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LONG WAVE ATMOSPHERIC NOISE MODEL—PHASE I

Volume II—Mode Parameters

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Technical Report

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19 ABSTRACT (Continue on reverse if necessary and identify by block number)

The ~~PSR~~ full-wave propagation code is used to calculate waveguide mode parameters in spread-debris environments in order to develop a long wave atmospheric noise model. The parameters are stored for retrieval whenever the model is exercised. Because the noise-model data encompass parameters of all significant modes for a wide range of ground conductivities, frequencies, and nuclear environment intensities, graphs of those parameters are presented in this volume in handbook format. Keywords.

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SUMMARY

In order to develop a model of long wave atmospheric noise, Pacific-Sierra Research Corporation (PSR) used its full-wave propagation code to calculate waveguide mode parameters in spread-debris nuclear environments. Those parameters will be stored for retrieval whenever the model is exercised. Such precalculation, storage, and retrieval is far more efficient than recalculating mode parameters each time the model is used. A similar, but far less extensive set of mode parameters was calculated and graphed by Field and Dore [1975], who treated only the attenuation rate of the lowest order TM and TE modes for propagation over sea water.

PSR has, over the years, received many requests for those graphs, as well as numerous inquiries as to (1) the behavior of parameters other than attenuation rate and (2) the dependence of mode parameters on ground conductivity. Because the noise-model data encompass the parameters of all significant modes for a wide range of ground conductivities, frequencies, and nuclear environment intensities, it seemed worthwhile to publish graphs of those parameters in handbook format. For all practical purposes then, this volume is that handbook.

The electron and ion density profiles for the spread-debris nuclear environments and the collision frequency profiles are given and discussed in Vol. I of the present report and in more detail by Field and Dore [1975]. The mode parameters plotted are attenuation rate, excitation factor, phase velocity, and eigencosine. The number of modes considered varies from as few as two, for intense environments where attenuation is severe, to as many as five, for weak environments where attenuation is low and more modes must be retained. By using the graphs in conjunction with Eq. (6) in Vol. I and a handheld calculator, estimates of nuclear-weapon-induced signal loss can be made.

This volume consists of three sections, each of which presents the numerical data in a somewhat different form. Section 1 plots mode parameters versus ground conductivity for eight spread-debris environ-

ments that span the range $2 \times 10^{-8} \geq W \geq 2 \times 10^{-15}$ and frequencies that span the range 15 - 45 kHz in 5 kHz steps.* These data make up our data base; Secs. 2 and 3 display the data. Section 2 plots the mode parameters versus W and thus extends the graphs given by Field and Dore [1975]. Section 3 plots the mode parameters versus frequency.

We use the definitions of excitation values and height gains given by Pappert et al. [1970] for the E_z field from a vertical dipole for transverse magnetic (TM) modes and for the E_y field from a horizontal dipole for transverse electric (TE) modes. The TM height gains are unity on the ground and up to aircraft altitudes; the TE height gains can be approximated by

$$f_{\perp}(z) \simeq n_g kz \ . \qquad (1)$$

Because TE mode attenuation rates are independent of ground conductivity, we do not plot that data in Sec. 1. However, data for the least attenuated TE mode appears in Secs. 2 and 3. The TE excitation value is proportional to the E_y field on the ground and does depend on the conductivity. In fact, the TE excitation value is almost directly proportional to $1/n_g^2$. Note that the height-gain functions are nearly proportional to n_g, so the product of the TE excitation value and the two height-gain functions is virtually independent of ground conductivity at aircraft altitudes.

The data presented here were generated using our anisotropic full-wave computer code, WAVEPROP. The WAVEPROP code had its origins in an isotropic code developed by Field, Lewinstein, and Dore [1976], with major additions based on the anisotropic code developed at the Naval Ocean Systems Center (see, for example, Ferguson and Snyder, 1987). These codes use model ionospheres which specify the number density of electrons and ions at altitudes above the earth. They then solve an

---

*W is the well-known spread-debris intensity parameter [Knapp and Schwartz, 1975; Field and Dore, 1975].

equation, called the modal equation, of the form

$$M(\sigma_g,\omega,C) = 0 \ , \tag{2}$$

for the eigenvalue C, which is the cosine of the complex angle of incidence of the wave with the ionosphere. In the figures presented in Sec. 1, the modes are numbered in order of their attenuation rates at high conductivity ($\sigma_g = 1$ S/m). To number the modes at lower values of σ_g, we decreased σ_g in small steps and calculated mode parameters at each step. Each mode was assigned the number of the mode that was nearest to it (in C value) at the prior step.

The fourth graph in each set shows the path of C in the complex C plane. Section 1 shows the path as conductivity changes, Sec. 2 as W changes, and Sec. 3 as frequency changes. As noted on the graphs, one end of the path is marked. The graphs in Sec. 1 show both TE and TM modes. Since C values for the TE modes are not sensitive to σ_g, they do not appear to have a tail in the plots. In certain cases, as conductivity decreases, the attenuation rate for the second TM mode becomes very high and exceeds the attenuation of the third (and even higher) modes. That behavior occurs when C approaches the cosine of the Brewster's angle, and we call this mode the Brewster's mode. The Brewster's mode is easily identified by its path in the c-plane. In Fig. 55, for example, model 2 is the Brewster's mode. Note that its path is much longer than the other modes, and that the path passes over the paths of several other modes. That is when the real part of the Brewster's mode is the same as the real part of another mode, the imaginary part of the Brewster's mode is larger. Indeed the only time that two modes have the same real part is when one of them is a Brewster's mode. Note also in this figure that the TM modes that lie inside the path of the Brewster's mode (modes 3 and 4 in Fig. 55) loop counter clockwise, whereas the TM mode that lies outside it (mode 5) loops clockwise. By looping counter clockwise, we mean that the real part of C decreases as conductivity gets smaller, whereas in the paths that loop clockwise, the real part of C increases as conductivity decreases. For the TM modes that lie inside the Brewster's mode, the imaginary part of C increase as conductivity decreases. The maximum is reached at the conductivity where the real part of C is the same as the real part of the cosine of the Brewster's angle.

Section 1 shows all significant modes; Secs. 2 and 3 show only the two modes with the lowest attenuation rate. In certain cases the second least attenuated mode is the second mode at high conductivities and the third mode at low conductivities. This mode-switch causes a discontinuity in the excitation and phase velocity graphs. However the program that generated the figures uses a cubic spline to interpolate between the points, and so the curves in those graphs appear to oscillate near the transition point (see for example Fig. 76). This is unphysical, but the graphs were unreadable until the cubic spline was used.

We define a mode as being either TE or TM by examining the ratio

$$r = \left| \frac{{}_{\perp}R_{\perp}^{ion}\,{}_{\perp}R_{\perp}^{gnd} - 1}{{}_{\parallel}R_{\parallel}^{ion}\,{}_{\parallel}R_{\parallel}^{gnd} - 1} \right| . \tag{3}$$

The numerator and denominator of this equation are the isotropic TE and TM modal equations, respectively. Recall that the condition for a mode is that the model equation be zero. Therefore, $r \gg 1$ for TM modes, and $r \ll 1$ for TE modes. For the disturbed ionospheres considered here, it was easy to identify and label the type of mode. Under nighttime conditions, the ratio [Eq. (3)] might approach one which would make a clear distinction difficult.

The data in this volume were generated assuming that the electron-neutral collision frequency was:

$$\nu(z) = 1.8 \times 10^{11}\ e^{-z/6.67}\ s^{-1} . \tag{4}$$

Here z is the altitude in kilometers. The mass of the ions is taken to be 32 AMU, and the ion-neutral collision frequency is 1/40 of Eq. (4). The relative permittivity of the ground is taken to be 15.

CONVERSION TABLE

Conversion factors for U.S. Customary to metric (SI) units of measurement

MULTIPLY ——→	BY ——→	TO GET
TO GET ←——	BY ←——	DIVIDE
angstrom	1.000 000 X E -10	meters (m)
atmosphere (normal)	1.013 25 X E +2	kilo pascal (kPa)
bar	1.000 000 X E +2	kilo pascal (kPa)
barn	1.000 000 X E -28	meter^2 (m^2)
British thermal unit (thermochemical)	1.054 350 X E +3	joule (J)
calorie (thermochemical)	4.184 000	joule (J)
cal (thermochemical)/cm^2	4.184 000 X E -2	mega joule/m^2 (MJ/m^2)
curie	3.700 000 X E +1	*giga becquerel (GBq)
degree (angle)	1.745 329 X E -2	radian (rad)
degree Fahrenheit	$t_K = (t°f + 459.67)/1.8$	degree kelvin (K)
electron volt	1.602 19 X E -19	joule (J)
erg	1.000 000 X E -7	joule (J)
erg/second	1.000 000 X E -7	watt (W)
foot	3.048 000 X E -1	meter (m)
foot-pound-force	1.355 818	joule (J)
gallon (U.S. liquid)	3.785 412 X E -3	meter^3 (m^3)
inch	2.540 000 X E -2	meter (m)
jerk	1.000 000 X E +9	joule (J)
joule/kilogram (J/kg) (radiation dose absorbed)	1.000 000	Gray (Gy)
kilotons	4.183	terajoules
kip (1000 lbf)	4.448 222 X E +3	newton (N)
kip/inch^2 (ksi)	6.894 757 X E +3	kilo pascal (kPa)
ktap	1.000 000 X E +2	newton-second/m^2 (N-s/m^2)
micron	1.000 000 X E -6	meter (m)
mil	2.540 000 X E -5	meter (m)
mile (international)	1.609 344 X E +3	meter (m)
ounce	2.834 952 X E -2	kilogram (kg)
pound-force (lbs avoirdupois)	4.448 222	newton (N)
pound-force inch	1.129 848 X E -1	newton-meter (N·m)
pound-force/inch	1.751 268 X E +2	newton/meter (N/m)
pound-force/foot^2	4.788 026 X E -2	kilo pascal (kPa)
pound-force/inch^2 (psi)	6.894 757	kilo pascal (kPa)
pound-mass (lbm avoirdupois)	4.535 924 X E -1	kilogram (kg)
pound-mass-foot^2 (moment of inertia)	4.214 011 X E -2	kilogram-meter^2 (kg·m^2)
pound-mass/foot^3	1.601 846 X E +1	kilogram/meter^3 (kg/m^3)
rad (radiation dose absorbed)	1.000 000 X E -2	**Gray (Gy)
roentgen	2.579 760 X E -4	coulomb/kilogram (C/kg)
shake	1.000 000 X E -8	second (s)
slug	1.459 390 X E +1	kilogram (kg)
torr (mm Hg, 0° C)	1.333 22 X E -1	kilo pascal (kPa)

*The becquerel (Bq) is the SI unit of radioactivity; 1 Bq = 1 event/s.
**The Gray (Gy) is the SI unit of absorbed radiation.

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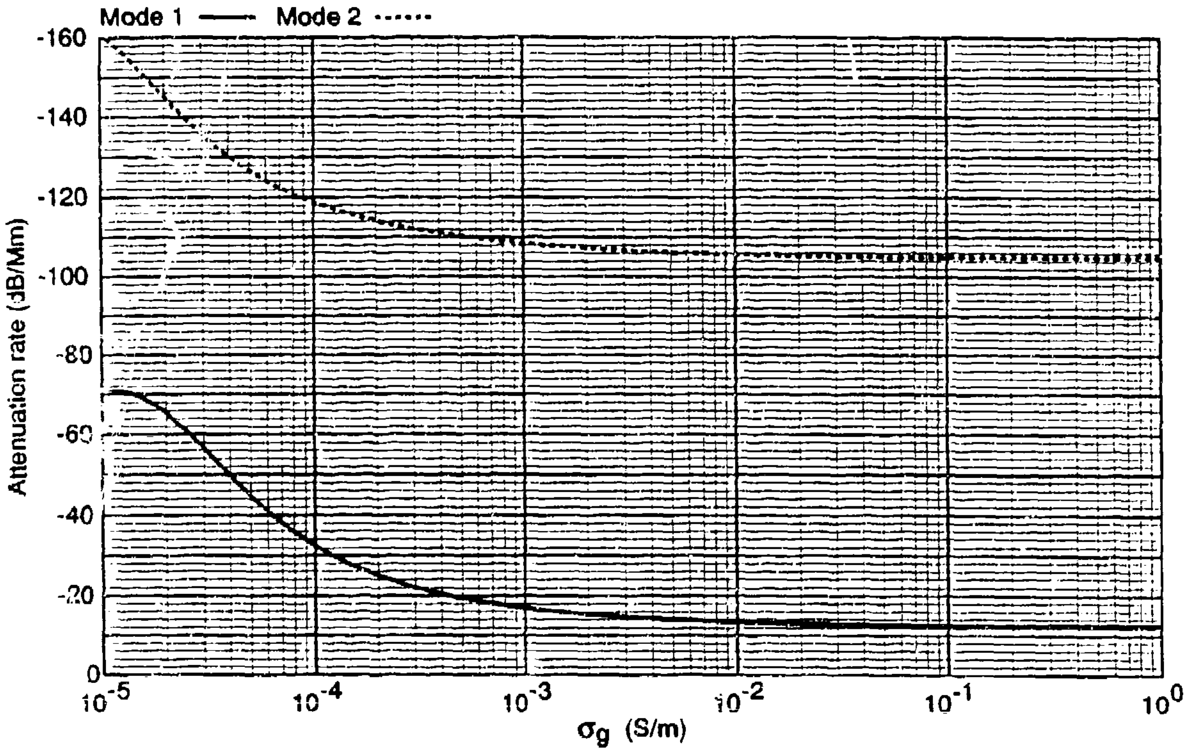
a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

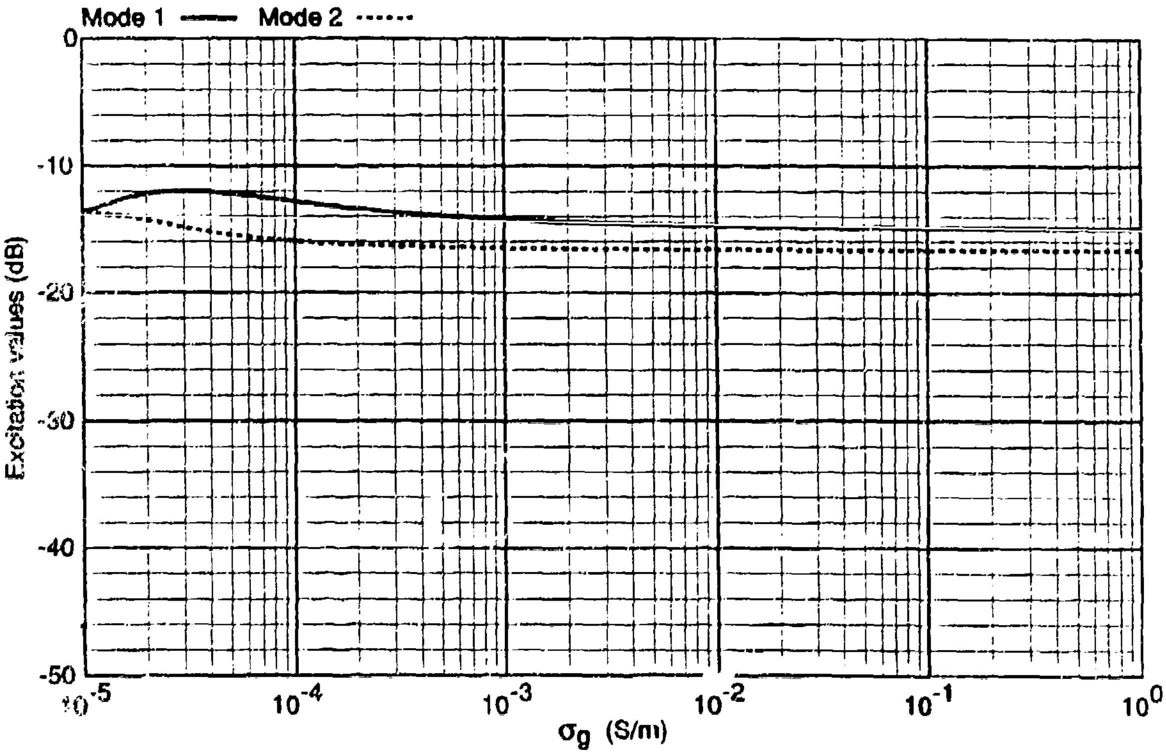
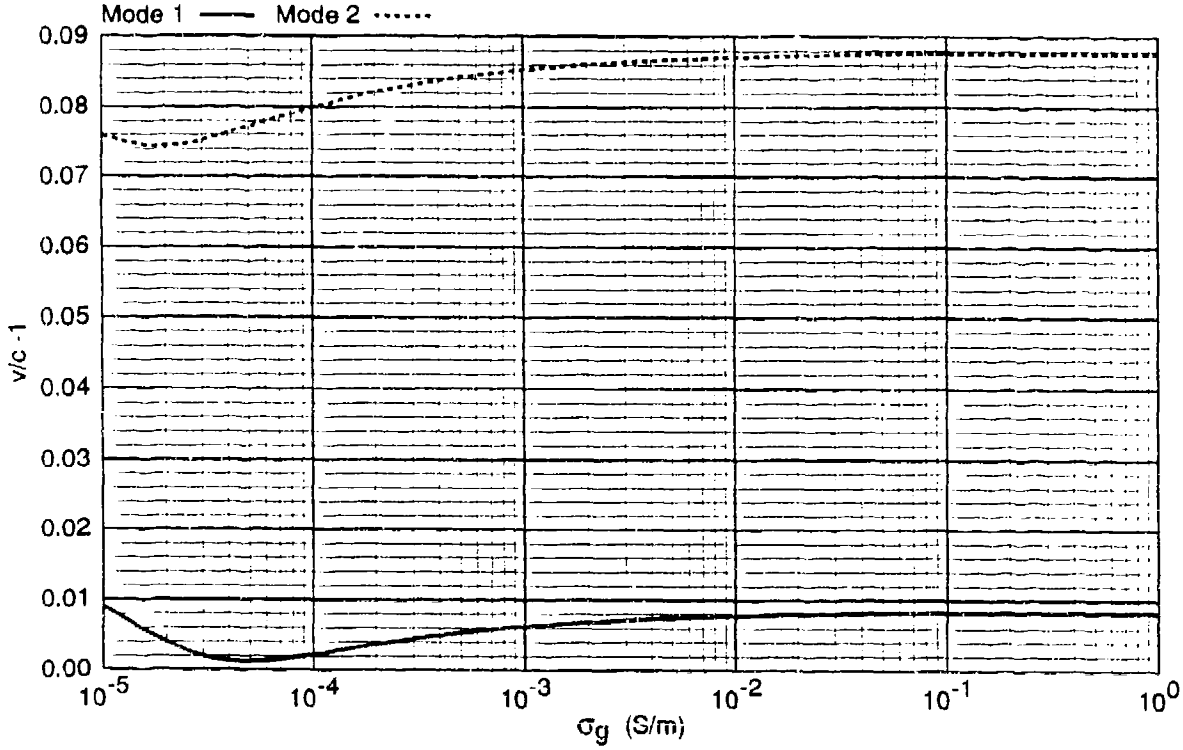


Figure 1. Parameters for $W = 2 \times 10^{-8}$, frequency = 15 kHz.

c. Relative phase velocity as a function of ground conductivity.



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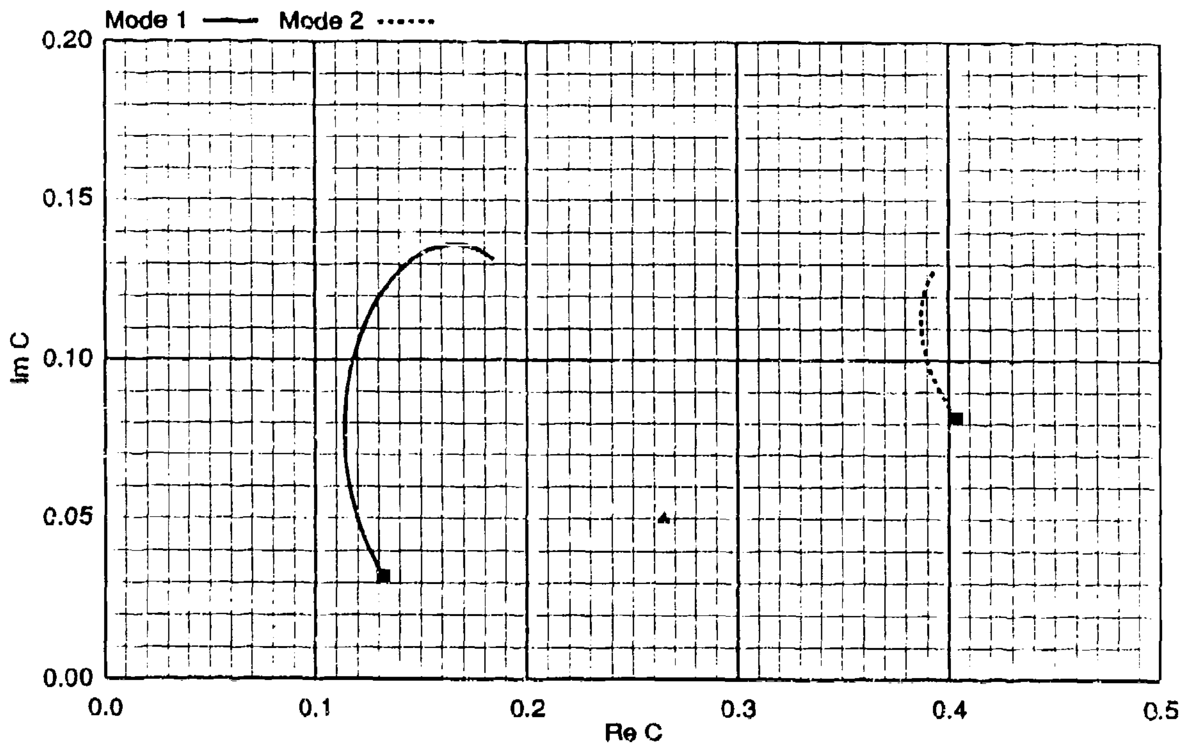
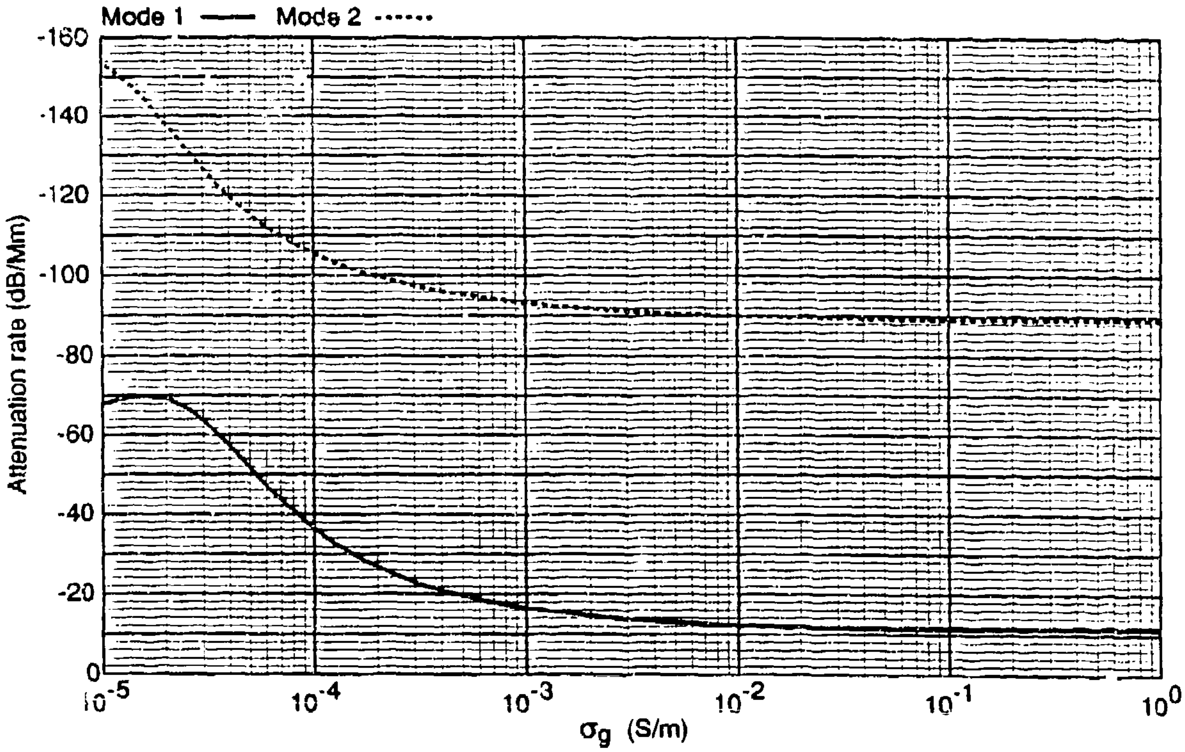


NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 1. Parameters for W = 2 x 10^{-8}, frequency = 15 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

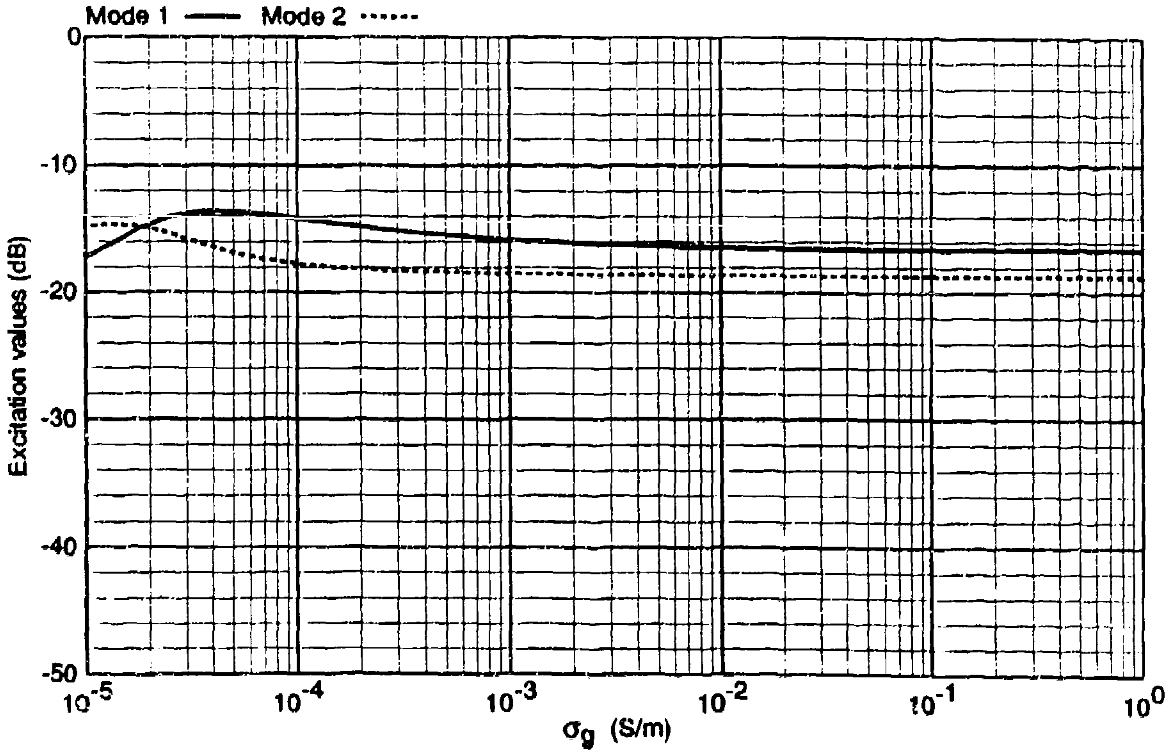
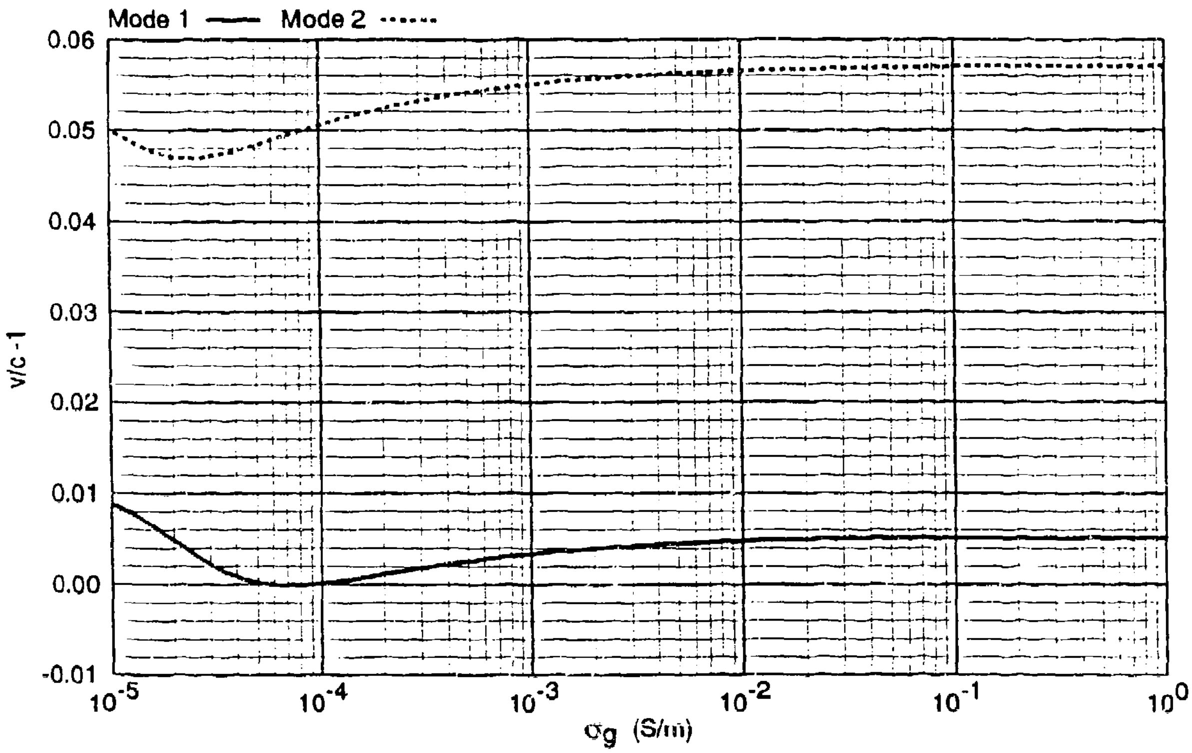
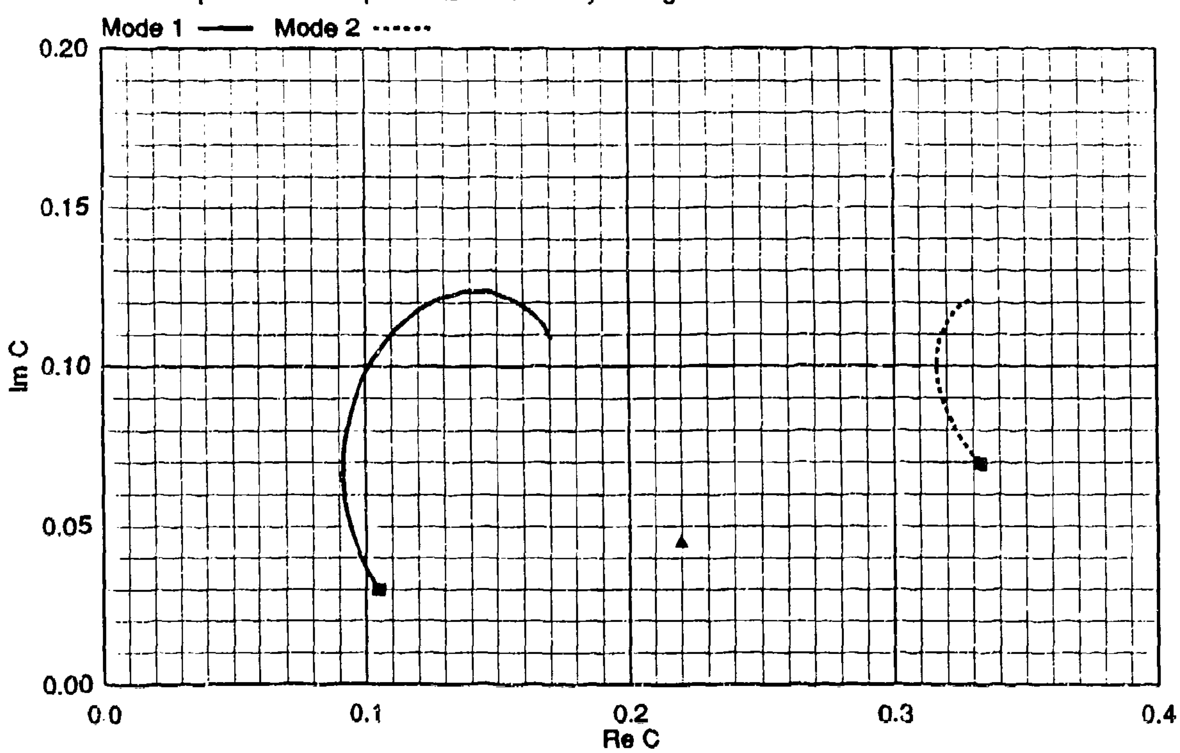


Figure 2. Parameters for $W = 2 \times 10^{-8}$, frequency = 20 kHz.

c. Relative phase velocity as a function of ground conductivity.



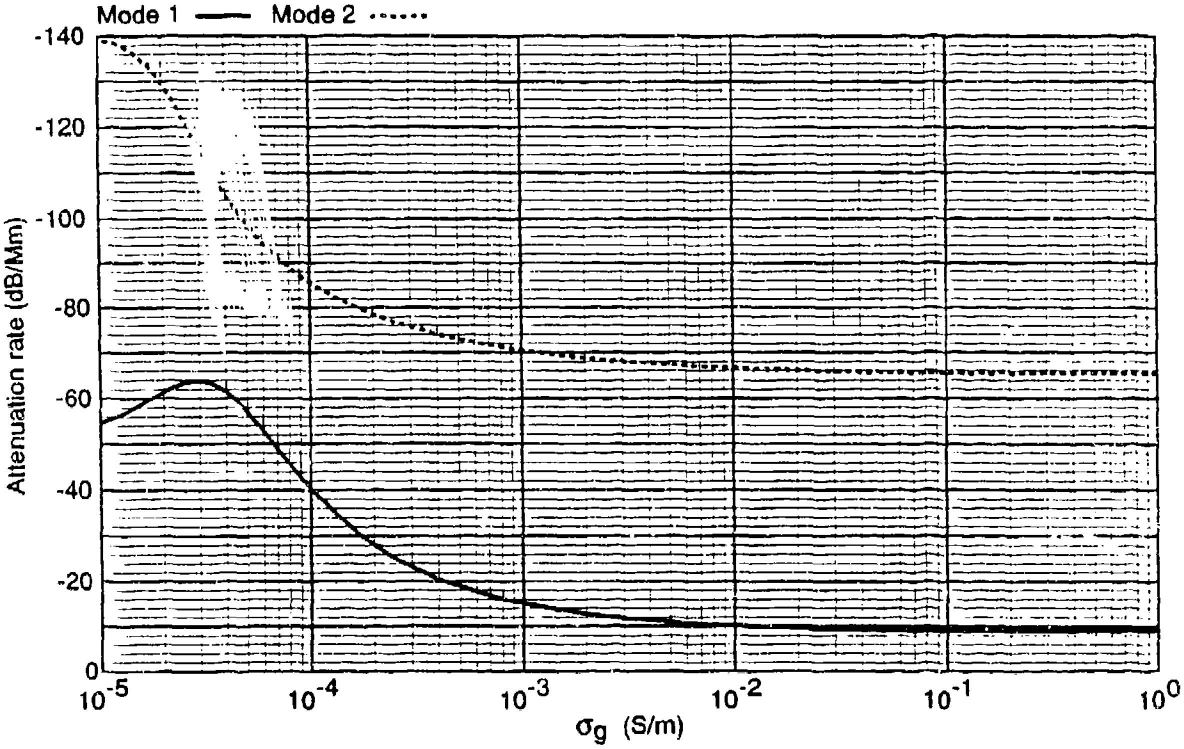
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 2. Parameters for W = 2 x 10^{-8}, frequency = 20 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

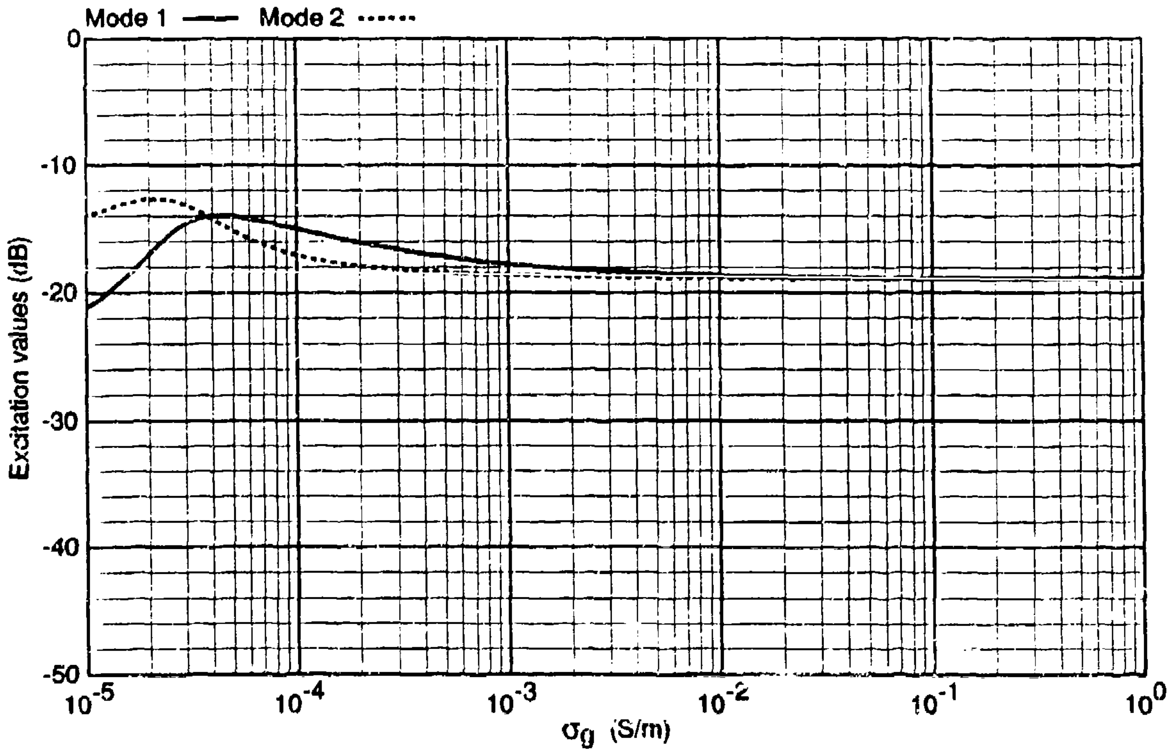
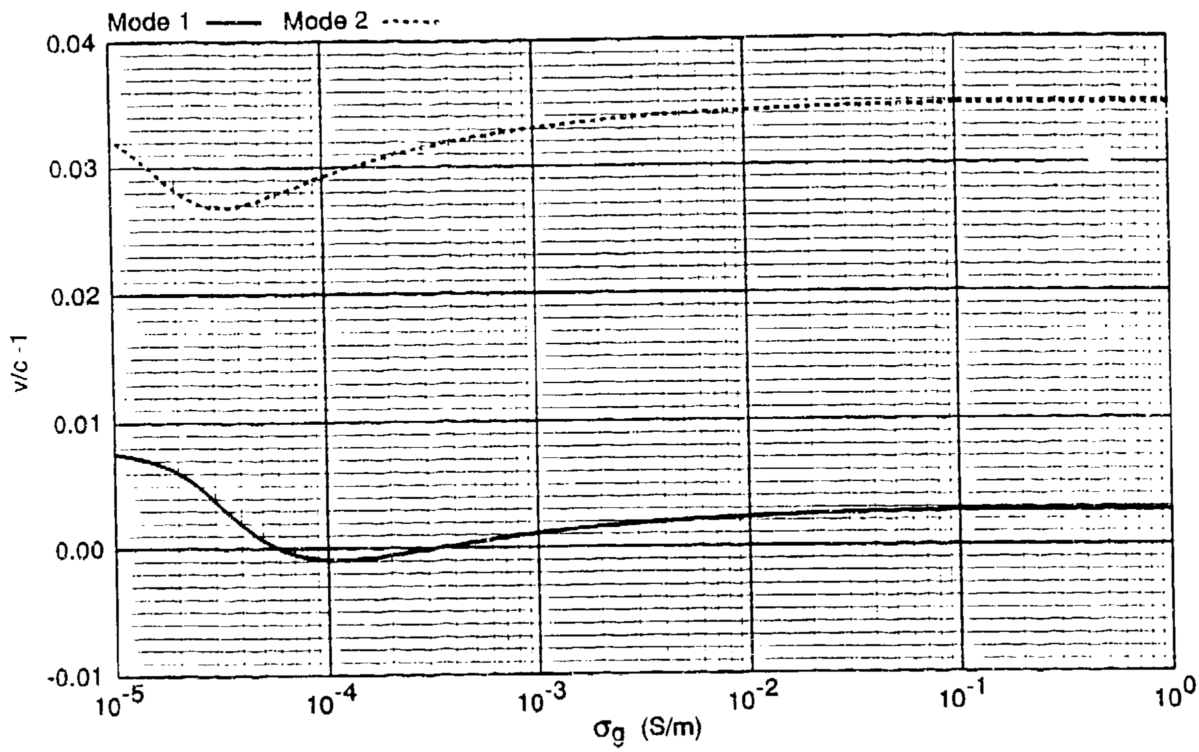


Figure 3. Parameters for $W = 2 \times 10^{-8}$, frequency = 25 kHz.

c. Relative phase velocity as a function of ground conductivity.



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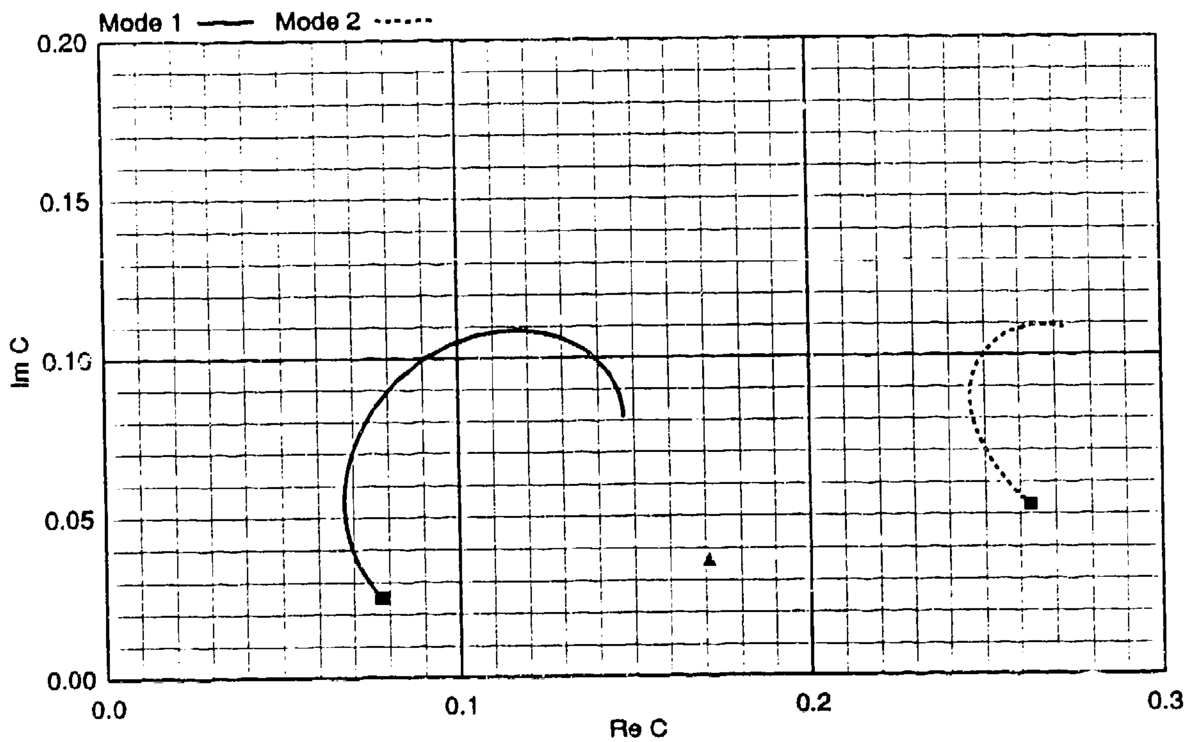


NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 3. Parameters for W = 2 x 10^{-8}, frequency = 25 kHz (Concluded).

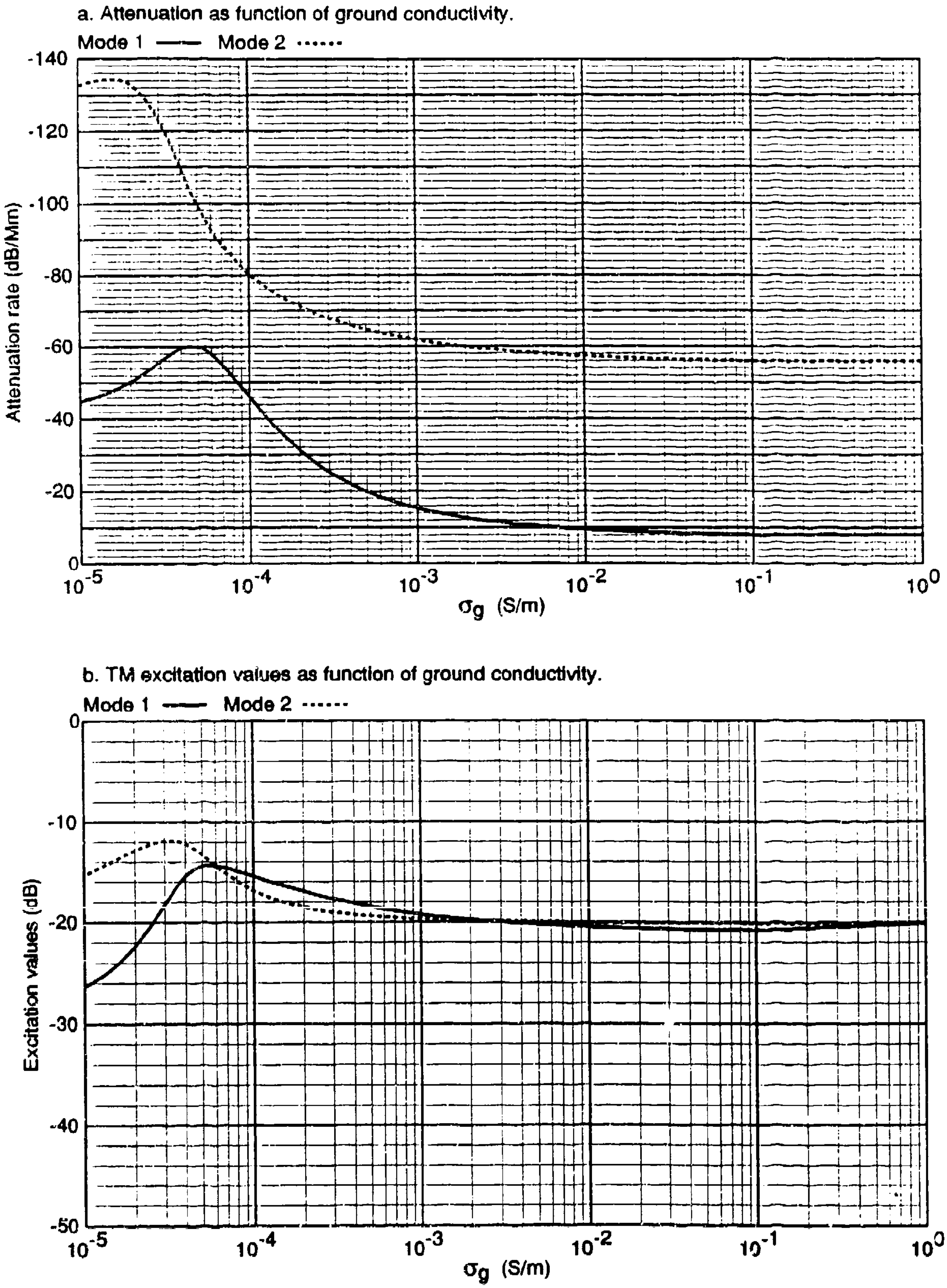
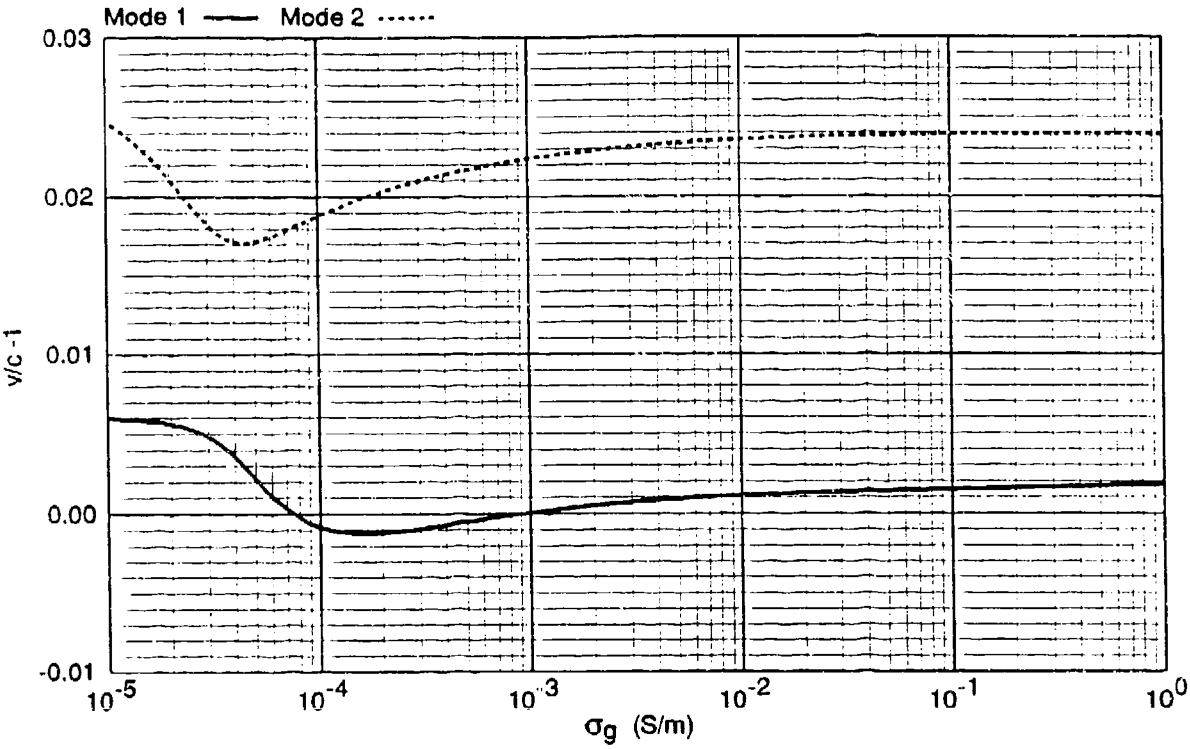
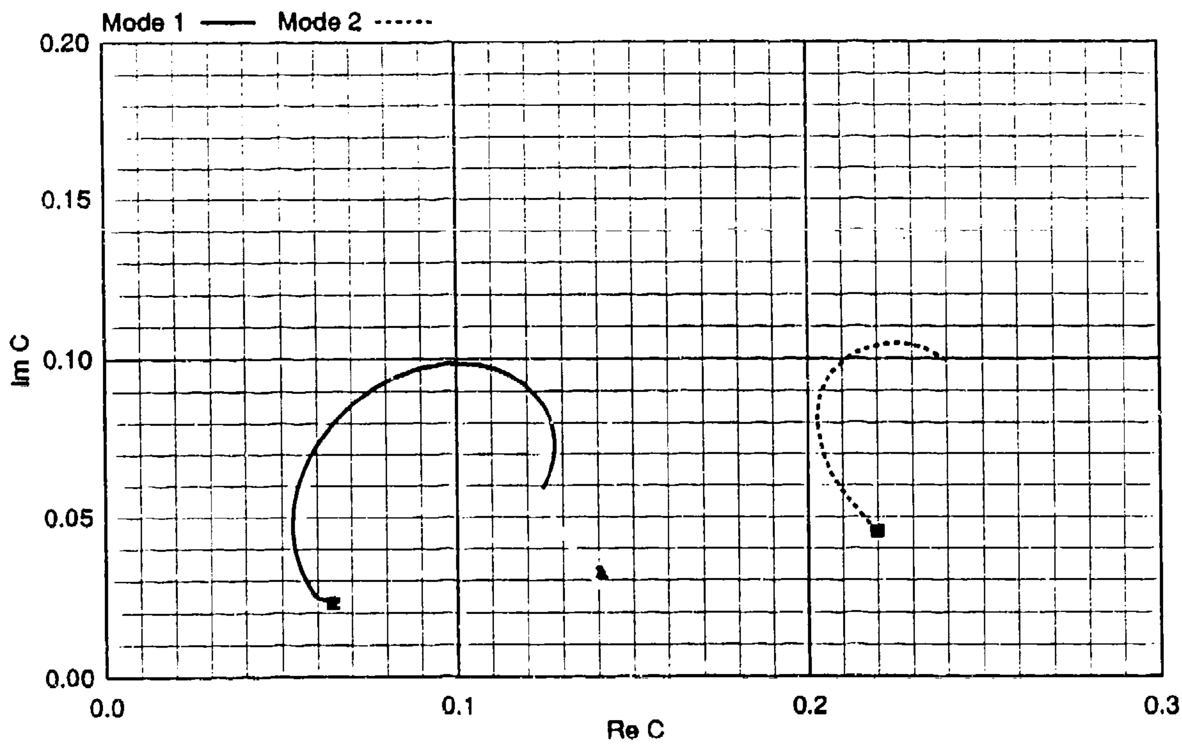


Figure 4. Parameters for $W = 2 \times 10^{-8}$, frequency = 30 kHz.

c. Relative phase velocity as a function of ground conductivity.

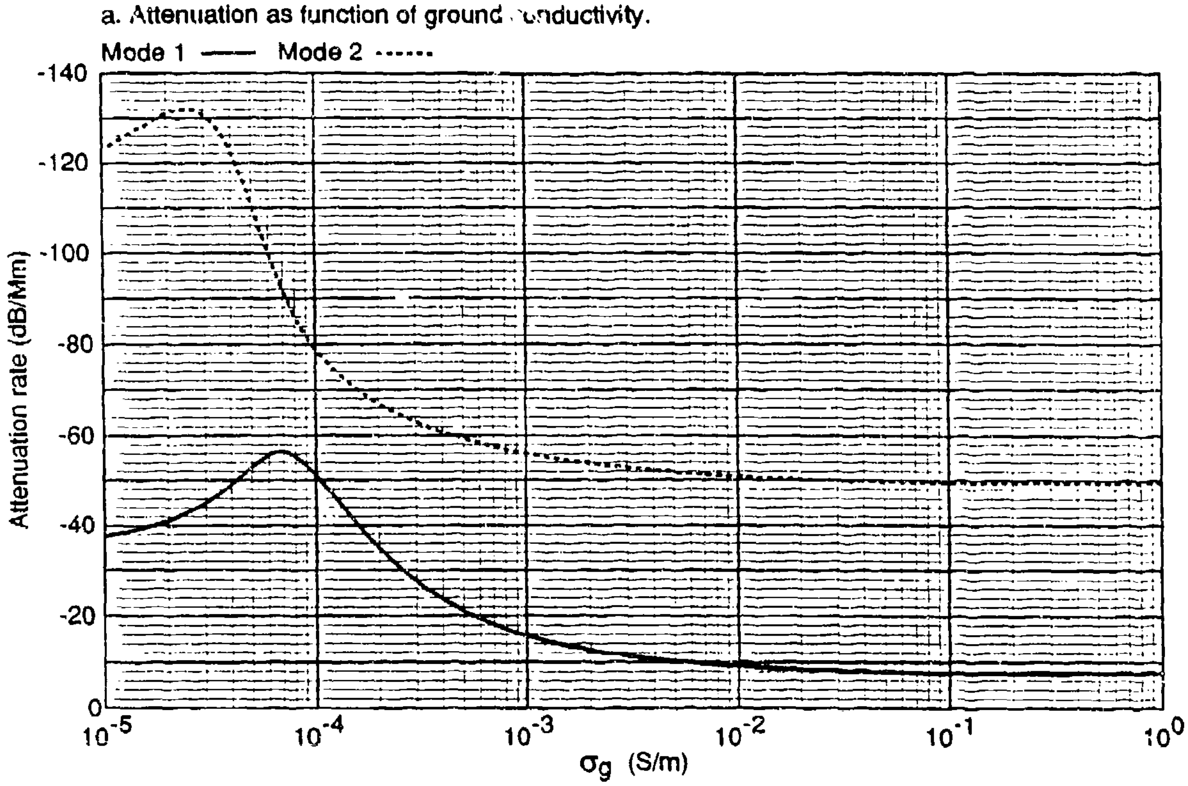


d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 4. Parameters for W = 2 x 10^{-8}, frequency = 30 kHz (Concluded).



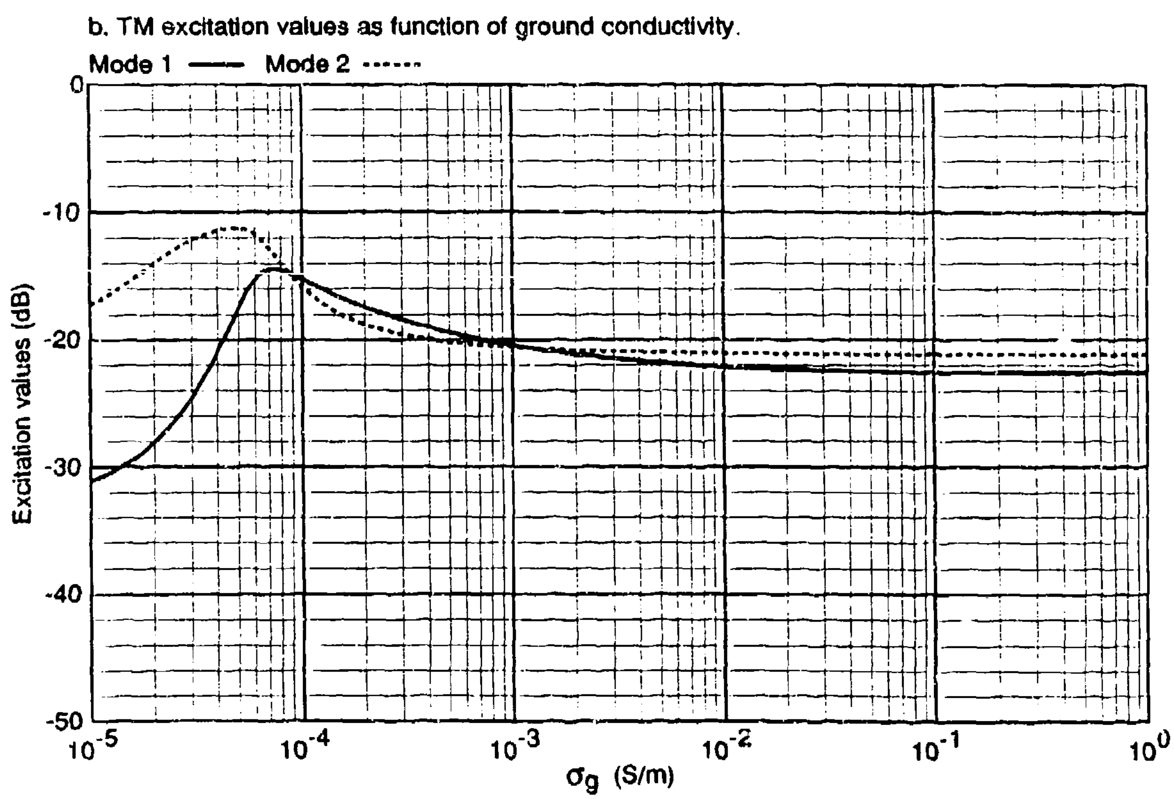
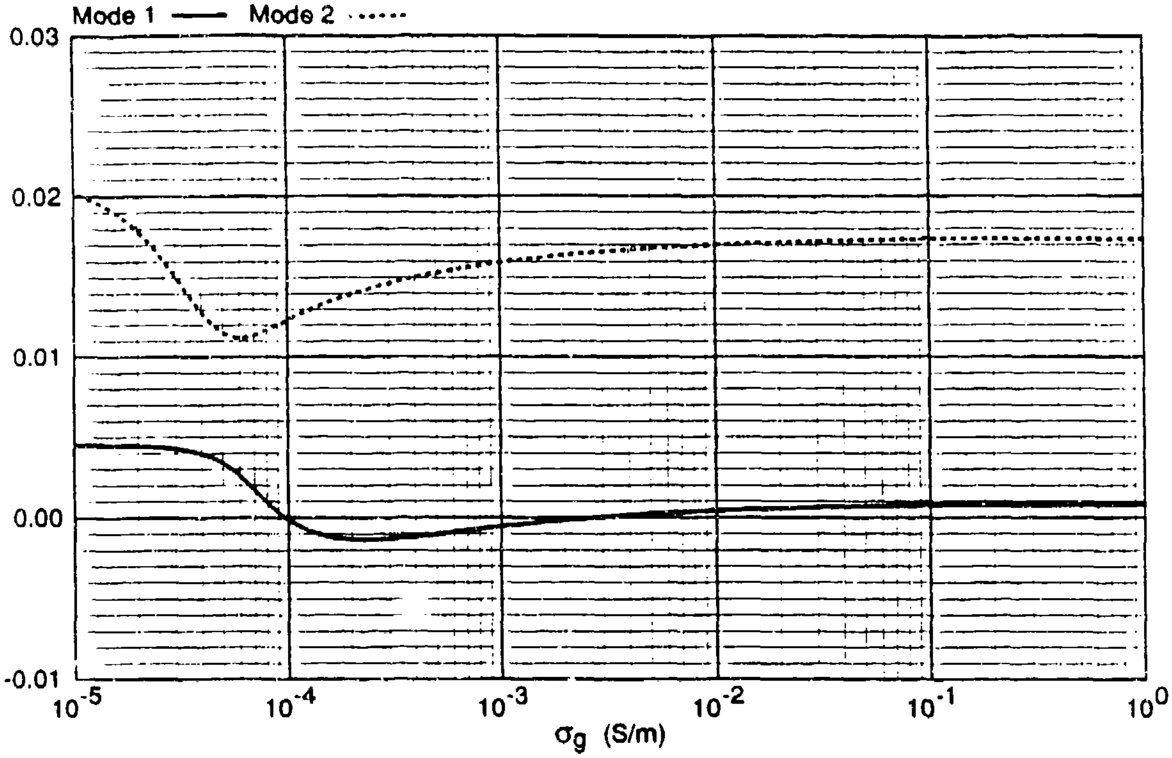


Figure 5. Parameters for $W = 2 \times 10^{-8}$, frequency = 35 kHz.

c. Relative phase velocity as a function of ground conductivity.



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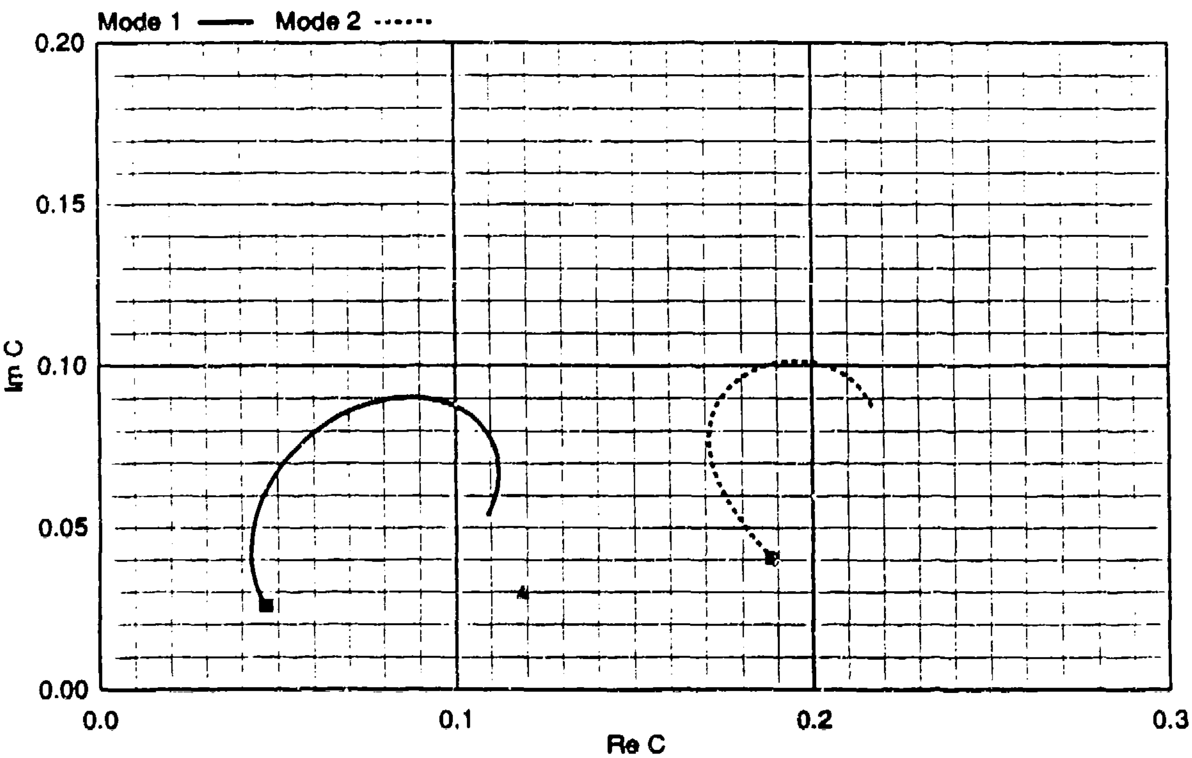
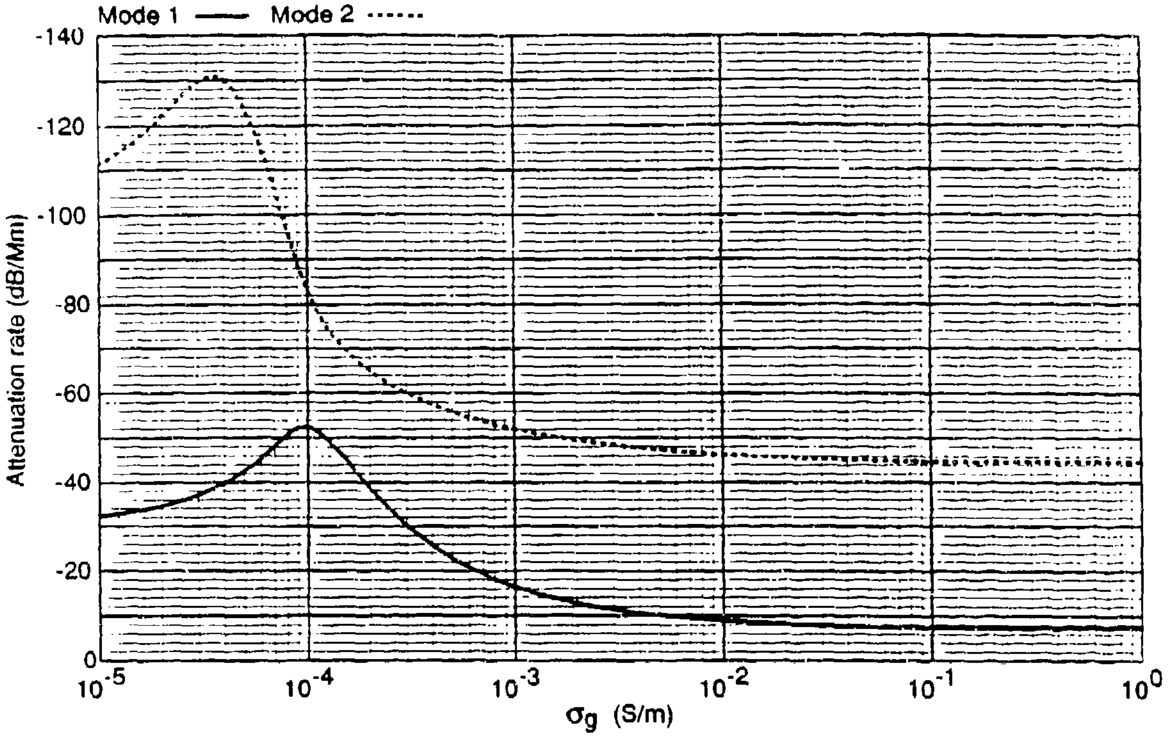


NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 5. Parameters for W = 2 x 10^{-8}, frequency = 35 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

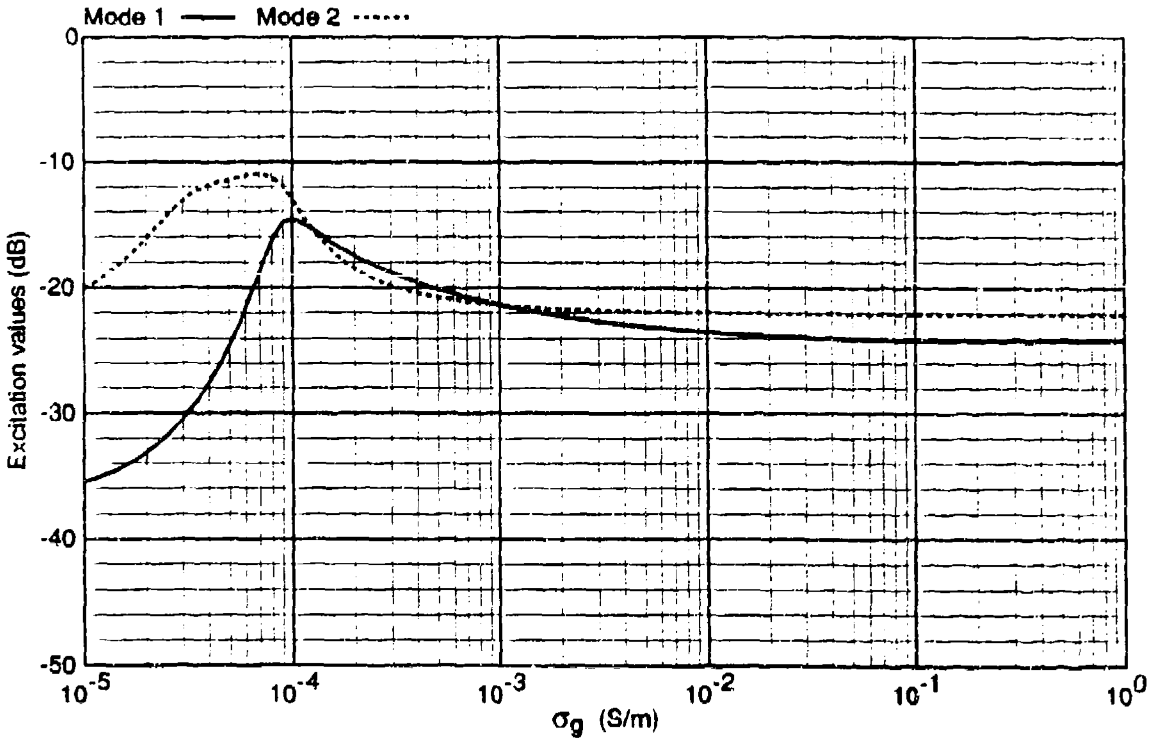
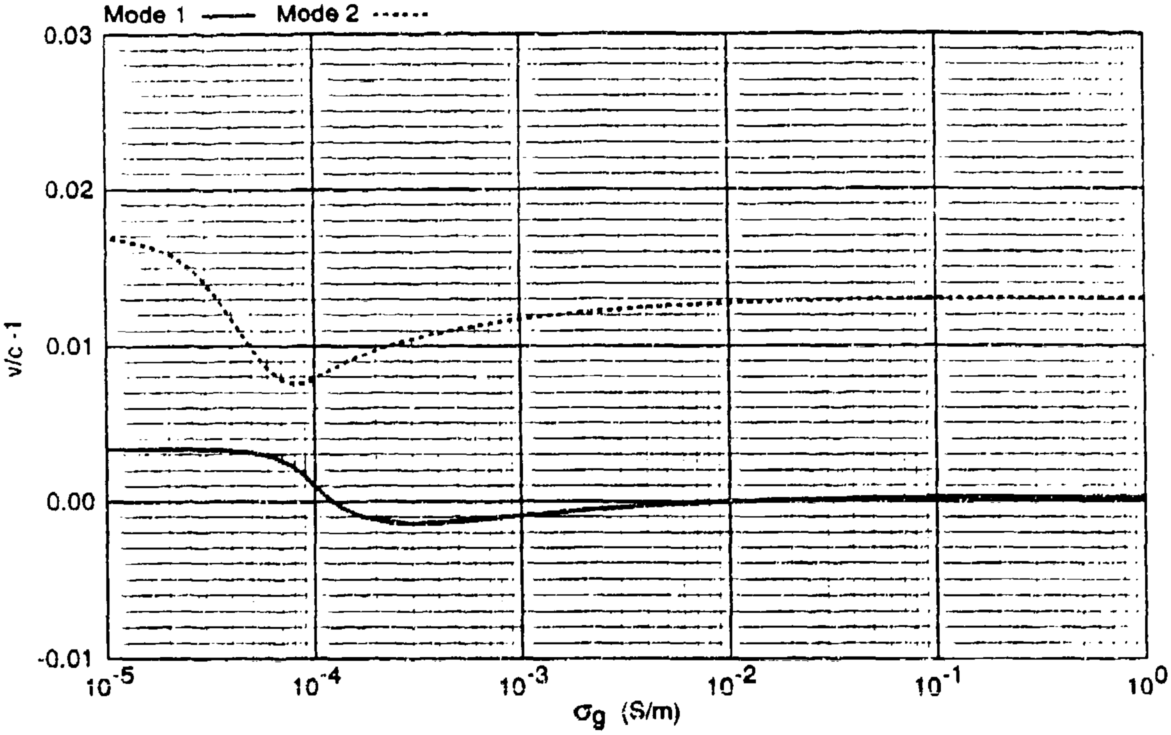
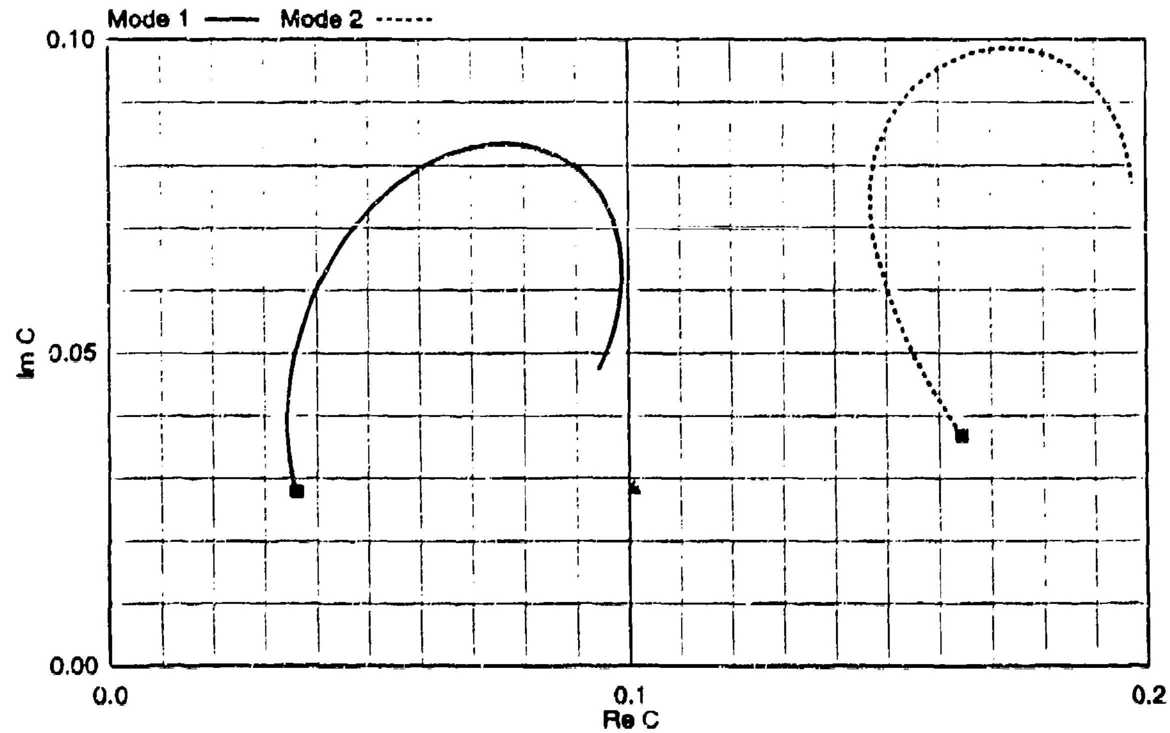


Figure 6. Parameters for $W = 2 \times 10^{-8}$, frequency = 40 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 6. Parameters for W = 2 x 10^{-8}, frequency = 40 kHz (Concluded).

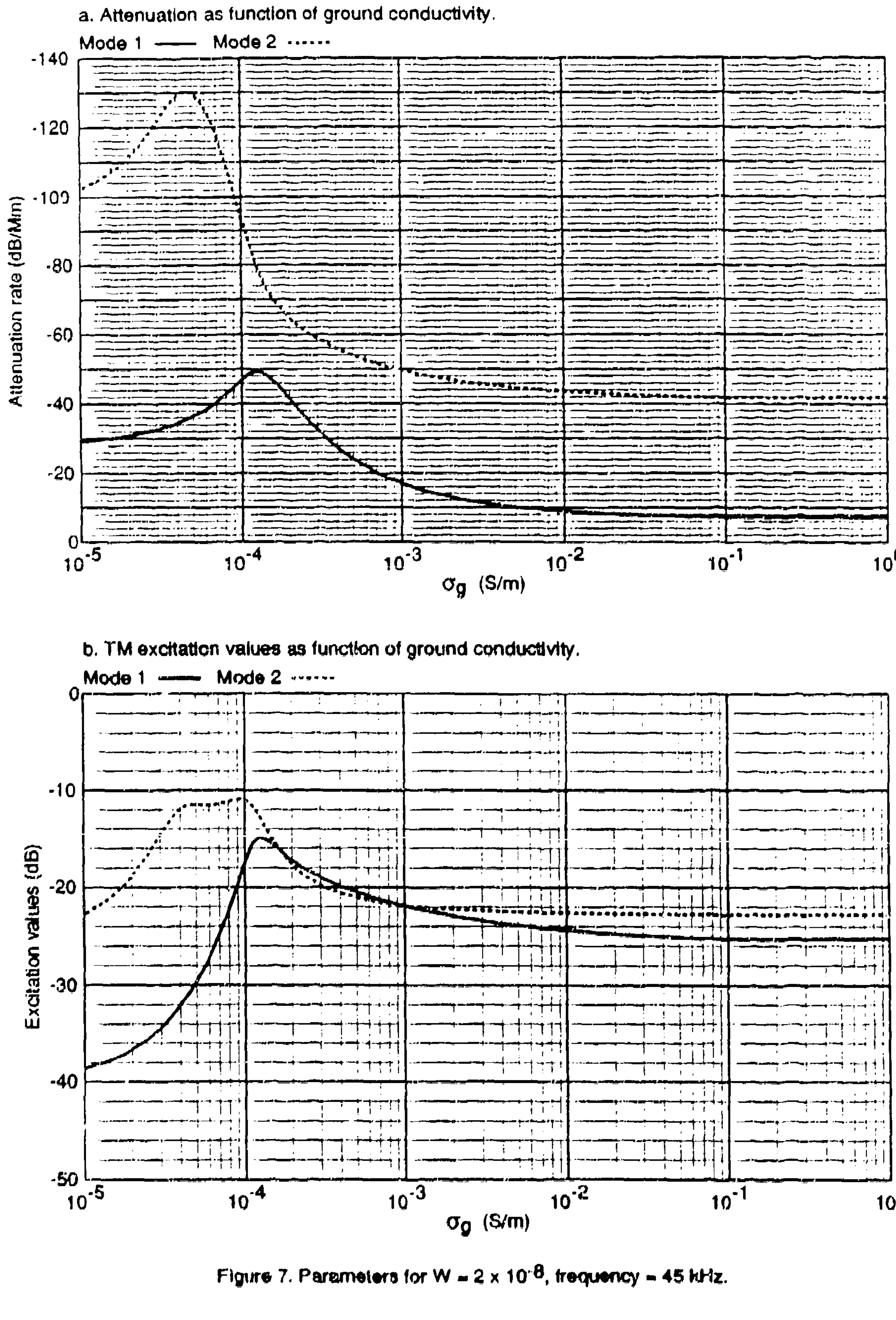
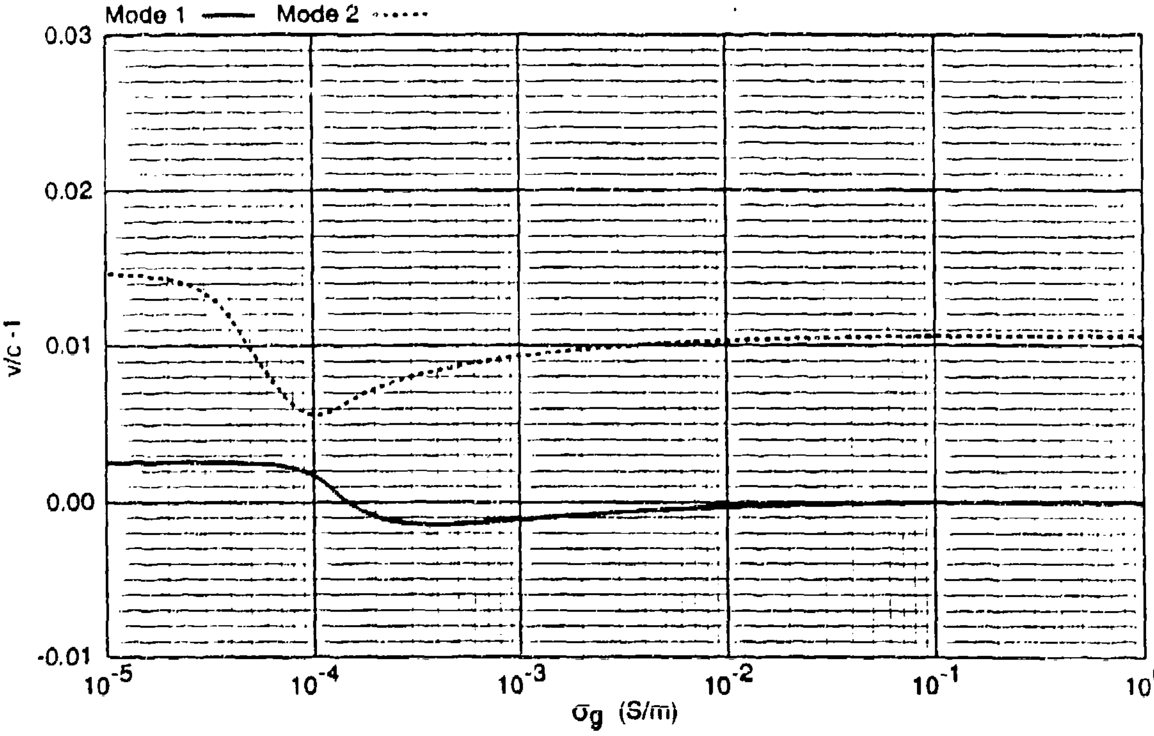
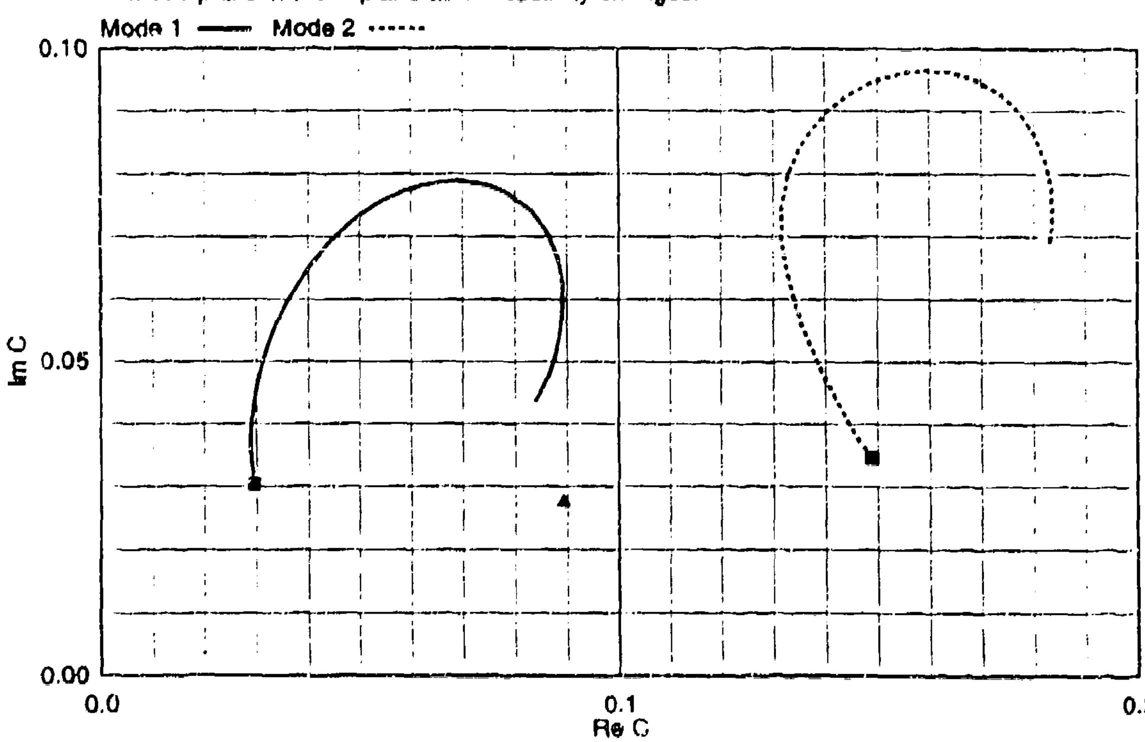


Figure 7. Parameters for $W = 2 \times 10^{-8}$, frequency = 45 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 7. Parameters for W = 2 x 10^{-8}, frequency = 45 kHz (Concluded).

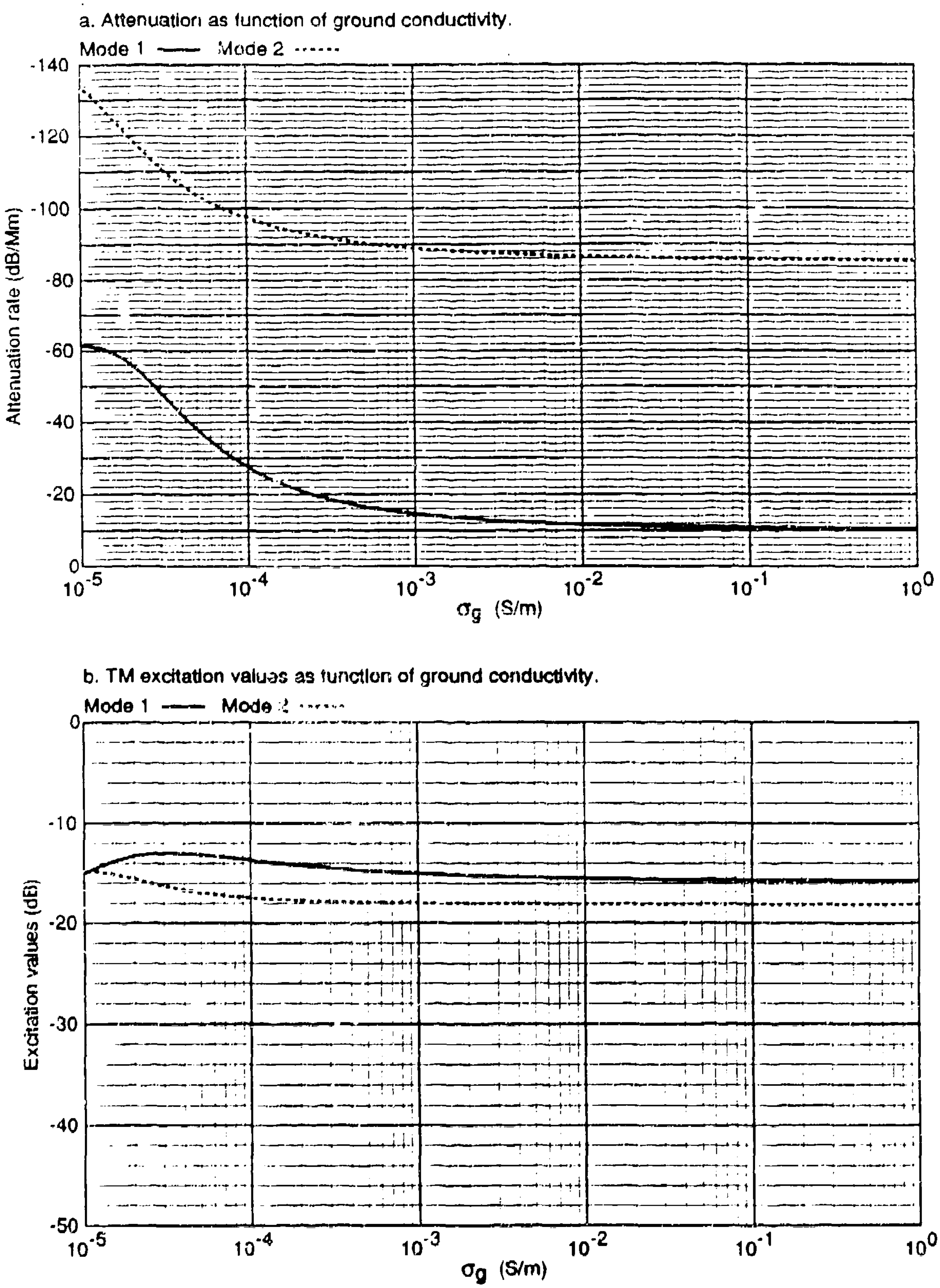
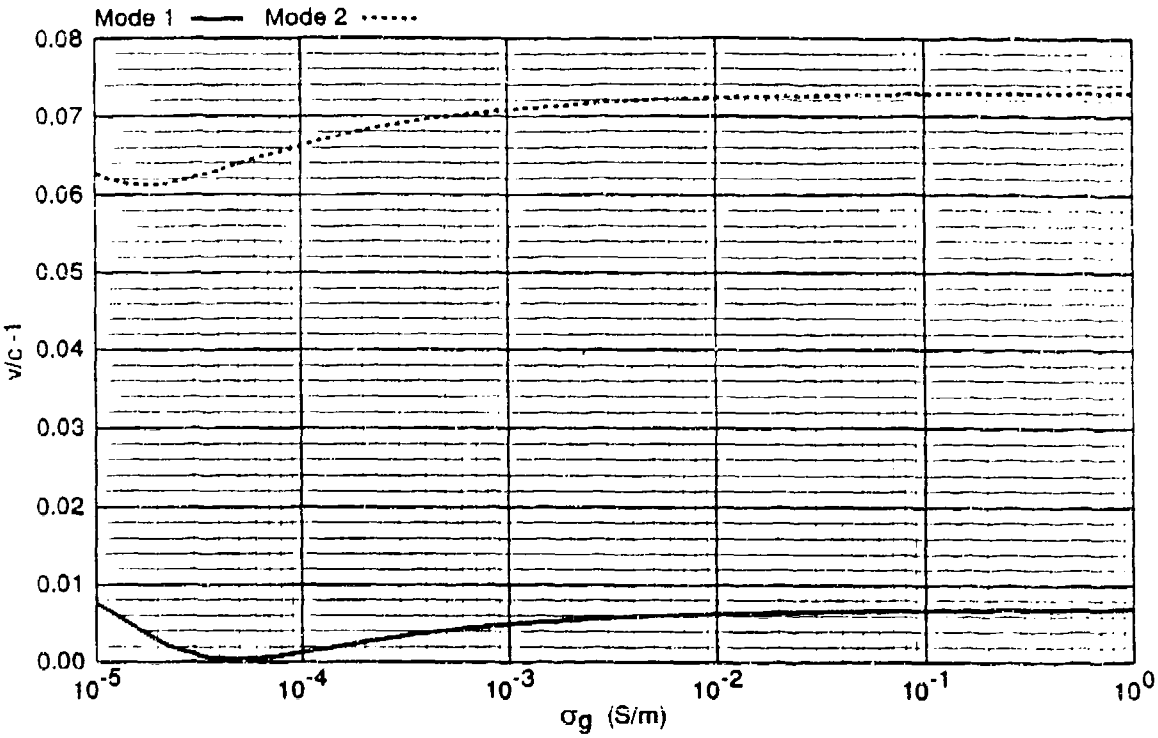
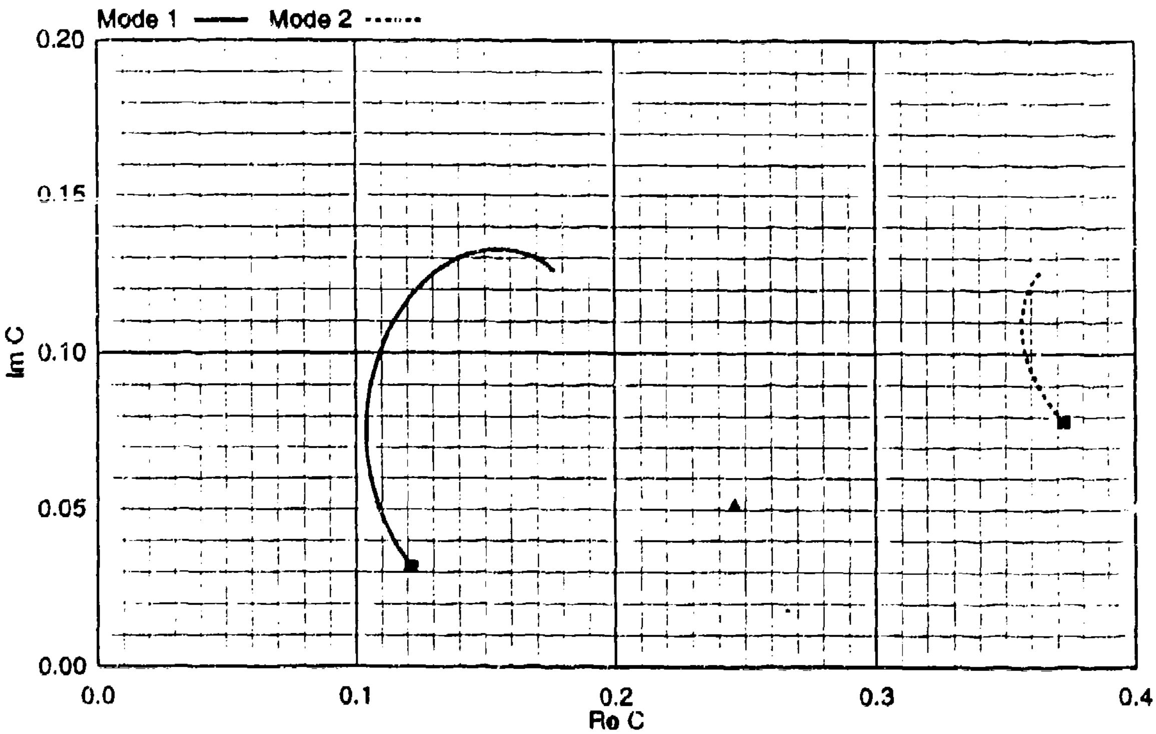


Figure 8. Parameters for $W = 2 \times 10^{-9}$, frequency = 15 kHz.

c. Relative phase velocity as a function of ground conductivity.



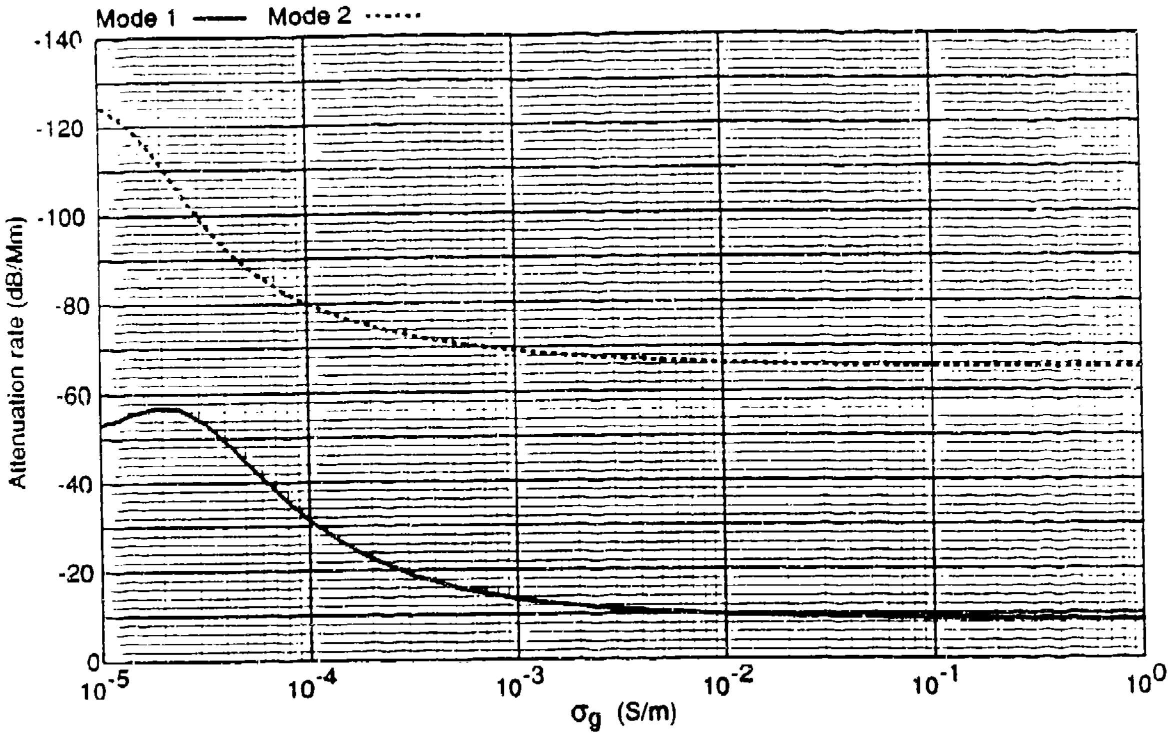
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 8. Parameters for W = 2×10^{-9}, frequency = 15 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

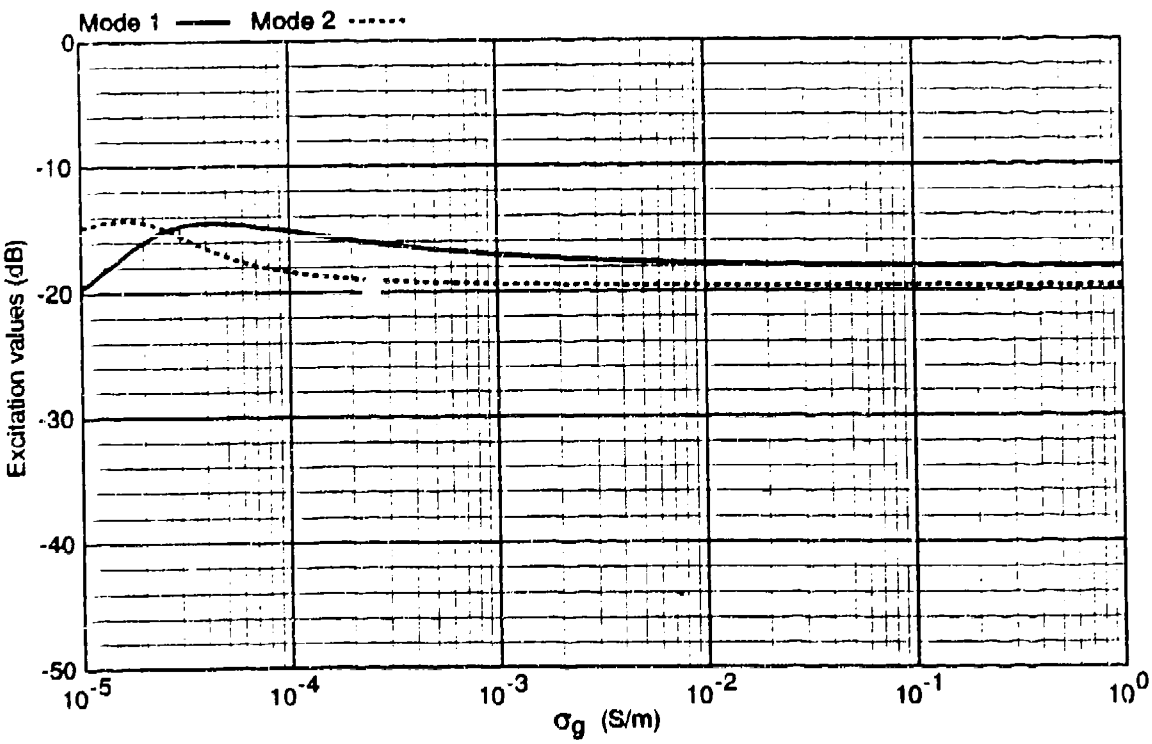
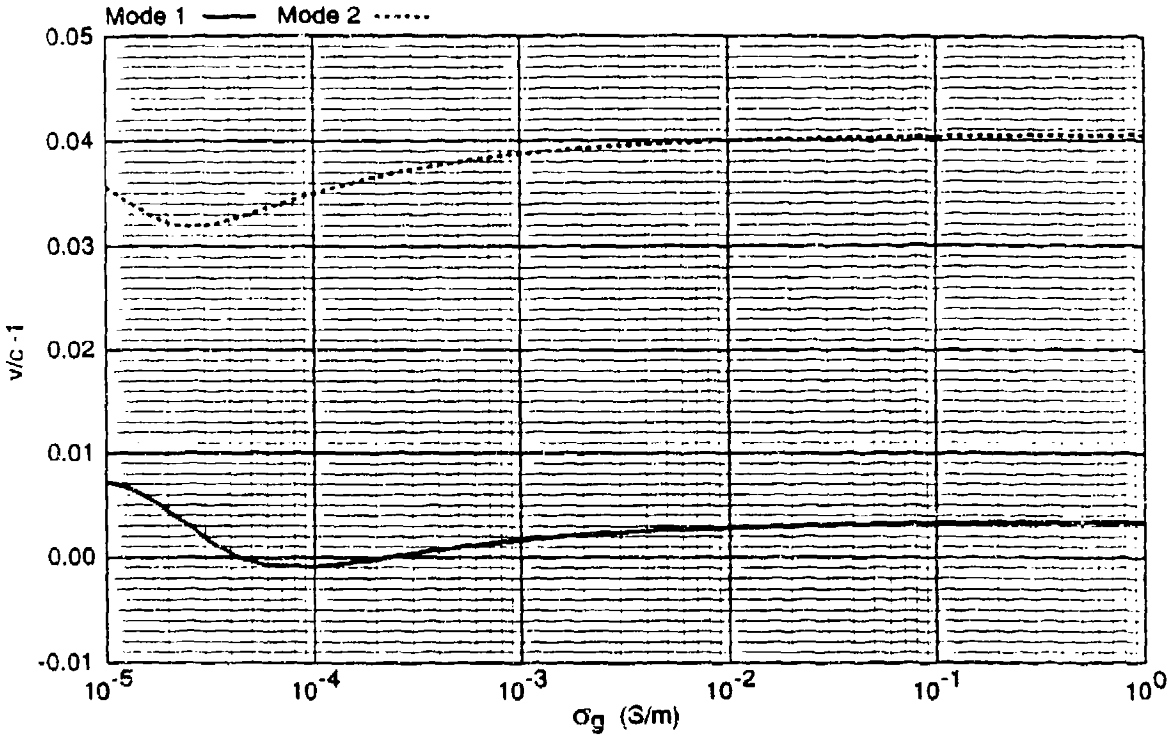
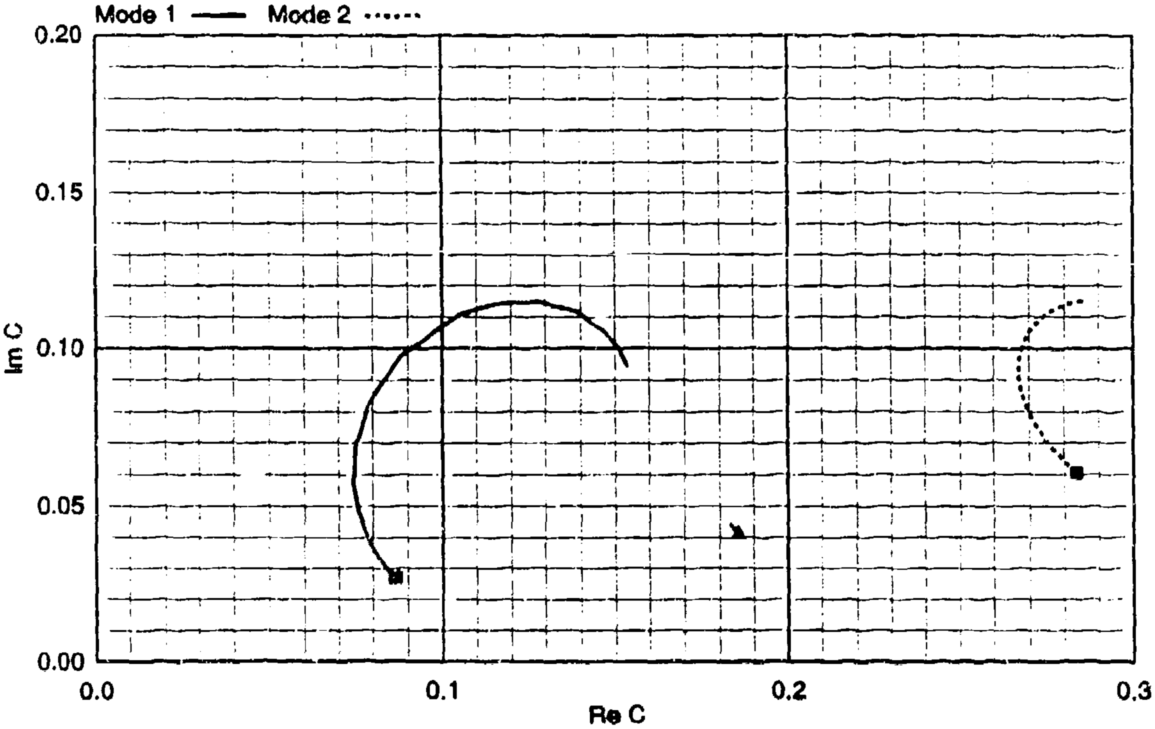


Figure 9. Parameters for $W = 2 \times 10^{-9}$, frequency = 20 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 9. Parameters for W = 2 x 10^{-9}, frequency = 20 kHz (Concluded).

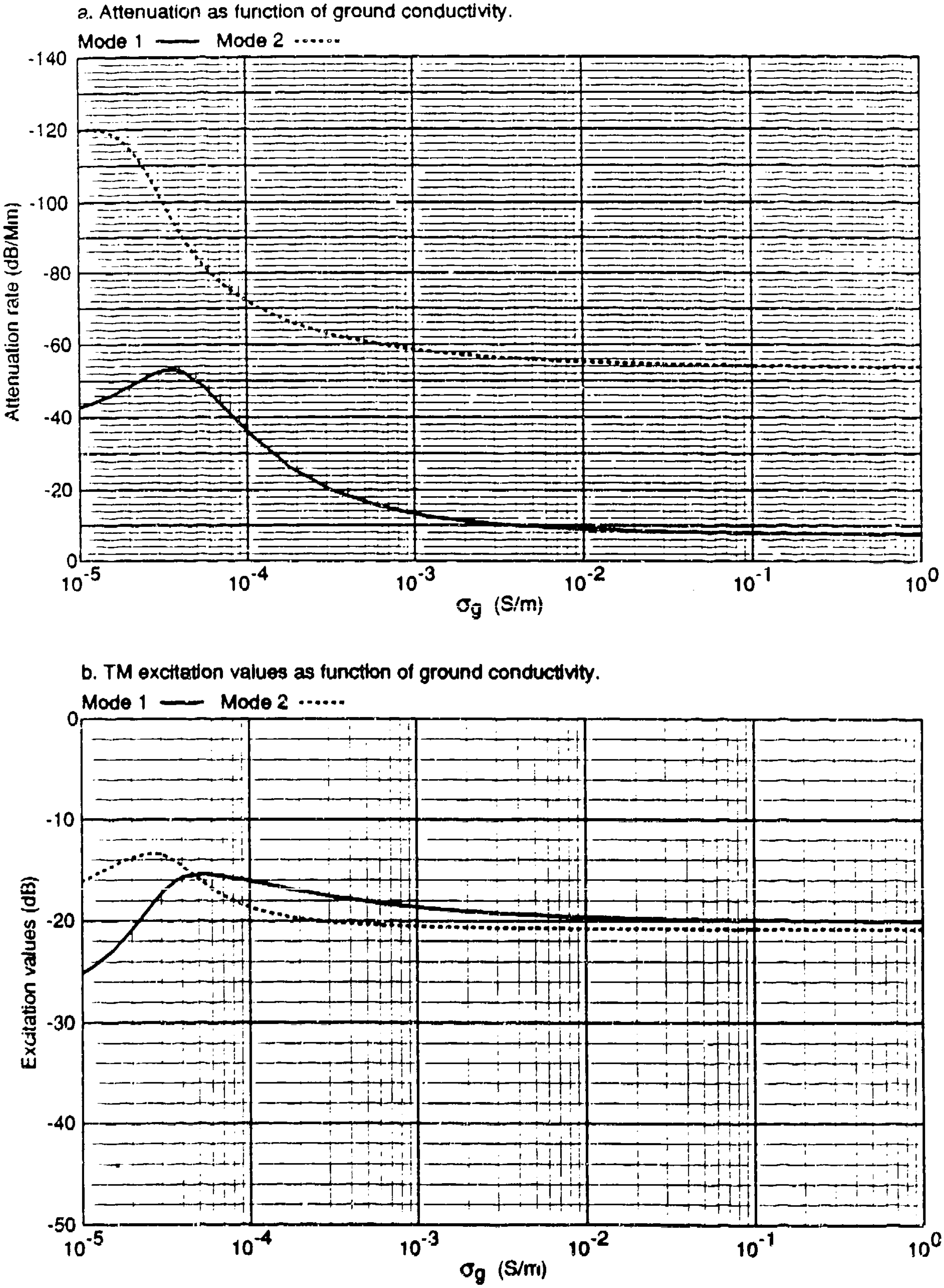
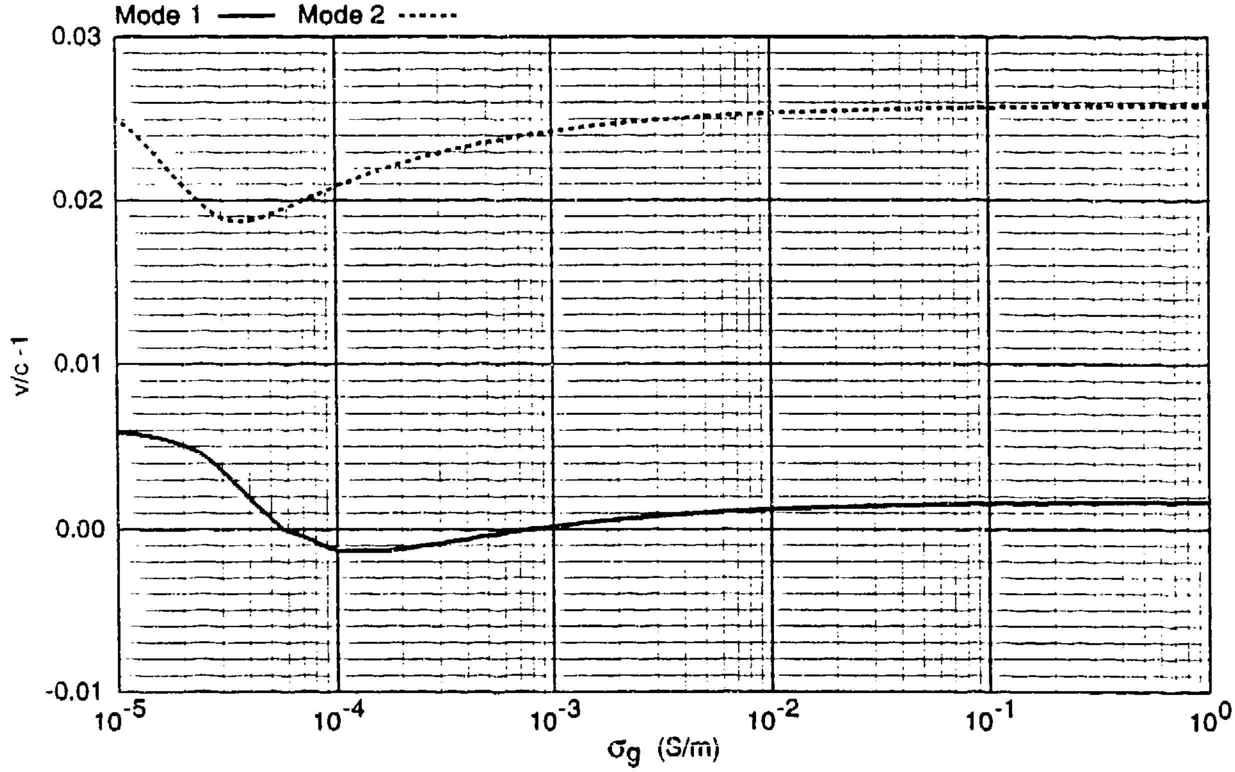
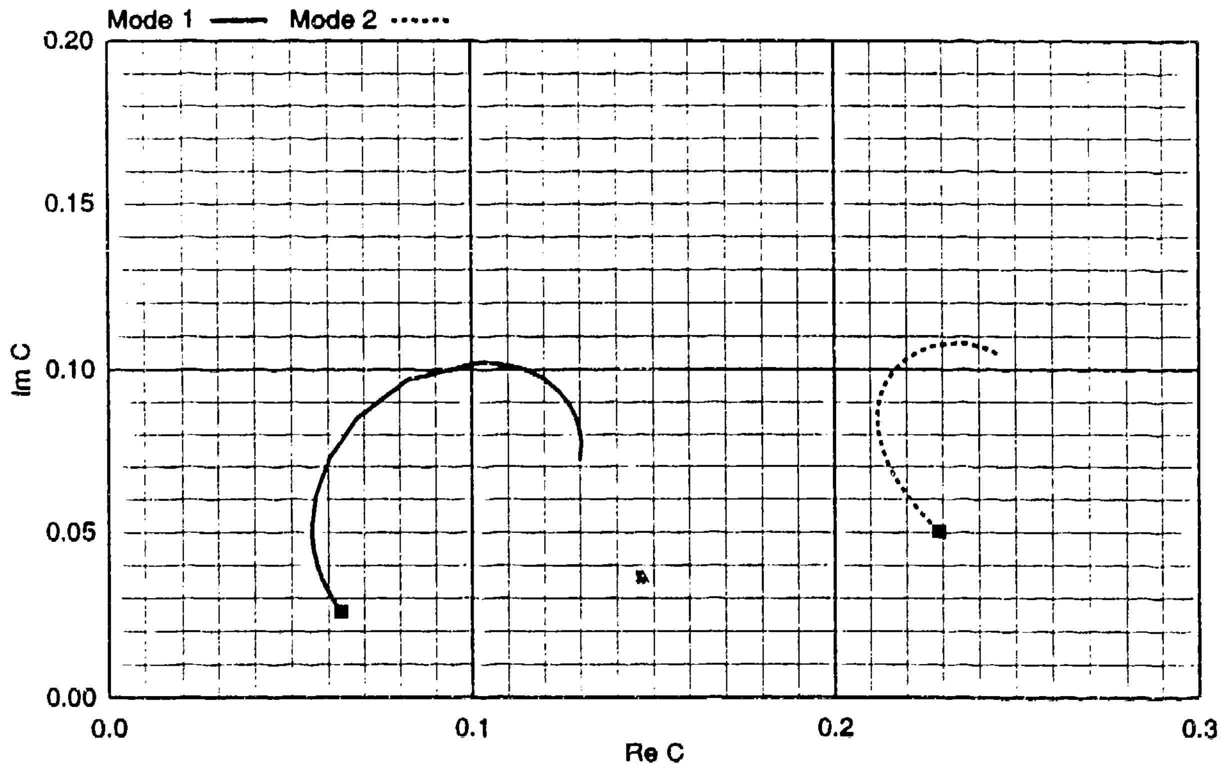


Figure 10. Parameters for $W = 2 \times 10^{-9}$, frequency = 25 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 10. Parameters for W = 2×10^{-9}, frequency = 25 kHz (Concluded).

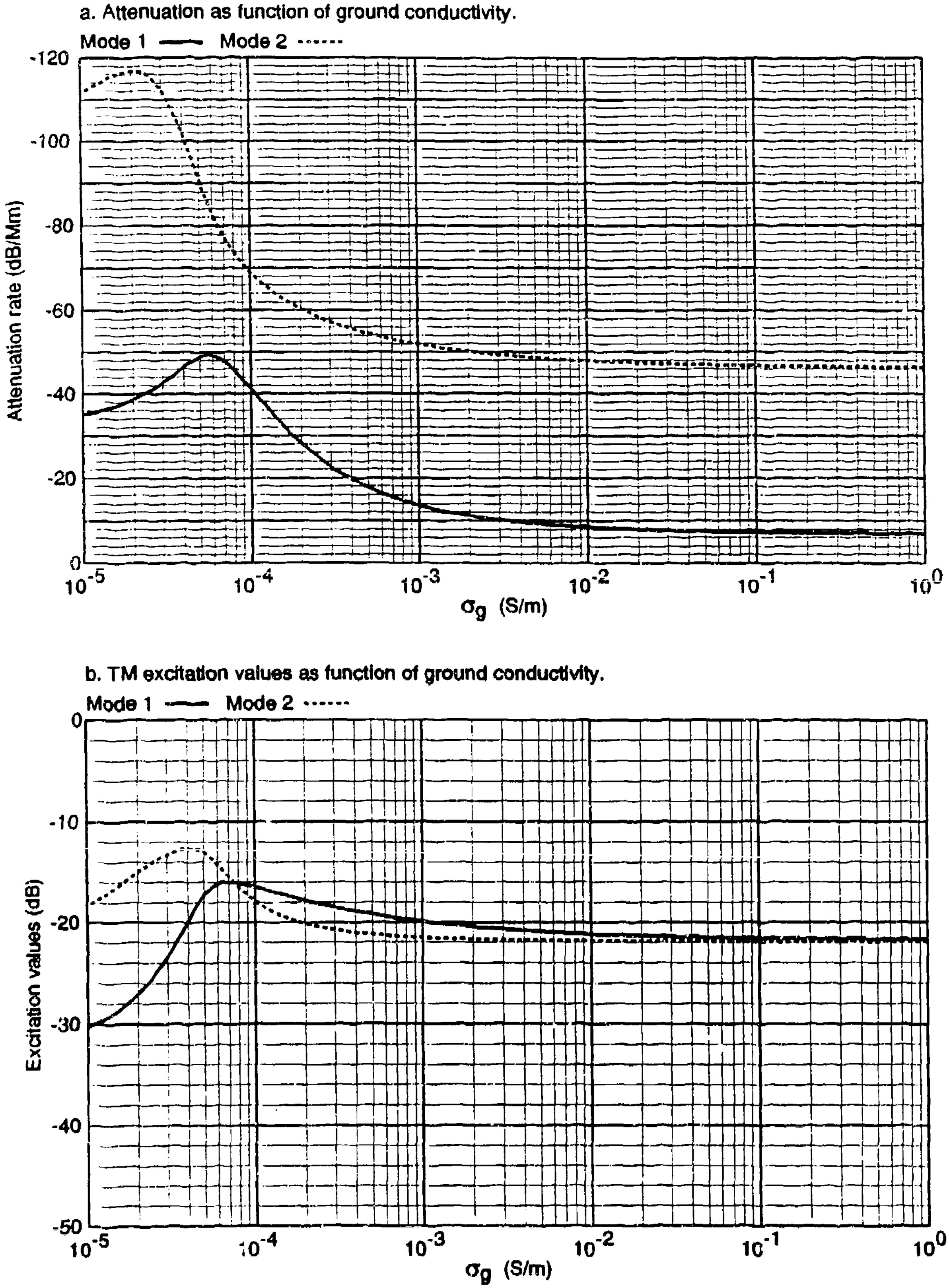
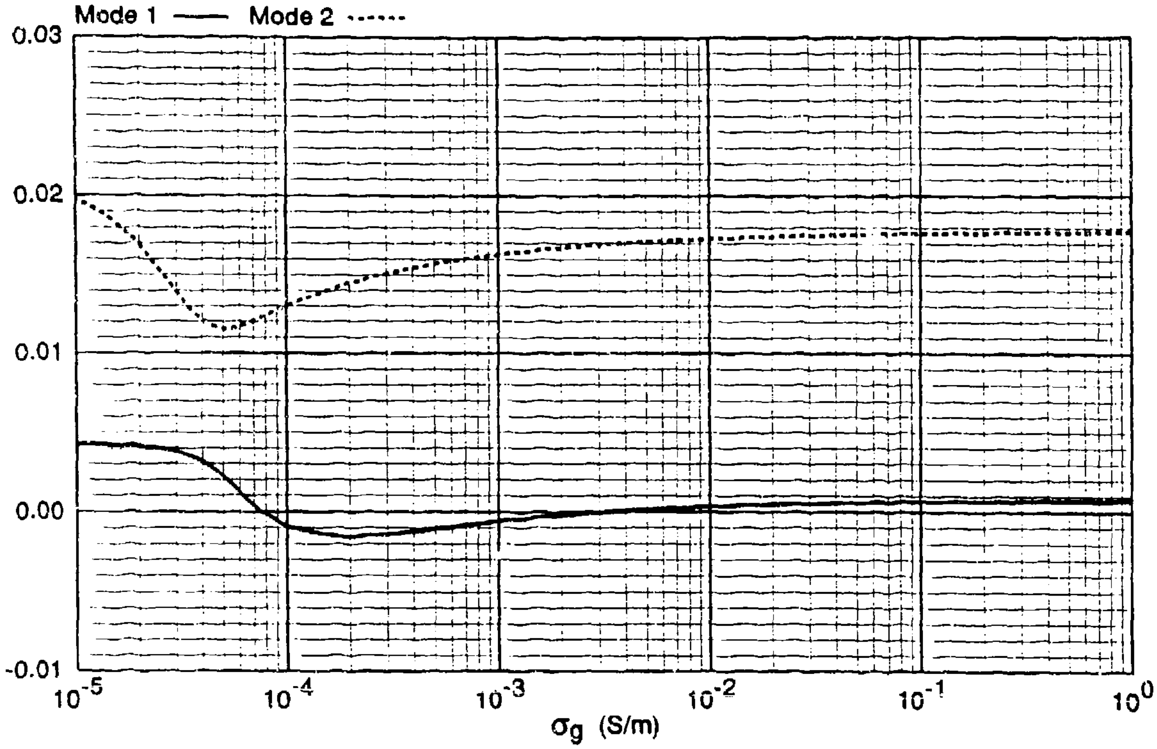
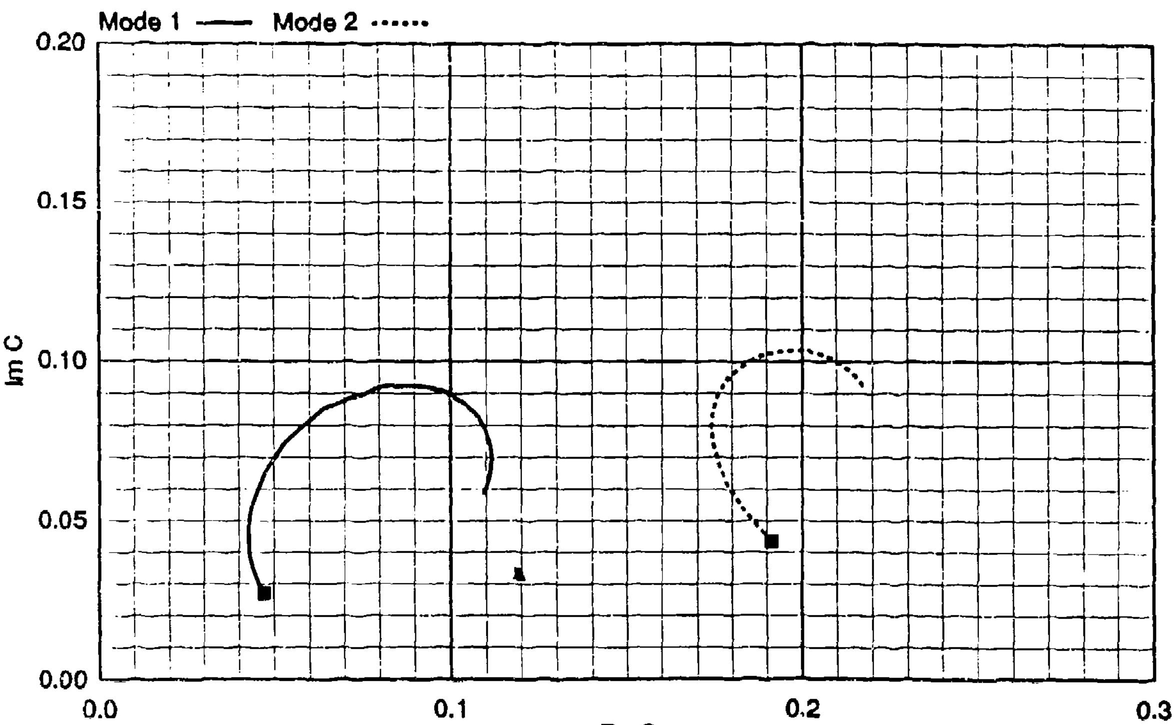


Figure 11. Parameters for $W = 2 \times 10^{-9}$, frequency = 30 kHz.

c. Relative phase velocity as a function of ground conductivity.



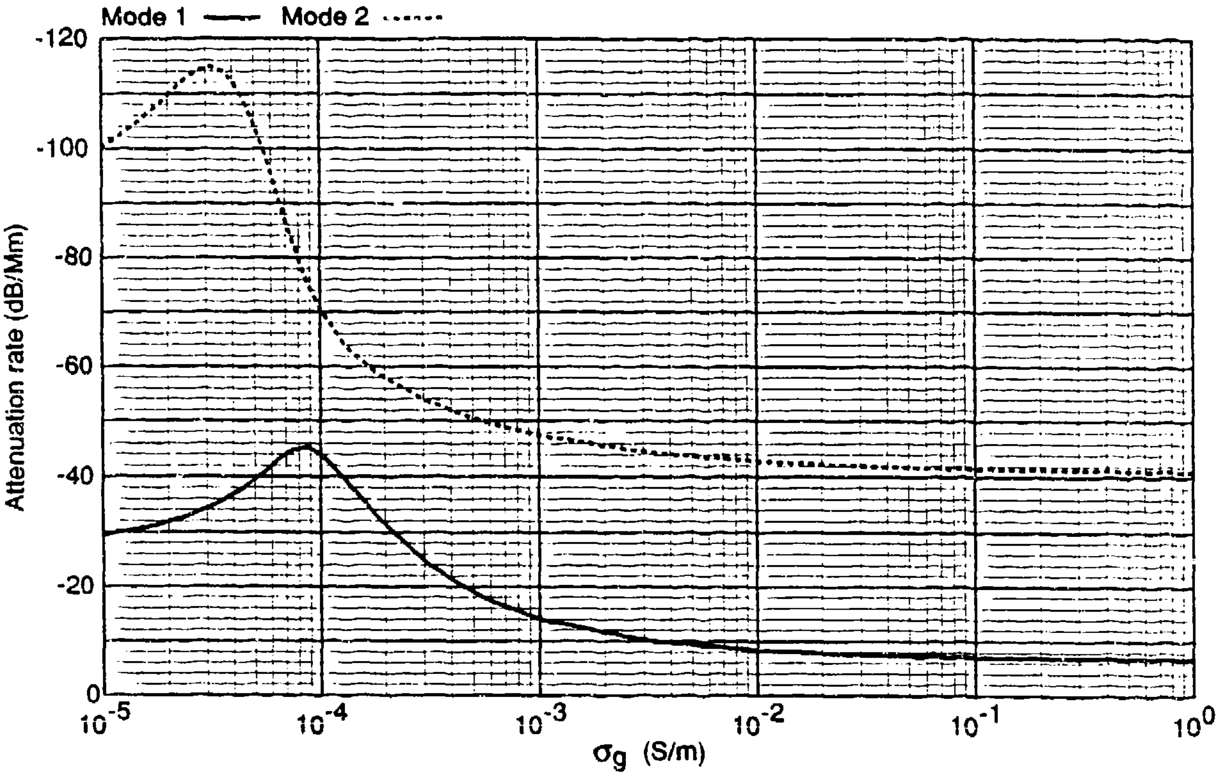
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 11. Parameters for W = 2 x 10^{-9}, frequency = 30 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

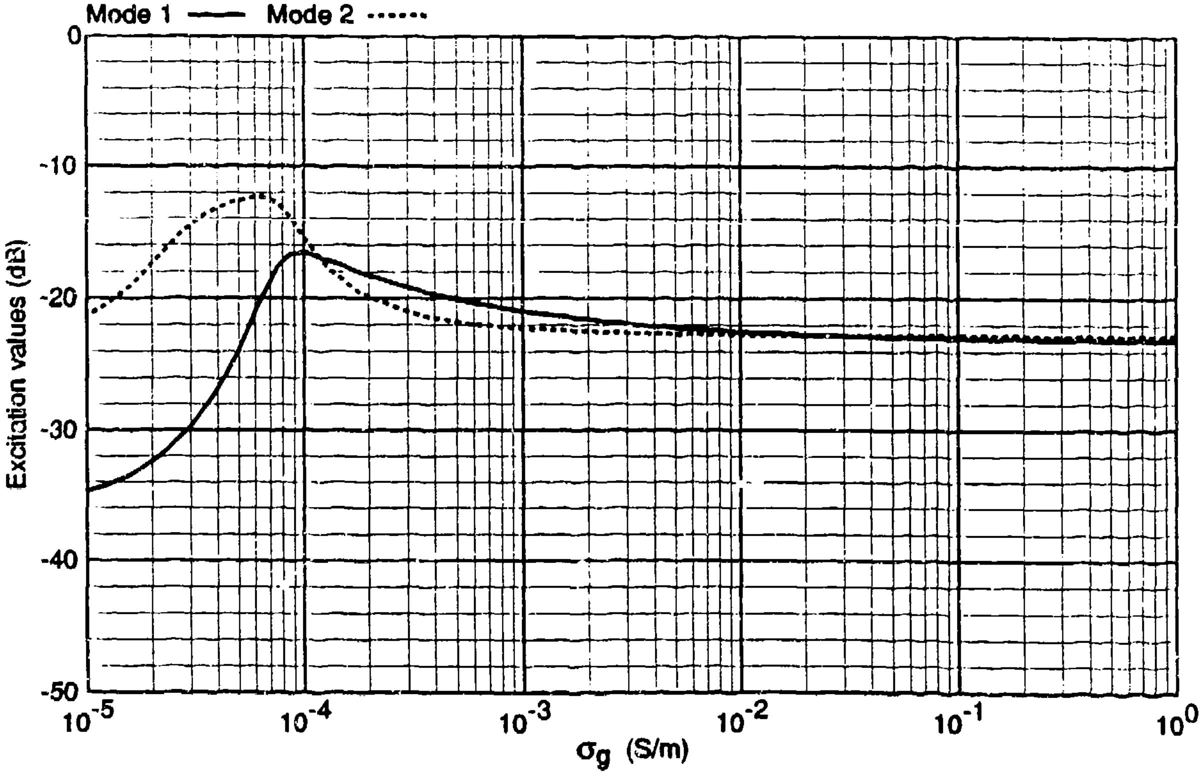
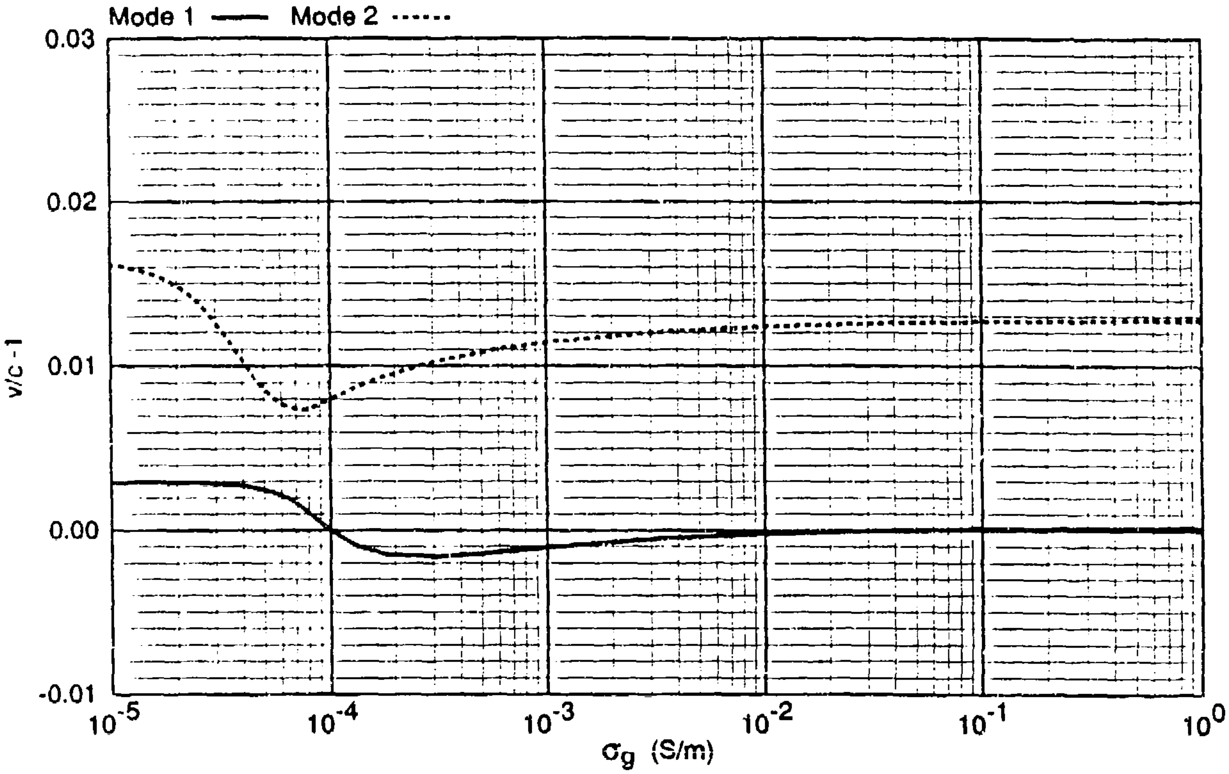
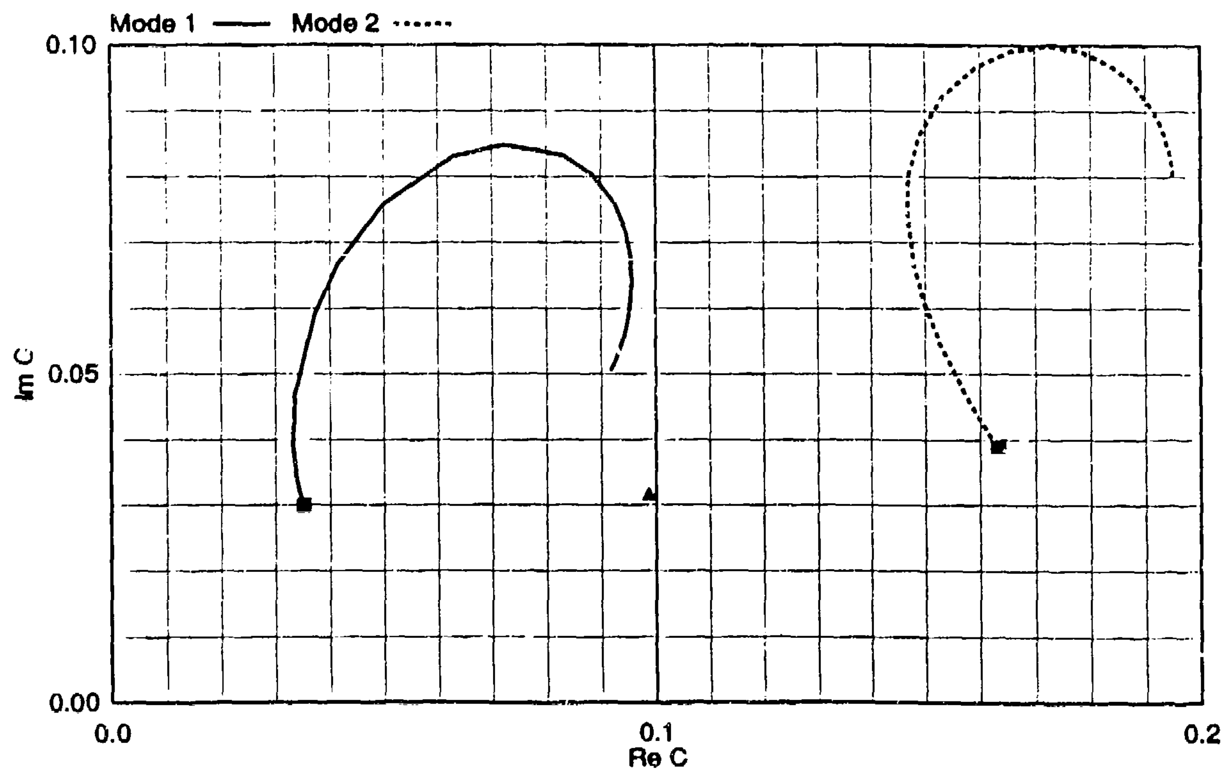


Figure 12. Parameters for $W = 2 \times 10^{-9}$, frequency = 35 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 12. Parameters for $W = 2 \times 10^{-9}$, frequency = 35 kHz (Concluded).

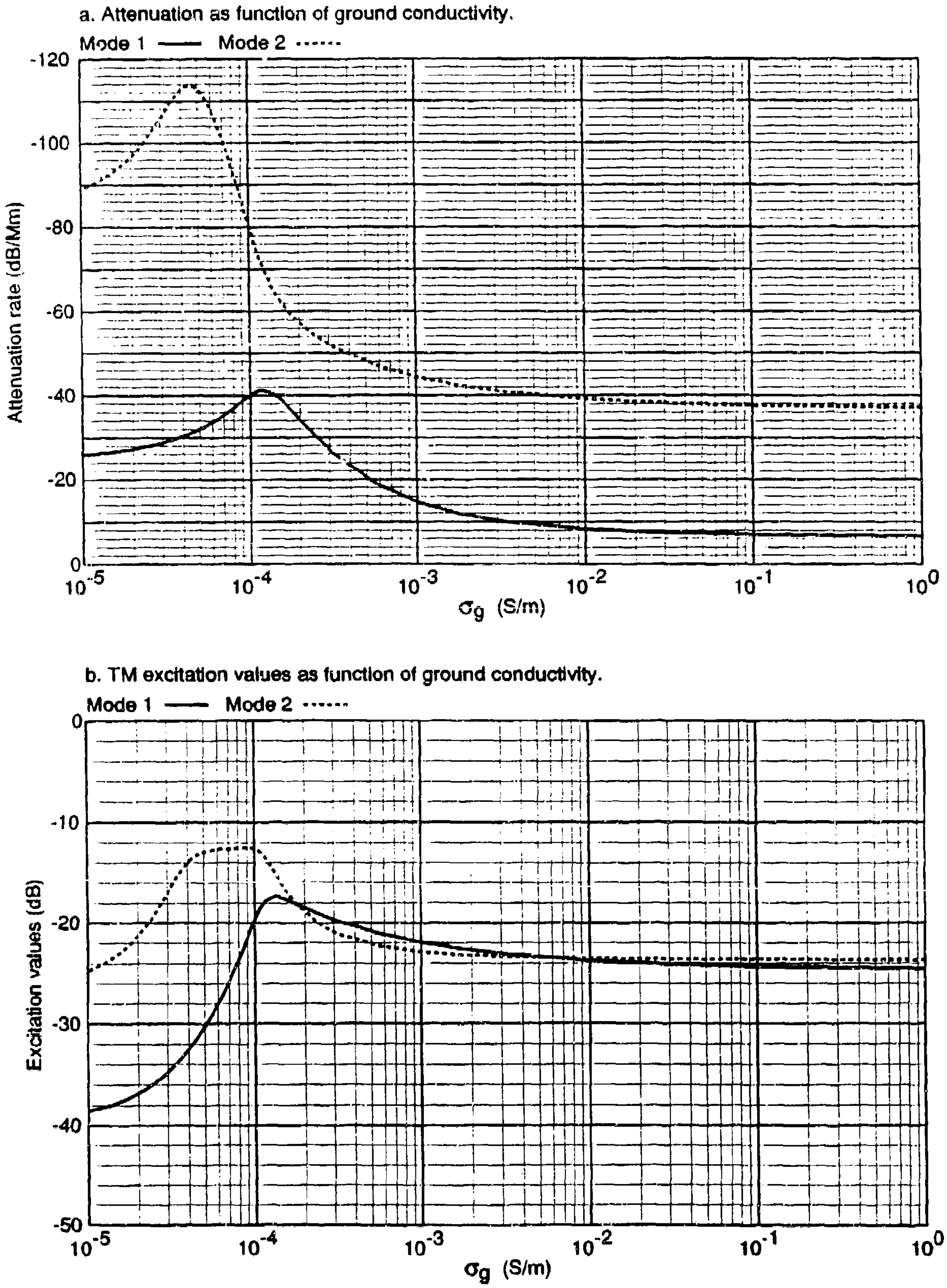
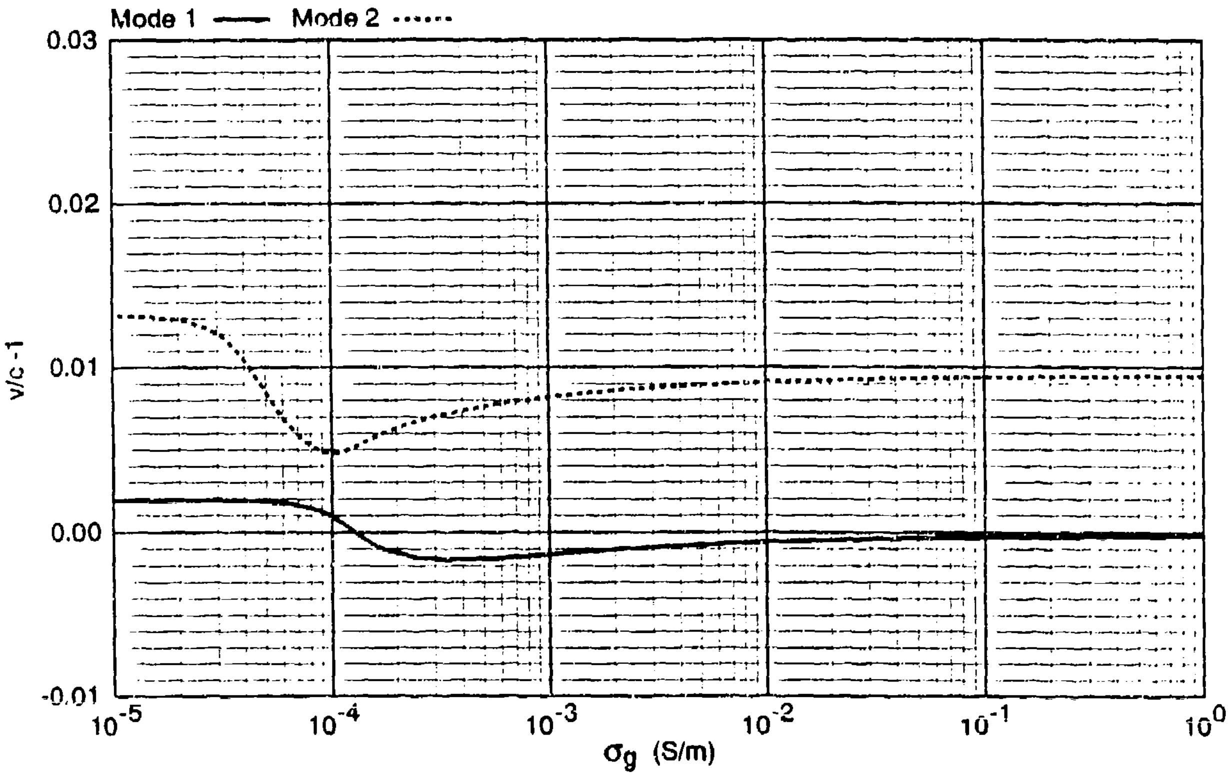
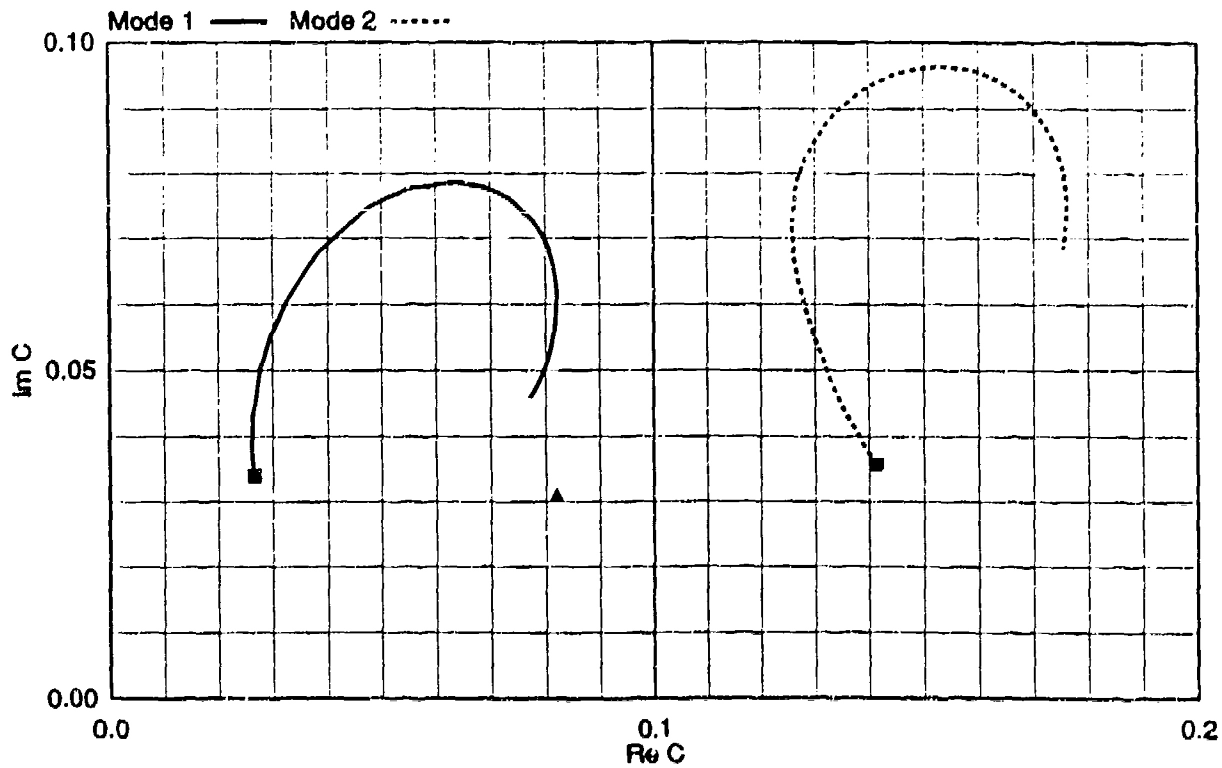


Figure 13. Parameters for $W = 2 \times 10^{-9}$, frequency = 40 kHz.

c. Relative phase velocity as a function of ground conductivity.



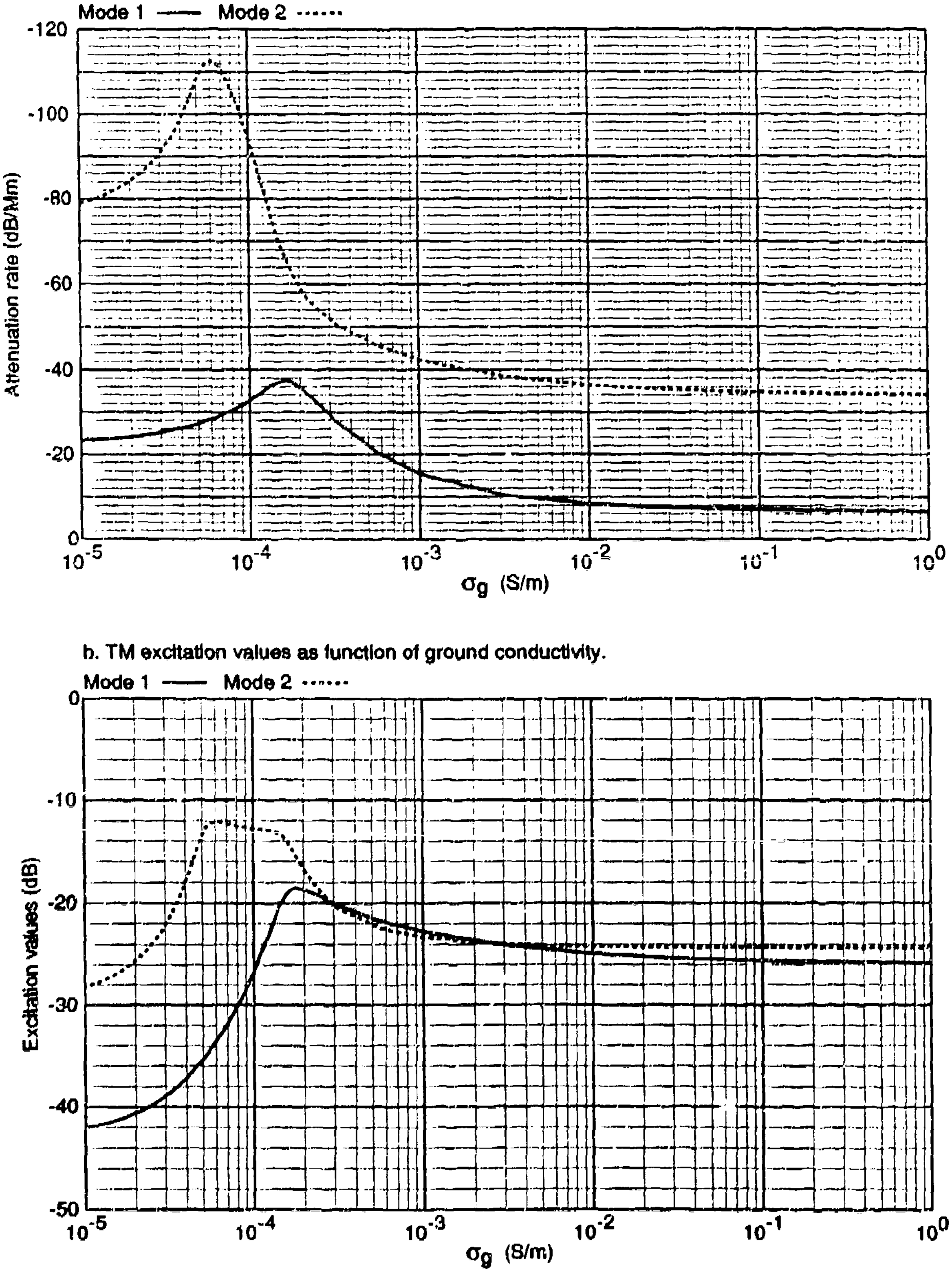
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 13. Parameters for W = 2 x 10^{-9}, frequency = 40 kHz (Concluded).

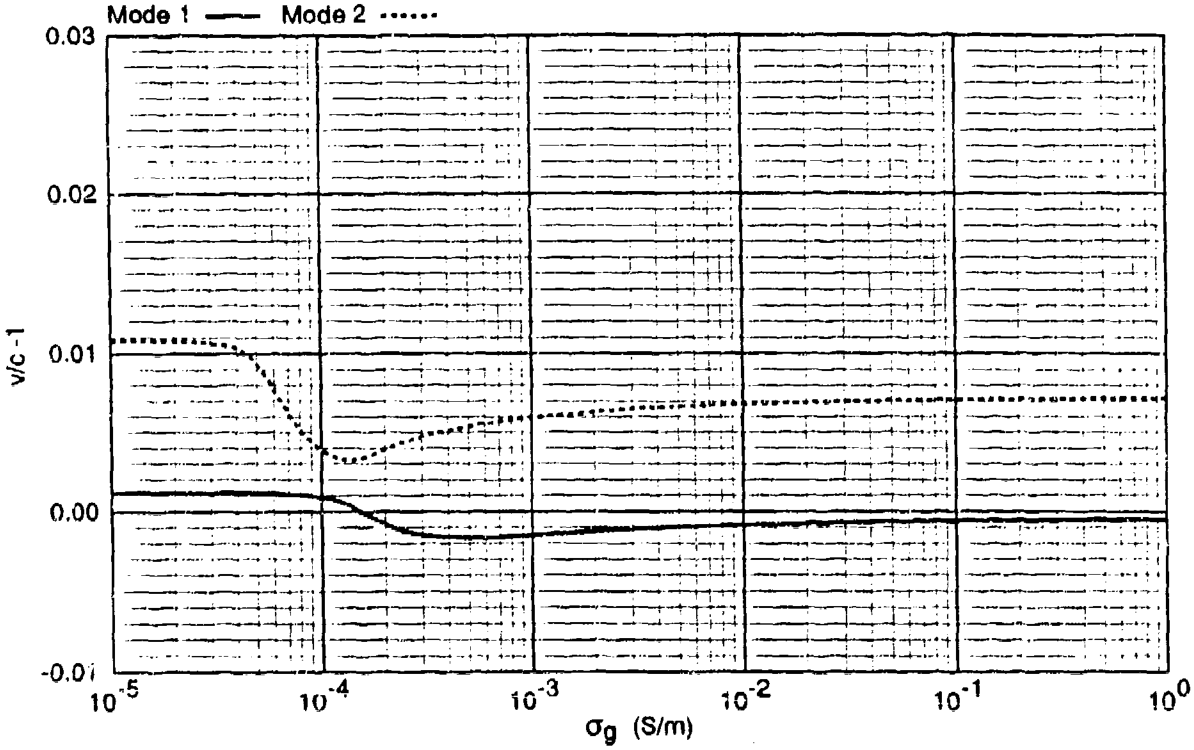
a. Attenuation as function of ground conductivity.



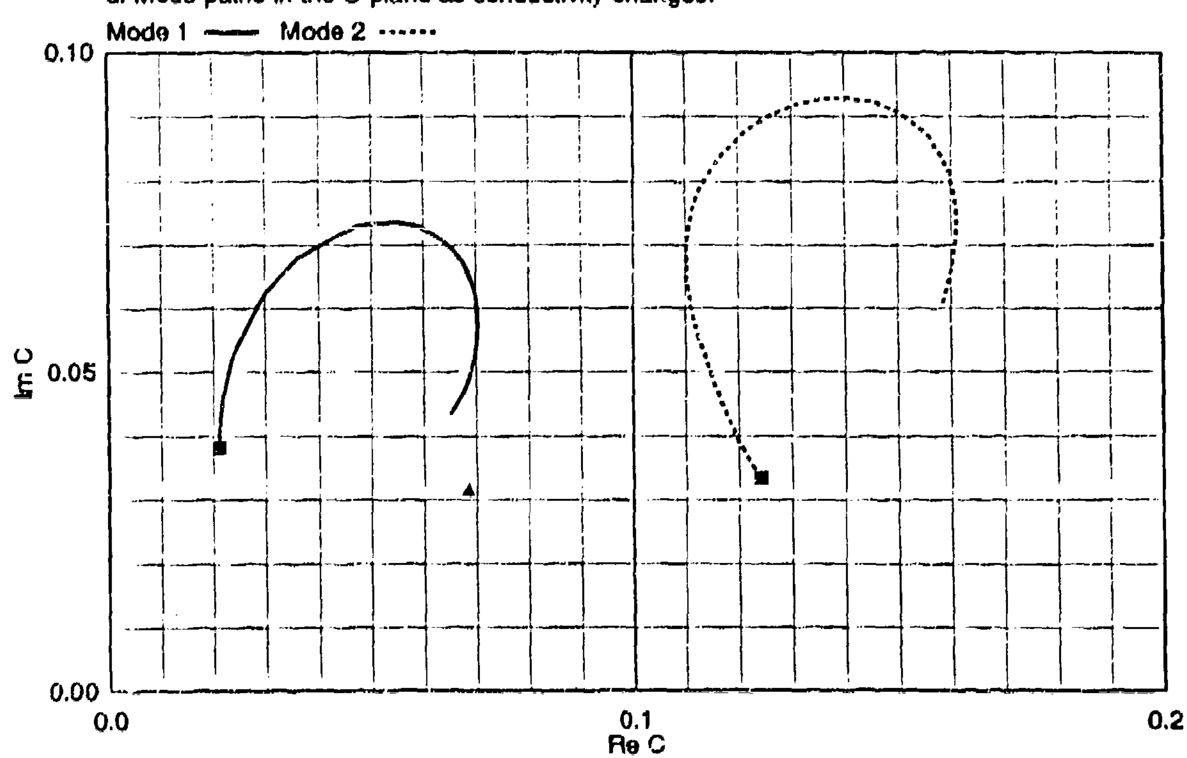
b. TM excitation values as function of ground conductivity.

Figure 14. Parameters for $W = 2 \times 10^{-9}$, frequency = 45 kHz.

c. Relative phase velocity as a function of ground conductivity.



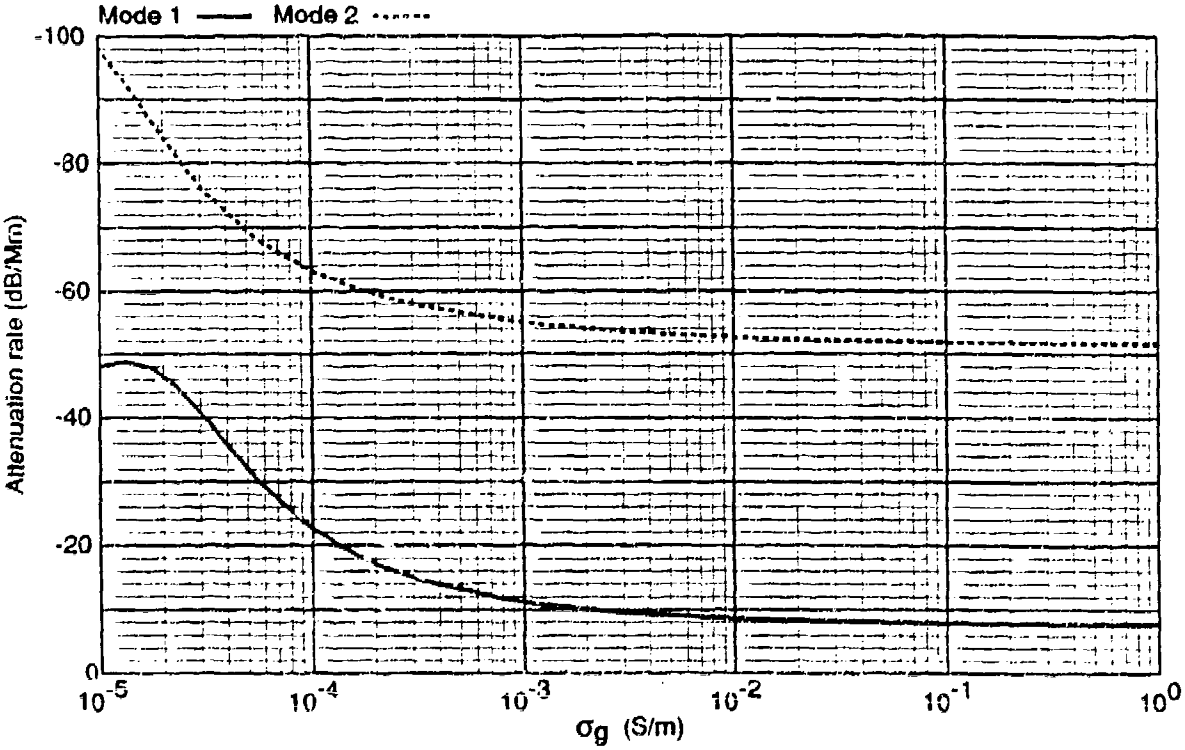
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 14. Parameters for $W = 2 \times 10^{-9}$, frequency = 45 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

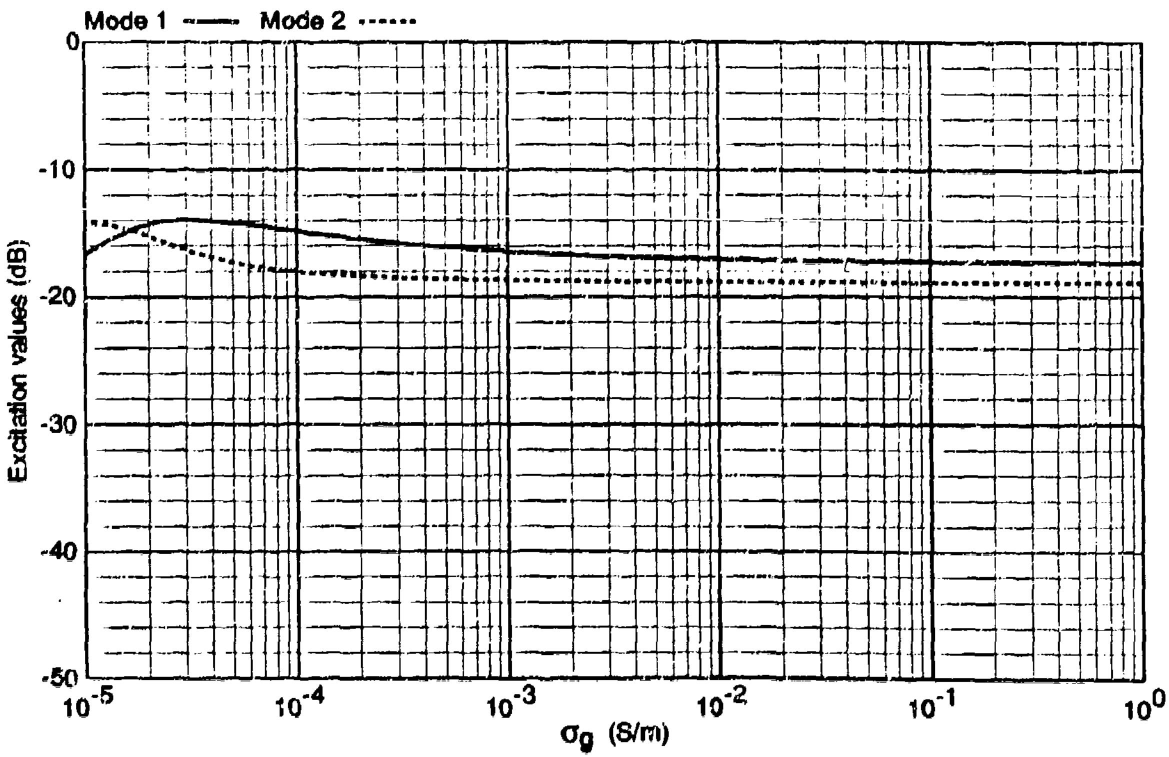
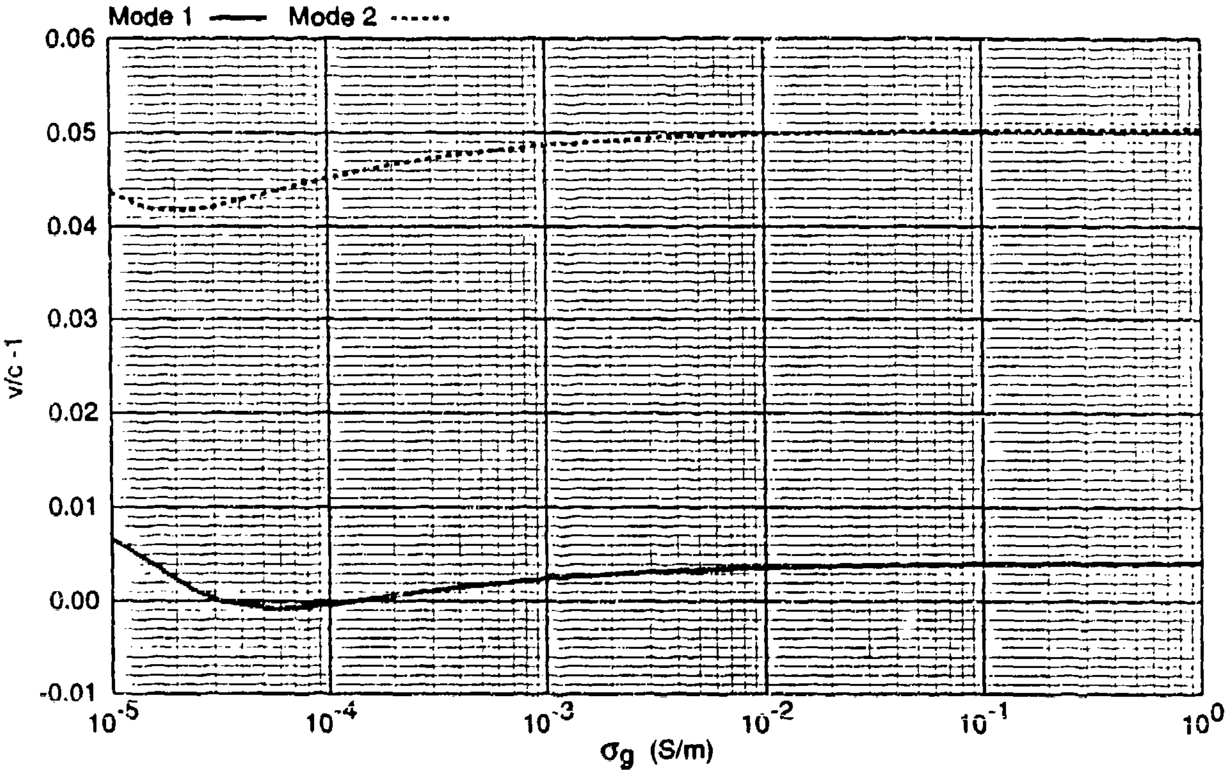
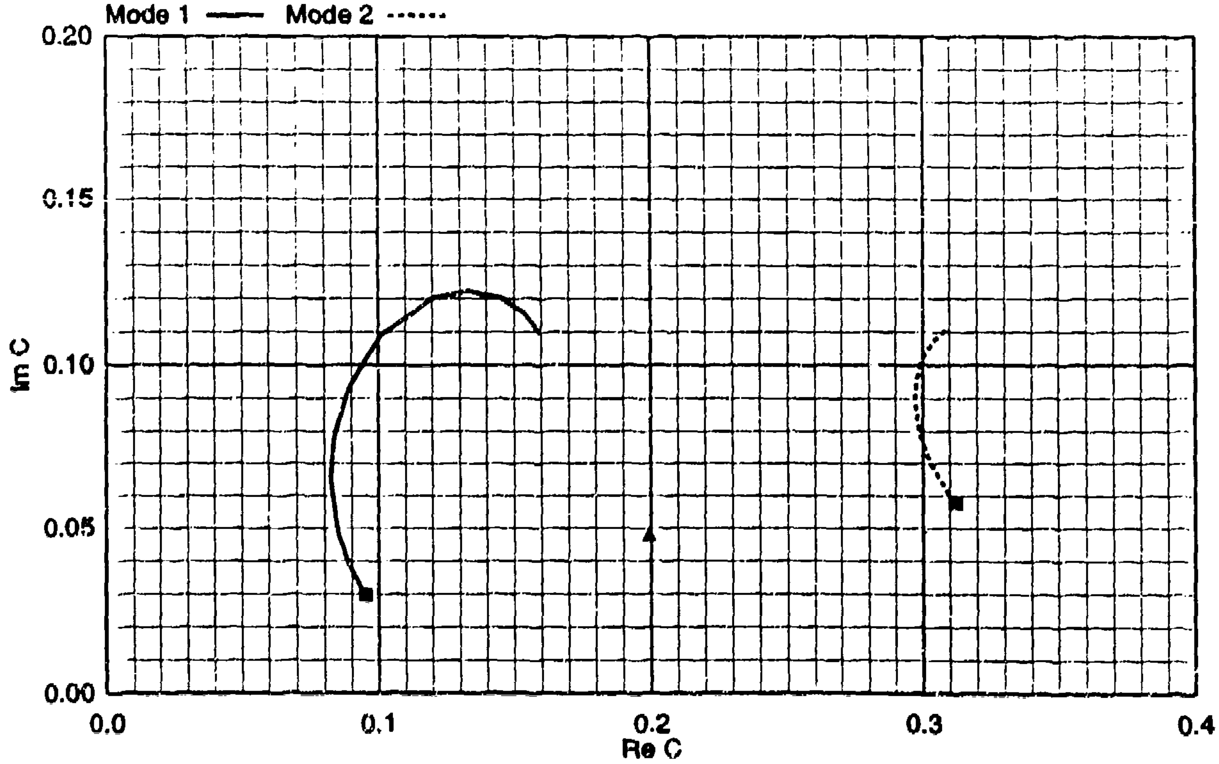


Figure 15. Parameters for $W = 2 \times 10^{-10}$, frequency = 15 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 15. Parameters for W = 2 x 10^{-10}, frequency = 15 kHz (Concluded).

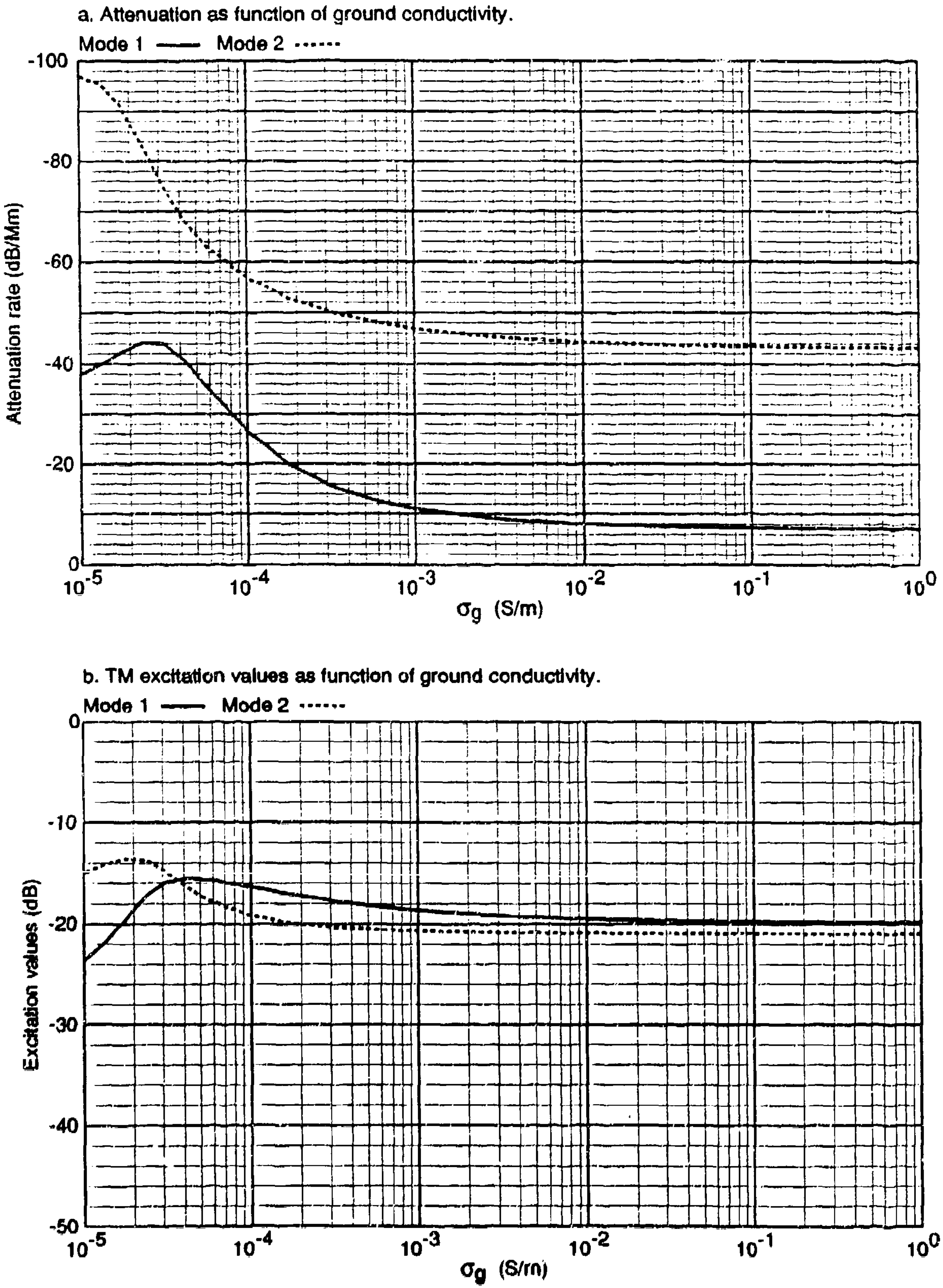
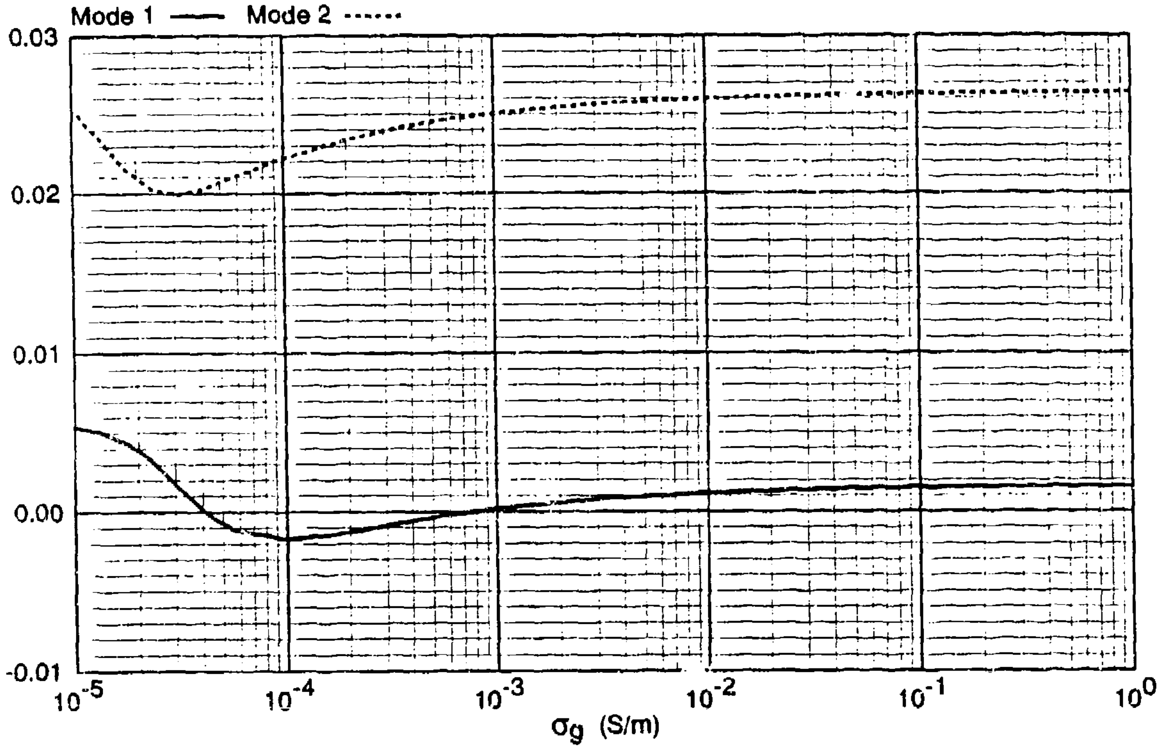
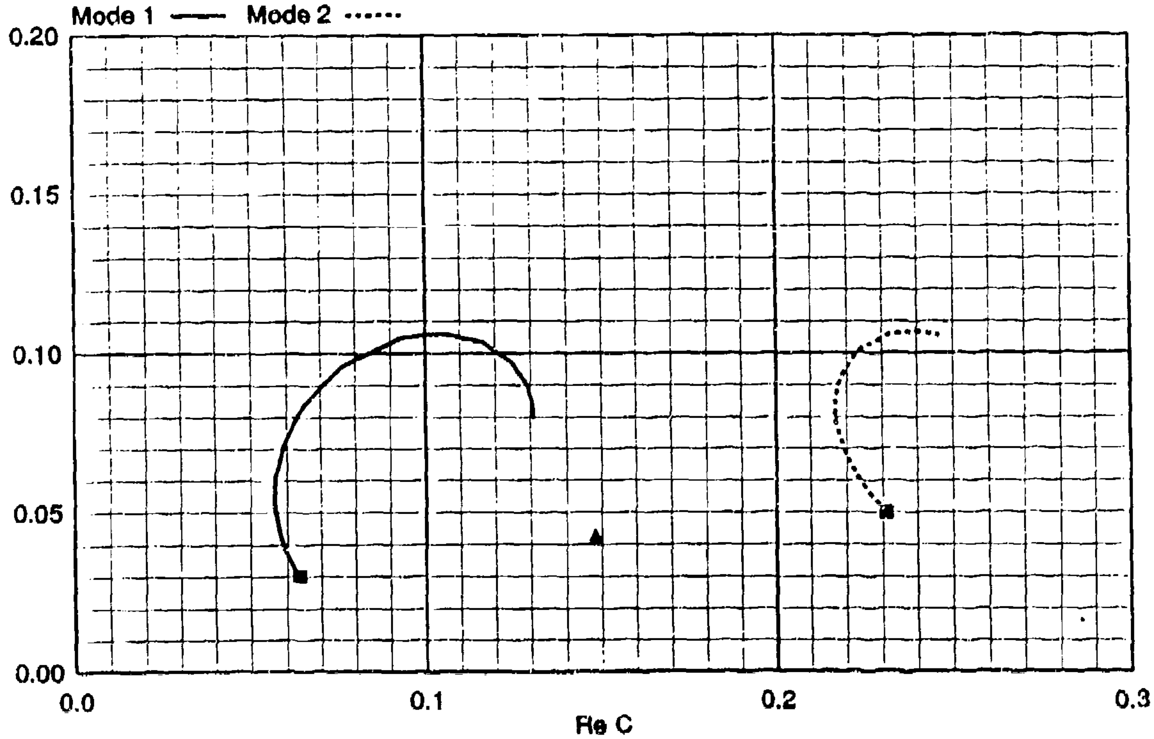


Figure 16. Parameters for $W = 2 \times 10^{-10}$, frequency = 20 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 16. Parameters for W = 2 x 10^{-10}, frequency = 20 kHz (Concluded).

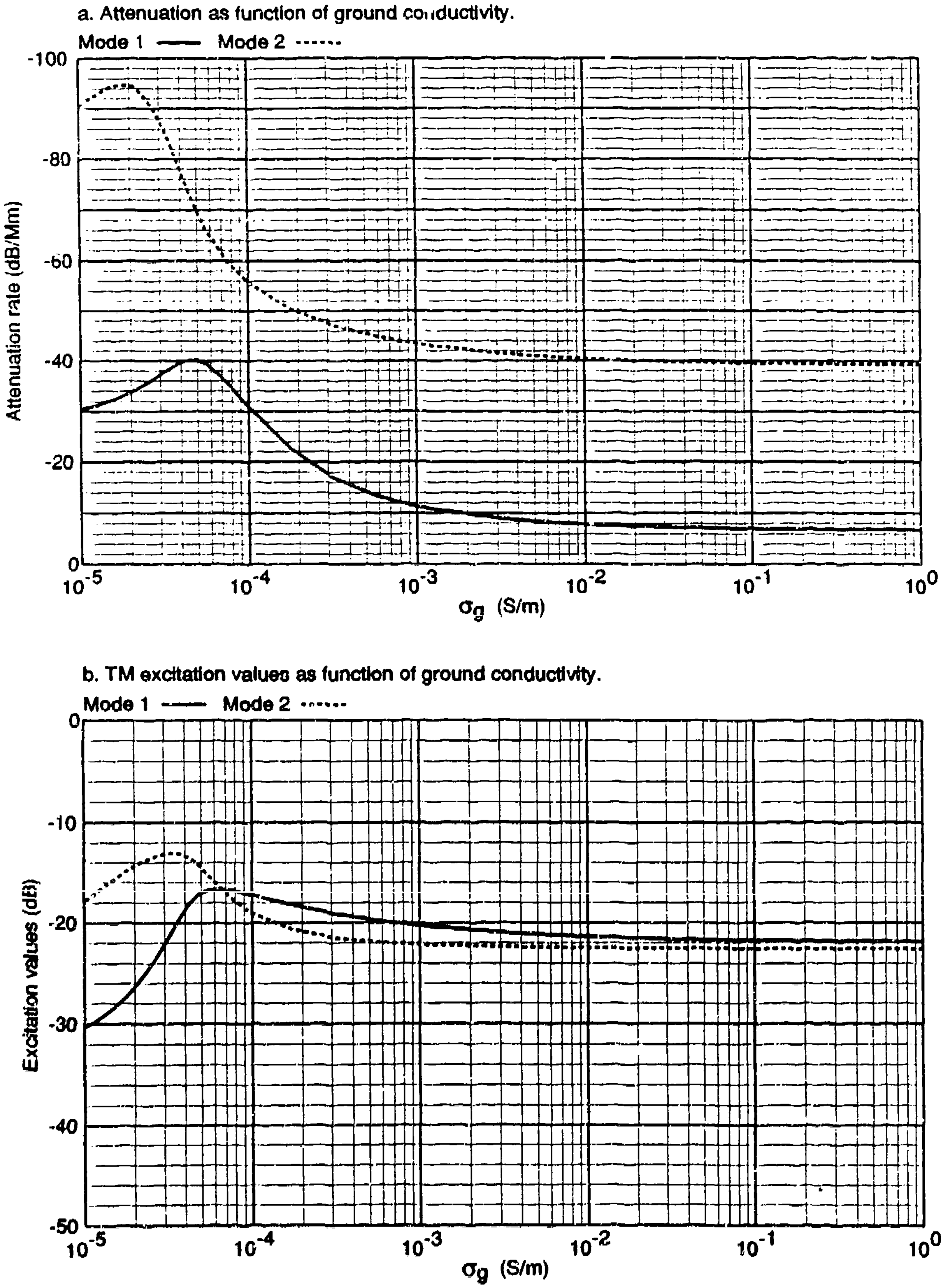
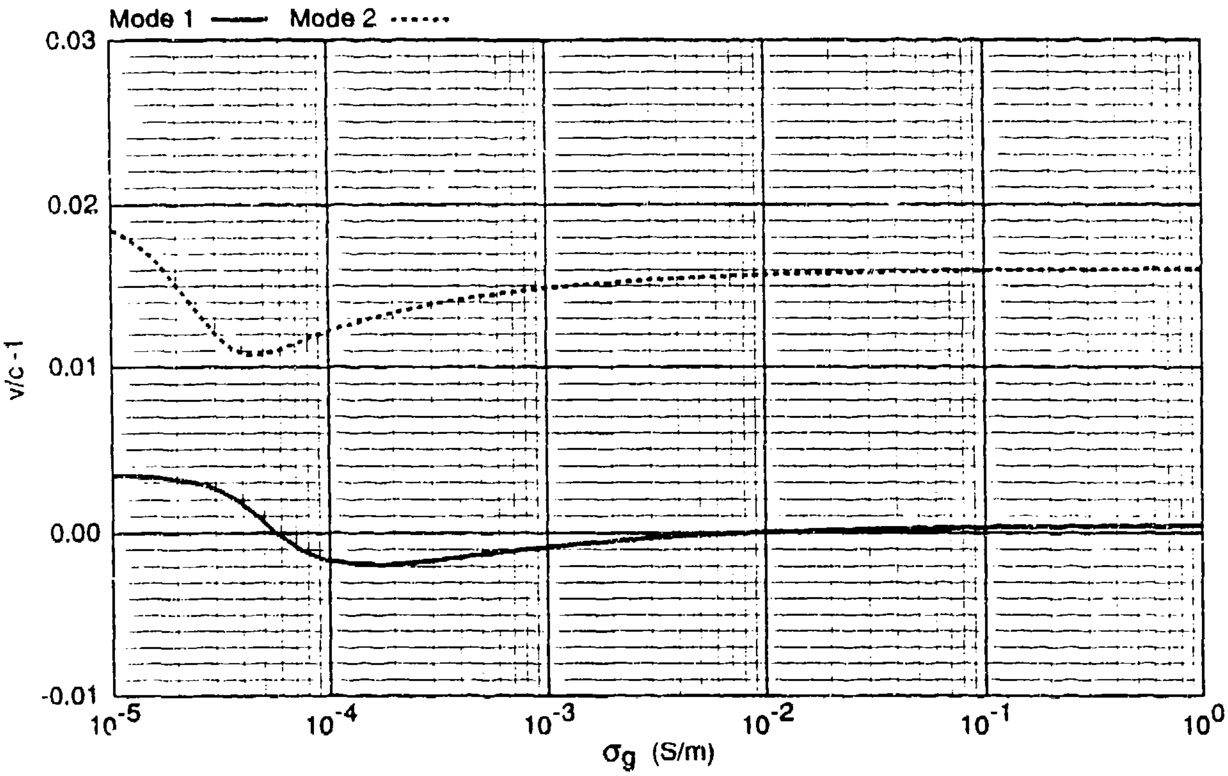
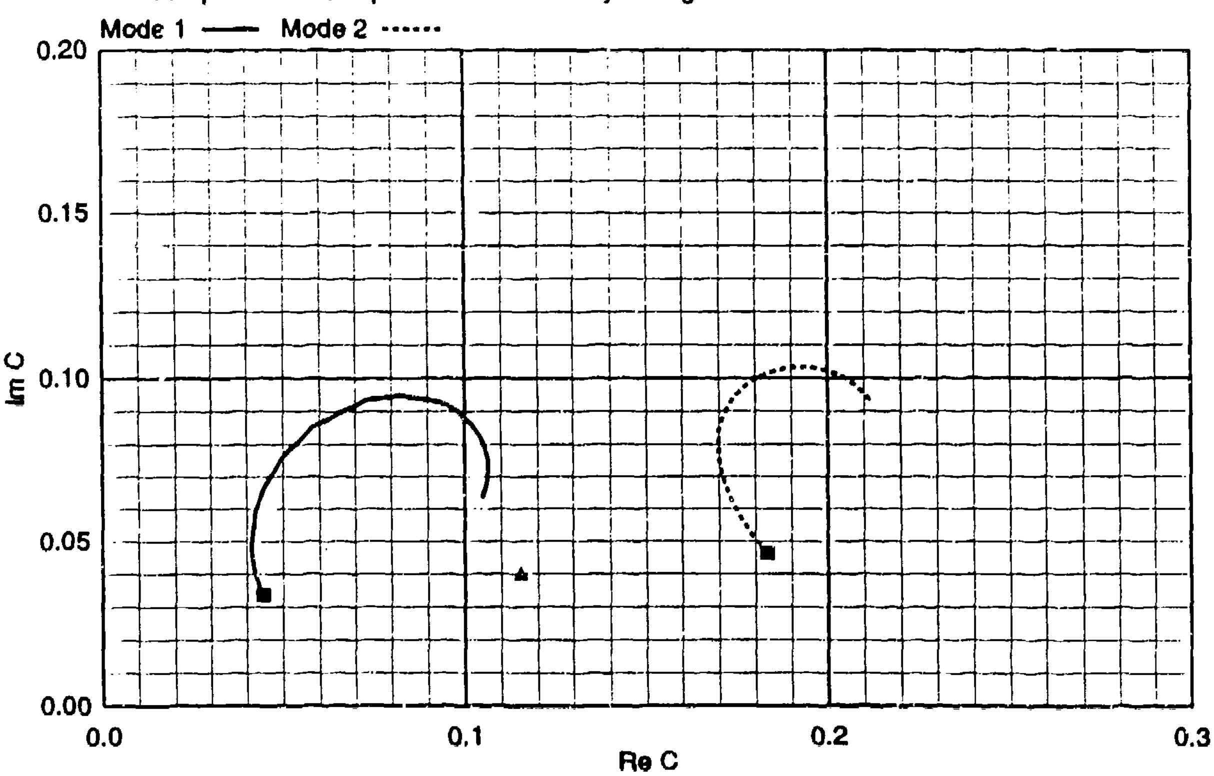


Figure 17. Parameters for W = 2 x 10^{-10}, frequency = 25 kHz.

c. Relative phase velocity as a function of ground conductivity.



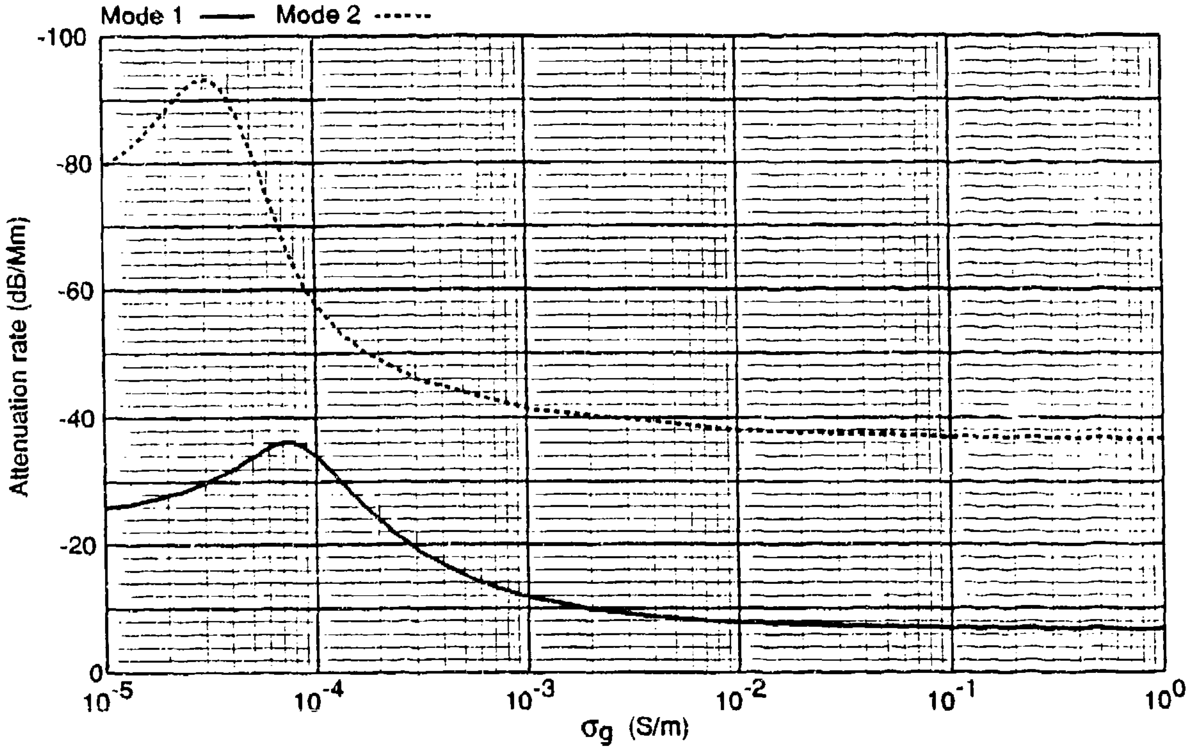
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 17. Parameters for W = 2 x 10^{-10}, frequency = 25 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

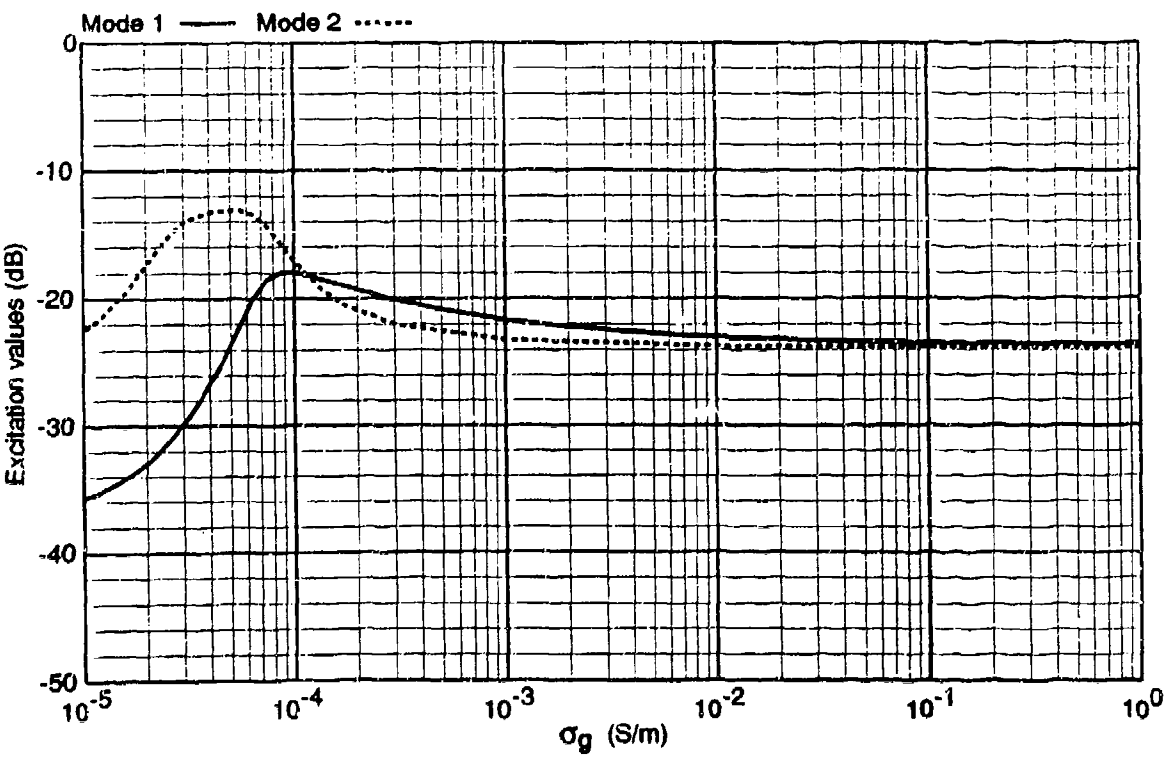
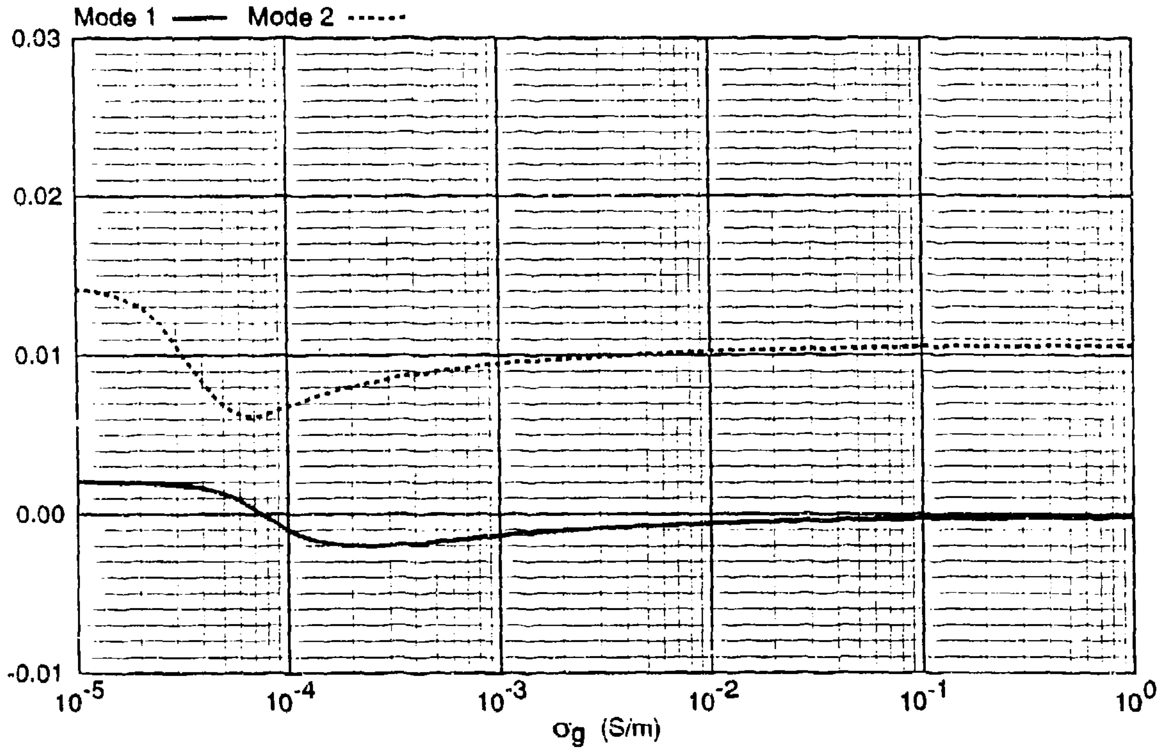
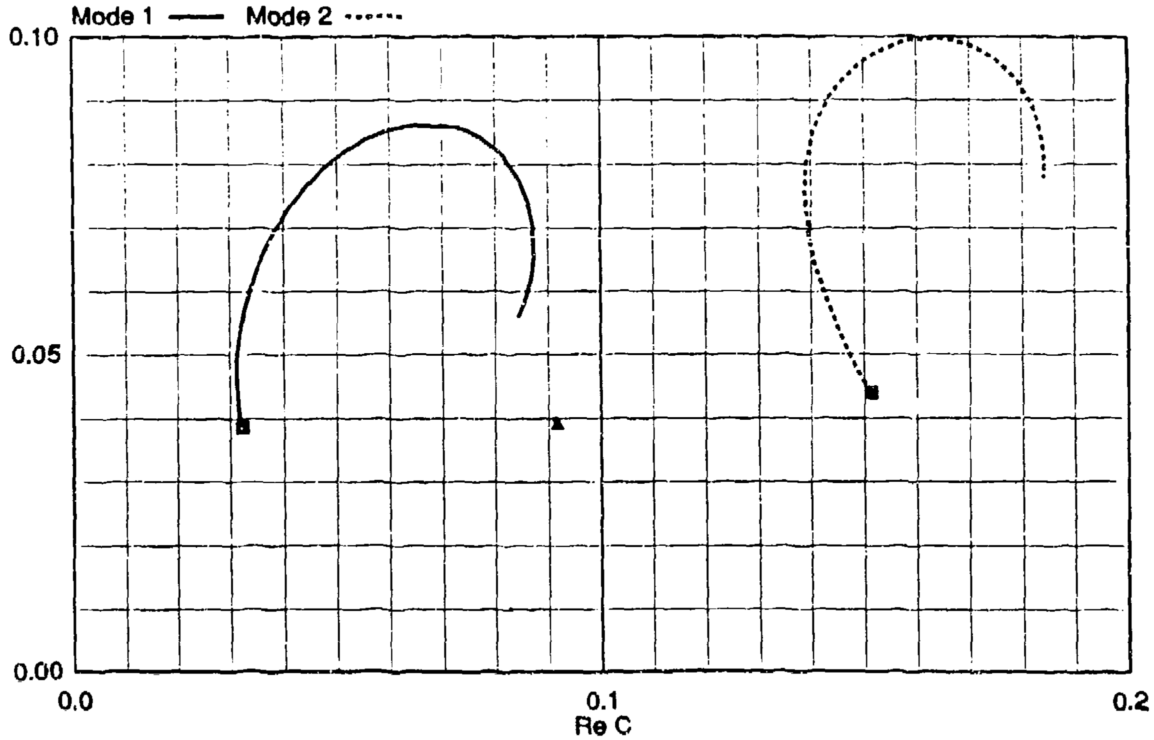


Figure 18. Parameters for $W = 2 \times 10^{-10}$, frequency = 30 kHz.

c. Relative phase velocity as a function of ground conductivity.



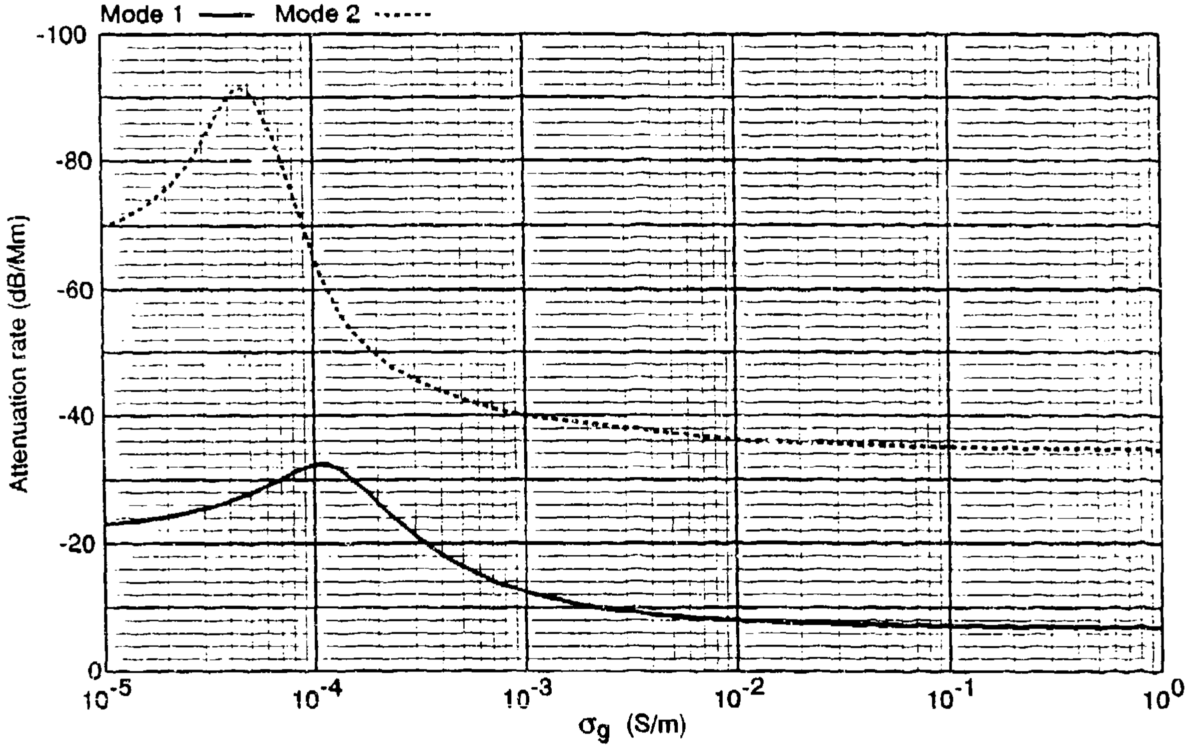
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 18. Parameters for W = 2 x 10^{-10}, frequency = 30 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

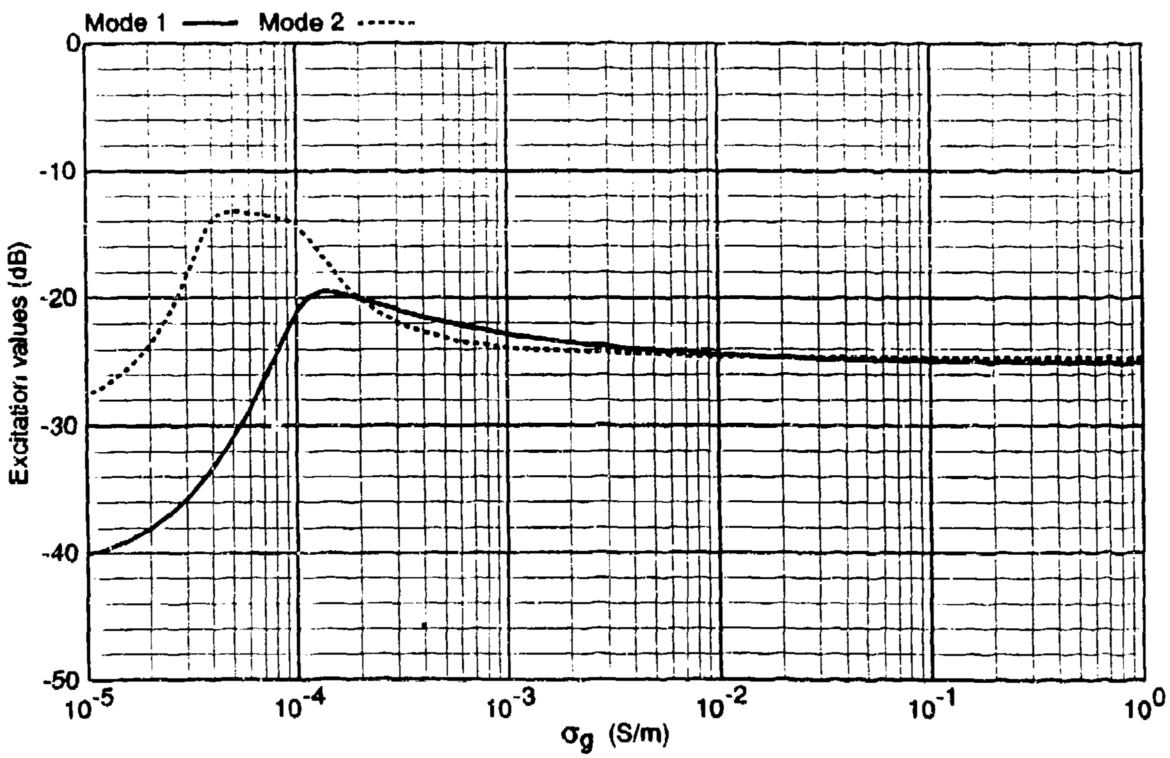
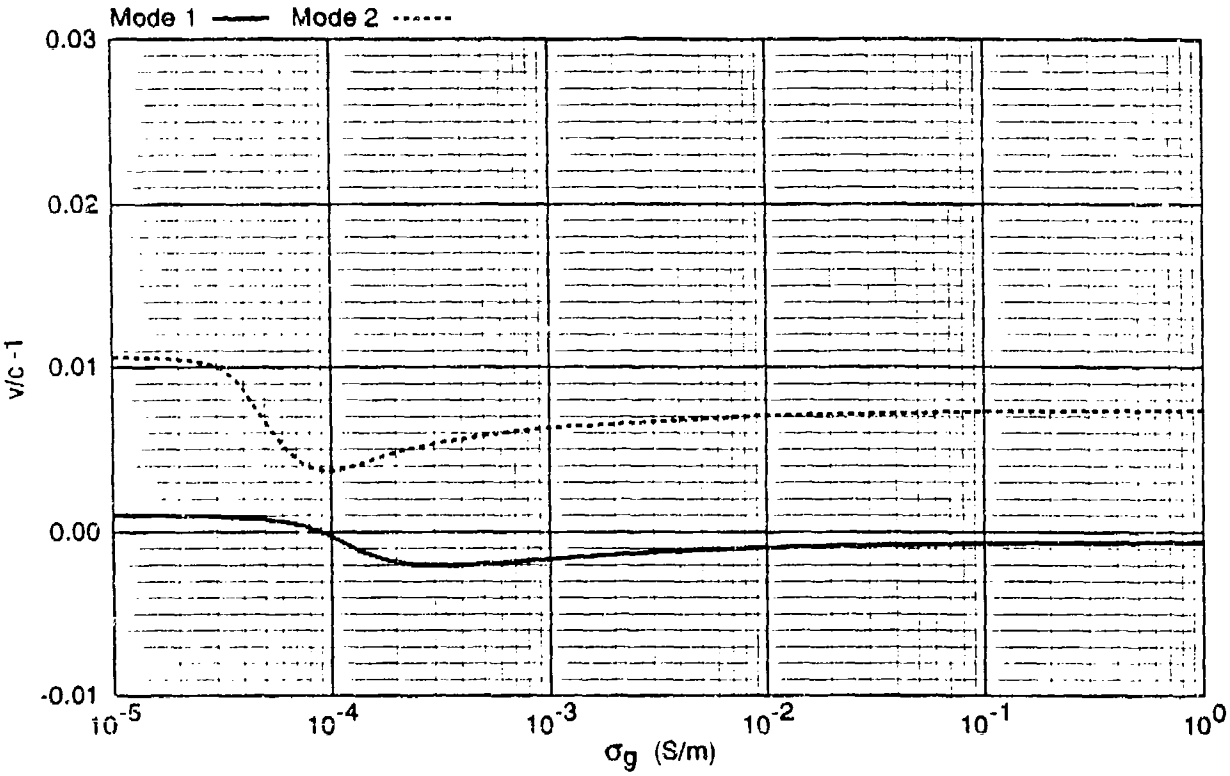
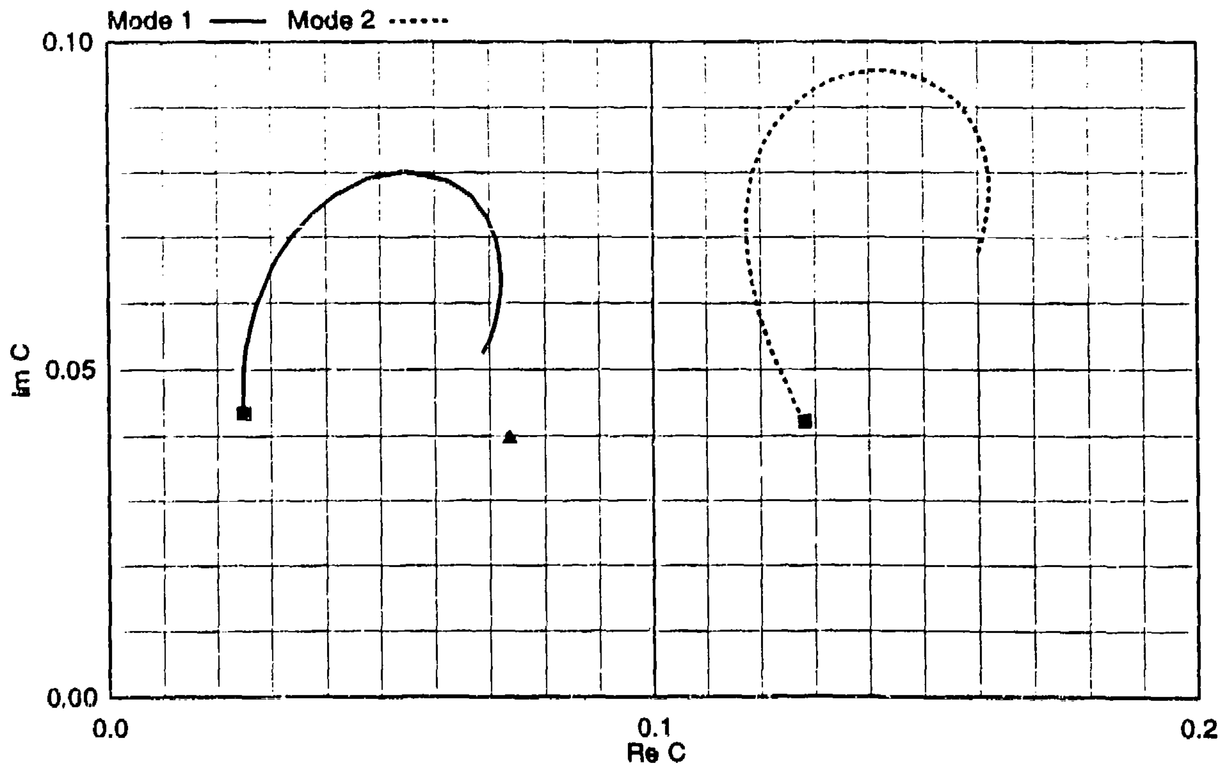


Figure 19. Parameters for $W = 2 \times 10^{-10}$, frequency = 35 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 19. Parameters for W = 2 x 10^{-10}, frequency = 35 kHz (Concluded).

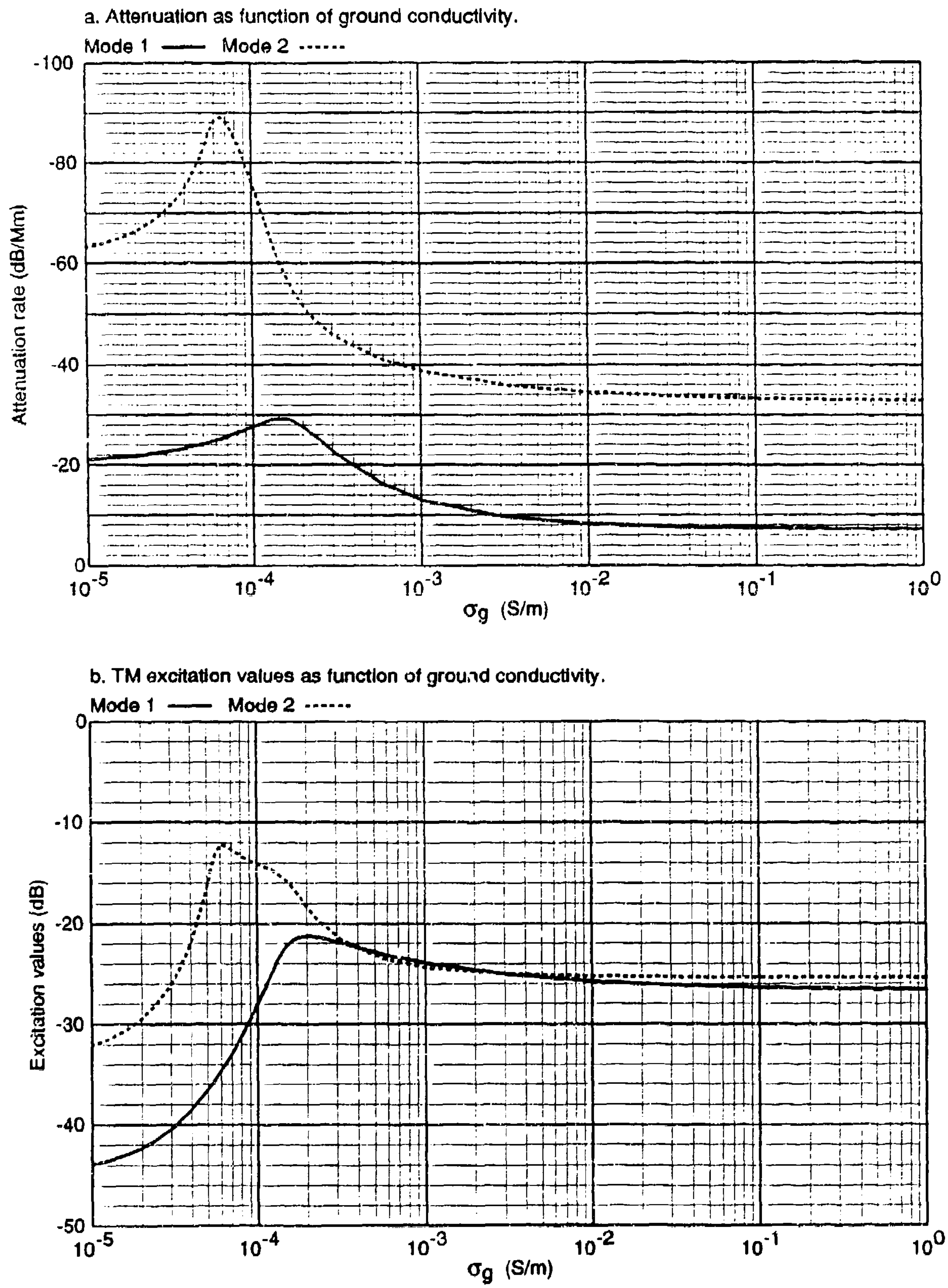
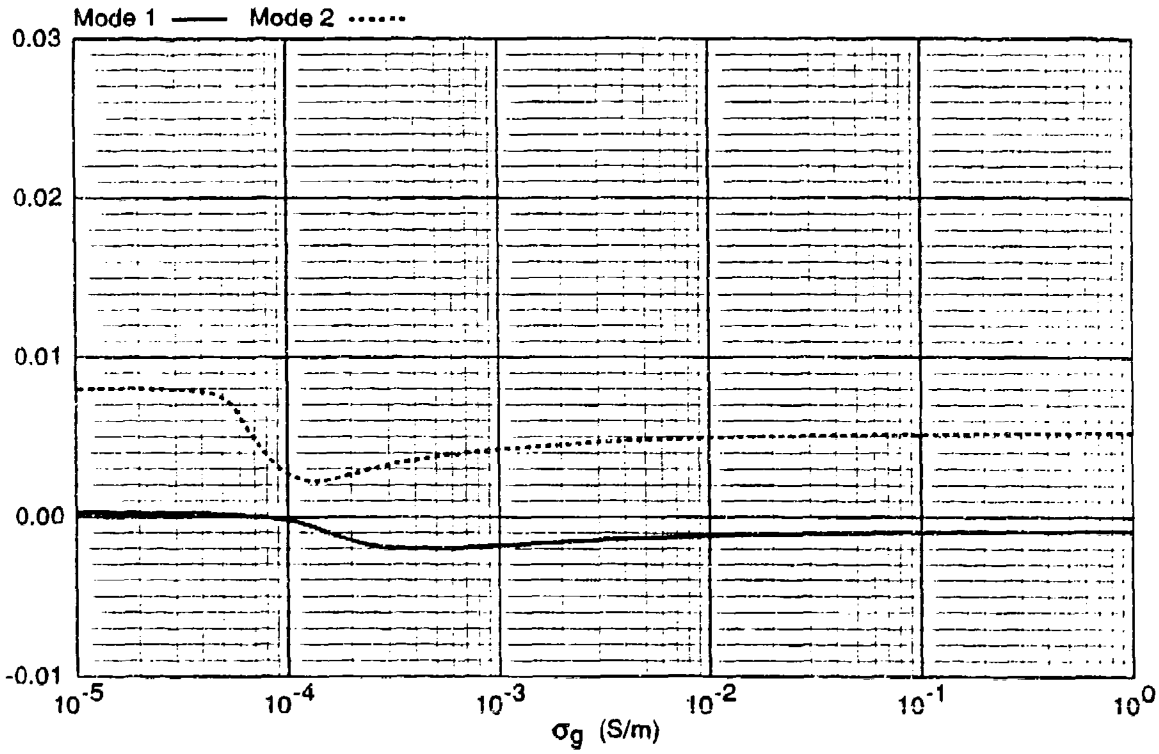
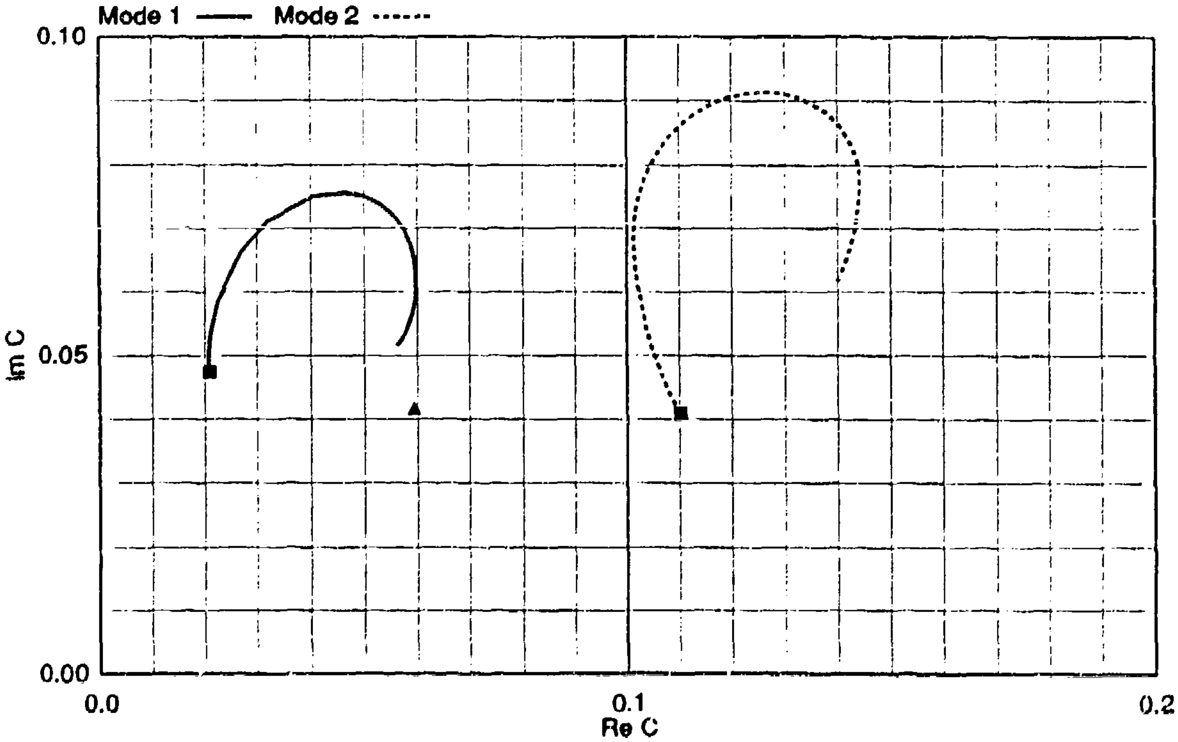


Figure 20. Parameters for $W = 2 \times 10^{-10}$, frequency = 40 kHz.

c. Relative phase velocity as a function of ground conductivity.



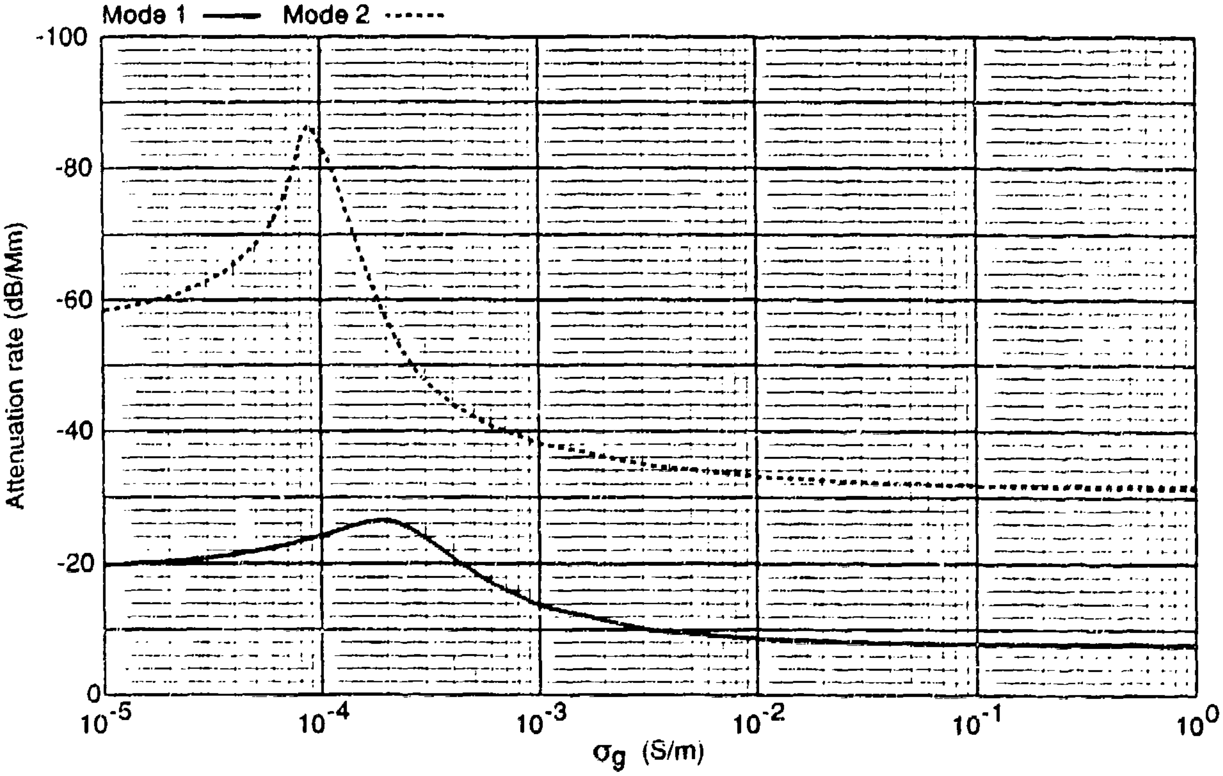
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 20. Parameters for W = 2 × 10^{-10}, frequency = 40 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

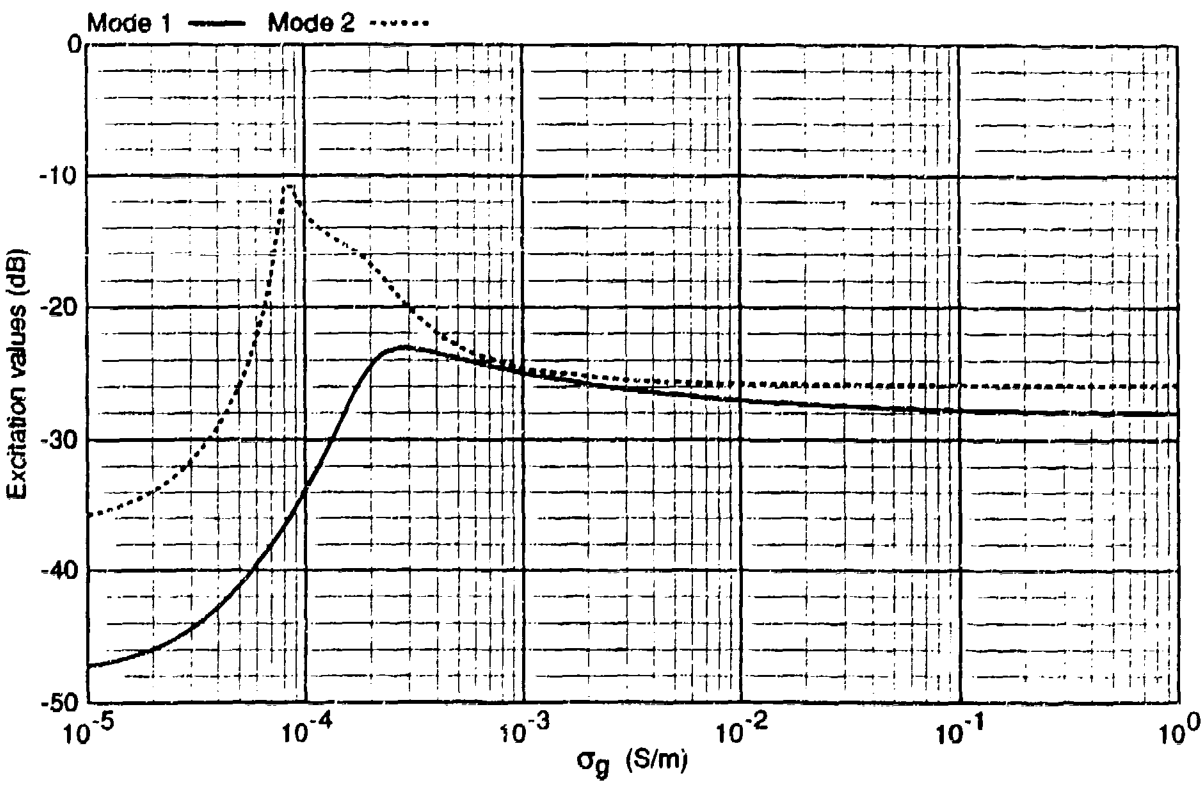
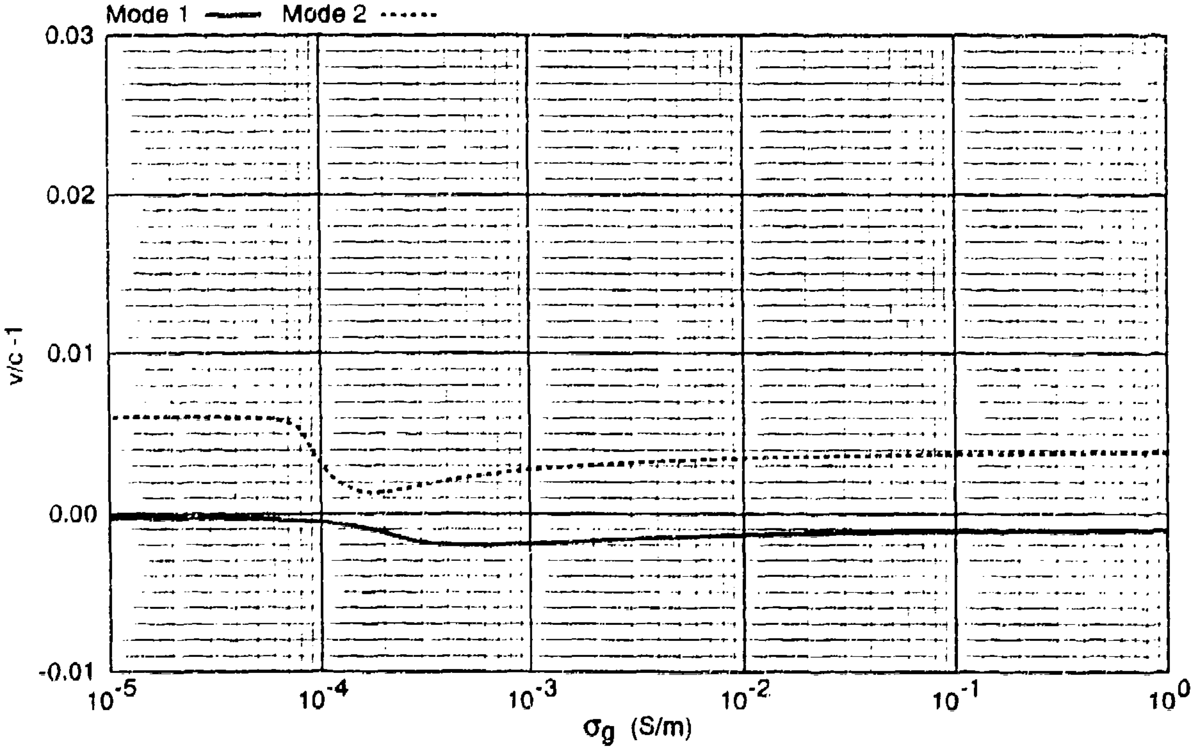
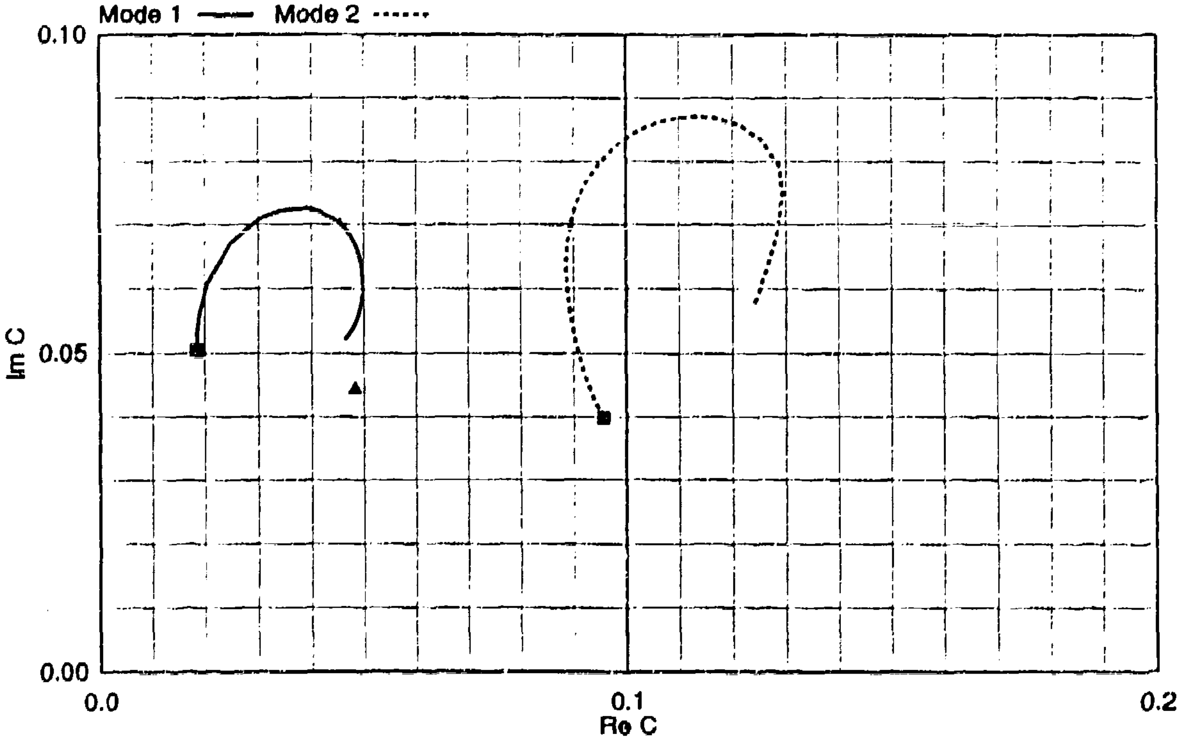


Figure 21. Parameters for $W = 2 \times 10^{-10}$, frequency = 45 kHz.

c. Relative phase velocity as a function of ground conductivity.



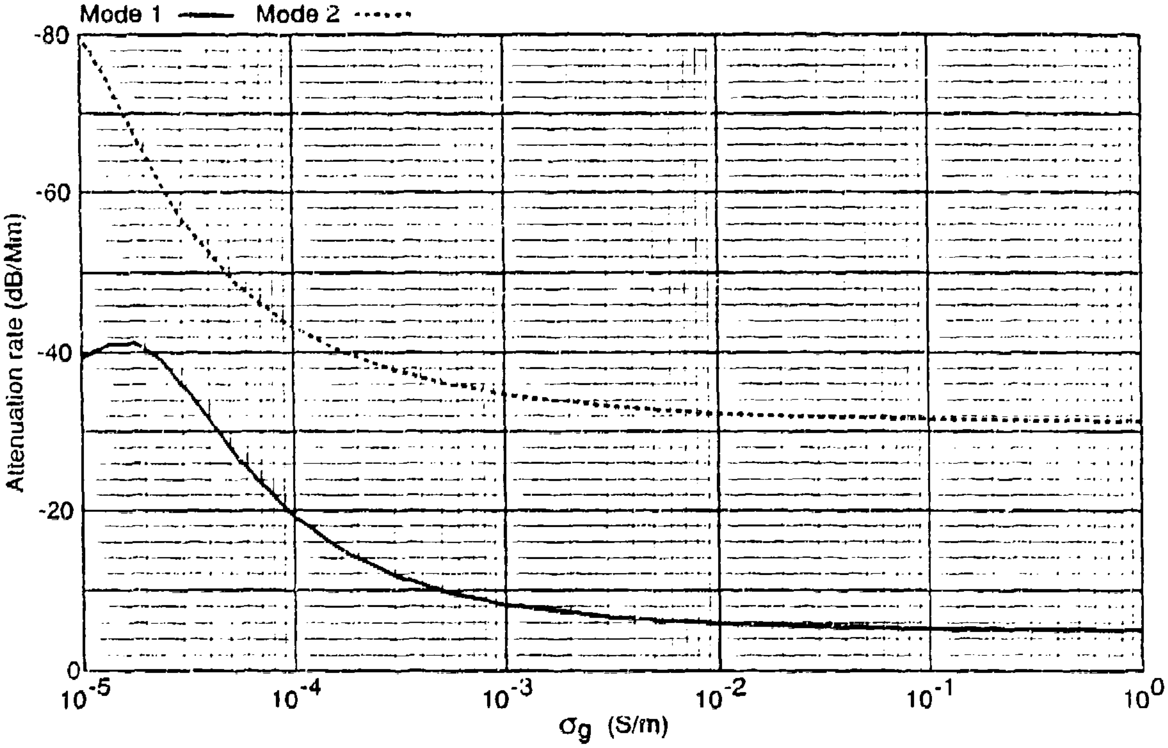
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 21. Parameters for $W = 2 \times 10^{-10}$, frequency = 45 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

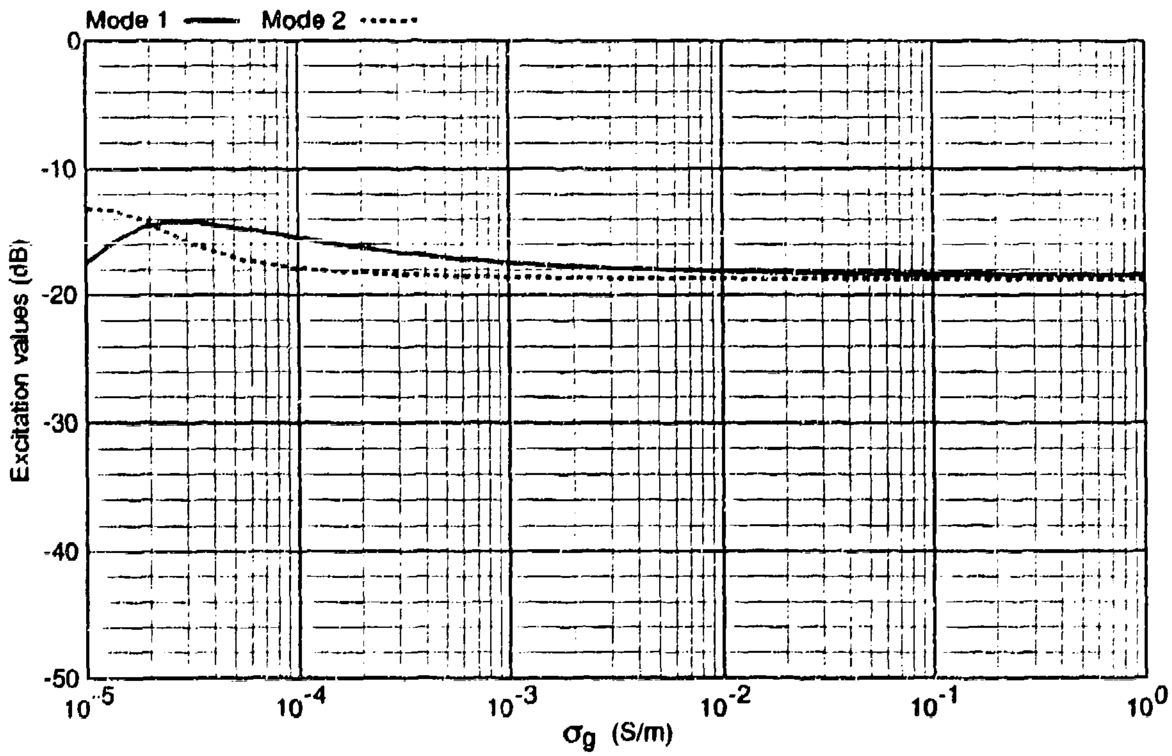
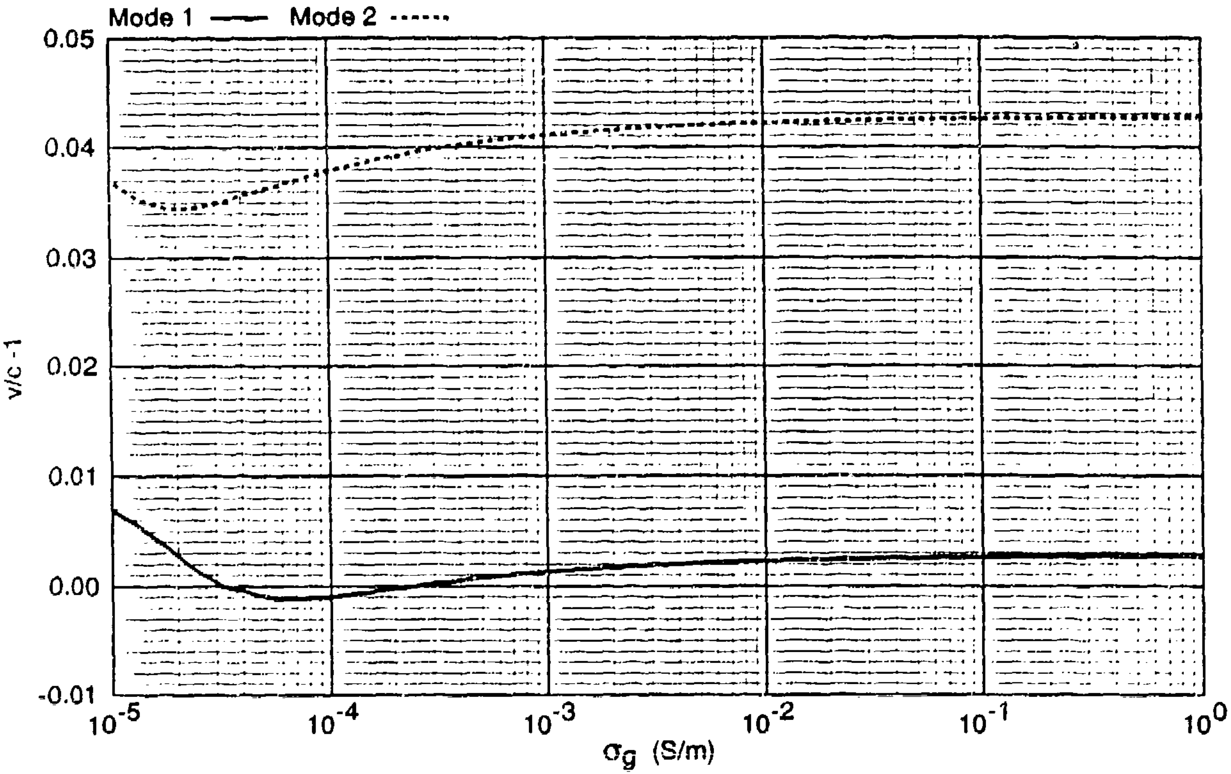
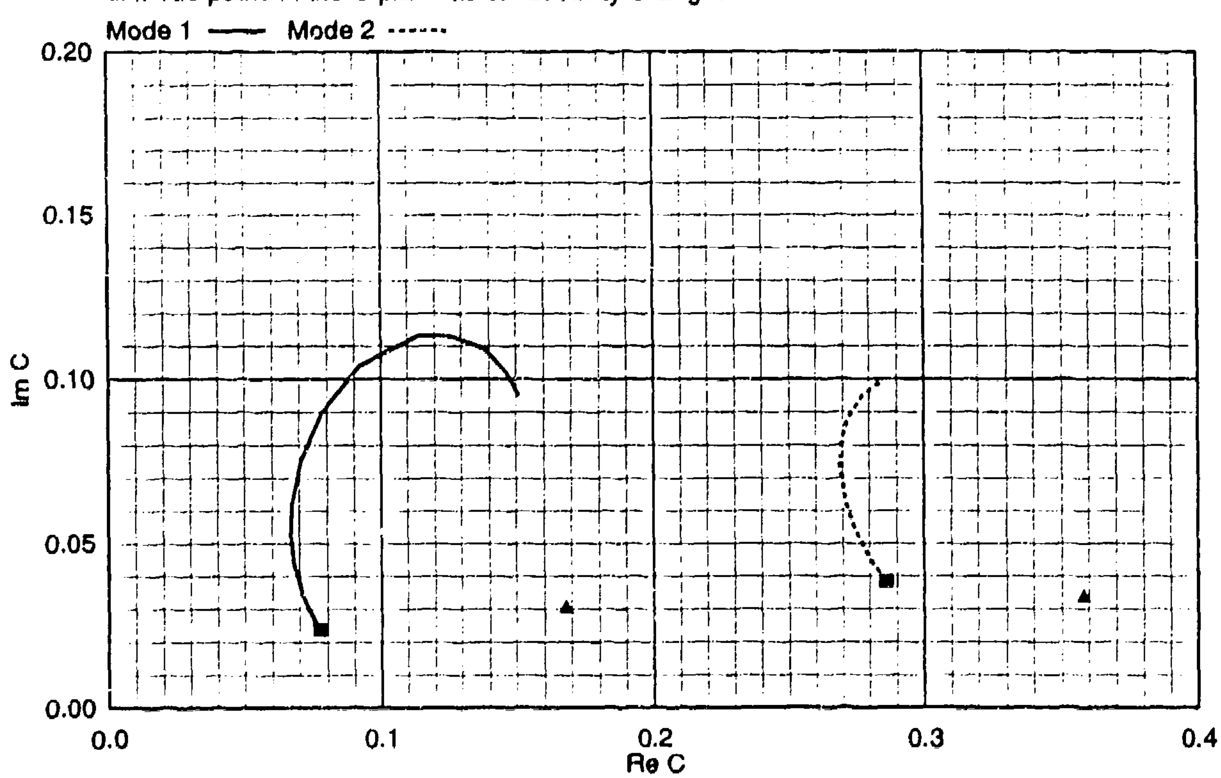


Figure 22. Parameters for $W = 2 \times 10^{-11}$, frequency = 15 kHz.

c. Relative phase velocity as a function of ground conductivity.



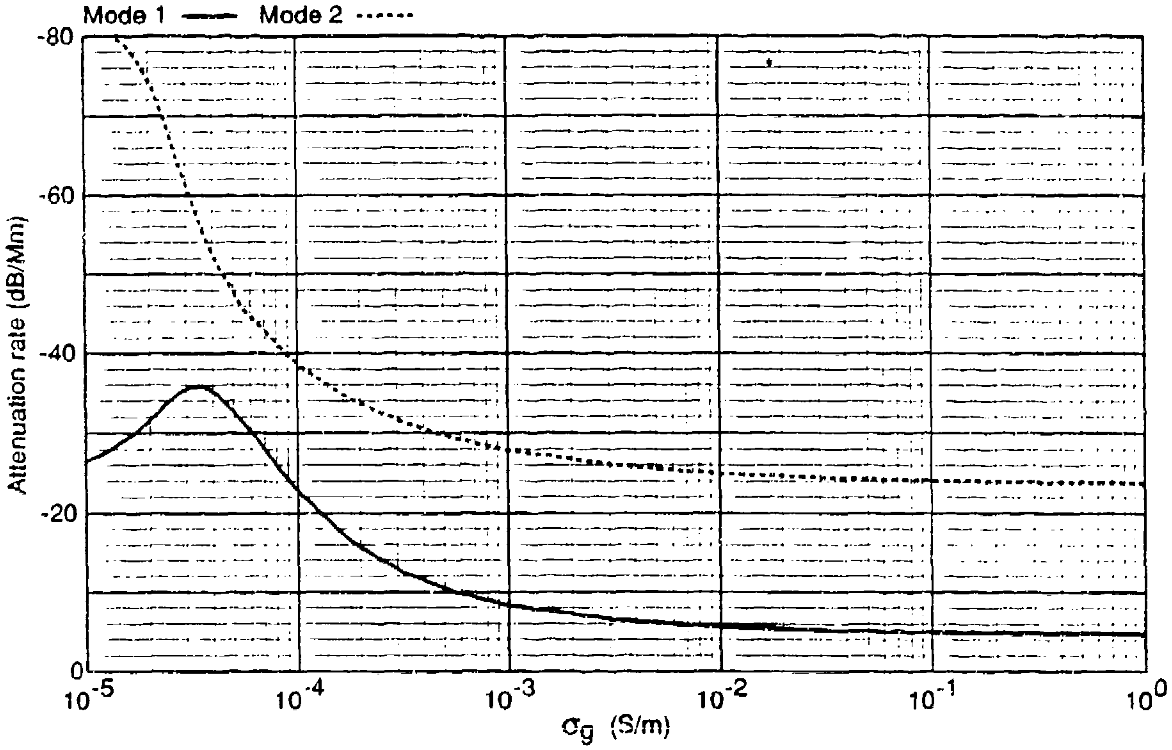
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 22. Parameters for W = 2 x 10^{-11}, frequency = 15 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

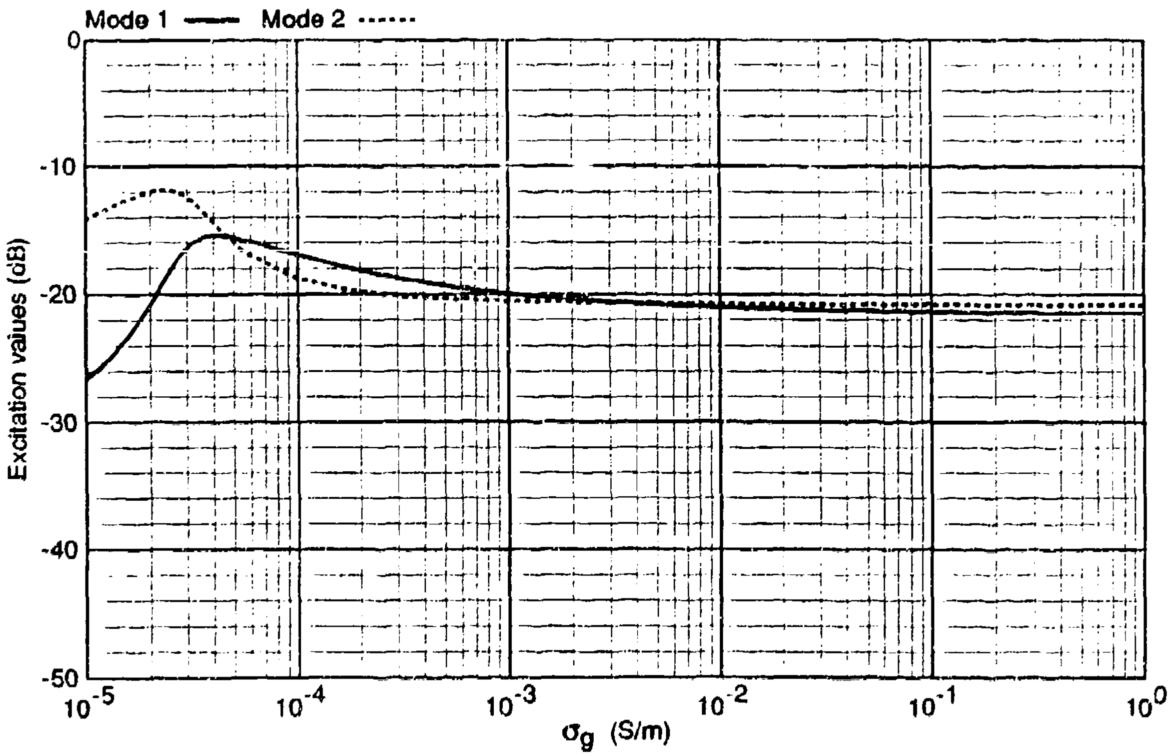
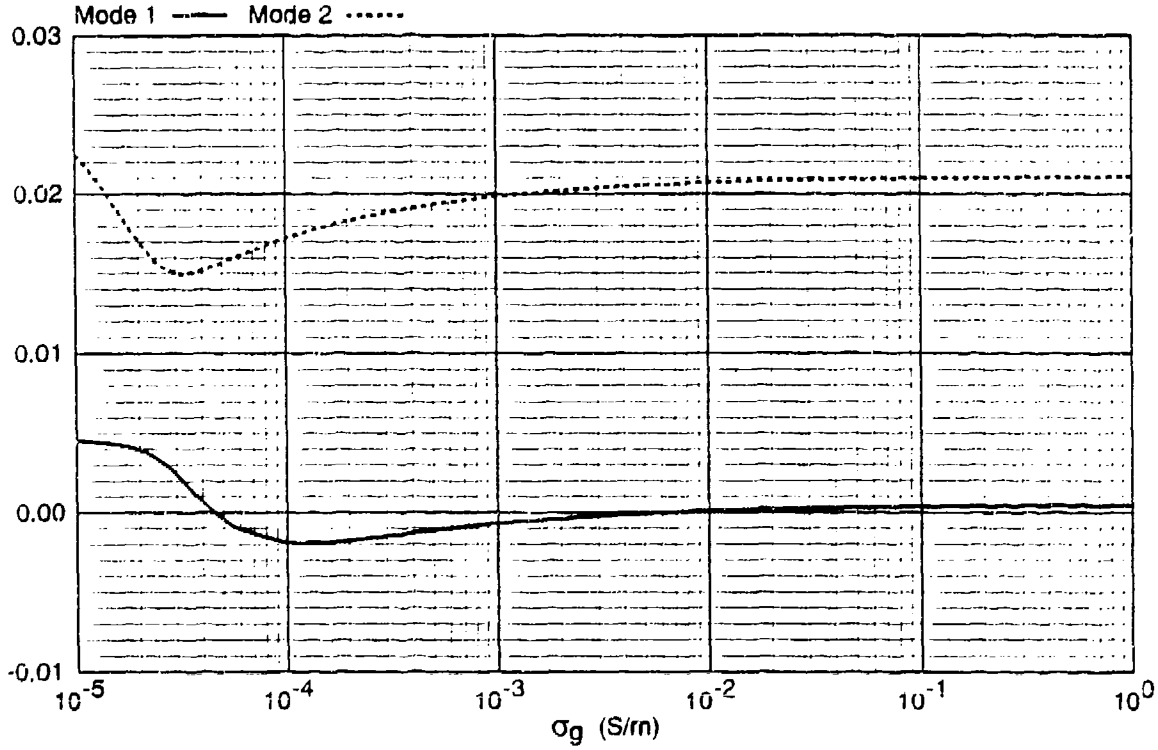
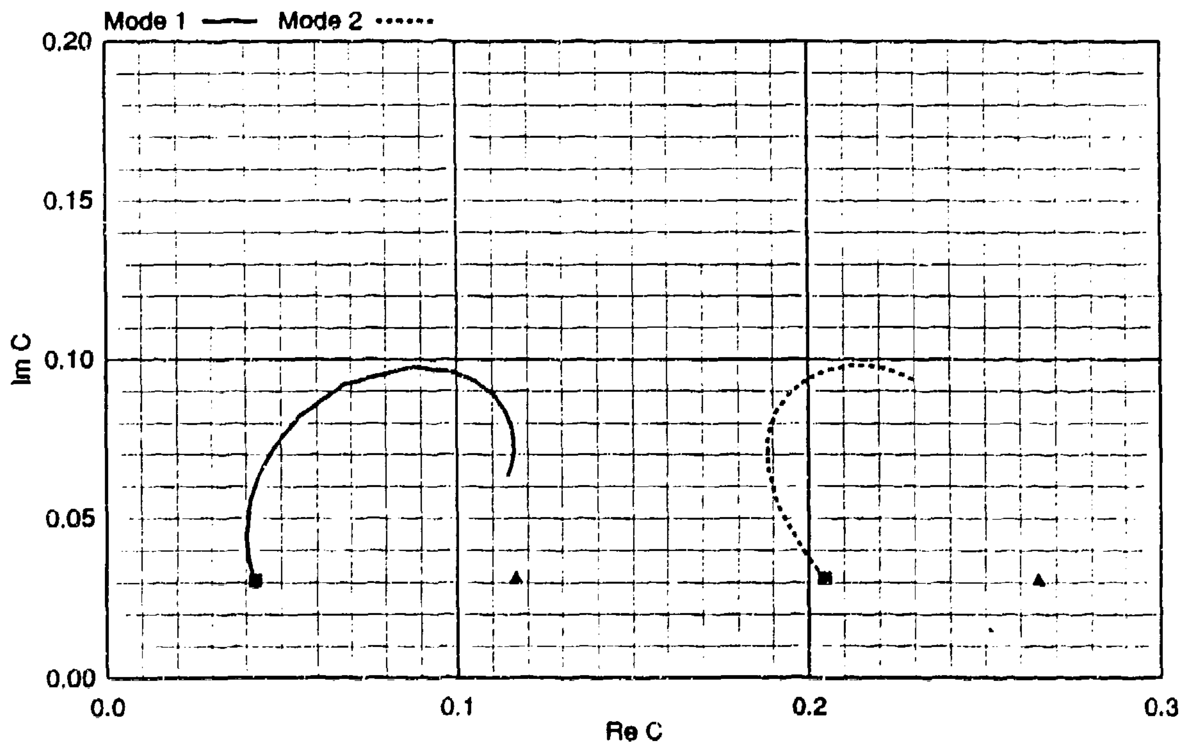


Figure 23. Parameters for $W = 2 \times 10^{-11}$, frequency = 20 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 23. Parameters for W = 2 x 10^{-11}, frequency = 20 kHz (Concluded).

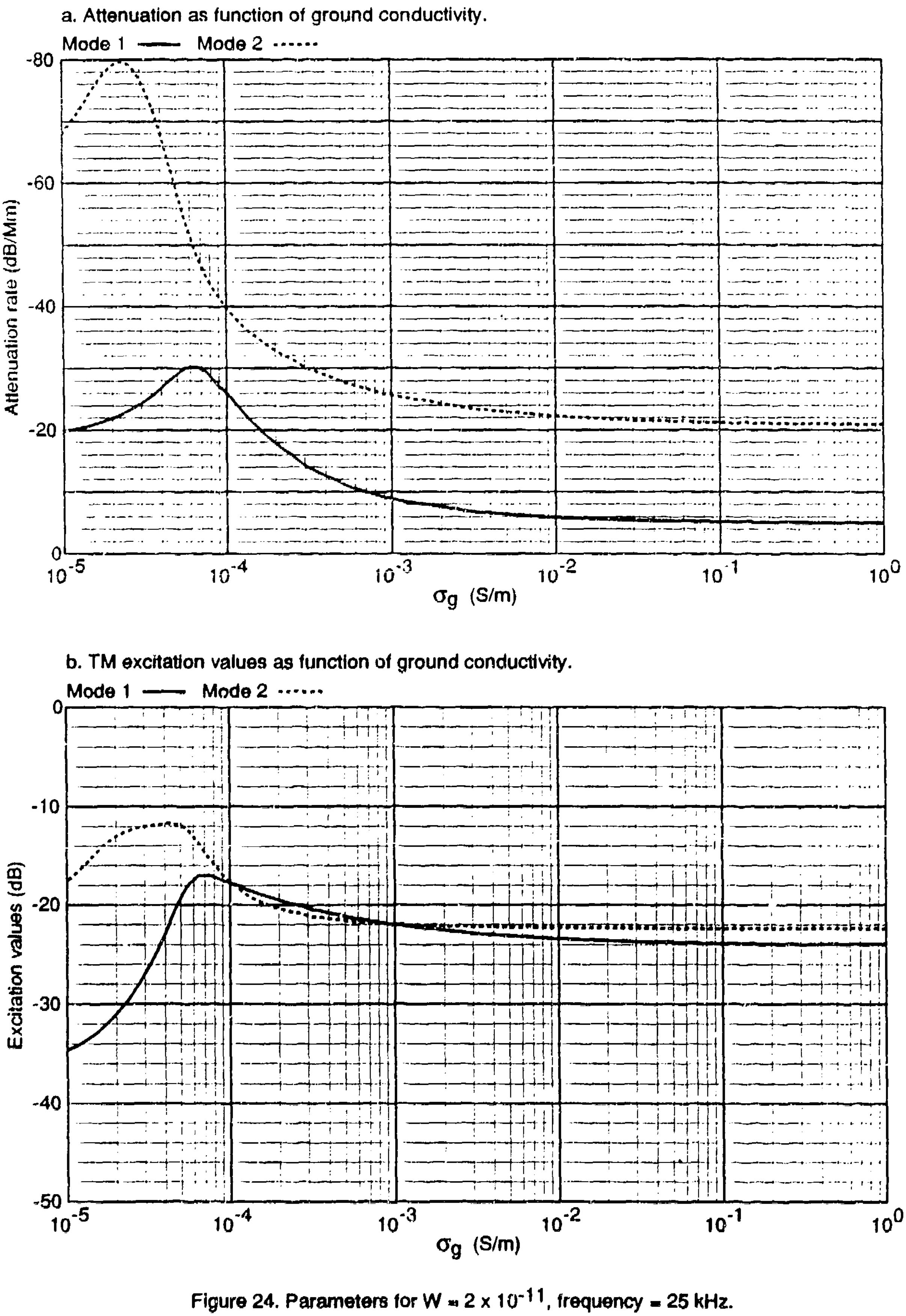
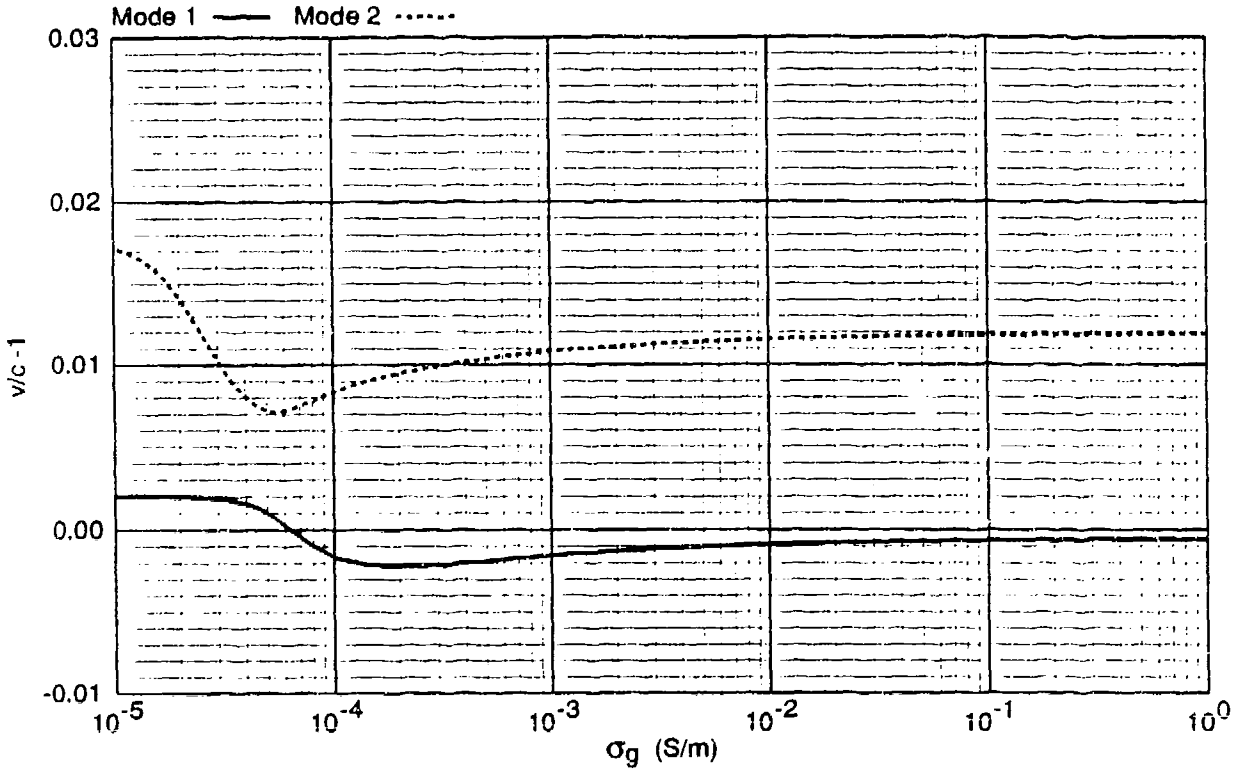
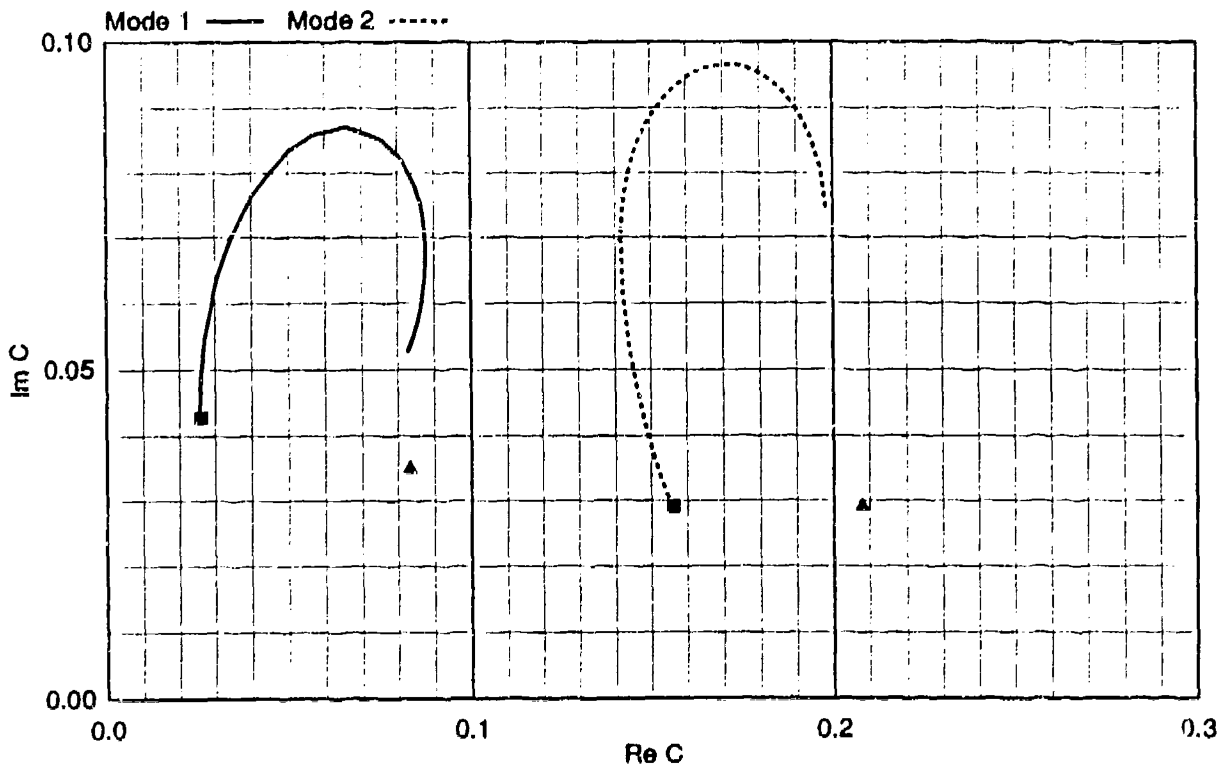


Figure 24. Parameters for $W = 2 \times 10^{-11}$, frequency = 25 kHz.

c. Relative phase velocity as a function of ground conductivity.



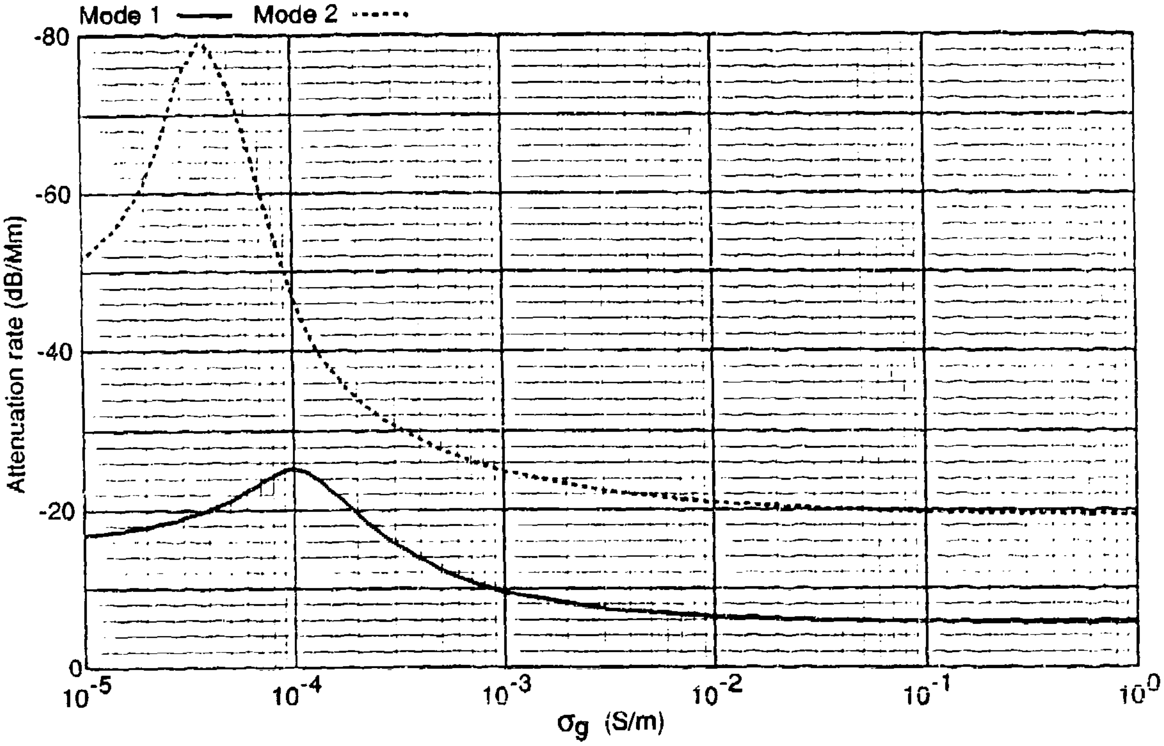
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 24. Parameters for W = 2 x 10^{-11}, frequency = 25 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

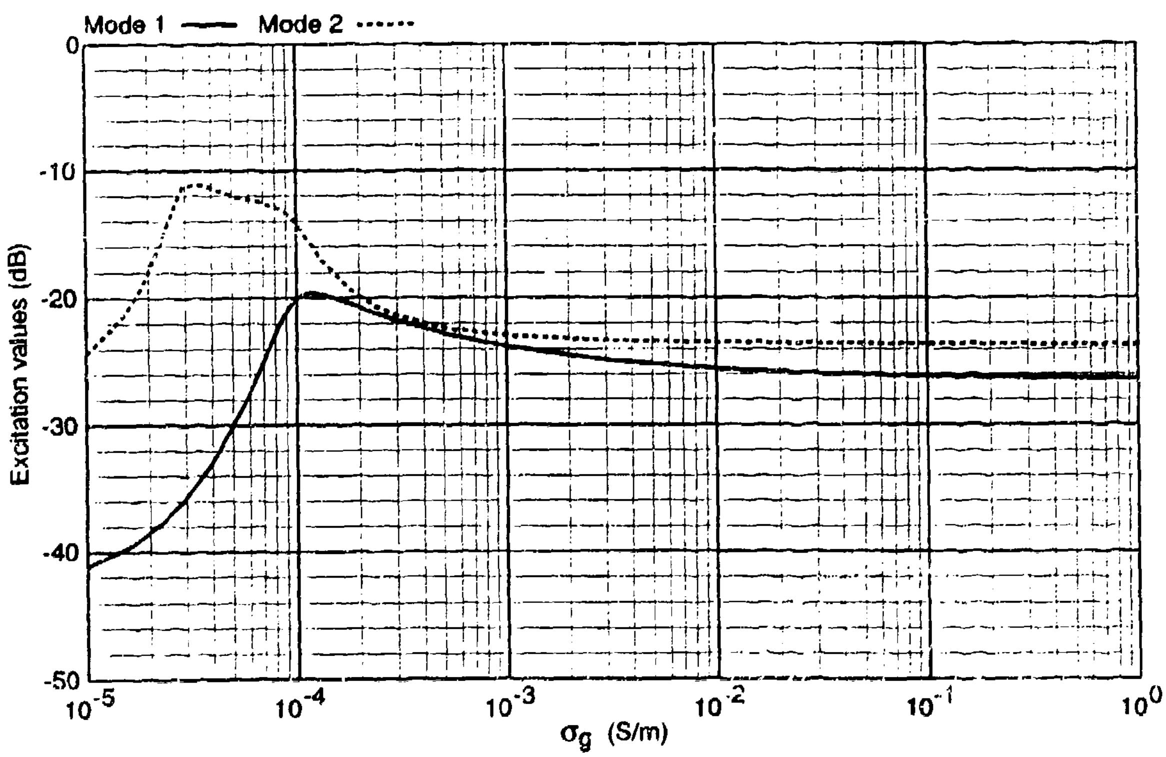
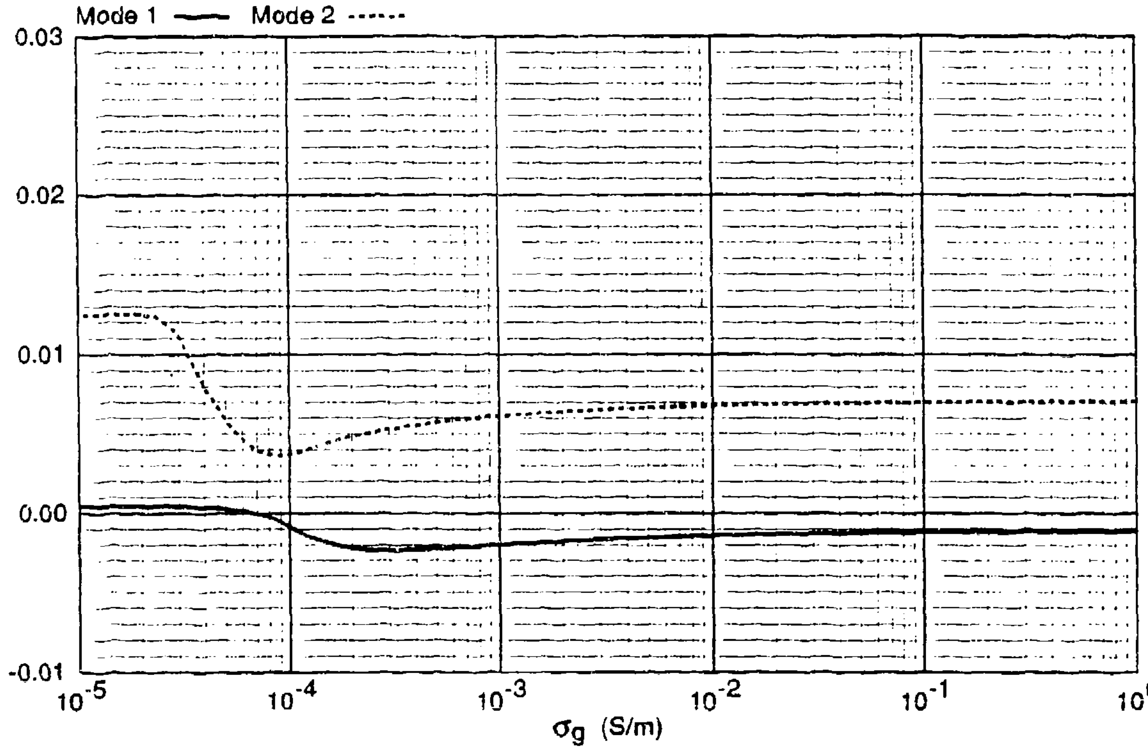
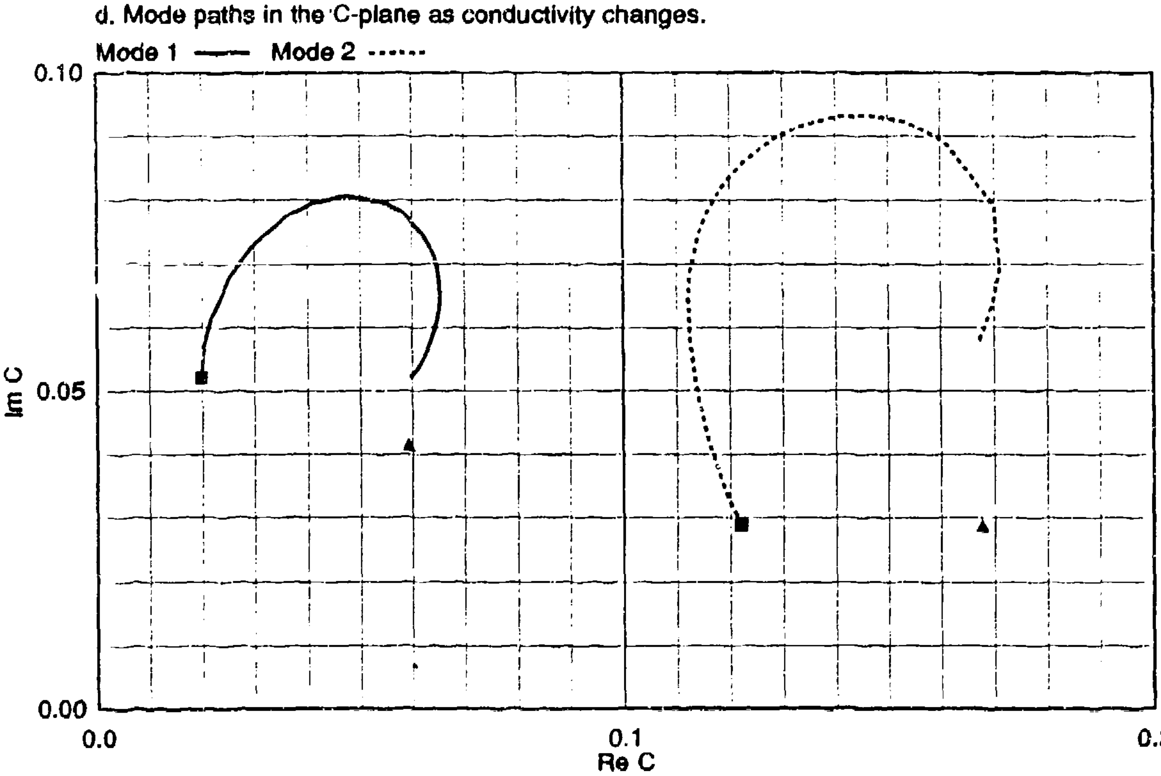


Figure 25. Parameters for $W = 2 \times 10^{-11}$, frequency = 30 kHz.

c. Relative phase velocity as a function of ground conductivity.



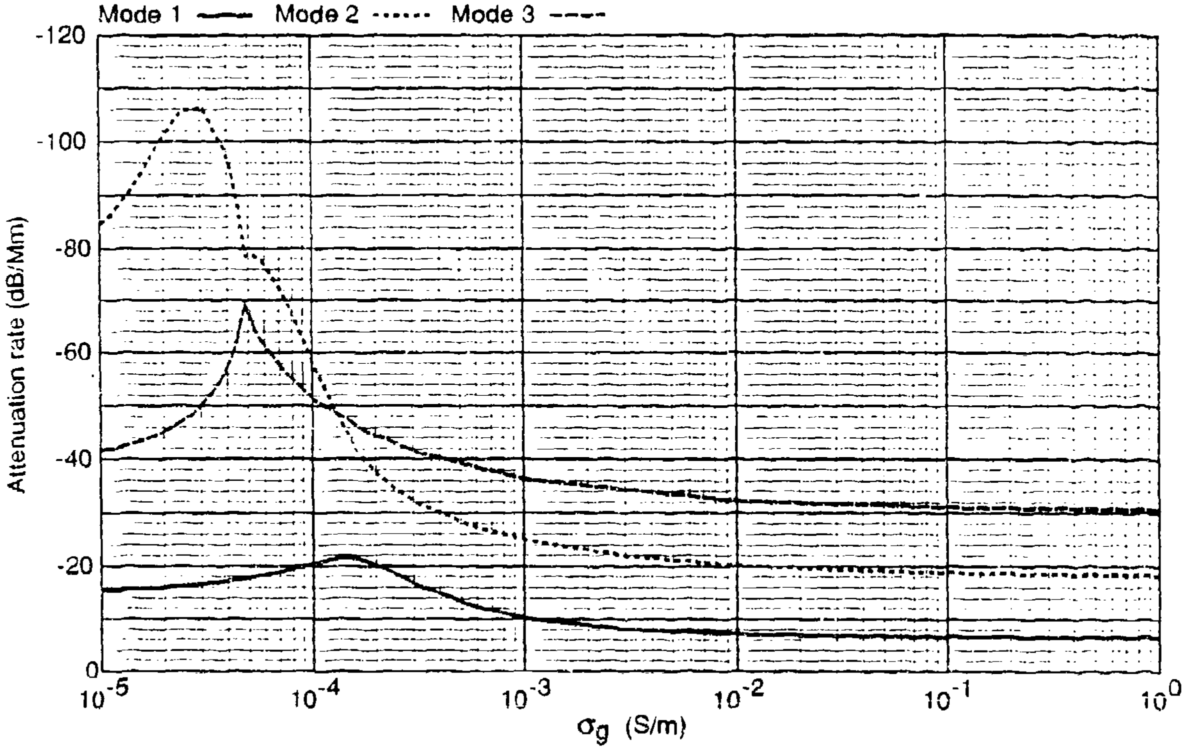
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 25. Parameters for W = 2 x 10^{-11}, frequency = 30 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

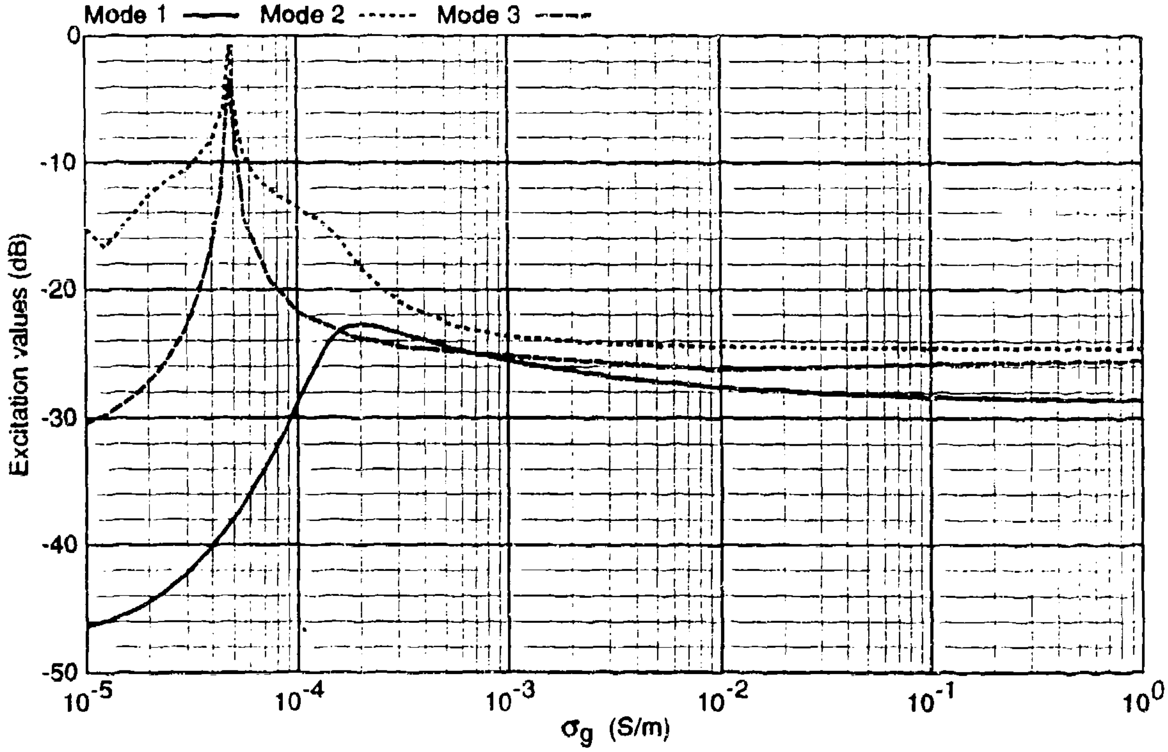
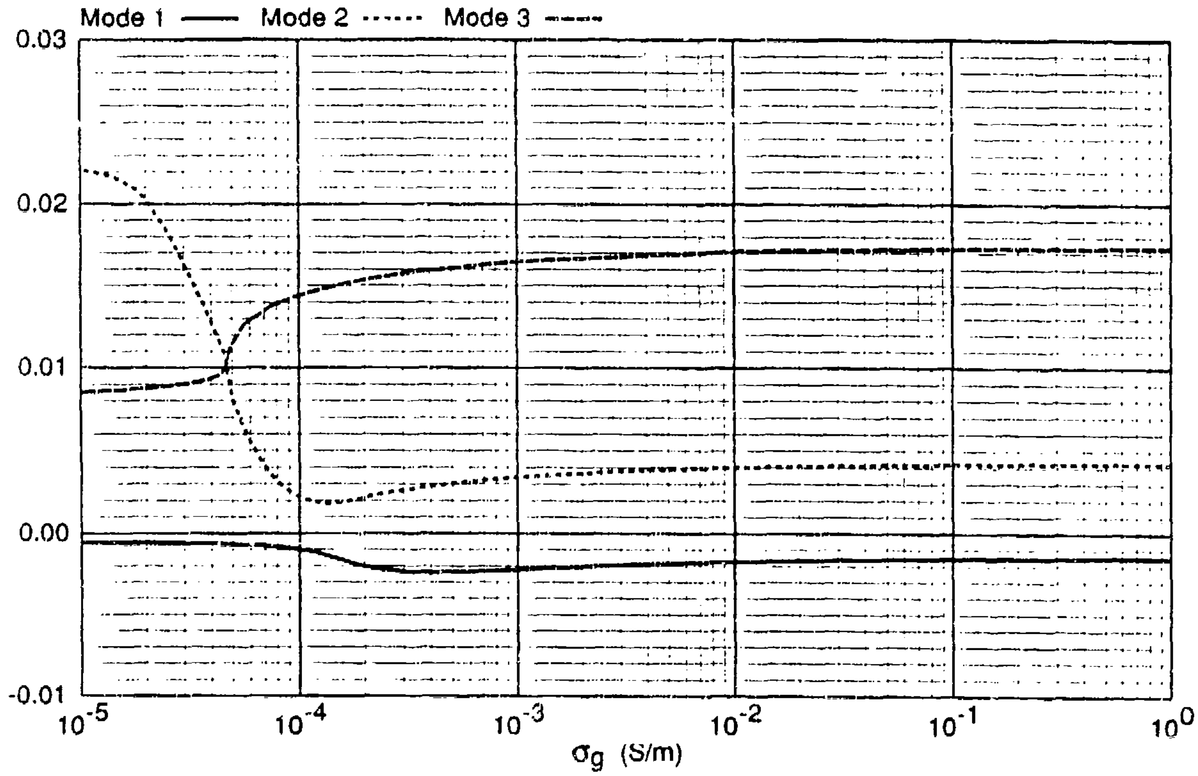
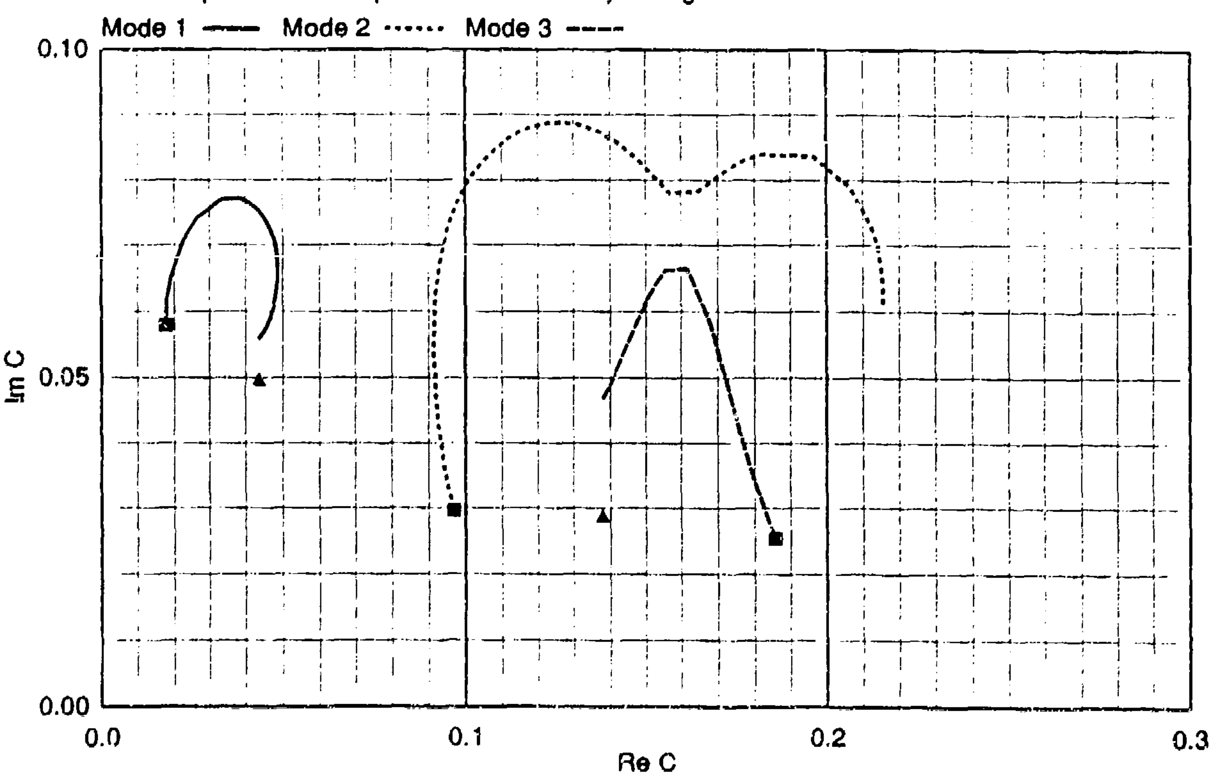


Figure 26. Parameters for $W = 2 \times 10^{-11}$, frequency = 35 kHz.

c. Relative phase velocity as a function of ground conductivity.



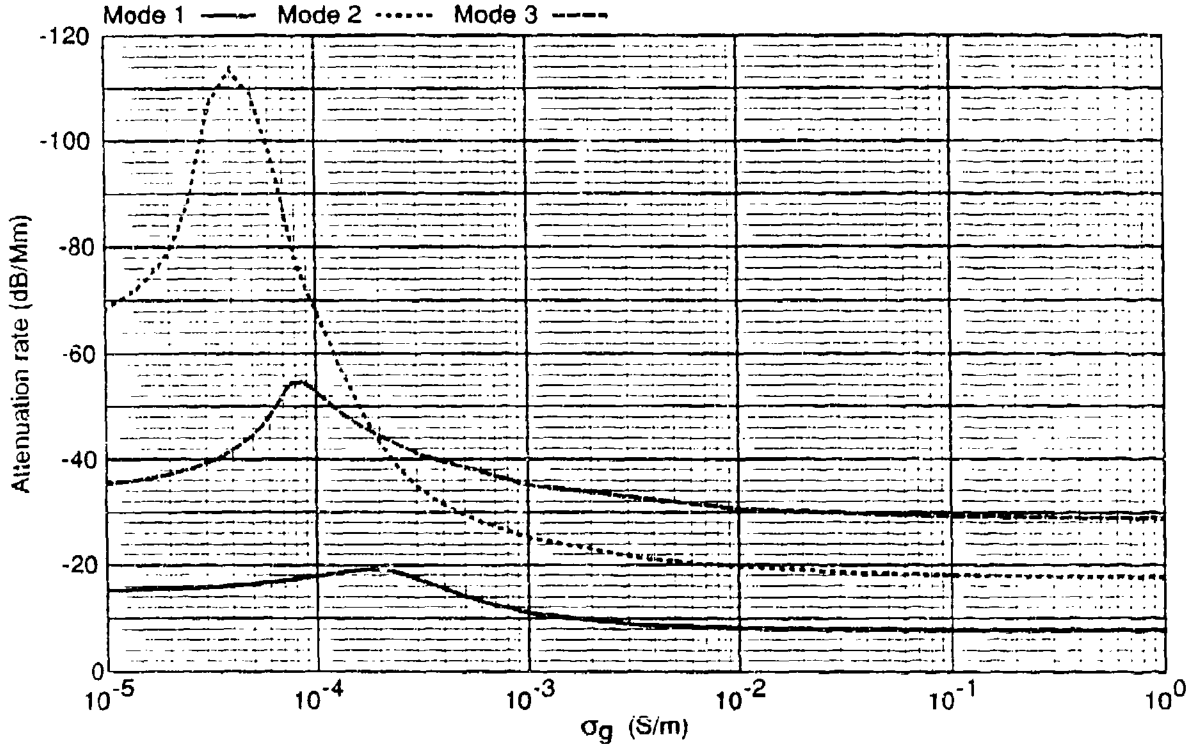
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 26. Parameters for W = 2×10^{-11}, frequency = 35 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

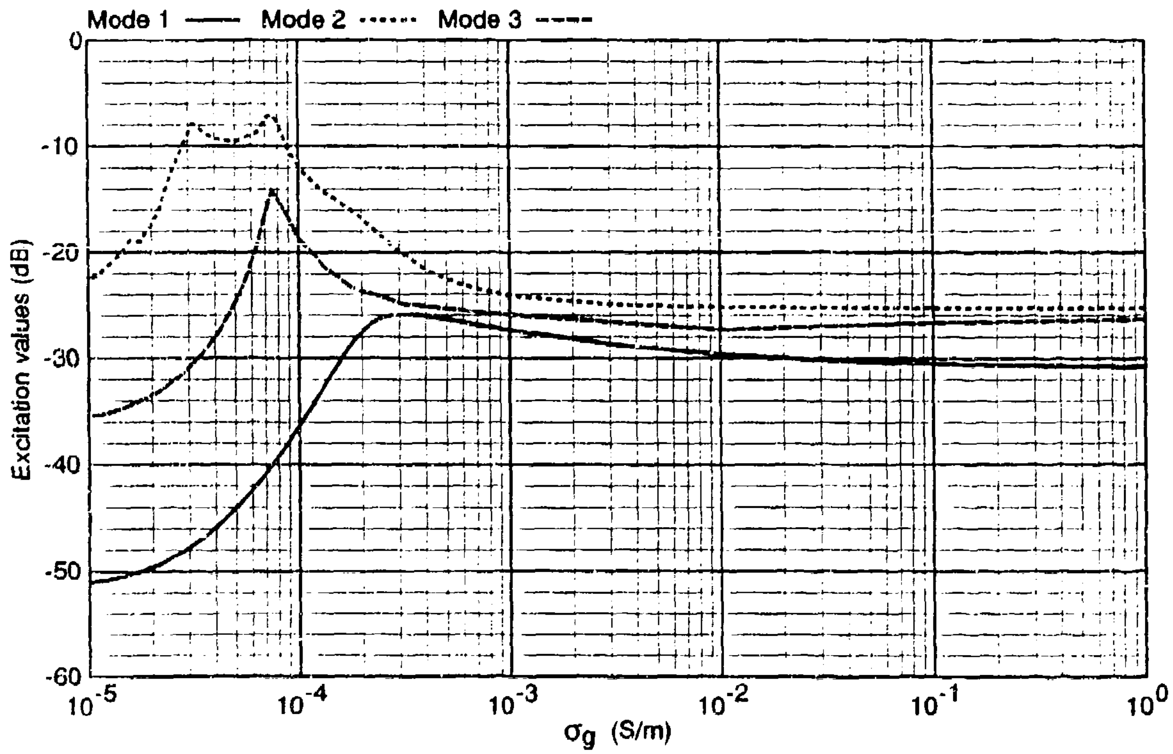
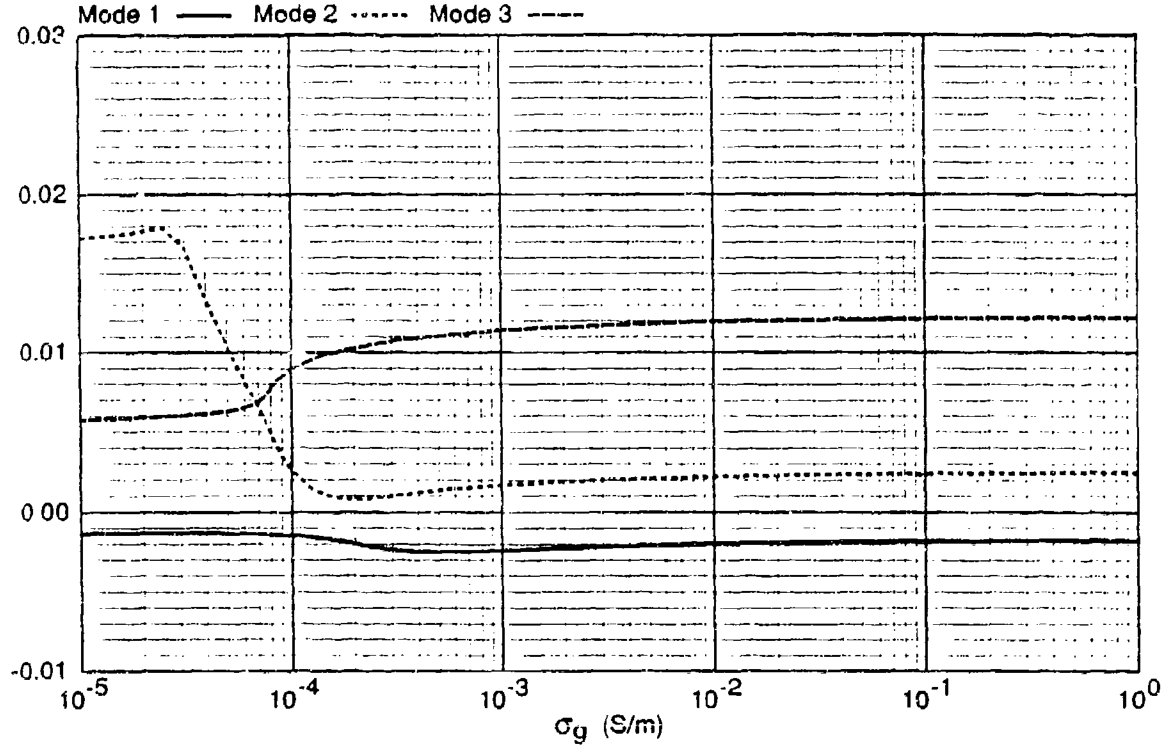
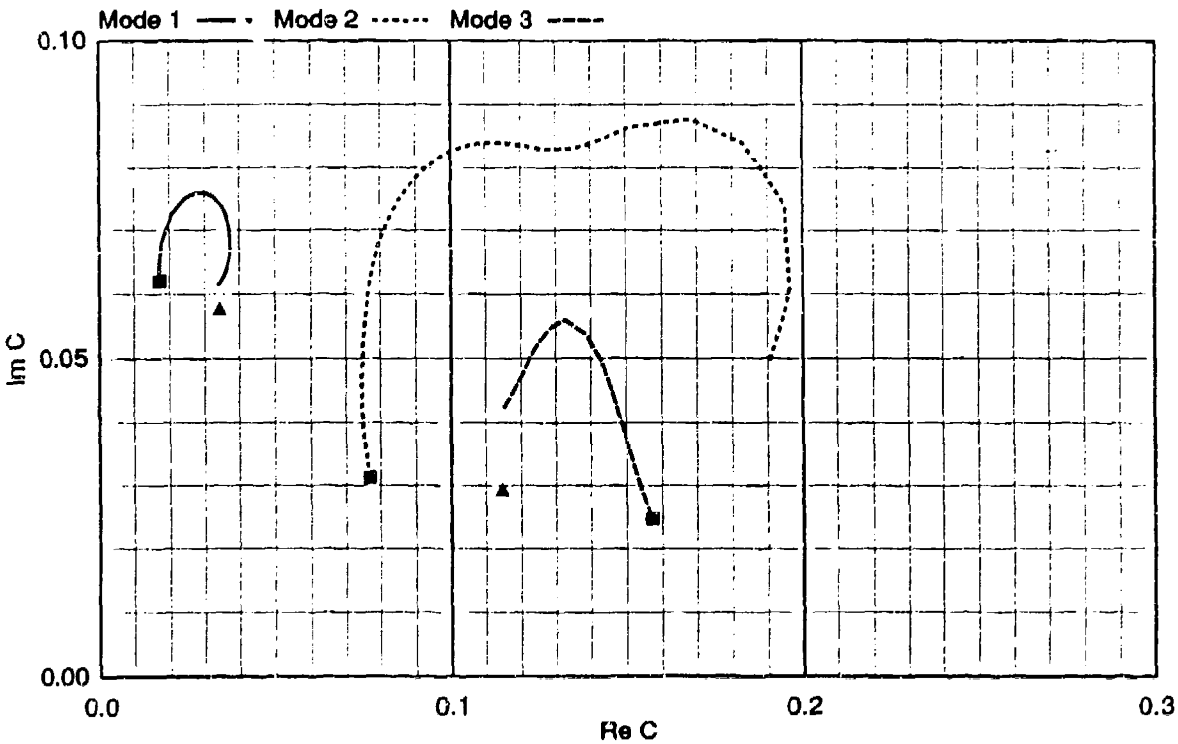


Figure 27. Parameters for $W = 2 \times 10^{-11}$, frequency = 40 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 27. Parameters for W = 2 x 10^{-11}, frequency = 40 kHz (Concluded).

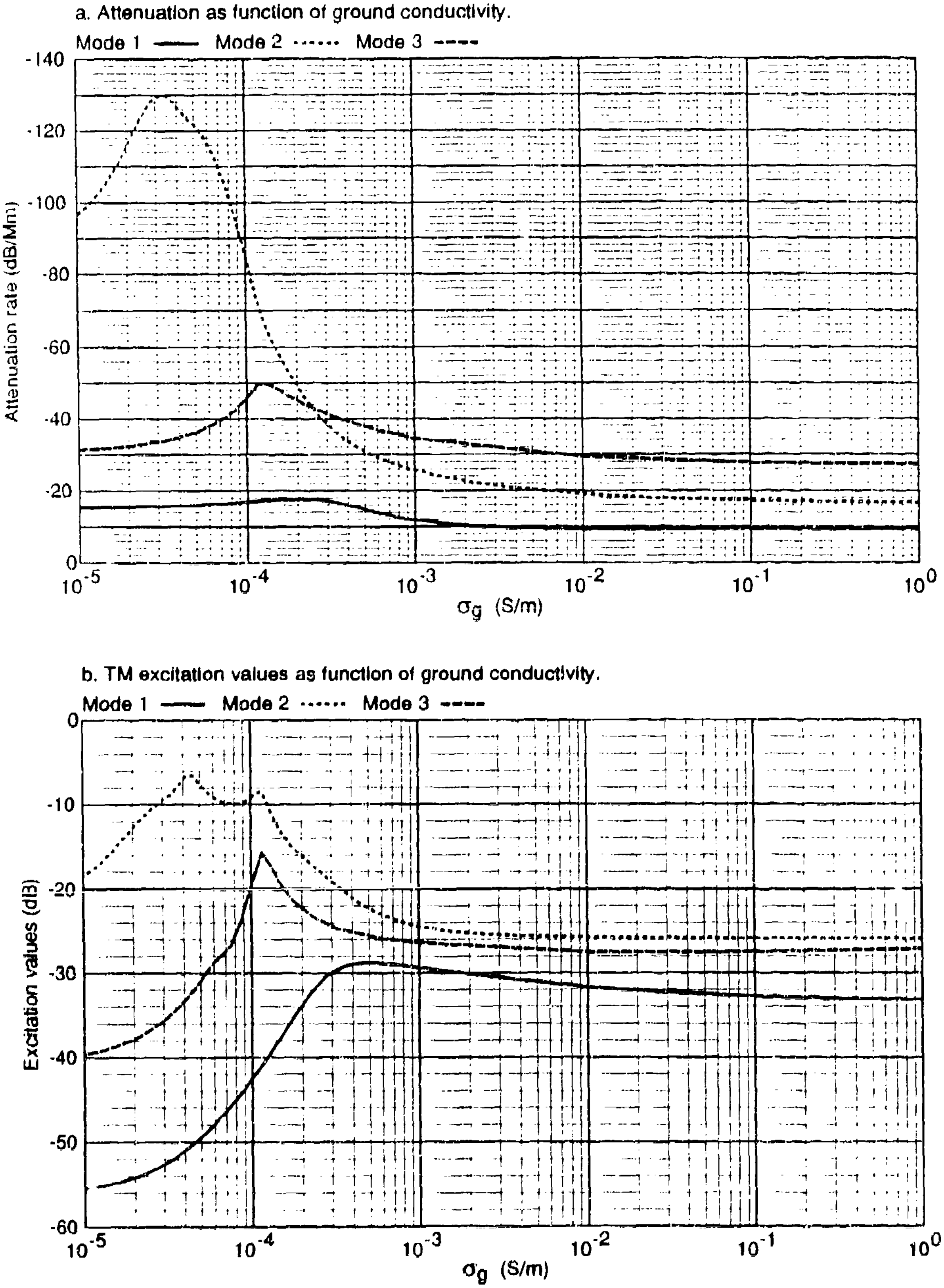
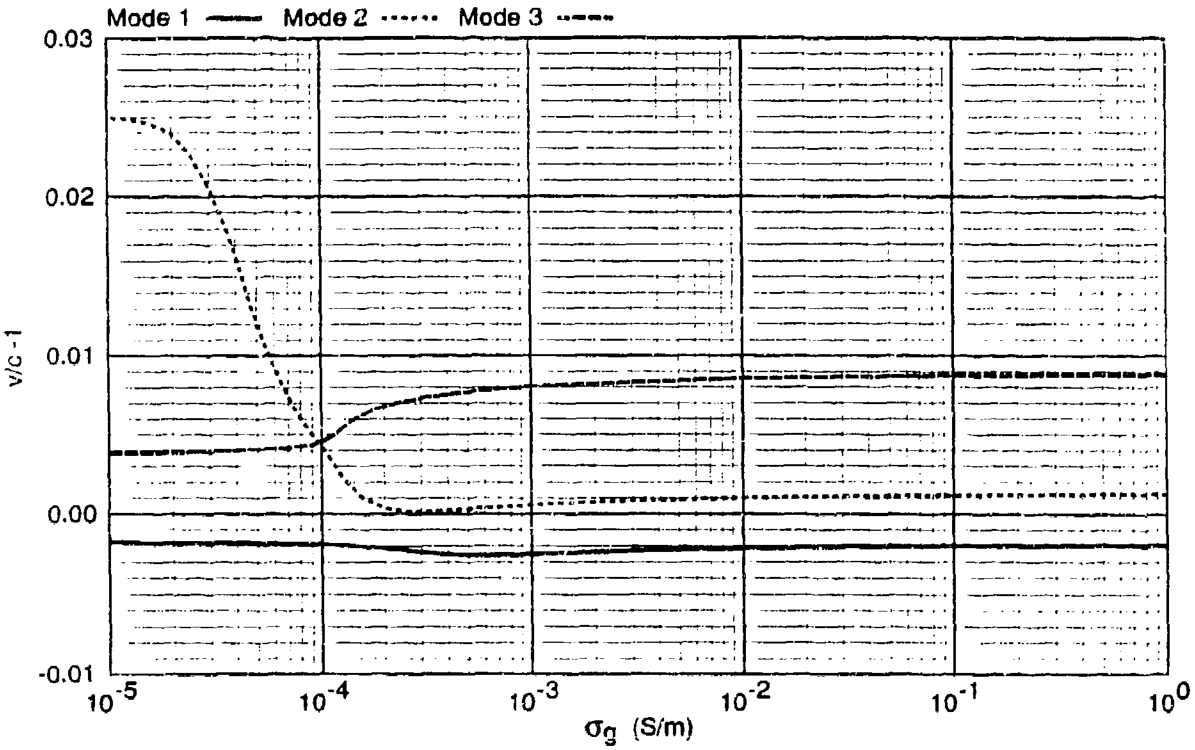
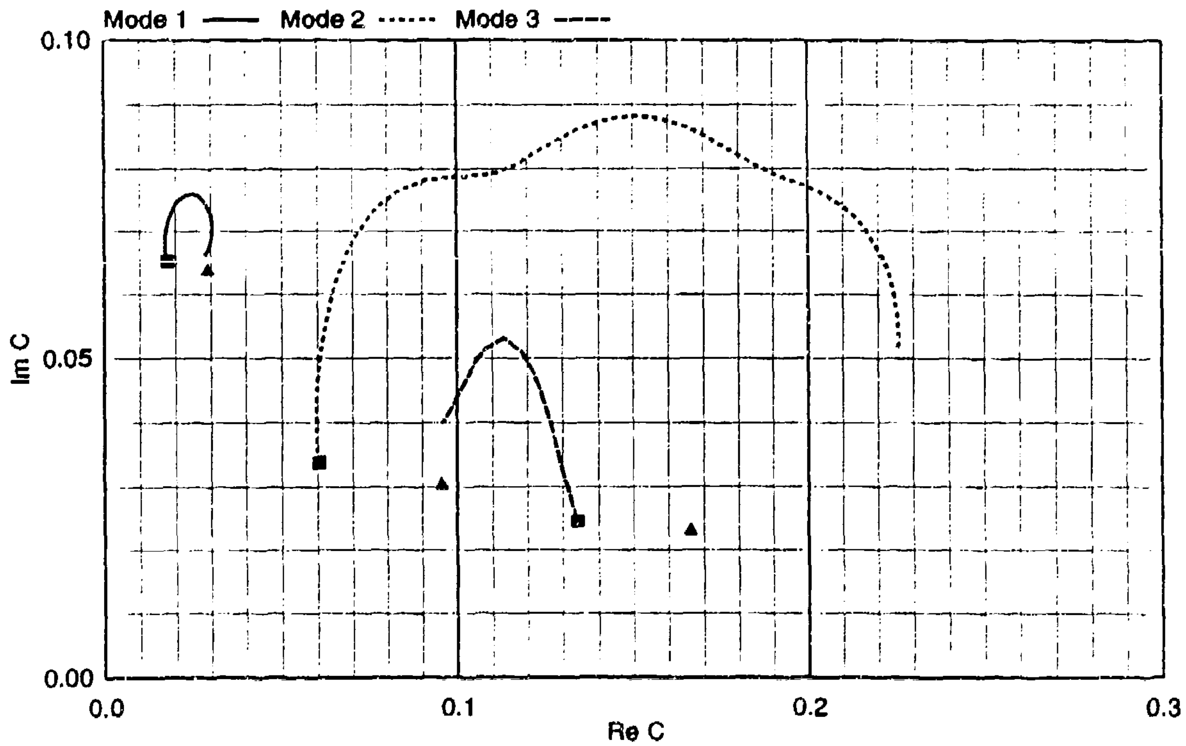


Figure 28. Parameters for $W = 2 \times 10^{-11}$, frequency = 45 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 28. Parameters for W = 2 x 10^{-11}, frequency = 45 kHz (Concluded).

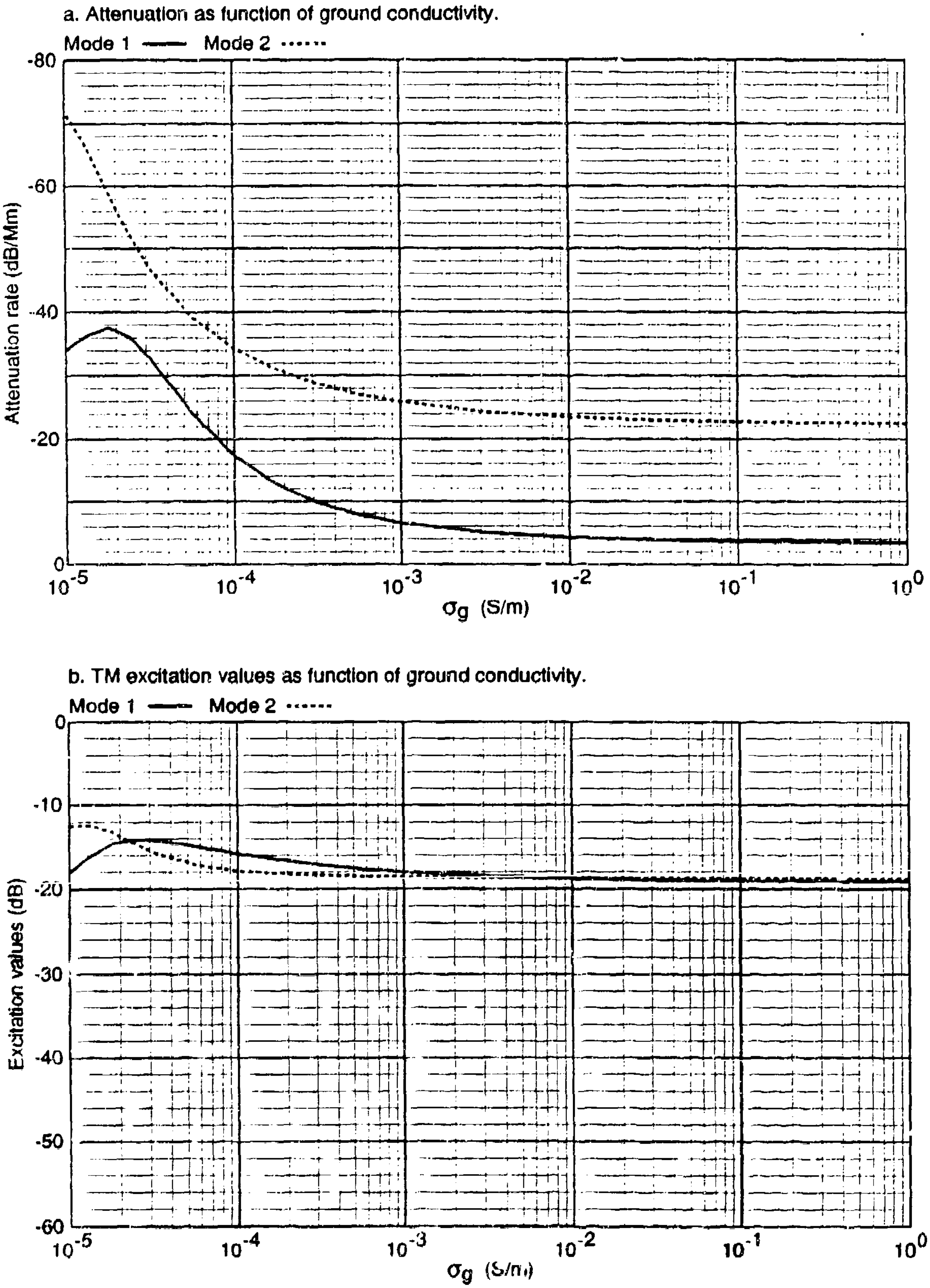
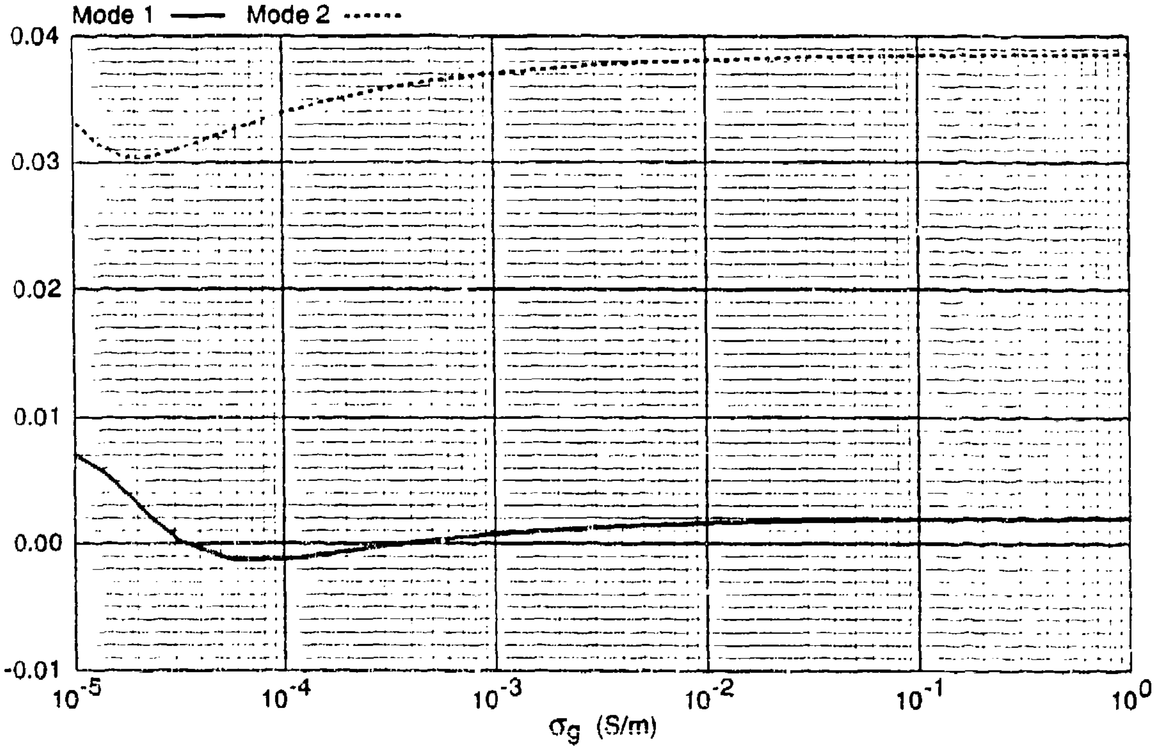
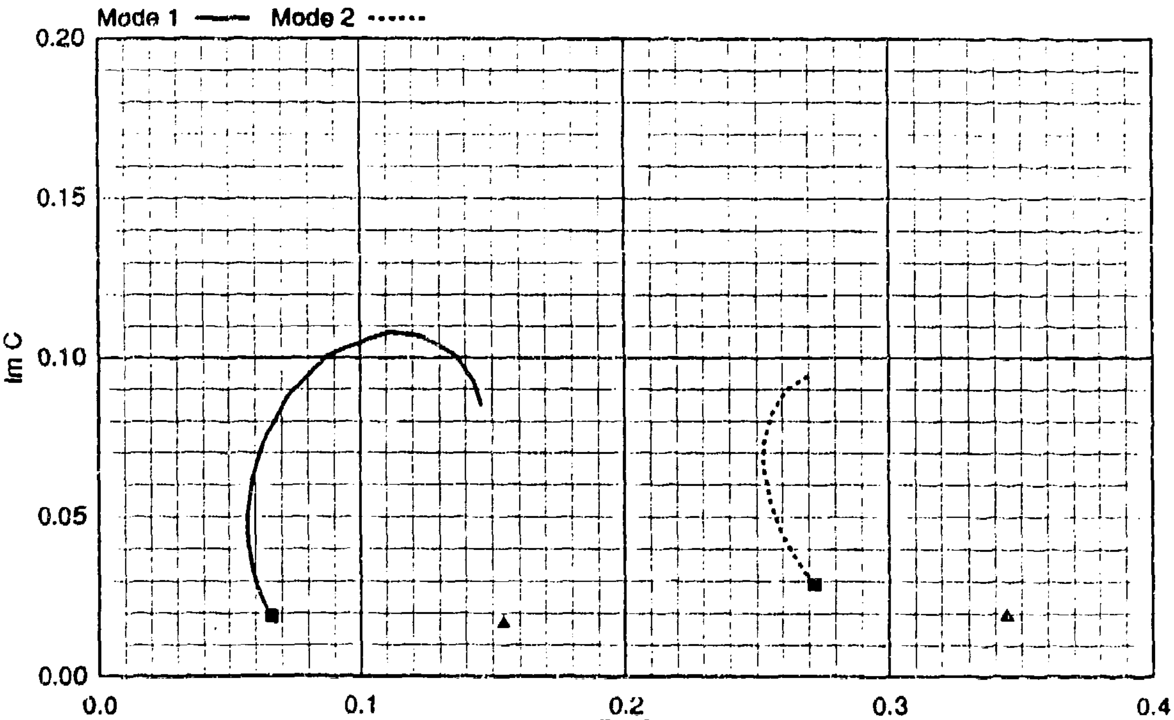


Figure 29. Parameters for W = 2×10^{-12}, frequency = 15 kHz.

c. Relative phase velocity as a function of ground conductivity.



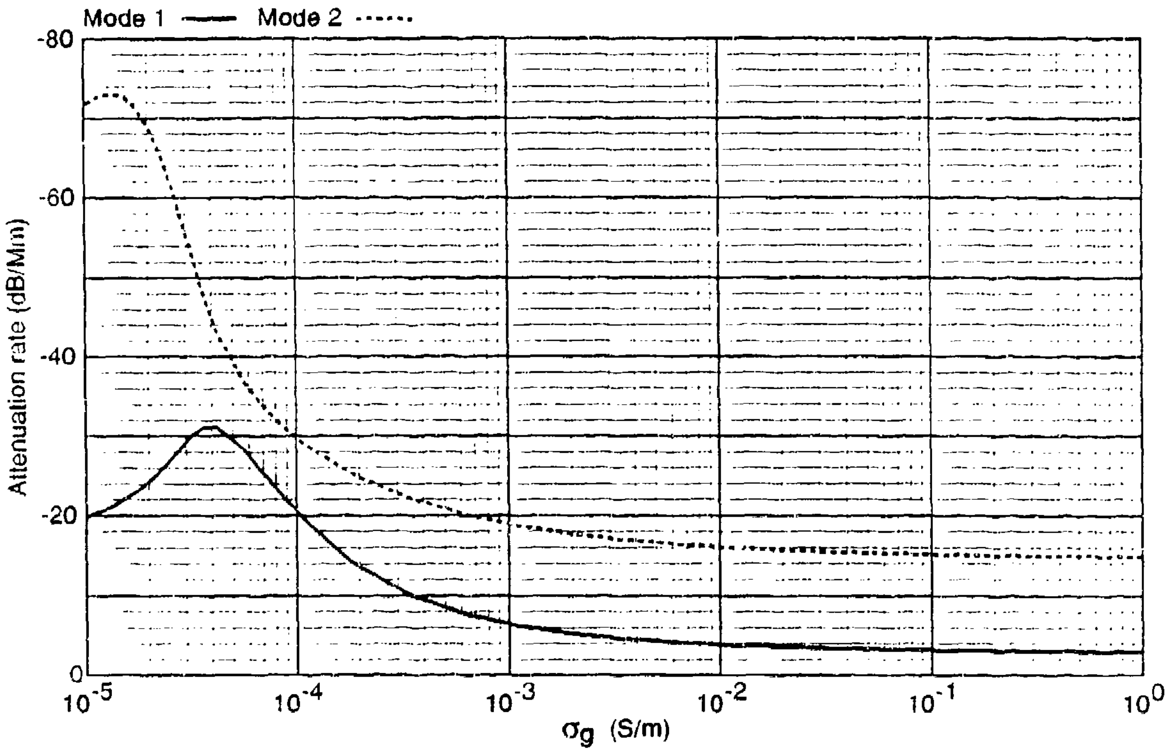
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 29. Parameters for W = 2×10^{-12}, frequency = 15 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

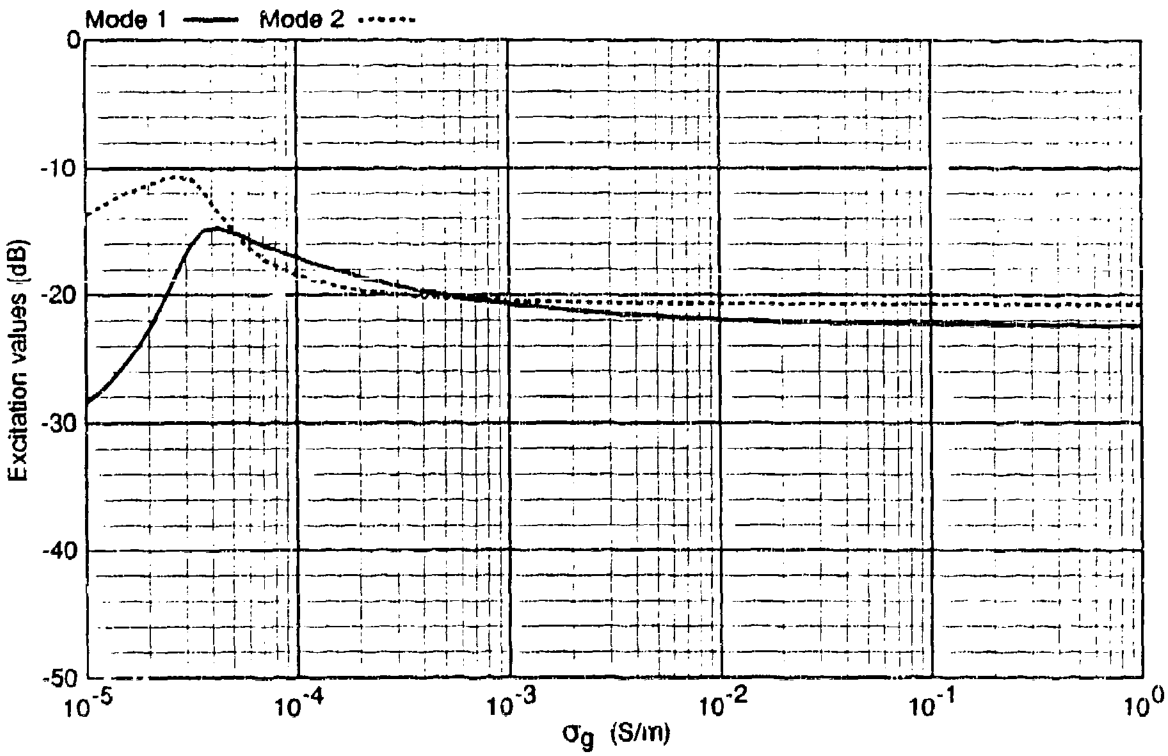
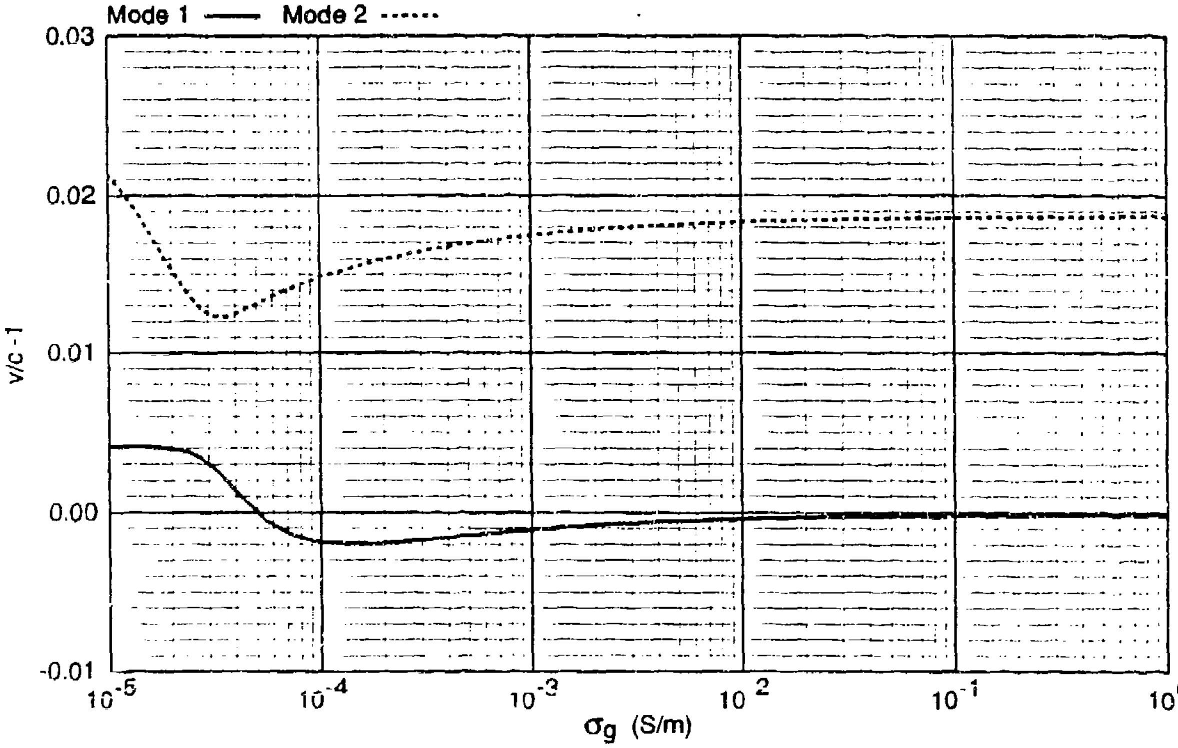
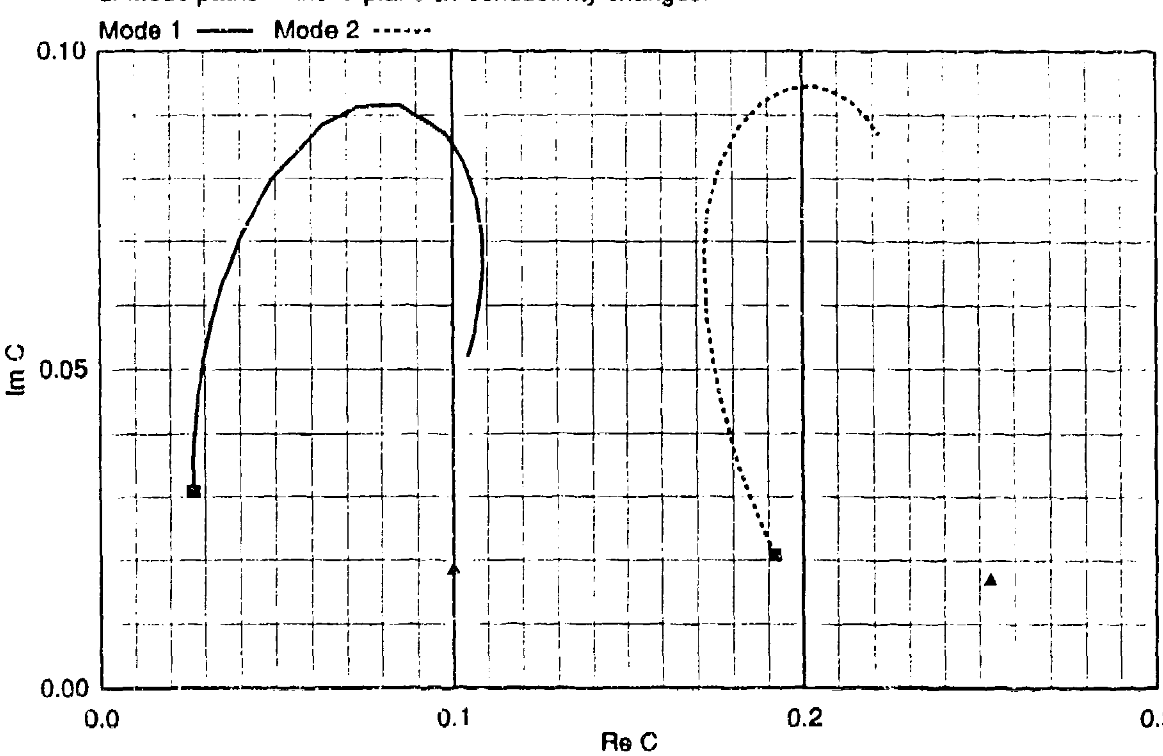


Figure 30. Parameters for W = 2 x 10^{-12}, frequency = 20 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 30. Parameters for W = 2 x 10^{-12}, frequency = 20 kHz (Concluded).

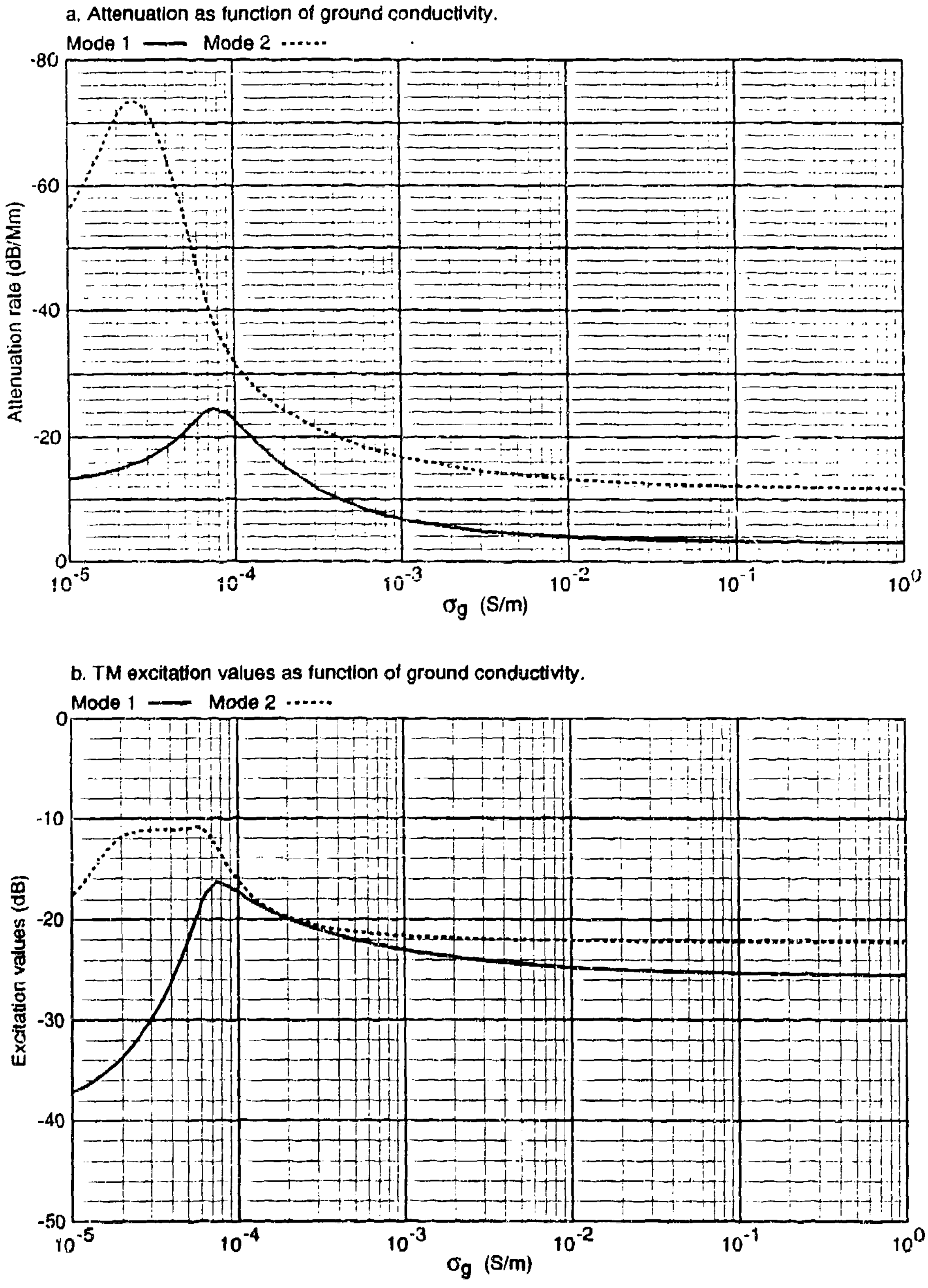
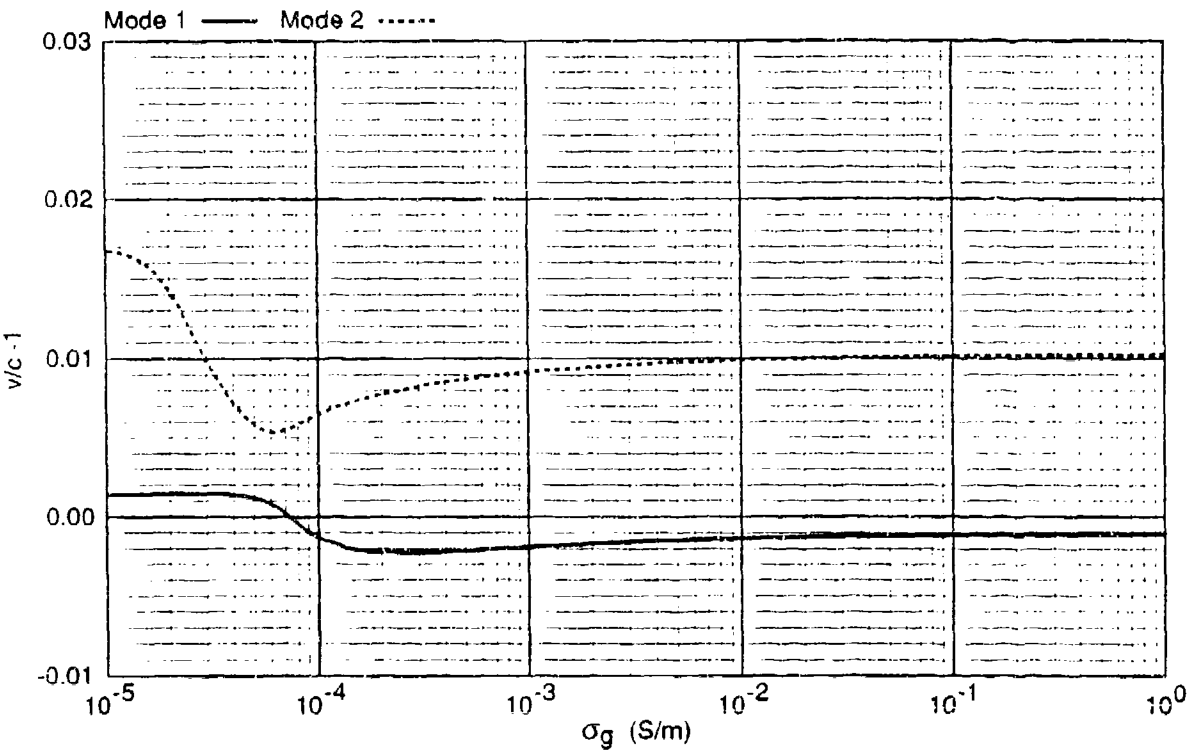
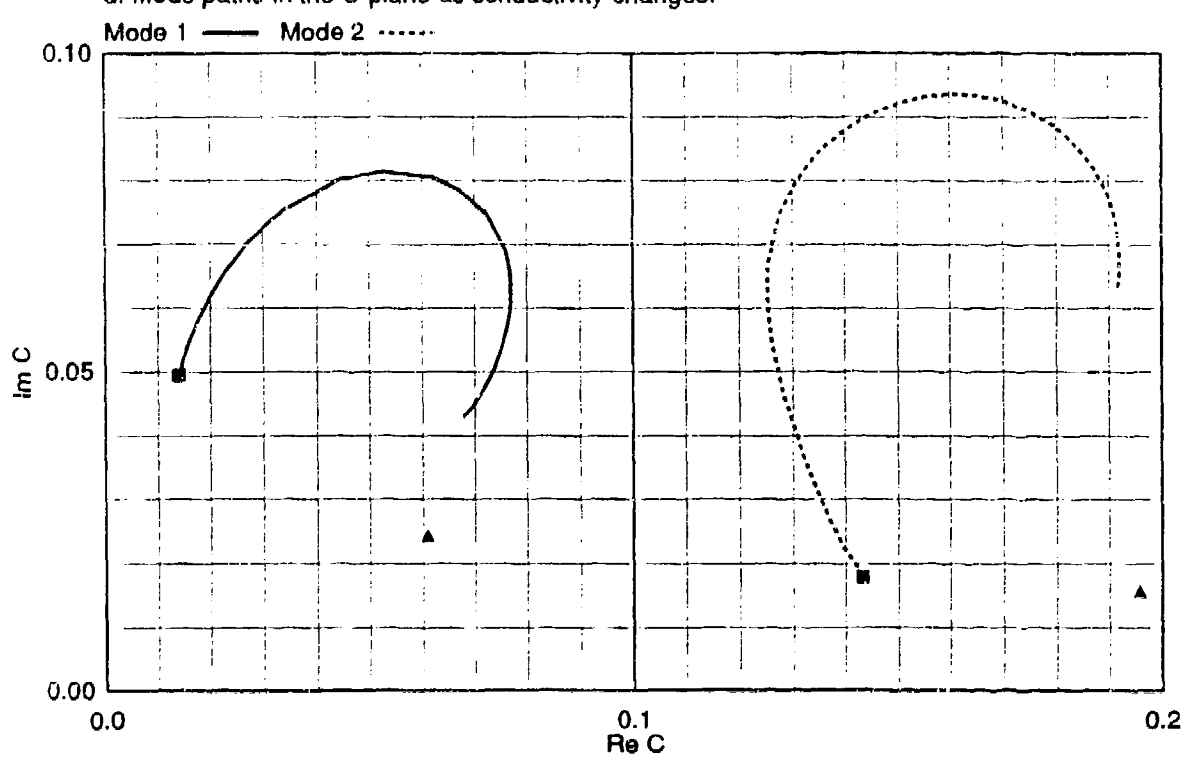


Figure 31. Parameters for $W = 2 \times 10^{-12}$, frequency = 25 kHz.

c. Relative phase velocity as a function of ground conductivity.

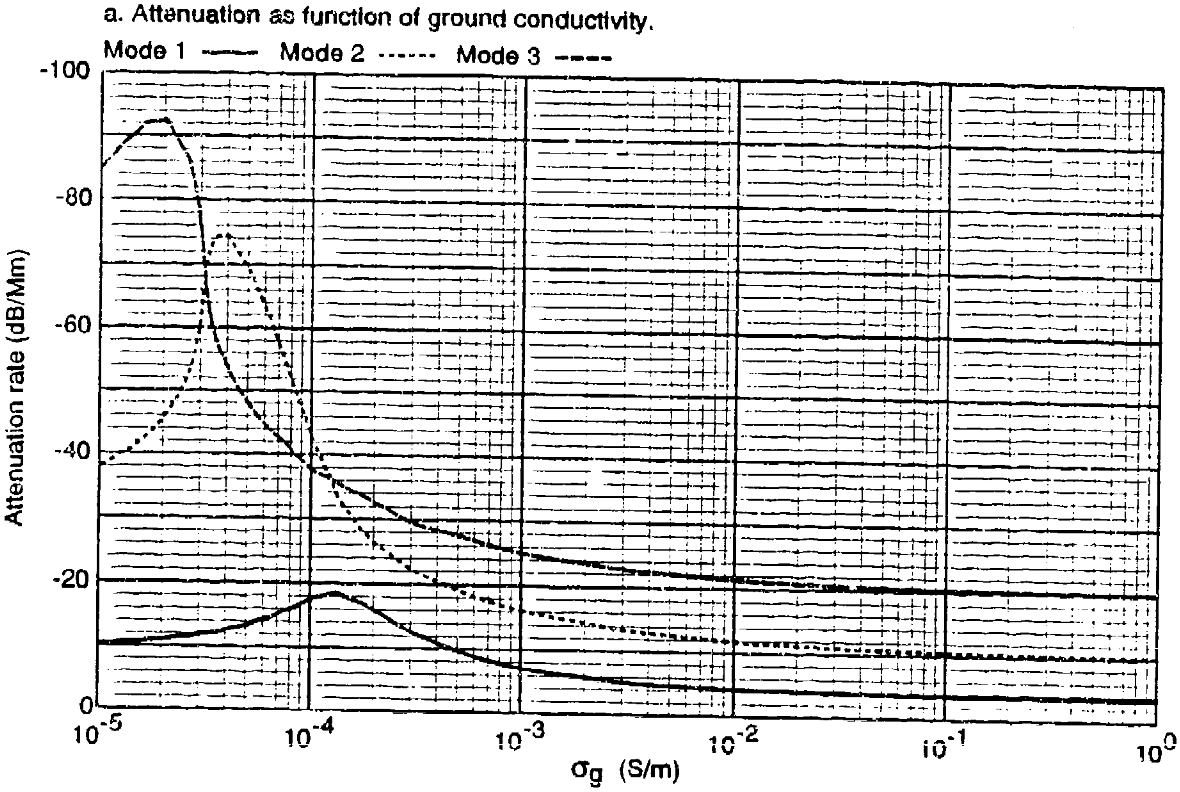


d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 31. Parameters for W = 2 x 10^{-12}, frequency = 25 kHz (Concluded).



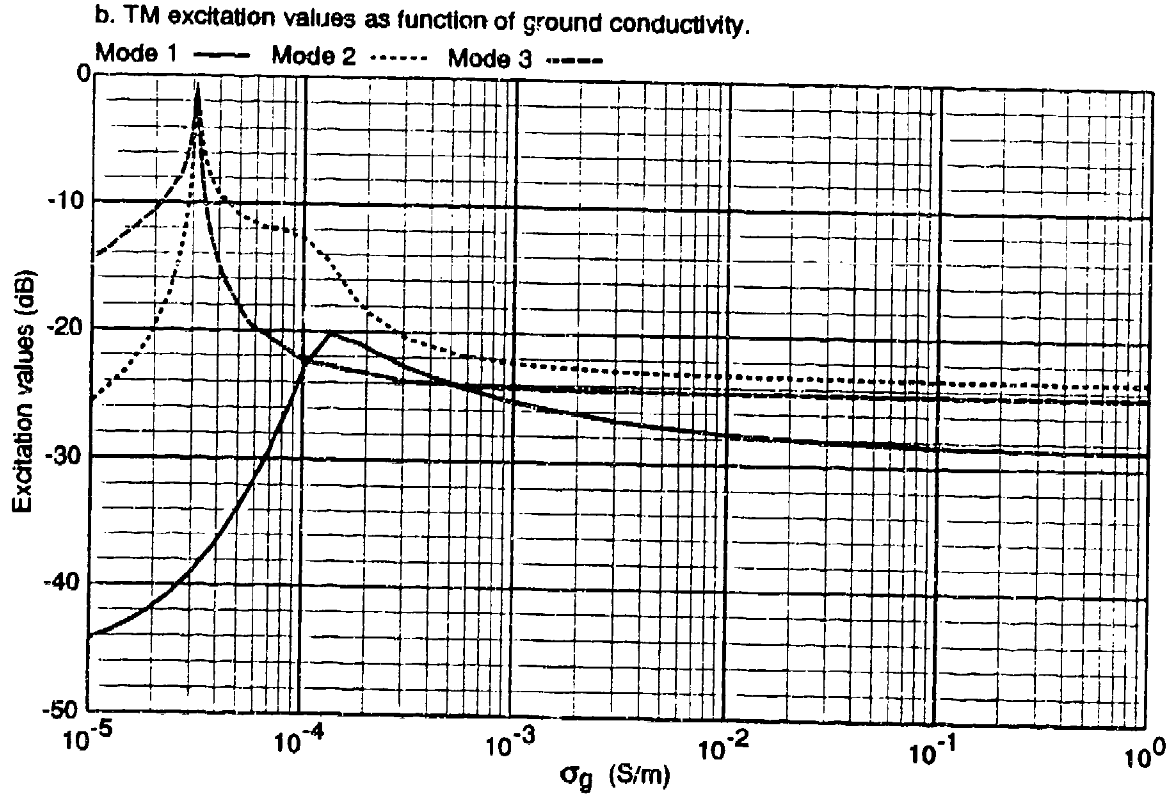
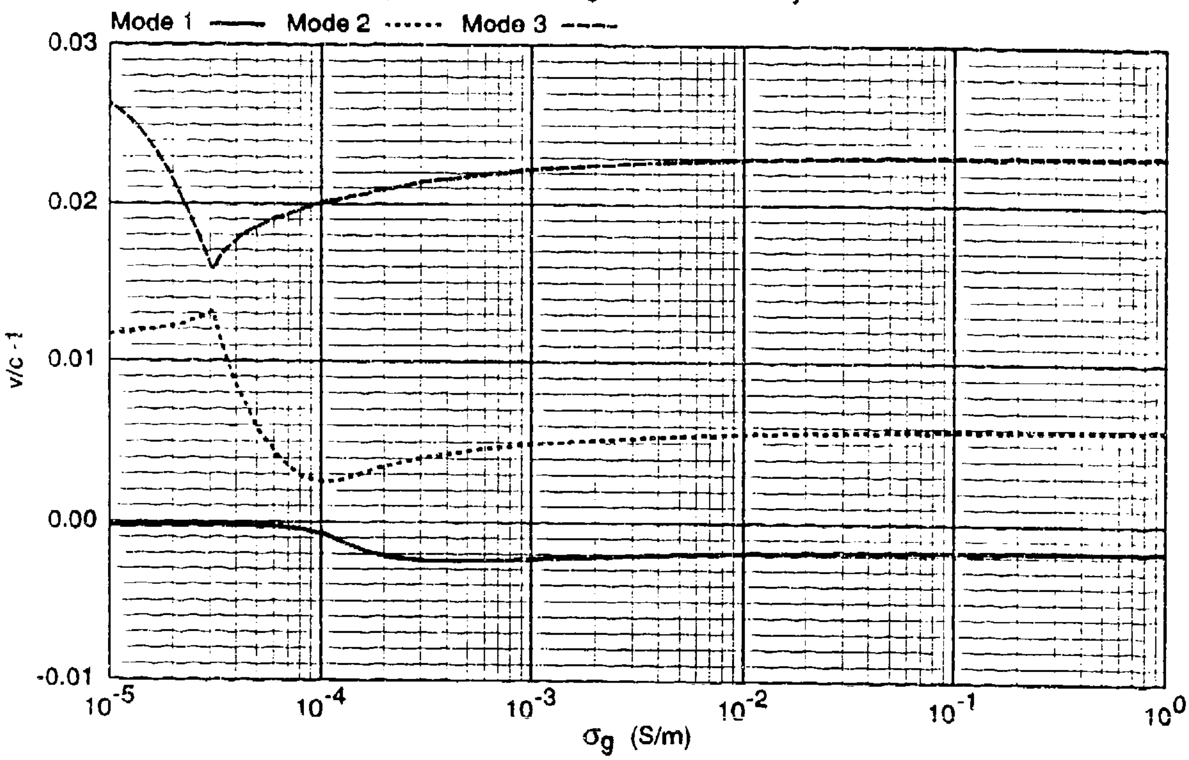
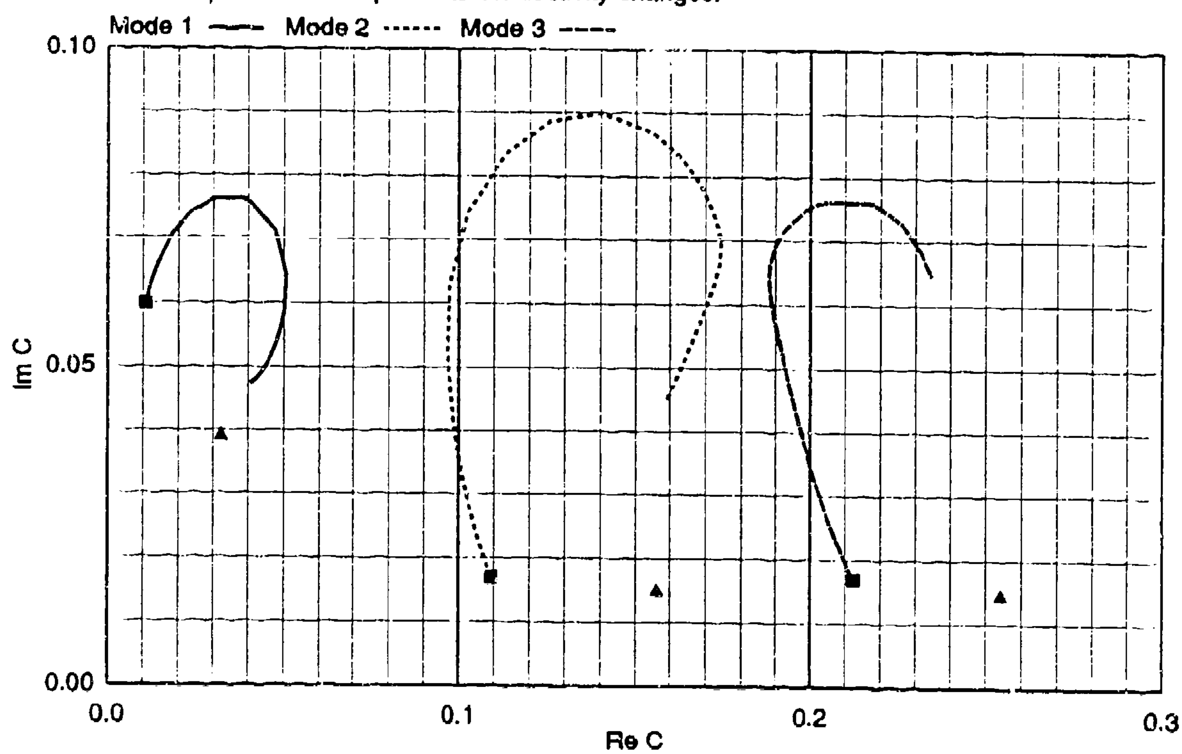


Figure 32. Parameters for $W = 2 \times 10^{-12}$, frequency = 30 kHz.

c. Relative phase velocity as a function of ground conductivity.

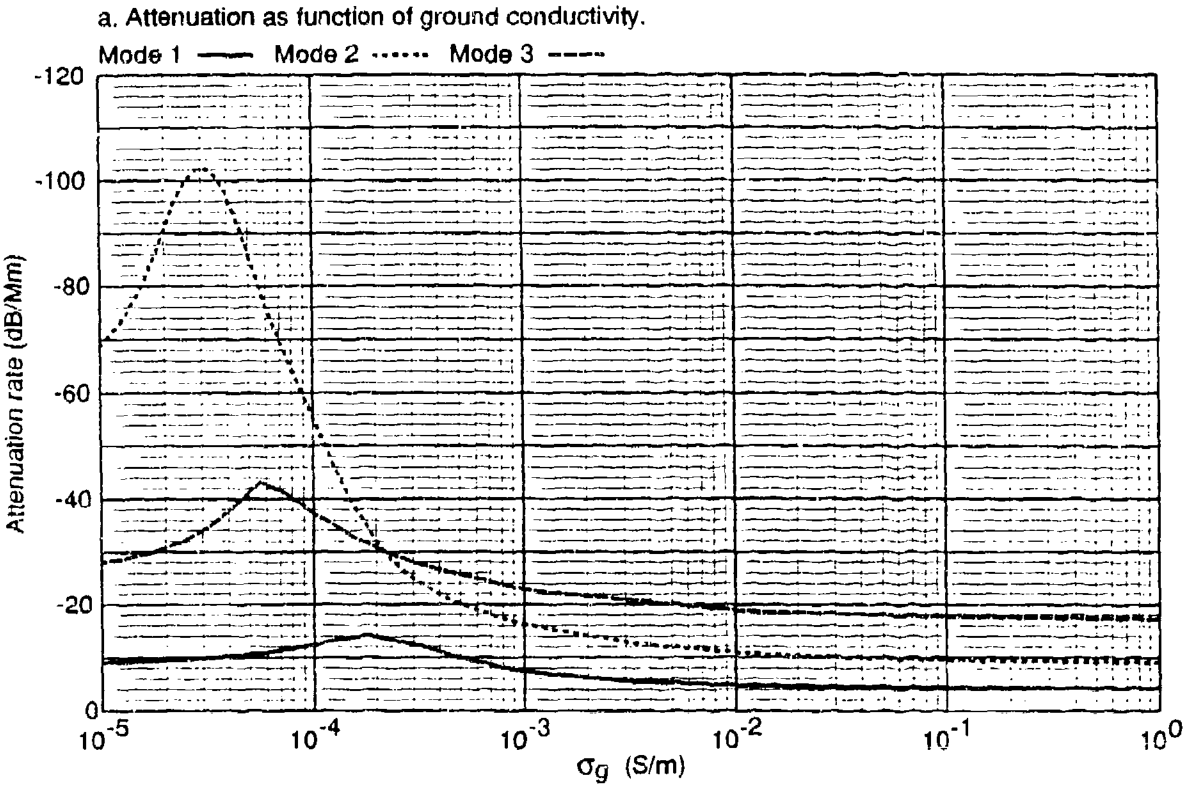


d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 32. Parameters for W = 2 x 10^{-12}, frequency = 30 kHz (Concluded).



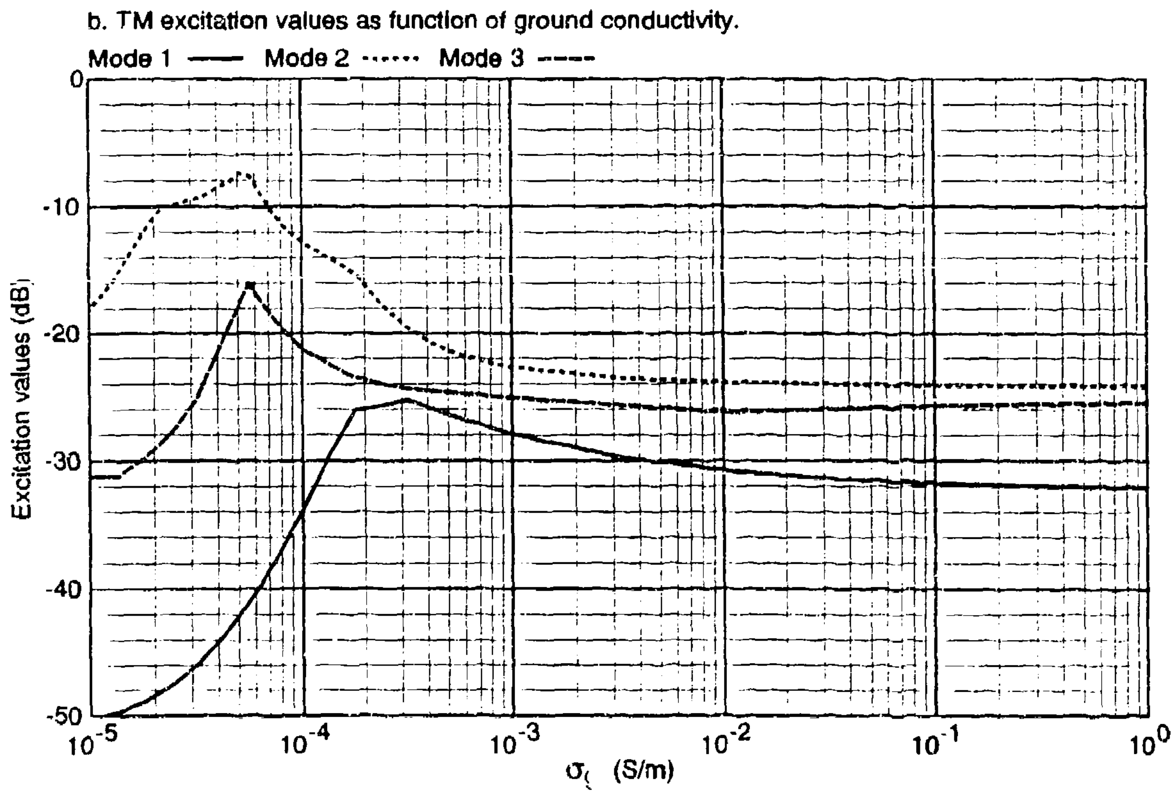
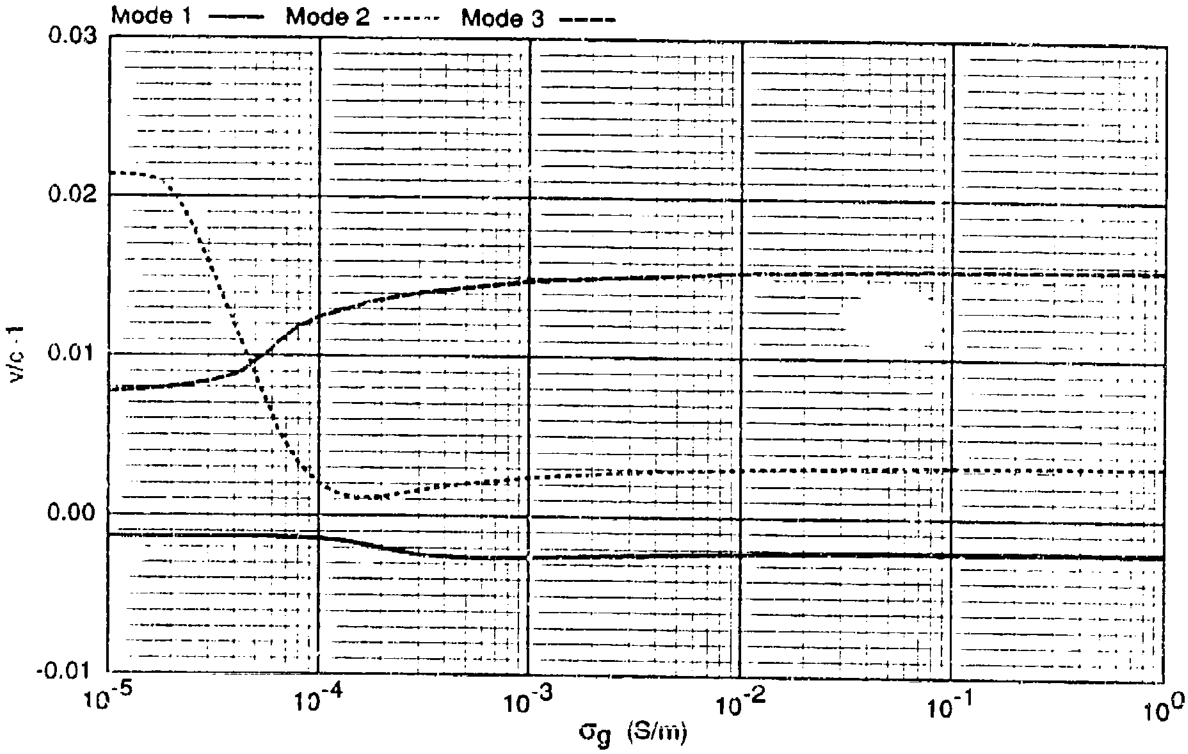
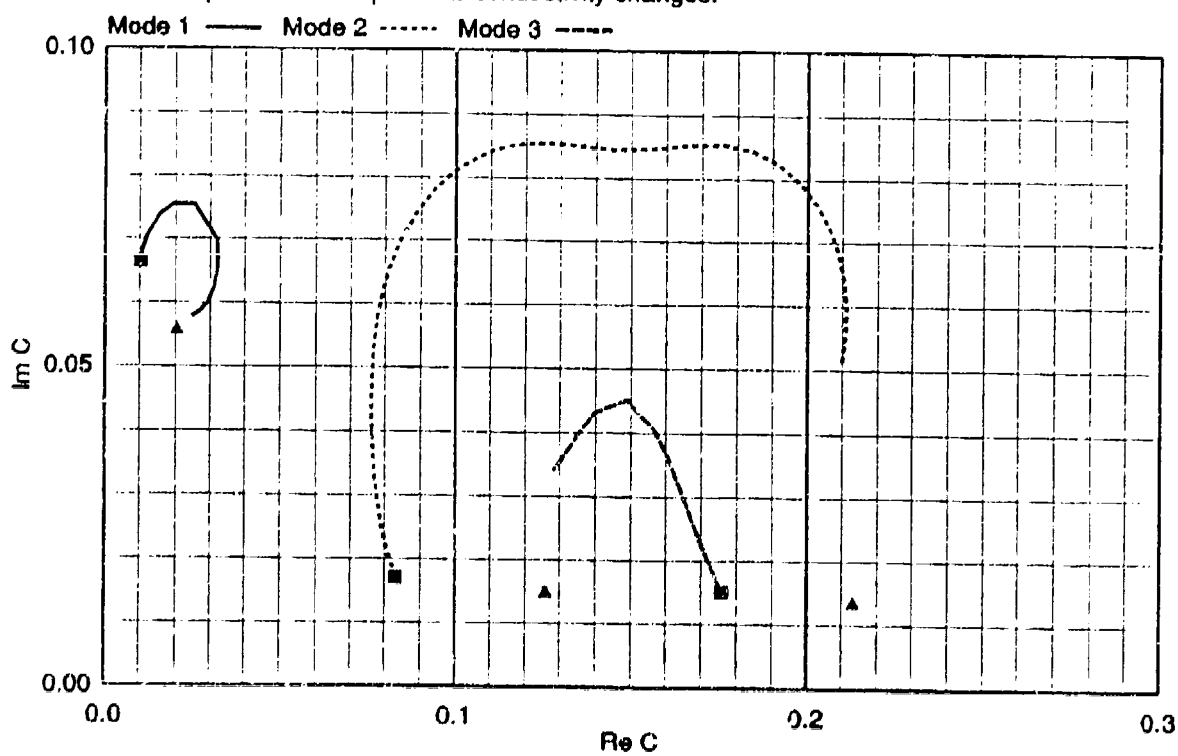


Figure 33. Parameters for W = 2 x 10^{-12}, frequency = 35 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 33. Parameters for W = 2 x 10^{-12}, frequency = 35 kHz (Concluded).

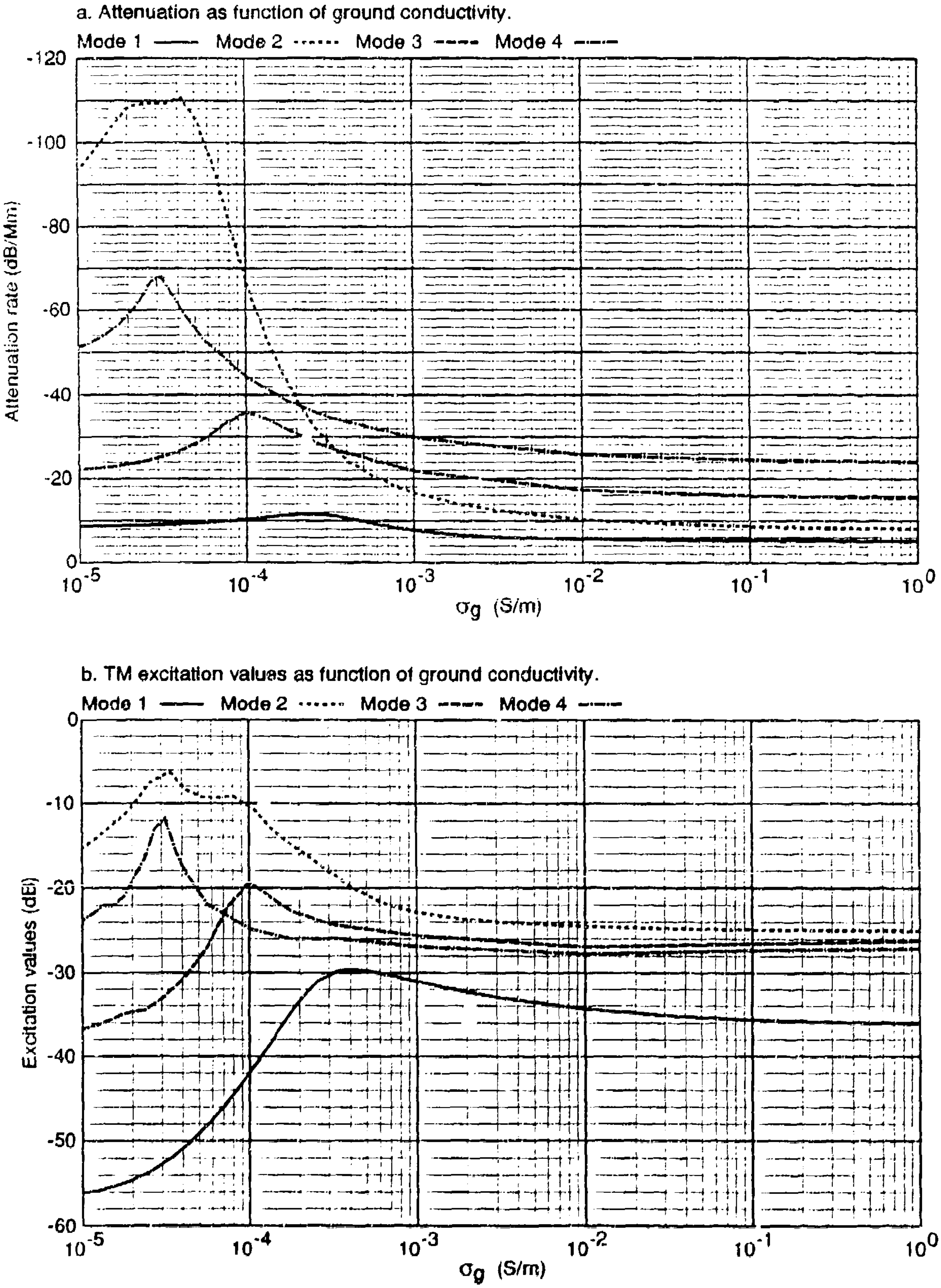
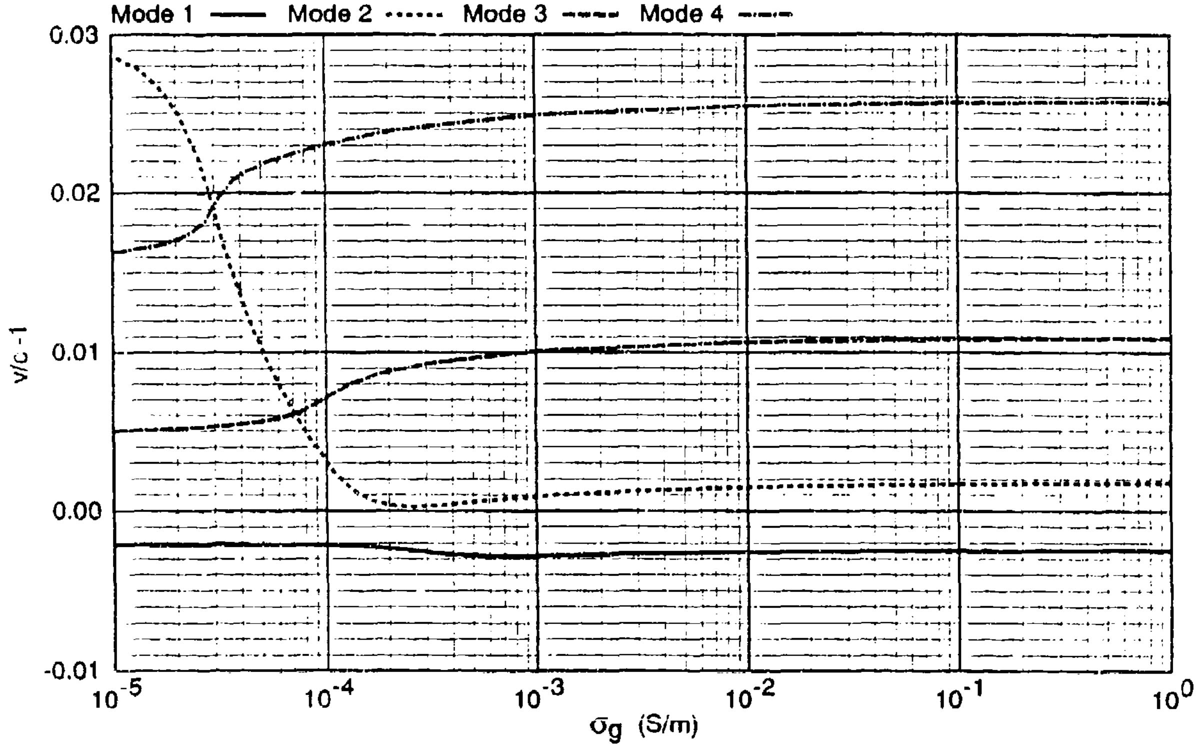
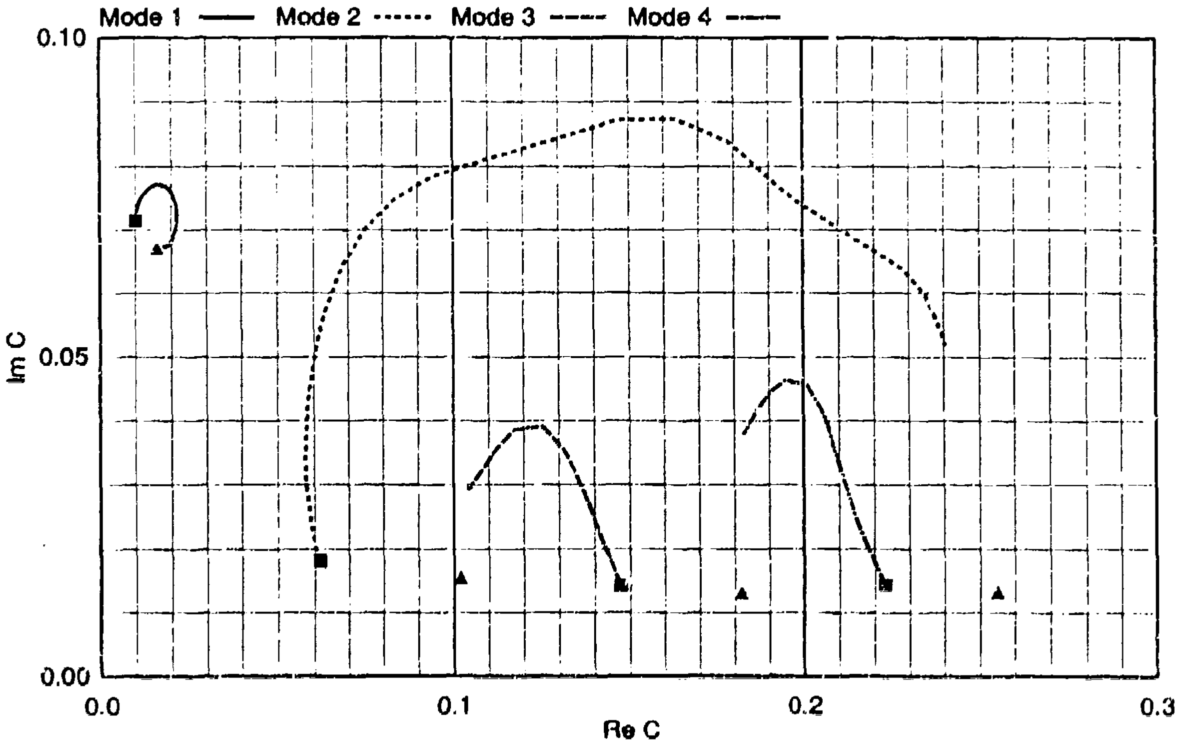


Figure 34. Parameters for $W = 2 \times 10^{-12}$, frequency = 40 kHz.

c. Relative phase velocity as a function of ground conductivity.



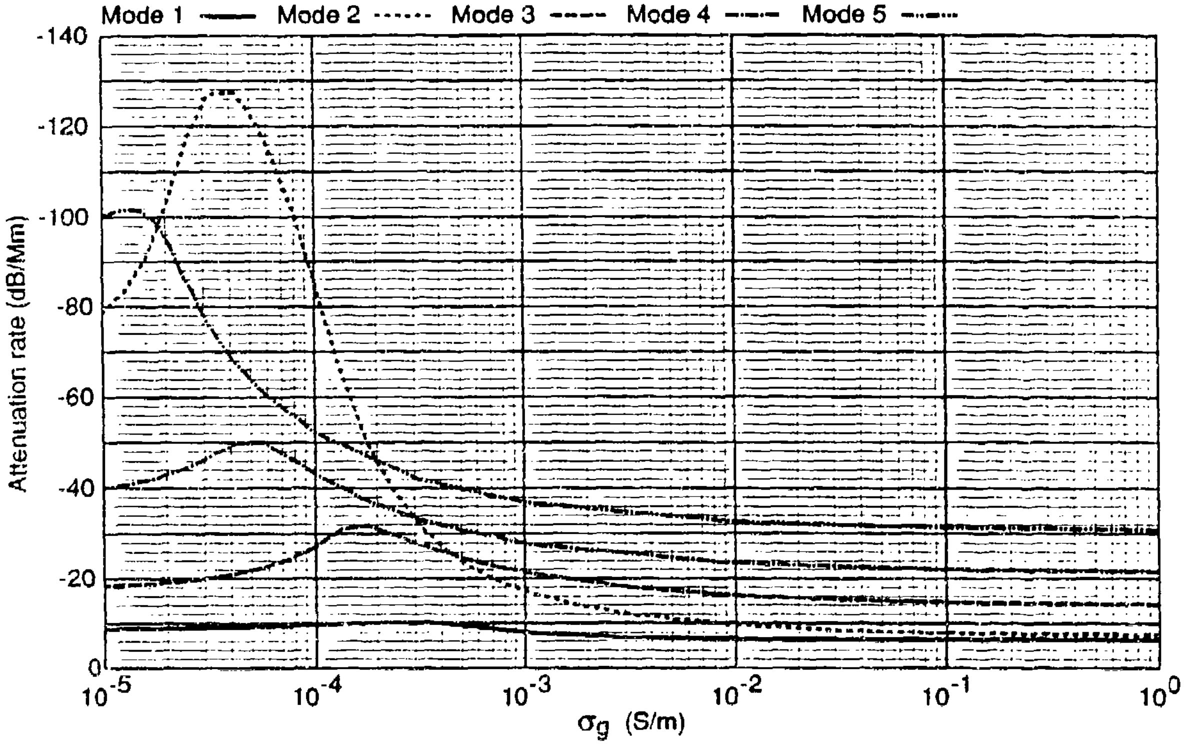
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 34. Parameters for W = 2 x 10^{-12}, frequency = 40 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

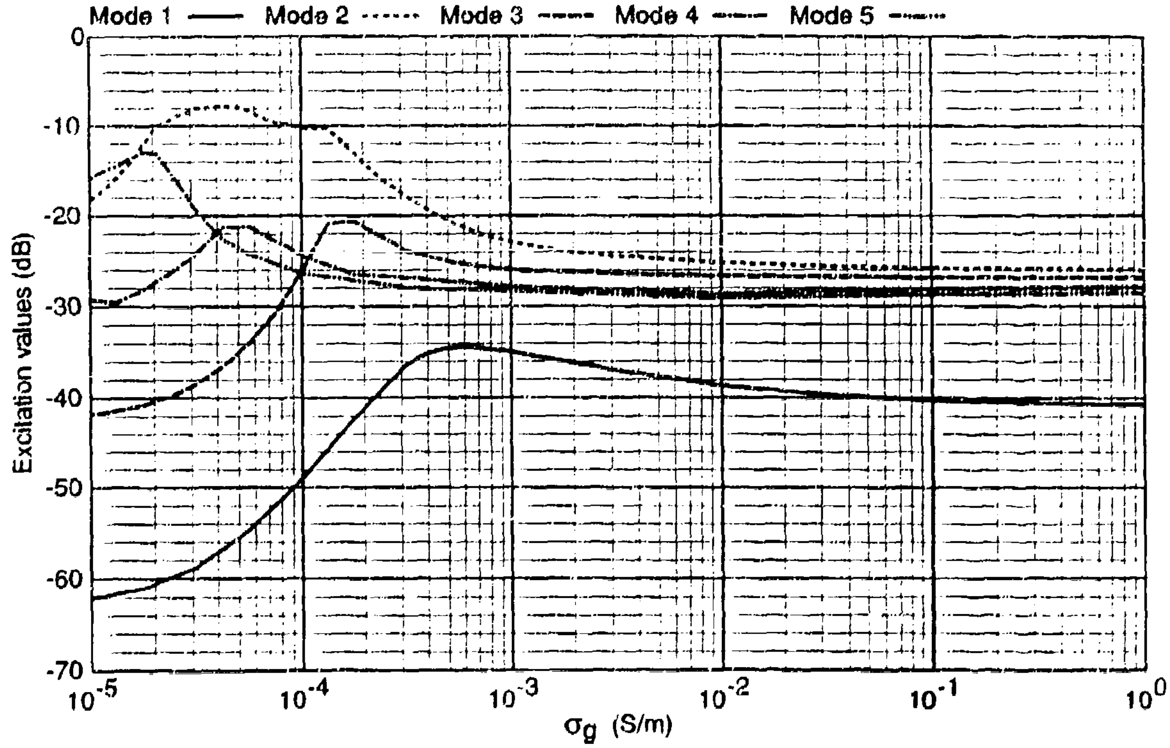
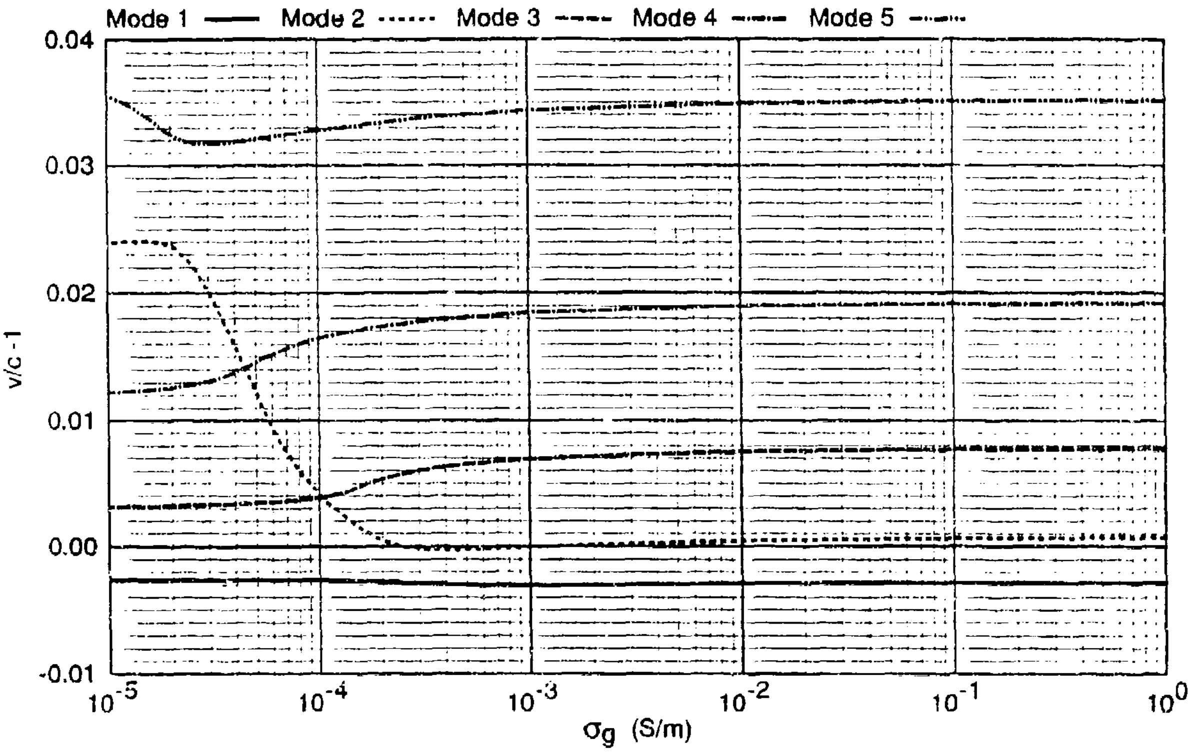
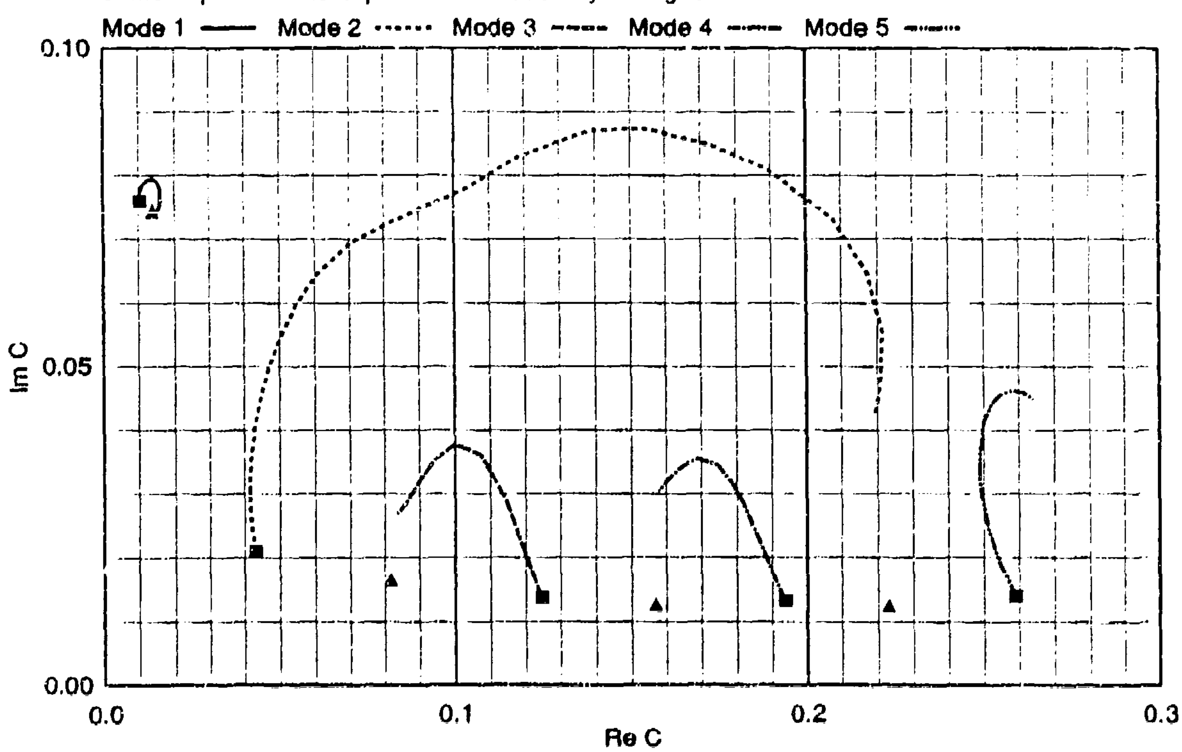


Figure 35. Parameters for $W = 2 \times 10^{-12}$, frequency = 45 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 35. Parameters for $W = 2 \times 10^{-12}$, frequency = 45 kHz (Concluded).

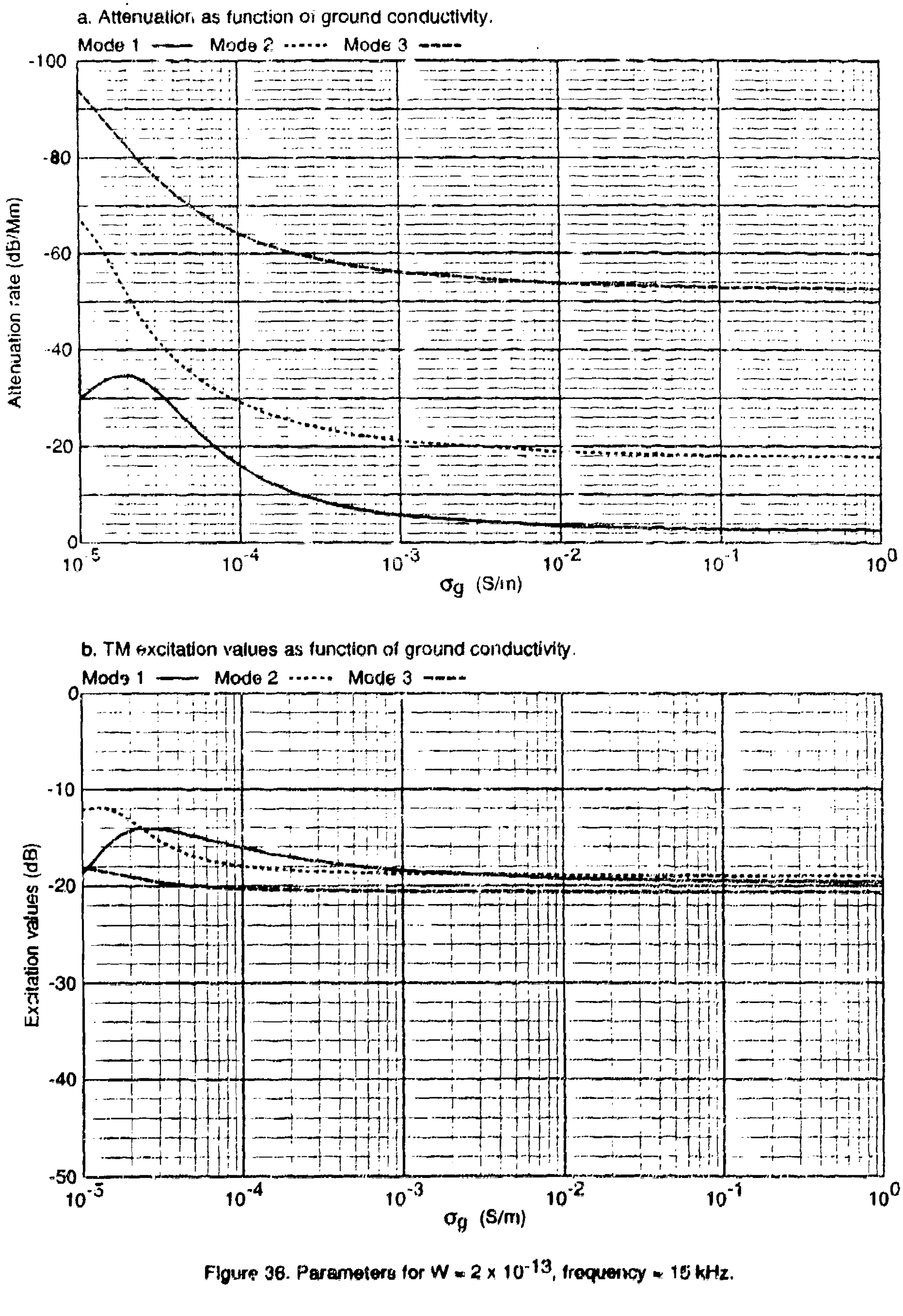
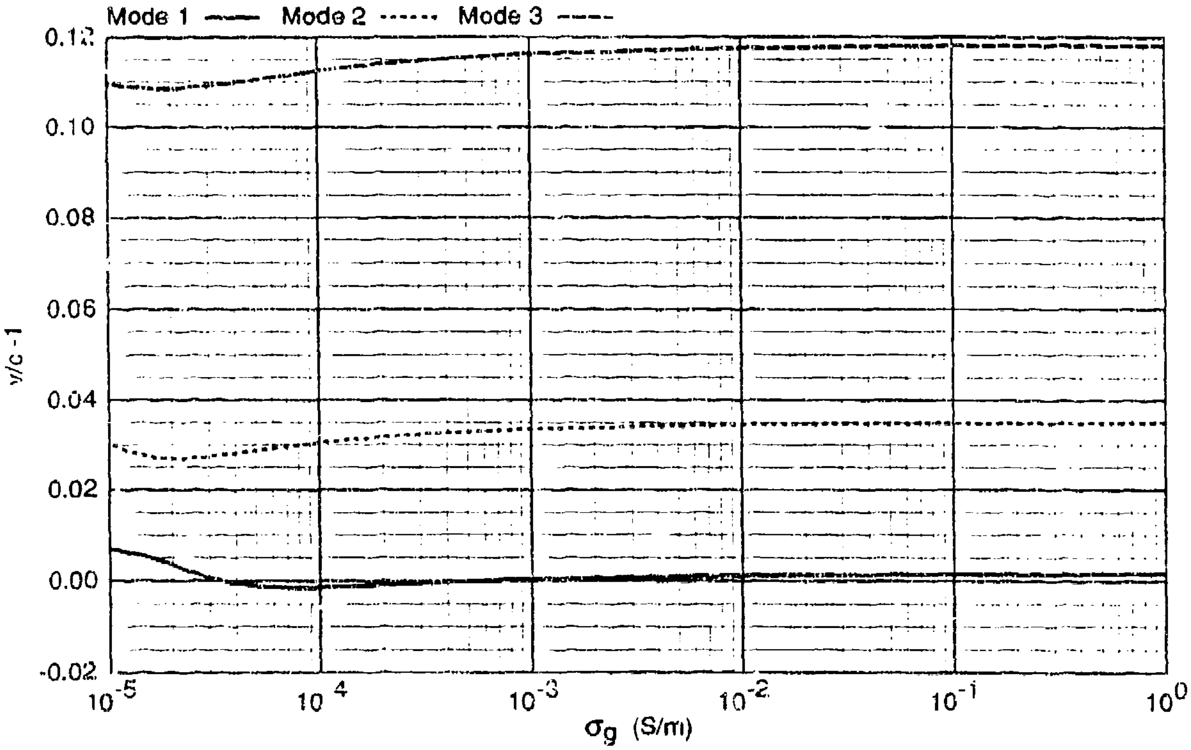
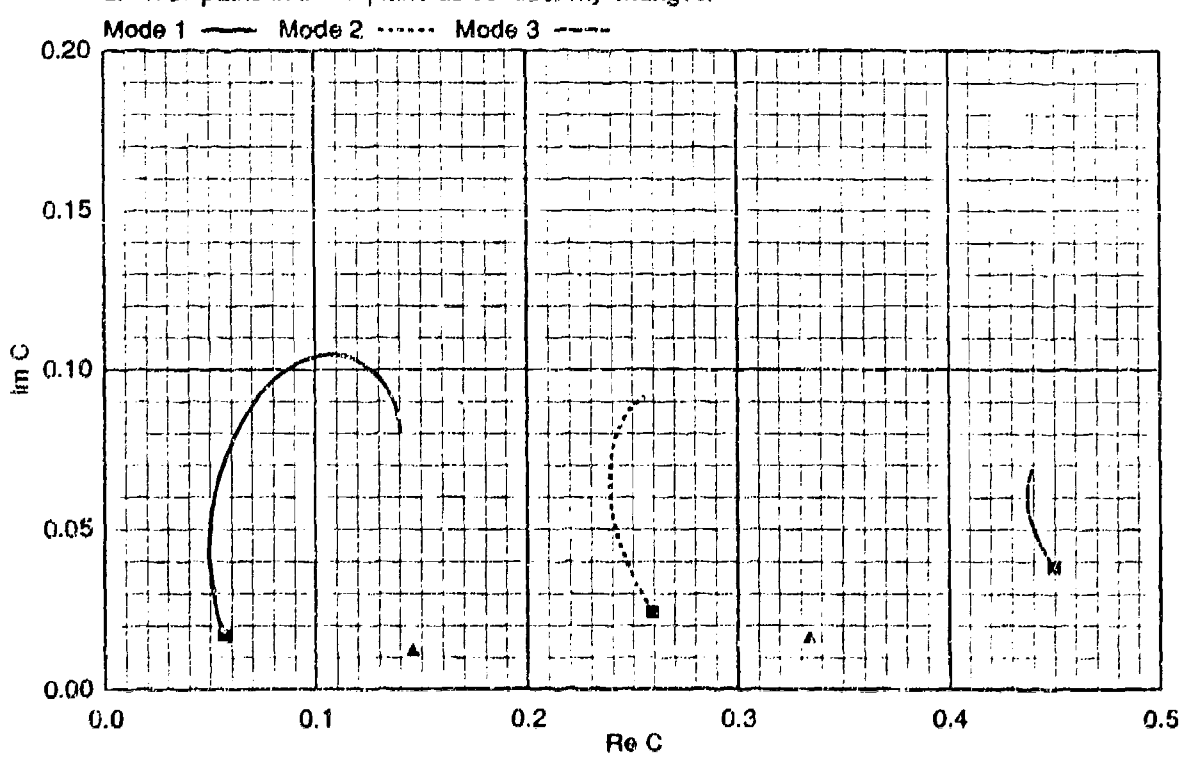


Figure 36. Parameters for $W = 2 \times 10^{-13}$, frequency = 15 kHz.

c. Relative phase velocity as a function of ground conductivity.



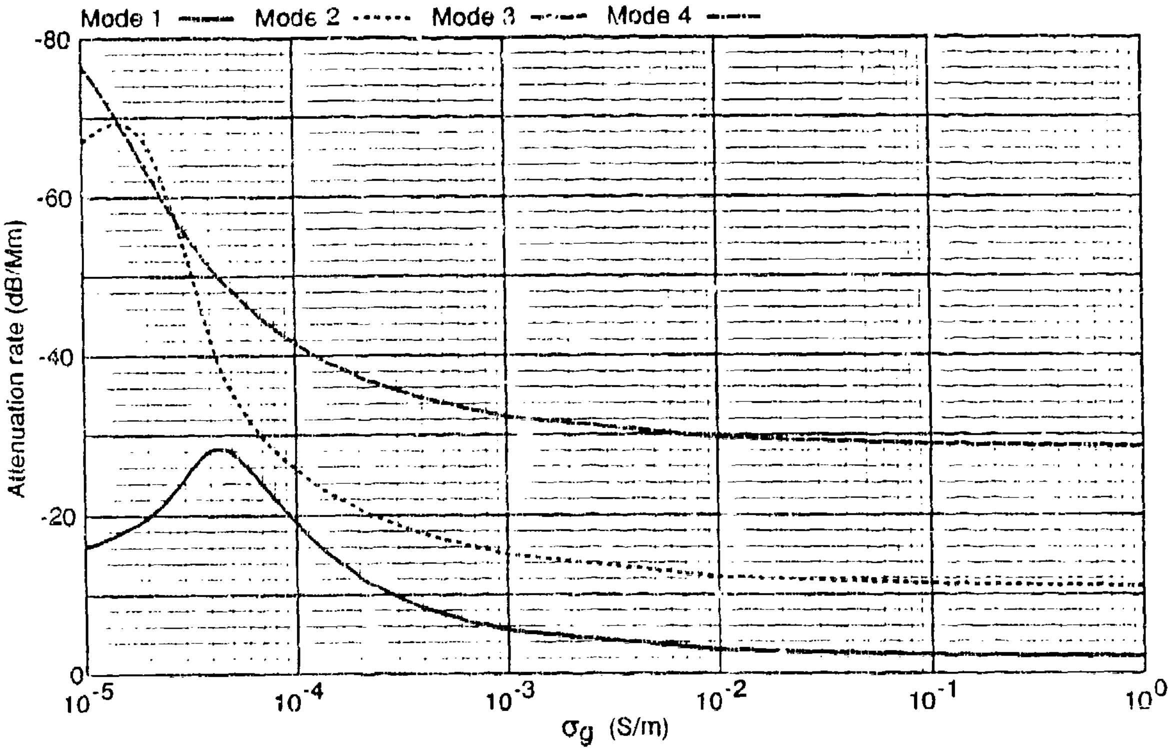
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 36. Parameters for $W = 2 \times 10^{-13}$, frequency = 15 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

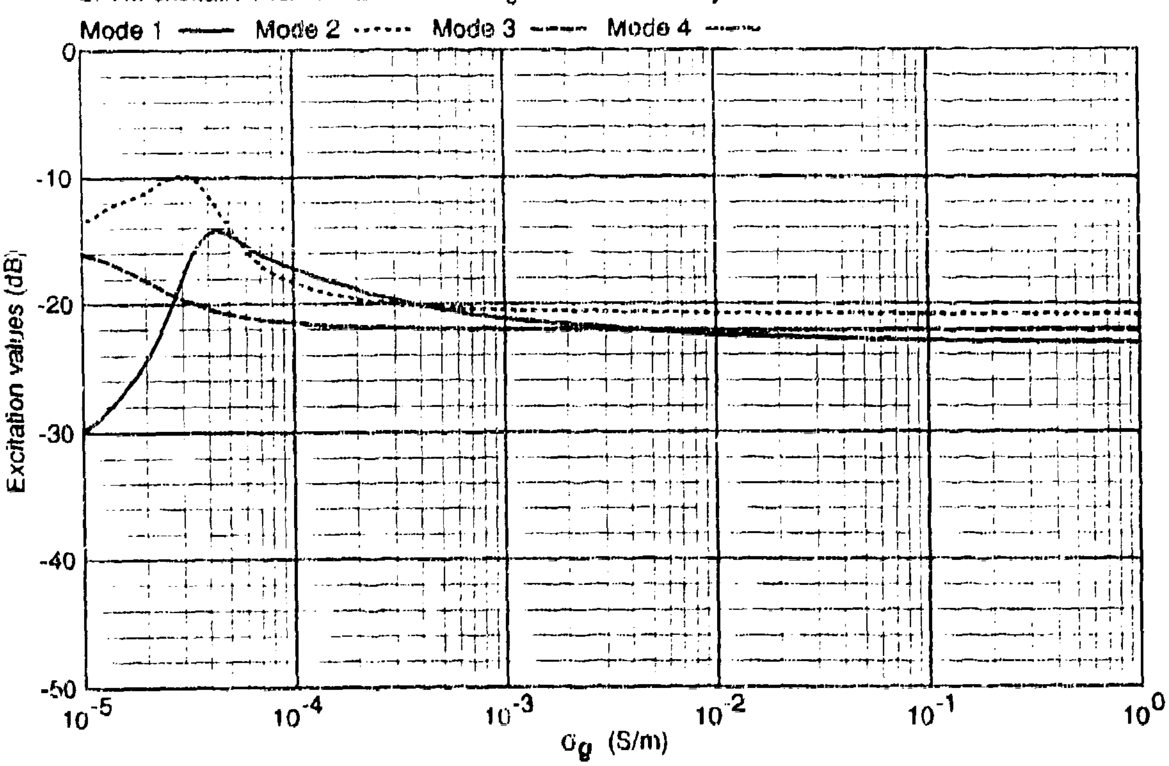
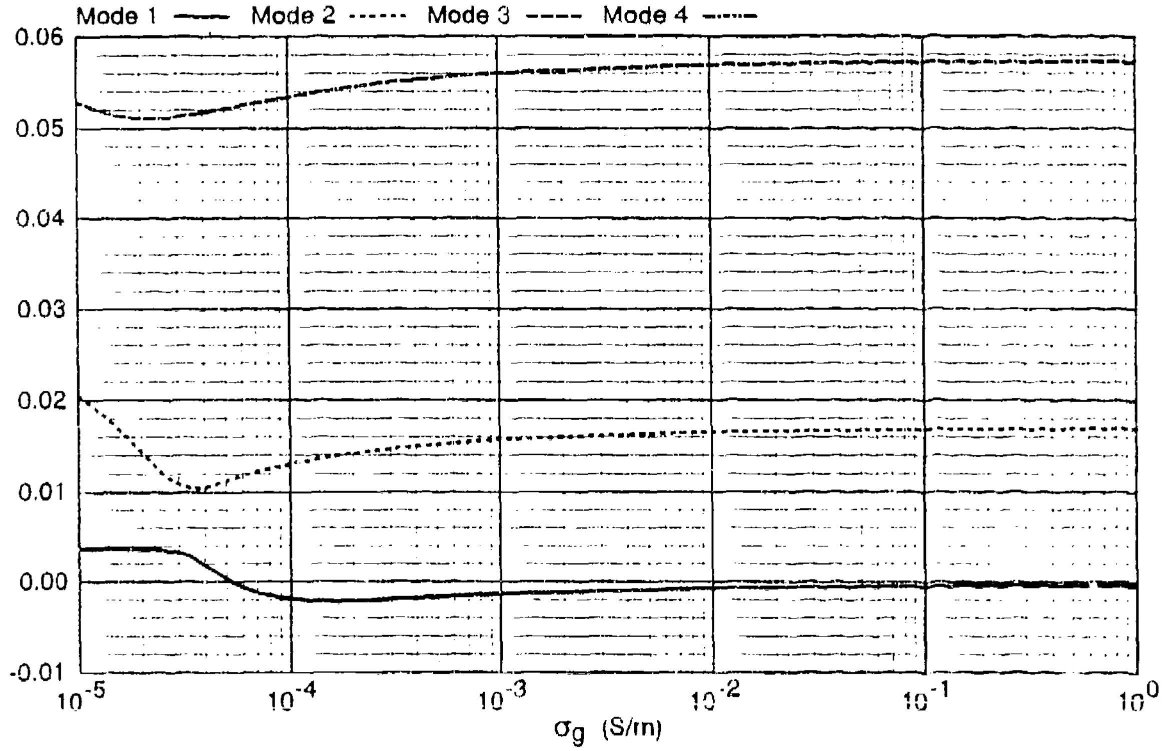
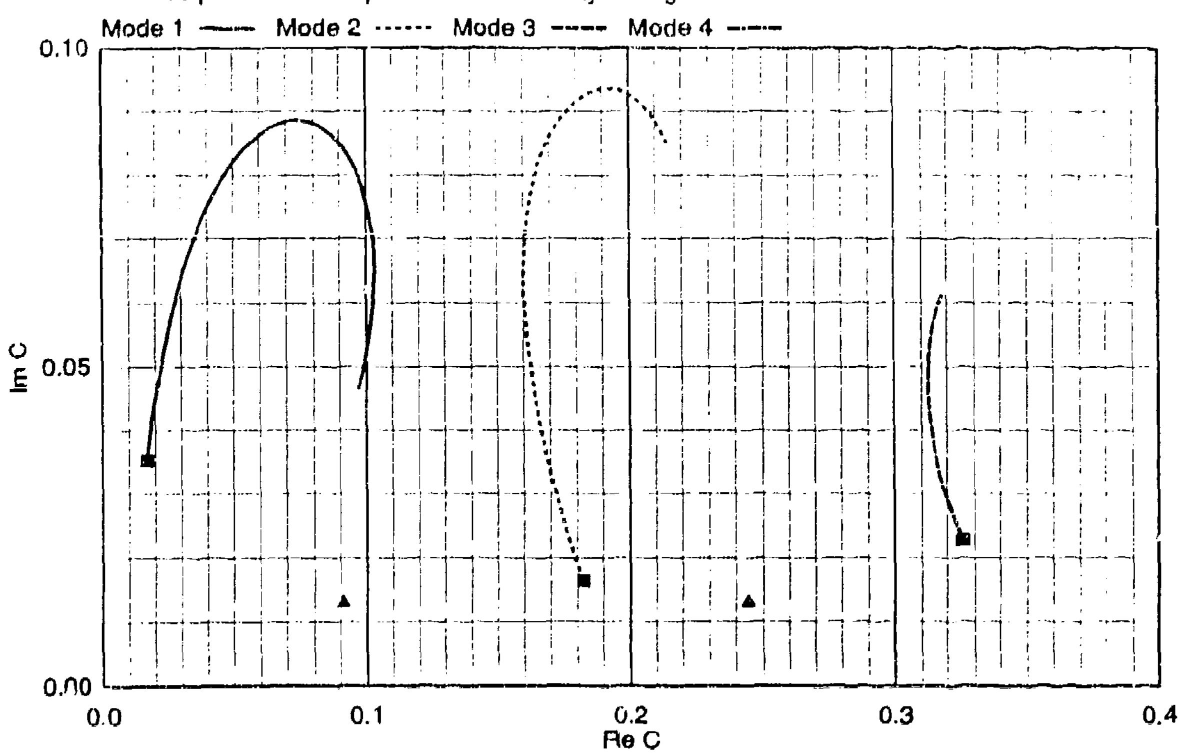


Figure 37. Parameters for $W = 2 \times 10^{-13}$, frequency = 20 kHz.

c. Relative phase velocity as a function of ground conductivity.

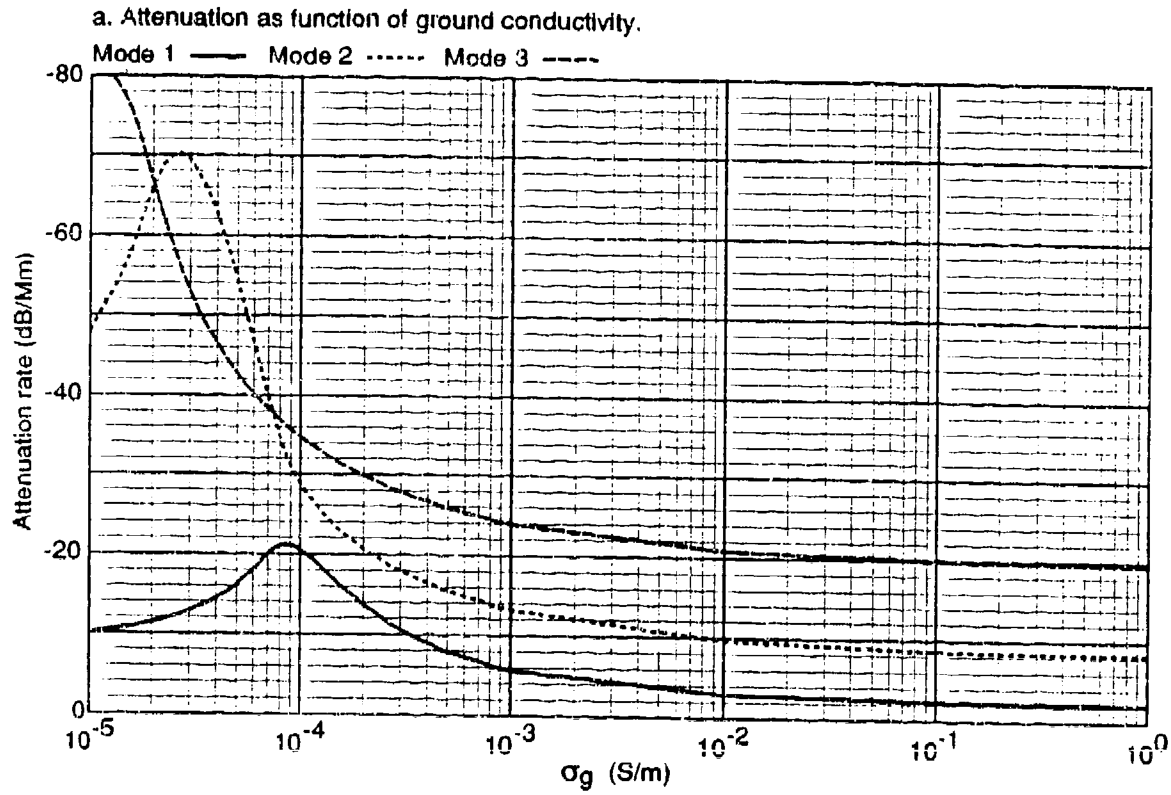


d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 37. Parameters for W = 2 x 10^{-13}, frequency = 20 kHz (Concluded).



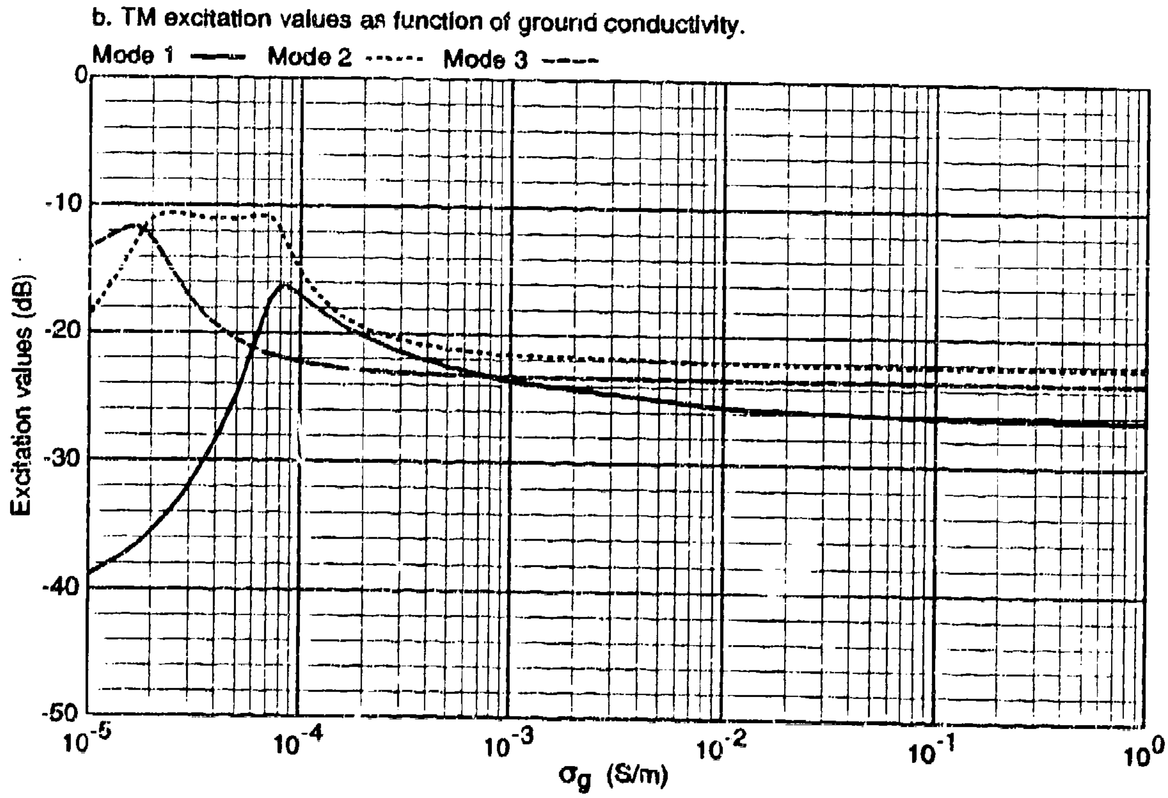
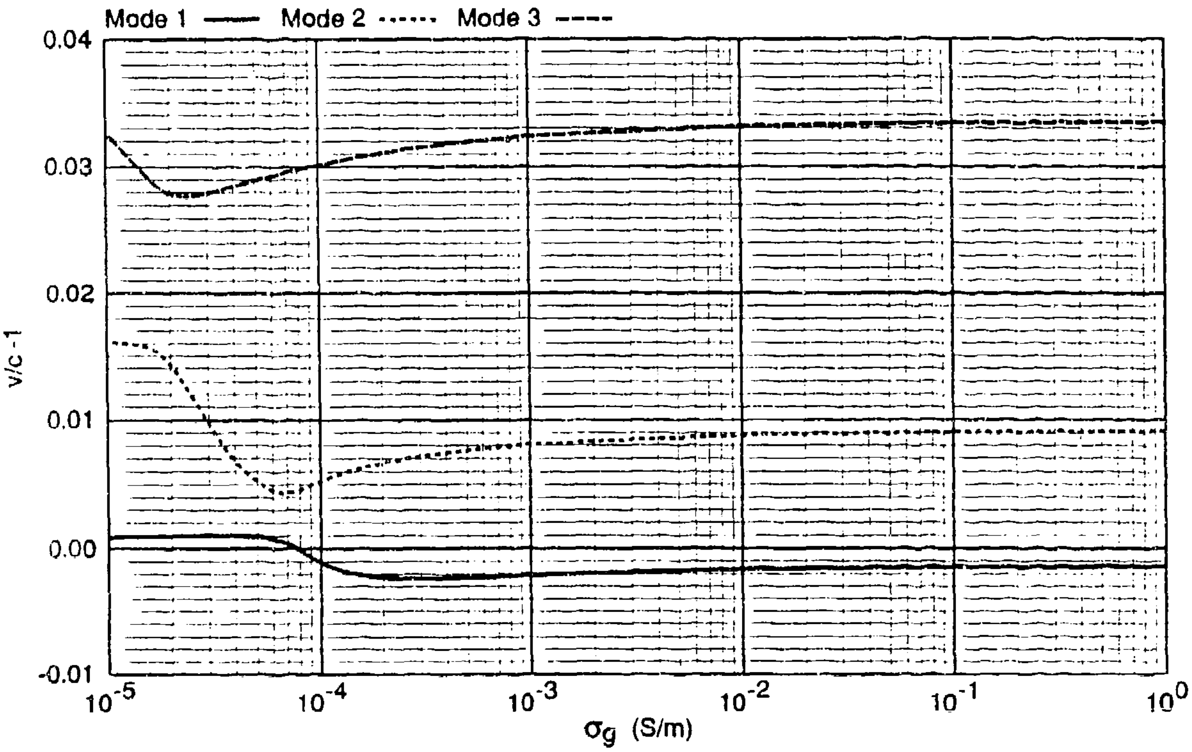
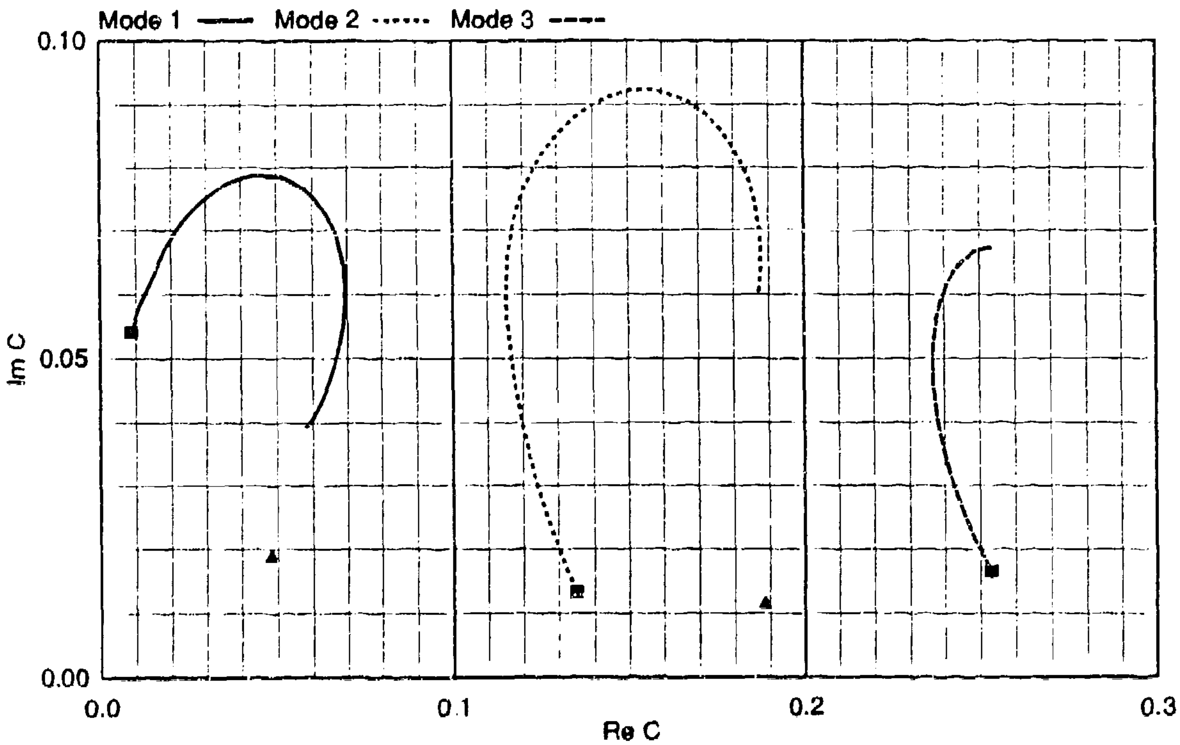


Figure 38. Parameters for $W = 2 \times 10^{-13}$, frequency = 25 kHz.

c. Relative phase velocity as a function of ground conductivity.

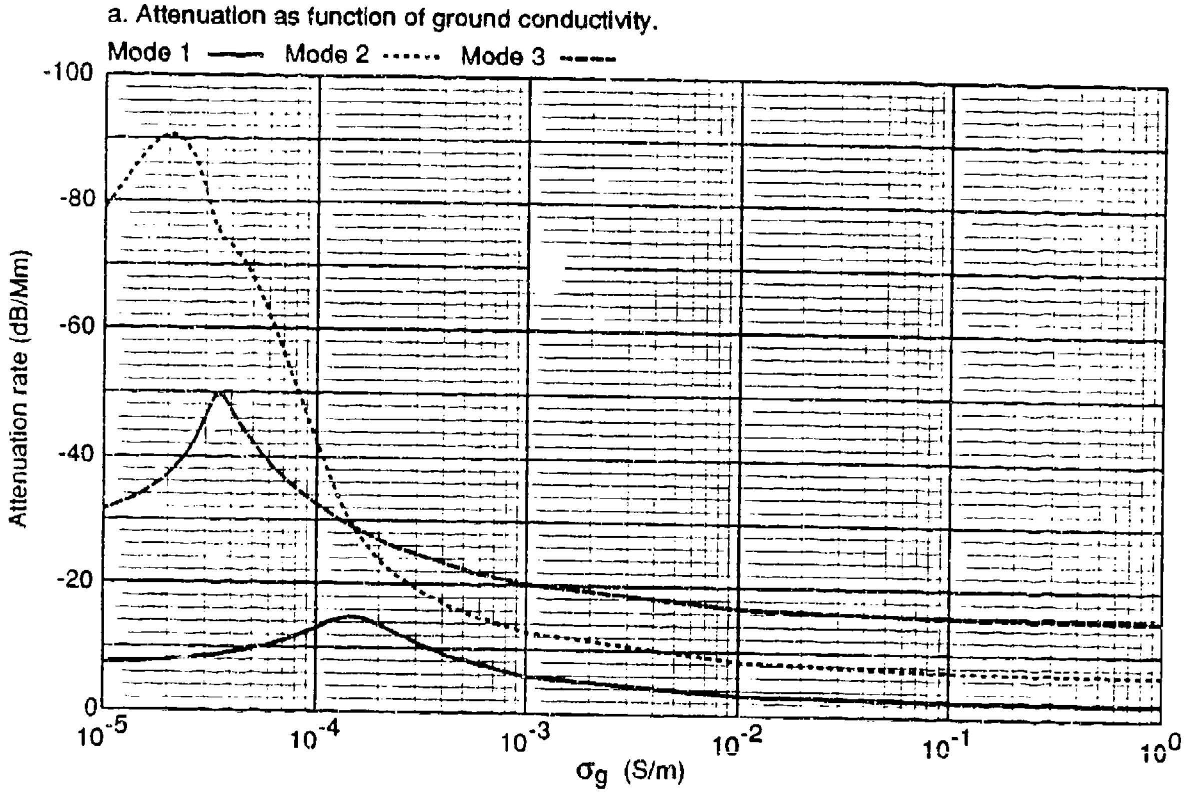


d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 38. Parameters for W = 2 x 10^{-13}, frequency = 25 kHz (Concluded).



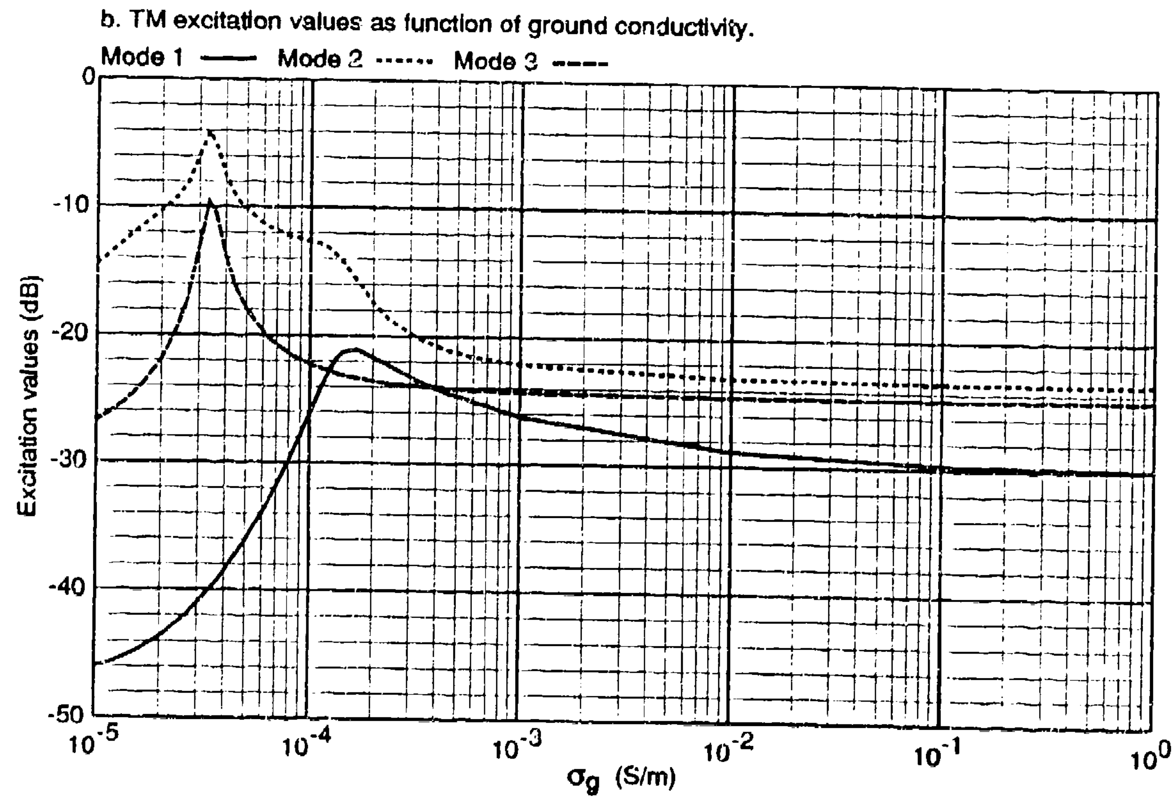
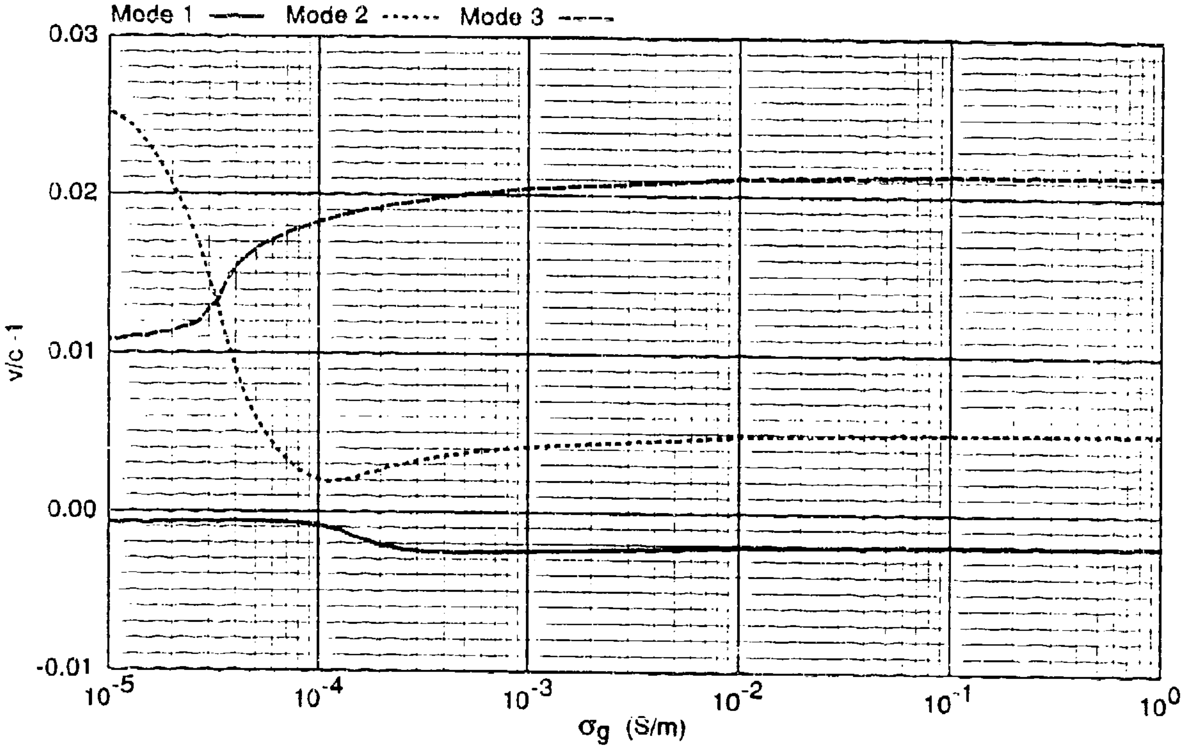
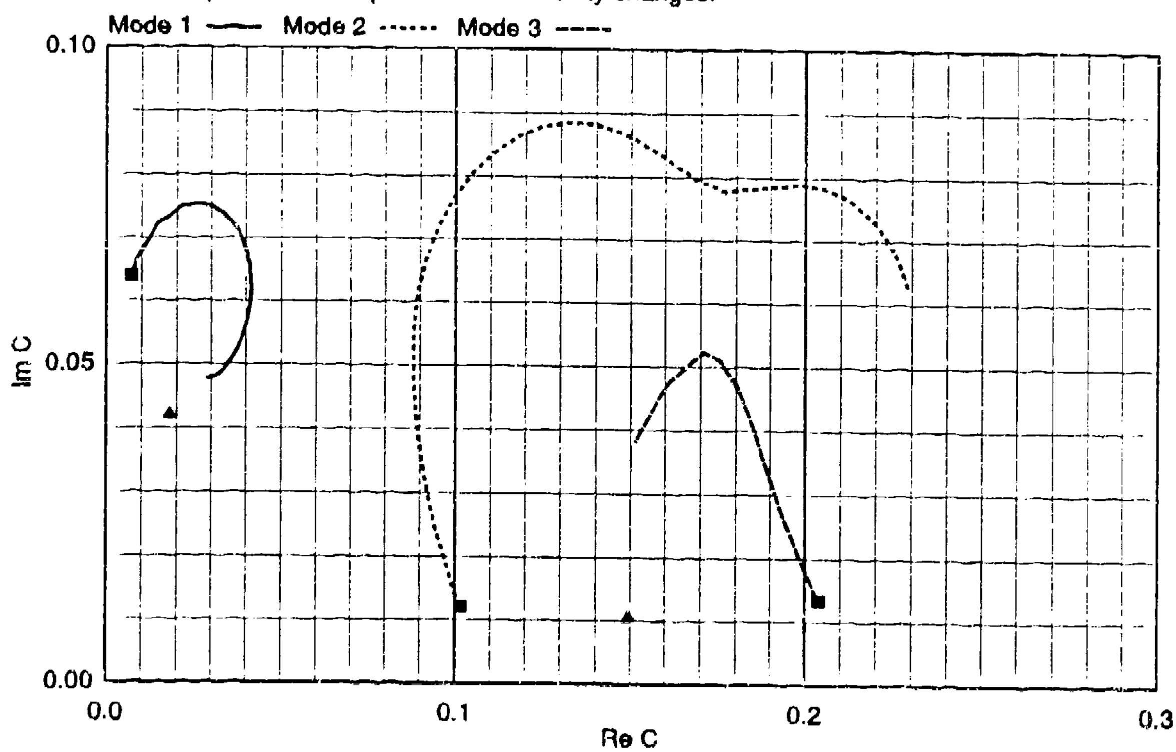


Figure 39. Parameters for $W = 2 \times 10^{-13}$, frequency = 30 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 39. Parameters for W = 2 x 10^{-13}, frequency = 30 kHz (Concluded).

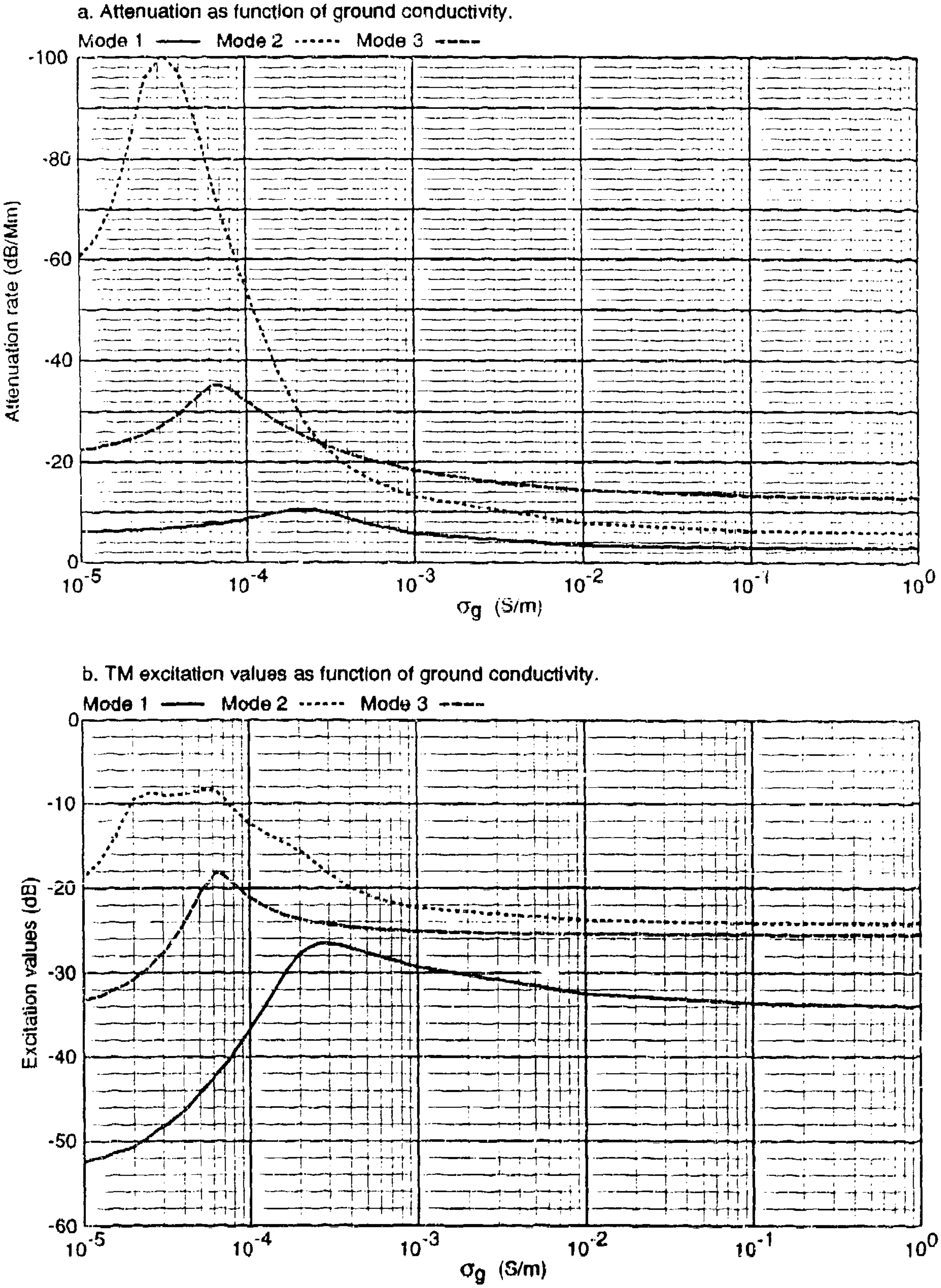
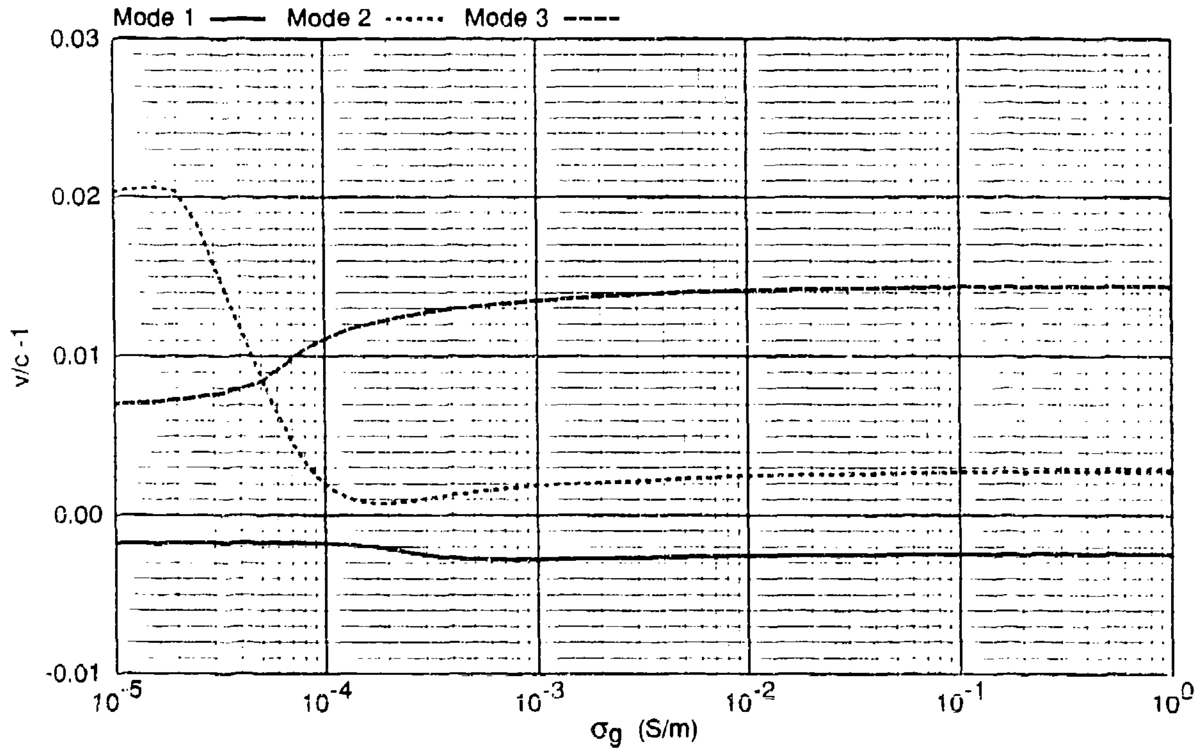
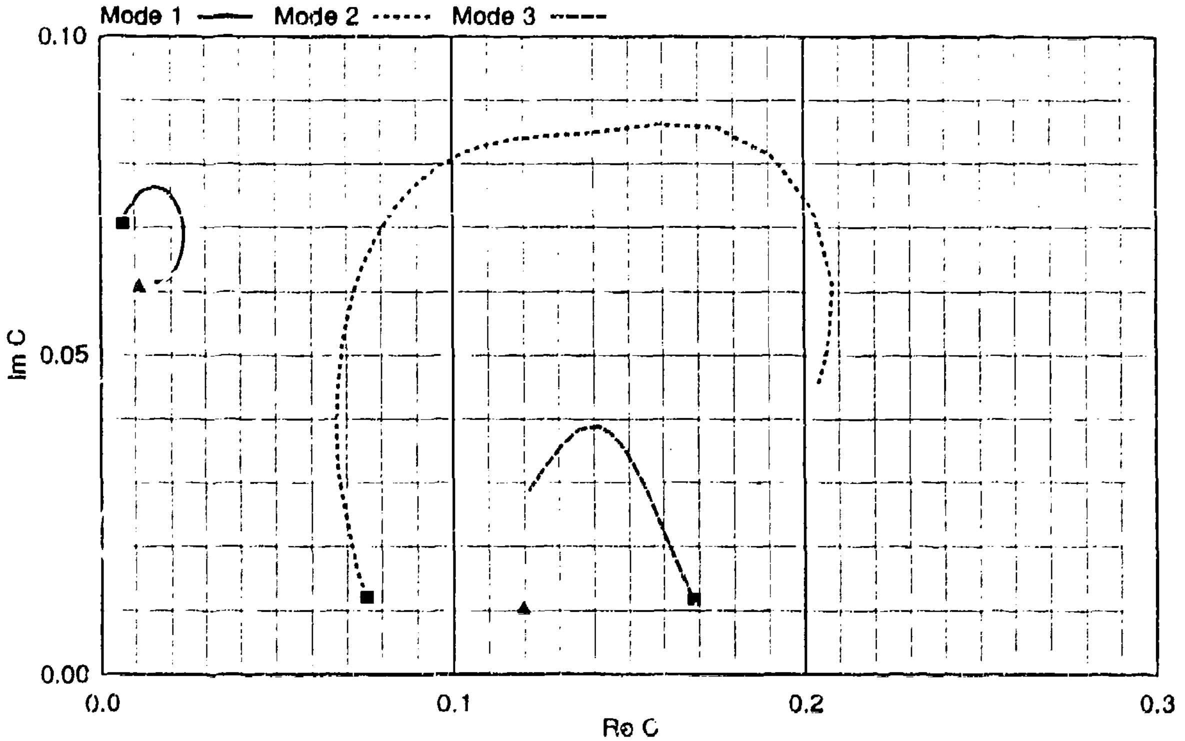


Figure 40. Parameters for $W = 2 \times 10^{-13}$, frequency = 35 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 40. Parameters for W = 2×10^{-13}, frequency = 35 kHz (Concluded).

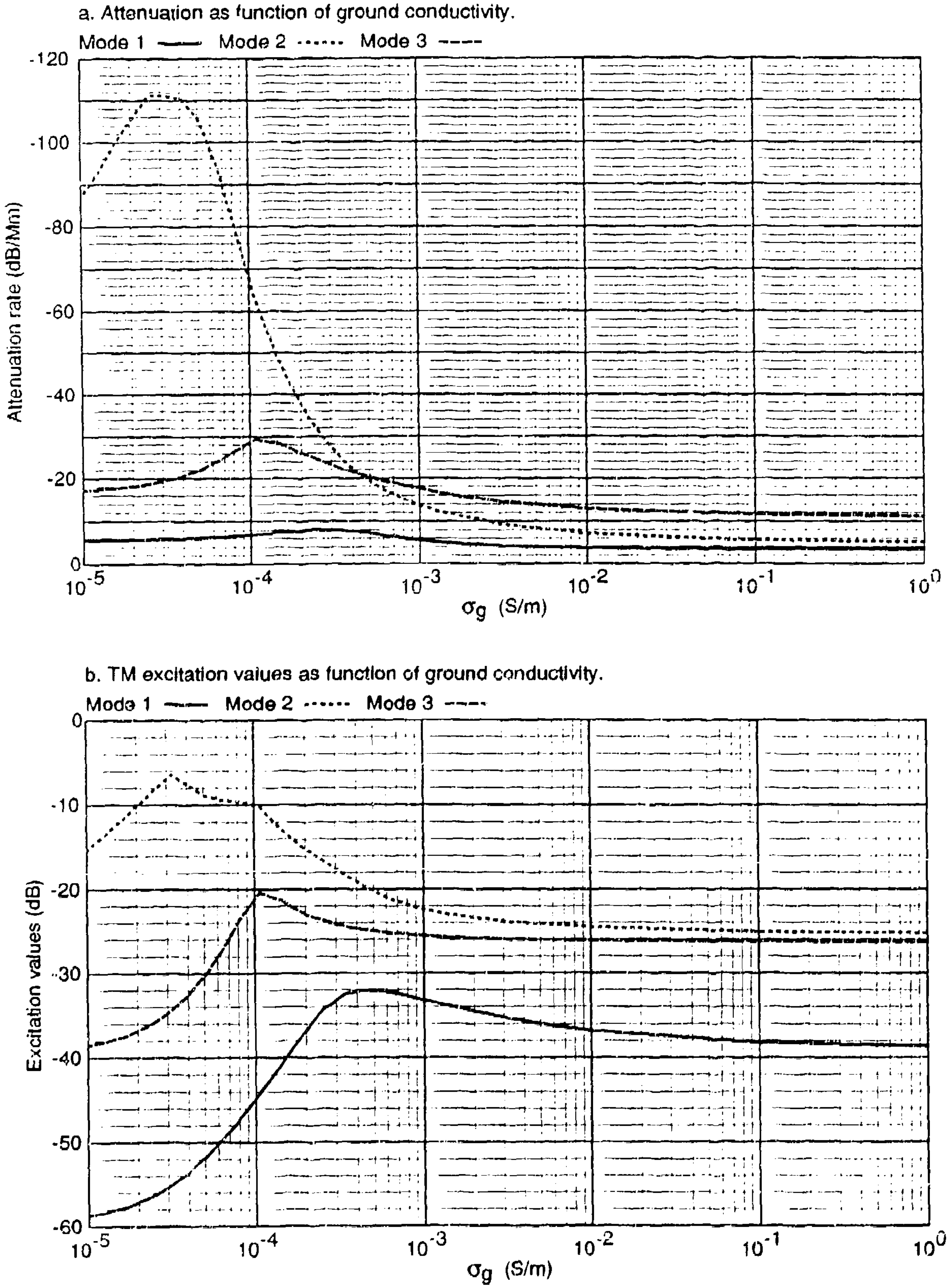
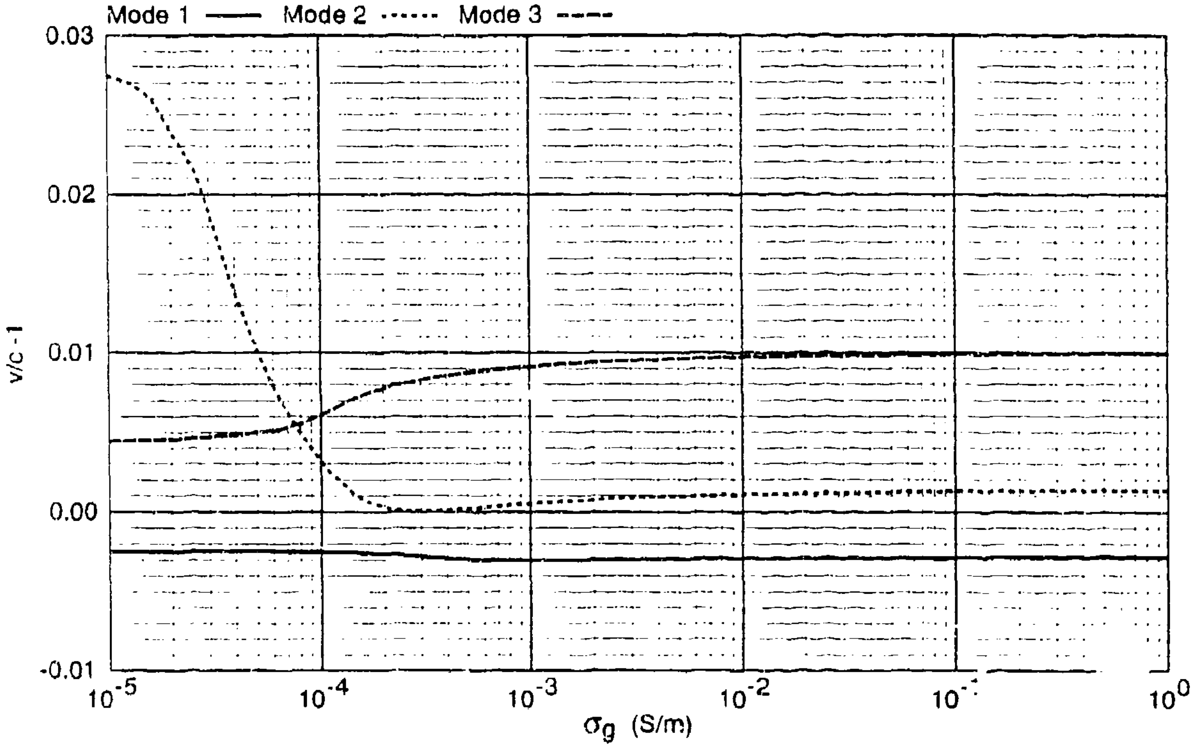
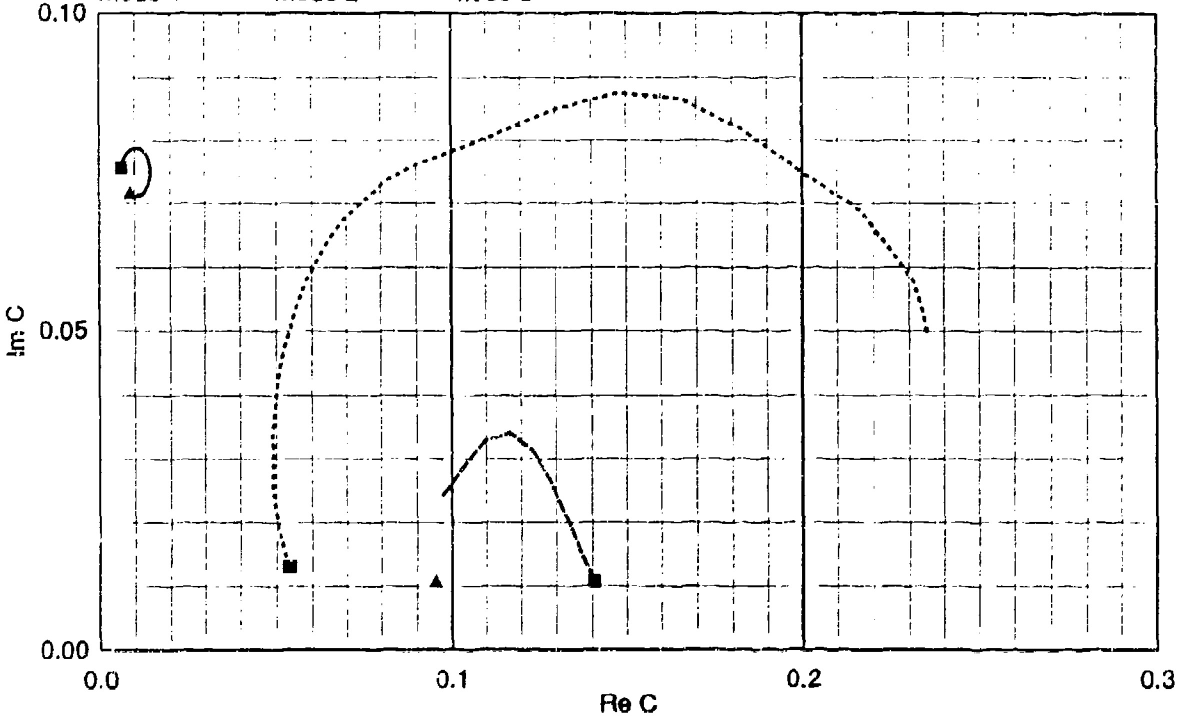


Figure 41. Parameters for W = 2 x 10^{-13}, frequency = 40 kHz.

c. Relative phase velocity as a function of ground conductivity.



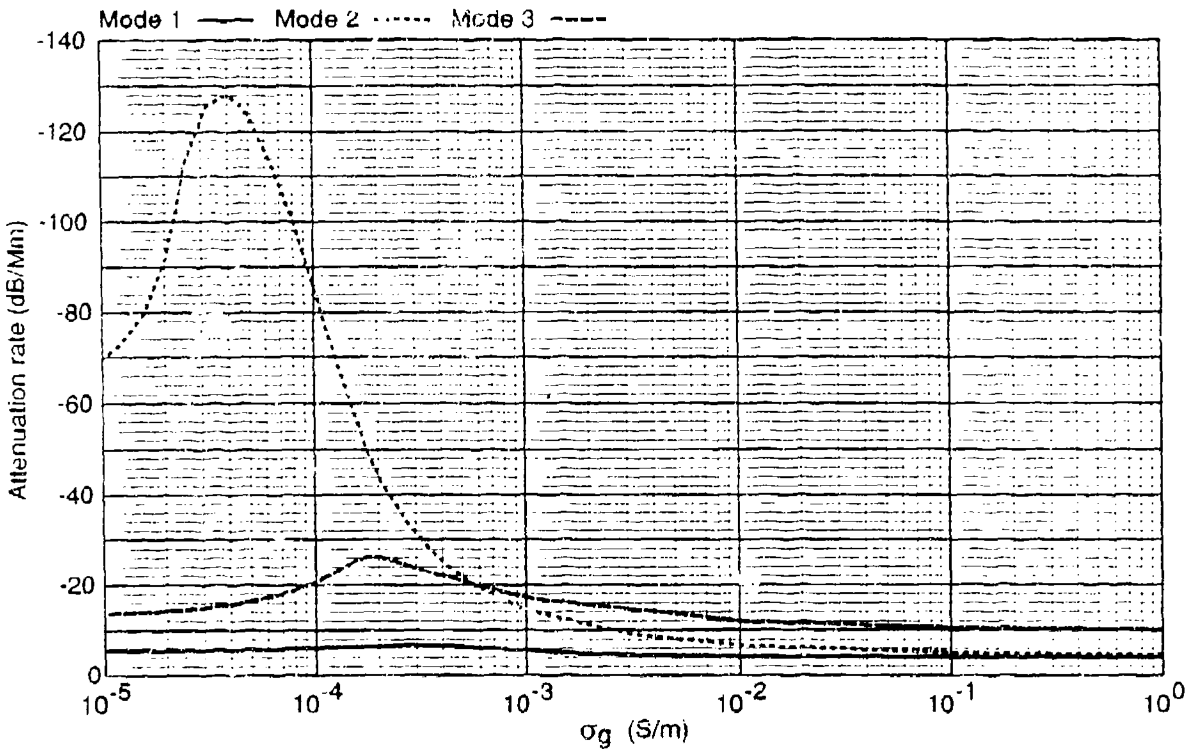
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 41. Parameters for $W = 2 \times 10^{-13}$, frequency = 40 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

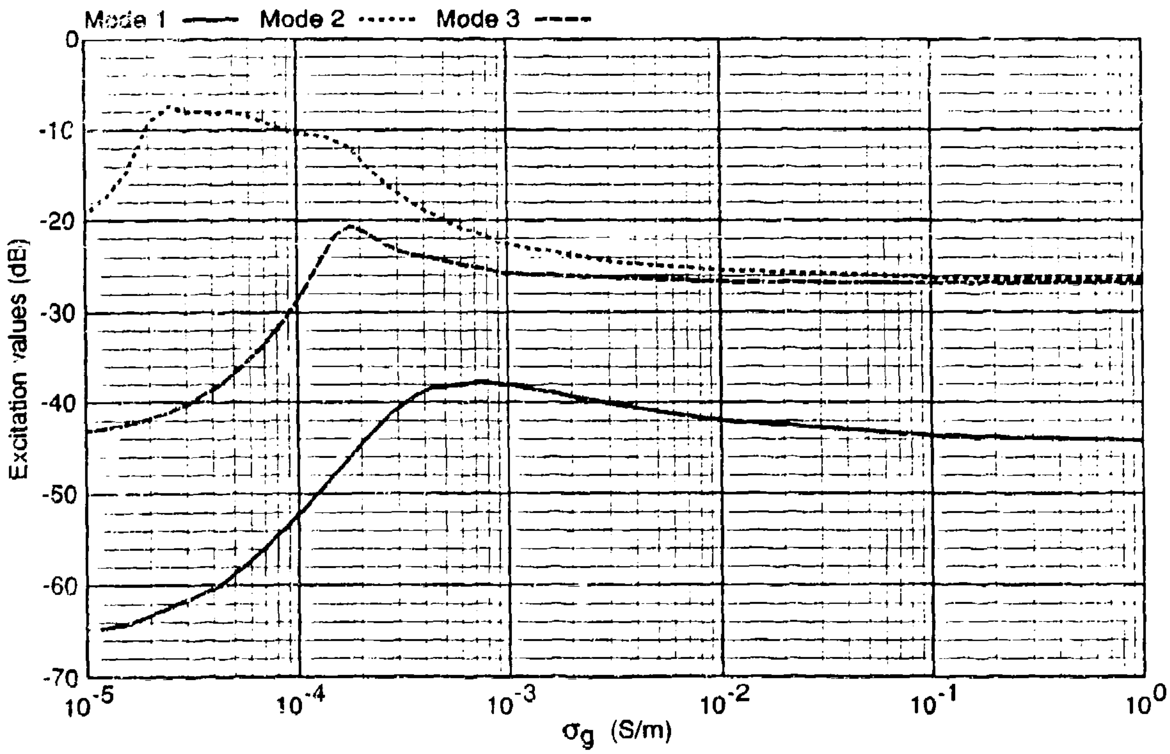
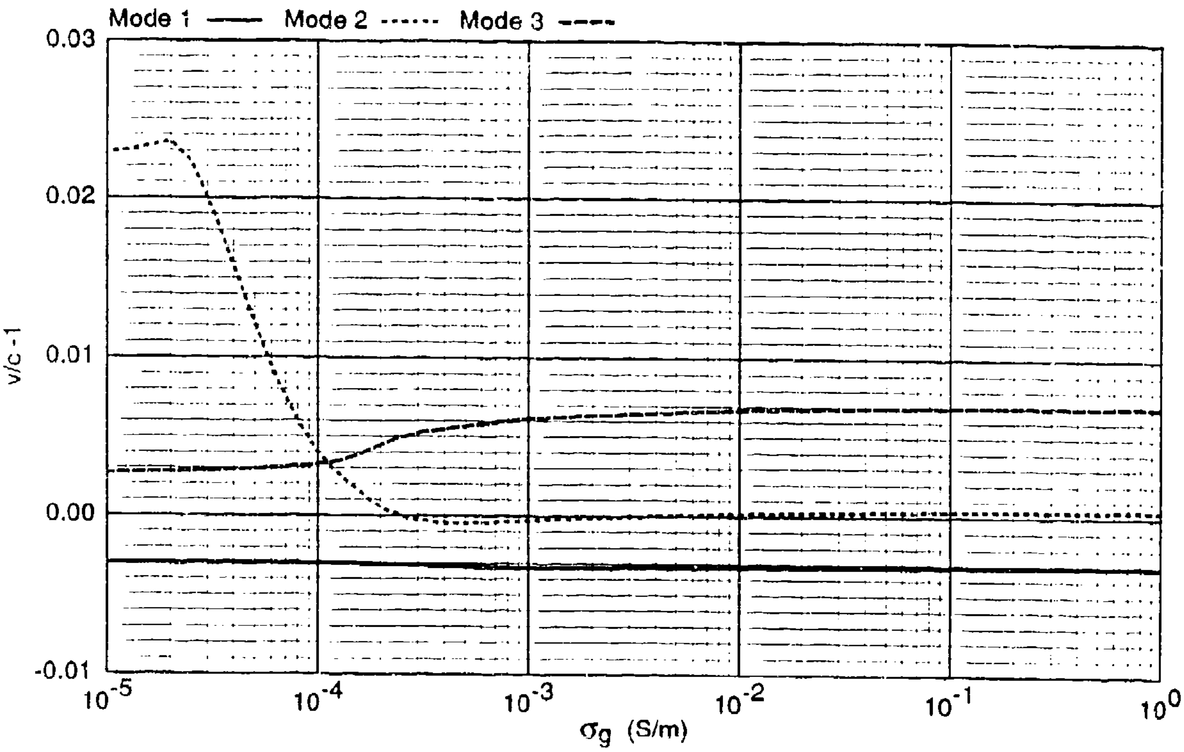
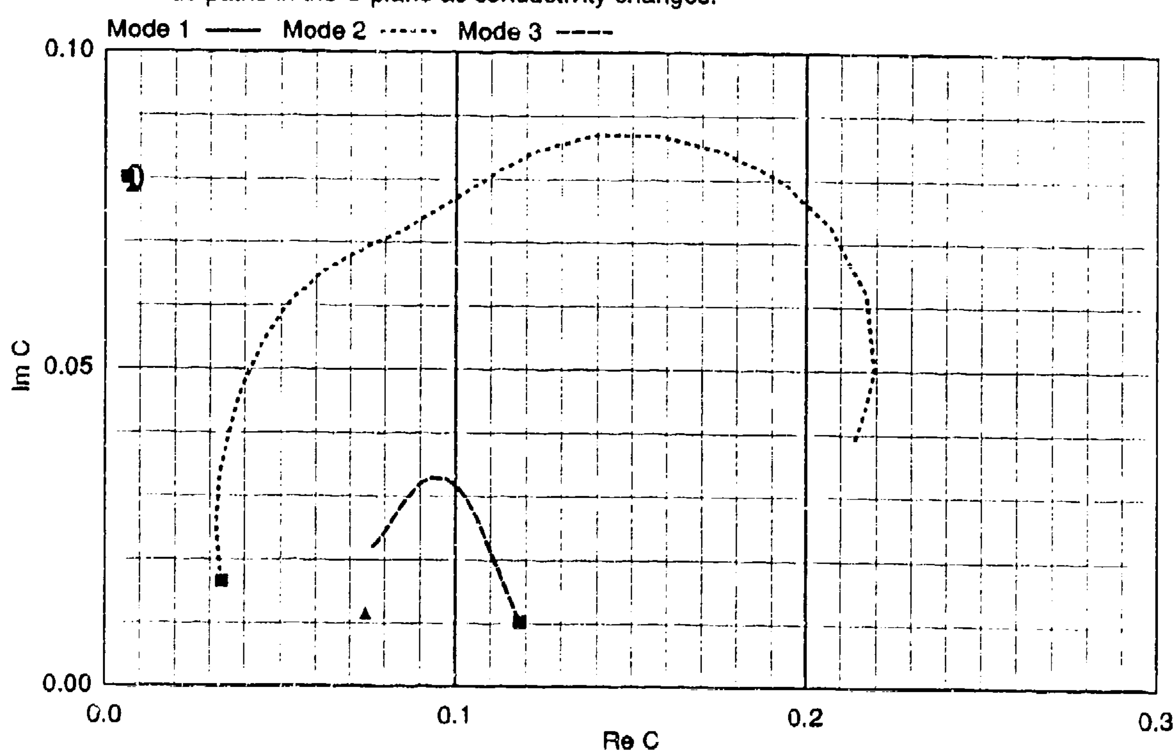


Figure 42. Parameters for $W = 2 \times 10^{-13}$, frequency = 45 kHz.

c. Relative phase velocity as a function of ground conductivity.

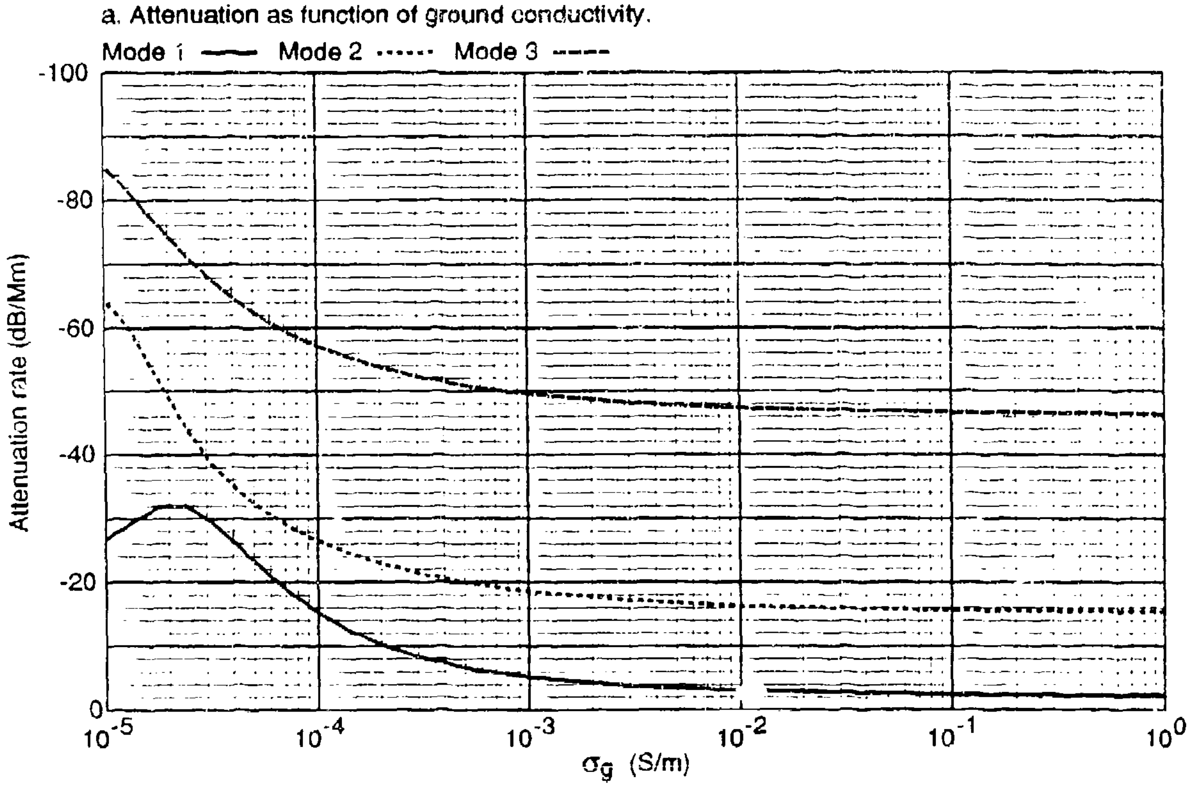


d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 42. Parameters for W = 2 x 10^{-13}, frequency = 45 kHz (Concluded).



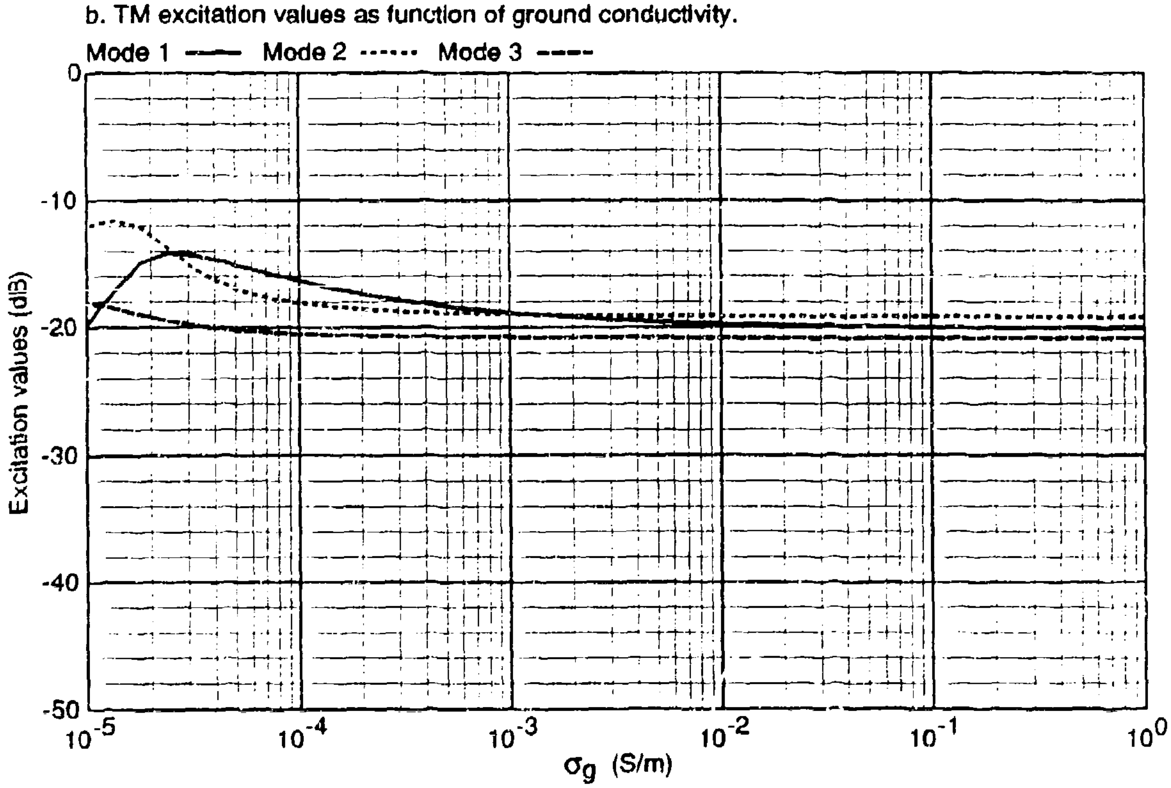
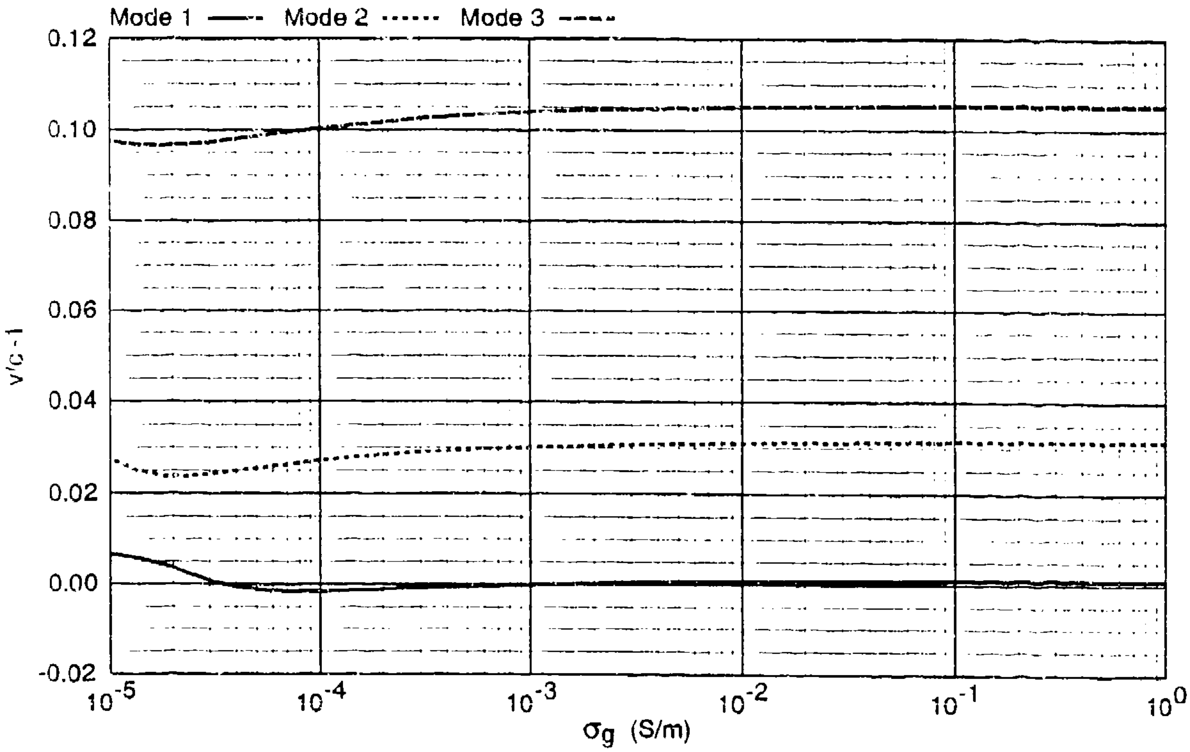
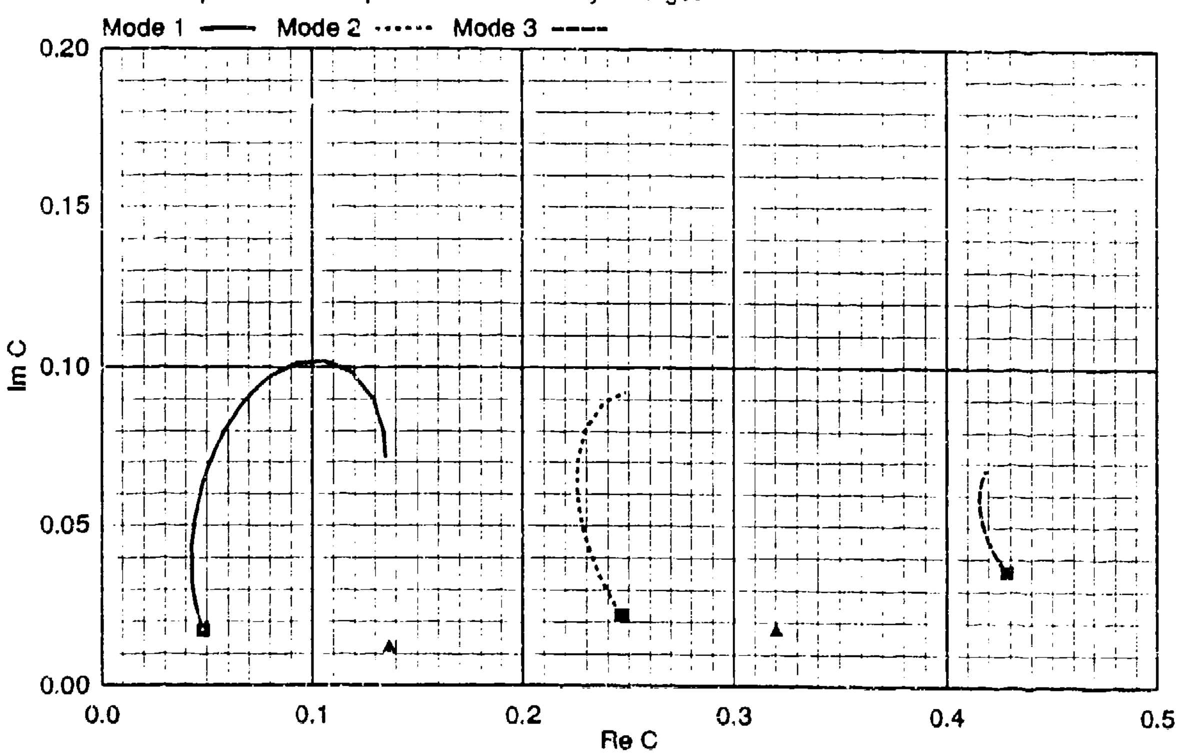


Figure 43. Parameters for $W = 2 \times 10^{-14}$, frequency = 15 kHz.

c. Relative phase velocity as a function of ground conductivity.



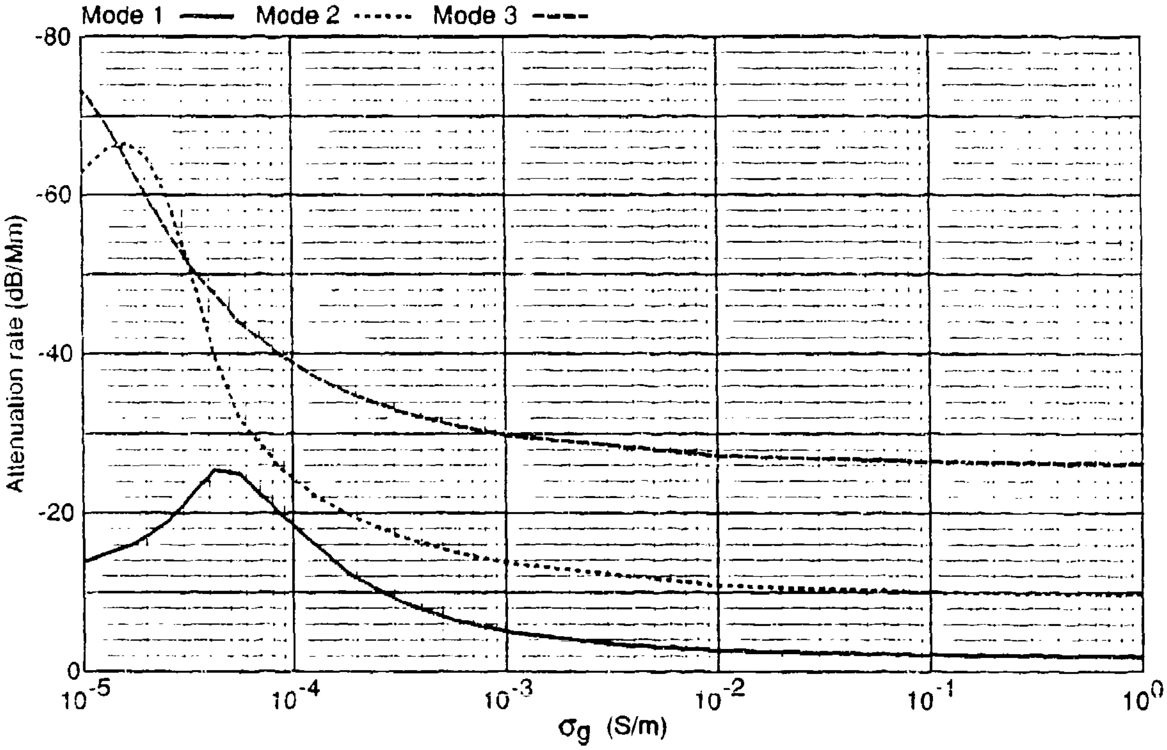
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 43. Parameters for W = 2 x 10^{-14}, frequency = 15 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

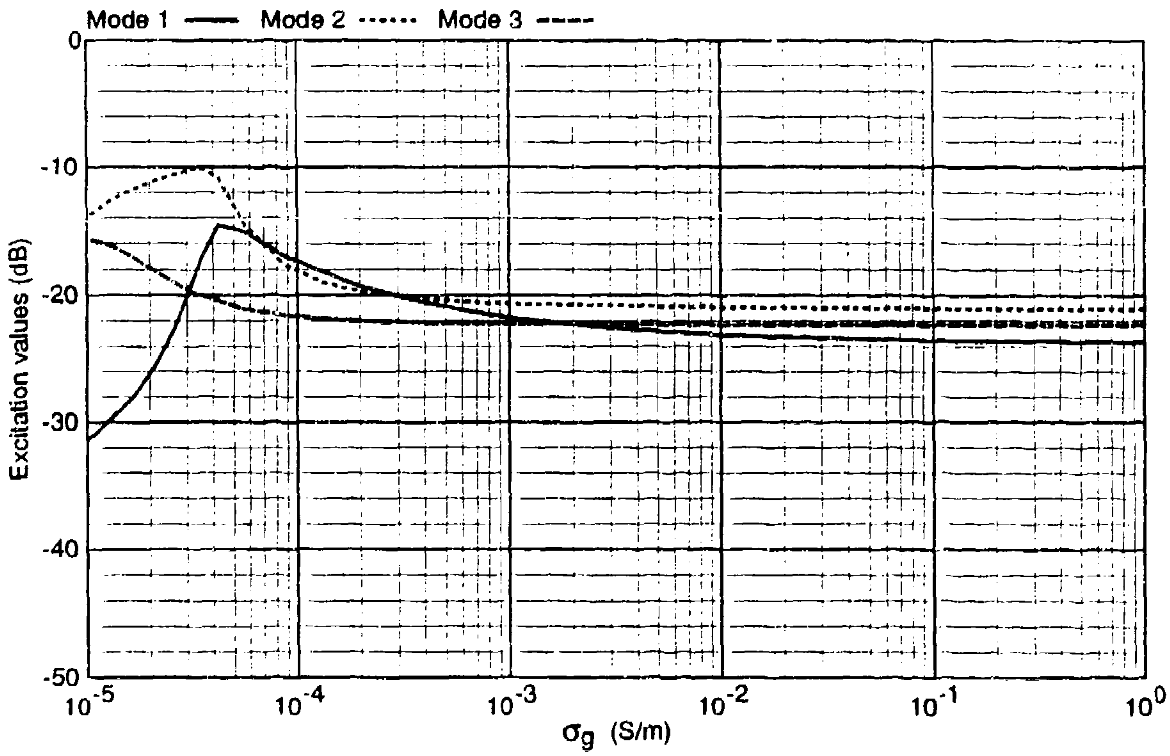
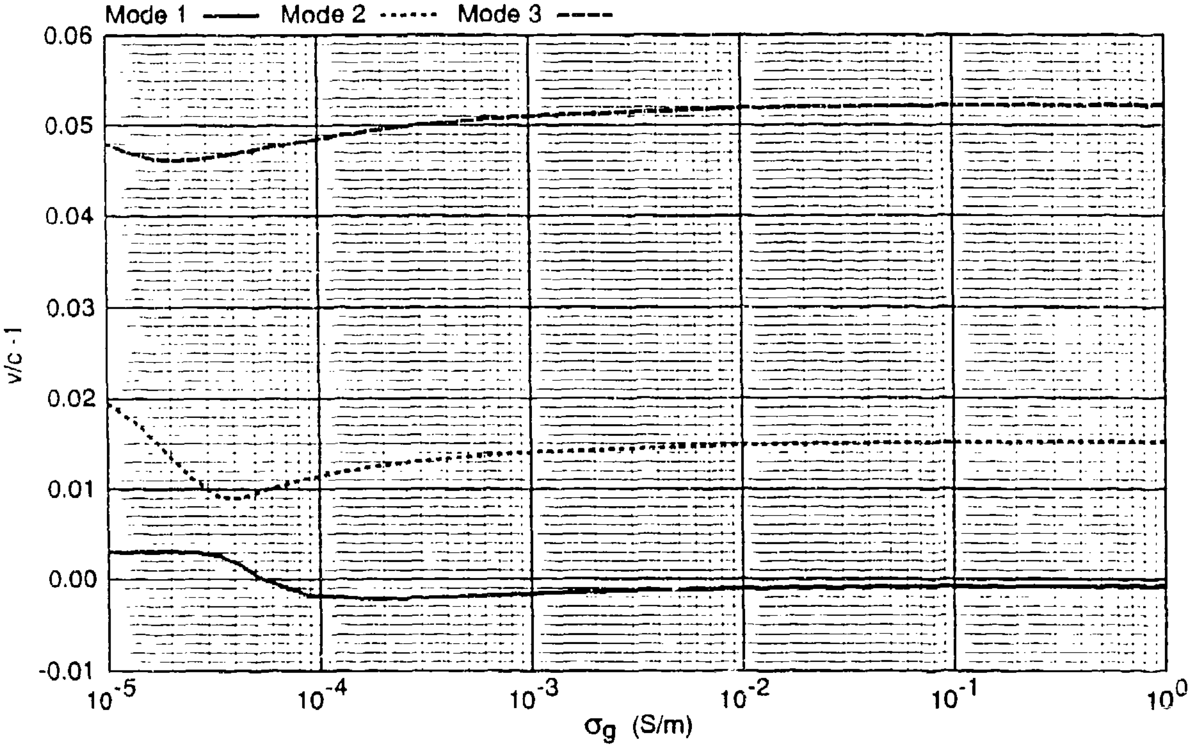
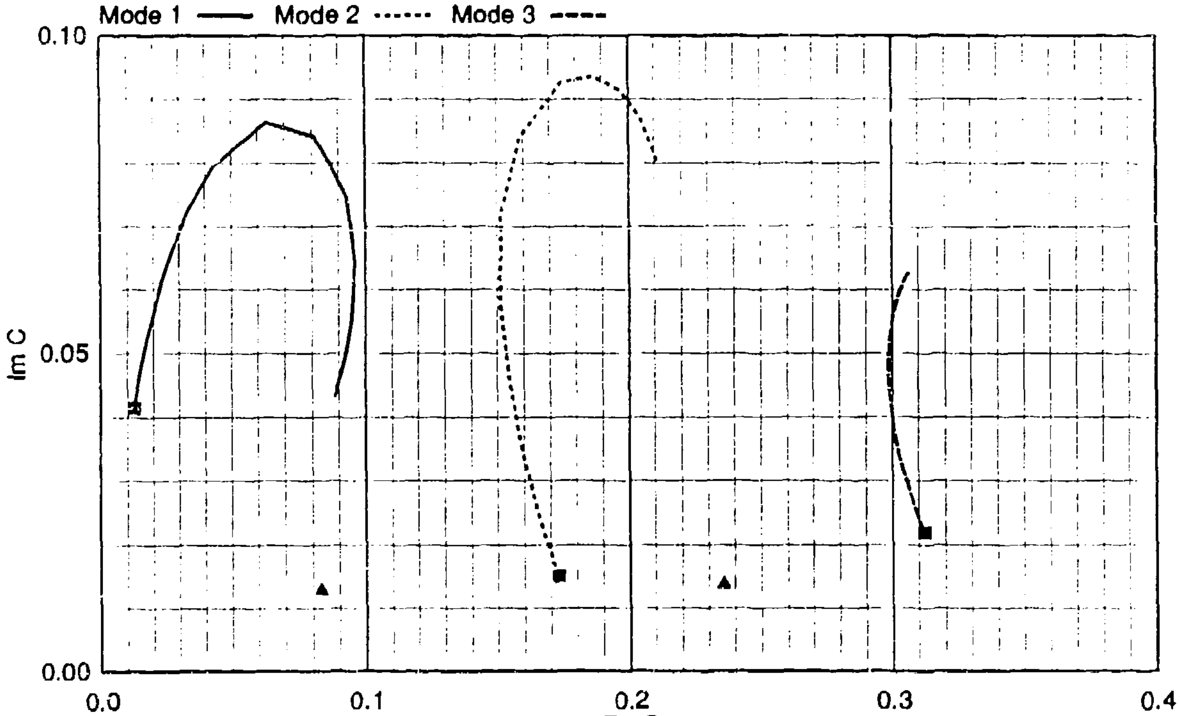


Figure 44. Parameters for $W = 2 \times 10^{-14}$, frequency = 20 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 44. Parameters for W = 2 x 10^{-14}, frequency = 20 kHz (Concluded).

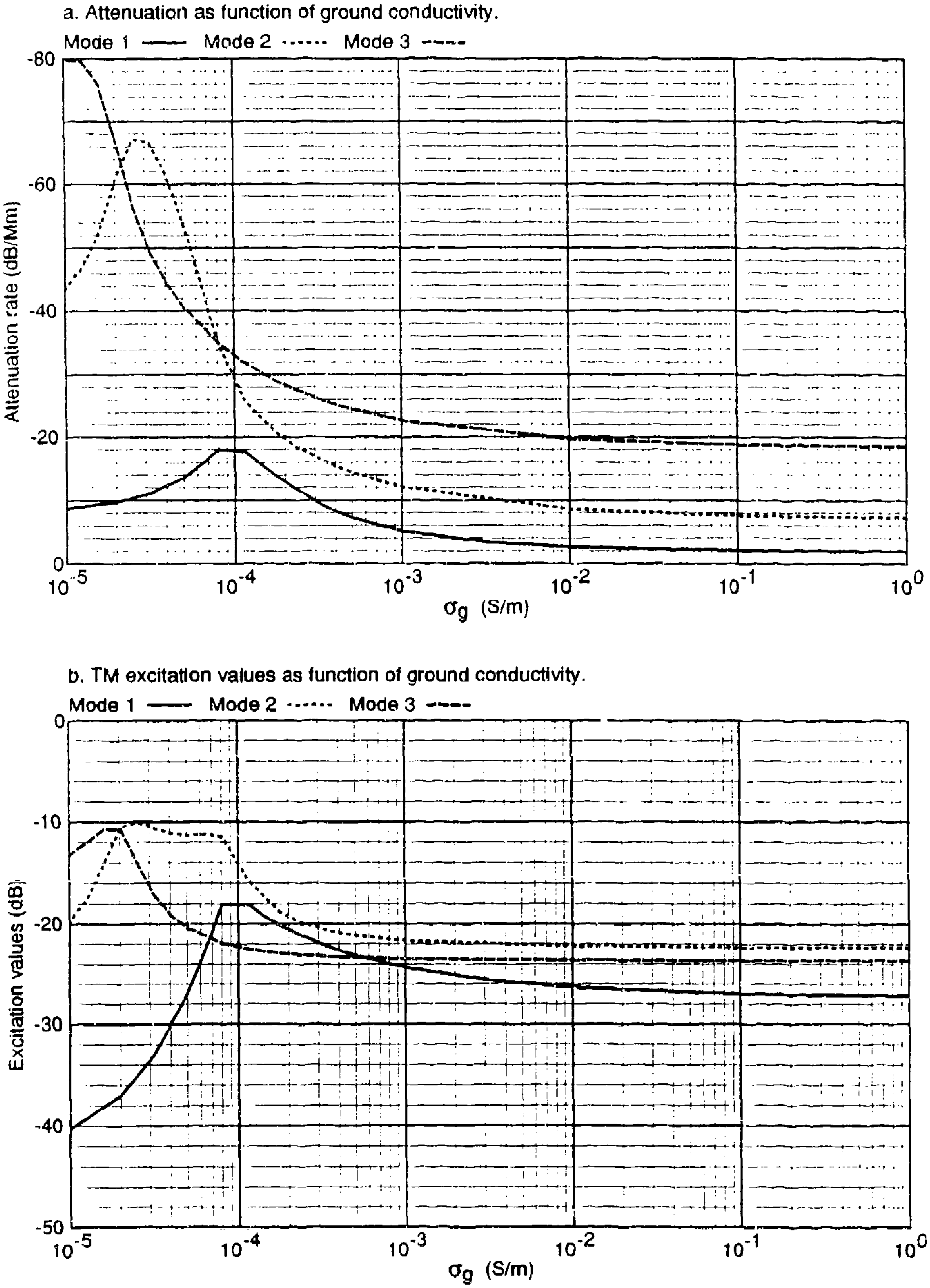
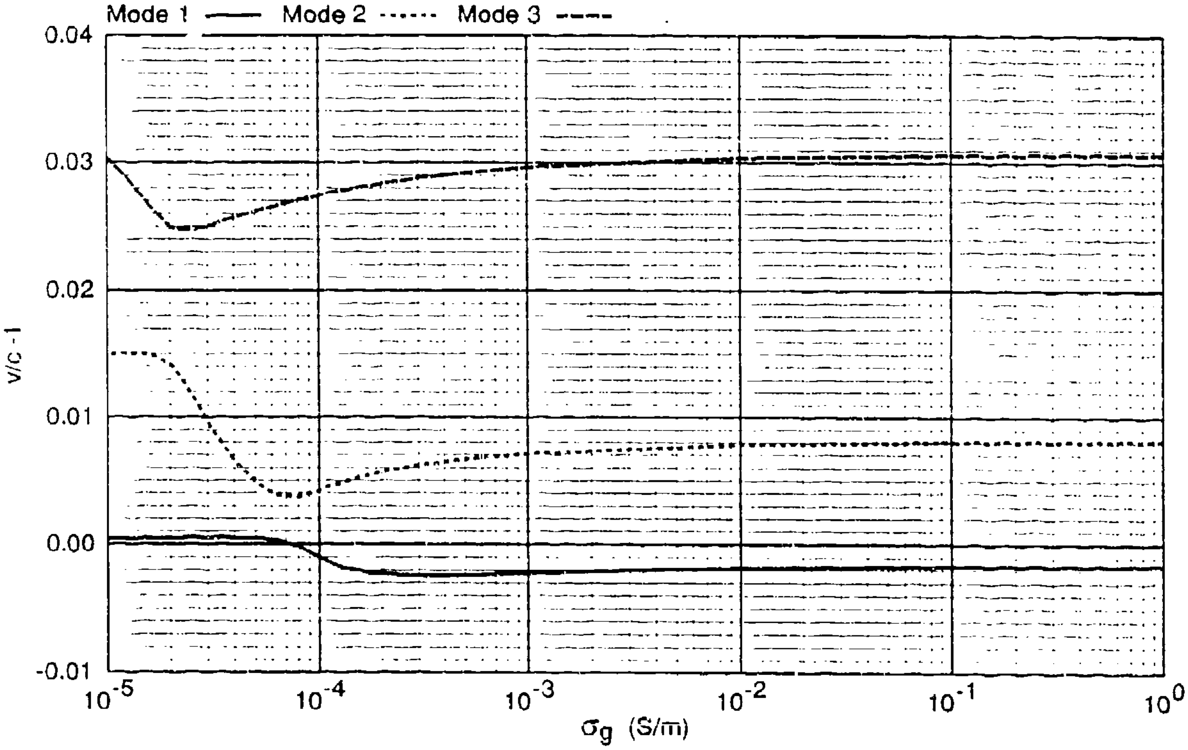
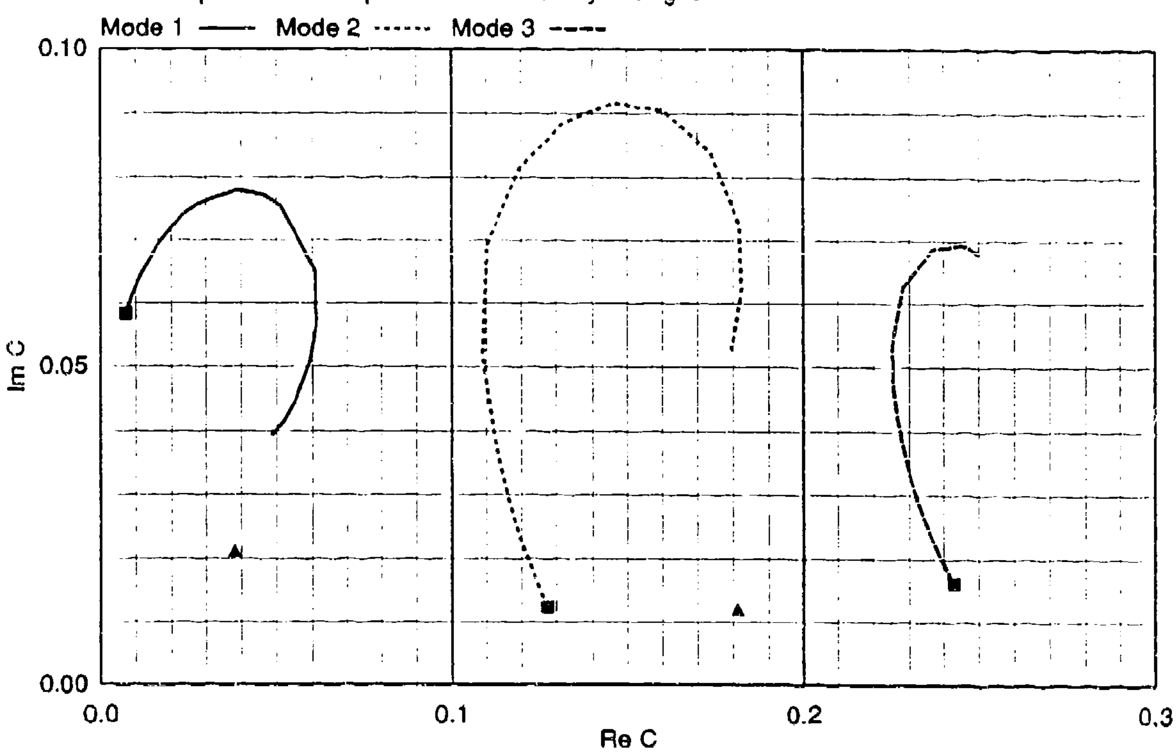


Figure 45. Parameters for $W = 2 \times 10^{-14}$, frequency = 25 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 45. Parameters for W = 2 x 10^{-14}, frequency = 25 kHz (Concluded).

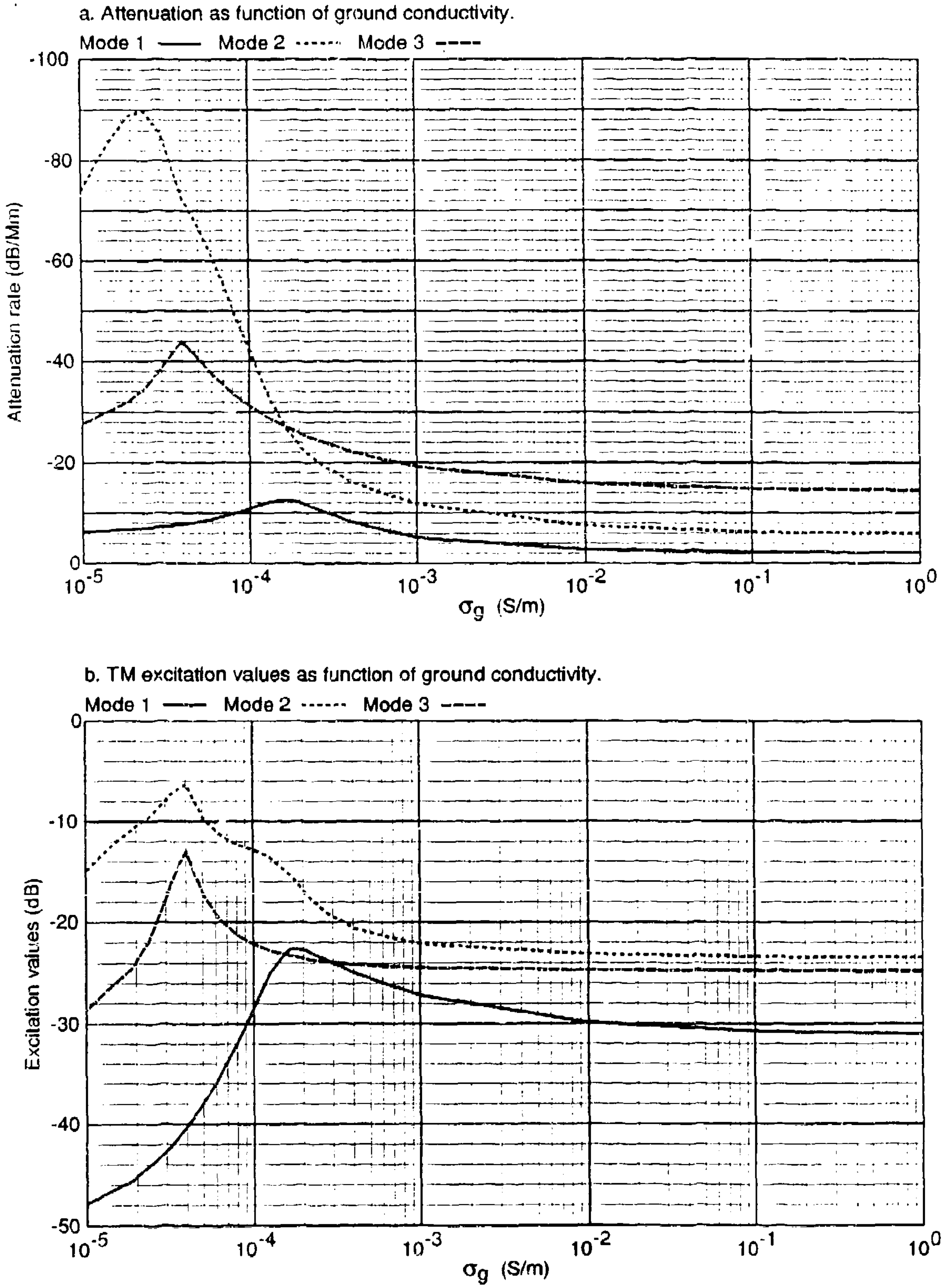
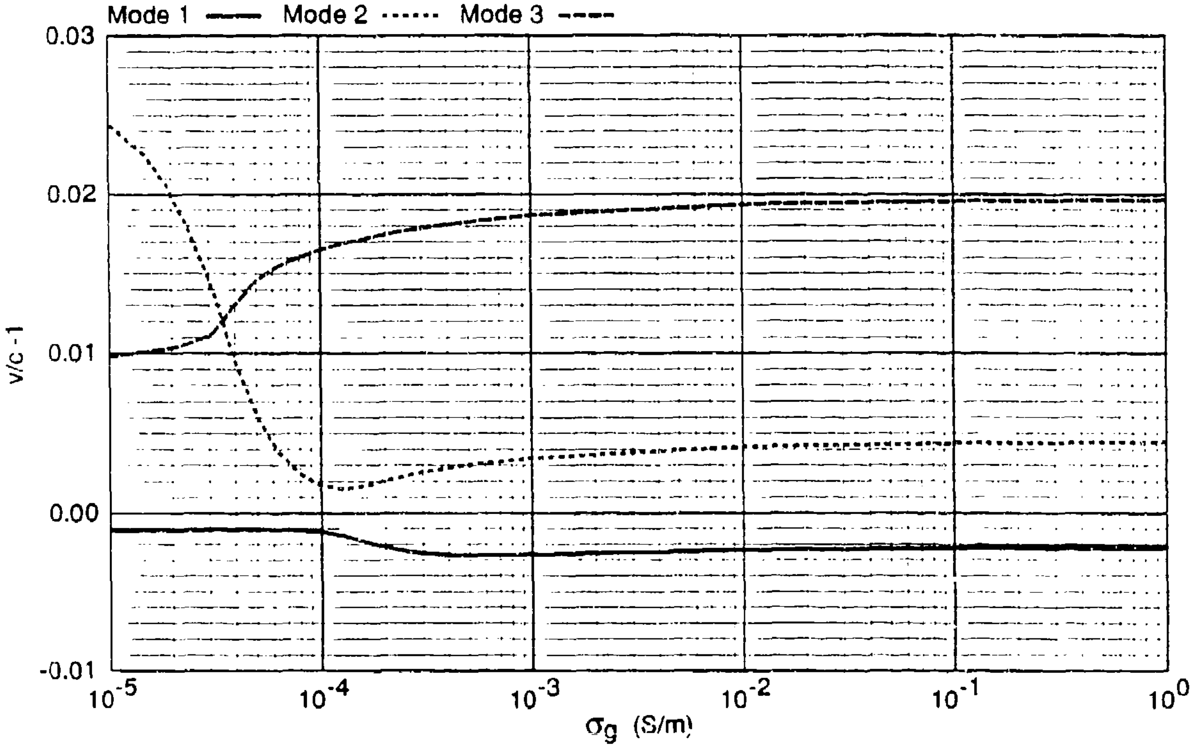
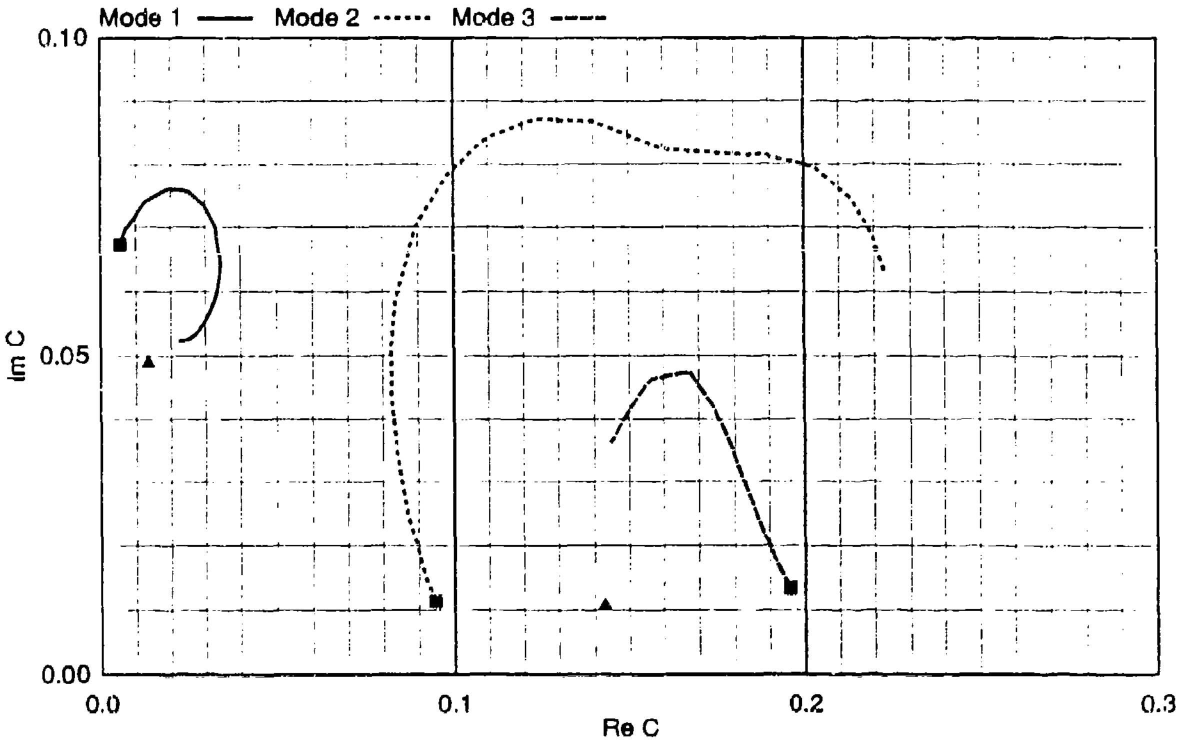


Figure 46. Parameters for $W = 2 \times 10^{-14}$, frequency = 30 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 46. Parameters for W = 2 x 10^{-14}, frequency = 30 kHz (Concluded).

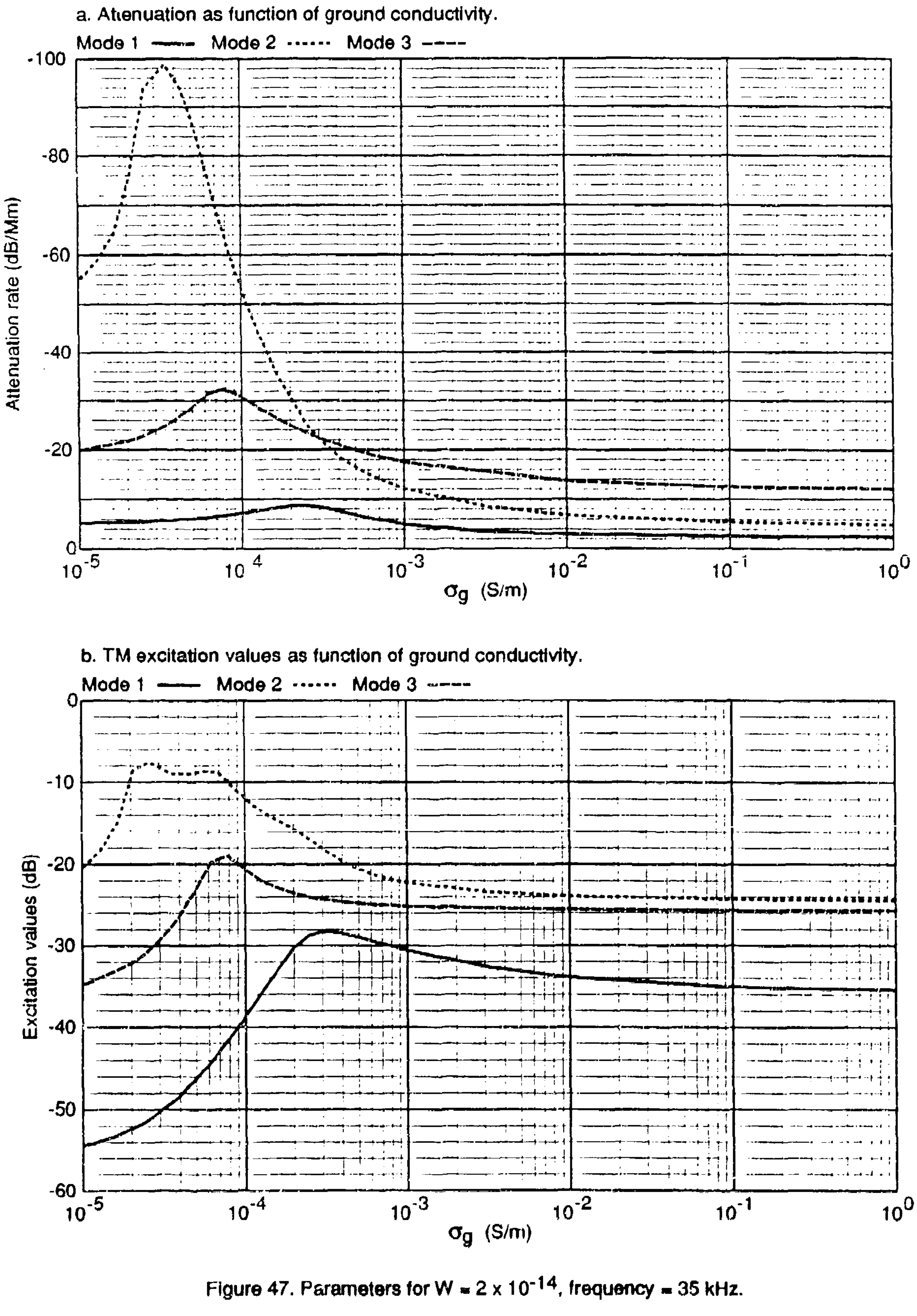
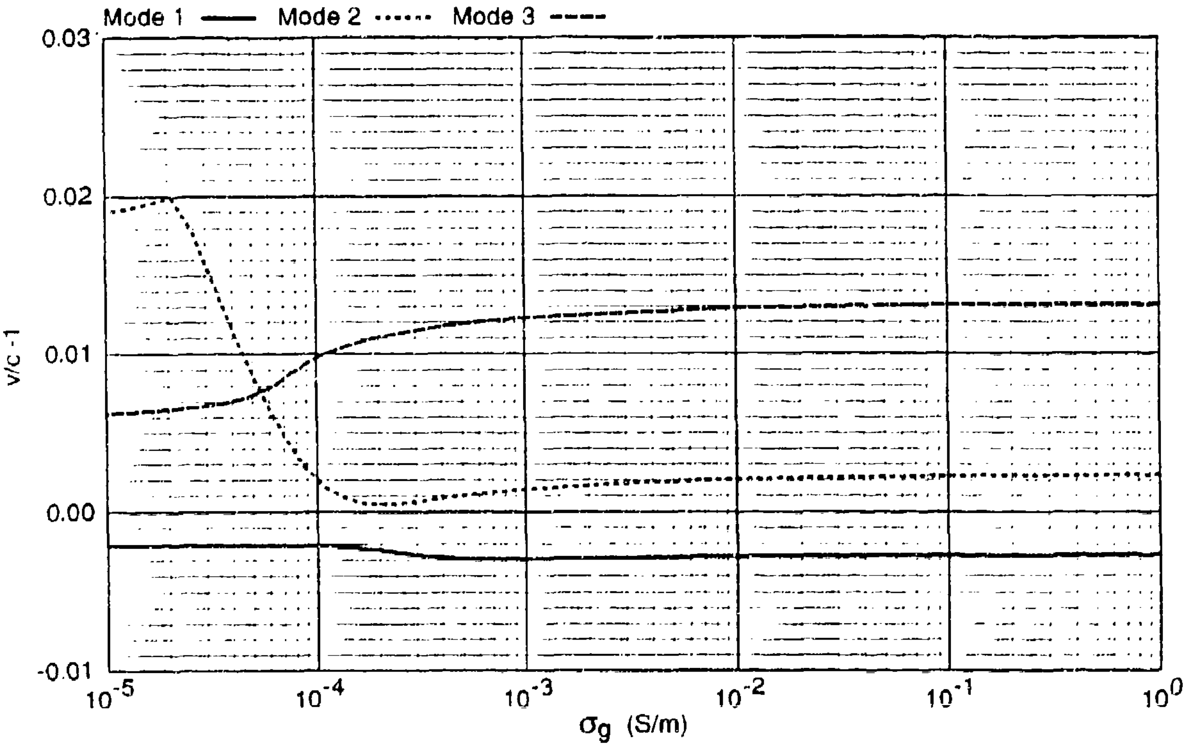
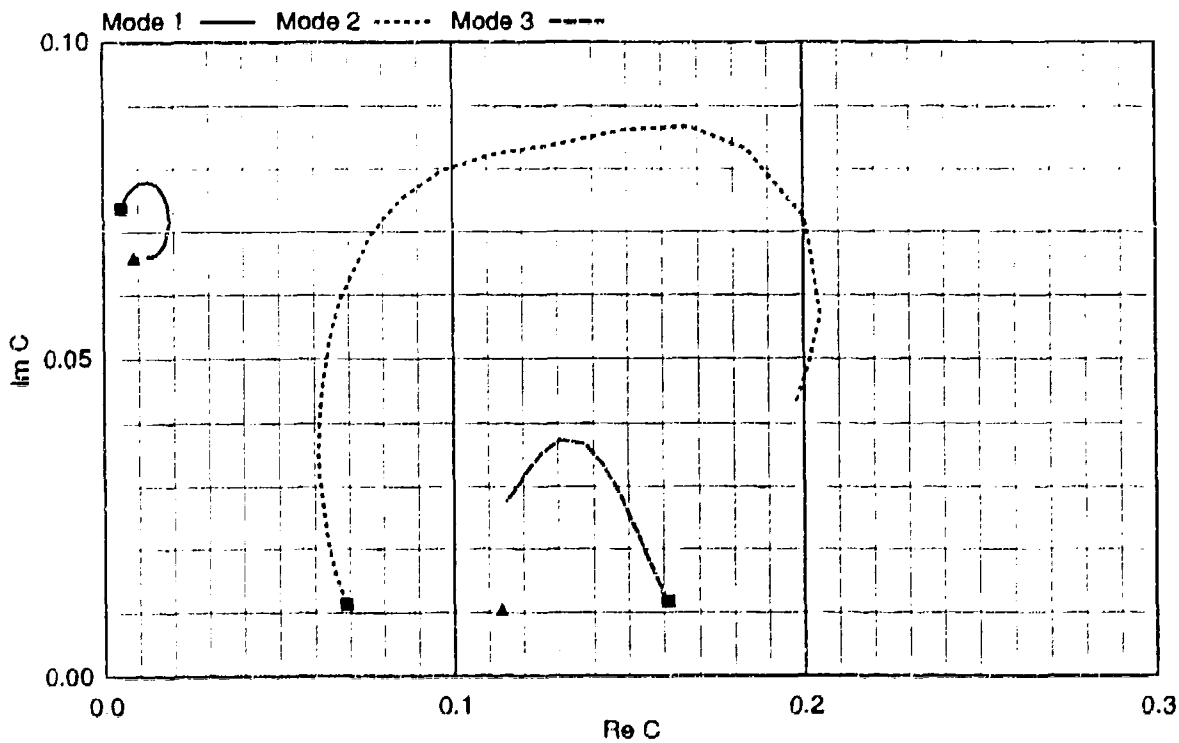


Figure 47. Parameters for $W = 2 \times 10^{-14}$, frequency = 35 kHz.

c. Relative phase velocity as a function of ground conductivity.



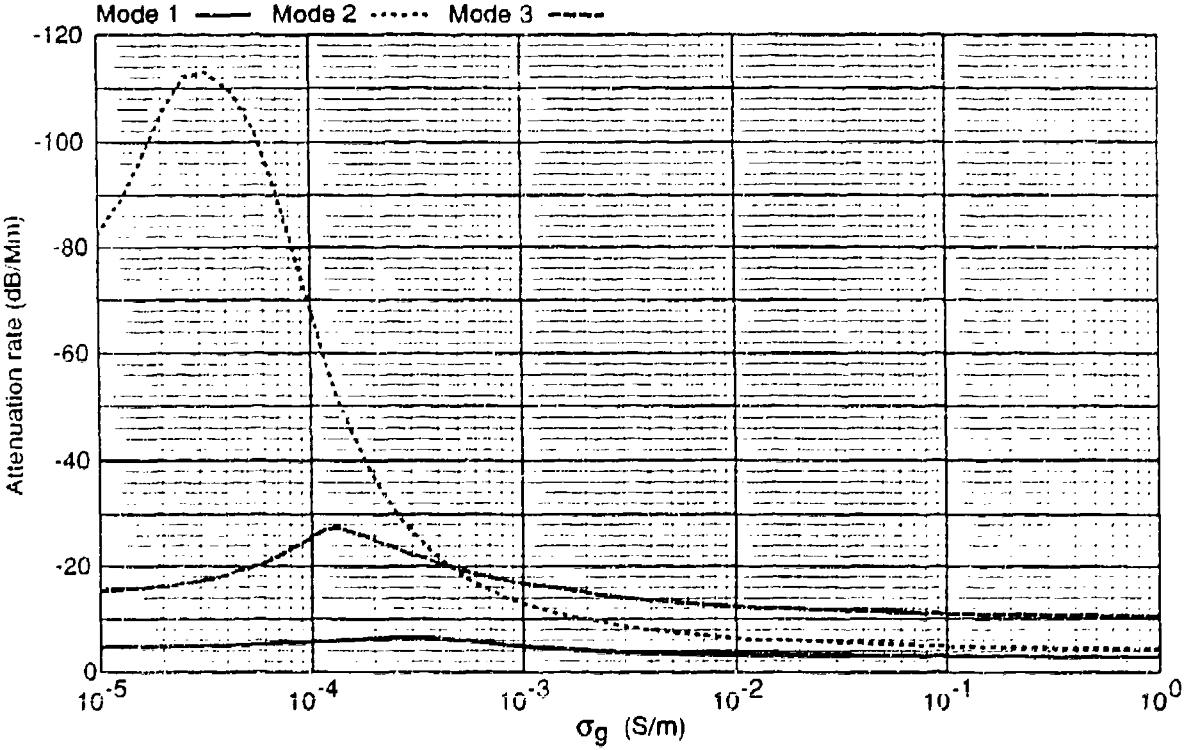
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 47. Parameters for W = 2×10^{-14}, frequency = 35 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

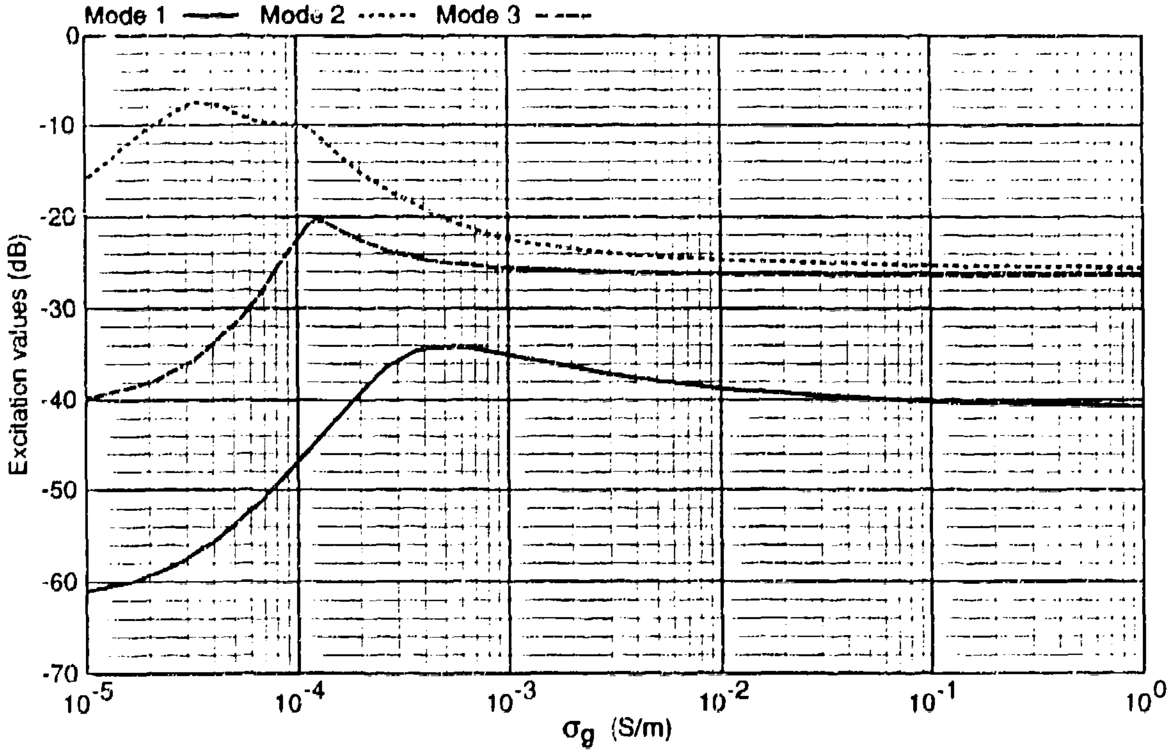
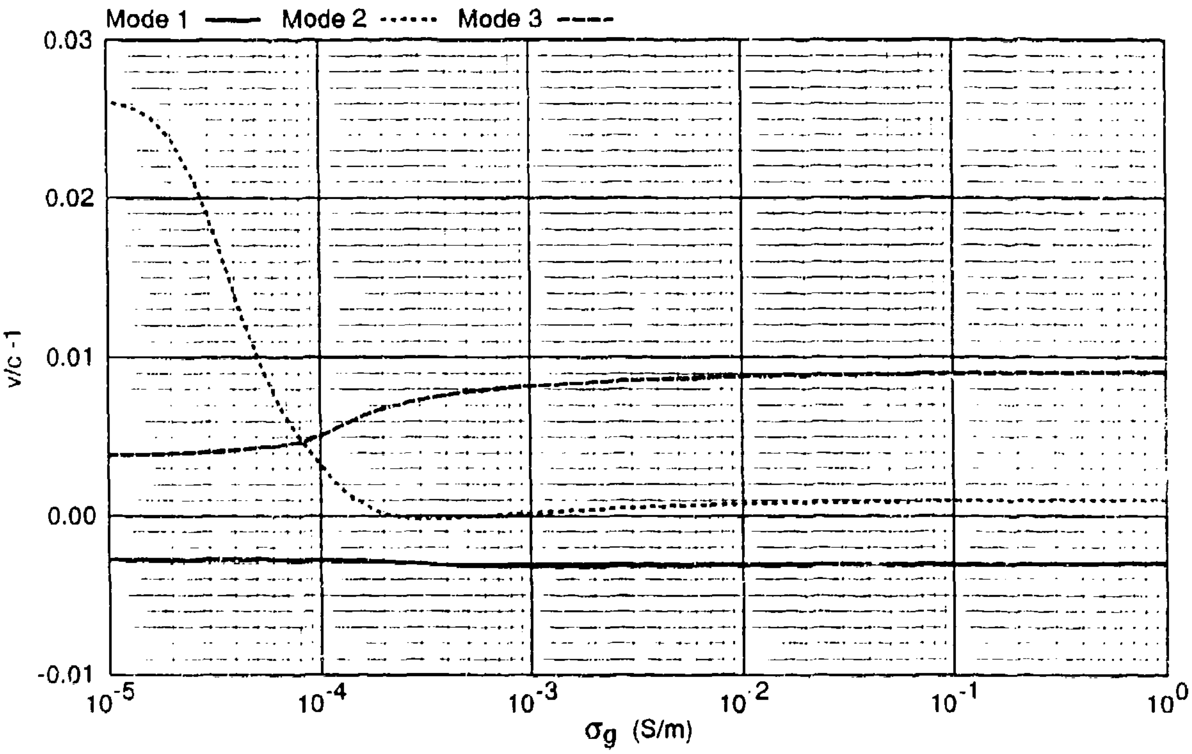
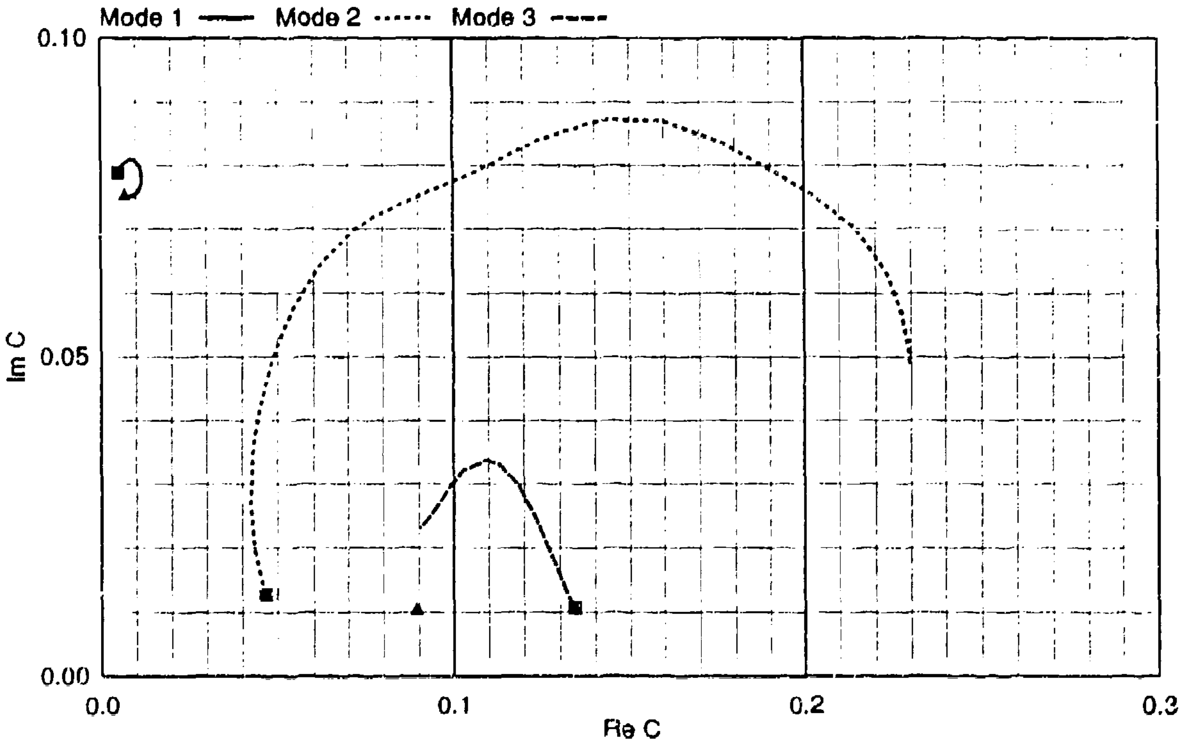


Figure 48. Parameters for $W = 2 \times 10^{-14}$, frequency = 40 kHz.

c. Relative phase velocity as a function of ground conductivity.



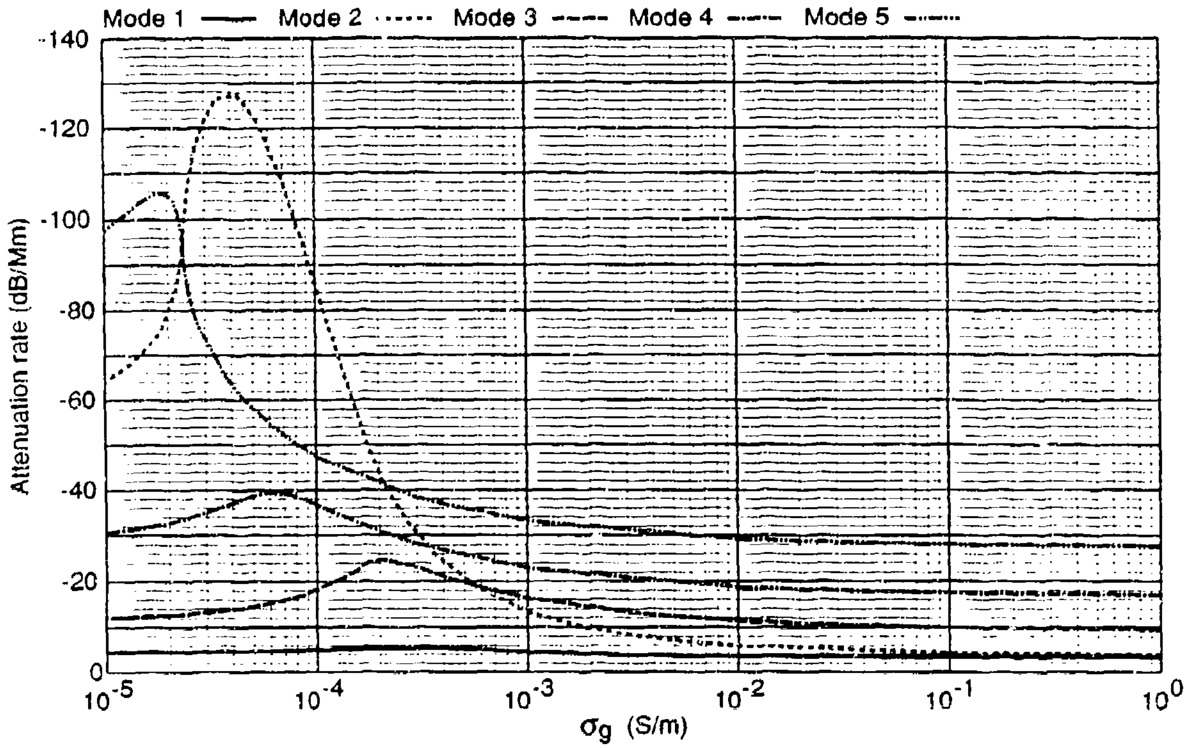
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 48. Parameters for W = 2 x 10^{-14}, frequency = 40 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

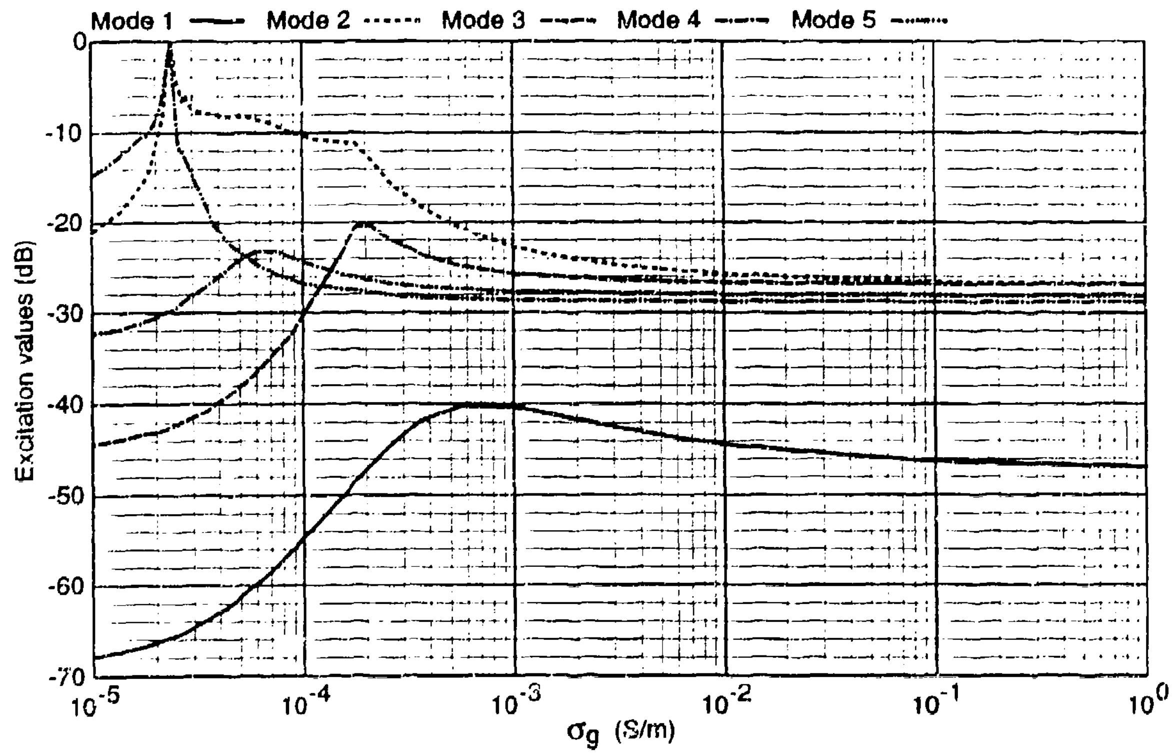
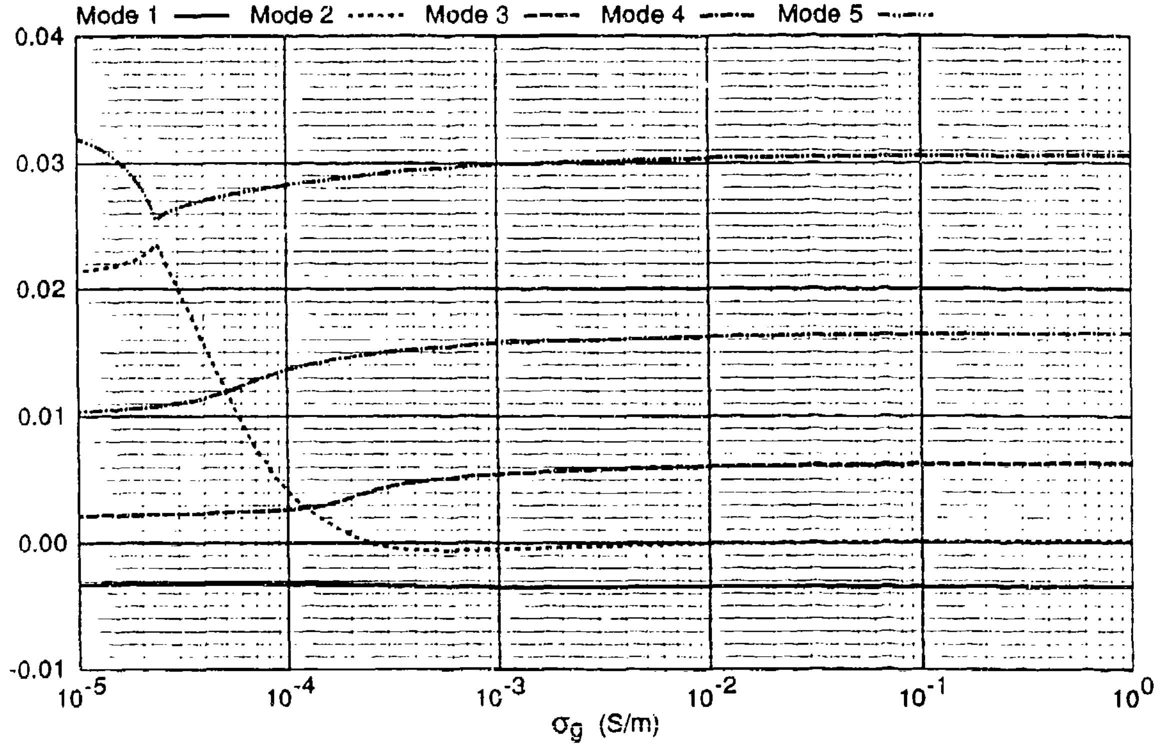
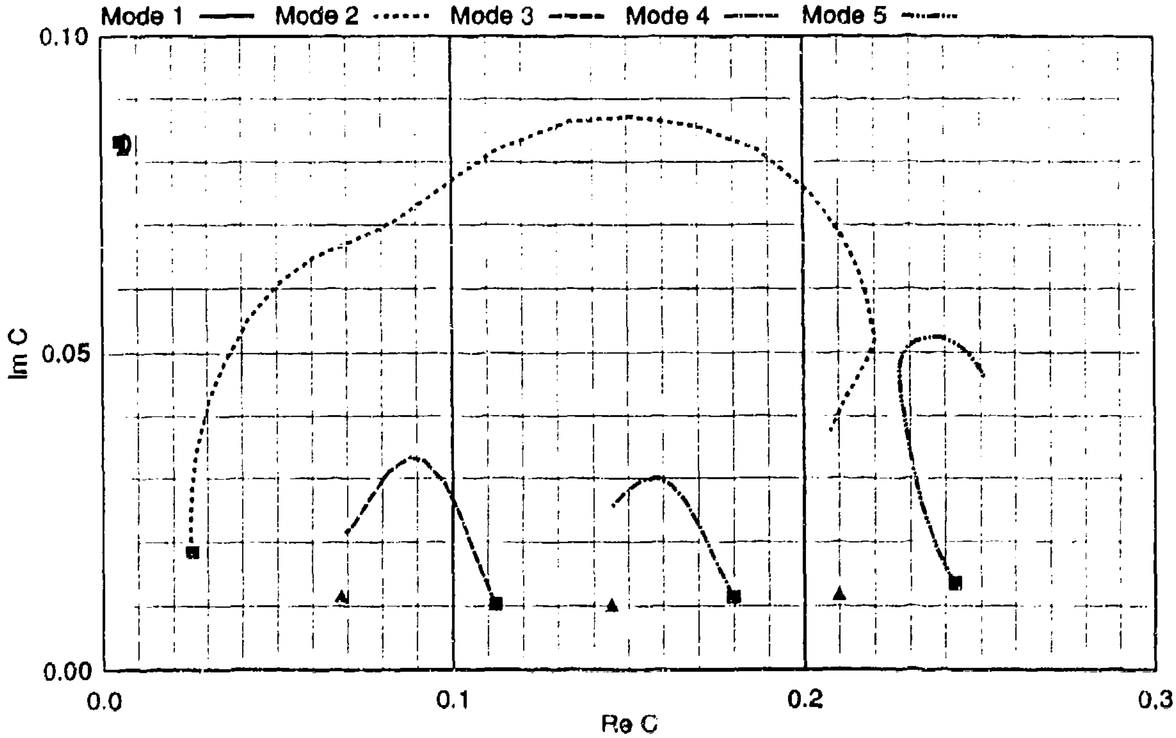


Figure 49. Parameters for $W = 2 \times 10^{-14}$, frequency = 45 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 49. Parameters for W = 2 x 10^{-14}, frequency = 45 kHz (Concluded).

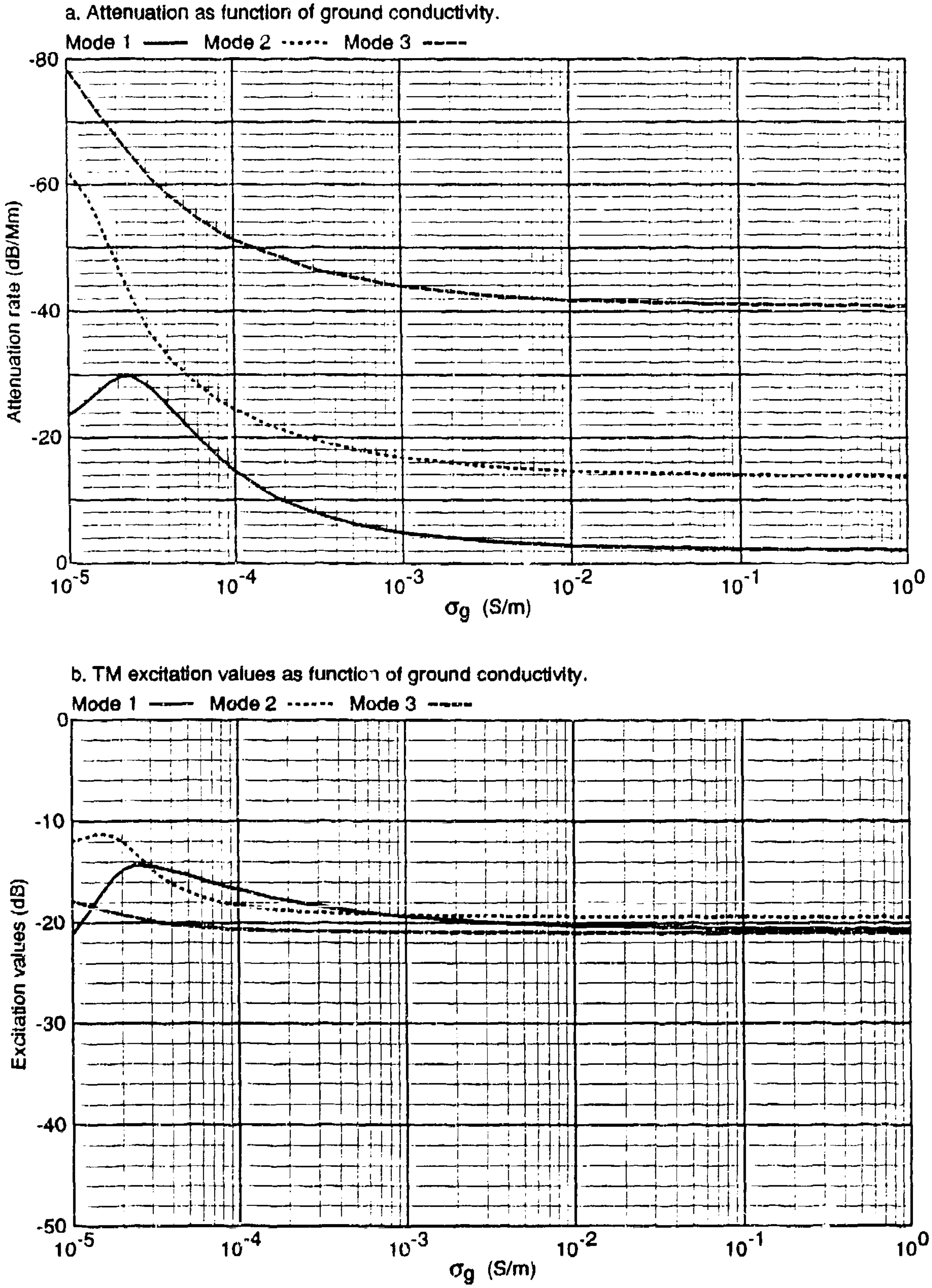
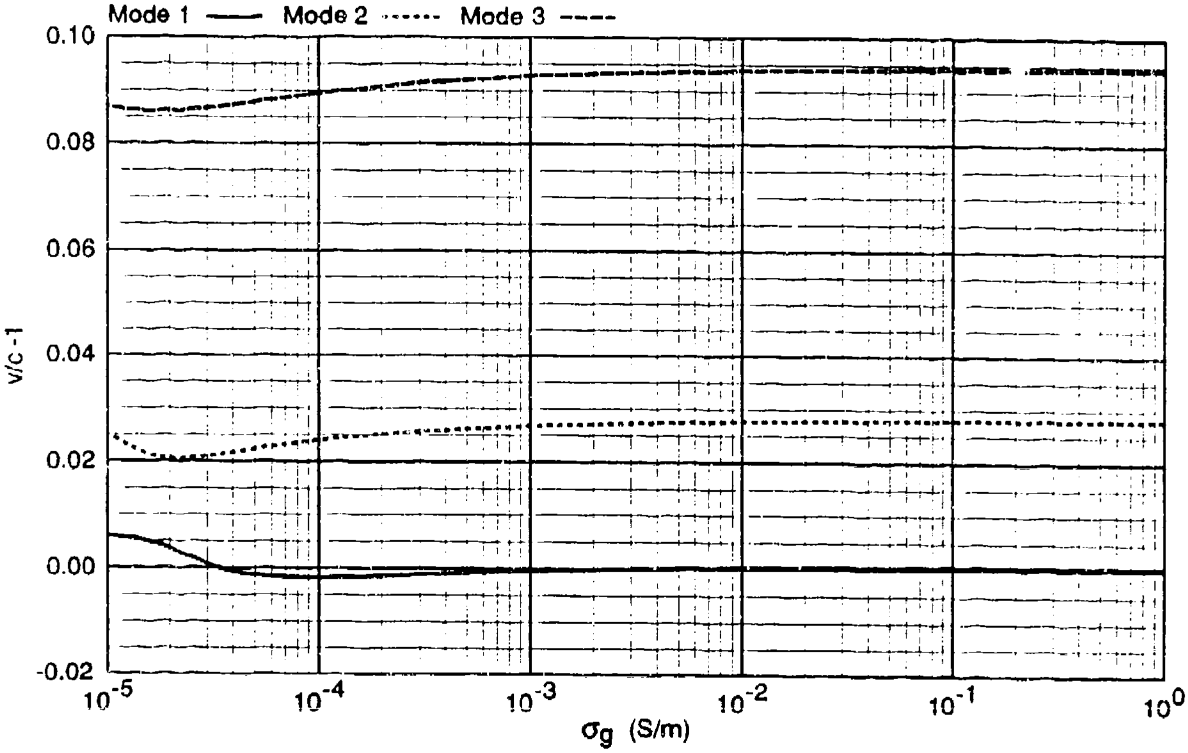
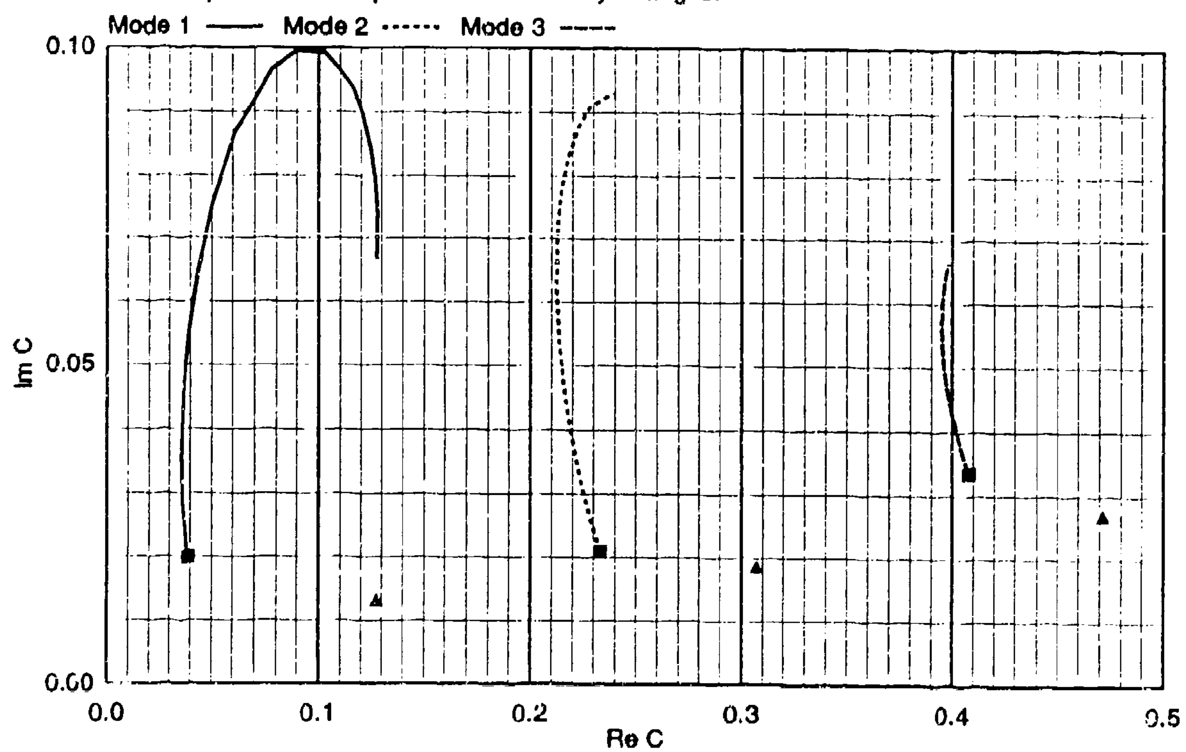


Figure 50. Parameters for $W = 2 \times 10^{-15}$, frequency = 15 kHz.

c. Relative phase velocity as a function of ground conductivity.

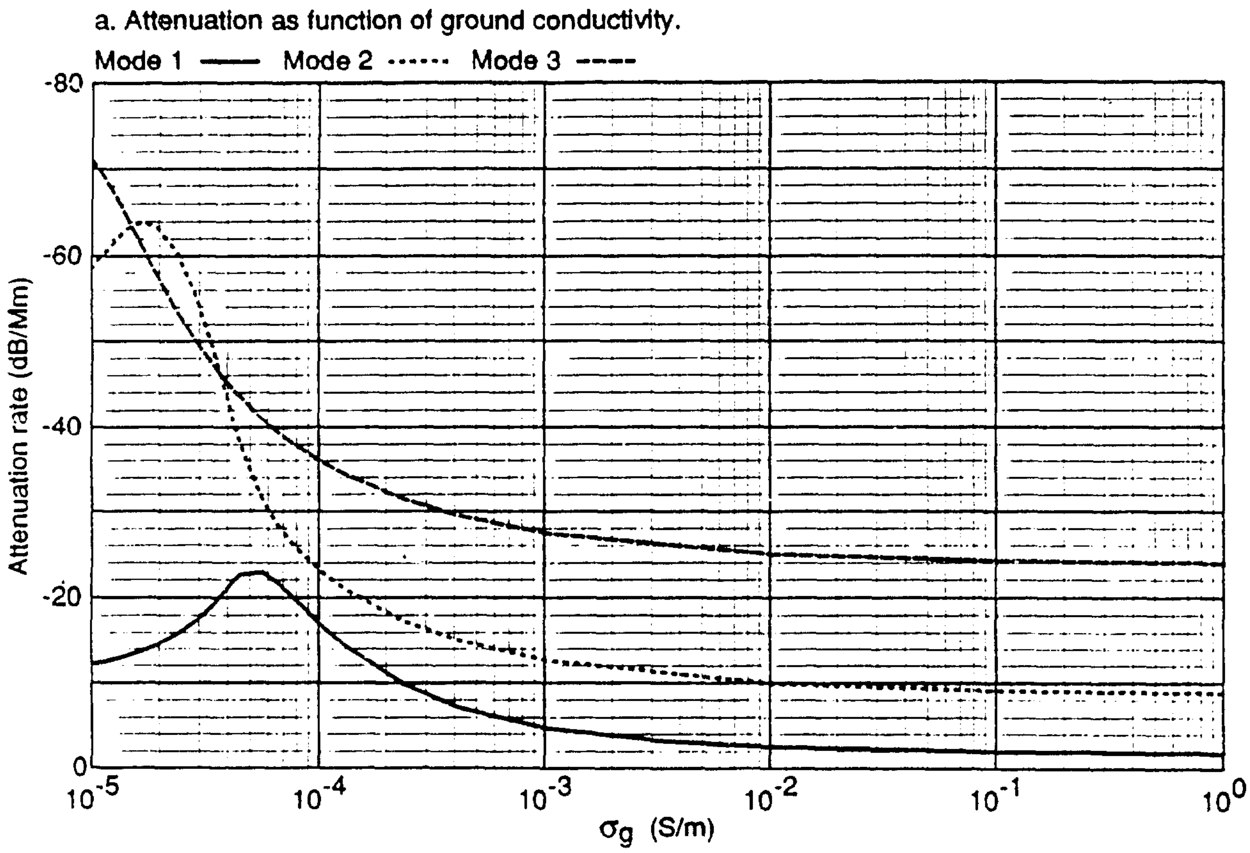


d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 50. Parameters for $W = 2 \times 10^{-15}$, frequency = 15 kHz (Concluded).



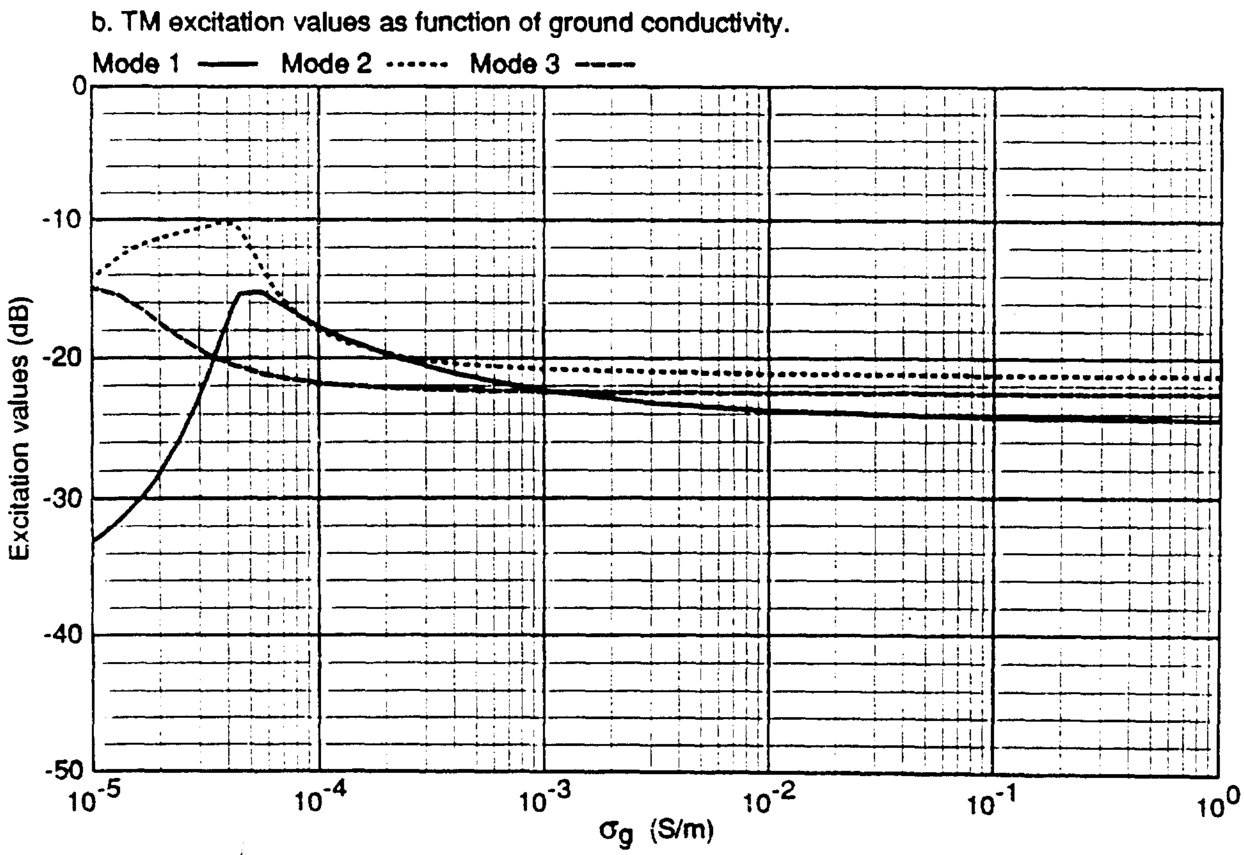
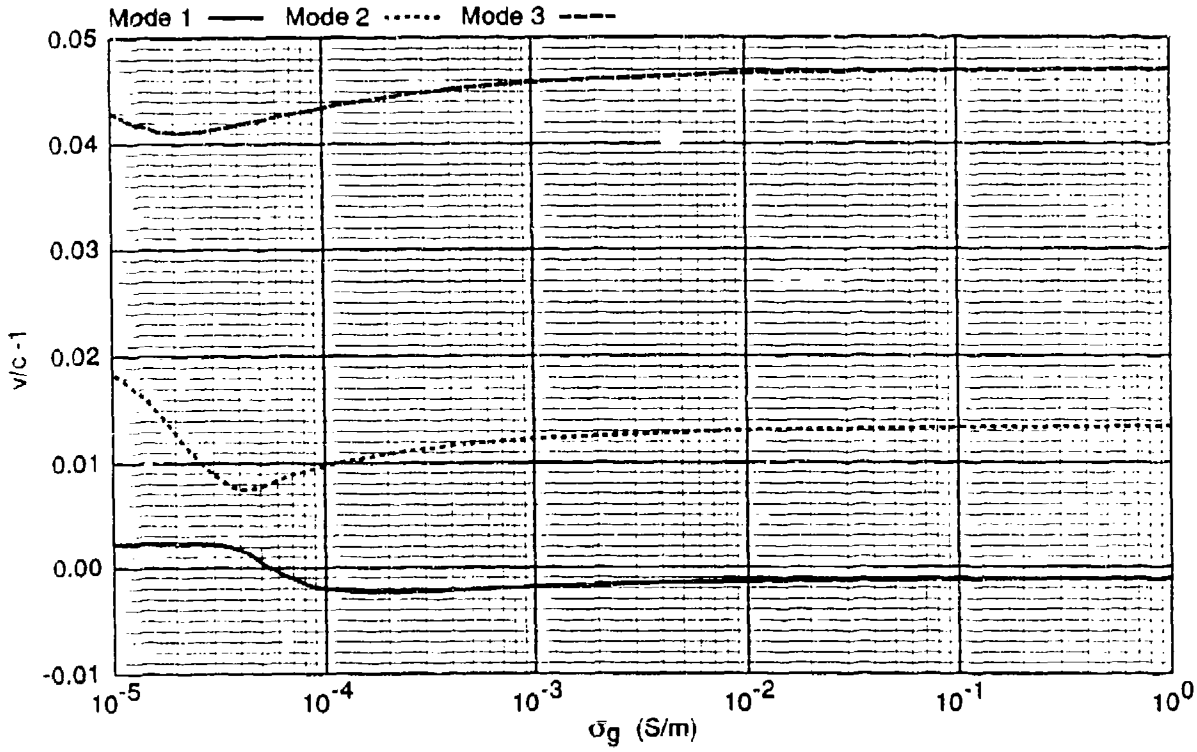
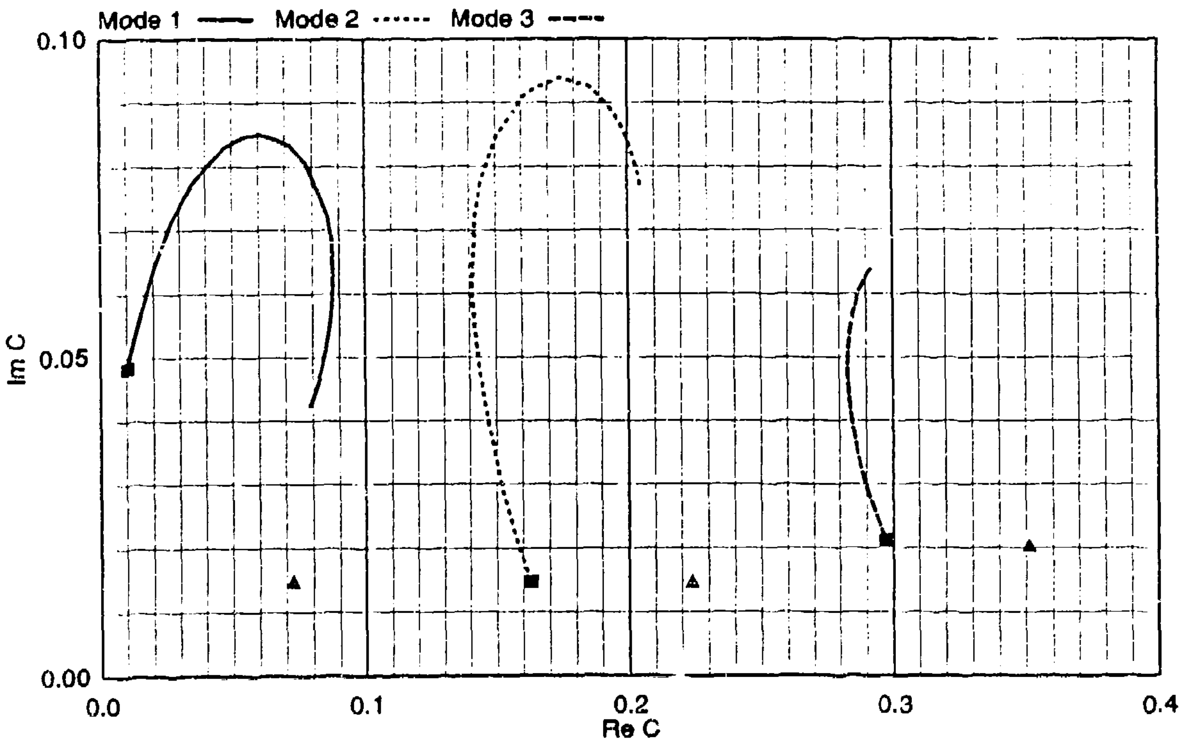


Figure 51. Parameters for $W = 2 \times 10^{-15}$, frequency = 20 kHz.

c. Relative phase velocity as a function of ground conductivity.



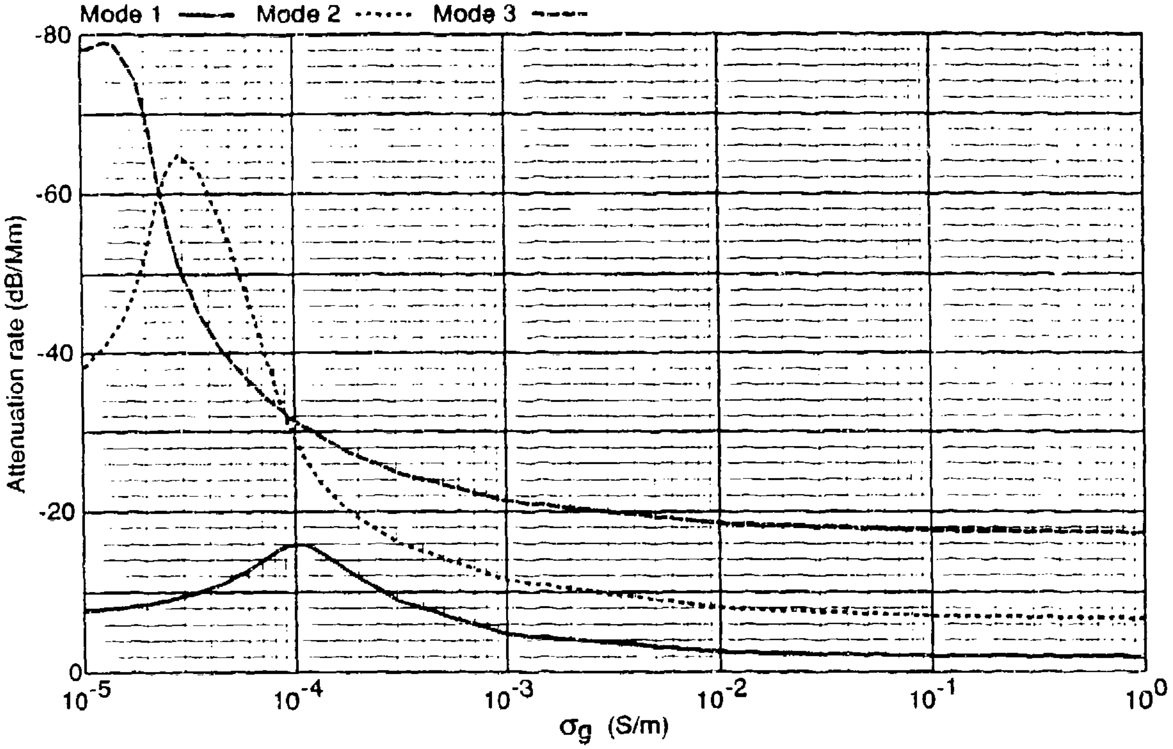
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 51. Parameters for W = 2 x 10^{-15}, frequency = 20 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

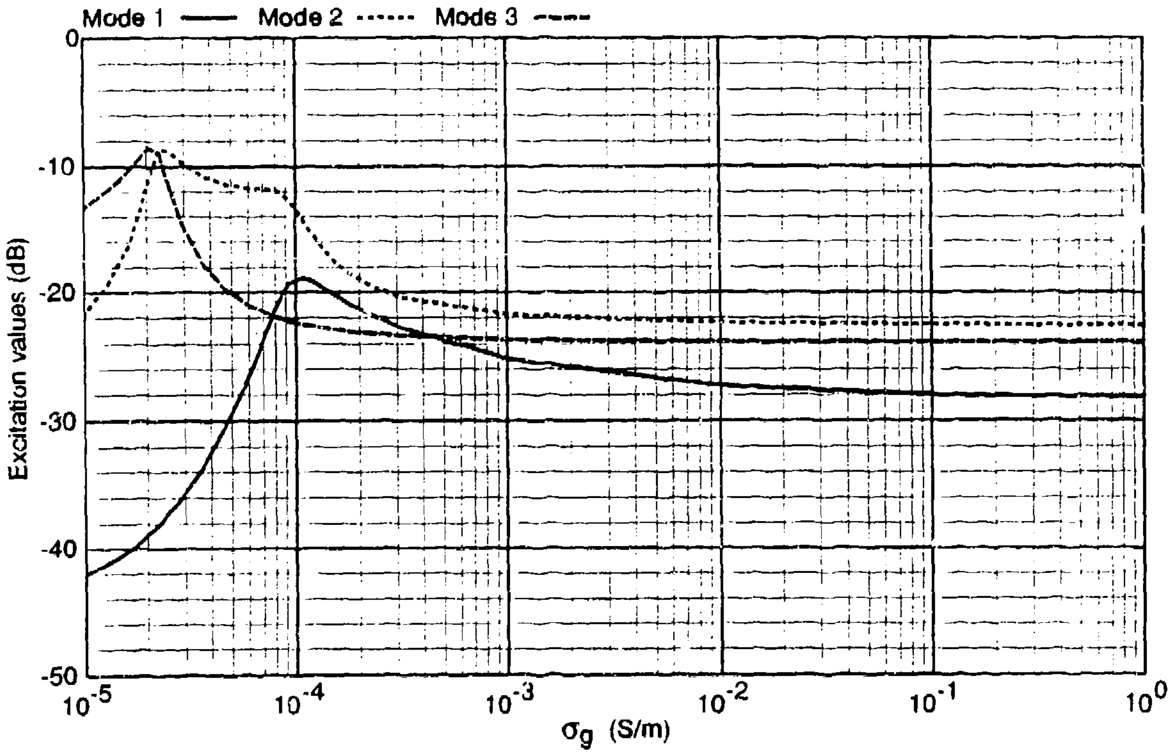
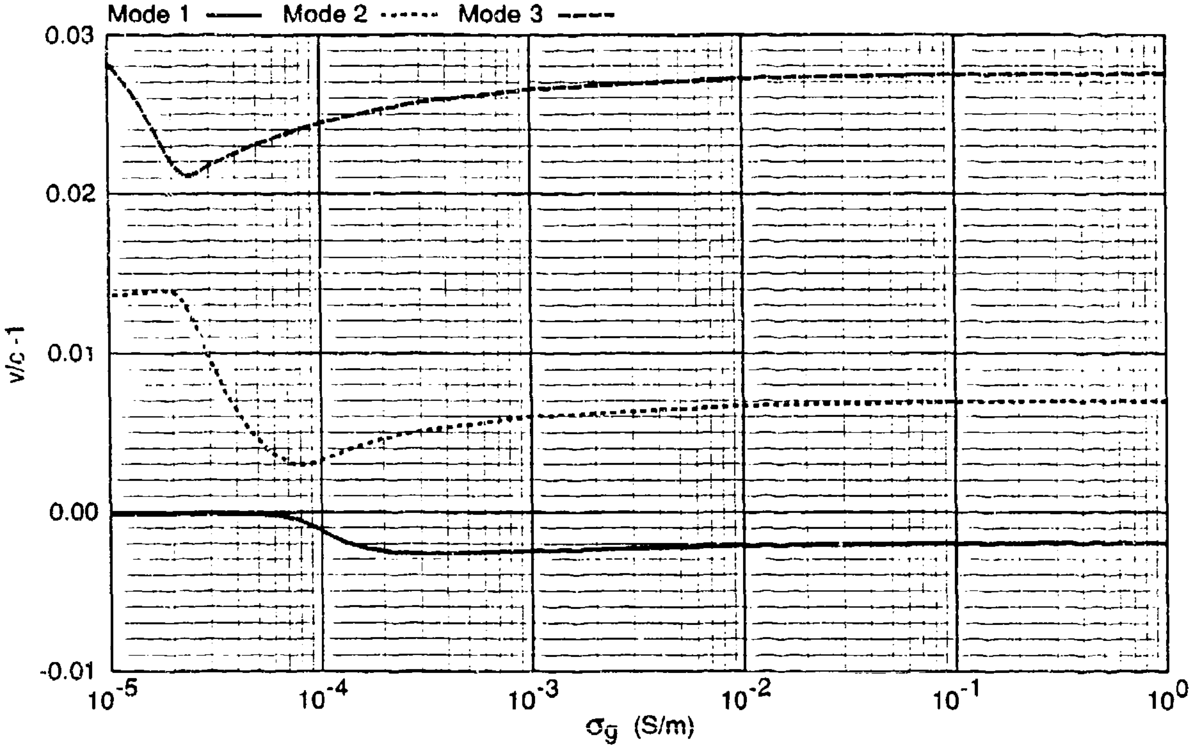
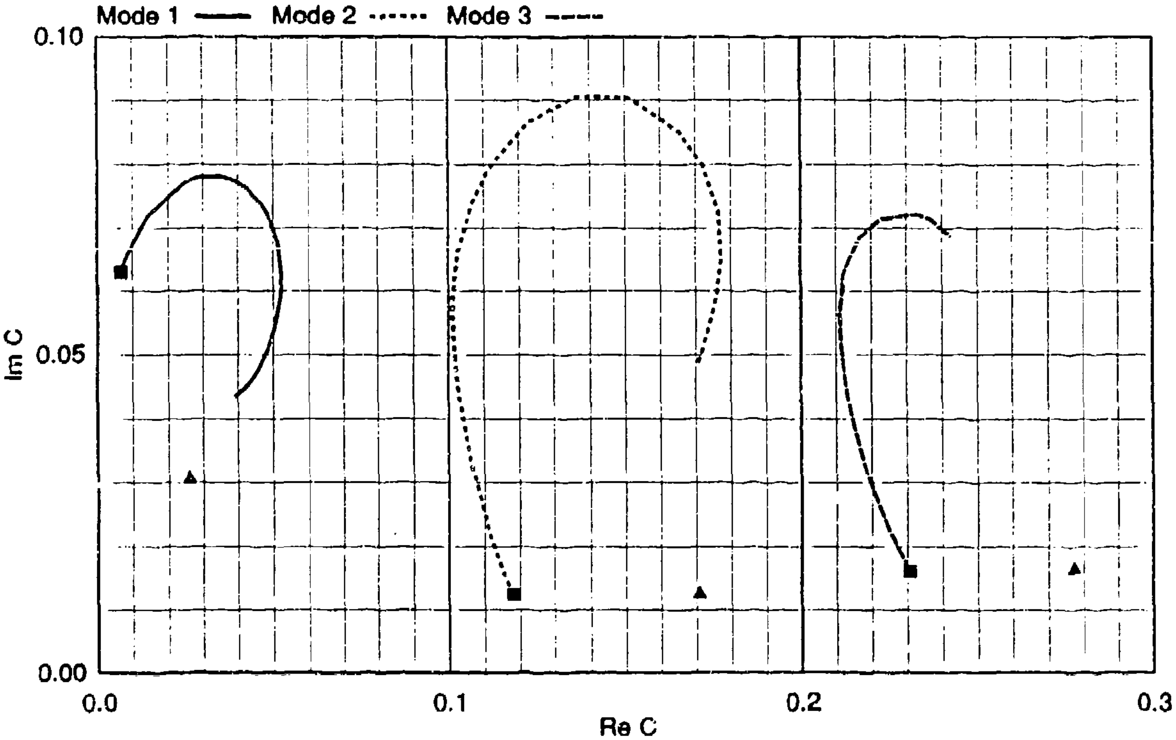


Figure 52. Parameters for $W = 2 \times 10^{-15}$, frequency = 25 kHz.

c. Relative phase velocity as a function of ground conductivity.



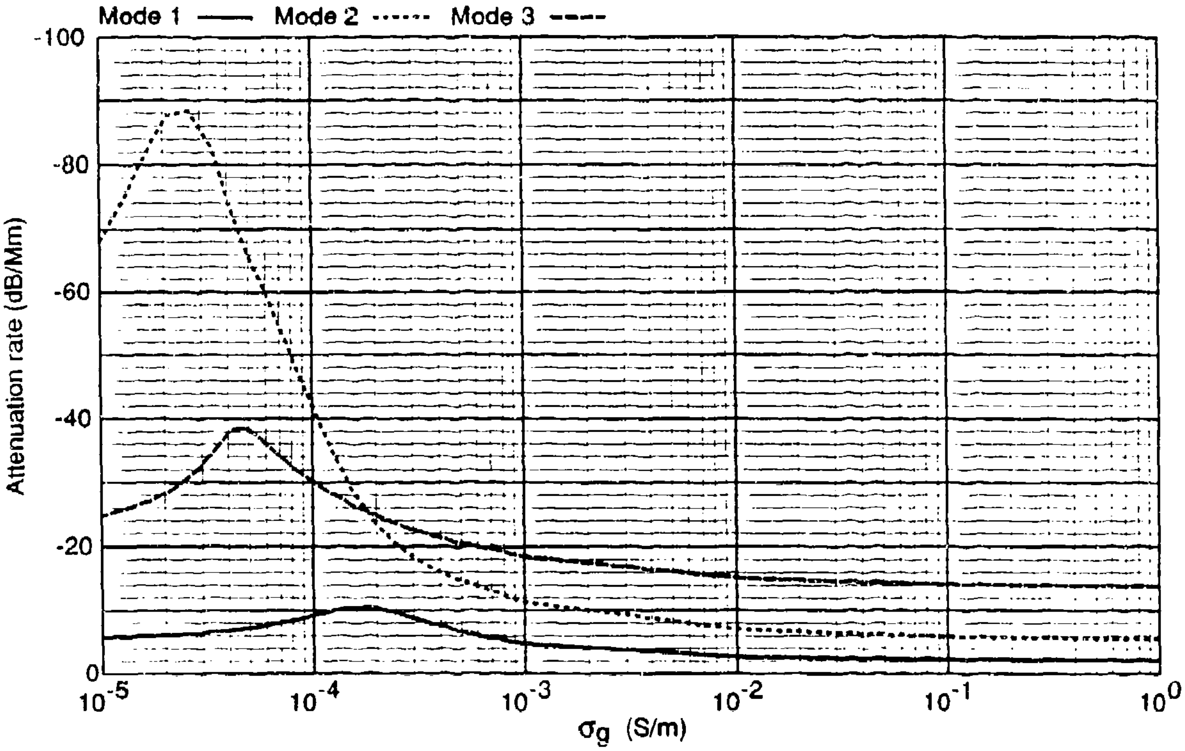
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 52. Parameters for W = 2 x 10^{-15}, frequency = 25 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

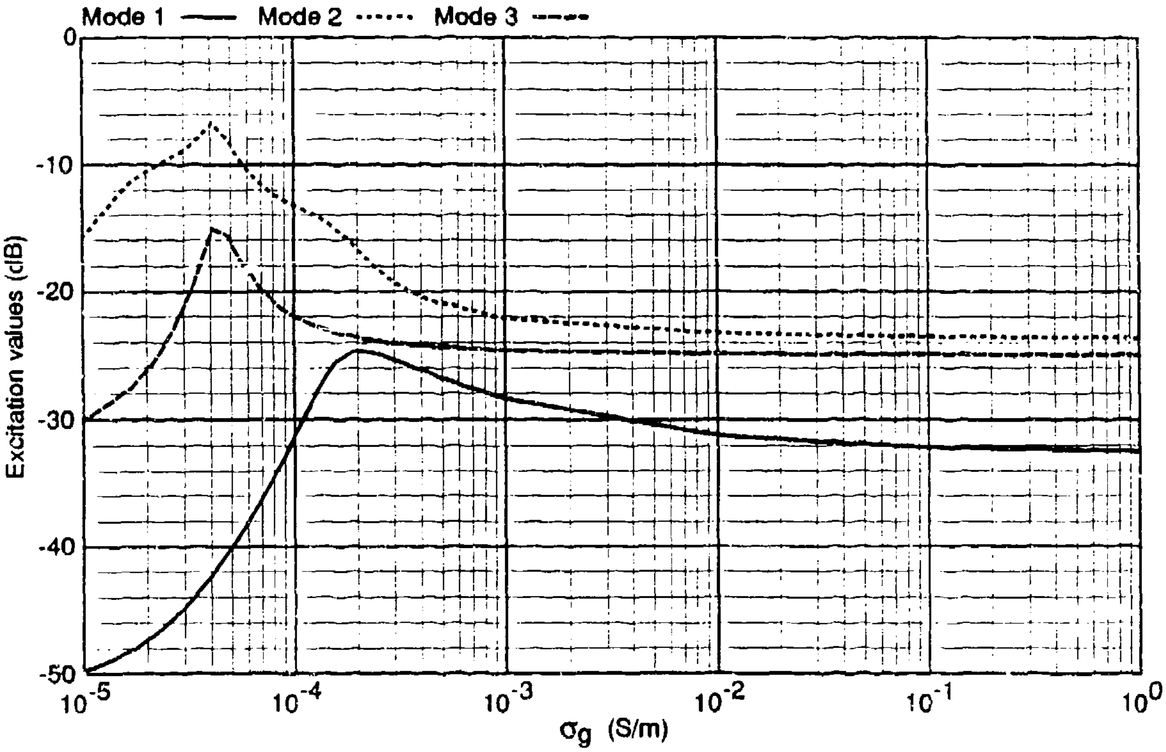
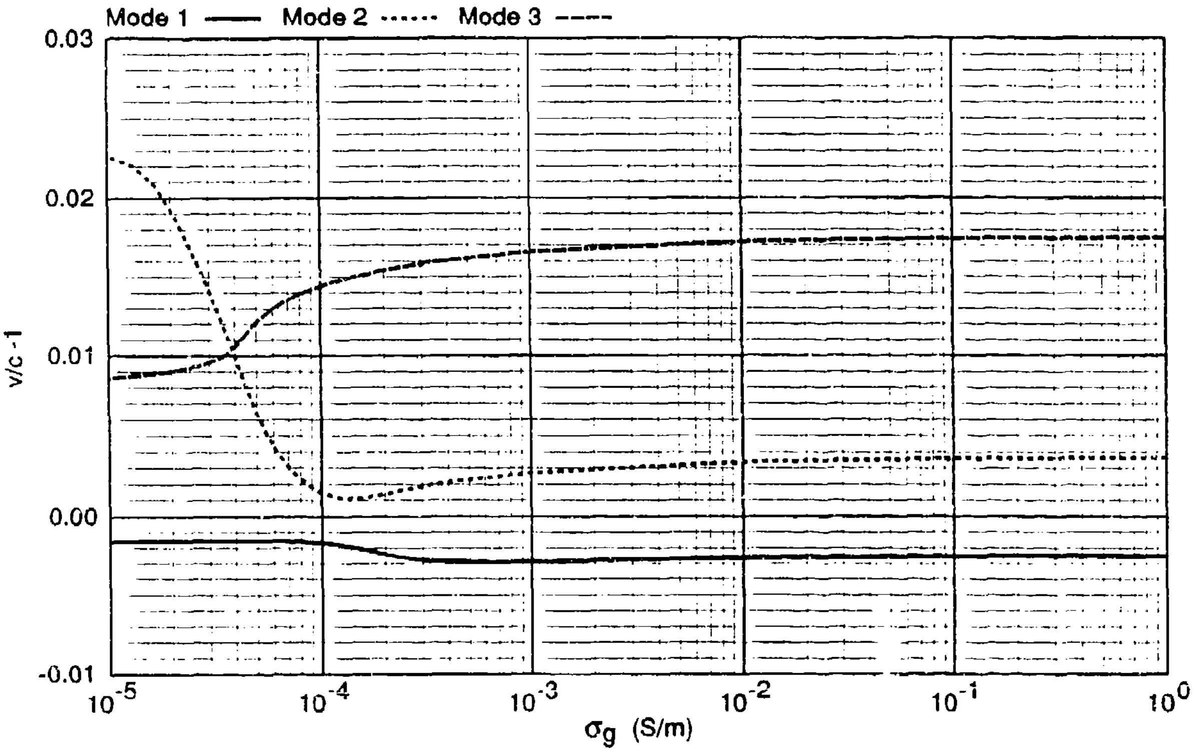
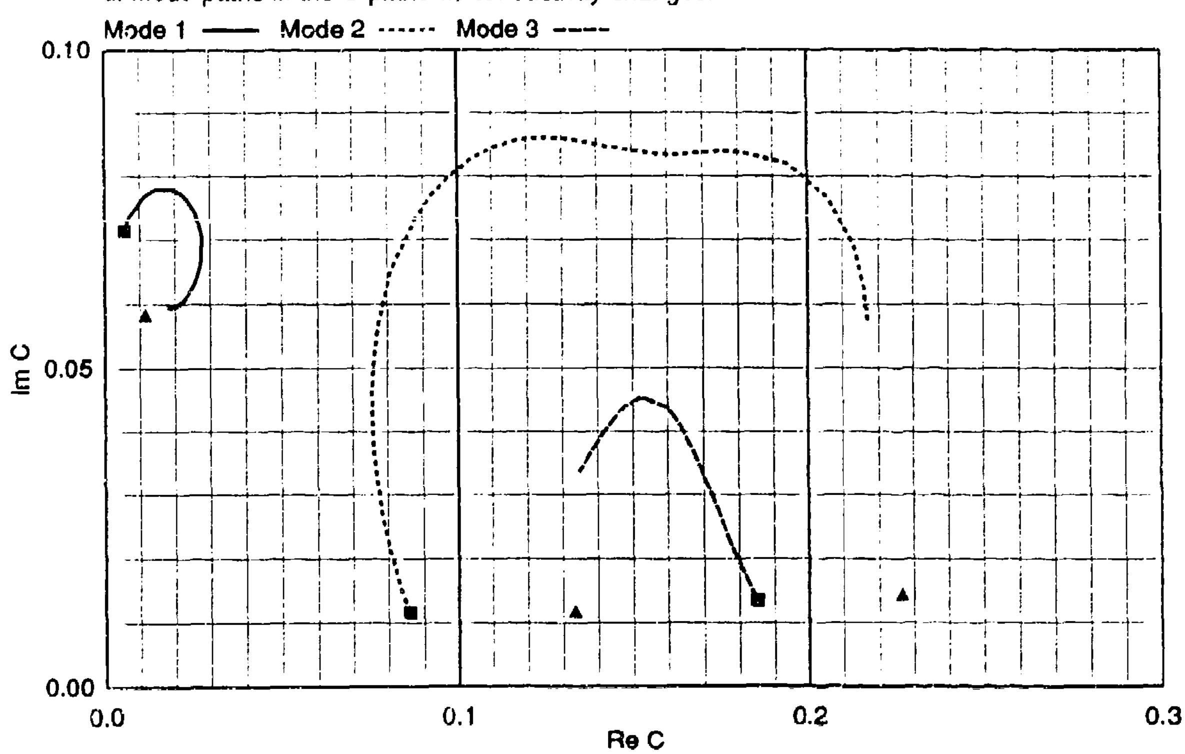


Figure 53. Parameters for $W = 2 \times 10^{-15}$, frequency = 30 kHz.

c. Relative phase velocity as a function of ground conductivity.



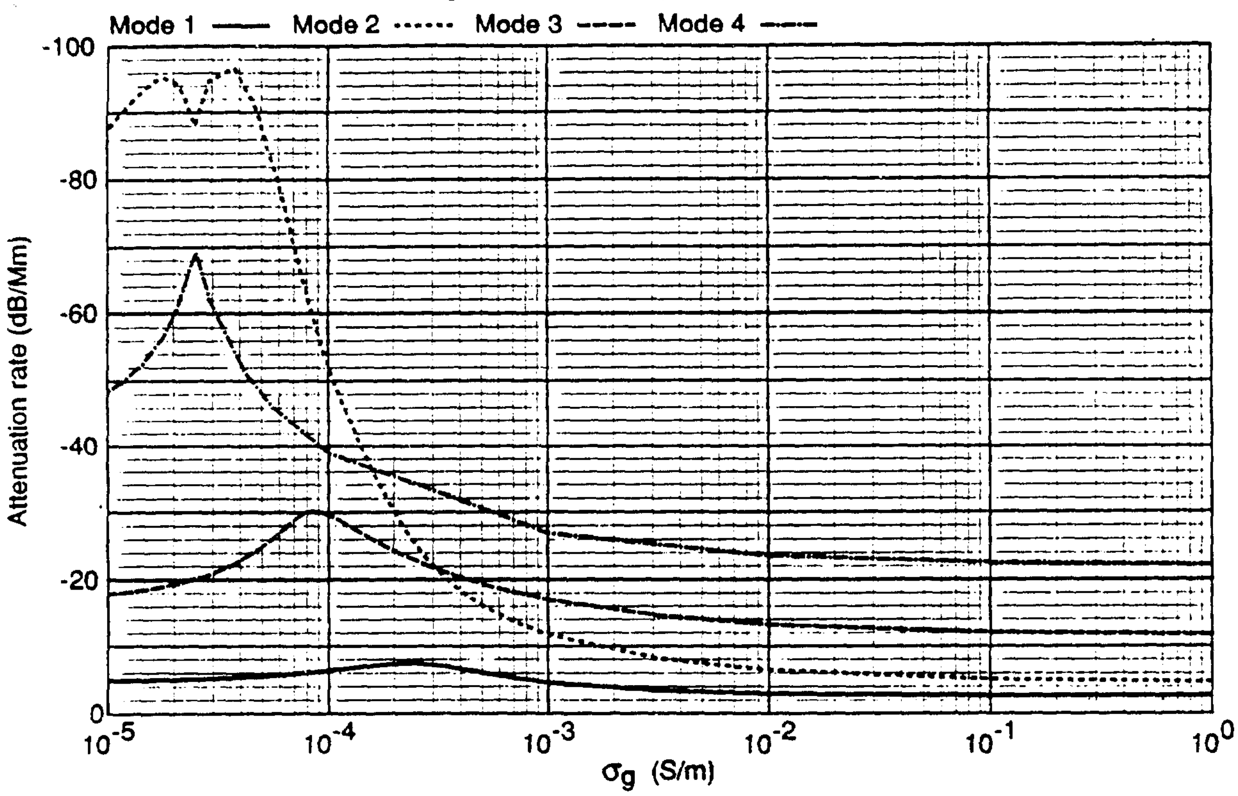
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 53. Parameters for W = 2 x 10^{-15}, frequency = 30 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

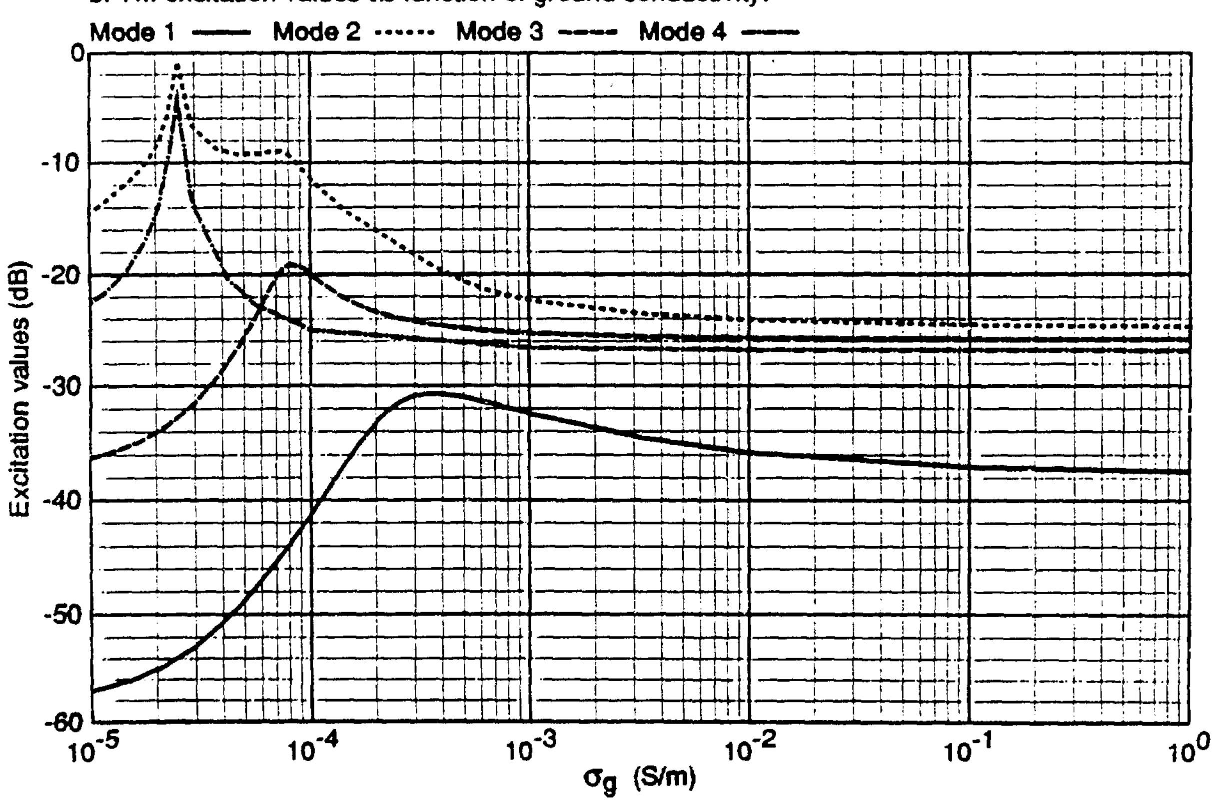
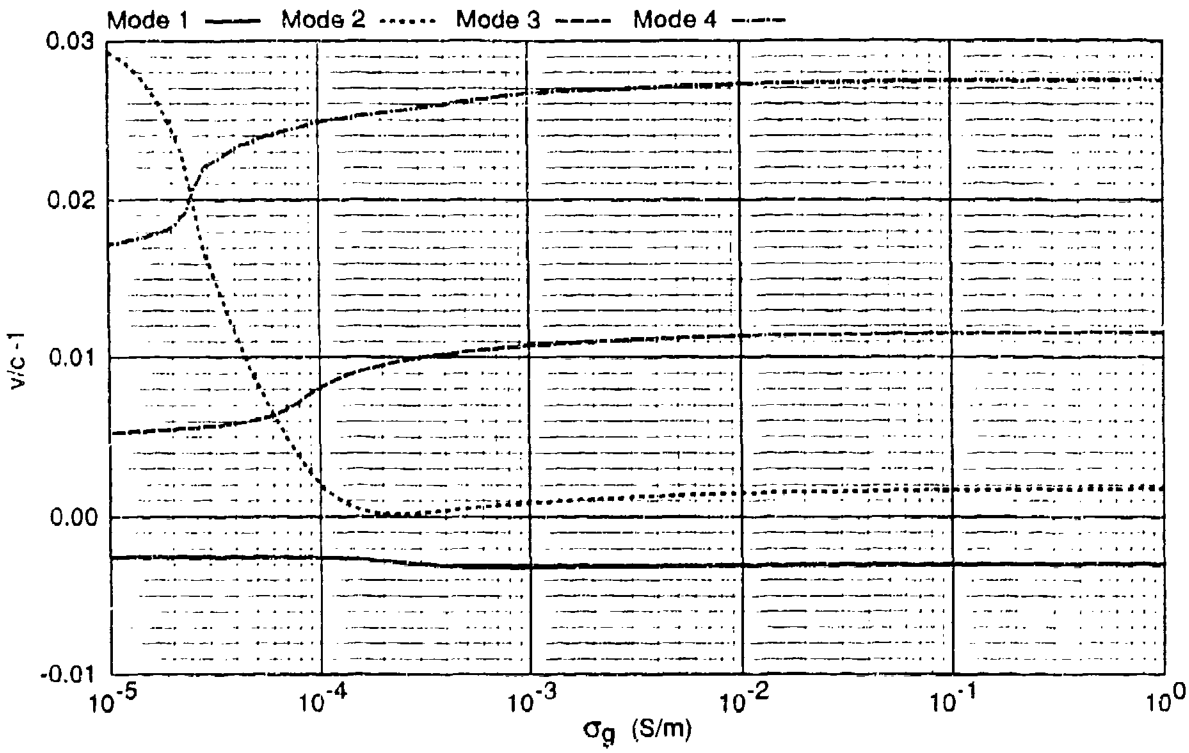
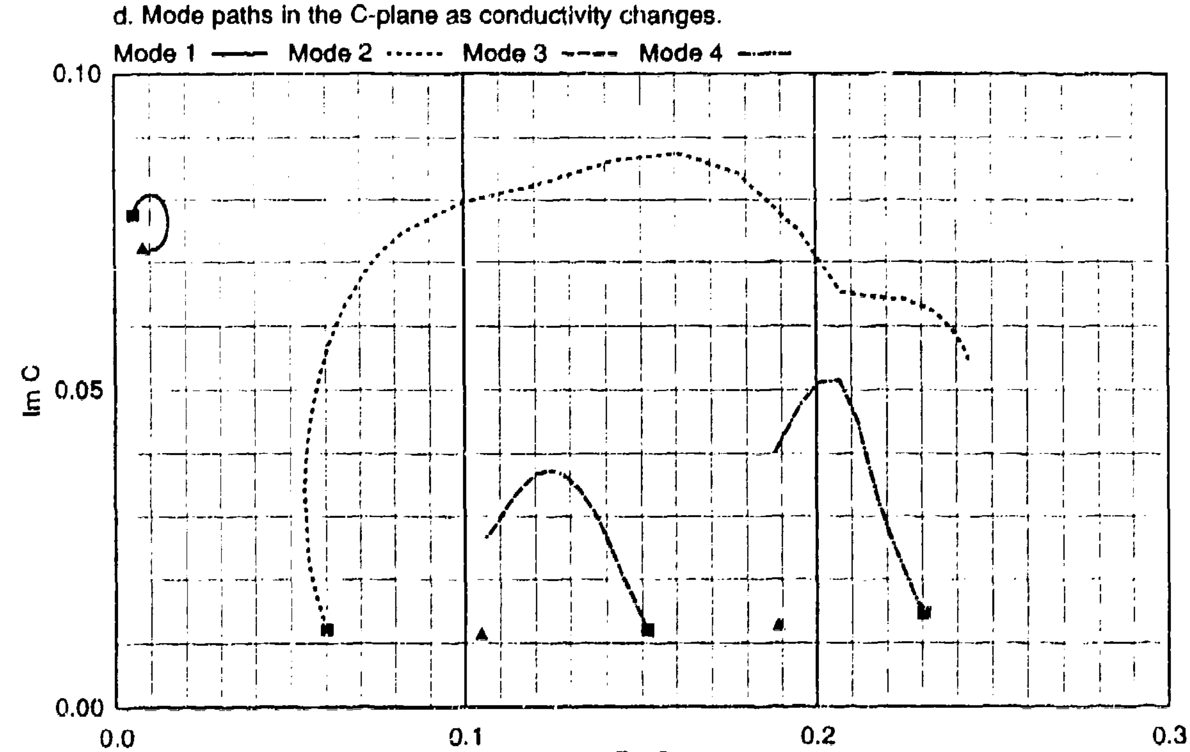


Figure 54. Parameters for $W = 2 \times 10^{-15}$, frequency = 35 kHz.

c. Relative phase velocity as a function of ground conductivity.



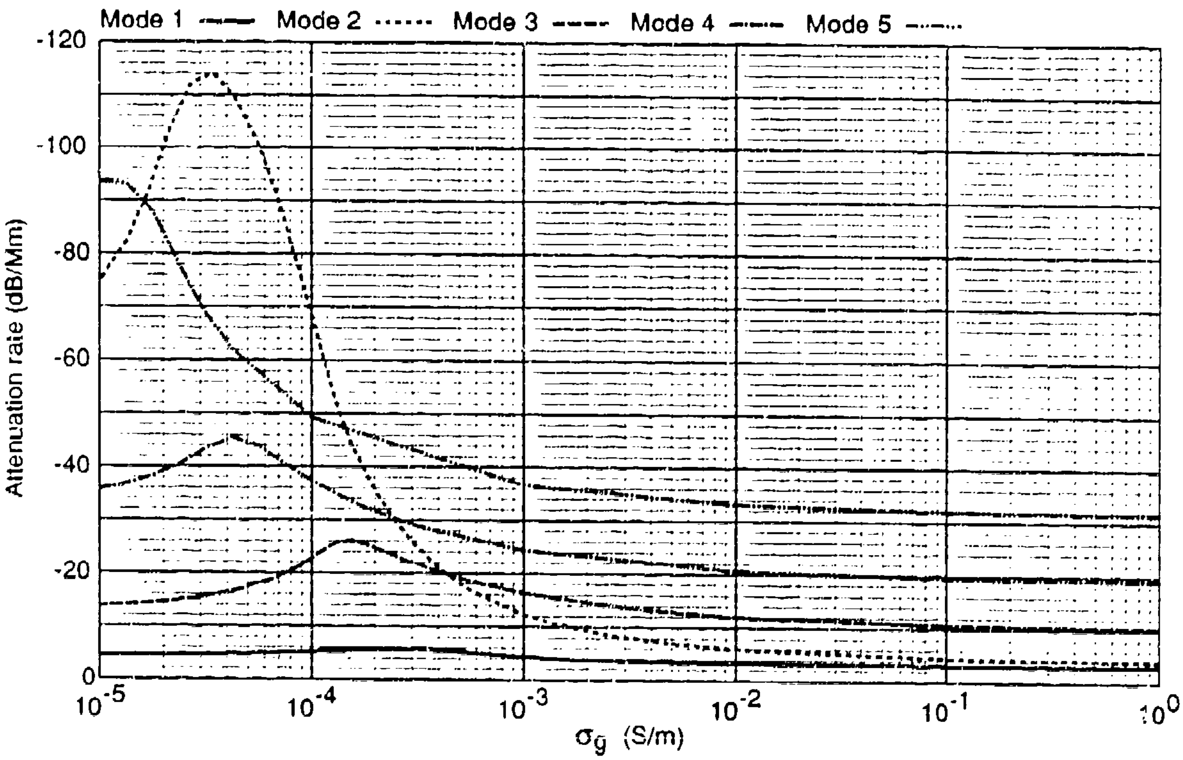
d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 54. Parameters for W = 2 x 10^{-15}, frequency = 35 kHz (Concluded).

a. Attenuation as function of ground conductivity.



b. TM excitation values as function of ground conductivity.

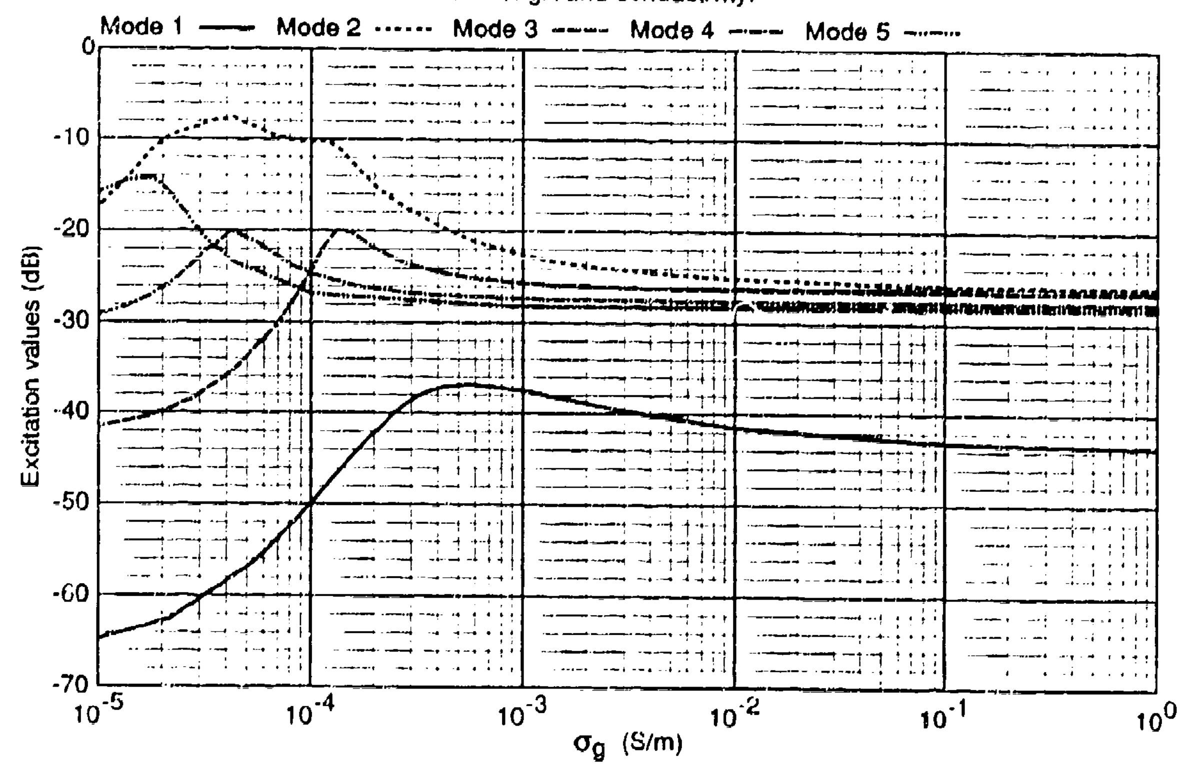
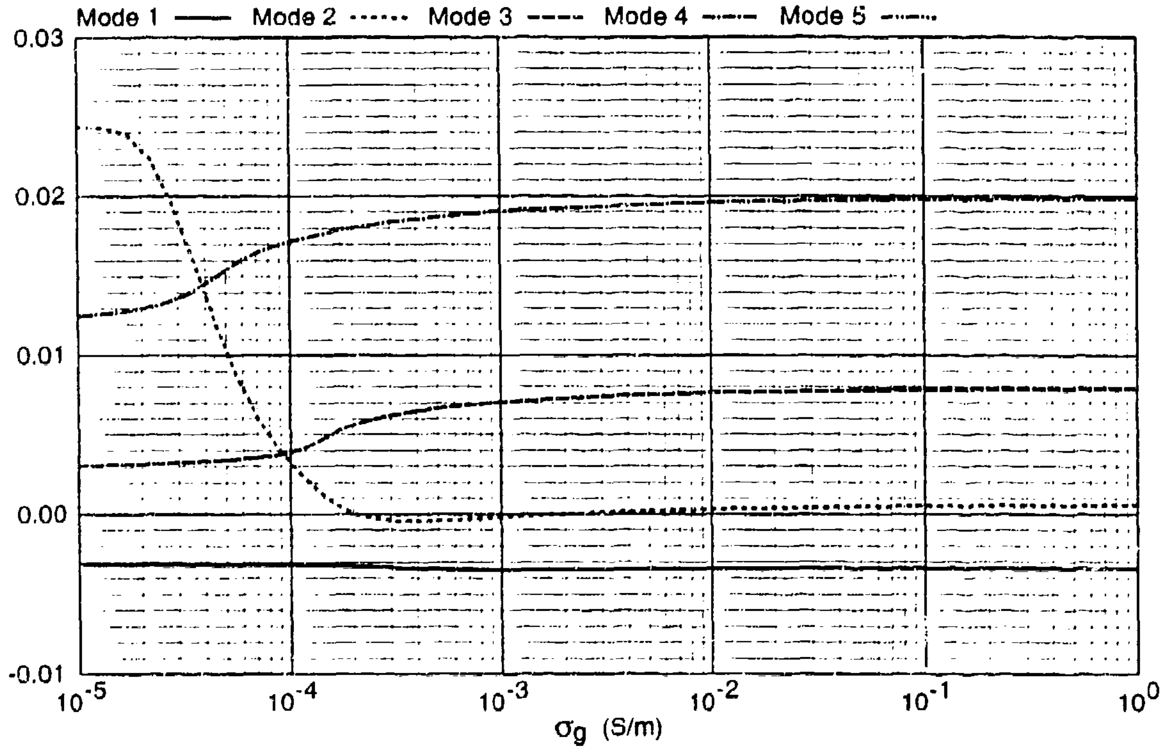
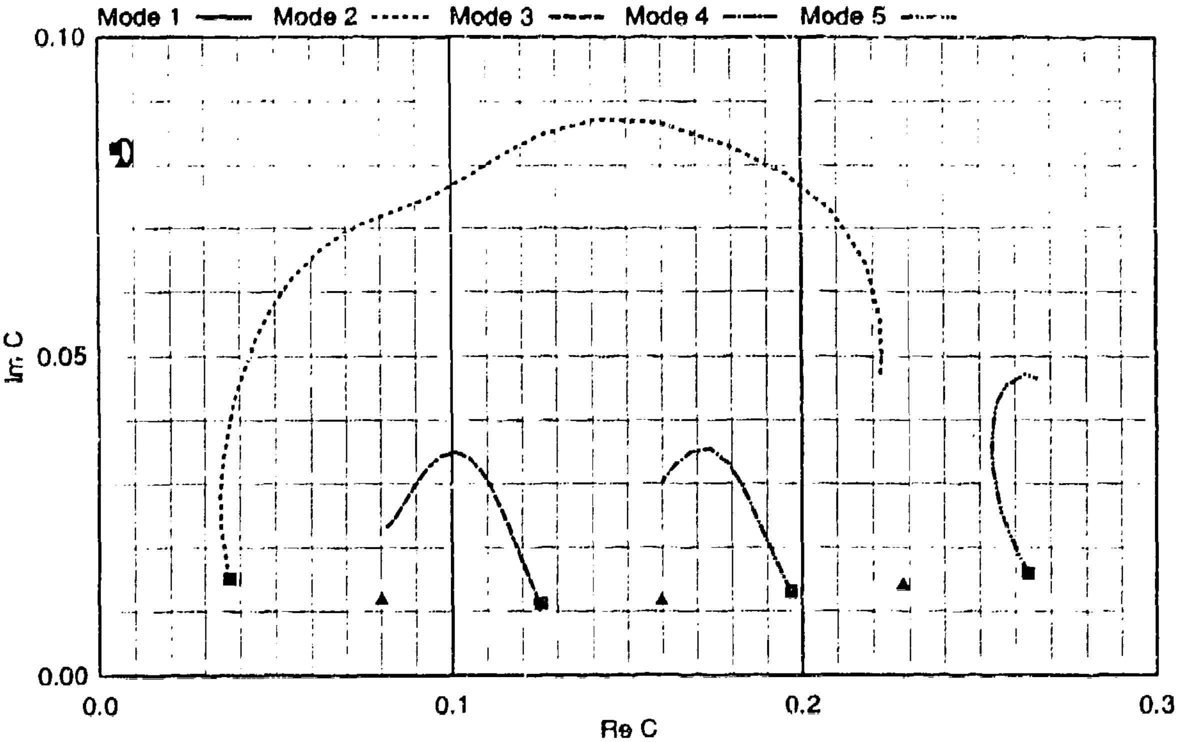


Figure 55. Parameters for $W = 2 \times 10^{-15}$, frequency = 40 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 55. Parameters for W = 2 x 10^{-15}, frequency = 40 kHz (Concluded).

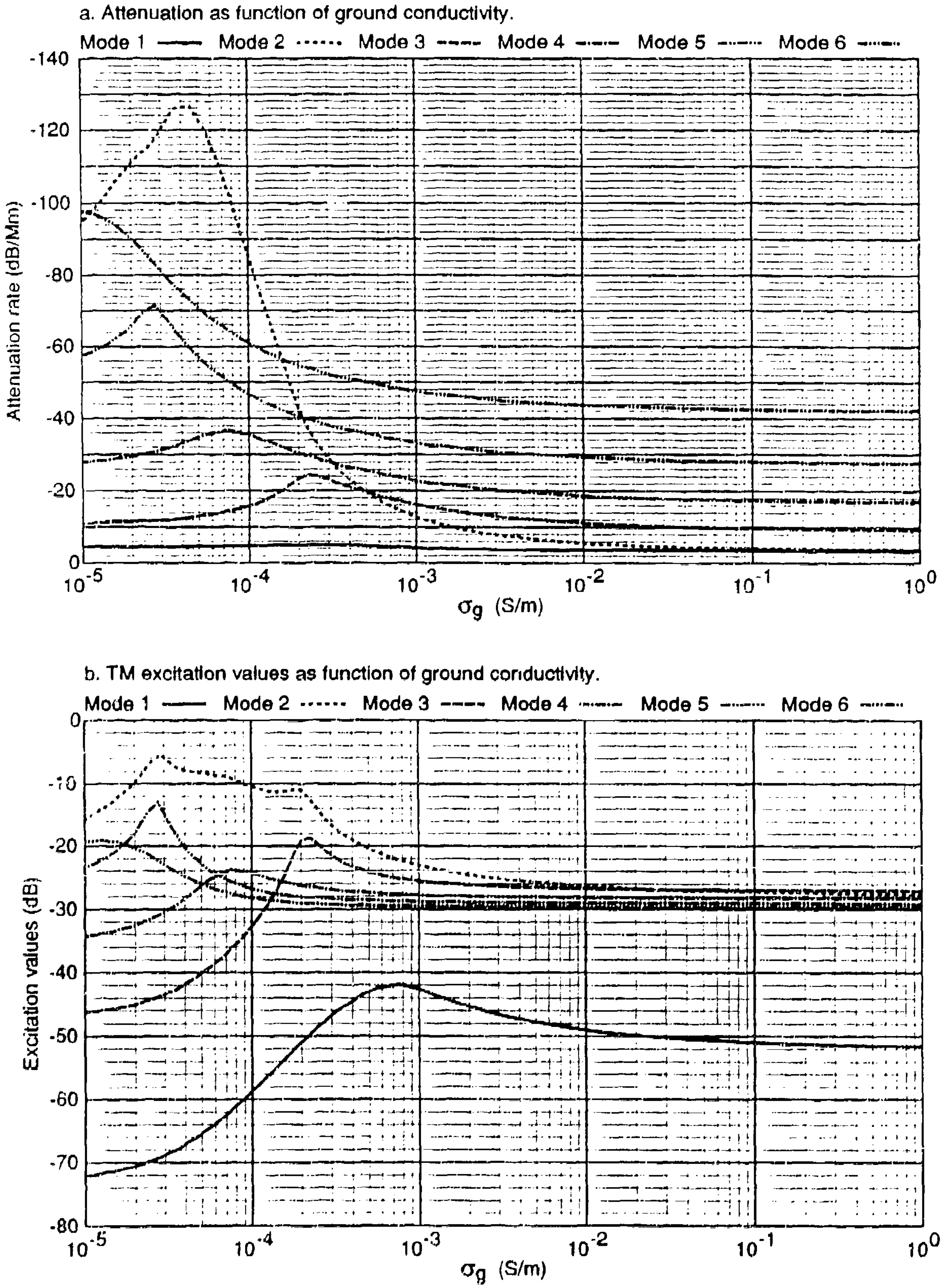
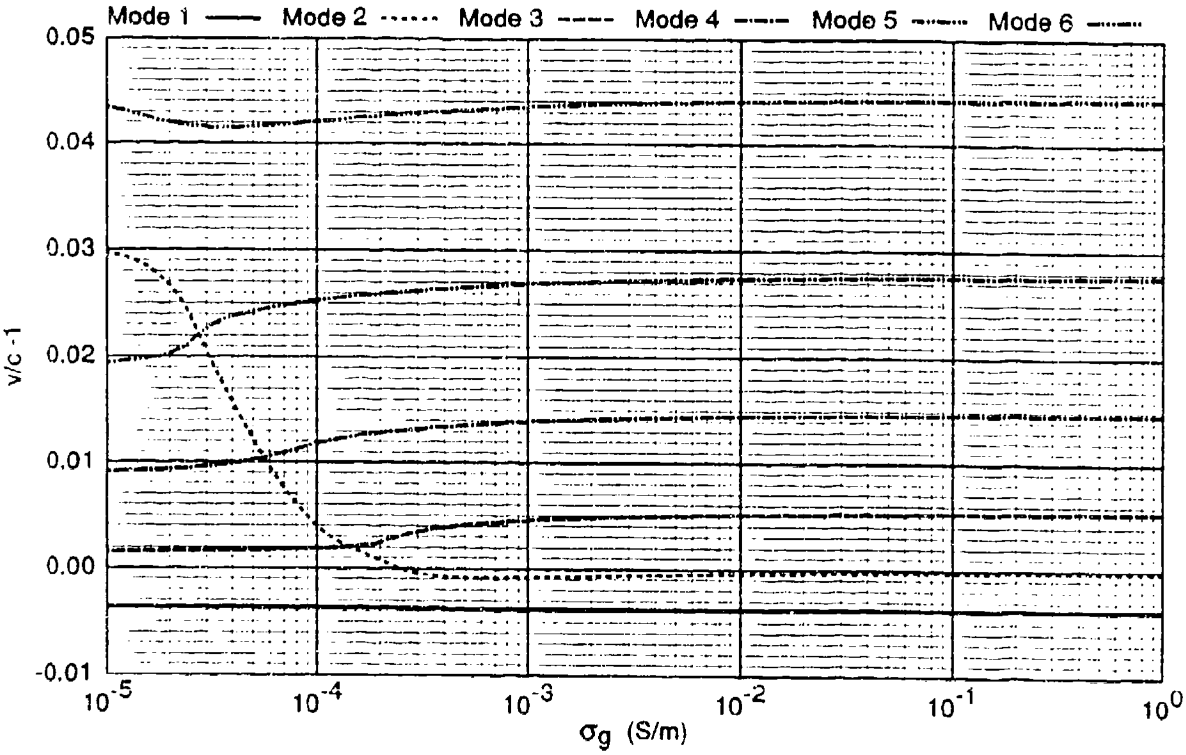
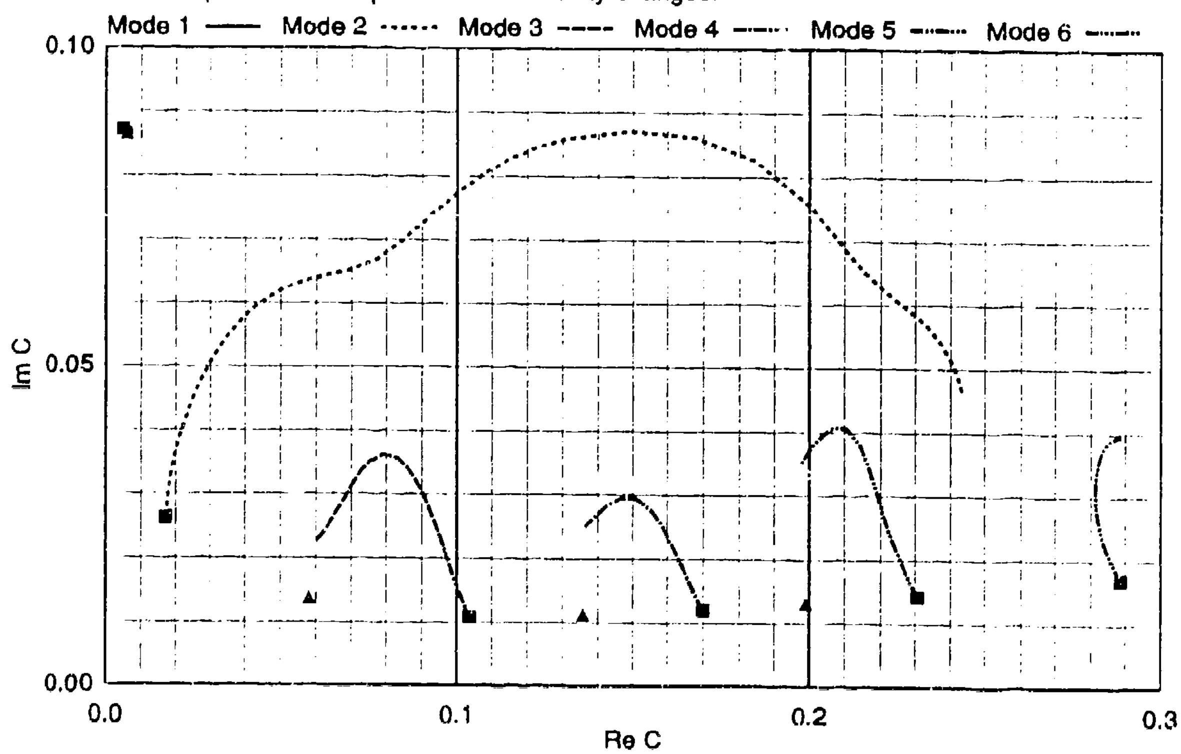


Figure 56. Parameters for W = 2 x 10^{-15}, frequency = 45 kHz.

c. Relative phase velocity as a function of ground conductivity.



d. Mode paths in the C-plane as conductivity changes.



NOTE: High conductivity point marked with ■ for TM modes, ▲ for TE.

Figure 56. Parameters for W = 2 x 10^{-15}, frequency = 45 kHz (Concluded).

SECTION 2

PARAMETERS AS A FUNCTION OF W

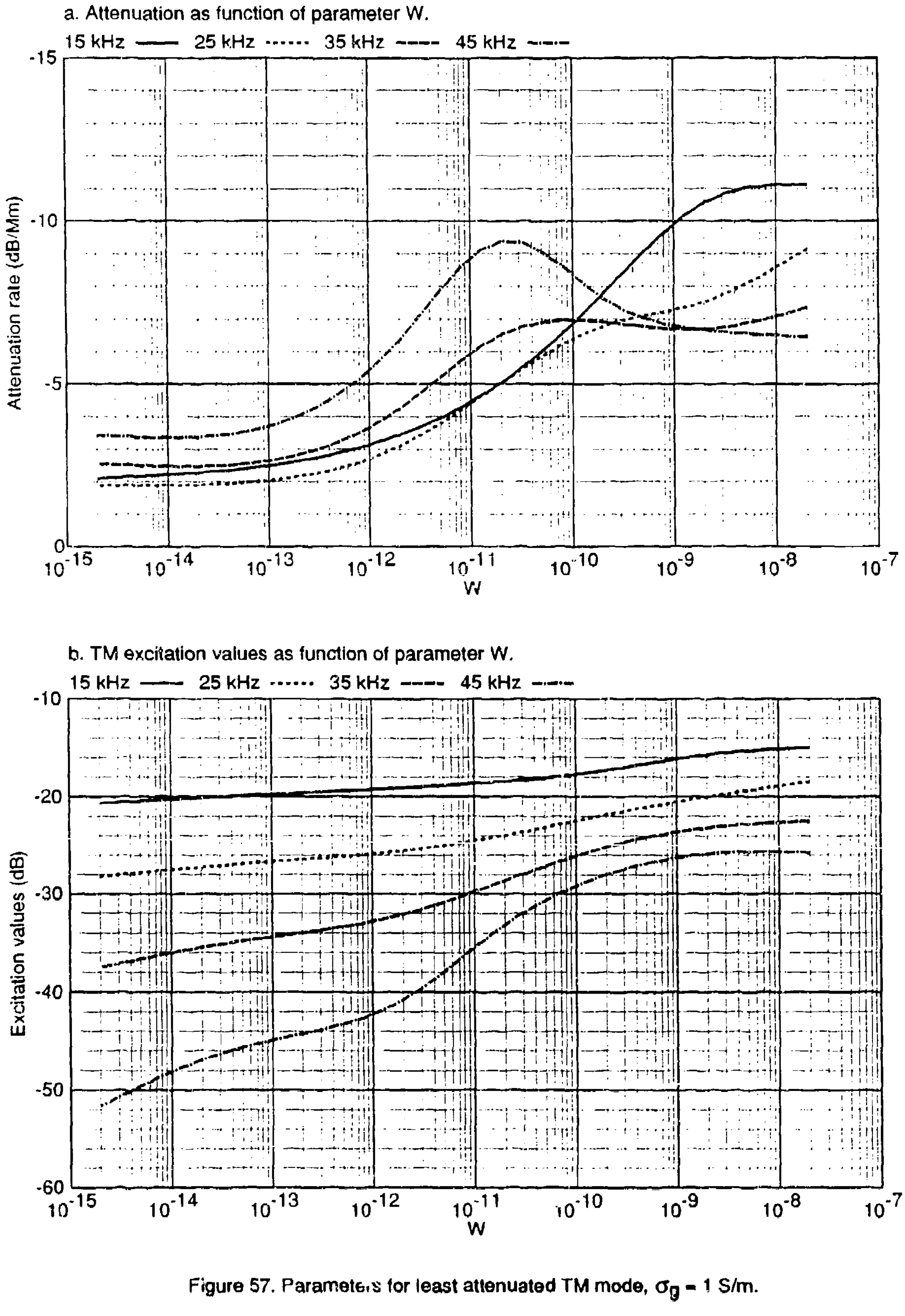
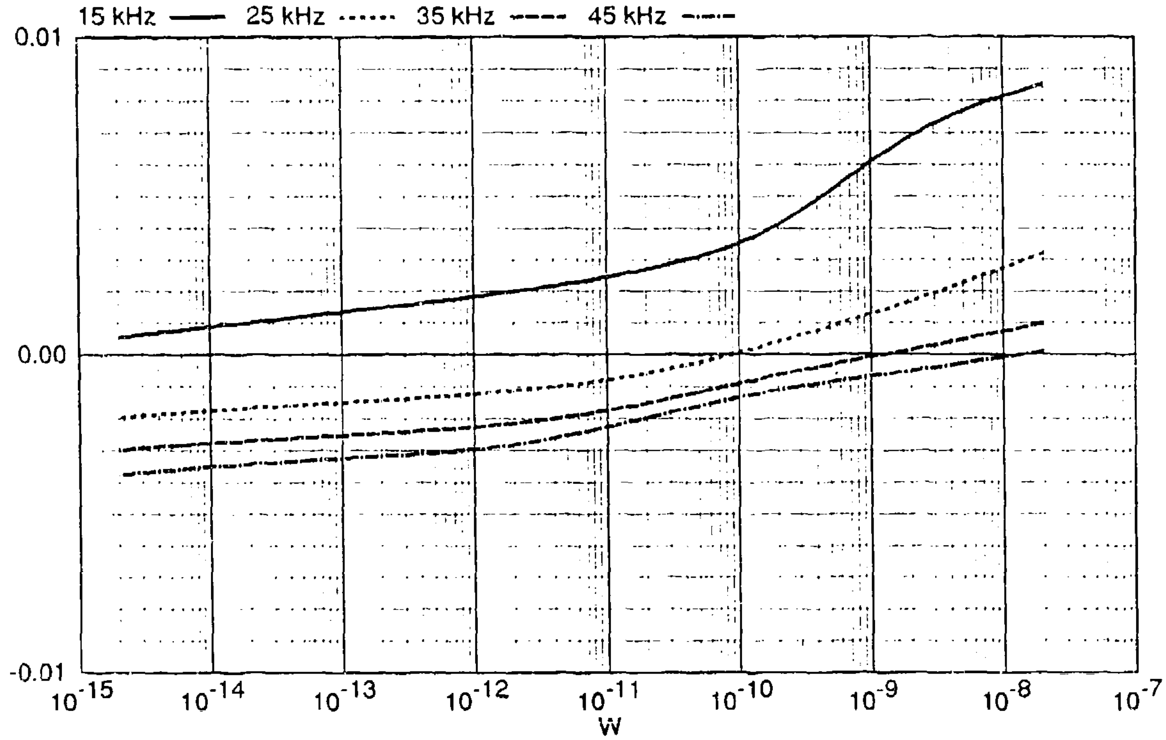
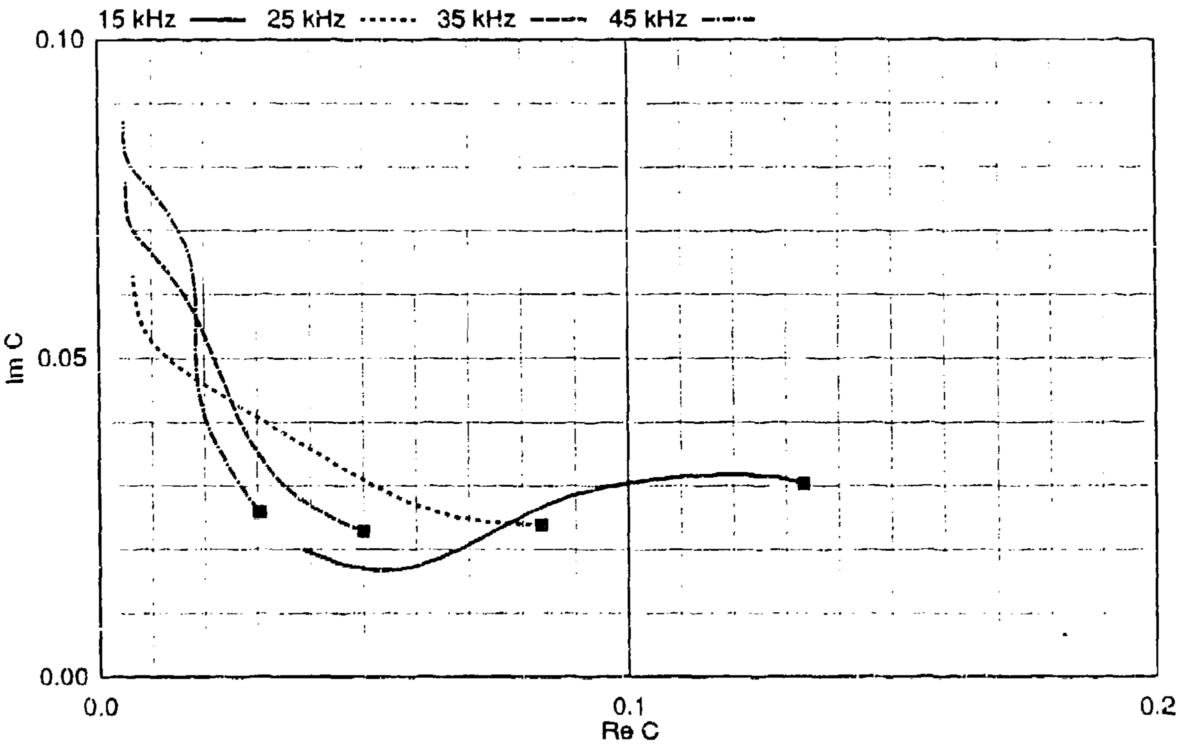


Figure 57. Parameters for least attenuated TM mode, $\sigma_g = 1$ S/m.

c. Relative phase velocity as a function of parameter W.



d. Mode paths in the C-plane as W changes.



NOTE: The point for highest W marked with ■

Figure 57. Parameters for least attenuated TM mode, $\sigma_g = 1$ S/m (Concluded).

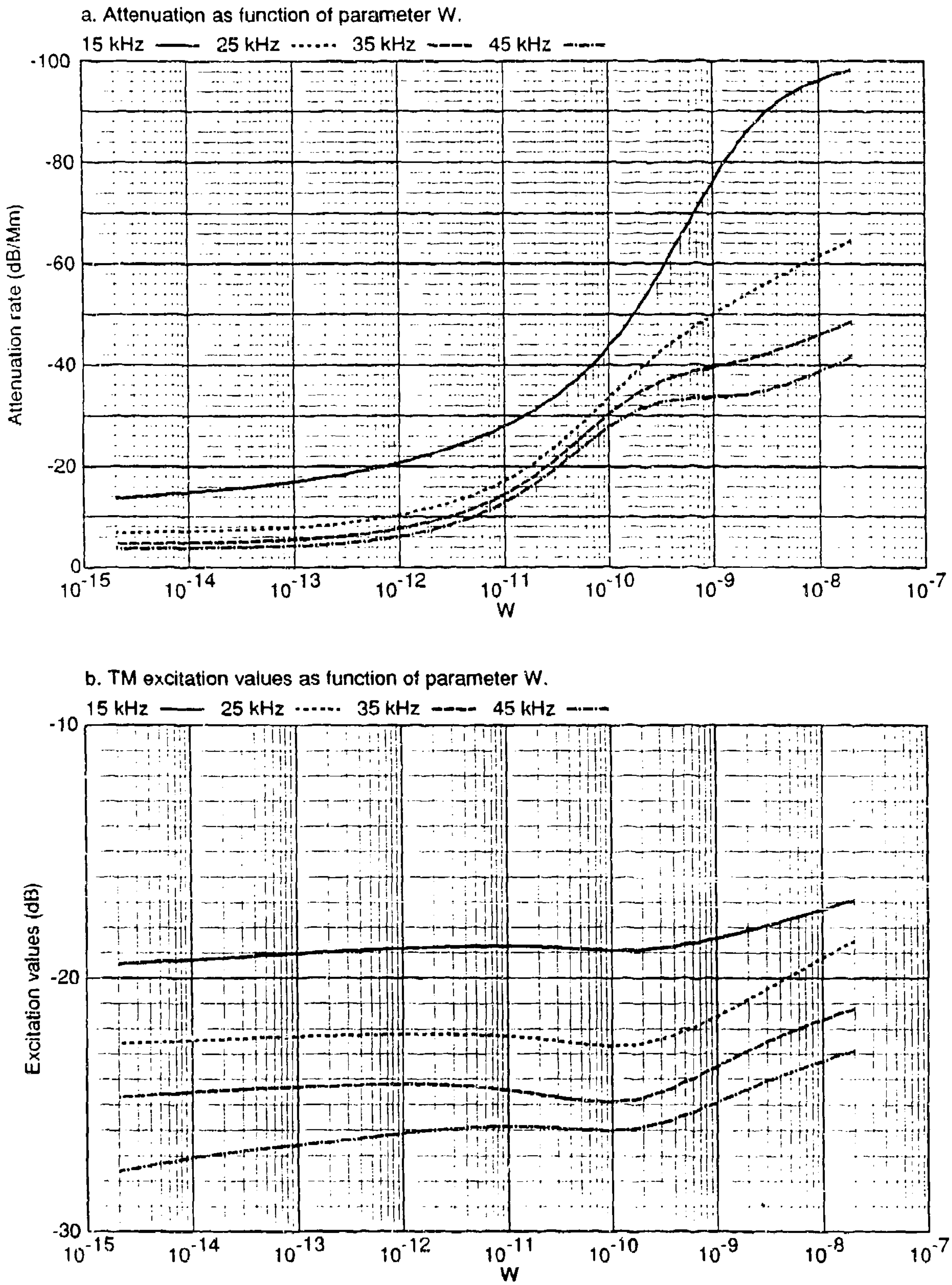
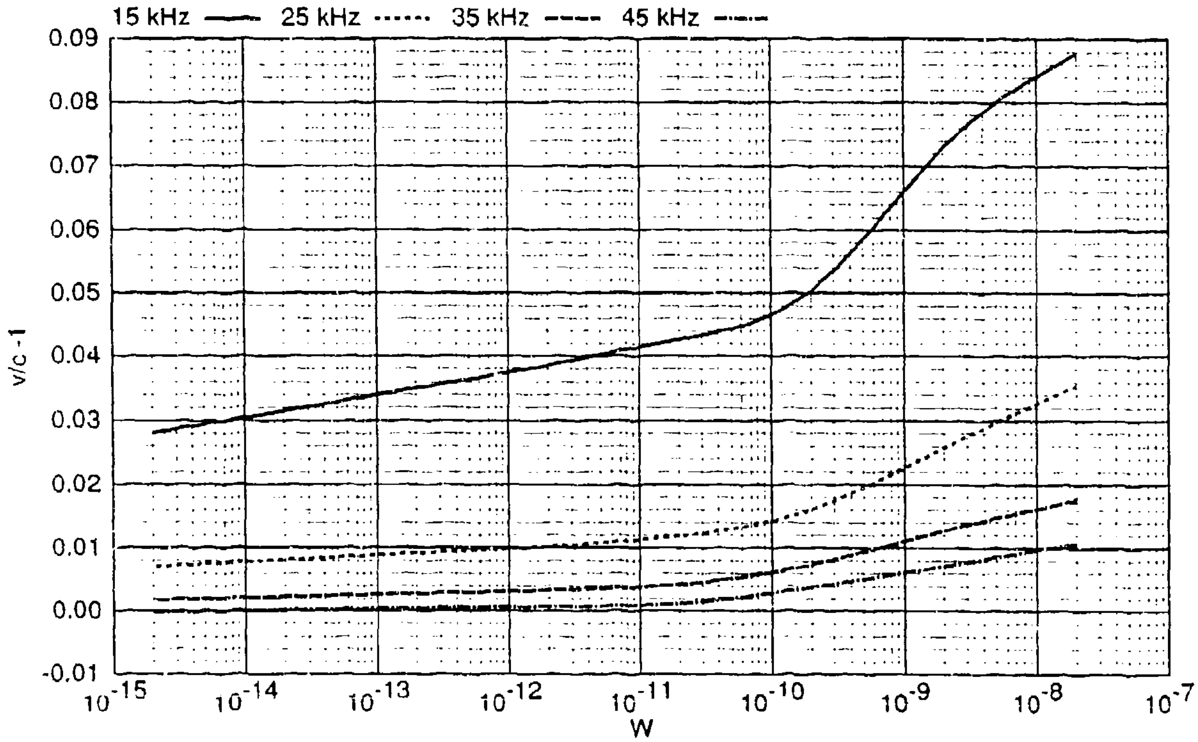
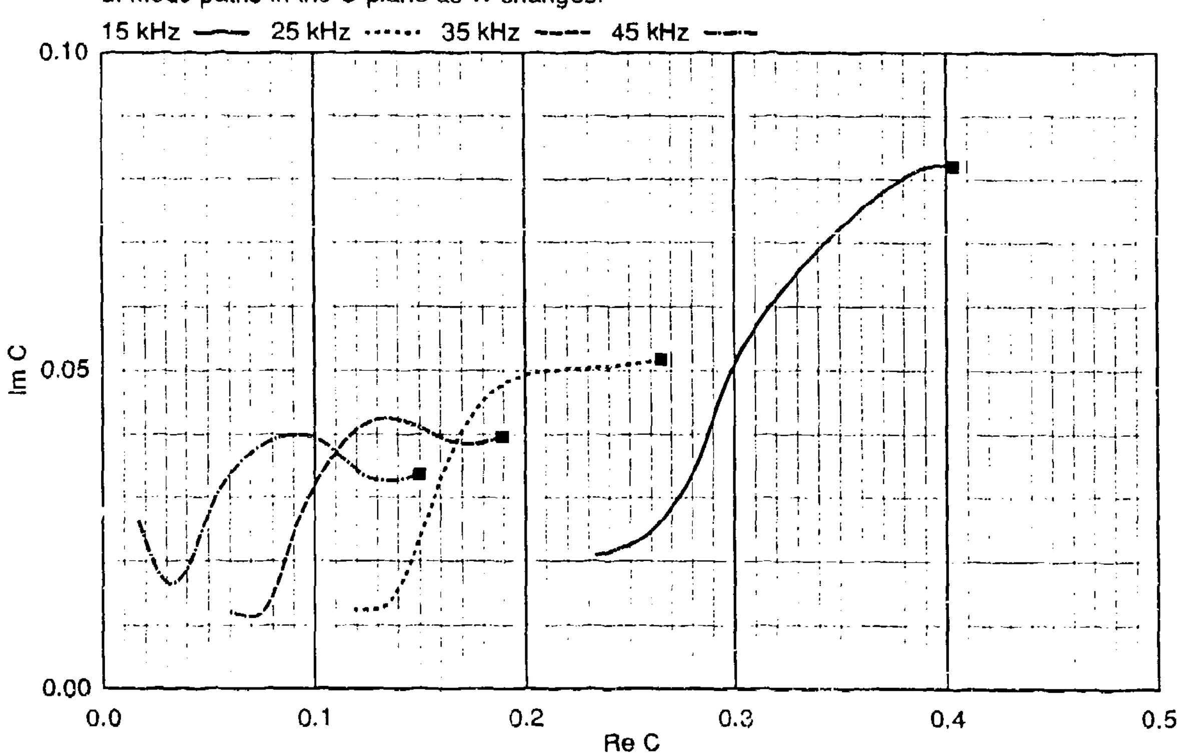


Figure 58. Parameters for second least attenuated TM mode, $\sigma_g = 1$ S/m.

c. Relative phase velocity as a function of parameter W.



d. Mode paths in the C-plane as W changes.



NOTE: The point for highest W marked with ■

Figure 58. Parameters for second least attenuated TM mode, σ_g = 1 S/m (Concluded).

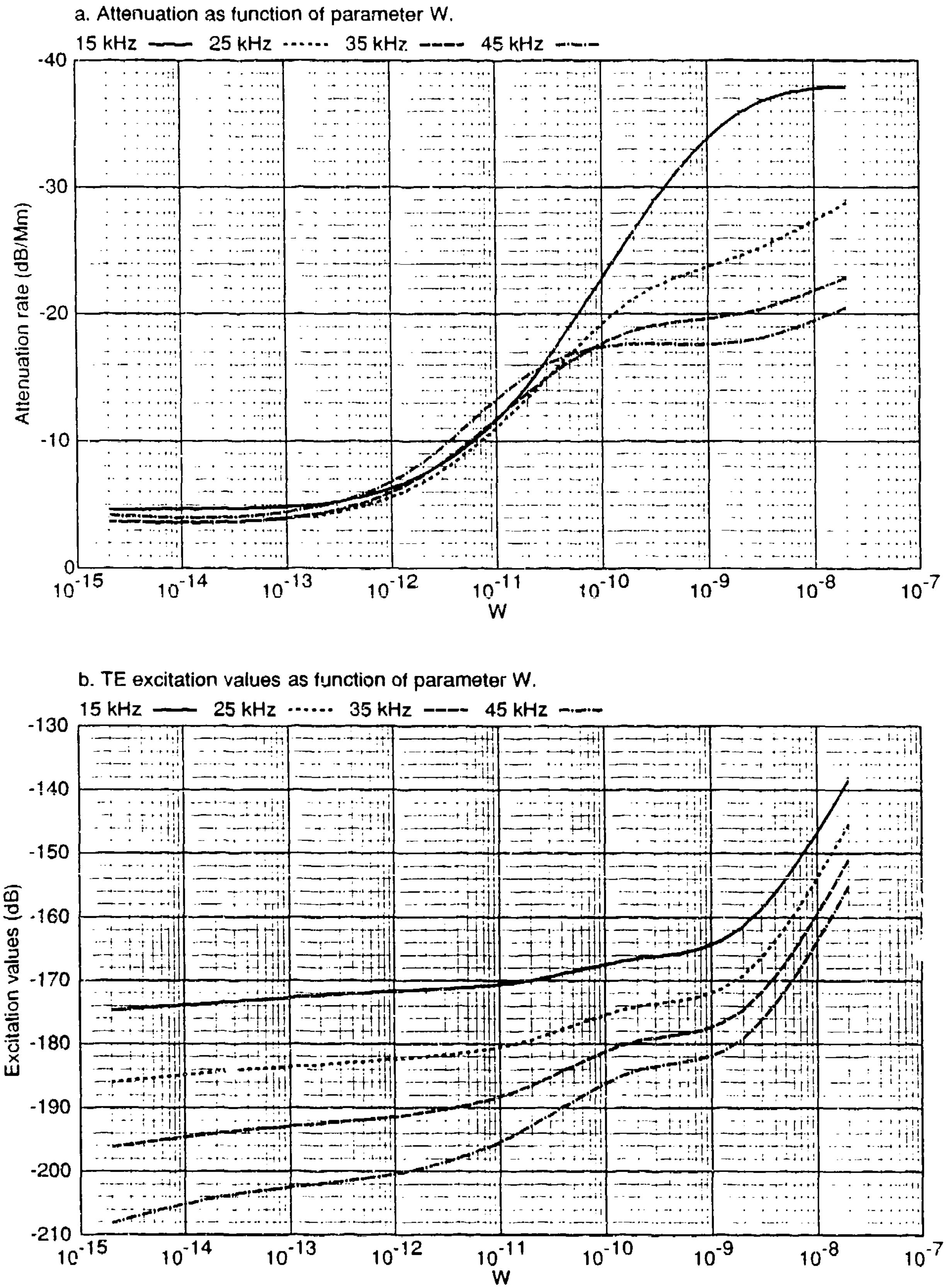
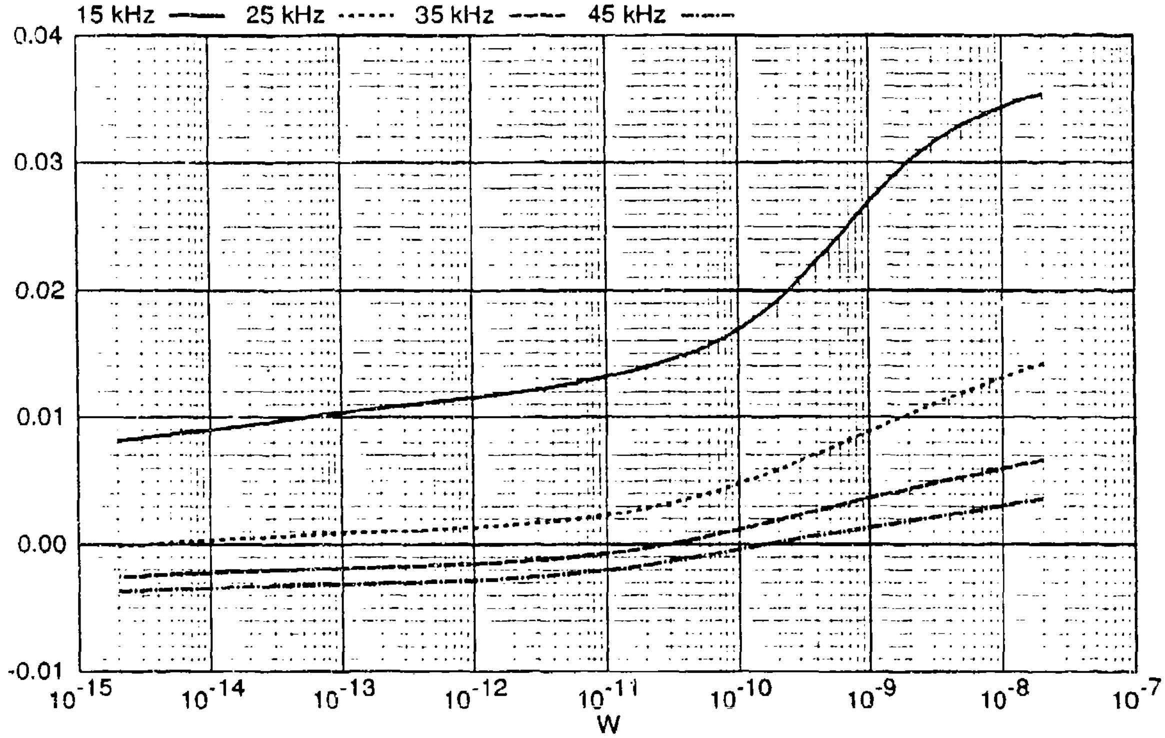


Figure 59. Parameters for least attenuated TE mode, $\sigma_g = 1$ S/m.

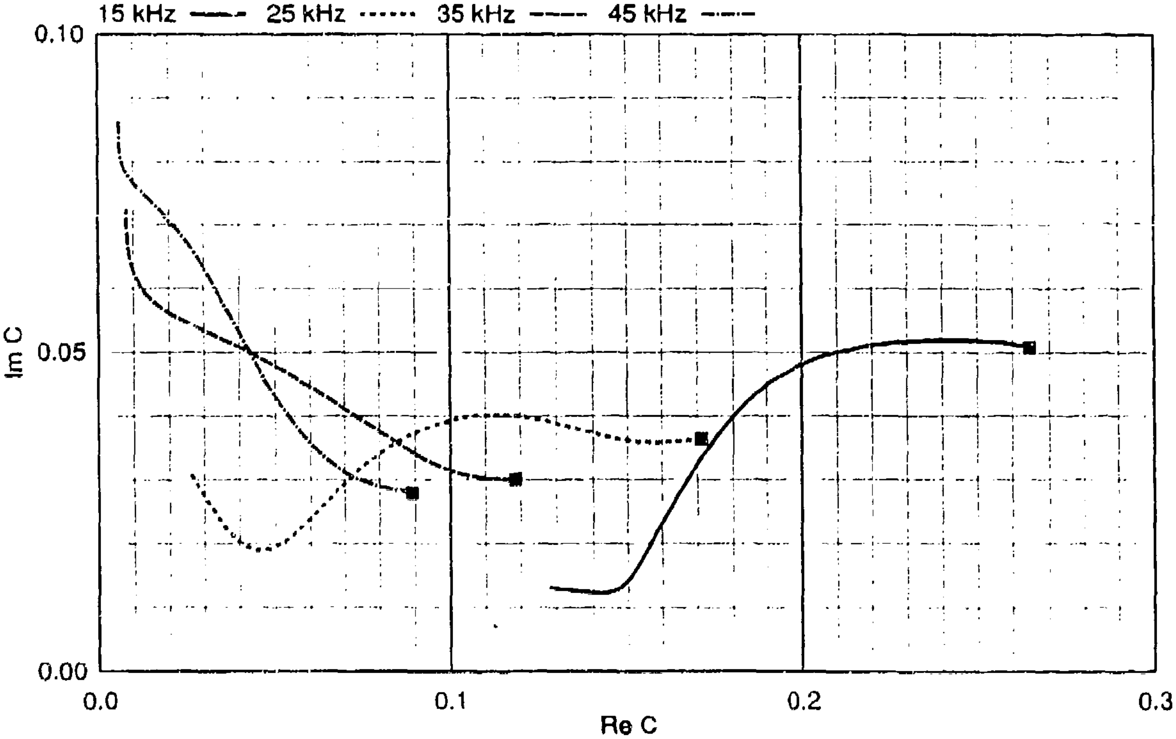
c. Relative phase velocity as a function of parameter W.

15 kHz —— 25 kHz ······ 35 kHz ---- 45 kHz -·-·-



d. Mode paths in the C-plane as W changes.

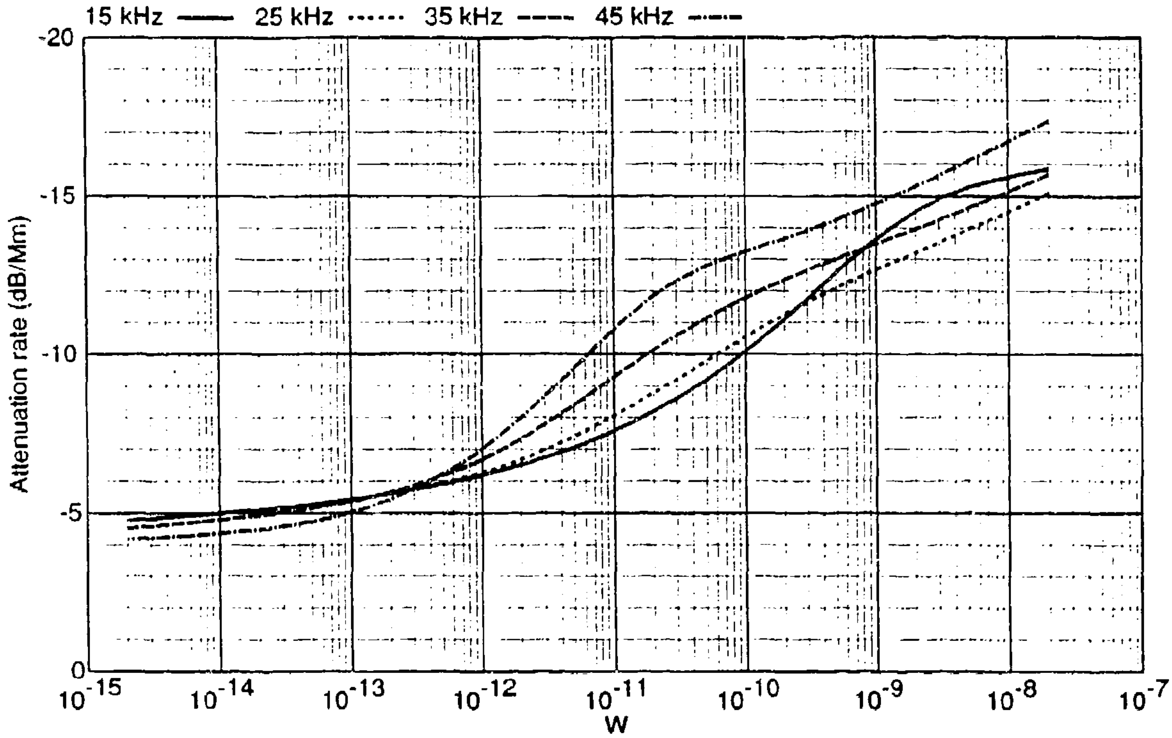
15 kHz —— 25 kHz ······ 35 kHz ---- 45 kHz -·-·-



NOTE: The point for highest W marked with ■

Figure 59. Parameters for least attenuated TE mode, σ_g = 1 S/m (Concluded).

a. Attenuation as function of parameter W.



b. TM excitation values as function of parameter W.

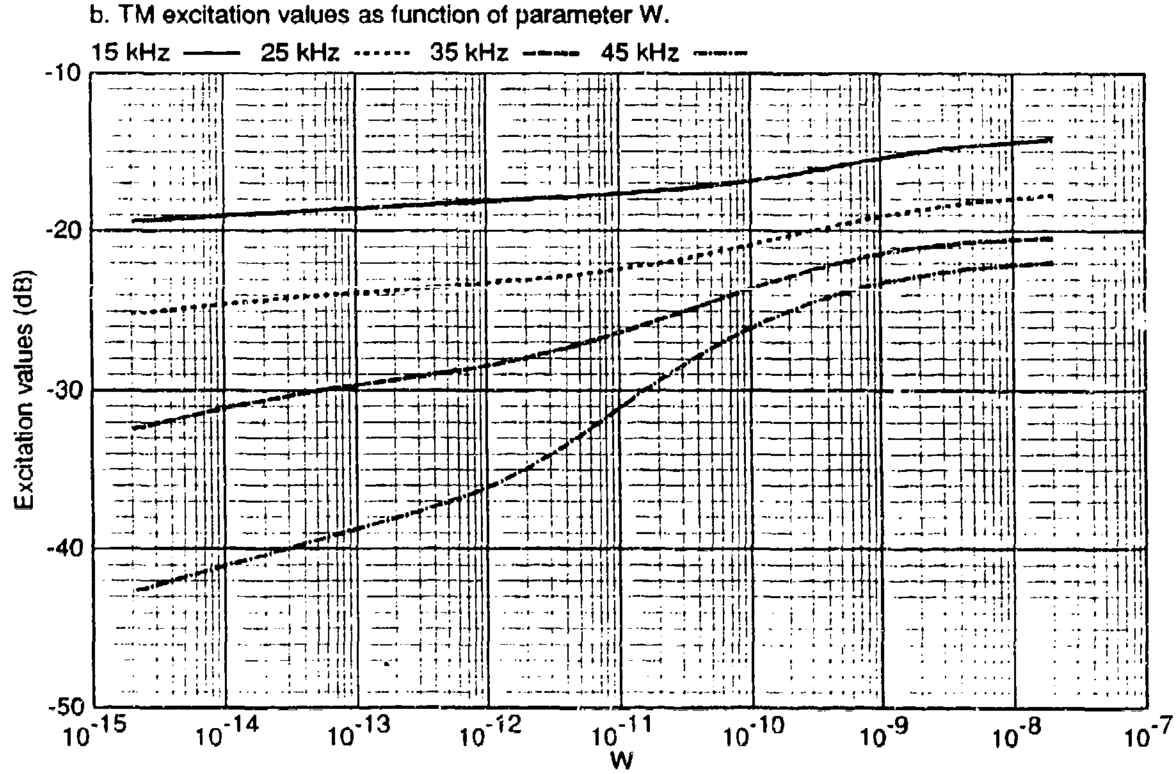
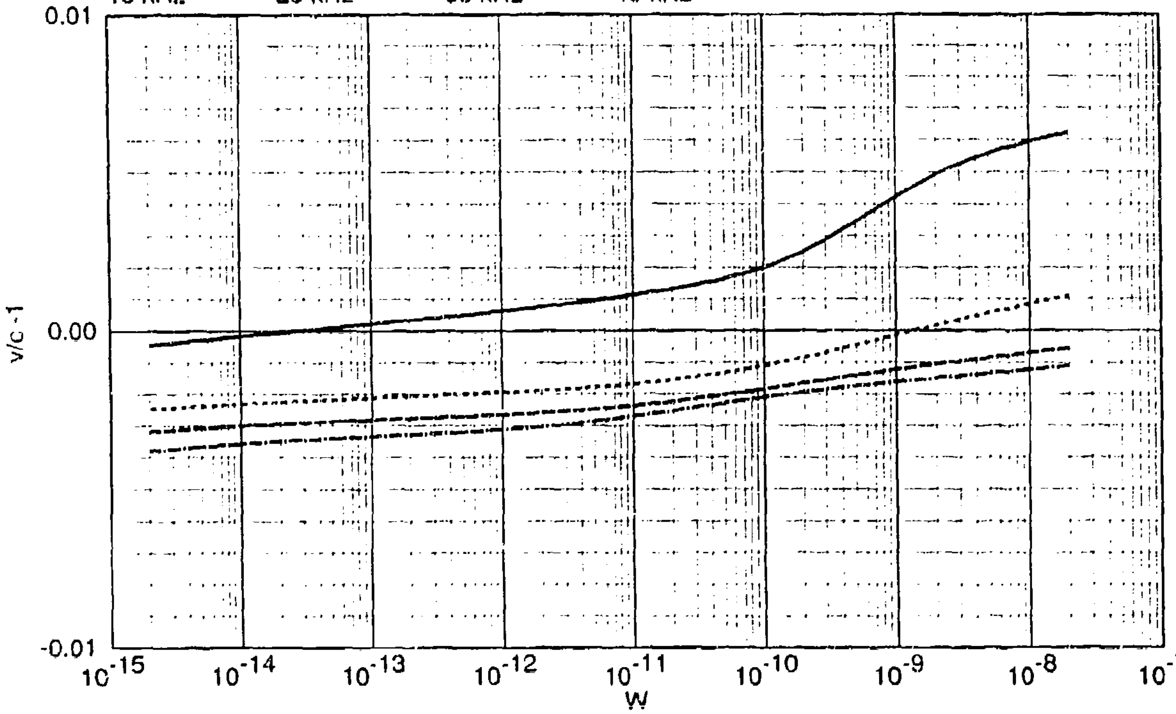


Figure 60. Parameters for least attenuated TM mode, $\sigma_g = 10^{-3}$ S/m.

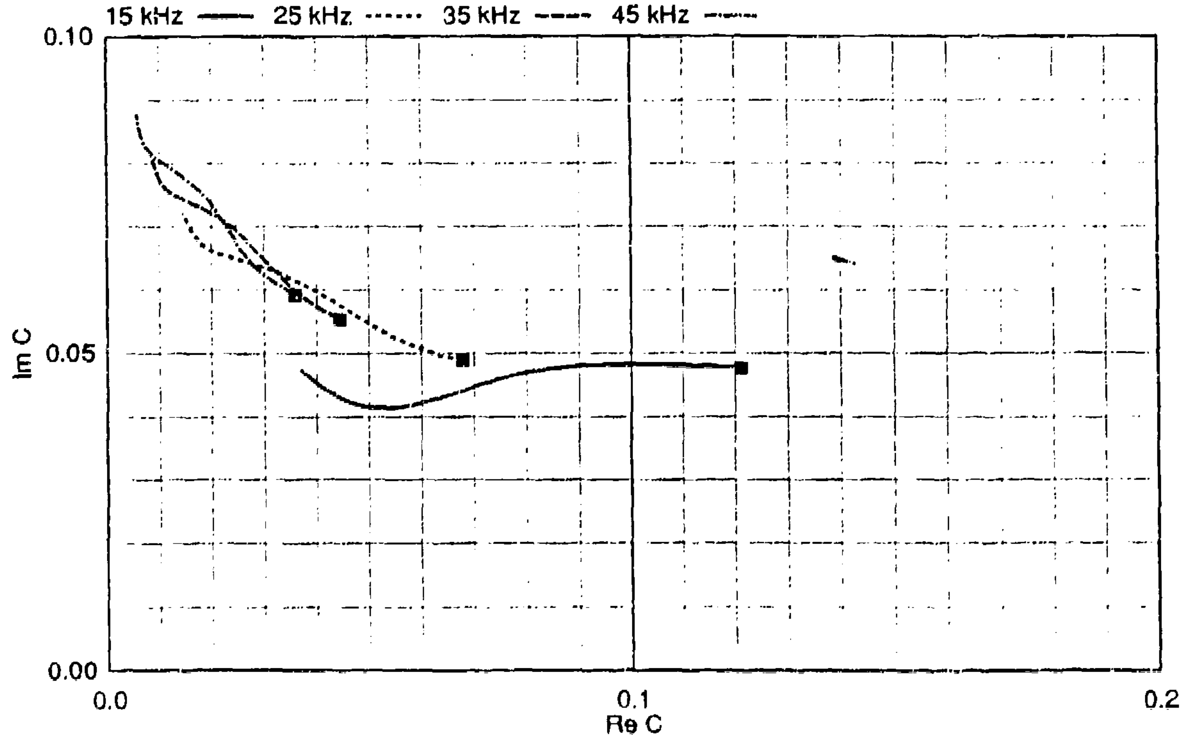
c. Relative phase velocity as a function of parameter W.

15 kHz —— 25 kHz ······ 35 kHz ---- 45 kHz -·-·-



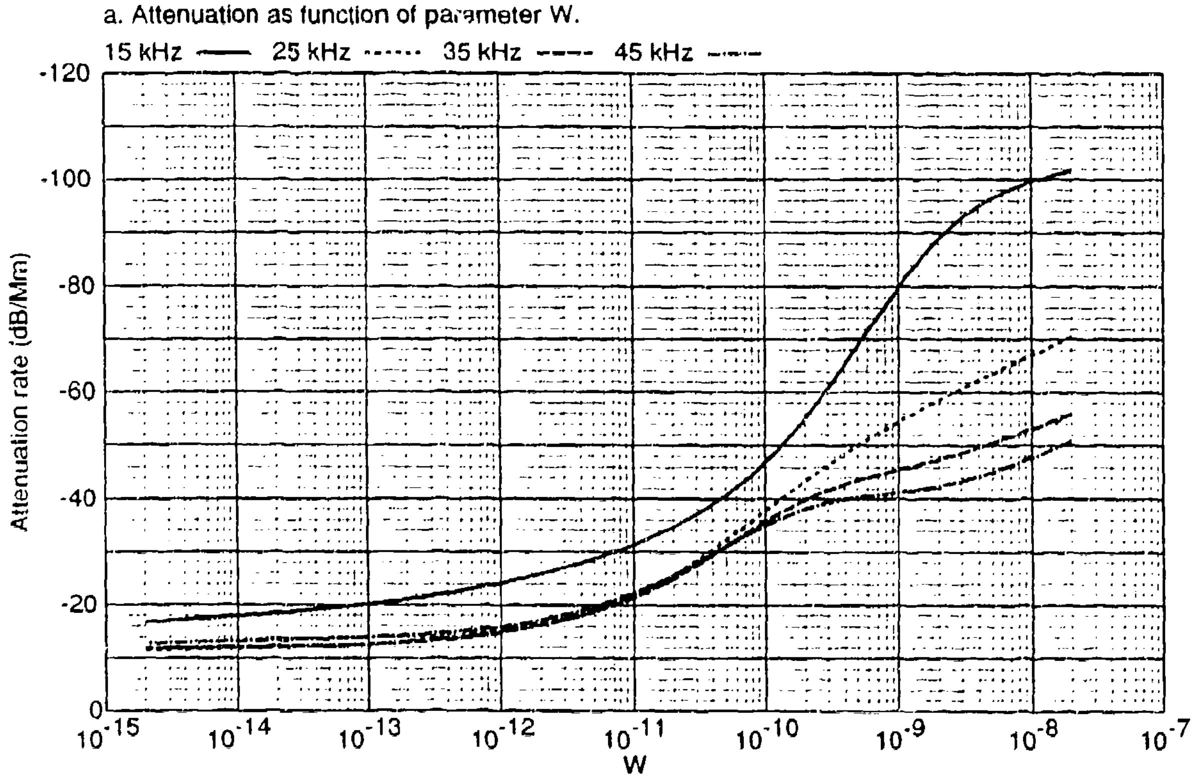
d. Mode paths in the C-plane as W changes.

15 kHz —— 25 kHz ······ 35 kHz ---- 45 kHz -·-·-



NOTE: The point for highest W marked with ■

Figure 60. Parameters for least attenuated TM mode, $\sigma_g = 10^{-3}$ S/m (Concluded).



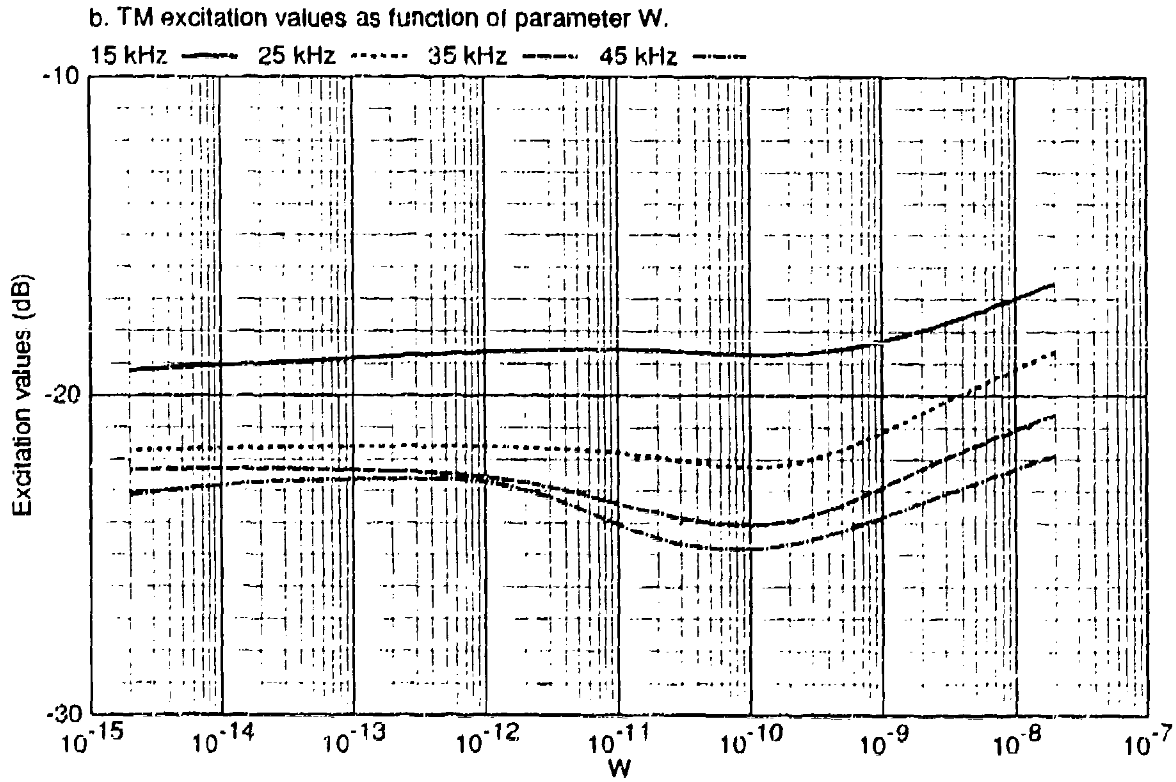
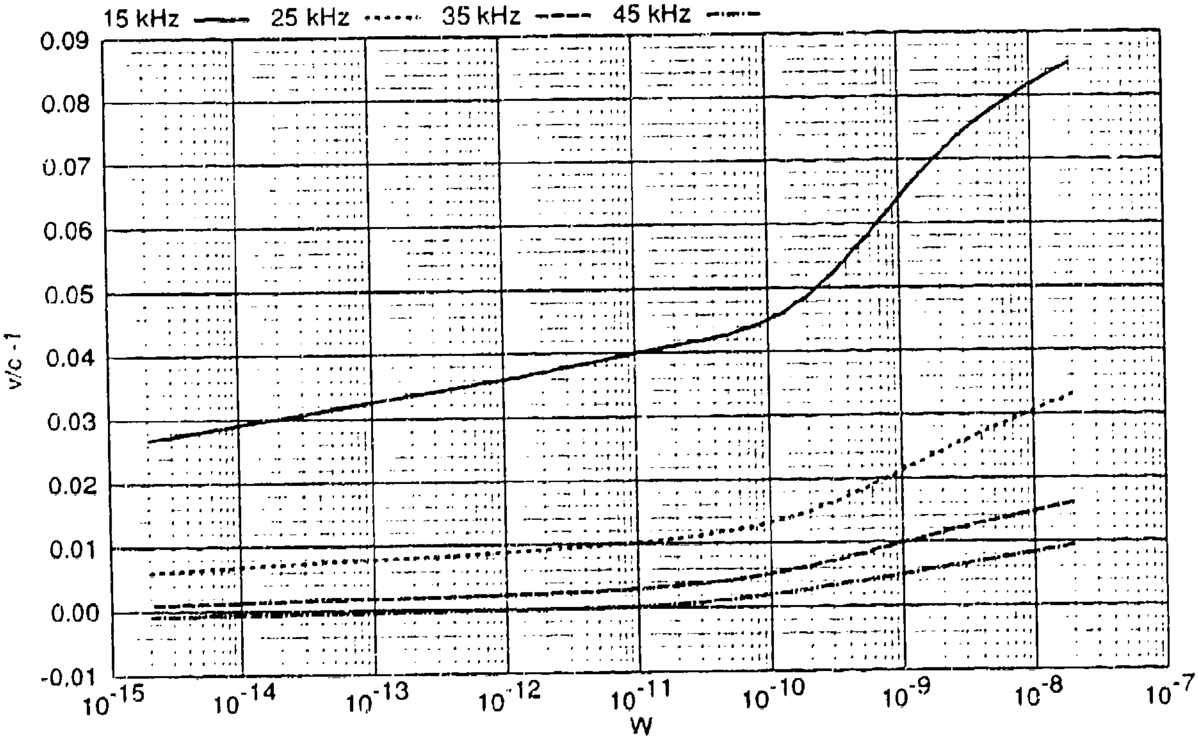
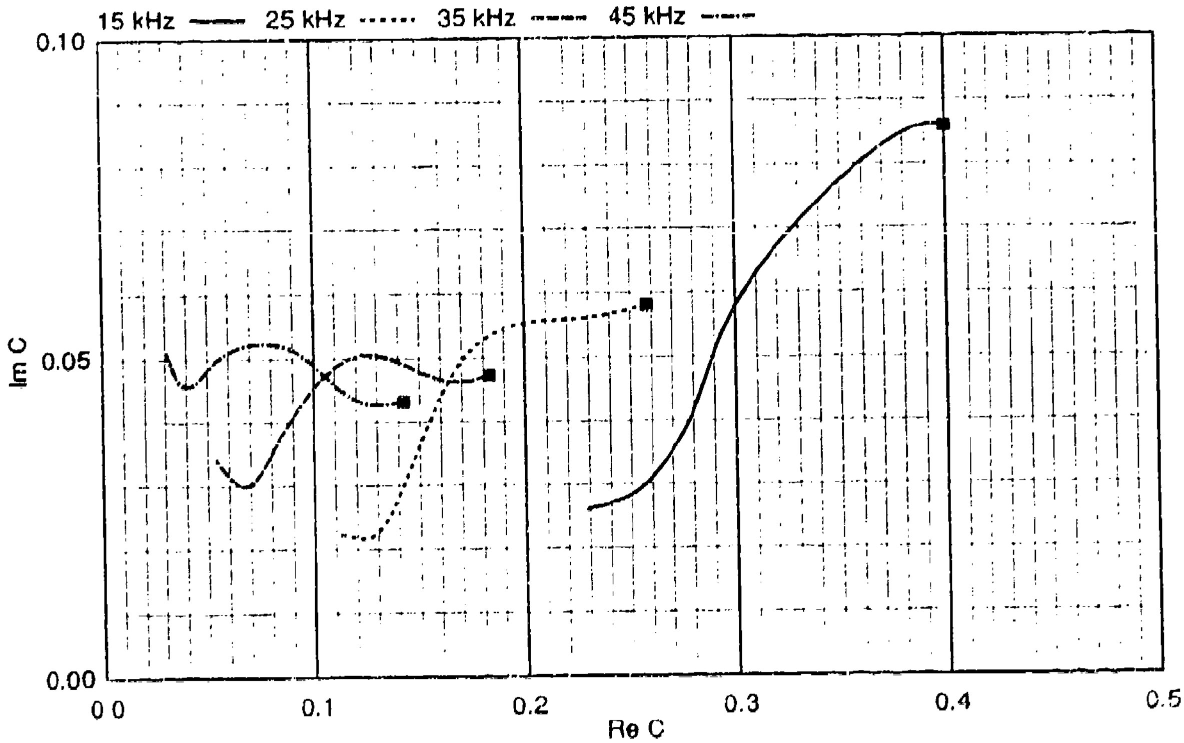


Figure 61. Parameters for second least attenuated TM mode, $\sigma_g = 10^{-3}$ S/m.

c. Relative phase velocity as a function of parameter W.



d. Mode paths in the C-plane as W changes.

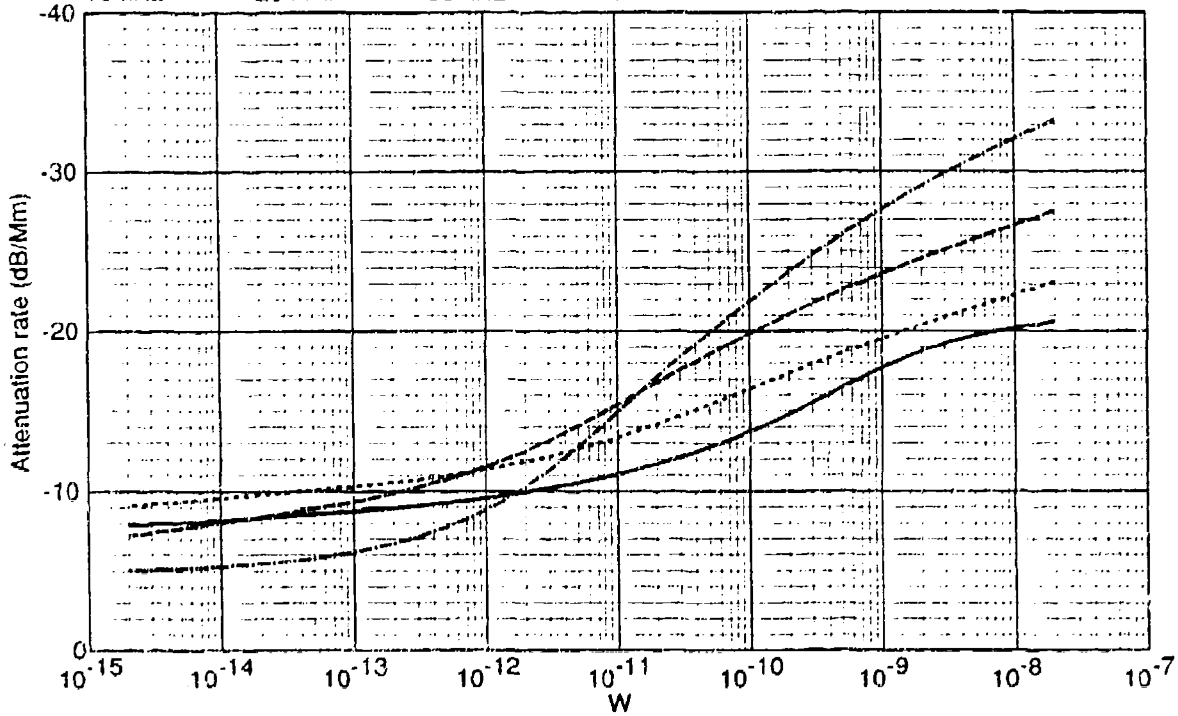


NOTE: The point for highest W marked with ■

Figure 61. Parameters for second least attenuated TM mode, $\sigma_g = 10^{-3}$ S/m (Concluded).

a. Attenuation as function of parameter W.

15 kHz —— 25 kHz ------ 35 kHz ---- 45 kHz -·-·-



b. TM excitation values as function of parameter W.

15 kHz —— 25 kHz ------ 35 kHz ---- 45 kHz -·-·-

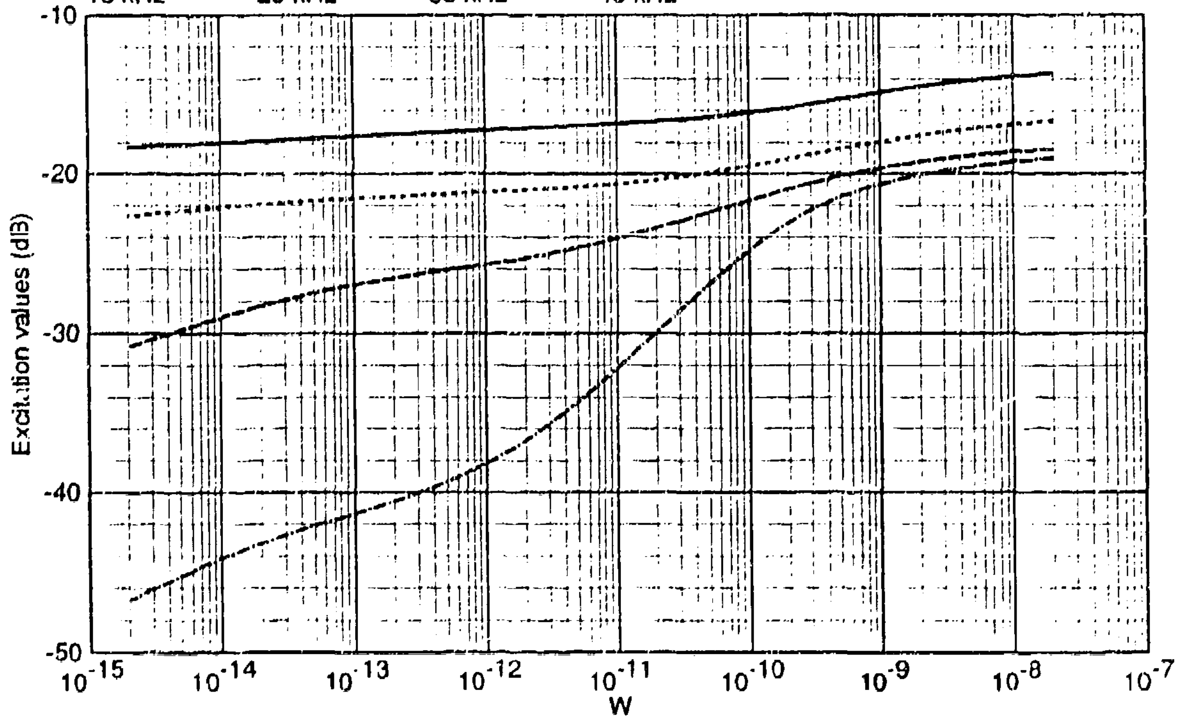
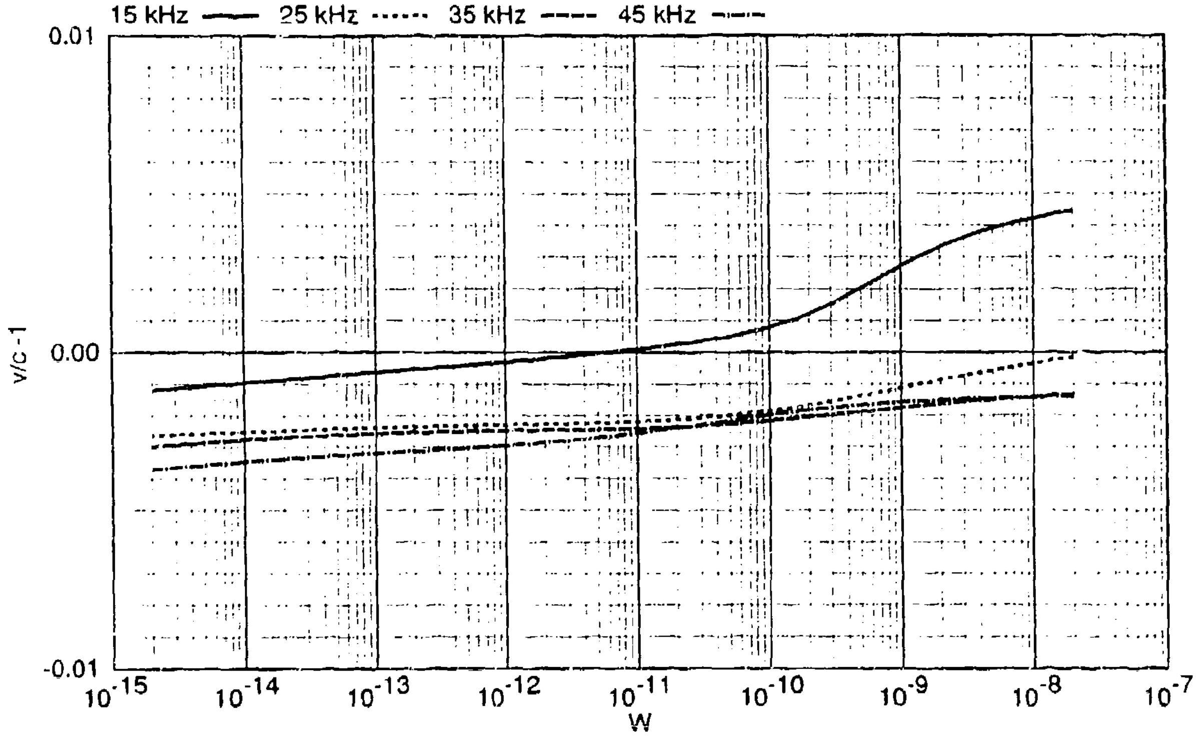
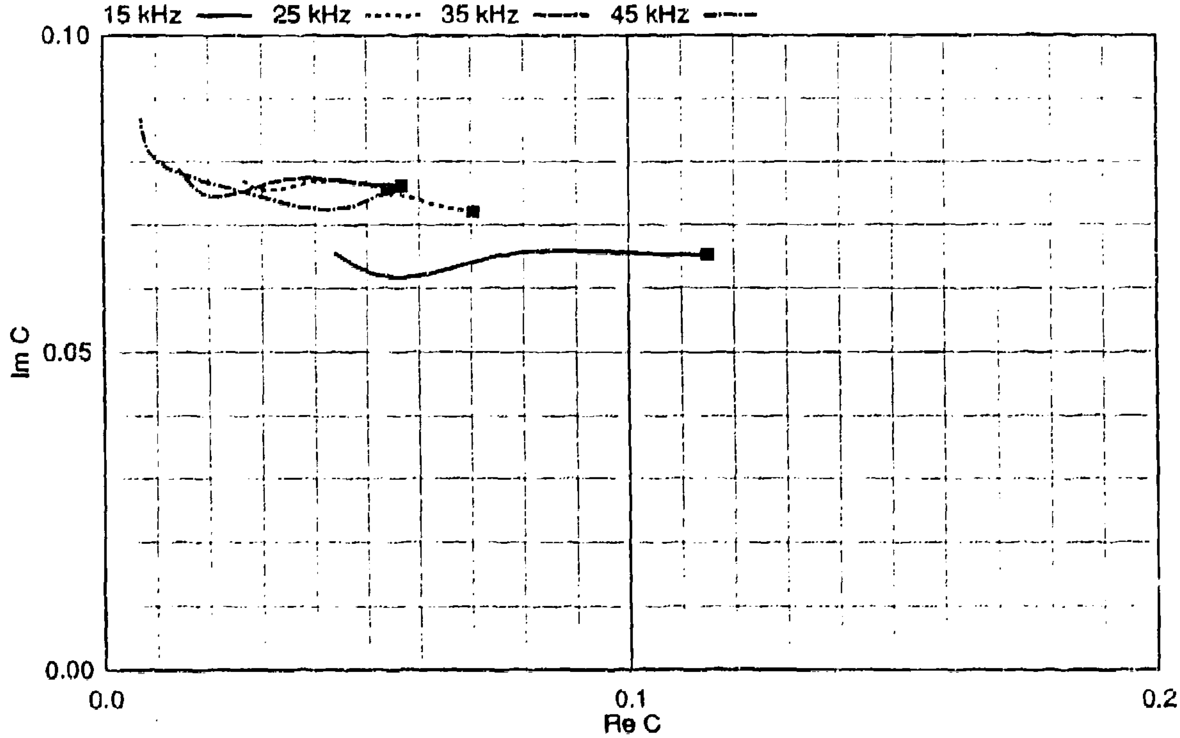


Figure 62. Parameters for least attenuated TM mode, $\sigma_g = 3 \times 10^{-4}$ S/m.

c. Relative phase velocity as a function of parameter W.



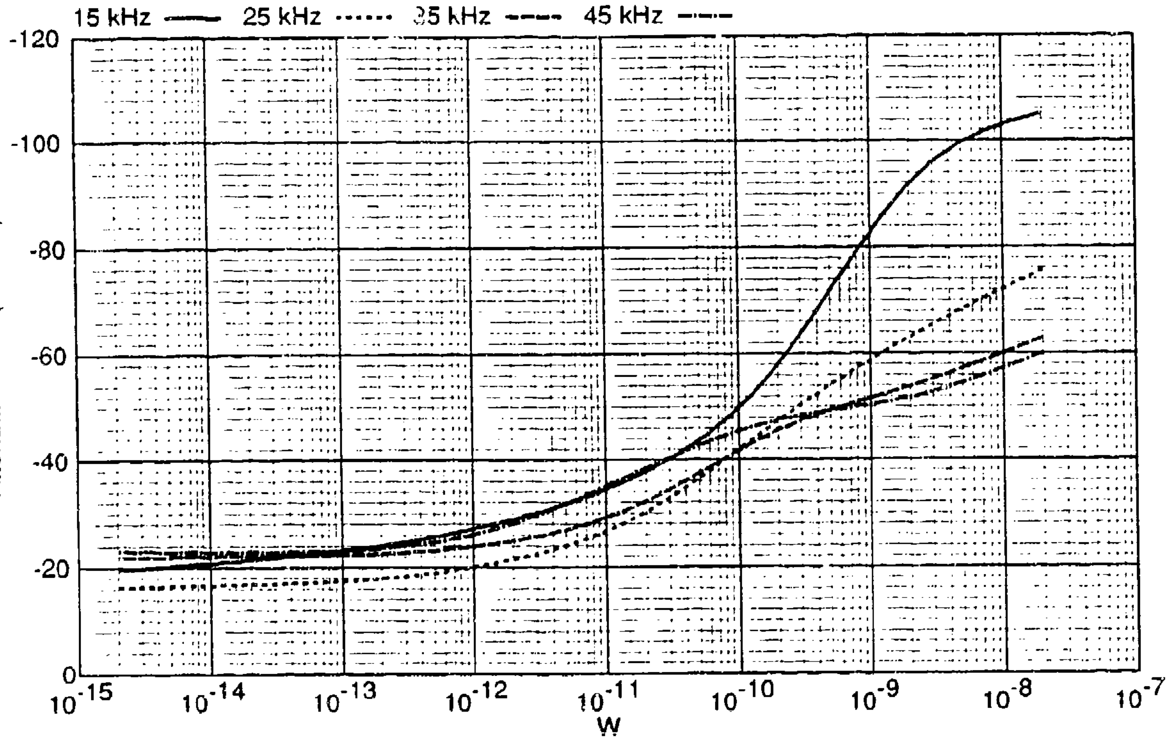
d. Mode paths in the C-plane as W changes.



NOTE: The point for highest W marked with ■

Figure 62. Parameters for least attenuated TM mode, $\sigma_g = 3 \times 10^{-4}$ S/m (Concluded).

a. Attenuation as function of parameter W.



b. TM excitation values as function of parameter W.

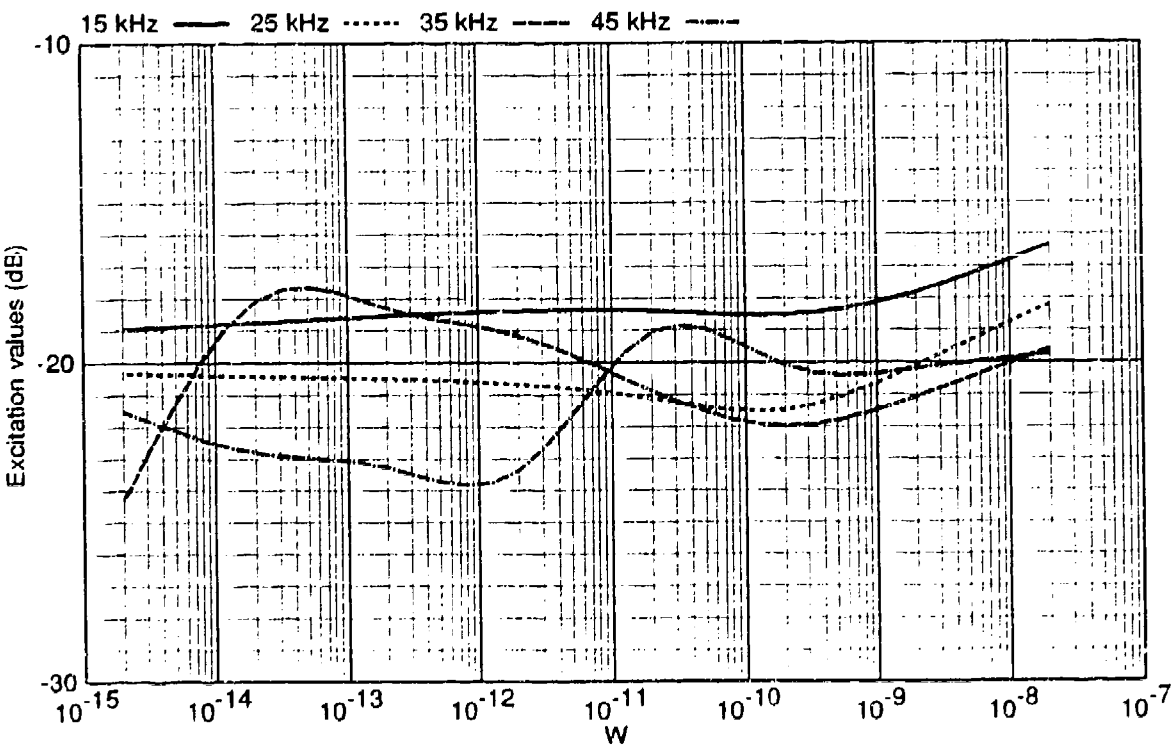
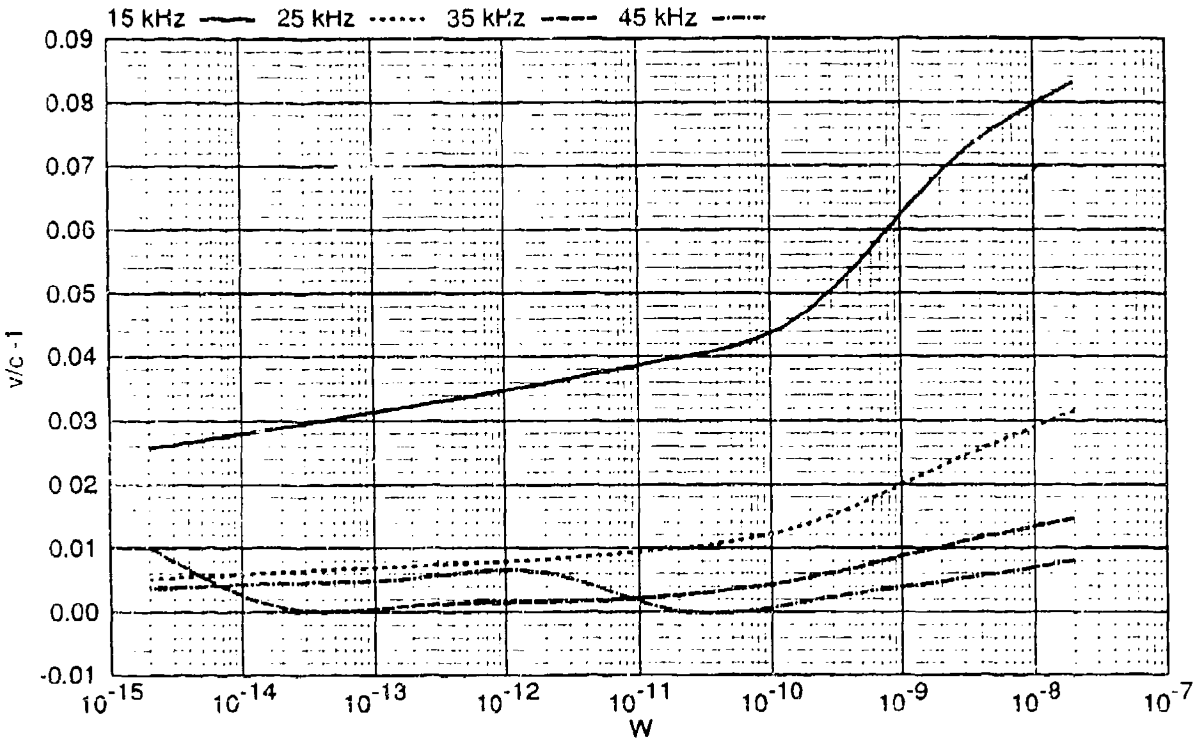
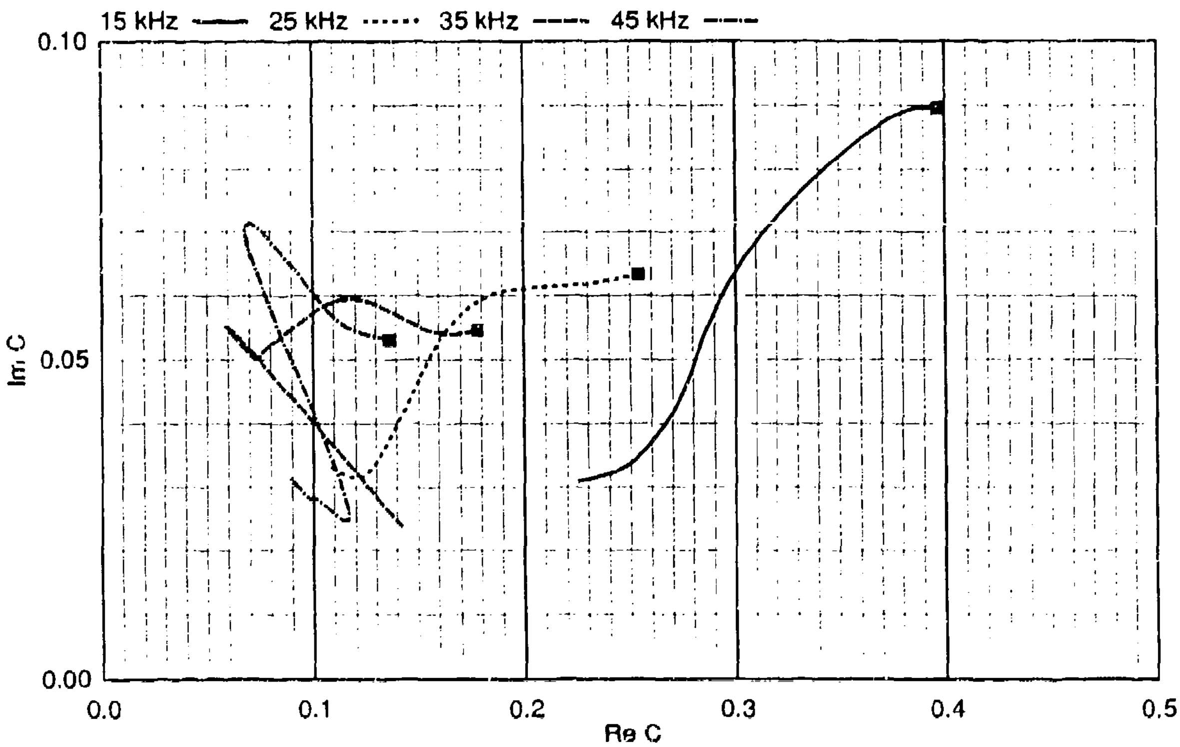


Figure 63. Parameters for second least attenuated TM mode, $\sigma_g = 3 \times 10^{-4}$ S/m.

c. Relative phase velocity as a function of parameter W.

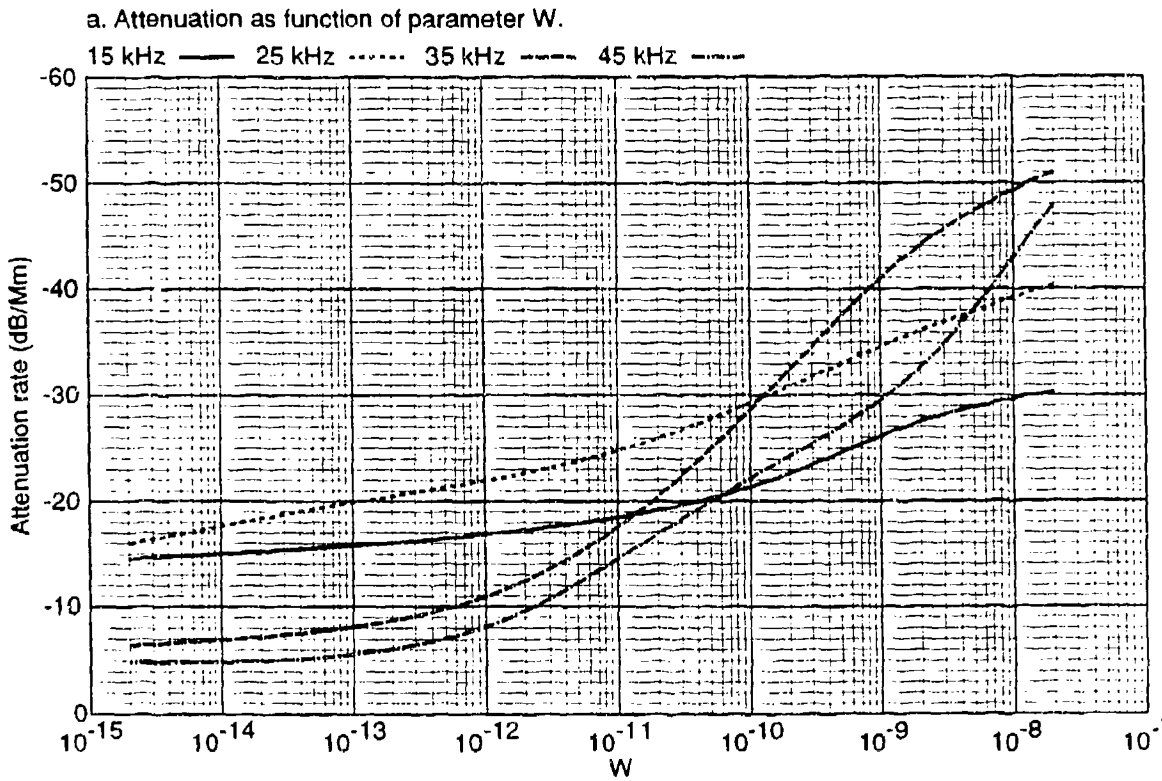


d. Mode paths in the C-plane as W changes.



NOTE: The point for highest W marked with ■

Figure 63. Parameters for second least attenuated TM mode, $\sigma_g = 3 \times 10^{-4}$ S/m (Concluded).



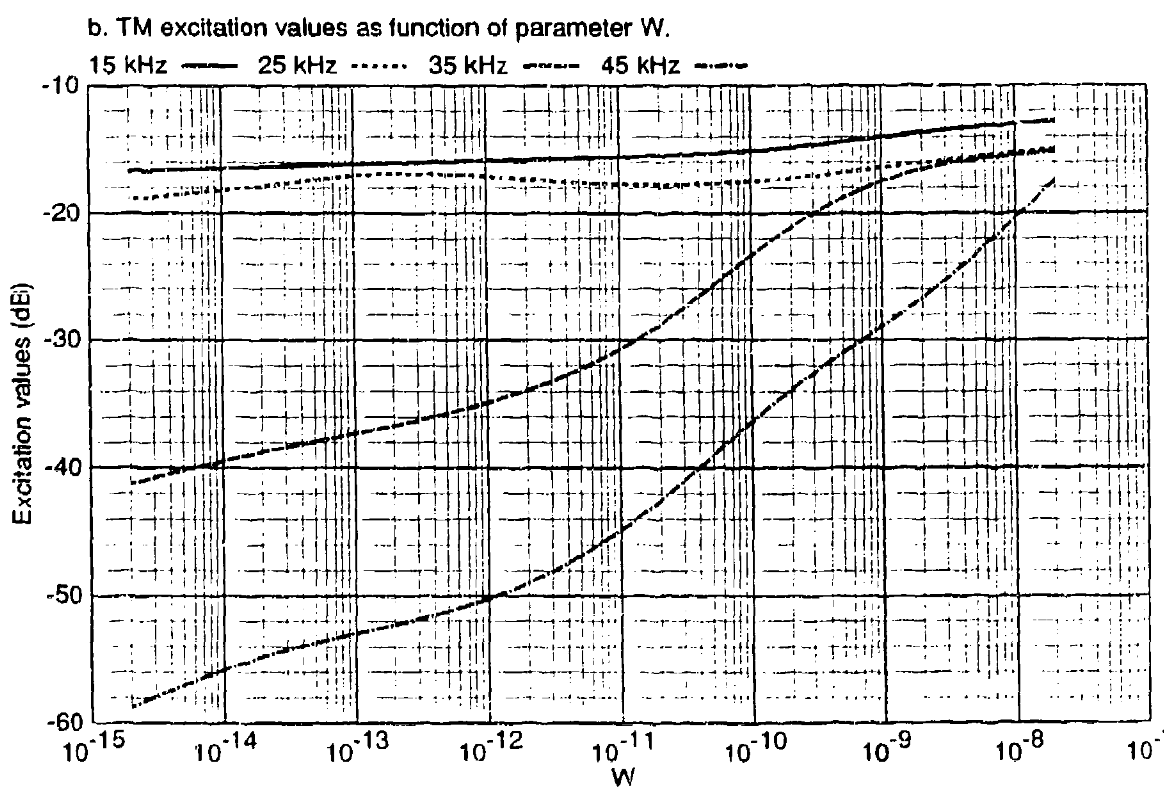
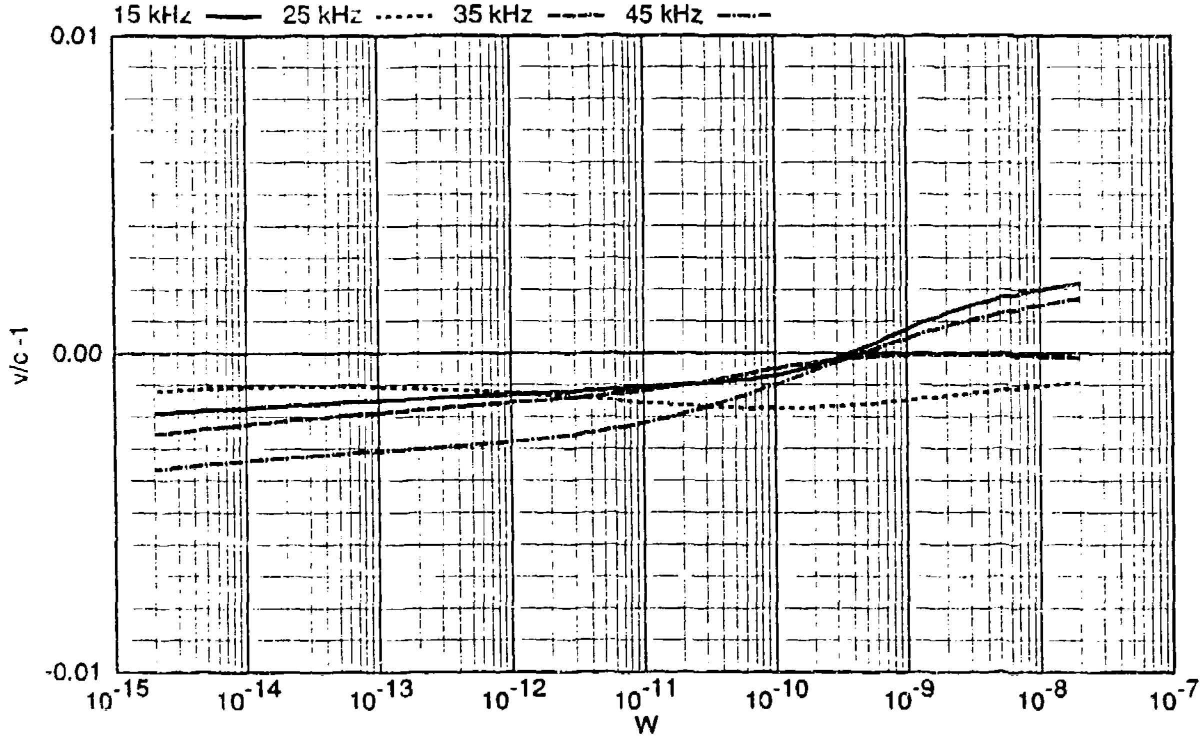
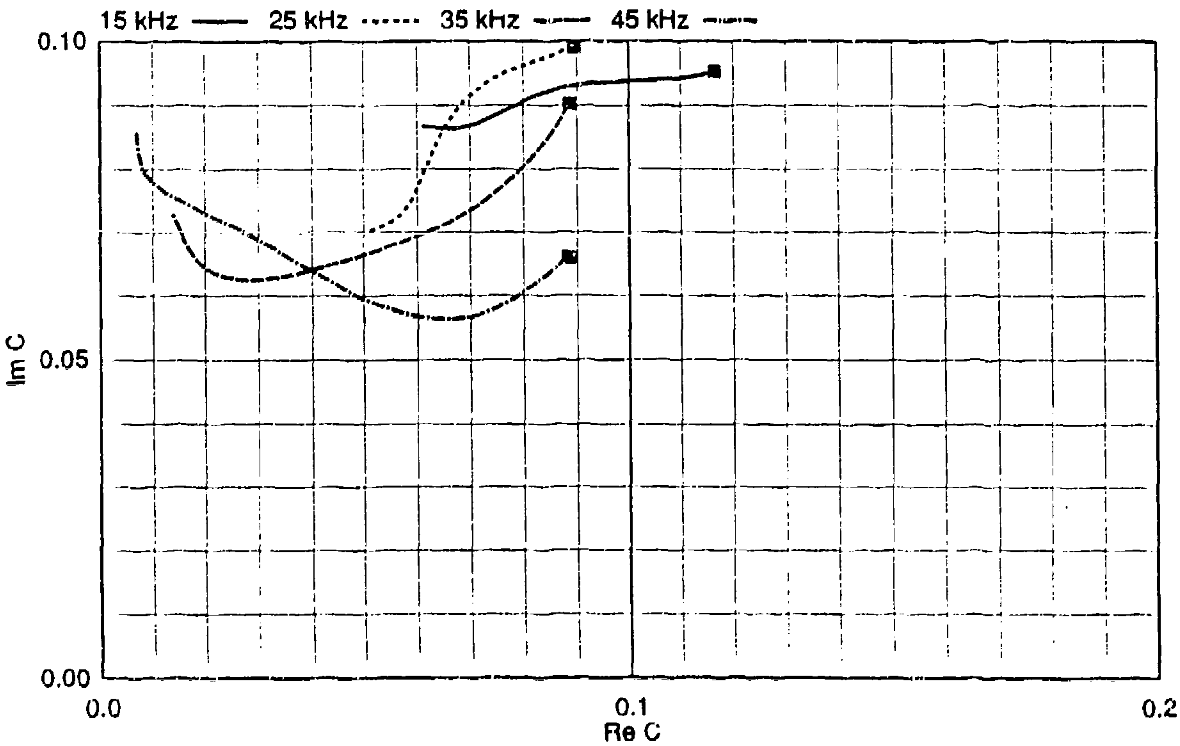


Figure 64. Parameters for least attenuated TM mode, $\sigma_g = 10^{-4}$ S/m.

c. Relative phase velocity as a function of parameter W.



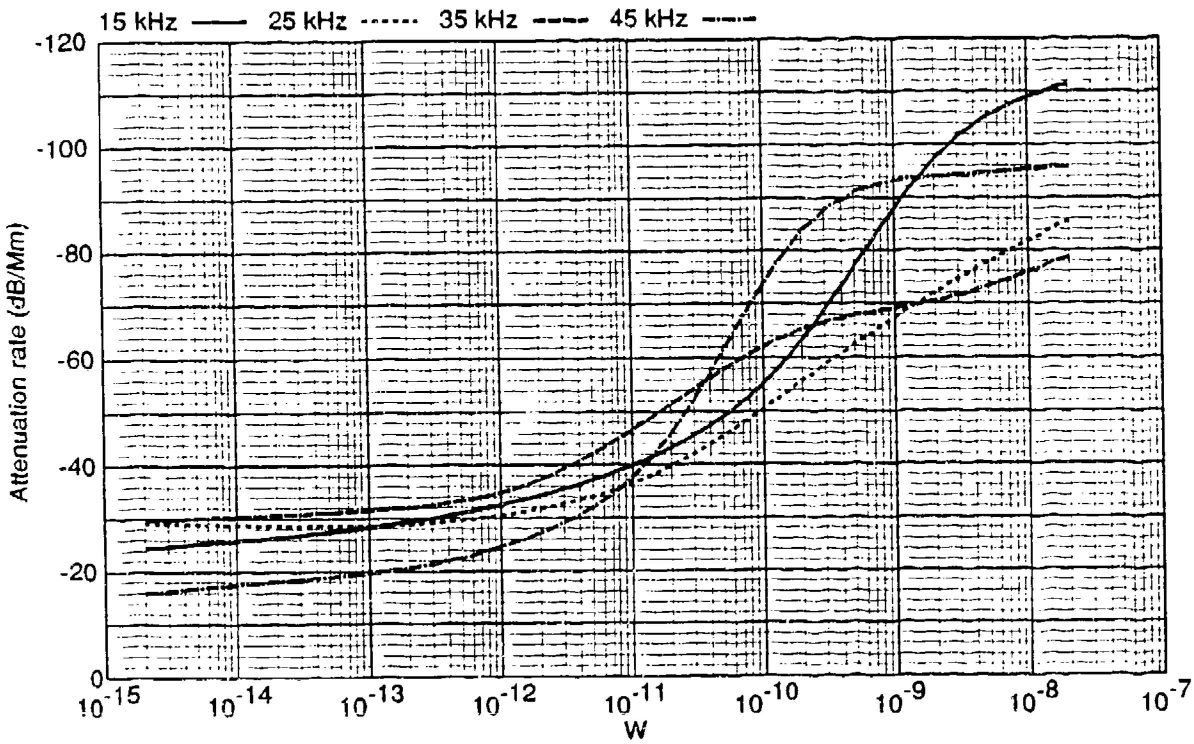
d. Mode paths in the C-plane as W changes.



NOTE: The point for highest W marked with ■

Figure 64. Parameters for least attenuated TM mode, $\sigma_g = 10^{-4}$ S/m (Concluded).

a. Attenuation as function of parameter W.



b. TM excitation values as function of parameter W.

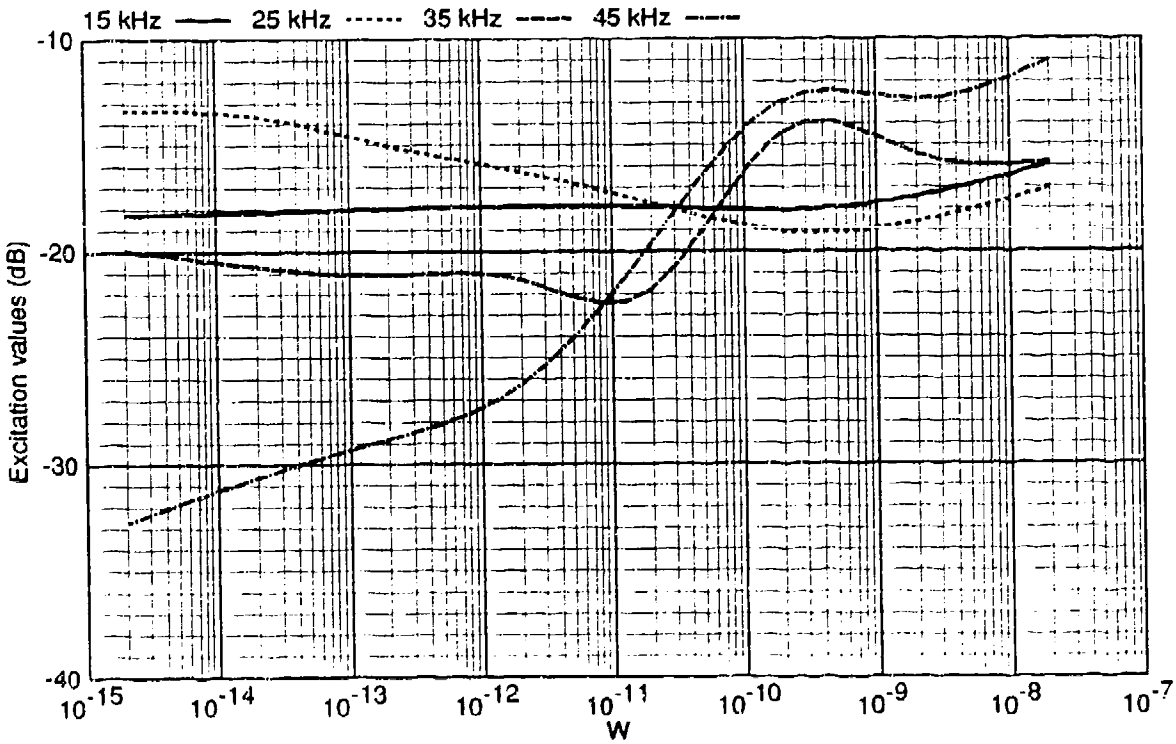
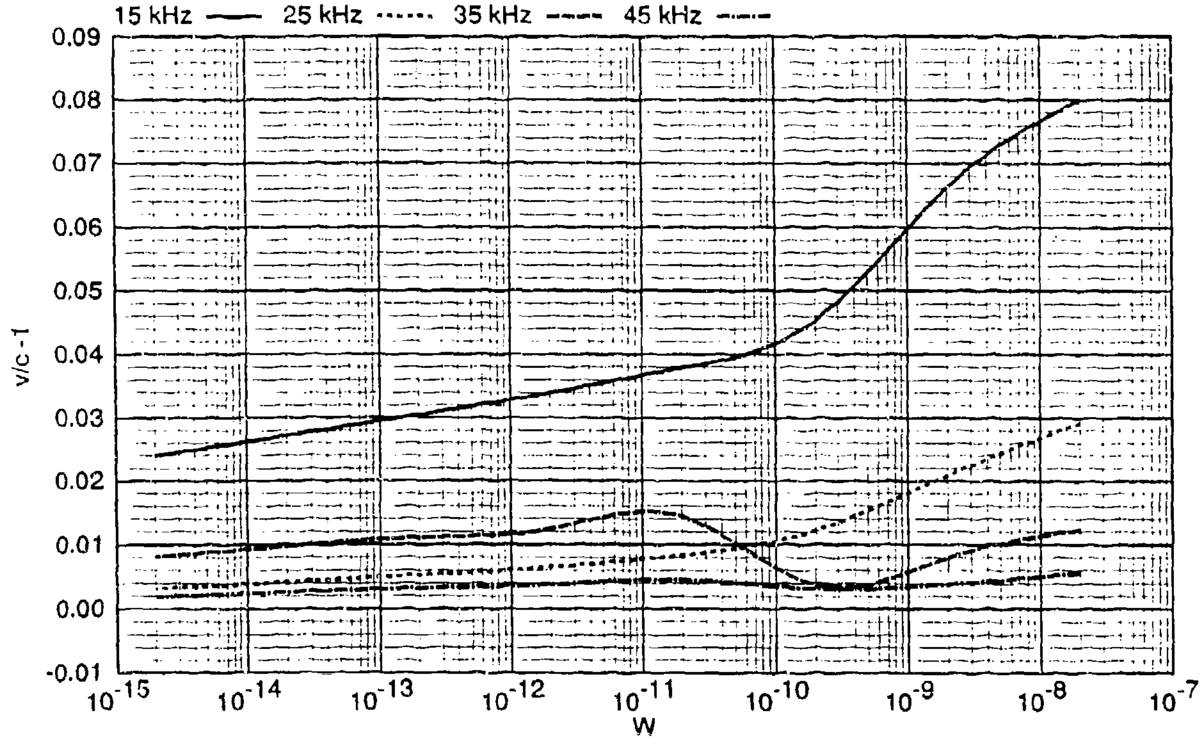
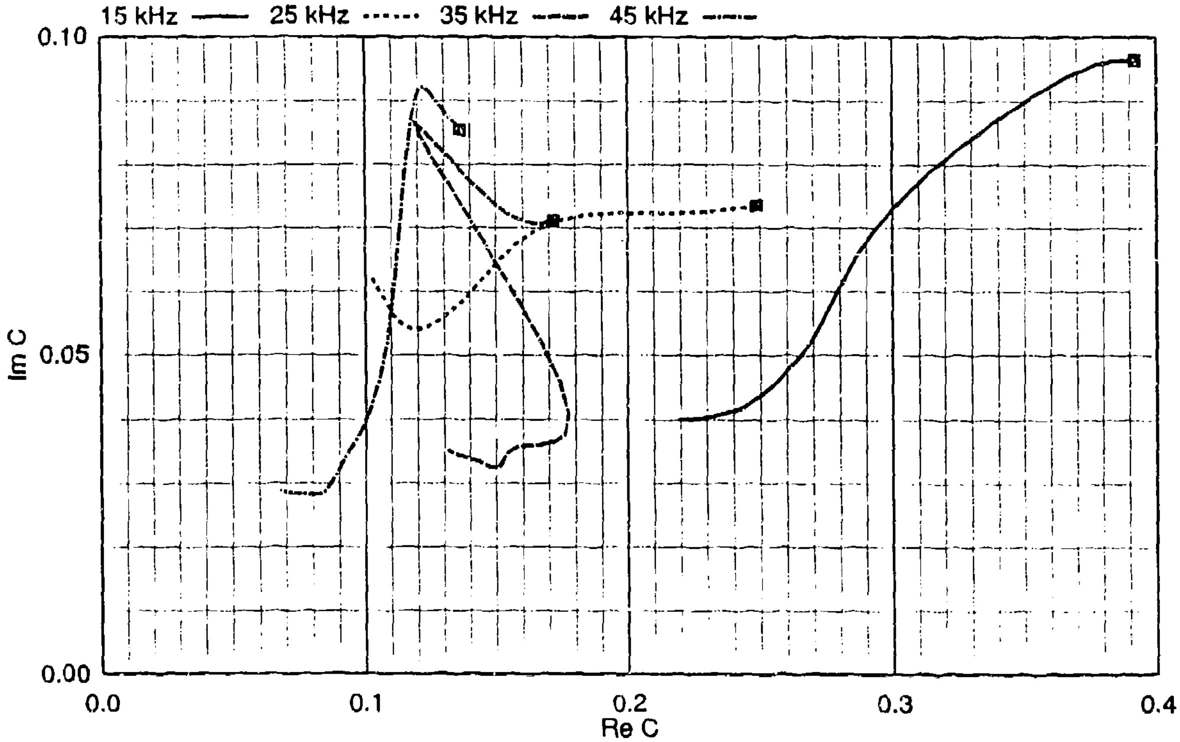


Figure 65. Parameters for second least attenuated TM mode, $\sigma_g = 10^{-4}$ S/m.

c. Relative phase velocity as a function of parameter W.



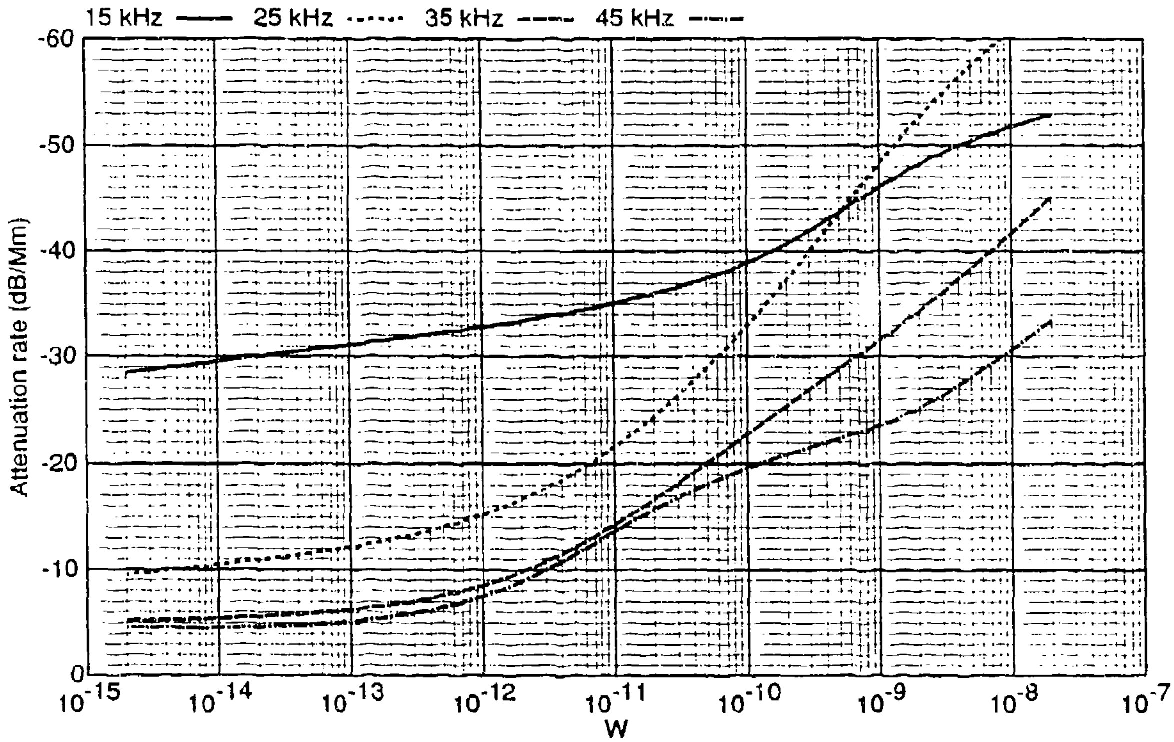
d. Mode paths in the C-plane as W changes.



NOTE: The point for highest W marked with ■

Figure 65. Parameters for second least attenuated TM mode, $\sigma_g = 10^{-4}$ S/m (Concluded).

a. Attenuation as function of parameter W.



b. TM excitation values as function of parameter W.

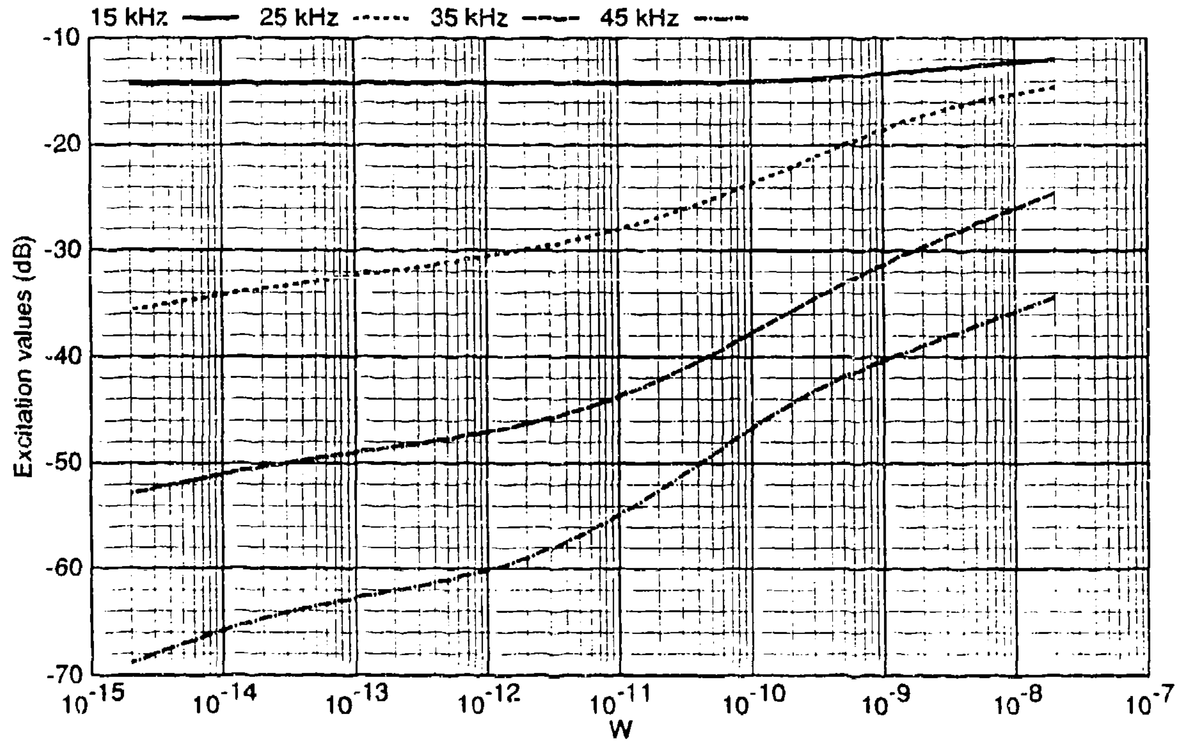
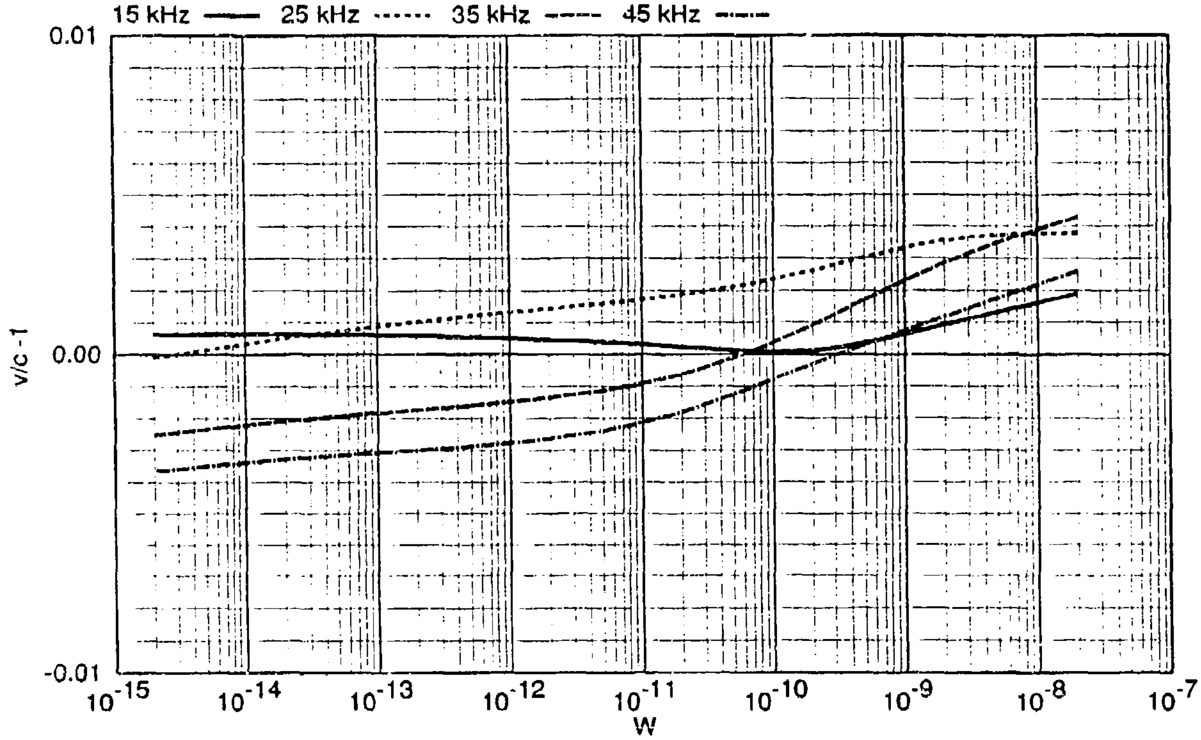
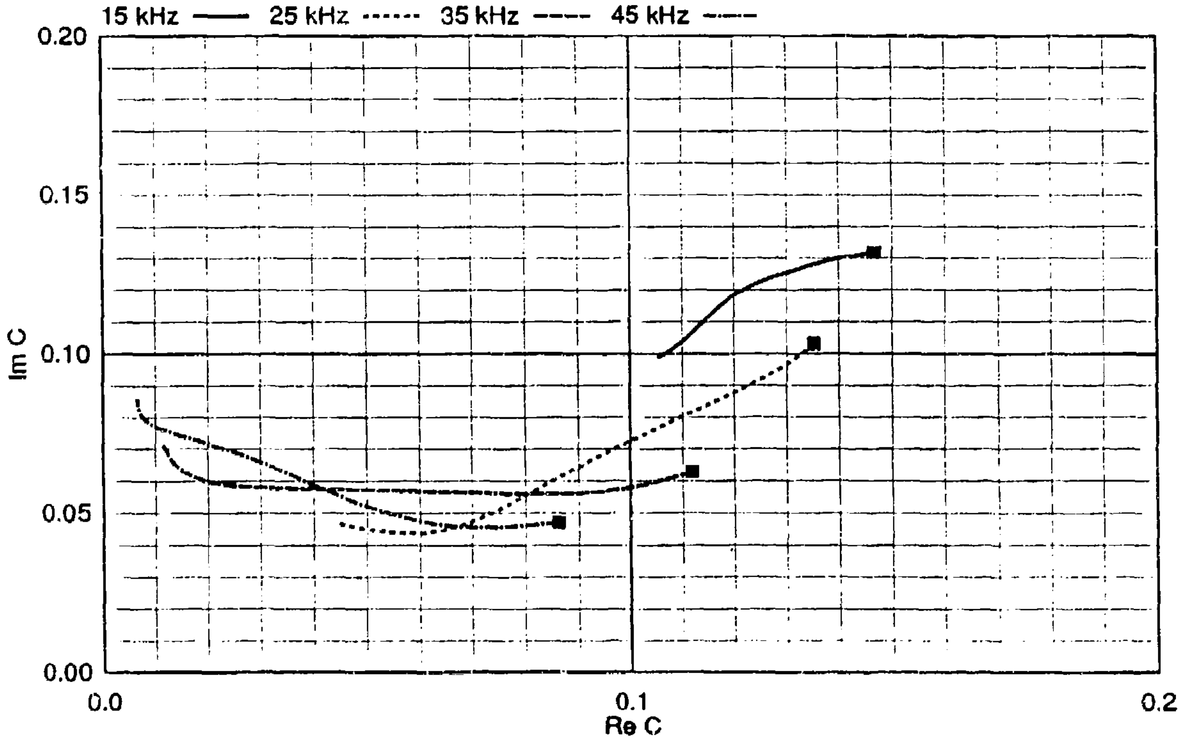


Figure 66. Parameters for least attenuated TM mode, $\sigma_g = 3 \times 10^{-5}$ S/m.

c. Relative phase velocity as a function of parameter W.

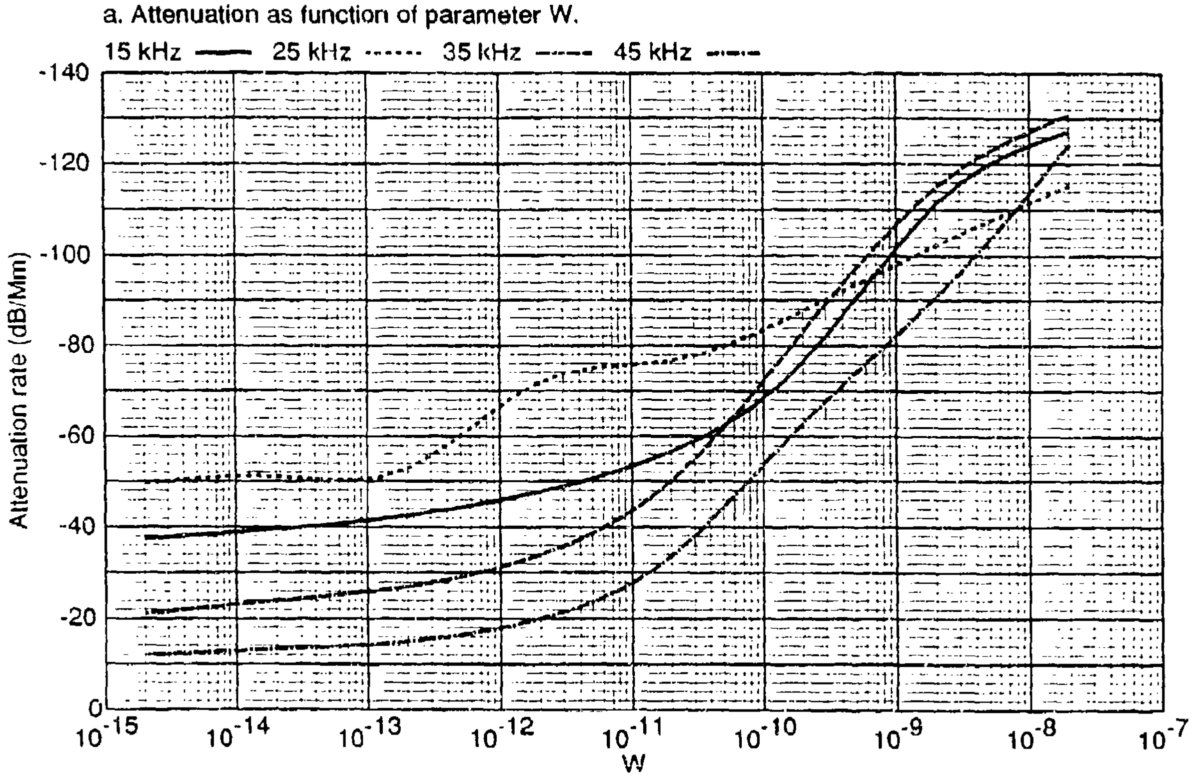


d. Mode paths in the C-plane as W changes.



NOTE: The point for highest W marked with ■

Figure 66. Parameters for least attenuated TM mode, $\sigma_g = 3 \times 10^{-5}$ S/m (Concluded).



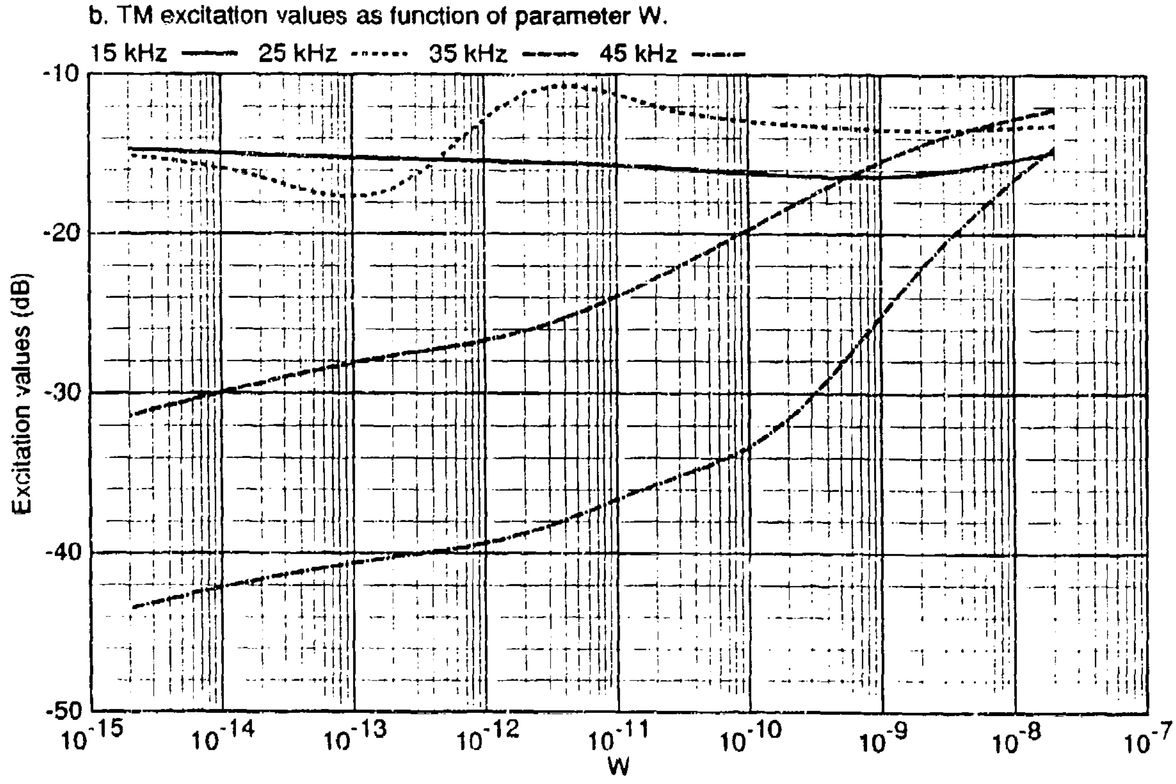
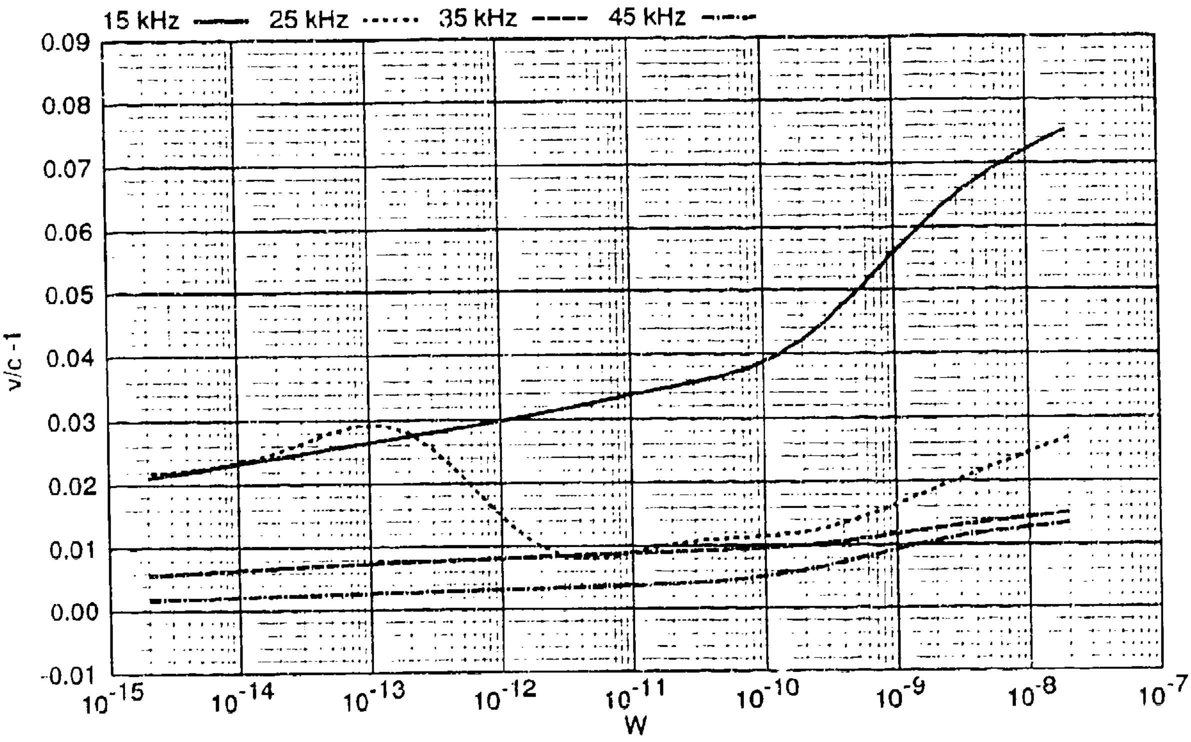
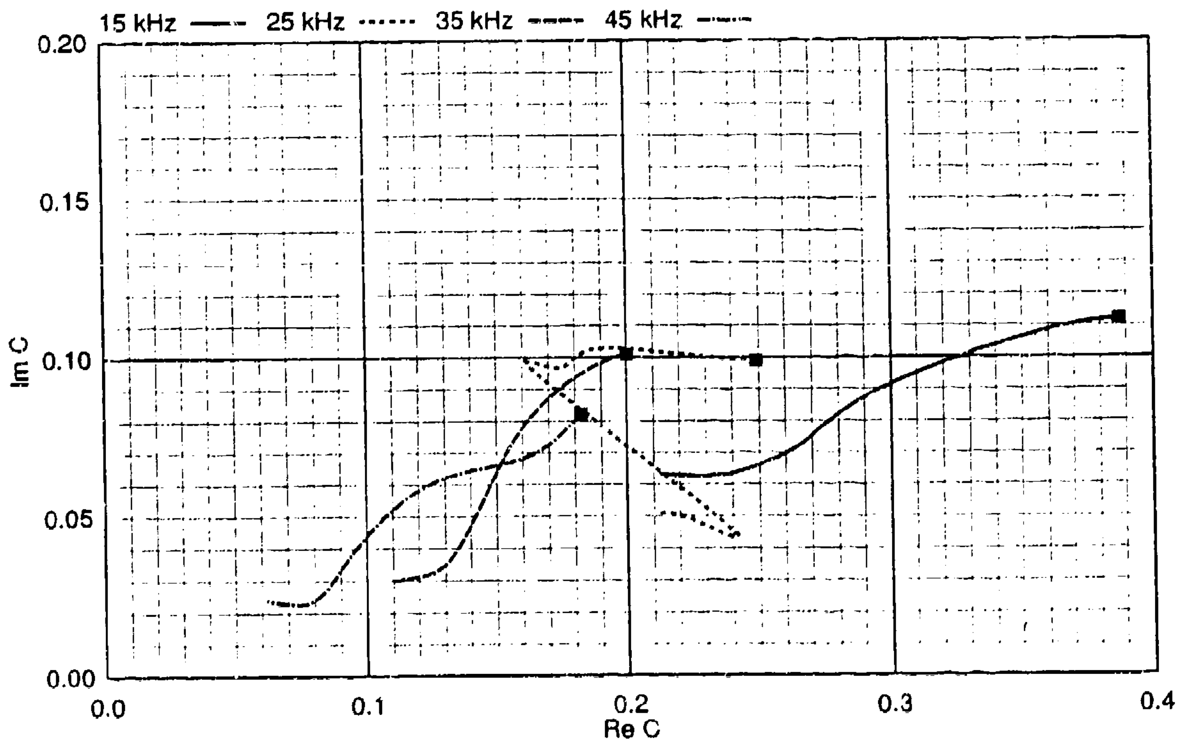


Figure 67. Parameters for second least attenuated TM mode, $\sigma_g = 3 \times 10^{-5}$ S/m.

c. Relative phase velocity as a function of parameter W.



d. Mode paths in the C-plane as W changes.



NOTE: The point for highest W marked with ■

Figure 67. Parameters for second least attenuated TM mode, $\sigma_g = 3 \times 10^{-5}$ S/m (Concluded).

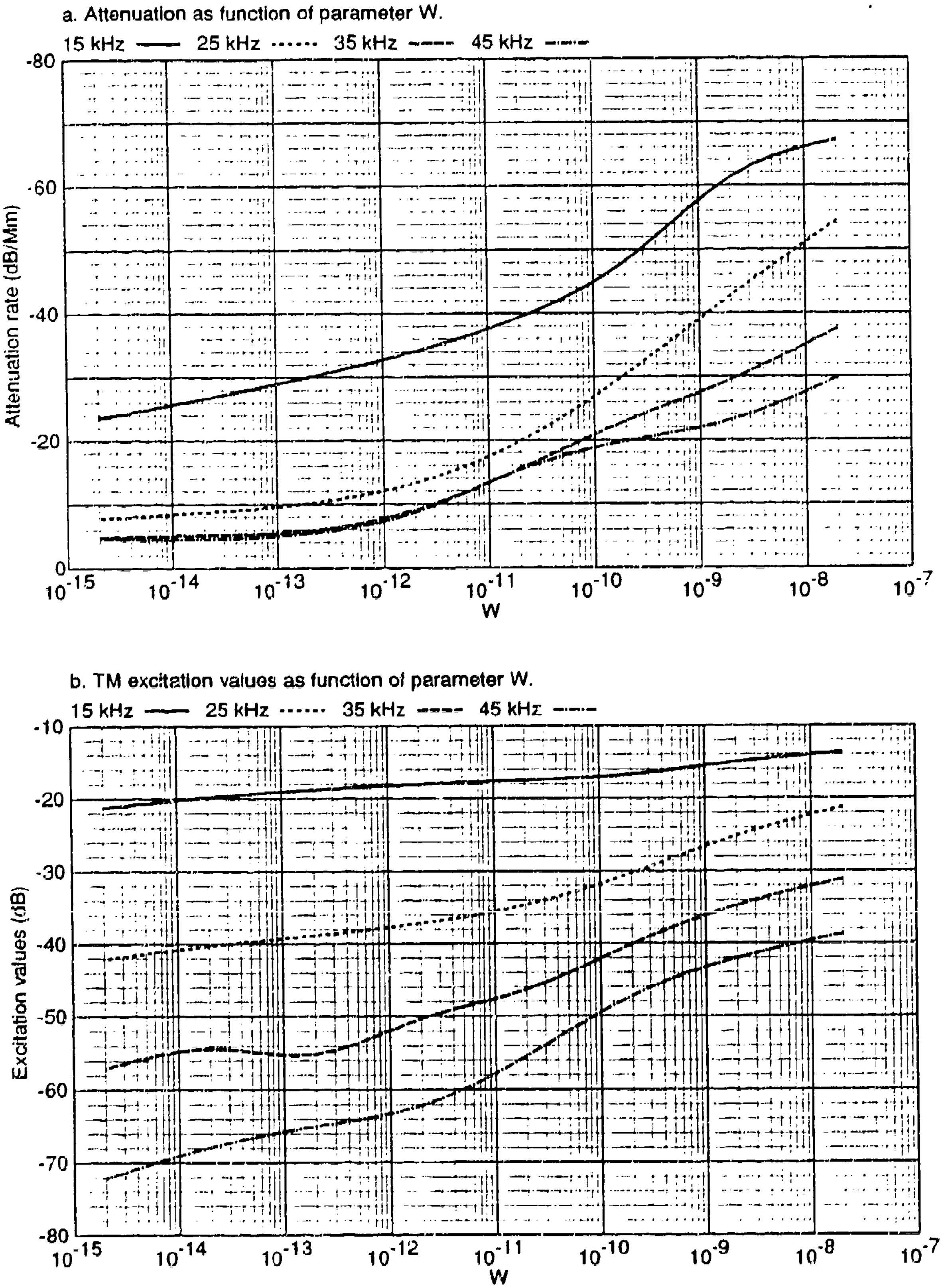
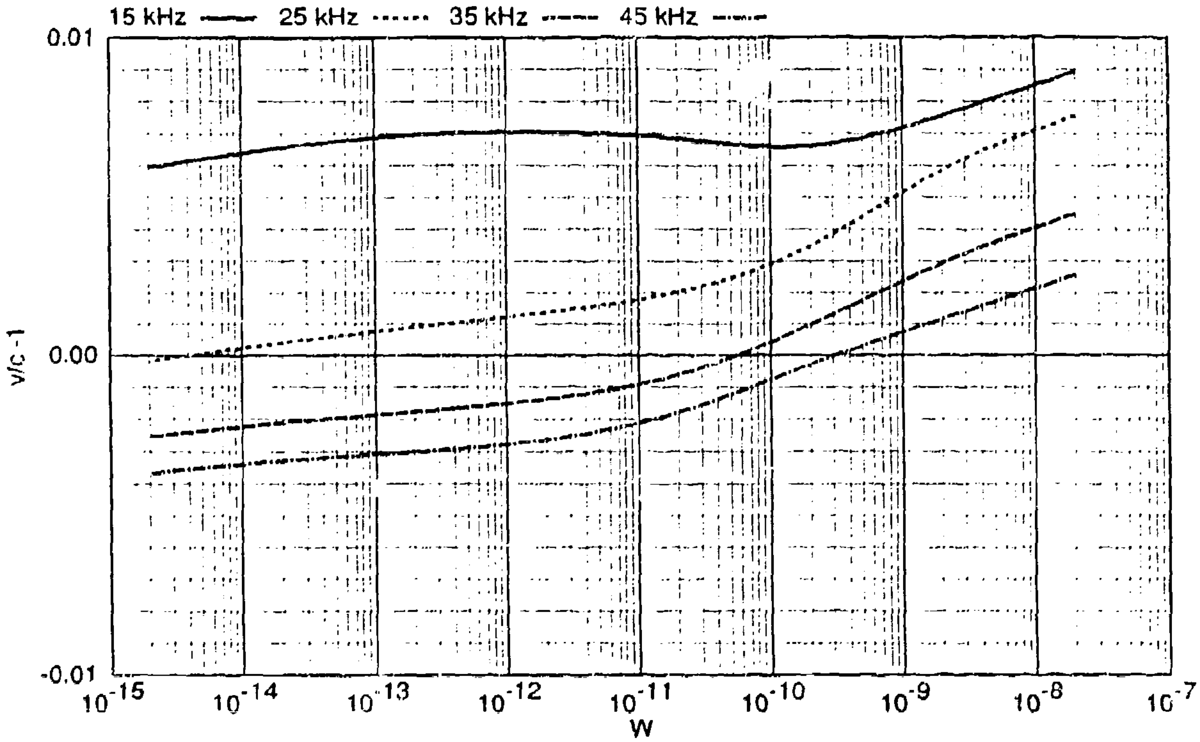
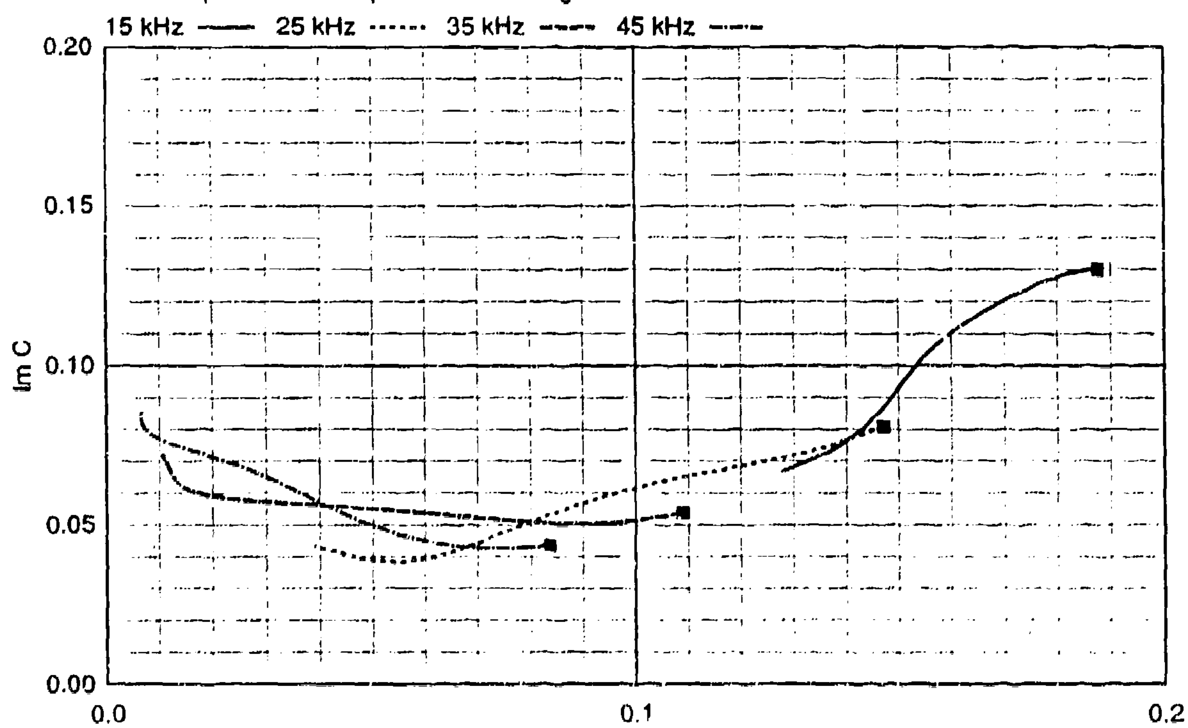


Figure 68. Parameters for least attenuated TM mode, $\sigma_g = 10^{-5}$ S/m.

c. Relative phase velocity as a function of parameter W.

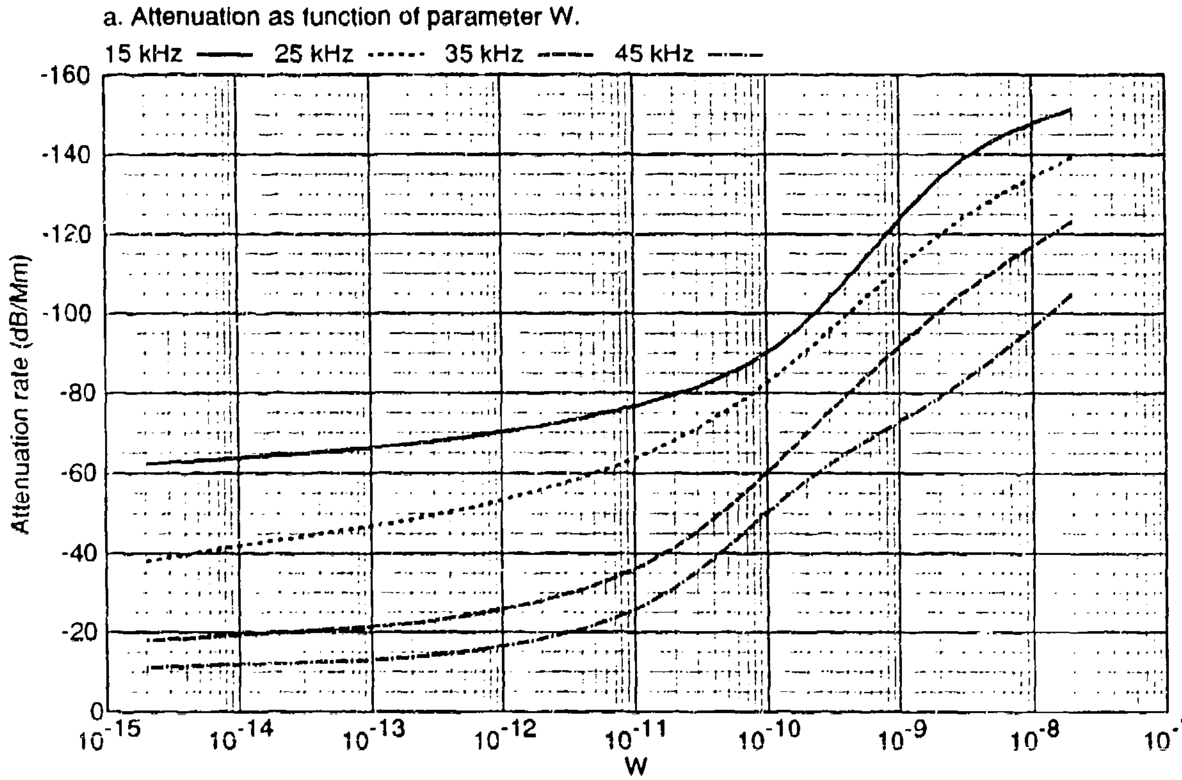


d. Mode paths in the C-plane as W changes.



NOTE: The point for highest W marked with ■

Figure 68. Parameters for least attenuated TM mode, $\sigma_g = 10^{-5}$ S/m (Concluded).



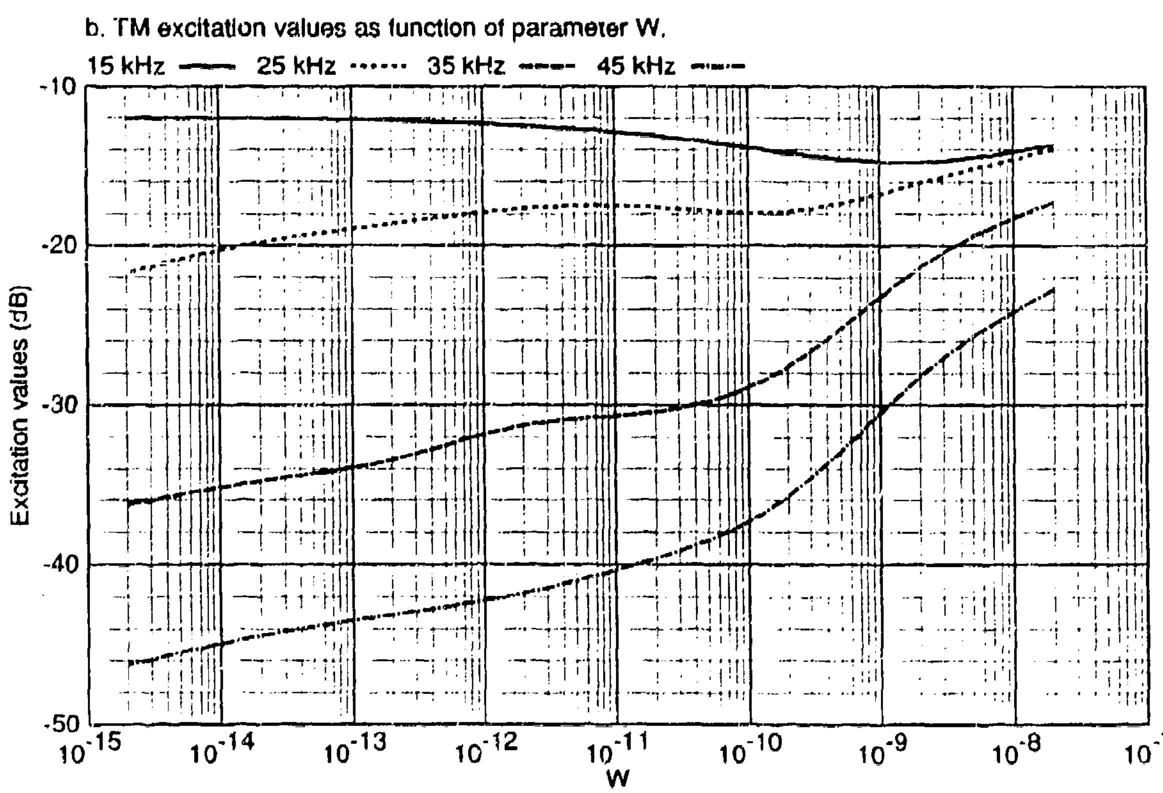
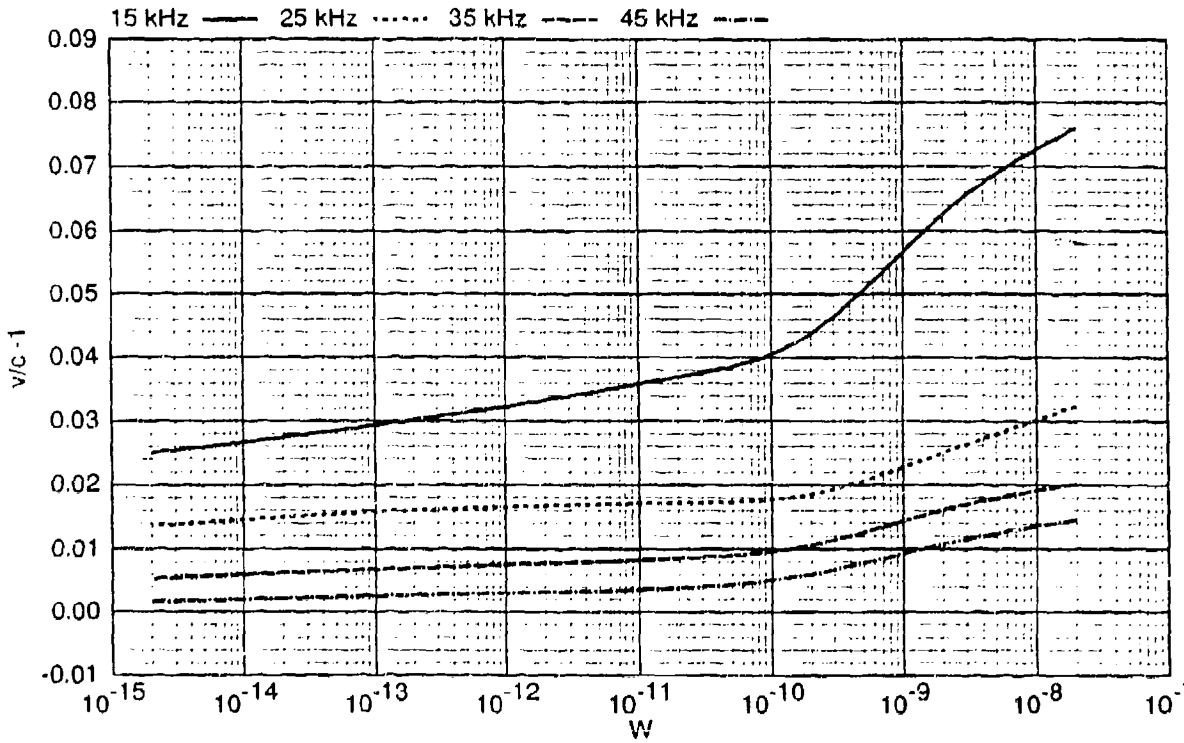
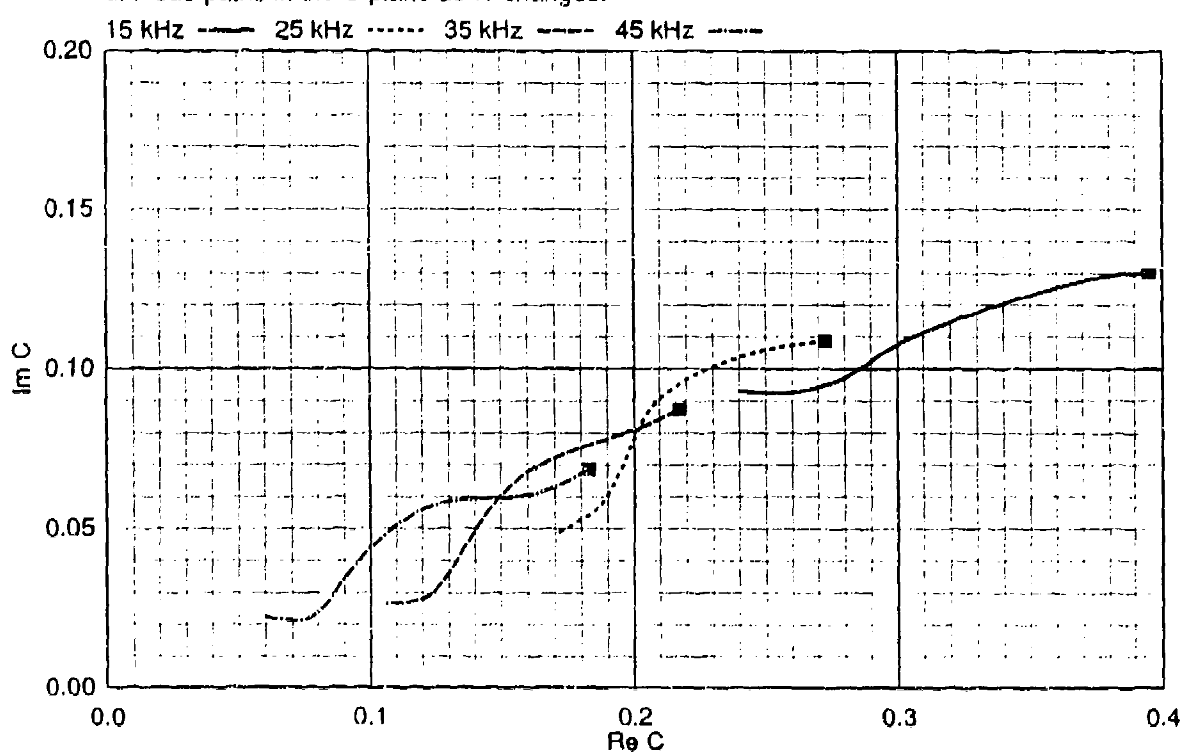


Figure 69. Parameters for second least attenuated TM mode, $\sigma_g = 10^{-5}$ S/m.

c. Relative phase velocity as a function of parameter W.



d. Mode paths in the C-plane as W changes.



NOTE: The point for highest W marked with ■

Figure 69. Parameters for second least attenuated TM mode, $\sigma_g = 10^{-5}$ S/m (Concluded).

SECTION 3

PARAMETERS AS A FUNCTION OF FREQUENCY

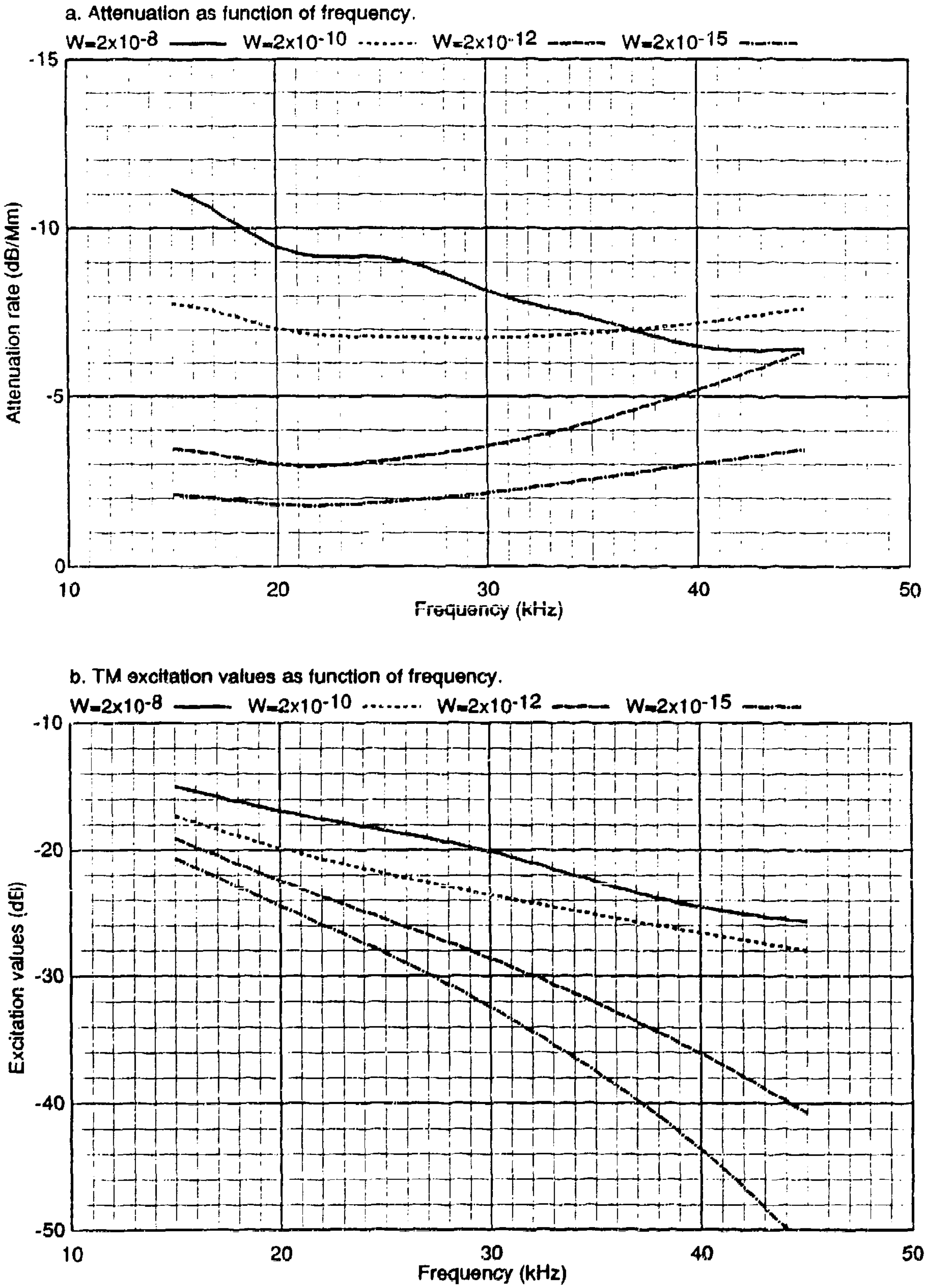
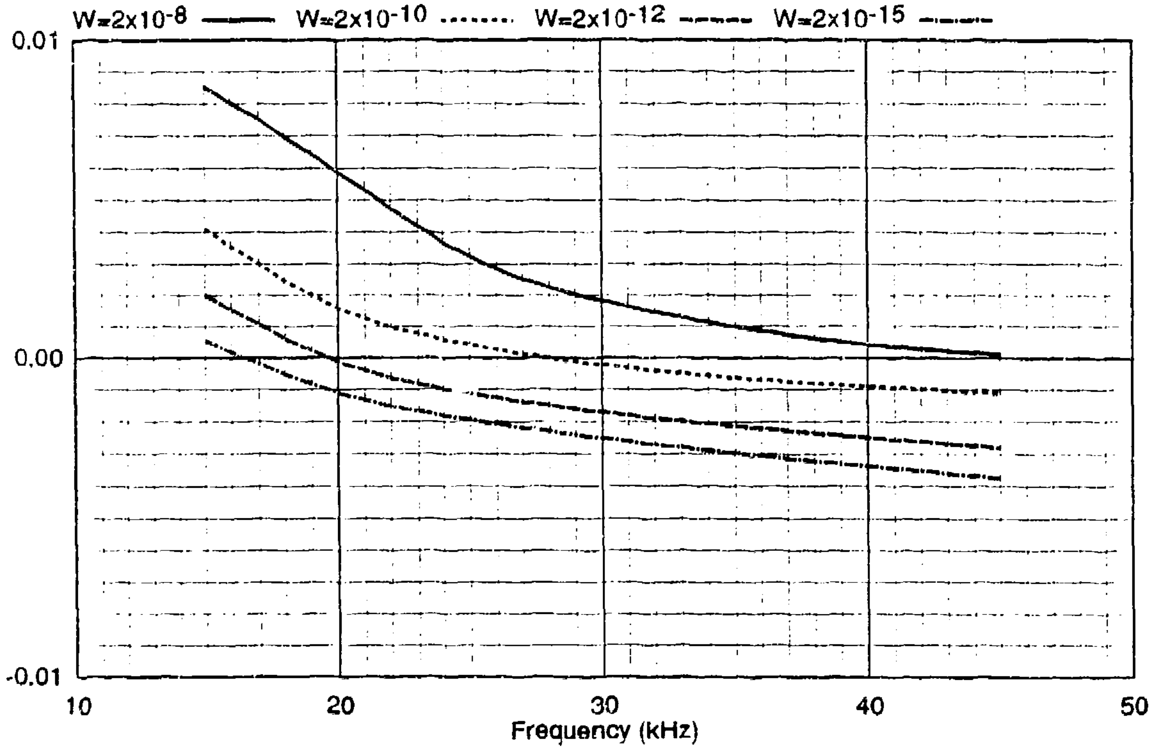
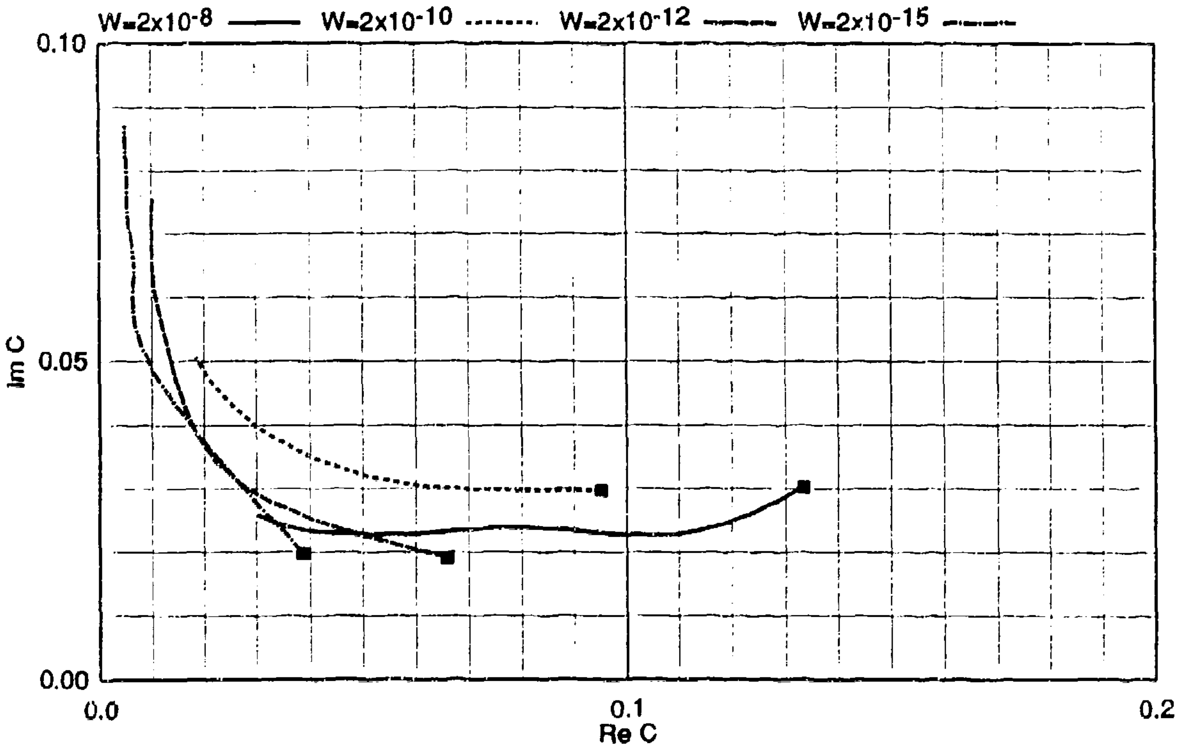


Figure 70. Parameters for least attenuated TM mode, σ_g = 1 S/m.

c. Relative phase velocity as function of frequency.



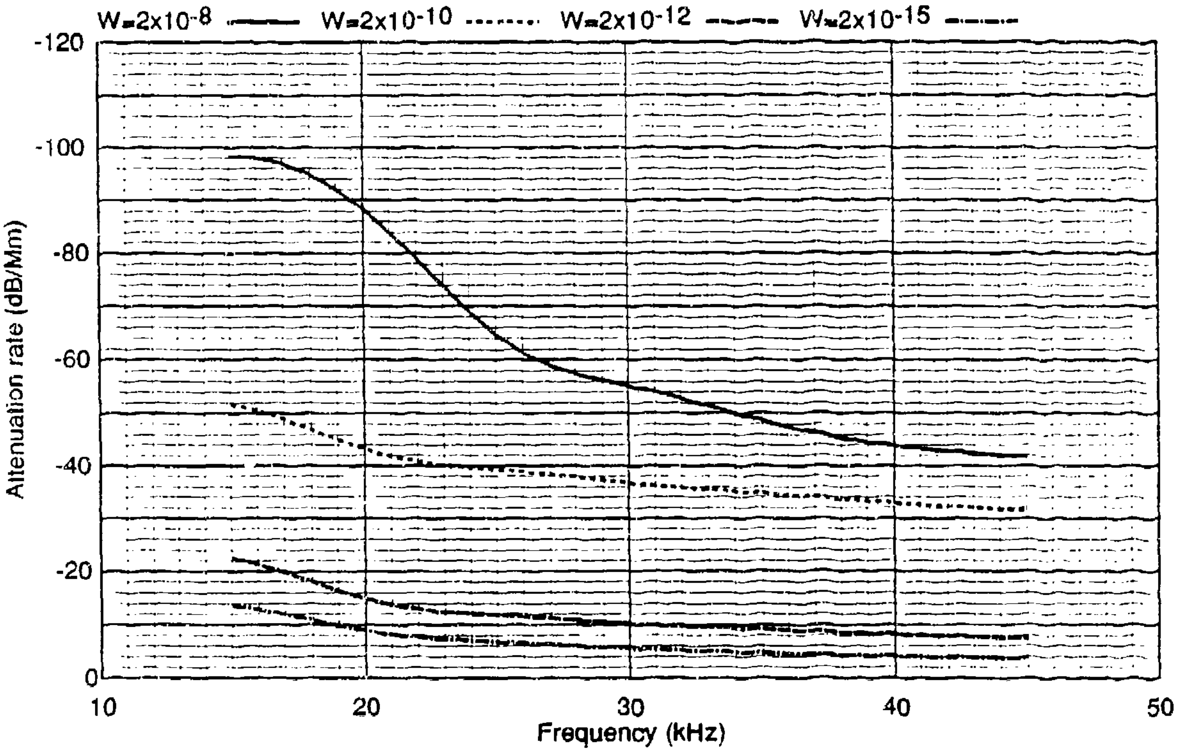
d. Mode paths in the C-plane as frequency changes.



NOTE: The point for lowest frequency marked with ■

Figure 70. Parameters for least attenuated TM mode, $\sigma_g = 1$ S/m (Concluded).

a. Attenuation as function of frequency.



b. TM excitation values as function of frequency.

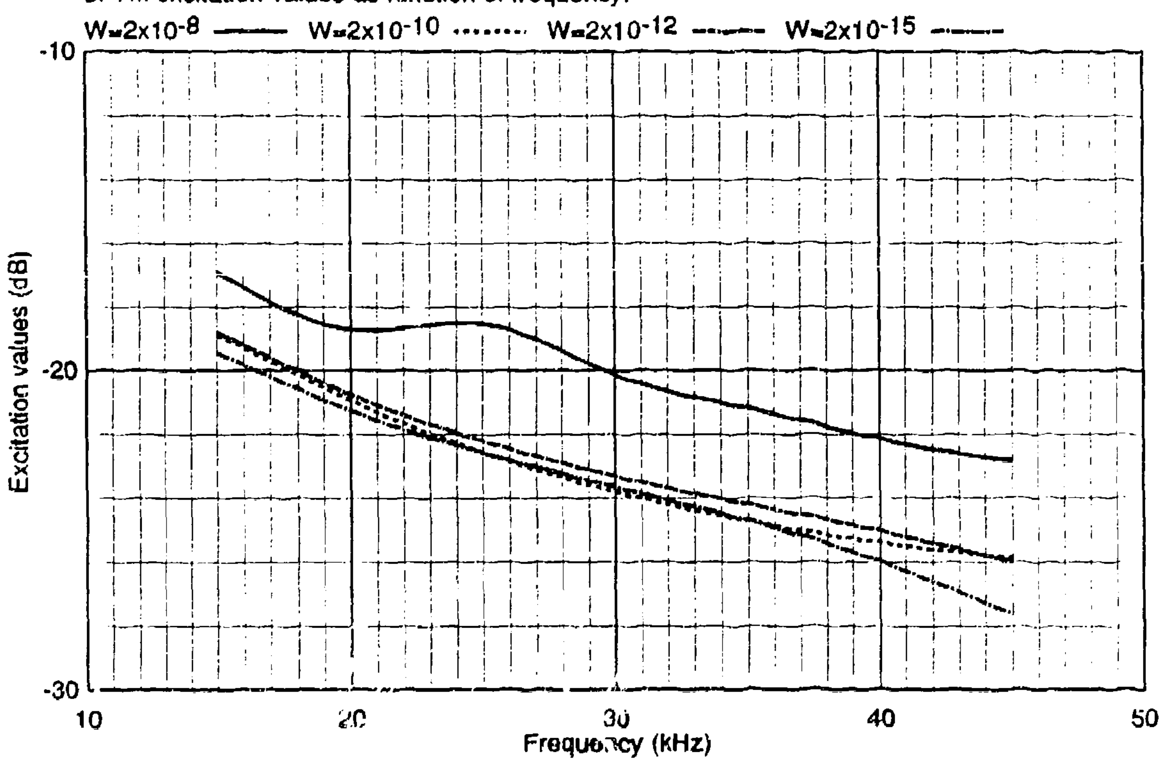
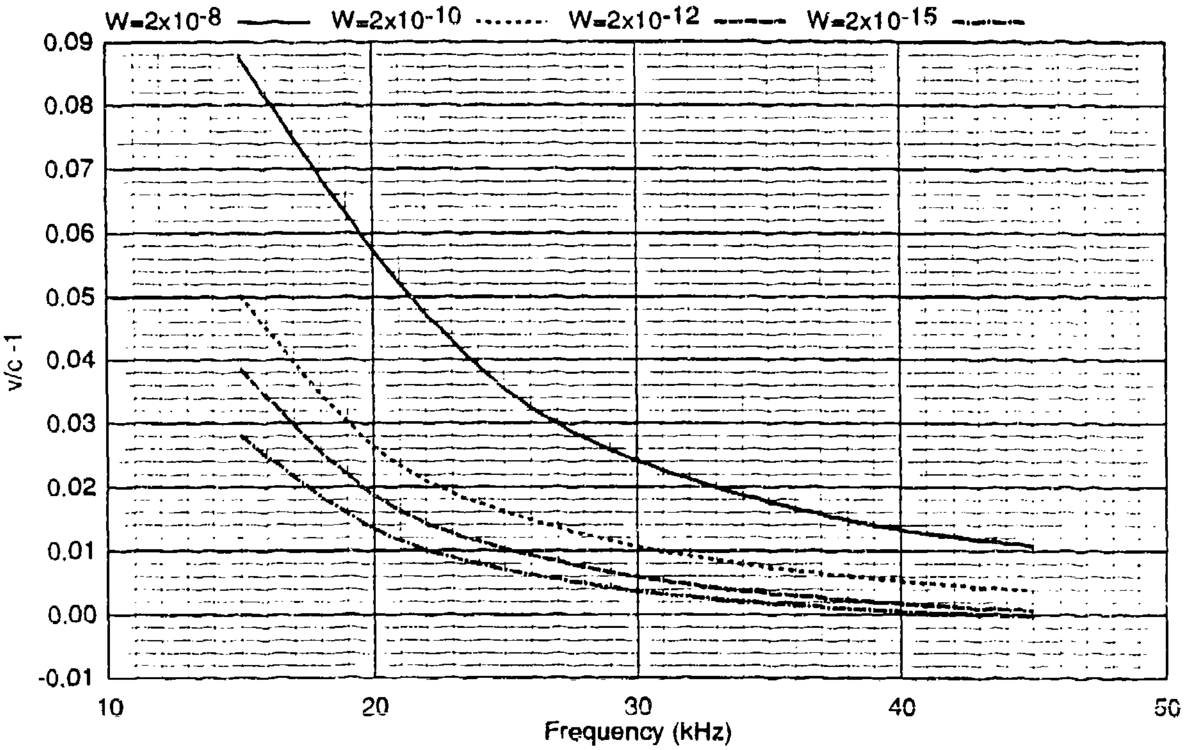
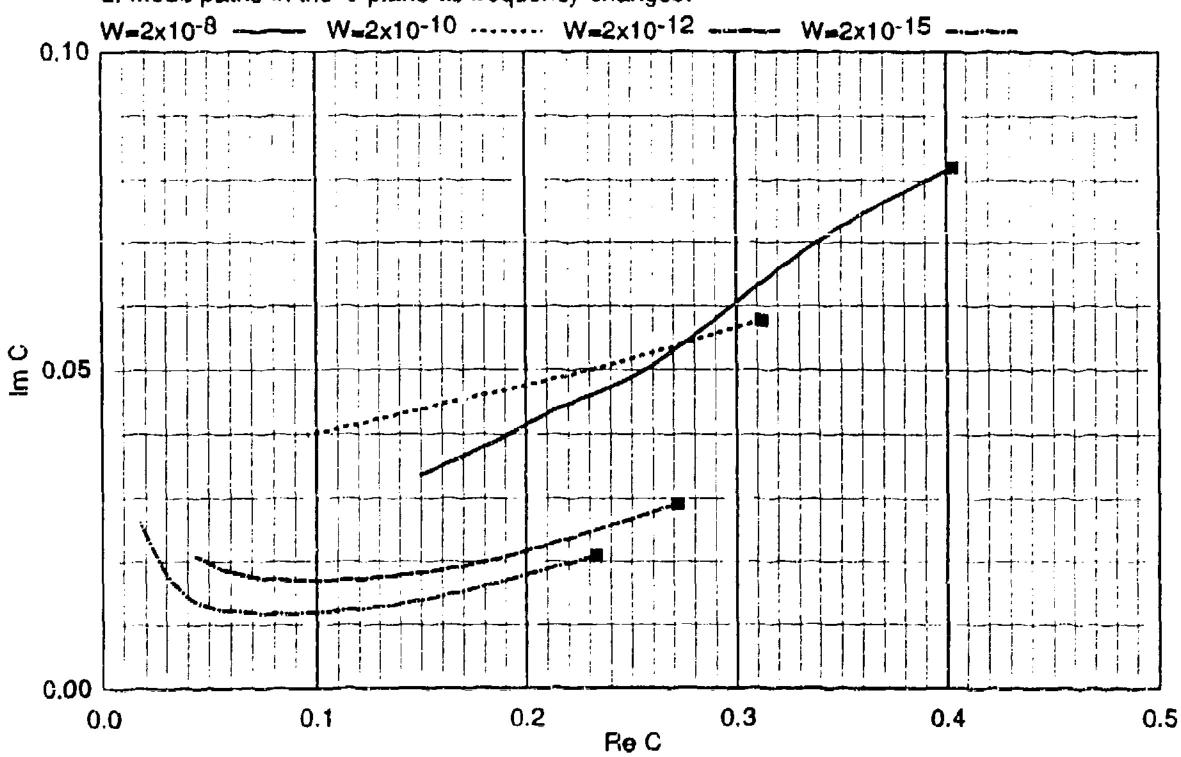


Figure 71. Parameters for second least attenuated TM mode, σ_g = 1 S/m.

c. Relative phase velocity as function of frequency.

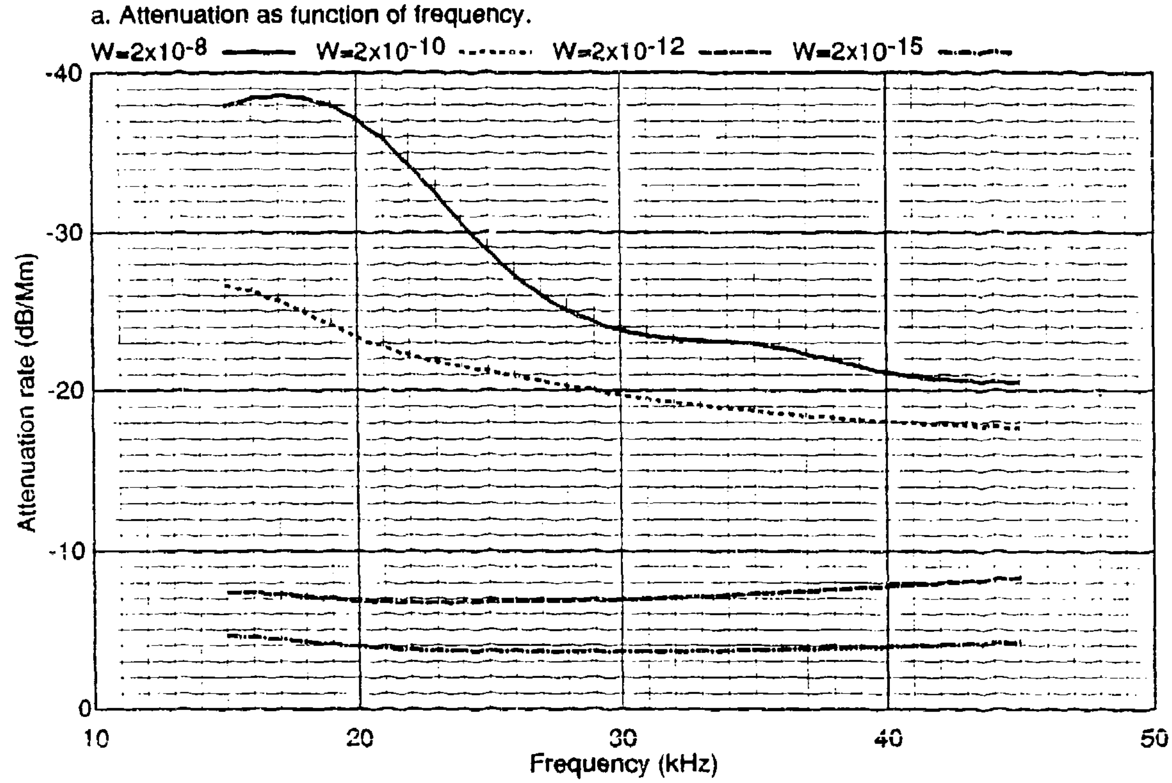


d. Mode paths in the C-plane as frequency changes.



NOTE: The point for lowest frequency marked with ■

Figure 71. Parameters for second least attenuated TM mode, σ_g = 1 S/m (Concluded).



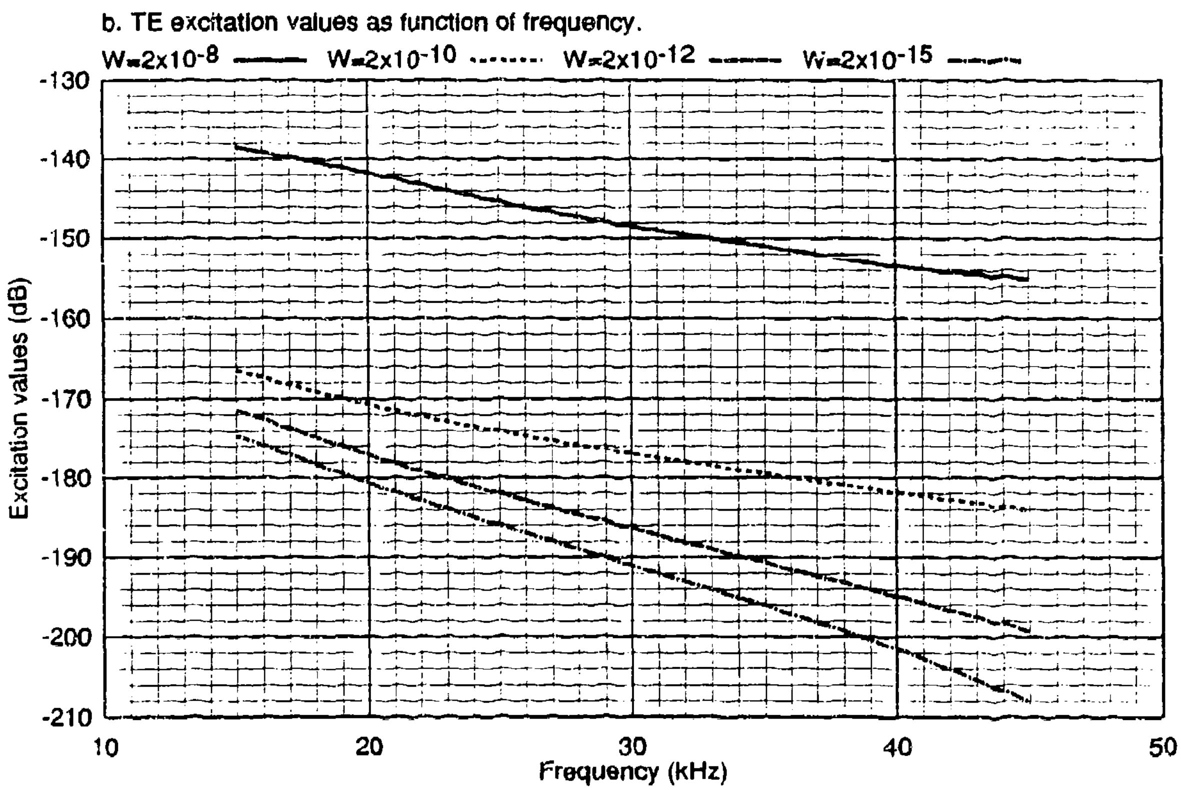
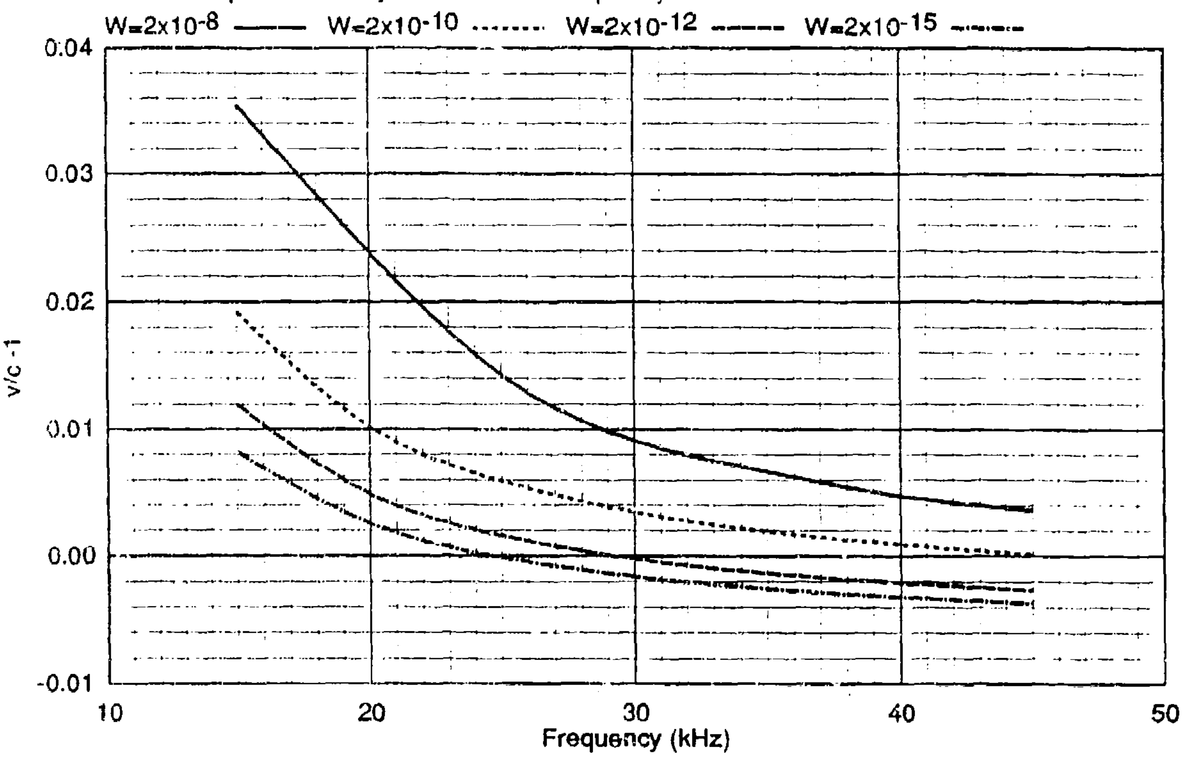
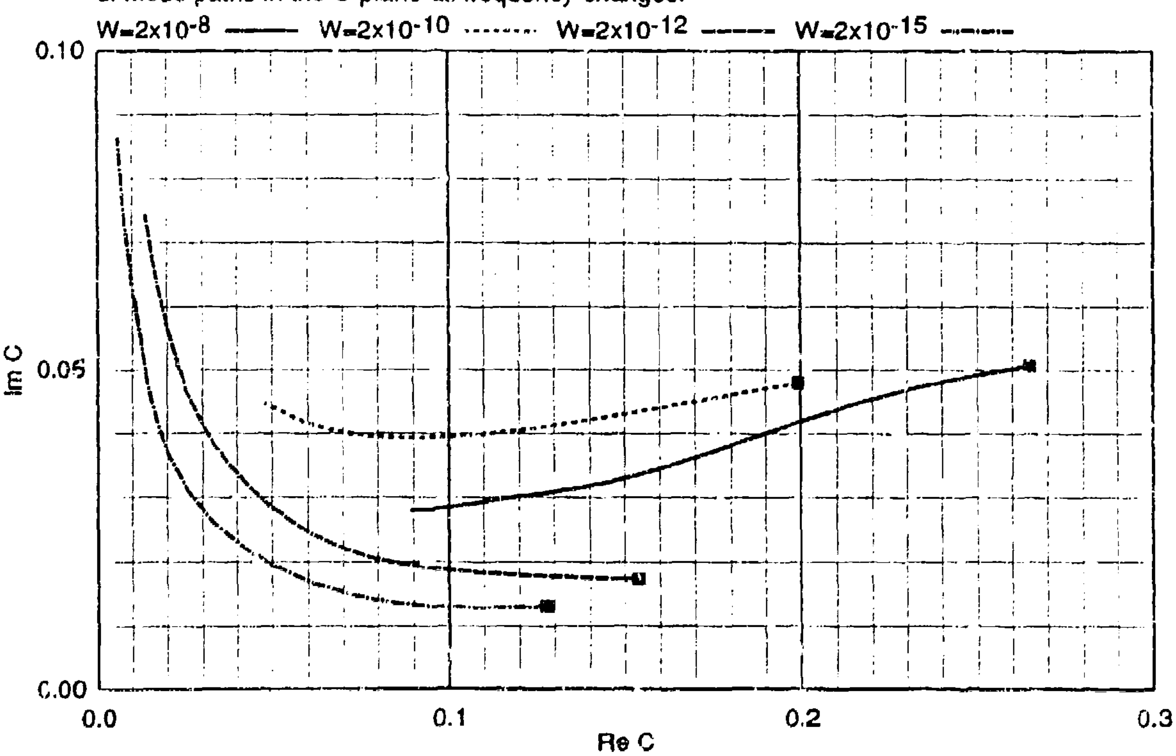


Figure 72. Parameters for least attenuated TE mode, σ_g = 1 S/m.

c. Relative phase velocity as function of frequency.

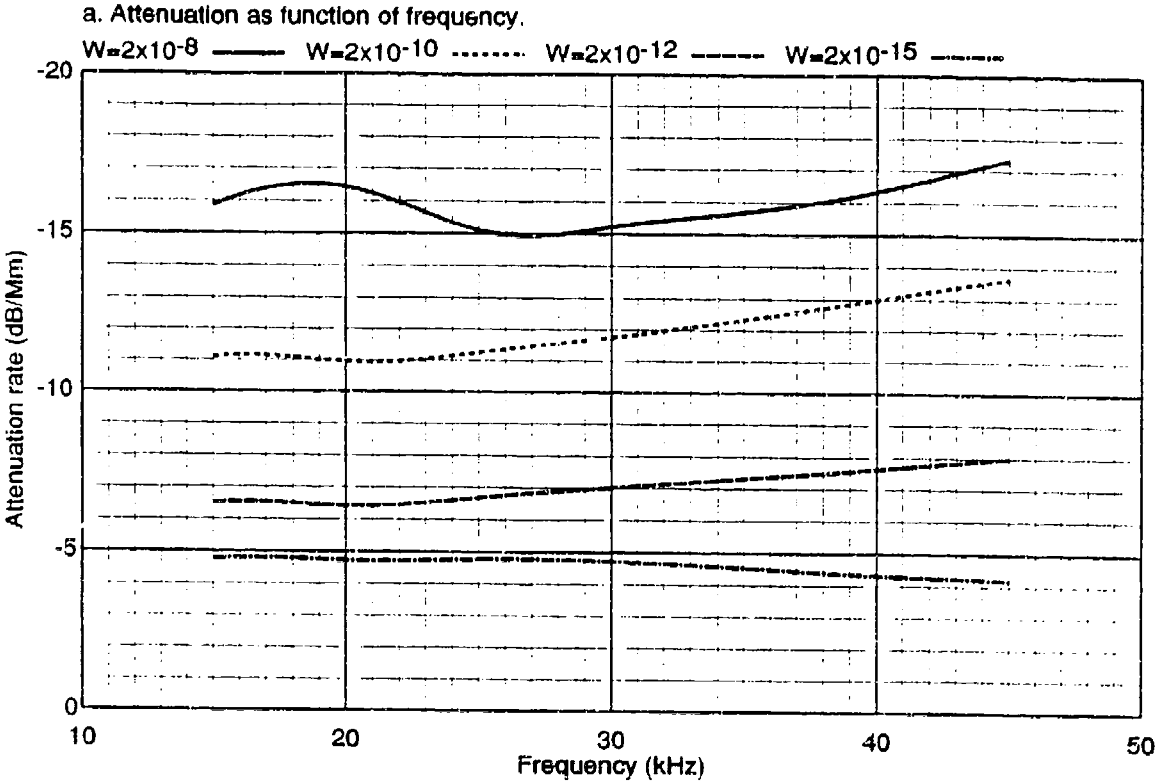


d. Mode paths in the C-plane as frequency changes.



NOTE: The point for lowest frequency marked with ■

Figure 72. Parameters for least attenuated TE mode, $\sigma_g = 1$ S/m (Concluded).



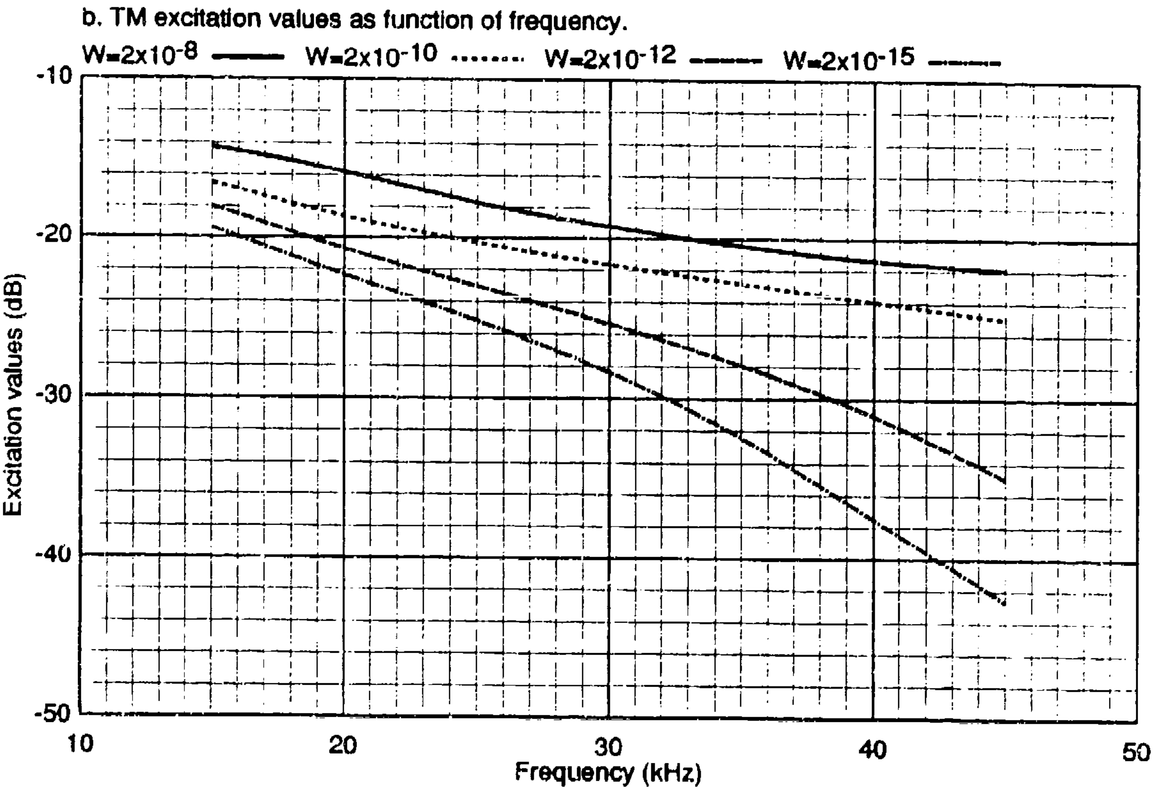
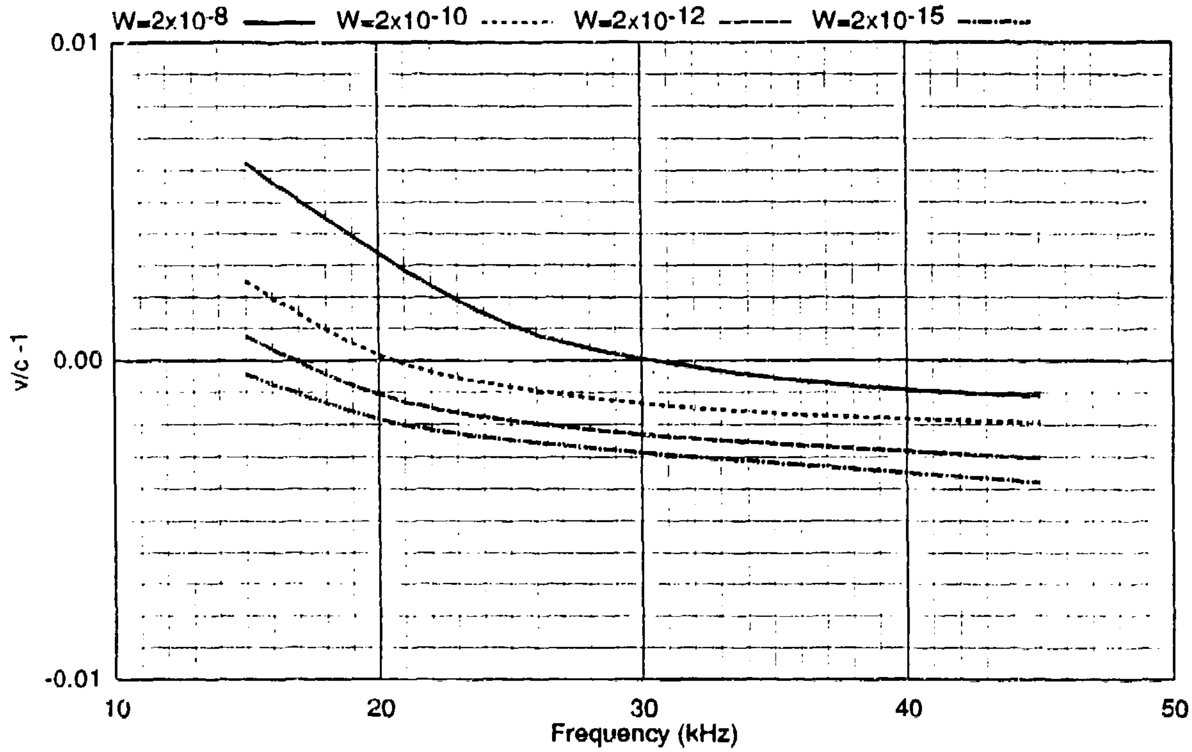
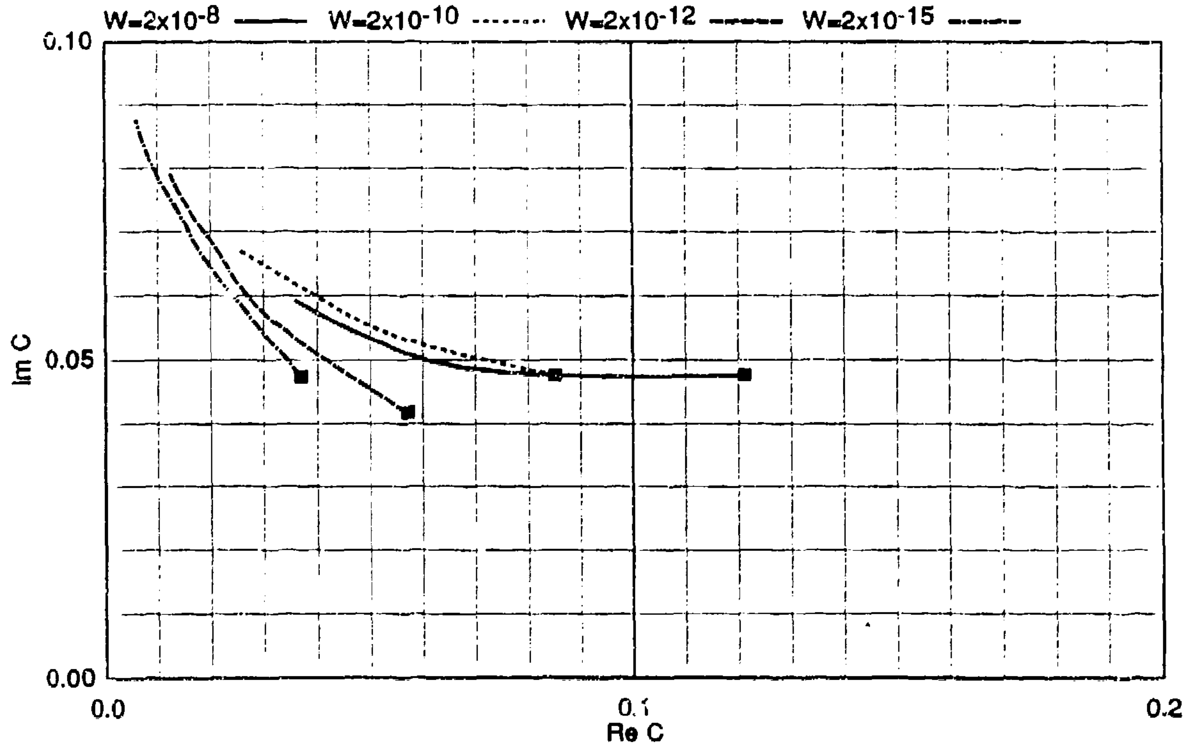


Figure 73. Parameters for least attenuated TM mode, $\sigma_g = 10^{-3}$ S/m.

c. Relative phase velocity as function of frequency.



d. Mode paths in the C-plane as frequency changes.



NOTE: The point for lowest frequency marked with ■

Figure 73. Parameters for least attenuated TM mode, $\sigma_g = 10^{-3}$ S/m (Concluded).

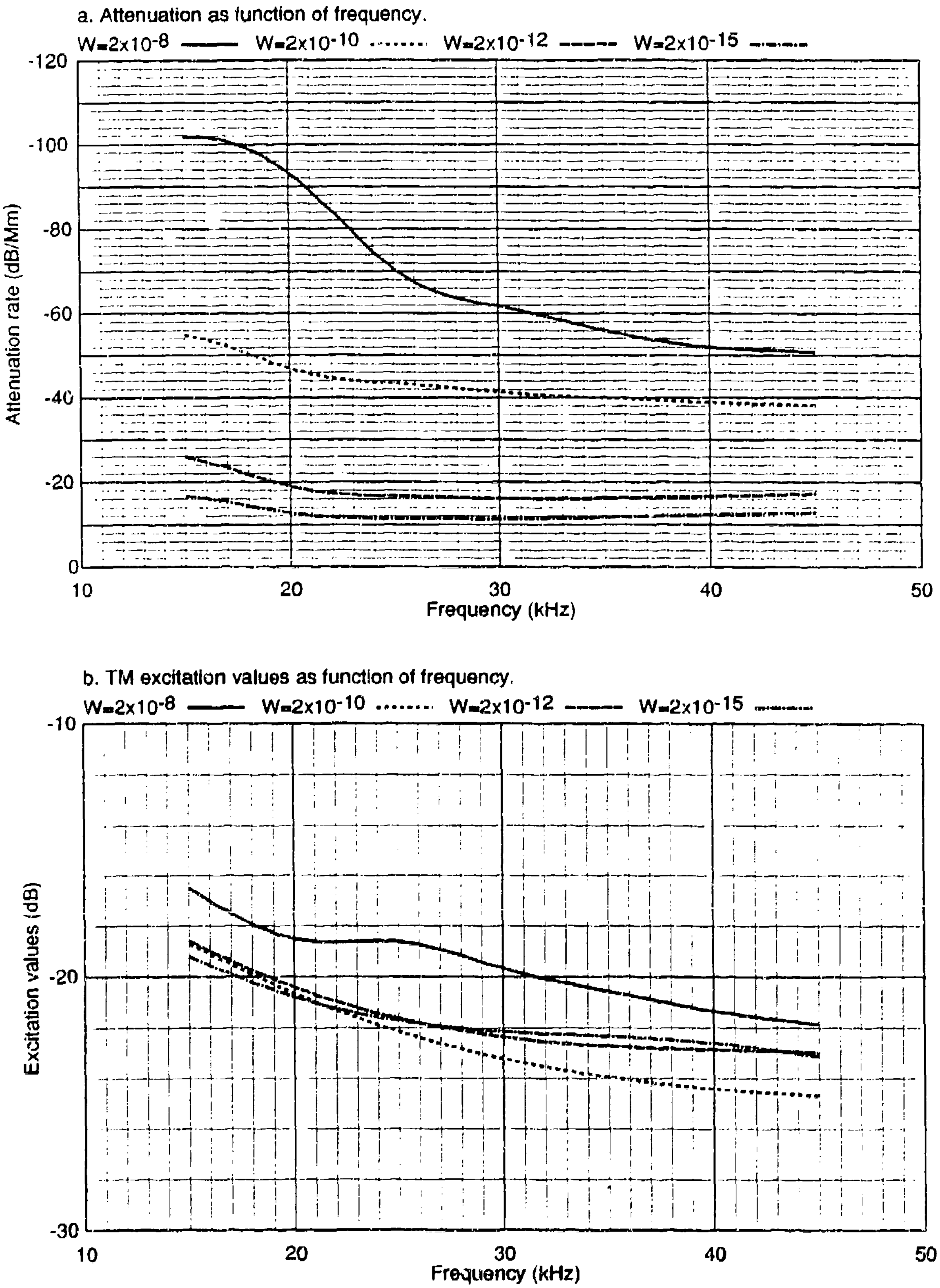
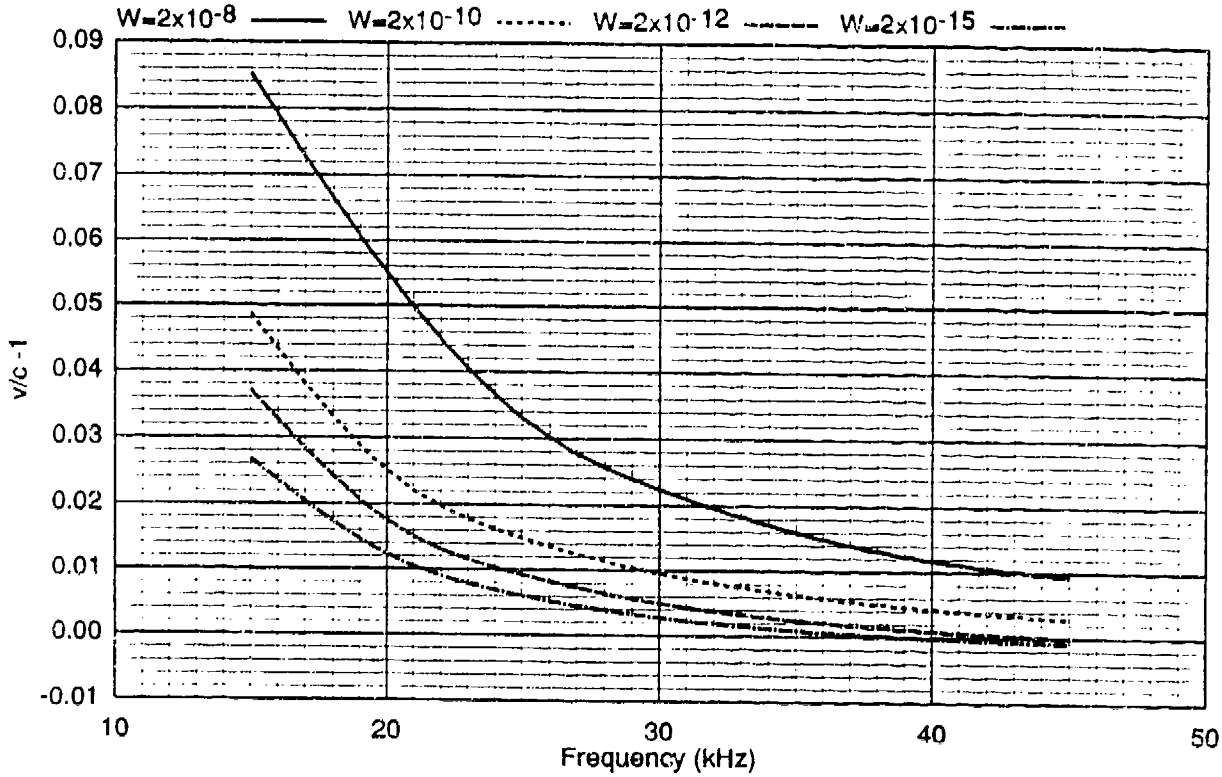
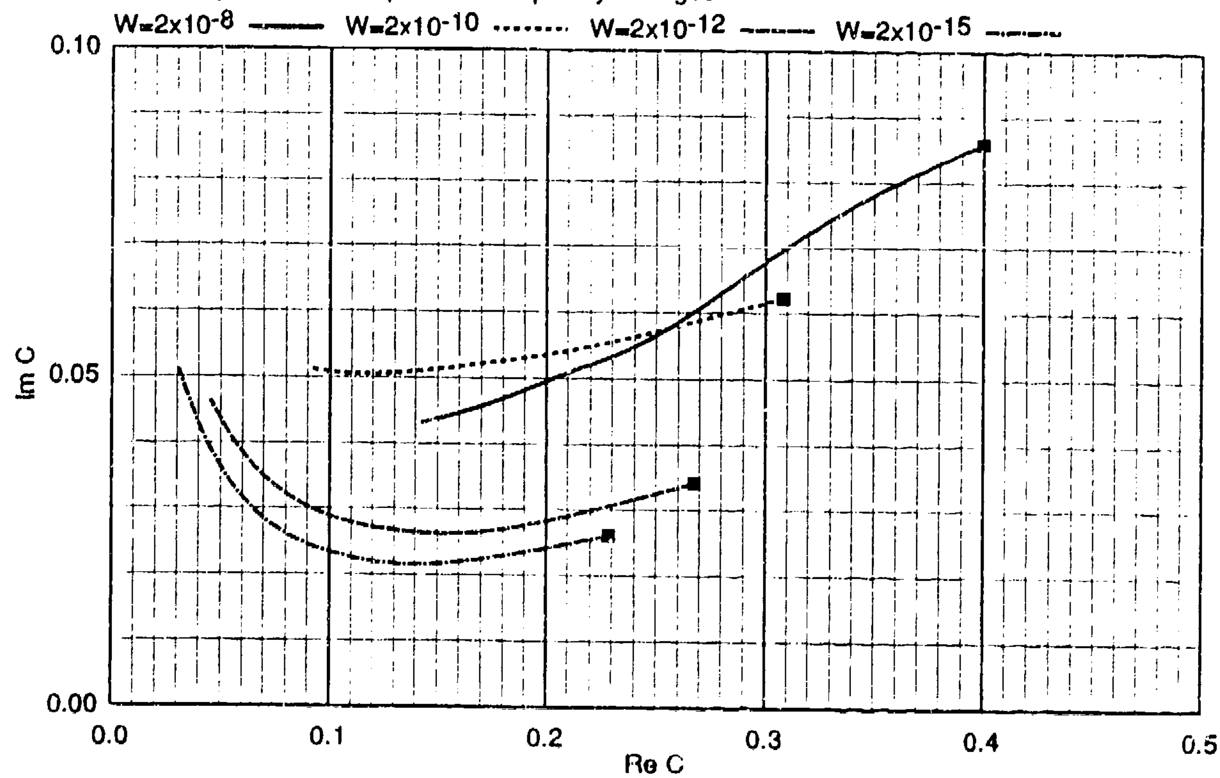


Figure 74. Parameters for second least attenuated TM mode, $\sigma_g = 10^{-3}$ S/m.

c. Relative phase velocity as function of frequency.



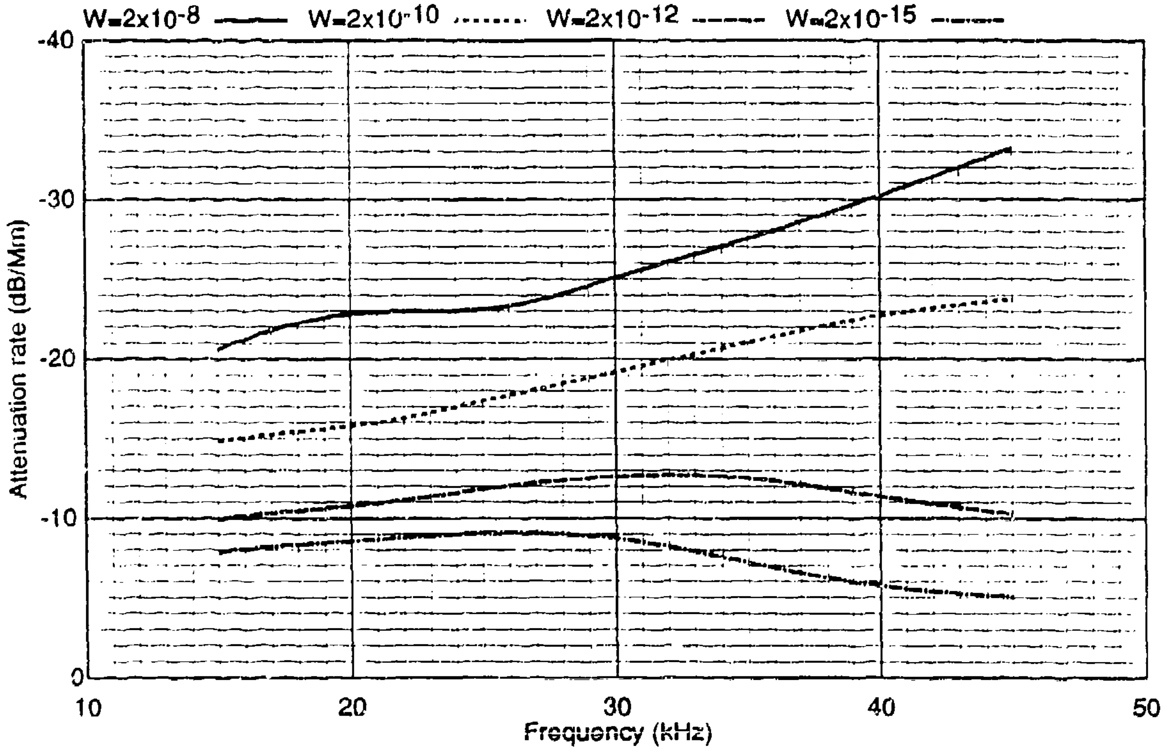
d. Mode paths in the C-plane as frequency changes.



NOTE: The point for lowest frequency marked with ■

Figure 74. Parameters for second least attenuated TM mode, $\sigma_g = 10^{-3}$ S/m (Concluded).

a. Attenuation as function of frequency.



b. TM excitation values as function of frequency.

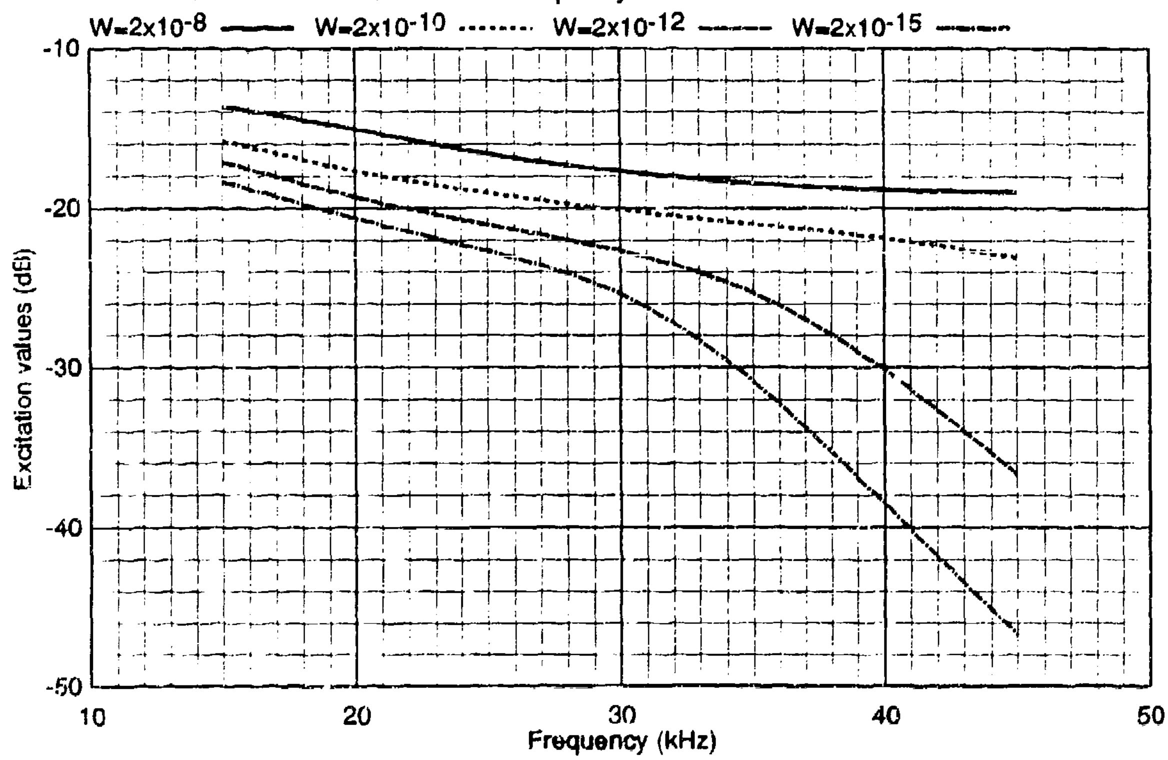
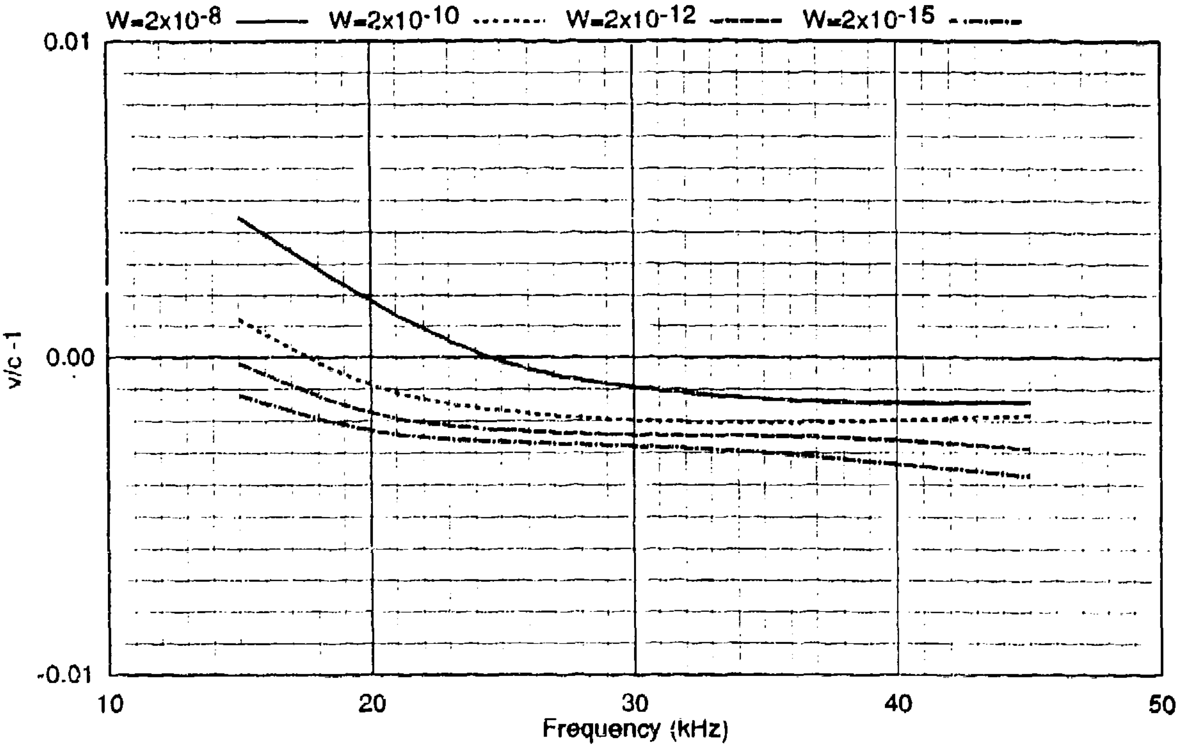
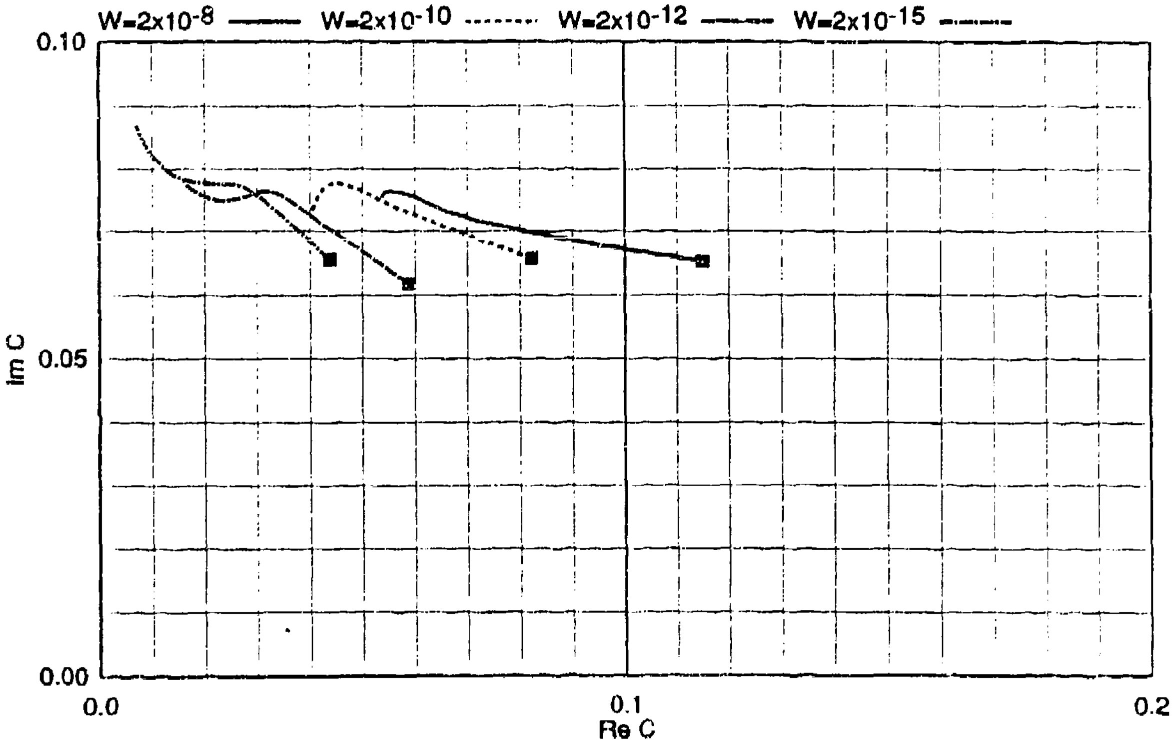


Figure 75. Parameters for least attenuated TM mode, $\sigma_g = 3 \times 10^{-4}$ S/m.

c. Relative phase velocity as function of frequency.

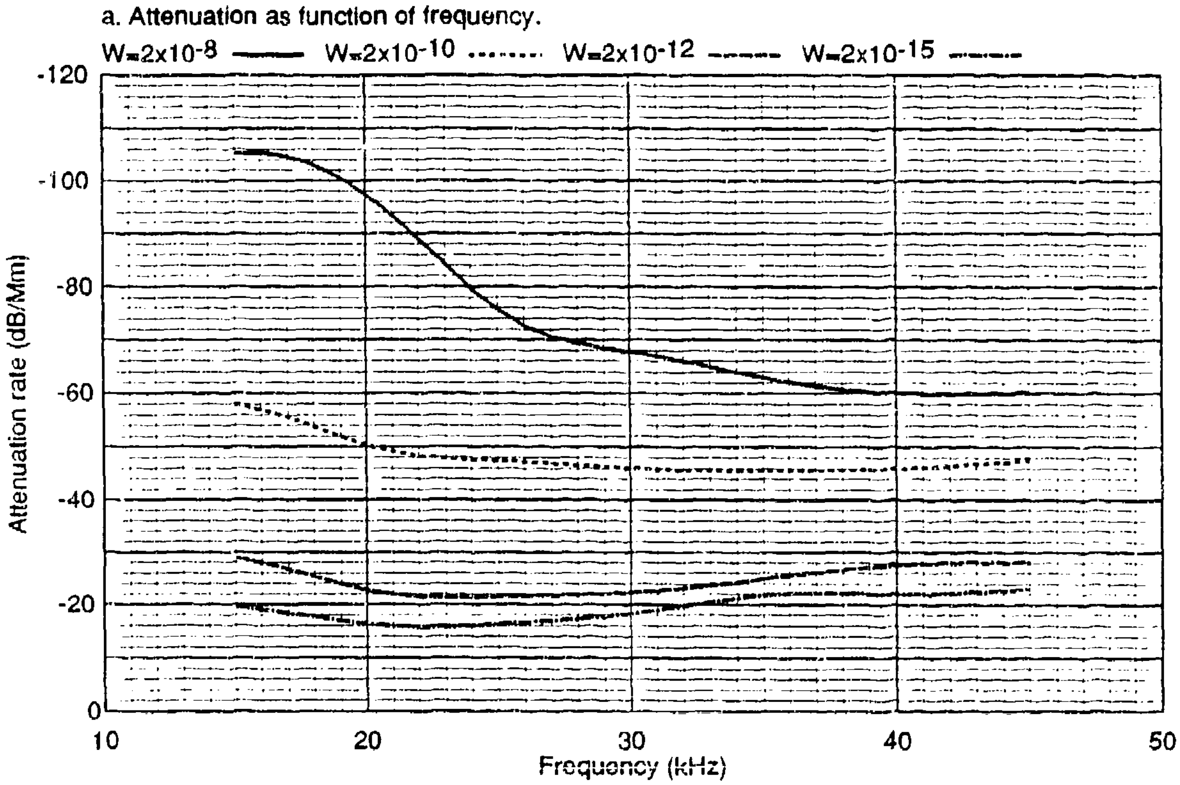


d. Mode paths in the C-plane as frequency changes.



NOTE: The point for lowest frequency marked with ■

Figure 75. Parameters for least attenuated TM mode, $\sigma_g = 3 \times 10^{-4}$ S/m (Concluded).



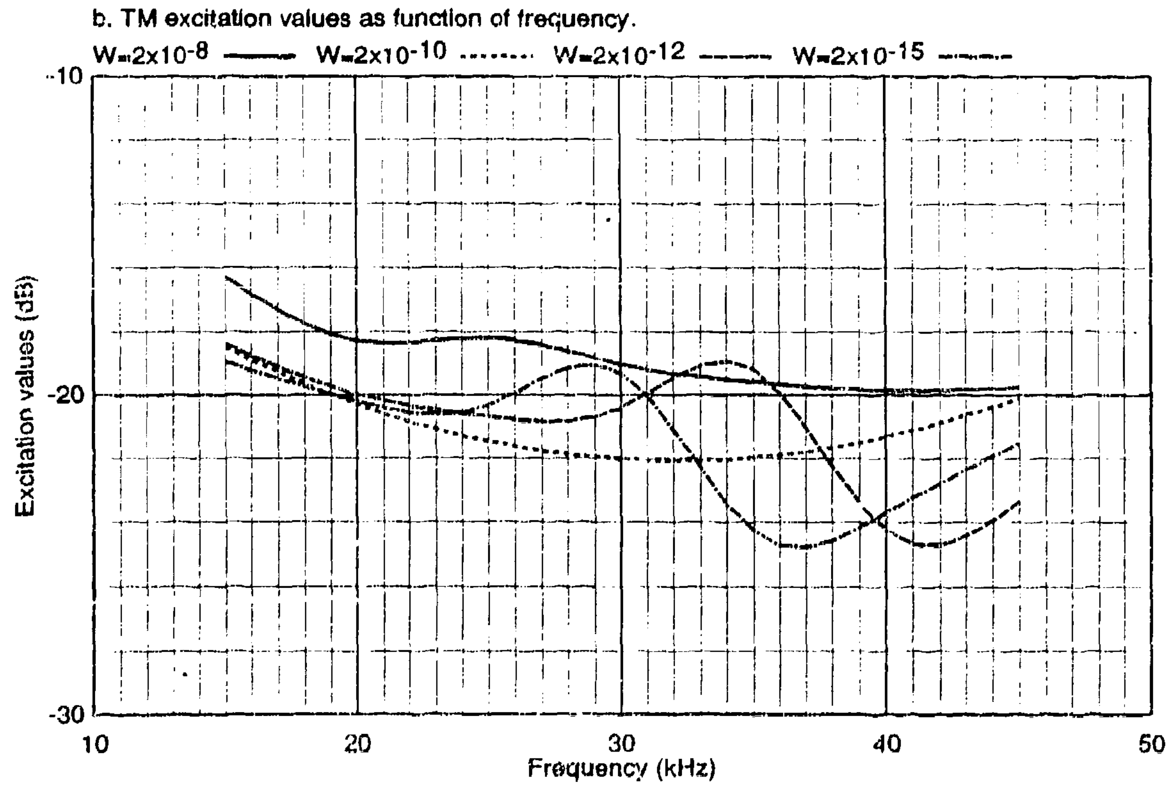
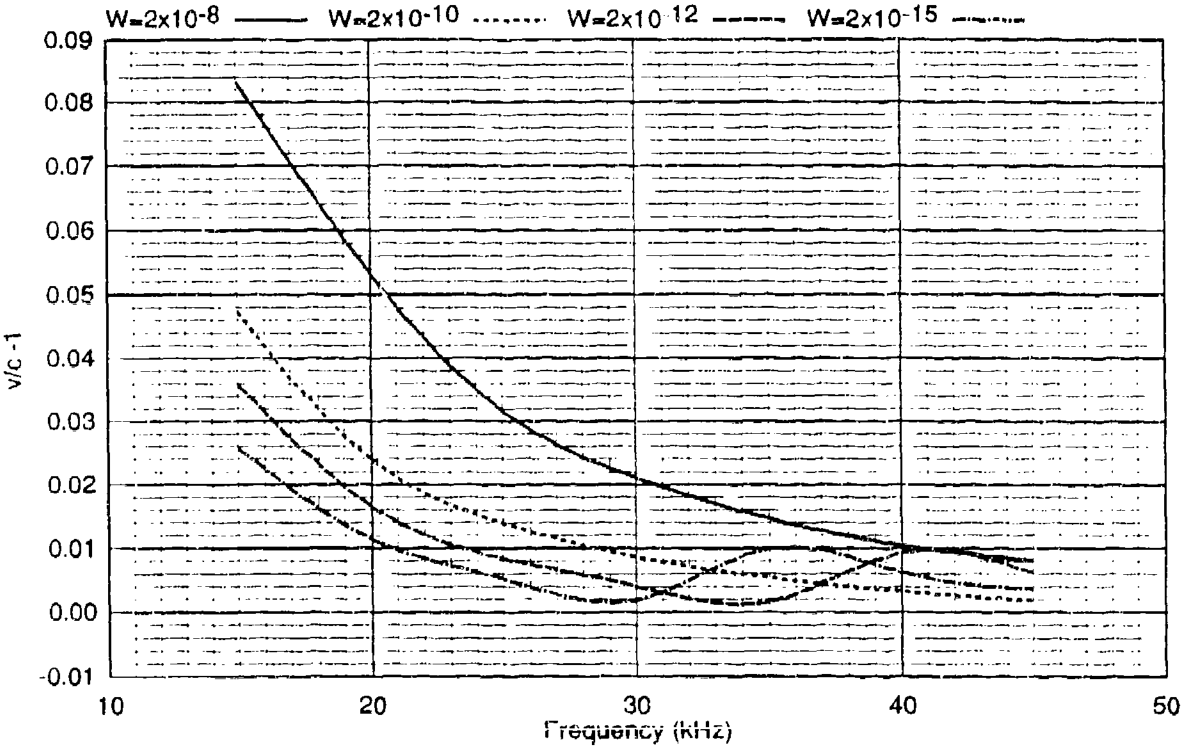
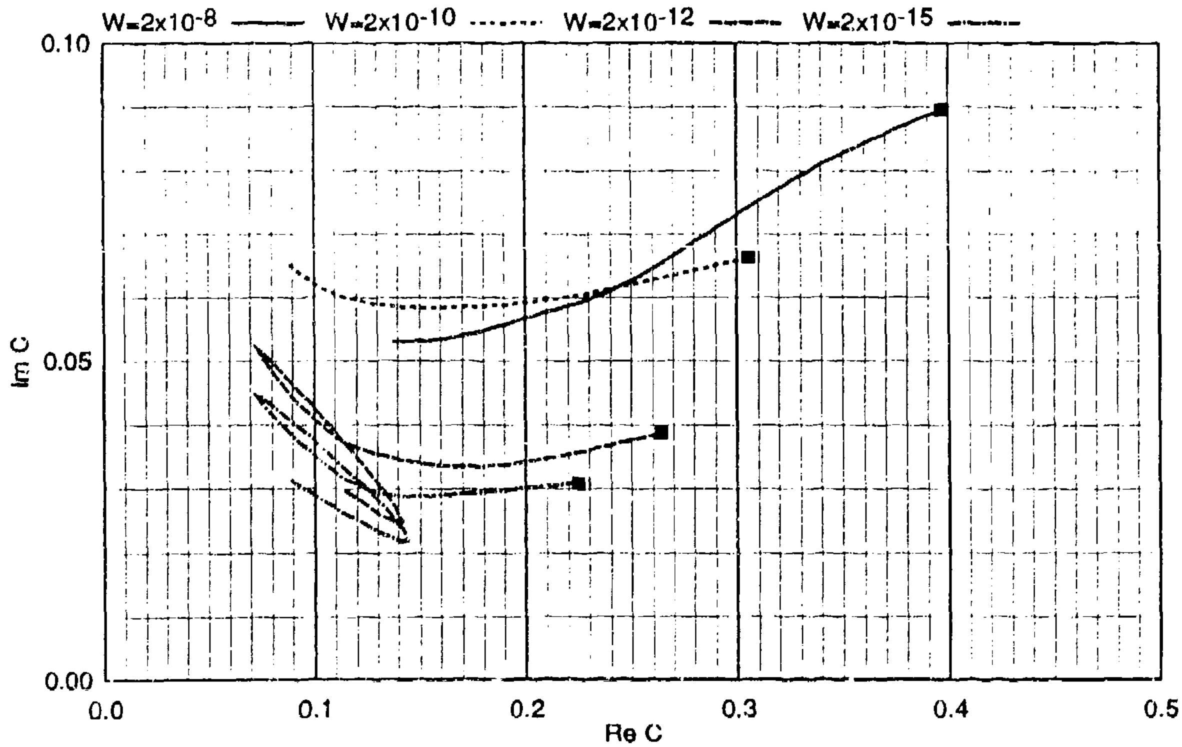


Figure 76. Parameters for second least attenuated TM mode, $\sigma_g = 3 \times 10^{-4}$ S/m.

c. Relative phase velocity as function of frequency.

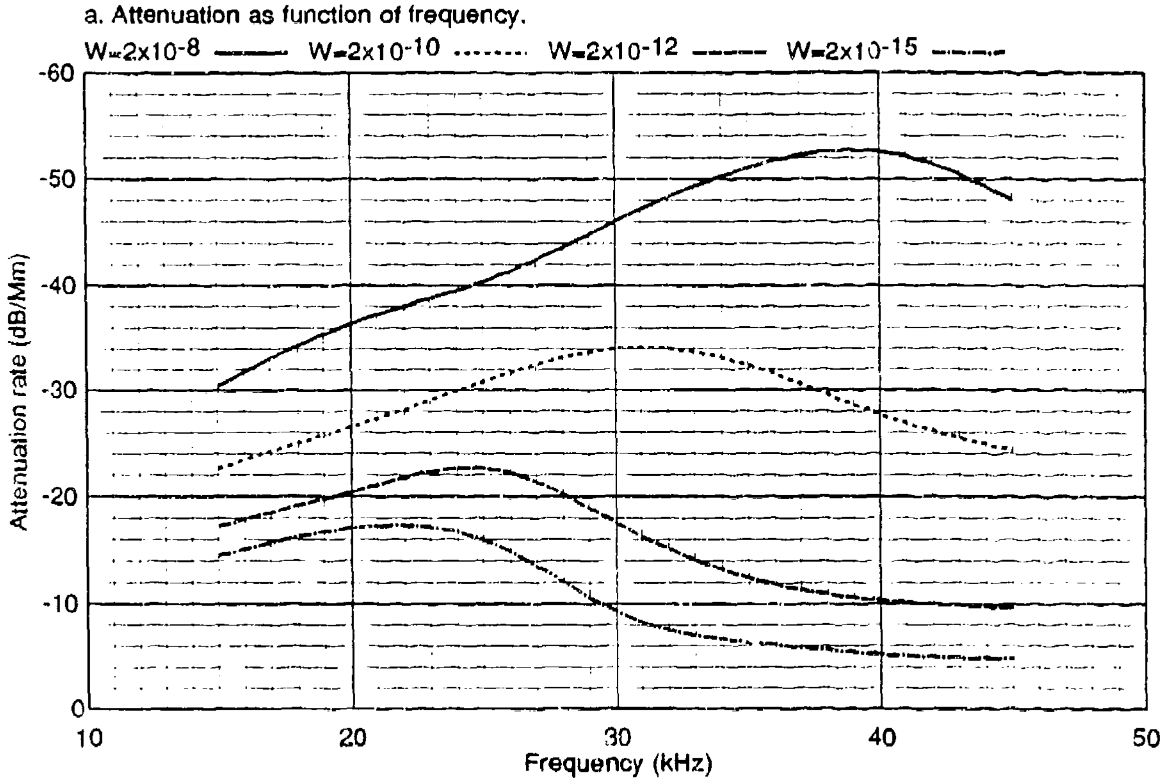


d. Mode paths in the C-plane as frequency changes.



NOTE: The point for lowest frequency marked with ■

Figure 76. Parameters for second least attenuated TM mode, $\sigma_g = 3 \times 10^{-4}$ S/m (Concluded).



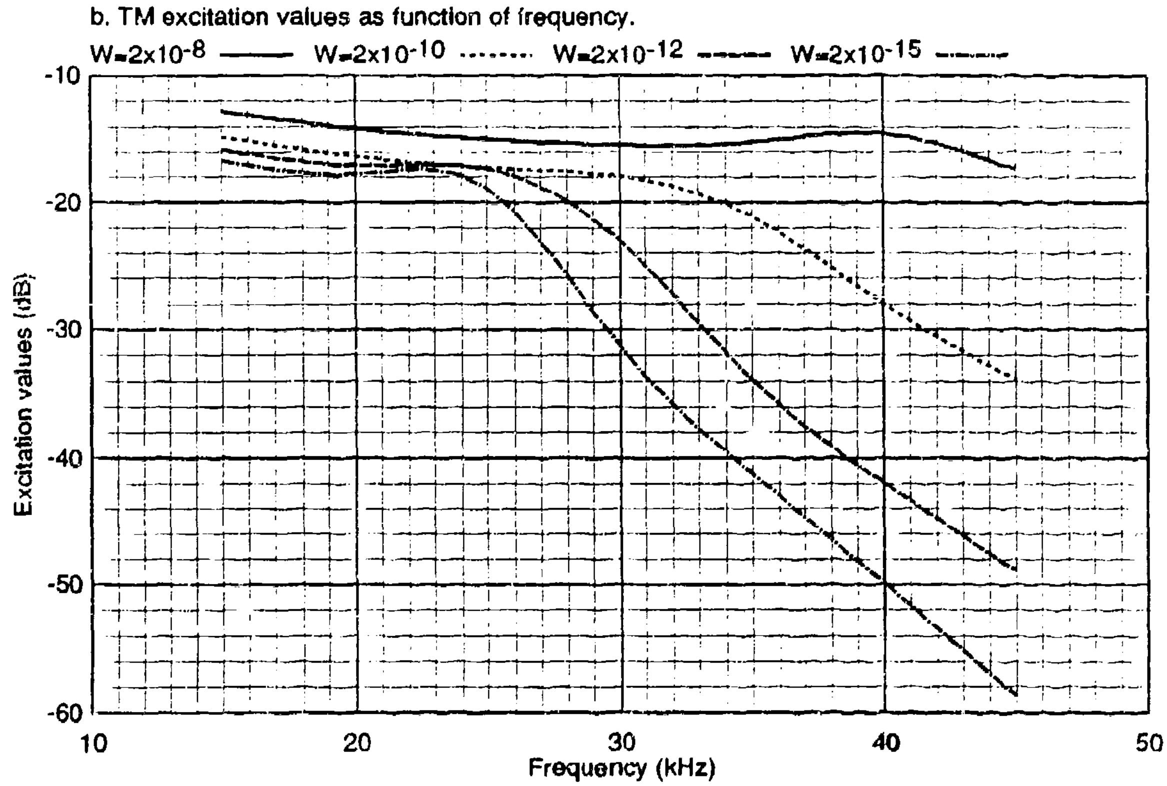
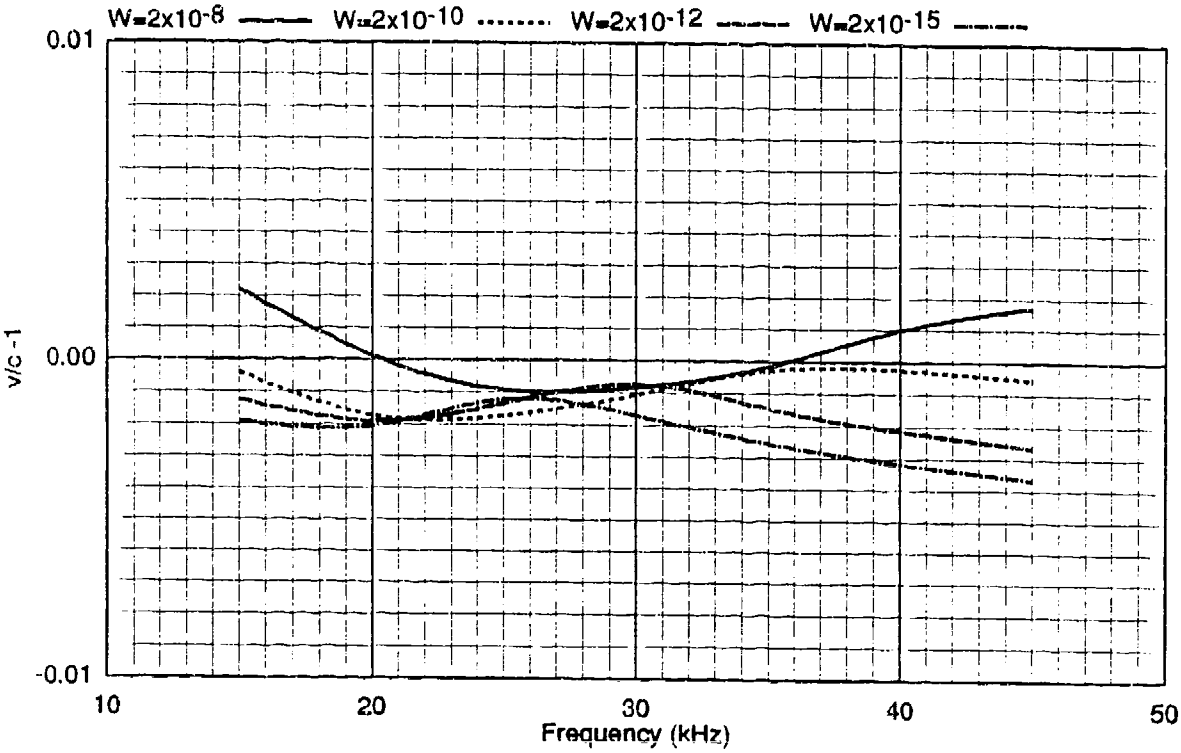
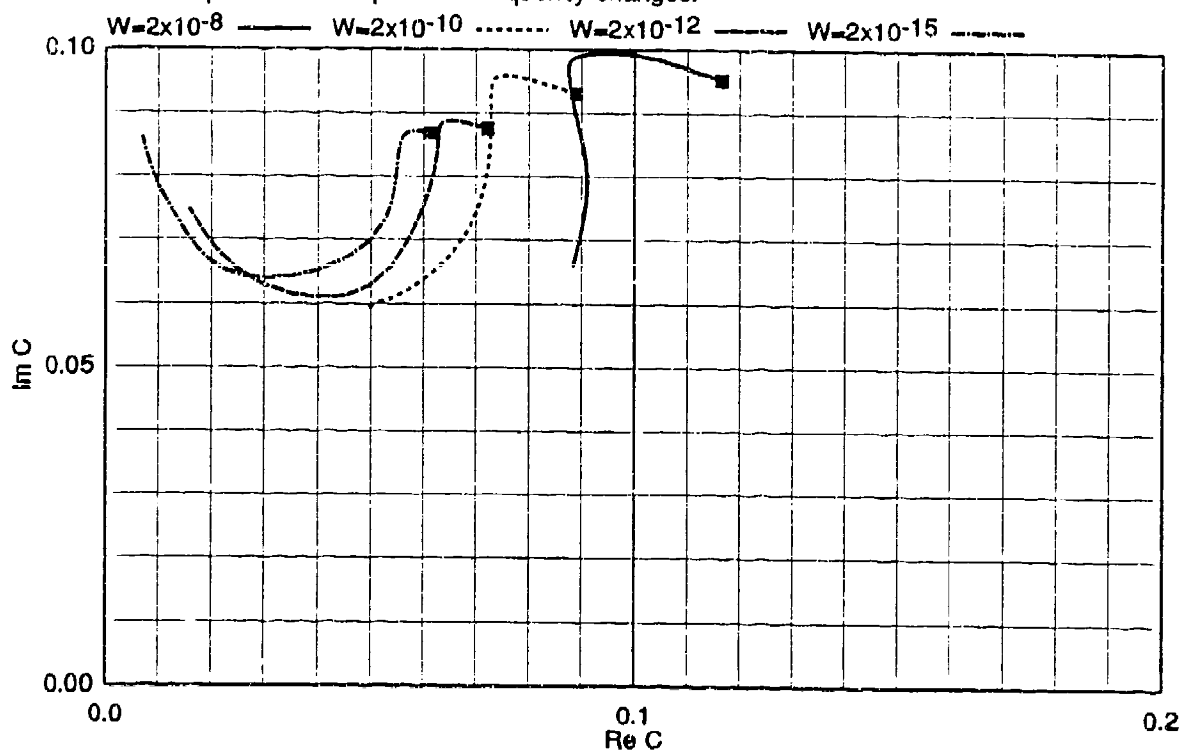


Figure 77. Parameters for least attenuated TM mode, $\sigma_g = 10^{-4}$ S/m.

c. Relative phase velocity as function of frequency.

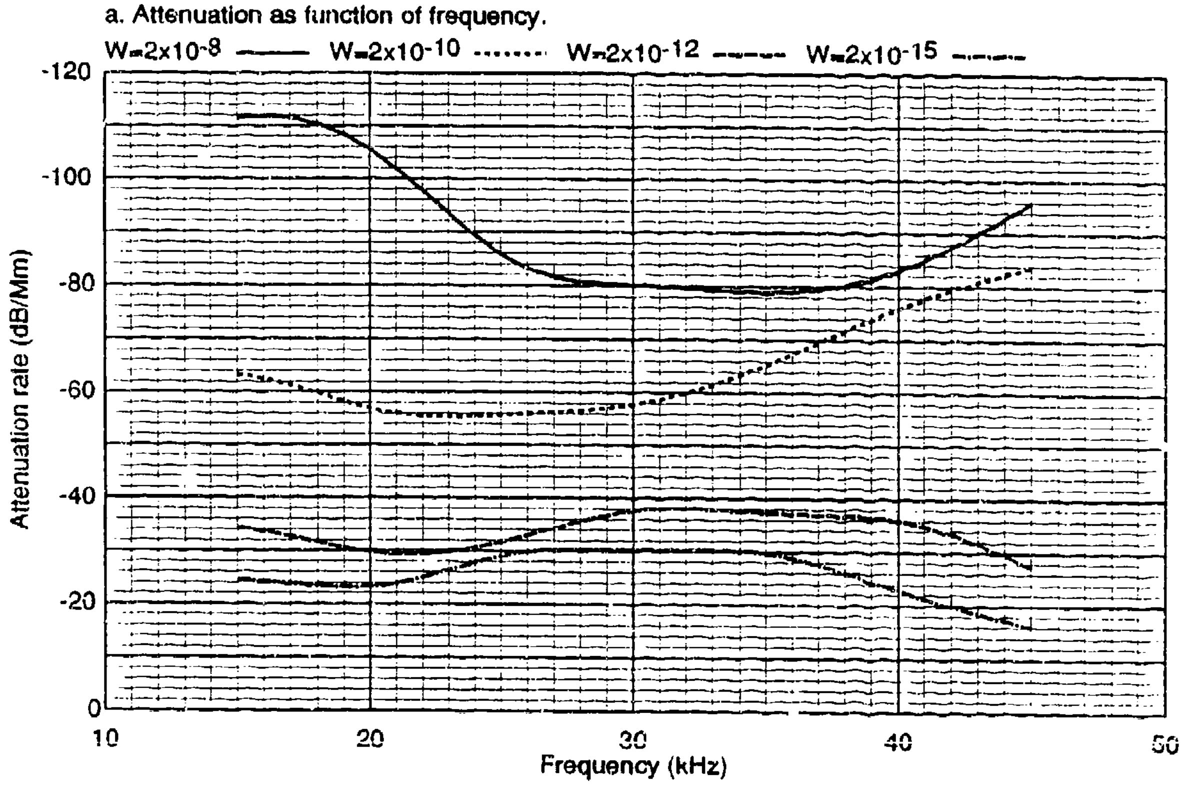


d. Mode paths in the C-plane as frequency changes.



NOTE: The point for lowest frequency marked with ■

Figure 77. Parameters for least attenuated TM mode, $\sigma_g = 10^{-4}$ S/m (Concluded).



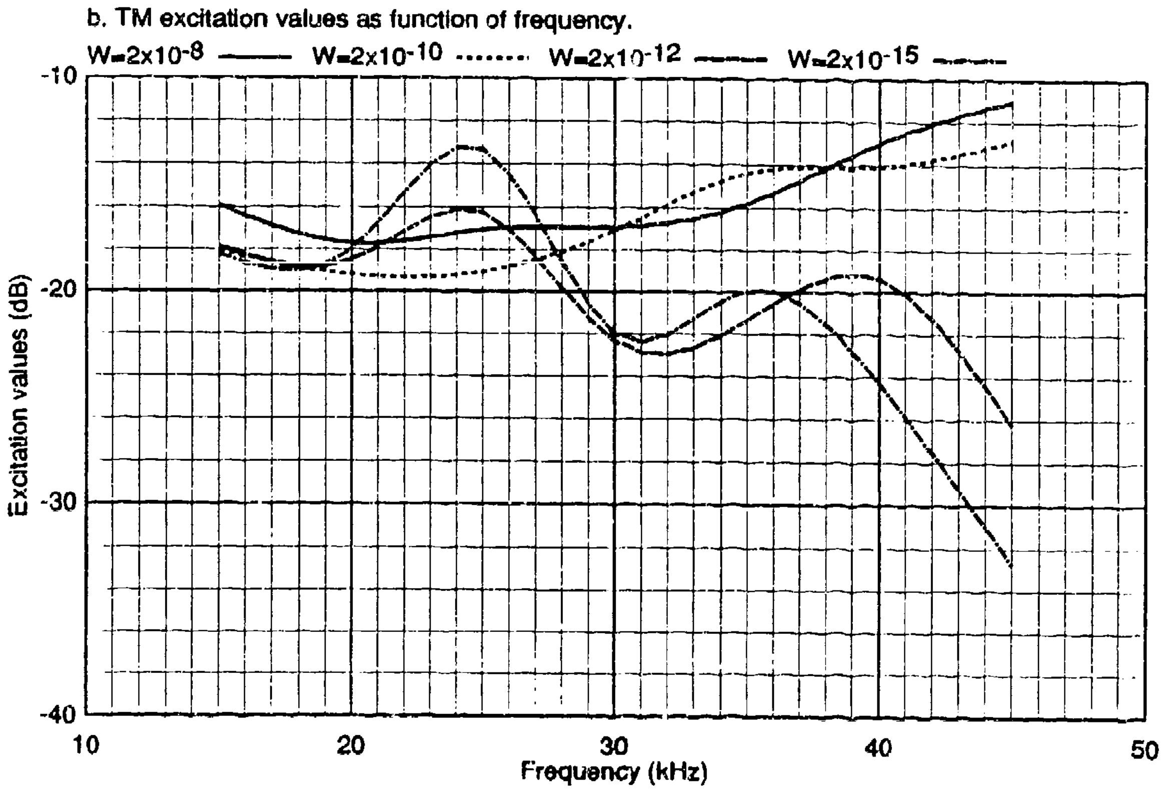
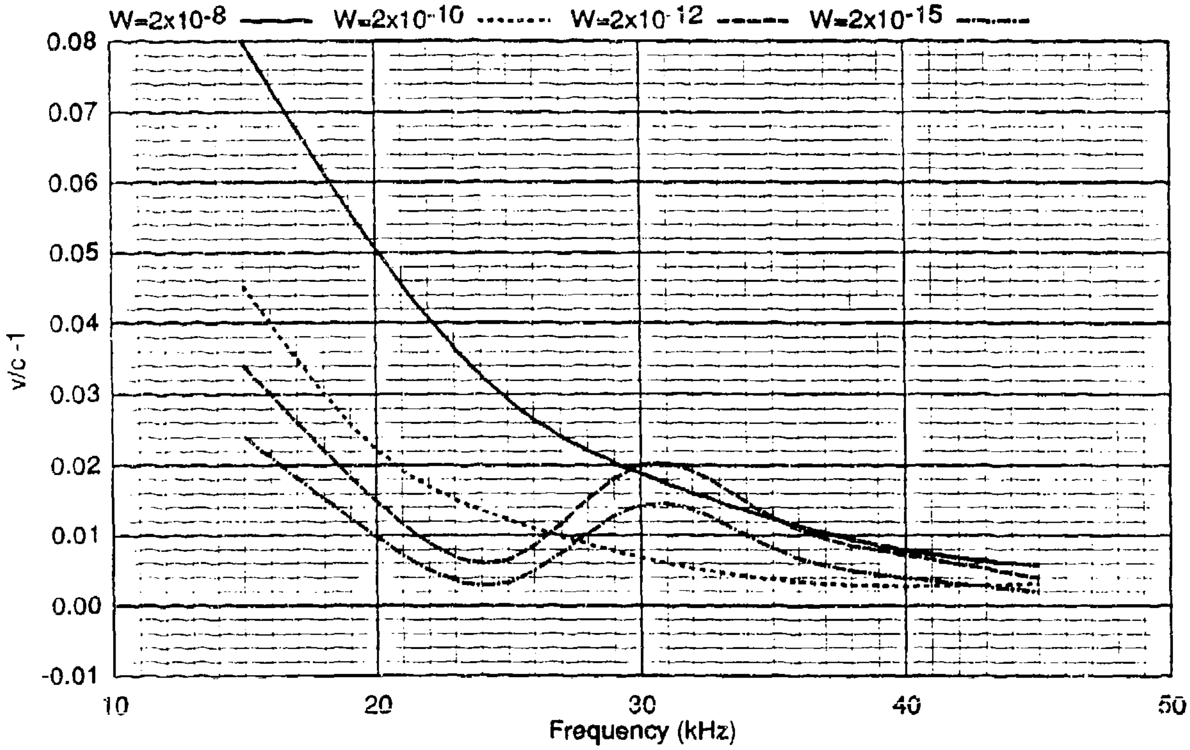
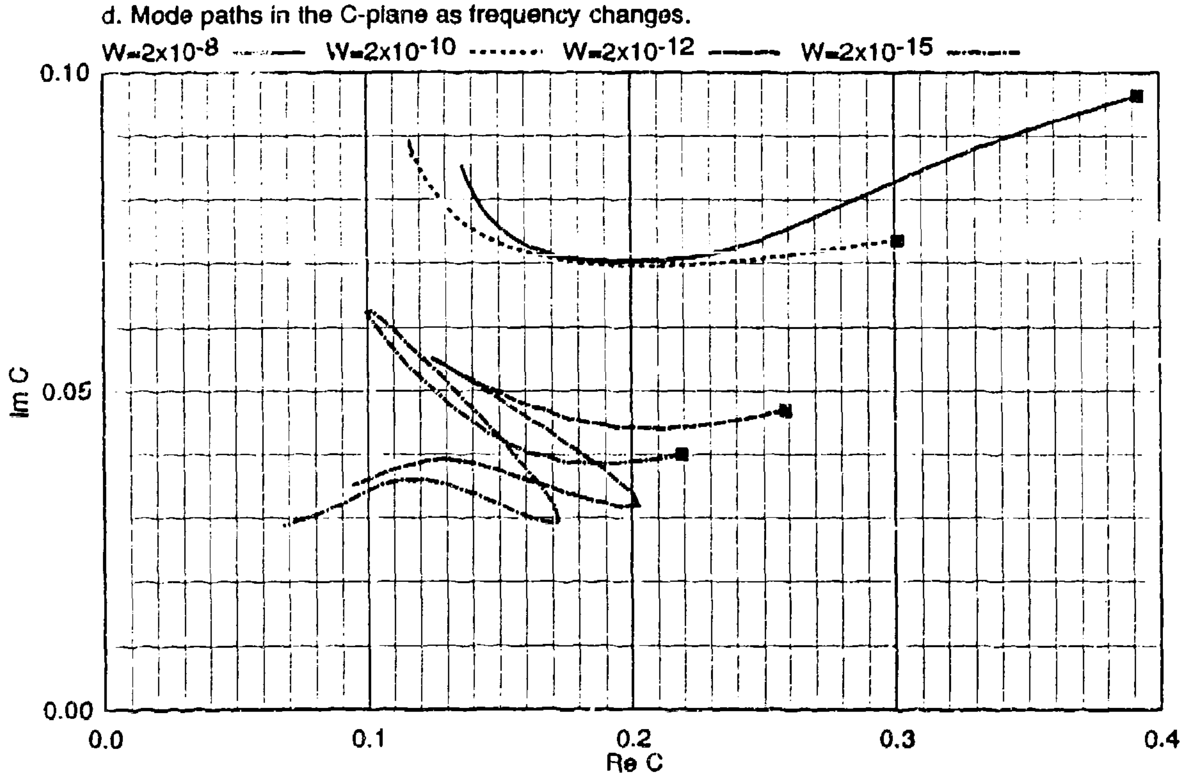


Figure 78. Parameters for second least attenuated TM mode, $\sigma_g = 10^{-4}$ S/m.

c. Relative phase velocity as function of frequency.

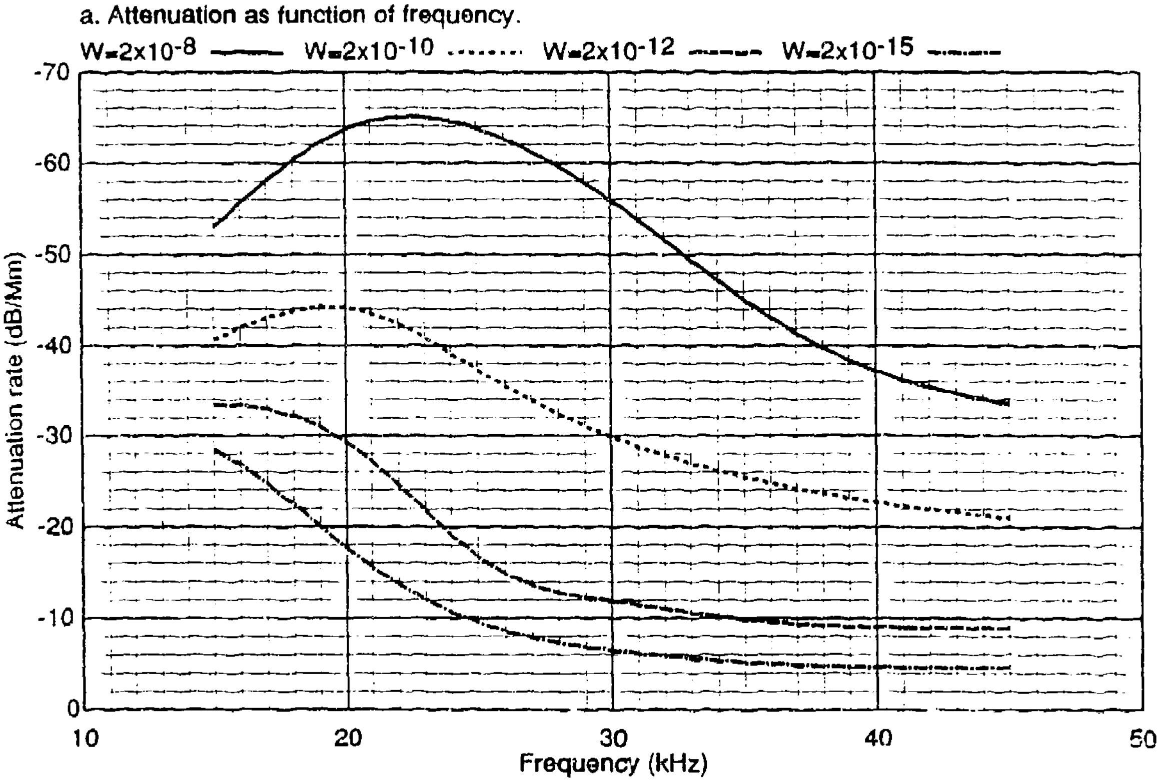


d. Mode paths in the C-plane as frequency changes.



NOTE: The point for lowest frequency n .rked with ■

Figure 78. Parameters for second least attenuated TM mode, $\sigma_g = 10^{-4}$ S/m (Concluded).



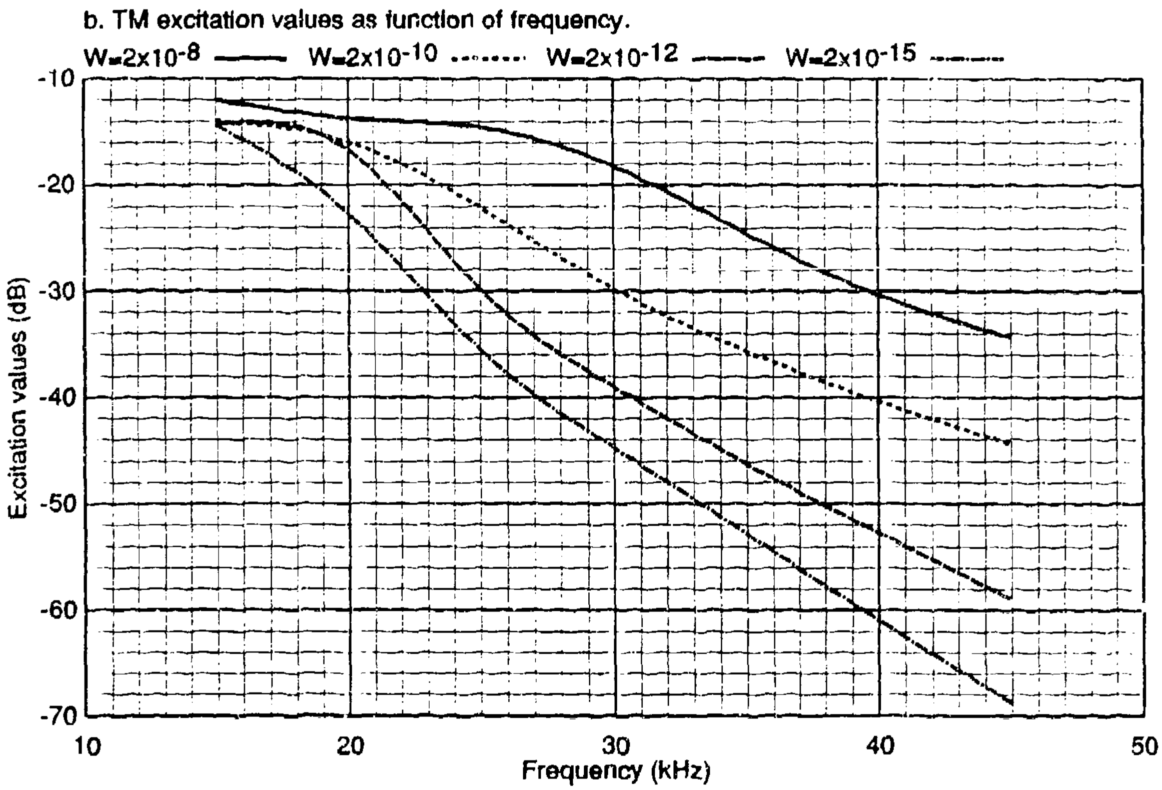
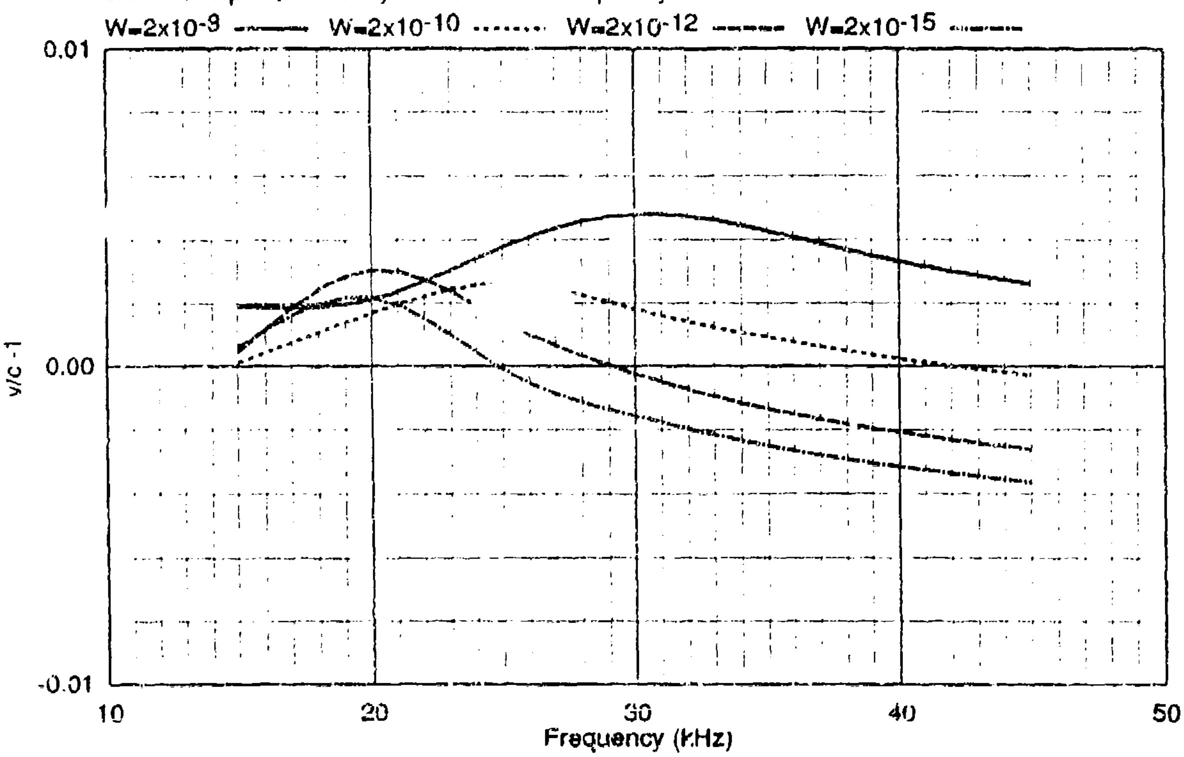
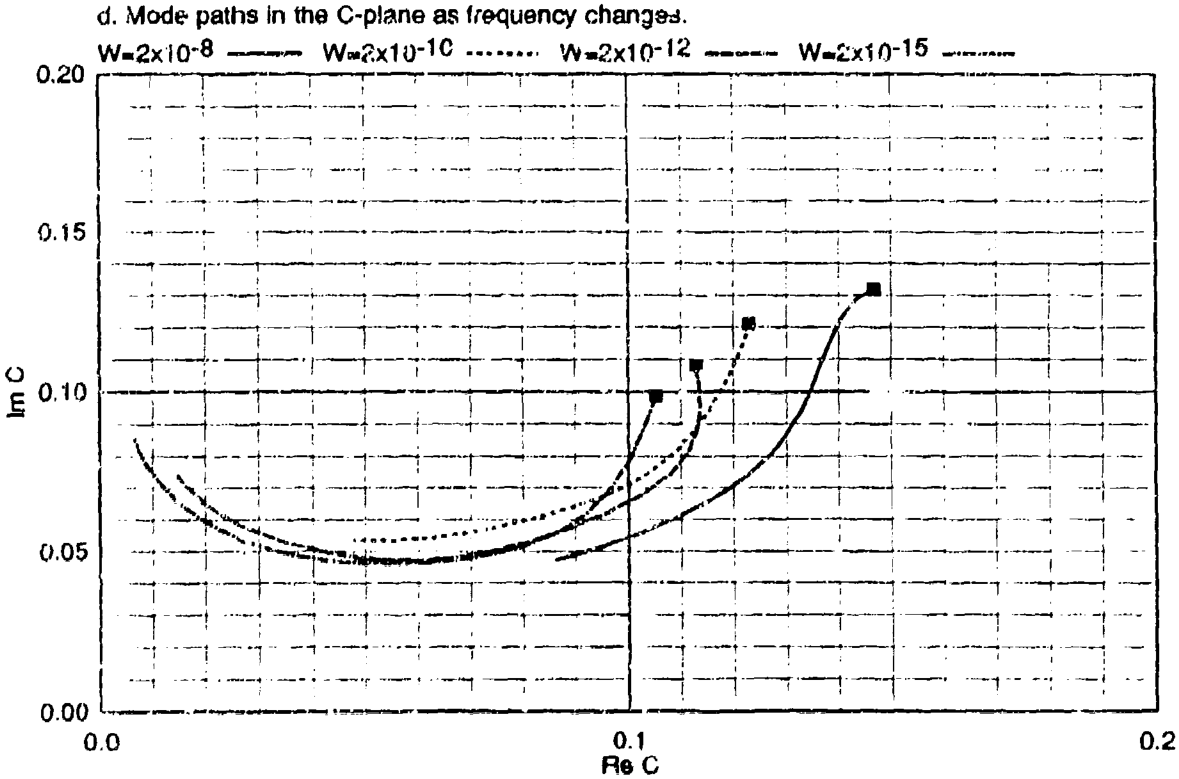


Figure 79. Parameters for least attenuated TM mode, $\sigma_g = 3 \times 10^{-5}$ S/m.

c. Relative phase velocity as function of frequency.



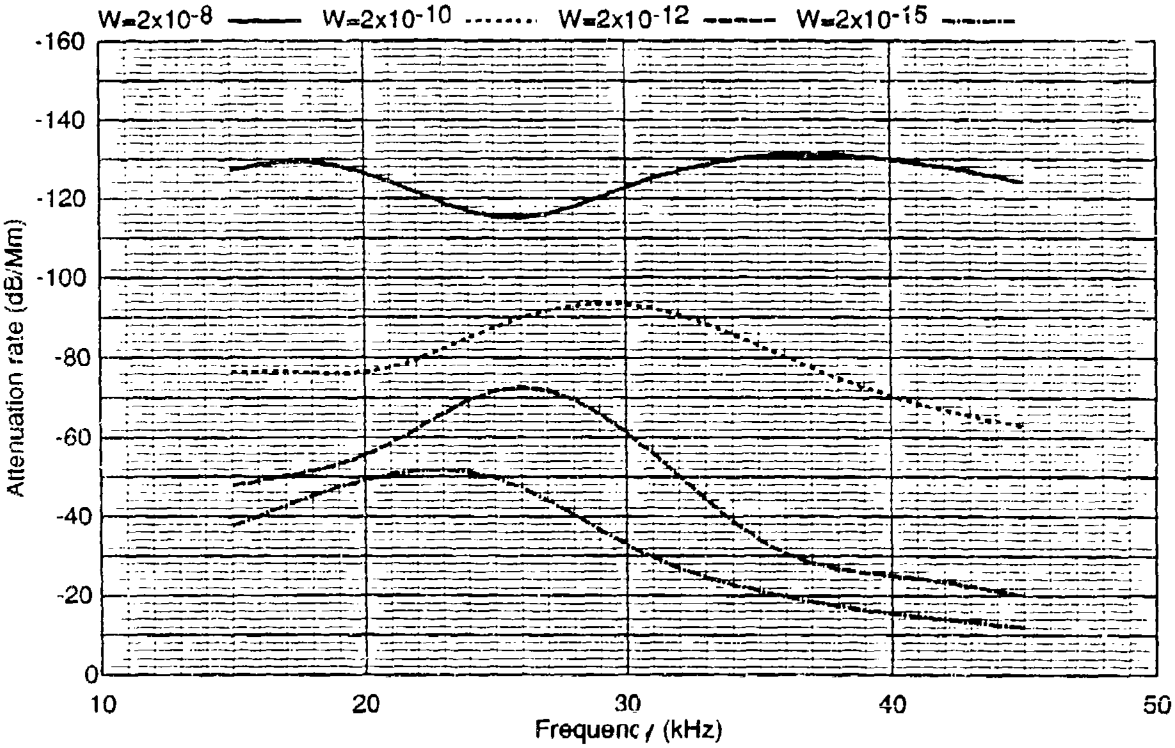
d. Mode paths in the C-plane as frequency changes.



NOTE: The point for lowest frequency marked with ■

Figure 79. Parameters for least attenuated TM mode, $\sigma_g = 3 \times 10^{-5}$ S/m (Concluded).

a. Attenuation as function of frequency.



b. TM excitation values as function of freququency.

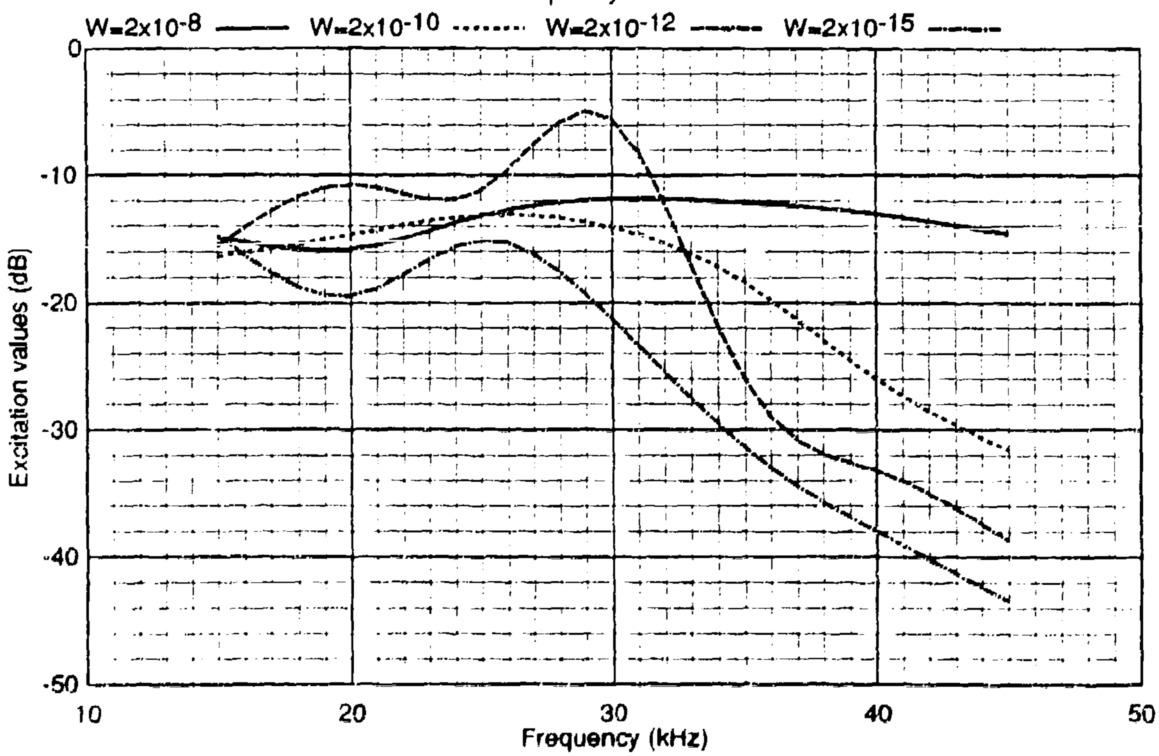
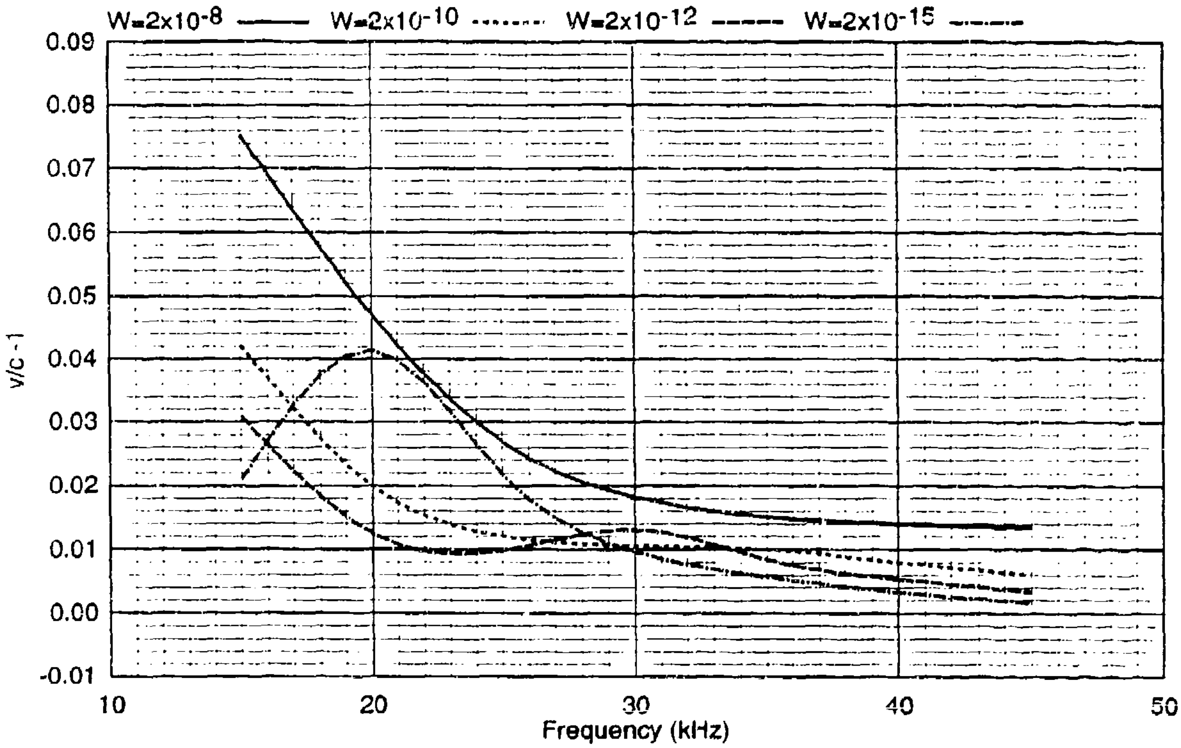
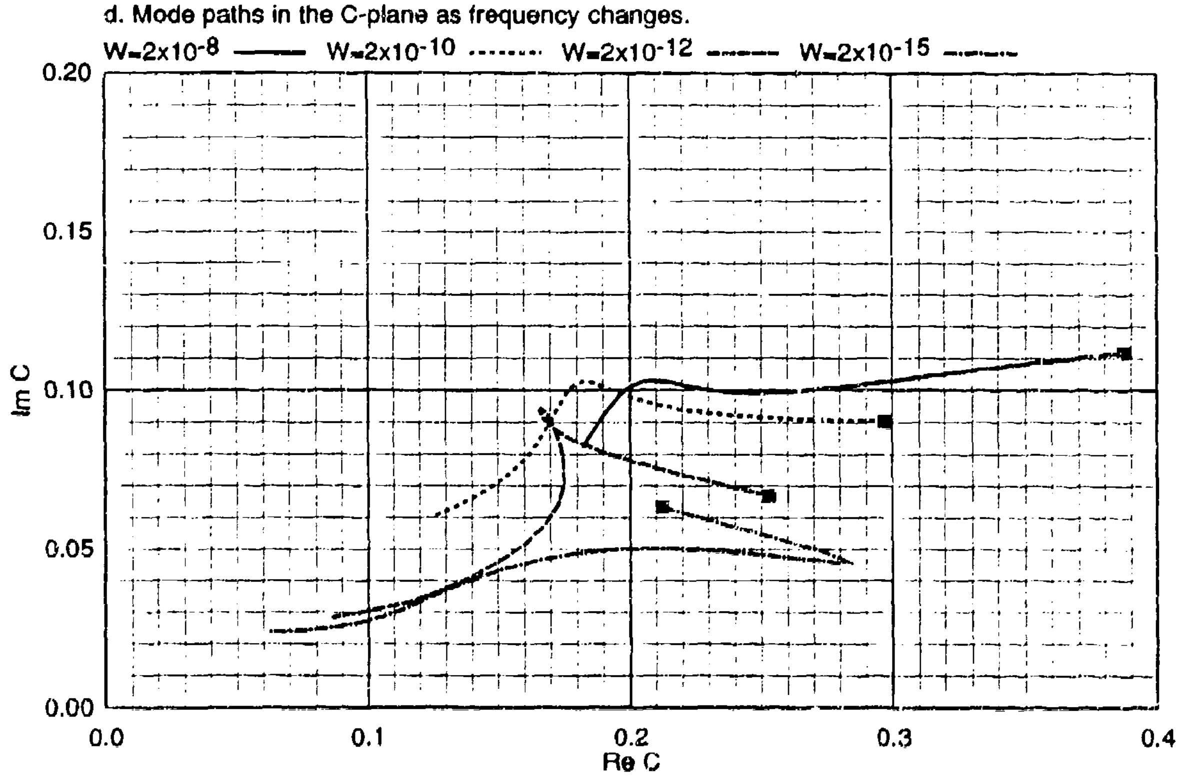


Figure 80. Parameters for second least attenuated TM mode, $\sigma_g = 3 \times 10^{-5}$ S/m.

c. Relative phase velocity as function of frequency.

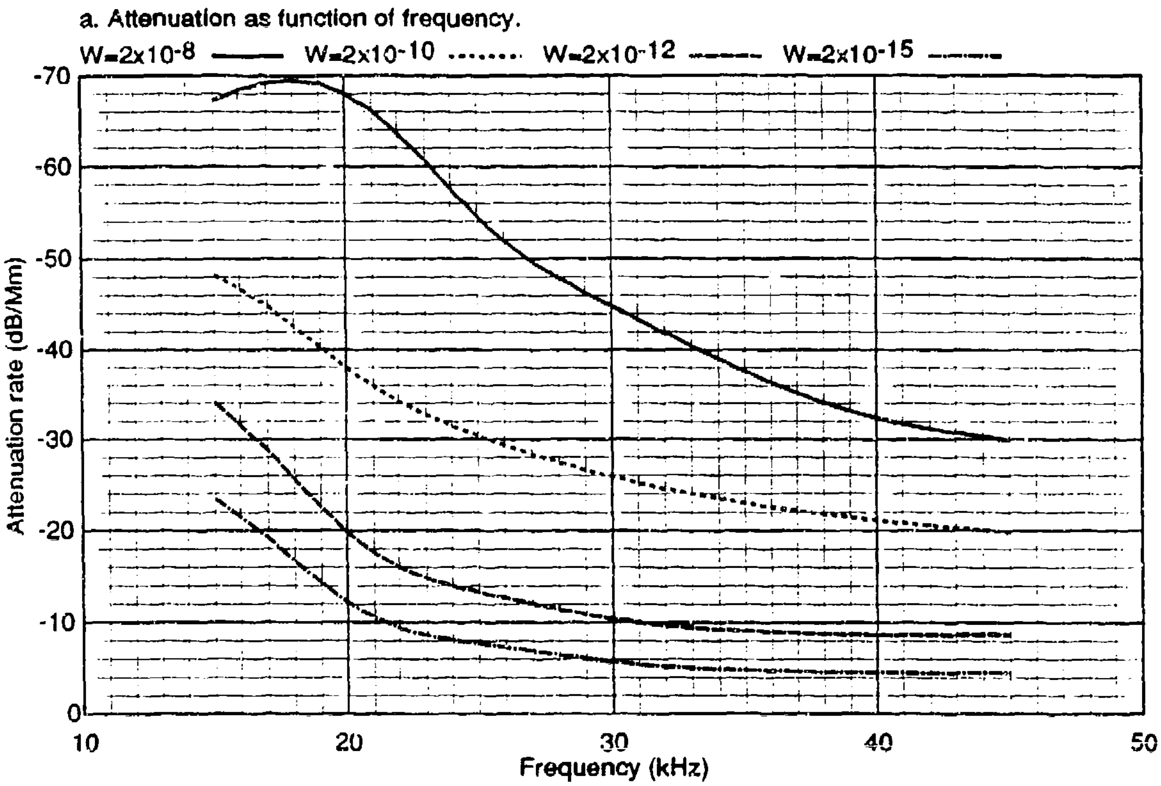


d. Mode paths in the C-plane as frequency changes.



NOTE: The point for lowest frequency marked with ■

Figure 80. Parameters fo, second least attenuated TM mode, $\sigma_g = 3 \times 10^{-5}$ S/m (Concluded).



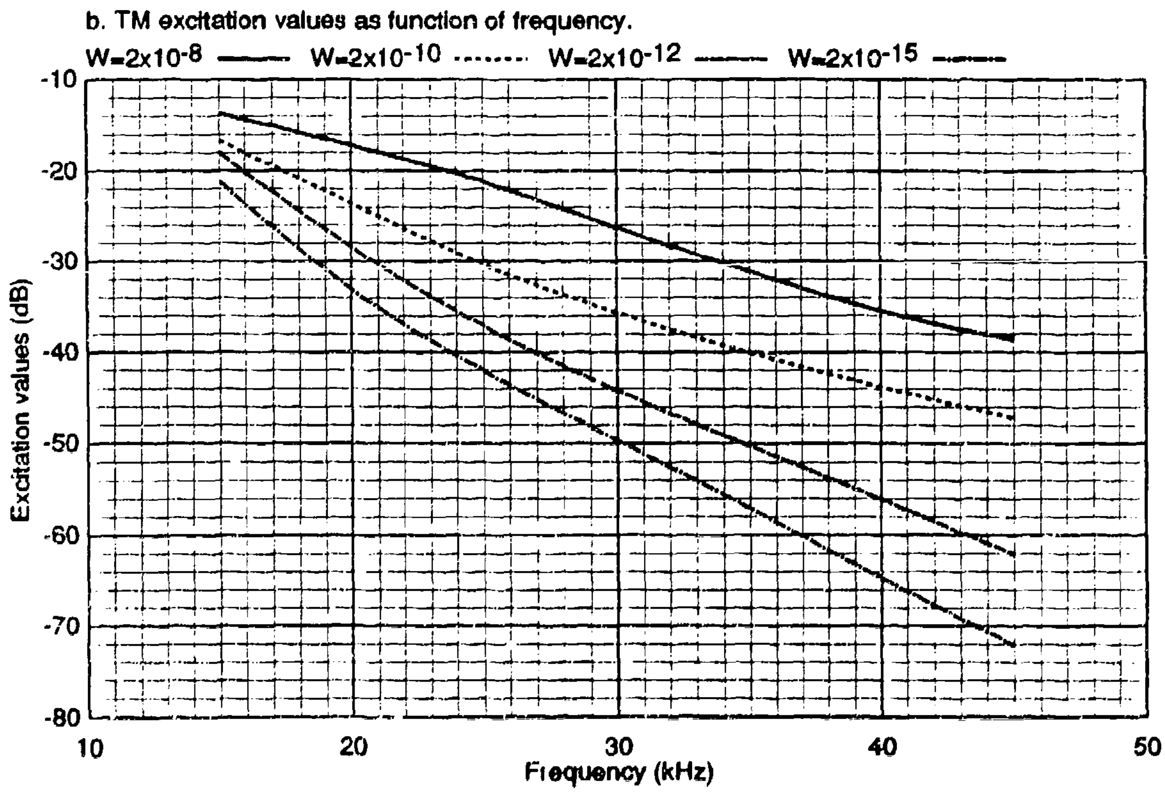
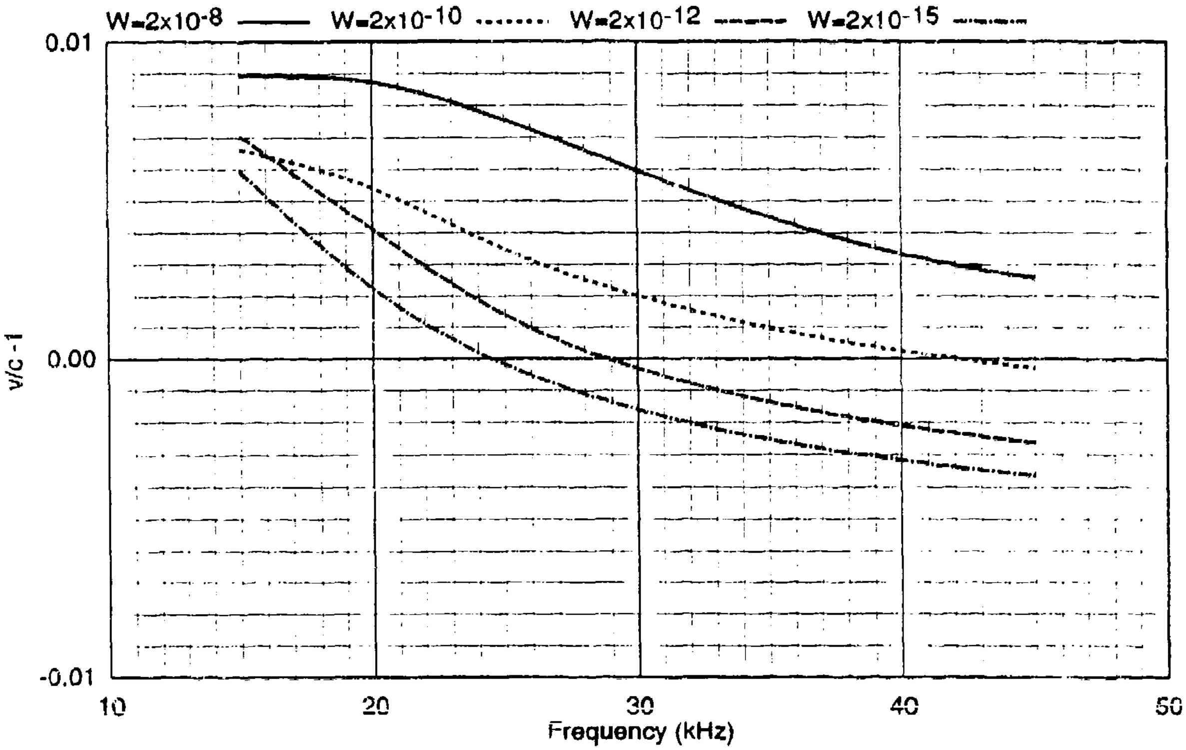
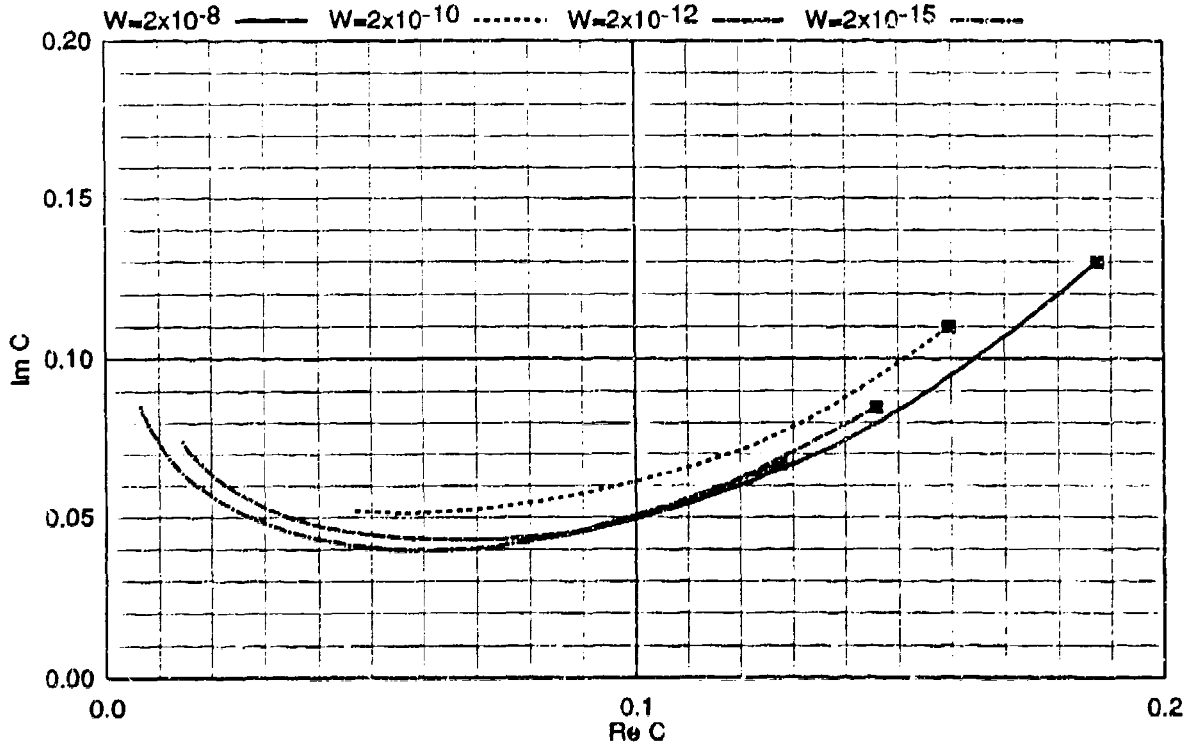


Figure 81. Parameters for least attenuated TM mode, $\sigma_g = 10^{-5}$ S/m

c. Relative phase velocity as function of frequency.

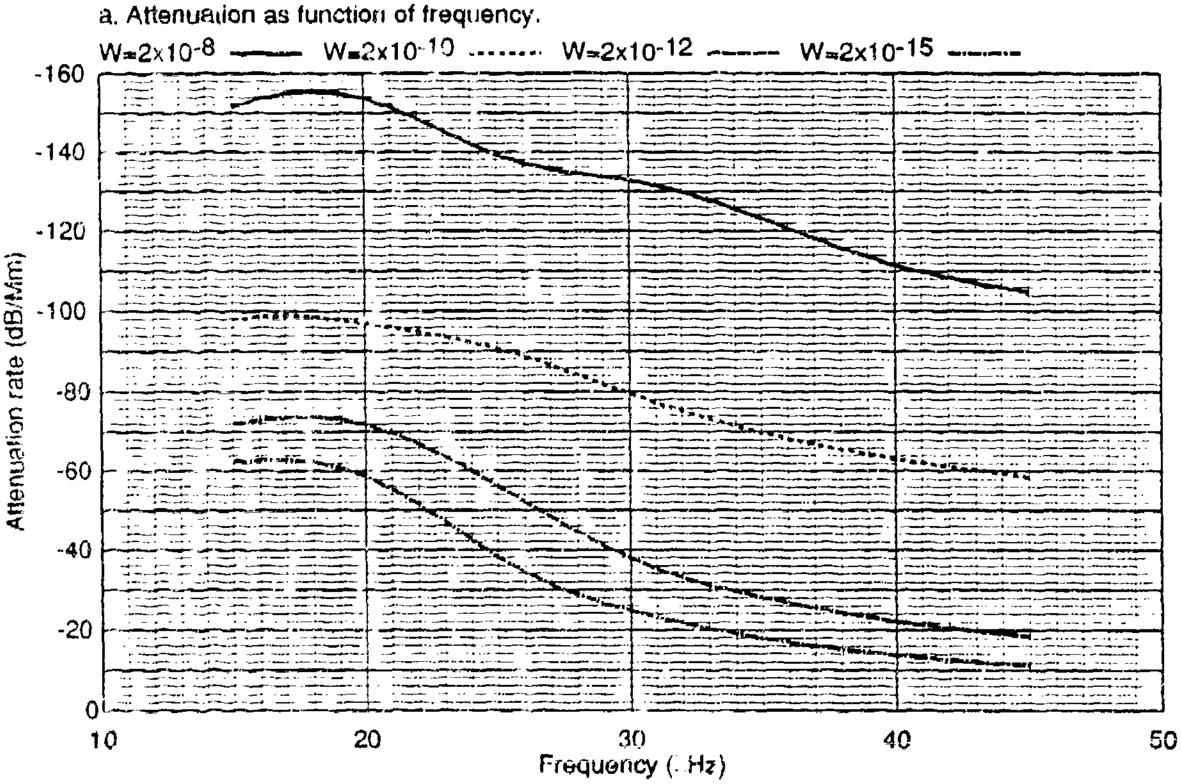


d. Mode paths in the C-plane as frequency changes.



NOTE: The point for lowest frequency marked with ■

Figure 81. Parameters for least attenuated TM mode, $\sigma_g = 10^{-5}$ S/m (Concluded).



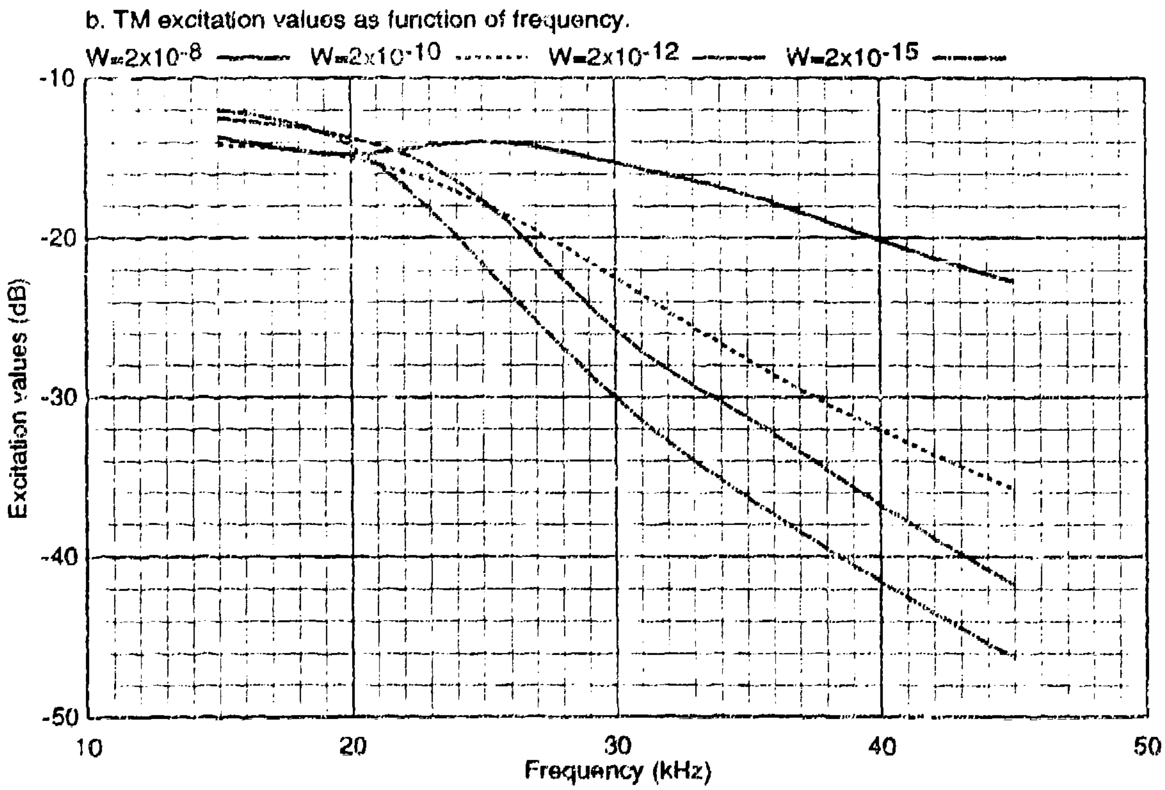
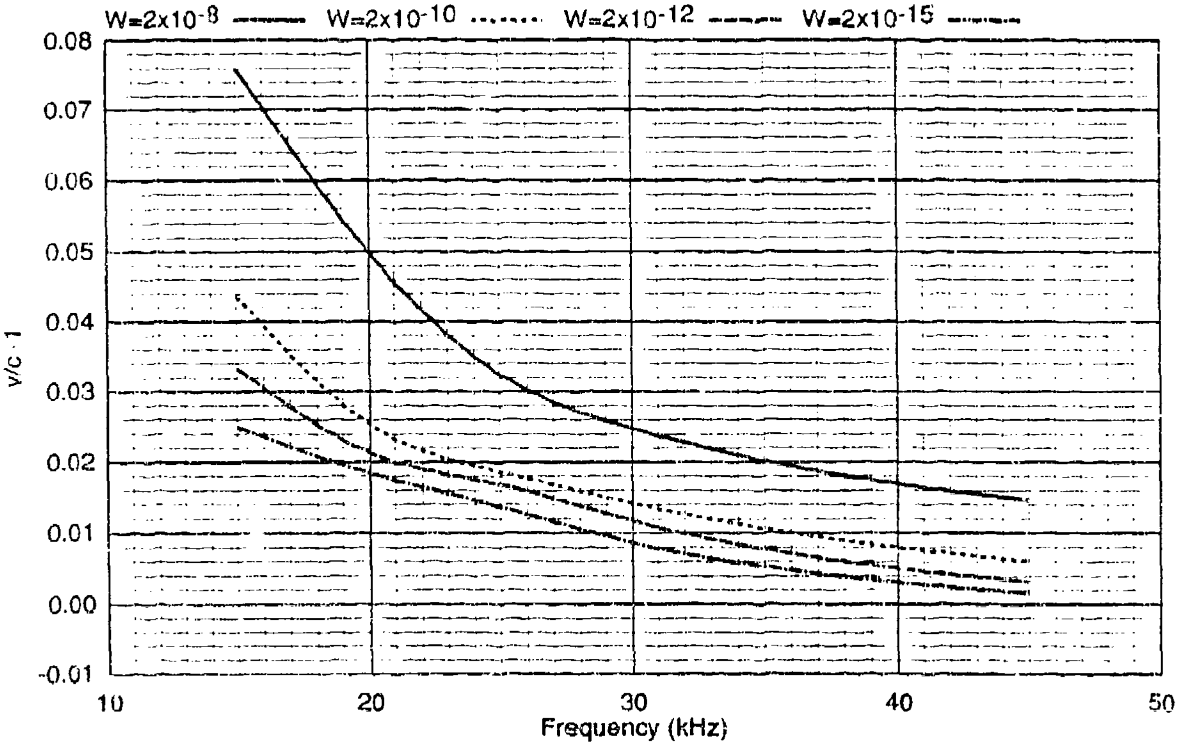
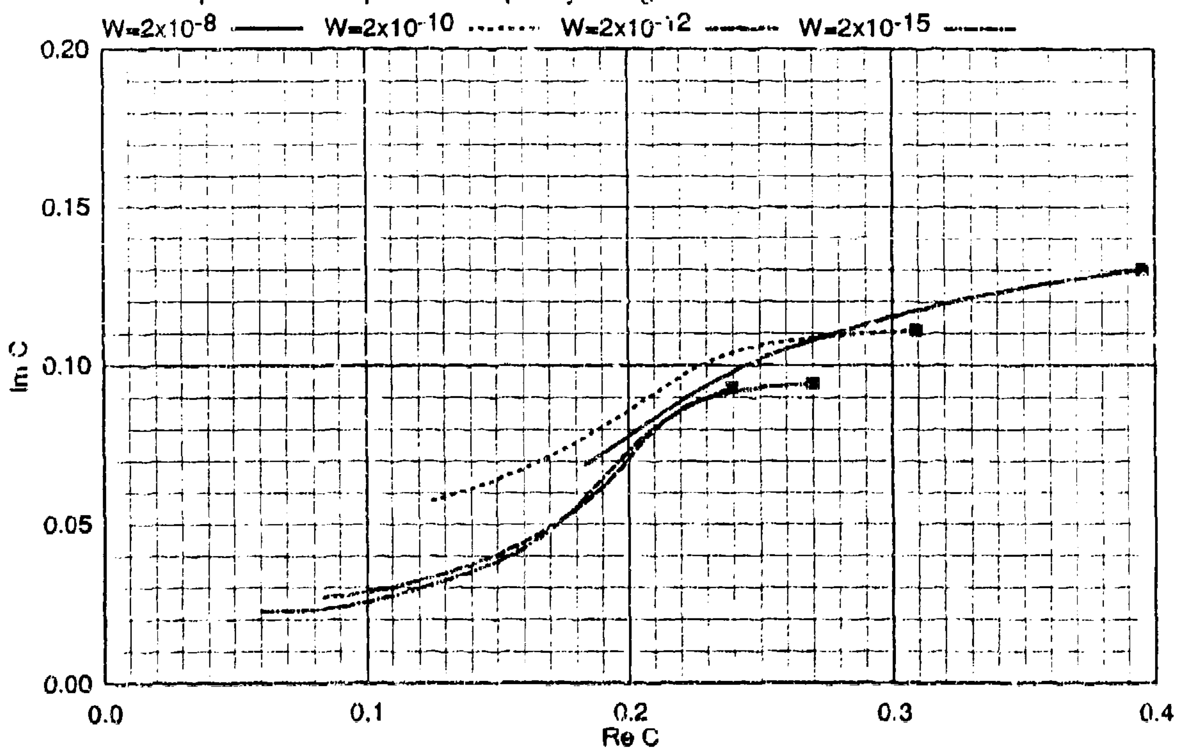


Figure 82. Parameters for second least attenuated TM mode, $\sigma_g = 10^{-5}$ S/m.

c. Relative phase velocity as function of frequency.



d. Mode paths in the C-plane as frequency changes.



NOTE: The point for lowest frequency marked with ■

Figure 82. Parameters for second least attenuated TM mode, $\sigma_g = 10^{-5}$ S/m (Concluded).

SECTION 4

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