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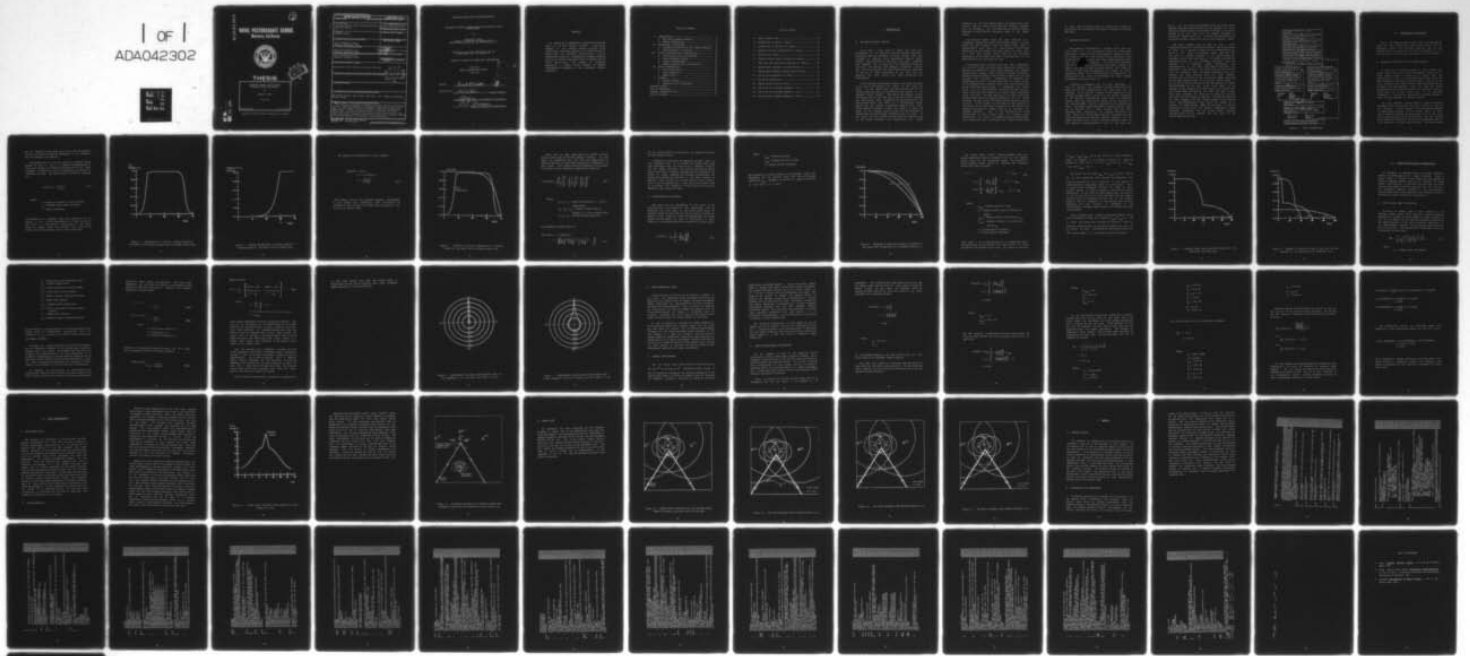
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ELECTRONIC WARFARE SUPPORT JAMMING
PRE-MISSION ROUTE OPTIMIZATION

by

Kenneth D. Watts

June 1977

Thesis Advisor:

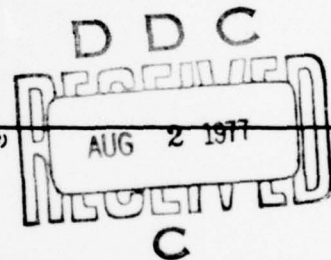
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ELECTRONIC WARFARE SUPPORT JAMMING PRE-MISSION ROUTE
OPTIMIZATION

by

Kenneth D. Watts
Captain, United States Marine Corps
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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

from the
NAVAL POSTGRADUATE SCHOOL
June 1977

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ABSTRACT

An algorithm is developed to determine an optimum route for an ECM support aircraft. Constraints imposed on the problem include aircraft speed limitations, tolerable exposure of the ECM aircraft to enemy fire, and available jammer assets. A priori information required to implement the program consists only of the hostile electronic order of battle and the strike group route. The program is purposely simplified to enable future transfer to smaller minicomputers available to the electronic warfare squadrons.

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I. INTRODUCTION

A. THE ROUTE PLANNING PROBLEM

In the past, a great deal of effort has gone into development of new airborne electronic warfare equipment. Extensive tests and evaluation of these systems have been conducted to optimize their performance against threat systems. When delivered to the fleet, they truly represent good systems, but it seems that the optimization stops at that time. The systems, with computer assistance, perform well for the situations and environments they are subjected to, but what is often overlooked is the fact that the operator has some control over these situations and environments.

In the airborne ECM support mission, the policy has been to fly one of two profiles; the escort or the stand off route. In the escort role, the ECM aircraft flies in the strike group formation and concentrates his assets on the terminal threat radars. This may be advantageous in some situations, but for the most part, with the threat density and Home-On-Jam (HOJ) capability of current missiles, the ECM aircraft would only serve as a billboard threat magnet and his chances of survival would be slim. Also, after ordnance delivery, he would be unable to keep the speed of the exiting strike group, and the advantage of radar-strike aircraft-jammer alignment would be lost. In the stand off role the ECM aircraft does not penetrate any of the threat envelopes and concentrates his assets

primarily on the wider beamed search and acquisition (ACQ) radars. This is a good tactic where ECM aircraft exposure must be minimized, but good radar-strike aircraft-jammer alignment is sacrificed and excessive range of the jammer occurs.

The modified escort route has been suggested as a compromise between the escort and standoff routes. In this route, the ECM aircraft flies an escort role until a predetermined point where it alters course to avoid high exposure areas and rejoins the strike group on their exit leg. This type mission offers some of the increased performance of the escort role while retaining some of the survivalability of the stand off role.

If presented with a strike route, the EOB, permissible ECM aircraft threat exposure, jammer assets, and speed, the operator can determine a route which maximizes the jamming effectiveness against enemy emitters for these conditions. Current planning documents and tactical manuals give the ECM operator the necessary information to determine the effectiveness against a single radar from any given point. If the operator flies anything other than a pure escort role he must determine which radars to concentrate his assets upon; i.e., he must determine a priority for each emitter. These priorities will change as the strike group progresses along its route. For each position of the strike route the operator must check all possible locations for his jammer platform to come up with the best possible position for his aircraft. He then repeats this process for each position of the strike route, each time re-prioritizing each emitter and checking each possible jammer location to determine his optimum position. When he has performed all these calculations he must select within the aircraft speed limitations, the route for maximum jamming effectiveness. For a moderately dense environment and a simple strike route

it would take an operator days to research all information and perform the calculations necessary to develop an optimum ECM route.

B. PROGRAM DESCRIPTION

The problem of determining an optimum route does not lend itself well to a continuous solution by conventional techniques. Because of the fixed number of jammers on board the aircraft and the rather abrupt lethal envelopes of the threat systems, there arise many sharp discontinuities which defy the continuous solution. In a very short period of time the various emitter priorities can change grossly and jammer assignments should instantly change. As a result of this the problem must be approached as a series of static situations which can be solved within the constraints. An optimum route can then be determined by using dynamic programming techniques [Ref. 1].

A program to accomplish this has been developed. It does not generate the absolute optimum route since this would take far more computer size and time than will be available to the aircrew. Because of the constraint of ECM aircraft maximum speed, a majority of the points calculated in the absolute optimization would have to be discarded anyway, since they could not be reached by the aircraft in the time available. Several approaches to the problem were tried. The method chosen represents a nearly optimum route and is obtained with a small program size and short execution time. Essentially, the program determines the point where the strike group exposure is greatest and for this time computes the absolute optimum position for the jammer platform within its own tolerable exposure limits. It then computes a high performance route to and from this

point. For the typical environment where the strike group exposure increases monotonically to this maximum, the route generated should approach the absolute optimum. It should be pointed out at this time that the program generates a horizontal flight route only. As such, all beam widths and radiation patterns referred to are in the horizontal plane.

The basic program flow is seen in Fig 1. It is comprised primarily of two parallel paths. The strike route is input as a series of points that are separated by one minute in time. After the allowable jammer positions and the point of highest exposure to the strike group are computed, the ten best positions for the jammer platform are determined from all the allowable positions. Ten was selected as a reasonable number considering the characteristics of the Wang 2200 computer expected to be available to the operator. The strike route is then divided into two segments about the highest exposure point. The program then takes parallel paths for each segment. Starting with the first of the ten possible jammer positions at the high exposure point, a circle with radius equal to the one minute flight distance of the ECM aircraft is drawn. The performance for the next strike route point in the segment is then computed from every point in the circle with the highest being retained as the next ECM route point. This point becomes the center of the circle for the next time slot and the process is repeated. The routes generated for both segments are then joined together to form an ECM route. The performances at each point are summed for a measure of effectiveness (MOE) for the route. A route is generated for each of the ten highest performance jammer positions determined for the strike group's greatest exposure point, and the operator has his choice of the routes based on the MOE.

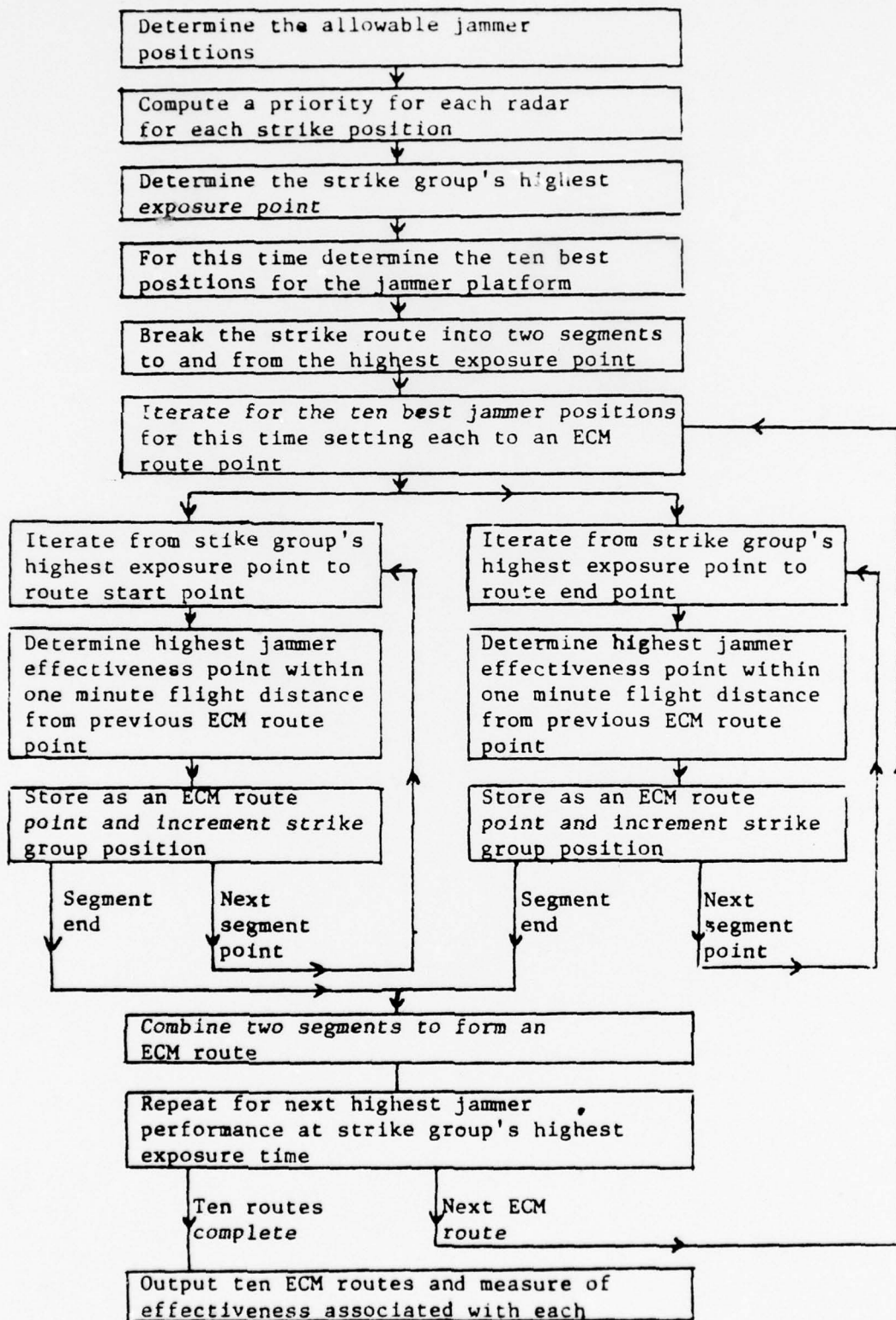


Figure 1 - BASIC PROGRAM FLOW

II. PRELIMINARY CALCULATIONS

Before the jamming effectiveness values are determined, there are some preliminary calculations which must be performed. First, the allowable positions for the ECM aircraft must be defined, and then for each position of the strike route, a priority must be assigned to each emitter.

A. ALLOWABLE POSITIONS FOR THE JAMMER PLATFORM

If there were an unlimited supply of ECM aircraft and crews, there would be no problem determining a route to fly. Every mission would be flown as an escort role and effectiveness would be outstanding until such time as the ECM aircraft was destroyed by HOJ missiles. Such is not the case, however, since these aircraft and their crews are few in number and very expensive. They also lack the flight performance characteristics essential to fly escort with the strike group in a high threat area. It is therefore necessary to restrict the operation of the ECM aircraft to areas of lower exposure to terminal threats.

For this program a pucker factor is used to determine allowable areas of operation. This pucker factor is input by the operator. It is a measure of his permissible exposure to enemy weapons systems. If the pucker factor is zero, then no threat envelopes are penetrated; if it is one, there are no restrictions, and the ECM aircraft may fly through areas where his probability of being hit approaches unity if he is selected as a weapon system target. The pucker factor

may be anywhere in the range zero to one, and the operator is free to select the value he determines to be necessary for the success of the mission.

The probability of a kill vs. range for a typical weapon system is seen in Fig 2. To obtain an approximation of this curve suitable for computer calculations, it was first necessary to generate a curve of probability of survival as a function of range. The model chosen is given by equation (1).

$$P(\text{SURVIVAL}) = \left(\frac{r}{R_L} \right)^n \quad (1)$$

Where:

r = range of aircraft at time of launch

R_L = maximum lethal range of weapon

n = emitter parameter

The parameter n is dependent upon the lethality of the weapon. A plot of this survivability vs. range is seen in Fig 3 with n = 4. The low kill probability at the short range is ignored since the aircraft would have to fly through the higher exposure area to reach that point.

KILL
PROBABILITY

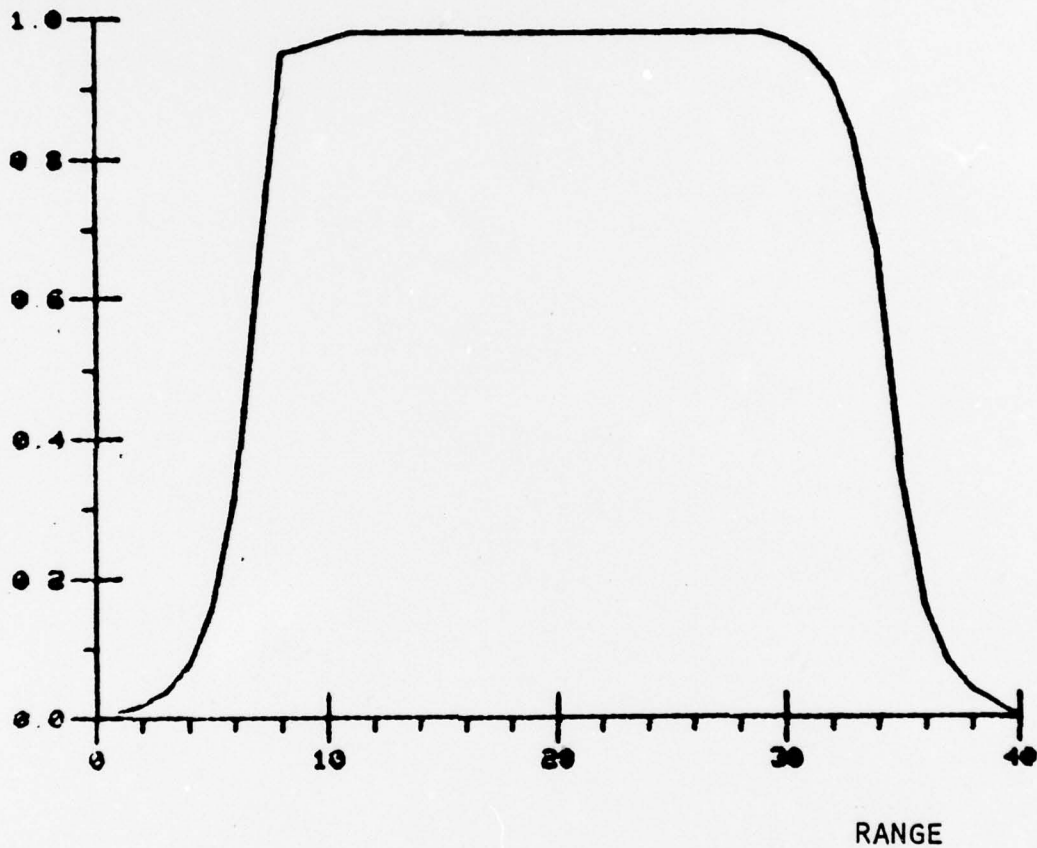


Figure 2 - PROBABILITY OF A KILL BY A HOSTILE WEAPON VS.
THE RANGE OF THE TARGET AIRCRAFT FROM THE WEAPON LAUNCH SITE.

PROBABILITY OF SURVIVAL

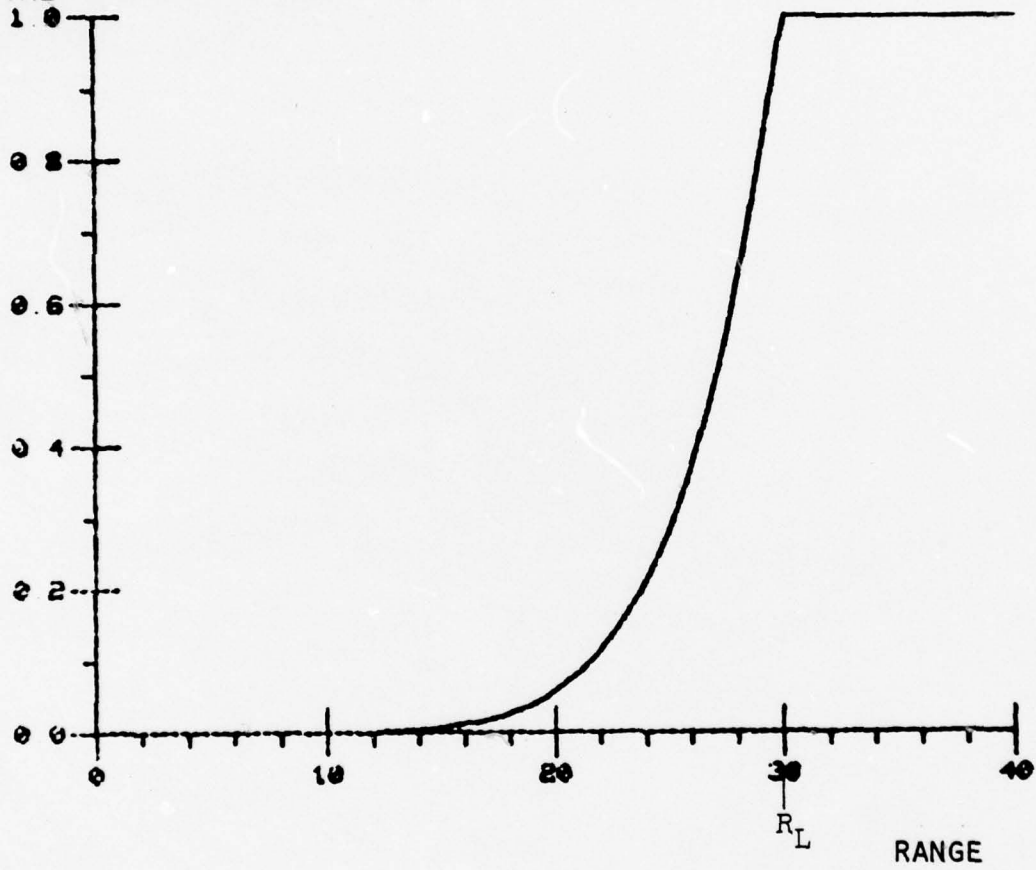


Figure 3 - ASSUMED PROBABILITY OF SURVIVAL AGAINST A HOSTILE WEAPON VS. THE RANGE FROM THE WEAPON SITE.

The exposure, or probability of kill, becomes:

$$\begin{aligned} \text{EXPOSURE} &= P(\text{KILL}) \\ &= 1 - P(\text{SURVIVAL}) \\ &= 1 - \left(\frac{r}{R_L} \right)^n \end{aligned} \tag{2}$$

Fig 4 shows a plot of the calculated exposure superimposed on the typical kill probability curve. The factor n is selected to give the best fit between the two curves in the area of the greater range.

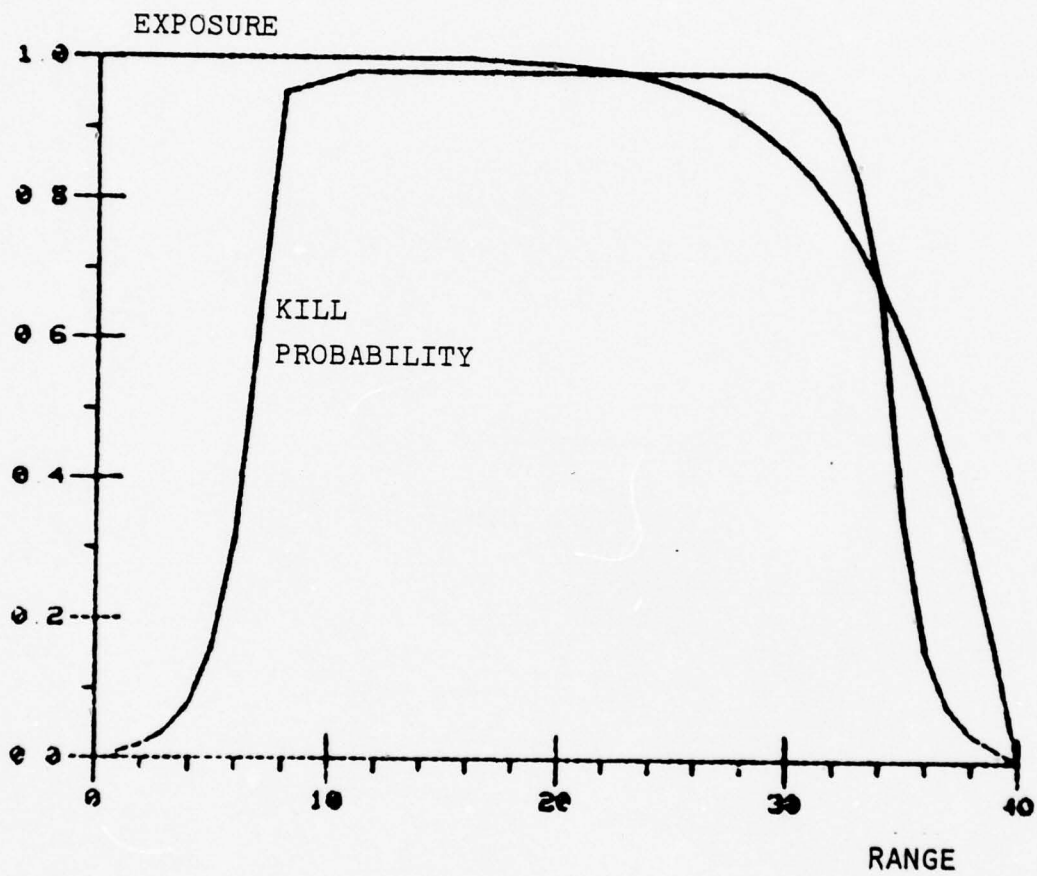


Figure 4 - EXPOSURE TO AND KILL PROBABILITY OF A HOSTILE WEAPON VS. THE RANGE FROM THE WEAPON LAUNCH SITE.

There will be some areas where the aircraft could be within lethal range of multiple weapons systems. In this case, the assumption was made that the probabilities of survival against the individual weapons were independent of each other. The overall survival probability then becomes the product of the individual probabilities given by:

$$P(\text{SURVIVAL}) = \left(\frac{r_1}{R_{L1}} \right)^{n_1} \left(\frac{r_2}{R_{L2}} \right)^{n_2} \left(\frac{r_3}{R_{L3}} \right)^{n_3} \dots \quad (3)$$

Where:

r_1, r_2, r_3 = Range from emitters 1, 2, and 3
respectively

R_{L1}, R_{L2}, R_{L3} = Maximum lethal range of
weapons 1, 2, and 3 respectively

n_1, n_2, n_3 = Stored emitter parameters

The exposure is again equal to:

$$\begin{aligned} \text{EXPOSURE} &= 1 - P(\text{SURVIVAL}) \\ &= 1 - \left[\left(\frac{r_1}{R_{L1}} \right)^{n_1} \left(\frac{r_2}{R_{L2}} \right)^{n_2} \left(\frac{r_3}{R_{L3}} \right)^{n_3} \dots \right] \quad (4) \end{aligned}$$

If more threat ranges are penetrated, the exposure will more rapidly approach unity.

A subroutine calculates the exposure for each point in the operating area. If it exceeds the pucker factor then that particular point is thrown out as a possible location for the jammer platform. The routine then deletes points which might have a tolerable exposure but are surrounded by points of higher exposure and therefore inaccessible. The points which remain are returned to the main program as possible route points. If a pucker factor of one is input, then it can be expected that a route close to an escort will be generated, and likewise, a pucker factor of zero will generate a pure stand off route.

B. PRIORITIZATION OF EMITTERS

The next step in determining an ECM route is the prioritization of the emitters. This calculation must be performed for each point in the strike group route. The priority should be zero when the strike group is outside the maximum radar detection range and maximum when the strike passes over the radar. For ease of calculation, a model similar to the exposure model was chosen and is given below.

$$\text{PRIORITY} = P_{\text{max}} \left[1 - \left(\frac{r}{R_{\text{max}}} \right)^n \right] \quad (5)$$

Where:

P_{\max} = maximum priority

R_{\max} = maximum detection range

n = stored emitter parameter

The parameter n is again stored in the parameter table and determines how the priority will roll off as the range approaches R_{\max} . Examples of priority vs. range are plotted in Fig 5 for $n = 2, 3, \text{ and } 4$.

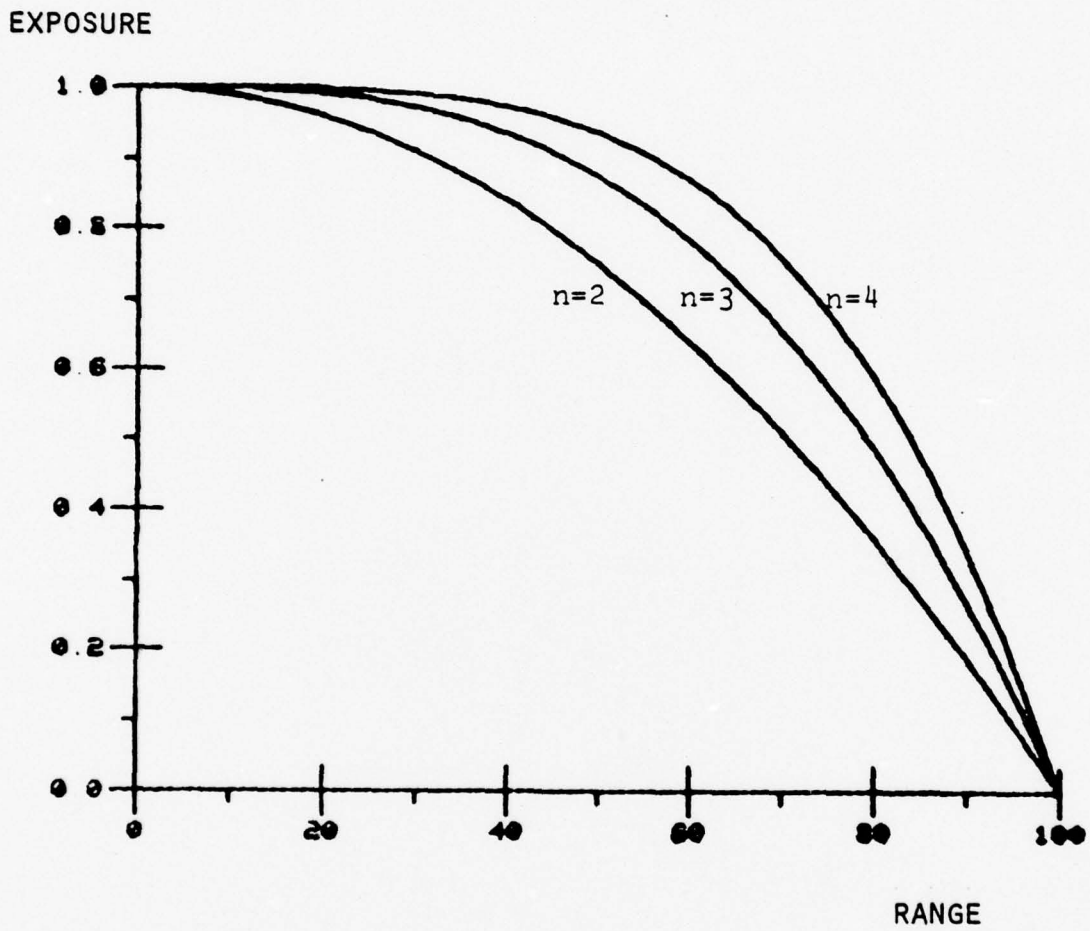


Figure 5 - EXAMPLES OF PRIORITY ASSIGNED TO EMITTERS VS. THE RANGE FROM THE EMITTERS FOR DIFFERENT VALUES OF n.

For radars which control weapons systems, there is a second significant range to consider, that of the maximum lethal range of the associated weapon. The priority of these terminal threat radars is adjusted for distances within this range as below.

$$\text{PRIORITY} = 0 \qquad r > R_{\text{max}} \qquad (6)$$

$$= P_{\text{max}} \left[1 - \left(\frac{r}{R_{\text{max}}} \right)^n \right] \qquad R_L < r < R_{\text{max}}$$

$$= P'_{\text{max}} \left[1 - \left(\frac{r}{R_L} \right)^m \right] + P_{\text{max}} \qquad 0 < r < R_L$$

Where:

R_{max} = Maximum detection range

R_L = Maximum lethal range of associated
weapon

P_{max} = Maximum priority when outside R_L

P'_{max} = Maximum increase in priority when
within R_L

m = Stored emitter parameter

n = Stored emitter parameter

Once again m is a characteristic of the associated weapon and determines how the priority will roll off as the range approaches the maximum lethal range. This factor in addition

to P_{\max} , P'_{\max} , R_{\max} , and R_L are stored in a radar parameter table. An example of a typical priority vs. range is plotted in Fig 6 for $n = 5$, $m = 6$, $R_{\max} = 60$, $R_L = 30$, $P_{\max} = 0.3$, and $P'_{\max} = 0.6$.

The sum of the two terms p_{\max} and p'_{\max} will not exceed one so the priorities will already be normalized. The resultant priority is then indicative of the degree of threat posed by a particular radar at a given range. Fig 7 is a plot of the normalized priority vs. range of three typical radars, a missile control, a gun control, and an acquisition. If all three of these radars were co-located, it can be seen that as the range decreases from one hundred miles to zero, the acquisition starts out as the highest priority and is surpassed by the missile radar as range decreases, and this priority is surpassed by the anti-aircraft artillery (AAA) radar as the lethal gun range is penetrated.

This prioritization scheme is relatively simple and is only a function of range. The constants P_{\max} , P'_{\max} , n , and m , which are stored can be changed if desired to alter the priority relationships. For the EW/ACQ radars, the value of R_L stored is zero, indicating an associated weapon with zero lethal range; i.e., no directly associated weapon.

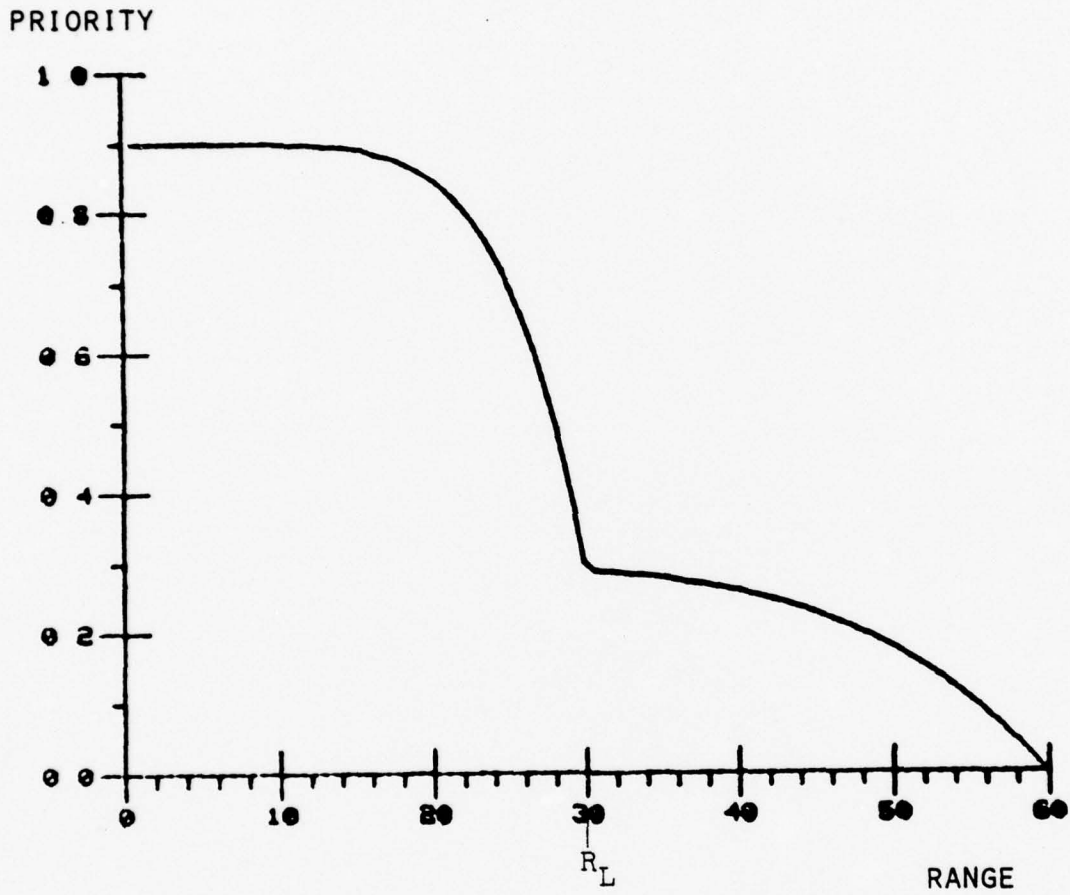


Figure 6 - TERMINAL THREAT RADAR PRIORITY ASSIGNED VS. THE RANGE FROM THE RADAR SITE.

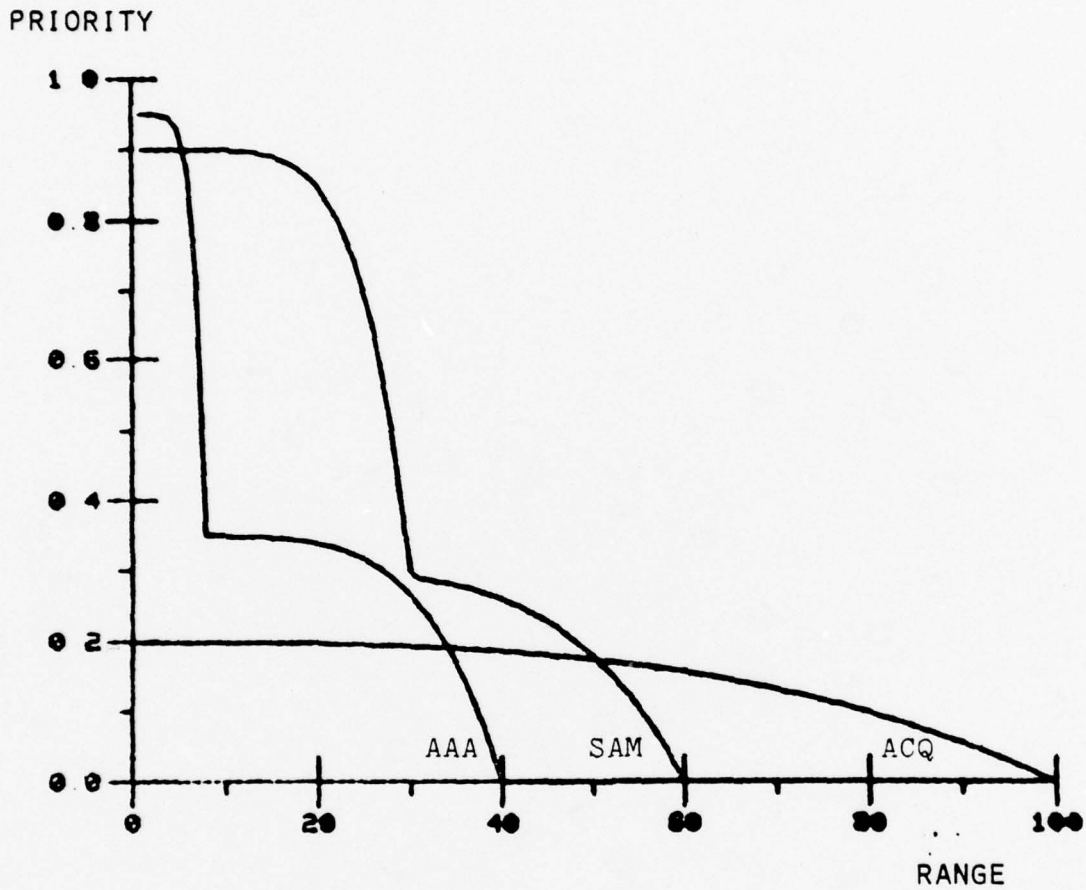


Figure 7 - EXAMPLES OF RELATIVE VALUES OF SAM, AAA, AND ACQ PRIORITY VS. THE RANGE FROM THE RESPECTIVE SITE.

III. JAMMING EFFECTIVENESS DETERMINATION

To determine an optimum route by any method requires a measure of performance for the jammer platform. Given a strike group to protect at any instant of time against an enemy air defense network, with an ECM aircraft of fixed jammer configuration, an operator must have some factor by which he can compare possible locations for his aircraft. The performance measure utilized in this program was a jam-to-signal power ratio weighted by the respective emitter priority and jammer modulation vulnerability.

A. JAM-TO-SIGNAL RATIO CALCULATION

The ratio of jammer power at the receiver to the received signal power (J/S) provides a good performance measure for a jammer. Since the jammer is fixed in power, if the J/S is computed for the different possible positions of the jammer platform, it will give a relative indication of the effectiveness against that particular radar from each point in the area. The formula [Ref. 2] used for the J/S in the program is given below.

$$\frac{J}{S} = \frac{4 \pi P_j B G_{jr} G_{rj} R_t^4 g_j^2}{P_r G_{rt}^2 \sigma R_j^2 g_t^4} \quad (7)$$

Where:

P_j = Jammer power (Watts/MHz)

B = Victim radar noise bandwidth (MHz)
 G_{jr} = Jammer antenna gain
 G_{rj} = Radar antenna gain toward jammer
 R_t = Strike group range (meters)
 g_j = Radar-to-target propagation factor
 P_r = Radar power (Watts)
 G_{rt} = Maximum radar antenna gain
 σ = Strike group cross section (square meters)
 R_j = Jammer range (meters)
 g_j = Radar-to-jammer propagation factor

All the values in this expression are readily available from stored tables or intermediate calculations with the exception of G_{rj} , the gain of the radar in the direction of the jammer platform.

Although the antenna patterns for all hostile emitters are not available, estimates of the maximum gain, beamwidth, maximum side lobe level, and average side lobe level are available from various sources. With this information it is possible to approximate an antenna aperture dimension and an N th order cosine electric field aperture distribution [Ref. 3]. Given the aperture distribution and dimension, the side lobes in the proximity of the main lobe can be determined.

To simplify the calculations, it was assumed in the program that terminal threat radars would have uniform (zero order cosine) aperture distributions and EW/ACQ radars would

have first order cosine distributions. The half power beamwidths for each case are stored in the parameter table and can be used with wavelength to determine the aperture dimension a as given below.

THREAT RADAR:

$$a = \frac{51 \lambda}{B} \quad (8A)$$

EW/ACQ RADAR:

$$a = \frac{69 \lambda}{B} \quad (8B)$$

WHERE:

B = Half power beamwidth ($^{\circ}$)

λ = wavelength (m.)

a = Aperture dimension (m.)

Knowing a, the normalized radiation pattern for both cases can be determined from the following formulas.

THREAT RADAR:

$$E(\phi) = \frac{\text{SIN}(\psi)}{\psi} \quad (9A)$$

EW/ACQ RADARS:

$$E(\phi) = \frac{\pi}{4} \left[\frac{\text{SIN}\left(\psi + \frac{\pi}{2}\right)}{\psi + \frac{\pi}{2}} + \frac{\text{SIN}\left(\psi - \frac{\pi}{2}\right)}{\psi - \frac{\pi}{2}} \right] \quad (9B)$$

WHERE:

$$\psi = \pi \left(\frac{a}{\lambda} \right) \text{SIN}(\phi)$$

E = Far-field electric field intensity

ϕ = Azimuth

Since these expressions represent normalized patterns, they have to be multiplied by the maximum gain which is also stored in the parameter table to obtain absolute patterns. From these patterns, the program computes each side lobe level and sets the pattern equal to that level across the entire lobe to eliminate the narrow nulls. When the side lobes fall below the average side lobe level, which is a stored table value, the remainder of the pattern is set equal to this average level.

Only the maximum gain, beamwidth, average side lobe level, frequency, and EW/ACQ or terminal threat designation therefore need to be known to generate a radiation pattern approximation. Fig 8 shows an ACQ and Fig 9 a terminal threat pattern generated by this procedure. As would be expected, the ACQ radar has low side levels but it pays for this with a lower gain and wider main beam. The terminal threat radar pattern has a narrower main beam and higher gain but the side lobe levels are higher.

With the pattern information to provide an approximation

of the radar antenna gain when the actual value is unavailable, the J/S can be computed from every allowable jammer position in the operating area.

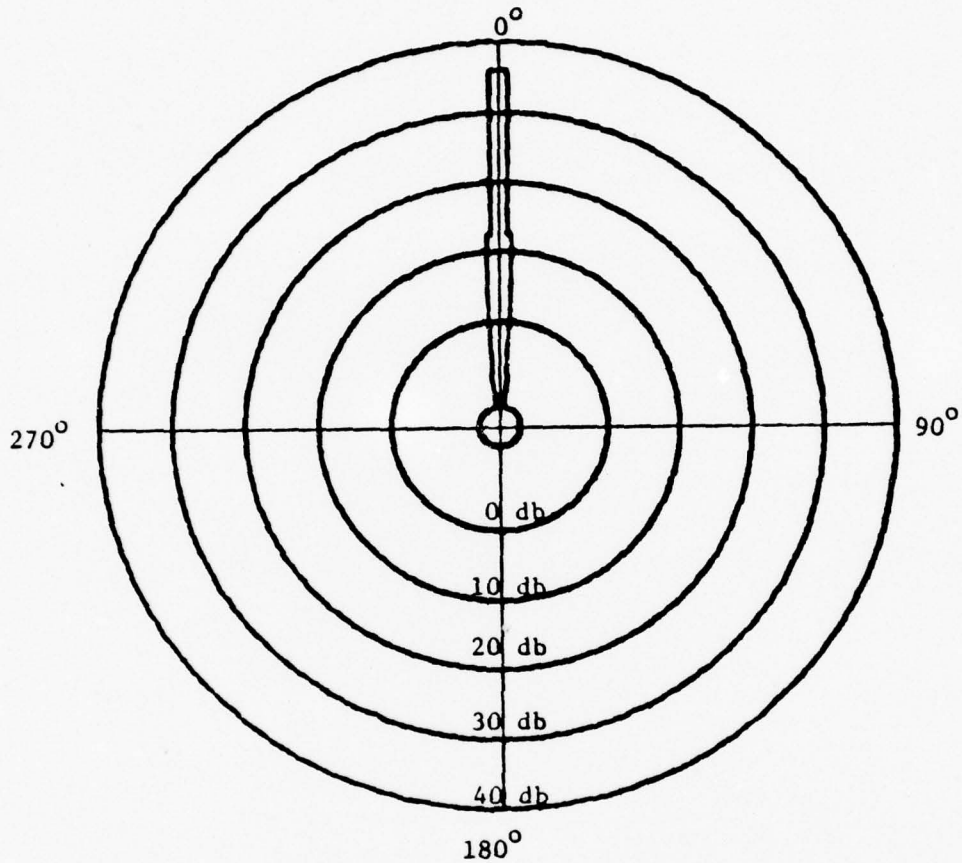


Figure 8 - APPROXIMATED ACQ RADAR PATTERN WHERE GAIN = 36 DB, BEAMWIDTH = 1.5°, AND SIDE LOBE LEVEL = -10 DB.

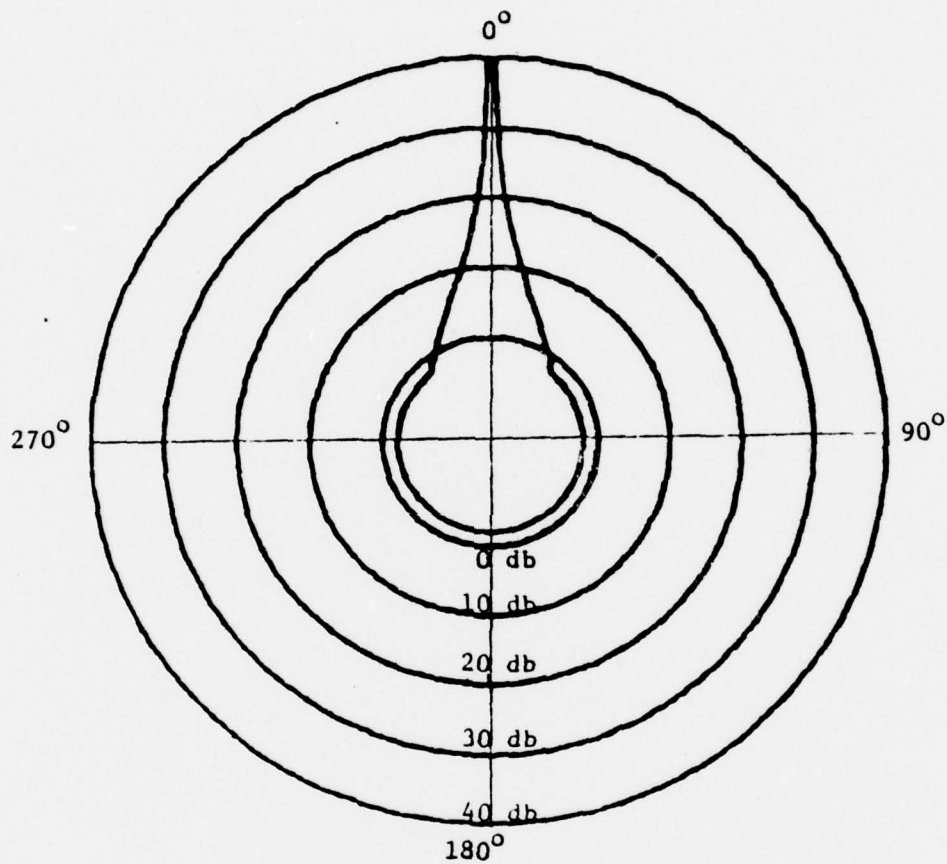


Figure 9 - APPROXIMATED THREAT RADAR PATTERN WHERE GAIN = 40 DB, BEAMWIDTH = 0.8°, AND AVERAGE SIDE LOBE LEVEL = -2 DB.

B. POWER MANAGEMENT SCHEME

An ECM aircraft is limited in the number of jammers it can carry. In a moderately dense environment there will be cases when all radars cannot be jammed. The power management scheme determines the assignments and for this program it was made very straightforward. Since a priority is computed for each radar, the available jammers are assigned on a one to one basis against the radars in descending order of priority. Therefore, the J/S is computed only against those higher priority radars for which jammers are available.

It may be possible to increase the jammer bandwidth to cover multiple signals with a single jammer but the power per MHz would be reduced and the overall effectiveness lessened. With the power management scheme utilized, if all the jammers in a band are assigned, the lower priority radars simply go uncountered. This policy makes possible the generation of a new EOB of uncoverable signals. This EOB can be run with a second aircraft of lower pucker factor through the same program to generate two mission routes without unnecessary duplication of jammer assignments.

C. OVERALL EFFECTIVENESS

The J/S varies over a wide range and can easily be as low as 10^{-6} or as high as 10^6 . Excessively high values of the J/S beyond that necessary for maximum degradation of the victim radar would be wasteful of jammer power and therefore not desired. Likewise, extremely low values of J/S would

essentially be useless against a radar and would likely waste a jammer asset which could be more useful elsewhere. The program therefore converts the J/S to db and limits it to a -25 db to +50 db range and normalizes this range. The range can be altered to reflect any desired values of minimum and maximum values for an effective J/S. The J/S figures are then multiplied by their respective priorities and jammer modulation vulnerabilities to give a weighted performance indicator for the ECM aircraft against particular radars. The modulation vulnerability is a stored table parameter associated with each emitter. It is determined experimentally and is referenced to unity being the effect of noise jamming only.

The weighted performances are then summed for all the radars that can be jammed to give a total performance factor for a particular point in the operating area. A high value for this number indicates that the high priority signals are being jammed by a high J/S with an effective jammer modulation.

D. SAMPLE EFFECTIVENESS CALCULATIONS

As an example of some of the numerical values encountered in these calculations, consider a simple static situation where there are a SAM and ACQ radar co-located at latitude $30^{\circ}30'$ and longitude $90^{\circ}30'$. If a strike aircraft with cross-section of nine square meters is located at latitude $30^{\circ}20'$ and longitude $90^{\circ}20'$, the jammer performance for a given test point latitude $30^{\circ}10'$ and longitude $90^{\circ}10'$ would be calculated as follows.

First the exposure of the ECM aircraft would have to be determined for the test point to see whether it is

acceptable. The strike group range would be 13.22 nm. and the jammer range would be 26.44 nm. Since there is only one direct threat, the SAM radar, the exposure would be calculated from equation (2) where the values of the table constants are as specified below.

$$\begin{aligned} \text{EXPOSURE} &= 1 - \left(\frac{r}{R_L} \right)^n \\ &= 1 - \left(\frac{26.44}{30.00} \right)^5 \\ &= 0.468 \end{aligned}$$

Where:

$$\begin{aligned} R_L &= 30.0 \text{ nm} \\ n &= 5 \end{aligned}$$

If the maximum exposure to the ECM aircraft were 0.5, this point would be an allowable jammer position.

The next step would be to determine the priorities of each radar for the given strike position. For the ACQ radar using equation (5) the priority is determined below for the specified table constants.

$$\begin{aligned}
 \text{PRIORITY} &= P_{\max} \left[1 - \left(\frac{r}{R_{\max}} \right)^n \right] \\
 &= 0.2 \left[1 - \left(\frac{13.22}{100.0} \right)^3 \right] \\
 &= 0.1995
 \end{aligned}$$

Where:

$$\begin{aligned}
 P_{\max} &= 0.2 \\
 R_{\max} &= 100.0 \text{ nm} \\
 n &= 3
 \end{aligned}$$

The SAM priority is determined likewise from equation (6) with the range between zero and the maximum lethal range as seen below.

$$\begin{aligned}
 \text{PRIORITY} &= P'_{\max} \left[1 - \left(\frac{r}{R_L} \right)^m \right] + P_{\max} \\
 &= 0.6 \left[1 - \left(\frac{13.22}{30.00} \right)^6 \right] + 0.3 \\
 &= 0.8956
 \end{aligned}$$

Where:

$$\begin{aligned}P'_{\max} &= 0.6 \\R_L &= 30.0 \text{ nm.} \\m &= 6 \\P_{\max} &= 0.3\end{aligned}$$

If the ECM aircraft carries two jammers with frequency coverage such that one can cover the SAM radar while the other covers the ACQ radar, the total jamming performance can be computed for the test point. Using equation (7), the J/S can be computed for each radar as seen below for the specified radar and jammer parameters. The problem is simplified since perfect radar-strike-jammer alignment is attained at the test point. For the ACQ radar the J/S is computed as follows.

$$\begin{aligned}\frac{J}{S} &= \frac{4\pi P_j B G_{jr} G_{rj} R_t^4 g_j^2}{P_r G_{rt}^2 \sigma R_j^2 g_t^4} \\&= 105.12 \\&= 40.44 \text{ db.}\end{aligned}$$

Where:

$$\begin{aligned}P_j &= 200.0 \text{ W/MHz} \\B &= 1.0 \text{ MHz} \\G_{jr} &= 10.0 \text{ db}\end{aligned}$$

$$G_{rj} = 36.0 \text{ db}$$

$$R_t = 13.22 \text{ nm}$$

$$g_j = g_t = 1.0$$

$$P_r = 1.0 \text{ Mw}$$

$$G_{rt} = 36.0 \text{ db}$$

$$\sigma = 9.0 \text{ m}^2$$

$$R_j = 26.44 \text{ nm}$$

For the SAM radar the J/S is similarly determined.

$$\frac{J}{S} = 55.80$$

$$= 34.94 \text{ db.}$$

Where:

$$P_j = 200.0 \text{ W/MHz}$$

$$B = 0.8 \text{ MHz}$$

$$G_{jr} = 10.0 \text{ db}$$

$$G_{rj} = 40.0 \text{ db}$$

$$R_t = 13.22 \text{ nm}$$

$$g_j = g_t = 1.0$$

$$P_r = 600.0 \text{ Kw}$$

$$G_{rt} = 40.0 \text{ db}$$

$$\sigma = 9.0 \text{ m}^2$$

$$R_j = 26.44 \text{ nm}$$

These J/S values are then limited if they do not fall in the -25 db to +50 db range and then normalized. For the ACQ and SAM radars the normalized effectivenesses are adjusted as below.

$$\frac{J}{S} \text{ NORMALIZED} = \frac{\left[\frac{J}{S} \right] + 0.5}{1.5}$$

ACQ:

$$\frac{J}{S} \text{ NORMALIZED} = 0.8725$$

SAM:

$$\frac{J}{S} \text{ NORMALIZED} = 0.7992$$

If both jammers use complex modulations which have been determined to be twice as effective as Gaussian noise jamming, the J/S values are weighted by this modulation vulnerability factor of two. The J/S is also weighted by the corresponding emitter priority computed previously to give a performance indication as shown below.

$$\text{PERFORMANCE} = \left(\frac{J}{S} \right) (\text{MODULATION VULNERABILITY}) (\text{PRIORITY})$$

$$\begin{aligned} \text{ACQ PERFORMANCE} &= (0.8724)(2.0)(0.1995) \\ &= 0.3481 \end{aligned}$$

$$\begin{aligned} \text{SAM PERFORMANCE} &= (0.7991)(2.0)(0.8956) \\ &= 1.4313 \end{aligned}$$

The performances against the individual radars are summed for a total performance measure for this test point.

$$\begin{aligned} \text{TOTAL PERFORMANCE} &= \text{ACQ PERFORMANCE} + \text{SAM PERFORMANCE} \\ &= 0.3481 + 1.4313 \\ &= 1.7794 \end{aligned}$$

This performance becomes the MOE for this test point. The MOE is used as a comparison between the different test points to determine the best position to designate as an ECM route point.

IV. ROUTE DETERMINATION

A. THE OPTIMUM ROUTE

The problem of determining an optimum route can most readily be determined in a case such as this through a dynamic programming approach [ref. 1]. By starting at the desired final position of the ECM aircraft, one could compute positions of high performance and by iterating back in time and retaining the optimum routes eventually come up with the optimum route which maximizes the total ECM performance. The problem encountered however is the execution time and machine size required for such a solution. For example, in a one hundred nautical mile square area in which a resolution to the nearest nautical mile in both dimensions is desired, there are ten thousand possible ECM aircraft locations. If there are thirty points in the strike route and an EOB of fifty emitters there could be fifteen million effectiveness values to be computed. Because of the flight speed constraint on the ECM aircraft, many of these results would eventually be discarded in the route determination. If the parameters of each emitter must be stored in an external device and read for each calculation, it is obvious that the time of execution will exceed that available to the aircrew.

B. ROUTE GENERATION

There are some peculiarities to the ECM route problem which allow a high performance route close to the optimum to be computed in much less time. First, the strike route will generally be planned to minimize exposure and will usually have a distinct maximum as the strike passes over the area of the target. The exposure will typically increase monotonically to this maximum and decrease in the same manner. The total priority (sum of the individual emitter priorities for a particular strike group point) will be indicative of the strike group exposure and thus reach a maximum at this same point as seen in Fig 10. Since the performance is weighted by this priority the optimum ECM route can be expected to pass through the point where performance is maximum for this particular time. This time can be determined from the priorities previously computed. All possible jammer locations for this time slot can then be checked and the ten positions of highest performance retained as possible ECM route points.

Because the total priorities decrease monotonically for strike points either side of the highest priority point, the total performances at earlier and later optimum ECM route points can be expected to decrease in the same manner since they again are weighted by the priorities. As a result, it is not necessary to look at all possible jammer locations for the next route point, only those within the one time unit ECM aircraft flight distance from the previous point. For a well defined strike exposure maximum, this is the path the optimum route would be expected to follow. This will significantly reduce the execution time and required storage space. The time unit between successive route points must be large enough so that a distinct maximum performance point can be determined but not so large as to overlook significant interim high performance points or to overfly large areas of non-allowable positions. For this program a one minute time space between route points was used.

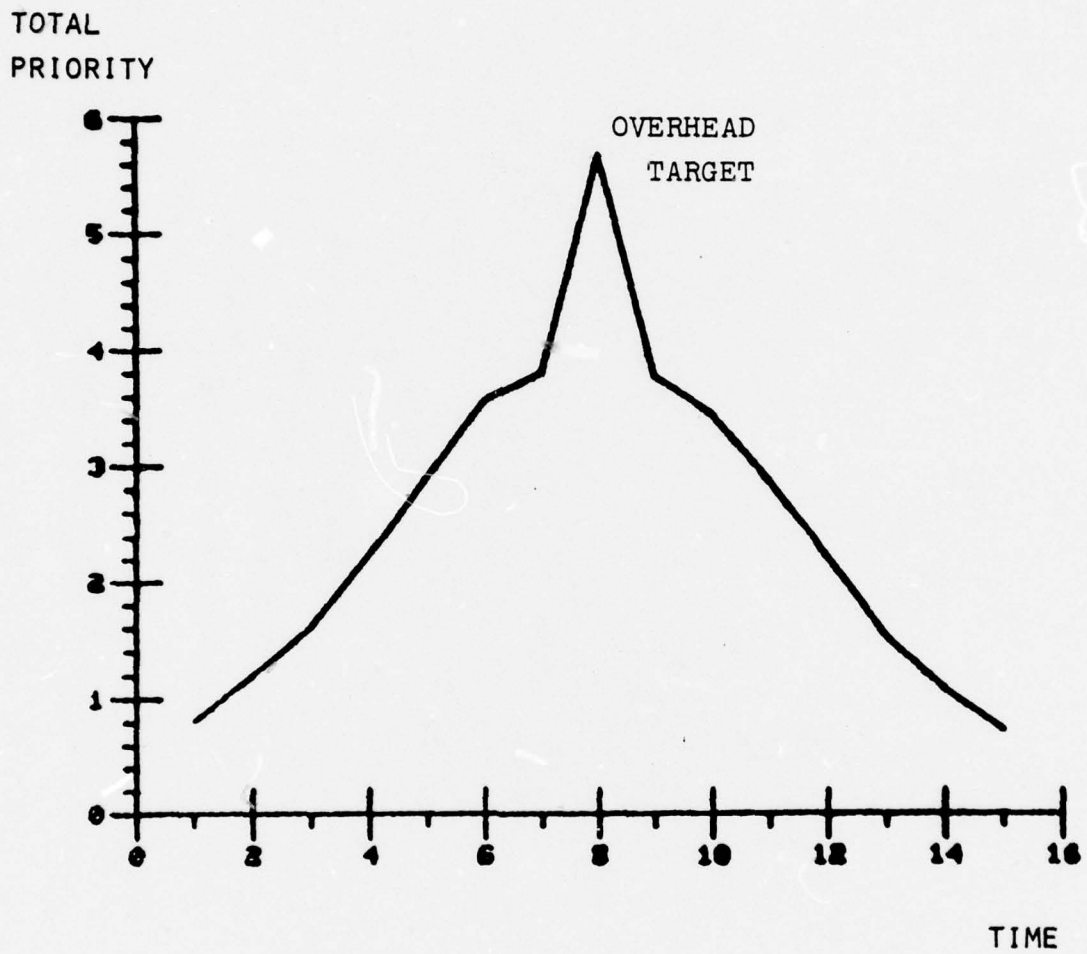


Figure 10 - STRIKE GROUP EXPOSURE (TOTAL PRIORITY AT EACH POINT) VS. TIME.

Starting with the highest strike group priority point the ECM route can be generated in two segments by iterating away from this point toward the start and finish strike group points. For each iteration, the ECM route point is determined as the highest performance point within the one minute ECM aircraft flight distance from the preceding route point as seen in Fig 11. When all these points have been calculated, the two high performance route segments to and from the optimized point are connected to form a route. The total performance at each point in the route is summed and associated with the route as its MOE. For this program, when the performance is being computed from each of the allowable jammer locations for the time of highest strike exposure, the ten points of highest performance are retained. A route is computed for each of the ten points and output with its MOE. Usually the first route will have the highest MOE but the operator has his choice of the ten.

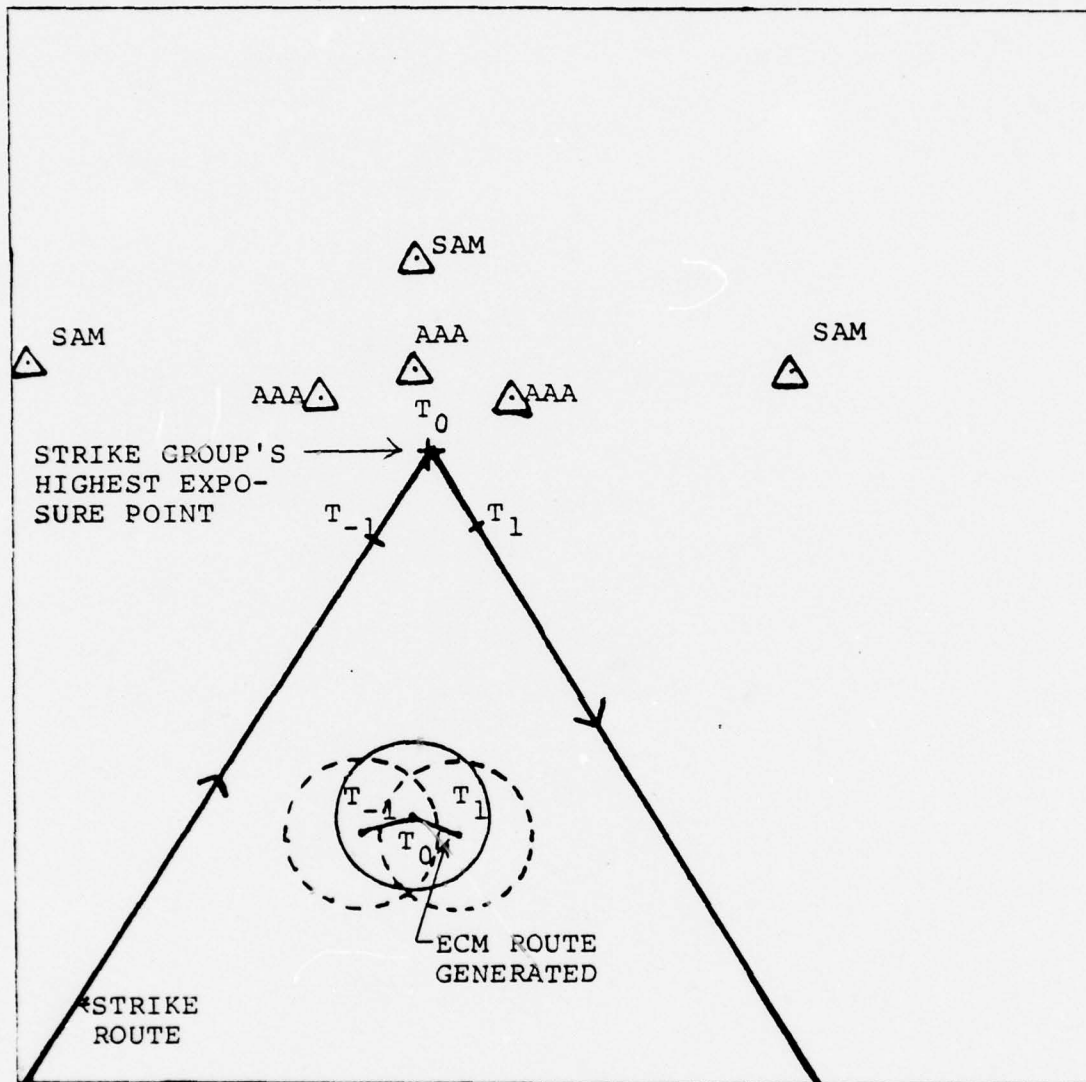


Figure 11 - ECM ROUTE GENERATION BY ITERATING FORWARD AND BACKWARD IN TIME FROM THE OPTIMUM ECM ROUTE POINT AT T_0 .

C. SAMPLE ROUTE

To illustrate the route generated by the program, consider a simple EOB of one acquisition, three SAM, and three AAA radars. The operating area will be considered a square bounded by latitude $00^{\circ} 00'$ and $01^{\circ} 30'$ and longitude $00^{\circ} 00'$ and $01^{\circ} 30'$. The strike route, threat emitter locations and maximum lethal ranges are seen in Fig 12, a blow up of the area of interest in the operating area. The ECM routes for maximum exposures of 0.0, 0.9, and 0.99 are seen in Fig 13 through Fig 15 respectively. If the exposure is set to 1.0, then as expected an escort route will be generated.

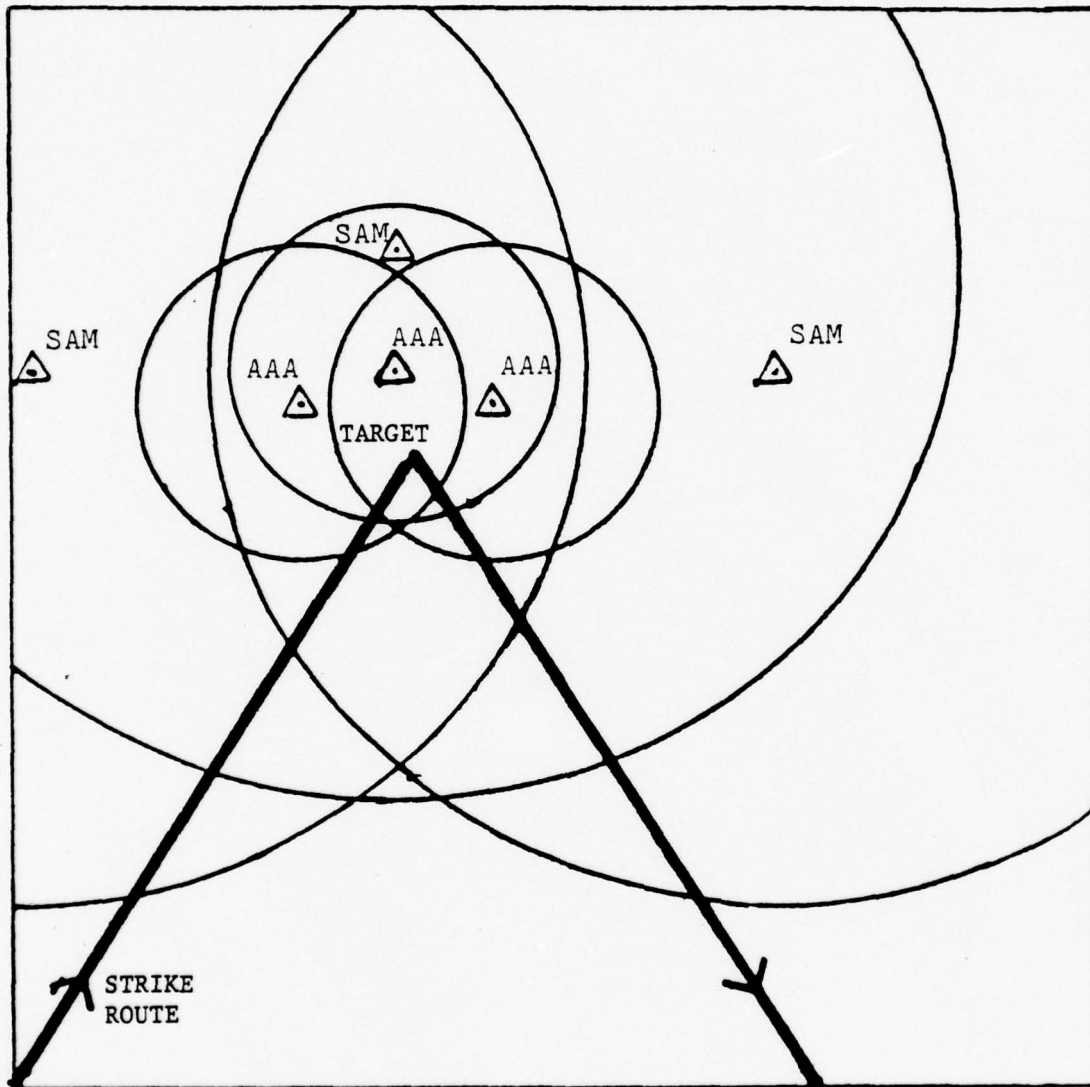


Figure 12 - SAMPLE STRIKE ROUTE AND EOB WITH MAXIMUM LETHAL RANGES OF WEAPONS ASSOCIATED WITH THE EMITTERS.

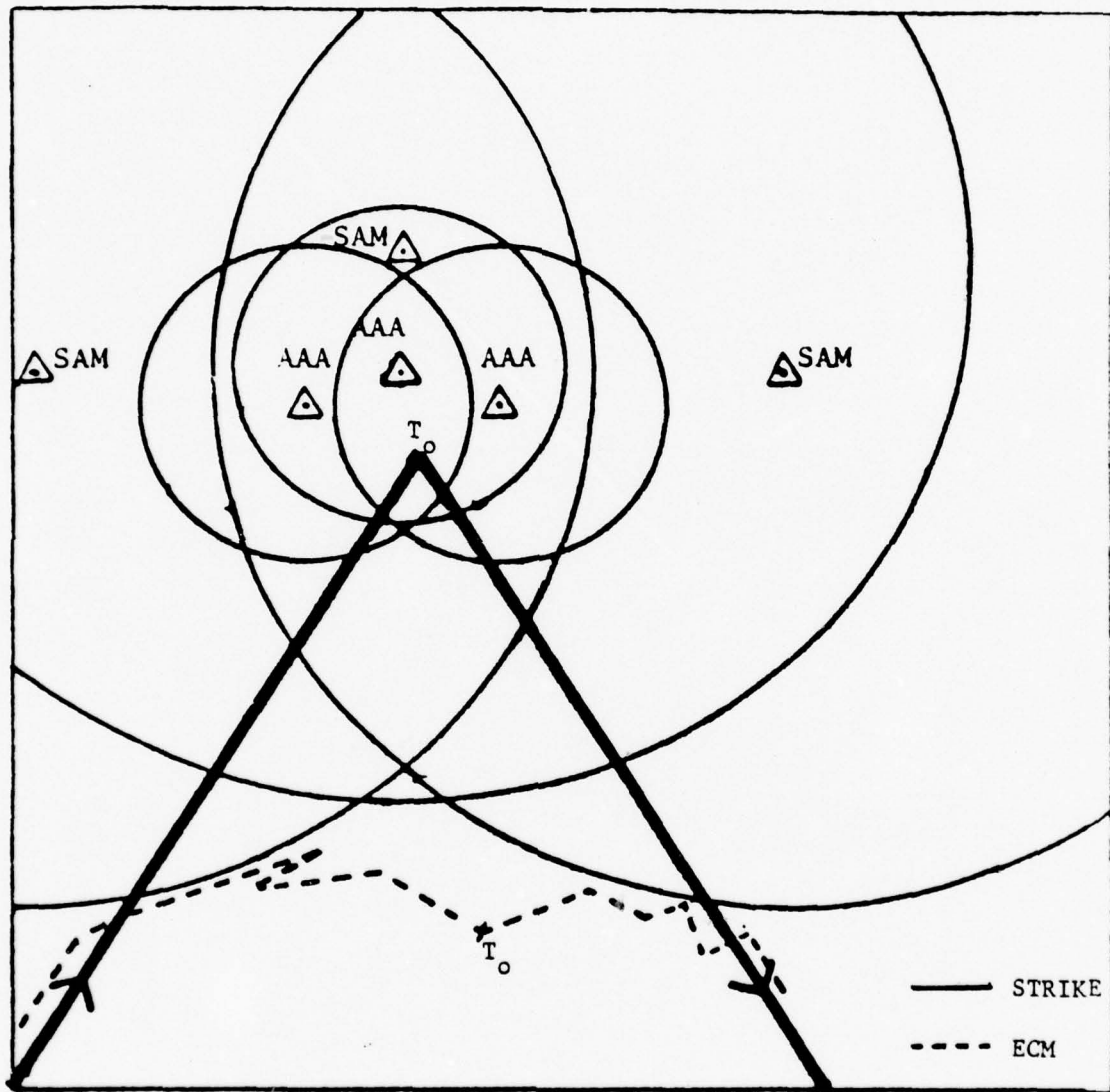


Figure 13 - ECM ROUTE GENERATED WHEN MAXIMUM EXPOSURE = 0.0.

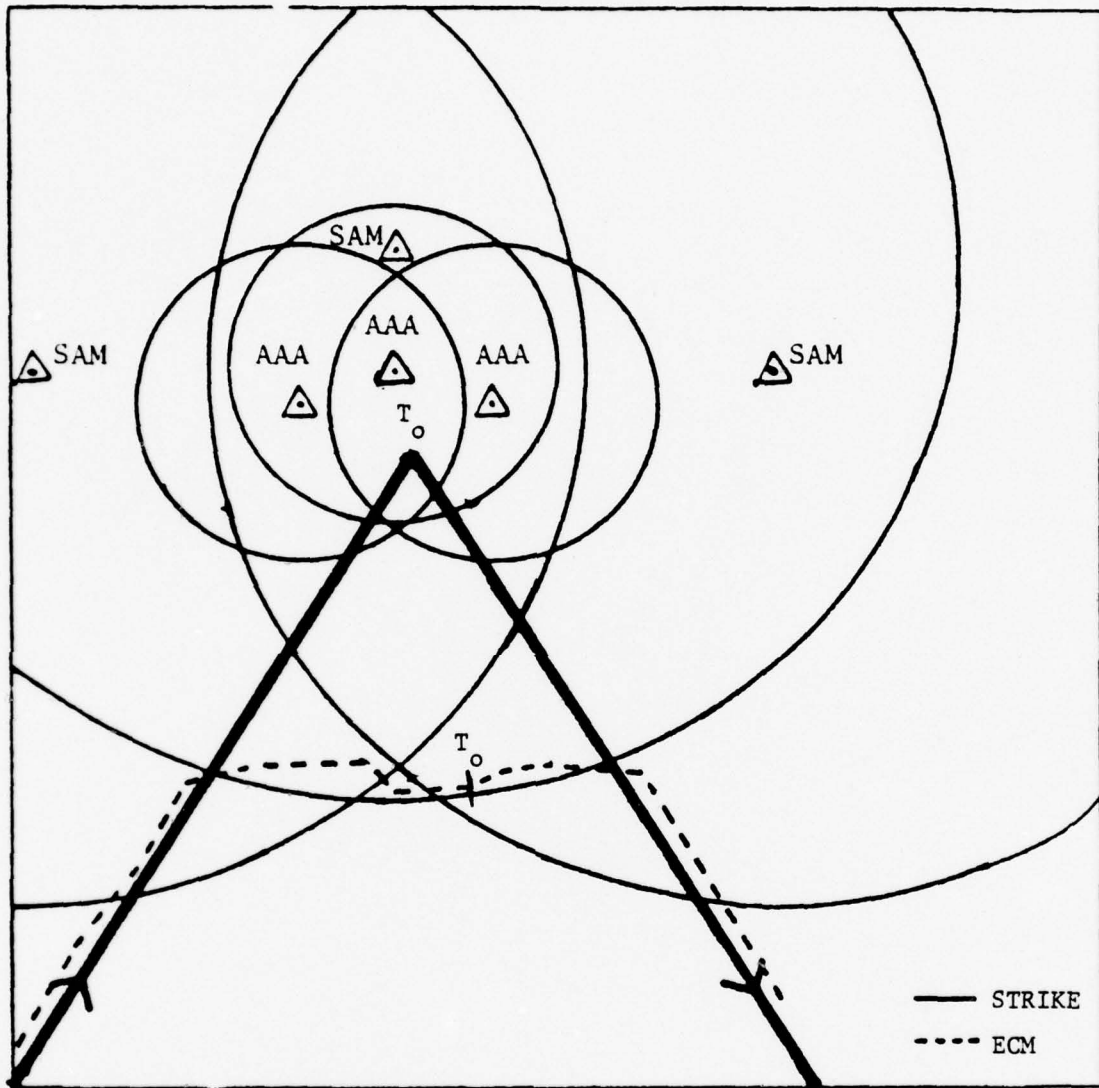


Figure 14 - ECM ROUTE GENERATED WHEN MAXIMUM EXPOSURE = 0.9.

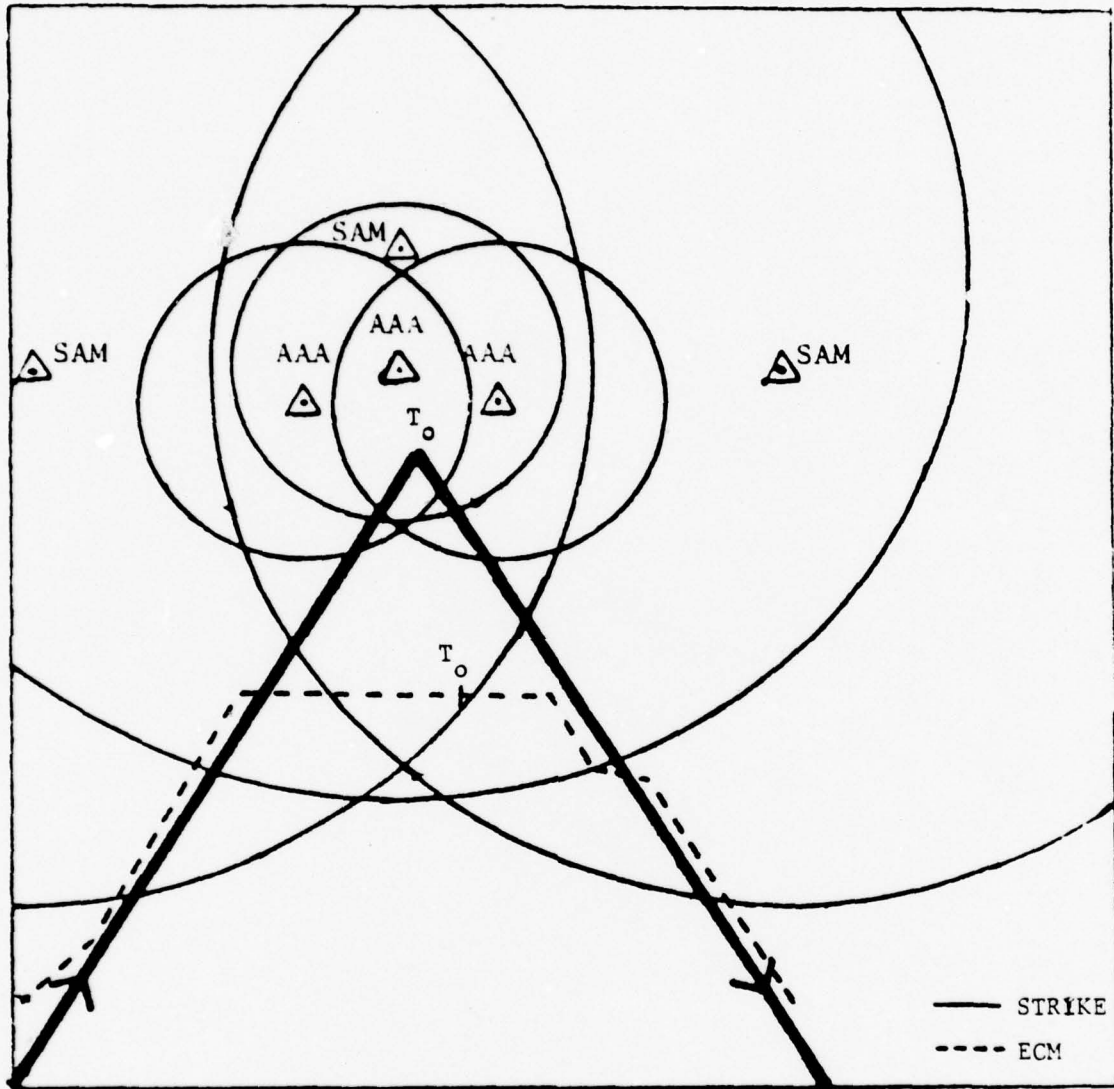


Figure 15 - ECM ROUTE GENERATED WHEN MAXIMUM EXPOSURE = 0.99.

V. SUMMARY

A. CURRENT PROGRAM

The program as presented in the preceding sections to determine a route for an ECM aircraft is very simple. In its present form it uses an excessive amount of core storage but only because of the intermediate testing done during its development. In translating to a smaller machine it can be readily compacted to significantly reduce the size required. It must be remembered that the route generated is not the absolute optimum, but a one point optimization with a high performance route to and from this point. For the typical strike route and EOB though, the route should come close to the absolute optimum. The program listing is enclosed at the end of this report. The program was run on the Naval Postgraduate School IBM-360/67 computer under CP/CMS System and for the sample routes generated it took approximately twelve minutes of computer time.

B. SUGGESTIONS FOR IMPROVEMENT

If external storage such as floppy disk is available on the system which incorporates this program, there are several areas where the program performance could be enhanced without a significant increase in size or execution time. The antenna patterns could be pre-computed for all hostile emitters and stored in an external table for simple

lookup of the value needed. If this is done the aperture can be better approximated and a more accurate pattern can be computed since the computation time would not be a factor. The J/S could be weighted by an additional factor indicative of experimental results of jammer effectiveness measurements against known system types. This factor would also be predetermined for each hostile emitter and stored externally as a function of jammer range. In computing the allowable positions for the ECM aircraft within the maximum exposure limits, the computed exposure can be modified to reflect the reduced exposure to the ECM aircraft due to its own jamming. The jamming performance can also be adjusted to indicate increased performance when jammer frequencies and pointing angles overlap. This would possibly require a different jammer management scheme. It would also be easy to observe the total priority as a function of strike group position to determine how it increases to its highest point and then falls off. This characteristic could then be translated to indicate to the operator how far from the optimum the generated route deviates. The final program should be checked with a complete dynamic programming optimization to determine when it becomes unreliable as a planning tool.


```

0150 FCFMAT(F10.6,13,F10.6)
C
C
C
0170 INPUT THE ECM ROUTE START POINT BY LAT/LCN(CLAT/CLCN)
READ(5,017J)CLAT,CLCN
FCFMAT((2F10.2)
LAB=DGMN(CLAT)-DGMN(ALAT))+.1
LCE=DGMN(CLCN)-DGMN(ALON))+.1
C
C INPUT THE ECM AIRCRAFT JAMMER CONFIGURATION.
C JXN=0 IF THE JAMMER IS ALREADY IN USE
C 1 IF THE JAMMER IS AVAILABLE (INITIAL SET)
C F1 = LOW END FREQUENCY (HZ)
C F2 = HIGH END FREQUENCY (HZ)
C PWR = JAMMER OUTPUT POWER (W)
C GAN = JAMMER ANTENNA GAIN (DB)
C
C180 READ(2,018J) (JXN(I),F1(I),F2(I),PWR(I),GAN(I),I=1,NJAM)
FCFMAT(I2,4E16.8)
C
C CHANGE THE JAMMER FREQUENCIES FROM MHZ. TO FZ.
C
C C181 I=1,NJAM
C F1(I)=F1(I)*10000000.
C F2(I)=F2(I)*100000000.
C CCNTINUE
C
C INPUT THE RADAR PARAMETER TABLE
C RADN1 AND RADN2 = 8 ALPHANUMERIC CHARACTERS FOR ELINT NUMBER
C RMAX = MAXIMUM DETECTION RANGE
C RL = MAXIMUM LETHAL RANGE OF ASSOCIATED WEAPCN
C PMAX = MAXIMUM PRIORITY OUTSIDE LETHAL RANGE
C PPMAX = MAXIMUM INCREASE IN PRIORITY WITHIN LETHAL RANGE
C FM = PRIORITY ROLL-OFF EXPONENT FOR RANGES WITHIN RL
C FN = PRIORITY ROLL-OFF EXPONENT FOR RANGES OUTSIDE RL
C FRFQ = RADAR FREQUENCY
C RPWR = RADAR PEAK POWER OUTPUT
C GMAX = MAXIMUM RADAR ANTENNA GAIN
C BEAM = ANTENNA HALF POWER BEAMWIDTH
C AVGSLL = AVERAGE SIDE LOBE LEVEL
C ITRAK = 0 FOR ACQUISITION RADARS
C 1 FOR TRACKING RADARS
C FMCD = RADAR VULNERABILITY TO JAMMER MODULATION
C
C REAC(I,0190)(RADN1(I),RADN2(I),RMAX(I),RL(I),PPMAX(I),FM(I),
1) ,FN(I),FRFQ(I),RPWR(I),GMAX(I),BEAM(I),AVGSLL(I),ITRAK(I),FMCD(I))
2, I=1,NTAB)
0190 FCFMAT(2A4,6F10.4,/,2E12.4,3F10.6,I1,F1J.6)

```

```

MAN00490
MAN00500
MAN00510
MAN00520
MAN00530
MAN00540
MAN00550
MAN00560
MAN00570
MAN00580
MAN00590
MAN00600
MAN00610
MAN00620
MAN00630
MAN00640
MAN00650
MAN00660
MAN00670
MAN00680
MAN00690
MAN00700
MAN00710
MAN00720
MAN00730
MAN00740
MAN00750
MAN00760
MAN00770
MAN00780
MAN00790
MAN00800
MAN00810
MAN00820
MAN00830
MAN00840
MAN00850
MAN00860
MAN00870
MAN00880
MAN00890
MAN00900
MAN00910
MAN00920
MAN00930
MAN00940
MAN00950
MAN00960

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MAN00970
MAN00980
MAN00990
MAN01000
MAN01010
MAN01020
MAN01030
MAN01040
MAN01050
MAN01060
MAN01070
MAN01080
MAN01090
MAN01100
MAN01110
MAN01120
MAN01130
MAN01140
MAN01150
MAN01160
MAN01170
MAN01180
MAN01190
MAN01200
MAN01210
MAN01220
MAN01230
MAN01240
MAN01250
MAN01260
MAN01270
MAN01280
MAN01290
MAN01300
MAN01310
MAN01320
MAN01330
MAN01340
MAN01350
MAN01360
MAN01370
MAN01380
MAN01390
MAN01400
MAN01410
MAN01420
MAN01430
MAN01440

```

DETERMINE THE SCALE FACTOR(SKAL) FOR THE LONGITUDE DISTANCES

```

SKAL=COS(ALAT/57.25577951)
SHIFT THE OPERATING AREA TO A 0/0 REFERENCE POINT AND DIMENSION IN
MINUTES OF LATITUDE AND LONITUDE
CC 0210 I=1,NTOT
RLAT(I)=DGMN(RLAT(I))-DGMN(ALAT)
RLON(I)=(DGMN(RLON(I))-DGMN(ALON))*SKAL
CCNTINUE
CC 0215 I=1,ISTK
SLAT(I)=DGMN(SLAT(I))-DGMN(ALAT)
SLCN(I)=(DGMN(SLON(I))-DGMN(ALON))*SKAL
CCNTINUE
DETERMINE THE INTEGER DIMENSIONS OF THE OPERATING AREA
LAT=DGMN(BLAT)-DGMN(ALAT)+.1
LCN=DGMN(BLON)-DGMN(ALON)+.1
DETERMINE THE ALLOWABLE POSITIONS FOR THE ECM AIRCRAFT(IMITE=1)
CC 0220 I=1,LAT
DC 0220 J=1,LCN
IMITE(I,J)=0
PLAT=I
PLCN=J*SKAL
CALL KURAJ(PLAT,PLON,RLAT,RLON,ELNT1,ELNT2,NTOT,DXPCZ,NTAB,RADN1,
1RACN2,RL,FM)
DXPCZ IS THE DEGREE OF EXPCSURE AT POINT I,J
IF(DXPCZ.GT.PUKR)IMITE(I,J)=-1
CCNTINUE
IMITE(LAB,LCB)=1
REMOVE THE ALLOWABLE POINTS THAT ARE INACCESSIBLE
FIRST, SHIFT THE ARRAY IMITE ONE UNIT UP IN LAT AND LON
LAT1=0
LCN1=0
LAT=LAT+1
LCN=LCN+1
LAT=LON+1
LAT2=LAT+2
LCN2=LCN+2
DC 0230 M=1,LAT
DC 0230 N=1,LCN
K=LA2-M
L=LC2-N

```

```

MAN0145J
MAN01460
MAN01470
MAN01480
MAN01490
MAN01500
MAN01510
MAN01520
MAN01530
MAN01540
MAN01550
MAN01560
MAN01570
MAN01580
MAN01590
MAN01600
MAN01610
MAN01620
MAN01630
MAN01640
MAN01650
MAN01660
MAN01670
MAN01680
MAN01690
MAN01700
MAN01720
MAN01730
MAN01740
MAN01750
MAN01760
MAN01770
MAN01780
MAN01790
MAN01800
MAN01810
MAN01820
MAN01830
MAN01840
MAN01850
MAN01860
MAN01870
MAN01880
MAN01890
MAN01900
MAN01910
MAN01920

I=LAI-M
J=LAI-N
IMITE(K,L)=IMITE(I,J)
CCNTINUE
NCW FRAME IMITE IN -1'S (ALLOWS NO FLIGHTS CUT OF AREA)
DC 0240 IN=1,LA2
IMITE(IN,I)=-1
IMITE(IN,LO2)=-1
CCNTINUE
DC 0250 IN=1,LO2
IMITE(I,IN)=-1
IMITE(LA2,IN)=-1
CCNTINUE

NCW SWEEP REPEATEDLY ACROSS IMITE SETTING ACCESSIBLE 0'S TO 1
NLC=2#LAT
CC 0260 NSWEP=1,NUD
CC 0260 M=2,LAI
DC 0260 N=2,LOI
LCCATE THE START POINT OR EVENTUAL ACCESSIBLE POINTS
IF(IMITE(M,N).NE.1)GO TO 0260 FROM THIS POINT TO 1
IF(CHANGE EVERY ACCESSIBLE ZERO FROM THIS POINT TO 1
IF(IMITE(M,N-1).EQ.0)IMITE(M,N-1)=1
IF(IMITE(M+1,N-1).EQ.0)IMITE(M+1,N-1)=1
IF(IMITE(M+1,N).EQ.0)IMITE(M+1,N)=1
IF(IMITE(M+1,N+1).EQ.0)IMITE(M+1,N+1)=1
IF(IMITE(M,N+1).EQ.0)IMITE(M,N+1)=1
IF(IMITE(M-1,N+1).EQ.0)IMITE(M-1,N+1)=1
IF(IMITE(M-1,N).EQ.0)IMITE(M-1,N)=1
IF(IMITE(M-1,N-1).EQ.0)IMITE(M-1,N-1)=1
CCNTINUE
REMOVE THE FRAME AND SHIFT IMITE ONE UNIT DCWN IN LAT/LON
CC 0270 M=1,LAT
CC 0270 N=1,LCN
IMITE(M,N)=IMITE(M+1,N+1)
CCNTINUE

DETERMINE THE STRIKE ROUTE POINT OF HIGHEST TOTAL PRIORITY. THIS
POINT WILL BE A MUST POINT LATER FOR HIGHEST JAMMING EFFECTIVENESS
ITERATE FOR EACH STRIKE GROUP POINT
FTEMP=0.
DC 0350 I=1,ISTK
IFRTY(I)=0.
ITERATE FOR EACH RADAR IN THE EOB
CC 0340 J=1,NTOT
SEARCH THE PARAMETER TABLE FOR THIS RADAR
DC 0330 K=1,NTAB
IF((RADN1(K).EQ.ELNT1(J)).AND.(RACN2(K).EQ.ELNT2(J)))GO TO 0331

```

```

033J CCNTINUE THE RANGE FROM THIS RADAR TO THE STRIKE
033I CCNTINUE THE RANGE FROM THIS RADAR TO THE STRIKE
C R=RANJ(SLAT(I),SLON(I),RLAT(J),RLCN(J))
C BASED ON THIS RANGE ASSIGN THE PROPER PRIORITY TO THE RADAR
C IF(R.LE.RL(K))PRTY(I,J)=PPMAX(K)*(1.-(R/RL(K))*PMAX(K)
C IF((R.GT.RL(K)).AND.(R.LE.RMAX(K)))PRTY(I,J)=PMAX(K)*(1.-(R/RMAX(K)
C 1))*FN(K))
C IF(R.GT.RMAX(K))PRTY(I,J)=0.
C DETERMINE THE TOTAL PRIORITY(TPRTY) AT THIS STRIKE POSITION
C TPRTY(I)=TPRTY(I)+PRTY(I,J)
C CCNTINUE
C340 CCNTINUE THE TOTAL PRIORITY FOR EACH STRIKE GROUP POSITION TO
C CPSEERVE HOW IT FALLS OFF FROM MAXIMUM EXPOSURE POINT.
C THIS RCLL-OFF WILL INDICATE HOW CLOSE THE RCUTE TO BE
C GENERATED WILL COME TO AN ABSOLUTE OPTIMUM ROUTE.
C WRITE(6,34)TPRTY(I)
C FCRMAT(20X,E16.8)
C RETAIN THE HIGHEST PRIORITY STRIKE POINT(IMAX)
C IF(TPRTY(I).LE.PTEMP)GO TO 0350
C PTEMP=TPRTY(I)
C IMAX=I
C CCNTINUE
0350
C
C
C
C DIVIDE THE STRIKE ROUTE INTO TWO SECTIONS ABOUT THE HIGHEST
C PRIORITY POINT(IMAX)
C I=IMAX
C I=1,ISTK1
C DC C400 I=1,ISTK1
C J=IMAX+1-I
C SLAT(I)=SLAT(J)
C SLCN(I)=SLCN(J)
C DC C400 KK=1,NTOT
C PRTY(I,KK)=PRTY(J,KK)
C CCNTINUE
C DC C410 I=1,ISTK2
C J=IMAX-1+I
C SLAT(I)=SLAT(J)
C SLCN(I)=SLCN(J)
C DC C410 KK=1,NTOT
C PRTY(I,KK)=PRTY(J,KK)
C CCNTINUE
0410
C
C
C DETERMINE THE ANTENNA PATTERNS FOR THE RADARS
C DC C440 I=1,NTOT
C SEARCH THE PARAMETER TABLE FOR THIS RADAR
C DC C430 J=1,NTAB

```

```

MAN01930
MAN01940
MAN01950
MAN01960
MAN01970
MAN01980
MAN01990
MAN02000
MAN02010
MAN02020
MAN02030
MAN02040
MAN02050
MAN02060
MAN02070
MAN02080
MAN02090
MAN02100
MAN02110
MAN02120
MAN02130
MAN02140
MAN02150
MAN02160
MAN02170
MAN02180
MAN02190
MAN02200
MAN02210
MAN02220
MAN02230
MAN02240
MAN02250
MAN02260
MAN02270
MAN02280
MAN02290
MAN02300
MAN02310
MAN02320
MAN02330
MAN02340
MAN02350
MAN02360
MAN02370
MAN02380
MAN02390
MAN02400

```

```

0430 IF ((RADN1(J).EQ.ELNT1(I)).AND.(RACN2(J).EQ.ELNT2(I)))GO TO 0431
0431 CCNTINUE
      CALL ANTDG(GMAX(J),BEAM(J),AVGSL(J),FREQ(J),ITRAK(J),GN)
      CC 0435 KL=1,180
      G(I,KL)=GN(KL)
      CCNTINUE
      CC 0440 DC 0461 KL=1,10
      L1(KL)=0
      L2(KL)=0
      TCTP(KL)=0.
      CCNTINUE
      CC 0461 CHANGE ALL MAXIMUM ANTENNA GAIN VALUES FROM DB TO LINEAR
      CC 0462 I=1,NTAB
      GMAX(I)=10.**((GMAX(I))/10.)
      CCNTINUE
      CC 0462 DETERMINE THE ORDER OF PRIORITY
      CALL ORDER(PRTY,NTOT,NPRTY,IMAX)
      CC
      CC 0462 DETERMINE THE TEN BEST LOCATIONS FOR THE JAMMER AT THE STRIKE
      GROUP'S HIGHEST PRIORITY POINT
      ITERATE FOR ALLOWABLE OPERATING PCINTS
      DO 0490 M=1,LAT
      DO 0490 N=1,LCN
      IF (IMITE(M,N).NE.1)GO TO 049J
      ACJUST THIS POINT TO THE OPERATING AREA DISTANCE SCALE
      PLAT=M
      PLCN=N*SKAL
      CC 0465 INITIALIZE THE TOTAL EFFECTIVENESS VALUE(TEFF) TO RERC
      TEFF=0.
      ITERATE FOR RADARS IN DESCENDING ORDER OF PRIORITY
      DO 0485 I=1,NTOT
      CC 0485 J=1,NTAB
      IF ((RADN1(J).EQ.ELNT1(NPRTY(I)).AND.(RADN2(J).EQ.ELNT2(NPRTY(I))))
      1)GC TO 0466
      CCNTINUE
      CC 0466 CHECK TO SEE IF A JAMMER IS AVAILABLE
      CC 0470 K=1,NJAM
      IF ((FREQ(J).LT.F1(K)).OR.(FREQ(J).GT.F2(K))) GO TO 0470
      IF (JXN(K).EQ.0)GO TO 0470
      JXN(K)=0
      JAMMER K IS AVAILABLE
      CC 0472 GC TO 0472
MAN02410
MAN02420
MAN02430
MAN02440
MAN02450
MAN02460
MAN02470
MAN02480
MAN02490
MAN02500
MAN02510
MAN02520
MAN02530
MAN02540
MAN02550
MAN02560
MAN02570
MAN02580
MAN02590
MAN02600
MAN02610
MAN02620
MAN02630
MAN02640
MAN02650
MAN02660
MAN02670
MAN02680
MAN02690
MAN02700
MAN02710
MAN02720
MAN02730
MAN02740
MAN02750
MAN02760
MAN02770
MAN02780
MAN02790
MAN02800
MAN02810
MAN02820
MAN02830
MAN02840
MAN02850
MAN02860
MAN02870
MAN02880

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0473 CCNTINUE IS AVAILABLE GO TO NEXT RADAR
C NC JAMMER IS AVAILABLE GO TO NEXT RADAR
C TO 0485
0472 CCNTINUE THE J/S
C CCMPUTE THE RADAR- STRIKE(RSTK) AND RADAR-JAMMER(RJX) RANGES
C FIRST COMPUTE THE RADAR- STRIKE(RSTK) AND RADAR-JAMMER(RJX) RANGES
C RSTK=1852.*RANJ(RLAT(NPRTY(I)),RLCN(NPRTY(I)),SLAT(IMAX),SLON(IMAX
1))
R JX=1852.*RANJ(RLAT(NPRTY(I)),RLCN(NPRTY(I)),PLAT,PLCN)
C SET THE MINIMUM RANGE TO ONE NAUTICAL MILE. THIS WILL PREVENT
C THE J/S FROM GOING TO INFINITY FOR JAMMER POSITIONS OVERHEAD
C A RADAR SITE
IF(RSTK.LT.1852.)RSTK=1852.
IF(RJX.LT.1852.)RJX=1852.
C MEASURE THE STRIKE-RADAR-JAMMER ANGLE (THETA)
THETA=ABS((ATAN2(RLN(NPRTY(I))-SLON(IMAX),RLAT(NPRTY(I))-SLAT(IMAX
1)))-(ATAN2(RLN(NPRTY(I))-PLON,RLAT(NPRTY(I))-PLAT)))*57.29577951
IF(THETA.GT.180.)THETA=360.-THETA
ITHETA=THETA+1.
C COMPUTE THE J/S (EFFECT)
EFFECT=((49*3.141592654*PWR(K)*(10.**((GAN(K)/10.))*G(NPRTY(I),ITHETA
1))*RSTK**4)/(RPWR(J)*GMAX(J)**2*CRSCT*RJX**2))
C INVERT THE J/S AND LIMIT IT TO A RANGE OF -25DB TO +50DB
NCRMALIZE THIS RANGE ZERO TO ONE
EFFECT=(20.*ALOG10(EFFECT))/50.+0.5)/1.5
IF(EFFECT.GT.1.)EFFECT=1.
IF(EFFECT.LT.0.)EFFECT=0.
C WEIGHT THE J/S BY THE PRIORITY AND THE MODULATION VULNERABILITY
(PMCD) OF THE ASSOCIATED RADAR
PERF=EFFECT*PRTY(IMAX,NPRTY(I))*FMCC(J)
C SUM THE PERFORMANCES AGAINST THE INDIVIDUAL RADARS FOR A TOTAL
PERFORMANCE (TEFF) INDICATION FROM THIS JAMMER LOCATION
TEFF=TEFF+PERF
CCNTINUE
C RETAIN THE TEN BEST PERFORMANCE POINTS
CALL GDPTS(M,N,TEFF,LT1,LT2,LT3,LT4,LT5,LT6,LT7,LT8,LT9,LT10)
C
C RESET THE JAMMER AVAILABILITY
DC 0490 JI=1,NJAM
C JX(JI)=1
0490 CCNTINUE
C OUTPUT THE TEN BEST LOCATIONS FOR THE JAMMER FOR THE STRIKE GROUP'S
C HIGHEST EXPOSURE PCINT
WFITE(6,0471)(LT1(I),LNI(I),TOTP(I),I=1,10)
0471 FCFRMT(215,EI6.8)
C SET THE INITIAL ECM ROUTE POINTS TO THE BEST POINTS AT IMAX
DC 0600 I=1,10

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MAN02890
MAN02900
MAN02910
MAN02920
MAN02930
MAN02940
MAN02950
MAN02960
MAN02970
MAN02980
MAN02990
MAN03000
MAN03010
MAN03020
MAN03030
MAN03040
MAN03050
MAN03060
MAN03070
MAN03080
MAN03090
MAN03100
MAN03110
MAN03120
MAN03130
MAN03140
MAN03150
MAN03160
MAN03170
MAN03180
MAN03190
MAN03200
MAN03210
MAN03220
MAN03230
MAN03240
MAN03250
MAN03260
MAN03270
MAN03280
MAN03290
MAN03300
MAN03310
MAN03320
MAN03330
MAN03340
MAN03350
MAN03360

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060C ELAT1(I,I)=LTI(I)
C ELAT2(I,I)=LTI(I)
C ELCN1(I,I)=LNI(I)
C ELCN2(I,I)=LNI(I)
C CCNTINUE
C ITERATE FOR THE TEN IMAX POINTS
DC C80J I=1,10
R1FACT(I)=0.
R2FACT(I)=0.
ITERATE FOR ROUTE SEGMENT ONE
I=1-ISTK1-1
IF(I=1.EQ.0)GO TO 0650
DC C650 J=1,IS1
CALL ORDER(PRTY1,NTOT,NPRTY,J)
ITERATE FOR THE POINTS IN THE OPERATING AREA
TLAST=0.
DC C640 M=1,LAT
DC C64J N=1,LCN
TFRM OUT POINTS THAT ARE NOT ALLOWED OR TOO FAR FROM PREVIOUS PT
PLAT=M
PLCN=N*SKAL
IF((LIMITE(M,N).NE.1).OR.(RANJ(PLAT,PLON,ELAT1(J,I),ELON1(J,I))*SKAL
1).GT.DMAX))GO TO 0640
TEFF=0.
C ITERATE FOR RADARS IN THE EOB IN DESCENDING ORDER OF PRIORITY
DC C630 K=1,NTOT
SEARCH THE PARAMETER TABLE
DC C605 II=1,NTAB
IF((RADN1(II).EQ.ELNT1(NPRTY(K)).AND.(RADN2(II).EQ.ELNT2(NPRTY(K)
1J))GO TO 0606
CCNTINUE
CCNTINUE
CHECK TO SEE IF A JAMMER IS AVAILABLE
DC C620 L=1,NJAM
IF((FREQ(II).LT.F1(L)).OR.(FREQ(II).GT.F2(L)))GO TO 0620
IF(JXN(L).EQ.0)GO TO 0620
JXN(L)=0.
JAMMER L IS AVAILABLE
GC TO 0621
CCNTINUE
CCNTINUE
NC JAMMER IS AVAILABLE, GO TO NEXT LOWER PRIORITY RADAR
GC TO 0630
CCNTINUE
CCMPUTE THE J/S
CCMPUTE THE DISTANCE FROM THE RADAR TO THE STRIKE AND JAMMER
FIRST MEASURE THE DISTANCE FROM THE RADAR TO THE STRIKE AND JAMMER
RSTK=1852.*RANJ(RLAT(NPRTY(K)),RLCN(NPRTY(K)),SLATI(J+1),SLONI(J
1+1))
MAN03370
MAN03380
MAN03390
MAN03400
MAN03410
MAN03420
MAN03430
MAN03440
MAN03450
MAN03460
MAN03470
MAN03480
MAN03490
MAN03500
MAN03510
MAN03520
MAN03530
MAN03540
MAN03550
MAN03560
MAN03570
MAN03580
MAN03590
MAN03600
MAN03610
MAN03620
MAN03630
MAN03640
MAN03650
MAN03660
MAN03670
MAN03680
MAN03690
MAN03700
MAN03710
MAN03720
MAN03730
MAN03740
MAN03750
MAN03760
MAN03770
MAN03780
MAN03790
MAN03800
MAN03810
MAN03820
MAN03830
MAN03840

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C C R J X = 1852. * R A N J ( R L A T ( N P R T Y ( K ) ) , R L C N ( N P R T Y ( K ) ) , P L A T , P L C N )
C C L I M I T   T H E   R A N G E S   T O   O N E   N A U T I C A L   M I L E .   T H I S   K E E P S   T H E   J / S   F R O M
C C G O I N G   T O   I N F I N I T Y   F O R   J A M M E R   L O C A T I O N S   O V E R H E A D   A   R A D A R .
C C I F ( R S T K . L T . 1852. ) R S T K = 1852.
C C I F ( R J X . L T . 1852. ) R J X = 1852.
C C M E A S U R E   T H E   S T R I K E - R A D A R - J A M M E R   A N G L E
C C T H E T A = A B S ( ( A T A N 2 ( R L O N ( N P R T Y ( K ) ) - S L O N 1 ( J + 1 ) , R L A T ( N P R T Y ( K ) ) - S L A T 1 ( J + 1 ) ) )
C C 1 ) ) ) - ( A T A N 2 ( R L O N ( N P R T Y ( K ) ) - P L O N , R L A T ( N P R T Y ( K ) ) - P L A T ) ) * 57.29577951
C C I F ( T H E T A . G T . 180. ) T H E T A = 360. - T H E T A
C C C O M P U T E   T H E   J / S   ( E F C T )
C C E F C T = ( ( 4. * 3.141592654 * P W R ( L ) * ( 10. ** ( G A N ( L ) / 10. ) ) * G ( N P R T Y ( K ) , T H E T A +
C C 1 ) ) * R S T K * 4 ) / ( R P W R ( I ) * G M A X ( I ) * 2 * C R S C T * R J X * 2 ) )
C C C O N V E R T   T H E   J / S   T O   D B   A N D   L I M I T   I T   T O   A   R A N G E   O F   - 25 D B   T O   + 50 C B
C C N C R M A L I Z E   T H I S   R A N G E   Z E R O   T O   O N E
C C E F C T = ( ( 20. * A L O G 10 ( E F C T ) ) / 50. + . 5 ) / 1.5
C C I F ( E F C T . L T . C. ) E F C T = 1.
C C I F ( E F C T . L T . C. ) E F C T = 0.
C C W E I G H T   T H E   J / S   B Y   T H E   P R I O R I T Y   A N D   M O D U L A T I O N   V U L N E R A B I L I T Y
C C P E R F = E F C T * P R T Y 1 ( J + 1 , N P R T Y ( K ) ) * F M C C ( I )
C C S U M   T H E   P E R F O R M A N C E S   A G A I N S T   T H E   I N D I V I D U A L   R A D A R S   F O R   A   T C T A L
C C P E R F O R M A N C E   I N D I C A T O R   F R O M   T H I S   J A M M E R   L O C A T I O N
C C T E F F = T E F F + P E R F
C C C O N T I N U E
C C R E T A I N   T H E   B E S T   P O I N T   A S   A N   E C M   R O U T E   P O I N T
C C I F ( T E F F . L T . T L A S T ) G O   T O   0635
C C T L A S T = T E F F
C C E L A T 1 ( J + 1 , I ) = M
C C E L C N 1 ( J + 1 , I ) = N
C C R E S E T   T H E   J A M M E R   A V A I L A B I L I T Y
C C D C   0640   J A = 1 , N J A M
C C J X N ( J N ) = 1
C C C O N T I N U E
C C R I F A C T ( I ) = R I F A C T ( I ) + T L A S T
C C C O N T I N U E
C C I T E R A T E   F O R   R O U T E   S E G M E N T   T W O
C C I F ( I S 2 . E Q . 0 ) G O   T O   0750
C C I F ( I S 2 . E Q . 0 ) G O   T O   0750
C C C A L L   O R D E R ( P R T Y 2 , N T O T , N P R T Y , J )
C C I T E R A T E   F O R   P O I N T S   I N   T H E   O P E R A T I N G   A R E A
C C T L A S T = 0.
C C D C   0740   M = 1 , L A T
C C D C   0740   N = 1 , L C N
C C T H R O W   O U T   T H E   P O I N T S   T H A T   A R E   N O T   A L L O W E D   O R   T O O   F A R   F R O M   P R E V I O U S
C C P L A T = M
C C P L C N = N * S K A L
C C I F ( L I M I T E ( M , N ) . N E . 1 ) . O R . ( R A N J ( P L A T , P L O N , E L A T 2 ( J , I ) , E L O N 2 ( J , I ) ) * S K A L
C C 1 ) . G T . D M A X ) G O   T O   0740

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MAN03850
MAN0386J
MAN03870
MAN03880
MAN0389J
MAN03900
MAN03910
MAN03920
MAN03930
MAN0394J
MAN03950
MAN03960
MAN0397J
MAN03980
MAN03990
MAN04000
MAN04010
MAN04020
MAN04030
MAN04040
MAN04050
MAN04060
MAN04070
MAN04080
MAN04090
MAN04100
MAN04110
MAN04120
MAN04130
MAN04140
MAN04150
MAN04160
MAN04170
MAN04180
MAN04190
MAN04200
MAN04210
MAN04220
MAN04230
MAN0424J
MAN04250
MAN04260
MAN04270
MAN04280
MAN04290
MAN04300
MAN04310
MAN04320

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TEFF=0.
ITERATE FOR THE RACARS IN THE OPERATING AREA
DO C 0730 K=1,NTOT
SEARCH THE PARAMETER TABLE
DC 0705 II=1,NTAB
IF((RADN1(II)).EQ.ELNT1(NPRTY(K)).AND.(RADN2(II)).EQ.ELNT2(NPRTY(K)
1)) GO TO 0706
CCNTINUE
CCNTINUE SEE IF A JAMMER IS AVAILABLE
CHECK TO L=1,NJAM
DC 0720 L=1,NJAM
IF((FREQ(II)).LT.F1(L)).OR.(FREQ(II)).GT.F2(L))GO TO 0720
IF(JXN(L).EQ.0)GO TO 0720
JXN(L)=0
JAMMER L IS AVAILABLE
GC TO 0721
CCNTINUE
NC JAMMER AVAILABLE
GC TO 0730
CCNTINUE THE J/S
COMPUTE THE RANGE FROM THE RADAR TTC THE STRIKE
FIRST JAMMER
ANL JAMMER
RSTK=1852.*RANJ(RLAT(NPRTY(K)),RLCN(NPRTY(K)),SLAT2(J+1),SLON2(J+1
1))
RSTK=1852.*RANJ(RLAT(NPRTY(K)),RLCN(NPRTY(K)),SLAT2(J+1),SLON2(J+1
LIMIT THE MINIMUM RANGE TO ONE NAUTICAL MILE. THIS WILL KEEP
THE J/S FROM GOING TO INFINITY FOR JAMMER LOCATIONS CVERHEAD A
KALCAR SITE
IF(RSTK.LT.1852.)RSTK=1852.
IF(RJX.LT.1852.)RSTK=1852.
MEASURE THE STRIKE-RADAR-JAMMER ANGLE
THETA=ABS(ATAN2(RLN(NPRTY(K))-SLON2(J+1),RLAT(NPRTY(K))-SLAT2(J+
1)))-ATAN2(RLN(NPRTY(K))-PLON,RLAT(NPRTY(K))-PLAT))*57.29577951
IF(THETA.GT.180.)THETA=360.-THETA
COMPUTE THE J/S
EFFECT=((4.*3.141592654*PWR(L)*(10.*((GAN(L)/10.))*G(NPRTY(K),THETA+
1))*RSTK**4)/(RPWR(II))*GMAX(II))*2*CRSCT*RJX**2))
CCNVERT THE J/S TO DB AND LIMIT IT TO A RANGE OF -25DB TO +50CB
ACRVALIZE THIS RANGE ZERO TO ONE
EFFECT=((20.*ALOG10(EFFECT))/50.+0.5)/1.5
IF(EFFECT.GT.1.)EFFECT=1.
IF(EFFECT.LT.0.)EFFECT=J.
WEIGHT THE J/S BY THE PRIORITY AND MODULATION VULNERABILITY
PERF=EFFECT*PRTY2(J+1,NPRTY(K))*FMCC(II)
SUM THE INDIVIDUAL PERFORMANCES FOR A TOTAL PERFORMANCE INDICATOR
FRCC THIS IS JAMMER LOCATION
TEFF=TEFF+PERF

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MAN04330
MAN04340
MAN04350
MAN04360
MAN04370
MAN04380
MAN04390
MAN04400
MAN04410
MAN04420
MAN04430
MAN04440
MAN04450
MAN04460
MAN04470
MAN04480
MAN04490
MAN04500
MAN04510
MAN04520
MAN04530
MAN04540
MAN04550
MAN04560
MAN04570
MAN04580
MAN04590
MAN04600
MAN04610
MAN04620
MAN04630
MAN04640
MAN04650
MAN04660
MAN04670
MAN04680
MAN04690
MAN04700
MAN04710
MAN04720
MAN04730
MAN04740
MAN04750
MAN04760
MAN04770
MAN04780
MAN04790
MAN04800

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MAN04810
 MAN04820
 MAN04830
 MAN04840
 MAN04850
 MAN04860
 MAN04870
 MAN04880
 MAN04890
 MAN04900
 MAN04910
 MAN04920
 MAN04930
 MAN04940
 MAN04950
 MAN04960
 MAN04970
 MAN04980
 MAN04990
 MAN05000
 MAN05010
 MAN05020
 MAN05030
 MAN05040
 MAN05050
 MAN05060
 MAN05070
 MAN05080
 MAN05090
 MAN05100
 MAN05110
 MAN05120
 MAN05130
 MAN05140
 MAN05150
 MAN05160
 MAN05170
 MAN05180
 MAN05190
 MAN05200
 MAN05210
 MAN05220
 MAN05230
 SBR00010
 SBR00020
 SBR00030
 SBR00040
 SBR00050

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073C CCNTINUE THE BEST PCINT AS AN ECM RCUTE POINT
C     IF (TEFF.LT.TLAST)GO TO 0735
      TLAST=TEFF
      ELAT2(J+1,I)=M
      ELCN2(J+1,I)=N
      RESET THE JAMMER AVAILABILITY
C 0735 CC 0740 JN=1,NJAM
      JXN(JN)=1
      CCNTINUE
      R2FACT(I)=R2FACT(I)+TLAST
      CCNTINUE
      TOTP(I)=TOTP(I)+R1FACT(I)+R2FACT(I)
      CCNTINUE
      SHIFT THE 0/0 REFERENCED AREA USED DURING CALCULATIONS BACK
      TO ITS INITIAL LAT/LON. OUTPUT THE ROUTE NUMBER, MEASURE OF
      EFFECTIVENESS, AND ROUTE POINTS.
      CC 0900 I=1,10
      WRITE(6,805)I,TOTP(I)
      FCRMAT(7,2X,13,5X,E16.8)
      CC 0850 J=1,ISTK1
      AA=(DGMN(ALAT)+ELAT1(J,I)+.1)/60.
      BB=(DGMN(ALCN)+ELON1(J,I)+.1)/60.
      ELAT1(J,I)=(AA-INT(AA))*6+INT(AA)
      ELCN1(J,I)=(BB-INT(BB))*6+INT(BB)
      CCNTINUE
      CC 0870 J=1,ISTK2
      CC=(DGMN(ALAT)+ELAT2(J,I)+.1)/60.
      CL=(DGMN(ALCN)+ELON2(J,I)+.1)/60.
      ELAT2(J,I)=(CC-INT(CC))*6+INT(CC)
      ELCN2(J,I)=(DD-INT(DD))*6+INT(DD)
      CCNTINUE
      CC 0890 KK=1,ISTK1
      K=ISTK1-KK+1
      WRITE(6,875)ELAT1(K,I),ELON1(K,I)
      FCRMAT(10X,F10.2,5X,F10.2)
      CCNTINUE
      CC 0875 EQ.1)GO TO 0895
      CC 0890 IF(ISTK2.EQ.1)GO TO 0875)ELAT2(LL,I),ELON2(LL,I),LL=2,ISTK2)
      CCNTINUE
      STCP
      END
      FUNCTION RANJ(Y1,X1,Y2,X2)
      RANJ DETERMINES THE RANGE BETWEEN (X1,Y1) AND (X2,Y2)
      RANJ=SQRT((Y1-Y2)**2+(X1-X2)**2)
      RETURN
      END
  
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FUNCTION DGMN(X)
DGMN CONVERTS DEGREES AND MINUTES FROM DD.MM FORMAT TO
MINUTES ONLY
DGMN=(X-INT(X))*100.+INT(X)*60.
RETURN
END
SUBROUTINE KURAJ(PLAT,PLON,KLAT,RLGN,ELNT1,ELNT2,NTCT,DXPOZ,NEOB,
1RADN1,RADN2,RL,FM)
KURAJ DETERMINES THE EXPOSURE OF A POINT IN THE OPERATING AREA
ANC RETURNS IT AS DXPOZ.
DIMENSION RLAT(50),RLON(50),ELNT1(50),ELNT2(50),RADN1(50),RADN2(50)
1),RL(50),FM(50)
INTEGER RADN1,RADN2,ELNT1,ELNT2
DXPOZ=0.
PUKRF=1. FOR EACH RADAR IN THE EOB
ITERATE 1.
DO 200 I=1,NTOT
SEARCH THE PARAMETER TABLE FOR THIS RADAR
CC 210 J=1,NEOB
IF ((RADN1(J).EQ.ELNT1(I)).AND.(RADN2(J).EQ.ELNT2(I)))GO TO 211
CCNTINUE
CCNTINUE
CHECK TO SEE IF THE RADAR IS A THREAT RADAR (RL > J)
IF(RL(J).EQ.0.)GO TO 200
MEASURE THE RANGE FROM THE STRIKE TO THE RADAR
R=RANJ(PLAT,PLON,RLAT(I),RLON(I))
IF THE STRIKE IS WITHIN THE LETHAL RANGE COMPUTE THE EXPOSURE
IF(R.LT.RL(J))PUKRF=PUKRF*(R/RL(J))*FM(J)
DXPOZ=1.--PUKRF
CCNTINUE
RETURN
END
SUBROUTINE ANTDDB(GAIN,BEAM,AVGSLL,FREQ,IIRAK,RFACT)
ANTDDB GENERATES 180 DEGREES OF AN ANTENNA PATTERN. IT IS
ASSUMED THAT THE PATTERN IS SYMMETRIC FOR THE OTHER 180 DEGREES.
THE APERTURE E-FIELD DISTRIBUTION IS ASSUMED UNIFORM FOR
TRACKING RADARS AND FIRST ORDER COSINE FOR EW/ACQ RADARS.
DIMENSION BNUL(180),PATRN(180),RFACT(181)
PI=.141592654
DETERMINE THE WAVELENGTH (WAVE) AT THE FREQUENCY (FREQ)
WAVE=299792500./FREQ
DETERMINE THE APERTURE DIMENSION FOR AN ACQ RADAR
APERT=(69.*WAVE)/BEAM
CCONVERT GAIN FROM DB TO LINEAR
GAIN=1J.*(GAIN/10.)
CCONVERT AVERAGE SIDE LOBE LEVEL FROM DB TO LINEAR
AVGSLL=(10.**((AVGSLL/10.)/GAIN)
IF THE RADAR IS A TRACKER RECOMPUTE THE APERTURE

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SBR00060
SBR00070
SBR00080
SBR00090
SBR00100
SBR00110
SBR00120
SBR00130
SBR00140
SBR00150
SBR00160
SBR00170
SBR00180
SBR00190
SBR00200
SBR00210
SBR00220
SBR00230
SBR00240
SBR00250
SBR00260
SBR00270
SBR00280
SBR00290
SBR00300
SBR00310
SBR00320
SBR00330
SBR00340
SBR00350
SBR00360
SBR00370
SBR00380
SBR00390
SBR00400
SBR00410
SBR00420
SBR00430
SBR00440
SBR00450
SBR00460
SBR00470
SBR00480
SBR00490
SBR00500
SBR00510
SBR00520
SBR00530

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IF (ITRAK.EQ.1)APERT=(51.*WAVE)/BEAM
PATRN(1)=1
ITERATE FOR 180 DEGREES IN ONE DEGREE INCREMENTS
DC 200 N=1,180
SET THE VALUE OF PSI DEPENDING ON WHETHER THE RADAR IS A
TRACKER OR ACQ TO THE VALUE WHERE THE PATTERN NULLS OCCUR
PSI=(N+.5)*PI
IF (ITRAK.EQ.1)PSI=N*PI
CCMPUTE THE POSITION OF THE PATTERN NULLS
BNUL(N)=ARCSIN((PSI*WAVE)/(PI*APERT))*57.29577951
SET PSI TO THE VALUE WHERE THE PATTERN MAXIMA OCCUR
PSI=(N+1)*PI
IF (ITRAK.EQ.1)PSI=(N+.5)*PI
CCMPUTE THE VALUES OF THE PATTERN MAXIMA
PATRN(N+1)=(ABS((PI/4.))*((SIN(PSI+PI/2.)))/(PSI+PI/2.))+((SIN(P
1SI-PI/2.))/(PSI-PI/2.))**2)
IF (ITRAK.EQ.1)PATRN(N+1)=(ABS((SIN(PSI))/PSI))**2
CHECK TO SEE IF THE PATTERN MAXIMA HAVE FALLEN BELOW THE
AVERAGE SIDE LOBE LEVEL
IF (PATRN(N+1).LT.AVGSLL)GO TO 300
IF THE LOBE POSITIONS ARE GETTING CLOSE TO 90 DEG. GO AHEAD AND
SET THE PATTERN TO THE SIDE LOBE LEVEL SINCE TAKING THE ARCSIN
OF VALUES GREATER THAN ONE WILL CAUSE AN ERROR
IF (BNUL(N).GT.80.)GO TO 300
CCCONTINUE
CCCONTINUE
BNUL(N+1)=181
SET THE VALUE OF THE PATTERN TO THE VALUE OF THE PARTICULAR
SET THE INTERMEDIATE PATTERN VALUES TO THE MAXIMUM VALUE OF
THE SIDE LOBE WHICH THEY LIE IN TO ELIMINATE THE NARROW NULLS
RFACT(181)=AVGSLL*GAIN
L=0
DC 500 K=1,180
M=L+1
IF (K.GT.BNUL(L+1))L=L+1
RFACT(K)=PATRN(M)*GAIN
CCCONTINUE
RESET THE GAIN TO CB
GAIN=1.0.*(ALDGLD(GAIN))
RETURN
END
SUBROUTINE GDPTS(M,N,TEFF,LT,LN,TCTP)
GDPTS SORTS THE PERFORMANCES AND RETAINS THE TEN BEST
PERFORMANCES AND THEIR POSITIONS.
DIMENSION LT(10),LN(10),TOTP(10)
DC 500 K=1,10
IF (TEFF.LE.TOTP(K))GO TO 500
KK=10-K

```

```

SBRJ054J
SBR00550
SBR00560
SBR00570
SBR00580
SBRJ059J
SBR00600
SBR00610
SBRJ0620
SBR00630
SBR00640
SBR00650
SBR00660
SBRJ067J
SBR00680
SBR00690
SBRJ070J
SBR00710
SBR00720
SBRJ0730
SBR00740
SBR00750
SBR00760
SBR00770
SBRJ078J
SBR00790
SBR00800
SBR00810
SBR00820
SBR00830
SBR00840
SBR00850
SBRJ086J
SBR00870
SBR00880
SBRJ0890
SBR00900
SBR00910
SBR00920
SBR00930
SBRJ0940
SBR00950
SBR00960
SBR00970
SBR00980
SBRJ0990
SBR01000
SBR01010

```

SBR01020
 SBR01030
 SBR01040
 SBR01050
 SBR01060
 SBR01070
 SBR01080
 SBR01090
 SBR01100
 SBR01110
 SBR01120
 SBR01130
 SBR01140
 SBR01150
 SBR01160
 SBR01170
 SBR01180
 SBR01190
 SBR01200
 SBR01210
 SBR01220
 SBR01230
 SBR01240
 SBR01250
 SBR01260
 SBR01270
 SBR01280
 SBR01290
 SBR01300
 SBR01310
 SBR01320
 SBR01330
 SBR01340
 SBR01350
 SBR01360
 SBR01370
 SBR01380
 SBR01390
 SBR01400
 SBR01410
 SBR01420

```

DC 400 J=1, KK
LL=11-J
MM=10-J
LT(LL)=LT(MM)
LN(LL)=LN(MM)
TCIP(LL)=TCIP(MM)
CCNTINUE
LT(K)=M
LN(K)=N
TCIP(K)=TEFF
GC TO 600
CCNTINUE
CCNTINUE
RETURN
END
SUBROUTINE ORDER (PRTY, NTOT, NPRTY, I, STK)
ORDER ARRANGES THE PRIORITIES IN DESCENDING ORDER BY
SUBSCRIPTS ONLY. ONLY THE SUBSCRIPTS ARE COMPUTED; THE PRIORITY
ARRAY IS NOT REARRANGED.
DIMENSION PRTY(50,50), PRTEMP(50), NPRTY(50)
DC 1100 I=1, NTOT
PRTEMP(I)=0.
CCNTINUE
DC 1160 I=1, NTOT
IF (PRTY(I, STK, I).LE. PRTEMP(K)) GO TO 1150
KK=NTOT-K
IF (KK.EC.0) GO TO 1140
DC 1140 J=1, KK
LL=NTOT+1-J
MM=NTOT-J
PRTEMP(LL)=PRTEMP(MM)
NPRTY(LL)=NPRTY(MM)
CCNTINUE
PRTEMP(K)=PRTY(ISTK, I)
NPRTY(K)=I
GC TO 1160
CCNTINUE
CCNTINUE
RETURN
END
SAMPLE Emitter Parameter Table for an ACQ, SAM, and AAA Radar.
C FLINT NO. MAX DETECTION RANGE, MAX LETHAL RANGE, P'MAX, M; N
C FREQ, POWER, MAX RANGE, MAX LETHAL RANGE, SIDE LOBE LEVEL, ITRAK, FMOD, , ,
A100Z 1.5E 09 0.3 1.5 0.6 -2. 7. 0 1.0 4.
A200Z 2.5E 09 0.6E 0640. 1.0 0.6 5.0 1 1.0
  
```

400

500
600

C
C
C

1100

1140

1150
1160

C
C
C
A100Z
A200Z

A300Z 40.
3.5E 09 0.4E 0640. 0.3 1.0 C.65 5.0 7. 1 1.0⁴.

LIST OF REFERENCES

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3. Skolnik, Introduction To Radar Systems, p. 264 to 269, McGraw Hill, 1962.

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