	0.825	0.945
155.	0.044	0.129	0.296	0.533	0.767	0.918	0.980
165.	0.039	0.117	0.276	0.509	0.748	0.908	0.977
175.	0.012	0.044	0.129	0.296	0.534	0.768	0.919
185.	0.001	0.004	0.014	0.050	0.143	0.321	0.567
195.	0.000	0.001	0.003	0.013	0.047	0.137	0.317
AVE =	0.013	0.042	0.109	0.228	0.394	0.577	0.745

	14.	16.	18.	20.	22.	24.
105.	0.979	0.996	0.999	1.000	1.000	1.000
115.	0.902	0.975	0.995	0.999	1.000	1.000
125.	0.665	0.886	0.979	0.998	1.000	1.000
135.	0.892	0.975	0.997	1.000	1.000	1.000
145.	0.988	0.998	1.000	1.000	1.000	1.000
155.	0.996	1.000	1.000	1.000	1.000	1.000
165.	0.996	0.999	1.000	1.000	1.000	1.000
175.	0.980	0.996	1.000	1.000	1.000	1.000
185.	0.801	0.941	0.990	0.999	1.000	1.000
195.	0.574	0.818	0.954	0.994	1.000	1.000
AVE =	0.877	0.958	0.991	0.999	1.000	1.000

TABLE XVII

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$T_1 = 1/4010$ $T_2 = 1/2645$

$P_F = 10^{-5}$

FOR RECEIVER CASE 1

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.000	0.001	0.005	0.018	0.056	0.143	0.296
115.	0.009	0.030	0.081	0.176	0.311	0.463	0.607
125.	0.031	0.084	0.180	0.316	0.469	0.612	0.729
135.	0.026	0.071	0.160	0.290	0.442	0.588	0.711
145.	0.004	0.015	0.046	0.114	0.227	0.373	0.505
155.	0.000	0.001	0.002	0.006	0.023	0.072	0.181
165.	0.002	0.006	0.019	0.057	0.135	0.256	0.405
175.	0.010	0.032	0.086	0.184	0.321	0.474	0.616
185.	0.026	0.071	0.160	0.291	0.443	0.591	0.717
195.	0.035	0.095	0.207	0.371	0.557	0.726	0.849
AVE =	0.014	0.041	0.095	0.182	0.298	0.430	0.564

	14.	16.	18.	20.	22.	24.
105.	0.492	0.681	0.824	0.912	0.959	0.982
115.	0.726	0.316	0.882	0.927	0.958	0.978
125.	0.818	0.888	0.922	0.950	0.968	0.980
135.	0.804	0.878	0.916	0.946	0.965	0.978
145.	0.560	0.768	0.849	0.907	0.947	0.972
155.	0.357	0.563	0.741	0.864	0.935	0.971
165.	0.555	0.684	0.785	0.857	0.907	0.941
175.	0.733	0.820	0.882	0.923	0.951	0.969
185.	0.817	0.898	0.939	0.969	0.985	0.993
195.	0.925	0.965	0.985	0.993	0.997	0.999
AVE =	0.689	0.794	0.872	0.925	0.957	0.976

TABLE XVII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$T_1 = 1/4010$ $T_2 = 1/2645$

$P_F = 10^{-5}$

FOR RECEIVER CASE 2

VELOCITY	S/N RATIO (DB) 0.	2.	4.	6.	8.	10.	12.
105.	0.001	0.002	0.006	0.092	0.071	0.176	0.347
115.	0.012	0.038	0.131	0.289	0.354	0.566	0.646
125.	0.048	0.104	0.214	0.368	0.513	0.653	0.759
135.	0.033	0.089	0.171	0.332	0.487	0.628	0.742
145.	0.006	0.020	0.059	0.140	0.266	0.419	0.568
155.	0.000	0.001	0.002	0.023	0.030	0.092	0.221
165.	0.002	0.007	0.025	0.078	0.163	0.271	0.450
175.	0.013	0.042	0.107	0.219	0.345	0.519	0.655
185.	0.033	0.089	0.192	[illegible]	0.488	0.631	0.758
195.	0.045	0.118	0.247	[illegible]	0.609	0.767	0.876
AVE =	0.018	0.051	0.114	0.218	0.335	0.467	0.681

VELOCITY	14.	16.	18.	20.	22.	24.
105.	0.549	0.789	0.856	0.930	0.968	0.986
115.	0.757	0.839	0.897	0.938	0.965	0.982
125.	0.839	0.875	0.932	0.956	0.972	0.982
135.	0.827	0.886	0.926	0.953	0.978	0.981
145.	0.694	0.796	0.869	0.921	0.956	0.977
155.	0.414	0.619	0.784	0.898	0.949	0.977
165.	0.597	0.718	0.810	0.875	0.919	0.949
175.	0.763	0.842	0.896	0.933	0.957	0.972
185.	0.841	0.907	0.950	0.975	0.988	0.993
195.	0.940	0.973	0.988	0.995	0.998	0.999
AVE =	0.722	0.820	0.891	0.937	0.964	0.948

TABLE XVII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

T_1 = 1/4010 T_2 = 1/2645

P_F = 10^{-5}

FOR RECEIVER CASE 3

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.001	0.003	0.012	0.045	0.141	0.335	0.593
115.	0.023	0.078	0.200	0.391	0.600	0.772	0.883
125.	0.061	0.207	0.399	0.608	0.777	0.886	0.947
135.	0.066	0.179	0.362	0.572	0.751	0.871	0.939
145.	0.010	0.039	0.119	0.273	0.479	0.678	0.825
155.	0.000	0.001	0.004	0.015	0.058	0.181	0.410
165.	0.003	0.014	0.051	0.145	0.314	0.524	0.714
175.	0.025	0.084	0.212	0.406	0.614	0.782	0.889
185.	0.067	0.179	0.363	0.573	0.753	0.873	0.942
195.	0.091	0.232	0.449	0.684	0.860	0.952	0.987
AVE =	0.037	0.101	0.217	0.371	0.535	0.685	0.813

	14.	16.	18.	20.	22.	24.
105.	0.812	0.934	0.982	0.996	0.999	1.000
115.	0.945	0.976	0.990	0.997	0.999	1.000
125.	0.976	0.990	0.996	0.998	0.999	1.000
135.	0.973	0.988	0.995	0.998	0.999	1.000
145.	0.914	0.962	0.984	0.994	0.998	1.000
155.	0.676	0.868	0.959	0.990	0.998	1.000
165.	0.846	0.926	0.967	0.986	0.994	0.998
175.	0.948	0.977	0.990	0.996	0.998	0.999
185.	0.977	0.992	0.998	0.999	1.000	1.000
195.	0.997	0.999	1.000	1.000	1.000	1.000
AVE =	0.907	0.961	0.986	0.995	0.998	0.999

TABLE XVII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$T_1 = 1/4010$ $T_2 = 1/2645$

$P_F = 10^{-5}$

FOR RECEIVER CASE 4

S/N RATIO (DB)

VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.001	0.004	0.014	0.054	0.165	0.376	0.637
115.	0.028	0.092	0.228	0.429	0.636	0.797	0.899
125.	0.096	0.235	0.437	0.643	0.802	0.901	0.954
135.	0.079	0.205	0.399	0.609	0.779	0.888	0.947
145.	0.013	0.047	0.138	0.306	0.517	0.710	0.846
155.	0.000	0.001	0.005	0.019	0.070	0.211	0.456
165.	0.004	0.017	0.061	0.168	0.349	0.561	0.744
175.	0.031	0.099	0.241	0.444	0.650	0.807	0.904
185.	0.079	0.205	0.400	0.610	0.780	0.890	0.951
195.	0.138	0.263	0.491	0.721	0.883	0.962	0.990
AVE =	0.044	0.117	0.241	0.400	0.563	0.710	0.833

	14.	16.	18.	20.	22.	24.
105.	0.842	0.948	0.986	0.997	0.999	1.000
115.	0.953	0.980	0.992	0.997	0.999	1.000
125.	0.980	0.992	0.996	0.999	0.999	1.000
135.	0.977	0.990	0.996	0.998	0.999	1.000
145.	0.926	0.967	0.987	0.995	0.999	1.000
155.	0.718	0.892	0.968	0.992	0.998	1.000
165.	0.867	0.937	0.972	0.988	0.995	0.998
175.	0.956	0.981	0.992	0.997	0.999	0.999
185.	0.981	0.994	0.998	1.000	1.000	1.000
195.	0.998	1.000	1.000	1.000	1.000	1.000
AVE =	0.920	0.968	0.989	0.996	0.999	1.000

TABLE XVIII

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 1

VELOCITY	S/N RATIO (DB) 0.	2.	4.	6.	8.	10.	12.
105.	0.010	0.031	0.083	0.180	0.316	0.469	0.612
115.	0.002	0.008	0.027	0.074	0.165	0.297	0.449
125.	0.000	0.001	0.004	0.014	0.044	0.117	0.252
135.	0.002	0.007	0.022	0.064	0.148	0.277	0.435
145.	0.014	0.044	0.110	0.221	0.366	0.518	0.653
155.	0.032	0.085	0.182	0.319	0.472	0.614	0.731
165.	0.029	0.078	0.171	0.305	0.457	0.602	0.721
175.	0.010	0.032	0.085	0.183	0.320	0.472	0.615
185.	0.001	0.003	0.011	0.036	0.094	0.198	0.345
195.	0.000	0.001	0.003	0.011	0.034	0.092	0.201
AVE =	0.010	0.029	0.070	0.141	0.241	0.365	0.501

	14.	16.	18.	20.	22.	24.
105.	0.729	0.818	0.880	0.922	0.950	0.968
115.	0.594	0.716	0.808	0.874	0.919	0.950
125.	0.438	0.632	0.789	0.891	0.948	0.977
135.	0.597	0.740	0.848	0.920	0.961	0.982
145.	0.761	0.841	0.896	0.934	0.959	0.976
155.	0.819	0.881	0.923	0.950	0.968	0.980
165.	0.812	0.876	0.919	0.948	0.967	0.979
175.	0.732	0.819	0.881	0.924	0.952	0.971
185.	0.512	0.672	0.802	0.892	0.946	0.975
195.	0.361	0.547	0.716	0.842	0.921	0.963
AVE =	0.636	0.754	0.846	0.910	0.949	0.972

TABLE XVIII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

T_1 = 1/3268 T_2 = 1/4950

$P_F = 10^{-5}$

FOR RECEIVER CASE 2

VELOCITY	S/N RATIO (DB) 0.	2.	4.	6.	8.	10.	12.
105.	0.012	0.040	0.104	0.214	0.360	0.513	0.650
115.	0.003	0.011	0.035	0.093	0.197	0.339	0.493
125.	0.000	0.001	0.005	0.018	0.056	0.145	0.298
135.	0.002	0.009	0.029	0.081	0.179	0.320	0.483
145.	0.019	0.056	0.135	0.259	0.410	0.561	0.689
155.	0.041	0.105	0.217	0.362	0.516	0.653	0.761
165.	0.037	0.097	0.204	0.348	0.502	0.641	0.752
175.	0.013	0.041	0.106	0.217	0.363	0.516	0.653
185.	0.001	0.004	0.015	0.046	0.116	0.235	0.391
195.	0.000	0.001	0.004	0.014	0.044	0.114	0.240
AVE =	0.013	0.037	0.085	0.165	0.274	0.404	0.541

	14.	16.	18.	20.	22.	24.
105.	0.759	0.839	0.895	0.932	0.956	0.972
115.	0.634	0.747	0.831	0.890	0.930	0.957
125.	0.494	0.683	0.825	0.913	0.959	0.982
135.	0.641	0.775	0.873	0.935	0.969	0.986
145.	0.789	0.860	0.909	0.942	0.965	0.980
155.	0.840	0.896	0.933	0.957	0.972	0.983
165.	0.834	0.891	0.930	0.955	0.971	0.982
175.	0.762	0.841	0.896	0.934	0.959	0.976
185.	0.560	0.713	0.833	0.912	0.957	0.981
195.	0.412	0.599	0.759	0.871	0.937	0.971
AVE =	0.672	0.784	0.868	0.924	0.958	0.977

TABLE XVIII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 3

VELOCITY	S/N RATIO (DB) 0.	2.	4.	6.	8.	10.	12.
105.	0.024	0.081	0.206	0.399	0.608	0.777	0.886
115.	0.005	0.020	0.070	0.185	0.371	0.582	0.758
125.	0.001	0.002	0.009	0.034	0.111	0.279	0.526
135.	0.004	0.016	0.058	0.162	0.340	0.555	0.747
145.	0.037	0.113	0.264	0.469	0.669	0.819	0.910
155.	0.082	0.209	0.403	0.611	0.779	0.888	0.947
165.	0.074	0.194	0.383	0.593	0.766	0.880	0.943
175.	0.025	0.083	0.210	0.404	0.612	0.780	0.888
185.	0.002	0.007	0.029	0.092	0.229	0.431	0.646
195.	0.000	0.002	0.007	0.026	0.087	0.224	0.438
AVE =	0.025	0.073	0.164	0.298	0.457	0.621	0.769

	14.	16.	18.	20.	22.	24.
105.	0.947	0.976	0.990	0.996	0.998	0.999
115.	0.875	0.941	0.974	0.989	0.995	0.998
125.	0.761	0.909	0.973	0.993	0.999	1.000
135.	0.881	0.954	0.986	0.996	0.999	1.000
145.	0.959	0.982	0.992	0.997	0.999	1.000
155.	0.977	0.990	0.996	0.998	0.999	1.000
165.	0.975	0.989	0.995	0.998	0.999	1.000
175.	0.948	0.977	0.990	0.996	0.998	0.999
185.	0.819	0.925	0.975	0.993	0.998	1.000
195.	0.672	0.852	0.948	0.98	0.997	0.999
AVE =	0.881	0.950	0.982	0.994	0.998	0.999

TABLE XVIII (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-5}$

FOR RECEIVER CASE 4

	S/N RATIO (DB)						
VELOCITY	0.	2.	4.	6.	8.	10.	12.
105.	0.030	0.096	0.235	0.437	0.643	0.802	0.901
115.	0.006	0.025	0.083	0.212	0.408	0.618	0.785
125.	0.001	0.003	0.011	0.041	0.131	0.317	0.571
135.	0.005	0.020	0.070	0.187	0.376	0.593	0.777
145.	0.045	0.132	0.296	0.507	0.702	0.841	0.923
155.	0.097	0.238	0.441	0.647	0.805	0.903	0.955
165.	0.088	0.222	0.420	0.628	0.792	0.896	0.951
175.	0.030	0.098	0.239	0.442	0.647	0.805	0.903
185.	0.002	0.009	0.035	0.109	0.259	0.470	0.682
195.	0.001	0.002	0.008	0.032	0.103	0.255	0.480
AVE =	0.030	0.084	0.184	0.324	0.487	0.650	0.793

	14.	16.	18.	20.	22.	24.
105.	0.954	0.980	0.992	0.996	0.999	0.999
115.	0.891	0.949	0.978	0.991	0.996	0.999
125.	0.796	0.926	0.979	0.995	0.999	1.000
135.	0.899	0.963	0.989	0.997	0.999	1.000
145.	0.965	0.985	0.994	0.998	0.999	1.000
155.	0.980	0.992	0.997	0.999	0.999	1.000
165.	0.979	0.991	0.996	0.998	0.999	1.000
175.	0.955	0.980	0.992	0.997	0.999	1.000
185.	0.844	0.938	0.980	0.995	0.999	1.000
195.	0.710	0.875	0.958	0.989	0.997	0.999
AVE =	0.897	0.958	0.985	0.995	0.999	1.000

TABLE XIX

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$T_1 = 1/4010$ $T_2 = 1/2645$

$P_F = 10^{-6}$

```
GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 101,1
  V        PD1A       PD1B       PDS
  105      0.557      0.711      0.872
  115      0.045      0.901      0.905
  125      0.000      0.937      0.937
  135      0.000      0.932      0.932
  145      0.052      0.872      0.879
  155      0.568      0.552      0.806
  165      0.823      0.000      0.823
  175      0.904      0.000      0.904
  185      0.932      0.340      0.955
  195      0.939      0.832      0.990

AVERAGE PROB. =  0.900

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 42,1
  V        PD1A       PD1B       PDS
  105      0.267      0.454      0.600
  115      0.003      0.780      0.781
  125      0.000      0.856      0.856
  135      0.000      0.845      0.845
  145      0.004      0.724      0.725
  155      0.278      0.262      0.467
  165      0.632      0.000      0.632
  175      0.787      0.000      0.787
  185      0.846      0.098      0.861
  195      0.861      0.649      0.951

AVERAGE PROB. =  0.750
```

TABLE XIX (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$T_1 = 1/4010$ $T_2 = 1/2645$

$P_F = 10^{-6}$

```
GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 16.55,1
   V        PD1A        PD1B        PDS
   105       0.055       0.161       0.207
   115       0.000       0.543       0.543
   125       0.000       0.680       0.680
   135       0.000       0.659       0.659
   145       0.000       0.455       0.455
   155       0.060       0.053       0.110
   165       0.332       0.000       0.332
   175       0.554       0.000       0.554
   185       0.659       0.010       0.662
   195       0.688       0.353       0.798

AVERAGE PROB. =  0.500

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 86.5,2
   V        PD2A        PD2B        PDS
   105       0.555       0.710       0.871
   115       0.041       0.901       0.905
   125       0.000       0.937       0.937
   135       0.000       0.932       0.932
   145       0.048       0.872       0.879
   155       0.566       0.550       0.805
   165       0.823       0.000       0.823
   175       0.904       0.000       0.904
   185       0.932       0.335       0.955
   195       0.939       0.832       0.990

AVERAGE PROB. =  0.900
```

TABLE XIX (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$T_1 = 1/4010$ $T_2 = 1/2645$

$P_F = 10^{-6}$

```
GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 36.2,2
 V        PD2A        PD2B        PDS
 105       0.264       0.453       0.597
 115       0.003       0.781       0.782
 125       0.000       0.857       0.857
 135       0.000       0.846       0.846
 145       0.004       0.725       0.726
 155       0.275       0.259       0.463
 165       0.632       0.000       0.632
 175       0.788       0.000       0.788
 185       0.846       0.094       0.861
 195       0.862       0.650       0.952

AVERAGE PROB. =  0.750
```

```
GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 14.35,2
 V        PD2A        PD2B        PDS
 105       0.052       0.158       0.202
 115       0.000       0.545       0.545
 125       0.000       0.682       0.682
 135       0.000       0.661       0.661
 145       0.000       0.456       0.456
 155       0.057       0.050       0.104
 165       0.332       0.000       0.332
 175       0.556       0.000       0.556
 185       0.661       0.008       0.664
 195       0.691       0.353       0.800

AVERAGE PROB. =  0.502
```

TABLE XIX (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$T_1 = 1/4010$ $T_2 = 1/2645$

$P_F = 10^{-6}$

```
GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 30, 3
  V         PD3A        PD3B        PDS
  105        0.402       0.657       0.795
  115        0.003       0.942       0.942
  125        0.000       0.975       0.975
  135        0.000       0.971       0.971
  145        0.004       0.909       0.909
  155        0.419       0.394       0.648
  165        0.840       0.000       0.840
  175        0.945       0.000       0.945
  185        0.971       0.138       0.975
  195        0.977       0.855       0.997

AVERAGE PROB. =  0.900


GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 15.65, 3
  V         PD3A        PD3B        PDS
  105        0.140       0.360       0.449
  115        0.000       0.836       0.836
  125        0.000       0.923       0.923
  135        0.000       0.912       0.912
  145        0.000       0.760       0.760
  155        0.150       0.135       0.265
  165        0.624       0.000       0.624
  175        0.844       0.000       0.844
  185        0.912       0.025       0.914
  195        0.927       0.650       0.974

AVERAGE PROB. =  0.750
```

TABLE XIX (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

T_1 = 1/4010 T_2 = 1/2645

P_F = 10^{-6}

```
GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 7,2,3
  V        PD3A        PD3B        PDS
  105      0.017       0.085       0.100
  115      0.000       0.561       0.561
  125      0.000       0.751       0.751
  135      0.000       0.723       0.723
  145      0.000       0.434       0.434
  155      0.019       0.016       0.034
  165      0.268       0.000       0.268
  175      0.576       0.000       0.576
  185      0.723       0.002       0.724
  195      0.762       0.296       0.832

AVERAGE PROB. =  0.500

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 27.8,4
  V        PD4A        PD4B        PDS
  105      0.399       0.656       0.794
  115      0.003       0.943       0.943
  125      0.000       0.975       0.975
  135      0.000       0.972       0.972
  145      0.003       0.910       0.910
  155      0.416       0.391       0.645
  165      0.841       0.000       0.841
  175      0.946       0.000       0.946
  185      0.972       0.134       0.975
  195      0.977       0.855       0.997

AVERAGE PROB. =  0.900
```

TABLE XIX (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$T_1 = 1/4010$ $T_2 = 1/2645$

$P_F = 10^{-6}$

```
GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 14.55,4
   V        PD4A        PD4B        PDS
  105       0.136       0.358       0.445
  115       0.000       0.838       0.838
  125       0.000       0.924       0.924
  135       0.000       0.913       0.913
  145       0.000       0.761       0.761
  155       0.147       0.131       0.259
  165       0.624       0.000       0.624
  175       0.846       0.000       0.846
  185       0.913       0.023       0.915
  195       0.928       0.651       0.975

AVERAGE PROB. =  0.750
```

```
GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 6.7,4
   V        PD4A        PD4B        PDS
  105       0.015       0.082       0.096
  115       0.000       0.562       0.562
  125       0.000       0.753       0.753
  135       0.000       0.725       0.725
  145       0.000       0.433       0.433
  155       0.017       0.014       0.031
  165       0.266       0.000       0.266
  175       0.577       0.000       0.577
  185       0.725       0.001       0.725
  195       0.764       0.293       0.833

AVERAGE PROB. =  0.500
```

TABLE XX

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-6}$

```
GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 118,1
  V        PD1A       PD1B       PDS
  105      0.000      0.916      0.916
  115      0.003      0.863      0.863
  125      0.543      0.728      0.876
  135      0.853      0.379      0.909
  145      0.927      0.010      0.928
  155      0.946      0.000      0.946
  165      0.944      0.000      0.944
  175      0.917      0.006      0.917
  185      0.813      0.348      0.878
  195      0.377      0.714      0.822

AVERAGE PROB. =  0.900

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 50.7,1
  V        PD1A       PD1B       PDS
  105      0.000      0.817      0.817
  115      0.000      0.714      0.714
  125      0.263      0.490      0.624
  135      0.696      0.129      0.735
  145      0.840      0.001      0.840
  155      0.880      0.000      0.880
  165      0.875      0.000      0.875
  175      0.818      0.000      0.818
  185      0.624      0.109      0.665
  195      0.128      0.469      0.537

AVERAGE PROB. =  0.750
```

TABLE XX (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-6}$

```
GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 20.55,1
  V        PD1A        PD1B        PDS
 105       0.000       0.614       0.614
 115       0.000       0.449       0.449
 125       0.057       0.197       0.243
 135       0.424       0.016       0.433
 145       0.656       0.000       0.656
 155       0.733       0.000       0.733
 165       0.724       0.000       0.724
 175       0.617       0.000       0.617
 185       0.333       0.012       0.341
 195       0.016       0.180       0.193

AVERAGE PROB. =  0.500

GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 101.3,2
  V        PD2A        PD2B        PDS
 105       0.000       0.916       0.916
 115       0.002       0.863       0.864
 125       0.542       0.728       0.875
 135       0.854       0.376       0.909
 145       0.927       0.009       0.928
 155       0.947       0.000       0.947
 165       0.944       0.000       0.944
 175       0.917       0.005       0.917
 185       0.813       0.344       0.878
 195       0.374       0.714       0.821

AVERAGE PROB. =  0.900
```

TABLE XX (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

T_1 = 1/3268 T_2 = 1/4950

P_F = 10^{-6}

```
GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 43.6,2
   V        PD2A        PD2B        PD5
   105      0.000       0.817       0.817
   115      0.000       0.714       0.714
   125      0.260       0.488       0.621
   135      0.696       0.124       0.734
   145      0.840       0.003       0.840
   155      0.881       0.000       0.881
   165      0.876       0.000       0.876
   175      0.819       0.000       0.819
   185      0.624       0.105       0.664
   195      0.123       0.468       0.533

AVFRAGE PROB. =  0.750


GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 17.6,2
   V        PD2A        PD2B        PD5
   105      0.000       0.616       0.616
   115      0.000       0.450       0.450
   125      0.054       0.194       0.238
   135      0.424       0.015       0.433
   145      0.658       0.000       0.658
   155      0.735       0.000       0.735
   165      0.726       0.000       0.726
   175      0.619       0.000       0.619
   185      0.332       0.011       0.339
   195      0.014       0.178       0.189

AVERAGE PROB. =  0.500
```

TABLE XX (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-6}$

```
GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 34.6,3
  V        PD3A       PD3B       PDS
  105      0.000      0.956      0.956
  115      0.000      0.895      0.895
  125      0.375      0.681      0.801
  135      0.882      0.171      0.902
  145      0.966      0.000      0.966
  155      0.981      0.000      0.981
  165      0.979      0.000      0.979
  175      0.957      0.000      0.957
  185      0.822      0.142      0.847
  195      0.169      0.657      0.715

AVERAGE PROB. =  0.900
```

```
GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 18.6,3
  V        PD3A       PD3B       PDS
  105      0.000      0.877      0.877
  115      0.000      0.740      0.740
  125      0.132      0.403      0.482
  135      0.713      0.037      0.724
  145      0.903      0.000      0.903
  155      0.943      0.000      0.943
  165      0.938      0.000      0.938
  175      0.879      0.000      0.879
  185      0.606      0.028      0.617
  195      0.036      0.374      0.397

AVERAGE PROB. =  0.750
```

TABLE XX (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-6}$

```
GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 8.95,3
  V        PD3A       PD3B       PDS
  105      0.000      0.662      0.662
  115      0.000      0.427      0.427
  125      0.018      0.117      0.133
  135      0.391      0.003      0.393
  145      0.719      0.000      0.719
  155      0.818      0.000      0.818
  165      0.806      0.000      0.806
  175      0.666      0.000      0.666
  185      0.269      0.002      0.271
  195      0.003      0.102      0.105

AVERAGE PROB. =  0.500
```

```
GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 32,4
  V        PD4A       PD4B       PDS
  105      0.000      0.956      0.956
  115      0.000      0.895      0.895
  125      0.371      0.680      0.799
  135      0.882      0.166      0.902
  145      0.967      0.000      0.967
  155      0.981      0.000      0.981
  165      0.980      0.000      0.980
  175      0.957      0.000      0.957
  185      0.823      0.137      0.847
  195      0.164      0.656      0.712

AVERAGE PROB. =  0.900
```

TABLE XX (Continued)

DETECTION PROBABILITY FOR COHERENT MTI MODE

Beam Numbers A and E

Center (No Beam Averaging)

$T_1 = 1/3268$ $T_2 = 1/4950$

$P_F = 10^{-6}$

```
GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 17.3,4
  V       PD4A       PD4B       PDS
  105     0.000      0.879      0.879
  115     0.000      0.741      0.741
  125     0.128      0.402      0.479
  135     0.715      0.035      0.725
  145     0.905      0.000      0.905
  155     0.944      0.000      0.944
  165     0.940      0.000      0.940
  175     0.881      0.000      0.881
  185     0.606      0.026      0.617
  195     0.034      0.373      0.394

AVERAGE PROB. =  0.750


GIVE SN OF SINGLE PULSE, AND RECEIVER CASE
= 8.35,4
  V       PD4A       PD4B       PDS
  105     0.000      0.664      0.664
  115     0.000      0.427      0.427
  125     0.016      0.115      0.129
  135     0.391      0.003      0.393
  145     0.722      0.000      0.722
  155     0.820      0.000      0.820
  165     0.809      0.000      0.809
  175     0.668      0.000      0.668
  185     0.268      0.002      0.269
  195     0.003      0.099      0.102

AVERAGE PROB. =  0.560
```

TABLE XXI

S/N FOR SCAN MODE $P_F = 10^{-4}$

Comparison Ward - Vannicola

	Probability of Detection				
	50%	75%	90%	95%	BEAMS
Ward	4.4	6.8	9.4	10.9	Center A only
Using Barton	5.8	7.8	9.7	10.7	AUB Position Average
Vannicola Using	4.5	7.2	9.8	11.7	Center A only
Appendix B	5.7	8.0	10.1	11.3	AUB Position Average

TABLE XXII

S/N (DB) FOR 75% DETECTION PROBABILITY

		BEAMS	SCAN	MTI	MTI LOSS
Ward $P_F = 10^{-4}$	I^2	AUB	7.8	14.8	7.0
Average Velocity	$I^2 + Q^2$	AUB	7.8	11.1	3.3
	I^2	AUBUCUD		14.3	
Vannicola 10^{-4}	I^2	AUB	8.0	19.1	11.1
Average over all T	$I^2 + Q^2$	AUB	8.0	15.0	7.0
Vannicola $P_F = 10^{-5}$	I^2	Center	5.2	14.9	9.7
Average over all T	$I^2 + Q^2$	AUE	5.2	11.0	5.8
Vannicola $P_F = 10^{-5}$	I^2	AUE	7.4	17.0	9.6
Average over all T	$I^2 + Q^2$	AUE	7.4	13.0	5.6
$P_F = 10^{-5}$	I^2	AUB	8.8	19.1	10.3
$T_1 = 1/4010$ $T_2 = 1/2645$	$I^2 + Q^2$	AUB	8.8	15.0	6.2
$P_F = 10^{-5}$	I^2	(AUB)U(EUF)	6.7	14.7	8.0
$T_1 = 1/4010$ $T_2 = 1/2645$	$I^2 + Q^2$	(AUB)U(EUF)	6.7	11.6	4.9

APPENDIX A

DETECTION OF SLOW FLUCTUATING TARGETS WITH FREQUENCY DIVERSITY CHANNELS

by

Vincent Vannicola

Introduction

In this appendix an exact closed-form expression for the radar detection probability is derived and tabulated for a frequency diversity radar receiver. The receiver model performs post detection integration on all received pulses in all diversity channels. The target model assumed is the slow fluctuating Rayleigh-distributed (Swerling Case I Target) scatterer. Each of the M frequency diverse channels receives N amplitude correlated returns to give a total of NM post square law detection integrations. The tabulated data computed herein falls between the two extreme cases; that for which all the returns are amplitude correlated and that for which each return is independent. The plotted results fall close to the figures obtained through simple empirical relationships.

Returns from radar targets generally fluctuate in amplitude and phase according to some probability density function and some fluctuation rate. If one is to analytically determine the detection probability for a particular type of target in a noise environment, it is necessary that the statistics of target return and noise be known. Although it is not always possible to characterize the actual target return statistics, one can make a good approximation which gives remarkable results for a wide variety of target and noise situations.

The four target cases modeled and evaluated by Swerling[1] are well known to radar engineers and have met with great acceptance. The situations which these cases cover are of two extremes:

1. That of a slowly fluctuating target where the cross section is random and remains correlated during the scan time. The pulses reflected off such a target are correlated with each other in amplitude during that scan although the pulse-to-pulse phase may be independent.

2. That of a rapidly fluctuating target where the cross section becomes uncorrelated from pulse to pulse. The received amplitude and phase are independent from pulse to pulse. The noise in all four models is zero-mean white Gaussian.

An excellent treatment of these four cases is given by DiFranco and Rubin[2] wherein the optimum receiver along with its performance is derived and plotted [illegible] curves.

For partially correlated received pulses, several papers have been written.

Swerling has developed[3] a method which is applicable to a large family of probability density functions and for fairly general correlation properties of the signal fluctuations. His method yields the characteristic function of the probability density of sum random variables defined as Y. To obtain p (Y) and p_d with this technique requires computer evaluations.

Schwartz[4] considered the partially correlated case for N = 2 and a Rayleigh amplitude density function. As to be expected, his curves fall between those of the two extremes: zero correlation and complete correlation.

In a recent paper by Barton[5] an approximate formula is given for determining the signal-to-noise required for a given detection probability when there are N pulses representing n_e independent signal samples. The method is based on a very simple empirical relationship which appears to interpolate between complete correlation and zero correlation from pulse to pulse. For the examples tested it is shown that this approach renders remarkably accurate results.

A similar expression involving interpolation methods is given by Swerling[6].

In this appendix, the case of M frequency diverse channels each containing N correlated pulses each with Rayleigh amplitude density function is evaluated. An exact closed-form solution is derived for the output probability density function and the detection probability for a given false alarm probability and signal-to-noise ratio when all MN pulses are square law detected and combined as shown in Figure A-1. Each of the MN pulses has independent Gaussian noise, and each group of N pulses has an independent Gaussian signal giving a total of M independent signals in all MN pulses.

DERIVATION OF PROBABILITY DENSITY FUNCTION

We may start the derivation simply by using the results of DiFranco and Rubin.[2]

DETERMINING THE THRESHOLD FOR FALSE ALARM

The output probability density function for no signal present may be written from equation[2] (10.4-17) with MN representing the total number of pulses and the variable Y representing the "convenient modified form" of equation (10.4-4)

$$Y = \sum_{i=1}^{MN} \frac{1}{2} r_i^2 \qquad \text{(A-1)}$$

$$p(Y;0) = \frac{Y^{MN-1}e^{-Y}}{(MN-1)!} \qquad \text{(A-2)}$$

From (A-2) we may write the false alarm probability using[2] (10.4-18a)

$$p_F = \int_{Y_b}^{\infty} p(Y;0)\,dY = \int_{Y_b}^{\infty} \frac{Y^{MN-1}e^{-Y}}{(MN-1)!}\,dY \qquad \text{(A-3)}$$

This integral has been evaluated by Pachares[7] for $1 \leq MN \leq 150$ and false alarm probabilities equal to $10^{-m'}$ where m' is an integer ranging between 1 and 12. Using the Pachares tables, one may obtain threshold Y_b to four decimal places.

DETECTION PROBABILITY

Next the probability of detection is derived. We may start with the characteristic function of the signal out of the N pulse integrator which corresponds to the Swerling Case I given by DiFranco and Rubin[2] in (11.2-23) and is repeated here.

$$\overline{C_{Y_i}(\xi)_{A_i}} = \frac{(-1)^N}{(1+NA_0^2)\left(-\frac{1}{1+NA_0^2}+j\xi\right)(-1+j\xi)^{N-1}} \qquad \text{(A-4)}$$

where A_0^2 is the variance of the target return signal.

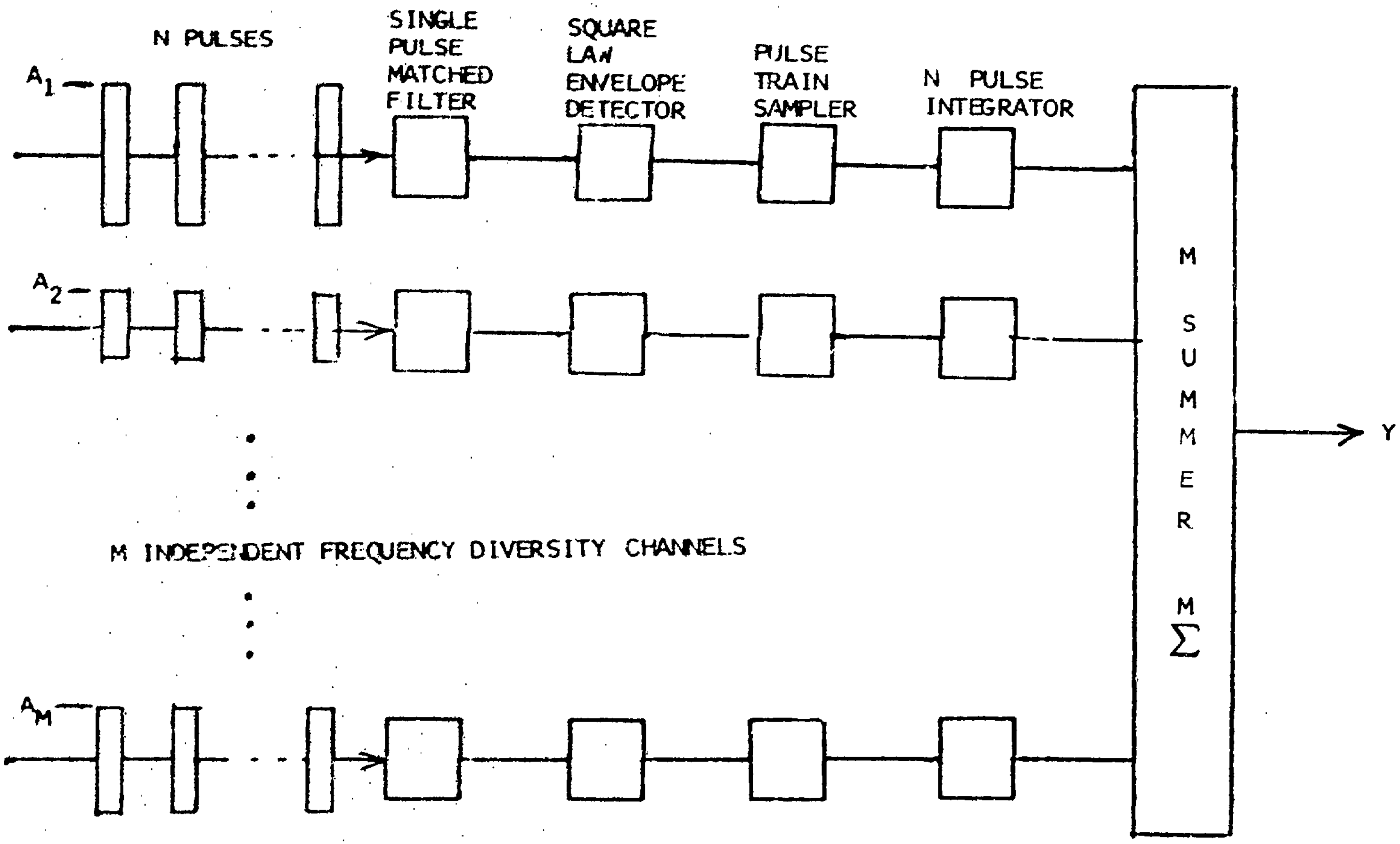

Figure A-1. M Channel MN Pulse Combiner

When we add M of these outputs through the adder,

$$Y = \sum_{i=1}^{M} Y_i \tag{A-5}$$

where Y_i having amplitude A_i is independent of $Y_j, i \neq j$, the result is

$$\overline{C_Y(\xi)_{A_1, A_2, \ldots A_M}} = \frac{(-1)^{MN}}{(1+NA_o^2)^M \left(-\frac{1}{1+NA_o^2} + j\xi\right)^M (-1+j\xi)^{M(N-1)}} \tag{A-6}$$

$$p(Y) = p(Y;1)$$

Probability density p(Y) is obtained first by factoring (6)

$$\overline{C_Y(\xi)_{A_1, A_2, \ldots A_M}} = \tag{A-7}$$

$$\frac{(-1)^{M-1}}{(1+NA_o^2)^{M-1}\left(-\frac{1}{1+NA_o^2} + j\xi\right)^{M-1}} \times \frac{(-1)^{M(N-1)+1}}{(1+NA_o^2)\left(-\frac{1}{1+NA_o^2} + j\xi\right)(-1+j\xi)^{M(N-1)}}$$

Next we use the results of[2] (11.2-28) which allows us to write the anti-characteristic function of the second factor of (A-7)

$$p'(Z) = \frac{\beta e^{\beta Z}}{[M(N-1)-1]!\,(1+\beta)^{M(N-1)}}\, \gamma\,[M(N-1), (\beta+1)Z] \tag{A-8}$$

where the substitution $\beta = -1/(1+NA_o^2)$ has been made.

The first factor in (A-7) results in (M-1)-fold integration over the incomplete gamma function, $\gamma\,[M(N-1), (\beta+1)Z]$, of (8) with the additional multiplier β^{M-1} in order to obtain p(Y;1). The probability density function p(Y) is thus written

$$p(Y) = \frac{\beta^M e^{\beta Y}}{(1+\beta)^{M(N-1)}} \int_0^Y \int_0^{Z_{M-1}} \underset{\cdots\cdots}{(M-1)} \int_0^{Z_2} \frac{\gamma\,[M(N-1), (\beta+1)Z_1]}{[M(N-1)-1]!}\, dZ_1, dZ_2 \ldots dZ_{M-1} \tag{A-9}$$

This (M-1) fold integral is evaluated by expanding the integrand[8] to the form

$$\frac{\gamma(n,x)}{(n-1)!} = 1 - \left[1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \ldots \frac{x^{n-1}}{(n-1)!}\right] e^{-x} \tag{A-10}$$

performing the integrations, and collecting terms. The result is

$$p(Y) = \frac{\beta^{M} e^{\beta Y}}{(1+\beta)^{MN-1}} \left\{ \frac{[(1+\beta)Y]^{M-1}}{(M-1)!} + \left(\sum_{i=0}^{M-2} (-1)^{1+i} (-1)^{M-1-i} \frac{(MN-2-i)!}{(MN-M-1)!\,(M-1-i)!} \right. \right.$$

$$\left. \left. \frac{[(1+\beta)Y]^{i}}{i!} \right) + 1\, e^{-(1+\beta)Y} \left(\sum_{j=0}^{MN-M-1} \frac{(MN-2-j)!}{(MN-M-1-j)!\,(M-1)!} \frac{[(1+\beta)Y]^{j}}{j!} \right) \right\} \qquad \text{(A-11)}$$

The probability of detection

$$P_D = \int_{Y_b}^{\infty} p(Y)\,dY = 1 - \int_{0}^{Y_b} p(Y)\,dY \qquad \text{(A-12)}$$

can be found in a similar manner by performing the integration and collecting terms. The expression which results can be contracted using the incomplete gamma functions expansion according to equation (A-10) to yield

$$P_D = 1 - \frac{\beta^{M-1}}{(1+\beta)^{MN-1}} \left\{ \left[\sum_{i=0}^{M-1} \left(\frac{1+\beta}{\beta}\right)^{i} \frac{(MN-2-i)!}{(MN-M-1)!\,(M-1-i)!} \frac{\gamma(1+i, \beta Y_b)}{i!} \right] \right.$$

$$\left. + \beta \left[\sum_{j=0}^{MN-M-1} (1+\beta)^{j} \frac{(MN-2-j)!}{(MN-M-1-j)!\,(M-1)!} \frac{\gamma(1+j, Y_b)}{j!} \right] \right\} \qquad \text{(A-13)}$$

from which curves may be constructed after choosing the appropriate threshold, Y_b, from Pachares[7] tables. In using Pachares tables, the total number of pulses m corresponds to MN

The expression in equation (A-13) resembles an expression derived by James[9] for target detection in noise when the target fading period is less than the post detection integration and greater than the interpulse period. His expression is in terms of target, post-correlator, and noise bandwidths and with a degree of effort can be related to the topic treated in this report.

COMPUTATIONAL RESULTS AND CHECKING WITH OTHER RESULTS

Equation (A-13) is used to compute the curves in Figures A-2 and A-3. These figures present the probability of detection versus single pulse rms signal-to-noise ratio for different combinations of correlated pulses per channel, N, and number of diversity channels, M. Each figure shows a family of curves for a given false alarm probability. Note that these curves fall between the two extreme cases, i.e., when M = 1, Swerling Case I and N = 1, Swerling Case II as presented in DiFranco and Rubin.[2] The curves for Case I, M = 1 and Case II, N = 1 have been repeated here and as expected they check with those of the above reference. The 3 dB discrepancy between the curves presented herein and those of DiFranco and Rubin is due to the fact that we are plotting P_D against the average signal-to-noise ratio A_0^2 rather than the average of the peak $R_p = 2A_0^2$ of that reference. The points on Figures A-2 and A-3 are computed using Barton's[5] paper. Note the agreement of these points with the curves which were plotted using equation (A-13). Regions of departure occur at high probabilities of detection as well as low probabilities.

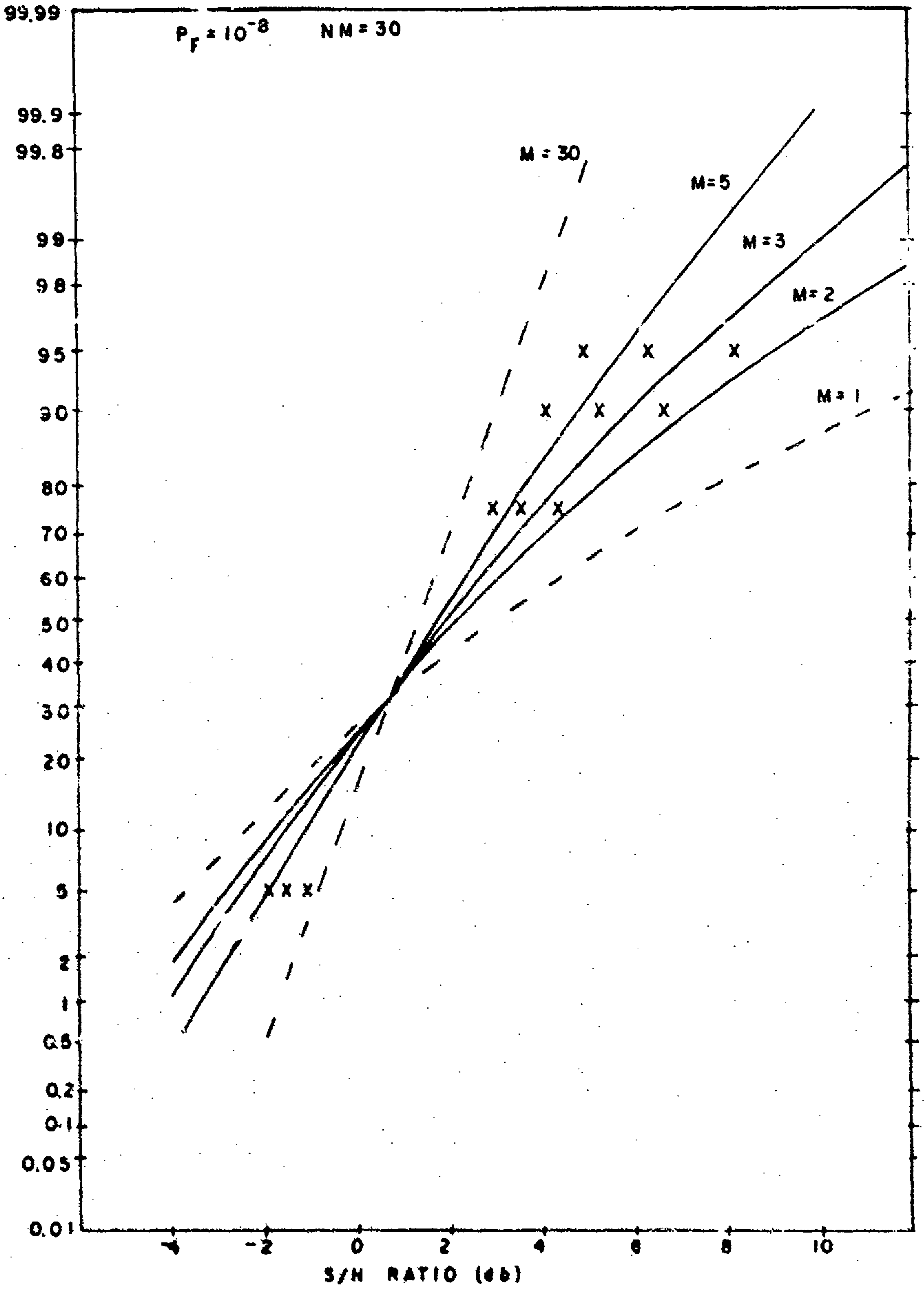

Figure A-2. Probability of Detection for Six Block Correlated Pulses

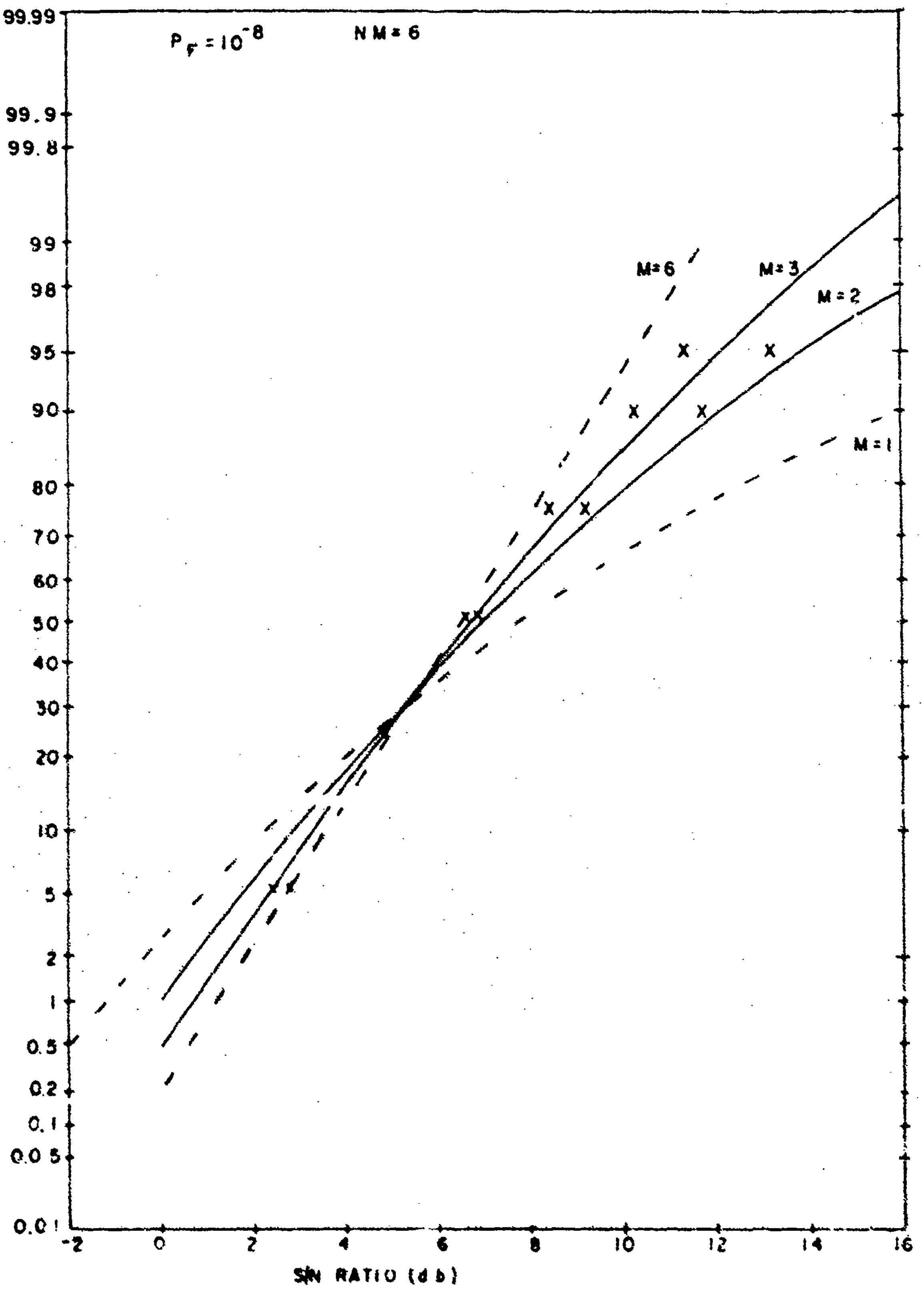

Figure A-3. Probability of Detection for Thirty Block Correlated Pulses

The computer programming ran into some accuracy difficulties when the number of channels M was made large. This was due largely to overflows and underflows encountered in the terms of equation (A-13). A discussion on this topic is presented in Appendix C authored by E. Bromley who did all the programming for obtaining the numerical results reported herein.

REFERENCES

1. P. Swerling, "Probability of Detection for Fluctuating Targets," *IEEE Trans. Information Theory,* Vol IT-6, No. 2, pp 269-308, April 1960.

2. J.V. DiFranco and W.L. Rubin, *Radar Detection,* Englewood Cliffs, N.J. Prentice-Hall, Inc. 1968, Chapters 9-11.

3. P. Swerling, "Detection of Fluctuating Pulsed Signals in the Presence of Noise," *IRE Trans. Information Theory,* Vol IT-3, No. 3, pp 175-178, September 1957.

4. M. Swartz, "Effects of Signal Fluctuation on the Detection of Pulse Signals in Noise," *IRE Trans. Information Theory,* Vol IT-2, No. 2, pp 66-71, June 1956.

5. D.K. Barton. "Simple Procedures for Radar Detection Calculations," *IEEE Trans. Aerospace and Electronic Systems,* Vol AES-5, No. 5, pp 837-846, September 1969.

6. P. Swerling, "Recent Developments in Target Models for Radar Detection Analysis," *The AGARD Avionics Technical Symposium on Advanced Radar Systems* 25-29, May 1970, Istanbul, Turkey.

7. J. Pachares, "A Table of Bias Levels Useful in Radar Detection Problems," *IRE Trans. Information Theory,* Vol IT-4, No. 1, pp 38-45, March 1958.

8. M. Abramowitz and I.A. Stegun, "Handbook of Mathematical Functions," Washington, D.C. National Bureau of Standards, 1965, pp 260-262.

9. P.W. James, "Detection of Fading Targets in Noise: the Case in Which the Fading is Neither Fast Nor Slow," Royal Aircraft Establishment, U.K., Tech. Note RAD 828, AD 406158, January 1963.

APPENDIX B

DERIVATION OF PROBABILITY OF DETECTION FOR THE FOUR MTI RECEIVER CASES

by

Vincent Vannicola

This Appendix presents the derivation of the probability density function of the variable ℓ_i and computation of the threshold γ_i for each receiver case.

The receiver cases are shown in Figure 3 of the basic report. The input into each port is a zero mean Gaussian random variable with variance σ^2. (This variance may be either $\sigma_0{}^2$ or $\sigma_1{}^2$ depending on H_0 or H_1.) For simplicity let us denote the inputs by x_1, x_2, etc. Then the input pdf at each port is

$$px\,(X) = \frac{1}{\sqrt{2\pi}\sigma}\exp\left(-\frac{x^2}{2\sigma^2}\right) \tag{B-1}$$

(a) The pdf of the output of the absolute valuer is obtained as follows

$$p|x|(|X|) = |J|\,px(X)\Big|_{x<0} + |J|\,px(X)\Big|_{x>0} \tag{B-2}$$

where

$$|J| = \left|\frac{\partial x}{\partial|x|}\right| = 1$$

Letting $u = |X| = |-X|$ we have

$$pu(U) = \sqrt{\frac{2}{\pi}}\,\frac{1}{\sigma}\exp\left(-\frac{u^2}{2\sigma^2}\right) \; : \; u \geqslant 0 \tag{B-3}$$

$$pu(U) = 0 \qquad : u < 0$$

Since ℓ_1 is the sum of the two independent variables u_1 and u_2 we may obtain the pdf of ℓ_1 through the convolution integral

$$p_{\ell 1}(\ell_1) = \int_{-\infty}^{\infty} pu\,(\ell_1 - u)\,pu\,(u)\,du$$

$$= \frac{2}{\pi\sigma^2}\int_0^{\ell_1}\exp\left(-\frac{[\ell_1 - u]^2 + u^2}{2\sigma^2}\right)du$$

$$= \frac{2}{\sqrt{\pi}\sigma}\exp\left(\frac{\ell_1{}^2}{4\sigma^2}\right)\mathrm{erf}\left(\frac{\ell_1}{2\sigma}\right) \tag{B-4}$$

It can be seen that this expression is found in (7-A) of the report.

In order to determine the threshold, the false alarm probability must be evaluated using the integral

$$P_F = \int_{\gamma_1}^{\infty} p\ell_1(\ell_1)\, d\ell_1 = \frac{2}{\sqrt{\pi}\sigma} \int_{\gamma_1}^{\infty} \operatorname{erf}\left(\frac{\ell_1}{2\sigma_0}\right) \exp\left(-\frac{\ell_1^2}{4\sigma_0^2}\right) d\ell_1$$

$$= \Big|_{\gamma_1}^{\infty} \operatorname{erf}^2\left(\frac{\ell_1}{2\sigma_0}\right) = 1 - \operatorname{erf}^2\left(\frac{\gamma_1}{2\sigma_0}\right) \qquad \text{(B-5)}$$

For $P_F = 5 \times 10^{-7}$ we have

$$P_F = 1 - \operatorname{erf}^2\left(\frac{\ell_1}{2\sigma_0}\right) = 5 \times 10^{-7}$$

$$P_F = \left[1 + \operatorname{erf}\left(\frac{\gamma_1}{2\sigma_0}\right)\right] \left[1 - \operatorname{erf}\left(\frac{\gamma_1}{2\sigma_0}\right)\right] = 5 \times 10^{-7} \qquad \text{(B-6)}$$

We see that erf $\left(\frac{\gamma_1}{2\sigma_0}\right)$ is almost unity so (B-6) reduces to

$$\operatorname{erfc}\left(\frac{\gamma_1}{2\sigma_0}\right) = 2.5 \times 10^{-7} \qquad \text{(B-7)}$$

Solving for γ_1 [1-B], the threshold, we get

$$\gamma_1 = 3.65\,(2\sigma_0) = 7.30\,\sigma_0 \qquad \text{(B-8)}$$

which agrees with (12-A).

The detection probability is obtained by evaluating the same integral in (B-5) except that the variance is different.

$$P_D = \Big|_{\gamma_1}^{\infty} \operatorname{erf}^2\left(\frac{\ell_1}{2\sigma_1}\right) = 1 - \operatorname{erf}^2\left(\frac{\gamma_1}{2\sigma_1}\right) \qquad \text{(B-9)}$$

which is of the form corresponding to (14-A).

(b) This case is simply the sum of the square of two statistically zero mean Gaussin random variables.

$$\ell_2 = X_1^2 + X_2^2 \qquad \text{(B-10)}$$

Its probability density function is derived in many textbooks. Since it is simple to derive we will go through the basic steps here. We set

$$\ell_2 = X_1^2 + X_2^2 \qquad X_1 = \sqrt{\ell_2}\ \cos\theta$$

$$\theta = \tan^{-1}\left(\frac{X_2}{X_1}\right) \qquad X_2 = \sqrt{\ell_2}\ \text{sine}\ \theta$$

giving a Jacobian

$$|J| = \begin{vmatrix} \frac{1}{2\sqrt{\ell_2}}\cos\theta & \frac{1}{2\sqrt{\ell_2}}\sin\theta \\ -\sqrt{\ell_2}\ \sin\theta & \sqrt{\ell_2}\ \cos\theta \end{vmatrix} = \frac{1}{2} \tag{B-11}$$

The transformation may be written

$$p_{\ell_2\theta}(\ell_2, \theta) = |J|\, p_{x_1, x_2}(X_1, X_2) = \frac{1}{4\pi\sigma^2}\exp\left(-\frac{\ell_2}{2\sigma^2}\right) \tag{B-12}$$

The pdf of ℓ_2 is then evaluated

$$p_{\ell_2}(\ell_2) = \int_0^{2\pi} p_{\ell_2,\theta}(\ell_2, \theta)\, d\theta = \frac{1}{2\sigma^2}\exp\left(-\frac{\ell_2}{2\sigma^2}\right) \tag{B-13}$$

and is in agreement with (7-B).

In a manner similar to finding threshold and detection probability of case (a) we may write

$$P_F = \int_{\gamma_2}^{\infty} p_{\ell_2}(\ell_2)\, d\ell_2 = \Big|_{\gamma_2}^{\infty} -e^{\frac{\ell_2}{2\sigma_0}} = e^{-\frac{\gamma_2}{2\sigma^2}} = 5 \times 10^{-7} \quad \therefore \gamma_2 = 29\sigma_0^2 \tag{B-14}$$

which agrees with (12-B), and

$$P_D = \Big|_{\gamma_2}^{\infty} -\exp\left(-\frac{\ell_2}{2\sigma_1^2}\right) = \exp\left(\frac{\ell_2}{2\sigma_1^2}\right) \tag{B-15}$$

which corresponds to (14-B).

(c) To start with we may use the results of case b which have just developed. The pdf for $y^2 = \ell_2$ is equation (7-B).

$$P_{y^2}(y^2) = \frac{1}{2\sigma^2}\exp\left(-\frac{y^2}{2\sigma^2}\right) \tag{B-16}$$

and through a simple transformation

$$|J| = \frac{\partial y^2}{\partial y} = 2y$$

we see as expected that y has a Rayleigh distribution

$$p_y(y) = |J|\, p_{y^2}(y^2) = \frac{y}{\sigma^2} \exp(-\frac{y^2}{2\sigma^2}) \qquad \text{(B-17)}$$

Now the pdf of

$$\ell_3 = y_1 + y_2 \qquad \text{(B-18)}$$

where the y variables are statistically independent is found through the convolution integral

$$p_{\ell_3}(\ell_3) = \int_{-\infty}^{\infty} p_y(y) py\,({}_3 - y)\,dy$$

$$= \int_0^{\ell_3} \frac{y}{\sigma^2} \exp(-\frac{y^2}{2\sigma^2})\,[\frac{\ell_3}{\sigma^2} - \frac{y}{\sigma^2}]\,\exp(-\frac{\ell_3 - y}{2\sigma^2})^2\,dy \qquad \text{(B-19)}$$

$$= \frac{\ell_3}{2\sigma^2} \exp(-\frac{\ell_3^2}{2\sigma^2}) + \frac{\sqrt{\pi}}{2\sigma}(\frac{\ell_3^2}{2\sigma^2} - 1)\exp(-\frac{\ell_3^2}{4\sigma^2})\,\mathrm{erf}(\frac{\ell_3}{2\sigma})$$

This is an agreement with (7-C).

The false alarm probability is derived by integrating (B-19).

$$P_F = \int_{\gamma_3}^{\infty} p_{\ell_3}(\ell_3)\,d\ell_3 \qquad \text{(B-20)}$$

The integration may be simplified by a change in variables

$$a = \frac{\ell_3}{2\sigma}$$

giving

$$P_F = \int_{\frac{\gamma_3}{2\sigma}}^{\infty} 2a\exp(-2a^2)\,da + \sqrt{\pi}\int_{\frac{\gamma_3}{2\sigma}}^{\infty} 2a^2 esp(-a^2)\,\mathrm{erf}(a)\,da - \sqrt{\pi}\int_{\frac{\gamma_3}{2\sigma}}^{\infty} \exp(-a^2)\,\mathrm{erf}(a)\,da \qquad \text{(B-21)}$$

The first integral of (B-21) is

$$\int_{\frac{\gamma_3}{2\sigma}}^{\infty} 2a\exp(-2a^2)\,da = -\frac{1}{2}\,\Big|_{\frac{\gamma_3}{2\sigma}}^{\infty}\exp(-2a^2)$$

the second integral is

$$\sqrt{\pi} \int_{\frac{\gamma_3}{2\sigma}}^{\infty} 2a^2 \exp(-a^2)\,\mathrm{erf}\,(a)\,da$$

$$= -\sqrt{\pi} \Big|_{\frac{\gamma_3}{2\sigma}}^{\infty} a \exp(-a^2)\,\mathrm{erf}\,(a) + \frac{\pi}{4} \Big|_{\frac{\gamma_3}{2\sigma}}^{\infty} \mathrm{erf}^2\,(a) - \frac{1}{2} \Big|_{\frac{\gamma_3}{2\sigma}}^{\infty} \exp(-2a^2)$$

and the third is

$$-\sqrt{\pi} \int_{\frac{\gamma_3}{2\sigma}}^{\infty} a \exp(-a^2)\,\mathrm{erf}\,(a)\,da = -\frac{\pi}{4} \Big|_{\frac{\gamma_3}{2\sigma}}^{\infty} \mathrm{erf}^2\,(a)$$

Combining we have

$$P_F = -\sqrt{\pi} \Big|_{\frac{\gamma_3}{2\sigma}}^{\infty} a \exp(-a^2)\,\mathrm{erf}\,(a) - \Big|_{\frac{\gamma_3}{2\sigma}}^{\infty} \exp(-2a^2)$$

$$= \sqrt{\pi}\,\frac{\gamma_3}{2\sigma_0} \exp\left(-\frac{\gamma_3^2}{4\sigma_0^2}\right) \mathrm{erf}\left(\frac{\gamma_3}{2\sigma_0}\right) + \exp\left(-\frac{\gamma_3^2}{2\sigma_0^2}\right) \qquad \text{(B-22)}$$

which is in agreement with (11-C).

To find the threshold γ_3 we set P_F equal to 5×10^{-7} and note that for the large value of γ_3 which satisfies this condition the following approximation holds:

$$a \exp(-a^2) \cong \frac{1}{\sqrt{\pi}}\; 5 \times 10^{-7} \qquad \text{(B-23)}$$

Equation (B-23) may be put into logarithmic form giving

$$a^2 = \ell n\,(a) + 15.0$$

and through trial and error we find this relation to be satisfied when

$$a = \frac{\gamma_3}{2\sigma_0} = 4.05$$

$$\gamma_3 = 8.1\,\sigma_0 \qquad \text{(B-24)}$$

which agrees with (12-C).

The detection probability is simply

$$P_D = \sqrt{\pi}\frac{\gamma_3}{2\sigma_1}\exp\left(-\frac{\gamma_3^2}{4\sigma_1^2}\right)\mathrm{erf}\left(\frac{\gamma_3}{2\sigma_1}\right) + \exp\left(-\frac{\gamma_3^2}{2\sigma_1^2}\right) \tag{B-25}$$

in agreement with (14-C).

(d) For this receiver case the variable ℓ_4 is the sum of two independent variables y_1^2 and y_2^2 each having probability density function as that for ℓ_2 of case (b) given in equation (B-13).

$$p_{\ell_2}(\ell_2) = \frac{1}{2\sigma^2}\exp\left(-\frac{\ell_2}{2\sigma^2}\right)$$

Since

$$\ell_4 = y_1^2 + y_2^2 \tag{B-26}$$

and

$$p_{y_1^2}(y^2) = p_{y_2^2}(y^2) = p_{\ell_2}(y^2) = p_{\ell_2}(\ell_2) \tag{B-27}$$

for $\ell_2 = y_2$ the probability density function of ℓ_4 may be derived from the convolution integral

$$p_{\ell_4}(\ell_4) = \int_0^{\ell_4} \frac{1}{2\sigma^2}\exp\left(-\frac{\ell_2}{2\sigma^2}\right)\frac{1}{2\sigma^2}\exp\left(-\frac{\ell_4-\ell_2}{2\sigma^2}\right)d\ell_2$$

$$= \frac{1}{4\sigma^4}\exp\left(-\frac{\ell_4}{2\sigma^2}\right)\int_0^{\ell_4} d\ell_2 \tag{B-28}$$

$$= \frac{\ell_4}{4\sigma^4}\exp\left(-\frac{\ell_4}{2\sigma^2}\right)$$

giving the same expression as in (7-D).

This is recognized as a chi square distribution with four degrees of freedom as should be expected.

Now the false alarm probability is

$$P_F = \int_{\gamma_4}^{\infty} p_{\ell_4}(\ell_4)\,d\ell_4 = \int_{\gamma_4}^{\infty}\frac{\ell_4}{4\sigma^4}\exp\left(-\frac{\ell_4}{2\sigma^2}\right)d\ell_4$$

$$= \Big|_{\gamma_4}^{\infty} \frac{\ell_4}{2\sigma}\exp\left(-\frac{\ell_4}{2\sigma^2}\right) + \int_{\gamma_4}^{\infty}\frac{1}{2\sigma^2}\exp\left(-\frac{\ell_4}{2\sigma^2}\right)d\ell_4 \tag{B-29}$$

$$= \left(\frac{\gamma_4}{2\sigma_0^2} + 1\right) \exp\left(-\frac{\gamma_4}{2\sigma_0^2}\right)$$

which corresponds to equation (11-D).

The threshold may be evaluated by setting

$$P_F = \left(\frac{\gamma_4}{2\sigma_0^2} + 1\right) \exp\left(-\frac{\gamma_4}{2\sigma_0^2}\right) = 5 \times 10^{-7}$$

or in logarithmic form letting $a = \frac{\gamma_4}{2\sigma_0 2}$

$$a = \ln(a+1) - \ln 5 + 7 \ln 10$$

$$a = \ln(a+1) + 14.5$$

and solving for

$$a = 17.5$$

we have

$$\gamma_4 = 35\,\sigma_0^2 \qquad \text{(B-30)}$$

which corresponds to equation (12-D).

The detection probability is obtained by substituting into equation (B-29) σ_1^2 for σ_0^2 and the value for γ_4 of (B-30) and results in

$$P_D = \left(\frac{\gamma_4}{2\sigma_1^2} + 1\right) \exp\left(-\frac{\gamma_4}{2\sigma_1^2}\right) \qquad \text{(B-31)}$$

This corresponds to equation (14-D).

REFERENCES

1-B M. Abramowitz and I.A. Stegun, *Handbook of Mathematical Functions,* Washington, D.C., National Bureau of Standards, 1965.

APPENDIX C

COMPUTATIONAL PROCEDURE FOR PROBABILITIES OF DETECTION

by

Eugene Bromley
Sgt, USAF

The expression for the probability of detection is given by equation (A-13)

$$P_D = 1 - \frac{\beta m}{\rho(Nm + N - 1)} \left[\sum_{i=0}^{m} \left(\frac{\rho}{\beta}\right)^i \frac{(n + m - i - 1)!}{(n - 1)!\,(m - i)!} \; \frac{\gamma(i + 1, -\beta Y_0)}{i!} \right.$$

$$\left. + \beta \sum_{j=0}^{n-1} \rho^j \frac{(n + m - j - 1)!}{(n - j - 1)!\,m!} \; \frac{\gamma(j + 1, Y_0)}{j!} \right] \qquad (C\text{-}1)$$

where $m = M - 1$

$n = M(N - 1)$

$\beta = -\dfrac{1}{1 + NA_0^2}$

$\rho = \beta + 1$

$\gamma(k, x)$ = incomplete gamma function

The evaluation of this function presents some computational difficulties which were not entirely resolved in the time available. For typical values of the parameters many of the quantities (the factorials, β^m, or $\gamma(k, x)$) become greater than 10^{38} or less than 10^{-38} and exceed the capacity of the computer. This problem was overcome very simply by taking logarithms. However, for cases involving relatively large m and low S/N ratio the numbers comprising the summations become very large and opposite in sign. For example, for $m = 14$ and $N = 2$ the largest terms are on the order of 10^{20}. Since the final answer is a probability, it must lie between 0 and 1. As such more than 20 place accuracy is required in the terms of the summations, whereas single precision on a computer offers only 8 places. Also, much greater accuracy can be required for other combinations of the parameters.

For the present we have not included results over the entire range of interest of all the variables. It is expected, however, that the expression could be rewritten or re-expressed to be compatible with the limitations of the computer. The following is a listing of the actual Fortran Program used to calculate the results.

```
10   COMMON FAC(400),H(200),GAM2(2,200),ISIG(200)
20 COMMON PDT(30),YO(30,5),NPR(30,36),NP(30),A(20)
60  READ: NT
70  READ: NC
80  DO 8 I=1,NC;8 READ: (YO(I,J),J=1,5)
90  READ: (NP(I),I=1,NC)
100  DO 10 I=1,NC;NPAIR=2*NP(I)
110  10  READ: (NPR(I,K),K=1,NPAIR)
120 DO 55 I=1,9;55 A(I)=2.*I-10.
130  ISIG(1)=1
140  DO 81 I=2,NT;J=I-1;81 ISIG(I)=-1*ISIG(J)
150  2 FORMAT (3X,F12.4,6X,I2,6X,I3,6X,F7.2,6X,F12.8)
160   FAC(1) = 0.
170  FAC(2)=0.
180  DO 80 I=3,NT
190  J=I-1
200  80  FAC(I)=FAC(J)+ALOG(FLOAT(J))
210  DO 6 I1=1,NC;NPAIR=2*NP(I1)
220  DO 6 K=2,NPAIR,2;K1=K-1;M=NPR(I1,K1);N=NPR(I1,K);XN=N
222  PRINT 102,N,M;102 FORMAT ("- FOR N =",I3," AND M =",I3)
229  PRINT 104;PRINT 103,(A(I),I=1,9);PRINT 120;120 FORMAT ("0")
230  DO 6 J=1,5;Y=YO(I1,J)
233  104 FORMAT ("-                         < S/N RATIO (DB) >")
236  103 FORMAT ("    Y    ",9F6.0)
240  M=NPR(I1,K1);N=NPR(I1,K);XN=N
244  DO 5 M1=1,9;A2=0.
246 AO=10.**(A(M1)/20.)
248  BETA=-1./(1.+XN*AO*AO)
250  P=-BETA*Y
252  MS=M+1;CALL GA(2,MS,P)
255  B1=ALOG(-BETA)
258  NS=(M+1)*(N-1);ROA=BETA+1.;R1=ALOG(ROA)
260  N6=N*M+N-1
270  IF(M1.EQ.1) CALL GA(1,NS,Y)
272  DO 4 I=1,NS;IA=I-1;M12=M+2;M13=ISIG(M12)
274  H2=ALOG(FAC2(NS,M,IA))
276  H3=(M+1)*B1;H4=(N6-IA)*R1
278  A7=H3-H4+GAM2(1,I)+H2;IF(ABS(A7).GT. 50.) GOTO 4
280  A2=A2+M13*EXP(A7);4 CONTINUE

READY

*
```

```
330  MS=M+1;DO 3 I=1,MS;IA=I-1;M10=M-IA+1
344  G2=ALOG(FAC1(NS,M,IA))
345  G3=(M-IA)*B1;G4=(N6-IA)*R1
350  A6=G3-G4+GAM2(2,I)+G2;IF(ABS(A6).GT.50.) GOTO 3
360  A2=A2+ISIG(M10)*EXP(A6); 3 CONTINUE
620  IF(ABS(A2).GT. 50.) A2=-50.
630  PD=1.0-A2
640  PDT(M1)=PD;5 CONTINUE;PRINT 89,Y,(PDT(J8),J8=1,9)
650  89 FORMAT (F7.2,1X,9F6.3)
660  6 CONTINUE
670  STOP;END
680   FUNCTION FAC1(NS,M,IA)
690   N = M - IA
700   P = 1.
710   DO 10 I = 1,N
720   10 P = P*(NS-1+I)/I
730   FAC1 = P
740   IF(M .EQ. IA)FAC1 = 1.
750   RETURN
760   END
770   FUNCTION FAC2(NS,M,IA)
780   N = M
790   P = 1.
800   DO 10 I = 1,N
810   10 P = P*(NS-IA-1+I)/I
820   FAC2 = P
830   IF(M .EQ. 0) FAC2 = 1.
840   RETURN
850   END
1000  SUBROUTINE GA(I3,NS,X)
1005  COMMON FAC(400),H(200),GAM2(2,200)
1010  C=ALOG(X)
1020   NMAX=2.*X+10.;IF(NMAX.GT.30) NMAX=30
1030  IMAX=NS+NMAX;XN=1.5*X
1040  DO 10 I=1,IMAX;IA=I-1
1050  10 H(I)=IA*C-X-FAC(I);H5=1.0
1060  DO 20 I=1,NS;GAM2(I3,I)=0.
1070  G3=I
1080  IF(XN.GT.G3) GOTO 80
1090  J=I+1;J1=J+NMAX-1;H8=H(J);GAM=0.
1100  DO 30 K=J,J1
1110  H1=H(K)-H8;IF(ABS(H1).GT.50.) GOTO 30
1120  GAM=GAM+EXP(H1)
1130  GAM2(I3,I)=ALOG(GAM)+H8
1140  30 CONTINUE;GO TO 20
1150  80 IF(ABS(H(I)).GT.50.) GOTO 20
1160  H5=H5-EXP(H(I))
1170  GAM2(I3,I)=ALOG(H5)
1180  20 CONTINUE;RETURN;END

READY

*
```