SPACE SCIENCES LABORATORY

INTEGRAL EQUATION FORMULATIONS OF SCATTERING FROM TWO-DIMENSIONAL INHOMOGENEITIES IN A CONDUCTIVE EARTH

By
John Robert Parry

Final Report on
NASA Contract NAS2-5078
Item 324
Part II

August 1969

Space Sciences Laboratory Series 11 Issue 47

UNIVERSITY OF CALIFORNIA, BERKELEY

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Berkeley, California 94720

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LIST OF FIGURES

Figure 104... Coordinate system used in deriving the small argument solution for the jth interval.

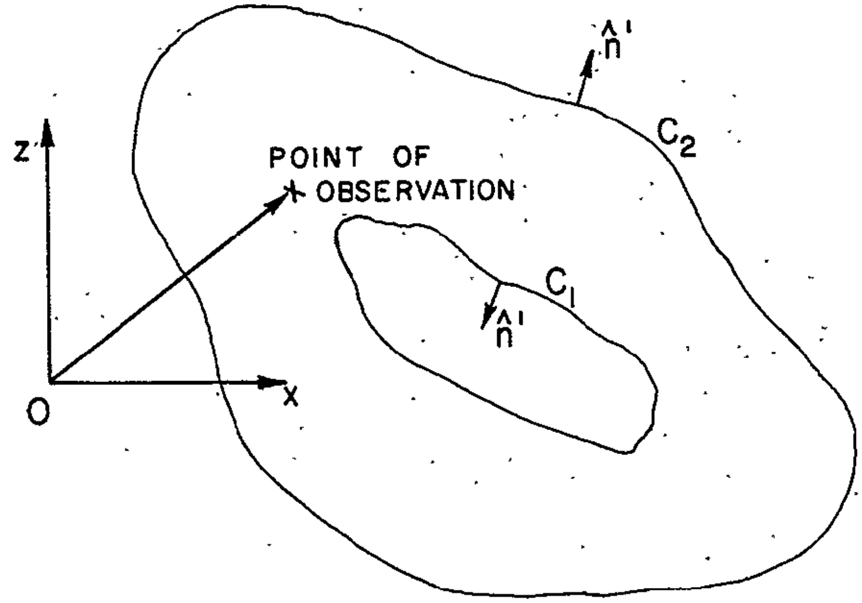
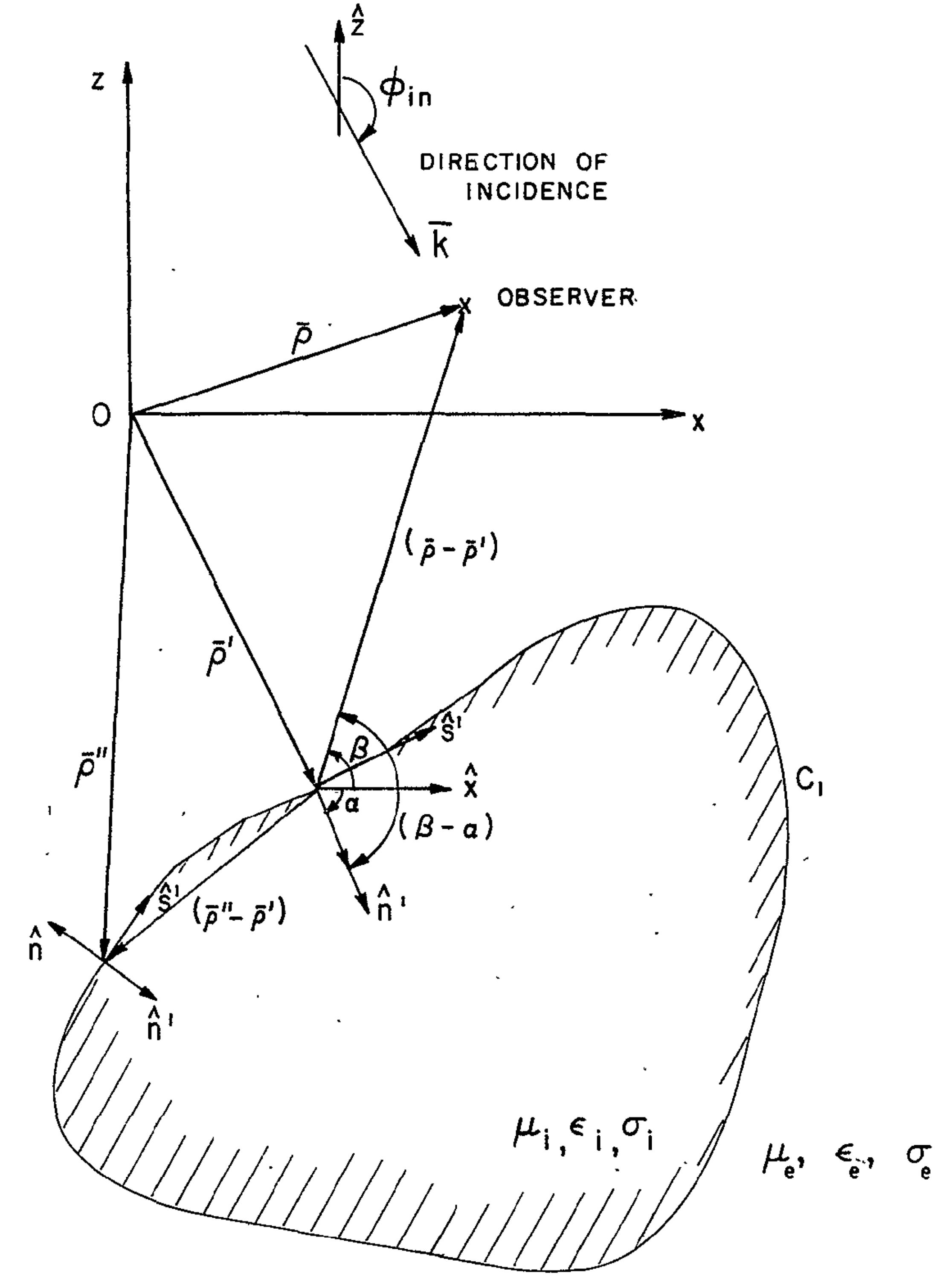
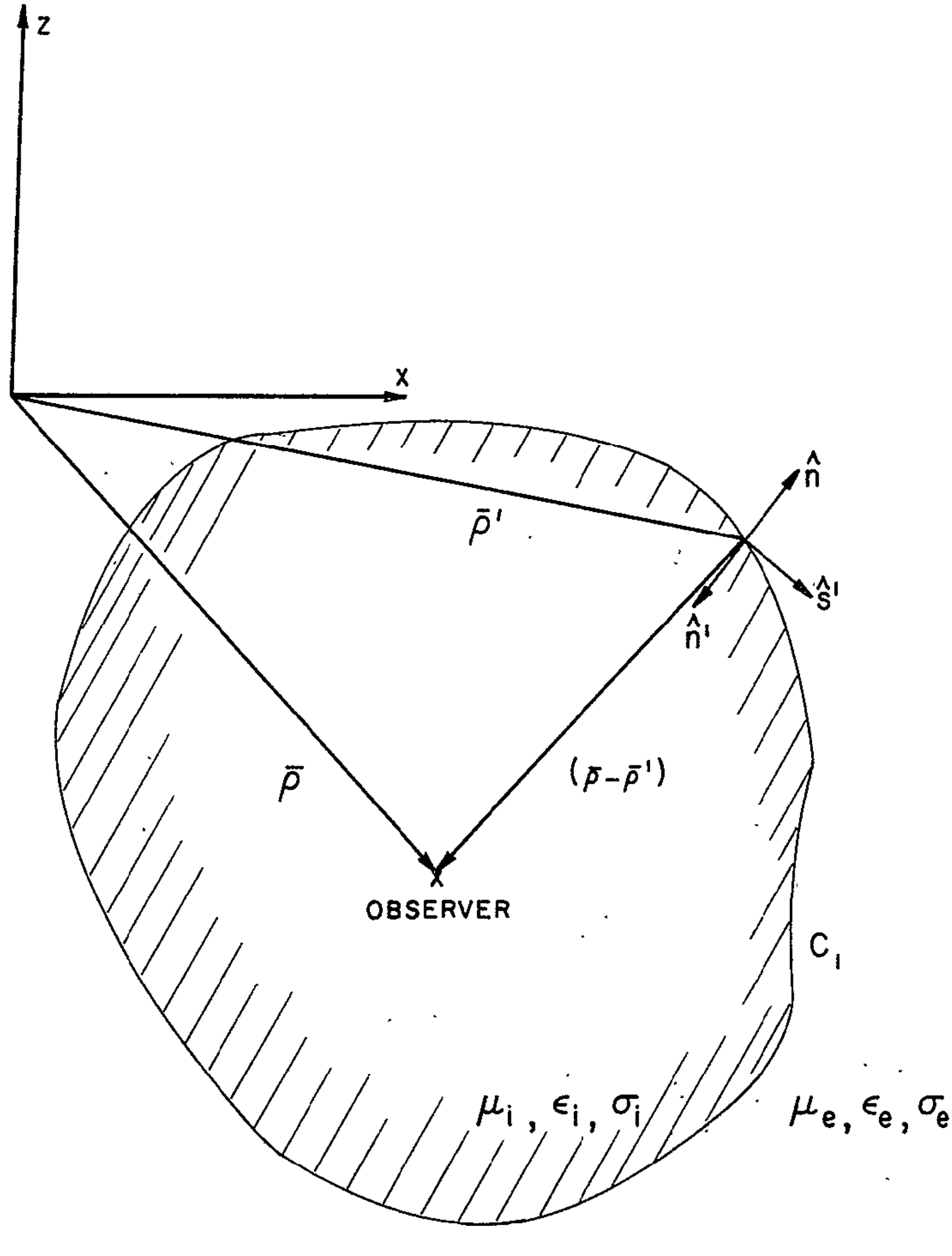


FIG 1



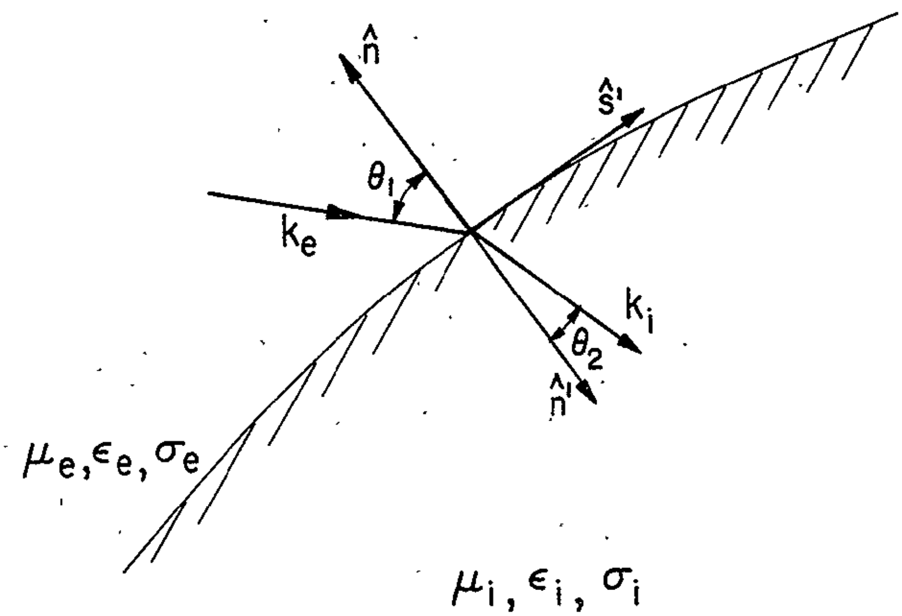
ẑ
φin
DIRECTION OF INCIDENCE
k̄
z
OBSERVER
ρ̄
O
x
(ρ̄ − ρ̄')
ρ̄'
ρ̄''
ŝ'
β
x̂
C1
α
(β − α)
ŝ'
(ρ̄'' − ρ̄')
n̂'
n̂
n̂'
μi, εi, σi
μe, εe, σe

FIG 2



z
x
$\hat{n}$
$\bar{\rho}'$
$\hat{s}'$
$\hat{n}'$
$\bar{\rho}$
$(\bar{\rho}-\bar{\rho}')$
OBSERVER
C_i
$\mu_i, \epsilon_i, \sigma_i$
$\mu_e, \epsilon_e, \sigma_e$

FIG 3



$\hat{n}$
$\hat{s}'$
θ_1
k_e
k_i
θ_2
$\hat{n}'$
$\mu_e, \epsilon_e, \sigma_e$
$\mu_i, \epsilon_i, \sigma_i$

FIG 4

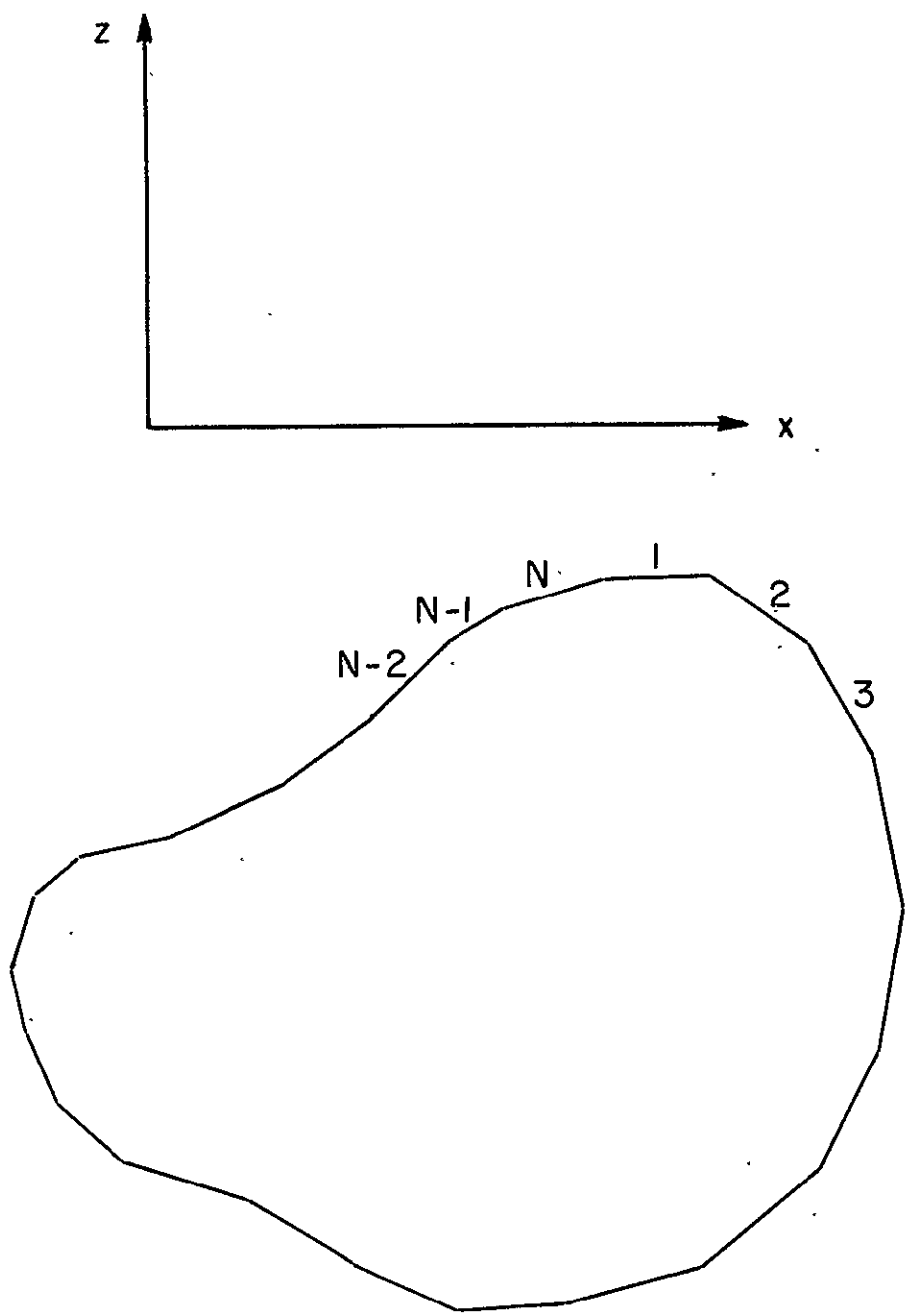


FIG 5

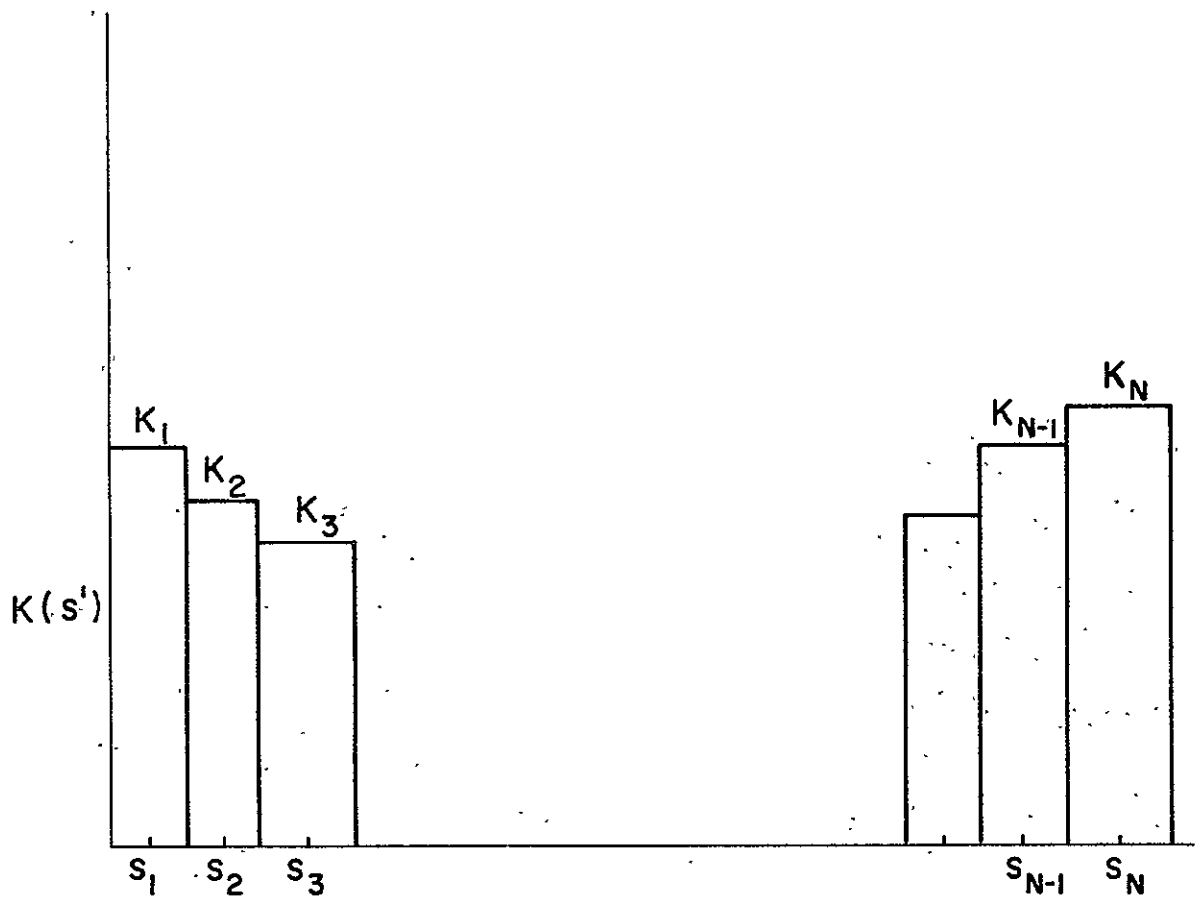


FIG 6

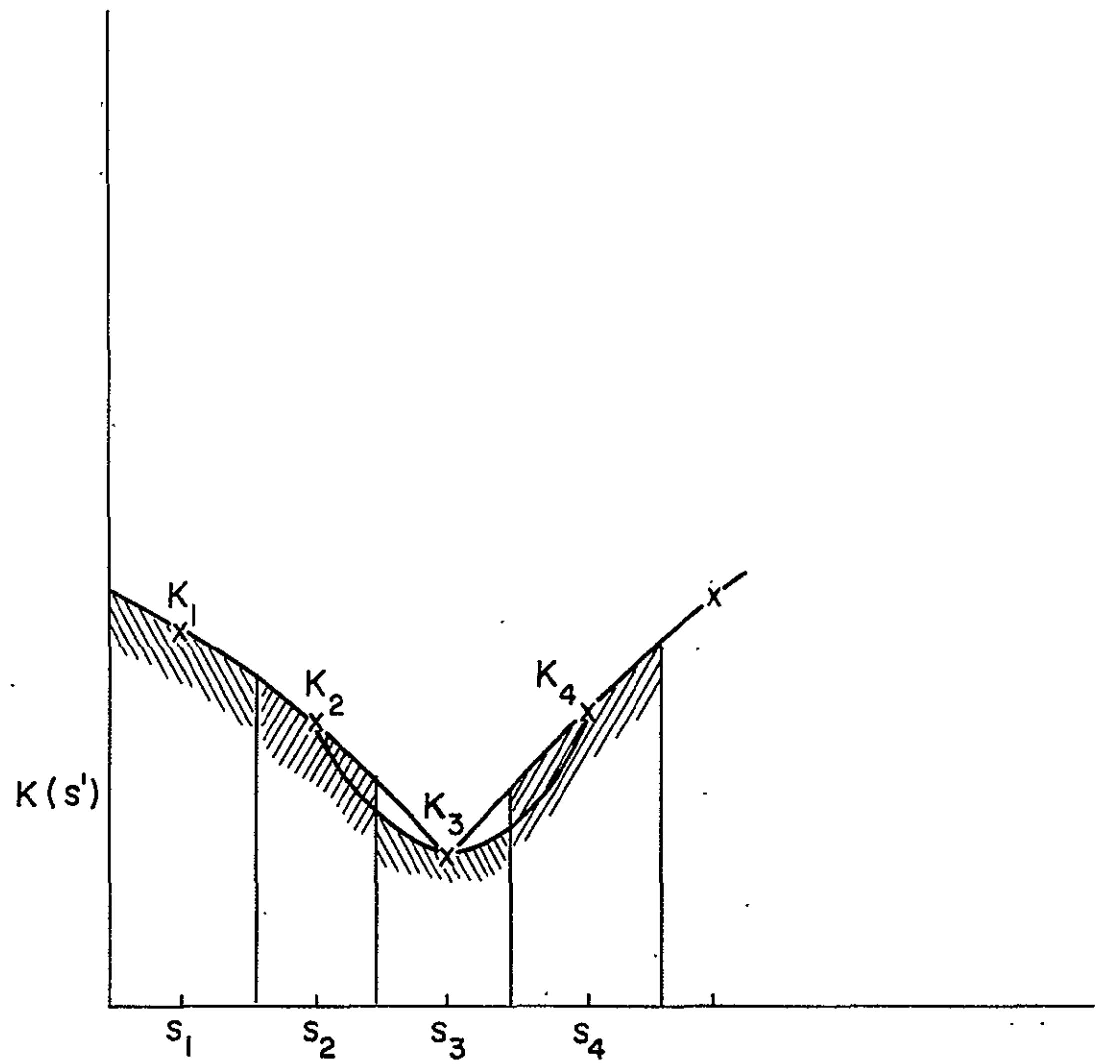
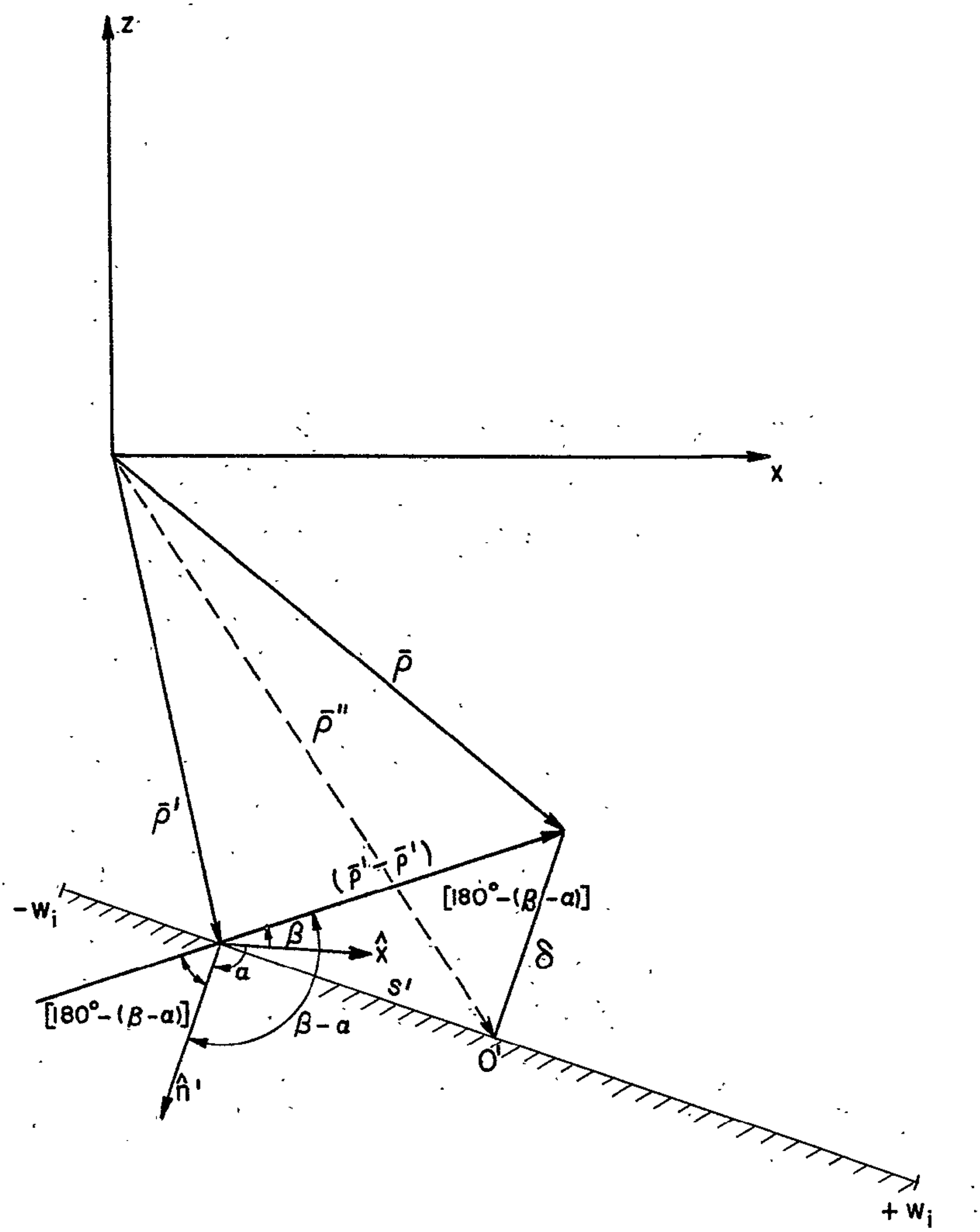
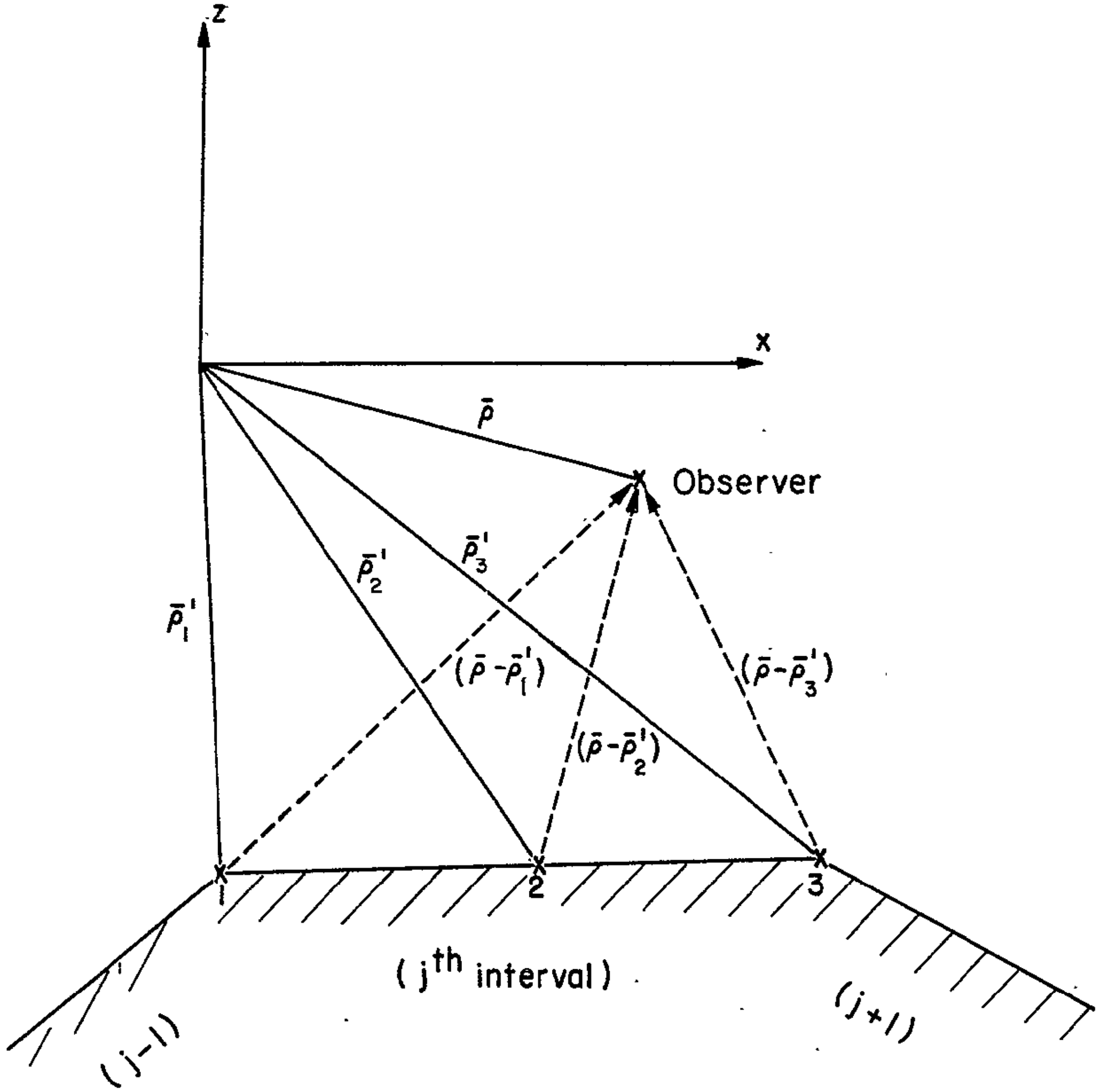


FIG 7



z
x
$\bar{\rho}$
$\bar{\rho}''$
$\bar{\rho}'$
$(\bar{\rho}' - \bar{\rho}')$
[180° − (β − α)]
−w_i
β
$\hat{x}$
δ
α
s'
[180° − (β − α)]
β − α
O'
$\hat{n}'$
+w_i

FIG. 8



z
x
$\bar{\rho}$
Observer
$\bar{\rho}_1'$
$\bar{\rho}_2'$
$\bar{\rho}_3'$
$(\bar{\rho}-\bar{\rho}_1')$
$(\bar{\rho}-\bar{\rho}_2')$
$(\bar{\rho}-\bar{\rho}_3')$
1
2
3
(jth interval)
(j-1)
(j+1)

FIG 9

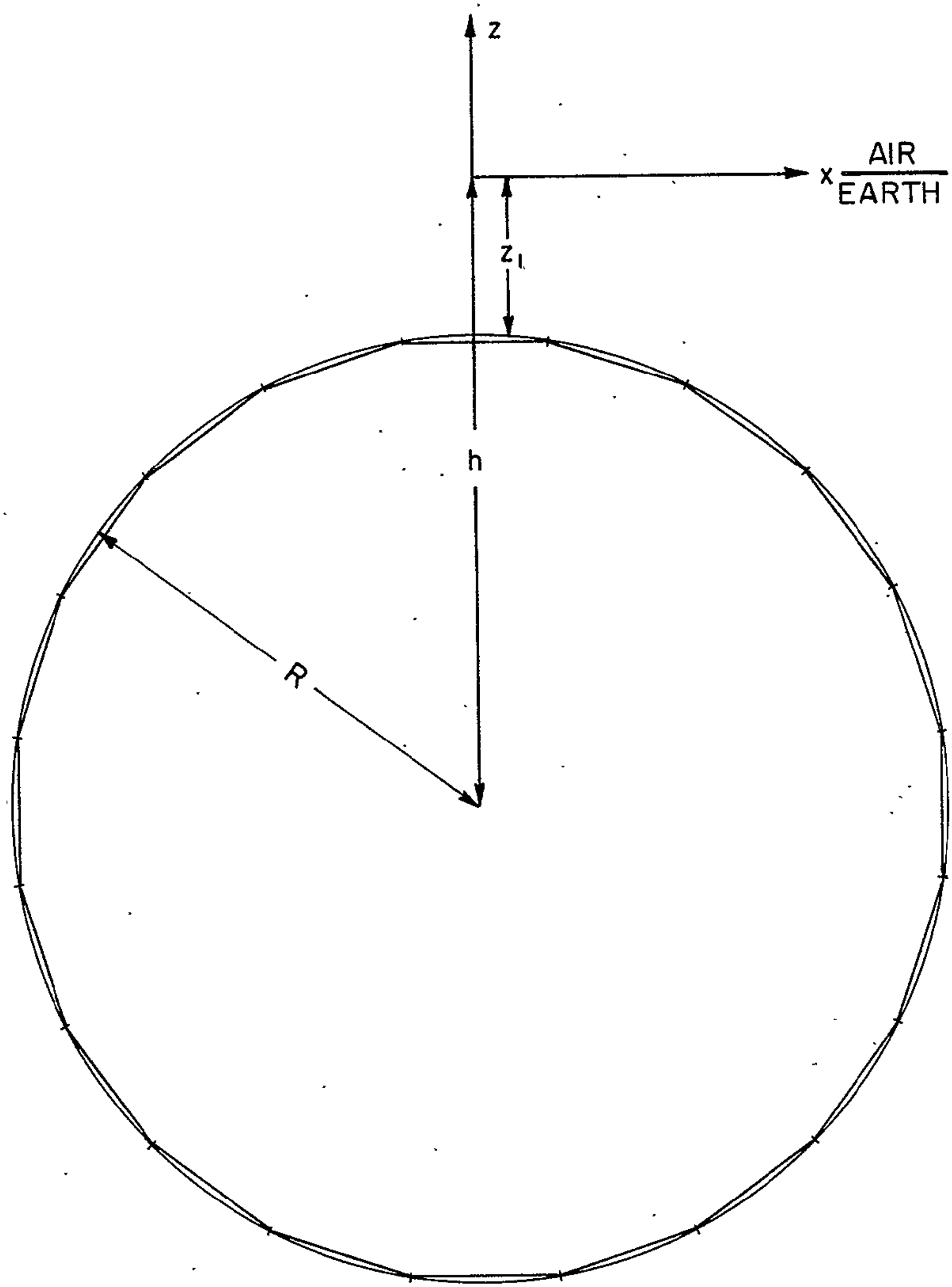
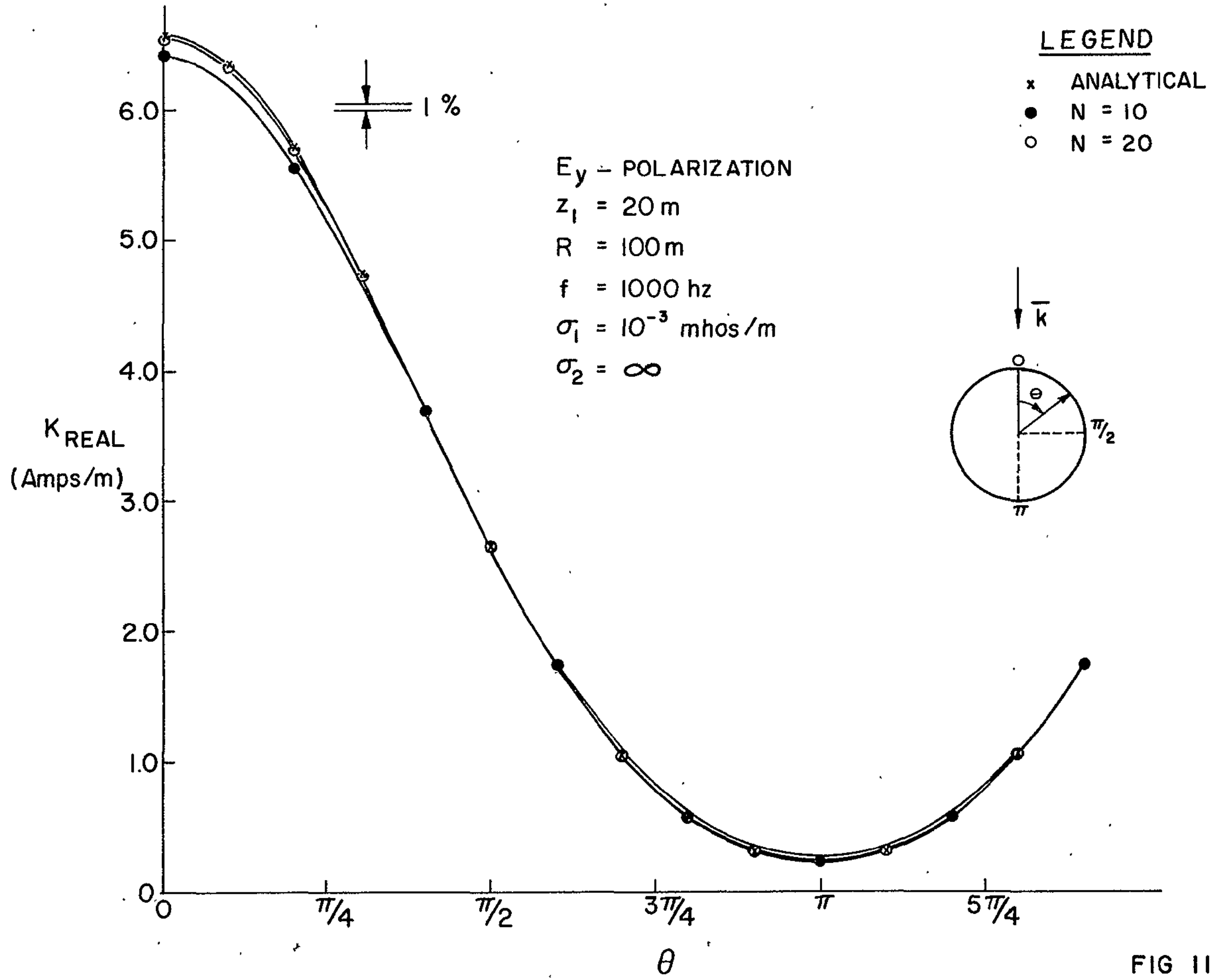


FIG 10



LEGEND
x ANALYTICAL
● N = 10
○ N = 20
1 %
E_y - POLARIZATION
z_1 = 20 m
R = 100 m
f = 1000 hz
$\sigma_1 = 10^{-3}$ mhos/m
$\sigma_2 = \infty$
$\bar{k}$
θ
π/2
π
K_{REAL}
(Amps/m)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
π/4
π/2
3π/4
π
5π/4
θ

FIG 11

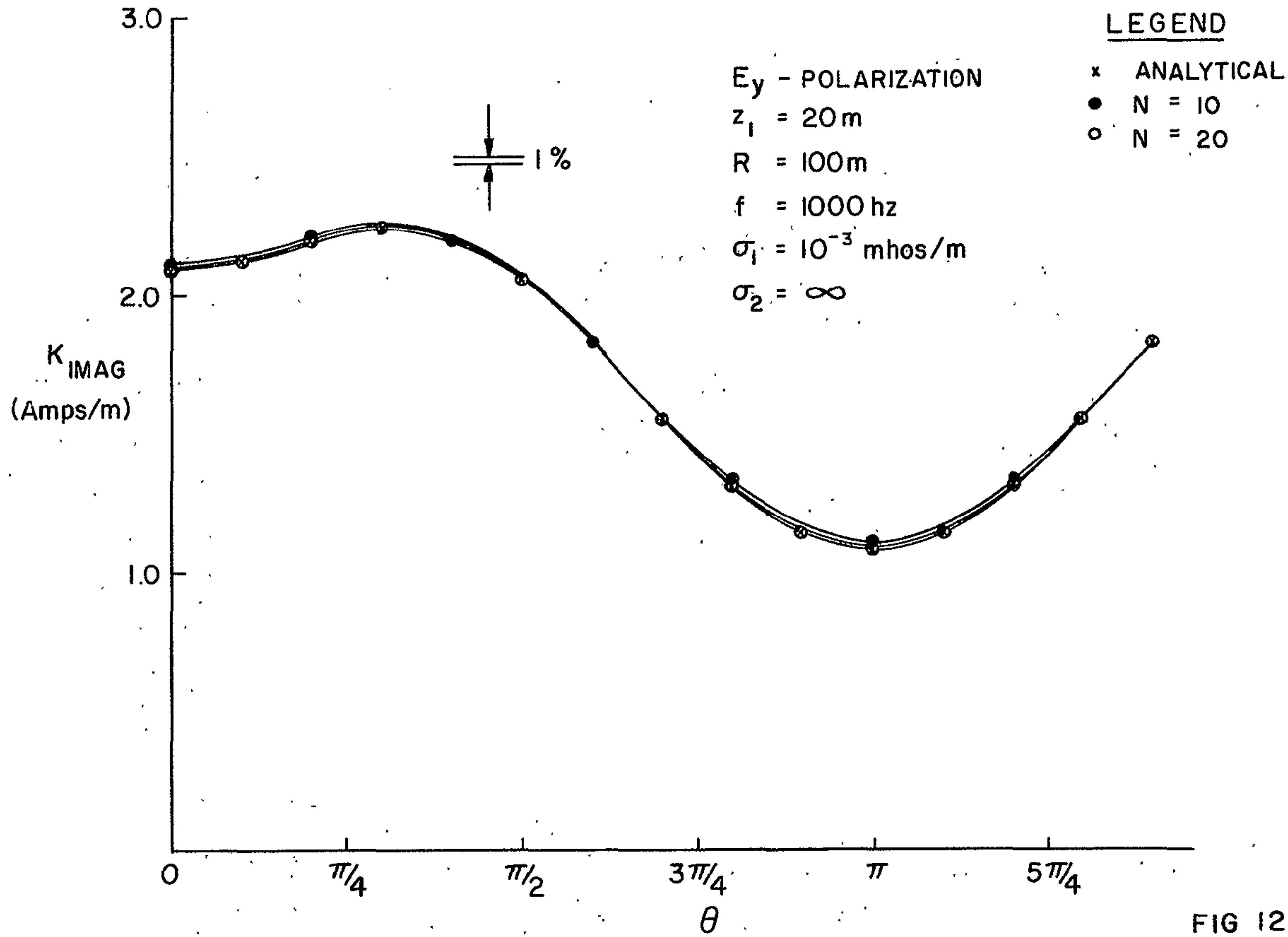
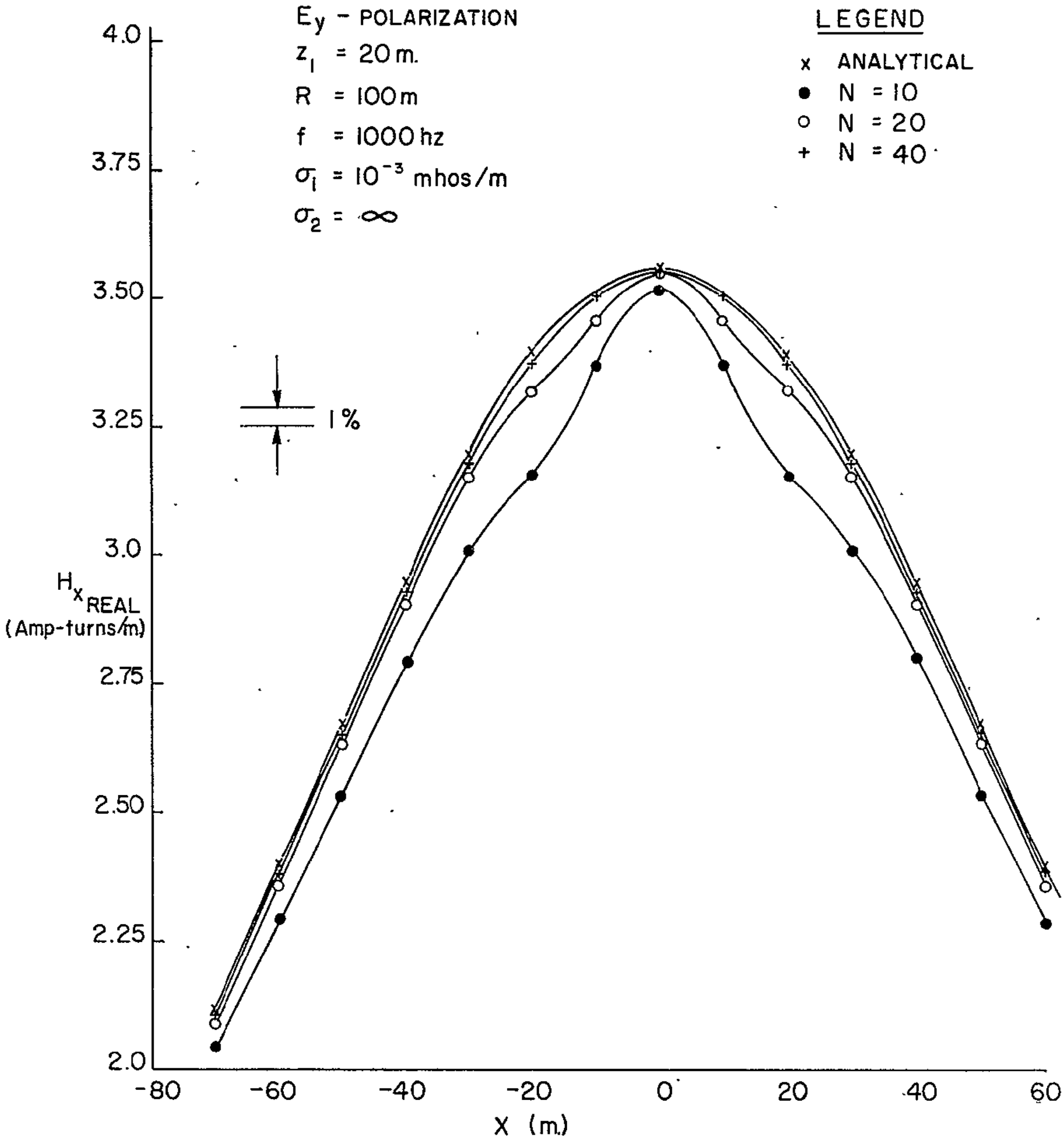

3.0
2.0
1.0
K IMAG
(Amps/m)
0
π/4
π/2
3π/4
π
5π/4
θ
1%
Ey - POLARIZATION
z1 = 20 m
R = 100 m
f = 1000 hz
σ1 = 10^-3 mhos/m
σ2 = ∞
LEGEND
x ANALYTICAL
● N = 10
○ N = 20

FIG 12



E_y - POLARIZATION
z_1 = 20 m.
R = 100 m
f = 1000 hz
$\sigma_1 = 10^{-3}$ mhos/m
$\sigma_2 = \infty$
LEGEND
x ANALYTICAL
● N = 10
○ N = 20
+ N = 40
1%
4.0
3.75
3.50
3.25
3.0
2.75
2.50
2.25
2.0
$H_{x_{REAL}}$
(Amp-turns/m)
-80
-60
-40
-20
0
20
40
60
X (m.)

FIG 13

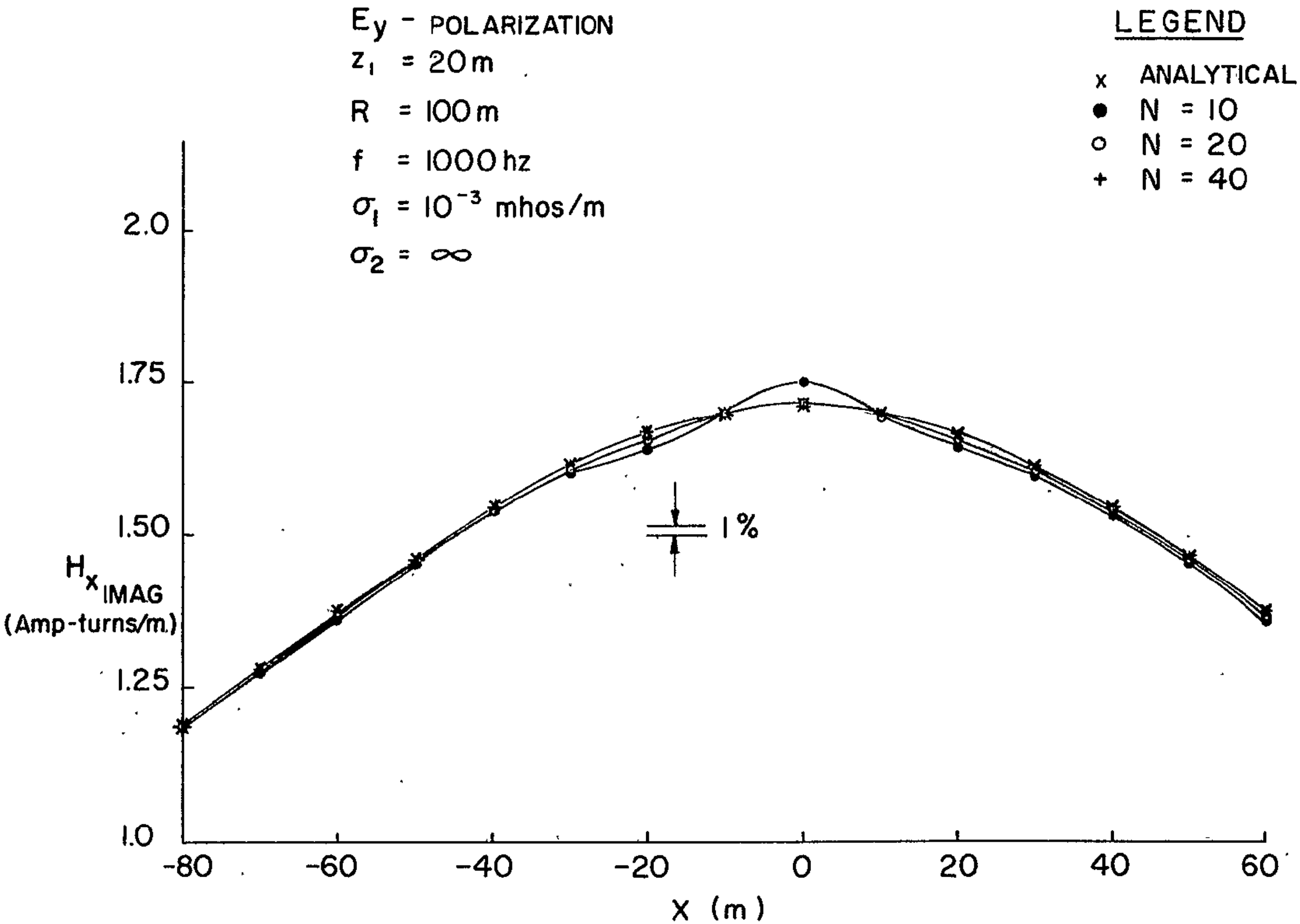
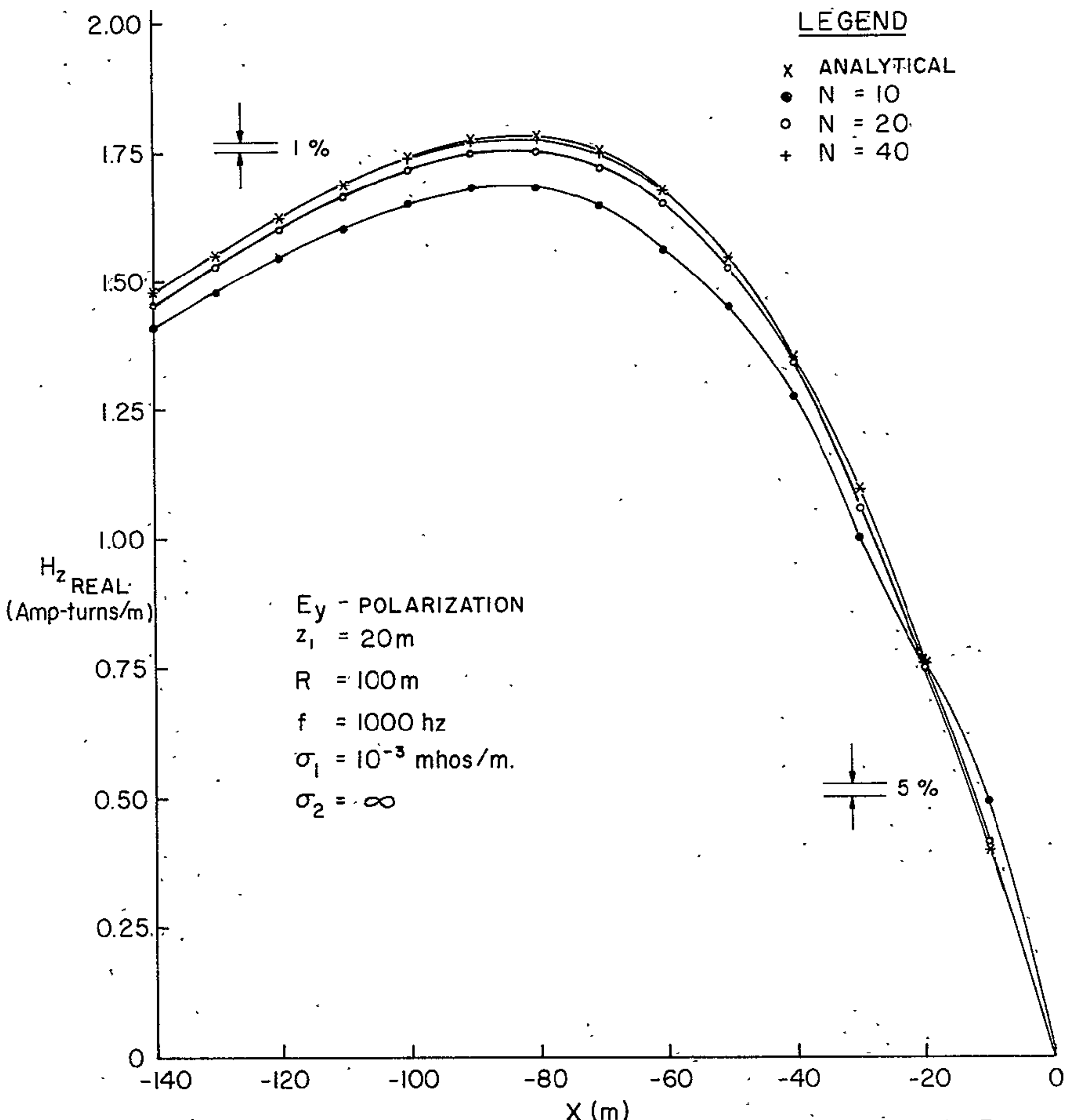

Ey - POLARIZATION
z1 = 20 m
R = 100 m
f = 1000 hz
σ1 = 10^-3 mhos/m
σ2 = ∞
LEGEND
x ANALYTICAL
● N = 10
○ N = 20
+ N = 40
2.0
1.75
1.50
1.25
1.0
Hx IMAG
(Amp-turns/m.)
1 %
-80
-60
-40
-20
0
20
40
60
X (m)

FIG 14



LEGEND
x ANALYTICAL
● N = 10
o N = 20
+ N = 40
1 %
5 %
E_y - POLARIZATION
z_1 = 20m
R = 100m
f = 1000 hz
$\sigma_1 = 10^{-3}$ mhos/m.
$\sigma_2 = \infty$
H_z REAL (Amp-turns/m)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0
-140
-120
-100
-80
-60
-40
-20
0
X (m)

FIG 15

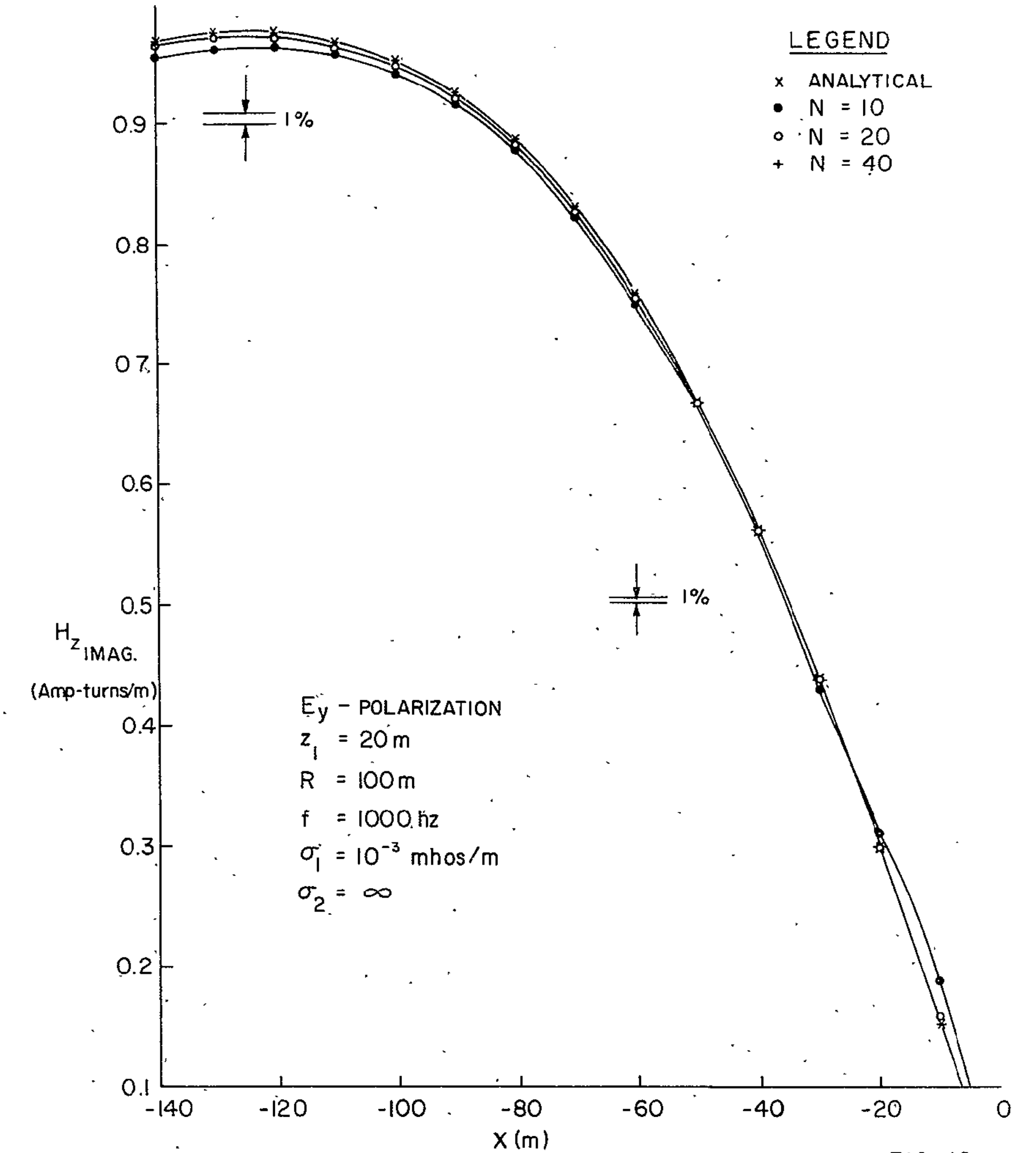
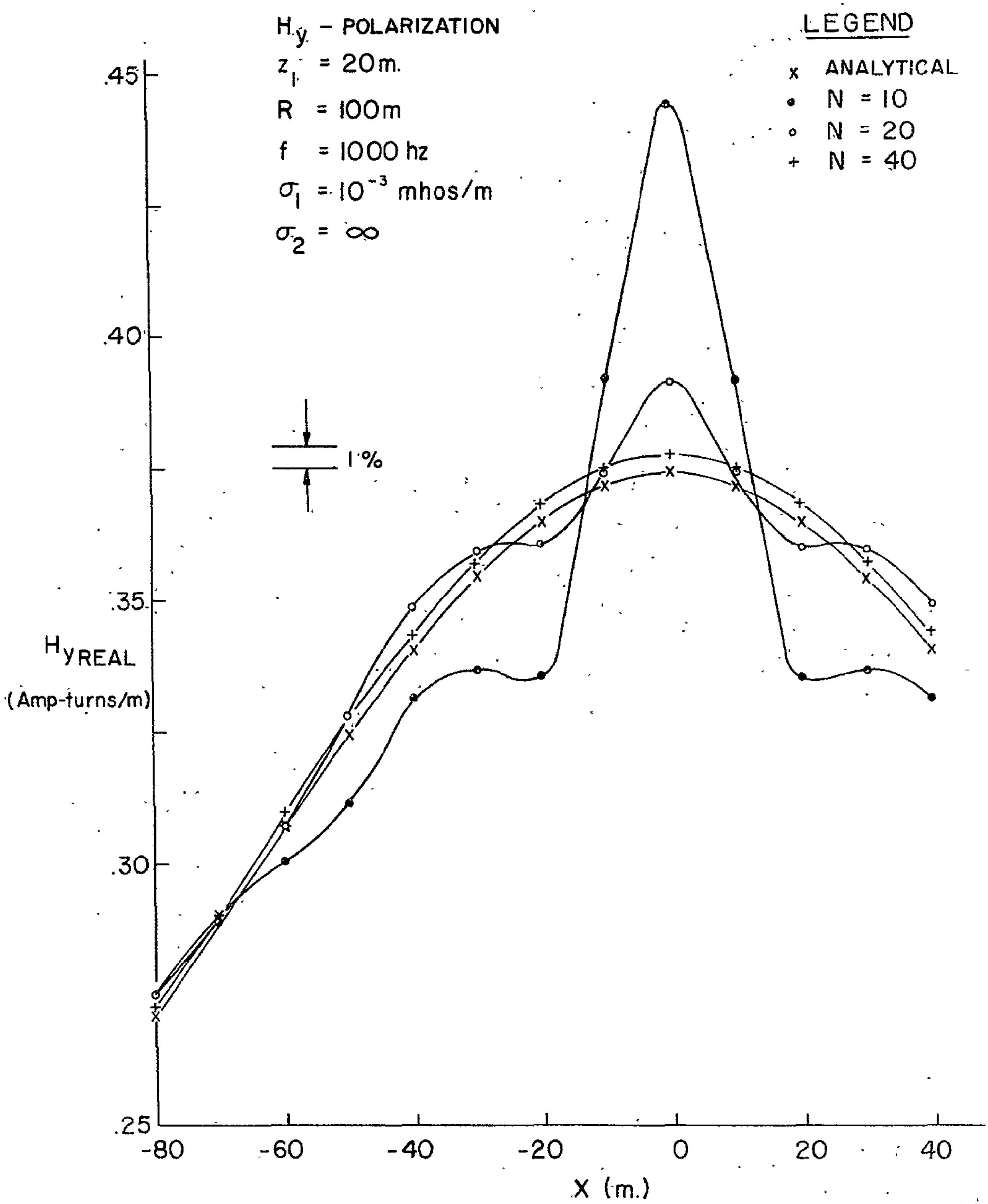
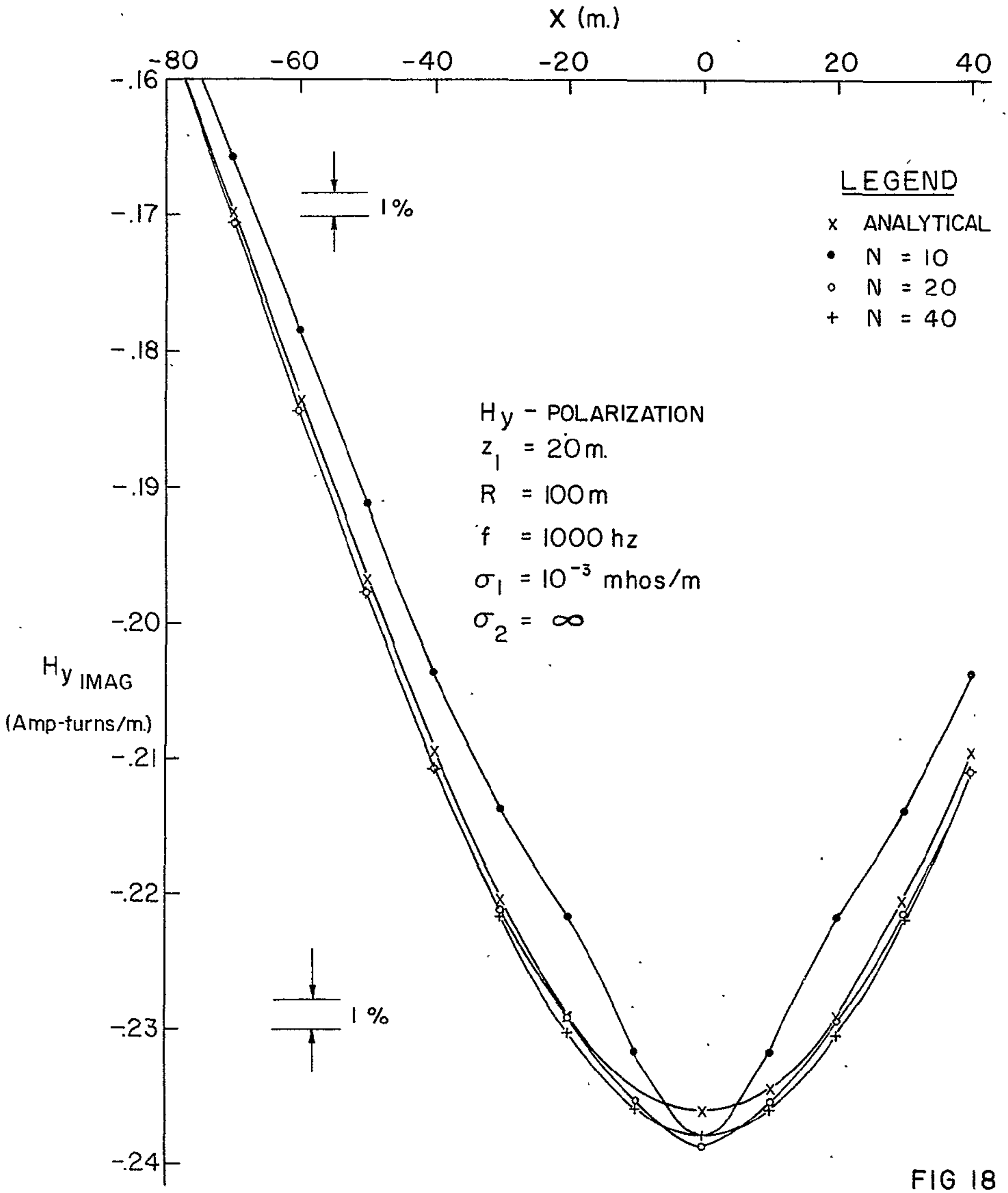

LEGEND
x ANALYTICAL
● N = 10
○ N = 20
+ N = 40
1%
1%
$H_{z\,IMAG.}$
(Amp-turns/m)
E_y – POLARIZATION
z_1 = 20 m
R = 100 m
f = 1000 hz
$\sigma_1 = 10^{-3}$ mhos/m
$\sigma_2 = \infty$
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-140
-120
-100
-80
-60
-40
-20
0
X (m)

FIG 16



Hy - POLARIZATION
z1 = 20m.
R = 100m
f = 1000 hz
σ1 = 10^-3 mhos/m
σ2 = ∞
LEGEND
x ANALYTICAL
• N = 10
o N = 20
+ N = 40
1%
.45
.40
.35
.30
.25
Hy REAL
(Amp-turns/m)
-80
-60
-40
-20
0
20
40
X (m.)

FIG 17



X (m.)
-80
-60
-40
-20
0
20
40
-.16
-.17
-.18
-.19
-.20
-.21
-.22
-.23
-.24
Hy IMAG
(Amp-turns/m.)
1%
1 %
LEGEND
x ANALYTICAL
• N = 10
∘ N = 20
+ N = 40
Hy - POLARIZATION
z1 = 20 m.
R = 100 m
f = 1000 hz
σ1 = 10^-3 mhos/m
σ2 = ∞

FIG 18

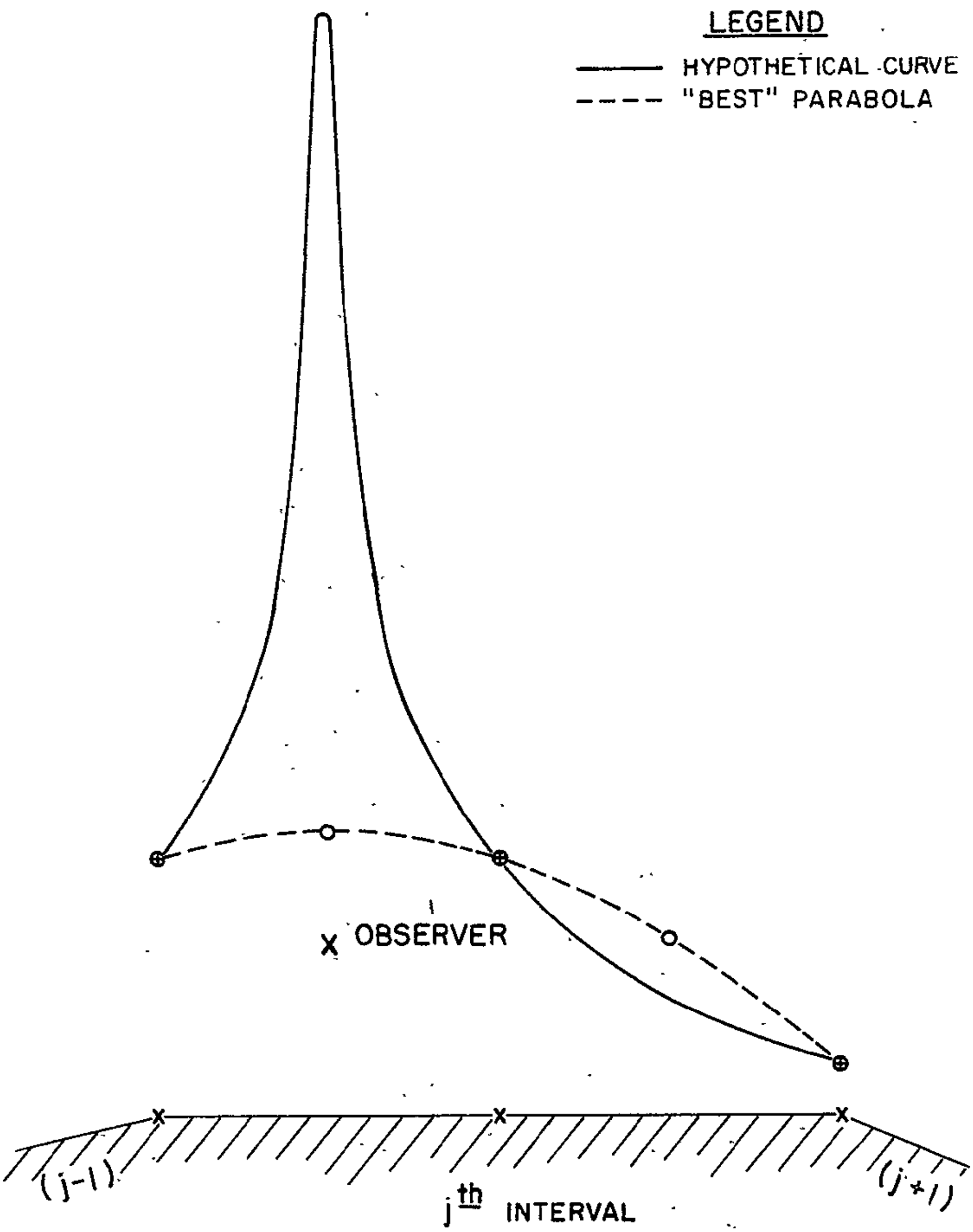

LEGEND
HYPOTHETICAL CURVE
"BEST" PARABOLA
X OBSERVER
(j-1)
j th INTERVAL
(j+1)

FIG 19

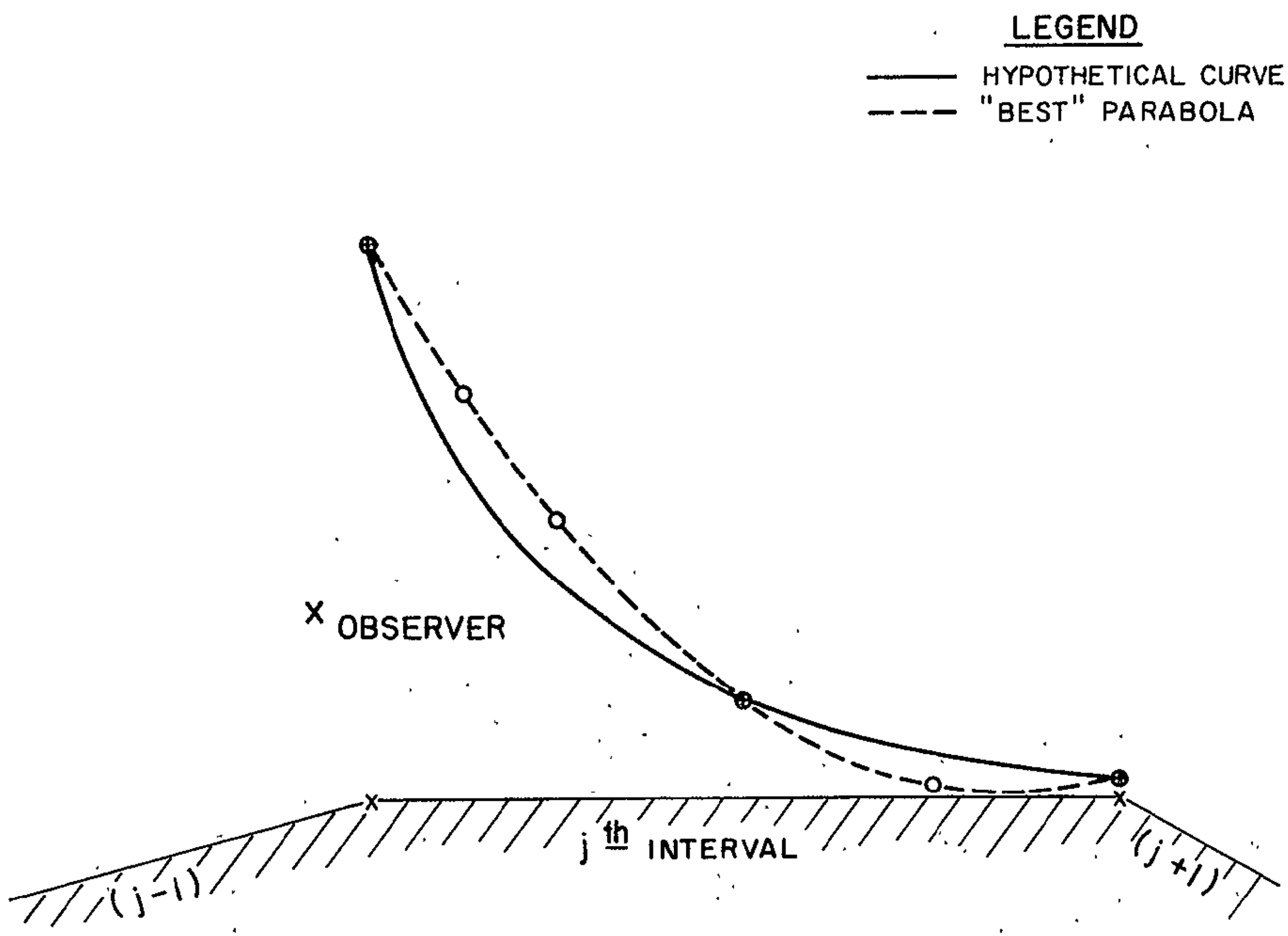

LEGEND
HYPOTHETICAL CURVE
"BEST" PARABOLA
X OBSERVER
j th INTERVAL
(j-1)
(j+1)

FIG 20

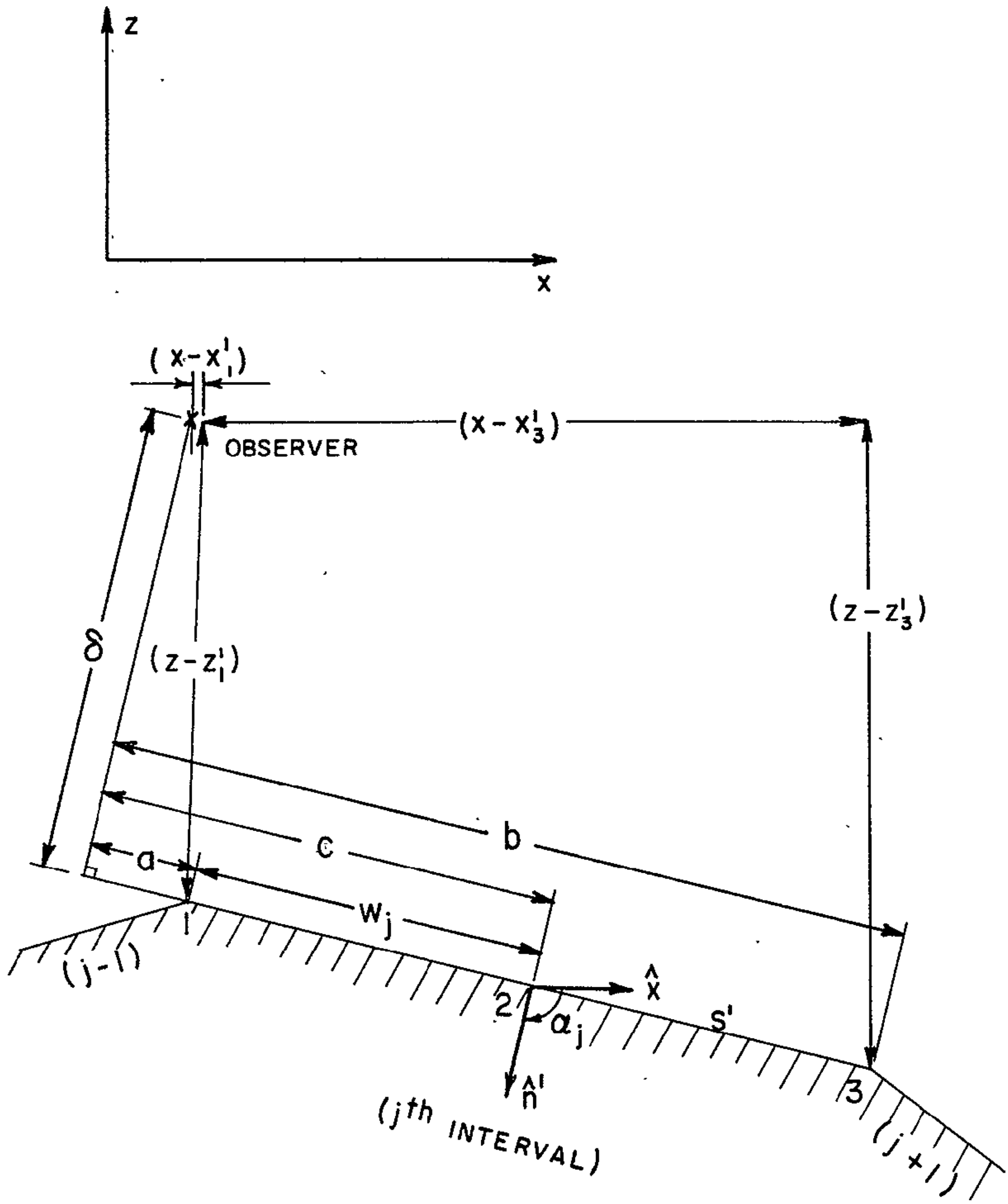

z
x
(x − x'₁)
OBSERVER
(x − x'₃)
δ
(z − z'₁)
(z − z'₃)
b
c
a
Wj
1
2
3
(j−1)
x̂
αj
s'
n̂'
(jth INTERVAL)
(j+1)

FIG 21

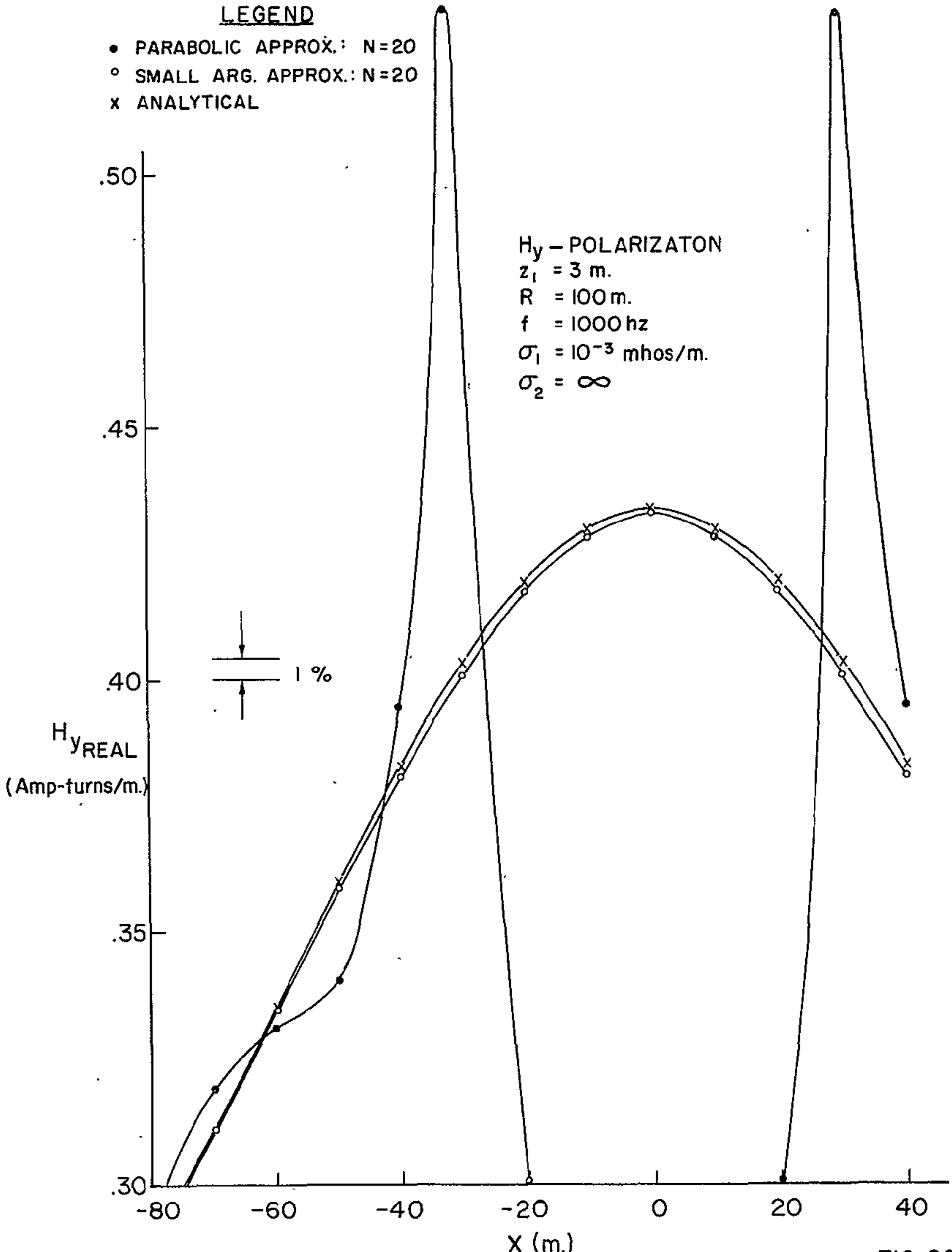
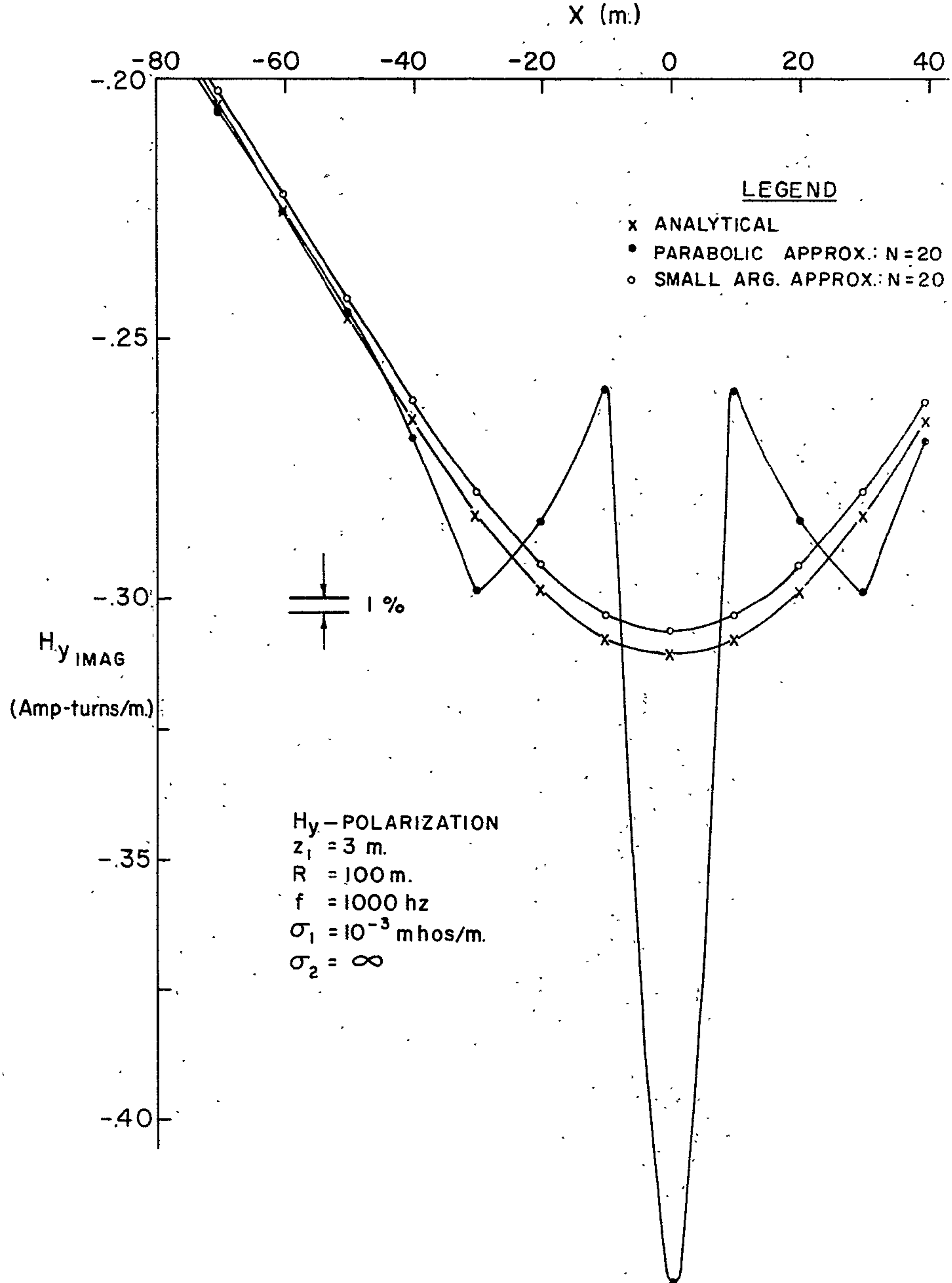

LEGEND
• PARABOLIC APPROX.: N=20
○ SMALL ARG. APPROX.: N=20
x ANALYTICAL
Hy – POLARIZATON
z1 = 3 m.
R = 100 m.
f = 1000 hz
σ1 = 10^-3 mhos/m.
σ2 = ∞
1 %
Hy REAL
(Amp-turns/m.)
.50
.45
.40
.35
.30
-80
-60
-40
-20
0
20
40
X (m.)

FIG 22



X (m.)
-80
-60
-40
-20
0
20
40
-.20
-.25
-.30
-.35
-.40
LEGEND
x ANALYTICAL
• PARABOLIC APPROX.: N=20
o SMALL ARG. APPROX.: N=20
1 %
Hy IMAG
(Amp-turns/m.)
Hy – POLARIZATION
z1 = 3 m.
R = 100 m.
f = 1000 hz
σ1 = 10⁻³ mhos/m.
σ2 = ∞

FIG 23

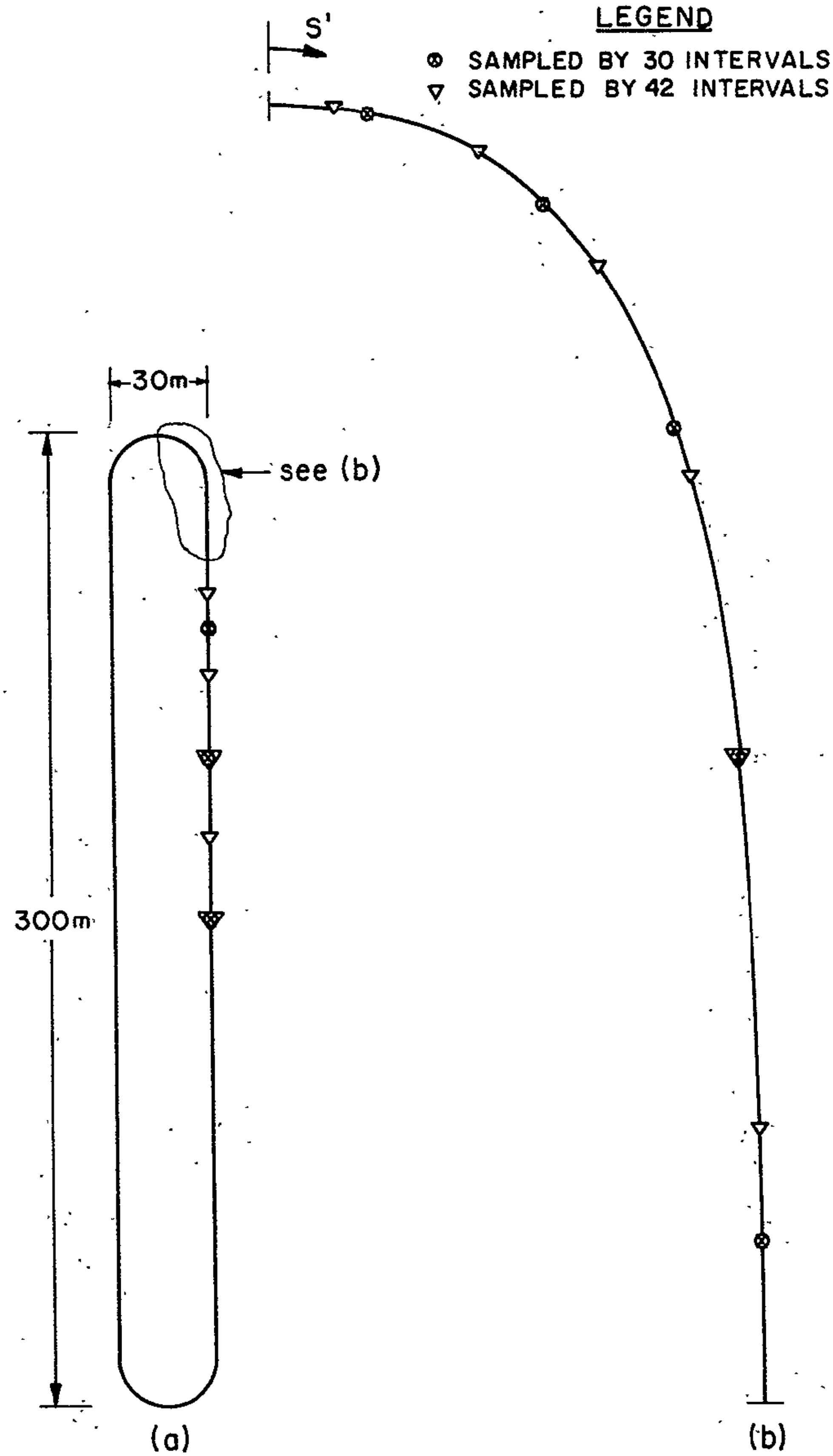
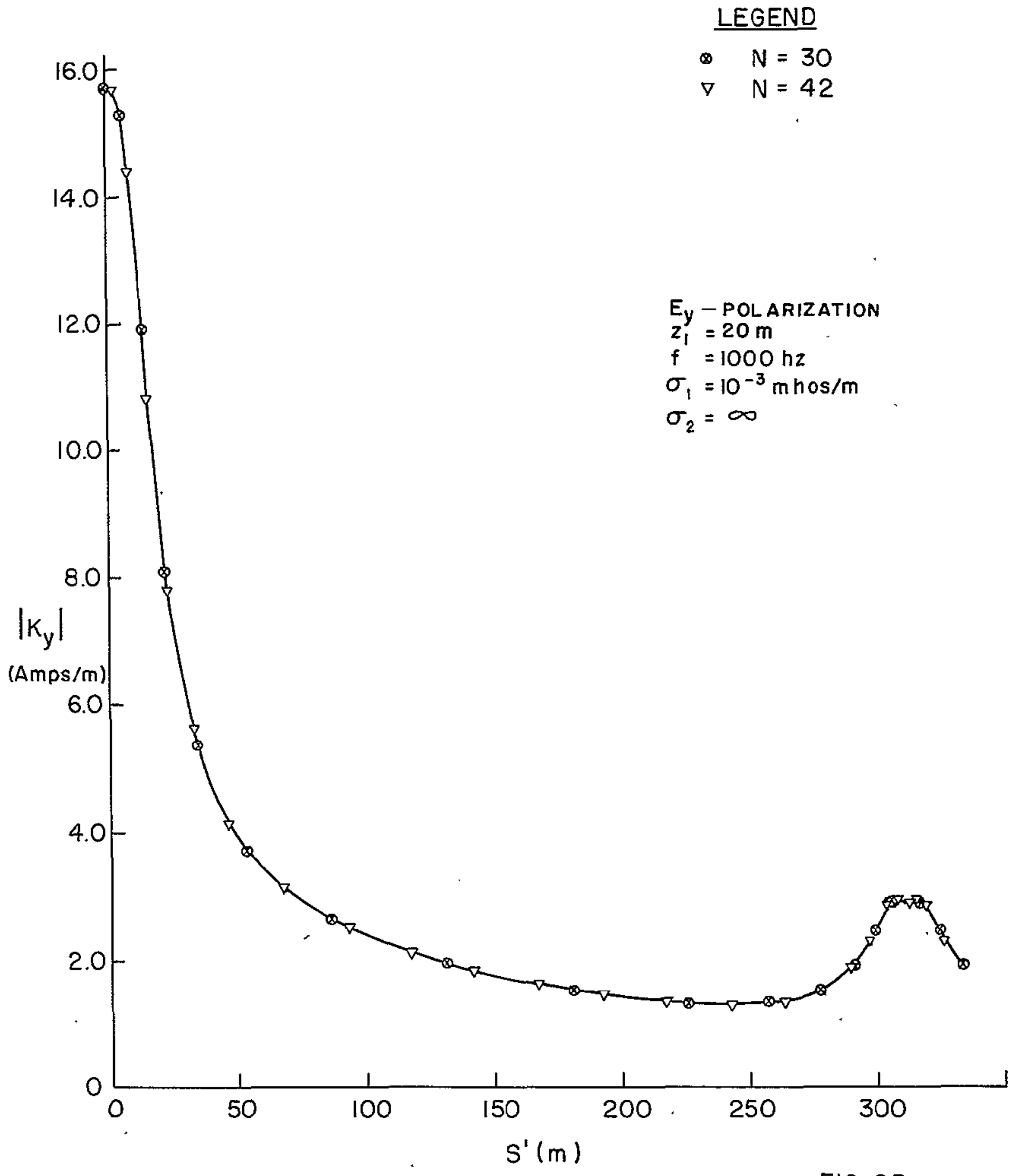

LEGEND
SAMPLED BY 30 INTERVALS
SAMPLED BY 42 INTERVALS
S'
30m
see (b)
300m
(a)
(b)

FIG 24



LEGEND
⊗ N = 30
▽ N = 42
E_y — POLARIZATION
z_1 = 20 m
f = 1000 hz
$\sigma_1 = 10^{-3}$ mhos/m
$\sigma_2 = \infty$
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
$|K_y|$
(Amps/m)
0
50
100
150
200
250
300
S' (m)

FIG 25

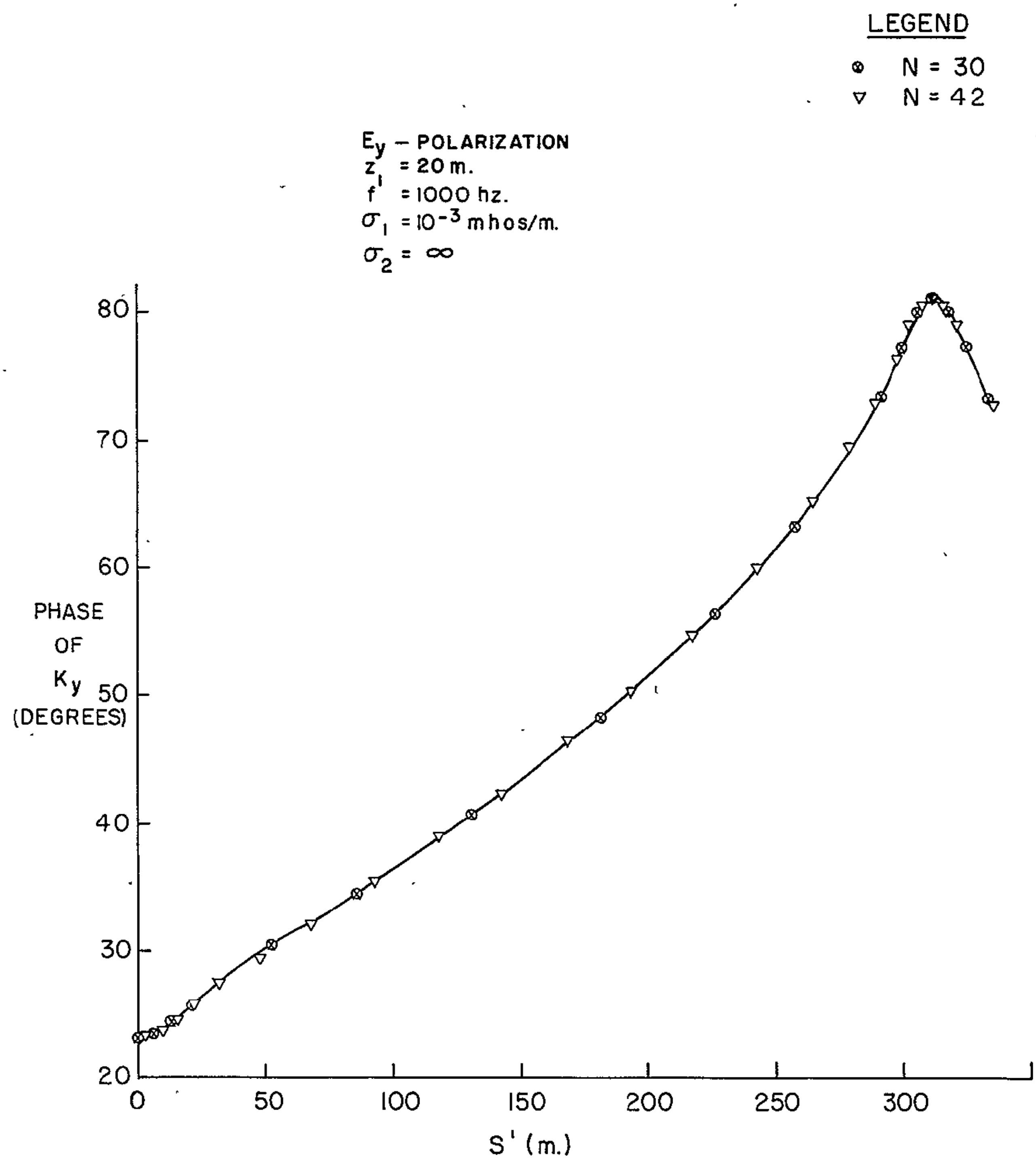
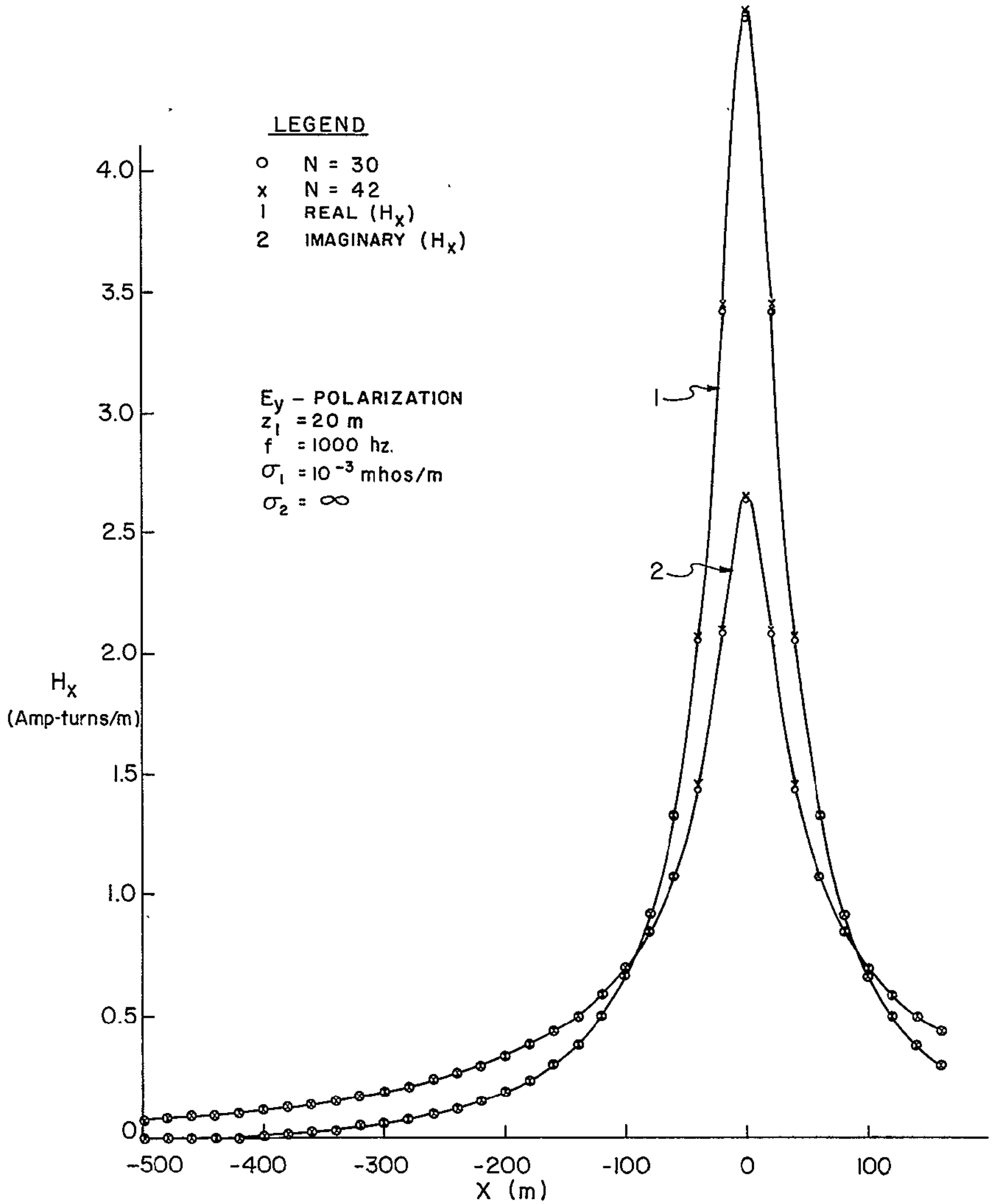

LEGEND
N = 30
N = 42
Ey – POLARIZATION
z' = 20 m.
f' = 1000 hz.
σ1 = 10^-3 mhos/m.
σ2 = ∞
PHASE OF Ky (DEGREES)
80
70
60
50
40
30
20
0
50
100
150
200
250
300
S' (m.)

FIG 26



LEGEND
o N = 30
x N = 42
1 REAL (H_x)
2 IMAGINARY (H_x)
E_y - POLARIZATION
z_1 = 20 m
f = 1000 hz.
σ_1 = 10^{-3} mhos/m
σ_2 = ∞
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
H_x
(Amp-turns/m)
1
2
-500
-400
-300
-200
-100
0
100
X (m)

FIG 27

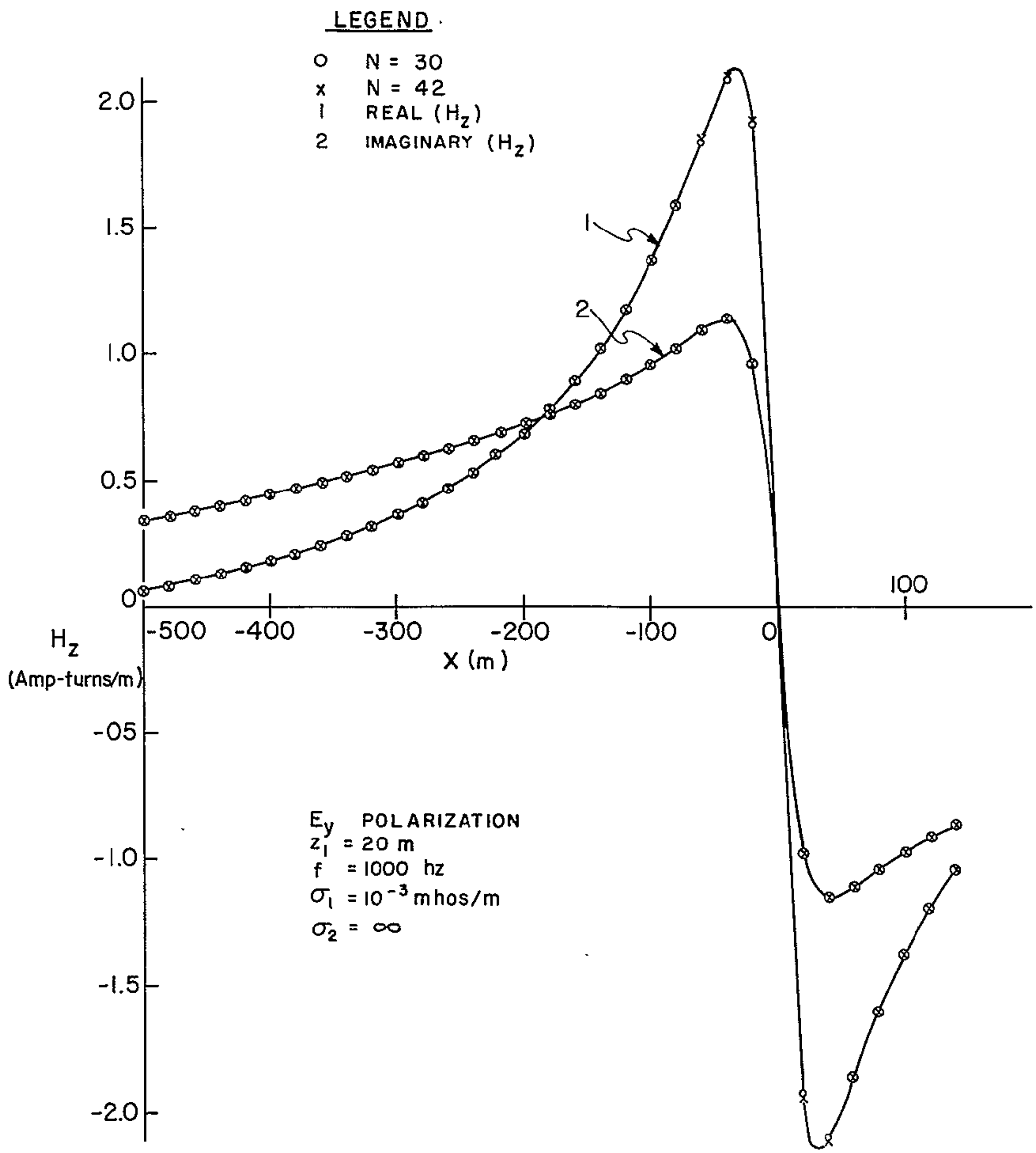

LEGEND
o N = 30
x N = 42
1 REAL (H_z)
2 IMAGINARY (H_z)
2.0
1.5
1.0
0.5
0
-05
-1.0
-1.5
-2.0
H_z
(Amp-turns/m)
-500
-400
-300
-200
-100
0
100
X (m)
1
2
E_y POLARIZATION
z_1 = 20 m
f = 1000 hz
σ_1 = 10^{-3} mhos/m
σ_2 = ∞

FIG 28

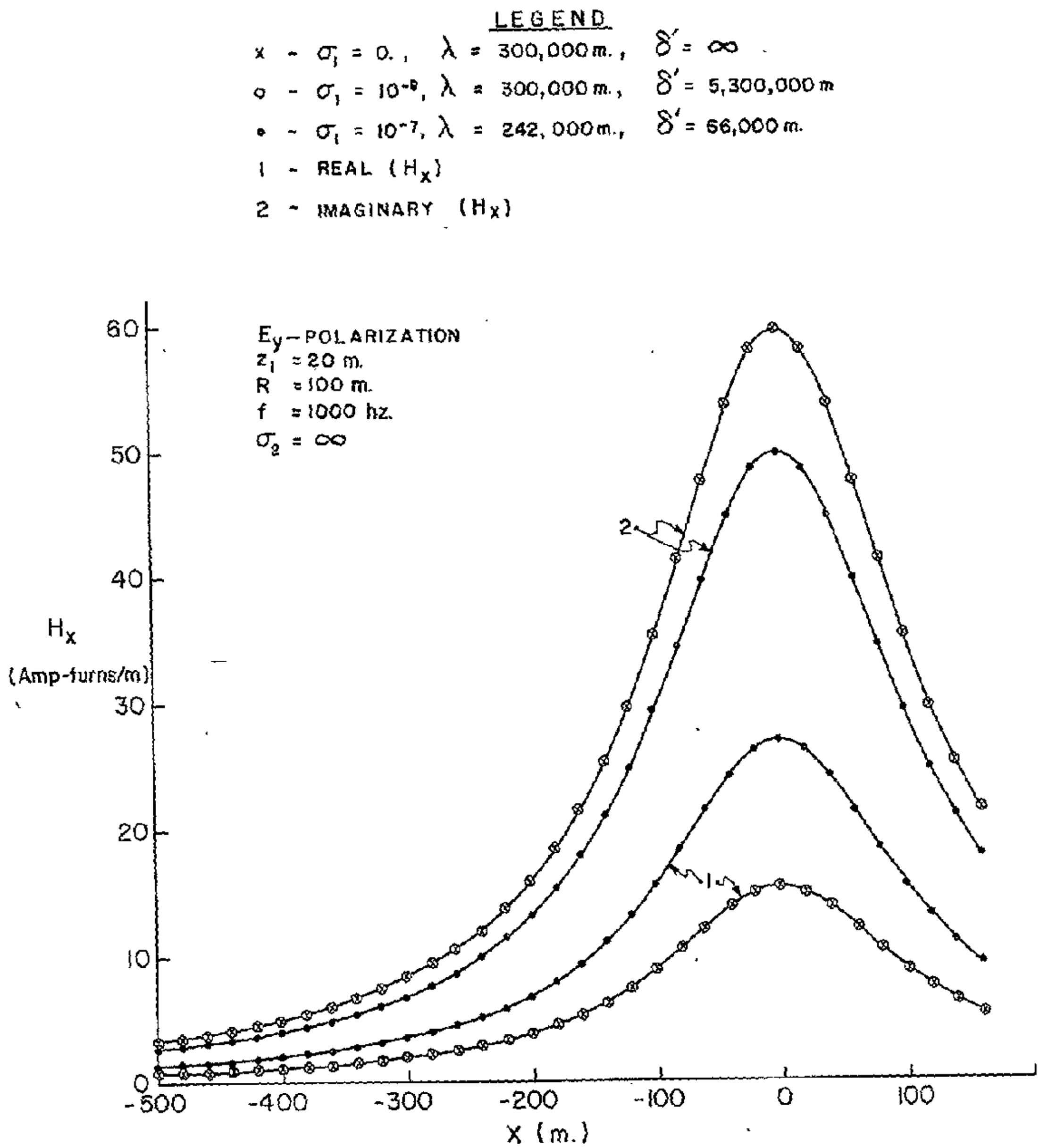

LEGEND
x - σ1 = 0., λ = 300,000 m., δ' = ∞
o - σ1 = 10⁻⁸, λ = 300,000 m., δ' = 5,300,000 m
• - σ1 = 10⁻⁷, λ = 242,000 m., δ' = 66,000 m.
1 - REAL (Hx)
2 - IMAGINARY (Hx)
Ey - POLARIZATION
z1 = 20 m.
R = 100 m.
f = 1000 hz.
σ2 = ∞
Hx
(Amp-turns/m)
X (m.)
60
50
40
30
20
10
0
-500
-400
-300
-200
-100
0
100
1
2

FIG 29

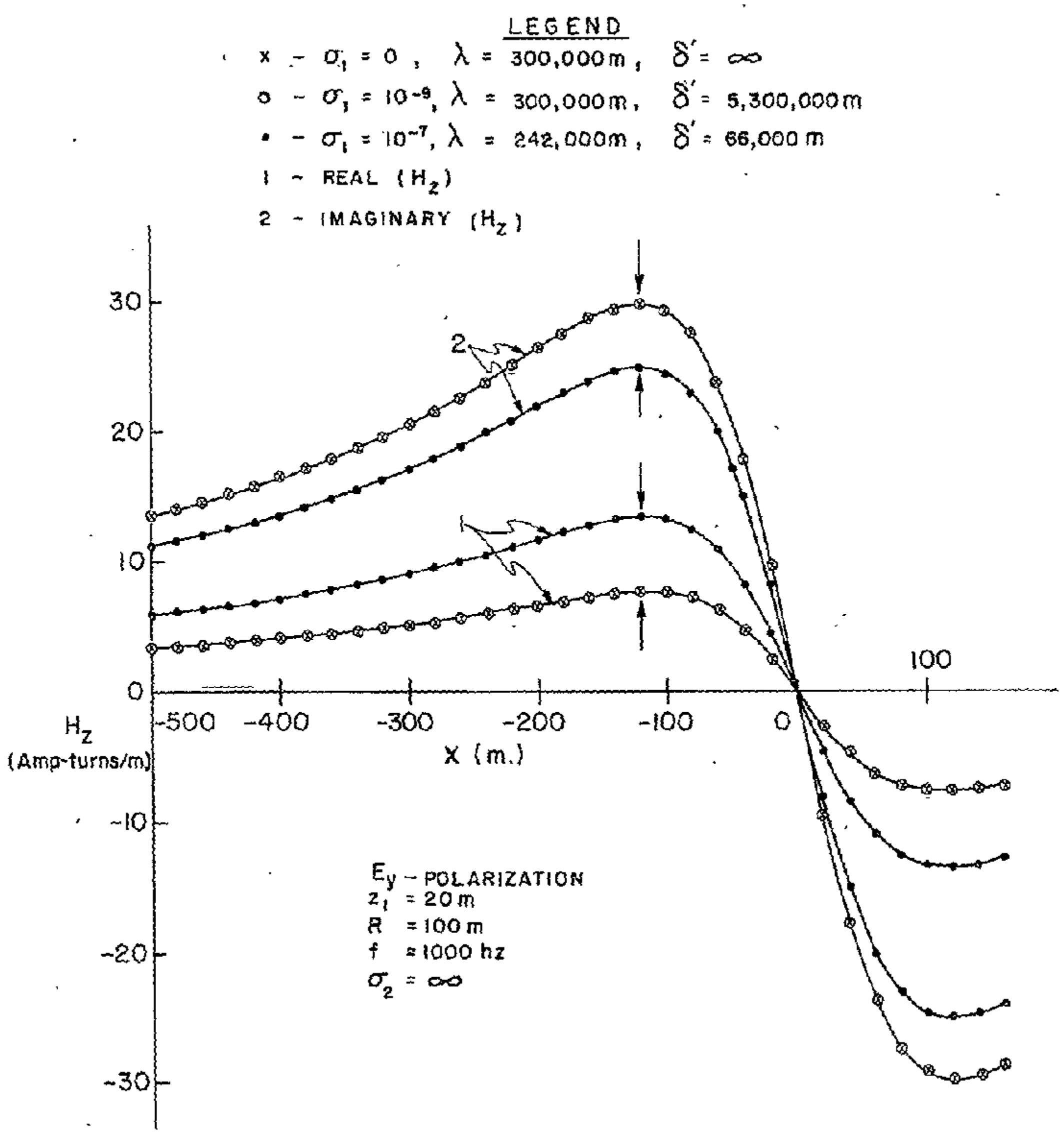
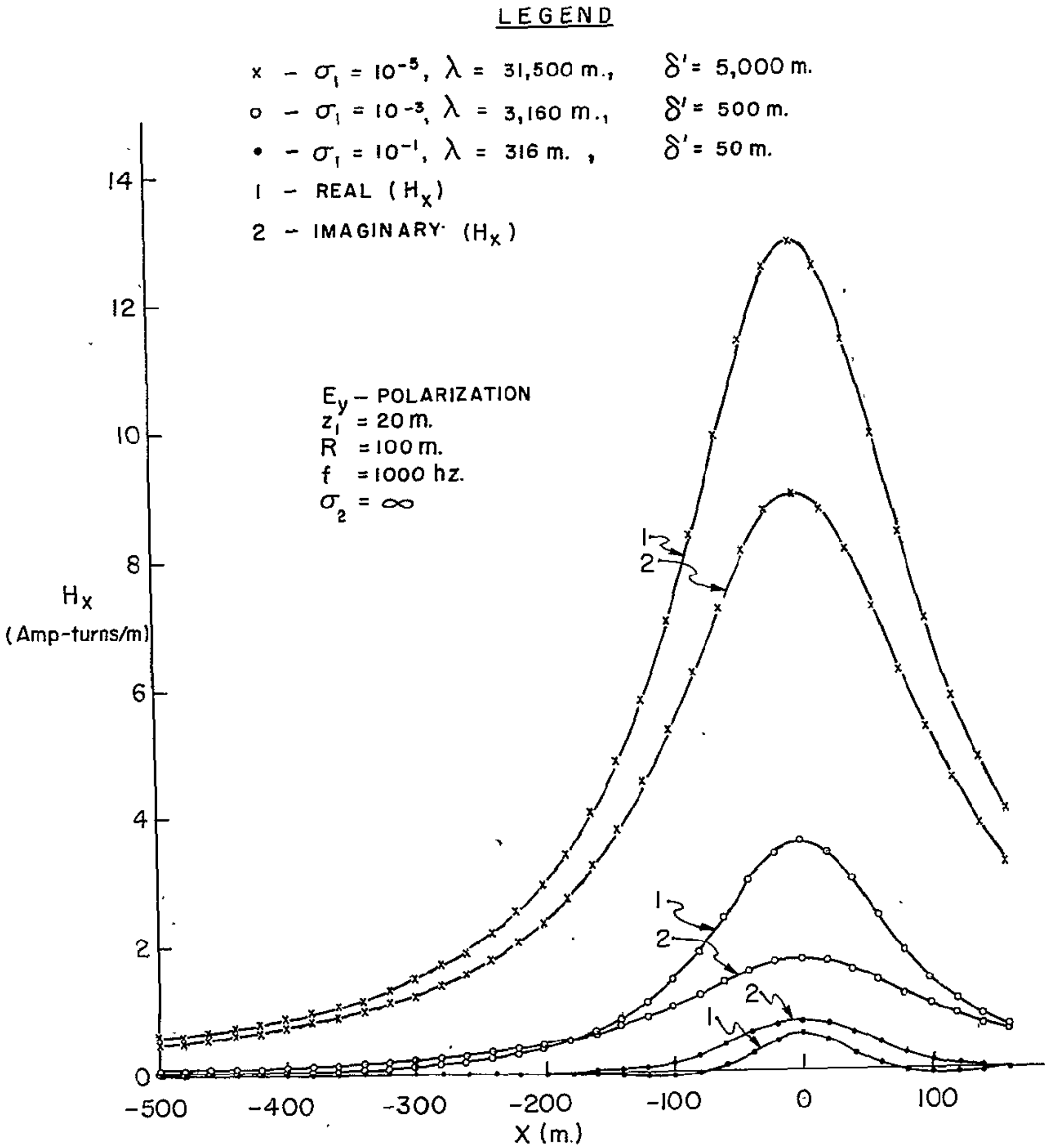

LEGEND
x – σ_1 = 0 , λ = 300,000 m , δ' = ∞
o – σ_1 = 10^{-9}, λ = 300,000 m , δ' = 5,300,000 m
• – σ_1 = 10^{-7}, λ = 242,000 m , δ' = 66,000 m
1 – REAL (H_z)
2 – IMAGINARY (H_z)
30
20
10
0
-10
-20
-30
H_z
(Amp-turns/m)
-500
-400
-300
-200
-100
0
100
X (m.)
2
1
E_y – POLARIZATION
z_1 = 20 m
R = 100 m
f = 1000 hz
σ_2 = ∞

FIG 30



LEGEND
x – $\sigma_1 = 10^{-5}$, λ = 31,500 m., δ' = 5,000 m.
o – $\sigma_1 = 10^{-3}$, λ = 3,160 m., δ' = 500 m.
• – $\sigma_1 = 10^{-1}$, λ = 316 m., δ' = 50 m.
1 – REAL (H_x)
2 – IMAGINARY (H_x)
E_y – POLARIZATION
z_1 = 20 m.
R = 100 m.
f = 1000 hz.
$\sigma_2 = \infty$
H_x
(Amp-turns/m)
X (m.)

FIG 31

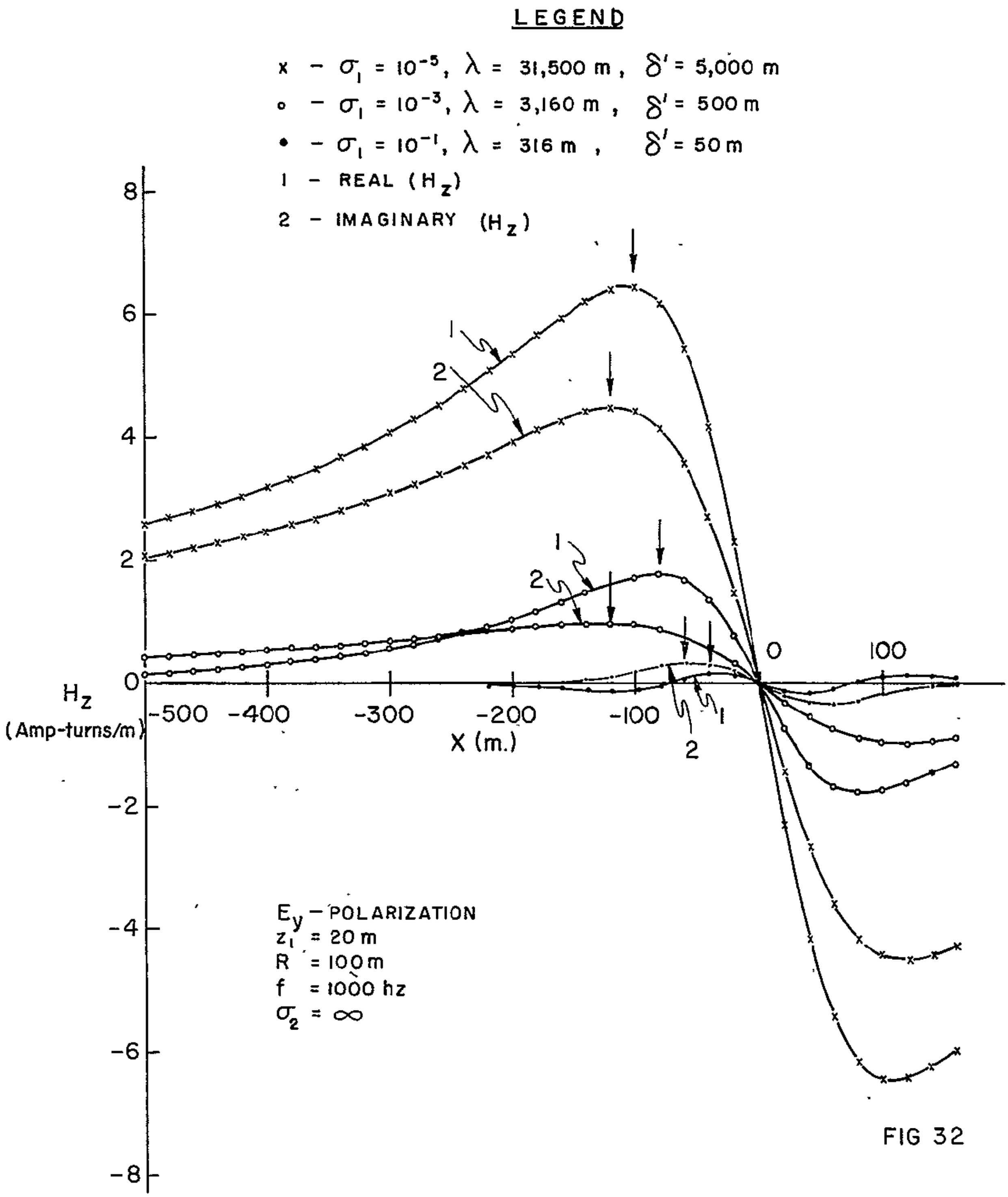

LEGEND
x – σ₁ = 10⁻⁵, λ = 31,500 m, δ' = 5,000 m
o – σ₁ = 10⁻³, λ = 3,160 m, δ' = 500 m
• – σ₁ = 10⁻¹, λ = 316 m, δ' = 50 m
1 – REAL (Hz)
2 – IMAGINARY (Hz)
Hz (Amp-turns/m)
X (m.)
Ey – POLARIZATION
z₁ = 20 m
R = 100 m
f = 1000 hz
σ₂ = ∞

FIG 32

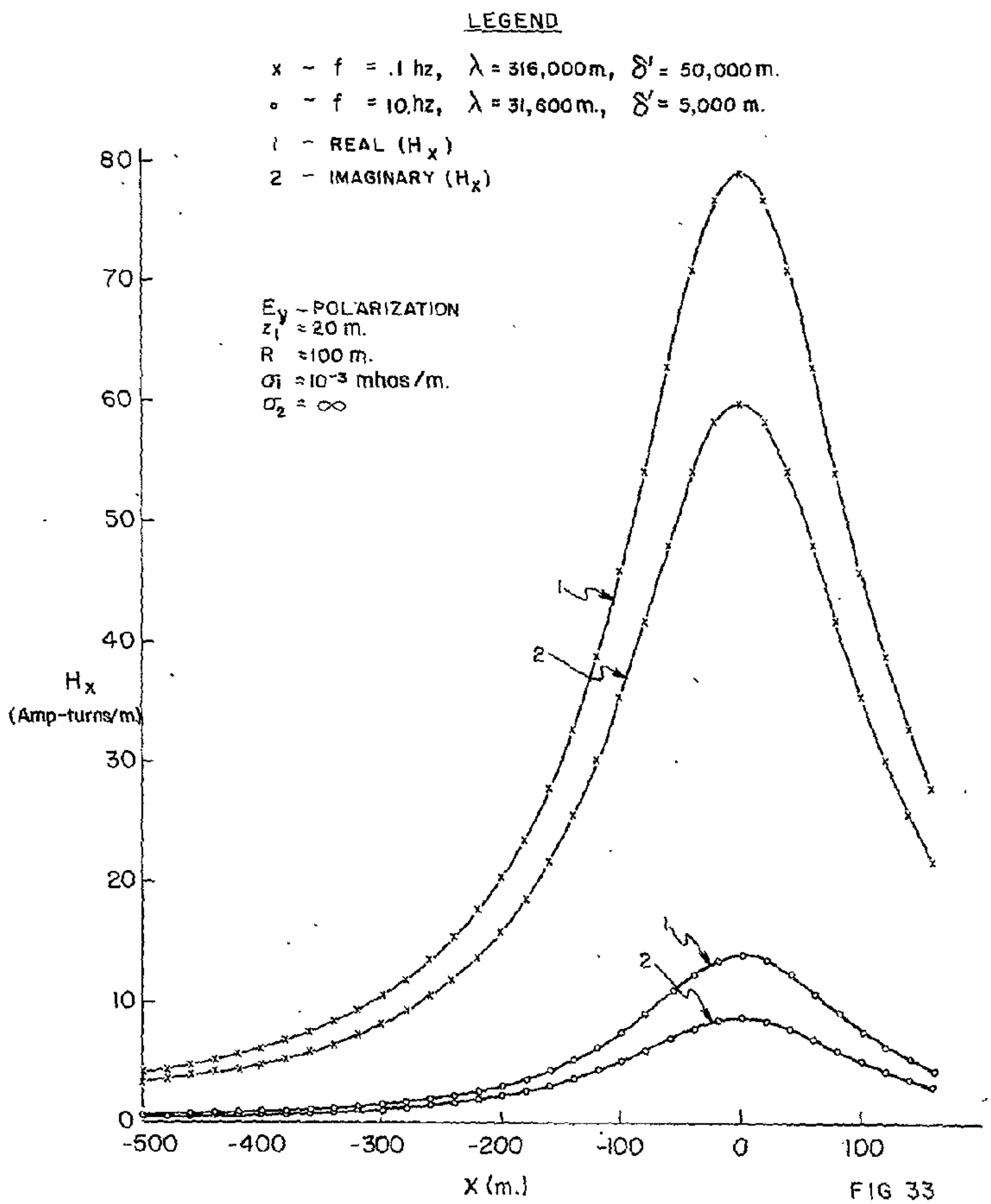

LEGEND
x ~ f = .1 hz, λ = 316,000 m, δ' = 50,000 m.
∘ ~ f = 10 hz, λ = 31,600 m., δ' = 5,000 m.
1 - REAL (Hx)
2 - IMAGINARY (Hx)
Ey - POLARIZATION
z1 = 20 m.
R = 100 m.
σ1 = 10⁻³ mhos/m.
σ2 = ∞
Hx (Amp-turns/m)
X (m.)
80
70
60
50
40
30
20
10
0
-500
-400
-300
-200
-100
0
100
1
2
1
2

FIG 33

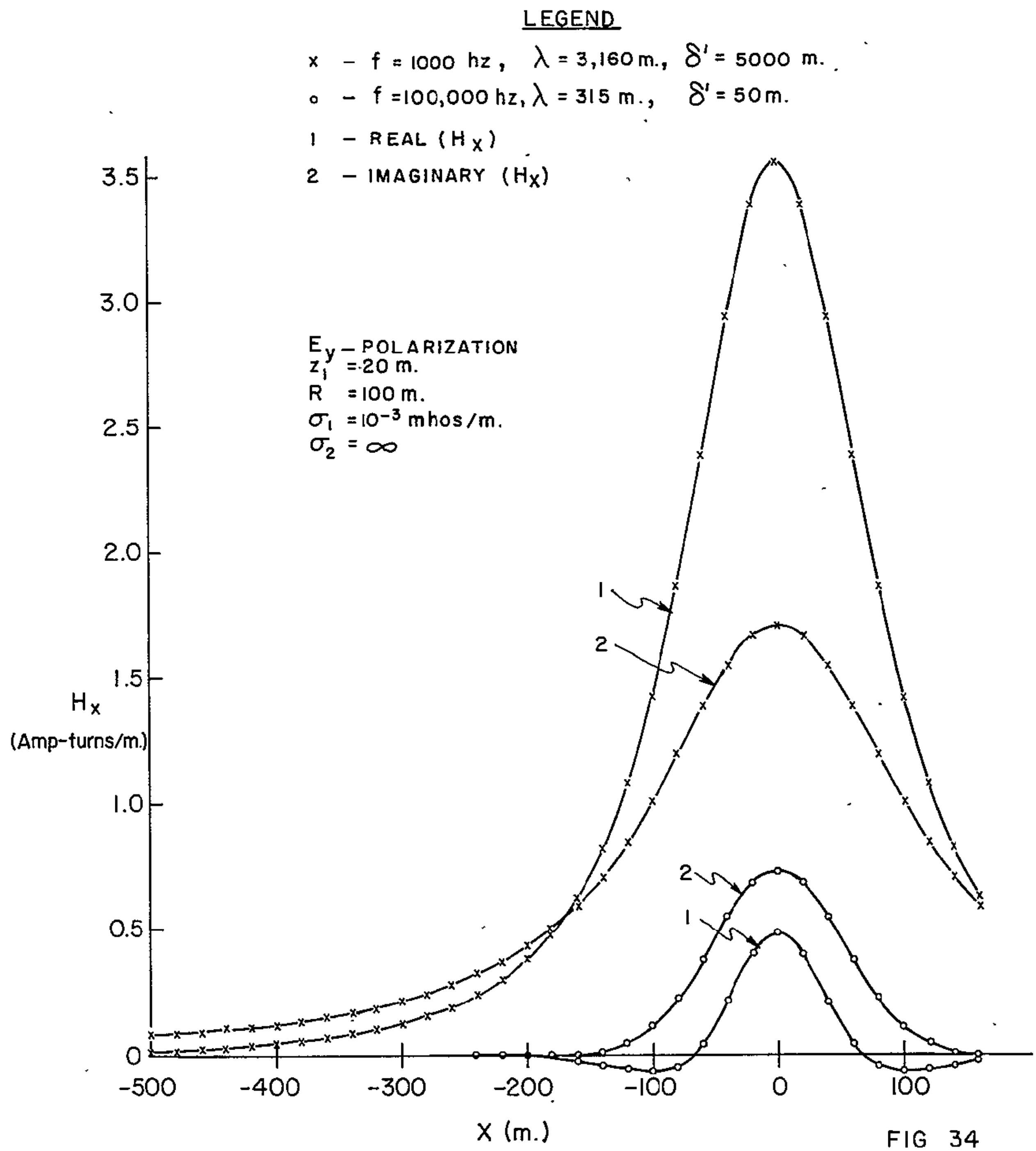

LEGEND
x – f = 1000 hz, λ = 3,160 m., δ' = 5000 m.
o – f = 100,000 hz, λ = 315 m., δ' = 50 m.
1 – REAL (H_X)
2 – IMAGINARY (H_X)
E_y – POLARIZATION
z_1 = 20 m.
R = 100 m.
σ_1 = 10^{-3} mhos/m.
σ_2 = ∞
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
H_x
(Amp-turns/m.)
1
2
2
1
-500
-400
-300
-200
-100
0
100
X (m.)

FIG 34

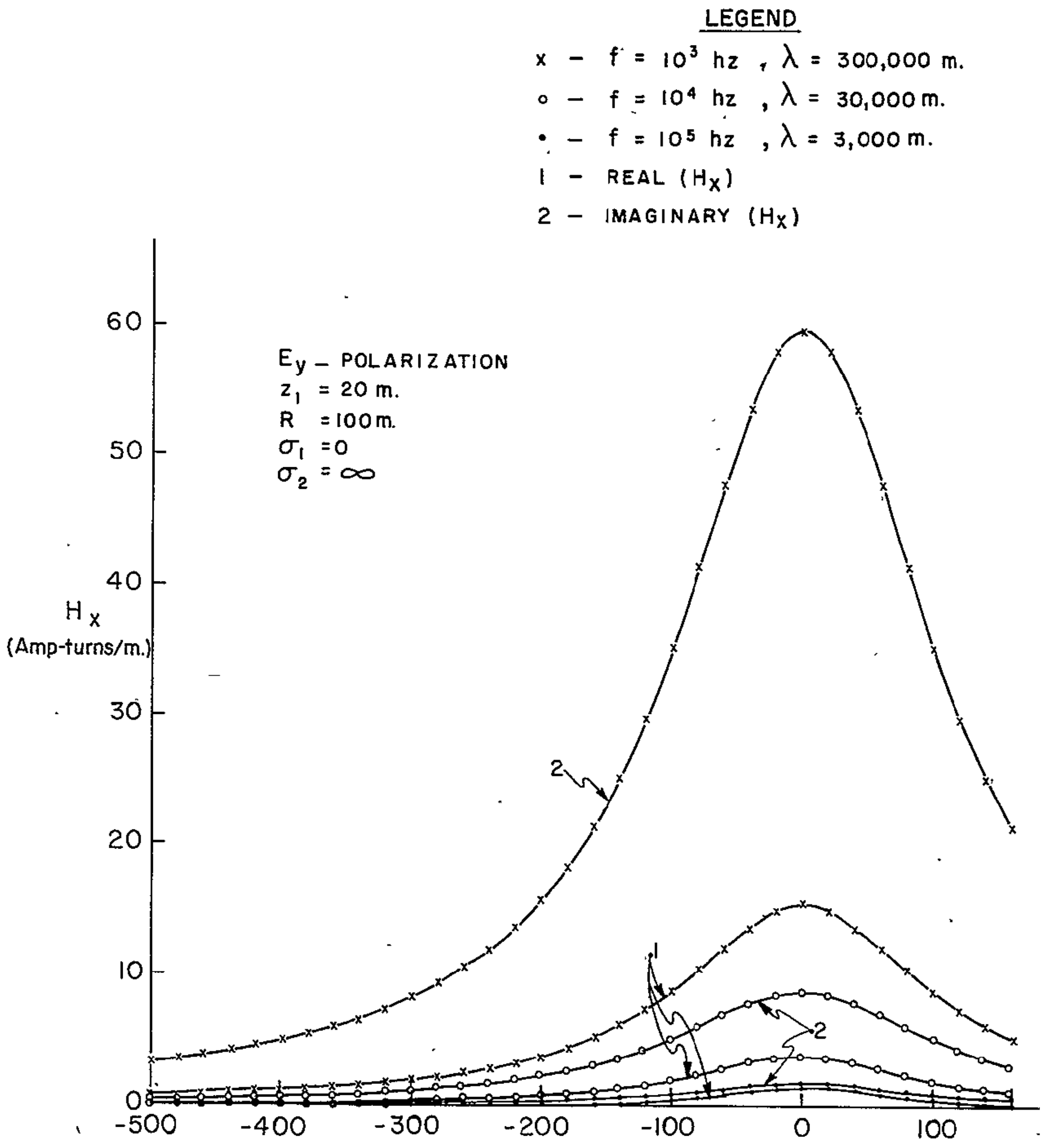

LEGEND
x — f = 10³ hz , λ = 300,000 m.
o — f = 10⁴ hz , λ = 30,000 m.
• — f = 10⁵ hz , λ = 3,000 m.
1 — REAL (Hx)
2 — IMAGINARY (Hx)
Ey — POLARIZATION
z1 = 20 m.
R = 100 m.
σ1 = 0
σ2 = ∞
Hx
(Amp-turns/m.)
60
50
40
30
20
10
0
-500
-400
-300
-200
-100
0
100
1
2
2

FIG 35

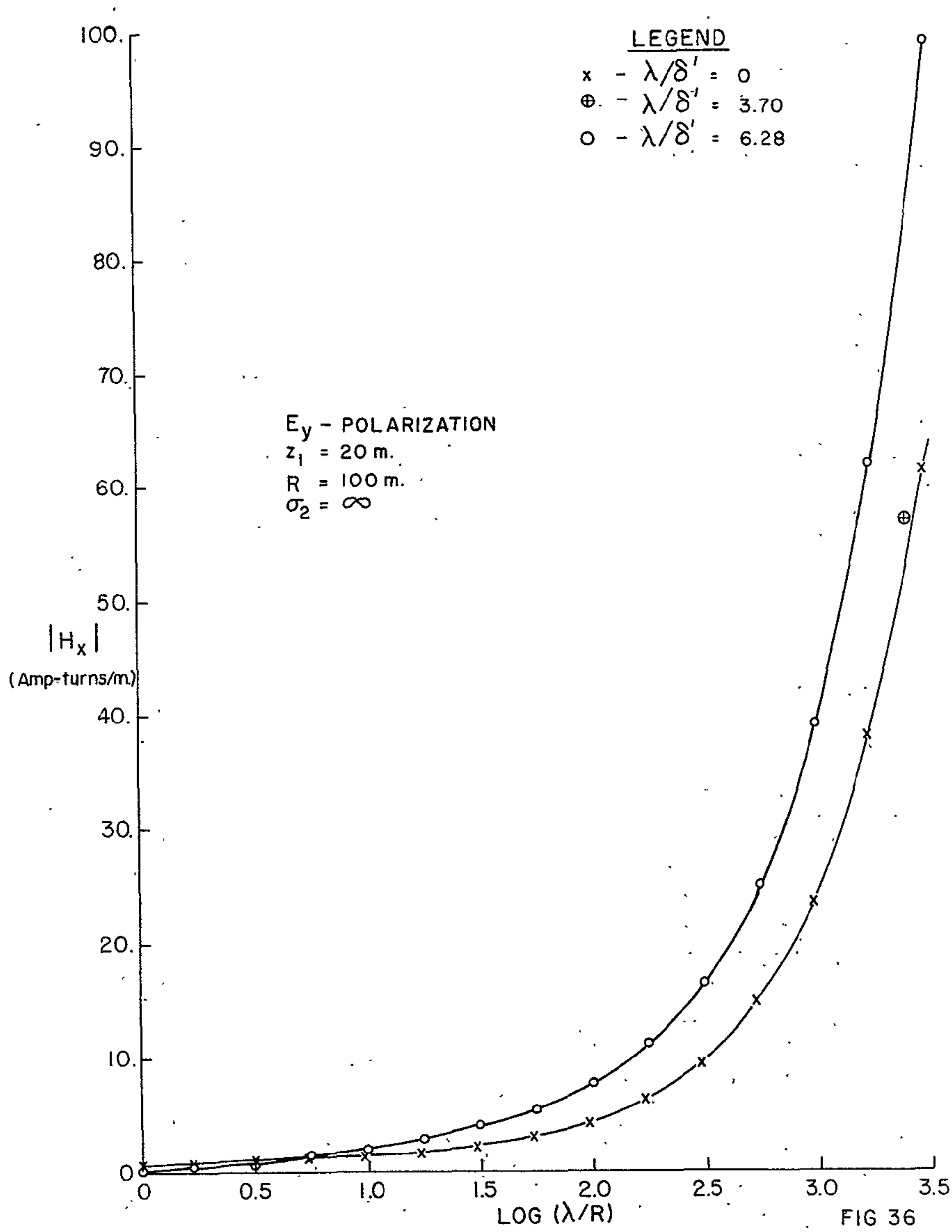

LEGEND
x - λ/δ' = 0
⊕ - λ/δ' = 3.70
o - λ/δ' = 6.28
Ey - POLARIZATION
z1 = 20 m.
R = 100 m.
σ2 = ∞
|Hx|
(Amp-turns/m.)
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
LOG (λ/R)

FIG 36

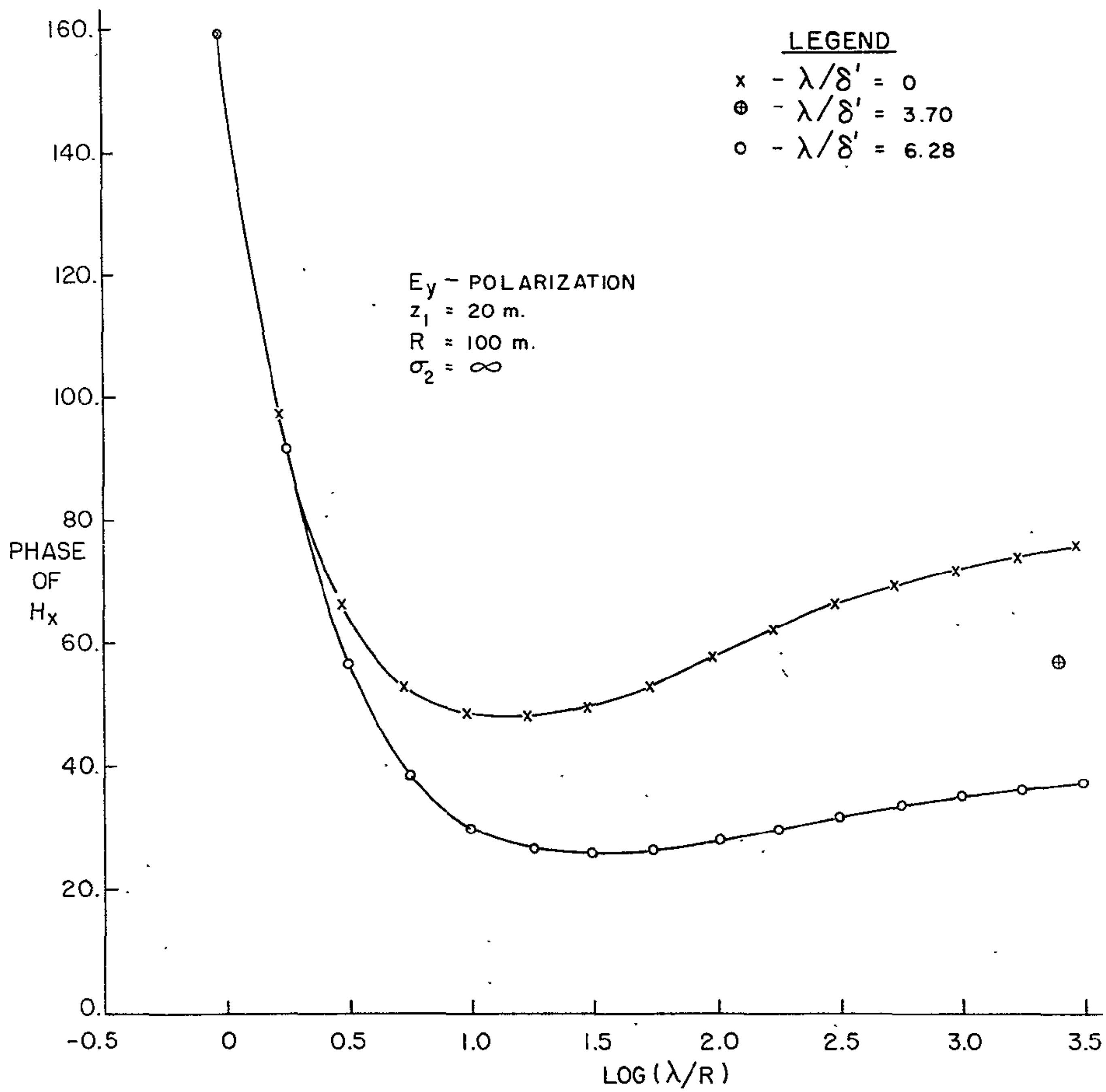

LEGEND
x - λ/δ' = 0
⊕ - λ/δ' = 3.70
o - λ/δ' = 6.28
E_y – POLARIZATION
z_1 = 20 m.
R = 100 m.
$\sigma_2 = \infty$
PHASE OF H_x
160.
140.
120.
100.
80
60.
40.
20.
0.
-0.5
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
LOG (λ/R)

FIG 37

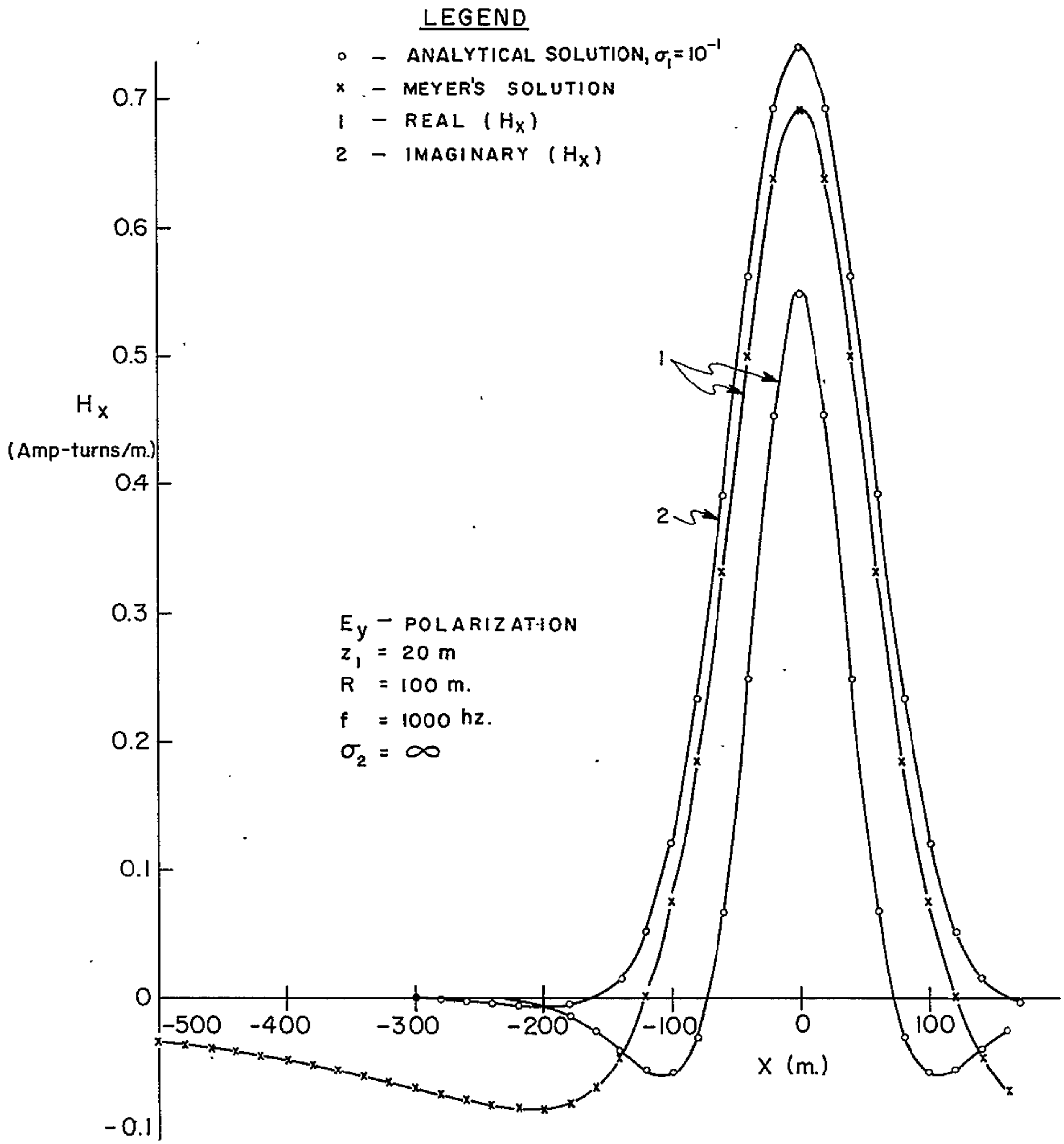

LEGEND
o – ANALYTICAL SOLUTION, $\sigma_1 = 10^{-1}$
x – MEYER'S SOLUTION
1 – REAL (H_x)
2 – IMAGINARY (H_x)
H_x
(Amp-turns/m.)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
E_y – POLARIZATION
z_1 = 20 m
R = 100 m.
f = 1000 hz.
$\sigma_2 = \infty$
1
2
-500
-400
-300
-200
-100
0
100
X (m.)

FIG 38

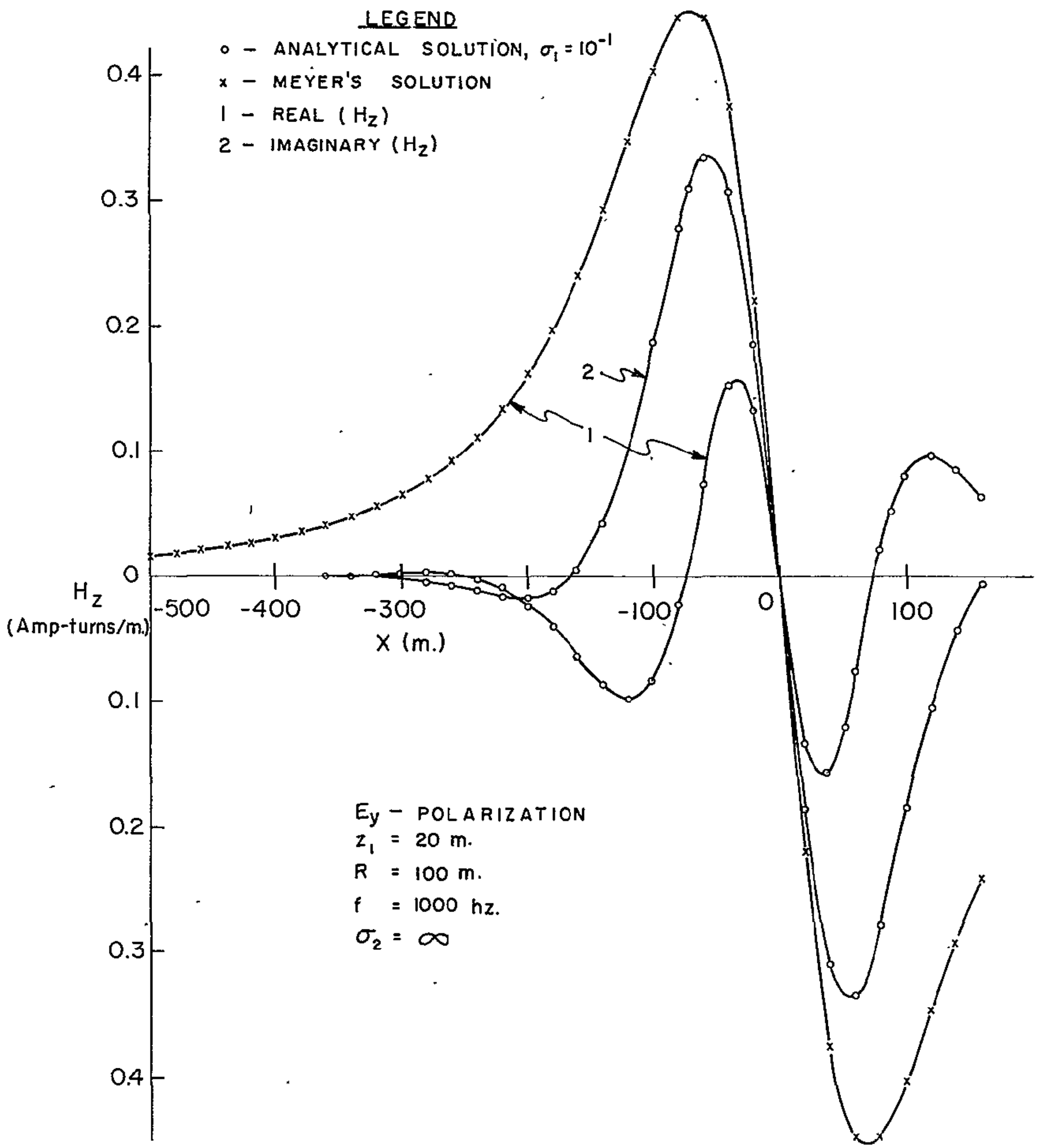
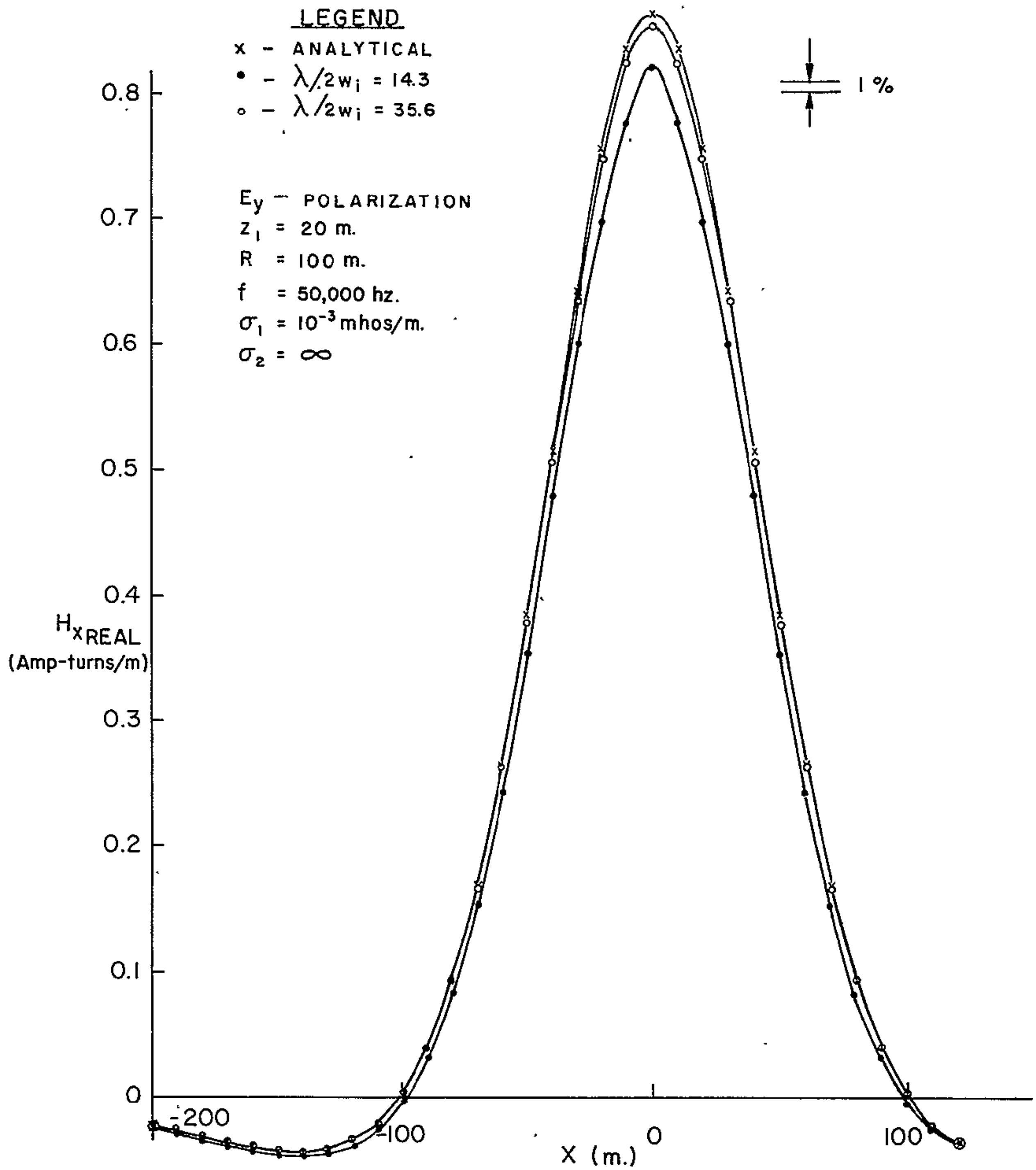

LEGEND
o – ANALYTICAL SOLUTION, $\sigma_1 = 10^{-1}$
x – MEYER'S SOLUTION
1 – REAL (H_z)
2 – IMAGINARY (H_z)
0.4
0.3
0.2
0.1
0
0.1
0.2
0.3
0.4
H_z
(Amp-turns/m.)
-500
-400
-300
-100
0
100
X (m.)
1
2
E_y – POLARIZATION
z_1 = 20 m.
R = 100 m.
f = 1000 hz.
$\sigma_2 = \infty$

FIG 39



LEGEND
x - ANALYTICAL
• - λ/2w_i = 14.3
o - λ/2w_i = 35.6
E_y - POLARIZATION
z_1 = 20 m.
R = 100 m.
f = 50,000 hz.
σ_1 = 10^-3 mhos/m.
σ_2 = ∞
1 %
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
H_x REAL (Amp-turns/m)
-200
-100
0
100
X (m.)

FIG 40

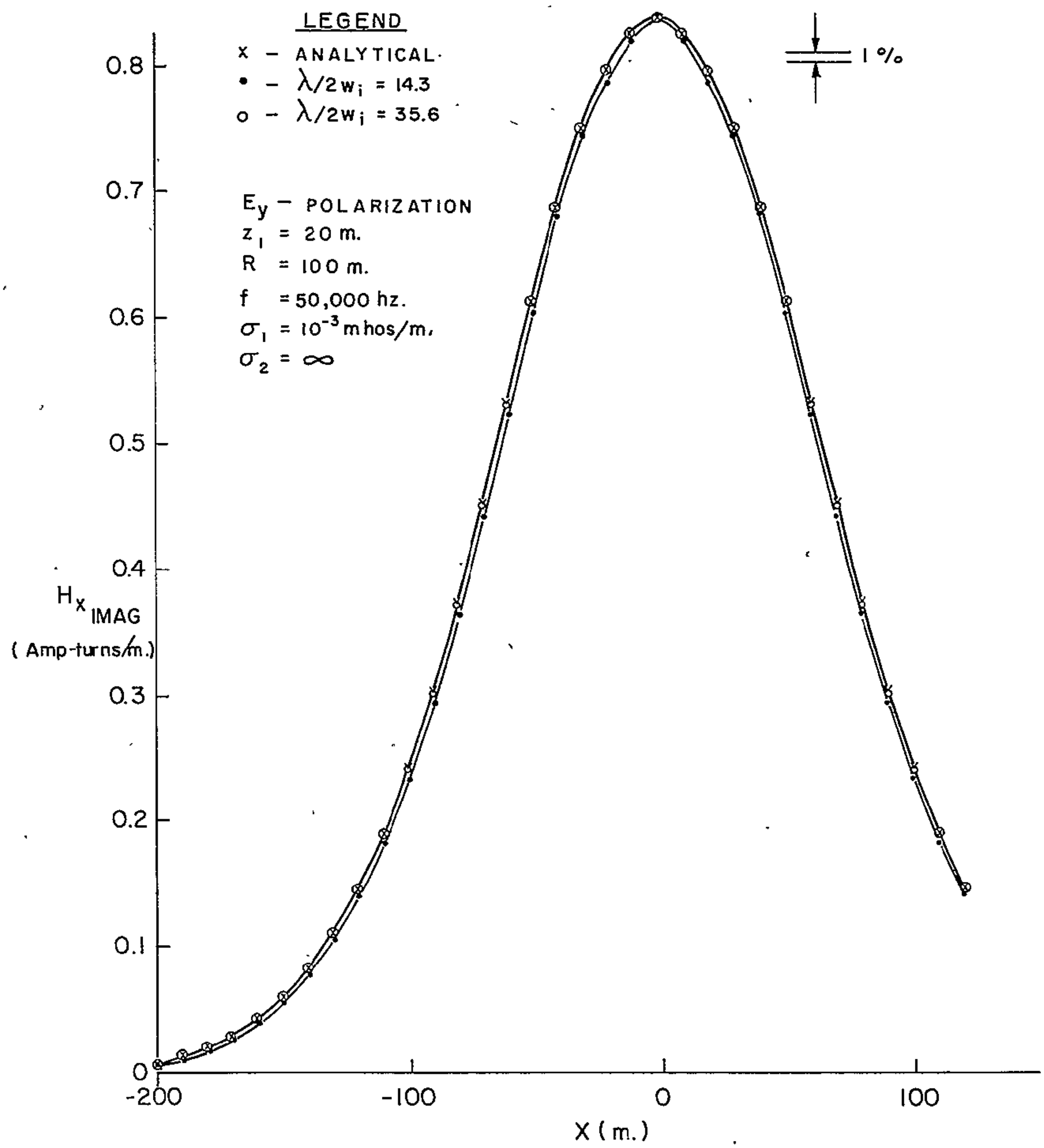

LEGEND
x – ANALYTICAL
• – λ/2w_i = 14.3
o – λ/2w_i = 35.6
1 %
E_y – POLARIZATION
z_1 = 20 m.
R = 100 m.
f = 50,000 hz.
σ_1 = 10^-3 mhos/m.
σ_2 = ∞
H_x IMAG
(Amp-turns/m.)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-200
-100
0
100
X (m.)

FIG 41

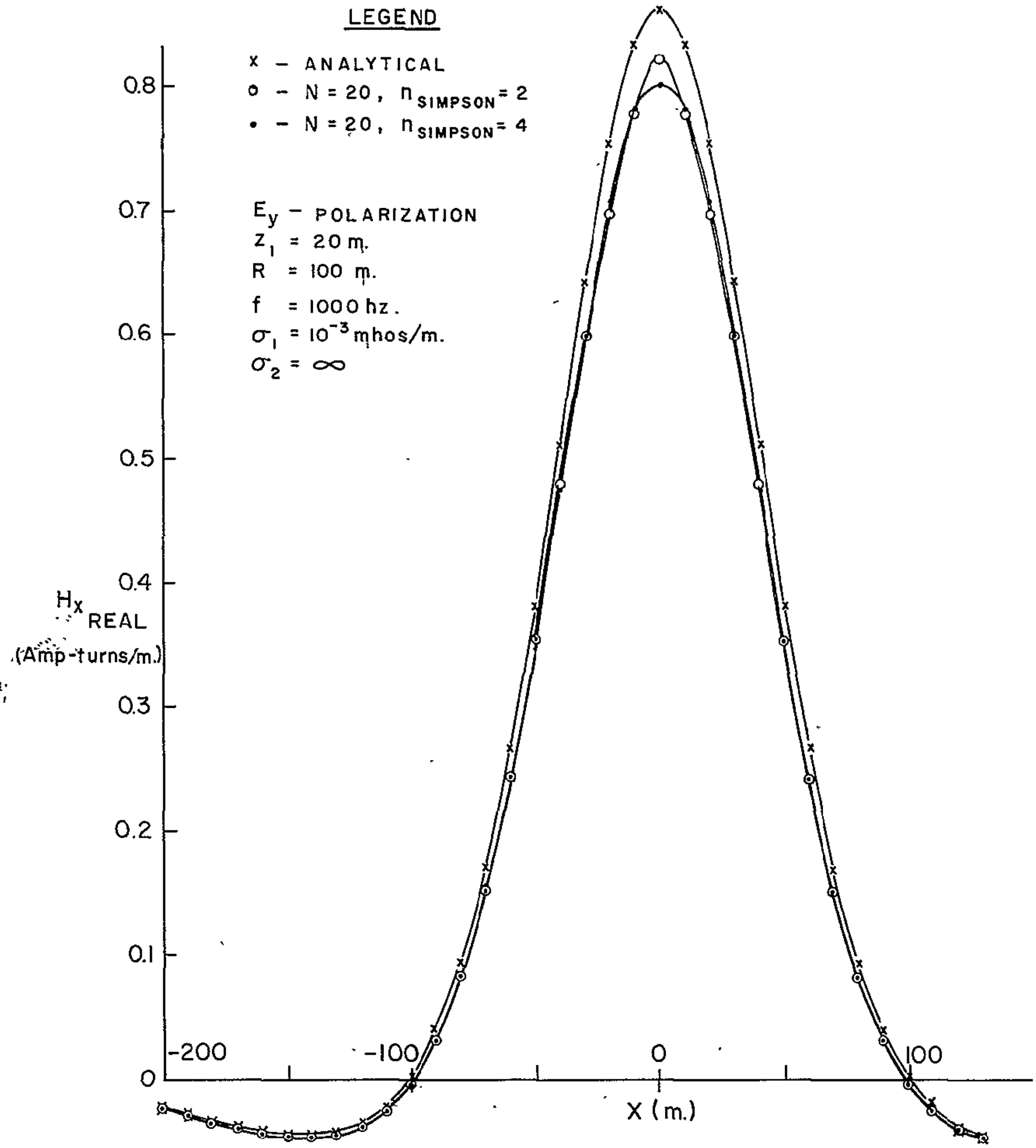

LEGEND
x – ANALYTICAL
o – N = 20, n SIMPSON = 2
• – N = 20, n SIMPSON = 4
E y – POLARIZATION
Z 1 = 20 m.
R = 100 m.
f = 1000 hz.
σ 1 = 10^-3 mhos/m.
σ 2 = ∞
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
H X REAL (Amp-turns/m.)
-200
-100
0
100
X (m.)

FIG 42

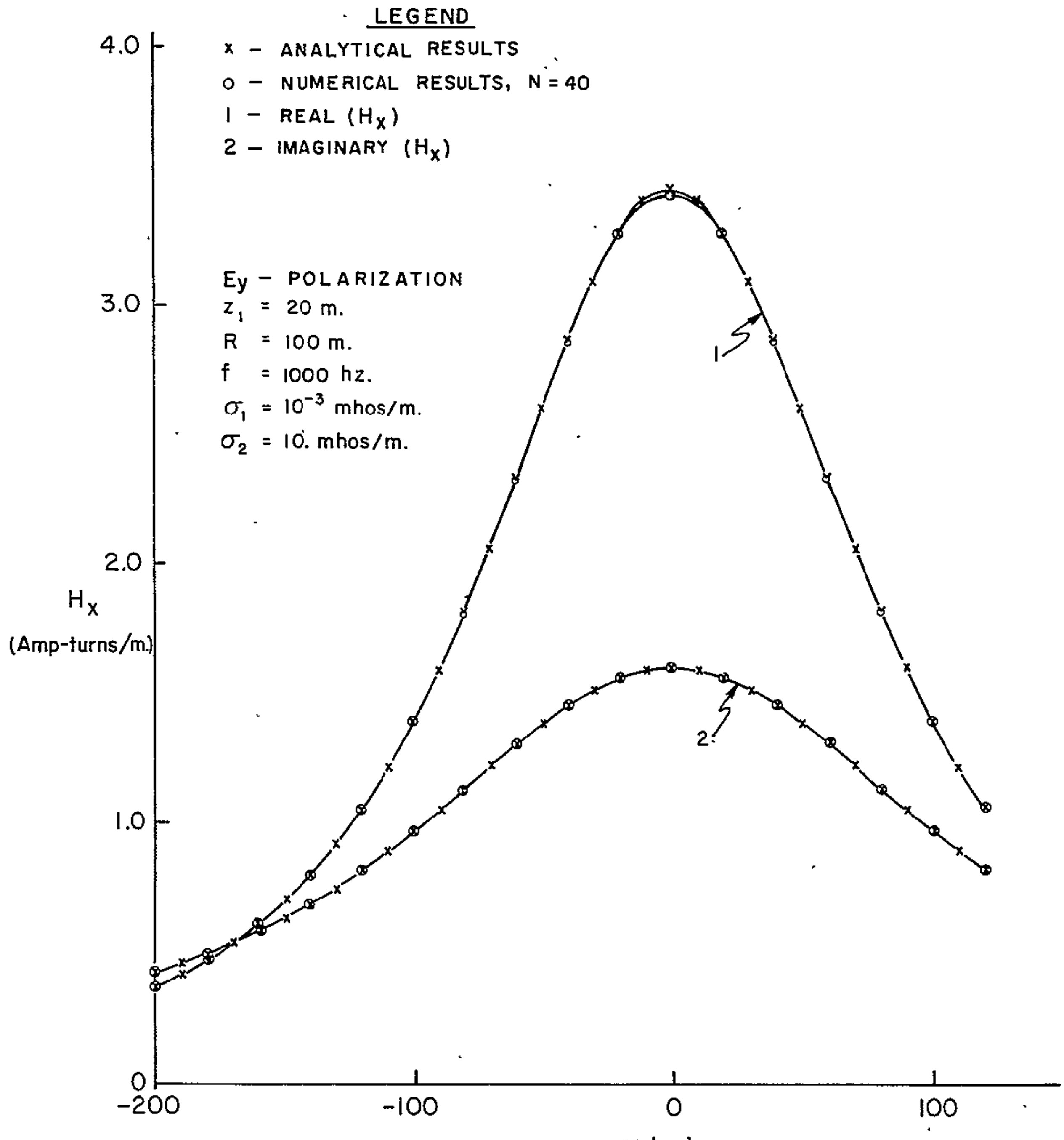

LEGEND
x – ANALYTICAL RESULTS
o – NUMERICAL RESULTS, N = 40
1 – REAL (H_x)
2 – IMAGINARY (H_x)
Ey – POLARIZATION
z_1 = 20 m.
R = 100 m.
f = 1000 hz.
σ_1 = 10^{-3} mhos/m.
σ_2 = 10. mhos/m.
4.0
3.0
2.0
1.0
0
H_x
(Amp-turns/m.)
1
2
-200
-100
0
100
X (m.)

FIG 43

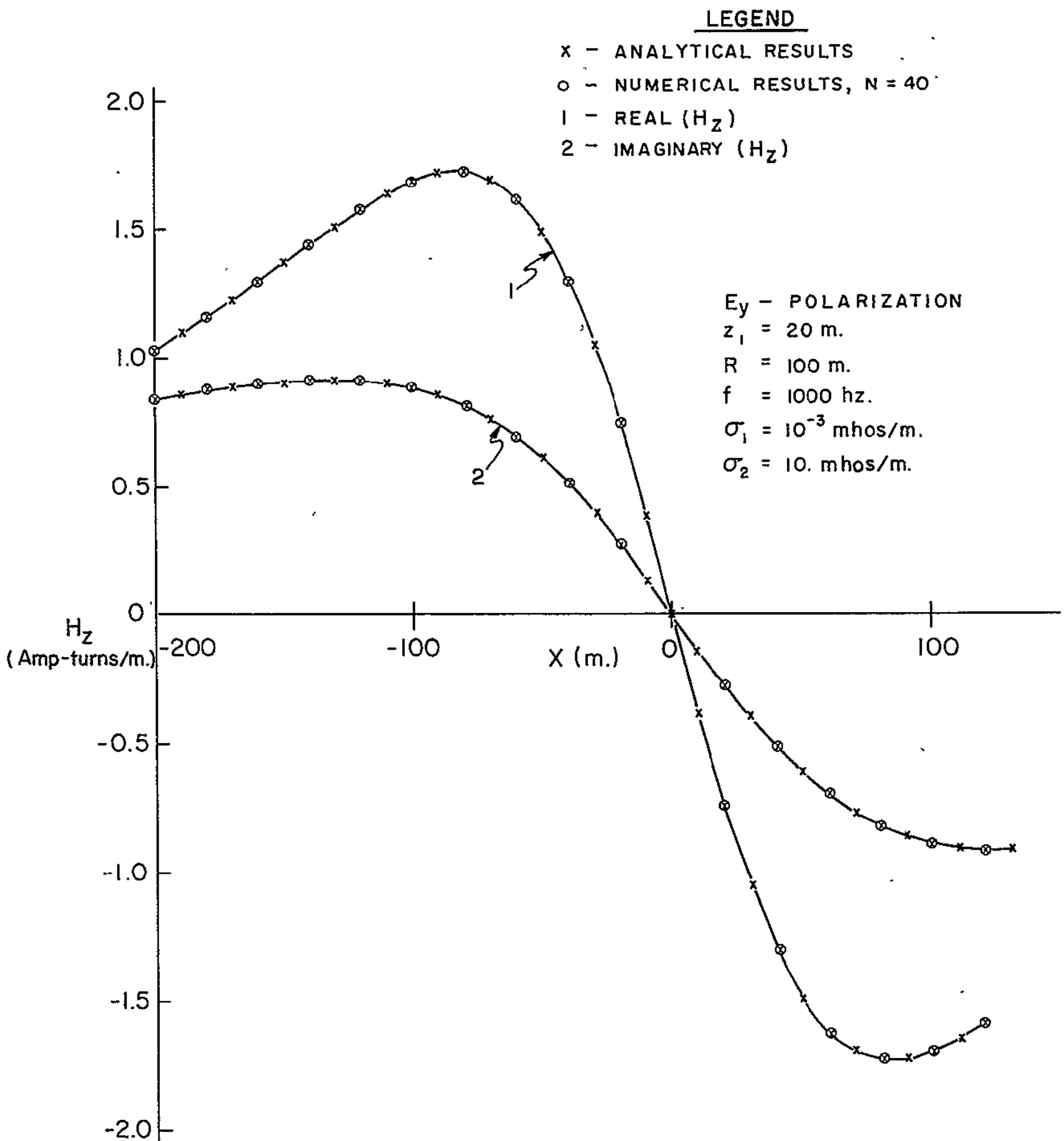

LEGEND
x – ANALYTICAL RESULTS
o – NUMERICAL RESULTS, N = 40
1 – REAL (Hz)
2 – IMAGINARY (Hz)
Ey – POLARIZATION
z1 = 20 m.
R = 100 m.
f = 1000 hz.
σ1 = 10^-3 mhos/m.
σ2 = 10. mhos/m.
Hz
(Amp-turns/m.)
X (m.)
2.0
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
-2.0
-200
-100
0
100
1
2

FIG 44

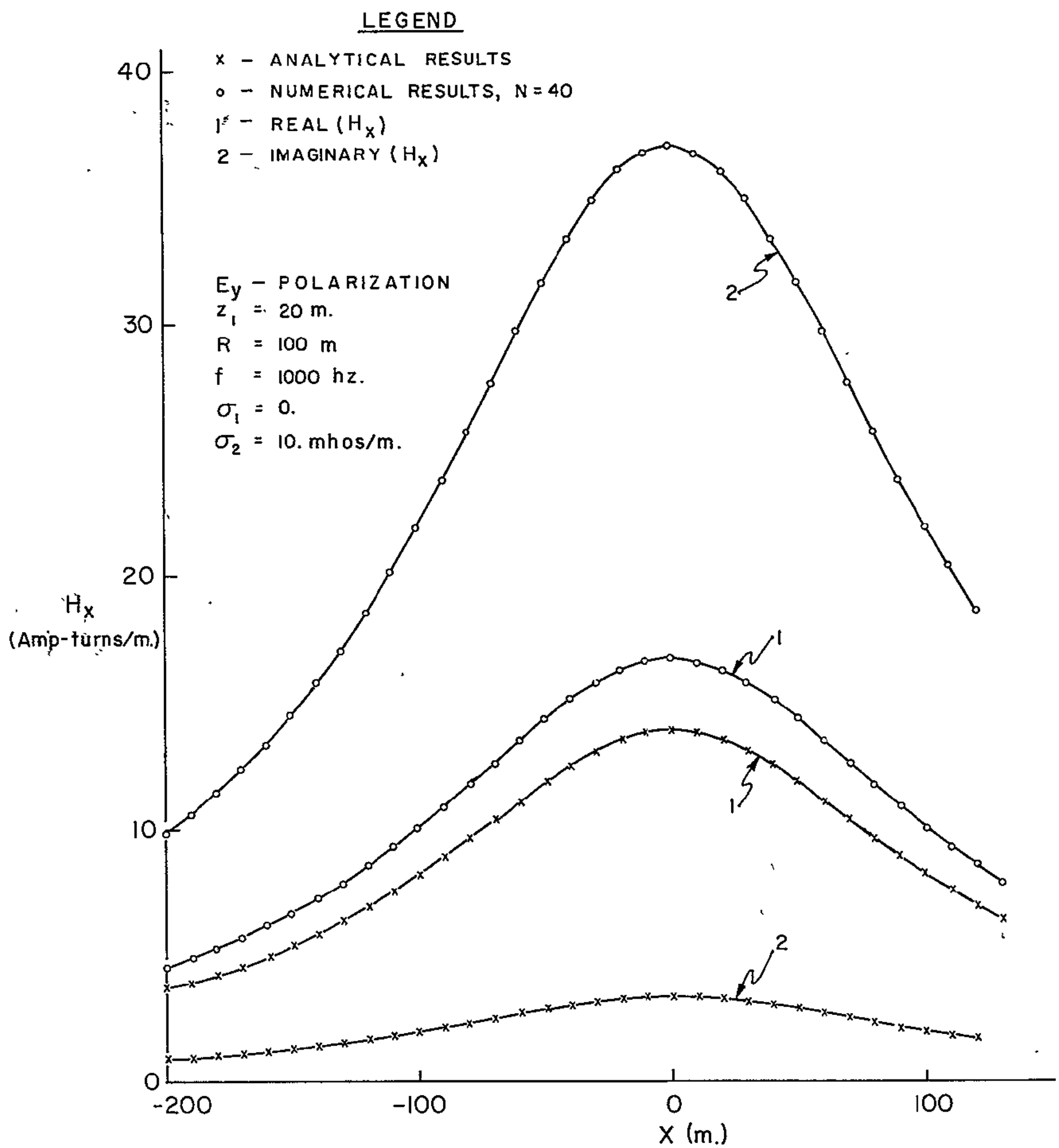
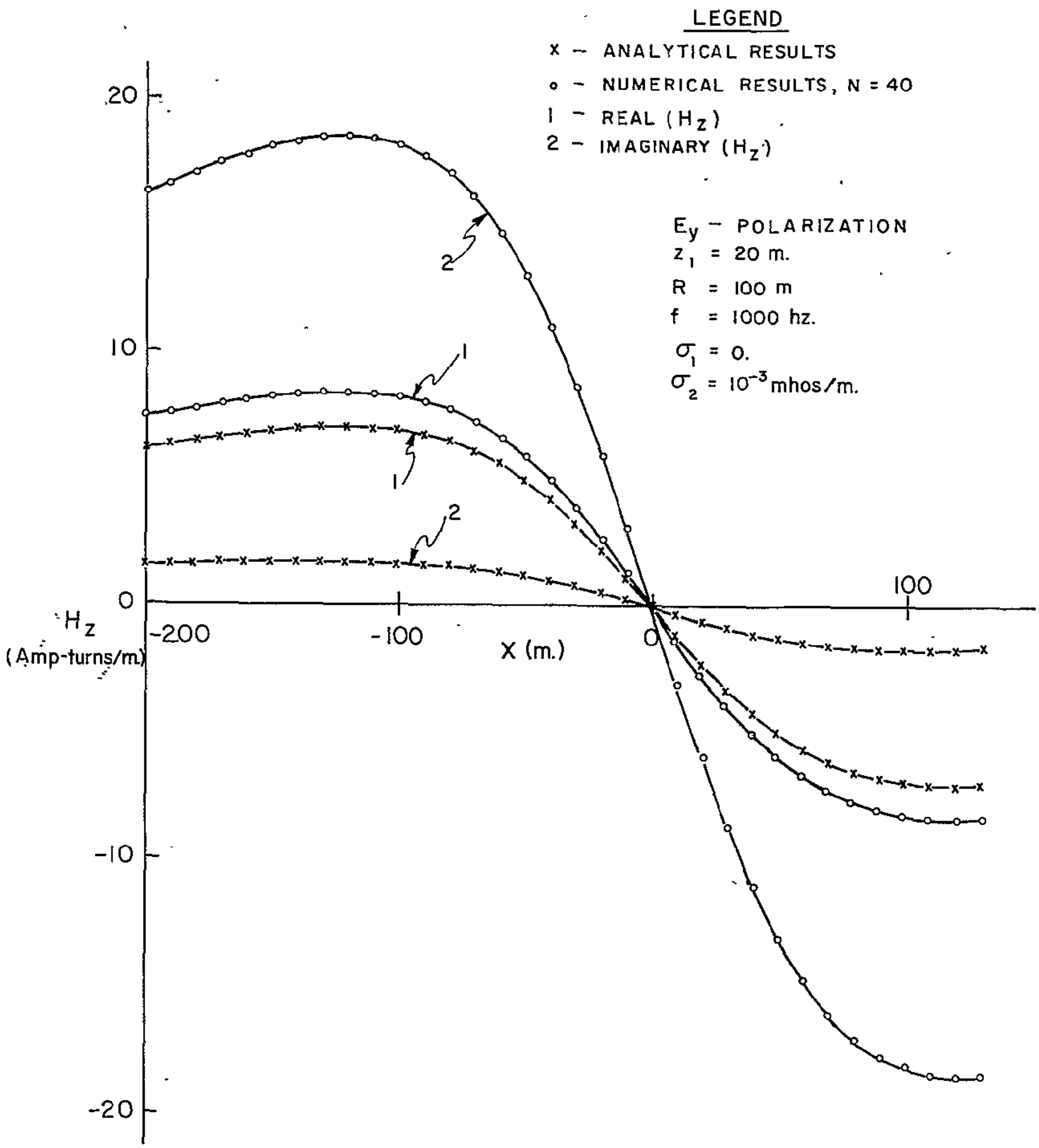

LEGEND
x – ANALYTICAL RESULTS
o – NUMERICAL RESULTS, N=40
1 – REAL (H_X)
2 – IMAGINARY (H_X)
Ey – POLARIZATION
z1 = 20 m.
R = 100 m
f = 1000 hz.
σ1 = 0.
σ2 = 10. mhos/m.
Hx
(Amp-turns/m.)
X (m.)
40
30
20
10
0
-200
-100
0
100
1
2

FIG 45



LEGEND
x – ANALYTICAL RESULTS
o – NUMERICAL RESULTS, N = 40
1 – REAL (Hz)
2 – IMAGINARY (Hz)
Ey – POLARIZATION
z1 = 20 m.
R = 100 m
f = 1000 hz.
σ1 = 0.
σ2 = 10^-3 mhos/m.
20
10
0
-10
-20
Hz
(Amp-turns/m)
-200
-100
0
100
X (m.)
1
2

FIG 46

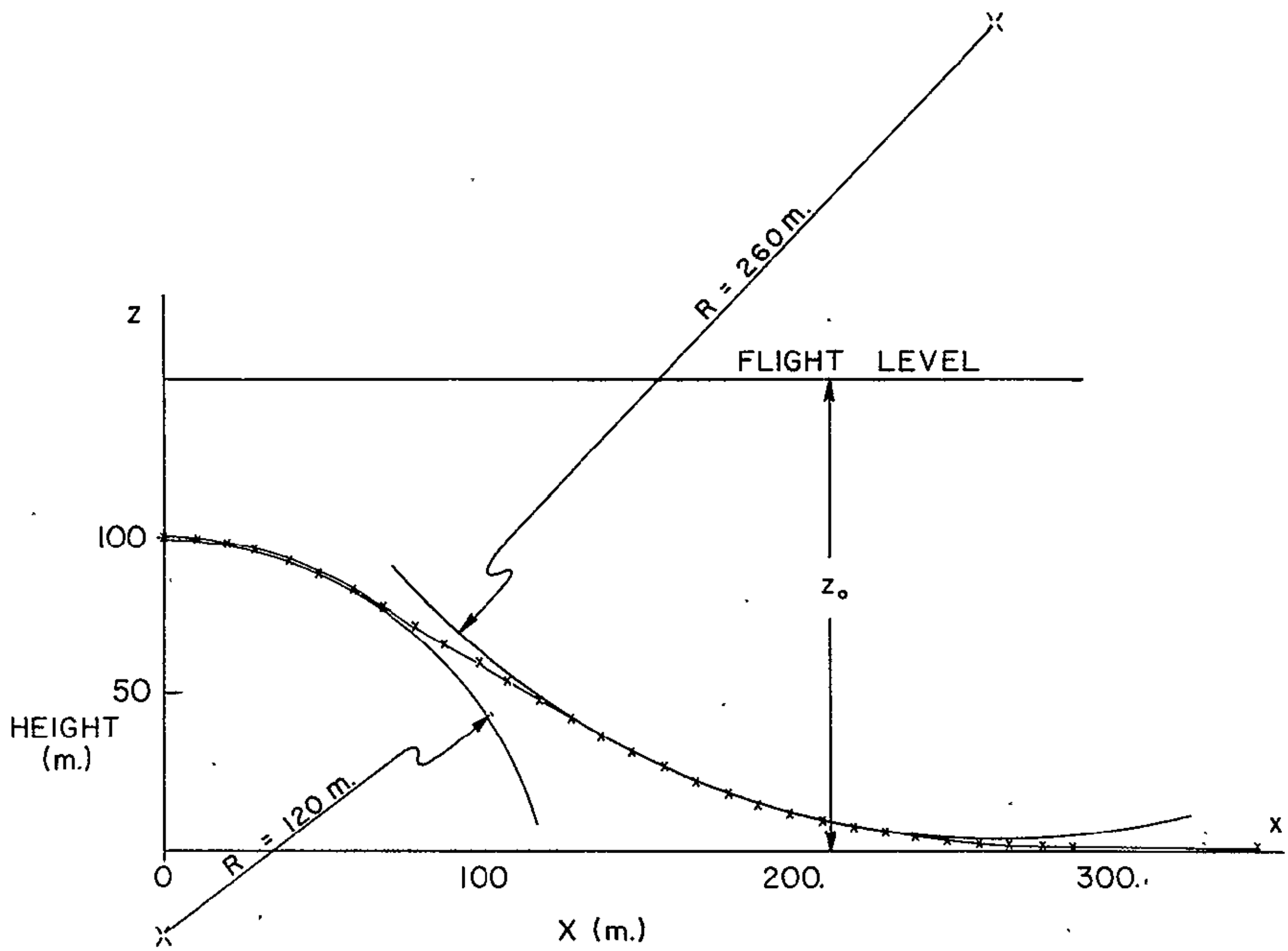
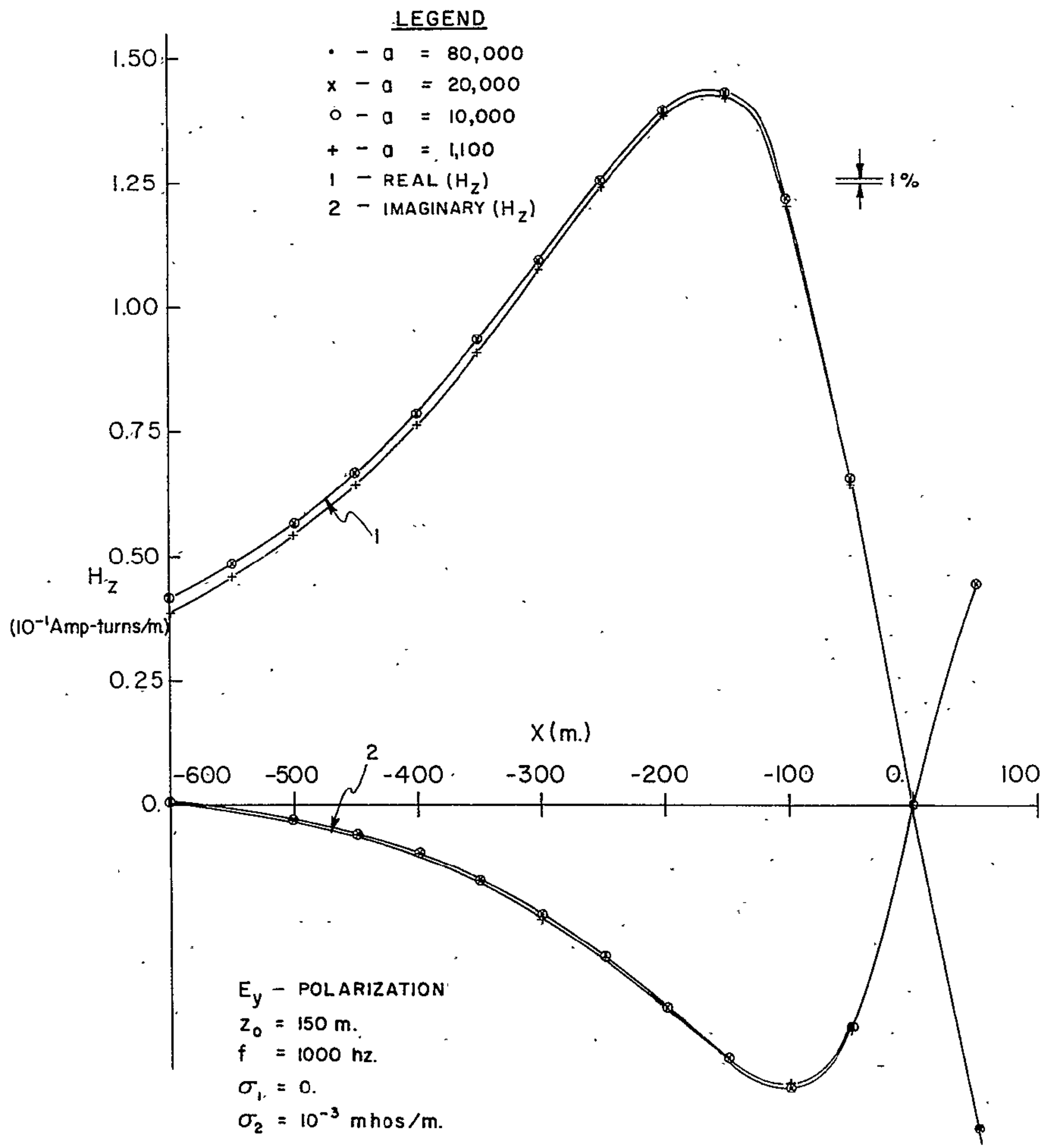


FIG 47



LEGEND
• – a = 80,000
x – a = 20,000
o – a = 10,000
+ – a = 1,100
1 – REAL (H_Z)
2 – IMAGINARY (H_Z)
1%
1.50
1.25
1.00
0.75
0.50
0.25
0.
H_Z
(10⁻¹ Amp-turns/m)
X (m.)
-600
-500
-400
-300
-200
-100
0.
100
1
2
E_y – POLARIZATION
Z_0 = 150 m.
f = 1000 hz.
σ_1 = 0.
σ_2 = 10⁻³ mhos/m.

FIG 48

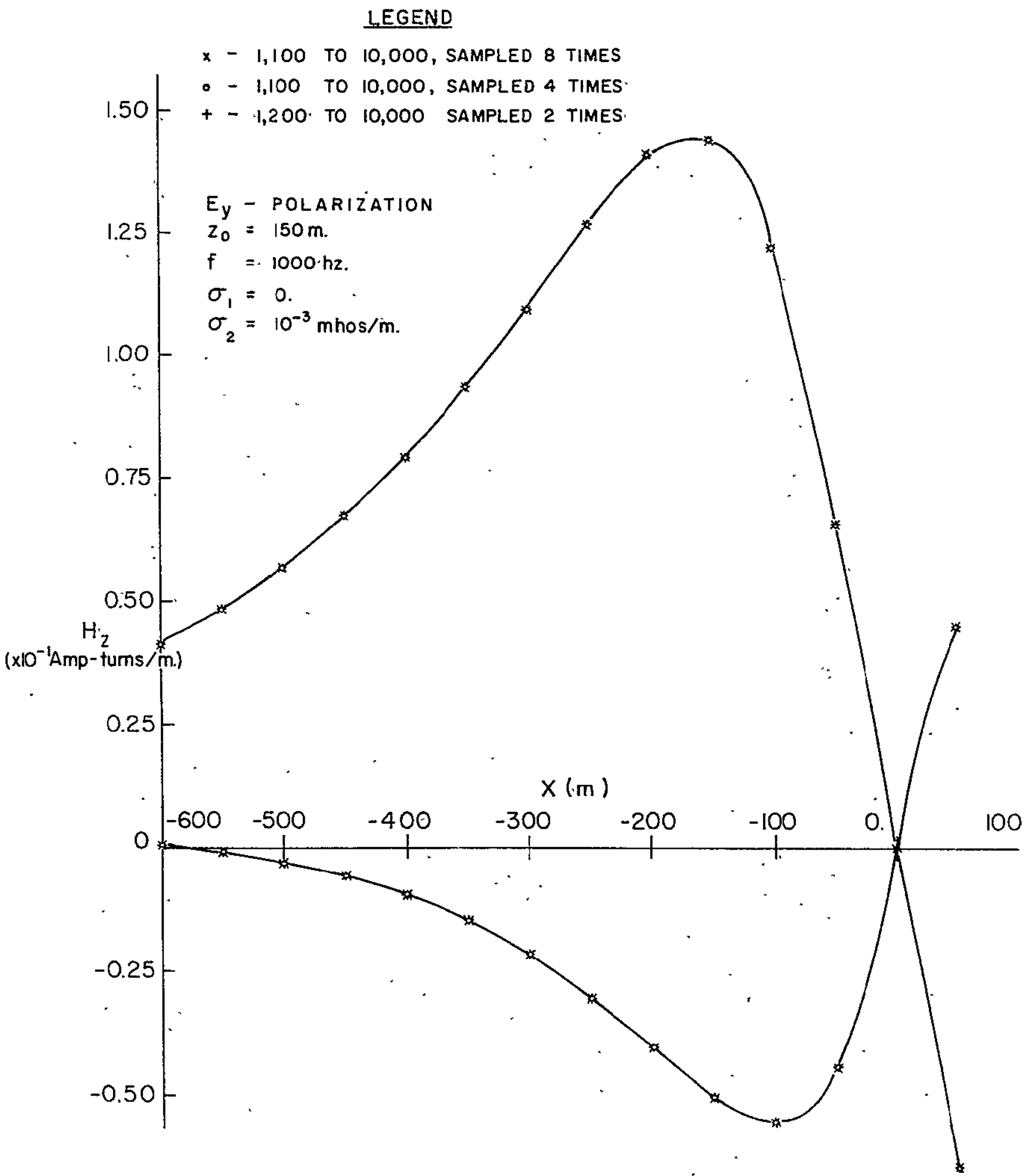

LEGEND
x - 1,100 TO 10,000, SAMPLED 8 TIMES
o - 1,100 TO 10,000, SAMPLED 4 TIMES
+ - 1,200 TO 10,000 SAMPLED 2 TIMES
Ey - POLARIZATION
z0 = 150 m.
f = 1000 hz.
σ1 = 0.
σ2 = 10^-3 mhos/m.
1.50
1.25
1.00
0.75
0.50
0.25
0
-0.25
-0.50
Hz
(x10^-1 Amp-turns/m.)
X (m)
-600
-500
-400
-300
-200
-100
0.
100

FIG 49

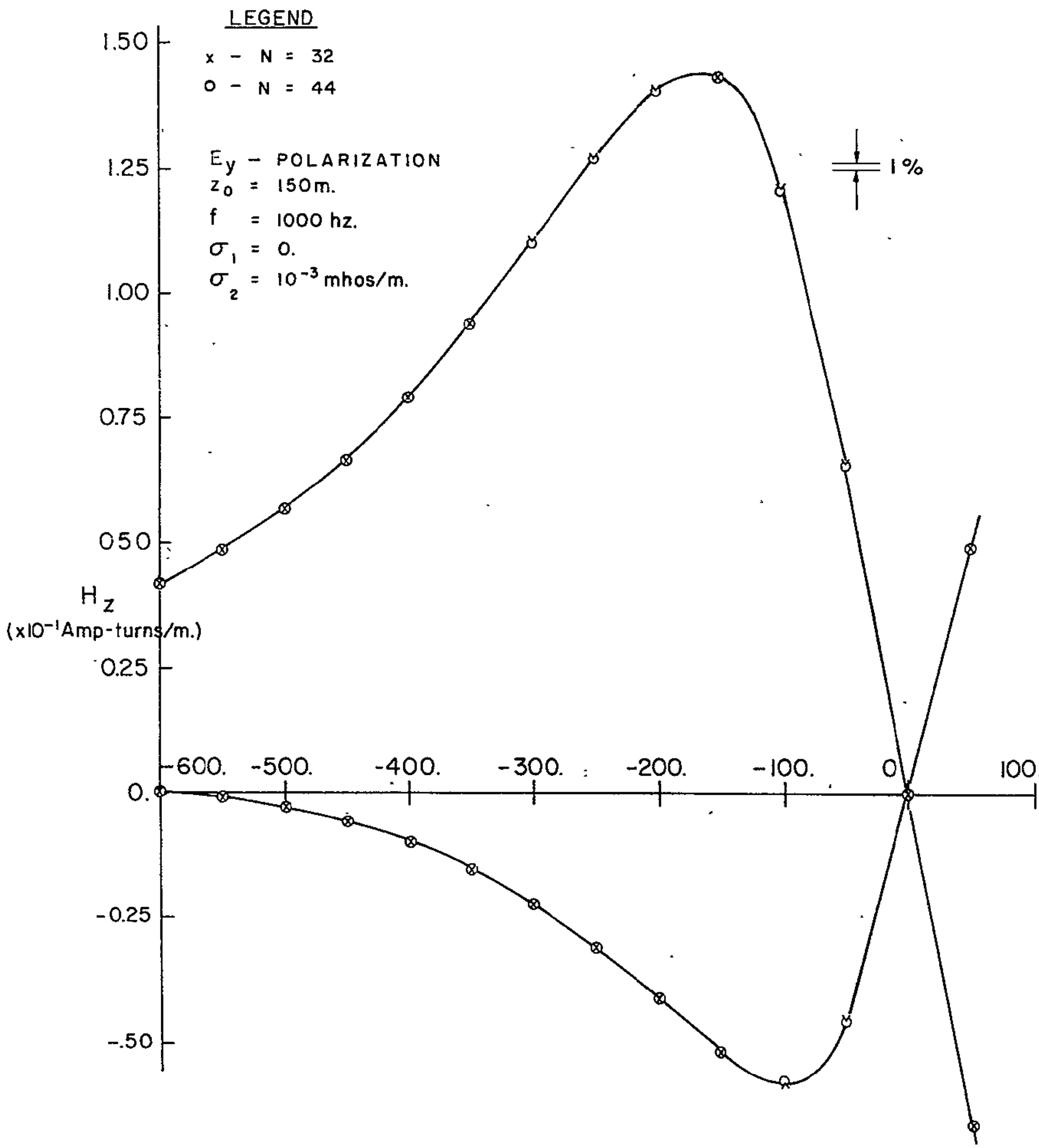

LEGEND
x - N = 32
o - N = 44
Ey - POLARIZATION
z0 = 150m.
f = 1000 hz.
σ1 = 0.
σ2 = 10^-3 mhos/m.
1%
Hz
(x10^-1 Amp-turns/m.)
1.50
1.25
1.00
0.75
0.50
0.25
0.
-0.25
-.50
-600.
-500.
-400.
-300.
-200.
-100.
0
100.

FIG 50

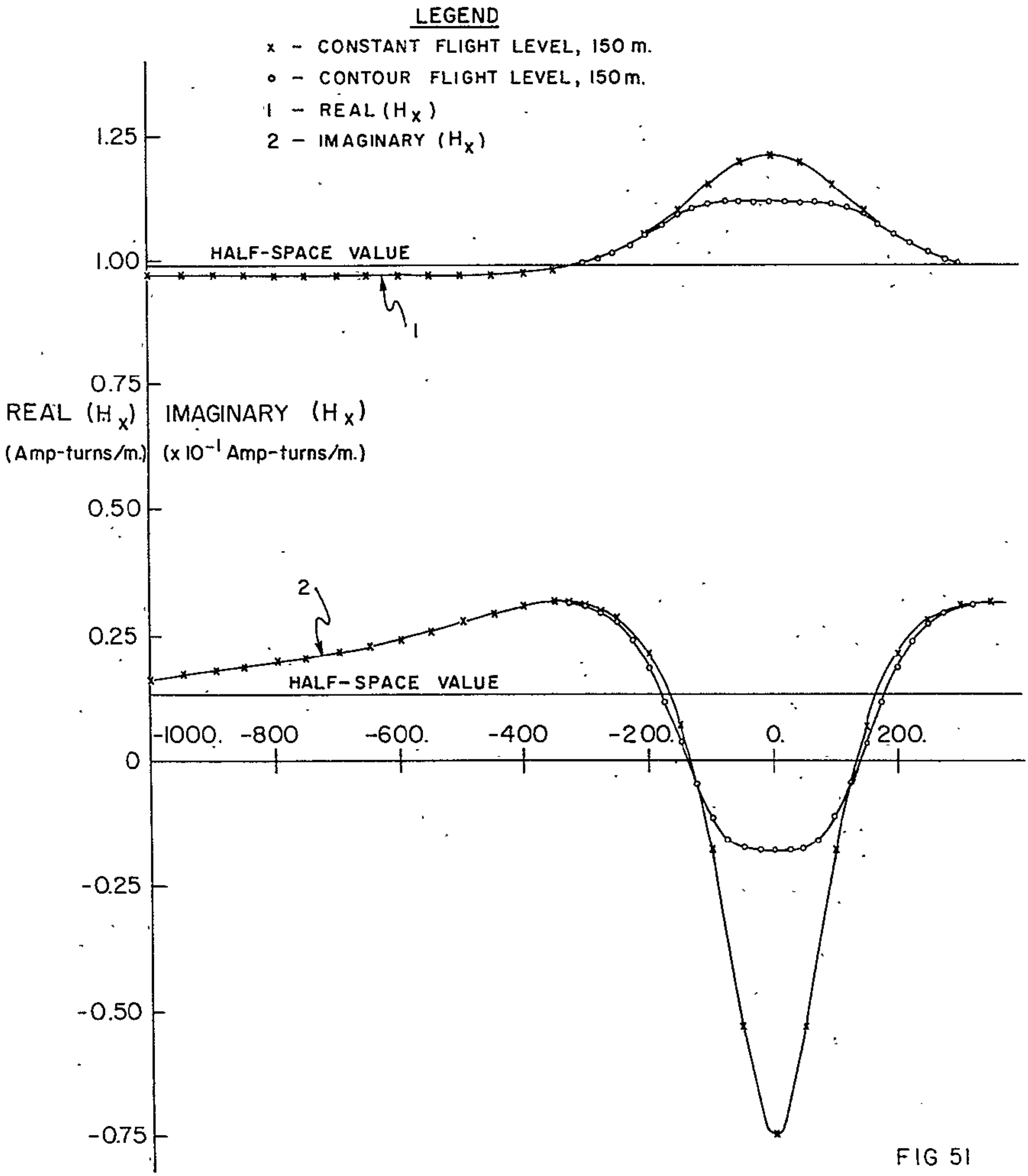

LEGEND
x – CONSTANT FLIGHT LEVEL, 150 m.
o – CONTOUR FLIGHT LEVEL, 150 m.
1 – REAL (Hx)
2 – IMAGINARY (Hx)
1.25
1.00
HALF-SPACE VALUE
1
0.75
REAL (Hx)
(Amp-turns/m.)
IMAGINARY (Hx)
(x 10⁻¹ Amp-turns/m.)
0.50
2
0.25
HALF-SPACE VALUE
-1000.
-800
-600.
-400
-200.
0.
200.
0
-0.25
-0.50
-0.75

FIG 51

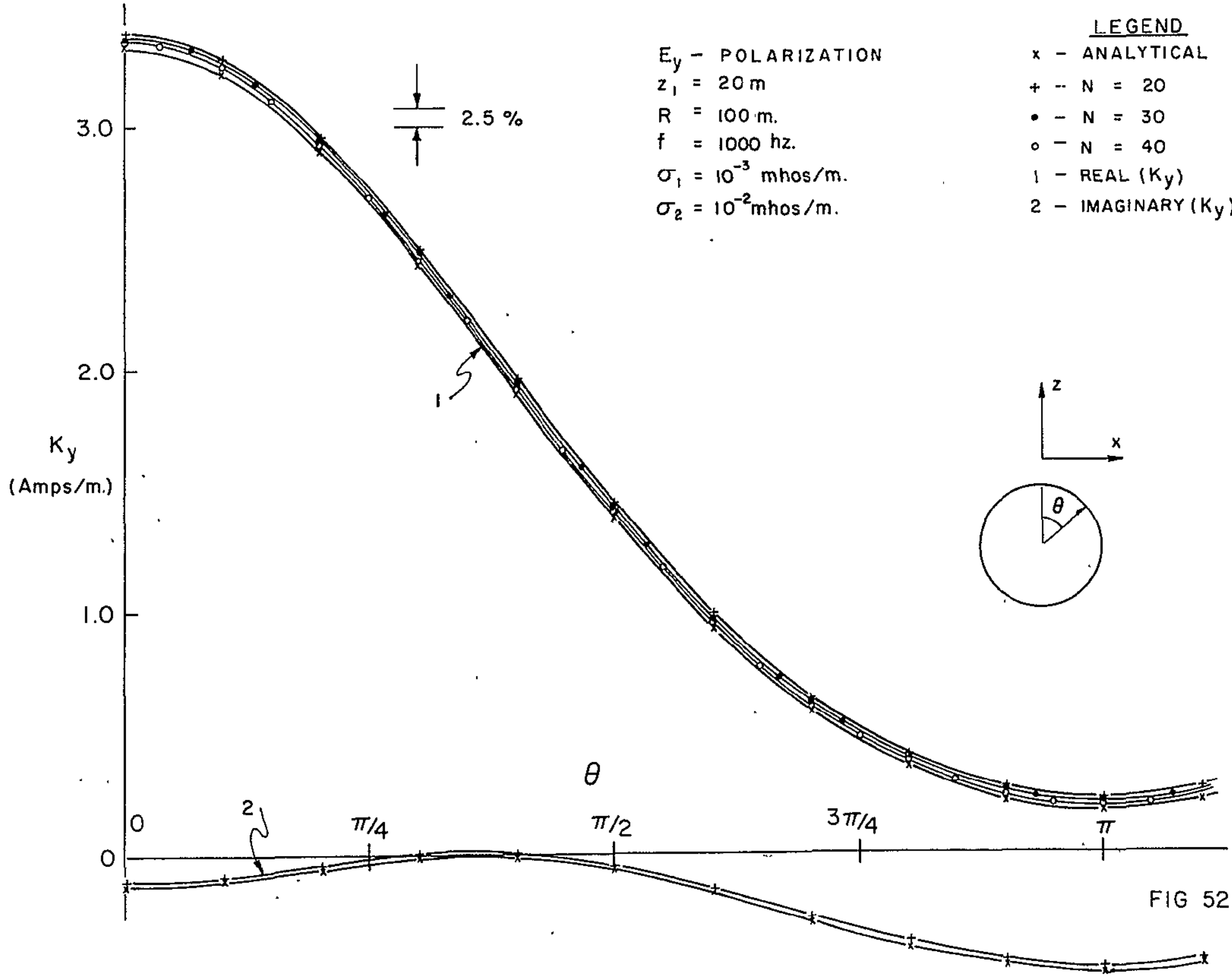
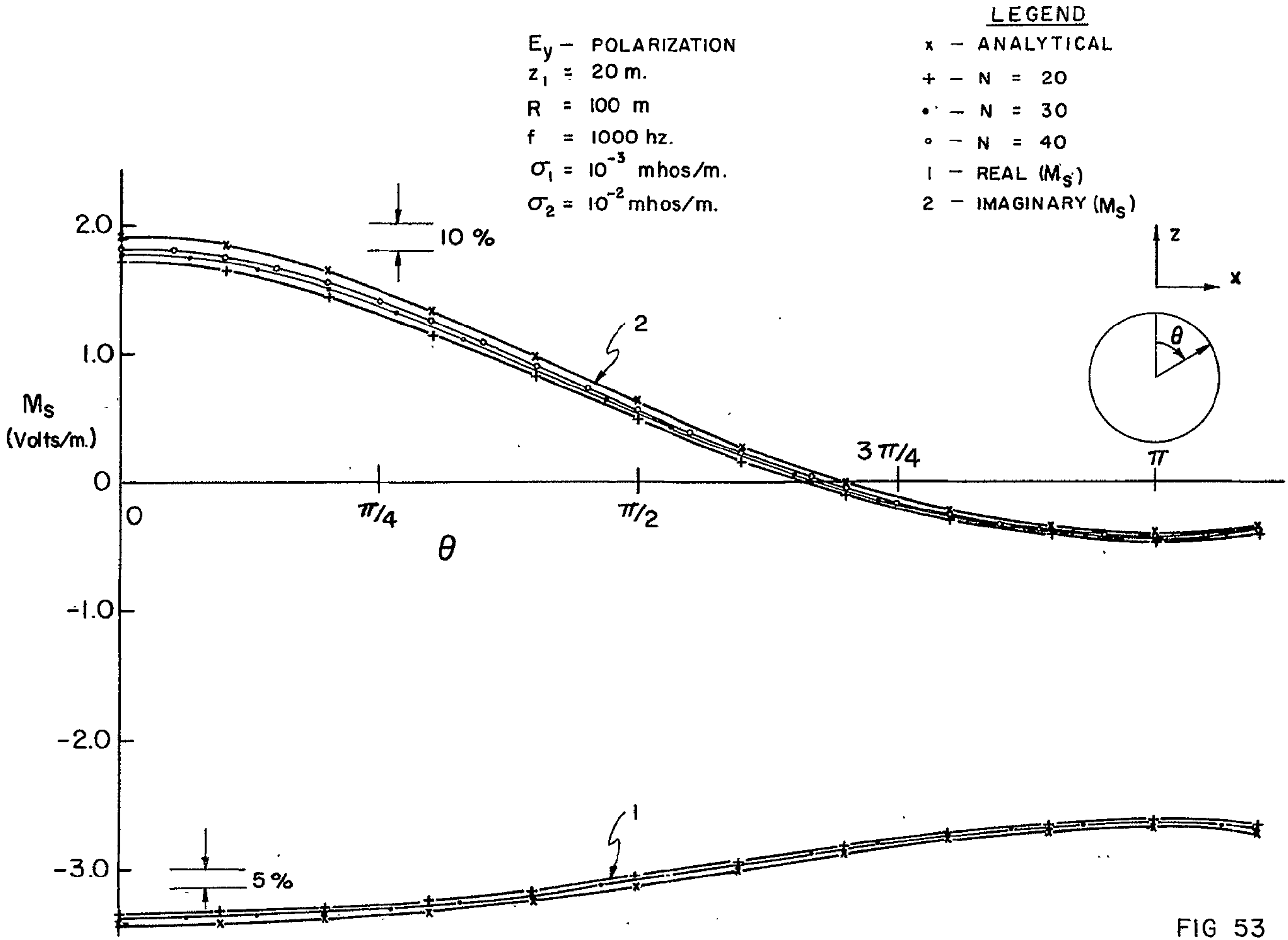
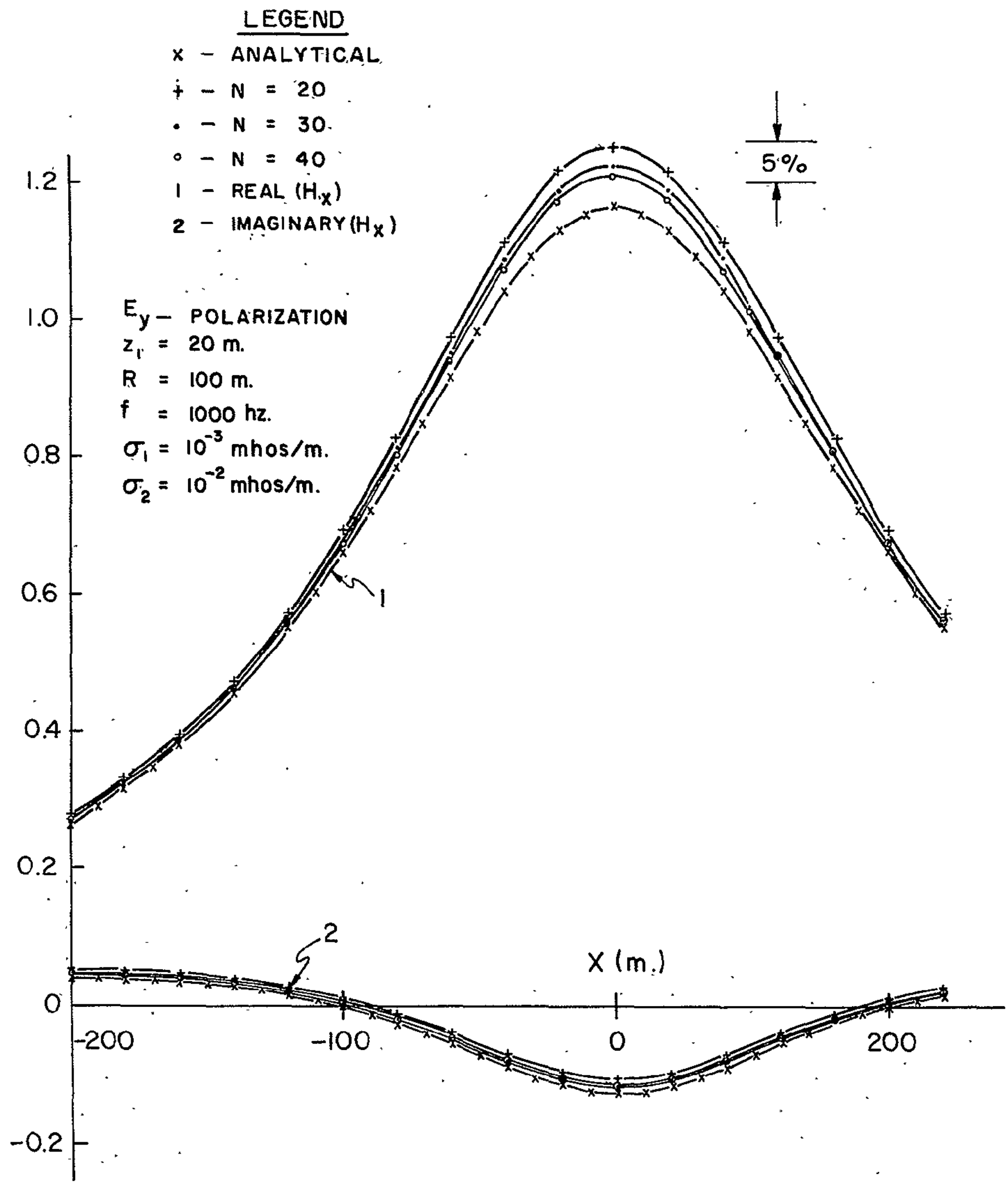

Ey - POLARIZATION
z1 = 20 m
R = 100 m.
f = 1000 hz.
σ1 = 10^-3 mhos/m.
σ2 = 10^-2 mhos/m.
LEGEND
x - ANALYTICAL
+ - N = 20
• - N = 30
o - N = 40
1 - REAL (Ky)
2 - IMAGINARY (Ky)
2.5 %
3.0
2.0
1.0
0
Ky
(Amps/m.)
θ
0
π/4
π/2
3π/4
π
1
2
z
x
θ

FIG 52



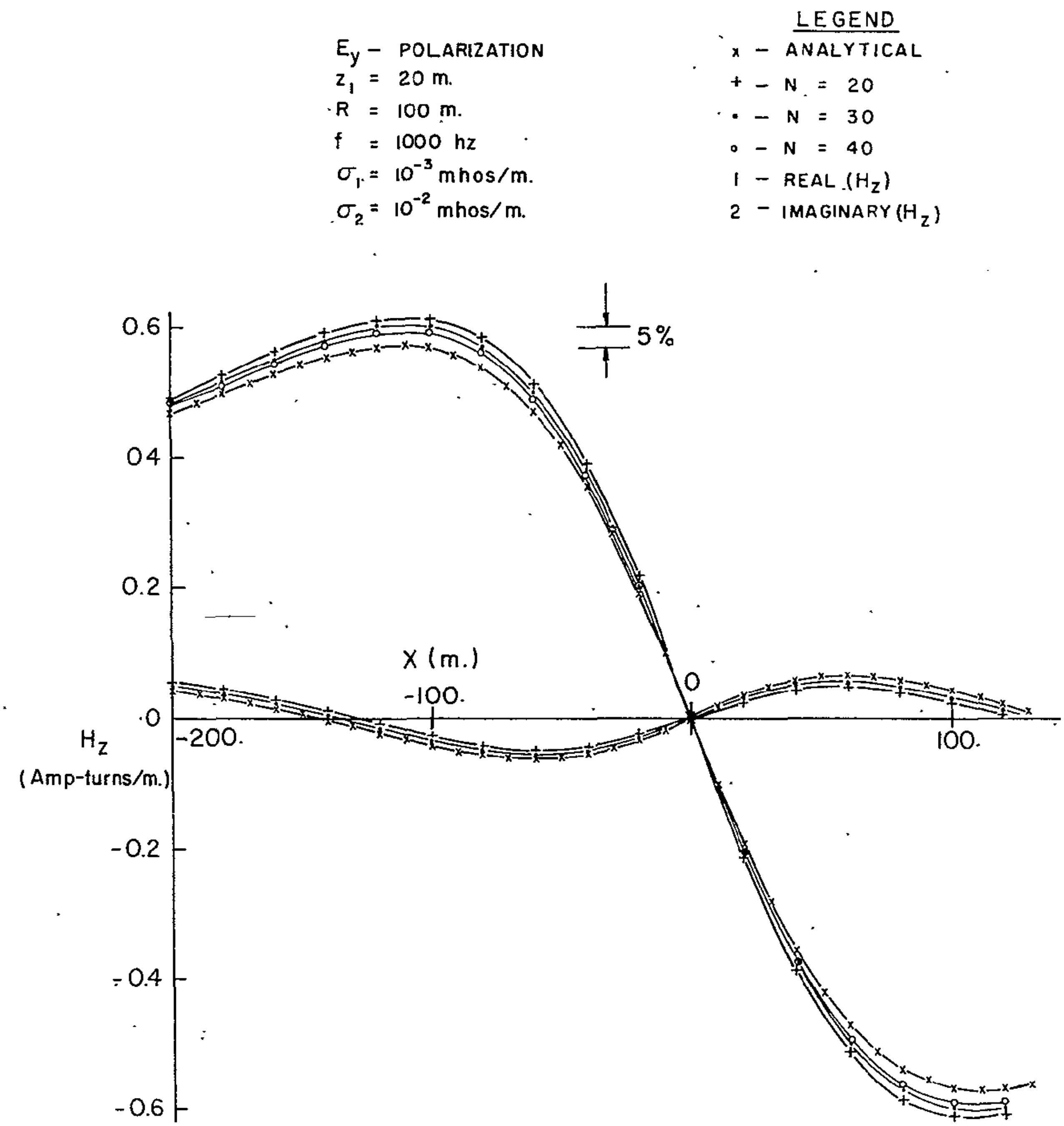
Ey – POLARIZATION
z1 = 20 m.
R = 100 m
f = 1000 hz.
σ1 = 10^-3 mhos/m.
σ2 = 10^-2 mhos/m.
LEGEND
x – ANALYTICAL
+ – N = 20
• – N = 30
∘ – N = 40
1 – REAL (Ms)
2 – IMAGINARY (Ms)
10 %
5 %
Ms
(Volts/m.)
2.0
1.0
0
-1.0
-2.0
-3.0
0
π/4
π/2
3π/4
π
θ
1
2
z
x

FIG 53



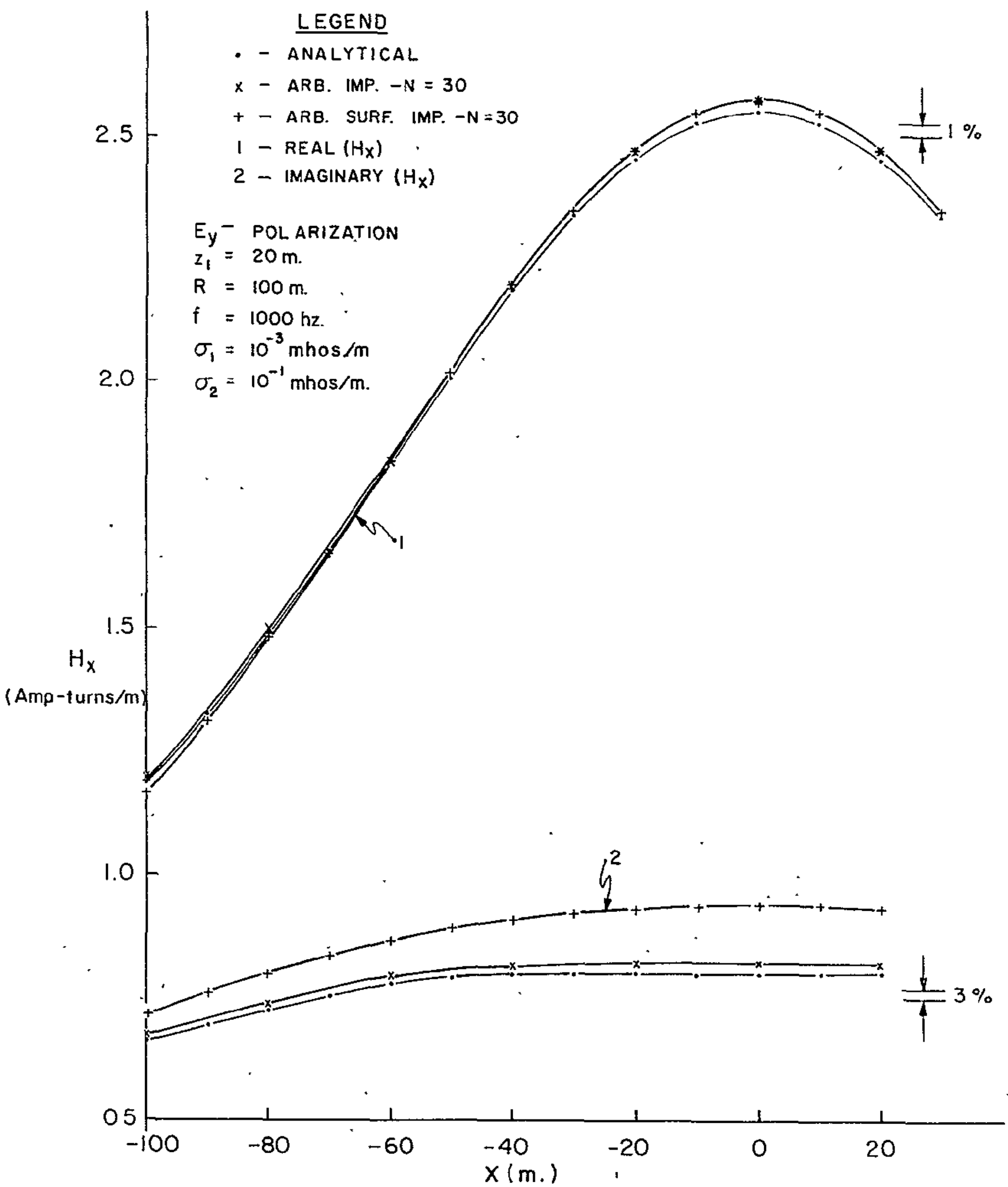
LEGEND
x – ANALYTICAL
+ – N = 20
• – N = 30
o – N = 40
1 – REAL (H_X)
2 – IMAGINARY (H_X)
E_y – POLARIZATION
z_1 = 20 m.
R = 100 m.
f = 1000 hz.
σ_1 = 10^-3 mhos/m.
σ_2 = 10^-2 mhos/m.
5%
1.2
1.0
0.8
0.6
0.4
0.2
0
-0.2
-200
-100
0
200
X (m.)
1
2

FIG 54



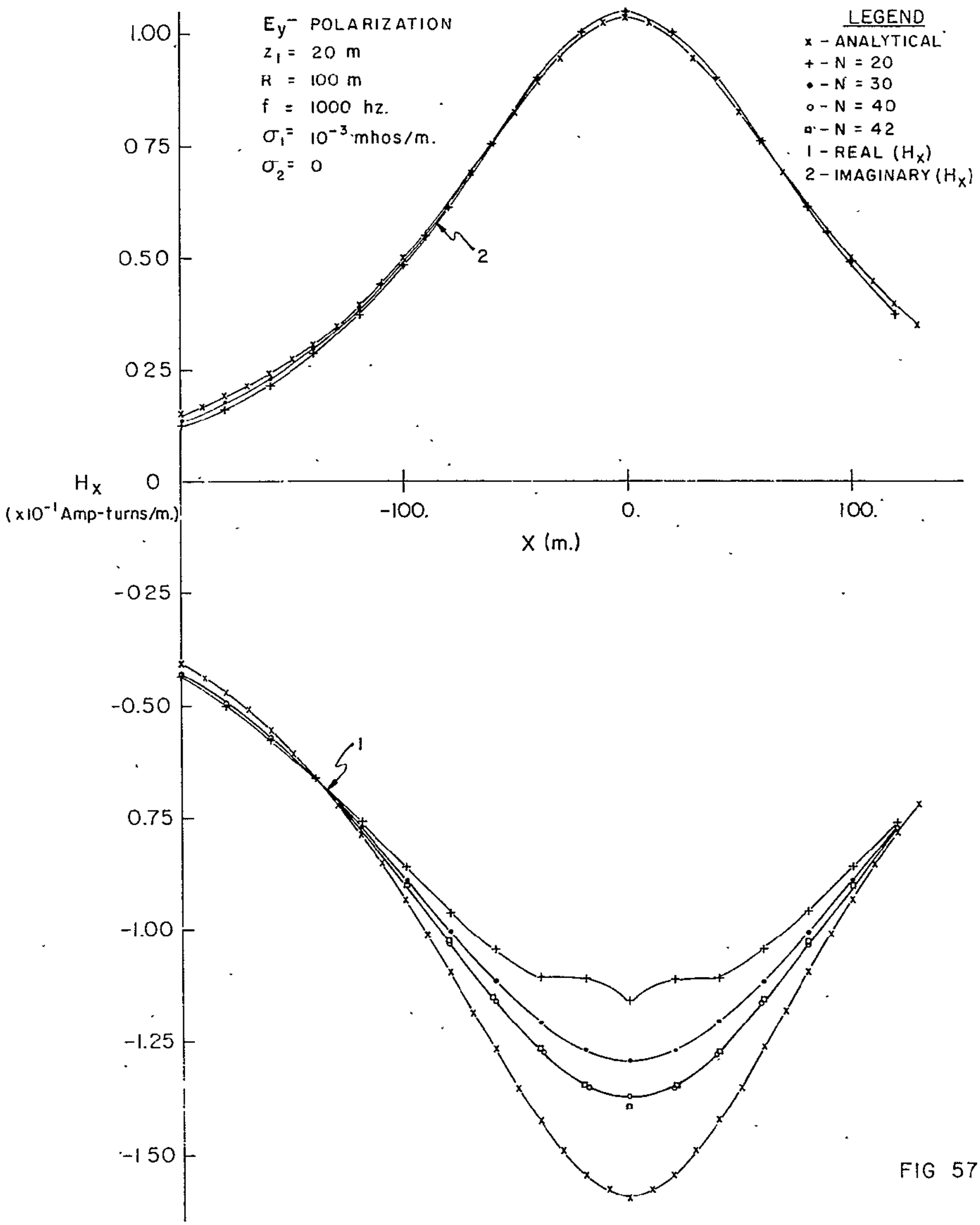
LEGEND
x — ANALYTICAL
+ — N = 20
• — N = 30
o — N = 40
1 — REAL (Hz)
2 — IMAGINARY (Hz)
Ey — POLARIZATION
z1 = 20 m.
R = 100 m.
f = 1000 hz
σ1 = 10^-3 mhos/m.
σ2 = 10^-2 mhos/m.
5%
0.6
0.4
0.2
.0
-0.2
-0.4
-0.6
Hz
(Amp-turns/m.)
X (m.)
-200.
-100.
0
100.

FIG 55



LEGEND
• – ANALYTICAL
x – ARB. IMP. –N = 30
+ – ARB. SURF. IMP. –N = 30
1 – REAL (H_X)
2 – IMAGINARY (H_X)
E_y – POLARIZATION
z_1 = 20 m.
R = 100 m.
f = 1000 hz.
$\sigma_1 = 10^{-3}$ mhos/m
$\sigma_2 = 10^{-1}$ mhos/m.
2.5
2.0
1.5
1.0
0.5
H_X
(Amp-turns/m)
1
2
1 %
3 %
-100
-80
-60
-40
-20
0
20
X (m.)

FIG 56



Ey- POLARIZATION
z1 = 20 m
R = 100 m
f = 1000 hz.
σ1 = 10^-3 mhos/m.
σ2 = 0
LEGEND
x - ANALYTICAL
+ - N = 20
• - N = 30
o - N = 40
□ - N = 42
1 - REAL (Hx)
2 - IMAGINARY (Hx)
1.00
0.75
0.50
0.25
0
-0.25
-0.50
0.75
-1.00
-1.25
-1.50
Hx
(x10^-1 Amp-turns/m.)
-100.
0.
100.
X (m.)
1
2

FIG 57

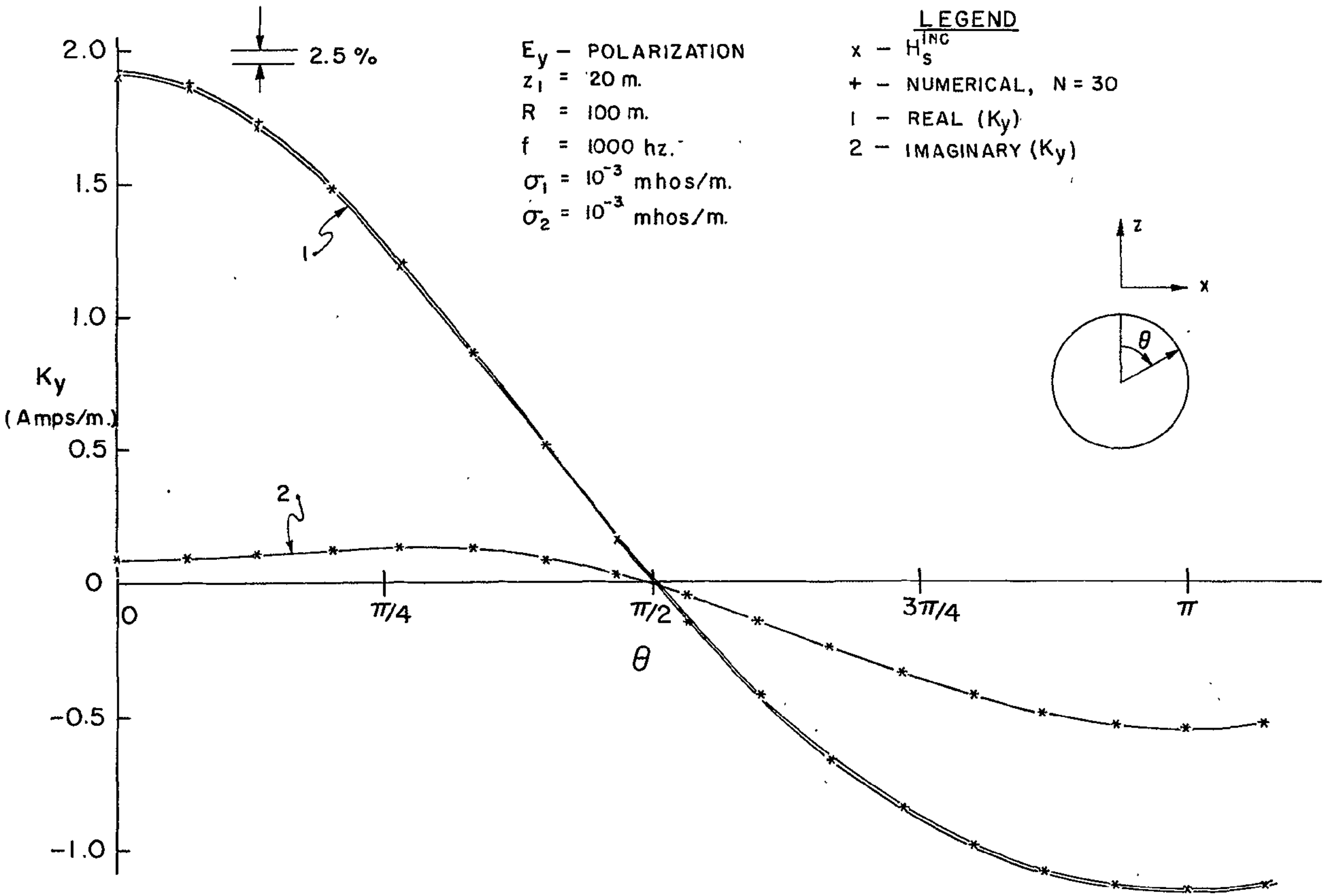
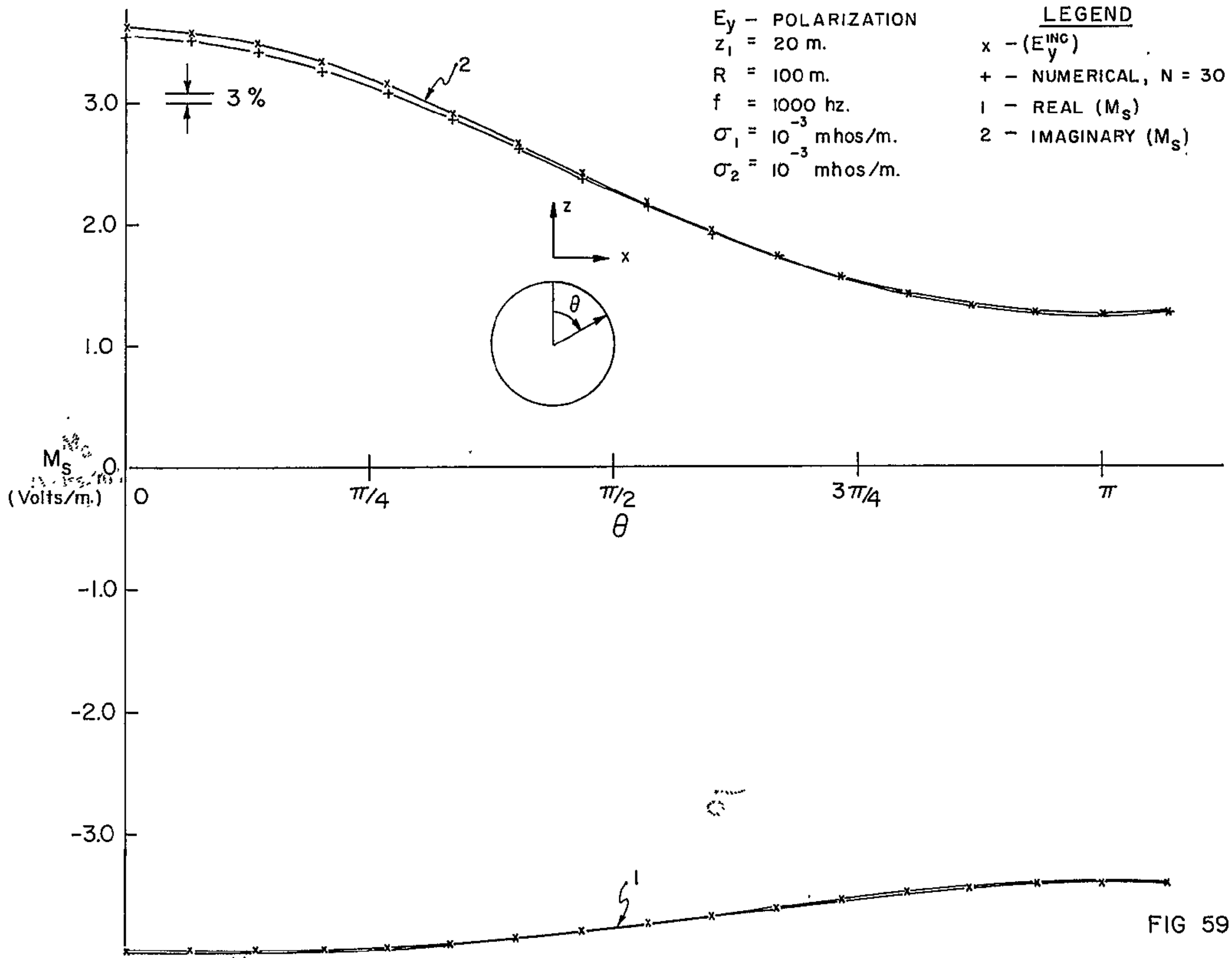

2.5 %
Ey – POLARIZATION
z1 = 20 m.
R = 100 m.
f = 1000 hz.
σ1 = 10^-3 mhos/m.
σ2 = 10^-3 mhos/m.
LEGEND
x – Hs^INC
+ – NUMERICAL, N = 30
1 – REAL (Ky)
2 – IMAGINARY (Ky)
Ky
(Amps/m.)
2.0
1.5
1.0
0.5
0
−0.5
−1.0
0
π/4
π/2
3π/4
π
θ
1
2
z
x
θ

FIG 58



E_y – POLARIZATION
z_1 = 20 m.
R = 100 m.
f = 1000 hz.
σ_1 = 10^{-3} mhos/m.
σ_2 = 10^{-3} mhos/m.
LEGEND
x – (E_y^{INC})
+ – NUMERICAL, N = 30
1 – REAL (M_s)
2 – IMAGINARY (M_s)
3 %
3.0
2.0
1.0
M_s 0
(Volts/m.)
-1.0
-2.0
-3.0
0
$\pi/4$
$\pi/2$
$3\pi/4$
π
θ
z
x
1
2

FIG 59

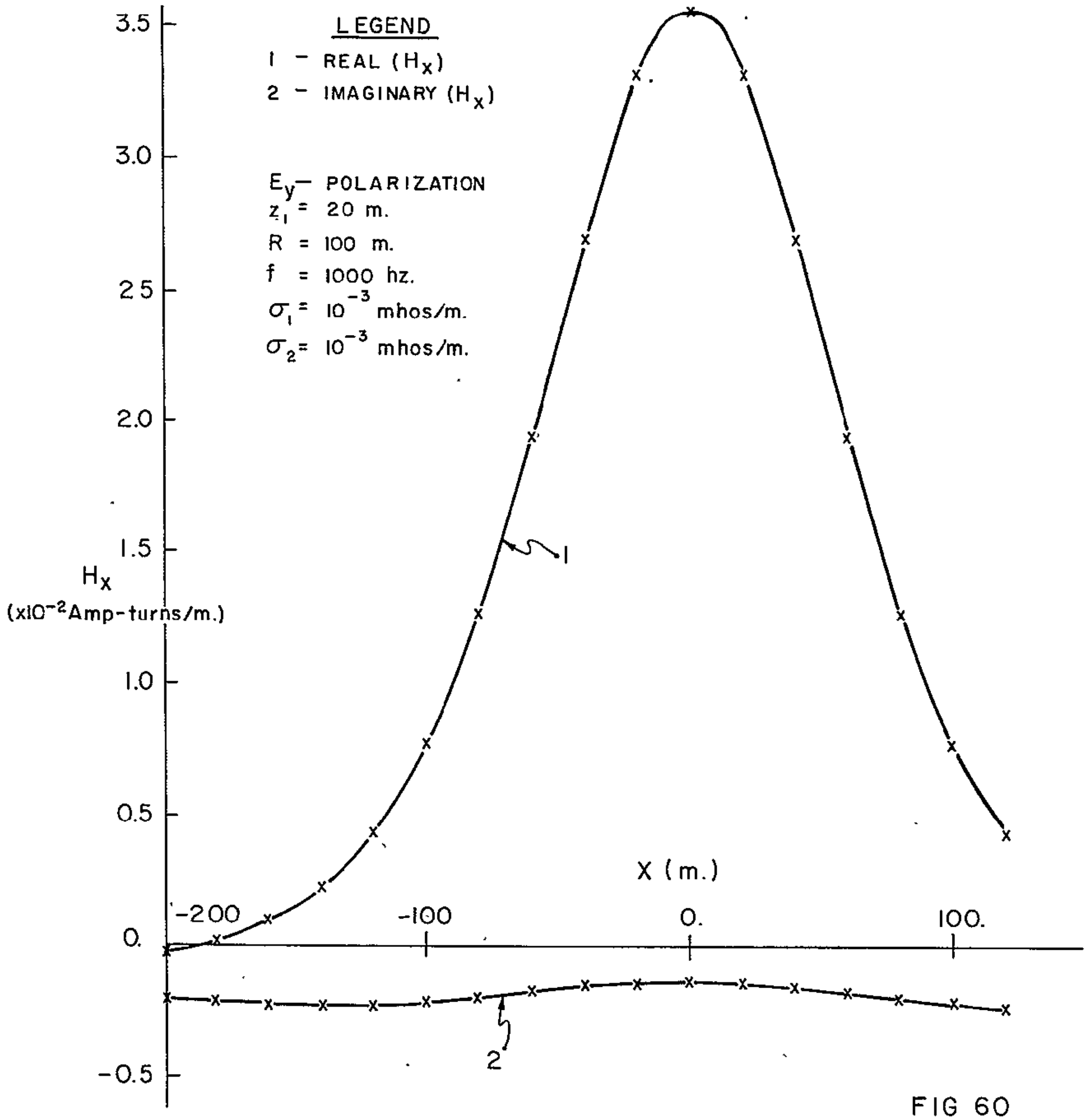
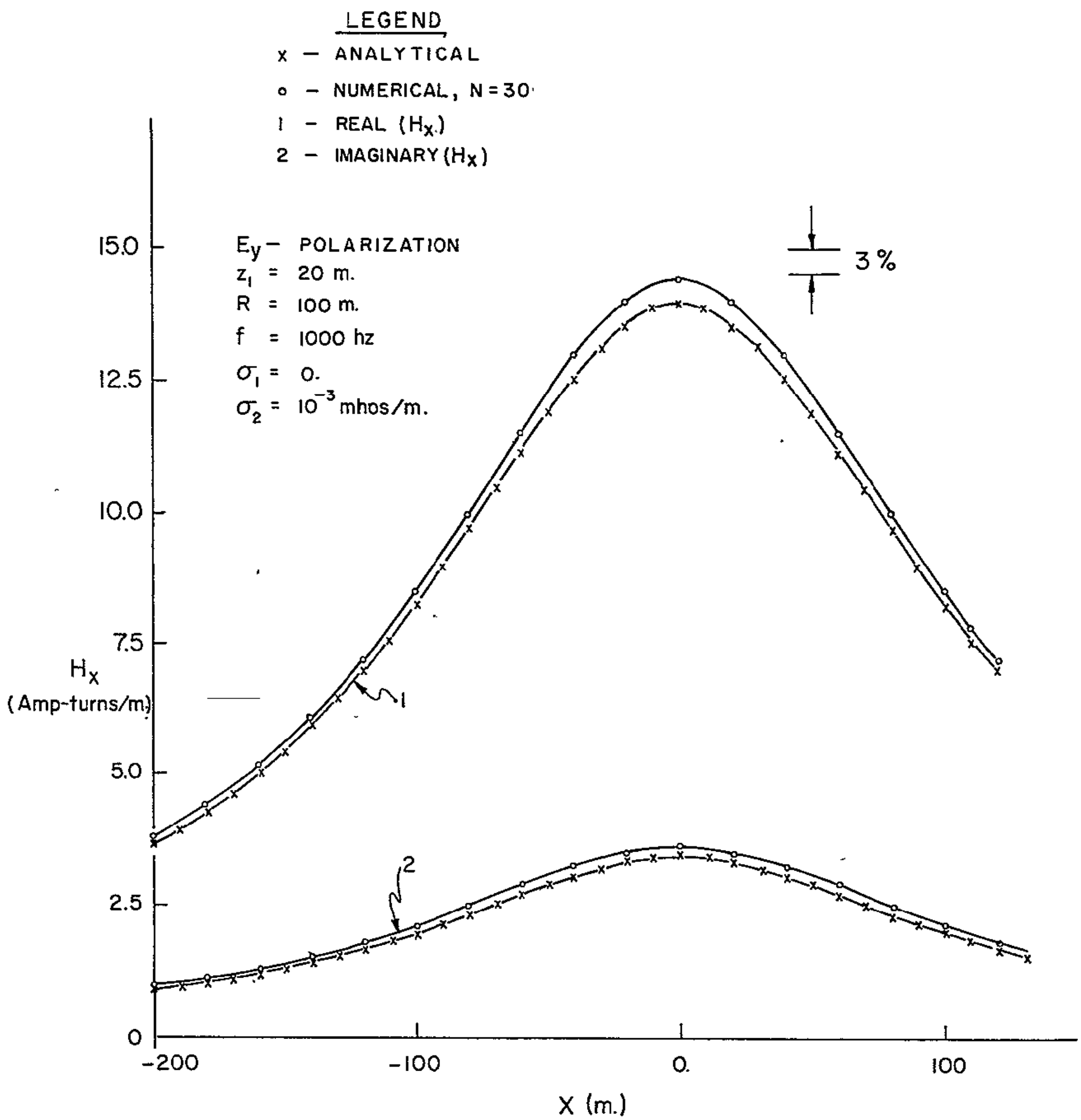
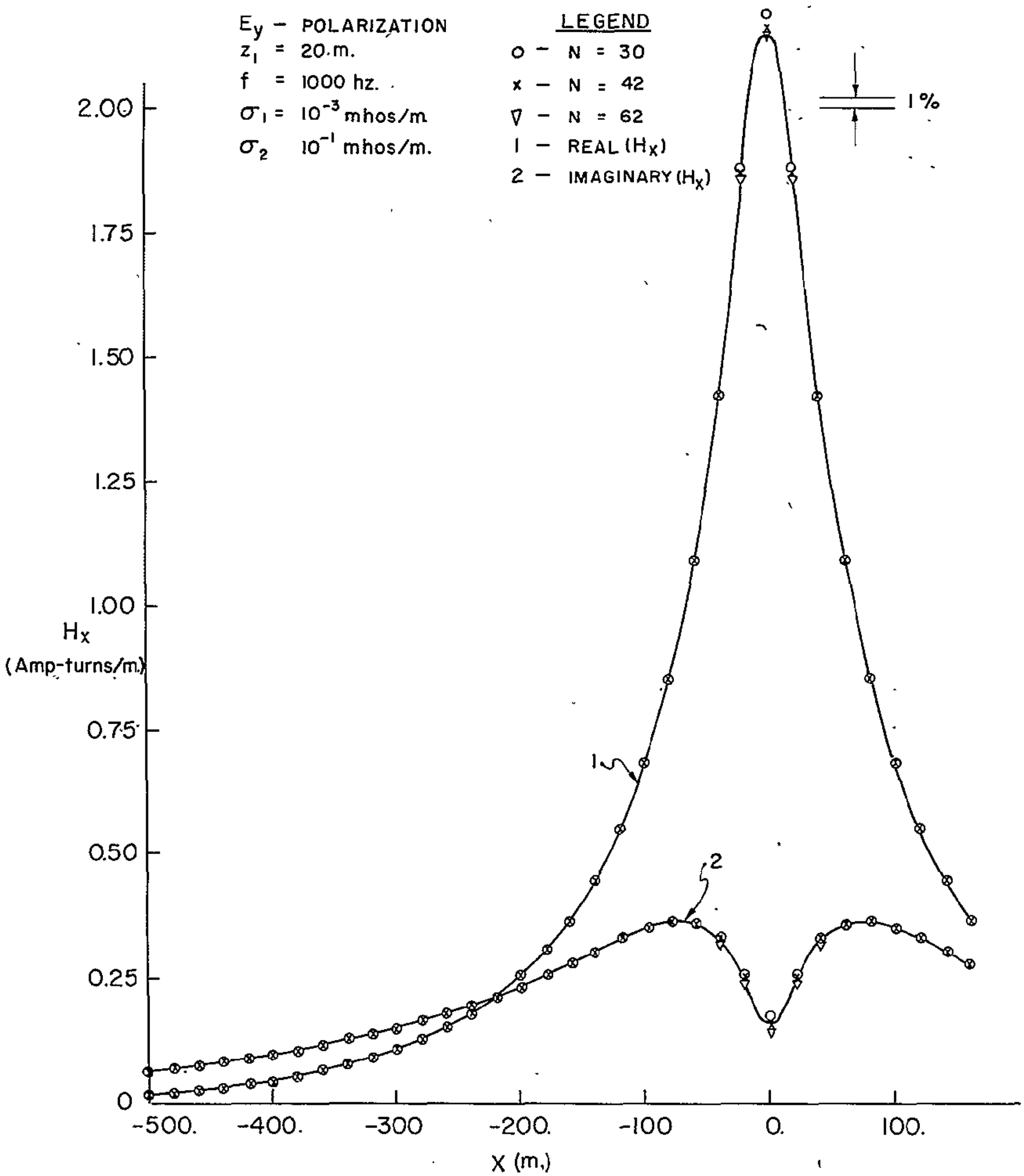

LEGEND
1 - REAL (H_x)
2 - IMAGINARY (H_x)
E_y — POLARIZATION
z_1 = 20 m.
R = 100 m.
f = 1000 hz.
$\sigma_1 = 10^{-3}$ mhos/m.
$\sigma_2 = 10^{-3}$ mhos/m.
H_x
($\times 10^{-2}$ Amp-turns/m.)
X (m.)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
-0.5
-200
-100
0.
100.
1
2

FIG 60



LEGEND
x — ANALYTICAL
o — NUMERICAL, N=30
1 — REAL (Hx)
2 — IMAGINARY (Hx)
Ey — POLARIZATION
z1 = 20 m.
R = 100 m.
f = 1000 hz
σ1 = 0.
σ2 = 10^-3 mhos/m.
3%
15.0
12.5
10.0
7.5
5.0
2.5
0
Hx
(Amp-turns/m)
1
2
-200
-100
0.
100
X (m.)

FIG 61



Ey - POLARIZATION
z1 = 20.m.
f = 1000 hz.
σ1 = 10^-3 mhos/m.
σ2 10^-1 mhos/m.
LEGEND
o - N = 30
x - N = 42
∇ - N = 62
1 - REAL (Hx)
2 - IMAGINARY (Hx)
1%
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0
Hx
(Amp-turns/m.)
1
2
-500.
-400.
-300
-200.
-100
0.
100.
X (m.)

FIG 62

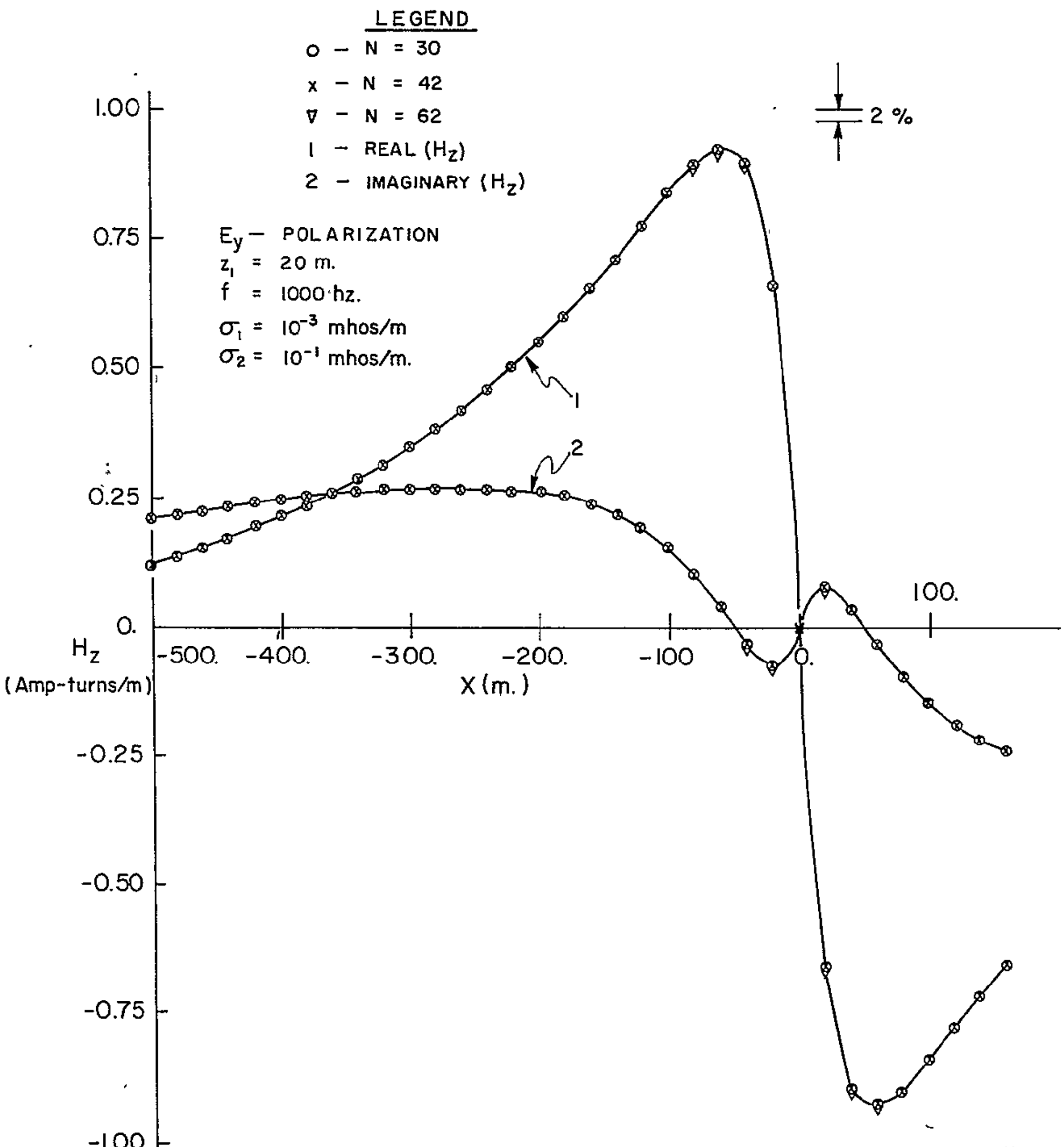

LEGEND
o — N = 30
x — N = 42
∇ — N = 62
1 — REAL (Hz)
2 — IMAGINARY (Hz)
Ey — POLARIZATION
z1 = 20 m.
f = 1000 hz.
σ1 = 10^-3 mhos/m
σ2 = 10^-1 mhos/m.
2 %
1.00
0.75
0.50
0.25
0.
-0.25
-0.50
-0.75
-1.00
Hz
(Amp-turns/m)
-500.
-400.
-300.
-200.
-100
0.
100.
X (m.)
1
2

FIG 63

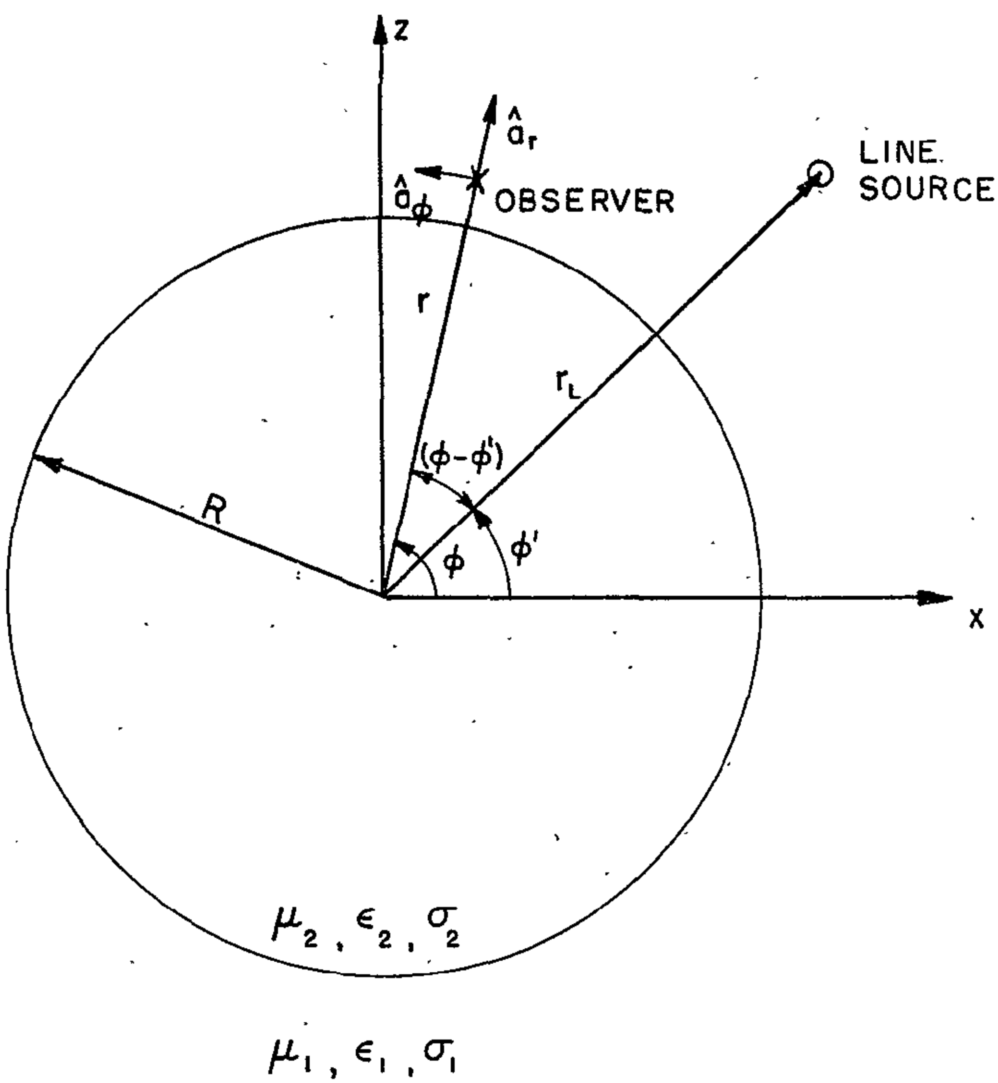

z
$\hat{a}_r$
$\hat{a}_\phi$
OBSERVER
LINE SOURCE
r
r_L
R
$(\phi-\phi')$
ϕ
ϕ'
x
$\mu_2, \epsilon_2, \sigma_2$
$\mu_1, \epsilon_1, \sigma_1$

FIG 64

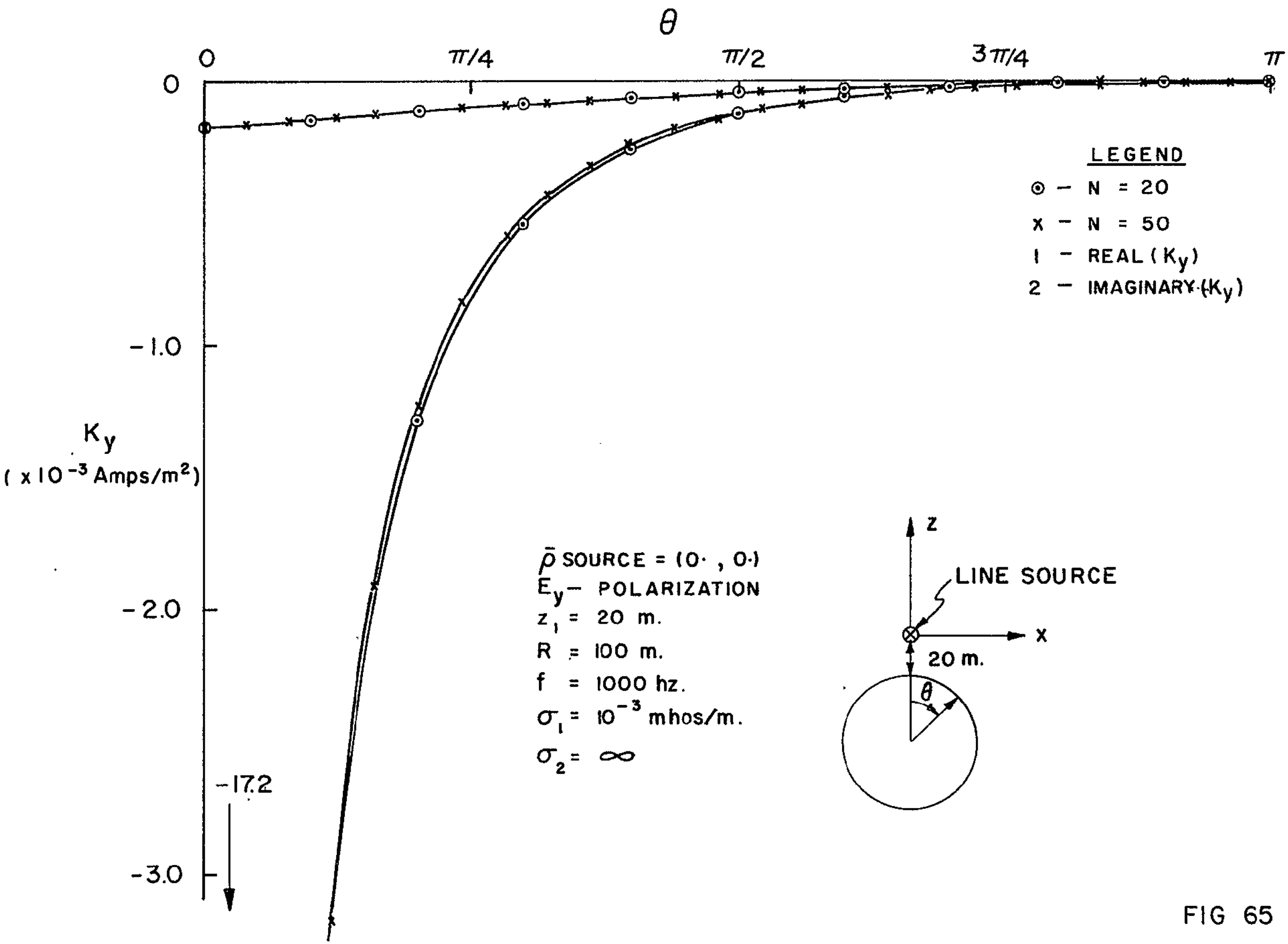

θ
0
π/4
π/2
3π/4
π
0
-1.0
-2.0
-3.0
K_y
(x 10^{-3} Amps/m²)
-17.2
LEGEND
⊙ – N = 20
x – N = 50
1 – REAL (K_y)
2 – IMAGINARY (K_y)
$\bar{\rho}$ SOURCE = (0· , 0·)
E_y– POLARIZATION
z_1 = 20 m.
R = 100 m.
f = 1000 hz.
σ_1 = 10^{-3} mhos/m.
σ_2 = ∞
z
LINE SOURCE
x
20 m.
θ

FIG 65

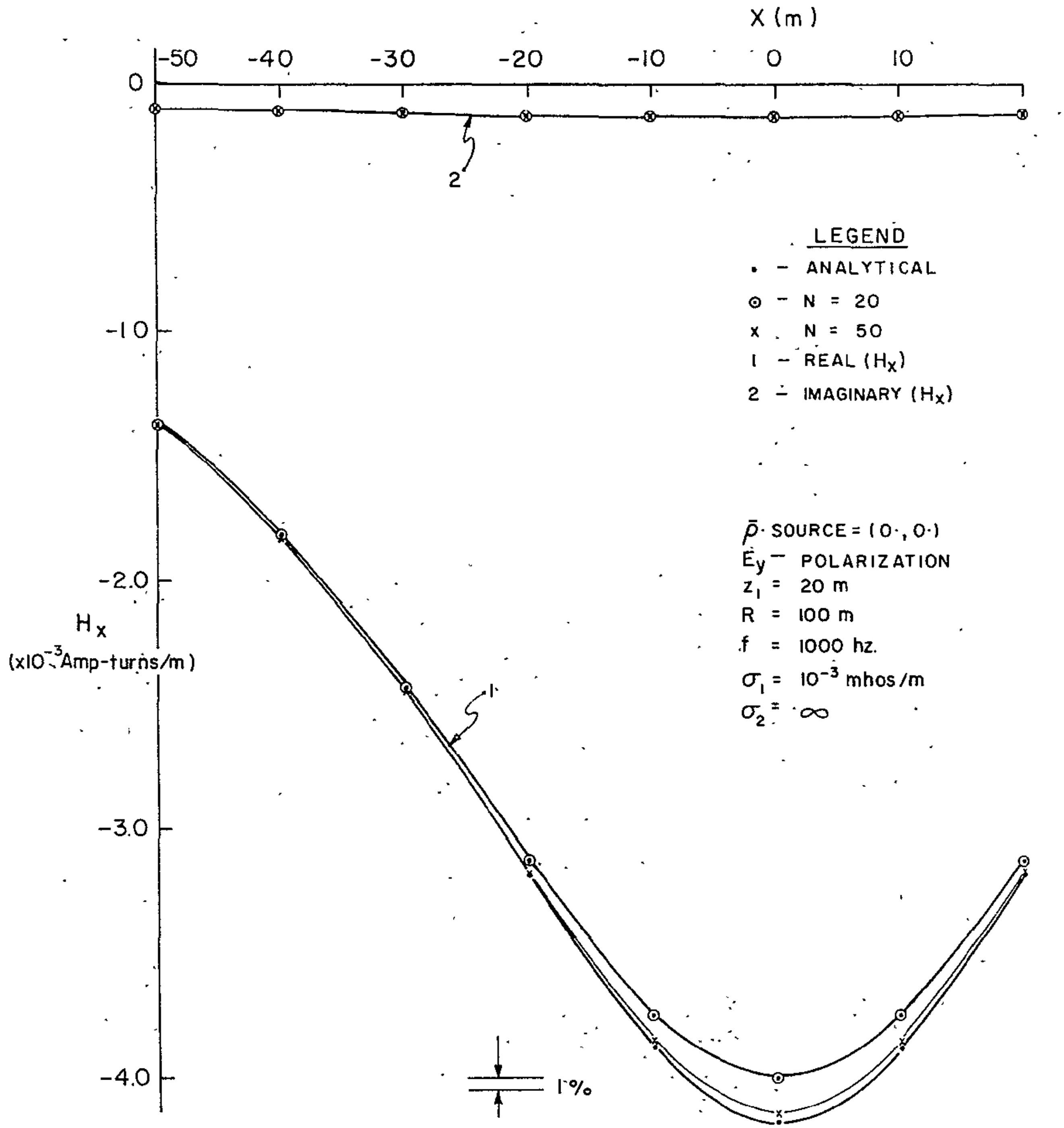
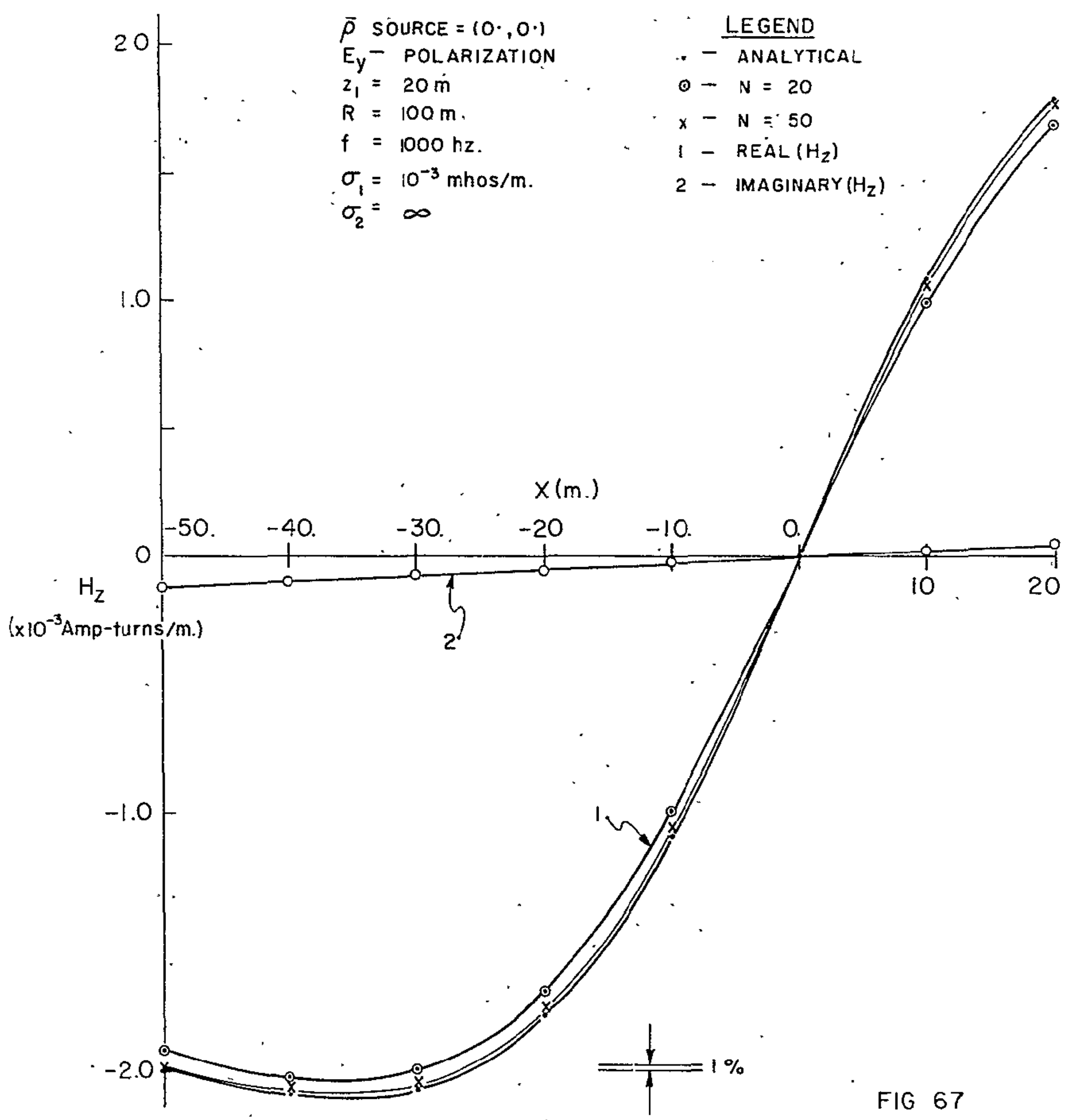

X (m)
-50
-40
-30
-20
-10
0
10
0
2
LEGEND
• – ANALYTICAL
⊙ – N = 20
x N = 50
1 – REAL (Hx)
2 – IMAGINARY (Hx)
-1.0
-2.0
Hx
(x10⁻³ Amp-turns/m)
-3.0
-4.0
1
1%
p̄ SOURCE = (0., 0.)
Ey – POLARIZATION
z1 = 20 m
R = 100 m
f = 1000 hz.
σ1 = 10⁻³ mhos/m
σ2 = ∞

FIG 66



$\bar{\rho}$ SOURCE = (0·, 0·)
E_y — POLARIZATION
z_1 = 20 m
R = 100 m.
f = 1000 hz.
σ_1 = 10^{-3} mhos/m.
σ_2 = ∞
LEGEND
· — ANALYTICAL
⊙ — N = 20
x — N = 50
1 — REAL (H_z)
2 — IMAGINARY (H_z)
2.0
1.0
0
-1.0
-2.0
X (m.)
-50.
-40.
-30.
-20
-10.
0.
10
20
H_z
($\times 10^{-3}$ Amp-turns/m.)
1
2
1 %

FIG 67

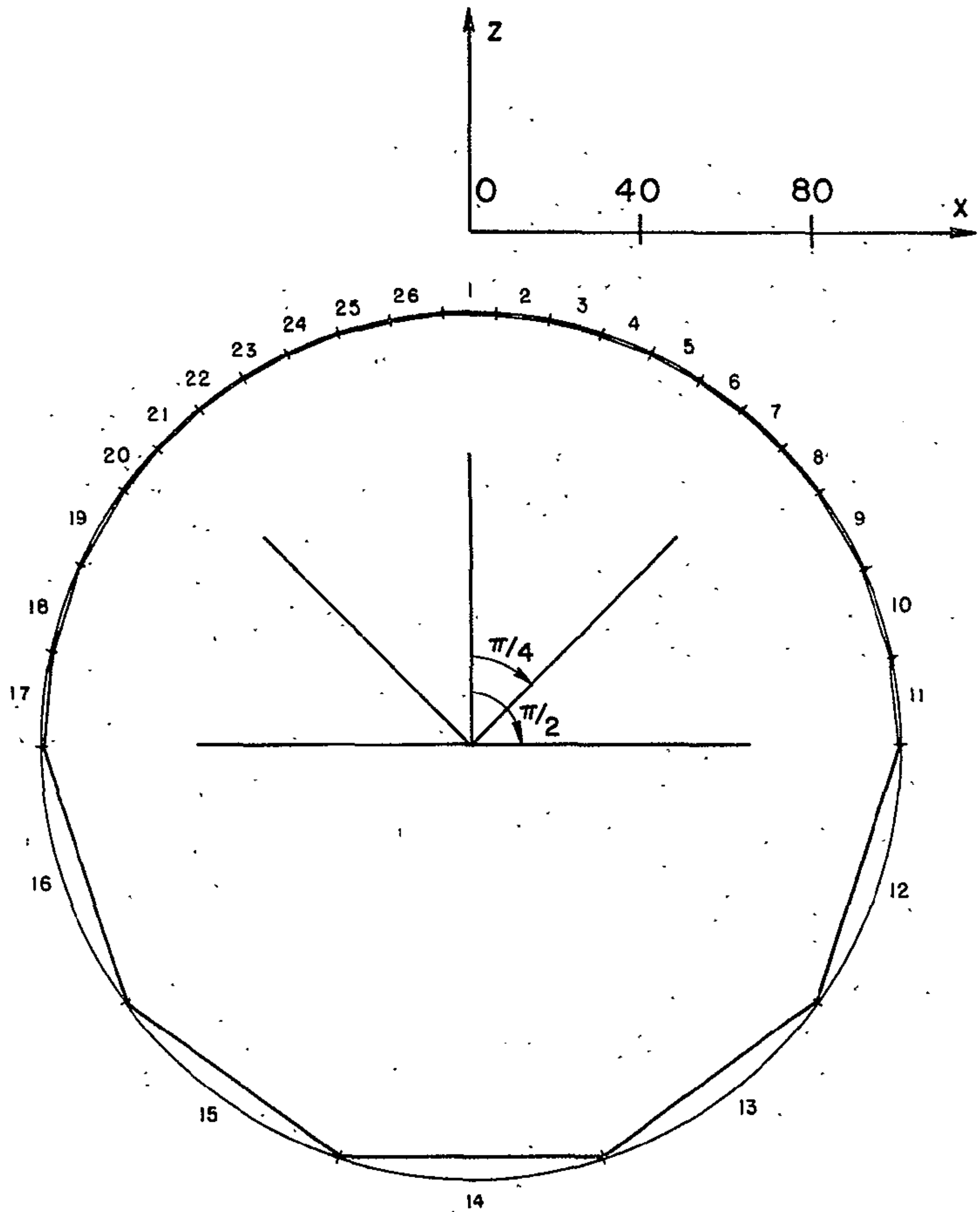
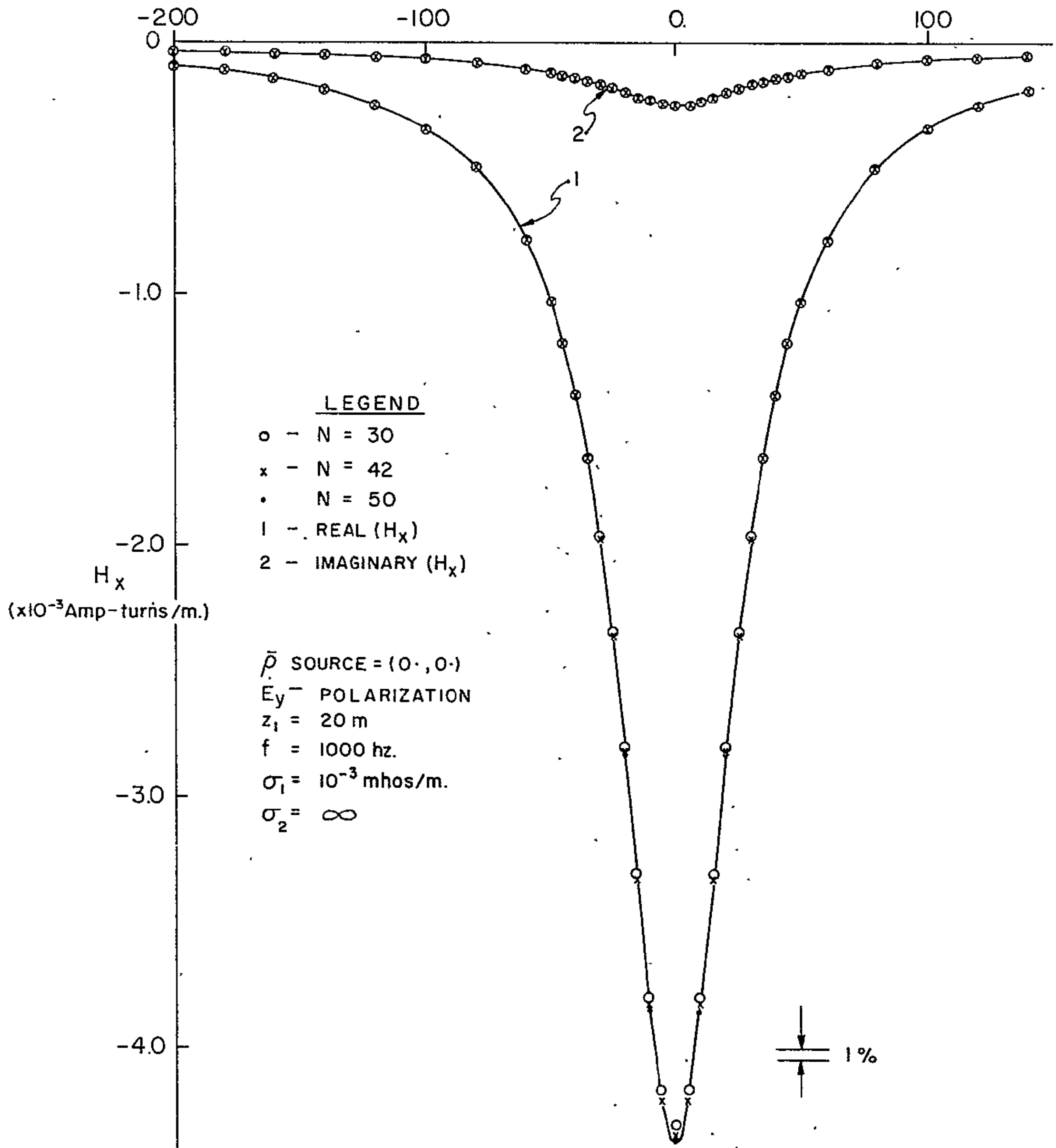

Z
0
40
80
X
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
π/4
π/2

FIG 68



-200
-100
0.
100
0
-1.0
-2.0
-3.0
-4.0
H X
(x10⁻³ Amp-turns/m.)
LEGEND
o – N = 30
x – N = 42
• N = 50
1 – REAL (Hx)
2 – IMAGINARY (Hx)
ρ̄ SOURCE = (0·, 0·)
Ey – POLARIZATION
z1 = 20 m
f = 1000 hz.
σ1 = 10⁻³ mhos/m.
σ2 = ∞
1
2
1 %

FIG 69

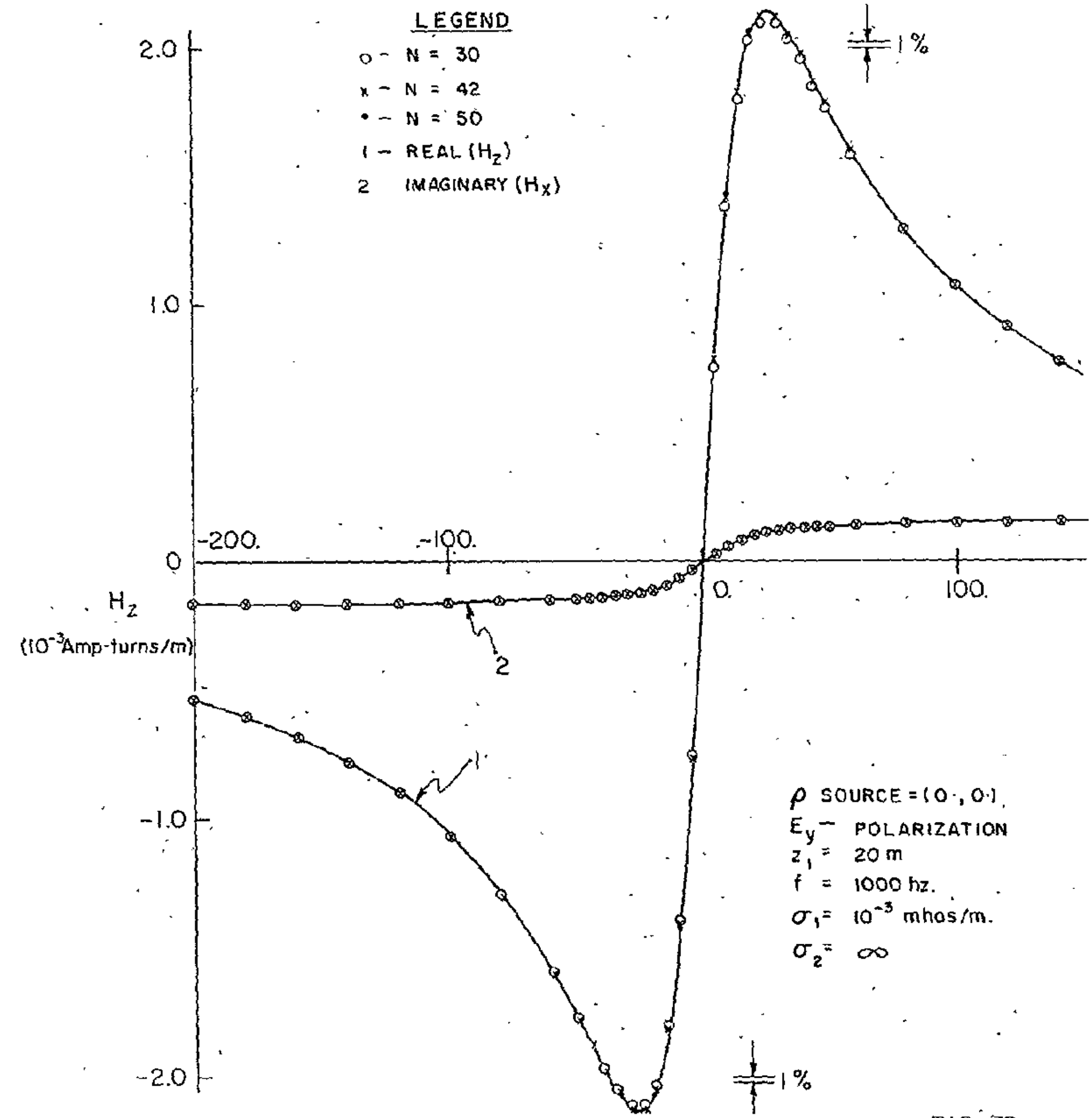
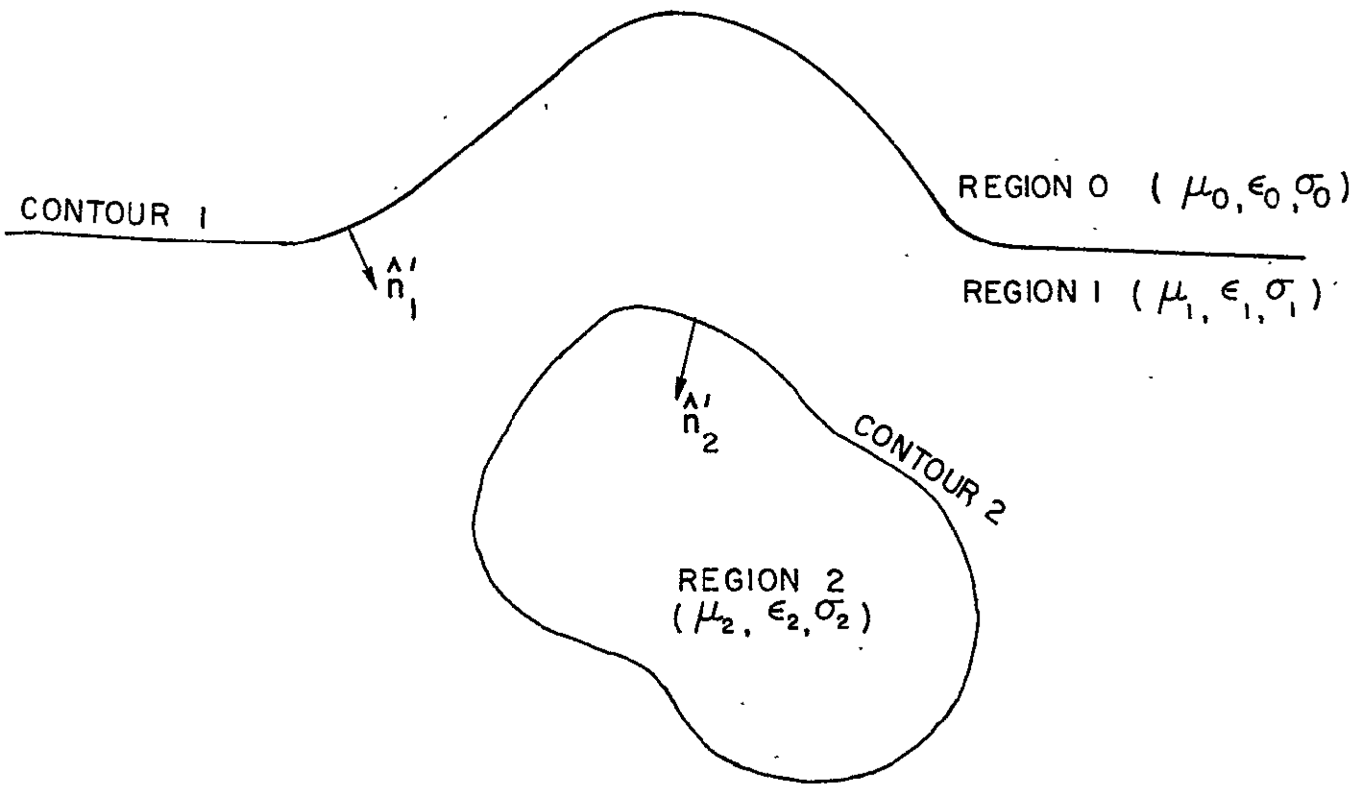

LEGEND
o – N = 30
x – N = 42
• – N = 50
1 – REAL (Hz)
2 IMAGINARY (Hx)
2.0
1.0
0
-1.0
-2.0
-200.
-100.
0.
100.
Hz
(10^-3 Amp-turns/m)
1%
1%
1
2
ρ SOURCE = (0., 0.)
Ey – POLARIZATION
z1 = 20 m
f = 1000 hz.
σ1 = 10^-3 mhos/m.
σ2 = ∞

FIG 70



CONTOUR 1
REGION 0 ($\mu_0, \epsilon_0, \sigma_0$)
REGION 1 ($\mu_1, \epsilon_1, \sigma_1$)
$\hat{n}'_1$
$\hat{n}'_2$
CONTOUR 2
REGION 2
($\mu_2, \epsilon_2, \sigma_2$)

FIG 71

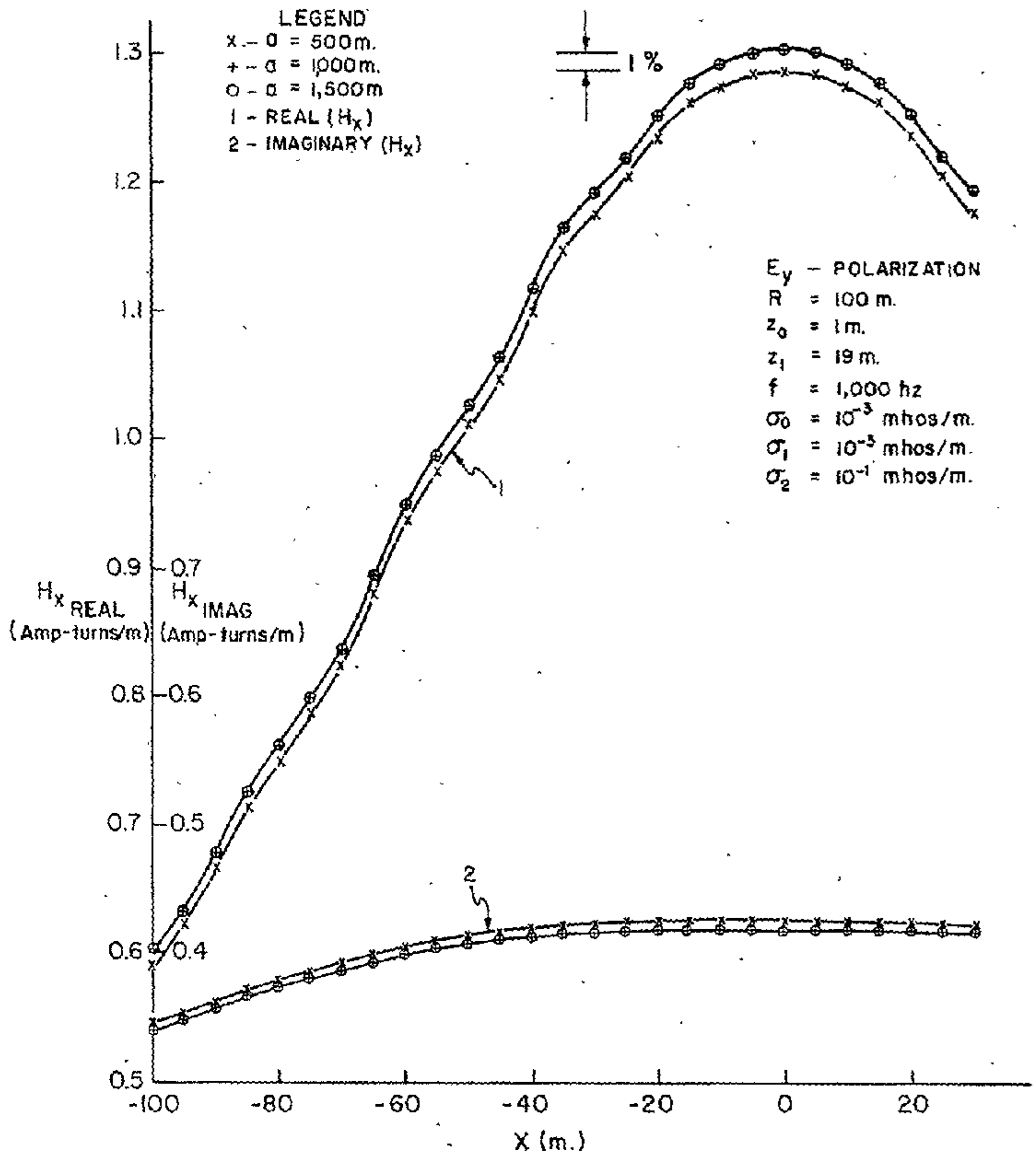
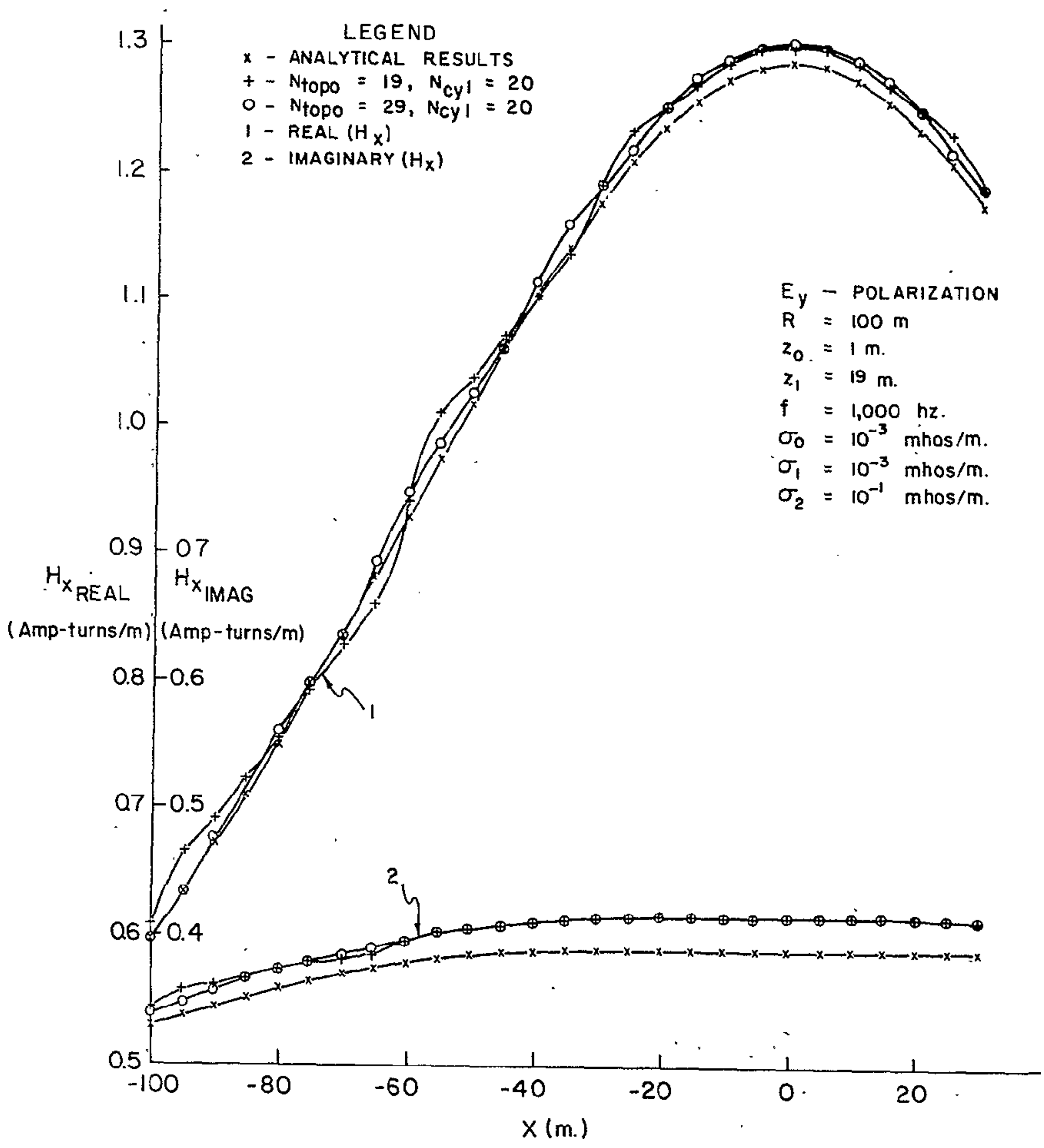
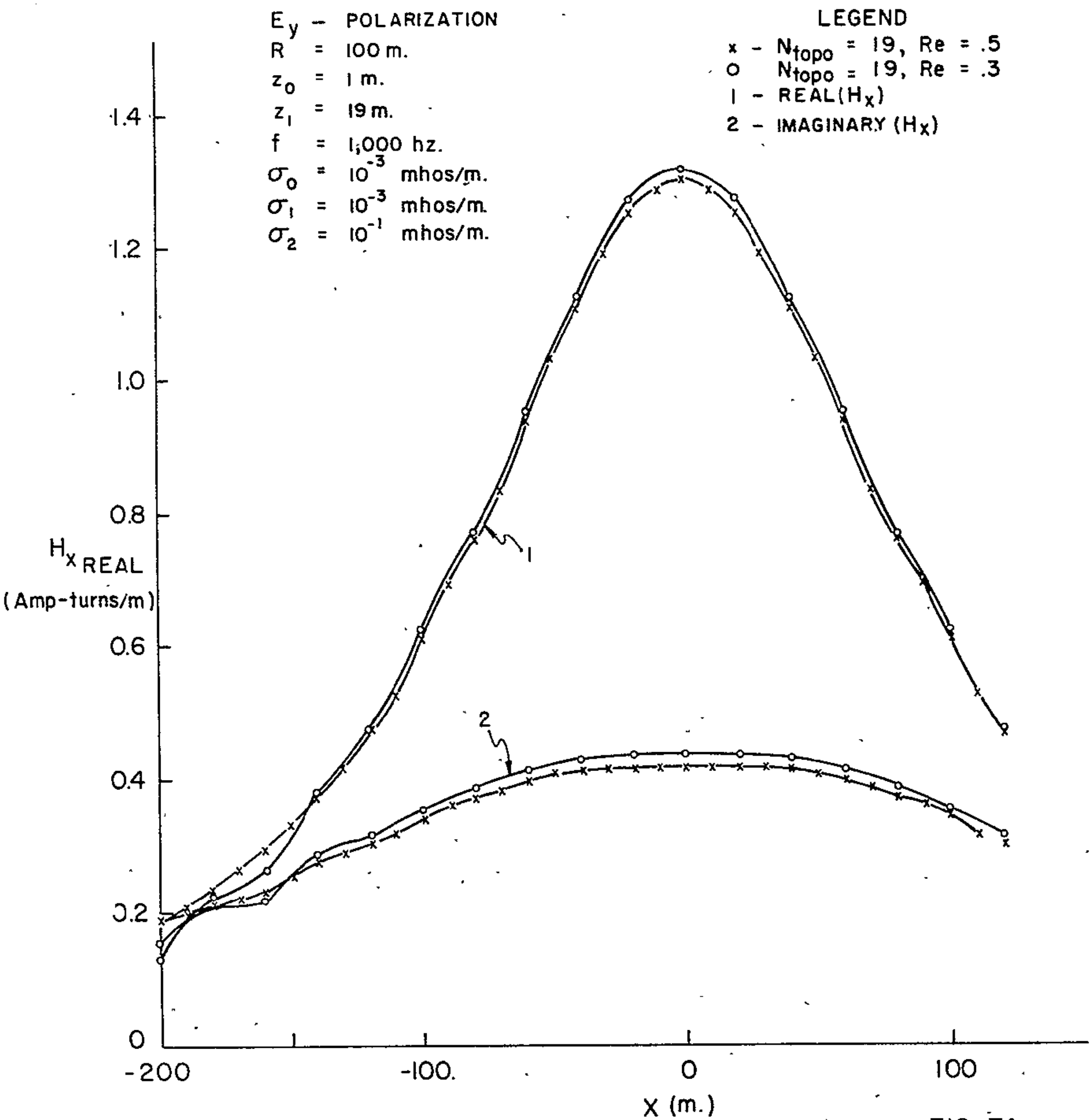

LEGEND
x - a = 500m.
+ - a = 1,000m.
o - a = 1,500m
1 - REAL (Hx)
2 - IMAGINARY (Hx)
1 %
Ey - POLARIZATION
R = 100 m.
z0 = 1 m.
z1 = 19 m.
f = 1,000 hz
σ0 = 10^-3 mhos/m.
σ1 = 10^-3 mhos/m.
σ2 = 10^-1 mhos/m.
Hx REAL (Amp-turns/m)
Hx IMAG (Amp-turns/m)
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.7
0.6
0.5
0.4
1
2
-100
-80
-60
-40
-20
0
20
X (m.)

FIG 72



LEGEND
x - ANALYTICAL RESULTS
+ - Ntopo = 19, Ncyl = 20
O - Ntopo = 29, Ncyl = 20
1 - REAL (Hx)
2 - IMAGINARY (Hx)
Ey — POLARIZATION
R = 100 m
z0 = 1 m.
z1 = 19 m.
f = 1,000 hz.
σ0 = 10^-3 mhos/m.
σ1 = 10^-3 mhos/m.
σ2 = 10^-1 mhos/m.
Hx REAL (Amp-turns/m)
Hx IMAG (Amp-turns/m)
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.7
0.6
0.5
0.4
1
2
-100
-80
-60
-40
-20
0
20
X (m.)

FIG 73



E_y – POLARIZATION
R = 100 m.
z_0 = 1 m.
z_1 = 19 m.
f = 1,000 hz.
σ_0 = 10^{-3} mhos/m.
σ_1 = 10^{-3} mhos/m.
σ_2 = 10^{-1} mhos/m.
LEGEND
x – N_{topo} = 19, Re = .5
o N_{topo} = 19, Re = .3
1 – REAL(H_X)
2 – IMAGINARY (H_X)
$H_{X\,REAL}$ (Amp-turns/m)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
-200
-100.
0
100
X (m.)
1
2

FIG 74

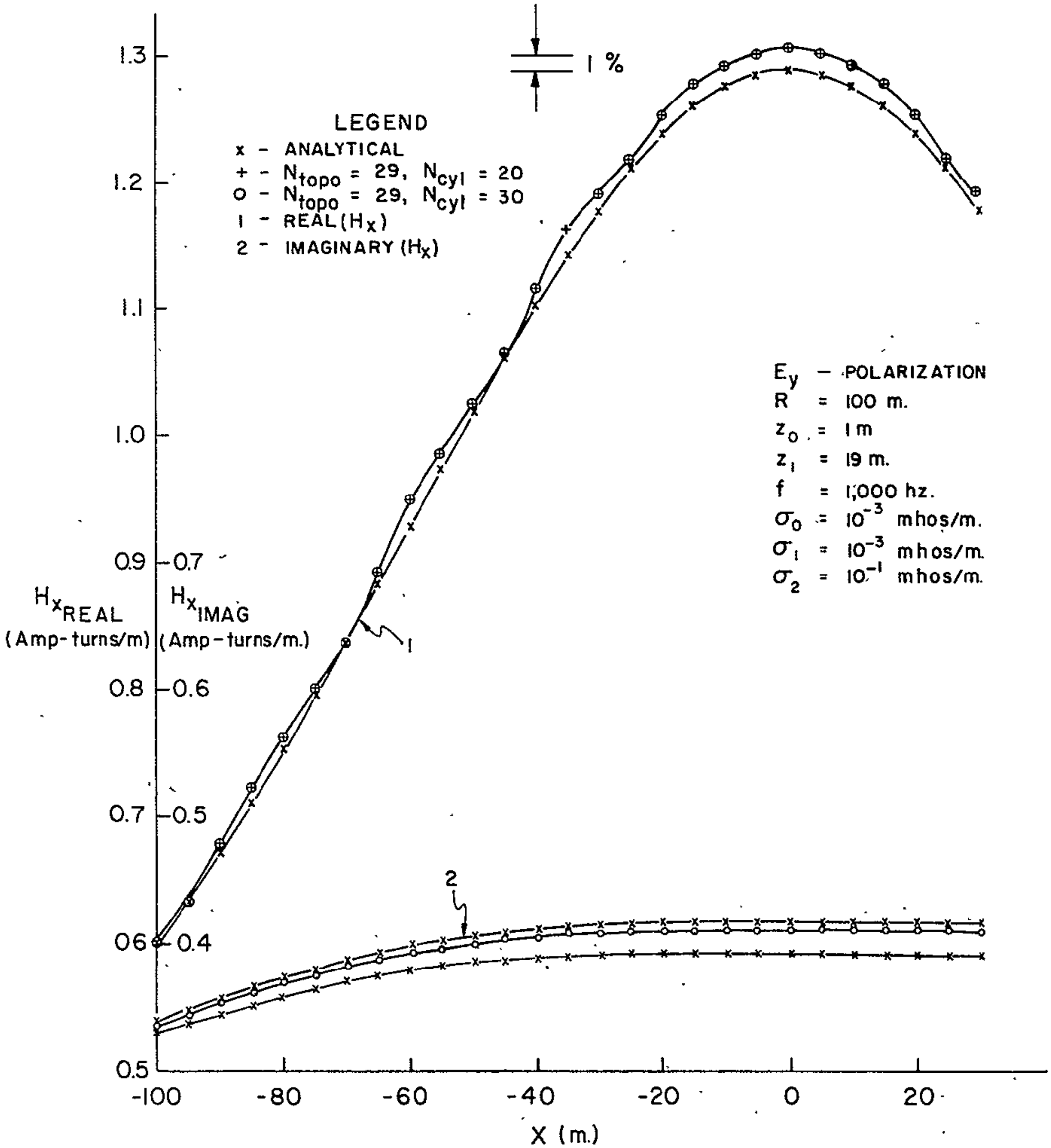

1 %
LEGEND
x - ANALYTICAL
+ - N_{topo} = 29, N_{cyl} = 20
o - N_{topo} = 29, N_{cyl} = 30
1 - REAL(H_x)
2 - IMAGINARY (H_x)
E_y — POLARIZATION
R = 100 m.
z_0 = 1 m
z_1 = 19 m.
f = 1,000 hz.
σ_0 = 10^{-3} mhos/m.
σ_1 = 10^{-3} mhos/m.
σ_2 = 10^{-1} mhos/m.
$H_{x_{REAL}}$ (Amp-turns/m)
$H_{x_{IMAG}}$ (Amp-turns/m.)
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.7
0.6
0.5
0.4
1
2
-100
-80
-60
-40
-20
0
20
X (m.)

FIG 75

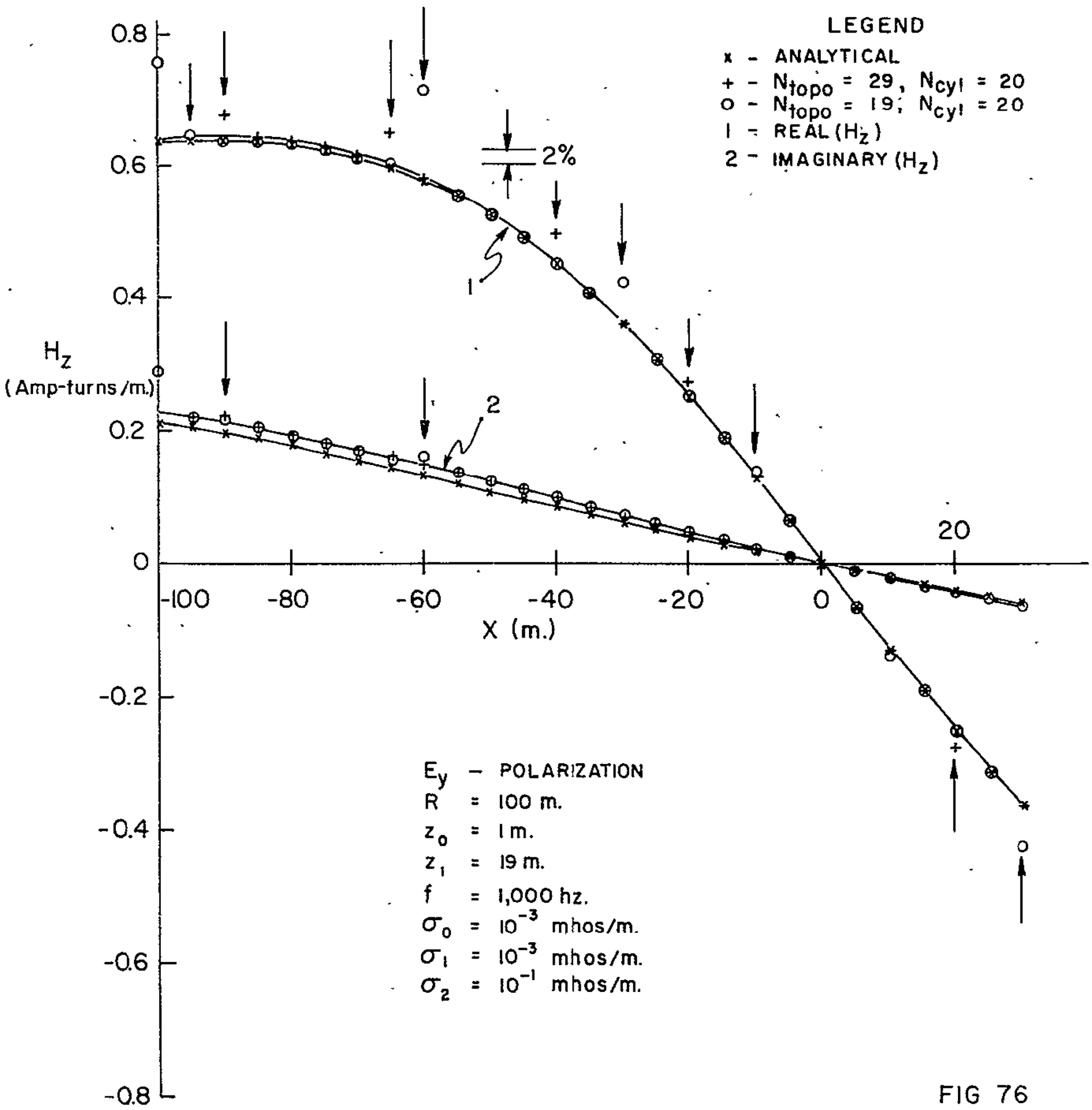
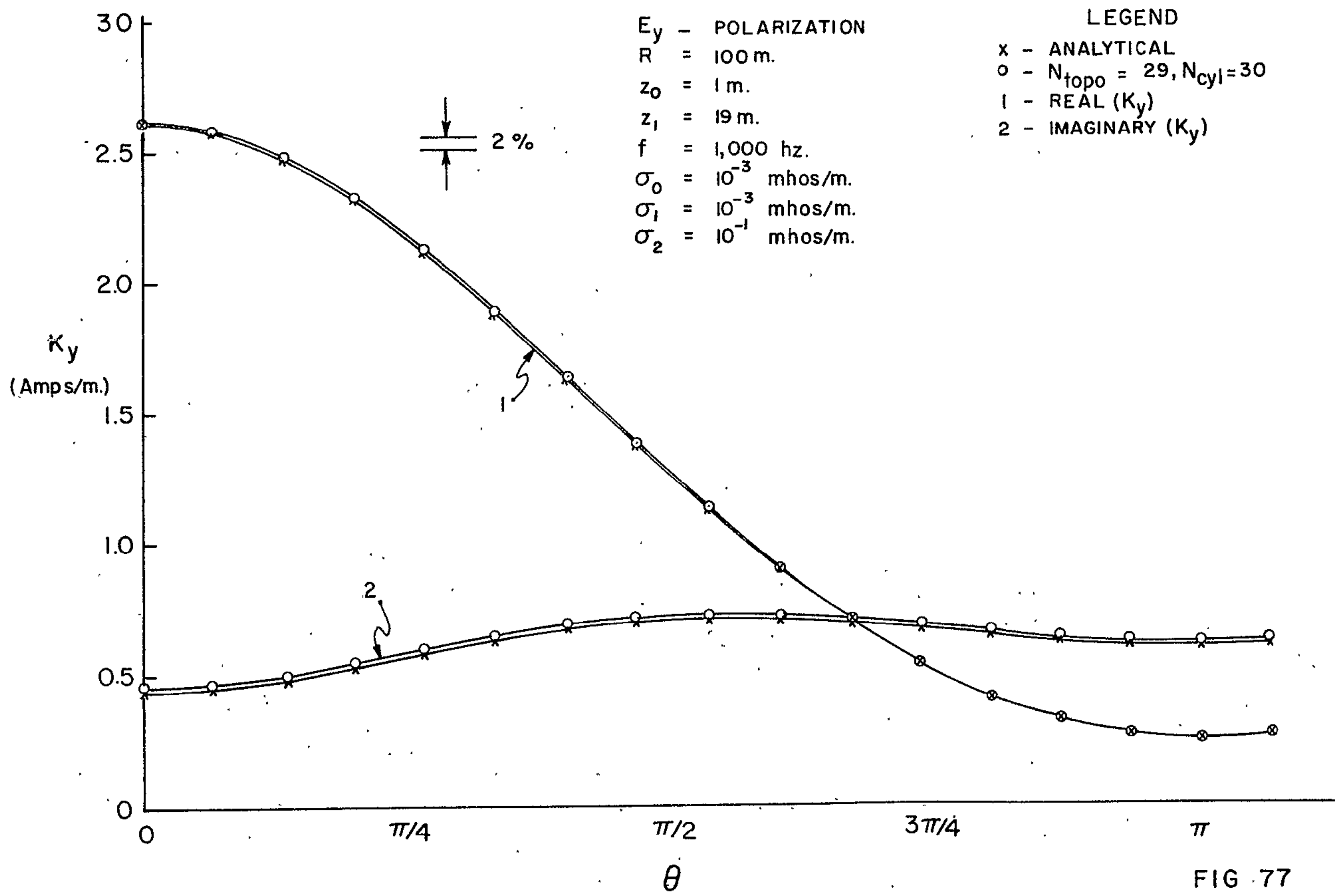

LEGEND
x - ANALYTICAL
+ - N_{topo} = 29, N_{cyl} = 20
o - N_{topo} = 19, N_{cyl} = 20
1 - REAL (H_z)
2 - IMAGINARY (H_z)
2%
H_z
(Amp-turns/m.)
X (m.)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-100
-80
-60
-40
-20
0
20
1
2
E_y - POLARIZATION
R = 100 m.
z_0 = 1 m.
z_1 = 19 m.
f = 1,000 hz.
σ_0 = 10^{-3} mhos/m.
σ_1 = 10^{-3} mhos/m.
σ_2 = 10^{-1} mhos/m.

FIG 76



E_y – POLARIZATION
R = 100 m.
z_0 = 1 m.
z_1 = 19 m.
f = 1,000 hz.
σ_0 = 10^{-3} mhos/m.
σ_1 = 10^{-3} mhos/m.
σ_2 = 10^{-1} mhos/m.
LEGEND
x – ANALYTICAL
o – N_{topo} = 29, N_{cyl} = 30
1 – REAL (K_y)
2 – IMAGINARY (K_y)
2 %
K_y
(Amps/m.)
3.0
2.5
2.0
1.5
1.0
0.5
0
0
π/4
π/2
3π/4
π
θ
1
2

FIG 77

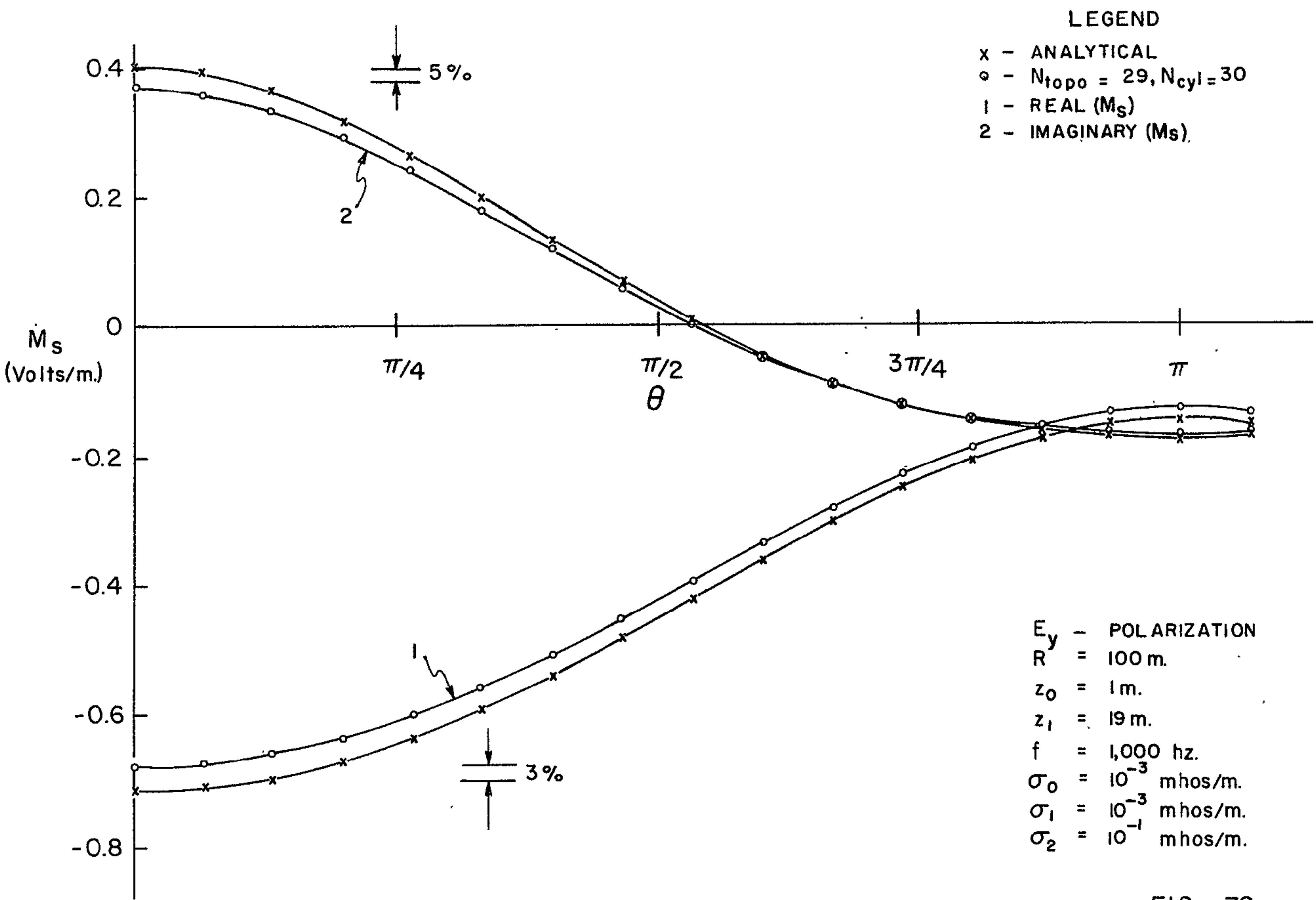
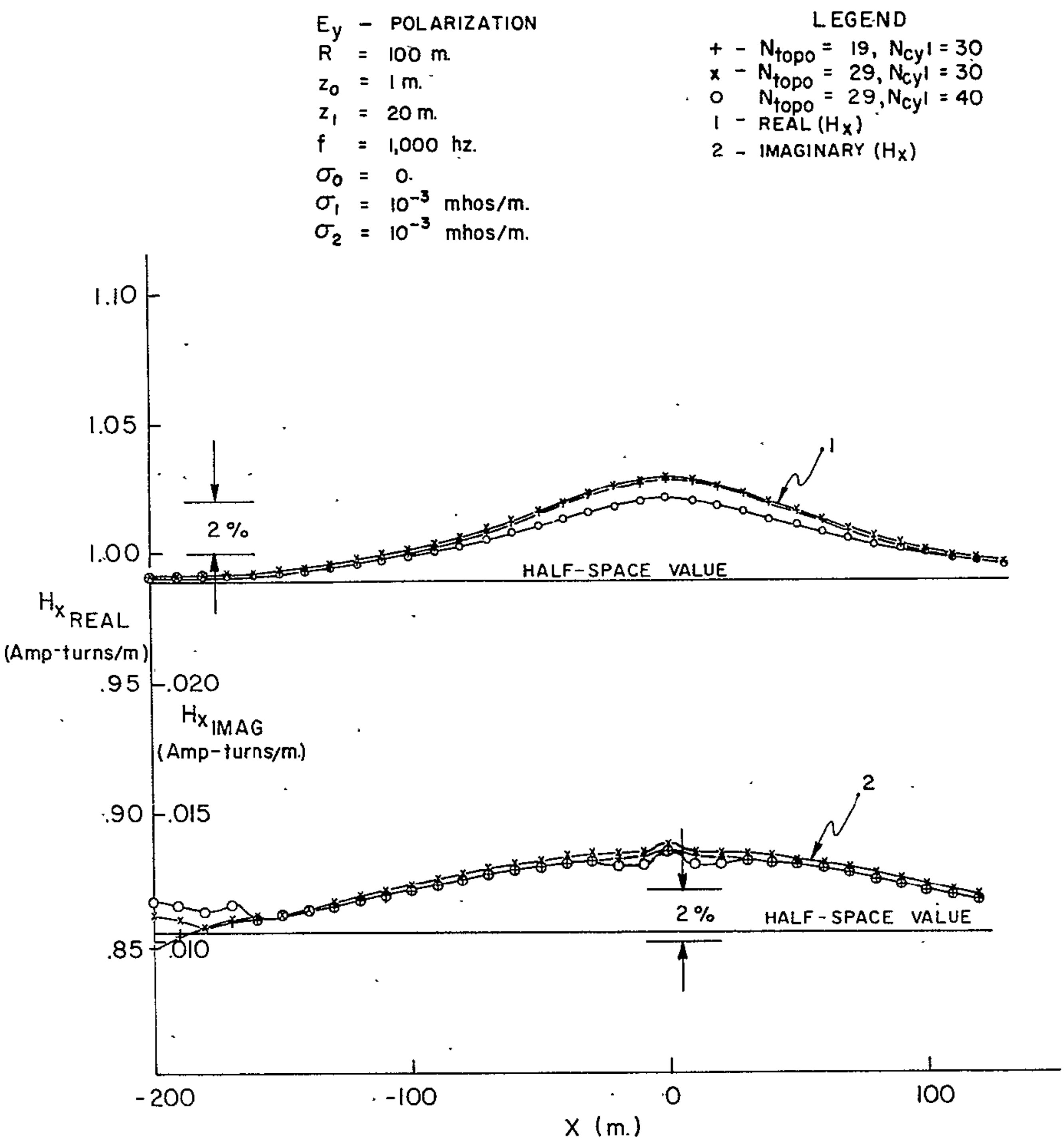

LEGEND
x - ANALYTICAL
o - Ntopo = 29, Ncyl = 30
1 - REAL (Ms)
2 - IMAGINARY (Ms)
5%
3%
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Ms (Volts/m.)
π/4
π/2
3π/4
π
θ
1
2
Ey - POLARIZATION
R = 100 m.
z0 = 1 m.
z1 = 19 m.
f = 1,000 hz.
σ0 = 10^-3 mhos/m.
σ1 = 10^-3 mhos/m.
σ2 = 10^-1 mhos/m.

FIG 78



Ey - POLARIZATION
R = 100 m.
z0 = 1 m.
z1 = 20 m.
f = 1,000 hz.
σ0 = 0.
σ1 = 10-3 mhos/m.
σ2 = 10-3 mhos/m.
LEGEND
+ - Ntopo = 19, Ncyl = 30
x - Ntopo = 29, Ncyl = 30
o Ntopo = 29, Ncyl = 40
1 - REAL (Hx)
2 - IMAGINARY (Hx)
1.10
1.05
1.00
.95
.90
.85
.020
.015
.010
2 %
HALF-SPACE VALUE
Hx REAL
(Amp-turns/m)
Hx IMAG
(Amp-turns/m.)
1
2
-200
-100
0
100
X (m.)

FIG 79

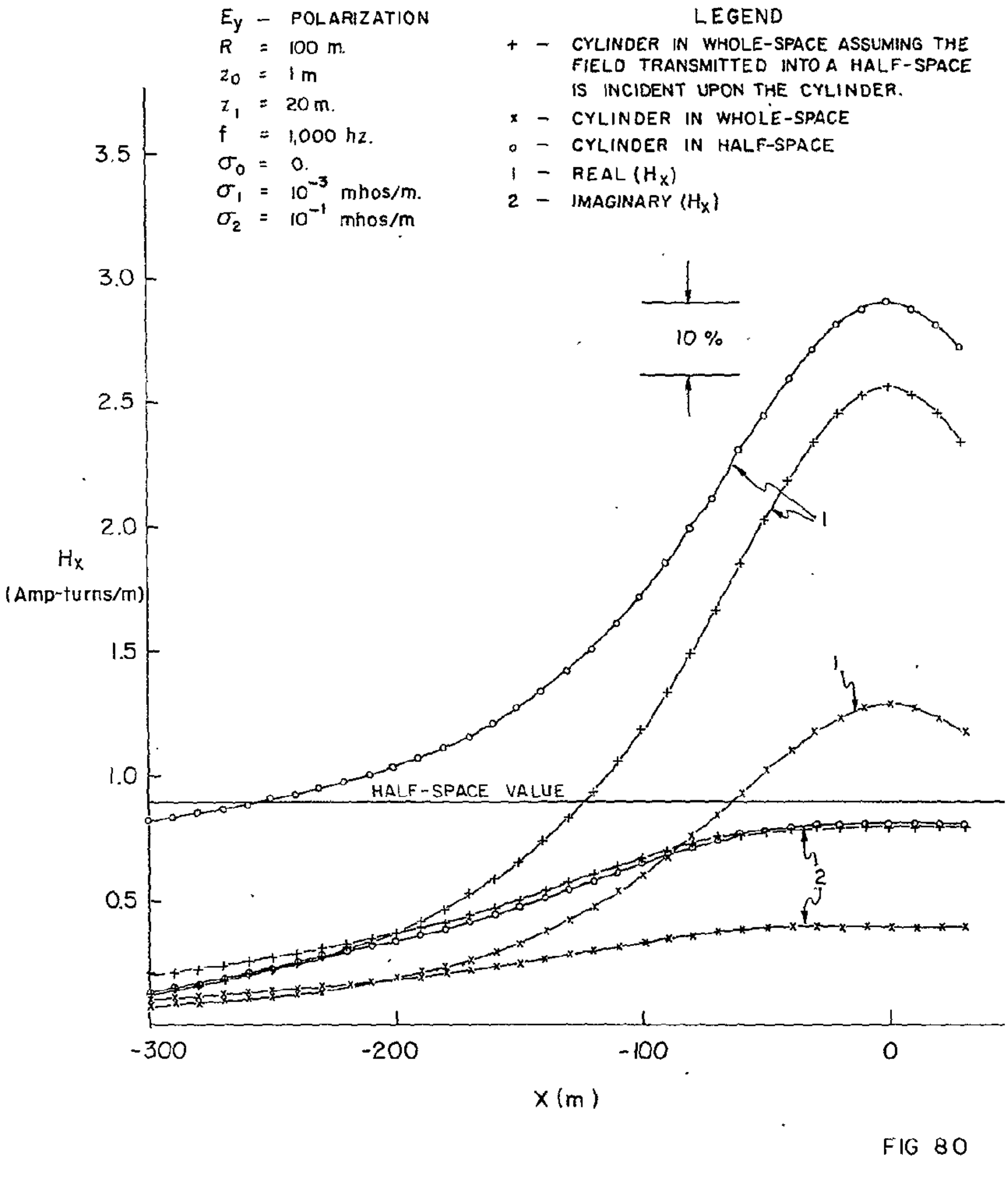
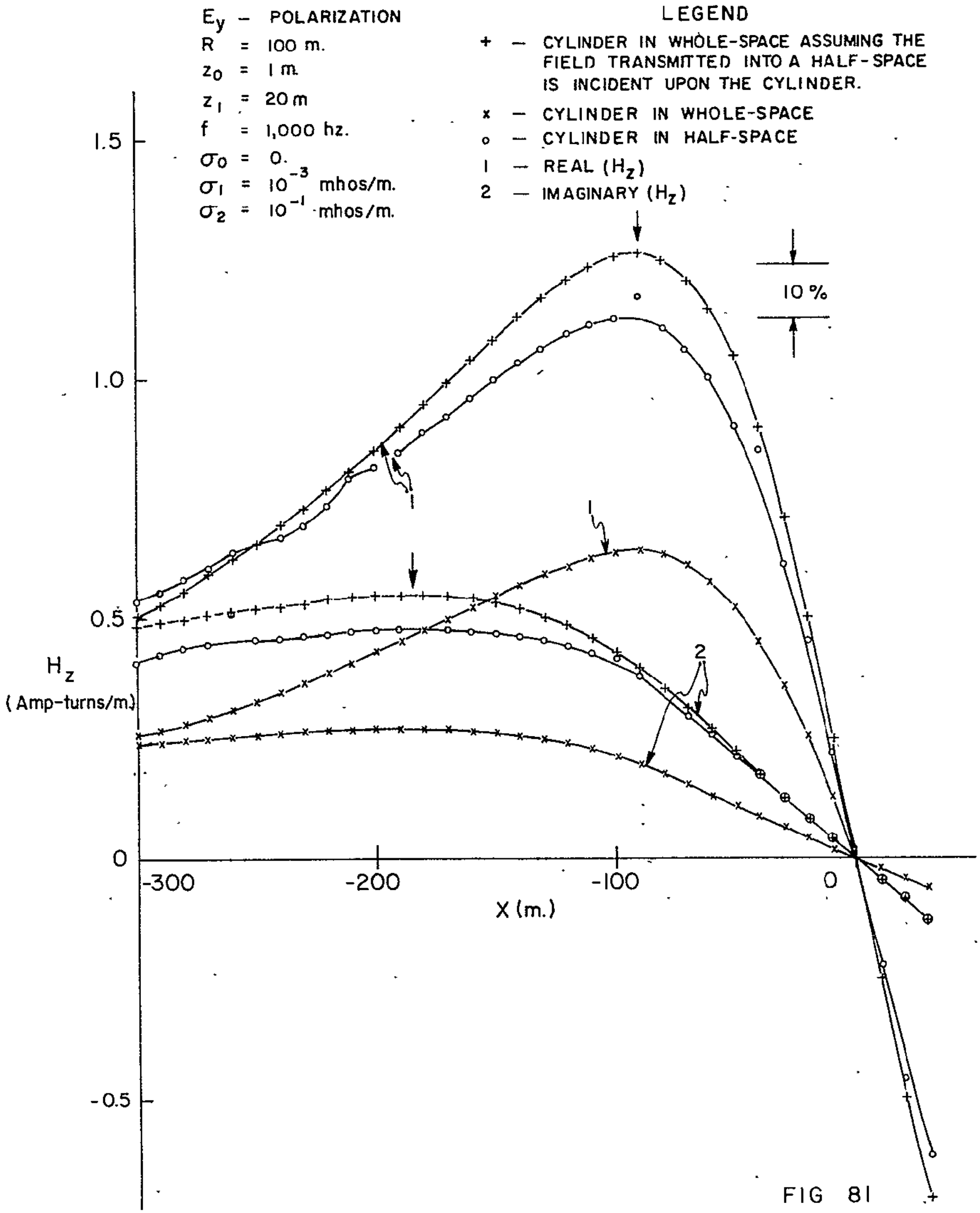
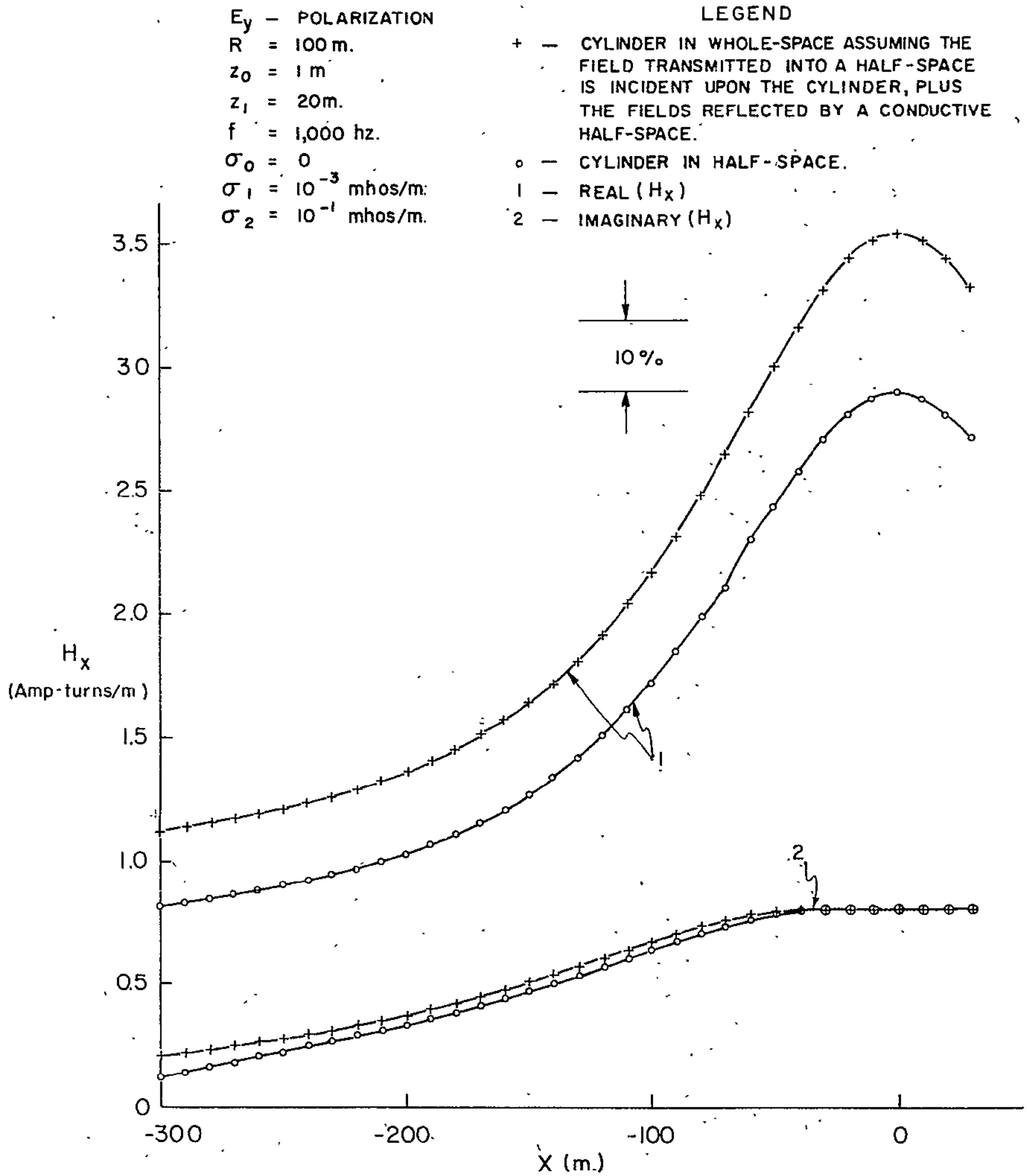

E_y — POLARIZATION
R = 100 m.
z_0 = 1 m
z_1 = 20 m.
f = 1,000 hz.
σ_0 = 0.
σ_1 = 10^{-3} mhos/m.
σ_2 = 10^{-1} mhos/m
LEGEND
+ — CYLINDER IN WHOLE-SPACE ASSUMING THE FIELD TRANSMITTED INTO A HALF-SPACE IS INCIDENT UPON THE CYLINDER.
x — CYLINDER IN WHOLE-SPACE
o — CYLINDER IN HALF-SPACE
1 — REAL (H_x)
2 — IMAGINARY (H_x)
10 %
HALF-SPACE VALUE
H_x
(Amp-turns/m)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
-300
-200
-100
0
X (m)

FIG 80



Ey – POLARIZATION
R = 100 m.
z0 = 1 m.
z1 = 20 m
f = 1,000 hz.
σ0 = 0.
σ1 = 10^-3 mhos/m.
σ2 = 10^-1 mhos/m.
LEGEND
+ – CYLINDER IN WHOLE-SPACE ASSUMING THE FIELD TRANSMITTED INTO A HALF-SPACE IS INCIDENT UPON THE CYLINDER.
x – CYLINDER IN WHOLE-SPACE
o – CYLINDER IN HALF-SPACE
1 – REAL (Hz)
2 – IMAGINARY (Hz)
10 %
1.5
1.0
0.5
0
-0.5
Hz
(Amp-turns/m)
1
2
-300
-200
-100
0
X (m.)

FIG 81



E_y — POLARIZATION
R = 100 m.
z_0 = 1 m
z_1 = 20m.
f = 1,000 hz.
σ_0 = 0
σ_1 = 10^{-3} mhos/m.
σ_2 = 10^{-1} mhos/m.
LEGEND
+ — CYLINDER IN WHOLE-SPACE ASSUMING THE FIELD TRANSMITTED INTO A HALF-SPACE IS INCIDENT UPON THE CYLINDER, PLUS THE FIELDS REFLECTED BY A CONDUCTIVE HALF-SPACE.
o — CYLINDER IN HALF-SPACE.
1 — REAL (H_x)
2 — IMAGINARY (H_x)
10 %
H_x (Amp-turns/m)
X (m.)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
-300
-200
-100
0
1
2

FIG 82

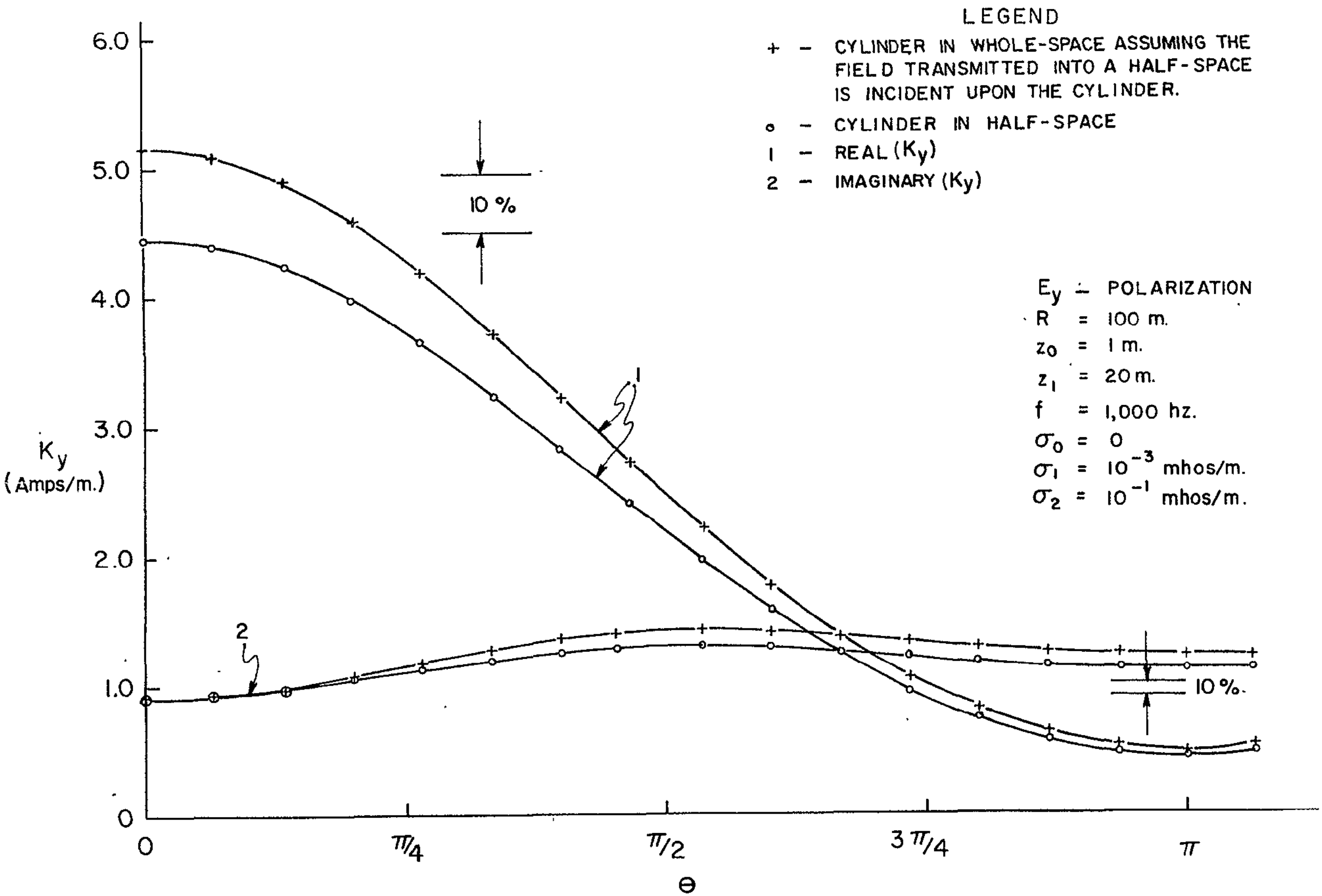
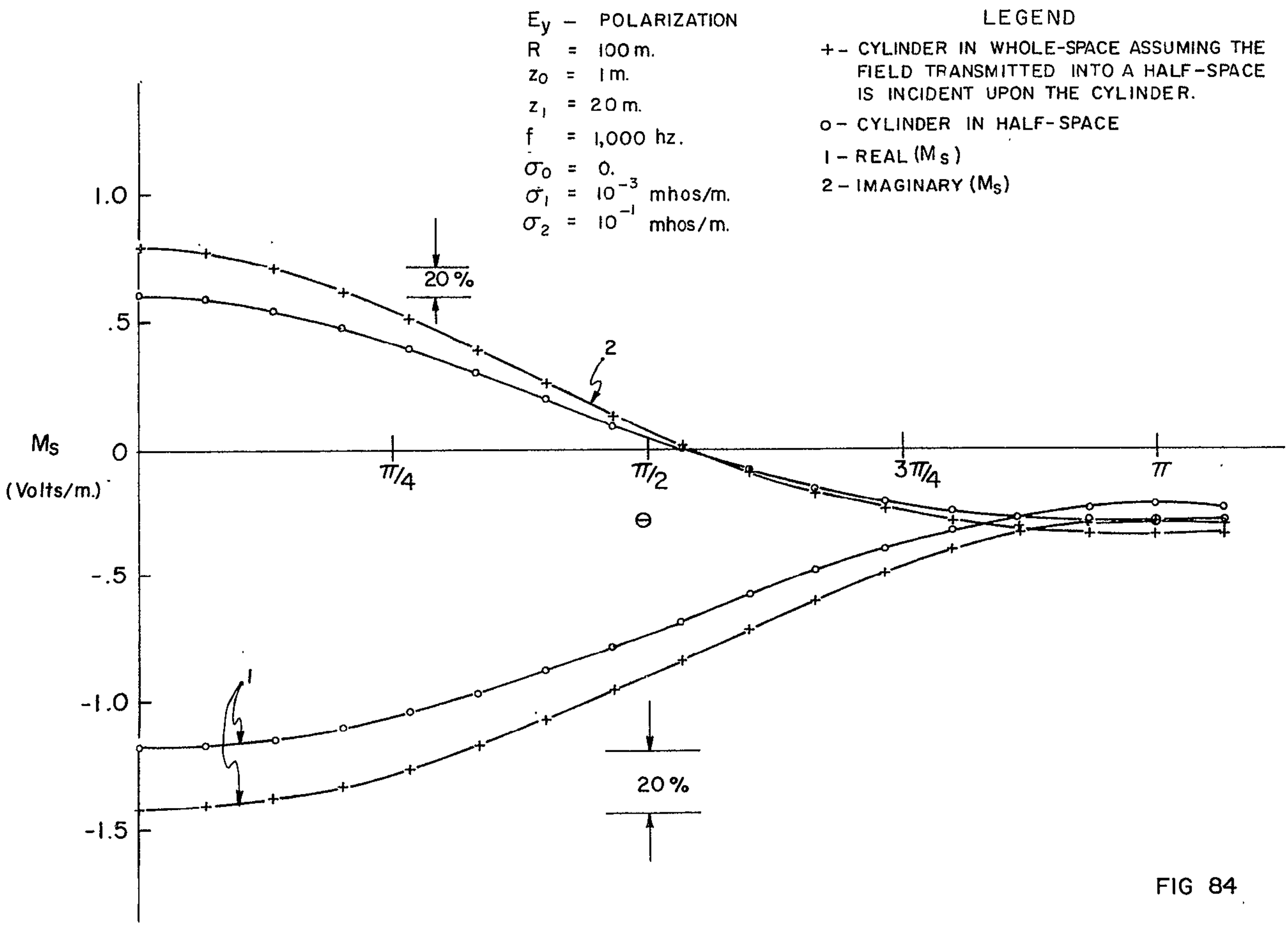
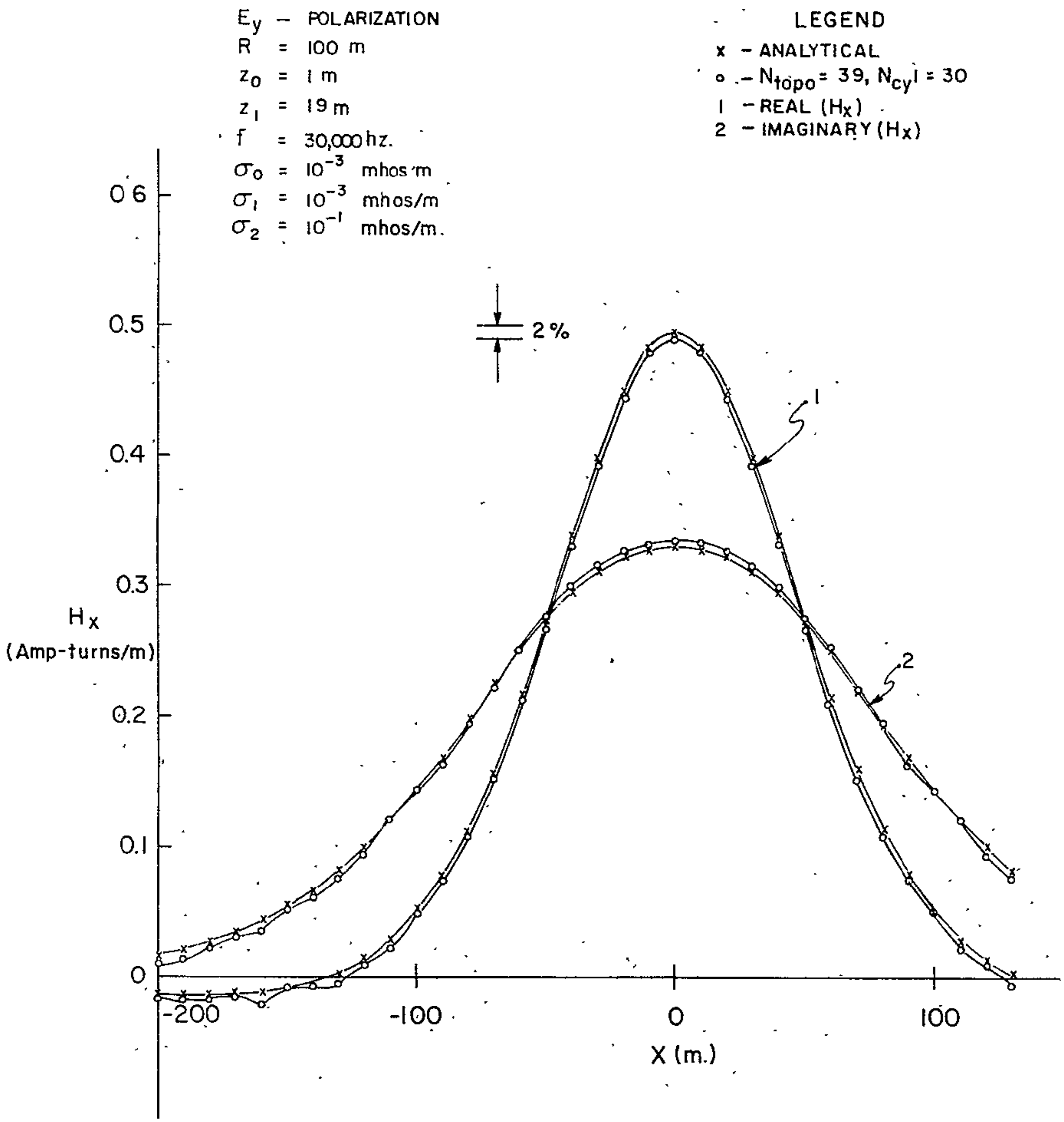

LEGEND
+ – CYLINDER IN WHOLE-SPACE ASSUMING THE FIELD TRANSMITTED INTO A HALF-SPACE IS INCIDENT UPON THE CYLINDER.
o – CYLINDER IN HALF-SPACE
1 – REAL (K_y)
2 – IMAGINARY (K_y)
10 %
E_y – POLARIZATION
R = 100 m.
z_0 = 1 m.
z_1 = 20 m.
f = 1,000 hz.
σ_0 = 0
σ_1 = 10^{-3} mhos/m.
σ_2 = 10^{-1} mhos/m.
K_y (Amps/m.)
6.0
5.0
4.0
3.0
2.0
1.0
0
1
2
10 %.
0
$\pi/4$
$\pi/2$
$3\pi/4$
π
Θ

FIG 83



E_y – POLARIZATION
R = 100 m.
z_0 = 1 m.
z_1 = 20 m.
f = 1,000 hz.
σ_0 = 0.
σ_1 = 10^{-3} mhos/m.
σ_2 = 10^{-1} mhos/m.
LEGEND
+ – CYLINDER IN WHOLE-SPACE ASSUMING THE FIELD TRANSMITTED INTO A HALF-SPACE IS INCIDENT UPON THE CYLINDER.
o – CYLINDER IN HALF-SPACE
1 – REAL (M_S)
2 – IMAGINARY (M_S)
20 %
20 %
M_S (Volts/m.)
1.0
.5
0
-.5
-1.0
-1.5
$\pi/4$
$\pi/2$
$3\pi/4$
π
Θ
1
2

FIG 84



E_y — POLARIZATION
R = 100 m
z_0 = 1 m
z_1 = 19 m
f = 30,000 hz.
σ_0 = 10^{-3} mhos/m
σ_1 = 10^{-3} mhos/m
σ_2 = 10^{-1} mhos/m.
LEGEND
x – ANALYTICAL
o – N_{topo} = 39, N_{cyl} = 30
1 – REAL (H_x)
2 – IMAGINARY (H_x)
2%
H_x
(Amp-turns/m)
0.6
0.5
0.4
0.3
0.2
0.1
0
-200
-100
0
100
X (m.)
1
2

FIG 85

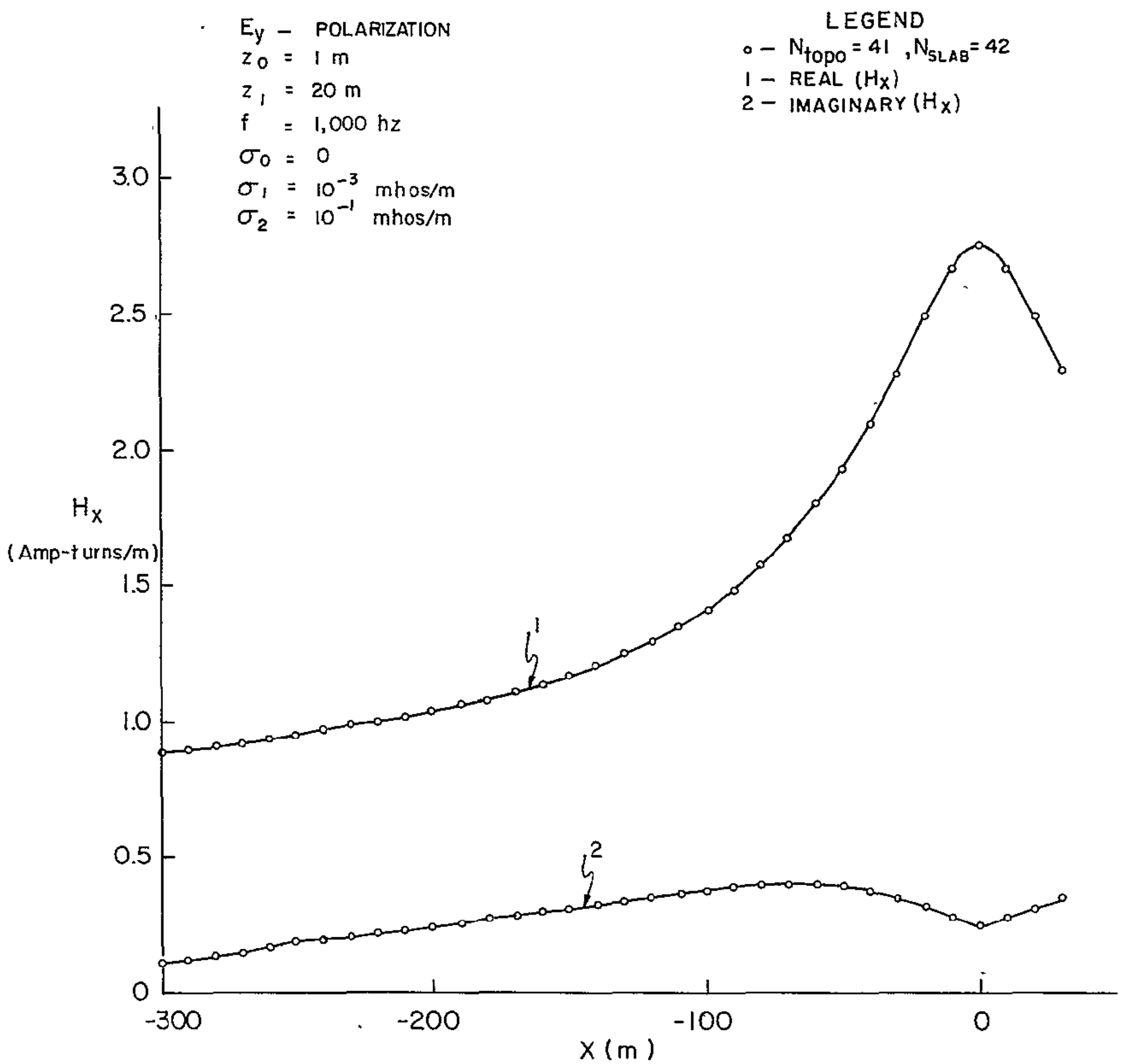
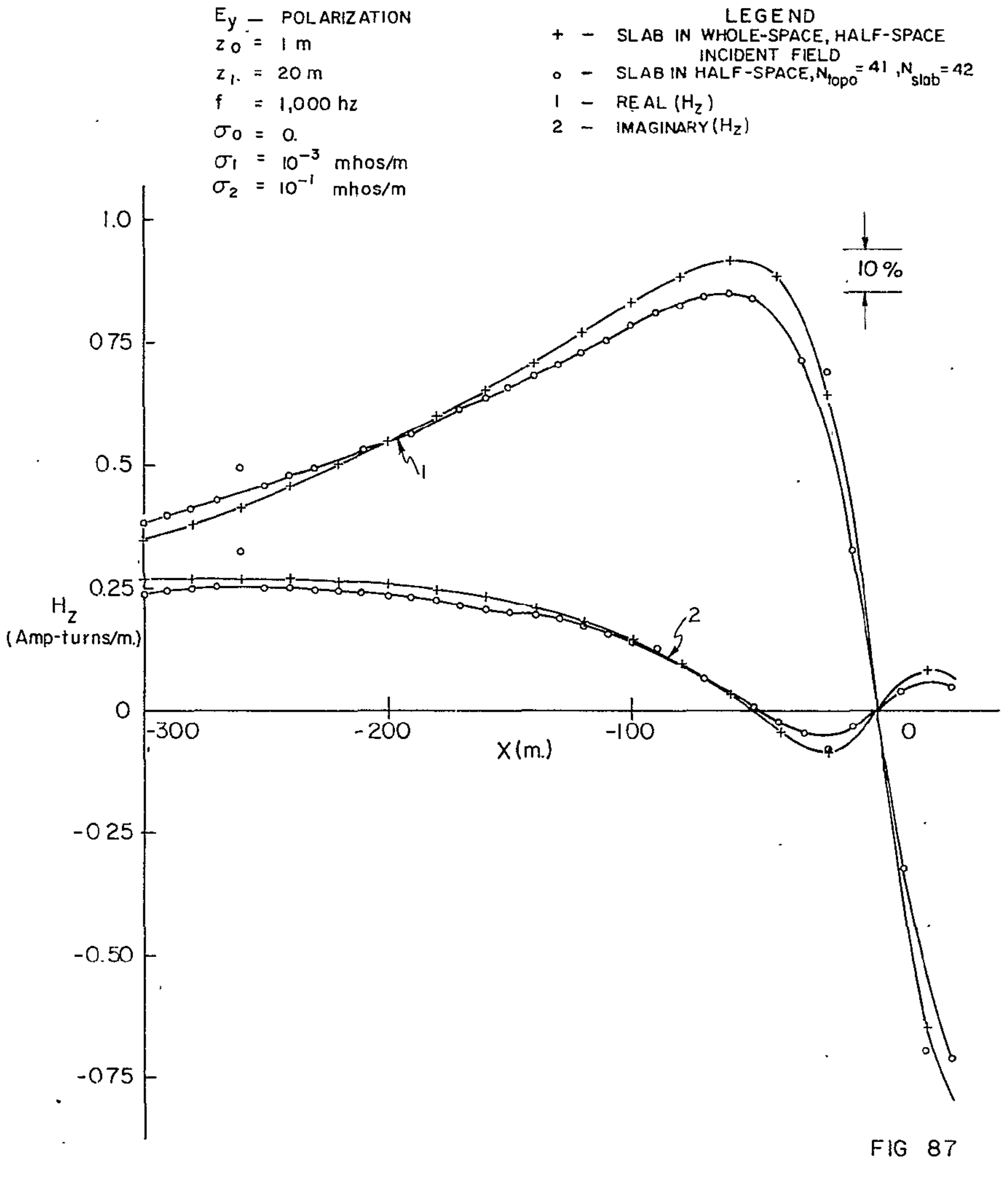
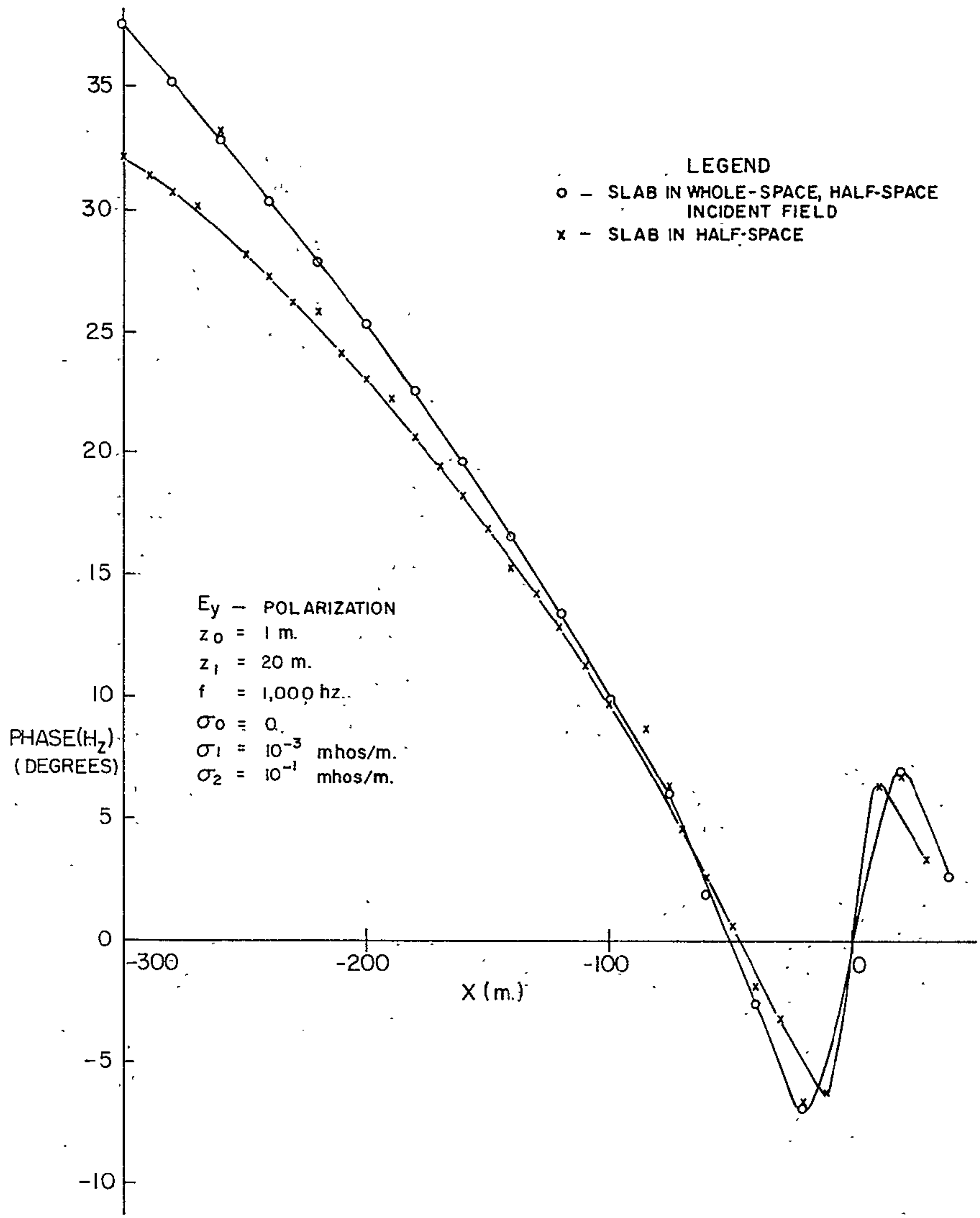

Ey — POLARIZATION
z0 = 1 m
z1 = 20 m
f = 1,000 hz
σ0 = 0
σ1 = 10^-3 mhos/m
σ2 = 10^-1 mhos/m
LEGEND
o — Ntopo = 41 , NSLAB = 42
1 — REAL (Hx)
2 — IMAGINARY (Hx)
Hx
(Amp-turns/m)
3.0
2.5
2.0
1.5
1.0
0.5
0
-300
-200
-100
0
X (m)
1
2

FIG 86



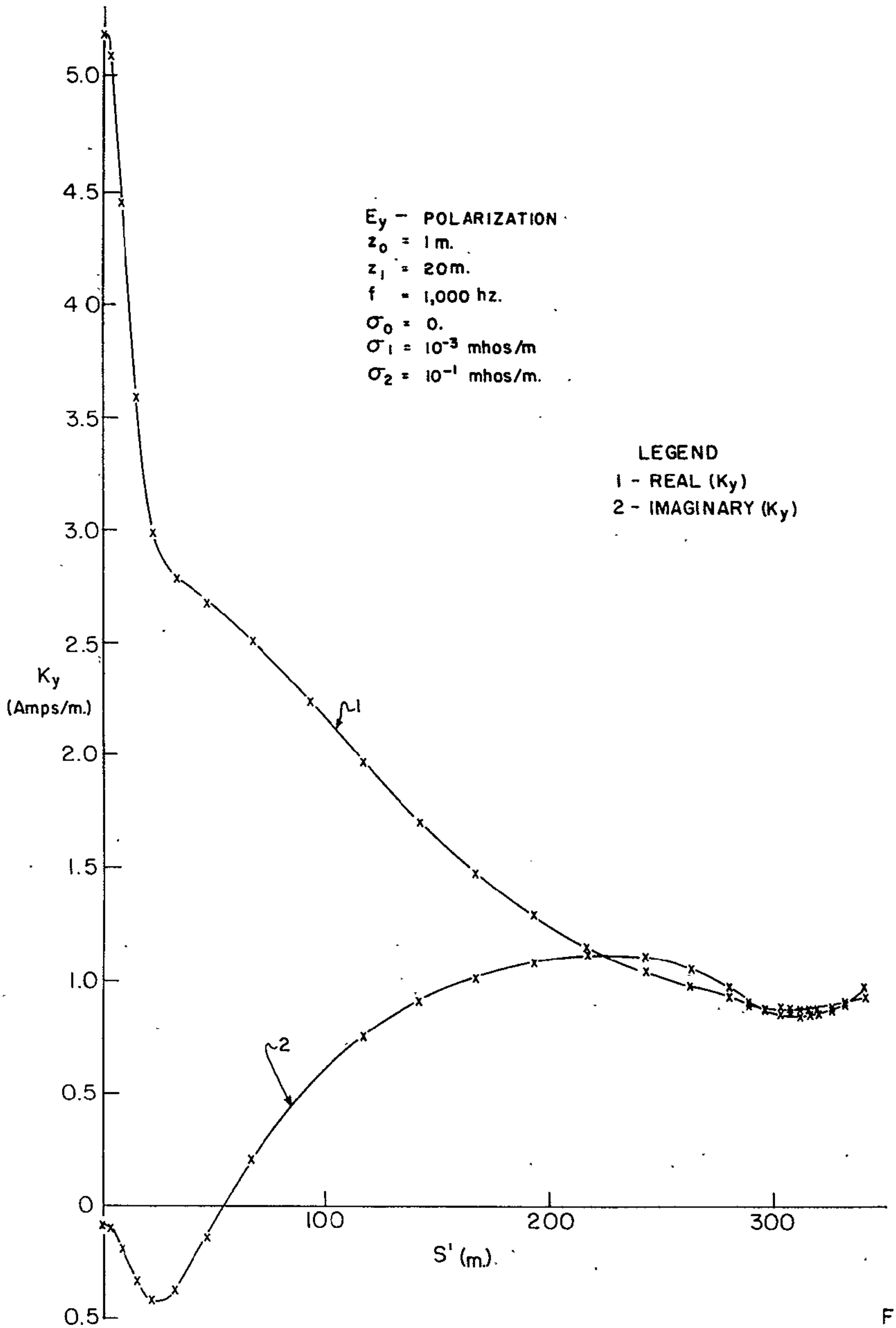
Ey — POLARIZATION
z0 = 1 m
z1 = 20 m
f = 1,000 hz
σ0 = 0.
σ1 = 10^-3 mhos/m
σ2 = 10^-1 mhos/m
LEGEND
+ — SLAB IN WHOLE-SPACE, HALF-SPACE INCIDENT FIELD
o — SLAB IN HALF-SPACE, Ntopo = 41, Nslab = 42
1 — REAL (Hz)
2 — IMAGINARY (Hz)
10%
1.0
0.75
0.5
0.25
0
-0.25
-0.50
-0.75
Hz
(Amp-turns/m.)
-300
-200
-100
0
X (m.)
1
2

FIG 87



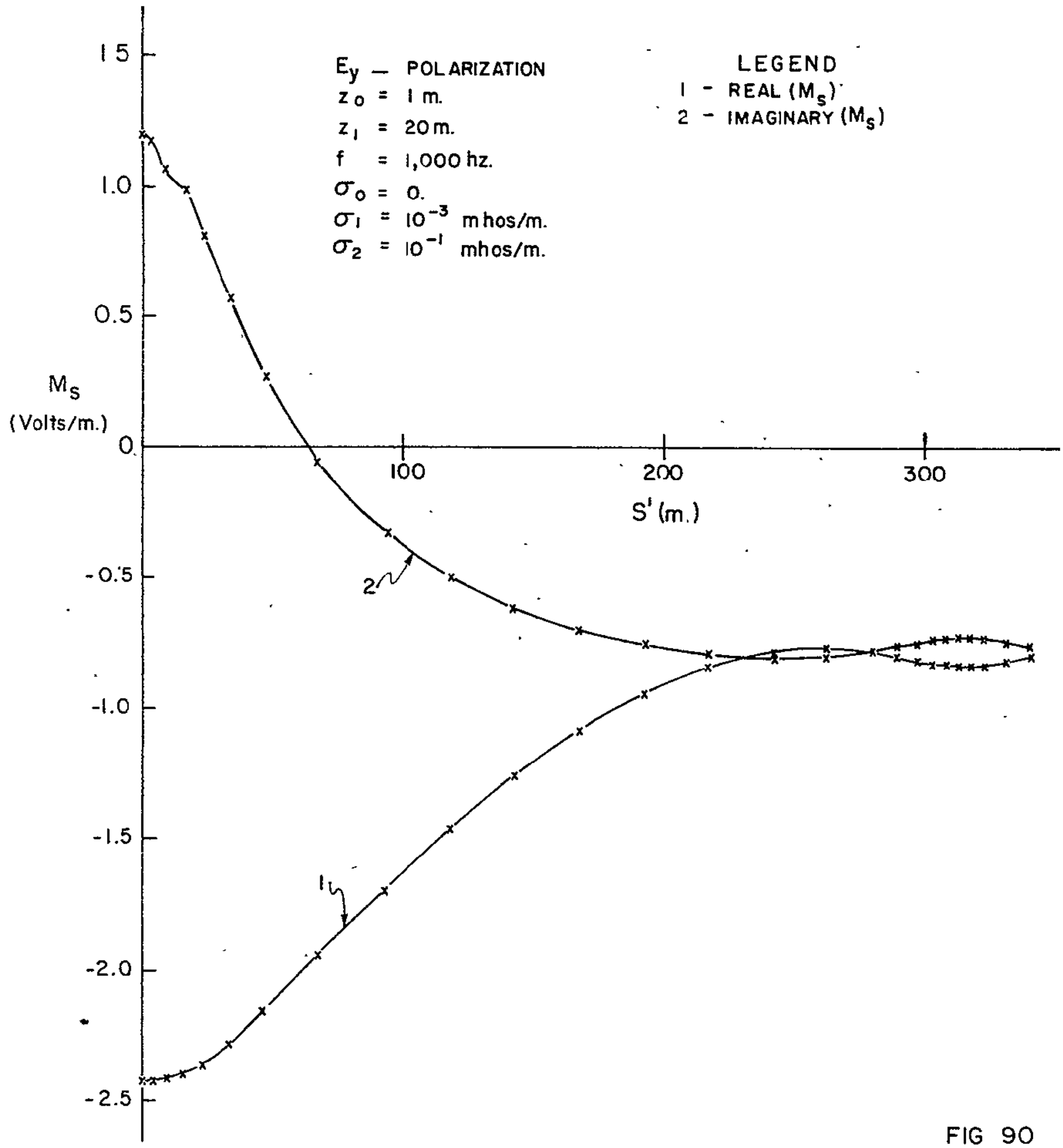
LEGEND
o – SLAB IN WHOLE-SPACE, HALF-SPACE INCIDENT FIELD
x – SLAB IN HALF-SPACE
Ey – POLARIZATION
z0 = 1 m.
z1 = 20 m.
f = 1,000 hz.
σ0 = 0.
σ1 = 10^-3 mhos/m.
σ2 = 10^-1 mhos/m.
PHASE(Hz) (DEGREES)
X (m.)
35
30
25
20
15
10
5
0
-5
-10
-300
-200
-100
0

FIG 88



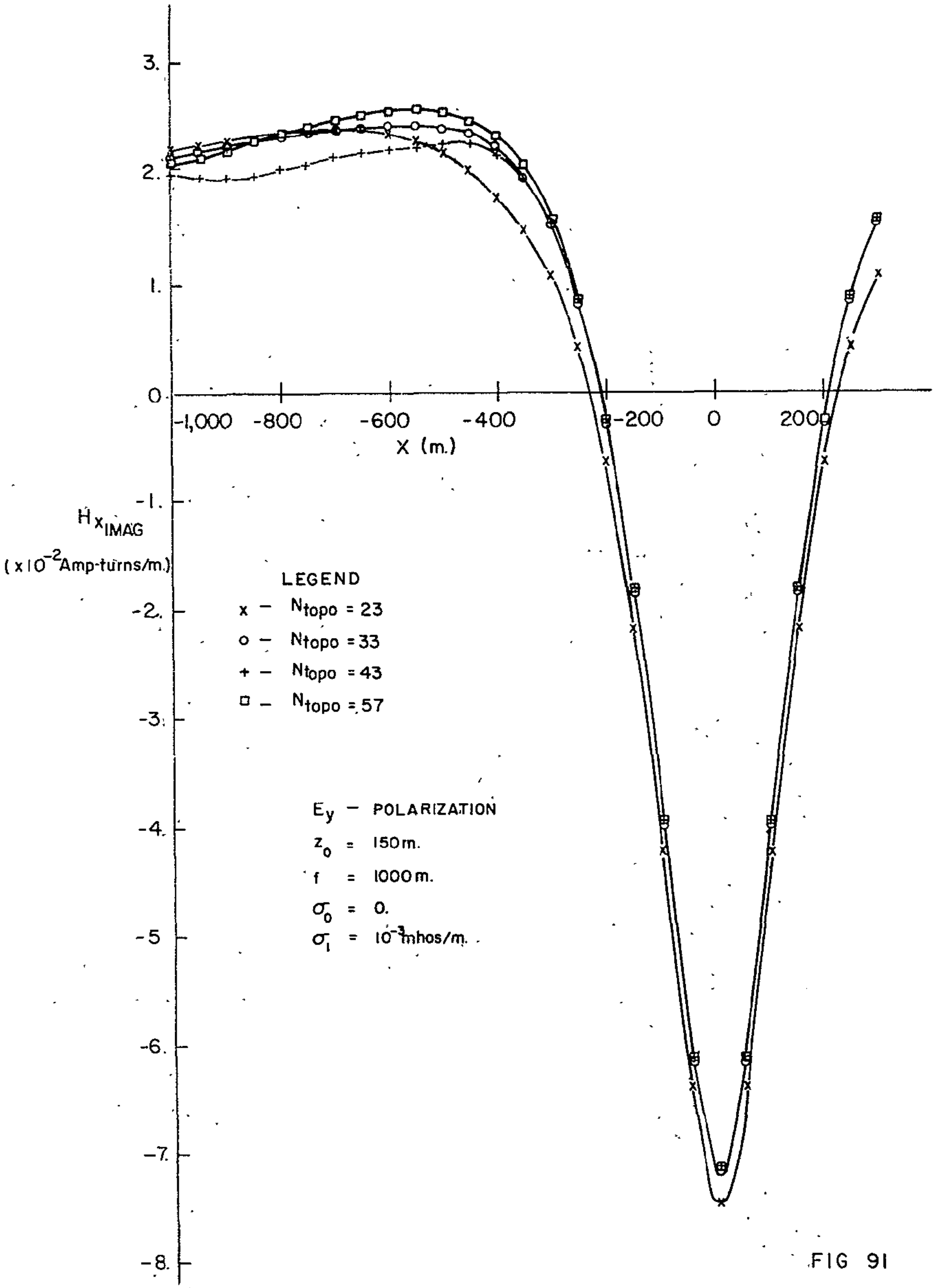
Ey - POLARIZATION
z0 = 1 m.
z1 = 20 m.
f = 1,000 hz.
σ0 = 0.
σ1 = 10-3 mhos/m
σ2 = 10-1 mhos/m.
LEGEND
1 - REAL (Ky)
2 - IMAGINARY (Ky)
Ky
(Amps/m.)
S' (m.)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
0.5
100
200
300
1
2

FIG 89



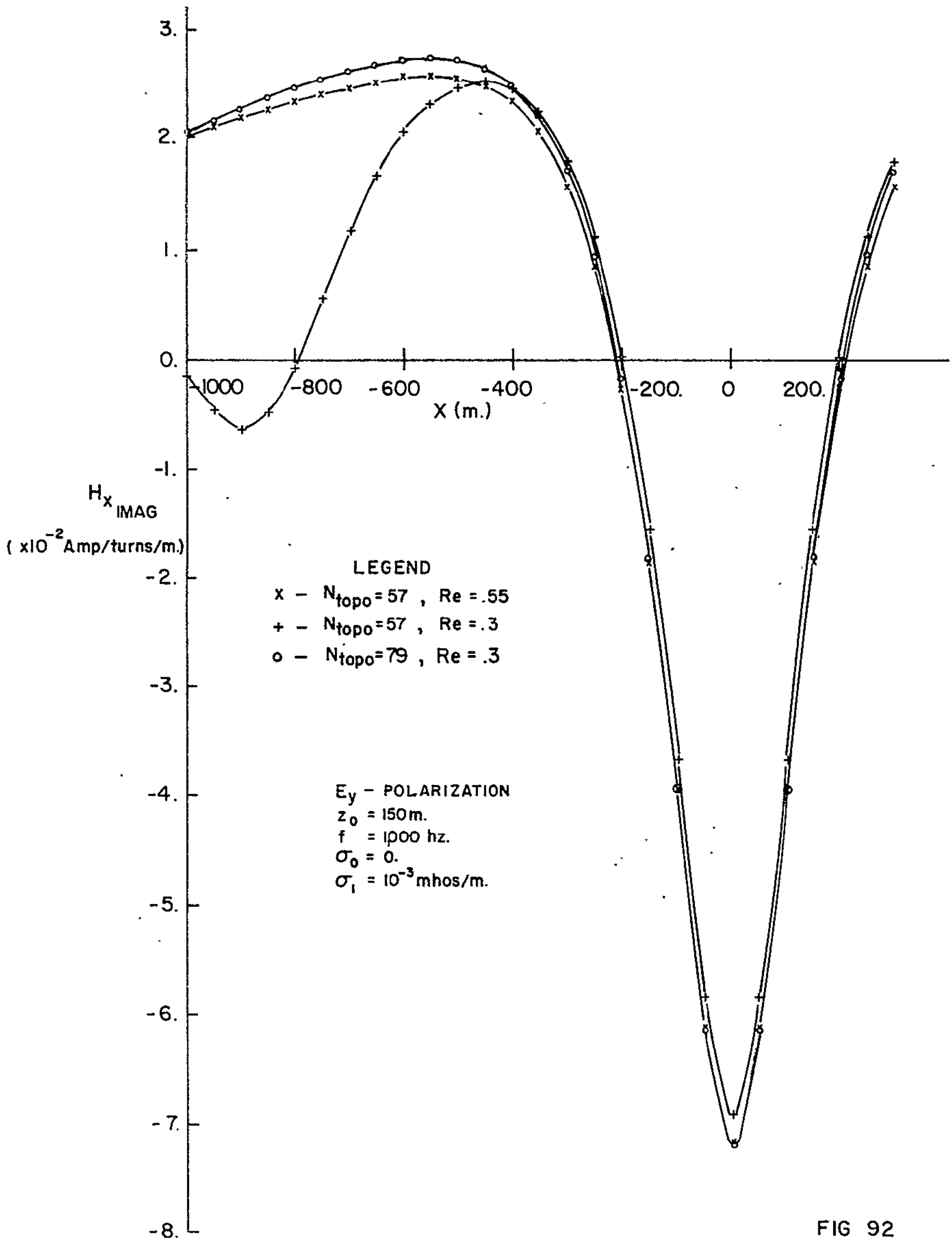
Ey — POLARIZATION
z0 = 1 m.
z1 = 20 m.
f = 1,000 hz.
σ0 = 0.
σ1 = 10^-3 mhos/m.
σ2 = 10^-1 mhos/m.
LEGEND
1 - REAL (Ms)
2 - IMAGINARY (Ms)
Ms
(Volts/m.)
S' (m.)
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
-2.0
-2.5
100
200
300
1
2

FIG 90



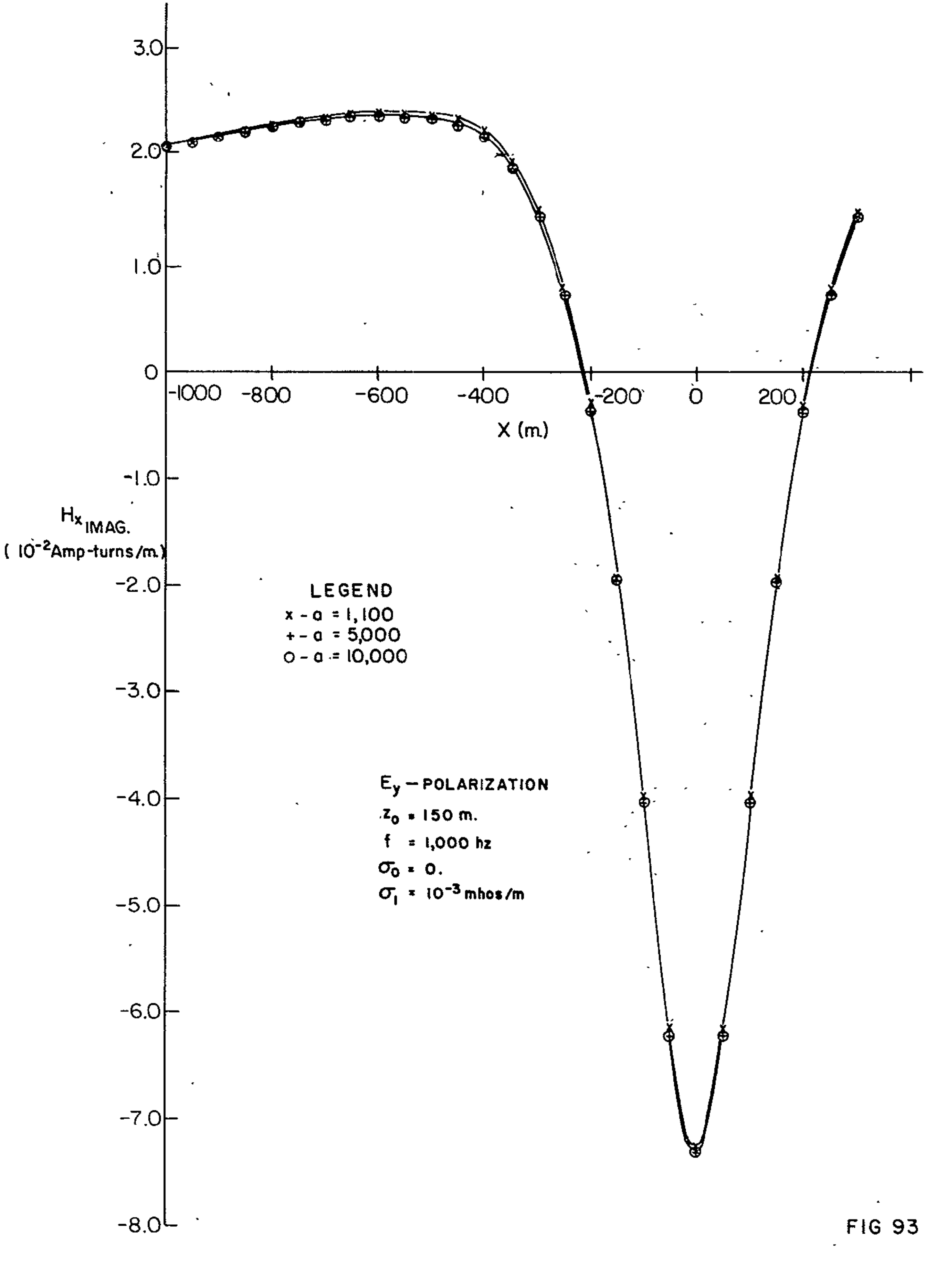
3.
2.
1.
0
-1.
-2.
-3.
-4.
-5
-6.
-7.
-8.
-1,000
-800
-600
-400
-200
0
200
X (m.)
Hx IMAG
(x10^-2 Amp-turns/m.)
LEGEND
x — Ntopo = 23
o — Ntopo = 33
+ — Ntopo = 43
□ — Ntopo = 57
Ey — POLARIZATION
z0 = 150m.
f = 1000m.
σ0 = 0.
σ1 = 10^-3 mhos/m.

FIG 91



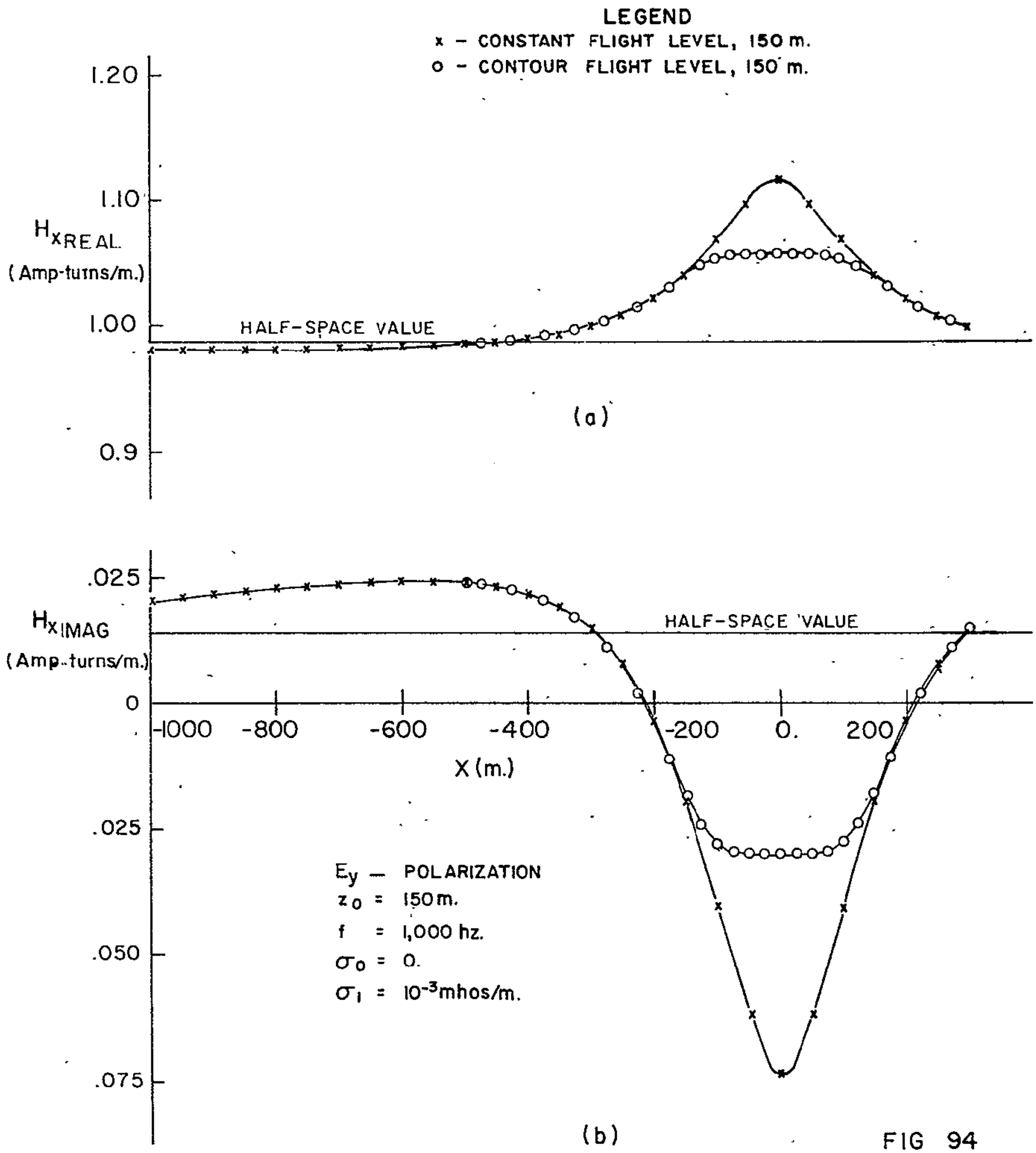
3.
2.
1.
0.
-1.
-2.
-3.
-4.
-5.
-6.
-7.
-8.
-1000
-800
-600
-400
-200.
0
200.
X (m.)
$H_{X_{IMAG}}$
(x10^{-2} Amp/turns/m.)
LEGEND
x – N_{topo}=57 , Re =.55
+ – N_{topo}=57 , Re =.3
o – N_{topo}=79 , Re =.3
E_y – POLARIZATION
z_0 = 150 m.
f = 1000 hz.
σ_0 = 0.
σ_1 = 10^{-3} mhos/m.

FIG 92



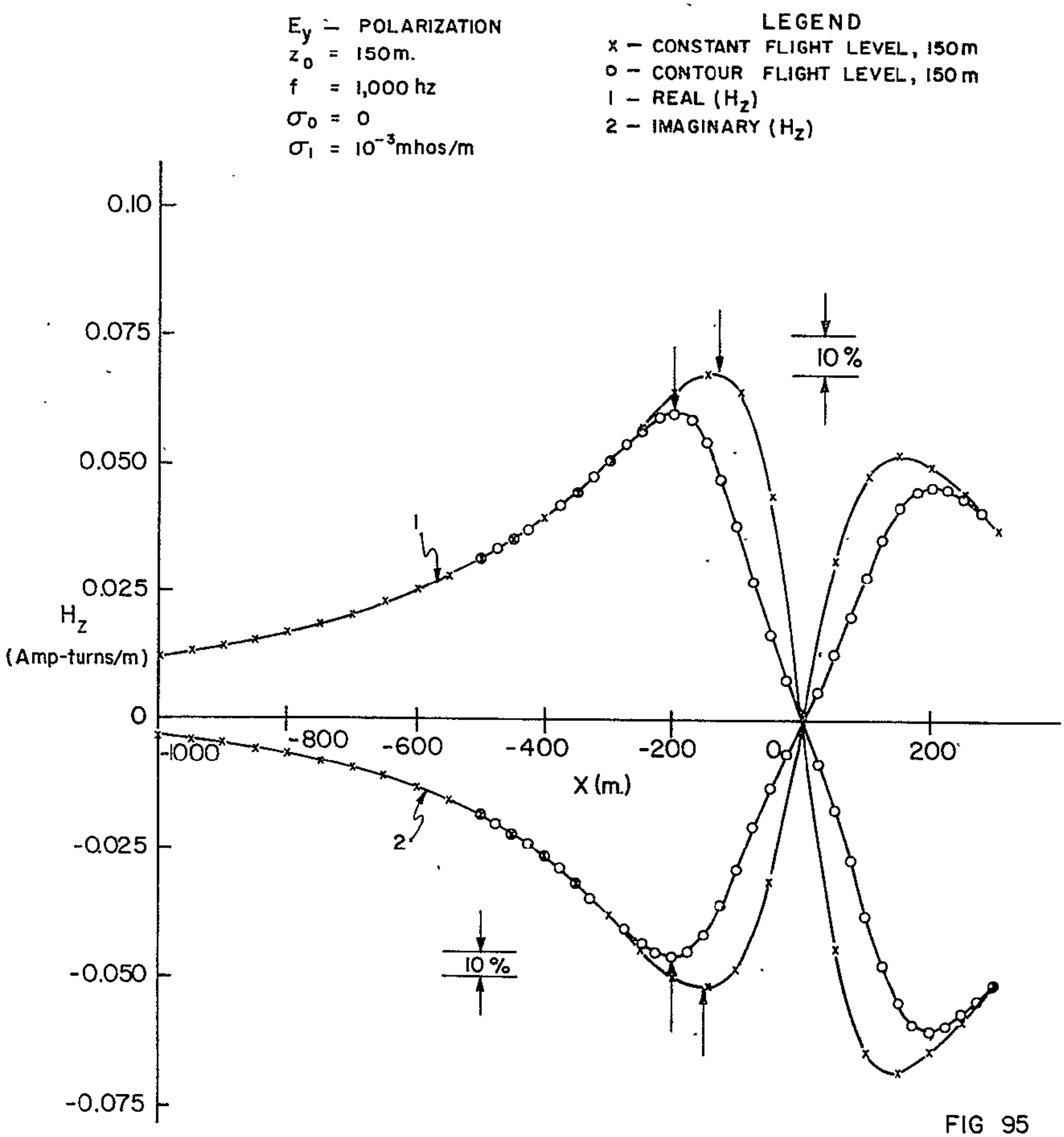
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
-7.0
-8.0
-1000
-800
-600
-400
-200
0
200
X (m.)
$H_{x_{IMAG.}}$
(10^{-2} Amp-turns/m.)
LEGEND
x - a = 1,100
+ - a = 5,000
o - a = 10,000
E_y — POLARIZATION
z_0 = 150 m.
f = 1,000 hz
σ_0 = 0.
σ_1 = 10^{-3} mhos/m

FIG 93



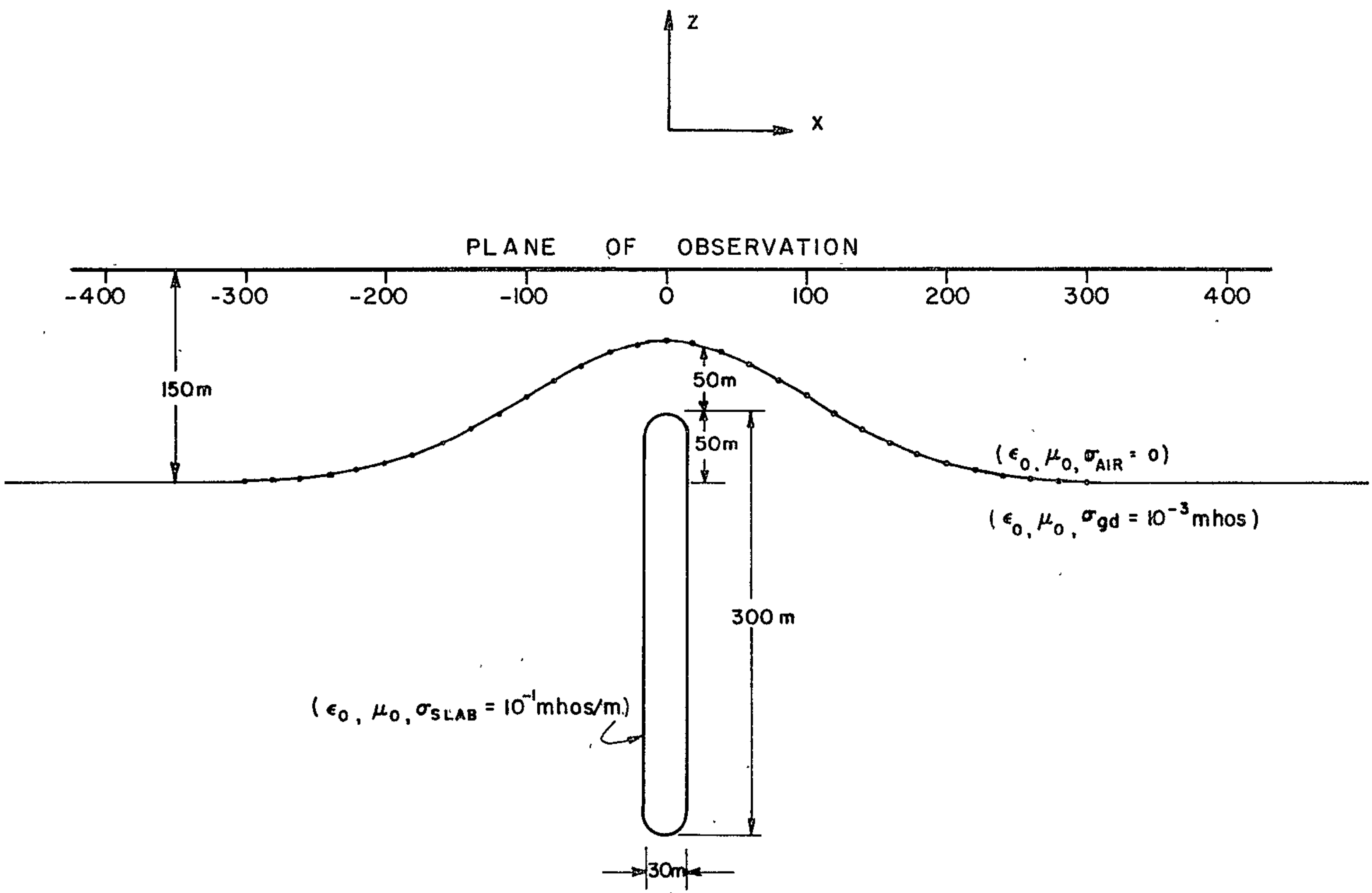
LEGEND
x - CONSTANT FLIGHT LEVEL, 150 m.
o - CONTOUR FLIGHT LEVEL, 150 m.
1.20
1.10
1.00
0.9
$H_{X REAL}$
(Amp-turns/m.)
HALF-SPACE VALUE
(a)
.025
0
.025
.050
.075
$H_{X IMAG}$
(Amp-turns/m.)
HALF-SPACE VALUE
-1000
-800
-600
-400
-200
0.
200
X (m.)
E_y — POLARIZATION
z_0 = 150 m.
f = 1,000 hz.
σ_0 = 0.
σ_1 = 10^{-3} mhos/m.
(b)

FIG 94



E_y — POLARIZATION
z_0 = 150 m.
f = 1,000 hz
σ_0 = 0
σ_1 = 10^{-3} mhos/m
LEGEND
x — CONSTANT FLIGHT LEVEL, 150 m
o — CONTOUR FLIGHT LEVEL, 150 m
1 — REAL (H_z)
2 — IMAGINARY (H_z)
0.10
0.075
0.050
0.025
0
-0.025
-0.050
-0.075
H_z
(Amp-turns/m)
-1000
-800
-600
-400
-200
0
200
X (m.)
10 %
10 %
1
2

FIG 95



Z
X
PLANE OF OBSERVATION
-400
-300
-200
-100
0
100
200
300
400
150m
50m
50m
300 m
(ϵ0 , μ0 , σAIR = 0)
(ϵ0 , μ0 , σgd = 10-3 mhos)
(ϵ0 , μ0 , σSLAB = 10-1 mhos/m)
30m

FIG. 96

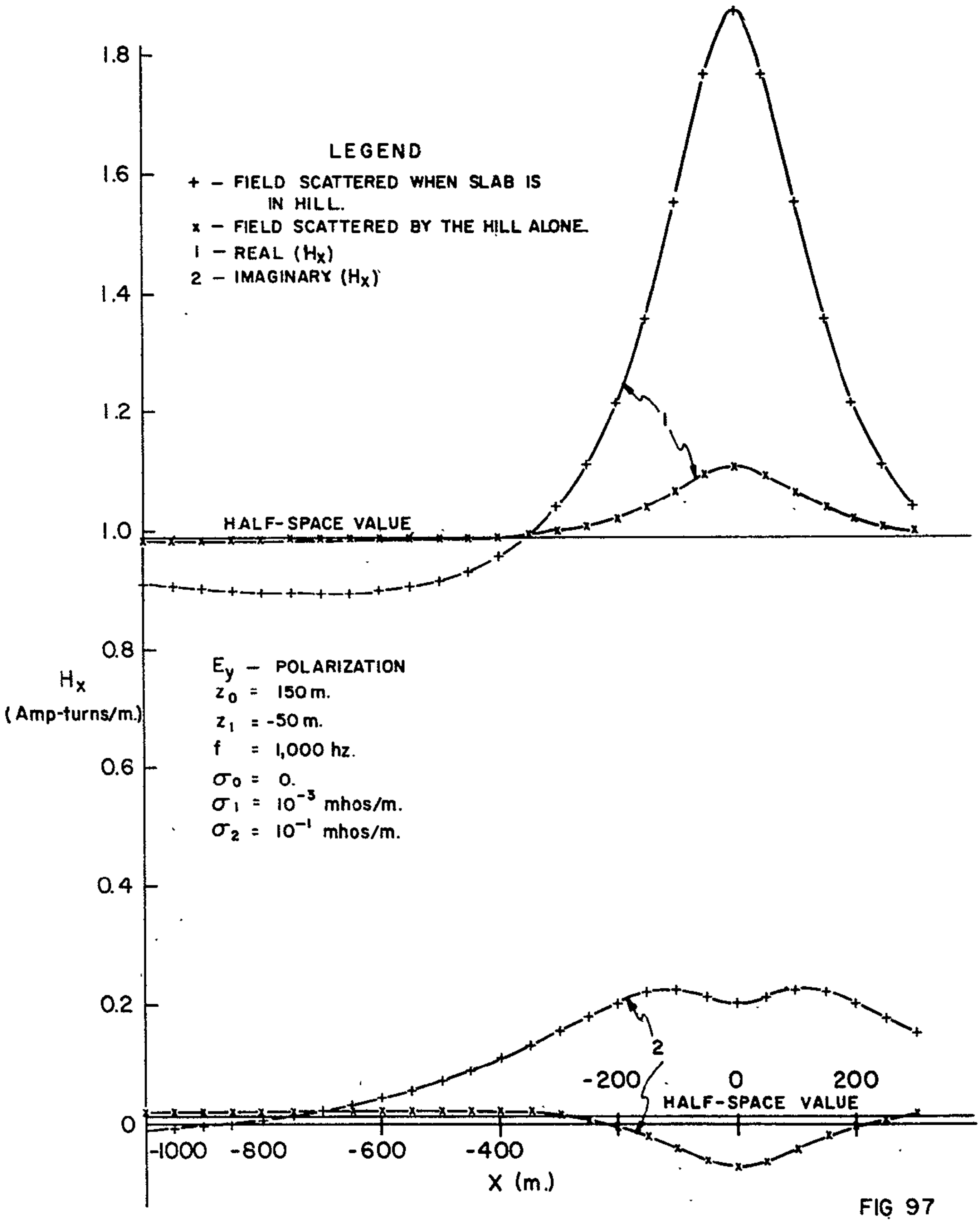

LEGEND
+ – FIELD SCATTERED WHEN SLAB IS IN HILL.
x – FIELD SCATTERED BY THE HILL ALONE.
1 – REAL (Hx)
2 – IMAGINARY (Hx)
HALF-SPACE VALUE
Hx
(Amp-turns/m.)
Ey – POLARIZATION
z0 = 150 m.
z1 = -50 m.
f = 1,000 hz.
σ0 = 0.
σ1 = 10^-3 mhos/m.
σ2 = 10^-1 mhos/m.
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
1
2
-200
0
200
HALF-SPACE VALUE
-1000
-800
-600
-400
X (m.)

FIG 97

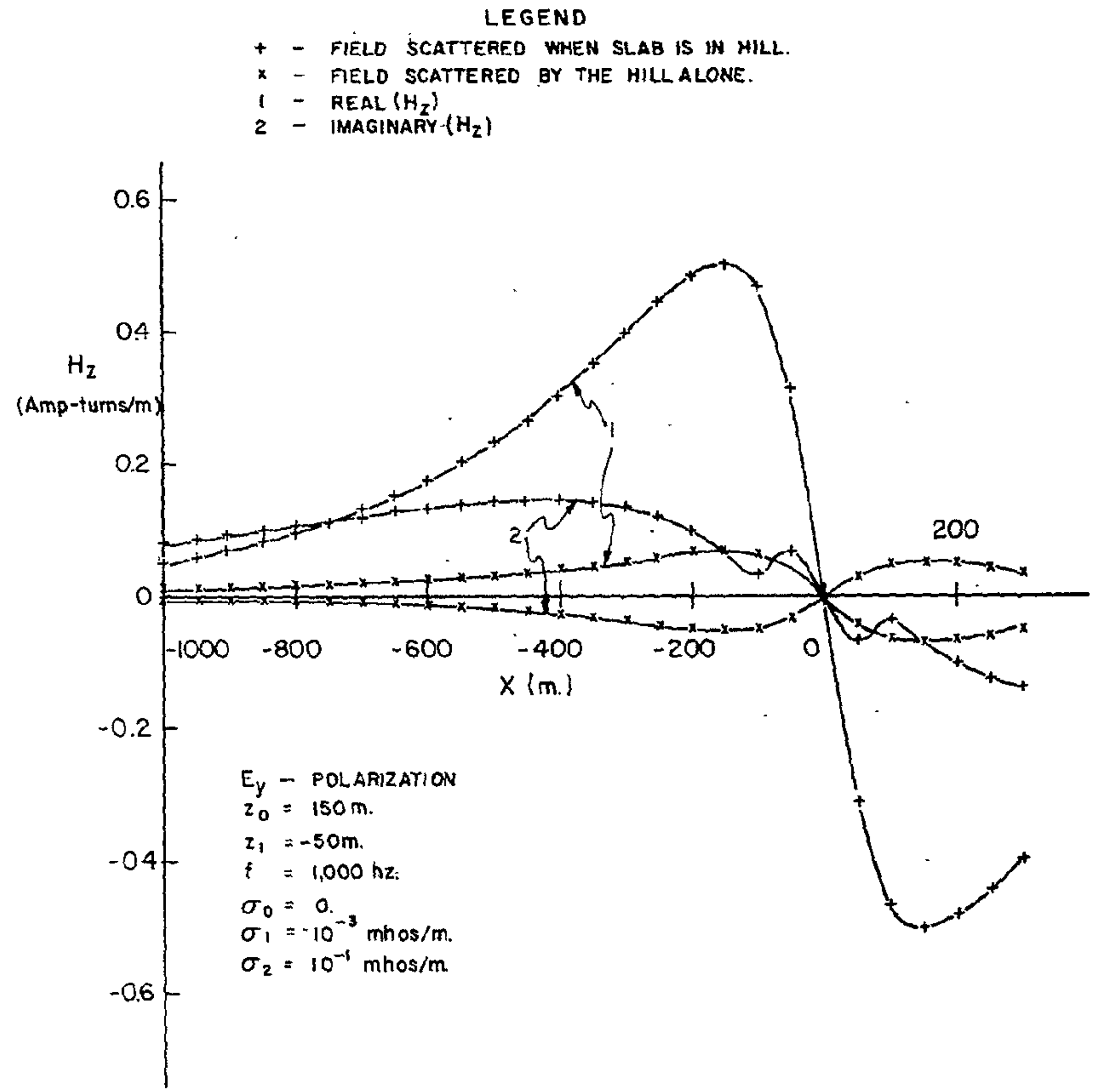
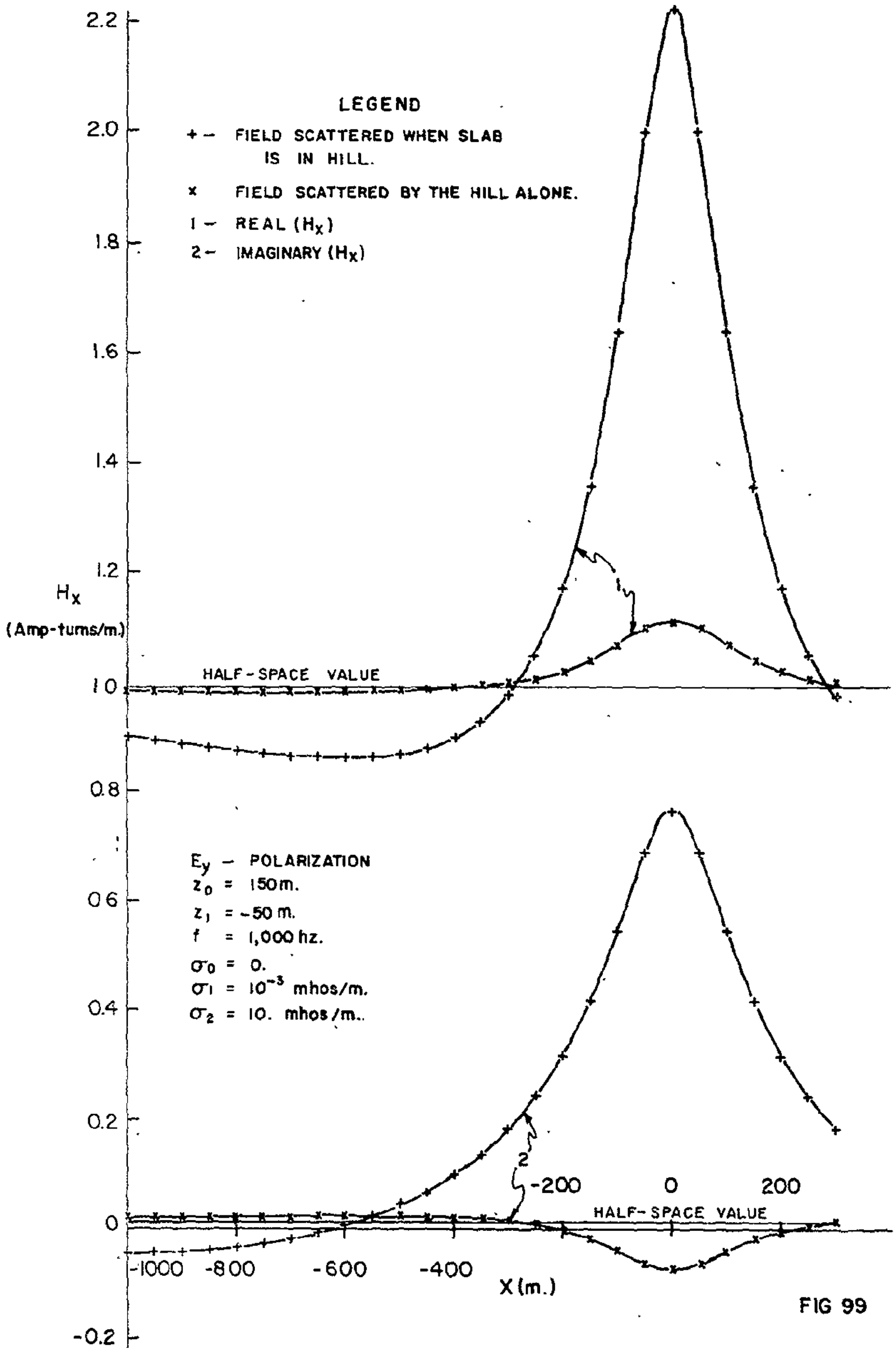
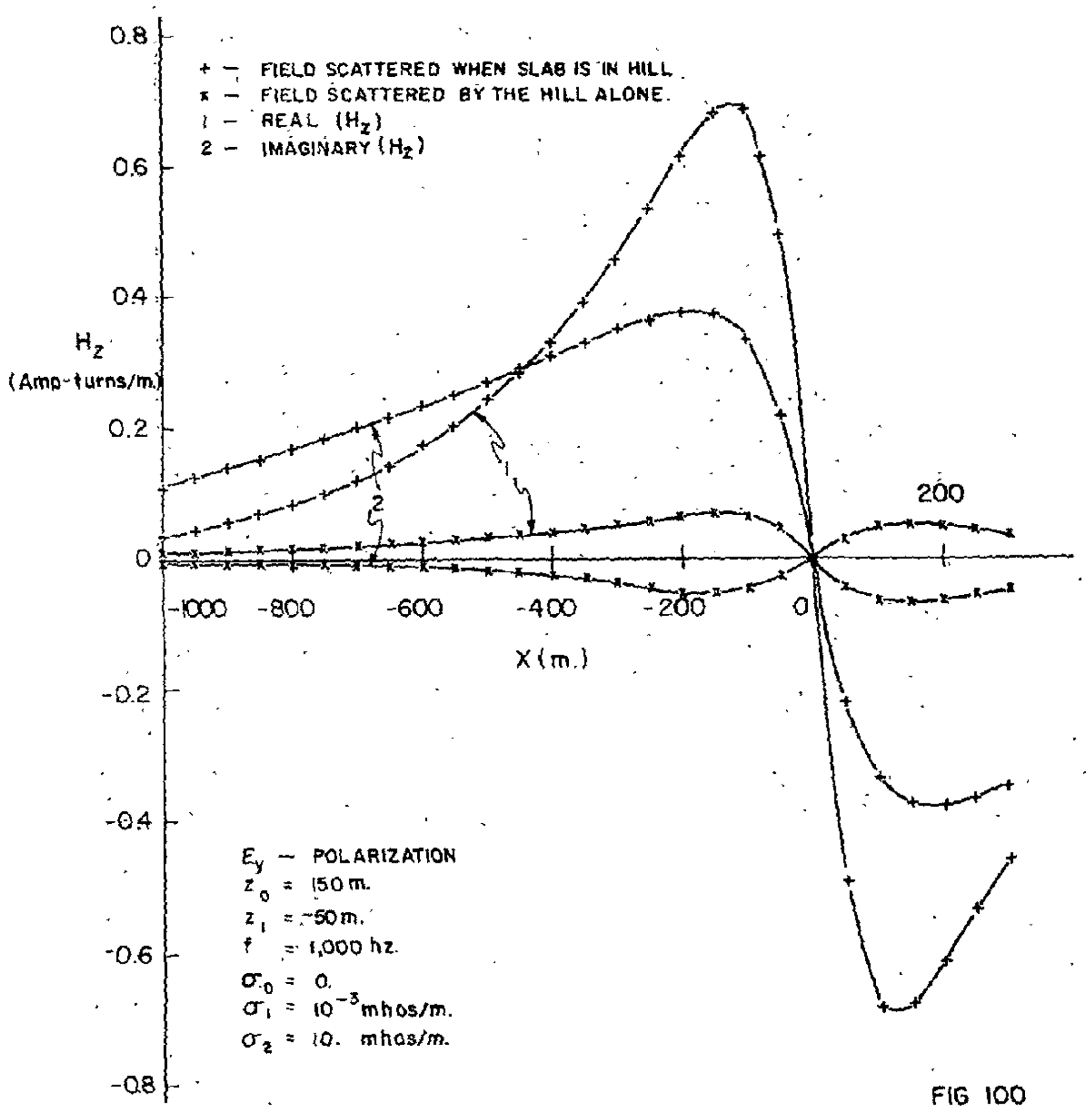

LEGEND
+ – FIELD SCATTERED WHEN SLAB IS IN HILL.
x – FIELD SCATTERED BY THE HILL ALONE.
1 – REAL (H_z)
2 – IMAGINARY (H_z)
H_z
(Amp-turns/m)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-1000
-800
-600
-400
-200
0
200
X (m.)
1
2
E_y – POLARIZATION
z_0 = 150 m.
z_1 = -50m.
f = 1,000 hz.
σ_0 = 0.
σ_1 = 10^{-3} mhos/m.
σ_2 = 10^{-1} mhos/m.

FIG 98



LEGEND
+ – FIELD SCATTERED WHEN SLAB IS IN HILL.
x FIELD SCATTERED BY THE HILL ALONE.
1 – REAL (H_X)
2 – IMAGINARY (H_X)
H_X
(Amp-turns/m.)
HALF-SPACE VALUE
E_y – POLARIZATION
z_0 = 150 m.
z_1 = –50 m.
f = 1,000 hz.
σ_0 = 0.
σ_1 = 10^{-3} mhos/m.
σ_2 = 10. mhos/m.
X (m.)
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
-0.2
-1000
-800
-600
-400
-200
0
200

FIG 99



0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
H_z
(Amp-turns/m.)
+ — FIELD SCATTERED WHEN SLAB IS IN HILL.
x — FIELD SCATTERED BY THE HILL ALONE.
1 — REAL (H_z)
2 — IMAGINARY (H_z)
-1000 -800 -600 -400 -200 0 200
X (m.)
1
2
E_y — POLARIZATION
z_0 = 150 m.
z_1 = -50 m.
f = 1,000 hz.
σ_0 = 0.
σ_1 = 10^{-3} mhos/m.
σ_2 = 10. mhos/m.

FIG 100

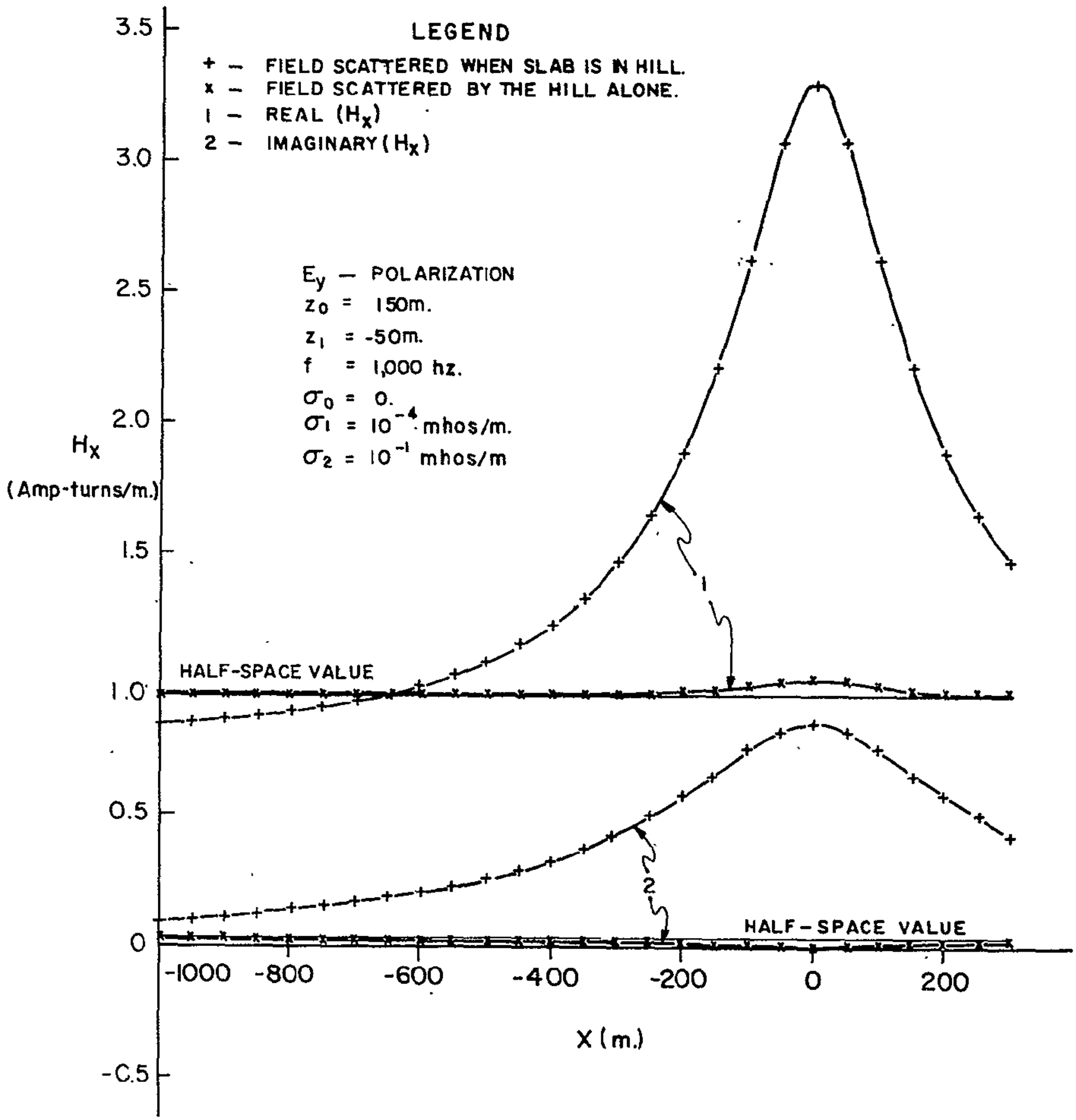
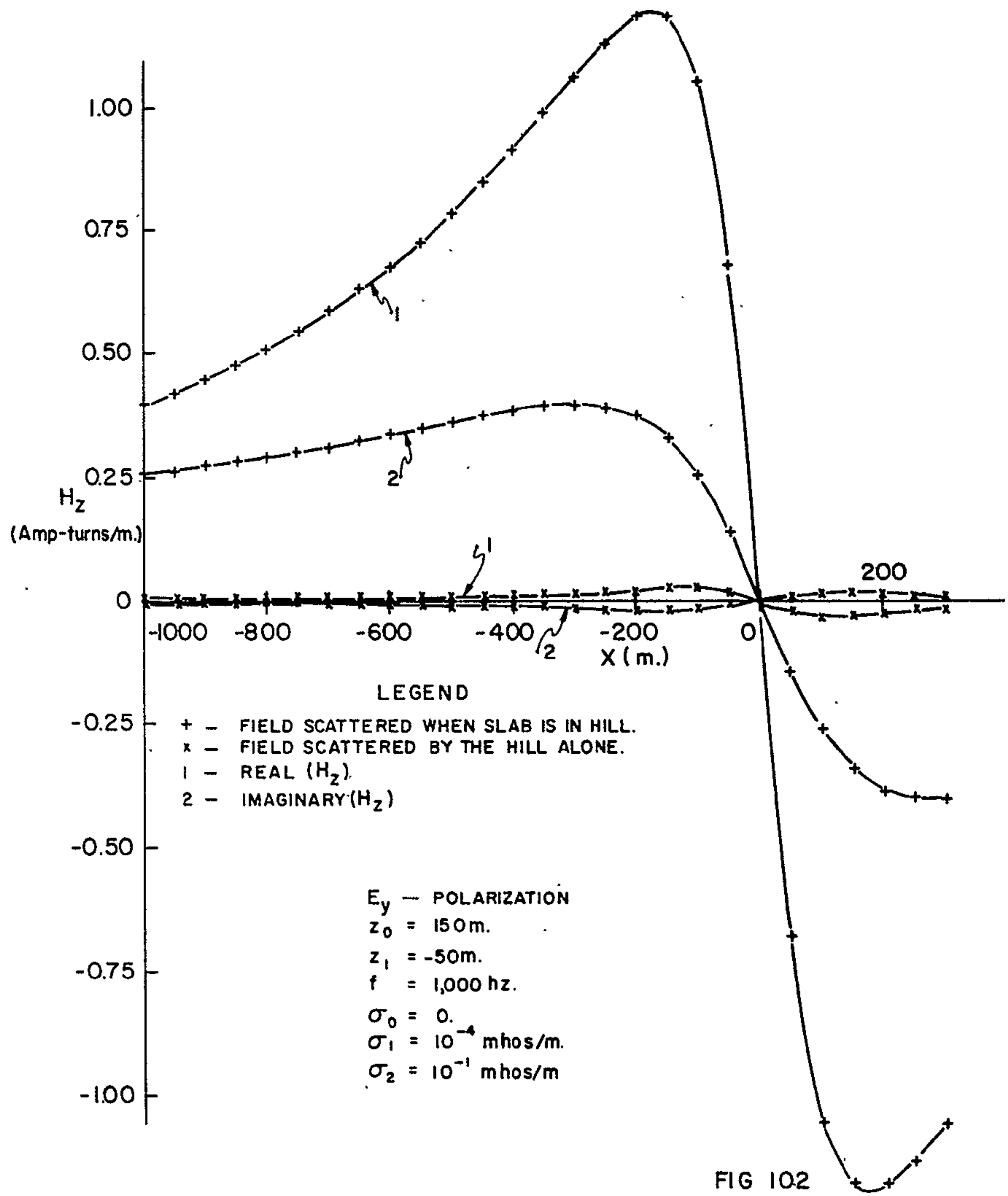

LEGEND
+ — FIELD SCATTERED WHEN SLAB IS IN HILL.
x — FIELD SCATTERED BY THE HILL ALONE.
1 — REAL (Hx)
2 — IMAGINARY (Hx)
Ey — POLARIZATION
z0 = 150m.
z1 = -50m.
f = 1,000 hz.
σ0 = 0.
σ1 = 10^-4 mhos/m.
σ2 = 10^-1 mhos/m
Hx
(Amp-turns/m.)
HALF-SPACE VALUE
HALF-SPACE VALUE
X (m.)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
-0.5
-1000
-800
-600
-400
-200
0
200
1
2

FIG 101



1.00
0.75
0.50
0.25
0
-0.25
-0.50
-0.75
-1.00
H_z
(Amp-turns/m.)
-1000
-800
-600
-400
-200
0
200
X (m.)
1
2
LEGEND
+ – FIELD SCATTERED WHEN SLAB IS IN HILL.
x – FIELD SCATTERED BY THE HILL ALONE.
1 – REAL (H_z)
2 – IMAGINARY (H_z)
E_y – POLARIZATION
z_0 = 150m.
z_1 = -50m.
f = 1,000 hz.
σ_0 = 0.
σ_1 = 10^-4 mhos/m.
σ_2 = 10^-1 mhos/m

FIG 102

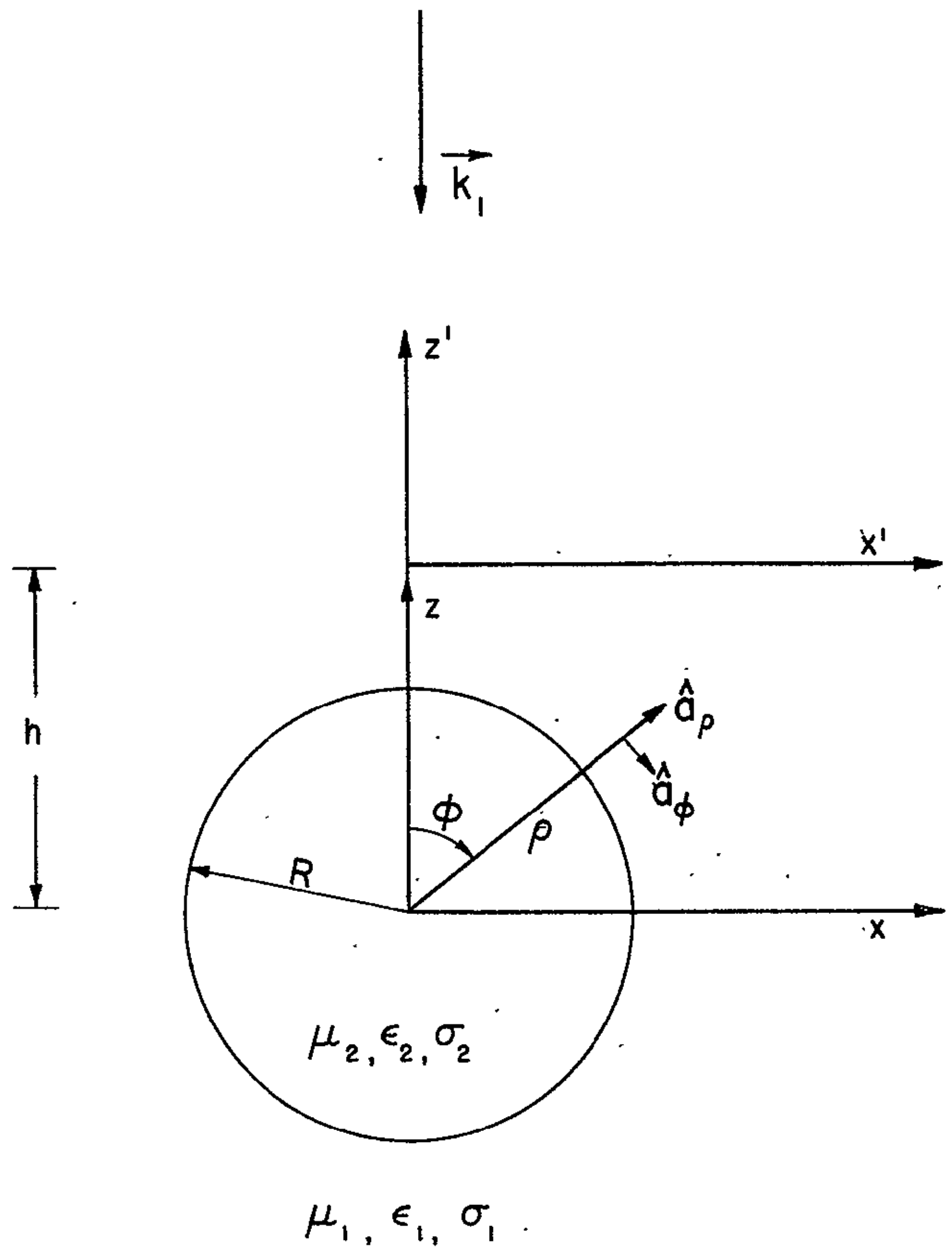
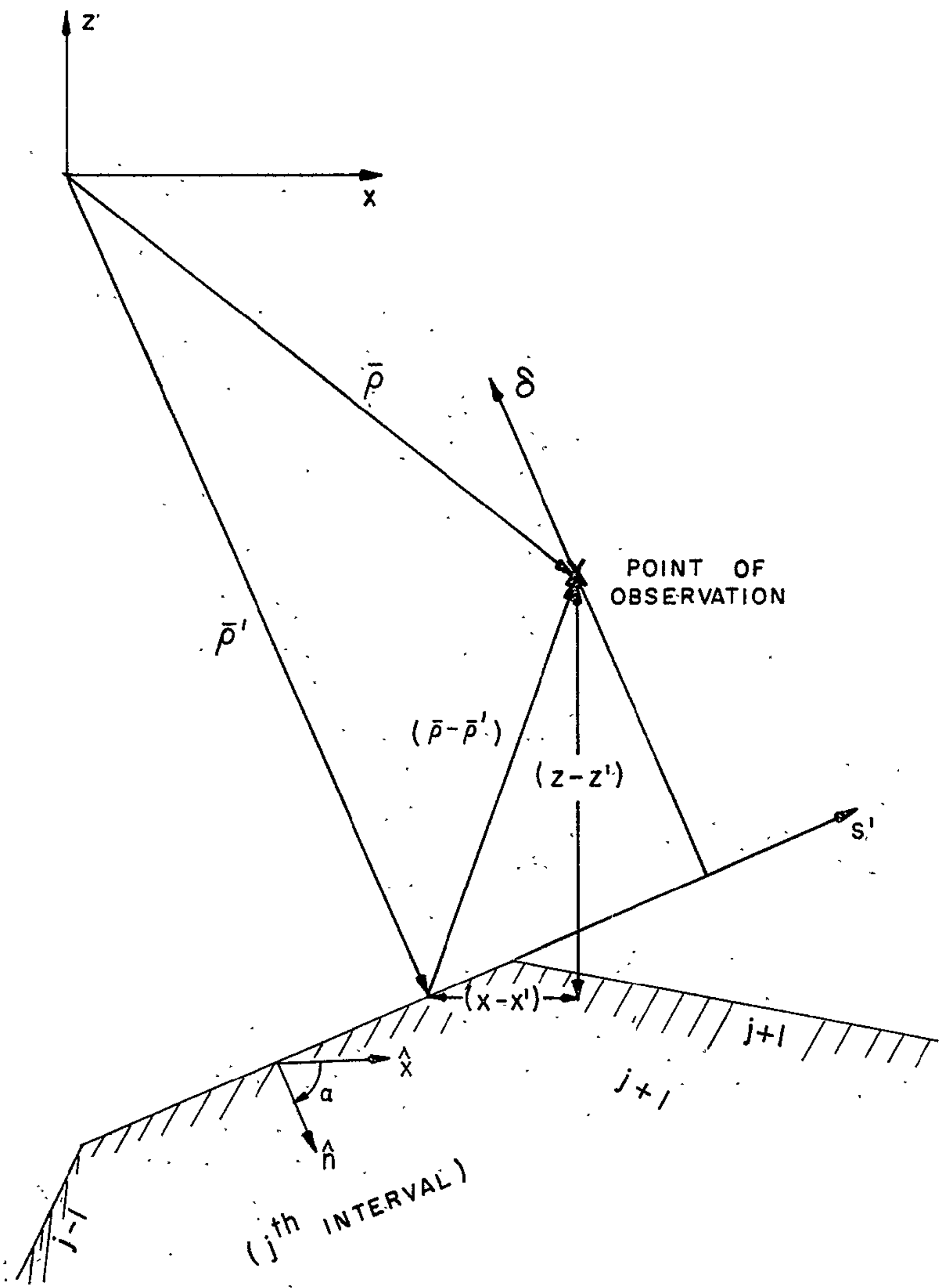


FIG 103



z'
x
$\bar{\rho}$
δ
POINT OF
OBSERVATION
$\bar{\rho}'$
$(\bar{\rho}-\bar{\rho}')$
$(z-z')$
s'
(x-x')
j+1
$\hat{x}$
a
j+1
$\hat{n}$
j-1
(j^{th} INTERVAL)

FIG 104

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LISTING

COMPUTER PROGRAMS

** L.R.L. 1401 CARD LIST **

```
      PROGRAM HAFSPAC(INPUT,OUTPUT)                                      $69.153
C...  HAFSPAC CALCULATES THE MAGNETIC FIELD INTENSITY SCATTERED BY A
C     FINITELY CONDUCTING CYLINDER IN A CONDUCTIVE HALF-SPACE. THE
C     INCIDENT FIELD IS ASSUMED TO BE AN EY-POLARIZED PLANE WAVE.
C     IF PHI IS NOT 180 DEGREES, THE PROGRAM IS NOT VALID.
C...  NOTE THAT THIS PROGRAM ASSUMES ALSO THAT THE TOPOGRAPHIC CONTOUR
C     AND CYLINDER CONTOUR ARE MIRROR SYMMETRIC ABOUT THE Z-AXIS. IF A
C     NON-SYMMETRIC SCATTERER IS TO BE CONSIDERED, THE CARD(S) WHICH
C     HAVE AN * IN COLUMN 1 MUST REPLACE THE CARD(S) WHICH FOLLOW IT
C     (THEM).
C...  INPUTS ARE...LOOP - THE NUMBER OF TIMES THE SOLUTION IS TO BE
C                        CONSIDERED (AND HENCE ALL NEW INPUT DATA).
C                  LLX - THE NUMBER OF STATIONS AT WHICH THE SCATTERED
C                        FIELD IS TO BE CALCULATED.
C                  NDEPTH - THE NUMBER OF BURIAL DEPTHS AT WHICH THE
C                           CYLINDER IS TO BE PLACED. THE SOLUTION IS
C                           REPEATED ASSUMING ALL OTHER PARAMETERS ARE
C                           THE SAME.
C                  NTOPO - THE NUMBER OF INTERVALS INTO WHICH THE
C                          TOPOGRAPHIC CONTOUR HAS BEEN DIVIDED. THE
C                          PROGRAM ASSUMES THAT NTOPO IS ODD (THE CENTER
C                          OF THE MID-PROFILE INTERVAL IS AT X=0.). THE
C                          FIRST TOPOGRAPHIC INTERVAL IS ON THE LEFT
C                          HAND OR NEGATIVE X-AXIS SIDE AND THE LAST
C                          INTERVAL IS ON THE RIGHT HAND SIDE.
C                  NINHOM - THE NUMBER OF INTERVALS INTO WHICH THE
C                           INHOMOGENEITY CONTOUR HAS BEEN DIVIDED. THE
C                           PROGRAM ASSUMES NINHOM IS EVEN .THE CENTER
C                           OF THE FIRST INTERVAL IS AT X=0. ON THE TOP
C                           OF THE CYLINDER, AND THE INTERVALS ARE
C                           DESCRIBED CLOCKWISE FROM HERE.
C                  NA1 - THE ORDER N IN SIMPSONS RULE PLUS 1 (THUS NA1
C                        IS ALWAYS ODD).NA1 DETERMINES INTEGRATION
C                        ACCURACY ON THOSE CONTOURS FOR WHICH /KR/ .LT.
C                        RE OVER THE ENTIRE WIDTH OF A SAMPLING INTERVAL
C                        IN THE EARTH. NORMALLY 3 OR 5 IF CONDUC1 IS
C                        1.E-03.
C                  NA2 - SAME AS NA1 EXCEPT THAT /KR/ .LT. RE OVER THE
C                        ENTIRE WIDTH OF A SAMPLING INTERVAL IN THE
C                        CYLINDER. NORMALLY 3 TO 11, DEPENDING ON CONDUC2.
C                  ITER - MAXIMUM NUMBER OF BISECTIONS OF THE INTEGRATION
C                         INTERVAL USED IN SUBROUTINE RMBRG.  NORMALLY
C                         ABOUT 10.
C                  PHI - THE ANGLE OF INCIDENCE, MEASURED CLOCKWISE
C                        FROM THE VERTICAL Z-AXIS.  PHI MUST BE 180 DEGREES.
C                  H0 - THE INCIDENT FIELD INTENSITY. (NORMALLY TAKEN
C                       TO BE 1.)
C                  X0 - THE INITIAL STATION.
C                  XINT - THE STATION INTERVAL.
C                  RE - THAT VALUE FOR WHICH THE SMALL ARGUMENT SOLUTION
C                       IS USED IF /KR/ .LT. RE OVER THE ENTIRE WIDTH
C                       OF A SAMPLING INTERVAL. NORMALLY ABOUT .5.
C                  TOLER - THE UPPER BOUND OF THE ABSOLUTE ERROR. THIS
C                          VALUE IS USED ONLY IN SUBROUTINE RMBRG. NORMALLY
C                          .001.
C                  SAMPLE - THE INTEGRATION SAMPLING RATE PER WAVELENGTH
```

```
C                                (SEE SECTION 4-3 OF THESIS FOR AN EXPLANATION
C                                OF THIS PARAMETER).SAMPLE IS USED TO DETERMINE
C                                INTEGRATION ACCURACY ALONG THE TOPOGRAPHIC
C                                PROFILE. NORMALLY 20. TO 30.
C                        ACC - DETERMINES THE WIDTH OF THE INTERVAL (DELTA/ACC
C                              ,DELTA*ACC) OVER WHICH FUNC IS NUMERICALLY
C                              INTEGRATED. NORMALLY ABOUT 30.
C                        Z0 - ELEVATION OF THE SURVEY OR FLIGHT LEVEL.
C                        Z1 - DEPTH TO THE TOP OF THE INHOMOGENEITY.
C                        FREQ - THE FREQUENCY OF THE INCIDENT FIELD.
C                        DIECST0 - THE DIELECTRIC CONSTANT OF THE AIR.
C                        MAGPER0 - THE MAGNETIC PERMEABILITY OF THE AIR.
C                        CONDUC0 - THE CONDUCTIVITY OF THE AIR.
C                        DIECST1 - THE DIELECTRIC CONSTANT OF THE EARTH.       $69.153
C                        MAGPER1 - THE MAGNETIC PERMEABILITY OF THE EARTH.     $69.153
C                        CONDUC1 - THE CONDUCTIVITY OF THE EARTH.              $69.153
C                        DIECST2 - THE DIELECTRIC CONSTANT OF THE INHOMOGENEITY.
C                        MAGPER2 - THE MAGNETIC PERMEABILITY OF THE INHOMOGENEITY.
C                        CONDUC2 - THE CONDUCTIVITY OF THE INHOMOGENEITY.
C                        SCX(J,K) AND SCZ(J,K) - THE COORDINATES OF THE EDGES OF THE
C                                INTERVALS WHICH DESCRIBE THE CYLINDER AND
C                                TOPOGRAPHIC PROFILES.NOTE THAT THE CYLINDER
C                                PROFILE MUST BE READ IN FIRST, AND ONLY THE
C                                NEGATIVE HALF OF THE TOPOGRAPHIC CONTOUR IS READ IN.
C...   SUBROUTINES CALLED BY HAFSPAC ARE
C       DATTOP, DATHOM, SMARG, HINT01, ACURAT, APPROX, ANSWER, EHHFSP,
C       EHFTSP, CUPIEQ, MANDK, CINVER, INVERT, FIELDS, FUNC, AND RMBRG.
C...   NOTE THAT ALL UNITS ARE MKS.
       DIMENSION SIJR(90,90),SIJI(90,90),FIELDR(200),FIELDI(200),Z0(50),
      1CURDEN(200),TEMP(2,200),Z1(10),FIELD(200)
       DIMENSION XT(50),SHXR(50),SHZR(50),SHXI(50),SHZI(50),PHASEX(50),
      1PHASEZ(50),HSECX(50),HSECZ(50)
       DIMENSION SCX(100,2),SCZ(100,2),X(100),Z(100),RALPHA(100),SCALPH(
      1100,2),HALFW(100)
       COMPLEX CARG0,BARG0,CARG2,BARG2,H01,H0A,H21,H2A,F01,F0A,F21,F2A,
      1TERMK,TERMPK,TERMMK,TIRMK,TIRMPK,TIRMMK,TERMM,TERMPM,TERMMM,TIRMM,
      2TIRMPM,TIRMMM,TEMP,AID
       COMPLEX TARG0,TARG2,R01,R21,T01,T21,HPHIX,HPHIZ
       COMPLEX DARG0,DARG2,H0D,H2D,F0D,F2D                                 +69.167
       COMPLEX PROPCT0,PROP0S,GMLOG0,AIMP0,TAC0,YIP0,ZIP0,ZAP0,CUREHF,     $69.167
      =CURMHF,FIELD                                                        $69.167
       COMPLEX AIMG,PROPCT1,PROPCT2,PROP1S,PROP2S,AIMP1,AIMP2,TAC1,TAC2,
      1YIP1,YIP2,ZIP1,ZIP2,ZAP1,ZAP2,PRIMEE,PRIMEH,CURDEN,GMLOG2,CST
       COMPLEX CMPXPI,AIMGPI,CPXZER,PROP1C,GMLOG,HK00,HK01,HK02,AI1,AI2,
      1AI3,AI4,AI5,AI6,AI7,AI8,AI9,AI10,AI11,AI12,AI13,HJ00,HJ01,HJ02,AJ1
      2,AJ2,AJ3,AJ4,AJ5,AJ6,AJ7,AJ8,AJ9,AJ10,AJ11,AJ12,AJ13,HIK0,HIK2,HIJ
      30,HIJ2
       COMPLEX ZSUM,HRCOEF,ERCOEF,HTCOEF,ETCOEF,ATTEN,ATTEN0,ATTEN1,EINC,
      1HINC,EREFL,HREFL,ETRANS,HTRANS,H0INT,H1INT,H2INT,H5INT,H6INT,H9INT
      2,H10INT,H11INT
       COMPLEX DIFFE,DIFFH
       COMMON /ZAP/ AJOP1,AMDA,BETA,AMDAP1,ONEMAM,SMALLA,SMALLB,DELTA,
      1SMALLC,CC2,SAIMA,CAIMA,DCAIMA
       COMMON /ZUP/ AIOP1,AMDB,BETB,AMDBP1,ONEMA
       COMMON /ZIP/ DD2
       COMMON /CONSTS/ ISTOP,ISTOP2,ISTP1,NTOPUP,NUPTOP,NSTP1,NTOPHF,
```

```
     1NTHFUP,NPTPP1,NINHHF,NUPHHF,NSYMUP,NMID,NMIDUP,NSYM,NSYM2,NMIDM,
     2NMIDP,NSYMM,NTOPO
      COMMON /VARIAB/ ITER,TOLER,ACC
      EXTERNAL FUNC
      REAL MAGPER0,MAGPER1,MAGPER2,MU0,MU1,MU2,IMAGK0,IMAGK1,IMAGK2
      READ 1, LOOP
      DO 2000 LOO=1,LOOP
      READ 1, LLX,NDEPTH,NTOPO,NINHOM,NA1,NA2,ITER
      READ 2, PHI,H0,X0,XINT,RE,TOLER,SAMPLE,ACC                      $69.167
************
      READ 2,(Z0(NZ),NZ=1,LLX)
************
      READ 2, (Z1(ND),ND=1,NDEPTH)                                    +69.167
      READ 2, FREQ,DIECST0,MAGPER0,DIECST1,MAGPER1,DIECST2,MAGPER2
      READ 3, CONDUC0,CONDUC1,CONDUC2
      IF(NINHOM.EQ.0) GO TO 12
      READ 2, ((SCX(I,K),K=1,2),I=1,NINHOM)
      READ 2, ((SCZ(I,K),K=1,2),I=1,NINHOM)
   12 CONTINUE
    1 FORMAT (10I3)
    2 FORMAT (8F9.4)
    3 FORMAT (5E15.7)
    5 FORMAT (8E15.7)
    6 FORMAT (5X,8E15.7)
   10 FORMAT (1H1)
   11 FORMAT (1H0)
      FOURPI=12.566370614359173
      TWOPI=6.2831853071795865
      PI=3.14159265358979324
      HALFPI=1.570796326794897
      TWOIPI=.636619772367581З
      RADIAN=.0174532925199432 96
      FOUR=4.000000000000000
      THREE=3.0000000000000000
      TWO=2.000000000000000
      ONE=1.000000000000000
      GAMMA=.57721566490153286
      ZERO=.000000000000000
      AIMG=CMPLX(ZERO,ONE)
      AIMGPI=AIMG/PI
      CMPXPI=TWO*AIMGPI
      CPXZER=CMPLX(ZERO,ZERO)
      PHI=PHI*RADIAN
      HX=H0*SIN(PHI-HALFPI)
      OMEGA=TWOPI*FREQ
      AMU=FOURPI*1.E-07
      MU0=MAGPER0*AMU                                                 +69.153
      MU1=MAGPER1*AMU
      MU2=MAGPER2*AMU
      FIP=MU0*OMEGA                                                   +69.153
      HIP=MU1*OMEGA
      GIP=MU2*OMEGA
      FIPPEE=FIP/FOUR                                                 +69.153
      HIPPEE=HIP/FOUR
      GIPPEE=GIP/FOUR
      EPA=8.8539803E-12
```

```
EPSILO0=DIECST0*EPA                                +69.153
EPSILO1=DIECST1*EPA
EPSILO2=DIECST2*EPA
A0=CONDUC0/(EPSILO0*OMEGA)                         +69.153
AS0=A0*A0                                          +69.153
AR0=SQRT(ONE+AS0)                                  +69.153
B0=MU0*EPSILO0/TWO                                 +69.153
REALK0=OMEGA*SQRT(B0*(AR0+ONE))                    +69.153
IMAGK0=OMEGA*SQRT(B0*(AR0-ONE))                    +69.153
A1=CONDUC1/(EPSILO1*OMEGA)
AS1=A1*A1
AR1=SQRT(ONE+AS1)
B1=MU1*EPSILO1/TWO
REALK1=OMEGA*SQRT(B1*(AR1+ONE))
IMAGK1=OMEGA*SQRT(B1*(AR1-ONE))
A2=CONDUC2/(EPSILO2*OMEGA)
AS2=A2*A2
AR2=SQRT(ONE+AS2)
B2=MU2*EPSILO2/TWO
REALK2=OMEGA*SQRT(B2*(AR2+ONE))
IMAGK2=OMEGA*SQRT(B2*(AR2-ONE))
PROPCT0=CMPLX(REALK0,IMAGK0)                       +69.153
PROPCT1=CMPLX(REALK1,IMAGK1)
PROPCT2=CMPLX(REALK2,IMAGK2)
PROP0S=PROPCT0*PROPCT0                             +69.153
PROP1S=PROPCT1*PROPCT1
PROP2S=PROPCT2*PROPCT2
PROP1C=PROP1S*PROPCT1
GMLOG0=GAMMA+CLOG(PROPCT0/TWO)                     +69.153
GMLOG=GAMMA+CLOG(PROPCT1/TWO)
GMLOG2=GAMMA+CLOG(PROPCT2/TWO)
ABSK0=CABS(PROPCT0)                                +69.167
ABSK1=CABS(PROPCT1)
ABSK2=CABS(PROPCT2)
WAVEL0=TWOPI/REALK0                                +69.153
WAVEL1=TWOPI/REALK1
WAVEL2=TWOPI/REALK2
WAVIT0=WAVEL0/SAMPLE                               +69.167
WAVIT1=WAVEL1/SAMPLE                               +69.167
SKIND0=ONE/IMAGK0                                  +69.167
SKIND1=ONE/IMAGK1                                  +69.167
SKIND2=ONE/IMAGK2                                  +69.167
AIMP0=FIP/PROPCT0                                  +69.153
AIMP1=HIP/PROPCT1                                  $69.153
AIMP2=GIP/PROPCT2                                  $69.153
TAC0=PROPCT0/AIMP0                                 +69.153
TAC1=PROPCT1/AIMP1
TAC2=PROPCT2/AIMP2
YIP0=AIMG*PROPCT0/FOUR                             +69.153
YIP1=AIMG*PROPCT1/FOUR
YIP2=AIMG*PROPCT2/FOUR
ZIP0=ONE/(FOUR*AIMP0)                              +69.153
ZIP1=ONE/(FOUR*AIMP1)
ZIP2=ONE/(FOUR*AIMP2)
ZAP0=ZIP0*PROPCT0                                  +69.153
ZAP1=ZIP1*PROPCT1
```

```
      ZAP2=ZIP2*PROPCT2
      CST = PROPCTO/(12.*AIMPO)                                         +69.167
      ISTOP=NTOPO+NINHOM                                                $69.167
      JSTOP=ISTOP                                                       $69.153
      ISTOP2=2*ISTOP
      JSTOP2=ISTOP2
      ISTP1=ISTOP+1
      ISTPUP=ISTOP+2
      NTOPUP=NTOPO+1                                                    $69.167
      NUPTOP=JSTOP+NTOPO                                                +69.153
      NSTP1=ISTOP+NTOPUP                                                +69.153
      NTOPHF=(NTOPO+1)/2
      NHFTOP=NTOPHF-1
      NHMHFP=NINHOM/2+1
      IF(NINHOM.EQ.0) NHMHFP=0
      NSYM=NTOPHF+NHMHFP
      NSYM2=NSYM+NSYM
      NSYMUP=NSYM+1
      NTHFUP=ISTOP+NTOPHF
      NMID=NTOPHF+1
      NMIDUP=NSYM+NMID
      NPTPP1=NUPTOP+1
      NINHHF=NTOPO+NHMHFP
      NUPHHF=ISTOP+NINHHF
      NTUPP=NTOPUP+1
      NINHFM=NINHHF-1
      NMIDP=NMID+1
      NMIDM=NMID-1
      NSYMM=NSYM-1
      DO 900 ND=1,NDEPTH                                                +69.167
      IF(NINHOM.EQ.0) GO TO 16                                          +69.167
      CALL DATHOM(NINHOM,SCX,SCZ,X,Z,RALPHA,SCALPH,HALFW)
      DO 15 I=1,NINHOM                                                  +69.153
      J=NINHOM+1-I
      JUP=NTOPO+J
      X(JUP)=X(J)                                                       +69.153
      Z(JUP)=Z(J)-Z1(ND)                                                $69.167
      RALPHA(JUP)=RALPHA(J)                                             +69.153
      DO 15 K=1,2                                                       +69.153
      SCX(JUP,K)=SCX(J,K)                                               +69.153
      SCZ(JUP,K)=SCZ(J,K)-Z1(ND)                                        $69.167
      SCALPH(JUP,K)=SCALPH(J,K)                                         +69.153
   15 HALFW(JUP)=HALFW(J)                                               +69.153
   16 CONTINUE                                                          +69.167
      READ 2, ((SCX(I,K),K=1,2),I=1,NTOPHF)
      READ 2, ((SCZ(I,K),K=1,2),I=1,NTOPHF)
      DO 17 I=1,NHFTOP
      NIAA=NTOPHF+I
      NIBB=NTOPHF-I
      SCX(NIAA,1)=-SCX(NIBB,2)
      SCX(NIAA,2)=-SCX(NIBB,1)
      SCZ(NIAA,1)=SCZ(NIBB,2)
   17 SCZ(NIAA,2)=SCZ(NIBB,1)
      CALL DATTOP(NTOPO,SCX,SCZ,X,Z,RALPHA,SCALPH,HALFW)                 69.167
      PRINT 10
      PRINT 20
```

```
20 FORMAT (9X,1HI,9X,1HK,17X,3HSCX,17X,3HSCZ,14X,6HSCALPH////)
   PRINT 25                                                            +69.153
25 FORMAT(15X,*TOPOGRAPHIC DATA*//)                                    +69.153
   DO 35 I=1,NTOPO                                                     $69.167
   DO 35 K=1,2                                                         +69.153
   DELT=SCALPH(I,K)/RADIAN
   PRINT 30, I,K,SCX(I,K),SCZ(I,K),DELT
30 FORMAT (2(7X,I3),3(10X,F10.4))
35 CONTINUE                                                            +69.153
   IF(NINHOM.EQ.0) GO TO 46                                            +69.167
   PRINT 40                                                            +69.153
40 FORMAT(1H0,15X,*INHOMOGENEITY DATA*//)                              +69.153
   DO 45 I=NTOPUP,ISTOP                                                +69.153
   DO 45 K=1,2                                                         +69.153
   DELT=SCALPH(I,K)/RADIAN                                             +69.153
   PRINT 30, I,K,SCX(I,K),SCZ(I,K),DELT                                +69.153
45 CONTINUE                                                            +69.153
46 CONTINUE                                                            +69.167
   PRINT 10
   PRINT 50
50 FORMAT (9X,1HI,19X,1HX,19X,1HZ,15X,5HALPHA,10X,10HHALF WIDTH////)
   PRINT 25                                                            +69.153
   DO 60 I=1,NTOPO
   ALPH=RALPHA(I)/RADIAN
   PRINT 55, I,X(I),Z(I),ALPH,HALFW(I)                                 $69.153
55 FORMAT (7X,I3,4(10X,F10.4))                                         $69.153
60 CONTINUE                                                            $69.153
   IF(NINHOM.EQ.0) GO TO 66                                            +69.167
   PRINT 40                                                            +69.153
   DO 65 I=NTOPUP,ISTOP                                                +69.153
   ALPH=RALPHA(I)/RADIAN                                               +69.153
   PRINT 55, I,X(I),Z(I),ALPH,HALFW(I)                                 +69.153
65 CONTINUE                                                            +69.153
66 CONTINUE                                                            +69.167
   ZSUM=AIMPO+AIMP1
   HRCOEF=(AIMPO-AIMP1)*HO/ZSUM
   ERCOEF=-AIMPO*HRCOEF
   HTCOEF=-TWO*AIMPO*HO/ZSUM
   ETCOEF=-AIMP1*HTCOEF
   CUREHF=-HTCOEF
   CURMHF=-ETCOEF
   PRINT 10
   PRINT 70, CUREHF,CURMHF
70 FORMAT (5X,*EQUIVALENT ELECTRIC CURRENT =*2(1PE15.7),5X,*EQUIVALEN
  1T MAGNETIC CURRENT =*2(1PE15.7))
*  DO 80 I=1,ISTOP2                                                    $69.167
   DO 80 I=1,NSYM2
*  DO 80 J=1,ISTOP2                                                    $69.167
   DO 80 J=1,NSYM2
   SIJR(I,J)=ZERO
80 SIJI(I,J)=ZERO
*  DO 81 I=1,ISTOP2                                                    +69.167
   DO 81 I=1,NSYM2
81 FIELD(I)=CPXZER                                                     +69.167
   DO 85 I=1,2
   DO 85 J=1,JSTOP2
```

```
   85 TEMP(I,J)=CPXZER
      PRINT 10
*     DO 200 I=1,ISTOP                                               $69.167
      DO 200 I=NTOPHF,NINHHF
*     I1=I
      I1=I-NHFTOP
*     I2=ISTOP+I                                                     $69.167
      I2=NSYM+I1
      SINAI=SIN(RALPHA(I))
      COSAI=COS(RALPHA(I))
      DO 160 J=1,JSTOP                                               +69.167
      IF(I.LE.NTOPO .AND. J.LE.NTOPO) GO TO 91                       +69.167
      IF(I.GT.NTOPO .AND. J.GT.NTOPO) GO TO 92                       +69.167
      NTEST=2                                                        +69.167
      GO TO 93                                                       +69.167
   91 NTEST=1                                                        +69.167
      GO TO 93                                                       +69.167
   92 NTEST=3                                                        +69.167
   93 JK=J                                                           +69.167
      JM=JSTOP+J
      IF(J.GE.2) GO TO 109                                           $69.153
      JJJ=1                                                          $69.153
      JJJK=1                                                         $69.153
      JJJM=ISTP1                                                     $69.153
      JJ=2
      JJK=2
      JJM=ISTPUP
  108 XIJO=X(I)-SCX(J,1)                                             $69.167
      ZIJO=Z(I)-SCZ(J,1)
      RIJO=SQRT(XIJO*XIJO+ZIJO*ZIJO)
      DARGO=CMPLX(REALKO*RIJO,IMAGKO*RIJO)                           +69.167
      CARGO=CMPLX(REALK1*RIJO,IMAGK1*RIJO)
      BARGO=CMPLX(REALK2*RIJO,IMAGK2*RIJO)
      ABDARO=CABS(DARGO)                                             +69.167
      ABCARO=CABS(CARGO)
      ABBARO=CABS(BARGO)
      IF(NTEST-2) 1080,1081,1082
 1080 CALL HINTO1(DARGO,HOD,FOD,IER)                                 +69.167
 1081 CALL HINTO1(CARGO,HO1,FO1,IER)
      GO TO 125
 1082 CALL HINTO1(CARGO,HO1,FO1,IER)
      CALL HINTO1(BARGO,HOA,FOA,IER)
      GO TO 125
  109 IF(J.NE.NTOPUP) GO TO 110                                      +69.153
      JJJ=JSTOP                                                      +69.153
      JJJK=JSTOP                                                     +69.153
      JJJM=JSTOP2                                                    +69.153
      JJ=NTOPUP+1                                                    +69.153
      JJK=JJ                                                         +69.153
      JJM=NSTP1+1                                                    +69.153
      GO TO 108                                                      +69.153
  110 JJJ=J-1
      JJJK=JJJ
      JJJM=JM-1
      IF(J.EQ.NTOPO) GO TO 115                                       $69.167
      IF(J.EQ.JSTOP) GO TO 116                                       +69.153
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```
      JJ=J+1
      JJK=JJ
      JJM=JM+1
      GO TO 120
  115 JJ=NTOPO                                                          $69.167
      JJK=NTOPO                                                         $69.167
      JJM=NUPTOP                                                        +69.153
      GO TO 120                                                         +69.153
  116 JJ=NTOPUP                                                         +69.153
      JJK=NTOPUP                                                        +69.153
      JJM=NSTP1                                                         +69.153
  120 XIJ0=XIJ2
      ZIJ0=ZIJ2
      RIJ0=RIJ2
      DARG0=DARG2                                                       +69.167
      CARG0=CARG2
      BARG0=BARG2
      ABDAR0=ABDAR2                                                     +69.167
      ABCAR0=ABCAR2
      ABBAR0=ABBAR2
      H0D=H2D                                                           +69.167
      F0D=F2D                                                           +69.167
      H01=H21
      F01=F21
      H0A=H2A
      F0A=F2A
  125 XIJ2=X(I)-SCX(J,2)
      ZIJ2=Z(I)-SCZ(J,2)
      RIJ2=SQRT(XIJ2*XIJ2+ZIJ2*ZIJ2)
      DARG2=CMPLX(REALK0*RIJ2,IMAGK0*RIJ2)                              +69.167
      CARG2=CMPLX(REALK1*RIJ2,IMAGK1*RIJ2)
      BARG2=CMPLX(REALK2*RIJ2,IMAGK2*RIJ2)
      ABDAR2=CABS(DARG2)                                                +69.167
      ABCAR2=CABS(CARG2)
      ABBAR2=CABS(BARG2)
      IF(NTEST-2) 1250,1251,1252
 1250 CALL HINT01(DARG2,H2D,F2D,IER)                                    +69.167
 1251 CALL HINT01(CARG2,H21,F21,IER)
      GO TO 1253
 1252 CALL HINT01(CARG2,H21,F21,IER)
      CALL HINT01(BARG2,H2A,F2A,IER)
 1253 AJOP1=HALFW(J)+HALFW(JJ)
      AJOM1=HALFW(J)+HALFW(JJJ)
      AMDA=AJOP1/AJOM1
      BETA=AJOP1*AJOM1
      AMDAP1=AMDA+ONE
      ONEMAM=ONE-AMDA
      W2=HALFW(J)*HALFW(J)
      IF(I.NE.J) GO TO 130                                              $69.167
      IF(NTEST-2) 128,126,129                                           +69.167
  126 PRINT 127                                                         +69.167
  127 FORMAT(10X,*ERROR IN NTEST DETECTED  IN I=J TEST*)                +69.167
      CALL EXIT                                                         +69.167
  128 NT0=3+2*IFIX(HALFW(I)/WAVIT0)                                     +69.167
      NT1=3+2*IFIX(HALFW(I)/WAVIT1)                                     +69.167
      CALL SMARG(NT0,CMPXPI,ABSK0,PROPCT0,GMLOG0,HALFW(J),              +69.167
```

```
     =ABDAR2,H2D,F2D,HK00,HK02,HIK0,HIK2,RE)                              +69.167
      CALL SMARG(NT1,CMPXPI,ABSK1,PROPCT1,GMLOG,HALFW(J),ABCAR2,H21,F21,  +69.167
     =HJ00,HJ02,HIJ0,HIJ2,RE)                                             +69.167
      HK00=FIPPEE*HK00+HIPPEE*HJ00                                        +69.167
      HIK0=ZIP0*HIK0+ZIP1*HIJ0                                            +69.167
      IF(I.EQ.1 .OR. I.EQ.NTOPO) GO TO 1280                               +69.168
      HK02=FIPPEE*HK02+HIPPEE*HJ02                                        +69.167
      HIK2=ZIP0*HIK2+ZIP1*HIJ2                                            +69.167
      GO TO 1290                                                          +69.167
 1280 TERMK=HK00                                                          +69.168
      TERMPK=CPXZER                                                       +69.168
      TERMMK=CPXZER                                                       +69.168
      TERMM=CPXZER                                                        +69.168
      TERMPM=CPXZER                                                       +69.168
      TERMMM=CPXZER                                                       +69.168
      TIRMK=CPXZER                                                        +69.168
      TIRMPK=CPXZER                                                       +69.168
      TIRMMK=CPXZER                                                       +69.168
      TIRMM=HIK0                                                          +69.168
      TIRMPM=CPXZER                                                       +69.168
      TIRMMM=CPXZER                                                       +69.168
      GO TO 155
  129 CALL SMARG(NA1,CMPXPI,ABSK1,PROPCT1,GMLOG,HALFW(J),ABCAR2,H21,F21,
     1HK00,HK02,HIK0,HIK2,RE)
      CALL SMARG(NA2,CMPXPI,ABSK2,PROPCT2,GMLOG2,HALFW(J),ABBAR2,H2A,F2A
     1,HJ00,HJ02,HIJ0,HIJ2,RE)
      HK00=HIPPEE*HK00+GIPPEE*HJ00
      HK02=HIPPEE*HK02+GIPPEE*HJ02
      HIK0=ZIP1*HIK0+ZIP2*HIJ0
      HIK2=ZIP1*HIK2+ZIP2*HIJ2
 1290 TERMK=HK00-HK02/BETA                                                $69.167
      TERMPK=HK02/(AMDAP1*BETA)
      TERMMK=-AMDA*TERMPK
      TERMM=CPXZER
      TERMPM=CPXZER
      TERMMM=CPXZER
      TIRMK=CPXZER
      TIRMPK=CPXZER
      TIRMMK=CPXZER
      TIRMM=HIK0-HIK2/BETA
      TIRMPM=HIK2/(AMDAP1*BETA)
      TIRMMM=-AMDA*TIRMPM
      GO TO 155                                                           $69.167
  130 SINA1=SIN(RALPHA(J))
      COSA1=COS(RALPHA(J))
      SMALLA=XIJ0*SINA1-ZIJ0*COSA1
      SMALLC=HALFW(J)+SMALLA
      SMALLB=HALFW(J)+SMALLC
      DELTA=-(XIJ0*COSA1+ZIJ0*SINA1)
      DD2=DELTA*DELTA
      CC2=SMALLC*SMALLC
      SAIMA=SINAI*COSA1-COSAI*SINA1
      CAIMA=SINAI*SINA1+COSAI*COSA1
      DCAIMA=DELTA*CAIMA
      IF(NTEST-2) 135,140,145                                             +69.167
  135 IF(ABDAR0.GT.RE .OR. ABDAR2.GT.RE) GO TO 1350                       +69.167
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```
      CALL ACURAT(PROPCTO,PROPOS,GMLOGO,HOD,H2D,FOD,F2D,HK00,HK01,HK02,   +69.167
     =AI1,AI2,AI3,AI4,AI5,AI6,AI7,AI8,AI9,AI10,AI11,AI12,AI13)              +69.167
      GO TO 1351                                                            +69.167
 1350 CONINT=SMALLB-SMALLA                                                  +69.167
      NTO=3+2*IFIX(CONINT/WAVITO)                                           +69.167
      CALL APPROX(NTO,HOD,H2D,FOD,F2D,PROPCTO,HK00,HK01,HK02,AI1,AI2,      +69.167
     =AI3,AI4,AI5,AI6,AI7,AI8,AI9,AI10,AI11,AI12,AI13)                      +69.167
 1351 IF(ABCARO.GT.RE .OR. ABCAR2.GT.RE) GO TO 1352                         +69.167
      CALL ACURAT(PROPCT1,PROP1S,GMLOG,H01,H21,F01,F21,HJ00,HJ01,HJ02,    +69.167
     =AJ1,AJ2,AJ3,AJ4,AJ5,AJ6,AJ7,AJ8,AJ9,AJ10,AJ11,AJ12,AJ13)              +69.167
      GO TO 1353                                                            +69.167
 1352 CONINT=SMALLB-SMALLA                                                  +69.167
      NT1=3+2*IFIX(CONINT/WAVIT1)                                           +69.167
      CALL APPROX(NT1,H01,H21,F01,F21,PROPCT1,HJ00,HJ01,HJ02,AJ1,AJ2,      +69.167
     =AJ3,AJ4,AJ5,AJ6,AJ7,AJ8,AJ9,AJ10,AJ11,AJ12,AJ13)                      +69.167
 1353 HK00=FIPPEE*HK00+HIPPEE*HJ00                                          +69.167
      HK01=FIPPEE*HK01+HIPPEE*HJ01                                          +69.167
      HK02=FIPPEE*HK02+HIPPEE*HJ02                                          +69.167
      AI1=YIP0*AI1+YIP1*AJ1                                                 +69.167
      AI2=YIP0*AI2+YIP1*AJ2                                                 +69.167
      AI3=YIP0*AI3+YIP1*AJ3                                                 +69.167
      AI4=YIP0*AI4+YIP1*AJ4                                                 +69.167
      AI5=ZAP0*AI5+ZAP1*AJ5                                                 +69.167
      AI6=ZAP0*AI6+ZAP1*AJ6                                                 +69.167
      AI7=ZAP0*AI7+ZAP1*AJ7                                                 +69.167
      AI8=ZAP0*AI8+ZAP1*AJ8                                                 +69.167
      AI9=ZIP0*AI9+ZIP1*AJ9                                                 +69.167
      AI10=ZIP0*AI10+ZIP1*AJ10                                              +69.167
      AI11=ZIP0*AI11+ZIP1*AJ11                                              +69.167
      AI12=ZIP0*AI12+ZIP1*AJ12                                              +69.167
      AI13=ZIP0*AI13+ZIP1*AJ13                                              +69.167
      GO TO 150                                                             +69.167
  140 IF(I.GT.NTOPO) GO TO 1402                                             +69.167
      IF(ABCARO.GT.RE .OR. ABCAR2.GT.RE) GO TO 1400                         +69.167
      CALL ACURAT(PROPCT1,PROP1S,GMLOG,H01,H21,F01,F21,HK00,HK01,HK02,    +69.167
     1AI1,AI2,AI3,AI4,AI5,AI6,AI7,AI8,AI9,AI10,AI11,AI12,AI13)              +69.167
      GO TO 1401                                                            +69.167
 1400 CALL APPROX(NA1,H01,H21,F01,F21,PROPCT1,HK00,HK01,HK02,AI1,AI2,      +69.168
     =AI3,AI4,AI5,AI6,AI7,AI8,AI9,AI10,AI11,AI12,AI13)                      +69.168
 1401 HK00=-HIPPEE*HK00                                                     +69.168
      HK01=-HIPPEE*HK01                                                     +69.168
      HK02=-HIPPEE*HK02                                                     +69.168
      AI1=-YIP1*AI1                                                         +69.168
      AI2=-YIP1*AI2                                                         +69.168
      AI3=-YIP1*AI3                                                         +69.168
      AI4=-YIP1*AI4                                                         +69.168
      AI5=-ZAP1*AI5                                                         +69.168
      AI6=-ZAP1*AI6                                                         +69.168
      AI7=-ZAP1*AI7                                                         +69.168
      AI8=-ZAP1*AI8                                                         +69.168
      AI9=-ZIP1*AI9                                                         +69.168
      AI10=-ZIP1*AI10                                                       +69.168
      AI11=-ZIP1*AI11                                                       +69.168
      AI12=-ZIP1*AI12                                                       +69.168
      AI13=-ZIP1*AI13                                                       +69.168
      GO TO 150                                                             +69.168
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1402 IF(ABCARO.GT.RE .OR. ABCAR2.GT.RE) GO TO 1403                     +69.168
     CALL ACURAT(PROPCT1,PROP1S,GMLOG,H01,H21,F01,F21,HK00,HK01,HK02,  +69.168
    =AI1,AI2,AI3,AI4,AI5,AI6,AI7,AI8,AI9,AI10,AI11,AI12,AI13)           +69.168
     GO TO 1401                                                        +69.168
1403 CONINT=SMALLB-SMALLA                                              +69.168
     NT1=3+2*IFIX(CONINT/WAVIT1)                                       +69.168
     CALL APPROX(NT1,H01,H21,F01,F21,PROPCT1,HK00,HK01,HK02,AI1,AI2,   +69.168
    =AI3,AI4,AI5,AI6,AI7,AI8,AI9,AI10,AI11,AI12,AI13)                  +69.168
     GO TO 1401                                                        +69.168
 145 IF(ABCARO.GT.RE.OR.ABCAR2.GT.RE) GO TO 1450                       $69.168
     CALL ACURAT(PROPCT1,PROP1S,GMLOG,H01,H21,F01,F21,HK00,HK01,HK02,
    1AI1,AI2,AI3,AI4,AI5,AI6,AI7,AI8,AI9,AI10,AI11,AI12,AI13)
     GO TO 1451                                                        $69.168
1450 CALL APPROX(NA1,H01,H21,F01,F21,PROPCT1,HK00,HK01,HK02,AI1,AI2,AI3 $69.168
    1,AI4,AI5,AI6,AI7,AI8,AI9,AI10,AI11,AI12,AI13)
1451 IF(ABBARO.GT.RE.OR.ABBAR2.GT.RE) GO TO 1452                       $69.168
     CALL ACURAT(PROPCT2,PROP2S,GMLOG2,H0A,H2A,F0A,F2A,HJ00,HJ01,HJ02,
    1AJ1,AJ2,AJ3,AJ4,AJ5,AJ6,AJ7,AJ8,AJ9,AJ10,AJ11,AJ12,AJ13)
     GO TO 1453                                                        $69.168
1452 CALL APPROX(NA2,H0A,H2A,F0A,F2A,PROPCT2,HJ00,HJ01,HJ02,AJ1,AJ2,AJ3 $69.168
    1,AJ4,AJ5,AJ6,AJ7,AJ8,AJ9,AJ10,AJ11,AJ12,AJ13)
1453 HK00=HIPPEE*HK00+GIPPEE*HJ00                                      $69.168
     HK01=HIPPEE*HK01+GIPPEE*HJ01
     HK02=HIPPEE*HK02+GIPPEE*HJ02
     AI1=YIP1*AI1+YIP2*AJ1
     AI2=YIP1*AI2+YIP2*AJ2
     AI3=YIP1*AI3+YIP2*AJ3
     AI4=YIP1*AI4+YIP2*AJ4
     AI5=ZAP1*AI5+ZAP2*AJ5
     AI6=ZAP1*AI6+ZAP2*AJ6
     AI7=ZAP1*AI7+ZAP2*AJ7
     AI8=ZAP1*AI8+ZAP2*AJ8
     AI9=ZIP1*AI9+ZIP2*AJ9
     AI10=ZIP1*AI10+ZIP2*AJ10
     AI11=ZIP1*AI11+ZIP2*AJ11
     AI12=ZIP1*AI12+ZIP2*AJ12
     AI13=ZIP1*AI13+ZIP2*AJ13
 150 CALL ANSWER (HK00,HK01,HK02,AI1,AI2,AI3,AI4,AI5,AI6,AI7,AI8,AI9,  $69.168
    1AI10,AI11,AI12,AI13,TERMK,TERMPK,TERMMK,TERMM,TERMPM,TERMMM,TIRMK,
    =TIRMPK,TIRMMK,TIRMM,TIRMPM,TIRMMM,AJOM1,J,NTOPO)                  $69.168
 155 TEMP(1,JK)=TEMP(1,JK)+TERMK
     TEMP(1,JM)=TEMP(1,JM)+TERMM
     TEMP(2,JK)=TEMP(2,JK)+TIRMK
     TEMP(2,JM)=TEMP(2,JM)+TIRMM
     TEMP(1,JJK)=TEMP(1,JJK)+TERMPK
     TEMP(1,JJM)=TEMP(1,JJM)+TERMPM
     TEMP(2,JJK)=TEMP(2,JJK)+TIRMPK
     TEMP(2,JJM)=TEMP(2,JJM)+TIRMPM
     TEMP(1,JJJK)=TEMP(1,JJJK)-TERMMK
     TEMP(1,JJJM)=TEMP(1,JJJM)-TERMMM
     TEMP(2,JJJK)=TEMP(2,JJJK)-TIRMMK
 160 TEMP(2,JJJM)=TEMP(2,JJJM)-TIRMMM
*    DO 165 J=1,JSTOP2                                                 +69.168
*      SIJR(I1,J)=REAL(TEMP(1,J))                                      +69.168
*      SIJI(I1,J)=AIMAG(TEMP(1,J))                                     +69.168
*      SIJR(I2,J)=REAL(TEMP(2,J))                                      +69.168
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* 165 SIJI(I2,J)=AIMAG(TEMP(2,J))                                    +69.168
      SIJR(I1,1)=REAL(TEMP(1,NTOPHF))
      SIJI(I1,1)=AIMAG(TEMP(1,NTOPHF))
      SIJR(I1,NSYMUP)=REAL(TEMP(1,NTHFUP))
      SIJI(I1,NSYMUP)=AIMAG(TEMP(1,NTHFUP))
      IF(NINHOM.EQ.0) GO TO 162                                       +69.199
      SIJR(I1,NMID)=REAL(TEMP(1,NTOPUP))
      SIJI(I1,NMID)=AIMAG(TEMP(1,NTOPUP))
      SIJR(I1,NMIDUP)=REAL(TEMP(1,NPTPP1))
      SIJI(I1,NMIDUP)=AIMAG(TEMP(1,NPTPP1))
      SIJR(I1,NSYM)=REAL(TEMP(1,NINHHF))
      SIJI(I1,NSYM)=AIMAG(TEMP(1,NINHHF))
      SIJR(I1,NSYM2)=REAL(TEMP(1,NUPHHF))
      SIJI(I1,NSYM2)=AIMAG(TEMP(1,NUPHHF))
  162 SIJR(I2,1)=REAL(TEMP(2,NTOPHF))                                 $69.199
      SIJI(I2,1)=AIMAG(TEMP(2,NTOPHF))
      SIJR(I2,NSYMUP)=REAL(TEMP(2,NTHFUP))
      SIJI(I2,NSYMUP)=AIMAG(TEMP(2,NTHFUP))
      IF(NINHOM.EQ.0) GO TO 163                                       +69.199
      SIJR(I2,NMID)=REAL(TEMP(2,NTOPUP))
      SIJI(I2,NMID)=AIMAG(TEMP(2,NTOPUP))
      SIJR(I2,NMIDUP)=REAL(TEMP(2,NPTPP1))
      SIJI(I2,NMIDUP)=AIMAG(TEMP(2,NPTPP1))
      SIJR(I2,NSYM)=REAL(TEMP(2,NINHHF))
      SIJI(I2,NSYM)=AIMAG(TEMP(2,NINHHF))
      SIJR(I2,NSYM2)=REAL(TEMP(2,NUPHHF))
      SIJI(I2,NSYM2)=AIMAG(TEMP(2,NUPHHF))
  163 DO 164 J=1,NHFTOP                                               $69.199
      JUP=ISTOP+J
      NJ=NTOPUP-J
      NJUP=ISTOP+NJ
      K=NMID-J
      KP=NSYM+K
      AID=TEMP(1,J)+TEMP(1,NJ)
      SIJR(I1,K)=REAL(AID)
      SIJI(I1,K)=AIMAG(AID)
      AID=TEMP(2,J)+TEMP(2,NJ)
      SIJR(I2,K)=REAL(AID)
      SIJI(I2,K)=AIMAG(AID)
      AID=TEMP(1,JUP)+TEMP(1,NJUP)
      SIJR(I1,KP)=REAL(AID)
      SIJI(I1,KP)=AIMAG(AID)
      AID=TEMP(2,JUP)+TEMP(2,NJUP)
      SIJR(I2,KP)=REAL(AID)
  164 SIJI(I2,KP)=AIMAG(AID)
      IF(NINHOM.EQ.0) GO TO 1649                                      +69.199
      DO 165 J=NTUPP,NINHFM
      JUP=ISTOP+J
      JHOM=J-NTUPP
      K=NMIDP+JHOM
      KP=NSYM+K
      NJ=ISTOP-JHOM
      NJUP=ISTOP+NJ
      AID=TEMP(1,J)+TEMP(1,NJ)
      SIJR(I1,K)=REAL(AID)
      SIJI(I1,K)=AIMAG(AID)
```

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      AID=TEMP(2,J)+TEMP(2,NJ)
      SIJR(I2,K)=REAL(AID)
      SIJI(I2,K)=AIMAG(AID)
      AID=TEMP(1,JUP)+TEMP(1,NJUP)
      SIJR(I1,KP)=REAL(AID)
      SIJI(I1,KP)=AIMAG(AID)
      AID=TEMP(2,JUP)+TEMP(2,NJUP)
      SIJR(I2,KP)=REAL(AID)
  165 SIJI(I2,KP)=AIMAG(AID)
 1649 DELTA=ABS(Z(I))                                                   +69.168
      DD2=Z(I)*Z(I)                                                     +69.168
      APOS=SCX(NTOPO,2)-X(I)
      AMIN=SCX(1,1)-X(I)
      IF(DELTA.LT.1.E-05) GO TO 1650
      CALL EHHFSP(AMIN,APOS,DELTA,PROPCT1,PROP1S,GMLOG,ABSK1,WAVIT1,
     1H0INT,H1INT,H2INT,H5INT,H6INT,H9INT,H10INT,H11INT,RE)
      FIELD(I1)=CUREHF*HIPPEE*H0INT+CURMHF*Z(I)*YIP1*H1INT
      HPHIX=CUREHF*YIP1*Z(I)*H1INT+CURMHF*ZAP1*(DD2*H5INT-(DD2*H9INT-
     1H11INT)/PROPCT1)
      HPHIZ=CUREHF*YIP1*H2INT+CURMHF*ZAP1*Z(I)*(H6INT-TWO*H10INT/PROPCT1
     1)
      GO TO 1651
 1650 CALL EHFTSP(AMIN,APOS,PROPCT1,PROP1S,GMLOG,ABSK1,WAVIT1,H0INT,
     1H2INT,H9INT,RE)
      FIELD(I1)=CUREHF*HIPPEE*H0INT-CURMHF/TWO
      HPHIX=-CUREHF/TWO-CURMHF*ZAP1*H9INT/PROPCT1
      HPHIZ=CUREHF*YIP1*H2INT
 1651 FIELD(I2)=-HPHIX*SINAI+HPHIZ*COSAI
      PRINT 5, FIELD(I1),FIELD(I2)
      DIFFE=FIELD(I1)
      DIFFH=FIELD(I2)
      IF(I-NTOPO) 1652,1652,1655
 1652 IF(DELTA.LT.1.E-05) GO TO 1653
      CALL EHHFSP(AMIN,APOS,DELTA,PROPCT0,PROPOS,GMLOGO,ABSKO,WAVITO,
     1H0INT,H1INT,H2INT,H5INT,H6INT,H9INT,H10INT,H11INT,RE)
      FIELD(I1)=FIELD(I1)+CUREHF*FIPPEE*H0INT+CURMHF*Z(I)*YIP0*H1INT
      HPHIX=CUREHF*YIP0*Z(I)*H1INT+CURMHF*ZAP0*(DD2*H5INT-(DD2*H9INT-
     1H11INT)/PROPCT0)
      HPHIZ=CUREHF*YIP0*H2INT+CURMHF*ZAP0*Z(I)*(H6INT-TWO*H10INT/PROPCT0
     1)
      GO TO 1654
 1653 CALL EHFTSP(AMIN,APOS,PROPCT0,PROPOS,GMLOGO,ABSKO,WAVITO,H0INT,
     1H2INT,H9INT,RE)
      FIELD(I1)=FIELD(I1)+CUREHF*FIPPEE*H0INT+CURMHF/TWO
      HPHIX=CUREHF/TWO-CURMHF*ZAP0*H9INT/PROPCT0
      HPHIZ=CUREHF*YIP0*H2INT
 1654 FIELD(I2)=FIELD(I2)-HPHIX*SINAI+HPHIZ*COSAI
      DIFFE=FIELD(I1)-DIFFE
      DIFFH=FIELD(I2)-DIFFH
      PRINT 6, DIFFE,DIFFH
 1655 CONTINUE
      DO 170 J=1,JSTOP2
      TEMP(1,J)=CPXZER
  170 TEMP(2,J)=CPXZER
  200 CONTINUE
  310 FORMAT(1H02X,8E16.8)
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      XT(1)=X0
      DO 500 LX=1,LLX
  500 XT(LX+1)=XT(LX)+XINT
*     CALL CUPIEQ(SIJR,SIJI,ISTOP)
      CALL CUPIEQ(SIJR,SIJI,NSYM)
      PRINT 10
*     DO 300 I=1,NTOPO                                               $69.168
      DO 300 I=NTOPHF,NTOPO
*     IE=I
      IE=I-NHFTOP
*     IH=ISTOP+I
      IH=NSYM+IE
      ELEV=ABS(Z(I))
      EXPON=EXP(IMAGKO*Z(I))
      EXPONO=EXP(-IMAGKO*ELEV)
      EXPON1=EXP(-IMAGK1*ELEV)
      ARG=-REALKO*Z(I)
      ARGO=REALKO*ELEV
      ARG1=REALK1*ELEV
      ATTEN=HO*EXPON*CMPLX(COS(ARG),SIN(ARG))
      ATTENO=EXPONO*CMPLX(COS(ARGO),SIN(ARGO))
      ATTEN1=EXPON1*CMPLX(COS(ARG1),SIN(ARG1))
      SALPH=SIN(RALPHA(I))
      EINC=AIMPO*ATTEN
      HINC=-SALPH*ATTEN
      EREFL=ERCOEF*ATTENO
      HREFL=-SALPH*HRCOEF*ATTENO
      ETRANS=ETCOEF*ATTEN1
      HTRANS=SALPH*HTCOEF*ATTEN1
      IF(Z(I).GT.1.E-05) GO TO 297
      IF(Z(I).LT.-1.E-05) GO TO 298
      PRIMEE=EINC+EREFL-ETRANS
      PRIMEH=HINC+HREFL-HTRANS
      GO TO 299
  297 PRIMEE=EINC+EREFL
      PRIMEH=HINC+HREFL
      GO TO 299
  298 PRIMEE=-ETRANS
      PRIMEH=-HTRANS
  299 FIELDR(IE)=REAL(PRIMEE+FIELD(IE))
      FIELDI(IE)=AIMAG(PRIMEE+FIELD(IE))
      FIELDR(IH)=REAL(PRIMEH-FIELD(IH))
      FIELDI(IH)=AIMAG(PRIMEH-FIELD(IH))
      PRINT 5, FIELDR(IE),FIELDI(IE),FIELDR(IH),FIELDI(IH)
  300 CONTINUE
      IF(NINHOM.EQ.0) GO TO 306
*     DO 305 I=NTOPUP,ISTOP
      DO 305 I=NTOPUP,NINHHF
*     IE=I                                                           +69.168
      IE=I-NHFTOP
*     IH=ISTOP+I                                                     +69.168
      IH=NSYM+IE
      IF(Z(I).GT.1.E-05) GO TO 303
      ELEV=ABS(Z(I))
      EXPON1=EXP(-IMAGK1*ELEV)
      ARG1=REALK1*ELEV
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      ATTEN1=EXPON1*CMPLX(COS(ARG1),SIN(ARG1))
      SALPH=SIN(RALPHA(I))
      ETRANS=ETCOEF*ATTEN1
      HTRANS=SALPH*HTCOEF*ATTEN1
      PRIMEE=ETRANS
      PRIMEH=HTRANS
      GO TO 304
  303 PRIMEE=CPXZER
      PRIMEH=CPXZER
  304 FIELDR(IE)=REAL(PRIMEE-FIELD(IE))
      FIELDI(IE)=AIMAG(PRIMEE-FIELD(IE))
      FIELDR(IH)=REAL(PRIMEH+FIELD(IH))
      FIELDI(IH)=AIMAG(PRIMEH+FIELD(IH))
      PRINT 5,FIELDR(IE),FIELDI(IE),FIELDR(IH),FIELDI(IH)               +69.168
  305 CONTINUE                                                          +69.168
  306 CONTINUE
C     NOW PROCEED TO COMPUTE M AND K.
      CALL MANDK(FIELDR,FIELDI,SIJR,SIJI,CURDEN)
C     COMPUTER SCATTERED FIELDS.                                        +69.168
      DO 700 LX=1,LLX
************
      NZ=LX
************
      SHXR(LX)=ZERO
      SHZR(LX)=ZERO
      SHXI(LX)=ZERO
      SHZI(LX)=ZERO
      DO 600 I=1,NTOPO                                                  $69.168
      IK=I
      IM=ISTOP+I
      IF(I.GE.2) GO TO 510
      III=1                                                             $69.168
      IIIK=1                                                            $69.168
      IIIM=ISTOP+1                                                      $69.168
      II=2
      IIK=2
      IIM=ISTOP+2                                                       $69.168
      XLIO=XT(LX)-SCX(I,1)
      ZLIO=ZO(NZ)-SCZ(I,1)
      RLIO=SQRT(XLIO*XLIO+ZLIO*ZLIO)
      TARGO=CMPLX(REALKO*RLIO,IMAGKO*RLIO)                              $69.168
      ABTARO=CABS(TARGO)
      CALL HINTO1(TARGO,RO1,TO1,IER)
      GO TO 525
  510 III=I-1
      IIIK=III
      IIIM=IM-1
      IF(I.EQ.ISTOP) GO TO 515
      II=I+1
      IIK=II
      IIM=IM+1
      GO TO 520
  515 II=ISTOP                                                          $69.168
      IIK=ISTOP                                                         $69.168
      IIM=ISTOP2                                                        $69.168
  520 XLIO=XLI2
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      ZLIO=ZLI2
      RLIO=RLI2
      TARGO=TARG2
      ABTARO=ABTAR2
      R01=R21
      T01=T21
  525 XLI2=XT(LX)-SCX(I,2)
      ZLI2=ZO(NZ)-SCZ(I,2)
      RLI2=SQRT(XLI2*XLI2+ZLI2*ZLI2)
      TARG2=CMPLX(REALKO*RLI2,IMAGKO*RLI2)                             $69.168
      ABTAR2=CABS(TARG2)
      CALL HINT01(TARG2,R21,T21,IER)
      TSINA1=SIN(RALPHA(I))
      TCOSA1=COS(RALPHA(I))
      AIOP1=HALFW(I)+HALFW(II)
      AIOM1=HALFW(I)+HALFW(III)
      AMDB=AIOP1/AIOM1
      BETB=AIOP1*AIOM1
      AMDBP1=AMDB+ONE
      ONEMA=ONE-AMDB
      SMALLA=XLIO*TSINA1-ZLIO*TCOSA1
      SMALLC=HALFW(I)+SMALLA
      SMALLB=HALFW(I)+SMALLC
      DELTA=-(XLIO*TCOSA1+ZLIO*TSINA1)
      DD2=DELTA*DELTA
      CC2=SMALLC*SMALLC
      IF(ABTARO.GT.RE.OR.ABTAR2.GT.RE) GO TO 530
      CALL ACURAT(PROPCTO,PROPOS,GMLOGO,R01,R21,T01,T21,HK00,HK01,HK02, $69.168
     1AI1,AI2,AI3,AI4,AI5,AI6,AI7,AI8,AI9,AI10,AI11,AI12,AI13)
      GO TO 535
  530 CONINT=SMALLB-SMALLA                                             +69.168
      NA=3+2*IFIX(CONINT/WAVITO)                                       +69.168
      CALL APPROX(NA,R01,R21,T01,T21,PROPCTO,HK00,HK01,HK02,AI1,AI2,AI3 $69.168
     1,AI4,AI5,AI6,AI7,AI8,AI9,AI10,AI11,AI12,AI13)
  535 CALL FIELDS(PROPCTO,REALKO,IMAGKO,CST,TCOSA1,TSINA1,CURDEN,IK,IM, $69.168
     1IIK,IIM,IIIK,IIIM,AI1,AI2,AI3,AI4,AI5,AI6,AI7,AI8,AI9,AI10,AI11,
     2AI12,AI13,AIOM1,NTOPO,HPHIX,HPHIZ)                               $69.168
      SHXR(LX)=SHXR(LX)+REAL(HPHIX)
      SHZR(LX)=SHZR(LX)+REAL(HPHIZ)
      SHXI(LX)=SHXI(LX)+AIMAG(HPHIX)
  600 SHZI(LX)=SHZI(LX)+AIMAG(HPHIZ)
      DELTA=ABS(ZO(NZ))                                                +69.168
      DD2=DELTA*DELTA                                                  +69.168
      APOS=SCX(NTOPO,2)-XT(LX)                                         +69.168
      AMIN=SCX(1,1)-XT(LX)
      IF(DELTA.LT.1.E-05) GO TO 605
      CALL EHHFSP(AMIN,APOS,DELTA,PROPCTO,PROPOS,GMLOGO,ABSKO,WAVITO,
     1H0INT,H1INT,H2INT,H5INT,H6INT,H9INT,H10INT,H11INT,RE)
      HPHIX=CUREHF*YIPO*ZO(NZ)*H1INT+CURMHF*ZAPO*(DD2*H5INT-(DD2*
     =H9INT-H11INT)/PROPCTO)
      HPHIZ=CUREHF*YIPO*H2INT+CURMHF*ZAPO*ZO(NZ)*(H6INT-TWO*H10INT/
     =PROPCTO)
      GO TO 610
  605 CALL EHFTSP(AMIN,APOS,PROPCTO,PROPOS,GMLOGO,ABSKO,WAVITO,H0INT,
     1H2INT,H9INT,RE)
      HPHIX=CUREHF/TWO-CURMHF*ZAPO*H9INT/PROPCTO
```

```
      HPHIZ=CUREHF*YIPO*H2INT
  610 EXPONO=EXP(-IMAGKO*DELTA)
      ARGO=REALKO*DELTA
      ATTENO=EXPONO*CMPLX(COS(ARGO),SIN(ARGO))
      HREFL=HRCOEF*ATTENO
      HINC=HO*ATTENO
      IF(ZO(NZ).LT.-1.E-05) GO TO 615
      HPHIX=HREFL-HPHIX
      HPHIZ=-HPHIZ
      GO TO 620
  615 HPHIX=-HINC-HPHIX
      HPHIZ=-HPHIZ
  620 SHXR(LX)=SHXR(LX)+REAL(HPHIX)                                      +69.168
      SHXI(LX)=SHXI(LX)+AIMAG(HPHIX)                                     +69.168
      SHZR(LX)=SHZR(LX) +REAL(HPHIZ)                                     +69.168
      SHZI(LX)=SHZI(LX)+AIMAG(HPHIZ)                                     +69.168
      PHASX=ATAN2(SHXI(LX),SHXR(LX))
      PHASZ=ATAN2(SHZI(LX),SHZR(LX))
      PHASEX(LX)=PHASX/RADIAN
      PHASEZ(LX)=PHASZ/RADIAN
      TUE=SHXI(LX)*SHXI(LX)+SHXR(LX)*SHXR(LX)
      WED=SHZI(LX)*SHZI(LX)+SHZR(LX)*SHZR(LX)
      HSECX(LX)=SQRT(TUE)
  700 HSECZ(LX)=SQRT(WED)
      PRINT 10
      PRINT 710
  710 FORMAT(20X,*MAGNETIC FIELDS ABOVE TWO DIMENSIONAL INHOMOGENEITIES
     1IN A CONDUCTIVE HALF SPACE*)
      PRINT 11                                                           +69.168
      PRINT 711                                                          +69.168
  711 FORMAT(5X,*PARAMETERS OF THE AIR ARE .....*)                       +69.168
      PRINT 720, CONDUCO,DIECSTO,MAGPERO                                 +69.168
      PRINT 11
      PRINT 715
  715 FORMAT(5X,*PARAMETERS OF THE HALF SPACE ARE .....*)                $69.168
      PRINT 720, CONDUC1,DIECST1,MAGPER1
  720 FORMAT (10X,*CONDUCTIVITY =*1PE12.3,*,*5X,*DIELECTRIC CONSTANT =*1
     1PE12.3,*,*5X,*MAGNETIC PERMEABILITY =*1PE12.3)
      PRINT 11
      PRINT 725
  725 FORMAT (5X,*PARAMETERS OF THE INHOMOGENEITY ARE ....*)
      PRINT 720, CONDUC2,DIECST2,MAGPER2
      PRINT 726, R
  726 FORMAT (10X,*RADIUS =*1PE12.3)
      PRINT 11
      PHIANG=PHI/RADIAN                                                  $69.168
      PRINT 730, FREQ,PHIANG                                             $69.168
  730 FORMAT(5X,*PARAMETERS OF THE SURVEY ARE .....*10X,*FREQUENCY= *    $69.168
     =1PE12.3,*,*5X,*ANGLE OF INCIDENCE= *0PF9.2)                        +69.168
      PRINT 735, WAVELO,SKINDO,AIMPO                                     +69.168
  735 FORMAT(7X,*IN AIR , *14X,*WAVELENGTH = * 1PE12.3,*,*5X,*SKIN DEPTH +69.168
     = = *1PE12.3,*,*5X,*WAVE IMPEDANCE = *1P2E12.3)                     +69.168
      PRINT 736, WAVEL1,SKIND1,AIMP1                                     +69.168
  736 FORMAT(7X,*IN THE GROUND , *7X,                                    +69.168
     =                            *WAVELENGTH = * 1PE12.3,*,*5X,*SKIN DEPTH +69.168
     = = *1PE12.3,*,*5X,*WAVE IMPEDANCE = *1P2E12.3)                     +69.168
```

```
      PRINT 737, WAVEL2,SKIND2,AIMP2                                    +69.168
  737 FORMAT(7X,*IN THE INHOMOGENEITY , *                               +69.168
     =                            *WAVELENGTH = * 1PE12.3,*,*5X,*SKIN DEPTH +69.168
     = = *1PE12.3,*,*5X,*WAVE IMPEDANCE = *1P2E12.3)                    +69.168
      PRINT 11
      PRINT 738
  738 FORMAT (5X*NUMERICAL PARAMETERS ARE .....*)
      PRINT 739, NA1,NA2,SAMPLE,RE,TOLER,ITER
  739 FORMAT (7X,*NA1 =*I5,*,*5X,*NA2 =*I5,*,*5X,*SAMPLE =*F8.3,*,*10X,
     1*RE =*F8.3,*,*10X,*TOLER =*F8.3,*,*10X,*ITER =*I5)
      PRINT 11
************
      NZ=1
************
      PRINT 740,Z0(NZ),Z1(ND)                                           $69.168
  740 FORMAT (5X,*ELEVATION OF THE SURVEY IS = *F12.3,*,*10X,*DEPTH FROM +69.168
     = THE HALF SPACE TO THE TOP OF THE CYLINDER IS = * F12.3)          +69.168
      PRINT 11
      PRINT 745
  745 FORMAT (10X,*HXR*10X,*HXI*6X,*X PHASE*11X,*HX*10X,*HZR*10X,*HZI*6X
     1,*Z PHASE*11X,*HZ*4X,*ELEVATION*6X,*STATION*)
      PRINT 11
************
      PRINT 750, (SHXR(LX),SHXI(LX),PHASEX(LX),HSECX(LX),SHZR(LX),SHZI(L
     1X),PHASEZ(LX),HSECZ(LX),Z0(LX),     XT(LX),LX=1,LLX)
************
  750 FORMAT (9(1X,1PE12.4),3X,0PF8.3)
      PRINT 11
      PRINT 11
      ARG=REALK0*Z0(NZ)
      HREFL=HRCOEF*(EXP(-IMAGK0*Z0(NZ)))*CMPLX(COS(ARG),SIN(ARG))
      PRINT 751, HREFL
  751 FORMAT (10X,*EXACT REFLECTED MAGNETIC FIELD INTENSITY =*2E12.4)
  900 CONTINUE                                                          +69.168
 2000 CONTINUE
      STOP                                                              $69.168
      END
```

```
      SUBROUTINE DATTOP(NANGLE,SCX,SCZ,X,Z,RALPHA,SCALPH,HALFW)
C...  SUBROUTINE DATTOP TAKES THE CO-ORDINATES OF THE EDGES OF THE (NANGLE)
C     INTERVALS (SCX,SCZ) INTO WHICH THE TOPOGRAPHIC CONTOUR HAS BEEN
C     DIVIDED AND RETURNS THE CO-ORDINATES OF THE MIDPOINT OF EACH INTERVAL
C     (X,Z), THE INWARD NORMAL AT THE MIDPOINT (RALPHA), THE AVERAGE
C     INWARD NORMAL AT THE CORNERS OF EACH INTERVAL (SCALPH), AND THE
C     HALF-WIDTH (HALFW) OF EACH INTERVAL.
      DIMENSION SCX(100,2),SCZ(100,2),X(100),Z(100),RALPHA(100),SCALPH(
     1100,2),HALFW(100)
      TWO=2.00000000000000
      HALFPI=1.57079632679489
      DO 100 I=1,NANGLE
      DX=SCX(I,2)-SCX(I,1)
      DZ=SCZ(I,2)-SCZ(I,1)
      DL=SQRT(DX*DX+DZ*DZ)
      HALFW(I)=DL/TWO
      BET=ATAN2(DZ,DX)
      X(I)=SCX(I,1)+HALFW(I)*COS(BET)
      Z(I)=SCZ(I,1)+HALFW(I)*SIN(BET)
  100 RALPHA(I)=BET-HALFPI
      SCALPH(1,1)=RALPHA(1)
      SCALPH(NANGLE,2)=RALPHA(NANGLE)
      NM1=NANGLE-1
      DO 105 I=1,NM1
      IP1=I+1
      DX=X(IP1)-X(I)
      DZ=Z(I+1)-Z(I)
      SCALPH(I,2)=ATAN2(DZ,DX)-HALFPI
  105 SCALPH(IP1,1)=SCALPH(I,2)
      RETURN
      END
```

```
      SUBROUTINE DATHOM(NANGLE,SCX,SCZ,X,Z,RALPHA,SCALPH,HALFW)
C...  SUBROUTINE DATHOM TAKES THE CO-ORDINATES OF THE EDGES OF THE (NANGLE)
C     INTERVALS (SCX,SCZ) INTO WHICH THE CYLINDER CONTOUR HAS BEEN DIVIDED AND
C     RETURNS THE CO-ORDINATES OF THE MIDPOINT OF EACH INTERVAL (X,Z), THE
C     INWARD NORMAL AT THE MIDPOINT (RALPHA), THE AVERAGE INWARD NORMAL AT
C     THE CORNERS OF EACH INTERVAL (SCALPH), AND THE HALF-WIDTH (HALFW) OF
C     EACH INTERVAL.
      DIMENSION SCX(100,2),SCZ(100,2),X(100),Z(100),RALPHA(100),SCALPH(
     1100,2),HALFW(100)
      TWO=2.000000000000000
      HALFPI=1.57079632679489
      DO 100 I=1,NANGLE
      DX=SCX(I,2)-SCX(I,1)
      DZ=SCZ(I,2)-SCZ(I,1)
      DL=SQRT(DX*DX+DZ*DZ)
      HALFW(I)=DL/TWO
      BET=ATAN2(DZ,DX)
      X(I)=SCX(I,1)+HALFW(I)*COS(BET)
      Z(I)=SCZ(I,1)+HALFW(I)*SIN(BET)
  100 RALPHA(I)=BET-HALFPI
      DO 105 I=1,NANGLE
      IP1=I+1
      IF(NANGLE-I) 101,101,102
  101 IP1=1
  102 DX=X(IP1)-X(I)
      DZ=Z(IP1)-Z(I)
      SCALPH(I,2)=ATAN2(DZ,DX)-HALFPI
  105 SCALPH(IP1,1)=SCALPH(I,2)
      RETURN
      END
```

```
      SUBROUTINE SMARG(NA,CMPXPI,ABSK1,PROPCT1,GMLOG,HALFW,ABCAR2,H21,
C...  SUBROUTINE SMARG COMPUTES THE LIMITING VALUE OF THE INTEGRALS IN
C     THE SINGULAR INTERVAL.
     1F21,HK00,HK02,HIK0,HIK2,RE)
      DIMENSION S2(500)
      COMPLEX CMPXPI,PROPCT1,GMLOG,H21,F21,HK00,HK02,HIK0,HIK2,CPXZER,
     1SUMH00,SUMH02,SUMA1,ARG,H0,H1,CARG2,PROD2,SPEC,FACTA,FACTB,FACTC
      COMMON /TERMS/ S(500),DIST(500),DIST2(500),H0(500),H1(500)
      IF(NA.LT.495) GO TO 6
      PRINT 5
    5 FORMAT (10X*DIMENSION EXCEEDED. SUBROUTINE SMARG.*)
      CALL EXIT
    6 CPXZER=(0.,0.)
      SUMH00=CPXZER
      SUMH02=CPXZER
      SUMA1=CPXZER
      IF(ABCAR2.LT.RE) GO TO 30
      S(1)=RE/ABSK1
      S2(1)=S(1)*S(1)
      ARG=PROPCT1*S(1)
      CALL HINT01(ARG,H0(1),H1(1),IER)
      DIFF=HALFW-S(1)
      NM1=NA-1
      H=DIFF/FLOAT(NM1)
      HTHIRD=H/3.
      DO 10 L=2,NM1
      S(L)=S(L-1)+H
      S2(L)=S(L)*S(L)
      ARG=PROPCT1*S(L)
   10 CALL HINT01(ARG,H0(L),H1(L),IER)
      S(NA)=HALFW
      S2(NA)=S(NA)*S(NA)
      H0(NA)=H21
      H1(NA)=F21
      DO 20 L=1,NM1,2
      L1=L+1
      L2=L+2
      SUMH00=SUMH00+H0(L)+4.*H0(L1)+H0(L2)
      SUMH02=SUMH02+S2(L)*H0(L)+4.*S2(L1)*H0(L1)+S2(L2)*H0(L2)
   20 SUMA1=SUMA1+H1(L)/S(L)+4.*H1(L1)/S(L1)+H1(L2)/S(L2)
      SUMH00=HTHIRD*SUMH00
      SUMH02=HTHIRD*SUMH02
      SUMA1=HTHIRD*SUMA1
      SMALLA=S(1)
      W3=SMALLA*S2(1)
      GO TO 40
   30 SMALLA=HALFW
      W3=SMALLA**3
   40 CARG2=PROPCT1*SMALLA
      PROD2=CARG2*CARG2
      SPEC=GMLOG+ALOG(SMALLA)
      FACTA=1.-PROD2/12.
      FACTB=1.-.15*PROD2
      FACTC=1.-PROD2/24.
      HK00=2.*(SUMH00+SMALLA*(FACTA+CMPXPI*(FACTA*SPEC-(1.-PROD2/9.))))
      HK02=2.*(SUMH02+W3*(FACTB+CMPXPI*(FACTB*SPEC-(1.-.54*PROD2)/3.))/3
```

```
1.)
 HIKO=-2.*(SUMA1+CMPXPI/CARG2)-CARG2*(FACTC+CMPXPI*(FACTC*SPEC-(1.5
1-19.*PROD2/288.)))
 HIK2=(2.*HALFW*H21-HK00)/PROPCT1
 RETURN
 END
```

```
      SUBROUTINE HINT01(Z,H0,H1,IER)
C...  SUBROUTINE HINT01 CALCULATES HANKEL FUNCTIONS OF THE FIRST KIND OF
C     ORDER 0 AND 1 (H0 AND H1, RESPECTIVELY) FROM THE DEFINITION OF THE
C     MODIFIED BESSEL FUNCTION (K) OF THE SECOND KIND.  (THE SUBROUTINE TO
C     COMPUTE K IS A MODIFIED VERSION OF BESK, GIVEN IN THE I.B.M. SCIENTIFIC
C     SUBROUTINE PACKAGE (V. 2) ).
C...  INPUTS ARE  Z - THE COMPLEX ARGUMENT
C                 H0 AND H1 - COMPLEX ANSWER
C                 IER - ERROR CODE - 0 - NORMAL RETURN
C                                    1 - ABSOLUTE VALUE OF THE ARGUMENT
C                                        EXCEEDS 170.
      COMPLEX Z,X,H0,H1,ZILCH,A,B,C,D,BK,AXC
      PI2=.63661977236758134
      H0=-CMPLX(0.,PI2)
      H1=-CMPLX(PI2,0.)
      ZILCH=(0.,1.)
      X=-ZILCH*Z
      CX=CABS(X)
      IF(CX.LE.170.) GO TO 99
      IER=1
      PRINT 10
   10 FORMAT (10X*ABSOLUTE VALUE OF THE ARGUMENT OF THE HANKEL FUNCTION
     1 IS GREATER THAN 170.*)
      CALL EXIT
      RETURN
   99 IF(CX.GT.4.5) GO TO 100
*  COMPUTE K(0) USING SERIES EXPANSION
      B=X*.5
      A=.5772156649+CLOG(B)
      C=B*B
      BK=-A
      D=(1.,0.)
      F=1.
      H=0.
      DO 4 J=1,10
      R=1./FLOAT(J)
      D=D*C
      F=F*R*R
      H=H+R
    4 BK=BK+D*F*(H-A)
      H0=H0*BK
*  COMPUTE K(1) USING SERIES EXPANSION
      D=B
      F=1.
      H=1.
      BK=1./X+D*(.5+A-H)
      DO 5 J=2,12
      FJ=FLOAT(J)
      D=D*C
      R=1./FJ
      F=F*R*R
      H=H+R
    5 BK=BK+D*F*(.5+(A-H)*FJ)
      H1=H1*BK
      IER=0
      RETURN
```

```
*  COMPUTE K(0) USING POLYNOMIAL APPROXIMATION
  100 B=1./X
      AXC=CEXP(-X)*CSQRT(B)
      H0=AXC*((((((((((((.0091893830*B-.0668097672)*B+.2184518096)*B
     =-.4262632912)*B+.5575368367)*B-.5247277331)*B+.3792409730)*B
     =-.2299850328)*B+.1344596228)*B-.0913909546)*B+.0881112782)*B
     =-.1566641816)*B+1.2533141373)*H0
*  COMPUTE K(1) USING POLYNOMIAL APPROXIMATION
      H1=AXC*(((((((((((-.0108241775*B+.0788000118)*B-.2581303765)*B
     =+.5050238576)*B-.6632295430)*B+.6283380681)*B-.4594342117)*B
     =+.2847618149)*B-.1736431637)*B+.1280426636)*B-.1468582957)*B
     =+.4699927013)*B+1.2533141373)*H1
      IER=0
      RETURN
      END
```

```
      SUBROUTINE ACURAT(PROPCT1,PROP1S,GMLOG,H01,H21,F01,F21,HK00,HK01,
     1HK02,AI1,AI2,AI3,AI4,AI5,AI6,AI7,AI8,AI9,AI10,AI11,AI12,AI13)
C...  SUBROUTINE ACURAT COMPUTES THE INTEGRALS OF THE INTEGRAL REPRESENTIATIONS
C     USING THE SMALL ARGUMENT SOLUTIONS GIVEN IN APPENDIX D.
      COMPLEX AIMGPI,CMPXPI,PROPCT1,PROP1S,GMLOG,H01,H21,F01,F21,PD1,P2A
     12,P2B2,P2D2,ALOG2,ALOG3,TERM1,TERM2,TERM3,TERM4,TERM5,HK00,HK01,
     2HK02,AI1,AI2,AI3,AI4,AI5,AI6,AI7,AI8,AI9,AI10,AI11,AI12,AI13
      EXTERNAL FUNC
      COMMON /ZAP/ AJOP1,AMDA,BETA,AMDAP1,ONEMAM,SMALLA,SMALLB,DELTA,
     1SMALLC,CC2,SAIMA,CAIMA,DCAIMA
      COMMON /ZIP/ DD2
      COMMON /VARIAB/ ITER,TOLER,ACC
      REAL LARGEA,LARGEB
      THREE=3.0000000000000000
      TWO=2.0000000000000000
      ONE=1.0000000000000000
      ZERO=0.0000000000000000
      PIINV=.31830988618379067
      AIMGPI=CMPLX(ZERO,PIINV)
      CMPXPI=TWO*AIMGPI
      AA2=SMALLA*SMALLA
      AA3=AA2*SMALLA
      AA4=AA2*AA2
      AA5=AA3*AA2
      BB2=SMALLB*SMALLB
      BB3=BB2*SMALLB
      BB4=BB2*BB2
      BB5=BB3*BB2
      PD1=PROPCT1*DELTA
      P2A2=PROP1S*AA2
      P2B2=PROP1S*BB2
      P2D2=PROP1S*DD2
      BMA=SMALLB-SMALLA
      B2MA2=BB2-AA2
      B3MA3=BB3-AA3
      B4MA4=BB4-AA4
      B5MA5=BB5-AA5
      D2PA2=DD2+AA2
      D2PB2=DD2+BB2
      ALOGA=ALOG(D2PA2)
      ALOGB=ALOG(D2PB2)
      ALOG1=ALOGB-ALOGA
      ALOG2=GMLOG+.5*ALOGA
      ALOG3=GMLOG+.5*ALOGB
      TAN=ATAN(SMALLB/DELTA)-ATAN(SMALLA/DELTA)
      TERM1=ONE-.25*P2D2
      TERM2=ONE-.125*P2D2
      TERM3=ONE-.3125*P2D2
      TERM4=ONE-CMPXPI
      TERM5=.25*PROP1S*(SMALLB*ALOG3-SMALLA*ALOG2-(BMA-DELTA*TAN))
      HK00=TERM1*BMA-PROP1S*B3MA3/12.+.5*AIMGPI*(P2D2*BMA+PROP1S*B3MA3/
     1THREE)+CMPXPI*(SMALLB*(TERM1-P2B2/12.)*ALOG3-SMALLA*(TERM1-P2A2/12
     2.)*ALOG2+PROP1S*B3MA3/36.-(ONE-P2D2/6.)*(BMA-DELTA*TAN))
      HK01=.5*TERM1*B2MA2-.0625*PROP1S*B4MA4+.25*AIMGPI*(P2D2*B2MA2+.5*
     1PROP1S*B4MA4)+AIMGPI*(BB2*(TERM1-.125*P2B2)*ALOG3-AA2*(TERM1-.125*
     2P2A2)*ALOG2+.03125*PROP1S*B4MA4-.5*(ONE-.125*P2D2)*(B2MA2-DD2*ALOG
     31))
```

```
      HK02=TERM1*B3MA3/THREE-.05*PROP1S*B5MA5+.5*AIMGPI*(P2D2*B3MA3/THRE
     1E+.2*PROP1S*B5MA5)+CMPXPI*(BB3*(TERM1-.15*P2B2)*ALOG3-AA3*(TERM1
     2-.15*P2A2)*ALOG2+.03*PROP1S*B5MA5-(ONE-.1*P2D2)*(B3MA3/THREE-DD2
     3*(BMA-DELTA*TAN)))/THREE
      AI1=(PROPCT1/TWO)*(TERM2*BMA-PROP1S*B3MA3/24.-CMPXPI*(TWO*TAN/(PRO
     1PCT1*PD1)+.5*TERM3*BMA-PROP1S*B3MA3/19.2)+CMPXPI*(SMALLB*(TERM2-
     2P2B2/24.)*ALOG3-SMALLA*(TERM2-P2A2/24.)*ALOG2+PROP1S*B3MA3/72.-
     3(ONE-P2D2/12.)*(BMA-DELTA*TAN)))
      AI2=(H01-H21)/PROPCT1
      AI3=(SMALLA*H01-SMALLB*H21+HK00)/PROPCT1
      AI4=(AA2*H01-BB2*H21+TWO*HK01)/PROPCT1
      IF (DELTA.NE.0.) GO TO 600
      AIAB=0.
      GO TO 529
  600 DELT=ABS(DELTA)
      XL=DELT/ACC
      XU=DELT*ACC
      ITEST=1
      IF(SMALLA.LT.0. .AND. SMALLB.GT.0.) GO TO 630
      IF(SMALLA.LE.0. .AND. SMALLB.LE.0.) GO TO 620
      LARGEA=SMALLA
      LARGEB=SMALLB
  601 IF(LARGEA.LT.XU) GO TO 602
      AIAB=-TWO*((ALOG(LARGEB)+ONE)/LARGEB-(ALOG(LARGEA)+ONE)/LARGEA)
      GO TO 611
  602 IF(LARGEB.GT.XL) GO TO 603
      AIAB=TWO*ALOG(DELT)*(LARGEB-LARGEA)/DD2
      GO TO 611
  603 IF(LARGEA.GE.XL) GO TO 604
      SUM1=TWO*ALOG(DELT)*(XL-LARGEA)/DD2
      XLL=XL
      GO TO 605
  604 SUM1=0.
      XLL=LARGEA
  605 IF(LARGEB.LE.XU) GO TO 606
      SUM3=-TWO*((ALOG(LARGEB)+1.)/LARGEB-(ALOG(XU)+1.)/XU)
      XUU=XU
      GO TO 607
  606 SUM3=0.
      XUU=LARGEB
  607 AIER=RMBRG(FUNC,XLL,XUU,TOLER,SUM2)
      IF(AIER) 608,610,610
  608 PRINT 609, AIER,XLL,XUU,DELTA
  609 FORMAT (10X,*DID NOT OBTAIN CONVERGENCE FOR AIAB (EHHFSP) *4E15.7)
  610 AIAB=SUM1+SUM2+SUM3
  611 IF(ITEST-2) 529,631,635
  620 LARGEA=ABS(SMALLB)
      LARGEB=ABS(SMALLA)
      GO TO 601
  630 ABA=ABS(SMALLA)
      IF(ABA.GT.SMALLB) GO TO 634
      ITEST=2
      INDEX=1
      LARGEA=0.
      LARGEB=ABA
      GO TO 601
```

```
631 IF(ABA.EQ.SMALLB) GO TO 633
    IF(INDEX.EQ.2) GO TO 632
    INDEX=2
    LARGEA=ABA
    LARGEB=SMALLB
    TEMP=AIAB
    GO TO 601
632 AIAB=2.*TEMP+AIAB
    GO TO 529
633 AIAB=2.*AIAB
    GO TO 529
634 ITEST=3
    INDEX=1
    LARGEA=0.
    LARGEB=SMALLB
    GO TO 601
635 IF(INDEX.EQ.2) GO TO 636
    INDEX=2
    LARGEA=SMALLB
    LARGEB=ABA
    TEMP=AIAB
    GO TO 601
636 AIAB=2.*TEMP+AIAB
529 AI5=TAN/DELTA-.25*PROP1S*BMA*TERM4+CMPXPI*(GMLOG*TAN/DELTA+.5*AIAB
   1-TERM5)
    AI6=.5*ALOG1-.125*PROP1S*B2MA2*TERM4+AIMGPI*(GMLOG*ALOG1+.25*(ALOG
   1B*ALOGB-ALOGA*ALOGA)-.25*PROP1S*(BB2*ALOG3-AA2*ALOG2-.5*(B2MA2-DD2
   2*ALOG1)))
    AI7=HK00-DD2*AI5
    AI8=HK01-DD2*AI6
    AI9=.5*PROPCT1*(TAN/DELTA-.125*PROP1S*BMA-CMPXPI*((SMALLB/D2PB2-
   1SMALLA/D2PA2)/P2D2+(ONE/P2D2+.5-GMLOG)*TAN/DELTA-PROP1S*BMA/6.4)+
   2AIMGPI*(AIAB-TERM5))
    AI10=.5*(F01/SQRT(D2PA2)-F21/SQRT(D2PB2)+PROPCT1*AI6)
    AI11=AI1-DD2*AI9
    AI12=AI2-DD2*AI10
    AI13=AI3-DD2*AI11
    RETURN
    END
```

```
      SUBROUTINE APPROX(NA,H01,H21,F01,F21,PROPCT1,HK00,HK01,HK02,AI1,
     1AI2,AI3,AI4,AI5,AI6,AI7,AI8,AI9,AI10,AI11,AI12,AI13)
C...  SUBROUTINE APPROX COMPUTES THE INTEGRALS OF THE INTEGRAL REPRESENTATIONS
C     USING SIMPSON'S RULE.  THE INTERVAL IS DIVIDED INTO NA-1 SUBDIVISIONS,
C     AND NO ACCURACY CHECK IS MADE.
      DIMENSION S2(500)
      COMMON /TERMS/ S(500),DIST(500),DIST2(500),H0(500),H1(500)
      COMPLEX H01,H21,F01,F21,PROPCT1,HK00,HK01,HK02,AI1,AI2,AI3,AI4,AI5
     1,AI6,AI7,AI8,AI9,AI10,AI11,AI12,AI13,CPXZER,ARG,H0,H1,SCRACH,SUMH0
     20,SUMH01,SUMH02,SUMAI1,SUMAI5,SUMAI6,SUMAI9,T1,T2,T3,T4,T5,T6
      COMMON /ZAP/ AJOP1,AMDA,BETA,AMDAP1,ONEMAM,SMALLA,SMALLB,DELTA,
     1SMALLC,CC2,SAIMA,CAIMA,DCAIMA
      COMMON /ZIP/ DD2
      IF(NA.LT.499) GO TO 10
      PRINT 5, NA
    5 FORMAT (10X,*INTERVAL TOO LARGE FOR DIMENSION STATEMENT. SUBROUTIN
     1E APPROX. NA=*I6)
      CALL EXIT
   10 CPXZER=(0.,0.)
      NM1=NA-1
      H=(SMALLB-SMALLA)/FLOAT(NM1)
      HTHIRD=H/3.
      AA2=SMALLA*SMALLA
      BB2=SMALLB*SMALLB
      S(1)=SMALLA
      DO 100 L=2,NA
      S(L)=S(L-1)+H
      S2(L)=S(L)*S(L)
      DIST2(L)=DD2+S2(L)
  100 DIST(L)=SQRT(DIST2(L))
      DO 200 L=2,NM1
      ARG=PROPCT1*DIST(L)
  200 CALL HINT01(ARG,H0(L),H1(L),IER)
      H0(1)=H01
      H0(NA)=H21
      H1(1)=F01
      H1(NA)=F21
      S2(1)=AA2
      DIST2(1)=DD2+AA2
      DIST(1)=SQRT(DIST2(1))
      SUMH00=CPXZER
      SUMH01=CPXZER
      SUMH02=CPXZER
      SUMAI1=CPXZER
      SUMAI5=CPXZER
      SUMAI6=CPXZER
      SUMAI9=CPXZER
      DO 300 L=1,NM1,2
      L1=L+1
      L2=L+2
      SUMH00=SUMH00+H0(L)+4.*H0(L1)+H0(L2)
      T1=S(L)*H0(L)
      T2=4.*S(L1)*H0(L1)
      T3=S(L2)*H0(L2)
      SUMH01=SUMH01+T1+T2+T3
      SUMH02=SUMH02+S2(L)*H0(L)+4.*S2(L1)*H0(L1)+S2(L2)*H0(L2)
```

```
      T4=H1(L)/DIST(L)
      T5=4.*H1(L1)/DIST(L1)
      T6=H1(L2)/DIST(L2)
      SUMAI1=SUMAI1+T4+T5+T6
      SUMAI5=SUMAI5+H0(L)/DIST2(L)+4.*H0(L1)/DIST2(L1)+H0(L2)/DIST2(L2)
      SUMAI6=SUMAI6+T1/DIST2(L)+T2/DIST2(L1)+T3/DIST2(L2)
  300 SUMAI9=SUMAI9+T4/DIST2(L)+T5/DIST2(L1)+T6/DIST2(L2)
      HK00=HTHIRD*SUMH00
      HK01=HTHIRD*SUMH01
      HK02=HTHIRD*SUMH02
      AI1=HTHIRD*SUMAI1
      AI2=(H01-H21)/PROPCT1
      AI3=(SMALLA*H01-SMALLB*H21+HK00)/PROPCT1
      AI4=(AA2*H01-BB2*H21+2.*HK01)/PROPCT1
      AI5=HTHIRD*SUMAI5
      AI6=HTHIRD*SUMAI6
      AI7=HK00-DD2*AI5
      AI8=HK01-DD2*AI6
      AI9=HTHIRD*SUMAI9
      AI10=.5*(F01/DIST(1)-F21/DIST(NA)+PROPCT1*AI6)
      AI11=AI1-DD2*AI9
      AI12=AI2-DD2*AI10
      AI13=AI3-DD2*AI11
      RETURN
      END
```

```
      SUBROUTINE ANSWER (HK00,HK01,HK02,AI1,AI2,AI3,AI4,AI5,AI6,AI7,AI8,
     1AI9,AI10,AI11,AI12,AI13,C111,C11P1,C11M1,C121,C12P1,C12M1,C211,C21
     2P1,C21M1,C221,C22P1,C22M1,AJOM1,J,JSTOP)
C...  SUBROUTINE ANSWER TAKES THE VALUES FOR THE INTEGRALS OF THE INTEGRAL
C     REPRESENTATIONS AND RETURNS COEFFICIENTS OF THE COUPLED INTEGRAL EQUATION
C     MATRIX.
      COMPLEX HK00,HK01,HK02,AI1,AI2,AI3,AI4,AI5,AI6,AI7,AI8,AI9,AI10,
     1AI11,AI12,AI13,TODE1,TODE2,CODE1,CODE2,APART1,APART2,APART3,CODE3,
     2CODE4,BPART1,BPART2,BPART3,CODE5,CODE6,CPART1,CPART2,CPART3,CODE7,
     3CODE8,DPART1,DPART2,DPART3,CODE9,CODE10,EPART1,EPART2,EPART3,CODE1
     41,CODE12,FPART1,FPART2,FPART3,CODE13,CODE14,GPART1,GPART2,GPART3,C
     5111,C11P1,C11M1,C121,C12P1,C12M1,C211,C21P1,C21M1,C221,C22P1,C22M1
     6,CPXZER
      COMMON /ZAP/ AJOP1,AMDA,BETA,AMDAP1,ONEMAM,SMALLA,SMALLB,DELTA,
     1SMALLC,CC2,SAIMA,CAIMA,DCAIMA
      COMMON /ZIP/ DD2
      TWO=2.000000000000000
      CPXZER=(0.,0.)
      IF(J.EQ.JSTOP) GO TO 20
      TODE1=(HK01-SMALLC*HK00)/AJOP1
      CODE1=(AI3-SMALLC*AI2)/AJOP1
      CODE3=(AI2-SMALLC*AI1)/AJOP1
      CODE5=(AI7-SMALLC*AI6)/AJOP1
      CODE7=(AI6-SMALLC*AI5)/AJOP1
      CODE9=(AI10-SMALLC*AI9)/AJOP1
      CODE11=(AI12-SMALLC*AI11)/AJOP1
      CODE13=(AI11-SMALLC*AI10)/AJOP1
      IF(J.EQ.1) GO TO 10
      TODE2=(HK02-TWO*SMALLC*HK01+CC2*HK00)/BETA
      CODE2=(AI4-TWO*SMALLC*AI3+CC2*AI2)/BETA
      APART1=(AI2-ONEMAM*CODE1-CODE2)
      APART2=(CODE1+CODE2)/AMDAP1
      APART3=AMDA*(AMDA*CODE1-CODE2)/AMDAP1
      CODE4=(AI3-TWO*SMALLC*AI2+CC2*AI1)/BETA
      BPART1=(AI1-ONEMAM*CODE3-CODE4)
      BPART2=(CODE3+CODE4)/AMDAP1
      BPART3=AMDA*(AMDA*CODE3-CODE4)/AMDAP1
      CODE6=(AI8-TWO*SMALLC*AI7+CC2*AI6)/BETA
      CPART1=(AI6-ONEMAM*CODE5-CODE6)
      CPART2=(CODE5+CODE6)/AMDAP1
      CPART3=AMDA*(AMDA*CODE5-CODE6)/AMDAP1
      CODE8=(AI7-TWO*SMALLC*AI6+CC2*AI5)/BETA
      DPART1=(AI5-ONEMAM*CODE7-CODE8)
      DPART2=(CODE7+CODE8)/AMDAP1
      DPART3=AMDA*(AMDA*CODE7-CODE8)/AMDAP1
      CODE10=(AI11-TWO*SMALLC*AI10+CC2*AI9)/BETA
      EPART1=(AI9-ONEMAM*CODE9-CODE10)
      EPART2=(CODE9+CODE10)/AMDAP1
      EPART3=AMDA*(AMDA*CODE9-CODE10)/AMDAP1
      CODE12=(AI13-TWO*SMALLC*AI12+CC2*AI11)/BETA
      FPART1=(AI11-ONEMAM*CODE11-CODE12)
      FPART2=(CODE11+CODE12)/AMDAP1
      FPART3=AMDA*(AMDA*CODE11-CODE12)/AMDAP1
      CODE14=(AI12-TWO*SMALLC*AI11+CC2*AI10)/BETA
      GPART1=(AI10-ONEMAM*CODE13-CODE14)
      GPART2=(CODE13+CODE14)/AMDAP1
```

```
      GPART3=AMDA*(AMDA*CODE13-CODE14)/AMDAP1
      C111=HK00-ONEMAM*TODE1-TODE2
      C11P1=(TODE1+TODE2)/AMDAP1
      C11M1=AMDA*(AMDA*TODE1-TODE2)/AMDAP1
      C121=DELTA*BPART1
      C12P1=DELTA*BPART2
      C12M1=DELTA*BPART3
      C211=-(APART1*SAIMA+BPART1*DCAIMA)
      C21P1=-(APART2*SAIMA+BPART2*DCAIMA)
      C21M1=-(APART3*SAIMA+BPART3*DCAIMA)
      C221=DELTA*(TWO*GPART1-CPART1)*SAIMA+((EPART1-DPART1)*DD2-FPART1)
     1*CAIMA
      C22P1=DELTA*(TWO*GPART2-CPART2)*SAIMA+((EPART2-DPART2)*DD2-FPART2)
     1*CAIMA
      C22M1=DELTA*(TWO*GPART3-CPART3)*SAIMA+((EPART3-DPART3)*DD2-FPART3)
     1*CAIMA
      RETURN
   10 C111=HK00-TODE1
      C11P1=TODE1
      C11M1=CPXZER
      C121=DELTA*(AI1-CODE3)
      C12P1=DELTA*CODE3
      C12M1=CPXZER
      C211=-((AI2-CODE1)*SAIMA+(AI1-CODE3)*DCAIMA)
      C21P1=-(CODE1*SAIMA+CODE3*DCAIMA)
      C21M1=CPXZER
      C221=DELTA*(TWO*(AI10-CODE13)-AI6+CODE5)*SAIMA+((AI9-CODE9-AI5+
     1CODE7)*DD2-AI11+CODE11)*CAIMA
      C22P1=DELTA*(TWO*CODE13-CODE5)*SAIMA+((CODE9-CODE7)*DD2-CODE11)*
     1CAIMA
      C22M1=CPXZER
      RETURN
   20 TODE1=(HK01-SMALLC*HK00)/AJOM1
      CODE1=(AI3-SMALLC*AI2)/AJOM1
      CODE3=(AI2-SMALLC*AI1)/AJOM1
      CODE5=(AI7-SMALLC*AI6)/AJOM1
      CODE7=(AI6-SMALLC*AI5)/AJOM1
      CODE9=(AI10-SMALLC*AI9)/AJOM1
      CODE11=(AI12-SMALLC*AI11)/AJOM1
      CODE13=(AI11-SMALLC*AI10)/AJOM1
      C111=HK00+TODE1
      C11P1=CPXZER
      C11M1=TODE1
      C121=DELTA*(AI1+CODE3)
      C12P1=CPXZER
      C12M1=DELTA*CODE3
      C211=-((AI2+CODE1)*SAIMA+(AI1+CODE3)*DCAIMA)
      C21P1=CPXZER
      C21M1=-(CODE1*SAIMA+CODE3*DCAIMA)
      C221=DELTA*(TWO*(AI10+CODE13)-AI6-CODE5)*SAIMA+((AI9+CODE9-AI5-
     1CODE7)*DD2-AI11-CODE11)*CAIMA
      C22P1=CPXZER
      C22M1=DELTA*(TWO*CODE13-CODE5)*SAIMA+((CODE9-CODE7)*DD2-CODE11)*
     1CAIMA
      RETURN
      END
```

```
      SUBROUTINE EHHFSP(A,B,DELTA,PROPCT1,PROP1S,GMLOG,ABSK1,WAVINT,
     1H0INT,H1INT,H2INT,H5INT,H6INT,H9INT,H10INT,H11INT,RE)
C...  SUBROUTINE EHHFSP COMPUTES THE INTEGRALS OF THE INTEGRAL REPRESENTATIONS
C     ALONG A FLAT HALF-SPACE OVER THE INTERVAL (A,B), ASSUMING THE POINT OF
C     OBSERVATION IS NOT ON THE CONTOUR.
      COMPLEX PROPCT1,PROP1S,GMLOG,H0INT,H1INT,H2INT,H5INT,H6INT,H9INT,
     1H10INT,H11INT,CPXZER,AIMG,AIMGPI,CMPXPI,ARG,H0,H1,T1,T2,T3,HK00,
     2AI1,AI5,AI6,AI9,PD1,P2A2,P2B2,P2D2,ALOG2,ALOG3,TERM1,TERM2,TERM3,
     3TERM4,TERM5,ARGA,ARGB,HXA0,HXA1,HXB0,HXB1
      COMMON /TERMS/ S(500),DIST(500),DIST2(500),H0(500),H1(500)
      COMMON /VARIAB/ ITER,TOLER,ACC
      EXTERNAL FUNC
      REAL LARGEA,LARGEB
      THREE=3.0000000000000000
      TWO=2.000000000000000
      ONE=1.000000000000000
      ZERO=0.0000000000000000
      PIINV=.31830988618379067
      CPXZER=CMPLX(ZERO,ZERO)
      AIMG=CMPLX(ZERO,ONE)
      AIMGPI=CMPLX(ZERO,PIINV)
      CMPXPI=TWO*AIMGPI
      DD2=DELTA*DELTA
      ASQ=A*A
      ABDIST=SQRT(ASQ+DD2)
      ABARG=ABDIST*ABSK1
      BSQ=B*B
      BADIST=SQRT(BSQ+DD2)
      BBARG=BADIST*ABSK1
      IF(ABARG.LT.RE) GO TO 100
      S(1)=A
      SMALLA=-RE/ABSK1
      CONINT=SMALLA-A
      NA=3+2*IFIX(CONINT/WAVINT)
      IF(NA.LT.490) GO TO 5
      PRINT 6
    6 FORMAT (10X*DIMENSION STATEMENT EXCEEDED (EHHFSP).*)
      CALL EXIT
    5 NM1=NA-1
      H=CONINT/FLOAT(NM1)
      HTHIRD=H/3.
      DO 10 L=1,NA
      DIST2(L)=S(L)*S(L)+DD2
      DIST(L)=SQRT(DIST2(L))
      ARG=PROPCT1*DIST(L)
      CALL HINT01(ARG,H0(L),H1(L),IER)
   10 S(L+1)=S(L)+H
      H0INT=CPXZER
      H1INT=CPXZER
      H5INT=CPXZER
      H6INT=CPXZER
      H9INT=CPXZER
      DO 20 L=1,NM1,2
      L1=L+1
      L2=L+2
      H0INT=H0INT+H0(L)+4.*H0(L1)+H0(L2)
```

```
      H1INT=H1INT+H1(L)/DIST(L)+4.*H1(L1)/DIST(L1)+H1(L2)/DIST(L2)
      T1=HO(L)/DIST2(L)
      T2=4.*HO(L1)/DIST2(L1)
      T3=HO(L2)/DIST2(L2)
      H5INT=H5INT+T1+T2+T3
      H6INT=H6INT+S(L)*T1+S(L1)*T2+S(L2)*T3
   20 H9INT=H9INT+H1(L)/(DIST2(L)*DIST(L))+4.*H1(L1)/(DIST2(L1)*DIST(L1
     1)+H1(L2)/(DIST2(L2)*DIST(L2))
      HK00=HTHIRD*H0INT
      AI1=HTHIRD*H1INT
      AI5=HTHIRD*H5INT
      AI6=HTHIRD*H6INT
      AI9=HTHIRD*H9INT
      GO TO 101
  100 SMALLA=A
      HK00=CPXZER
      AI1=CPXZER
      AI5=CPXZER
      AI6=CPXZER
      AI9=CPXZER
  101 IF(BBARG.LT.RE) GO TO 200
      SMALLB=RE/ABSK1
      S(1)=SMALLB
      CONINT=B-SMALLB
      NA=3+2*IFIX(CONINT/WAVINT)
      IF(NA.LT.490) GO TO 105
      PRINT 6
      CALL EXIT
  105 NM1=NA-1
      H=CONINT/FLOAT(NM1)
      HTHIRD=H/3.
      DO 110 L=1,NA
      DIST2(L)=S(L)*S(L)+DD2
      DIST(L)=SQRT(DIST2(L))
      ARG=PROPCT1*DIST(L)
      CALL HINT01(ARG,HO(L),H1(L),IER)
  110 S(L+1)=S(L)+H
      H0INT=CPXZER
      H1INT=CPXZER
      H5INT=CPXZER
      H6INT=CPXZER
      H9INT=CPXZER
      DO 120 L=1,NM1,2
      L1=L+1
      L2=L+2
      H0INT=H0INT+HO(L)+4.*HO(L1)+HO(L2)
      H1INT=H1INT+H1(L)/DIST(L)+4.*H1(L1)/DIST(L1)+H1(L2)/DIST(L2)
      T1=HO(L)/DIST2(L)
      T2=4.*HO(L1)/DIST2(L1)
      T3=HO(L2)/DIST2(L2)
      H5INT=H5INT+T1+T2+T3
      H6INT=H6INT+S(L)*T1+S(L1)*T2+S(L2)*T3
  120 H9INT=H9INT+H1(L)/(DIST2(L)*DIST(L))+4.*H1(L1)/(DIST2(L1)*DIST(L1
     1)+H1(L2)/(DIST2(L2)*DIST(L2))
      H0INT=HK00+HTHIRD*H0INT
      H1INT=AI1+HTHIRD*H1INT
```

```
      H5INT=AI5+HTHIRD*H5INT
      H6INT=AI6+HTHIRD*H6INT
      H9INT=AI9+HTHIRD*H9INT
      GO TO 201
  200 SMALLB=B
      H0INT=HK00
      H1INT=AI1
      H5INT=AI5
      H6INT=AI6
      H9INT=AI9
  201 AA2=SMALLA*SMALLA
      AA3=AA2*SMALLA
      BB2=SMALLB*SMALLB
      BB3=BB2*SMALLB
      PD1=PROPCT1*DELTA
      P2A2=PROP1S*AA2
      P2B2=PROP1S*BB2
      P2D2=PROP1S*DD2
      BMA=SMALLB-SMALLA
      B2MA2=BB2-AA2
      B3MA3=BB3-AA3
      D2PA2=DD2+AA2
      D2PB2=DD2+BB2
      ALOGA=ALOG(D2PA2)
      ALOGB=ALOG(D2PB2)
      ALOG1=ALOGB-ALOGA
      ALOG2=GMLOG+.5*ALOGA
      ALOG3=GMLOG+.5*ALOGB
      TAN=ATAN(SMALLB/DELTA)-ATAN(SMALLA/DELTA)
      TERM1=ONE-P2D2/4.
      TERM2=ONE-.125*P2D2
      TERM3=ONE-.3125*P2D2
      TERM4=ONE-CMPXPI
      TERM5=.25*PROP1S*(SMALLB*ALOG3-SMALLA*ALOG2-(BMA-DELTA*TAN))
      HK00=TERM1*BMA-PROP1S*B3MA3/12.+.5*AIMGPI*(P2D2*BMA+PROP1S*B3MA3/
     1THREE)+CMPXPI*(SMALLB*(TERM1-P2B2/12.)*ALOG3-SMALLA*(TERM1-P2A2/12
     2.)*ALOG2+PROP1S*B3MA3/36.-(ONE-P2D2/6.)*(BMA-DELTA*TAN))
      AI1=(PROPCT1/TWO)*(TERM2*BMA-PROP1S*B3MA3/24.-CMPXPI*(TWO*TAN/(PRO
     1PCT1*PD1)+.5*TERM3*BMA-PROP1S*B3MA3/19.2)+CMPXPI*(SMALLB*(TERM2-
     2P2B2/24.)*ALOG3-SMALLA*(TERM2-P2A2/24.)*ALOG2+PROP1S*B3MA3/72.-
     3(ONE-P2D2/12.)*(BMA-DELTA*TAN)))
      IF (DELTA.NE.0.) GO TO 600
      AIAB=0.
      GO TO 529
  600 DELT=ABS(DELTA)
      XL=DELT/ACC
      XU=DELT*ACC
      ITEST=1
      IF(SMALLA.LT.0. .AND. SMALLB.GT.0.) GO TO 630
      IF(SMALLA.LE.0. .AND. SMALLB.LE.0.) GO TO 620
      LARGEA=SMALLA
      LARGEB=SMALLB
  601 IF(LARGEA.LT.XU) GO TO 602
      AIAB=-TWO*((ALOG(LARGEB)+ONE)/LARGEB-(ALOG(LARGEA)+ONE)/LARGEA)
      GO TO 611
  602 IF(LARGEB.GT.XL) GO TO 603
```

```
      AIAB=TWO*ALOG(DELT)*(LARGEB-LARGEA)/DD2
      GO TO 611
  603 IF(LARGEA.GE.XL) GO TO 604
      SUM1=TWO*ALOG(DELT)*(XL-LARGEA)/DD2
      XLL=XL
      GO TO 605
  604 SUM1=0.
      XLL=LARGEA
  605 IF(LARGEB.LE.XU) GO TO 606
      SUM3=-TWO*((ALOG(LARGEB)+1.)/LARGEB-(ALOG(XU)+1.)/XU)
      XUU=XU
      GO TO 607
  606 SUM3=0.
      XUU=LARGEB
  607 AIER=RMBRG(FUNC,XLL,XUU,TOLER,SUM2)
      IF(AIER) 608,610,610
  608 PRINT 609, AIER,XLL,XUU,DELTA
  609 FORMAT (10X,*DID NOT OBTAIN CONVERGENCE FOR AIAB (EHHFSP) *4E15.7)
  610 AIAB=SUM1+SUM2+SUM3
  611 IF(ITEST-2) 529,631,635
  620 LARGEA=ABS(SMALLB)
      LARGEB=ABS(SMALLA)
      GO TO 601
  630 ABA=ABS(SMALLA)
      IF(ABA.GT.SMALLB) GO TO 634
      ITEST=2
      INDEX=1
      LARGEA=0.
      LARGEB=ABA
      GO TO 601
  631 IF(ABA.EQ.SMALLB) GO TO 633
      IF(INDEX.EQ.2) GO TO 632
      INDEX=2
      LARGEA=ABA
      LARGEB=SMALLB
      TEMP=AIAB
      GO TO 601
  632 AIAB=2.*TEMP+AIAB
      GO TO 529
  633 AIAB=2.*AIAB
      GO TO 529
  634 ITEST=3
      INDEX=1
      LARGEA=0.
      LARGEB=SMALLB
      GO TO 601
  635 IF(INDEX.EQ.2) GO TO 636
      INDEX=2
      LARGEA=SMALLB
      LARGEB=ABA
      TEMP=AIAB
      GO TO 601
  636 AIAB=2.*TEMP+AIAB
  529 AI5=TAN/DELTA-.25*PROP1S*BMA*TERM4+CMPXPI*(GMLOG*TAN/DELTA+.5*AIAB
     1-TERM5)
      AI6=.5*ALOG1-.125*PROP1S*B2MA2*TERM4+AIMGPI*(GMLOG*ALOG1+.25*(ALOG
```

```
1B*ALOGB-ALOGA*ALOGA)-.25*PROP1S*(BB2*ALOG3-AA2*ALOG2-.5*(B2MA2-DD2
2*ALOG1)))
 AI9=.5*PROPCT1*(TAN/DELTA-.125*PROP1S*BMA-CMPXPI*((SMALLB/D2PB2-
1SMALLA/D2PA2)/P2D2+(ONE/P2D2+.5-GMLOG)*TAN/DELTA-PROP1S*BMA/6.4)+
2AIMGPI*(AIAB-TERM5))
 H0INT=H0INT+HK00
 H1INT=H1INT+AI1
 ARGA=PROPCT1*ABDIST
 ARGB=PROPCT1*BADIST
 CALL HINT01(ARGA,HXA0,HXA1,IER)
 CALL HINT01(ARGB,HXB0,HXB1,IER)
 H2INT=(HXA0-HXB0)/PROPCT1
 H5INT=H5INT+AI5
 H6INT=H6INT+AI6
 H9INT=H9INT+AI9
 H10INT=(HXA1/ABDIST-HXB1/BADIST+PROPCT1*H6INT)/TWO
 H11INT=H1INT-DD2*H9INT
 RETURN
 END
```

```
      SUBROUTINE EHFTSP(A,B,PROPCT1,PROP1S,GMLOG,ABSK1,WAVINT,HOINT,
     1H2INT,H1INT,RE)
C...  SUBROUTINE EHFTSP COMPUTES THE INTEGRALS OF THE INTEGRAL REPRESENTATIONS
C     ALONG A FLAT HALF-SPACE OVER THE INTERVAL (A,B), ASSUMING THE POINT OF
C     OBSERVATION IS ON THE CONTOUR.
      COMPLEX PROPCT1,PROP1S,GMLOG,HOINT,H2INT,H1INT,CPXZER,AIMG,AIMGPI,
     1CMPXPI,ARG,HKOO,AI1,P2A2,P2B2,ALOG2,ALOG3,HO,H1
      COMMON /TERMS/ S(500),DIST(500),DIST2(500),HO(500),H1(500)
      THREE=3.0000000000000000
      TWO=2.0000000000000000
      ONE=1.0000000000000000
      ZERO=0.0000000000000000
      PIINV=.31830988618379067
      CPXZER=CMPLX(ZERO,ZERO)
      AIMG=CMPLX(ZERO,ONE)
      AIMGPI=CMPLX(ZERO,PIINV)
      CMPXPI=TWO*AIMGPI
      ABARG=A*ABSK1
      BBARG=B*ABSK1
      IF(ABS(ABARG).LT.RE) GO TO 100
      SMALLA=-RE/ABSK1
      S(1)=ABS(SMALLA)
      CONINT=ABS(A)-S(1)
      NA=3+2*IFIX(CONINT/WAVINT)
      IF(NA.LT.490) GO TO 5
      PRINT 6
    6 FORMAT (10X*DIMENSION STATEMENT EXCEEDED (EHFTSP).*)
      CALL EXIT
    5 NM1=NA-1
      H=CONINT/FLOAT(NM1)
      HTHIRD=H/3.
      DO 10 L=1,NA
      ARG=PROPCT1*S(L)
      CALL HINT01(ARG,HO(L),H1(L),IER)
   10 S(L+1)=S(L)+H
      HOINT=CPXZER
      H1INT=CPXZER
      DO 20 L=1,NM1,2
      L1=L+1
      L2=L+2
      HOINT=HOINT+HO(L)+4.*HO(L1)+HO(L2)
   20 H1INT=H1INT+H1(L)/S(L)+4.*H1(L1)/S(L1)+H1(L2)/S(L2)
      HKOO=HTHIRD*HOINT
      AI1=HTHIRD*H1INT
      GO TO 101
  100 SMALLA=A
      HKOO=CPXZER
      AI1=CPXZER
  101 IF(BBARG.LT.RE) GO TO 200
      SMALLB=RE/ABSK1
      S(1)=SMALLB
      CONINT=B-SMALLB
      NA=3+2*IFIX(CONINT/WAVINT)
      IF(NA.LT.490) GO TO 105
      PRINT 6
      CALL EXIT
```

```
105 NM1=NA-1
    H=CONINT/FLOAT(NM1)
    HTHIRD=H/3.
    DO 110 L=1,NA
    ARG=PROPCT1*S(L)
    CALL HINT01(ARG,H0(L),H1(L),IER)
110 S(L+1)=S(L)+H
    H0INT=CPXZER
    H1INT=CPXZER
    DO 120 L=1,NM1,2
    L1=L+1
    L2=L+2
    H0INT=H0INT+H0(L)+4.*H0(L1)+H0(L2)
120 H1INT=H1INT+H1(L)/S(L)+4.*H1(L1)/S(L1)+H1(L2)/S(L2)
    H0INT=HK00+HTHIRD*H0INT
    H1INT=AI1+HTHIRD*H1INT
    GO TO 201
200 SMALLB=B
    H0INT=HK00
    H1INT=AI1
201 AA2=SMALLA*SMALLA
    AA3=AA2*SMALLA
    BB2=SMALLB*SMALLB
    BB3=BB2*SMALLB
    P2A2=PROP1S*AA2
    P2B2=PROP1S*BB2
    BMA=SMALLB-SMALLA
    B3MA3=BB3-AA3
    ALOG2=GMLOG+ALOG(ABS(SMALLA))
    ALOG3=GMLOG+ALOG(SMALLB)
    HK00=BMA-PROP1S*B3MA3/12.+.5*AIMGPI*PROP1S*B3MA3/THREE+CMPXPI*(
   1SMALLB*(ONE-P2B2/12.)*ALOG3-SMALLA*(ONE-P2A2/12.)*ALOG2+PROP1S*
   2B3MA3/36.-BMA)
    AI1=(PROPCT1/TWO)*(BMA-PROP1S*B3MA3/24.-CMPXPI*(BMA/TWO-PROP1S*
   1B3MA3/19.2)+CMPXPI*(SMALLB*(ONE-P2B2/24.)*ALOG3-SMALLA*(ONE-P2A2/
   224.)*ALOG2+PROP1S*B3MA3/72.-BMA))
    H0INT=H0INT+HK00
    ARG=PROPCT1*ABS(A)
    CALL HINT01(ARG,H0(1),H1(1),IER)
    ARG=PROPCT1*B
    CALL HINT01(ARG,H0(2),H1(2),IER)
    H2INT=(H0(1)-H0(2))/PROPCT1
    H1INT=-H1INT-CMPXPI*(ONE/SMALLB-ONE/SMALLA)/PROPCT1-AI1
    RETURN
    END
```

```
      SUBROUTINE CUPIEQ(SIJR,SIJI,ISTOP)
C...  SUBROUTINE CUPIEQ INVERTS THE MATRICES SIJR, SIJI OF THE COUPLED INTEGRAL
C     EQUATIONS AND RETURNS THEM IN SIJR, SIJI.
      DIMENSION SIJR(90,90),SIJI(90,90),TEMPR(45,45),TEMPI(45,45),D(45,
     145)
      ZERO=0.0000000000000000
C     PLACE C11 IN TEMPR AND TEMPI AND OBTAIN ITS INVERSE.
      DO 205 I=1,ISTOP
      DO 205 J=1,ISTOP
      TEMPR(I,J)=SIJR(I,J)
  205 TEMPI(I,J)=SIJI(I,J)
      CALL CINVER (TEMPR,TEMPI,ISTOP,D)
C     OBTAIN (C21*C11INV) AND STORE IN C11.
      DO 210 I=1,ISTOP
      IUP=ISTOP+I
      DO 210 J=1,ISTOP
      SIJR(I,J)=ZERO
      SIJI(I,J)=ZERO
      DO 210 K=1,ISTOP
      SIJR(I,J)=SIJR(I,J)+SIJR(IUP,K)*D(K,J)-SIJI(IUP,K)*TEMPI(K,J)
  210 SIJI(I,J)=SIJI(I,J)+SIJR(IUP,K)*TEMPI(K,J)+SIJI(IUP,K)*D(K,J)
C     STORE (C11INV) IN C21, OBTAIN (C21*C11INV)*C12 AND PLACE IN TEMPR
C     AND TEMPI.
      DO 215 I=1,ISTOP
      IUP=ISTOP+I
      DO 215 J=1,ISTOP
      JUP=ISTOP+J
      SIJR(IUP,J)=D(I,J)
      SIJI(IUP,J)=TEMPI(I,J)
      TEMPR(I,J)=ZERO
      TEMPI(I,J)=ZERO
      DO 215 K=1,ISTOP
      TEMPR(I,J)=TEMPR(I,J)+SIJR(I,K)*SIJR(K,JUP)-SIJI(I,K)*SIJI(K,JUP)
  215 TEMPI(I,J)=TEMPI(I,J)+SIJR(I,K)*SIJI(K,JUP)+SIJI(I,K)*SIJR(K,JUP)
C     OBTAIN THE INVERSE OF ((C21*C11INV)*C12-C22) AND STORE IN C22.
      DO 220 I=1,ISTOP
      IUP=ISTOP+I
      DO 220 J=1,ISTOP
      JUP=ISTOP+J
      TEMPR(I,J)=TEMPR(I,J)-SIJR(IUP,JUP)
  220 TEMPI(I,J)=TEMPI(I,J)-SIJI(IUP,JUP)
      CALL CINVER(TEMPR,TEMPI,ISTOP,D)
      DO 225 I=1,ISTOP
      IUP=ISTOP+I
      DO 225 J=1,ISTOP
      JUP=ISTOP+J
      SIJR(IUP,JUP)=D(I,J)
  225 SIJI(IUP,JUP)=TEMPI(I,J)
      RETURN
      END
```

```
      SUBROUTINE MANDK (FIELDR,FIELDI,SIJR,SIJI,CURDEN)
C...  SUBROUTINE MANDK COMPUTES THE EQUIVALENT CURRENT DENSITIES M AND K
C     FROM THE INCIDENT FIELDS AND MATRIX INVERSES OF THE COUPLED INTEGRAL
C     EQUATIONS.
C...  NOTE THAT THIS SUBROUTINE ASSUMES THAT THE TOPOGRAPHIC AND CYLINDER
C     CONTOURS ARE MIRROR SYMMETRIC ABOUT THE Z-AXIS.  IF A NON-SYMMETRIC
C     SCATTERER IS TO BE CONSIDERED, THE CARD(S) WHICH HAVE AN * IN COLUMN
C     1 MUST REPLACE THE CARD(S) WHICH FOLLOW IT(THEM).
      DIMENSION FIELDR(200),FIELDI(200),SIJR(90,90),SIJI(90,90),REALCU(
     1200),IMAGCU(200),CURDEN(200),AMP(200),PHASE(200)
      COMMON /CONSTS/ ISTOP,ISTOP2,ISTP1,NTOPUP,NUPTOP,NSTP1,NTOPHF,
     1NTHFUP,NPTPP1,NINHHF,NUPHHF,NSYMUP,NMID,NMIDUP,NSYM,NSYM2,NMIDM,
     2NMIDP,NSYMM,NTOPO
      COMPLEX CURDEN
      REAL IMAGCU
   10 FORMAT (1H1)
   11 FORMAT (1H0)
  310 FORMAT(1H02X,8E16.8)
      RADIAN=.017453292519943296
      ZERO=0.0000000000000000
C     OBTAIN THE COLUMN MATRIX (C21*C11INV)*E AND STORE IN REALCU AND
C     IMAGCU.
*     DO 400 I=1,ISTOP
      DO 400 I=1,NSYM
      REALCU(I)=ZERO
      IMAGCU(I)=ZERO
*     DO 400 J=1,ISTOP
      DO 400 J=1,NSYM
      REALCU(I)=REALCU(I)+SIJR(I,J)*FIELDR(J)-SIJI(I,J)*FIELDI(J)
  400 IMAGCU(I)=IMAGCU(I)+SIJR(I,J)*FIELDI(J)+SIJI(I,J)*FIELDR(J)
C     OBTAIN THE COLUMN MATRIX (C21*C11INV)*E-H AND STORE IN H.
*     DO 401 I=1,ISTOP
      DO 401 I=1,NSYM
*     IUP=ISTOP+I
      IUP=NSYM+I
      FIELDR(IUP)=REALCU(I)-FIELDR(IUP)
  401 FIELDI(IUP)=IMAGCU(I)-FIELDI(IUP)
C     OBTAIN THE COLUMN MATRIX ((C21*C11INV)*C12-C22)INV)*((C21*C11INV)*E-H)
C     AND PUT IN REALCU AND IMAGCU.
*     DO 402 I=1,ISTOP
      DO 402 I=1,NSYM
*     IUP=ISTOP+I
      IUP=NSYM+I
      REALCU(IUP)=ZERO
      IMAGCU(IUP)=ZERO
*     DO 402 J=1,ISTOP
      DO 402 J=1,NSYM
*     JUP=ISTOP+J
      JUP=NSYM+J
      REALCU(IUP)=REALCU(IUP)+SIJR(IUP,JUP)*FIELDR(JUP)-SIJI(IUP,JUP)*
     1FIELDI(JUP)
  402 IMAGCU(IUP)=IMAGCU(IUP)+SIJR(IUP,JUP)*FIELDI(JUP)+SIJI(IUP,JUP)*
     1FIELDR(JUP)
C     OBTAIN THE MATRIX (C11INV)*C12 AND STORE IN C11.
*     DO 403 I=1,ISTOP
      DO 403 I=1,NSYM
*     IUP=ISTOP+I
```

```
      IUP=NSYM+I
*     DO 403 J=1,ISTOP
      DO 403 J=1,NSYM
*     JUP=ISTOP+J
      JUP=NSYM+J
      SIJR(I,J)=ZERO
      SIJI(I,J)=ZERO
*     DO 403 K=1,ISTOP
      DO 403 K=1,NSYM
      SIJR(I,J)=SIJR(I,J)+SIJR(IUP,K)*SIJR(K,JUP)-SIJI(IUP,K)*SIJI(K,JUP
     1)
  403 SIJI(I,J)=SIJI(I,J)+SIJR(IUP,K)*SIJI(K,JUP)+SIJI(IUP,K)*SIJR(K,JUP
     1)
C     FORM THE COLUMN MATRICES (C11INV)*E AND (C11INV*C12)*M.
*     DO 404 I=1,ISTOP
      DO 404 I=1,NSYM
*     IUP=ISTOP+I
      IUP=NSYM+I
      REALCU(I)=ZERO
      IMAGCU(I)=ZERO
      FIELDR(IUP)=ZERO
      FIELDI(IUP)=ZERO
*     DO 404 J=1,ISTOP
      DO 404 J=1,NSYM
*     JUP=ISTOP+J
      JUP=NSYM+J
      REALCU(I)=REALCU(I)+SIJR(IUP,J)*FIELDR(J)-SIJI(IUP,J)*FIELDI(J)
      IMAGCU(I)=IMAGCU(I)+SIJR(IUP,J)*FIELDI(J)+SIJI(IUP,J)*FIELDR(J)
      FIELDR(IUP)=FIELDR(IUP)+SIJR(I,J)*REALCU(JUP)-SIJI(I,J)*IMAGCU(JUP
     1)
  404 FIELDI(IUP)=FIELDI(IUP)+SIJR(I,J)*IMAGCU(JUP)+SIJI(I,J)*REALCU(JUP
     1)
C     FORM THE COLUMN MATRIX C11INV*E-(C11INV*C12)*M
*     DO 405 I=1,ISTOP
      DO 405 I=1,NSYM
*     IUP=ISTOP+I
      IUP=NSYM+I
      REALCU(I)=REALCU(I)-FIELDR(IUP)
  405 IMAGCU(I)=IMAGCU(I)-FIELDI(IUP)
C     COMPUTE THE VALUES OF THE SYMMETRIC SURFACE CURRENT DENSITIES.
      CURDEN(NTOPHF)=CMPLX(REALCU(1),IMAGCU(1))
      CURDEN(NTHFUP)=CMPLX(REALCU(NSYMUP),IMAGCU(NSYMUP))
      IF(ISTOP.EQ.NTOPO) GO TO 4049
      CURDEN(NTOPUP)=CMPLX(REALCU(NMID),IMAGCU(NMID))
      CURDEN(NPTPP1)=CMPLX(REALCU(NMIDUP),IMAGCU(NMIDUP))
      CURDEN(NINHHF)=CMPLX(REALCU(NSYM),IMAGCU(NSYM))
      CURDEN(NUPHHF)=CMPLX(REALCU(NSYM2),IMAGCU(NSYM2))
 4049 DO 4050 I=2,NMIDM
      IM=I-1
      IUP=NSYM+I
      JP=NTOPHF+IM
      JUPP=ISTOP+JP
      J=NTOPHF-IM
      JUP=ISTOP+J
      CURDEN(JP)=CMPLX(REALCU(I),IMAGCU(I))
      CURDEN(JUPP)=CMPLX(REALCU(IUP),IMAGCU(IUP))
```

```
      CURDEN(J)=CURDEN(JP)
 4050 CURDEN(JUP)=CURDEN(JUPP)
      IF(ISTOP.EQ.NTOPO) GO TO 4052
      DO 4051 I=NMIDP,NSYMM
      IM=I-NMID
      IUP=NSYM+I
      J=NTOPUP+IM
      JUP=ISTOP+J
      JP=ISTP1-IM
      JUPP=ISTOP+JP
      CURDEN(J)=CMPLX(REALCU(I),IMAGCU(I))
      CURDEN(JUP)=CMPLX(REALCU(IUP),IMAGCU(IUP))
      CURDEN(JP)=CURDEN(J)
 4051 CURDEN(JUPP)=CURDEN(JUP)
 4052 DO 406 I=1,ISTOP2
*     CURDEN(I)=CMPLX(REALCU(I),IMAGCU(I))
      REALCU(I)=REAL(CURDEN(I))
      IMAGCU(I)=AIMAG(CURDEN(I))
      AMP(I)=SQRT(REALCU(I)*REALCU(I)+IMAGCU(I)*IMAGCU(I))
  406 PHASE(I)=ATAN2(IMAGCU(I),REALCU(I))/RADIAN
      PRINT 10
      PRINT 410
  410 FORMAT (15X*DISTRIBUTION OF INDUCED CURRENTS*)
      PRINT 11
      PRINT 420
  420 FORMAT (10X,*REAL PART*2X,*IMAGINARY PART*9X,*MODULUS*11X*PHASE*)
      PRINT 11
      PRINT 430
  430 FORMAT (5X*ELECTRIC CURRENTS*)
      PRINT 11
      PRINT 431
  431 FORMAT (20X*TOPOGRAPHIC CURRENTS*)
      PRINT 11
      DO 432 I=1,NTOPO
      PRINT 310, CURDEN(I),AMP(I),PHASE(I)
  432 CONTINUE
      IF(ISTOP.EQ.NTOPO) GO TO 441
      PRINT 11
      PRINT 433
  433 FORMAT (20X*INHOMOGENEITY CURRENTS*)
      PRINT 11
      DO 440 I=NTOPUP,ISTOP
      PRINT 310, CURDEN(I),AMP(I),PHASE(I)
  440 CONTINUE
  441 CONTINUE
      PRINT 10
      PRINT 450
  450 FORMAT (5X*MAGNETIC CURRENTS*)
      PRINT 11
      PRINT 431
      PRINT 11
      DO 451 I=ISTP1,NUPTOP
      PRINT 310, CURDEN(I),AMP(I),PHASE(I)
  451 CONTINUE
      IF(ISTOP.EQ.NTOPO) GO TO 461
      PRINT 11
```

```
      PRINT 433
      PRINT 11
      DO 460 I=NSTP1,ISTOP2
      PRINT 310, CURDEN(I),AMP(I),PHASE(I)
  460 CONTINUE
  461 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE CINVER (AR,AI,N,D)
C...  SUBROUTINE CINVER INVERTS A COMPLEX MATRIX BY SOLVING THE TWO
C     EQUATIONS WHICH RESULT FROM THE DEFINITION OF MATRIX INVERSE,
C     C(-1)*C = I.
C...  INPUTS ARE AR (THE REAL PART OF THE COMPLEX MATRIX TO BE INVERTED)
C                 AI (THE IMAG PART OF THE COMPLEX MATRIX TO BE INVERTED)
C                 N  (THE ORDER OF THE COMPLEX MATRIX TO BE INVERTED)
C...  OUTPUTS ARE D  (THE REAL PART OF THE INVERSE)
C                  AI (THE IMAG PART OF THE INVERSE)
      DIMENSION T1(45),T2(45)
      DIMENSION AR(45,45),AI(45,45),ARI(45,45),D(45,45)
      DO 10 I=1,N
      DO 10 J=1,N
   10 ARI(I,J)=AI(I,J)
      CALL INVERT(ARI,N,45,T1,T2)
      DO 20 I=1,N
      DO 20 J=1,N
      DO 20 L=1,N
      DO 20 K=1,N
   20 AI(I,J)=AI(I,J)+AR(I,L)*ARI(L,K)*AR(K,J)
      DO 40 I=1,N
      DO 40 J=1,N
   40 AI(I,J)=-AI(I,J)
      CALL INVERT (AI,N,45,T1,T2)
      DO 30 I=1,N
      DO 30 J=1,N
      D(I,J)=0.0
      DO 30 L=1,N
      DO 30 K=1,N
   30 D(I,J)=D(I,J)-ARI(I,L)*AR(L,K)*AI(K,J)
      RETURN
      END
```

```
      SUBROUTINE INVERT(A,NN,N,M,C)                                     *END  20
CCCCCC
CCCCCC THIS ROUTINE INVERTS REAL MATRICES.
CCCCCC A IS THE ARRAY CONTAINING THE ELEMENTS OF THE MATRIX.
CCCCCC AFTER THE RETURN TO THE CALLING PROGRAM A CONTAINS THE INVERSE.
CCCCCC NN IS THE ORDER OF THE MATRIX.
CCCCCC N IS THE FIRST SUBSCRIPT OF THE DIMENSION OF THE ARRAY A.
CCCCCC M AND C ARE SINGLE SUBSCRIPTED ARRAYS OF LENGTH AT LEAST NN.
CCCCCC AFTER THE RETURN ARRAYS M AND C CONTAIN GARBAGE.
CCCCCC
      DIMENSION A(1),M(1),C(1)                                          *END  40
CCCCCC
CCCCCC SINCE THIS ROUTINE DOES NOT STRICTLY OBEY THE FORTRAN IV RULES
CCCCCC ABOUT ARRAYS IT MAY NOT WORK ON SOME MACHINES.  IF IT WORKS IT IS
CCCCCC MORE EFFICIENT THAN A STRICTLY LEGAL ROUTINE.
CCCCCC
      ND = N - NN                                                       *END  60
      IF (NN-1) 80,70,80                                                *END  70
   70 A(1)=1./A(1)                                                      *END  80
      GO TO 300                                                         *END  90
   80 DO 90 I=1, NN                                                     *END 100
   90 M(I)=-I                                                           *END 110
CCCCCC
      DO 140 I=1,NN                                                     *END 130
CCCCCC
CCCCCC LOCATE LARGEST ELEMENT.
CCCCCC
      D=0.0                                                             *END 170
      DO 112 L=1,NN                                                     *END 180
      IF (M(L)) 100,100,112                                             *END 190
  100 J=L                                                               *END 200
      DO 110 K=1,NN                                                     *END 210
      IF (M(K)) 103,103,108                                             *END 220
  103 IF (ABS(D)-ABS(A(J))) 105,105,108                                 *END 230
  105 LD=L                                                              *END 240
      KD=K                                                              *END 250
      D=A(J)                                                            *END 260
  108 J=J+N                                                             *END 270
  110 CONTINUE                                                          *END 280
  112 CONTINUE                                                          *END 290
CCCCCC
CCCCCC INTERCHANGE ROWS.
CCCCCC
      IF (D) 401,402,401
  401 ITEMP=-M(LD)                                                      *END 330
      M(LD)=M(KD)                                                       *END 340
      M(KD)=ITEMP                                                       *END 350
      L=LD                                                              *END 360
      K=KD                                                              *END 370
      DO 114 J=1,NN                                                     *END 380
      C(J)=A(L)                                                         *END 390
      A(L)=A(K)                                                         *END 400
      A(K)=C(J)                                                         *END 410
      L=L+N                                                             *END 420
  114 K=K+N                                                             *END 430
CCCCCC
```

```
CCCCCC DIVIDE COLUMN BY LARGEST ELEMENT.
CCCCCC
      NR=(KD-1)*N+1                                                     *END 470
      NH = NR + NN - 1                                                  *END 480
      DO 115 K=NR,NH                                                    *END 490
  115 A(K)=A(K)/D                                                       *END 500
CCCCCC
CCCCCC REDUCE REMAINING ROWS AND COLUMNS.
CCCCCC
      L=1
      DO 135 J=1,NN                                                     *END 550
      IF (J-KD) 130,125,130                                             *END 560
  125 L=L+N                                                             *END 570
      GO TO 135                                                         *END 580
  130 DO 134 K=NR,NH                                                    *END 590
      A(L)=A(L)-C(J)*A(K)                                               *END 600
  134 L=L+1                                                             *END 610
      L = L + ND                                                        *END 620
  135 CONTINUE                                                          *END 630
CCCCCC
CCCCCC REDUCE ROW.
CCCCCC
      C(KD)=-1.0                                                        *END 670
      J=KD                                                              *END 680
      DO 140 K=1,NN                                                     *END 690
      A(J)=-C(K)/D                                                      *END 700
  140 J=J+N                                                             *END 710
CCCCCC
CCCCCC INTERCHANGE COLOMNS.
CCCCCC
      DO 200 I=1,NN                                                     *END 750
      L=0                                                               *END 760
  150 L=L+1                                                             *END 770
      IF(M(L)-I) 150,160,150                                            *END 780
  160 K=(L-1)*N+1                                                       *END 790
      J=(I-1)*N+1                                                       *END 800
      M(L)=M(I)                                                         *END 810
      M(I)=I                                                            *END 820
      DO 200 L=1,NN                                                     *END 830
      TEMP=A(K)                                                         *END 840
      A(K)=A(J)                                                         *END 850
      A(J)=TEMP                                                         *END 860
      J=J+1                                                             *END 870
  200 K=K+1                                                             *END 880
CCCCCC
  300 RETURN                                                            *END 900
CCCCCC
  402 PRINT 403
  403 FORMAT (15HSINGULAR MATRIX)
      CALL EXIT
      RETURN
      END                                                               *END 920
```

```
      SUBROUTINE FIELDS(PROPCT1,REALK1,IMAGK1,CST,TCOSA1,TSINA1,CURDEN,
     1IK,IM,IIK,IIM,IIIK,IIIM,AI1,AI2,AI3,AI4,AI5,AI6,AI7,AI8,AI9,AI10,
     2AI11,AI12,AI13,AIOM1,ISTOP,HPHIX,HPHIZ)
C...  SUBROUTINE FIELDS TAKES THE VALUES FOR THE INTEGRALS OF THE INTEGRAL
C     REPRESENTATIONS AND RETURNS THE HORIZONTAL MAGNETIC FIELD INTENSITY
C     (HPHIX) AND THE VERTICAL MAGNETIC FIELD INTENSITY (HPHIZ).
      DIMENSION CURDEN(200)
      COMPLEX CURDEN,PROPCT1,CST,AI1,AI2,AI3,AI4,AI5,AI6,AI7,AI8,AI9,
     1AI10,AI11,AI12,AI13,CODE1,CODE2,APART1,APART2,APART3,CODE3,CODE4,
     2BPART1,BPART2,BPART3,CODE5,CODE6,CPART1,CPART2,CPART3,CODE7,CODE8,
     3DPART1,DPART2,DPART3,CODE9,CODE10,EPART1,EPART2,EPART3,CODE11,
     4CODE12,FPART1,FPART2,FPART3,CODE13,CODE14,GPART1,GPART2,GPART3,
     5BIGA,BIGB,BIGC,BIGD,BIGE,BIGF,BIGG,PERFEC,FINITE,AHELP,BHELP,CHELP
     6,DHELP,EHELP,FHELP,GHELP,HELP1,HELP2,HPHIX,HPHIZ
      COMMON /ZAP/ AJOP1,AMDA,BETA,AMDAP1,ONEMAM,SMALLA,SMALLB,DELTA,
     1SMALLC,CC2,SAIMA,CAIMA,DCAIMA
      COMMON /ZUP/ AIOP1,AMDB,BETB,AMDBP1,ONEMA
      COMMON /ZIP/ DD2
      REAL IMAGK1
      FOUR=4.000000000000000
      THREE=3.000000000000000
      TWO=2.000000000000000
      IF(IK.EQ.ISTOP) GO TO 20
      CODE1=(AI3-SMALLC*AI2)/AIOP1
      CODE3=(AI2-SMALLC*AI1)/AIOP1
      CODE5=(AI7-SMALLC*AI6)/AIOP1
      CODE7=(AI6-SMALLC*AI5)/AIOP1
      CODE9=(AI10-SMALLC*AI9)/AIOP1
      CODE11=(AI12-SMALLC*AI11)/AIOP1
      CODE13=(AI11-SMALLC*AI10)/AIOP1
      IF(IK.EQ.1) GO TO 10
      CODE2=(AI4-TWO*SMALLC*AI3+CC2*AI2)/BETB
      APART1=(AI2-ONEMA*CODE1-CODE2)*CURDEN(IK)
      APART2=(CODE1+CODE2)*CURDEN(IIK)/AMDBP1
      APART3=AMDB*(AMDB*CODE1-CODE2)*CURDEN(IIIK)/AMDBP1
      CODE4=(AI3-TWO*SMALLC*AI2+CC2*AI1)/BETB
      BPART1=(AI1-ONEMA*CODE3-CODE4)*CURDEN(IK)
      BPART2=(CODE3+CODE4)*CURDEN(IIK)/AMDBP1
      BPART3=AMDB*(AMDB*CODE3-CODE4)*CURDEN(IIIK)/AMDBP1
      CODE6=(AI8-TWO*SMALLC*AI7+CC2*AI6)/BETB
      CPART1=(AI6-ONEMA*CODE5-CODE6)*CURDEN(IM)
      CPART2=(CODE5+CODE6)*CURDEN(IIM)/AMDBP1
      CPART3=AMDB*(AMDB*CODE5-CODE6)*CURDEN(IIIM)/AMDBP1
      CODE8=(AI7-TWO*SMALLC*AI6+CC2*AI5)/BETB
      DPART1=(AI5-ONEMA*CODE7-CODE8)*CURDEN(IM)
      DPART2=(CODE7+CODE8)*CURDEN(IIM)/AMDBP1
      DPART3=AMDB*(AMDB*CODE7-CODE8)*CURDEN(IIIM)/AMDBP1
      CODE10=(AI11-TWO*SMALLC*AI10+CC2*AI9)/BETB
      EPART1=(AI9-ONEMA*CODE9-CODE10)*CURDEN(IM)
      EPART2=(CODE9+CODE10)*CURDEN(IIM)/AMDBP1
      EPART3=AMDB*(AMDB*CODE9-CODE10)*CURDEN(IIIM)/AMDBP1
      CODE12=(AI13-TWO*SMALLC*AI12+CC2*AI11)/BETB
      FPART1=(AI11-ONEMA*CODE11-CODE12)*CURDEN(IM)
      FPART2=(CODE11+CODE12)*CURDEN(IIM)/AMDBP1
      FPART3=AMDB*(AMDB*CODE11-CODE12)*CURDEN(IIIM)/AMDBP1
      CODE14=(AI12-TWO*SMALLC*AI11+CC2*AI10)/BETB
      GPART1=(AI10-ONEMA*CODE13-CODE14)*CURDEN(IM)
```

```
      GPART2=(CODE13+CODE14)*CURDEN(IIM)/AMDBP1
      GPART3=AMDB*(AMDB*CODE13-CODE14)*CURDEN(IIIM)/AMDBP1
      BIGA=APART1+APART2-APART3
      BIGB=BPART1+BPART2-BPART3
      BIGC=CPART1+CPART2-CPART3
      BIGD=DPART1+DPART2-DPART3
      BIGE=EPART1+EPART2-EPART3
      BIGF=FPART1+FPART2-FPART3
      BIGG=GPART1+GPART2-GPART3
      GO TO 30
   10 BIGA=(AI2-CODE1)*CURDEN(IK)+CODE1*CURDEN(IIK)
      BIGB=(AI1-CODE3)*CURDEN(IK)+CODE3*CURDEN(IIK)
      BIGC=(AI6-CODE5)*CURDEN(IM)+CODE5*CURDEN(IIM)
      BIGD=(AI5-CODE7)*CURDEN(IM)+CODE7*CURDEN(IIM)
      BIGE=(AI9-CODE9)*CURDEN(IM)+CODE9*CURDEN(IIM)
      BIGF=(AI11-CODE11)*CURDEN(IM)+CODE11*CURDEN(IIM)
      BIGG=(AI10-CODE13)*CURDEN(IM)+CODE13*CURDEN(IIM)
      GO TO 30
   20 CODE1=(AI3-SMALLC*AI2)/AIOM1
      CODE3=(AI2-SMALLC*AI1)/AIOM1
      CODE5=(AI7-SMALLC*AI6)/AIOM1
      CODE7=(AI6-SMALLC*AI5)/AIOM1
      CODE9=(AI10-SMALLC*AI9)/AIOM1
      CODE11=(AI12-SMALLC*AI11)/AIOM1
      CODE13=(AI11-SMALLC*AI10)/AIOM1
      BIGA=(AI2+CODE1)*CURDEN(IK)-CODE1*CURDEN(IIIK)
      BIGB=(AI1+CODE3)*CURDEN(IK)-CODE3*CURDEN(IIIK)
      BIGC=(AI6+CODE5)*CURDEN(IM)-CODE5*CURDEN(IIIM)
      BIGD=(AI5+CODE7)*CURDEN(IM)-CODE7*CURDEN(IIIM)
      BIGE=(AI9+CODE9)*CURDEN(IM)-CODE9*CURDEN(IIIM)
      BIGF=(AI11+CODE11)*CURDEN(IM)-CODE11*CURDEN(IIIM)
      BIGG=(AI10+CODE13)*CURDEN(IM)-CODE13*CURDEN(IIIM)
   30 PERFEC=CMPLX(-IMAGK1/FOUR,REALK1/FOUR)
      FINITE=CST*THREE
      AHELP=BIGA*PERFEC
      BHELP=BIGB*DELTA*PERFEC
      CHELP=BIGC*DELTA*FINITE
      DHELP=BIGD*DD2*FINITE
      EHELP=BIGE*DD2*FINITE/PROPCT1
      FHELP=BIGF*FINITE/PROPCT1
      GHELP=TWO*BIGG*DELTA*FINITE/PROPCT1
      HELP1=-AHELP-CHELP+GHELP
      HELP2=-BHELP-DHELP+EHELP-FHELP
      HPHIX=HELP1*TCOSA1+HELP2*TSINA1
      HPHIZ=HELP1*TSINA1-HELP2*TCOSA1
      RETURN
      END
```

```
      FUNCTION FUNC(S)
C...  FUNC IS THE FUNCTION IN THE SMALL ARGUMENT SOLUTION OF APPENDIX D
C     WHICH MUST BE INTEGRATED NUMERICALLY.
      COMMON /ZIP/ DD2
      S2=S*S
      SUM=S2+DD2
      FUNC=(ALOG(SUM))/SUM
      RETURN
      END
```

```
      FUNCTION RMBRG(F,A,B,EPS,AREA)
C...  FUNCTION RMBRG PERFORMS THE INTEGRATION OF A GIVEN FUNCTION BY THE
C     TRAPEZOIDAL RULE TOGETHER WITH ROMBERG/S EXTRAPOLATION METHOD.
C     THE SUBROUTINE WAS WRITTEN BY THE E.O. LAWRENCE RADIATION LABORATORY,
C     BERKELEY.
C...  INPUTS ARE  F - EXTERNAL FUNCTION TO BE INTEGRATED
C                 A, B - LOWER AND UPPER BOUNDS OF THE INTERVAL, RESPECTIVELY
C     OUTPUTS ARE AREA - RESULTING APPROXIMATE VALUE OF THE INTEGRAL
C                 RMBRG - ERROR CODE - 1 IF REQUIRED ACCURACY NOT REACHED.
C                         OTHERWISE, RMBRG = NUMBER OF SUBDIVISIONS REQUIRED TO
C                         OBTAIN SPECIFIED ACCURACY.
C..   THIS ROUTINE IS SPECIFIC TO A CONTROL DATA CORPORATION 6000-SERIES
C     (CDC 6400/6500/6600) MACHINE.
      DATA MXR,MXC,INDEF/20,4,1777000000000000000B/
      DIMENSION T(20,20)
      COMMON /VARIAB/ ITER,TOLER,ACC
      AI=0.
      IF(EPS .LT. 0.) AI=AREA
      ERR=0.
      BA=B-A
      TNEW=(F(A) + F(B) ) /2.
      T(1,1)=TNEW
      DEN1=1.
         DO 100 L=2,MXR
         RMBRG= L
         DEN2=2 * DEN1
         DX=BA/DEN2
         KUP=DEN2-1.
         SUM=0.0
            DO 120 K=1,KUP,2
            X=A+K*DX
  120       SUM=SUM+F(X)
         T(L,1) = (SUM/DEN1 + T(L-1,1))/2.
         D4=1.
         JC=MIN0(L,MXC)
         IF(JC .EQ. 1 ) GO TO 210
            DO 200 J=2,JC
            D4=4.*D4
  200       T(L,J)=T(L,J-1)+(T(L,J-1) -T(L-1,J-1))/(D4-1.)
  210    TOLD=TNEW
         TNEW=T(L,JC)
         DA=TNEW-TOLD
         IF(ABS(DA) .LE. ABS(EPS*(TNEW+AI)) ) GO TO 150
      IF(L.GT.ITER) GO TO 101
  100    DEN1=DEN2
  101 RMBRG=-1.
      ERR=DA*BA
C****************************** ERROR RETURN ******************************
      AREA = INDEF . OR. MXR
      RETURN
C**************************************************************************
  150 AREA=TNEW*BA
      RETURN
      END
```

```
      PROGRAM FINESCT (INPUT,OUTPUT)
C...  FINESCT CALCULATES THE MAGNETIC FIELD INTENSITY
C     SCATTERED BY A FINITELY CONDUCTING CYLINDER IN A CONDUCTIVE
C     WHOLE SPACE.THE INCIDENT PLANE WAVE IS ASSUMED TO BE POLARIZED
C     SUCH THAT THE ELECTRIC FIELD VECTOR IS PARALLEL TO THE LONG AXIS
C     OF THE CYLINDER. THE INCIDENT FIELD IS ASSUMED TO BE THE
C     TRANSMITTED FIELD OF A WAVE NORMALLY INCIDENT (PHI=180.) UPON
C     A CONDUCTIVE HALF SPACE.
C...  INPUTS ARE...LLX - THE NUMBER OF STATIONS.
C                   NZINC - THE NUMBER OF DEPTHS OF BURIAL TO BE
C                           CONSIDERED.
C                   LSTOP - THE NUMBER OF TERMS TO WHICH THE SERIES HAS
C                           BEEN TRUNCATED.
C                   PHI - THE ANGLE OF INCIDENCE, MEASURED CLOCKWISE
C                         FROM THE VERTICAL Z-AXIS (IT WILL DIFFER FROM
C                         180. IF A HALF SPACE TRANSMITTED FIELD IS NOT
C                         NECESSARILY BEING CONSIDERED.)
C                   HO - THE INCIDENT FIELD INTENSITY. (NORMALLY TAKEN
C                        TO BE 1.)
C                   XO - THE INITIAL STATION.
C                   XINT - THE STATION INTERVAL.
C                   R - THE RADIUS OF THE CYLINDER.
C                   ZO - THE DEPTH TO THE TOP OF THE CYLINDER.
C                   FREQ - THE FREQUENCY OF THE INCIDENT FIELD.
C                   DIECST1 - THE DIELECTRIC CONSTANT OF THE WHOLE SPACE.
C                   MAGPER1 - THE MAGNETIC PERMEABILITY OF THE WHOLE
C                             SPACE.
C                   DIECST2 - THE DIELECTRIC CONSTANT OF THE CYLINDER.
C                   MAGPER2 - THE MAGNETIC PERMEABILITY OF THE CYLINDER.
C                   CONDUC1 - THE CONDUCTIVITY OF THE WHOLE SPACE.
C                   CONDUC2 - THE CONDUCTIVITY OF THE CYLINDER.
C...  SUBROUTINES CALLED BY FINESCT ARE - BESZIP,HINTGR, AND BESK.
C...  NOTE THAT ALL UNITS ARE MKS.
      DIMENSION XT(100),SHXR(100),SHZR(100),SHXI(100),SHZI(100),PHASEX(1
     100),PHASEZ(100),HSECX(100),HSECZ(100),DIPMAJ(100),ZO(10)
      DIMENSION HELP(110),OUT1(110),HL1C1(110),HL1(110),OUT2(110)
      DIMENSION DERJK1(110),DERHK1(110),FI(110),CURRK(110),CURRM(110),
     1PHASEK(110),PHASEM(110),AMPK(110),AMPM(110)
      COMPLEX ARG,ARGCST1,OUT1,HL1C1,HL2C1,HELP,OUTO1,HL1CO,HELPO,AJAY,
     1HC,HL1,HL2,AJAYP,AJAYN,SUMPHI,SUMRHO,CST,HILL,WHOLE,TERM,HPHI,HRHO
     2,HL2CO,CNO,ZIP1,ZIP2,DERJK1,DERJK2,DERHK1,CN
      COMPLEX ARGCST2,OUT2,TOP,BOTTOM,OUTO2,TOPO,BOTTOMO
      COMPLEX ZAIR,ZEARTH,ZRATIO,HREFL,COEFF,AIMP1,AIMP2,PROPCT1,PROPCT2
      COMPLEX ADDK,ADDM,CURRK,CURRM
      REAL MAGPER1,MU1,IMAGK1,MAGPER2,MU2,IMAGK2
      READ 1, LOOP
      DO 2000 LOO=1,LOOP
      READ 1, LLX,NZINC,LSTOP,NPHI
      READ 2, PHI,HO,XO,XINT,R
      READ 2, (ZO(NZ),NZ=1,NZINC)
      READ 2, FREQ,DIECST1,MAGPER1,DIECST2,MAGPER2
      READ 3, CONDUC1,CONDUC2
    1 FORMAT (9I3)
    2 FORMAT (8F9.4)
    3 FORMAT (5E15.7)
    5 FORMAT (8E15.7)
   10 FORMAT (1H1)
```

```
11 FORMAT (1H0)
   FOURPI=12.566370614359173
   TWOPI=6.2831853071795865
   HALFPI=1.570796326794897
   TWOIPI=.6366197723675813
   RADIAN=.017453292519943296
   FOUR=4.000000000000000
   THREE=3.0000000000000000
   TWO=2.00000000000000
   ONE=1.00000000000000
   ZERO=.000000000000000
   AJAY=CMPLX(ZERO,ONE)
   PHI=PHI*RADIAN
   HX=HO*SIN(PHI-HALFPI)
   OMEGA=TWOPI*FREQ
   AMU=FOURPI*1.E-07
   MU1=MAGPER1*AMU
   MU2=MAGPER2*AMU
   EPA=8.8539803E-12
   EPSILO1=DIECST1*EPA
   EPSILO2=DIECST2*EPA
   CONAIR=1.E-17
   AAIR=CONAIR/(EPA*OMEGA)
   AAIR2=AAIR*AAIR
   ARAIR=SQRT(ONE+AAIR2)
   BAIR=AMU*EPA/TWO
   AIRKR=OMEGA*SQRT(BAIR*(ARAIR+ONE))
   AIRKI=OMEGA*SQRT(BAIR*(ARAIR-ONE))
   ZAIR=AMU*OMEGA/(CMPLX(AIRKR,AIRKI))
   A1=CONDUC1/(EPSILO1*OMEGA)
   AS1=A1*A1
   AR1=SQRT(ONE+AS1)
   B1=MU1*EPSILO1/TWO
   REALK1=OMEGA*SQRT(B1*(AR1+ONE))
   IMAGK1=OMEGA*SQRT(B1*(AR1-ONE))
   A2=CONDUC2/(EPSILO2*OMEGA)
   AS2=A2*A2
   AR2=SQRT(ONE+AS2)
   B2=MU2*EPSILO2/TWO
   REALK2=OMEGA*SQRT(B2*(AR2+ONE))
   IMAGK2=OMEGA*SQRT(B2*(AR2-ONE))
   PROPCT1=CMPLX(REALK1,IMAGK1)
   PROPCT2=CMPLX(REALK2,IMAGK2)
   ABSK1=CABS(PROPCT1)
   ABSK2=CABS(PROPCT2)
   WAVEL1=TWOPI/REALK1
   WAVEL2=TWOPI/REALK2
   AIMP1=MU1*OMEGA/PROPCT1
   AIMP2=MU2*OMEGA/PROPCT2
   ZEARTH=AIMP1
   ZRATIO=ZEARTH/ZAIR
   HREFL=((ONE-ZRATIO)/(ONE+ZRATIO))*HX
   HORRE=HX+REAL(HREFL)
   HORIM=AIMAG(HREFL)
   PHASEO=ATAN2(HORIM,HORRE)
   HHOR2=HORRE*HORRE+HORIM*HORIM
```

```
      HHOR=SQRT(HHOR2)
      XT(1)=X0
      DO 100 LX=1,LLX
  100 XT(LX+1)=XT(LX)+XINT
      ARGCST1=CMPLX(REALK1*R,IMAGK1*R)
      ARGCST2=CMPLX(REALK2*R,IMAGK2*R)
      CALL BESZIP(ZERO,OUT01,ARGCST1,4,15)
      CALL BESZIP(ONE,OUT1(1),ARGCST1,4,15)
      CALL HINTGR(0,ARGCST1,HL1C0,HL2C0)
      CALL HINTGR(1,ARGCST1,HL1C1(1),HL2C1)
      IF(CONDUC2-1.E+03) 101,101,102
  101 CALL BESZIP(ZERO,OUT02,ARGCST2,4,15)
      CALL BESZIP(ONE,OUT2(1),ARGCST2,4,15)
      CN0=AIMP2*OUT02/(AIMP1*OUT2(1))
      TOP0=OUT01-CN0*OUT1(1)
      BOTTOM0=HL1C0-CN0*HL1C1(1)
      HELP0=-TOP0/BOTTOM0
      GO TO 103
  102 HELP0=-OUT01/HL1C0
  103 CONTINUE
      DO 120 L=1,LSTOP
      LP1=L+1
      ORD=FLOAT(LP1)
      CALL BESZIP(ORD,OUT1(LP1),ARGCST1,4,15)
      CALL HINTGR(LP1,ARGCST1,HL1C1(LP1),HL2C1)
      IF(CONDUC2-1.E+03) 105,105,110
  105 CALL BESZIP(ORD,OUT2(LP1),ARGCST2,4,15)
      ZIP1=(FLOAT(L))/ARGCST1
      ZIP2=(FLOAT(L))/ARGCST2
      DERJK1(L)=ZIP1*OUT1(L)-OUT1(LP1)
      DERJK2=ZIP2*OUT2(L)-OUT2(LP1)
      DERHK1(L)=ZIP1*HL1C1(L)-HL1C1(LP1)
      CN=AIMP2*OUT2(L)/(AIMP1*DERJK2)
      TOP=OUT1(L)-CN*DERJK1(L)
      BOTTOM=HL1C1(L)-CN*DERHK1(L)
      HELP(L)=-TOP/BOTTOM
      GO TO 120
  110 HELP(L)=-OUT1(L)/HL1C1(L)
  120 CONTINUE
      DO 300 NZ=1,NZINC
      HEIGHT=Z0(NZ)+R
      TRANSL=REALK1*HEIGHT
      COEFF=(TWO/(ONE+ZRATIO))*EXP(-IMAGK1*HEIGHT)
      HC=COEFF*CMPLX(-SIN(TRANSL),COS(TRANSL))
      PRINT 10
      DO 200 LX=1,LLX
      RHO=SQRT(HEIGHT*HEIGHT+XT(LX)*XT(LX))
      ARG=CMPLX(REALK1*RHO,IMAGK1*RHO)
      CALL HINTGR(1,ARG,HL1(1),HL2)
      AJAYP=CMPLX(ONE,ZERO)
      AJAYN=AJAYP
      AL1=ONE
      SUMPHI=CMPLX(ZERO,ZERO)
      SUMRHO=CMPLX(ZERO,ZERO)
      PPHI=ATAN2(XT(LX),HEIGHT)
      DO 140 L=1,LSTOP
```

```
      LLU=L+1
      CALL HINTGR(LLU,ARG,HL1(LLU),HL2)
      AL1=-AL1
      AL2=-AL1
      AJAYN=AJAYN*AJAY
      AJAYP=AL1*AJAYN
      AL=FLOAT(L)
      TRGARG=AL*PPHI
      CST=AJAYP*HELP(L)
      HILL=AL*CST*HL1(L)
      WHOLE=(HILL/ARG-HL1(LLU)*CST)*COS(TRGARG)
      SUMPHI=SUMPHI+WHOLE
      SUMRHO=SUMRHO+HILL*SIN(TRGARG)
  140 CONTINUE
      TERM=-HELPO*HL1(1)
      HPHI=TERM+TWO*SUMPHI
      HPHI=HC*HPHI
      HRHO=TWO*HC*SUMRHO/ARG
      PRINT 5, TERM,WHOLE,HPHI
      PRINT 5, TERM,HILL,HRHO
      HPHIR=REAL(HPHI)
      HPHII=AIMAG(HPHI)
      HRHOR=REAL(HRHO)
      HRHOI=AIMAG(HRHO)
      TILL=HEIGHT/RHO
      TOLL=XT(LX)/RHO
      SHXR(LX)=HRHOR*TOLL+HPHIR*TILL
      SHZR(LX)=HRHOR*TILL-HPHIR*TOLL
      SHXI(LX)=HRHOI*TOLL+HPHII*TILL
      SHZI(LX)=HRHOI*TILL-HPHII*TOLL
      PHASX=ATAN2(SHXI(LX),SHXR(LX))
      PHASZ=ZERO
      IF(SHZI(LX).EQ.0..AND.SHZR(LX).EQ.0.) GO TO 141
      PHASZ=ATAN2(SHZI(LX),SHZR(LX))
  141 PHASEX(LX)=PHASX/RADIAN
      PHASEZ(LX)=PHASZ/RADIAN
      TUE=SHXI(LX)*SHXI(LX)+SHXR(LX)*SHXR(LX)
      WED=SHZI(LX)*SHZI(LX)+SHZR(LX)*SHZR(LX)
      HSECX(LX)=SQRT(TUE)
      HSECZ(LX)=SQRT(WED)
      THUR=HSECZ(LX)*(HHOR*COS(PHASZ-PHASEO)+HSECX(LX)*COS(PHASX-PHASZ))
      FRI=(TUE-WED+HHOR2+TWO*HHOR*HSECX(LX)*COS(PHASX-PHASEO))
      SAT=-THUR
      ROOT=SQRT(FRI*FRI-FOUR*THUR*SAT)
      DENOM=TWO*THUR
      DIPMAJ(LX)=ZERO
      IF(DENOM.EQ.0.) GO TO 200
      DIPMAJ(LX)=(ATAN((-FRI+ROOT)/DENOM))/RADIAN
  200 CONTINUE
      PRINT 10
      PRINT 710
  710 FORMAT(20X*MAGNETIC FIELDS ABOVE TWO DIMENSIONAL INHOMOGENEITIES I
     1N A CONDUCTIVE WHOLE SPACE*)
      PRINT 11
      PRINT 715
  715 FORMAT (5X,*PARAMETERS OF THE WHOLE SPACE ARE ....*)
```

```
      PRINT 720, CONDUC1,DIECST1,MAGPER1
  720 FORMAT (10X,*CONDUCTIVITY =*1PE12.3,*,*5X,*DIELECTRIC CONSTANT =*1
     1PE12.3,*,*5X,*MAGNETIC PERMEABILITY =*1PE12.3)
      PRINT 11
      PRINT 725
  725 FORMAT (5X,*PARAMETERS OF THE CYLINDER ARE ....*)
      PRINT 720, CONDUC2,DIECST2,MAGPER2
      PRINT 726, R
  726 FORMAT (10X,*RADIUS =*1PE12.3)
      PRINT 11
      PRINT 730
  730 FORMAT (5X,*PARAMETERS OF THE SURVEY ARE ....*)
      PRINT 735, FREQ,WAVEL1,AIMP1
  735 FORMAT (10X,*FREQUENCY =*1PE12.3,*,*5X,*WAVELENGTH 1 =*1PE12.3,*,*
     15X,*WAVE IMPEDANCE 1 =*2(1PE12.3))
      PHIANG=PHI/RADIAN
      PRINT 736, PHIANG,WAVEL2,AIMP2
  736 FORMAT (10X,*ANGLE OF INC =*F9.2,*,*5X,*WAVELENGTH 2 =*1PE12.3,*,*
     15X,*WAVE IMPEDANCE 2 =*2(1PE12.3))
      PRINT 11
      PRINT 740, ZO(NZ)
  740 FORMAT (35X,3HZ =F12.3)
      PRINT 11
      PRINT 745
  745 FORMAT (10X,*HXR*10X,*HXI*6X,*X PHASE*11X,*HX*10X,*HZR*10X,*HZI*6X
     1,*Z PHASE*11X,*HZ*4X,*DIP MAJOR*6X,*STATION*)
      PRINT 11
      PRINT 750, (SHXR(LX),SHXI(LX),PHASEX(LX),HSECX(LX),SHZR(LX),SHZI(L
     1X),PHASEZ(LX),HSECZ(LX),DIPMAJ(LX),XT(LX),LX=1,LLX)
  750 FORMAT (9(1X,1PE12.4),3X,0PF8.3)
      IF(CONDUC2.GT.1.E+03) GO TO 300
      ANGLE=TWOPI/FLOAT(NPHI)
      FI(1)=ZERO
      DO 800 N=2,NPHI
  800 FI(N)=FI(N-1)+ANGLE
      DO 820 N=1,NPHI
      ADDK=CMPLX(ZERO,ZERO)
      ADDM=CMPLX(ZERO,ZERO)
      AJAYN=CMPLX(ONE,ZERO)
      DO 810 L=1,LSTOP
      AJAYN=AJAYN/AJAY
      TRG=COS(FLOAT(L)*FI(N))
      ADDK=ADDK+AJAYN*(DERJK1(L)+HELP(L)*DERHK1(L))*TRG
  810 ADDM=ADDM+AJAYN*(OUT1(L)+HELP(L)*HL1C1(L))*TRG
      ADDK=TWO*ADDK-OUT1(1)-HELPO*HL1C1(1)
      ADDM=TWO*ADDM+OUTO1+HELPO*HL1CO
      CURRK(N)=HC*ADDK
      CURRM(N)=-ZEARTH*HC*ADDM/AJAY
      PHASEK(N)=ATAN2(AIMAG(CURRK(N)),REAL(CURRK(N)))/RADIAN
      PHASEM(N)=ATAN2(AIMAG(CURRM(N)),REAL(CURRM(N)))/RADIAN
      AMPK(N)=CABS(CURRK(N))
  820 AMPM(N)=CABS(CURRM(N))
      PRINT 10
      PRINT 410
  410 FORMAT (15X*DISTRIBUTION OF INDUCED CURRENTS*)
      PRINT 11
```

```
      PRINT 420
  420 FORMAT (10X,*REAL PART*2X,*IMAGINARY PART*9X,*MODULUS*11X*PHASE*)
      PRINT 11
      PRINT 430
  430 FORMAT (5X*ELECTRIC CURRENTS*)
      PRINT 11
      DO 440 N=1,NPHI
      PRINT 435, CURRK(N),AMPK(N),PHASEK(N)
  435 FORMAT (1H02X,8E16.8)
  440 CONTINUE
      PRINT 10
      PRINT 450
  450 FORMAT (5X*MAGNETIC CURRENTS*)
      PRINT 11
      DO 460 N=1,NPHI
      PRINT 435, CURRM(N),AMPM(N),PHASEM(N)
  460 CONTINUE
  300 CONTINUE
 2000 CONTINUE
      STOP
      END
```

```
      SUBROUTINE BESZIP (ORD,OUT,ARG,NTERMS,NLOW)
C..   INPUTS ARE ORD (ORDER OF THE BESSEL FUNCTION OF THE FIRST KIND)
C                ARG (COMPLEX ARGUMENT OF THE BESSEL FUNCTION OF THE
C                     FIRST KIND)
C                NTERMS (NUMBER OF TERMS TO BE USED IN THE ASYMPTOTIC
C                        EXPANSION)
C                NLOW (NUMBER OF TERMS TO BE USED IN THE SERIES EXPANSION)
C...  OUTPUTS ARE OUT (COMPLEX ANSWER)
      COMPLEX ARG,FA,ECH,COSFAC,SINFAC,PLAY,TERMC,TERMS,OUT
      DIMENSION FA  (200)
      NORD = IFIX(ORD)
      FL = 1.0
      IF(NORD .EQ. 0) GO TO 800
      DO 805 K = 1,NORD
  805 FL = FL*FLOAT(K)
  800 CONTINUE
      N2T=2*NTERMS
      IF(CABS(ARG).LT.12.0) N2T=NLOW
      ECH=(1.0,0.0)
      DO 720 J=1,N2T
      NQ=J+1
      NR=J
      NP=(2*J)-1
      PQ=FLOAT(NP)
      QUIP=FLOAT(NR)
      IF(CABS(ARG).LT.12.0) GO TO 790
      FA  (J)=(((-1.0)**NQ)*((4.0*(ORD**2))-(PQ**2)))/(FLOAT(NR)*8.0*ARG
     1)
      GO TO 791
  790 FA  (J)=(ARG*ARG*0.250)/(QUIP*(ORD+QUIP) )
  791 FA  (J)=FA  (J)*ECH
  720 ECH=FA  (J)
      COSFAC=(0.0,0.0)
      SINFAC=(0.0,0.0)
      DO 780 J=2,N2T,2
      COSFAC=COSFAC+FA  (J)
  780 SINFAC=SINFAC+FA  (J-1)
      IF(CABS(ARG).LT.12.0) GO TO 792
      PLAY=ARG-0.785398-(1.57079*ORD)
      TERMC=(CCOS(PLAY))*(1.0+COSFAC)
      TERMS=(CSIN(PLAY))*SINFAC
      OUT=(0.797884*(TERMC-TERMS))/CSQRT(ARG)
      GO TO 793
  792 OUT=(((ARG*0.5)**NORD)*(1.0+COSFAC-SINFAC))*(1.0/FL)
  793 RETURN
      END
```

```
      SUBROUTINE HINTGR(N,Z,H1,H2)
C...  SUBROUTINE HINTGR CALCULATES HANKEL FUNCTIONS OF THE FIRST AND
C     SECOND KIND FROM THE MODIFIED BESSEL FUNCTION (K) OF THE SECOND
C     KIND.
C...  INPUTS ARE  N - INTEGER ORDER OF THE HANKEL FUNCTION
C                 Z - COMPLEX ARGUMENT
C     OUTPUTS ARE H1 - COMPLEX ANSWER (HANKEL FUNCTION OF THE FIRST KIND)
C                 H2 - COMPLEX ANSWER (HANKEL FUNCTION OF THE SECOND KIND)
      COMPLEX Z,H1,H2,AJAY,ARG,BK
      PI=3.14159265358979
      TWOIPI=.63661977236758134
      TWO=2.000000000000000
      ONE=1.0000000000000
      ZERO=0.000000000000000
      AJAY=CMPLX(ZERO,ONE)
      ARG=-AJAY*Z
      CALL BESK(ARG,N,BK,IER)
      IF(IER) 9,20,9
    9 PRINT 10, IER
   10 FORMAT (25X,*IER =*I9)
      CALL EXIT
   20 TARG=FLOAT(N)*PI/TWO
      H1=-CMPLX(TWOIPI*SIN(TARG),TWOIPI*COS(TARG))*BK
      H2=CONJG(H1)
      RETURN
      END
```

```
      SUBROUTINE BESK(X,N,BK,IER)
C...  SUBROUTINE BESK CALCULATES MODIFIED BESSEL FUNCTIONS (K) OF THE
C     SECOND KIND.  THIS ROUTINE HAS BEEN MODIFIED FROM THAT GIVEN IN THE
C     I.B.M. SCIENTIFIC SUBROUTINE PACKAGE (V. 2) TO INCLUDE COMPLEX
C     ARGUMENTS.
C...  INPUTS ARE  X - COMPLEX ARGUMENT
C                 N - INTEGER ORDER
C     OUTPUTS ARE BK - COMPLEX ANSWER
C                 IER - ERROR CODE - 0 - NORMAL RETURN
C                                    1 - THE ORDER (N) IS NEGATIVE
C                                    3 - ABSOLUTE VALUE OF THE ARGUMENT
C                                        EXCEEDS 170.
C                                    4 - ABSOLUTE VALUE OF THE ANSWER
C                                        EXCEEDS 10.**70.
      DIMENSION T(14)
      COMPLEX X,BK,G0,G1,T,A,B,C,GJ,X2J
      TWO=2.000000000000000
      ONE=1.000000000000000
      ZERO=0.000000000000000000
      BK=CMPLX(ZERO,ZERO)
      IF(N)10,11,11
   10 IER=1
      RETURN
   11 CX=CABS(X)
      IF(CX-170.) 22,22,21
   21 IER=3
      RETURN
   22 IER=0
      IF(CX-4.5) 36,36,25
   25 A=CEXP(-X)
      B=ONE/X
      C=CSQRT(B)
      T(1)=B
      DO 26 L=2,12
   26 T(L)=T(L-1)*B
      IF(N-1) 27,29,27
C
C...  COMPUTE K0 USING POLYNOMIAL APPROXIMATION.
C
   27 G0=A*(1.2533141373-.1566641816*T(1)+.0881112782*T(2)-.0913909546*T
     1(3)+.1344596228*T(4)-.2299850328*T(5)+.3792409730*T(6)-.5247277331
     2*T(7)+.5575368367*T(8)-.4262632912*T(9)+.2184518096*T(10)-.0668097
     3672*T(11)+.0091893830*T(12))*C
      IF(N) 10,28,29
   28 BK=G0
      RETURN
C
C...  COMPUTE K1 USING POLYNOMIAL APPROXIMATION.
C
   29 G1=A*(1.2533141373+.4699927013*T(1)-.1468582957*T(2)+.1280426636*T
     1(3)-.1736431637*T(4)+.2847618149*T(5)-.4594342117*T(6)+.6283380681
     2*T(7)-.6632295430*T(8)+.5050238576*T(9)-.2581303765*T(10)+.0788000
     3118*T(11)-.0108241775*T(12))*C
      IF(N-1) 10,30,31
   30 BK=G1
      RETURN
```

```
C
C...  FROM K0, K1, COMPUTE KN USING RECURRENCE RELATION.
C
   31 DO 35 J=2,N
      GJ=TWO*(FLOAT(J)-ONE)*G1/X+G0
      IF(CABS(GJ)-1.0E70) 33,33,32
   32 IER=4
      GO TO 34
   33 G0=G1
   35 G1=GJ
   34 BK=GJ
      RETURN
   36 B=X/TWO
      A=.5772156649+CLOG(B)
      C=B*B
      IF(N-1) 37,43,37
C
C...  COMPUTE K0 USING SERIES EXPANSION.
C
   37 G0=-A
      X2J=CMPLX(ONE,ZERO)
      FACT=ONE
      HJ=ZERO
      DO 40 J=1,10
      RJ=ONE/FLOAT(J)
      X2J=X2J*C
      FACT=FACT*RJ*RJ
      HJ=HJ+RJ
   40 G0=G0+X2J*FACT*(HJ-A)
      IF(N) 43,42,43
   42 BK=G0
      RETURN
C
C...  COMPUTE K1 USING SERIES EXPANSION.
C
   43 X2J=B
      FACT=ONE
      HJ=ONE
      G1=ONE/X+X2J*(.5+A-HJ)
      DO 50 J=2,12
      X2J=X2J*C
      RJ=ONE/FLOAT(J)
      FACT=FACT*RJ*RJ
      HJ=HJ+RJ
   50 G1=G1+X2J*FACT*(.5+(A-HJ)*FLOAT(J))
      IF(N-1) 31,52,31
   52 BK=G1
      RETURN
      END
```