U. S. DEPARTMENT OF THE INTERIOR

U. S. GEOLOGICAL SURVEY

# Laboratory Measurements of the Radiofrequency Electrical and Magnetic Properties of Soils from near Yuma, Arizona

by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and nomenclature.

Use of brand names and model numbers in this report is for the sake of description only, and does not constitute endorsement by the U.S. Geological Survey.

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## Introduction

As part of a test of airborne ground penetrating radar systems, soil samples were collected and measured in the laboratory to determine their properties of importance to the subsurface propagation of electromagnetic energy over the frequency range from 1 to 1,000 MHz. The measured electrical and magnetic properties data along with models parameterizing the data are presented in this report. Surface and airborne ground penetrating radar results and a description of the overall test are presented in other reports.

## Electrical Properties

The electrical properties that control electromagnetic propagation through a material are the complex dielectric permittivity and the DC (direct current) electrical conductivity (or its reciprocal: electrical resistivity). The electrical conductivity describes the ability of electric charge to be transported through the material. The dielectric permittivity describes the ability of opposite electric charges within the material to be separated by a distance (polarized). At high frequencies, the DC electrical conductivity is a fixed, frequency-independent, real number. The dielectric permittivity is a frequency dependent complex quantity. The dielectric permittivity is presented here as the relative permittivity (dielectric permittivity of the material divided by the permittivity of vacuum or free space, $\epsilon_o = 8.854 \times 10^{-12}$ Farad/meter).

To parameterize the data, the electrical properties are described by the Cole-Cole model (Cole and Cole, 1941), all relative to the free space permittivity:

$$\epsilon_r' - i\,\epsilon_r'' = \epsilon_\infty + (\epsilon_\iota - \epsilon_\infty) / (1 + (i\,\omega\,\tau_\epsilon)^{\alpha_\epsilon})$$

with the electric loss tangent given as:

$$\tan\delta_\epsilon = \epsilon_r''/\epsilon_r' + \sigma/\omega\epsilon_r'$$

where $\epsilon_r'$ = real part of the relative complex dielectric permittivity
$\epsilon_r''$ = imaginary part of the relative complex dielectric permittivity
$\epsilon_\iota$ = low frequency limit of permittivity
$\epsilon_\infty$ = high frequency limit of permittivity
$\omega = 2\,\pi f$ = radian frequency [f is frequency in $10^6$ Hz]
$i = \sqrt{(-1)}$
$\tau_\epsilon$ = time constant of relaxation [$10^{-6}$ seconds]
$\alpha_\epsilon$ = Cole-Cole relaxation breadth distribution parameter
( = 0 for infinitely broad, = 1 for single relaxation)
$\sigma$ = DC conductivity [Siemens/m].

## Magnetic Properties

The magnetic property that controls electromagnetic propagation through a material is the complex magnetic permeability. The magnetic permeability is commonly assumed to be that of free space, $\mu_o = 4\,\pi \times 10^{-7}$ Henry/meter, and a real, fixed parameter, independent of frequency. However, in a few of these soil samples, the magnetic permeability was found to be significantly higher than that for free space, complex and frequency dependent, describing the lossy magnetic polarization of the material.

To parameterize the data, the magnetic properties are also described by the Cole-Cole model (Olhoeft, 1972), all relative to the free space permeability:

$$\mu_r' - i\,\mu_r'' = \mu_\infty + (\mu_\iota - \mu_\infty) / (1 + (i\,\omega\tau_\mu)^{\alpha_\mu})$$

with the magnetic loss tangent given as:

$$\tan\delta_\mu = \mu_r''/\mu_r'$$

where $\mu_r'$ = real part of the relative complex magnetic permeability
$\mu_r''$ = imaginary part of the relative complex magnetic permeability
$\mu_\iota$ = low frequency limit of permeability
$\mu_\infty$ = high frequency limit of permeability
$\omega = 2\,\pi f$ = radian frequency [f is frequency in $10^6$ Hz]
$i = \sqrt{(-1)}$
$\tau_\mu$ = time constant of relaxation [$10^{-6}$ seconds]
$\alpha_\mu$ = Cole-Cole relaxation breadth distribution parameter
( = 0 for infinitely broad, = 1 for single relaxation)

**Laboratory Measurements**

Samples were collected in the field by Lincoln Laboratory, U.S. Geological Survey, and the Swedish Carabas team personnel. The samples collected by the USGS (Figures 2 through 158) are all located on the map in Figure 1. The locations of the other samples are less certain.

Samples were weighed in their collection bottles before and after vacuum drying (with the weight of the empty bottle subtracted) to determine the natural water content. Samples from the subsurface were measured dry and at various water contents (by adding distilled water). Samples were placed into gold-plated, solid-coin-silver, General Radio GR-900 precision coaxial air lines, 3 cm long, for measurement with a Hewlett Packard 8753 network analyzer, using full 12-port transmission-reflection-through, open-short-load calibrations (using updated procedures similar to Kutrubes (1986)). Forward and reverse measurements were made using the reflection and transmission from one end of the sample holder (forward) and then again from the other end (reverse). Sample holder air lines were weighed empty, with dry sample, and at various added water amounts to determine sample dry bulk density and weight percent water contents.

In each figure, the upper left plot is the relative dielectric permittivity, the lower left plot is the electric loss tangent, the upper right plot is the relative magnetic permeability, and the lower right plot is the magnetic loss tangent, each versus log frequency. Each plot shows the forward and reverse measurements (the jagged lines) and a smooth curve showing the fit of the model parameters. The unchanging line with a minimum near 100 MHz in both loss tangent plots represents the minimum resolvable losses for the sample holder and measurement system. Also labelled on the plots are the dry bulk density (upper left), water content (lower right), and dielectric and magnetic Cole-Cole model parameters (lower plots). The text label at the bottom of each figure is whatever was written on the field sample container. Some samples were subsampled to test measurement repeatability and sample heterogeneity (for examples, Figures 4-34), and subsamples were designated #1, #2, and so forth. At the highest measured frequencies, sample holder resonance sometimes appears (exhibited by a rapidly increasing permittivity with increasing frequency) and should be ignored.

The forward and reverse measurements are good indicators of the errors in the measurement process and the heterogeneity of the sample. In an ideal, homogeneous, isotropic sample with a perfect measurement apparatus, the two curves should be identical. When the two curves are separated by the same distance over the frequency range of measurement, cumulative instrument and computational error are represented by that separation. Divergence of the curves with increasing frequency is an indication of heterogeneity in the sample (e.g., the sample holder is not uniformly packed with soil or is unevenly water-wet throughout).

**Discussion**

The soil samples exhibited natural water contents from a fraction of one percent to several percent by weight. All samples were disturbed by the sampling acquisition process and were measured at dry bulk densities probably lower than in situ. However, the disturbance of digging and burying test targets for the ground penetrating radars probably represents an equivalent amount of soil density reduction in the replaced soil above the targets. In situ undisturbed electrical properties are probably higher in permittivity and loss than shown in these measurements.

Most of the soils measured appear to be representative of low water content sandy soils that could be found almost anywhere in the world (Kutrubes, 1986; Olhoeft, 1987). All exhibited strongly frequency dependent dielectric properties when wet, even with fractional-weight-percent water contents. However, some soil samples exhibited properties indicative of clay minerals with much stronger frequency dependence and correspondingly higher losses. A few soil samples exhibited extremely unusual and highly lossy magnetic properties. Some lossy magnetic soils had magnetic losses higher than electrical losses, which were easily explained in terms of high iron content from a mineral like magnetite. A second type of lossy magnetic soils were like no other previously known soils and require further investigation. Frequency dependent dielectric permittivity and magnetic permeability result in varying velocity of electromagnetic propagation with frequency (dispersion).

The data presented in Figures 2 through 158 are from the USGS sampling which traversed the site from north to south (Figure 1). The remaining data in Figure 159 through 208 are from the Lincoln Laboratory and Carabas Team soil sampling.

Figures 2 through 43 show measurements on the samples collected near -500 meters, site Hood, where the trucks were buried. Figures 2, 3, 4, 34 and 39 show the electromagnetic properties in their natural water content state as a function of depth. The remaining figures show the results with artificially varying water content. Note how the electrical resistivity and losses vary by nearly two orders of magnitude with less than a factor of 6 variation in water content from the surface to 50 cm depth. Either salts or clay minerals must be present in these samples to account for the rapid change in electrical properties with changing water content (Olhoeft, 1987). The magnetic properties are normal and essentially those of free space.

Figures 44 through 49 show measurements on the samples collected near +500 meters, site Sheridan, where the dipole array was located. The properties are those of normal sand, showing lower losses than site Hood at -500 meters. The magnetic properties are normal and essentially those of free space.

Figures 50 and 51 show measurements on the samples collected near +1050 meters, site Jackson, where the semilog periodic array was located. The water content is very low here, yielding very low loss from normal sands. The magnetic properties are normal and essentially those of free space.

Figure 52 through 57 show measurements on the samples collected near +1680 meters, site Moseby, where the repeaters were located. The water content is very low here, yielding very low loss from normal sands. The magnetic properties are normal and essentially those of free space.

Figures 58 through 95 show measurements on the samples collected near +2040 meters, site Butler, where the plastic and steel pipes are buried. The water content varies widely at this site, but the electrical properties are still mostly those of low loss sand. Despite the presence of magnetite sands at this site, the relative magnetic permeability is still low (< 1.2), and magnetic losses do not exceed electrical losses (for example, Figure 88). The magnetic properties could be safely assumed to be essentially those of free space.

Figures 96 through 101 show measurements on the samples collected near +2270 meters, site Stuart, where the repeaters were buried. The water content is very low here, yielding very low loss from normal sands. The magnetic properties are normal and essentially those of free space.

Figures 102 through 121 show measurements on the samples collected near +2500-2640 meters, site Custer, where the dipoles are buried. The water content is highly variable at this site, causing very low loss at the surface but very high losses at about 50 cm depth. At Custer subsite D, an anomalous magnetic behavior was observed, yielding magnetic losses an order of magnitude higher than dry electrical losses (Figure 119) with a high magnetic permeability. No known natural material has been previously observed to behave this way nor exhibit these properties, though we have since observed similar behavior in anomalous soil samples from Idaho.

Figures 122 through 127 show measurements on the samples collected near +3000 meters, site McClellan, where the long wire is buried. The water content is highly variable at this site, causing very low loss at the surface but very high losses at about 50 cm depth. The anomalous magnetic behavior was again observed, yielding magnetic losses an order of magnitude higher than dry electrical losses with a high magnetic permeability. These samples (Figures 126 and 127) also exhibited magnetic losses high enough to compete with high-water-content electrical losses. There is no known explanation for this behavior.

Figures 128 through 133 show measurements on the samples collected near +3120 meters, site Beauregard, where repeaters were buried. The water content is highly variable at this site, causing very low loss at the surface but very high losses at about 50 cm depth. The anomalous magnetic behavior was again observed (Figure 132) though not high enough at this site to compete with the electrical properties in the wet soils.

Figures 134 through 140 show measurements on the samples collected near +3200 meters, site Douglas, where the dipoles are buried. The water content is highly variable at this site, causing very low loss at the surface but very high losses at about 50 cm depth. The anomalous magnetic behavior was again observed, yielding magnetic losses an order of magnitude higher than dry electrical losses with a high magnetic permeability. These samples (Figures 137 and 140) also exhibited magnetic losses high enough to compete with high-water-content electrical losses. There is no known explanation for this behavior.

Figures 141 through 149 show measurements on the samples collected near +3400 meters, site Stanton (also called Mudd in the surveying data files), where the mines are buried. Despite highly variable water contents, the samples all exhibit very low losses, typical of dry sandy materials. There are slight indications of possible magnetic losses (Figures 146 to 149), but none are significant in comparison to the electrical losses.

Figures 150 through 158 show measurements on the samples collected near +3450 meters, site Stanton, where the mines are buried. The water content is highly variable at this site, causing very low loss at the surface and higher losses at about 50 cm depth. The anomalous magnetic behavior was again observed (Figures 157 and 158) though not high enough at this site to compete with the electrical properties in the wet soils.

The remaining soil sample results in Figures 159 through 208 are not as well

located (the data in Figures 183 through 208 are located on the grid points shown in the plot labels), but essentially show similar behavior. The anomalous magnetic loss appears again in Figures 164 and 165.

In Figures 171, 176, 183 and 204 another type of magnetic loss appears. This appears to be caused by the presence of iron metal or iron-bearing minerals. This second type of magnetic behavior can be simulated with mixtures of iron and silica powder (Figures 184 through 194). The soil sample in Figure 183, for example, is very similar to the simulant in Figure 187, suggesting about 30 percent iron-equivalent in the soil. Note also that the natural water content in the soil of Figure 183 produces electrical losses that are lower than the magnetic losses -- particularly above about 60 MHz. No simulant has yet been found for the first, more anomalous magnetic loss (as in Figure 119).

**Summary**

In general, the near surface soils are very low water content (fraction of one weight percent), high electrical resistivity (thousands of ohm-meters), low electromagnetic loss materials. Beginning from 20 to 50 cm depth throughout the site, there is a general increase in water content (up to several weight percent) with electrical resistivity dropping to tens of ohm-meters or less and dielectric permittivity rising. In general the losses are also higher at the North end of the site than at the South end. The anomalous magnetic loss becomes significant in the middle of the site.

In nearly all cases, the high frequency model parameters and Cole-Cole distribution parameters are well resolved in fits to the data. However, the time constants and the low frequency parameters are only minimum limiting values.

**References**

Cole, K. S. and Cole, R. S., 1941, Dispersion and adsorption in dielectrics, I, alternating current characteristics: J. Chem. Phys., v. 9, p. 341-351.

Kutrubes, D. L., 1986, Dielectric permittivity measurements of soils saturated with hazardous fluids: MSc Thesis, Dept. of Geophysics, Colo. School of Mines, Golden, CO, 300p.

Olhoeft, G. R., 1972, Time dependent magnetization and magnetic loss tangents: MSc Thesis, Dept. of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, MA, 94p.

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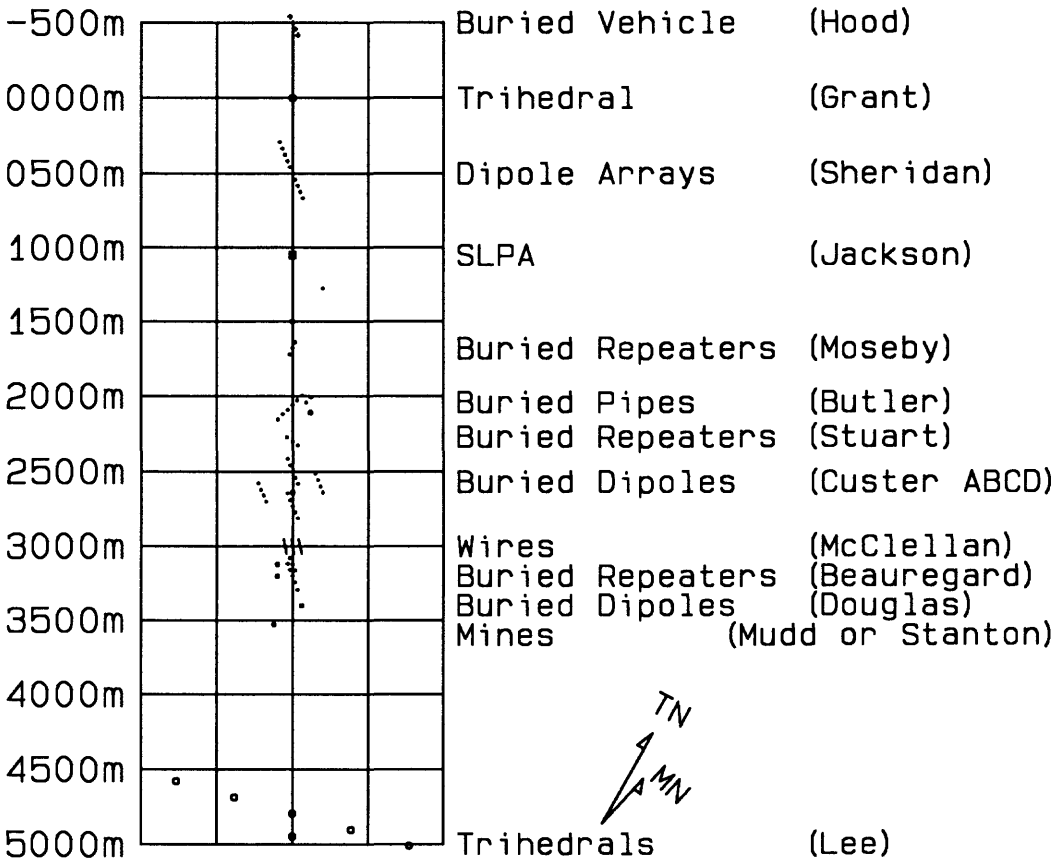



Figure 1 - Plan map of the test area. Numbers along the left axis are distances in meters along the length of the line. In each sample figure caption, those numbers are given to help locate the sample (where known).

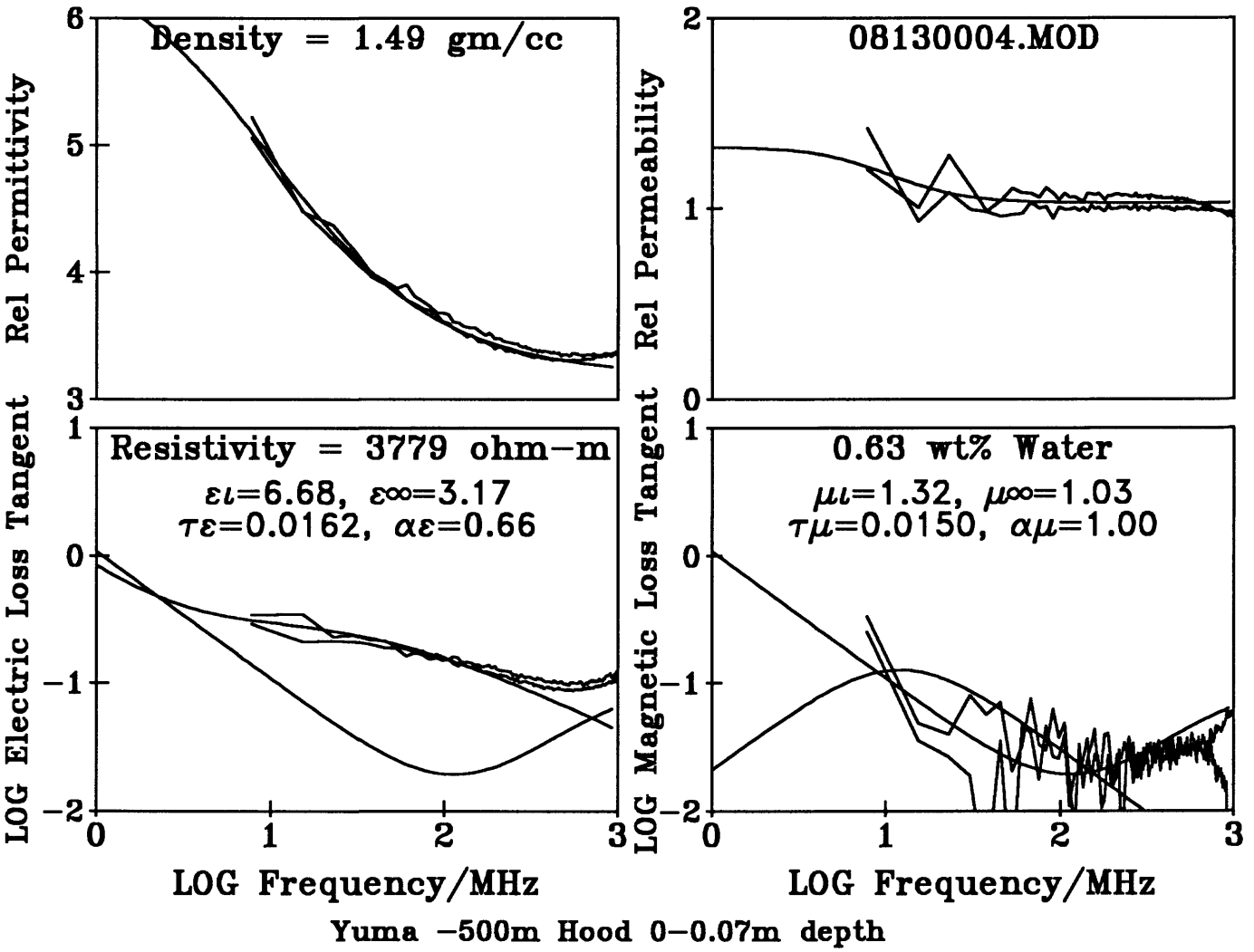



Figure 2 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

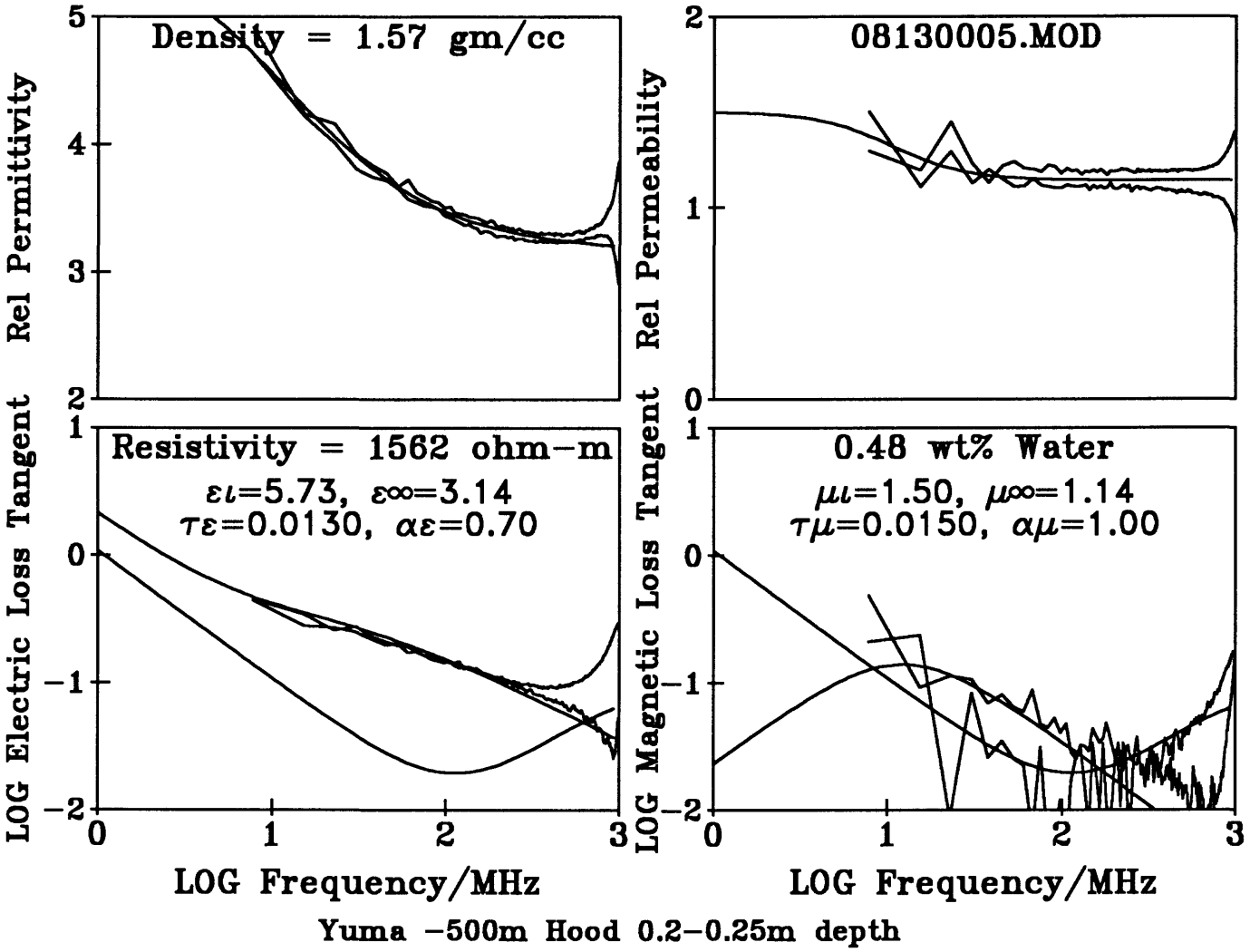



Figure 3 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

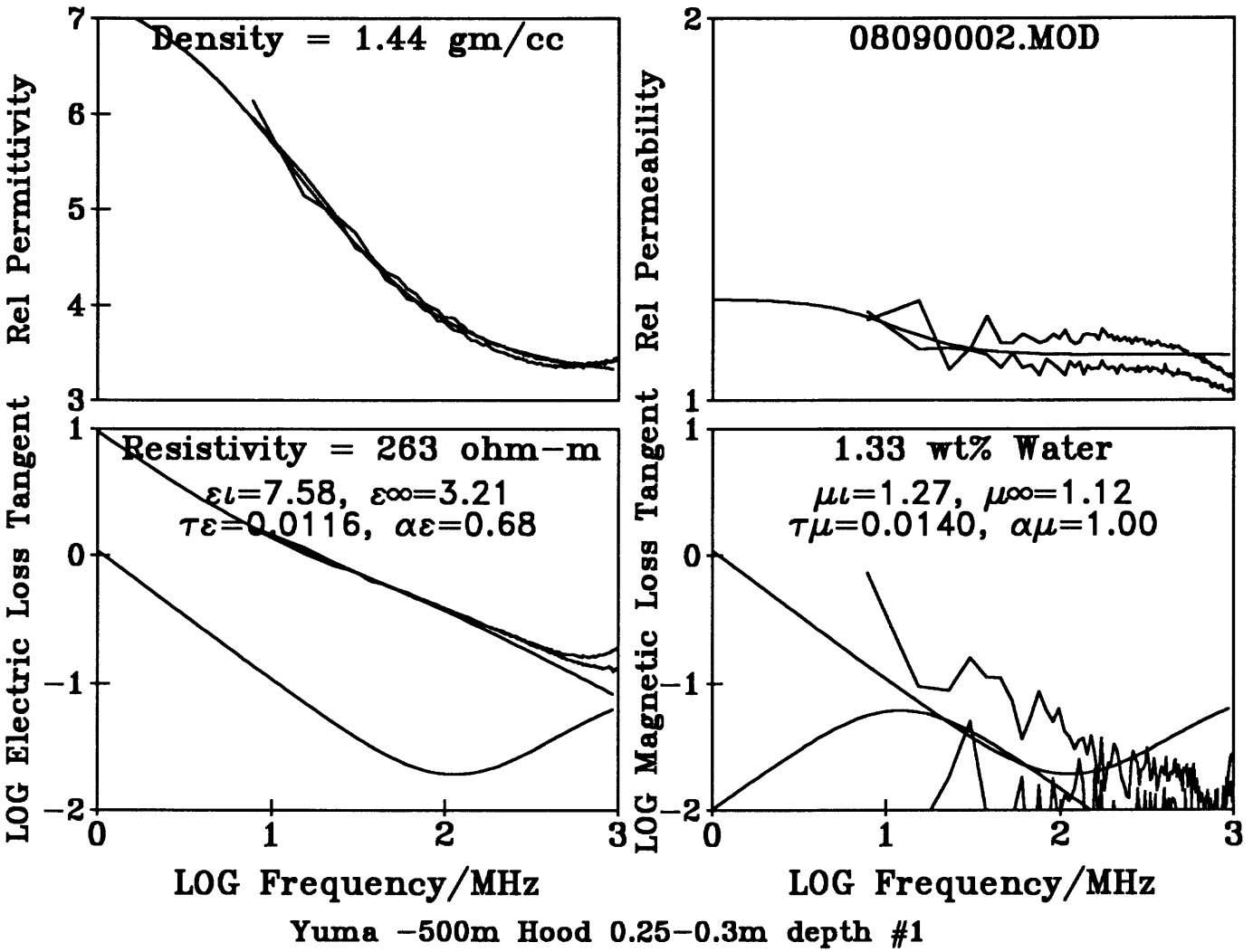



Figure 4 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

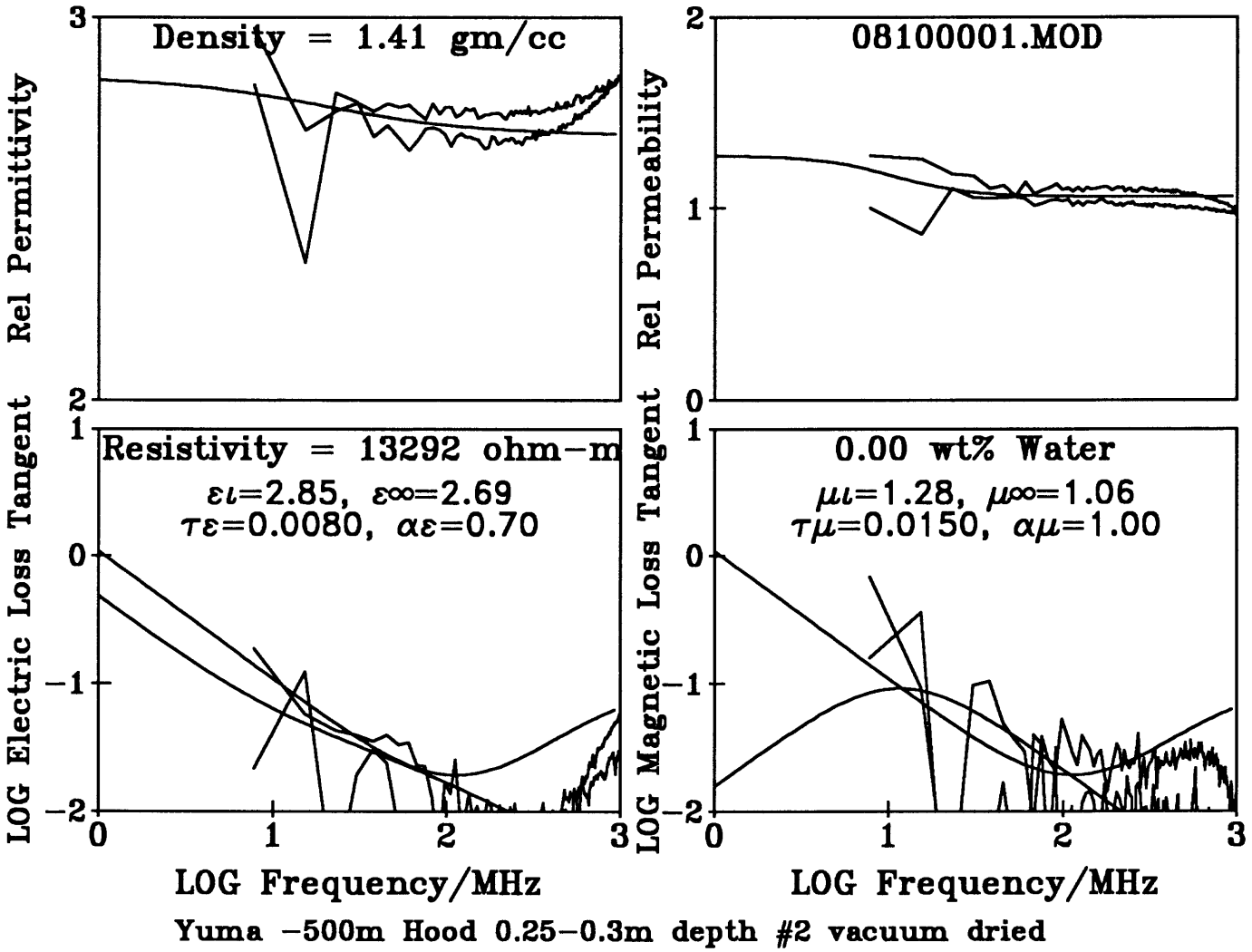

Density = 1.41 gm/cc
08100001.MOD
Resistivity = 13292 ohm-m
ει=2.85, ε∞=2.69
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.28, μ∞=1.06
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #2 vacuum dried

Figure 5 -

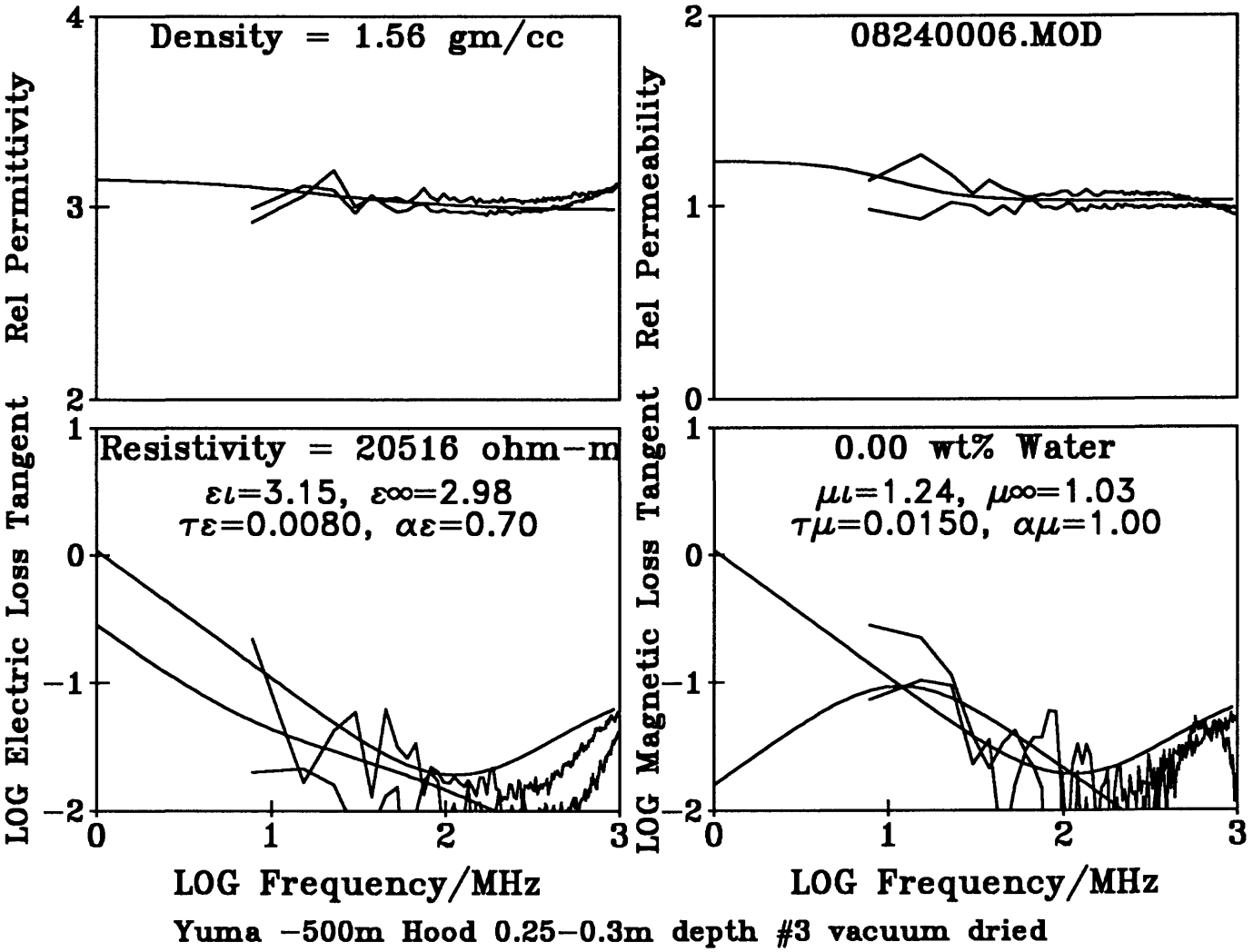
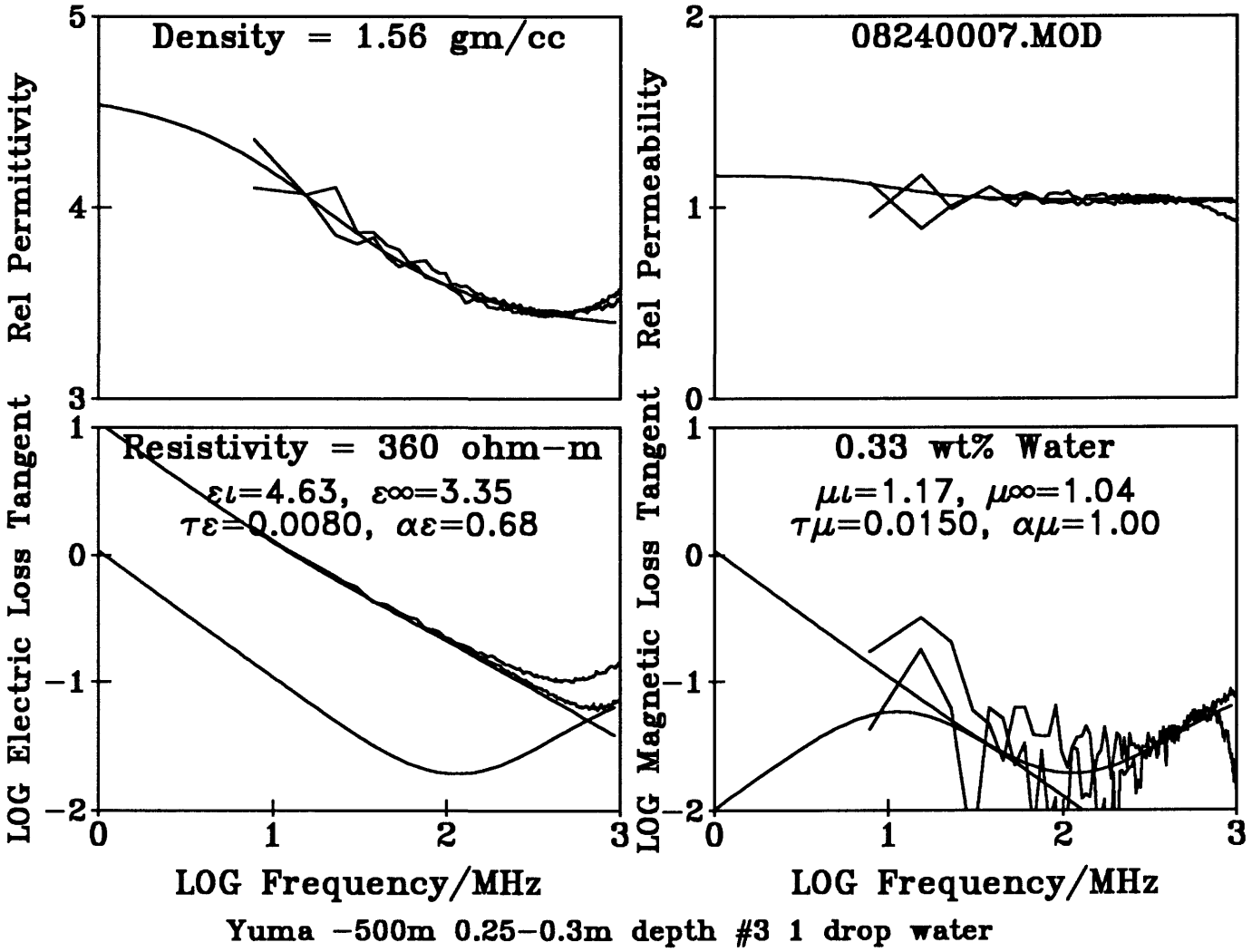

Density = 1.56 gm/cc
08240006.MOD
Rel Permittivity
Rel Permeability
Resistivity = 20516 ohm-m
ει=3.15, ε∞=2.98
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.24, μ∞=1.03
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #3 vacuum dried

Figure 6 -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08240007.MOD
Rel Permittivity
Rel Permeability
Resistivity = 360 ohm-m
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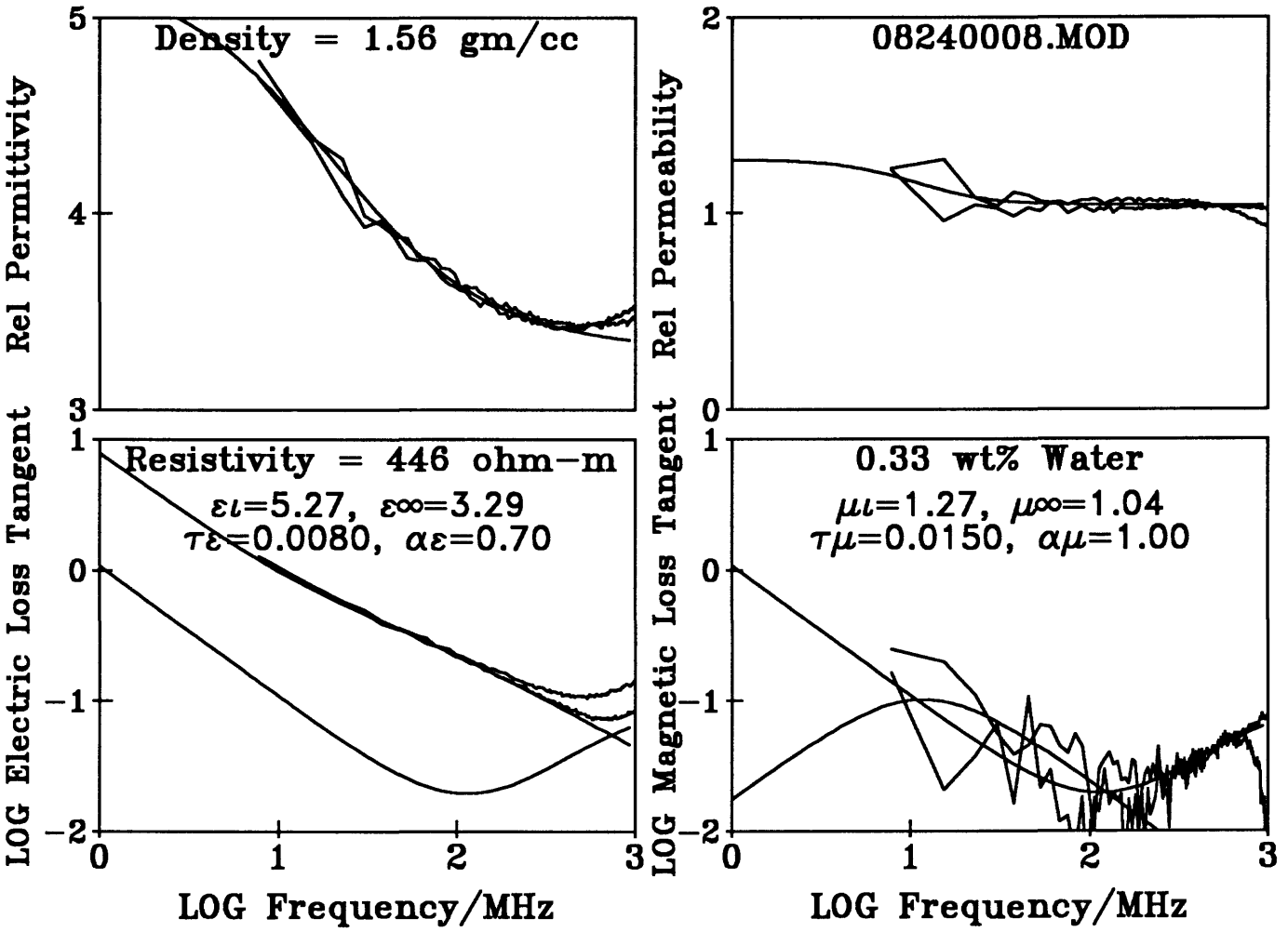
τε=0.0080, αε=0.68
0.33 wt% Water
μι=1.17, μ∞=1.04
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m 0.25-0.3m depth #3 1 drop water

Figure 7 -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08240008.MOD
Rel Permittivity
Rel Permeability
Resistivity = 446 ohm-m
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τε=0.0080, αε=0.70
0.33 wt% Water
μι=1.27, μ∞=1.04
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #3 1 drop water + 30 min.

Figure 8 -

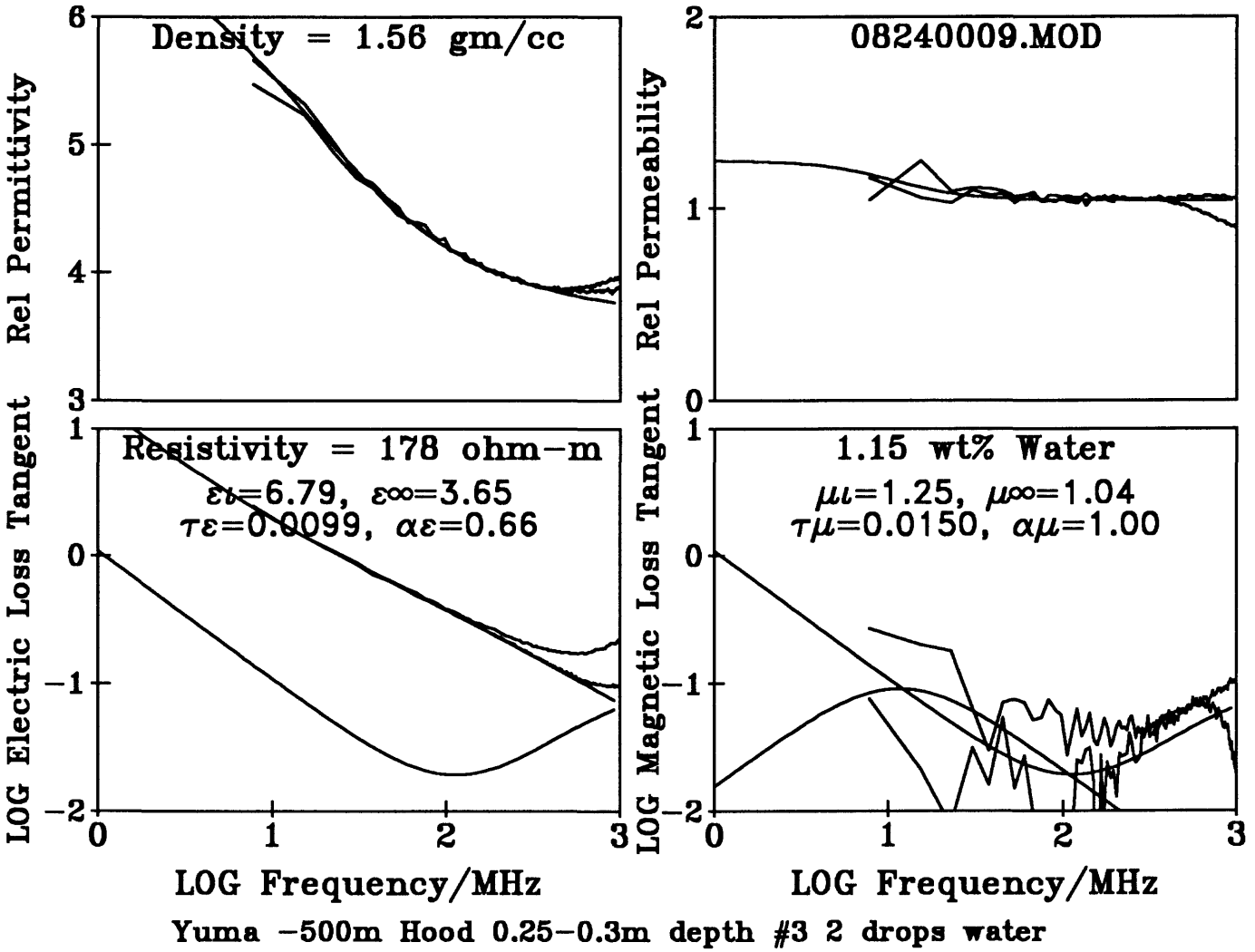

Density = 1.56 gm/cc
08240009.MOD
Resistivity = 178 ohm-m
ει=6.79, ε∞=3.65
τε=0.0099, αε=0.66
1.15 wt% Water
μι=1.25, μ∞=1.04
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #3 2 drops water

Figure 9 -

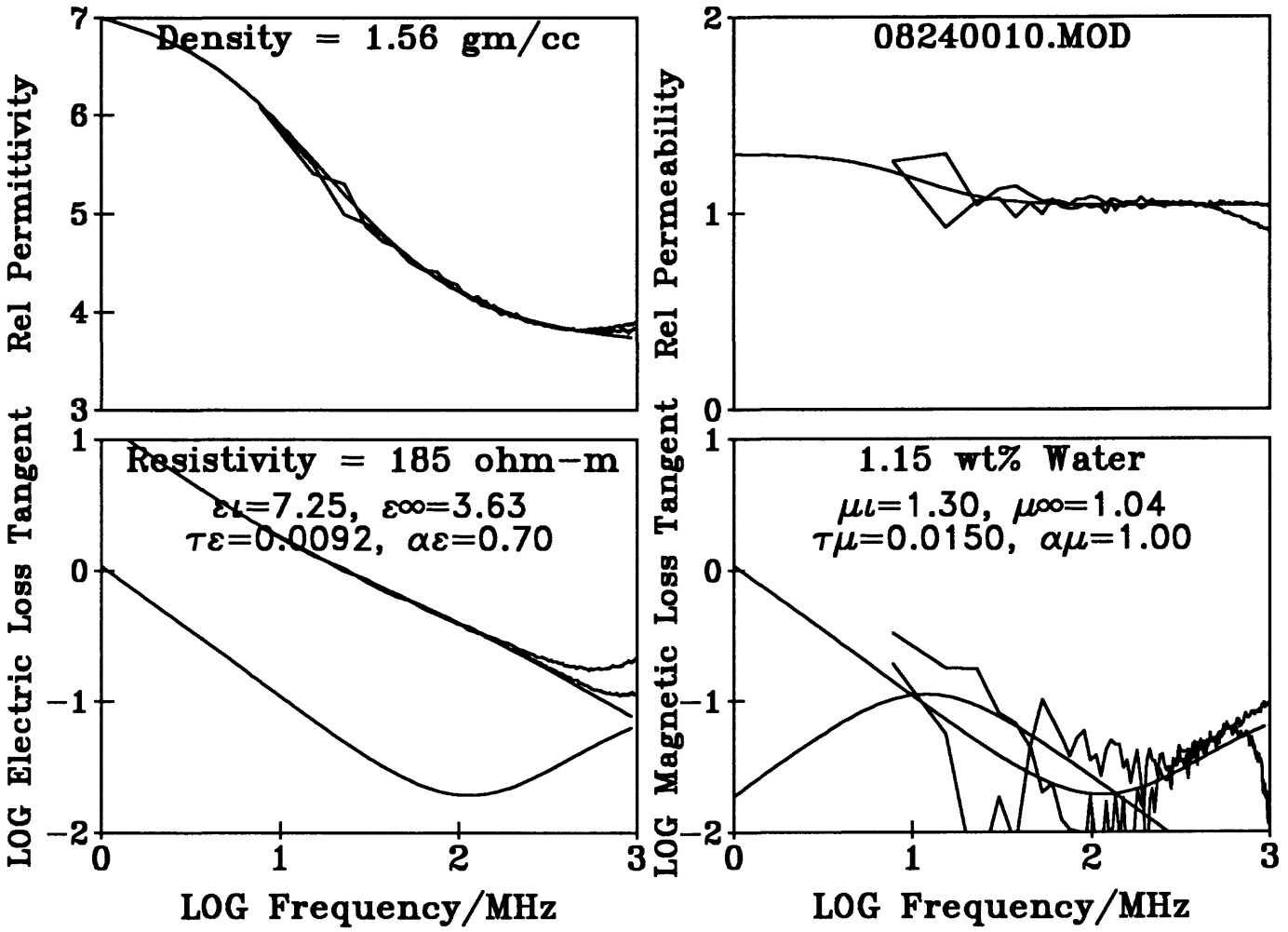
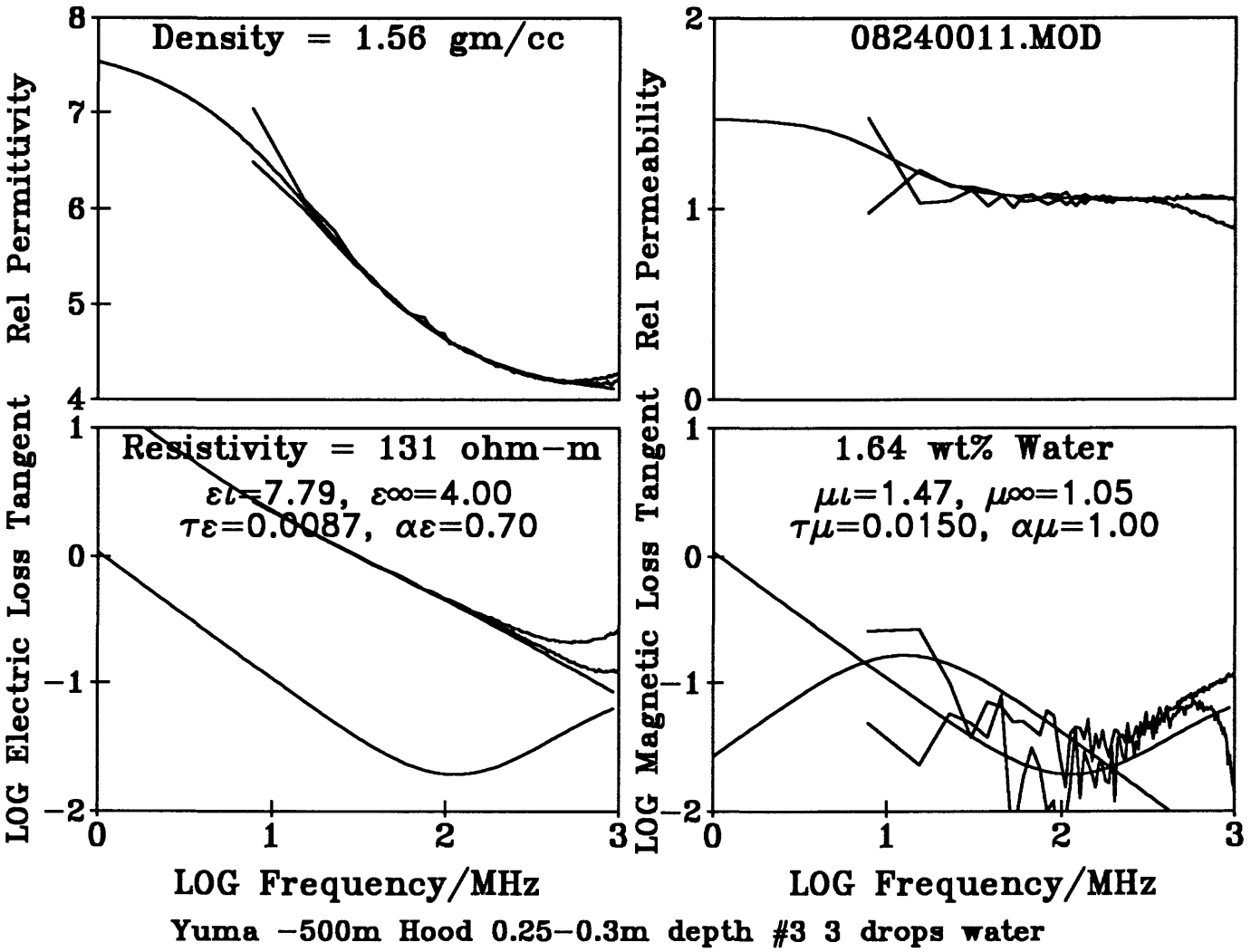

Density = 1.56 gm/cc
08240010.MOD
Resistivity = 185 ohm-m
ει=7.25, ε∞=3.63
τε=0.0092, αε=0.70
1.15 wt% Water
μι=1.30, μ∞=1.04
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #3 2 drops water + 30 min.

Figure 10 -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08240011.MOD
Rel Permittivity
Rel Permeability
Resistivity = 131 ohm-m
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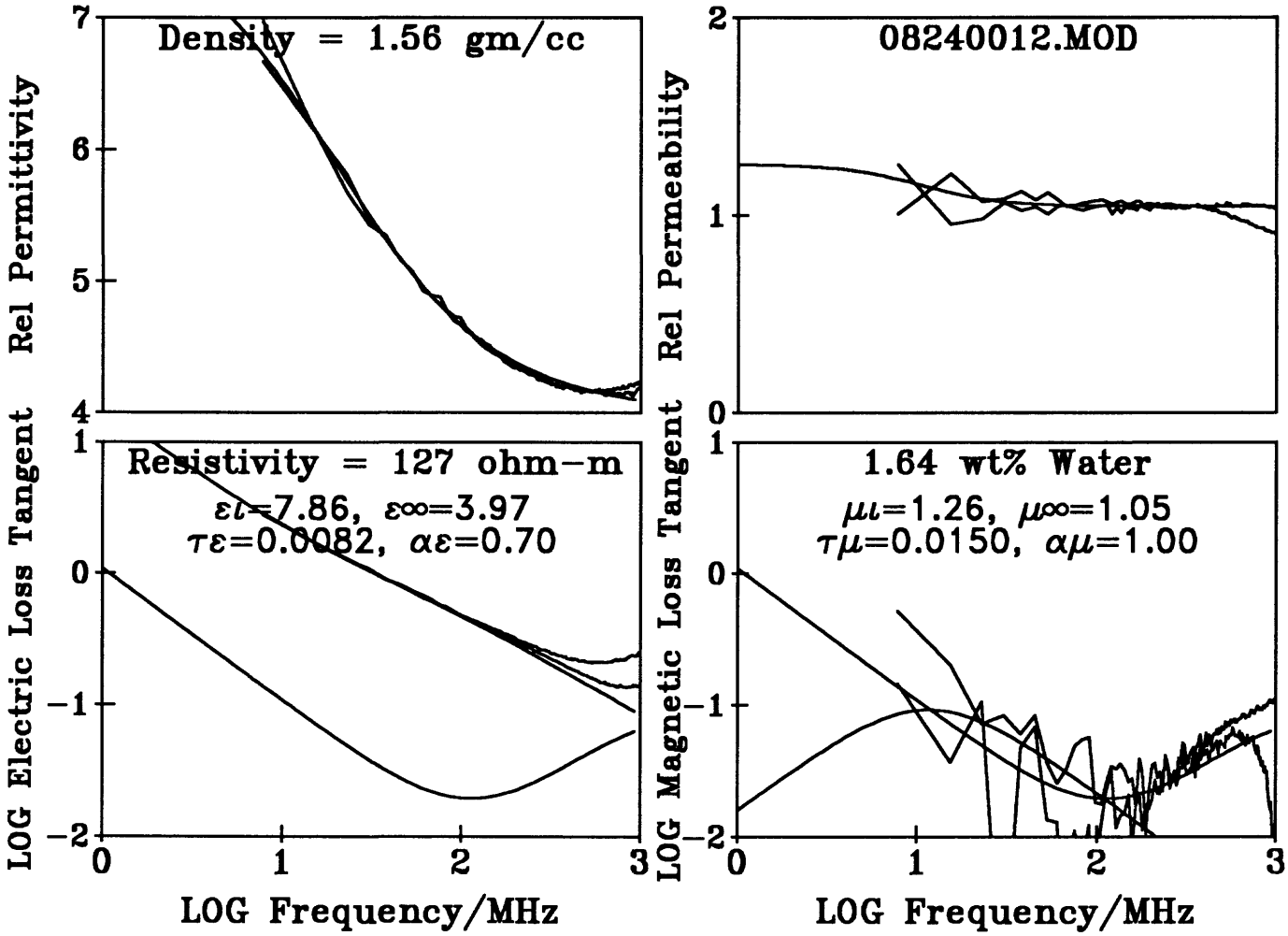
τε=0.0087, αε=0.70
1.64 wt% Water
μι=1.47, μ∞=1.05
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #3 3 drops water

Figure 11 -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08240012.MOD
Rel Permittivity
Rel Permeability
Resistivity = 127 ohm-m
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τε=0.0082, αε=0.70
1.64 wt% Water
μι=1.26, μ∞=1.05
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #3 3 drops water + 30 min.

Figure 12 -

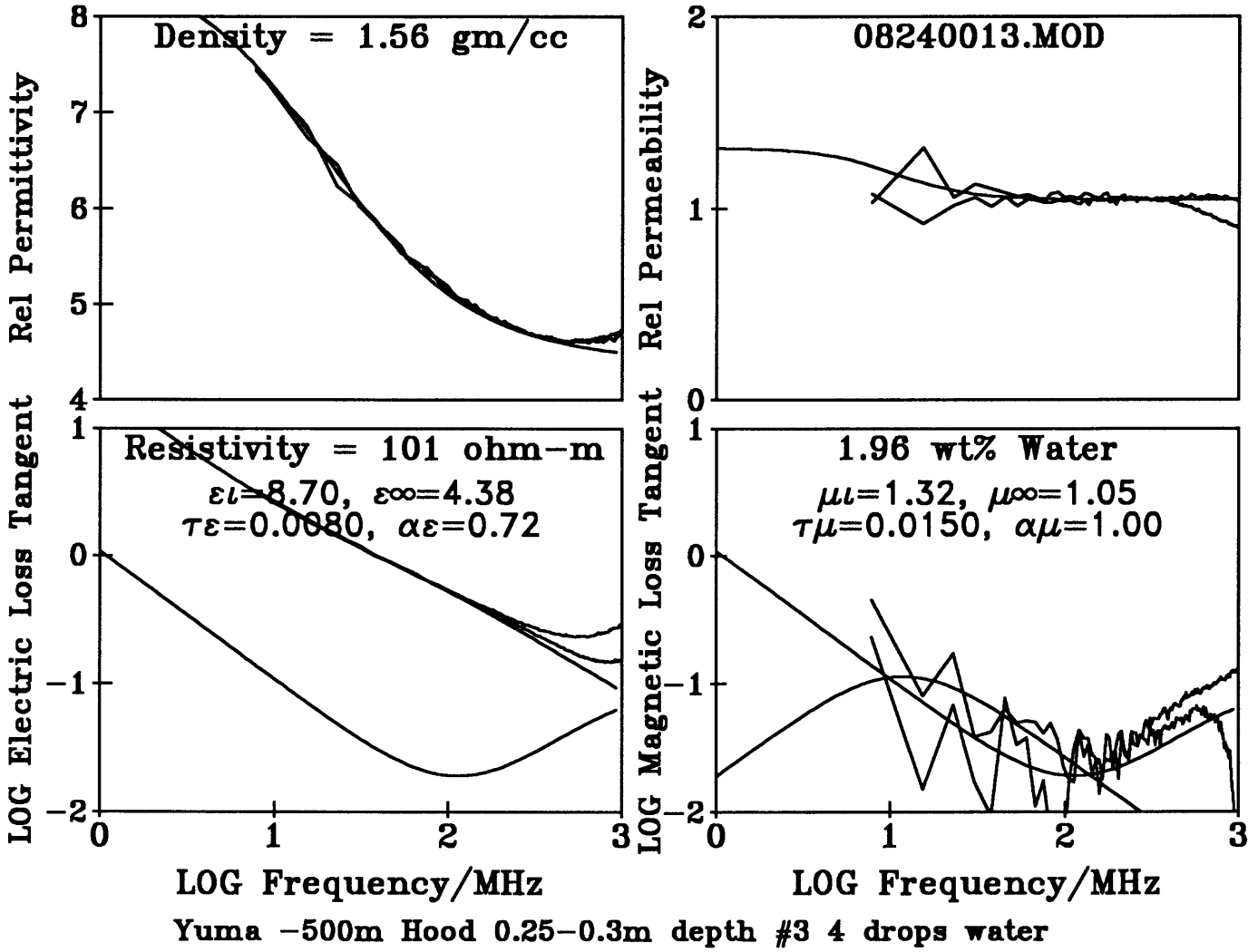
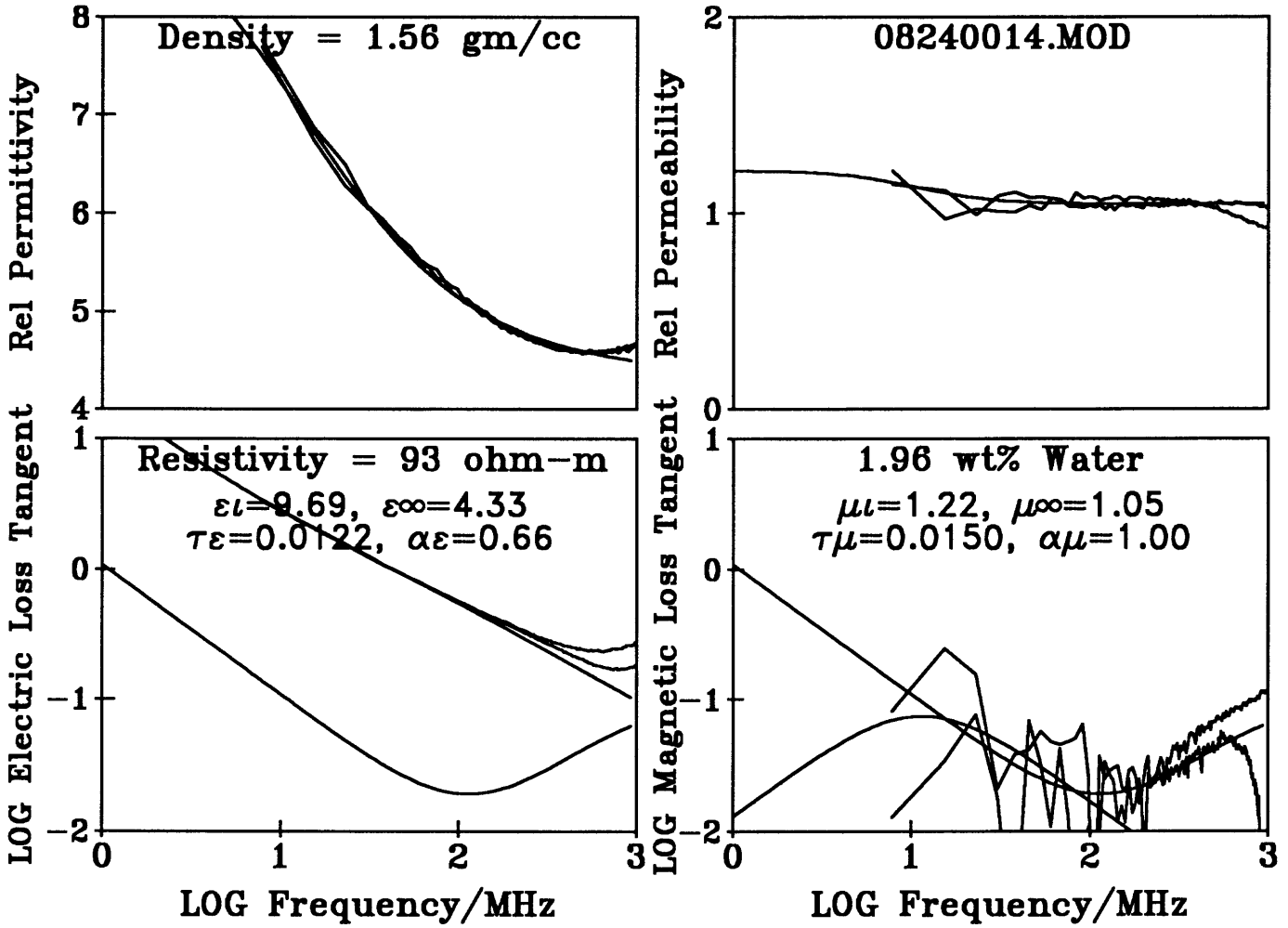

Density = 1.56 gm/cc
08240013.MOD
Rel Permittivity
Rel Permeability
Resistivity = 101 ohm-m
ει=8.70, ε∞=4.38
τε=0.0080, αε=0.72
1.96 wt% Water
μι=1.32, μ∞=1.05
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #3 4 drops water

Figure 13 -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Rel Permeability
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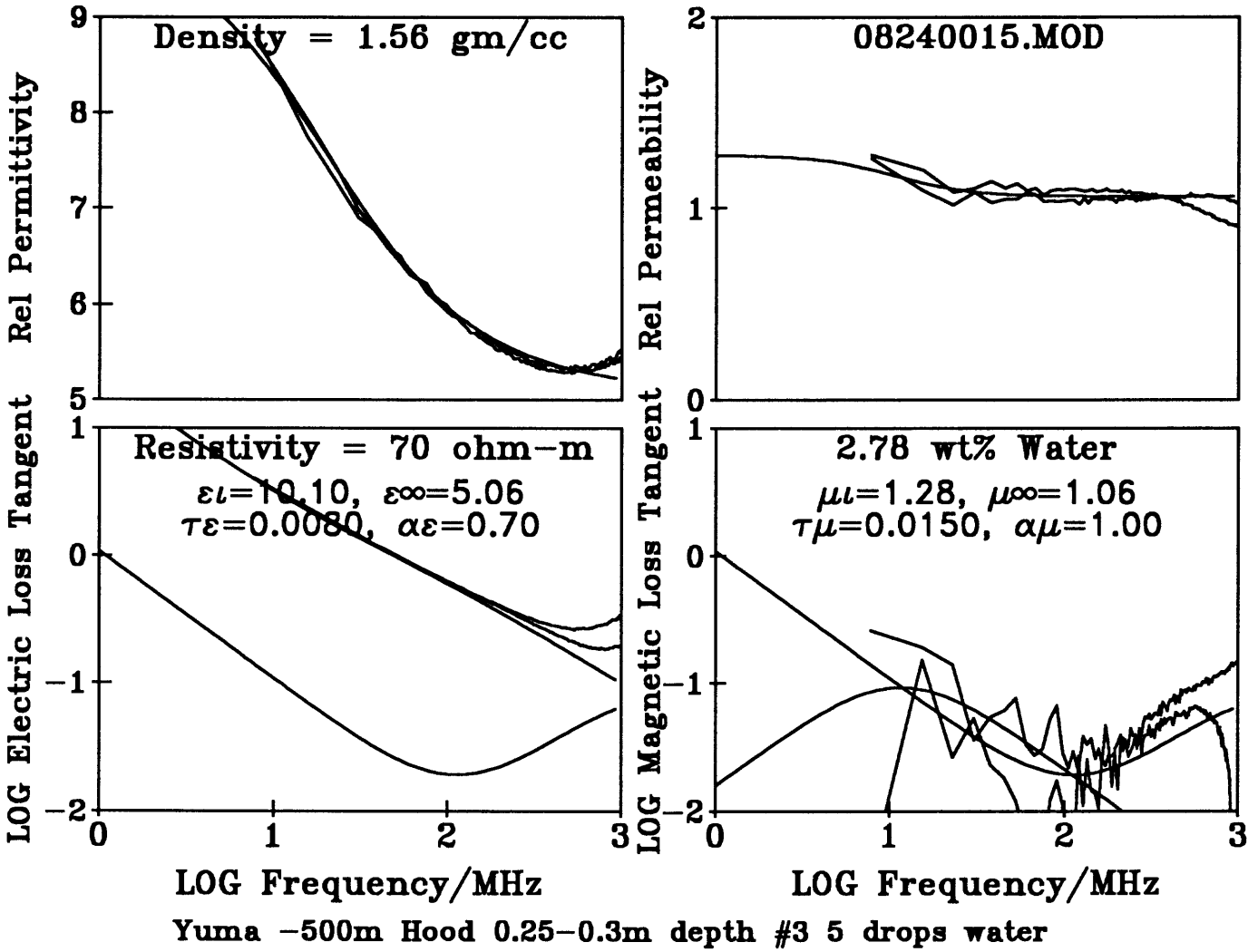
τε=0.0122, αε=0.66
1.96 wt% Water
μι=1.22, μ∞=1.05
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #3 4 drops water + 30 min.

Figure 14 -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08240015.MOD
Resistivity = 70 ohm-m
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τε=0.0080, αε=0.70
2.78 wt% Water
μι=1.28, μ∞=1.06
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #3 5 drops water

Figure 15 -

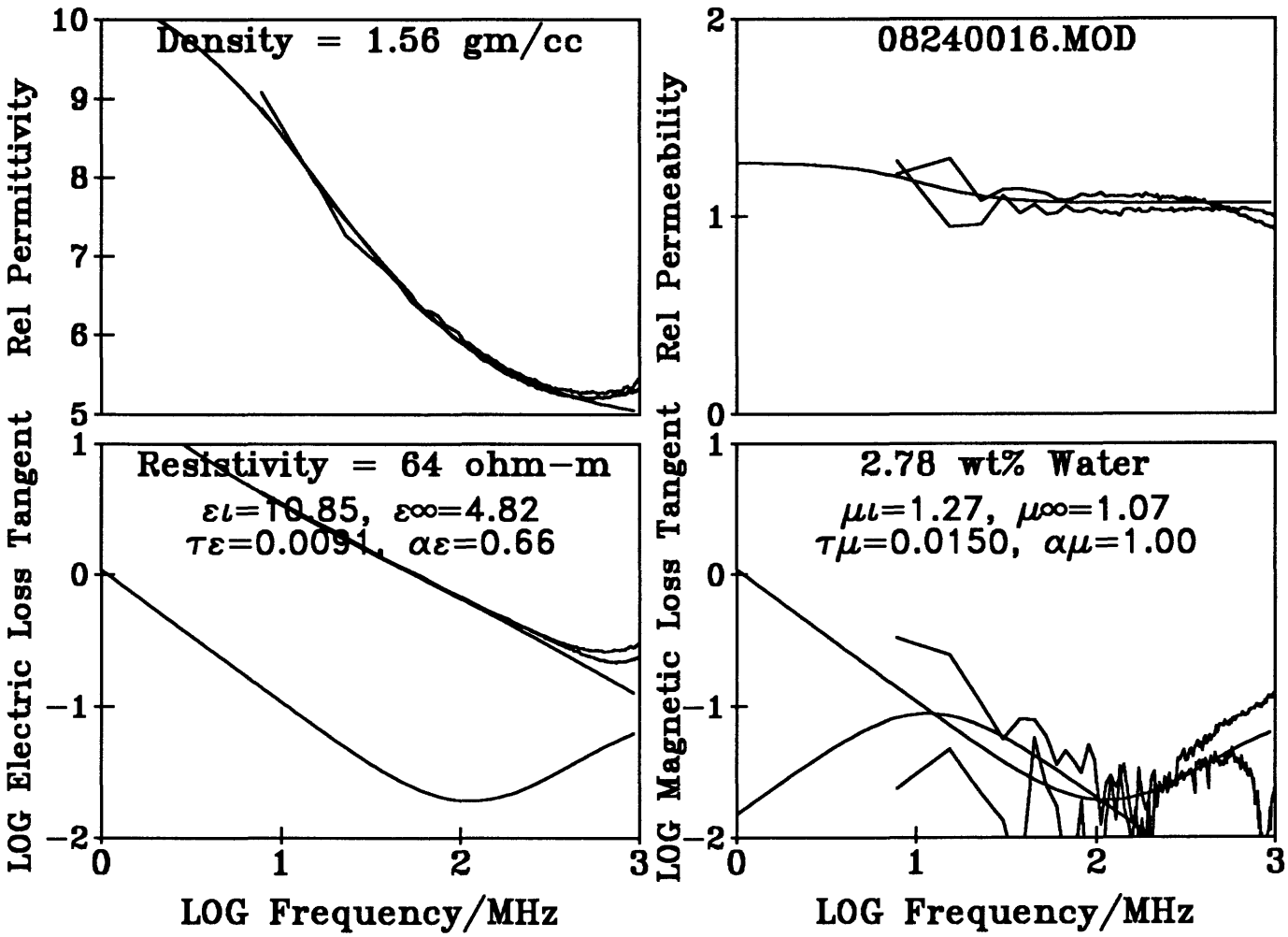

Density = 1.56 gm/cc
08240016.MOD
Rel Permittivity
Rel Permeability
Resistivity = 64 ohm-m
ει=10.85, ε∞=4.82
τε=0.0091, αε=0.66
2.78 wt% Water
μι=1.27, μ∞=1.07
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #3 5 drops water + 30 min.

Figure 16 -

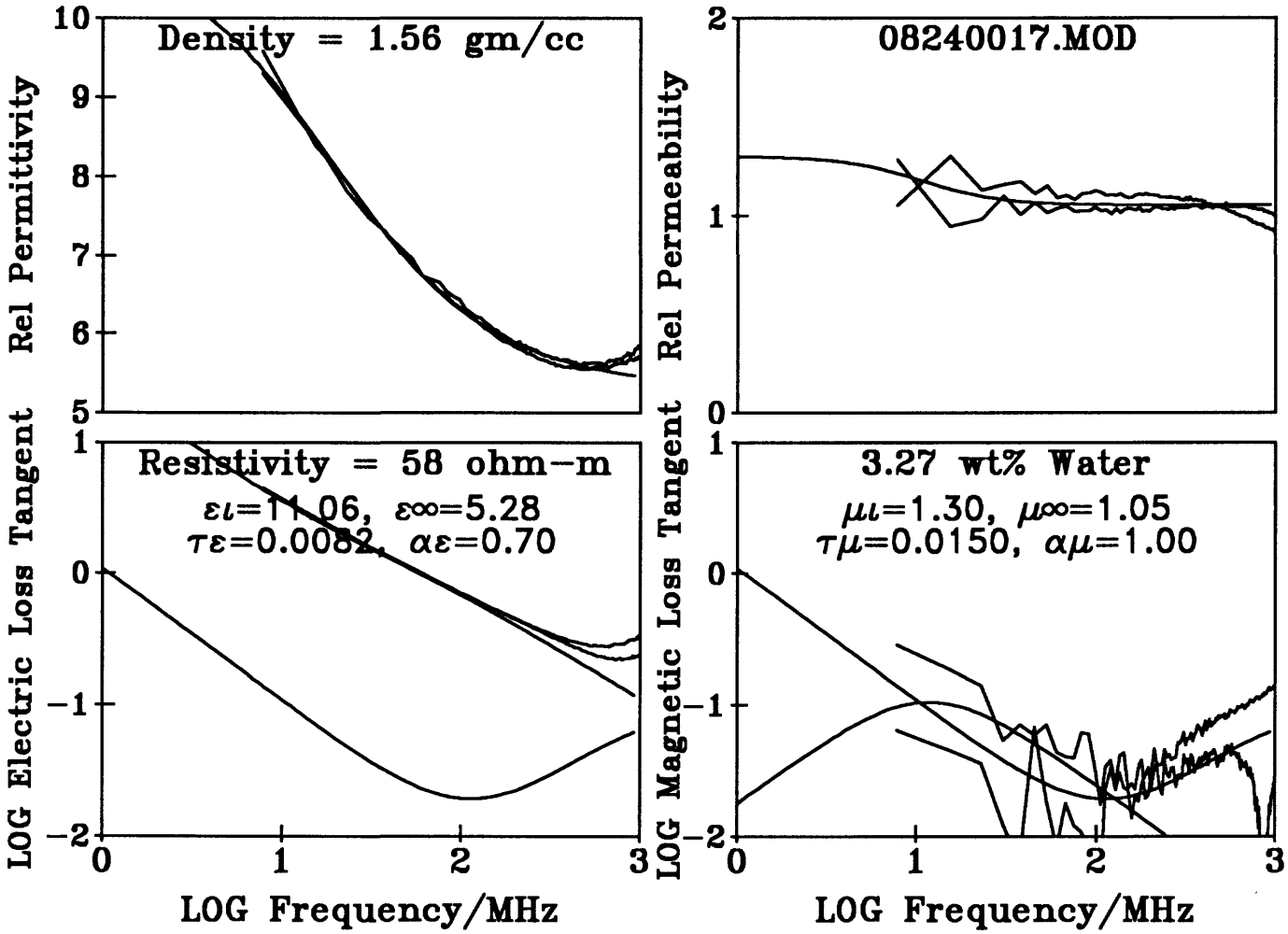

Density = 1.56 gm/cc
08240017.MOD
Rel Permittivity
Rel Permeability
Resistivity = 58 ohm-m
ει=11.06, ε∞=5.28
τε=0.0082, αε=0.70
3.27 wt% Water
μι=1.30, μ∞=1.05
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #3 6 drops water

Figure 17 -

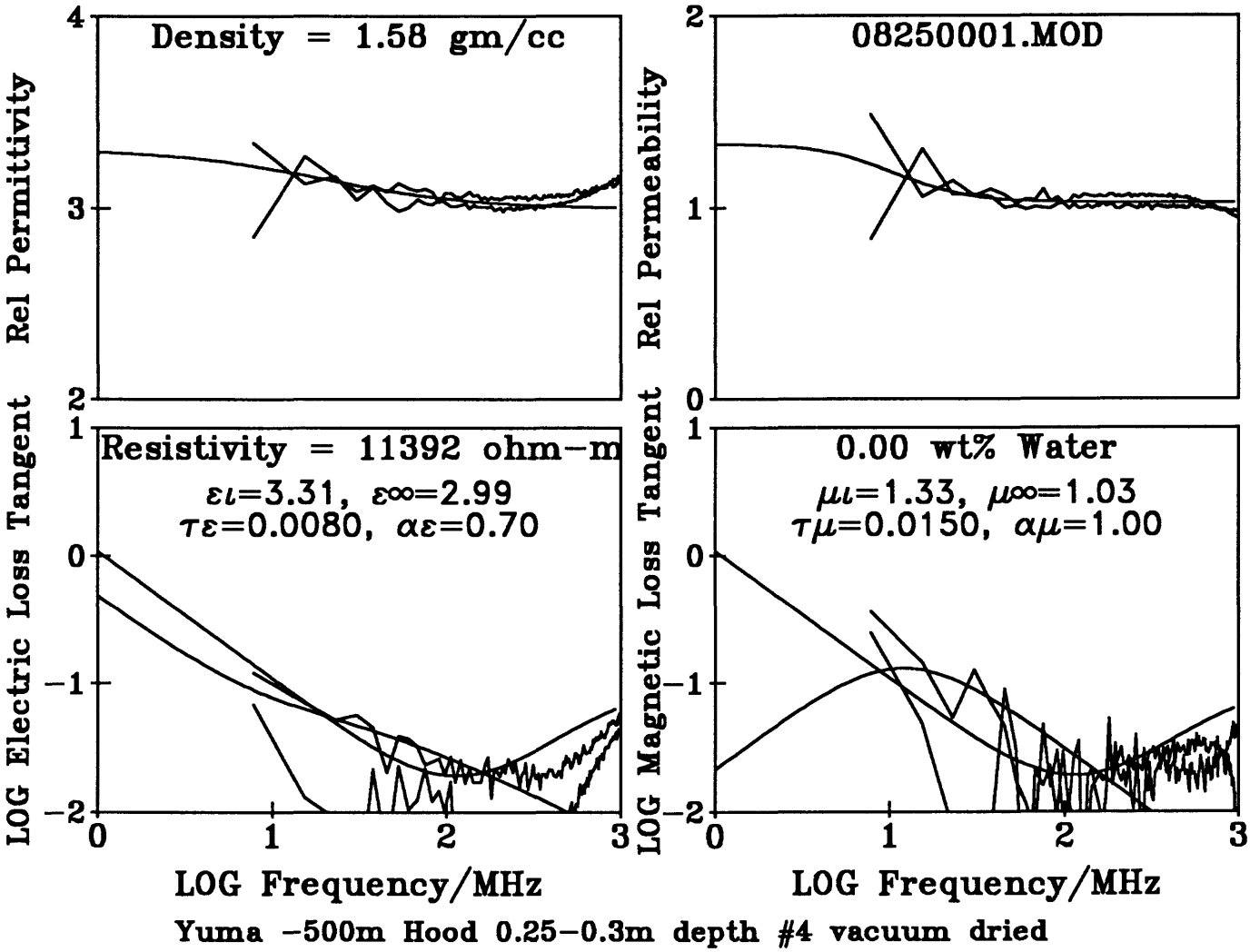

Density = 1.58 gm/cc
08250001.MOD
Rel Permittivity
Rel Permeability
Resistivity = 11392 ohm-m
ει=3.31, ε∞=2.99
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.33, μ∞=1.03
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #4 vacuum dried

Figure 18 -

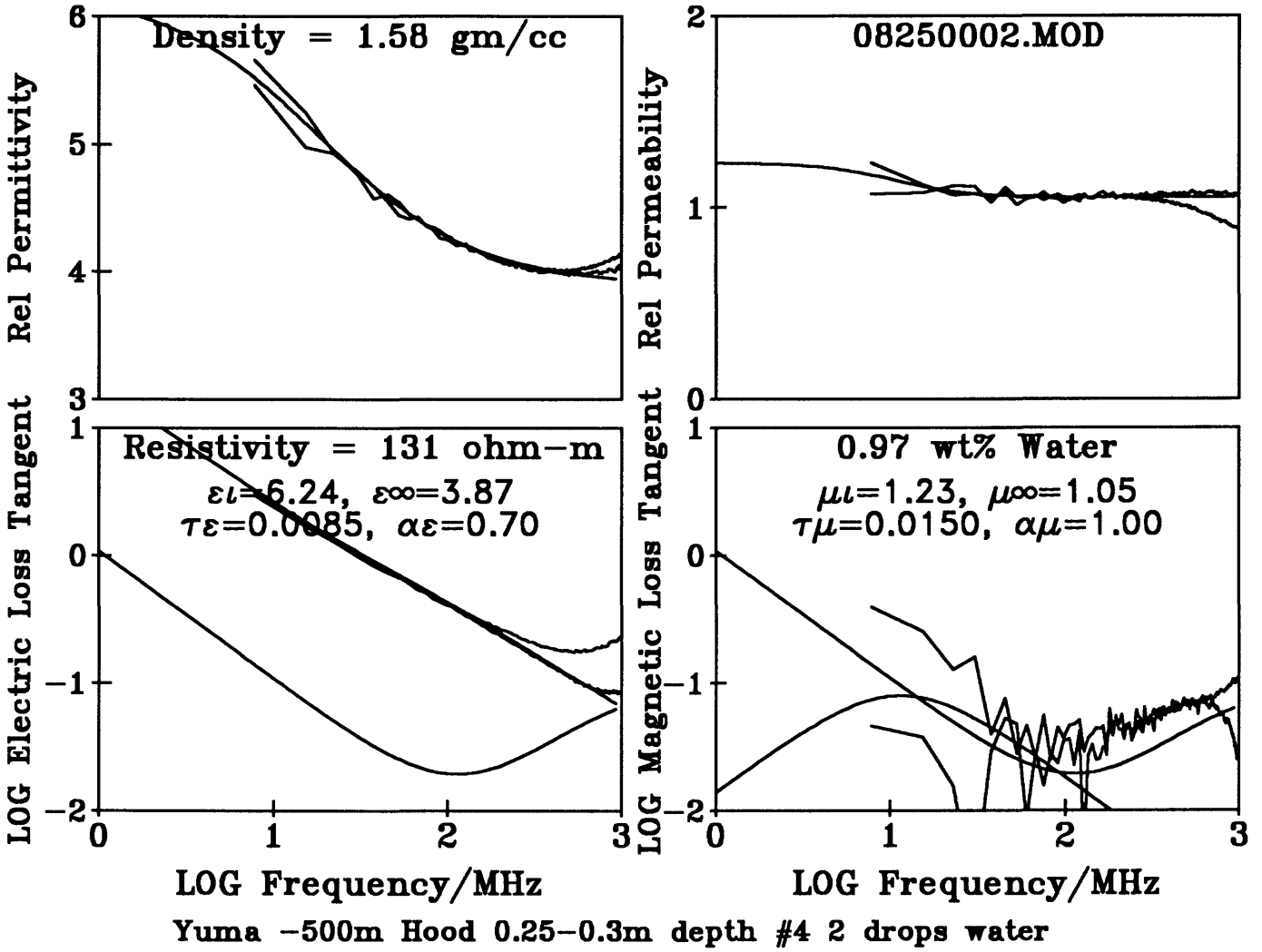

Density = 1.58 gm/cc
08250002.MOD
Rel Permittivity
Rel Permeability
Resistivity = 131 ohm-m
ει=6.24, ε∞=3.87
τε=0.0085, αε=0.70
0.97 wt% Water
μι=1.23, μ∞=1.05
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #4 2 drops water

Figure 19 -

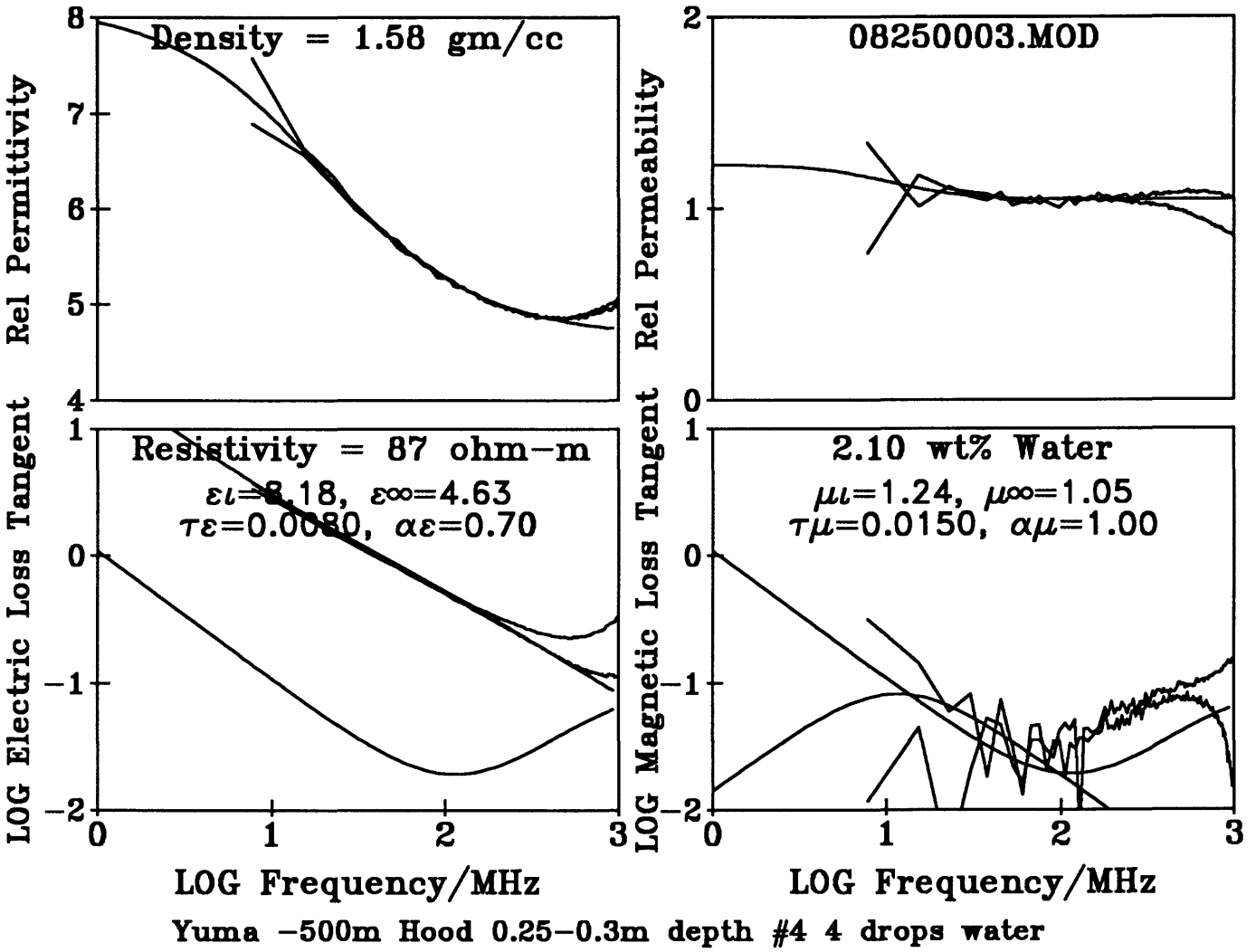

Density = 1.58 gm/cc
08250003.MOD
Rel Permittivity
Rel Permeability
Resistivity = 87 ohm-m
ει=8.18, ε∞=4.63
τε=0.0080, αε=0.70
2.10 wt% Water
μι=1.24, μ∞=1.05
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #4 4 drops water

Figure 20 -

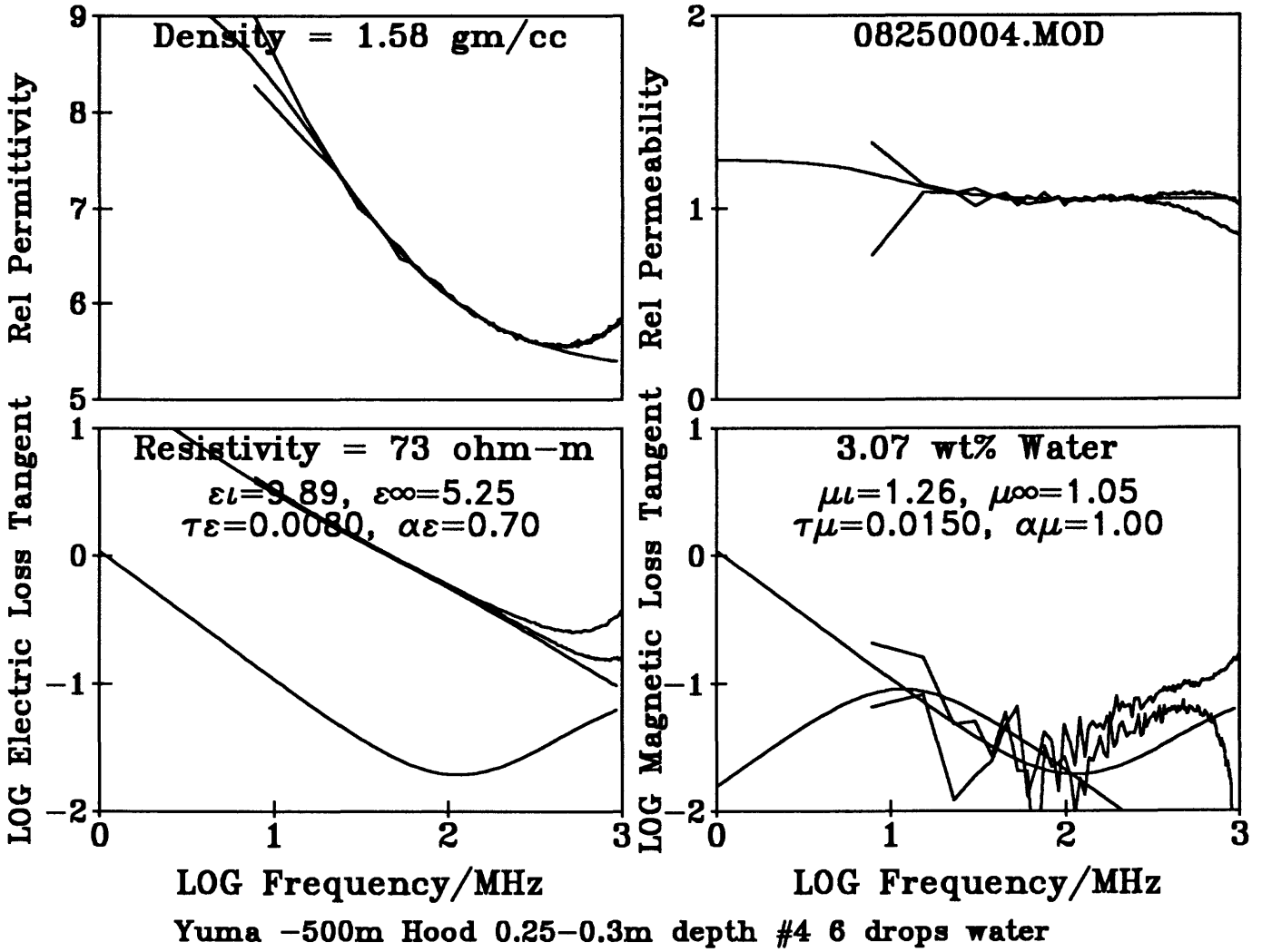

Density = 1.58 gm/cc
08250004.MOD
Resistivity = 73 ohm-m
ει=9.89, ε∞=5.25
τε=0.0080, αε=0.70
3.07 wt% Water
μι=1.26, μ∞=1.05
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #4 6 drops water

Figure 21 -

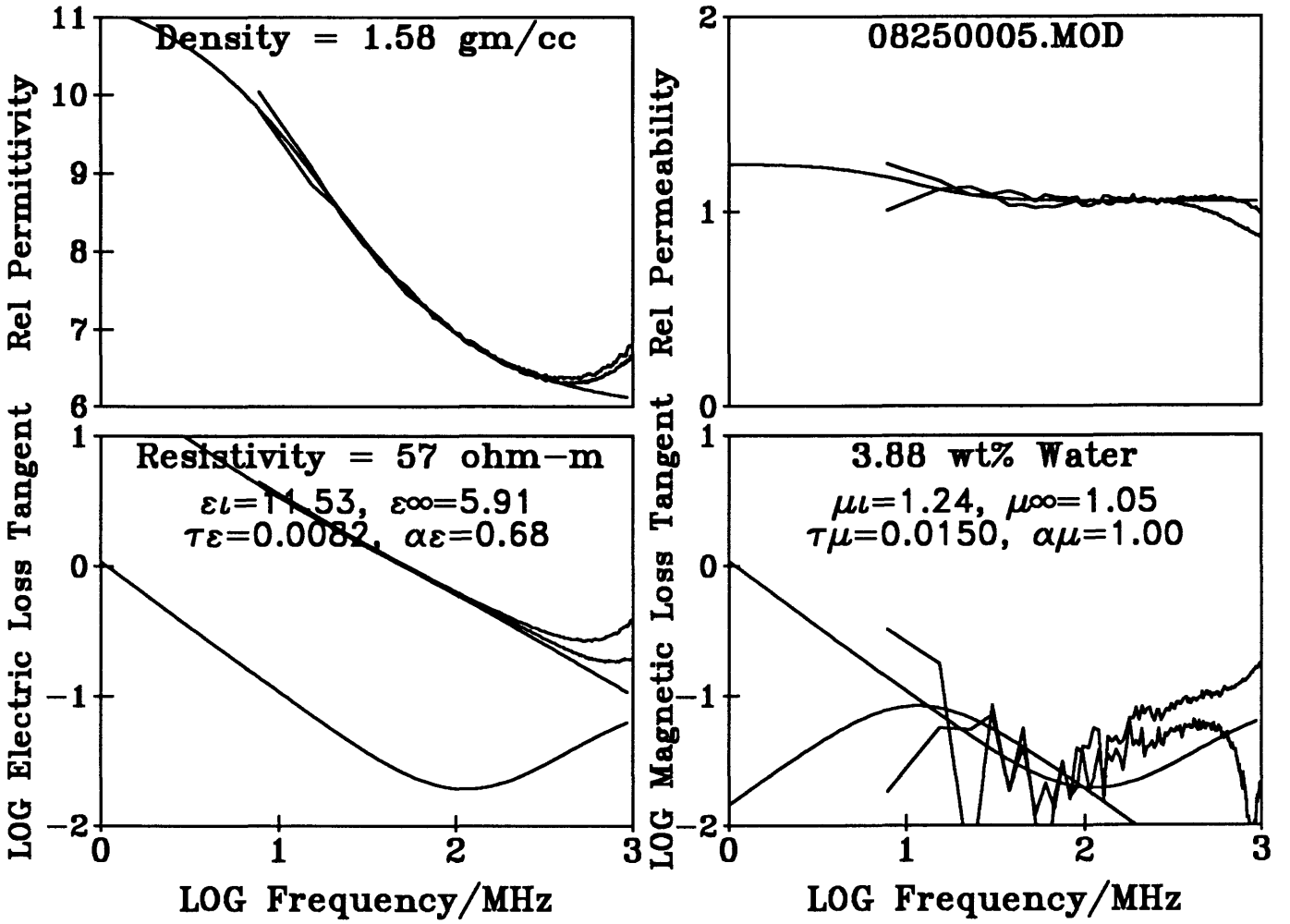

Density = 1.58 gm/cc
08250005.MOD
Resistivity = 57 ohm-m
ει=11.53, ε∞=5.91
τε=0.0082, αε=0.68
3.88 wt% Water
μι=1.24, μ∞=1.05
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent Rel Permittivity
LOG Magnetic Loss Tangent Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #4 8 drops water

Figure 22 -

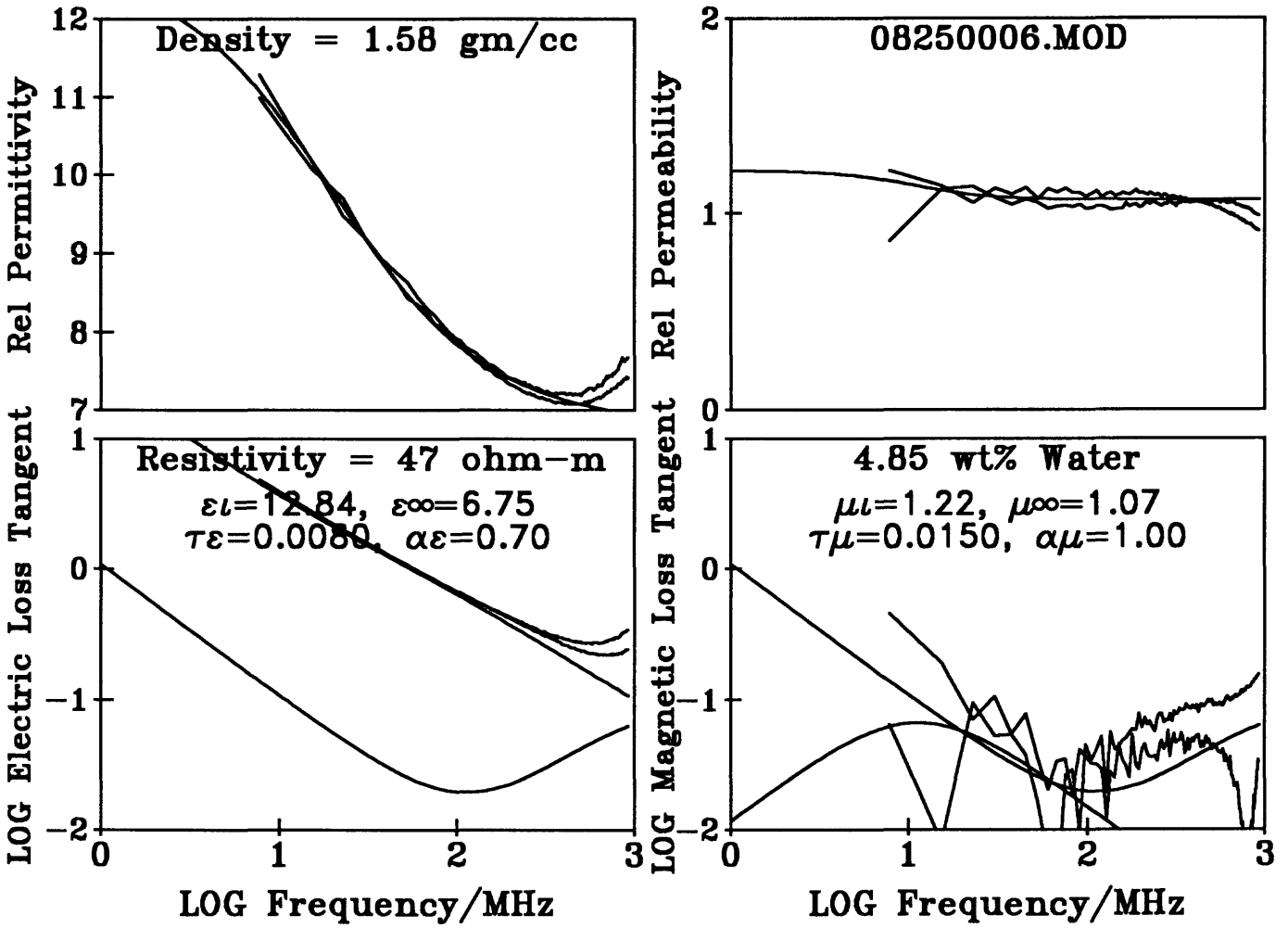

Density = 1.58 gm/cc
08250006.MOD
Resistivity = 47 ohm-m
ει=12.84, ε∞=6.75
τε=0.0080, αε=0.70
4.85 wt% Water
μι=1.22, μ∞=1.07
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #4 10 drops water

Figure 23 -

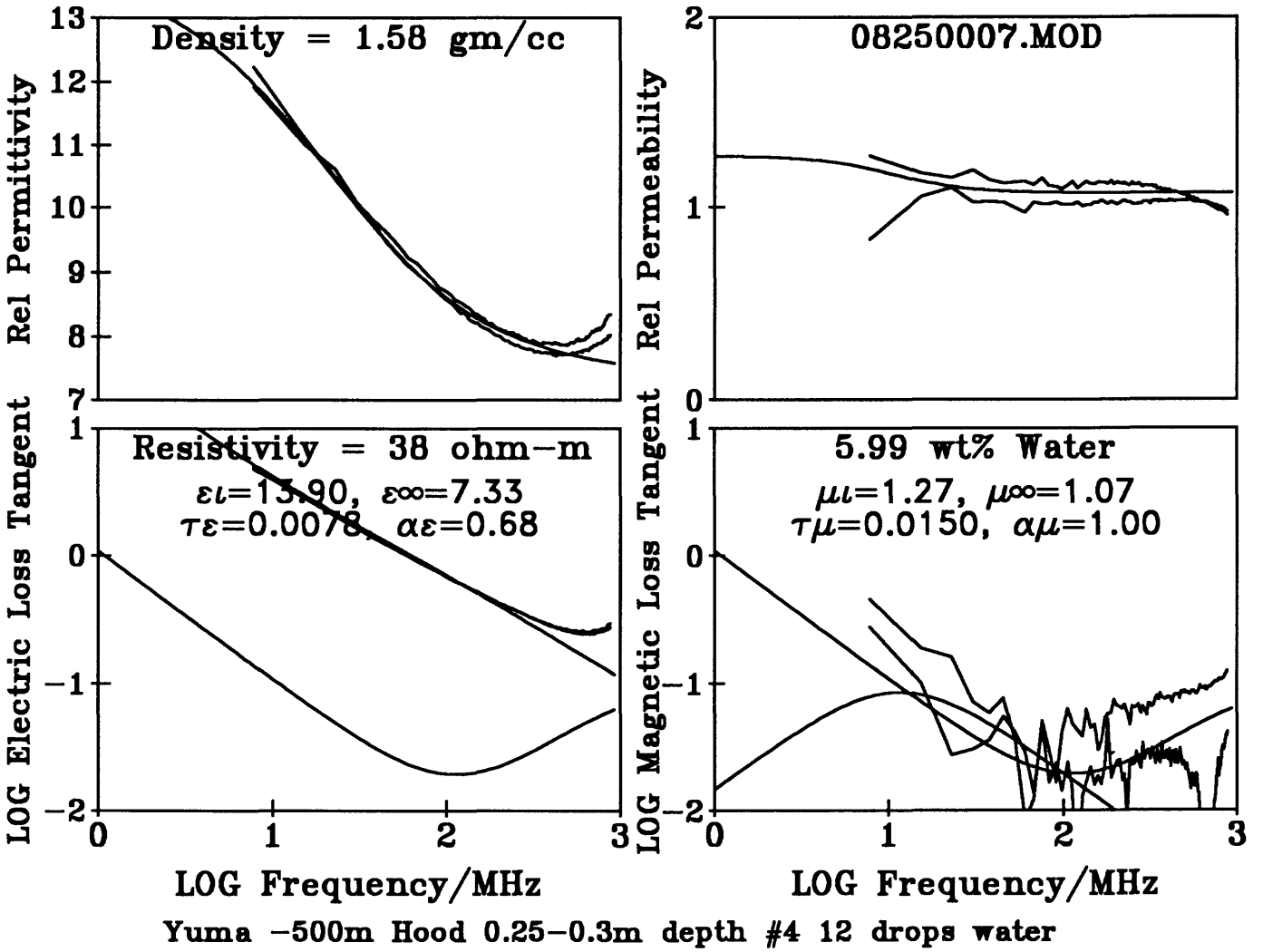

Density = 1.58 gm/cc
08250007.MOD
Resistivity = 38 ohm-m
ει=13.90, ε∞=7.33
τε=0.0078, αε=0.68
5.99 wt% Water
μι=1.27, μ∞=1.07
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #4 12 drops water

Figure 24 -

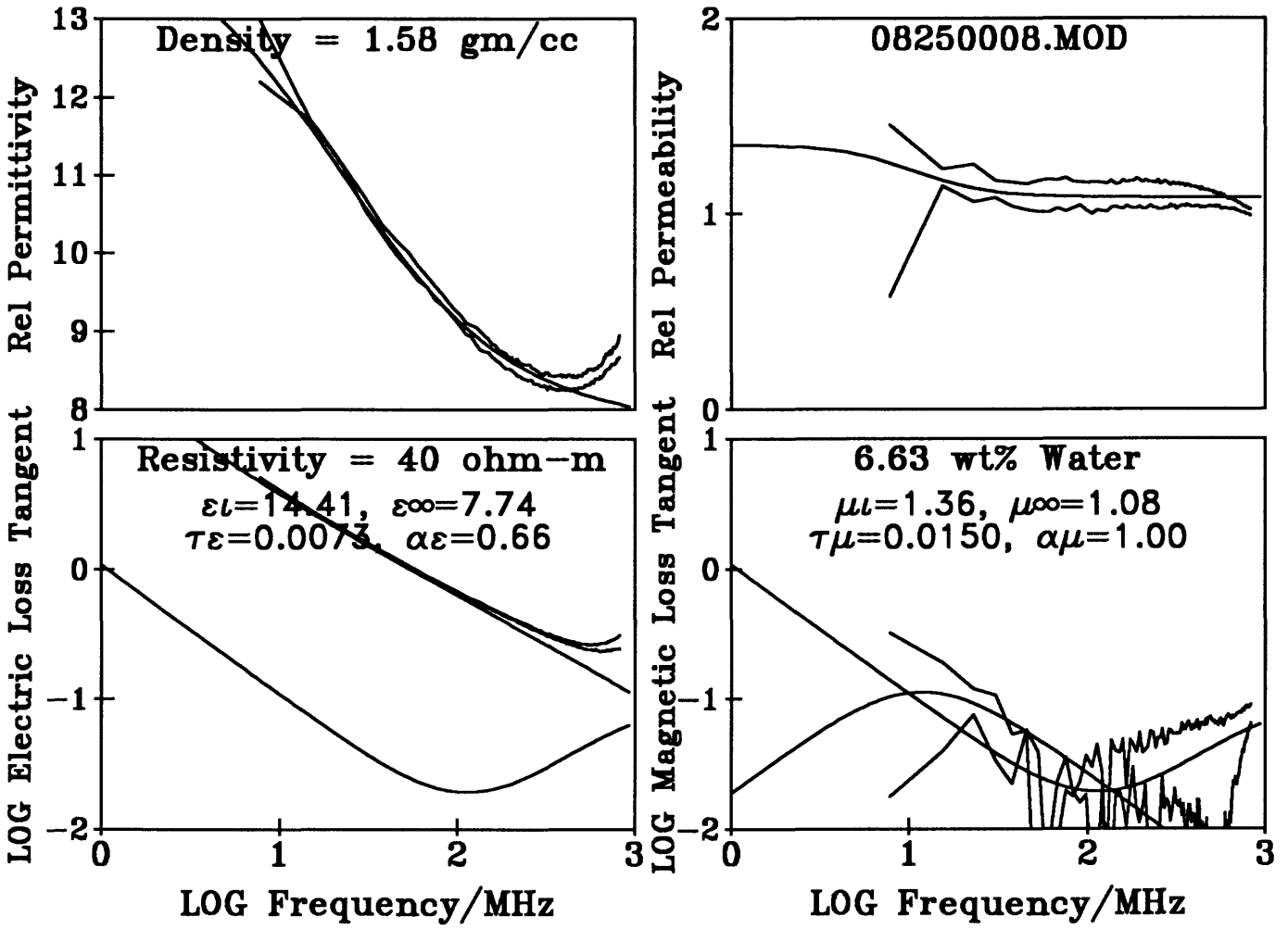

Density = 1.58 gm/cc
08250008.MOD
Rel Permittivity
Rel Permeability
Resistivity = 40 ohm-m
ει=14.41, ε∞=7.74
τε=0.0073, αε=0.66
6.63 wt% Water
μι=1.36, μ∞=1.08
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #4 14 drops water

Figure 25 -

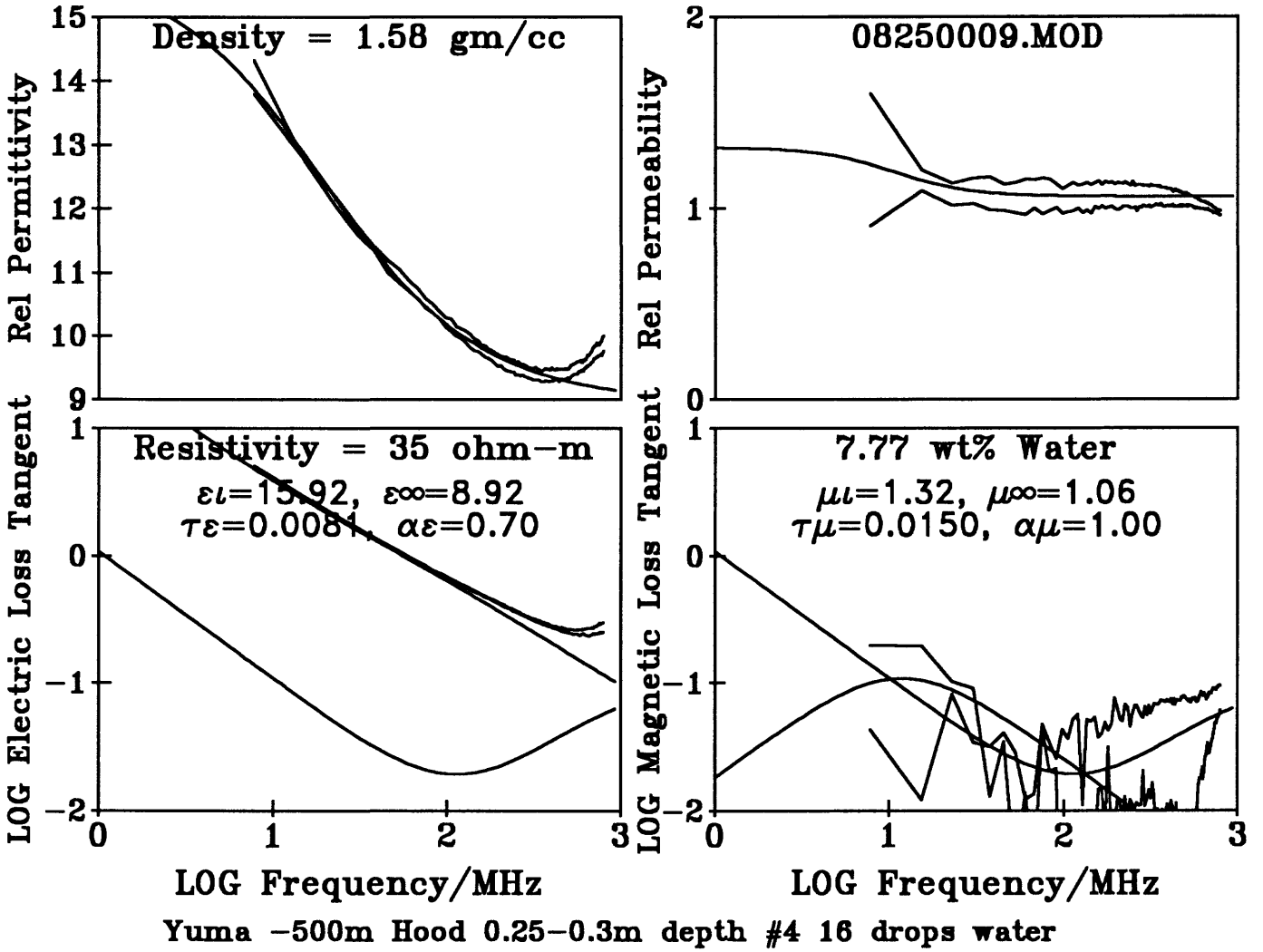

Density = 1.58 gm/cc
08250009.MOD
Resistivity = 35 ohm-m
ει=15.92, ε∞=8.92
τε=0.0081, αε=0.70
7.77 wt% Water
μι=1.32, μ∞=1.06
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #4 16 drops water

Figure 26 -

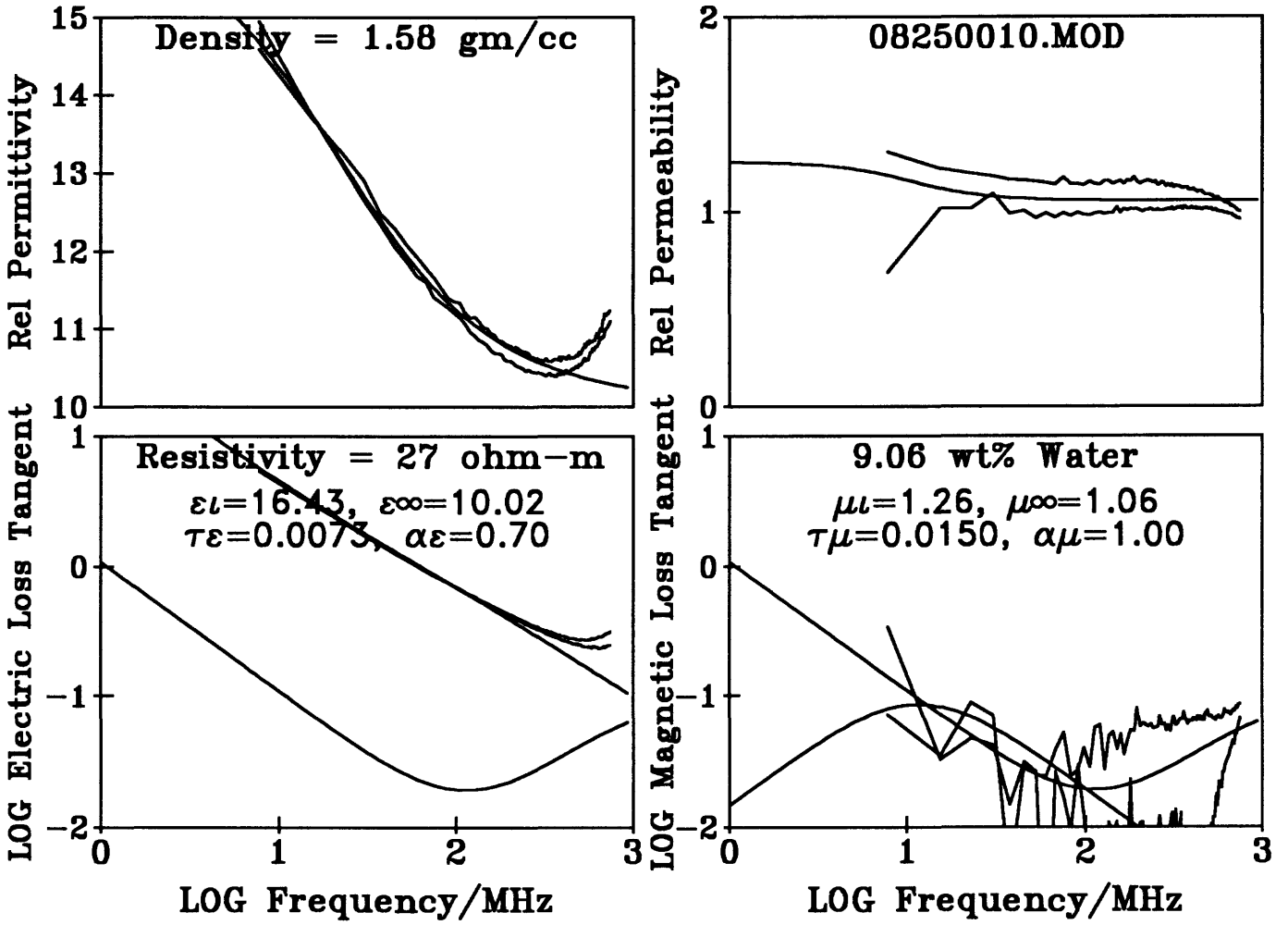

Density = 1.58 gm/cc
08250010.MOD
Resistivity = 27 ohm-m
ει=16.43, ε∞=10.02
τε=0.0073, αε=0.70
9.06 wt% Water
μι=1.26, μ∞=1.06
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #4 18 drops warer

Figure 27 -

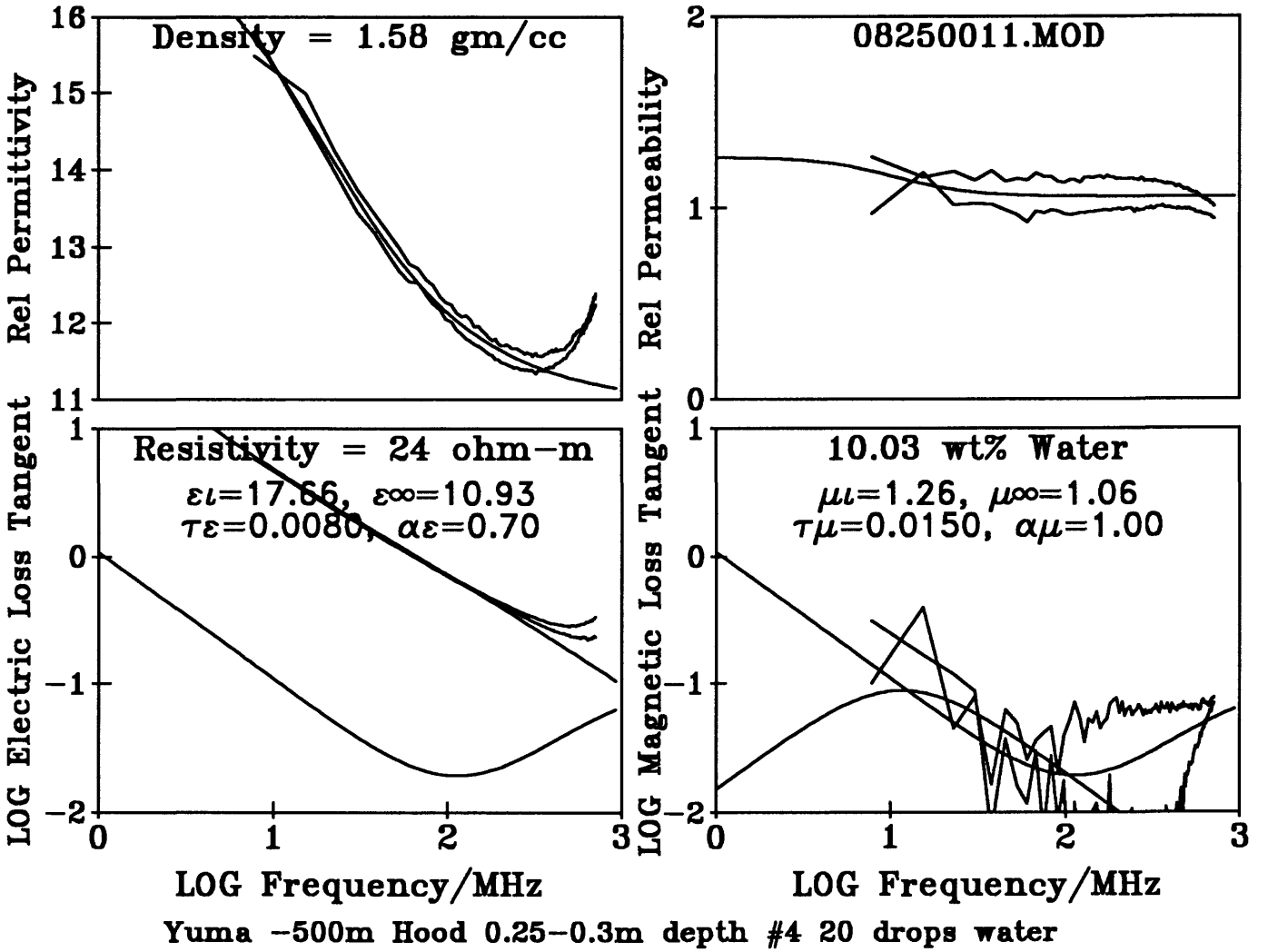

Density = 1.58 gm/cc
08250011.MOD
Rel Permittivity
Rel Permeability
Resistivity = 24 ohm-m
ει=17.66, ε∞=10.93
τε=0.0080, αε=0.70
10.03 wt% Water
μι=1.26, μ∞=1.06
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #4 20 drops water

Figure 28 -

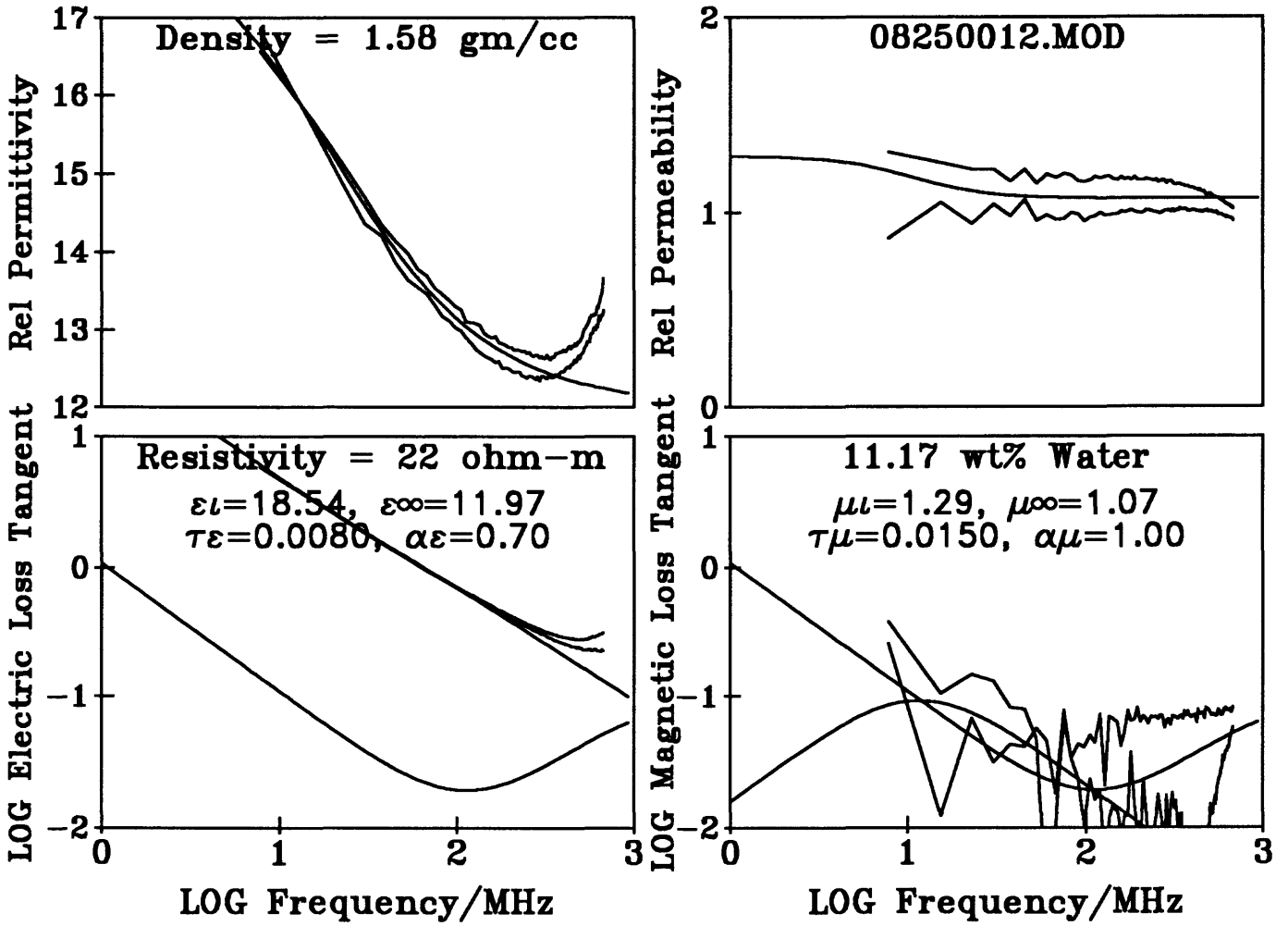

Density = 1.58 gm/cc
08250012.MOD
Rel Permittivity
Rel Permeability
Resistivity = 22 ohm-m
ει=18.54, ε∞=11.97
τε=0.0080, αε=0.70
11.17 wt% Water
μι=1.29, μ∞=1.07
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #4 22 drops water

Figure 29 -

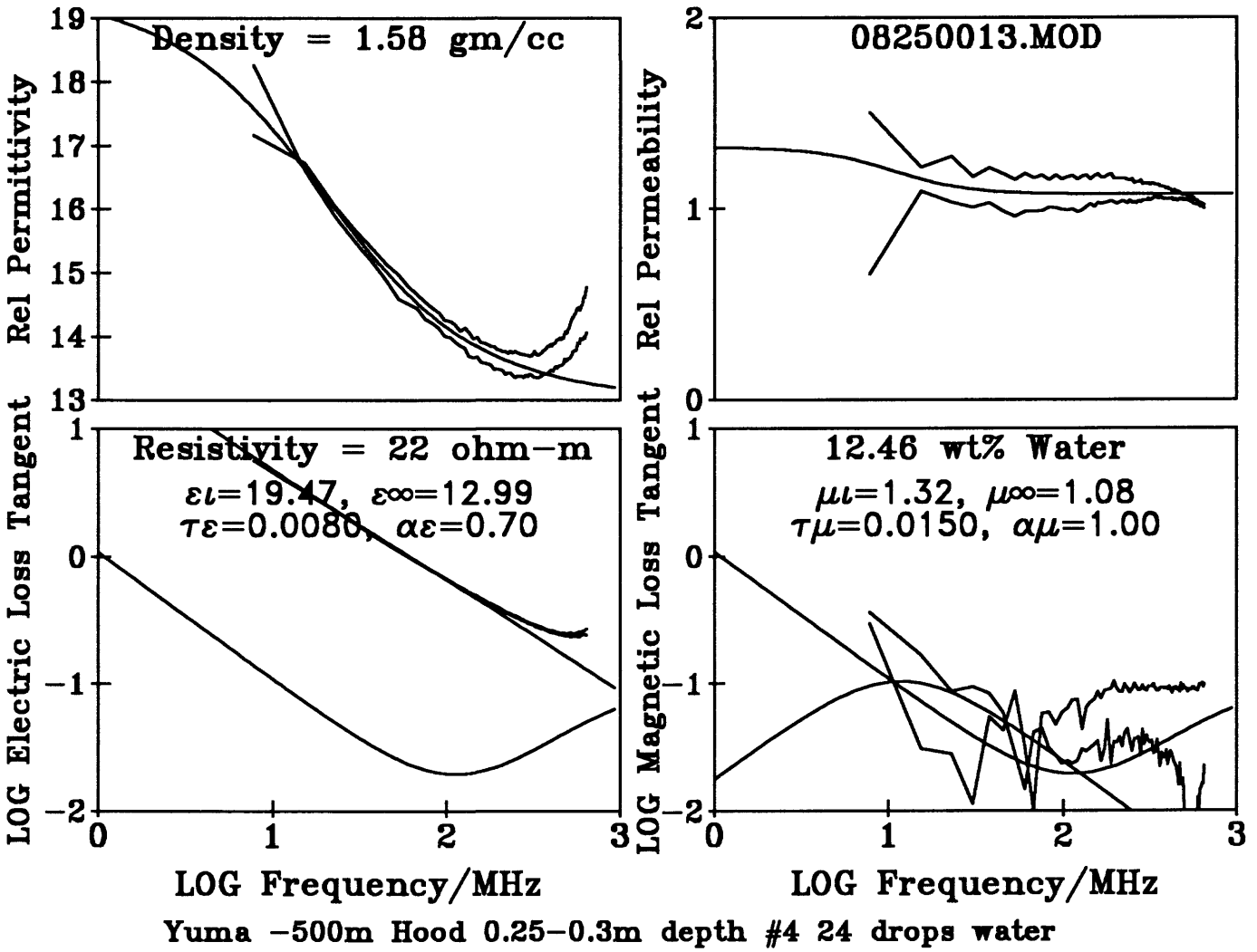

Density = 1.58 gm/cc
08250013.MOD
Rel Permittivity
Rel Permeability
Resistivity = 22 ohm-m
ει=19.47, ε∞=12.99
τε=0.0080, αε=0.70
12.46 wt% Water
μι=1.32, μ∞=1.08
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #4 24 drops water

Figure 30 -

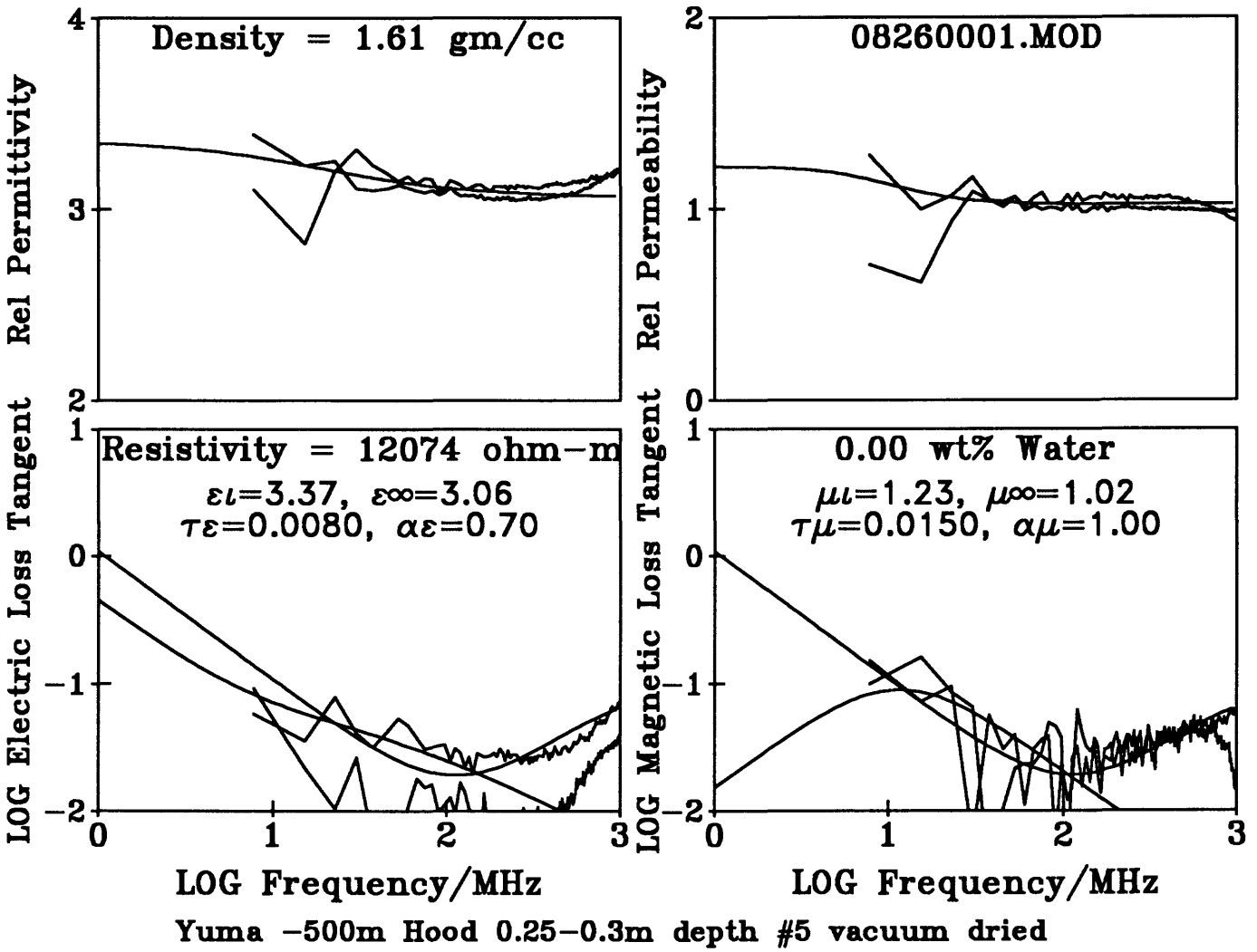

Density = 1.61 gm/cc
08260001.MOD
Rel Permittivity
Rel Permeability
Resistivity = 12074 ohm-m
ει=3.37, ε∞=3.06
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.23, μ∞=1.02
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #5 vacuum dried

Figure 31 -

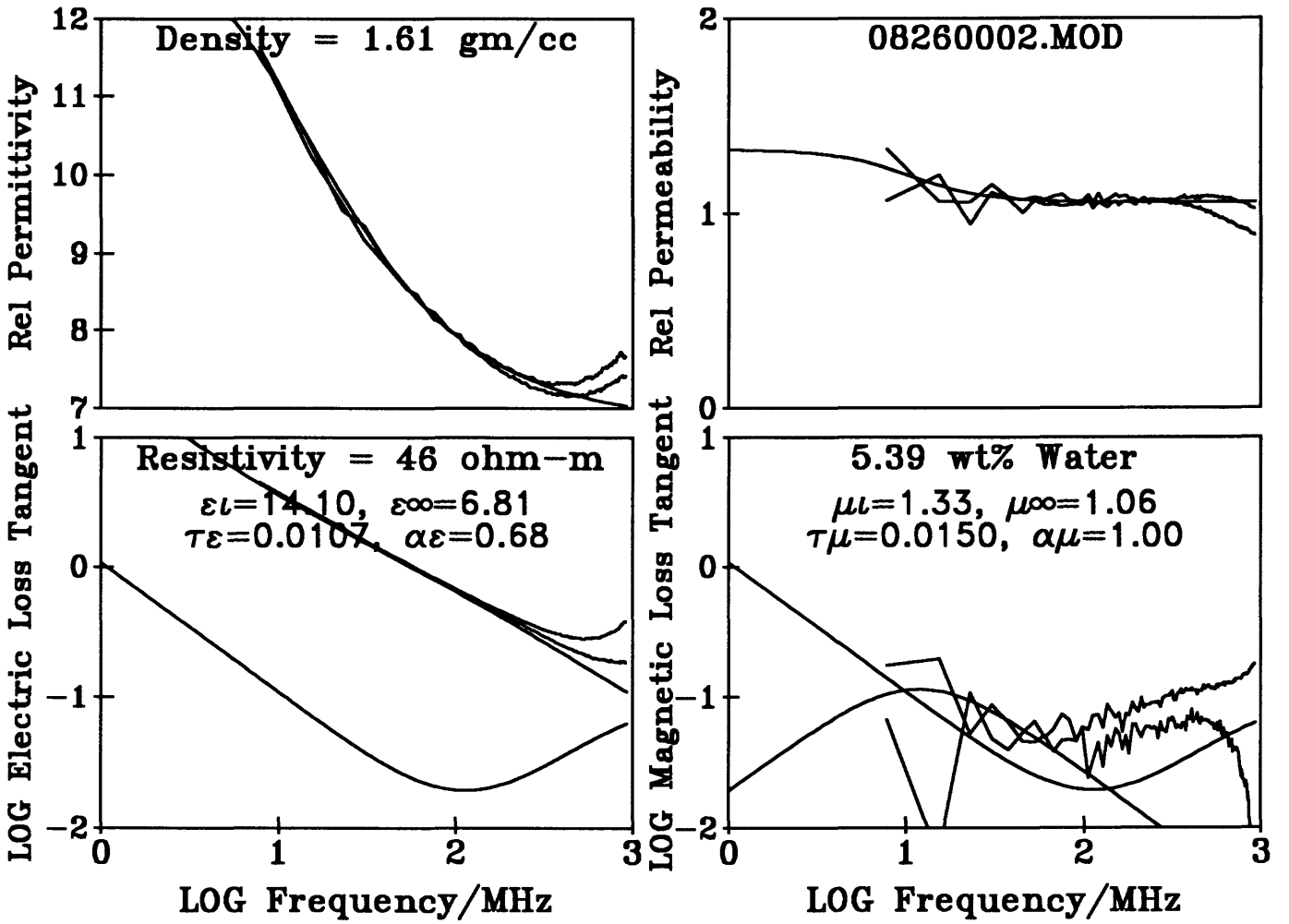

Density = 1.61 gm/cc
08260002.MOD
Rel Permittivity
Rel Permeability
Resistivity = 46 ohm-m
ει=14.10, ε∞=6.81
τε=0.0107, αε=0.68
5.39 wt% Water
μι=1.33, μ∞=1.06
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #5 6 drops water

Figure 32 -

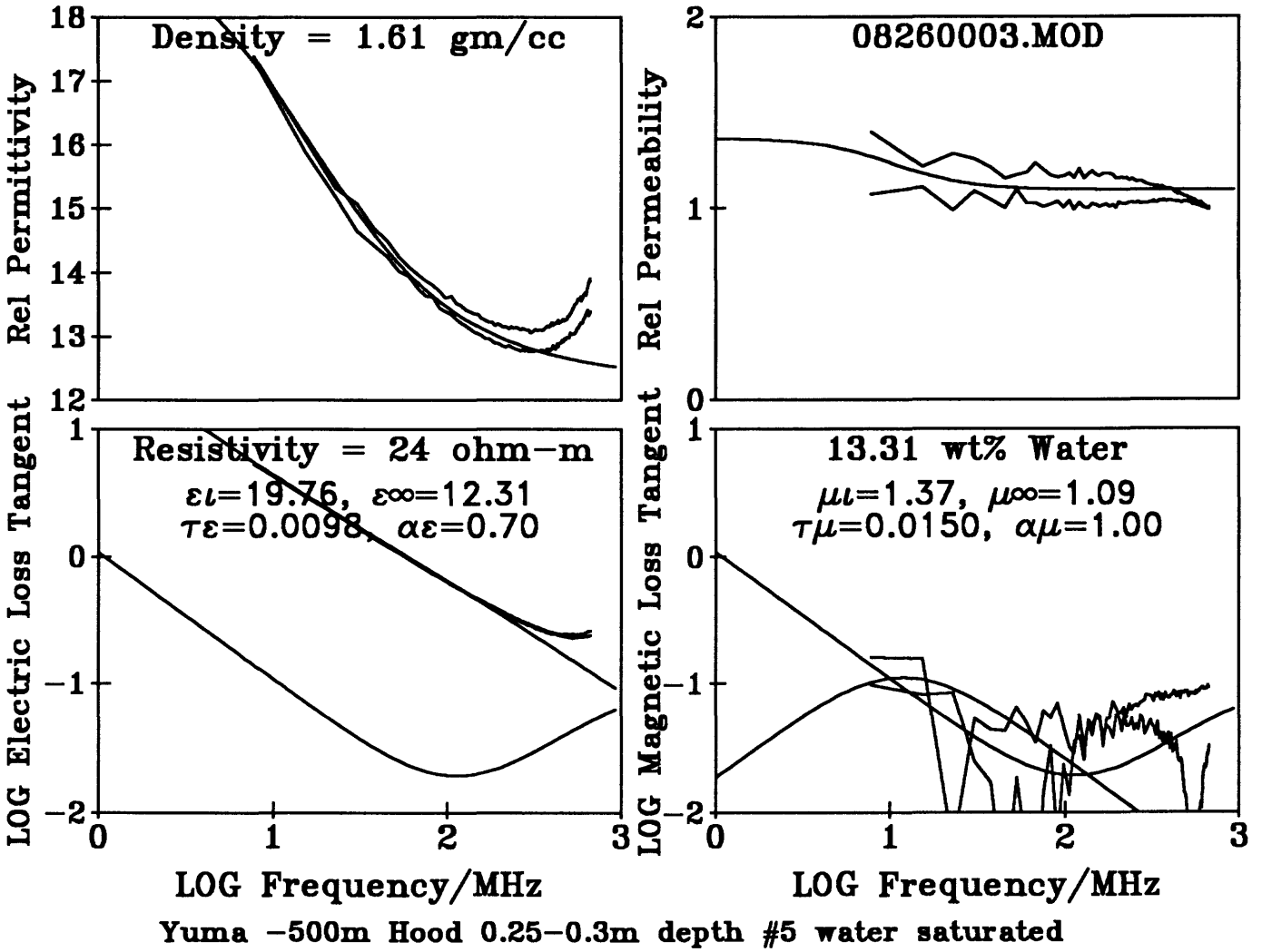

Density = 1.61 gm/cc
08260003.MOD
Rel Permittivity
Rel Permeability
Resistivity = 24 ohm-m
ει=19.76, ε∞=12.31
τε=0.0098, αε=0.70
13.31 wt% Water
μι=1.37, μ∞=1.09
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.25-0.3m depth #5 water saturated

Figure 33 -

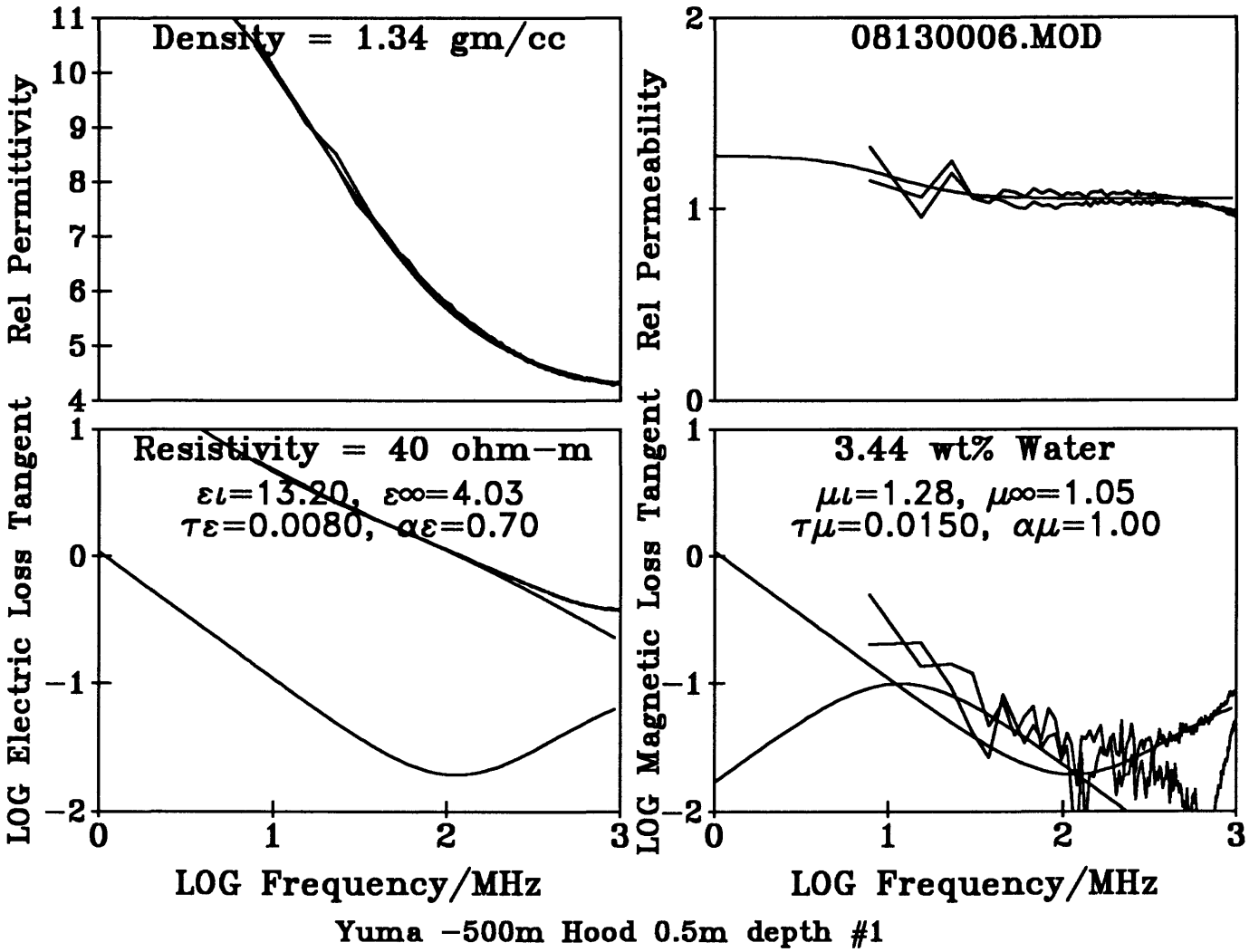



Figure 34 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

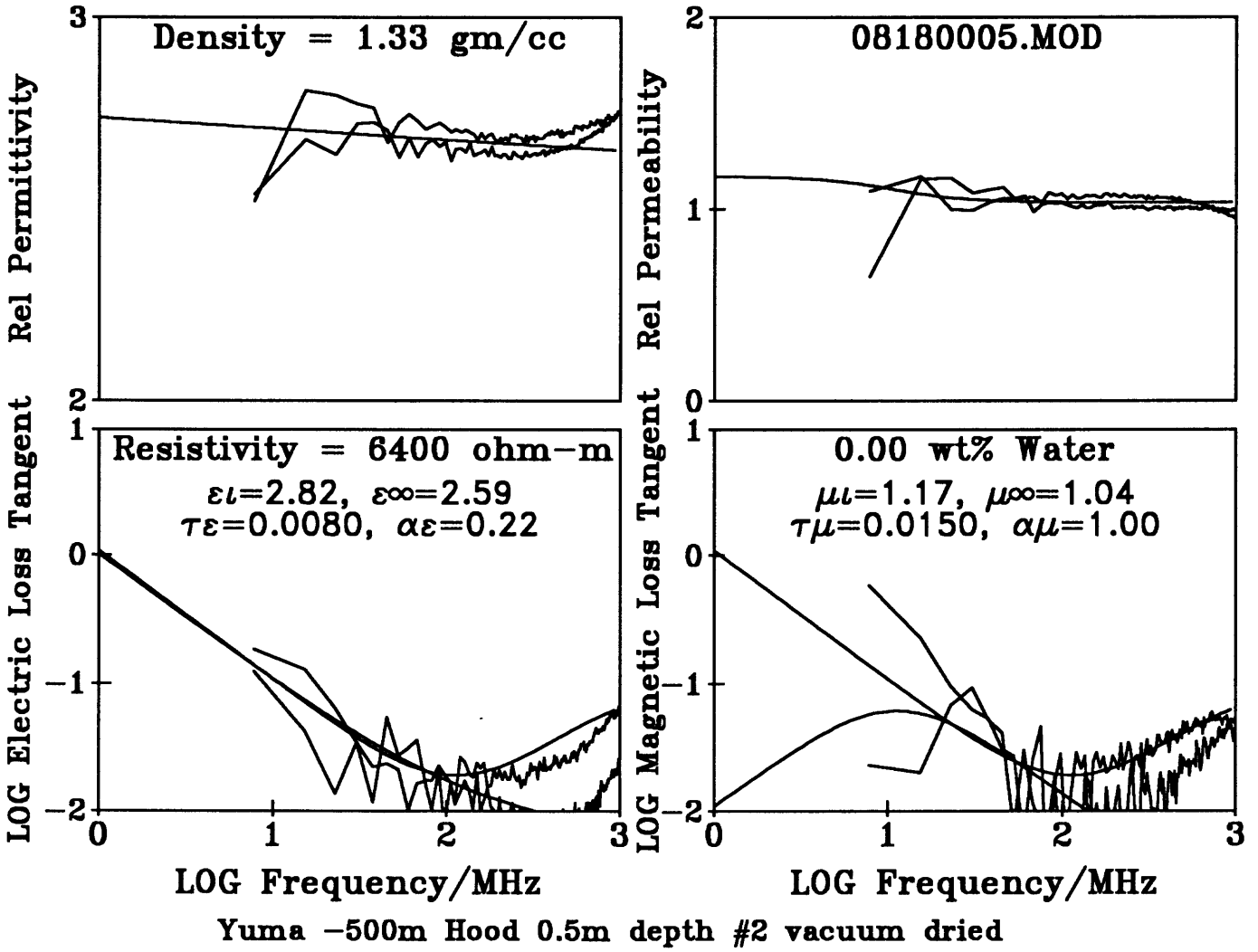

Density = 1.33 gm/cc
08180005.MOD
Rel Permittivity
Rel Permeability
Resistivity = 6400 ohm-m
ει=2.82, ε∞=2.59
τε=0.0080, αε=0.22
0.00 wt% Water
μι=1.17, μ∞=1.04
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.5m depth #2 vacuum dried

Figure 35 -

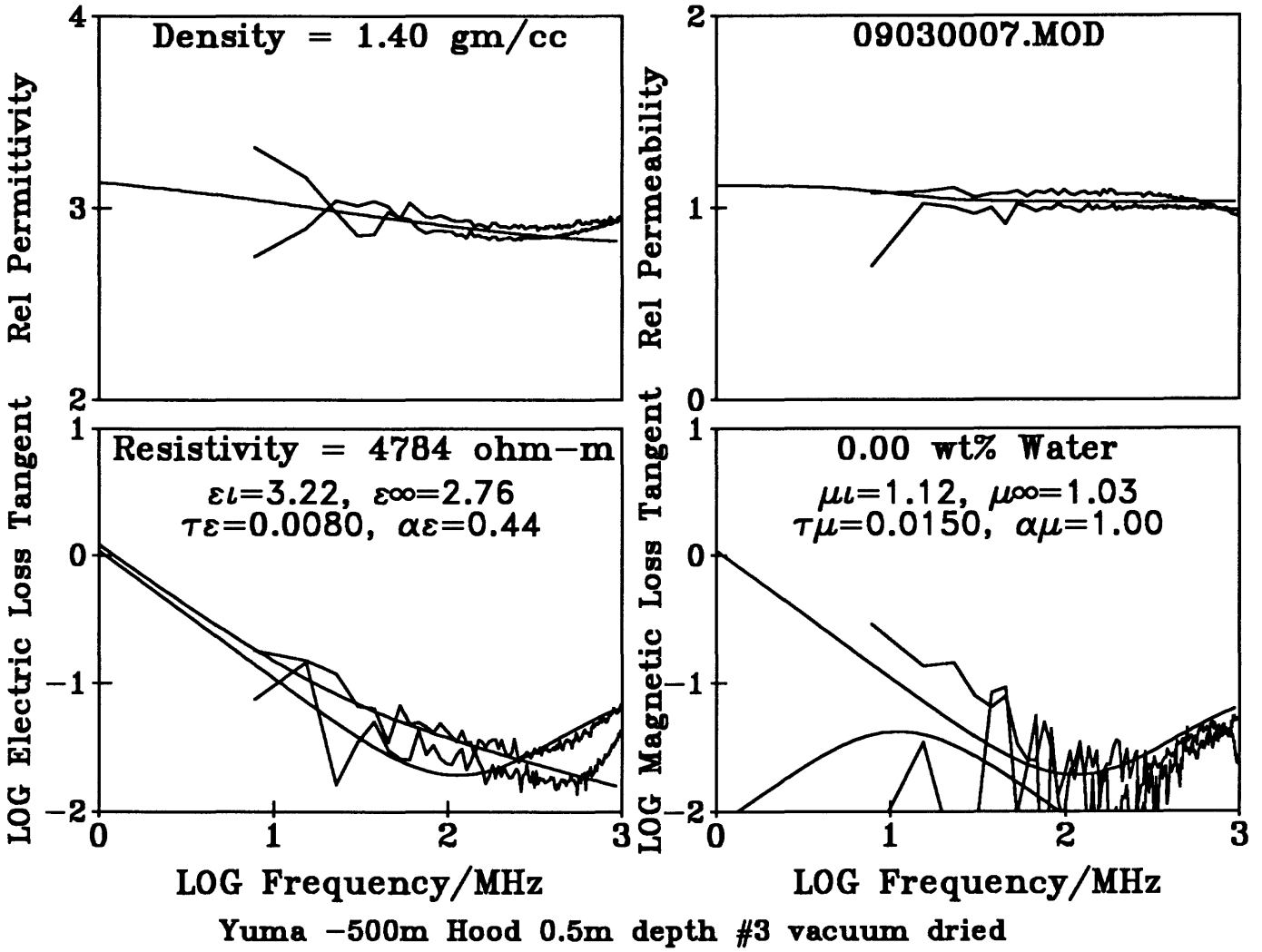

Density = 1.40 gm/cc
09030007.MOD
Resistivity = 4784 ohm-m
ει=3.22, ε∞=2.76
τε=0.0080, αε=0.44
0.00 wt% Water
μι=1.12, μ∞=1.03
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.5m depth #3 vacuum dried

Figure 36 -

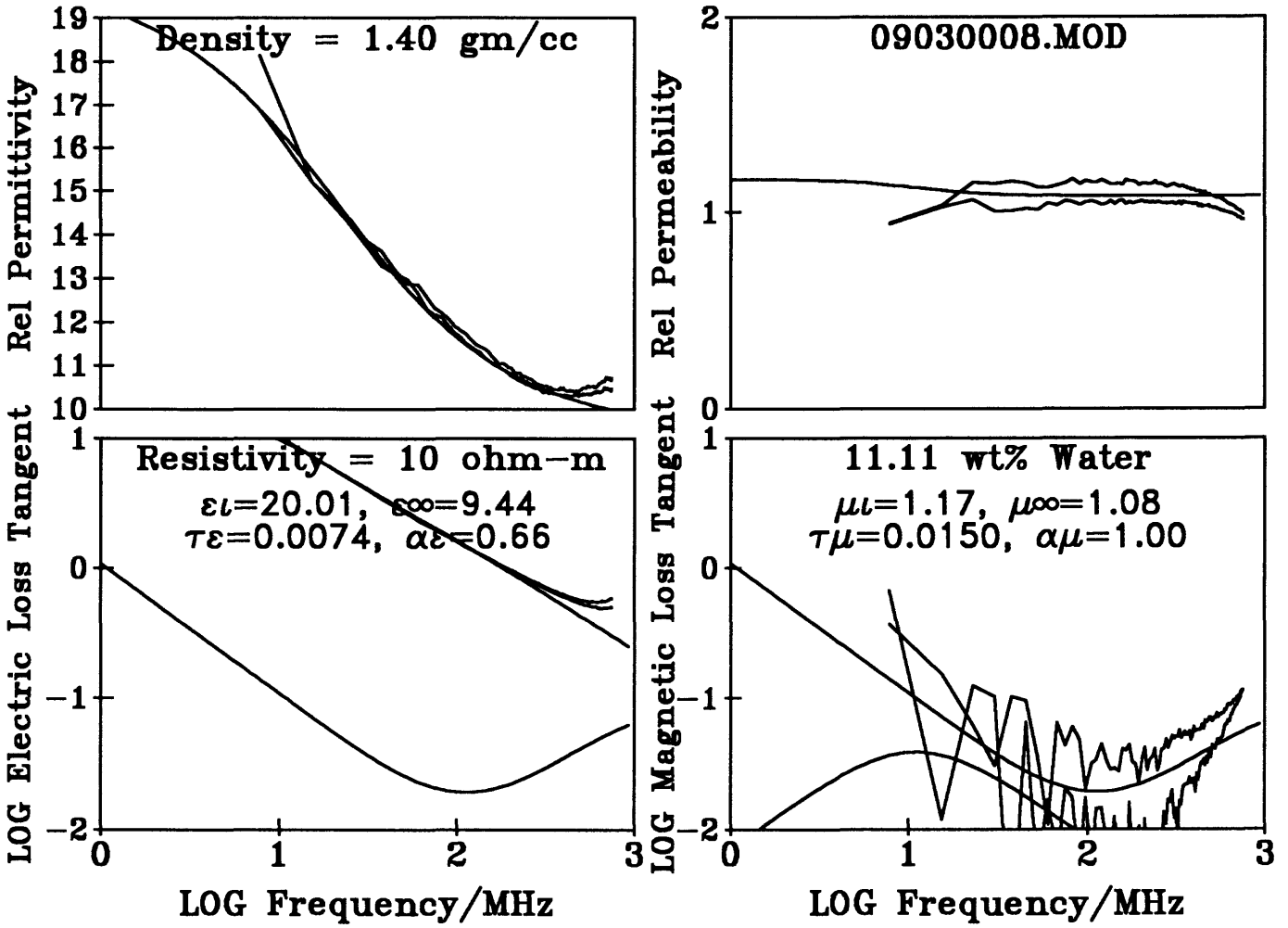

Density = 1.40 gm/cc
09030008.MOD
Resistivity = 10 ohm-m
ει=20.01, ε∞=9.44
τε=0.0074, αε=0.66
11.11 wt% Water
μι=1.17, μ∞=1.08
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent Rel Permittivity
LOG Magnetic Loss Tangent Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.5m depth #3 10 drops water

Figure 37 -

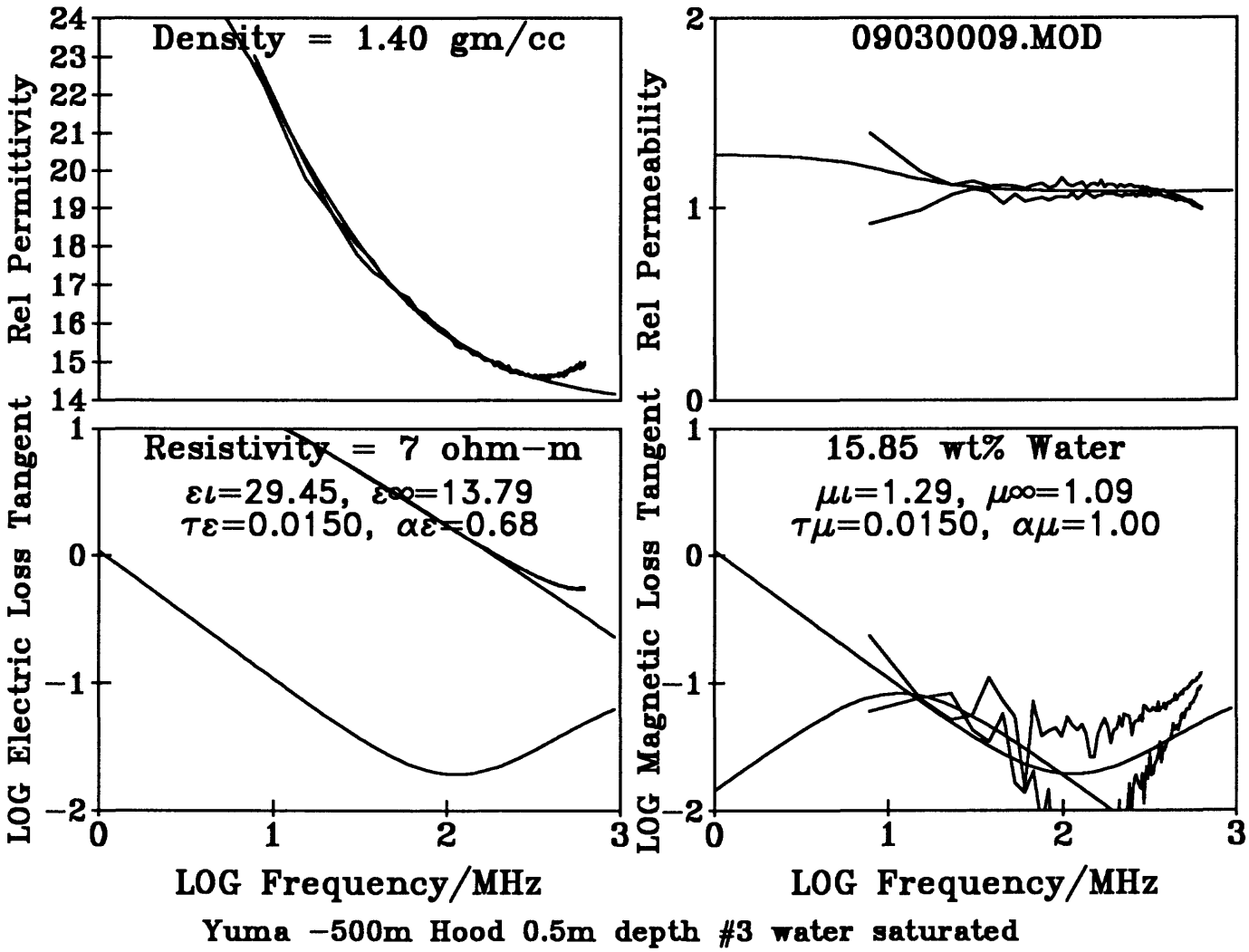

Density = 1.40 gm/cc
09030009.MOD
Resistivity = 7 ohm-m
ει=29.45, ε∞=13.79
τε=0.0150, αε=0.68
15.85 wt% Water
μι=1.29, μ∞=1.09
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent Rel Permittivity
LOG Magnetic Loss Tangent Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.5m depth #3 water saturated

Figure 38 -

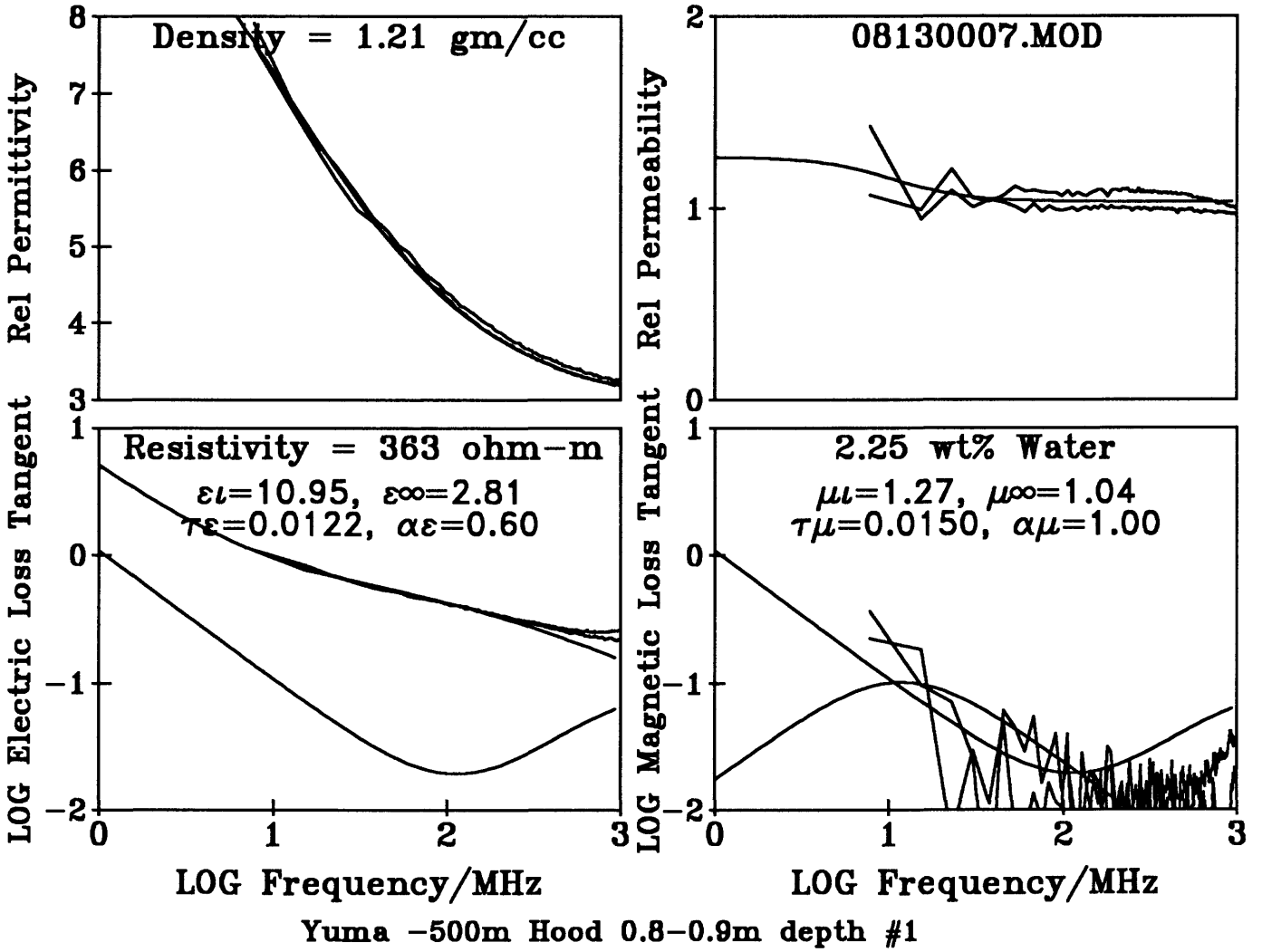



Figure 39 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

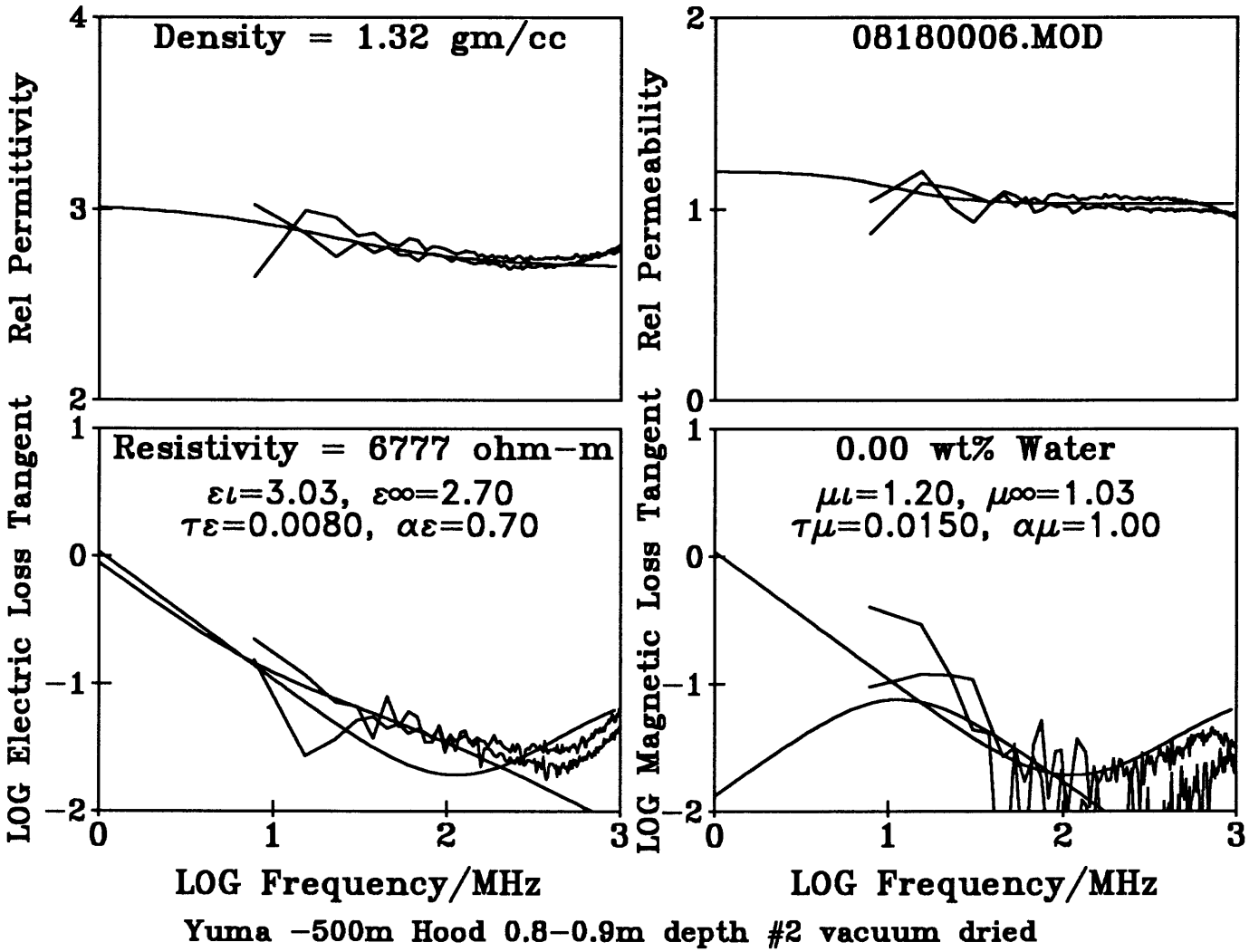

Density = 1.32 gm/cc
08180006.MOD
Rel Permittivity
Rel Permeability
Resistivity = 6777 ohm-m
ει=3.03, ε∞=2.70
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.20, μ∞=1.03
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.8-0.9m depth #2 vacuum dried

Figure 40 -

p

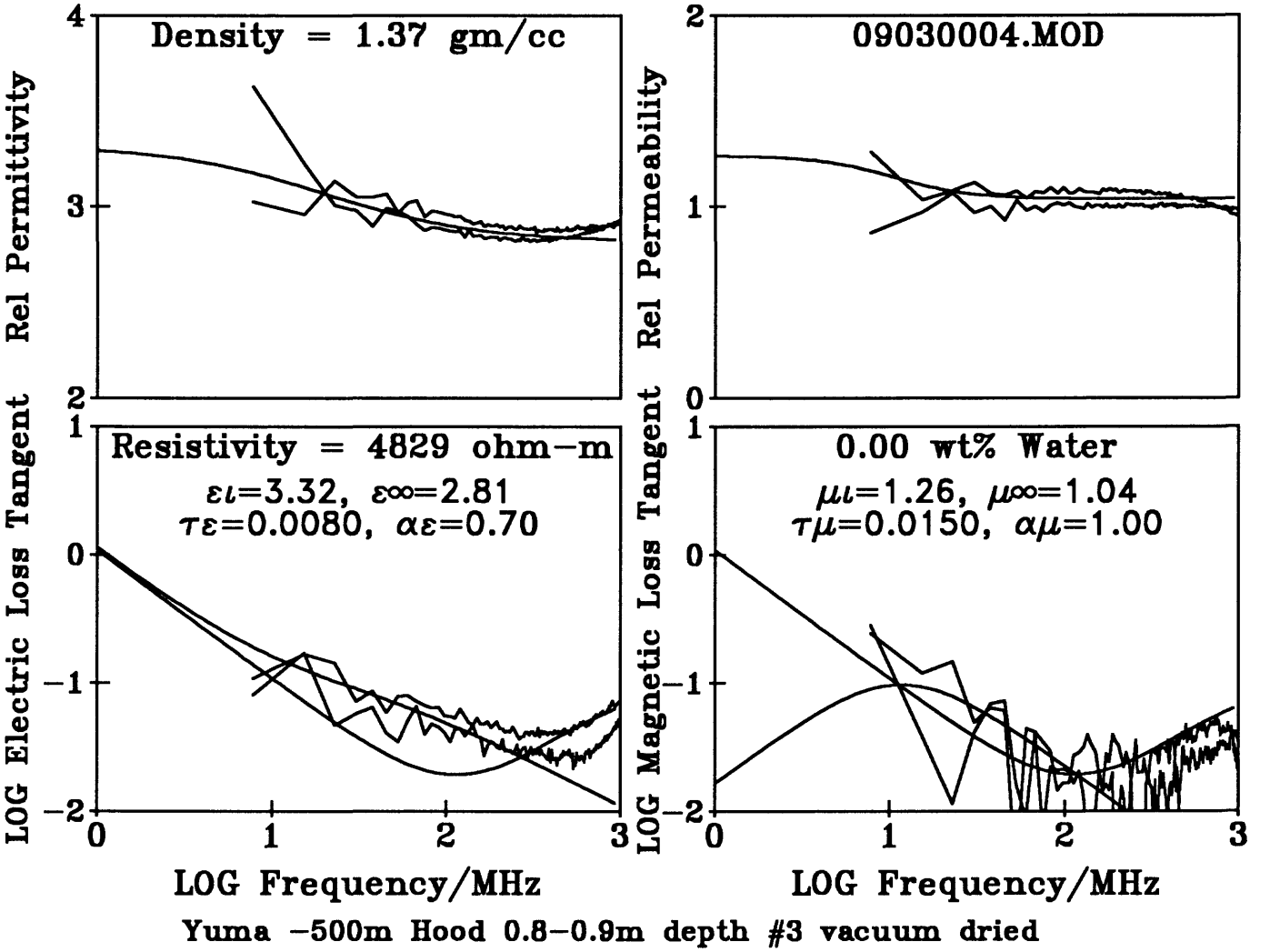

Density = 1.37 gm/cc
09030004.MOD
Rel Permittivity
Rel Permeability
Resistivity = 4829 ohm-m
ει=3.32, ε∞=2.81
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.26, μ∞=1.04
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.8-0.9m depth #3 vacuum dried

Figure 41 -

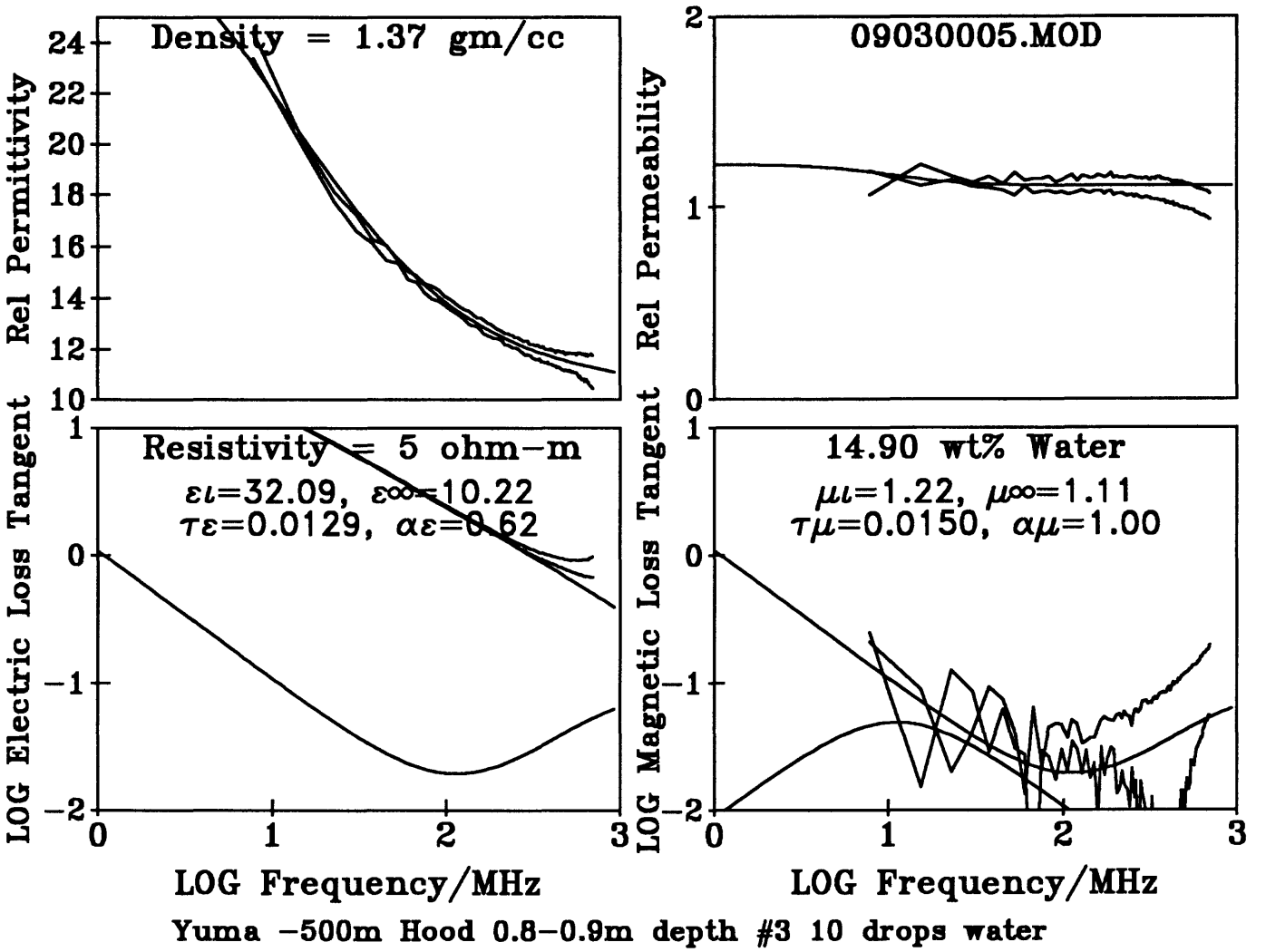

Density = 1.37 gm/cc
09030005.MOD
Resistivity = 5 ohm-m
ει=32.09, ε∞=10.22
τε=0.0129, αε=0.62
14.90 wt% Water
μι=1.22, μ∞=1.11
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.8-0.9m depth #3 10 drops water

Figure 42 -

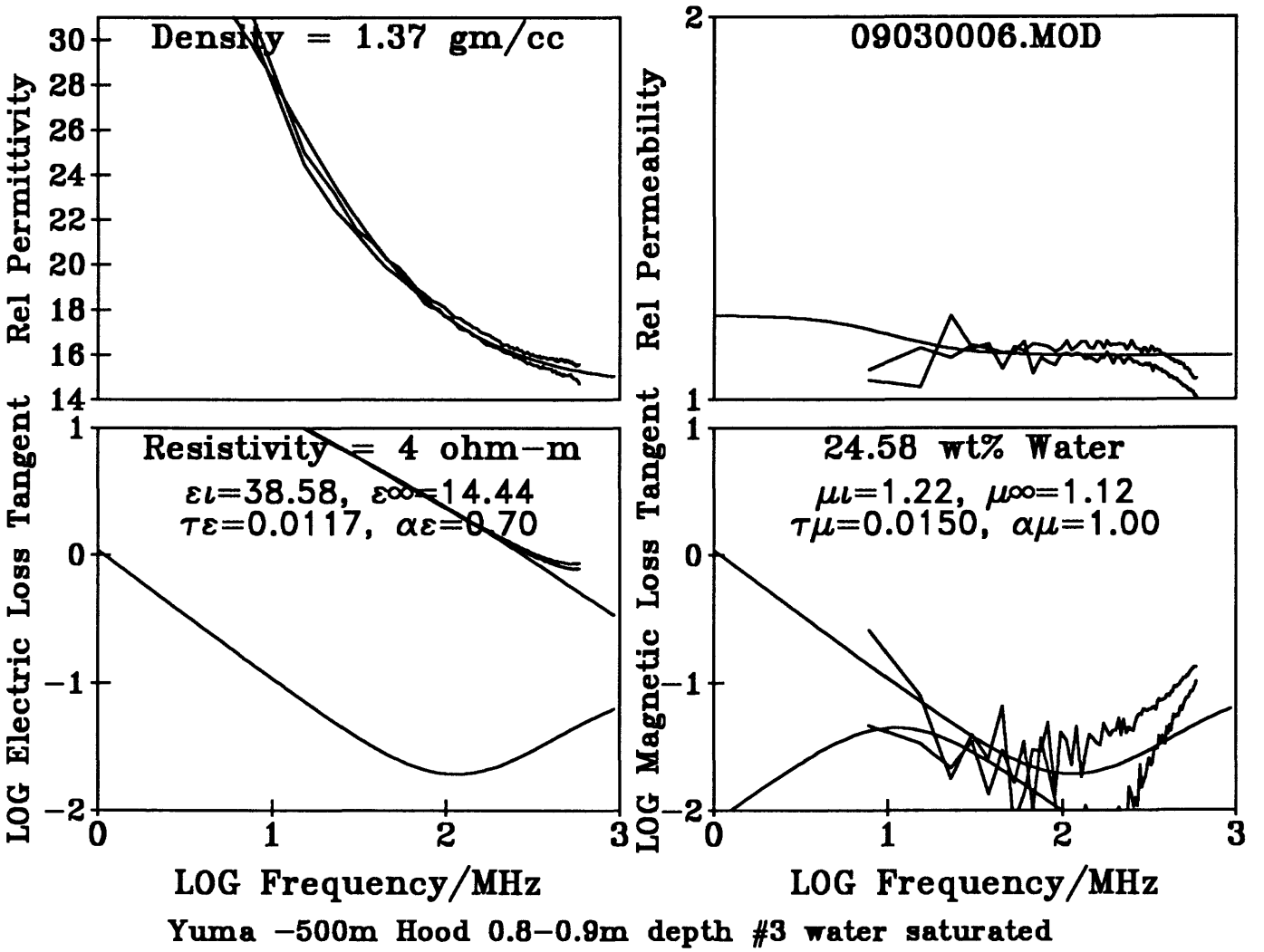

Density = 1.37 gm/cc
09030006.MOD
Resistivity = 4 ohm-m
ει=38.58, ε∞=14.44
τε=0.0117, αε=0.70
24.58 wt% Water
μι=1.22, μ∞=1.12
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent Rel Permittivity
LOG Magnetic Loss Tangent Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma -500m Hood 0.8-0.9m depth #3 water saturated

Figure 43 -

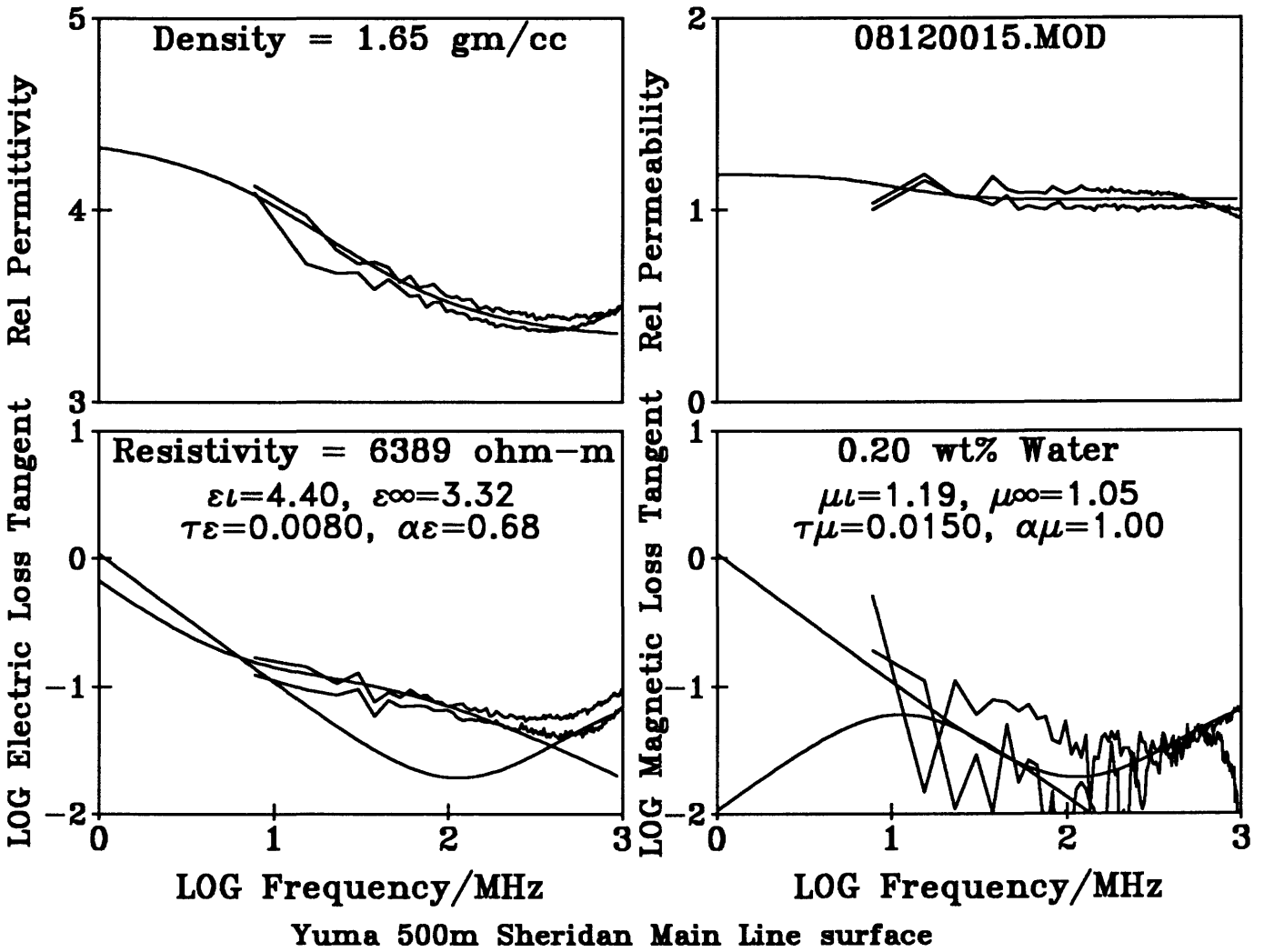



Figure 44 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

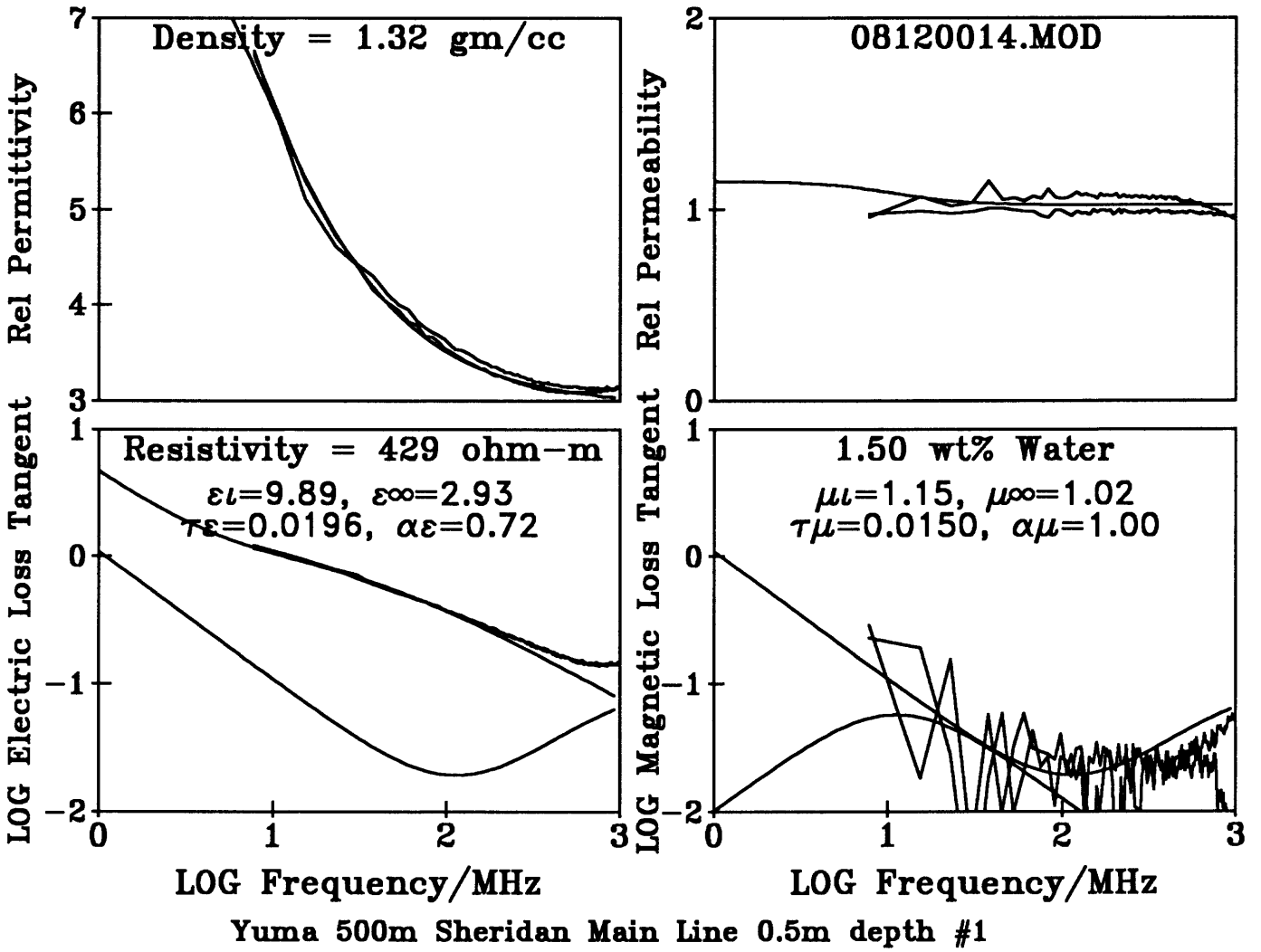



Figure 45 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

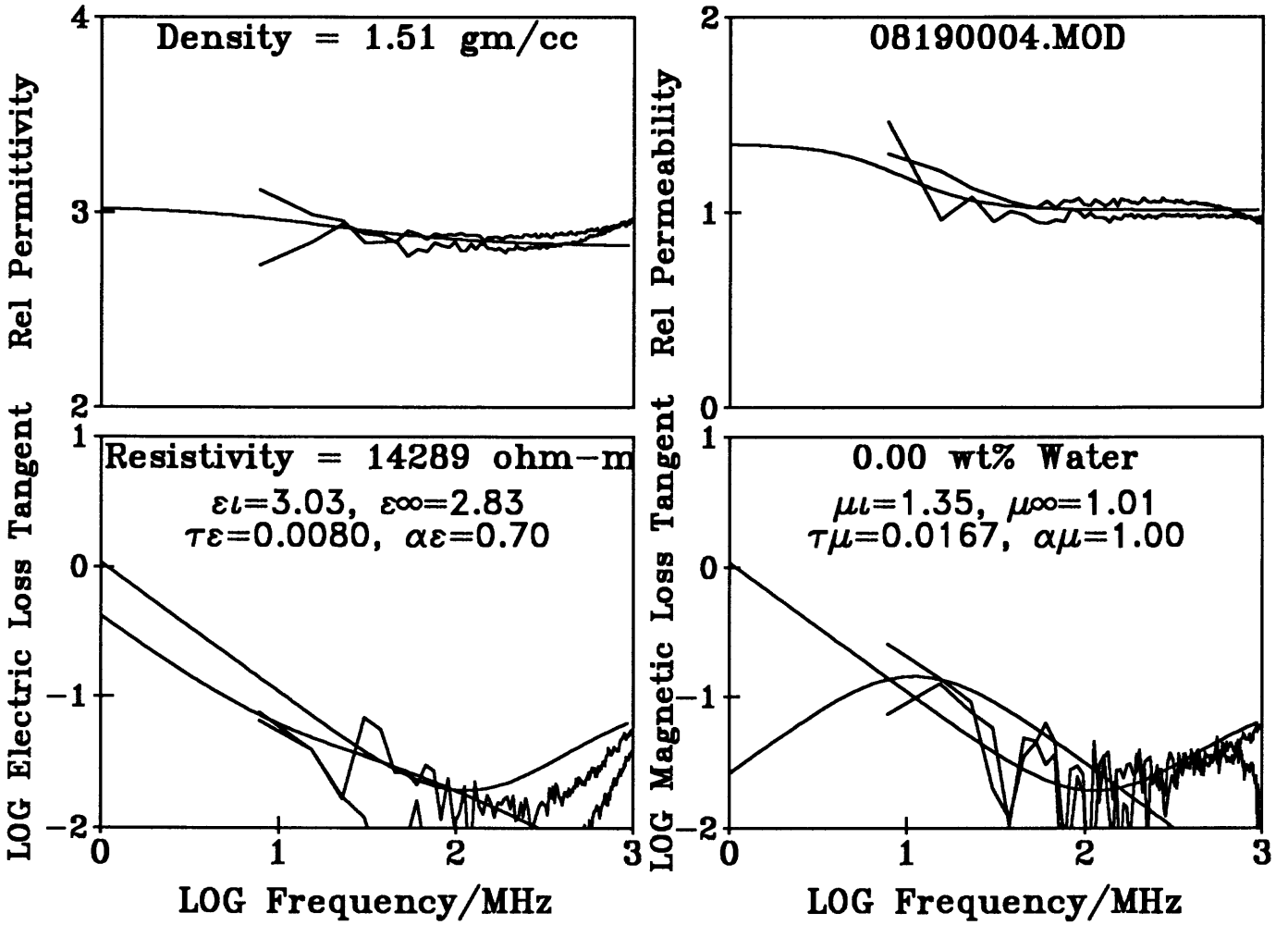

Density = 1.51 gm/cc
08190004.MOD
Resistivity = 14289 ohm-m
ει=3.03, ε∞=2.83
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.35, μ∞=1.01
τμ=0.0167, αμ=1.00
LOG Electric Loss Tangent
Rel Permittivity
LOG Magnetic Loss Tangent
Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 500m Sheridan Main Line 0.5m depth #1 vacuum dried

Figure 46 -

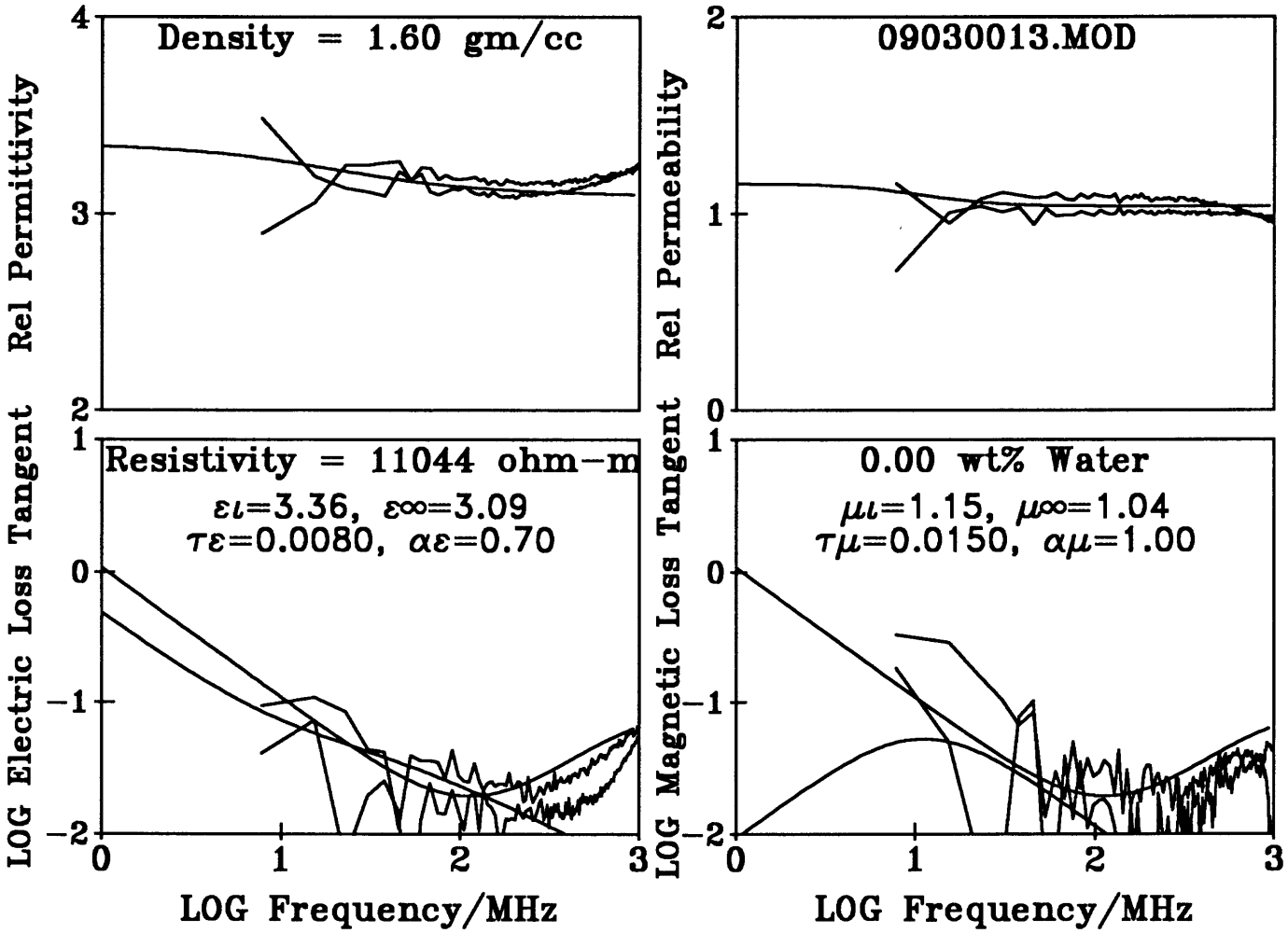

Density = 1.60 gm/cc
09030013.MOD
Resistivity = 11044 ohm-m
ει=3.36, ε∞=3.09
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.15, μ∞=1.04
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent Rel Permittivity
LOG Magnetic Loss Tangent Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 500m Sheridan Main Line 0.5m depth #3 vacuum dried

Figure 47 -

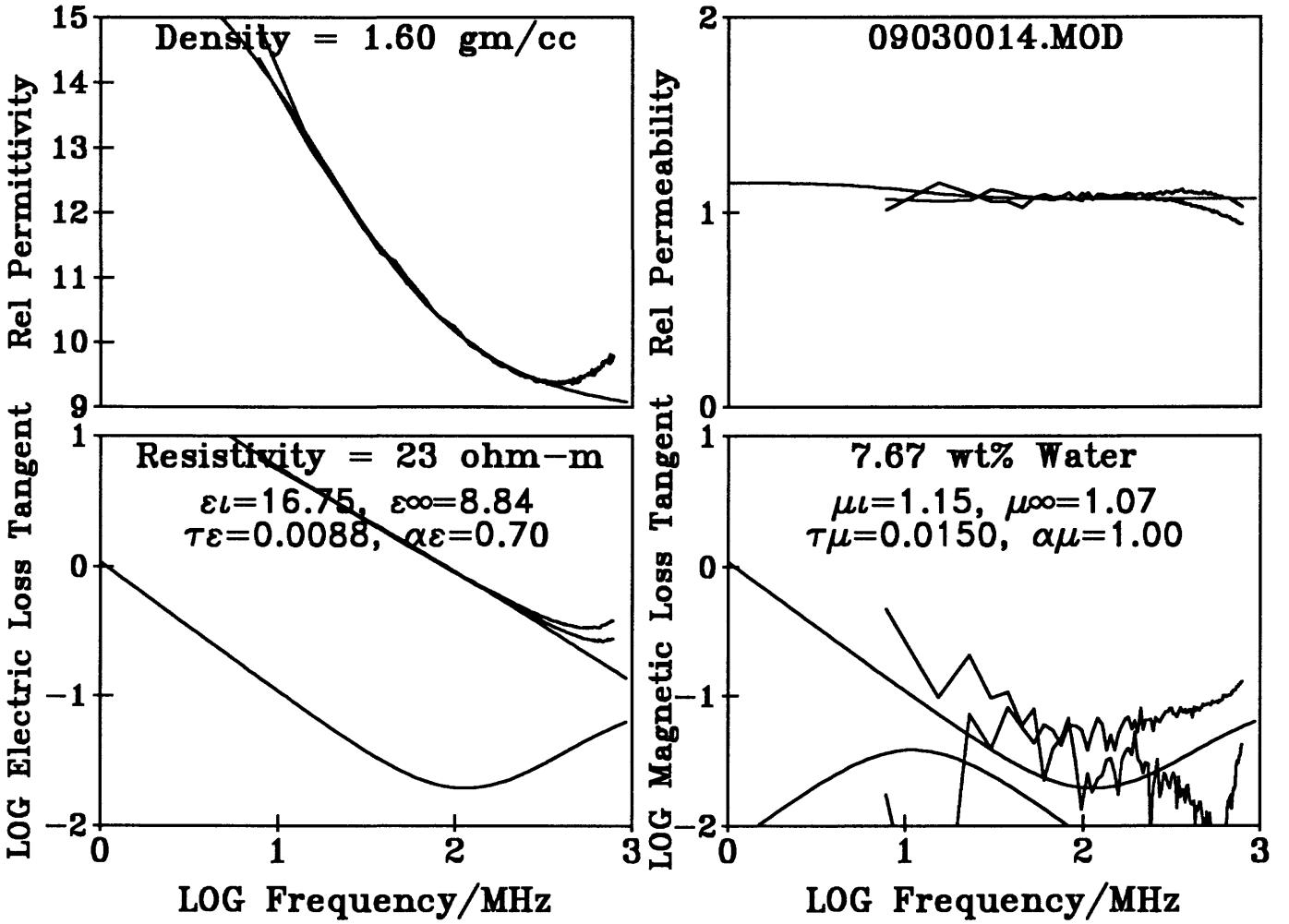

Density = 1.60 gm/cc
09030014.MOD
Resistivity = 23 ohm-m
ει=16.75, ε∞=8.84
τε=0.0088, αε=0.70
7.67 wt% Water
μι=1.15, μ∞=1.07
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 500m Sheridan Main Line 0.5m depth #3 8 drops water

Figure 48 -

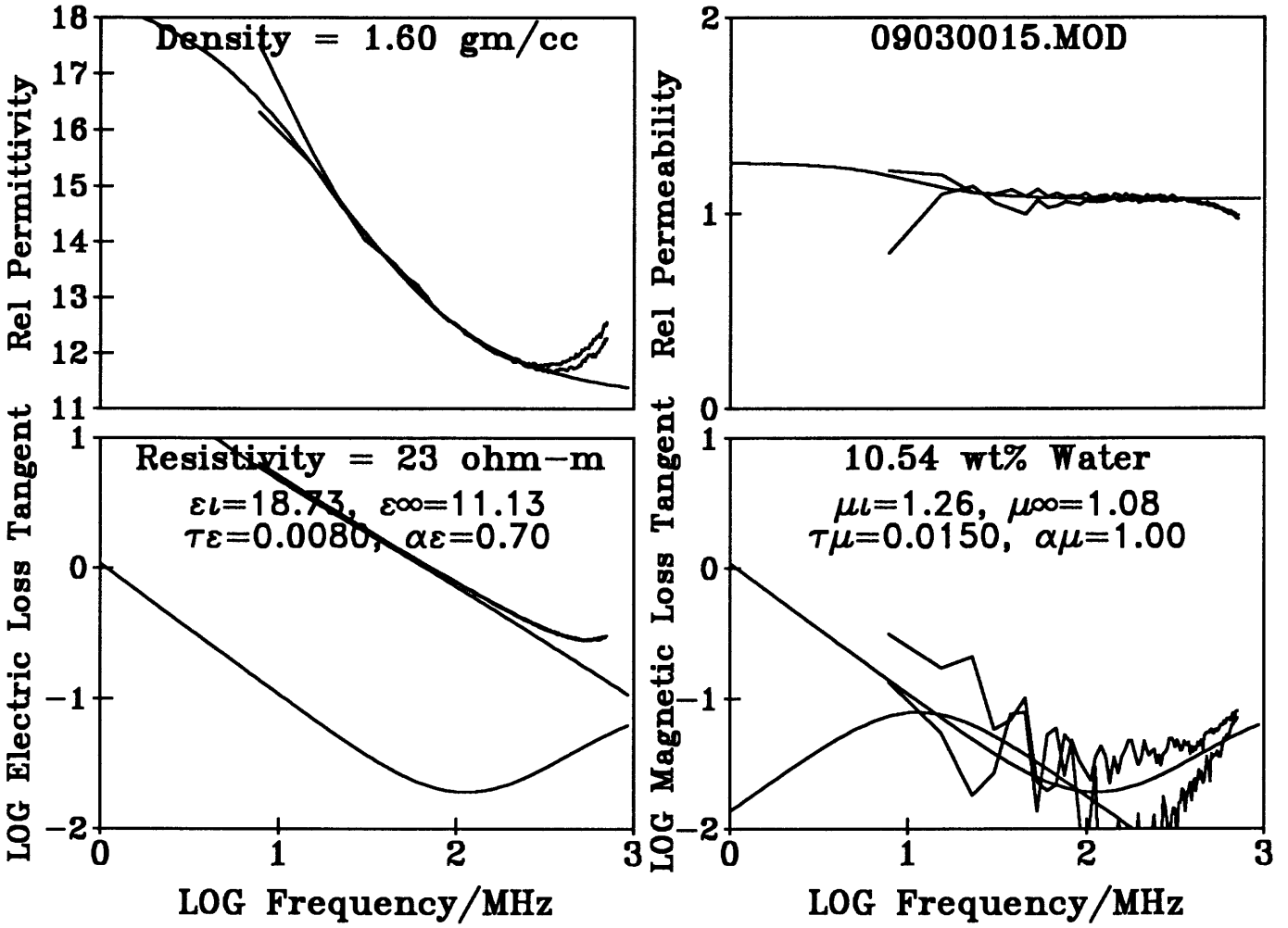

Density = 1.60 gm/cc
09030015.MOD
Resistivity = 23 ohm-m
ει=18.73, ε∞=11.13
τε=0.0080, αε=0.70
10.54 wt% Water
μι=1.26, μ∞=1.08
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 500m Sheridan Main Line 0.5m depth #3 water saturated

Figure 49 -

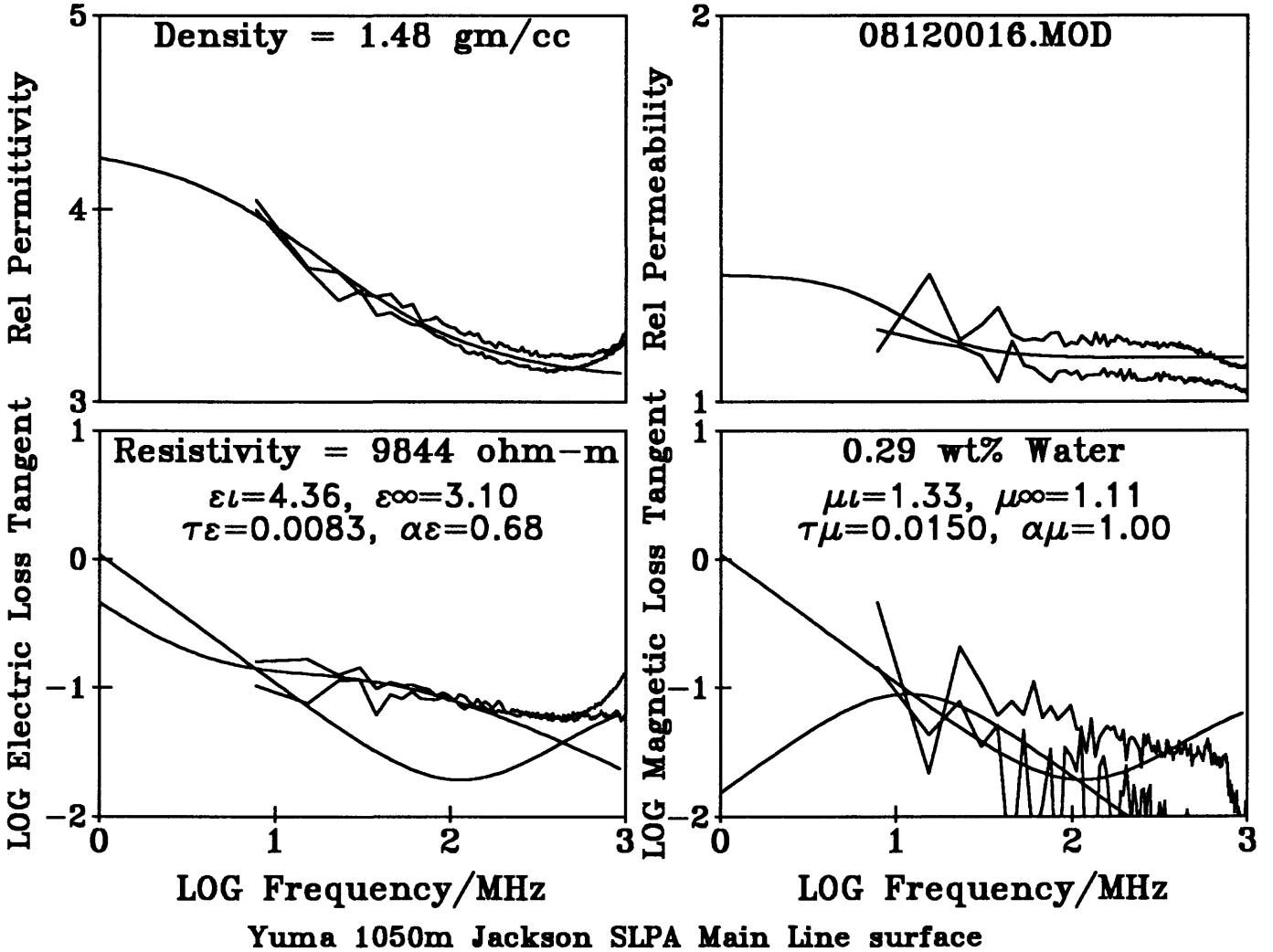



Figure 50 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

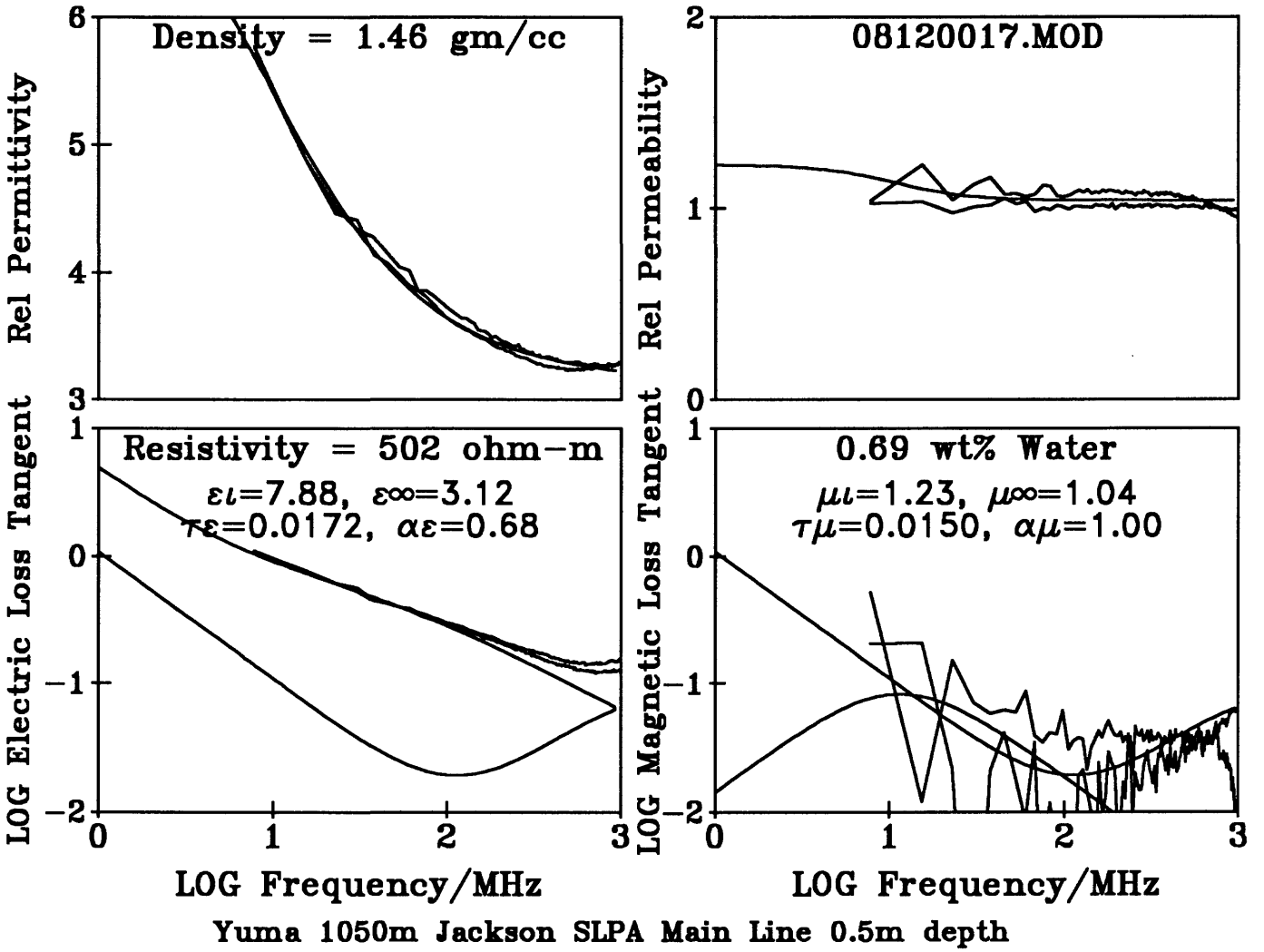



Figure 51 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

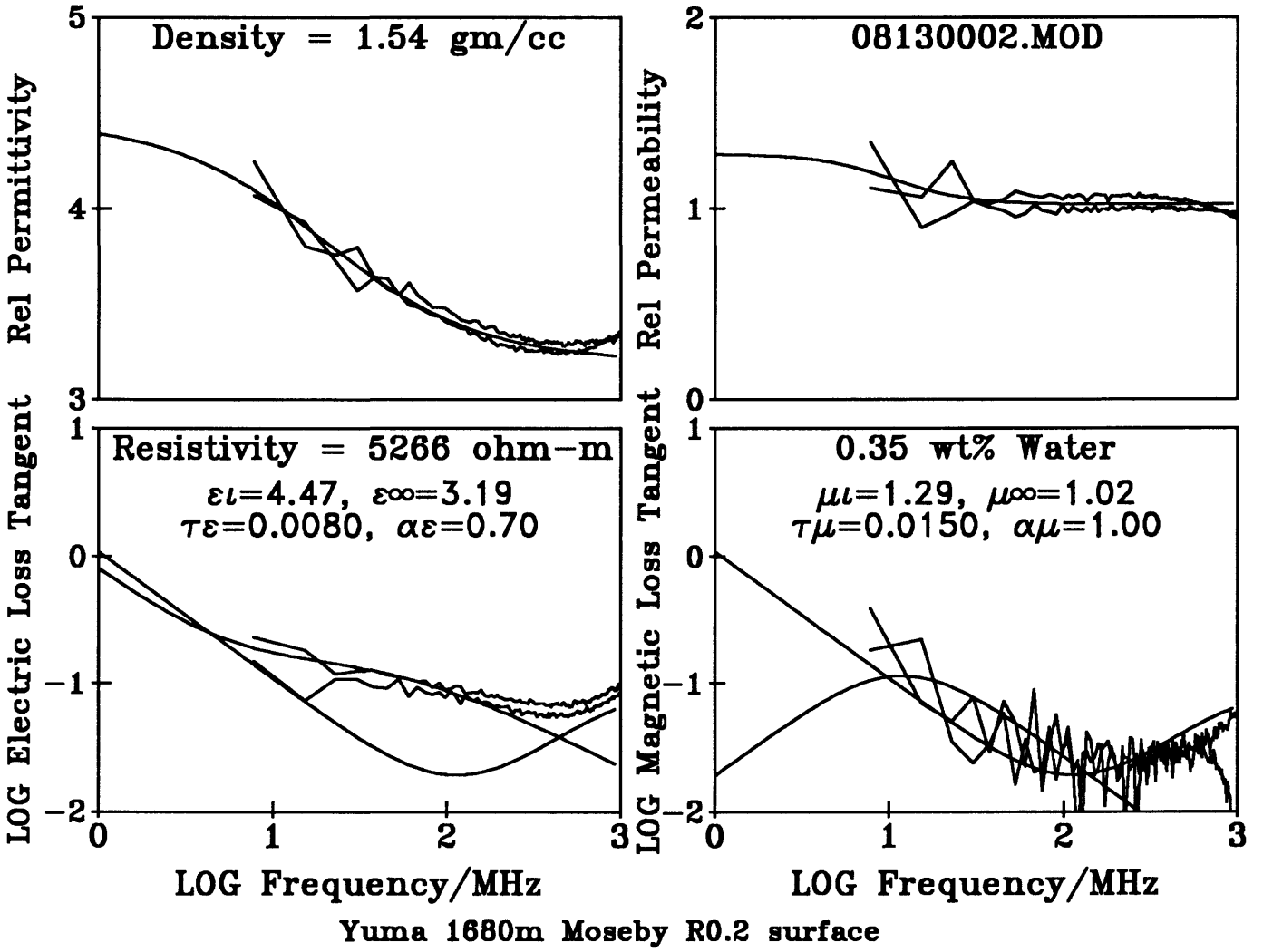



Figure 52 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

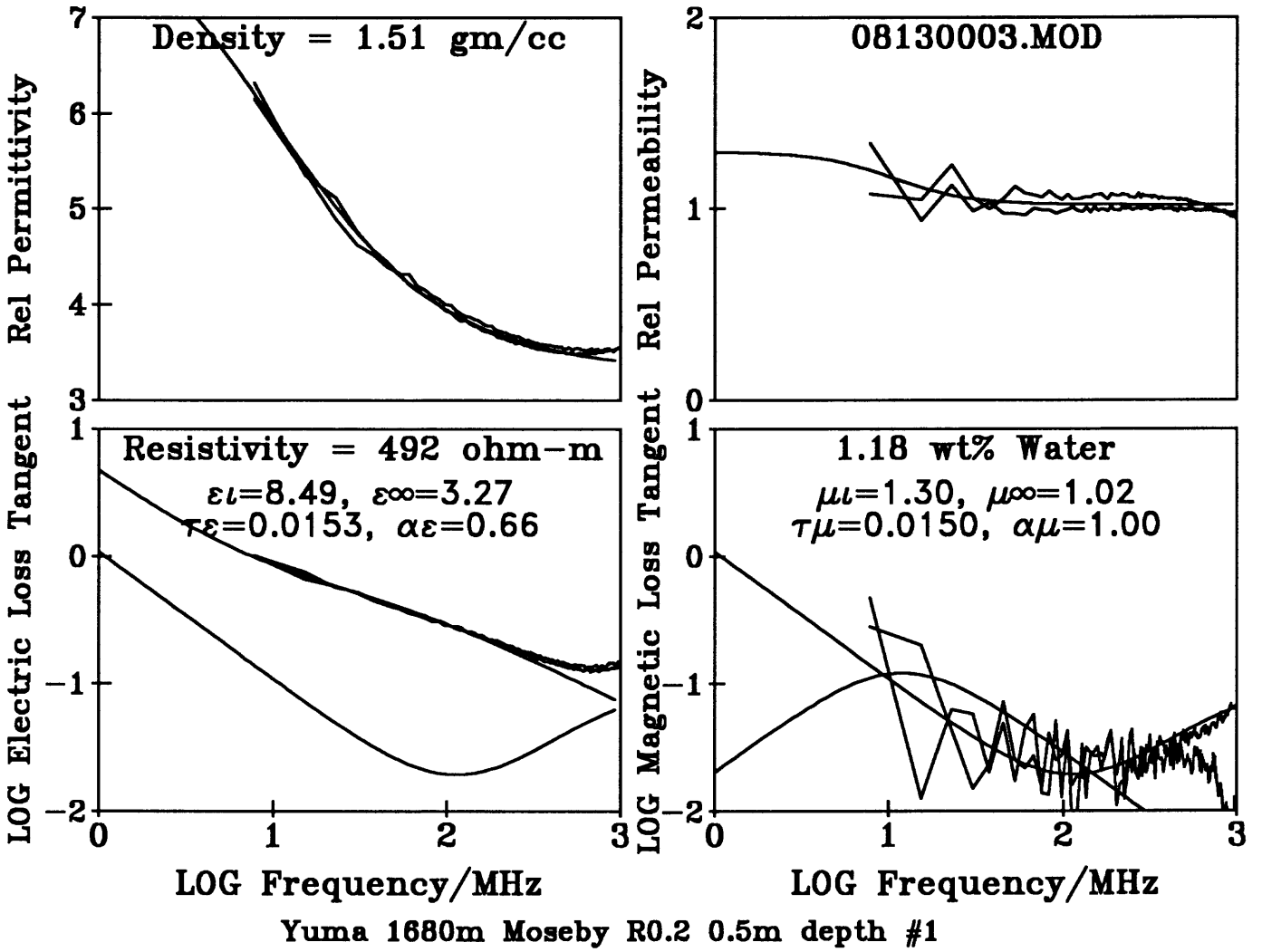



Figure 53 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

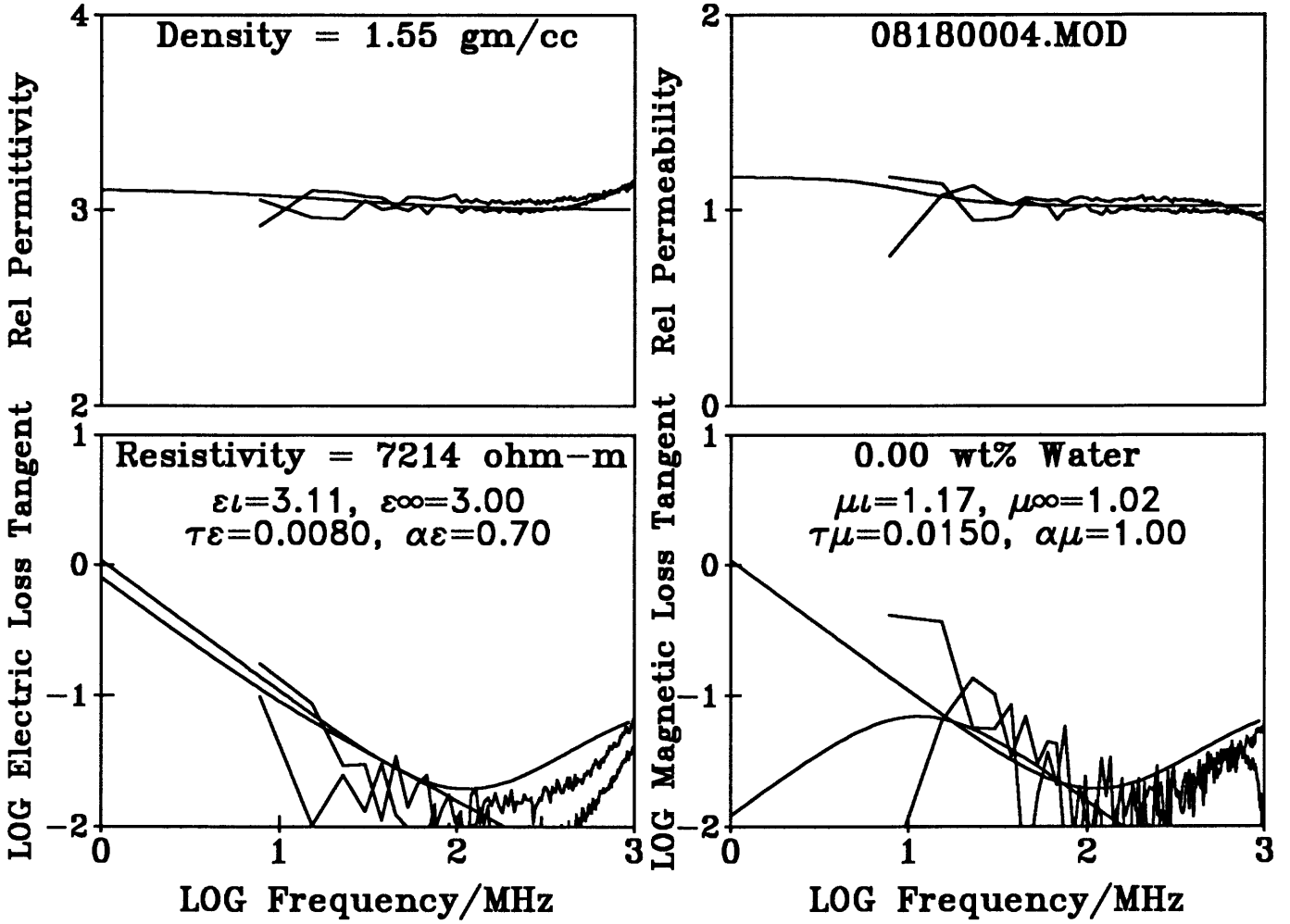

Density = 1.55 gm/cc
08180004.MOD
Rel Permittivity
Rel Permeability
Resistivity = 7214 ohm-m
ει=3.11, ε∞=3.00
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.17, μ∞=1.02
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 1680m Moseby R0.2 0.5m depth #2 vacuum dried

Figure 54 -

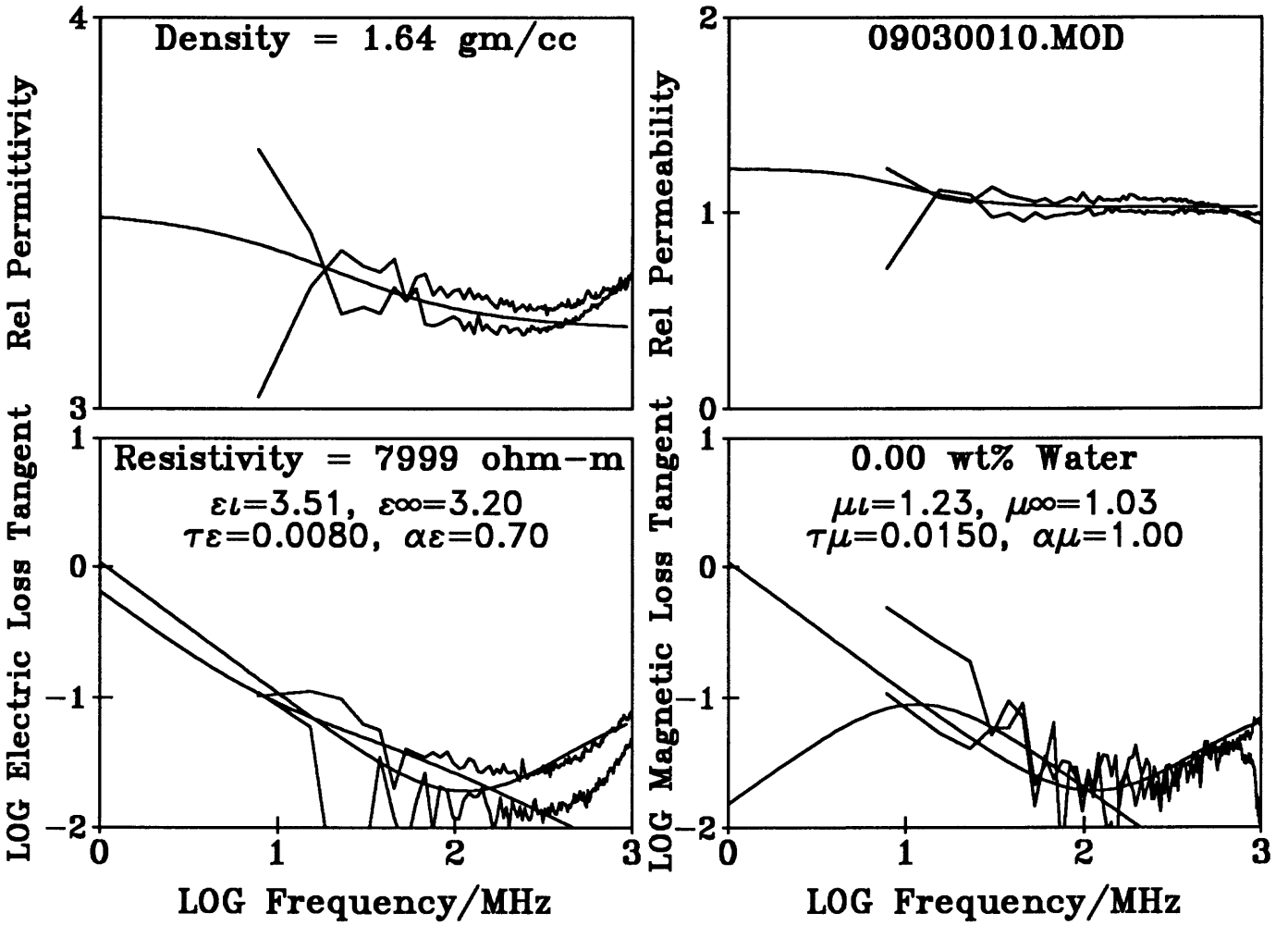

Density = 1.64 gm/cc
09030010.MOD
Resistivity = 7999 ohm-m
ει=3.51, ε∞=3.20
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.23, μ∞=1.03
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 1680m Moseby R0.2 0.5m depth #3 vacuum dried

Figure 55 -

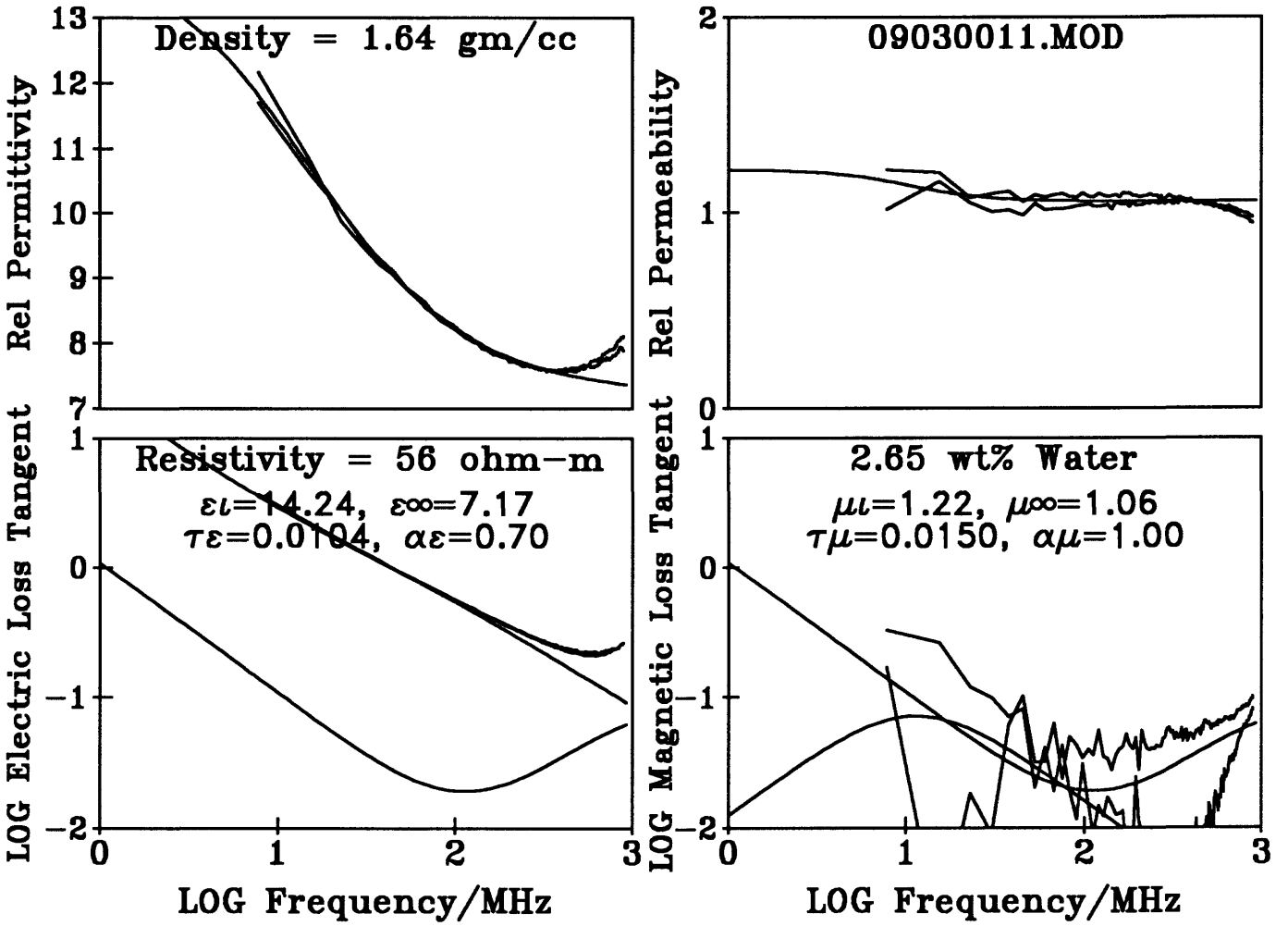

Density = 1.64 gm/cc
09030011.MOD
Resistivity = 56 ohm-m
ει=14.24, ε∞=7.17
τε=0.0104, αε=0.70
2.65 wt% Water
μι=1.22, μ∞=1.06
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 1680m Moseby R0.2 0.5m depth #3 8 drops water

Figure 56 -

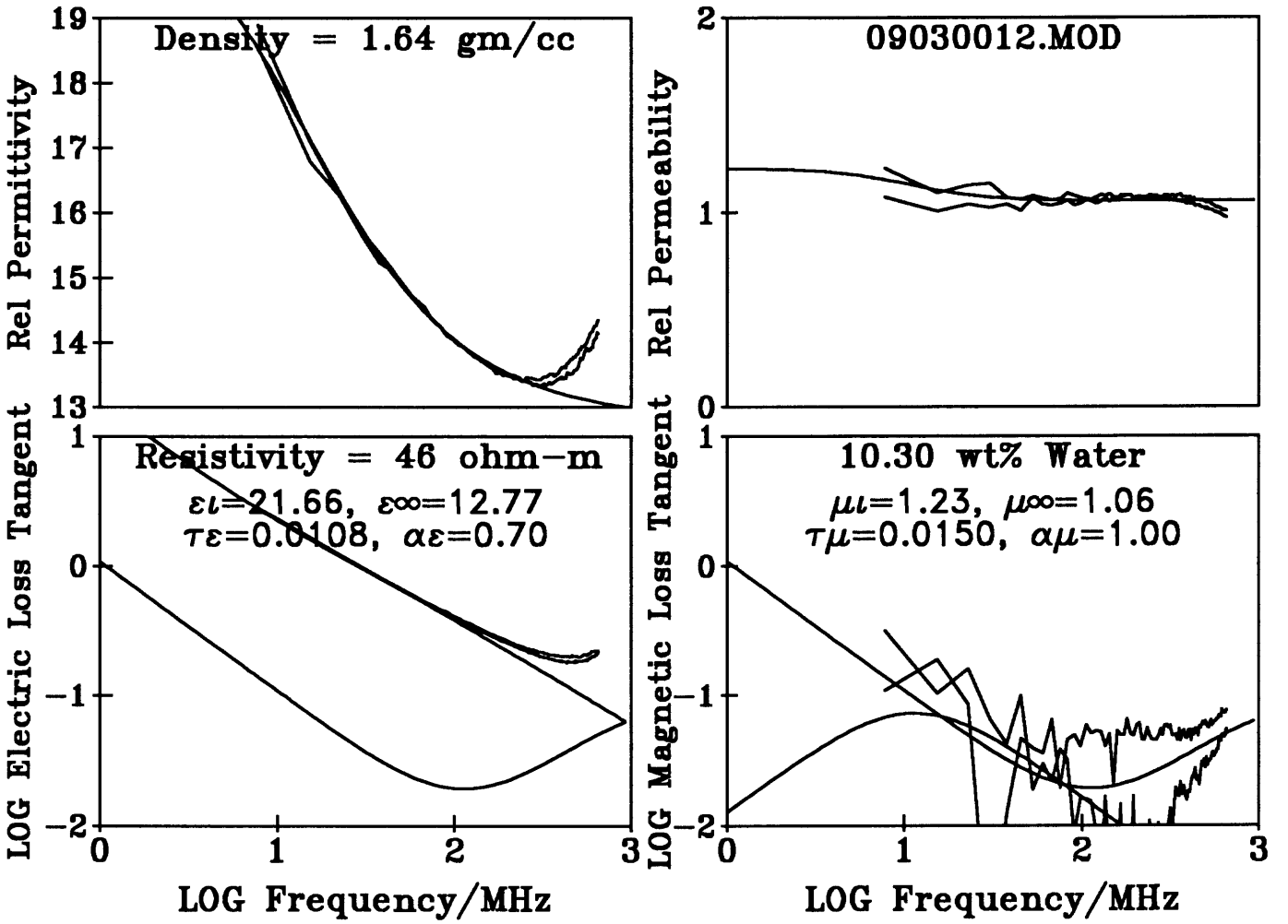

Density = 1.64 gm/cc
09030012.MOD
Rel Permittivity
Rel Permeability
Resistivity = 46 ohm-m
ει=21.66, ε∞=12.77
τε=0.0108, αε=0.70
10.30 wt% Water
μι=1.23, μ∞=1.06
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 1680m Moseby R0.2 0.5m depth #3 water saturated

Figure 57 -

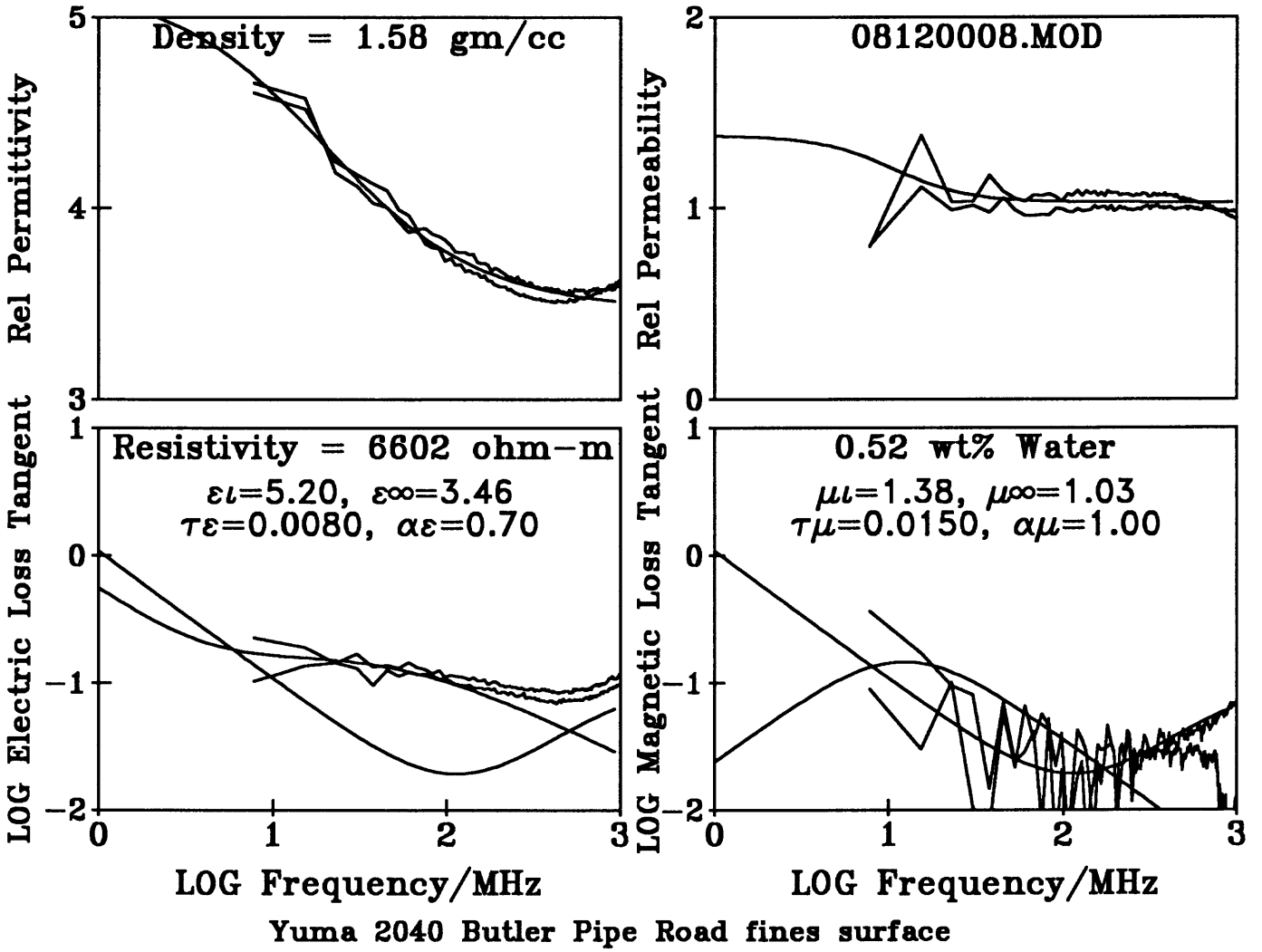



Figure 58 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

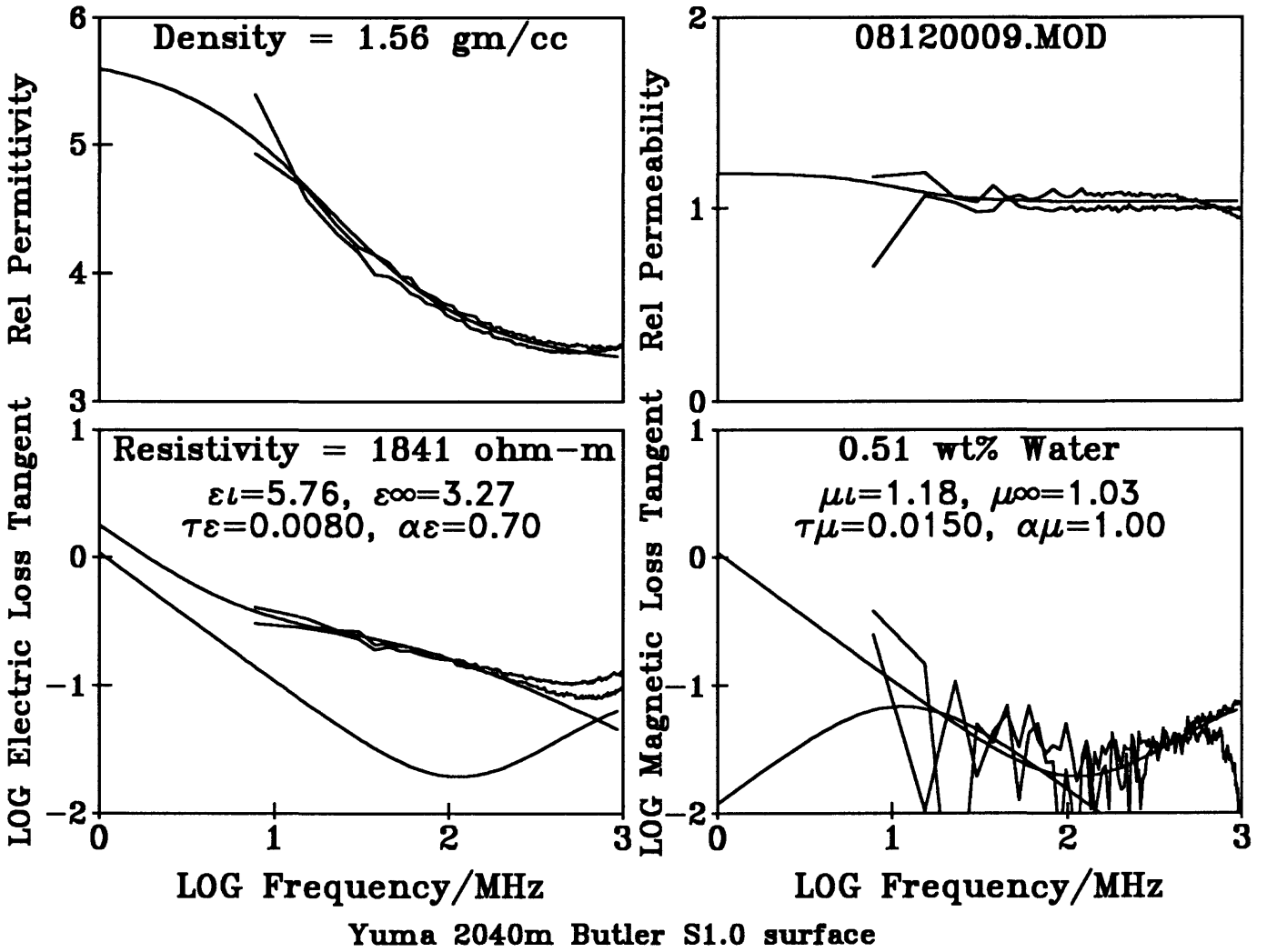



Figure 59 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

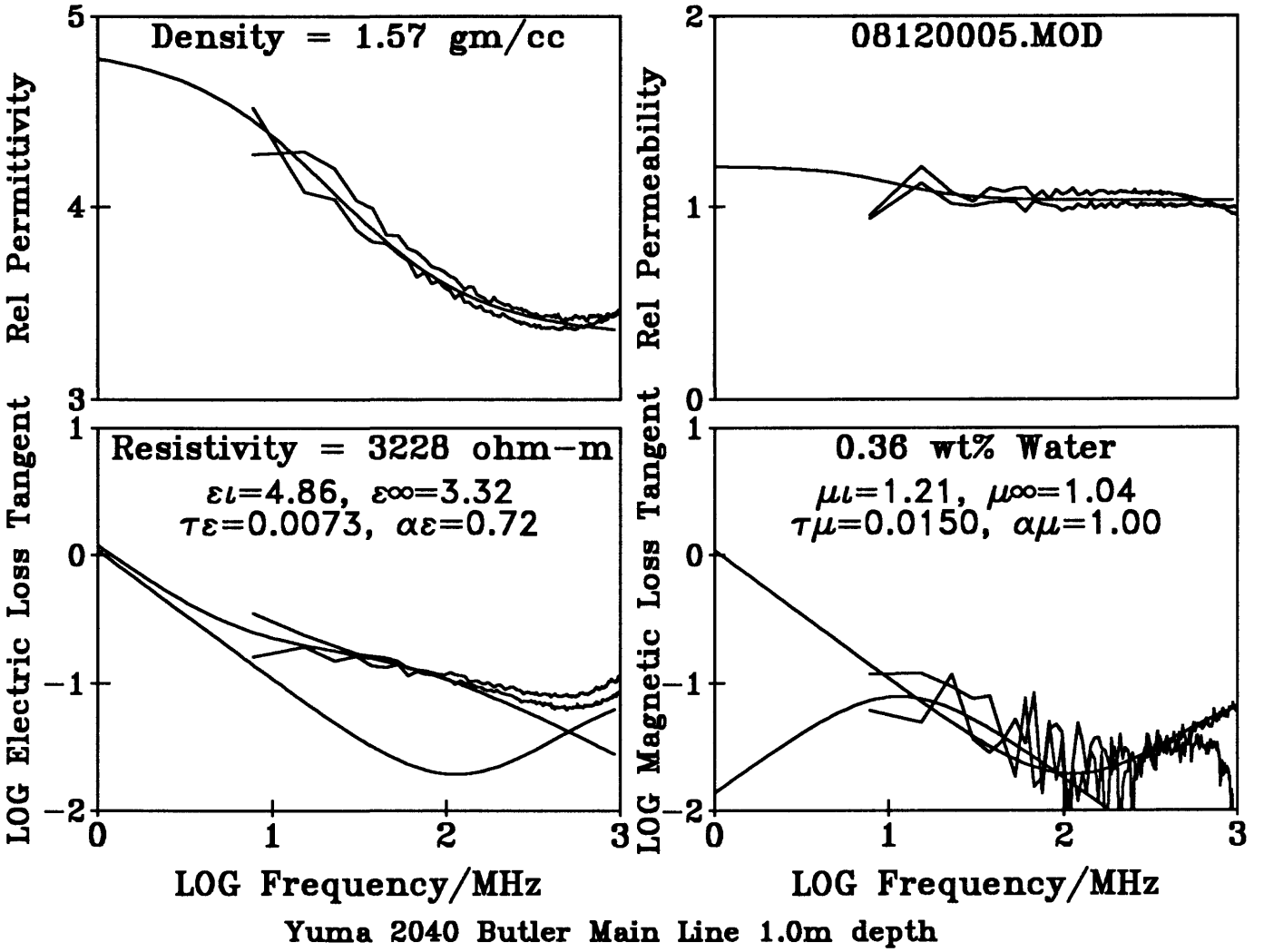



Figure 60 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

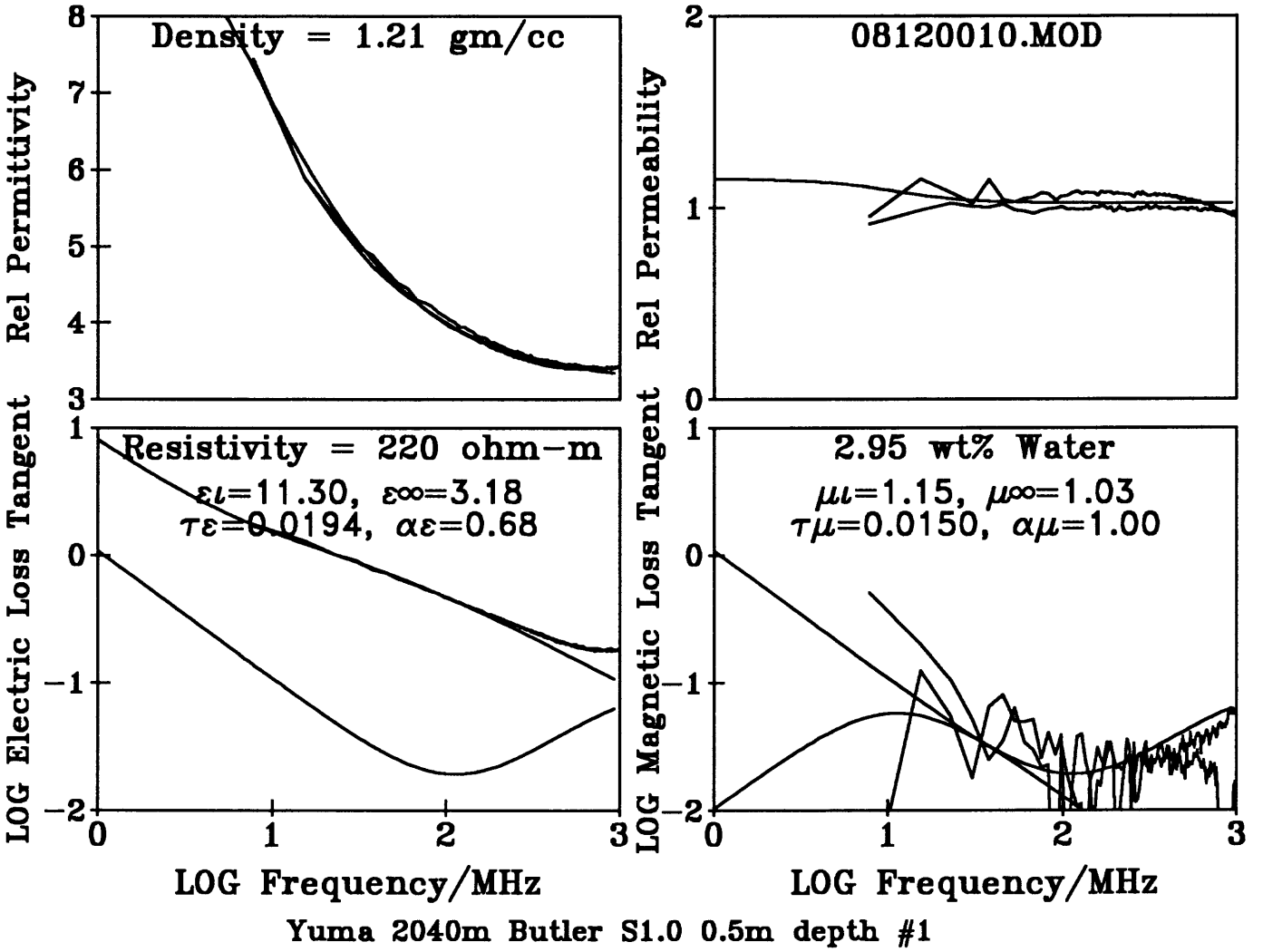



Figure 61 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

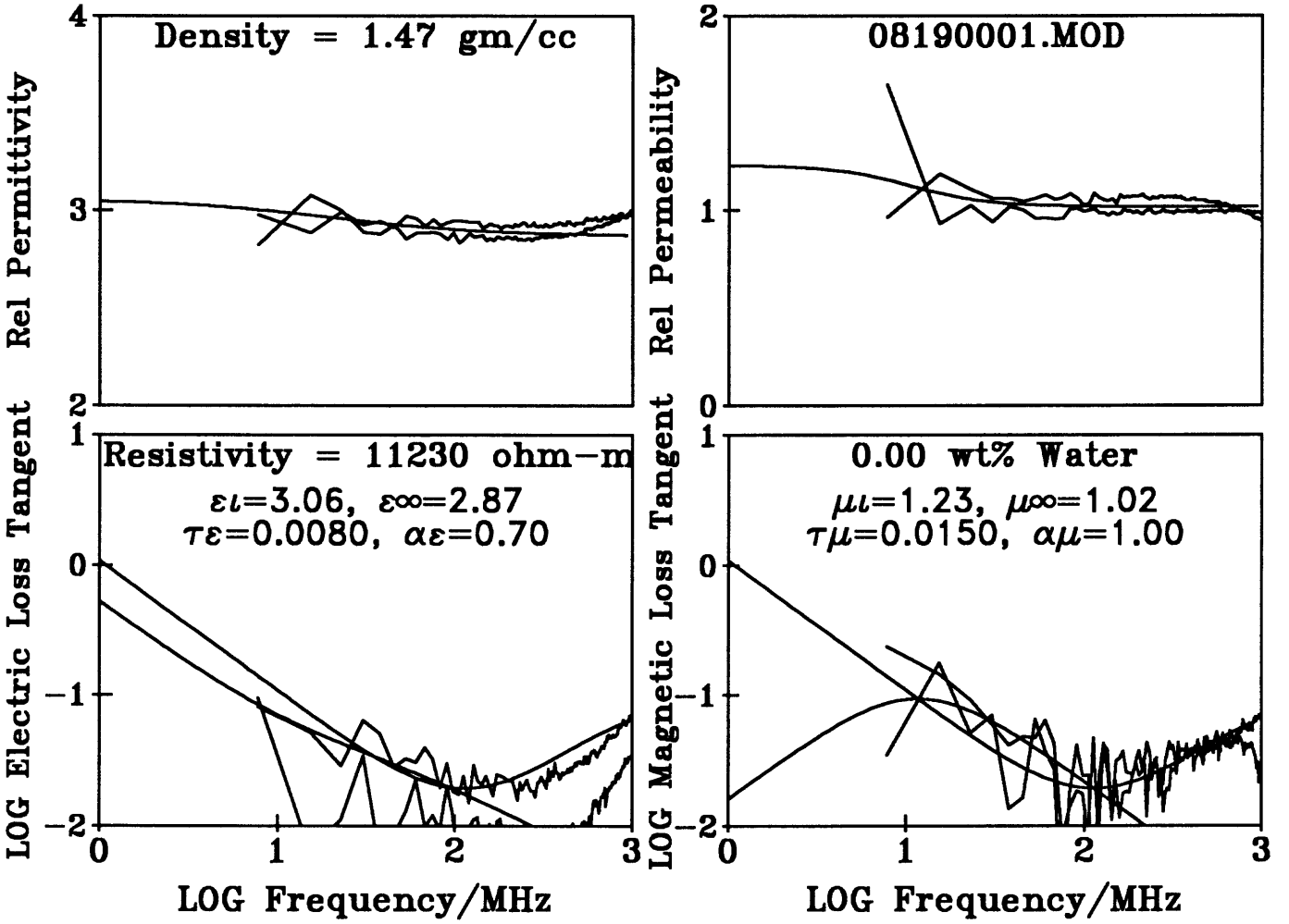

Density = 1.47 gm/cc
08190001.MOD
Rel Permittivity
Rel Permeability
Resistivity = 11230 ohm-m
ει=3.06, ε∞=2.87
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.23, μ∞=1.02
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2040m Butler S1.0 0.5m depth #2 vacuum dried

Figure 62 -

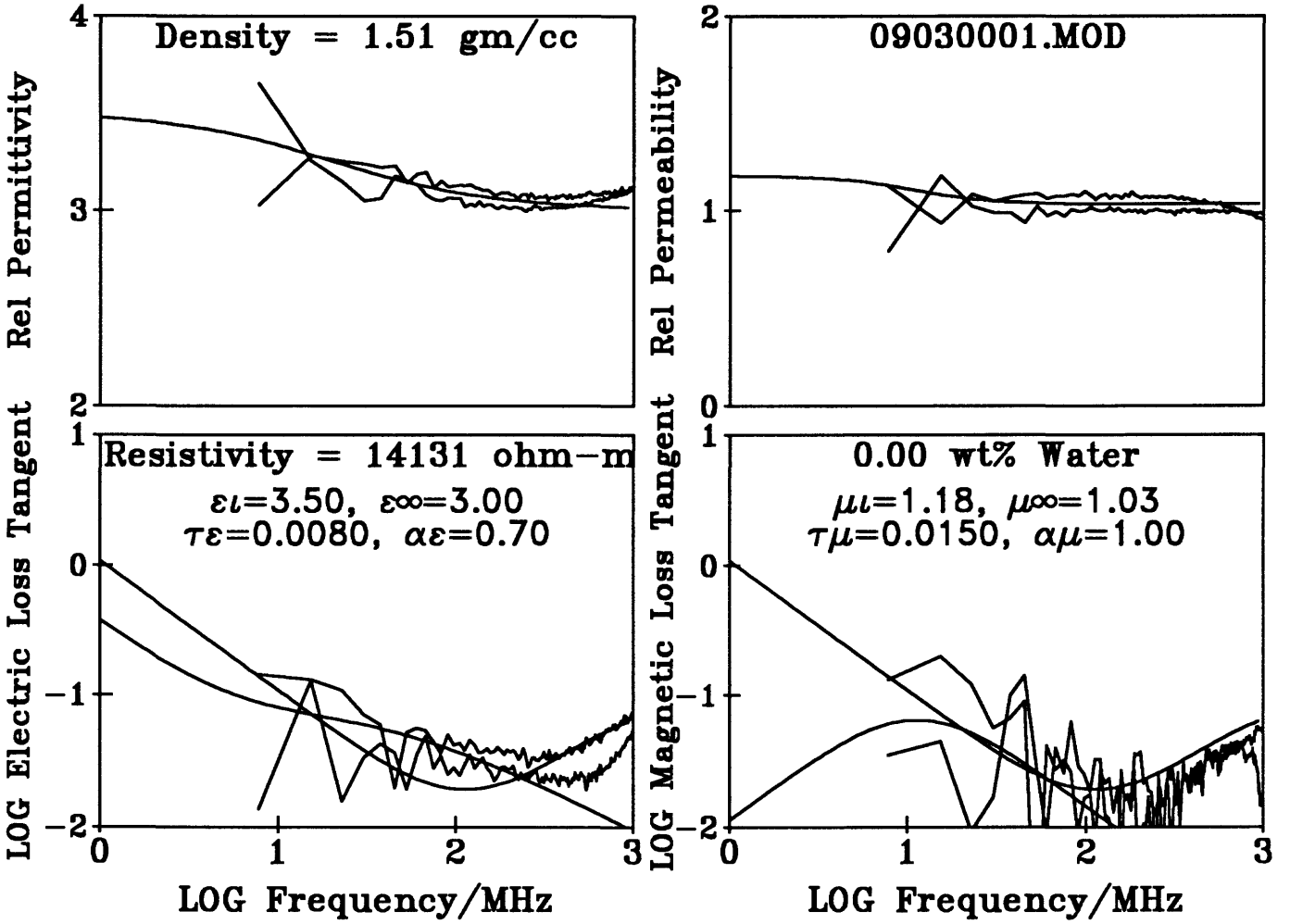

Density = 1.51 gm/cc
09030001.MOD
Resistivity = 14131 ohm-m
ει=3.50, ε∞=3.00
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.18, μ∞=1.03
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2040m Butler S1.0 0.5m depth #3 vacuum dried

Figure 63 -

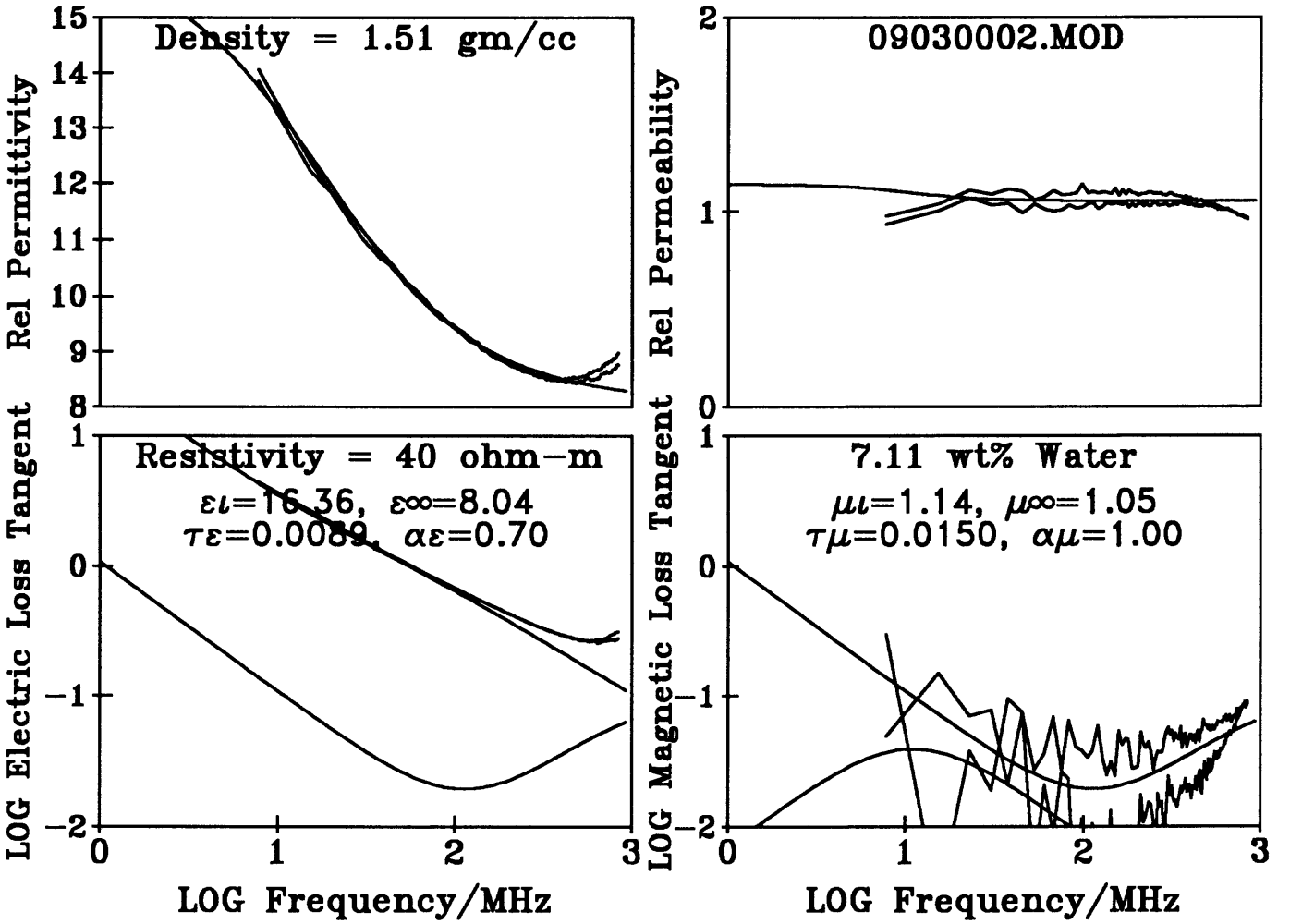

Density = 1.51 gm/cc
09030002.MOD
Rel Permittivity
Rel Permeability
Resistivity = 40 ohm-m
ει=16.36, ε∞=8.04
τε=0.0089, αε=0.70
7.11 wt% Water
μι=1.14, μ∞=1.05
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2040m Butler S1.0 0.5m depth #3 10 drops water

Figure 64 -

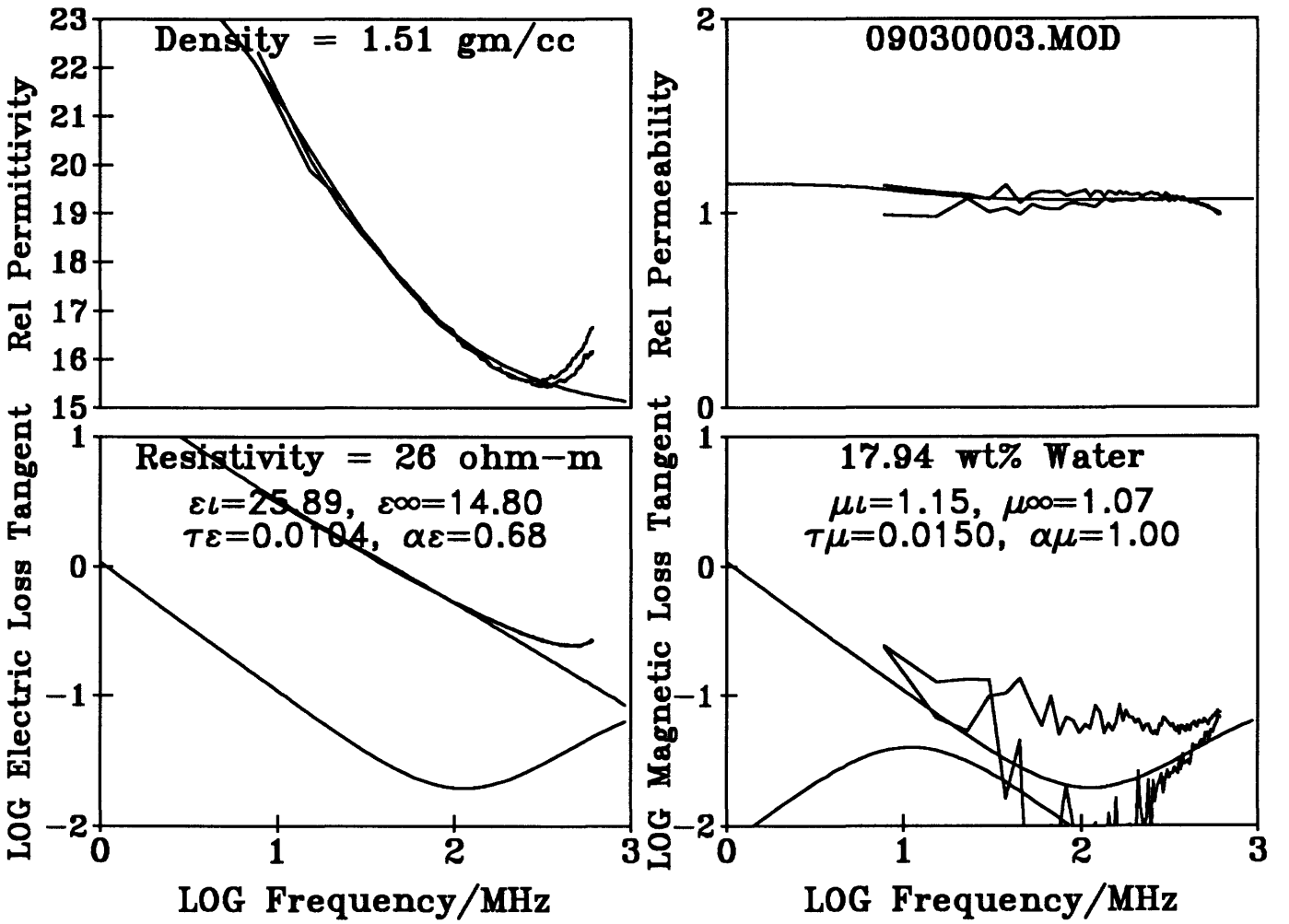

Density = 1.51 gm/cc
09030003.MOD
Resistivity = 26 ohm-m
ει=25.89, ε∞=14.80
τε=0.0104, αε=0.68
17.94 wt% Water
μι=1.15, μ∞=1.07
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
Rel Permittivity
LOG Magnetic Loss Tangent
Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2040m Butler S1.0 0.5m depth #3 water saturated

Figure 65 -

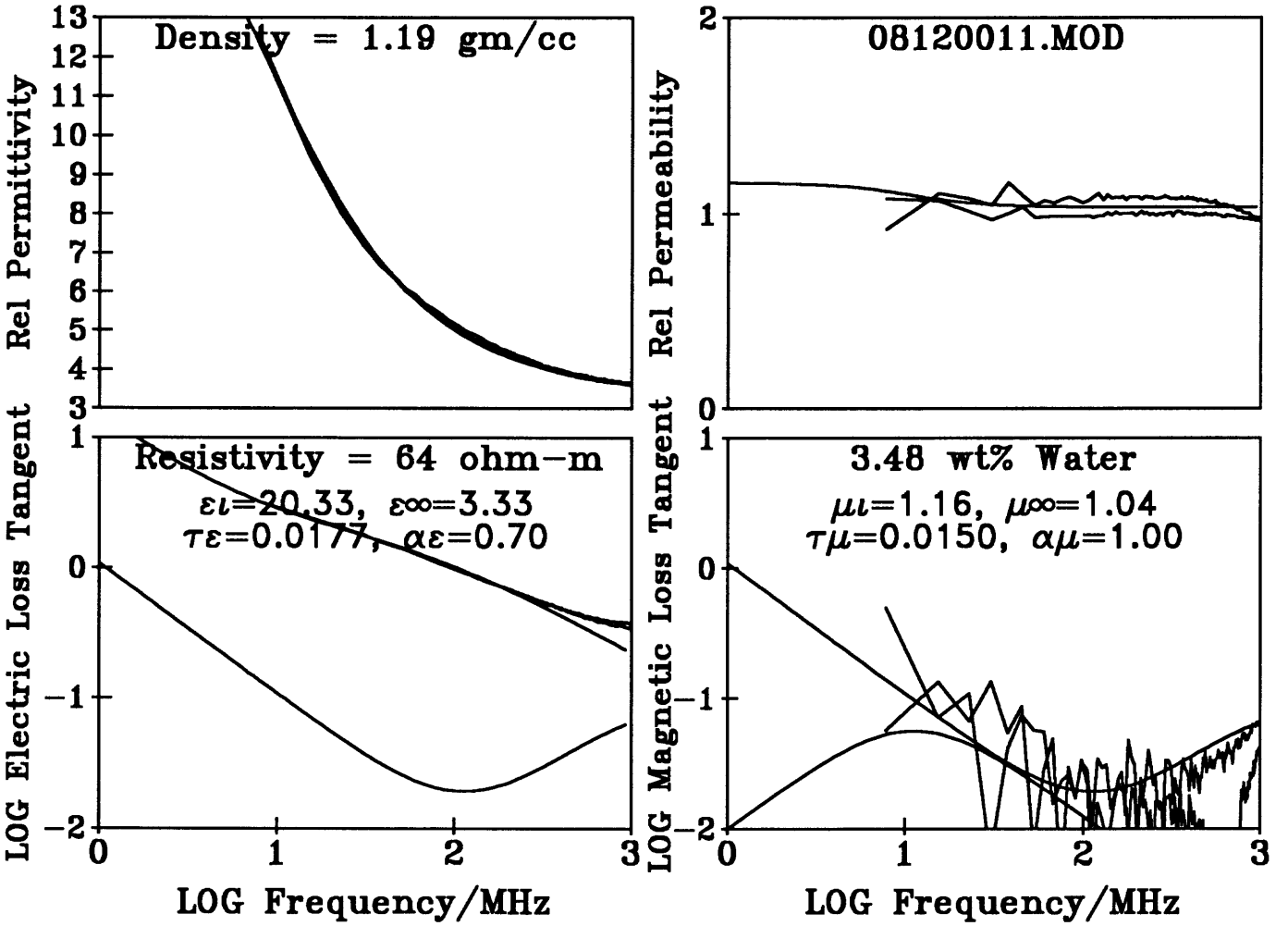



Figure 66 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

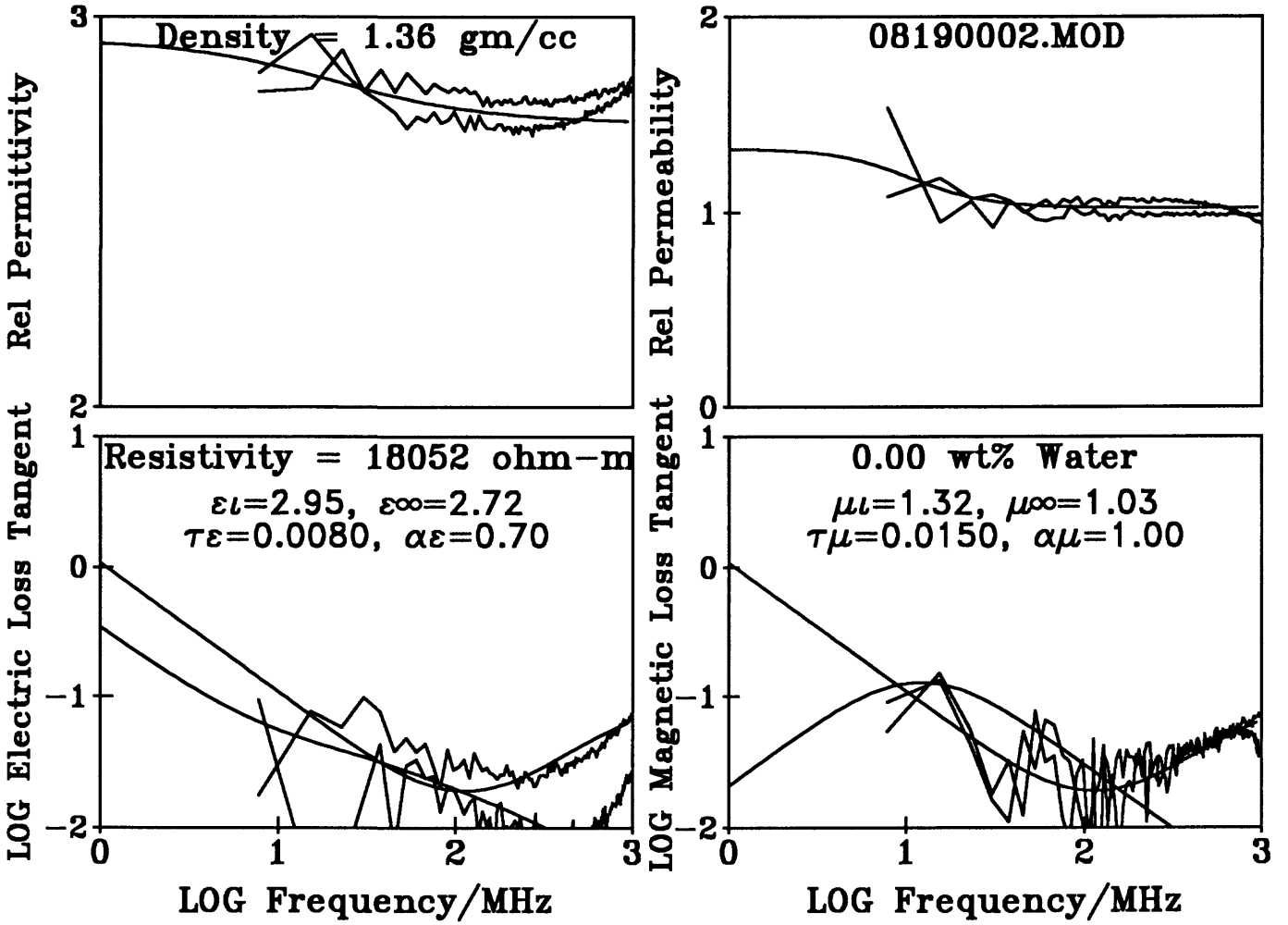

Density = 1.36 gm/cc
08190002.MOD
Rel Permittivity
Rel Permeability
Resistivity = 18052 ohm-m
ει=2.95, ε∞=2.72
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.32, μ∞=1.03
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2040m Butler S1.0 1.0m depth #2 vacuum dried

Figure 67 -

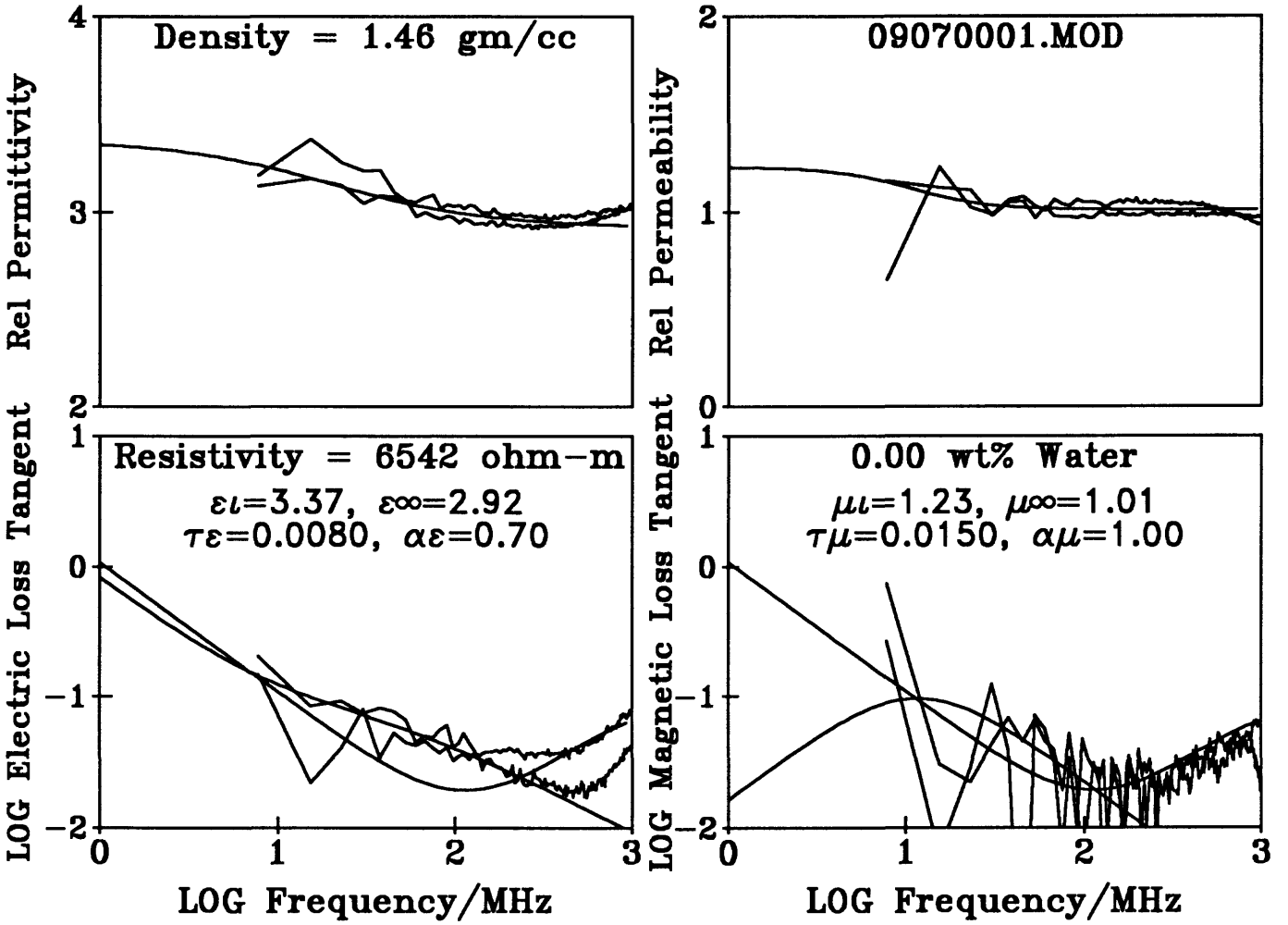

Density = 1.46 gm/cc
09070001.MOD
Resistivity = 6542 ohm-m
ει=3.37, ε∞=2.92
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.23, μ∞=1.01
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent Rel Permittivity
LOG Magnetic Loss Tangent Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2040m Butler S1.0 1.0m depth #3 vacuum dried

Figure 68 -

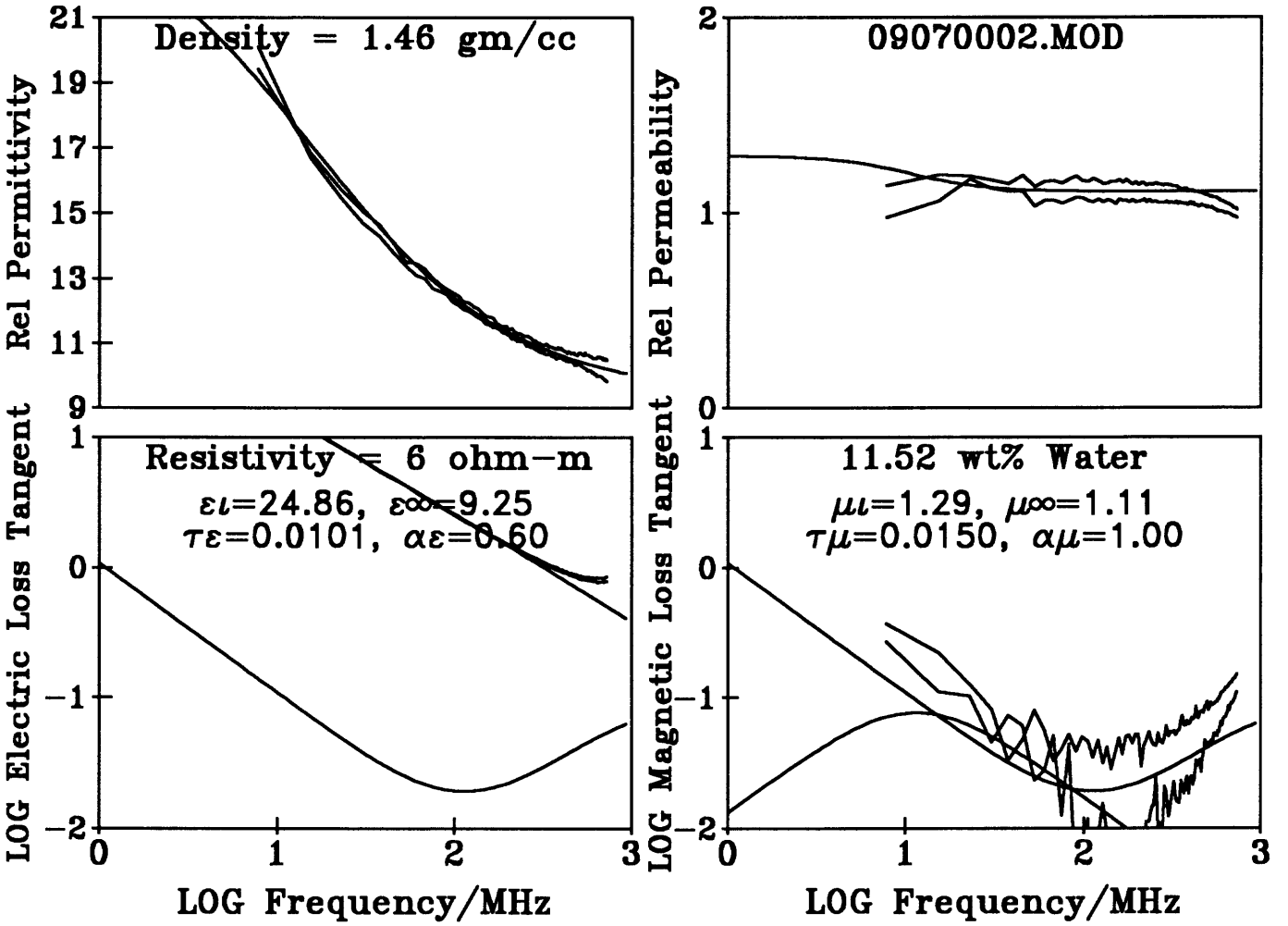

Density = 1.46 gm/cc
09070002.MOD
Resistivity = 6 ohm-m
ει=24.86, ε∞=9.25
τε=0.0101, αε=0.60
11.52 wt% Water
μι=1.29, μ∞=1.11
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2040m Butler S1.0 1.0m depth #3 10 drops water

Figure 69 -

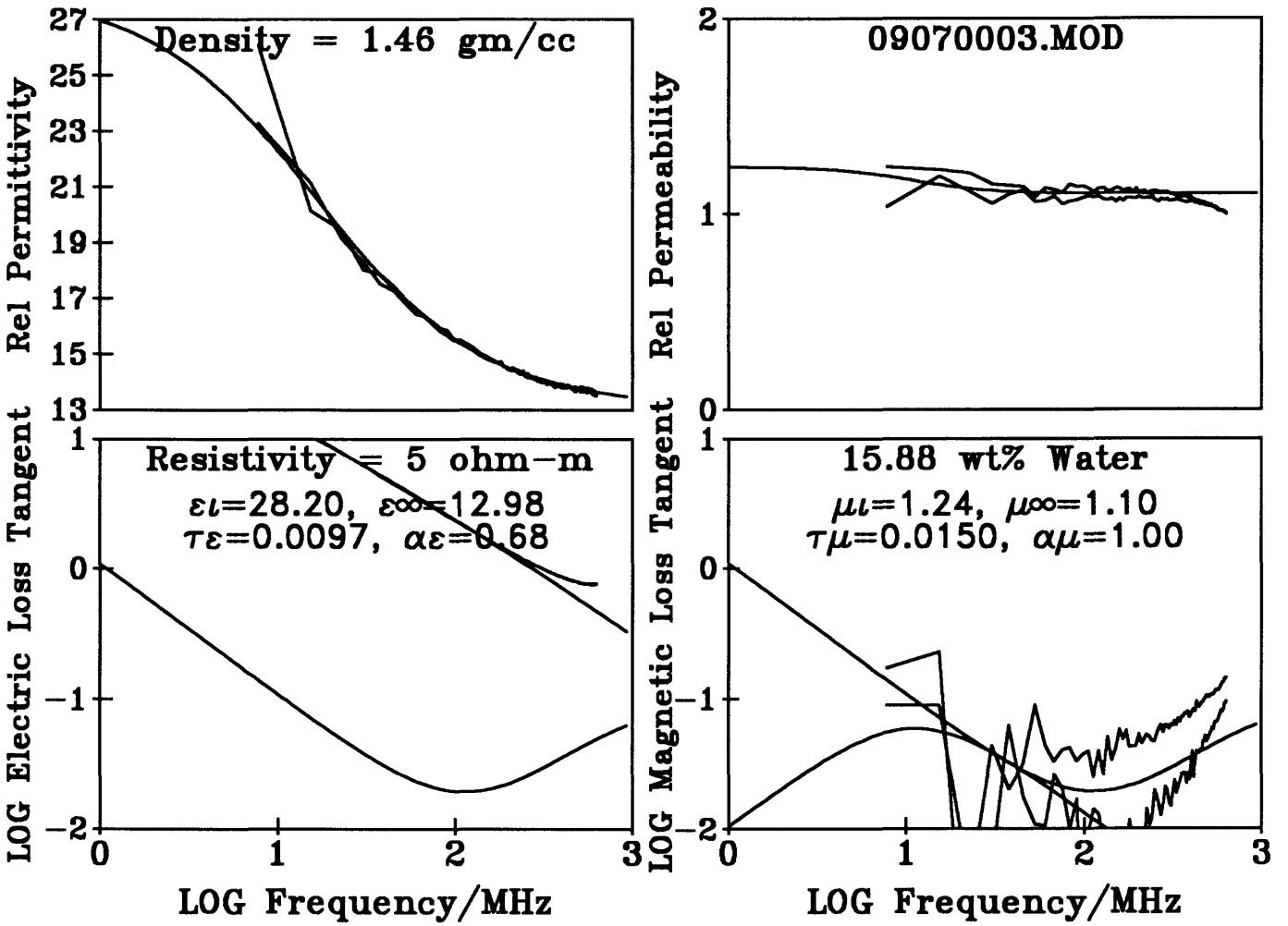

Density = 1.46 gm/cc
09070003.MOD
Resistivity = 5 ohm-m
ει=28.20, ε∞=12.98
τε=0.0097, αε=0.68
15.88 wt% Water
μι=1.24, μ∞=1.10
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2040m Butler S1.0 1.0m depth #3 water saturated

Figure 70 -

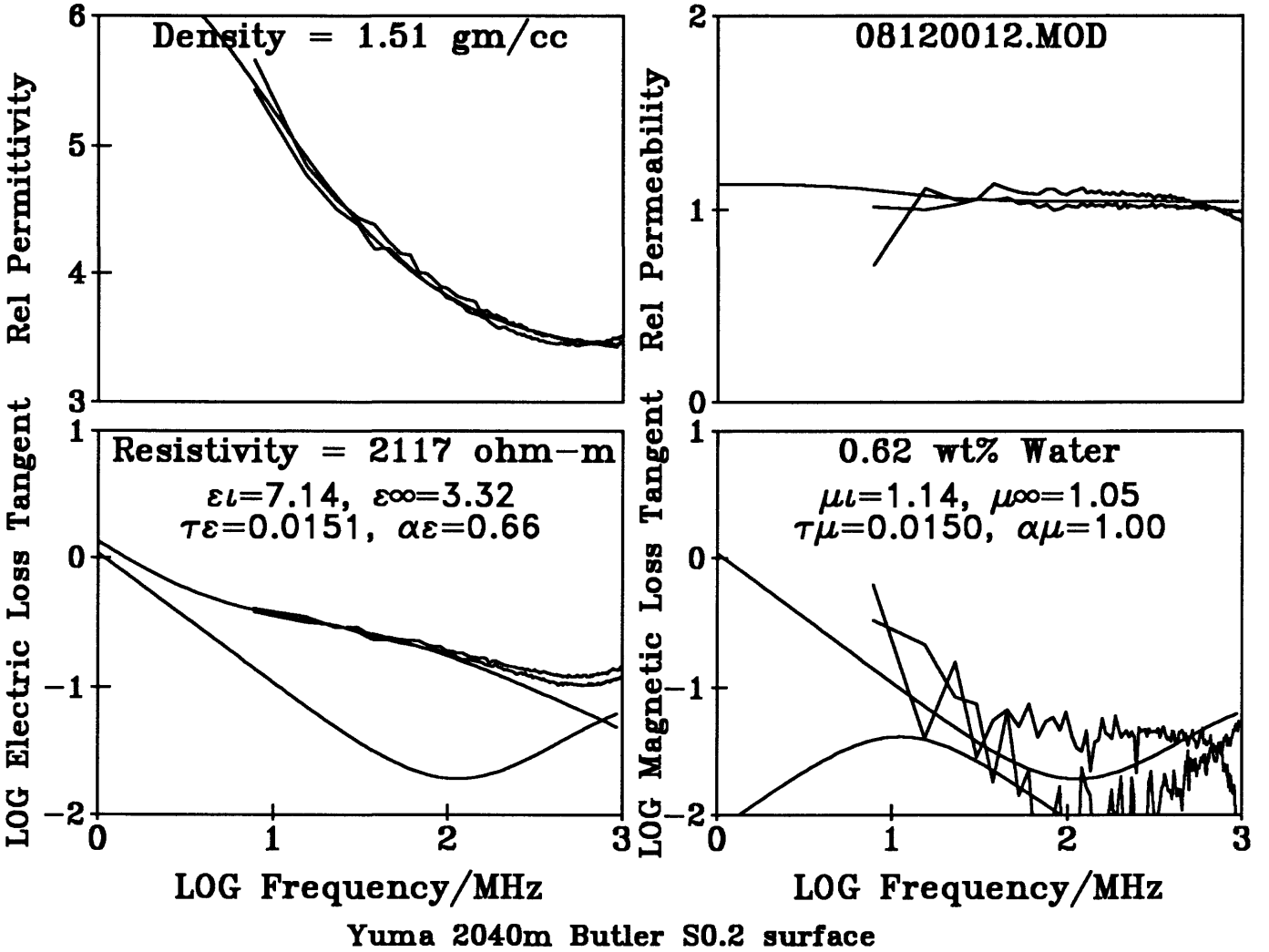



Figure 71 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

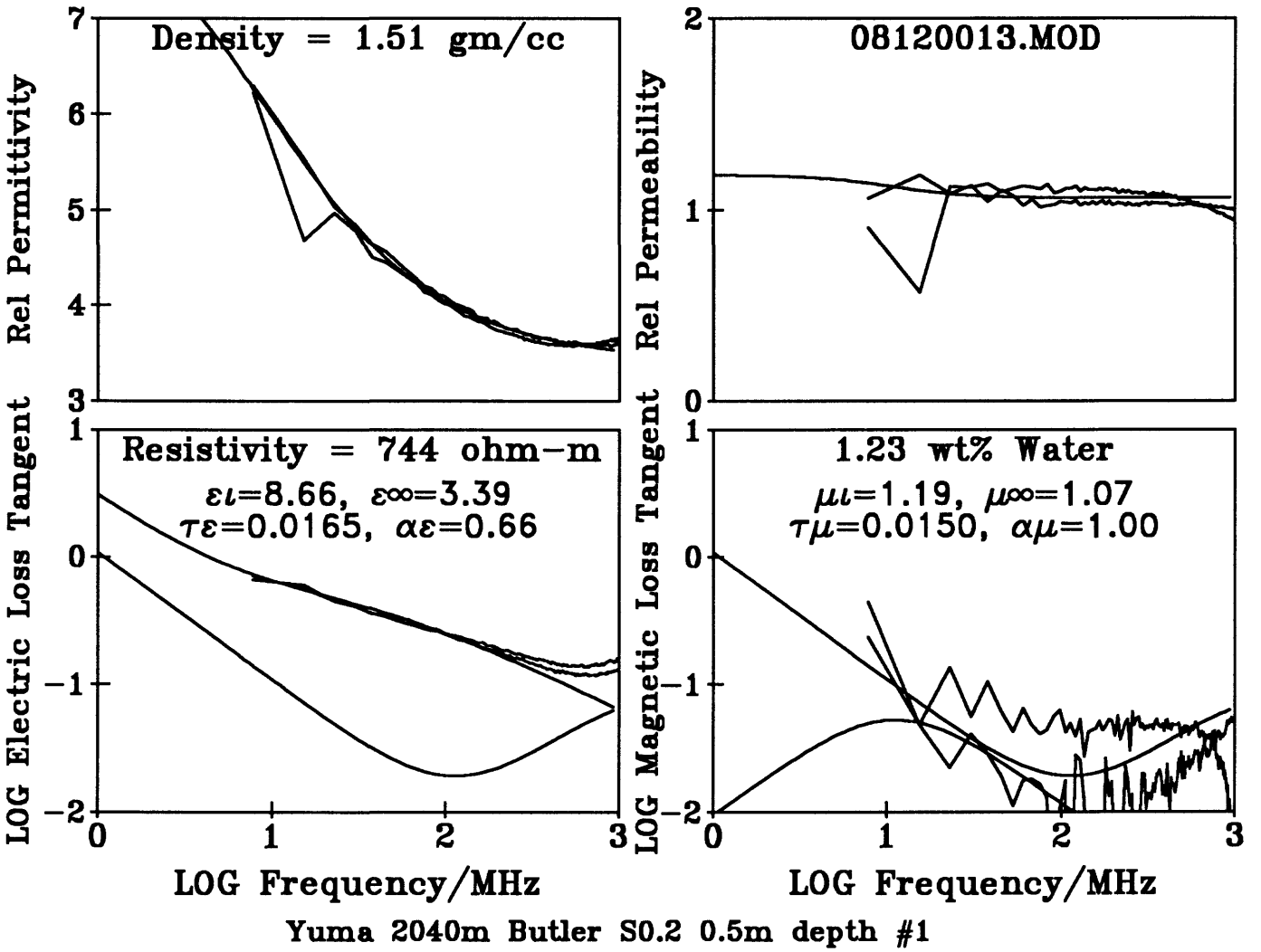



Figure 72 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

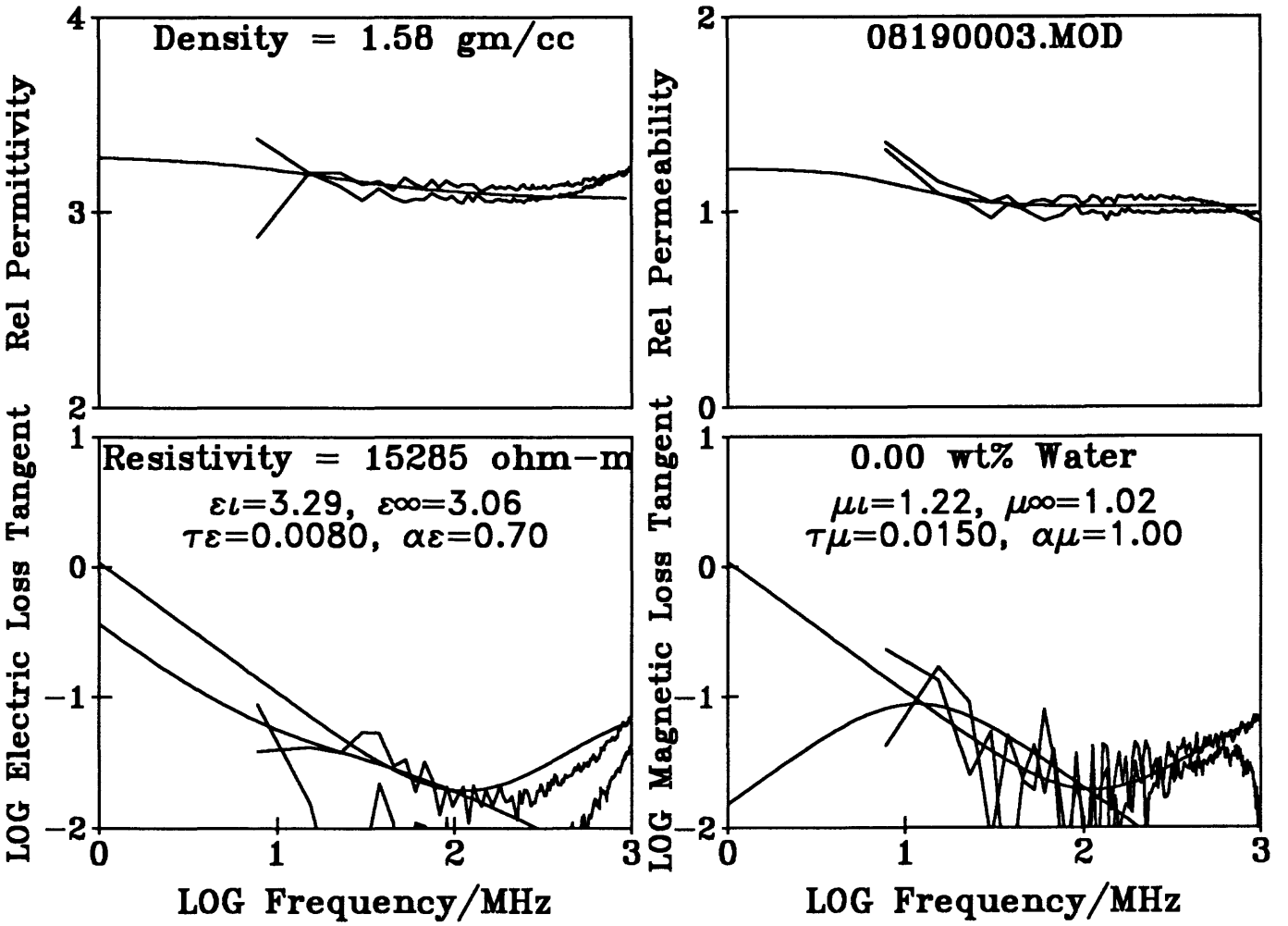

Density = 1.58 gm/cc
08190003.MOD
Rel Permittivity
Rel Permeability
Resistivity = 15285 ohm-m
ει=3.29, ε∞=3.06
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.22, μ∞=1.02
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2040m Butler S0.2 0.5m depth #2 vacuum dried

Figure 73 -

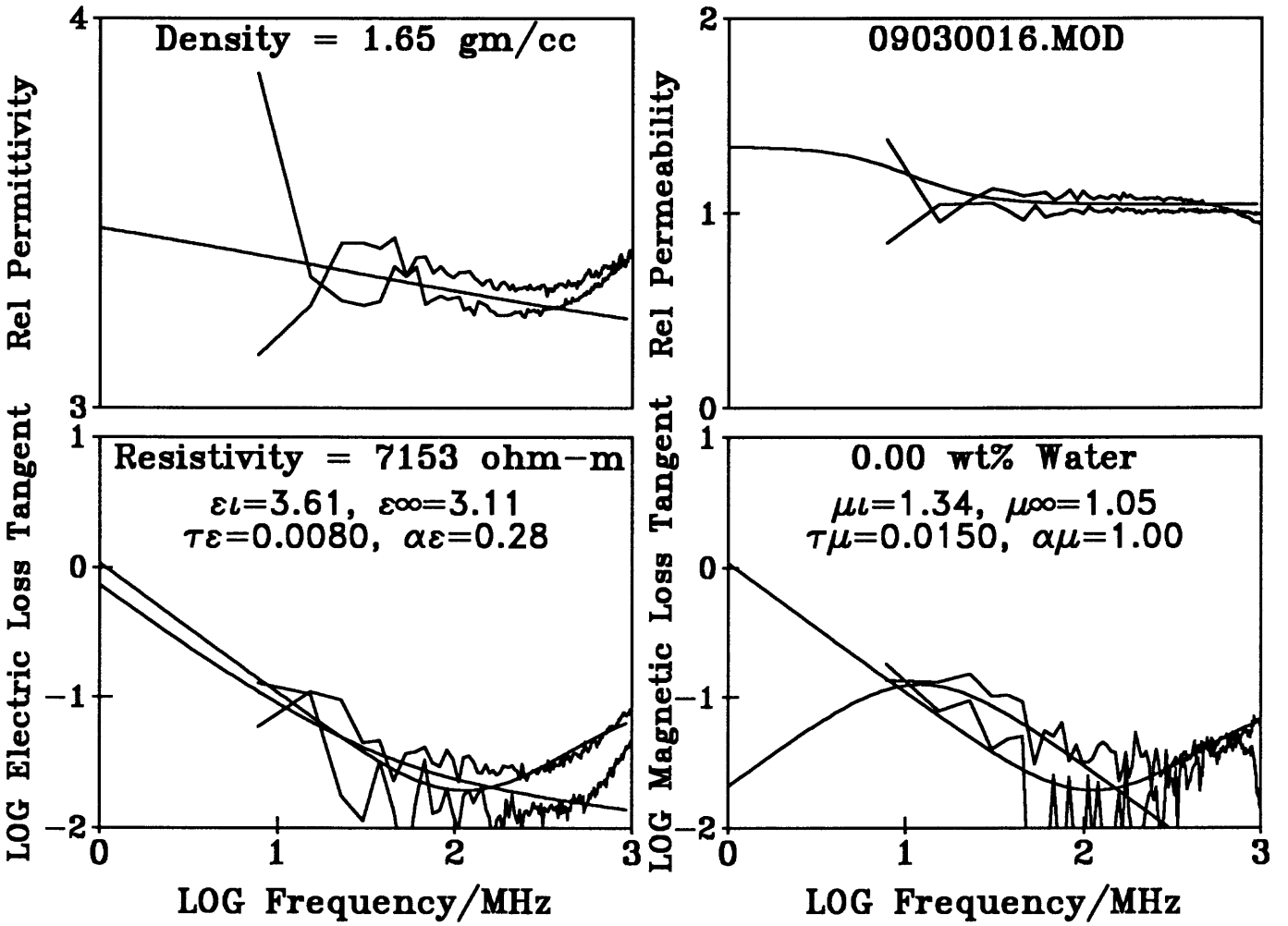

Density = 1.65 gm/cc
09030016.MOD
Resistivity = 7153 ohm-m
ει=3.61, ε∞=3.11
τε=0.0080, αε=0.28
0.00 wt% Water
μι=1.34, μ∞=1.05
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2040m Butler S0.2 0.5m depth #3 vacuum dried

Figure 74 -

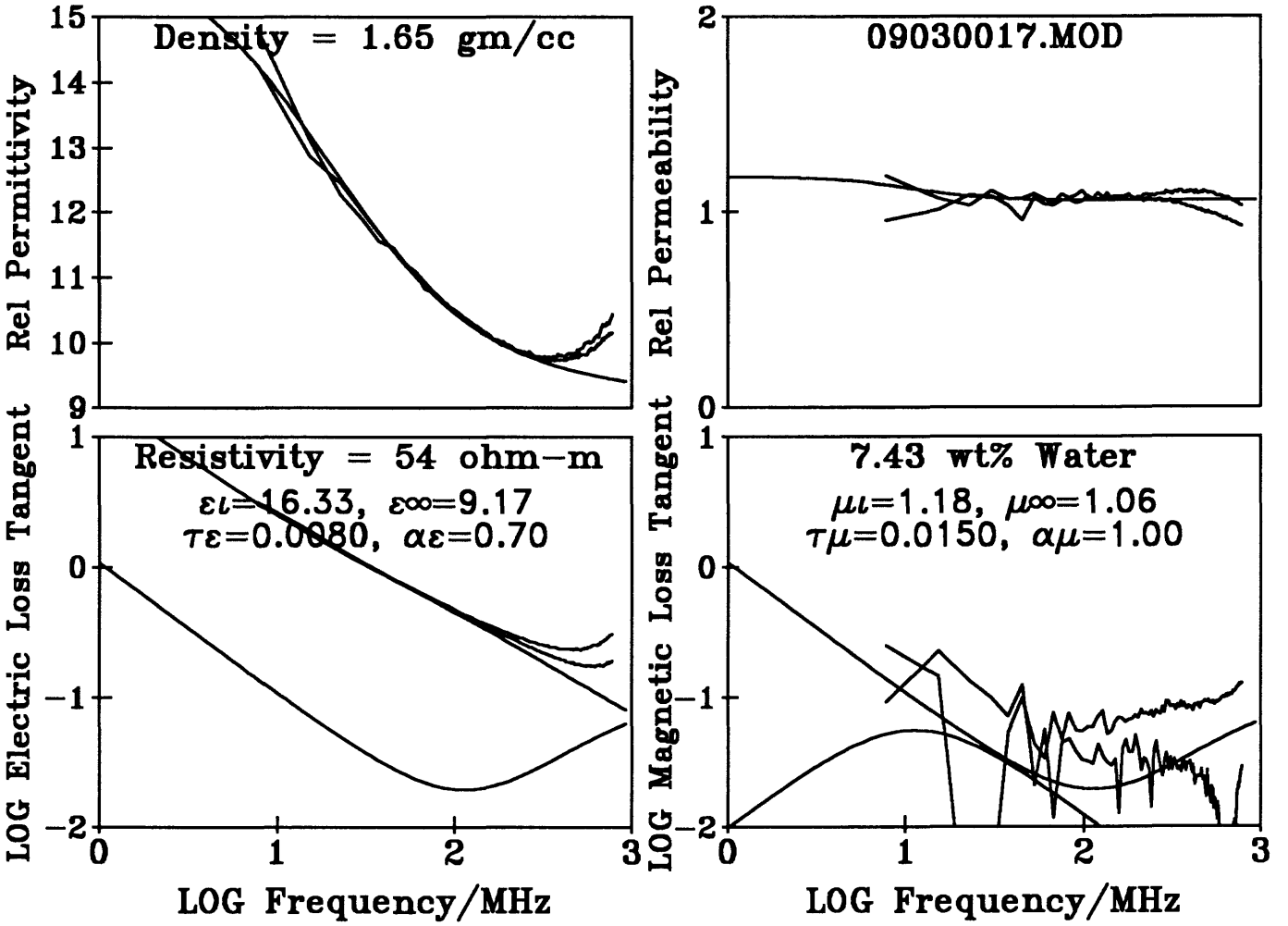

Density = 1.65 gm/cc
09030017.MOD
Resistivity = 54 ohm-m
ει=16.33, ε∞=9.17
τε=0.0080, αε=0.70
7.43 wt% Water
μι=1.18, μ∞=1.06
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2040m Butler S0.2 0.5m depth #3 8 drops water

Figure 75 -

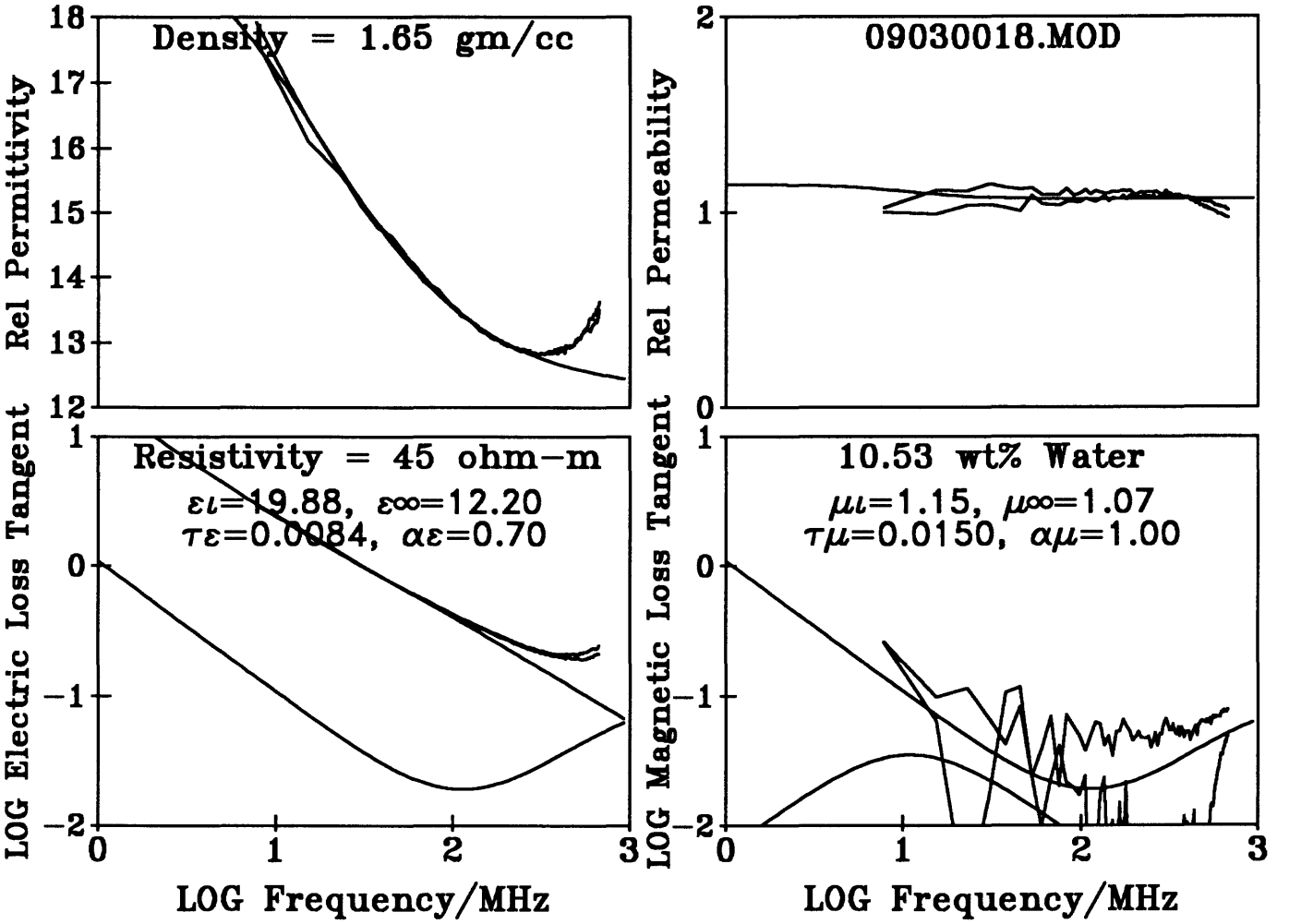

Density = 1.65 gm/cc
09030018.MOD
Rel Permittivity
Rel Permeability
Resistivity = 45 ohm-m
ει=19.88, ε∞=12.20
τε=0.0084, αε=0.70
10.53 wt% Water
μι=1.15, μ∞=1.07
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2040m Butler S0.2 0.5m depth #3 water saturated

Figure 76 -

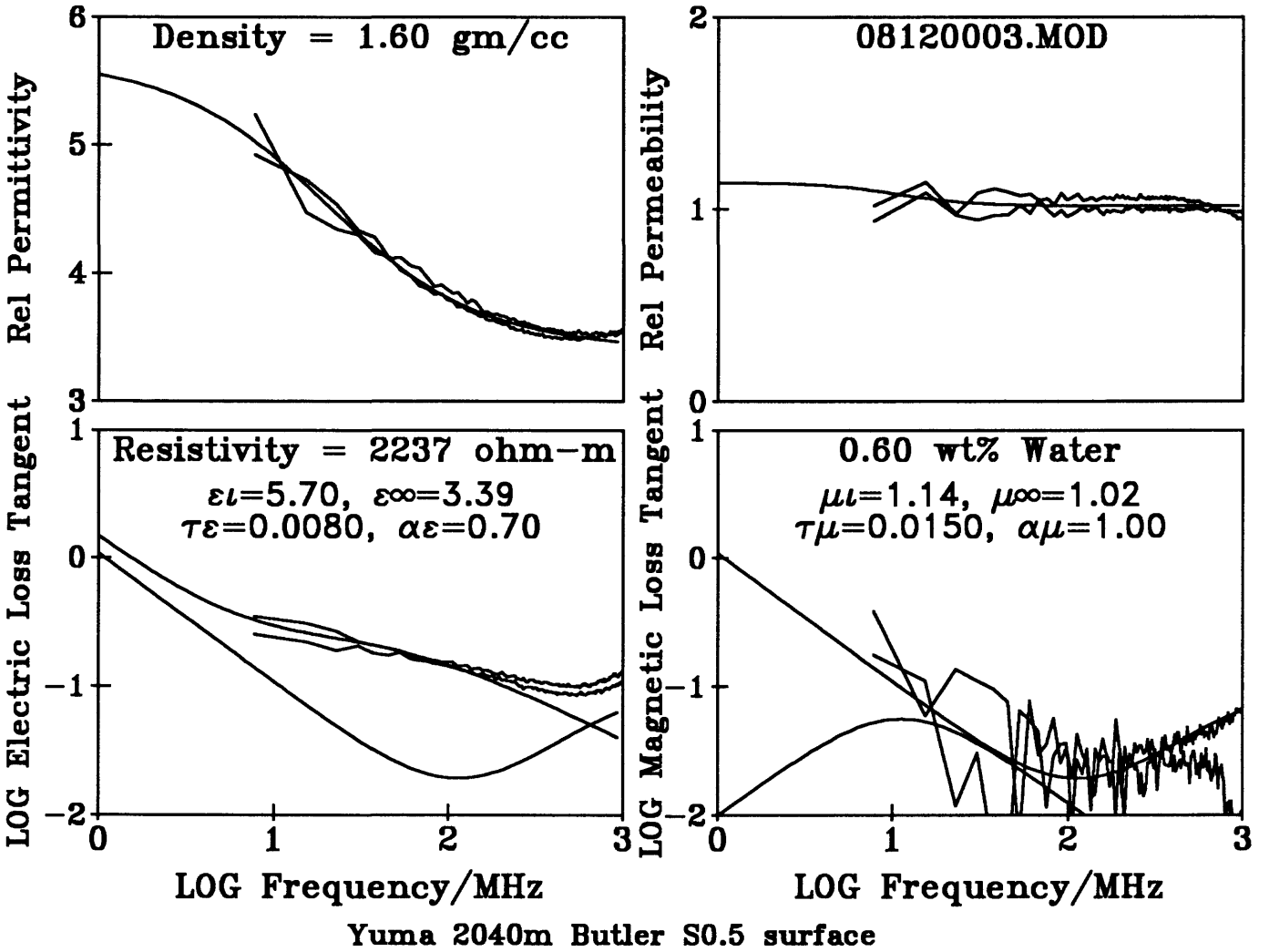



Figure 77 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

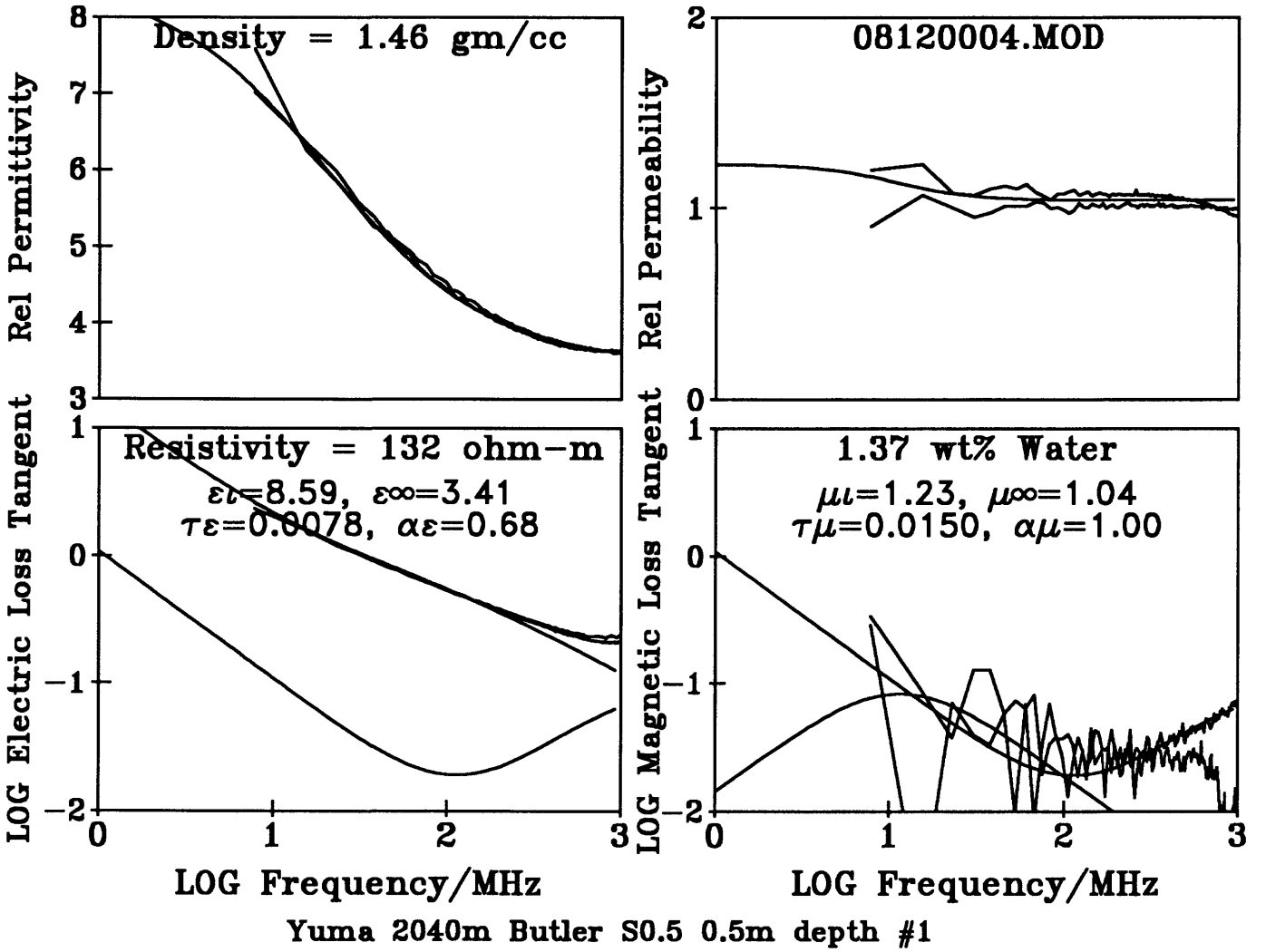



Figure 78 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

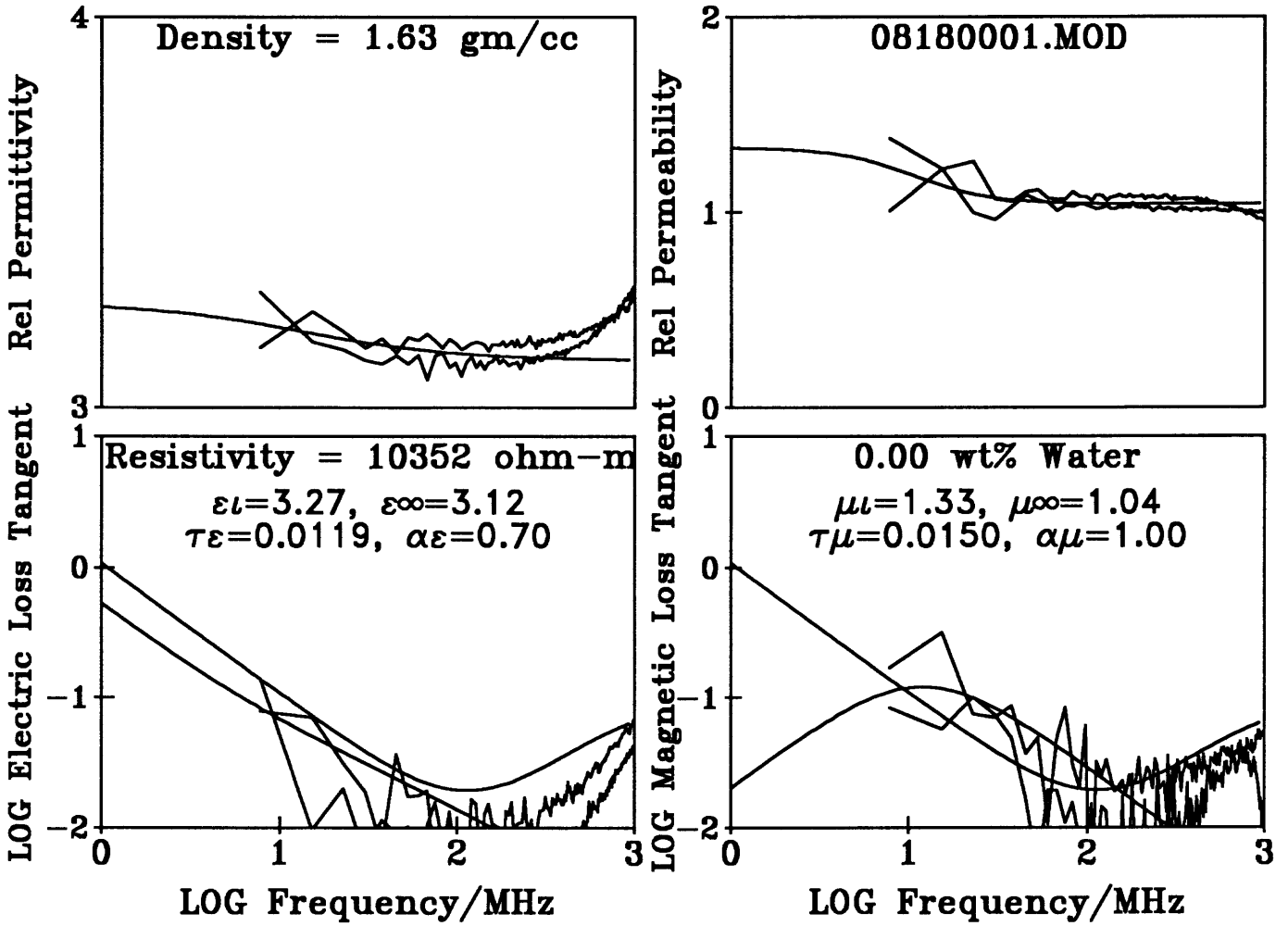

Density = 1.63 gm/cc
08180001.MOD
Resistivity = 10352 ohm-m
ει=3.27, ε∞=3.12
τε=0.0119, αε=0.70
0.00 wt% Water
μι=1.33, μ∞=1.04
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
Rel Permittivity
LOG Magnetic Loss Tangent
Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2040m Butler S0.5 0.5m depth #2 vacuum dried

Figure 79 -

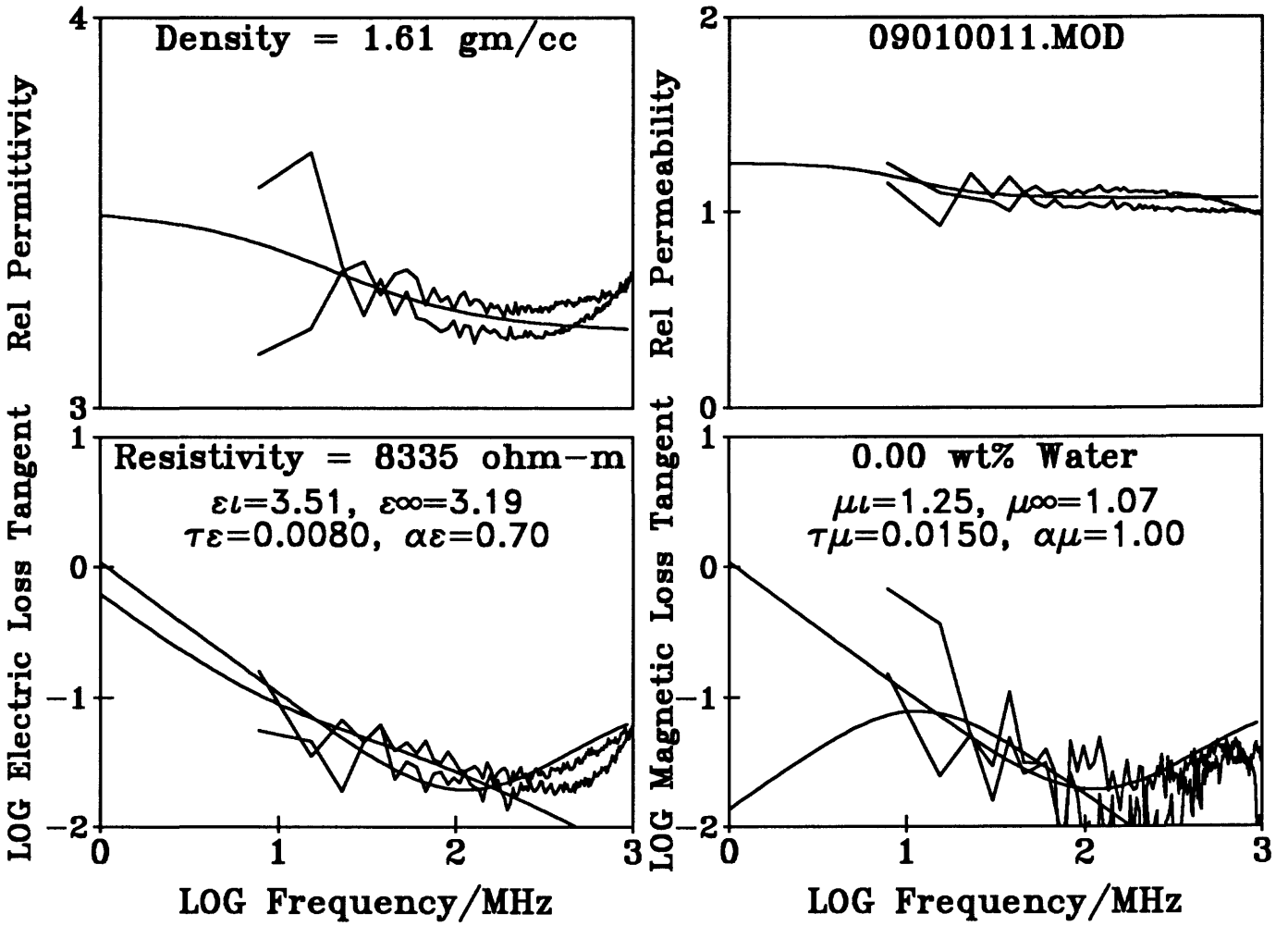

Density = 1.61 gm/cc
09010011.MOD
Resistivity = 8335 ohm-m
ει=3.51, ε∞=3.19
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.25, μ∞=1.07
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2040m Butler S0.5 0.5m depth #3 vacuum dried

Figure 80 -

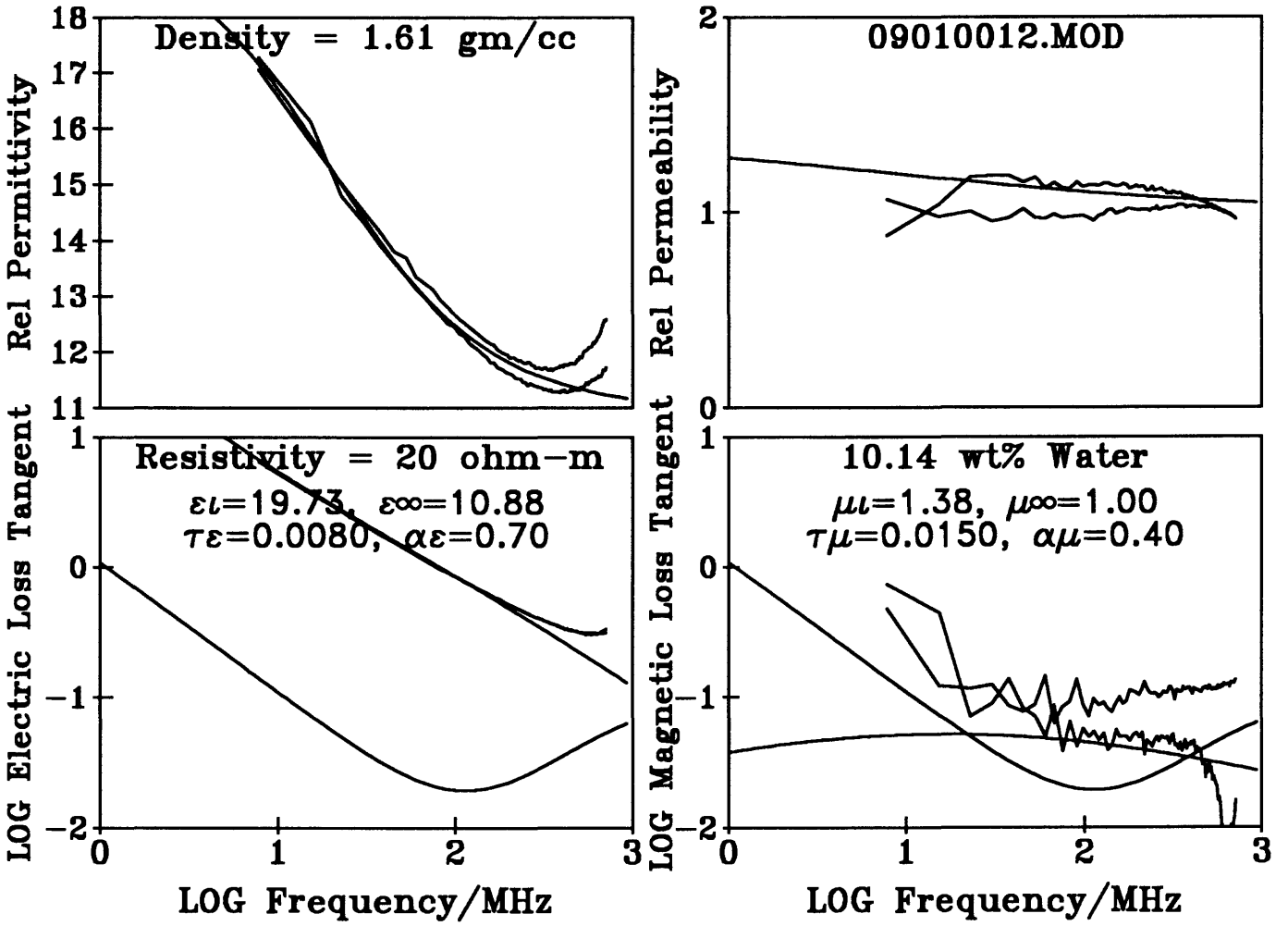

Density = 1.61 gm/cc
09010012.MOD
Resistivity = 20 ohm-m
ει=19.73, ε∞=10.88
τε=0.0080, αε=0.70
10.14 wt% Water
μι=1.38, μ∞=1.00
τμ=0.0150, αμ=0.40
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2040m Butler S0.5 0.5m depth #3 16 drops water

Figure 81 -

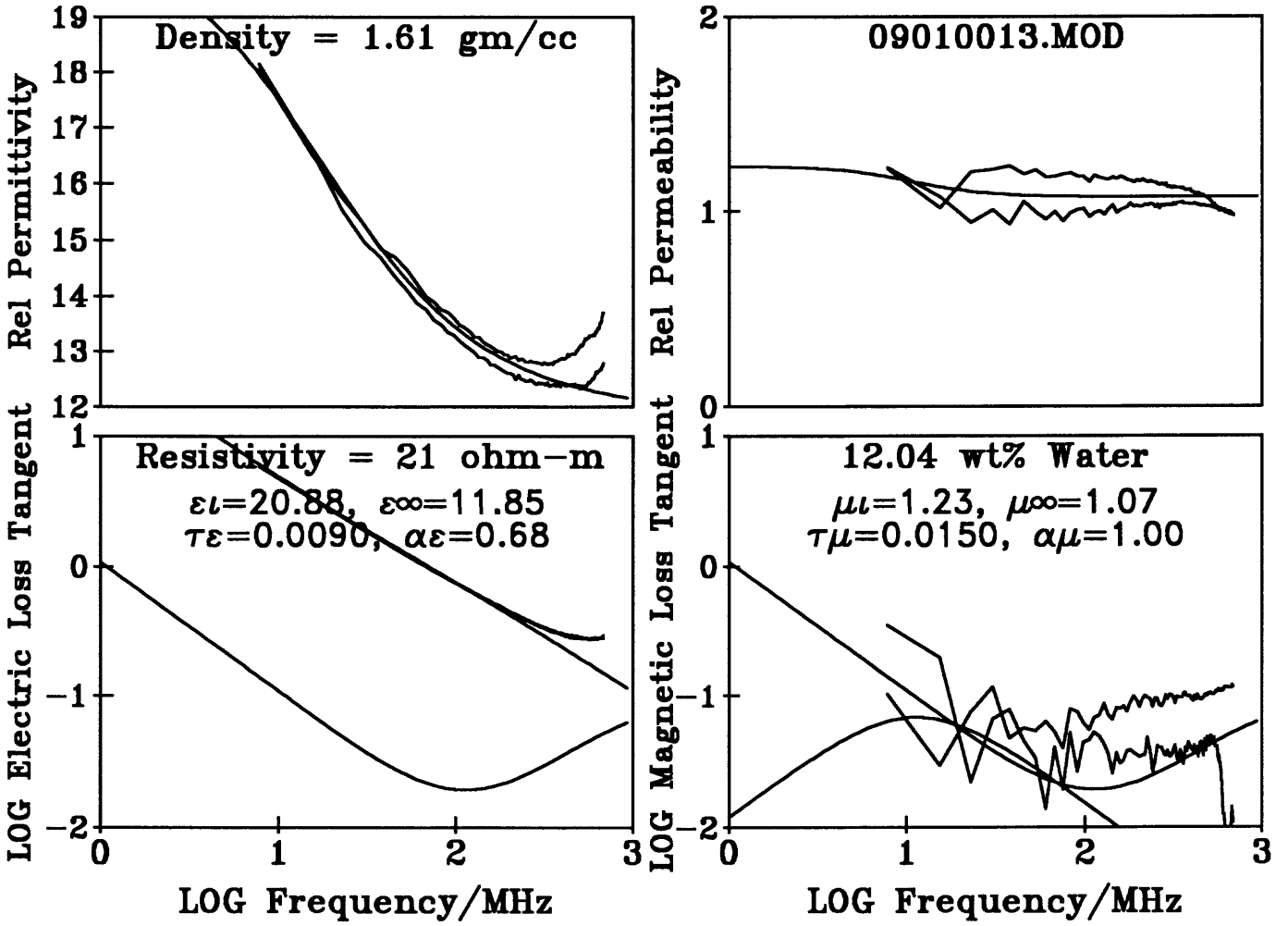

Density = 1.61 gm/cc
09010013.MOD
Resistivity = 21 ohm-m
ει=20.88, ε∞=11.85
τε=0.0090, αε=0.68
12.04 wt% Water
μι=1.23, μ∞=1.07
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2040m Butler S0.5 0.5m depth #3 water saturated

Figure 82 -

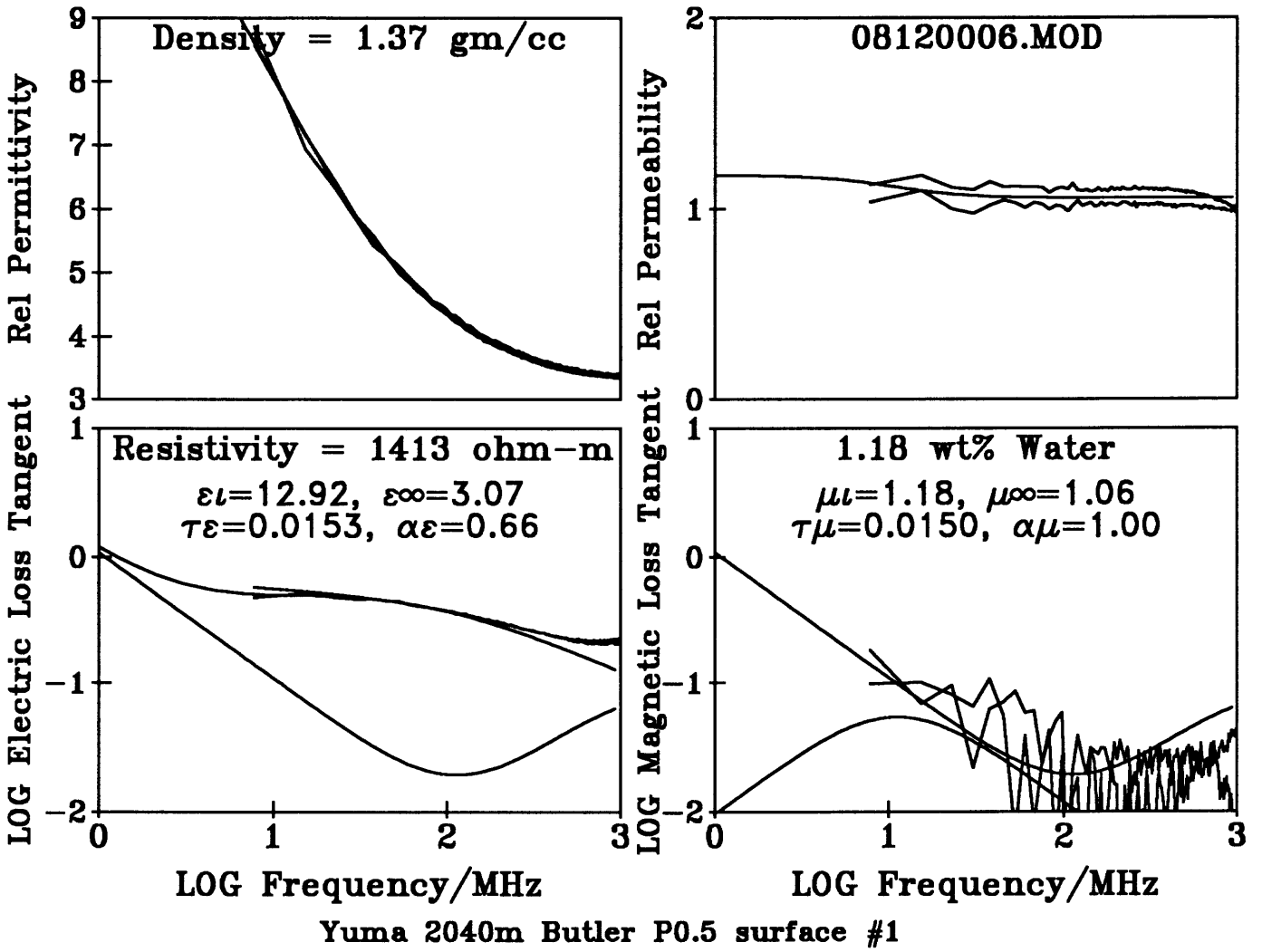



Figure 83 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

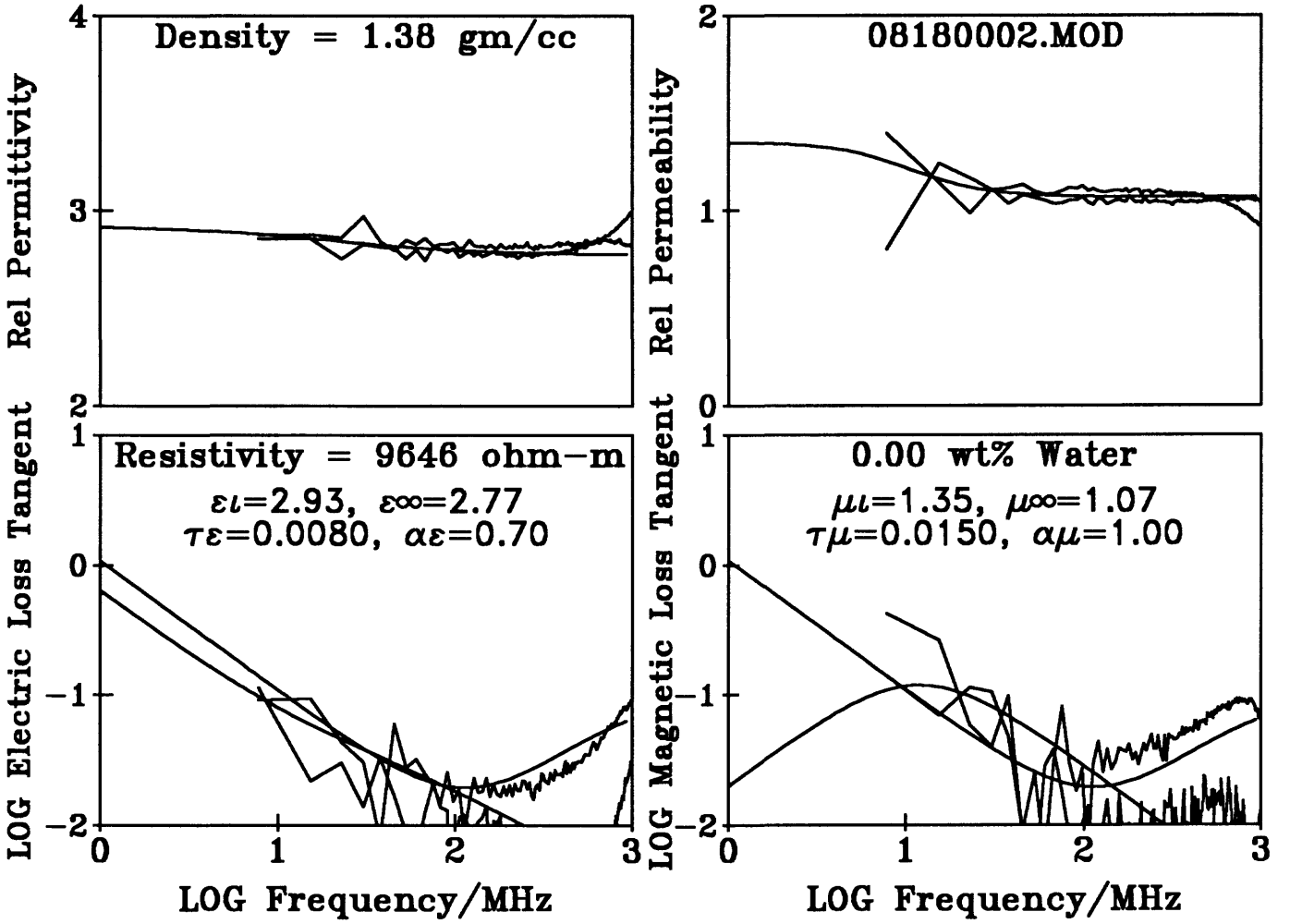

Density = 1.38 gm/cc
08180002.MOD
Resistivity = 9646 ohm-m
ει=2.93, ε∞=2.77
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.35, μ∞=1.07
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
Rel Permittivity
LOG Magnetic Loss Tangent
Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2040m Butler P0.5 surface #2 vacuum dried

Figure 84 -

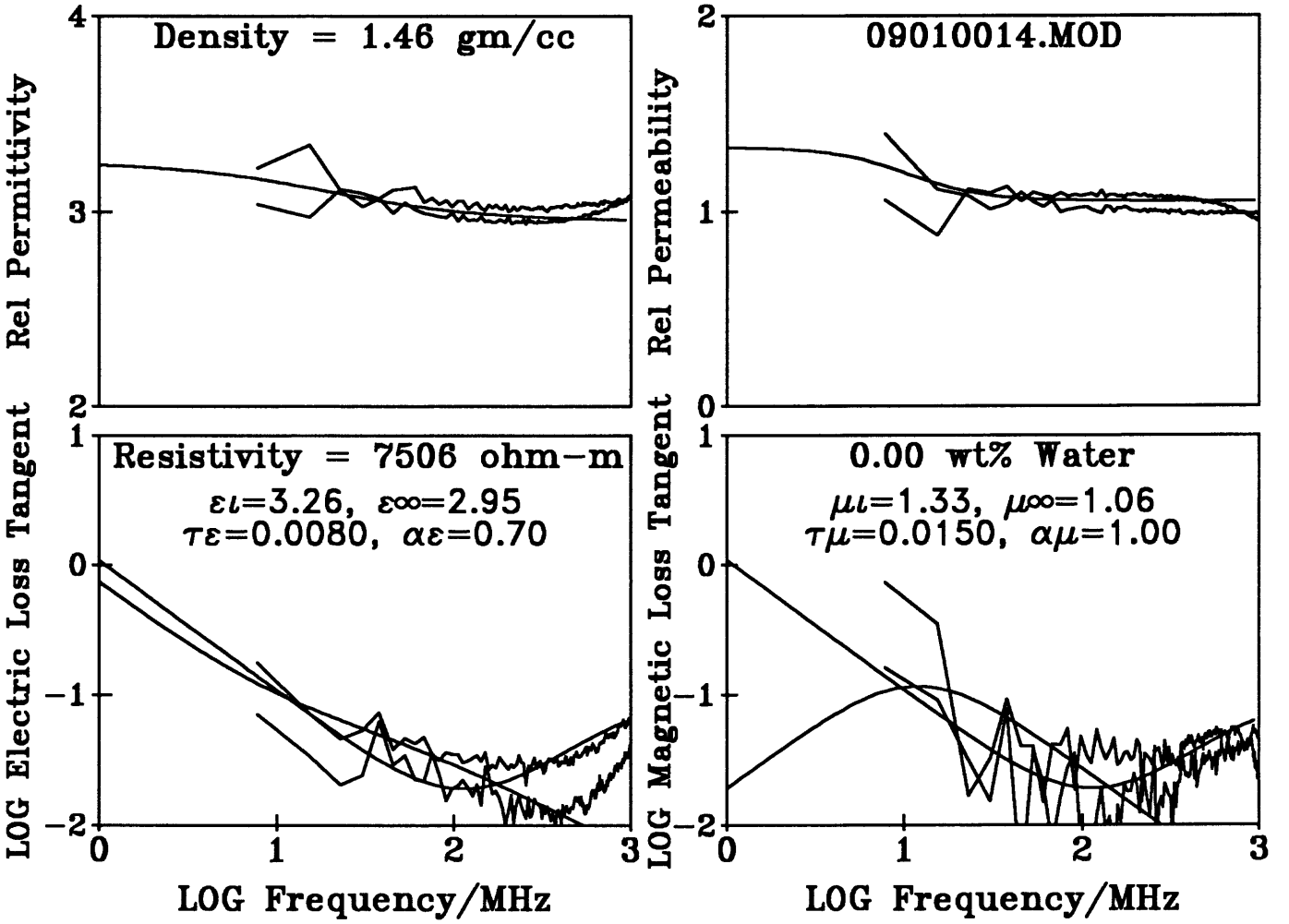

Density = 1.46 gm/cc
09010014.MOD
Resistivity = 7506 ohm-m
ει=3.26, ε∞=2.95
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.33, μ∞=1.06
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent Rel Permittivity
LOG Magnetic Loss Tangent Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2040m Butler P0.5 surface #3 vacuum dried

Figure 85 -

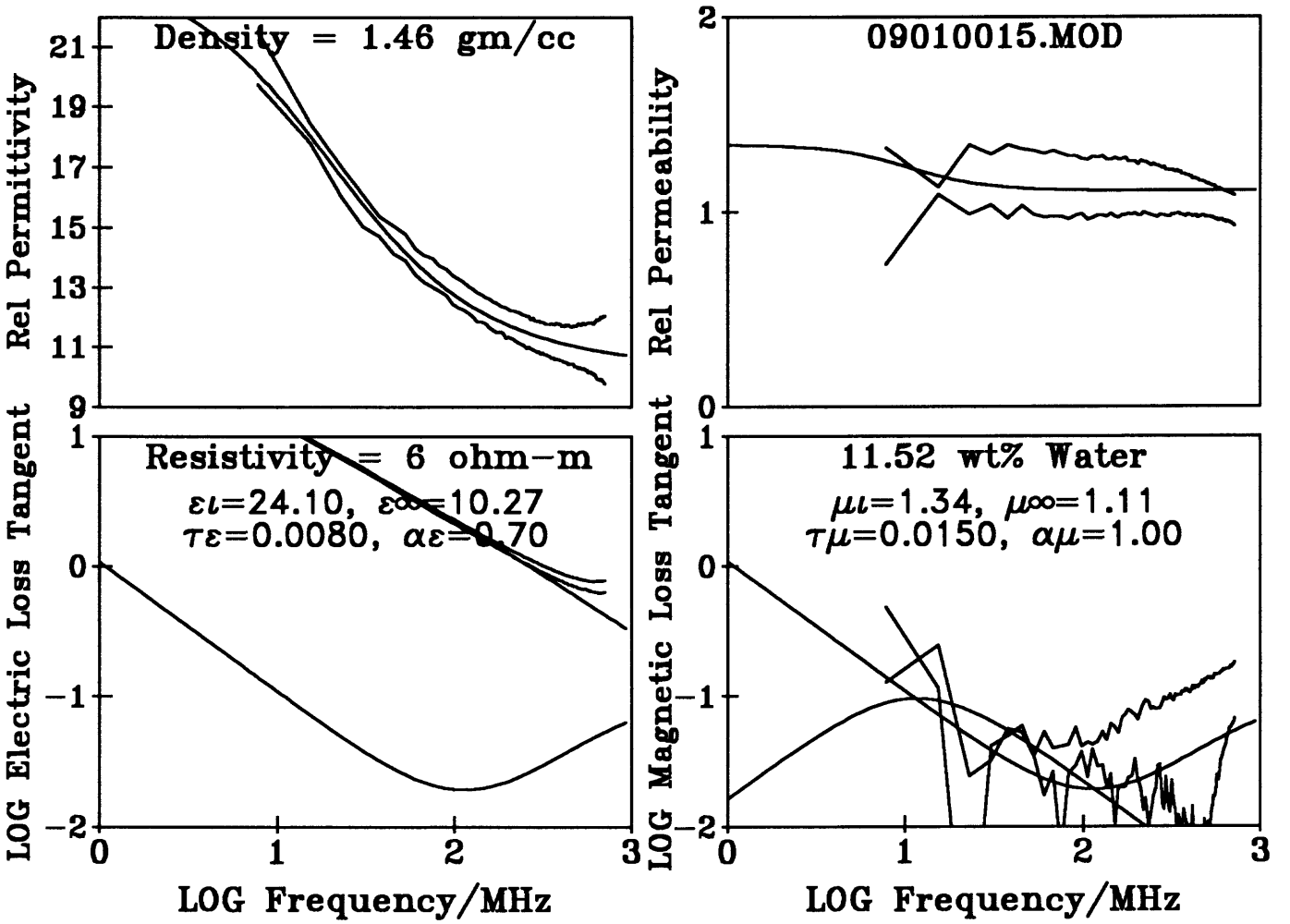

Density = 1.46 gm/cc
09010015.MOD
Rel Permittivity
Rel Permeability
Resistivity = 6 ohm-m
ει=24.10, ε∞=10.27
τε=0.0080, αε=0.70
11.52 wt% Water
μι=1.34, μ∞=1.11
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2040m Butler P0.5 surface #3 10 drops water

Figure 86 -

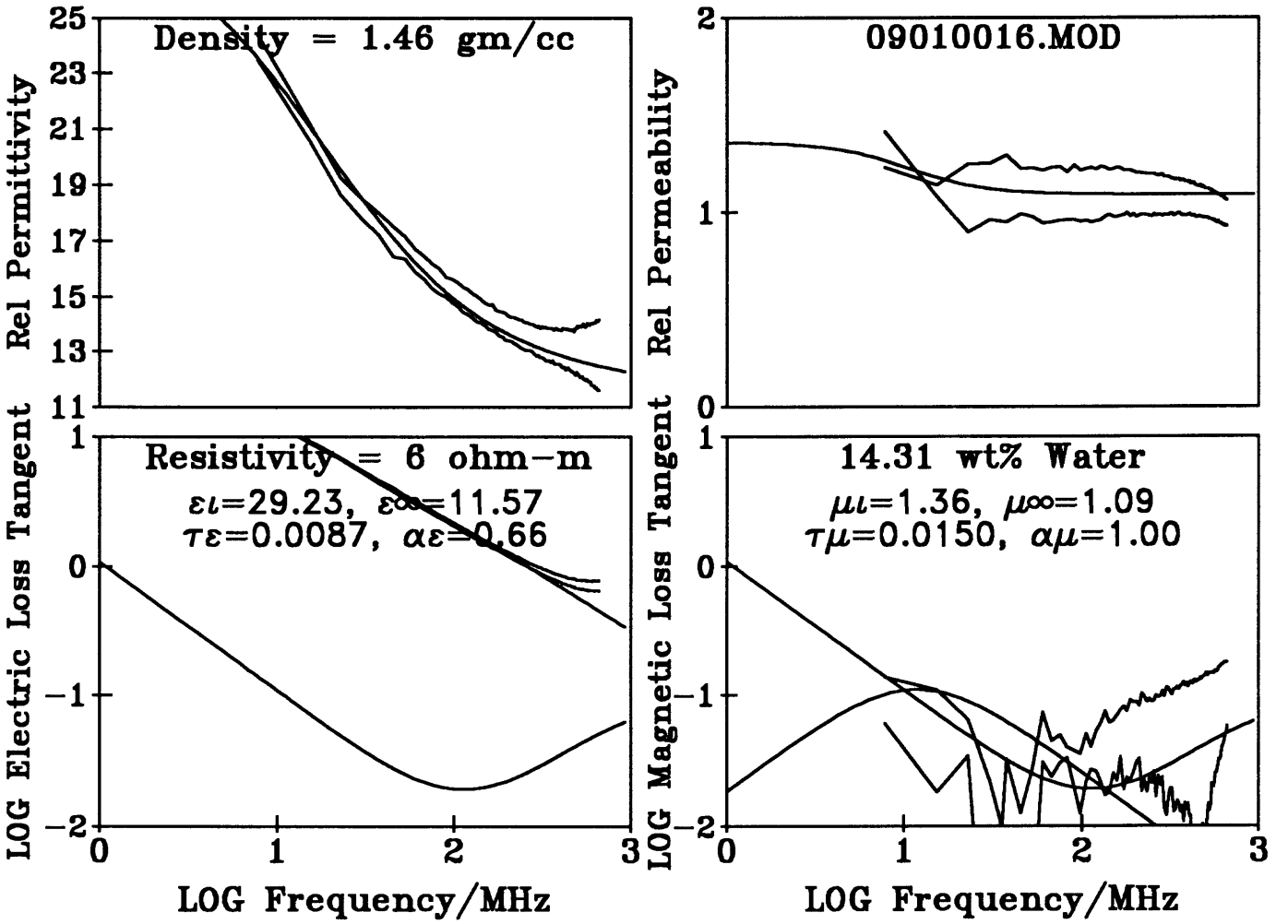

Density = 1.46 gm/cc
09010016.MOD
Resistivity = 6 ohm-m
ει=29.23, ε∞=11.57
τε=0.0087, αε=0.66
14.31 wt% Water
μι=1.36, μ∞=1.09
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2040 Butler P0.5 surface #3 water saturated

Figure 87 -

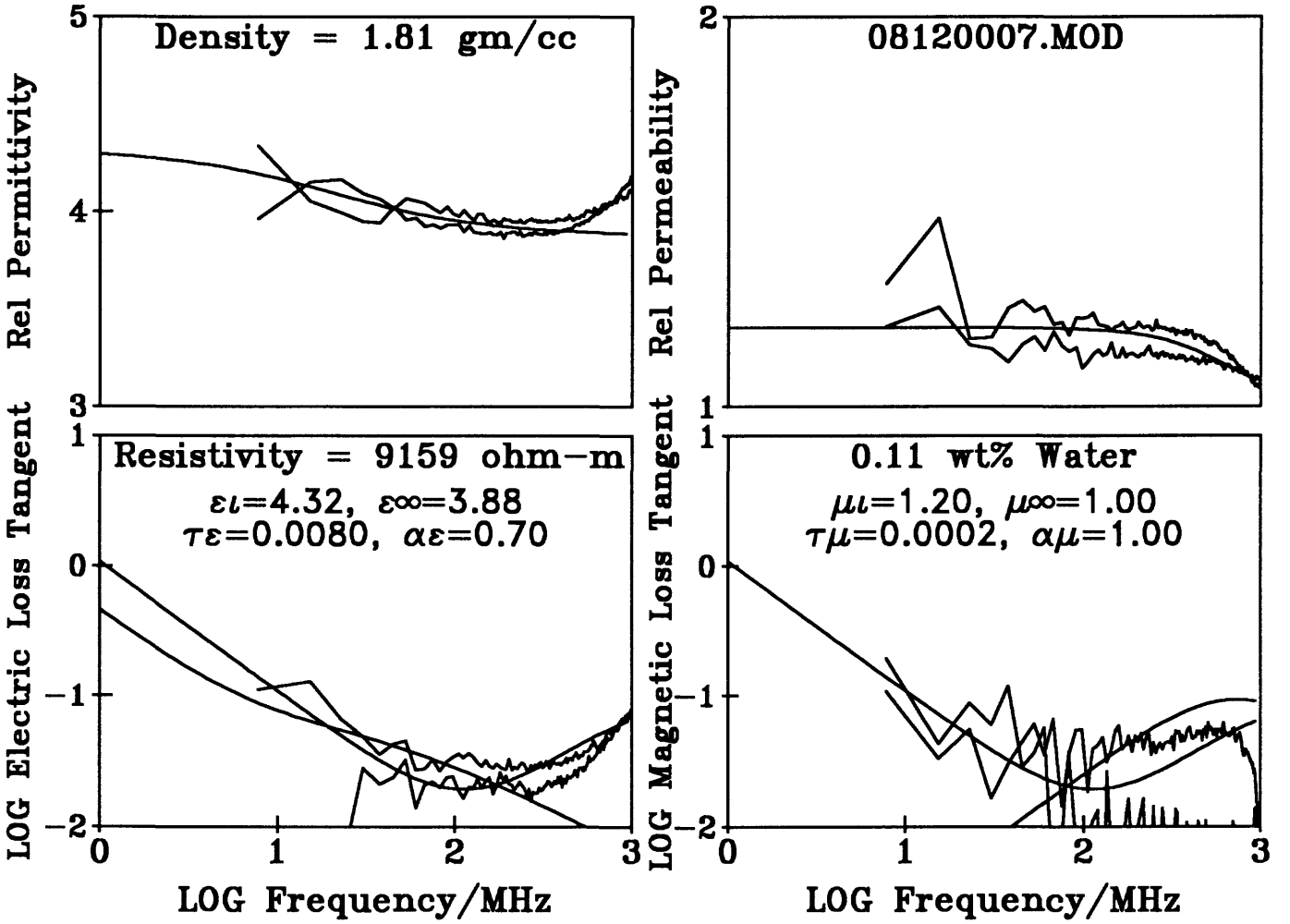



Figure 88 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

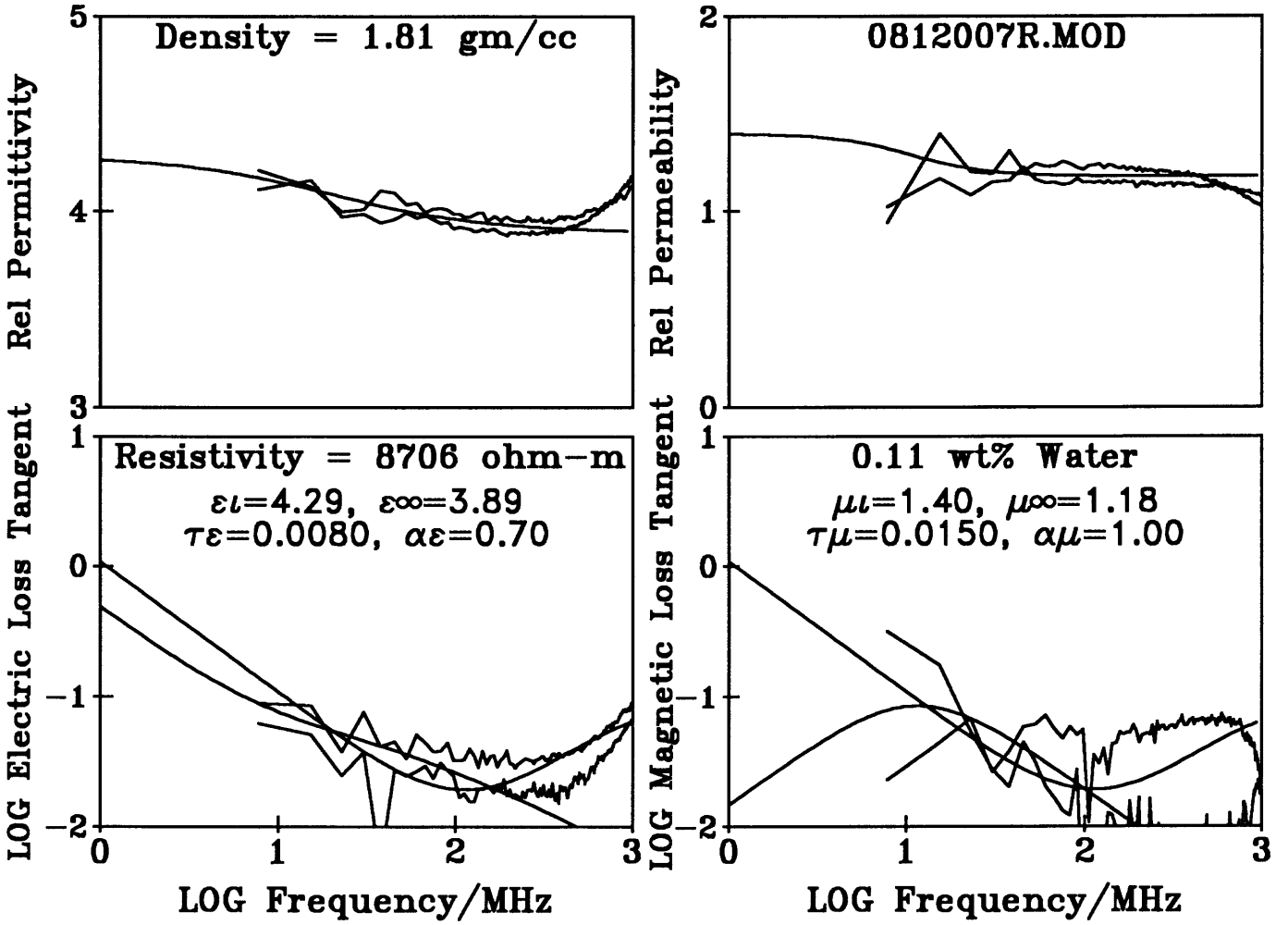
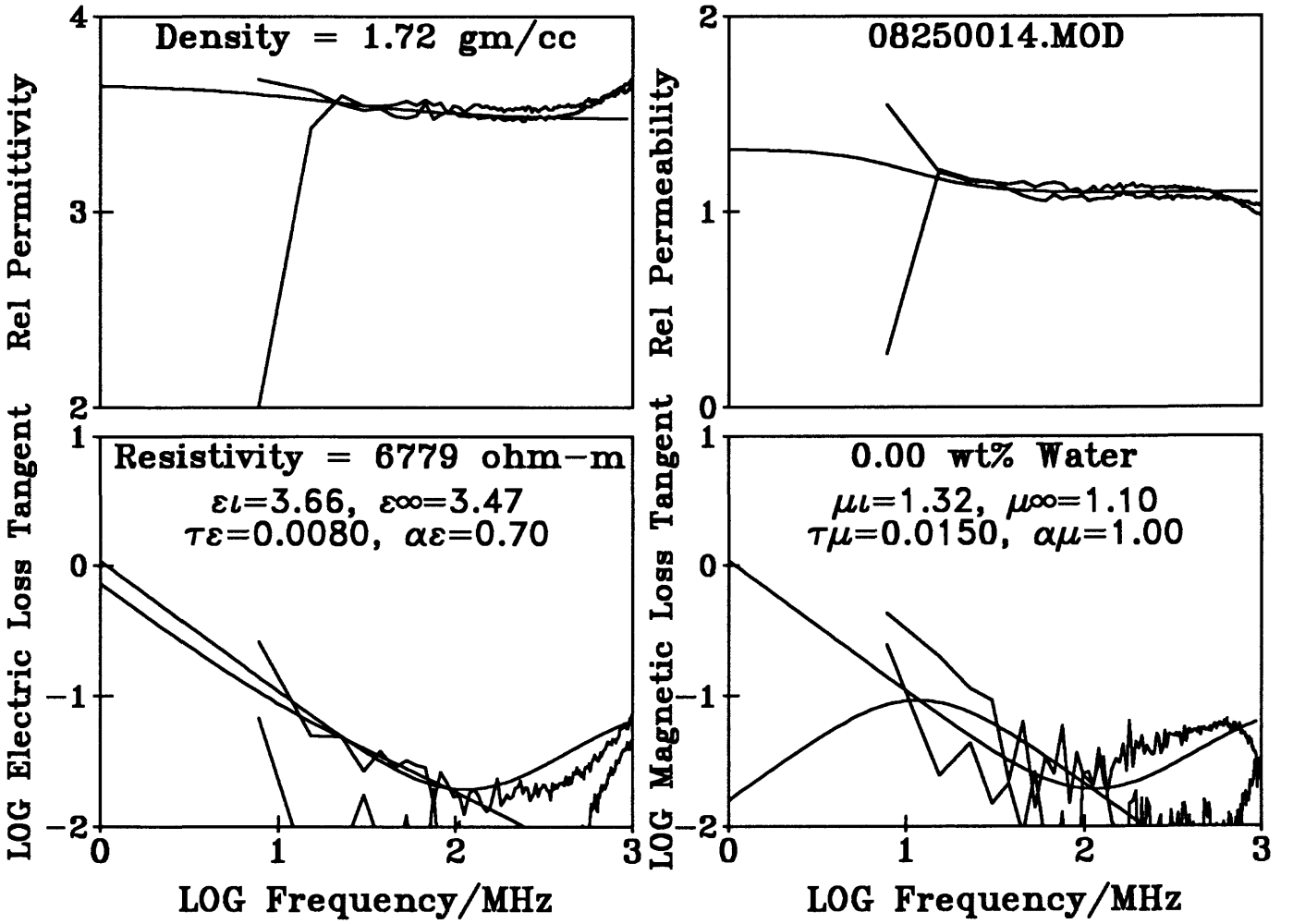
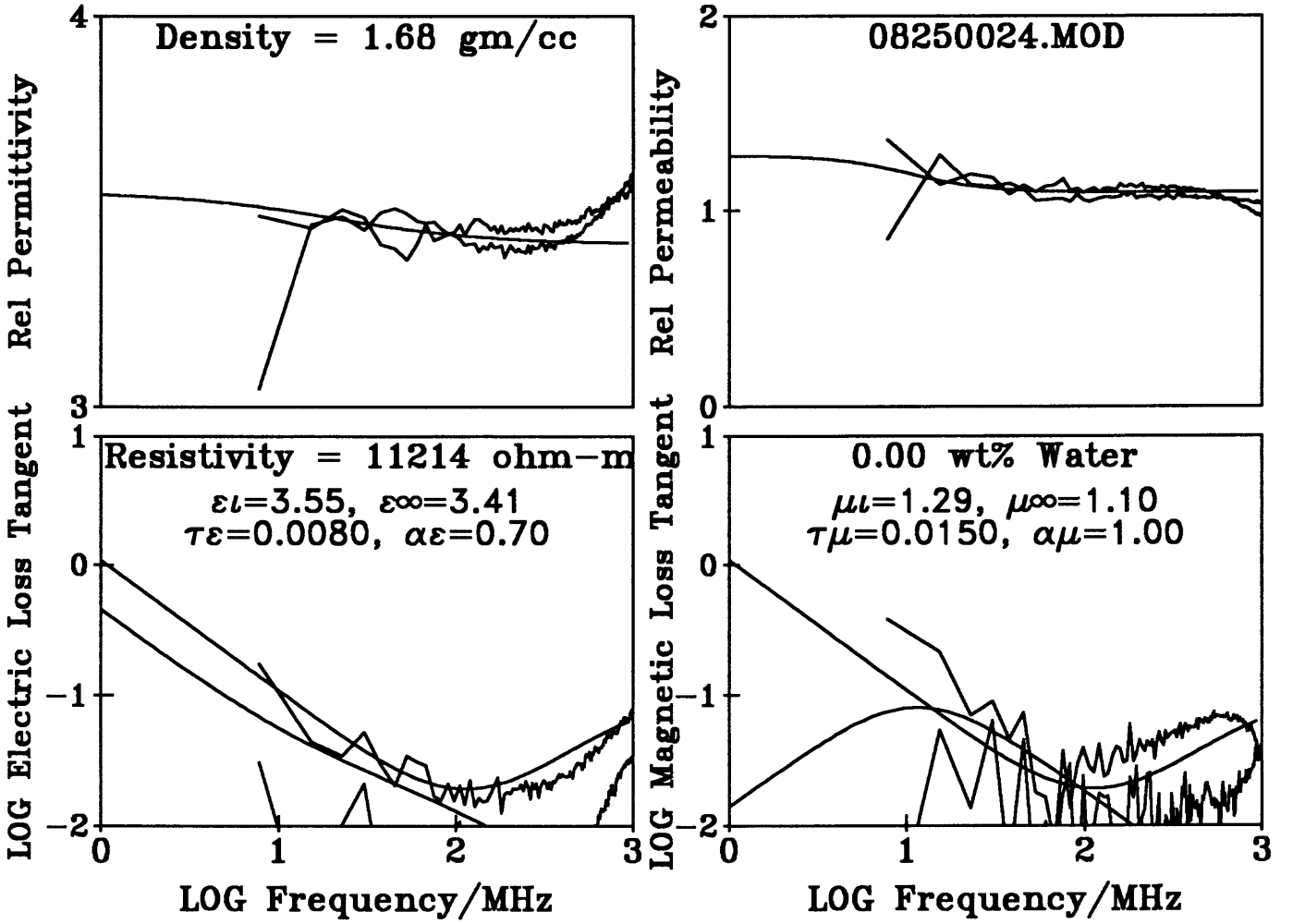



Figure 89 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.



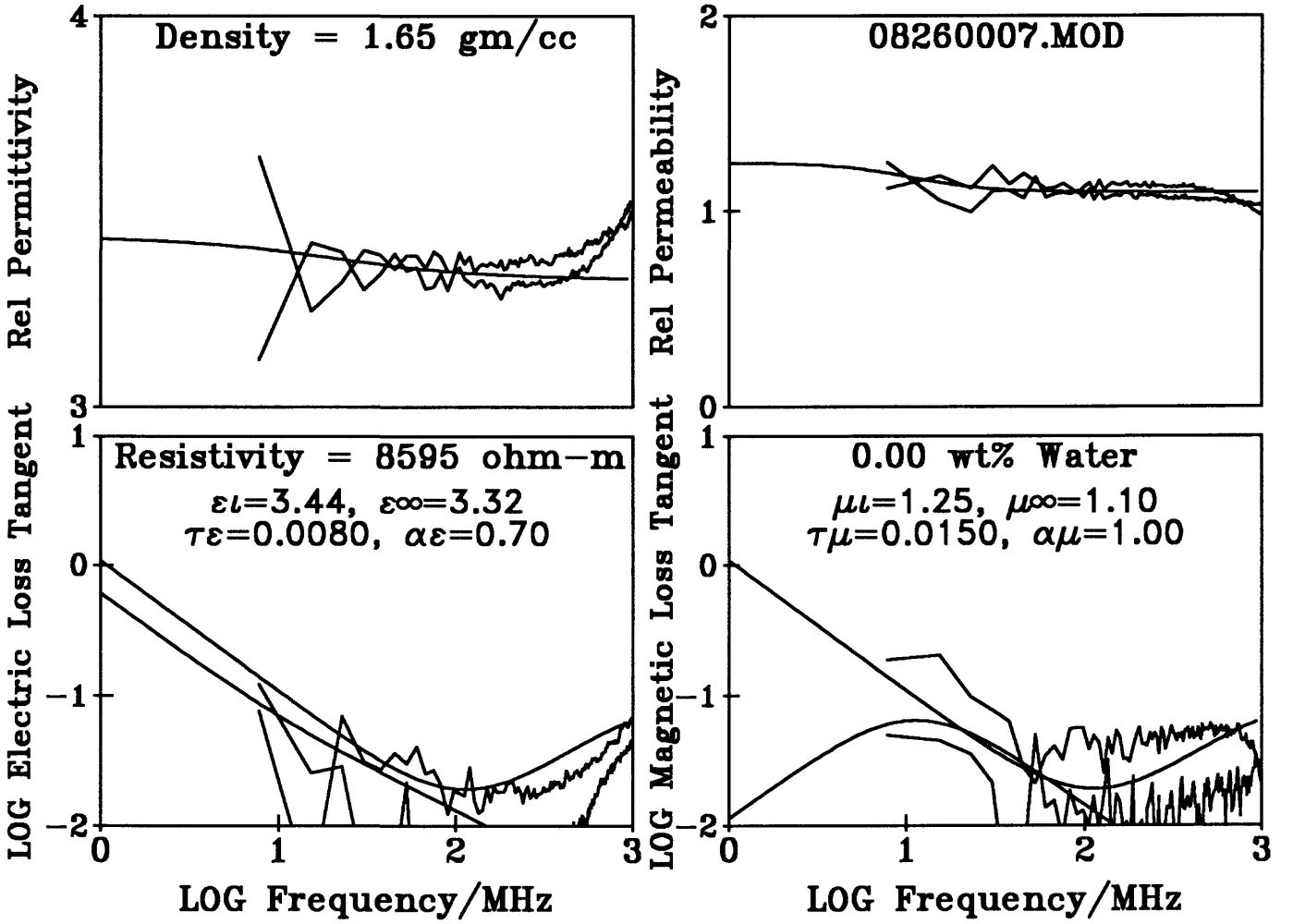

**Yuma 2040m Butler Fe304 sand in stream channel N of S0.5 #3 vac. dried**

Figure 90 -



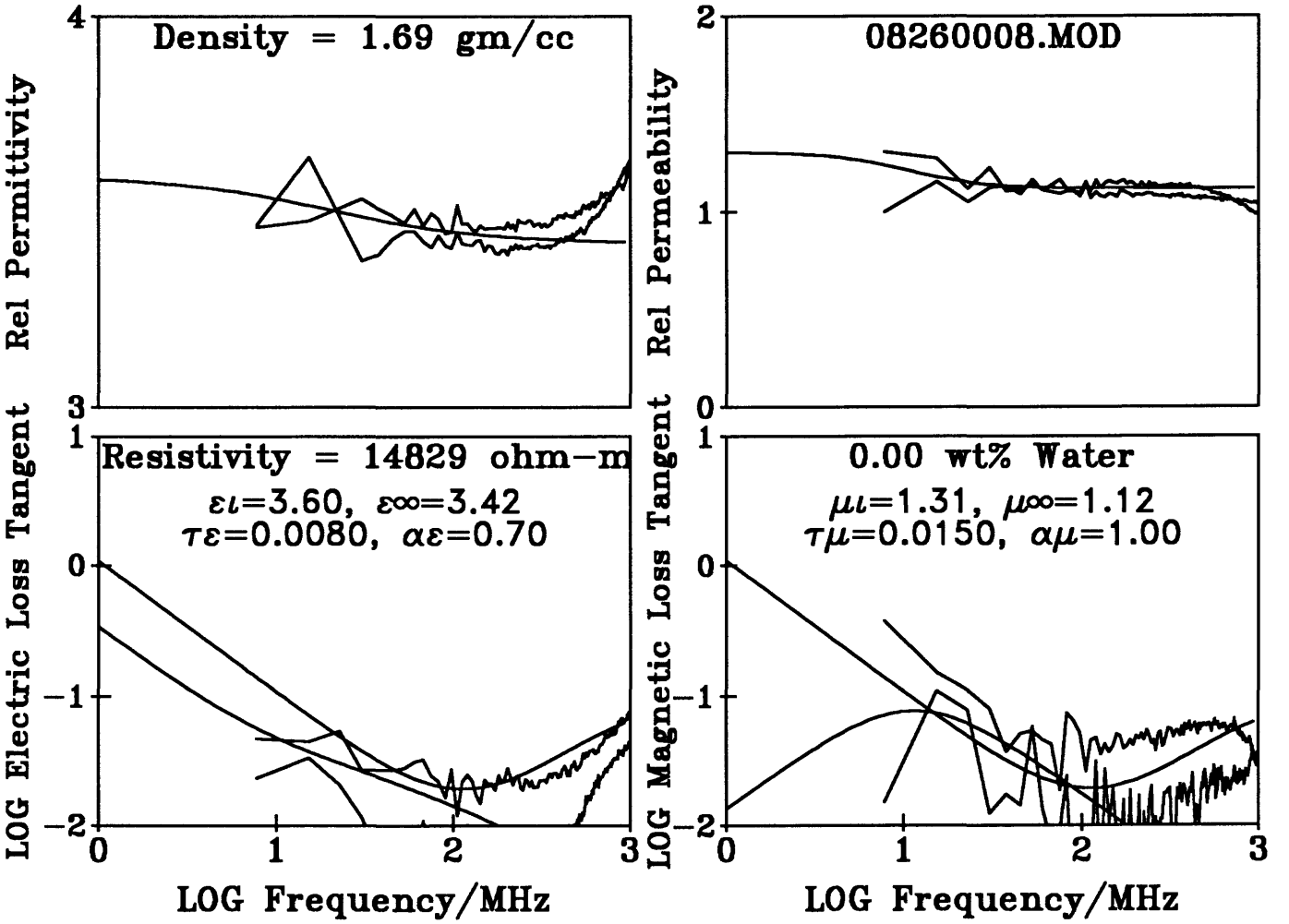

**Yuma 2040m Butler Fe304 sand in stream channel N of S0.5 #4 vac. dried**

Figure 91 -



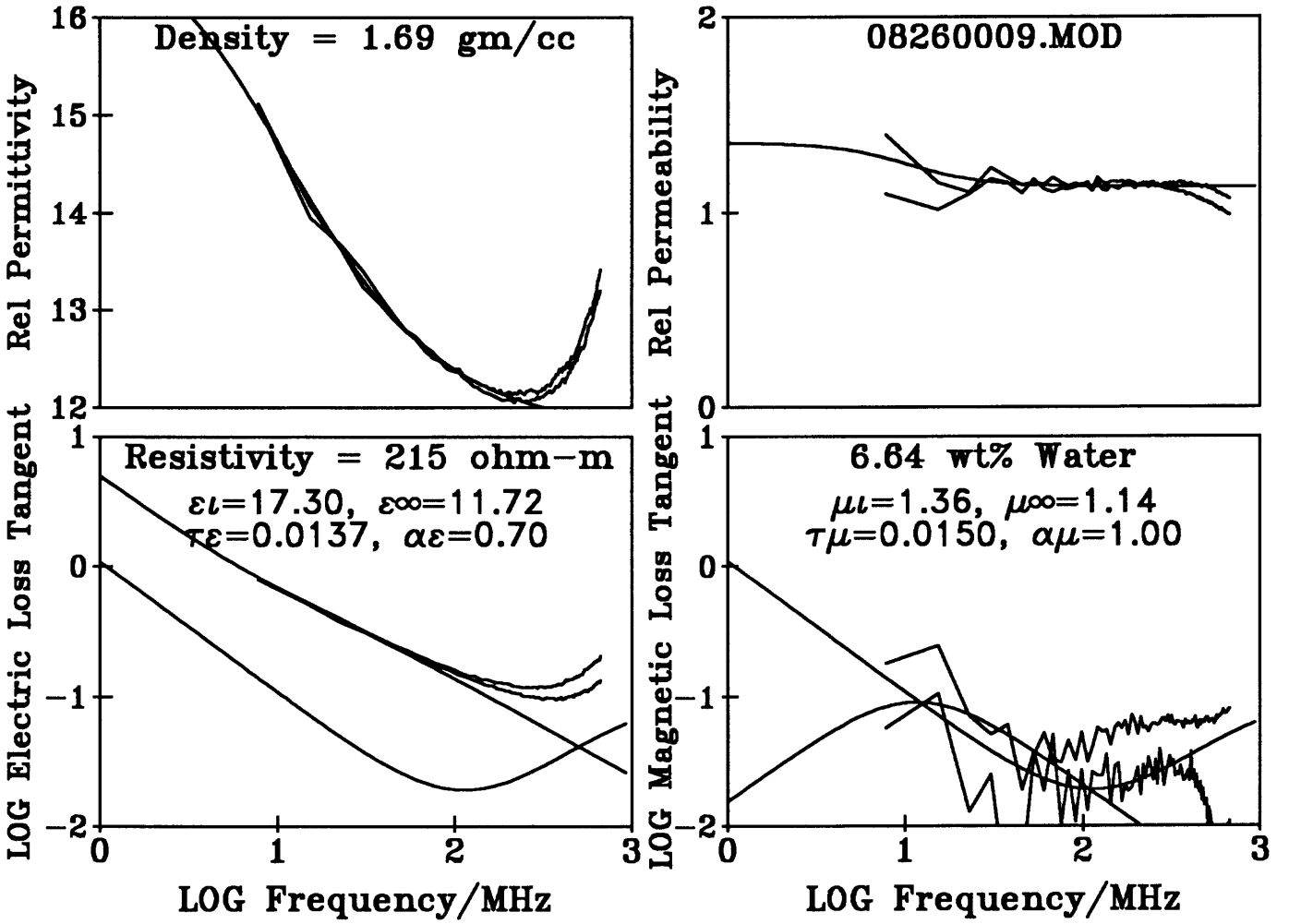

**Yuma 2040m Butler Fe304 sand in stream channel N of S0.5 #5 vac. dried**

Figure 92 - Vacuum dry



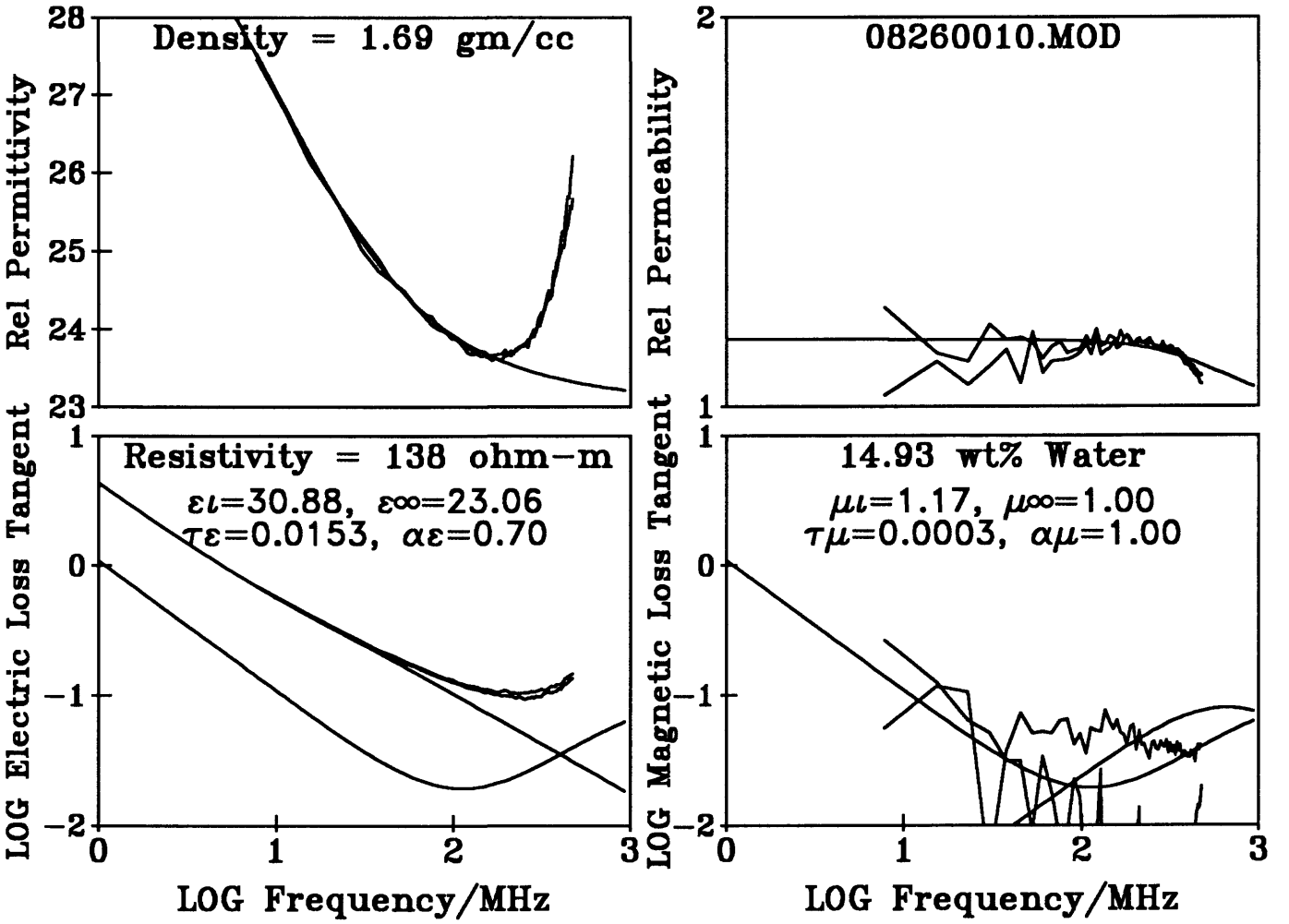

**Yuma 2040m Butler Fe304 sand in stream channel N of S0.5 #6 vac. dried**

Figure 93 -




**Yuma 2040m Butler Fe304 stream channel sand N of S0.5 #6 9-drops water**

Figure 94 -




**Yuma 2040m Butler Fe304 sand in stream channel N of S0.5 #6 water sat.**

Figure 95 -

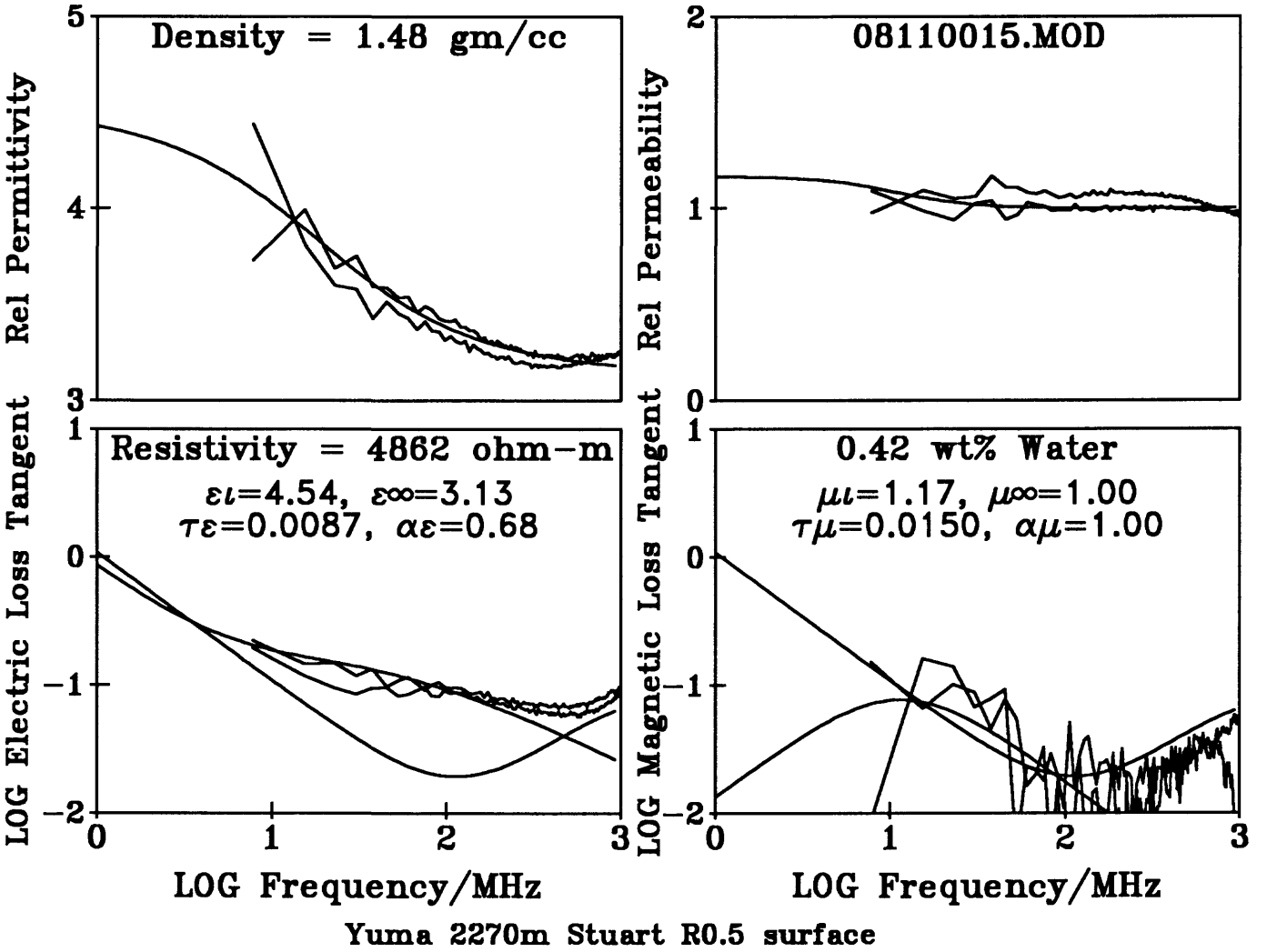



Figure 96 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

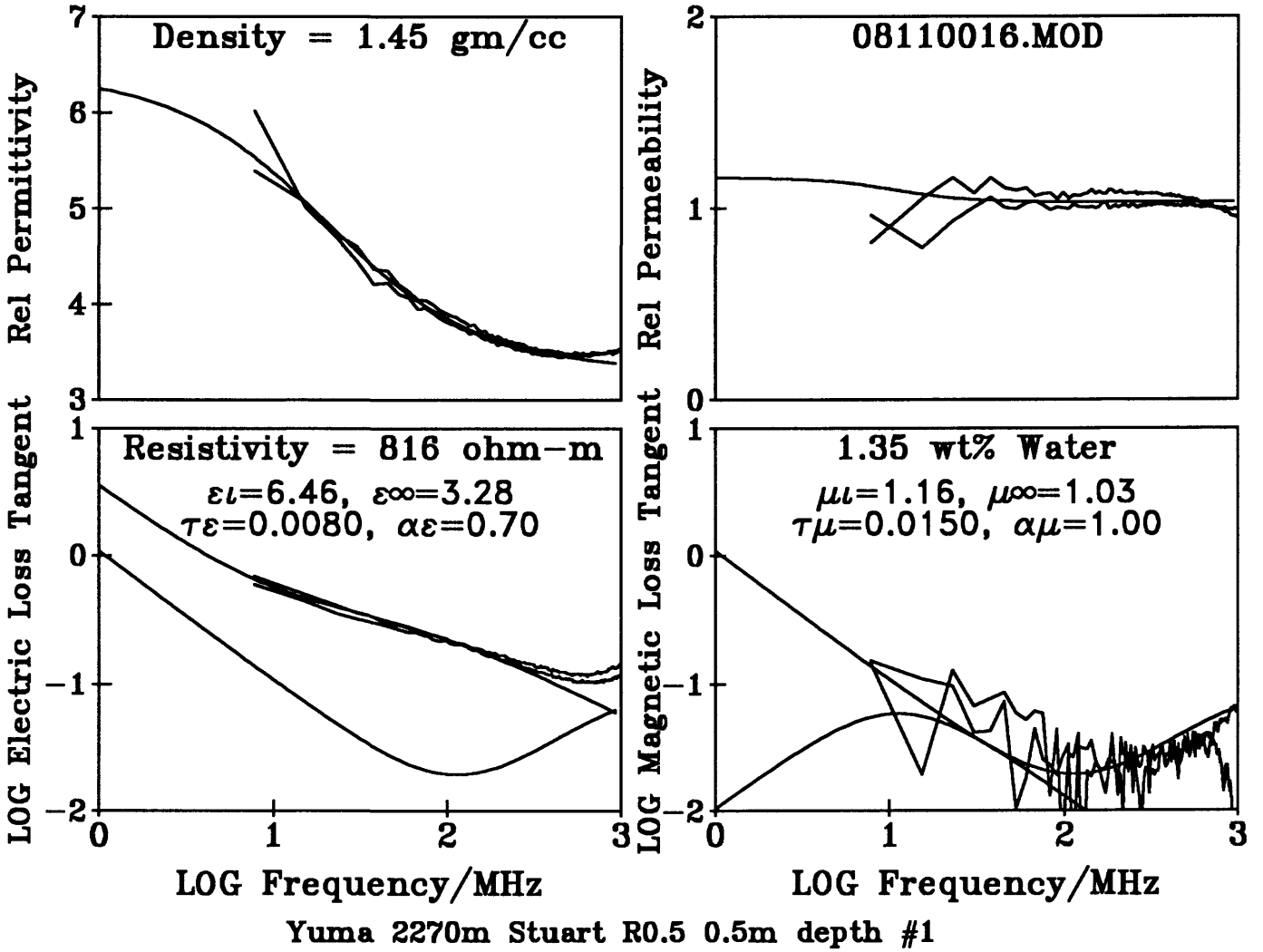



Figure 97 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

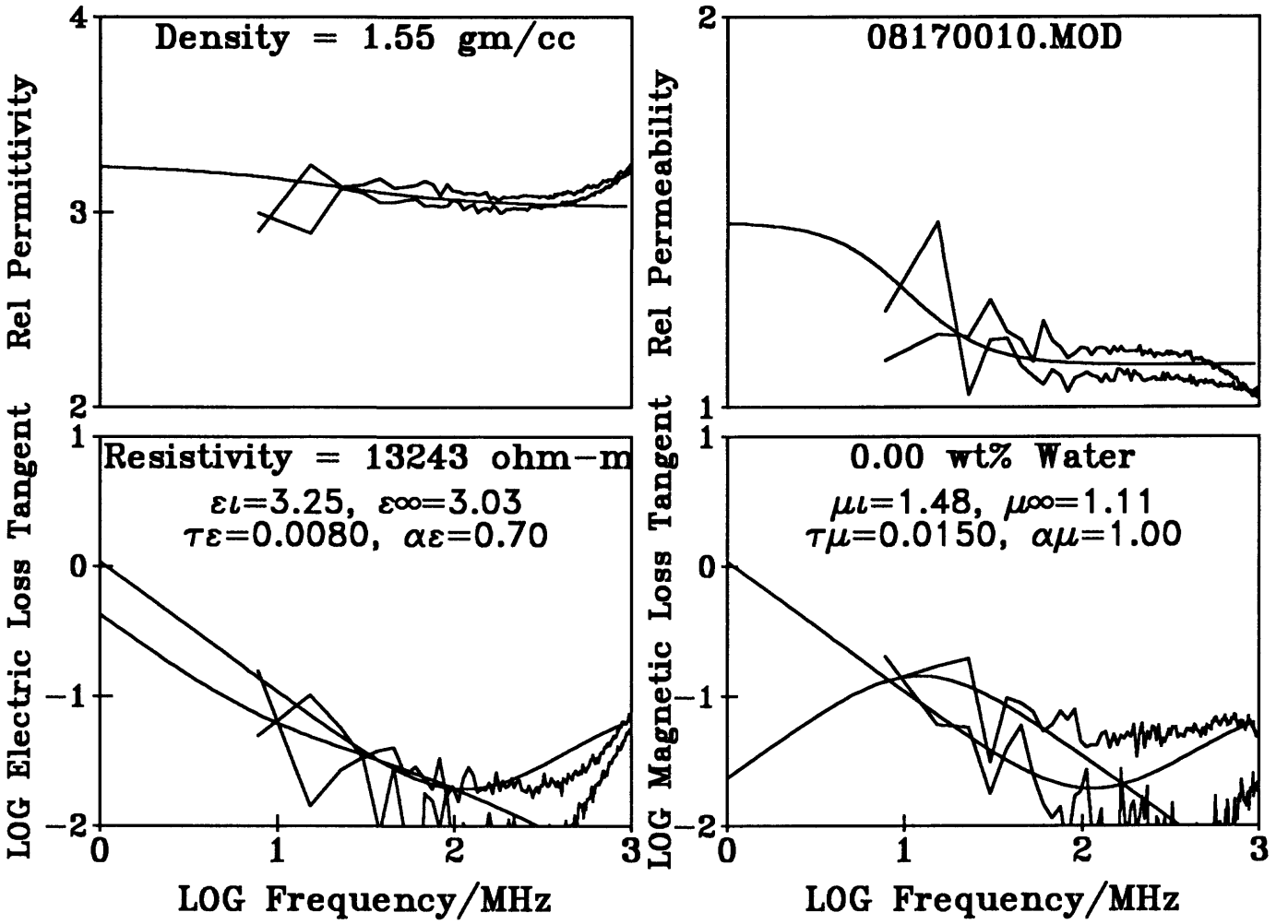

Density = 1.55 gm/cc
08170010.MOD
Resistivity = 13243 ohm-m
ει=3.25, ε∞=3.03
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.48, μ∞=1.11
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent Rel Permittivity
LOG Magnetic Loss Tangent Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2270m Stuart R0.5 0.5m depth #2 vacuum dried

Figure 98 -

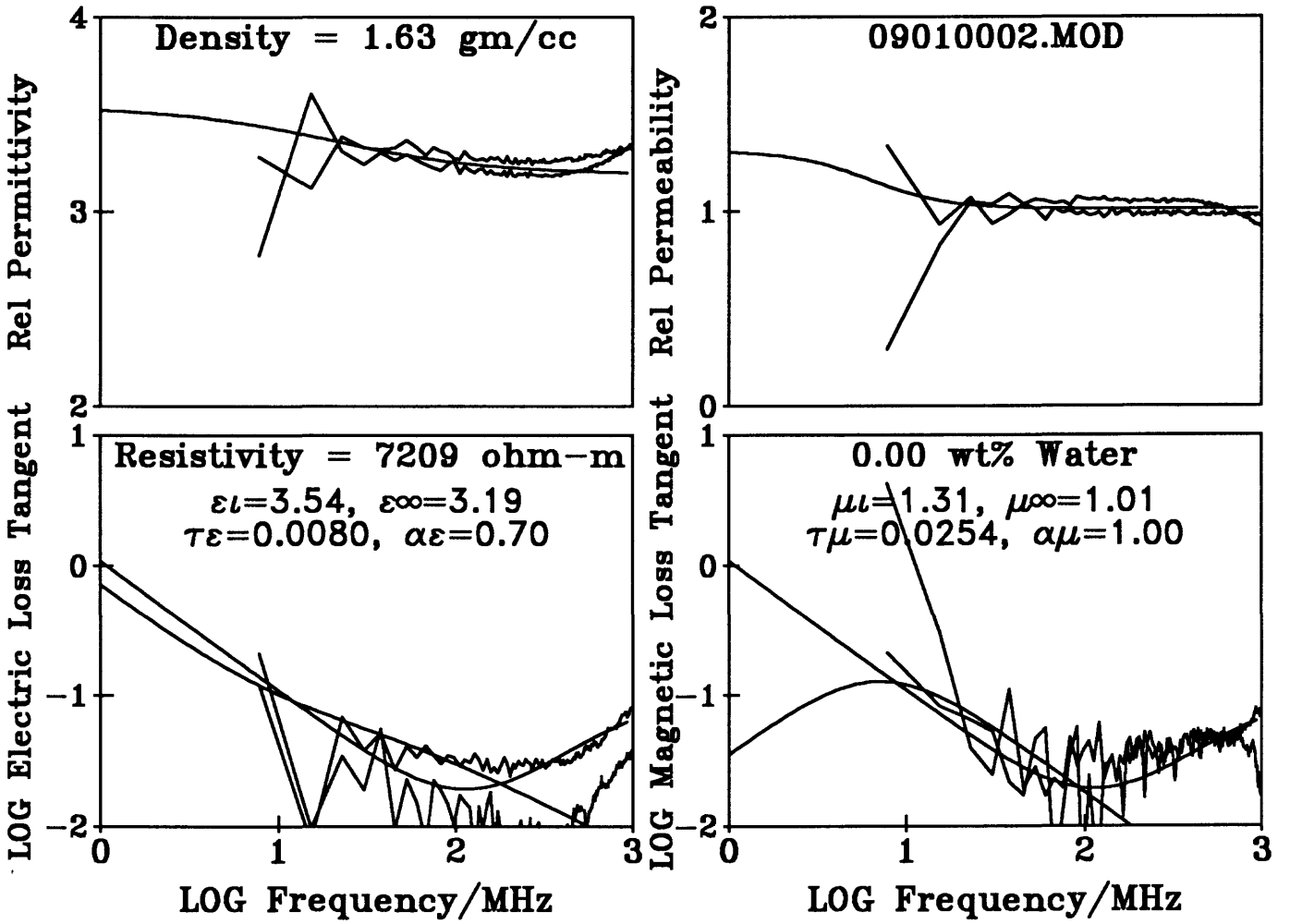

Density = 1.63 gm/cc
09010002.MOD
Rel Permittivity
Rel Permeability
Resistivity = 7209 ohm-m
ει=3.54, ε∞=3.19
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.31, μ∞=1.01
τμ=0.0254, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2270m Stuart R0.5 0.5m depth #3 vacuum dried

Figure 99 -

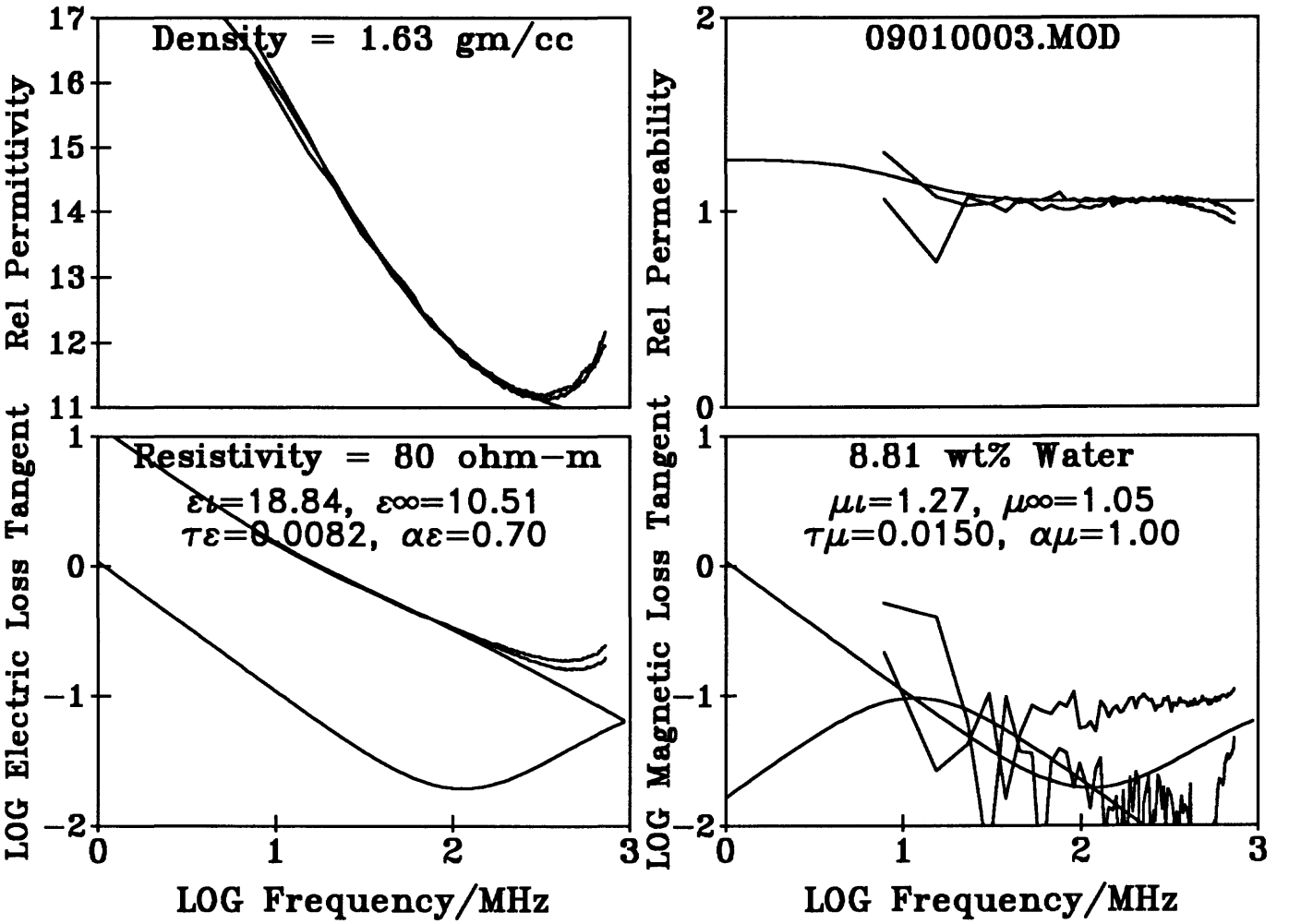

Density = 1.63 gm/cc
09010003.MOD
Resistivity = 80 ohm-m
ει=18.84, ε∞=10.51
τε=0.0082, αε=0.70
8.81 wt% Water
μι=1.27, μ∞=1.05
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent Rel Permittivity
LOG Magnetic Loss Tangent Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2270m Stuart R0.5 0.5m depth #3 16 drops water

Figure 100 -

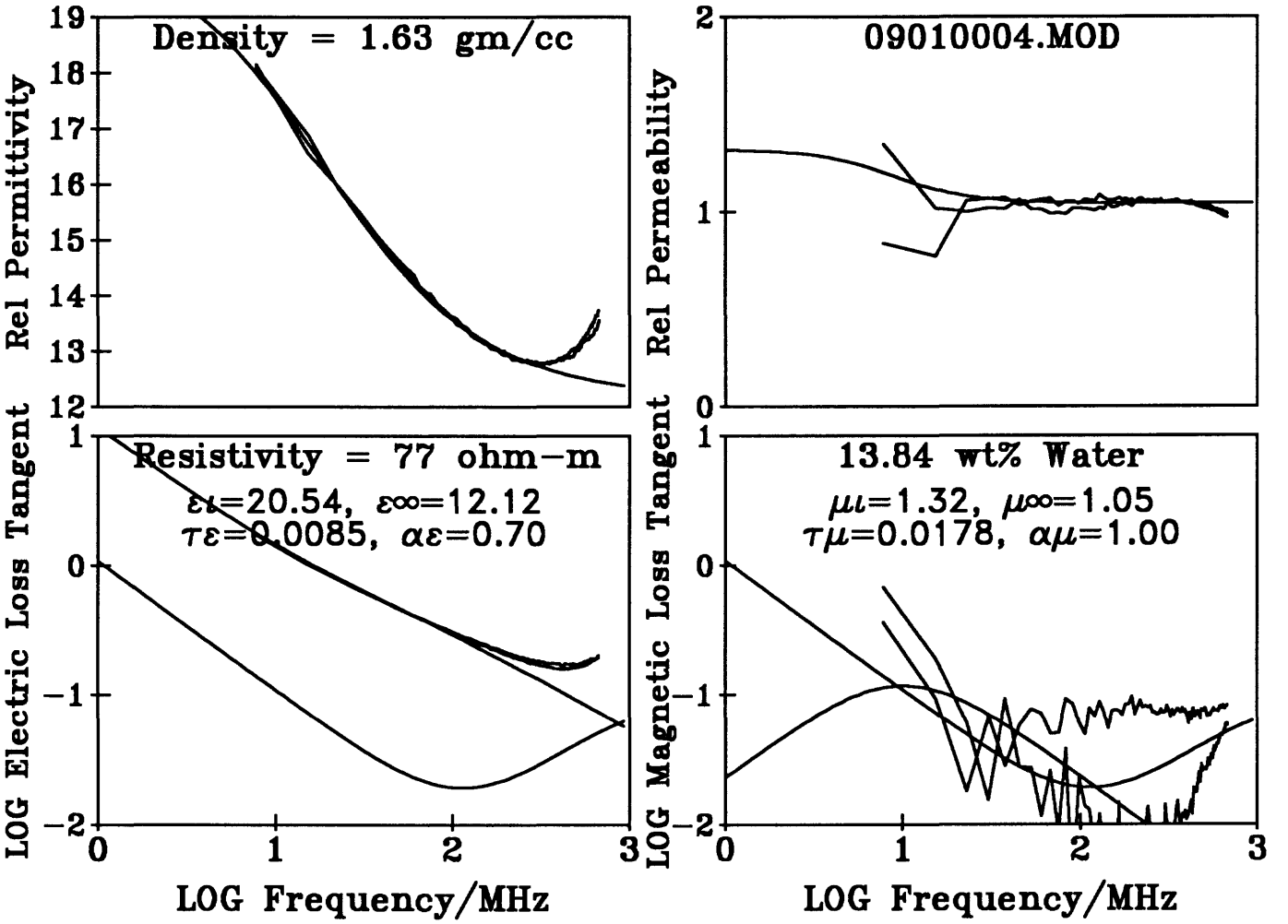

Density = 1.63 gm/cc
09010004.MOD
Resistivity = 77 ohm-m
ει=20.54, ε∞=12.12
τε=0.0085, αε=0.70
13.84 wt% Water
μι=1.32, μ∞=1.05
τμ=0.0178, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2270m Stuart R0.5 0.5m depth #3 water saturated

Figure 101 -

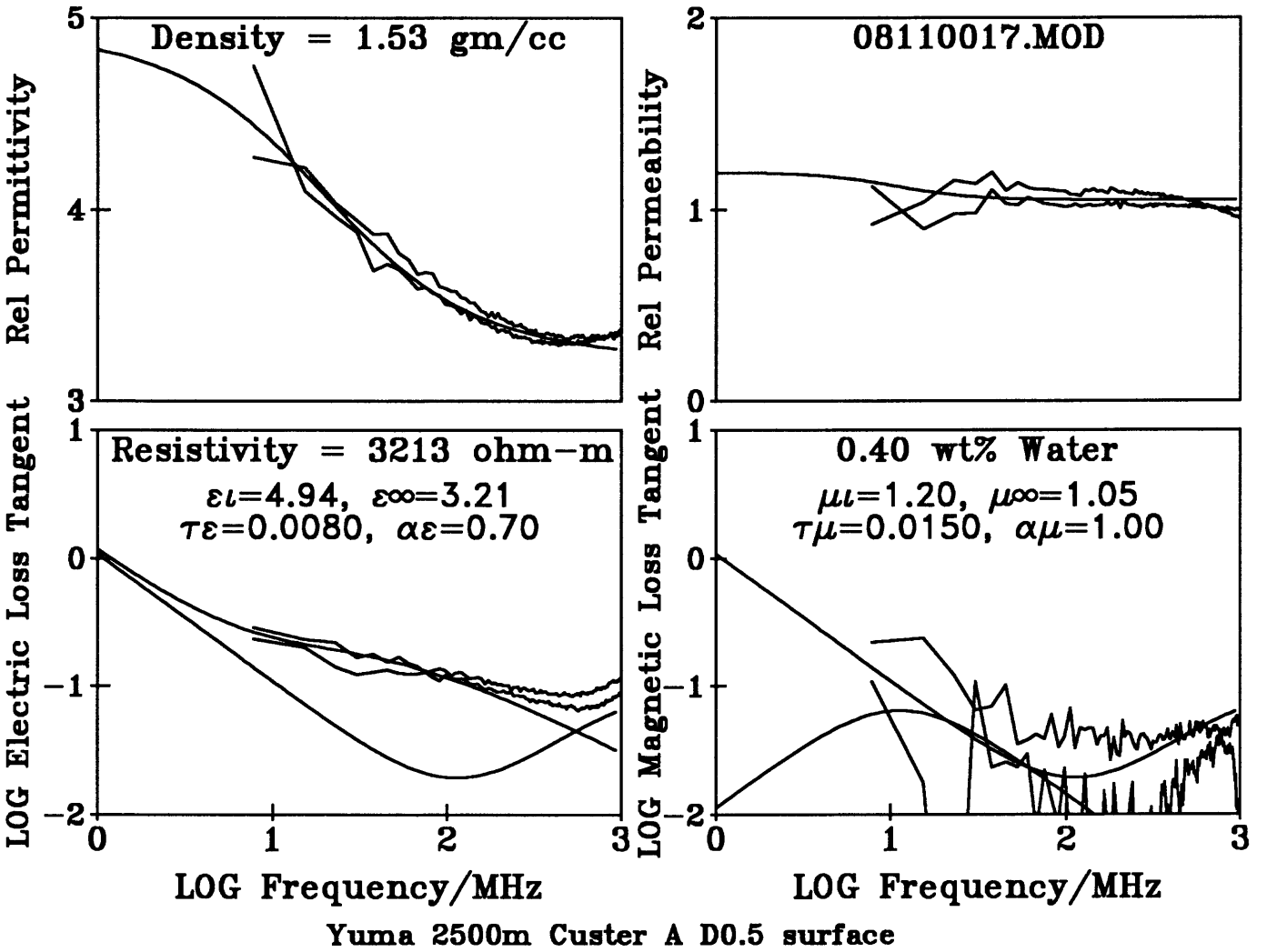



Figure 102 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

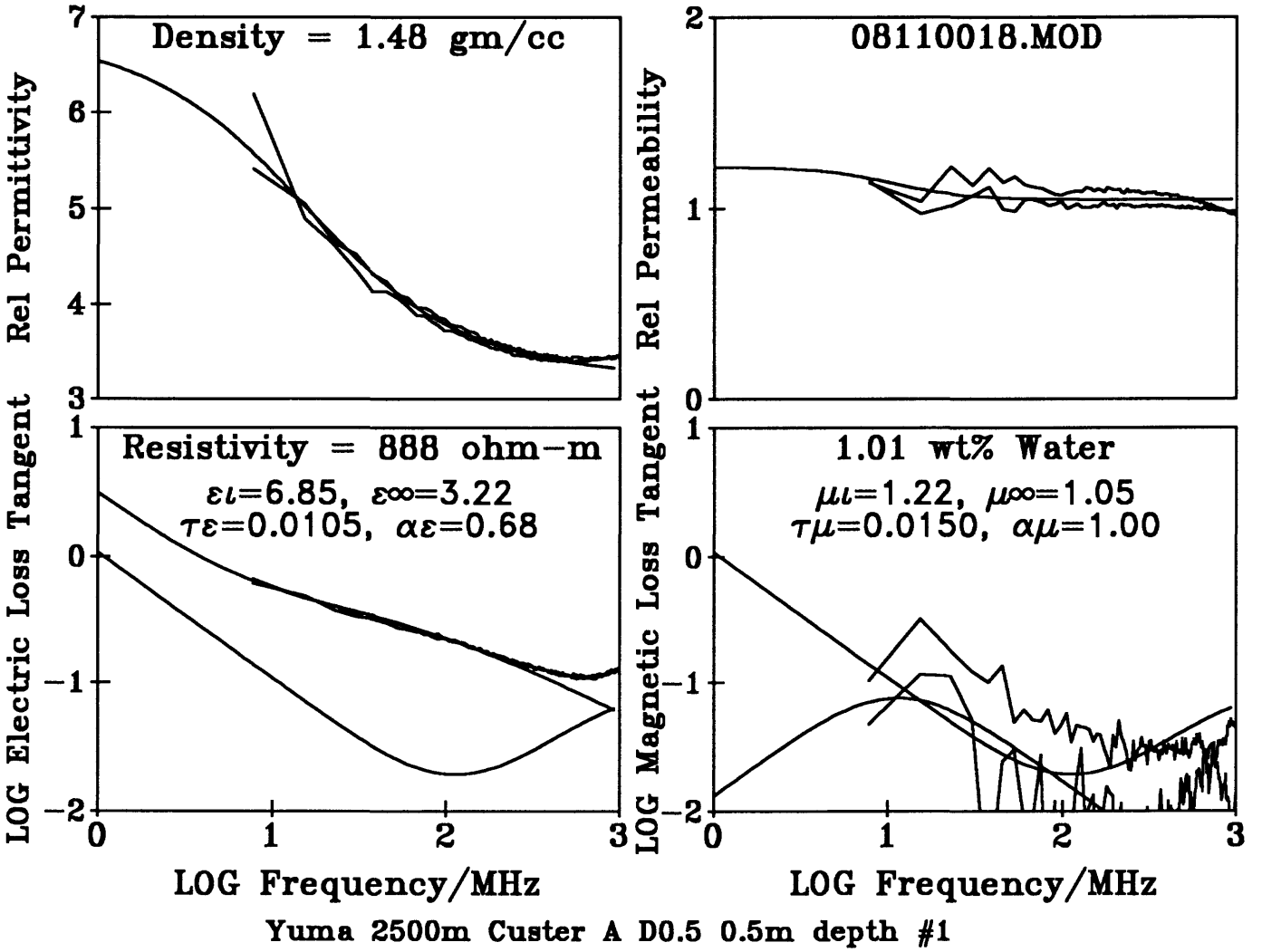



Figure 103 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

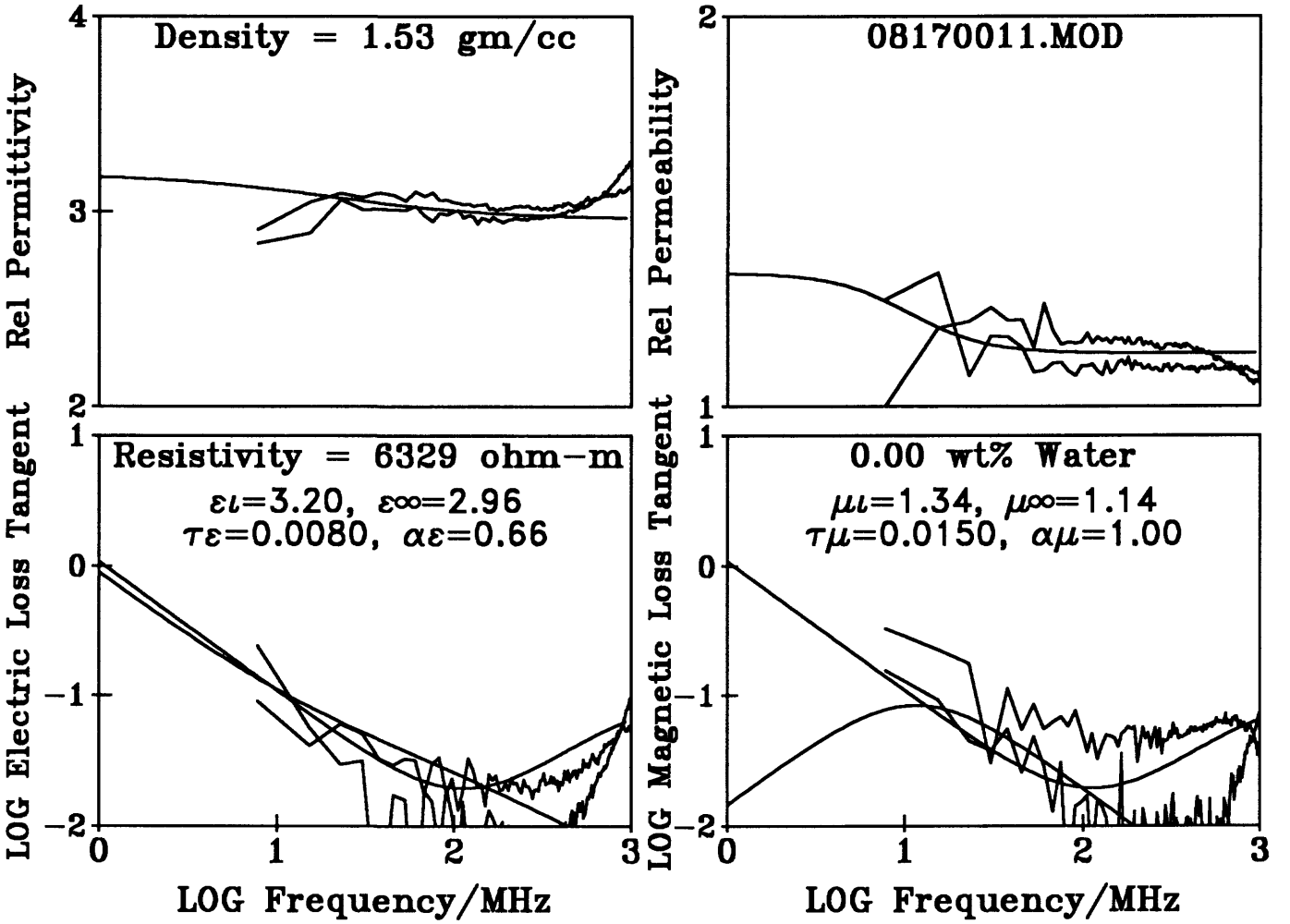

Density = 1.53 gm/cc
08170011.MOD
Resistivity = 6329 ohm-m
ει=3.20, ε∞=2.96
τε=0.0080, αε=0.66
0.00 wt% Water
μι=1.34, μ∞=1.14
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent Rel Permittivity
LOG Magnetic Loss Tangent Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2500m Custer A D0.5 0.5m depth #2 vacuum dried

Figure 104 -

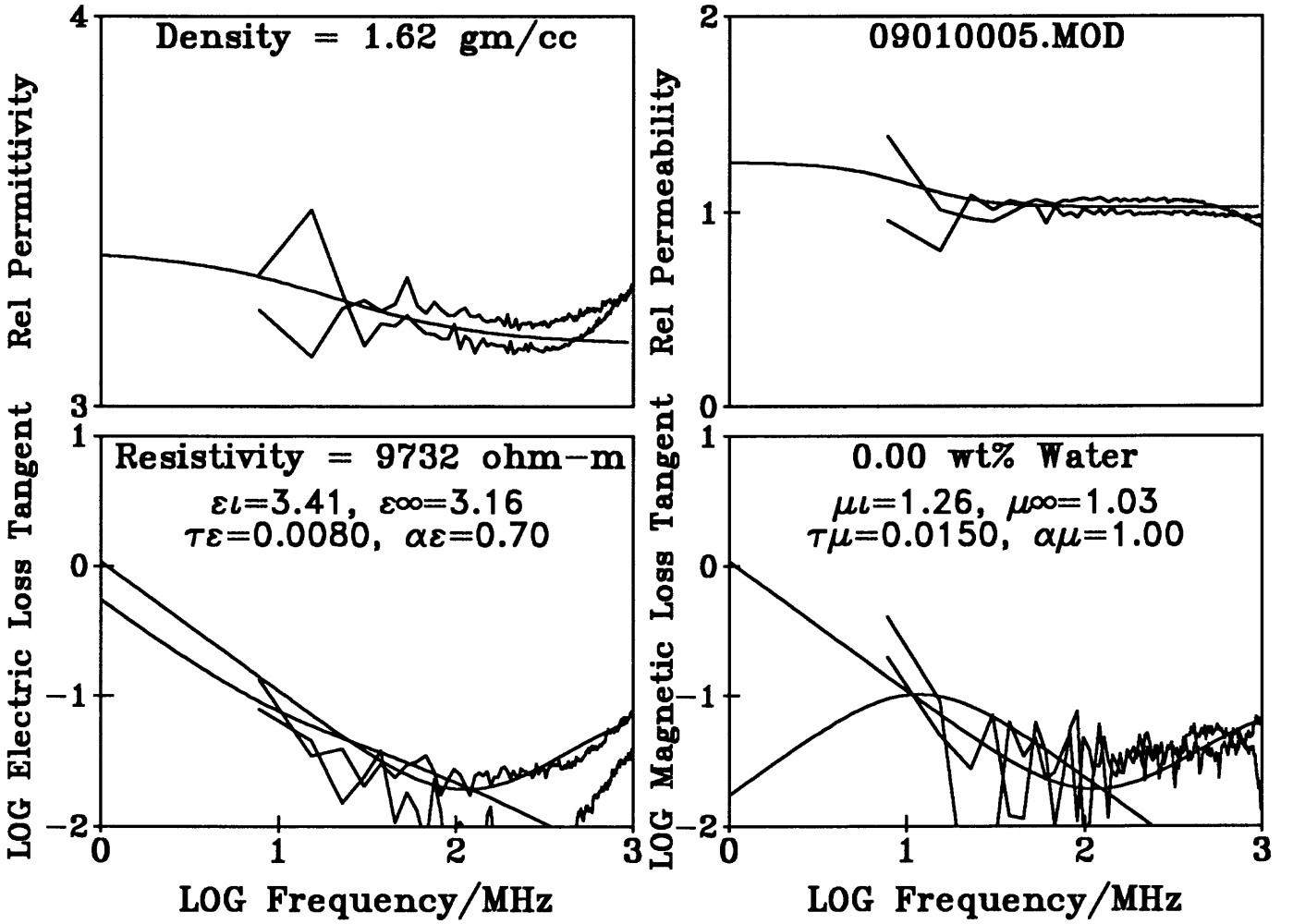

Density = 1.62 gm/cc
09010005.MOD
Resistivity = 9732 ohm-m
ει=3.41, ε∞=3.16
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.26, μ∞=1.03
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2500m Custer A D0.5 0.5m depth #3 vacuum dried

Figure 105 -

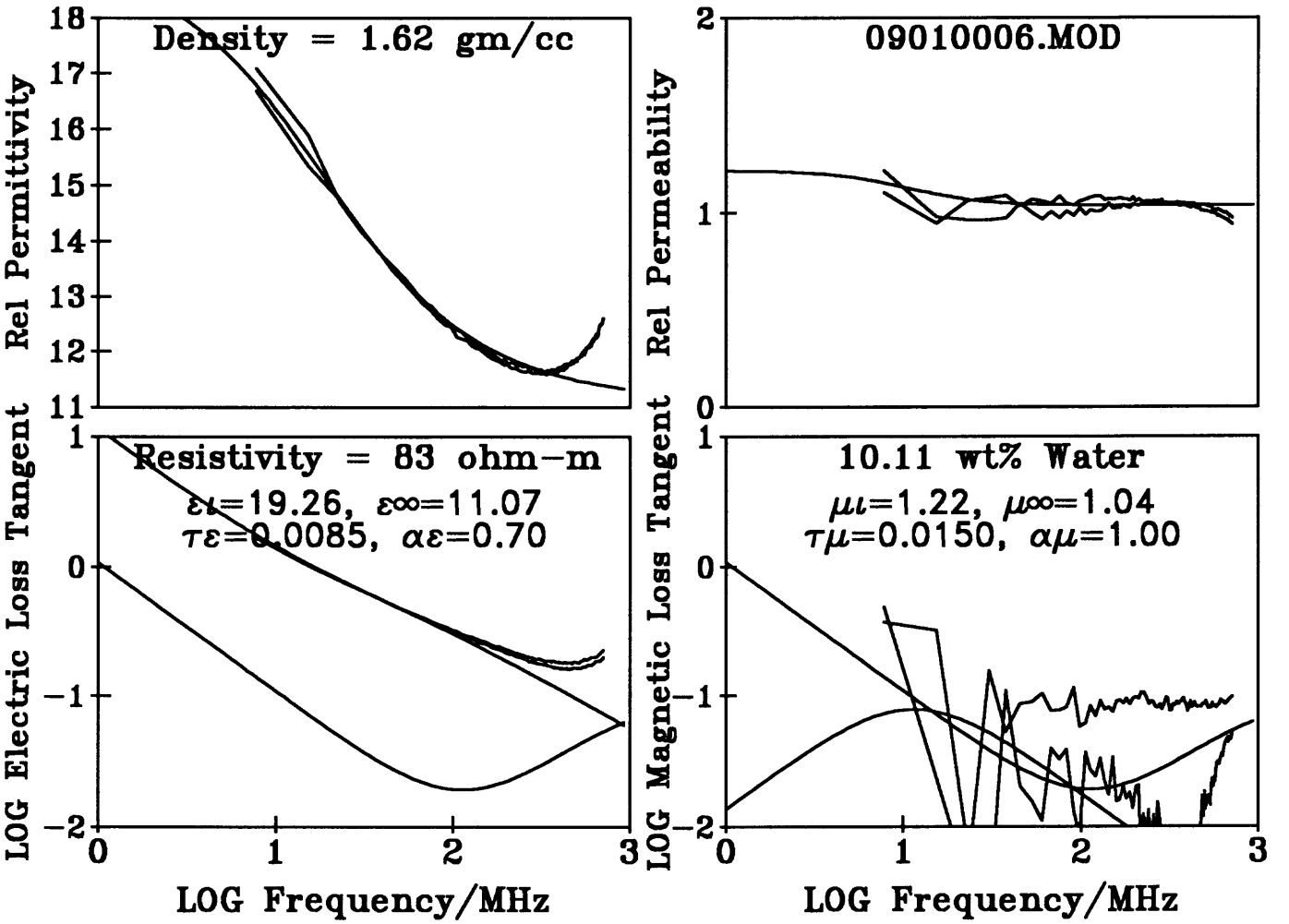

Density = 1.62 gm/cc
09010006.MOD
Resistivity = 83 ohm-m
ει=19.26, ε∞=11.07
τε=0.0085, αε=0.70
10.11 wt% Water
μι=1.22, μ∞=1.04
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2500m Custer A D0.5 0.5m depth #3 16 drops water

Figure 106 -

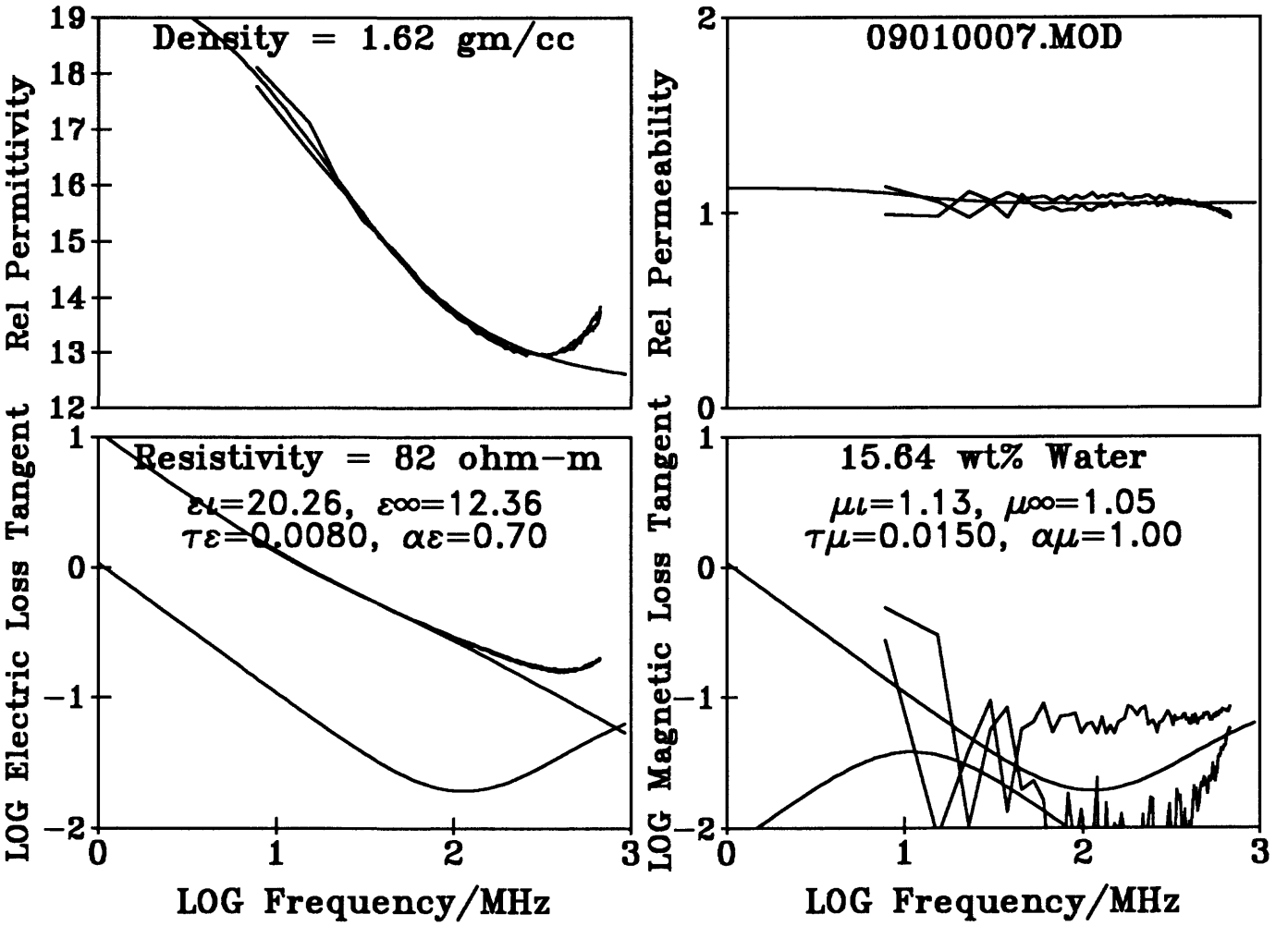

Density = 1.62 gm/cc
09010007.MOD
Rel Permittivity
Rel Permeability
Resistivity = 82 ohm-m
ει=20.26, ε∞=12.36
τε=0.0080, αε=0.70
15.64 wt% Water
μι=1.13, μ∞=1.05
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2500m Custer A D0.5 0.5m depth #3 water saturated

Figure 107 -

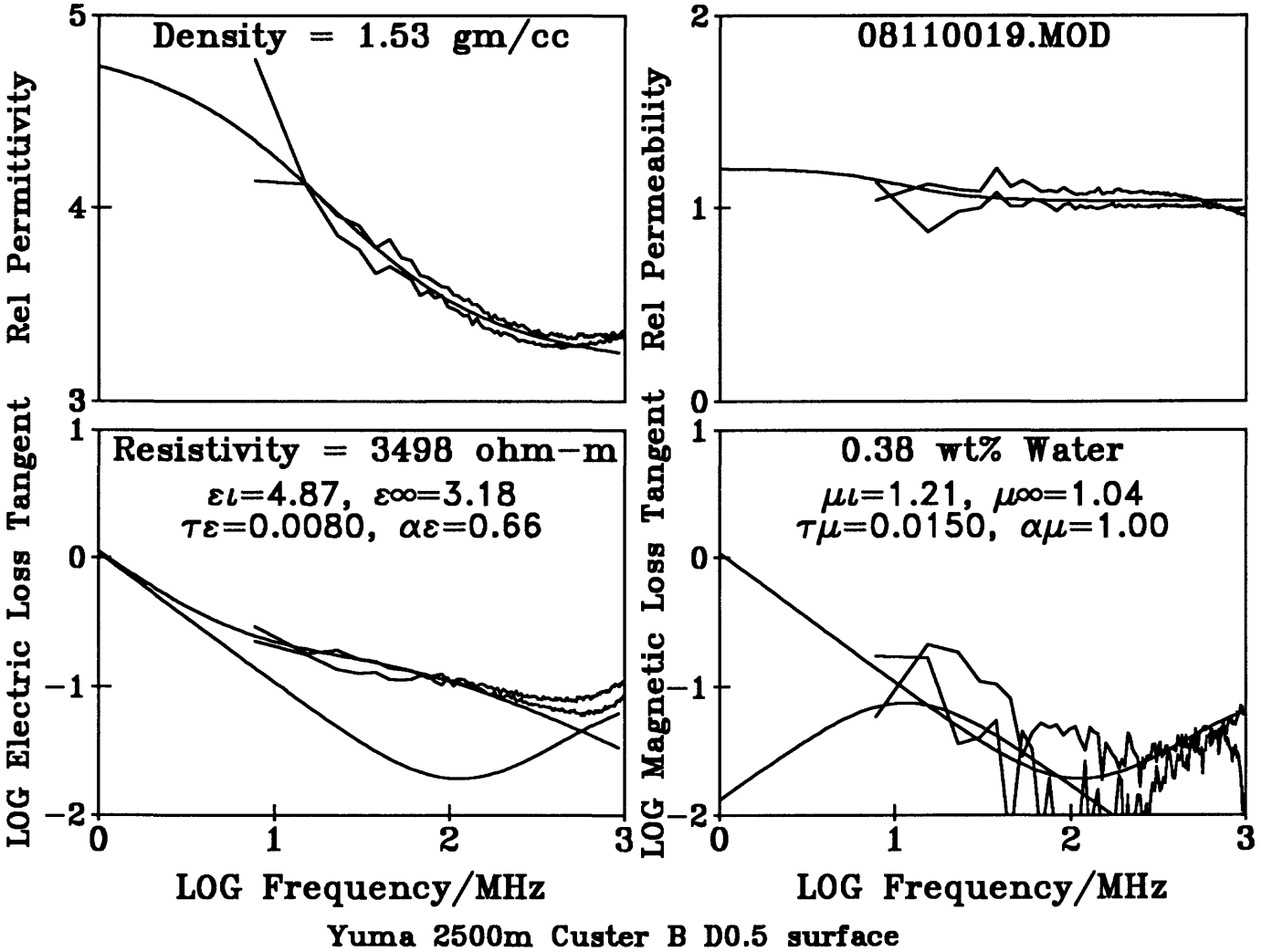



Figure 108 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

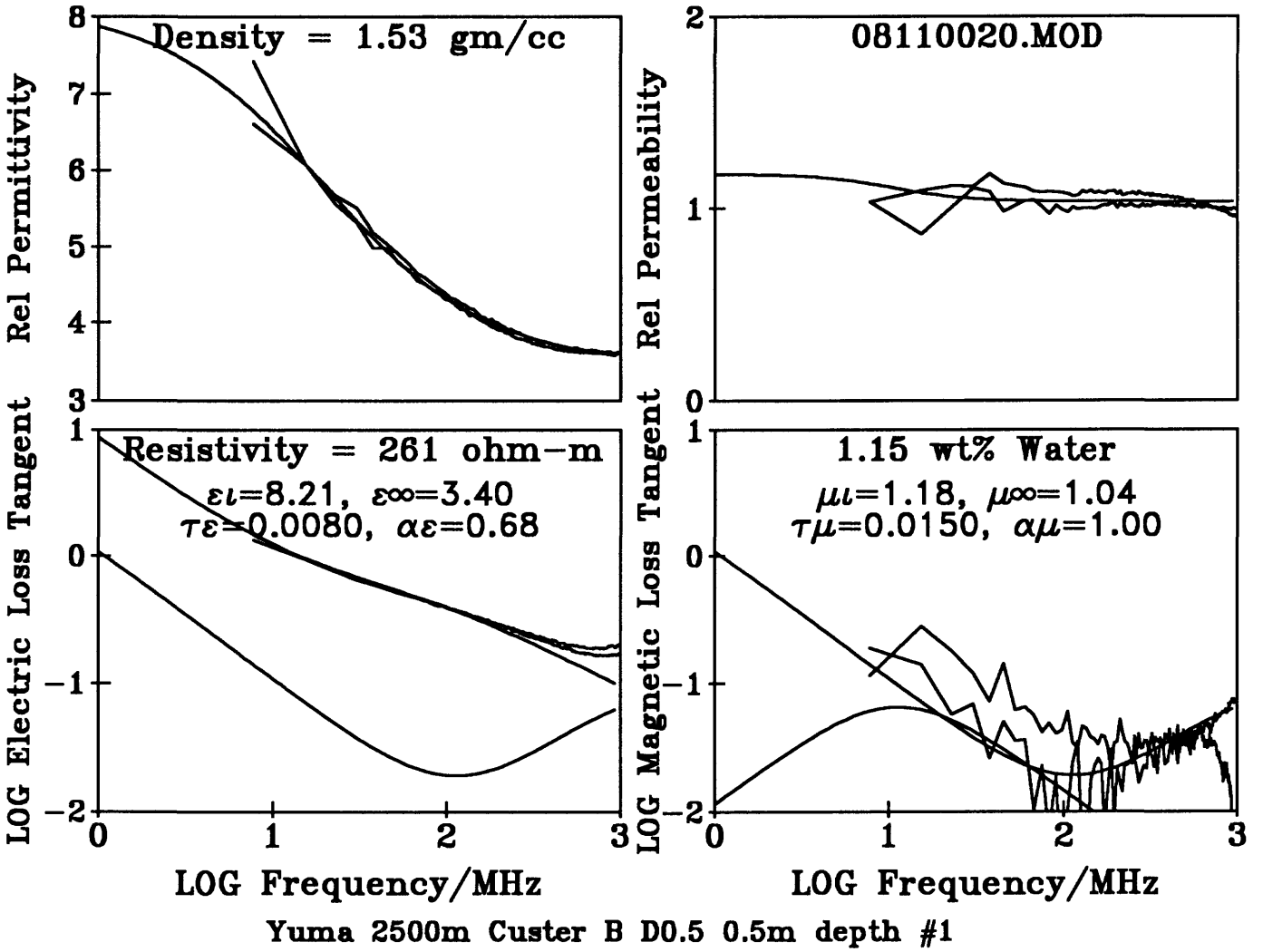



Figure 109 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

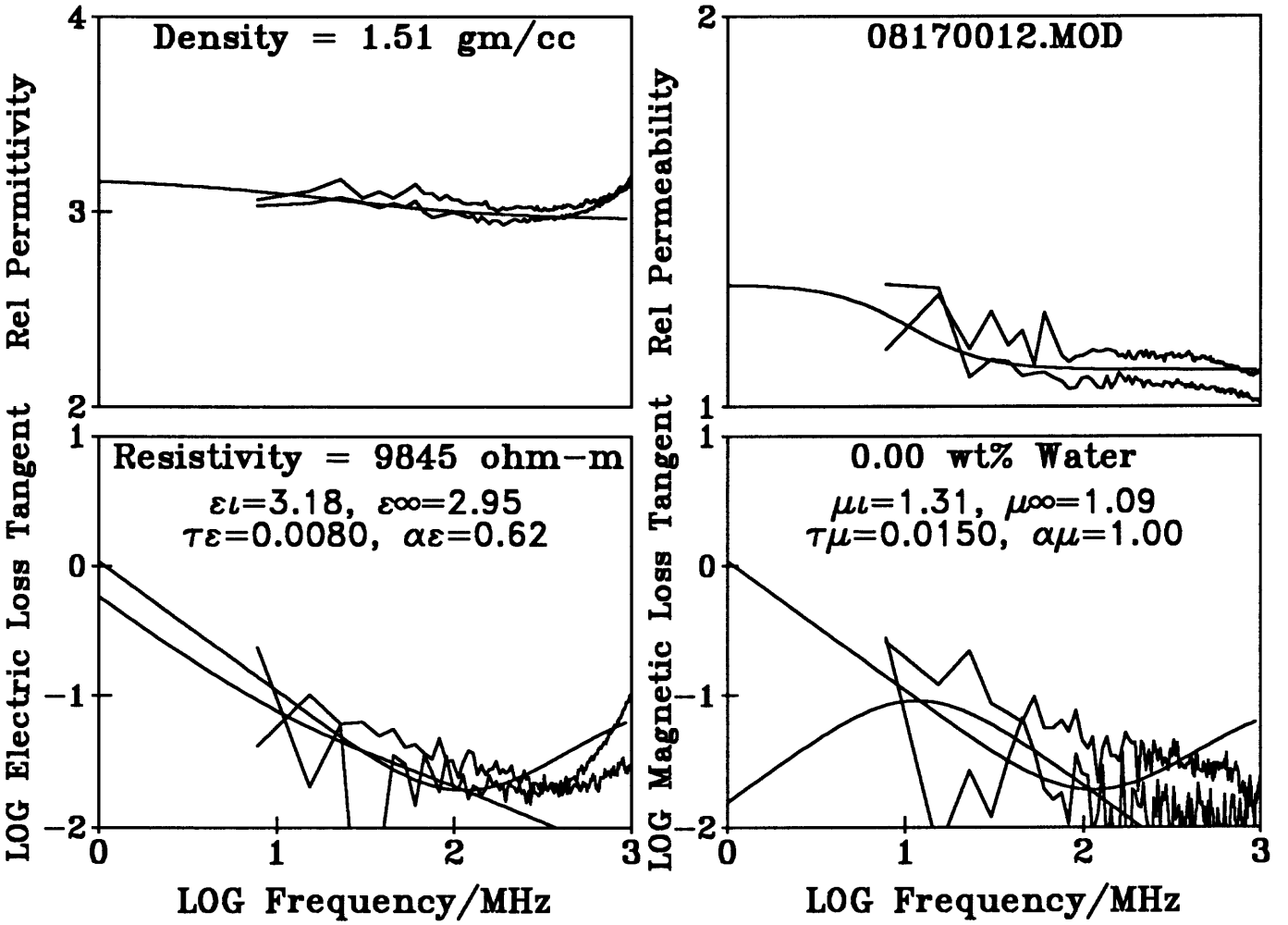

Density = 1.51 gm/cc
08170012.MOD
Resistivity = 9845 ohm-m
ει=3.18, ε∞=2.95
τε=0.0080, αε=0.62
0.00 wt% Water
μι=1.31, μ∞=1.09
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2500m Custer B B0.5 0.5m depth #2 vacuum dried

Figure 110 -

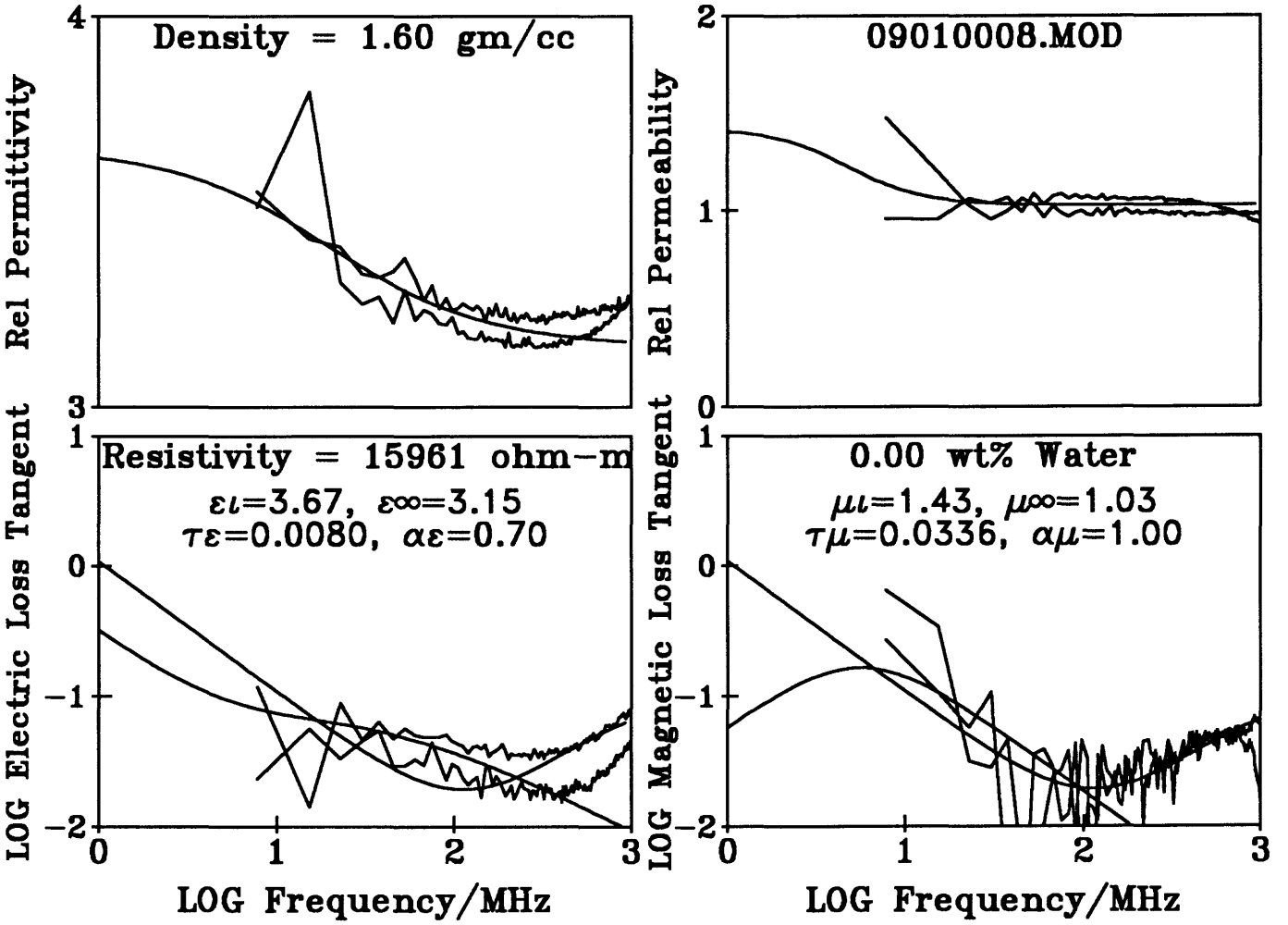

Density = 1.60 gm/cc
09010008.MOD
Rel Permittivity
Rel Permeability
Resistivity = 15961 ohm-m
ει=3.67, ε∞=3.15
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.43, μ∞=1.03
τμ=0.0336, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2500m Custer B D0.5 0.5m depth #3 vacuum dried

Figure 111 -

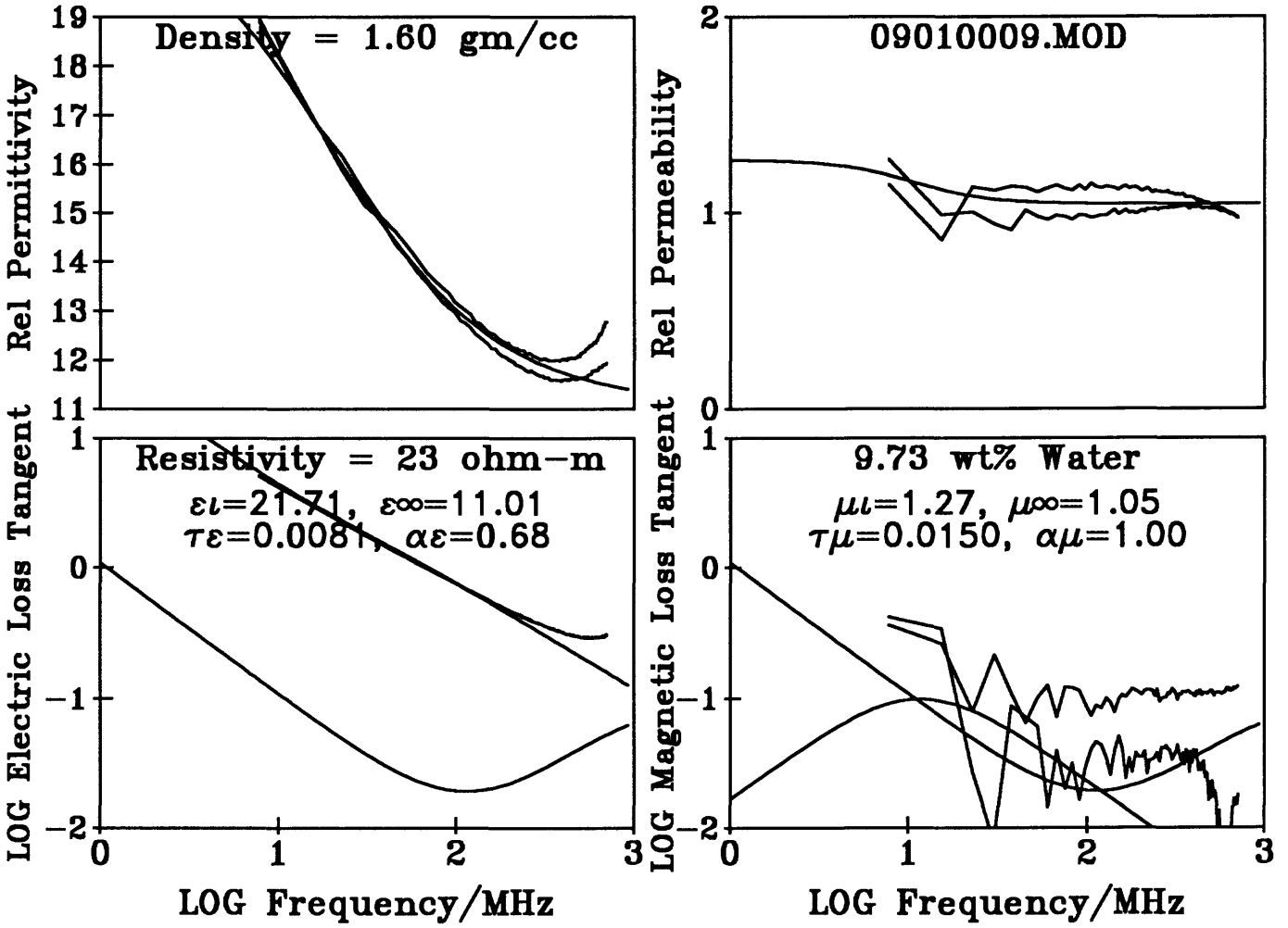

Density = 1.60 gm/cc
09010009.MOD
Resistivity = 23 ohm-m
ει=21.71, ε∞=11.01
τε=0.0081, αε=0.68
9.73 wt% Water
μι=1.27, μ∞=1.05
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2500m Custer B D0.5 0.5m depth #3 20 drops water

Figure 112 -

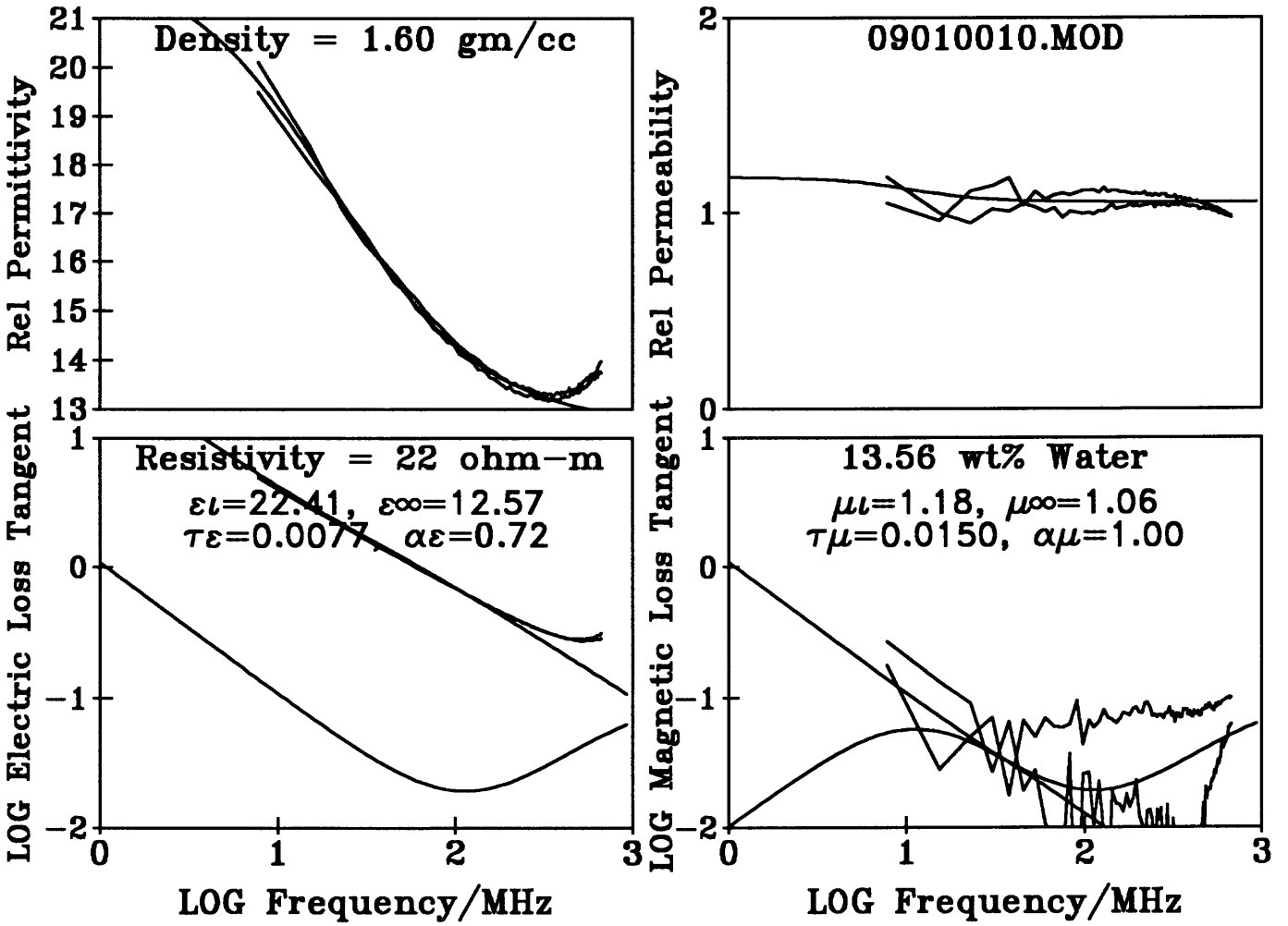

Density = 1.60 gm/cc
09010010.MOD
Resistivity = 22 ohm-m
ει=22.41, ε∞=12.57
τε=0.0077, αε=0.72
13.56 wt% Water
μι=1.18, μ∞=1.06
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2500m Custer B D0.5 0.5m depth #3 water saturated

Figure 113 -

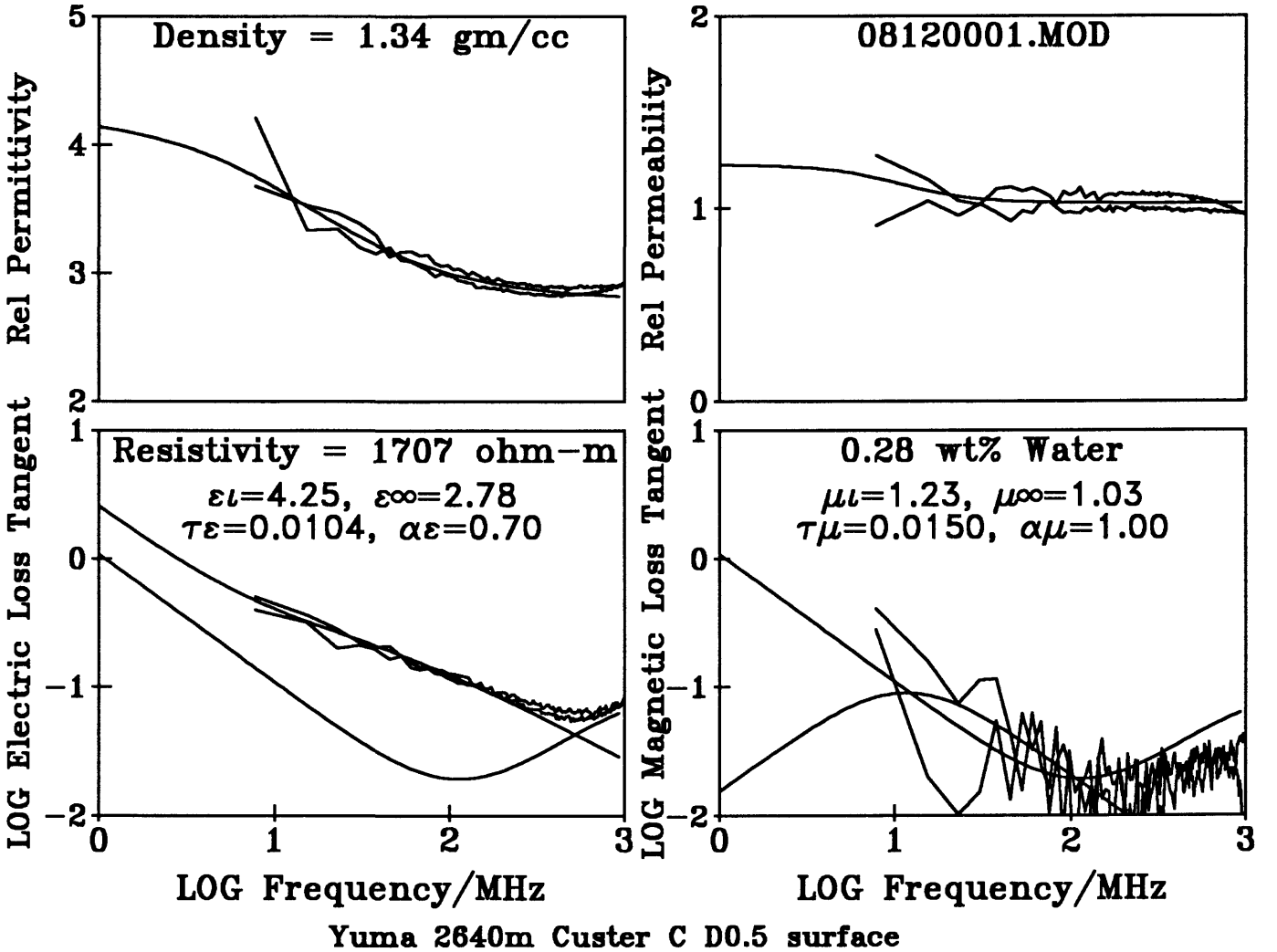



Figure 114 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

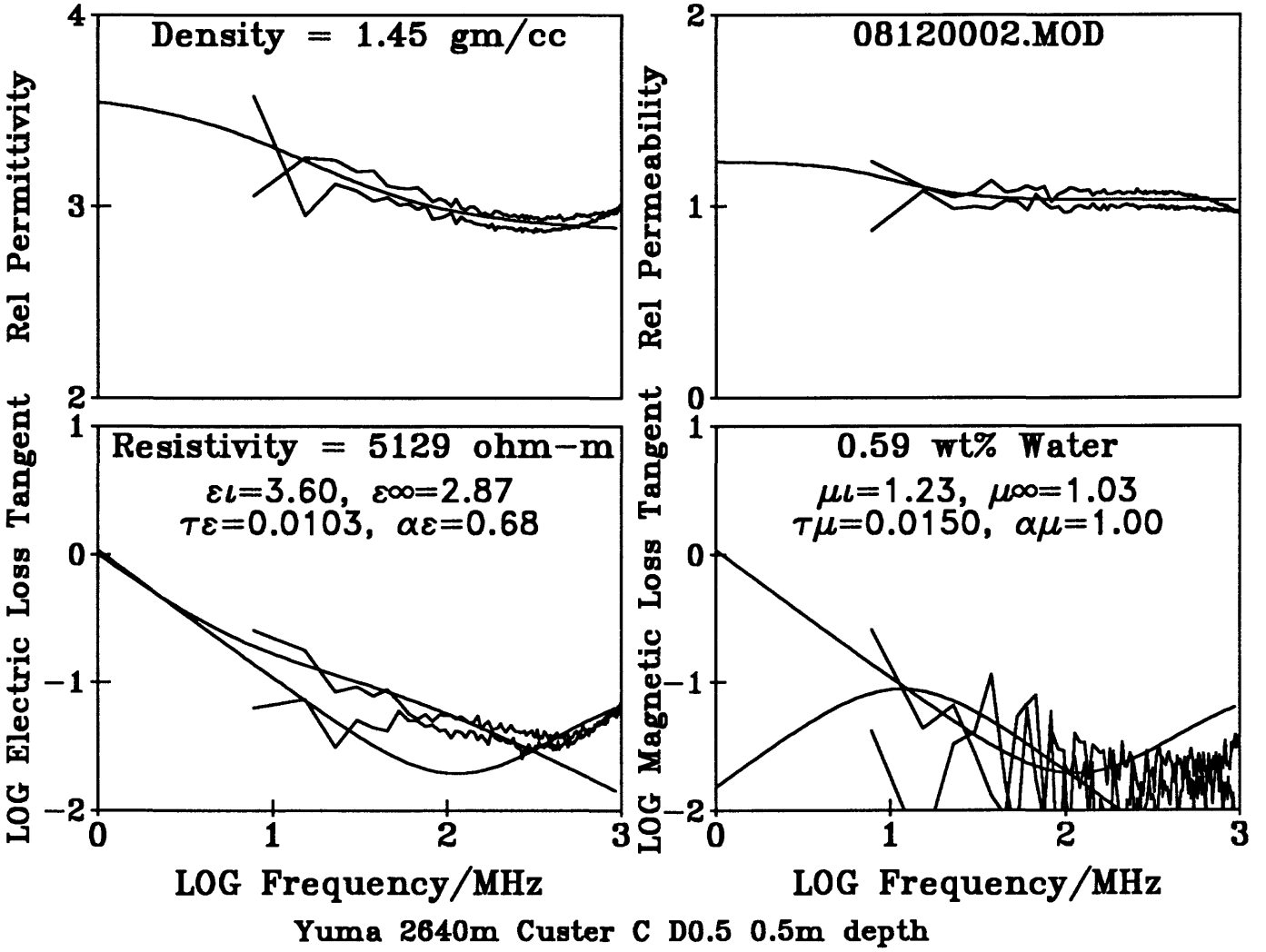



Figure 115 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

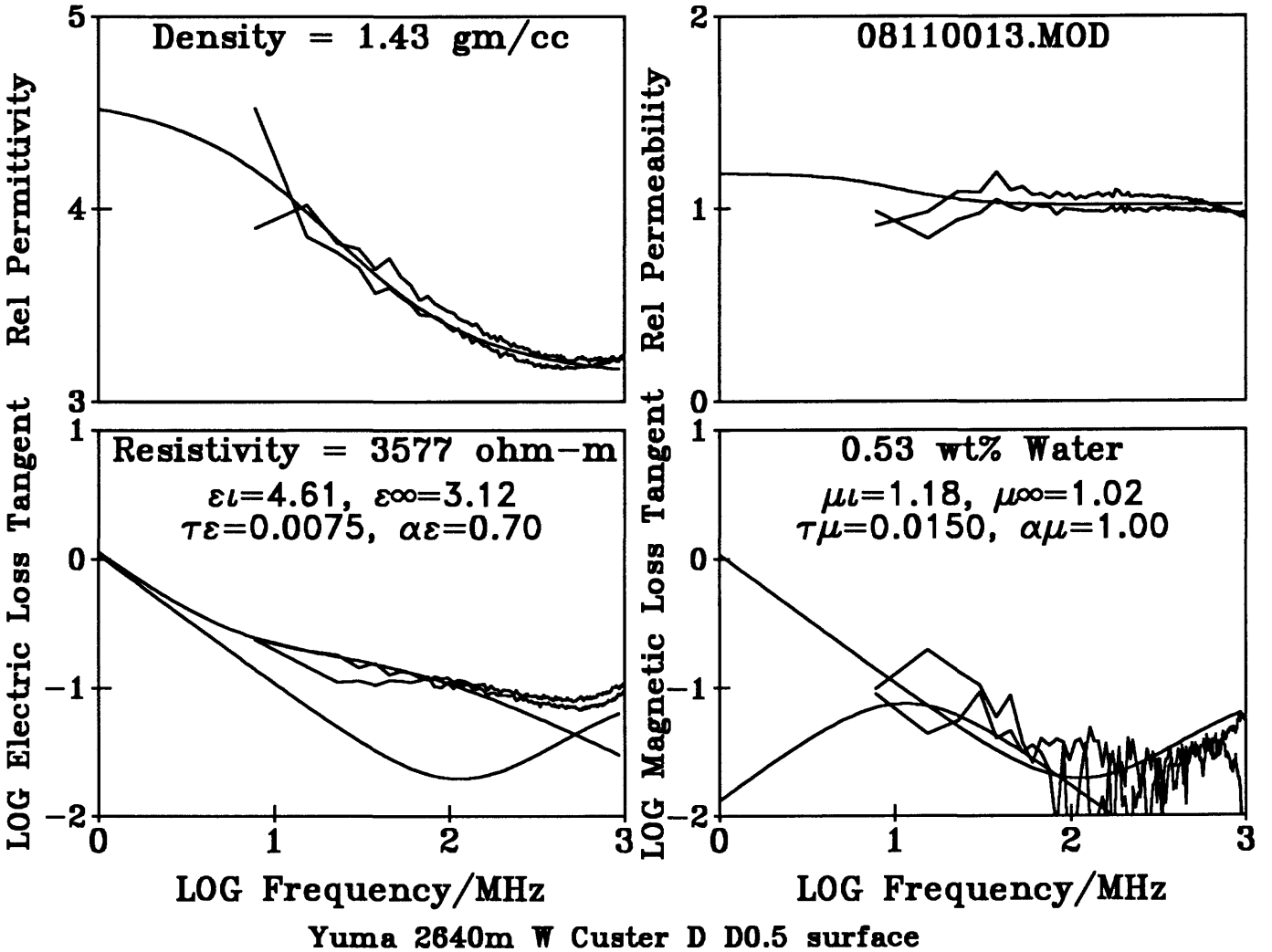



Figure 116 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

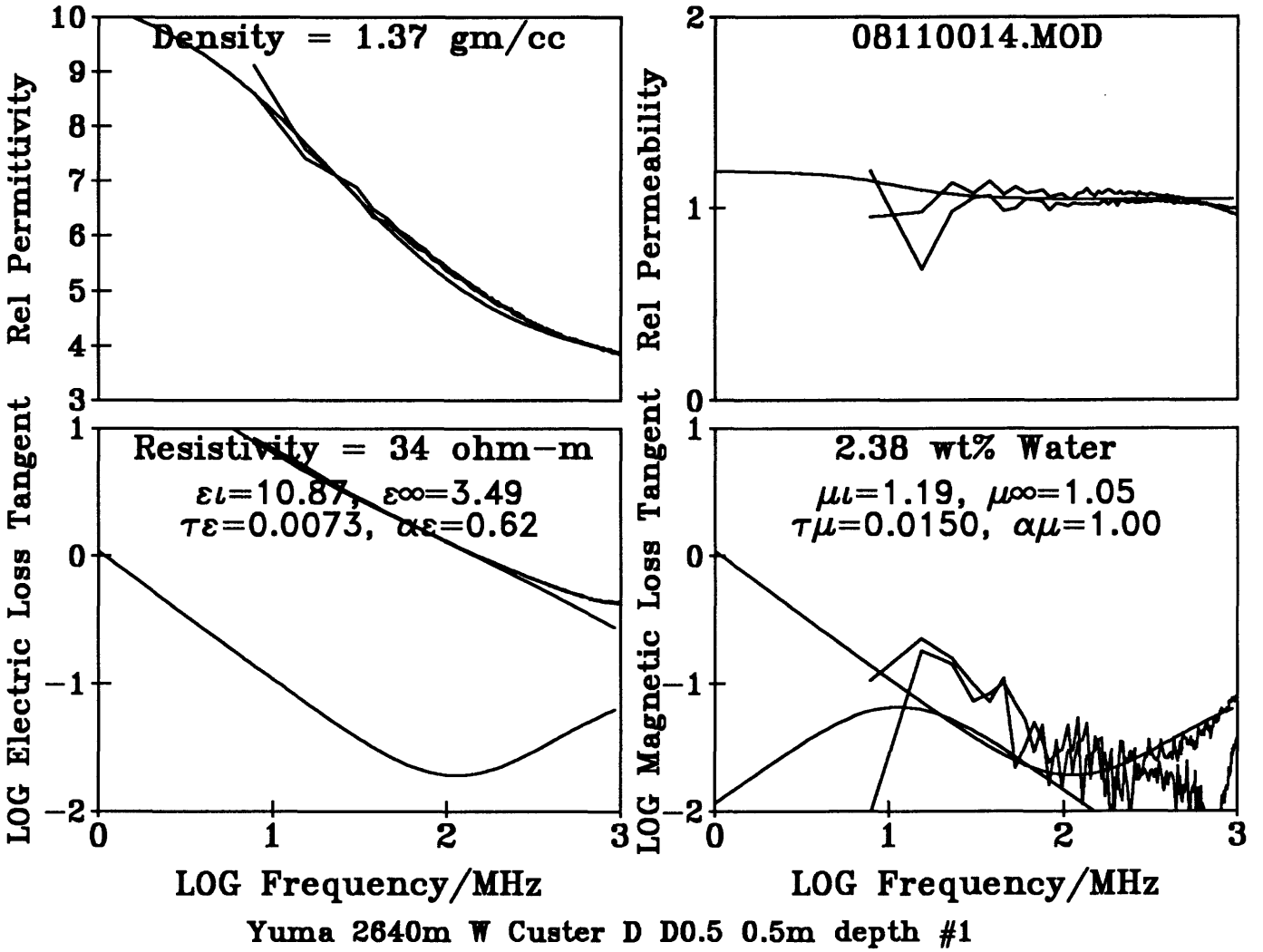



Figure 117 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

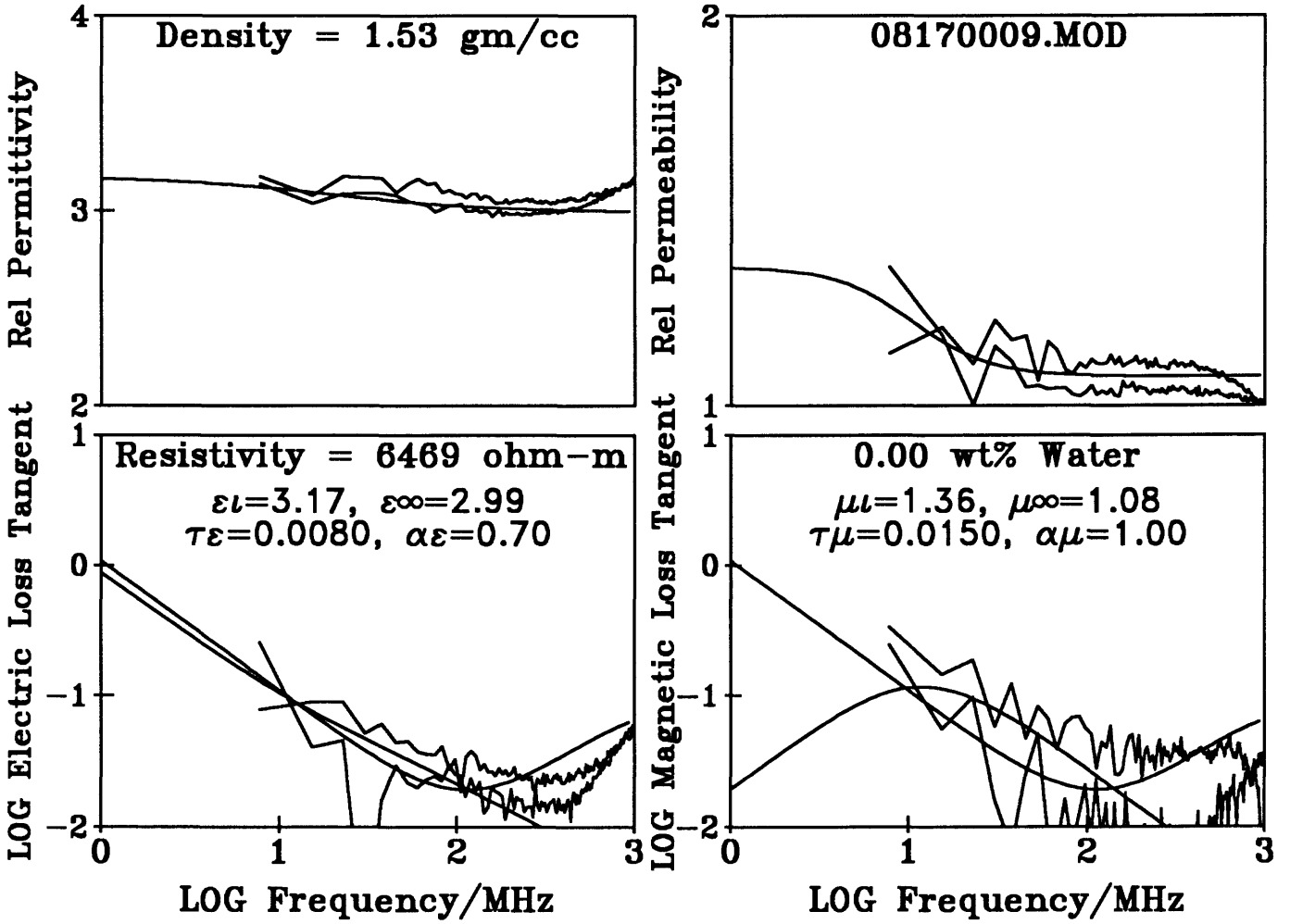

Density = 1.53 gm/cc
08170009.MOD
Resistivity = 6469 ohm-m
ει=3.17, ε∞=2.99
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.36, μ∞=1.08
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent Rel Permittivity
LOG Magnetic Loss Tangent Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2640m W Custer D D0.5 0.5m depth #2 vacuum dried

Figure 118 -

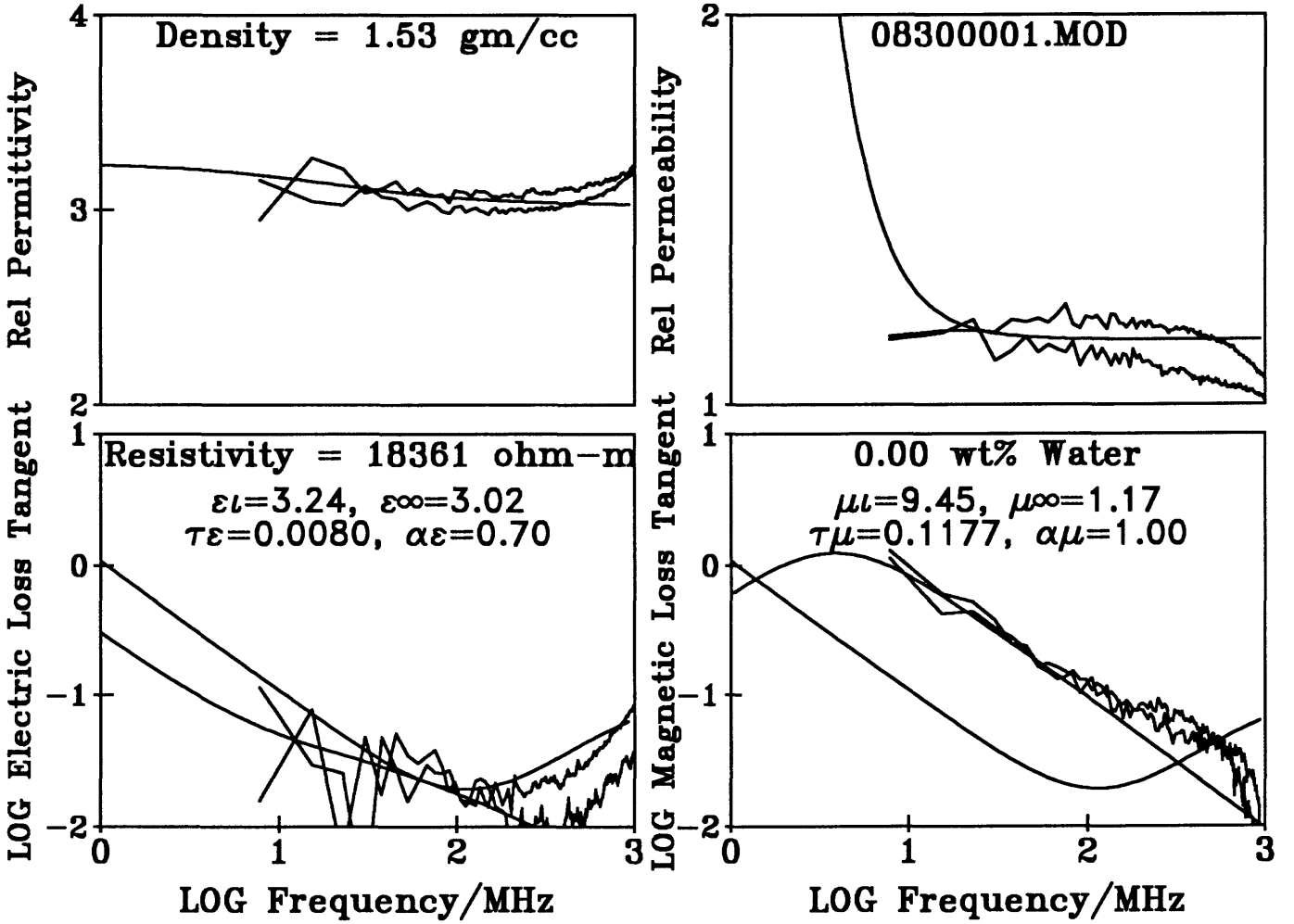

Density = 1.53 gm/cc
08300001.MOD
Resistivity = 18361 ohm-m
ει=3.24, ε∞=3.02
τε=0.0080, αε=0.70
0.00 wt% Water
μι=9.45, μ∞=1.17
τμ=0.1177, αμ=1.00
LOG Electric Loss Tangent
Rel Permittivity
LOG Magnetic Loss Tangent
Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2640m W Custer D D0.5 0.5m depth #3 vacuum dried

Figure 119 -

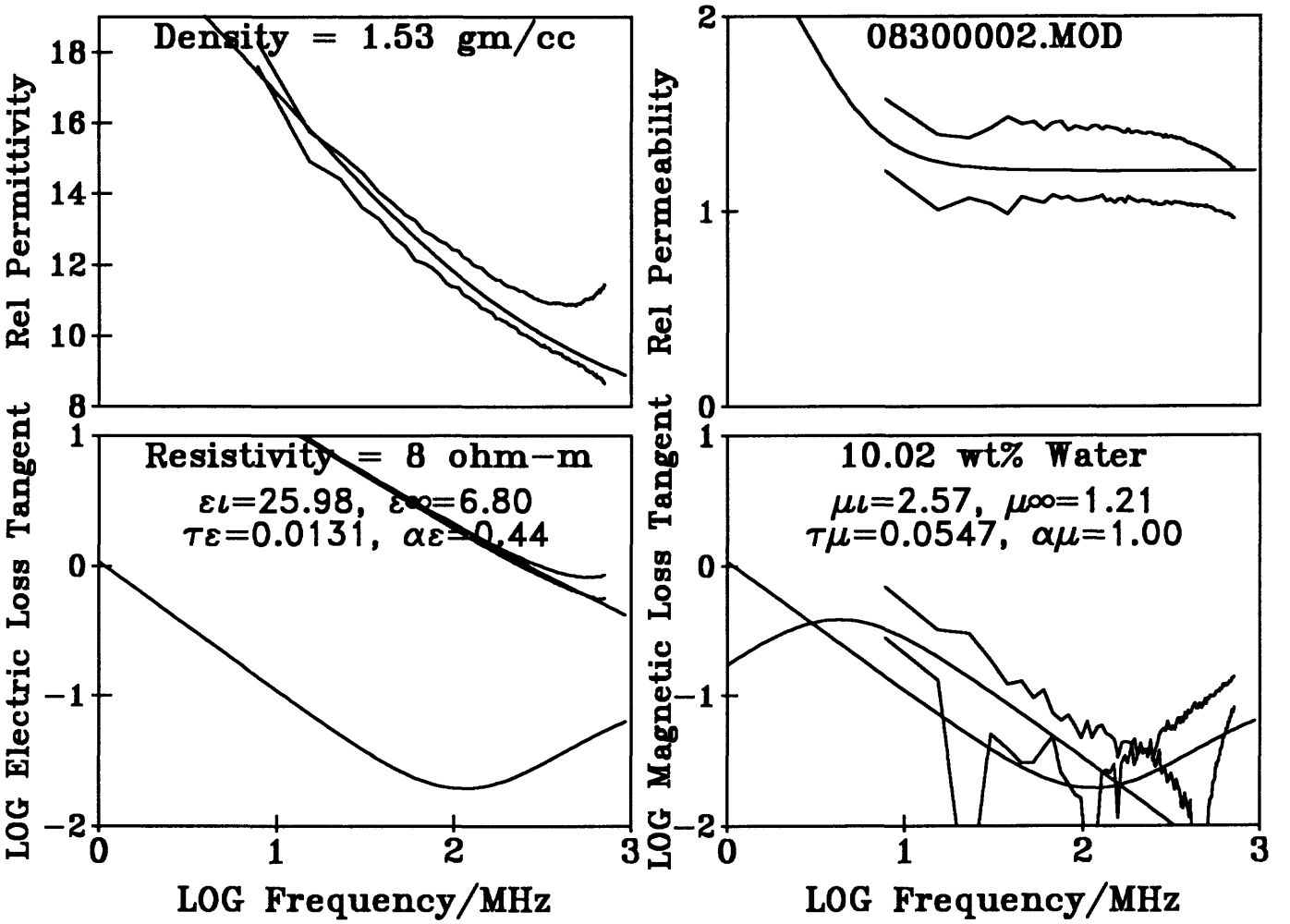

Density = 1.53 gm/cc
08300002.MOD
Resistivity = 8 ohm-m
ει=25.98, ε∞=6.80
τε=0.0131, αε=0.44
10.02 wt% Water
μι=2.57, μ∞=1.21
τμ=0.0547, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2640m W Custer D D0.5 0.5m depth #3 10 drops water

Figure 120 -

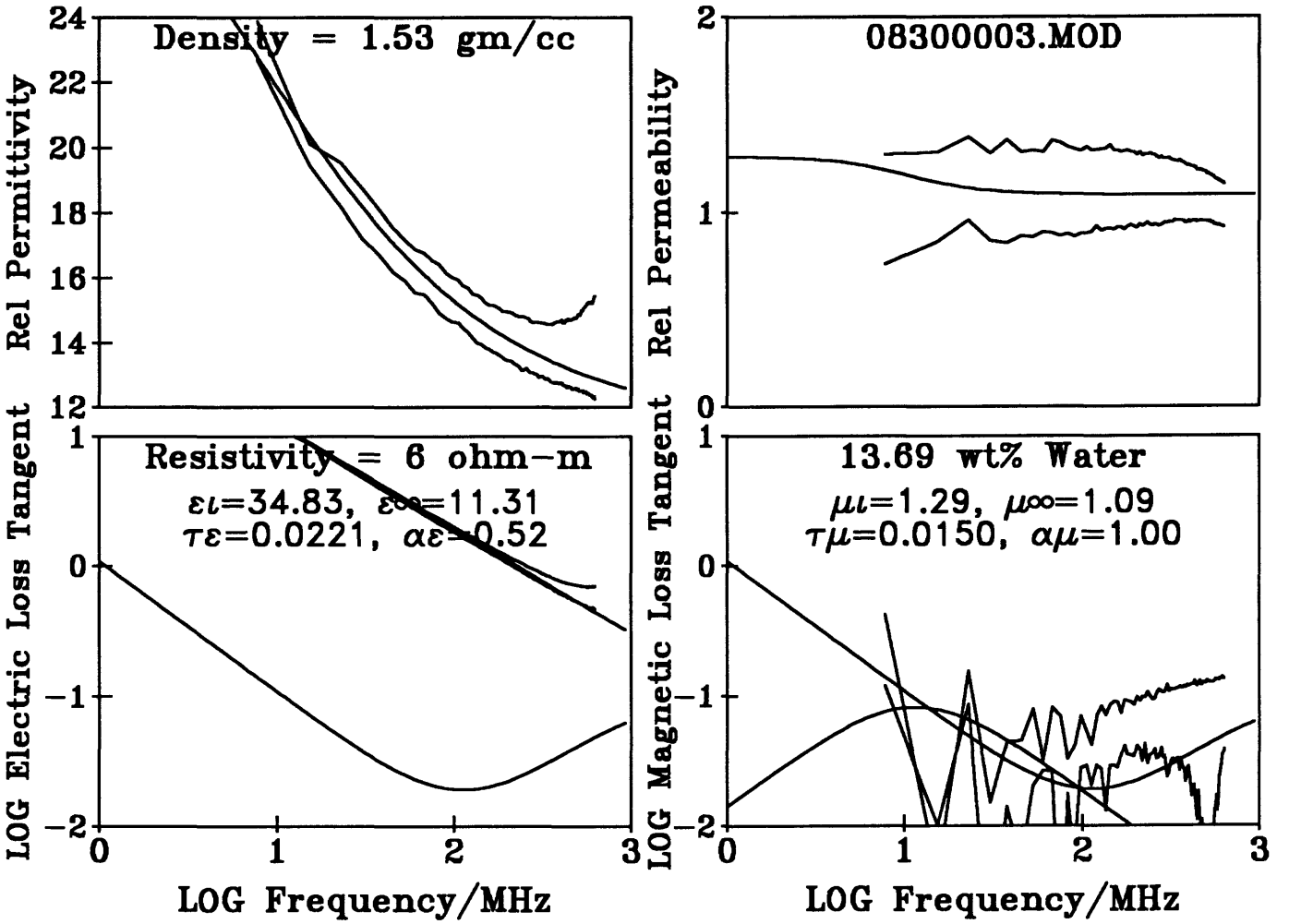

Density = 1.53 gm/cc
08300003.MOD
Resistivity = 6 ohm-m
ει=34.83, ε∞=11.31
τε=0.0221, αε=0.52
13.69 wt% Water
μι=1.29, μ∞=1.09
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 2640m W Custer D D0.5 0.5m depth water saturated

Figure 121 -

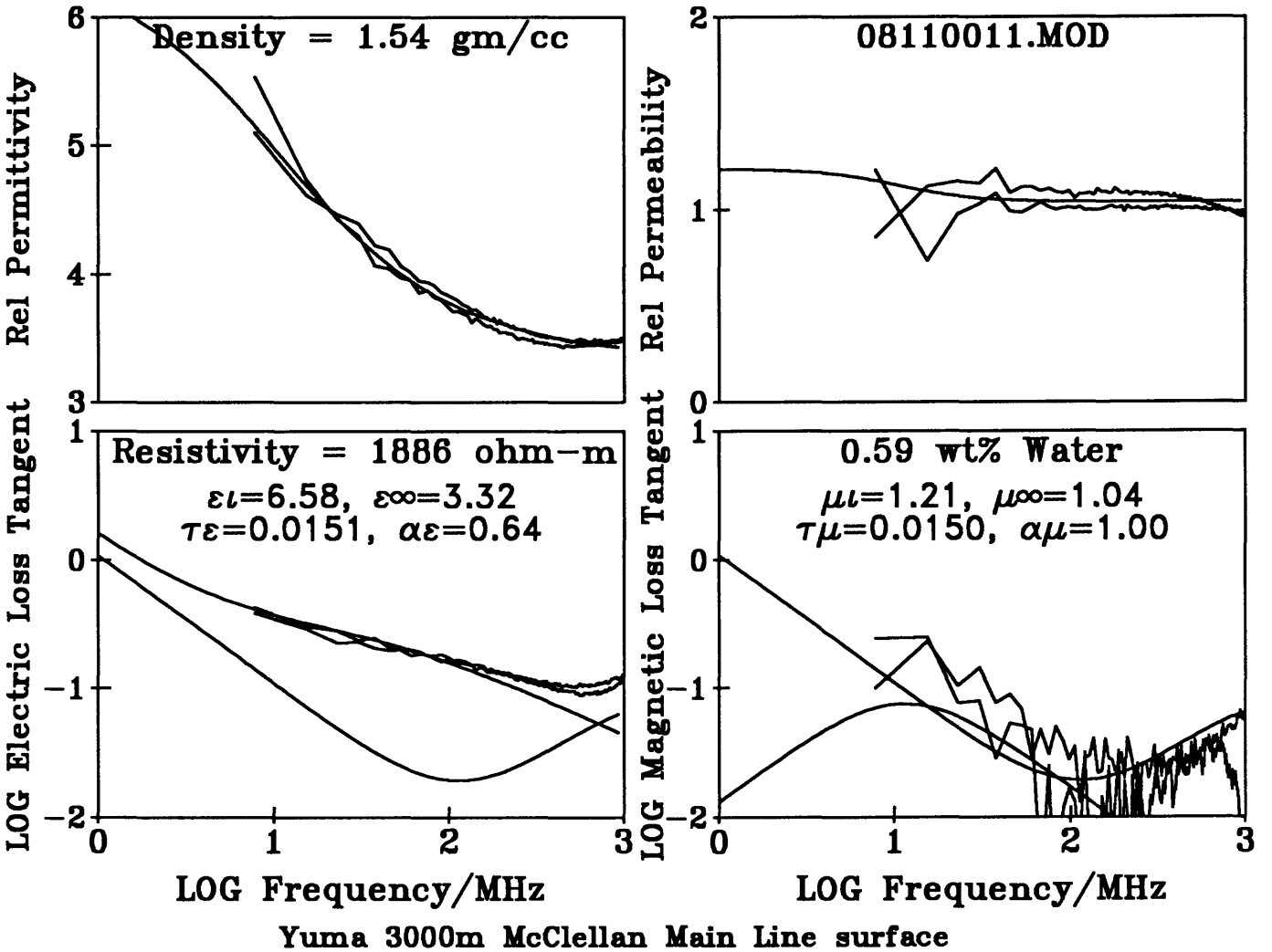



Figure 122 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

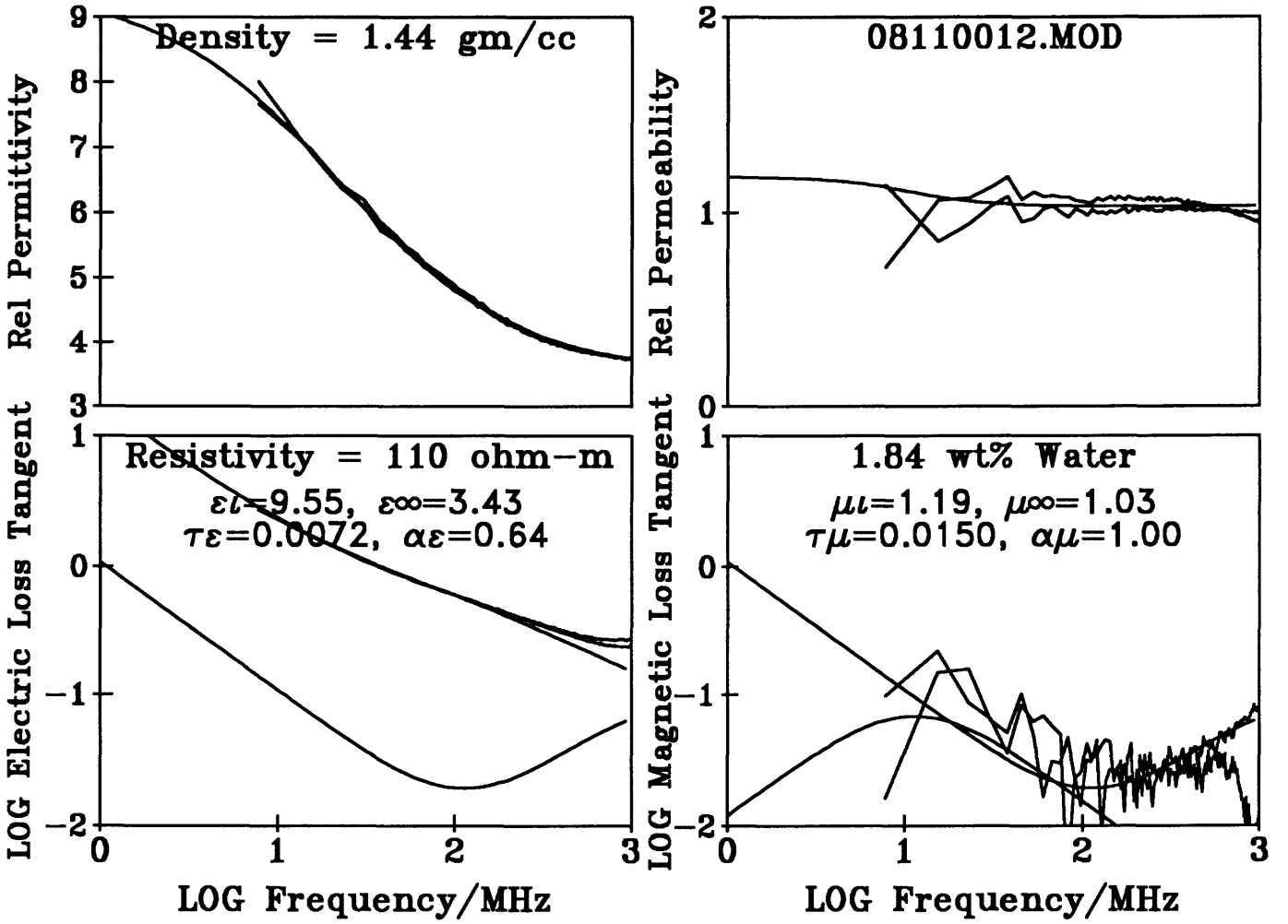



Figure 123 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

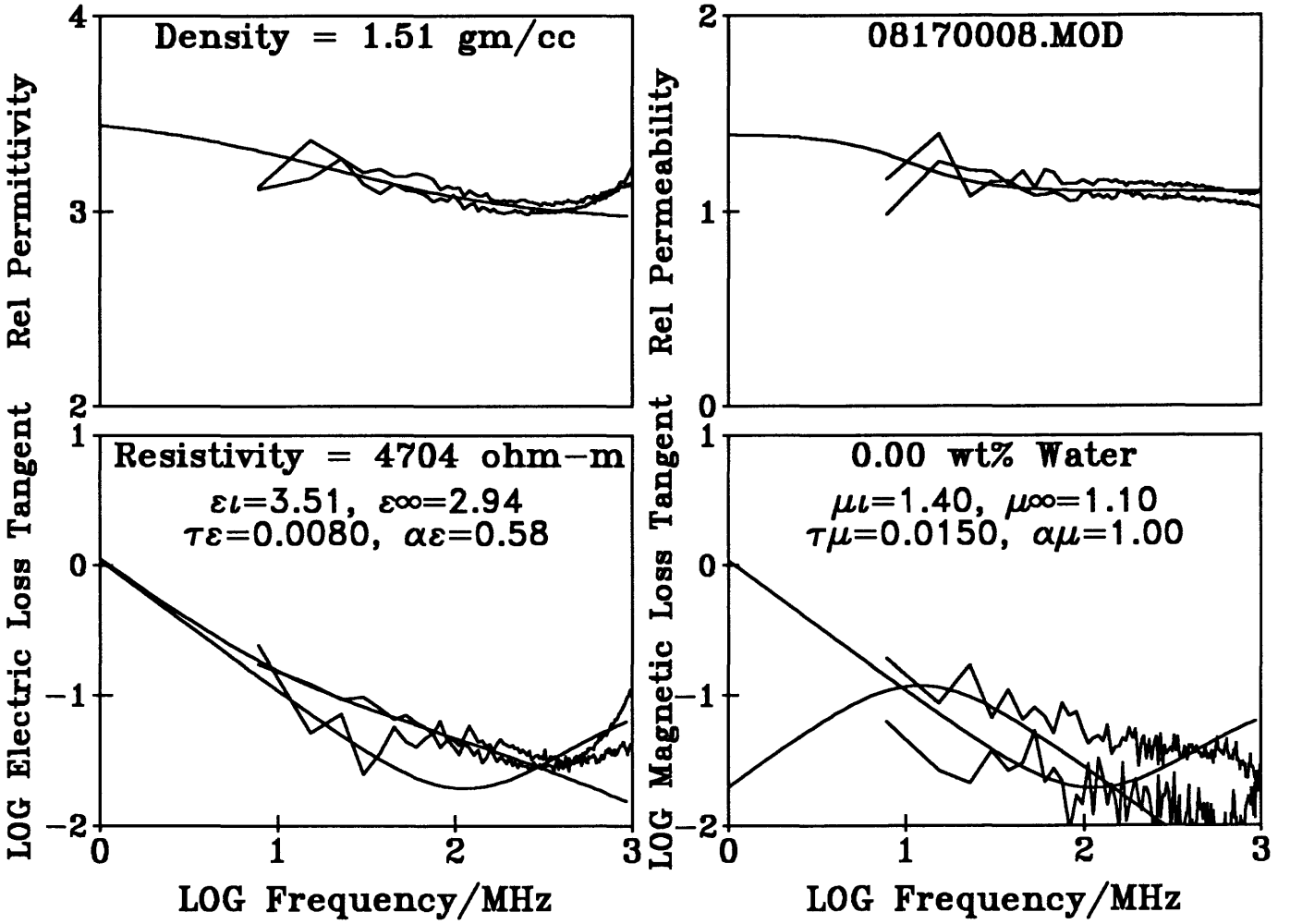

Density = 1.51 gm/cc
08170008.MOD
Resistivity = 4704 ohm-m
ει=3.51, ε∞=2.94
τε=0.0080, αε=0.58
0.00 wt% Water
μι=1.40, μ∞=1.10
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent Rel Permittivity
LOG Magnetic Loss Tangent Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 3000m McClellan Main Line 0.5m depth #2 vacuum dried

Figure 124 -

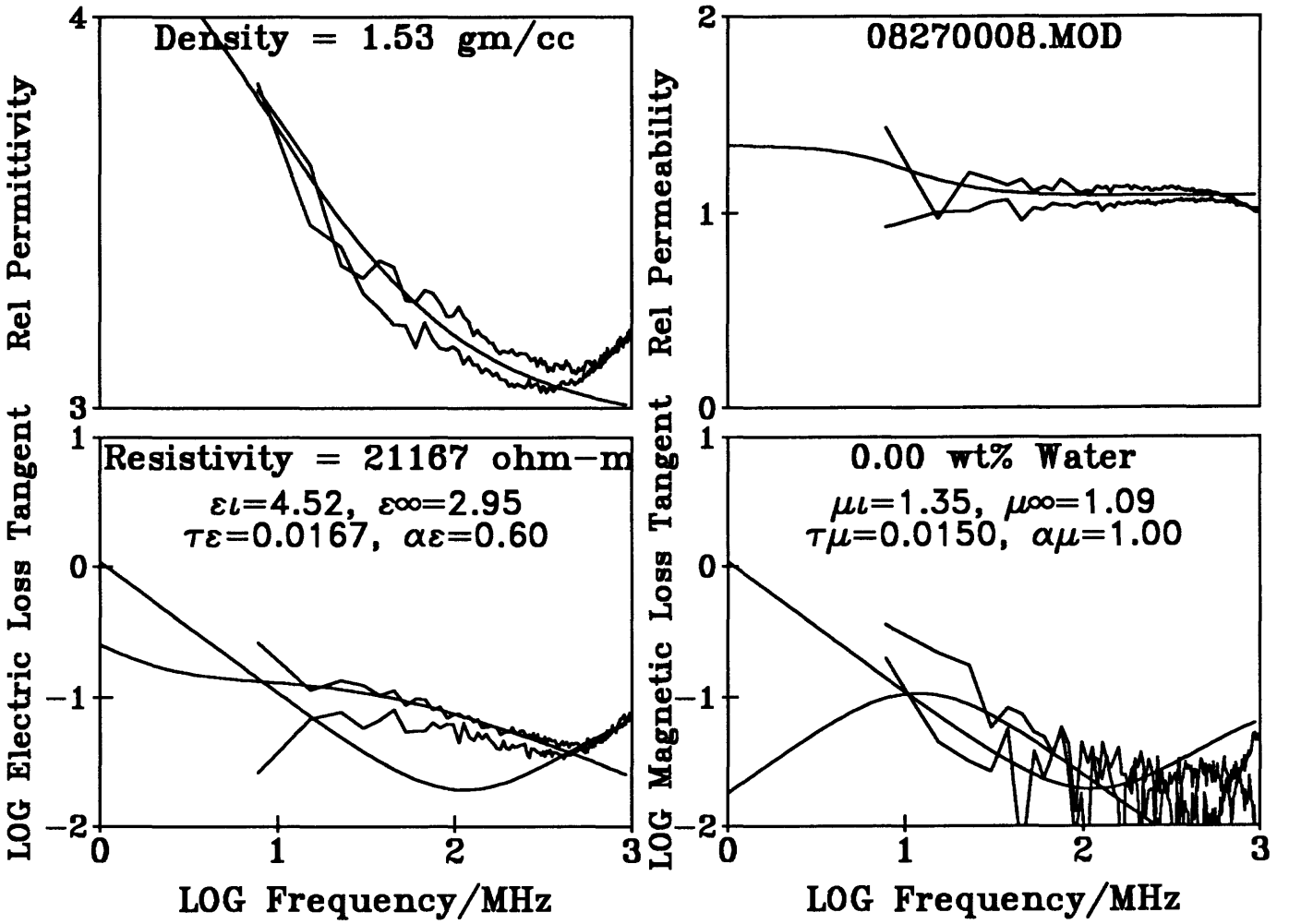

Density = 1.53 gm/cc
08270008.MOD
Resistivity = 21167 ohm-m
ει=4.52, ε∞=2.95
τε=0.0167, αε=0.60
0.00 wt% Water
μι=1.35, μ∞=1.09
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent Rel Permittivity
LOG Magnetic Loss Tangent Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 3000m McClellan Main Line 0.5m depth #3 vacuum dried

Figure 125 -

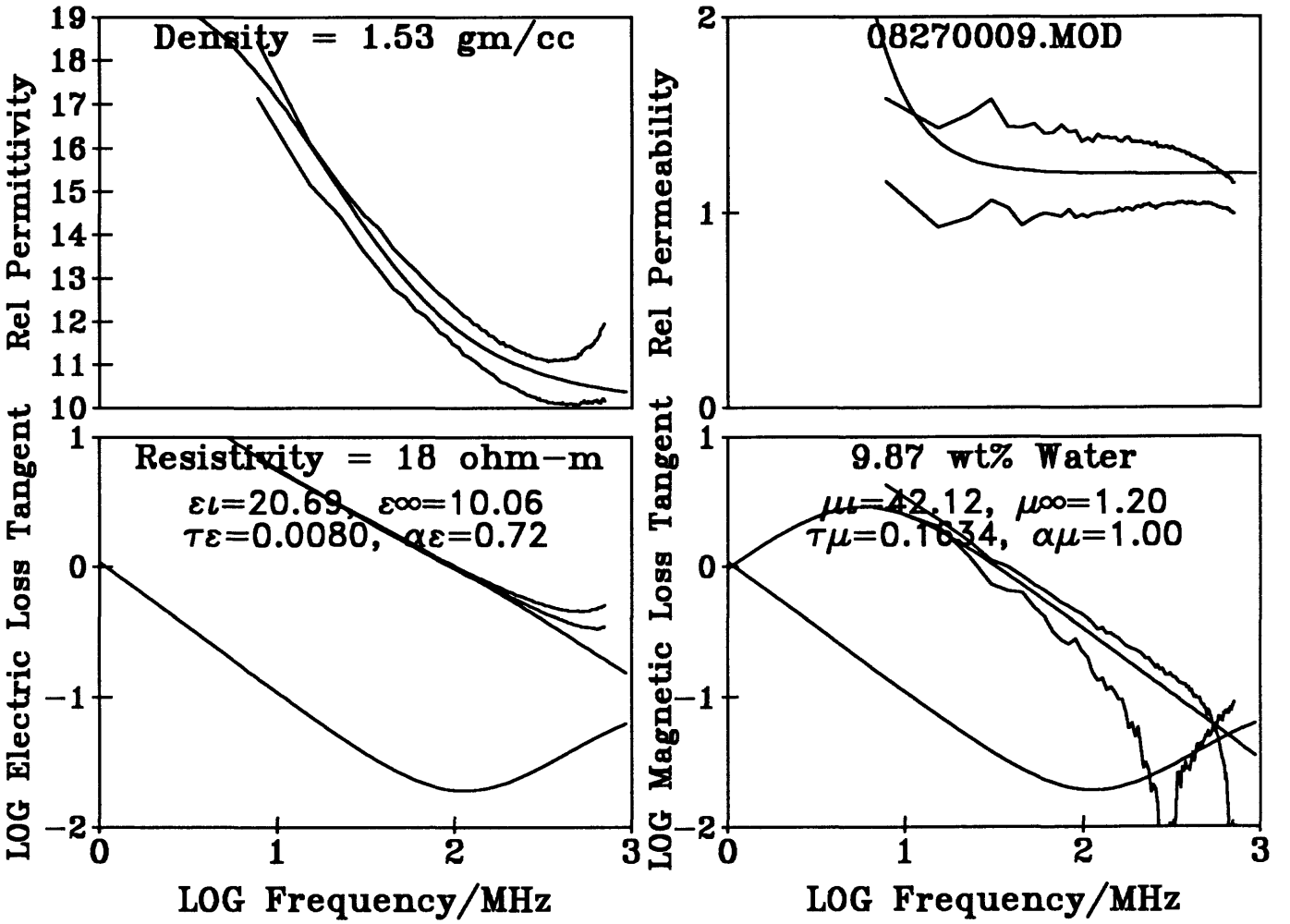

Density = 1.53 gm/cc
08270009.MOD
Resistivity = 18 ohm-m
ει=20.69, ε∞=10.06
τε=0.0080, αε=0.72
9.87 wt% Water
μι=42.12, μ∞=1.20
τμ=0.1634, αμ=1.00
LOG Electric Loss Tangent
Rel Permittivity
LOG Magnetic Loss Tangent
Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 3000m McClellan Main Line 0.5m depth #3 14 drops water

Figure 126 -

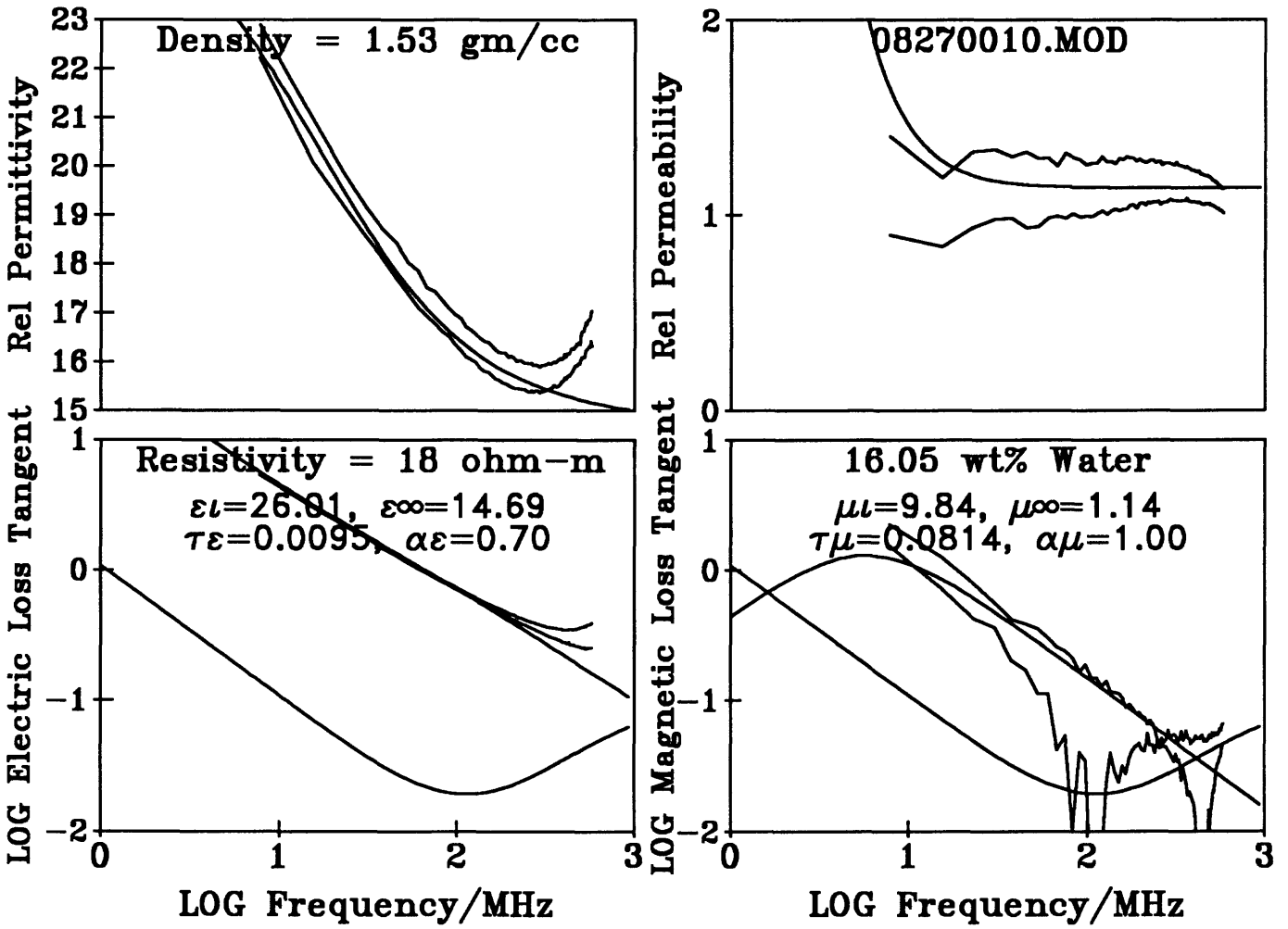

Density = 1.53 gm/cc
08270010.MOD
Resistivity = 18 ohm-m
ει=26.01, ε∞=14.69
τε=0.0095, αε=0.70
16.05 wt% Water
μι=9.84, μ∞=1.14
τμ=0.0814, αμ=1.00
LOG Electric Loss Tangent Rel Permittivity
LOG Magnetic Loss Tangent Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 3000m McClellan Main Line 0.5m depth #3 water saturated

Figure 127 -

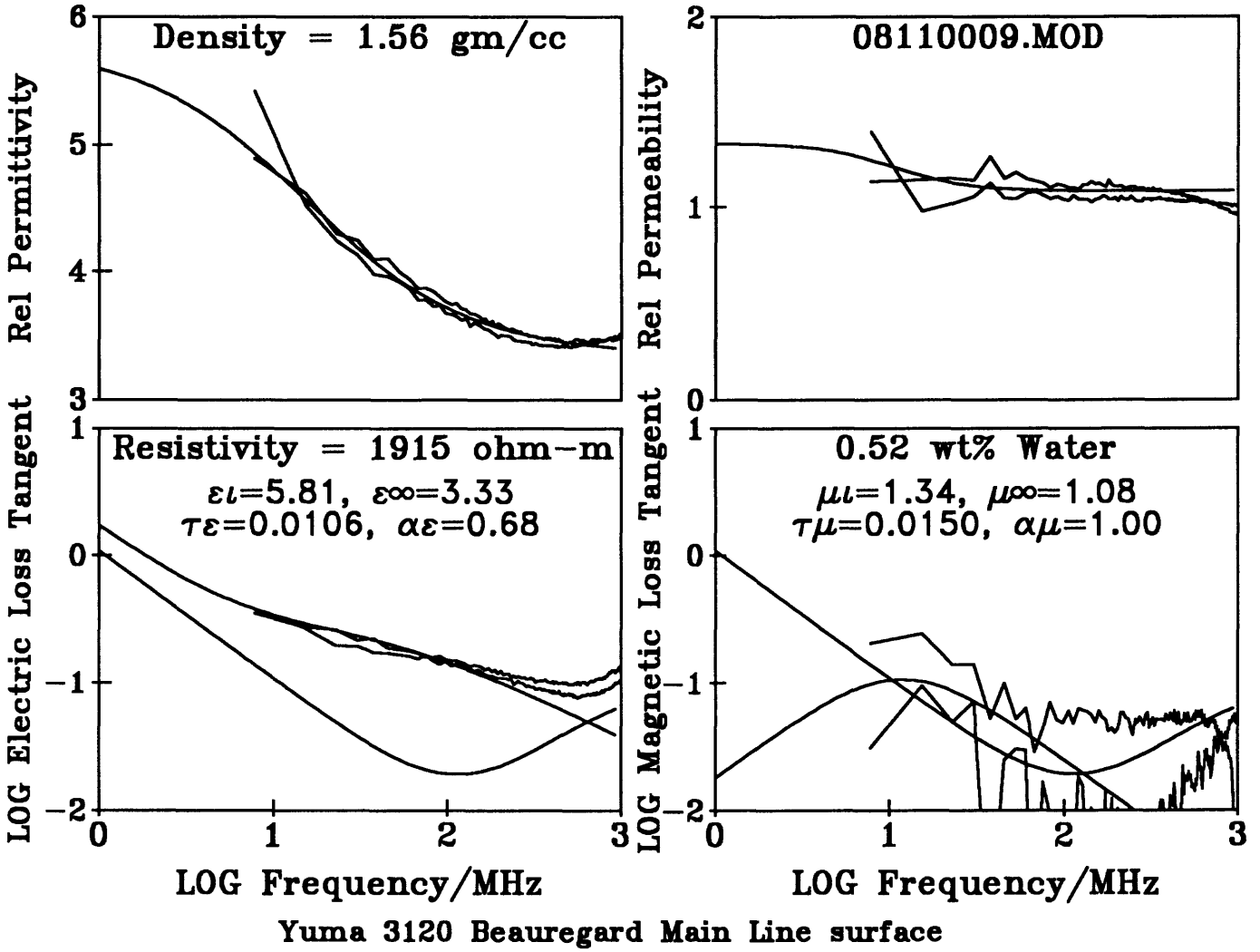



Figure 128 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

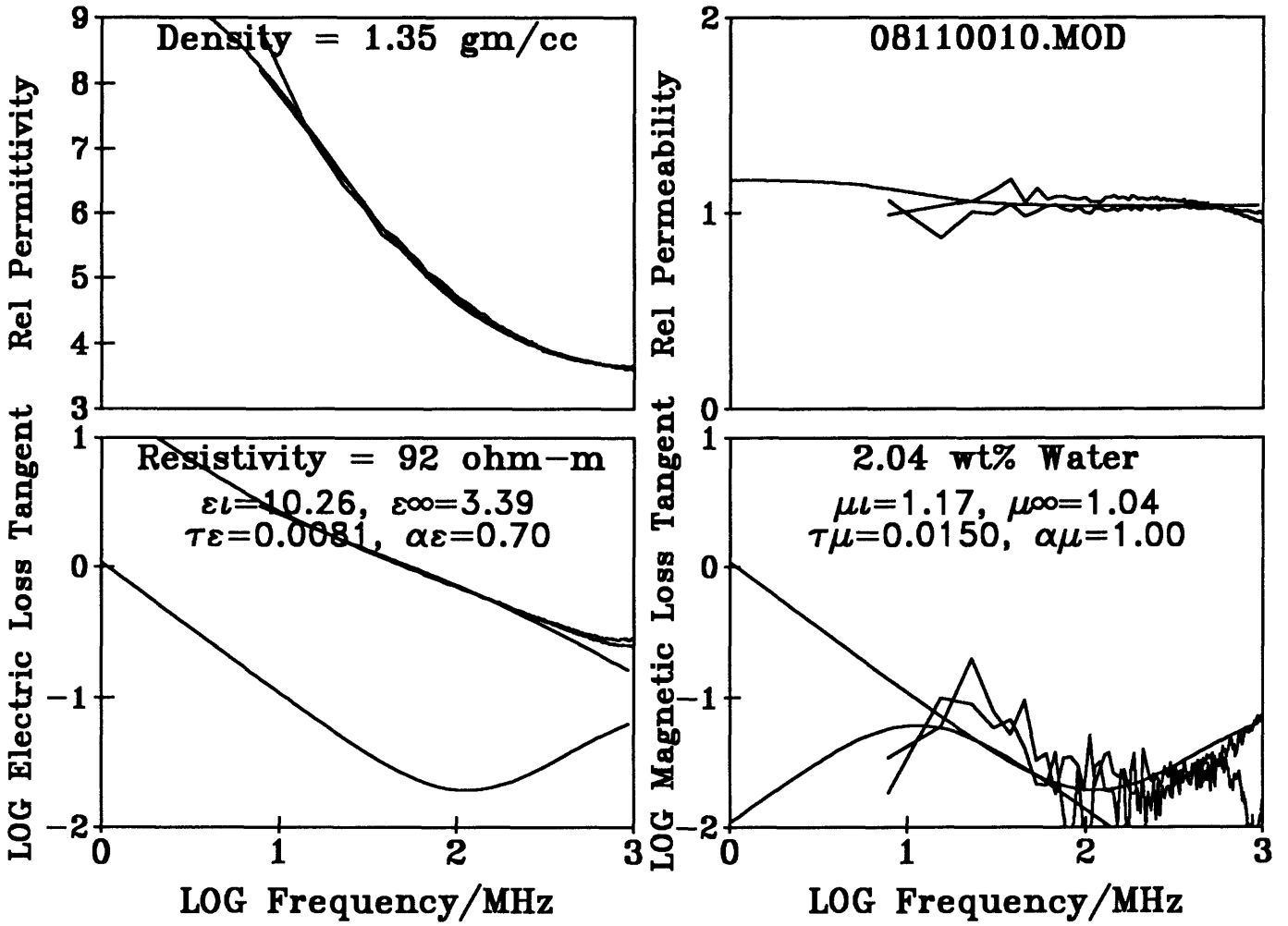
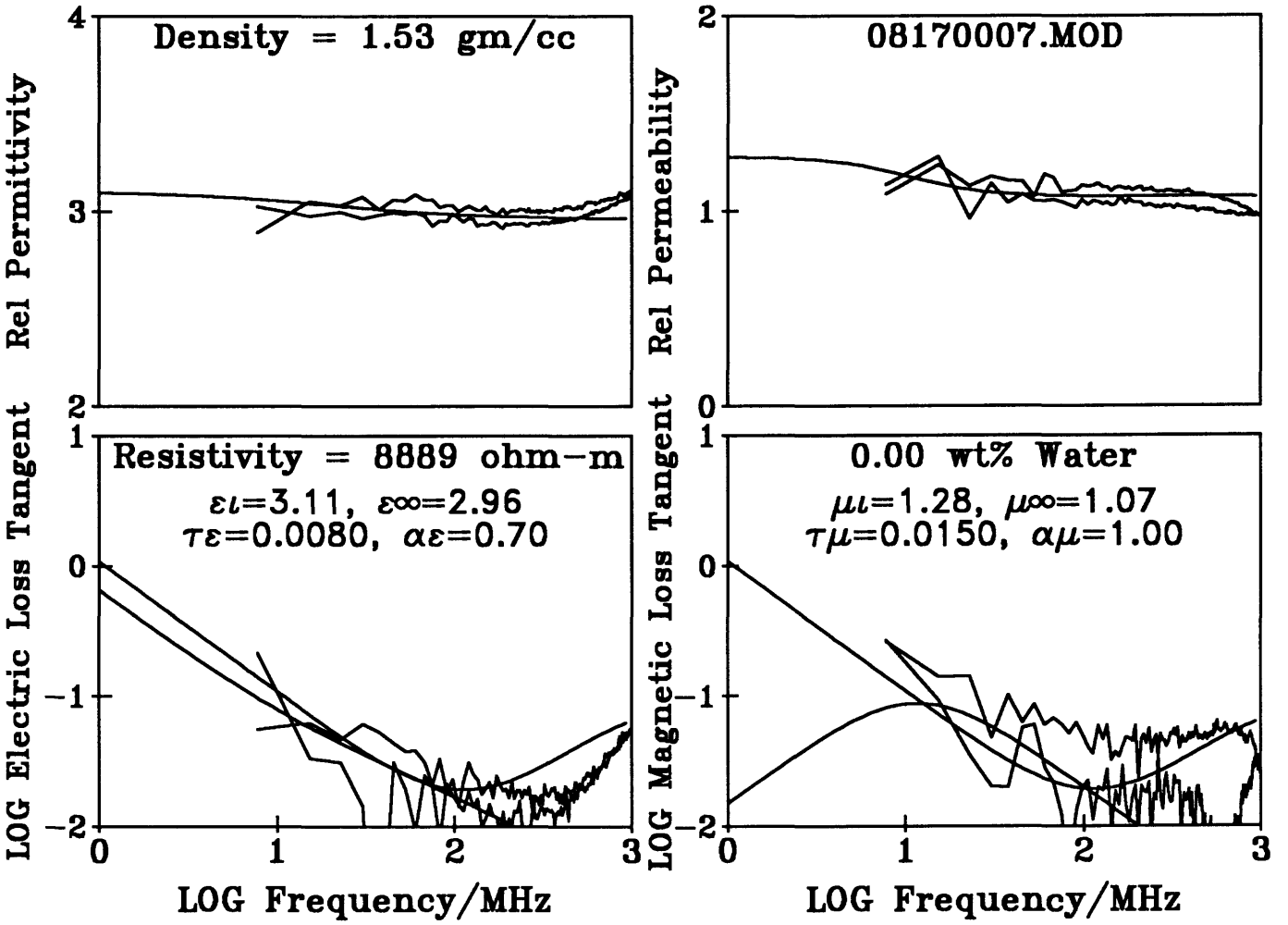



Figure 129 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.




**Yuma 3120m Beauregard Main Line 0.5m depth #2 vacuum dried**

Figure 130 -

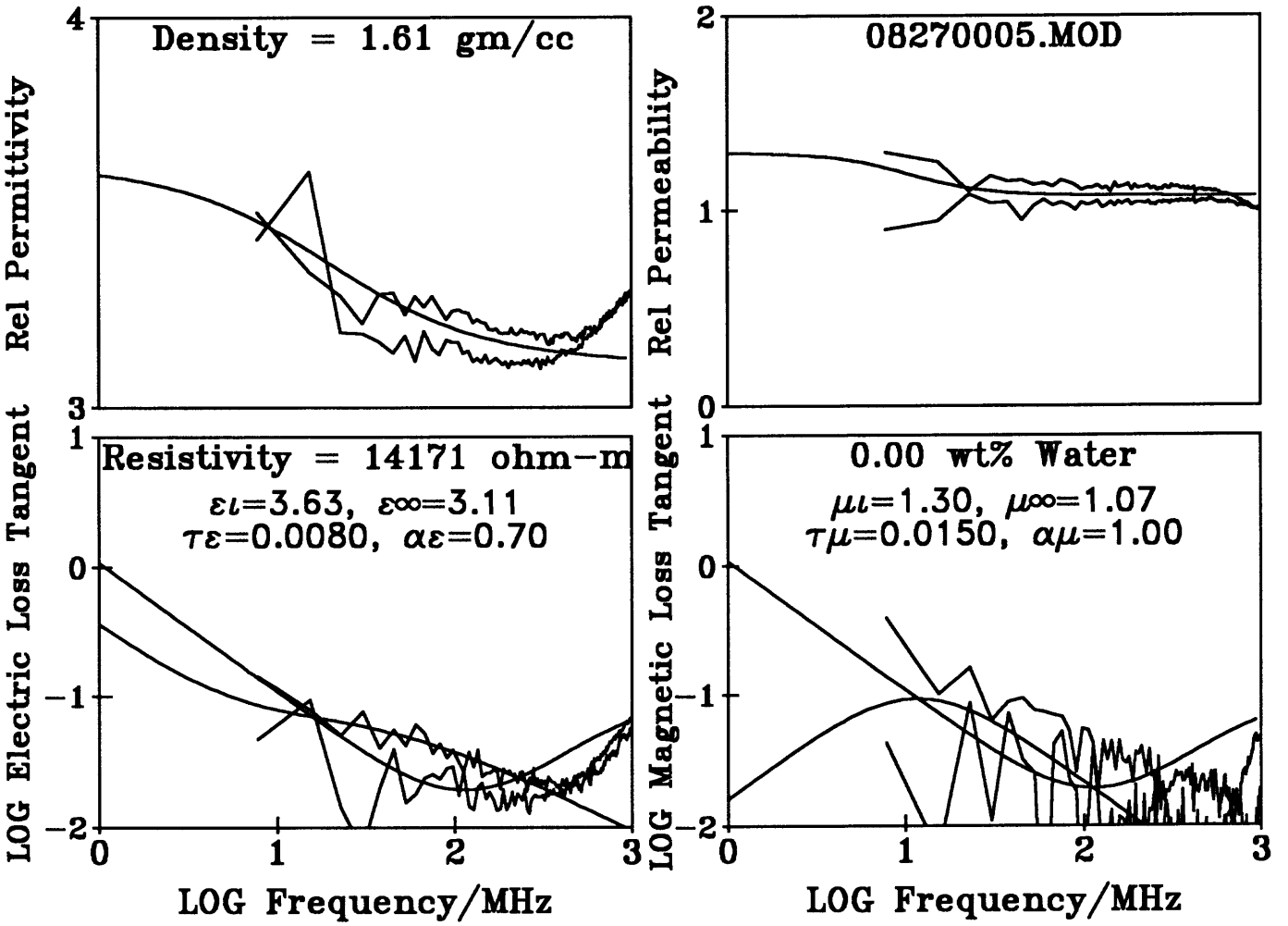

Density = 1.61 gm/cc
08270005.MOD
Resistivity = 14171 ohm-m
ει=3.63, ε∞=3.11
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.30, μ∞=1.07
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent Rel Permittivity
LOG Magnetic Loss Tangent Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 3120m Beauregard Main Line 0.5m depth #3 vacuum dried

Figure 131 -

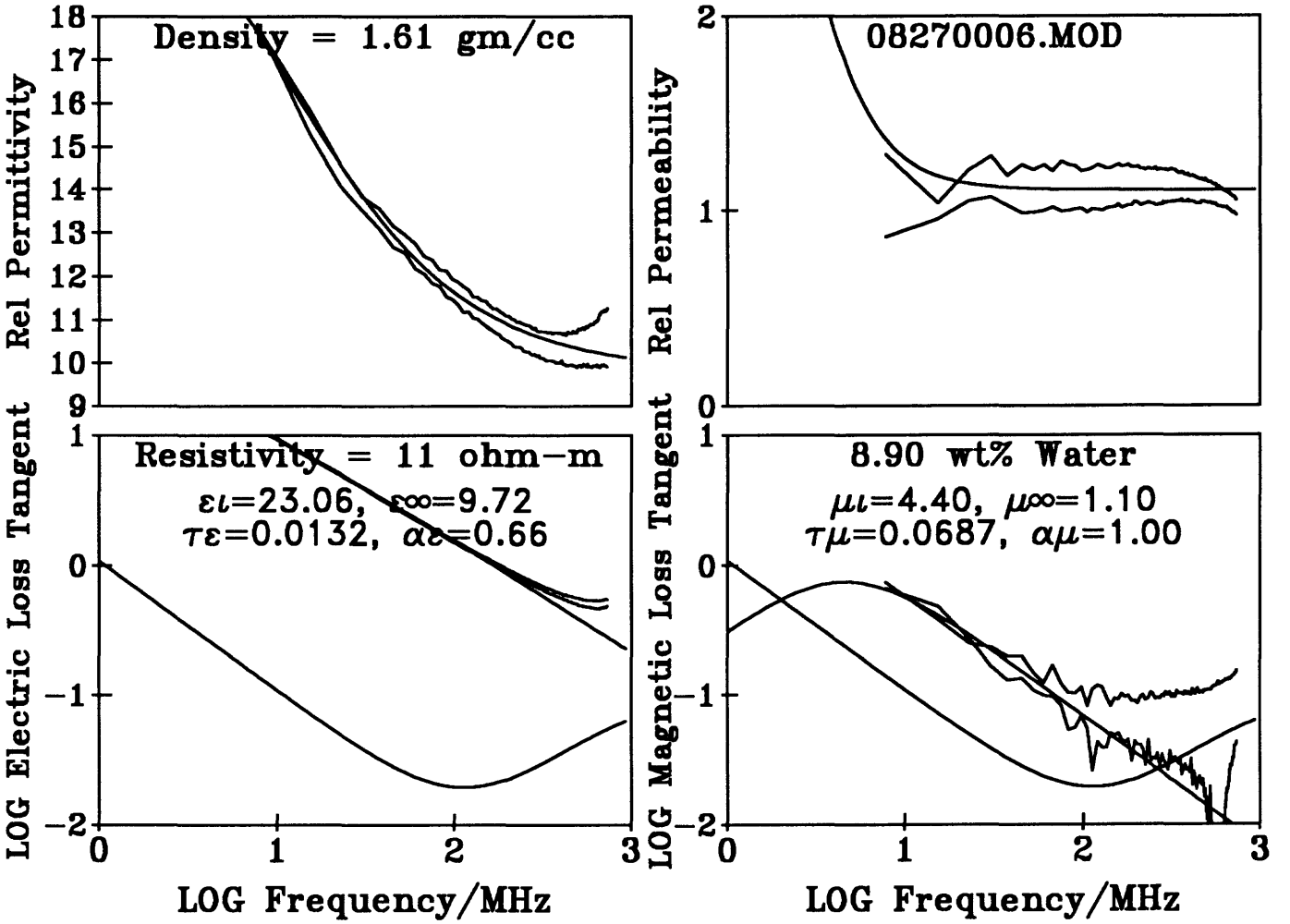

Density = 1.61 gm/cc
08270006.MOD
Resistivity = 11 ohm-m
ει=23.06, ε∞=9.72
τε=0.0132, αε=0.66
8.90 wt% Water
μι=4.40, μ∞=1.10
τμ=0.0687, αμ=1.00
LOG Electric Loss Tangent
Rel Permittivity
LOG Magnetic Loss Tangent
Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 3120m Beauregard Main Line 0.5m depth #3 9 drops water

Figure 132 -

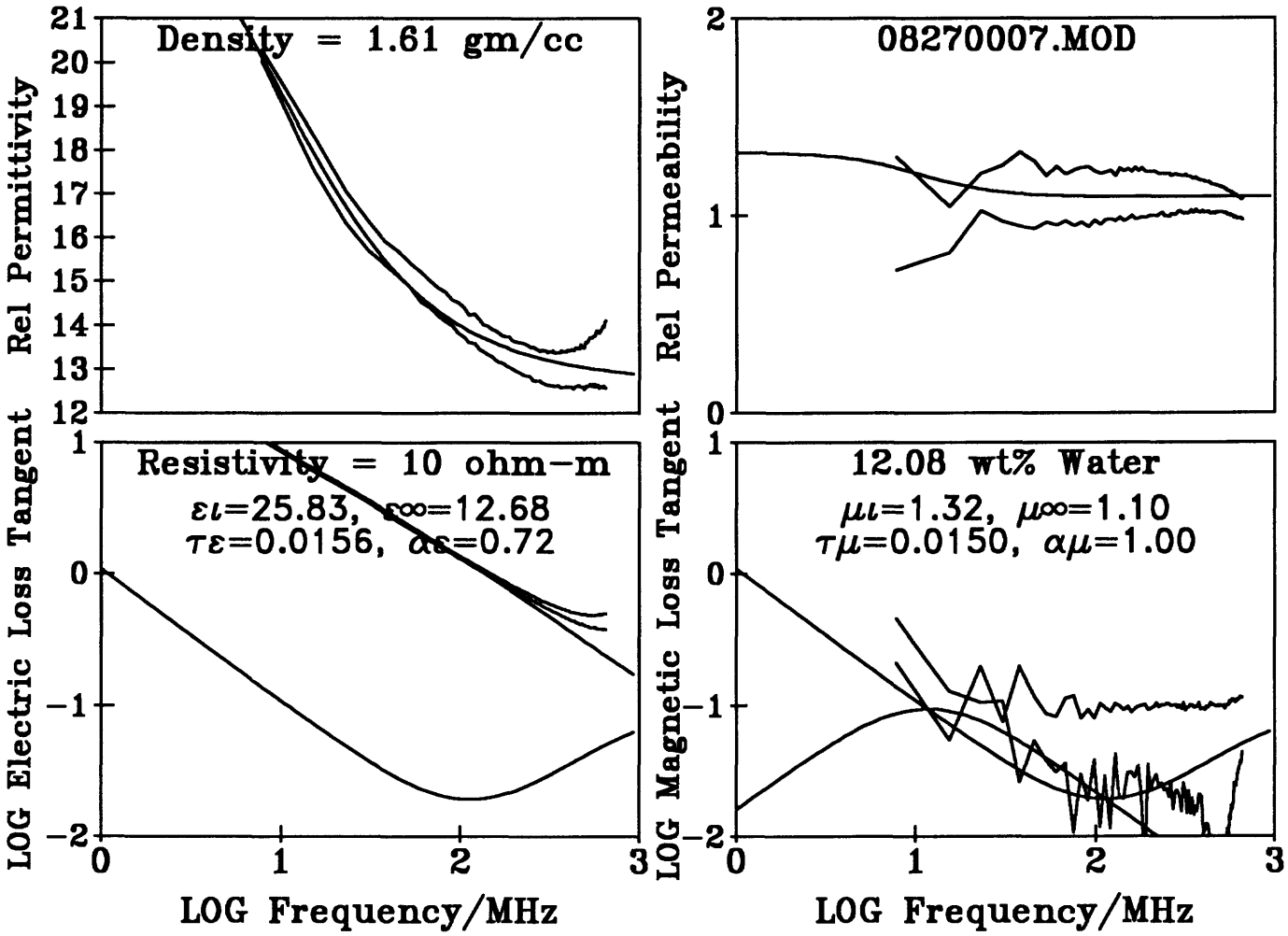

Density = 1.61 gm/cc
08270007.MOD
Resistivity = 10 ohm-m
ει=25.83, ε∞=12.68
τε=0.0156, αε=0.72
12.08 wt% Water
μι=1.32, μ∞=1.10
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 3120m Beauregard Main Line 0.5m depth #3 water saturated

Figure 133 -

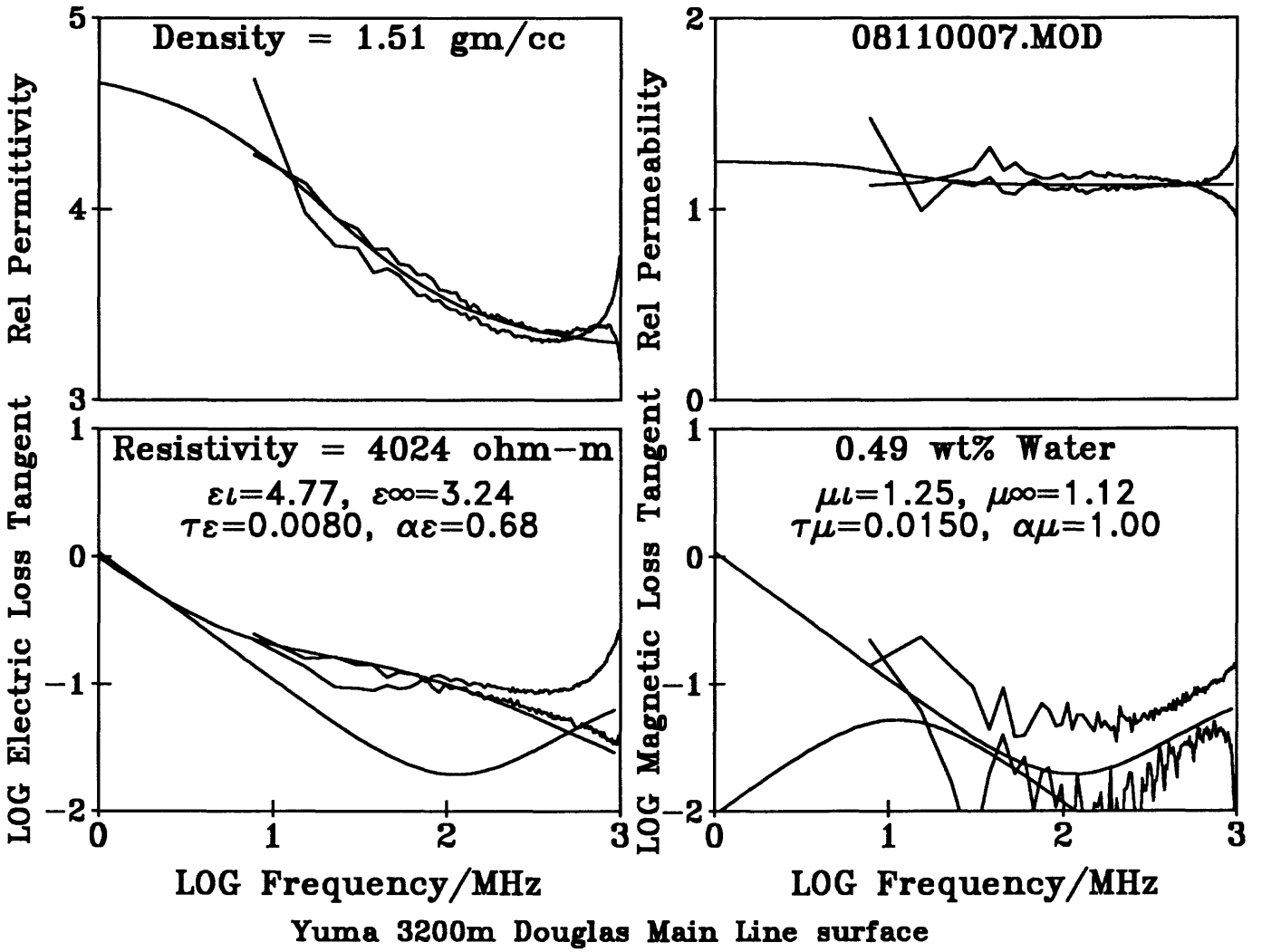



Figure 134 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

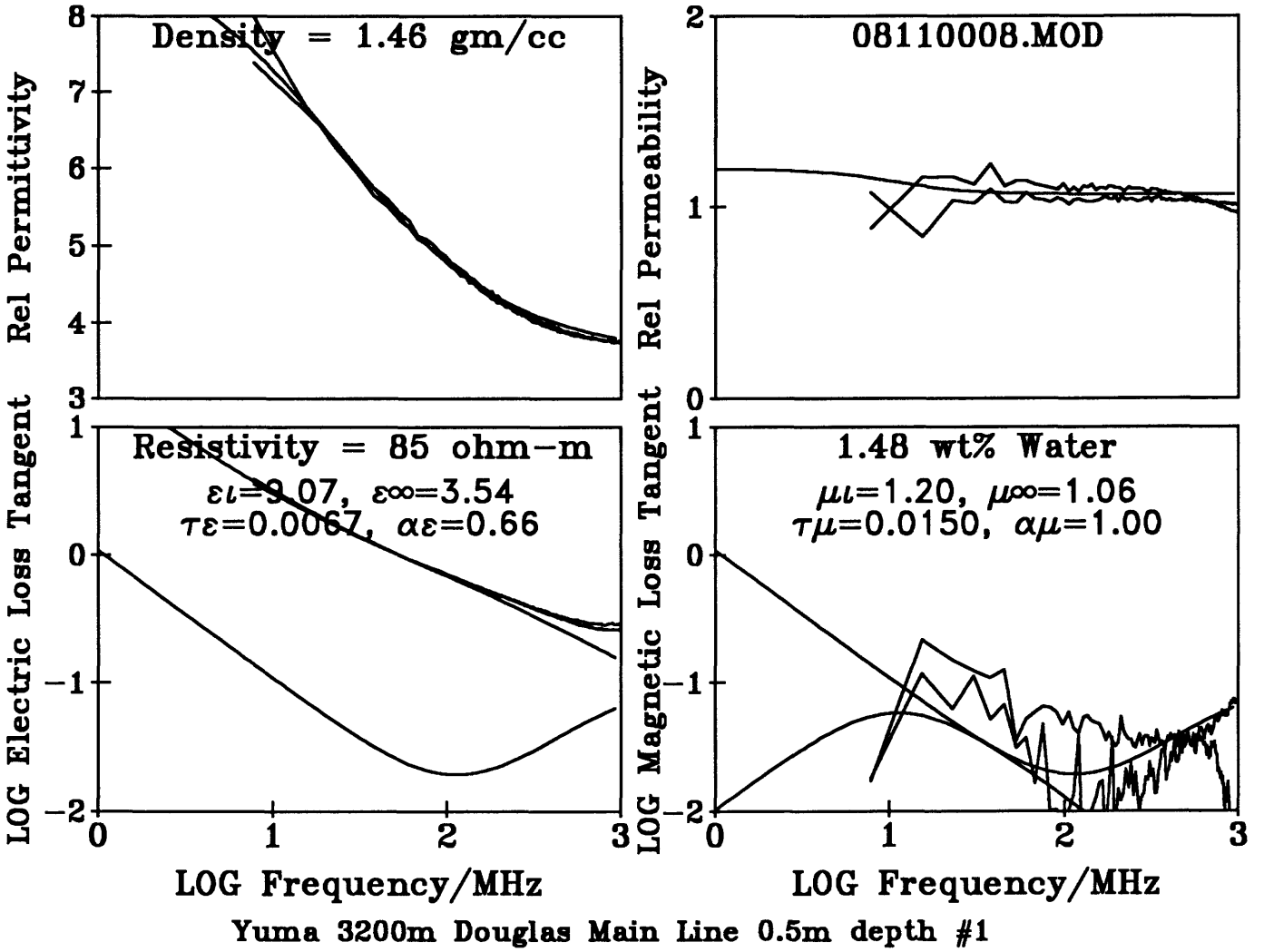



Figure 135 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

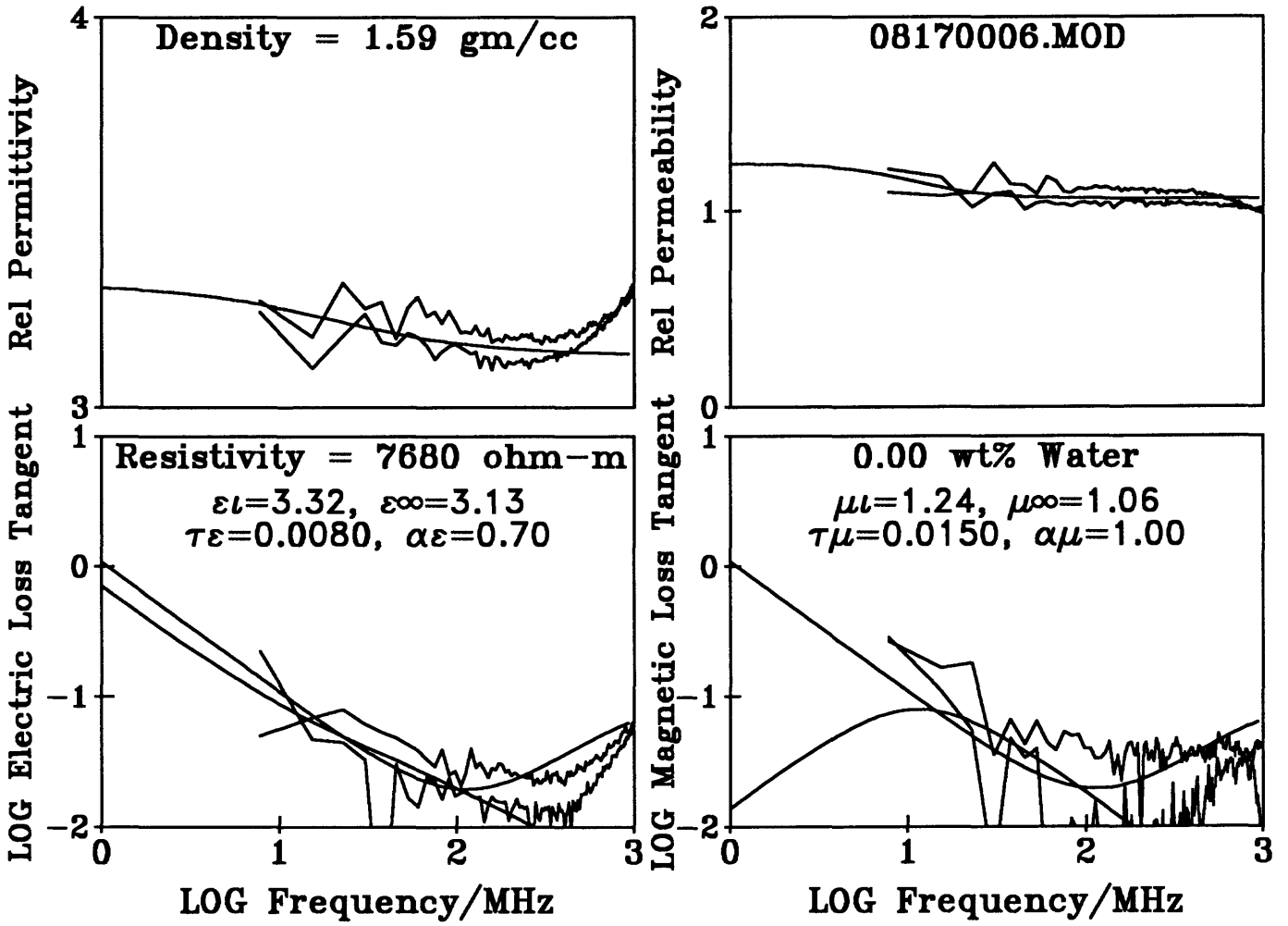

Density = 1.59 gm/cc
08170006.MOD
Rel Permittivity
Rel Permeability
Resistivity = 7680 ohm-m
ει=3.32, ε∞=3.13
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.24, μ∞=1.06
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 3200m Douglas Main Line 0.5m depth #2 vacuum dried

Figure 136 -

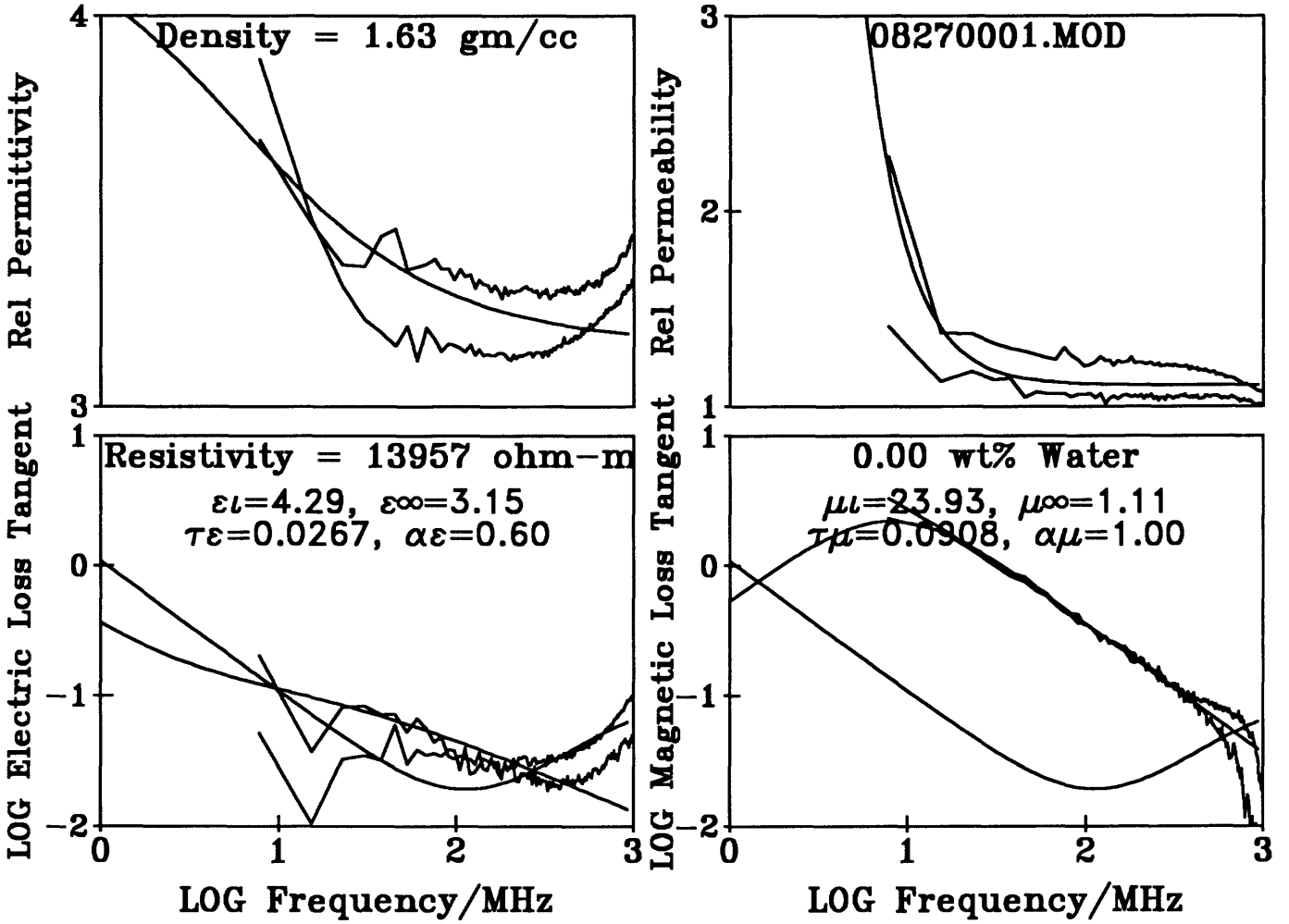

Density = 1.63 gm/cc
08270001.MOD
Resistivity = 13957 ohm-m
ει=4.29, ε∞=3.15
τε=0.0267, αε=0.60
0.00 wt% Water
μι=23.93, μ∞=1.11
τμ=0.0908, αμ=1.00
LOG Electric Loss Tangent Rel Permittivity
LOG Magnetic Loss Tangent Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 3200m Douglas Main Line 0.5m depth #3 vacuum dried

Figure 137 -

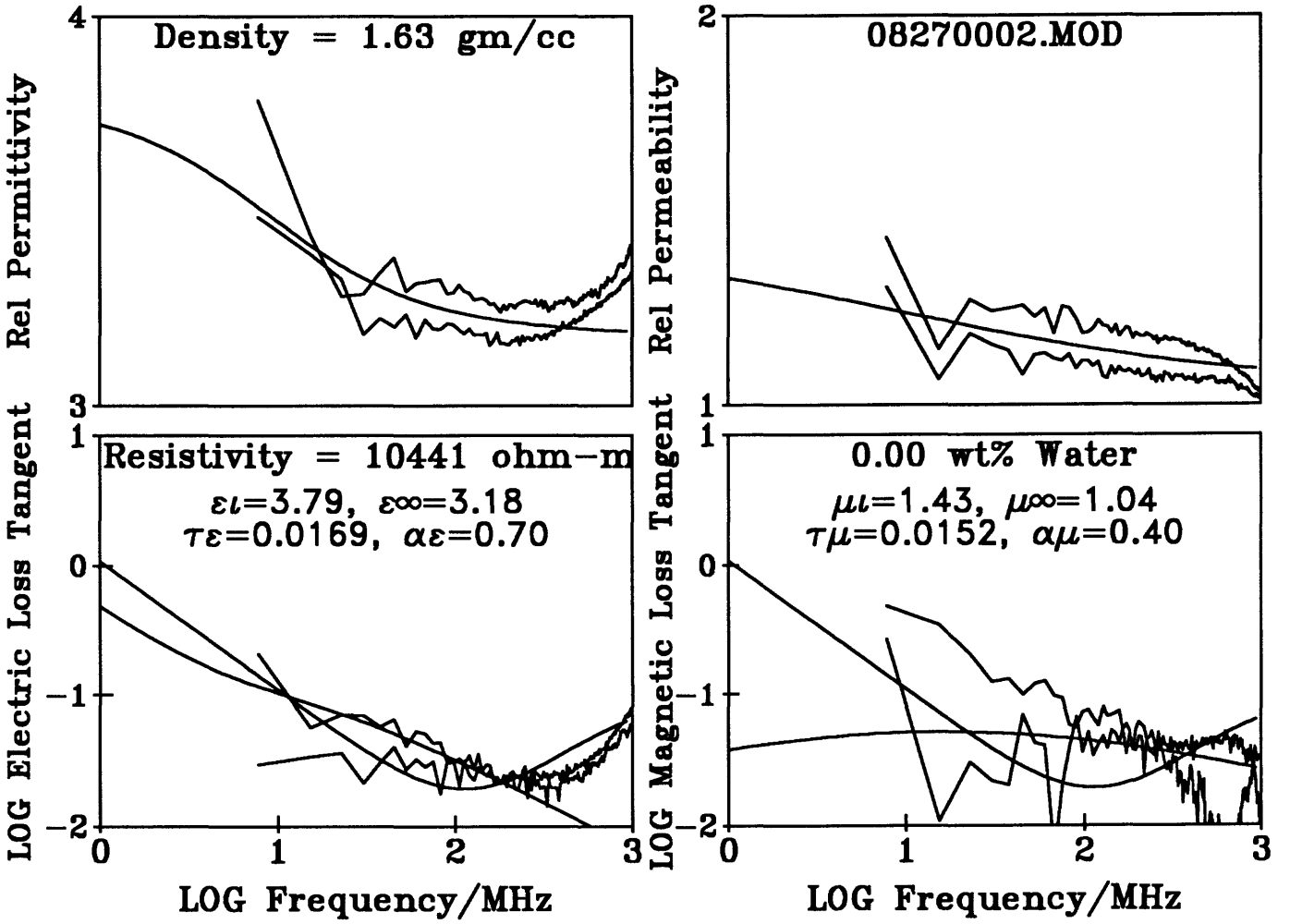

Density = 1.63 gm/cc
08270002.MOD
Resistivity = 10441 ohm-m
ει=3.79, ε∞=3.18
τε=0.0169, αε=0.70
0.00 wt% Water
μι=1.43, μ∞=1.04
τμ=0.0152, αμ=0.40
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 3200m Douglas Main Line 0.5m depth #4 vacuum dried

Figure 138 -

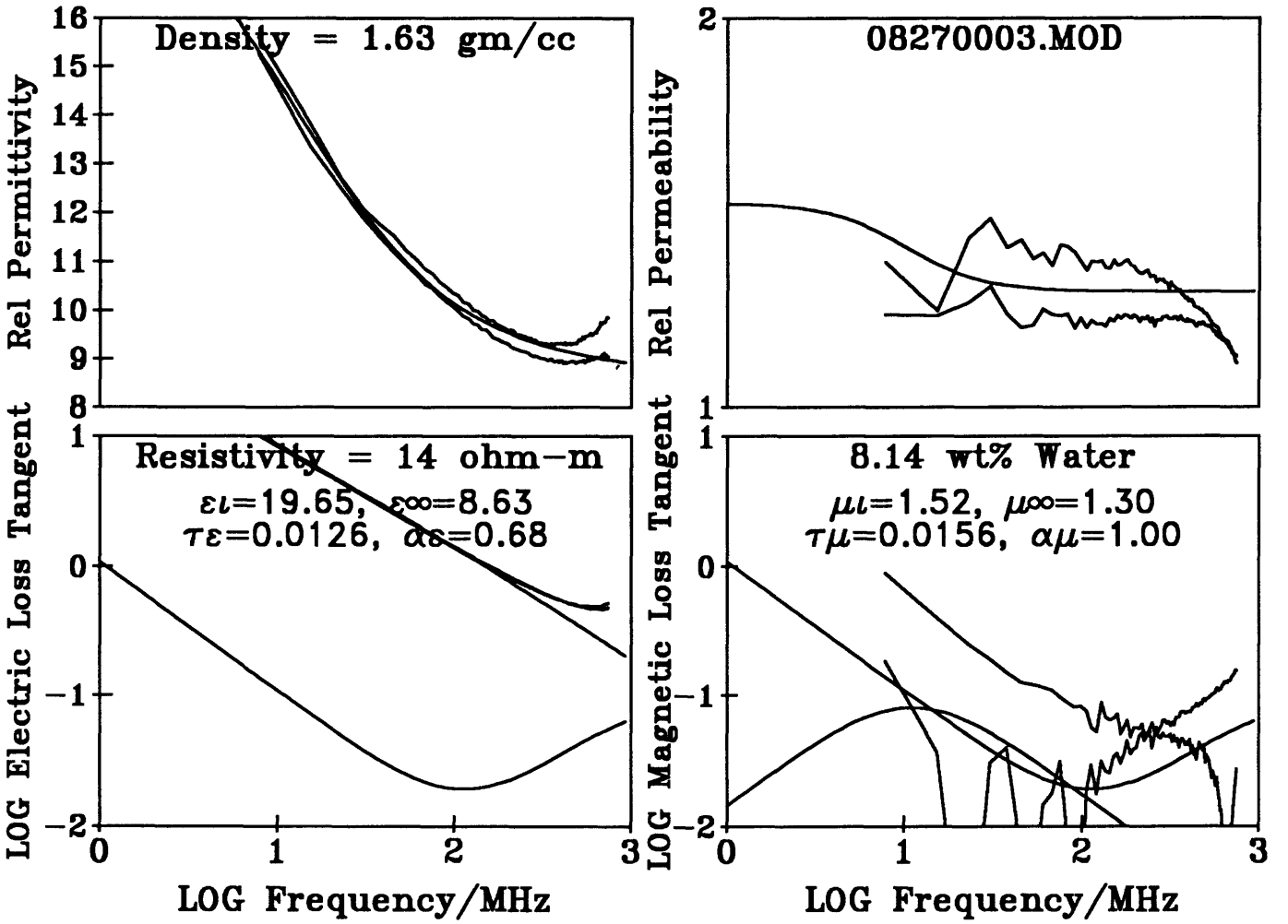
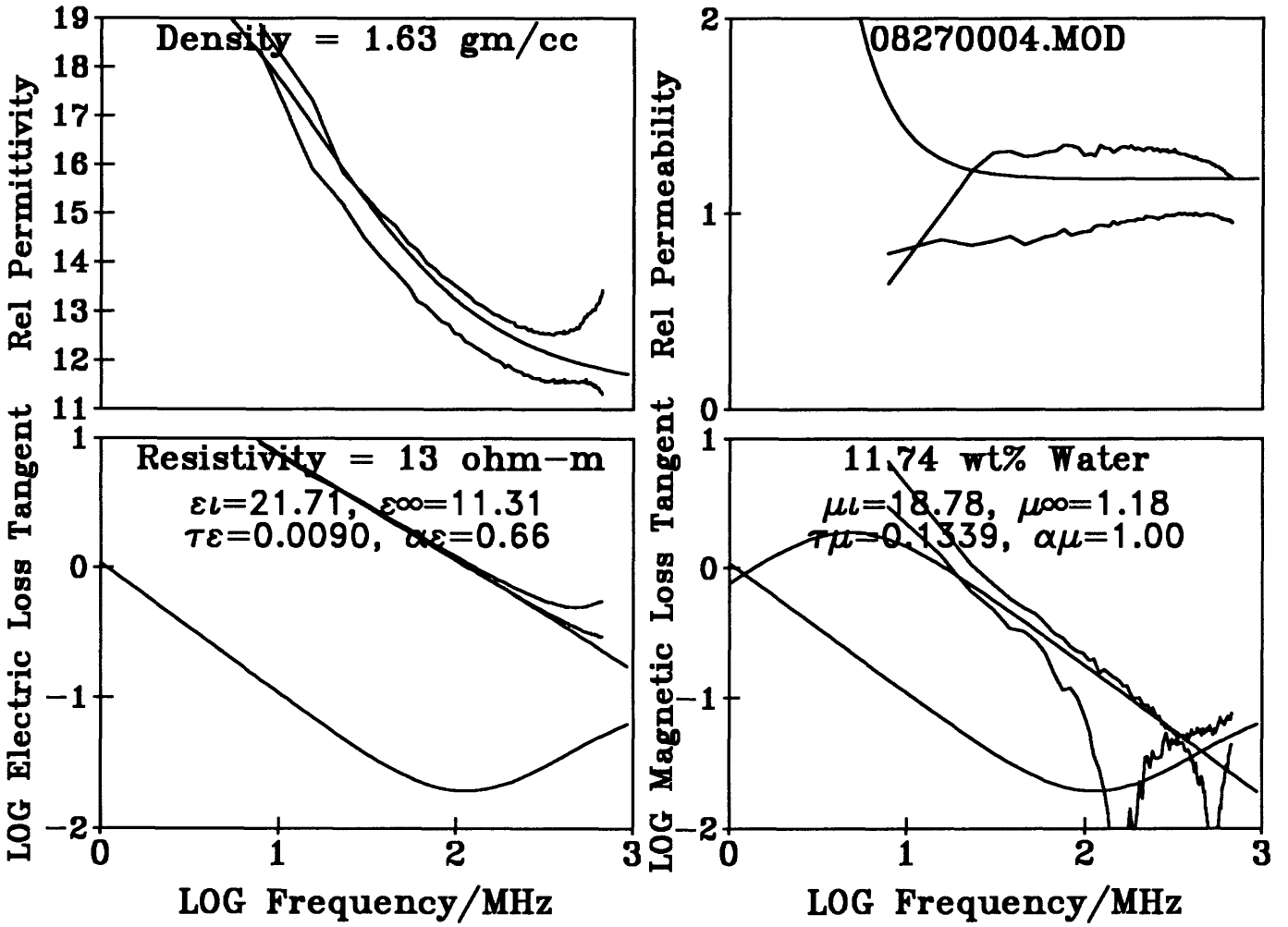

Density = 1.63 gm/cc
08270003.MOD
Resistivity = 14 ohm-m
ει=19.65, ε∞=8.63
τε=0.0126, αε=0.68
8.14 wt% Water
μι=1.52, μ∞=1.30
τμ=0.0156, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 3200m Douglas Main Line 0.5m depth #4 8 drops water

Figure 139 -




**Yuma 3200m Douglas Main Line 0.5m depth #4 water saturated**

Figure 140 -

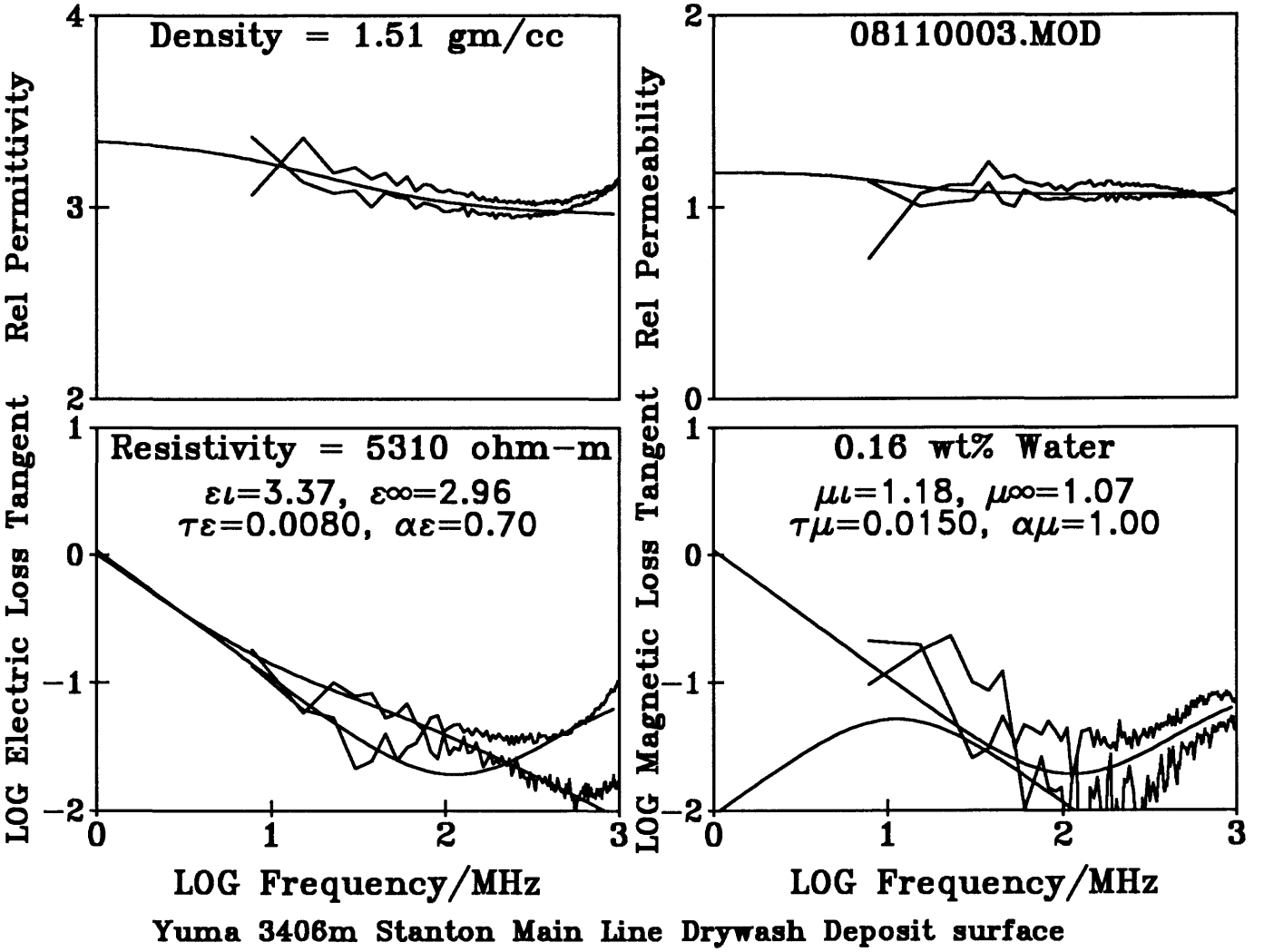



Figure 141 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

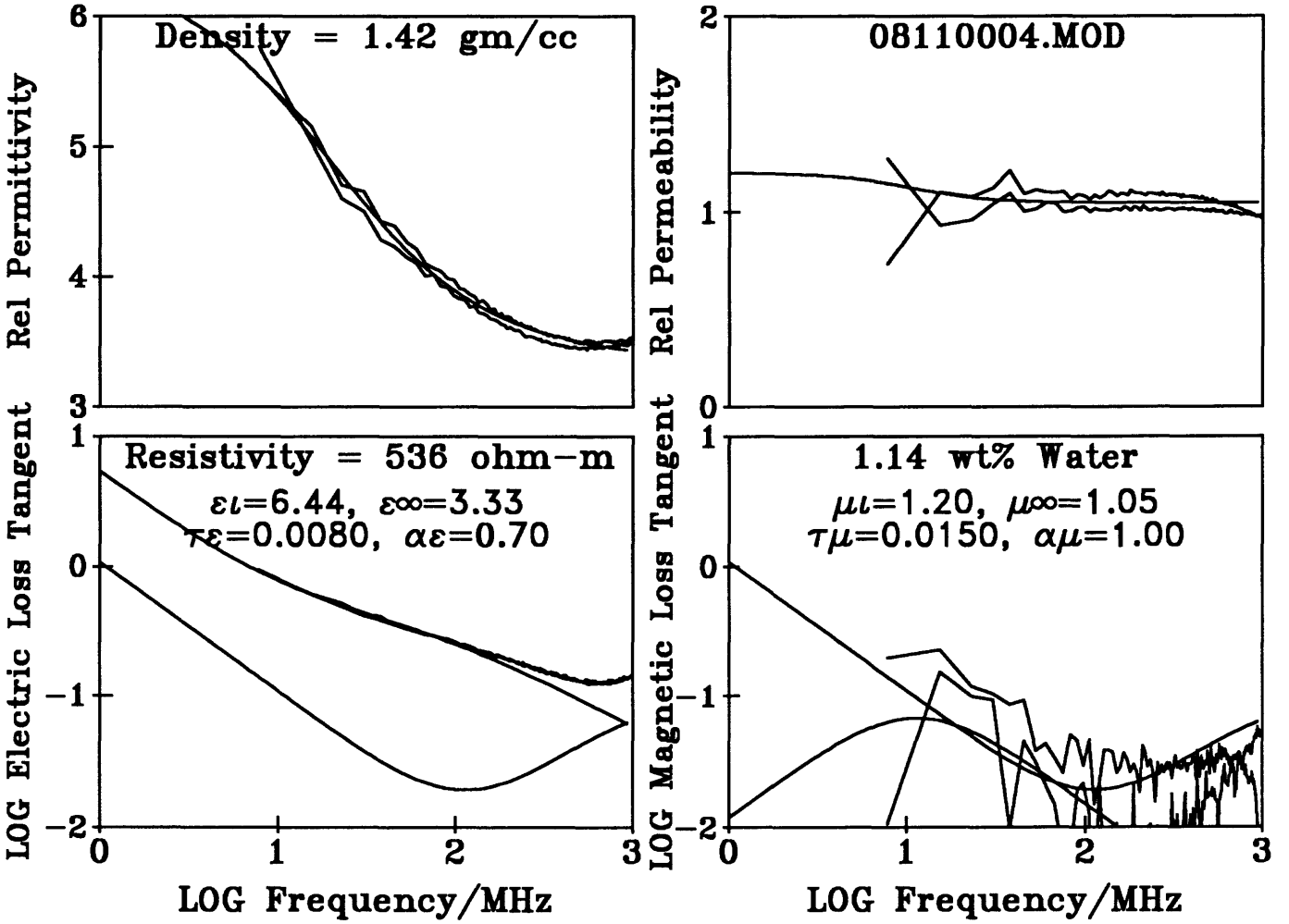



Figure 142 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

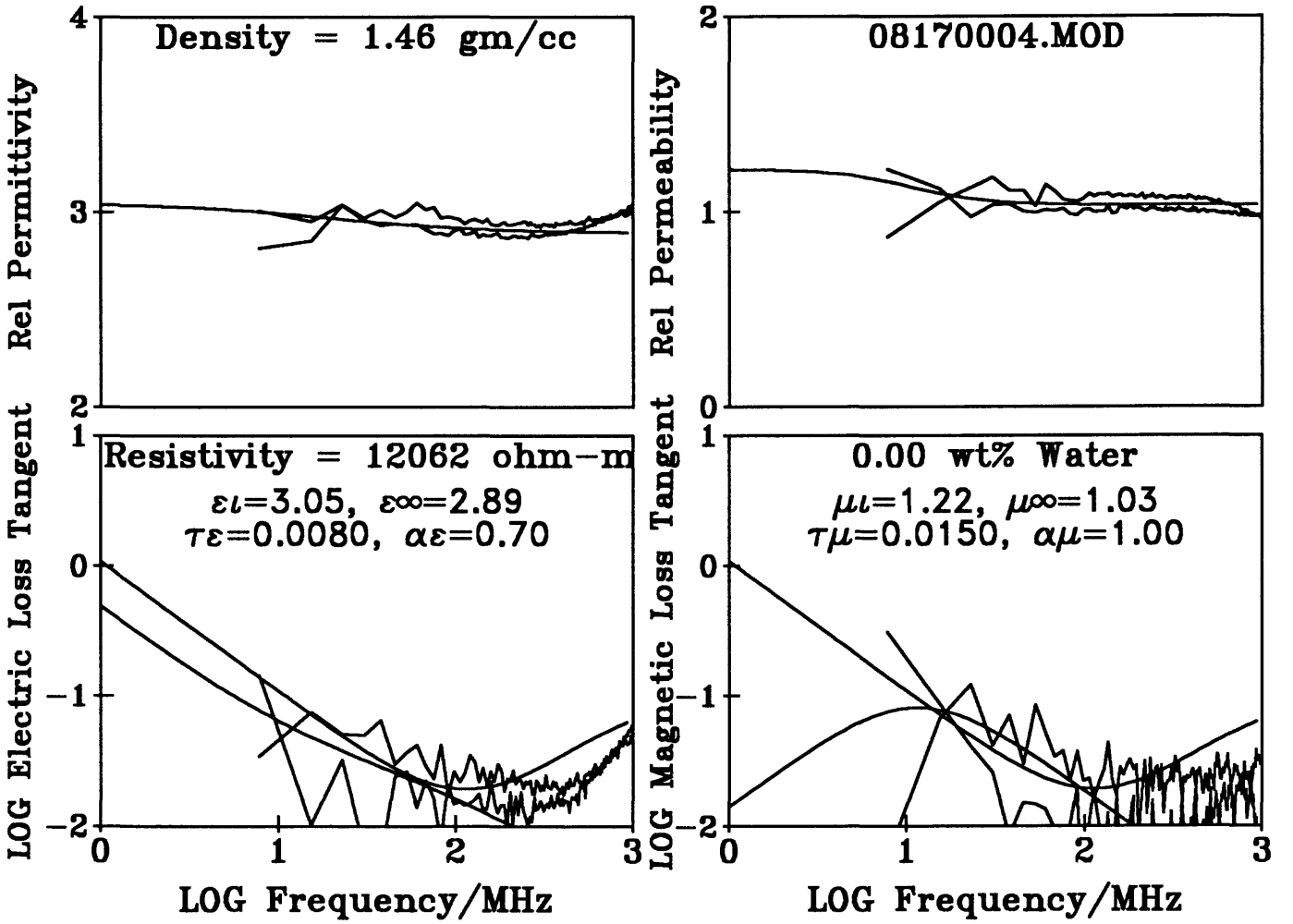
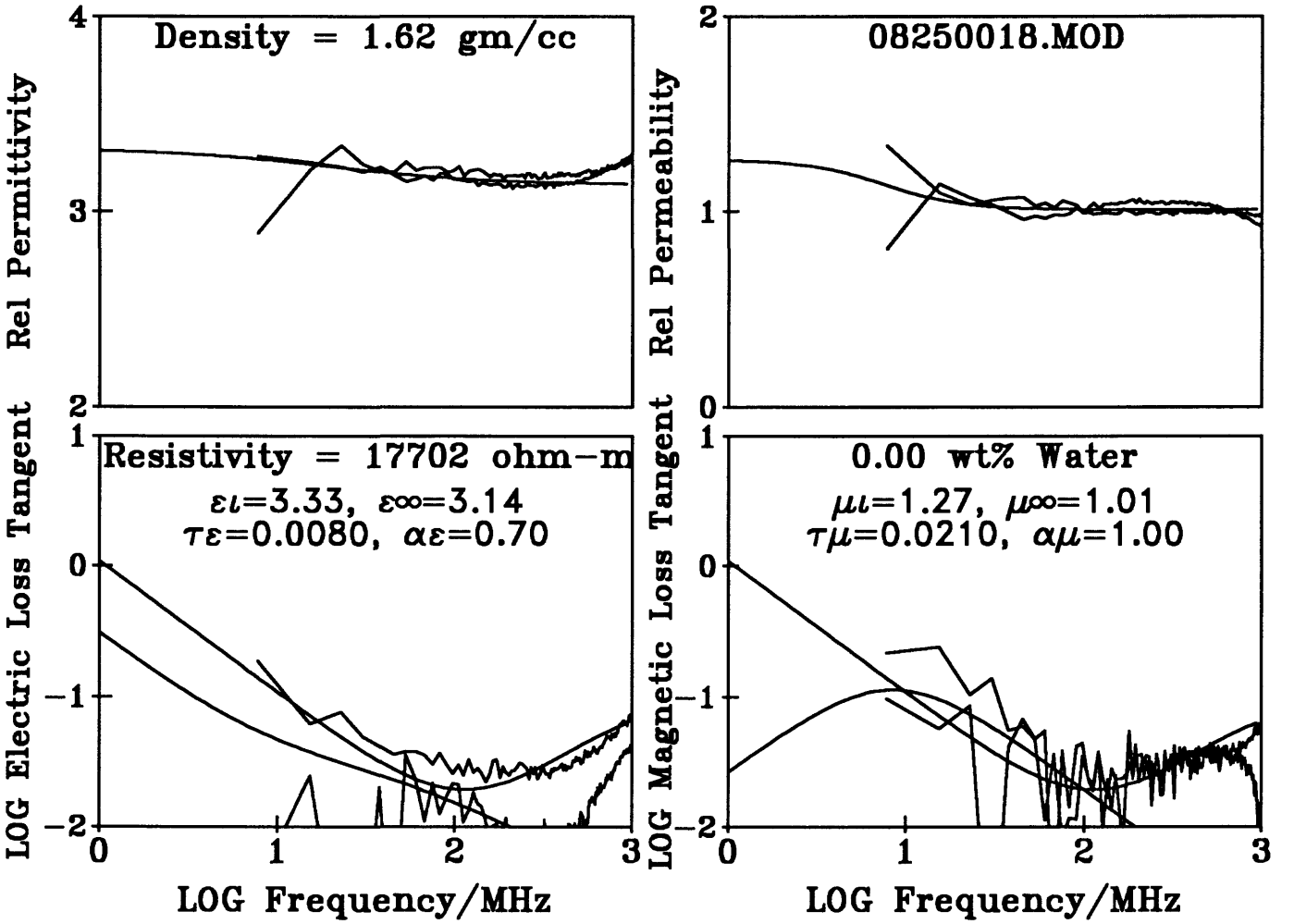

Density = 1.46 gm/cc
08170004.MOD
Rel Permittivity
Rel Permeability
Resistivity = 12062 ohm-m
ει=3.05, ε∞=2.89
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.22, μ∞=1.03
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 3406m Stanton Main Line drywash 0.5m depth #2 vacuum dried

Figure 143 -




**Yuma 3406m Stanton Main Line drywash 0.5m depth #3 vacuum dried**

Figure 144 -

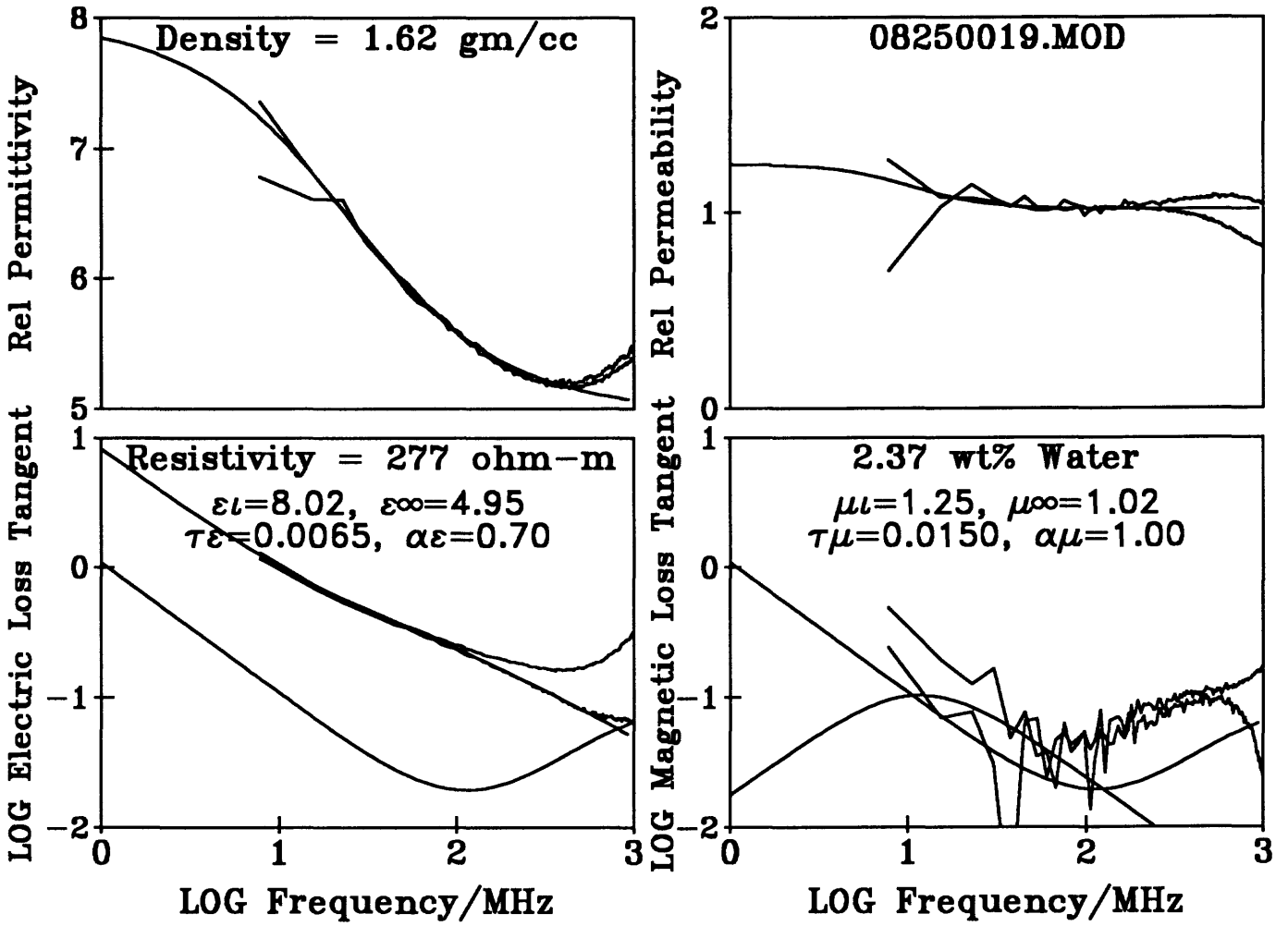

Density = 1.62 gm/cc
08250019.MOD
Resistivity = 277 ohm-m
ει=8.02, ε∞=4.95
τε=0.0065, αε=0.70
2.37 wt% Water
μι=1.25, μ∞=1.02
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
Rel Permittivity
LOG Magnetic Loss Tangent
Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 3406m Stanton Main Line drywash 0.5m depth #3 4-drops water

Figure 145 -

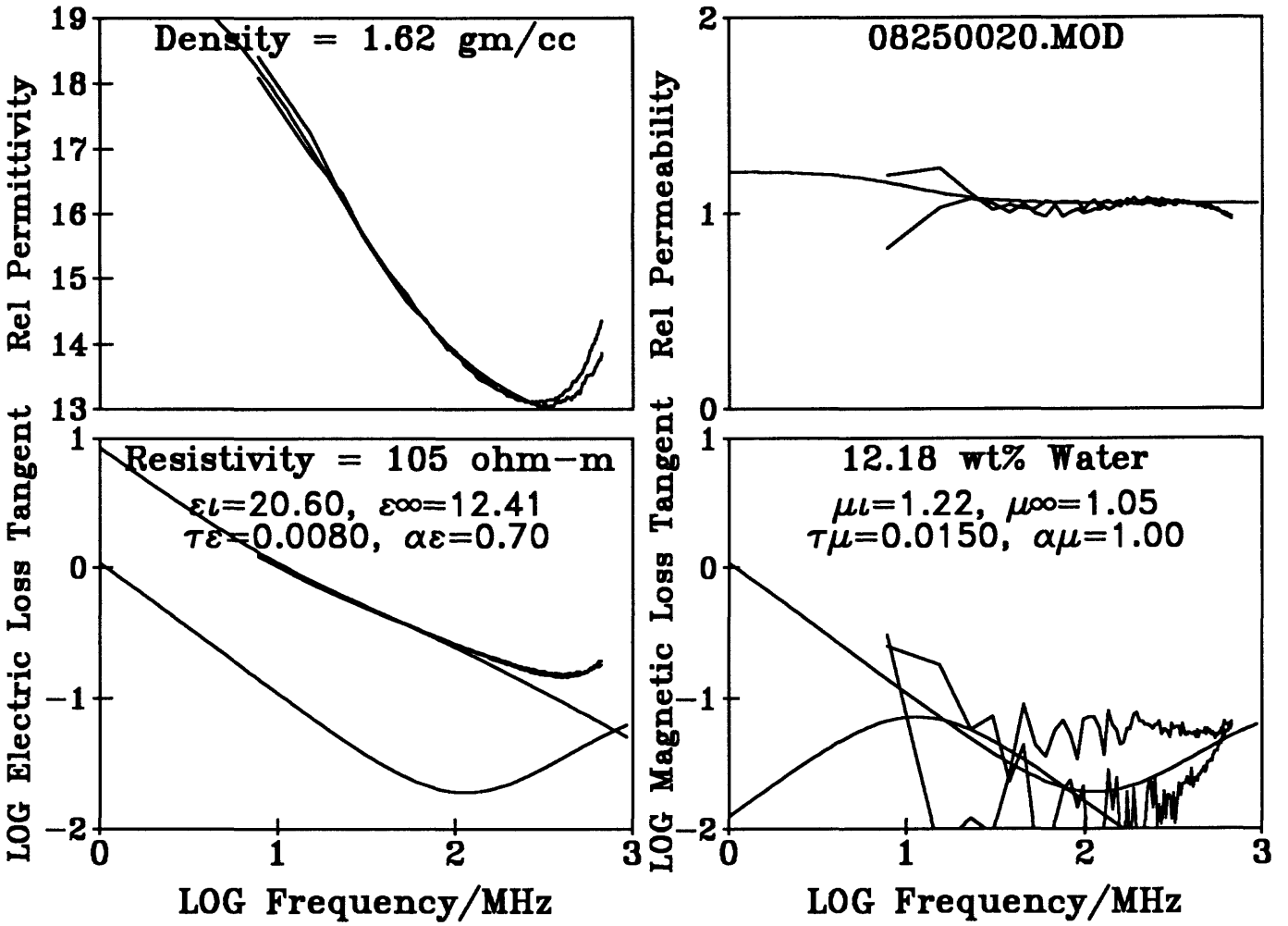
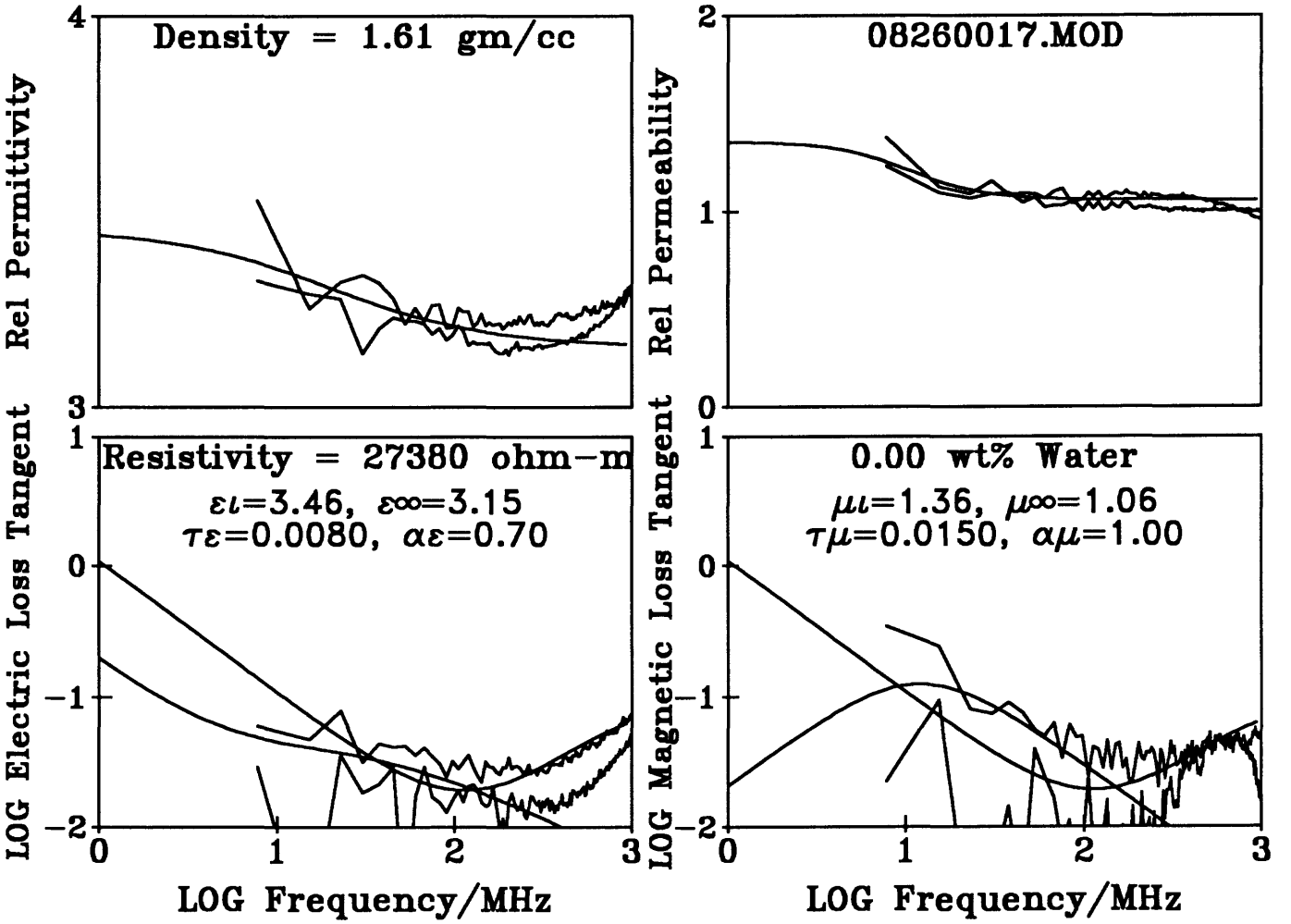
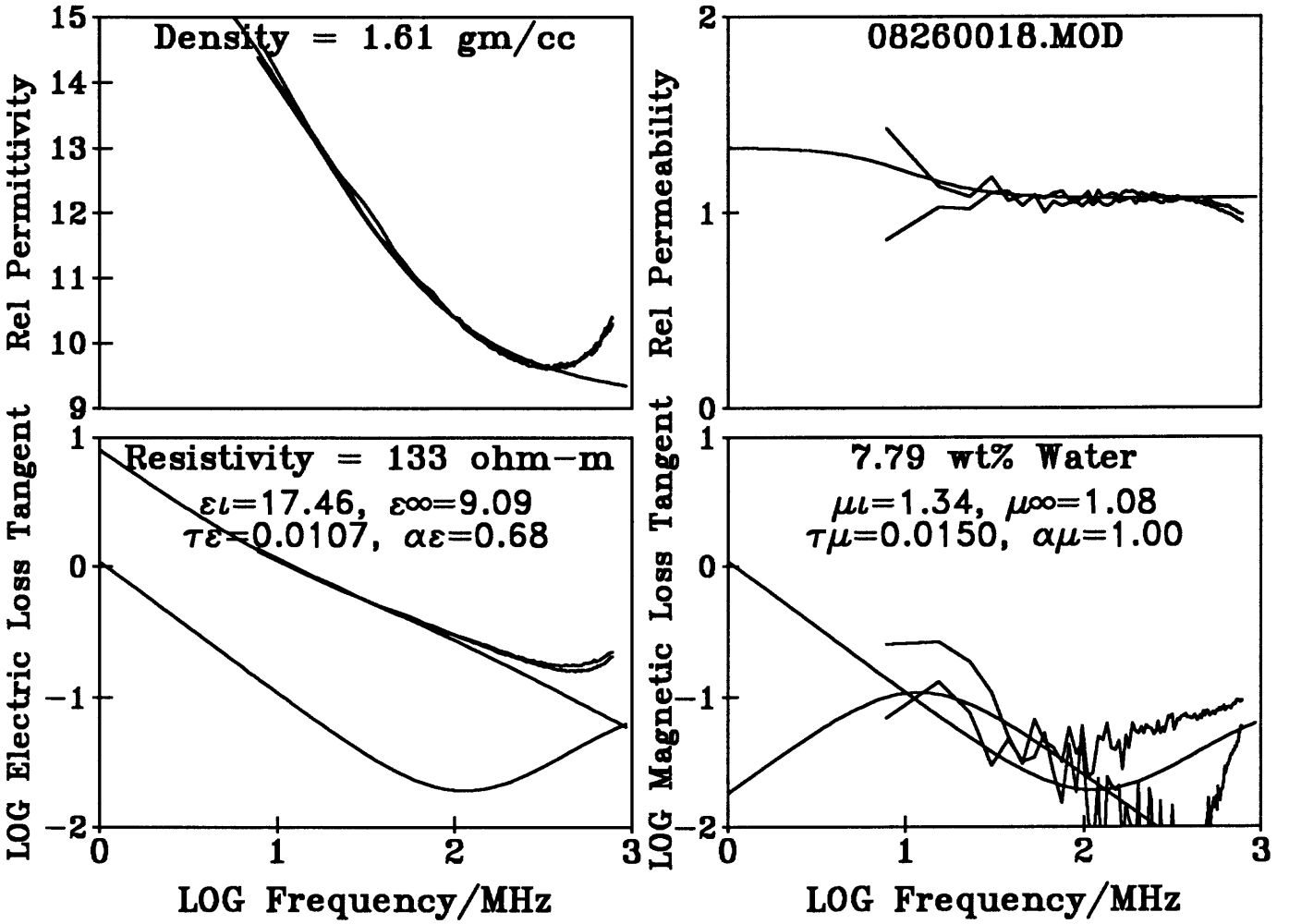

Density = 1.62 gm/cc
08250020.MOD
Resistivity = 105 ohm-m
ει=20.60, ε∞=12.41
τε=0.0080, αε=0.70
12.18 wt% Water
μι=1.22, μ∞=1.05
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma 3406m Stanton Main Line drywash 0.5m depth #3 water saturated

Figure 146 -



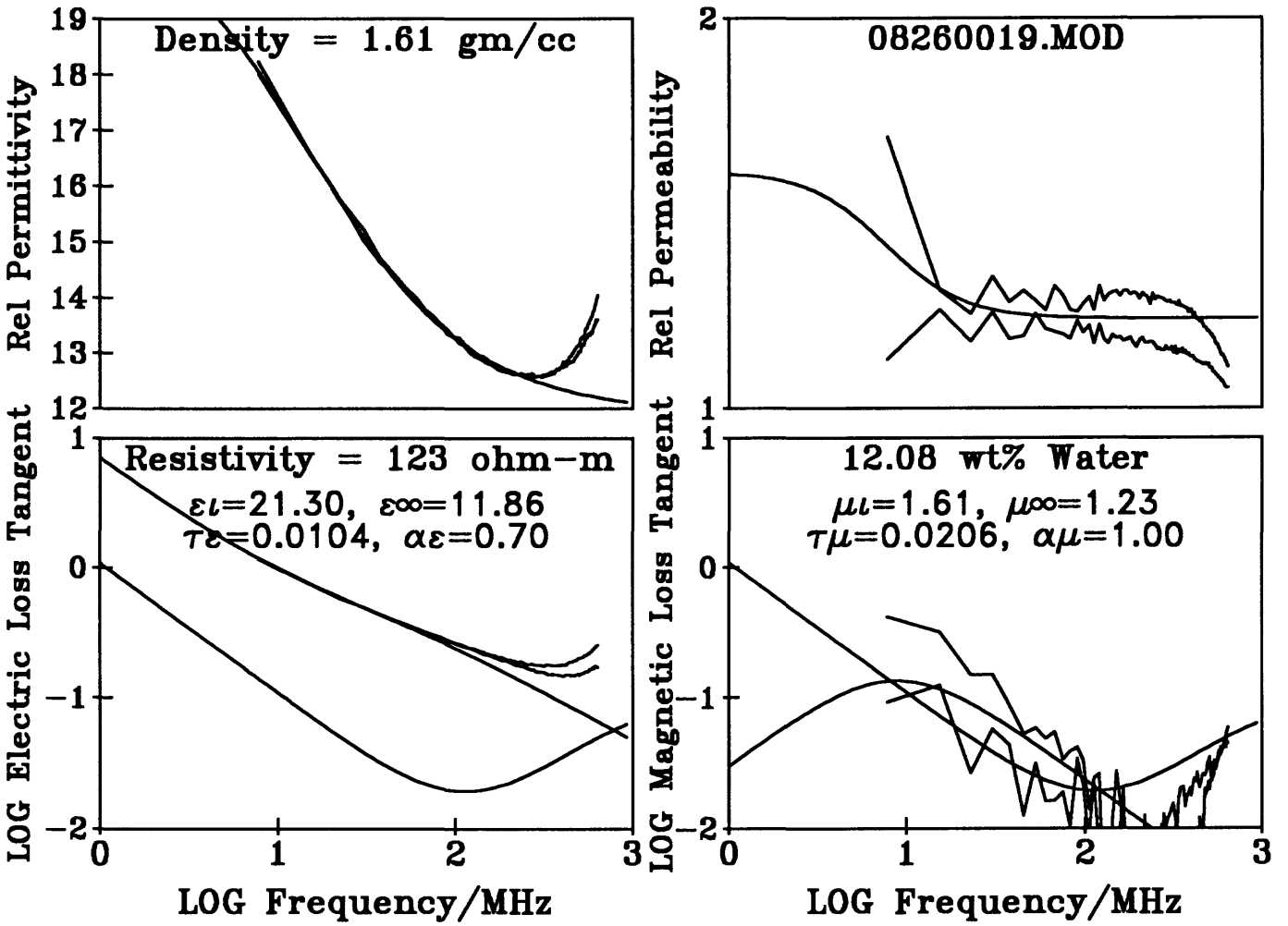

**Yuma 3406m Stanton Main Line drywash 0.5m depth #4 vacuum dried**

Figure 147 -




**Yuma 3406m Stanton Main Line drywash 0.5m depth #4 10-drops water**

Figure 148 -




**Yuma 3406m Stanton Main Line drywash 0.5m depth #4 water saturated**

Figure 149 -

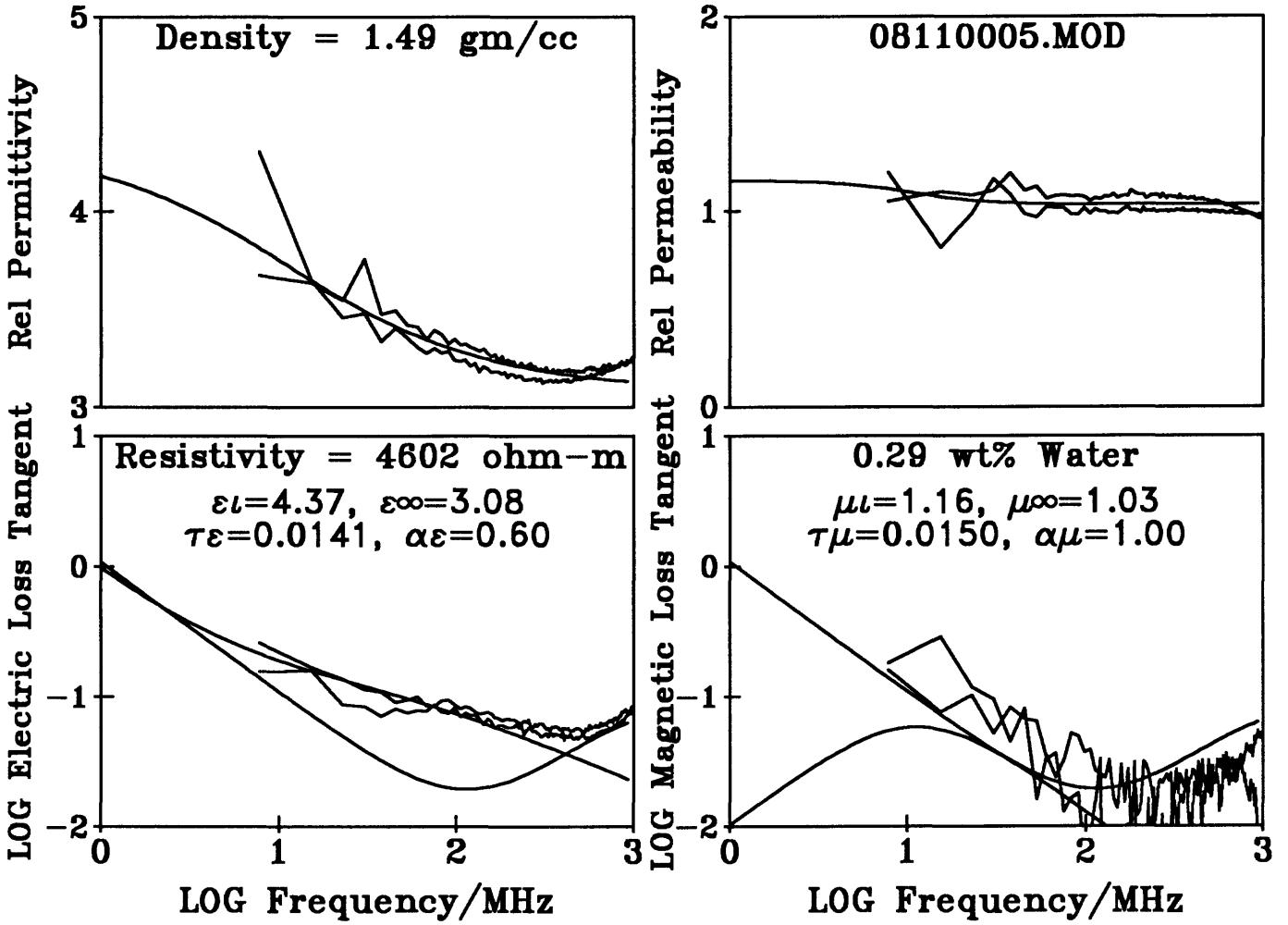



Figure 150 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.

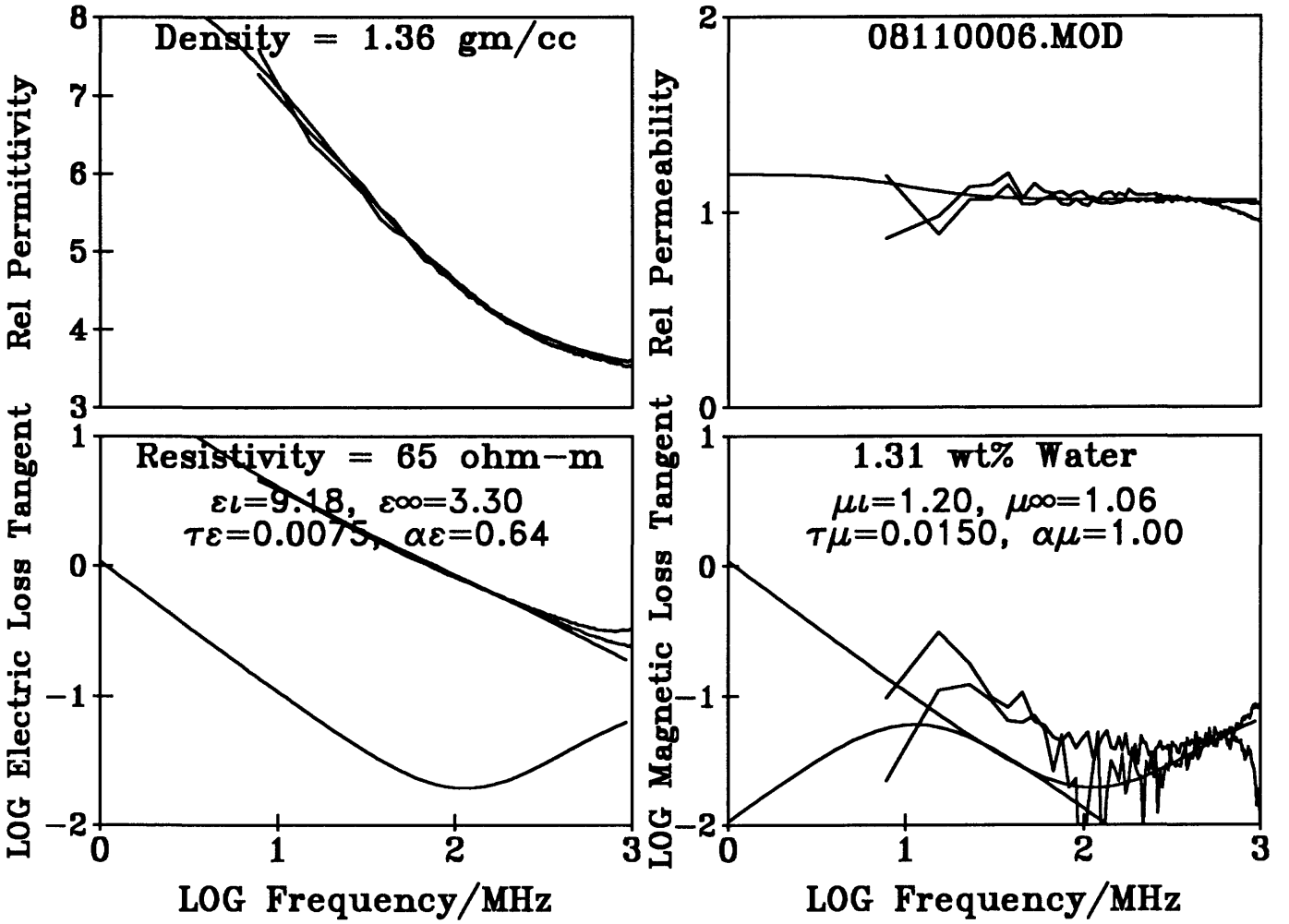
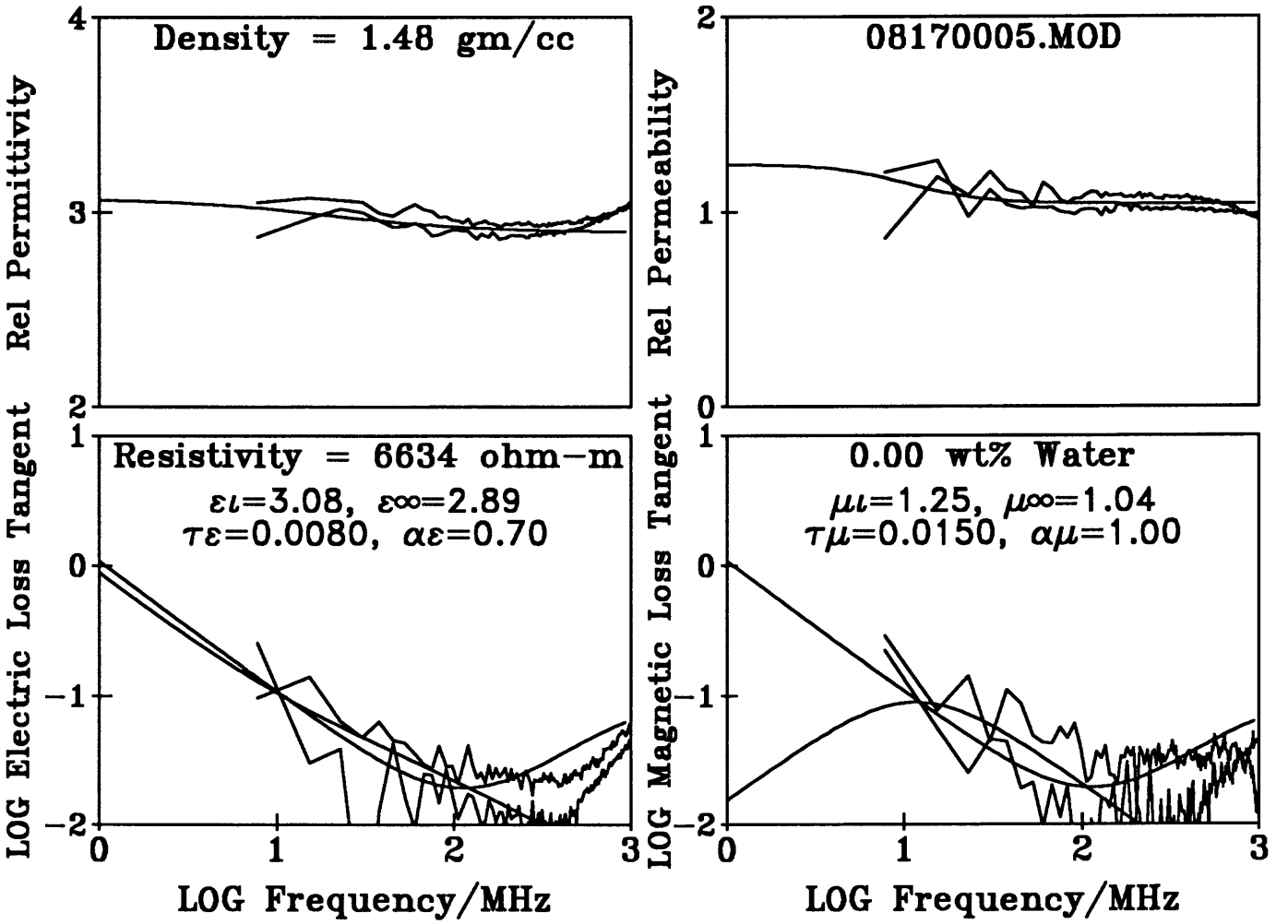
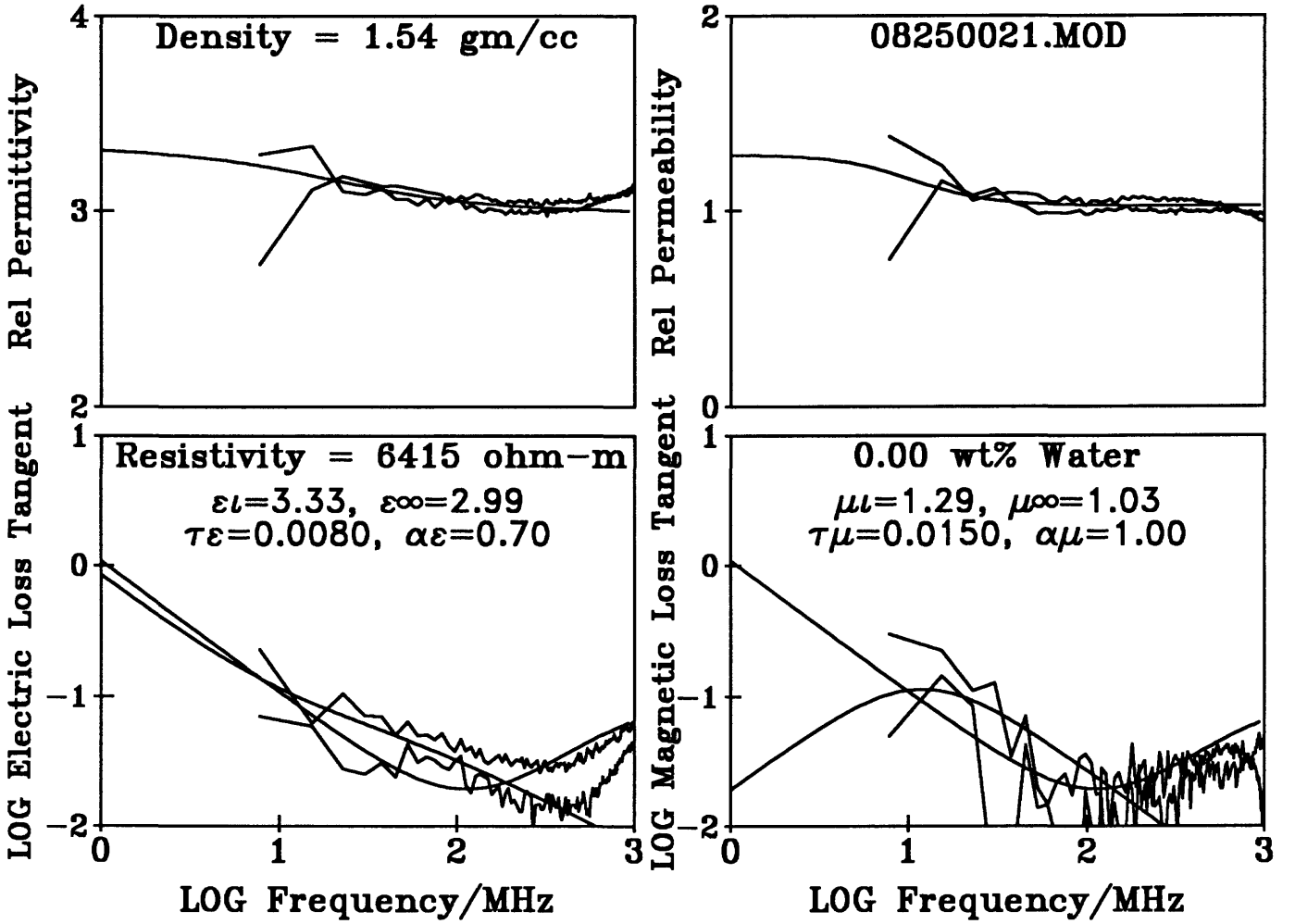



Figure 151 -
Natural state electromagnetic properties with water content preserved in sealed, taped, sample bottle.



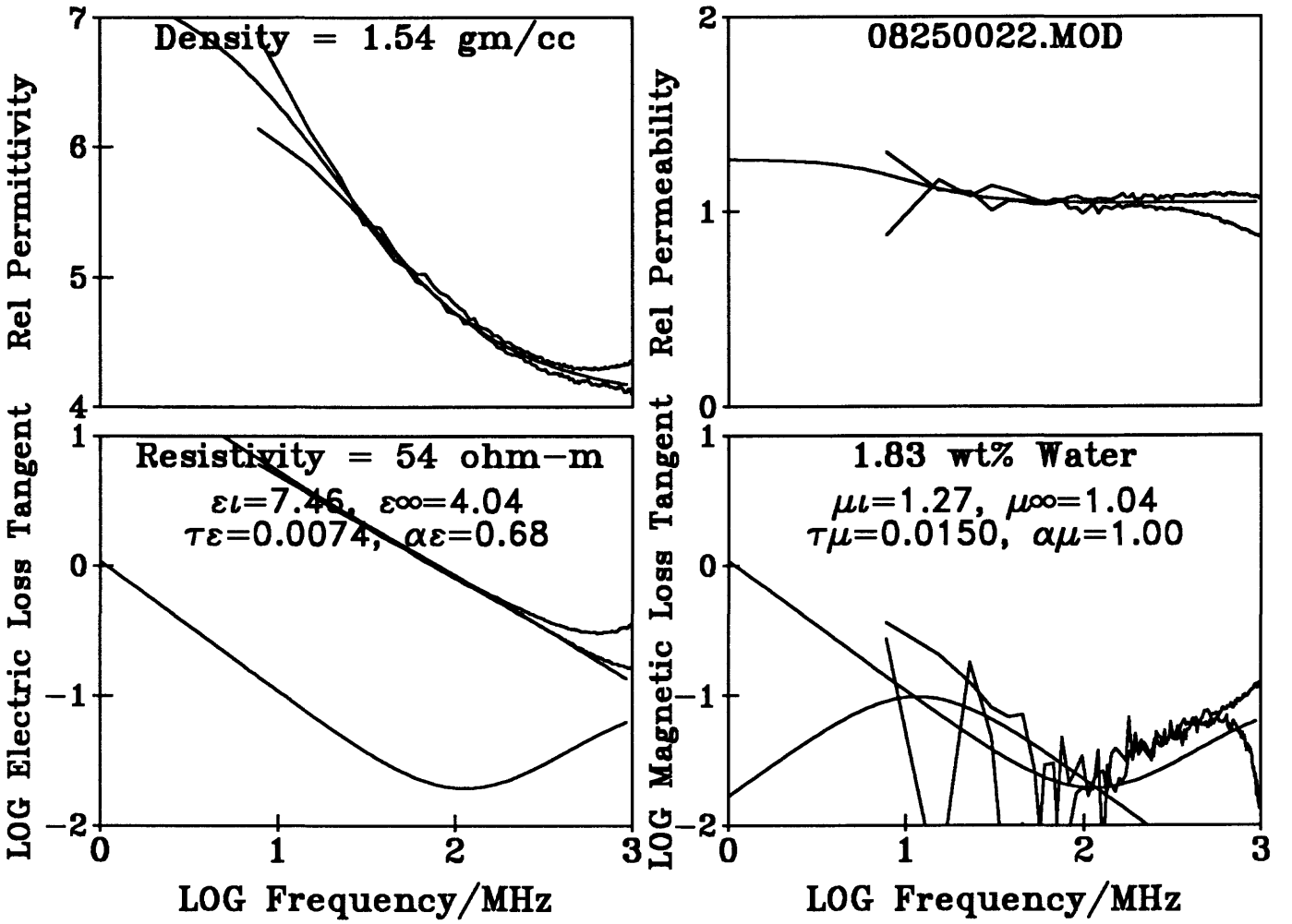

**Yuma 3450m on Main Line among buried mines 0.5m depth #2 vacuum dried**

Figure 152 -



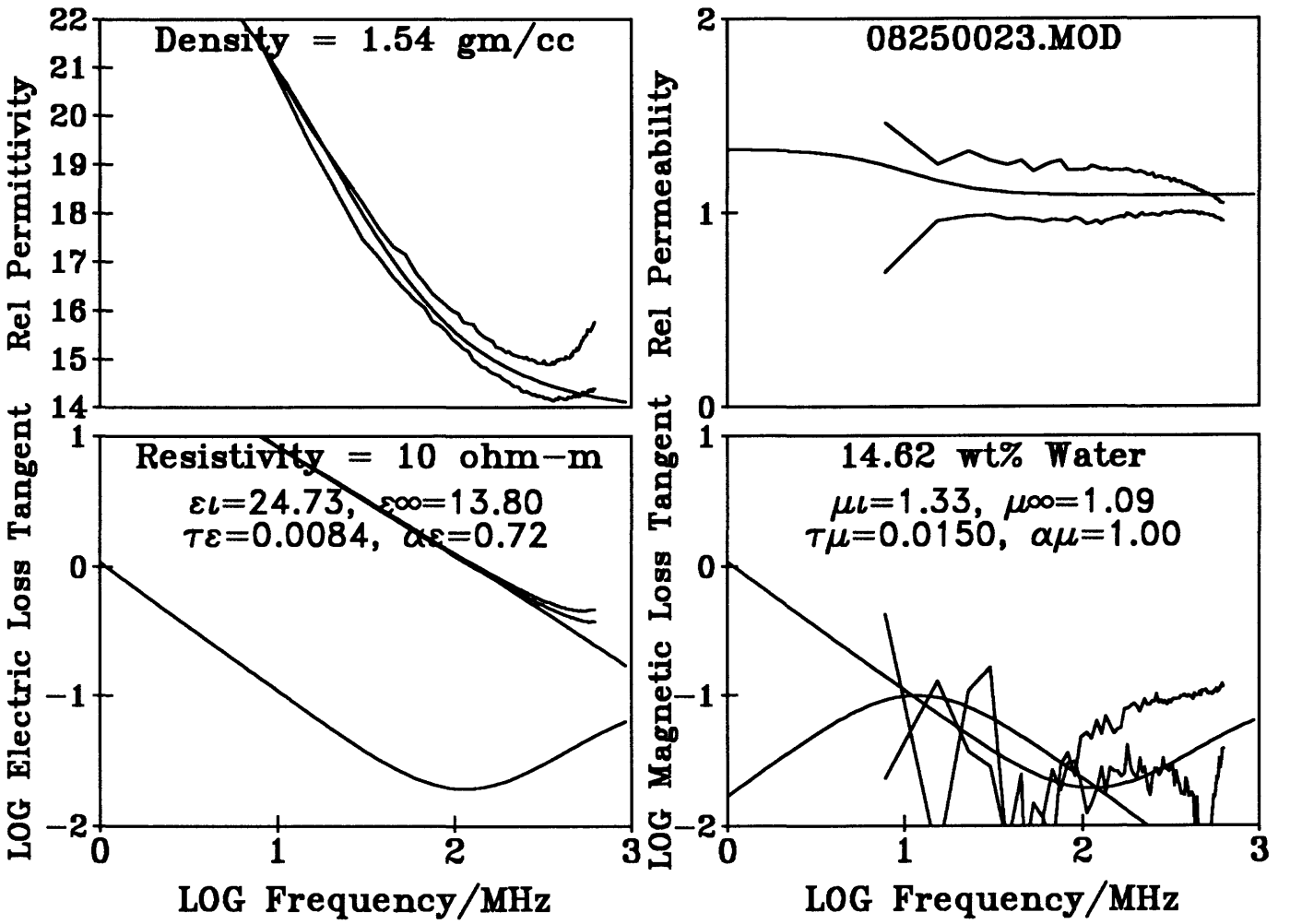

**Yuma 3450m on Main Line among buried mines 0.5m depth #3 vacuum dried**

Figure 153 -



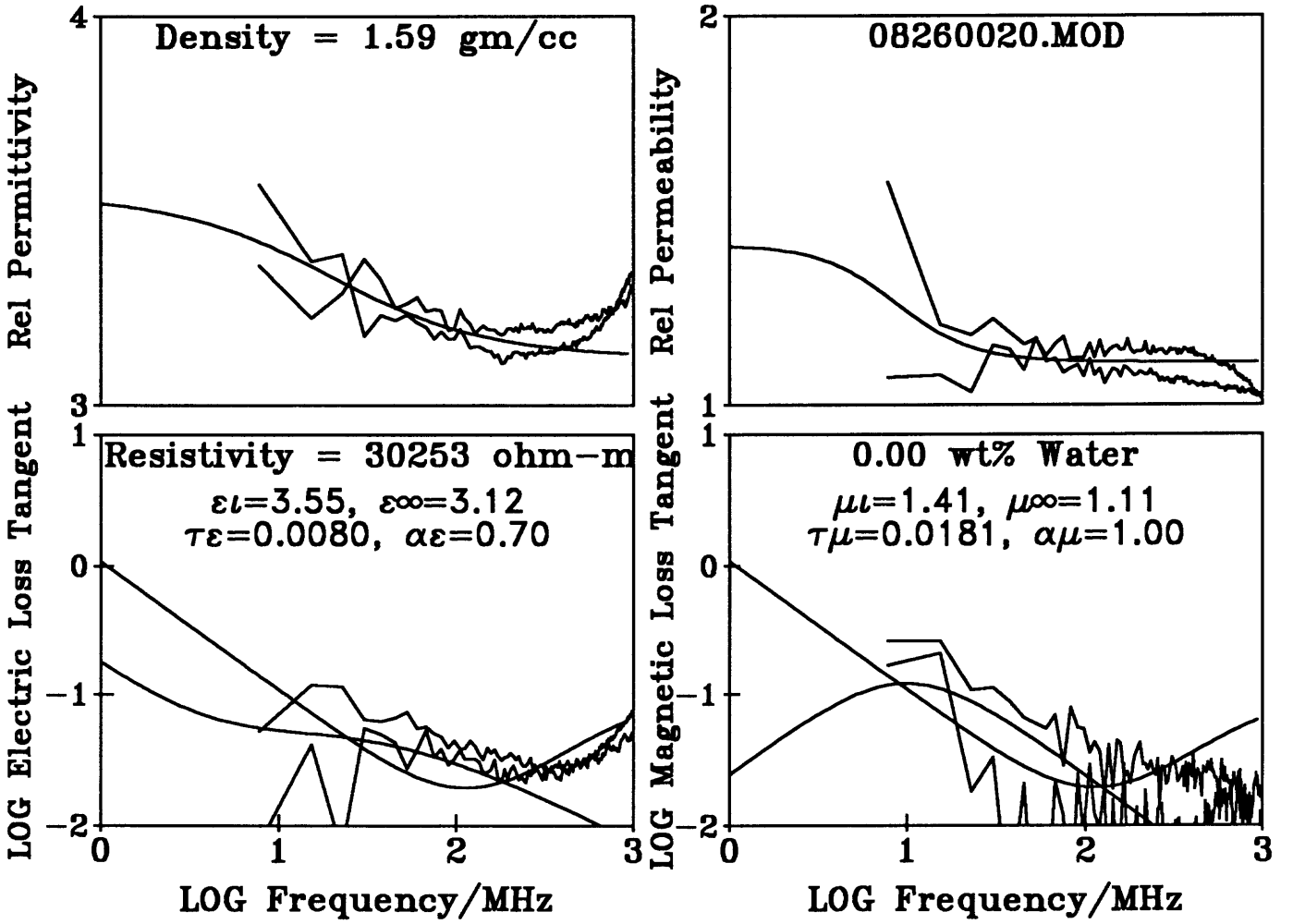

**Yuma 3450m Main Line among buried mines 0.5m depth #3 4-drops water**

Figure 154 -



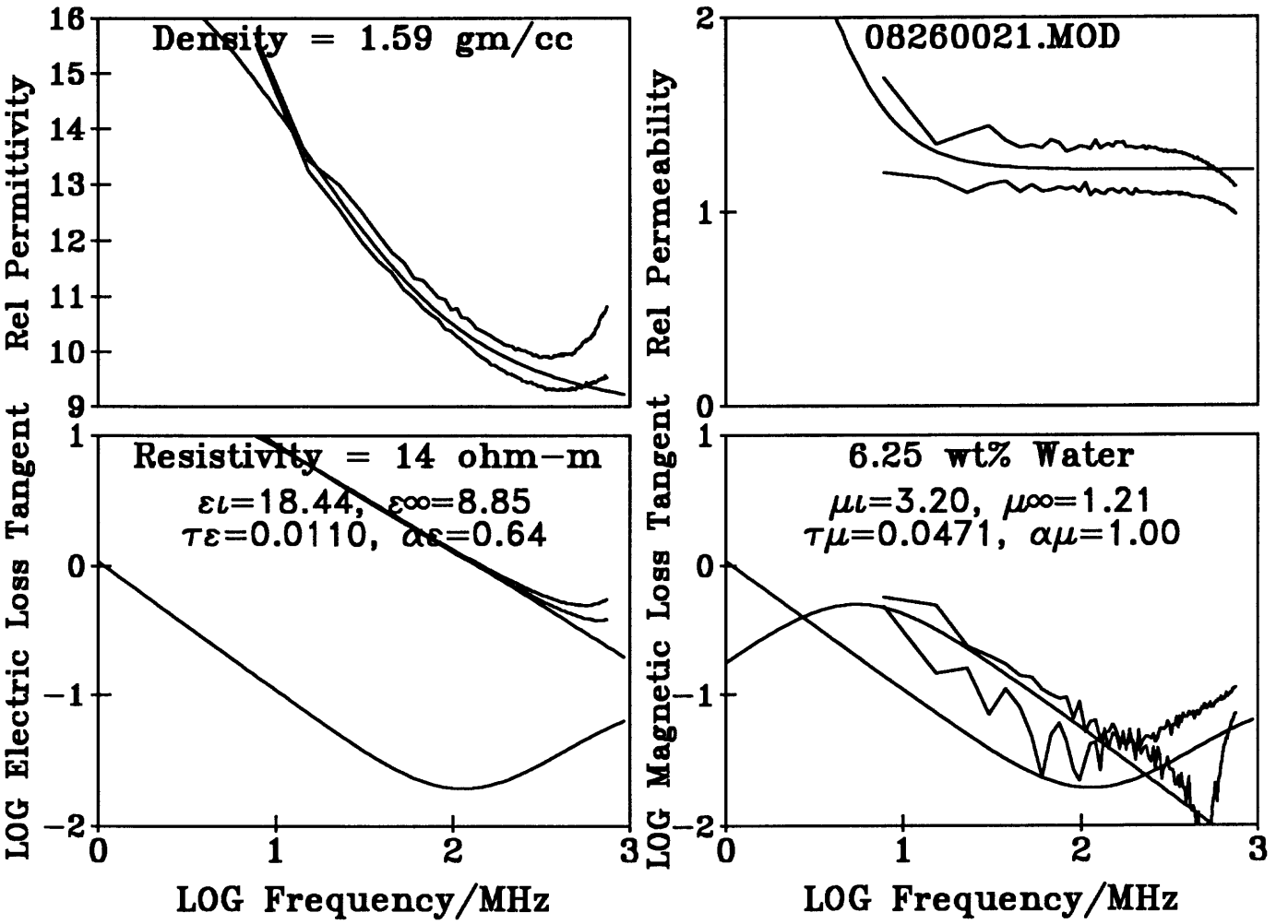

**Yuma 3450m Main Line among buried mines 0.5m depth #3 water saturated**

Figure 155 -



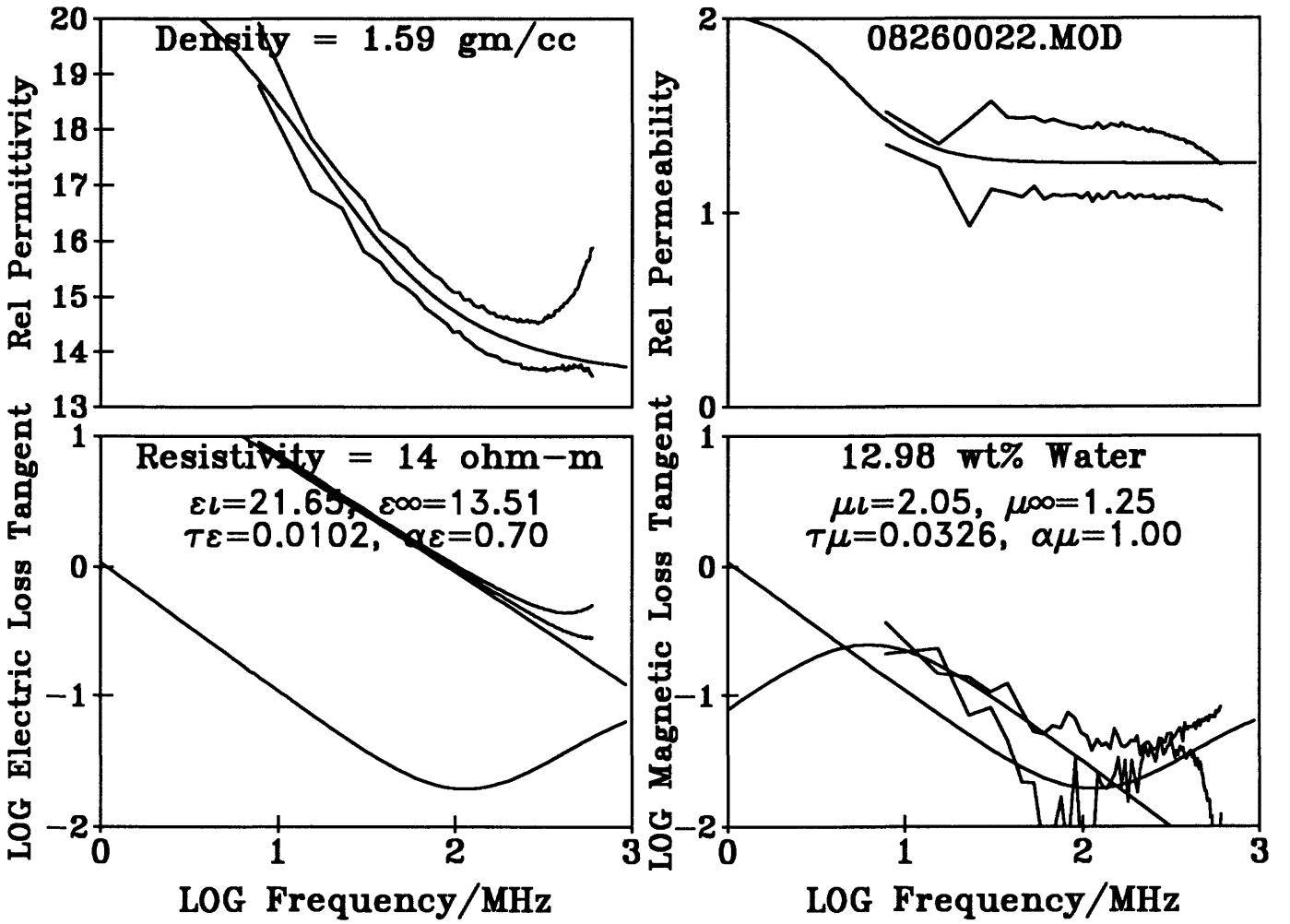

**Yuma 3450m on Main Line among buried mines 0.5m depth #4 vacuum dried**

Figure 156 -




**Yuma 3450m Main Line among buried mines 0.5m depth #4 9-drops water**

Figure 157 -




**Yuma 3450m Main Line among buried mines 0.5m depth #4 water saturated**

Figure 158 -

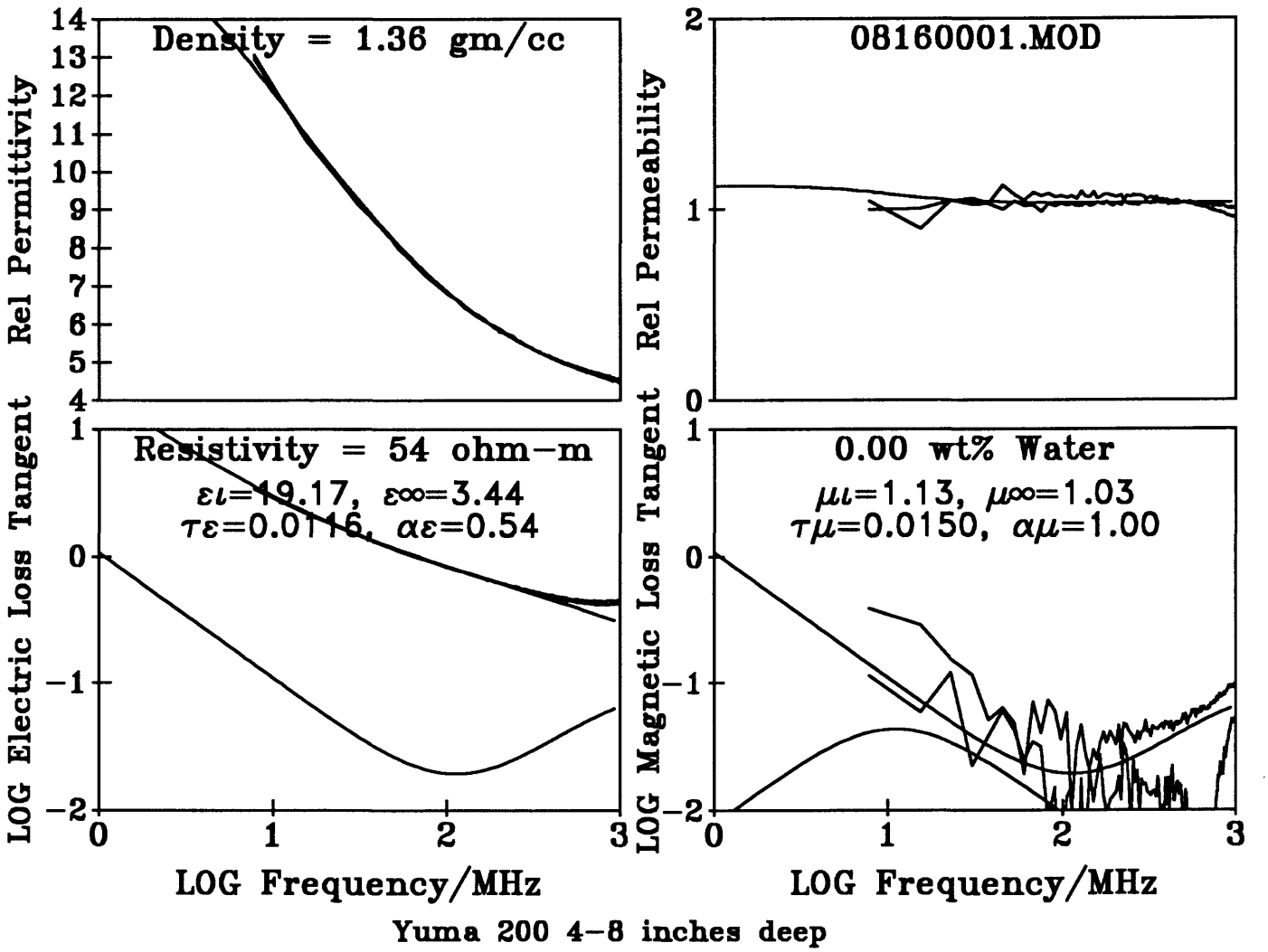



Figure 159 -
Sample provided by Lincoln Laboratory in a ziplock bag -- water content and location unknown.

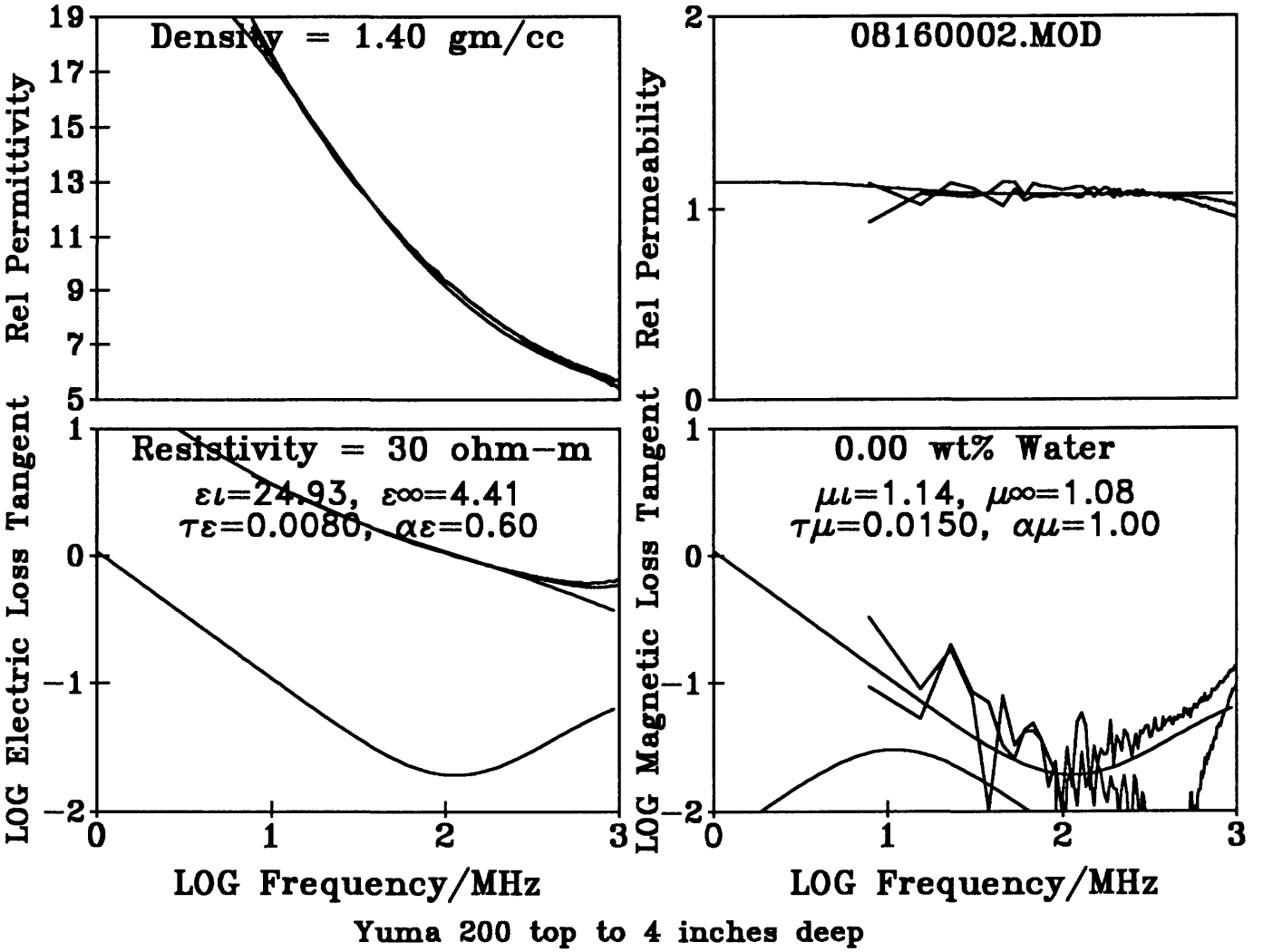



Figure 160 -
Sample provided by Lincoln Laboratory in a ziplock bag -- water content and location unknown.

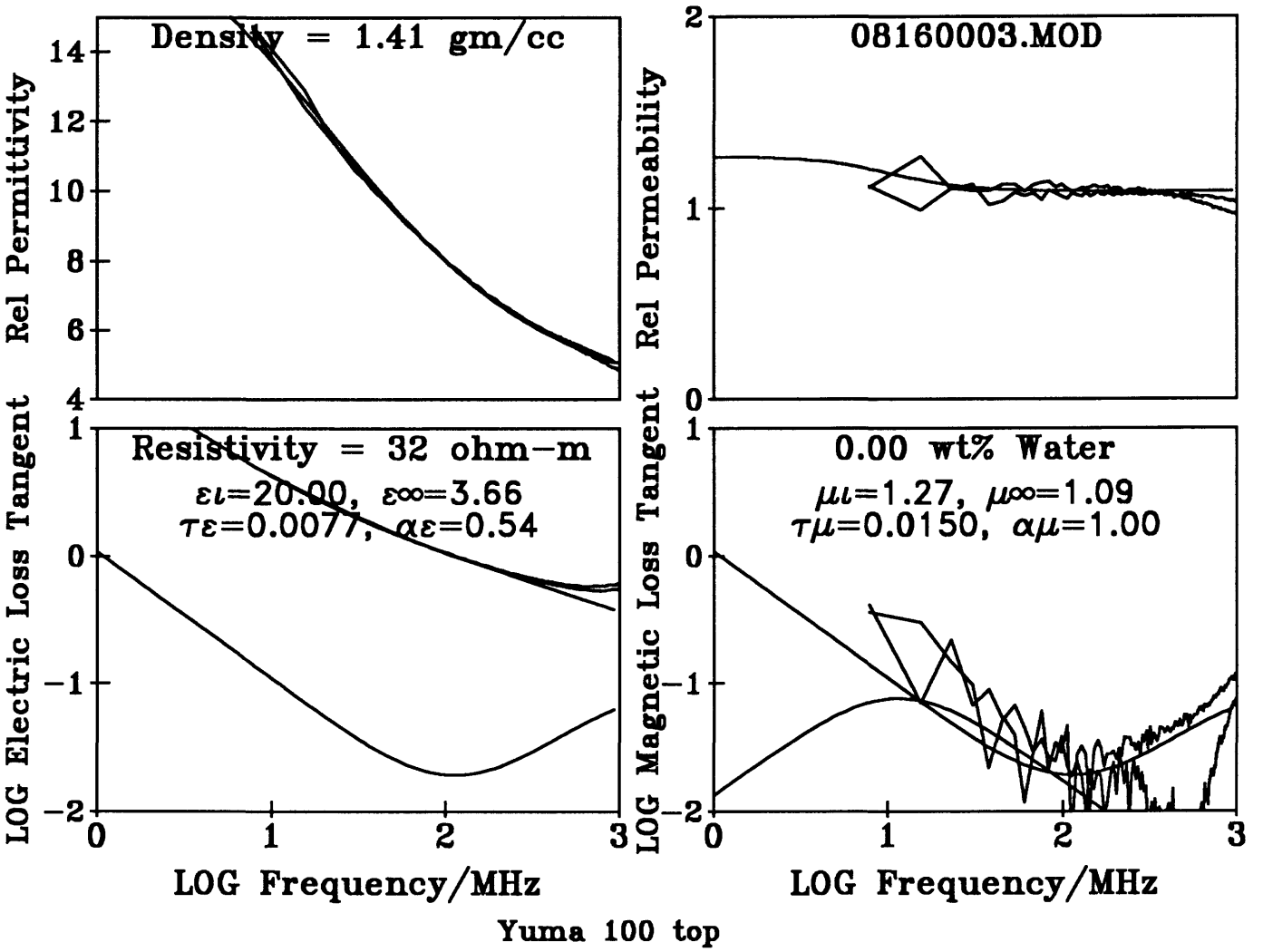



Figure 161 -
Sample provided by Lincoln Laboratory in a ziplock bag -- water content and location unknown.

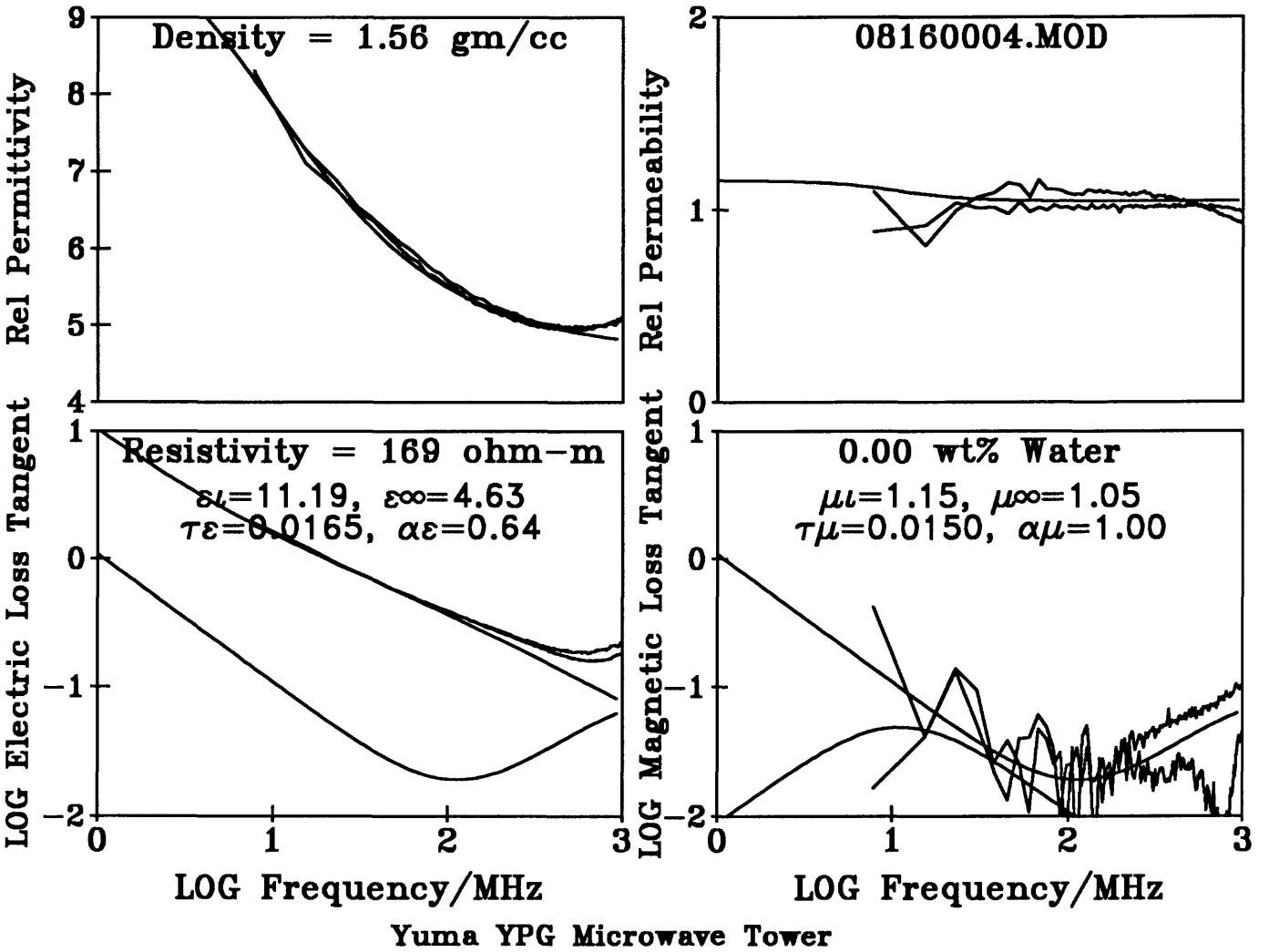



Figure 162 -
Sample provided by Lincoln Laboratory in a ziplock bag -- water content and location unknown.

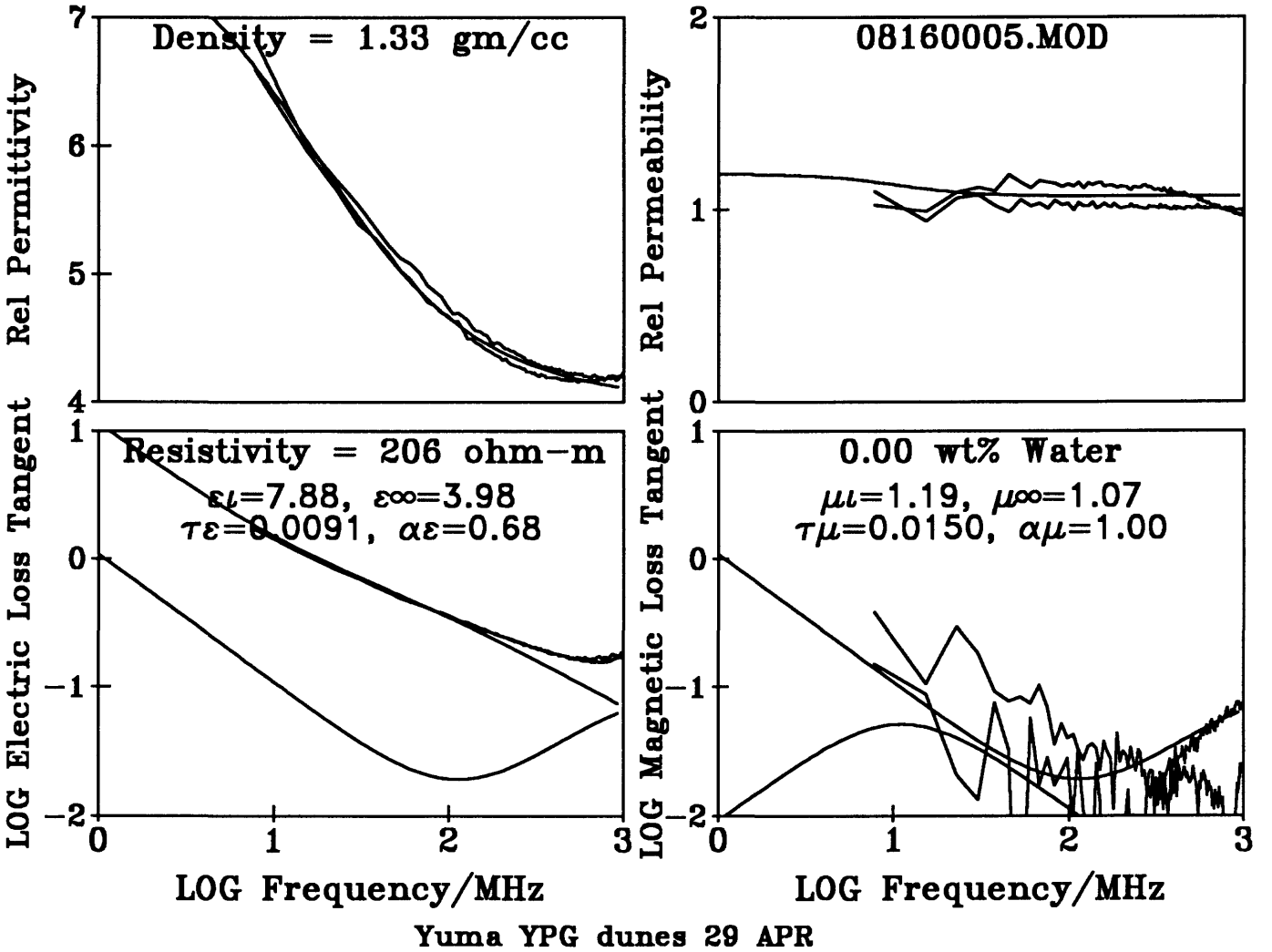



Figure 163 -
Sample provided by Lincoln Laboratory in a ziplock bag -- water content and location unknown.

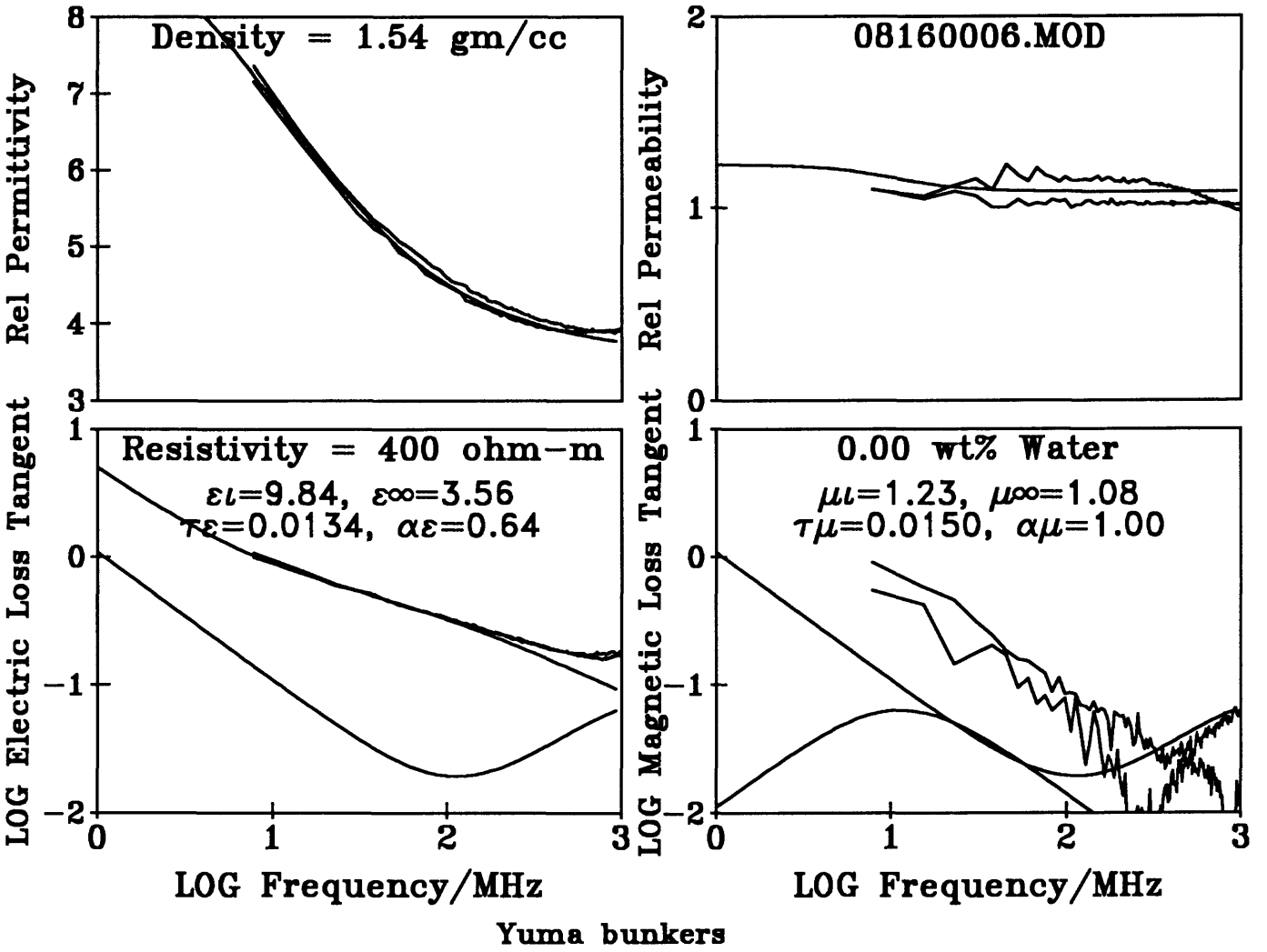



Figure 164 -
Sample provided by Lincoln Laboratory in a ziplock bag -- water content and location unknown.

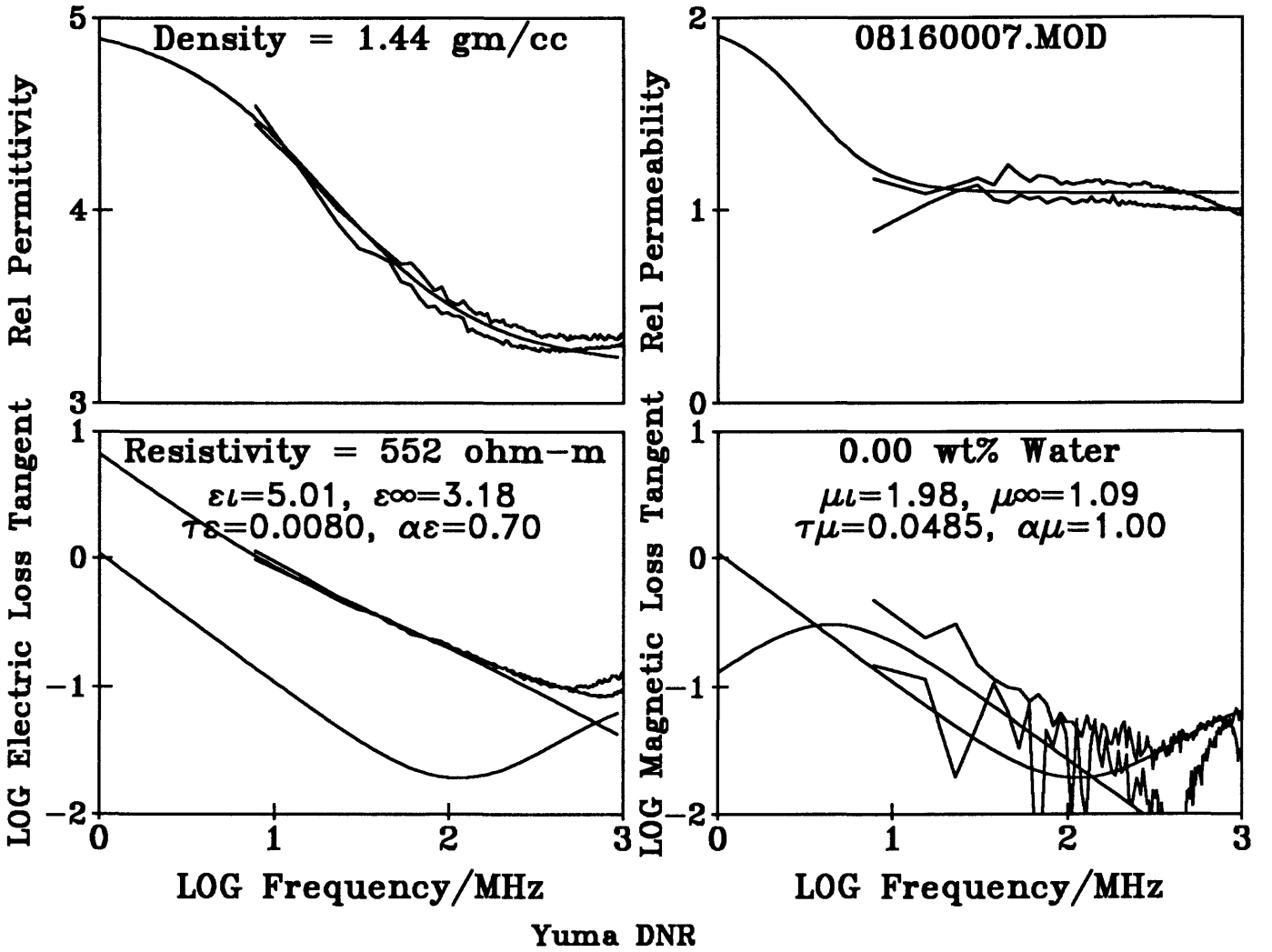



Figure 165 -
Sample provided by Lincoln Laboratory in a ziplock bag -- water content and location unknown.

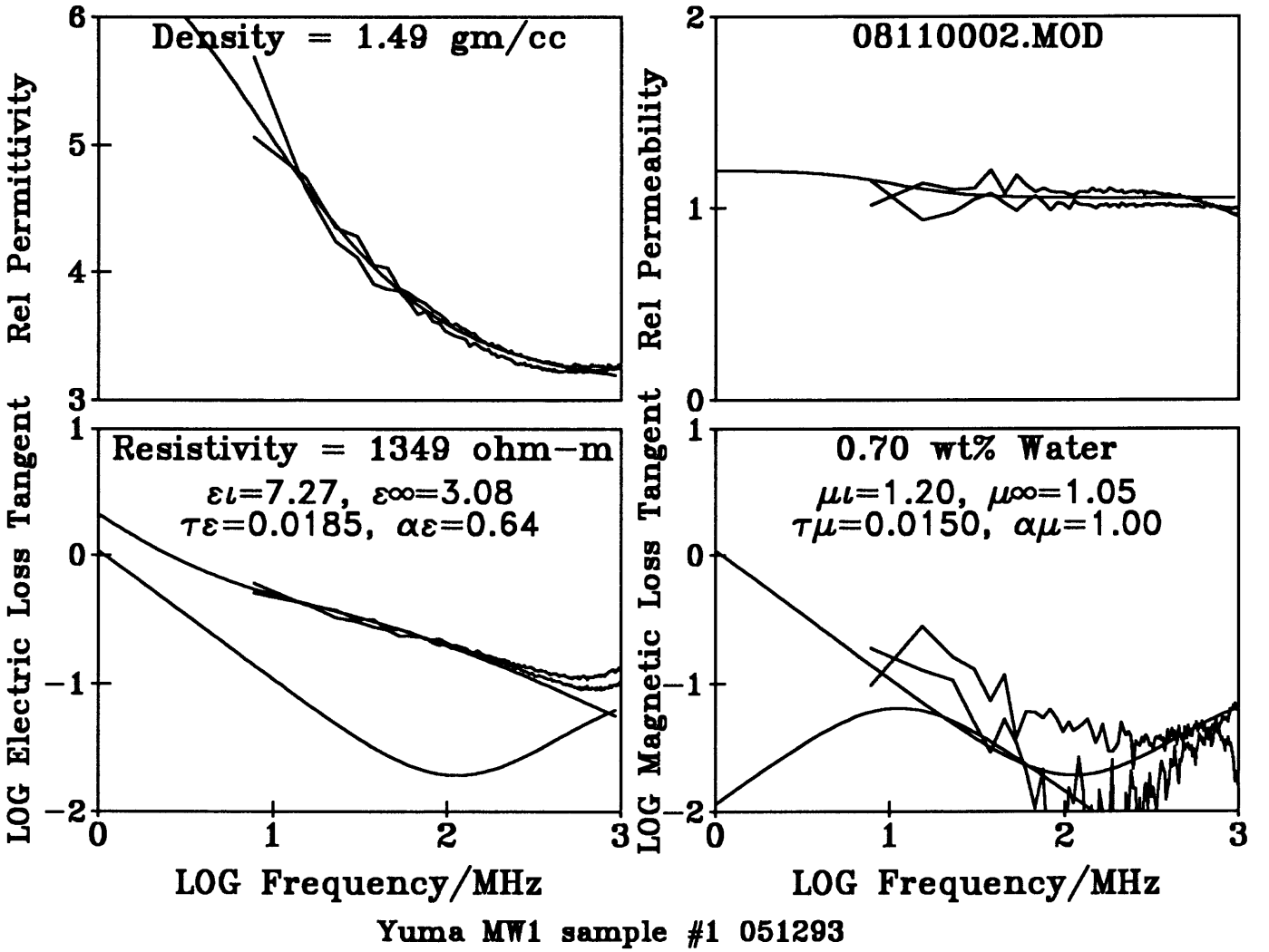



Figure 166 -
Sample provided by Lincoln Laboratory in a sealed bottle -- presumed natural water content -- location unknown.

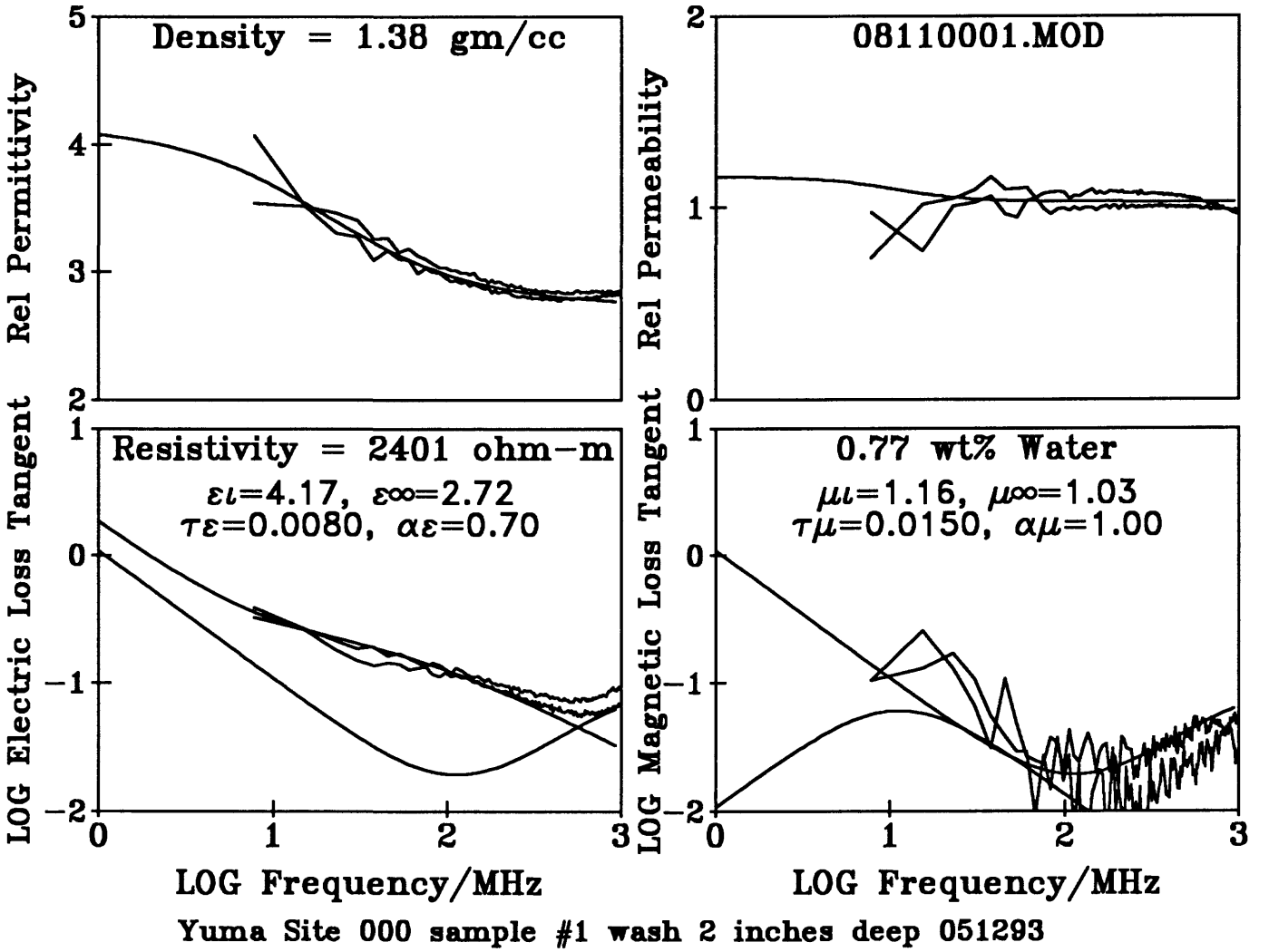



Figure 167 -
Sample provided by Lincoln Laboratory in a sealed bottle -- presumed natural water content -- location unknown.

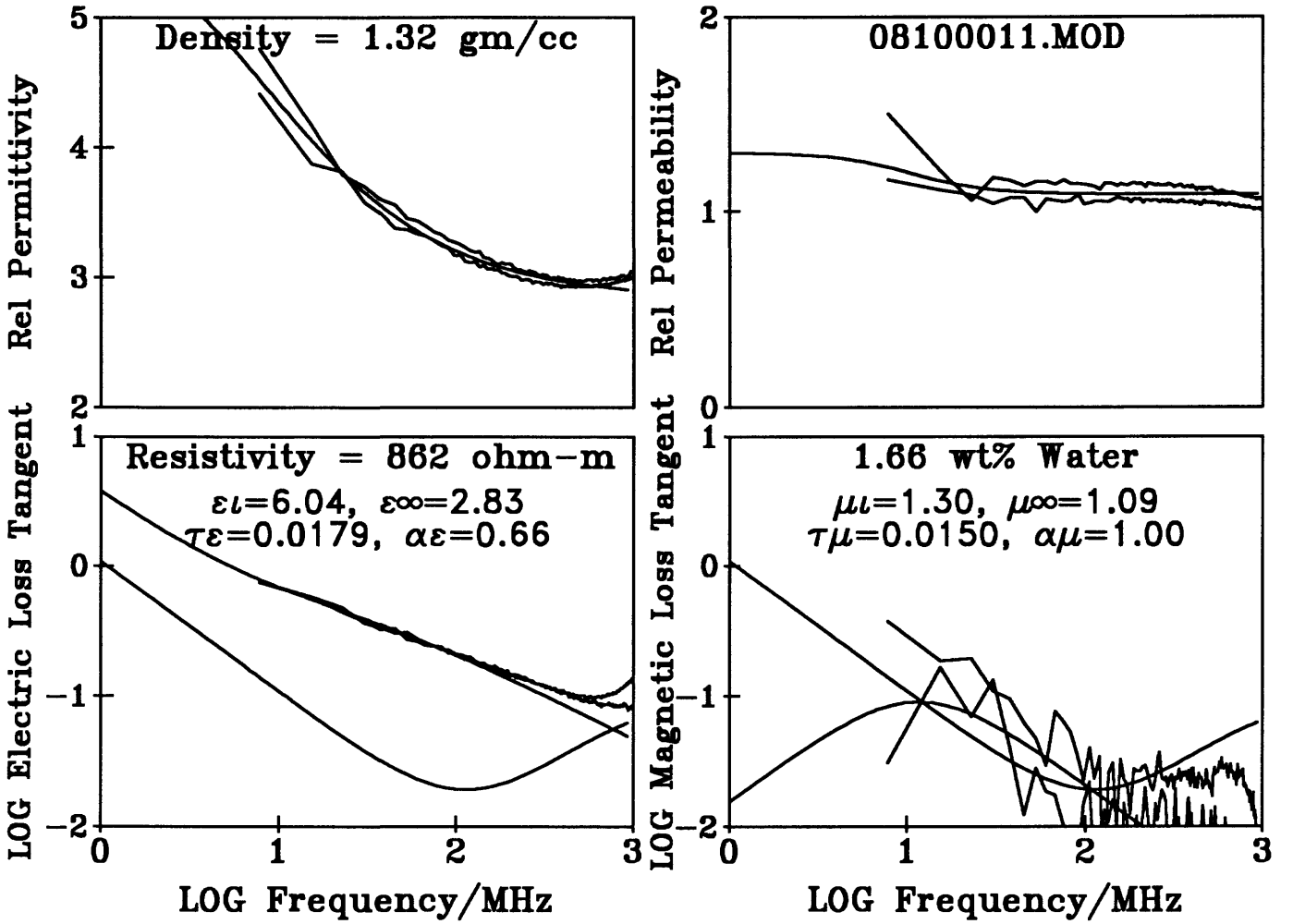
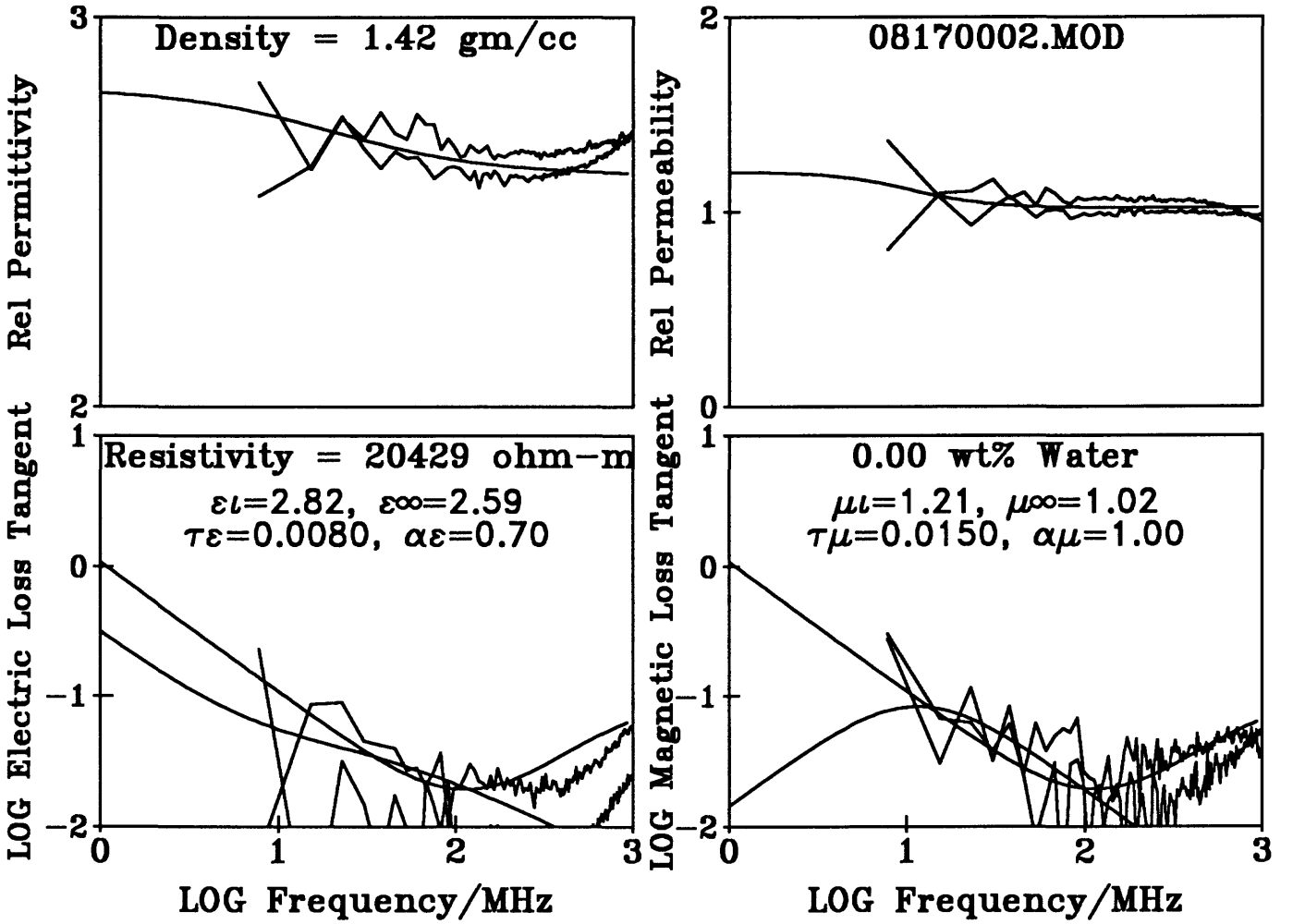



Figure 168 -
Sample provided by Lincoln Laboratory in a sealed bottle -- presumed natural water content -- location unknown.




**Yuma Site 000 sample #2 crest of dune (2nd) 4-in deep 051293 #2 vac.dry**

Figure 169 -

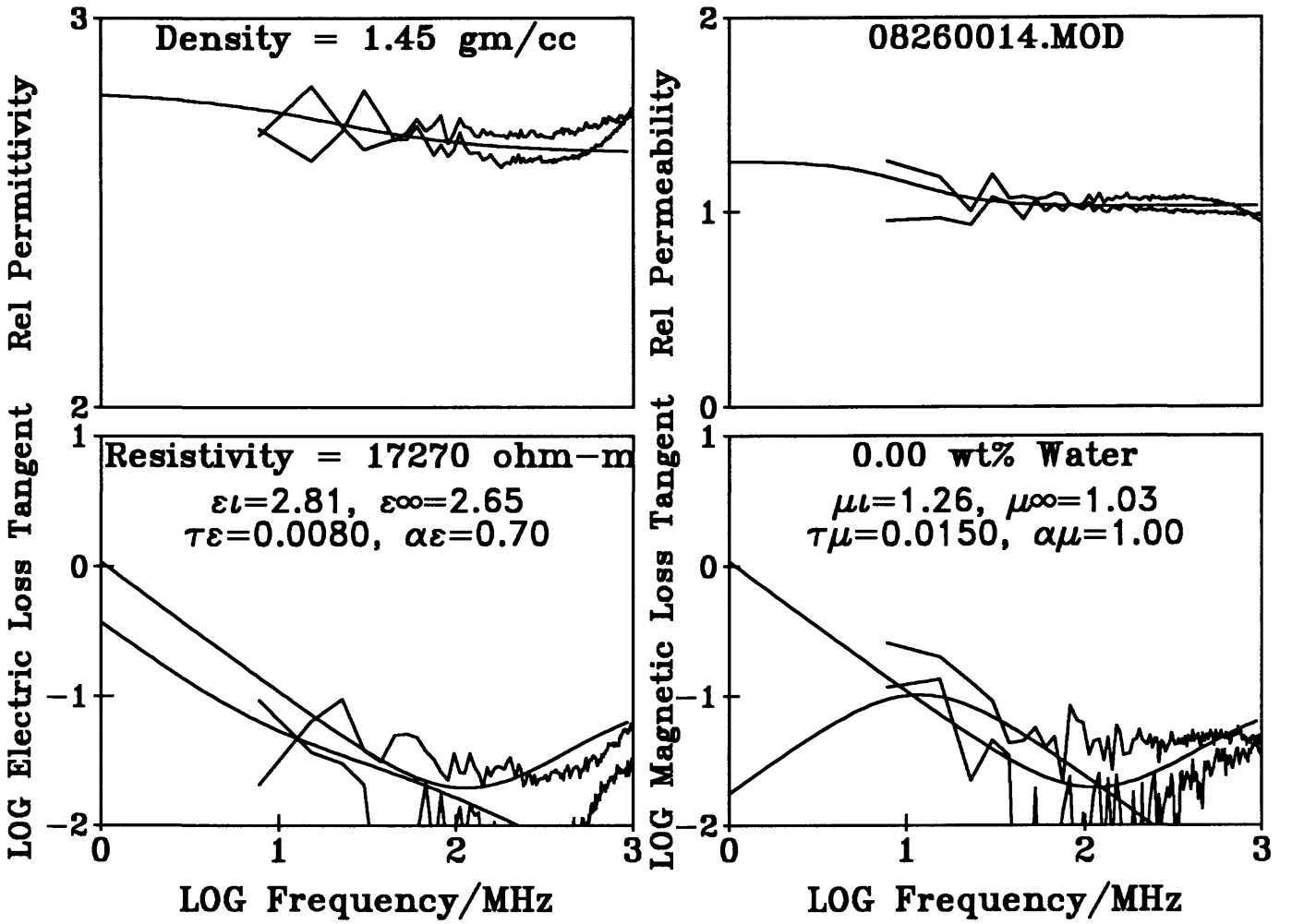

Density = 1.45 gm/cc
08260014.MOD
Rel Permittivity
Rel Permeability
Resistivity = 17270 ohm-m
ει=2.81, ε∞=2.65
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.26, μ∞=1.03
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma Site 000 sample #2 crest of dune (2nd) 4-in deep 051293 #3 vac. dry

Figure 170 -

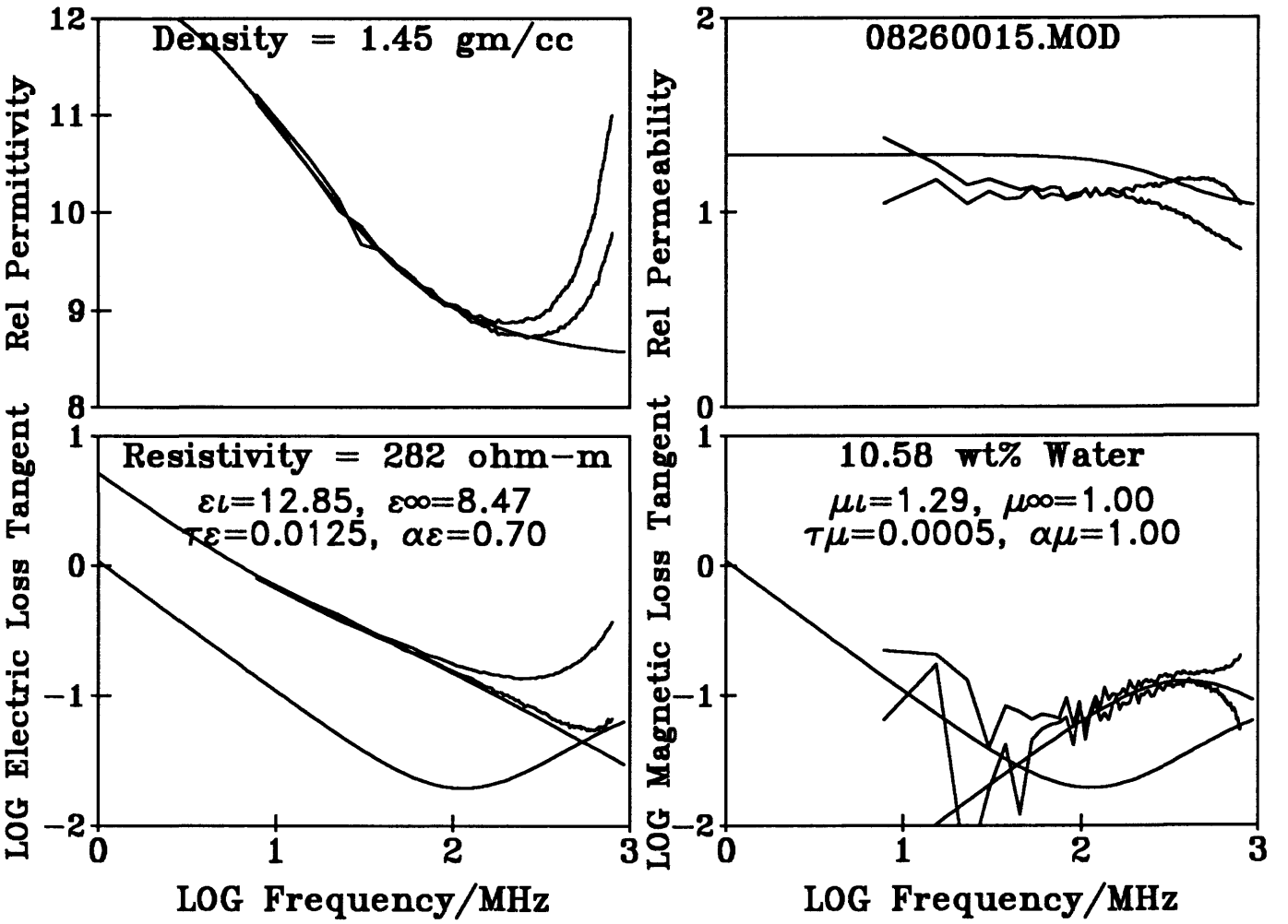
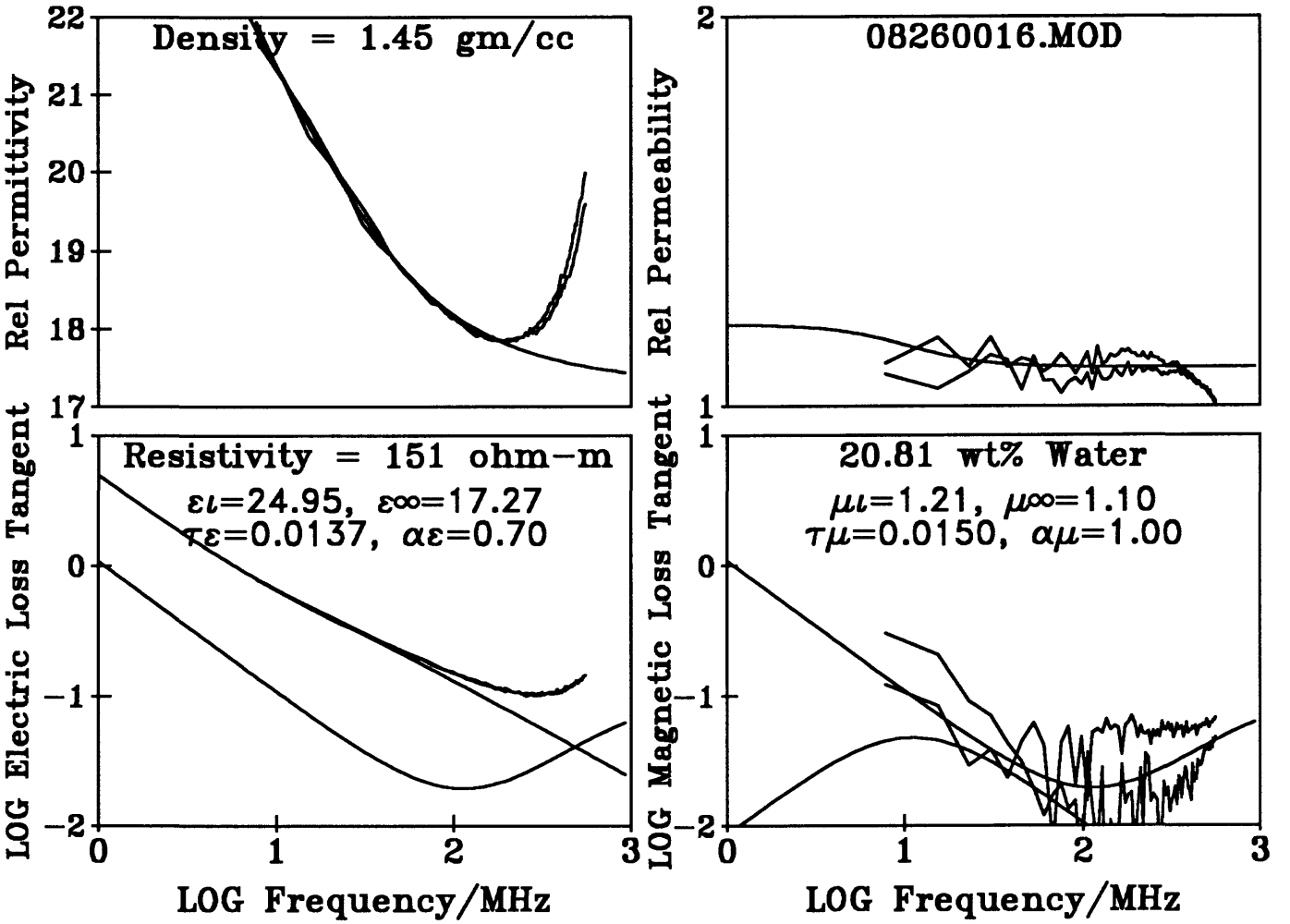

Density = 1.45 gm/cc
08260015.MOD
Rel Permittivity
Rel Permeability
Resistivity = 282 ohm-m
ει=12.85, ε∞=8.47
τε=0.0125, αε=0.70
10.58 wt% Water
μι=1.29, μ∞=1.00
τμ=0.0005, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma Site 000 Smpl.#2 crest of dune (2nd) 4-in deep #3 14-drops water

Figure 171 -




**Yuma Site 000 smpl. #2 crest of dune (2nd) 4 in. deep 051293 #3 water sat.**

Figure 172 -

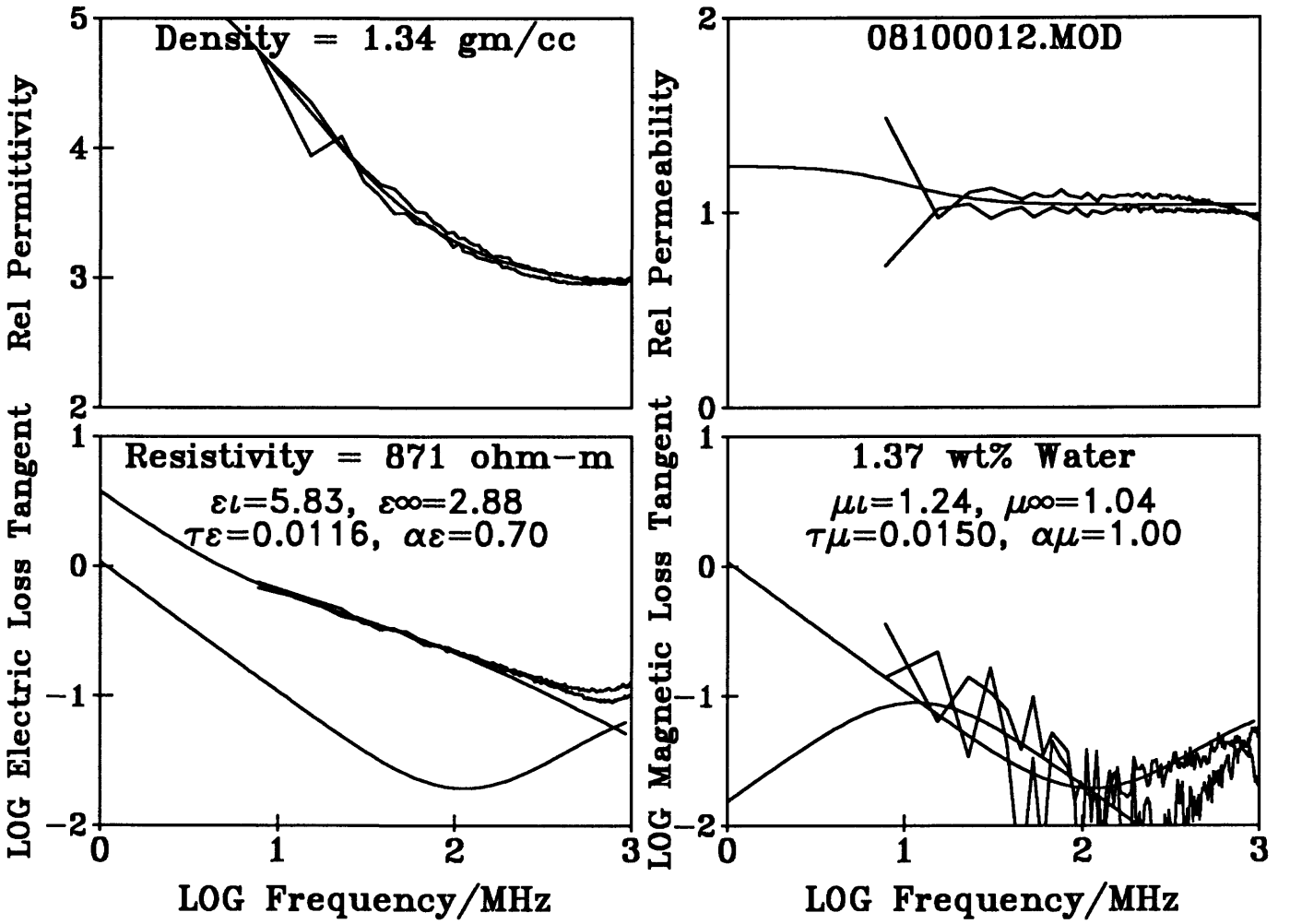
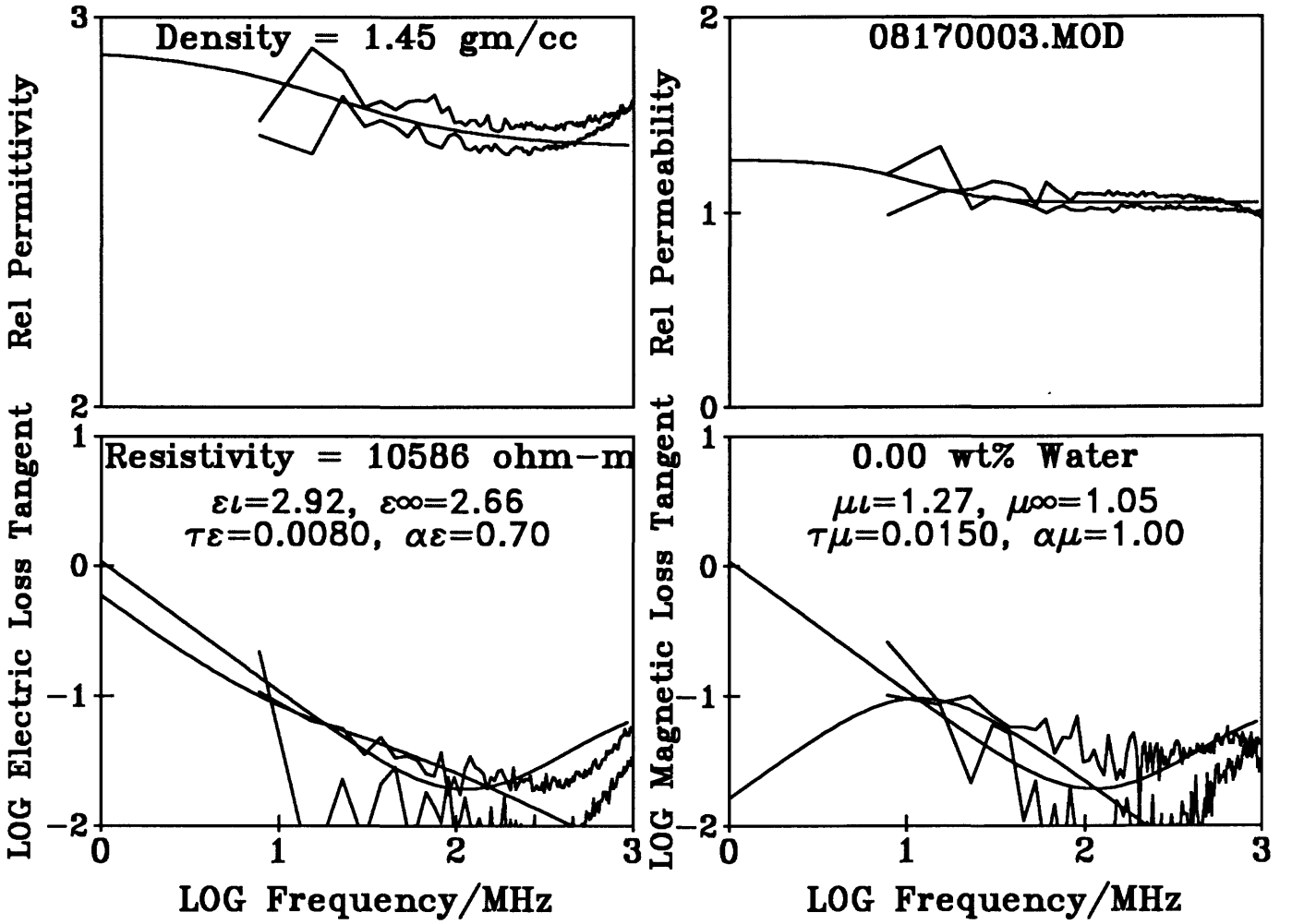



Figure 173 -
Sample provided by Lincoln Laboratory in a sealed bottle -- presumed natural water content -- location unknown.




**Yuma Site 001 smpl#1 (low area) bowl of dune 2-in deep 051293 #2 vac.dry**

Figure 174 -

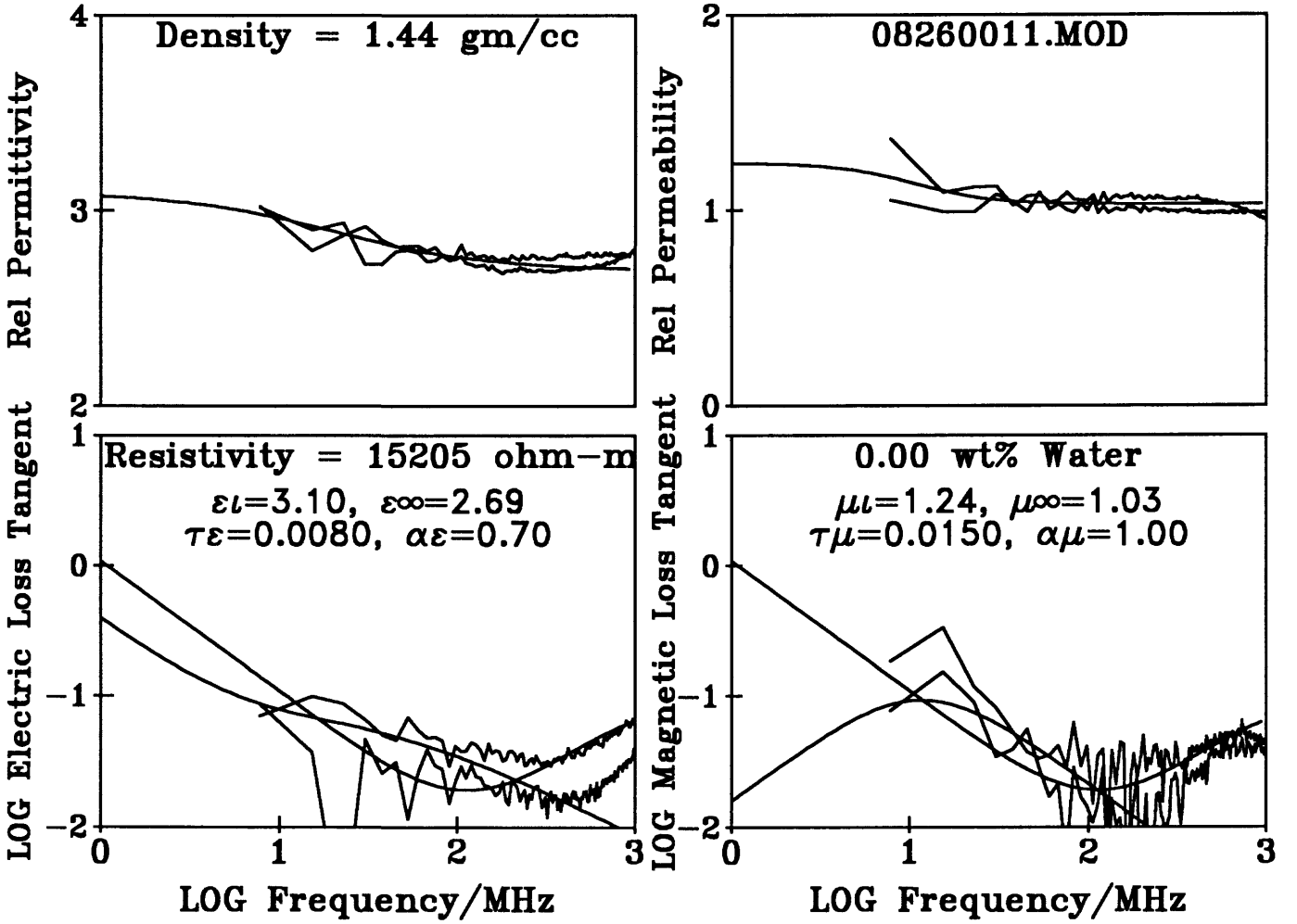
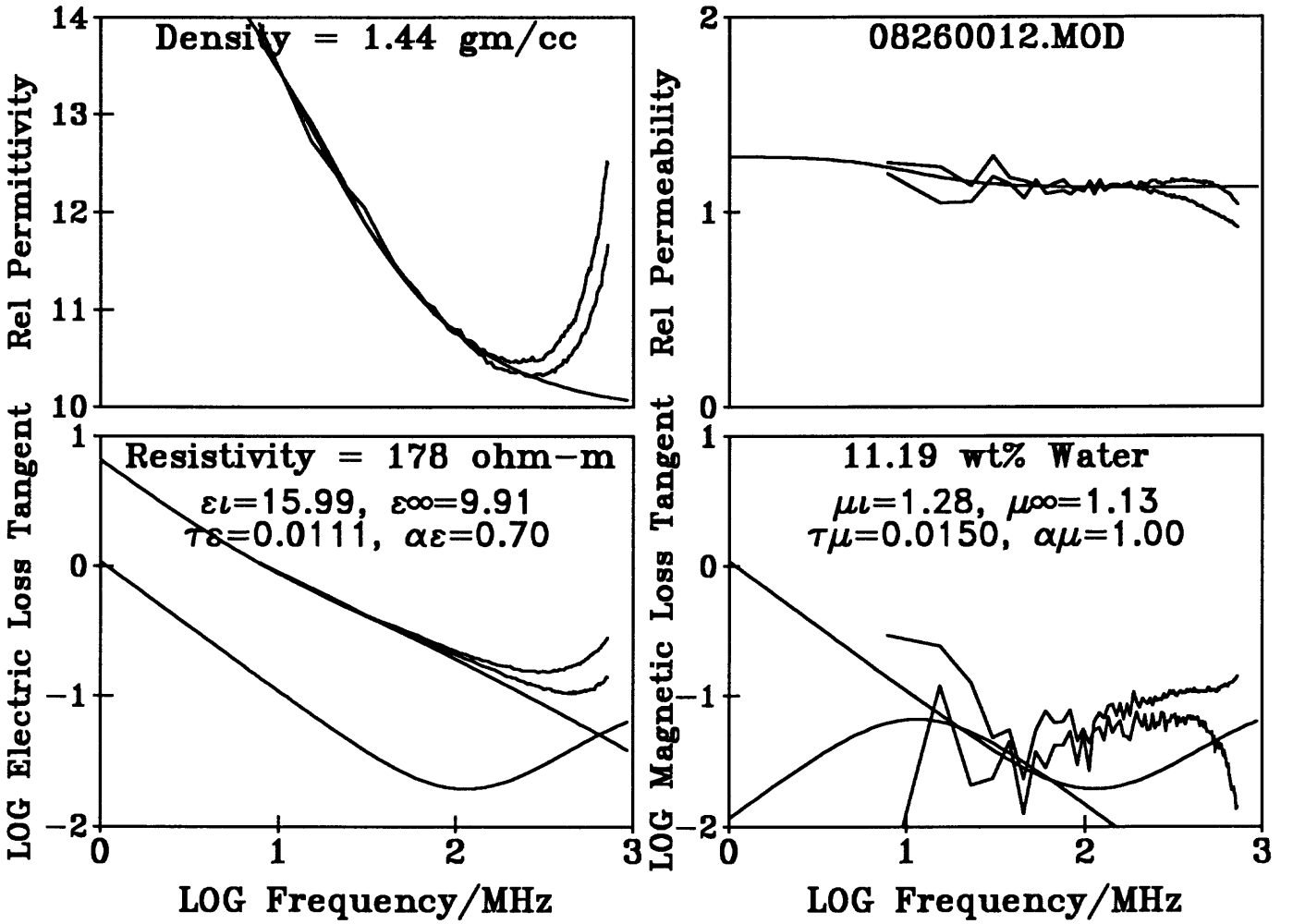
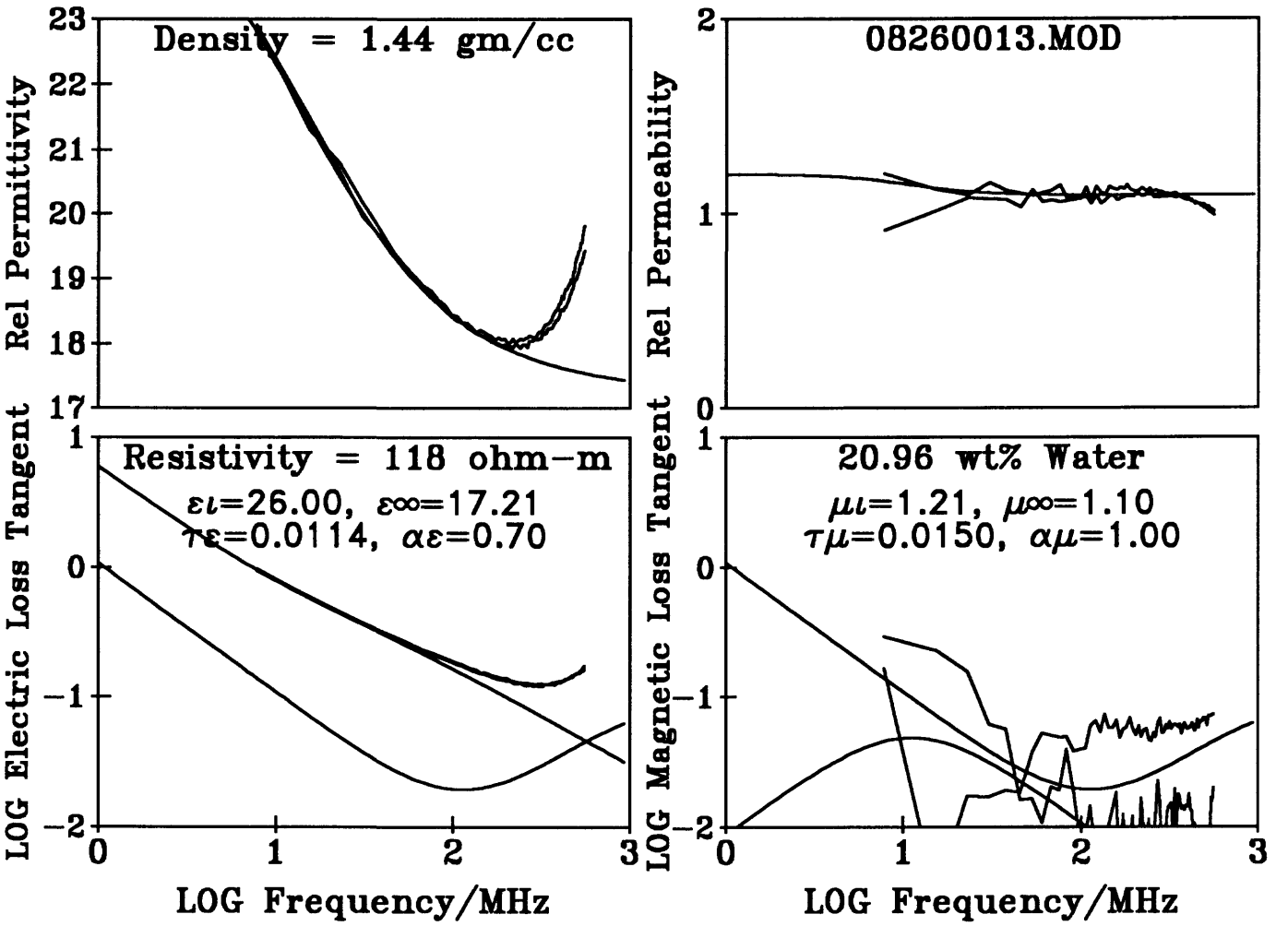

Density = 1.44 gm/cc
08260011.MOD
Rel Permittivity
Rel Permeability
Resistivity = 15205 ohm-m
ει=3.10, ε∞=2.69
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.24, μ∞=1.03
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma Site 001 smpl#1 (low area) bowl of dune 2-in deep 051293 #3 vac.dry

Figure 175 -




**Yuma Site 001 smpl. #1 (low area) bowl of dune 2in. dp. #3 14 drops water**

Figure 176 -




**Yuma Site 001 smpl#1 (low area) bowl of dune 2-in deep 051293 #3 wat.sat.**

Figure 177 -

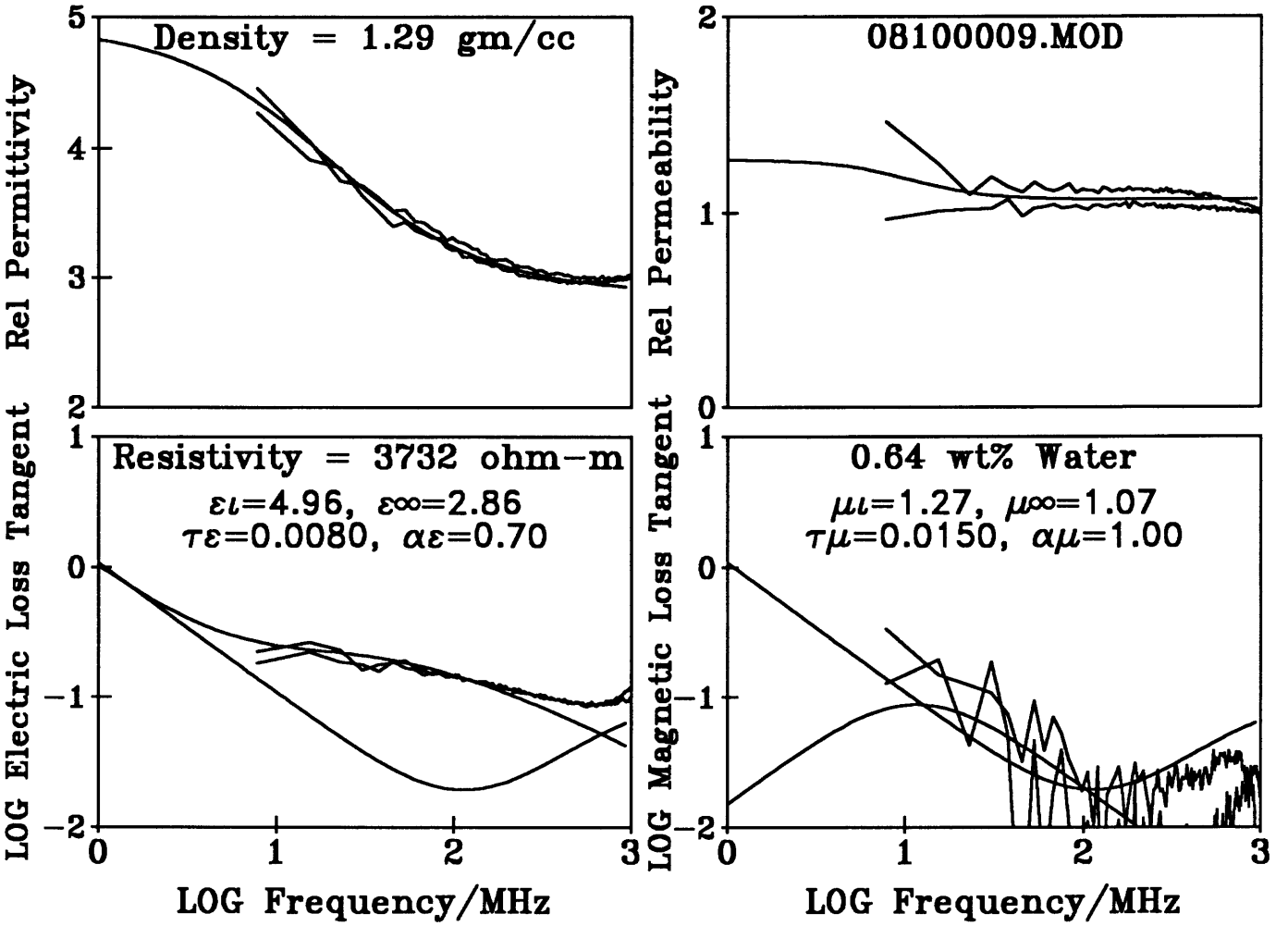



Figure 178 -
Sample provided by Lincoln Laboratory in a sealed bottle -- presumed natural water content -- location unknown.

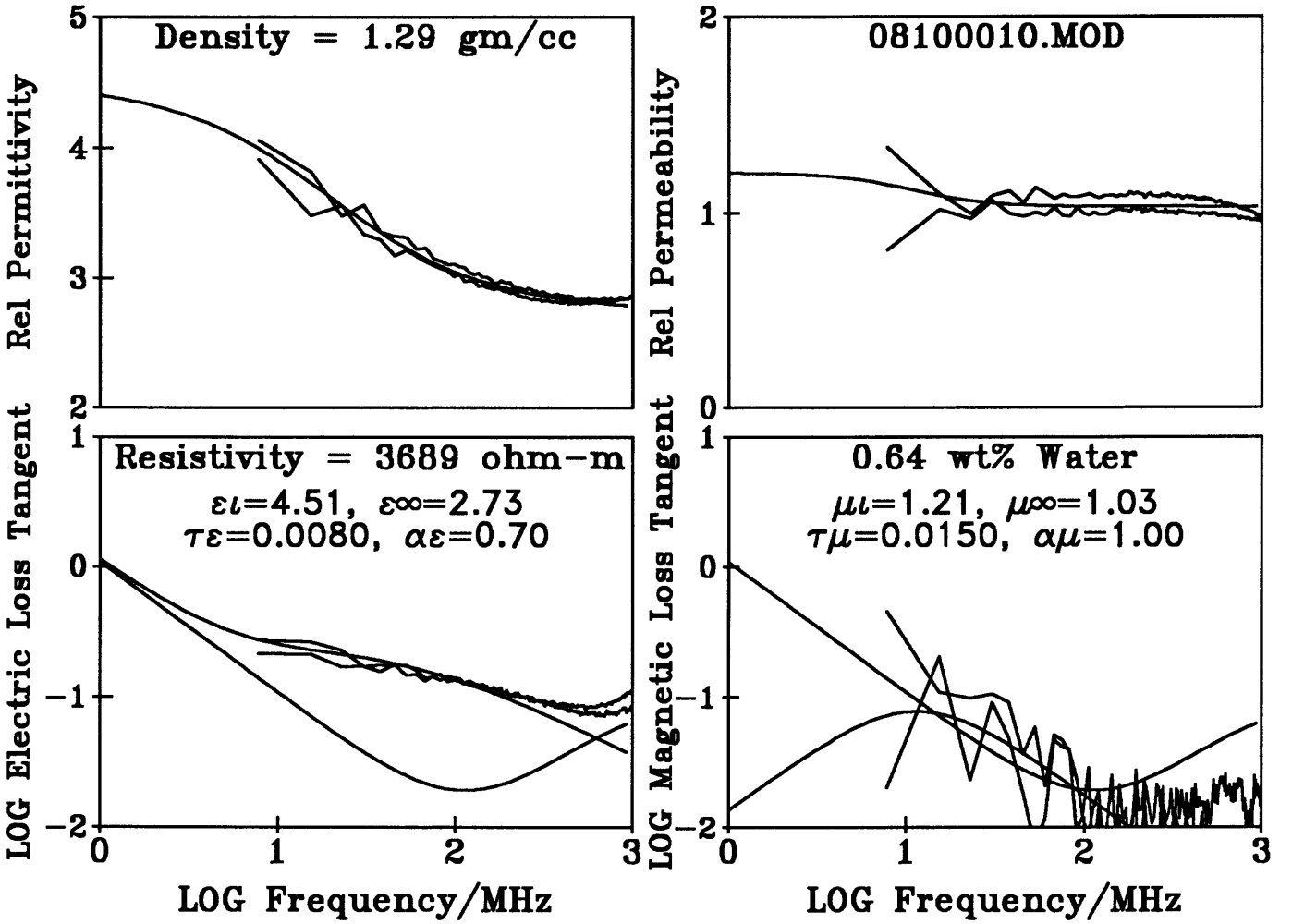

Density = 1.29 gm/cc
08100010.MOD
Resistivity = 3689 ohm-m
ει=4.51, ε∞=2.73
τε=0.0080, αε=0.70
0.64 wt% Water
μι=1.21, μ∞=1.03
τμ=0.0150, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma Luke 1 top of 4 door bunker 1 inch deep 051293 (repeat)

Figure 179 -

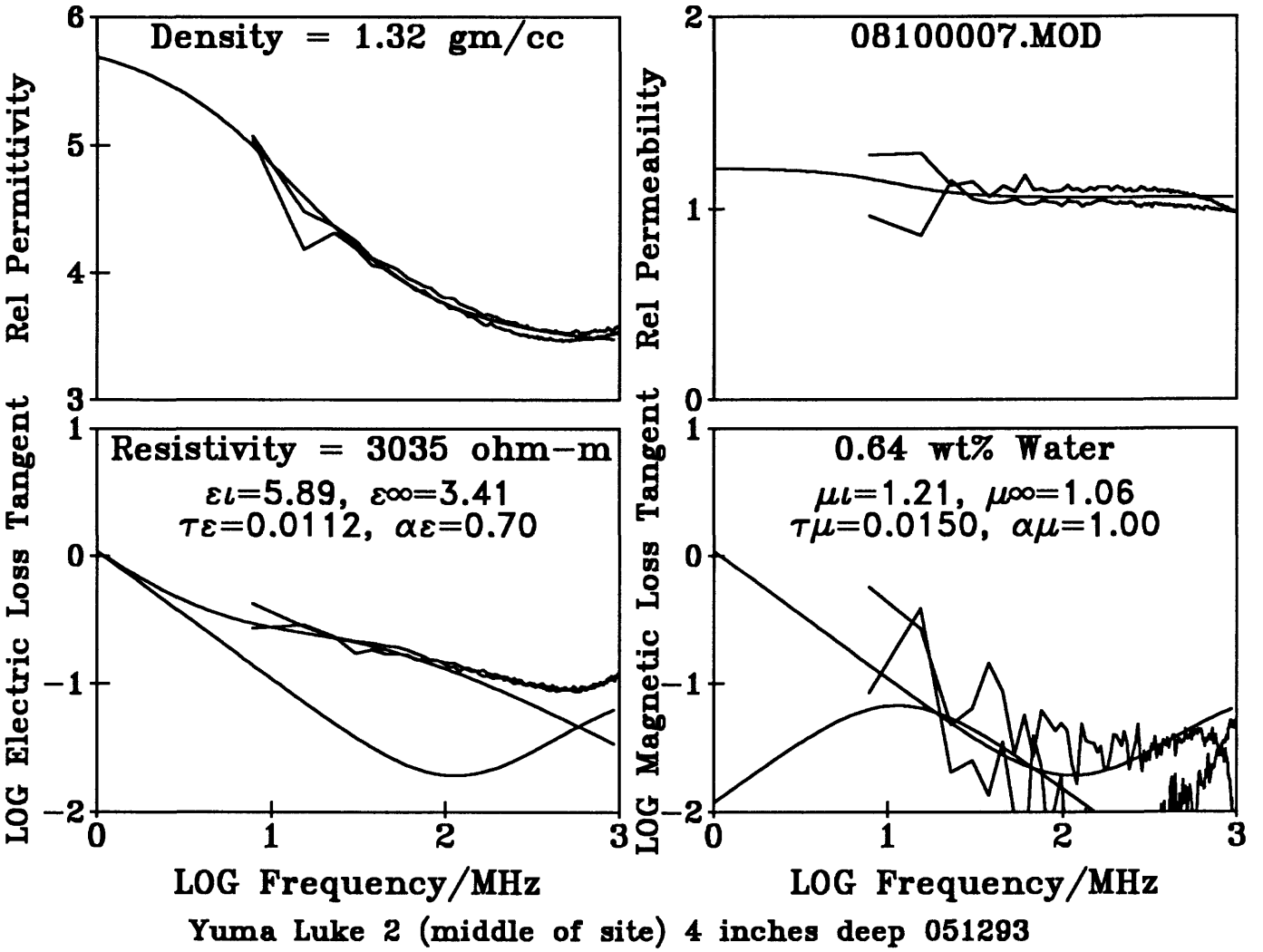



Figure 180 -
Sample provided by Lincoln Laboratory in a sealed bottle -- presumed natural water content -- location unknown.

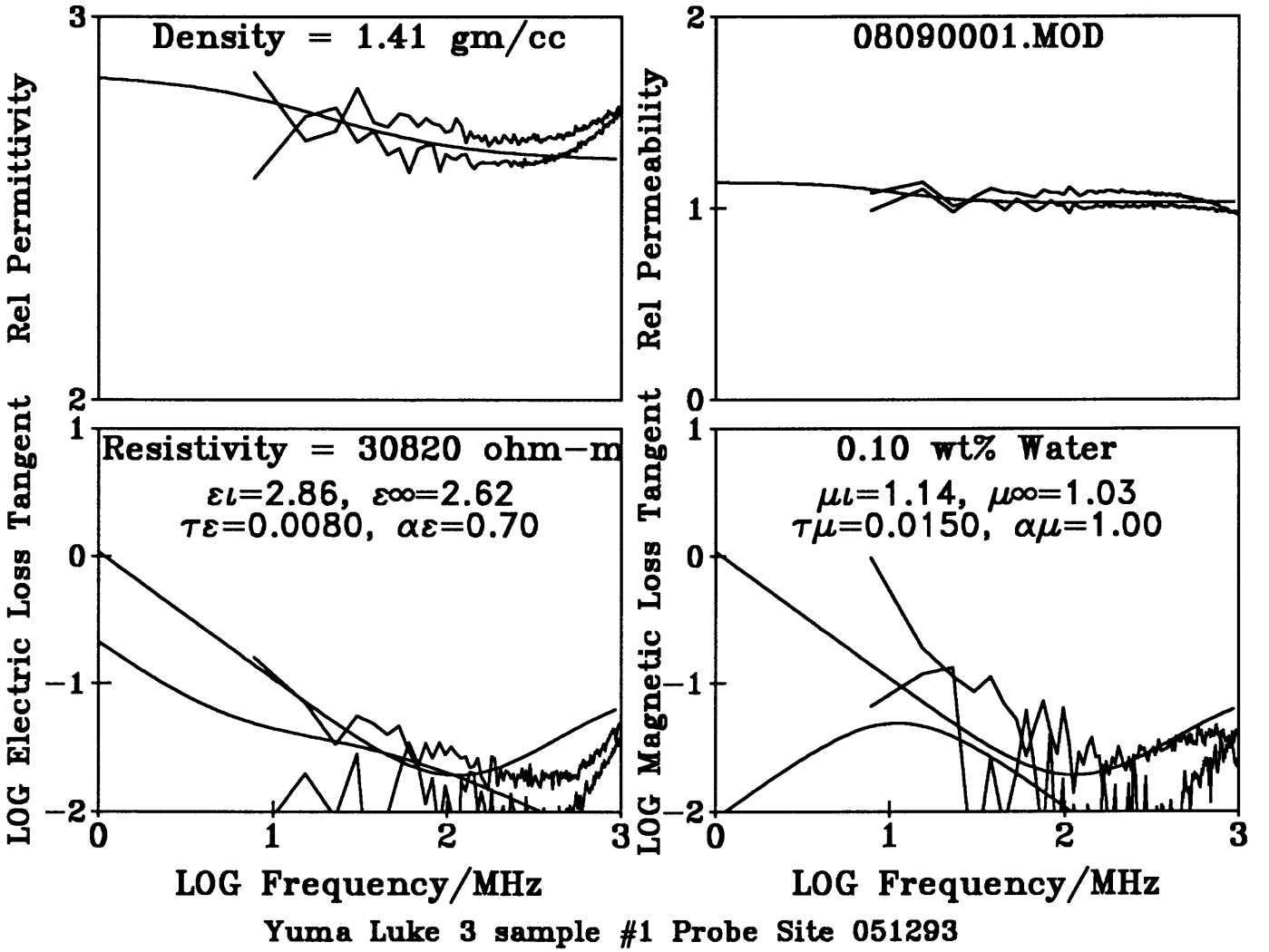



Figure 181 -
Sample provided by Lincoln Laboratory in a sealed bottle -- presumed natural water content -- location unknown.

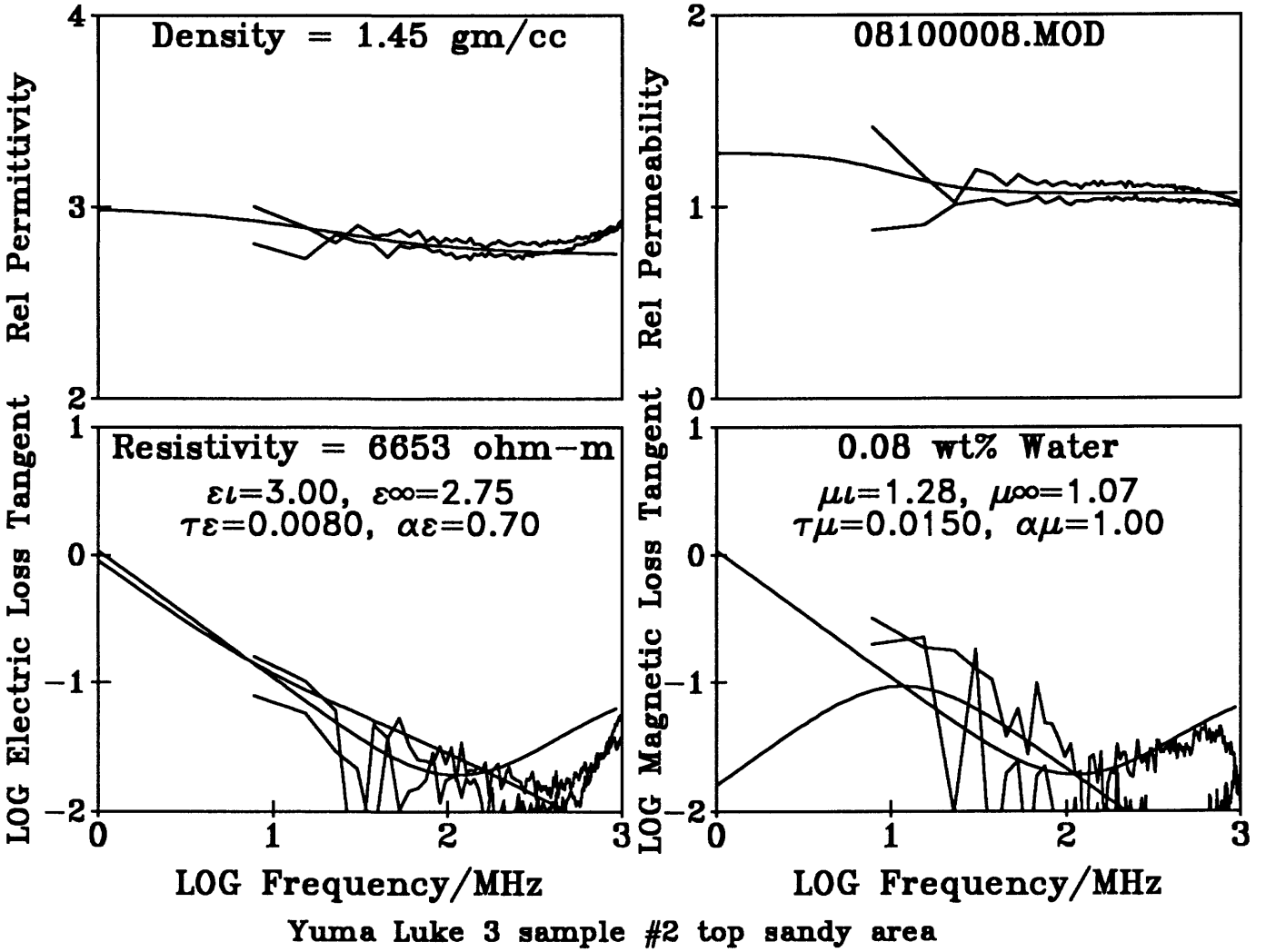



Figure 182 -
Sample provided by Lincoln Laboratory in a sealed bottle -- presumed natural water content -- location unknown.

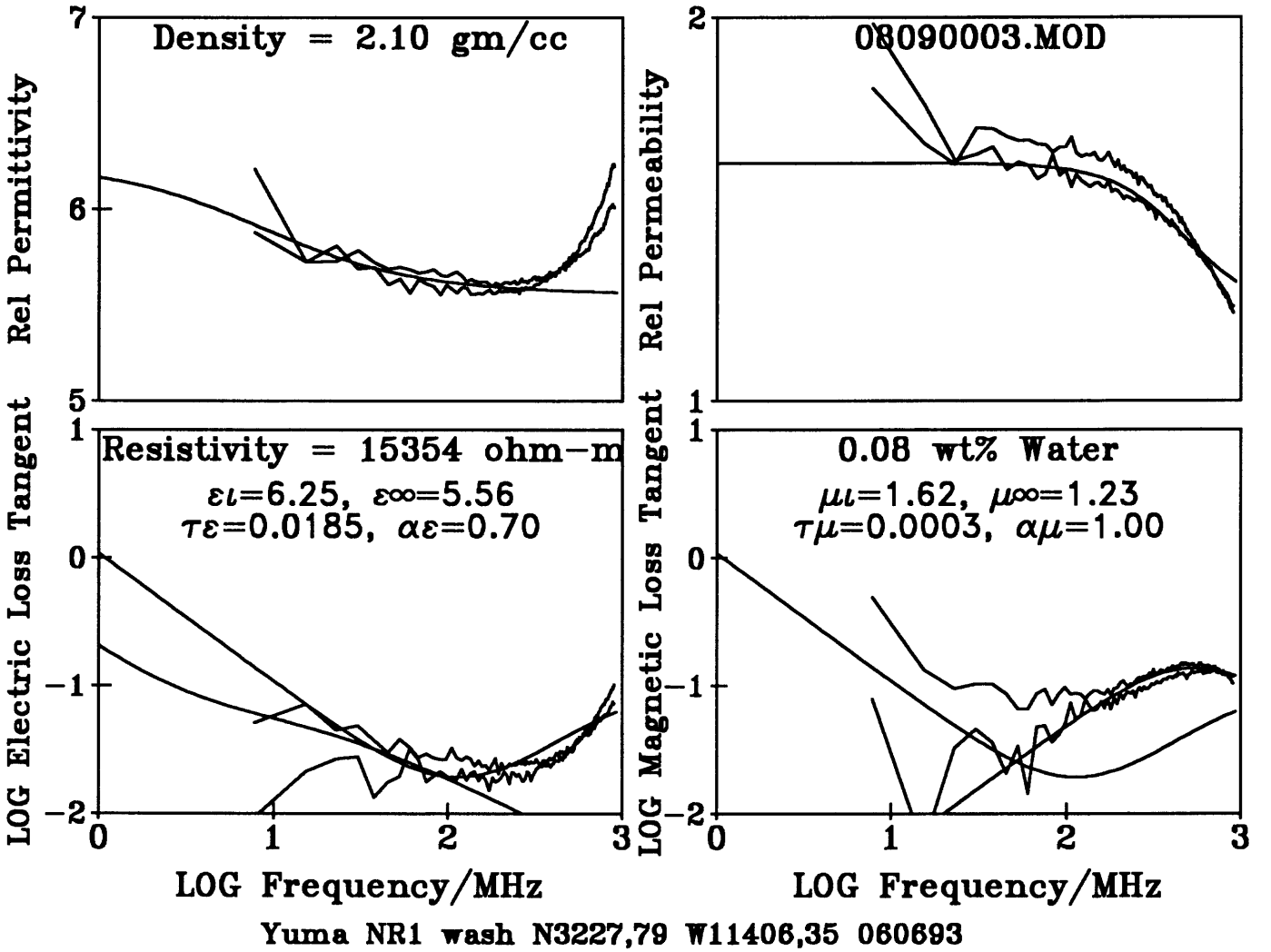



Figure 183 -
Sample provided by Carabas Team in a sealed bottle -- presumed natural water content. Note large magnetic losses compared to electrical losses. Comparing this result to Figures 184 through 194, this sample has the equivalent of 30 percent iron in silica sand.

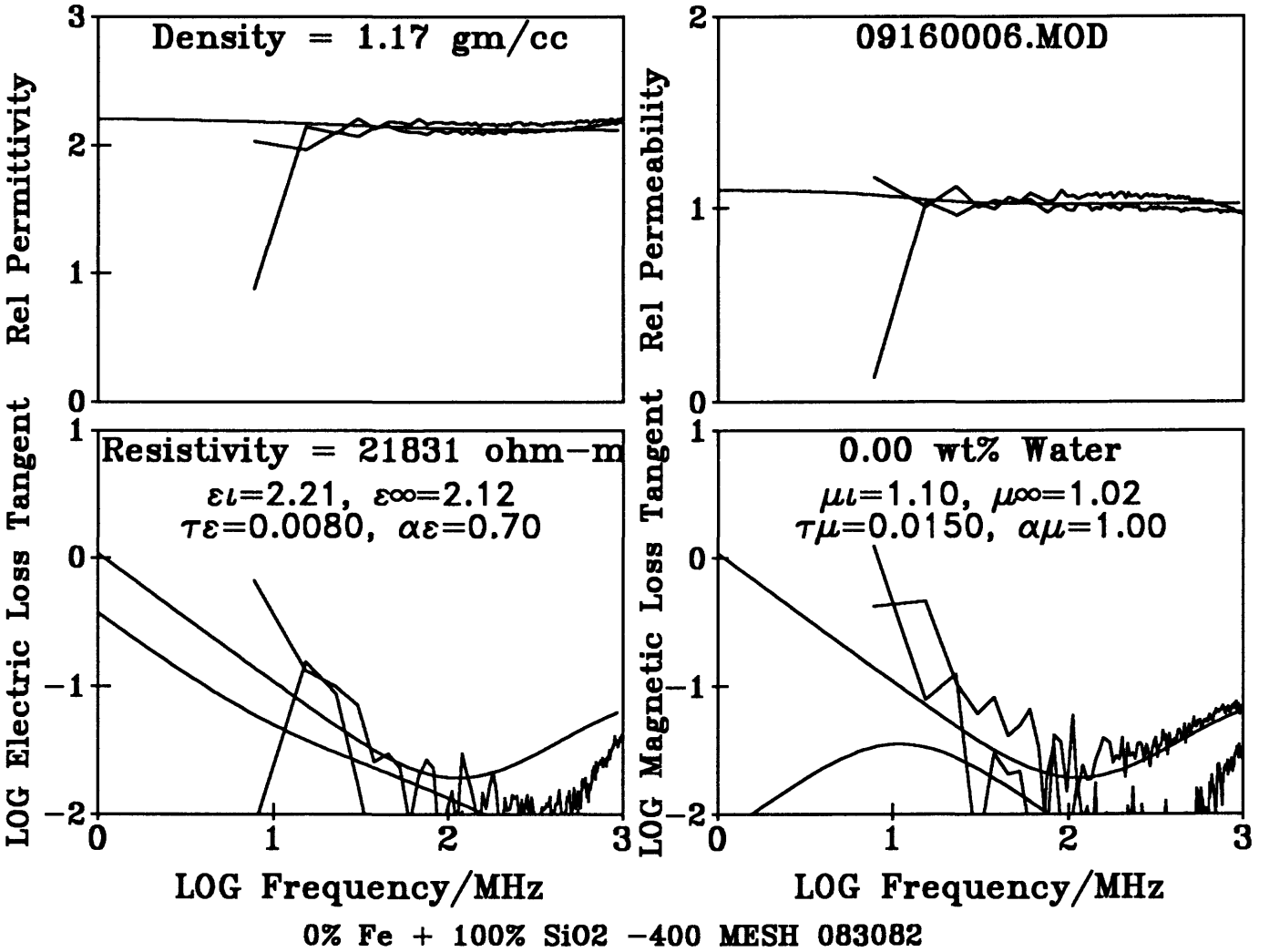



Figure 184 -
Artificial sample composed of a mixture of -400 mesh iron filings in a silica sand matrix.

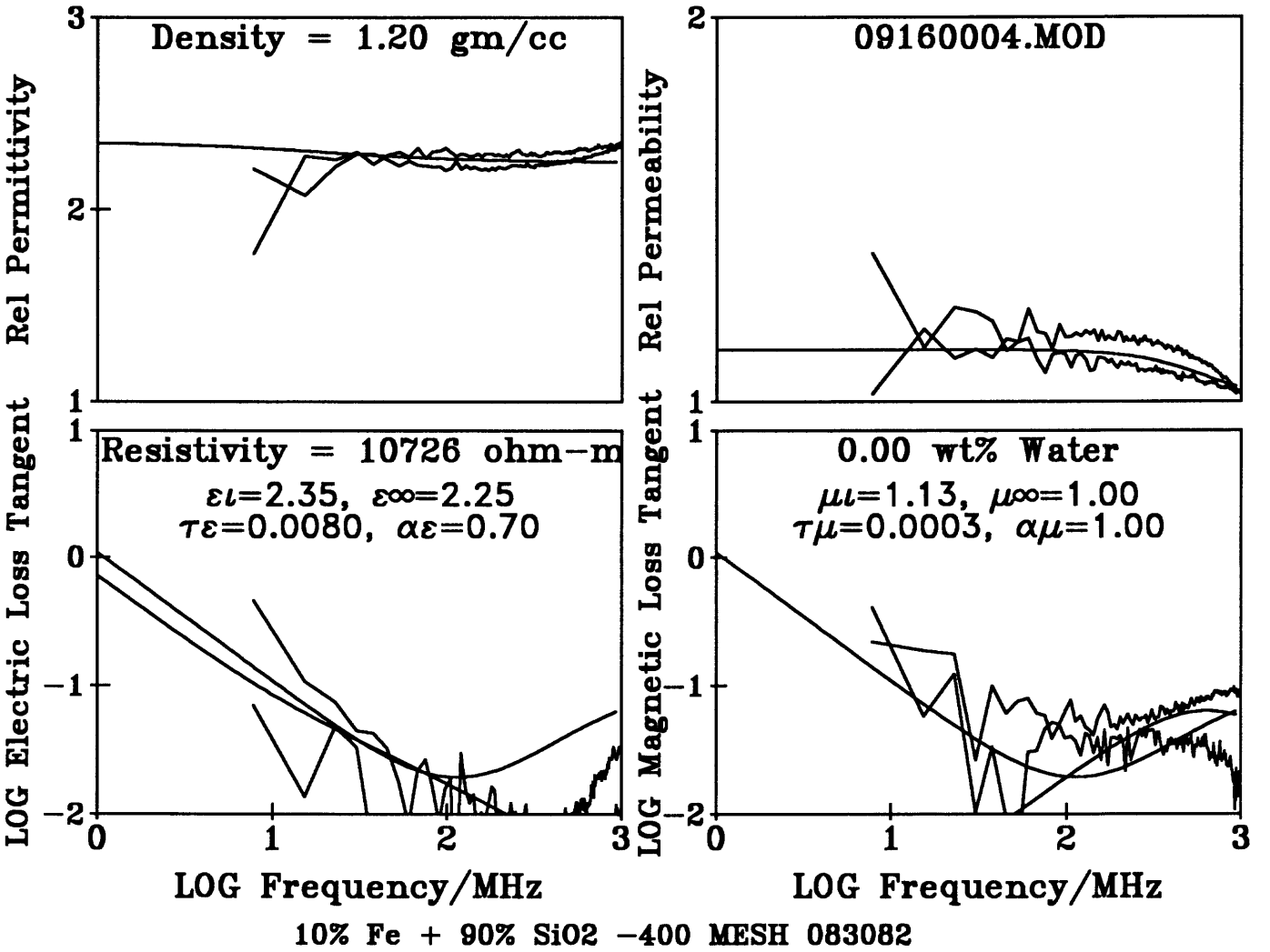



Figure 185 -
Artificial sample composed of a mixture of -400 mesh iron filings in a silica sand matrix.

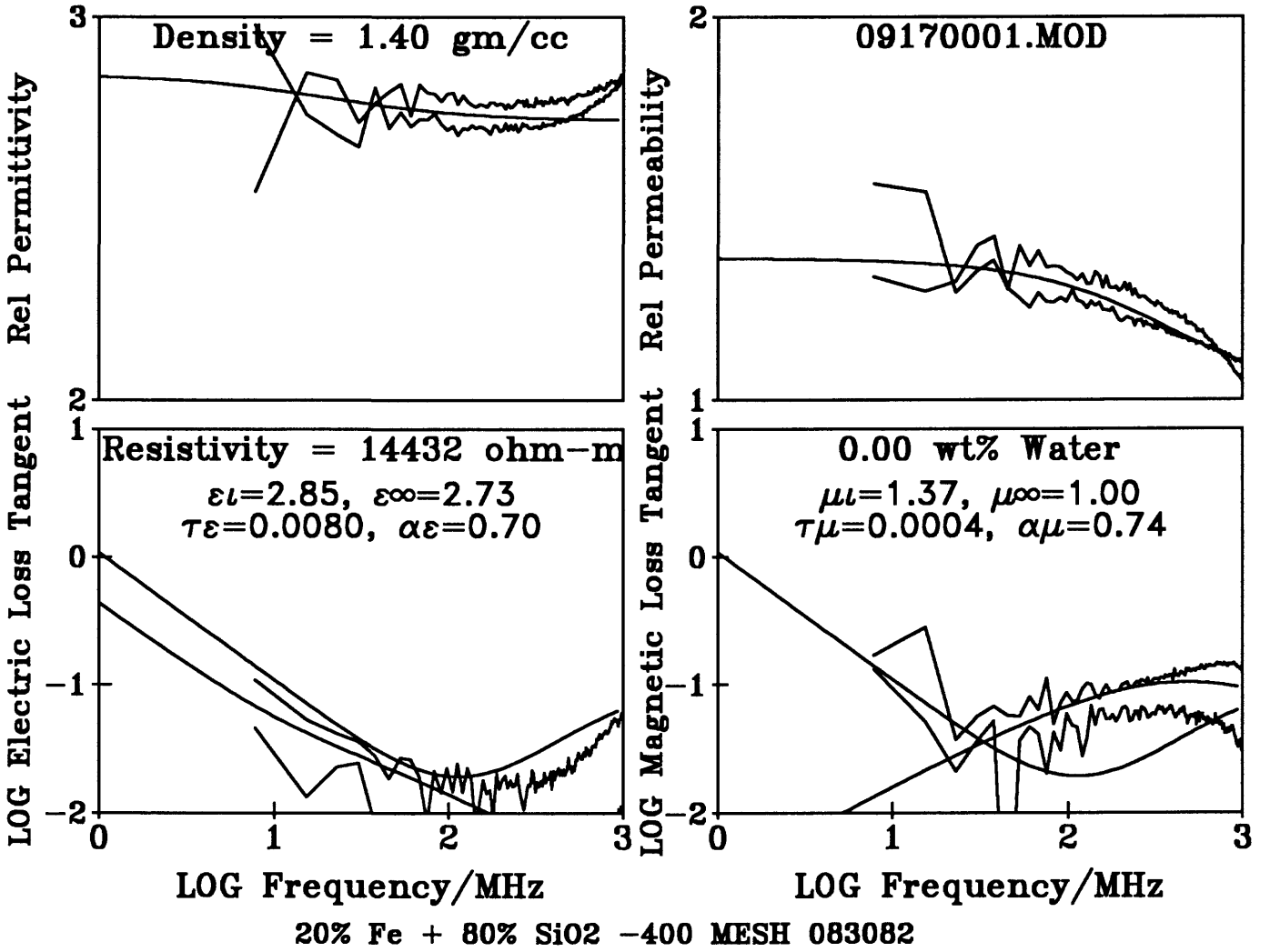



Figure 186 -
Artificial sample composed of a mixture of -400 mesh iron filings in a silica sand matrix.

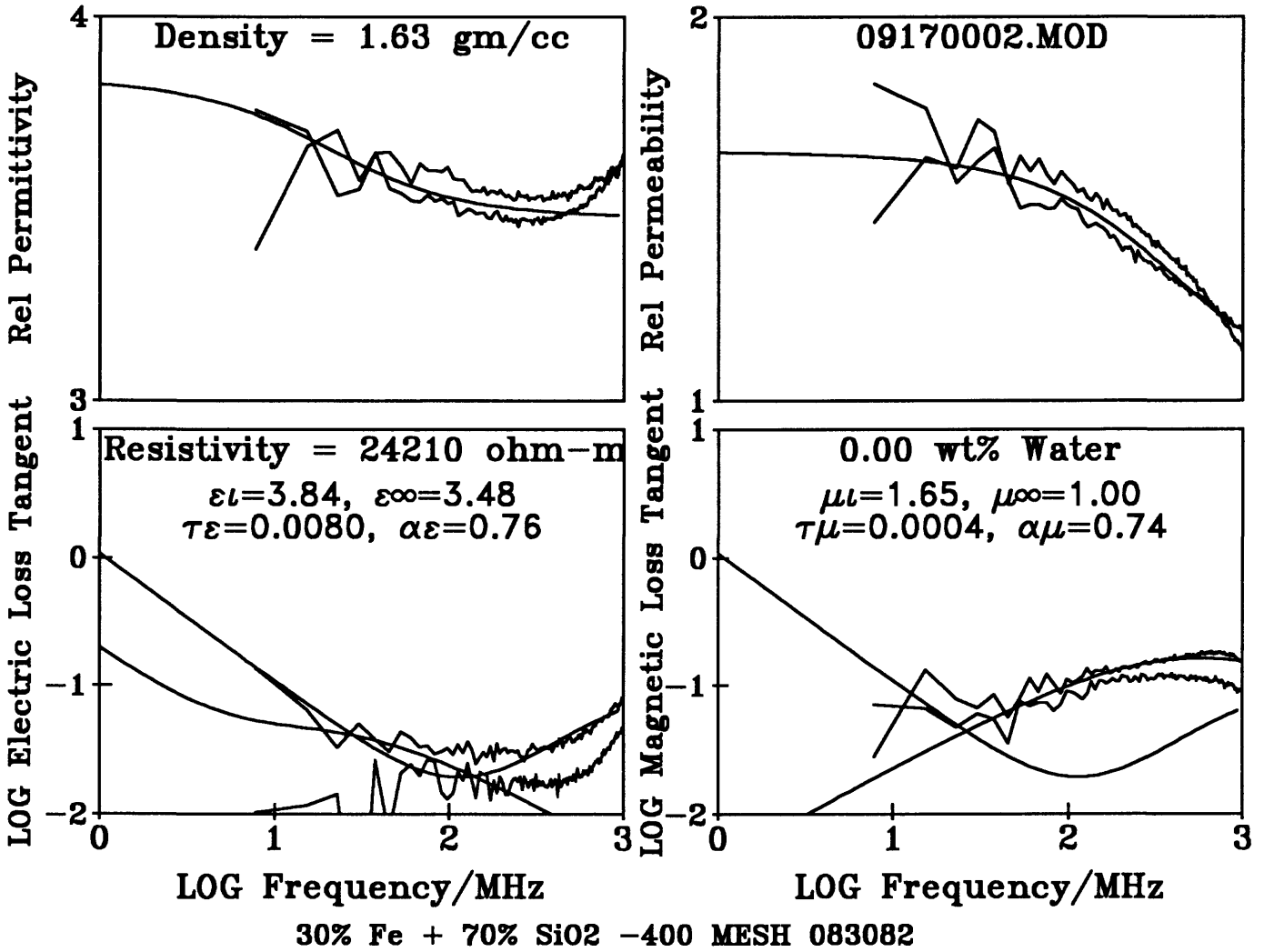



Figure 187 -
Artificial sample composed of a mixture of -400 mesh iron filings in a silica sand matrix.

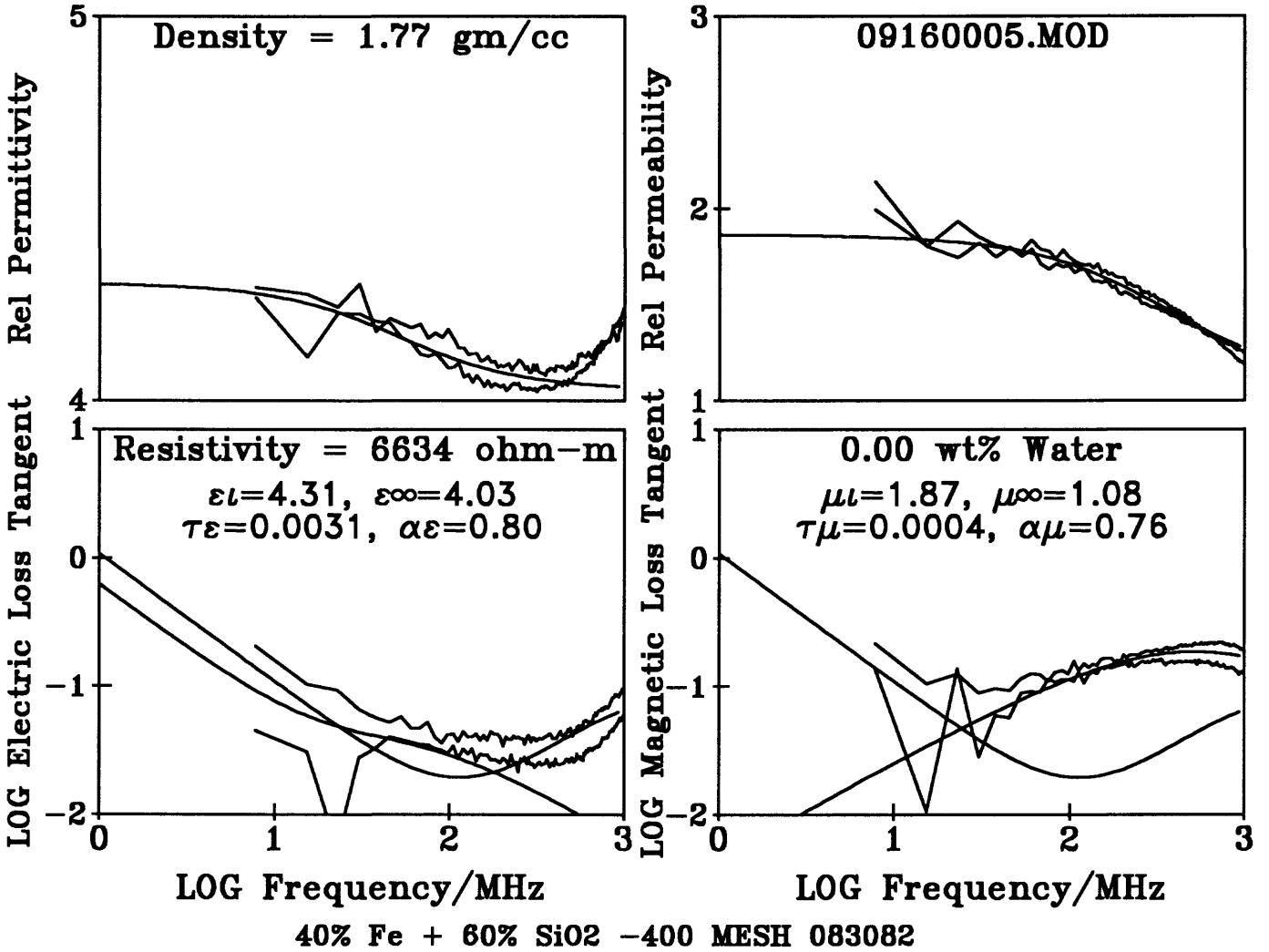



Figure 188 -
Artificial sample composed of a mixture of -400 mesh iron filings in a silica sand matrix.

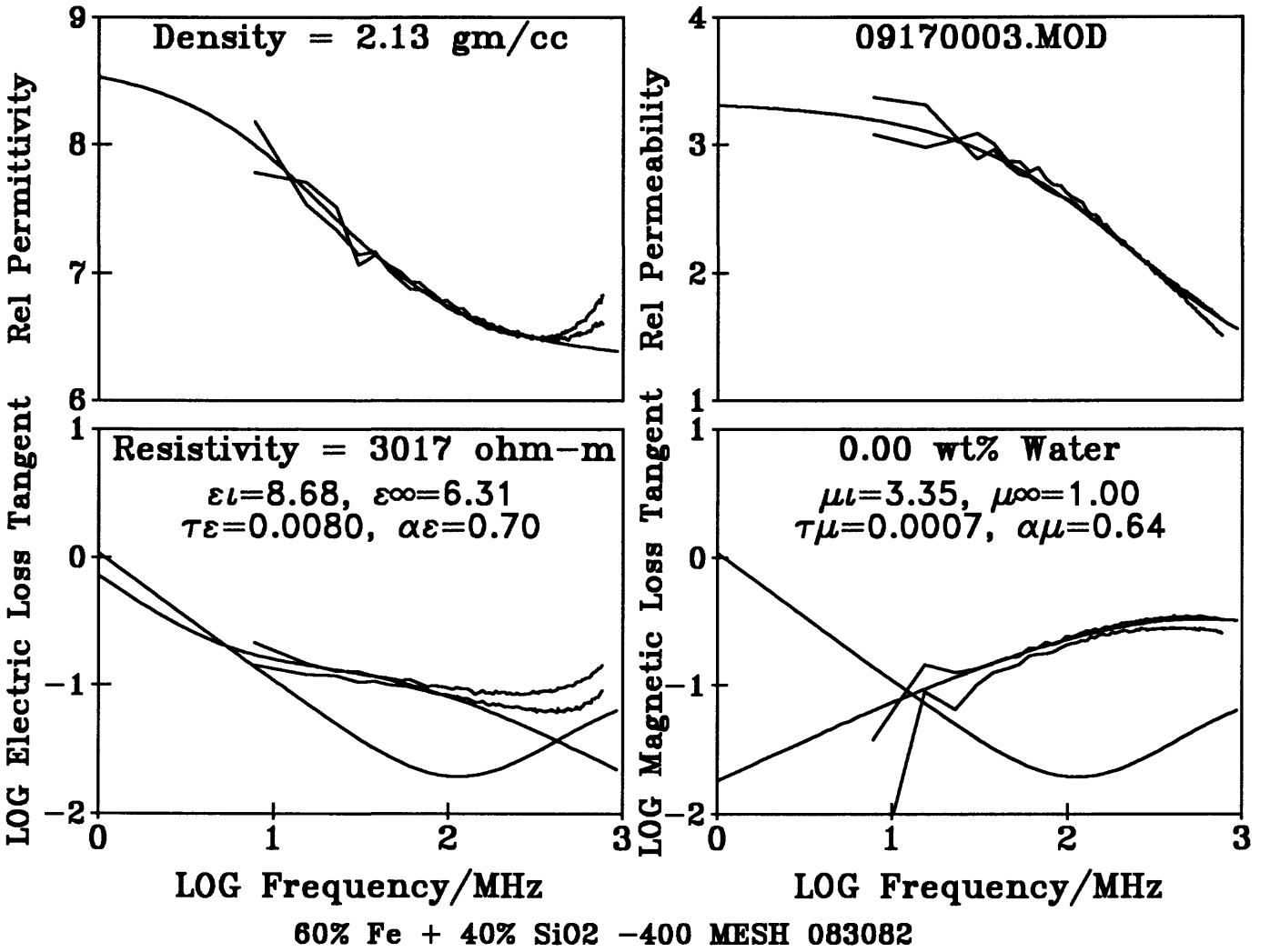



Figure 189 -
Artificial sample composed of a mixture of -400 mesh iron filings in a silica sand matrix.

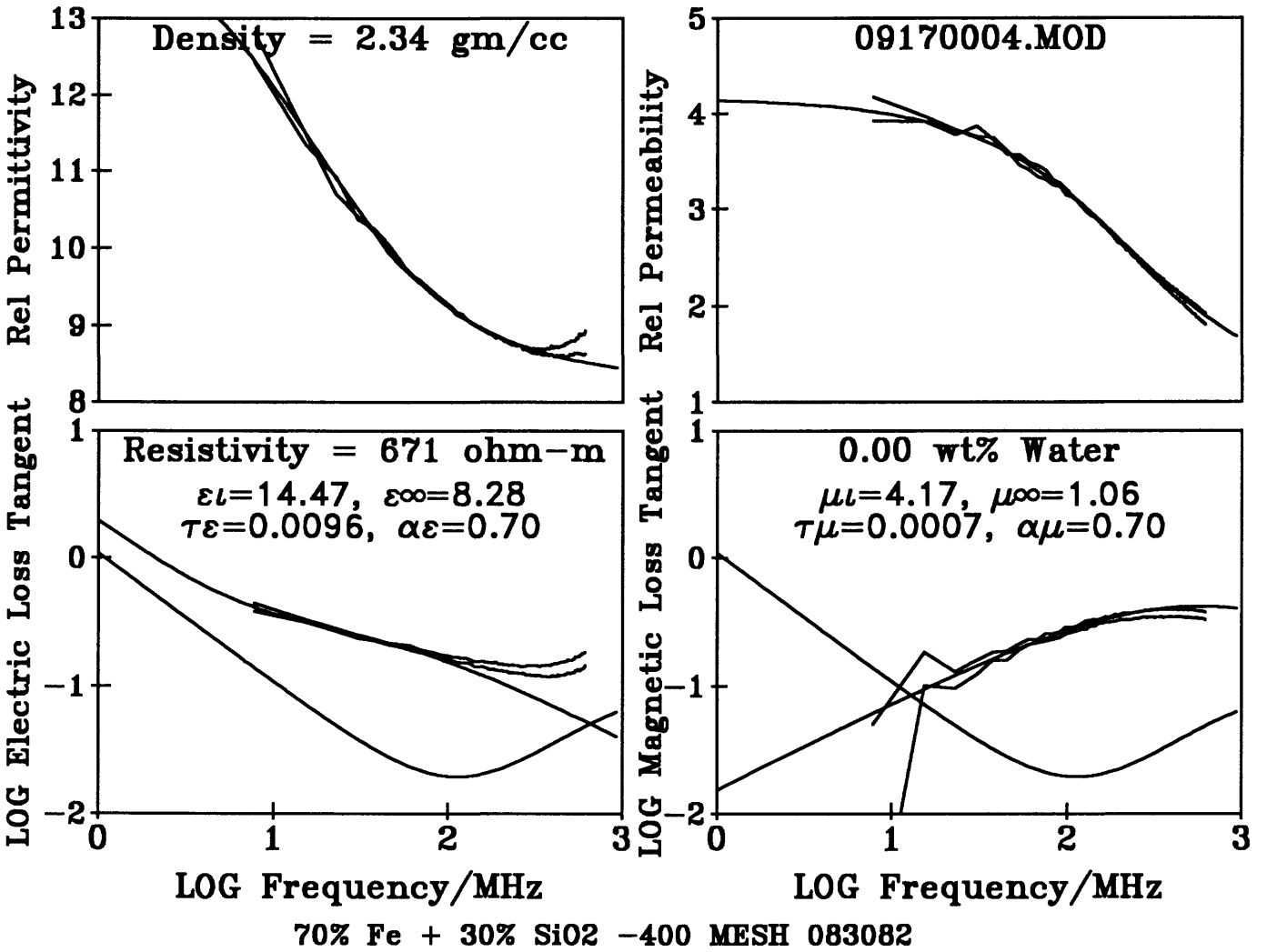



Figure 190 -
Artificial sample composed of a mixture of -400 mesh iron filings in a silica sand matrix.

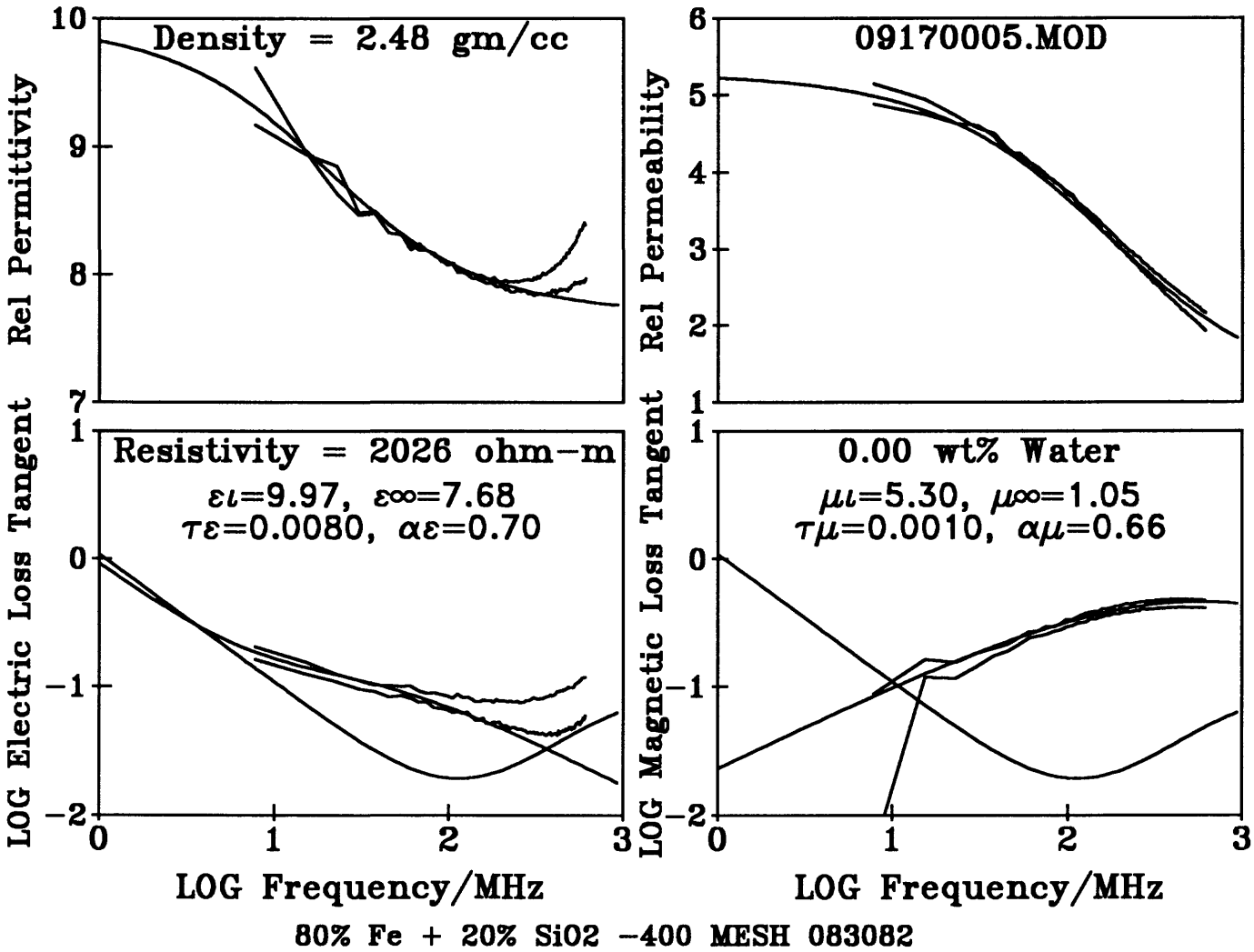



Figure 191 -
Artificial sample composed of a mixture of -400 mesh iron filings in a silica sand matrix.

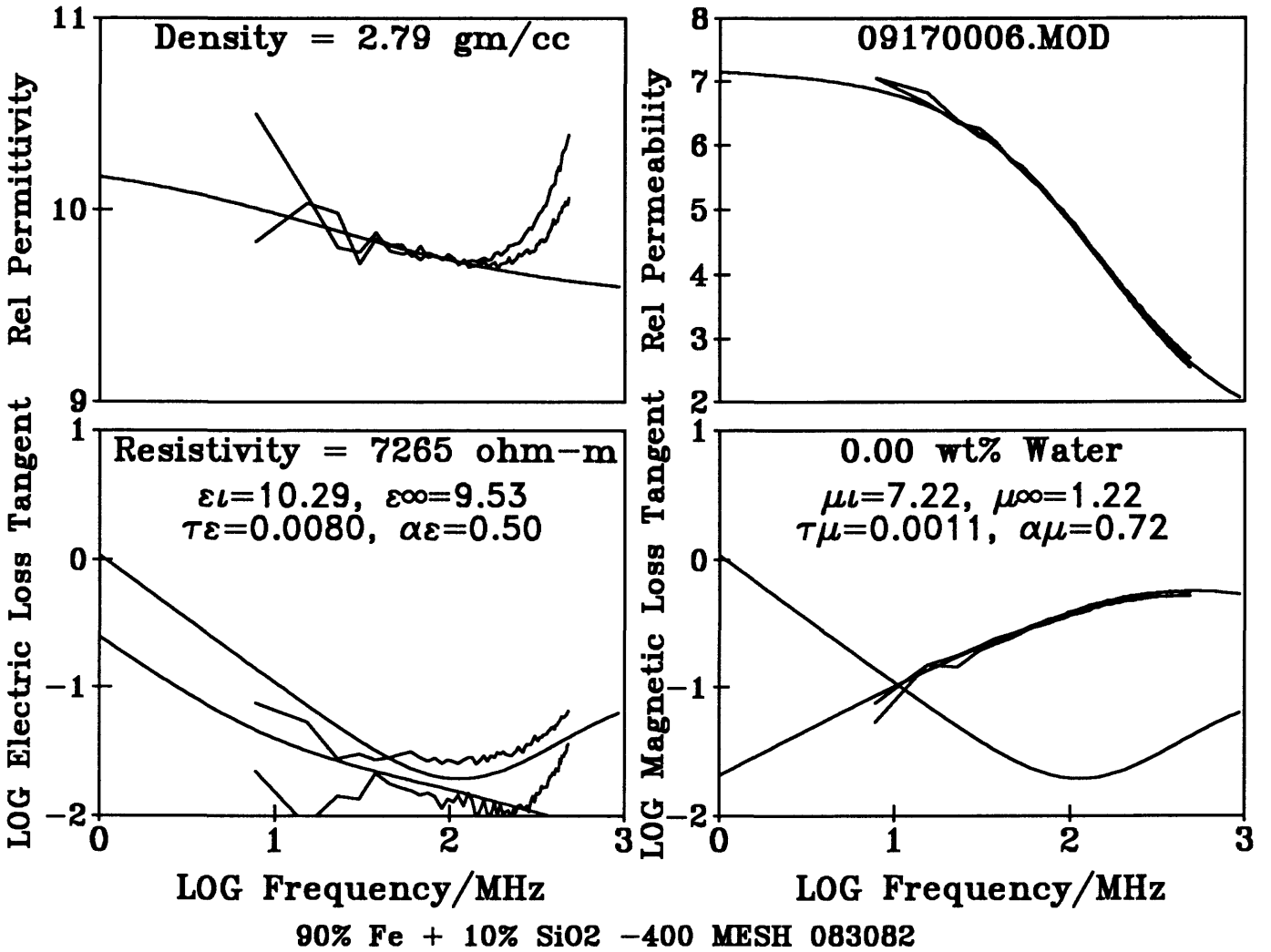



Figure 192 -
Artificial sample composed of a mixture of -400 mesh iron filings in a silica sand matrix.

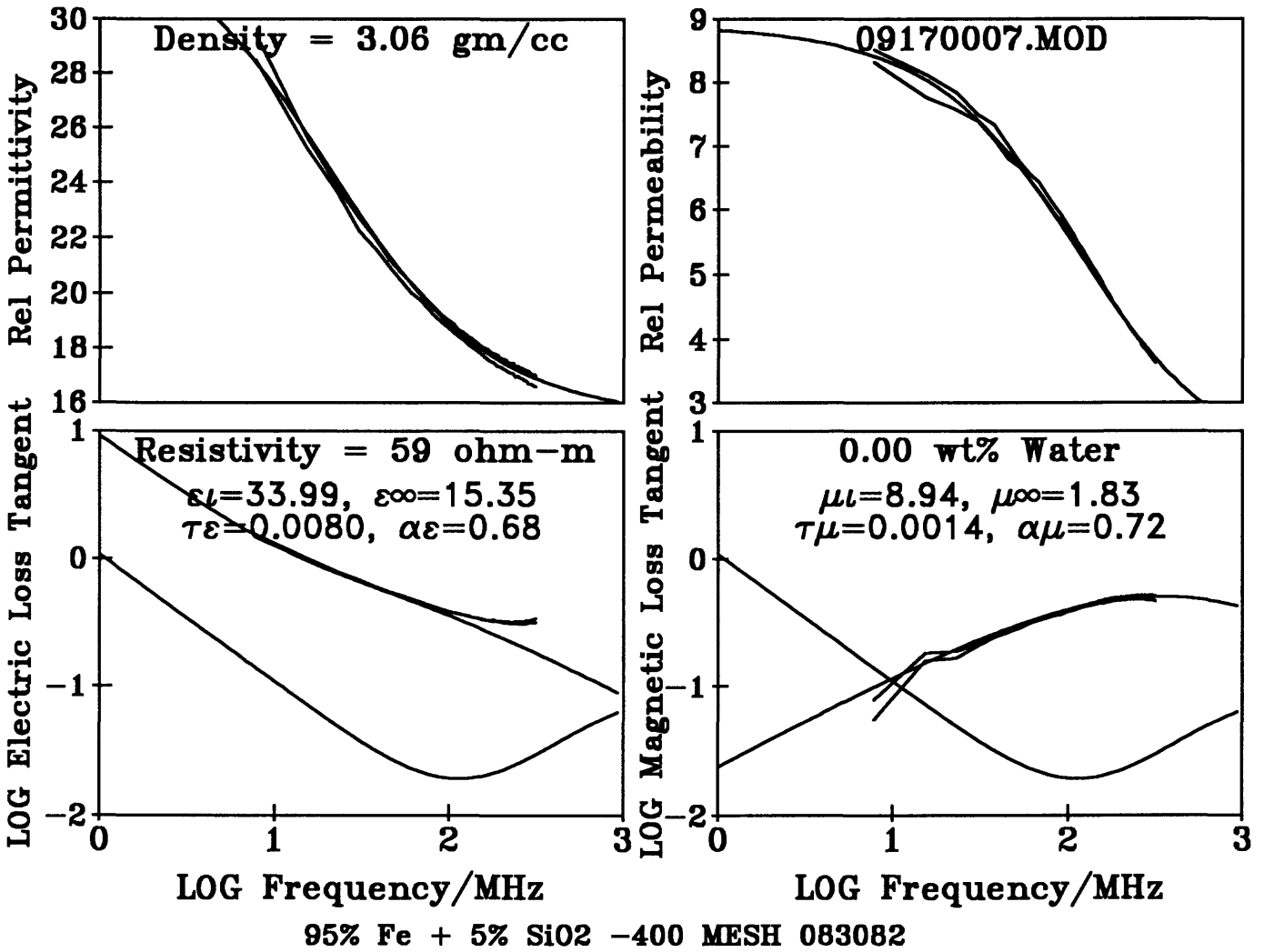



Figure 193 -
Artificial sample composed of a mixture of -400 mesh iron filings in a silica sand matrix.

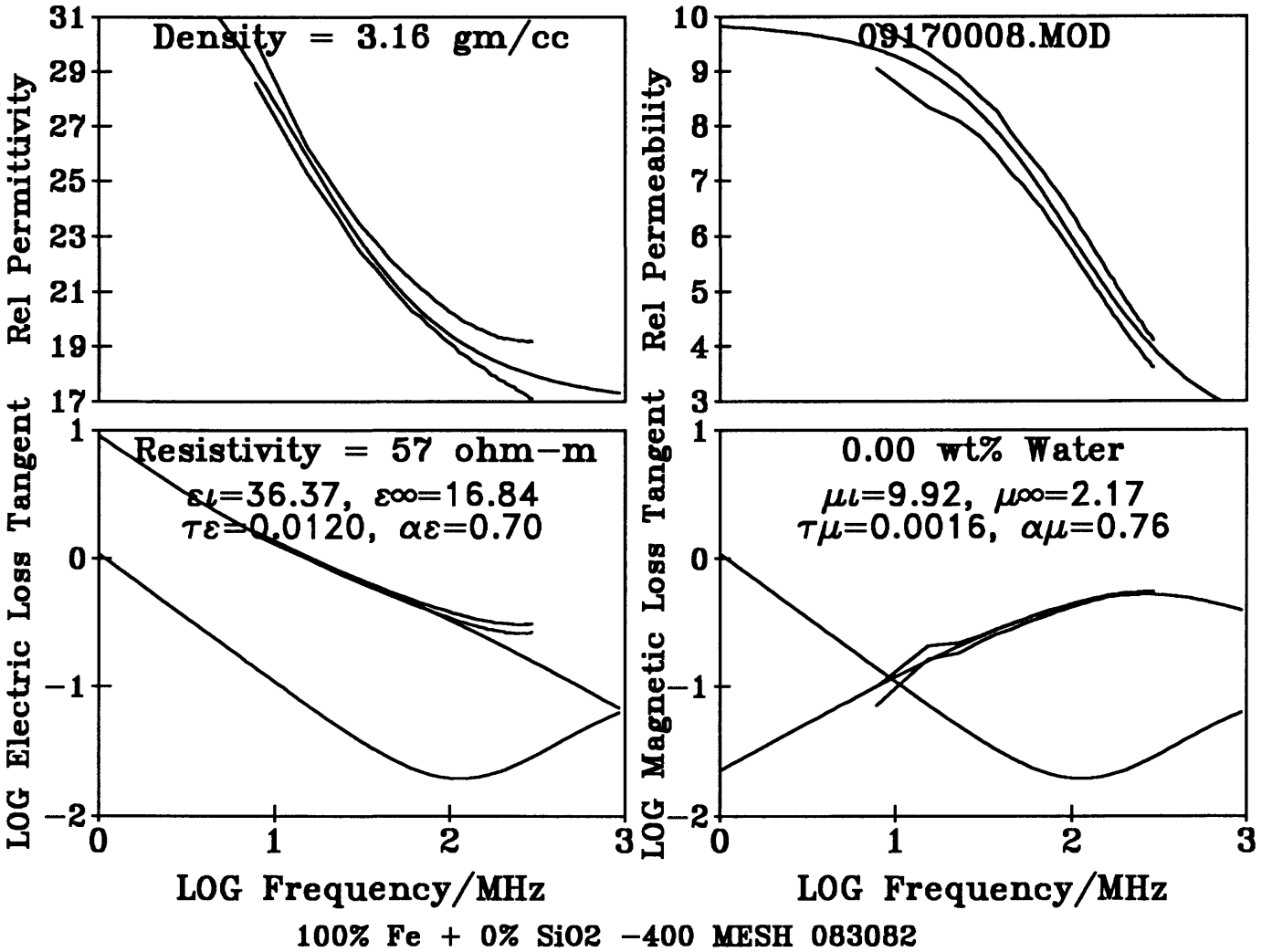



Figure 194 -
Artificial sample composed of a mixture of -400 mesh iron filings in a silica sand matrix.

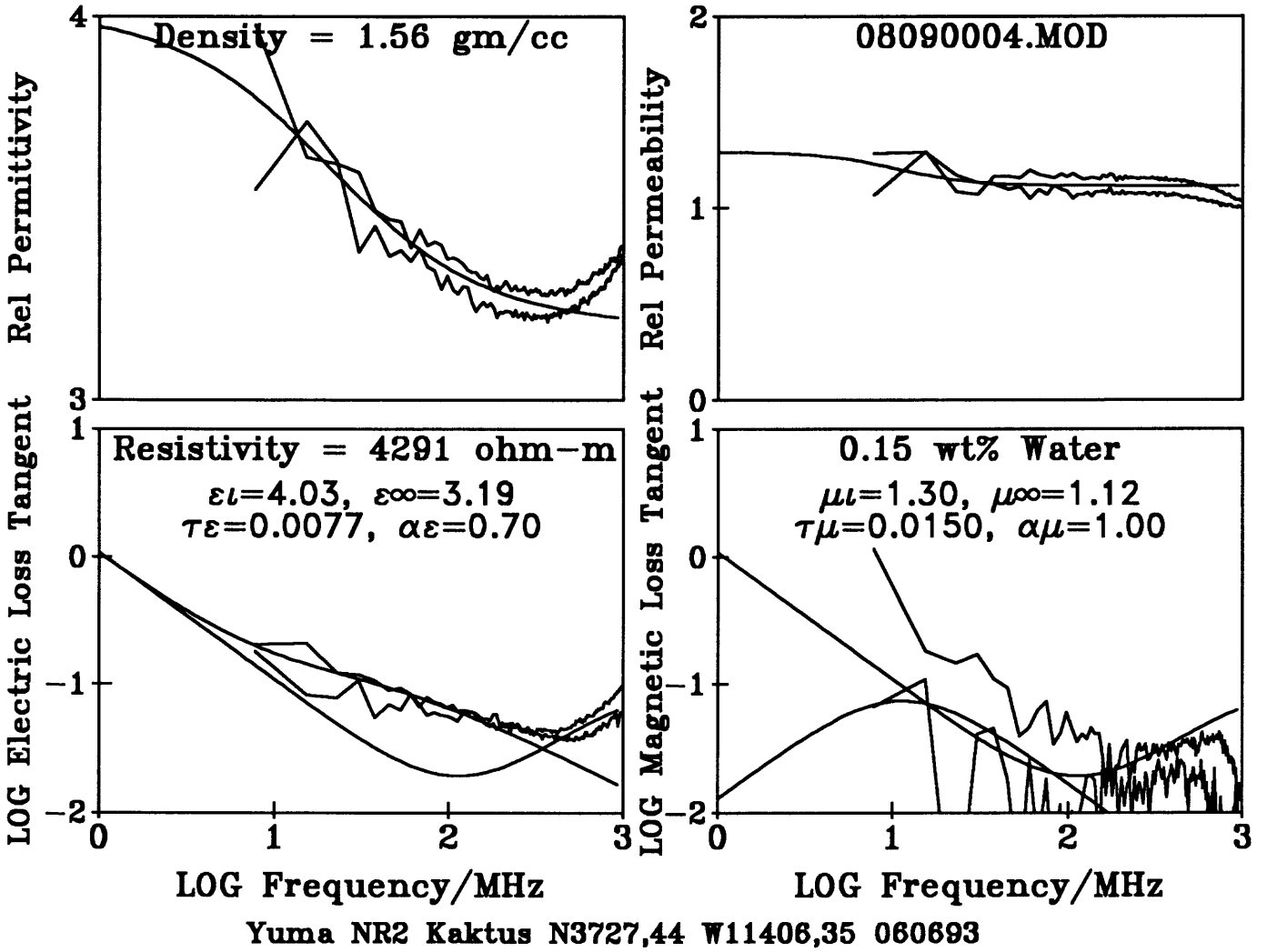



Figure 195 -
Sample provided by Carabas Team in a sealed bottle -- presumed natural water content.

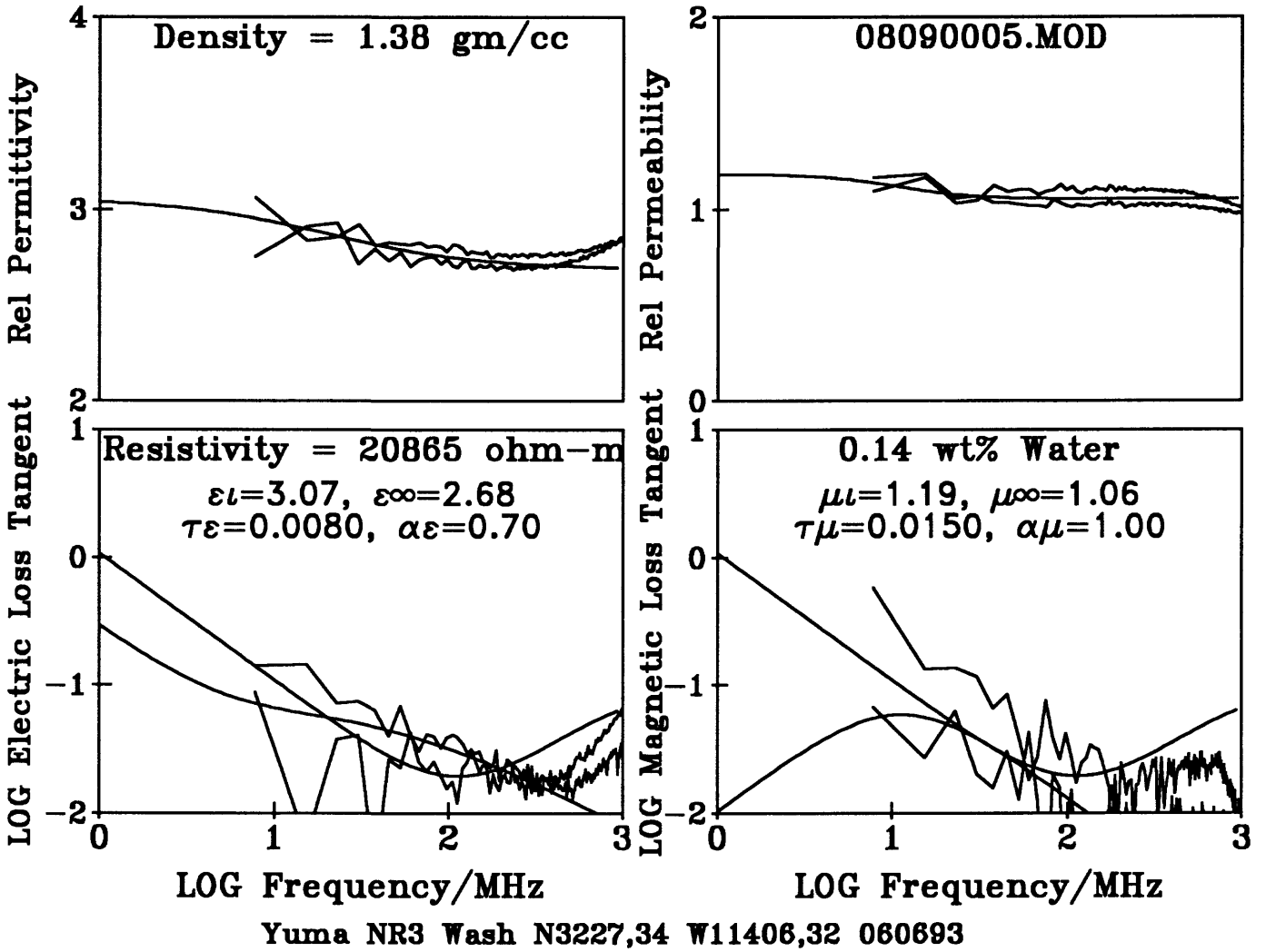



Figure 196 -
Sample provided by Carabas Team in a sealed bottle -- presumed natural water content.

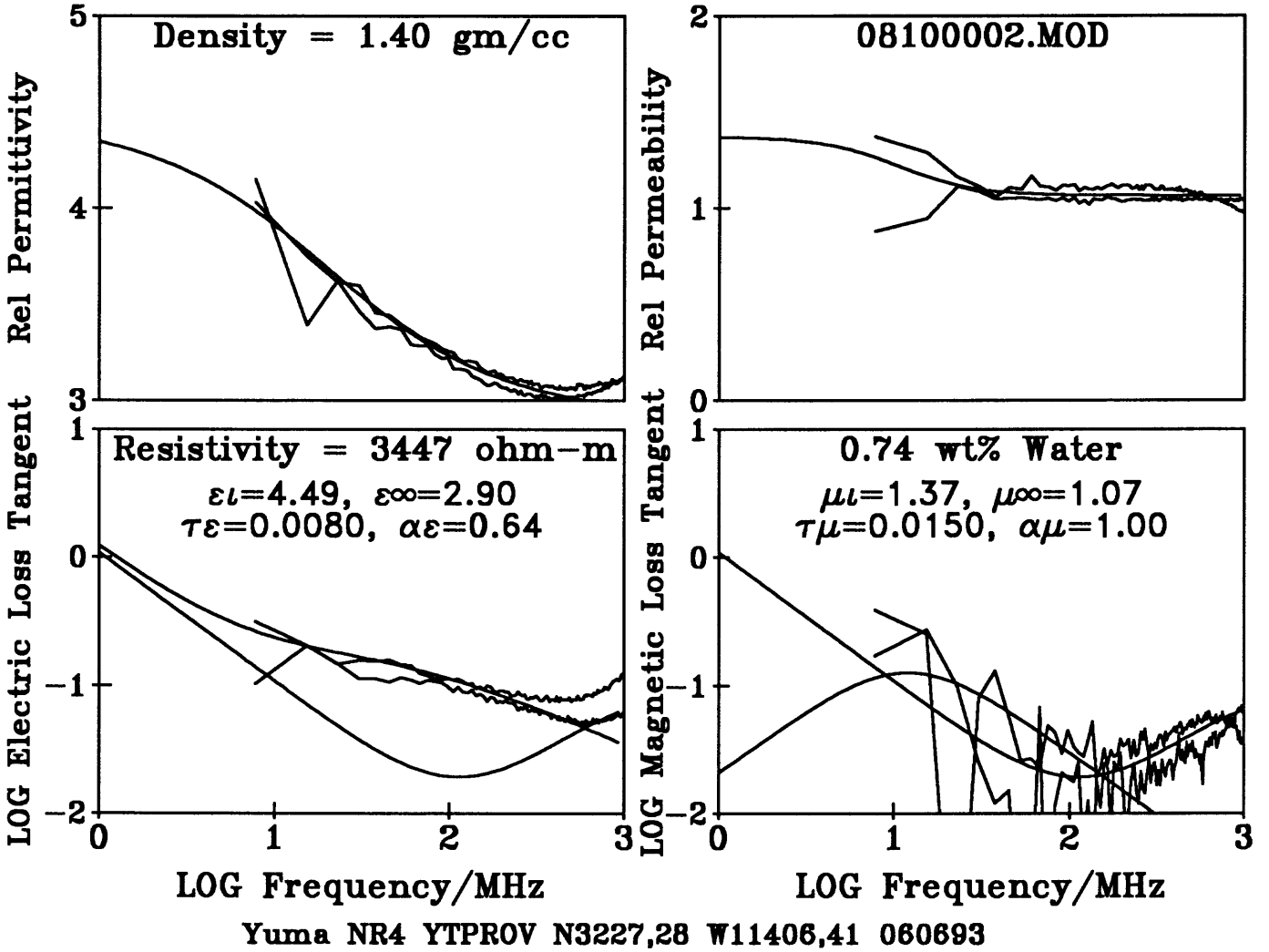



Figure 197 -
Sample provided by Carabas Team in a sealed bottle -- presumed natural water content.

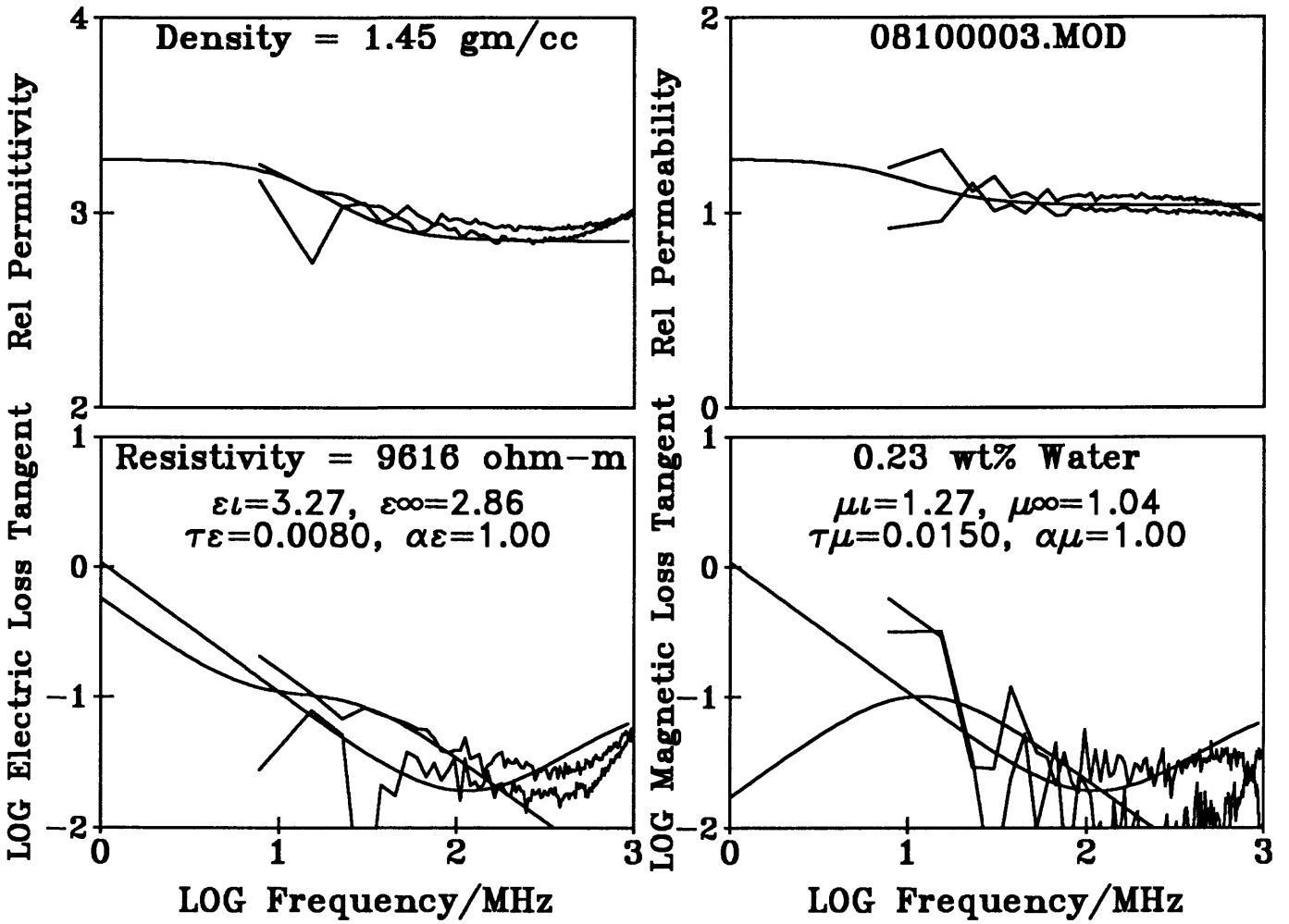



Figure 198 -
Sample provided by Carabas Team in a sealed bottle -- presumed natural water content.

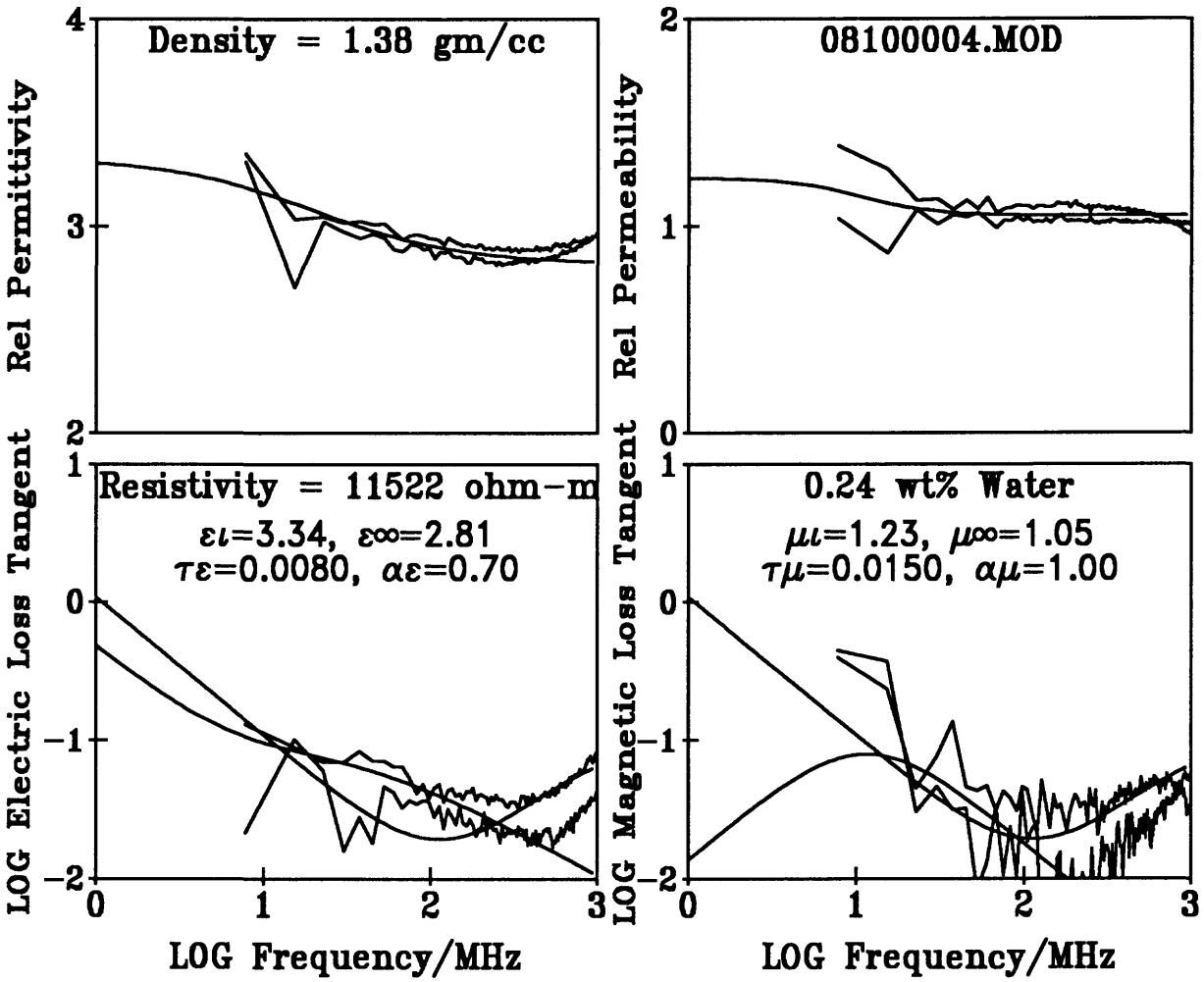



Figure 199 -
Sample provided by Carabas Team in a sealed bottle -- presumed natural water content.

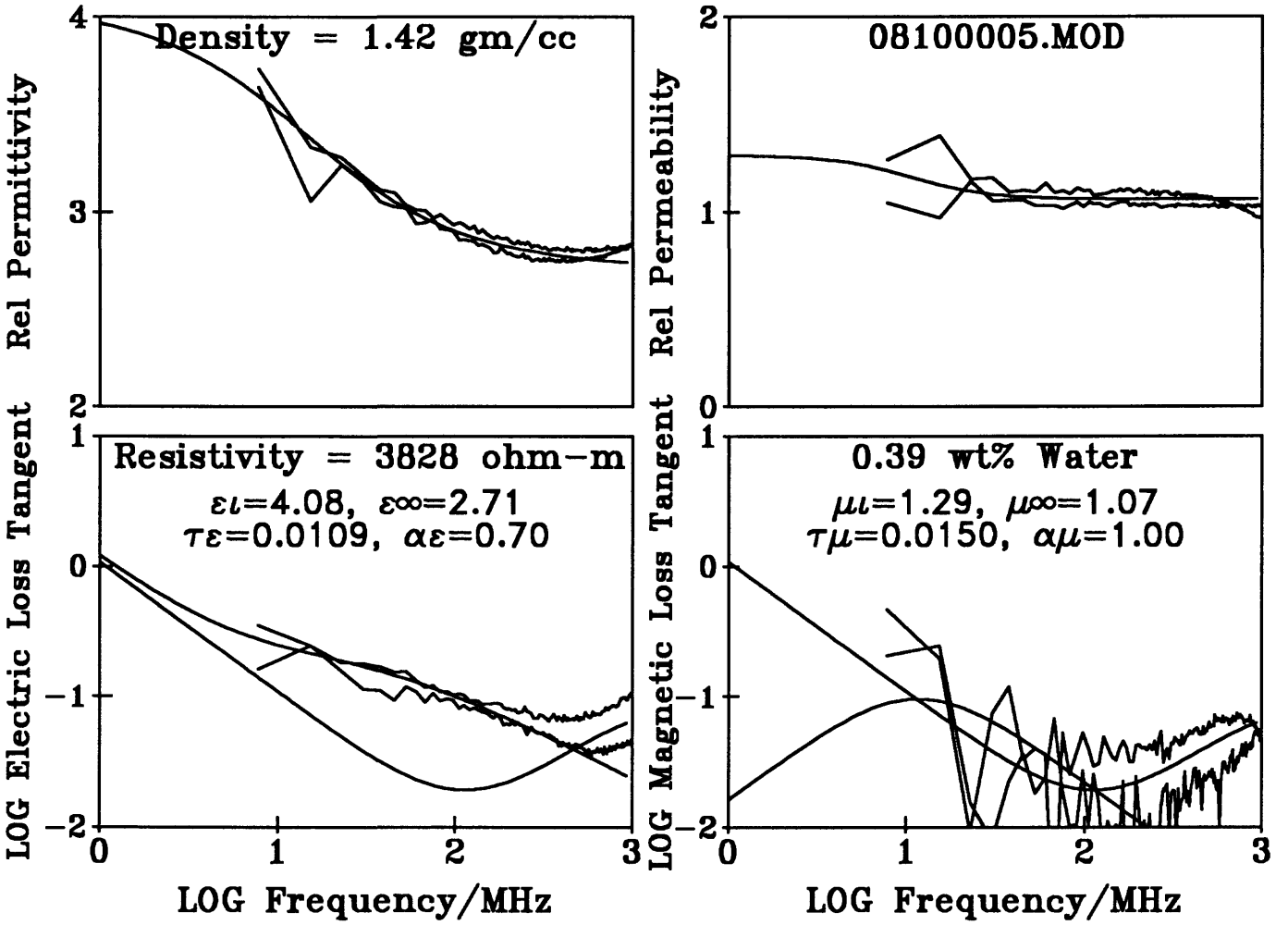



Figure 200 -
Sample provided by Carabas Team in a sealed bottle -- presumed natural water content.

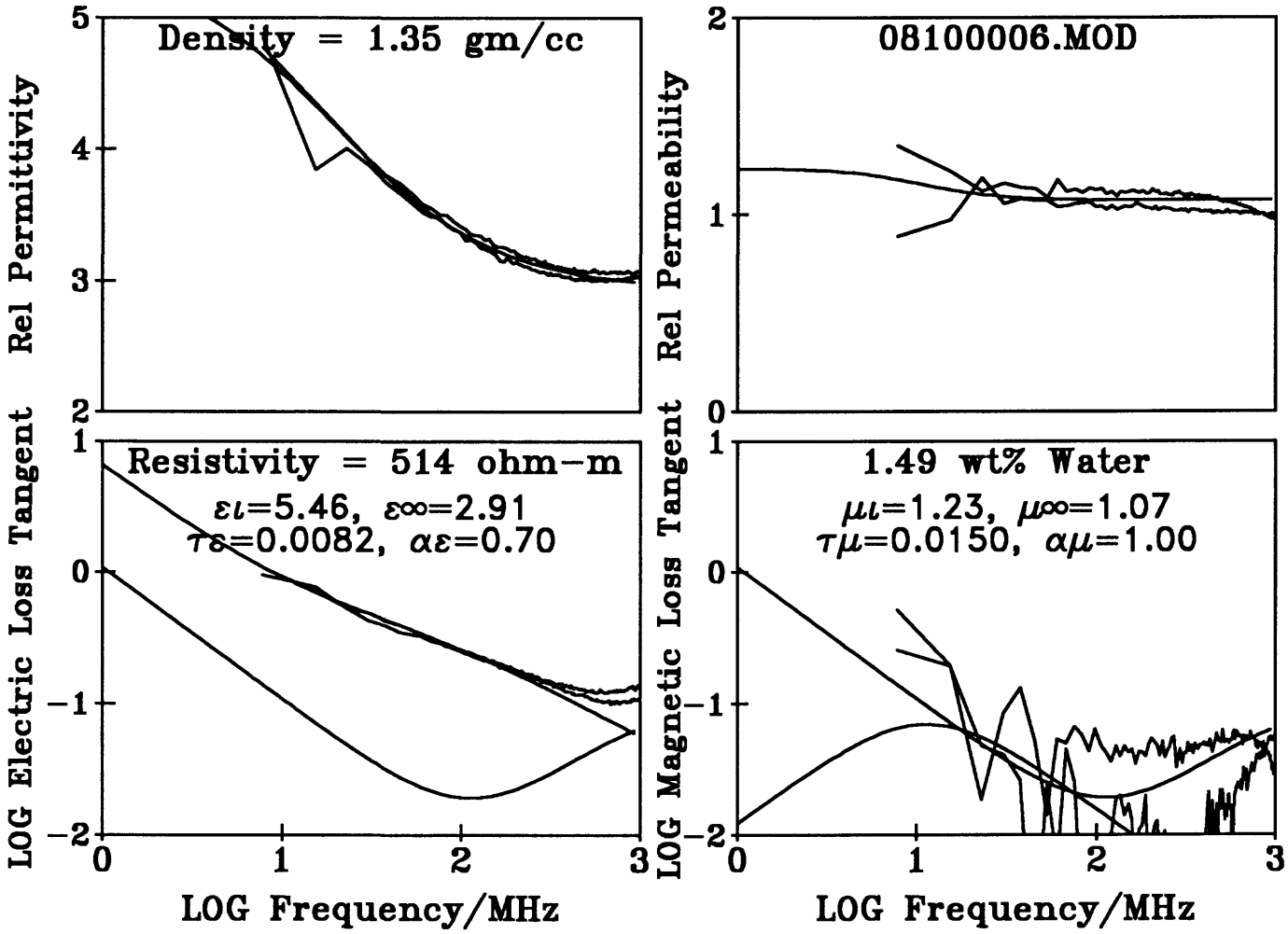



Figure 201 -
Sample provided by Carabas Team in a sealed bottle -- presumed natural water content.

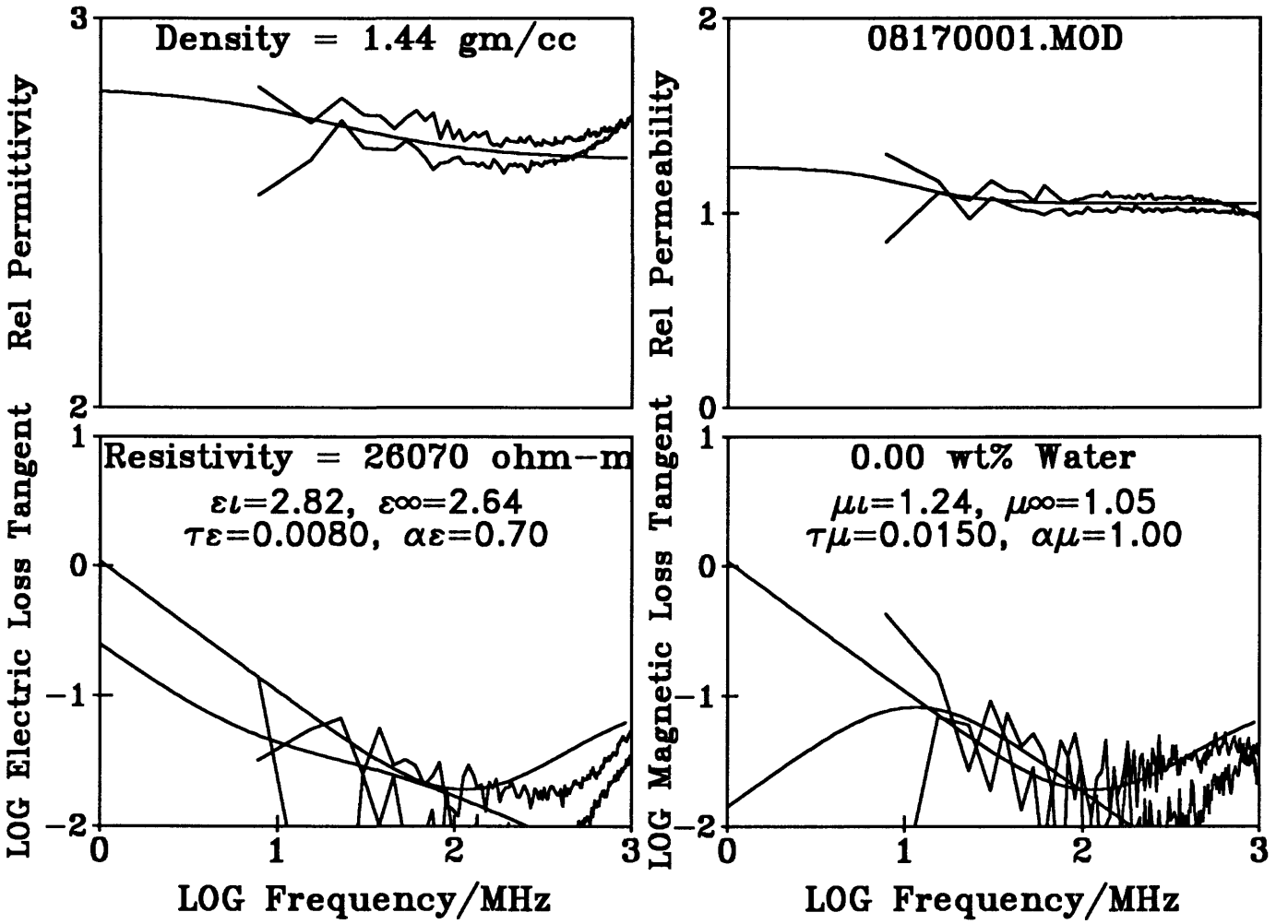

Density = 1.44 gm/cc
08170001.MOD
Resistivity = 26070 ohm-m
ει=2.82, ε∞=2.64
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.24, μ∞=1.05
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent Rel Permittivity
LOG Magnetic Loss Tangent Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma NR8 same as NR7 but deeper (wet sand) 080693 #2 vac.dry

Figure 202 -

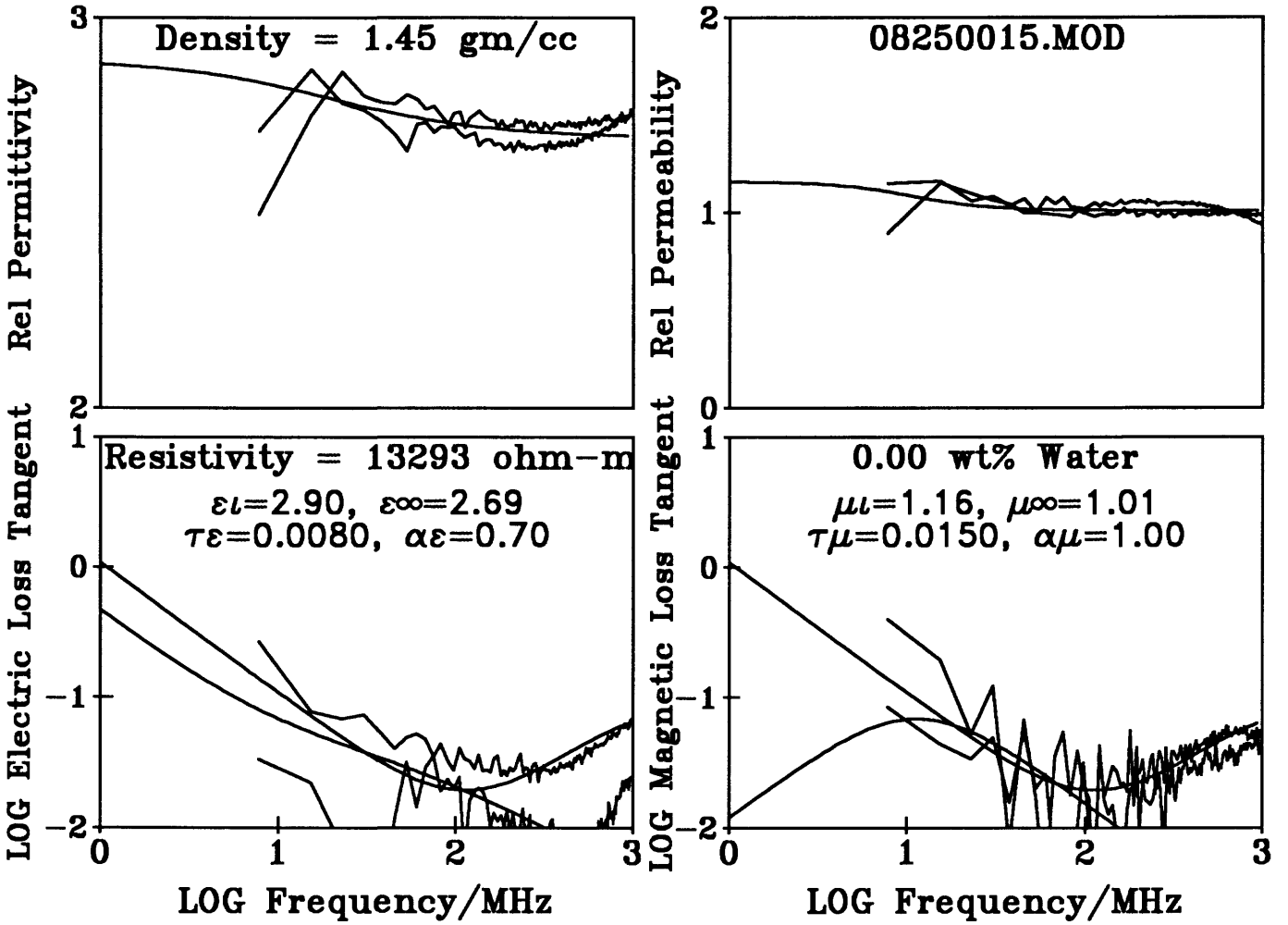

Density = 1.45 gm/cc
08250015.MOD
Resistivity = 13293 ohm-m
ει=2.90, ε∞=2.69
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.16, μ∞=1.01
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent Rel Permittivity
LOG Magnetic Loss Tangent Rel Permeability
LOG Frequency/MHz
LOG Frequency/MHz
Yuma NR8 same as NR7 but deeper (wet sand) 080693 #3 vac. dry

Figure 203 -

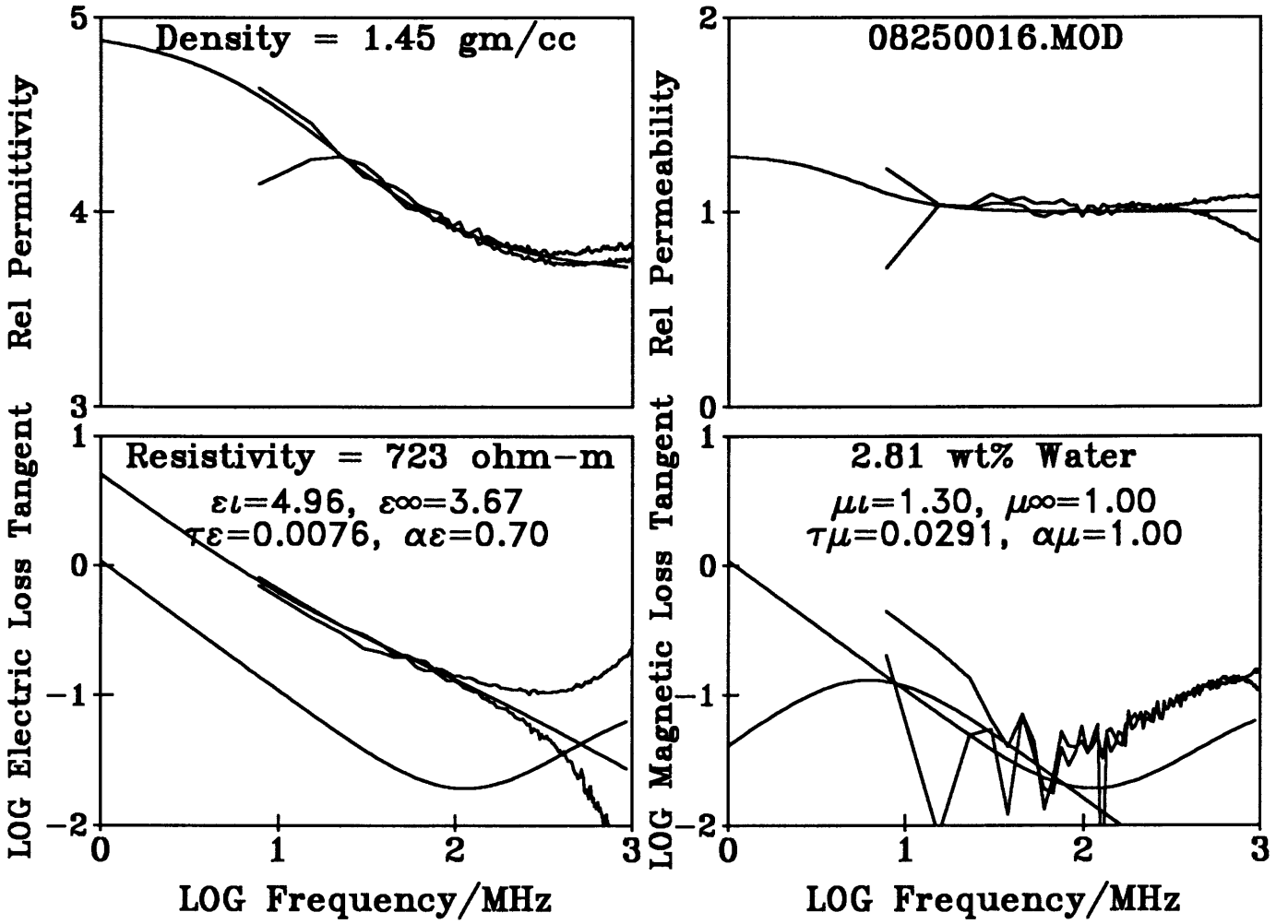

Density = 1.45 gm/cc
08250016.MOD
Resistivity = 723 ohm-m
ει=4.96, ε∞=3.67
τε=0.0076, αε=0.70
2.81 wt% Water
μι=1.30, μ∞=1.00
τμ=0.0291, αμ=1.00
Rel Permittivity
Rel Permeability
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma NR8 same as NR7 but deeper (wet sand) 080693 #3 4-drops water

Figure 204 -

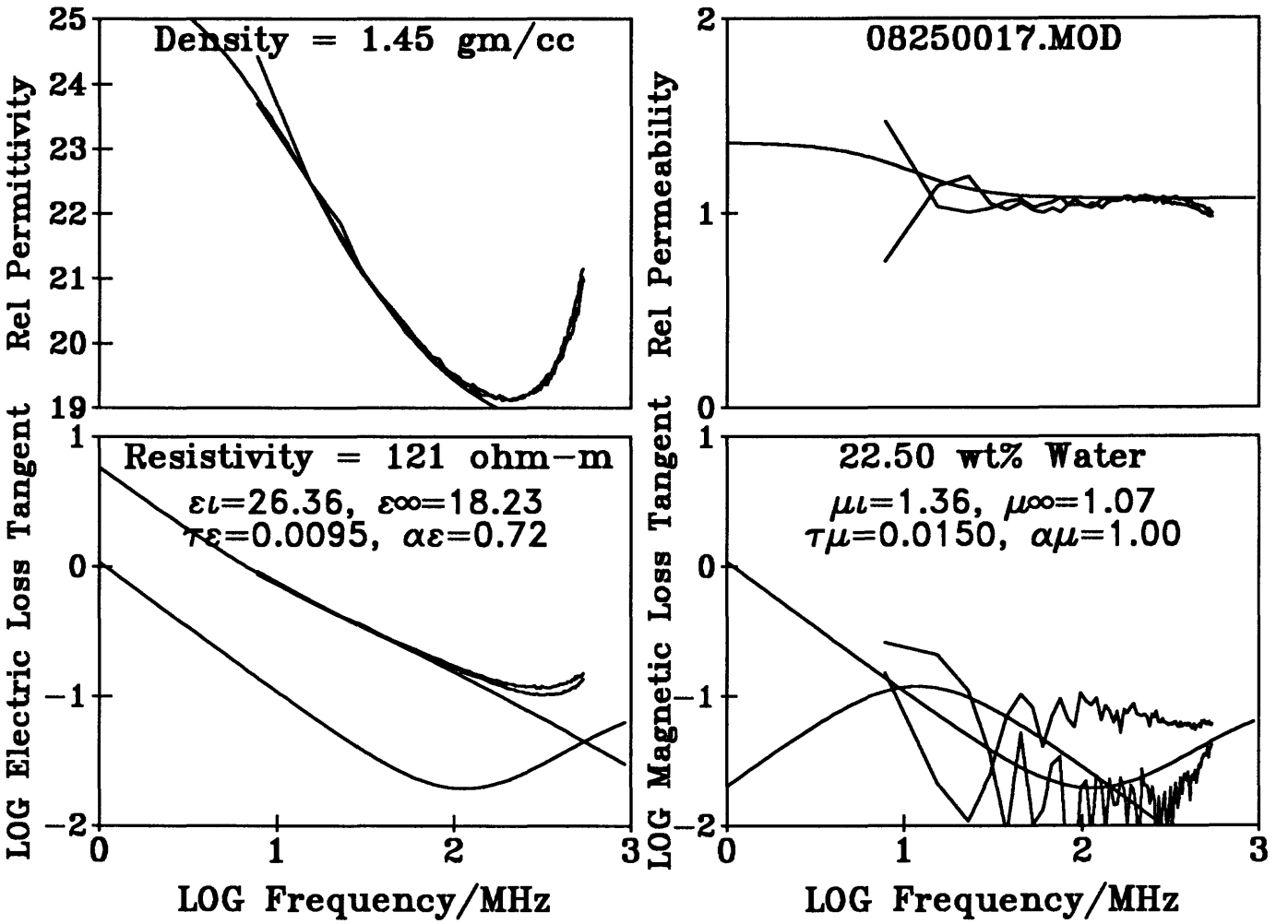

Density = 1.45 gm/cc
08250017.MOD
Rel Permittivity
Rel Permeability
Resistivity = 121 ohm-m
ει=26.36, ε∞=18.23
τε=0.0095, αε=0.72
22.50 wt% Water
μι=1.36, μ∞=1.07
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma NR8 same as NR7 but deeper (wet sand) 080693 #3 water saturated

Figure 205 -

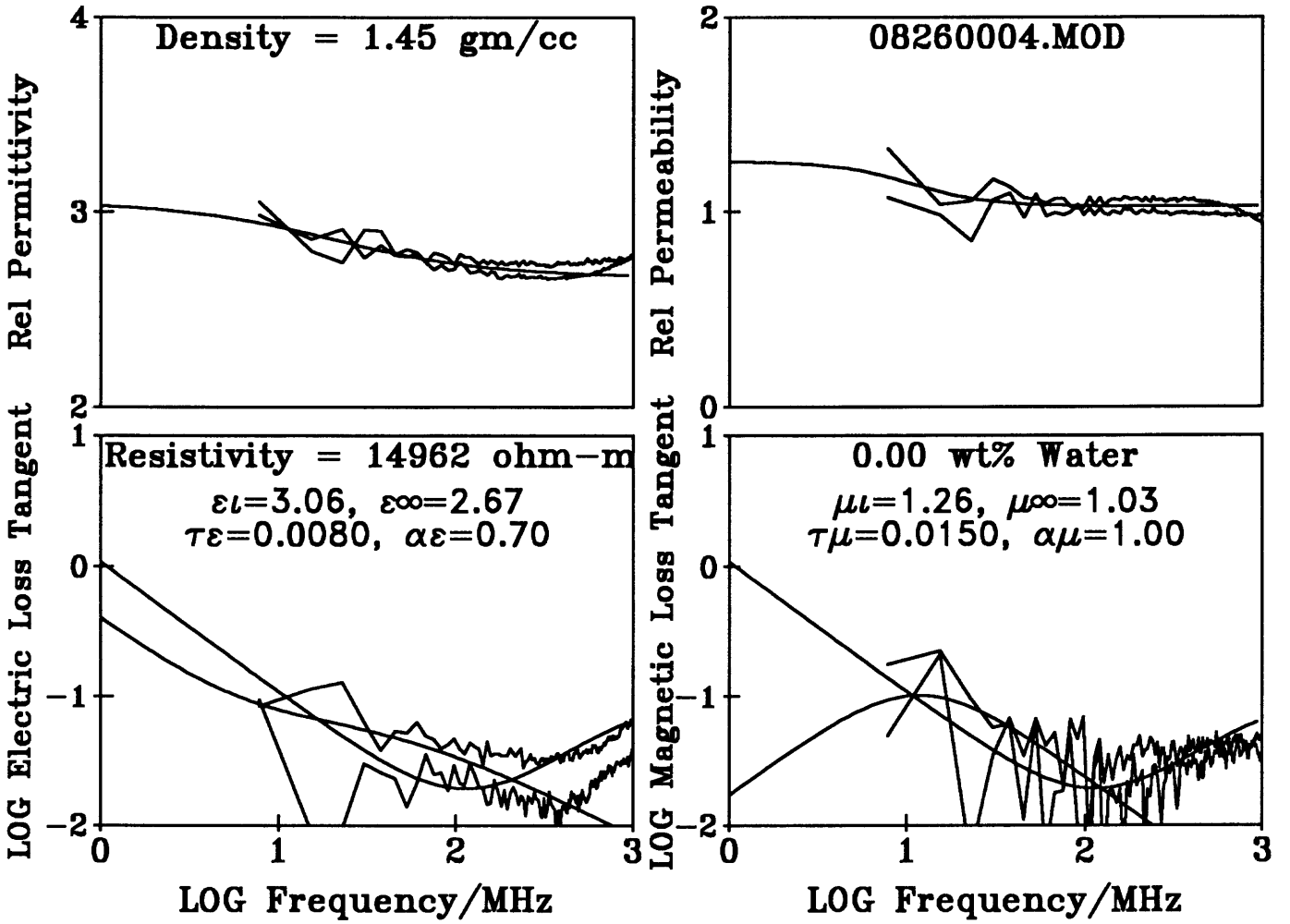

Density = 1.45 gm/cc
08260004.MOD
Rel Permittivity
Rel Permeability
Resistivity = 14962 ohm-m
ει=3.06, ε∞=2.67
τε=0.0080, αε=0.70
0.00 wt% Water
μι=1.26, μ∞=1.03
τμ=0.0150, αμ=1.00
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma NR8 same as NR7 but deeper (wet sand) 080693 #4 vac.dry

Figure 206 -

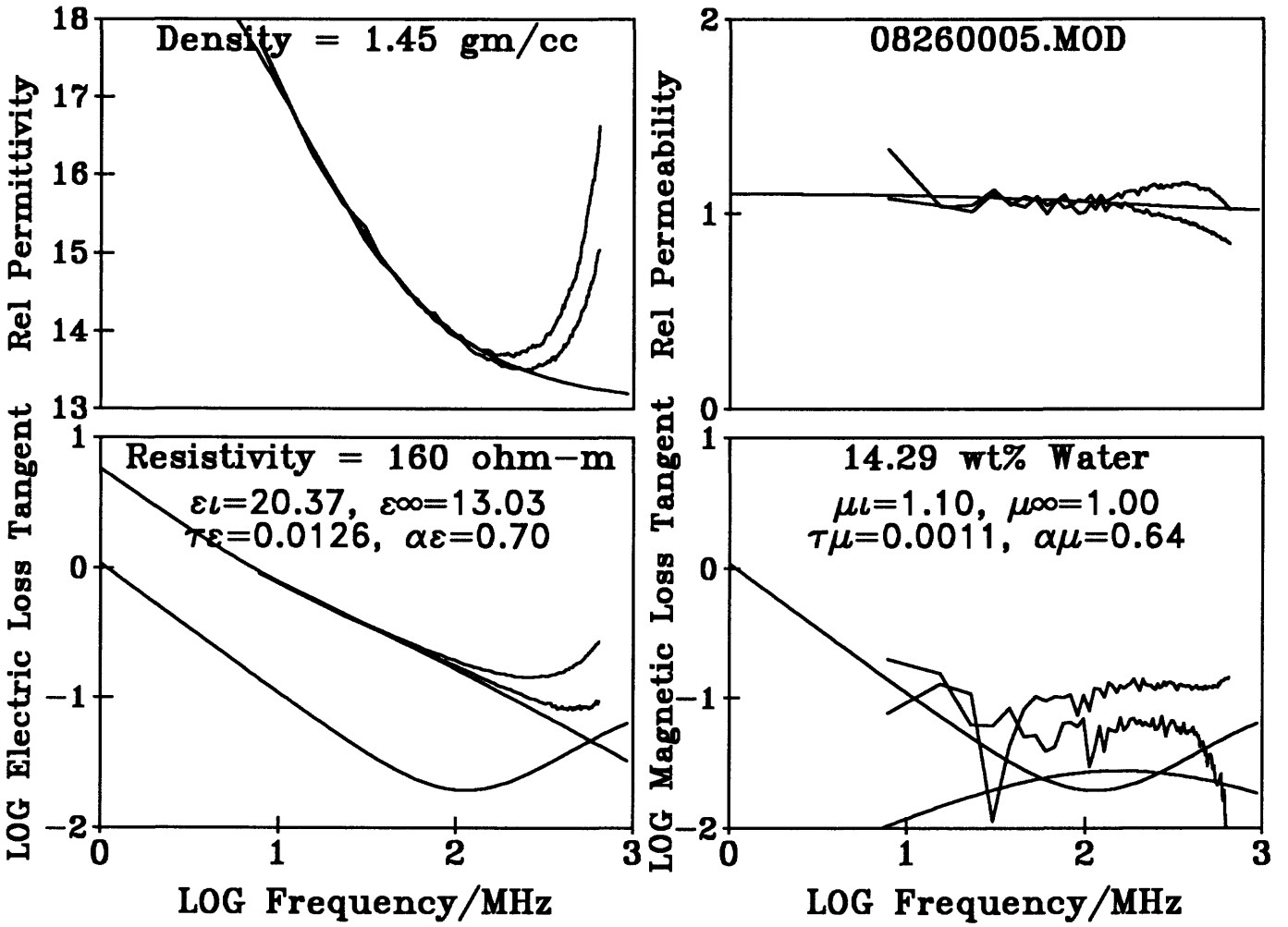

Density = 1.45 gm/cc
08260005.MOD
Rel Permittivity
Rel Permeability
Resistivity = 160 ohm-m
ει=20.37, ε∞=13.03
τε=0.0126, αε=0.70
14.29 wt% Water
μι=1.10, μ∞=1.00
τμ=0.0011, αμ=0.64
LOG Electric Loss Tangent
LOG Magnetic Loss Tangent
LOG Frequency/MHz
LOG Frequency/MHz
Yuma NR8 same as NR7 but deeper (wet sand) 080693 #4 4-drops water

Figure 207 -

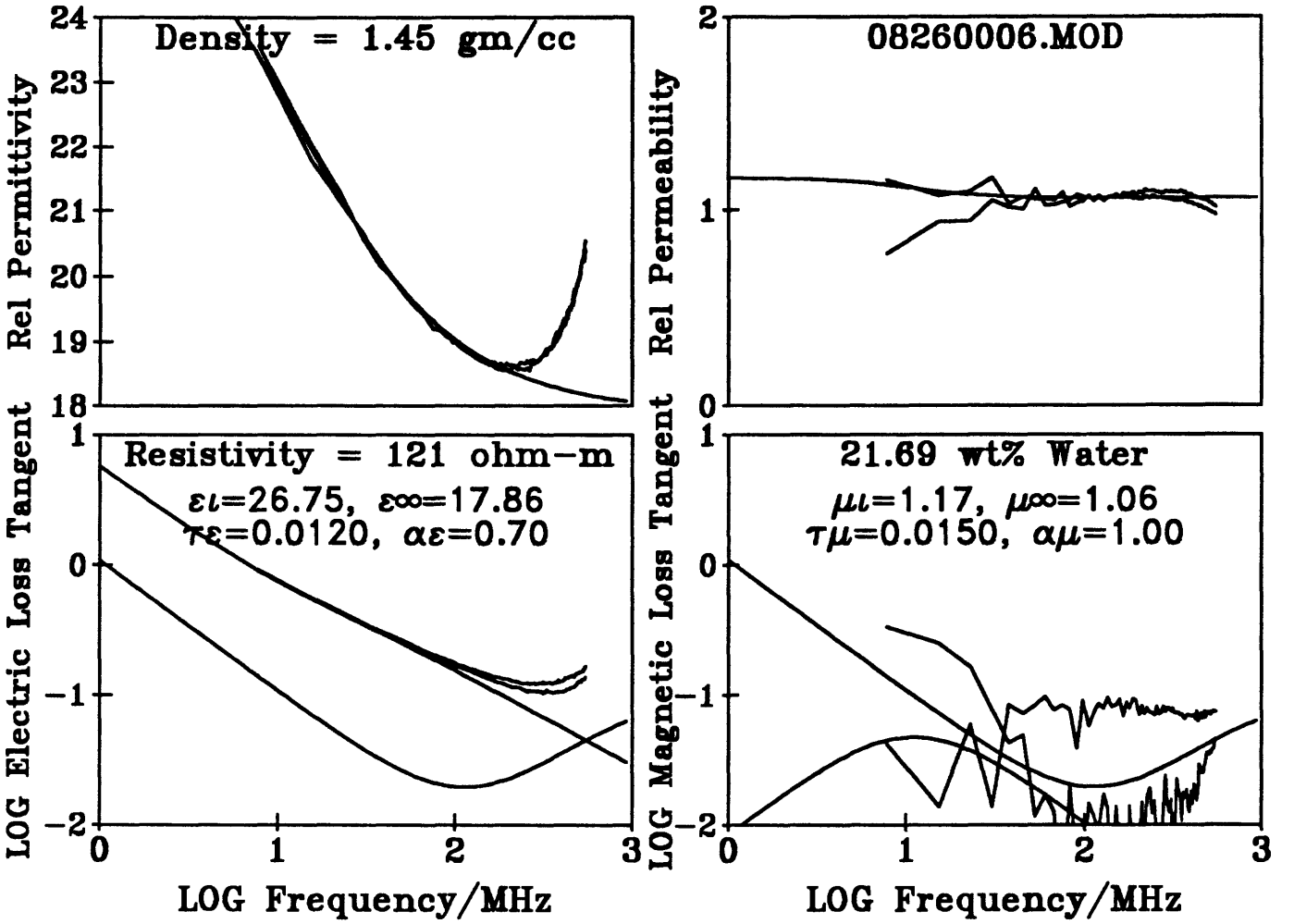

Density = 1.45 gm/cc
Rel Permittivity
24
23
22
21
20
19
18
08260006.MOD
Rel Permeability
2
1
0
Resistivity = 121 ohm-m
ει=26.75, ε∞=17.86
τε=0.0120, αε=0.70
LOG Electric Loss Tangent
1
0
−1
−2
21.69 wt% Water
μι=1.17, μ∞=1.06
τμ=0.0150, αμ=1.00
LOG Magnetic Loss Tangent
0
1
2
3
LOG Frequency/MHz
LOG Frequency/MHz
Yuma NR8 same as NR7 but deeper (wet sand) 080693 #4 water saturated

Figure 208 -