NUCOM/BREM:
An Improved HF Propagation Code for Ambient and Nuclear Stressed Ionospheric Environments

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1 October 1976

Final Report for Period 19 April 1976 —30 September 1976

CONTRACT No. DNA 001-76-C-0261

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THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.
The NUCOM/BREM computer code extends the NUCOM II HF propagation code to include direct ray and groundwave propagation modes for airborne and ground-based communications links. Provision is made for user-supplied airborne antenna patterns for both vertical and horizontal polarizations, and for corrected horizontal noise-factors for airborne terminals. A variety of airborne antenna patterns are included and sample links are evaluated.
20. ABSTRACT (Continued)

computer code greatly extends the usefulness of NUCOM II for the analysis of HF links employing airborne terminals and relay aircraft.
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SECTION 1.0
INTRODUCTION TO NUCOM/BREM

NUCOM II is a sophisticated and versatile HF communication prediction code for both ambient and nuclear stressed ionospheric environments \(^{(1,2)}\). However, because NUCOM II considered only ionospherically propagated paths from ground-based terminals it could not be employed to predict the performance of groundwave and direct ray propagation between ground-based and elevated terminals. This limitation was particularly serious for the communication system analyst concerned with the performance of airborne HF assets in a nuclear environment.

A typical C³ communications link employing an airborne terminal is shown in Figure 1-1. An HF link between an airborne command post and a ground entry point within radio line-of-sight is analyzed for nuclear induced propagation disturbances using both NUCOM II and NUCOM/BREM. Prior to the burst the dominant propagation mode found by each code is the 1E ionospheric skip mode which provides a received signal-to-noise ratio adequate for reliable communication. Five minutes after the detonation, however, the median signal-to-noise ratio predicted by NUCOM II is far below the acceptable threshold due to the high level of nuclear-induced nondeviative ionospheric absorption. The possibility that com-
Figure 1-1. Comparison of Typical C³ Links as Analyzed by NUCOM/BREM and NUCOM II
munication may continue through the post-attack environment via direct line-of-sight or extended groundwave modes is neglected by the unmodified NUCOM II code with the result that unduly pessimistic predictions of HF blackout result. This is especially important where elevated transmitters and/or receivers are concerned due to the substantial height gains which can provide extensive coverage using the groundwave mode. In fact the improved NUCOM/BREM code predicts that the direct signal ray path for the example will continue to support adequate HF communication in the absence of the ionospheric component as shown in Figure 1-1.

This neglect of nonionospheric propagation modes by the unmodified NUCOM II code and the resulting pessimistic predicted link performance for certain airborne assets in stressed environments is particularly troublesome in view of the critical importance of short distance air-to-ground airborne command post and TACAMO relay aircraft links in C³ network analysis. Some typical types of C³ circuits which cannot be analyzed by the unmodified NUCOM II code but are treated by NUCOM/BREM are illustrated in Figure 1-2.

The NUCOM/BREM propagation code described in this report extends the basic NUCOM II approach to include non-ionospheric HF propagation calculations for ground-to-ground, air-to-ground and air-to-air HF links. The groundwave and direct ray signal
Figure 1-2. Types of $C^3$ radio links which cannot be analyzed by NUCOM II but are analyzed by NUCOM/BREM.
path field strengths are calculated with modified Bremmer\textsuperscript{(3)} and van der Pol\textsuperscript{(4)} equations independent of the normal ionospheric ray tracing calculations performed by the RAYTRACE subprogram of NUCOM II. The non-ionospheric HF signal paths are subsequently combined with the ionospheric ray paths in the COMEFF subprogram of NUCOM/BREM to yield a composite received signal power and an all mode signal-to-noise ratio. The overall computational architecture of NUCOM II and NUCOM/BREM is summarized in Figure 1-3. A more detailed description of the basic NUCOM II propagation code may be found in References 1 and 2.

Transmitting and receiving antenna gains may be either isotropic or arbitrary and specified in tabular format in both codes as provided by the user. The antenna vertical pattern input provisions for NUCOM II have been extended in NUCOM/BREM to also include negative radiation angles as required by elevated terminals. The input antenna pattern feature has been further modified to permit both horizontal and vertical polarization component pattern tables to be input independently. Direct ray and groundwave calculations are carried out separately for each polarization component in NUCOM/BREM since some elevated HF antennas may demonstrate strongly horizontal polarization patterns especially tail-to-fuselage wires, nose cap, and wing tip probes. Height gain functions for elevated terminals are calculated using
Figure 1-3. General Functional Program Architecture for NUCOM II and NUCOM/BREM

- **NATPAT** - Calculates ambient ionospheric parameters control points along great circle path linking transmitter and receiver coordinates including atmospheric noise levels.

- **NUCEFMB** - Calculates nuclear disturbances to ionospheric electron density vertical profiles.

- **ORDER** - Orders nuclear-modified ionospheric profiles along the great circle circuit path between transmitter and receiver and includes shockwave effects (if present).

- **RAYTRACE** - Calculates ionospheric ray paths through ambient and nuclear disturbed ionospheres and evaluates path losses for each ray path. Non-ionospheric ray path parameters are calculated in the NUCOM/BREM version.

- **COMEFF** - Combines path loss and atmospheric noise level data from RAYTRACE with user input antenna and power information to calculate overall effects on received median signal-to-noise ratio.
modified Hankel functions of the first kind and order one-third (5).

The NUCOM/BREM code allows the user several options for the treatment of effective earth parameters for the calculation of groundwave field strengths. Effective ground conductivity and dielectric constants may be user input or automatically calculated from the ITS numerical world map data (6) in NUCOM/BREM. Two different methods of treatment for inhomogeneous ground paths are provided based upon the Suda (7) and Millington (8) techniques with the latter particularly suited for mixed land-sea signal paths.

A somewhat novel feature of NUCOM/BREM permits the user to assess the effects of sea state parameters on the apparent conductivity of the ocean surface for long distance groundwave signal paths. The condition of the sea surface along a groundwave path may be described by a user supplied average wind velocity which is used to compute the effective sea surface conductivity in the fashion of Barrick (9) and Kaliszewski (10).

Provision is also made in the NUCOM/BREM code for the inclusion of a user-specified horizontally polarized HF noise-height compensation factor to provide appropriate atmospheric noise level values for predominantly horizontally polarized airborne HF antennas.
The final output of the NUCOM/BREM code is the all-mode median received signal-to-noise ratio, $P_{TA}$, given by

$$P_{TA} = 10 \log_{10} \left( \frac{P_{TI} + P_{TV} + P_{TH}}{P_{NV} + P_{NH}} \right) \text{ dBW} \quad (1-1)$$

where

- $P_{TI}$ is the total received ionospheric signal power density,
- $P_{TH}$ is the total received non-ionospheric signal power density polarized in the horizontal plane,
- $P_{TV}$ is the total received non-ionospheric signal power density polarized in the vertical plane,
- $P_{NV}$ is the received atmospheric noise density in the vertical plane and
- $P_{NH}$ is the received atmospheric noise density in the horizontal plane.

This report details the modifications to NUCOM II to incorporate these features and discusses the applicability and limitations of the non-ionospheric propagation calculations. Sample calculations are presented and discussed for typical link geometries and examples of airborne HF antenna patterns are provided for the guidance of the user.

NUCOM/BREM is coded in IBM FORTRAN IV G for the IBM System 370/145.
REFERENCES


5. Reference Tables of the Modified Hankel Functions of Order One - Third and Their Derivatives, Staff of the Computation Laboratory, Harvard University Publication, 1945.


REFERENCES....CONT'D.

SECTION 2.0
DESCRIPTION OF ANALYTIC APPROACH

2.1 Calculation of Uncompensated Field Strength

The NUCOM II subprogram RAYTRACE calculates an effective
path loss for each ionospheric ray and incorporates this path
loss figure into a power flux summation expression in COMEFF
which gives the total received ionospheric signal power density
for all propagating rays on the circuit, \( P_{TI} \), as follows:

\[
P_{TI} = \frac{\sum_{i=1}^{n} P_0 (G_{Ti}) (GR_i) C^2}{4\pi \log_{10} (Li/10) \cdot f^2 \cdot 10^{12}}
\]  
(Watts) (1-2)

where

- \( P_0 \) = transmitter power density in W/Hz
- \( G_{Ti} \) = power gain of transmitting antenna at \( \theta \) and \( \phi \)
in question, relative to isotropic
- \( GR_i \) = power gain of receiving antenna at \( \theta \) and \( \phi \) in
question, relative to isotropic
- \( Li \) = path loss for \( i \)-th ray including free space loss, ground
reflection, deviative and nondeviative absorption and
defocussing losses
- \( c \) = velocity of light
- \( f \) = frequency in MHz
- \( n \) = number of found ionospheric rays, and
- \( \theta, \phi \) = elevation and azimuth angles respectively.
Because of reciprocity we may categorize all non-ionospheric paths in the present application as consisting of one or more of the following computational types:

a. Direct Ray (line-of-sight)
b. Groundwave, and
c. Reflected Ray.

The analytic approach of the Bremmer-van der Pol computational algorithms makes expression of the nonionospheric components in the formulation of Equation (1-2) somewhat awkward however. Instead we shall first calculate the groundwave and direct ray electric field strengths at the receiver assuming that radiation occurs from an optimally oriented elementary electric dipole radiating the ideal one kilowatt effective power as defined by Bremmer (3). The resulting value of received field strength will then be compensated for user specified antenna gains and actual transmitted power density to yield a value of received power which can then be directly combined with the ionospheric ray power flux summation in COMEFF to yield the all mode expression shown in Equation 1-1. This process is repeated for each polarization component and the term uncompensated received field will be used to refer to the calculated basic Bremmer-van der Pol received electric field value before adjustment for actual transmitter powers and antenna gains. This approach has the additional advantage of readily permitting compari-
Figure 2-1 Types of Nonionospheric Computational Geometry
son of results with the tabulated values given by Bremmer (3).

Table 2-1 shows the types of computations required for each of the five different geometries which may exist with airborne terminals and which are illustrated in Figure 2-1.

**TABLE 2-1**

**TYPES OF NON-SKY WAVE COMPUTATIONAL GEOMETRY**

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<th></th>
<th>Groundwave</th>
<th>Direct Ray</th>
<th>Reflected Way</th>
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<tr>
<td>Both terminals on ground</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One airborne terminal</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>line of sight</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One airborne terminal,</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>beyond horizon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both terminals airborne,</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>line of sight</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Both terminals airborne,</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>beyond horizon</td>
<td></td>
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In the following sections we discuss each computational type in turn.

2.1.1 **Groundwave Field Strength Calculation**

This computation employs the Bremmer-van der Pol equations with height gain evaluation using modified Hankel functions of
Figure 2-2 (a) Definition of variables in groundwave calculation.

Figure 2-2 (b) Definition of variables used in direct ray analysis.

Figure 2-2 (c) Definition of variables used in reflected ray analysis.
the first kind and order one-third. As shown in Figure 2-2(a), for the standard one-kW transmitted ERP as specified by Bremmer and a short optimally oriented dipole of appropriate polarization orientation the uncompensated rms field strength (\(\mu V/m\)) as given by Bremmer (op. cit.) is:

\[
E = \frac{752.0}{D_m} \sqrt{\chi} \left| \sum_{s=0}^{\infty} f_s(h_1) f_s(h_2) \frac{e^{i\tau_s}}{2\tau_s - 1/\delta_e^2} \right| \mu V/m \tag{2-1}
\]

\[
K_e = 0.002924 \frac{1/3}{\lambda_m} \frac{\sqrt{\frac{\varepsilon^4 + 36 \cdot 10^{24} \sigma^2}{\varepsilon^2 + 6.10^{12} \sigma^2 e_m^2}}}{\varepsilon^2 + 6.10^{12} \sigma^2 e_m^2} \tag{2-2}
\]

\[
\psi_e = \arctan \left( \frac{\varepsilon}{6.10^{12} \sigma e_m^2} \right) - \frac{1}{2} \arctan \left( \frac{\varepsilon - 1}{6.10^{12} \sigma e_m^2} \right) \tag{2-3}
\]

\[
\chi = 53.7 \frac{D_m}{\lambda_m^{1/3}} \tag{2-4}
\]

\[
\delta_e = K_e e^{i(135^\circ - \psi_e)} \tag{2-5}
\]

\(D_m\) = distance in meters

\(\varepsilon\) = dielectric constant (relative)
\( \sigma_e = \) conductivity, e.m.u. units
\( \lambda_m = \) wavelength in meters
\( h_1 = \) transmitter height in meters
\( h_2 = \) receiver height in meters

The values of \( \tau_s \) follow from \( \tau_s = \text{Re } \tau_s + i \text{Im } \tau_s \)

(a) \( K_e \) small:

\[
\text{Im } \tau_o = 1.607 - K_e \sin(45^\circ + \psi_e) - 1.237 K_e^3 \sin(75^\circ + 3\psi_e) + \\
\frac{1}{2} K_e^4 \sin(4\psi_e) - 2.755 K_e^5 \sin(75^\circ - 5\psi_e) + \ldots
\]

\[
\text{Im } \tau_1 = 2.810 - K_e \sin(45^\circ + \psi_e) - 2.163 K_e^2 \sin(75^\circ + 3\psi_e) + \\
\frac{1}{2} K_e^4 \sin(4\psi_e) - 8.422 K_e^5 \sin(75^\circ - 5\psi_e) + \ldots
\]

\[
\text{Im } \tau_2 = 3.795 - K_e \sin(45^\circ + \psi_e) - 2.921 K_e^3 \sin(75^\circ + 3\psi_e) + \\
\frac{1}{2} K_e^4 \sin(4\psi_e) - 15.36 K_e^5 \sin(75^\circ - 5\psi_e) + \ldots
\]

\[
\text{Im } \tau_s \approx 1.932 (s + 3/4)^{2/3} - K_e \sin(45^\circ + \psi_e) + \ldots \quad (s > 2)
\]
\[ \text{Re } \tau_0 = 0.928 + K_e \cos(45^\circ + \psi_e) + 1.237 K_e^3 \cos(75^\circ + 3\psi_e) - \]
\[ - \frac{1}{2} K_e^4 \cos(4\psi_e) - 2.775 K_e^5 \cos(75^\circ - 5\psi_e) \ldots \]

\[ \text{Re } \tau_1 = 1.622 + K_e \cos(45^\circ + \psi_e) + 2.163 K_e^3 \cos(75^\circ + 3\psi_e) - \]
\[ - \frac{1}{2} K_e^4 \cos(4\psi_e) - 8.422 K_e^5 \cos(75^\circ - 5\psi_e) \ldots \]

\[ \text{Re } \tau_2 = 2.191 + K_e \cos(45^\circ + \psi_e) + 2.921 K_e^3 \cos(75^\circ + 3\psi_e) - \]
\[ - \frac{1}{2} K_e^4 \cos(4\psi_e) - 15.36 K_e^5 \cos(75^\circ - 5\psi_e) \ldots \]

\[ \text{Re } \tau_s = 1.116 (s + 3/4)^{2/3} + K_e \cos(45^\circ + \psi_e) \ldots \ (s > 2) \]

(b) \( K_e \) large:

\[ \text{Im } \tau_0 = 0.7003 - 0.6183 \frac{\sin(15^\circ - \psi_e)}{K_e} + 0.2364 \frac{\cos(2\psi_e)}{K_e^2} - \]
\[ - 0.0533 \frac{\sin(15^\circ + 3\psi_e)}{K_e^3} - 0.00226 \frac{\sin(60^\circ - 4\psi_e)}{K_e^4} \ldots \]

\[ \text{Im } \tau_1 = 2.232 - 0.1940 \frac{\sin(15^\circ - \psi_e)}{K_e} + 0.0073 \frac{\cos(2\psi_e)}{K_e^2} + \]
\[ + 0.0120 \frac{\sin(15^\circ + 3\psi_e)}{K_e^3} + 0.00160 \frac{\sin(60^\circ - 4\psi_e)}{K_e^4} \ldots \]

\[ \text{Im } \tau_s = 1.932 \left( s + \frac{1}{4} \right)^{2/3} - \frac{0.2241}{(s + 1/4)^{2/3}} \frac{\sin(15^\circ - \psi_e)}{K_e} \ldots \ (s > 1) \]
\[
\text{Re } \tau_0 = 0.4043 + 0.618 \frac{\cos(15^\circ - \psi_e)}{K_e} - 0.236 \frac{\sin(2 \psi_e)}{K_e^2} - 0.0533 \frac{\cos(15^\circ + 3 \psi_e)}{K_e^3} + 0.00226 \frac{\cos(60^\circ - 4 \psi_e)}{K_e^4} \ldots \\
\text{Re } \tau_1 = 1.288 + 0.194 \frac{\cos(15^\circ - \psi_e)}{K_e} - 0.0073 \frac{\sin(2 \psi_e)}{K_e^2} + 0.0120 \frac{\cos(15^\circ + 3 \psi_e)}{K_e^3} - 0.00160 \frac{\cos(60^\circ - 4 \psi_e)}{K_e^4} \ldots \\
\text{Re } \tau_s = 1.116 (s + 1/4)^{2/3} + \frac{0.2241 \cos(15^\circ - \psi_e)}{(s + 1/4)^{2/3}} K_e \cdot (s > 1)
\]

The height gain factor \( f_s(h_1) \) is computed from

\[
f_s(h_1) = \sqrt{\frac{2}{x_1 - 2 \tau_s}} \frac{H_{1/3}(1)}{H_{1/3}(1)} \left\{ \frac{1}{3} (x_1^2 - 2 \tau_s)^{3/2} \right\} \\
(2-8)
\]

(for the value of \( H_{1/3} \), see Appendix C; \( \text{Im}(x_1^2 - 2 \tau_s) < 0 \)

and \( \text{Im}(-2 \tau_s) > 0 \))

in which

\[
x_1^2 = 0.043674 \frac{h_{1m}}{x_m^{2/3}} \quad (2-9)
\]

2-9
or as follows when $|\delta| \ll 1$:

(a) approximately $h_{1m} > 60\lambda_m^{2/3}$:

$$f_s(h_1) = e^{-i\pi/4} + \frac{i}{3}(\lambda_1^2 - 2\tau_s)^{3/2} \left(1 - i\frac{0.2083}{(\lambda_1^2 - 2\tau_s)^{3/2}} - \frac{0.3342}{(\lambda_1^2 - 2\tau_s)^{3/2}} \right) -$$

$$\frac{e^{i\pi/4} - \frac{i}{3}(\lambda_1^2 - 2\tau_s)^{3/2} \left(1 + i\frac{0.2083}{(\lambda_1^2 - 2\tau_s)^{3/2}} \right)}{\delta e^{\frac{4}{\lambda_1^2 - 2\tau_s}}}$$

$$(2-10)$$

$(-45^0 < \arg\frac{4}{\lambda_1^2 - 2\tau_s} < 0)$

$$A_0 = 0.3582 \ e^{i120^0}; \quad A_1 = 0.3129 \ e^{-i60^0}$$

$$A_2 = 0.2903 \ e^{i120^0}; \quad A_3 = 0.2760 \ e^{-i60^0}$$

$$A_s = 0.3440 \ \frac{(-1)^{s+1}}{(s + 3/4)^{1/6}} \ e^{-i\pi/3} \quad (s > 3)$$

$$(2-11)$$

(b) approximately $h_{1m} < 60\lambda_m^{2/3}$:

$$f_s(h_1) = 1 + 6.283\left(\frac{1}{x^{1/3}} - \frac{1}{x} \right) \frac{h_1}{\lambda} - 39.48 \ \frac{(1 - x^{2/3}\delta e^{\frac{\tau_s}{\lambda}})h_1^2}{x^{4/3}\delta e} \ ... ,$$

in which

$$x = \frac{4.107}{\lambda_m^7}.$$  

$$(2-12)$$
The second height-gain factor is computed in the same way except that \( h_1 \) is replaced by \( h_2 \). The same formula apply to the horizontal dipole, \( \delta_e \) being replaced by \( \delta_m \) where

\[
\delta_m = K_m e^{i(45^\circ + \psi_m)}. \tag{2-13}
\]

These expressions thus provide the uncompensated field strength at the receiver for each polarization mode. The received power density is then obtained by compensating the results of the above calculations for user specified antenna gains and actual power density as described in Section 2.3.

2.1.2 Direct Ray Calculation

The power flux due to an isotropic radiator at a distance \( d \) is given by:

\[
P_F = \frac{P_T}{4\pi d^2} \quad \text{Watts/meter}^2 \tag{2-14}
\]

when \( d \) is expressed in meters, and \( P_T \) is the total radiated power in Watts. The power gain of a short maximally oriented dipole relative to isotropic is 1.5 which gives a flux at the receiver of

\[
P_F = \frac{1.5 P_T}{4\pi d^2} \quad \text{Watts/meter}^2 \tag{2-15}
\]

Equating this expression to power flux in terms of rms field strength and rearranging yields
E = \left[ \frac{1.5 \eta_0 P_T}{4 \pi d^2 \sqrt{2}} \right]^{1/2} \text{ Volts/meter} \quad (2-16)

where \( \eta_0 \) is the characteristic impedance of free space (≈ 120 Ω). For the standard 1 kW ERP of Bremmer (op. cit.) this reduces to

\[ E = \frac{1.50 \times 10^5}{d} \quad \mu V/m \quad (2-17) \]

where d is expressed in kilometers. This is the direct ray field strength at a distance D from a 1 kW ERP transmitter using a short optimally oriented dipole remote from ground. Note that the same expressions may be employed to predict both horizontal and vertical polarization components.

This expression is employed to evaluate the line-of-sight direct ray between airborne terminals as shown in Figure 2-2(b). The ground reflected component is evaluated separately as described in 2.1.3.

2.1.3 Reflected Ray Calculations

A line-of-sight signal path between elevated terminals may be decomposed into a direct and a reflected ray for each polarization type. The direct ray is subject only to free space transmission loss as discussed in Section 2.1.2.

The reflected ray losses may be considered to result from three sources: free space loss over the total path length, the
Fresnel reflection loss at the surface, and the defocusing or divergence loss at reflection due to the convex shape of the assumed perfectly spherical surface of the earth. For the standard 1 kW ERP of Bremmer and an optimally oriented dipole the received reflected field strength as shown in Figure 2-2(c) is given by Bremmer (3) as:

\[
E = \frac{150}{D} \left| \alpha \frac{D}{(D_1 + D_2)} \right| R(\tau_2)e \frac{2\pi i \frac{A}{\lambda}}{\mu V/m}
\]

(2-18)

\[
\alpha = \frac{R_e (D_1 + D_2) \sqrt{\sin \tau_2 \cos \tau_2}}{\sqrt{b \cdot \gamma \cdot \theta (D_1 \gamma \cos \tau_4 + D_2 b \cos \tau_1)}}
\]

(2-19)

where \( \tau_1, \tau_2, \tau_4, D_1, \) and \( D_2 \) are as defined in Figure 2-2(c) and

\[
a = R_e \text{ (or equivalent earth radius)}
\]

\[
b = R_e + h_t
\]

\[
\gamma = R_e + h_r
\]
in which
\[
R(\tau_2) = \begin{cases} 
\frac{\mu^2 \cos \tau_2 - \sqrt{\mu^2 - \sin^2 \tau_2}}{\mu^2 \cos \tau - \sqrt{\mu^2 - \sin^2 \tau_2}} & \text{,(vertical dipole)} \\
\frac{\cos \tau_2 - \sqrt{\mu^2 - \sin^2 \tau_2}}{\cos \tau_2 + \sqrt{\mu^2 - \sin^2 \tau_2}} & \text{,(horizontal dipole)}
\end{cases}
\] (2-20)

\[
\mu^2 = \sqrt{\varepsilon^2 + 36 \cdot 10^{-24} \sigma \frac{2}{\lambda_m^2}} e^{i \arctan(6 \cdot 1.12 \sigma \lambda_m / \varepsilon)},
\]
or, for \(\tau_2 = \pi/2\):
\[
R(\tau_2) = -1 - 2 ix^{1/3} \delta \cos \tau_2 + 2x^{2/3} \delta^2 \cos^2 \tau_2 \ldots \quad (2-21)
\]

\[x = \frac{4 \cdot 10^7}{\lambda_m} \quad ; \quad \delta = \delta_e, \delta_m \ \text{resp.}\]

\(\tau_2, D_1, D_2\) and \(\Delta\) are to be determined in succession from
\[
\tan \tau_2 = \frac{D_0}{h_1 + h_2} + \frac{D_0 \text{ km}}{6366} \left( \frac{h_1^2 + h_2^2}{(h_1 + h_2)^2} \right) \left( 1 + \frac{D_0^2}{2(h_1 + h_2)^2} \right) \ldots,
\] (2-22)

\(D_0\), distance measured along the earth's surface between the projections of the transmitter and the receiver)
\[
\cos \tau_1 = \sqrt{\cos^2 \tau_2 + 3.142 \cdot 10^{-7} \sin^2 \tau_2 h_1 m},
\]
\[
\cos \tau_4 = \sqrt{\cos^2 \tau_2 + 3.142 \cdot 10^{-7} \sin^2 \tau_2 h_2 m},
\]
\[
D_1 \text{ km} = 6366 (\cos \tau_1 - \cos \tau_2) + 0.001 \cos \tau_1 h_1 m,
\]
\[
D_2 \text{ km} = 6366 (\cos \tau_4 - \cos \tau_2) + 0.001 \cos \tau_4 h_2 m,
\]
\[
\cot \psi = \frac{(D_2 - D_1)}{(D_2 + D_1)} \cot \tau_2,
\]
\[
\Delta = \left( \frac{\sin \psi}{\sin^2 \tau} - 1 \right) D
\]
and \( R_E = 6366 \text{ km} \).
2.2 Calculation of Effective Ground Parameters

The conductivity $\sigma$ and dielectric constant $\varepsilon$ on the surface of the earth determine not only the reflection coefficient for an HF signal reflected from the ground surface but also the rate of attenuation of a groundwave signal with distance. For a perfectly homogeneous spherical earth the groundwave predictive techniques of Bremmer and van der Pol provide excellent solutions. Except possibly for paths along smooth sea surfaces, however, real signal paths are usually inhomogeneous. The complete solution for groundwave propagation along an inhomogeneous unsmooth path whose ground parameters may vary with distance requires extensive numerical integration of the Volterra equations as well as a detailed description of both the ground parameters and vertical terrain profiles along the entire path $(1,2)$. Since few, if any, paths can be so completely specified, a variety of approximation techniques have been developed and tested against real measurements by various authors in an attempt to simplify the prediction of groundwave signal strengths over inhomogeneous paths. Both the Millington (op.cit) and Suda(op.cit.) techniques have been extensively applied to practical broadcasting problems for many years and usually provide reasonable agreement with measurements. The reader is referred to Sections 2.2.2 and 2.2.3 and to the original papers by these authors for further details.

Depending upon the particular groundwave path to be analyzed by NUCOM/BREM the user has several options insofar as inhomogeneous groundwave analysis is concerned within the scope of the Suda and
Millington techniques. Generally speaking the Suda technique should provide more realistic predictions when the variations in surface parameters are relatively gradual along the path whereas the Millington approach is more suitable for sharp transitions such as mixed land-sea paths. The user is urged to compare the results of both techniques in questionable cases and to interpret the results for complex inhomogeneous paths with some care.

One particular type of inhomogeneous path geometry which deserves special comment is that featuring a sharp land-to-sea boundary. From the earliest days of radio research it has been known that transmission and reception at coastal stations sited near the sea often differs markedly from that at nearby sites further inland from the beach. Two types of anomalous behavior are commonly observed near land-sea interfaces: distorted direction finding behavior and anomalous variations of signal amplitude. While the rather misleading term "coastal refraction" continues to be used to describe these coastal effects, the work of Grunberg (3), Millington (4), Wait (5) and others (6,7) has shown both analytically and experimentally that these coastal phenomena must be described in terms of diffraction-like interface boundary effects. The "anomalous" amplitude variations near land-sea interfaces are generally termed "recovery effects" and are beyond the scope of the present analysis. Complete prediction of the HF field strength behavior near a land-sea boundary requires detailed description of the subsurface interface geometry as has been shown by Wait and Spies (8) although Millington (4) and others (9,10) have shown experimentally that the "Millington Technique" yields good results in areas away from the
interface region. It is suggested that calculations made by NUCOM/BREM employing the Millington technique (see Section 2.2.3) should be considered as possibly suspect within 100\(\lambda\) of the interface due to these boundary effects.

The groundwave calculation subroutines in NUCOM/BREM assume a homogeneous earth surface and require as input both conductivity \(\sigma\) and relative dielectric constant \(\varepsilon\). NUCOM/BREM permits use of either a user specified set of ground constants or the calculation of effective mean homogeneous ground constants for nonionospheric paths from the ITS numerical map data in NUCOM/BREM using the method of Suda (op.cit). Furthermore the user has the option of either a homogeneous path solution or an approximate inhomogeneous solution employing the method of Millington.

NUCOM II and NUCOM/BREM require ground constant data to calculate the Fresnel ground reflection loss coefficients in RAYTRACE as part of the determination of total ray path loss for ionospheric rays as well as for groundwave calculations of path loss. Figure 2-3 shows the program flow for the NUCOM II and NUCOM/BREM ground reflection calculations. NATPAT reads the ITS "Blue Binary" world ground numerical map \(^{(11)}\) from logical unit 1 and transfers the coefficients to logical unit 4 for later use by RAYTRACE. These world map coefficients have been produced from geographical world maps of ground constants using the well-known spherical harmonic techniques of Jones and Gallet \(^{(12)}\).

When RAYTRACE needs to calculate the ground loss at a geographical particular point on the surface of the earth it passes the geographical coordinates, frequency, and ray arrival angle to the
subroutine GLOSS. GLOSS, in turn, passes the geographical coordinates to the subroutine NWOMAP which applies the inverse mapping transformation to the coefficients read from unit 4 and returns a dimensionless variable WLD to GLOSS.

Using the conversion factors described in Section 2.2.1 GLOSS then converts the returned value of WLD to a conductivity and dielectric constant for the point in question as shown in Figure 2-3.

The subroutine GLOSS then applies the ordinary Fresnel reflection equations to the ground constants so determined to yield the horizontal and vertical reflection coefficients, $R_H$ and $R_V$, whose RMS value is taken as the effective average reflection coefficient for a randomly polarized skywave approaching the ground at the point in question.

NUCOM/BREM determines the effective ground parameters needed for groundwave calculations as follows. The user first specifies whether he is providing his own effective ground constants or wishes them to be automatically calculated from the ITS world map data available on unit 4 from NATPAT. He further specifies whether the path is to be considered homogeneous or heterogeneous. If the user is providing the effective constants they are directly employed for the analysis and computation proceeds as in Figure 2-4(a). If the user wishes to use map data for a homogeneous path calculation the program calls NWOMAP to evaluate the numerical coefficients at each of the n points whose geographical coordinates have been defined by the particular path geometry in question. After conversion of the map variable values to ground parameters the effective mean
FIGURE 2.4(a). HOMOGENEOUS, USER SUPPLIED CONSTANTS

FIGURE 2.4(b). NONHOMOGENEOUS, SUDA METHOD

$\sigma_s = \frac{1}{n} \sum_{i=1}^{n} \sigma_i$

$\varepsilon_s = \frac{1}{n} \sum_{i=1}^{n} \varepsilon_i$

FIGURE 2.4(c). NONHOMOGENEOUS, MILLINGTON METHOD

$\sigma_{TS} = \frac{1}{m} \sum_{i=1}^{m} \sigma_{Ti}$

$\sigma_{RS} = \frac{1}{m} \sum_{i=1}^{m} \sigma_{Ri}$

$\varepsilon_{TS} = \frac{1}{m} \sum_{i=1}^{m} \varepsilon_{Ti}$

$\varepsilon_{RS} = \frac{1}{m} \sum_{i=1}^{m} \varepsilon_{Ri}$
constants are determined as the distance-weighted effective values as used by Suda in the special case of equal length path segments. Control then passes to begin evaluation of path characteristics using the effective ground parameters thus computed as shown in Figure 2-4(b).

In the event the user decides that a Millington approximate heterogeneous path calculation will be more appropriate (for example in the case of a mixed land-sea path) he must also input a quantity m which is the number of segments of length \(d/(m \cdot n)\) into which the two path end segments are to be divided to calculate the required pair of effective ground constants for the Millington analysis as shown in Figure 2-4(c). The effective ground parameters at the receiver and transmitter path ends are thus calculated by the Suda method to provide the user an increased degree of spatial resolution control over the calculation.

The effects of wind on the apparent equivalent conductivity of the sea surface can substantially influence the coverage range of some HF signals. These effects are modelled using the Phillips isotropic ocean wave spectrum and the user may input an average wind velocity to compensate for known meteorological conditions.

NUCOM/BREM provides the user with considerable flexibility in regard to the choice of ground parameters and inhomogeneous path analysis techniques. The parameter n controls the resolution of numerical map data employed by the Suda averaging technique and the parameter m is directly related to the effective ground parameter values in the region between the path ends and the boundaries of

2-22
the ground discontinuity in the Millington method. Thus the user has the option of either incorporating his own ground parameter data or relying on the ITS numerical map data with a selectable spatial smoothing function and the choice of Suda or Millington methods for inhomogeneous paths. This approach generalizes the conditions of applicability of the basic groundwave calculation techniques to include all reasonable situations with acceptable accuracy.

2.2.1 NWOMAP Data

NUCOM/BREM permits the user the option of either supplying his own effective ground parameters or permitting the data from the ITS Blue Binary data (11) to be automatically retrieved and used.

The ITS world conductivity numerical maps are held as spherical harmonic coefficients for a dimensionless variable WLD which is returned from the call to the subroutine NWOMAP.

The returned value of WLD is transformed by the subroutine GLOSS to an equivalent $\sigma$ and $c$ value according to the algorithms given in Table 2-2. It should be noted that a linear relationship between $\sigma$ and $c$ has been assumed a priori by ITS; this is consistent with a first order approximation to the empirical relationship between $\sigma$ and $c$ of

$$c = 50 \ (\sigma)^{1/5} \quad (2-20)$$

as determined by Hanle, et al. (13)

It is left to the judgement of the user to decide whether the ground parameter data as returned from NWOMAP is adequate for his
**TABLE 2-2**

ALGORITHMS USED BY NUCOM II AND NUCOM/BREM TO DETERMINE $\sigma$ AND $\varepsilon$ FROM ITS WORLD NUMERICAL MAP COEFFICIENTS

<table>
<thead>
<tr>
<th>VALUE OF WLD RETURNED FROM NWOMAP</th>
<th>TRANSFORMED GROUND PARAMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\sigma$ (MHO/m)</td>
</tr>
<tr>
<td>WLD $\geq$ 0.75</td>
<td>0.001</td>
</tr>
<tr>
<td>$0.25 &lt; \text{WLD} &lt; 0.75$</td>
<td>$7.4995 - 9.998\times\text{WLD}$</td>
</tr>
<tr>
<td>$\varepsilon = 3.985 + 15.203\sigma$</td>
<td>(0.001 $&lt; \sigma &lt; 5.0$)</td>
</tr>
<tr>
<td>$0.25 \leq \text{WLD} \leq 0.25$</td>
<td>$\sigma = 4.0$</td>
</tr>
<tr>
<td>$-0.75 &lt; \text{WLD} &lt; -0.25$</td>
<td>$7.49995 + 9.9998\times\text{WLD}$</td>
</tr>
<tr>
<td>$\varepsilon = 3.998 + 15.200\sigma$</td>
<td>(0.0001 $&lt; \sigma &lt; 5.0$)</td>
</tr>
</tbody>
</table>
particular application both in terms of data quality and spatial resolution. In order to provide guidance to the user NUCOM/BREM prints the values of \( \sigma \) and \( \varepsilon \) returned from NWOMAP for each point along the great circle path determined by the particular selection of \( n \) and \( m \) specified as input, as well as the Suda mean value when appropriate.

In order to help the user to visualize the ITS ground data we have performed the inverse mapping transformation on the world ground constant data in NUCOM II and NUCOM/BREM and present it as a geographical map in Appendix II of this report.

2.2.2 Inhomogeneous Path - Suda Method

The simplest commonly used technique to calculate the equivalent homogeneous ground parameters for an inhomogeneous path is the Suda method which provides essentially a distance weighted average value for ground constants along the path.

The user specified parameter \( n \) establishes the number of path segments of length \( (D/m) \) into which the path is to be segmented for Suda computation where \( D \) is the length of the path. The subroutines NWOMAP and GLOSS return the corresponding values of conductivity and dielectric constant for each segment of the path as described in Section 2.2.1. From these values are computed the homogeneous equivalent values defined as

\[
\sigma_E = \frac{1}{n} \sum_{i=1}^{n} \sigma_i
\]

and

\[
\varepsilon_E = \frac{1}{n} \sum_{i=1}^{n} \varepsilon_i.
\]
According to Suda (op. cit) this approach yields the best results when the values of ground parameters do not change rapidly along the path, for example on a transcontinental path which does not cross coastal boundaries or across the open sea.

In the case of groundwave signal paths which cross land-sea boundaries the Millington method is probably more appropriate.

2.2.3 Inhomogeneous Paths - Millington Method

Inhomogeneous groundwave paths which cross boundaries between regions with very different ground parameters such as paths across sea coasts are best handled with the semi-empirical Millington method (4).

Consider a nonhomogeneous path with ground parameters $\sigma_T$, $\varepsilon_T$ at the transmitting end and $\sigma_R$, $\varepsilon_R$ at the receiving end. Suppose the received signal field corresponding to a homogeneous path with parameters $\sigma_R$ and $\varepsilon_R$ is $E_R$, and the corresponding value for a uniform path with the parameters at the transmitter end of the path is $E_T$. Millington has shown that the field due to the two segment path is given by the geometrical mean of the received fields:

$$E = \sqrt[2]{E_T E_R}$$  \hspace{1cm} (2-22)

as long as the field is measured distant from the boundary interface location.

NUCOM/BREM permits a combination of Suda and Millington techniques. In the case where the user wishes a Millington analysis he specifies both a segmentation parameter n and an end parameter m.
The code will then perform a Suda average based on \( m \) steps of equal length for the segments of length \( (d/n) \) at each end of the path. The resulting two values, one for each end of the path, are used then for the Millington calculation. Two independent groundwave calculations are then performed using each end value in turn and the inhomogeneous path value is taken as the geometrical mean of the two resulting field strength values as described above.

2.2.4 Sea State Correction

The classical theory of groundwave propagation as treated by van der Pol and Bremmer (op. cit.) assumes a smooth and electrically homogeneous spherical surface. For a propagation path over such a surface it is necessary only to specify two ground constants, conductivity \( \sigma \) and the relative dielectric constant \( \varepsilon \). These two constants characterize the electrical properties of the path and its loss (absorption) properties.

An alternative way to characterize the propagation path is through the definition of the ground surface impedance. It can be shown that for a plane wave incident upon a homogeneous ground at the angle \( \tau_o \), the impedance has to be of the following form:

\[
z = \frac{\eta_0}{\mu} \left[ 1 - \frac{\cos^2 \tau_o}{\mu^2} \right]^{1/2}
\]

where

\[
\mu = (\varepsilon - j 60 \lambda \sigma)^{1/2}
\]

\[
\eta_0 \approx 120\pi
\]
and $\varepsilon$, $\sigma$, and $\lambda$ are the relative dielectric constant, conductivity and the free space wavelength, respectively (14).

For grazing incidences ($\tau_0 = 0^\circ$) in a sea environment where the conductivity $\sigma$ is very high and at frequencies below VHF the impedance expression takes an even simpler form (15). Normalizing $Z$ with respect to $\eta_0$, we can then write

$$\frac{Z}{\eta_0} = \bar{Z} = R_{\Delta} - jX_{\Delta}$$

where

$$R_{\Delta} = X_{\Delta} = \frac{5.271 \times 10^{-3}}{\sqrt{\sigma}} \frac{\sqrt{F}}{\text{MHz}}.$$  

In the above we have retained the conductivity explicitly instead of incorporating it into the constant. The reasons for this will become apparent shortly.

For homogeneous smooth surfaces the conductivity parameter $\sigma$ accounts for the absorption due to ground losses. For rough surfaces such as the sea absorption is not the sole source of loss; scattering by the irregularities of the surface must also be accounted for. One approach to the problem of representing the losses over a rough finitely conducting surface is to postulate the existence of an apparent effective conductivity which represents all losses and is dependent on the surface roughness (15).

The criteria for surface roughness are usually expressed in terms of the mean height, the distribution of variation from the
mean, and the associated correlation function. For the sea surface formed only by surface winds a convenient and meaningful roughness criterion is that of the surface wind velocity. Assuming that the apparent conductivity is a function of the surface wind velocity, we may write

\[ R_A (\text{ROUGH}) \approx \frac{5.271 \times 10^{-3}}{\sqrt{\sigma(v)}} \sqrt{f_{\text{MHz}}} \]  

(2-25)

where

\[ \sigma \bigg|_{v=0} = 4 \text{ mho/m} \],

or, written differently,

\[ R_A (\text{ROUGH}) \approx \beta(v) \times \sqrt{f_{\text{MHz}}} \]  

(2-26)

and therefore

\[ \sigma(v) = 2.778 \times 10^{-5} (1/\beta(v))^2 \]  

(2-27)

To determine the precise form of the apparent conductivity the above functions must be derived from suitable models of the surface structure and impedances.

For the so-called Phillips (isotropic) ocean wave height spectrum and the model of the surface impedance as given by Barrick (op.cit.), the following relation has been derived by Kaliszewski (15):
\[ \beta(v) = 2.635 \times 10^{-3} + 8.784 \times 10^{-5} \]  \hspace{1cm} (2-28) 

where \( v \) is the surface wind velocity in meters/second.

Expressions similar but not linear in \( v \) can be obtained for the Neuman-Pierson ocean wave height spectrum \((17)\).

Substitution of Eq. (2-28) into Eq. (2-27) then gives \( \sigma(v) \). A plot of \( \sigma(v) \) for the Phillips and Neuman-Pierson ocean wave height spectra is shown in Figure 2-5. The abscissa in that figure is labeled in both meters/second and sea state parameters.

We thus construct an equivalent smooth sea surface in place of a rough one and assigned to it the property of an apparent equivalent conductivity. As is evident from Figure 2-5, the value of the apparent conductivity is affected by the surface roughness and is smaller than the rougher (or more disturbed) sea surface. The difference in values of the conductivity for smooth and rough surface represents the contribution to the propagation losses of the surface scatter.

That such a difference can be significant can be seen from Figure 2-6 where we have plotted the difference in the propagation losses obtained via the NUCOM/BREM groundwave prediction program for the indicated parameters. The difference is termed the excess loss (i.e., relative to a smooth surface) and is shown as a function of frequency. Note the resonant nature of the curve with the peak at about 14 MHz. Also plotted are values obtained by Berrick (op. cit.) from a considerably more extensive computation involving the full complex surface impedance of the surface.
2-31

FIGURE 2-5. APPARENT CONDUCTIVITY OF A ROUGH SEA

PHILLIPS
CROSS-WIND
UP DOWN-WIND

WIND VELOCITY, METERS/SEC.

APPEARANT CONDUCTIVITY, MHS/M
FIGURE 2-6. FREQUENCY DEPENDENCE OF EXCESS LOSS DUE TO ROUGH SEA. (GROUND-BASED, VERTICAL ANTENNAS)
In summary, NUCOM/BREM employs a computationally efficient groundwave prediction subroutine based on the analysis for a smooth, homogeneous earth and modifies it for use in rough sea environments. The modification takes the form of an algorithm for the apparent sea conductivity by which, in turn, is a function of the surface wind velocity (i.e., sea state). The input to NUCOM/BREM can take the form of a wind velocity, in meters/second, or a precalculated value of the apparent conductivity (say, from Figure 2-5).

It has been suggested by Wait (18) that the equivalent surface impedance approach to the disturbed sea surface may be unsuitable at the exact resonance frequency and the user should exercise caution in this special case.
2.3 Antenna Pattern Considerations

NUCOM II permits the user to specify two methods for treating antenna gains. Either he may specify that both transmitter and receiver are using isotropic antennas or alternatively he may supply his own antenna patterns. NUCOM II has a limited antenna pattern facility as shown in Figure 2-7(a). User supplied antenna pattern tables expressed in dB above isotropic are input for each one-degree of elevation angle (relative to the horizon) from $1^\circ$ to $40^\circ$. For angles in the range $0^\circ \leq 1^\circ$ the value at $1^\circ$ is used; for angles $> 40^\circ$ the value at $40^\circ$ is used. The input antenna gain patterns supplied by the user are applied to the incoming ionospheric signal rays in NUCOM II by the power flux equation (Eq. 1-2) in subprogram COMEFF independent of signal polarization (which is assumed to be random).

Table 2-3 summarizes the additional antenna input features available in NUCOM/BREM. As shown in Figure 2-7(b), the range of input antenna gain elevations has been extended to $\pm 90^\circ$ and both vertical and horizontal polarization patterns may be input independently. Furthermore the previous restrictions on the amount of antenna pattern data input have been relaxed for NUCOM/BREM by allowing a user specified minimum and maximum angle separately for transmitter and receiver patterns.

We have chosen to maintain the antenna pattern card input formats and angular conventions from NUCOM II to eliminate conversion problems for pattern decks punched for NUCOM II. In particular we have retained the reference angle convention of $0^\circ$ corresponding to the local horizon.
90° ASSUMED CONSTANT GAIN ABOVE 40°

PRESENT RANGE OF ANTENNA GAIN INPUT (0-40°)

Figure 2-7(a). Original Antenna Pattern Limitations in NUCOM II

90°

Figure 2-7(b). Extended Antenna Input Form Includes Data for Evaluations in the Range $-90^\circ \leq \theta \leq 90^\circ$
The official MIL coordinate system for airborne antenna patterns (21) is based upon the standard spherical (θ, φ) coordinate system and is shown in Figure 2-8. It is customary to describe θ measured from the local zenith and φ measured in a counterclockwise direction from the nose of the aircraft. Refining polarization components in this coordinate system avoids the ambiguity associated with the terms horizontal and vertical for angles near the zenith. Throughout the present work we shall use the terms "E_φ" and "horizontally polarized field" interchangeably.

**Table 2-3**

Comparison of input antenna features between NUCOM II and NUCOM/BREM

<table>
<thead>
<tr>
<th>NUCOM II</th>
<th>NUCOM/BREM</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Range limited to 1°-40° in 1° steps</td>
<td>a) Range + 90° in 1° steps</td>
</tr>
<tr>
<td>b) All 40 values must be supplied by user</td>
<td>b) User specifies minimum and maximum values separately for transmitter and receiver patterns</td>
</tr>
<tr>
<td>c) Full eight frequencies must be input</td>
<td>c) One to eight frequencies may be input</td>
</tr>
<tr>
<td>d) No polarization</td>
<td>d) Horizontal and vertical gain patterns input independently</td>
</tr>
<tr>
<td>e) Out of range values fixed by last value</td>
<td>e) Out of range values assumed isotropic</td>
</tr>
</tbody>
</table>
Figure 2-8. MIL coordinate system for airborne antennas.
The term "vertical polarization component" is generally used interchangeably with "E₀" except in the context of ambiguous geometries where E₀ as defined as in Figure 2-8 will be used explicitly.

The airborne HF liaison antennas in popular usage at the present time fall into several distinct design categories although their performances tend to be rather similar. These categories are:

i) Notch antennas, e.g., wing or tail notch
ii) Cap antennas, e.g., wing tip, tail, and nose-caps, and
iii) Extended wire antennas, e.g., tail-to-fuselage wires.

The problem of calculation of the radiation pattern of a real airborne HF antenna is almost hopelessly intractable from an analytic point of view due to the influence of the airframe on the pattern. Figure 2-9 illustrates the charge separation and field fringing effects which are of particular concern in the lower HF frequency range where the signal wavelength is still fairly large compared with the dimensions of the airframe. Consider an aircraft flying through a uniform vertical electrostatic field. The field will result in a charge separation as shown in Figure 2-9(a) with positive charge on the lower portion of the body. Because of the field line fringing of the field about the airframe, the local field strength along the upper and lower centerlines will exceed the imposed field while the strength along the sides at the boundary of the charge separation region will approach zero.

The same pattern of charge distribution will result from the imposition of a relatively low HF frequency signal field except that the polarization will vary with cos(ωt). If the impressed field were
Figure 2-9. Charge separation and E-field fringing on airframe at HF.
polarized in the direction of flight, a charge distribution similar to that in Figure 2-9(b) will be produced; similarly a transverse field will polarize the airframe as in Figure 2-9(c). It is then obvious that a particular antenna element will respond generally to each of the three imposed components in a fashion dependent strongly on the location of the antenna element relative to the airframe. As discussed in detail by Granger and Bolljahn (22), the intense field fringing at the top of the vertical stabilizer makes tail cap antennas particularly useful when vertical polarization sensitivity is to be optimized; likewise wing-cap antennas perform well for horizontal fields although in both cases structural factors may outweigh communications advantages.

Numerous authors (23, 24) have attempted to compute HF airborne antenna performances by decomposition of the airframe structural elements into elementary current filaments but the results have been disappointing. Much of the analytic difficulty arises from the near-resonant behavior of structural elements in the high frequency range. Figure 2-10 shows the two dominant types of resonance modes excited by HF fields which are conveniently classified as symmetric and antisymmetric (25). Generally, both modes are excited by actual coupling elements and consequently the pattern symmetries to be expected from simple current decompositions are rarely observed in practice (26).

The outstanding failure of attempts to predict airborne antenna patterns has led to a variety of empirical methods for pattern determination and evaluation including electrostatic (27) and scale model RF (28) measurement procedures, and semi-empirical and statistical techniques (29-32).
Figure 2-10. Dominant airframe resonance modes for HF range.
Wong (33) and Granger (25) have presented data showing the relative performances of various types of airborne antennas as expressed in terms of the "radiation pattern efficiency" which is defined as the ratio of power radiated in the elevation angle range of $\theta = 90^\circ \pm 30^\circ$ to the total radiated power. Figure 2-11(a) shows Wong's results for a CL-28 and Figure 2-11(b) presents Granger's data for a C-54. The marked resonant effect around 8 MHz of the phased wing caps on the C-54 is interpreted as a structural resonance.

Wong (33) has also evaluated the relative polarization efficiencies of a variety of antenna types on the CL-28. Figure 2-12 shows the ratio of vertically polarized power to total radiated power as a function of frequency. The complexity of structural resonance phenomena is quite evident.

As an aid to users of NUCOM/BREM we here provide some typical measured patterns for several classes of HF airborne liaison antennas to provide guidance in the modeling of airborne communications links. Tabulated patterns in the format required by NUCOM/BREM are listed in Appendix B.

Figures 2-13(a) through 2-13(c) present measured model patterns for a wing notch antenna on the Vulcan bomber. Figures 2-13(a) and (b) show the azimuthal ($\phi$) pattern at 2.02 and 21.5 MHz respectively (34). Note the essentially omnidirectional behavior at low frequencies and the conspicuous lobe-splitting at higher frequencies. Figure 2-13(c) shows the corresponding vertical plane pitch pattern for both polarization components at 2.02 MHz. The pattern nulls at $\theta = 0^\circ$ and $180^\circ$ for the horizontal component are typical of wing notch pattern behavior (35).
Figure 2-11(a). Relative pattern efficiencies for various types of airborne HF antennas on C-54 after Granger.

Figure 2-11(b). Relative pattern efficiencies for various types of airborne HF antennas on CL-28 after Wong.
Figure 2-12. Relative power in vertical polarization component for various HF airborne antenna types after Wong.
Figure 2-13(a). Azimuthal power pattern for using notch antenna; vertical component in dBi at 2.02 MHz.
Figure 2-13(b)  Azimuthal power pattern of wing notch antenna of 2-13(a) except at 21.5 MHz.
Figure 2-13. Vertical ($E_\theta$) pattern for using notch antenna at 2.02 MHz.

2-47
Notch antennas are employed on the fuselage less commonly than on leading wing surfaces. Figures 2-14(a) and (b) show measured model azimuthal ($\theta$) patterns for a dorsal notch on the Vulcan airframe at 6.6 and 23.3 MHz respectively.

Whereas notch antennas consisting of short segments insulated from wing surfaces essentially act as shunt feeds to the structural elements of the airframe, the wing and tail cap antennas are usually actively driven against the airframe. The radiation efficiency of a cap antenna appears to depend strongly upon area of the cap segment insulated from the airframe but the form of the pattern (i.e., shape) is supposedly rather invariant to the physical dimensions of the cap. Figures 2-15 and 2-16 show the model measured patterns for wing and tail cap antennas respectively for the Douglas DC series of airframes. For this frequency (2 MHz) at least the patterns are seen to vary smoothly with cap area.

Extended wire antennas operating at frequencies near those of structural element resonances are probably the most difficult to generalize. Figures 2-17(a) through 2-17(b) show measured vertical polarization model gains on a 1/25 scale EC-135 for a single tail-fuselage wire. These patterns extrapolated to $\theta = 0^\circ$ have been digitized and are presented in Appendix B in a format suitable for inclusion into NUCOM/BREM. The horizontal polarization component has been derived from the vertical component gain by applying the corrections due to Wong.
Figure 2-14(a). Azimuthal pattern for dorsal fuselage notch antenna at 6.6 MHz.

Figure 2-14(b). Azimuthal pattern for dorsal fuselage notch at 23.3 MHz.
Figure 2-15. Measured pattern of using cap antenna on DC airframe as a function of cap area.
Figure 2-16. Measured pattern of tail cap antenna on DC airframe as a function of cap area.
Figures 2-17(a) & (b) Measured model patterns for EC-135 tail-to-fuselage wire antenna.
Figures 2-17(c) & (d). Measured model patterns for EC-135 tail-to-fuselage wire antenna.
2.4 Antenna and Power Compensations

NUCOM II and NUCOM/BREM calculate the total path loss for each ionospheric ray path assuming isotropic radiators at each terminal and unity transmitted power density. The vertical plane power patterns for both transmitting and receiving antennas are input to NUCOM II in the form of tables giving power gain in dBi for each one degree of elevation angle from 1° to 40°. Above 40° and below 1° the values at 40° and 1° are assumed respectively.

In NUCOM/BREM we have elaborated considerably upon this approach to permit the user to input both horizontal and vertical polarization component vertical plane power patterns independently. Furthermore, the input angle calculation range has been extended to a full +90° to permit inclusion of airborne antenna pattern effects for terminals located at elevation angles as high as the zenith.

Adjustment of uncompensated received signal power levels for user input antenna patterns and actual radiated power is performed as follows. Suppose the standard 1 kW ERP transmitter of Bremmer produces a calculated r.m.s. field at the receiver of E microvolts/meter from the standard short optimally oriented electric dipole radiator. The power flux at the receiver is then given by

$$ p_F = \frac{E^2 \cdot 10^{-12}}{\eta_o} \text{ Watts/m}^2 $$  \hspace{1cm} (2-28)

where $\eta_o$ is the impedance of free space approximately equal to approximately 120$\Omega$ or 377.0$\Omega$. The power then received by an
isotropic radiator located at the receiver is then equal to the product of the power flux and the effective capture area of the isotropic antenna or,

$$p = \frac{2 \times 10^{-12}}{\eta_o} \times \frac{\lambda^2}{4\pi}$$

(2-29)

where $\lambda$ is the wavelength.

Expressed in dBW this becomes

$$P = 20 \log_{10} \lambda + 20 \log_{10} E - 156.755 \text{ dBW}$$

(2-30)

Since the gain of a short optimally oriented dipole is 1.761 dB relative to an isotropic radiator, the received compensated power may be expressed as

$$P_C = 20 \log_{10} E + 20 \log_{10} \lambda - 188.516 + G_R + G_T + P_T \text{ dBW}$$

(2-31)

where $G_R$ and $G_T$ are the power gains in dB of the receiving and transmitting antennas relative to isotropic for the polarization component of interest and $P_T$ is the actual radiated power density in dB relative to one Watt/Hz. This quantity $P_C$ is then incorporated into the ionospheric ray received power sum to yield the total power for all received signal modes. Up to four nonionospheric power components may be involved: the horizontal and vertical components of the direct ray between elevated line-of-sight terminals and the corresponding components of the reflected ray.
In the most general case of two line-of-sight aircraft with ionospheric paths the all mode power sum becomes that of Equation 1-2,

\[ P_{TA} = 10 \log_{10} \left( \frac{P_{TI} + P_{TV} + P_{TH}}{P_{NV} + P_{NH}} \right) \text{ dBW} \]  

(2-32)

where

- \( P_{TI} \) is the total received ionospheric power density,
- \( P_{TV} \) is the total received non-ionospheric vertically polarized signal power density,
- \( P_{TH} \) is the total received non-ionospheric horizontally polarized signal power density,
- \( P_{NV} \) is the received atmospheric vertically polarized noise density, and
- \( P_{NH} \) is the received atmospheric horizontally polarized noise density.

Each of the two non-ionospheric power components, \( P_{TV} \) and \( P_{TH} \), will consist of both direct and reflected components,

\[ P_{TV} = P_{DV} + P_{RV}, \text{ and} \]

\[ P_{TH} = P_{DH} + P_{RH} \]  

(2-33)

where

- \( P_{DV} \) is the compensated vertically polarized power density from the direct ray,
- \( P_{DH} \) is the compensated horizontally polarized power density from the direct ray,
$P_{RV}$ is the compensated vertically polarized power density from the reflected ray, and

$P_{RH}$ is the compensated horizontally polarized power density from the reflected ray.
2.5 Horizontal Noise Corrections

Since the performance of HF links using both ionospheric and nonionospheric modes of propagation is usually limited by the received noise level, in the end the goodness of a propagation prediction made from a code such as NUCOM will depend as much upon the accuracy of the atmospheric or man-made noise level figures as it will upon the propagation analysis.

The noise figure values used in NUCOM II (and in all ionospheric propagation codes for that matter) are directly adapted from the data presented in CCIR Report 322 (42). This data was taken by the worldwide ARN-2 instrumentation network and provides noise parameters assuming "a short vertical antenna over a perfectly conducting ground plane". As CCIR 322 is the international standard it is appropriate to quote their findings regarding noise polarization and directional effects,

8. The influence of the directivity and polarization of antennae

All the noise information presented in this Report, including the examples given in the last section, relates to a short vertical receiving antenna. Although such an antenna may be used in practice at low frequencies, long-distance communication at high frequencies is normally achieved by the use of a highly-directional antenna. Some allowance must therefore be made for the effects of directivity and polarization on the signal-to-signal noise ratio.

It is assumed that the signal gain is reasonably well-known, although it is dependent on the relative importance of the various propagation modes, which varies with time. The effective noise factor of the antenna, insofar as it is determined by atmospheric noise, may be influenced in several ways. If the noise sources were distributed isotropically, the noise factor would be independent of the directional properties. In practice, however, the azimuthal direction of the beam may coincide with the direction of an area where thunderstorms are prevalent, and
the noise factor will be increased correspondingly, compared with the omnidirectional antenna. On the other hand, the converse may be true. The directivity in the vertical plane may be such as to differentiate in favour of, or against, the reception of noise from a strong source. The movement of storms in and out of the antenna beam may be expected to increase the variability of the noise, even if the average intensity is unchanged.

Experimental information on the effects of directivity is scarce, and in some respects conflicting. In an equatorial region (Singapore), the median value of $F_a$ for certain directional antennae was found to be somewhat higher (about 4 db on the average), than that for a vertical rod antenna over the same period. This figure is considerably lower than the maximum possible antenna over the same period. This figure is considerably lower than the maximum possible antenna gain, as would be expected from the widespread nature of the storms, but the fact that there was, on the average, some gain in noise in a wide range of storm conditions suggests that there was, on the average, some gain in noise in a wide range of storm conditions suggests that there was a tendency for the noise to be received more from the lower angles of elevation. In the F.R. of Germany also, directional antenna had, on the average, higher noise factors\(^{(43,44)}\). On the other hand, in experiments in Australia, the average noise factors of several antennae, beamed in different directions, were a few decibels lower than that of a vertical rod antenna, the interpretation being that there was significant noise incident at high angles\(^{(45)}\). It appears therefore that, in general terms, the gain in signal-to-noise ratio is likely to be approximately that in the signal alone (which may, however, be less than the optimum gain), and that if more precise figures are needed, it is necessary to take into account the storm locations and the critical frequencies of the ionosphere in addition to the antenna polar diagram. More investigations are required before the allowances can be made reasonably precise, but it appears that the differences will usually be less than 6 db.

Even less information is available on the effects of antenna polarization, but for a first approximation, it may be assumed that the received noise would be comparable with either polarization, provided the antenna height is large compared with the wavelength.
Gallenberger and Bickel (46) report that measurements of the vertical and horizontal components of noise at VLF to elevations of 20,000 feet indicate that the horizontal component is down as much as 30 dB. It however must be pointed out that 20,000 feet is still less than $\lambda/2$ at VLF and that such behavior is not to be expected at HF, above a few wavelengths. It is therefore not unreasonable to assume that the noise power for horizontal polarization will be the same as that for vertical polarization above, say, 10 $\lambda$ or about 1 km. Below that height the amplitude of horizontally polarized noise will drop in amplitude to a low value near the surface of the earth, due to the behavior of the Fresnel reflection coefficient for horizontally polarized fields near the surface. The precise behavior of the horizontal noise value with height has not been experimentally investigated and will depend on some complex function of the precise reflective properties of the ground and the vertical and azimuthal disturbances of incoming ionospherically propagated HF noise.

It has been suggested by Bickel (47) that an exponential height model should be an acceptable first approximation for the behavior of horizontally polarized noise power at HF. We have therefore used an exponential function with a user specified height constant to allow fitting of empirical data should the user so desire. It should be pointed out however that the height regime where attenuation of the horizontal noise power due to ground effects is important at HF is below
the heights used for most C³ airborne assets.

An even more uncertain question is that of the relationship between receiver antenna polarization and pattern characteristics and the received noise power $P_N$. Without a detailed description of the distribution of each polarization component of noise with both $\theta$ and $\phi$ no meaningful antenna correction can be accomplished. This no doubt explains why the CCIR figure RNOYS is employed in NUCOM II without further antenna pattern compensation.

Since airborne antennas may feature predominantly horizontal polarization characteristics, however, some form of rough pattern compensation is desirable. If the noise power is assumed to be isotropic then the received noise power is proportional to the noise power flux for the polarization component in question and also the effective area of the antenna. Thus, for example, a purely horizontal antenna will respond only to horizontally polarized noise, etc. If we further assume that the effective area of the receiving antenna is proportional to the gain averaged over $\theta$ and $\phi$ we may write

$$N_v \propto \frac{\bar{\sigma}_v}{\bar{\sigma}_v + \bar{\sigma}_h} \frac{P}{\bar{\sigma}_v + \bar{\sigma}_h} \quad (2-34)$$

and

$$N_h \propto \frac{\bar{\sigma}_h}{\bar{\sigma}_v + \bar{\sigma}_h} \frac{P (1-e^{-kz})}{\bar{\sigma}_v + \bar{\sigma}_h} \quad (2-35)$$
Where

- $N_v$ is the received noise power density (vertical)
- $N_h$ is the received noise power density (horizontal)
- $\bar{G}_v$ is the average gain for vertical polarization
- $\bar{G}_h$ is the average gain for horizontal polarization
- $P$ is the noise power density from NWOMAP (corrected for frequency and bandwidth)
- $K$ is the user specified horizontal height power factor and
- $Z$ is the height of the terminal above ground in kilometers.

The total received noise power as used in the all mode power sum (Eq.1-1) is then simply

$$N_a = N_v + N_h.$$ \hspace{1cm} (2-36)

A default value of $k=3.1$ is employed in NUCOM/BREM. This value corresponds to a recovery in horizontal noise power of 99% at a height of $10\lambda$ (at 2 MHz) or 1.5km.
REFERENCES


18. J. Wait, Personal Communication.


37. The Notch Aerial and Some Applications to Aircraft Radio Installations, W. A. Johnson, IEE, 102, part IIIA, p 211, 1955.


40. Boeing Aircraft Company, Seattle, Wash., private communication.


SECTION 3.0
SOFTWARE IMPLEMENTATION

Rather extensive modifications to certain parts of NUCOM II were necessary to implement the new features previously discussed. Approximately 1,100 new lines of code have been added to the RAYTRACE and COMEFF subprograms and several hundred more lines of existing code have been modified.

Because of the considerable complexity of the case stacking logic of the original NUCOM II code, every attempt was made to isolate the modifications required to calculate the nonionospheric modes in order to minimize the effects on the case control logic. The task of modifying NUCOM II has been simplified somewhat by its linear subprogram organizational structure which allowed us to limit the NUCOM/BREM modifications to the subprograms RAYTRACE and COMEFF without affecting the subprograms NATPAT, NUCEFMB, or ORDER.

All of the original NUCOM II features and outputs have been retained in NUCOM/BREM. The new nonionospheric calculations are made within the case control logic as if they were a special type of ionospheric ray path and the results of the nonionospheric analysis are presented independent of the original NUCOM II ionospheric analysis outputs.

Only the expanded antenna pattern elevation range feature directly enters into the ionospheric computations and then only to provide the user with the option of entering tabular pattern gain values for elevation angles as high as 90° instead of the maximum of 40° in NUCOM II. Computations using these high angle pattern
gains for ionospheric rays proceed as in NUCOM II.

The new or modified subroutines in RAYTRACE and COMEFF are heavily commented in the source code and subroutine structure has been kept as simple and straightforward as possible consistent with the constraints imposed by the preexisting code. The remainder of this Section details the software implementation of NUCOM/BREM; detailed descriptions of the unmodified code will be found in Reference 1 of Section 1.

NUCOM/BREM is coded in IBM FORTRAN IV G for the IBM System 370/145. The original IBM code is derived from the GE TEMPO version described in Reference 2 of Section 1.
3.1 Overview of NUCOM/BREM Software Modifications

The basic strategy in the modification of NUCOM II to include nonionospheric propagation modes is shown in Figure 3-1. Upon completion of ionospheric ray processing in the subroutine RAYTRACE of the last propagating ray for a case and frequency the main program flow is diverted to the control subroutine BREM10. It in turn calls other subroutines to calculate the power densities for the nonionospheric rays after calculating effective ground parameters where necessary. The nonionospheric path component power densities are flagged as "special" but otherwise are written onto unit 7 along with the normal ionospheric ray components for processing by the subroutine COMEFF. This approach results in minimal disruption of the case stacking logic and case control flow.

The "special" flagged components read from unit 7 by the subroutine COMEFF are processed separately to yield a total nonionospheric received compensated power density which in turn becomes a term in all mode signal to noise power calculation as shown in Figure 3-2. The subroutine COMEFF has been modified to read in extended elevation range antenna pattern tables for both vertical and horizontal polarization components and values interpolated from these tables are applied to each of the nonionospheric "special" components passed from unit 7 along with the user supplied power density correction to yield the compensated power density. The power density for each received component is combined in the nonionospheric power flux calculation in the subroutine COMEFF. After correcting the vertical noise
Figure 3-1. Overall software modification strategy for NUCOM/BREM. Nonionospheric propagation modes are calculated by BREM called by RAYTRACE; nonionospheric rays are written onto temporary storage as "special" ionospheric rays and input by COMEFF for power flux summation.
figure from the ITS Blue Binary Tape processed in the subroutine in NATPAT to compensate for terminal heights and the polarization ratio for the user supplied patterns, the subprogram COMEFF computes the all mode power density to noise ratio including both ionospheric and nonionospheric components. The subprogram COMEFF prints both the normal ionospheric mode outputs as well as a variety of nonionospheric intermediate results in addition to all the mode figures.

Table 3-1 shows the subroutines which have been added or modified for NUCOM/BREM.

Table 3-1

Subroutines Affected by NUCOM/BREM Modification

Asterisk indicates a wholly new subroutine.

<table>
<thead>
<tr>
<th>Subprogram RAYTRACE</th>
<th>Subprogram COMEFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASGEPS *</td>
<td>BLK DATA</td>
</tr>
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<td>BREM1O *</td>
<td>CPOWER *</td>
</tr>
<tr>
<td>FSGEPS *</td>
<td>F1</td>
</tr>
<tr>
<td>GRNDWV *</td>
<td>INITLC</td>
</tr>
<tr>
<td>MDHNKL *</td>
<td>ONE</td>
</tr>
<tr>
<td>RAYTRA</td>
<td>RDATNA *</td>
</tr>
<tr>
<td>RFLXRA *</td>
<td>READ</td>
</tr>
</tbody>
</table>
3.2 Modifications to Subprogram RAYTRACE

The modifications to the subprogram RAYTRACE are concerned only with the calculation of nonionospheric mode signal powers. Aside from the addition of a new user input card to describe the type of groundwave treatment required (i.e., Suda or Millington) and to provide user sophisticated ground and sea state parameters, the modification to the subroutine RAYTRACE are strictly computational in nature. Table 3-2 summarizes the nature of the changes to preexisting subroutines and the function of the new subroutines. The overall flowchart of Figure 3-3 shows the effects of the NUCOM/BREM modification to the subprogram flow.
Figure 3-3. Subroutine calling flow for subprogram RAYTRACE calls to BREM10 for nonionospheric calculations
### TABLE 3-2

New or modified subroutines in subprogram RAYTRACE

<table>
<thead>
<tr>
<th>Subroutine</th>
<th>Changes/Description</th>
</tr>
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<tbody>
<tr>
<td>ASGEPS</td>
<td>Did not previously exist. Calculates the effective ground constants at selected points along signal path using NWOMAP data and sea state corrections.</td>
</tr>
<tr>
<td>BREM10</td>
<td>Did not previously exist. This is the control subroutine for calculation of non-ionospheric signal powers. Determines the type of signal mode to be processed and prints intermediate results for user guidance.</td>
</tr>
<tr>
<td>FSGEPS</td>
<td>Did not previously exist. Transforms the dimensionless variable GAMMA returned by NWOMAP to effective ground parameters and applies sea state corrections for effective equivalent conductivity.</td>
</tr>
<tr>
<td>GRNDWV</td>
<td>Did not previously exist. Calculates ground-wave field strength for both polarization components using Bremer - van der Pol equations. Calculates height gains using modified Hankel function routine MDHNKL.</td>
</tr>
<tr>
<td>MDHNKL</td>
<td>Did not previously exist. Calculates modified Hankel function of the first kind and order one-third for the evaluation of height gains for elevated terminals.</td>
</tr>
<tr>
<td>RAYTRA</td>
<td>Main line RAYTRACE control subroutine; one line modified to call BREM10 for nonionospheric power calculations.</td>
</tr>
<tr>
<td>RFLXRA</td>
<td>Did not previously exist. Calculates the reflected ray powers for elevated terminals using Fresnel and defocusing losses plus free space losses.</td>
</tr>
</tbody>
</table>
3.2.1 Subroutine ASGEPS

Description

Subroutine ASGEPS determines the effective ground constants at various points along the great circle signal path using NWOMAP and calculates the Suda average values including the effects of sea state disturbances if any. Given a pair of geographical end point coordinates XLOC and YLOC, the great circle bearing DIR, and step size SEGSIZE, ASGEPS uses the subroutine COOR to determine the geographical coordinates for each of ISGCNT segments. These coordinates are passed to NWOMAP and the returned dimensionless variable GAMMA is corrected to sigma and epsilon by FSGEPS. If a nonzero wind velocity WVEL is specified the correction is made in FSGEPS. The resulting averages values SOUT and EOUT are returned by ASGEPS. A flow chart for ASGEPS is presented in Figure 3-4.

Call Statement

CALL ASGEPS (SEGSIZ, ISGCNT, XLOC, YLOC, DIR, WVEL, SOUT, EOUT)

Arguments

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>TYPE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEGSIZ</td>
<td>Input</td>
<td>Great circle distance from end point, km</td>
</tr>
<tr>
<td>ISGCNT</td>
<td>Input</td>
<td>Number of segments of length SEGSIZ</td>
</tr>
<tr>
<td>XLOC</td>
<td>Input</td>
<td>Latitude of start point</td>
</tr>
<tr>
<td>YLOC</td>
<td>Input</td>
<td>Longitude of start point</td>
</tr>
<tr>
<td>DIR</td>
<td>Input</td>
<td>Great circle bearing of path from start point</td>
</tr>
<tr>
<td>SYMBOL</td>
<td>TYPE</td>
<td>DESCRIPTION</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
<td>-------------</td>
</tr>
<tr>
<td>WVEL</td>
<td>Input</td>
<td>Wind velocity, km/sec.</td>
</tr>
<tr>
<td>SOUT</td>
<td>Out</td>
<td>Effective sigma</td>
</tr>
<tr>
<td>EOUT</td>
<td>Out</td>
<td>Effective epsilon</td>
</tr>
</tbody>
</table>

Common Storage Arguments Used

ERTHR, P1, RAD, DEG, P1BY2, TWOP1, REFINP, FREQ, BON, LONG, LAT, GAMMA, GMT, IO

Internal Subroutines Required

NWOMAP, COOR, FSGEPS

Number of Locations Required

940

10
Figure 3-4. Flowchart for subroutine AGSEPS
3.2.2 Subroutine BREM10

Description

Subroutine BREM10 is the control program for the calculation of nonionospheric signal components in RAYTRACE. Given the coordinates and heights of the terminals BREM10 calculates the non-ionospheric path geometry in order to determine computational types (i.e., line-of-sight, groundwave, reflected ray) to be computed. User supplied inputs for nonionospheric modes are read. If ground constants are required and are not user supplied BREM10 initiates calculation of the appropriate Suda or Millington values with corrections for sea state if necessary. The uncorrected field strengths for all relevant modes are calculated and corrected to unity power density. Computed nonionospheric mode powers and necessary elevation angles are written for COMEFF. BREM10 also prints relevant nonionospheric mode parameters including the segment values of ground constants and resulting effective homogeneous values for Suda or Millington treatments. A flow chart for BREM10 is presented in Figure 3-5.

Call Statement

CALL BREM10 (PLNGT, TLATD, TLONGD, RLATD, RLONGD, BER)

Arguments

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>TYPE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLNGT</td>
<td>Input</td>
<td>Path length along great circle in kilometers</td>
</tr>
<tr>
<td>TLATD</td>
<td>Input</td>
<td>Transmitter latitude</td>
</tr>
<tr>
<td>TLONGD</td>
<td>Input</td>
<td>Transmitter longitude</td>
</tr>
<tr>
<td>SYMBOL</td>
<td>TYPE</td>
<td>DESCRIPTION</td>
</tr>
<tr>
<td>---------</td>
<td>--------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>RLATD</td>
<td>Input</td>
<td>Receiver latitude</td>
</tr>
<tr>
<td>RLONGD</td>
<td>Input</td>
<td>Receiver longitude</td>
</tr>
<tr>
<td>BER</td>
<td>Input</td>
<td>Great circle bearing</td>
</tr>
</tbody>
</table>

User Supplied Input Common

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>FORMAT</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>THT</td>
<td>F10.3</td>
<td>Transmitter height, meters</td>
</tr>
<tr>
<td>RHT</td>
<td>F10.3</td>
<td>Receiver height, meters</td>
</tr>
<tr>
<td>SIGMA</td>
<td>F10.3</td>
<td>User supplied conductivity, Mho/m</td>
</tr>
<tr>
<td>EPSILON</td>
<td>F10.3</td>
<td>User supplied, dielectric constant, relative units</td>
</tr>
<tr>
<td>WNDVEL</td>
<td>F10.3</td>
<td>User supplied mean wind velocity, meters/second.</td>
</tr>
<tr>
<td>NSEGS</td>
<td>I5</td>
<td>Number of segments for Suda segmentation</td>
</tr>
<tr>
<td>MPTS</td>
<td>I5</td>
<td>Number of segments for Millington segmentation</td>
</tr>
<tr>
<td>FACHNZ</td>
<td>F10.3</td>
<td>User supplied horizontal noise height factor.</td>
</tr>
</tbody>
</table>

Output Variables to COMEFF

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>FORMAT</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTT</td>
<td>F6.0</td>
<td>Time (s)</td>
</tr>
<tr>
<td>FACHNZ</td>
<td>F10.3</td>
<td>Horizontal noise height correction factor</td>
</tr>
<tr>
<td>FREQ</td>
<td>F6.2</td>
<td>Frequency, MHz</td>
</tr>
<tr>
<td>BETA</td>
<td>F6.2</td>
<td>Last ionospheric transmitter beta (dummy)</td>
</tr>
<tr>
<td>DMY2</td>
<td>F6.2</td>
<td>Dummy</td>
</tr>
<tr>
<td>DMY3</td>
<td>F7.1</td>
<td>Dummy</td>
</tr>
<tr>
<td>THT</td>
<td>F7.1</td>
<td>Transmitter height, meters</td>
</tr>
<tr>
<td>RHT</td>
<td>F9.1</td>
<td>Receiver height, meters</td>
</tr>
<tr>
<td>RNOYS</td>
<td>F7.1</td>
<td>Noise power density</td>
</tr>
<tr>
<td>SYMBOL</td>
<td>FORMAT</td>
<td>DESCRIPTION</td>
</tr>
<tr>
<td>--------</td>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>JHOUR</td>
<td>I5</td>
<td>Hour (GMT)</td>
</tr>
<tr>
<td>DMY6</td>
<td>F10.5</td>
<td>Dummy</td>
</tr>
<tr>
<td>DBV</td>
<td>G12.6</td>
<td>Power density (dBW), vertical component</td>
</tr>
<tr>
<td>DBH</td>
<td>G12.6</td>
<td>Power density (dBW), horizontal component</td>
</tr>
<tr>
<td>DBL</td>
<td>G12.6</td>
<td>Power density (dBW) for LOS component</td>
</tr>
<tr>
<td>TBD</td>
<td>F10.3</td>
<td>Angle of direct ray at transmitter</td>
</tr>
<tr>
<td>TBR</td>
<td>F10.3</td>
<td>Angle of reflected ray at transmitter</td>
</tr>
<tr>
<td>RBD</td>
<td>F10.3</td>
<td>Angle of direct ray at receiver</td>
</tr>
<tr>
<td>RBR</td>
<td>F10.3</td>
<td>Angle of reflected ray at receiver.</td>
</tr>
</tbody>
</table>

Common Storage Arguments Used

EARTH, P1, RAD, DEG, P1BY2, TWOP1, REFIND, FREQ/BON/LONG,
LAT, GAMMA, GMT, 10, /GWA/V/SMGA, EPSILON, THT, RHT, DKM, DLOS,
THETA, LAMBDA, J
/P0/ JK, KL, IFCT, GR LOSS, ALA1, ALA2, LLF, IHRC, P200, DB,
HTCAL, JHOUR, RNOYS(80), FHNAME(12), BETA, TTT.

Internal Subroutines Used

RFLXRA, GRNDWV, ASGEPS, COOR

Number of Storage Locations Required

412610
RAYTRA

ENTER WITH
PLONGT, TLATD
TLONCD, RLATD
RLONGR, BER

CALCULATE
THETA

$\theta > \theta_1$?

YES

A

BOTH
ELEVATED?

YES

CALL
RFLXRA

REPORT
SECTION
OUTPUT

CORRECT
tO POWER
DENSITY

WRITE
FOR
COMEFF

RETURN

Figure 3-5(a).
Flow Chart of
BREM10
Figure 3-5(b). Flow-Chart for SUDA/MILLINGTON portion of BREM10
3.2.3 Subroutine FSGEPS

Description

Subroutine FSGEPS transforms from the dimensionless quantity GAMMA (= WLD) returned by the world ground constant subroutine NWOMAP to sigma and epsilon according to the algorithms described in Table 2-2. User input wind velocity corrections to conductivity are calculated per Equations 2-27 and 2-28. A flow chart for FSGEPS is presented in Figure 3-6.

Call Statement

CALL FSGEPS (GAMMA, SIGMA, EPSILON, WNDVEL)

Arguments

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>INPUT</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAMMA</td>
<td>Input</td>
<td>Returned from NWOMAP</td>
</tr>
<tr>
<td>SIGMA</td>
<td>Output</td>
<td>Calculated conductivity</td>
</tr>
<tr>
<td>EPSILON</td>
<td>Output</td>
<td>Calculated dielectric constant</td>
</tr>
<tr>
<td>WNDVEL</td>
<td>Input</td>
<td>Wind velocity, meters/second</td>
</tr>
</tbody>
</table>

Common Storage Arguments Used

None.

Internal Subroutines Used

None.

Number of Storage Locations Used

654,10
Figure 3-6. Flowchart of subroutine FSGEPS
3.2.4 Subroutine GRNDWV

Description

Subroutine GRNDWV calculates the groundwave field strength using the Bremmer-van der Pol equations as described in Section 2.1.1. The input switch POLAR determines whether the vertical or horizontal polarization component is to be calculated. The input parameters in COMMON describe the geometry of the path in terms of DKM, the path length in kilometers; THT, the transmitter elevation in meters; RHT, the receiver elevation in meters; SIGMA, the effective homogeneous ground conductivity; EPSLON, the effective homogeneous ground dielectric constant; and FREQ, the frequency in MHz. The output of GRNDWV consists of the arguments EV and EH which are the receiver site uncompensated fields the vertical and horizontal components respectively. Computation proceeds in a straightforward manner using the equations of Section 2.1.1 and the modified Hankel function of the first kind and order one-third as returned from the subroutine MDHNL for height gain evaluation. A flow chart for the subroutine GRNDWV is presented in Figure 3-7.

Call Statement

CALL GRNDWV (EH, EV)

Arguments

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>TYPE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>EH</td>
<td>Output</td>
<td>Electric field strength, rms, dB above 1μV/m, horizontal component</td>
</tr>
<tr>
<td>EV</td>
<td>Output</td>
<td>Electric field strength, rms, dB above 1μV/m, vertical component</td>
</tr>
</tbody>
</table>
Input Variables through Common

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>TYPE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIGMA</td>
<td>Input</td>
<td>Effective ground conductivity</td>
</tr>
<tr>
<td>EPSLON</td>
<td>Input</td>
<td>Effective ground dielectric constant</td>
</tr>
<tr>
<td>THT</td>
<td>Input</td>
<td>Transmitter height, meters</td>
</tr>
<tr>
<td>RHT</td>
<td>Input</td>
<td>Receiver height, meters</td>
</tr>
<tr>
<td>DKM</td>
<td>Input</td>
<td>Path length on surface, kilometers</td>
</tr>
<tr>
<td>DLOS</td>
<td>Input</td>
<td>Line-of-sight distance, kilometers</td>
</tr>
<tr>
<td>THETA</td>
<td>Input</td>
<td>Central earth angle subtended by path, radians</td>
</tr>
<tr>
<td>LAMBD A</td>
<td>Input</td>
<td>Wavelength, meters</td>
</tr>
</tbody>
</table>

Internal Subroutines Used

MDHNKL

Number of Storage Locations Used

941210
Figure 3-7. Flowchart of subroutine GRNDMV.
3.2.5 Subroutine MDHNK1

Description

The subroutine MDHNK1 calculates the modified Hankel function of the first kind and order one-third, $H_{1/3}^{(1)}$, as described in Reference 5 of Section 1. The subroutine MDHNK1 is called by the subroutine GRNDWV as part of the evaluation of the transmitter and/or receiver height gain functions given in Equations 2-8 through 2-13. A flow chart for this subroutine is presented in Figure 3-8.

Call Statement

CALL MDHNK1 (Z, H1, H2, H1PRIME, H2PRIME).

Arguments

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>TYPE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>Input</td>
<td>Input argument to Hankel function</td>
</tr>
<tr>
<td>H1</td>
<td>Output</td>
<td>First Hankel solution</td>
</tr>
<tr>
<td>H2</td>
<td>Output</td>
<td>Second Hankel solution</td>
</tr>
<tr>
<td>H1PRIME</td>
<td>Output</td>
<td>Derivative of first Hankel solution</td>
</tr>
<tr>
<td>H2PRIME</td>
<td>Output</td>
<td>Derivative of second Hankel solution</td>
</tr>
</tbody>
</table>

(Note: All arguments double precision complex)

Internal Subroutines Used

None.

Number of Storage Locations Used

568410
Figure 3-8. Flowchart of subroutine MDHNKL.
3.2.6 Subroutine RAYTRA

Description

RAYTRA is the MAIN subroutine for the subprogram RAYTRACE. The only modification to RAYTRA is the insertion of a one-line call to the subroutine BREML0 to initiate calculation of non-ionospheric comments. This call is made following computation of the last ionospheric ray for a case frequency time. This change is line 36670 RAYTRA.
3.2.7 Subroutine RFLXRA

Description

The subroutine RFLXRA calculates the field strength of the ground reflected ray when two elevated terminals are within line-of-sight. The computations follow directly from Equations 2-18 through 2-25 of Section 2.1.3 and Figure 2-2(c). Three distinct sources of loss are evaluated by RFLXRA: the free space loss, the Fresnel reflection loss, and the defocussing loss as defined by Equation 2-19. If the user has supplied the ground constants for the reflection point via card input, computation begins directly. Otherwise, the subroutines NWOMAP and FSGEPS are called to determine the ground parameters at the reflection point. The Fresnel angle of incidence, the geographical coordinate of the reflection point, and the angles \( r_4 \) and \( r_2 \) (TAU4 and TAU2) of Figure 2-3(c) then evaluated. The ground constants are corrected for wind effects if any by FSGEPS, and the resulting effective values used in the computation of first the horizontal and then vertical reflection coefficients and received uncompensated fields. A flowchart of RFLXRA is presented in Figure 3-9.

Call Statement

```
CALL RFLXRA (TRANSX, TRANSY, BER, WINDVEL, TBD, TBR, 
RBD, RBR, EH, EV)
```
Arguments.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRANSX</td>
<td>INPUT</td>
<td>Transmitter latitude</td>
</tr>
<tr>
<td>TRANSY</td>
<td>INPUT</td>
<td>Transmitter longitude</td>
</tr>
<tr>
<td>BER</td>
<td>INPUT</td>
<td>Great circle bearing to receiver</td>
</tr>
<tr>
<td>WNDVEL</td>
<td>INPUT</td>
<td>Wind velocity for sea state correction, meters/second.</td>
</tr>
<tr>
<td>TBD</td>
<td>OUTPUT</td>
<td>Direct ray angle at transmitter measured relative to zenith.</td>
</tr>
<tr>
<td>TBR</td>
<td>OUTPUT</td>
<td>Reflected ray angle at transmitter measured relative to zenith.</td>
</tr>
<tr>
<td>RBD</td>
<td>OUTPUT</td>
<td>Direct ray angle at receiver measured relative to zenith.</td>
</tr>
<tr>
<td>RBR</td>
<td>OUTPUT</td>
<td>Reflected ray angle at receiver measured relative to zenith.</td>
</tr>
<tr>
<td>EH</td>
<td>OUTPUT</td>
<td>Uncompensated field strength for horizontal polarization component, (\mu)V/m.</td>
</tr>
<tr>
<td>EV</td>
<td>OUTPUT</td>
<td>Uncompensated field strength for vertical polarization component, (\mu)V/m.</td>
</tr>
</tbody>
</table>

Common Storage Arguments Used.

ER, THR, P1, RAD, DEG, P1BY2, TWOP1, REFIN1, FMC
/BON/YLOC, XLOC, GAMMA, GMT, 10
IGWAVE/SIGMA, EPSILON, THT, RHT, DKM,
DLOS, THETA, LAMBDA, J

Internal Subroutines Used.

COOR, WOMAP, FSGEPS

Number of Storage Locations Used.

29920
Figure 3-9. Flowchart of subroutine RFLXRA
3.3 Modifications to Subprogram COMEFF

The modifications to COMEFF fall into two broad areas: those concerned with incorporation of the nonionospheric components into the all mode power sum, and those concerned with the significantly expanded input antenna capability of NUCOM/BREM. Table 3-3 summarizes the changes to preexisting subroutines and the functions of the new subroutines. The overall flowchart of Figure 3-10 summarizes the effects of the NUCOM/BREM modification to such program flow.
Figure 3-10. Overall program flow in subprogram COMEFF due to addition of nonionospheric components.
<table>
<thead>
<tr>
<th>Subroutine</th>
<th>Changes/Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPOWER</td>
<td>Did not previously exist. All calculations resulting from nonionospheric modes in RAYTRACE are handled in this subroutine.</td>
</tr>
<tr>
<td>F1 (FUNCTION)</td>
<td>Interpolates antenna gain values (or returns 1.0 for isotropic). Substantially rewritten to permit user specified antenna patterns to +90°, to permit distinct vertical and horizontal polarization patterns, to reduce restrictions on number of frequencies input, and to permit transmitter and receiver patterns to have different ranges.</td>
</tr>
<tr>
<td>INITLC</td>
<td>Rewritten to permit NAMELIST input of user specified parameters: transmitter antenna pattern range, receiver antenna pattern range, number of frequencies supplied, antenna file number. The antenna pattern input function is now contained in a new subroutine RDATNA.</td>
</tr>
<tr>
<td>ONE</td>
<td>Rewritten slightly to permit accumulation of ionospheric ray power for CPOWER.</td>
</tr>
<tr>
<td>RDATNA</td>
<td>New subroutines to permit increased antenna input features.</td>
</tr>
<tr>
<td>READ</td>
<td>New input card type and call to CPOWER to permit processing of nonionospheric components.</td>
</tr>
<tr>
<td>BLK DATA</td>
<td>Significantly expanded to accomodate new data structures.</td>
</tr>
</tbody>
</table>
3.3.1 BLK DATA

Description

BLK DATA establishes dimensions and data types for the new data structure in NUCOM/BREM. A flowchart of BLK DATA is presented in Figure 3-10.

Call Statement
Not Applicable

Arguments
Not Applicable

Common Storage Arguments Used

/Data/C2, FOURPI, EFPL, TABLFR(15), 1 DUMM, MAX, IDEBUG
/SPPASS/NOPREQ, INPFIL, VGTOT, RGTOT, HGTOT
/SAVSIG/HIRAY P, IFLAG
/SWITCH/KSW1, KSW2, JF, 1 BETA, JCARD, NEWANT
/XLIT/AST, LIN, BLANK, STAR

Internal Subroutine Used
NONE

Storage Locations Used

\[ 2^{38} \times 10 \]
Figure 3-11. Flowchart of block data subprogram BLK DATA.
3.3.2 Subroutine CPOWER

Description
The subroutine CPOWER calculates the total received compensated power of each polarization type and the all mode power sum. Using input data from file JF, CPOWER calculates the total received signal power compensated for antenna gain and actual power density for direct, reflected, and groundwave rays of each polarization. Each compensated raytype power including the ionospheric power sum is then summed to provide the all mode signal power sum. The vertically polarized ionospheric noise power RNOIS from the ITS data is NWOMAP is corrected to compensate for the user-supplied noise height factor FACHNZ and the relative antenna pattern factor CONHNZ to provide the received horizontal noise power FH. The power sum of the horizontal and vertical noise power densities is then used to compute the all mode signal to noise ratio. A considerable number of intermediate computations are printed to provide guidance to the user in evaluating the parameters which contribute to the final all mode signal to noise ratio. A flowchart of CPOWER is presented in Figure 3-12.

Call Statement
CALL CPOWER (P, TP, ALPSUM)

Arguments

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>INPUT</td>
<td>User specified power density, W/Hz</td>
</tr>
<tr>
<td>TP</td>
<td>OUTPUT</td>
<td>Total received nonionospheric signal power, dBW</td>
</tr>
<tr>
<td>ALPSUM</td>
<td>OUTPUT</td>
<td>All mode power sum, dBW</td>
</tr>
</tbody>
</table>
Common Arguments Used
T, FACHN, FR, DT, DR, RHT, VNOIZ, THT
/SWITCH/KSW1, KSW2, 5F, IBETA
/SAVSIG/HIRAYP
/ANTDAT/TABLV(181,8), TABLH(181,8),
    TABLV(181,8), TABLH(181,8)
/SPPASS/IANT, ANTFIL, UGTOT, RGTOT, HGTOT

Internal Subroutines Used
None

Number of Storage Locations Used

340410
Figure 3-12(a). Flowchart of power flux portion of subroutine CPWPOWER.
Figure 3-12(b). Flowchart of noise and SNR portion of subroutine CPOWER.
3.3.3 Function F1

Description
The function F1 provides the antenna gain for a particular angle, frequency, and polarization type. If no antenna patterns have been supplied or if the angle in question is outside the specified range of antenna data, an isotropic gain is assumed and a warning is printed for the user. Interpolation on frequency and angle is performed with power ratios (not in dB) assuming linearity. The user input antenna patterns are printed in tabular format for energy 1 or 10 values depending upon the user parameter PRNT. A flowchart for the function F1 is given in Figure 3-13.

Call Statement
FUNCTION (X, TABL, NPAT)

Arguments
Symbol Type Description
X INPUT Angle for which gain is required
TABL INPUT Antenna table vector
NPAT INPUT Distinguishes between transmitter and receiver tables

Common Arguments Used
PT(1000, 3), A(1000), PHASE(1000), TAUS(1000), MODE (60), TIME (30), FREQ (30), SIGTAU (20,20), SIGNO1 (20,20)
/ANTDAT/ TABL1V (181,8), TABL1H (181,8)  
TABL2V (181,8)  TABL2H (181,8) 
MXANGL (2), MNANGL(2), KRXN(2),  
NANGLS(2) 
/SPPASS/NUMF 
/SWITCH/ KSW1, KSW2, JF, BETA 
/DATA/ C2, FOURPI, EFPL, TABLFR (15), ISW, MX1, IDEBUG 
/NAMELIST/INTRPL/ IANGL, KANGL, DELNGL, DELFR, G1, G2, F1 

Internal Subroutines Used 
None 

Number of Storage Locations Used 

182810
Figure 3-13. Flowchart for function Fl.
3.3.4 Subroutine INITLC

Description

The subroutine INITLC initializes counters and arrays, prints the identification card and reads the antenna calibration tables when they are provided. ANTFIL is a new variable to allow reading of patterns from disk or tape files as well as card decks. Five spaces have been taken from the front of the KSW1 field for the ANTFIL parameter input. If ANTFIL is left blank or set equal to zero, and KSW1 is blank or zero, then the subroutine RDATNA will set ANTFIL equal to five and look for the input antenna patterns on the card input file. A flowchart for subroutine INITLC is presented in Figure 3-14.

Call Statement

CALL INITLC

Parameters

NONE

Common Arguments Used

PT (1000, 3), A(1000), PHASE (1000), TAUS (1000)
MODE (60), TIME (30), FREQ (30), SIG TAU (20, 20),
SIGNO1 (20, 20)
/ANTDAT/TABLV (181, 8), TBL1H (181, 8),
TBL2V (181, 8), TBL2H (181, 8),
MXANGL (2), MNANGL (2), KRXN (2),
NANGLS (2)

/CONTRO/ PLREJ

/DATA/ C2, FOURP1, EFPL, TABLFR (15), ISW, MX1, IDEBUG

/SWITCH/ KSW1, KSW2, JF, IBETA, JCARD, NEWANT

3-41
/SPPASS/ NOFREQ, ANTFIL, VGTOT, RGTOT, HQTOT

/NAMELIST/IINIT/NOFREQ, KSW1, KSW2,
   JCARD, NEWANT,
   MXANGT, MXANCR,
   ANTFIL, P, BAUD,
   PLRFJ, IBETA, MNANGT,
   MNANCR, IDEBUG

Internal Subroutines Used
RDATNA

Number of Storage Locations Used

188010
Figure 3-14. Flowchart of subroutine INITLC
3.3.5 Subroutine ONE

Description
Subroutine ONE performs the power flux summation for the ionospheric components. The modification for NUCOM/BREM consists of redefinitions of the antenna data arrays to permit the increased flexibility of the input antenna formats to be incorporated into the ionospheric components. The vertical polarization component antenna pattern takes the place of the original NUCOM II pattern for ionospheric rays. A flowchart showing the modifications to subroutine ONE is given in Figure 3-15.

Call Statement
CALL ONE

Arguments
NONE

Common Arguments Used
PT (1000, 3), A (1000), PHASE (1000), TAUS (1000),
MODE (60), TIME (30), FREQ (30), SIGTAU (20, 20),
SIGNOI (20, 20)

/ANT DAT/ TABL 1V (181, 8), TABL1H (181, 8),
TABL 2V (181, 8), TABL2H (181, 8),
MXANGL (2), MNANGL (2),
KRXN (2), NANGLS (2)

/MIN/ DBMIN, DTMIN, DRMIN
/CONTRO/ PLREJ
/SAVSIG/ HIRAYP, IFLAG
/DATA/ C2, FOURPI, EFPL, TABLFR (15), IDUMM, MAX, IDEBUG

Internal Subroutines Used
None
Number of Storage Locations Used

3640_{10}
Figure 3-15. Flowchart for subroutine ONE modification.
3.3.6 Subroutine RDATNA

**Description**

The subroutine RDATNA reads in the antenna pattern tables if supplied. User supplied NAMELIST variables define the minimum and maximum angles for the transmitter and receiver patterns (which need not have the same values). Antenna pattern data must be supplied for every integer degree from the minimum to the maximum value. Pairs of cards are supplied for each angle, the first being the vertical component and the second the horizontal. Values are in dB relative to isotropic and blank values are assumed to be isotropic. Angles are defined relative to local horizontal as in NUCOM II except that the range of angles now extends to ±90°. The subroutine RDATNA reads the input tables for both receiver and transmitter and converts to relative power from dB. All inputs are checked for errors and appropriate warnings are printed in the event of incorrect deck setup. A flowchart of subroutine RDATNA is presented in Figure 3-16.

**CALL STATEMENT**

CALL RDATNA

**Arguments**

**NONE**

**Common Arguments Used**

/ANTDAT/ TABL1V (181, 8), TABL1H (181, 8),
  TABL2V (181, 8), TABL2H (181, 8),
  MXANGL (2), MNANGL (2),
  KRxn(2), NANGLS (2)

/DATA/ C2, FOURPI, EFPL, TABLFR (15),
  I$W, MX1, IDEBUG

/SPPASS/ IANT, ANTFIL, VGTOT, RGTOT, HGTOT
Internal Subroutines Used
   NONE

Number of Storage Locations Used
   4740_{10}
Figure 3-16. Flowchart of subroutine RDATNA.
3.3.7 Subroutine READ

Description
The subroutine READ reads the data cards and builds tables for modes, times, and frequencies. The modifications to this subroutine permit the use of aliases for the use of nonionospheric calculations. These changes maintain the original NUCOM II stacking logic. A flow-chart for the subroutine READ is given in Figure 3-17.

Call Statement
CALL READ

Arguments
NONE

Common Arguments Used
PT (1000, 3), A(1000), PHASE (1000),
TAUS (1000), MODE (60), TIME (30), FREQ (30),
SIGTAU (20, 20), SIGNOI (20, 20)

/ANTDAT/ TABL 1V (181, 8), TABL 1H (181, 8),
TABL 2V (181, 8), TABL2H (181, 8),
MXANGL (2), MNANGL (2), KRXN(2),
NANGLS (2)

/DATA/ C2, FOURPI, EFPL, TABLFR (15), IDUMM, MAX, IDEBUG
/XLIT/ AST, LIN, BLANK, STAR
/MIN/ DBMIN, DTMIN, DRMIN
/SWITCH/ KSW1, KSW2, JF, BETA

Internal Subroutines Used
ONE

Number of Storage Locations Used
2174

3-50
Figure 3-17. Flowchart for modification to subroutine READ.
The most important question of "just how good" a propagation prediction code is can never be fully resolved without extensive comparisons with observed data.

In most cases the accuracy of the predicted values of the nonionospheric components in NUCOM/BREM should far exceed the accuracy of the ionospheric predictions, particularly the nuclear-stressed predictions. While many of the limitations of NUCOM II are discussed in Reference 1 of Section 1, a short summary is desirable to permit comparison between uncertainties in ionospheric and nonionospheric propagation modes.

Areas of modelling uncertainty which may influence predicted values in a nuclear stressed environment include uncertainties in reaction rates and chemistry, the neglect of neutral wind drift of debris in the WEPH V phenomenology code, limited experimental data to confirm daytime and multiburst modelling, the neglect of bomb-induced field aligned $E_s$-like propagation modes, the neglect of deviated propagation paths due to large-scale ionospheric tilting and lateral electron density gradients, and the oversimplified modelling of shockwave effects.

For the ambient ionosphere significant areas of predictive uncertainty include the known deficiencies of the ITS world map ionospheric data, the use of a three layer parabolic isotropic ray tracing technique, the lack of modelling for ionospheric effects due to SID and auroral/geomagnetic activities, the neglect of...
sporadic E and spread F modes, and the absence of modelling for deviated and chordal propagation paths. Many of these areas remain beyond the predictive abilities of any present day propagation codes.

The question of noise characterization in NUCOM II (and all other propagation codes for that matter) will also introduce uncertainties. As discussed in Section 2.5 the lack of precise knowledge of the directional and polarization properties of HF noise is perhaps as serious as all of the propagation uncertainties. The CCIR 322 data disagrees with similar measurements made by ITS\(^{(1)}\) and recently by Raytheon Company\(^{(2)}\) by as much as 10 dB. Furthermore, no verifiable models exist to predict the effects of nuclear disturbances on the worldwide radio noise distribution although observations of noise levels made during the Pacific Test Series suggest these effects are important.

Several areas of uncertainty exist for the nonionospheric component predictions as well. The use of the Bremmer-van der Pol equations for a smooth and homogeneous earth will limit prediction accuracy for propagation paths over highly irregular and inhomogeneous path terrain. Certain situations are to be avoided in the use of NUCOM/BREM. The seacoast transition region as discussed in Section 2.4 should be avoided due to the recovery effects there. Our use of power flux summations for air-to-air links with ground reflections provides the envelope field and power but neglects the possible existence of deep interference nulls which may be present and modulated by aircraft motion.
Long paths over disturbed sea whose wave height spectral properties peak near the signal frequency are also to be avoided.

The modelling of the ionospheric paths from airborne terminals in NUCOM/BREM assumes the terminal to be close enough to the surface that the vertical ionospheric path geometry is not significantly changed. For realistic aircraft heights and path lengths this is not a serious limitation. By the same token the possibility of ground reflected rays then launched into the ionosphere from airborne terminals is ignored due to the obvious computational limitations in the raytracing portion of the code. Additional gain for the user supplied aircraft antenna patterns may be used to compensate for the ground reflected ionospheric components if desired.
REFERENCES


SECTION 5.0
SELECTED LINK EVALUATIONS

For the guidance of users of NUCOM/BREM we have included five sample link runs and one sample deck setup. The link examples have been chosen to show a variety of nonionospheric propagation modes which would be ignored by the unmodified NUCOM II code. NUCOM/BREM provides a substantial body of intermediate calculation outputs for the guidance of the user and these outputs are explained in the examples to follow.
5.1 Ground to Ground Link - Above MUF

This is an example of a short (100.02 km) HF path on a frequency sufficiently above the MUF for the path in question that no ionospheric propagation occurs.

All outputs are as from NUCOM II until RAYTRACE. The BREM input parameters are listed showing transmitter and receiver heights of zero and a Suda segmentation parameter of 10. Next appears the effective ground parameters from NWOMAP for each of the 10 Suda segments and the average value for the path. The BREM ANALYSIS RESULTS section gives the uncompensated signal powers for vertical and horizontal components and the arrived angles. The normal output from RAYTRACE indicates no ionospheric propagation for the path.

The COMEFF output shows first the NAMELIST variables input by the user, followed by the input antenna patterns, first for vertical and then for horizontal polarization. Then are given the uncompensated powers and power and antenna gain compensation factors used to obtain the compensated powers as given for vertical and horizontal components respectively. The SIGNAL ANALYSIS INCLUDING BREM ANALYSIS output gives total vertical and horizontal compensated powers at the receiver, the ionospheric signal sum, vertical and corrected noise levels, and the final corrected all mode signal to noise ratio. The last line is the normal RAYTRACE output for the situation where no ionospheric propagation occurs. The resulting all mode S/N of 10.7 dB predicts adequate copy for the 20 wpm CW transmitter of 20 kW average power modelled here.
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<th>TRANSMITTER</th>
<th>RECEIVER</th>
<th>MONTH</th>
<th>GMT</th>
<th>SSN</th>
<th>PATH(KM)</th>
<th>AZ</th>
<th>DELTAD</th>
<th>NO. CONTROL POINTS</th>
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GROUNDWAVE ONLY EXAMPLE

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<th>CHI</th>
<th>HMF1</th>
<th>YMF1</th>
<th>FOFL</th>
<th>HMFL</th>
<th>YMF2</th>
<th>FOFL</th>
<th>ESU</th>
<th>ES</th>
<th>ESL</th>
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GROUNDWAVE ONLY EXAMPLE

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<th>TX LONG</th>
<th>-128.20 DEG</th>
<th>RX LAT</th>
<th>-17.90 DEG</th>
<th>RX LONG</th>
<th>-128.20 DEG</th>
<th>RX BEARING</th>
<th>180.00 DEG</th>
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</thead>
<tbody>
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<td>-128.20 DEG</td>
<td>-17.90 DEG</td>
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<tr>
<td>TRANS HEIGHT</td>
<td>RCVR HEIGHT</td>
<td>SIGMA</td>
</tr>
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**FROM TRANSMITTER**

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<thead>
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<th>LATITUDE</th>
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<th>SIGMA</th>
<th>EPSILON</th>
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<td>4.0000</td>
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<td>4.0000</td>
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**BREM ANALYSIS RESULTS**

<table>
<thead>
<tr>
<th>POLARIZATION</th>
<th>RELATIVE POWER COMPONENTS</th>
<th>LINE OF SIGHT</th>
<th>TRANSMITTER</th>
<th>READER ZENITH ANGLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>VERTICAL DBW</td>
<td>HORIZONTAL DBW</td>
<td>DBW</td>
<td>DIRECT DEGREES</td>
<td>REFLECTED DEGREES</td>
</tr>
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<td>-149.</td>
<td>-180.</td>
<td>0.0</td>
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<td>0.0</td>
</tr>
</tbody>
</table>

---

*Note:* The table and data provided are placeholders and should be replaced with actual data relevant to the context of the document.
5.2 Ground to Air Link - Line of Sight, Below MUF

In this short link (245.0 km) both ionospheric and non-ionospheric modes exist. The transmitter is elevated at 10 km and a Suda parameter of 10 was chosen. The line of sight power figure (-92.8 dBW) is printed and the corresponding ray angles are given.

The COMEFF output indicates that we have not supplied receiver antenna pattern data for high enough angles to include the ionospheric rays; after printing the warning computation proceeds with an assumed isotropic gain for the missing values. In this case the nonionospheric power sum is close to the ionospheric mode and the net effect as shown in the all mode S/N is only a slight improvement. Were the ionospheric component to vanish, however, either through MUF failure or ionospheric stressing the nonionospheric components would of course remain.
<table>
<thead>
<tr>
<th>TIME (SEC) = -1</th>
<th>HME</th>
<th>YME</th>
<th>FOE</th>
<th>CHI</th>
<th>HMF1</th>
<th>YMF1</th>
<th>FOF1</th>
<th>HMF2</th>
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NUCOM BREM AIR TO GROUND TEST
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**.F2**

MODE: .F2

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HEIGHT RANGE

<p>| 140.00 | 67.16 |</p>
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<th>Height (ft)</th>
<th>Range (mi)</th>
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**Note:** Next ray is more than 2 km from rec.

**F2**

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**MODE .F2**

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**F2**

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**MODE .F2 .F2**

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**F2**

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**BREM ANALYSIS RESULTS**

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ALL MODE COMEFF INPUT DATA FROM RAYTRACE

NUCOM BREM AIR TO GROUND TEST

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TRANSMITTER GAIN(DB) ANGLE(DEG) BY FREQUENCY(MHz)

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NUCOM BREM AIR TO GROUND TEST

***** ANGLE 63.83000 OUT OF SPECIFIED RANGE: 30 -- -30
***** ANTENNA CALIBRATION TABLES NOT USED *

***** ANGLE 63.83000 OUT OF SPECIFIED RANGE: 30 -- -30
***** ANTENNA CALIBRATION TABLES NOT USED *

***** ANGLE 75.92999 OUT OF SPECIFIED RANGE: 30 -- -30
***** ANTENNA CALIBRATION TABLES NOT USED *

***** ANGLE 75.92999 OUT OF SPECIFIED RANGE: 30 -- -30
***** ANTENNA CALIBRATION TABLES NOT USED *

***** ANGLE 79.99001 OUT OF SPECIFIED RANGE: 30 -- -30
***** ANTENNA CALIBRATION TABLES NOT USED *

***** ANGLE 79.99001 OUT OF SPECIFIED RANGE: 30 -- -30
***** ANTENNA CALIBRATION TABLES NOT USED *
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<th>RDG</th>
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**DB FROM PREM**

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<th>COMPENSATED POWER</th>
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**SIGNAL ANALYSIS INCLUDING BREM ANALYSIS**

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<th>DIRECT VERTICAL</th>
<th>IONOSPHERIC SIGNAL SUM</th>
<th>VERTICAL NOISE</th>
<th>CORRECTED SIGNAL NOISE</th>
<th>CORRECTED ALL NOISE</th>
<th>S/N RATIO</th>
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<th>MGT</th>
<th>2SIGMA</th>
<th>SIGNAL</th>
<th>S/N</th>
<th>EFPL</th>
<th>(S/N)MAX</th>
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<td>0.197E+03</td>
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5.3 Air to Air Link - Line of Sight, Above MUF

This example shows a 600.08 km air to air link between elevated terminals at 10 km operating above the MUF. The output from RAYTRACE shows both direct line of sight and ground reflected signal components as well as the effective ground parameters at the reflection point as determined by NWOMAP and FSGEPS. The all mode S/N shown in the COMEFF section shows the nonionospheric mode ignored by the unmodified NUCOM II. The predicted value of 48.15 dB is excellent for the 3 kHz SSB link modelled.
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<td>AIR TO AIR LINE OF SIGHT EXAMPLE</td>
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<td>Refr Height</td>
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<td>-------------</td>
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<td>10000.000</td>
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Reflected Ray Calculations:
At Lat -19.279 and Long 128.200
Sigma = 0.001  Epsilon = 4.000 (Effective Values)

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<th>Polarization</th>
<th>Relative Power Components</th>
<th>Line of Sight</th>
<th>Transmitter Direct</th>
<th>Transmitter Reflected</th>
<th>Receiver Direct</th>
<th>Receiver Reflected</th>
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ALL MODE COMEFF INPUT DATA FROM RAYTRACE

AIR TO AIR LINE OF SIGHT EXAMPLE

G  -1.  0.0  4.00  0.0  0.0  0.010000  0.0  0.0  0.0  0.0  148.6  1206  0.0
8-107,992  -107,297  -103,068  -2.708  -3.397  -2.708  -3.397

&INIT
NDFREG= 1+KSW1= 0+KSW2= 1+JCARD= 0+NEWANT= 1+MXANGT= 5+MXANGP= 0,
ANTFIL= 5+P= 3.33300018 +RAUD= 10000000E-01,PLREJ= 400.000000 +IRETA= 0,MMANGT= -5,MMANGP= 0.

&END

TRANSMITTER GAIN(DB)  ANGLE(DEC) BY FREQUENCY(MHZ)

FREQUENCY

4.0000
-5  -3.50  -2.40
-4  -3.40  -2.30
-3  -3.30  -2.20
-2  -3.20  -2.10
-1  -3.10  -2.00
 0  -3.00  -1.90

RECEIVER GAIN(DB)  ANGLE(DEC) BY FREQUENCY(MHZ)

FREQUENCY

4.0000
-5  -3.50  -2.40
-4  -3.40  -2.30
-3  -3.30  -2.20
-2  -3.20  -2.10
-1  -3.10  -2.00
 0  -3.00  -1.90
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<th>DBL</th>
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DB FROM BREM

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<th>RECEIVER GAIN</th>
<th>COMPENSATED POWER</th>
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**Signal Analysis Including Brem Analysis**

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**GMT | TIME (SEC) | FREQ | NMODES | MGT (MS) | 2*SIGMA | SIGNAL (DB) | S/N | EFPL | (S/N)MAX |
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5.4 Air to Air Link - Beyond Line of Sight, Above MUF

This 800.1 km link operates above the MUF between terminals at a height of 10 km and no ionospheric propagation occurs. A Suda factor of 10 has been chosen and the returned constants as shown indicate that a sea path is involved. The resulting all mode S/N of 17.7 dB is that of the groundwave mode only and indicates that the link in question which has been modelled as a 3 kHz SSB circuit with a 1 kW transmitter will maintain acceptable communications in the absence of skywave propagation.
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<th>FOE</th>
<th>CHI</th>
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<th>YMF1</th>
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<th>HMF2</th>
<th>YMF2</th>
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Brem Analysis Results

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<td>Reflected Degrees</td>
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- From Transmitter
ALL MODE COEFF INPUT DATA FROM RAYTRACE

AIR TO AIR BEYOND LOS EXAMPLE

\[
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\end{array}
\]

\[
\begin{array}{cccccccc}
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\]

\[
\begin{array}{cccccccc}
\text{LUNIT} & \text{JOFFREG} & \text{10KSW1} & \text{10KSW2} & \text{10CARD} & \text{10NEWANT} & \text{10MXANT} & \text{00MXANGR} & \text{00MXANGR} & \text{00MXANGR} & \text{00MXANGR} & \text{00MXANGR} & \text{00MXANGR} \\
\end{array}
\]

\[
\begin{array}{cccccccc}
\text{INTFIL} & \text{5P} & \text{5P} & \text{5P} & \text{5P} & \text{5P} & \text{5P} & \text{5P} & \text{5P} & \text{5P} & \text{5P} & \text{5P} & \text{5P} \\
\end{array}
\]

\[
\begin{array}{cccccccc}
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TRANSMITTER GAIN(OR) ANGLE(DEC) BY FREQUENCY(MHZ)

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RECEIVER GAIN(OR) ANGLE(DEC) BY FREQUENCY(MHZ)

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<td>DBV</td>
<td>DBH</td>
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**DB FROM BREM**

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**SIGNAL ANALYSIS INCLUDING BREM ANALYSIS**

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<th>DIRECT</th>
<th>VERTICAL</th>
<th>HORIZONTAL</th>
<th>IONOSPHERIC</th>
<th>VERTICAL</th>
<th>CORRECTED</th>
<th>CORRECTED</th>
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<th>GROUND OR REFLECTED</th>
<th>HORIZONTAL</th>
<th>S/N RATIO</th>
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<td>DBW</td>
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<th>TIME</th>
<th>FREQ</th>
<th>NMODES</th>
<th>MGTL</th>
<th>2SIGMA</th>
<th>SIGNAL</th>
<th>S/N</th>
<th>EFPL</th>
<th>(S/N)MAX</th>
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5-33
5.5 Air to Air Link - Beyond Line of Sight, Nuclear Stressed Ionosphere

The same 800.1 km link between 10 km elevated terminals is computed for a nuclear stressed ionosphere produced by detonation of a 1.3 Mt device at a height of 70 km midway along the path.

The output from ORDER indicates a nuclear stressed daytime ionosphere and the RAYTRACE output for the ionospheric components shows extremely high nonderivative absorption. The corrected all mode S/N now reflects just beyond the horizon groundwave component since the ionospheric rays have been blacked out. Again, the indicated S/N of 15.3 dB is adequate for communications on this circuit.
<table>
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<th>TRANSMITTER</th>
<th>RECEIVER</th>
<th>MONTH</th>
<th>GMT</th>
<th>SSN</th>
<th>PATH(KM)</th>
<th>AZ</th>
<th>DELTA N</th>
<th>CONTROL POINTS</th>
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**STRESSED TEST RUN AIR TO AIR**

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<th>YME</th>
<th>FLF</th>
<th>CHF</th>
<th>HME1</th>
<th>YME1</th>
<th>FOE1</th>
<th>HME2</th>
<th>YME2</th>
<th>FOE2</th>
<th>ESU</th>
<th>ES</th>
<th>ESL</th>
<th>M(3000)</th>
<th>DIST</th>
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<td>39.05</td>
<td>1.91</td>
<td>273.18</td>
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<td>7.74</td>
<td>5.86</td>
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DATA IS IN BEGIN COMPUTATION

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<td>PATH AZIMUTH AND LENGTH</td>
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EVALUATION TIME (SEC) = 60,000
Burst Time 0.0 Latitude -20.00 Longitude -128.00 Yield 1.35 Altitude 70.00

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<th>DISTANCE FROM TRANSMITTER =</th>
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</tr>
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DISTANCE OF FIELD POINT FROM BURST = 167.43
DISTANCE FROM TRANSMITTER = 500.00

| HT AMBIENT NUCLEAR                |    | 0.0                         |
| AMBIENT NUCLEAR                   |    | 115.0                      |
| AMBIENT NUCLEAR                   |    | 125.0                      |
| AMBIENT NUCLEAR                   |    | 155.0                      |
| AMBIENT NUCLEAR                   |    | 165.0                      |
| AMBIENT NUCLEAR                   |    | 175.0                      |
| AMBIENT NUCLEAR                   |    | 205.0                      |

Input tape, rapture, completed for this time
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**STRESSED TEST RUN AIR TO AIR**

**TIME= 60.0**

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<th>YMF</th>
<th>DFE</th>
<th>HMF1</th>
<th>YMF1</th>
<th>FOF1</th>
<th>HMF2</th>
<th>YMF2</th>
<th>FOF2</th>
<th>EMEC DEN (65KM)</th>
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<td>2.2</td>
<td>166.</td>
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<td>254.</td>
<td>87.9</td>
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### Stressed Test Run Air to Air

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<tr>
<th>Path Length</th>
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<th>TX Long</th>
<th>RX Lat</th>
<th>RX Long</th>
<th>RX Bearing</th>
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<tr>
<td>600.10 km</td>
<td>-17.00</td>
<td>-128.20</td>
<td>-24.20</td>
<td>-128.20</td>
<td>190.00</td>
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</table>

<table>
<thead>
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<th>MHz</th>
<th>Deg</th>
<th>Deg</th>
<th>Sec</th>
<th>Sec</th>
<th>K</th>
<th>DBW</th>
<th>DB</th>
<th>DB</th>
<th>DB</th>
<th>DB</th>
<th>DB</th>
<th>DB</th>
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<tbody>
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<td>8.74</td>
<td>2.744</td>
<td>2.740</td>
<td>-1.1</td>
<td>151.</td>
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</table>

**Note:** Next ray is more than 10 km from rec

<table>
<thead>
<tr>
<th>MHz</th>
<th>Deg</th>
<th>Deg</th>
<th>Sec</th>
<th>Sec</th>
<th>K</th>
<th>DBW</th>
<th>DB</th>
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<th>DB</th>
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**Note:** Next ray is more than 10 km from rec

<table>
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<th>MHz</th>
<th>Deg</th>
<th>Deg</th>
<th>Sec</th>
<th>Sec</th>
<th>K</th>
<th>DBW</th>
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<th>DB</th>
<th>DB</th>
<th>DB</th>
<th>DB</th>
<th>DB</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
<td>21.00</td>
<td>29.64</td>
<td>2.991</td>
<td>2.917</td>
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**Note:** Next ray is more than 10 km from rec

<table>
<thead>
<tr>
<th>MHz</th>
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<th>Deg</th>
<th>Sec</th>
<th>Sec</th>
<th>K</th>
<th>DBW</th>
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<td>0.0</td>
<td>0.0</td>
<td>7732.9</td>
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**Note:** Next ray is more than 10 km from rec

<table>
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<th>MHz</th>
<th>Deg</th>
<th>Deg</th>
<th>Sec</th>
<th>Sec</th>
<th>K</th>
<th>DBW</th>
<th>DB</th>
<th>DB</th>
<th>DB</th>
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**Note:** Next ray is more than 10 km from rec

<table>
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<th>Deg</th>
<th>Deg</th>
<th>Sec</th>
<th>Sec</th>
<th>K</th>
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**BREM Analysis Results**

**Relative Power Components**

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**Ray Zenith Angles**

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<th>Reflected Degrees</th>
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<table>
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<th>Reflected Degrees</th>
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### All Mode COmef Input Data From Raytrace

#### Stressed Test Run Air to Air

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### END

**TRANSMITTER GAIN(DB)**

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<tr>
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<td>10.00</td>
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</table>

**Frequency Table**

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Gain (dB)</th>
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<tbody>
<tr>
<td>2.0000</td>
<td>12.00</td>
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<tr>
<td>3.0000</td>
<td>12.00</td>
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<td>7.0000</td>
<td>12.00</td>
</tr>
<tr>
<td>10.0000</td>
<td>12.00</td>
</tr>
</tbody>
</table>

**Angle (Deg)**

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Angle (Deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0000</td>
<td>12.00</td>
</tr>
<tr>
<td>3.0000</td>
<td>12.00</td>
</tr>
<tr>
<td>4.0000</td>
<td>12.00</td>
</tr>
<tr>
<td>5.0000</td>
<td>12.00</td>
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<td>7.0000</td>
<td>12.00</td>
</tr>
<tr>
<td>10.0000</td>
<td>12.00</td>
</tr>
</tbody>
</table>

**Note:**

- **KSW1:** 0
- **KSW2:** 1
- **JCARO:** 0
- **NEWANT:** 0
- **MXANGT:** 0
- **MXANGR:** 0
5.6 Sample of Deck Setup

The following listing shows a typical deck setup for NUCOM/BREM.
I
APPENDIX A

INVERSE MAPPING TRANSFORMATION FROM NWOMAP

The following four maps show the NWOMAP data from the ITS numerical world map in NUCOM/BREM and NUCOM II. These maps were obtained by calling NWOMAP for each point on a fine grid of latitude and longitude values and then applying the transformations in FSGEPS to each point. The symbols are defined in terms of conductivity as follows:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>( \sigma ) RANGE, Mho/m</th>
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</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>&quot;.&quot;</td>
<td>3.75-5.0</td>
</tr>
<tr>
<td>&quot;X&quot;</td>
<td>2.5-3.75</td>
</tr>
<tr>
<td>&quot;Q&quot;</td>
<td>1.25-2.5</td>
</tr>
<tr>
<td>&quot;M&quot;</td>
<td>0-1.25</td>
</tr>
</tbody>
</table>
APPENDIX B

AIRBORNE ANTENNA PATTERNS

This section contains digitized airborne antenna pattern data in a format suitable for direct inclusion in NUCOM/BREM. This data has been digitized from the graphical information in Section 2.

The tail-to-fuselage wire data for the EC-135 has been extrapolated by the assumption that the pattern is symmetrical about the $\theta = 90^\circ$ plane. Horizontal powers have been obtained by application of the results of Wong (op.cit.).

The notch antenna patterns have been reduced from the data in Figure 2-47 for a frequency of 2.0 MHz.
EC-135 tail-fuselage wire, frequencies, 2.0, 3.0, 4.0, 5.0, 7.0, 10.0, 15.0 MHz. Pattern in $\varnothing = 0^\circ$ plane.
EC-135 tail-fuselage wire, frequencies 2.0, 3.0, 4.0, 5.0, 7.0, 10.0, 15.0 MHz. Pattern in $\varnothing = 180^\circ$ plane.
EC-135 tail-fuselage wire, frequencies 2.0, 3.0, 4.0, 5.0, 7.0, 10.0, 15.0 MHz. Pattern in $\varnothing = 90^\circ$ plane (both sides averaged).
Notch antenna, Douglas DC series airframe, pattern in $\Phi = 0^\circ$ plane. Frequency 2.0 MHz.
LEVEL 2.1 (JAN 74)  BREV10  OS/360 FORTRAN H EXTENDED  DATE 77.271/15.29.12  PAGE 2

ISN 0035  THETA1 = ARCOS(ETHETA/2)
ISN 0036  DZ = SQRT((1+Z)**2 + (2+Z)**2 - 2 + Z**2 + COS(THETA1))
ISN 0037  IF (THETA1 < 0.0) GOTO 100

COMPUTE LINE OF SIGHT VOLTAGE AND ZENITH ANGLES AT TRANSMITTER AND RECEIVER

ISN 0039  FLNORM = 1.000/OLS
ISN 0040  SINX = Z*THETA1/OLDS
ISN 0041  IF (SINX,GT,1.0000) SINX = 1.0000
ISN 0042  RAN = PIBY2 - ARSIN(SINX)
ISN 0043  SINX = Z1*THETA1/OLDS
ISN 0044  IF (SINX,GT,1.0000) SINX = 1.0000
ISN 0045  TAN = PIBY2 - ARSIN(SINX)

CORRECT QUADRANT ON DIRECT ANGLES UNLESS ONE IS UPWARD

ISN 0046  IF (THLT.LE.,90.0) RAN = - RAN
ISN 0047  IF (THLT.LE.,90.0) TAN = - TAN
ISN 0048  IF (THLT.LE.,0.0) GOTO 500

IF BOTH ANTENNAS ARE ELEVATED, COMPUTE POWER AND ZENITH ANGLES FOR REFLECTED RAY ALSO

ISN 0049  CALL RELXRAY(THLAT,THLON,THR,THBL,THB,THF)
ISN 0050  PROCEED TO REPORT SECTOR
GOTO 500

ISN 0051  IF REPEATER IS BEYOND HORIZON, COMPUTE HORIZON TRANSITION CRITERIA
GOTO 500

ISN 0052  CONTINUE
ISN 0053  OTUPA = THETA - THETA1
ISN 0054  MFLX = ETHETA*SQRT(1.0/(1+OTUPA))**2 - 1.0
ISN 0055  NELH = DELX*THETA1/OLDS
ISN 0056  OTUPA = 1000*DELH*ETHETA/(1.0+ETHETA)

IF REPEATER IS BELOW LINE OF SIGHT MOVE ON TO GROUND WAVE LOGIC

ISN 0057  IF (THLT.LE.,TRANS) GOTO 200

COMPUTE LINE OF SIGHT VOLTAGE AND ZENITH ANGLES AT TRANSMITTER AND RECEIVER

ISN 0058  FLNORM = 1.000/OLS
ISN 0059  SINX = Z1*THETA1/OLDS
ISN 0060  IF (SINX,GT,1.0000) SINX = 1.0000
ISN 0061  RAN = PIBY2 - ARSIN(SINX)
ISN 0062  SINX = Z1*THETA1/OLDS
ISN 0063  IF (SINX,GT,1.0000) SINX = 1.0000
ISN 0064  TAN = PIBY2 - ARSIN(SINX)

CORRECT QUADRANT ON DIRECT ANGLES UNLESS ONE IS UPWARD

ISN 0065  IF (THLT.LE.,90.0) RAN = - RAN
ISN 0066  IF (THLT.LE.,90.0) TAN = - TAN
ISN 0067  IF (THLT.LE.,0.0) GOTO 500

ISN 0068  ...
IF BOTH ANTENNAS ARE ELEVATED COMPUTE POWER AND ZENITH ANGLES FOR REFLECTED RAY ALSO

CALL REFLECT(LATI,T,LONG,RE,MOVAL,THR,R,TH,EC,EF)

PROCEED TO NEXT SECTION

GO TO 400

200 CONTINUE

CALL GROUNDWH,EVF

GO TO 400

210 CONTINUE

C SIGMA NOT PROVIDED USE METHOD OF SUDA OR WOW DEPENDING ON WPTS

IF(NSGES.LE.0) GO TO 9901

PRINT 211

FORMAT(//'21X,'LATITUDE',6X,'LONGITUDE',6X,'SIGMA',6X,'EPSILON')

PRINT 212

FORMAT(//'4X,'FROM TRANSMITTER'//)

SIGLNT = PLGST/NEGES

IF(WPTS.GT.0.) GO TO 220

USE THE METHOD OF SUDA WITH NSGES + 1 POINTS

NSGES = NSGES + 1

CALL ASGEMS(SIGLNT,NSGES,LATI,T,LONG,RE,MOVAL,SIGMA,EPSON)

USE THE METHOD OF WILLINGTON TO DETERMINE SIGMA AND EPSILON

220 CONTINUE

FURTHER SUBDIVIDE THE SEGMENTS INTO WPTS STEPS FOR AVERAGING VALUES

WPTS = SIGLNT/WPTS

NO CALCULATIONS ONCE FOR TRANSMITTER AND ONCE FOR RECEIVER

AVERAGE SIGMA AND EPSILON VALUES DETERMINED AT WPTS + 1 POINTS WITHIN ONE SEGMENT OF THE TRAN/RCVR

WPTS = WPTS + 1

CALL ASGEMS(WMST,WPTS,LATI,T,LONG,RE,MOVAL,SIGMA,EPSON)

SAVE IF'S CONTENTS WITH TRANSMITTER VALUES FOR LATER USE

CALL GROUNDWH,EVF

FIND STARTING POINTS FOR RECEIVER CALCULATIONS

DIST = (NSGES - 1)*SIGLNT
<p>| LSN 0105 | CALL CONRTLAT0,RLONG,RE1,RLAT,RLAT,RLONG | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0106 | PRINT 224 | IDENTICAL AS LSN 0104 |
| LSN 0107 | 224 FORMAT //X, F TOWARD RECEIVER //I | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0108 | CALL ASESSвлечен,Hot,RLAT,RLAT,RLONG,RE1,LENOEL,SLAGMA,EPSON | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0109 | CALL RAINORV(F, EV) | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0110 | FH = SORT(FH+2 + FH+2) | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0111 | FV = SORT(FV+2 + FV+2) | AFW10 | IDENTICAL AS LSN 0104 |
| C | PROCEED WITH POWER CALCULATIONS AND REPORTING | AFW10 | IDENTICAL AS LSN 0104 |
| C | 500 CONTINUE | AFW10 | IDENTICAL AS LSN 0104 |
| C | COMPUTE RECEIVED POWER IN OAW' ASSUMING | AFW10 | IDENTICAL AS LSN 0104 |
| C | A 1 WATT ISOTROPIC RADIATON | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0112 | FLOW = 1.000.000 * 20. * ALG(10) (VERTANCE) | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0113 | IF(FLONST,GT,0.0) DNL = 20. * ALG(FLONST) + FLOW | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0114 | IF(EV0,GT,0.0) DNV = 20. * ALG(10) (EV) + FLOW | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0115 | IF(EH0,GT,0.0) DNH = 20. * ALG(10) (EH) + FLOW | AFW10 | IDENTICAL AS LSN 0104 |
| C | CONVERT RADIANS TO DEGREES FOR OUTPUT | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0116 | TRN = TRA<em>DEG | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0117 | THR = THR</em>DEG | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0118 | RAD = RAD*DEG | AFW10 | IDENTICAL AS LSN 0104 |
| C | PRINT 9018 | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0119 | WRITE OUT RESULTS TO UNIT 7 FOR CODEFF | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0120 | WRITE(7,9191) TIT,FACHZ,FREQ,RAE,OMY,OMY,OMY,THT,RHT, | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0121 | 1 RADYS(TEC),JHOUR,OMY6 | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0122 | WRITE(7,9200) DNV,DNH,DNL,TRN,THR,RAD,RAD | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0123 | IF(DNR,GE,-1.0) GO TO 510 | AFW10 | IDENTICAL AS LSN 0104 |
| C | PRINTOUT FOR GROUNDWAVE | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0124 | PRINT 9011, DNV,DNH,TRN,THR | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0125 | RETURN | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0126 | 510 CONTINUE | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0127 | IF(THT,GT,0.0) AND,RHT,GT,0.0) GO TO 520 | AFW10 | IDENTICAL AS LSN 0104 |
| C | PRINTOUT FOR LINE OF SIGHT ONLY CASE | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0128 | PRINT 9012, DNL, TRN, RAD | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0129 | RETURN | AFW10 | IDENTICAL AS LSN 0104 |
| C | PRINTOUT FOR LINE OF SIGHT AND REFLECTED RAY CASE | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0130 | 520 CONTINUE | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0131 | PRINTOUT FOR LINE OF SIGHT AND REFLECTED RAY CASE | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0132 | PRINT 9013, DNV, DNH, DNL, TRN, THR, RAD, RBB | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0133 | RETURN | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0134 | 3810 FORMAT //6X,12CHARFEN ANALYSIS RESULTS,1X, | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0135 | 1 2XRELATIVE POWER COMPONENT,3X1,7XZENITH ANGLES,1X, | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0136 | 2 12XPOLARIZATION,2X1,13XLINE OF SIGHT,1X14XTRANSMITTER,2X, | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0137 | 3 ARRCEIVER,1X15XANTENNA,1X16X10XHORIZONTAL,2X, | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0138 | 4 2X,6XDEPCT,7X9XREFLECTED,1X13X,3X20X,16X,3X20X,20X,3X20X, | AFW10 | IDENTICAL AS LSN 0104 |
| LSN 0139 | 5 11X14X7X3DEGREES,1XI) | AFW10 | IDENTICAL AS LSN 0104 |</p>
<table>
<thead>
<tr>
<th>TSN</th>
<th>Line</th>
<th>Comment</th>
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<tr>
<td>0140</td>
<td>9011</td>
<td>FORMAT(140,4X,9(015,1,5x),20X,F15,5,15x,F15,3)</td>
</tr>
<tr>
<td>0141</td>
<td>9012</td>
<td>FORMAT(140,4X,9(015,1,15x),18X,F15,3)</td>
</tr>
<tr>
<td>0142</td>
<td>9013</td>
<td>FORMAT(140,4X,5(015,1,5x),4F15,1)</td>
</tr>
<tr>
<td>0143</td>
<td>9100</td>
<td>FORMAT(1HG,F6,0,F10,3,3F6,2,2F7,1,F9,1,F7,1,15,F10,1)</td>
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<tr>
<td>0144</td>
<td>9200</td>
<td>FORMAT(148,5G12,6,4F10,3)</td>
</tr>
<tr>
<td>0145</td>
<td>RETURN</td>
<td></td>
</tr>
<tr>
<td>0146</td>
<td>9901</td>
<td>CONTINUE</td>
</tr>
<tr>
<td>0147</td>
<td>PRINT 9902, FREQ,SIG,THT,RHT,NSIGS,NPTS</td>
<td></td>
</tr>
<tr>
<td>0148</td>
<td>9902</td>
<td>FORMAT(/10X,'STOP : INSUFFICIENT DATA', 4F10,4,/)</td>
</tr>
<tr>
<td>0149</td>
<td>STOP</td>
<td></td>
</tr>
<tr>
<td>0150</td>
<td>END</td>
<td></td>
</tr>
</tbody>
</table>
SUBROUTINE RLXMOD(TRANX,TRANSY,RER,WNLOL,TAR,TARH,TARL,TARLE)

THIS SUBROUTINE calculates the strength of the reflected wave when the receiver is in line-of-sight of the transmitter.

REAL K,WAWADA

COMPLEX J,МИФФ,ЦФФ,CDAT,REF,EVAL,CONST

COMMON ERTHPT,RAH,ERHPT,TWORT,REFIND,FMC

COMMON /GAVE/ SIGMA,EPSON,THT,RHT,OKW,OLOS,THETA,LWADA,J

POLAR = -1.

FIND ANGLE OF INCIDENCE PLUS TAU1 AND TAU2

2T = FRTHA + THT*0.001

2P = FRTHP + RHT*0.001

HUH = THT + RHT

HUM = THT**2 + RHT**2

HUM2 = (THT + RHT)**2

DSTH2 = 1000.0*OKW/HUM

ARGT2 = DSTH2 + THETA*(HUM/HUM2)*(1.0 + (DSTH2**2)/2.0)

TAU2 = TAN(ARGT2)

ARGT2 = (ERTH2/2T)**2 + SIN(TAU2)

ARGT2 = (ERTH2/2P)**2 + SIN(TAU2)

TAU2 = ARCSTN(ARGT2)

TAU2 = ARCSTN(ARGT1)

CALCULATE TRANSMITTER PROPAGATION ANGLES

TAN = TAU1 - PIRY2

CALCULATE RECEIVER ANGLES

TAN = TAU1 + PIRY2

FIND SIGMA AND EPSILON IF THEY HAVE NOT BEEN PROVIDED

IF (SIGMA,GTH,GT,GT) GOTO 100

REFL = ERTHP*TAU1 - TAU2

VXCP = C*TRANSX*TRANSY*REFL*PLAT,OLNG

VXCP = OLOC*PLAT*OPAD

VXCP = OLOC*OLNG*OPAD

VXCP = CALL NVMAP

CALL FSQER(GAMMA,SIGMA,EPSON,WNLOL)

PRINT 95, PLAT,OLNG,SIGMA,EPSON

IF (FORMAT/14K,REFLECTED PAY CALCULATIONS/2PAK,

1 LAT *,F8,3,2* AND LOSN *,F8,3,2* + SIGMA = *,F7,4,3* EPSION = *,F7,4,3* (EFFECTIVE VALUES)*/(ARE)GOTO 290

CONTINUE

PROCED WITH VOLTAGE CALCULATIONS
C
TEN 0075 F1=F(I)
TEN 0076 IF I = 2 THEN 1 = 1
TEN 0077 F1=F(I)
TEN 0078 IF(CARSI*1.0) GO TO 200
TEN 0079 100 CONTINUE
TEN 0080 200 CONTINUE
TEN 0081 IF(POLAR = 0) GO TO 220
TEN 0082 C
TEN 0083 C SET UP FOR VERTICAL POLARIZATION
TEN 0084 C FH = F3
TEN 0086 POLAR = 1.
TEN 0087 PSY = ATAN(EPSON/WK) - ATAN((EPSON = 1.0)/WK)/2.
TEN 0088 K = K+10F((EPSON**2 + WK**2)
TEN 0089 C PRINT 124,PSY,K
TEN 0090 124 FORMAT(5X,'VERTICAL POLARIZATION COMPONENTS'/5X,'PSY'=,F10.5,5X,'KBE04610
TEN 0091 C GO TO 100
TEN 0092 200 CONTINUE
TEN 0093 C
TEN 0094 C SAVE VERTICAL FIELD AND RETURN
TEN 0095 C FH = F3
TEN 0096 C PRINT 300,FH,FV
TEN 0097 C 300 FORMAT(5X,'HORIZONTAL',G12.6,5X,'VERTICAL',G12.6)
TEN 0098 C RETURN
TEN 0099 C END
TEN 0100 * OPTIONS IN EFFECT: NAME(MAIN) NONOPTIMIZE LINECOUNT(60) SIZE(228K) AUTODRL(NONE)
* OPTIONS IN EFFECT: SOURCE PROCIC NOLIST NODECK OBJECT NOSMP NOSFORMAT GOSTMT NOSREF NOALSF NOANSF TERMINAL FLAG(I)
*STATISTICS* SOURCE STATEMENTS = 92, PROGRAM SIZE = 10142, SUBPROGRAM NAME =GDRNWV
*STATISTICS* NO DIAGNOSTICS GENERATED
***** END OF COMPILATION *****

92K BYTES OF CORE NOT USED
LEVEL 2.1 (I AP 75) MDHNL 09/360 FORTRAN IV EXTENDED DATE 77.27/15.31.47 PAGE 3

TN 0643
TN 0644
TN 0645
TN 0646
TN 0647
TN 0648
TN 0649
TN 0650
TN 0651
TN 0652
TN 0653
TN 0654
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TN 0659
TN 0660
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TN 0664
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TN 0673
TN 0674
TN 0675
TN 0676
TN 0677
TN 0678
TN 0679
TN 0680
TN 0681
TN 0682
TN 0683
TN 0684
TN 0685
TN 0686
TN 0687
TN 0688
TN 0689
TN 0690
TN 0691
TN 0692
TN 0693
TN 0694

*OPTIONS IN EFFECT* NAME(WITH) NOOPTIMIZE LINECOUNT(60) SIZE(224K) AUTO DOUBLE(NONE)

*OPTIONS IN EFFECT* SOURCE FREDIC VOLTIC NODREAD OBJECT NOPRINTF GOSTMT NOREF NODSCL NODSNK TERMINAL Flag(I)

*STATISTICS* SOURCE STATEMENTS = 93, PROGRAM SIZE = 6649, SUBPROGRAM NAME = MDHNL

*STATISTICS* NO DIAGNOSTICS GENERATED

***** END OF COMPILATION *****

96K BYTES OF CORE NOT USED
SUBROUTINE ASGEP(S,EPS,Z,ISGNT,XLOC,YLOC,DIR,WVEL,SOUT,FOUT) BFE06160
COMMON ERHRT,P1,PA,DEG,PBY2,TOPI,REFD,REQ BFE06170
COMMON /BOV/ LON,LAT,GAMMA,GMT,IO
REAL LON,LAT, EPS = 0.0
SIGMA = 0.
PTHOST = 0.
OLAT = XLOC
DLONG = YLOC
DO 100 KCNT = 1, ISGNT
100 CONTINUE
LAT = OLATRAD
LONG = DLONGRAD
CALL NUCMAP BFE06280
CALL FSGEP(S,GAMMA,XSIG,XPOL,WVEL) BFE06290
PRINT 115,OLAT,DLONG,XSIG,XPOL BFE06300
SIGMA = SIGMA + XSIG
FPLON = FPLON + WPOL
PTHOST = PTHOST + EPSIG
CALL COORT(XLOC,YLOC,DIR,PTHOST,OLAT,DLONG) BFE06310
PRINT 115,OLAT,DLONG,SOUT,FOUT BFE06320
FORMAT(15X,4(5X,F10.4)) BFE06330
RETURN
END
REQUESTED OPTIONS: IN

OPTIONS IN EFFECT: NAME('MAIN'), NONOPTIMIZE LINECOUNT(60), SIZE(0228K) AUTODBL(NONE)

SOURCE F90 F90 WLIST NODECK OBJECT NOUNAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

*OPTIONS IN EFFECT* NAME('MAIN'), NONOPTIMIZE LINECOUNT(60), SIZE(0228K) AUTODBL(NONE)

*OPTIONS IN EFFECT* SOURCE F90 F90 WLIST NODECK OBJECT NOUNAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

*STATISTICS* SOURCE STATEMENTS = 23, PROGRAM SIZE = 600, SUBPROGRAM NAME = FSGEPS

*STATISTICS* NO DIAGNOSTICS GENERATED

***** END OF COMPILATION *****

124K BYTES OF CORE NOT USED
LEVEL 2.1 (JAN 74) C POWER 05/360 FORTRAN IV EXTENDED DATE 7/27/71 15.32.36 PAGE 2

C...REFLECTED RAY OR GROUND WAVE CALCULATIONS (IF ORH,GT,CRIT)

ISH 0040 IF(ORH,LE,CRIT) GO TO 30

ISH 0041 C...CALCULATE GAINS AND COMPENSATION

ISH 0042 GTHM' 15.0,ALOG10(F1(TRM,TARL,TARL1+11))

ISH 0043 GTHM = 15.0,ALOG10(F1(TRM,TARL,TARL+11))

ISH 0044 CRTHM = ORH+GTHM

ISH 0045 PRINT 951, ORH, P, GTM, GTM, CRTHM

ISH 0046 10 CONTINUE

CSET UP FOR COMPUTATION OF TOTAL COMPENSATED POWER BY

C...ADJUST OF COMPONENTS NOT MORE THAN 100 OR DOWN FROM

C...MOST SIGNIFICANT COMPONENT

ISH 0047 PLARGE = -1.0E79

ISH 0048 PSWALL = 1.0E79

ISH 0049 NO 50 I = 1,4

ISH 0050 IF(PVAL(I),GT,PLARGE) PLARGE = PVAL(I)

ISH 0051 IF(PVAL(I),LT,PSWALL) PSWALL = PVAL(I)

ISH 0052 10 CONTINUE

ISH 0053 DIF = PLARGE - PSWALL

ISH 0054 IF(DIF,LE,100.00) GO TO 55

ISH 0055 PSWALL = PLARGE - 100.00

ISH 0056 55 CONTINUE

C...RESET ORIGIN TO PREVENT OVERFLOW UNDERFLOW

ISH 0060 LBASE = PSWALL

ISH 0061 TPCOMP = 0.00

ISH 0062 NO 100 I = 14

ISH 0063 IF(PVAL(I),LT,PSWALL) GO TO 100

ISH 0064 DIF = PVAL(I) - LBASE

ISH 0065 100 CONTINUE

C...FORMAT //**** PVAL,12,2X,G15.6** USING DIF = '1.615.6)

ISH 0066 PRINT 956, I, PVAL(I), DIF

ISH 0067 956 FORMAT(//10X,**** PVAL,F12.2,F15.6)

C...CONVERT OR TO POWER AND AND

ISH 0068 TPCOMP = TPCOMP + 10.00*(DIF/10.00)

ISH 0069 PRINT 966, TPCOMP

ISH 0070 966 FORMAT(//10X,**** TPCOMP NOW = '1.615.6/)

ISH 0071 100 CONTINUE

C...CONVERT POWER TO DB AND CORRECT ORIGIN FOR TOTAL POWER

ISH 0072 TP = LBASE + 10.00*ALOG10(TPCOMP)

ISH 0073 1000 CONTINUE

C...CALCULATE ALL WOOF POWER SUM....

ISH 0074 IF(HIRAYP,GT,TP) GO TO 120

ISH 0075 DIF = TP - HIRAYP

ISH 0076 IF(DIF,LE,100.00) GO TO 110

ISH 0077 ALDSUM = TP

ISH 0078 GO TO 130

ISH 0079 110 CONTINUE

ISH 0080 TP = HIRAYP

ISH 0081 GO TO 140

ISH 0082 120 CONTINUE

ISH 0083 DIF = HIRAYP - TP

ISH 0084 IF(DIF,LE,100.00) GO TO 130

ISH 0085 130 CONTINUE

ISH 0086 140 CONTINUE

ISH 0087 150 CONTINUE
<table>
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<tr>
<th>LEVEL 2.1 (JAN 75)</th>
<th>CP-POWER</th>
<th>OS/160</th>
<th>FORTRAN 4 EXTENDED</th>
<th>DATE 77.271/15.32.36</th>
<th>PAGE x</th>
</tr>
</thead>
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<tr>
<td>TSN 0043</td>
<td>ALPSUM = HIRAYP</td>
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<tr>
<td>TSN 0044</td>
<td>GO TO 150</td>
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<tr>
<td>TSN 0045</td>
<td>140 CONTINUE</td>
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<tr>
<td>TSN 0046</td>
<td>LBASE = TP</td>
<td></td>
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<td>TSN 0047</td>
<td>140 CONTINUE</td>
<td></td>
<td></td>
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<tr>
<td>TSN 0048</td>
<td>TCOMP = 10.00*(TP - LBASE)/10.00</td>
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<td></td>
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<tr>
<td>TSN 0049</td>
<td>TCOMP = TCOMP + 10.00*(HIRAYP - LBASE)/10.00</td>
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<tr>
<td>TSN 0050</td>
<td>ALPSUM = 10.00*ALOG10(TCOMP) + LBASE</td>
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<tr>
<td>TSN 0051</td>
<td>140 CONTINUE</td>
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<tr>
<td>C</td>
<td>CALCULATE CORRECTED NOISE POWER AND S/N RATIO</td>
<td></td>
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</tr>
<tr>
<td>C</td>
<td>CONHNZ = (1.00 - EXPI(-(FACNHZ*PHI))*HGTOT/HGTOT)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>C</td>
<td>CONHVZ = VGTOT/GTGT</td>
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<tr>
<td>C</td>
<td>DEBUG OUTPUT.....</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>C</td>
<td>PRINT GSN, HGTOT, VGTOT, AGTOT, CONHNZ, CONHVZ</td>
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<td></td>
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</tr>
<tr>
<td>TSN 0054</td>
<td>THOT = VNOIZ + 10.00*ALOG10(CONHNZ + CONHVZ)</td>
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<tr>
<td>TSN 0055</td>
<td>CTOSNR = ALPSUM + THOT</td>
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<td>TSN 0056</td>
<td>PRINT 925</td>
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<tr>
<td>TSN 0057</td>
<td>PRINT 936, (PVAL(I), I = 1,4), HIRAYP, VNOIZ, THOT, CTOSNR</td>
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<tr>
<td>TSN 0058</td>
<td>PRINT 94</td>
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<tr>
<td>TSN 0059</td>
<td>PRINT 902</td>
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<tr>
<td>TSN 0100</td>
<td>RETURN</td>
<td></td>
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</tr>
<tr>
<td>TSN 0101</td>
<td>FORMAT (1H,7X,3HGTOT,3X,4HTIME,3X,4HFREQ,3X,6HNMODE,4X,3HTOT,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* 4X,THOT*SIGMA,6X,6H[SIGNAL,9X,THAYN,11X,5HFDL,15X,5,5HMAX,</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>* 1H,13X,5H(SCF),19X,4H(M),6X,4H(D),10X,6H(DR),4X,4H(DRA),</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>* 1X,4H(DRA),10X,4H(DRA),/)</td>
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</tr>
<tr>
<td>TSN 0102</td>
<td>FORMAT //1X,1NOISE,10I(4******),/20X,</td>
<td></td>
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<tr>
<td></td>
<td>1 * HGTOT</td>
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<tr>
<td></td>
<td>2 /30X,5(9,10,5,3X),/1X,10(4******)</td>
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<tr>
<td>TSN 0103</td>
<td>FORMAT /35X,15(4******),/45X,&quot;SIGNAL ANALYSIS INCLUDING PREM&quot;,</td>
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<tr>
<td></td>
<td>1 &quot;ANALYSIS&quot;/10X,&quot;GROUND OR REFLECTED&quot;,10X,&quot;DIRECT&quot;,14X,</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>4 10X,&quot;NOISE&quot;,8X,&quot;ALL MODE&quot;,/8X,5X,1(DRA),6X,2(5X,1-DRW,6X),</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>5 3X,&quot;S/N RATIO&quot;,/)</td>
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<td>TSN 0104</td>
<td>FORMAT /4X,8I(12,6,5X)/</td>
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<tr>
<td>TSN 0105</td>
<td>FORMAT /4X,10(4******)/</td>
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<tr>
<td>TSN 0106</td>
<td>END</td>
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LEVEL 2.1 (JAN 74)
05/360 FORTRAN IV EXTENDED
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PAGE 1

REQUESTED OPTIONS: TO

OPTIONS IN EFFECT: HAPTEM(MAIN) NONOPTIMIZE LINECOUNT(40) SIZE(10228K) AUTOHAL(NONE)
SOURCE FRRCE SCALE HOLE HOLE OBJECT NOMAP NOTOFORMAT GOSTM HOMERHO NOAMSF TERMINAL FLAG(I)

ISN 0002

FUNCTION F1(X,LIBL,NUMB)

CALCULATE THE ANTENNA CALIBRATION TABLES ARE
NOT READ IN, SENSE SWITCH 1 IS ON AND THE ANTENNA GAIN WITH
RESPECT TO ISOTROPIC IS SET TO 1.

VARIBALES WHICH ARE READ IN FROM CARDS

ISN 0003


VARIBALES WHICH ARE COMPUTED

ISN 0004

COMMON LIMIT,NTIM,FREQ,OLDT,OLDR,OLDSWM,T1,S2,K1,NCD

VARIABLE ARRAYS

ISN 0005

COMMON PT(1001,1),A1(1001),PHA(1001),TAU(1001),
*= MODE(1001),TIMF(1001),FREQ(1001),
*= SIGTUM(1001),SIGTLM(1001),SIGTUM(1001),

ISN 0006

COMMON /ANTNT/ TACLIV1(181),TACLH1(181),TACL1(181),
*=TAR2IV1(181),MXANGL,1(181),MYANGL,(181),KRNK(181)

ISN 0007

COMMON /SPRASE/NUMF

ISN 0008

COMMON /SWITCH/KSW1,KSW2,F2,F3,F4,F5,F6,F7,F8,F9,F10

ISN 0009

INTERGER X, Y, OLSWM, OFFSET

ISN 0010

REAL N, M, S, A

ISN 0011

DIMENSION TACL(181),A

ISN 0012

COMMON /DATA/ C1, ARRAY, EFPL, TALFLR(115), TALFLR, N, M, X1, IDERH

ISN 0013

DATA WESPRT, MP1/

ISN 0014

NAMELIST /INFLFL/ TANGL,KANGL,DELNGL,DELFR,S1,S2,F1

ISN 0015

IF(KSW1.EQ.0) GO TO 100

ISN 0016

IF(MESPR,T,EQ.0) GO TO 50

ISN 0017

IF(MESPR,T.EQ.0) GO TO 50

ISN 0018

NDFRT = 1

ISN 0019

PRINT 905

ISN 0020

CONTINUE

ISN 0021

F1 = 1,00

ISN 0022

RETURN

ISN 0023

100 CONTINUE

ISN 0024

IFR = 1

ISN 0025

IFR = 1

ISN 0026

DELFR = 0,00

ISN 0027

FIRST CASE ONLY ONE FREQUENCY PROVIDED --
NO INTERPOLATION ON FREQUENCY

ISN 0028

IF(HNUMF.EQ.1) GO TO 200

ISN 0029

IF FREQUENCY IS OUT OF RANGE USE ISOTROPIC WITH WARNING

ISN 0030

IF(FR.LT.TALFLR(1).OR.FR.GT.TALFLR(NUMF)) GO TO 500

ISN 0031

IF(HNUMF.EQ.1) GO TO 200
<table>
<thead>
<tr>
<th>ISN</th>
<th>0040</th>
<th>OTHERWISE BRACKET FREQUENCY AND DETERMINE DELTA (DELFR)</th>
<th>AREF0680</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISN</td>
<td>0041</td>
<td>IF X &lt; 0.0, CORRECT IANGL TO FIT INTERPOLATION ASSUMPTIONS</td>
<td>AREF0850</td>
</tr>
<tr>
<td>ISN</td>
<td>0042</td>
<td>ADJUST IANGL SO THAT IT POINTS TO CORRECT ROW IN GAIN TABLE</td>
<td>AREF0850</td>
</tr>
<tr>
<td>ISN</td>
<td>0045</td>
<td>IF IANGL &lt; MINANG, OR, IANGL &gt; MAXANG, GO TO 250</td>
<td>AREF0890</td>
</tr>
<tr>
<td>ISN</td>
<td>0046</td>
<td>IF IANGL IS OK BUT IANGL IS TOO LARGE, F1 = 61</td>
<td>AREF0890</td>
</tr>
<tr>
<td>ISN</td>
<td>0048</td>
<td>IF (KANGL, F1, NUMANG) GO TO 240</td>
<td>AREF0910</td>
</tr>
<tr>
<td>ISN</td>
<td>0049</td>
<td>G2 = TABLE(KANGL, F1) + DELFR*TABLE(KANGL, F1) - TABLE(KANGL, F1)</td>
<td>AREF0910</td>
</tr>
<tr>
<td>ISN</td>
<td>0050</td>
<td>250 CONTINUE</td>
<td>AREF0910</td>
</tr>
<tr>
<td>ISN</td>
<td>0052</td>
<td>IF (IANGL, F1) WRITE(6, INTRPL) RETURN</td>
<td>AREF0910</td>
</tr>
<tr>
<td>ISN</td>
<td>0054</td>
<td>500 CONTINUE</td>
<td>AREF0910</td>
</tr>
<tr>
<td>ISN</td>
<td>0056</td>
<td>PRINT 901, FR, TABLE(1), TABLE(NUMF)</td>
<td>AREF0910</td>
</tr>
<tr>
<td>ISN</td>
<td>0057</td>
<td>PRINT 902, X, MAXANG, MINANG</td>
<td>AREF0910</td>
</tr>
<tr>
<td>ISN</td>
<td>0058</td>
<td>550 CONTINUE</td>
<td>AREF0910</td>
</tr>
</tbody>
</table>
LEVEL 2 1 (JAN 74) 05/60 FORTRAN IV EXTENDED DATE 77.271/15.32.49 PAGE 3

101 0071 PRINT 905
102 0072   F1 = 1.00
103 0073 RETURN
104 0074 901 FORMAT(*x,***** F10.5,
105 0075   ' OUT OF SPECIFIED RANGE: *', F10.5, ' TO ', F10.5)
106 0076 902 FORMAT(*x,***** ANGLE: *', F10.5, ' OUT OF SPECIFIED RANGE: *', F10.5)
107 0077 905 FORMAT(*x,***** ANTEenna CALIBRATION tarles NOT USed *'1
108 0078 END

*OPTIONS IN EFFECT* NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTOEBL(NONE)

*OPTIONS IN EFFECT* SOURCE EREDUC HOLECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOAIC NOANSF TERMINAL FLG(I)

*STATISTICS* SOURCE STATEMENTS = 76, PROGRAM SIZE = 1014, SUBPROGRAM NAME = 9338F1

*STATISTICS* NO DIAGNOSTICS GENERATED

***** END OF COMPIILATION *****

116K BYTES OF CORE NOT USED
SUBROUTINE INTLC

    INITIALIZES COUNTERS AND ARRAYS, PRINTS THE IDENTIFICATION CARD AND READS THE ANTENNA CALIBRATION TABLES WHEN THEY ARE PROVIDED.

    DECLARATION STATEMENTS

    VARIABILIES WHICH ARE READ IN FROM CARDS

COMMON T,W,F,S,ORT,PLN,PT1,TAU(60),GMT,RAUD,P

    VARIABILIES WHICH ARE COMPUTED

COMMON LIMIT,NITEN,NERQ,OLDT,ONFR,OLDSMT,S1,S2,K,N,NCD,NCOL

VARIABLE ARRAYS

COMMON PT(1000,3),A(1000),PHASFT(1000),TAUS(1000),
    SIGT(20,20),SIGNO(20,20)

COMMON /ORBIT/ K=1,2,F1,S1,TAU(1000),TAU2(1000),
            DXL(1000,3),MNANGL(2),MANGL(2),TKNX(2),NKNX(2)

COMMON /CONTR/ , PLBES

COMMON /DATA/ C1,F2,CD1,FLL1,FLRL1(1000),FR1,FR2,FR3,FR4

COMMON SWITCH,SW1,SW2,FL1,FL2,FL3,FL4,FL5,FL6,FL7,FLOAT

COMMON /SPRINT/ NOFREV,ANTFIL,HOSTOT

COMMON /NAMELIST/ IINIT, NFRQ,KWW1,KWW2,JCARD,NEWANT

1 ANTFIL,D,RAUD,PLBES,FL1,FL2,FL3,FL4,FL5,FL6,FL7,FLOAT

DATA BLK/200, ' ', NC0LLS ' /

DIMENSION HEADER(7)

EQUIVALENCE (MNANGL(1),MNANGT(1),MNANGT(2),MNANGT(3),MNANG)

EXTERNAL HEADER

REAL HEADER

REAL N

REAL MODE

ENTRY INITIA

FR = 1.0

P = 3.33

RAUN = 0.01

PLBE = 0.0

SF = 1

DO 5 J = 1, 20

DO 5 J = 1, 20

5 CONTINUE

IF INPUT POWER AND/OR RAUD LENGTH ARE LESS THAN OR EQUAL TO 0.01, RAUD TO 3.33 AND/OR RAUD LENGTH TO 0.01.

THOSE VALUES DO NOT CHANGE UNTIL RESET BY AN INPUT CARD.

END
LEVEL 2.1 (JAN 75)  INITLC  OS/360  FORTRAN IV EXTENDED  DATE 77.271/15.33.00  PAGE 3

**ISN 0067**
READ (JF,906) HEADER

**ISN 0068**
PRINT 906, HEADER

**ISN 0069**
M1 = 0

**ISN 0070**
RETURN

**ISN 0071**
900 FORMAT (3F10.0)

**ISN 0072**
903 FORMAT(16F9.0)

**ISN 0073**
904 FORMAT (14, I4, F12, J, I4, F6, 1)

**ISN 0074**
906 FORMAT (14, I4, 2F10.3)

**ISN 0075**
906 FORMAT (17H1, 10X, //)

**ISN 0076**
910 FORMAT (1I4, 2I10, 13, 14, 13, 3F10.0, 110)

**ISN 0077**
911 FORMAT (9X, 15F9.0)

**ISN 0078**
915 I=' NEW ANT PAT = ', ', 1/1

**ISN 0079**
935 FORMAT(/6X, 'USF OLD ANTIENN PATERN REQUESTED',
936 I 'WHEN NO PREVIOUS PATERNs AVAILABLE', ' ', '/20X,
937 * WRI SET SOT THAT NO ANTIENN PATERNs WIIIL BE USEd', ' ')

**ISN 0080**
END
LEVEL 2.1 (JAN 75) INITLC OS/360 FORTRAN II EXTENDED DATE 77/271/15.33.00 PAGE 4

NUMBER LEVEL FORTRAN II EXTENDED ERROR MESSAGES
1FE301/1 4(W) NAME 3RLNK THE DATA STATEMENT CONTAINS A VARIABLE THAT IS NOT REFERENCED.
*OPTIONS IN EFFECT NAME (MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(1022K) AUTOORG(NONE)
*OPTIONS IN EFFECT SOURCE ERadic NODECK OBJECT NOMAP NODFORMAT GOSTMT NOXREF NOAUC NOANSF TERMINAL FLAG(I)
*STATISTICS SOURCE STATEMENTS = 79, PROGRAM SIZE = 1932, SUBPROGRAM NAME =INITLC
*STATISTICS 1 DIAGOSTICS GENERATED, HIGHEST SEVREITY CODE IS 4

***** END OF COMPILATION ***** 116K BYTES OF CORE NOT USED
SUBROUTINE ONE

CALCULATIONS FOR A MAPPATH, COMBINES THESE CALCULATIONS
FOR ALL MAPPATHS AT A GIVEN TIME AND FREQUENCY.

DECLARATION STATEMENTS

VARIABLES WHICH ARE READ IN FROM CARDS

COMMON T,W,FR,DT,OR,PL,PT1,TAU(60),SMT,BAUD,P

VARIABLES WHICH ARE COMPUTED

COMMON LIMIT,TIME,NFREQ,DLDT,DLDF,ODLGMT,51,52,K,LM,NCDS

VARIABLE ARRAYS

COMMON PT(100,3),A(1000),PHASET(1000),TAU(1000),
* NOME(60),TIME(30),FREQ(30),
* SIUTA(20,20),SIGM0I(20,20)

COMMON WNYAT,tabl(181,1),tabl(181,2),tabl(181,3),
*tabl2(181,4),xvangl(2),mangl(2),xangl(2),mangls(2)

DIMENSION PATHS (60), SIGDIAN(60)

INTEGER I0,OLGDM,T,W
REAL N
REAL NO,NG
REAL NAME,NG
REAL MOME,NG
REAL NAME,NG

COMMON WINN,DWIN,DWIN,DWIN

COMMON /CONTROL/ PLRE,
COMMON /SAVEIG/ HIRAYL, IFLAG

COMMON /DATA/ C4,F0URPl, EFLP, TABFR(15), IOMW, MAX, IOMER

ALG101C2((FC4F0URPl*1,E12))=3.8550326

ENTER HERE FOR EACH CARD

TAU(N1)= TAU(N1)= 0.001

PT1= PT1 * 1,NE-05

NOLD = N

IF THE PATH LOSS IS GREATER THAN PLRE OR OR IF THE TRANSMITTER REE11060
OR RECEIVER CANNOT BE CALIBRATED, IGNORE THIS CARD.

IF(PLLT,PLRE) GO TO 5

PATHS(N1) = PLRE

GO TO 8

5 CONTINUE

GTV = F1(DT,TABL1V,1)

GTDF1(DT,TABL1H+1)

GRV = F1(DR,TABL2V,2)

GRDF1(DR,TABL2H+2)

SIGD(N1) = 10.0*ALG101(P*GTB*GRV/(FR*FR)) * 38.550326 - PL
LEVEL 2.1 (JAN 75) | BORONE | 09/360 | FORTRAN H EXTENDED | DATE 77.271/15.33.19 | PAGE 2

TSN 0099
C
PATHS(N1) = PL
C
C INITIALIZE VARIABLES FOR A GIVEN TIME AND/OR FREQUENCY
C
TSN 0099
C
IF(IFLAG,GT,0) GO TO 50
C
TSN 0099
C
IFLAG = 1
C
TSN 0099
C
HRAVP = SIGDA(N1)
C
TSN 0099
C
SIGMAX = HRAVP
C
TSN 0099
C
PATHM = PL
C
TSN 0099
C
GO TO A
C
C UPDATE VALUES AS REQUIRED
C
TSN 0099
C
50 CONTINUE
C
TSN 0099
C
IF(PL,LT,PATHM) PATHM = PL
C
TSN 0099
C
IF(SIGDA(N1),GT,SIGMAX) SIGMAX = SIGDA(N1)
C
TSN 0099
C
DIF = SIGDA(N1) - HRAVP
C
TSN 0099
C
IF(DIFF,-100,0) GO TO A
C
TSN 0099
C
IF(DIFF,100,0) GO TO 60
C
TSN 0099
C
HRAVP = SIGDA(N1)
C
TSN 0099
C
GO TO A
C
TSN 0099
C
60 CONTINUE
C
TSN 0099
C
DVAL = 1.09 + 10.0*(DIFF/YH)
C
TSN 0099
C
A K = K+1
C
TSN 0099
C
TAU(K) = TAU(N1)
C
TSN 0099
C
DT(K,1) = PT1
C
TSN 0099
C
DT(K,2) = TIMEF(T)
C
TSN 0099
C
DO 211 K = 1,LIMIT
C
TSN 0099
C
IF(M,NE,None(N1)) GO TO 211
C
TSN 0099
C
GO TO A22
C
TSN 0099
C
A21 CONTINUE
C
TSN 0099
C
DT(K,3) = 0.0
C
TSN 0099
C
DT(K,3) = I
C
TSN 0099
C
DT(K,3) = None(K)
C
TSN 0099
C
PHASET(K) = PT1
C
TSN 0099
C
RETURN
C
C ENTER HERE ON CHANGE OF FREQUENCY OR TIME
C
TSN 0099
C
ENTRY TWO
C
TSN 0099
C
ST = 0.0
C
TSN 0099
C
TWOSIG = ST
C
TSN 0099
C
HI = HI - 1
C
TSN 0099
C
PATHM = 10.
C
TSN 0099
C
GTV = F1(OMATN,TABL1+1)
C
TSN 0099
C
GTV = F1(OMATN,TABL1+1)
C
TSN 0099
C
GTV = F1(OMATN,TABL2+2)
C
TSN 0099
C
GTV = F1(OMATN,TABL2+2)
C
TSN 0099
C
SIGMAX = 10.0*LOG10(PGTV*GTV/(FR*FR)) + 38.550326 - NMIN2
C
TSN 0099
C
17 IF (OLDFP,GT,-1.0) GO TO 12
C
TSN 0099
C
GO TO 20
C
TSN 0099
C
OLDFP = FR
C
TSN 0099
C
OLDFP = FR
C
TSN 0099
C
CONTINUE
C
TSN 0099
C
IF(IFLAG,GT,0.0) GO TO 215
C
TSN 0099
C
MIN = MAX + 1
C
TSN 0099
C
REI1180
TSN 0099
C
REI1180
TSN 0099
C
REI1180
TSN 0099
C
REI1190
TSN 0099
C
REI1200
TSN 0099
C
REI1210
TSN 0099
C
REI1220
TSN 0099
C
REI1230
TSN 0099
C
REI1240
TSN 0099
C
REI1250
TSN 0099
C
REI1260
TSN 0099
C
REI1270
TSN 0099
C
REI1280
TSN 0099
C
REI1290
TSN 0099
C
REI1300
TSN 0099
C
REI1310
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C
REI1320
TSN 0099
C
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C
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C
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TSN 0099
C
REI1360
TSN 0099
C
REI1370
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C
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C
REI1400
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C
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C
REI1470
TSN 0099
C
REI1480
TSN 0099
C
REI1490
TSN 0099
C
REI1500
TSN 0099
C
REI1510
TSN 0099
C
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TSN 0099
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TSN 0099
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REI1550
TSN 0099
C
REI1560
TSN 0099
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REI1570
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C
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C
REI1590
TSN 0099
C
REI1600
TSN 0099
C
REI1610
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C
REI1620
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C
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C
REI1670
TSN 0099
C
REI1680
TSN 0099
C
REI1690
TSN 0099
C
REI1700
TSN 0099
C
REI1710
TSN 0099
C
REI1720
TSN 0099
C
REI1730
TSN 0099
C
REI1740
TSN 0099
C
REI1750
C-29

LEVEL 2.1 (JAN 75) ASROTH 09/360 FORTRAN IV EXTENDED DATE 77.271/15.35.19 PAGE 3

0045 MX = MAX + 1
0046 J RELATES TO K-LOOP BETWEEN ASTERISKS, I TO N1-LOOP BETWEEN TIMES AND FREQ
0047 DO 210 J = MIN, MX
0048 IF PATHLS (J,EQ.PL1N1J) GO TO 210
0049 PATHLS (J,EQ.PL1N1J) GO TO 202
0050 PATHLS (J,EQ.PL1N1J) GO TO 210
0051 PATHLS (J,EQ.PL1N1J) GO TO 210
0052 IF SIGOR(J,LT.SIGMAY-10.) GO TO 210
0053 REDUCE AMPLITUDE A(J) CAN BE USED IN MEAN AND SIGMA CALC

205 A(J) = 10.*** (SIGOR(J)-SIGMAY)/10.**
0056 S1 = S1 + A(J)
0057 S2 = S2 + A(J)*TAU(J)
0058 210 CONTINUE

0059 IF(S1.GT.0.0) GO TO 82
0060 CONTINUE
0061 S = -1.0E75
0062 TAUBAR = 0.0
0063 T = -5.0E75
0064 SN = -1.0E75
0065 SN = -1.0E75
0066 GO TO 25
0067 TAUJAR = 2.0/S1
0068 IF (J1 .NE. 1) GO TO 21
0069 DO 10 J = MIN, MX
0070 S3 = S3 + A(JI * (TAUSIJ) - TAUBAR)**2
0071 10 CONTINUE
0072 CONTINUE
0073 TWSIG = 2.0*SORT(S/S1)
0074 SN = SIGMAY + 10.*LOG10(S/S1)
0075 SN = S + NLS
0076 TAUJAR = TAUBAR * S1/S
0077 S = -S
0078 IF (J1 .NE. 1) GO TO 29
0079 TWSIG = TWS16 * 1000.
0080 IF PATHOT .NE.0.0) GO TO 27
0081 EFPL = PATHM1 - 10.0*LOG10(PATHM1) 
0082 IF(S1,EQ.0.) GO TO 265
0083 TWSIG = TWSIG - TWS16
0084 GO TO 275
0085 PRINT 990, OLDTW, OLDTW, TAUJAR, TWSIG, S, SN, EFPL, SNW
0086 30 I = FABOF(OLDT)
0087 J = TIMEF(OLDT)
0088 SIGM1 (I,J) = SN
0089 SIGTAR(J,J) = TWS16 * 0.001
0090 EFPL = 0.0
0091 NA = 31 I=1,6A
0092 SIGS(TI) = SN
0093 PATHM1 (I) = 0.0
0094 TAUJAR = TAUJAR
0095 TAUJAR = TAUJAR
0096 OLDM = GWT
0097 OLDM = GWT
0098 OLDFR = FR
0099 OLDFR = FR
0100 OLDFR = FR
0101 OLDFR = FR
0102 OLDFR = FR

C-29

0045 MX = MAX + 1
0046 J RELATES TO K-LOOP BETWEEN ASTERISKS, I TO N1-LOOP BETWEEN TIMES AND FREQ
0047 DO 210 J = MIN, MX
0048 IF PATHLS (J,EQ.PL1N1J) GO TO 210
0049 PATHLS (J,EQ.PL1N1J) GO TO 202
0050 PATHLS (J,EQ.PL1N1J) GO TO 210
0051 PATHLS (J,EQ.PL1N1J) GO TO 210
0052 IF SIGOR(J,LT.SIGMAY-10.) GO TO 210
0053 REDUCE AMPLITUDE A(J) CAN BE USED IN MEAN AND SIGMA CALC

205 A(J) = 10.*** (SIGOR(J)-SIGMAY)/10.**
0056 S1 = S1 + A(J)
0057 S2 = S2 + A(J)*TAU(J)
0058 210 CONTINUE

0059 IF(S1.GT.0.0) GO TO 82
0060 CONTINUE
0061 S = -1.0E75
0062 TAUBAR = 0.0
0063 T = -5.0E75
0064 SN = -1.0E75
0065 SN = -1.0E75
0066 GO TO 25
0067 TAUJAR = 2.0/S1
0068 IF (J1 .NE. 1) GO TO 21
0069 DO 10 J = MIN, MX
0070 S3 = S3 + A(JI * (TAUSIJ) - TAUBAR)**2
0071 10 CONTINUE
0072 CONTINUE
0073 TWSIG = 2.0*SORT(S/S1)
0074 SN = SIGMAY + 10.*LOG10(S/S1)
0075 SN = S + NLS
0076 TAUJAR = TAUBAR * S1/S
0077 S = -S
0078 IF (J1 .NE. 1) GO TO 29
0079 TWSIG = TWS16 * 1000.
0080 IF PATHOT .NE.0.0) GO TO 27
0081 EFPL = PATHM1 - 10.0*LOG10(PATHM1) 
0082 IF(S1,EQ.0.) GO TO 265
0083 TWSIG = TWSIG - TWS16
0084 GO TO 275
0085 PRINT 990, OLDTW, OLDTW, TAUJAR, TWSIG, S, SN, EFPL, SNW
0086 30 I = FABOF(OLDT)
0087 J = TIMEF(OLDT)
0088 SIGM1 (I,J) = SN
0089 SIGTAR(J,J) = TWS16 * 0.001
0090 EFPL = 0.0
0091 NA = 31 I=1,6A
0092 SIGS(TI) = SN
0093 PATHM1 (I) = 0.0
0094 TAUJAR = TAUJAR
0095 TAUJAR = TAUJAR
0096 OLDM = GWT
0097 OLDM = GWT
0098 OLDFR = FR
0099 OLDFR = FR
0100 OLDFR = FR
0101 OLDFR = FR
<table>
<thead>
<tr>
<th>LEVEL</th>
<th>MONTH</th>
<th>ROATNA</th>
<th>DATE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>JAN 75</td>
<td>05/360</td>
<td>17.21/15.34.06</td>
<td>2</td>
</tr>
</tbody>
</table>

PS 915, (TALFR(I),I = 1:IANT) 98 CONTINUE
PS 916 READ GAIN DATA PRINT IF REQUIRED AND CONVERT TO RELATIVE POWER
PS 917 CONTINUE
PS 918 DO 96 ICT = 1,2
PS 919 KRNX(ICT) = 1 - M Richmond
PS 920 CONTINUE
PS 921 M = MANGL(1)
PS 922 M = MANGL(1)
PS 923 NO = 100 + 1: NIMANG
PS 924 READINITFL.991 END=600) TANG, (ANGLG(1,FREQ), (FREQ = 1:100)
PS 925 IF (TANG.EQ.0,J) GO TO 125
PS 926 IF (TANG.LE.XANG, AND IANG.GE.MINANG) GO TO 120
PS 927 PRINT 941, TANG, (ANGLG(FREQ), FREQ = 1:100)
PS 928 STOP PROCESSING BECAUSE HORIZONTAL IS OUT OF RANGE AND
PS 929 OUT OF SYNCH
PS 930 CONTINUE
PS 931 STOP 990001 100 CONTINUE
PS 932 PRINT 955, TANG, (ANGLG(FREQ), FREQ = 1:100)
PS 933 CONTINUE
PS 934 CONTINUE
PS 935 CONTINUE
PS 936 CONTINUE
PS 937 CONTINUE
PS 938 CONTINUE
PS 939 CONTINUE
PS 940 CONTINUE
PS 941 CONTINUE
PS 942 CONTINUE
PS 943 CONTINUE
PS 944 CONTINUE
PS 945 CONTINUE
PS 946 CONTINUE
PS 947 CONTINUE
PS 948 CONTINUE
PS 949 CONTINUE
PS 950 CONTINUE
PS 951 CONTINUE
PS 952 CONTINUE
PS 953 CONTINUE
PS 954 CONTINUE
PS 955 CONTINUE
PS 956 CONTINUE
PS 957 CONTINUE
PS 958 CONTINUE
PS 959 CONTINUE
PS 960 CONTINUE

**Notes:**
- The code snippet appears to be a part of a Fortran program, possibly for a radar or sonar application.
- The program includes variable declarations, calculations, and control structures.
- The program reads initialization data and processes it based on certain conditions.
- The output includes printing of data and control statements for synchronization and processing.

**Technical Details:**
- The program uses double precision variables for accuracy in calculations.
- It includes a loop that processes data for each frequency step.
- The program checks for horizontal and vertical conditions and handles them accordingly.
- It also includes a section for processing receiver patterns.
LEVEL 2.1 (JAN 75) DATA A.0//FORTRAN Extended DATE 77.271/15.34.06 PAGE 3

ISK 0081 OFFSET = XWNV(2)
ISK 0082 WAXANG = XWNV(2)
ISK 0083 WMAXW = XWNV(2)
ISK 0084 DO 250 I = 1, NUMANG
ISK 0085 READ(AUNIT),END=255) IANG, (ANGLSV(IFREQ), IFREQ = 1, IANT)
ISK 0086 IF IANG.LE.WAXANG.AND.IANG.GE.WMAXW) GO TO 255
ISK 0087 PRINT 940
ISK 0088 PRINT 941, IANG, (ANGLSV(IFREQ), IFREQ = 1, IANT)
ISK 0089 READ(AUNIT),END=255) IANG, (ANGLSH(IFREQ), IFREQ = 1, IANT)
ISK 0090 IF IANG.LE.WAXANG.AND.IANG.GE.WMAXW) GO TO 255
ISK 0091 PRINT 941, IANG, (ANGLSH(IFREQ), IFREQ = 1, IANT)
ISK 0092 GO TO 250
ISK 0093 250 CONTINUE
ISK 0094 JANG = IANG
ISK 0095 = JANG + OFFSET
ISK 0096 DO 219 J = 1, IANT
ISK 0097 DATVAL = 10.0*(ANGLSH(J)/10.0)
ISK 0098 TAPLVK(J) = PATVAL
ISK 0099 VSOT = VSTOT + PATVAL
ISK 0100 219 CONTINUE
ISK 0101 READ(AUNIT),END=255) IANG, (ANGLSH(IFREQ), IFREQ = 1, IANT)
ISK 0102 IF IANG.LE.WAXANG.AND.IANG.GE.WMAXW) GO TO 220
ISK 0103 PRINT 941, IANG, (ANGLSH(IFREQ), IFREQ = 1, IANT)
ISK 0104 STOP PROCESING BECAUSE HORIZONTAL IS OUT OF RANGE AND
ISK 0105 OUT OF SYNC
ISK 0106 STOP 00002
ISK 0107 220 CONTINUE
ISK 0108 PRINT 955, IANG, (ANGLSH(IFREQ), IFREQ = 1, IANT)
ISK 0109 229 CONTINUE
ISK 0110 K = JANG + OFFSET
ISK 0111 DO 239 J = 1, IANT
ISK 0112 DATVAL = 10.0*(ANGLSH(J)/10.0)
ISK 0113 TAPLVK(J) = PATVAL
ISK 0114 VSOT = VSTOT + PATVAL
ISK 0115 239 CONTINUE
ISK 0116 LINCNT = LINCNT + 1
ISK 0117 IF (LINCNT.LT.LINES) GO TO 250
ISK 0118 PRINT 920, IANG, (ANGLSV(J), ANGLSH(J), J = 1, IANT)
ISK 0119 LINCNT = 0
ISK 0120 250 CONTINUE
ISK 0121 IF (IEREG.J,ST,10) WRITE(6,ACRDATA)
ISK 0122 VSOT = VSTOT + HSTOT
ISK 0123 RETURN
ISK 0124 500 CONTINUE
ISK 0125 HSTOT = VSTOT + HSTOT
ISK 0126 RETURN
ISK 0127 502 FORMAT//,X,5.50(1HE)/,X,
ISK 0128 DATA ENDS UNEXPECTED WITH ANGLE #1,15.
ISK 0129 2 //X,Y, IFSEG DATA MAY BE REPLACED BY ONE,
ISK 0130 3 //X,Y,501(1HE)/
ISK 0131 RETURN
ISK 0132 901 FORMAT(15,15E0)
ISK 0133 902 FORMAT(14,1A)
ISK 0134 903 FORMAT(15,15E0)
ISK 0135 100 FORMAT(15,14E0)
LEVEL 2.1 (JAN 75)  
ROATNA  
05/160 FORTRAN IV EXTENDED  
DATE 77,371/53,456  
PAGE 4

| ISN 0144 | 910 FORMAT(F5,0)  
| ISN 0147 | 910 FORMAT/I7X, R(2X,F10.4,3Y)  
| ISN 0148 | 910 FORMAT/I7X, R(2X,F10.4,3Y)  
| ISN 0149 | 910 FORMAT/I7X, R(2X,F10.4,3Y)  
| ISN 0150 | 910 FORMAT/I7X, R(2X,F10.4,3Y)  
| ISN 0151 | 910 FORMAT/I7X, R(2X,F10.4,3Y)  
| ISN 0152 | 910 FORMAT/I7X, R(2X,F10.4,3Y)  
| ISN 0153 | 910 FORMAT/I7X, R(2X,F10.4,3Y)  
| ISN 0154 | END  

*OPTIONS IN EFFECT:NAME(MAIN) NOOPTIMIZE LINECOUNT(40) SIZE(5228K) AUTOBL(INONE)  
*OPTIONS IN EFFECT:SOURCE FACILITY NOLIST NODECK OBJECT NOSAP NOFORMAT COSTMT NOREF NOALC NOUNSF TERMINAL FLAG(I)  
*STATISTICS: SOURCE STATEMENTS = 153, PROGRAM SIZE = 4432, SUBPROGRAM NAME =ROATNA  
*STATISTICS: NO DIAGNOSTICS GENERATED  
***** END OF COMPILATION *****  

| 96K BYTES OF CORE NOT USED |
SUBROUTINE READ

COMMON T,M,FR,DT,DR,PL,N,PT1,TAU(E),(6),G,M,B,A,D,P

COMMON LIMIT,TIME,NFREQ,OLDT,OLDFR,OLDGMT,S1,S2,K,FIN,NCOS

INTEGER L3

DATA S5/14/
LEVEL 2,1 (JAN 71) BREAD 05/360 FORTRAN H EXTENDED DATE 77.271/15.34.33 PAGE 2

C C BUILD TABLE OF MODES C C
SIN 0054 28 IF (LIMIT .GT. 0) GO TO 21
SIN 0060 GO TO 23
SIN 0061 21 DO 22 I = 1, LIMIT
SIN 0062 IF (I .NE. MODE(I)) GO TO 22
SIN 0064 GO TO 24
SIN 0065 22 CONTINUE
SIN 0066 23 LIMIT = LIMIT - 1
SIN 0067 IF (.NOT. LIMIT .GT. 0) GO TO 110
SIN 0069 43 MODE(LIMIT) = M
C C BUILD TABLE OF TIMES C C
SIN 0070 IF TIME = -1, USE GMT INSTEAD
SIN 0071 24 IF (T .EQ. -1.0) GO TO 40
SIN 0072 GO TO 41
SIN 0073 40 IGMT1 = GMT / 100
SIN 0074 IGMT2 = GMT - IGMT1 * 100
SIN 0075 T = IGMT1 * 3600 + IGMT2 * 60
SIN 0076 41 IF (TIME .GT. 0) GO TO 25
SIN 0078 GO TO 27
SIN 0079 26 DO 26 I = 1, NTIME
SIN 0080 IF (T .NE. TIME(I)) GO TO 26
SIN 0082 GO TO 26
SIN 0084 26 CONTINUE
SIN 0085 27 NTIME = NTIME + 1
SIN 0086 IF (TIME .GT. 20) GO TO 120
SIN 0088 44 TIME(NTIME) = T
C C BUILD TABLE OF FREQUENCIES C C
SIN 0089 28 IF (NfREQ .GT. 0) GO TO 35
SIN 0090 GO TO 37
SIN 0091 39 DO 39 I = 1, NfREQ
SIN 0092 IF (F .NE. FREQ(I)) GO TO 36
SIN 0094 GO TO 39
SIN 0096 36 CONTINUE
SIN 0097 37 FREQ = FREQ + 1
SIN 0098 IF (NfREQ .GT. 20) GO TO 130
SIN 0099 45 FREQ(NFREQ) = FR
SIN 0100 46 RETURN C C END OF FILE PROCESSING C C
SIN 0101 290 CONTINUE
SIN 0102 APW = 10.0 * ALOG10(P)
SIN 0103 THK = 0.001 * THK
SIN 0104 RHT = 0.001 * RHT
SIN 0106 IF (FACM2 = 0.00) FACM2 = 0.02
SIN 0107 CALL POWER(APW, WP, ALPHM)
SIN 0108 49 RETURN C
C C RETURN TO READ NEXT INPUT WITHOUT INCREMENTING NI C C
SIN 0109 GO TO 5
LEVEL 2,1 (JAN 76) BBREAD 09/360 FORTRAN IV EXTENDED DATE 77.271/15.34.33 PAGE 3

0089 30 CALL TWO
0091 CALL INITIA
0092 GO TO 4
0093 50 CALL TWO
0094 CALL PRINT
0094 STOP
0094 100 PRINT 002
0097 STOP 2
0098 110 PRINT 003
0099 STOP 3
0100 120 PRINT 004
0101 STOP 4
0102 130 PRINT 005
0103 STOP 5
0104 920 FORMAT (A1,F6.0,F10.0,3F6.2,2F7.3,F9.1,F7.1,F10.1)
0105 924 FORMAT (/2X,A1,F6.0,F10.0,3F6.2,2F7.3,F9.1,F7.1,F10.1)
0106 931 FORMAT(F10.3)
0107 940 FORMAT (N00 TOO MANY INPUT CARDS -- MAXIMUM = 1000 )
0108 908 FORMAT (21H1 TOO MANY MACHINES )
0109 944 FORMAT (21H1 TOO MANY TIMES )
0110 948 FORMAT (21H1 TOO MANY FREQUENCIES )
0111 END

*OPTIONS IN EFFECT* NAME(MATH) NOOPTIMIZE LINECOUNT(60) SIZE(5228K) AUTO DBL(NONE)

*OPTIONS IN EFFECT* SOURCE FACRIC NOLIST NODECK OBJECT NOMEM NOFORMAT NOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(1)

*STATISTICS* SOURCE STATEMENTS = 110, PROGRAM SIZE = 2070, SUBPROGRAM NAME =BBREAD

*STATISTICS* NO DIAGNOSTICS GENERATED

***** END OF COMPILATION *****

104K BYTES OF CORE NOT USED
| ISN 0002 | BLACK DATA                  | 15620  |
| ISN 0003 | COMMON /ANTNAT/ TAIL1V(1A1,R), TAIL1H(1A1,R), TAIL2V(1A1,R), TAIL2H(1A1,R), | 15630  |
| ISN 0004 | COMMON /DATA/ C2, FOURPI, EPSL, TABLER(15), TDM, MAX, IDEBUG | 15640  |
| ISN 0005 | COMMON /SPRESS/ NOFREQ, INPFIL, RGTOT, HGOTOT | 15650  |
| ISN 0006 | COMMON /SAXIIG/ HIRAYP, IFLAG | 15660  |
| ISN 0007 | COMMON/SWITCH/KSW1,KSW2,JF,IBETA,JCARD,NEWANT | 15670  |
| ISN 0008 | COMMON/XLTV/ATL, BLANK, STAR | 15680  |
| ISN 0009 | DIMENSION LTN(20) | 15690  |
| ISN 0010 | INTEGER*4 ATL, BLANK, STAR | 15700  |
| ISN 0011 | DATA ACT/*FF*/ | 15710  |
| ISN 0012 | DATA LTN/*DNS*/ | 15720  |
| ISN 0013 | DATA BLANK/* | 15730  |
| ISN 0014 | DATA STAR /*FF*/ | 15740  |
| ISN 0015 | DATA HIRAYP=1, OFTS=1, NFLAG=-1, NEWANT=KSW1/2=1,JF=7 | 15750  |
| ISN 0016 | DATA KSW2, JCARD, THETA/300, INPFIL=5/, NOFREQ=1 | 15760  |
| ISN 0017 | DATA MWXG, MNXG, NANGL=90, 90, 90, -90, -90, 181, 181 | 15770  |
| ISN 0018 | DATA C2, FOURPI, EPSL, MAX=9, 0E16, 12, 5663796, 0, 0, 0 | 15780  |
| ISN 0019 | DATA RGTOT, HGOTOT /3=100, IDEBUG=0/ | 15790  |
| ISN 0020 | END | 15800  |

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APPENDIX D

Supplement to NUCOM II Users Guide

The modifications to NUCOM II to produce the NUCOM/BREM version were designed to minimize the changes to existing NUCOM II deck setup and case stacking logic. In RAYTRACE one new control card has been added to input the problem description for the nonionospheric modes.

In COMEPP the CARD 1 input has been altered and a namelist input feature has been added. The input antenna format has been altered slightly to permit inclusion of horizontal as well as vertical polarization parameters.

These new input cards are described as follows:

<table>
<thead>
<tr>
<th>BREM INPUT CARD - RAYTRACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAME</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>HTR</td>
</tr>
<tr>
<td>HTT</td>
</tr>
<tr>
<td>SIGMA</td>
</tr>
<tr>
<td>EPSILON</td>
</tr>
<tr>
<td>WNDVEL</td>
</tr>
<tr>
<td>SUDAM</td>
</tr>
<tr>
<td>MILLM</td>
</tr>
<tr>
<td>FACHNZ</td>
</tr>
</tbody>
</table>
NAME LIST INPUT FOR COMEFF.

The format for the name list is "VARIABLE NAME-VALUE" and successive name list variables are separated by commas. The namelist is initiated with the term '&INIT' beginning in column 2. The namelist is terminated by the term '&END' anywhere. Namelist variables may appear in any order. The namelist variables may span more than one card but must always begin in column 2.
<table>
<thead>
<tr>
<th>NAMELIST VARIABLE</th>
<th>FORMAT</th>
<th>DESCRIPTION</th>
<th>VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>KSW1</td>
<td>I1</td>
<td>ISOTROPIC OR INPUT ANTENNA PATTERNS</td>
<td>≠ 0 ISOTROPIC = 0 INPUT PATTERNS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DOPPLER SHIFT</td>
<td>= 0 NO DOPPLER ≠ 1 DOPPLER OUTPUT</td>
</tr>
<tr>
<td>KSW2</td>
<td>I1</td>
<td>LOWEST ANGLE FOR PATTERN SUPPLIED-TRANSMITTER</td>
<td>INTEGER VALUE IN DEGREES</td>
</tr>
<tr>
<td>MNANGT</td>
<td>I2</td>
<td>HIGHEST ANGLE FOR PATTERN SUPPLIED TRANSMITTER</td>
<td>INTEGER VALUE IN DEGREES</td>
</tr>
<tr>
<td>MNANGR</td>
<td>I2</td>
<td>LOWEST ANGLE FOR PATTERN SUPPLIED-RECEIVER</td>
<td>INTEGER VALUE IN DEGREES</td>
</tr>
<tr>
<td>MXANGR</td>
<td>I2</td>
<td>HIGHEST ANGLE PATTERN SUPPLIED-RECEIVER</td>
<td>INTEGER VALUE IN DEGREES</td>
</tr>
<tr>
<td>NOFREQ</td>
<td>I2</td>
<td>NUMBER OF FREQUENCIES FOR WHICH ANTENNA PATTERNS VIGEN</td>
<td>INTEGER ≤ 8</td>
</tr>
<tr>
<td>PLREJ</td>
<td>F5.3</td>
<td>PATH LOSS LIMIT</td>
<td>RAY IGNORED IF PATH LOSS &gt;PLREJ</td>
</tr>
<tr>
<td>P</td>
<td>F7.3</td>
<td>POWER DENSITY</td>
<td>WATTS/Hz DEFAULT=3.33</td>
</tr>
<tr>
<td>NEWANT</td>
<td>I2</td>
<td>NEW ANTENNA PATTERN</td>
<td>≠ 0 USE PREVIOUS ANTENNA PATTERN = 0 INPUT NEW PATTERN</td>
</tr>
<tr>
<td>BAUD</td>
<td>F7.3</td>
<td>SIGNALLING ELEMENT DURATION</td>
<td>DEFAULT = 10msec</td>
</tr>
</tbody>
</table>
Example of NAMELIST INPUT:

&INIT KSW=0, KSW2=1, MXANGT=40, MNANGT=-40  MXANGR=40, MNANGR=-40
P=10, NOFREQ=2, PLREJ=200, NEWANT=0 & END

PRINT CONTROL CARD

This parameter controls printing of input antenna patterns.

<table>
<thead>
<tr>
<th>NAME</th>
<th>FORMAT</th>
<th>COLUMNS</th>
<th>VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>VBL</td>
<td>I1</td>
<td></td>
<td>&quot;PRNT&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1-4</td>
<td>a 1 in column 9 causes every tenth angle to be printed</td>
</tr>
<tr>
<td>VBL</td>
<td>I1</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>a 1 in column 10 causes every angle to be printed.</td>
</tr>
</tbody>
</table>
FREQUENCY INPUT CARD

This card describes the frequencies for which antenna pattern data is to be input. This card is similar to the original NUCOM II card except the fields are compressed.

<table>
<thead>
<tr>
<th>NAME</th>
<th>FORMAT</th>
<th>COLUMNS</th>
<th>DESCRIPTION</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TABLFR(1)</td>
<td>F5.1</td>
<td>1-6</td>
<td>FIRST FREQUENCY</td>
<td>MHz</td>
</tr>
<tr>
<td>TABLFR(2)</td>
<td>F5.1</td>
<td>6-10</td>
<td>2nd FREQUENCY</td>
<td>MHz</td>
</tr>
<tr>
<td>TABLFR(3)</td>
<td>F5.1</td>
<td>11-15</td>
<td>3rd FREQUENCY</td>
<td>MHz</td>
</tr>
<tr>
<td>TABLFR(4)</td>
<td>F5.1</td>
<td>16-20</td>
<td>4th FREQUENCY</td>
<td>MHz</td>
</tr>
<tr>
<td>TABLFR(5)</td>
<td>F5.1</td>
<td>21-25</td>
<td>5th FREQUENCY</td>
<td>MHz</td>
</tr>
<tr>
<td>TABLFR(6)</td>
<td>F5.1</td>
<td>26-30</td>
<td>6th FREQUENCY</td>
<td>MHz</td>
</tr>
<tr>
<td>TABLFR(7)</td>
<td>F5.1</td>
<td>31-35</td>
<td>7th FREQUENCY</td>
<td>MHz</td>
</tr>
<tr>
<td>TABLFR(8)</td>
<td>F5.1</td>
<td>36-40</td>
<td>8th FREQUENCY</td>
<td>MHz</td>
</tr>
</tbody>
</table>
ANTENNA PATTERN INPUT

Each antenna pattern card includes an integer angle and one to eight values of power gain relative to isotropic as specified in the namelist variable NOFREQ. Pattern values must start with MNANGT for transmitter and MNANGR for receiver patterns and end with MXANGT for transmitter and MXANGR for receiver patterns. Transmitter patterns are given first and for each angle specified the first card corresponds to vertical polarization and the second card to horizontal polarization. The values of MNANGR and MNANGT, MXANGR and MXANGT need not be the same; this allows use of small pattern decks for air-to-air and air-to-ground links when no ionospheric rays are present.

Antenna Gain Pattern (MXANGT-MNANGT+1 cards)

<table>
<thead>
<tr>
<th>NAME</th>
<th>FORMAT</th>
<th>COLUMN</th>
<th>DESCRIPTION</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>IANG</td>
<td>I5</td>
<td>1-5</td>
<td>ANGLE</td>
<td>in degrees</td>
</tr>
<tr>
<td>TABL1(1)</td>
<td>F5.1</td>
<td>6-10</td>
<td>antenna gains for vertical polarization for NOFREQ</td>
<td></td>
</tr>
<tr>
<td>TABL1(2)</td>
<td>F5.1</td>
<td>11-15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TABL1(3)</td>
<td>F5.1</td>
<td>16-20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TABL1(4)</td>
<td>F5.1</td>
<td>21-26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TABL1(5)</td>
<td>F5.1</td>
<td>26-30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TABL1(6)</td>
<td>F5.1</td>
<td>31-35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TABL1(7)</td>
<td>F5.1</td>
<td>36-40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TABL1(8)</td>
<td>F5.1</td>
<td>41-45</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A second card with identical format gives the horizontal component values. Examples of complete pattern decks will be found in APPENDIX C.
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Navy Department
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ATTN: SUL

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ATTN: TN

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