Dielectric Constant Evaluation of Rough Surfaced Materials

HP Product Note 4291A-5

HP 4291A
RF Impedance/Material Analyzer

Introduction

Among the various methods available for dielectric constant evaluations, the parallel plate method is widely used because of its ability to make accurate measurements using a simple setup. The system described here consists of the HP 4291A RF Impedance/Material Analyzer and the HP 16453A Dielectric Constant Fixture. This system uses the parallel plate method to provide easy measurements of the dielectric constant of the material under test (MUT). The HP 4291A (Option 002) has a built-in function that reflects the electrode characteristics of the HP 16453A. This option is used to calculate and display all the dielectric constant parameters, such as complex dielectric constant ($\varepsilon r' - \varepsilon r''$) and loss tangent ($\varepsilon r' - \tan \delta$).

However, due to a theoretical constraint of the parallel method, the system may cause a measurement error if the MUT surface is not smooth enough. This solution note describes a technique to measure a MUT with rough surfaces more accurately using the HP 4291A and the HP 16453A.

The Parallel Plate Method

The parallel plate method derives the dielectric constant of the MUT by measuring the capacitance between the two parallel plates (electrodes) between which the MUT is sandwiched (Figure 1). The dielectric constant is determined by the area of the plates, A [m^2], the distance between the plates (that is the thickness of the MUT), t , and the capacitance, Cp [F], as shown in Figure 1. (Note, the fringe capacitance of the plates should also be considered in practical applications.)

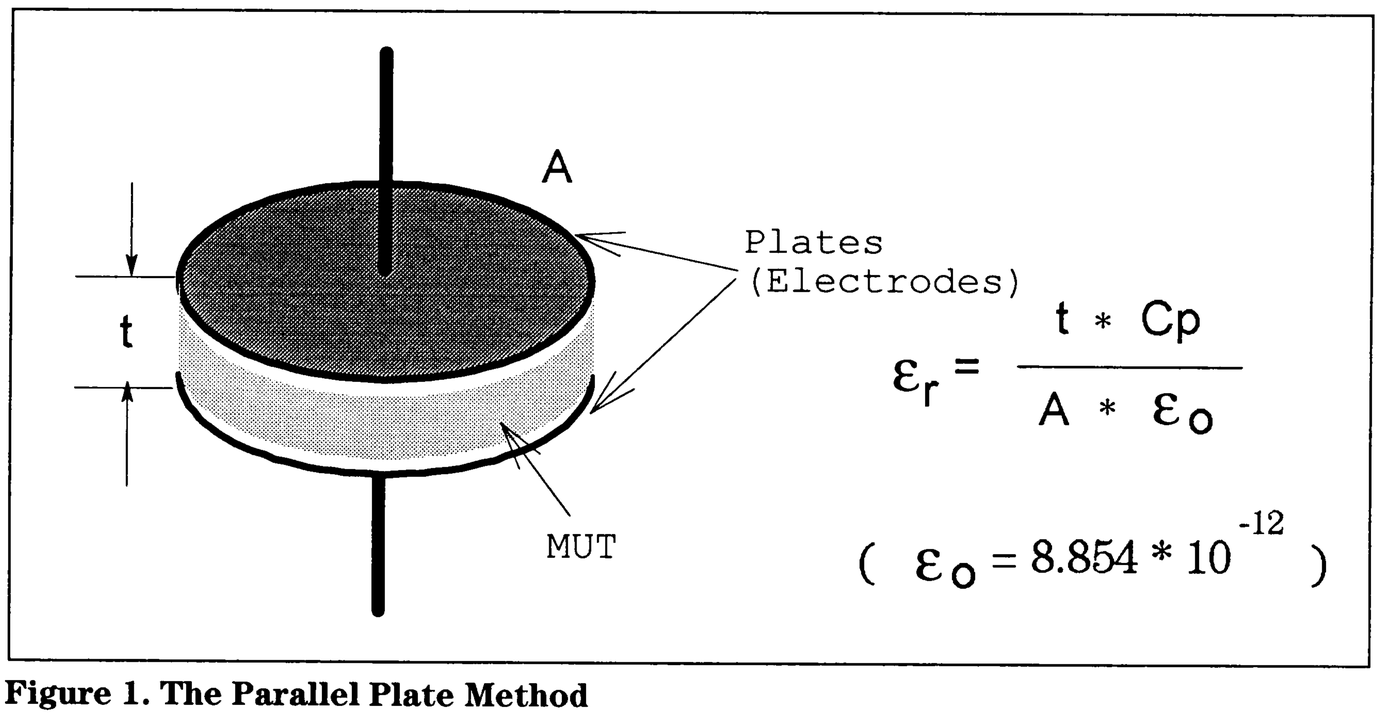

Figure 1. The Parallel Plate Method

HP 16453A

The HP 16453A Dielectric Material Fixture performs the dielectric constant evaluation at 1 MHz to 1.8 GHz using the parallel plate method. The HP 16453A has a pair of electrodes (upper and lower) that are used as plates in this method. The upper electrode has a spring inside it that holds the MUT at an appropriate pressure to help provide stable and repeatable measurements.

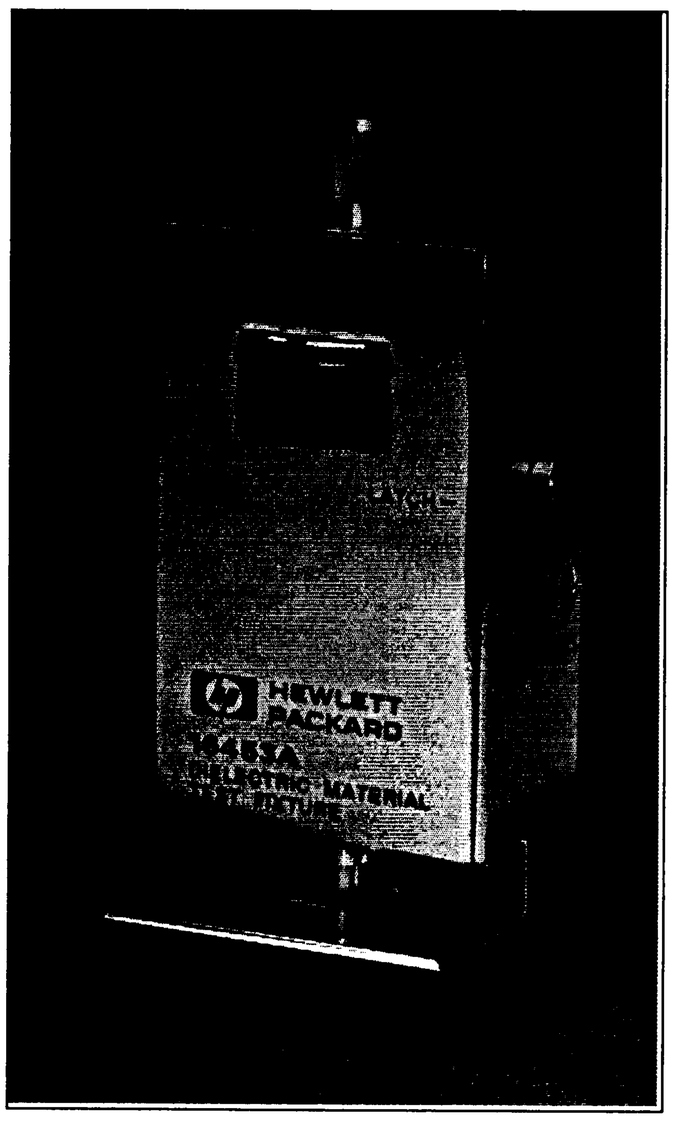

Figure 2. HP 16453A

As shown above, the HP 16453A allows easy measurements of dielectric constants. However, the system does not work well if the MUT surfaces are not smooth. This is because a rough surfaced MUT tends to have a micro-air-gap between the MUT and the electrodes. This air gap causes a decrease in capacitance, resulting in a shifted measurement of the dielectric constant (Figure 3). For example, when t = 1.0 [μm], $\varepsilon r' = 4.0$, and the surface roughness Ra = 12 [μm], the measured dielectric constant (real part) will shift as much as 10%.

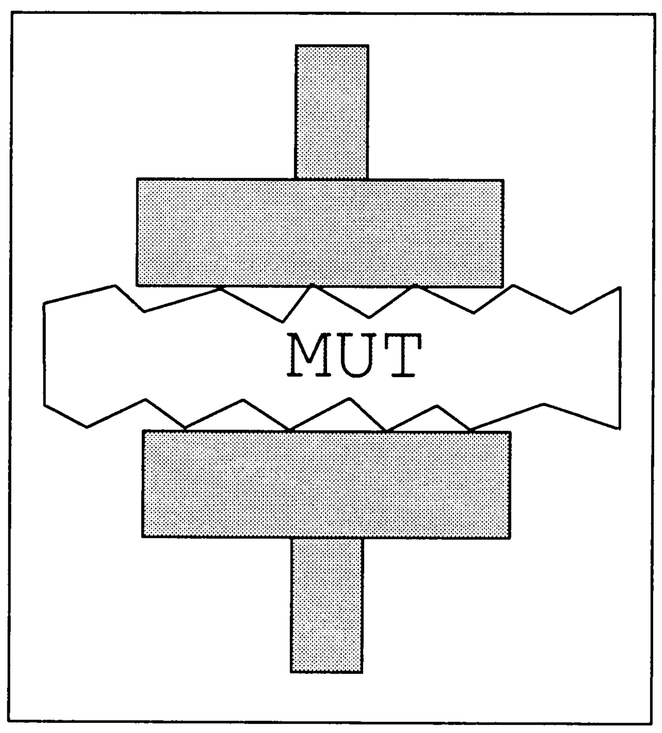

Figure 3. Error Caused by Air Gap

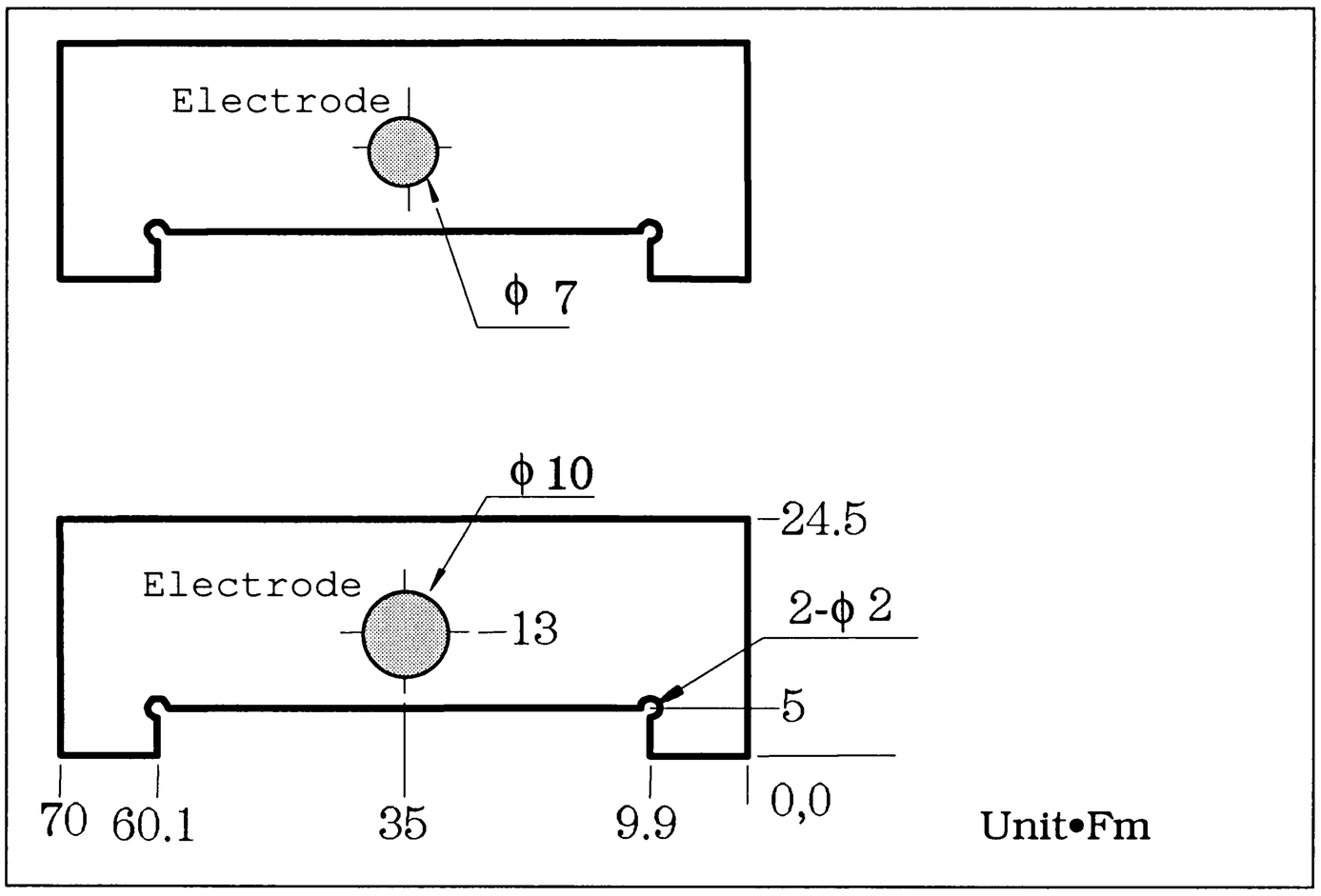

Figure 4. MUT Electrodes Shape and Position

Solution

For more accurate evaluation of the MUT, the air gap between the MUT and the electrodes must be reduced as much as possible. For this purpose, lapping the surfaces of the MUT can be very effective. However, it is not always practical to this much preparation work on the MUT. Another technique is to make electrodes on the MUT surfaces. These electrodes will reduce the air gap significantly, and will provide more accurate measurements.

As shown in the Figure 4, the electrodes should be formed on both surfaces of the MUT so that each electrode matches the corresponding electrode on the HP 16453A in terms of position and shape. (The figure also shows a recommended shape for the MUT that makes positioning the MUT easier). Because of the matched size and position of the electrodes, the measurement results on the HP 4291A (Option 002) can be used without any calculation or conversion.

Summary

By making electrodes for the MUT, a rough surfaced MUT can be evaluated by the HP 4291A and HP 16453A without degrading the ease of use of the system.

Measurement Example

Figure 5 shows the measurement results of a rough surfaced material. A complex dielectric constant was measured on the MUT without electrodes (left) and with electrodes (right) at 1 MHz to 1.8 GHz. At 100 MHz, there is a 6% improvement (from 4.46 to 4.73) in εr' (real part) on the MUT with electrodes. This technique provides comparable results to a smooth surfaced MUT with the same material.

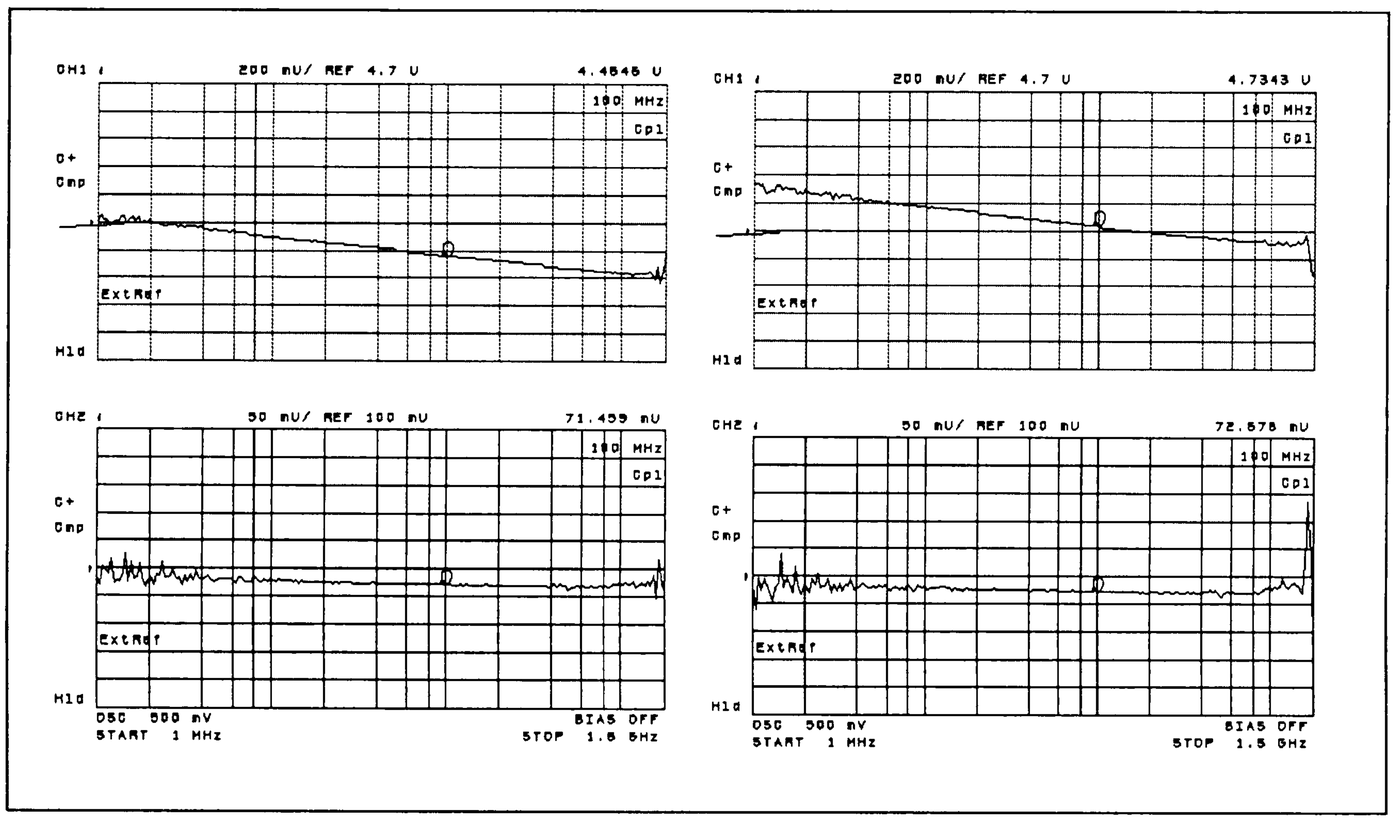

Figure 5. Measurement Example

HEWLETT® PACKARD

For more information on Hewlett-Packard Test and Measurement products, applications, or services please call your local Hewlett-Packard sales office. A current listing is available via the Web through AccessHP at http://www.hp.com. If you do not have access to the internet, please contact one of the HP centers listed below and they will direct you to your nearest HP representative.

United States:
Hewlett-Packard Company
Test and Measurement Organization
5301 Stevens Creek Blvd.
Bldg. 51L-SC
Santa Clara, CA 95052-8059
1 800 452 4844

Canada:
Hewlett-Packard Canada Ltd.
5150 Spectrum Way
Mississauga, Ontario
L4W 5G1
(905) 206 4725

Europe:
Hewlett-Packard
European Marketing Centre
P.O. Box 999
1180 AZ Amstelveen
The Netherlands

Japan:
Hewlett-Packard Japan Ltd.
Measurement Assistance Center
9-1, Takakura-cho, Hachioji-shi,
Tokyo 192, Japan
Tel: (81) 426 56 7832
Fax: (81) 426 56 7840

Latin America:
Hewlett-Packard
Latin American Region Headquarters
5200 Blue Lagoon Drive
9th Floor
Miami, Florida 33126
U.S.A.
(305) 267 4245/4220

Australia/New Zealand:
Hewlett-Packard Australia Ltd.
31-41 Joseph Street
Blackburn, Victoria 3130
Australia
1 800 629 485

Asia Pacific:
Hewlett-Packard Asia Pacific Ltd
17-21/F Shell Tower, Times Square,
1 Matheson Street, Causeway Bay,
Hong Kong
Fax: (852) 2506 9285

Data subject to change
Printed in U.S.A. 9/96
5965-5055E