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LUNAR COMMUNICATIONS

(LUNCOM) PROGRAM

HV016A

VOLUME I - USER'S MANUAL

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ABSTRACT

The Lunar Communications (LUNCOM) Program simulates a communication link between two "close" points on a two-dimensional, geometrically and electromagnetically continuous lunar terrain. Four basic terrain profiles may be simulated. These are: exponential hill and valley, N^{th} degree grade, and terrain wave. The output of the LUNCOM Program is an attenuation function which may be printed or output on a plot tape for use with the TRWPLT General Plot Program.

The LUNCOM Program is written in FORTRAN V for use on the UNIVAC 1108 EXEC II computing system.

CONTENTS

1. PROBLEM DESCRIPTION

Given two "close" points on the surface of the moon (by "close" we shall mean that the lunar curvature may be neglected for our problem). We wish to simulate a communication link within the plane perpendicular to the lunar terrain, which contains these two points. We assume that the lunar terrain is geometrically and electromagnetically continuous. We shall approximate the lunar terrain by exponential hills and valleys, N^{th} degree grades and low amplitude terrain waves.

1.1 INTRODUCTION

Hufford[1] has shown that the attenuation of the transmitted signal at a distance x from the transmitting source is given by the complex valued function, W, defined by the integral equation

$$W(x) = g(x) - \beta \int_0^x K(x,s)W(s)ds \qquad (1\text{-}1)$$

where g is the antenna pattern function defined by

$$g(x) = \begin{cases} 1 \ , & x=0 \\ e^{\frac{ikh_o^2}{2x}} \ , & x>0 \end{cases} \ , \qquad (1\text{-}2)$$

$k = 2\pi/\lambda$, where λ is the wave length of the transmitted signal and h_o is the height of the transmitting source above the lunar terrain at the origin. The constant, β, is defined by

$$\beta = \sqrt{\frac{1}{\lambda}}\, e^{-i\frac{\pi}{4}} \ . \qquad (1\text{-}3)$$

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[1] G. A. Hufford, "An Integral Equation Approach to the Problem of Wave Propagation Over an Irregular Terrain", Quarterly Applied Mathmatics, Volume 9, pp. 391-396, 1952.

The kernel of equation (1-1) is defined by

$$K(x,s)=\left[\delta + p(x, s)\right] e^{ikq(x,s)} \sqrt{\frac{x}{s(x-s)}} \tag{1-4}$$

where

$$\delta = \begin{cases} \left(\varepsilon_r + i\frac{\sigma}{\omega\varepsilon_o}\right)^{-1/2} & \text{, for vertical polarization} \\ \left(\varepsilon_r + i\frac{\sigma}{\omega\varepsilon_o}\right)^{1/2} & \text{, for horizontal polarization} \end{cases} , \tag{1-5}$$

ε_r is the relative permeativity of the lunar surface, ε_o is the permeativity of free space, σ is the conductivity of the lunar surface and ω is the radian frequency of the transmitted signal. The functions p and q depend upon the terrain geometry and may be approximated by

$$p(x,s) \doteq f'(s) - \frac{f(x)-f(s)}{x-s} \tag{1-6}$$

$$q(x,s) \doteq \frac{sx}{2(x-s)} \left[\frac{f(s)}{s} - \frac{f(x)}{x}\right]^2 \tag{1-7}$$

where f(x) gives the height of the terrain, above the source, at a distance x from the origin.

1.2 NUMERICAL SOLUTION

It has been shown[2] that if the x-axis is partitioned into m number of "small" intervals of width Δx the function W may be approximated by

$$W(\ell\Delta x) = \frac{g(\ell\Delta x) - \beta \sum_{j=o}^{\ell-1} C(\ell,j) W(j\Delta x)}{1+\beta C(\ell,\ell)} \quad , \; 0 < \ell \leq m \tag{1-8}$$

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[2] "Bimonthly Technical Report Number 3", TRW Report 11176-H099-RO-00, 7 January 1969.

where $W(0)=g(0)$ and

$$C(\ell,j) = \begin{cases} \int_0^h \left(1-\frac{s}{\Delta x}\right) K(\ell\Delta x,s)ds, & j=0 \\ \int_{(j-1)\Delta x}^{j\Delta x} \left[\frac{s-(j-1)\Delta x}{\Delta x}\right] K(\ell\Delta x,s)\, ds & \\ + \int_{j\Delta x}^{(j+1)\Delta x} \left[\frac{(j+1)\Delta x-s}{\Delta x}\right] K(\ell\Delta x,s)\, ds, & 0<j<\ell \\ \int_{(\ell-1)\Delta x}^{\ell\Delta x} \left[\frac{s-(\ell-1)\Delta x}{\Delta x}\right] K(\ell\Delta x,s)\, ds, & j=\ell \end{cases} \quad , \; 0<\ell\leq m \qquad (1\text{-}9)$$

We describe below each of the four terrain functions which will be used for this simulation.

1.2.1 Exponential Hill

The height of the exponential hill above the source is given by

$$f(x)=h\left[e^{-S_t(x-x_o)^2} - e^{-S_t x_o^2}\right]-h_o \qquad (1\text{-}10)$$

where h is the peak height of the hill above the origin, S_t is the "steepness" of the hill and x_o is the distance from the origin at which the height, h, is achieved.

1.2.2 Exponential Valley

The height of the exponential valley above the source is given by

$$f(x) = -h\left[e^{-S_t(x-x_o)^2} - e^{-S_t x_o^2}\right] - h_o \qquad (1\text{-}11)$$

1.2.3 Nth Degree Grade

The height of the n^{th} degree grade above the source is given by

$$f(x) = h\left(\frac{1}{1-S_o x^n} - 1\right) - h_o \qquad (1\text{-}12)$$

where h is the maximum height of the grade above the source and S_o is the "slope" of the grade.

1.2.4 Terrain Wave

The height of the low amplitude terrain wave above the source is given by

$$f(x) = h \sin \omega x - h_o \qquad (1\text{-}13)$$

where h is the amplitude of the terrain wave and ω is the radian frequency of the terrain wave.

2. INPUT

A data deck is defined as all of the Hollerith cards, in their proper sequence, which the user must submit for any particular computer run, exclusive of machine control cards. The LUNCOM data deck is divided into successive data cases with each data case being in the same format.

Data for each data case is entered (all at one time) via the FORTRAN namelist $INPUT. The symbols "$INPUT" must appear in columns 2 thru 7 of the first data card. Input parameters may then be entered in any order, beginning in any column (except column 1), in the form PARAM1 = xxxxx, PARAM2 = xxxxx,... The only restrictions are that no punch ever appear in column 1 and that no entry be split between two Hollerith cards. The latter restriction is imposed because a comma is automatically assumed at the end of each Hollerith card.

After all the desired input parameters have been entered (not every parameter need be entered), a card containing the symbols "$END" in columns 2 thru 5 must appear immediately after the last data card; this signifies the end of input data for this particular data case. Following the "$END" card, from 0 to 5 comment/description cards may appear. These cards will be printed as headings to the output listing for this particular data case. After the last comment/description card, another data case may appear.

Each of the LUNCOM parameters listed below is initialized to zero unless otherwise specified. The value of each LUNCOM parameter remains unchanged from one data case to the next unless it is explicitly changed by the user. LUNCOM parameters are unaffected by program calculations; each parameter has the value to which it was initialized or the value to which it was last set by the user.

2.1 DETAILED DESCRIPTION OF INPUT PARAMETERS

Mnemonic	Description
CLIGHT	Speed of light in free space CLIGHT is initialized to 3.0E+08.
COMENT	Number of comment/description cards for this data case

Mnemonic	Description
DEGREE	Degree of grade DEGREE is initialized to 1.
DELTAX	Increment of distance (in meters) along terrain
EO	Permeativity of free space EO is initialized to 0.88419414E-11.
ER	Relative permeativity of the lunar surface ER is initialized to 2.8.
FREQ	Frequency of link (in Hz)
HEIGHT	Peak height (in meters) of terrain above or below its height at the origin
HO	Height of the transmitting source (in meters) above the terrain at the origin
OMEGA	Frequency of the terrain wave (in radians per meter)
PLOT	= 0, No effect = 1, Plot tape will be generated on unit F (FORTRAN ID 8) PLOT is initialized to 1.
POLAR	= 1, Waves are horizontally polarized = -1, Waves are vertically polarized POLAR is initialized to 1.
PRINT	= 0, No effect = 1, Attenuation function will be printed out PRINT is initialized to 1.
SIGMA	Conductivity of the lunar surface SIGMA is initialized to 1.0E-05.
SLOPE	Slope of grade SLOPE is initialized to 1.
STEEP	Steepness of exponential hill or valley STEEP is initialized to 1.
TAPEIN	= 0, No effect = N, Indicates that initial values of the attenuation function will be read in from the N^{th} file of a previously generated plot tape mounted on unit E (FORTRAN ID 7)

Mnemonic	Description
TERAIN	= 1, Terrain is a grade of degree "DEGREE" and slope "SLOPE" = 2, Terrain is an exponential hill of steepness "STEEP" = 3, Terrain is an exponential valley of steepness "STEEP" = 4, Terrain is a wave of frequency "OMEGA" TERAIN is initialized to 2.
XMAX	Maximum distance (in meters) from the origin to be considered
XO	Distance from the origin (in meters) at which hill peak or valley null occurs

3. OUTPUT

Output for the LUNCOM program is in the form of printed output and data tape output. Described here are the output formats; refer to Chapter 4 for the actual printed output from a computer run.

3.1 DETAILED DESCRIPTION OF PRINTED OUTPUT

The input parameters are printed on a header page for each data case. If the input parameter PRINT=1, the attenuation function will be printed in 7 columns headed: Distance from the Origin, Terrain Function, Attenuation Function (real and imaginary parts), Gain (ratio and dB), and Phase (degrees). Print output is headed by the comment/description cards for that case.

At the conclusion of the run a summary page is printed.

3.2 DETAILED DESCRIPTION OF DATA TAPE OUTPUT

When the input parameter PLOT=1 one file on a plot tape will be generated for this data case. One 7-word record will be generated for each point. The seven words of each record correspond, respectively, to the seven columns of print output.

4. SAMPLE CASE

A sample computer run is included to demonstrate program capabilities and options. Since this program is designed to be used with the TRWPLT general plotting program, the plot input and output are included with this sample case.

DATE 12 Feb 69 PRIORITY _____ PAGE 1 OF 2

NAME Argile PROBLEM NO 227810 TRW SYSTEMS

EXT 2503 SPECIAL CHARACTERS HOUSTON COMPUTING CENTER

NO. OF CARDS 36 80 COLUMN FREE KEY PUNCH FORM

CARD STOCK ☑ PLAIN yellow ☐ FORTRAN SOURCE ☐ 7094 SYMBOLIC

KEYPUNCHED BY _____ VERIFIED BY _____

```
$INPUT
COMENT=1
DELTAX=32.0
ER=10.0
FREQ=1.0E+07
HEIGHT=100.0
POLAR=-1
SIGMA=0.01
STEEP=1.0E-06
XMAX=8000.0
XO=5000.0
$END
                TEST CASE
$INPUT
COMENT=2
DELTAX=66.666666
FREQ=1.0E+06
HEIGHT=9.0
XMAX=10000.0
$END
```

STL FORM 706 REV. 5-65

DATE ______ PRIORITY ______

NAME ______ PROBLEM NO ______

EXT ______ SPECIAL CHARACTERS

NO. OF CARDS ______

TRW SYSTEMS
HOUSTON COMPUTING CENTER

80 COLUMN FREE KEY PUNCH FORM

CARD STOCK
- ☐ PLAIN
- ☐ FORTRAN SOURCE
- ☐ 7090 SYMBOLIC

PAGE 2 OF 2

KEYPUNCHED BY ______

VERIFIED BY ______

```
                                   TEST CASE
                                 FLAT TERRAIN
▽ XQT TRWPLT
NØIREC=1
TITLE=ID=TEST CASE
XLABEL=ID=RANGE(METERS)
YLABEL=ID=TERRAIN -- GAIN
PLØT=1,2,6,ENDLST
ENDPLT
ENDFIL
TITLE=ID=FLAT TERRAIN TEST CASE
YLABEL=ID=GAIN -- PHASE
PLØT=1,6,7,ENDLST
ENDPLT
ENDFIL
ENDRUN
```

STL FORM 700 REV. 6-65

4.2 SAMPLE OUTPUT

```
16627616

& XQT HVC16A
```

LUNAR COMMUNICATIONS PROGRAM

DATA CASE NO. 1

TEST CASE

INPUT OPTIONS

CLIGHT	=	3.0000+08
COMENT	=	1
DEGREE	=	1.0000+00
DELTAX	=	3.2000+01
EO	=	8.8419-12
ER	=	1.0000+01
FREQ	=	1.0000+07
HEIGHT	=	1.0000+02
HO	=	0.0000
OMEGA	=	0.0000
PLOT	=	1
POLAR	=	-1
PRINT	=	1
SIGMA	=	1.0000-02
SLOPE	=	1.0000+00
STEEP	=	1.0000-06
TAPEIN	=	0
TERAIN	=	2
XMAX	=	8.0000+03
XO	=	5.0000+03

LUNAR COMMUNICATIONS PROGRAM

DATA CASE NO. 1

TEST CASE

DISTANCE TO ORIGIN (METERS)	TERRAIN FUNCTION	ATTENUATION FUNCTION (REAL)	(IMAGINARY)	GAIN (RATIO)	(DB)	PHASE (DEG)
0.0000	0.0000	1.0000+00	0.0000	1.0000+00	0.0000	0.0000
3.2000+01	5.2180-10	6.8919-01	5.1039-01	8.5761-01	-1.3343+00	3.6523+01
6.4000+01	1.2343-09	4.7143-01	5.8521-01	7.5148-01	-2.4817+00	5.1146+01
9.6000+01	2.2050-09	3.2069-01	5.9272-01	6.7391-01	-3.4279+00	6.1584+01
1.2800+02	3.5250-09	2.0994-01	5.7399-01	6.1118-01	-4.2766+00	6.9910+01
1.6000+02	5.3161-09	1.2682-01	5.4384-01	5.5844-01	-5.0605+00	7.6874+01
1.9200+02	7.7413-09	6.3755-02	5.0913-01	5.1310-01	-5.7959+00	8.2862+01
2.2400+02	1.1018-08	1.5649-02	4.7332-01	4.7358-01	-6.4921+00	8.8106+01
2.5600+02	1.5437-08	-2.1106-02	4.3826-01	4.3877-01	-7.1553+00	9.2757+01
2.8800+02	2.1382-08	-4.9143-02	4.0489-01	4.0786-01	-7.7898+00	9.6920+01
3.2000+02	2.9366-08	-7.0429-02	3.7366-01	3.8024-01	-8.3988+00	1.0067+02
3.5200+02	4.0063-08	-8.6454-02	3.4477-01	3.5544-01	-8.9847+00	1.0408+02
3.8400+02	5.4367-08	-9.8363-02	3.1821-01	3.3306-01	-9.5495+00	1.0718+02
4.1600+02	7.3453-08	-1.0704-01	2.9391-01	3.1280-01	-1.0095+01	1.1001+02
4.4800+02	9.8868-08	-1.1317-01	2.7176-01	2.9439-01	-1.0622+01	1.1261+02
4.8000+02	1.3264-07	-1.1731-01	2.5160-01	2.7760-01	-1.1131+01	1.1500+02
5.1200+02	1.7742-07	-1.1987-01	2.3327-01	2.6227-01	-1.1625+01	1.1720+02
5.4400+02	2.3667-07	-1.2120-01	2.1661-01	2.4822-01	-1.2103+01	1.1923+02
5.7600+02	3.1490-07	-1.2157-01	2.0148-01	2.3531-01	-1.2567+01	1.2111+02
6.0800+02	4.1799-07	-1.2119-01	1.8772-01	2.2344-01	-1.3017+01	1.2285+02
6.4000+02	5.5354-07	-1.2022-01	1.7521-01	2.1249-01	-1.3453+01	1.2446+02
6.7200+02	7.3140-07	-1.1881-01	1.6382-01	2.0237-01	-1.3877+01	1.2595+02
7.0400+02	9.6428-07	-1.1707-01	1.5345-01	1.9301-01	-1.4288+01	1.2734+02
7.3600+02	1.2686-06	-1.1508-01	1.4399-01	1.8433-01	-1.4688+01	1.2863+02
7.6800+02	1.6653-06	-1.1292-01	1.3535-01	1.7627-01	-1.5077+01	1.2984+02
8.0000+02	2.1816-06	-1.1063-01	1.2746-01	1.6877-01	-1.5454+01	1.3096+02
8.3200+02	2.8519-06	-1.0826-01	1.2023-01	1.6178-01	-1.5821+01	1.3200+02
8.6400+02	3.7203-06	-1.0584-01	1.1360-01	1.5527-01	-1.6178+01	1.3297+02
8.9600+02	4.8432-06	-1.0341-01	1.0752-01	1.4918-01	-1.6526+01	1.3388+02
9.2800+02	6.2920-06	-1.0099-01	1.0193-01	1.4349-01	-1.6864+01	1.3473+02
9.6000+02	8.1573-06	-9.8589-02	9.6785-02	1.3816-01	-1.7193+01	1.3553+02
9.9200+02	1.0554-05	-9.6221-02	9.2040-02	1.3315-01	-1.7513+01	1.3627+02
1.0240+03	1.3626-05	-9.3898-02	8.7659-02	1.2846-01	-1.7825+01	1.3697+02

DISTANCE TO ORIGIN (METERS)	TERRAIN FUNCTION	ATTENUATION FUNCTION (REAL)	(IMAGINARY)	GAIN (RATIO)	(DB)	PHASE (DEG)
1.0560+03	1.7557-05	-9.1627-02	8.3607-02	1.2404-01	-1.8129+01	1.3762+02
1.0880+03	2.2576-05	-8.9413-02	7.9855-02	1.1988-01	-1.8425+01	1.3823+02
1.1200+03	2.8969-05	-8.7259-02	7.6376-02	1.1596-01	-1.8714+01	1.3881+02
1.1520+03	3.7097-05	-8.5169-02	7.3144-02	1.1227-01	-1.8995+01	1.3934+02
1.1840+03	4.7408-05	-8.3142-02	7.0137-02	1.0877-01	-1.9270+01	1.3985+02
1.2160+03	6.0461-05	-8.1180-02	6.7336-02	1.0547-01	-1.9537+01	1.4033+02
1.2480+03	7.6950-05	-7.9282-02	6.4724-02	1.0235-01	-1.9799+01	1.4077+02
1.2800+03	9.7736-05	-7.7448-02	6.2283-02	9.9385-02	-2.0054+01	1.4119+02
1.3120+03	1.2388-04	-7.5676-02	6.0000-02	9.6576-02	-2.0303+01	1.4159+02
1.3440+03	1.5670-04	-7.3966-02	5.7861-02	9.3909-02	-2.0546+01	1.4196+02
1.3760+03	1.9781-04	-7.2315-02	5.5855-02	9.1374-02	-2.0784+01	1.4232+02
1.4080+03	2.4919-04	-7.0722-02	5.3971-02	8.8963-02	-2.1016+01	1.4265+02
1.4400+03	3.1327-04	-6.9186-02	5.2199-02	8.6668-02	-2.1243+01	1.4297+02
1.4720+03	3.9303-04	-6.7703-02	5.0530-02	8.4481-02	-2.1465+01	1.4326+02
1.5040+03	4.9209-04	-6.6273-02	4.8957-02	8.2395-02	-2.1682+01	1.4355+02
1.5360+03	6.1485-04	-6.4893-02	4.7472-02	8.0403-02	-2.1895+01	1.4381+02
1.5680+03	7.6667-04	-6.3561-02	4.6069-02	7.8501-02	-2.2103+01	1.4407+02
1.6000+03	9.5401-04	-6.2276-02	4.4741-02	7.6682-02	-2.2306+01	1.4431+02
1.6320+03	1.1847-03	-6.1036-02	4.3483-02	7.4941-02	-2.2506+01	1.4453+02
1.6640+03	1.4682-03	-5.9838-02	4.2291-02	7.3275-02	-2.2701+01	1.4475+02
1.6960+03	1.8158-03	-5.8682-02	4.1159-02	7.1677-02	-2.2892+01	1.4495+02
1.7280+03	2.2410-03	-5.7565-02	4.0084-02	7.0146-02	-2.3080+01	1.4515+02
1.7600+03	2.7603-03	-5.6485-02	3.9061-02	6.8676-02	-2.3264+01	1.4533+02
1.7920+03	3.3928-03	-5.5442-02	3.8088-02	6.7264-02	-2.3444+01	1.4551+02
1.8240+03	4.1618-03	-5.4433-02	3.7160-02	6.5907-02	-2.3621+01	1.4568+02
1.8560+03	5.0946-03	-5.3457-02	3.6276-02	6.4603-02	-2.3795+01	1.4584+02
1.8880+03	6.2238-03	-5.2513-02	3.5432-02	6.3348-02	-2.3965+01	1.4599+02
1.9200+03	7.5877-03	-5.1599-02	3.4625-02	6.2140-02	-2.4133+01	1.4614+02
1.9520+03	9.2315-03	-5.0714-02	3.3855-02	6.0976-02	-2.4297+01	1.4627+02
1.9840+03	1.1208-02	-4.9857-02	3.3117-02	5.9854-02	-2.4458+01	1.4641+02
2.0160+03	1.3581-02	-4.9027-02	3.2412-02	5.8772-02	-2.4617+01	1.4653+02
2.0480+03	1.6422-02	-4.8222-02	3.1736-02	5.7728-02	-2.4772+01	1.4665+02
2.0800+03	1.9817-02	-4.7442-02	3.1089-02	5.6721-02	-2.4925+01	1.4676+02
2.1120+03	2.3864-02	-4.6685-02	3.0469-02	5.5748-02	-2.5075+01	1.4687+02
2.1440+03	2.8680-02	-4.5950-02	2.9874-02	5.4808-02	-2.5223+01	1.4697+02
2.1760+03	3.4396-02	-4.5238-02	2.9303-02	5.3899-02	-2.5368+01	1.4707+02
2.2080+03	4.1168-02	-4.4545-02	2.8756-02	5.3021-02	-2.5511+01	1.4716+02
2.2400+03	4.9172-02	-4.3873-02	2.8231-02	5.2171-02	-2.5651+01	1.4724+02
2.2720+03	5.8612-02	-4.3219-02	2.7728-02	5.1349-02	-2.5789+01	1.4732+02

DISTANCE TO ORIGIN (METERS)	TERRAIN FUNCTION	ATTENUATION FUNCTION (REAL)	(IMAGINARY)	GAIN (RATIO)	(DB)	PHASE (DEG)
2.3040+03	6.9722-02	-4.2584-02	2.7245-02	5.0554-02	-2.5925+01	1.4739+02
2.3360+03	8.2767-02	-4.1967-02	2.6782-02	4.9784-02	-2.6058+01	1.4745+02
2.3680+03	9.8052-02	-4.1366-02	2.6339-02	4.9039-02	-2.6189+01	1.4751+02
2.4000+03	1.1592-01	-4.0781-02	2.5915-02	4.8318-02	-2.6318+01	1.4757+02
2.4320+03	1.3677-01	-4.0211-02	2.5509-02	4.7620-02	-2.6444+01	1.4761+02
2.4640+03	1.6104-01	-3.9657-02	2.5122-02	4.6944-02	-2.6568+01	1.4765+02
2.4960+03	1.8922-01	-3.9117-02	2.4753-02	4.6291-02	-2.6690+01	1.4767+02
2.5280+03	2.2188-01	-3.8590-02	2.4402-02	4.5658-02	-2.6810+01	1.4769+02
2.5600+03	2.5965-01	-3.8076-02	2.4069-02	4.5046-02	-2.6927+01	1.4770+02
2.5920+03	3.0322-01	-3.7575-02	2.3754-02	4.4454-02	-2.7042+01	1.4770+02
2.6240+03	3.5338-01	-3.7086-02	2.3458-02	4.3883-02	-2.7154+01	1.4769+02
2.6560+03	4.1100-01	-3.6609-02	2.3180-02	4.3331-02	-2.7264+01	1.4766+02
2.6880+03	4.7703-01	-3.6143-02	2.2921-02	4.2798-02	-2.7372+01	1.4762+02
2.7200+03	5.5254-01	-3.5687-02	2.2681-02	4.2285-02	-2.7476+01	1.4756+02
2.7520+03	6.3869-01	-3.5241-02	2.2461-02	4.1791-02	-2.7578+01	1.4749+02
2.7840+03	7.3677-01	-3.4805-02	2.2262-02	4.1316-02	-2.7678+01	1.4740+02
2.8160+03	8.4816-01	-3.4378-02	2.2084-02	4.0860-02	-2.7774+01	1.4728+02
2.8480+03	9.7440-01	-3.3959-02	2.1927-02	4.0424-02	-2.7867+01	1.4715+02
2.8800+03	1.1171+00	-3.3549-02	2.1794-02	4.0007-02	-2.7957+01	1.4699+02
2.9120+03	1.2782+00	-3.3146-02	2.1684-02	3.9609-02	-2.8044+01	1.4681+02
2.9440+03	1.4594+00	-3.2750-02	2.1599-02	3.9232-02	-2.8127+01	1.4659+02
2.9760+03	1.6630+00	-3.2361-02	2.1540-02	3.8874-02	-2.8207+01	1.4635+02
3.0080+03	1.8910+00	-3.1977-02	2.1509-02	3.8538-02	-2.8282+01	1.4607+02
3.0400+03	2.1459+00	-3.1599-02	2.1505-02	3.8222-02	-2.8354+01	1.4576+02
3.0720+03	2.4302+00	-3.1225-02	2.1531-02	3.7928-02	-2.8421+01	1.4541+02
3.1040+03	2.7466+00	-3.0854-02	2.1588-02	3.7656-02	-2.8483+01	1.4502+02
3.1360+03	3.0977+00	-3.0486-02	2.1677-02	3.7407-02	-2.8541+01	1.4459+02
3.1680+03	3.4867+00	-3.0120-02	2.1800-02	3.7181-02	-2.8594+01	1.4410+02
3.2000+03	3.9164+00	-2.9754-02	2.1958-02	3.6979-02	-2.8641+01	1.4357+02
3.2320+03	4.3901+00	-2.9388-02	2.2152-02	3.6802-02	-2.8683+01	1.4299+02
3.2640+03	4.9110+00	-2.9020-02	2.2385-02	3.6650-02	-2.8719+01	1.4235+02
3.2960+03	5.4825+00	-2.8648-02	2.2656-02	3.6524-02	-2.8748+01	1.4166+02
3.3280+03	6.1079+00	-2.8272-02	2.2968-02	3.6426-02	-2.8772+01	1.4091+02
3.3600+03	6.7908+00	-2.7889-02	2.3321-02	3.6355-02	-2.8789+01	1.4010+02
3.3920+03	7.5346+00	-2.7497-02	2.3718-02	3.6313-02	-2.8799+01	1.3922+02
3.4240+03	8.3428+00	-2.7096-02	2.4158-02	3.6301-02	-2.8802+01	1.3828+02
3.4560+03	9.2187+00	-2.6681-02	2.4642-02	3.6319-02	-2.8797+01	1.3728+02
3.4880+03	1.0166+01	-2.6251-02	2.5171-02	3.6369-02	-2.8785+01	1.3620+02
3.5200+03	1.1187+01	-2.5804-02	2.5746-02	3.6451-02	-2.8766+01	1.3507+02

DISTANCE TO ORIGIN (METERS)	TERRAIN FUNCTION	ATTENUATION FUNCTION (REAL)	(IMAGINARY)	GAIN (RATIO)	(DB)	PHASE (DEG)
3.5520+03	1.2286+01	-2.5338-02	2.6366-02	3.6567-02	-2.8738+01	1.3386+02
3.5840+03	1.3465+01	-2.4849-02	2.7031-02	3.6717-02	-2.8703+01	1.3259+02
3.6160+03	1.4727+01	-2.4334-02	2.7741-02	3.6902-02	-2.8659+01	1.3126+02
3.6480+03	1.6075+01	-2.3793-02	2.8495-02	3.7123-02	-2.8607+01	1.2986+02
3.6800+03	1.7510+01	-2.3221-02	2.9292-02	3.7380-02	-2.8547+01	1.2841+02
3.7120+03	1.9034+01	-2.2618-02	3.0129-02	3.7674-02	-2.8479+01	1.2690+02
3.7440+03	2.0648+01	-2.1979-02	3.1005-02	3.8006-02	-2.8403+01	1.2533+02
3.7760+03	2.2354+01	-2.1305-02	3.1918-02	3.8375-02	-2.8319+01	1.2372+02
3.8080+03	2.4151+01	-2.0593-02	3.2864-02	3.8783-02	-2.8227+01	1.2207+02
3.8400+03	2.6038+01	-1.9843-02	3.3839-02	3.9228-02	-2.8128+01	1.2039+02
3.8720+03	2.8016+01	-1.9054-02	3.4840-02	3.9710-02	-2.8022+01	1.1867+02
3.9040+03	3.0083+01	-1.8227-02	3.5863-02	4.0229-02	-2.7909+01	1.1694+02
3.9360+03	3.2236+01	-1.7362-02	3.6902-02	4.0782-02	-2.7791+01	1.1520+02
3.9680+03	3.4472+01	-1.6462-02	3.7952-02	4.1369-02	-2.7667+01	1.1345+02
4.0000+03	3.6788+01	-1.5529-02	3.9009-02	4.1986-02	-2.7538+01	1.1171+02
4.0320+03	3.9179+01	-1.4569-02	4.0065-02	4.2632-02	-2.7405+01	1.0998+02
4.0640+03	4.1641+01	-1.3584-02	4.1115-02	4.3301-02	-2.7270+01	1.0828+02
4.0960+03	4.4166+01	-1.2583-02	4.2152-02	4.3990-02	-2.7133+01	1.0662+02
4.1280+03	4.6749+01	-1.1571-02	4.3170-02	4.4694-02	-2.6995+01	1.0500+02
4.1600+03	4.9381+01	-1.0558-02	4.4162-02	4.5406-02	-2.6858+01	1.0345+02
4.1920+03	5.2055+01	-9.5524-03	4.5120-02	4.6120-02	-2.6722+01	1.0195+02
4.2240+03	5.4762+01	-8.5650-03	4.6039-02	4.6829-02	-2.6590+01	1.0054+02
4.2560+03	5.7491+01	-7.6071-03	4.6911-02	4.7524-02	-2.6462+01	9.9211+01
4.2880+03	6.0233+01	-6.6908-03	4.7729-02	4.8195-02	-2.6340+01	9.7980+01
4.3200+03	6.2977+01	-5.8288-03	4.8486-02	4.8835-02	-2.6225+01	9.6855+01
4.3520+03	6.5711+01	-5.0340-03	4.9175-02	4.9432-02	-2.6120+01	9.5845+01
4.3840+03	6.8423+01	-4.3195-03	4.9789-02	4.9976-02	-2.6025+01	9.4958+01
4.4160+03	7.1102+01	-3.6984-03	5.0322-02	5.0458-02	-2.5941+01	9.4203+01
4.4480+03	7.3734+01	-3.1834-03	5.0766-02	5.0866-02	-2.5871+01	9.3588+01
4.4800+03	7.6307+01	-2.7862-03	5.1115-02	5.1191-02	-2.5816+01	9.3120+01
4.5120+03	7.8809+01	-2.5175-03	5.1362-02	5.1424-02	-2.5777+01	9.2806+01
4.5440+03	8.1226+01	-2.3870-03	5.1500-02	5.1556-02	-2.5754+01	9.2654+01
4.5760+03	8.3546+01	-2.4019-03	5.1523-02	5.1579-02	-2.5751+01	9.2669+01
4.6080+03	8.5756+01	-2.5680-03	5.1424-02	5.1488-02	-2.5766+01	9.2859+01
4.6400+03	8.7845+01	-2.8884-03	5.1196-02	5.1277-02	-2.5801+01	9.3229+01
4.6720+03	8.9800+01	-3.3636-03	5.0834-02	5.0945-02	-2.5858+01	9.3786+01
4.7040+03	9.1611+01	-3.9914-03	5.0331-02	5.0489-02	-2.5936+01	9.4534+01
4.7360+03	9.3268+01	-4.7665-03	4.9683-02	4.9911-02	-2.6036+01	9.5480+01
4.7680+03	9.4760+01	-5.6864-03	4.8884-02	4.9213-02	-2.6158+01	9.6628+01

DISTANCE TO ORIGIN (METERS)	TERRAIN FUNCTION	ATTENUATION FUNCTION (REAL)	(IMAGINARY)	GAIN (RATIO)	(DB)	PHASE (DEG)
4.8000+03	9.6079+01	-6.7216-03	4.7931-02	4.8400-02	-2.6303+01	9.7983+01
4.8320+03	9.7217+01	-7.8755-03	4.6820-02	4.7478-02	-2.6470+01	9.9548+01
4.8640+03	9.8167+01	-9.1244-03	4.5551-02	4.6456-02	-2.6659+01	1.0133+02
4.8960+03	9.8924+01	-1.0448-02	4.4122-02	4.5342-02	-2.6870+01	1.0332+02
4.9280+03	9.9483+01	-1.1824-02	4.2536-02	4.4149-02	-2.7102+01	1.0554+02
4.9600+03	9.9840+01	-1.3229-02	4.0795-02	4.2886-02	-2.7354+01	1.0797+02
4.9920+03	9.9994+01	-1.4635-02	3.8907-02	4.1568-02	-2.7625+01	1.1061+02
5.0240+03	9.9942+01	-1.6017-02	3.6879-02	4.0207-02	-2.7914+01	1.1348+02
5.0560+03	9.9687+01	-1.7348-02	3.4722-02	3.8815-02	-2.8220+01	1.1655+02
5.0880+03	9.9229+01	-1.8602-02	3.2451-02	3.7404-02	-2.8542+01	1.1982+02
5.1200+03	9.8570+01	-1.9755-02	3.0081-02	3.5987-02	-2.8877+01	1.2329+02
5.1520+03	9.7716+01	-2.0784-02	2.7631-02	3.4575-02	-2.9225+01	1.2695+02
5.1840+03	9.6671+01	-2.1670-02	2.5124-02	3.3178-02	-2.9583+01	1.3078+02
5.2160+03	9.5442+01	-2.2396-02	2.2581-02	3.1804-02	-2.9950+01	1.3476+02
5.2480+03	9.4035+01	-2.2951-02	2.0029-02	3.0462-02	-3.0325+01	1.3889+02
5.2800+03	9.2459+01	-2.3328-02	1.7491-02	2.9156-02	-3.0705+01	1.4314+02
5.3120+03	9.0724+01	-2.3522-02	1.4993-02	2.7894-02	-3.1090+01	1.4749+02
5.3440+03	8.8840+01	-2.3536-02	1.2560-02	2.6677-02	-3.1477+01	1.5191+02
5.3760+03	8.6816+01	-2.3375-02	1.0215-02	2.5510-02	-3.1866+01	1.5640+02
5.4080+03	8.4665+01	-2.3051-02	7.9782-03	2.4393-02	-3.2255+01	1.6091+02
5.4400+03	8.2399+01	-2.2577-02	5.8692-03	2.3328-02	-3.2643+01	1.6543+02
5.4720+03	8.0029+01	-2.1970-02	3.9022-03	2.2314-02	-3.3029+01	1.6993+02
5.5040+03	7.7568+01	-2.1248-02	2.0887-03	2.1351-02	-3.3412+01	1.7439+02
5.5360+03	7.5029+01	-2.0434-02	4.3631-04	2.0438-02	-3.3791+01	1.7878+02
5.5680+03	7.2425+01	-1.9547-02	-1.0513-03	1.9575-02	-3.4166+01	-1.7692+02
5.6000+03	6.9768+01	-1.8609-02	-2.3739-03	1.8760-02	-3.4535+01	-1.7273+02
5.6320+03	6.7071+01	-1.7641-02	-3.5346-03	1.7992-02	-3.4898+01	-1.6867+02
5.6640+03	6.4346+01	-1.6662-02	-4.5396-03	1.7269-02	-3.5255+01	-1.6476+02
5.6960+03	6.1606+01	-1.5687-02	-5.3974-03	1.6590-02	-3.5603+01	-1.6101+02
5.7280+03	5.8861+01	-1.4734-02	-6.1180-03	1.5953-02	-3.5943+01	-1.5745+02
5.7600+03	5.6124+01	-1.3813-02	-6.7132-03	1.5358-02	-3.6273+01	-1.5408+02
5.7920+03	5.3405+01	-1.2937-02	-7.1954-03	1.4803-02	-3.6593+01	-1.5092+02
5.8240+03	5.0714+01	-1.2112-02	-7.5772-03	1.4287-02	-3.6901+01	-1.4797+02
5.8560+03	4.8059+01	-1.1344-02	-7.8711-03	1.3807-02	-3.7198+01	-1.4525+02
5.8880+03	4.5451+01	-1.0638-02	-8.0890-03	1.3364-02	-3.7481+01	-1.4275+02
5.9200+03	4.2896+01	-9.9956-03	-8.2423-03	1.2956-02	-3.7751+01	-1.4049+02
5.9520+03	4.0401+01	-9.4173-03	-8.3413-03	1.2580-02	-3.8006+01	-1.3847+02
5.9840+03	3.7974+01	-8.9028-03	-8.3953-03	1.2237-02	-3.8247+01	-1.3668+02
6.0160+03	3.5620+01	-8.4504-03	-8.4126-03	1.1924-02	-3.8472+01	-1.3513+02

DISTANCE TO ORIGIN (METERS)	TERRAIN FUNCTION	ATTENUATION FUNCTION (REAL)	(IMAGINARY)	GAIN (RATIO)	(DB)	PHASE (DEG)
6.0480+03	3.3344+01	-8.0581-03	-8.4000-03	1.1640-02	-3.8681+01	-1.3381+02
6.0800+03	3.1149+01	-7.7226-03	-8.3638-03	1.1384-02	-3.8874+01	-1.3272+02
6.1120+03	2.9039+01	-7.4410-03	-8.3089-03	1.1154-02	-3.9052+01	-1.3185+02
6.1440+03	2.7016+01	-7.2100-03	-8.2393-03	1.0949-02	-3.9213+01	-1.3119+02
6.1760+03	2.5083+01	-7.0257-03	-8.1585-03	1.0767-02	-3.9358+01	-1.3073+02
6.2080+03	2.3241+01	-6.8845-03	-8.0689-03	1.0607-02	-3.9488+01	-1.3047+02
6.2400+03	2.1490+01	-6.7829-03	-7.9725-03	1.0467-02	-3.9603+01	-1.3039+02
6.2720+03	1.9830+01	-6.7172-03	-7.8706-03	1.0347-02	-3.9703+01	-1.3048+02
6.3040+03	1.8261+01	-6.6843-03	-7.7645-03	1.0245-02	-3.9789+01	-1.3072+02
6.3360+03	1.6781+01	-6.6804-03	-7.6547-03	1.0160-02	-3.9862+01	-1.3111+02
6.3680+03	1.5390+01	-6.7028-03	-7.5416-03	1.0090-02	-3.9922+01	-1.3163+02
6.4000+03	1.4086+01	-6.7482-03	-7.4256-03	1.0034-02	-3.9971+01	-1.3226+02
6.4320+03	1.2865+01	-6.8138-03	-7.3067-03	9.9908-03	-4.0008+01	-1.3300+02
6.4640+03	1.1727+01	-6.8969-03	-7.1849-03	9.9594-03	-4.0035+01	-1.3383+02
6.4960+03	1.0667+01	-6.9951-03	-7.0603-03	9.9388-03	-4.0053+01	-1.3473+02
6.5280+03	9.6831+00	-7.1060-03	-6.9328-03	9.9277-03	-4.0063+01	-1.3571+02
6.5600+03	8.7720+00	-7.2273-03	-6.8024-03	9.9251-03	-4.0065+01	-1.3673+02
6.5920+03	7.9304+00	-7.3570-03	-6.6693-03	9.9300-03	-4.0061+01	-1.3781+02
6.6240+03	7.1549+00	-7.4934-03	-6.5331-03	9.9415-03	-4.0051+01	-1.3892+02
6.6560+03	6.4420+00	-7.6345-03	-6.3944-03	9.9586-03	-4.0036+01	-1.4005+02
6.6880+03	5.7882+00	-7.7789-03	-6.2531-03	9.9806-03	-4.0017+01	-1.4121+02
6.7200+03	5.1902+00	-7.9252-03	-6.1093-03	1.0007-02	-3.9994+01	-1.4237+02
6.7520+03	4.6444+00	-8.0720-03	-5.9635-03	1.0036-02	-3.9969+01	-1.4354+02
6.7840+03	4.1475+00	-8.2185-03	-5.8157-03	1.0068-02	-3.9941+01	-1.4472+02
6.8160+03	3.6962+00	-8.3632-03	-5.6665-03	1.0102-02	-3.9912+01	-1.4588+02
6.8480+03	3.2873+00	-8.5056-03	-5.5160-03	1.0138-02	-3.9881+01	-1.4704+02
6.8800+03	2.9176+00	-8.6449-03	-5.3646-03	1.0174-02	-3.9850+01	-1.4818+02
6.9120+03	2.5842+00	-8.7805-03	-5.2127-03	1.0211-02	-3.9818+01	-1.4930+02
6.9440+03	2.2842+00	-8.9118-03	-5.0607-03	1.0248-02	-3.9787+01	-1.5041+02
6.9760+03	2.0149+00	-9.0383-03	-4.9089-03	1.0285-02	-3.9756+01	-1.5149+02
7.0080+03	1.7738+00	-9.1599-03	-4.7576-03	1.0322-02	-3.9725+01	-1.5255+02
7.0400+03	1.5583+00	-9.2760-03	-4.6073-03	1.0357-02	-3.9695+01	-1.5359+02
7.0720+03	1.3661+00	-9.3868-03	-4.4582-03	1.0392-02	-3.9666+01	-1.5460+02
7.1040+03	1.1952+00	-9.4919-03	-4.3106-03	1.0425-02	-3.9639+01	-1.5558+02
7.1360+03	1.0436+00	-9.5914-03	-4.1648-03	1.0457-02	-3.9612+01	-1.5653+02
7.1680+03	9.0932-01	-9.6852-03	-4.0211-03	1.0487-02	-3.9587+01	-1.5745+02
7.2000+03	7.9071-01	-9.7733-03	-3.8797-03	1.0515-02	-3.9564+01	-1.5835+02
7.2320+03	6.8615-01	-9.8558-03	-3.7407-03	1.0542-02	-3.9542+01	-1.5922+02
7.2640+03	5.9421-01	-9.9329-03	-3.6044-03	1.0567-02	-3.9521+01	-1.6006+02

DISTANCE TO ORIGIN (METERS)	TERRAIN FUNCTION	ATTENUATION FUNCTION (REAL)	(IMAGINARY)	GAIN (RATIO)	(DB)	PHASE (DEG)
7.2960+03	5.1353-01	-1.0005-02	-3.4707-03	1.0590-02	-3.9502+01	-1.6087+02
7.3280+03	4.4290-01	-1.0071-02	-3.3401-03	1.0611-02	-3.9485+01	-1.6165+02
7.3600+03	3.8120-01	-1.0133-02	-3.2123-03	1.0630-02	-3.9469+01	-1.6241+02
7.3920+03	3.2743-01	-1.0190-02	-3.0876-03	1.0647-02	-3.9455+01	-1.6314+02
7.4240+03	2.8066-01	-1.0242-02	-2.9661-03	1.0662-02	-3.9443+01	-1.6385+02
7.4560+03	2.4008-01	-1.0289-02	-2.8476-03	1.0676-02	-3.9432+01	-1.6453+02
7.4880+03	2.0495-01	-1.0332-02	-2.7323-03	1.0687-02	-3.9423+01	-1.6519+02
7.5200+03	1.7460-01	-1.0371-02	-2.6201-03	1.0697-02	-3.9415+01	-1.6582+02
7.5520+03	1.4845-01	-1.0407-02	-2.5110-03	1.0705-02	-3.9408+01	-1.6643+02
7.5840+03	1.2595-01	-1.0438-02	-2.4050-03	1.0711-02	-3.9403+01	-1.6703+02
7.6160+03	1.0664-01	-1.0466-02	-2.3019-03	1.0716-02	-3.9399+01	-1.6760+02
7.6480+03	9.0109-02	-1.0491-02	-2.2019-03	1.0719-02	-3.9397+01	-1.6815+02
7.6800+03	7.5984-02	-1.0512-02	-2.1047-03	1.0721-02	-3.9395+01	-1.6868+02
7.7120+03	6.3942-02	-1.0531-02	-2.0104-03	1.0721-02	-3.9395+01	-1.6919+02
7.7440+03	5.3699-02	-1.0546-02	-1.9189-03	1.0719-02	-3.9397+01	-1.6969+02
7.7760+03	4.5004-02	-1.0559-02	-1.8301-03	1.0717-02	-3.9399+01	-1.7017+02
7.8080+03	3.7646-02	-1.0570-02	-1.7438-03	1.0713-02	-3.9402+01	-1.7063+02
7.8400+03	3.1416-02	-1.0578-02	-1.6603-03	1.0708-02	-3.9406+01	-1.7108+02
7.8720+03	2.6168-02	-1.0584-02	-1.5791-03	1.0701-02	-3.9411+01	-1.7151+02
7.9040+03	2.1752-02	-1.0588-02	-1.5005-03	1.0693-02	-3.9418+01	-1.7193+02
7.9360+03	1.8044-02	-1.0590-02	-1.4240-03	1.0685-02	-3.9425+01	-1.7234+02
7.9680+03	1.4938-02	-1.0590-02	-1.3499-03	1.0675-02	-3.9432+01	-1.7274+02
8.0000+03	1.2341-02	-1.0588-02	-1.2779-03	1.0665-02	-3.9441+01	-1.7312+02

LUNAR COMMUNICATIONS PROGRAM

DATA CASE NO. 2

TEST CASE
FLAT TERRAIN

INPUT OPTIONS

CLIGHT	=	3.0000+08
COMENT	=	2
DEGREE	=	1.0000+00
DELTAX	=	6.6667+01
E0	=	8.8419-12
ER	=	1.0000+01
FREQ	=	1.0000+06
HEIGHT	=	0.0000
H0	=	0.0000
OMEGA	=	0.0000
PLOT	=	1
POLAR	=	-1
PRINT	=	1
SIGMA	=	1.0000-02
SLOPE	=	1.0000+00
STEEP	=	1.0000-06
TAPEIN	=	0
TERAIN	=	2
XMAX	=	1.0000+04
X0	=	5.0000+03

LUNAR COMMUNICATIONS PROGRAM

DATA CASE NO. 2

TEST CASE
FLAT TERRAIN

DISTANCE TO ORIGIN (METERS)	TERRAIN FUNCTION	ATTENUATION FUNCTION (REAL)	(IMAGINARY)	GAIN (RATIO)	(DB)	PHASE (DEG)
0.0000	0.0000	1.0000+00	0.0000	1.0000+00	0.0000	0.0000
6.6667+01	0.0000	9.9169-01	1.0385-01	9.9711-01	-2.5110-02	5.9785+00
1.3333+02	0.0000	9.8305-01	1.4849-01	9.9420-01	-5.0547-02	8.5895+00
2.0000+02	0.0000	9.7476-01	1.8225-01	9.9166-01	-7.2781-02	1.0590+01
2.6667+02	0.0000	9.6665-01	2.1033-01	9.8927-01	-9.3676-02	1.2275+01
3.3333+02	0.0000	9.5867-01	2.3474-01	9.8699-01	-1.1375-01	1.3759+01
4.0000+02	0.0000	9.5078-01	2.5651-01	9.8478-01	-1.3325-01	1.5098+01
4.6667+02	0.0000	9.4298-01	2.7627-01	9.8262-01	-1.5232-01	1.6329+01
5.3333+02	0.0000	9.3525-01	2.9442-01	9.8050-01	-1.7106-01	1.7474+01
6.0000+02	0.0000	9.2759-01	3.1124-01	9.7842-01	-1.8951-01	1.8548+01
6.6667+02	0.0000	9.2000-01	3.2694-01	9.7637-01	-2.0774-01	1.9564+01
7.3333+02	0.0000	9.1247-01	3.4168-01	9.7434-01	-2.2576-01	2.0529+01
8.0000+02	0.0000	9.0500-01	3.5557-01	9.7234-01	-2.4362-01	2.1450+01
8.6667+02	0.0000	8.9758-01	3.6872-01	9.7036-01	-2.6133-01	2.2333+01
9.3333+02	0.0000	8.9021-01	3.8121-01	9.6840-01	-2.7890-01	2.3182+01
1.0000+03	0.0000	8.8290-01	3.9309-01	9.6646-01	-2.9635-01	2.4000+01
1.0667+03	0.0000	8.7564-01	4.0444-01	9.6453-01	-3.1370-01	2.4791+01
1.1333+03	0.0000	8.6843-01	4.1528-01	9.6262-01	-3.3094-01	2.5557+01
1.2000+03	0.0000	8.6127-01	4.2567-01	9.6072-01	-3.4810-01	2.6300+01
1.2667+03	0.0000	8.5415-01	4.3564-01	9.5883-01	-3.6517-01	2.7023+01
1.3333+03	0.0000	8.4708-01	4.4522-01	9.5696-01	-3.8217-01	2.7726+01
1.4000+03	0.0000	8.4006-01	4.5443-01	9.5509-01	-3.9909-01	2.8411+01
1.4667+03	0.0000	8.3308-01	4.6330-01	9.5324-01	-4.1595-01	2.9080+01
1.5333+03	0.0000	8.2614-01	4.7185-01	9.5140-01	-4.3275-01	2.9733+01
1.6000+03	0.0000	8.1925-01	4.8011-01	9.4957-01	-4.4948-01	3.0372+01
1.6667+03	0.0000	8.1241-01	4.8808-01	9.4775-01	-4.6617-01	3.0997+01
1.7333+03	0.0000	8.0560-01	4.9578-01	9.4593-01	-4.8280-01	3.1609+01
1.8000+03	0.0000	7.9884-01	5.0323-01	9.4413-01	-4.9938-01	3.2209+01
1.8667+03	0.0000	7.9212-01	5.1043-01	9.4233-01	-5.1591-01	3.2798+01
1.9333+03	0.0000	7.8543-01	5.1741-01	9.4055-01	-5.3241-01	3.3375+01
2.0000+03	0.0000	7.7879-01	5.2418-01	9.3877-01	-5.4885-01	3.3943+01
2.0667+03	0.0000	7.7220-01	5.3073-01	9.3699-01	-5.6526-01	3.4501+01

DISTANCE TO ORIGIN (METERS)	TERRAIN FUNCTION	ATTENUATION FUNCTION (REAL)	(IMAGINARY)	GAIN (RATIO)	(DB)	PHASE (DEG)
2.1333+03	0.0000	7.6564-01	5.3708-01	9.3523-01	-5.8163-01	3.5049+01
2.2000+03	0.0000	7.5911-01	5.4325-01	9.3347-01	-5.9797-01	3.5589+01
2.2667+03	0.0000	7.5263-01	5.4923-01	9.3172-01	-6.1427-01	3.6120+01
2.3333+03	0.0000	7.4619-01	5.5503-01	9.2998-01	-6.3053-01	3.6643+01
2.4000+03	0.0000	7.3979-01	5.6067-01	9.2824-01	-6.4676-01	3.7158+01
2.4667+03	0.0000	7.3342-01	5.6615-01	9.2651-01	-6.6296-01	3.7666+01
2.5333+03	0.0000	7.2709-01	5.7147-01	9.2479-01	-6.7913-01	3.8166+01
2.6000+03	0.0000	7.2080-01	5.7664-01	9.2307-01	-6.9527-01	3.8660+01
2.6667+03	0.0000	7.1454-01	5.8167-01	9.2136-01	-7.1139-01	3.9147+01
2.7333+03	0.0000	7.0832-01	5.8656-01	9.1966-01	-7.2747-01	3.9628+01
2.8000+03	0.0000	7.0214-01	5.9131-01	9.1796-01	-7.4353-01	4.0102+01
2.8667+03	0.0000	6.9600-01	5.9593-01	9.1627-01	-7.5957-01	4.0571+01
2.9333+03	0.0000	6.8989-01	6.0042-01	9.1458-01	-7.7557-01	4.1034+01
3.0000+03	0.0000	6.8381-01	6.0480-01	9.1290-01	-7.9156-01	4.1491+01
3.0667+03	0.0000	6.7778-01	6.0905-01	9.1122-01	-8.0752-01	4.1943+01
3.1333+03	0.0000	6.7177-01	6.1319-01	9.0955-01	-8.2346-01	4.2390+01
3.2000+03	0.0000	6.6580-01	6.1722-01	9.0789-01	-8.3938-01	4.2831+01
3.2667+03	0.0000	6.5987-01	6.2114-01	9.0623-01	-8.5527-01	4.3268+01
3.3333+03	0.0000	6.5397-01	6.2496-01	9.0457-01	-8.7115-01	4.3700+01
3.4000+03	0.0000	6.4810-01	6.2867-01	9.0292-01	-8.8700-01	4.4128+01
3.4667+03	0.0000	6.4227-01	6.3229-01	9.0128-01	-9.0284-01	4.4551+01
3.5333+03	0.0000	6.3647-01	6.3580-01	8.9964-01	-9.1865-01	4.4970+01
3.6000+03	0.0000	6.3071-01	6.3923-01	8.9800-01	-9.3445-01	4.5384+01
3.6667+03	0.0000	6.2498-01	6.4256-01	8.9637-01	-9.5023-01	4.5795+01
3.7333+03	0.0000	6.1928-01	6.4581-01	8.9475-01	-9.6599-01	4.6201+01
3.8000+03	0.0000	6.1361-01	6.4896-01	8.9313-01	-9.8173-01	4.6604+01
3.8667+03	0.0000	6.0798-01	6.5204-01	8.9151-01	-9.9745-01	4.7002+01
3.9333+03	0.0000	6.0238-01	6.5503-01	8.8990-01	-1.0132+00	4.7398+01
4.0000+03	0.0000	5.9681-01	6.5794-01	8.8830-01	-1.0289+00	4.7789+01
4.0667+03	0.0000	5.9128-01	6.6077-01	8.8669-01	-1.0445+00	4.8177+01
4.1333+03	0.0000	5.8577-01	6.6353-01	8.8510-01	-1.0602+00	4.8562+01
4.2000+03	0.0000	5.8030-01	6.6621-01	8.8350-01	-1.0758+00	4.8943+01
4.2667+03	0.0000	5.7486-01	6.6882-01	8.8192-01	-1.0915+00	4.9321+01
4.3333+03	0.0000	5.6944-01	6.7135-01	8.8033-01	-1.1071+00	4.9695+01
4.4000+03	0.0000	5.6406-01	6.7382-01	8.7875-01	-1.1227+00	5.0067+01
4.4667+03	0.0000	5.5872-01	6.7622-01	8.7718-01	-1.1383+00	5.0435+01
4.5333+03	0.0000	5.5340-01	6.7856-01	8.7561-01	-1.1538+00	5.0801+01
4.6000+03	0.0000	5.4811-01	6.8082-01	8.7404-01	-1.1694+00	5.1164+01
4.6667+03	0.0000	5.4285-01	6.8303-01	8.7248-01	-1.1849+00	5.1523+01

DISTANCE TO ORIGIN (METERS)	TERRAIN FUNCTION	ATTENUATION FUNCTION (REAL)	(IMAGINARY)	GAIN (RATIO)	(DB)	PHASE (DEG)
4.7333+03	0.0000	5.3762-01	6.8517-01	8.7092-01	-1.2004+00	5.1880+01
4.8000+03	0.0000	5.3242-01	6.8725-01	8.6936-01	-1.2160+00	5.2235+01
4.8667+03	0.0000	5.2726-01	6.8928-01	8.6781-01	-1.2315+00	5.2586+01
4.9333+03	0.0000	5.2212-01	6.9124-01	8.6627-01	-1.2470+00	5.2935+01
5.0000+03	0.0000	5.1701-01	6.9315-01	8.6473-01	-1.2624+00	5.3281+01
5.0667+03	0.0000	5.1193-01	6.9500-01	8.6319-01	-1.2779+00	5.3625+01
5.1333+03	0.0000	5.0688-01	6.9680-01	8.6165-01	-1.2933+00	5.3966+01
5.2000+03	0.0000	5.0185-01	6.9854-01	8.6012-01	-1.3088+00	5.4305+01
5.2667+03	0.0000	4.9686-01	7.0023-01	8.5860-01	-1.3242+00	5.4642+01
5.3333+03	0.0000	4.9189-01	7.0187-01	8.5707-01	-1.3396+00	5.4976+01
5.4000+03	0.0000	4.8696-01	7.0346-01	8.5556-01	-1.3550+00	5.5308+01
5.4667+03	0.0000	4.8205-01	7.0499-01	8.5404-01	-1.3704+00	5.5637+01
5.5333+03	0.0000	4.7717-01	7.0648-01	8.5253-01	-1.3858+00	5.5965+01
5.6000+03	0.0000	4.7231-01	7.0793-01	8.5102-01	-1.4012+00	5.6290+01
5.6667+03	0.0000	4.6749-01	7.0932-01	8.4952-01	-1.4165+00	5.6613+01
5.7333+03	0.0000	4.6269-01	7.1067-01	8.4802-01	-1.4319+00	5.6934+01
5.8000+03	0.0000	4.5792-01	7.1198-01	8.4652-01	-1.4472+00	5.7252+01
5.8667+03	0.0000	4.5317-01	7.1324-01	8.4503-01	-1.4626+00	5.7569+01
5.9333+03	0.0000	4.4846-01	7.1446-01	8.4354-01	-1.4779+00	5.7884+01
6.0000+03	0.0000	4.4377-01	7.1563-01	8.4206-01	-1.4932+00	5.8197+01
6.0667+03	0.0000	4.3911-01	7.1677-01	8.4057-01	-1.5085+00	5.8507+01
6.1333+03	0.0000	4.3447-01	7.1786-01	8.3910-01	-1.5238+00	5.8816+01
6.2000+03	0.0000	4.2986-01	7.1891-01	8.3762-01	-1.5390+00	5.9123+01
6.2667+03	0.0000	4.2528-01	7.1992-01	8.3615-01	-1.5543+00	5.9429+01
6.3333+03	0.0000	4.2072-01	7.2090-01	8.3468-01	-1.5696+00	5.9732+01
6.4000+03	0.0000	4.1619-01	7.2183-01	8.3322-01	-1.5848+00	6.0034+01
6.4667+03	0.0000	4.1168-01	7.2273-01	8.3176-01	-1.6000+00	6.0333+01
6.5333+03	0.0000	4.0720-01	7.2359-01	8.3030-01	-1.6153+00	6.0631+01
6.6000+03	0.0000	4.0275-01	7.2442-01	8.2885-01	-1.6305+00	6.0928+01
6.6667+03	0.0000	3.9832-01	7.2521-01	8.2740-01	-1.6457+00	6.1222+01
6.7333+03	0.0000	3.9392-01	7.2597-01	8.2595-01	-1.6609+00	6.1515+01
6.8000+03	0.0000	3.8954-01	7.2669-01	8.2451-01	-1.6761+00	6.1807+01
6.8667+03	0.0000	3.8518-01	7.2738-01	8.2307-01	-1.6913+00	6.2096+01
6.9333+03	0.0000	3.8086-01	7.2803-01	8.2163-01	-1.7064+00	6.2385+01
7.0000+03	0.0000	3.7655-01	7.2865-01	8.2020-01	-1.7216+00	6.2671+01
7.0667+03	0.0000	3.7227-01	7.2924-01	8.1877-01	-1.7368+00	6.2956+01
7.1333+03	0.0000	3.6802-01	7.2980-01	8.1734-01	-1.7519+00	6.3240+01
7.2000+03	0.0000	3.6379-01	7.3033-01	8.1592-01	-1.7670+00	6.3521+01
7.2667+03	0.0000	3.5958-01	7.3083-01	8.1450-01	-1.7822+00	6.3802+01

DISTANCE TO ORIGIN (METERS)	TERRAIN FUNCTION	ATTENUATION FUNCTION (REAL)	(IMAGINARY)	GAIN (RATIO)	(DB)	PHASE (DEG)
7.3333+03	0.0000	3.5540-01	7.3130-01	8.1308-01	-1.7973+00	6.4081+01
7.4000+03	0.0000	3.5124-01	7.3174-01	8.1167-01	-1.8124+00	6.4358+01
7.4667+03	0.0000	3.4711-01	7.3215-01	8.1026-01	-1.8275+00	6.4634+01
7.5333+03	0.0000	3.4300-01	7.3253-01	8.0885-01	-1.8426+00	6.4909+01
7.6000+03	0.0000	3.3891-01	7.3288-01	8.0745-01	-1.8577+00	6.5182+01
7.6667+03	0.0000	3.3485-01	7.3321-01	8.0605-01	-1.8728+00	6.5454+01
7.7333+03	0.0000	3.3081-01	7.3351-01	8.0465-01	-1.8878+00	6.5725+01
7.8000+03	0.0000	3.2679-01	7.3378-01	8.0326-01	-1.9029+00	6.5994+01
7.8667+03	0.0000	3.2280-01	7.3402-01	8.0187-01	-1.9180+00	6.6262+01
7.9333+03	0.0000	3.1883-01	7.3424-01	8.0048-01	-1.9330+00	6.6528+01
8.0000+03	0.0000	3.1488-01	7.3444-01	7.9909-01	-1.9481+00	6.6794+01
8.0667+03	0.0000	3.1095-01	7.3461-01	7.9771-01	-1.9631+00	6.7058+01
8.1333+03	0.0000	3.0705-01	7.3476-01	7.9633-01	-1.9781+00	6.7320+01
8.2000+03	0.0000	3.0317-01	7.3488-01	7.9496-01	-1.9931+00	6.7582+01
8.2667+03	0.0000	2.9931-01	7.3498-01	7.9358-01	-2.0081+00	6.7842+01
8.3333+03	0.0000	2.9548-01	7.3505-01	7.9222-01	-2.0231+00	6.8101+01
8.4000+03	0.0000	2.9166-01	7.3510-01	7.9085-01	-2.0381+00	6.8359+01
8.4667+03	0.0000	2.8787-01	7.3513-01	7.8949-01	-2.0531+00	6.8615+01
8.5333+03	0.0000	2.8410-01	7.3514-01	7.8812-01	-2.0681+00	6.8871+01
8.6000+03	0.0000	2.8035-01	7.3512-01	7.8677-01	-2.0831+00	6.9125+01
8.6667+03	0.0000	2.7663-01	7.3509-01	7.8541-01	-2.0980+00	6.9378+01
8.7333+03	0.0000	2.7292-01	7.3503-01	7.8406-01	-2.1130+00	6.9630+01
8.8000+03	0.0000	2.6924-01	7.3495-01	7.8271-01	-2.1279+00	6.9881+01
8.8667+03	0.0000	2.6557-01	7.3485-01	7.8137-01	-2.1429+00	7.0130+01
8.9333+03	0.0000	2.6193-01	7.3473-01	7.8003-01	-2.1578+00	7.0379+01
9.0000+03	0.0000	2.5831-01	7.3459-01	7.7869-01	-2.1728+00	7.0626+01
9.0667+03	0.0000	2.5471-01	7.3443-01	7.7735-01	-2.1877+00	7.0873+01
9.1333+03	0.0000	2.5114-01	7.3426-01	7.7602-01	-2.2026+00	7.1118+01
9.2000+03	0.0000	2.4758-01	7.3406-01	7.7468-01	-2.2175+00	7.1362+01
9.2667+03	0.0000	2.4404-01	7.3384-01	7.7336-01	-2.2324+00	7.1605+01
9.3333+03	0.0000	2.4052-01	7.3361-01	7.7203-01	-2.2473+00	7.1848+01
9.4000+03	0.0000	2.3703-01	7.3336-01	7.7071-01	-2.2622+00	7.2089+01
9.4667+03	0.0000	2.3355-01	7.3309-01	7.6939-01	-2.2771+00	7.2329+01
9.5333+03	0.0000	2.3010-01	7.3280-01	7.6807-01	-2.2919+00	7.2568+01
9.6000+03	0.0000	2.2666-01	7.3249-01	7.6676-01	-2.3068+00	7.2806+01
9.6667+03	0.0000	2.2325-01	7.3217-01	7.6545-01	-2.3217+00	7.3043+01
9.7333+03	0.0000	2.1985-01	7.3183-01	7.6414-01	-2.3365+00	7.3279+01
9.8000+03	0.0000	2.1647-01	7.3148-01	7.6284-01	-2.3514+00	7.3514+01
9.8667+03	0.0000	2.1312-01	7.3110-01	7.6153-01	-2.3662+00	7.3748+01

DISTANCE TO ORIGIN (METERS)	TERRAIN FUNCTION	ATTENUATION FUNCTION (REAL)	(IMAGINARY)	GAIN (RATIO)	(DB)	PHASE (DEG)
9.9333+03	0.0000	2.0978-01	7.3072-01	7.6023-01	-2.3811+00	7.3982+01
1.0000+04	0.0000	2.0646-01	7.3031-01	7.5894-01	-2.3959+00	7.4214+01

```
END OF LUNCCM EXECUTION.  NORMAL TERMINATION.  2 DATA CASE(S) PROCESSED.
```

& XQT TRWPLT

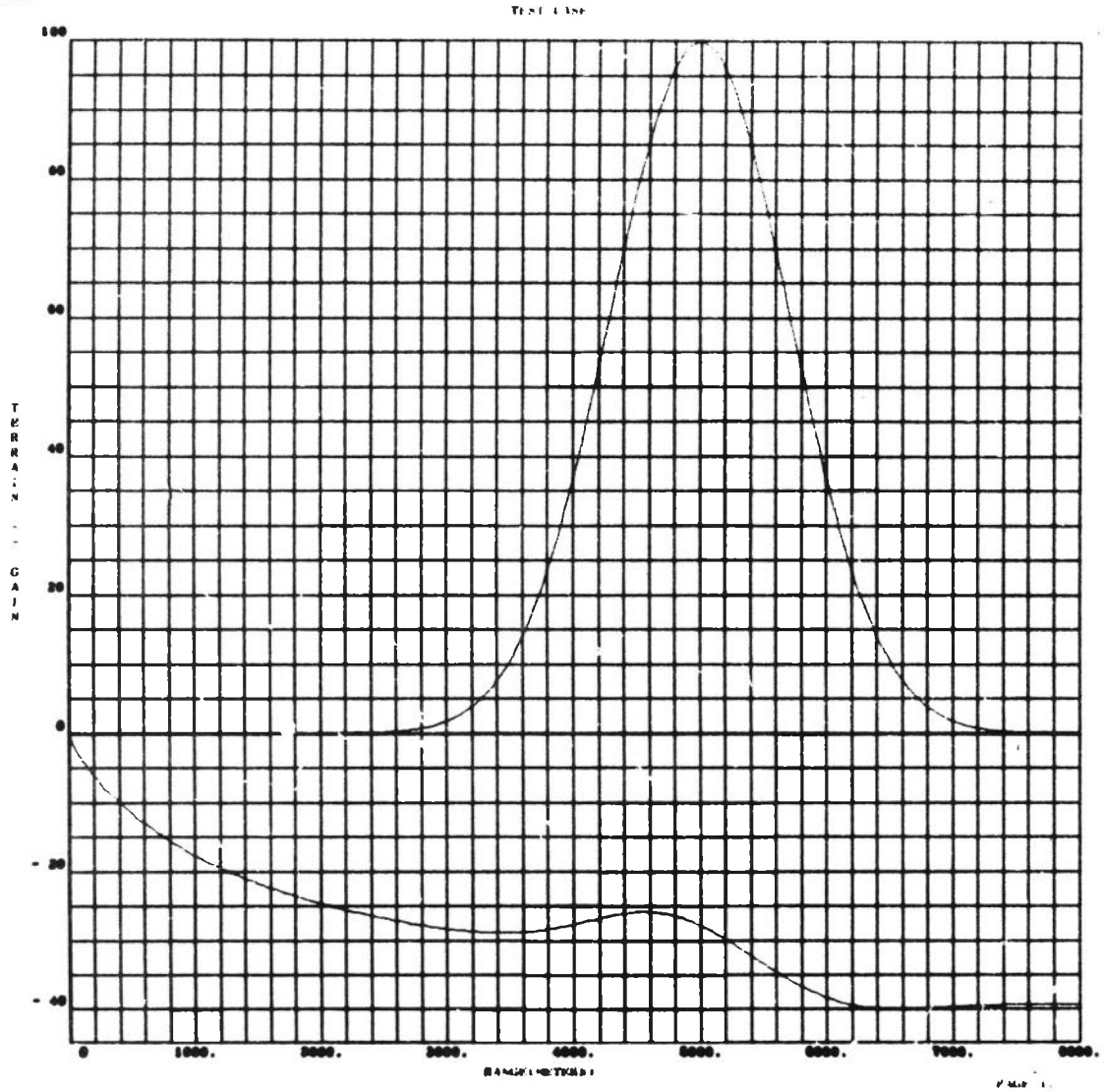
16637642

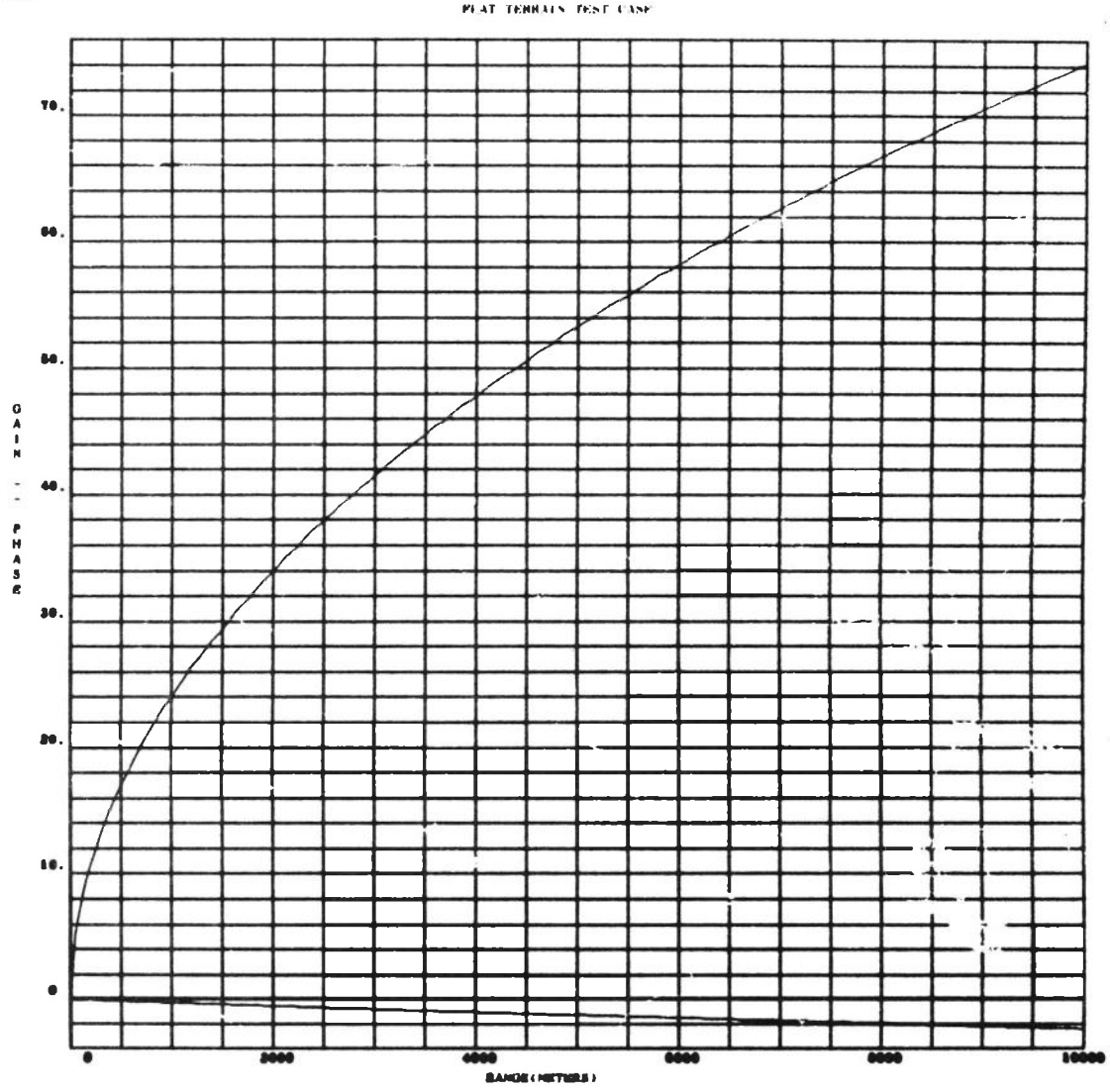
```
                NOIREC=1
                TITLE=ID=TEST CASE
                XLABEL=ID=RANGE(METERS)
                YLABEL=ID=TERRAIN -- GAIN
                PLOT=1,2,6,ENDLST
                ENDPLT
                ENDFIL

MICROFILM PLOT COMPLETED
                TITLE=ID=FLAT TERRAIN TEST CASE
                YLABEL=ID=GAIN -- PHASE
                PLOT=1,6,7,ENDLST
                ENDPLT
                ENDFIL

MICROFILM PLOT COMPLETED
                ENDRUN
```

& EOF

FOE & 16&38&14

4.3 SAMPLE PLOTS




FLAT TERRAIN TEST CASE
70.
60.
50.
40.
30.
20.
10.
0
GAIN - PHASE
0
2000
4000
6000
8000
10000
RANGE (METERS)

5. OPERATING PROCEDURES

The LUNCOM Program is written in FORTRAN V for use with the UNIVAC 1108 EXEC II system. Presently this program is in production only for the 1108 system. One tape may be input to this program in addition to the standard input tapes required by the 1108 system.

The LUNCOM Program requires the use of one output tape. If no tape assignments are made, a drum file will be used, and the user must indicate this on his run request form. Drum files may be used when the user does not require any plot output and when he does not wish to save a LUNCOM data tape.

If tape assignments are made without the use of "=", a FASTRAND file will be used for the output tape, and the user must indicate this on his run request form. FASTRAND files may be used when the user requires plot output but does not wish to save a LUNCOM data tape.

If tape assignments are made with the use of "=", an actual output tape will be generated and may be saved by the user. Tape may be used in lieu of drum files and FASTRAND files and must be used when the user desires to save a LUNCOM data tape.

A previously generated plot tape may be input for the program on unit E.

5.1 LUNCOM DECK SETUP

5.1.1 No Plot Output Desired, No Data Tape Saved, No Input Tape

```
c
c
1
+
$JOB, etc.
▽ΔASGΔX=(PCF tape number)
▽ΔXQTΔCUR
ΔTRWΔX
ΔINΔX
ΔTRIΔX
▽ΔXQTΔHV016A
[
|LUNCOM data deck
[
▽ΔEOF
```

5.1.2 Plot Output Desired, No Data Tape Saved, No Input Tape

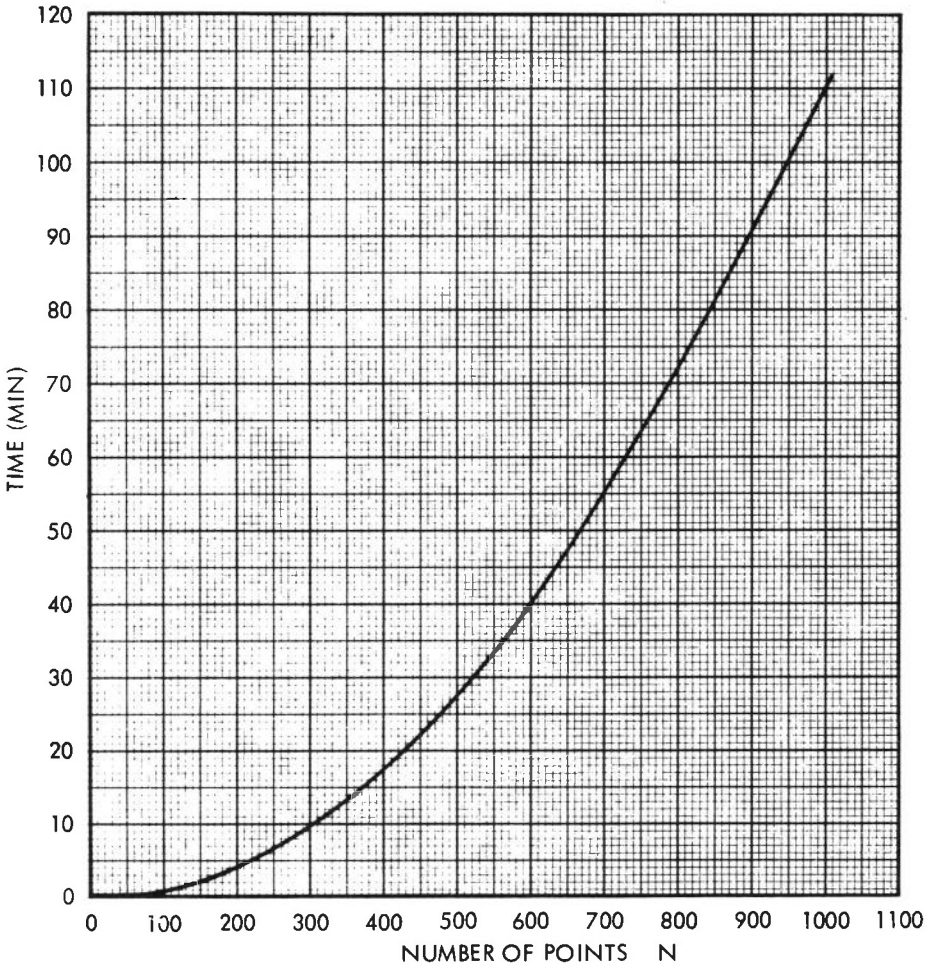
```
c
c
1
$JOB, etc.
▽ΔASGΔX=(PCF tape number)
▽ΔASGΔF
▽ΔXQTΔCUR
ΔTRWΔX
ΔINΔX
ΔTRIΔX
▽ΔXQTΔHV016A
[
|LUNCOM data deck
[
▽ΔXQTΔTRWPLT
[
|TRWPLT data deck
[
▽ΔEOF
```

5.1.3 No Plot Output Desired, Data Tape Saved, Input Tape

```
c
c
1
$JOB, etc.
▽ΔASGΔX=(PCF tape number)
▽ΔASGΔE=(Plot tape number)
▽ΔASGΔF=SAVE1
▽ΔXQTΔCUR
ΔTRWΔX
ΔINΔX
ΔTRIΔX
▽ΔXQTΔHV016A
[
|LUNCOM data deck
[
▽ΔEOF
```

5.2 COMPUTER RUN REQUEST

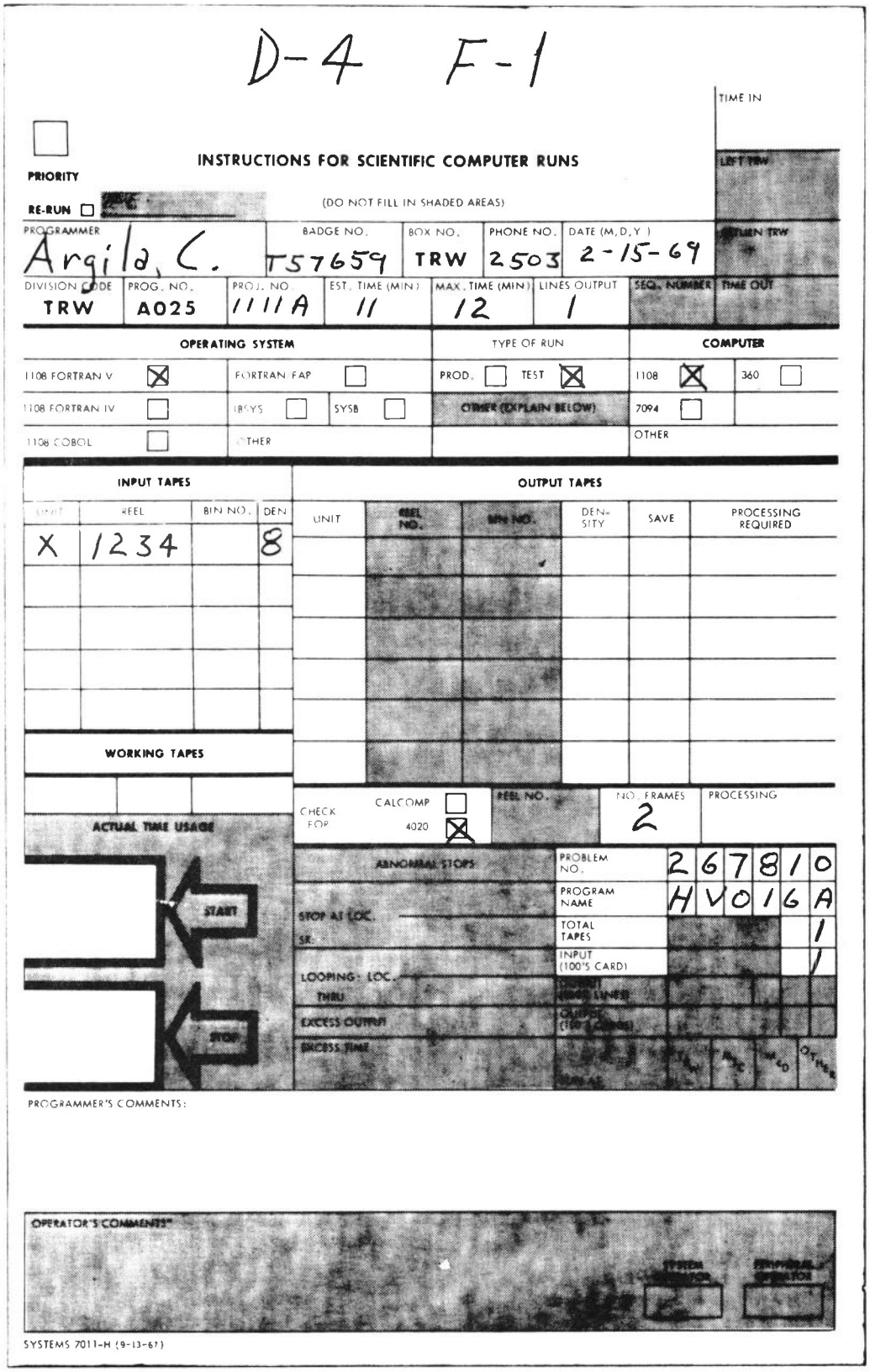
In submitting the card deck for a computer run, the run time (in minutes) per data case may be approximated by the following curve



where N is the number of data points $\left(\text{given by } \left[\frac{\text{XMAX}}{\text{DELTAX}}\right]\right)$. The print output may be estimated at approximately 10 pages per data case, one hundred pages minimum.

Microfilm and CalComp output will depend on the number of plots generated by the plot program.

5.2.1 Sample Run Request Form



D-4 F-1

TIME IN

PRIORITY

INSTRUCTIONS FOR SCIENTIFIC COMPUTER RUNS

LEFT TRW

RE-RUN ☐ (DO NOT FILL IN SHADED AREAS)

RETURN TRW

PROGRAMMER	BADGE NO.	BOX NO.	PHONE NO.	DATE (M,D,Y)
Argila, C.	T57659	TRW	2503	2-15-69

DIVISION CODE	PROG. NO.	PROJ. NO.	EST. TIME (MIN.)	MAX. TIME (MIN.)	LINES OUTPUT	SEQ. NUMBER	TIME OUT
TRW	A025	1111A	11	12	1		

OPERATING SYSTEM				TYPE OF RUN	COMPUTER	
1108 FORTRAN V	☒	FORTRAN FAP	☐	PROD. ☐ TEST ☒	1108 ☒	360 ☐
1108 FORTRAN IV	☐	IRSYS ☐	SYSB ☐	OTHER (EXPLAIN BELOW)	7094 ☐	
1108 COBOL	☐	OTHER			OTHER	

INPUT TAPES

UNIT	REEL	BIN NO.	DEN.
X	1234		8

OUTPUT TAPES

UNIT	REEL NO.	BIN NO.	DEN-SITY	SAVE	PROCESSING REQUIRED

WORKING TAPES

CHECK FOR: CALCOMP ☐ 4020 ☒

REEL NO.

NO. FRAMES: 2

PROCESSING

ACTUAL TIME USAGE

START

STOP

ABNORMAL STOPS

STOP AT LOC.

SR.

LOOPING: LOC.

THRU

EXCESS OUTPUT

PROCESS TIME

PROBLEM NO.	267810
PROGRAM NAME	HV016A
TOTAL TAPES	1
INPUT (100'S CARD)	1

PROGRAMMER'S COMMENTS:

OPERATOR'S COMMENTS

SYSTEMS 7011-H (9-13-67)