

report

Collins Radio Company

Volume 3 Theoretical Data Base

Research and Development Contract for Coal Mine Communication System



report

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Page

Section 1 Theoretical Approach to VLF Through- the-Earth Propagation	1-1
Section 2 Signal-to-Noise Analysis for Loop-to-Loop Mine Communications	2-1
2.1 Abstract	2-1
2.2 Introduction	2-1
2.3 Loop-to-Loop Power Transfer Within a	
Homogeneous Medium	2-2
2.4 Loop-to-Loop Power Transfer on or Within	
a Lossy Half-Space	2-5
2.4.1 System Signal-to-Noise Analysis	2-8
2.5 Computer Signal-to-Noise Analysis for	2.0
Loop-to-Loop Mine Communications	2-9
2.5.1 Relation of Loop Design to System	9 11
2.5.2. System Noise Depresentation	2 - 11 2 - 12
2.5.2 System Noise Representation	2 - 12 2 - 12
2.5.6 Dignal and Noise Processing	
2.5.4 Results of Signal-to-Roise Ratio Analysis	2-13
	2 10
Section 3 The Horizontal Electric Dipole 3-	
3.1 The Field Equations for a Submerged	
Horizontal Electric Dipole	3-1
3.2 The Submerged Vertical Magnetic Dipole	3-5
3.3 The Submerged HED and VMD	3-6
3.4 The Field Components of a Submerged	
Infinite Line Source	3-9
3.4.1 Results of the Submerged Infinite	
Line Source Analysis	3-12
Section 4 Signal-to-Noise Analysis for Down-Link	
Line Source Mine Communications	4-1
4.1 The Subsurface H-Fields for a Line	
Current Source	4-1
4.1.1 Signal-to-Noise Ratios	$\bar{4}-\bar{2}$
4.2 Computational Results	4-3
4.3 Theoretical Predictions for S/N ₀	4-4

Table of Contents (Cont)

Section 5 LF Communication	5-1
 5.1 On Intramine Wireless LF Communications 5.1.1 Comparison of Experiment With Theory 5.1.2 System Design of Basic Intramine Paths 5.1.3 Conclusions and Recommendations 	5-1 5-2 5-9 5-16
Section 6 The Application of Recent NBS Noise Data to Mine Communications	6-1
 6.1 Method of Analysis	6-1 6-1 6-8 6-19 6-26 6-30 6-32
Section 7 Analysis of Mine Communications Propagation Programs	7-1
 7.1 User's Guide for the Mine Communication's Propagation Programs. 7.2 Program Number One. 7.3 Program Number Two 7.4 Program Number Three. 7.5 Theoretical Predictions for In-Mine 	7-1 7-2 7-7 7-12
 7.5 Theoretical Treaterions for the shife Propagation	7-16
Station - NG 14) 7.5.2 LF Propagation (Theoretical - Portable - NG 14) 7.5.3 LF Propagation (Theoretical - NG 14)	7-33 7-34 7-35
7.6 Summary	7-36

Figure

Page

2-1	Transmitting VMD	2-2
2-2	Transmitting Loop at Surface	2-5
2-3	Equivalent Background Noise Fields	2 - 10
2-4	Receive Signal-to-Noise Ratios as a Function of	
	Lateral Displacement and Frequency (100 m)	2-15
2-5	Receive Signal-to-Noise Ratios as a Function of	
	Lateral Displacement and Frequency (300 m)	2-16
2-6	Receive Signal-to-Noise Ratios as a Function of	
	Lateral Displacement and Frequency (500 m)	2 - 17
2-7	Receive Signal-to-Noise Ratios as a Function of	_
	Lateral Displacement and Frequency (100 m)	2-18
2-8	Receive Signal-to-Noise Ratios as a Function of	
	Lateral Displacement and Frequency (300 m)	2 - 19
2-9	Receive Signal-to-Noise Ratios as a Function of	
	Lateral Displacement and Frequency (500 m)	2 - 20
3-1	Submerged Horizontal Electric Dipole	3 - 1
3-2	Submerged Infinite Line Source	3-9
3-3	Submerged Infinite Line Source	3 - 13
3-4	Submerged Line Source	3-14
4-1	Line Current Source	4-1
4 - 2	Receive Signal-to-Noise Ratios as a Function of	
	Lateral Displacement and Frequency (300 m)	4-5
4- 3	Receive Signal-to-Noise Ratios as a Function of	
	Lateral Displacement and Frequency (500 m) VMD	4-6
4-4	Receive Signal-to-Noise Ratios as a Function of	
	Lateral Displacement and Frequency (500 m) HMD	4-7
4-5	Receive Signal-to-Noise Ratios as a Function of	
	Lateral Displacement and Frequency (300 m) HMD	4-8
4-6	Receive Signal-to-Noise Ratios as a Function	
	of Lateral Displacement and Frequency	
	(300 m) Loop	4-9
4-7	Receive Signal-to-Noise Ratios as a Function	
	of Lateral Displacement and Frequency	
	(500 m) Loop	4-10
5-1	Comparison of Theoretical and Measured	
	Transmission Losses Between Line	
	Sources - $E\phi/\phi = \pi/2$	5-3
5 - 2	Comparison of Theoretical and Measured	
	Transmission Losses Between Line	
	Sources – $E \rho / \phi = 0$	5-4
5-3	Comparison of Theoretical and Measured	
	Transmission Losses Between Line	
	Sources – $H\phi$. $\phi = 0$	5-5
	······································	

List of Illustrations (Cont)

Figure

5-4	Comparison of Theoretical and Measured	
	Transmission Losses Between Line	
	Sources - H ρ ϕ = 90	5-6
5-5	Comparison of Theoretical and Measured	
	Transmission Losses Between Line	
	Sources - Hz $\phi = 90$	5-7
5-6	Portable VMD to Line Source	5-10
5-7	Portable VMD to VMD	5-11
5-8	Line Source to Line Source (Broadside)	5 - 12
5-9	VMD to VMD	5-13
5-10	Line Source to VMD/Displacement - 100 Meters	5-14
5-11	Line Source to VMD/Displacement - 200 Meters	5-15
6-1	Robena Bensema Noise Spectrum Data/	
• -	Trollev and Face Area Noise Levels	6-3
6-2	Robena Bensema Noise Spectrum Data/	
	Noise Components Crosscuts 7 and 9	6-4
6-3	Robena Kandu APD-Data Spectrum (RMS)	6-5
6-4	Robena H _M (H) Extremes (RMS) Subsurface	6-6
6-5	Robena $H_{M}(V)$ Extremes.	6 - 7
6-6	McElroy Spectrum Data/Vertical Noise Fields,	
	Face Area, and Location No. 2	6-9
6-7	McElroy Spectrum Data/Vertical Noise Fields,	
	Headpiece, Crosscut, and Shaft	6-10
6-8	McElroy Spectrum Data/APD (RMS)	6 - 11
6-9	McElroy Spectrum Data/Additional	
	Vertical Field Data	6 - 12
6-10	McElroy Spectrum Data/Various	
	Locations and Components	6 - 13
6 - 11	McElroy Spectrum Data/Additional High Vertical	
	Noise Fields, Crosscuts and Face Areas	6 -1 4
6-12	McElroy Surface Spectrum Data	6 - 15
6-13	McElroy Spectrum Data	6-16
6-14	McElroy Spectrum Data/H _N Extremes	6-17
6-15	McElroy Surface Spectrum Data/Summary	6-18
6-16	Itman Spectrum Data/Noise Levels -	
	Portal Buses and Cabin Creek	6-20
6 - 17	Itman Spectrum Data Farley Panel/Noise –	0.01
	16 Ft From Miner	6-21
6-18	Itman Spectrum Data Farley Panel/Noise –	
	16 Ft From Miner – Continued	6-22
6-19	Itman Spectrum Data/30 Ft From Miner	6-23
6-20	Itman Spectrum Data/APD	6-24
6-21	Itman Spectrum Data/Extremes	6-25
6-22	Geneva Spectrum Data/H _N (H) East-West	6-26

Figure

6-23	Geneva Spectrum Data/H _N (H) North-South	6-27
6-24	Geneva Spectrum Data/H _N (V)	6-28
6-25	Geneva Spectrum/Data Extremes	6-29
6-26	All Mines/Extremes	6-31
6-27	Vector Relationships of Electric and Magnetic	
	Field Components for Printouts on Pages 6-34	
	Through 6-83	6-33
7 - 1	Loop-to-Loop Lateral Transmission for	
	Varying Displacements	7 - 17
7-2	Line Source to Loop Lateral Transmission	
	for Varving Displacements	7 - 18
7-3	Loop-to-Loop S/N Ratio for Various	
	Displacements - Noise Grade 14	7 - 19
7-4	Loop-to-Loop S/N Ratio for Various	
	Displacements - Noise Grade 2	7-20
7-5	Loop-to-Loop Lateral Transmission for	
	Varying Displacements	7-21
7-6	Line Source-to-Loop S/N Ratio for Various	
	Displacements Down-Link	7-22
7-7	Line Source-to-Loop S/N Ratio for Various	
	Displacements Down-Link	7-23
7-8	Line Source-to-Loop S/No Ratio for Various	
	Displacements Down-Link	7-24
7-9	Down-Link Loop-to-Loop S/N Ratio for	
	Various Displacements	7-25
7-10	Down-Link Loop-to-Loop S/N Ratio for	
	Various Displacements - Continued	7-26
7-11	Down-Link Loop-to-Loop S/N Ratio for	
	Various Displacements - Continued	7 - 27
7-12	Down-Link Loop-to-Loop S/N Ratio for	
	Various Displacements - Continued	7-28
7-13	Up-Link Loop-to-Loop S/N Ratio for	
	Various Displacements	7-29
7-14	Up-Link Loop-to-Loop S/N Ratio for	
	Various Displacements - Continued	7-30
7-15	Up-Link Loop-to-Loop S/N Ratio for	
	Various Displacements - Continued	7-31
7-16	Up-Link Loop-to-Loop S/N Ratio for	
	Various Displacements - Continued	7-32
7 - 17	LF Propagation (Theoretical - Fixed Station -	
-	NG 14)	7-33
7-18	LF Propagation (Theoretical - Portable -	
	NG 14)	7-34
7-19	LF Propagation (Theoretical - NG 14)	7-35

Section 1

Theoretical Approach to VLF Through-the-Earth Propagation

A knowledge of the mechanics of wave propagation through the earth is essential if reliable communication systems are to be designed for coal mine environments. To obtain a reliable basis from which accurate propagation predictions could be drawn, a series of theoretical studies have been prepared for the US Bureau of Mines by Mr. Ramsay Decker of Spectra Associates, Inc. through a subcontract with Collins Radio Group. These reports formulate the analytical techniques from which we may derive frequencies and antenna configurations that yield the optimum signal-to-noise ratios over the greatest distances in mine environments.

The reports of sections 2 and 4 deal with analytical techniques for determining the signal-tonoise ratio within a mine environment for loop-to-loop and line source-to-loop antenna configurations. The analytical results of these reports were then implemented into computer programs to obtain predictions concerning through-the-earth signal propagation. These preliminary predictions are based on noise data compiled by Bensema, Maxwell and Stone, and WVU prior to the extensive research conducted by the National Bureau of Standards (NBS). These initial measurements indicated a 20- to 30-dB lower noise level than that measured recently by NBS. The recent NBS data is that used by Collins in the final predictions.

The following outline indicates the order and subject matter treated in the subsequent sections:

- Section 2 Signal-to-Noise Analysis for Loop-to-Loop Mine Communications
- Section 3 The Horizontal Electric Dipole
- Section 4 Signal-to-Noise Analysis for Down-Link Line Source Mine Communications
- Section 5 LF Communication
- Section 6 The Application of Recent NBS Noise Data to Mine Communications
- Section 7 Analysis of Mine Communication Propagation Programs

Section 2

Signal-to-Noise Analysis for Loop-to-Loop Mine Communications

2.1 ABSTRACT

A method is developed for determining the signal-to-noise power density ratio for a horizontal surface loop (vertical magnetic dipole) to an underground horizontal loop antenna system for use in mine communications. The analysis accounts for the loop weight and diameter, depth, lateral displacement, and external noise fields. The analytic results provide for a computer method of numerical computation which can incorporate available noise data and data which may be derived from noise measurement programs in progress.

2.2 INTRODUCTION

Within the last few years there has been a concentration of theoretical and experimental investigations related to the delineation of telecommunications systems performance in mines. This has been emphasized because of the Mine Safety Act of 1969 and the several recent occurrences of mine disasters. The net result has been to stress the need for the requirements of an optimally integrated mine communications system, one in which both the operational and disaster modes could be accommodated.

As a first step in understanding those modes which may be useful in such systems, we consider through-the-earth propagation paths. Low frequency waves are transmitted through overburdens ranging in thickness from 150 to 1,500 feet. Two common methods of coupling into the mediums are employed; the loop or magnetic dipole and the line source, sometimes referred to as an earth probe (surface) or roof bolt (subsurface) antenna. This report considers loop-to-loop paths, and in particular only horizontal loops, (vertical magnetic dipole). Such loops (parallel vertical magnetic dipoles) exhibit maximum coupling when coplanar, while horizontal magnetic dipoles exhibit nulls and maxima as the antenna rotates, making it an unattractive coupling device for mine communications. Horizontal magnetic dipoles (HMD)* however, may be used as a subsurface source element for location determination since they produce a null in the vertical magnetic field component, and thus a VMD* used for detection would yield a higher S/N ratio since the surface atmospheric noise usually has a strong horizontal component; an additional argument in favor of the VMD.

^{*}Horizontal magnetic dipole, HMD; vertical magnetic dipole, VMD.

2.3 LOOP-TO-LOOP POWER TRANSFER WITHIN A HOMOGENEOUS MEDIUM

Layman* has recently published his doctoral dissertation in which he is concerned exclusively with communications through the earth between VMD's. The expressions are written for the magnetic field of a transmitting VMD (figure 2-1), located within a homogeneous medium of infinite extent (spherical coordinate system):

$$H_{r} = \frac{IA}{2\pi} \left(\frac{1+i}{\delta r^{2}} + \frac{1}{r^{3}} \right) \cos \theta e^{-\frac{r}{\delta}} \text{ amperes/meter}$$
(2-1)

$$H_{\theta} = \frac{IA}{4\pi} \left(\frac{2i}{\delta^2 r} + \frac{1+i}{\delta r^2} + \frac{1}{r^3} \right) \sin \theta e^{-\frac{r}{\delta}} \text{ amperes/meter}$$
(2-2)

in which
$$I = current$$
 in loop - amperes
 $A = loop area - square meters$
 $\delta = the skin depth - meters$

where

$$\frac{1}{\sqrt{\pi f u \sigma}}$$
 - meters

δ =

 $\sigma = \text{conductivity-mhos/meter}$

- μ = permeability -4 $\pi \times 10^{-7}$ henrys/meter
- f = frequency in Hz



Figure 2-1. Transmitting VMD.

^{*}Layman, G. E., "Optimization of an EM through the Earth Communication System" WVU PhD Thesis, Morgantown, West Virginia.

The vertical magnetic field at loop 2 is

$$H_{2z} = H_r \cos \theta - H_\theta \sin \theta \qquad (2-3)$$

and the open circuit voltages at the loop 2 terminals:

$$V_{02} = 4 \pi \omega N_2 A_2 H_{2Z} \times 10^{-7} \text{ volts}$$
 (2-4)

When the receive loop is matched to the real part of its self-impedance, the available received power is

$$\mathbf{P_r} = \frac{\mathbf{V_{02}}^2}{4\mathbf{R}_2} \text{ watts}$$
(2-5)

while the input power to the transmit loop is

$$P_{T} = I_{1}^{2} R_{1} \text{ watts}$$
 (2-6)

so that

$$\frac{P_{r}}{P_{t}} = \frac{V_{02}^{2}}{4R_{1}R_{2}I_{1}^{2}}$$
(2-7)

 R_1 and R_2 consist of the ohmic loss resistance plus the radiation resistance of the transmit and receive loops, respectively. The radiation resistance of an electrically small loop in free space is

$$R_{r} = 20\pi^{2} (ka)^{4} n^{2}$$
(2-8)

where

 $k = \frac{2\pi}{\lambda}$ a = loop radius in meters n = number of turns λ = wavelength in meters

If the loop were to be completely immersed and surrounded by the lossy medium, a considerable increase in the radiation resistance would occur. This situation is, however, neither operationally desirable nor advantageous from a propagation standpoint. It is far more realistic to consider the loop within an air filled cavity, in which case the effect of the lossy medium may be calculated:

$$R_{r} = \frac{\sigma \left(\omega \mu AN\right)^{2}}{6 \pi b} \left(1 + \frac{b}{\delta}\right) e^{-\frac{2b}{\delta}}$$
(2-9)

~ 1

where b is the cavity radius $<<\lambda$.

This equation shows simply that at typical cavity radii that loop wire losses greatly exceed the radiation resistance for frequencies below, say, 100 kHz.

Thus, considering only loop wire losses with coplanar loops, $\theta = \pi/2$ radians

$$H_{2z} = -H_{\theta}$$
$$V_{02} = -4 \pi \omega N_2 A_2 H_{\theta} \times 10^{-7}$$

then

so that

$$\frac{P_{r}}{P_{t}} \left| \theta = \frac{\pi}{2} = \frac{(\omega \mu N_{1} A_{1} N_{2} A_{2})^{2}}{64 \pi^{2} R_{1} R_{2} r^{2}} \left[\frac{4}{\delta^{4}} + \frac{4}{\delta^{3} r} + \frac{2}{\delta^{2} r^{2}} + \frac{2}{\delta r^{3}} + \frac{1}{r^{4}} \right] e^{-\frac{2r}{\delta}}.$$
 (2-10)

Similarly for $\theta = \pi$, coaxial magnetic dipoles

$$\frac{P_{r}}{P_{t}} \bigg|_{\theta} = \pi = \frac{(\omega \mu N_{1} A_{1} N_{2} A_{2})^{2}}{16 \pi^{2} R_{1} R_{2} r^{4}} \bigg[\frac{2}{\delta^{2}} + \frac{2}{\delta r} + \frac{1}{r^{2}} \bigg] e^{-\frac{2r}{\delta}}$$
(2-11)

The low frequency loss resistance of the loop can be estimated from $R_1 = 2\pi N_a R_W$ where R_W is the wire dc resistance Ω/m . The ratio of received to transmit power now becomes:

$$\frac{P_{r}}{P_{t}} \bigg|_{\theta} = \frac{\pi}{2} = \frac{f^{2} \mu^{2} \pi^{2} a_{1}^{3} a_{2}^{3} N_{1} N_{2}}{64 R_{w1} R_{w2} r^{2}} \bigg[\frac{4}{\delta^{4}} + \frac{4}{\delta^{3} r} + \frac{2}{\delta^{2} r^{2}} + \frac{2}{\delta r^{3}} + \frac{1}{r^{4}} \bigg] e^{-\frac{2r}{\delta}}$$
(2-12)

$$\frac{P_{r}}{P_{t}} \bigg|_{\theta} = \pi = \frac{f^{2} \mu^{2} \pi^{2} a_{1}^{3} a_{2}^{3} N_{1} N_{2}}{16 R_{w1} R_{w2} r^{4}} \bigg[\frac{2}{\delta^{2}} + \frac{2}{\delta r} + \frac{1}{r^{2}} \bigg] e^{-\frac{2r}{\delta}}$$
(2-13)

The terms which have a frequency dependence are collected viz $f^2 \begin{bmatrix} \\ \end{bmatrix} e^{-\frac{1}{\delta}}$, a differentiation with respect to f is performed, and an f_{opt} determined for the two cases:

$$\mathbf{f}_{\text{opt}} \middle|_{\boldsymbol{\Theta}} = \frac{\pi}{2} = \frac{3.78 \times 10^6}{\sigma \,\mathrm{r}^2} \tag{2-14}$$

$$f_{\text{opt}} = \pi = \frac{2.03 \times 10^6}{\sigma r^2}$$
, where r is in meters. (2-15)

These f_{opt} 's in turn yield a skin depth at the optimum frequency. The maximum power transfer conditions are found when these are substituted in equations (2-12) and (2-13).

$$\frac{P_{r}}{P_{t}} \bigg|_{\substack{\theta = \frac{\pi}{2}}} = \frac{1.81a_{1}^{3}a_{2}^{3}N_{1}N_{2}}{\sigma^{2}R_{w1}R_{w2}r^{10}}$$
(2-16)

and

$$\frac{P_{r}}{P_{t}} \bigg|_{\substack{\theta = \pi}} = \frac{.345a_{1}^{3}a_{2}^{3}N_{1}N_{2}}{\sigma^{2}R_{w1}R_{w2}r^{10}}$$
(2-17)

showing that under the assumed conditions f_{opt} is a function only of conductivity and loop separation and that at f_{opt} the power loss is proportional to separation to the tenth power.

2.4 LOOP-TO-LOOP POWER TRANSFER ON OR WITHIN A LOSSY HALF-SPACE

While the above analysis has shown some interesting results, the presence of the air-earth interface poses the problem which is considerably more realistic, that is, loop-to-loop communication on or within a lossy half space. Layman proceeds to formulate the classic boundary value problem (flat earth) with the magnetic Hertz vector, and a solution given in terms of a primary field and a secondary field resulting from the effect of the boundary. The secondary field was presented in terms of some rather cumbersome integral and numerical integrations which were performed. Calculations were made for various depths, loop separations, conductivities, for loops on the surface to subsurface loops and between subsurface loops. The upshot of these calculations showed the dominance of the primary field at the lower frequencies (corresponding to the infinite homogeneous medium) with respect to the secondary field. As a result, Layman was able to show that the maximum power transfer condition derived on the basis of an infinite homogeneous medium was also essentially valid for the lossy half space. The secondary field generally increased the power transfer at higher frequencies and thus is in essential agreement with Wait's* results, although a direct comparison is difficult since Layman failed to show losses between VMD loop on surface to subsurface VMD loop directly beneath.

The important observations from this analysis are as follows:

- a. The transmission path between two loops within a mine separated by a distance much greater than the depth is primarily through the upper half space at high frequencies.
- b. Placing the transmitting loop at the surface rather than within the mine results in only a small loss in received power if the range (R) is at least four times the depth (h). (See figure 2-2.)



Figure 2-2. Transmitting LCop at Surface.

^{*}Wait, J. R., "Location of a Buried Source by the EM Induction Technique:, IEEE Transactions of Geoscience Electronics, April 1971.

While the analysis has produced some meaningful results, and particularly in view of the second observation above, we are led to conclude that Wait's*,** recent analyses relative to VMD loops on or within a lossy half space are most applicable to the solution of mine S/N calculations. In an elegant fashion Wait proceeds to show that when the boundary value problem is properly formulated and the solution reduced to integrals that can be handled easily numerically that a lower loss is encountered through the medium than would be calculated by equation (2-1) or (2-2).

Now we consider a buried VMD with a receive loop on the surface. The vertical component of the magnetic field at the surface is

$$H_{z} = \frac{I_{1}A_{1}N_{1}Q}{2\pi h^{3}}$$
(2-18)

where	h = depth of transmit loop, km
	I = current in transmit loop in amperes
	N = number of turns in transmit loop

and

$$Q = \int_{0}^{\infty} \frac{x^{3} e^{-(x^{2} + iH^{2})} J_{0}(xD) dx}{x + (x^{2} + iH^{2})^{1/2}}$$

Proceeding as before we find for $\frac{P_r}{P_t}$,

$$\frac{P_{r}}{P_{t}} = \frac{\left[2\pi f N_{1} N_{2} A_{1} A_{2} Q \times 10^{-7}\right]^{2}}{R_{1} R_{2} h^{6}}$$
(2-19)

Now, of all the ways in which one can describe the practical limitations on loop size, weight and diameter have the most significance. Therefore, equation (2-19) will be rewritten in these terms. First, we substitute for the ohmic wire losses (dc)

$$R_1 = 2\pi N_1 a_1 R_w \text{ approximately}$$
(2-20)

now

$$R_w = \frac{1}{\sigma_w A_w}$$

^{*}Wait, J. R., "Location of a Buried Source by the EM Induction Technique", IEEE Transactions of Geoscience Electronics, April 1971.

^{**}Wait, J. R., "Subsurface EM Fields of a Circular-Loop of Current Located Above Ground", IEEE Transactions on Antennas and Propagation, July 1972.

$$\sigma_{\rm W}$$
 = wire conductivity, mhos/meter

$$A_W$$
 = wire area square meters

and

$$A_{w} = \frac{W}{2\pi a N \rho}$$
 square meters

w = weight in kg
$$\rho$$
 = wire density kg/m³

combining the above relations we have

$$\frac{P_{r}}{P_{t}} = \frac{\pi^{2} f^{2} a_{1}^{2} a_{2}^{2} (\frac{\sigma_{W}}{\rho})^{2} W_{1} W_{2} Q^{2} \times 10^{-14}}{4 h^{6}}$$
(2-21)

now

$$\frac{\sigma w}{\rho} = 6.52 \times 10^3 m^2 / \Omega - kg \text{ (copper)}$$

with a_1 , a_2 in meters W in kg, h in km, equation (2-22) becomes

$$\frac{P_{r}}{P_{t}} = \frac{1.05f^{2}a_{1}^{2}a_{2}^{2}W_{1}W_{2}Q^{2} \times 10^{-24}}{h^{6}}$$
(2-22)

 R_1 and R_2 have been taken simply as the dc resistance of loop. Because of skin effect the effective ac resistance will be somewhat higher. From Terman* for typical multilayer air core loops,

$$\frac{R_{ac}}{R_{dc}} \approx 1 + \frac{1}{4} (5.2m)^2 \left(\frac{d_0}{c}\right)^2 \frac{x^4}{64} \text{ for } x \gtrsim 2.5$$
(2-23)

where

 $x = .1078 \text{ d}\sqrt{f}$ d = wire diameter in cm m = number of layers $\frac{d_0}{c} = \text{effective wire spacing factor}$

where effective wire spacing factor = $\frac{\text{diameter of wire (cm)}}{\text{center-center spacing between turns on same layer}}$ Equation (2-23) will reduce $\frac{P_r}{P_t}$ for both loops, hence $\frac{P_r}{P_t}$ should be divided by $\left(\frac{R_{ac}}{R_{dc}}\right)^2$ for identical loops.

^{*}Terman, F. E., Radio Engineers Handbook, McGraw Hill, 1943, p 81.

2.4.1 System Signal-to-Noise Analysis

The equivalent noise figure of a receiving system is

$$\mathbf{F}_{s} = \mathbf{F}_{x} - 1 + \frac{\mathbf{F}_{r}}{\eta_{A}}$$
(2-24)

where

 F_X = the external noise figure

 F_r = the receive-noise figure

 η_A = the efficiency of the receive antenna

multiplying equation (2-24) by kT_0

$$kT_0F_s = kT_0(F_x-1) + \frac{kT_0F_r}{\eta_A}.$$

where K = Boltzmann's constant $T_0 = temperature in degree Kelvin$

The first term on the right is the available received noise power, hence we write

$$\mathbf{F}_{s} = \frac{\mathbf{P}_{nr}}{\mathbf{k}T_{0}} + \frac{\mathbf{F}_{r}}{\eta_{A}}$$
(2-25)

 \mathbf{or}

$$\mathbf{F_s} = \frac{\mathbf{V_{oc}}^2}{4\mathbf{R_r}^k\mathbf{T_0}} + \frac{\mathbf{F_rR_L}}{\mathbf{R_r}}$$

where R_r is the radiation resistance of a lossless antenna and R_L is the loss resistance. Now for systems analysis, it is reasonable to require the external noise contribution to be say 10 times that due to receiver noise and antenna inefficiency, hence we write

> $V_{oc}^{2} > 40 k T_{0} F_{r} R_{L}$ (2-26) $V_{oc} = 8 \pi^{2} f N_{2} A_{2} 10^{-7} H_{N}$

substituting

where ${\rm H}_N$ is the external noise field in <code>amperes/m/\sqrt{Hz}</code>

since
$$R_L = 2\pi N_2 a_2 R_W$$

and
$$R_{W} = \frac{2\pi a_{2}N_{2}}{W_{2}} \frac{\rho}{\sigma}$$

Solving for a_2 , the minimal radius of the receive loop is

$$a_2 > \frac{1.26 \times 10^{-6}}{fH_N} \sqrt{\frac{F_R}{W_2}}$$
 meters (2-27)

The Q_1 of the transmitter or receive loop can be estimated from the approximate inductance

$$L \approx 2.92 \text{aN}^2 \log_{10}(96.5a) \times 10^{-6}$$
 Henrys

Using the above relations for weight and wire losses we find

$$Q_{l} \approx \frac{1.515 \text{ f } \log_{10}(96.5a) \text{W x } 10^{-3}}{a}$$
 (2-28)

Now on the assumption that equation (2-27) holds, the system noise power/Hz bandwidth is

$$P_{nr} = 4\pi^4 f^2 a_2^2 H_N^2 W_2 \frac{\sigma}{\rho} \times 10^{-14}$$

Combining this with equation (2-22) we have finally for the received S/N power density ratio

$$\frac{P_{s}}{P_{no}} = \frac{4.13a_{1}^{2}W_{1}Q^{2}P_{T} \times 10^{-17}}{H_{N}^{2}h^{6}}$$
(2-29)

The equivalent background noise fields are shown in figure 2-3 for various noise conditions. These have been derived from Bensema*, WVU**, and Maxwell and Stone***. In the next paragraph, we shall describe a computer method for the S/N analysis which will incorporate the noise data of figure 2-3.

2.5 COMPUTER SIGNAL-TO-NOISE ANALYSIS FOR LOOP-TO-LOOP MINE COMMUNICATIONS

Based on the methods described in the preceding paragraphs, a computer method was written and calculations performed over the parametric ranges of interest.

^{*}Bensema, W. D., "Coal Mine ELF EM Noise Measurements," NBS Report 10739.

^{**}Mine Communication and Monitoring Second Quarterly and Intermediate Annual Technical Progress Report (5 September 1971 to 4 December 1971) Department of Electrical Engineering, WVU, Morgantown, West Virginia.

^{***}Maxwell and Stone, PGTAP, May 1963, page 339.



Figure 2-3. Equivalent Background Noise Fields.

2.5.1 Relation of Loop Design to System Performance

From equations (2-28) and (2-29), we note that the gain-bandwidth product of a loop-to-loop communications system is proportional to

$$\frac{{a_1}^3}{(1.984 + \log_{10} a_1)}$$

at frequencies generally in the audio range. From this, we see that the diameter of the transmit loop is far more important for information transfer than loop weight. When transmit loop diameter is maintained at a practical maximum and weight held at a minimum, then not only is the gain-bandwidth product improved, but it becomes more feasible to match the receive loop Q to the transmit loop Q so as to approach the minimum required radius of the receive loop. In other words, the minimum radius of the receive loop is not practically realizable for matched loop Q's unless the radius to weight ratio of the transmit loop is quite high, which increases the system gain-bandwidth product in the process. This requires a solution to the following equation:

$$\frac{a_1}{W_1(1.984 + \log_{10} a_1)} = \frac{a_2}{W_2(1.984 + \log_{10} a_2)}$$
(2-30)
$$a_2 = a_{2\min} = \frac{1.26 \times 10^{-6}}{fH_N} \sqrt{\frac{F_R}{W_2}}$$

The number of turns in a loop is

$$N = \frac{3.53 \,\mathrm{W} \,\mathrm{x} \,\,10^4}{\mathrm{aA_c}} \tag{2-31}$$

where

W = loop copper weight in kg a = loop radius - meters A_c = loop wire area in circular-mils

Thus, an optimal transmit loop is one of large diameter with a minimal number of turns.

The minimum number of turns for a fixed receive loop radius is

$$N_{\min} = \frac{4.41F_{R} \times 10^{-8} \pi}{f^{2} H_{N}^{2} A_{c} \times 4a_{2}^{3}}$$
(2-32)

2.5.2 System Noise Representation

As shown in figure 2-3, equivalent background noise fields were derived from the data of Bensema, WVU and Maxwell and Stone. For the down-link path three noise grades were established as follows:

- Noise Grade 1: Bensema figure 30, severe trolley noise. For frequencies above 3 kHz, this was merged into WVU's maximal noise data.
- Noise Grade 2: Bensema figure 27, no trolley noise. For frequencies above 3 kHz, this was given a frequency decrement derived from typical WVU data.
- Noise Grade 3: Bensema figure 37, 100 feet from borehole. For frequencies above 3 kHz, this was merged into WVU minimal noise.

For the up-link path, two noise grades were established as follows:

- Noise Grade 1: Maxwell and Stone "quasi" maximum surface noise. For frequencies below 1 kHz this was merged into Bensema's figure 25.
- Noise Grade 2: Maxwell and Stone median surface noise. For frequencies below 1 kHz this was merged into Bensema's figure 39.

2.5.3 Signal and Noise Processing

Low data rate transmission, which can be accommodated in the system bandwidth, offers no difficulty insofar as signal attenuation calculations at a specific carrier frequency is concerned. For broadband, for example, direct up or down-link voice transmission, however, the rms signal power must be calculated over the bandwidth of interest, that is,

$$\frac{P_{r}}{P_{t}} = \frac{4\pi^{2}N_{1}^{2}N_{2}^{2}A_{1}^{2}A_{2}^{2}\int_{1}^{f_{2}}f^{2}Q^{2}(f)df}{R_{1}R_{2}h^{6}}$$
(2-33)

The rms noise power is handled in exactly the same way.

$$P_{N} = \frac{64 \pi^{4} N_{2}^{2} A_{2}^{2} \times 10^{-14}}{4R_{2}} \int_{f_{1}}^{f_{2}} f^{2} H_{N}^{2}(f) df \qquad (2-34)$$

If the noise is primarily broadband impulsive, then the integral in equation (2-34) becomes simply a summation of the harmonic noise components. Because the effect of the overburden is to integrate the transmitted signal, it is self-suggestive that for broadband application the signal be differentiated before transmission and signal and/or noise differentiated upon reception. A. D. Little in their working memorandum no. 5 has considered this and has come to the conclusion that there is little to be gained by differentiation except for mine depths of approximately 400 feet or less. For the shallower depths, a 6-dB improvement in received S/N ratif can be realized for the same transmitter output power.

^{*}These noise grades were based on the noise data available at the time the analysis was done. They were ultimately replaced by new data. (See section 6 for more recent data.)

Reference should also be made to A. D. Little working memorandum no. 8 in which a hybrid harmonic commutator type filter is described. The author indicates a practical method of rejecting the impulsive harmonic content of the external noise fields.

2.5.4 Results of Signal-to-Noise Ratio Analysis

The techniques of the preceding sections have been incorporated in a computer method for the calculation of expected received signal-to-noise ratios. For the examples selected $\sigma = .01$ mho/m, a value which according to G. Keller is a good value to assume for coal mines less than 1,000 feet in depth. For the up-link we have assumed the following:

 $W_1 = 10 \text{ kg}$ $a_1 = 0.6 \text{ m} \text{ (transmit loop radius)}$ $P_t = 10 \text{ watts}$ Noise grade 2

For the down-link we have the following parameters:

 $W_1 = 200 \text{ kg}$ $a_1 = 10 \text{ m}$ $P_t = 10,000 \text{ watts}$ Noise grade 3

The received signal-to-noise ratios were calculated for depths of 100, 300, and 500 meters and lateral displacements of 0, 100, 200, 300, 400, and 500 meters. The results are shown in figures 2-4 through 2-9 of this section. We note at the shallower depths the optimal frequency is extremely broad, for example, where the depth equals the displacement. In fact a secondary maxima occurs at about 20 kHz. This is in essential agreement with Layman. With increasing depths the peak is nore pronounced and occurs essentially at 2 kHz. It appears that for an up-link with a portable transmit loop and a reasonable transmitter power, a 20 dB S/N₀ is practical on the surface for the 90 percentile mine depth of 300 meters. At the 500-meter depth with a maximum S/N₀ of 0 dB, obviously only extremely low data rates could be employed. The down-link curves indicate that at least a 40-dB increase in system gain can be achieved with respect to the up-link case. See page 2-14 for the correction factor for other transmit loop weights and diameters.

2.6 PREDICTIONS FOR THEORETICAL S/N₀

From the foregoing development of theoretical signal-to-noise analysis for the loop-to-loop configuration, we may state the following:

- a. VMD (verticle magnetic dipole) arrangement yields a higher S/N_0 ratio than does HMD (horizontal magnetic dipole).
- b. The transmission path between two loops within a mine separated by a distance much greater than the depth is primarily through the upper half space at high frequencies.
- c. Placing the transmitting loop at the surface rather than within the mine results in only a small loss in received power if the separation is at least four times the depth.

- d. Diameter of the transmit loop is far more important for information transfer than loop weight. By maintaining transmit loop diameter at a practical maximum and weight at a minimum, improved gain bandwidth can be obtained and it becomes more feasible to match the receive loop Q to transmit loop Q.
- e. Optimal frequency range is extremely broad at shallower depths, but becomes more pronounced with increased depth.
- f. Correction factor for loop-to-loop transmission is as follows:

$$10 \log \left(\frac{W}{W_0}\right) + 20 \log \left(\frac{a}{a_0}\right) + 10 \log \left(\frac{P}{P_0}\right)$$

where W = weight of transmitting loop

 W_0 = weight of reference loop

- a = radius of transmitting loop
- $a_0 = radius$ of reference loop

P = power into transmitting loop

 P_0 = power into reference loop











Figure 2-6. Receive Signal-to-Noise Ratios as a Function of Lateral Displacement and Frequency (500 m).



Figure 2-7. Receive Signal-to-Noise Ratios as a Function of Lateral Displacement and Frequency (100 m).









Section 3

The Horizontal Electric Dipole

We shall now develop the signal-to-noise power density ratio for a horizontal electric dipole as we did for the loop source in section 2. A method described by Sommerfeld in 1909 forms the basis for determining the field components due to an elementary vertical or horizontal dipole located near the interface of a conducting half space. The hertz vector in this problem is comprised of the primary potential of the source plus the secondary potential due to the interface.

3.1 THE FIELD EQUATIONS FOR A SUBMERGED HORIZONTAL ELECTRIC DIPOLE

Assume a plane interface between air and earth, with the horizontal hertz dipole source located on the z-axis in the conducting half space at a depth of +h and aligned with the x-axis (figure 3-1). A cylindrical coordinate system is employed, with the z-axis vertical with ρ measured radially along the surface, and with the angle ϕ measured from the x-axis. A time factor e^{iwt} is assumed.



Figure 3-1. Submerged Horizontal Electric Dipole.

The hertz potential underground for this case has two components that follow directly from Sommerfeld:

$$II_{\mathbf{X}} = \frac{IdI}{4\pi(\sigma + i\epsilon_{1}\omega)} \int_{0}^{\infty} J_{0}(\lambda\rho) \left[e^{-u_{1}(z-h)} + \frac{u_{1}^{-u_{0}}}{u_{1}^{+u_{0}}} e^{-u_{1}(z+h)} \right] \frac{\lambda d\lambda}{u_{1}}$$
(3-1)

$$II_{z} = \frac{Idl \cos \phi}{2\pi (\sigma + i\epsilon_{1}\omega)\gamma_{0}^{2}} \int_{0}^{\infty} J_{1}(\lambda \rho) \frac{u_{1} - u_{0}}{N_{1}^{2} u_{0}^{+} u_{1}} e^{-u_{1}(z+h)\lambda^{2}} d\lambda$$
(3-2)

where
$$Y_1^2 = j\mu_0 \omega (\sigma_1 + j\epsilon_1 \omega)$$

 $\gamma_0^2 = j\mu_0 \omega (j\epsilon_0 \omega)$
 $u_0 = (\lambda^2 + \gamma_0^2)^{1/2}$
 $u_1 = (\lambda^2 + \gamma_1^2)^{1/2}$
 $\mu_0 = 4 \pi \ge 10^{-7} \text{ H/m}$
 $\omega = 2\pi f$
 $\epsilon_0 = \frac{1}{36\pi} \ge 10^{-9} \text{ F/m}$
 $N_1^2 = \frac{\gamma_1^2}{\gamma_0^2} = \frac{(\sigma_1 + j\epsilon_1 \omega)}{j\epsilon_0 \omega}$

Equations (3-1) and (3-2) represent a solution of the wave equation that satisfies the boundary conditions requiring the tangential components of E and H to be continuous across the boundary, between media.

The electric and magnetic fields may be obtained from

$$\tilde{E} = \text{grad div II} - \gamma_1^2 \text{II}$$
(3-3)

and

$$\widetilde{H} = \frac{\gamma_1^2}{j\omega\mu_0} \text{ curl II}$$
(3-4)

from equations (3-3) and (3-4), we obtain the tangential and vertical components of \widetilde{E} and \widetilde{H} :

$$E_{\rho} = -\gamma_1^2 \cos\phi II_x + \cos\phi \frac{\delta^2 II_x}{\delta_{\rho^2}} + \frac{\delta^2 II_z}{\delta_z \delta_{\rho}}$$
(3-5)

$$E\phi = \gamma_1^2 \sin\phi II_x - \frac{\sin\phi}{\rho} \frac{\delta II_x}{\delta\rho} + \frac{1}{\rho} \frac{\delta^2 II_z}{\delta_z \delta\phi}$$
(3-6)

$$E_{z} = -\gamma_{1}^{2}II_{z} + \cos\phi \frac{\delta^{2}II_{x}}{\delta\rho\delta_{z}} + \frac{\delta^{2}II_{z}}{\delta_{z}^{2}}$$
(3-7)

$$H_{\rho} = \frac{\gamma_{1}^{2}}{j\mu_{0}\omega} (\sin\phi \frac{\delta II_{x}}{\delta_{z}} + \frac{1}{\rho} \frac{\delta II_{z}}{\delta\phi})$$
(3-8)

$$H_{\phi} = \frac{\gamma_1^2}{j\mu_0 \omega} (\cos \phi \frac{\delta II_x}{\delta_z} - \frac{\delta II_z}{\delta \rho})$$
(3-9)

0

$$H_{z} = \frac{-\sin\phi\gamma_{1}^{2}}{j\mu_{0}\omega} \frac{\delta II_{x}}{\delta\rho}$$
(3-10)

Thus we see that for $\mathbf{E} \boldsymbol{\rho}$

$$E\rho = \cos\phi \left[-\gamma_1^2 + \frac{\delta^2}{\delta\rho^2} \right] \left[II_x^{(p)} + II_x^{(s)} \right] + \frac{\delta^2 II_z}{\delta z \delta\rho}$$
(3-11)

where

$$II_{X}^{(p)} = \frac{Idl}{4\pi(\sigma + i\epsilon\omega)} \int_{0}^{\infty} J_{0}(\lambda\rho) e^{-u_{1}(z-h)} \frac{\lambda d\lambda}{\mu_{1}} = \frac{Idl}{4\pi(\sigma + i\epsilon\omega)} \frac{\exp(-\gamma_{1}r)}{r}$$
(3-12)

(primary field)

where

$$\mathbf{r} = \left[\boldsymbol{\rho}^{2} + (z - h)^{2} \right]^{1/2}$$

II_x^(s) = $\frac{\mathrm{Idl}}{4\pi(\sigma + i\epsilon\omega)} \int_{0}^{\infty} J_{0}(\lambda \rho) \frac{(u_{1} - u_{0})}{(u_{0} + u_{1})} - u_{1}(z + h)}{\frac{\lambda d\lambda}{u_{1}}}$ (3-13)

(secondary potential due to interface)

The primary field $E \rho^{(p)}$ follows easily from equation (3-12).

$$E\rho^{(p)} = \frac{-\mathrm{Idl}\,\cos\phi\,\mathrm{e}^{-\gamma}r}{4\pi(\sigma+\,\mathrm{i}\epsilon\omega)\rho^{3}} \left(\frac{\rho}{r}\right)^{3} \left[1 + \gamma\,\mathrm{r} + \gamma^{2}r^{2} - \left(\frac{\rho}{r}\right)^{2} \left[3 + 3\gamma\,\mathrm{r} + \gamma^{2}r^{2}\right]\right]$$
(3-14)

where $\rho = r$ (point P at same depth as HED)

$$E \rho^{(p)} = \frac{+IdI \cos \phi e^{-\gamma \rho} \left[\gamma \rho + 1\right]}{2\pi (\sigma + i\epsilon \omega) \rho^3}$$
(3-15)

Utilizing the recurrence relations for the derivatives of the Bessel functions:

_

$$\frac{\mathrm{dJ}_{0}(\lambda\rho)}{\mathrm{d}\rho} = -\lambda J_{1}(\lambda\rho)$$
$$\frac{\mathrm{dJ}_{1}(\lambda\rho)}{\mathrm{d}\rho} = \lambda \left[-\frac{J_{1}(\lambda\rho)}{\rho\lambda} + J_{0}(\lambda\rho) \right]$$

and

The secondary field (including that due to II_{Z}) is therefore:

$$E_{\rho}^{(S)} = \frac{\mathrm{Idl}\cos\phi}{4\pi(\sigma+\mathrm{i}\epsilon\omega)} \int_{0}^{\infty} \frac{\left[J_{0}(\lambda\rho)u_{1}^{2}\lambda\rho - J_{1}(\lambda\rho)\lambda^{2}\right]}{\rho u_{1}} \frac{u_{0}^{-u}u_{1}}{u_{1}^{+u}u_{0}} e^{-u_{1}(z+h)} d\lambda$$
$$+ \frac{\mathrm{Idl}\cos\phi}{2\pi(\sigma+\mathrm{i}\epsilon\omega)} \gamma_{0}^{2} \int_{0}^{\infty} \frac{1\lambda^{2}}{\rho} \left[J_{0}(\lambda\rho)\lambda\rho - J_{1}(\lambda\rho)\right] \frac{u_{0}^{-u}u_{1}}{N_{1}^{2}u_{0}^{+u}u_{1}} e^{-u_{1}(z+h)} d\lambda \quad (3-16)$$

Similarly for E_{ϕ} :

$$E\phi = \sin\phi \left[\gamma_1^2 - \frac{1}{\rho} \frac{d}{d\rho}\right] \left[\Pi_x^{(p)} + \Pi_x^{(s)}\right] + \frac{1}{\rho} \frac{\delta \Pi_z^{.}}{\delta z \delta \phi}$$
(3-17)

$$E\phi^{(p)} = \frac{IdI \sin\phi e^{-\gamma \dot{r}}}{4\pi (\sigma + i\epsilon\omega)\rho^3} \left(\frac{\rho}{r}\right)^3 \left[\gamma^2 r^2 + \gamma r + 1\right]$$
(3-18)

$$\mathbf{E}\boldsymbol{\phi}^{(\mathbf{S})} = \frac{\mathrm{Idl}\,\sin\boldsymbol{\phi}\,\boldsymbol{\gamma}_{1}^{2}}{4\pi(\boldsymbol{\sigma}+\,\mathbf{i}\,\boldsymbol{\epsilon}\,\boldsymbol{\omega})} \int_{0}^{\infty} \mathbf{J}_{0}(\boldsymbol{\lambda}\boldsymbol{\rho}) \frac{\mathbf{u}_{1}-\mathbf{u}_{0}}{\mathbf{u}_{0}+\mathbf{u}_{1}} e^{-\mathbf{u}_{1}(\mathbf{z}+\mathbf{h})} \frac{\boldsymbol{\lambda}\,\mathrm{d}\,\boldsymbol{\lambda}}{\mathbf{u}_{1}}$$
(3-19)

$$+ \frac{\operatorname{Idl} \sin \phi}{4\pi(\sigma + i\epsilon\omega)} \int_{0}^{\infty} \frac{J_{1}(\lambda\rho)}{\rho} \frac{u_{1}^{-u_{0}}}{u_{0}^{+u_{1}}} e^{-u_{1}(z+h)} \frac{\lambda^{2} d\lambda}{u_{1}}$$
$$+ \frac{\operatorname{Idl} \sin \phi}{2\pi(\sigma + i\epsilon\omega)\gamma_{0}^{2}} \int_{0}^{\infty} \frac{J_{1}(\lambda\rho)}{\rho} \frac{u_{1}^{-u_{0}}}{N_{1}^{2}u_{0}^{+u_{1}}} e^{-u_{1}(z+h)} u_{1}\lambda^{2} d\lambda$$

We are interested primarily in

$$H_{\phi}^{(p)} = \frac{-\mathrm{Idl}\cos\phi}{4\pi} \frac{\mathrm{e}^{-\mathrm{r}}}{\rho^{2}} \left(\frac{\rho}{\mathrm{r}}\right)^{2} \left[\gamma_{\mathrm{r}} + 1\right] \left[1 - \frac{\rho^{2}}{\mathrm{r}^{2}}\right]^{1/2}$$
(3-21)

$$H_{\phi}^{(S)} = \frac{-IdI \cos \phi}{4\pi} \int_{0}^{\infty} J_{0}(\lambda \rho) \frac{u_{1} - u_{0}}{u_{0} + u_{1}} e^{-u_{1}(z+h)} \lambda d\lambda$$
(3-22)

$$+ \frac{\mathrm{Idl}\cos\phi}{2\pi\gamma_0^2} \int_0^\infty \left[\frac{\mathrm{J}_1(\lambda\rho)}{\rho} - \lambda \mathrm{J}_0(\lambda\rho) \right] \frac{\mathrm{u}_1 - \mathrm{u}_0}{\mathrm{N}_1^2 \mathrm{u}_0 + \mathrm{u}_1} e^{-\mathrm{u}_1(z+h)} \lambda^2 \mathrm{d} \lambda$$

$$H_{\rho} = \frac{\gamma_{1}^{2}}{j\mu_{0}\omega} \sin\phi \frac{\delta}{\delta z} \left[II_{x}^{(p)} + II_{x}^{(s)} \right] + \frac{\gamma_{1}^{2}}{j\mu_{0}\omega} \frac{1}{\rho} \frac{\delta II_{z}}{\delta \phi}$$
(3-23)

$$H\rho^{(p)} = \frac{-IdI}{4\pi} \frac{\sin \phi}{\rho^2} \frac{e^{-\gamma r}}{\rho^2} \left(\frac{\rho}{r}\right)^2 \left[\gamma r + 1\right] \left[1 - \frac{\rho^2}{r^2}\right]^{1/2}$$
(3-24)

3-4

$$H_{\rho}^{(S)} = \frac{-\mathrm{Idl} \sin \phi}{4 \pi} \int_{0}^{\infty} J_{0}^{(\lambda \rho)} \frac{u_{1}^{-u_{0}}}{u_{0}^{+u_{1}}} e^{-u_{1}^{(z+h)}} \lambda d\lambda \qquad (3-25)$$
$$-\frac{-\mathrm{Idl} \sin \phi}{2 \pi \gamma_{0}^{2}} \int_{0}^{\infty} \frac{J_{1}^{(\lambda \rho)}}{\rho} \frac{u_{1}^{-u_{0}}}{N_{1}^{2} u_{0}^{+u_{1}}} e^{-u_{1}^{(z+h)}} \lambda^{2} d\lambda$$

$$H_{z} = \frac{-\sin\phi\gamma_{1}^{2}}{j\mu_{0}\omega} \frac{\delta}{\delta\rho} \left[\Pi_{x}^{(p)} + \Pi_{x}^{(s)} \right]$$
(3-26)

$$H_{z}^{(p)} = \frac{\text{Idl } \sin\phi}{4\pi\rho^{2}} \left(\frac{\rho}{r}\right)^{3} e^{-\gamma r} \left[\gamma r + 1\right]$$
(3-27)

$$H_{z}^{(s)} = \frac{IdI \sin \phi}{4\pi} \int_{0}^{\infty} J_{1}(\lambda \rho) \frac{u_{1}^{-u_{0}}}{u_{1}^{+u_{0}}} e^{-u_{1}(z+h)} \frac{\lambda^{2} d\lambda}{u_{1}}$$
(3-28)

Thus we see that broadside to the dipole ($\phi = \pi/2$), we have H_{\rho} and H_z field components, whereas at $\phi = 0$, H ϕ is the only magnetic field component. The primary field contributions to H_ρ and H_φ vanish however at $\rho = r$ (receiving point at same depth as the dipole).

3.2 THE SUBMERGED VERTICAL MAGNETIC DIPOLE

For completeness in intramine communications we shall indicate the expressions for the submerged VMD. The VMD on the surface has been treated exhaustively by Wait 1, 2; however, computational procedures are needed for the submerged VMD which will adequately account for the interfaces. The hertz potential is

$$II_{z}^{*} = \frac{IdA}{4\pi} \int_{0}^{\infty} J_{0}(\lambda\rho) \left(e^{-u_{1}(z-h)} + \frac{u_{1}-u_{0}}{u_{1}+u_{0}} \right) e^{-u_{1}(z+h)} \frac{\lambda d\lambda}{u_{1}}$$
$$H_{z} = \left(-\gamma_{1}^{2} + \frac{\delta}{\delta_{z}^{2}} \right) \left(II_{z}^{*(p)} + II_{z}^{*(s)} \right)$$

and

by some simple algebra we find

$$H_{z}^{(p)} = \frac{IdA}{4\pi\rho^{3}} e^{-\gamma r} \left(\frac{\rho}{r}\right)^{3} \left\{ -1 - \gamma r(1 + \gamma r) + \left[1 - \left(\frac{\rho}{r}\right)^{2}\right] x \left[3(1 + \gamma r) + \gamma^{2} r^{2}\right] \right\}$$

^{1.} Characteristics of Antennas Over Lossy Earth, J. R. Wait. Chapter 23 of "Antenna Theory," Edited by Collin and Zucker.

^{2.} On Radio Propagation Through the Earth, J. R. Wait. IEEE Transactions on Antennas and Propagation, volume AP-19, no. 6, November 1971, pp 796-798.

$$H_{z}^{(s)} = \frac{-IdA \gamma_{1}^{2}}{4 \pi} \int_{0}^{\infty} J_{0}(\lambda \rho) \frac{u_{1} - u_{0}}{u_{1} + u_{0}} e^{-u_{1}(z+h)} \frac{\lambda d\lambda}{u_{1}}$$
$$+ \frac{IdA}{4 \pi} \int_{0}^{\infty} J_{0}(\lambda \rho) \frac{u_{1} - u_{0}}{u_{1} + u_{0}} e^{-u_{1}(z+h)} u_{1} \lambda d\lambda$$
$$= \frac{IdA}{4 \pi} \int_{0}^{\infty} J_{0}(\lambda \rho) \frac{u_{1} - u_{0}}{u_{1} + u_{0}} e^{-u_{1}(z+h)} \frac{\lambda^{3}}{u_{1}} d\lambda$$
$$E \rho \equiv 0 \quad : \quad E \phi^{(p)} = \frac{-j\mu_{0}\omega I_{0} dA e^{-\gamma r} [\gamma_{1}r + 1]}{4 \pi} \frac{\rho}{r^{3}}$$
$$E \phi^{(s)} = \frac{jI_{0} dA \mu_{0} \omega}{4 \pi} \int_{0}^{\infty} J_{1}(\lambda \rho) \frac{u_{0} - u_{1}}{u_{0} + u_{1}} e^{-u_{1}(z+h)} \frac{\lambda^{2} d\lambda}{u_{1}} = \frac{jI_{0} dA \mu_{0} \omega I_{2}}{4 \pi}$$

3.3 THE SUBMERGED HED AND VMD*

From the foregoing development we may write the expressions for the primary fields at a point P (ρ,ϕ,z) for a submerged HED.

$$E_{\rho}^{(p)} = -A\cos\phi \frac{e^{-\gamma r}}{\rho^{3}} \left(\frac{\rho}{r}\right)^{3} \left[1 + \gamma r + \gamma^{2} r^{2} - \left(\frac{\rho}{r}\right)^{2} \left[3 + 3\gamma r + \gamma^{2} r^{2}\right]\right] \qquad (3-29)$$

$$E\phi^{(p)} = A\sin\phi \frac{e^{-\gamma r}}{\rho^3} \left(\frac{\rho}{r}\right)^3 \left[\gamma^2 r^2 + \gamma r + 1\right]$$
(3-30)

$$H\phi^{(p)} = -B\cos\phi \frac{e^{-\gamma_{r}}}{\rho^{2}} \left(\frac{\rho}{r}\right)^{2} \left[\gamma_{r} + 1\right] \left[1 - \frac{\rho^{2}}{r^{2}}\right]^{1/2}$$
(3-31)

$$H\rho^{(p)} = -B\sin\phi \frac{e^{-\gamma r}}{\rho^2} \left(\frac{\rho}{r}\right)^2 \left[\gamma r + 1\right] \left[1 - \frac{\rho^2}{r^2}\right]^{1/2}$$
(3-32)

$$H_{z}^{(p)} = B \sin \phi \frac{e^{-\gamma r}}{\rho^{2}} \left(\frac{\rho}{r}\right)^{3} \left[\gamma r + 1\right]$$
(3-33)

For the VMD our prime concern is ${\rm H}_{\rm Z}$

$$H_{z}^{(p)} = \frac{C}{\rho 3} e^{-\gamma r} \left(\frac{\rho}{r}\right)^{3} \left[-1 - \gamma r (1 + \gamma r) + \left[1 - \frac{\rho^{2}}{r^{2}} \right] x \left[3(1 + \gamma r) + \gamma^{2} r^{2} \right] \right]$$
(3-34)

where

and

A =
$$\frac{I(dl)}{4\pi (\sigma + i\epsilon\omega)}$$
 B = $\frac{I(dl)}{4\pi}$ C = $\frac{IAN}{4\pi}$

^{*(}a) The Field Equations for a Submerged Horizontal Electric Dipole, 4 January 1973, R. P. Decker, Spectra Associates, Inc.

⁽b) The Submerged HED and VMD-II, 8 January 1973, R. P. Decker, Spectra Associates, Inc.

For the computation of the secondary fields we define the following integrals:

$$I_{1} = \int_{0}^{\infty} J_{0}(\lambda \rho) \frac{u_{0}^{-u} I}{u_{1}^{+u} 0} e^{-u_{1}(z+h)} u_{1}^{\lambda} d\lambda$$
(3-35)

$$I_{2} = \int_{0}^{\infty} \frac{J_{1}(\lambda \rho)}{\rho} \frac{u_{0} - u_{1}}{u_{1} + u_{0}} e^{-u_{1}(z+h)} \frac{\lambda^{2}}{u_{1}} d\lambda$$
(3-36)

$$I_{3} = \int_{0}^{\infty} J_{0}(\lambda \rho) \frac{u_{0} - u_{1}}{N_{1}^{2} u_{0} + u_{1}} e^{-u_{1}(z+h)} u_{1} \lambda^{3} d\lambda \qquad (3-37)$$

$$I_{4} = \int_{0}^{\infty} \frac{J_{1}(\lambda \rho)}{\rho} \frac{u_{0} - u_{1}}{N_{1}^{2} u_{0} + u_{1}} e^{-u_{1}(z+h)} u_{1} \lambda^{2} d\lambda \qquad (3-38)$$

$$I_{5} = \int_{0}^{\infty} J_{0}(\lambda \rho) \frac{u_{0}^{-u} 1}{u_{0}^{+u} 1} e^{-u_{1}(z+h)} \frac{\lambda d\lambda}{u_{1}}$$
(3-39)

$$I_{6} = \int_{0}^{\infty} J_{0}(\lambda \rho) \frac{u_{0}^{-u_{1}}}{u_{0}^{+u_{1}}} e^{-u_{1}(z+h)} \lambda d\lambda$$
(3-40)

$$I_{7} = \int_{0}^{\infty} \frac{J_{1}(\lambda \rho)}{\rho} \frac{u_{0} - u_{1}}{N_{1}^{2} u_{0} + u_{1}} e^{-u_{1}(z+h)} \lambda^{2} d\lambda$$
(3-41)

$$I_8 = \int_0^\infty J_0(\lambda \rho) \frac{u_0 - u_1}{N_1^2 u_0 + u_1} e^{-u_1(z+h)} \lambda^3 d\lambda$$
(3.-42)

$$I_{9} = \int_{0}^{\infty} J_{1}(\lambda \rho) \frac{u_{0}^{-u} 1}{u_{1}^{+u} 0} e^{-u_{1}(z+h)} \frac{\lambda^{2} d \lambda}{u_{1}}$$
(3-43)

$$I_{10} = \int_0^\infty J_0(\lambda \rho) \frac{u_0 - u_1}{u_1 + u_0} e^{-u_1(z+h)} \frac{\lambda^3 d\lambda}{u_1}$$
(3-44)

The field equations therefore become

$$E_{\rho} = E_{\rho}^{(p)} + A\cos\phi(I_1 - I_2) + \frac{2A\cos\phi}{\gamma_0^2}(I_3 - I_4)$$
(3-45)

$$\mathbf{E}\boldsymbol{\phi} = \mathbf{E}\boldsymbol{\phi}^{(\mathbf{p})} - \gamma_1^2 \mathbf{A} \sin \boldsymbol{\phi} \mathbf{I}_5 + \mathbf{A} \sin \boldsymbol{\phi} \mathbf{I}_2 + 2\mathbf{A} \sin \boldsymbol{\phi} \mathbf{I}_4 \qquad (3-46)$$

3 - 7

$$H\phi = H\phi^{(p)} + B\cos\phi I_{6} - \frac{2B\cos\phi}{\gamma_{0}^{2}}I_{7} + \frac{2B\cos\phi}{\gamma_{0}^{2}}I_{8}$$
(3-47)

$$H_{\rho} = H_{\rho}^{(p)} + Bsin\phi I_{6} + \frac{2Bsin\phi}{\gamma_{0}^{2}} I_{7}$$

$$H_{z} = H_{z}^{(p)} - Bsin\phi I_{9}$$

$$H_{z}(VMD) = H_{z}^{(p)}(VMD) - CI_{10}$$
(3-48)

Now we introduce the transformations used by Wait

$$x = \lambda \rho$$

$$D = (z+h)/\rho$$

$$\Gamma = \gamma \rho$$

$$U = (x^{2} + \Gamma^{2})^{1/2}$$

$$U_{0} = (x^{2} - (\frac{\omega \rho}{c})^{2})^{1/2}$$

$$K = N_{1}^{2}$$

$$R(x) = \frac{U_{0} - U_{1}}{U_{1} + KU_{0}}$$

$$T(x) = \frac{U_{0} - U_{1}}{U_{0} + U_{1}}$$

The transformed integrals become

$$I_{1} = \frac{1}{\rho^{3}} \int_{0}^{\infty} J_{0}(x) T(x) \exp(-UD) Ux dx$$
 (3-49)

$$I_2 = \frac{1}{\rho^3} \int_0^\infty J_1(x) T(x) \exp\left(\frac{-UD}{U}\right) x^2 dx$$
 (3-50)

$$I_{3} = \frac{1}{\rho 5} \int_{0}^{\infty} J_{0}(x) R(x) \exp(-UD) Ux^{3} dx \qquad (3-51)$$

$$I_{4} = \frac{1}{\rho 5} \int_{0}^{\infty} J_{1}(x) R(x) \exp(-UD) Ux^{2} dx \qquad (3-52)$$

$$I_{5} = \frac{1}{\rho} \int_{0}^{\infty} J_{0}(x) T(x) \exp\left(\frac{-UD}{U}\right) x dx$$
 (3-53)

$$I_{6} = \frac{1}{\rho^{2}} \int_{0}^{\infty} J_{0}(x) T(x) \exp(-UD) x dx$$
 (3-54)

3 - 8
$$I_{7} = \frac{1}{\rho 4} \int_{0}^{\infty} J_{1}(x) R(x) \exp(-UD) x^{2} dx \qquad (3-55)$$

$$I_8 = \frac{1}{\rho 4} \int_0^\infty J_0(x) R(x) \exp(-UD) x^3 dx$$
 (3-56)

$$I_{9} = \frac{1}{\rho^{2}} \int_{0}^{\infty} J_{1}(x) T(x) \exp\left(\frac{-UD}{U}\right) x^{2} dx \qquad (3-57)$$

$$I_{10} = \frac{1}{\rho^3} \int_0^\infty J_0(x) T(x) \exp(-UD) x^3 dx$$
 (3-58)

As pointed out by Wait, these integrals must be integrated cautiously because of the various branch points and poles. Following the same approach we define the limits of each subinter-val used for integration.

$$\begin{aligned} \mathbf{x}_{1} &= 0, \, \mathbf{x}_{2} = \mathbf{Z}_{0} - \Delta_{0}, \, \mathbf{x}_{3} = \mathbf{Z}_{0} - \Delta_{\mathrm{K}}, \, \mathbf{x}_{4} = \mathbf{Z}_{0} + \Delta_{\mathrm{K}}, \, \mathbf{x}_{5} = \mathbf{Z}_{0} + \Delta_{0} \\ \mathbf{x}_{6} &= \left[\mathbf{R}_{e} \Gamma^{2} \right]^{1/2}, \, \mathbf{x}_{7} = 2\mathbf{x}_{6}, \, \mathbf{x}_{8} = 3\mathbf{x}_{6}, \, \mathbf{x}_{9} = 4\mathbf{x}_{6}, \, \mathbf{x}_{10} = 6\mathbf{x}_{6} \\ \mathbf{Z}_{0} &= \frac{\omega\rho}{c} \qquad \Delta = \mathbf{Z}_{0} \, \left| 1 - \left(\frac{\mathrm{K}}{\mathrm{K} + 1} \right)^{1/2} \right| \end{aligned}$$

The results of this analysis will be described in paragraph 3.4. For the line source, we shall use a contact resistance of 100 ohms. For the VMD, the current moment will be computed from

IAN =
$$0.5a \sqrt{(W)(P_t)(6.52)(10^{+3})}$$
 (3-59)

where

W = weight of loop in kg

 P_t = transmitted power in watts

a = loop radius in meters

3.4 THE FIELD COMPONENTS OF A SUBMERGED INFINITE LINE SOURCE

In this note we assume a wire of infinite length located in the xz-plane at a depth, h, and carrying a current of uniform amplitude and phase, $Ie^{i\omega t}$. Such an antenna radiates a cylindrical wave, in contrast to the spherical wave radiated from a hertz dipole (figure 3-2). We are concerned first with an expression for the primary hertz potential, that is, that under ground.



Figure 3-2. Submerged Infinite Line Source.

The hertz potential due to the elementary current moment I(dx) is

$$dII = \frac{I(\delta x)e}{4\pi(\sigma + i\epsilon\omega)R}$$

$$R = \sqrt{r^2 + x^2} \quad \text{and } r = \sqrt{v^2 + (z-h)^2}$$
(3-60)

where

and R is the distance between the current element and point P (in y-z plane), and $r = \sqrt{y^2 + (y-h)^2}$ is the radial distance of P from the wire.

This potential has only an x-component. The total potential at P is

$$II = \frac{I}{4\pi(\sigma + i\epsilon\omega)} \int_{-\infty}^{\infty} \frac{e^{-\gamma_1 R}}{R} dx = \frac{I}{2\pi(\sigma + i\epsilon\omega)} \int_{0}^{\infty} \frac{e^{-\gamma_1 R}}{R} dx$$
(3-61)

since

we have

$$dR = \frac{xdx}{R} \quad \text{or} \quad dx = \frac{RdR}{\sqrt{R^2 - r^2}}$$
$$II = \frac{I}{2\pi(\sigma + i\epsilon\omega)} \int_{r}^{\infty} \frac{e^{-\gamma_1 R}}{\sqrt{R^2 - r^2}} dR \quad (3-62)$$

Let $\dot{R} = r\mu$, where μ is a new variable of integration and r is a fixed radial distance. Then

$$II = \frac{I}{2\pi (\sigma + i\epsilon\omega)} \int_{1}^{\infty} \frac{e^{-\gamma_{1}r\mu}}{\sqrt{\mu^{2} - 1}}$$
(3-63)

since

$$\int_{1}^{\infty} \frac{e^{-ixt}dt}{\sqrt{t^2 - 1}} = -i\frac{\pi}{2} H_0^{(2)}(x)$$

equation (3-63) becomes

$$II = \frac{-I}{4(\sigma + i\epsilon\omega)} H_0^{(2)} (-j\gamma_1 r)$$
(3-64)

Here, $H_0^{(2)}$ is the second kind of Hankel function of zero order. Its asymptotic form at large distances is

$$H_0^{(2)}(-j\gamma_1 r) \cong \left(\frac{2}{-j\pi\gamma_1 r}\right)^{1/2} e^{i\pi/4} e^{-\gamma_1 r}$$
(3-65)

This is clearly an outgoing cylindrical wave.

By the use of the Sommerfeld integral representation for the Hankel function

$$H_0^{(2)}(-j\gamma_1 r) = \frac{1}{\pi} \int_{-(\pi/2 + i\infty)}^{(\pi/2 + i\infty)} e^{-\gamma_1 r \cos \gamma} d\gamma$$
(3-66)

The Weyl transformation

$$H_0^{(2)}(-j\gamma_1 r) = \frac{1}{\pi} \int e^{-\gamma_1 r \cos a} da \qquad (3-67)$$

and the boundary conditions

$$\gamma_0^2 II_0 = \gamma_1^2 II_1$$

$$\gamma_0^2 \frac{\delta II_0}{\delta z} = \gamma_1^2 \frac{\delta II_1}{\delta z}$$
(3-68)

We finally arrive at the hertz potential below ground

$$II = \frac{I}{4\pi (\sigma + i\epsilon\omega)} \int_{-\infty}^{\infty} e^{-i\lambda y} \left[e^{\pm u} \frac{1}{2} (z-h) + \frac{u}{u} \frac{1-u}{u} e^{-u} \frac{1}{2} (z+h) \right] \frac{d\lambda}{u_1}$$
(3-69)

where \boldsymbol{u}_1 and \boldsymbol{u}_0 are defined on page 3-2.

Note that the upper sign applies when z > h and the lower sign when $0 \le z \le h.$ Now since

$$Ex = -Y_1^2 II$$

$$Hy = \frac{\gamma^2}{j\omega\mu_0} \frac{\delta II}{\delta z} = (\sigma + i\epsilon\omega) \frac{\delta II}{\delta z}$$
(3-70)

$$H_{z} = -(\sigma + i\epsilon\omega)\frac{\delta H}{\delta y}$$

We have finally

$$Ex = \frac{-j\mu_0 \omega I}{4\pi} \int_{-\infty}^{\infty} e^{-i\lambda y} \left[e^{\pm u_1(z-h)} + \frac{u_1 - u_0}{u_1 + u_0} e^{-u_1(z+h)} \right] \frac{d\lambda}{u_1}$$
(3-71)

$$Hy = \frac{-I}{4\pi} \int_{-\infty}^{\infty} e^{-i\lambda y} \left[\pm e^{\pm u} 1^{(z-h)} + \frac{u_1 - u_0}{u_1 + u_0} e^{-u} 1^{(z+h)} \right] d\lambda$$
(3-72)

$$H_{z} = \frac{iI}{4\pi} \int_{-\infty}^{\infty} e^{-i\lambda y} \left[e^{\pm u_{1}(z-h)} + \frac{u_{1}^{-u_{0}}}{u_{1}^{+u_{0}}} e^{-u_{1}(z+h)} \right] \frac{\lambda d\lambda}{u_{1}}$$
(3-73)

3 - 11

3.4.1 Results of the Submerged Infinite Line Source Analysis

From paragraph 3.4, the field components can be restated as:

$$Ex = \frac{-j\mu_0\omega I}{2\pi} \int_0^\infty \cos(\lambda y) \left[e^{-u_1(z-h)} + \frac{u_1 - u_0}{u_1 + u_0} e^{-u_1(z+h)} \right] \frac{d\lambda}{u_1}$$
$$Hy = \frac{-I}{2\pi} \int_0^\infty \cos(\lambda y) \left[\pm e^{-u_1(z-h)} + \frac{u_1 - u_0}{u_1 + u_0} e^{-u_1(z+h)} \right] d\lambda$$
$$Hz = \frac{I}{2\pi} \int_0^\infty \sin(\lambda y) \left[e^{-u_1(z-h)} + \frac{u_1 - u_0}{u_1 + u_0} e^{-u_1(z+h)} \right] \frac{\lambda d\lambda}{u_1}$$

These can be suitably transformed by

$$x = \lambda h \qquad D = y/h \qquad Z = z/h$$

so that
$$u_0 = \left[x^2 - \left(\frac{\omega h}{c}\right)^2 \right] \frac{1/2}{h}$$
$$u_1 = (x^2 + \Gamma^2)^{1/2} \qquad \Gamma = \gamma_1 h$$

When $z \neq h$ these integrals offer no particular difficulty in integration. With z = h, there are:

$$Ex = \frac{-j\mu_0\omega I}{2\pi} \left[\int_0^\infty \frac{\cos(\lambda y)d\lambda}{u_1} + \int_0^\infty \cos(\lambda y) \frac{u_1^{-u_0}}{u_1^{+u_0}} e^{-2u} \frac{1}{u_1^{+u_0}} \frac{d\lambda}{u_1} \right]$$
$$Hy = \frac{-I}{2\pi} \int_0^\infty \cos(\lambda y) \frac{u_1^{-u_0}}{u_1^{+u_0}} e^{-2u} \frac{1}{u_1^{+u_0}} \frac{d\lambda}{u_1^{+u_0}}$$
$$Hz = \frac{I}{2\pi} \left[\int_0^\infty \frac{\sin(\lambda y)\lambda d\lambda}{u_1^{+u_0}} + \int_0^\infty \sin(\lambda y) \frac{u_1^{-u_0}}{u_1^{+u_0}} e^{-2u} \frac{1}{u_1^{+u_0}} \frac{d\lambda}{u_1} \right]$$

The first integrals in Ex and Hz cannot be evaluated as they stand. However, they are related to the modified Bessel functions:

$$K_0(\gamma_1 y) = \int_0^\infty \frac{\cos(\lambda y) d\lambda}{\mu_1}; \ \gamma_1 K_1(\gamma_1 y) = \int_0^\infty \frac{\sin(\lambda y) \lambda d\lambda}{\mu_1}$$

Considerable effort has been made to evaluate K_0 and K_1 , without resorting to special numerical techniques. Further work must be done, however, for adequate accuracy. The field components that are valid have been computed, viz those on the surface and Hy at z = h. The results have been prepared in terms of S/N_0 as a function of frequency for a transmitter depth of 300 meters, $\sigma = 0.01$ mhos/m and Pt = 100 W*. Figure 3-3 depicts S/N_0 at the surface, whereas figure 3-4 shows S/N_0 at 300 meters and a displacement of 200 meters taken from elementary dipole computations.

These generally show an optimum up-link frequency of about 10 kHz, and an optimum intramine frequency for a displacement of 200 meters of 25 to 50 kHz.



Figure 3-3. Submerged Infinite Line Source.

^{*}With preliminary noise grades.



Figure 3-4. Submerged Line Source.

Section 4

Signal-to-Noise Analysis for Down-Link Line Source Mine Communications

This section is part of a continuing series of notes regarding analytical techniques for calculating signal-to-noise ratios in a mining environment. These propagation modes consist of low-frequency waves transmitted through the earth or within the mine itself.

Some of the antenna configurations that may be used for coupling energy into the medium and detection are loop-to-loop, line source-to-loop, line source-to-line source, etc. Except for intramine loop communication, the loop-to-loop case was handled previously. This note considers a line current source on the surface for down-link communications.

4.1 THE SUBSURFACE H-FIELDS FOR A LINE CURRENT SOURCE

Consider a line current source (figure 4-1) in which there are no variations in the z direction.



Figure 4-1. Line Current Source.

Then from Wait* the H-field components below the surface at (x,y) are

$$H_{y} = \frac{I}{2\pi h} B(H, X)$$
(4-1)

$$H_{x} = \frac{-I}{2\pi h} A(H, X)$$
(4-2)

^{*}J. R. Wait and K. P. Spies, "Subsurface EM Fields of a Line Source On A Conducting Half Space," Radio Science 6, 8-9, 1971 page 781.

where

B(H, X) =
$$2 \int_0^\infty \frac{s e^{-(s^2 + iH^2)^{1/2}} sin(sx)ds}{s + (s^2 + iH^2)^{1/2}}$$
 (4-3)

A(H, X) =
$$2 \int_0^\infty \frac{(s^2 + iH^2)^{1/2} e^{-(s^2 + iH^2)^{1/2}} \cos(sx)ds}{s + (s^2 + iH^2)^{1/2}}$$
 (4-4)

and

$$X = x/h, H = (\sigma \mu_0 \omega)^{1/2} h$$

The electric field is

$$E = \frac{-i\mu\omega I F(H, X)}{2\pi}$$
(4-5)

where

F(H, X) =
$$\int_0^\infty \frac{e^{-(s^2 + iH^2)^{1/2}} \cos(sx)ds}{s + (s^2 + iH^2)^{1/2}}$$

4.1.1 Signal-to-Noise Ratios

Now in the case of surface line sources, the current produced by a given input power is dependent to a large extent on the contact resistance that can be obtained near the earth probes. According to Dr. Geyer "porous pots" may be used to reduce this resistance to as low as 10 ohms. Typical values for the input resistance to a line source will then range from 10Ω to 200Ω .

As before, the ratio of received to transmit power is

$$\frac{P_{r}}{P_{t}} = \frac{V_{02}^{2}}{4R_{1}R_{2}I_{1}^{2}}$$
(4-6)

for a loop receive antenna

$$V_{02} = 4\pi\omega N_2 A_2 H \times 10^{-7}$$

so that

$$\frac{P_{r}}{P_{t}} = \frac{4\omega^{2}N_{2}^{2}A_{2}^{2}B^{2}(H, X) \times 10^{-14}}{R_{1}R_{2}h^{2}}$$
(4-7)

the noise power received per Hz bandwidth is

$$P_{nr} = \frac{64 \pi^2 f^2 N_2^2 A_2^2 H_N^2 \times 10^{-14}}{4R_2}$$

therefore

$$S/N_0 = \frac{P_T B^2(H, X)}{h^2 H_n^2 R_1}$$
 (h in meters) (4-8)

Line source on surface to VMD subsurface

and

$$S/N_{0} = \frac{P_{T}A^{2}(H, X)}{h^{2}H_{n}^{2}R_{1}}, \qquad (4-9)$$

line source on surface to HMD subsurface.

Likewise for the E field at a submerged line source

$$\frac{P_{r}}{P_{t}} = \frac{\omega^{2} F^{2}(H, X) L_{2}^{2} x 10^{-14}}{R_{1}R_{2}}$$
(4-10)

where L_2 is the length of the receive line source.

Since

$$P_{nr} = \frac{E_n^2 L_2^2}{4R_2}$$
$$S/N_0 = \frac{16\pi^2 f^2 F^2(H, X) P_T \times 10^{-14}}{R_1 E_n^2}$$
(4-11)

where E_n is the electric noise field in V/m/Hz.

The above relations for S/N_0 all assume the loop or line source is adequately dimensioned so that the external noise pickup exceeds receiver noise.

2 2

4.2 COMPUTATIONAL RESULTS

Equations (4-8) and (4-9) were employed in a computer method for the calculation of S/N_0 for depths of 300 m and 500 m as a function of frequency for various displacements (figure 4-2). Since Wait's A, B, and F functions are similar to his P and Q functions, the modification to the computer program was straightforward. All of these various S/N_0 calculations can now be made with the basic computer program by selection of the desired option.

The results are shown in figures 4-3 through 4-7 (with preliminary noise grades). A contact resistance of 100Ω has been assumed for the line source. The VMD, of course, will produce a null directly below the line source, thus there would be a preference for the HMD. At the 500-meter displacement, however, there is little difference between the two.

For comparison purposes, figures 4-6 and 4-7 show a 100-meter radius loop, 200-kg weight driven by the same power as the line source. The subsurface S/N_0 is comparable to the line source case considering the size of the transmit loop.

The E-field signal-to-noise ratios were not presented because of the inadequacy of E-field subsurface noise data. A few sample calculations made with Dr. Geyer's* line source surface noise data indicate that with the same subsurface noise fields, the signal-to-noise at 2 kHz would be comparable to the H-field cases.

Future plans call for the injection of new noise data in the computer program as it becomes available and the consideration of intramine paths.

4.3 THEORETICAL PREDICTIONS FOR S/N₀

As a result of the theoretical analysis of this section, several predictions can be made. For a line source, typical values of input resistance will range from 10 to 200 ohms. For a loop receiving antenna, the HMD orientation is preferable to the VMD orientation at shallower depths due to the null created by the VMD in the horizontal plane. However, at depths around 500 meters, the two arrangements are relatively equal. For the line source transmitter configuration, the frequencies in the 1- to 2-kHz range appear to yield the optimum signal-tonoise ratios.

^{*}R. Geyer, G. Keller, M. Major. "Research on the Transmission of Acoustic and EM Signals Between Mine Workings and the Surface." Quarterly technical report. Colorado School of Mines, December 30, 1971.







Figure 4-3. Receive Signal-to-Noise Ratios as a Function of Lateral Displacement and Frequency.









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Figure 4-6. Receive Signal-to-Noise Ratios as a Function of Lateral Displacement and Frequency.



Figure 4-7. Receive Signal-to-Noise Ratios as a Function of Lateral Displacement and Frequency.



Figure 4-6. Receive Signal-to-Noise Ratios as a Function of Lateral Displacement and Frequency.



Figure 4-7. Receive Signal-to-Noise Ratios as a Function of Lateral Displacement and Frequency.

Section 5

LF Communication

Paragraph 5.1 provides an overview of the mechanics of wave propagation within a coal mine and a preliminary look at optimum intramine frequencies. The report employs the techniques developed in the prior reports to analyze overall propagation for loop-to-loop and line sourceto-loop transmission for both HED and VMD orientations. There are 10 basic input parameters for computer programs. These are as follows:

- a. Transmitted output power
- b. Weight of VMD in kg
- c. Radius of VMD in meters
- d. Frequency in Hz
- e. Relative dielectric constant of overburden
- f. Conductivity of overburden in mhos/m
- g. Earth probe contact resistance of HED
- h. Depth of HED or VMD in meters
- i. *Noise grade
- j. Length of HED in meters

Seven field components, five for submerged HED and two for VMD, are calculated for each receiving point. Comparison of theoretical and Collins measured values of transmission losses between line sources and the magnetic field components produced by these line sources are also included. While the agreement is fairly good, there are certain discrepancies. These can be explained at least partially by the following:

- a. Elementary dipoles employed in theory instead of extended sources
- b. The array of roof bolts between transmitter and receiver can and undoubtedly do distort the E and H fields

5.1 ON INTRAMINE WIRELESS LF COMMUNICATIONS

Collins has recently completed a series of brief but significant mine communications experiments.** In this section we wish to comment on their relevance to intramine communications and compare their results with theory in the frequency range 1 kHz to 100 kHz.

The theory presented in the previous sections has been incorporated into a basic computer program which evaluates five field components for the submerged HED:

$$\begin{split} & E_{\boldsymbol{\rho}} \Big|_{\boldsymbol{\phi} = 0}, \quad \text{and} \quad E_{\boldsymbol{\phi}} \Big|_{\boldsymbol{\phi} = \pi/2}, \quad \text{and} \quad H_{\boldsymbol{\rho}} \Big|_{\boldsymbol{\phi} = \pi/2}, \text{ and} \\ & H_{\boldsymbol{\phi}} \Big|_{\boldsymbol{\phi} = 0}, \quad \text{and} \quad H_{z} \Big|_{\boldsymbol{\phi} = \pi/2} \end{split}$$

For the VMD we compute Hz and E

^{*}Preliminary noise grades.

^{**}Coal Mine Communications Field Test Report, Collins Radio Company, December 29, 1972.

The basic input parameters for the computer program are as follows:

- a. Transmitted output power
- b. Weight of VMD in kg
- c. Radius of VMD in meters
- d. Length of HED in meters
- e. Frequency in Hz
- f. Relative dielectric constant of overburden
- g. Conductivity of overburden in mhos/m
- h. Earth probe contact resistance of HED
- i. Depth of HED or VMD in meters
- j. Noise grade

For each set of the above parameters, the seven field components are computed for receiving point depths of 0 to 350 meters in 50-meter steps and for receiving point displacements of 100 to 1000 meters in 100-meter steps. The seven field components required the integration of 10 Sommerfeld type integrals, which were effectively performed simultaneously. As indicated previously, due caution was employed in the determination of the various subinterval limits and experimentation performed near the branch points and poles until confidence was obtained for adequate engineering accuracy.*

5.1.1 Comparison of Experiment With Theory

In figures 5-1 through 5-5 of this section, we have shown a comparison of Collins measured values of transmission losses between line sources and the magnetic field components produced by these line sources with their corresponding theoretical values. Collins measured field components, which, for an elementary dipole do not exist viz $E \phi$ at $\phi = 0$, $E\rho$ at $\phi = \pi$, $H\phi$ at $\phi = \pi$, $H\rho$ at $\phi = 0$, and Hz at $\phi = 0$. For an extended line source, particularly for the first three components, these fields actually do exist, of course, since the fields should be integrated over the length of the conductor.

Referring now to figure 5-1, we have shown $E\phi at\phi = \pi$ (line sources broadside). For this and those through figure 5-5 we have selected $E_r = 10$, and $\sigma = 0.005$ mhos/m. This value appeared to offer the best fit in the loss decrement characteristic with frequency and distance and therefore is probably reasonably close to the average overburden value. We note insofar as this field component is concerned, theory actually indicates a lower loss than experiment below 50 kHz, but a higher value above 50 kHz. In figure 5-2, $E\rho$ at $\phi = 0$ (line sources end fire) we find the same effect, however, somewhat more emphasized. Figure 5-3 shows H ϕ at $\phi = 0$ now plotted in magnetic field strength dB > 1 μ A/m. We find now that theory predicts a lower loss (about 10 dB) than experiment indicates. For H ρ at $\phi = 90^{\circ}$ (figure 5-4) and Hz at $\phi = 90^{\circ}$ (figure 5-5) a good agreement with an rms error of 2 to 3 dB is observed.

While the agreement is fairly good, the discrepancies can be explained partially at least by the following:

- a. Elementary dipoles employed in theory instead of extended sources.
- b. The array of roof bolts between transmitter and receiver can and do undoubtedly distort the E and H fields.

^{*}R. P. Decker, "Signal-to-Noise Analysis for Loop-to-Loop Mine Communications," Subject Data C-684420, 25 September 1972.



Figure 5-1. Comparison of Theoretical and Measured Transmission Losses Between Line Sources - $\mathbf{E}\boldsymbol{\phi} \Big| \boldsymbol{\phi} = \pi/2$.















Figure 5-5. Comparison of Theoretical and Measured Transmission Losses Between Line Sources - $H_z = \frac{1}{2} \phi = 90^{\circ}$

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5 - 7

The extended line sources can be handled fairly easily as far as their primary fields are concerned; however, the "bed of nails" in the overburden may be an intractable theoretical problem.

As time permits we will calculate the effect of an extended source on the received field strength and open circuit voltage of a receiving line source and the vertical magnetic field component, with the receiver at the same depth as the transmitter.

For $E\rho$, $\phi = 0$

$$E\rho^{(p)} = \frac{I}{2\pi(\sigma + i\epsilon\omega)} \int_{\rho_0 - \ell/2}^{\rho_0 + \ell/2} \frac{e^{-\gamma R}(\gamma R + 1)dR}{R^3}$$
(5-1)

The open circuit voltage on an identical receive line source is:

$$V_{\boldsymbol{\rho}_{0}}^{(\mathbf{p})} = \frac{I}{2\pi(\sigma + i\epsilon\omega)} \int_{\boldsymbol{\rho}_{0}-\boldsymbol{l}/2}^{\boldsymbol{\rho}_{0}+\boldsymbol{l}/2} \int_{\boldsymbol{\rho}-\boldsymbol{l}/2}^{\boldsymbol{\rho}+\boldsymbol{l}/2} \frac{e^{-\boldsymbol{\gamma}_{\mathrm{R}}}(\boldsymbol{\gamma}_{\mathrm{R}}+1)\mathrm{d}\mathrm{R}\mathrm{d}\boldsymbol{\rho}}{\mathrm{R}^{3}}$$
(5-2)

For $E\phi^{(p)}, \phi_0 = \pi/2$

$$\mathbf{E}\boldsymbol{\phi}^{(\mathbf{p})} = \frac{\mathbf{I}}{2\pi(\sigma + \mathbf{i}\epsilon\omega)} \int_{\boldsymbol{\rho}_0}^{\sqrt{\boldsymbol{\rho}_0^2 + (\mathbf{k}/2)^2}} \frac{\boldsymbol{\rho}}{\mathbf{R}}$$
(5-3)

$$\frac{e^{-\gamma_{\rm R}}}{R^3} \left[\gamma^2 R^2 + \gamma_{\rm R} + 1 \right] \frac{RdR}{\sqrt{R^2 - \rho_0^2}}$$

$$V\phi^{(p)} = \frac{I}{2\pi(\sigma + i\epsilon\omega)\rho_0} \int_{\rho_0} \sqrt{\rho_0^2 + (\ell/2)^2} \int_{\rho_0} \sqrt{\rho_0^2 + (\ell/2)^2}$$

$$\frac{\rho e^{-\gamma_{\rm R}}}{R^3} \left[\gamma^2 R^2 + \gamma_{\rm R} + 1 \right] \frac{dRd\rho}{\sqrt{R^2 - \rho_0^2}}$$
(5-4)

For $H_{z}^{(p)}, \phi = \pi/2$

$$H_{z}^{(p)} = \frac{I\rho_{0}}{2\pi} \int_{\rho_{0}}^{\sqrt{\rho_{0}^{2} + (1/2)^{2}}} \frac{e^{-\gamma R}}{R^{2}} \frac{[\gamma_{R} + 1]dR}{\sqrt{R^{2} - \rho_{0}^{2}}}$$
(5-5)

A significant aspect of this data is that above 50 kHz, say 50 to 100 kHz, theory is consistently pessimistic for both the E and H field components. Also, field components exist where none would under the half-space model and elementary dipole conditions. From the Collins measurements apparently these components are seldom less than 15 dB below the main component.

5.1.2 System Design of Basic Intramine Paths

With the basic computational tools in hand, we now proceed to examine some basic intramine path configurations. Consider first a personal portable transmitting loop with a receiving line source within a mine working section. For this we have taken $\sigma = 0.01$ mhos/m, depth 222 meters, a displacement of 100 meters (half the length of a working section) a power of 1 watt into a 6-inch-diameter loop with a weight of 0.25 kg. We need, of course, E-field noise data which is essentially nonexistent. However, by establishing the quiet mine E-field noise at 20 kHz deduced from Collins measurements and the use of R. Geyer's limited surface noise data, we have been able to assemble a first or zero order approximation to the max and min values of this noise from 1 to 100 kHz.

The results are plotted in figure 5-6 in terms of S/N_0 . They show a possibility for quite acceptable voice quality in the frequency range of 70 to 100 kHz. This would also include a "loop orientation variability" margin of at least 15 dB.

In figure 5-7 we have taken the same transmit loop, but now reception is on another VMD. Adequate noise data is available for this case and the S/N_0 is shown versus frequency for the extreme cases.* Here we find essentially the same optimum frequency range; however, the maximum S/N_0 is approximately 28 dB lower than in the case of the line source receiver.

The next type of intramine path which is self-suggestive is a line source to line source link between working sections (figure 5-8). We have taken a power of 100 watts and a line source length of 16 meters and a displacement of 200 meters. Using the maximum noise characteristic, the optimum frequency range of 25 to 50 kHz produces an output S/N_0 of about 55 dB. This should also be an acceptable value for a voice link. (Note that larger paths exhibit a lower optimum frequency range.)

The next logical case is VMD to VMD between working sections (figure 5-9). Here we have used a 4-meter diameter 10-kg transmit loop with a power of 100 watts. We find the same optimum frequency range as the previous one, but the (max) S/N_0 is 10 dB lower. This could be made up by a 12-meter diameter transmitting loop, but would be considerably more expensive and less convenient than line source to line source.

Figure 5-10 depicts the expected S/N_0 for a line source transmitter to a VMD receiver within a working section, Pt = 100 watts and a line source length of 16 meters. Figure 5-11 is identical except for a displacement of 200 meters.

This clearly demonstrates that a line source with a reasonable power input at maximum noise conditions has a maximum voice range of about 140 meters (460 feet).*

^{*}With preliminary noise grades.



Figure 5-6. Portable VMD to Line Source.



Figure 5-7. Portable VMD to VMD.



Figure 5-8. Line Source to Line Source (Broadside).



Figure 5-9. VMD to VMD.



Figure 5-10. Line Source to VMD/Displacement - 100 Meters.



Figure 5-11. Line Source to VMD/Displacement - 200 Meters.

5.1.3 Conclusions and Recommendations

From the above analysis we can formulate some basic conclusions for intramine communications:

- a. For personal portable lf wireless communications within a working section a loop-line source 2-way link is indicated as optimum in the frequency range of 70 to 100 kHz. The portable loop input power should be approximately 0.5 to 1.0 watt.
- b. For relayed transmission between working sections a line source to line source (broadside) 2-way link is indicated as optimum in the frequency range of 25 to 50 kHz. Line source lengths should be 16 meters (or more) with an input power of about 100 watts.

While these conclusions are quite significant, the VMD to line source link needs experimental verification and a series of measurements should be outlined to confirm the efficacy of the link under maximum noise conditions encountered in a working section. Also, we must again stress the urgent need for subsurface E-field noise data.

Section 6

The Application of Recent NBS Noise Data to Mine Communications

Recently, NBS has generated a considerable amount of surface and subsurface mine noise data, principally that of the horizontal and vertical magnetic field components at a representative sampling of locations, all under power-on conditions. The spectrum date of W. Bensema generally covers the range of 1 to 100 kHz, while Kandu's APD data was taken at 6 or 8 frequencies beginning at 10 kHz and extending into the hf range. While the location sampling was representative, there appeared to be considerable attention given to finding the maximum noise possible (for example, trolley noise with car pull). Also, the spectrum data was again, in several instances, system noise limited, which is an inherent problem with wide bandwidth analysis in setting the system gain unless a low-pass filter is employed below, say, 10 kHz. An additional comment is that frequencies of interest were generally considered to be below 20 kHz, whereas, frequencies for certain intramine paths exhibited optimal S/N performance at frequencies in the range of 30 to 90 kHz, based on previously available noise data. All things considered, the data is of excellent quality, covers several types of mines, and lends itself well to mine communication system analysis.

The following discussions consider data from the following mines:

MINE	TYPE
Robena	600 V dc, rail haulage
McElroy	Ac/dc, underground rectification, belt and rail haulage
Itman	Same as McElroy
Geneva	Ac/dc, rail haulage

6.1 METHOD OF ANALYSIS

Each curve of W. Bensema's spectrum data was subjected to a regression analysis to determine the equivalent running average of the minimum noise between spectral peaks. About 100 sampling points were used for each curve. This was done principally to improve the accuracy of noise representation and facilitate the injection of this data into the general intramine path propagation program. The functional dependence was determined entirely in terms of $dB > /\mu A/meter / \sqrt{Hz}$.

6.2 ROBENA MINE

The Robena mine is a 600 V dc mine, (dc conversion on surface) with rail haulage. The summary of the equivalent background (between peaks) noise fields are shown in figures 6-1 through 6-5. Both horizontal and vertical magnetic field noise components were measured and a few roof-bolt measurements were included. Figure 6-1 shows trolley and face area noise levels. The trolley noise indicated in the upper curve represents some of the highest noise fields ever measured in a mine. The face area levels are many dB less, but the vertical component at the face area is roughly 25 dB higher than either horizontal component. Figure 6-2 represents noise components in crosscuts 7 and 9 in which the spectrum display was system noise limited. The only conclusion that can be obtained from these curves is that the true noise levels are no greater than those shown in this figure. The APD data in figure 6-3, shows generally the same levels of noise that were determined from spectrum data aside from trolley noise. We note here a high degree of variance of horizontal component with frequency. Figure 6-4 illustrates the extremes and means of the subsurface horizontal component and figure 6-5 the same for the vertical component.

The mean of the vertical component is about the same as the mean of the horizontal component. The vertical component of the surface noise field is also shown in figure 6-5. The roof-bolt noise data was examined, but the conversion factor to absolute values was lacking. As soon as this conversion is available, W. Bensema will inform the writer.

The conclusions that were reached from the Robena data are as follows:

- a. There is no preference between the horizontal and vertical magnetic noise fields from the standpoint of their mean values as a function of frequency.
- b. Less system gain protection factor is needed for the vertical component to allow for noise level variations with location.
- c. Noise pickup on roof bolts does not increase with separation.
- d. The surface noise fields were less than the minimum power-on subsurface fields, for the data presented.
- e. The extreme noise fields represented, for example, by trolley noise may preclude the application of LF quasi-static propagation paths intramine with receive antennas near this noise source.


Figure 6-1. Robena Bensema Noise Spectrum Data/Trolley and Face Area Noise Levels.



Figure 6-2. Robena Bensema Noise Spectrum Data/Noise Components Crosscuts 7 and 9.



Figure 6-3. Robena Kandu APD-Data Spectrum (RMS).



Figure 6-4. Robena $\mathrm{H}_{N}(\mathrm{H})$ Extremes (RMS) Subsurface.



Figure 6-5. Robena $\mathrm{H}_{\mathrm{N}}(\mathrm{V})$ Extremes.

6.3 MCELROY MINE

The McElroy mine is a dc mine with underground rectification and belt and rail haulage. Summaries of the equivalent background noise fields are shown in figures 6-6 through 6-15. Vertical noise fields in the face area and in location no. 2, which have a relatively small variation in the means, are shown in figure 6-6. The composite of this data is shown in figure 6-12 and can be considered to be a quasi-maximum average of face area noise. Kandu's APD equivalent of Bensema's figure 97-83 is also shown, but there is little correlation except at 10 kHz. Vertical noise fields for the head piece, middle of crosscut, and elevator shaft are shown in figure 6-7. There appears to be quite a bit of variance in these noise fields; however, considerably quieter fields are noted at the elevator shaft.

Figure 6-8 summarizes Kandu's APD measurements, showing about the same mean levels as in figure 6-7 at 10 kHz and for corresponding conditions in the Robena data, but with less variance. Figure 6-9 shows additional vertical field data at the head piece and arc welder. The 10-kHz peak for the head piece is an extremely high level for this frequency. An assortment of various locations and components is shown in figure 6-10.

The power entry is a maximal noise condition, while the site farthest from the power entry exhibits the quietest noise fields. Figure 6-11 shows additional high vertical noise fields in crosscuts and face areas. We note here the extension of high noise fields out to 50 kHz. Surface noise fields are shown in figure 6-12. These fields are relatively quiet and show a small degree of variance. The extremes and the means of the noise fields for the McElroy mine are shown in figure 6-14. The extremes for Robena are higher than those of McElroy, principally because of trolley noise, but the means are rather close except that McElroy exhibits higher levels between 12 and 50 kHz. McElroy also shows lower power-on minimums than Robena. Figure 6-15 shows the surface noise summary for McElroy and the correlation of McElroy data with Robena, Maxwell and Stone, and Geneva. The agreement is reasonably good with a relatively small degree of variance. Roof-bolt noise was not examined because of lack of calibrating data.

The conclusions that may be drawn with respect to the McElroy mine data are as follows:

- a. Mean noise fields are about the same as Robena noise fields.
- b. The surface noise fields lie between the mean and minimum subsurface noise fields, power-on.
- c. There appears to be a high degree of correlation between the surface noise data for the McElroy and Robena mines.







Figure 6-7. McElroy Spectrum Data/Vertical Noise Fields, Headpiece, Crosscut, and Shaft.



Figure 6-8. McElroy Spectrum Data/APD (RMS).







Figure 6-10. McElroy Spectrum Data/Various Locations and Components.



Figure 6-11. McElroy Spectrum Data/Additional High Vertical Noise Fields, Crosscuts and Face Areas.



Figure 6-12. McElroy Surface Spectrum Data.

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Figure 6-13. McElroy Spectrum Data.



Figure 6-14. McElroy Spectrum Data/HN Extremes.



Figure 6-15. McElroy Surface Spectrum Data/Summary.

6.4 ITMAN MINE

The Itman mine is also a dc mine with underground rectification and belt and rail haulage. Summaries of the equivalent background noise fields are shown in figures 6-16 through 6-21. All magnetic field noise data correspond to the vertical component. Figure 6-16 shows noise levels for portal buses and in the Cabin Creek area. Figures 6-17 and 6-18 were recorded at the Farley Panel and Bensema's figure 39-85 (figure 6-17) is considered to be an especially good representative sample of noise 16 ft from the miner in the 10-kHz to 100-kHz region. Figure 6-19, 30 ft from miner, also exhibits very similar characteristics to the previous three figures with little variance. Figure 6-20, Kandu's APD data is also consistent with the previous data except for data from the 2nd day which exhibits anomalously high fields in the 50- to 100-kHz region. The extremes and the means of the Itman data are shown in figure 6-21. Note the small variance between the mean and the maximum. The sudden drop in the minimum level at 10 kHz is due to the inclusion of APD data.

The general conclusions which may be drawn with respect to Itman data are as follows:

- a. The noise data is quite consistent with little variation in the medians.
- b. The means are lower than either Robena or McElroy, particularly above 5 kHz.

Again, the roof-bolt noise was not examined, because of the lack of a calibration factor.







Figure 6-17. Itman Spectrum Data Farley Panel/Noise - 16 Ft From Miner.







Figure 6-19. Itman Spectrum Data/30 Ft From Miner.



Figure 6-20. Itman Spectrum Data/APD.



Figure 6-21. Itman Spectrum Data/Extremes.

6.5 GENEVA MINE

The Geneva mine is also a dc mine with underground rectification and belt and rail haulage. All measurements on hand for the Geneva mine are surface noise fields. Summaries of the equivalent background noise fields are shown in figures 6-22 through 6-25. These results show generally that there is a small variance in the means of the horizontal component, but very little variance in the mean of the vertical component. The surface fields measured at Geneva are the quietest of the four mines.



Figure 6-22. Geneva Spectrum Data/ $H_N(H)$ East-West.











6.6 SUMMARY

The data from the above mentioned four mines by the NBS/ITS team is valuable data and is characteristic generally of noise conditions encountered under power-on conditions. Sufficient data has been reduced to represent various mine locations for 3 mine types, plus surface noise. Fourteen noise grades have been defined as follows:

NOISE GRADE

(1)	Dc mine, maximum trolley
$600 \text{ V} \text{ dc mine} \langle 2 \rangle$. Dc mine, face area, mean
3	Dc mine, face area, minimum
Č 4	. Ac/dc mine, head piece, maximum
5	. Ac/dc mine, face area, quasi-maximum
Ac/dc mine $\langle 6$. Ac/dc mine, mean noise
7	, Ac/dc elevator shaft
L 8	, Ac/dc power-on, quasi-minimum
Oujeter $20/do$ 9	, Ac/dc maximum (Itman)
$\frac{10}{10}$, Ac/dc mean
11 (11	, Ac/dc quasi-minimum
12	. Surface noise - mean
13	. Surface noise - power-on, minimum
14	, Mean noise - all mines subsurface

The extremes and means of the four mines are shown in figure 6-26. The maximum level is that due to Robena trolley noise, while minimum levels are principally due to Itman. The mean has been determined by averaging all data and is given by the following:

 $H_N = 121.5 - 32.5 \log_{10} f$ (Hz)

 $\rm H_{N}$ is in dB>/ $\mu\rm A/meter/~\sqrt{Hz}$

The above relation and the application of the 14 noise grades should shed new light on optimal intramine frequencies. In the next section we shall give results of the S/N analysis for various paths and noise conditions.



Figure 6-26. All Mines/Extremes.

6.7 RESULTS OF PROPAGATION PROGRAM ANALYSIS

Figure 6-27 shows the relationships of the electric and magnetic field components from transmit line and loop sources respectively in the spherical coordinate system for the computer printouts on the following pages.

The printouts incorporate the updated noise data with the communication propagation analysis program; for example, if we required the magnetic field component from a transmit line source at some perpendicular distance Y, from the source, we could read this component from the Hz (PHI=90) column at a specific transmitter depth and displacement. Such would be the case if the perpendicular magnetic field component were required for a receiving loop in the X-Y plane at some displacement from the transmit line source. For a horizontal surface loop to an underground horizontal loop antenna, the Hz (perpendicular field component) is taken from the Hz (VMD) column of the printout at the desired loop displacement and separation.

Although the depth of transmitter is a variable, as far as the printout is concerned, reciprocity still applies and transmit position and field sample points may be interchanged. All data is referenced to dB greater than 1 ampere/meter or 1 volt/meter.

To apply the data to a typical situation, one must first calculate a correction factor for that situation. See figure 6-27 for correction factor formulas. This factor is then added to the printout data to correct relative field intensity data to the actual power level, loop diameter, line source length or loop weight used. Subtracting the appropriate noise grade from the corrected field intensity data yields the S/N_0 ratio at the sample point in question. If it is necessary to know the open-circuit volts from a loop immersed in a known field, one can apply the equations from section 2 to the corrected field data from the computer printout.



Figure 6-27. Vector Relationships of Electric and Magnetic Field Components for Printouts on Pages 6-34 Through 6-83.

	-97 - 88	-100.19	-105.19	-116.99	-116.90	-106.10	-111.21	• 00	400.00
	-97-88	-100.19	-105.19	-116.99	-116.99	-106.10	-111.21	• 00	400.00
	-81-63	-82.21	-86.70	-116.99	-116.99	-87.05	-86.70	• 00	200.00
	-81.63	-82.21	-86.70	-116.99	-116.99	-87.05	-86.70	• 00	200.00
	-68-42	-65.46	-72.60	-116.99	-116.99	-70.76	-66.58	• 00	100.00
	-68 • 42	-65.46	-72.60	-116.99	-116.99	-70.76	-66.58	• 00	00,001
	-56-12	-47.89	-60.06	-116.99	-116.99	-53.67	-48.02	• 00	50.00
	-56 • 12	-47.89	-60.06	-116.99	-116.99	-53.67	-48.02	• 00	50.00
	-44.04	-29.92	-47.92	-116.99	-116.99	-35.82	-29.86	• 00	25.00
	-44-04	-29.92	-47.92	-116.99	-116.90	-35.82	-29.86	• ೧೦	25.00
	-16-07	12.00	-19.94	-116.99	-116.99	6.08	12.10	• ೧೮	5.00
	-16.07	12.00	-19,94	-116-99	-116.99	5.08	12.10	• 00	5.00
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					ALM NOISE GRA	25.00 DB .GT. 1/	NOISE = -1:		
				100 - 10 - 11	ATH NOISE GRA	14.00 DB .GT. 1/	NOISE = -1		
					A/M NOISE GRA	56.00 NB .GT. 1/			
				IDE . a	ATM NOISE GRA	19.00 DB .GT. 1/	NOISE = -1		
					A/M NOISE GRA	19.00 D3.6T.1/	NOISE = -1		
					AND ADISE GRA	97.00 UB 61. 1.	NOISE = -		
				DE = 4	A/M HOISE GRA	77.00 DB .GT. 1/	NOISE #		
				DE = 3	ATH HOISE GRA	10.00 DB .GT. 1/	NOISE = -1		
					AVM NOISE GRA	1 15 EU 00 66	NUISE .		
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				OHMS	CE ■ 100.00	UNTACT RESISTAND	LINE SOURCE C		
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	FR E0#	1000.00 HZ	COND. =	HH 10.	05/M E	6PS= 10	-00 POW	R=	10.00 WATTS XM	41T LOUP	weight= ó.	00.
	XMIT LO	UP RADIUS=	20.0C M	LINES	OURCE 1	ENGTH=	100-00	M DE	EPTH OF TRANSMIT	ITER≖	50.00	
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		NOI SE =	-99.00	08 .61.	1 A/M	NOISE G	RADE =	2				
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5.00	50-0	0 12.	10	6.08	ī	10.81	-11.	98	-19-94	12.00	-76.38	
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100.00	50.0	0 - 65.	. 68	-70.78	ĩ	14.97	-82	62	-72.43	-65.11	-80.53	
200.00	ō.	0 - 81 -	. 10	-87.85	Ĩ	15.21	184	57	-86.59	-83.96	-86.83	
200-00	50.0	0 -82.		-86.63	-10	11.51	- 88 -	41	-85.91	-82.01	-86.17	
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	-86.17	-81.64	-86-27	-96.76	-109.65	-86.45	-86.14	100-00	200.00
	-88.66	-89.21	-89.20	-86.32	-101.28	- 69 - 34	-86.97	• 00	200.00
	-80.53	-64.95	-72.53	-92.99	-96.18	-70-65	- 66 • 81	100.00	100.00
	-85.73	-83.32	-81.92	-76.50	-80.53	-78.96	-83+21	- 00	100.00
	-78.19	-47.75	-60.05	-91.76	-92.58	-53.65	-48.07	100.00	50.00
	-88.14	-66.99	-81.46	-71.35	-72.42	-73.52	-74.37	.00	50.00
	-77.14	-29.90	-47.92	-91.43	-91.63	-35-82	- 29 - 87	100.00	25.00
	-93.03	-62.31	-85.27	-69.54	-69.81	-71.61	-67.47	• 00	25.00
	-76.37	12.00	-19.94	-91.32	-91.33	6•0 8	12.10	100.00	5.00
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	EPH (VMD)	H2 (VM0)	HZ(PHI=90)) HPHI(PHI=0)	HRH0(PH1=90)	EPHI (PH = 90)	ERHQ(PH[=0)	DEPTH(M)	DISP(M)
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				RADE = 10	LA/M NOISE GI	-97.00 DB .GT.	NOISE -		
				RADE = 9	LA/M NOISE GF	-86-00 D8 .GT.	NOISE -		
				RADE = /	LA/N NOISE GE	119-00 DB _GT-	NOISE		
				RADE = 6	LA/M NOISE GI	-97.00 DB .GT.	NOI SE .		
					LA/H NOISE GH	-90.00 DB .GT.	NOISE -		
					LA/M NOISE GP	-77.00 D8 _GT.			
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					- 				
	0.00	TTER= 10	TH OF TRANSMI	100.00 M DEP	URCE LENGTH=	0.00 M LINE SO	RADIUS= 2	XMIT LOOP	
5+00 KG	EIGHT= 0	MIT LOOP W	D-00 WATTS XI	.00 POWER= 10	S/M EPS= 10.	ND01 MHO	000-00 HZ CO	FREQ= 10	

	FREQ= 1	1000°00 HZ	COND. ≈	.01 MH	IOS/M E	:PS= 10,	.00 PDWER=	10.00 WATTS X	MIT LOOP WE	IGHT= 6.00
	XMIT LOUF	P RADIUS-	20.00	N LINE S	OURCE 1	ENGTH-	100.00 M	DEPTH OF TRANSMI	TTER- 200	. 00
		LINE SOUR	CE CONTAC	CT RESIST	ANCE -	100-00	SMH0 C			
			-66.00	0 D8 -61.	14/4	NOISE GE	(ADE =]			
		NULSE =	-110.00	08 .61.	IA/H	NOISE GF				
		NOI SE	-11.0(0 08 .61.	IA/M	NOISE GF	ADE = 4			
			00-26-			NOISE G				
		NOISE =	-119.00	DB . 61.	IA/M	NOISE GF	TADE - 7			
		= 35 ION	-119-00	0 08 .61.	1 A/H	NOI SE GF	2 A D E = 8			
		NOISE *	-86.00	0 08 .67.	IA/H	NOI SE GF	24DE = 9			
			-114-00	0 08 .61.	TA/M	NUISE 6	4405 = 10 1405 = 11			
		NOISE #	-125.00	08 .61	IA/M	NOISE GR	TADE = 12			
		NOI SE	-144.00	08 .61.	1A/H	NOISE GF	(ADE = 13			
		* 3310N	-96-01	0 D8 .61.	LA/H	NOTSE GF	3ADE = 14			
		- 30104	• • • •							
(m) dS [0	DEPTH(M)	Е Е НОСРИ	±0) Ept	06= Hd } F	и ненс	06=1H4)(НИСТИНСИ	(06*IHd)7H {0=	(0HA) ZH	EPH(VMD)
5.00	• 00	-82.	14	-86.62	Ĩ	32.70	-82.70	-118.16	-80.78	-118.23
5.00	200-00	12.	10	6.03	-10	8.93	-108.93	-19-94	12.00	-76.37
25.00	0 0 •	- 92 -	61	-86.79	1	12.96	-82.89	-104.41	-81.18	-104.40
25.00	200.00	-29.	86	-35.82	-10	60-61	-108.97	-47.92	-29.90	-77.14
50.00	• 00	- 84 -	C 6	-87.31	3	33.76	-83.46	10*66-	-82.51	-98.86
50°00	200 •0 0	-48-	02	-53.66	-10	19.32	-109.09	-60.06	-47.74	-78.19
100.00	00.	-86-	60	-89.18	-	36.70	-85.51	-95.52	-87.71	-94.68
100.00	200.00	- 66 -	61	-70.73	-11	10.49	-109.55	-72.60	-64.84	-80.53
200.00	00.	-105-	68	-94.75	ĩ	16.09	-91.49	-96-97	-102-13	-94.84
200.00	200-00	-86.	68	-86.88	-11	14.98	-111.26	-86.65	-81.18-	-86.17
400-00	0 0 •	-112.		-107-03	-11	15.74	-103.72	-107.36	-105.37	-107.68
400-00	200-00	-110.	- 61	-104.99	-13	10.69	-116.84	-104.62	16°66-	-101.77

6.00 KG

400.00	400-00	200.00	200.00	100.00	100.00	50.00	50.00	25.00	25.00	5.00	5.00	OISP(M)																	
300.00	•00	300-00	• 00	300 -0 0	• 00	300-00	• 00	300.00	• 0 0	300-00	• 00	DEPTH(M)	XMIT LOOP																
-111.29	-126.72	-86.68	-105.17	- 66 - 58	- 96 - 04	-48.02	-93.57	- 29 . 86	- 92.94	12.10	- 92 . 73	ERHO(PHI=0	RADIUS # RADIUS # LINE SOURCE NOISE # NOISE #																
-105-98	-110-92	-87.07	-101-24	-70.76	-97.76	-53-67	-96.76	-35-82	-96-50	ဂ် - 0 ဗု	-96.42) EPHI (PHI=90)	CONTACT RESISTA CONTACT RESISTA -66.00 DB .GT. -99.60 DB .GT. -77.00 DB .GT. -77.00 DB .GT. -97.00 DB .GT. -119.00 DB .GT. -119.00 DB .GT. -119.00 DB .GT. -114.00 DB .GT. -114.00 DB .GT. -144.00 DB .GT. -91.00 DB .GT.																
-136.23	-116.58	-126.78	-100.23	-124.27	-94-62	-123.64	-93.04	-123.48	-92.64	-123.43	-92.50	HRH0(PH[=90)	INCE LENGTH NCE LENGTH INCE 100.00 INCE 100.00 INCE 100.00 INCE CR INCE CR																
-128.77	-107.98	-124.88	-97.88	-123.80	-94.03	-123.52	-92.89	-123.45	-92.60	-123.42	-92.50	HÞH] (PH] =0)	000000000000000000000000000000000000																
-105.15	-112.43	-86.70	-105.72	-72.61	-107-09	-60.06	-111.78	-47.92	-117.45	-19.94	-131.31	HZ (PH1=90)	10.00 WATTS 1																
-100.05	-112.12	-81.12	-106.89	-64.83	-97.53	-47.74	-95.00	-29.90	-94.41	12.00	-94.28	HZ(VMD)	ITTER= 30																
-101.77	-115.34	-86.17	-103.23	-80.53	-104.39	-78.19	-109-12	-77.14	-114.79	-76.37	-128.55	EPH (VMD)	6. 00 00 00																
													• 00 ×6																
400.00	400.00	200.00	200-00	100.00	100-00	50.00	50.00	25.00	25.00	5.00	5.00	01SP(M)															,	•	-
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50.00	.00	50-00	.00	50.00	• 00	50.00	• 00	50.00	• 00	50.00	• 00	DEPTH(M)																	REQ= 20
-109.50	-107.30	-84.91	-83.71	-66.64	-67.40	-48.37	-64.07	-29.94	-57.52	12.10	-47.95	ERHO(PH l= 0	NUISE =	NOI SE	NOISE =				N01 SE =	NOI SE -	NOISE .	NDISE -		NOISE =	NOISE =	LINE SOURCE	750103-		00.00 HZ CI
-105.45) -104.50	-85-54	-86+63	-69.63	-72.63	-53-31	-61.95	-35.76	-56.23	6.08	-53.59) EPHI [PH]=(-90 00 CK-	-107.00 08 .61	-147.00 DB .G	-130.00 D8 .G	-173-00 DA -01	-113 00 00 .e.	-139.00 08 .61	-129.00 DB .GI	-107.00 D8 .G1	-99.00 D8 -61-	-120.00.00.00.01- 00.00.00.021-	-103.00 08 .61	-71.00 08 .61	CONTACT RESIS		20-00 M - 1NF	010 ONU
-110.69	-106-91	-102.48	-95.61	-95.72	-88.21	-82.95	-67.90	-79.53	-60.04	-78.37	-56.71	90) HRH0(PH I= 9)	• TALL HUISE	- IA/M NOISE	- IN/H NOISE	- IA/M NOISE	IA/M NOISE	- 14/H NOISE (- IA/H NOISE	. LA/M NOISE (- 1A/M NOISE (- LA/H NOISE	ANN NUISE	A A MUISE	- IA/H NOISE	TANCE = 100.0		SOURCE LENGTH	
-103.95	-100.69	-90.73	-85.64	-83.25	-73.34	-79.86	-63.99	-78.74	-58.99	-78.34	-56-67	0) HPHI(PH I- 0)		GRADE = 14	GRADE = 13	GRADE = 12	GRADE = 11	3RADE = 10	CRADE = 8	SRADE = 7	GRADE = 6	GRADE = 5			SRADE I	DU UHHS		100.00 M DE	
-108-15	-107.70	-87.84	-88-39	-73.02	-75.97	-60-17	-69-37	-47.94	-69.10	-19.94	-80-25	HZ (PH1=90)																PTH OF TRANSMIT	
-98.50	-96.33	-81.64	-83.40	-64.38	-72.46	-47.47	-64.36	-29.84	-48.42	12.00	-42.51	H2 (VM0)																rrea= 5	
-113.86	-115.17	-79.79	-80.71	-70-67	-72.59	-67.08	-71.53	-65.53	-74.51	-64.41	-87.41	EPH (VMD)																0.00	

GHT= 6.0	00																EPH (NHD)	-96.83	-64.40	-83+24	-65.52	-78.61	-67.08	-77.14	-70.67	-83+32	-79.79	-120.03	-113.92
IL LOOP WEI	ITER= 100.																(GMA)ZH	-61.42	12.00	-63.06	-29.84	-67.95	-47.42	-84.09	-64.06	-88.24	-81.18	-98.81	-101.18
0.00 WATTS XN	TH OF TRANSMIT																(06=1Hd)7H	-99.01	-19.94	-85.85	-47.95	-82.14	-60.21	-82.96	-73.23	-91.43	-88-55	-109.27	-109.22
) POWER= 10	100-00 M DEP.	SMHC)E = 1	0E = 2)E = 3	JE = 4)E = 5	DE = 6)E = 7	н н н н н н н н			JE = 12)E = 13	JE = 14	JE = 15	(0=IHd) IHdH	-69.48	-93.29	-70.16	-93.41	-72.05	-93.79	-77.50	-95.21	-88.22	-99-66	-103.94	-110-59
EPS= 10.00	E LENGTH= 1	= 100°00 (M NOISE GRAC	M NDISE GRAD	M NOISE GRAC	M NUISE GRAC	M NOISE GRAC	M NOISE GRAI	H NOISE GRAC	M NOISE GRAC	M NUISE GKAL	MUTCE CPAI	M NOISE GRAD	M NOISE GRAI	M NOISE GRAU	M NOISE GRAC	RH0(PH1=90)	-69-49	-93.29	-70.44	-93.63	-73.17	-94.66	-81.75	-98.60	-102.44	-113.17	-110.47	-119.51
W/SDHW 10.	LINE SOURCI	T RESISTANCE	08 -GT- 14/1	DB .GT. 1A/	DB .GT. 14/1	D8 . GT. 1A/	DR . 6T. 1A/1	DB .GT. 14/1	D8 .GT. 1A/1	D6 . 61. 1A/1	DB -61. IA/		DB .67. 14/1	DB .6T. 1A/1	D8 .61. 14/1	DB . CT. 1V/	IH (06=1Hd)]	-69-83	6.08	-70.49	-35,75	-72.33	-53-29	-77.64	-69.65	-88.45	-65.88	106.21	15.20
COND.=	20.00 M	RCE CONTAC	-71-00	-103-00	-128.00	-87.00	-99.00	-107.00	-129.00	-139-00	-113 00		00-021-	-147.00	-107.00	00*96-	HU3 (0=1	. 73	.10	- 12	. R9	• 8 •	• 23	. 10.	. 53	- 02 -	• 64	- 03	1
2000•00 HZ	P RADIUS=	LINE SOU	N015F =	NDI SF =	NOI SE #	* 3S ION	* 3SION	NOI SE #	NOI SE 🛥	NOISE #				NDISE =	= 35 10N	= 35 ION) ЕКНО(РН	- 64	12	-66	-29	-72	-48	- 85	-67	681	188	-110	-112
FR.EQ=	XMIT LOO																UEPTH(M	00•	100-00	00•	100.00	00 •	100-00	00•	100-00	- OC	100.00	0 0 •	100-00
																	015P(M)	5.00	5.00	25.00	25.00	50.00	50.00	100.00	100.00	200-00	200-00	400.00	400-00

	-113.95	-102.91	-111.27	-125.33	-138.33	-108.74	-117.15	200.00	400.00
	-123.66	-105.08	-113.88	-109.63	-118-49	-110-04	-118.16	• 0 0	400.00
	-79.79	-80.88	-69-09	-118.03	-122.18	-86.80	-89.15	200-00	200.00
	-92.73	-101.51	-100.46	-94.96	-100.06	-95.04	-108.73	• 00	200.00
	-70.67	-63.93	-73.31	-115.81	-116-86	-69.85	-67.28	200-00	100.00
	-89.34	-90.50	-98-01	-38.10	-89.41	-88.68	-89.28	• 00	100.00
	-67.08	-47.40	-60.22	-115.22	-115.48	-53.33	-48.17	200-00	50.00
	-92.73	-84.93	-101.26	-85.79	-86.12	-86.62	-83.95	.00	50.00
	-65.52	-29.83	-47.95	-115.07	-115.14	-35.76	-29.89	200.00	25.00
	-98.06	-d3.54	-106.53	-85.15	-85.23	-86.06	-82.54	• 0 0	25.00
	-64.40	12.00	-19.94	-115.02	-115.02	6.08	12.10	200.00	5.00
	-111.72	-83.16	-120.26	-84.94	-84.94	-85.87	- 82 - 08	• 00	5.00
	EPH(VMD)	HZ (VMO)	HZ (PHI=90)	HPHI(PHI=0)	HRH0(PH1=90)	EPHI (PHI=90)	ERH0(PH[=0)	DEPTH(M)	DISP(M)
				10E = 14	IA/M NOISE GR/ IV/M NOISE GR/	.95.00 DB .GT.	NDISE = -1		
				VUE = 13	LATH NOISE GRA	147.00 DB .GT.	NOISE = -		
				10E = 12	LA/M NOISE GRA	130.00 DB .61.			
					LATE NOISE GRO	123.60 08 6T.			
				9 10 10	LA/M NOISE GRI	100.00 08 .GT.	NOISE = -		
				ADE = 8	LATH NOISE GRA	139.00 DB .GT.	NOISE = -		
				10E = 7	LAZM NOISE GRA	129.00 D8 .61.	NOISE # 1		
				10E = 5	LA/M NOISE GRA	-99.00 DE .GT.	NOISE -		
				10E = 4	IA/H NOISE GRA	-87.00 DB .GT.	NOISE =		
					LA/M NOISE GR/	128.00 DB .GT.			
				55m # #	LAIM NOISE GRA	-71.00 DH .GT.			
				0HM S	NCE = 100.00	CONTACT RESISTA	LINE SOURCE (
	• 00	TTER= 200	TH OF TRANSMIT	100.00 K DEP	URCE LENGTH=	D. CO M LINE SO	RADIUS= 20	XM17 L00P	
- KG	IGHT= 6.00	MIT LOOP WE	0+00 WATTS XI	Jú POWER≠ 1	S/M EPS= 10.(40.= .01 MHO	000-00 HZ CO	F₽ EQ = 20	

XMIT LOOP DISP(M) DEPTH(M)	RADTUS RADITUS RADTUS R	0.00 M LINE SDU .00 LACT RESISTAT .01 ACT RESISTAT .01 00 Db GT .07	JRCE LENGTH= JCE LENGTH= LA/M NOISE GR LA/M NOISE CA/M NOISE C	100.00 M DEP UHMS DEP UDE N 100 M DE 100 M DE 10	TH UF TRANSMIT H2(PH1=90)	ITER= 300 H2(VMD]	0.00 EPH(VMD)
DISP(M) DEPTH(M)	LINE SOURCE C NOISE NOIS	CONTACT RESISTAN -71.00 DH 61 -71.00 DH 61 -71.00 DH 61 -71.00 DH 61 -87.00 DH 61 -87.00 DH 61 -97.00 DH 61 -113.00 DH 61 -123.00 DH	VCE = 100.00 IA/M NOISE CR IA/M NOISE CR	QHMS QHMS ADE	(06 =]Hd}]	10WA)7H	EPH(VMD)
DISP(M) DEPTH(M)	NUOI SE EN	-71.00 Dh .67. -71.00 Dh .67. -7.00 DB .61. -87.00 DB .61. -99.00 DB .61. -99.00 DB .61. -99.00 DB .61. -113.00 DB .61	LA/M NOISE GRU LA/M NOISE GRU LA/M NOISE GRU LA/M NOISE GRU NOISE GRU LA/M NOISE GRU LA/M NOISE GRU LA/M NOISE GRU HRHO(PHIEG GRU CPHIEG GRU HRHO(PHIEG GRU CPHIEG GRU HRHO(PHIEG GRU CPHIEG GRU HRHO(PHIEG GRU CPHIEG GRU HRHO(PHIEG GRU CPHIEG GRU HRHO(PHIEG GRU CPHIEG GRU CPHIEG GRU HRHO(PHIEG GRU CPHIEG GRU CPHIEG GRU HRHO(PHIEG GRU CPHIEG GRU CPHIEG GRU HRHO(PHIEG GRU CPHIEG GRU CPHIEG GRU CPHIEG GRU CPHIEG GRU CPHIEG CPHIEG GRU CPHIEG CPH	HPHI(PHI=0)	(06 =]Hd}]7H	10HA)ZH	EPH(VMD)
DISP(M) DEPTH(M)	A Discrete state s	EPHI (PHI = 90)	HAVM NOISE GRUNDISE G	HPHI(PHI=0)	(06 =]Hd}ZH	10WA)7H	EPH(VMD)
DISP(M) DEPTH(M)	Nol SE Nol SE NO	(27.00 08 61. -87.00 08 61. -97.00 08 61. -97.00 08 61. 29.00 08 61. 29.00 08 61. 23.00 08 61. -113.00 08 61113.00 08 61. -113.00 08 61113.00	HATH NOISE GRUNDISE G	исе на кака и советна и с	(06 =]Hd}2H	10HA)ZH	EPH(VMD)
DISP(M) DEPTH(M)	NUCLSE NU	 99.00 08 61 99.00 08 61 29.00 08 61 39.00 08 61 13.00 08 61 13.00 08 61 13.00 08 61 147.00 08 61 195.00 08 61 195.00 08 61 1119 1119	HAVM NOISE GRUNDISE G	HPHI(PHI=0)	(06 =]Hd}7H	10WA)ZH	EPH(VMD)
DISP(M) DEPTH(M)	NOI SE RHO(PHIGO)	C C C C C C C C C C C C C C C C C C C	HA/H NOISE GRUNDISE G	HPHI(PHI=0)	(06 =]Hd}7H	10WA)ZH	EPH(VMD)
DISP(M) DEPTH(M)	NOTSE *	(23,00 08 61. (39,00 08 61. (00,00 08 61. (13,00 08 61. (13,00 08 61. (14,00 08 61. (17,00 08 61. (1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,	LA/M NOISE GR LA/M NOISE GR LA/M NOISE GR LA/M NOISE GR LA/M NOISE GR HRHD NOISE GR HRHD (PHI=90)	106 - 7 106 - 8 206 - 10 206 - 11 206 - 12 206 - 12 206 - 12 206 - 15 206 - 15 206 - 15 206 - 15 206 - 15 206 - 15 207 - 10 200 - 20 200 - 20 20 20 20 20 20 20 20 20 20 20 20 20 2	(06 =]Hd}7H	(OWA)7H	EPH(VMD)
DISP(M) DEPTH(M)		EPHI (PHI = 90)	HAVM NOISE GRUNDLEANM N	иссано 106	(06 =]Hd}ZH	(OWA) ZH	EPH(VHD)
DISP(M) DEPTH(M)	NULLSE NULLSE NULLSE NULLSE NULLSE R R H I C R H C C H I C C H I C C C H I C C C C C C	EPHI(PHI=90) EPHI(PHI=90)	LA/M NOISE GRUNDLSE G	ИОЕ = 10 106 = 11 406 = 12 406 = 12 106 = 14 106 = 15 HPH[(PH]=0]	{06 =]Hd}ZH	(OWA) ZH	EPH(VHD)
DISP(M) DEPTH(M)	NOI SE # -1 NOI SE # -1 NOI SE # -1 NOI SE # -1 NOI SE # -1 ERHO(PHI=0)	EPHI(PH1=90) EPHI(PH1=90)	LA/M NOISE GRU LA/M NOISE GRU LA/M NOISE GRU LA/M NOISE GRU HRHO(PHI=90)	106 = 11 106 = 12 106 = 13 106 = 14 106 = 15 106 = 15 HPHI(PHI=0)	{06 =]Hd}7H	10MA)ZH	EPH(VHD)
DISP(M) DEPTH(M)		EPHI(PHI=90)	HAHA NOISE GRU HAHA NOISE GRU HAHO(PHI=90)	06 = 13 06 = 14 06 = 15 06 = 15 HPHI(PHI=0)	[06 =]Hd}7H	(OWA)ZH	EPH(VMD)
DISP(M) DEPTH(M)	NOI SE = -1 NOI SE = ERHO(PHI=0)	.07.00 08 .61. 1 .95.00 08 .61. 1 	LA/M NOISE GRU LV/M NOISE GRU HRHO(PHI=90)	ЮЕ = 14 102 = 15 НРНІ(РНІ=0)	{06 =]Hd}7H	(0WA)ZH	EPH(VHD)
DISP(M) DEPTH(M)	ERH0(PH[=0)	(06=1Hd)1Hd3	HRHO(PHI=90)	(0= IHd) I HdH	(06=]Hd)7H	(OMV)2H	EPH(VMD)
			Ĩ				
5 • 00 •00	-94.31	-97.38	+	-96.73	-135.34	-98.66	-127.39
5.00 300.00	12-10	6 • 08	-133.91	-133.91	-19.94	12.00	-64.41
25.00 .00	-94.52	-97.48	-96-89	-96.85	-121.49	-98.72	-113.88
25.00 300.00	-29.89	-35.76	-133.98	-133.94 [.]	-47.95	-29.83	-65.52
50.00 .00	-95.18	61.79~	-97.36	-97.19	-115.88	-99.28	-108.45
50°00 300°00	-48.17	-53.33	-134.17	-134-04	-60.22	-47.40	-67.08
100.00 .00	-97.75	-98-98	-99.20	-98.53	-111.42	-101-92	-104.66
100.00 300.00	-67.29	-69.86	-134.95	-134.41	-73.31	-63-93	-70.67
200-00 +00	-107.30	-103-14	-105.80	-103.12	-110.86	-110.84	-107.94
200-00 300-00	-89.06	-86.86	-138.03	-135.86	-89.10	-80.90	-79.79
400-00 .00	-133.53	-115.35	-123.99	-115.54	-120-21	-112.99	-118.41
00*00E 00*00 *	-117.61	-109-77	-149.53	-141.13	-111.74	-103.66	-113.95

200.00 400.00	50.00 100.00 100.00	DISP(M) 5.00 25.00	
• • • • • • • • • • • • • • • • • • •	• • • • • • • • • • • • • • • • • • •	DEPTH(1) .00 .00	х т Я Н С С С С С С С С С С С С С С С С С С С
-94.92 -132.12 -132.12	- 48.70 - 48.70 - 69.27 - 69.27 - 94.92	ERH0(PH1=0 12.10 12.10 -29.99	
-120,12	I I I I I I B 6 6 7 N 5 6 B 6 8 8 8 8 8 B 8 8 8 4 4 9 B 8 8 8 4 4 9 B 8 8 8 8 8 4 4 9 B 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	EPHI(PHI 6,08 -35.52	0.010. .01 .01 Hd NO.000 M LINE S0 CUNTACT RESIST .01 Hd 1.162.000 DB .GT .GT 1.120.000
=116.99 =116.99	-116.99 -116.99 -116.99	HRH0(PH1=90) -116.99 -116.99 -116.99	DURCE ERST 10. NCE ENGTH 10. NCE I LENGTH 10. NCE I LO. NCE E CRT NCE ERST 10. NCE ERST 10. N
-116.99 -116.99	-116.99 -116.99 -116.99 -116.99 -116.99	HPH1(PH]=0 -116.99 -116.99	
-94.52 -126.10 -126.10	- 48.05 - 60.74 - 75.29 - 75.29	- 12(P7[#90) - 19.94 - 19.94 - 19.94 - 48.05	10.00 WATTS X
-111.05 -111.05	-29-79 -47-24 -63-93 -63-93 -82-62	HZ (VMD) 12.00 12.00	
-73.10 -95.28 -98.28	- 30 - 12 - 42 - 49 - 55 - 99 - 73 - 10	ЕРН(V М Ш) - 2 • 0 9 - 2 • 0 9 - 3 3 • 1 2	
			ະ ວ ວ ວ ະ ຄ

	FREQ=	2000-00 HZ CC	= • 0NC	0HM 10.	S/M EPS=	10-00	POWER=	10.00 WATTS	XMIT LOOP	₩EIGHT=	6.00 KG
	XMIT LOO	P RADIUS=	20.00 M	LINE SOI	URCE LENG	TH= 1	00-00 M D	EPTH OF TRANS	MITTER=	300-00	
		LINE SOURCE	CONTACT	RESISTA	«CE = 1	00-00	SMH				
		NOI SE	-71.00	DH .61.	IA/M NOI	SE GRAL					
		NDI SE	-128.00	DB .GT.]	LA/M NUL	SE GRAU	5 m m 2 1 m				
		NOI SE	-87.00	DH .GT.	ION W/VI	SE GRAC	1 t i 8 1 U i				
		NOISE =	-99.00	DR . GT.]	ION W/WI	SE GRAC	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1				
		NOISE =	-129.00	DB . GT . 1	ION W/M	SE GRAC	~ ~				
		NOISE #	-139.00	DB .61.]	IDN W/VI	SE GRAD	د الس الس الس الس الس الس الس الس الس الس				
			-113.00	DB 61. 1	TON WOL	SE GRAD	10 4 10 4				
		NOISE =	-123-00	06 . 67.	ION W/WI	SE GRAD					
		NOISE #	-130.00	DB . GT. 1 DB . GT. 1	TON MAL	SE GRAD					
		NOI SE =	-107-00	DB 61.	ION W/M	SE GRAD	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1				
		NOISE =	-95.00	DB • GT• 1		SE GRAD	С в 1 5				
(M)4510	DEPTH(M) ERHO(PHI=0)	IHd3 ((06=1Hd)	нано (рн	(06=1	0= [нд } [ндн	06=IHd)7H (OWA) ZH) ЕРН(VHD	_
5.00	• 00	-94.31	I	97.38	-96-7	4	-96.73	-135.34	-98.66	-127.	19
5+00	300-00	12.10		6.08	-133.9	T	-133.91	-19.94	12.00	- 64 - 4	1
25+00	00•	-94.52	I	97.48	-96-8	0	-96.85	-121.49	-98.72	-113.6	38
25.00	300°00	-29.89	1	35.76	-133.9	æ	-133.94	-47.95	-29.83	- 45 -	52
50.00	0 0 •	-95.18	1	97.79	-97.3	ç	-97.19	-115.88	-99.28	-108-	5
50+00	300°00	-48.17	I	53 .3 3	-134.1	7	-134.04	-60.22	-47.40	-67.(8
100.00	00.	-97.75	I	98 . 98	-99.21	0	-96.53	-111.42	-101-92	-104-6	0
100.00	300-00	-67.29	ł	69 . 86	-134.9	۶¢	-134.41	-73.31	-63-93	-10.6	1
200-00	.00	-107.30	1	03.19	-105.8	0	-103.12	-110.86	-110.64	-101-	4
200.00	300-00	-89.06	I	86.86	-138-0	e	-135.86	-89-10	-80.90	- 79 - 7	5
400-00	• 00	-133.53	-1	15.35	-123-9	6	-115.54	-120-21	-112.99	-118.4	1
400+00	300°00E	-117.61	1-	77.00	-149.5	e	-141.13	-111.74	-103.66	-113.9	15

400,00	400.00	200,00	200.00	100.00	100-00	50.00	50.00	25,00	25.00	5.00	5.00	DISP(M)		
•°00	• 00	• 00	• 00	• 00	• 00	• 00	• 00	• 00	• 00	• 00	• • • •	DEPTH(i1)	X 3 1 7 7 00	
-132.12	-132-12	-94.92	-94.92	-69.27	-69.27	-48.70	-48.70	-29.99	-29.99	12.10	12.10	ERHQ(PH1=0		000.00 HZ C
-120,12	-120,12	188.88	-88.88	-68.82	-68.82	-52.43	-52.43	-35.52	-35.52	6.08	6.04)	CUNTACT RESIST CUNTACT RESIST -1205 00 DB .GT -1113.00 DB .GT -1120.00 DB .GT	01 MH
-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99) HRHQ(PH I=9 0)	A CURCE A C	05/M EPS= 10.
-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	HPH1 (PH1=0		
-126.10	-126.10	-94.92	-94.92	-75.29	-75.29	-60.74	-60.74	-48.05	-48.05	-19.94	-19.54	(C6=]4d)ZH		10.00 WATTS
-111.05	-111.05	-82.62	-82.62	-63.93	-63.93	-47.24	-47.24	-29.79	-29.79	12.00	12.00	HZ (VMD)		XMIT LOOP
-98-28	-93-28	-73-10	-73-10	-55-99	-55-99	-42.49	-42.49	-30 - 12	-30 • 12	-2.09	-2-09	EPH(VMD)	•	Æ I GHT H
م ل	Ð	0	J	ç	Ţ	J	J	i v	iv.	Ţ	v			в•00 жб

ХG																								
00																								
IGHT= 6.	• 00											EPH(VHD)	-73.42	-48-64	-60-89	-50.49	-58.72	-53.17	-62.48	-59.72	-80.59	-78.75	-109-08	-108.44
LOOP WE	50											(QMA)	40*E	2.01	1.9.17	9.61	15.55	6.63	0.81	3•36	11.70	12.04	1.22	11.20
TIMX	HITTER											7H (Ĩ	-	1	i	7	4	ï	9	ĩ	ĩ	1	-10
DO WATTS	OF TRANSI											06=1Hd)7)	.80.64	-19.94	·69.58	+8.04	-70-14	60.67	+1.15	-74.82	-93.12	92.88	20.37	122.18
10.0	DEPTH											1 (0)	ł	ł	•	r	ľ	1	I	·	1	•	ï	1
POWER=	H 00-00	SMH	8 8 4 0 0	а в в м 4	н н с	0 • •	00 0 # 1		11 11 11 11	и 13 13 13	шш н в ч п	- IHd) IHdH	-57.07	61.61-	-59.48	-80.23	-64.70	-81.51	-74.76	-85.46	-88.92	-94.81	-107.49	-112.70
10.00		0.00	GRAD	GRAD	CRAD	GRAD	GRAU	GRAD	C CRAD	GRAD	GRADI	106-											•	•
EPS≡	LENGTH	100	NOI SE	NOISE	SION	SION	NOISE	SION	IS ION	I ON STON	NOT SE NOT SE	- IHd) Dł	-57.12	-79.82	-60.56	-81.06	-68.79	-84.75	-89.61	-98.54	-96.65	04.86	13.48	18.96
M/S01	OURCE	ANCE	1A/H 1A/H	IA/H IA/H	LA/M		IA/M		LA/M	H/H/H/H/H/H/H/H/H/H/H/H/H/H/H/H/H/H/H/	IA/H IV/H	HRI I		•	•	•	•	•	•	·	•	ĩ	ī	ī
-01 MH	LINE S	RESIST	08 . 67.	08 • 61•	08 . GT.	08 - 61.	08 . GT.	08 6T.	08 . GT.	08 6T.	08 . GT.	06= 1 Hd	52.64	6.08	55.12	35.50	5 0 •48	52.29	06 • 01	58 . 0E	36.66	96.20	76.70	13.56
	W 00.	ONTACT	82.50 13.00	• 1 • 00 • 1 • 00	15.00	38.00	60.00	28.001	37.00	53.00	19.00	EPHI	ť		Ĩ	ï	ĩ	ĩ	1	ĩ	ī	ĩ	ī	-1
IZ CON	20	IURCE C	1		1		1		1			(0=1H	7.35	2.10	5.83	0.05	5.62	8.93	9.63	6.74	8.58	32.0	18.36	5.01
00.00 H	RADIUS	LINE SO	NOI SE	NOISE	NOI SE	NULSE #	NOI SE	NOISE	NOI SE		NOI SE	ERHO(P	4		5	1	1	1	9 1	1	1	5	-10	-11
=REQ= 50	KMIT LOUP											069 TH(M)	• 00	50 •0 0	• 00	50.00	•0•	50 -0 0	0 0 •	50 °0 0	00.	50.00	• 00	50.00
-	[°]											(W) dS10	5.00	5.00	25.00	25+00	50+00	50.00	100.00	100-00	200-00	200.00	400-00	400*00

€ N	-108.4	-107.57	-123.04	-122.95	-129.56	-116-20	-126-16	100-00	400.00
76	-110.9	-101-01	-123.14	-113.06	-118.26	-113.31	-114.45	• 00	400.00
76	-78.	-82.49	-94.38	-107.09	-120.84	-87.79	-94.48	100.00	200.00
96	-86-3	-87.05	-97.08	-93.26	-104.32	-89.60	- 96 • 04	• 00	200.00
12	~59.7	-62.91	-75.25	-101.06	-104.89	-68.68	-69.42	100.00	100.00
4	-69-4	-83.89	-85.85	-80.37	-85.11	-76.60	- 86 - 56	• 00	100.00
17	-53-1	-46.51	-60.74	-99.20	-100.17	-52.41	-48.72	100.00	50.00
. Э	-68.4	-70.41	-84.13	-74.14	-75.37	-70.83	-71.29	• 00	50.00
63	-50.4	-29.60	-48.05	-98.70	-98.94	-35.52	- 29 - 99	100.00	25.00
₽ 8	-72.4	-65.09	-87.59	-72.02	-72.33	-68.92	-65.86	• 00	25.00
4	-48.0	12.01	-19.94	-98-53	-98.54	6.08	12.10	100-00	5.00
75	-85.	-63.38	-100.67	-71.27	-71.28	-68-24	- 64 . 02	• 00	5.00
	EPH(VMD)	HZ(VMD)	(06=1Hd)2H	HPH[(PH[=0)	HRH0 (PH I = 90)	EPHI (PHI =90)	ERHO(PHI=O)	OEPTH(M)	UISP(M)
				ADE = 15	V/M NOISE GR	107.50 DB .GT. 1	NOTSE a		
					A/M NOISE GR	119.00 D8 .GT. 1	NOISE = -		
				ADF = 13	A/M NOISE GR	153-00 08 -GT- 1			
					A/M NUISE GR	137.09 08 .61. I			
				ADE = 10	A/H NOISE GR	128-00 DH -GT- 1	NOISE = -		
				ADE = 9	A/M NOISE GR	118.00 DB .GT. 1	NOISE * -		
					A/M NOISE GR	190.00 DB .GT. 1			
					A/M NOISE GR	120-00 DB -GT- 1	NOI SE -		
				ADE = 5	A/M NOISE GR	115.00 DB .GT. 1	NO1 SE = -		
					A/M NOISE GR	106-00 DB -GT- 1	NOISE = -		
					A/H NOISE GR	141-00 DB _GT_ 1			
					A/M NUISE GR	-82.50 D8 .GT. 1	NOISE #		
				OHMS	CE = 100.00	CONTACT RESISTAN	LINE SOURCE (
	00.00	ITTER= L	TH OF TRANSMI	100.00 M DEF	RCE LENGTH=	D.00 M LINE SOU	RADIUS= 20	XMIT LOOP	
6.00 KG	WEIGHT=	MIT LOOP	LO. DO WATTS X	OC POWER# 1	/M EPS= 10.	•01 MHOS	100-00 HZ CO	FREQ= 50	

	FREQ= 5	5000.00 HZ	C GND . =	HH 10.	M/SD	EPS= 10.	OO POME	R M	10.00 WATTS	XWIT LOOP	161GH1= 6.
	XMIT LOOF	● RADIUS +	20.00 H	LINE S	OURCE	LENGTH=	100-00	M DE	PTH OF TRANSM	ITTER= 20	0.00
		LINE SOUR	CE CONTACI	RESIST	ANCE =	100.00	SMHD				
			-113.00	DH .GT.	IA/H	NUISE GR	AUE *	~ •			
		NOI SE .	-141.00	06 . 67.	IA/M	NOISE GR		v ~			
		= 3310N	-106.00	08 .61.	1A/M	NOI SE GR	ADE =	4			
			-115.00	08 .61.	1A/M	NOISE GR	A05 =	Ş			
		NOI SE =	-138.00	08 .6T.		NUISE GR	A0€ = A05	••			
		NOI SE =	-160.00	DB . GT.	IA/H	NOISE GR	ADE =	- യ			
		NOI SE	-118-00	DB .GT.	1A/H	NOISE GR.	ADE =	6			
			-128.00	08 .61.	1A/M	NOISE GR	ADE = 1	10			
		NOI SE #	-144-00	DB . GT .	10/1	NULSE GR					
		= 3SION	-153.00	08 .61.	IA/M	NOISE GR.		20			
		NOI SE =	-119.00	DB . GT. DB . GT.	IV/H IV/H	NOISE GR	ADE = 1	4 5			
D15P(M)	06PTH(M)	Е В НО С РН] =	1ндэ (о	(06=1Hd)	НАНС	(06=1Hd)(a / 1 H d H	10- 1 H	100-110761		
									106+144174		
5.00	• 00	-84.1	ī 80	97 . 16	ĩ	0.55	-90*5	4	-125.60	-88.94	-110.41
5.00	200-00	12.1	0	6.0 8	-12	8.90	-128.9	0	-19-94	12.01	-48.64
25.00	00•	-84-6	ĩ	97.39	6-	06-01	9-90-8	0	-111.92	-89.21	-97.20
25.00	200-00	- 29 - 9	6	35.52	-12	9°05	-128.9	2	-48.05	-29.60	-50.49
20.00	•••	-86.1	ء ب	98.10	61	1.98	-91.5	6	-106.82	-90.63	-92.62
50.00	200-00	-48.7	0	52.43	-12	9.50	-129.1	\$	-60.74	-46.50	-53.17
100.00	00•	- 61 - 1	5 1 6	10.72	6-	6.02	-94.40-	6	-104.20	-96-55	-92.41
100.00	200-00	-69-2	6 - 6	8.82	-13	1.31	-130.0	¢	-75.29	-62.89	-59.73
200-00	• 00	-113.7(51	19.07	-10	9.24	-103.2	ъ	-108.53	-101-86	-109.75
200.00	200-00	-94-81	60 I	8.94	-13	8.31	-133.34	*	-94.94	-82.93	-78.76
400-00	• 00	-125.4	7 -12	0.93	-12	7.93	-123.3		-129.15	-109.72	-119.70
00-00+	200-00	11-161-	11- 1	9.82	-15	4.25	-144.49	6	-126.03	-113.30	-108.43

	-108.43	-114.24	-126.11	-167.89	-177.04	-120.17	-132.09	300-00	400.00
	-157.98	-120.39	-137.75	-132.68	-138.41	-128.65	-137.01	• 00	400.00
	-78.76	-82.96	-94.92	-159.66	-162.33	-88.88	- 94 - 93	300.00	200.00
	-108.08	-117.39	-122.70	-115.09	-118.37	-110.79	-115.51	.00	200.00
	59.73	-62.89	-75.29	-157.43	-158.09	-68.82	-69.27	300-00	100.00
	-110.53	-111.52	-121.55	-108.94	-109.75	-104.98	-104.39	.00	100.00
	-53.17	-46.50	-60.74	-156.85	-157.02	-52.43	-48.70	300.00	50.00
	-116.84	-108.89	-125-54	-107.17	-107.37	-103-35	-101.40	• 00	50.00
	-50.49	-29.60	-48.05	-156.71	-156.75	-35-52	-29.99	300.00	25.00
	-123.11	~108.50	-131.04	-106.71	-106.76	-102.93	-100.64	.00	25.00
	-48.64	12.01	-19.94	-156.66	-156.66	6.08	12.10	300.00	5.00
	-137.22	-108.64	~144.85	-106.56	-106.36	-102.79	-100-39	• 00	5.00
	MPH (VMD)	HZ (VMD)	HZ (PH] =90)) HPHI(PHI=0)	HRH0 (PH I = 9 0	EPHI (PHI =90)	ERHO(PHI=0)	DEPTH(N)	DISP(M)
	0 0	41 T∈R ■ 90	TH OF TRANSMI		VCCE ENGTHE NCCE ENGTHE LA/H NOISE GF LA/H NOISE GF CF	D.00 M LINE SO CONTACT RESISTA -82.50 DB .GT. 113.00 DB .GT. 1141.00 DB .GT. 115.00 DB .GT. 115.00 DB .GT. 115.00 DB .GT. 115.00 DB .GT. 118.00 DB .GT. 119.00 DB .GT. 119.00 DB .GT.	RADIUS NOISE SOURCE OURCE OURC	XMIT LOOP	
- 00 KG	E[GHT= 6.	MIT LOOP WI	0.00 WATTS X	.00 POWER= 1	5/M EPS= 10.	ND. = .01 MHO:	100.00 HZ CO	FREQ= 50	

	FXEU	7000-00 117	Cu∛Ď.= ,01	MHOS/M	EPS= 10.4	00 PJWER=	10.00 WATTS	XMIT LOOP W	EÌGH1=	
	אשן רסטו	P RADIUS=	20.00 M LIN	E SOURCE	LENGTHE	100-00 M	DEPTH OF TRANSM	ITTER=	00	
		LINE SOURC	E CONTACT RES	ISTANCE	• 100.00	SMHO				
		NO I SE	-116-00 DE	GT. 1A/M	NOISE GRU					
		NUJSE =	-149.00 08	14/W	NDISE CR					
		NOISE =	-106.00 DB	5T. 1A/M	NOISE GRI					
			-120.00 UB	GT. 1A/M	NOISE GRA	ADE = 5				
				5T. 1A/M	NOISE GRI	A DE				
		×01SE =	-163.00 113	51 - 14/M	NUISE GK					
		NOISE =	-120.00 DB	I. 1A/M	NOISE GRA					
			-135.00 PB .(T. 1A/M	NOISE GRA	10E = 10				
				1. 1A/M	NO ISE GX					
		NUISE =	-156.00 DB	T. 1A/M	NUISE GRA					
		NDISE #	-124.00 DB -1 -107.50 DB -1	T. 14/M	NOISE GRA					
D]SP(M)	UÊPTH(11)	ЕКНО(РН]#(о) ЕРН] (РН] =	90) HRF	(06=1H4)0H	=Ind)[mdH	(06=I4d)ZH (0	(0M7) ZH	EPH(VMD)	
5.00	• 00	12.10	5 ¢8	1	16.99	-116.99	-19-95	12.00	7 a .	
5. 60	°0.	12.10	5 6 0B	-	16.99	-116.99	-19.95	00.01		
25.00	• 00	-30-02	-35.35	1	16.99	-116.00				
25-00		-0 0E -		•			07 • 07	1/*62-	-27 - 24	
	•	0.00	-35.35		16.99	-116.99	-48.13	-29-71	-27 - 24	
50.00	00. •	-49.05	-51.98		16 . 99	-116.99	-61.09	-46.95	-39.76	
50°00	00.	-49.05	-51.96	1	16.99	-116.99	-61.09	-46.95	-39.76	
100.00	00.	-70.47	-68.73	-	16.99	-116.99	-76.49	-63.69	-53-82	
100.00	00.	-70.47	-68.73	1-	16.99	-116-94	-76.49	-03.69	-53.82	
200.00	• 00	-98.16	-90.64	-	16.90	-116.99	-98.16	-83.82	-72.49	
200.00	• 0.0	-98.16	-90 - 69	ī	16.99	-116.99	-98.16	-83.82	-72.49	
400.00	• 00	-139.72	-126.26	-	16.99	-116.99	-133.70	-115.75	-98.88	
400.00	.00	-139.72	-126.26	-	16.99	-116.94	-133.70	-115.75	-93.88	

	-122.21	-104.61	-131.01	-117.07	-123.26	-117.26	-116.59	50.00	400.00
	-124.29	-99.90	-126.50	-110.37	-116.55	-109-20	-109.16	• 00	400-00
	-84.20	-82.71	-95-80	-97.34	-106.60	-87.51	-93.40	50.00	200.00
	-87.49	-80.95	-95.90	-90.94	-97.80	-67.59	-91.06	• 00	200.00
	-56.69	-63.15	-75.96	-86.91	-100.30	-67.83	- 69 - 99	50.00	100.00
	- 59 • 96	-70.35	-78.85	-75.71	-90.17	-70.48	- 70 . 99	• 00	100.00
	-48.40	-46.18	-61.32	-82.62	-85.96	-51-79	-49.29	50.00	50.00
	54.58	-65.92	-70.66	-65.21	-69.40	-59.83	-66.53	• 00	50.00
	-45.10	-29.44	-48.12	-81.25	-82.10	-35.32	-30.13	50 .0 0	25.00
	-56.28	-49.66	-69.92	-59.83	-60.94	-54 • 52	- 55 . 07	• 00	25.00
	-42.87	12.01	-19-95	-80.77	-80.81	6.08	12.09	50.00	5.00
	-68.63	-43-39	16.08-	-57.37	-57.42	-52.09	-47.04	• 00	5.00
	EPH(VMD)	HZ (VMD)	H2 (PHI=90)	HPH](PH]=0)	HRH0(PH[=90)	ēPHI(PHI=90)	ERHO(PHI=0)	DEPTH(M)	DISP(M)
	0 0 0	117ER = 5	TH OF TRANSM	1000-00 X DED 1000-00 X DED 1000 X N N N N N N N N N N N N N N N N N	URCE LENGTH= NCE = 100.00 IA/H NOISE GRA IA/H NOISE GRA	0.00 M LINE SO CONTACT RESISTA 116.00 DB .GT. 116.00 DB .GT. 116.00 DB .GT. 120.00 DB .GT. 120.00 DB .GT. 122.00 DB .GT. 122.00 DB .GT. 125.00 DB .GT. 125.00 DB .GT. 135.00 DB .GT. 135.00 DB .GT. 135.00 DB .GT. 124.00 DB .GT.	RADIUS H NOISE SOURCE NURCE NOISE H H H H H H H H H H H H H H H H H H H	XMIT LOOP	
5.00 KG	EIGHT= 0	XMIT LOOP W	0.00 WATTS	O POWER 1	S/M EPS= 10.0	ND	000-00 HZ CO	FSEQ= 70	

	FR EQ=	7000.00 HZ	COND.=	10HW 10*	S/M EP	S= 10.	OO POWER=	10	.00 WATTS	XMII TOO	P WEIGHT=	6.0
	XHIT LOC	DP RADIUS≖	20.00 M	I LINE SOL	URCE LE	NGTH=	100°00 H	DEPT	H OF TRANSM	111ER=	100-00	
		LINE SOUR	ICE CONTAC	T RESISTAN	ACE =	100.00	OHMS					
		- 3010 4										
		NDI SE	00.041-	08 67								
		NOI SE	-106.00	09 61		DISE GR	40F = 4					
		* 3S ION	-120.00	DB .61. 1	IA/M N	UISE GR	ADE = 5					
		NO I SE =	-122.00	DB . GT. 1	LA/H N	UISE GR	ADE = 6					
		NOI SE =	-141-00	DB . GT. 1	LA/H N	OISE GR	ADE = 7					
		= 3510N	-163.00	DB .GT. 1	LA/M N	DISE GR	ADE - B					
		• ISION	-126-00	D6 .GT.]	IA/W N	OISE GR	ADE = 9					
		NOI SE #	-135.00	DB . CT. 1	A/M N	OISE GR	ADE = 10					
		NOI SE	-139.00	DB .GT. 1	LA/M N	OISE GR	ADE = 11					
		* BS ION	-145.00	DB . GT . 1	LAIM N	OISE GR	AUE = 12					
		# 35 ION	-156.00	08 .61. 1	A/H N	015E GR	ADE = 13					
			-124.00	08 .61.	LA/M N	DISE GR	ADE = 14					
				• • • •								
(W) dS10	DFPTH(w	THO JUNE T	H03 (0=	100=140)1	TUHBH	(06=1Ha	H0 1 H 0 H	1 U - 1	H110H1#001		101403 10	10
												2
5.00	• 00		10	-67.90	-12	• 4 0	-72.39	•	-101.72	-64.5	7 – B.	. 65
5.00	100-00	12.	10	6 • 0 ⁶	101-	•58	-101-57		-19.95	12.0	1-45	. 88
25.00	• 00	- 65 -	82	-68.60	-13	-51	-73-19		-88.69	- 66.3	- 69	1.56
25.00	100-00	-30-	07	-35,35	-102	•01	-101-75		-48.13	-29.4	9 - 4	.10
50 •00	0 0 •	-71.	17	-70.62	-76	•72	-75.44		-85.37	-71.81	-9-	.98
50.00	100-00	- 65 -	05	-51.97	-103	•34	-102.31		-61.09	-46.0	- + -	1.41
100-00	00.	-06-	05	-76.78	-87	•00	-82.10		-87.59	-83-51	99- 98	.52
100.00	100-00	-70.	55	-68.66	-108	.47	-104.42		-76.47	-62.7	56	• 69
200-00	00.	- 38-	16	-91.17	-105	• 10	-96.20	•	-100.32	-86-9	-103	•34
200.00	100-00	- 6-	64	-89.69	-124	.61	-111.32		-97.69	- 64 • 0	- 81	• 54
400*00	• 00	-116.	33	116.52	-122	•82	-117.29		-131.27	-104.3	le1- 131	. 87
400-00	100.00	-131.	- 56	122.98	-135	• 60	-129.70	•	-130.72	-112.3	1 -12	. 23

6.0C KC

.26	-122	-119.75	-133.73	-154.76	-163.01	-126.19	-138.63	200.00	400.00
• 4 3	-129	-114.01	-137.79	-130+46	-133.99	-127.90	-129-48	• 0 0	400.00
• 24	-84	-84.76	-98.17	-141.51	-146.85	-90.72	-98.10	200.00	200.00
.06	86	-103.08	-113.46	-107.88	-114.13	-102.10	-116.22	• 00	200.00
63	-56	-62.81	-76.49	-137.67	-139.02	-68.73	-70.46	200.00	100.00
• 51	-109	-99.65	-107.69	-98.06	-99.71	-92.67	-93.96	• 00	100.00
- 41	-48	-46.05	-61.09	-136.66	-136.99	-51.98	-49.05	200.00	50.00
• 5 6	66-	-93.73	86*601-	-94.86	-95.27	-89.74	- 88 - 04	• 00	50.00
.10	-45	-29.43	-48.13	-136-40	-136.48	-35-35	-30.07	200-00	25.00
• 95	-102.	-92+34	-114.99	-93-99	-94.09	-88.95	- 86 • 48	• 00	25.00
.88	-42.	12.01	-19.95	-136.32	-136.32	6.08	12.10	200.00	00 - د
.58	-115.	-92.15	-128.64	-93.70	-93.70	-88-69	- 85.97	• 00	5.00
2	EPHIVMC	H2 (VMD)	HZ (PH1=90)	HPH](PH I= 0)	HRH() (PH I = 90)	EPHI (PHI =90)	ERH0(PHI=0)	DEPTH(M)	ISP(M)
				ADE = 15	V/M NOISE GRA	7.50 D8 .GT. 1	NOI SE10		
				10E - 14	A/M NOISE GRA	6.00 D8 .GT. 1/	NOISE = -12		
					A/M NOISE GRA	5.00 DH .GT. 1/	NOISE14		
				10E = 11	A/M NOISE GRA	9.00 DB .GT. 1/	NOISE = -13		
				10E = 10	A/M NOISE GRA	5.00 DB .GT. 1/	NOISE = -13		
					A/M NOISE GRA	3.00 D8 .GT. 14	NOISE16		
				10E = 7	A/M NOISE GRA	1.00 DB .GT. 1/	NOISE = -14		
				IDE = 6	A/M NOISE GRA	2.00 DE .GT. 14	NOISE122		
					AVA NOISE GRA	5.00 D8 .GT. 14			
					A/M NOISE GRA	9.00 D8 .GT. 14	NOISE 14		
				10E = 2	A/M NOISE GRA	5.00 D6 .GT. 14	NOISE = -110		
				106 = 1	YM NOISE GRA	3.00 D8 .GT. 14	NOISE = -88		
				OHMS	CE = 100.00	WTACT RESISTANC	LINE SOURCE COM		
	00.0	TTER= 200	TH OF TRANSMI	100-00 M DEPT	ICE LENGTH-	DO M LINE SOUR	RADIUS= 20.(MIT LOUP	
6.00 KG	EIGHT =	MIT LOOP WE	D. DO WATTS X	10 POWER= 10	M EPS= 10.0	-01 MHOS/	00.00 HZ COND.	"REQ= 70	_

EQ= 7	000-00 HZ C	= • QND :	-01 MHUS/	M EPS= 10.	.00 POWER=	10.00 MATTS X	MIT LOOP WE	EIGHT= 6+00 K
æ	ADIUS =	20.00 M	LINE SOUR	ICE LENGTH=	100-00 W	DEPTH OF TRANSMI	TTER= 30(0.00
	INE SOURCE	CONTACT	RESISTANC	E = 100-00	S MHO C			
6 h. h.	40156 = 10156 = 10156 =	-116-00 0 -116-00 0	8 .61 1A 8 .61 1A 8 .61 1A	VM NDISE GF VM NDISE GF VM NDISE GF	AADE # 1 AADE # 2 AADE # 3			
Z Z.	101 SE =	-106.00 0	8 . GT. 1A	VM NOISE GR	14DE = 4 14DE = 5			
6. 6 .	4015E #	-122.00 D	8.61.1A	VM NOISE G	4ADE = 6 4ADE = 7			
	NOI SE	-163.00 0	6 .6T. IA	VN NOISE GE	24DE = 6			
	NOI SE #	-135.00 0	8 6T 1A	VH NOISE GE				
	NULSE = NOISE =	-145.00 0	B . 61. 1A	VM NOISE G	(AUE = 11 (ADE = 12			
	NOISE # NOISE # NOISE #	-156.00 D -124.00 D -107.50 U	8 67 14 8 67 14 8 67 14	VM NOISE GE	XADE = 13 XADE = 14 XADE = 15			
	ЕКНО(РН]=0) EPHI ((06=1Hd	нкн0 (рн1 = 90)	=1Hd)1HdH ((06=IHd)ZH (0	(0H A) 2H	EPH (V#D)
	-104-30	-10	6•49	-111.68	-111-88	-150-64	-114.01	-131.77
	12.10		6.08	-168.53	-168.53	-19-95	12.01	-42.88
	-104.56	-10	6.65	-112.10	-112.05	-136.25	-113.73	-118.22
	-30.07	E I	5.35	-168.63	-168.58	-48.13	-29.43	-45.10
	-105-39	-10	7.13	-112.78	-112.57	-130.82	-114.00	-112.69
	-49.05	-5 -	1.98	-168.94	-168.76	-61.09	-46.05	-48.41
	-103.62	-10	8.99	-115.44	-114.56	-127.06	-116.58	-108.69
	-70.47	91	8.73	-170.15	-169.43	-76.49	-62.81	-56.69
	-120.64	-11-	5.64	-125.07	-121-52	-129-09	-120-82	-112.86
	-98-17	ō 1	0.69	-174.97	-172.07	-98.16	-84.76	-84.24
	-142.06	-13	6.79	-145.99	-141-96	-147.24	-125.96	-131.68
	-139.74	-12	6.27	-190.80	-181-88	-133.70	-120.37	-122.26

	דאבטד 100 אאוד במטפ	ADIUS=	E CONTACT	.01 MHUS	те ерон Се семотн Се 100	10.00 POXER#	10.00 WATTS DEPTH OF TRANSM	XMIT LOOP I Itter=	•00	۵ • 00 * G
-		Н Н Н П Н Н Н Н Н Н Н Н Н Н Н Н Н Н Н Н	1 1			ССССССССССССССССС ПЛТТТТТТТТТТТТТТТ ПЛТТТТТТТТТТТТТТТТТ				
012P(M)	DEPTH(11)	ERHC(PHI#	0) EPHI	х 06 (06 =1 на)	HRH() (PH[=	90) HPHI.(PHI=	0) HZ(PhIm90)	H2 (VMD)	EPH(VHU)	~
5.00	• 00	12.0	Q	6.09	-116.99	-116.99	-19.95	12.01	6•£	S
25.00	• 00	-30-2	•	35.10	-116.99	-116.99	-48.26	-29.59	-24 - 21	0
25.00	• 00	-30.2	0	35.10	-116.99	-116-99	-48.26	-29.59	-24 - 21	0
50.00	• 0 0	-49.5	7 -5	51.49	-116.99	-116-99	-61.61	-46.59	-36-91	5
50.00	• 00	-49.5	3 - 2	51.49	-116.99	-116-99	-61.61	-46.59	-36-9	σ
100.00	• 00	-72.1	2	96*89	-116-9 <u>0</u>	-116.99	-78.14	-63.63	-51-7	Q
100.00	• 00	-72.1	~	53 . 96	-116.99	-116-99	-78.14	-63.63	-51.7	Q
200.00	• 00	-102.4	J.	93.45	-116.99	-116.99	-102.45	-82.88	-72.5	o
200.00	• 00	-102.4	ຫ -	93.45	-116-99	-116-99	-102.45	-85.88	-72.5	0
400.00	• 00	-149.5	4 -1	34.54	-116.99	-116.99	-143.52	-119.69	8•86	••
400.00	•00	-149.5	4	34.54	-116.99	-116.99	-143.52	-119.69	-98.8	-

		FREQ= 10	0000.00 HZ C	W 10" "ONO!	HOS/M EPS# 10	0.00 POWER=	10-00 WATTS X	CMIT LOOP	WEIGHT=	6.00 KG
		XMIT LOOP	- RADIUS -	20.00 M LINE	SOURCE LENGTH#	100-00 H C	EPTH OF TRANSMI	TTER=	50.00	
			LINE SURCE	CONTACT RESIS	TANCE = 100.0	SMHD DC				
			NOI SE #	-120.00 DB .61.	. IA/M NDISE (SRADE = 1 SRADE = 2				
			= 3S ION	-151.00 06 .67.	. LA/M NOISE (RADE = 3				
				-101.00 08 .67.	IA/M NOISE	SRADE = 4				
			NOI SE =	-125.00 DB .GT.	IA/M NOISE 6					
			NOI SE =	-137.00 DR .67.	. LA/M NOISE G	SRADE = 7				
			NUISE =	-165.00 DB .67.	IA/M NOISE 6					
			# #S10%	-142.00 DB .6T.	IA/M NOISE 6	RADE = 10				
			NOISE =	-181.00 DB .GT. -147.00 DB .GT.	IA/M NOISE G	SRADE = 11 PADE = 12				
			NOISE =	-160.00 08 .67.	IA/N NOISE 6	RADE = 13				
			NOISE = .	-129.00 DE .GT. -107.50 DB .GT.	IV/M NOISE 6	RADE = 14 RADE = 15				
	(W)dSI()	DEPTH(M)	ЕКНО(РН]=0)6=IH4) [ННЗ ()] HRHD[PH[=90	0=IHd)IHdH (1	(06=IHd)ZH ((QMA) ZH	EPH (VMD)	
	5.00	00 -	-46.70	-51.45	-57.87	-57.83	-81.34	-43.91	-63.83	
	5.00	50.00	12.09	6•09	-82.24	-82.20	-19.95	12.01	-36.78	
	25.00	00-	-54.30	-53.85	-61.51	-60.37	-70.43	-50.34	-51.75	
	25.00	50.00	-30.24	-35.06	-83.61	-82.73	-48.25	-29.19	-39.50	
	50.00	.00	-67.71	-59.19	-70.30	-65.96	-71.43	-66.12	-50.69	
	20.00	50.00	-49.81	-51.28	-87.70	-84.22	-61.54	-45.67	-43.65	
	100.00	.00	-72.87	-70.35	-90.75	-77.06	-80.41	-69-89	-58.45	
	100.00	50.00	-71.69	-67.92	-102.66	-88-98	-77-57	-63.16	-54.39	
	200-00	• 00	- 93.33	-89.35	-99.73	-93.69	-99.76	-80.62	-91.64	
	200-00	50.00	-97.49	-84.81	-109.21	-100.85	-99.78	-84.01	-94 • 66	
	400.00	0 0 •	-110.59	-110.45	-119.74	-113.46	-131.54	-104.46	-121.78	
6-5{	400-00	50-00	-119-11	-119.64	-128.19	-121.93	-142,98	-110.42	-121-55	
5										

400.00 1	400.00	200.00 1	200.00	100.00 1	100.00	50.00 1	50.00	25.00 1	25.00	5.00 1	5.00	DISP(M) DE	רד א קר אר חוד
00.00	• 00	00.00	• 00	00.00	• 0 0	00.00	• 00	00.00	• 00	00.00	• 00	PTH(K)	
-137.75	-119.11	-101-78	-101.87	-72.12	-91.71	-49.56	- 71 • 46	-30.19	-66.11	12.09	-64.29	ERHQ(PH[=0)	ADIUS
-133.71	-119.26	-92.63	-93.79	-68.97	-77.49	-51.50	-70.76	-35.10	-68-60	6.09	-67.84	EPH] [PH] = 90	00 H LINE S 01 ACT RESIST 01 ACT RESIST 01 ACT RESIST 02 00 08 GT 22 00 08 GT 22 00 08 GT 23 00 08 GT 23 00 08 GT 23 00 08 GT 47 00 08 GT
-143.69	-128-17	-129.36	-107.98	-113.25	-89.77	-107.60	-78.59	-106.13	-75.16	-105.66	-73.97) HRH0(PHI=90	ANCE ENGTH ANCE IOO.0 ANCE IOO.0 ANCISE G ANCE IOO.0 ANCISE G ANCISE G A
-138.16	-121.94	-116.96	-100.20	-108-93	-84.48	-106.51	-77.24	-105.86	-74.82	-105.65	-73-96) HPHI(PHI=0)	
-141.14	-140-84	-102.09	-104.71	-78-15	-89.98	-61.62	-87.10	-48.26	-90.24	-19-95	-103-20	H2 (PH]=90)	PTH OF TRANSMI
-119.69	-110.06	-86.57	-87.43	-62.99	-83-30	-45.56	-73.63	-29.17	-67.95	12.01	-66.20	HZ (VNO)	TTER. 10 10
-121.51	-123.04	-94.58	-89.49	-54.40	-69.70	-43.65	-64.46	-39.51	-67.45	-36.78	-80.28	EPH(VMD)	0.00 00 5.

	FREG= 10 XMIT LOOP	LINE SOUR LINE SOUR LINE SOUR NOISE NOISE NOISE NE NOISE NE	CCUND.= 20.00 M 20.00 M 20.00 M -95.00 -125.00 -125.00 -123.00 -125.00 -125.00 -121.00 -142.00 -141.00 -141.00 -129.00 -129.00	• 01 MHG LINE SC LINE SC CB • CT DB	112 112 112 112 112 112 112 112			≝ x ⊣∧м∢⊮∞≻∞∞⊙⊣⊴₫₫₫	J. OO WATTS TH UF TRANSI	X X H I I I I X X H I X X X H I X X X X		
(W)dS	DEPTH(M)	ЕКНО(РИ	EH43 (0=	(06=IHd)	нано (Р	(06=IH	d) I Hah	(0=] H	06=1Hd)7H	н и с	40) EPH(COWA
5 • 0D	0 0 •	-88-	- 11	-91 - 18	-97.	16	5-16-	1	-132.72	-96-	- 14	.27.14
5.00	200-00	12.	60	60.09	-145.	96	-145.9	96	-19-95	12.	- to	-36.78
25.00	• 00	- 69 -		74.19.	-98-	34	-98•3	53	-119.10	- 96 -	47 -1	11.72
25.00	200-00	-30-	20	-35.10	-146.	15	-146.0)6	-48.26	- 59-		13.96.
50.00	0 0 •	- 06 -	- 16	-92.37	•66-	65	- 66 -	0	-114.20	-61-	- 08	13.51
50 • 00	200-00	- 49 -	57 -	-51.49	-146.	73	-146.3	17	-61.61	-45.	56 -	÷3•65
00-00	0 0 •	- 61-	24	-95.70	-104.	59	-102-1	6	-112.34	-103-		74.26.
00 • 00	200-00	-72.		-68.96	-149.	63	-147.5	57	-78.14	-63-		54.40
00 * 00	00.	-119.	58 -1	.06.54	-120-	41	-113-9	96	-119-58	-105.	- 64	76.99.
00-00	200-00	-102.	-	-93.46	-157.	06	-152.1	12	-102.46	-81-	53	-94.59
00 - 00	0 0 •	-135.	34 -1	36.89	-142.	42	-138.9	2	-149.90	-120.	81 - 1	130.20
00.00	200• 0 0	-148-	53 -1	34.62	-174.	76	-168.2	50	-143.62	-128-	47 -1	21.50

.

6.00 KG

	-121.50	-128.62	-143.52	-199.93	-208-12	-134.54	-149.56	300+00	400.00
	-153.78	-134.18	-159.83	-154.05	-156.16	-148.29	-149-91	-00	400-00
	-94.59	-87.53	-102.45	-188.04	-191.20	-93.45	-102.45	300-00	200.00
	-132+90	-125.70	-137.44	-129.91	-133.75	-122-35	-127.66	-00	200.00
	-54.40	-63.04	-78.14	-184.88	-185.66	-68.96	-72.12	300.00	100.00
	-116.68	-123.16	-134-30	-121.90	-122.86	-114.63	-114.50	.00	100.00
	-43.65	-45.56	-61.61	-184.07	-184.26	-51.49	-49-57	300-00	50.00
	-117.98	-120.63	-137.75	-119.63	-119.86	-112.48	-110.95	• 0 0	50.00
	-39-51	-29.17	-48.26	-183.86	-183.91	-35-10	-30-20	300-00	25.00
	-122.86	-120.52	-143.10	-119.03	-119.09	-111.92	-110-04	-00	25.00
	-36.78	12.01	-19.95	-183.79	-183.80	6.09	12.09	300-00	5.00
	-136.00	-121.00	-156.87	-118.84	-118.84	-111.74	-109.75	• 00	5.00
	EPH (VMD)	HZ(VMD)	(06=] Hd) ZH	HPHI(PHI=0)	HRH0(PHI=90)	EPHI (PHI =90)	ERHO(PH1=0)	DEPTH(M)	DISP(M)
		TTER R 0	TH OF TRANSMI		URCE LENGTH: NCE 100.00 NCE 100.00 NCE 100.00 NCE CR IA/M NOISE GR IA/M NOISE GR	.00 M LINE SO DNTACT RESISTA 20.00 DB .GT. 20.00 DB .GT. 21.00 DB .GT. 23.00 DB .GT. 23.00 DB .GT. 25.00 DB .GT. 25.00 DB .GT. 37.00 DB .GT. 31.00 DB .GT. 37.00 DB .GT. 47.00 DB .GT. 60.00 DB .GT. 61.00 DB .GT. 61.00 DB .GT. 61.00 DB .GT. 61.00 DB .GT.	RADIUS = 20 LINE SOURCE C NOISE = 1 NOISE = 1	KMIT LOOP	
.00 KG	EIGHT= 6	MIT LOOP WI	0.00 WATTS X	DO POWER= 1	S/M EPS= 10.(01 MH0	100.00 HZ CUN	FREQ= 100	

		L L L L L L L L L L L L L L L L L L L	2H 00.0005	C UNIL .	.01 Mill	DS/M E	PS= 10	.00 PJAE		0.00 WATTS XI	MIT LOOP WE	I GHT=	5.00 ×G
		XMIT LOC	JP KADIUS⊨	M 00 CZ	LINE SC	DURCE L	ENG TH=	100.04	UE F	TH OF TRANSMI	11Ek=	• 00	
			LINE SOUR	CE CONTACI	r resist	ANCE	1000	O DHMS					
			NOISE #	-108.50	13 .61	M / M	NOISE G	340F =	-				
			NOISE =	-127.00	DB .61.	1 A / M	NOISE G	KADE =	i ni				
			NOISE #	-159.00	D8 .61.	1 A / M	NOISE 6	RADE =	ک ا				
				-112-00	DB .Cl.	1 A / M	NOISE G NOISE G	KADE . Valf .	4 .U				
			NOISE #	-125.00	ne .c1.	14/4	NOISE	KADE =	o o				
			NUISE #	-133.00	DB . GT.	1 A / M	NOISE 6	RADE =	7				
				-165.00	DB .61.	1 A / M	NOISE G	KADE .	രാ				
				-151.00	DB . 61.	1 A / M	NOISE 6	KADE .	10				
				-141.00	DB .61.	1 A / M	NOISE 6	KADE =	11				
				-153.00	. 19. BU	1 A / M	NOISE G		2 12				
				-138.00	08 61	Ψ.Υ.Υ.Υ.Υ.Υ.Υ.Υ.Υ.Υ.Υ.Υ.Υ.Υ.Υ.Υ.Υ.Υ.Υ.Υ	NDISE 6		40				
	(w) d\$ 1 0	DEPTH(0	1нд (рн]	■0) EPH]	106= I Hd)	нкно	06=[H4]) IHdri ((0=1+4)	(06=14d)ZH	H2(VMD)	ЕРН(VMD)	
	5.00	00.	12.	6 0	6.11	-11	66-9	-116.	66,	-19.56	12.01	9 • 94	
	5.00	00.	12.	60	6.11	- 11	66°9	-116.	66'	-19.56	12.01	9 • 94	
	25.00	00.	-30.	63	34.30	-11	0 6 •9	-116.	66,	-48.70	-29.18	-18.41	
	25.00	• 00	-30.	63. -	.34.36	11-	6 6 •9	-116.	66'	-48.70	-29.18	-18.41	
	00.06	• • •	-51.	- 50	-50.75	-11	6 6 ,	-116.	56'	-63.24	-45.87	-31-91	
	50.00	00.	-51.	50	-50.75	-11	6 6 9	-116.	66,	-63.24	-45.87	-31.91	
	100.00	00.	-76.	85 -	.70.81	-11-	6.99	-116.	66.	-82.67	-64.55	-49-01	
	100.00	00 •	-76.	۹2 ۲	.70.81		06*9	-116.	66,	-82.67	-64.55	-49.01	
	500-00	00.	-114.	04 - 1	02.04	-11	ŏ6°9	-116.	66,	-114.64	-92.98	-74.20	
	200.00	.00	-114.	04 -1	02.04	-11	66-99	-116.	66,	-114.04	-92,98	-74.20	
	400.00	00.	-175.	25 -1	57.24	-11	ó•99	-116.	66,	-169.23	-125.07	-98.65	
6.	400.00	00.	-175.	25 -1	157.24		66-9	-116.	66,	-169.23	-125.07	-98.65	
-59													

400.00	400-00	200.00	200.00	100-00	100.00	50.00	50.00	25.00	25.00	5.00	5.00	DISP(M)															
50.00	•00	50.00	•00	50.00	• 00	50.00	• 00	50.00	• 00	50.00	• 00	DEPTH(M)														XMIT LOOP	FREO 20
-126.47	-114.33	-108.11	- 96 • 40	-76.41	-77.98	-51+36	-70.49	-30.65	- 53 - 23	12.09	-46.19	ERHQ(PHI=0	NOISE =	NOISE -	NOISE -	NOISE *	NOISE =	NOISE =		NOISE -	NOISE -			NOISE =	LINE SOURCE	RADIUS=	1000.00 HZ C
-125.77	-113.94	-98.11	-95-23	-69.72	-71.53	-50.61	-58.53	134.34	-52.77	6-11	-50+27)PHI (PHI=90	-116.50 D8 .GT.	-138.00 DR .GT.	-153.00 DB .GT.	-181.00 DB .GT.	-151.00 D8 .GT.	-136.00 DB .GT.	-145-00 DB -61-	-125.00 DB .GT.	-117.00 D8 .GT.	-119.00 DB .GT.	-127.00 DB .GT.	-108-50 DE .GT.	CONTACT RESIST	20.00 M LINE S	01 WH
-138.47	-126.32	-117.52	-106.23	-108.77	-92.27	-92+83	-73.06	-88.12	-63.32	-86.54	-59-37) HRH0(PH1=90)	1V/M NDISE GR	IA/M NOISE GR	IA/M NOISE GR	LA/M NOISE GR	IA/M NOISE GR	IA/M NOISE GR	IA/M NOISE GR	IA/M NOISE GR	1A/M NOISE GR	IA/M NOISE GR	IA/M NUISE GR	LA/M NOISE GR	ANCE = 100.00	DURCE LENGTH=	105/M EPS= 10.
-132-04	-119.98	-110.88	-100.99	-95-04	-81.21	-89.00	-68-32	-87.14	-62.10	-86.50	-59-32	нрнI (рнI =0)	(ADE = 15		AUE = 12	LADE = 11	ADE = 10				(ADE = 5			ADE = 1	S WHO	100.00 M DE	OD POWER=
-151.68	-140.27	-110.97	-111.09	-82.33	-85.03	-63.21	-73.80	-48.69	-72.08	-19.96	-82.72	H2 (PH] =90)														PTH OF TRANSMI	10.00 WATTS >
-125.51	-113.02	-89.49	-82.94	-64.42	-68.98	-44.85	-65.81	-28.44	-52.34	12.03	-45.51	HZ (VMD)														ITTER=	(MIT LOOP N
-140.28	-141.05	-84.31	-86.85	-54.61	-62.26	-35.64	-45.34	-29.06	-44-40	-24.99	-55.73	EPH(VMD)														50.00	WEIGHT=
9	5	-	51	7	5	£	Ŧ	Ð	0	νΩ)	ų																6.00 KG

	FREQ# 20	2H 00.000	COND. +	DHM 10.	IS/H E	PS= 10.00	D POWER:	- 10	00 WATTS	XMIT LOOP W	EIGHT= 6.(
	XMIT LOOP	RADIUS=	20°00 M	LINE SC	URCE L	ENGTH=]	1 00.001	M DEPT	H OF TRANS!	HITTER= 10	0.00
		LINE SOUR	CE CUNTACI	R RESISTA	INCE =	100-00	SMHC				
							- - -	_			
		NOISE #	-127.00	UB .61.	H/H/H/	NUISE GRAC		4 04			
		NOI SE	-159.00	DB . GT.	IA/M	NOISE GRAC					
		= 35 ION	-119.00	D8 .GT.	IA/M	NOISE GRAL)E = 4	•			
		NOI SE	-117-00	DB .GT.	IA/M	NOISE GRAL		ŝ.			
		NOI SE =	-125.00	08 .67.	LA/H	NOISE GRAC	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	۰.			
			00-241-	08 . 61.		NUISE GRAL	 				
			00.001-	DB . GT.		NOISE GRAC					
		NOISE #	-151.00	DR .61.	IA/M	NOISE GRAC	JE = 1(0			
		NOI SE .	-181-00	DB .GT.	IA/M	NOISE GRAC	JE = 11				
		NOI SE	-153.00	08 .GT.	IA/H	NOISE GRAL		~			
		NOI SE	-169.00	08 .67.	14/4	NOISE GRAL		m .			
		NOISE =	-138.00	08 .6T.	H/A1	NUISE GRAC	0r = 15	e 10			
(M)4510	DEPTH(M)	ERHO(PHI	=0) EPHI	(06= I Hd)	нано	(06=IHd)	id) I HdH	(0- I H	06=1Hd)7H	H2 (VHD)	EPH (VMO)
5.00	• 00	- 66.	17 -	-69-12	Ĩ-	8.54	-78.52	24	-107.56	-70.87	-80-35
5.00	100-00	12.	03	6.11	-11-	6.86	-116.84		-19.96	12.03	-24.99
25.00	• 00	-68-	- 80	.70.03	- 7	9.93	-19-51	æ	-94.77	-72.56	-68.49
25.00	100.00	- 30.	63 -	34.36	-11	7.44	-117.1	~	-48.70	-28.44	-29.08
50.00	• 00	- 73.	72 -	.72.65	60 	3.97	-82.4		-92.14	-78.48	-68•29
50.00	100-00	-51.	- 61	-50.76	-11-	9.25	-118.0(~	-63.24	-44.82	-35-64
100.00	• 00	- 95.	60 -	66 • 08.	6	7.18	-91.23	e	-96.77	-83-60	-85.65
100.00	100-00	- 76.		70.87	-12(6.24	-121-2	•	-82.89	-64.86	-54.68
200.00	• 00	-101-	421	.02.84	-11	5.88	-111.24	٠	-117.09	-91.64	-95.58
200-00	100.00	-113.	02 -1	.01.74	-14.	2.18	-132.41		-113.97	-95.22	-84.33
400.00	00	-126.	48	25.87	-13	8.50	-132.03		-152.07	-125.65	-142.77
400.00	100-00	-150	80 -1	53.16	-16	3.03	-156.4	5	-172.05	-145.65	-140.45

-140.44	~151.63	-169.28	-203.70	-207.20	-157-32	75 -	-174.	200.00	400.00
-156.30	-144.59	-181.35	-156.32	-153.30	-150-31	- 16	-150.	• 00	400.00
-84.33	-96.12	-114.04	-190.08	-186.70	-102.04	- 40	-114.	200.00	200.00
-112.44	-114.38	-136.09	-130.41	-136.36	-119-87	+ + +	-129.	• 00	200-00
-54.68	-64.89	-82.87	-173.62	-175.34	-70.81	85	-76.	200.00	100-00
-101.62	-113.52	-124.99	-115.60	-117.73	105.21	28 -	-107.	• 0 C	100.00
-35.64	-44.83	-63.24	-171.92	-172.35	-50.75	20	-51-	200.00	50.00
-98-81	-108.65	-125.75	-110.99	-111.51	-100-83	8	- 66 -	• 00	50.00
-29-08	-28.44	-48.70	-171.49	-171.59	-34.36	63	-30.	200.00	25.00
-102.89	-107.53	-130.36	-109.74	-109.87	-99.65	85	-97.	• 0 0	25.00
-24.99	12.03	-19.96	-171-35	-171.35	6.11	60	12.	200-00	5.00
-115.87	-107.87	-143.88	-109.33	-109-33	-99.27	22	-97.	• 00	5.00
EPH(VMD)	H2 (VMD)	HZ(PH1=90)	HPHI (PHI =0)	HRH[(PHI = 90)	11 (PH1=90)	=0) EPH	ERHO(PHI	DEPTH(M)	OISP(M)
			406 H 12	V/M NOISE GRU	DE GT. 1	-116.50	NOISE		
			ADE = 13	A/M NOISE GRI		-138-00			
			ADE = 12	A/M NOISE GRI) DB .GT. L.	-153.00	= 3510N		
			ADE = 11	A/M NOISE GRA) DH .GT. 1.	-181.00	N I SE #		
				A/M NOISE GRA	DB 61. 1	-151-00	NOISE =		
				A/M NOISE CRU		-165-00			
			ADE = 7	A/M NOISE GRA	DB .GT. 1.	-133.00	NOISE =		
			ADE = 6	A/M NOISE GRA) DB .GT. L	-125.00	NO1 SE =		
				A/M NOISE GRA) D8 .GT. 1	-117.00	NOISE #		
							NOISE #		
				A/M NOISE GRA	00.61.1	-127-00			
				A/M NOISE GRI	DB .GT. 1.	-108.50	NOISE =		
			SWHD	CE = 100.00	T RESISTAN	CE CONTAC	LINE SOUR		
0-00	TTER= 20	TH OF TRANSMI	100.00 M DEP	RCE LENGTH=	I LINE SOU	20.03 M	RADIUS	XMIT LOOP	
EIGHT= 0	MIT LOOP W	0.00 WATTS X	OO POWER= 1	/M EPS= 10.0	•01 MHOS.	COND.=	2H 00.00	FRE0= 20	
			·						

= 6.00 KG														(CHV	47.41	-24-99	34.16	-25-08	29.07	35.64	27.12	54.68	64.61	84.33	71.16	40.44
P WEIGHT	300-00													(с			- 1	'	- 1	1	-	I	1	1	1-	
XMIT LOO	ITTER=													IMV) 2H	-139.4	12.03	-138.43	-28.44	-138-13	-44.83	-140.57	-64.89	-140.61	-96-12	-159.58	-151-32
03 MATTS	OF TRANSA													(06= I Hd) 21	175.07	.19.96	161.37	48.70	56.22	63.24	53.56	82.87	59.60	14.04	96.55	69•23
= 10.	M DEPTH		-	5	in a		ۍ.	~ 3		5			• 10	4 (0=1)	7	•	1	1	1	'	Ĩ	1	1 -	1-	1	7
NO POWER	100.00	OHMS	ADE =	ADE =	A0F =	406 =	ADE a	ADE =		ADE = 1(ADE = 1: ADE = 1:	ADE = 1	ADE = 14 ADE = 13	1d) I HdH	-137.31	-223.45	-137.57	-223-54	-138.35	-223-83	-141-36	-225-00	-152.11	-229-52	-181-65	-247.31
EPS= 10.	LENGTH=	100.00	NOISE GH	NOISE GR	NOTSE GR	NOISE GR	NUISE GR	NOISE GR	NOISE GR	NOISE CR	NULSE GR	NOI SE GR	NDISE GR NDISE GR	(06=IHd)0	37.32	23.45	37.64	23-60	36.63	10.4	12.52	5.93	6.44	13.28	4.63	2.60
HOS/M	SOURCE	TANCE =	· JA/M	. LA/M	14/4	. 1A/H	. 1A/M	. 1A/M	. 1A/M	- 14/M	. 14/M	• 1A/M	. 1// H	0) HRH(1-	- 2	-1	-23	-13	-23	-14	-22	-15	-23	-18	- 25
4 10 •	O M LINE	TACT RESIS	.50 DH .G1	.00 DR .61	00 DE 61	00 08 .61	.00 DB .GT	00 08 67	00 DA .GT	.00 DB .61	00 DH 61	00 08 .GT	50 08 .61	6=[Hd][Hd]	-126.91	6 .11	-127.16	-34.36	-127.91	-50-75	-130.81	-70.81	-141.36	-102.04	95.871-	-157.24
COND.	20-0	JRCE CON	-108	-127	-119.	-117	-125	-133	-136.	-151-	-153-	-169.	911- -110]=0)	• 26	60.	62	• 63	.74	-20	.14	85	10	•0	74	25
H 00.000	RADIUS=	LINE SUL	NOISE =	= 35 ION	NOISE #	* 33 I ON	* BSION	NOISE #	NOI SE #	NOI SE	NOI SE	NOI SE	NOISE #	ЕКНО(РН	-125	12	-125	06-	-126	15-	161-	- 75.	-147	-114	-173,	-175.
FRE1= 20	XMIT LOOP													0EPTH(M)	00.	300°00	00	300-00	• 00	300-00	00.	300-00	• 00	300-00	• 00	300-00
														015P(M)	5.00	5.00	25.00	25.00	50.00	50.00	100.00	100.00	200-00	200-00	400-00	400-00
																										6-63

-98-66	-133.09	-221.57	-116.99	-116.99	206.00	- 66	-227.	• 00	400.00
-93-66	-133.09	-221.57	-116.99	-116.99	206.00	66	-227.	• 00	400.00
-74-61	-103.29	-138.63	-116.99	-116.99	122.66	63 -	-138.	• 00	200.00
-74.61	-103.29	-138.63	-116.99	-116.99	122.66	- 53 -	-138.	• 00	200.00
-45.79	-69.60	-93.59	-116.99	-116.99	-77.60	57	-87.	• 0 U	100.00
-48.79	-69.60	-93.59	-116.99	-116.99	-77.60	57	-87.	• 00	100-00
-26-62	145.68	-67.36	-116.99	-116.99	-51.25	32	- IJ	• 00	50.00
-26-62	-45.68	-67.36	-116.99	-116.99	-51.25	32	- បូរ	• 00	50.00
-11.18	-28.28	-49.99	-116.99	-116.99	-33.13	56	-31.	• 00	25.00
-11-18	-28.28	-49.59	-116.99	-116.99	-33.13	56	-31.	• 00	25.00
17 • 89	12.04	- 19 . 99	-116.99	-116.99	6.18	05	12.	• 00	5.00
17 • 89	12.04	- 19.99	-116.99	-116.99	6.18	05	12.	• 00	5,00
EPH(V40)	HZ(VMD)	HZ(PhI=90)	HPH!(PH[=0)	HRH0(PH 1= 90)	[(PH]=90)	#0~ EP1	ERHO(PH]	DEPTH(11)	DISP(M)
				-					
			2ADE = 14	V/M NOISE GR	DB .GT. 1 DB .GT. 1	-148.00	NOISE .		
				A/M NOISE GH	DB .GI. 1	-179.00	NOISE #		
				A/M NOISE GH		-172.00			
			RADE = 10	A/M NOISE GH	DB .GT. 1	-158.00	NOISE		
			RADE = 9	A/M NOISE GR	DE .GT. 1	-151.00	NOISE .		
				A/M NOISE GR		-157-00			
				A/M NOISE GF	DB .GT. 1	-137.00			
			RADE = 5	A/M NOISE Gr	DB .GI. 1	-126.00	NOISE =		
				A/M NOISE GR	DB GT 1	-138.00			
				A/M NOISE GA		-153-00			
				A/M HOISE GE	D3 .G1. 1	-122.00	NOISE		
			OHMS	ICE = 100.00	T RESISTAN	CE CONTAC	LINE SOUR		
• 00	ITTËRE	OTH OF TRANSMI	100.00 H DEA	RCE LENGTH	LINE SOU	20.00 M	KAD1US=	XMIT LOUP	
					• • • • • • • • • • • • • • • • • • • •				
	ש פתה ו דואו	IN WATTS X		M EPSH 10	- 01 · MHOS		000 - 00 HZ		

5000	C.00 HZ	COND.**	6	DHW	S/M	EPS= 1	0.00 P	0 W E R =	10	- DO WATTS	T IMX	1000	WEIGHT= 50 00	6. 0(
•SUI QA	-	20.00 M		NE SO	URCE	LENGTH=	100	- 00 -	DEPT	H OF TRAN	SMITTER	R.	50.00	
INE S	ourc	CE CONTAC	TRE	SISTA	NCE .	100.	WH0 00	S						
OI SE	H	-122.00	DB.	.61.	14/4	NOISE	GRADE							
	H 1	-137.00	- CB	• 61.•		NUISE								
DISE	. 11	-138.00				NOISE	GRADE	·	_					
OISE		-126.00	08	.6T.	IA/M	NOTSE	GRADE	•	_					
01 SE	Ħ	-137.00	• 08	• 21•	IA/H	NOISE	GRADE	-or #						
	H #	-154.00	ສ ຄ ດ ເ		1 4 / 1	NUISE	CRACE CRACE							
01 SE	. 41	-151.00		61.		NOISE	GRADE	р ос 1 в						
0156		-158.00	08	61.	IA/H	NOISE	GRADE	- 10	_					
01 SE	H	-181.00	08	.19.	1A/M	NOISE	GRADE							
101 SE	н 1	-172.00	• 808		IA/M	NOISE	GRADE							
OI SE	n H	-148-00	80 80		1 4 / H	NUISE	GRACE							
01 SE	R	-118.50	08	-19	H M	NOISE	GRADE	-	_					
ERHI	• I H d) (4 3 (0*	IHG) II	(06=]	нян	6= [Hd) 0	IdH (0	Hd)[H	(0=1)	6= I Hd) ZH	2H (D	(AHD)	EPH(VH0)	
	-46.	83	-50.0	40	ĩ	63 . 30	i	63 . 24	-	-86.42	4	9.56	4.9.4-	9
	12.0	55	6 .]	61	ĭ	96.72	1	96.68	_	66*61-		2.10	-9-6	0
	-53.6	33	-53-0	20	ĩ	67.98	Î	66.58	_	-76.40	5	6.90	-40.2	\$
	-31.5	16	-33.1	15	ĭ	98.72	ì	97.59	-	66*6*-	- 2	1.20	-16.7	1
	- 74 . 7	11	-60.1	61	1	79.74	1	74.24		-79.76	4	5.17	-48-3	Q,
	- 55 -	28	-51.2	5 3	- 10	04.75	-1-	00.24	_	-67.38	4	5.28	-29.5	5
	-85.4	11	-17-5	46	ĭ	97.89	ī	91.14		-95.98	1-	10.14	-63.1	6
•	-86.7	78	-76.5	54	-1	20.75	1	09.11	_	-93.32	- 1	0.66	-60.4	8
1	103.2	- 12	102.7	78	ī	19.51	7	12.75		-132.71	6 +	6.94	-105.4	0
I	123.4	• •	126.1	12	1	37.61	1	31.68	_	-137.11	-10	17.71	-101-1	σ
1	121.6	56	120.5	52	1	37.75	1	30.50	-	-155.30	-12	2.20	-168.6	-
Ţ	41.5	- 03	139.6	56	1-	57.16	-1-	49.68	_	-174.37	-14	12.79	-182.2	5

.

-184.31	-179.04	-209+77	-188.04	-195.59	-177.73	-179.65	100-00	400.00
-185.34	-142.79	-174.36	-149.68	-157.16	-139.66	-141.20	• 00	400.00
-101.20	-116.84	-138.73	-165.97	-171.58	-122.77	-137.75	100.00	200.00
-125.10	-108.46	-147.85	-132.12	-136.79	-123.60	-121.87	-00	200.00
-60.43	-71.69	-93.59	-147.82	-153.86	-77.60	-87.57	100.00	100.00
-81.68	-89.48	-112.06	-106.41	-112.85	-91.95	-104.03	• 00	100.00
-29.52	-45.32	-67.36	-142.75	-144.28	-51-25	- 55 • 32	100.00	50.00
-69.15	-88.31	-103,75	-94.26	-96.15	-80.08	-81.78	•00	50.00
-16.77	-27.21	-49.99	-141.41	-141.79	-33.13	-31.93	100.00	25.00
-72.76	-82.72	-105.31	-90.38	-90.85	-76.45	-75.14	•00	25.00
-9.60	12.10	-19.99	-140.97	-140.99	6.18	12.05	100.00	5.00
-86-31	-81.39	-117.74	-89-03	-89.05	-75.20	-72.91	• 00	5.00
EPH(VND)	HZ (VMD)	H2(PHI=90)	HPHI(PHI=0)	HRH0(PHI=90)	06=1Hd)]Hd	ERH0(PH1=0) E	DEPTH(M)	Î.
			DE = 15	1/M NOISE GRA	50 D8 .GT. 11	NOISE = -118.		
			DE = 14	V/M NOISE GRA	00 DB .GT. 1/	NOISE = -148.		
			DE = 13	V/M NOISE GRA	00 DB .GT. 1/	NOISE = -179.		
			DE = 12	VH NOISE GRA	00 DB .GT. 1/	NOISE = -172.		
				AVE NOISE GRA	00 DH .GT. 1/			
				VM NOISE GRA	00 08 .GT. 1/	NOISE151-		
			DE m ce	VM NOISE GRA	00 DB .GT. 1/	NOISE = -167.		
			DE = 7	A/M NOISE GRA	00 08 .GT. 1/	NOISE = -154.		
			6 = 30	V/M NOISE GRA	00 DB .GT. 1/	NOISE = -137.		
			5 = 30	VM NOISE GRA	00 DB .GT. 1/	NOISE = -126.		
				A/M NOISE GRA	00 08 .67. 1/	NOISE = -138.		
				A DU				
				VIM NOISE GRA	DO DB .GT. 1/	NOISE = -122.		

	XMIT L	FREQ.
LINE SOUR	OOP RADIUS=	50000.00 HZ
CE CONTACI	20.00 M	COND. =
RESISTANCE	LINE SOURCE	•OI MHOS/M
= 100.00	LENGTH=	EPS= 10.
O UHMS	100.00 M	.00 POWER=
	DEPTH OF TRANSMITTER=	10.00 WATTS XMIT LOO
	100.00	P WEIGHT=
		6.00 KG

ε 6.0																	(GHA)	132.59	-9.60	20.07	.16.77	17.21		-29.52	-29.52	-29-52 131-14	-29.52 :31.14 •60.43	-29-52 .31.14 60.43 .42.30	29.52 31.14 60.43 42.30 01.20	.29.52 .31.14 .60.43 .42.30 .01.20
P WEIGHT	200-00)) EPH(-	~	1	-	I- E				· ī				
XHIT LOO	vITTER=)MY) 2H	-132.14	12.10	-130-84	-27.21	-131.68		-45.32	-45-32	-45.32 -133.7(-45.32 -133.7(-71.6(-45.32 -133.7(-71.6(-139.44	-45.32 -133.77 -71.66 -139.44	-45.32 -133.76 -71.66 -139.44 -116.74
10-00 WATTS	PTH OF TRANSA																(06 *] Hd) 7H	-167.92	-19.99	-154.60	66°64-	-150.58		-67.36	-67.36	-67. 36 -152. 07	-67.36 -152.07 -93.59	-67.36 -152.07 -93.59 -171.53	-67.36 -152.07 -93.59 -171.53 -138.63	-67.36 -152.07 -93.59 -171.53 -138.63 -212.37
O POWER=	100.00 M DE	SMHÜ					DE = 5	06 = 6	DE = 7	0E = 6	DE = 9	DE = 10	DE = 11	0E = 12	DE = 13		(0=]Hd }]HdH	-133.72	-223.71	-134.32	-223.93	-136.12		-224.62	-224.62	-224.62 -142.83	-224.62 -142.83 -227.35	-224.02 -142.83 -227.35 -166.12	-224.62 -142.83 -227.35 -166.12 -237.86	-224.02 -142.03 -227.35 -166.12 -237.86 -188.05
H EPS= 10.0	CE LENGTH=	E = 100-00		AN NUISE GRA	AM NOTSE CRA	/M NOISE GRA	/M NUISE GRA	/M NOISE GRAN	/M NOISE GRAN	/M NOISE GRA	/M NOISE GRA	/M NUISE GRA	/M NOISE GRAN	/M NOISE GRAN	/M NOISE GRAN	A NOISE GRAI	НКНО(РН[=90)	-133.73	-223.71	-134.48	-224.07	-136.79	-776 14	01	01	-145.53	-145.53 -229.52	-145.53 -145.53 -229.52 -168.15	-229.53 -229.52 -168.15 -244.94	-229.53 -229.52 -268.15 -244.94 -195.57
IC.= .01 MHDS/	.00 M LINE SOUR	ONTACT RESISTANC		37.00 NH . CT . 1A	63.00 DH .GT . 1A	38.00 DB GT 1A	26.00 DH .GT. 1A	37.00 DB .GT. 1A	54.00 DB .GT. 1A	67.00 DB .GT. 1A	51.00 UB .GT. 1A	58.00 DB .GT. 1A	81.00 DB .GT. 1A	72.00 DB .GT. 1A	79.00 DB .GT. IA	48.00 08 .GT. 1A	(06= [Hd] [Hd3	-119.30	6.18	-119.87	-33.13	-121.62	-51.25			-128.16	-128.16 -77.60	-128.16 -77.60 -151.94	-128.16 -77.60 -151.94 -122.66	-128.16 -77.60 -151.94 -122.66
1000-00 HZ CON	RADIUS= 20	LINE SOURCE C	1		NOISE = -1	NOI SE = -1	NDISE = -1"	NOI SE1	NOI SE1	NDISE = -1	NOI SE = -1-	NOI SE = -1-	NOI SE = -I	NOI SE1	NOI SEI	NOISE1	ERH0(PH1=0)	-117.70	12.05	-118.54	-31.93	-121-13	-55+32			10.161-	-131.01 -87.57	-131.01 -87.57 -154.65	-131.01 -87.57 -154.65 -138.63	-131.01 -87.57 -154.65 -138.63 -179.64
FR EQ= 50	XMIT LOOP																DEPTH(M)	00.	200-00	• 00	200-00	• 00	200-00			00•	•00 200•00	•00 200•00	•00 200•00 •00 200•00	.00 200.00 .00 200.00 .00
																	(H) dS I	5.00	5.00	25+00	25.00	20°00	50.00			100.00	100-00	100.00	100.00 100.00 200.00	100-00 200-00 200-00

		NOISE .	1179.00 D6 .GT. 1 148.00 D8 .GT. 1 118.50 D8 .GT. 1	LA/M NOISE GR/ LV/M NOISE GR/	1000			
DISP(M)	DEPTH(M)	EKHQ(PH]=0)	Eph i (ph i =90)	HRHQ(PH]=90)	нрн [(рн] = 0)	H2 (PH [=90]	HZ (VMD)	EPH (VMD)
5.00	.00	-159.78	-161.07	-175.78	-175.78	-213.20	-177.75	-199.50
5.00	00-00E	12.05	6.18	-304.10	-304.10	-19.99	12.10	-9.60
25,00	• 00	-160.28	-161.44	-176.24	-176.15	-199.63	-175.50	-187.62
25.00	300.00	-31.93	-33.13	-304-32	-304 - 25	-49.99	-27.21	-16.77
50.00	•00	-161.84	-162.58	-177.69	-177.32	-194.88	-174.72	-173.90
50.00	300.00	55 - 32	-51.25	-305.02	-304.72	-67.36	-45.32	-29.52
100-00	• 00	-167.95	-167.02	-183.33	-181.83	-193.80	-176.63	-163.02
100.00	300.00	-87.57	-77.60	-307.79	-306.60	-93.59	-71.68	-60.43
200.00	•00	-188.40	-183-63	-202-33	-198.56	-205.80	-176.98	-180.74
200.00	300.00	-138.63	-122.66	-318.57	-313.95	-138.63	-116.74	-101.20
400.00	• 00	-218.21	-215.94	-234.24	-226.32	-249.08	-223-17	-232.64
400.00	300.00	-227.99	-206.00	-345-49	-343.95	-221.97	-200.08	-184.37

NOISE .	NOISE -	NOISE -	NOISE -	NOISE .	NOISE =	NOISE -	NOISE -	NOISE -	NOISE .				
-148.00	-179.00	-172.00	-181.00	-158.00	-151.00	-167.00	-154.00	-137.00	-126-00	-138.00	-163.00	-137.00	-122.00
08	06	08	80	08	08	80	08	80	08	08	08	08	80
.GT.	•GT•	•GT•	•GT•	•GT•	•GT •	•GT •	•GT•	•GT.	•GT•	•GT•	•GT•	•GT•	.GT.
LAIH	1A/M	LA/H	LA/H	1A/H	1 A/M	1 A/M	10/4	1 A/H	LA/M	1A/H	1A/H	1 A / M	LATH
NOISE	NOISE	NOISE	NOISE	NOI SE	NOISE								
ŝ	~	~	0	0	0	G	G	G	ດ	G	G	ດ	G
RADE	GRADE	GRADE	RADE										
RADE =	GRADE =	GRADE =	RADE =	RADE =	RADE	RADE =	RADE	RADE =					

LINE SOURCE CONTACT RESISTANCE - 100.00 OHMS

XMIT LOOP RADIUS= FREQ= 50000.00 HZ COND.= 20.00 M LINE SOURCE LENGTH= 100.00 M DEPTH OF TRANSMITTER= 300.00 •01 MHOS/M EPS= 10.00 POWER= 10.00 WATTS XMIT LOOP WEIGHT= 6.00 KG

I GHT= 6.00	00.																		20.80	20.80	-8.74	-8.74	-25.31	-25.31	-49.073	-49.73	-74.56	-74 • 56	-98.66	-98.66
MIT LOOP WE	TTER=																		12.07	12.07	-27.93	-27.93	-46.15	-46.15	-73-19	-73.19	-105.86	-105.86	-136.01	-136.01
0.00 WATTS X	TH OF TRANSMI																		-20.01	-20.01	-50.60	-50.80	-69.70	-69.70	-99.31	-99.31	-151.31	-151.31	-248.68	-248.68
00 POWER= 1	100.00 M DEF	SMHO I	ADE = 1	RADE = 2	ADE = 3	KADE = 4	RADE = 5	(ADE = 6'	(ADE = 7	RADE = 8	RADE = 9	RADE = 10	(ADE = 11	RADE = 12	RADE = 13	<pre><ade 14<="" =="" pre=""></ade></pre>	₹A DE = 15		-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99
/M EPS= 10.	RCE LENGTH-	CE = 100.00	A /M NOISE GR	A/M NOISE GR	A/M NOISE GR	A/M NOISE GR	A/M NOISE GR	A/M NOISE GR	A/M NOISE GR	A/M NOISE GR	A/M NOISE GH	A/M JOISE GR	A/M NOISE GH	A/M NOISE GF	A/M NOISE GF	A/M NOISE GH	AIM NOISE GA	06 - I HA) OHNI	-116.99	-116.99	-116.99	-116,99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99	-116.99
01 MHUS	O M LINE SOU	TACT RESISTAN	1 TA BU		00 08 67 1	00 08 67 1	.00 DE .61. 1	.00 DB .GT. 1	.00 DB .GT. 1	.00 DB .GT. 1	.00 D3 .6T. 1	.00 DB .61. 1	.00 DB .GT. 1	.00 DB .61. 1	.00 DB .GT. 1	.00 DB .61. 1	50 DB . 6T. 1	EPH1 (PH1=90)	6.24	6.24	-32,78	-32.78	-52,10	-52.18	-81.87	-81.87	-133,89	-133.89	-231.26	-231.20
0.00 HZ CUNU.	ADIUS= 20.0	INE SOURCE CON	A1		101SE = -163	01SE = -141	101SE = -131	01SE = -153	101SE = -158	101SE = -171	01SE = -146	+UISE = -163	i01SE = -181	401SE = -175	401SE = -186	401SE = -155	401SE = -123	ERHU(PH1=0)	12.03	12.03	-32.73	-32.73	-57.66	-57.66	-93.29	-93.29	-151.31	-151.31	-254.70	-254.70
-REQ= 7000	KMIT LOUP R	L	2		: 2	2	Z	z	Ζ.	ž	Z	Z	Z	Z	2	Z	٤	<u> </u>	00.	00.	00.	00.	°0.	• 00	• 00	• 00	00.	00.	00.	00.
	7																	(m)dsta	5.00	5.00	25.00	25.00	50.00	50.00	100.00	100.00	200-00	200.00	400.00	400.00

() ¥

	94.17	1	-151.33	-184.12	~157.61	-166.07	-146.16	-148.65	50.00	100_00
	72.A9	1	-128.84	-161.51	-134.90	-143.31	-123.48	-125.87	• 00	4nn 100
	10.47	•	-120,45	-152.53	-140.41	-147.29	-135.40	-129.94	50.00	200 <u>0</u> 00
	17.42	!	-105,17	-137.47	-117,55	-124.55	-105.95	-107.02	.00	200 <u>'</u> 00
	5A.63	1	-74.98	-99.18	-116.74	-127.08	-81.47	-92.33	50,00	100.00
	55 - 85	1	-72.28	-102,11	-96-60	-101.75	-82.45	- 48 - 12	.00	inn 100
	29.78		-46.23	-69.73	~106.34	-111.16	452.25	-57,58	50.00	50.00
	65.48	•	-65.43	-93.12	-77.58	-83.40	-61.95	-76.59	• 00	5n:00
	12.92	1	-26,85	-50.80	-103.27	-104.48	-32.79	-32.72	50.00	25.00
	42.19		-59.29	-78.89	-69.15	-70.65	-53-09	-54.97	.00	25,00
	-4.02		12.16	-20.01	-102.22	-102.27	6,24	12.03	50.00	л. ОО
	49.67	•	-51.84	- 88.59	-65.51	-65.57	-50.71	-47.78	• 00	л.00
	(UWD	EPH (HZ(VMD	H7(PHI=90)	HPHI (PHI=0)	HRHN(PH[=90)	EPHI (PHI=90)	ERHO (PHI = 0)	DEPTH(M)	1SP(M)
					ANG = 12	IV/M NUTSE GR	23 . 50 D8 .01.	NOISE = -1		
						IA/H NOISE GR	55.00 DA .GT.	NOISE1		
					ADE = 13	14/M NOISE GR	86.00 DB .GT.	NOISE = -1		
						INTE NOISE GR	75.00 DB .GT	NOIST = -1		
						IA/M NOISE GR	63.00 DB .GT.			
					ADE = 9	14/M NOISE GR	46.00 DB .GT.	NOISE = -!		
					A DE = 8	14/M NOISE GR	71.00 DB .GT.	NOISE = -1		
						LATH NOISE GR				
						ALM NOTSE GR	31.00 DA .GT.			
					ADE = 4	IA/H NOISE GR	41.00 DB .GT.	NOISE 1		
						14/M NOISE GR	63.00 DB GT			
						IATH NOISE GR	26.00 DB .GT.			
					SWHD	NCE - 100.00	DNTACT RESISTA	LINE SOURCE C		
		50.00	1TTER#	H OF TRANSM	100.00 M NEPT	URCE LENGTH=	.00 M LINE SO	RADIUS= 20	XMIT LOOP	
KG	6.00	WEIGHT=	XMIT LOOP	ON WATTS	OO POWER= 10	S/M FPS= 10.	D.= .01 MHN	00.00 HZ CON	FREQ= 7n0	_

			.84.20	-4.02	.72.43	12.92	.72.87	.29.78	51.13	58.63	23.35	19.43	94.48	
100.00		I d L	•		•	•	•	•	•	•		- 1	•	
T T E R =		GMV) ZH	-87.00	12,16	-88.07	-26,45	-93.19	-46.26	-93° 96	-75.95	-120.25	-128.27	-151.33	
JE TRANSMI		(06=1Hd)/	73.27	10.00	11.02	50 . AO	10.01	59 . 70	0.21	12.04	۶7 . 09	51.34	44.12	
nEoTH		I= (C= I		r		1	•	t		Ĩ	Ť		•	
100.00 M		HAJIHAH	- 94.68	#153 ,50	-96,21	-154.02	-100.58	-155.60	-114.53	-161.61	-140,35	-183.45	-157.61	
ENGTH=		(PH1=90)	.20	53.52	36.71	54.43	02.64	57.26	20.69	58.05	47.37	17.72	56.07	
SOURCE I		0) HRH0	ĩ		Ĭ		1	1			i.	111		
M LINE		6=[Hd]]H	-79.24	6.24	-80.66	-32.78	-84,80	-52.18	-98.57	-81.87	-129.30	•133°98	-146.16	
- 00 - 02	C O N I I I I I I I I I I I I I I I I I I	10) EPI	4	£	2	Ð	2	9	ç	0	4	Ŧ	ŝ	
RADIUS.		ERHO(PH]=	- 77 - 1	12.0	-79-5	7.25.4	-86.7	-57.6	-108.9	- 43 - 3	-129.7	-150.7	-148.6	
KMIT LOOP		ЛЕРТН(M)	00.	100.00	00.	100.00	00.	100-00	00.	100.00	00 .	100.00	00.	
~		(M) 431 C	r, 00	5 ,00	25,00	25.00	50,00	50,00	100,00	100.001	200,00	00,004	00°0∪₹	

+0.00 WATTS XMIT LOOP WEICHT= .01 MHUS/M FPS# 10.00 POWFR# FREQ= 7000.00 HZ COND.=

6.00 KG

VHIT_NOP_RADIUS CONTROL						-271,26					
YHIT COND. (n) COND. (n) <thcond. (n)<="" th=""> <thcond.< td=""><td>3 -232.3</td><td>-196.2</td><td>-229.41</td><td>-203.05</td><td>-211.59</td><td>-191.53</td><td>-194.17</td><td>.00</td><td>400.00</td></thcond.<></thcond.>	3 -232.3	-196.2	-229.41	-203.05	-211.59	-191.53	-194.17	.00	400.00		
MALL CONDUM CONDUM <td>6 =119.4</td> <td>-127.9</td> <td>-151.31</td> <td>-267.32</td> <td>-273.99</td> <td>-133,89</td> <td>-151-31</td> <td>200.00</td> <td>200.00</td>	6 =119.4	-127.9	-151.31	-267.32	-273.99	-133,89	-151-31	200.00	200.00		
FFED 7000.00 HZ CDNUCP. CDI HUNCE LEVE LUNC DECK TOUR DADING COUNT ACT RESISTANCE = 100.00 H TRANSHITTER 200.00 H NUMPE SUURCE CONTACT RESISTANCE = 100.00 H TRANSHITTER 200.00 H NUMPE CONTACT RESISTANCE = 100.00 H TRANSHITTER 200.00 H NUMPE CONTACT RESISTANCE = 100.00 HH TRANSHITTER 200.00 H NUMPE CONTACT RESISTANCE = 100.00 HH TRANSHITTER 200.00 H NUMPE CONTACT RESISTANCE = 100.00 HH 100.00 HH 100.00 HH NUMPE CONTACT RESISTANCE = 100.00 HH 100.00 HH 100.00 HH 100.00 HH NUMPE CONTACT RESISTANCE = 100.00 HH 100.00 HH 100.00 HH 100.00 HH NUMPE CONTACT RESISTANCE = 100.00 HH 100.00 HH 100.00 HH 100.00 HH 100.00 HH NUMPE CONTACT RESISTANCE = 100.00 HH 100.00 HH 100.00 HH 100.00 HH 100.00 HH 100.00 HH NUMPE CONTACT RESISTANCE = 100.00 HH 100.00 HH 100.00 HH 100.00 HH 100.00 HH 100.00 HH <	6 -154.4	-154.0	-190.32	-184.96	-174.74	-170.55	-148-30	• 00	200-00		
FFEGP 7,000,00 MZ 20,00 H LINE SUNCE CONTACT RESISTANCE - 100,00 H REFN / NO.00 H<	-58.6	-75.9	-09.31	-254.64	-257.01	-81.87	-03-29	200.00	100_00		
FFEG YNDOLOG NZ COND. OI NHOSA EXAMPLE INCOMPTANT FERE YNDOLOG NZ COND. OI NHOSA EXAMPLE INCOMPTANT FERE CONTACT FERE	9 -129.2	-144.4	-166.09	-156.90	-159.A2	-140.67	-143.81	•00	100.00		
FREP 7000.00 MZ CNUL OLIMINAL FUNCTIONAL F	6 -29,7	-45.21	-69.70	-251.39	-251.98	-52,18	-57.66	200,00	50.00		
PREP 70000.00 HZ CDNU.* .01 PHISH 100.00 H RETH IN TANKITTER 200.00 VHIT LODE RADIUS 200.00 H LINE SOURCE CONTACT RESISTANCE = 100.00 CHMS 100.00 CHMS 100.00 CHMS LINE SOURCE CONTACT RESISTANCE = 100.00 CHMS N015E	5 -129.A	-143.6	-163.47	-149.12	-149.85	-133.03	-132.73	.00	50.00		
FRED 70000.00 HZ CDMD. OLIMISH 100.00 H REPT 100.00 H REPT	-12.9	-26.8	-50,80	-250.57	-250.71	-32,78	-32,73	200.00	25.00		
FRED 70000.00 HZ CDND.* .01 HH32H 100.00 HD* 100.000 HD* 100.00 HD*	7 -136.6	-142.8)	-167.19	-147.03	-147.21	-131.00	-129-82	• 00	25.00		
FFED 70000.00 HZ CDND.* OI MHOY FYN LONG FYN TOTAL FYN	-4.0	12.10	-20.01	~250.30	-250.31	6.24	12.03	200.00	5_00		
FFED 70000.00 HZ CMD. OI MASH FYS LOVO FARE TOVO FARE 200.00 HZ CMD. OI MASH FYS TOVO FARE 200.00 HZ CMD. 200.00 HZ CMD. TOVO FARE 200.00 HZ CMD. TOVO FARE 200.00 HZ CMD. TOVO FARE 200.00 HZ CMD. 200.00 HZ	-151-1	-144.63	-140.42	-146.34	-146.35	-130.34	-128.88	.00	s .00		
<pre>FRED= 70000.00 HZ GOND. OLIMIDSH ETST LOUVO FUTER 100.00 H REFH NF TRANSHITTER 200.00 LINE SOURCE CONTACT RESISTANCE = 100.00 CHHS NOISE = -126.00 DB .GT 11/H NOISE GRADE = 1 NOISE = -141.00 DB .GT 11/H NOISE GRADE = 1 NOISE = -153.00 DB .GT 11/H NOISE GRADE = 3 NOISE = -155.00 DB .GT 11/H NOISE GRADE = 3 NOISE = -155.00 DB .GT 11/H NOISE GRADE = 1 NOISE = 155.00 DB .GT 11/H NOISE GRADE =</pre>	FPH(VMD)) HZ(VMI	H7(PH1=90)	HPHI (PH I =0)	HRHN (PH [= 90)	EPH[(PH]=90)	ERH0(PH1=0)	DEPTH(M)	1750 (M)		
FREA 70000.00 HZ COND.* .01 HHDS/H ETS* 100.00 H NOTOTACT 200.00 H NOISE LINE SOURCE CONTACT RESISTANCE 100.00 HHS NOISE .126.00 DB .01 HHDS/H ETS* 100.00 HHS NOISE .126.00 DB .01 HHDS/H ETS* 100.00 HHS 100.00 HHS NOISE .126.00 DB .07 IA/H NOISE GRADE 1 NOISE .1241.00 DB .07 IA/H NOISE GRADE 2 NOISE .1241.00 DB .07 IA/H NOISE GRADE 3 NOISE .125.00 DB .07 IA/H NOISE GRADE 3 NOISE .131.00 DB .07 IA/H NOISE GRADE 3 NOISE .131.00 DB .07 IA/H NOISE GRADE 3 NOISE .14/H NOISE GRADE 3 3 NOISE .163.00 DB .07 IA/H NOISE GRADE </td <td></td> <td></td> <td></td> <td>ADE = 15</td> <td>IV/H NOISE GR</td> <td>3.50 D9 .CT.</td> <td>N01SE = -12</td> <td></td> <td></td>				ADE = 15	IV/H NOISE GR	3.50 D9 .CT.	N01SE = -12				
FREQ. 70000.00 HZ COND. OI HHNS/H EFST LGGO TORAT 10000 TORAT 200.00 H 200.00 H <td></td> <td></td> <td></td> <td>ADE = 13</td> <td>IA/H NOISE GR</td> <td>5,00 DB _GT</td> <td></td> <td></td> <td></td>				ADE = 13	IA/H NOISE GR	5,00 DB _GT					
FRED 70000.00 HZ COND.* OI HHDS/H EFS* LOUC FORM XMIT LOOP RADIUS 20.00 H LINE SNURCE LENGTH* 100.00 H NEPTH OF TRANSHITTER* 200.00 NOISE LINE SOURCE CONTACT RESISTANCE 100.00 OHMS 100.00 OHMS 100.00 OHMS NOISE LINE SOURCE CONTACT RESISTANCE 100.00 OHMS 100.00 OHMS 100.00 OHMS NOISE LIALSON DB GT 14/H NOISE GRADE 1 NOISE LIALSON DB GT 14/H NOISE GRADE 3 NOISE LIALSON DB GT 14/H NOISE GRADE 10				ADE = 12	1A/M NOISE GR	5.00 DB .GT.	NOISE = -17				
FREA 70000.00 HZ COND. OI MHNSH EPS 100.00 H NEPTH OF TRANSHITTER 200.00 XMIT LOOP RADIUS 20.00 H LIME SOURCE LENGTH 100.00 H NEPTH OF TRANSHITTER 200.00 NOISE -126.00 DB GT, 14/H NOISE GRADE 1 1 100.00 HHS NOISE -141.00 DB GT, 14/H NOISE GRADE 1 2 NOISE -141.00 DB GT, 14/H NOISE GRADE 2 NOISE -141.00 DB GT, 14/H NOISE GRADE 3 NOISE -144.00 DB GT, 14/H NOISE GRADE 3 NOISE -153.00 DB GT, 14/H NOISE GRADE 3 NOISE -154.00 DB GT, 14/H NOISE GRADE 3 NOISE -144.00 DB GT, 14/H NOISE GRADE 3 NOISE -154.00 DB GT, 14/H NOISE GRADE 3 NOISE -154.00 DB GT, 14/H NOISE GRADE 3 NOISE -154.00 DB GT, 14/H NOISE GRADE 3				ADE = 11	A/M NOISE GR	1.00 DB .GT.	NOISE 10				
FRED 70000.00 HZ COND. .01 HHOWH ETST 100.00 H HEPTH OF TRANSHITTER 200.00 XMIT LOOP RADIUS 20.00 H LINE SOURCE LENGTH= 100.00 H HEPTH OF TRANSHITTER 200.00 NOISE .126.00 DB .GT. 14/H NOISE GRADE = 1 1 100.00 DHS NOISE .126.00 DB .GT. 14/H NOISE GRADE = 1 1 1 100.00 DHS NOISE .141.00 DB .GT. 14/H NOISE GRADE = 1 1 1 1 1 NOISE .141.00 DB .GT. 14/H NOISE GRADE = 1					IATH NOISE GR	3.00 D8 .61.					
FRED 70000.00 HZ COND. .01 HHRSH EFST 100.00 H DEPTH OF TRANSHITTER. 200.00 NMIT LOOP RADIUS. 20.00 H LINE SOURCE LENGTH. 100.00 HMS 100.00 HMS NOISE .126.00 DB .GT. 1A/H NOISE GRADE . 1 100.00 HMS NOISE .126.00 DB .GT. 1A/H NOISE GRADE . 1 NOISE .141.00 DB .GT. 1A/H NOISE GRADE . 1 NOISE .141.00 DB .GT. 1A/H NOISE GRADE					IA/M NOISE GR	1.00 DB .GT	NOISF # -17				
FREA 70000.00 HZ COND. .01 HHRSH EFST 10000 FORMATION FORMATION FORMATION FORMATION FOR FOR FORMATION FOR FOR					IA/M NOTSE GR	8.00 DB .GT.	NOISE15				
FREA 70000.00 HZ COND. .01 HHRS/H EFST 100000 H DEPTH OF TRANSHITTER: 200.00 XMIT LOOP RADIUS 20.00 H LIME SOURCE LENGTH: 100.00 H DEPTH OF TRANSHITTER: 200.00 NOISE .126.00 DB .GT, 1A/H NOISE GRADE: 1 NOISE .126.00 DB .GT, 1A/H NOISE GRADE: 1 NOISE .141.00 DB .GT, 1A/H NOISE GRADE: 1 NOISE .141.00 DB .GT, 1A/H NOISE GRADE: 3				ADE - 5	A/H NOISE GR	S.ON DE .GT.	NOISE - 1				
FREAT 70000.00 HZ COND					IATH NOISE GR						
FREAT 70000.00 HZ COND01 MHOSTM ETST 10.00 TOMENT 10000.00 HZ COND. 20.00 M LINE SOURCE LENGTHT 100.00 M DEPTH OF TRANSMITTERT 200.00 LINE SOURCE CONTACT RESISTANCE = 100.00 OHMS NOISE = -126.00 DB .GT. 14/M NOISE GRADE = 1 NOISE = -141.00 DB .GT. 14/M NOISE GRADE = 1					A/M NOTOF GR		NOISE -10				
FREAT 70000.00 HZ COND.T .OI MHOSTH EPST 10.00 TOMENT 10.00 A.O. A.O. A.O. A.O. A.O. A.O. A.O.					A/M NOISE GR	1.00 DB .GT.	NOISE -14				
FREAF 70000.00 HZ COND.F .01 MHOSTH EPSE 10.00 POHENF 10.00 A.00 A.00 A.00 A.00 A.00 A.00 A.0					AVM NOISE GR	6 ON DE .GT.	NOISE				
FREAT 70000-00 HZ COND." .01 MHASTH ETST 10.00 TOMENT 100.00 M NEDTH OF TRANSMITTERT 200.00				OHMS	NCE - 100.00	NTACT RESISTA	LINE SOURCE CO				
FREAD 70000.00 HZ COND.D .01 HHHS/H EPST 10.00 FUHERT 10.00 FALLO ALLO ALLO ALLO ALLO ALLO ALLO ALL	200.00	ITTER=	TH OF TRANSM	100.00 M NEP	JRCE LENGTHE	DO H LINE SOU	RADIUS= 20.	XMIT LOOP			
		ARTI LOOM	0.00 47113	00 -0464- 1	5/H EPS= 10.	01 MHU	100.00 HZ CONE	FRED= 700			
	FREG# 70	000.00 HZ	COND.=	.01 MHC	H W SC	5PS= 10	.00 POWERS		D.OO WATTS	XMIT LOOP W	EIGHT= 6.00
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	XMJT LOOP	RADIUS_	20°00 M	LINE SC	JURCE I	ENGTH=	100°00 M	7697	TH OF TRANSM	ITTER= 30	0.00
		LINE SOURC	CE CONTACI	T RESIST	NCE -	0 001	SMHD 0				
		NOISE -	-126.00	DA .GT.	1 4 / M	NOISE G	RADE = 1				
		NO15F =	-141.00	DB .GT.	1 4 / 4	NOTSE G	RADE = 2				
			-163.00	DH 61.		NOTSE G	RADE = 3 Rade = 4				
		NOTSE -	-131.00	DH CT		NOTSE GI	RADE = 5				
		= LOION	-153.00	DB 61	1 1/H	NOISE G					
			-158.00			NOT SE C					
		NO I SF	-146.00								
		NOISE -	-163.00	DB .GT.	1 A / H	NOTSE G	RADE = 10				
		NOISF -	-181-00	DR .GT.	1 / M		RADE = 11				
		NOISE -	-175.00	08 61.	N/N	NOT SE G					
		NOISE .	-155.00	08 67		NOTSE G					
		NOI ST	-123.50	DB 61	E SI	NO I SE G	RADE = 15				
(W) AS I U	NEPTH(M)	ERHO(PH]-	-O) EPH]	(PH1=90)	I A I	0 (PH I = 90	на)[нан ((u =)	HZ(PH1=90)	(GM7) ZH	EPH (VMD)
5,00	00.	5-225-	96 	179.14		95.41	-195.41		-232.72	•197.24	-198,50
ы, 00	300-00	12.(33	6.24	i) I	44.77	-344.77		10.05-	12.16	-4.02
25.00	00.	-178-	- 23	179.57		95.95	-195,85		-219.22	+194.43	- 186.51
25,00	300.00	-32.	•	-32,78	n H	45.03	-344,95		-50,80	-26,85	=12,9 2
50,00	00.	- 1 A O - 1		180.92		97.52	-197.21		-214.67	-193.57	-154.63
50,00	300.00	-57.(56	•52 . 18	r) I	45.84	-345.51		-69.70	-46.26	-29.7A
100,00	00.	-187.	28 • I	186.12	- 2	04.12	-202.47		-214.38	+194,89	-192.16
00,001	300-00	- 63 · 5	•	*81.87	n T	49.06	-347.76		12.00-	-75.95	-56,63
200,00	00.	- 606-	54 52	206.10	Ň	25.23	-222.58		-229.49	197.01	-198.75
00-006	300.00	-151.	12	133,89	•	61.42	#356,56		-151.31	-127.96	-119.43
4 n n _ 00	٥ ٠	-239.(52 -2	00.355	1	56.99	-248,49		•274.12	#239 ,60	-265,76
400,00	300-00	(- 254 -)	, - , -	231.26	n T	38°82	-386.22		-248.68	-225.33	-207.97

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	F-264= 100	000.000 HZ	1 - N - H	.01 MHU	S/M EPS	5= 10-1	00 PD1	wER≡	10.00 WATTS X	KMIT LOOP	WEIGHT= 6	• 00
	XMII LOUP	чАЬ I US≡	20.00 M	LINE SO	URCE LEN	46 T H =	100.(0C M D1	EPTH OF TRANSMI	1 T T E R =	• 00	
		LINE SOURC	CONTACT	RESISTA	NCE -	100.00	SMHO					
			-148.00	19. 61. 19. 61		UISE GR		-4 0				
		NOISE =	-170.00	03 . GT.	1A/M NC	JISE GR.		מו				
		NOISË 🛎	-144.00	DB .GT.	1A/M NC	DISE GR.	A DE =	4	×			
		NOISE =	-137.00	DB .GT.	IA/M NC	DISE GR	ADE =	Ĵ				
		NÜISE =	-163.00	DB .61.	IA/M NC	DISE GR	ADE =	9				
		NOISE =	-161-00	08.61.	IA/M NC	DISE GR	► DE	2				
			-140.00	08 .61.		015E 6R		10 (
			00.001-					יר				
			-104-00	100. 101. 101.								
				13 . 61.				10				
		NDISE	-140,00					1 1				
		2012E #	-101.00	DB .61.		DISE GR.		4				
		NOISE #	-135.50	DB .GT.	IV M NC	DISE GR	A DE	15				
(w)4510	0EPTH(N)	ЕКНО(РН]	10) EPHI	(PH1=90)	нкно (Р	(06=[Hc	H	0=143)1	(Ph.1=90)	(EPH(V ⁴ D)	
								•				
5.00	00	11.5	60	6.33	-116.	66,	-11(6.99	-20.05	12.11	23.68	
5.00	• 00	11-5	66	6.33	-116.	99	-11	6.99	-20.05	12.11	23.88	
25.00	00.	- 33.6	37	32.58	-116.	66	- Î T (6.99	-51.93	-27.62	=6.34	
25.00	00.	-33-5	37	32.58	-116.	66	-11(6.99	-51.93	-27.62	-6.34	
00°04	• 00	-60.5	•	53.81	-116.	66	- 114	6.99	-72.64	-47.19	-24.44	
50.00	• 00	-60.5	-	53.81	-116.	66'	-11	6.99	-72.64	-47.19	-24.44	
00-00	• 00	-100.7	۰. ۲۰	87.77	-116.	ó6 1	-11	6•99	-106.75	-78.04	-50+61	
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200.00	00.	-167.5	53 -1	48.56	-116.	66	-11	6•99	-167.53	-108.99	-74.5R	
400.00	00.	-288.5	53 -2	63.60	-116.	66,	-11	6 • 99	-282.57	-139.11	-95-66	
400.00	00.	-288.5	52	63.60	-116.	66.	-11	6 • 9 9	-282.57	-139.11	-98.66	

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5.00 Kn													(44)	53,23	1.83	51.07	57*6-	51.32	33.42	03.59	66.73	34.87	27.36	76.65	
WEIGHT.	50.00) FPH(Ŧ		F		F	T	•	ŀ		•	1	•
MIT LOOP													ÚW7) ZH	-54,89	12.26	-62.34	-26.65	-66,36	-47.88	-76.11	-81.13	-110.57	-146.85	-134.76	
10.00 WATTS X	DTH OF TRANSMI												(00=1H4)4H	-91.54	-20°05-	-82.26	-51.93	- 87 . 60	-72.86	-110.41	-106.76	-144.57	-170.54	-168.50	
OO POWER	100,00 M TE	SMID	2ADE = 1	2405 = 2	ADE = 5	ADE = 6		ADE = 10	ADE = 11	24DE = 12 24DF = 13	ADE = 14	KADE = 15	(u= [H4] [H4H	• 68.57	-109.47	-72.60	-110.70	-82,03	114.31	-103,62	-126.72	-123.21	-150.30	-139.85	
	ACE LENGTHM	5E = 100.00	A/H NOISE GR	A/M NOISE GR	VM NUISE GR	A/M NOISE GR	AVM NOTSE GR	A/M NOISE GR	A/M NOISE GR	AVM NOTSE GR	AVM NOTSE GR	V/M NOTSE GR	HRHD (PH]=90)	-68.64	+109.52	-74.21	-112.01	-88.17	-119.51	-107.65	-135,57	-130,70	-158.09	-149,14	
SOHM 10	OO M LINE SAU	INTACT RESISTAN	28.00 DR .GT. 1	14.00 DB .CT. 1	57_00 DB _GT 1	53.00 DB 61.1		54.00 DB .GT. 1	31.00 DR .67. 1	36,00 DB .67 1		55-50 DB .GT. 1	ЕРНІ (РН 1 #90)	-52,06	6.33	=55 ,72	-32,58	-64 .74	-53,86	-89.02	-87.62	-110.15	-137.10	-126.90	
100+00 HZ CUNI	RADIUS. 20.	LINE SOURCE CC	NO1SF = -12	NOISF = -14	NOISE 11	NOISE = -1-		NOISE - IS	NOISE	NOISF = +15 NOISF - +10		NOISE	ERHJ(PH1=0)	-49.41	11.99	-56.93	99 ° Dr =	-78 - 98	-40.73	06-10-	-00°66	-111-76	-138.72	-130.18	
REG= 1000	(M]T LOOP												ВЕРТЧ(М)	00.	50.00	00.	50.00	00.	50.00	00.	50.00	• 00	50,00	00 .	
	~												(M) 48 F E	°00, ₹	₹. JO	25.00	25.00	50,00	50,00	00,001	100.00	00-006	00"004	400.00	

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IDISE GRADE 13 IDISE GRADE 14 IDISE GRADE 14 IDISE GRADE 14 PHIBOD HPHI(PHIE 58 -102.04 58 -102.04 58 -102.04 58 -102.04 58 -102.04 58 -102.04 58 -102.04 58 -1108.81 58 -1108.81 58 -1125.12 58 -125.12 58 -125.12 58 -125.12 58 -125.12 59 -125.12 59 -125.12 59 -125.12	- H7(PHI=90) -130.49 -20.05 -118.48 -118.48 -118.16 -72.84 -130.83 -16.75 -16.75	HZ (VHD) -94.27 12.26 -95.01 -26.66 -99.31 -47.89 -100.63 -139.50
IDISE GRADE # 13 IDISE GRADE # 14 IDISE GRADE # 14 IDISE GRADE # 15 PHIBOO HPHI(PHIE) -06 H169.57 -34 H169.57 -34 H169.57 -156 H169.57 -35 H169.57 -34 H169.57 -156 H169.57 -165 H102.04 -35 H172.08 -35 H172.08 -36 H172.08 -36 H172.08 -36 H172.08		H7(PHI=90) 130.49 130.49 130.05 130.05 130.5 130.5 130.5 172.34
IDISE GRADE # 13 IDISE GRADE # 14 IDISE GRADE # 14 IDISE GRADE # 15 PHI#90) HPHI(PHI#105 PHI#90) HPHI(PHI#105 56 H169 56 H169 56 H169 105 H102 56 H169 57 H169 58 H169 57 H169 57 H169 57 H169 57 H170 57 H172 57 H172	÷	H7(PHI=90) -130.49 -20.05 -118.48 -51.93 -118.16 -72.54 -130.83
IDISE GRADE # 13 IDISE GRADE # 14 IDISE GRADE # 14 PHI#90) HPHI(PHI#100 PHI#90 HPHI(PHI#100	Ū.	H7(PHI=90) -130.49 -20.05 -118.48 -31.93 -118.15 -72.54
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DISE GRADE = 13 DISE GRADE = 14 PHI=90) HPHI(PHI= -06 -102.04 -105 -169.57 -34 -102.57 -34 -103.79 -64 -170.18		H7(PH1=90) -1.30.49 -20.05 -1.18.48 -31.93
DISE GRADE = 13 DISE GRADE = 14 PH[=90) HPHI(PHI= 		H7(PH1=90) -1:10.49 -200.05 -1:18.48 -1:18.48
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u.	FREG= 100	2H 00.000	COND.	.01 MH	J H/SL	TPS= 10	OO POWER	•	AN WATTS X	MIT LOOP WE	[IGHT= 6	00 KG
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		= 3slow	-144.0	0 08 .61	11/4	NOISE G	RADE -	4				
		NO15E -	-137.00	0 DB .GT.	1 A / M	NO1SE G	RADE -	5				
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(W) 4510	nep th (M)	FRHD (PH [a 20 -	06=1Hd)1H	нан	06=1H4)u	9) 1Hah (1	(c=1H	106=1H4)2H	(@WA)ZH	EPH (VMD)	
	00	-143.	50	-144.82		62.51	-162,5	c	-106.44	-160,66	-158,46	
00	00-000		0	6.33	л Т	80 . 48	-284.0	2	-20.05	12.26	1.83	
25.00	00		57	-145.60	-	63.50	-163.3	0	-1 A3 . 34	-158,28	-147.23	
	00 000		A 7	-32.58	ŝ	A4.55	-284.3	0	-51.93	-26.66	-9.43	
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50°00	200.005	- 69 -	80	-53,81	1	86.03	-285.3	8	-72.84	-47.89	-33.42	
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100-00	200.00	-100-	.73	-87.77	č T	91.89	-289.2	6	-106.75	-81.84	-66.73	
200-006	00.	-140	.24	-197.39	-3	06.70	-206-7	0	-215.38	-173.91	-175.10	
00"006	200*002	- 1 4 7 -	,53	-148.56	۲. ۲	10.57	-304-8	15	-147.53	-142.63	-127.33	
400.00	00.	-112-	,79	-208.28	-2	30.75	-221.3	12	-249.70	-215.65	-255.69	
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6-77

400.00 300.00 - 2#	400.00 .00 -26	1- 00.00E 00[00¢	22- 00. 00 <u>00</u>	100.00 300.00 -10	100.00.00.00	50.00 300.00 -6	2°- 00° 00°- 50	25.00 300.00 -7	or.on .on -or	200 300.00 10 F		л1SP(M) DEPTH(M; ЕRHO(S	NDISF -	NOISE .	NOISE .	NOISE	NO I SE				NOISE	NOISE .	NOISE .	NOISE	NOISE 1	NOISE
a. 59	6.20	7.53	.69	0.73	2.16	0.80	4.13	13.A7	12.07	1.99	1.41	'H1=0; EP		-161.0	-190-0					-161.0		-137.0	= =144.0	-170.0	-144.0	128_0
-263,60	-262.54	-148,56	-235,58	-87.77	=210.77	-53.81	-204.59	-32.58	-203.00	6.33	#202 • 4 A	HI (PH1=90)	O DR GT I	O DB GT 1	O DA GT I					0 09 61 1	NO DB .GT. 1	O DB GT 1	O DH GT 1	O DB GT 1	O DR GT 1	I TO BE CT 1
-449.01	-285.17	-415.49	-254.22	-401-28	-230.56		-272.97	-396.55	-221.03	-396.25	-220 - 40	HRHD(PHI=30)	WIN NOTSE GRA	A/M NOISE GRA	AVM NOTSE GRA	AVE NOISE GRA		AVA NOTAT CAA	A/M NOISE GRA	A/H NOISE GRA	A/M NOISE GRA	A/M NOISE GRA	A/M NOISE GRA	A/M NOISE GRA	A/H NOISE GRA	A SU NUISE DRA
-438.60	-275.63	-410.51	-253.73	-399,85	-228.74	-397.14	-222.53	-396,46	-220,92	-396.24	-220,40	HPH1 (PH1=0)								DE = 7	DE = 6	DE = 5				
-242.57	-304.01	-167.53	-259.82	-106.75	-240.60	-72.84	-219.89	-51.93	-244.17	- 20 - 05	-257.59	H7(PHI=90)														
-257.68	-269.31	-142.63	-223.37	-81.84	-218,18	-47.89	-217.71	-26,66	-218.56	12.26	-222.03	HZ (VMD)														
-242.53	-303,77	-127.33	-248.32	-66.73	-211.31	-33.42	-206.87	-9.43	-208.12	1.83	-219.95	EPH (VMD)														

XMIT LOOP RADIUS. FRE0* 100000.00 HZ LINE SOURCE CONTACT RESISTANCE -COND. = 20.00 M LINE SOURCE LENGTH 100,00 M .01 MHOSIM EPSE 10.00 POWERE 100.00 CHMS NEPTH OF TRANSMITTER= 10.00 WATTS XMIT LOOP WEIGHT= 300.00 6.00 KG

С Х																								
00.																								
ι ν κ												(MD)	29.83	29.83	-2.50	-2.50	-24.68	-24 - 68	-50.52	-50.52	-74.58	-74.58	-98,66	-98.66
WE1GHT .00												Hau												
MIT LOOP TTER=												GMV) ZH	12.27	12.27	-27.58	-27.58	-51.49	-51.49	-85.23	-85.23	-115.03	-115.03	-145.13	-145.13
HATTS X TRANSMI												(06=1H	20	20	25	25	39	39	27	27	28	28	53	25
10.00 V EPTH OF) нд (-20	-20	-55-	-55	-81	-81.	-126.	-126.	-209.	-209.	-368	-368
JWER■	6	N P	04		~	<i>5</i> 00	10	i	21	2 7 7	12	0= I H J) I H	6.99	6.99	6-93	6.99	6.99	6.99	6.99	6-99	6.99	6.99	6.99	6°0,
10.00 PC	-00 OHMS	GRADE Grade Grade	GRADE		GRADE	GRADE -	GRADE	GRADE	GRADE -		GRADE	н 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	-11	-11		1				-1-	-1-	-		1
EPS= LENGTH	100	3510N 156 101 26	NOISE	NOISE	NOISE	NOISE	NOISE	NOISE	NOISE	NO I SE	NOISE	но (Рн] =	116.99	116,99	116,99	116.99	116.99	116,99	116,99	116.99	116.99	116,99	116,99	116.99
4HOS/M SOURCE	STANCE	[1 1 A / M	1. 1A/M	[1A/M	1 1 AV M	T. 1A/M		[1A/M	1. 1A/M	1 - 1 A / M		10 нк	•	•	•	•	•	·	•	•	I	·	F	•
.01 .	T RESIS								. DB			5=IHd) I	6.67	6.67	-33,12	-33.12	-59.39	-59.39	104.28	104.28	187.30	187.30	346,95	346,95
2 0 0 0 0 0 0 0 0 0 0 0 0	CONTAC	-130.00 -148.00	-150.00	-177.00	-167.00	-186.00	-178-00	-183.00	-198.00	-198.00	-149.50	ц Ц Ц			_				•	•	•	•	•	•
00.00 HZ C	-INE SOURCE	VOISE #		40155 #				401SE =	401SE #		VOISE =	ЕКНО (РНІ=0	11.84	11.84	-37.19	-,37 . 19	-69-35	-69-35	-120.25	-120.25	-209.28	-209.28	-374.95	≡374.95
- HEW= 2000	-			_ 2	£				-	- 6		DEPTH(11)	• 00	• 00	00.	00.	00.	• 00	00.	.00	• 00	00.	.00	00.
u. X												015P(M)	5.00	5.00	25,00	25.00	50.00	50.00	100.00	100.00	200-00	200.00	4,00,00	400.00

.

-222.80	-186.12	-220.65	-188.87	-192.92	-172.92	-170-94	50.00	400.00
-184.16	-144.27	-182.01	-150.53	-154.59	-134.60	-132-62	• 00	400.00
-159_39	-160.43	-196.76	-174.06	-173.50	-157.78	-161.56	50,00	200.00
-156.32	-124.37	-161.35	-135.84	-145.17	-119.85	-123-20	• 00	200.00
-76.90	-98.47	-126.37	-153.23	-159.29	-104.40	-119,38	50.00	100_00
-102.03	-90.10	-135.55	-119.39	-124.99	-104.82	-104.08	.00	100_00
-36,02	-53,47	-A1.39	-135,38	-141.37	-59-38	- 69.35	30.00	50.00
-57,51	-71.19	-99,79	-94.11	-100.51	•73,65	185,19	• 00	50.00
-5.37	-27.19	135.25	-130.36	-131.89	-33.11	-37.19	50.00	25.00
-44.79	-70.04	-91.53	-82.03	-83.91	-61.83	-63.53	• 00	24.00
12.96	12.60	-20.20	-128.65	-128.71	6.67	11.84	50.00	5.00
*55 * 69	-63,15	-09.72	* 77 . 00	-77.07	-57.14	-54 -97	. 00	. 00
FPL (VRD)	HZ (VMD)	HZ(PH1=90)	HPHI (PHI = 0)	HRHD (PH I = 90)	EPHI (PHI =90)	ERHO (PH] =0)	DEPTH(M)	19100(11)
				IV/M NOTSE GR	49.50 DB .GT.			
				14/M NOTSE GR	76 OO DE GT			
			ADE = 12	AN NOISE GR	BA ON DA GT.	NOISE		
				14/M NOISE GR	33 00 DB GT			
				IA/M NOTSE GR	SO ON DE GT.			
				AVM NOISE GR	36.00 D8 .GT.	NOISE = -1		
				AAM NOISE GR	57.00 DB .GT.			
				IA/M NOISE GR	15.00 DH GT.			
				IA/M NOISE GR	50.00 DR .GT.	NOISE		
			ADE = 3	1A/H NOISE GR	DB GT.	NOISE		
				AVM NOISE GR	18.00 DB .67.	NOISE = +1		
				1 A/M NOISE GR	JOLUU DE TET	2015F 1		
			OHMS	NCE = 100.00	UNTACT RESISTA	LINE SOURCE C		
50.00	ilTTER#	TH OF TRANSH	100.00 M DEP	URCE LENGTH=	OO M LINE SO	RADIUS= 20.	XH]T L00P	
WE I GHT	XMIT LOOP	TO.ON WATTS	OO POWER	S/H 2PS= 10.	0.= .01 MHD	000+00 HZ CON	FREQ= 2000	

6.00 KG

6-80

FREQ.	20-000-05	ZH C	COND.=	.01	W/SÜHW	EPSe	0.00 -0	NER=	10.00 WATTS	XHIT LOOP	WEIGHT=	0 •9
XMIT L	OOP RADIU	= 51	20.00 M	LINE	SOURCE	LENGTH	100	й Н 00	EPTH OF TRANS	MITTER=	100,00	
	LINE	sourc	E CONTAC	T RESI	STANCE	100	SMHD 00					
	NOISE	• 54	-130.00	D8 • 6	T. 14/H	NOISE	GRADE =					
	NO I SE	# 1	-148.00		T - 1 4 / M T - 1 4 / M	NOTSE	GRADE =	N P				
	NO1 SF	1 16	-150.00		T 1 1 / M	NOISE	GRADE =	- 1				
	NOI SE	H L	-145.00	DH G	T. 14/H	NOISE	GRADE =	ŝ				
	NOISE	18 14 1	-177.00	. 19 6.	T. 14/M	NOISE	GRADE =	÷				
	NO I SE	8 - 14 i	-167.00		T. 14/M	NOISE	GRADE =	~				
	SI ON		-186.00		T	JS L CN		¢ (
		U										
		8						0				
		86 1 a. 1										
		19 (1. 1.										
		10 I										
	1010N	U U	-149.50			NOTSE		121				
HEPTH ((M) ERHO	- I H d) C	0) EPH	*1Hd)1	90.) HR	6=[H4]CH	нан (о)	C=[H]=)) H7(PH1=90	0W7)ZH () EPH(VMD)	
č	ç	- 99.4	•	100.99	t	121.46	#12	1,43	-149.62	-113,30	-102.3	2
0 100.	00	9 - 1 :	4	6.67	ł	211.06	121	1.04	-20.20	12.60	12.5	ý
°.	•	-102.7	n	103.22	r	124.41	-12	3.74	-138.21	-113.28	-92.5	1
0 100.	00	-37.1	o	-33.12		212.46	-21	1.92	-55.25	-27.19		2
°.	• 00	-112.5	د	109.72	T	133,09	915	0.41	-139.67	-115,24	-108.1	4
0 100.	00	-69-3	ŝ	+20°36	t	216.78	12-	4.61	-A1.39	-53.46	-36.0	\$
°.	•	-136.2	•	133,33	T	155.74	-15	3.40	-159.04	+120.94	-118.1	80
0 100.	۰ ۵۵	-120.2	ء	104.28	T	10.155	122	4.96	-126.27	-98,36	-76.9	ç
•	•	-161-5	•	158.00	t	1 4 3 . 4 8	117	4.07	-199.24	-161.28	-193.0	-
0 100-	•	0-602-	n	187.30	ł	261.31	125	0.75	-209.28	-181-37	-159.5	5
Ĩ.	•	-170.9	4	172.92	I	192.92	-18	8.87	-220.65	m186.12	-222 .	ç
0 100.(•	-247.7	L N	249.55	•	269.69	1921	5.56	-297.24	-262,59	-299.6	4

6.00 KG

-	-327.10	-341.02	-368,93	-418,93	-423.24	-346,96	=374.55	200.00	400.00
	4£°66č-	+262.59	-297.24	-265.56	-269-69	=249.55	-247.72	• 00	400.00
-	-159,52	-181.38	-209.28	-401.22	-403.97	-187.30	■209•28	200-00	200_00
	-233,67	-231.86	-276.53	-250.48	-262.52	-234.08	-239.76	• 00	200.00
	-76.90	-98.36	-126.27	-377.67	-380.77	-104.28	-120.25	200.00	100.00
	-194.50	-197.93	-230.39	-221.28	1274.54	-200 - 31	#203.93	• • • •	100.00
	-36.02	-53.46	-A1.39	-372.09	-372.A7	-59.39	- 69 - 35	200.00	50,00
	-177.22	-199,21	-222.67	1208.58	-209-57	-187.64	-1A7.90	• 00	50,00
	-5.37	-27.19	-55-25	-370.67	-370.A6	*33.12	-37 - 19	200.00	24.00
	-178.61	-198,20	-225.05	n 205.23	-205.47	*184 . 32	+ J A 3 - 55	• 00	24,00
	12.96	12.60	~20 . 20	-370.21	-370.22	6.67	11.74	200.00	5.00
	-190.81	-201.77	-237.84	-204.13	-204.14	-183.23	-192.13	• 00	5.00
	EPH (VHD)	HZ (VMD)	H\$(PHI=90)	HPHI (PHI=0)	HRH0 (PH1=90)	Eput (PHI=90)	ERH0(PH1=0)	DEPTH(M)	T SP (H)
					VIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII				
	0 .00	TTER= 201	TH OF TRANSHI	100.00 M NEP	URCE LENGTHE	ON M LINE SOL	RADIUS= 20	XHIT LOOP	
6.00 KG	5 I GHT-	HIT LOOP W	0.00 WATTS X	00 POWER= 1	S/M EPS= 10.(₩ •••••••	000.00 HZ CON	FREQ= 2000	

	FREG# 200	2H UU-UUO	COND.	.01 M	HUS/H	FPS= 10.(00 POWER=	10.00 WATTS	XMIT LOOP	HT I CH L	÷.
	XMIT LOOP	RADIUSE	60° u c	M LINE	SOURCE	LENGTH=	100.00 M	NEPTH OF TRANS	3HITTER=	300,00	
		LINE SOUR	CE CONTA	CT RESIS	TANG	100.00	SMHD				
		10101									
		NDISF =	0.001-	C DB C	14/H	NOTSE GRI					
		NOISF	-150.0	0 DR .GT	. 14/H	NOTSE GR	ADE = 4				
		NO 1 SF =	-145.0	C DH GT	. 14/M	NOTSE GR.	ADE = 5				
		NOISF =	-177-0	C DH GI	. 1 A / M	NOTSE GR.	A 7 E = 6				
			-167-0	C DR CT	M/1 .	NOTSE GR					
					M/M						
					W/ 4 4						
		NO I SF				NDISE GR					
		NOISE	-176.0	O DH GT	IA/M	NOTSE GR	ADE = 14				
		NOISF .	-149.5	O DR .CT	. 1W/M	NUISE GR	ADE = 15				
(W) as 14	DEPTH(M)	ERHOLPHI	=0) EP	6=1Hd)1H	чан (о	10 (PH1=90)	INd) INdH	05=1Hd)2H (0=	0) HZ (VMD	1) EPH (VMD	-
F. 00	00.	-242-	3.5	-263,24	Ci I	A4.34	-284.34	-321,32	-285.36	-276.	61
s.00	300.00		Rd	6.67	10 1	27.06	-527.05	02-20-	12.60	12.	96
25.00	u u•	-263-	23	-263.96	č -	A5.20	-285.06	-308.11	-280.57	-263.	56
25.00	300.00	- 17 -	61	-33.12	LC) T	27.47	#527.37	-5°,25	-27.19	10 1 1 1	37
50.00	ůu.	- 245 -	00	-266.19	ĩ	A7.A4	-287.29	-304.48	-280.04	-250.	50
50.00	300.00	• 6¥ -	35	-59.39	1. 1	128.7A	-528.35	9.20 1 4 -	-53,46	-36-	20
100-00	ův.	-276.	67	-274.85	•	9A.N9	-295.93	-307-74	-278.71	-265.	54
100-00	300.00	-120-1	25	-104.28	10 1	13.04	-532.21	-126.27	-98-36	-76.	06
200.000	00.	- 6 C E -	22	-324.90	ю •	30 . 1 4	-331.79	4 I " 6 E E -	06.592-	-326-	06
00.006	300-002	- 60C -	2.B	-187,30	1 I	151.04	-547.73	-209.28	-181.38	-159.	52
400.00	с с •	-324.	Q Q	-326.1A	•	46.47	-342.24	+373 - B3	-339.04	+375+	96
00° ∪∪₹	300-00	- 174.	95	-346.95	in T	176.75	-572.28	10°848-	-341.02	-327.	10

6.00 KG 10.00 WATTS XMIT LOOP WEIGHTE

Section 7

Analysis of Mine Communications Propagation Programs

In paragraph 7.1 "User's Guide for the Mine Communication's Propagation Programs," computer programs are presented for the complete analysis of specific through-the-earth electromagnetic links. These links include the following:

- a. Communications between a VMD on the surface and a submerged VMD.
- b. Communications between an infinite line source on the surface and a submerged line source or VMD.
- c. Intramine communications between submerged horizontal electric dipoles (HED), between HED and VMD, or VMD to VMD.
- d. Intramine communications from an infinite line source.

7.1 USER'S GUIDE FOR THE MINE COMMUNICATION'S PROPAGATION PROGRAMS

In the course of the analytical work which was accomplished under subcontract Purchase Order No. C-684420 to Collins Radio Group for their Bureau of Mines project, several basic computer programs were written. These programs were generated for the following specific tasks:

- a. Communications between a vertical magnetic dipole (VMD) on the surface and a submerged VMD.*
- b. Communications between an infinite line source on the surface and a submerged line source or VMD.*
- c. Intramine communications between submerged horizontal electric dipoles (HED), between HED and VMD, or VMD to VMD.**
- d. Intramine communications from a submerged infinite line source.

The first program is employed for most up-link or down-link paths. It computes the H-fields on the surface from a submerged VMD at various displacements, or the subsurface H-fields from a VMD on the surface. It will also compute the subsurface E- and H-fields of interest from an infinite line source on the surface.

The results are displayed for various receiving point depths and displacements in terms of signal-to-noise spectral density.

^{*}With preliminary noise grades.

^{**}Includes updated noise grades defined in section 6.

The input requirements are as follows:

FORTRAN NOTATION	MEANING
РТ	Transmitter power in watts
W1	Weight of transmit loop, kg
AC	Circular mils area of loop wire
A1	Radius of transmit loop, meters
A2	Radius of receive loop, meters
SIG	Overburden conductivity mhos/meter
RNF	Receiver noise figure, dB
NOISE	Noise grade; 1, 2, or 3*
LINK	= 1 up-link, = 2 down-link
IT	If IT = 1, a large diameter surface XMIT is used
ITYPE	= 1, vertical H-fields from VMD
	= 2, vertical H-fields from infinite line source
	= 3, horizontal H-fields from infinite line source
	= 4, E-fields from infinite line source
LL	Number of frequencies to be skipped.

7.2 PROGRAM NUMBER ONE

The printed output first consists of a 2-dimensional array of Wait's functions used to compute the fields. After a listing of the basic input parameters, the noise power density, the minimum receive loop turns and the Q of the transmit and receive loops are presented. A 2-dimensional (depth and displacement) array of S/N_0 is then printed out.

*Preliminary noise grades.

```
COMPLEX SUM, FUN, nOONLE, ZAP
   DIMENSION UN(2,1%), FREQ(16), DN(3,1%), KLINK(2), QX(11,12), DS(11,12)
   PATA FREQ/100.,200.,300.,500.,700.,1000.,2000.,3000.,8000.,7000.,
  110000,,20000,,30000,,50000,,70000,,100000,/SKLINK/4H UP,4HDWN/
   DATA (UN(1,1)+1=1+16)/46.5+31.0+19.0+6.0+0+6.0+13.0+18.5+245
  15--28.5--33.0-41.0-46.0-50.0-53.5-57.0/ (U)(2.1), I=1.16)/30.0
  26.0,-5.0,-17.0,-5.0,-30.0,+37.5,-40.0,-40.0,+40.0,-40.0,-40.0,-49.0,-50
  3.0, -57.0, -58.0, -KA.0/+(DN(1.1), 1=1, 16)/59.0, 54.5, 51.0, 45.0, 42.5, 40
  4.0,31.0,21.0,1.5.-3.5,-15.0,-29.0,-34.0,-43.0,-65.0,-73.0/, (DN12,1
  5) = 1 = 1 = 16) / 47 . 0 = 37 . 0 = 19 . 0 = 12 . 0 = 11 . 0 = 11 . 0 = 11 . 0 = 0 = -9 . 0 = -22 . 0 = -32 . 0 =
  6-16.0,-55.0,-64.0,-69.0,-73.0/,(DN(3,1),1=1,16)/30.0,6.0,-6.0,-17.
  70==25.0==30.0==37.0==40.0==46.0==45.0==48.0==54.5==59.0==72.0==75.
  80--76-0/
   FXTERNAL FUN
   PI=3.141592654
 1 READ 2.PT.WI.AC.AJ.A2.SIG, RNF.NOISF.LINK.IT.ITYPE.LL
 2 FORMAT(7F10.2,51)
   TEIPT LT. OODI) MALL EXIT
   MINK=KLINK(LINK)
   IFITYPE.GT.1) Gn TO 20
   N 3 A
   TFILTNK . ED. 2. AND IT. ED. 1) N=1
20 n0 12 1=1.16.LL
   FRF=FRFQ(1)
   IFILINK GT . 1) GO TO 3
   HN-UN(NOISF.1)
   GO TO 4
 3 HN= "N(NOISE.1)
 4 CONTINUE
   DUMENN
   HN=10.++((HN=120))/20.)
PFN=10.++(PNF/10)
   IF(ITYPE.GT.1) Go TO 2.
   OL1=(1.515+FRE+A) 0G10(96.5+A1)+N1+1.E-3)/A1
21 MT=(4.41+RFN+1.E_A)/(FRE++2+HN++2+AC+A2++3)+1
   TNENT
   W2=(A0+TN+AC)/(2:78+1.E+4)
   RL2=(1_515+FRE+A] OG10(96_5+42)+W2+1_E-3)/A2
17 PNOD=10.+410G10(1.+PT*+4*6.52*W2)=230.+DUM+20.*ALDG10(FRE+A2)
   nn 7 1=1,12
   H= (05+ 05+FLOAT(1=1)
   SIGM=SIG+1000.
   Y= OR6+SORT (FRE*eIGM) *H
   no 7 K=1.11
   N= S+FLOAT(K-1)/4
   A=(A1/H)+1_E=3
   TEMP=1.E=6
   SUM=(0..0.)
  G=n.
   F=t.
   DO 5 (=1,10
   ZAP=DODDLE(1,G,E'X, D,A,N, ITYPE,FUN)
   SUM=SUM+7AP
   TFICARS(ZAP) LT. OOL+TEMP) GO TO 6
   TEMP=CABS(7AP)
   GEE
  F==.+G
 5 CONTINUE
```

```
6 D=CARS(SUM)
          1F(0.LF.0.)0=1.E_10
          IF(ITVPE.GT.1) Gn TO 22
          SNR==40.+10.+ALDc10(65.2+W1)=10.+ALDG10(16.+P1++2)+20.+ALDG10(A1+0
         1)-num=60.+ALOG10(H)+10.+ALOG10(PT)
          60 TO 28
       22 SNP=20. *ALOGIO(Q;H)-RUM+10. *ALOGIO(PT/100.)+60.
    C CAUTION FOR ITYPE 4 SUBSURFACE LINE SOURCE NOISE FIELDS ARE ONLY APPRO
    C XIMATE
          IF (ITYPE.ER.4) SNR=SNR+20 + ALOG10(H+FRE)=109.5
       28 08(K, J)=0
        7 RX(K,1)=SNR
          PRINT 19
       19 FORMAT(1H1,//. AOY, +WAITS O FUNCTION .//)
          PRINT 18,05
       18 FORMAT(1X.11F11.K/)
          IF(ITYPE.GT.1) Gn TO 24
          PRINT BEFREEPTEWIEW2.A1.A2.SIGEMINKENDISEERNE
        8 FORMAT(1H1, 10X, FRED. - + FR. 0. + HZ TRANSMITTER POWER + FR. 0. + WATTS
         1 XMIT LOOP WEIGHT +, FA.2, + KG ROVE LOOP WEIGHT +, FA.2, + KG +,//.
         210X, XMIT LOOP RADIUS + F6.2, M ROVE LOOP RADIUS + F6.2, M
         300ND . + F6.2, MHOS/M +, A4, +LINK NOISE ++ 12, + ROVR NF +, F4.0, +
         ADROI
          PRINT 13, PNON, NT OL1, OL2
       13 FORMAT(//. LOX. + NOISE POWER TENSITY +.F7.1. DBW. ROVE LOOP TURNS
         1 *.14, * XMIT LOOP Q *.F8.2.*. ROVE LOOP Q *.F8.2)
          CO TO 27
       24 PRINT 25, FRE, PT, eIG, MINK, NOISF, PNF
       25 FORMAT(1H1,10X. FRED. - FRA.O. HZ TRANS FOWER FFR.O. WATTS CON
         10. +, F6.2. + MHOS/M +, A4, +LINK NOISE# +, 12. + ROVR NF= +, F4.0, + DB*
         21
         PRINT 26
       26 FORMAT(//. 404. LINE SOURCE DOUNLINK .)
       27 PRINT Q
        9 FORMAT(///, 20%, PECETVED SIGNAL TO NOISE SPECTRAL DENSITY - //. 40%.
                                             .00
                                                    .05
         1. DISPLACEMENT-KM., /. DEPTH(KM)
                                                            .10
                                                                   .15
                                                                         .20
                                   .40
                                          . 45
                                                  .50 *./)
         2 .25 .30
                            .35
         n0 10 L=1+12
          H= 05+ 05+FL DAT(1-1)
       10 PPINT 11.H. (0X(M_L).M=1.11)
       11 FORMAT(1X+F6.2+2y+11F7.1/)
       12 CONTINUE
          GO TO J
          ENN
OF UNIVAR 1108 FORTRAN V COMPILATION.
                                           0 +DIAGNOSTIC+ HESSAGE(S)
```

```
COMPLEX FUNCTION DOODLE(N.A.B.C.D.E.K.L.FUN)
             COMPLEX FUN
             DATA (W(T), T=1,1K)/3,5093050E+3,8,1371974E+3,1,26960327E+2,
           1 1,71369314E=2,2,14179490F=2,2,54990296E=2,2,93420467F=2,
2 3.29111114F=2,3,61728971F=2,3,90969479E=2,4,16559621F=2,
3 4.38260465F=2,4,5586939F=2,4,692219954E=2,4,78193600F=2,
            4 4182700443E-2/
            DATA (V(1),1=1,20)/1.3680691E-3,7.19424422E-3,1.76188722E-2,
           2 3.25469620F-2,5 18394221F+2,7,53161931F-2,1,02758102F-1,

3 1.33908940F-1,1 68477866F-1,2,06142121E-1,2,46550045F-1,

4.2,89324361E-1,3,34065698E-1,3,803E6714F-1,2,46550045F-1,
           4 2 A9324361E-1,3 34065698E-1,3 80356318E-1,4 27764019E-1,

5 4 75846167E-1,5 24153832E-1,5 72235980E-1,6,19643681E-1,

5 6 65934301E-1,7 10675638E-1,7 53449934E-1,7 93657878E-1,

6 8 31522133E-1,8 66091059E-1,8 97241697E-1,9 24683806E-1,
           7 9 48160577F=1,9 67453037F-1/
            DATA (V(1),1=30,32)/9.823811278E-1,9.92805756E-1,9.98631931E-1/
            POOD E=(0.,0.)
            XX 🕿 A
            H=(B-A)/(FLOAT(N))
            no 5 t=1,16
            J=33-1
         5 W(J)=W(J)
        30 00 1 J#1,N
            nn 2 t=1,32
            X = X X + H + Y (I)
          2 NOONLE=DOONLE+W(;)+FUN(X,C+0,E+K+L)
          1 XX=XX+H
            BOON E=H+DOONLE
            RETURN
            ENn
E HATVAD LINA FORTRAN V COMPTLATION.
                                                         0 + DIAGNOSTIC+ (ESSAGE(S)
            COMPLEX FUNCTION FUN(X, H, D. G. K.L)
            COMPLEX Q
            DOURLE PRECISION XD. HD.C. E. U. V. W. 7. T
            ¥D=¥++2
            HD=H++2
            CALL CDSORT(YD, HD, C, E)
            U=DEYP(=C)+DCOS(F)
            V=_DFXP(-C)+DSIN(E)
            W=DRLF(X)+C
            CALL DODIZZ(U.V.W.E.7.T)
            D=CMPLX(SNGL(Z), CNGL(T))
            CO TO (1,2,3,4),
         1 FUN=X++3+Q+RSSL(Y+D+1)
            TEIK.FO.O.OR.X.LT.1.F-6)PETURN
            FILM=FILM+2.+RSSL(x+G,3)/(x+G)
            RETURN
         2 FUN=2 + X + Q + STN(X + D)
            RETURN
         3 FUN=2.+Q+CMPLX(SNGL(C),SNGL(E))+COs(X+D)
            RETURN
         A FUN=2.+0+COS(X+D)
           PETURN
           END
```

F HATVAC LINE FORTRAN V COMPLIATION.

DJAGNUSTIC HESSAGE(S)

```
NE DODTOS
              ENTRY POINT 000034
HSED (PLOCK, NAME, LENGTH)
101
      +CODF
               000050
100
      + DATA
               000010
102
      +RI ANK
              00000
 REFERENCES (RLOCK, NAME)
103
    NEPR34
ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)
000000 THJPS
*
           SURPOUTINE DCD122(A.R.C. D.X.Y)
۰.
           BOUPLE PRECISION A, R. C. P. X.Y
٤.+
           X = C + C + D + D
           Y = (B + C - A + D) / X
٠
*
           Y = (A + C + B + D) / Y
           RETURN
*
           ENn
٠
OF UNIVAC JIOA FORTRAN V COMPILATION. O +DIAGNOSTIC+ HESSAGE(S)
           SUDROUTINE COSORT (A.R.C.D)
*
۰.
           DOURLE PRECISION A, B, C, D, 72.7SR.F
:.
           72=A+A+8+8
           75P=050RT(72)
*
           C=nSORT(O_5DO*(A_7SR))
*
*
           F=7SP=A
           F=nMAY1(0,n0,7SR_A)
*
           N=NSIGN(1.000.€),NSORT(0.500+F)
*
           RETURN
٠
           ENIN
OF HNIVAC 1108 FORTRAN V COMPILATION. O +DIAGNOSTIC+ MESSAGE(S)
```

7.3 PROGRAM NUMBER TWO

The second program is used for most intramine paths. It computes the five field components of interest emanating from a submerged HED and the two field components due to a submerged VMD. These components are calculated on the surface and at the transmitter depth for various displacements. The input requirements are as follows:

FORTRAN NOTATION	MEANING
PT	Transmitter power in watts
W1	Weight of the transmitting VMD, kg
A1	Radius of transmitting VMD, meters
L1	Length of transmitting HED meters
FRX	Frequency in Hz
EPS	Relative dielectric constant of overburden
SIG	Conductivity of overburden mhos/meter
RS	Contact resistance of submerged HED
DS	Depth of transmitter, meters
NOISE	Noise grade (subsurface) 1, 2, or 3
LT	The number of displacements in 100-meter incre- ments from the transmitter.

The format for this data is (9F8.2, 2I2). An arbitrary number of these cards may be inputted for whatever combination of parameters are desired. The last card in the data deck is blank. The frequencies selected must be one of the following: 1 KHZ, 2 KHZ, 3 KHZ, 5 KHZ, 10 KHZ, 20 KHZ, 50 KHZ, 70 KHZ, 100 KHZ.

The field components computed are

$$\mathbf{E}_{\boldsymbol{\rho}} | \boldsymbol{\phi} = 0^{\circ}; \ \mathbf{E}_{\boldsymbol{\phi}} | \boldsymbol{\phi} = \boldsymbol{\pi}/2; \ \mathbf{H}_{\boldsymbol{\rho}} | \boldsymbol{\phi} = \boldsymbol{\pi}/2; \ \mathbf{H}_{\boldsymbol{\rho}} | \boldsymbol{\phi} = \boldsymbol{\pi}/2; \ \mathbf{H}_{\boldsymbol{\rho}} | \boldsymbol{\phi} = \mathbf{0}; \ \mathbf{and} \ \mathbf{H}_{\mathbf{Z}} | \boldsymbol{\phi} = \boldsymbol{\pi}/2$$

For the transmitting VMD, the field components are Hz and $E\phi$.

The output format first displays the basic input data and the noise fields for the three noise grades. The above seven field components are then printed out for the indicated displacement for receiving points located at the surface and at the transmitter depth.

```
------
  REAL LI
  COMPLEX Α,G1,G12,K,H,EP,EFH,HPH,HZ,HZV,JAM,U,T,BET,ALP,TEB,PLA
  DIMENSION FRED(19), UN(15, 17), O(10), H(10), P(25), FEP(8, 10)
 1. FEPH(8, 10), FHPH(8, 10), FHP(8, 10), FHZ(8, 10), FHZV(8, 10)
  DIMENSION FEPHV(8,10), DP(2), DX(6)
  DATA FRE0/100..200..300..500..700..1000..2000..3000..5000..7000...
 110000.,20000.,30000.,50000.,70000.,1.E+5,2.E+5,3.35E+5,4.E+5/
  DATA((DN(1,J),J=1,17),1=1,15)/88,,78,72,64,59,54,49,45,37,5
 1 • 32 • • 25 • • 11 • 5 • 4 • 5 • - 2 • • - 6 • • - 8 • • - 10 • • 45 • • 38 • • 33 • • 28 • • 25 • • 21 • • 17 • • 13 •
 2.7..4..0...7...12...17...21...24...28..51...39..31..22..16..10...8.
 3=-13-=-21-=-29-==31-=-39-=-43-=-43-=-43-=-50-=-70-=88-=74-=66-=56-
  4+49++43++33++23++14++14++19++1+++10+++18+++21+++24+++30++68++57++
 533, 42. 36. 30. 21. 14. 5. 0. - 3. 3. 0. - 6. - 11. - 17. - 25. 57. 46.
 6+40++33++28++23++13++7++0++-2++-5++-5++-13++-17++-33++-43++-57++30
 7.,21,,10,,5,,1.,-9,,-14,,-18,,-21,,-17,,-13,,-24,,-34,,-38,,-4
 81., -47., 57., 44., 33., 19., 10., 1., -19., -30., -40., -43., -45., -45., -45.,
 9-47...-51...-60...-66...81...67...58...48...41...34...20...12...2...-6...-11...
  x-15.,-22.,-31.,-26.,-30.,-40.,67.,54.,46.,30.,29.,23.,7.,0.,-6.,
  1-15..-22..-31..-34..-38..-43..-58..38..29..22..15..10..6..-3.
 3-1.,-3.,-10.,-16.,-24.,-25.,-27.,-33.,-39.,-52.,-55.,-66.,-78.,-7.
  3-12., -13., -19., -21., -24., -27., -29., -33., -36., -40., -49., -52., -59.,
  4-66.,-70.,-78.,56.5,46.5,41.,33.5,29.,24.,13.,6.,1.,-4.,-9.,-18.,
  5-23..-29..-35..-41..-56..42..40..38..36..33..29..25..19.5.12.5.
  612.3,12.5, 3.5, 2.5, 1.5, -3.5, -15.5, -29.5/
  DATA 0x/5.+25.+50.+100.+200.+400./
  PI=3.141592654
  E)=(1./(36.+P1))+1.E-9
  C=2.93796E+8
  J0=4.+P1+1.E-7
1 READ 2.PT.WI, AL, LI.FRX. EPS.SIG.RS.DS.NOISE.LT
2 FORMAT(9F8.2,212)
  IF(PT.LT.. 0001) CALL EXIT
  DO 16 1=1.19
THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
  IF(FRX_NE.FRED(I)) GO TO 16
  FREFFRY
  W=2.*PI*FRE
  G12=U0***(0...)*(SIG+(0...)*EPS*EC*W)
  CUR#SORT(PT/SS)
  GÚ=-(4/C)++2
  G1=CSORT(G12)
  CURMED SHAI+SURT(WI+PT+6.52E+3)
  K=(SIG+(0.,1.)*EPS*E0*W)/((0.,1.)*E0*W)
  A=(CUR*L1)/(4.*PI*(SIG+(0..1.)*EPS*E0*W))
  B#(CUR+L1)/(4.+PT)
  CK=CURM/(4.*PI)
  T = (0, 1, ) + U0 + W + CURM/(4, +PI)
  DP(1)=0.
  DP(2)=DS
  DO 12 J=1.2
  ZEDP(J)
  DO 12 L=1.LT
  RHO=DX(L)
  GAM=G12*RHO++2
  D=(Z+DS)/RHO
  R=$QRT(RH0++2+(Z=DS)++2)
  ZUBWARHO/C
  DEL0=Z0*(1.-1./SORT(2.)).
  DELK=ZO+CABS(1.-CSQRT(K/(K+1.)))
  P(11#0.
  P(2)=ZO=DELO
  P(3) = ZD=DELK
```

	P(4)=ZO+DELK
	P(5)=ZO+DELD
	P(5)=RHU+SQRT(-REAL(G12))
	P(7)=2.+P(6)
	P(A)#3,*P(ć)
	$P(3) = 4, \neq P(6)$
···· ··	P(10) = 6 + P(6)
	P(1)=16,+P(6)
ц О	
30	
20	
	IF(Z, GT-1AND.PS, GT.1.) (U 10 99/
	BE = 1 - (1 + G + R + 4 + G + 2 + R + + 2/9 + G + G + G + 2 + R + + 3/9 + C E XP (-G + R)
	1EB#18_*CK*6E1/(C12*KHU**5)
	FHZV(J_L)=20.+ALCG10(CABS(TER))
	ALP=1(1.+61+R+G12+R++2/3.)+CEXP(-01+R)
	PLA=E.+T+ALP/(G12+RH0++4)
	FEPHV(J+L)=20.+ALOG10(CARS(PLA))
	GO TO. 71
997	DO 7 M#1,19
	G#F(t)
	E=P(N+1)
	CALL HMU(1+G-F-T-70+K-GAM-D)
········	
15	H(1) = H(1) + O(1)
	CONTINUE
71	
r í	CONFICTE PRIMARY ETFLUE
6	
	C7 \ / D1 3
	12/////********************************
	TTT==D#UEAT(=G1#K)#(G1#K+1,)#SUK((I,=(KAU/K)##2)/K##2
	17(CARS/MEN/LL),1.CT9/MENE(1.CT9),
	r/=s+LFAP(=G1+R)+FHU+(G1+R+1,)/K++3
	HZV=CK+UEXP(-G1+F)*(-1G1*R-G12*R**2+(1(RH0/R)**2)*(3.*(1.*G1*R
	1)+G12*R*+2))/R++3
	FEP(J_L)=20.*ALOG10(CABS(EP+A*(H(1)-H(2))/RHO*+3+2.*A*(H(3)-H(4))/
	(GO*RHO**5)))
	FEPH(J_L)=20.*ALOG10(CABS(EPH=A*G12*H(5)/RH0+A*H(2)/RH0**3+2.*A*H(
	L4)/RH0**5))
	FHPH(J,L)=20.+ALOGIO(CABS(HPH+B+H(6)/RHO++2+2.+B+(H(8)-H(7))/(GO+
	RHO**4)))
	FHP(J_L)=20.*AL0G10(CABS(HPH+B+H(6)/RH0++2+2.*B+H(7)/(G0+RH0++4)))
	FHZ(J.L)=20.+ALOGIO(CABS(HZ-8+H(9)/RH0++2))
	IF(Z,LE.1.,AND.DS.LE.1.) GO TO 12
	FHZV(J_L)=20,+ALCG10(CABS(HZV-CK+H(10)/RH0++3))
	FEPHV(J+L)=20.+ALOGIO(CABS(EPHV+T+H(2)/RH0++3))
12	CONTINUE
	PRINT 30
	FORMAT(1H1)
00	PRINT 17.FRF.SIC.FPS.PT.W1.A1.L1.DE.PE
17	FORMATI//.109.FEDEDE F.EQ 2.F HZ COND - A EK O A HUDOJM CDD.
	I UNINITIFAUADITREM ISTYGES HE UUNUGE STOGZST MMUS/H LFS -
	, FROMENT FUNCTION FAR DEAL AND AND THE CONDAR FRAME A TAKA A MARKANA AND A MARKANA AND AND AND AND AND AND AND AND AND
1	IFARFTARTE GUUT RADINGR TETOSCET REGULAR BUURUS LENGING TETOSCET REALEST
	I DEFIN OF INANGHIILENE FOR COLLARUASTLINE OUUNCE CUNTACT REDISTAN
	10E = ', + 8, 2, + 0HMS', //)
	IF(1.GT.17) GO TO 221
	DO 79 NOISE=1.15

```
HN=UN (NUISE, I)-120.
   79 PRINT 22. HN. NOISE
   22 FORMAT(20X, 'NDISE = ',F10.2,' DB .GT. 14/M NOISE GRADE =',I4)
   221 PRINT 18
   18 FORMAT(//)
       PRINT 19
    19 FORMAT(2X, PISP(M) DEPTH(M) ERHO(PHI=0) EPHI(PHI=90)
                                                                   HRHO(PHI
                                        HZ(VHD) EPH(VMD) ///)
                           H2(PH1=90)
      1=90) HPHI(PHI=0)
       00 13 N=1.LT
       DISP=DX(N)
       EU 20 NN=1.2
       DPTH=DP(NN)
    20 PRINT 21. DISP. LPTH. FEF(NN.N). FEPH(NN.N). FHPH(NN.N). FHP(NN.N). FHZ(
      INNON) FHZY (NNON) FEPHY (NNON)
    21 FORMAT(2F9.2.7F13.2./)
    13 CONTINUE
    16 CONTINUE
       GO TO 1
       END
PILATION:
                  1 DIAGNOSTICS.
       SUBROUTINE HMO
                            ENTRY POINT 000161
     SUBROUTINE HMO(N, A.B.D.ZO, K.G12.R)
      CUMPLEX R.S.K.G12
       DIMENSIUN Y(32), W(32), R(10), S(10)
       DATA (W(I),I=1,16)/3.5093050E-3,8.1371974E-3,1.26960327E-2,
     1 1.71369314E-2.2.14179490E-2.2.54990296E-2.2.93420467E-2.
      2 3.29111114E=2,3.61728971E=2,3.90969479E=2,4.16559621E=2,
      3 4.38260465E-2,4.5586939E-2,4.692219954E-2,4.78193600E-2,
      4 4.82700443E-2/
       DATA (Y(I), I=1,29)/1,3680691E-3,7,19424422E-3,1,76188722E-2,
      2 3.25469620E-2.5.18394221E-2.7.53161931E-2.1.02758102E-1.
      3 1.33908940E-1.1.68477866E-1.2.06142121E-1.2.46550045E-1.
      4 2.89324361E=1.3.34065698E=1.3.80356318E=1.4.27764019E=1.
      5 4.75346167E-1,5.24153832E-1,5.72235980E-1,6.19643681E+1,
     5 6.65934301E-1.7.10675638E-1.7.53449954E-1.7.93857878E-1.
      6 8.31522133E-1,8.66091059E-1,8.97241897E-1,9.24683806E-1,
      7 9.48160577E=1.9.67453037E=1/
      DATA (Y(1), 1=30, 32)/9.823811278E=1,9,92805756E=1,9,98631931E=1/
       DO 8 1=1.10
     8 R(I)=(0+,0+)
      XX=A
       H=(B-A)/FLOAT(N)
       DO 5 1=1,16
       J=33-1
     5 H(J)=H(I)
       DO 1 Jal,N
      DO 2 1=1.32
       X = X \times 4 + 4 \times Y(1)
       CALL FUN(X, D, ZO, K, G12, S)
      DO 6 Malalo
     6 R(M)#R(M)+W(I)+8(M)
```

Q CONTINUE:

- 1 ******
- D) 7 L=1,10 7 R(L)=H+R(L)
- ZETURN END

END OF COMPILATION:

NO DIAGNOSTICS.

```
SUBROUTINE FUNIX, D. 20, K. G12, S)
  COMPLEX K.S.GI2, U. UO.R. T.E
  DIMENSION S(10)
  U=CSQRT(X++2+G12)
  Y=Y++2=Z)++2
  IF(Y.LT.O.) UD=CMPLX(0.,SQRT(ABS(Y)))
  IF(Y. 3E.D.) UD=CMPLX(SORT(Y).0.)
  R=(10-0)/(0+K+00)
  T=(J0~U)/(U0+U)
  IF(X.LT.1.E+S) GO TO 1
  AND.
  5=0.
  SJ 13 2
T A=BSSL(X,1)
  B=BSSL(X.3)
2 E=CEXP(-U+D)
  S(1)=1+T+E+U+X
  3(2)=3+1+E+X++2/U
  S(3)=1+K+E+U+X++3
  S(4)=3+R+E+U+X++2
  S(5)=4+T+E+X/J
  S(5)=A+T+E+X
  S(7)=3+R+E+X++2
  S(3)=A+R+E+X++3
  S(9)=B+T+E+X++2/U
  $(10)#A+T+E+X++3
  RETURN
  END
```

7.4 PROGRAM NUMBER THREE

The third program in the series pertains principally to the submerged infinite line source. It computes the E-field parallel to the line source, the vertical H-field and the horizontal H-field normal to the line source. The input requirements are as follows:

FORTRAN NOTATION	MEANING
РТ	Transmitter power, watts
FRX	Frequency, Hz
EPS	Relative dielectric constant
SIG	Overburden conductivity, mhos/meter
RS	Line source contact resistance, ohms
DS	Line source depth
NOISE	Noise grade: 1, 2, and 3
LT	The number of displacement increments to be computed

The basic input parameters are first printed out after which is displayed the noise fields for the three noise grades. The three field components of interest are then printed out at the surface and at the transmitter depth. These are repeated for each displacement. The last data card is left blank.

	COMPLEX GIGIZADOGAMAG
	STOFNATON UN(2.16) FREG(16) . NY(3.16) . Q(3) . Y(3) . P(15) . FLX(8.10) .
	$11 \exists y (\alpha, \gamma) = (\alpha + \gamma) $
1	
•	
•	'Ara (UN(1,1),1#1,15)/45,5,51,0,10,0,6,0,0,0,0,0,0,0,13,0,=18,5,=24+
	·
,	24.06.0,-17.0,-25.0,-30.0,-37.5,-10.0,-40.0,-40.0,-40.0,-40.0,-49.0,-50
	3.0FT.0FP.06A.0/.(0.(1.1).1=1.16)/59.0.54.5.51.0.45.0.42.5.40
	4 0.31 0.21 0.1.5+3.5+15.0-29.0+34.0+43.0+43.0+43.0+43.0+43.0+43.0+43
•	/0+=25,0+=30,0+=37,0+=40,0+=45,0+=45,0+=45,0+=34,0+=54,0+=54,0+=75,0+=72,0+=75,0+=75,0+=75,0+=75,0+=75,0+=75,0+=75,0+=75,0+=75,0+=75,0+=5,0+=5,0+=5,0+=5,0+=5,0+=5,0+=5,0+=
•	80, -74, 07
۲	PT=3.141592654
,	File File File File File File File File
-	· ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○
	anaster settet staffe7
*	: REAN 2, PT.FEY, FPS, STG. RS, NO. NOISE, []
	2 FOOMAT(6F8,2,212)
	FERTIT OCOLI CALL EXTT
;	NUMBER OF THE TEACHER STATE AND
,	PROVIDE THE FRANCH RECOVERED AND TO THE ADDRESS OF AND AN ADDRESS AND ADDRESS
1	ILLER OF ERENITY OF IC
1	, FREEDY
•	• • • • • • • • • • • • • • • • • • •
•	$c_1 2 = (0 + \alpha + (0 + 1 +) * (516 + (0 + 1 +) + EPS + ED + \alpha)$
-	NUP=SURT(PT/RS)
•	S (1 ± − () / () + + 2
•	Al=CSORT(G)2)
14	(A
	20=++0SZC
۰,	■ ULI 0=70+(1,-1,/SQRT(2,))
	F(1)=0_
	P()=70=1E(0
•	$\mathbf{F}(\mathbf{x}) = \mathbf{x} 0 + \mathbf{x} \mathbf{F} 1 0$
	P(A) = 0S + SOP1(-PEAL(D12))
	D(r) = 3 + 0(A)
•	$e_{1} = e_{1} + e_{2} + e_{1} + e_{1} + e_{2} + e_{1} + e_{2} + e_{2} + e_{1} + e_{2} + e_{2$
	$P(R) = \Phi_{\bullet} * P(\Lambda)$
•	P(0) = P(0) = 10
	50 90 LK#10#13
	96 96(1×)=3.**P(LK=1)
•	• • • • • • • • • • • • • • • • • • •
,	• 7=80.4FLOAT(J=1)
*	1F(J_E0.2)7=P5
	77#7/DQ
,	0 12 L=1.LT
,	PHO=100, +FLOAT(L=1)
	5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
	no go it=1.3
•	
•) FERTNATI BALL REACTING A REPORT TO A CONTRACT
*	CALL HOUNLE (I) HIGH GLES (V) DO GAMONI South All V
•	
*	(15) P((11)) ⊭P((11))
*	Z CONTTRUE
*	FEY(1,L)=20,*AL(0610(00*W*CUR*CARS(H(1))/(2,*PI))
	FHY(1.1)#20.*AL0@10(CUR*CA85(4(2))/(2.*P1*95))

```
JF(C149(H(3)),LT+1,E=14)H(3)=(1,E=14,1,E=14)
         IF(CARS(H(3)),GT+1,F+14)H(3)=(1,E+14,1,E+14)
PH7(J.L)=20.+ALOG10(CUR+CA85(H(3))/(2.+PI+05))
٠
      12 PONTINUE
٠
         PHINT 30
      30 FORMATILHI)
         PRINT 17. FHF. SIG. EPS. PT. AS. 48
      17 FURMAT(//+10X++FREN= +=F0-2++ HZ COND-= +=F6-3+ MH09/M EPS= +=
٠
        IFA.2. POWERS .FB.2. OFPIH OF TRANSMITTERS .FB.2.//.20X. LINE
.
        250URCE CONTACT RESISTANCE= +,F8,2.+ 0dMS+.//)
.
         00 79 NOTSE=1.3
٠
         79 PRINT 22, HN, NOISE
      22 FORMAT(20X, +NOISE = ++F10,2.+ DB .GT. 14/M NUISE GRANE = +.(4./)
*
         n0 13 N=1.17
*
         DISP=100.*FLOAT(N-1)
*
         PRINT 18,015P
      TA FRAMAT(77.10%. THE FIELD COMPONENTS IN DB GT 197M OR TAZM FOR A DI
        ISPLACEMENT OF +, FA. 2, + METERS+,//)
         PRINT 19
      19 FORMAT(2x, + DEPTH(M)
                                 sγ
                                             HY
.
                                                        HZ1 .//)
         DO 50 NN=1"5
٠
         DPTH=50. +FLOAT(NN-1)
*
         TEINE RU. 2) OFTHEDS
*
      20 PRINT 21, OPTH, FRX (AN, N), FHY (AN, N), FHZ (AN, N)
٠
      21 F.O. MAT(F8.2. 3F13.2.1)
٠
      13 CONTINUE
      14 00071006
         00 TO 1
         Film
٠
SUBPORTION POURLE(N, A.H. U. 20. T. G12. R)
         MOMPLEX P.S.G12
+
         TIMENATON Y(32), H(32), R(3), S(3)
٠
         BAYA (*(I), I=1,10)/3_5093050E-3,8,1371974E-3,1,26960327E-2,
*
            713693145-2.2.141794905-2.2.549902965-2.2.934204675-2.
         1 1
        2 3 29111114F-2, 3+61728971E-2, 3, 90969479E-2, 4, 16559621F-2,
٠
        3 4 380604655-2.4.55869395-2.4.6922199545-2.4.781936005-2.
.
        4 4 82700443F-2/
٠
         .
        2 3 25469620F-2, 5 18394221F-2, 7, 53161931E-2, 1, 02758102F-1,
        3 1.33903940F-1.1.68477866E-1.2.06142121E-1.2.46550045F-1.
٠
        4 2. 39324361F-1.3+3406569#E-1.3.80356318E-1.4.27764019F-1.
٠
        5 4_75846167F=1.5+24153832E=1.5.72235980E=1.6.190436A1F=1.
        5 6 65934301F-1,7+10675638E-1,7.53449954E-1,7,93357878E-1,
٠
        6 B
            315221335-1,d.56091059E-1.8,97241897E-1.9,24083806E-1.
*
        7 9 481605778-1,9:674530378-1/
*
         - EATA (V(1), J=30, 32)/9.823811278F=1,9.92805756E=1.9.98631931E=1/
         00 A 1=1.3
       3 P(1)=(0.,0,)
         XX=A
         H=(B=A)/FLOAT(N)
         DD 5 1=1,16
          1=73-1
٠
       5 0(1)=1(1)
```

7-15

10 7 L=1.3 7 P(1)=H+R(L) . PETURA * * Enn OF UNIVAC 1108 FORTRAN V COMPILATION. O +DIAGNOSTIC+ DESSAGE(S) SUAROUTINE FUNIX.D.70, P.C12.5) NUMPLEX GIZ.S.I.U.D.E.F.T. DIVENSION S(3) 11=rScat(x++2+G12) Y=++2=27++2 TF(Y.LT.O.)UC=CMPLX(O..SVRT(ABS(Y))) IF (Y, GE, N.) UO=CMPL X(SQRT(Y).0.) T=(U=00)/(U+00) TF(D,GT.1.)A=1. 「F(D。(E。1。)A=→1。 0≈∩. MOSTIC. THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT RE MEANINGFUL. 1F(D. 18.1.)C=A E=nEvp(-U+ABS(D-1.)) F=0Eyp(-1)+(1+1.)) S(1)=COS(X+R)+(E+T+F)/U S(2)=COS(X+R)+(E+C+T+F) S(3)=S(3)=S(2)+(2+R)+(2+A+T+F)++2/U PETURN ENH

10 1 1=1,4

10 2 1=1,32

¥=¥X+4+Y(I)

n1) & H=1,3

2 CONTINUE

: XX=XX+H

5 W(M)=P(M)+W(T)+S(M)

CALL FUNIX, P. 20, [, G12.5)

*

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*

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*

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7.5 THEORETICAL PREDICTIONS FOR IN-MINE PROPAGATION

From the analysis programs described in paragraph 7.1, a computer printout was obtained and its results listed in paragraph 6.7. These results incorporated the latest NBS noise data listed in paragraph 6.6.

The received signal strengths for various antenna configurations are combined with the specified noise grades and an equivalent S/N_0 is calculated. These resulting signal-to-noise ratios are plotted for various antenna configurations and displacements in figures 7-1 through 7-16 for a transmitted power of 10 watts into the specified transmitting antenna. It should be noted that a 37-dB S/N₀ ratio is the minimum requirement for communication of normal speech assuming 75-percent word intelligibility and a 1-Hz normalized bandwidth. From these experimental results, predictions are drawn concerning optimum usable frequency versus maximum transmission displacement for various antenna configurations. Figures 7-1 through 7-16 are the basis for these predictions.

The predictions that follow assume a noise grade 14 (mean noise-all mines subsurface) and an input power of 10 watts.

- a. Loop (VMD) to loop (VMD) provides highest S/N_0 ratio.
- b. For 20-meter radius transmit loop, a maximum of approximately 225 meters/740 ft separation can be achieved. (This assumes a minimum of 37 dB S/N₀ ratio for adequate information transfer with an optimum frequency of 10 kHz to 20 kHz.) At lesser separations, the 100-kHz to 200-kHz range provides the higher signal-to-noise ratios.
- c. For 8-inch/0.3032-meter diameter transmit loop, a maximum of approximately 80 meters/ 263 ft separation can be achieved at an optimum frequency of 70 to 100 kHz (37 dB S/N₀ ratio was minimum).
- d. For 100-meter/328-ft line source transmitter, a maximum of 200 meters/656 ft can be achieved at a frequency of 10 kHz. At separations below 500 ft, however, the 100-kHz frequency range provides the higher S/N_0 ratio.
- e. For up-link and down-link propagation, maximum transmit depth for 13.58 meter/44.68 foot radius loop was 175 meters/574 ft at a frequency of 10 kHz, and for the line source transmit, maximum depth was 225 m/730 ft at a frequency of 10 kHz (37 dB S/N₀ ratio was minimum).

Predictions for transmission from a loop to line source could not be made because reliable E-field noise data was not available for this mode of propagation. In the experimental measurements presented in volume 4 (Experimental Measurements), line source to loop transmission is included.

Figures 7-17 through 7-19 show typical mine entries and crosscuts with lf and vlf theoretical predictions illustrated. Darkened areas indicate loss of transmission.





(80) N**/**S



Figure 7-2. Line Source-to-Loop Lateral Transmission for Varying Displacements.



Figure 7-3. Loop-to-Loop S/N Ratio for Various Displacements - Noise Grade 14.

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Figure 7-13. Up-Link Loop-to-Loop S/N Ratio for Various Displacements.

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Figure 7-14. Up-Link Loop-to-Loop S/N Ratio for Various Displacements - Continued.

(80) OITAA _ON****S



(80) оідуя ⁰n**/**s

Figure 7-15. Up-Link Loop-to-Loop S/N Ratio for Various Displacements - Continued.







Figure 7-17. LF Propagation (Theoretical -Fixed Station - NG 14).

7.5.1 LF Propagation (Theoretical-Fixed Station - NG 14)

20-meter radius loop (fixed station) to loop transmission VMD to VMD Frequency - 10 to 20 kHz 37-dB minimum S/N $_0$ 10-watt input Darkened areas indicate loss of transmission



Figure 7-18. LF Propagation (Theoretical - Portable - NG 14).



8-inch-diameter loop (portable) to loop transmission VMD to VMD Frequency - 70 to 100 kHz 37-dB minimum S/N_0 10-watt input Darkened areas indicate loss of transmission



Figure 7-19. LF Propagation (Theoretical - NG 14).

7.5.3 LF Propagation (Theoretical - NG 14)

100-meter line source to loop transmission VMD to VMD Frequency - 10 kHz 37-dB minimum S/N_0 10-watt input Darkened areas indicate loss of transmission

7.6 SUMMARY

These reports, analyses, and propagation predictions provide a theoretical data base from which expected signal strengths and subsequent signal-to-noise ratios can be calculated. It is stressed that outdated noise data was employed in the early reports and discussions. However, the predictions made in paragraph 7.5 were based upon the more recent NBS noise data.

Also, because of recent in-mine tests, there appears to be a gap between the propagation predictions and the experimental results as frequencies increase beyond 50 kHz. Additional experimental work needs to be completed to obtain reliable predictions for the higher ranges of frequencies.