SECTION V

A study on the behavior of ingressive signals in a C.A.T.V. drop subject to various ground references

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"THE EVALUATION OF INGRESS AND EGRESS

PROBLEMS IN THE C.A.T.V. SUB LOW FREQUENCY SPECTRUM"

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CONTENTS

I (Cont'd)

FIGURES

III
GRAPHS

III (Cont'd)

PAGE

III (Cont'd) PAGE

IV

TABLES

APPENDICES

SYMBOLS USED

ℓ.........Length of drop

ω.........Angular frequency

Δz.......Incremental Length

γ.........Propogation constant

Ω.........Ohms

$>$.........Greater than

$<$.........Less than

α.........Attenuation constant of transmission line

β.........Phase constant of transmission line

f.........Frequency in hertz

∞.........Infinity

VII

INTRODUCTION

A theoretical analysis has been completed to analyse the effect of different grounding references and spacing on drop wire.

The material described herin makes use of transmission line theory to model ingressive signals in a drop line due to surrounding electromagnetic fields.

This section consists of four main subsections. Subsection one abbreviates the general theory of transmission lines. Subsection two expands this theory to model a simplified C.A.T.V. distribution system. Subsection three represents in a graphical format the theory developed in subsection two, while subsection four tries to correlate this theory with experimental results. A large amount of computer work was necessary to simulate this analysis, and pertinent computer programs are included in Appendix 5.3.1 and in 5.3.2.

5.1.0 DEVELOPMENT and DERIVATION of GENERAL MODEL

A typical signal distribution drop is shown in figure 5.1.1.

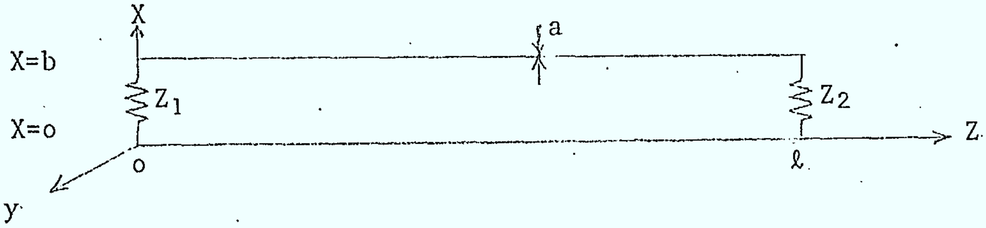


Figure 5.1.1
Typical signal distribution drop

b ... height above ground (meters).

ℓ ... length of drop (meters)

Z_1, Z_2 ground impedance (ohms)

a ... diameter of drop (meters).

Assuming that the earth acts as a perfect ground plane, then by the method of image the drop shown in figure 5.1.1 can be represented as a transmission line. See figure 5.1.2.

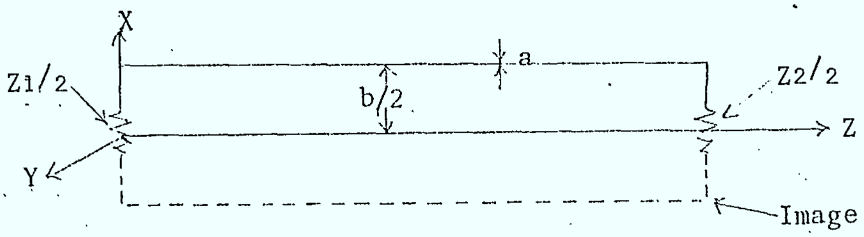


Figure 5.1.2.
General distribution drop represented as a transmission line

It is well known that a short section of a transmission line can be symbolized as in figure 5.1.3.

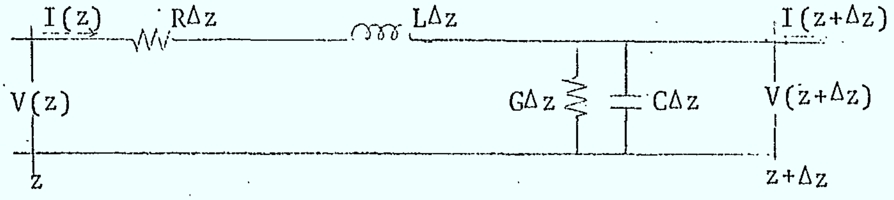


Figure 5.1.3:
Representation of a short section of a transmission line

Applying Kirchoff's law and letting the incremental distance Δz become very small (i.e. $\Delta z \to 0$), two differential equations to model a uniform transmission line can be found.

$$\frac{dV(z)}{dz} = -(R + j\omega L)\, I(z) \quad \ldots\ldots 1$$

$$\frac{dI(z)}{dz} = -(G + j\omega C)\, V(z) \quad \ldots\ldots 2$$

Note that in 1 and 2 the sinusoidal time factor $e^{j\omega t}$ is implied.

Differentiating and substituting, 1 and 2 yields

$$\frac{d^2V(z)}{dz^2} = (R + j\omega L)(G + j\omega C)\, V(z) \quad \ldots\ldots 3$$

$$\frac{d^2I(z)}{dz^2} = (R + j\omega L)(G + j\omega C)\, I(z) \quad \ldots\ldots 4$$

The solution of 3 and 4 can easily be verified by differentiation and substitution of equation 5 and 6.

$$V(z) = VA\, e^{-\gamma z} + VBe^{\gamma z} \qquad ....5$$

$$I(z) = IA\, e^{-\gamma z} + IBe^{\gamma z} \qquad ....6$$

WHERE: γ .... propagation constant

$\gamma^2 = (R + j\omega L)\ (G + j\omega C)$

VA, VB, IA, IB, ... constants to be determined by boundary conditions

Differentiating equation 5 and substituting into equation 1, and then solving for I(z) equation 6 may be rewritten in terms of VA and VB

$$I(z) = \frac{1}{Zo}\ (VAe^{-\gamma z} - VBe^{\gamma z}) \qquad ....7$$

WHERE: Zo ....characteristic impedance of the line

$= \sqrt{Z/Y} = \sqrt{(R + j\omega L)\ /\ (G + j\omega C)}$

5.1.1 Boundary Conditions

Let at $z = 0$, $V(0) = Vs$

$z = \ell \quad V(\ell) = V\ell = I(\ell)/Z\ell$

WHERE: Vs ..... source voltage

$V\ell$ ..... load voltage

$I(\ell)$ ... load current

$Z\ell$ ..... load impedance

Solving equations 5 and 6 subject to the above boundary conditions for VA and VB

$$VA = Vs/2 \quad \ldots\ldots\ldots\ldots 8$$

$$VB = \frac{Vs}{2} e^{-2\gamma\ell} \left[\frac{Z\ell - Zo}{Z\ell + Zo} \right] \quad \ldots\ldots\ldots\ldots 9$$

Using the hyperbolic identities

$$\sinh(x) = \frac{e^{x} - e^{-x}}{2}$$

$$\cosh(x) = \frac{e^{x} + e^{-x}}{2}$$

and solving equations 5 and 7 for VA and VB. The transmission line equation may be rewritten as follows

$$V(z) = Vs \left(\cosh(\gamma z) - \frac{Zo}{Zin} \sinh(\gamma z)\right) \quad \ldots\ldots\ldots\ldots 10$$

$$I(z) = Vs \left(\frac{1}{Zin} \cosh(\gamma z) - \frac{1}{Zo} \sinh(\gamma z) \right. \quad \ldots\ldots\ldots\ldots 11A$$

$$= I(o) \left(\cosh(\gamma z) - Zin/Zo \sinh(\gamma z) \right. \quad \ldots\ldots\ldots\ldots 11B$$

WHERE: $$Zin = \frac{V(o)}{I(o)} = Zo \frac{Z\ell + Zo \tanh(\gamma\ell)}{Zo + Z\ell \tanh(\gamma\ell)} \quad \ldots\ldots\ldots\ldots 12$$

Zin is found by solving equations 5 and 7 with equations 8 and 9 substitued in.

The impedance anywhere in the line can now be easily found.

$$Z(z) = \frac{V(z)}{I(z)} = Zo \frac{Z\ell + Zo \tanh^{\gamma}(\ell - z)}{Zo + Z\ell \tanh\gamma(\ell - z)} \quad \ldots\ldots\ldots\ldots 13$$

5.2.0 DERIVATION of CATV MODEL

5.2.1 Narrative Description of Problem

An electromagnetic wave incident to a shielded cable will excite a current distribution on the cable's outer shield. Since the shield is not a perfect conductor this current penetrates the shield and produces a voltage distribution along the inside length of the cable. This in turn produces an unwanted current in the internal load impedances. Figure 5.2.1 shows a graphical representation of a simplified C.A.T.V. drop wire.

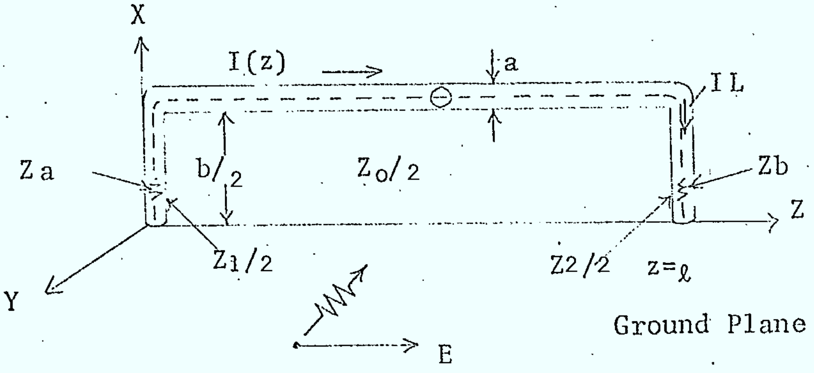


Figure 5.2.1
Simplified CATV distribution system

WHERE: E .... electric field

I(z)....... sheath current distribution(A)

ℓ .... length of cable (m)

b/2 .... height of cable above ground plane(m)

a .... outside diameter of cable (m)

$\frac{Z1}{2}$, $\frac{Z2}{2}$ .... terminating impedances of a cable shield treated as a single-wire transmission line over a ground plane(Ω)

Zo/2	characteristic impedances of cable shield treated as a single wire transmission line over a ground plane (Ω).
Za,Zb	interior load impedance (Ω).
Zc	characteristic impedance of coax (Ω).
IL	unwanted current in the interior load impedance Zb due to external electric field E (A).

The solution consists of representing this drop as a single wire transmission line. Having determined all important parameters for this type of transmission line, then by analogy it is possible to translate these to the coaxial line. Using this type of solution, one can then analyze the ingress current, produced (inside a coaxial line) by an external field.

5.2.2 Derivation of Sheath Current Distributions for Different Direction of Propagation and Field Polarization

An electromagnetic model of a C.A.T.V. drop representing the different existing electromagnetic fields surrounding a drop is shown in figure 5.2.2.

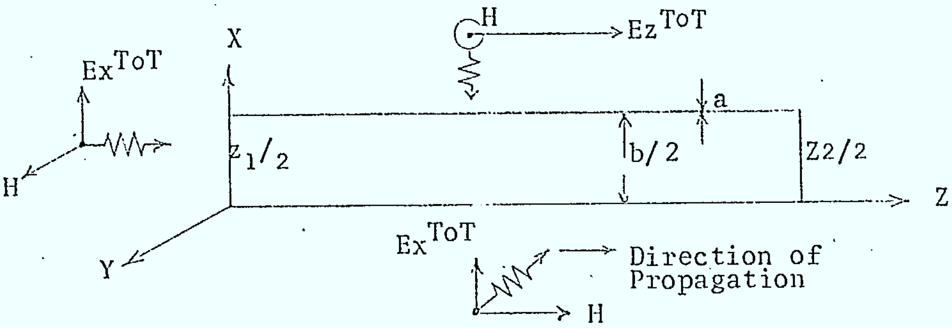


Figure 5.2.2
Electromagnetic model of C.A.T.V. drop

WHERE: E_x^{ToT} is a vertically polarized field which only excites vertical drop it is possible to look at two different directions of propagation

A. E_x^{ToT} propagating in the z direction

B. E_x^{ToT} Propagating in the -y direction

E_z^{ToT} is a horizontally polarized field that illuminates the entire cable. Direction of propagation taken to be in the xz plane.

To keep the analysis as simple as possible all these electromagnetics waves must be taken as plane waves under this constraint E_x and E_z are uniform over the length of the cable. The voltage induced on the drop may be represented as follows

$$Vs1 = \int_o^b E_x^{ToT}(x,o,\omega)dx \text{ (left vertical drop)}$$

$$Vs2 = \int_o^b E_x^{ToT}(x,\omega,\ell)dx \text{ (right vertical drop)}$$

$$\int d(V(z)) = \int_o^{\ell} K(z,\omega)dz \text{ (horizontal drop)}$$

WHERE: $k(z,\omega) = E_z^{ToT}(b,z,\omega) - E_z^{ToT}(o,z,\omega)$

The next step in the analysis is to derive an expression for the voltage and current distribution, in terms of the source voltage, source impedance and load impedance. This can be done by analysing a transmission line being driven at both ends, and a line which has distributed sources along its horizontal conductors.

5.2.3 DERIVATION of CURRENT DISTRIBUTION on VERTICAL DROP LINE

5.2.3.1 Line driven at one end

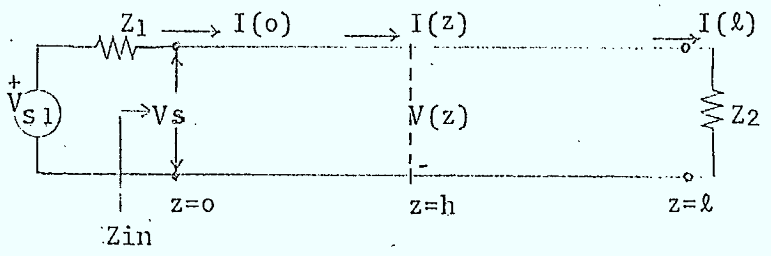


Figure 5.2.3

Representation of a transmission line being driven at one end

The sending voltage Vs shown in figure 5.2.3 is

$$Vs = \frac{Zin\ Vs_1}{Z_1 + Zin}$$

substituting into equation 11A, the expression for I(z) becomes

$$I(z) = \frac{Vs_1}{Zin+Z_1} \left[\cosh(\gamma z) - \frac{Zin}{Zo} \sinh(\gamma z) \right] \quad ....14$$

substituting 12 into 14 and using the following identities.

$$\sinh(A-B) = \sinh A \cosh B - \cosh A \sinh B$$

$$\cosh(A-B) = \cosh A \cosh B - \sinh A \sinh B$$

equation 14 becomes

$$I(z) = Vs_1 \left[\frac{Zo \cosh\gamma(\ell-z) + Z_2 \sinh\gamma(\ell-z)}{(ZoZ_1 + ZoZ_2)\cosh\gamma\ell + (Zo^2 + Z_1Z_2)\sinh\gamma\ell} \right] \quad ....15$$

The voltage distribution can easily be derived using the following definition and equation 13.

$$V(z) = I(z)\,Z(z)$$

Therefore

$$V(z) = V_{s1}\left[\frac{Z_oZ_2\cosh\gamma(\ell-z) + Z_o^2\sinh\gamma(\ell-z)}{(Z_oZ_1 + Z_oZ_2)\cosh\gamma\ell + (Z_o^2 + Z_1Z_2)\sinh\gamma\ell}\right]\ldots\ldots16$$

5.2.3.2 <u>Line driven at both ends</u>

Since voltage is generated in both drop, the above must be extended to a two conductor transmission line driven at both ends as represented by figure 5.2.4.

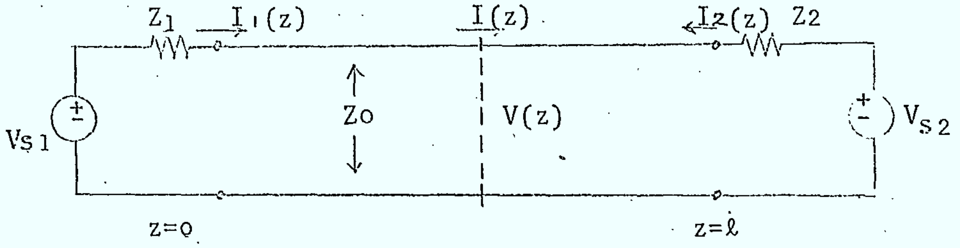


Figure 5.2.4
Representation of a transmission line being driven at both ends

The current distribution at any point on the line due to Vs1 is given by 15 as

$$I_1(z) = V_{s1}\left[\frac{Z_o\cosh\gamma(\ell-z) + Z_2\sinh\gamma(\ell-z)}{(Z_oZ_1 + Z_oZ_2)\cosh\gamma\ell + (Z_o^2 + Z_1Z_2)\sinh\gamma\ell}\right]\ldots\ldots\ldots17$$

The current distribution due to Vs2 follows directly by replacing Vs1 with Vs2, Z2 with Z1, (ℓ-z) with z.

$$I_2(z) = -V_{s2}\left[\frac{Z_o \cosh\gamma z + Z_1 \sinh\gamma z}{(Z_oZ_1 + Z_oZ_2)\cosh\gamma\ell + (Z_o^2 + Z_1Z_2)\sinh\gamma\ell}\right] \ldots\ldots\ldots 18$$

The negative sign is used to observe generator polarity as shown on figure 5.2.4.

The current distribution now becomes

$$I(z) = I_1(z) + I_2(z)$$

$$= \frac{V_{s1}}{D}\left[Z_o \cosh\gamma(\ell - z) + Z_2 \sinh\gamma(\ell - z)\right]$$

$$- \frac{V_{s2}}{D}\left[Z_o \cosh\gamma z + Z_1 \sinh\gamma z\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 19$$

WHERE: $D = (Z_oZ_1 + Z_oZ_2)\cosh\gamma\ell + (Z_o^2 + Z_1Z_2)\sinh\gamma\ell$

The generators V_{s1} and V_{s2} in figure 5.2.4 are completely independent from each other. However two cases are of special interest.

A. When both generators are identical both in phase and amplitude.

B. When both generators are identical in amplitude but displaced in phase by "$B\ell$" radians where $B = 2\pi/\lambda$, ℓ = length of drop.

Case A can be seen to occur when an electromagnetic wave travels in the -y direction as shown in figure 5.2.2.

Case B is represented by a wave travelling in the z direction where a delay will be introduced due to the span of the drop.

The current distribution for case A becomes

$$I(z) = \frac{V_s}{D}\left[Z_o \cosh\gamma(\ell - z) - Z_o \cosh\gamma z + Z_2 \sinh\gamma(\ell - z)\right.$$

$$\left. - Z_1 \sinh\gamma z\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 20$$

And the current distribution for case B due to a phase delay of $e^{-jB\ell}$ is

$$I(z) = \frac{Vs}{D} \left[Zo \cosh\gamma(\ell - z) + Z2 \sinh\gamma(\ell - z) - Zo \cosh(\gamma z)e^{-jB\ell} + Z1 \sinh(\gamma z)e^{-jB\ell} \right] \quad \ldots\ldots\ldots\ldots\ldots 21$$

5.2.4 DERIVATION of CURRENT DISTRIBUTION on the HORIZONTAL DROP LINE

5.2.4.1 Line driven at Midsection

Assume that the electromagnetic wave propagating in the xz plane will generate a single voltage source Vs(z) located at a point z = h in the midsection of the line as shown in figure 5.2.5.

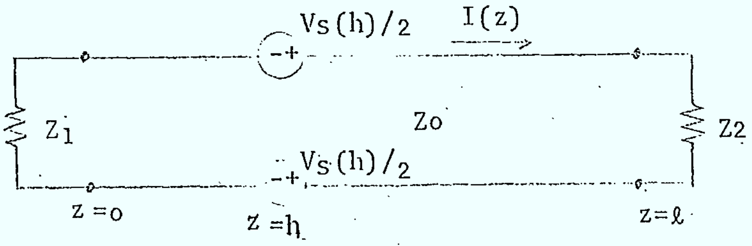


Figure 5.2.5
Representation of a transmission line
being driven at midsection

The current distribution to the right of the souce $z > h$ can be derived by replacing the left section of the line $z < h$ by its internal impedance Zin^{left}.

$$\therefore \quad Zin^{left} = Zo \left[\frac{Z1 + Zo \tanh \gamma h}{Zo + Z1 \tanh \gamma h} \right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 22$$

Similarly the impedance looking to the right of the source is

$$Zin^{right} = Zo\,\frac{Z2 + Zo\,\tanh\gamma(\ell-h)}{Zo + Z2\,\tanh\gamma(\ell-h)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 23$$

Figure 5.2.5 then becomes

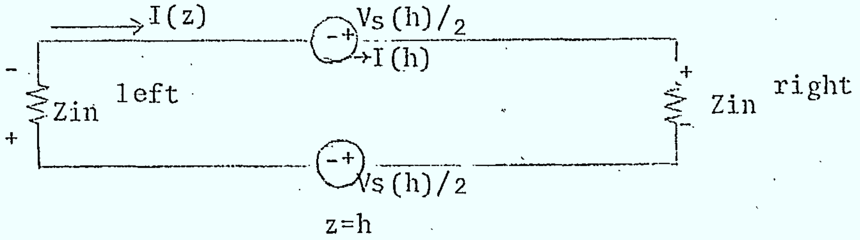


Figure 5.2.6

Equivalent circuit of a transmission line being driven at midsection

From Kirchoff's voltage law around a loop

$$I\,(h) = \frac{Vs(h)}{Zin^{left} + Zin^{right}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 24$$

using equation 11B and making the appropriate shift in co-ordinates yields.

$$I\,(z) = I\,(h)\,\left[\cosh\gamma(z-h) - \frac{Zin^{right}}{Zo}\sinh\gamma(z-h)\right] \quad \ldots\ldots\ldots\ldots 25$$

substituting equations 22, 23, 24 into equation 25 yields the final expression for I(z)

$$I^{right}(z) = \frac{Vs(h)}{ZoD}\left[Zo\cosh\gamma h + Z1\sinh\gamma h\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 26$$

$$X\ \left[Zo\cosh\gamma(\ell-z) + Z2\sinh(\ell-z)\right]$$

For z >h

$$I^{left}(z) = \frac{Vs(h)}{ZoD} [Zo \cosh \Upsilon z + Z_1 \sinh \Upsilon z] \times [Zo \cosh \Upsilon(\ell-h) + Z_2 \sinh \Upsilon(\ell-h)] \quad \ldots\ldots 27$$

for $z < h$

WHERE: $D = (ZoZ_1 + ZoZ_2) \cosh \Upsilon\ell + (Zo^2 + Z_1Z_2) \sinh \Upsilon\ell$.

5.2.4.2 Line Driven by an Infinite Number of Sources

An electromagnetic wave sweeping the horizontal drop will produce a continuous distribution of sources along the transmission line as shown in figure 5.2.7.

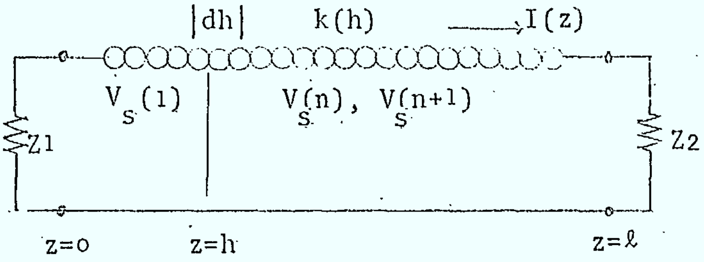


Figure 5.2.7

Representation of a transmission line being driven by an infinite number of sources

If K(h) is a continuous distribution of voltage sources along the line varying with position and having dimensions of volts per meter, then the incremental voltage on the line may be written as

$$\Delta V = V_s(n) + V_s(n+1) = K(h)\ \Delta z \quad \ldots\ldots\ldots\ldots 28$$

in the limit as Δz approaches zero equation 28 becomes

$$dV_s(h) = K(h)\ dh \quad \ldots\ldots\ldots\ldots 29$$

The current at any point z is found by substituting equation 29 for $V_s(h)$ in 26,27 and integrating over the length of the line.

$$\therefore \quad I(z) = \frac{Zo \cosh \gamma(\ell-z) + Z2 \sinh\gamma(\ell-z)}{ZoD}$$

$$\times \int_0^z K(h) \left[Zo \cosh\gamma h + Z1 \sinh \gamma h\right] dh$$

$$+ \frac{Zo \cosh\gamma z + Z1 \sinh \gamma z}{ZoD}$$

$$X \int_z^\ell K(h) \left[Zo \cosh\gamma(\ell-h) + Z2 \sinh\gamma(\ell-h)\right] dh \quad \ldots\ldots\ldots\ldots\ldots\ldots 30$$

WHERE: $D = (ZoZ1 + ZoZ2) \cosh\gamma\ell + (Zo^2 + Z1Z2) \sinh\gamma\ell$

The final expression for the current distribution due to all factors on the drop can be represented by equation 31.

$$I(z,\omega) = \underline{Zo \cosh \gamma(\ell-z) + Z2 \sinh\gamma(\ell-z)}$$

$$X \int_0^z 2\, K(h,\omega) \left[Zo \cosh\gamma h + Z1 \sinh \gamma h\right] dh$$

$$+ \frac{Zo \cosh\gamma z + Z1 \sinh\gamma z}{ZoD}$$

$$X \int_z^\ell 2K(h,\omega) \left[Zo \cosh \gamma(\ell-h) + Z2 \sinh\gamma(\ell-h)\right] dh$$

$$+ \frac{2}{D} \left[Zo \cosh \gamma(\ell-z) + Z2 \sinh\gamma(\ell-z)\right] \int_0^b Ex^i(x,o,\omega)\, dx$$

$$- \frac{2}{D} \left[Zo \cosh \gamma z + Z1 \sinh\gamma z\right] \int_0^b Ex^i(x,1,\omega)\, dx \quad \ldots\ldots\ldots\ldots 31$$

WHERE: $D = (ZoZ1 + ZoZ2) \cosh\gamma\ell + (Zo^2 + Z1Z2) \sinh\gamma\ell$

$K(h,\omega) = Ez^i(b,z,\omega) - Ez^i(o,z,\omega)$

Zo = characteristic impedance

$Ez^i(b,z,\omega)$ = field in z direction incident on upper conductor

$Ez^i(o,z,\omega)$ = field in z direction incident on lower conductor

$Ex^i(x,o,\omega)$ = field in x direction incident on left-hand termination

$Ex^i(x,l,\omega)$ = field in x direction incident on right hand termination

$\gamma = \alpha + jB$ propagation constant of line

α = attenuation constant of line

$B = 2\pi/\lambda$ phase constant of line

λ = wavelength

$\omega = 2\pi f$ angular frequency

f = frequency in hertz

Notice that a factor of 2 has been included to take into account the image of the drop.

5.2.5 DERIVATION of the LOAD CURRENT SPECTRUM

Equation 31 describes the current distribution on the shield of the drop produced by a surrounding electromagnetic field. The outer sheath current and the voltage induced along the inside of the cable are related by the surface transfer impedance.

$$d\,V(z) = Zs\,I(z)\,dz \qquad \text{.........................32}$$

where $V(z)$ = voltage induced along the inside of the cable

Zs = surface transfer impedance

the surface transfer impedance is defined in an elementary length of coaxial cable as the ratio of the potential gradient (voltage) in the disturbed circuit to the current flowing in the interfering circuit. When the cable is acting as a transmitting antenna (egressive signals) the disturbed circuit is the environment around the cable and the interfering circuit is within the cable. When the cable is acting as a receiving antenna (ingressive signals) the disturbed circuit is within the cable and the interfering circuit is the environment around the cable. Much work has been done on transfer impedance of coaxial cable. Papers on this subject can be found in references 1 to 4. Graph 5.4.12 shows the measured transfer impedance versus frequency for the most commonly used drop cables, as presented by Smith[1].

The current spectrum $I_L(\omega)$ in the interior load impedance Zb is obtained by integrating equation 32 over the length of the cable. By analogy the appropriate transmission line equation is equation 31 with $K(h,\omega)$ substituted by $ZtI(z,\omega)$ and with $Ex = o$, since in C.A.T.V. drops $\ell >> b$ always, therefore

$$I_L(\omega) = \frac{Zc\cosh\gamma i(\ell-z) + Zb\sinh\gamma i(\ell-z)}{ZcP}$$

$$\chi\int_0^z Zt\,I(z,\omega)\,[Zc\cosh\gamma i\,z + Za\sinh\gamma i\,z]\,dz$$

$$+\frac{Zc\cosh\gamma iz + Za\sinh\gamma iz}{ZcP}$$

$$\chi\int_z^\ell Zt\,I(z,\omega)\,[Zc\cosh\gamma i(\ell-z) + Zb\sinh\gamma i(\ell-z))\,dz \quad \text{.........33}$$

WHERE: $P = (ZcZa + ZcZb)\cosh\gamma i\ell + (Za^2 + ZaZb)\sinh\gamma i\ell$

The current produce in the load at the end of the drop ($z=\ell$) is expressed as

$$I_L(\omega) = \frac{1}{P}\int_0^\ell Zt\,I(z,\omega)\,[Zc\cosh\gamma iz + Za\sinh\gamma iz]\,dz \quad \text{................34}$$

substituting in for $I(z\ ,\omega)$ 34 becomes

$$I_L(\omega) = \frac{1}{P}\int_0^{\ell} Z_t\ \{ \frac{Z_o\cosh\gamma(\ell - z) + Z_2\sinh\gamma(\ell - z)}{Z_o D}$$

$$\times \int_0^{z} 2K(h,\omega)\ [Z_o\cosh\gamma h + Z_1\sinh\gamma h]\ dh$$

$$+ \frac{Z_o\cosh\gamma z + Z_1\sinh\gamma z}{Z_o D} \times \int_z^{\ell} 2K(h,\omega)\ [Z_o\cosh\gamma(\ell - h)$$

$$+ Z_2\sinh\gamma(\ell - h)]\ dh$$

$$+ \frac{2}{D}[Z_o\cosh\gamma(\ell - z) + Z_2\sinh\gamma(\ell - z)]\int_0^{b} E_x^{i}(x,0,\omega)\ dx$$

$$- \frac{2}{D}[Z_o\cosh\gamma z + Z_1\sinh\gamma z]\int_0^{b} E_x^{i}\ (x,\ell,\omega)\ dx\ \}$$

$$\times [Z_c\cosh\gamma_i z + Z_a\sinh\gamma_i z]\ dz \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 35$$

WHERE: P ..... $(Z_cZ_a + Z_cZ_b)\cosh\gamma_i\ell + (Z_c^2 + Z_aZ_b)\sinh\gamma_i\ell$

D ..... $(Z_oZ_1 + Z_oZ_2)\cosh\gamma\ell + (Z_o^2 + Z_1Z_2)\sinh\gamma\ell$

γ_i .... $\alpha_i + j\beta_i$ inside drop

γ ..... $\alpha + j\beta$ inside transmission line

The solution of 35 is

$$IL(\omega) = \left[\frac{-4Zt\;[j\sin(\beta^{b}/2\;\sin\Psi)]\;E_{z(\omega)}}{PD\;Zo}\right]\left\{\left[\frac{[ZaZoZ_1\;(\gamma^2-\gamma_i^2)+\gamma Z_2\;(\gamma ZaZo-\gamma_i ZcZ_1)]}{\gamma_i\gamma(\gamma^2-\gamma_i^2)}\cosh\gamma\ell+\frac{[ZaZo^2\;(\gamma^2-\gamma_i^2)+\gamma Z_2\;(\gamma ZaZ_1-\gamma_i ZcZo)]}{\gamma_i\gamma\;(\gamma^2-\gamma_i^2)}\sinh\gamma\ell+\frac{[\gamma_i Z_1\;(\gamma_i ZaZo+ZcZ_2)]}{\gamma_i\gamma(\gamma^2-\gamma_i^2)}\right]\cosh\gamma_i\ell\right.$$

$$+\left[\frac{[ZcZoZ_1\;(\gamma^2-\gamma_i^2)+\gamma Z_2\;(\gamma ZcZo-\gamma_i ZaZ_1)]}{\gamma_i\gamma(\gamma^2-\gamma_i^2)}\cosh\gamma\ell+\frac{[ZcZo^2\;(\gamma^2-\gamma_i^2)+\gamma Z_2\;(\gamma ZcZ1+\gamma_i ZaZo)]}{\gamma_i\gamma(\gamma^2-\gamma_i^2)}\sinh\gamma\ell+\frac{[\gamma_i Z_1\;(\gamma_i ZcZo+\gamma ZaZ2)]}{\gamma_i\gamma(\gamma^2-\gamma_i^2)}\right]\sinh\gamma_i\ell-\frac{[ZaZoZ2\;(\gamma^2-\gamma_i^2)+\gamma Z_1}{\gamma_i\gamma(\gamma^2-\gamma_i^2)}$$

$$\left.X\;\underline{(\gamma ZaZ_1+\gamma_i ZcZ_2)]}\;\cosh\gamma\ell-\frac{[ZaZo^2\;(\gamma^2-\gamma_i^2)+\gamma Z_1\;(\gamma ZaZ_2-\gamma_i ZcZo)]}{\gamma_i\gamma(\gamma^2-\gamma_i^2)}\sinh\gamma\ell-\frac{[\gamma_i\;(\gamma_i ZaZo-\gamma ZcZ_1)]}{\gamma_i\gamma(\gamma^2-\gamma_i^2)}\right\}$$

$$+\left[\frac{Ztb\;Ex}{PD}\right]\left\{\frac{[\gamma_i ZoZa+\gamma Z_2Zc]}{\gamma^2-\gamma_i^2}\cosh\gamma\ell+\frac{[\gamma_i Z_2Za+\gamma ZcZo]}{\gamma^2-\gamma_i^2}\sinh\gamma\ell-\frac{[\gamma_i ZoZa+\gamma Z_2Zc]}{\gamma^2-\gamma_i^2}\cosh\gamma_i\ell-\frac{[\gamma_i ZcZo+\gamma Z_2Za]}{\gamma^2-\gamma_i^2}\sinh\gamma_i\ell\right\}-\left[\frac{Ztb\;e^{-jBSin\Theta}}{PD}\right]\left\{\left[\frac{[\gamma Z^1Zc-\gamma^1ZoZa]}{\gamma^2-\gamma_i^2}\cosh\gamma\ell+\right.\right.$$

$$\left.\frac{[\gamma ZoZc-\gamma_i Z_1Za]}{\gamma^2-\gamma_i^2}\;\sinh\gamma\ell\right]\;\cosh\gamma_i\ell+\left[\frac{[\gamma Z_1Za-\gamma_i ZoZc]}{\gamma^2-\gamma_i^2}\cosh\gamma\ell+\frac{[\gamma ZoZa-\gamma_i Z\;Zc]}{\gamma^2-\gamma_i^2}\sinh\gamma\ell\right]\sinh\gamma_i\ell-\left[\frac{\gamma Z_1Zc-\gamma_i ZoZa}{\gamma^2-\gamma_i^2}\right]$$

5.3.0 GRAPHICAL REPRESENTATION of the THEORETICAL C.A.T.V. MODEL

The bulk of this subsection contains computer simulation results. Graphs 5.3.1 to 5.3.5 show the normalized load current transfer function versus frequency. Graphs 5.3.6 to 5.3.9 show the normalized load current transfer function versus the length of the horizontal drop. Graphs 5.3.9 to 5.3.18 show the normalized load current transfer function versus height of the vertical drop above ground. Graphs 5.3.19 and 5.3.20 show the normalized load current transfer function versus propagation velocity in the cable.

Each graph includes five different curves. The symbol shown on each curve gives the condition under which the curve was computed.

Graphs 5.3.1 and 5.3.2 show only the resulting current distribution in the load Rb due to the horizontal and vertical drops respectively. Graph 5.3.3 to 5.3.20 show the combined effect of the horizontal and vertical drops which is in fact the measured current in the load Rb.

5.3.1 DISCUSSION OF RESULTS

The following presents general points about the graphs found in this subsection.

5.3.1.1 General Observations

For Graphs 5.3.3 to 5.3.5

A - Ingress level decreases as frequency increases.

B - There appear to be three general grounding conditions:
1 high R (>100kΩ)
2 medium R (≈1kΩ)
3 low R (<10Ω)

For high ground resistance, ingress level is high.

For medium ground resistance, ingress level is low (approximately 40dB lower than high R case at HF).

For low ground resistence, ingress level is unstable with freq. and drop length - varies between two previous cases.

C - Difference in shielding for high R and medium R cases is greater at HF than at VHF.

D - Graph 5.3.4 slightly misrepresents ingressive level due to under-sampling of curve.

For Graphs 5.3.6 to 5.3.9

The following graphs were plotted to show the effect of increasing the drop length:

A - On all frequencies investigated levels are much worse for ungrounded drop.

B - Unstability of low ground reference is clearly represented on all tested frequencies.

For Graphs 5.3.10 to 5.3.19

The next 9 graphs are of special interest. They show the normalized load current transfer function as the drop height above ground is varied.

A - A first general observation is that ingress level increases as the height of the drop above ground increases for all tested frequencies.

B - Ground reference of 500 and 1200 ohms are the most stable, (i.e. show less variation for all computed conditions).

C - Ingress level decreases as frequency increases for 500 ohms ground reference but show unstability for a 3 ohms ground reference as represented by graph 5.3.16 and 5.3.15 respectively.

D - Ungrounded system shows the worst ingress level.

Graphs 5.3.19 and 5.3.20 are included as a point of interest.

Graph 5.3.19 shows the resulting shielding produced for different frequency conditions while graph 5.3.20 shows shielding for different length conditions. A common observation is that the normalized load current transfer function increases as the propagation velocity increases.

5.3.2 GENERAL COMMENT

A For the three grounding resistence cases described above, similar observations can be made.

For high ground resistence, ingress level is high.

For medium ground resistence, ingress level is low.

For low ground resistence, ingress level is unstable with length.

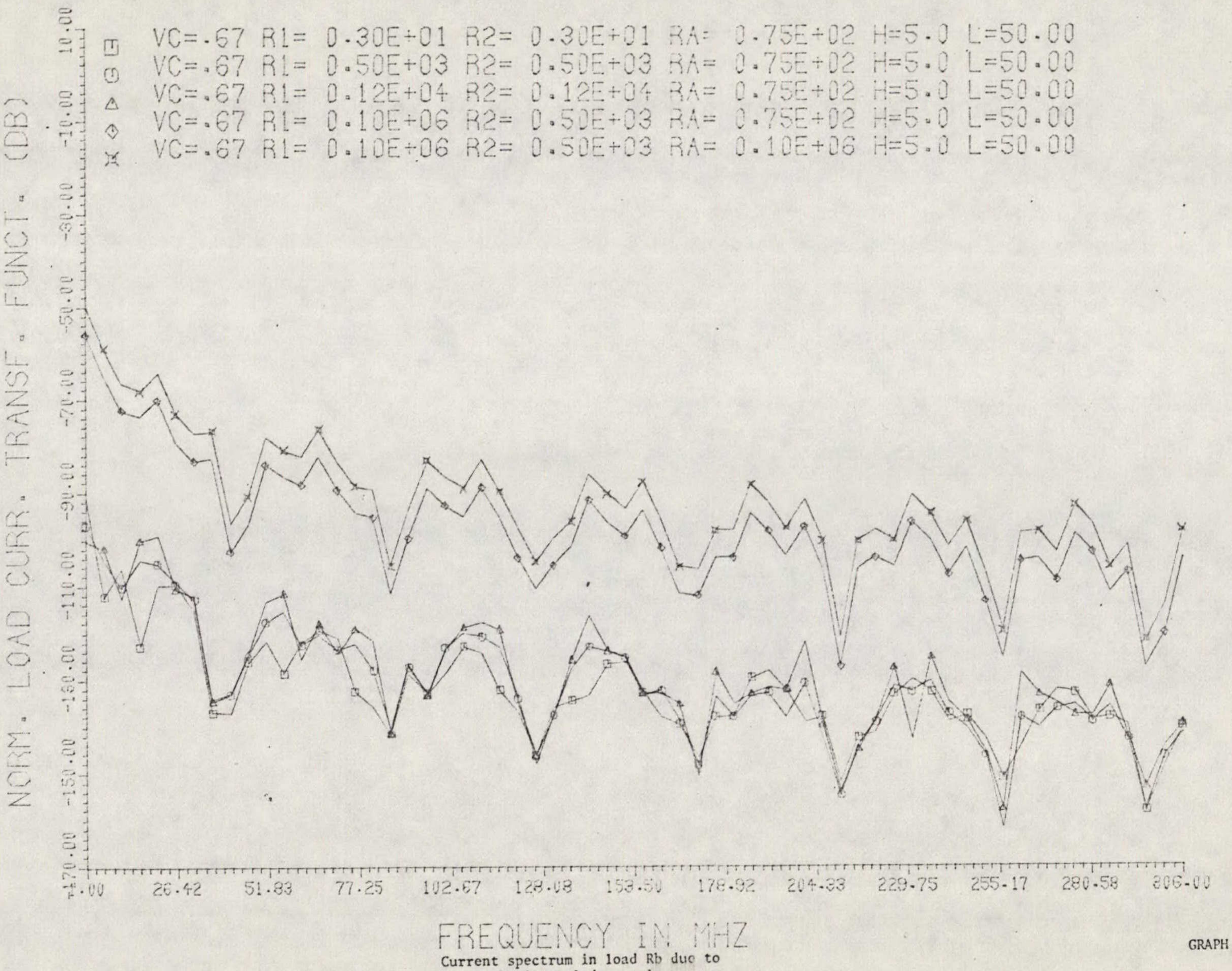
B It is possible that minimal ingress level will be achieved when ground reference equals the characteristic impedance of the transmission line Zo. Although this hypothesis has not yet been tested, Zo can be approximate by the following equation :

when b>>a

$$Zo = 276 \log_{10} 4b/a$$

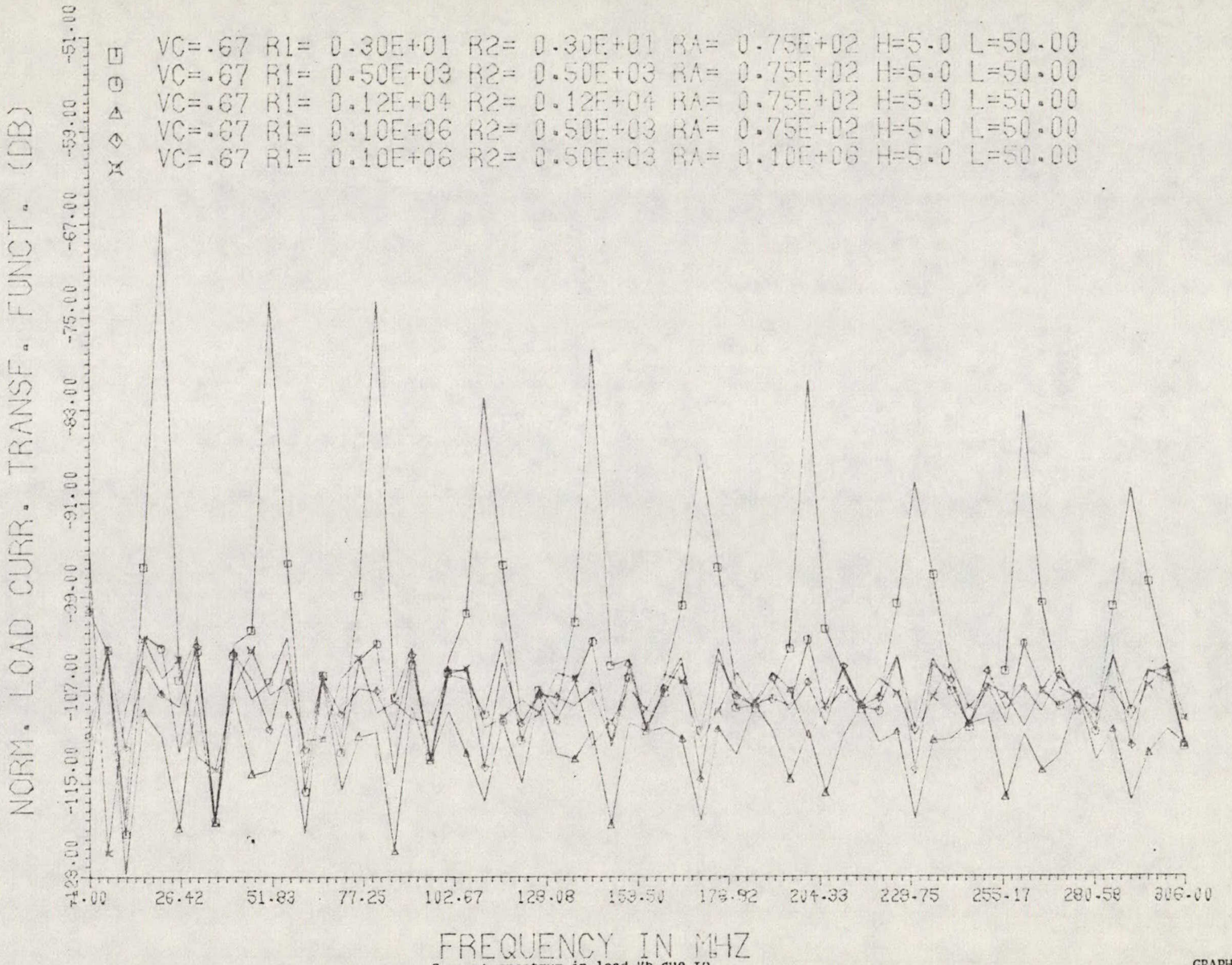
WHERE: b height above ground(m)
a is the drop diameter (m)

C Using three-dimensional graphic, it would be possible to optimise the effectiveness of radiation monitoring by choosing an optimum frequency(ies) at which the pilot carrier(s) could be located.



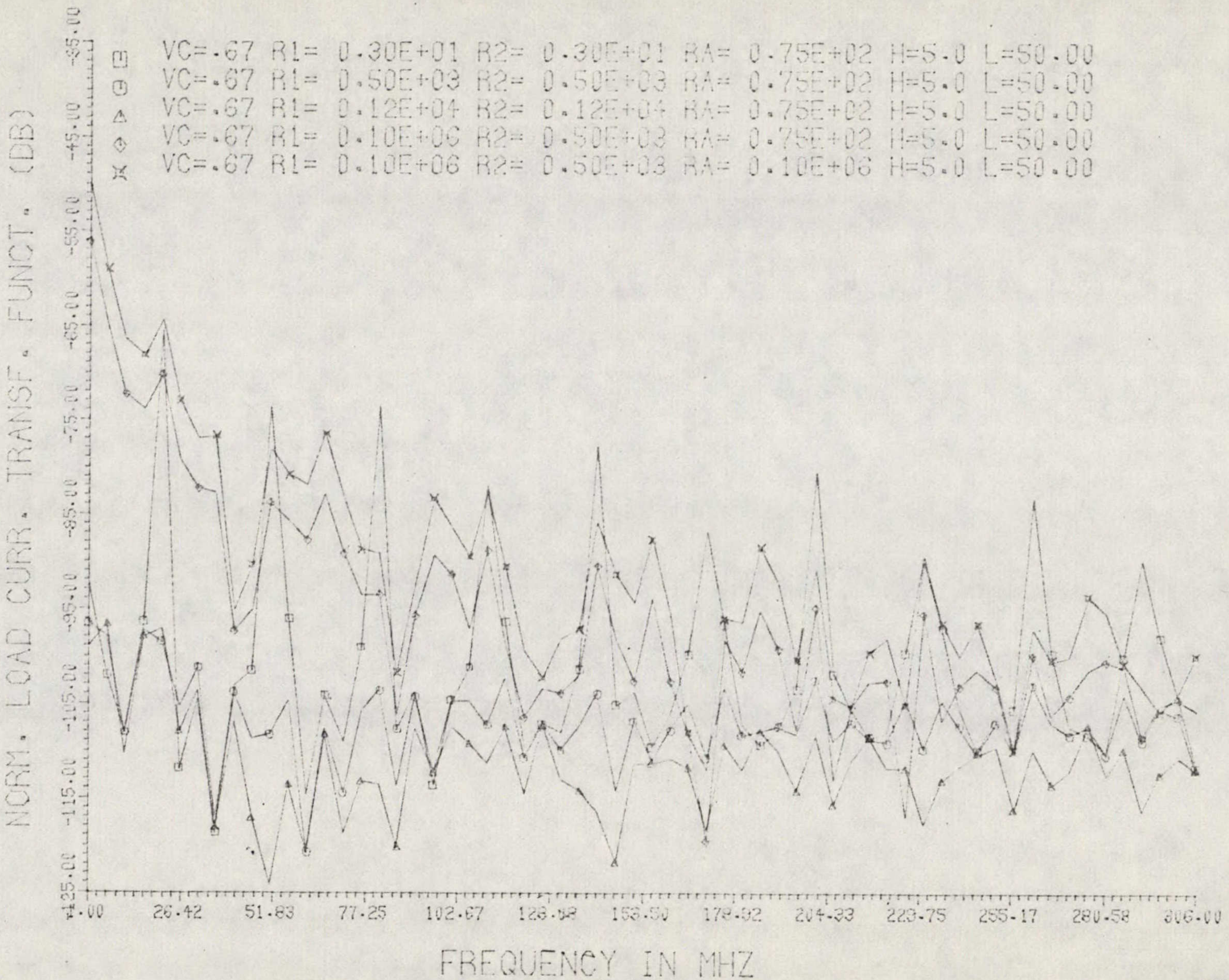
Current spectrum in load Rb due to horizontal drop only

GRAPH 5.3.1



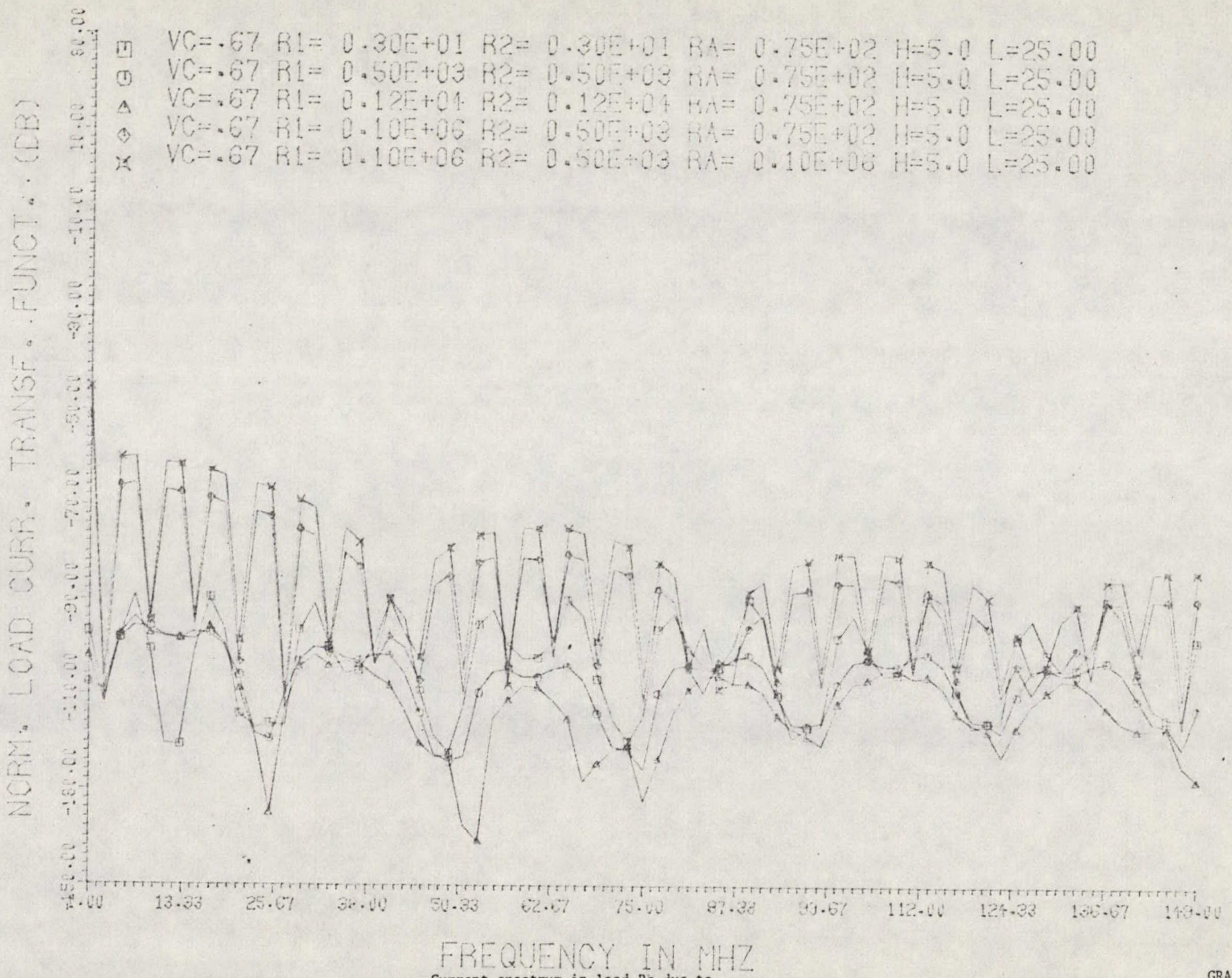
Current spectrum in load Rb due to
vertical drop only

GRAPH 5.3.2



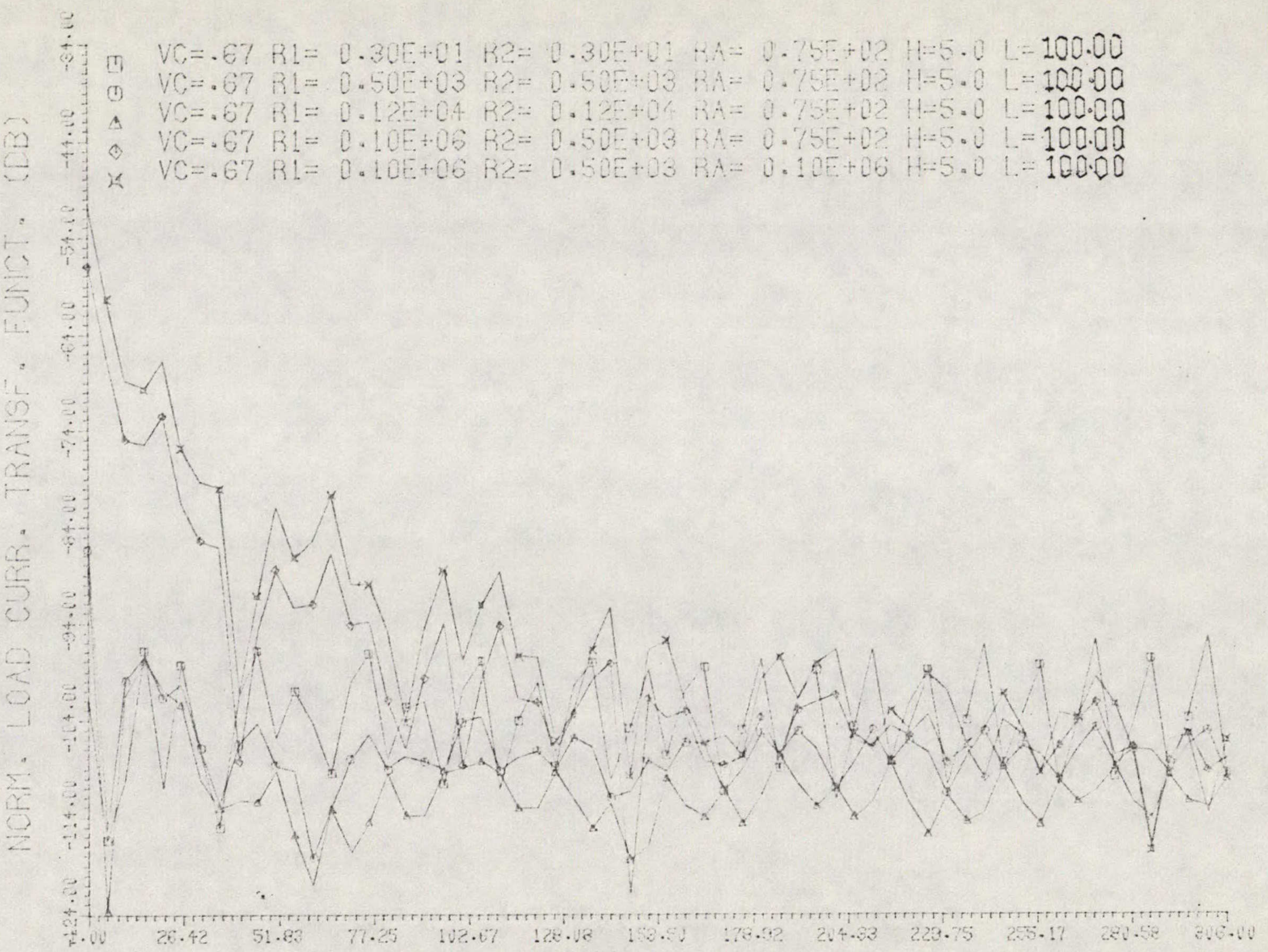
Current spectrum in load Rb due to
both horizontal and vertical drop

GRAPH 5.3.3



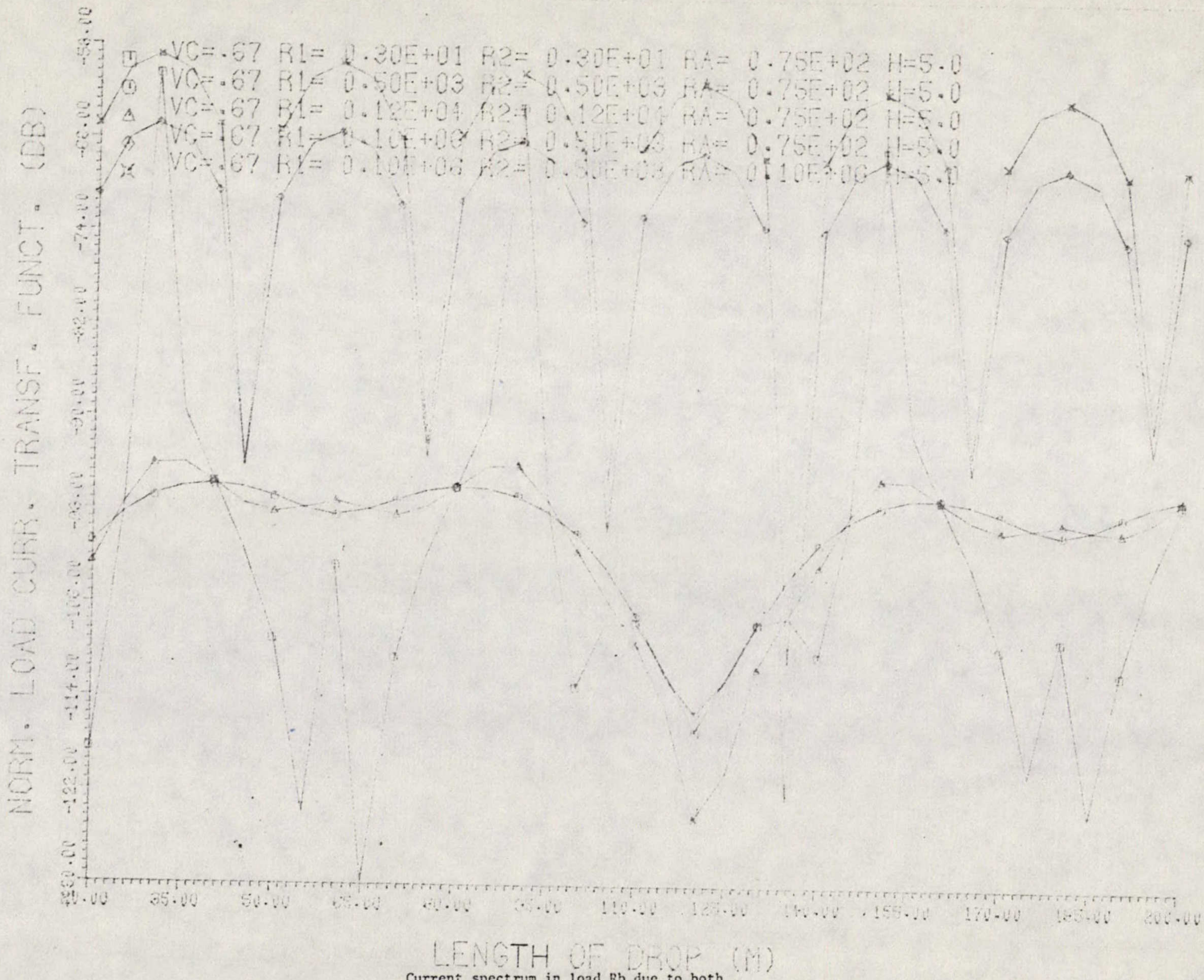
Current spectrum in load Rb due to
both horizontal and vertical drop

GRAPH 5.3.4



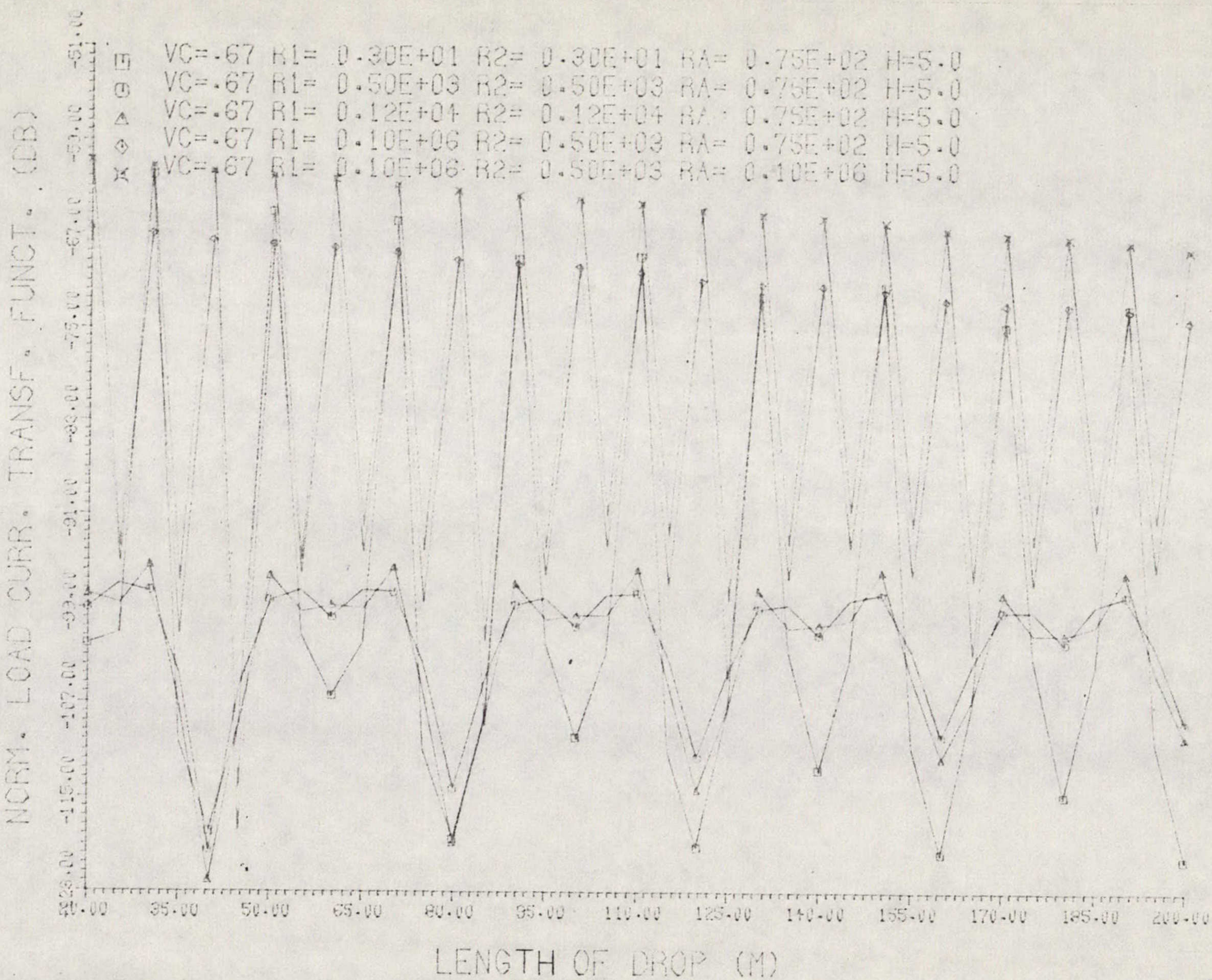
Current spectrum in load Rb due to
both horizontal and vertical drop

GRAPH 5.3.5



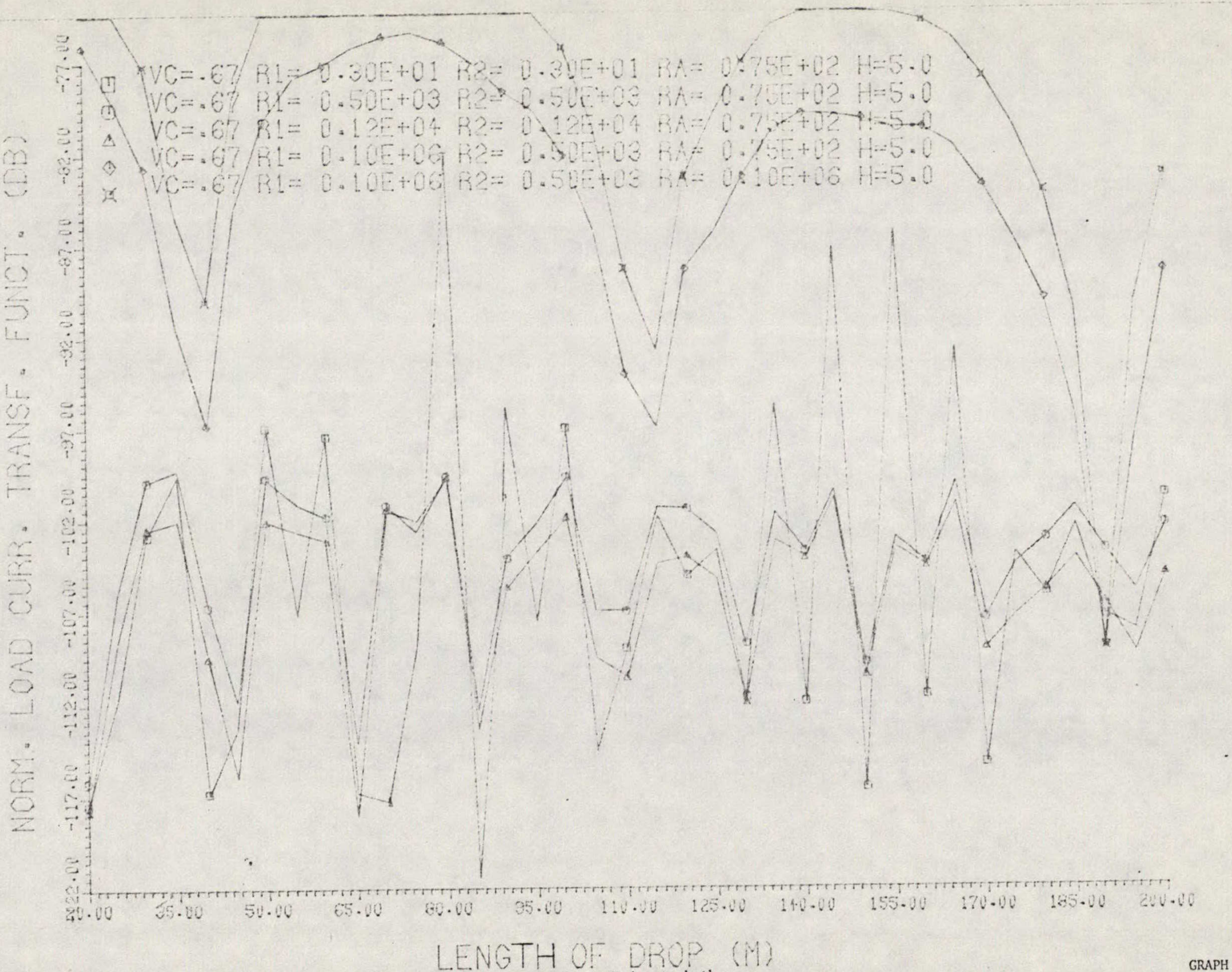
Current spectrum in load Rb due to both horizontal and vertical drop at 5MHZ

GRAPH 5.3.6



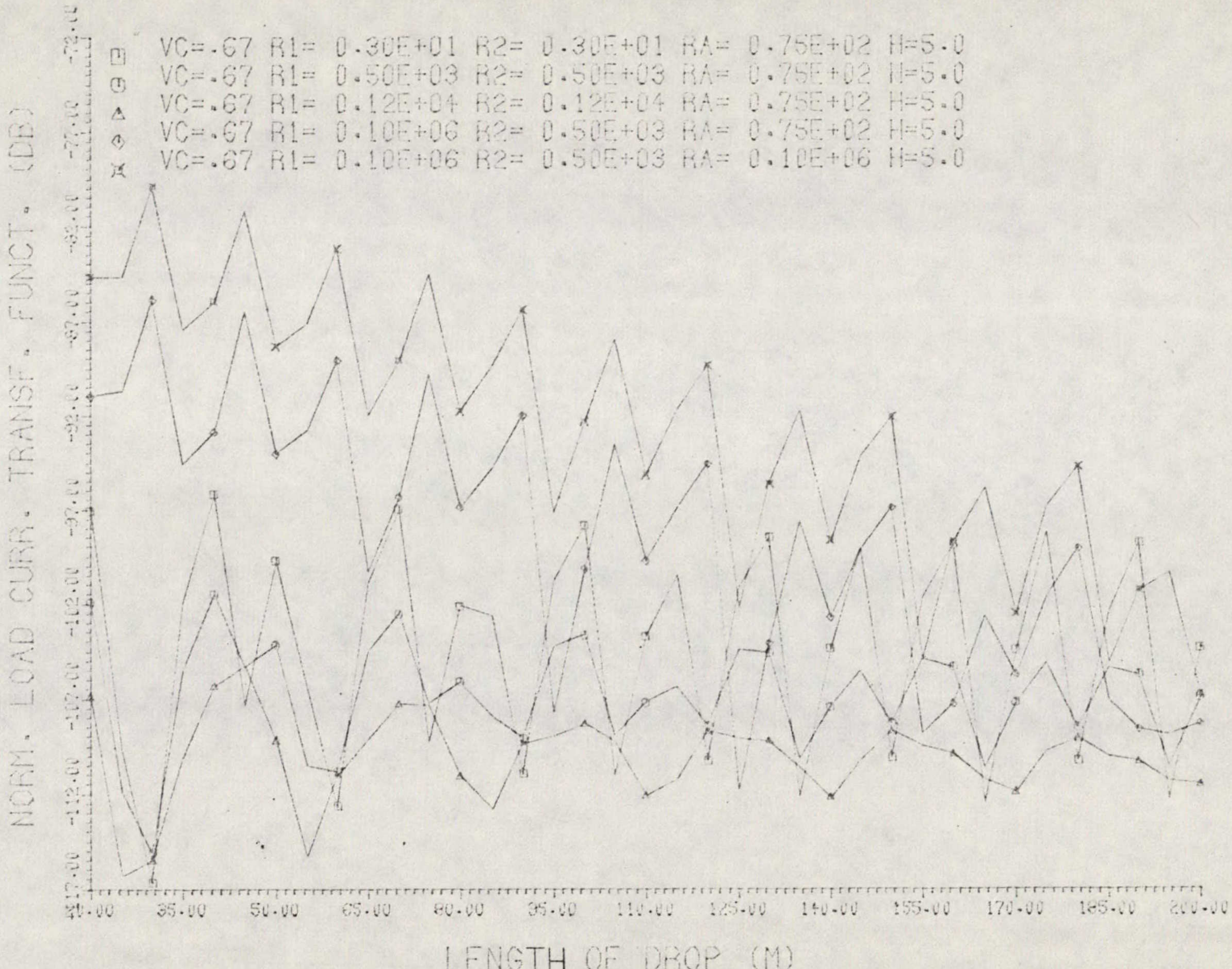
Current spectrum in load Rb due to both horizontal and vertical drop at 15MHZ

GRAPH 5.3.7



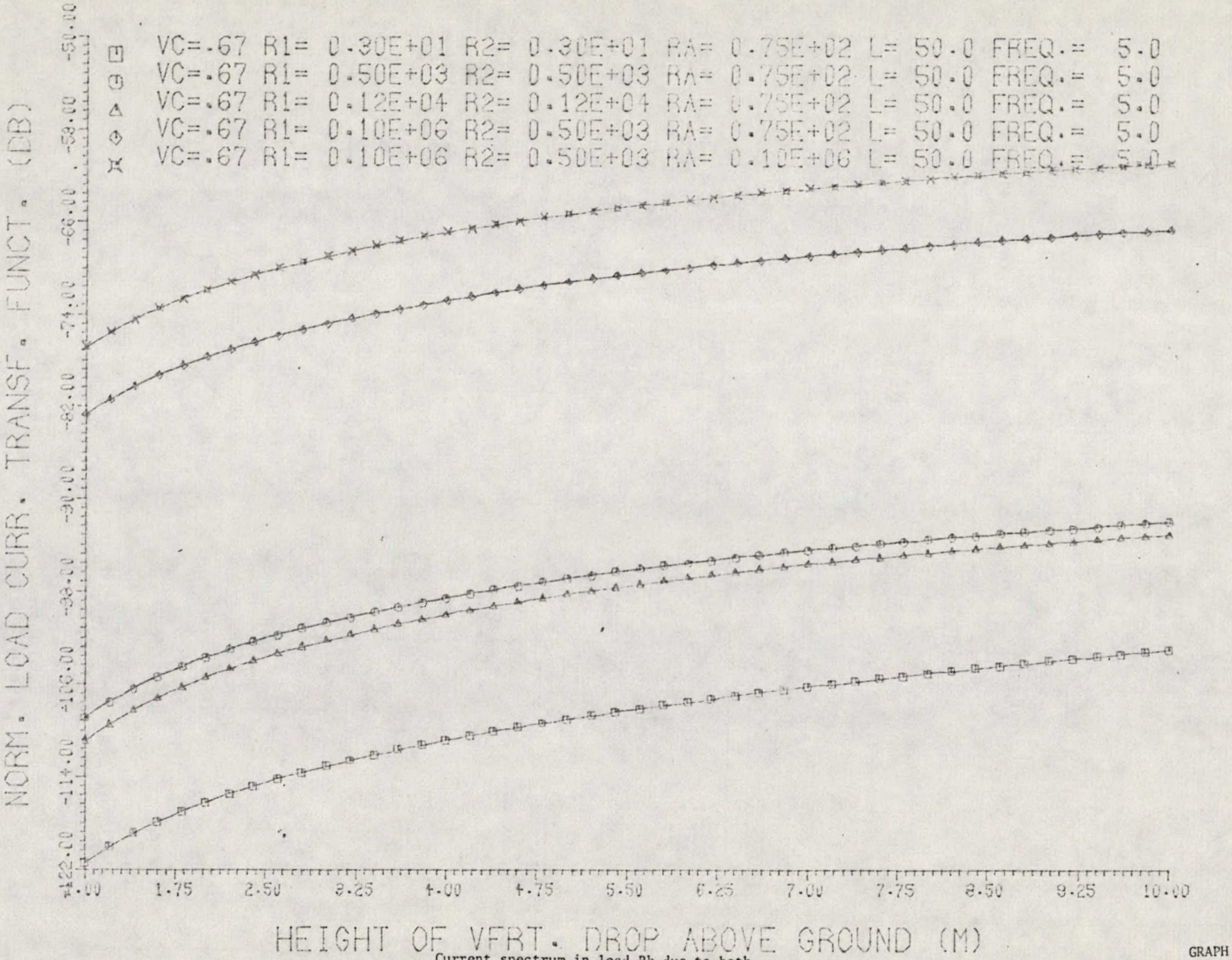
Current spectrum in load Rb due to both horizontal and vertical drop at 28MHZ

GRAPH 5.3.8



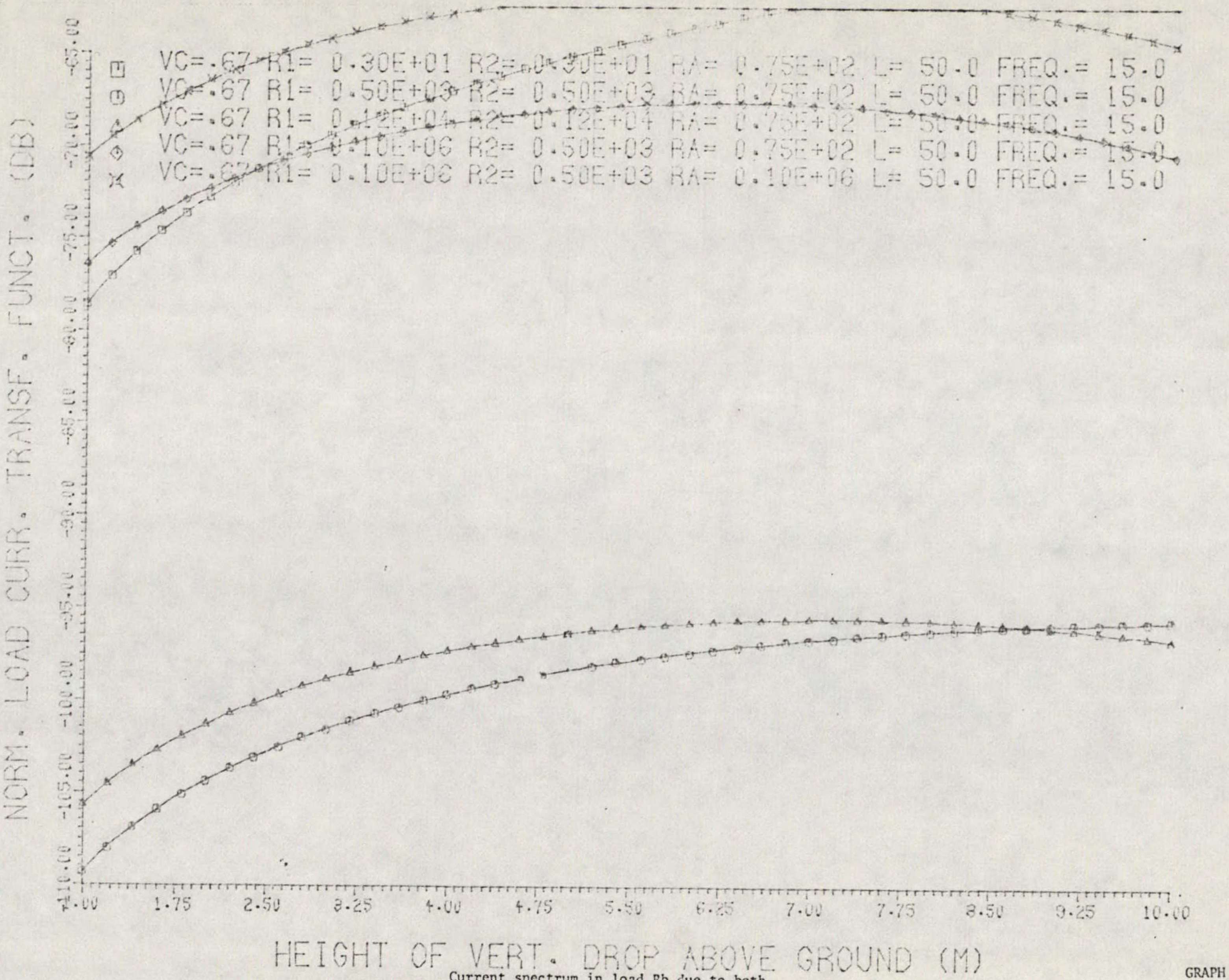
Current spectrum in load Rb due to both horizontal and vertical drop at 100MHZ

GRAPH 5.3.9



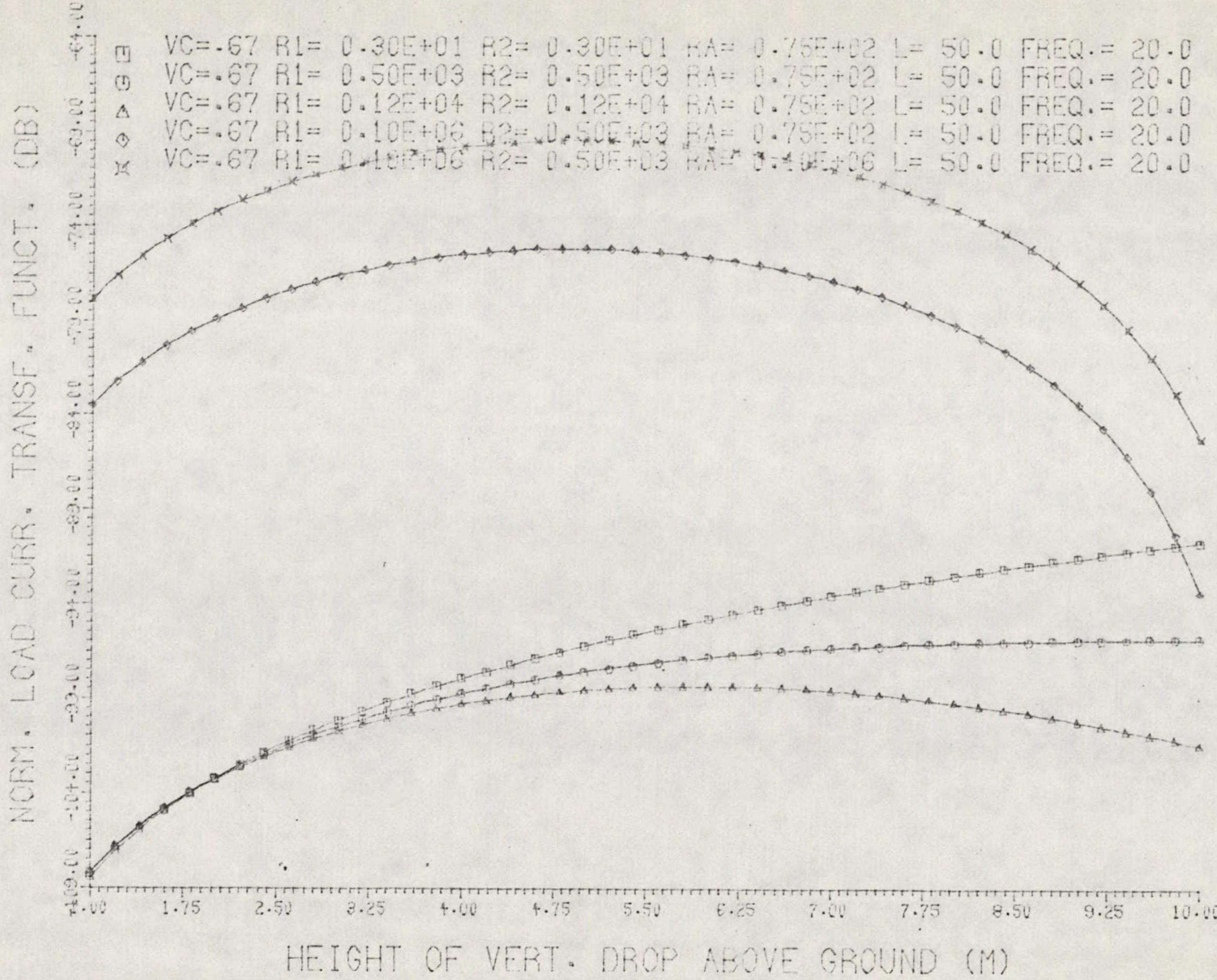
Current spectrum in load Rb due to both horizontal and vertical drop

GRAPH 5.3.10



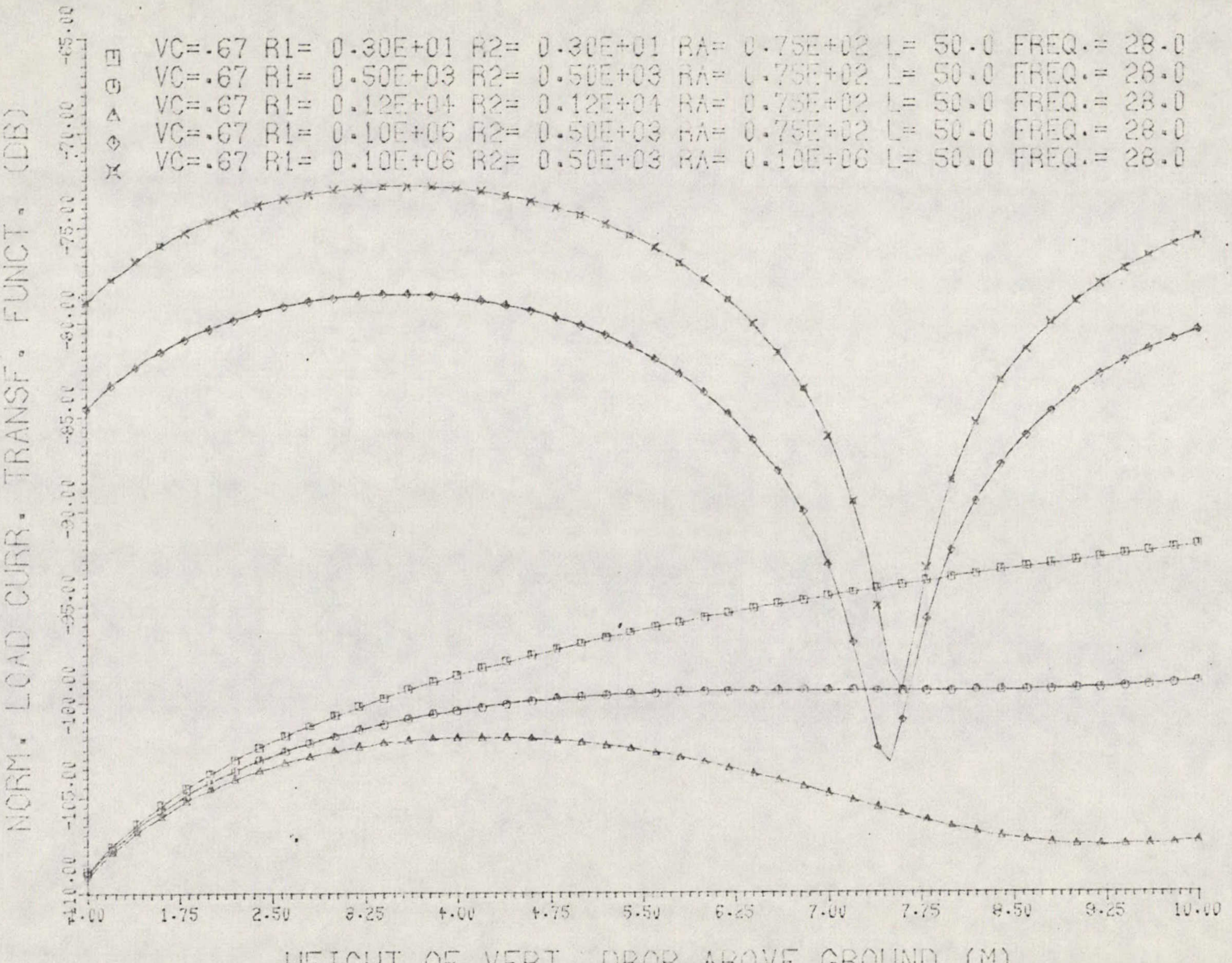
Current spectrum in load Rb due to both horizontal and vertical drop

GRAPH 5.3.11



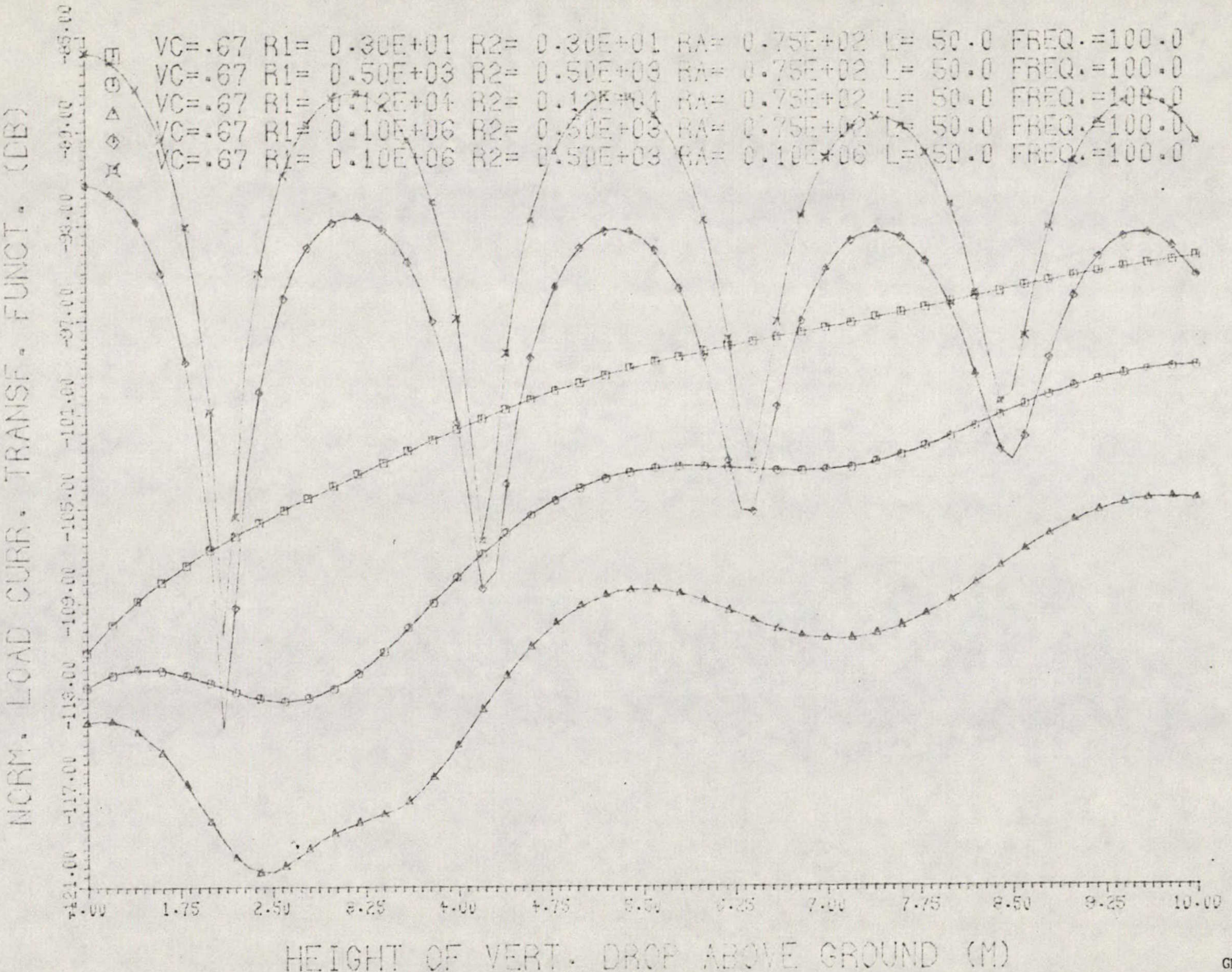
Current spectrum in load Rb due to both horizontal and vertical drop

GRAPH 5.3.12



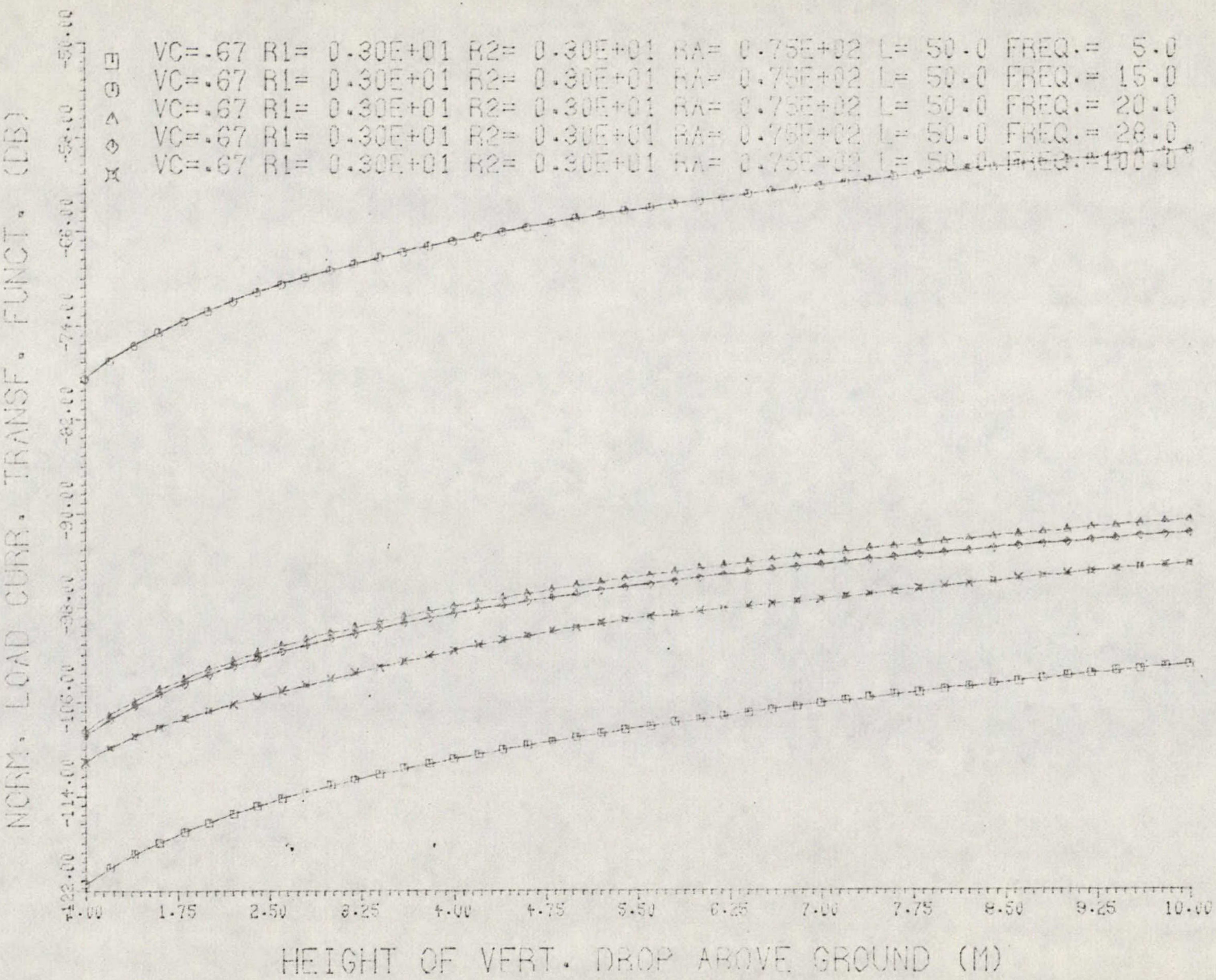
GRAPH 5.3.13

Current spectrum in load Rb due to both horizontal and vertical drop



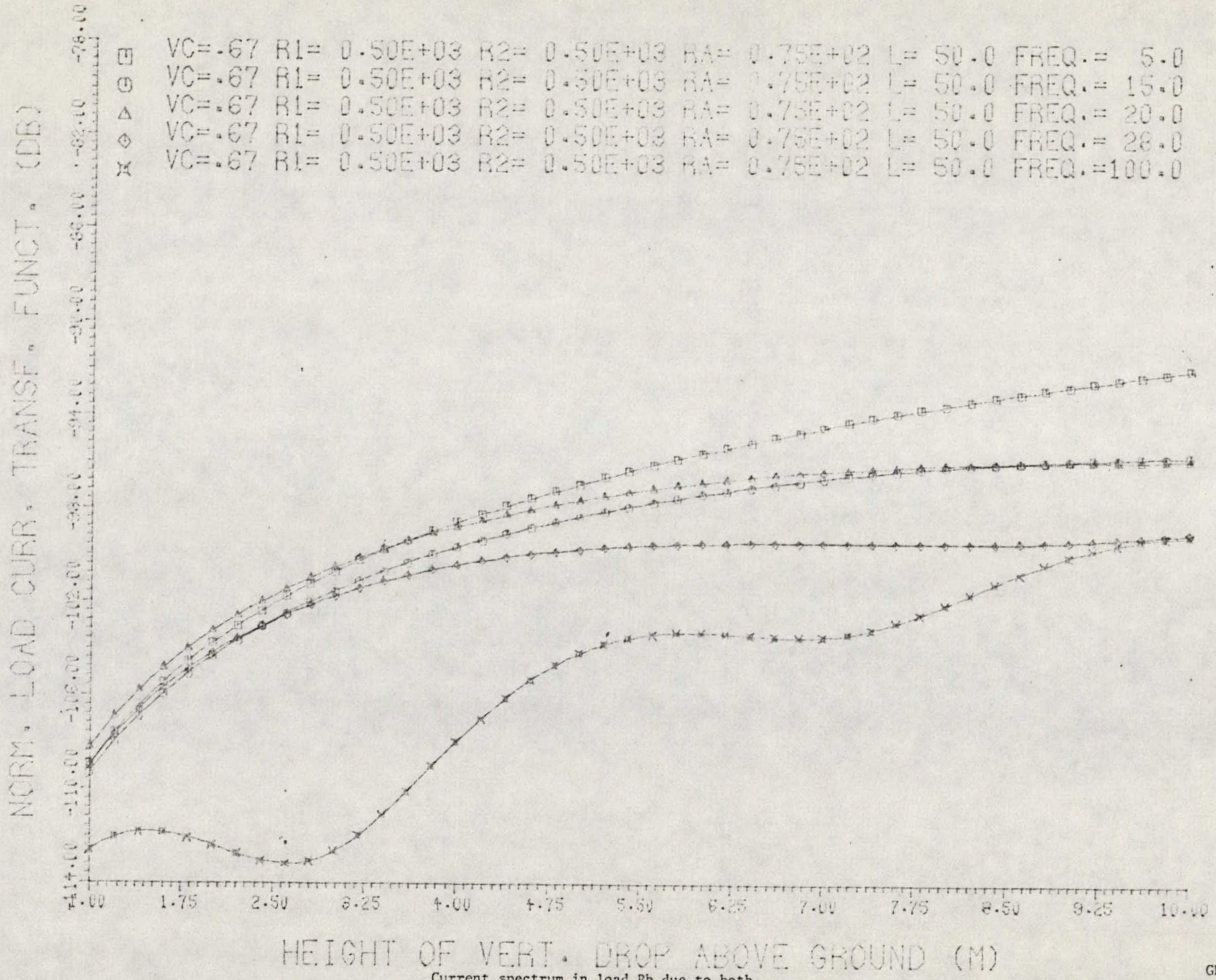
Current spectrum in load Rb due to both horizontal and vertical drop

GRAPH 5.3.14



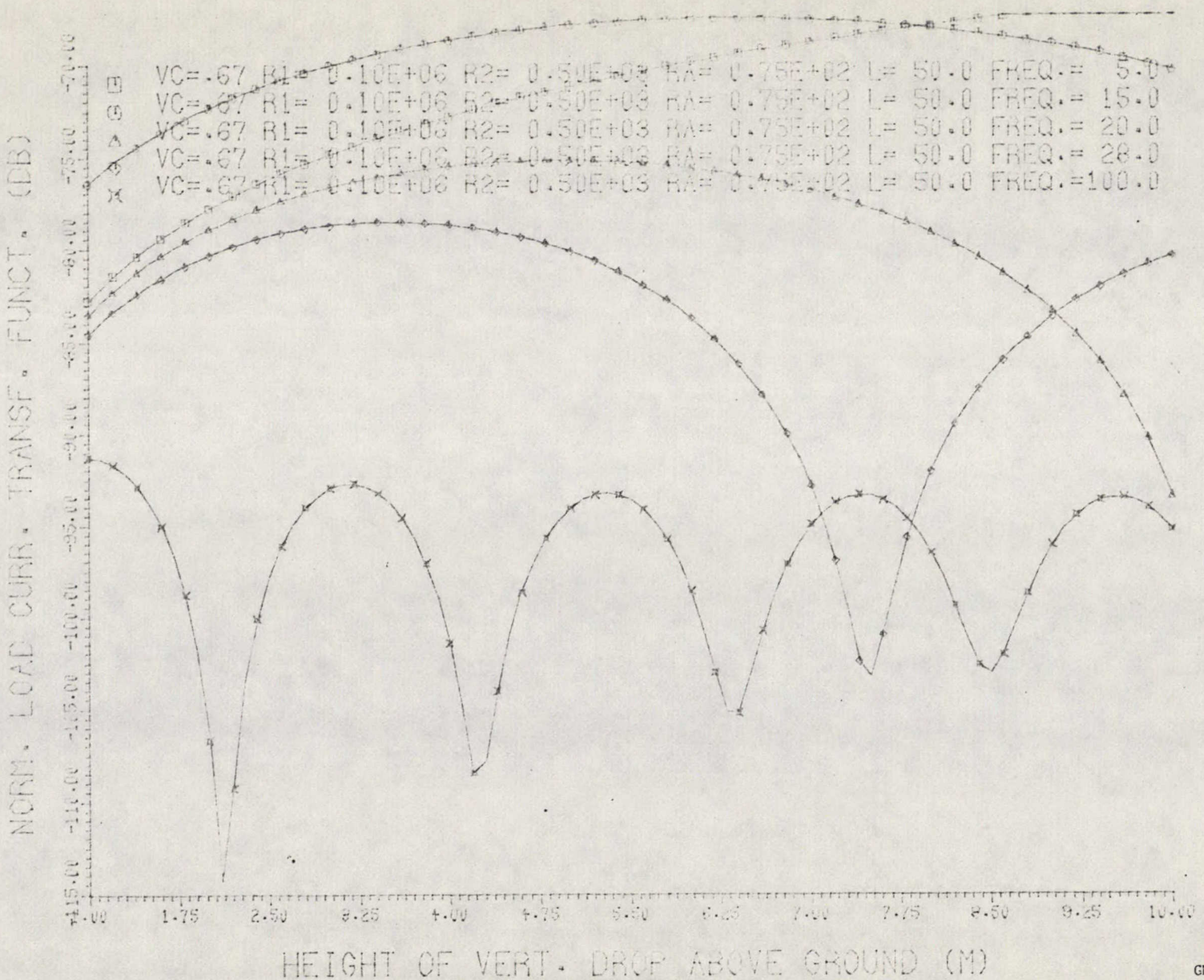
Current spectrum in load Rb due to both horizontal and vertical drop

GRAPH 5.3.15



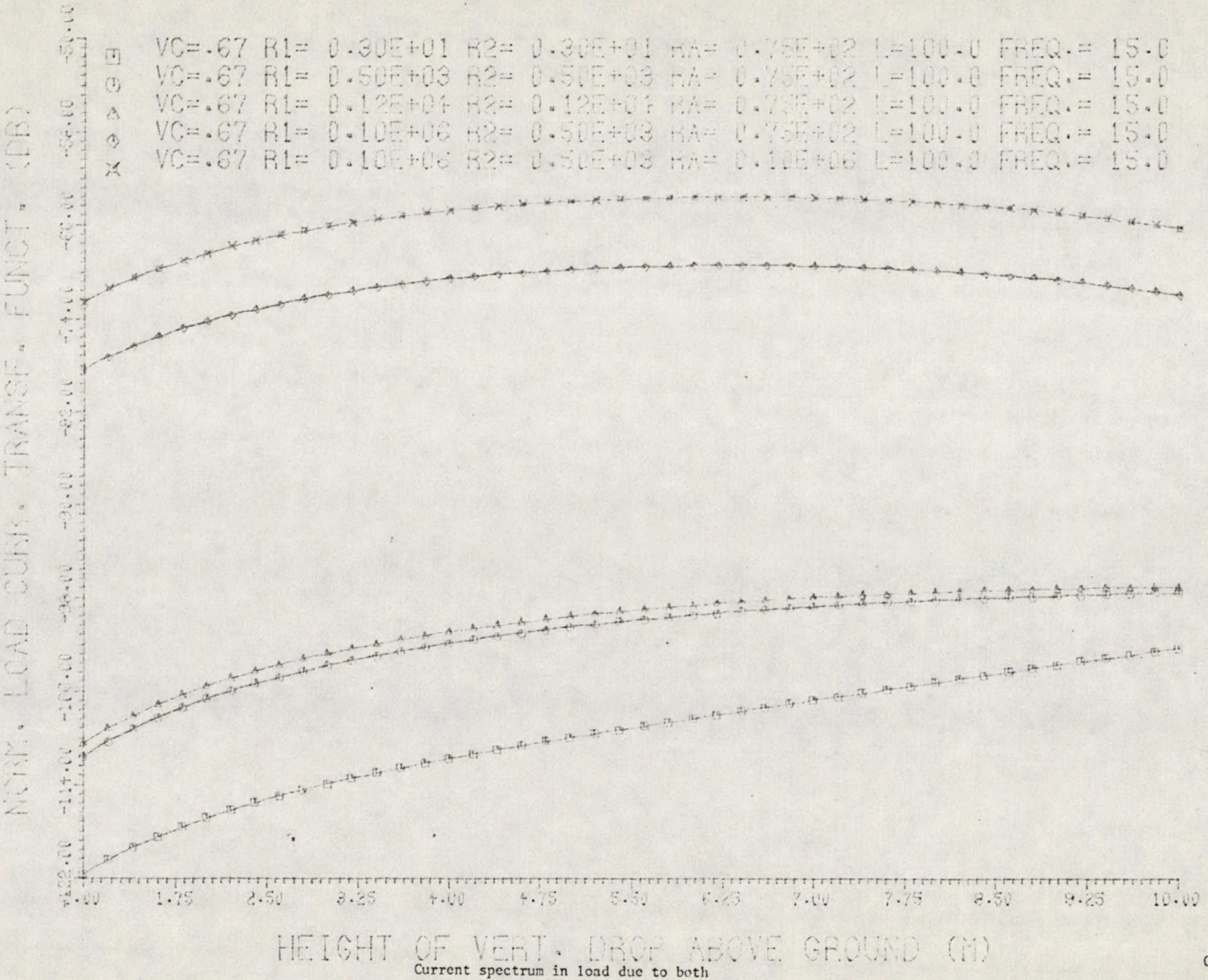
Current spectrum in load Rb due to both horizontal and vertical drop

GRAPH 5.3.16



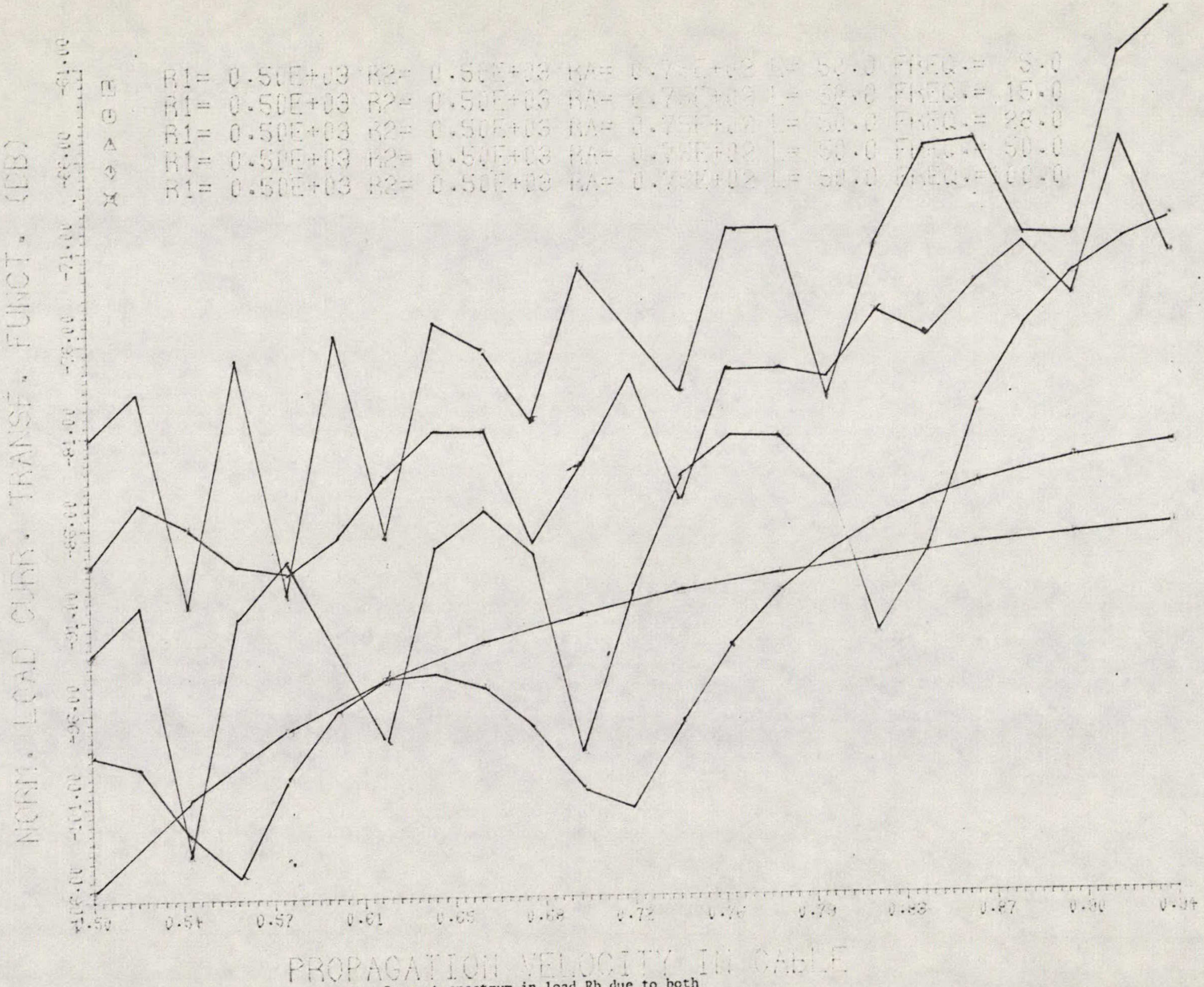
Current spectrum in load Rb due to both vertical and horizontal drop

GRAPH 5.3.17



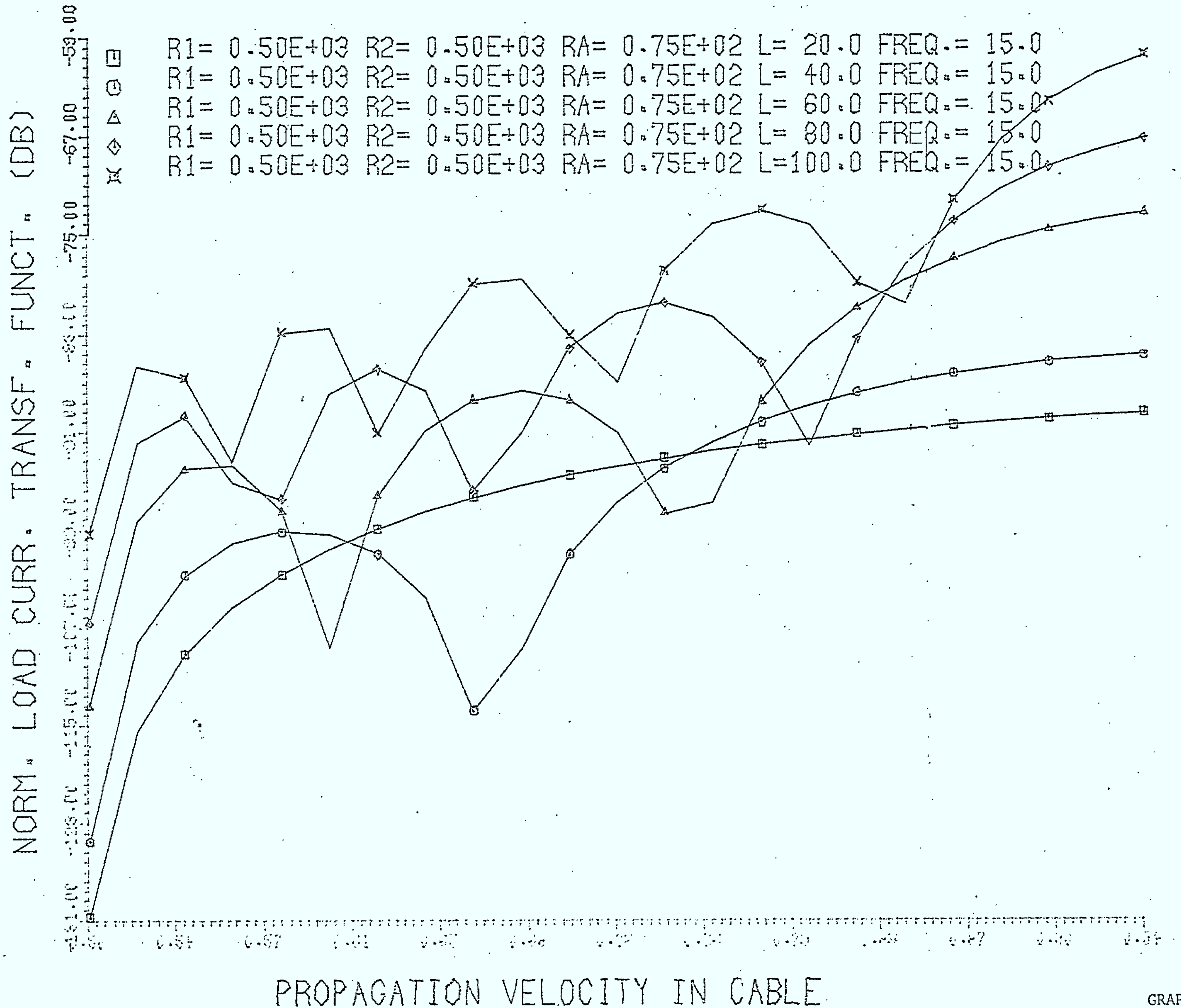
Current spectrum in load due to both vertical and horizontal drop

GRAPH 5.3.18



Current spectrum in load Rb due to both horizontal and vertical drop

GRAPH 5.3.19



Current spectrum in load Rb due to both horizontal and vertical drop

GRAPH 5.3.20

5.4.0 EXPERIMENTAL INVESTIGATION OF THE THEORY

5.4.1 DESCRIPTION OF EXPERIMENT

The experiment consists of illuminating a drop wire with electromagnetic energy and measuring how much of this energy penetrated that drop.

Tests were made subject to various ground references and terminating conditions. In this sub-section experimental results are compared to theoretical results. Observations are drawn from the resulting graphs, and theoretical analysis limitations pointed out. An artist's conception of the experimental set up is shown in figure 5.4.1.

Two different transmitting locations are shown. Location #2 enables the evaluation of ingressive signals subject to phase differences produced by the cable span, while ingressive signals produced by Location #1 are not subject to any phase differences.

5.4.1.1 TEST PROCEDURE TO MEASURE LOAD CURRENT DISTRIBUTION In a C.A.T.V. DROP

Approximately 84 meters of RG59/U shielded by a single braid over tape was used for the experimental drop wire. The shielded cable was mounted as shown in figure 5.4.1. A CW signal was applied to the broadband C.A.T.V. antenna and the ingressive signal from the cable measured with a field strength meter.

A frequency synthesizer was used as the signal source. Readings were taken between 25 and 150 MHz with a 5 MHz incremental step. The transmitting antenna was first located in the yz plane some 15 meters from the drops as shown by position 1 in Figure 5.4.1. Readings of ingress signals were taken for the following grounding and terminating conditions.

A) both ends of the cable grounded* to 3 ohms and terminated* into 75 ohms.

B) both ends grounded to 150 ohms and terminated into 75 ohms.

C) both ends grounded to 510 ohms and terminated into 75 ohms.

D) both ends grounded to 1200 ohms and terminated into 75 ohms.

E) only one end grounded to 3 ohms with the other end left open, and both ends terminated into 75 ohms.

F) both ends ungrounded and with only one end terminated into 75 ohms.

The transmitting antenna was then moved to location #2 as shown in figure 5.4.1 where the readings of ingress levels were taken under the following conditions.

A) both ends grounded to 3 ohms and terminated into 75 ohms.

B) one end grounded to 3 ohms with the other end left open and both ends terminated into 75 ohms.

C) both ends ungrounded and terminated into 75 ohms.

The surrounding electromagnetic field produced by the transmitting antenna was measured with a field intensity meter.

An equivalent electrical representation of the experimental set up is shown in figure 5.4.2.

* In this context the term "grounded" refers to the outer shield of the cable being connected to a reference ground while the term "terminated" means that the center conductor of the cable was connected through a 75 ohms resistor to the shield of that cable.

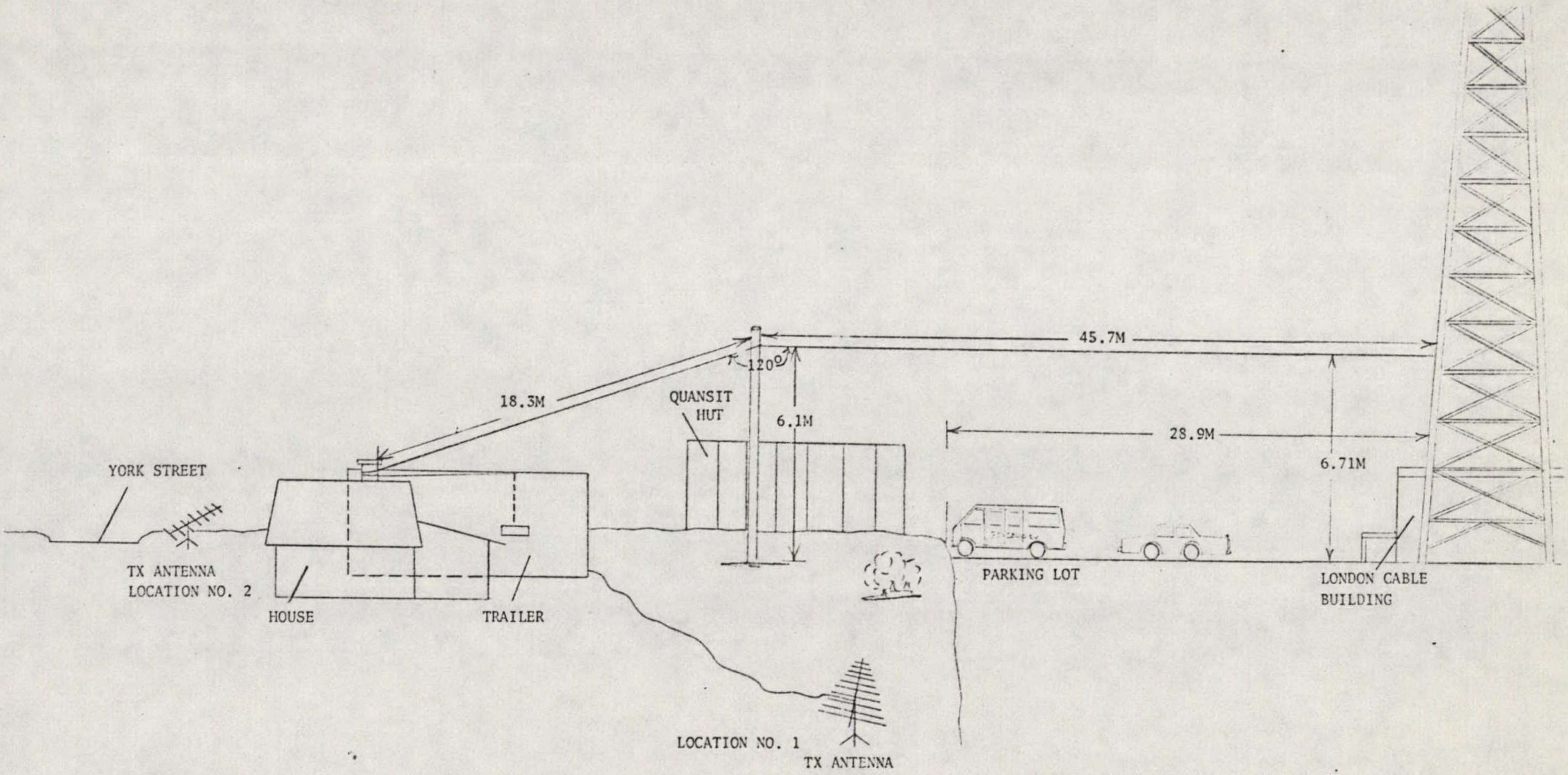


FIGURE 5.4.1

ARTIST'S CONCEPTION OF PHYSICAL LAYOUT

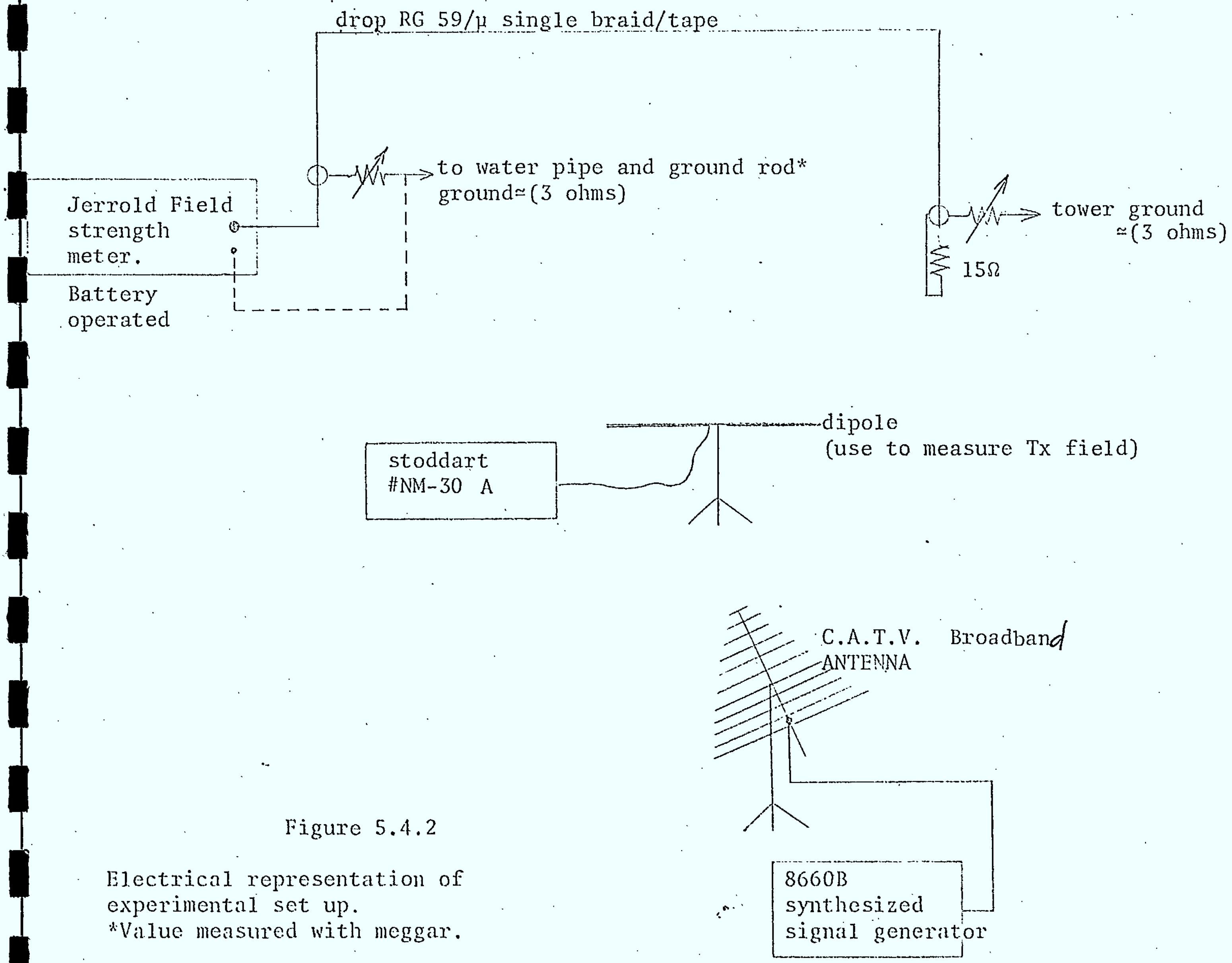


Figure 5.4.2

Electrical representation of experimental set up.
*Value measured with meggar.

5.4.2 DISCUSSION OF RESULTS

The first step in comparing the theoretical result to the experimental one, is to normalize the data to the surrounding electromagnetic field. This is done in the following way:

$$IL\ (\omega) = T\ (\omega)\ E^{TOT}$$

Where:
$IL\ (\omega)$ Load current spectrum
$T\ (\omega)$ Sheath current transfer function
E^{TOT} Total electromagnetic field surrounding the drop.

$$\therefore IL\ (\omega) = VL\ (\omega)/75$$

Where $VL\ (\omega)$ ... field strength meter reading
75Ω ... input impedance of field strength meter

The normalized load current transfer function is:

$$T\ (\omega)dB = VLdBmV - 20\log(75) - E^{TOT}dBmV$$

Knowing the surrounding electromagnetic field, one can easily find the load current at any frequency by simply:

$$IL\ (\omega)dB\underline{*} = T\ (\omega)dB + E^{TOT}dB\underline{*}$$

Where: $dB\underline{*}$ ... if E^{TOT} is dBmV, then $IL\ (\omega)$ is in dBmA
if E^{TOT} is dBμV, then $IL\ (\omega)$ is in dBμA etc.

5.4.2.1 OBSERVATION OF EXPERIMENTAL RESULTS

The following describes pertinent points of the experimental results:

A) To a first order approximation the experimental and the theoretical results corrolate.
- Note the common trend in data pattern in Graphs 5.4.1 to 5.4.9.

B) Peaks observed in experimental data at 35 MHz and 145 MHz on all graphs.

C) Graph 5.4.10 shows that in general over the frequencies observed both grounding references of 510 and 1200 ohms are no worse than the 3 ohms reference.

5.4.2.2 SOURCES OF ERRORS

Due to the complexity of the theory, many assumptions were made to carry the analysis through. The following presents the most important ones:

A) Plane wave propagations.

Theoretical analysis assumes plane wave propagation, meaning that the electromagnetic field is taken to be constant over the entire length of the drop. This assumption only holds true for distances greater than, or equal to, the far field region of the transmitting antenna. A more accurate analysis to compare the experimental and theoretical results would require splitting the field of the transmitting antenna into its radial and angular components as shown in figure 5.4.3.

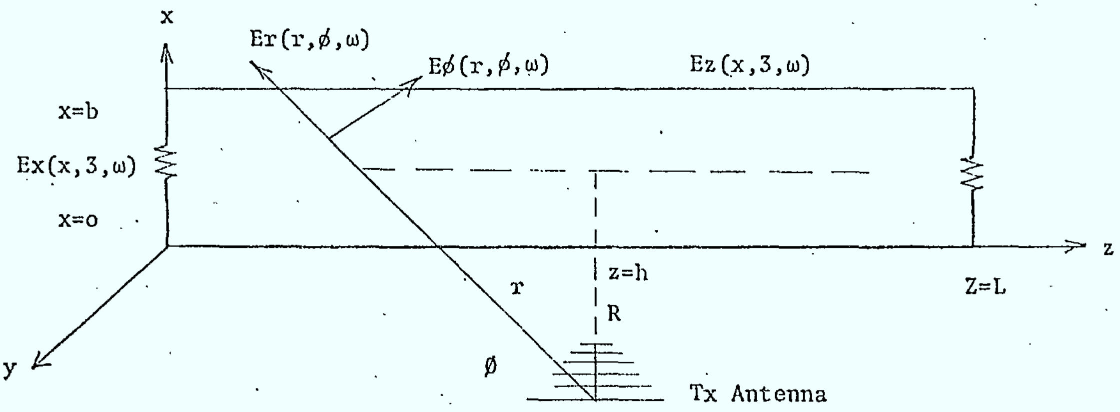


Figure 5.4.3

Representation of angular and radial components field of an antenna on a drop

WHERE: Er is the radial field component
Eϕ is the angular field component
R is the distance separating the transmitting antenna to the drop.

In this case Ex and Ez becomes:

$$Ez(x,z,\omega) = E\phi(r,\phi,\omega)\sin\phi - Er(r,\phi,\omega)\cos\phi$$

$$Ex(x,z,\omega) = E\phi(r,\phi,\omega)\cos\phi + Er(r,\phi,\omega)\sin\phi$$

The expression for Eϕ and Er are extremely complex making the evaluation of IL(ω) very tedious.

B) Layout of the experimental set up.

The discrepencies between the experimental and theoretical set up are listed below. A quick comparison between figure 5.2.1 and 5.4.1 clearly show that the:

1) height of the drop is not constant
2) the drop is not laid out in a straight line
3) surrounding buildings will produce multi-reflections
4) not a perfect ground plane

C) Ground reference.

In the theoretical analysis all ground reference were assumed to be real. Graph 5.4.11 clearly shows that this assumption does not hold, and that, in fact, ground impedance have imaginary parts associated with it.

D) The shielded drop.

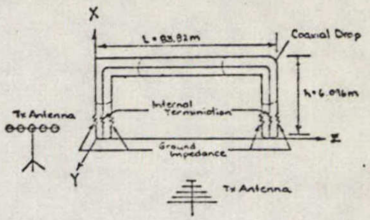
The computer program used to obtain the theoretical points only models a transfer impedance of a single braided cable. The actual cable used in the experiment had an outer shield made of braid plus aluminum tape. Graph 5.4.12 shows the measured transfer impedance versus frequency for the most commonly used drop cables. A similar analysis could be performed on any of these cable types.

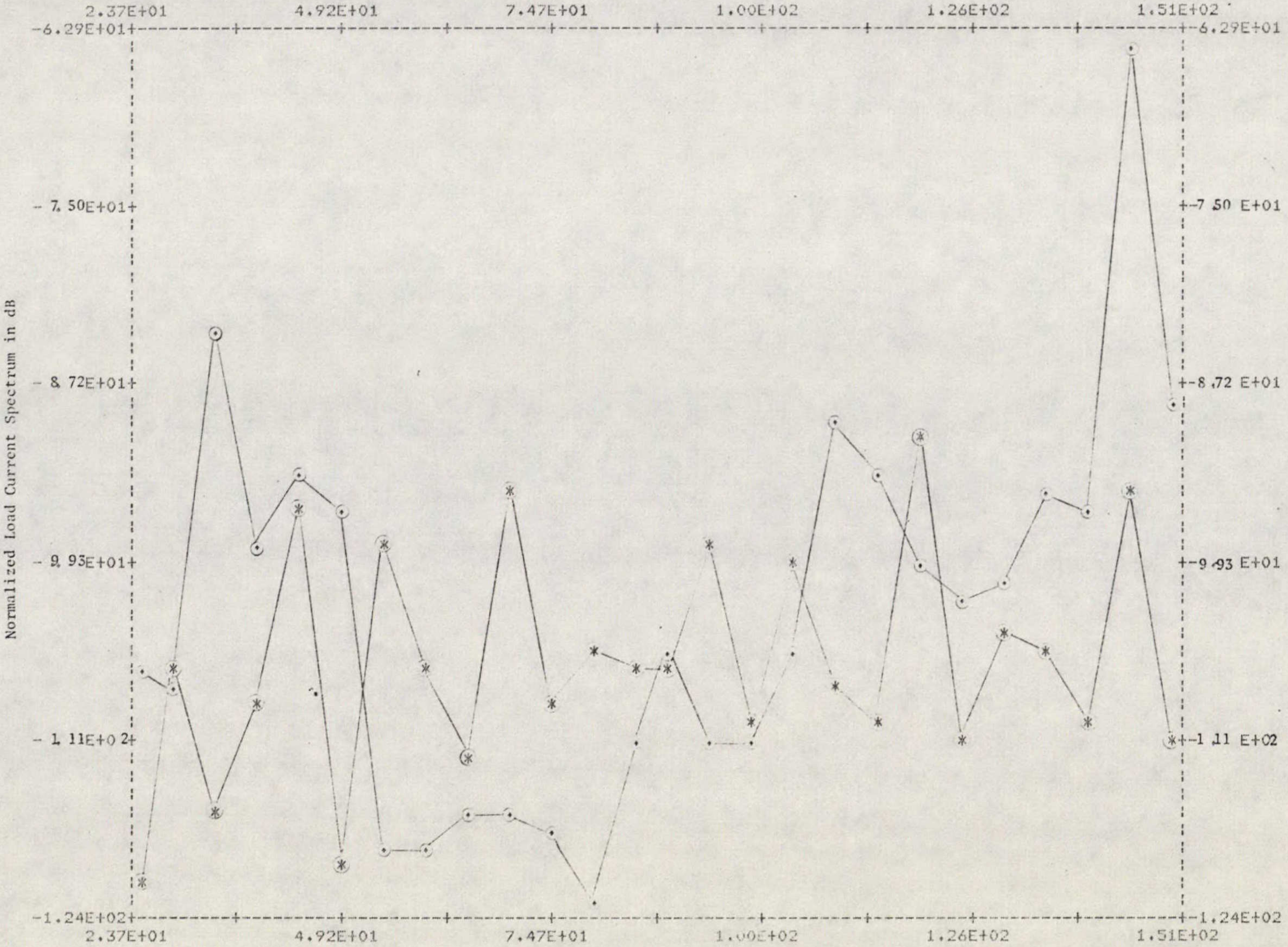
XMAX	XMIN	YMAX	YMIN
150.0000	25.00000	-63.50123	-123.5012

- Tx antenna horizontally polarized
- Tx antenna in "-Y" direction
- Both ends grounded to 3 ohms
- Both ends terminated to 75 ohms

Legend

· experimental data
* theoretical data





Graph 5.4.1

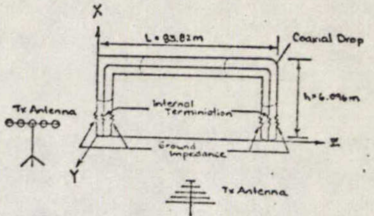
XMAX	XMIN	YMAX	YMIN
150.0000	25.00000	-71.50123	-122.5012

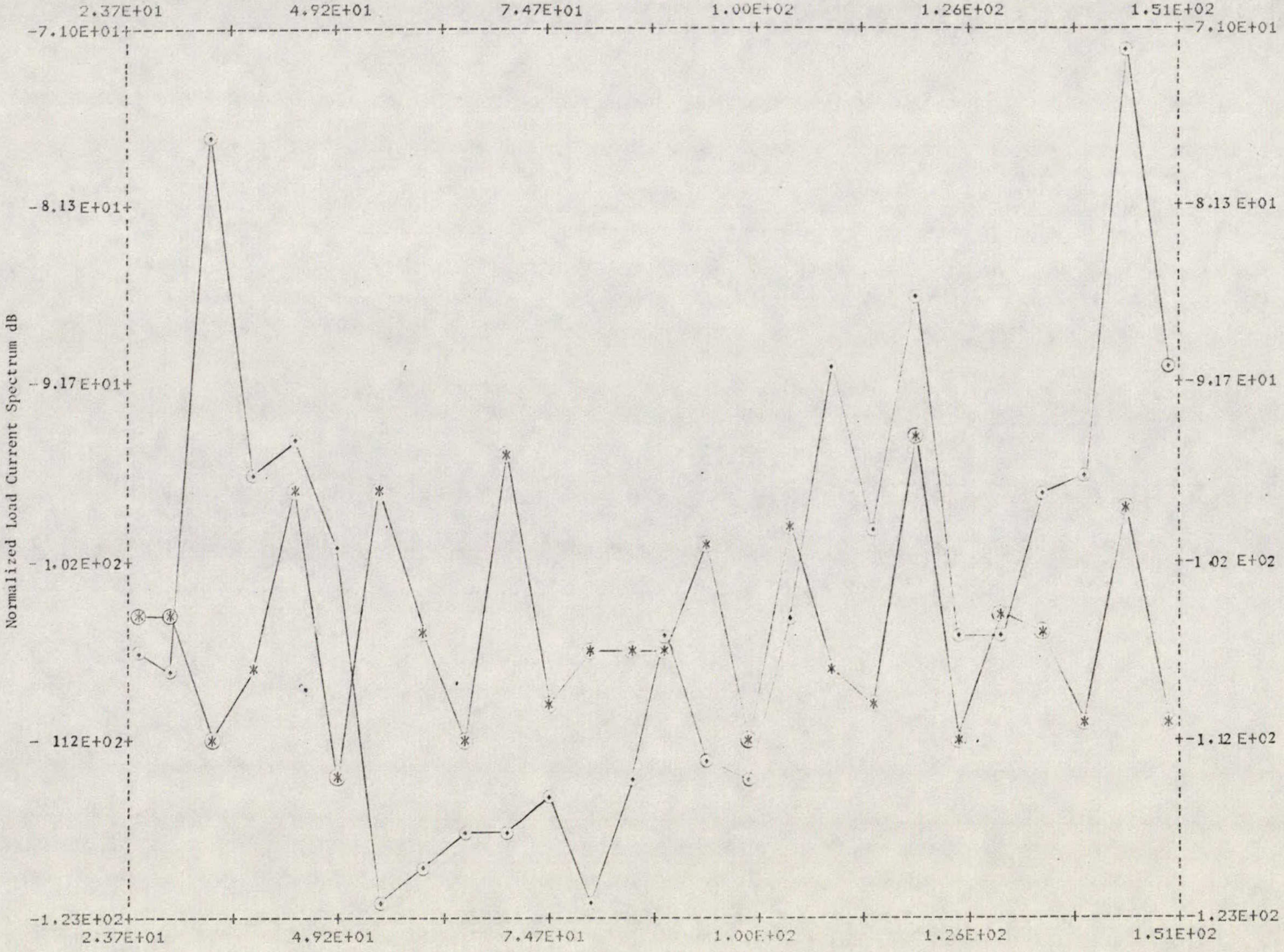
- Tx antenna horizontally polarized
- Tx antenna in "-Y" direction
- Both ends grounded to 150 ohms
- Both ends terminated to 75 ohms

Legend

· experimental

* theoretical





Graph 5.4.2

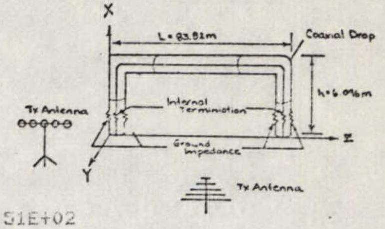
XMAX	XMIN	YMAX	YMIN
150.0000	25.00000	-70.50123	-123.5012

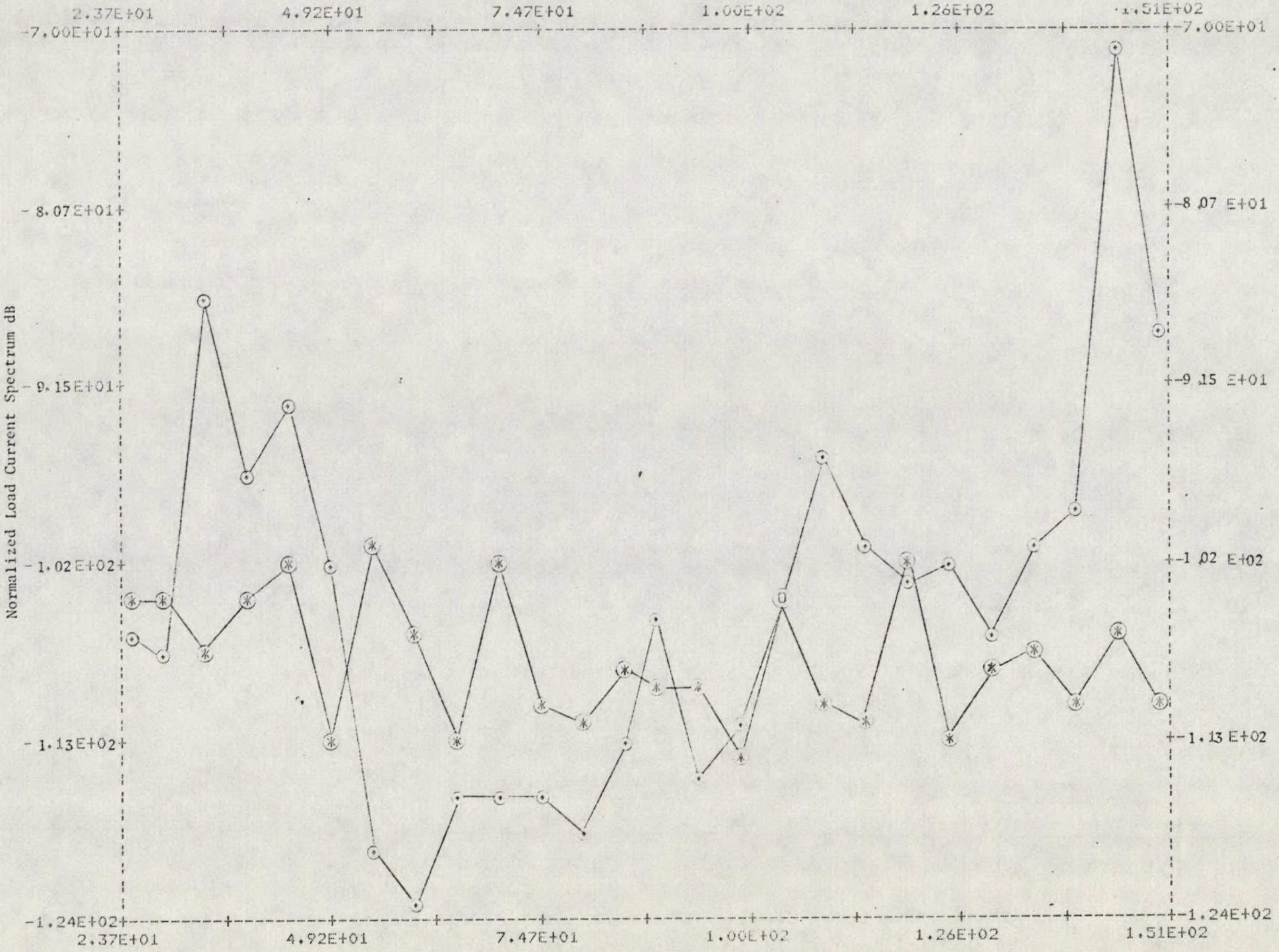
- Tx antenna horizontally polarized
- Tx antenna in "-Y" direction
- Both ends grounded to 510 ohms
- Both ends terminated to 75 ohms

Legend

· experimental

* theoretical





Graph 5.4.3

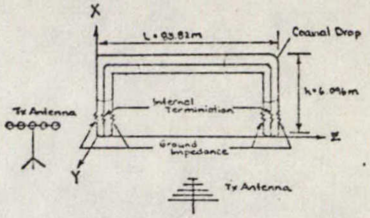
XMAX	XMIN	YMAX	YMIN
150.0000	25.00000	-68.50123	-123.5012

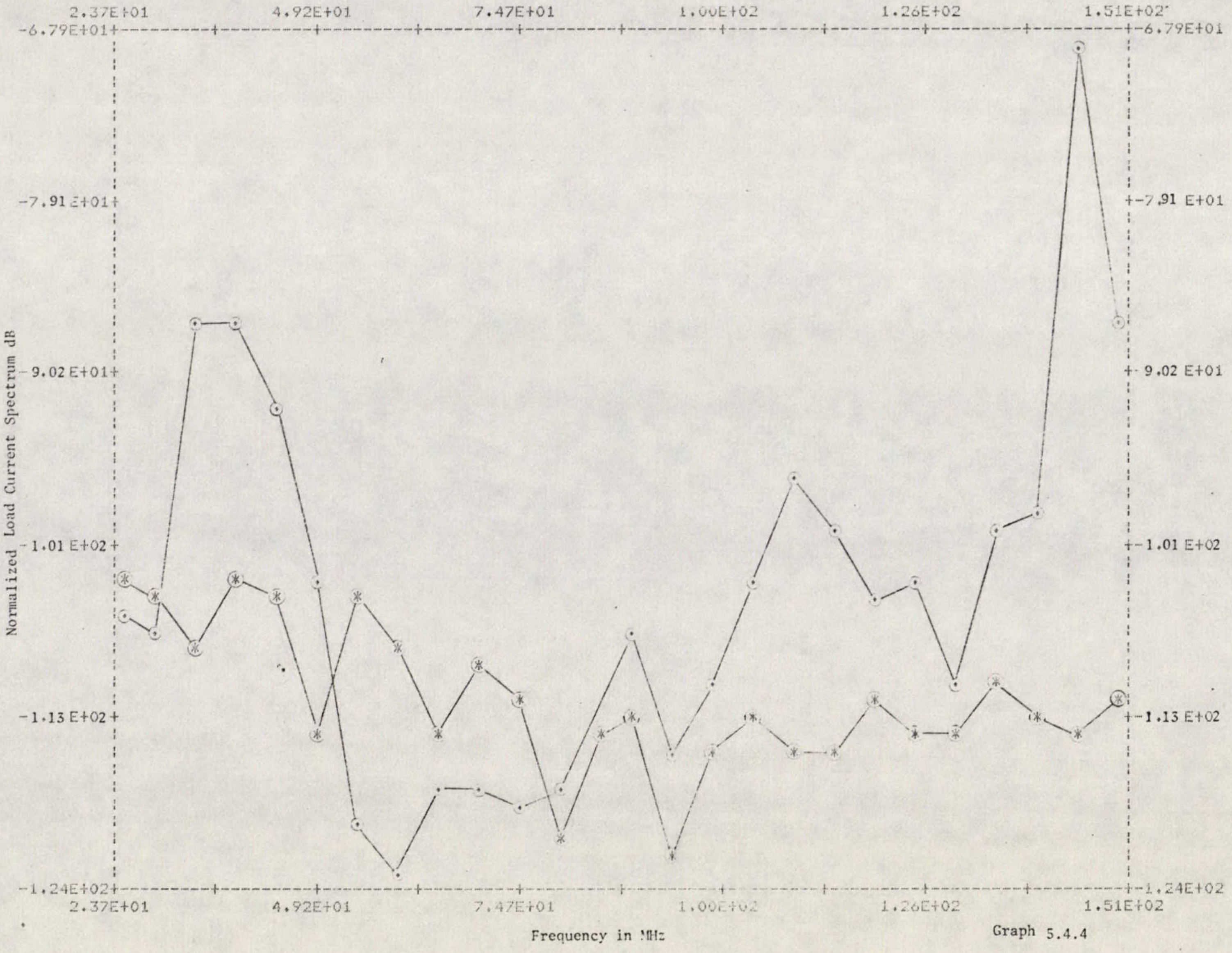
- Tx antenna horizontally polarized
- Tx antenna in "-Y" direction
- Both ends grounded to 1200 ohms
- Both ends terminated to 75 ohms

Legend

· experimental

* theoretical

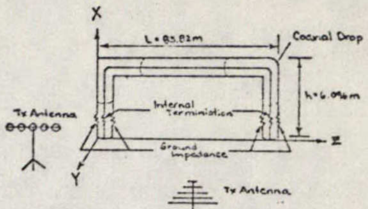


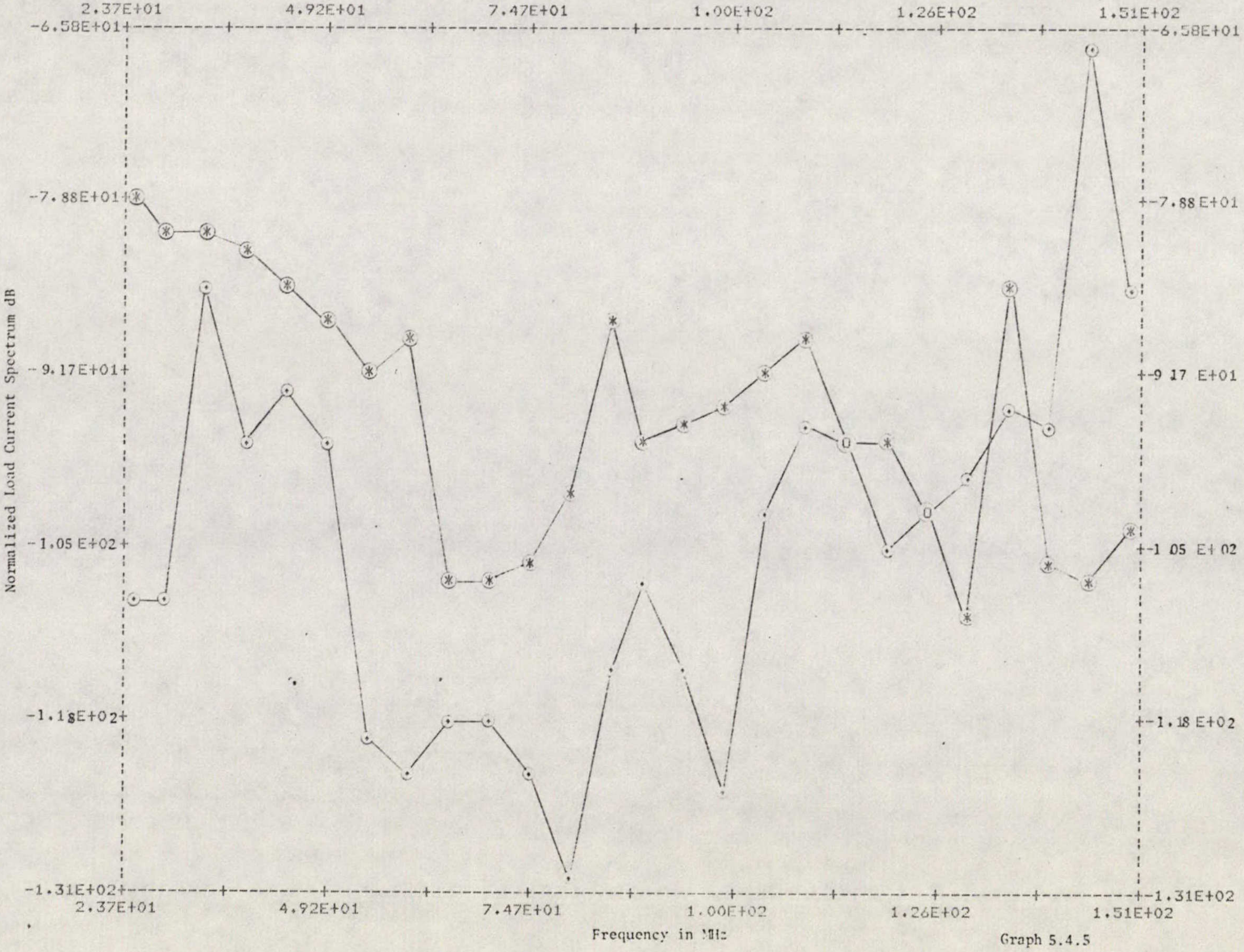


Graph 5.4.4

XMAX	XMIN	YMAX	YMIN
150.0000	25.00000	-66.50123	-130.5012

- Tx antenna horizontally polarized
- Tx antenna in "-Y" direction
- One end grounded to 3 ohms
- Both ends terminated to 75 ohms





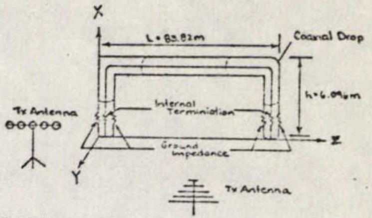
Graph 5.4.5

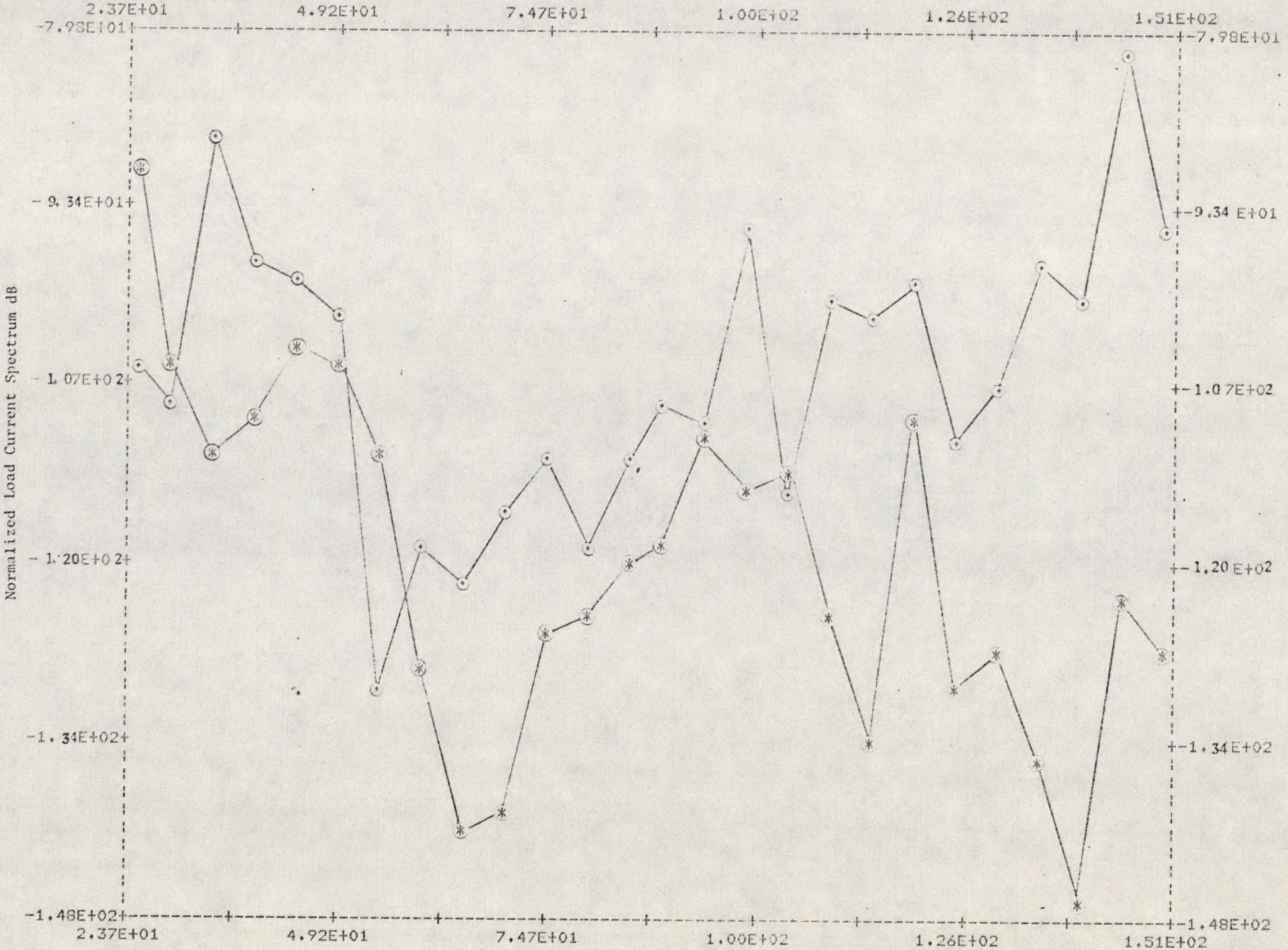
XMAX	XMIN	YMAX	YMIN
150.0000	25.00000	-80.50123	-147.1018

- Tx antenna horizontally polarized
- Tx antenna in "-Y" direction
- Both ends ungrounded
- One end unterminated

Legend

· experimental
* theoretical





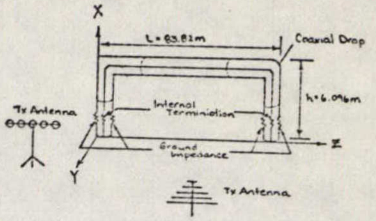
Graph 5.4.6

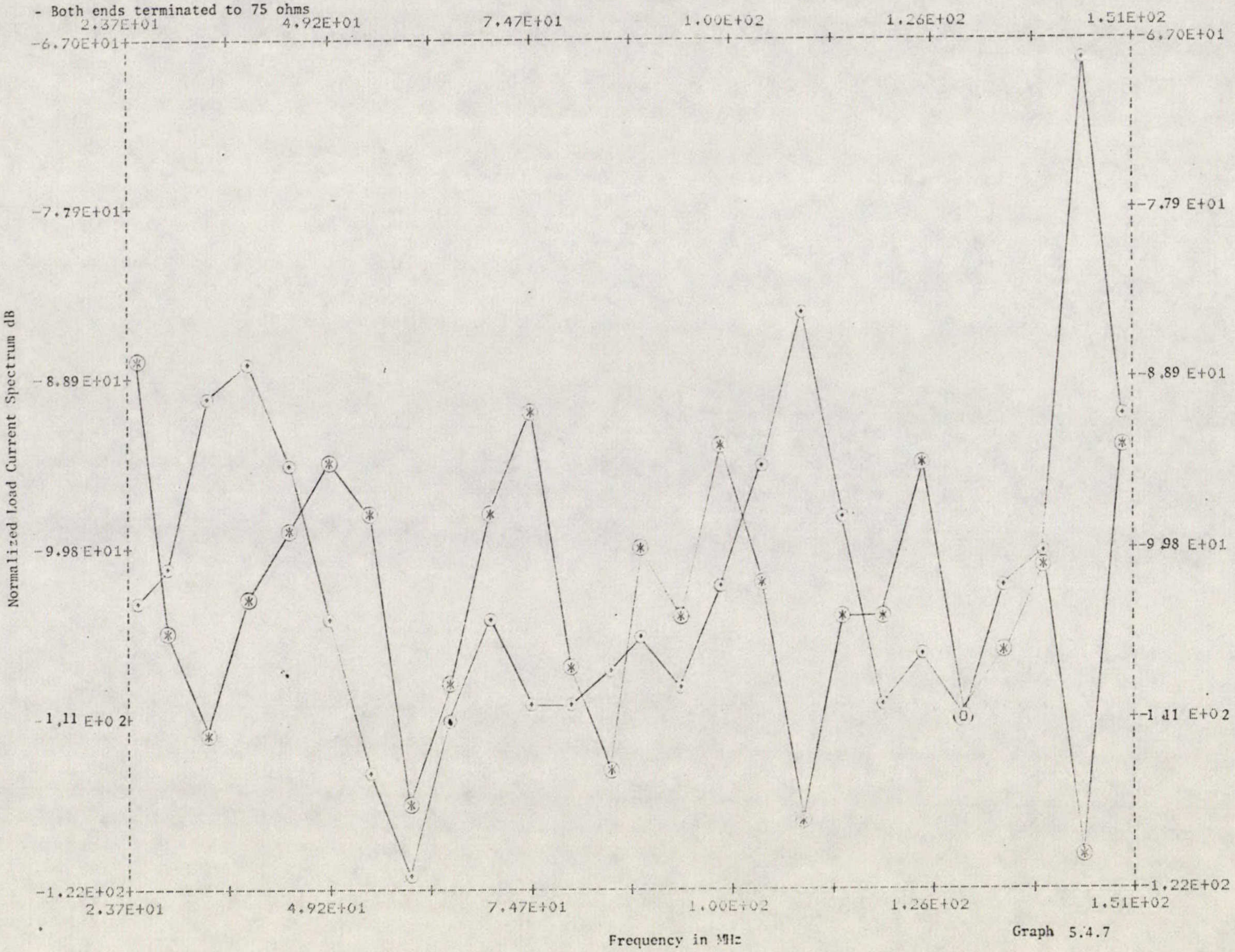
XMAX	XMIN	YMAX	YMIN
150.0000	25.00000	-67.50123	-121.5012

- Tx antenna horizontally polarized
- Tx antenna in "z" direction
- Both ends grounded to 3 ohms
- Both ends terminated to 75 ohms

Legend

- · experimental
- * theoretical





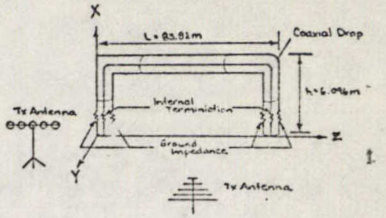
Graph 5.4.7

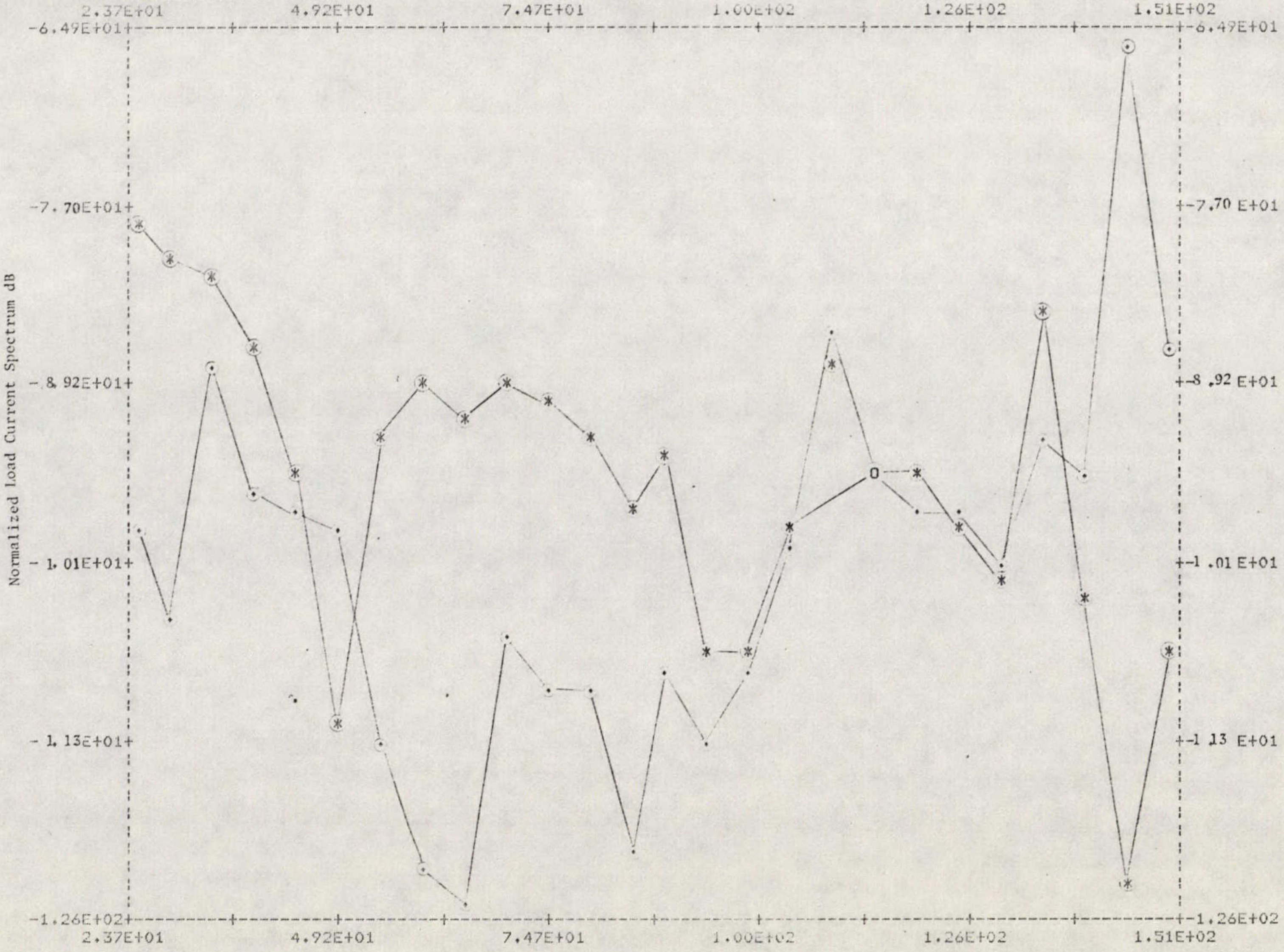
XMAX	XMIN	YMAX	YMIN
150.0000	25.00000	-65.50123	-125.5012

- Tx antenna horizontally polarized
- Tx antenna in "z" direction
- One end grounded to 3 ohms
- Both ends terminated to 75 ohms

Legend

· experimental
* theoretical





Graph 5.4.8

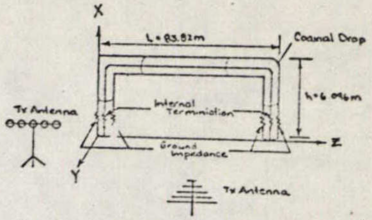
XMAX	XMIN	YMAX	YMIN
150.0000	25.00000	-62.50123	-146.3170

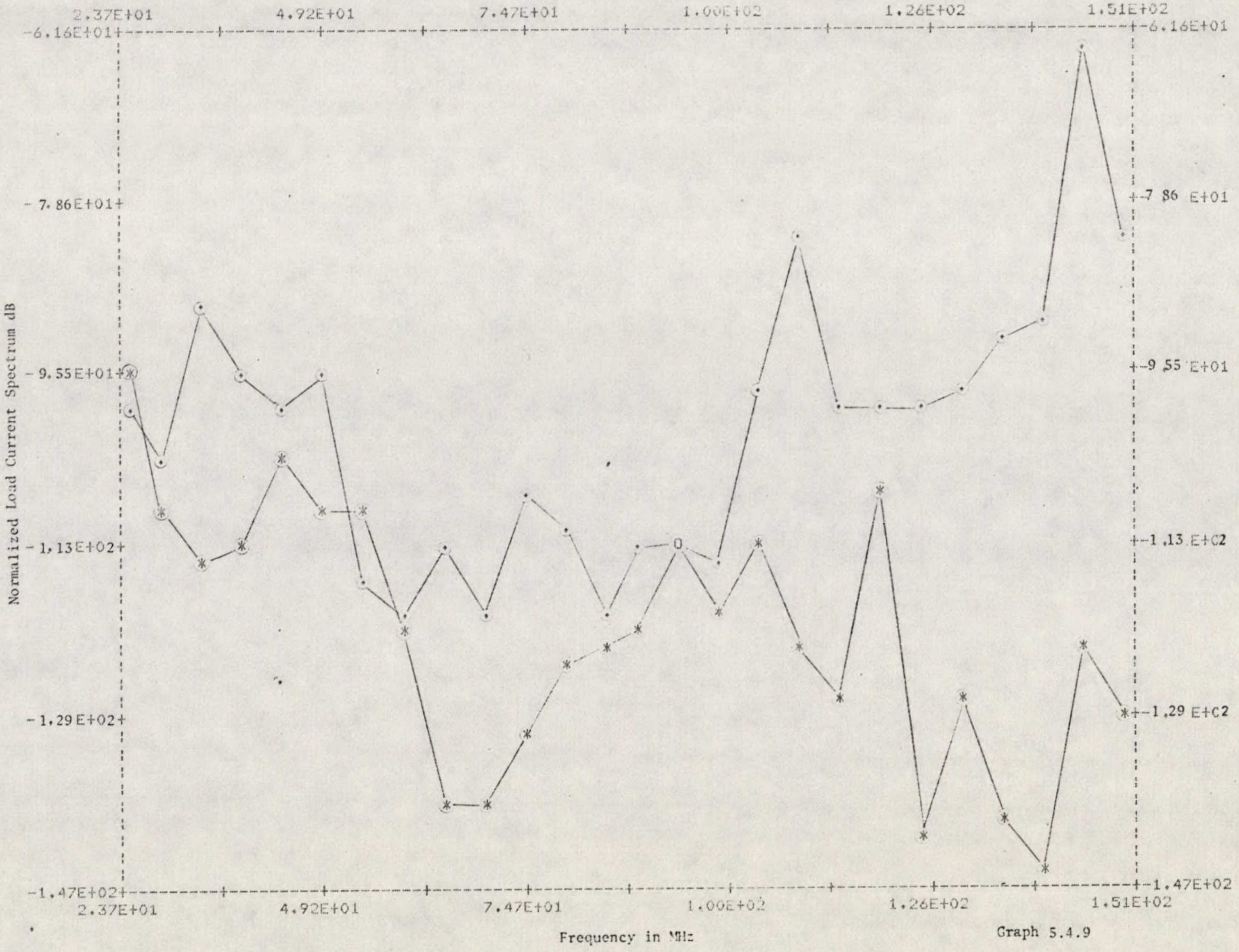
- Tx antenna horizontally polarized
- Tx antenna in "Z" direction
- Both ends ungrounded
- Both ends terminated to 75 ohms

Legend

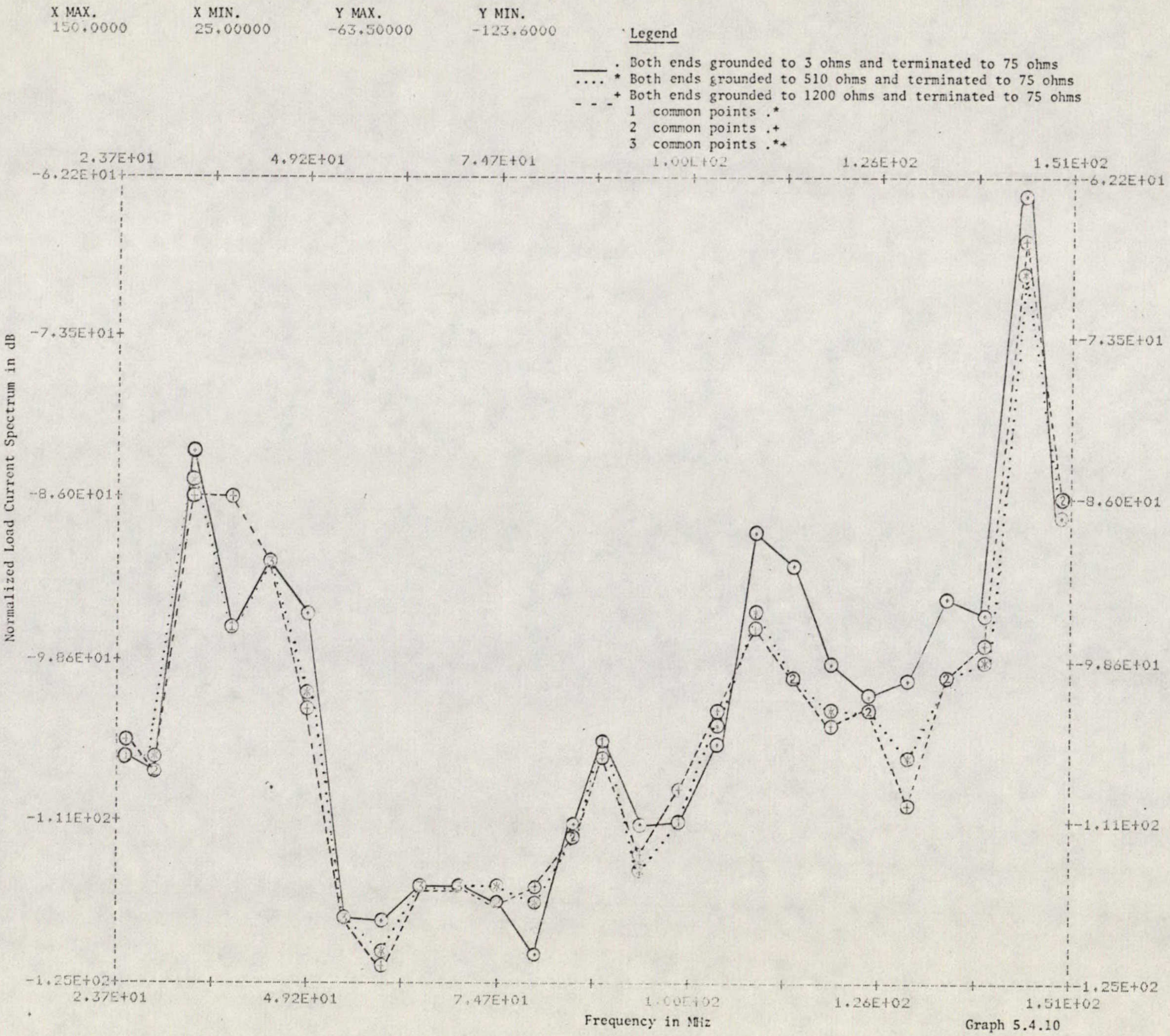
· experimental data

* theoretical data



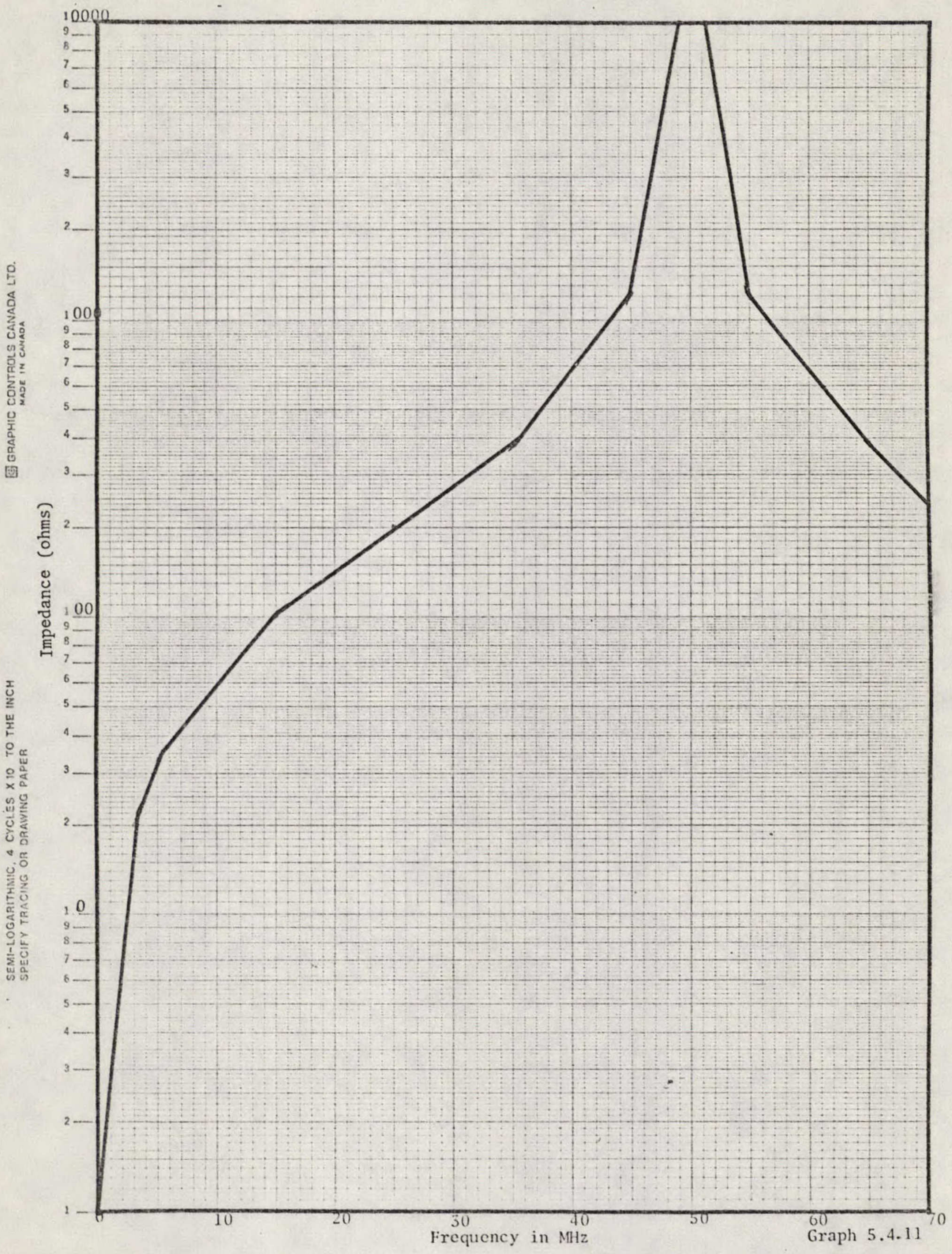


Graph 5.4.9


X MAX.
150.0000
X MIN.
25.00000
Y MAX.
-63.50000
Y MIN.
-123.6000
Legend
. Both ends grounded to 3 ohms and terminated to 75 ohms
* Both ends grounded to 510 ohms and terminated to 75 ohms
+ Both ends grounded to 1200 ohms and terminated to 75 ohms
1 common points .*
2 common points .+
3 common points .*+
2.37E+01
4.92E+01
7.47E+01
1.00E+02
1.26E+02
1.51E+02
-6.22E+01
-7.35E+01
-8.60E+01
-9.86E+01
-1.11E+02
-1.25E+02
Normalized Load Current Spectrum in dB
Frequency in MHz

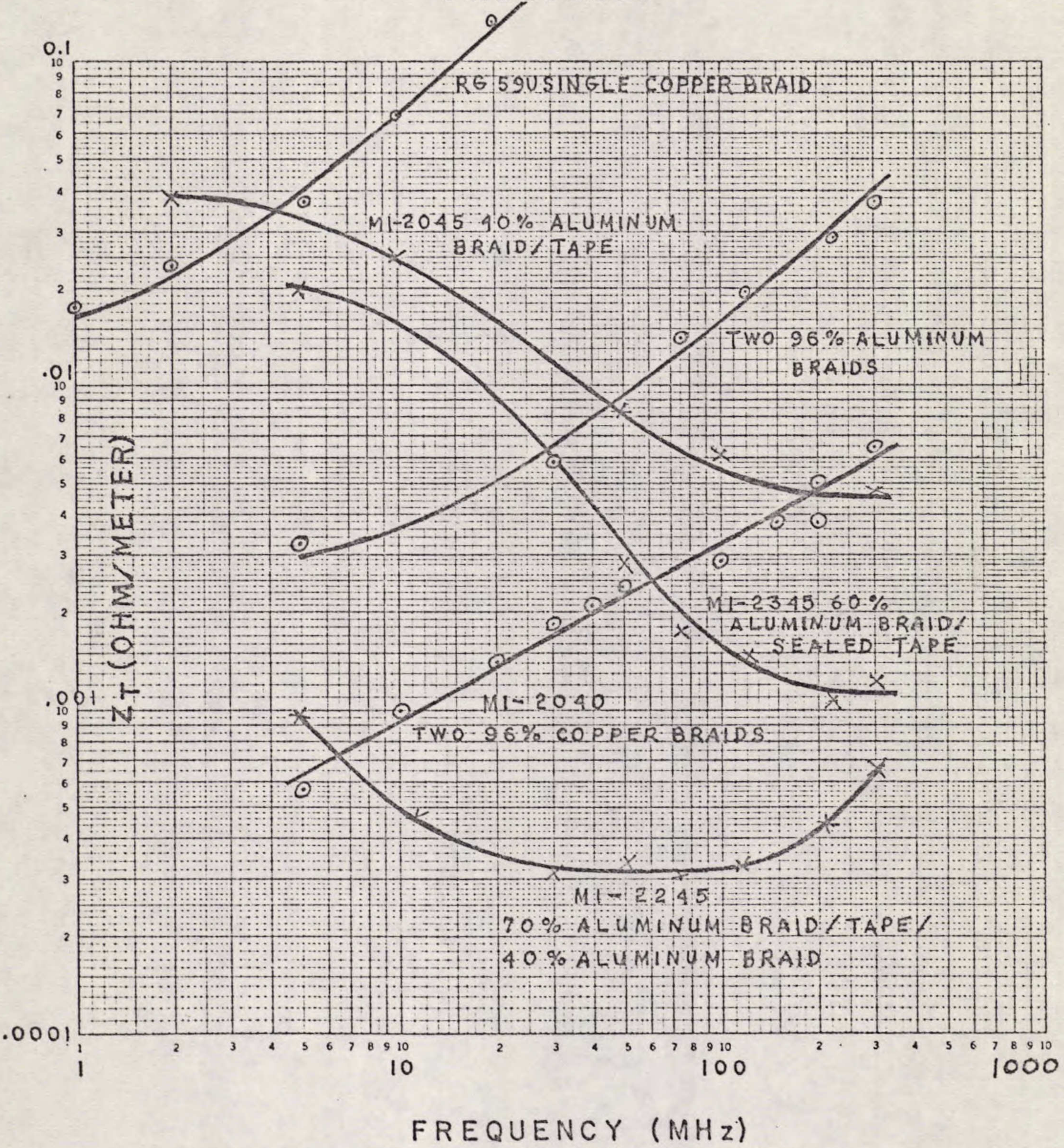
Graph 5.4.10

Impedance of a ground reference line as per G.H. Kunkel



Graph 5.4.11

MEASURED TRANSFER IMPEDANCE (Z_T) VS FREQUENCY



Graph 5.4.12

TABLE 5.4.1

- Tx antenna horizontally polarized
- Tx antenna in "-Y"direction
- Both ends grounded to 3 ohms
- Both ends terminated to 75 ohms

Freq MHz	Load Current Spectrum dB	
	Experimental	Theoretical
25.0	-108.5	-123.42
30.0	-109.5	-108.37
35.0	-84.5	-117.88
40.0	-98.5	-110.92
45.0	-93.5	-97.25
50.0	-96.5	-122.04
55.0	-120.5	-98.52
60.0	-120.5	-107.3
65.0	-117.5	-113.92
70.0	-118.5	-94.90
75.0	-119.5	-110.62
80.0	-123.5	-107.22
85.0	-113.5	-107.58
90.0	-106.5	-107.85
95.0	-113.5	-98.83
100.0	-113.5	-111.53
105.0	-106.5	-100.49
110.0	-90.5	-108.89
115.0	-93.5	-111.06
120.0	-100.5	-91.80
125.0	-103.5	-112.33
130.0	-101.5	-105.56
135.0	-95.5	-106.51
140.0	-96.5	-111.96
145.0	-63.5	-95.64
150.0	-89.5	-112.91

TABLE 5.4.2

- Tx antenna horizontally polarized
- Tx antenna in "-Y" direction
- Both ends grounded to 150 ohms
- Both ends terminated to 75 ohms

Freq MHz	Load Current Spectrum dB	
	Experimental	Theoretical
25.0	-108.5	-105.65
30.0	-109.5	-106.07
35.0	-77.5	-113.29
40.0	-97.5	-109.01
45.0	-95.5	-98.43
50.0	-101.5	-115.12
55.0	-122.5	-99.10
60.0	-120.5	-107.19
65.0	-118.5	-113.74
70.0	-118.5	-96.87
75.0	-116.5	-111.49
80.0	-122.5	-108.27
85.0	-115.5	-107.96
90.0	-107.5	-108.27
95.0	-114.5	-101.86
100.0	-115.5	-113.53
105.0	-106.5	-101.23
110.0	-91.0	-109.38
115.0	-100.5	-111.58
120.0	-86.5	-95.31
125.0	-107.5	-113.29
130.0	-107.5	-106.20
135.0	-98.50	-106.73
140.0	-97.0	-112.00
145.0	-71.5	-100.14
150.0	-91.5	-112.32

TABLE 5.4.3

- Tx antenna horizontally polarized
- Tx antenna in "-Y"direction
- Both ends grounded to 510 ohms
- Both ends terminated to 75 ohms

Freq MHz	Load Current Spectrum dB	
	Experimental	Theoretical
25.0	-107.5	-104.97
30.0	-108.5	-105.19
35.0	-86.5	-109.09
40.0	-97.5	-105.35
45.0	-93.5	-102.90
50.0	-103.5	-114.60
55.0	-120.5	-102.13
60.0	-123.5	-107.22
65.0	-117.5	-113.76
70.0	-117.5	-103.25
75.0	-117.5	-111.88
80.0	-119.5	-112.98
85.0	-114.5	-110.12
90.0	-106.5	-110.36
95.0	-116.5	-110.38
100.0	-112.5	-115.41
105.0	-105.5	-105.27
110.0	-96.5	-111.60
115.0	-101.5	-113.29
120.0	-104.5	-103.40
125.0	-103.5	-114.11
130.0	-107.5	-109.45
135.0	-101.5	-108.09
140.0	-100.0	-112.29
145.0	-70.5	-108.01
150.0	-88.5	-111.87

TABLE 5.4.4

- Tx antenna horizontally polarized
- Tx antenna in "-Y" direction
- Both ends grounded to 1200 ohms
- Both ends terminated to 75 ohms

Freq MHz	Load Current Spectrum dB	
	Experimental	Theoretical
25.0	-106.5	-104.41
30.0	-108.5	-105.9
35.0	-87.5	-108.78
40.0	-87.5	-104.78
45.0	-93.5	-106.04
50.0	-104.5	-114.76
55.0	-120.5	-105.74
60.0	-123.5	-108.89
65.0	-118.5	-115.23
70.0	-118.5	-110.07
75.0	-119.0	-112.13
80.0	-118.5	-121.52
85.0	-113.5	-115.36
90.0	-107.5	-113.83
95.0	-115.5	-122.37
100.0	-111.0	-116.15
105.0	-104.5	-114.13
110.0	-97.5	-116.28
115.0	-101.5	-115.49
120.0	-105.5	-112.57
125.0	-104.5	-114.54
130.0	-111.5	-115.46
135.0	-101.5	-111.59
140.0	-99.5	-113.44
145.0	-68.5	-114.33
150.0	-87.5	-112.08

TABLE 5.4.5

- Tx antenna horizontally polarized
- Tx antenna in "-Y"direction
- One end grounded to 3 ohms
- Both ends terminated to 75 ohms

Freq MHz	Load Current Spectrum dB	
	Experimental	Theoretical
25.0	-109.5	-79.21
30.0	-109.5	-81.52
35.0	-85.5	-81.66
40.0	-97.5	-82.63
45.0	-93.5	-86.16
50.0	-97.5	-89.05
55.0	-120.5	-92.64
60.0	-122.5	-90.37
65.0	-118.5	-107.84
70.0	-118.5	-108.24
75.0	-123.5	-106.53
80.0	-130.5	-102.26
85.0	-115.5	-89.07
90.0	-108.5	-97.45
95.0	-115.5	-96.59
100.0	-124.5	-95.47
105.0	-103.5	-92.97
110.0	-96.5	-89.20
115.0	-97.5	-98.22
120.0	-105.5	-97.27
125.0	-103.5	-103.29
130.0	-100.5	-111.66
135.0	-95.5	-85.62
140.0	-96.0	-106.92
145.0	-66.5	-108.85
150.0	-85.5	-103.93

TABLE 5.4.6

- Tx antenna horizontally polarized
- Tx antenna in "-Y"direction
- Both ends ungrounded
- One end unterminated

Freq MHz	Load Current Spectrum dB	
	Experimental	Theoretical
25.0	-105.5	-90.73
30.0	-109.5	-106.15
35.0	-88.5	-112.81
40.0	-98.5	-110.37
45.0	-99.5	-104.78
50.0	-101.5	-105.7
55.0	-130.5	-113.73
60.0	-119.5	-129.09
65.0	-122.5	-142.22
70.0	-117.5	-140.72
75.0	-113.5	-126.4
80.0	-120.5	-125.41
85.0	-113.5	-121.64
90.0	-108.5	-120.72
95.0	-110.5	-111.74
100.0	-94.5	-115.63
105.0	-116.5	-115.02
110.0	-100.5	-126.05
115.0	-101.5	-135.56
120.0	-99.5	-110.69
125.0	-111.5	-131.27
130.0	-107.5	-128.98
135.0	-98.5	-136.92
140.0	-100.5	-147.1
145.0	-80.5	-123.76
150.0	-95.5	-127.95

TABLE 5.4.7

- Tx antenna horizontally polarized
- Tx antenna in "z "direction
- Both ends grounded to 3 ohms
- Both ends terminated to 75 ohms

Freq MHz	Load Current Spectrum dB	
	Experimental	Theoretical
25.0	-104.5	-88.34
30.0	-101.5	-106.17
35.0	-90.5	-113.33
40.0	-88.5	-104.38
45.0	-94.5	-99.07
50.0	-105.5	-95.5
60.0	-121.5	-117.76
65.0	-112.5	-109.87
70.0	-105.5	-98.89
75.0	-110.5	-91.6
80.0	-110.5	-108.82
85.0	-109.0	-115.16
90.0	-106.5	-100.96
95.0	-109.5	-105.0
100.0	-103.5	-93.63
105.0	-94.5	-102.94
110.0	-84.5	-118.28
115.0	-98.5	-105.34
120.0	-110.5	-105.14
125.0	-107.5	-95.37
130.0	-111.5	-111.8
135.0	-102.5	-107.84
140.0	-100.5	-101.73
145.0	-67.5	-120.96
150.0	-91.5	-94.17

TABLE 5.4.8

- Tx antenna horizontally polarized
- Tx antenna in "z"direction
- One end grounded to 3 ohms
- Both ends terminated to 75 ohms

Freq MHz	Load Current Spectrum dB	
	Experimental	Theoretical
25.0	-99.5	-78.42
30.0	-106.5	-81.66
35.0	-88.5	-82.72
40.0	-97.5	-87.48
45.0	-98.5	-95.68
50.0	-99.5	-114.02
55.0	-114.5	-93.86
60.0	-123.5	-89.68
65.0	-125.5	-92.33
70.0	-107.5	-90.21
75.0	-111.5	-90.93
80.0	-111.5	-94.05
85.0	-122.5	-98.85
90.0	-109.5	-95.32
95.0	-114.5	-108.26
100.0	-110.5	-108.66
105.0	-101.0	-99.31
110.0	-86.5	-88.13
115.0	-95.5	-96.7
120.0	-98.5	-95.61
125.0	-98.5	-99.7
130.0	-102.5	-103.49
135.0	-93.5	-84.3
140.0	-95.5	-105.43
145.0	-65.5	-124.69
150.0	-87.5	-108.79

TABLE 5.4.9

- Tx antenna horizontally polarized
- Tx antenna in "z"direction
- Both ends ungrounded
- Both ends terminated to 75 ohms

Freq MHz	Load Current Spectrum dB	
	Experimental	Theoretical
25.0	-99.5	-96.37
30.0	-104.5	-109.74
35.0	-89.5	-116.18
40.0	-96.5	-113.18
45.0	-99.5	-104.66
50.0	-96.5	-110.62
55.0	-117.5	-110.37
60.0	-120.5	-123.60
65.0	-114.5	-139.77
70.0	-121.5	-140.84
75.0	-109.5	-133.26
80.0	-111.5	-126.78
85.0	-121.5	-125.30
90.0	-113.5	-123.55
95.0	-114.5	-113.25
100.0	-116.5	-120.69
105.0	-97.5	-114.49
110.0	-82.5	-124.12
115.0	-99.5	-129.15
120.0	-100.5	-109.17
125.0	-100.5	-144.50
130.0	-97.5	-129.65
135.0	-92.5	-141.79
140.0	-91.0	-146.31
145.0	-62.5	-123.72
150.0	-82.5	-131.02

APPENDIX 5.3.1

"Computer Program to simulate" equation 36

```
FORTRAN IV      V02.04      Tue 02Fri -72 01:34:42                  PAGE 001

0001          ALPHA(X)=(.302*X**.5+.00169*X)*3.77716E-3
0002          IMPLICIT COMPLEX(Z,Y,K)
0003          COMPLEX P,D
0004          REAL*8 AMILZ,BMILZ
0005          REAL*4 A1,A2,A3,A4,VC,L,H,RO,CC
0006          LOGICAL*4 ANS
0007          DATA PI,UO,EO/3.1415927,12.566371E-7,8.854E-12/
0008          DATA CL,IN,IOUT/2.99E8,5,7/
0009          DATA VM/2.204E-8/
0010          DATA VC,R1,R2,RA,RB,CC/.67,3.,3.,75.,75.,6.7257E-11/
0011          DATA BC,AC,OOCON/.0018542,2.921E-4,1.8334349E7/
0012          DATA H,L,RO,EZANGL,EXANGL/10.,100.,.0021717,90.,0./
0013          DATA UM,OOBRAI,AD,RDCBR/1.,2.8613995E7,1.6E-4,9.1605E-3/
      C
      C
      C
      C       NESCESSARY VARIABLE INPUT
      C
      C
      C
      C
      C       OPENNING APPROPRIATE FILE
      C
      C
      C
0014          CALL ASSIGN(1,'RPCD01.DAT',10,'NEW','NC',1)
0015          CALL ASSIGN(2,'RPCD02.DAT',10,'NEW','NC',1)
0016          CALL ASSIGN(3,'RPCD03.DAT',10,'NEW','NC',1)
0017          WRITE(1,100)
0018    100   FORMAT(10X,'ILZ CURRENT SPECTRUM')
0019          WRITE(2,200)
0020    200   FORMAT(10X,'ILX CURRENT SPECTRUM')
0021          WRITE(3,300)
0022    300   FORMAT(10X,'ILZ + ILX CURRENT SPECTRUM')
0023          GO TO 2
0024    25    WRITE(IOUT,990)
0025    990   FORMAT(/,' WANT TO INPUT NEW DATA ',$)
0026          READ(IN,995) ANS
0027    995   FORMAT(A4)
0028          IF(ANS .EQ.'YES' .OR. ANS .EQ. 'Y') GO TO 800
0030          GO TO 11
0031    800   WRITE(IOUT,1000)
0032    1000  FORMAT(/,' INPUT NEW VARIABLES BETWEEN COMMAS',/,/)
0033          WRITE(IOUT,1005)
0034    1005  FORMAT(/,5X,'VC',5X,'R1',5X,'R2',5X,'RA',5X,'RB',5X,'H',5X,'L')
0035          READ(IN,*)VC,R1,R2,RA,RB,H,L
0036    2     WRITE(IOUT,1015)
0037    1015  FORMAT(/,' WHAT FREQUENCY RANGE WOULD LIKE TO LOOK AT IN MHZ  ',$)
0038          READ(IN,*) ISTART,IFINIS
      C
      C
0039          EZANGL=EZANGL*PI/180.0
0040          EXANGL=EXANGL*PI/180.0
0041          Z1=CMPLX(R1,0.0)
```

```
0042          Z2=CMPLX(R2,0.0)
0043          ZA=CMPLX(RA,0.0)
0044          ZB=CMPLX(RB,0.0)
0045          ZDDF=CMPLX(1.0,1.0)
0046          U=UM*U0
0047          WRITE(1,150) VC,R1,R2,RA,H,L
0048    150   FORMAT(/,/,/,5X,'VC= ',F4.2,'  R1= ',E12.5,'R2= ',E12.5,'RA= '
             *,E12.5,'H= ',F6.2,' L= ',F6.2,/,/)
0049          WRITE(2,150) VC,R1,R2,RA,H,L
0050          WRITE(3,150) VC,R1,R2,RA,H,L
        C
        C     EVALUATION OF TRANSMISSION LINE PARAMETERS
        C
0051          DO 10 IFREQ=ISTART,IFINIS
0052          W=2.0*PI*FLOAT(IFREQ)*1.0E6
0053          WLT=W*U0*ALOG(H/2.0/R0+SQRT((H/2.0/R0)**2-1.0))/PI
0054          WCT=W*PI*E0/ALOG(H/2.0/R0+SQRT((H/2.0/R0)**2-1.0))
0055          RT=1.0/PI/R0*SQRT(W*U/2.0/OOBRAI)
0056          GT=WCT*.0002
0057          AZEZ=SIN(W/CL*H/2.0*SIN(EZANGL))
0058          ZEZ=CMPLX(0.0,AZEZ)
0059          ZTL=CMPLX(RT,WLT)
0060          YTL=CMPLX(GT,WCT)
0061          Z0=CSQRT(ZTL/YTL)
0062          YT=CSQRT(ZTL*YTL)
        C
        C
        C     EVALUATION OF COAXIAL PARAMETER
        C
        C
0063          WLC=W*U0/2.0/PI*ALOG(BC/AC)
0064          RC=1.0/2.0/PI*SQRT(W*U0/2.0/OOCON)*(1.0/AC+1.0/BC)
0065          WCC=W*CC
0066          GC=WCC*.0005
0067          ZCC=CMPLX(RC,WLC)
0068          YCC=CMPLX(GC,WCC)
0069          ZC=CSQRT(ZCC/YCC)
0070          ALPHAC=ALPHA(FLOAT(IFREQ))
0071          BETAC=W/VC/CL
0072          YC=CMPLX(ALPHAC,BETAC)
0073          SKIN0=SQRT(2.0/OOBRAI/W/U0)
0074          ZDD=ZDDF*AD/SKIN0
0075          KSINH=(CEXP(ZDD)-CEXP(-ZDD))/2.0
0076          ZD=RDCBR*(ZDD/KSINH)
0077          WVM=W*U0*VM/PI**2/(2.0*BC)**2
0078          ZM=CMPLX(0.0,WVM)
0079          ZT=ZD+ZM
0080          AMAZT=SQRT(REAL(ZT)**2+AIMAG(ZT)**2)
0081          BSIN0=W/CL*SIN(EXANGL)
0082          ZBSIN0=CMPLX(0.0,-BSIN0)
        C
        C
        C     EVALUATION OF LOAD  CURRENT SPECTRUM
        C
```

```
              C
              C     EVALUATION OF BASIS VARIABLE
              C
              C
 0083               ZA1=ZA*Z1
 0084               ZA0=ZA*Z0
 0085               ZAC=ZA*ZC
 0086               ZA2=ZA*Z2
 0087               ZAB=ZA*ZB
 0088               Z01=Z1*Z0
 0089               ZC1=Z1*ZC
 0090               ZC0=ZC*Z0
 0091               Z02=Z0*Z2
 0092               ZC2=ZC*Z2
 0093               ZBC=ZC*ZB
 0094               Y21=YT*YT-YC*YC
              C
              C
              C     COMPUTATION OF IL CONSTANTS
              C
              C
              C     CONSTANT OF Z FIELD
              C
              C
 0095               KEZ1=ZA0*Z1*Y21+YT*Z2*(YT*ZA0-YC*ZC1)
 0096               KEZ2=ZA0*Z0*Y21+YT*Z2*(YT*ZA1-YC*ZC0)
 0097               KEZ3=YC*Z1*(YC*ZA0+YT*ZC2)
 0098               KEZ4=ZC0*Z1*Y21+YT*Z2*(YT*ZC0-YC*ZA1)
 0099               KEZ5=ZC0*Z0*Y21+YT*Z2*(YT*ZC1-YC*ZA0)
 0100               KEZ6=YC*Z1*(YC*ZC0+YT*ZA2)
 0101               KEZ7=ZA0*Z2*Y21+YT*Z1*(YT*ZA1+YC*ZC2)
 0102               KEZ8=ZA0*Z0*Y21+YT*Z1*(YT*ZA2+YC*ZC0)
 0103               KEZ9=YC*Z2*(YC*ZA0-YT*ZC1)
              C
              C
              C     CONSTANT OF X FIELD
              C
              C
 0104               KEX1=YC*ZA0+YT*ZC2
 0105               KEX2=YC*ZA2+YT*ZC0
 0106               KEX3=YC*ZC0+YT*ZA2
 0107               KEX4=YT*ZC1-YC*ZA0
 0108               KEX5=YT*ZC0-YC*ZA1
 0109               KEX6=YT*ZA1-YC*ZC0
 0110               KEX7=YT*ZA0-YC*ZC1
              C
              C
              C     EVALUATION OD HYPERBOLIC
              C
              C
 0111               KCHYT=(CEXP(YT*L)+CEXP(-YT*L))/2.0
 0112               KSHYT=(CEXP(YT*L)-CEXP(-YT*L))/2.0
 0113               KCHYC=(CEXP(YC*L)+CEXP(-YC*L))/2.0
 0114               KSHYC=(CEXP(YC*L)-CEXP(-YC*L))/2.0
```

```
C
C
C     EVALUATION OF DENOMINATOR CONSTANT
C
C
      D=(Z01+Z02)*KCHYT+(Z0*Z0+Z1*Z2)*KSHYT
      P=(ZAC+ZBC)*KCHYC+(ZC*ZC+ZAB)*KSHYC
      KEZDIV=Z0*D*P*YT*YC*Y21
      KEXDIV=D*P*Y21
C
C
C     EVALUATION OF NUMERATOR CONSTANT
C
C
      KEZ13=(KEZ1*KCHYT+KEZ2*KSHYT+KEZ3)*KCHYC
      KEZ36=(KEZ4*KCHYT+KEZ5*KSHYT+KEZ6)*KSHYC
      KEZ79=KEZ7*KCHYT+KEZ8*KSHYT+KEZ9
C
C
C     EVALUATION OF ILZ(W)
C
C
      KILZ=-4.0*ZT*ZEZ/KEZDIV*(KEZ13+KEZ36-KEZ79)
C
C
C     EVALUATION OF EX CONSTANT
C
C
      KILX1=H*ZT/KEXDIV*(KEX1*KCHYT+KEX2*KSHYT-KEX1*KCHYC-KEX3*KSHYC)
      KEX45=(KEX4*KCHYT+KEX5*KSHYT)*KCHYC
      KEX67=(KEX6*KCHYT+KEX7*KSHYT)*KSHYC
      KILX2=H*CEXP(ZBSIN0)*ZT/KEXDIV*(KEX45+KEX67-KEX4)
      KILX=KILX1-KILX2
      KILW=KILZ+KILX
C
C
C     EVALUATION OF MAGNITUDE
C
C
      AMILZ=DSQRT(REAL(KILZ)**2+AIMAG(KILZ)**2)
      AMILX=SQRT(REAL(KILX)**2+AIMAG(KILX)**2)
      AMILW=SQRT(REAL(KILW)**2+AIMAG(KILW)**2)
      BMILZ=20.0*DLOG10(AMILZ)
      BMILX=20.0*ALOG10(AMILX)
      BMILW=20.0*ALOG10(AMILW)
      WRITE(1,*) FLOAT(IFREQ),BMILZ
      WRITE(2,*) FLOAT(IFREQ),BMILX
      WRITE(3,*) FLOAT(IFREQ),BMILW
10    CONTINUE
      GO TO 25
11    ENDFILE 1
      ENDFILE 2
      ENDFILE 3
      CALL CLOSE(1)
```

```
FORTRAN IV      V02.04
                                  Tue 02Fri -72 01:34:42                  PAGE 005

0144          CALL CLOSE(2)
0145          CALL CLOSE(3)
0146          CALL EXIT
0147          END
.MAIN.



FORTRAN IV       Storage Map for Program Unit .MAIN.

Local Variables, .PSECT $DATA, Size = 002054 (  534. words)

Name    Type  Offset      Name    Type  Offset      Name    Type  Offset
AC      R*4   000066      AD      R*4   000132      ALPHAC  R*4   000466
AMAZT   R*4   000566      AMILW   R*4   001352      AMILX   R*4   001346
AMILZ   R*8   000164      ANS     L*4   000224      AZEZ    R*4   000342
A1      R*4   000204      A2      R*4   000210      A3      R*4   000214
A4      R*4   000220      BC      R*4   000062      BETAC   R*4   000472
BMILW   R*4   001362      BMILX   R*4   001356      BMILZ   R*8   000174
BSINO   R*4   000572      CC      R*4   000056      CL      R*4   000016
D       C*8   000154      EXANGL  R*4   000116      EZANGL  R*4   000112
EO      R*4   000012      GC      R*4   000432      GT      R*4   000336
H       R*4   000076      IFINIS  I*2   000236      IFREQ   I*2   000314
IN      I*2   000022      IOUT    I*2   000024      ISTART  I*2   000234
KCHYC   C*8   001166      KCHYT   C*8   001146      KEXDIV  C*8   001216
KEX1    C*8   001056      KEX2    C*8   001066      KEX3    C*8   001076
KEX4    C*8   001106      KEX45   C*8   001276      KEX5    C*8   001116
KEX6    C*8   001126      KEX67   C*8   001306      KEX7    C*8   001136
KEZDIV  C*8   001206      KEZ1    C*8   000746      KEZ13   C*8   001226
KEZ2    C*8   000756      KEZ3    C*8   000766      KEZ36   C*8   001236
KEZ4    C*8   000776      KEZ5    C*8   001006      KEZ6    C*8   001016
KEZ7    C*8   001026      KEZ79   C*8   001246      KEZ8    C*8   001036
KEZ9    C*8   001046      KILW    C*8   001336      KILX    C*8   001326
KILX1   C*8   001266      KILX2   C*8   001316      KILZ    C*8   001256
KSHYC   C*8   001176      KSHYT   C*8   001156      KSINH   C*8   000522
L       R*4   000102      OOBRAI  R*4   000126      OOCON   R*4   000072
P       C*8   000144      PI      R*4   000002      RA      R*4   000046
RB      R*4   000052      RC      R*4   000422      RDCBR   R*4   000136
RT      R*4   000332      RO      R*4   000106      R1      R*4   000036
R2      R*4   000042      SKINO   R*4   000506      U       R*4   000310
UM      R*4   000122      UO      R*4   000006      VC      R*4   000032
VM      R*4   000026      W       R*4   000316      WCC     R*4   000426
WCT     R*4   000326      WLC     R*4   000416      WLT     R*4   000322
WVM     R*4   000542      X       R*4   000230      YC      C*8   000476
YCC     C*8   000446      YT      C*8   000406      YTL     C*8   000366
Y21     C*8   000736      ZA      C*8   000260      ZAB     C*8   000646
ZAC     C*8   000626      ZAO     C*8   000616      ZA1     C*8   000606
ZA2     C*8   000636      ZB      C*8   000270      ZBC     C*8   000726
ZBSINO  C*8   000576      ZC      C*8   000456      ZCC     C*8   000436
ZCO     C*8   000676      ZC1     C*8   000666      ZC2     C*8   000716
ZD      C*8   000532      ZDD     C*8   000512      ZDDF    C*8   000300
ZEZ     C*8   000346      ZM      C*8   000546      ZT      C*8   000556
ZTL     C*8   000356      ZO      C*8   000376      ZO1     C*8   000656
ZO2     C*8   000706      Z1      C*8   000240      Z2      C*8   000250
```

APPENDIX 5.3.2.

"Computer program to plot"

Five dependent variables versus

x on a Tektronix terminal

```
        REAL*4 X(500),Y0(500),Y1(500),Y2(500),Y3(500),YT(2500)
        REAL*4 Y4(500)
        INTEGER TITLX(8),TITLY1(16),TITLY0(16),TITLY2(16)
        INTEGER TITLY3(16),POINTS,TITLY4(16,,TITLE5(16)
        INTEGER TITLE1(16),TITLE2(16),TITLE3(16),TITLE4(16)
        REAL*8 FILE1,FILE2,FILE3,FILE4,FILE5
C
C
C
        WRITE(5,1000)
1000    FORMAT(/,' INPUT FILENAME ',$)
        READ(5,1010)FILE1
1010    FORMAT(A10)
        OPEN(UNIT=1,FILE=FILE1,ACCESS='SEQIN',MODE='ASCII')
        READ(1,1020)(TITLX(I),I=1,8)
        READ(1,1025)(TITLY0(I),I=1,16)
        READ(1,1025)(TITLE1(I),I=1,16)
C
C
C
        WRITE(5,1001)
1001    FORMAT(/,' INPUT FILENAME 2 ',$)
        READ(5,1010)FILE2
        OPEN(UNIT=2,FILE=FILE2,ACCESS='SEQIN',MODE='ASCII')
        READ(2,1020)(TITLX(I),I=1,8)
        READ(2,1025)(TITLY0(I),I=1,16)
        READ(2,1025)(TITLE2(I),I=1,16)
C
C
C
        WRITE(5,1003)
1003    FORMAT(/,' INPUT FILENAME 3 ',$)
        READ(5,1010)FILE3
        OPEN(UNIT=3,FILE=FILE3,ACCESS='SEQIN',MODE='ASCII')
        READ(3,1020)(TITLX(I),I=1,8)
        READ(3,1025)(TITLY0(I),I=1,16)
        READ(3,1025)(TITLE3(I),I=1,16)
C
C
C
        WRITE(5,1004)
1004    FORMAT(/,' INPUT FILENAME 4 ',$)
        READ(5,1010)FILE4
        OPEN(UNIT=4,FILE=FILE4,ACCESS='SEQIN',MODE='ASCII')
        READ(4,1020)(TITLX(I),I=1,8)
        READ(4,1025)(TITLY0(I),I=1,16)
        READ(4,1025)(TITLE4(I),I=1,16)
C
C
C
        WRITE(5,1005)
1005    FORMAT(/,' INPUT FILENAME 5 ',$)
        READ(5,1010)FILE5
        OPEN(UNIT=15,FILE=FILE5,ACCESS='SEQIN',MODE='ASCII')
        READ(15,1020)(TITLX(I),I=1,8)
        READ(15,1025)(TITLY0(I),I=1,16)
```

```
          READ(15,1025)(TITLE5(I),I=1,16)
1020      FORMAT(8A5)
1025      FORMAT(16A5)
          DO 10 I=1,500
          READ(1,*,ERR=200,END=20) X(I),Y0(I)
10        CONTINUE
200       STOP 'ERROR DEDECTED IN INPUT'
20        POINTS=I-1
          DO 15 I=1,POINTS
          READ(2,*)X(I),Y1(I)
          READ(3,*) X(I),Y2(I)
          READ(4,*) X(I),Y3(I)
          READ(15,*)X(I),Y4(I)
          YT(I)=Y0(I)
          YT(POINTS+I)=Y1(I)
          YT(2*POINTS+I)=Y2(I)
          YT(3*POINTS+I)=Y3(I)
          YT(4*POINTS+I)=Y4(I)
15        CONTINUE
          NPTN=5*POINTS
          XMAX=X(1)
          XMIN=X(1)
          DO 30 I=2,POINTS
          IF(XMAX .LT. X(I)) XMAX=X(I)
          IF(XMIN .GT. X(I)) XMIN=X(I)
30        CONTINUE
          XDA=(XMAX-XMIN)/12.0
          CALL PLOTS(30,16.5,10.75,2)
          CALL PLOT(2.0,1.250,-3)
          CALL SCALE4(YT,9.0,NPTN,1,0,AYMIN,YDA)
          CALL AXIS4(0.0,0.0,TITLX,40,-.25,-.125,12.,0.0,XMIN,XDA,
     *2,.1,10)
          CALL AXIS4(0.0,0.0,TITLY0,80,.25,.125,9.0,90.,AYMIN,YDA,
     *2,.1,10)
          CALL LINE4(X,Y0,POINTS,1,XMIN,XDA,AYMIN,YDA,2,0,0)
          CALL LINE4(X,Y1,POINTS,1,XMIN,XDA,AYMIN,YDA,2,1,0)
          CALL LINE4(X,Y2,POINTS,1,XMIN,XDA,AYMIN,YDA,2,2,0)
          CALL LINE4(X,Y3,POINTS,1,XMIN,XDA,AYMIN,YDA,2,5,0)
          CALL LINE4(X,Y4,POINTS,1,XMIN,XDA,AYMIN,YDA,2,10,0)
          CALL SYMBOL(.3,8.8,.15,0,0.0,-1)
          CALL SYMBOL(.6,8.8,.2,TITLE1,0.0,80)
          CALL SYMBOL(.3,8.5,.15,1,0.0,-1)
          CALL SYMBOL(.6,8.5,.2,TITLE2,0.0,80)
          CALL SYMBOL(.3,8.2,.15,2,0.0,-1)
          CALL SYMBOL(.6,8.2,.2,TITLE3,0.0,80)
          CALL SYMBOL(.3,7.9,.15,5,0.0,-1)
          CALL SYMBOL(.6,7.9,.2,TITLE4,0.0,80)
          CALL SYMBOL(.3,7.6,.15,10,0.0,-1)
          CALL SYMBOL(.6,7.6,.2,TITLE5,0.0,80)
          CALL PLTERR(0)
          CALL ENDPLT
          CALL EXIT
          END
```

```
MAIN.    RPPLO5.FOR      FORTRAN V.5A(621) /KI    16-MAR-80       1:38    PAGE 1-2



SUBPROGRAMS CALLED

ENDPLT
PLOTS    SYMBOL   AXIS4    PLTERR   EXIT     PLOT
LINE4    SCALE4

SCALARS AND ARRAYS [ "*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED ]

 .S0020 1          TITLY0 2          FILE1  22         %TITLY1           Y3     24
%TITLY2           %TITLY3           *AYMIN  1010      %TITLY4           *NPTN   1011
 YT     1012      *XMIN   5716      *YDA    5717       Y2     5720       FILE5  6704
 POINTS 6706       Y1     6707      *XMAX   7673       FILE4  7674      *XDA    7676
 .S0007 7677       .S0006 7700       Y0     7701       .S0005 10665      .S0004 10666
 .S0003 10667      .S0002 10670      .S0001 10671      .S0000 10672      FILE3  10673
 .S0017 10675      X      10676      .S0016 11662      .S0015 11663      .S0014 11664
 .S0013 11665      .S0012 11666      .S0011 11667      .S0010 11670      TITLE1 11671
 FILE2  11711      TITLE2 11713      TITLE3 11733      Y4     11753     *I      12737
 TITLE4 12740      TITLE5 12760      .S0021 13000      TITLX  13001

MAIN.    [ NO ERRORS DETECTED ]
*
$$OPR: - (INACT) JOB 20  [10041,1205] TTY103 WILL BE KILLED-- 02:36:12

$$OPR: - (INACT) IN  5.0 MINUTES IF STILL INACTIVE. 02:36:12

$$OPR: - (INACT) JOB 20  [10041,1205] TTY103 HAS BEEN KILLED 02:41:15
.










 ^C
```

APPENDIX 5.3.3

"Data for RG59/U

'single braid'

use in

computer program"

Vc;	Cable propagation velocity		= .67
R1;	Ground impedance	varies from	3 ohms to ∞
R2;	Ground impedance	varies from	3 ohms to ∞
RA;	Cable termination	has value of	75 ohms and ∞
Rb;	Cable termination	has value of	75 ohms
CC;	Cable capacitance		= $6.7257 \text{ X}10^{-11}$ Farad/meter
BC;	Inner radius of braid		= .0018542 meter
AC;	Radius of center conductor		= $2.921 \text{ X } 10^{-4}$ meter
Rϕ;	Outside radius of braid		= .0021717 meter
Oϕbrai;	Conductance of braid		= $2.8613995 \text{ X } 10^{7}$ ohms/meter
OϕCON;	Conductance of center rod		= $1.8334349 \text{ X } 10^{7}$ ohms/meter
Rdcbr;	Braid DC resistance		= $9.1605 \text{ X } 10^{-3}$ ohms/meter
AD;	Thickness of wire used for shield		= $1.6 \text{ X } 10^{-4}$ meter

APPENDIX 5.4.1

"Computer program to plot"

Two dependent variables

versus x on a Dec terminal

```
FORTRAN IV      V02.04     Tue 02Fri -72 01:42:24             PAGE 001

0001            REAL*4 X(600),Y(600),Z(600)
0002            LOGICAL*1 FILE(10)
0003            WRITE(7,10)
0004    10      FORMAT(/,' 1NPUT FILENAME  ',$)
0005            READ(5,20)(FILE(I),I=1,10)
0006    20      FORMAT(10A1)
0007            CALL ASSIGN(1,FILE,10,'RDO','NC',1)
0008            DO 15 I=1,601
0009            READ(1,*,END=30,ERR=40) X(I),Y(I),Z(I)
0010    15      CONTINUE
0011    30      N=I-1
0012            CALL PLOT(X,Y,Z,N)
0013            CALL CLOSE (1)
0014    40      CALL EXIT
0015            END
.MAIN.
```

```
FORTRAN IV      Storage Map for Program Unit .MAIN.

Local Variables, .PSECT $DATA, Size = 016070 ( 3612. words)

Name    Type  Offset      Name    Type  Offset      Name    Type  Offset
I       I*2   016062      N       I*2   016064

Local and COMMON Arrays:

Name       Type    Section Offset  -------Size------ Dimensions
FILE    L*1        $DATA   016040  000012 (     5.) (10)
X       R*4        $DATA   000000  004540 ( 1200.) (600)
Y       R*4        $DATA   004540  004540 ( 1200.) (600)
Z       R*4        $DATA   011300  004540 ( 1200.) (600)

Subroutines, Functions, Statement and Processor-Defined Functions:

Name    Type    Name    Type    Name    Type    Name    Type    Name    Type
ASSIGN  R*4     CLOSE   R*4     EXIT    R*4     PLOT    R*4
```

```
      SUBROUTINE PLOT(X,Y,Z0,NPTS)
      DIMENSION X(600),Y(600),Z0(600),GRAPH(50,100),S(101)
      REAL*4 Z(600)
      DO 10 J=1,49
      DO 10 K=1,99
10    GRAPH(J,K)=' '
      XMIN=X(1)
      XMAX=X(1)
      YMIN=Y(1)
      YMAX=Y(1)
      ZMIN=Z0(1)
      ZMAX=Z0(1)
      Z(1)=Z0(1)
      NPTS1=NPTS
      DO 20 I=2,NPTS
      IF(X(I) .GT. XMAX) XMAX=X(I)
      IF(Y(I) .GT. YMAX) YMAX=Y(I)
      IF(X(I) .LT. XMIN) XMIN=X(I)
      IF(Y(I) .LT. YMIN) YMIN=Y(I)
      IF(Z0(I) .LT. ZMIN) ZMIN=Z0(I)
      IF(Z0(I) .GT. ZMAX) ZMAX=Z0(I)
      Z(I)=Z0(I)
20    CONTINUE
      YMAX1=AMAX1(YMAX,ZMAX)
      YMIN1=AMIN1(YMIN,ZMIN)
      YMAX=YMAX1
      YMIN=YMIN1
      WRITE(7,*)XMAX,XMIN,YMAX,YMIN
      IF(XMAX .NE. XMIN .AND. YMAX .NE. YMIN) GO TO 40
      WRITE (7,50) XMAX,YMAX
50    FORMAT(/,' THE PLOT CONSISTS OF A SINGLE POINT LOCATED AT
     * X=',1PE8.3,' AND Y=',1PE8.3)
      GO TO 170
40    I=50.0+YMIN*49.0/(YMAX-YMIN)
      J=(-XMIN*98.0)/(XMAX-XMIN)+1.0
      IF(XMIN .GE.0.0) GO TO 28
      DO 25 KK=1,49
25    GRAPH(KK,J)='.'
28    IF(YMIN .GE. 0.0) GO TO 47
      DO 35 II=1,99
35    GRAPH(I,II)='.'
47    DO 30 JJ=1,NPTS1
      L=(X(JJ)-XMIN)*98.0/(XMAX-XMIN)+1.0
      M=50.0-((Y(JJ)-YMIN)/(YMAX-YMIN)*48.0+1.0)
      N=IFIX(50.0-((Z(JJ)-YMIN)/(YMAX-YMIN)*48.0+1.0))
      IF(M-N) 1000,101,1000
1000  GRAPH(M,L)='.'
      GRAPH(N,L)='*'
      GO TO 30
101   GRAPH(M,L)='G'
30    CONTINUE
      C=(XMAX-XMIN)/98.0
      DO 70 KK=1,101,20
70    S(KK)=XMIN-2.0*C+KK*C
```

```
               WRITE(7,100)(S(KK),KK=1,101,20)
      100      FORMAT(1H1,1X,1PE12.2,5(1PE20.2))
               D=(YMAX-YMIN)/48.0
               Q=YMAX+D
               WRITE(7,105)Q,Q
      105      FORMAT(1X,1PE9.2,10('+---------'),'+',1PE9.2)
               B=10.0
               DO 110 N=1,49
               IF(N .EQ. B) GO TO 120
               WRITE(7,130) (GRAPH(N,K),K=1,99)
      130      FORMAT(10X,'!',99A1,'!')
               GO TO 110
      120      T=YMAX-N*D+2.0*D
               B=B+10.0
      111      WRITE(7,140)(T,(GRAPH(N,M),M=1,99),T)
      140      FORMAT(1X,1PE9.2,'+',99A1,'+',1PE9.2)
      110      CONTINUE
               R=YMIN-D
               WRITE(7,105) R,R
               WRITE(7,190)(S(KK),KK=1,101,20)
      190      FORMAT(2X,1PE12.2,5(1PE20.2))
      170      RETURN
               END
PLOT
```

```
FORTRAN IV      Storage Map for Program Unit PLOT

Local Variables, .PSECT $DATA, Size = 054636 (11471. words)

Name    Type    Offset      Name    Type    Offset      Name    Type    Offset
B       R*4     054570      C       R*4     054554      D       R*4     054560
I       I*2     054526      II      I*2     054542      J       I*2     054470
JJ      I*2     054544      K       I*2     054472      KK      I*2     054540
L       I*2     054546      M       I*2     054550      N       I*2     054552
NPTS    I*2 @   000006      NPTS1   I*2     054524      Q       R*4     054564
R       R*4     054600      T       R*4     054574      XMAX    R*4     054500
XMIN    R*4     054474      YMAX    R*4     054510      YMAX1   R*4     054530
YMIN    R*4     054504      YMIN1   R*4     054534      ZMAX    R*4     054520
ZMIN    R*4     054514

Local and COMMON Arrays:

Name      Type    Section  Offset   ------Size------ Dimensions
GRAPH   R*4 Vec   $DATA    000010   047040 (10000.)  (50,100)
S       R*4       $DATA    047050   000624 (  202.)  (101)
X       R*4     @ $DATA    000000   004540 ( 1200.)  (600)
Y       R*4     @ $DATA    000002   004540 ( 1200.)  (600)
Z       R*4       $DATA    047674   004540 ( 1200.)  (600)
ZO      R*4     @ $DATA    000004   004540 ( 1200.)  (600)

Subroutines, Functions, Statement and Processor-Defined Functions:

Name    Type    Name    Type    Name    Type    Name    Type    Name    Type
AMAX1   R*4     AMIN1   R*4     IFIX    I*2
```

SUMMARY and SUGGESTIONS for FUTURE STUDY

There appears to be three different categories of ground references.

1) high ground references (>100KΩ)

2) medium ground references (≈500 to 1200Ω)

3) low ground references (<10Ω)

For the low ground resistance (which is the most common case in a C.A.T.V. System), shielding varies with frequency, drop length, height above ground and propagation velocity in the cable.

Medium ground resistances produce less variation in shielding than low ground resistance, but are unacceptable for safety reasons.

High ground resistances produce the lowest shielding in the high frequency band and should never be used.

Future study should concentrate on specific and important areas in modelling the ingress signals inside a drop wire in order to obtain greater accuracy. The next step should therefore take into account the imaginary component of ground impedance, the splitting of the fields of a transmitting antenna into its radial and angular component. The above results should be compared to experimental results under strictly controlled procedures.

The above would allow a good investigation in the minimization of ingress current and should therefore result in the establishment of matching procedures and standards. In addition, there is a great chance that the efficiency of radiation monitoring could be optimized.