Lab2 Measurement of dielectric constants and conductivity of liquid

Name _____ Student ID _____

TA _____ Score _____

Objectives

1. To understand the meaning of dielectric constant and conductivity.
2. To understand the characteristics of measuring permittivity and conductivity with coaxial probe method and the requirements for materials

features of coaxial probe method	Material assumptions
Broadband frequency	semi-infinite thickness
Simple and convenient (non-destructive)	non-magnetic
High accuracy for high loss materials	isotropic and homogeneous
Best for semi-solids or liquids	flat surface， No air gaps

3. To master the principle and method of coaxial probe method for measuring broadband dielectric constant and conductivity of different liquids. As shown in Figure 1, The open-ended coaxial probe is a cut off section of transmission line. The material is measured by immersing the probe into a liquid or touching it to the flat face of a solid (or powder) material. The fields at the probe end "fringe" into the material and change as they come into contact with the material under test. The reflected signal (S11) can be measured and related to ε_r.

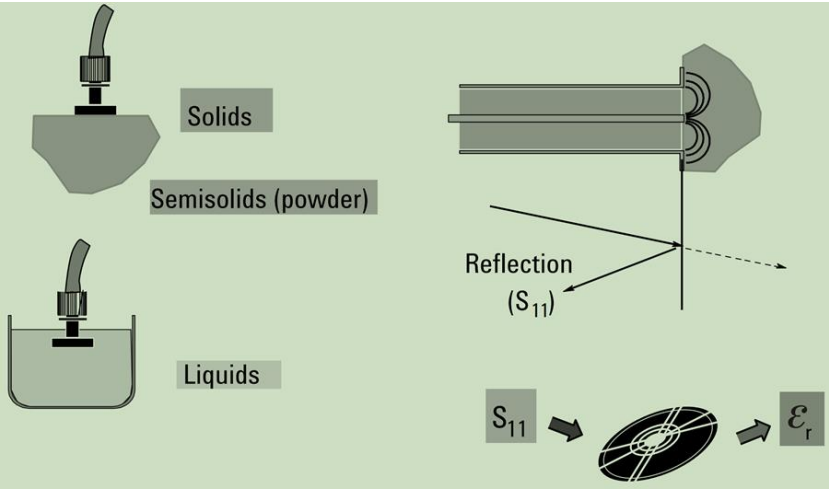

Figure 1. Coaxial probe method

4. Measure the broadband dielectric constant and conductivity of different liquids, and master the relationship between the dielectric constant and conductivity of different liquids and the change of frequency
    1) Deionized water;
    2) Different concentrations of saline (10 PPT is recommended);
    3) Alcohol;
    4) Oil;
    5) 42% alcohol and 53% alcohol;
    6) Milk, but you should be noticed that it is not transparent so you cannot see if there is a bubble at the end of the probe;
    7) Beverage, but you should noticed that some sodas have lots of bubbles;
    8) You can bring other enough liquid to measure, but corrosive liquid is forbidden!
5. To understand the measurement error sources of dielectric constant and conductivity.

Test and Measurement Equipment

1. FieldFox Handheld Microwave Analyzer
2. One PC (with relevant driver and graphic software installed);
3. One network cable;
4. One coaxial cable (3.5mm male at both ends);
5. N1501A Dielectric Probe Kit and a set of calibration parts;
6. Two adapters: one is used to connect the coaxial cable to one port of the handheld meter, and the other is used to connect the probe to the coaxial line;
7. A pair of bendable pliers;
8. One iron frame platform;
9. Liquid materials to be measured,

Procedure

1. Turn on the FieldFox Handheld Microwave Analyzer and preheat it for 20 minutes.
2. As shown in Figure 2, install and fix the high-precision probe on the iron stand, and then connect the high-precision probe with the output port of the FieldFox Handheld Microwave Analyzer

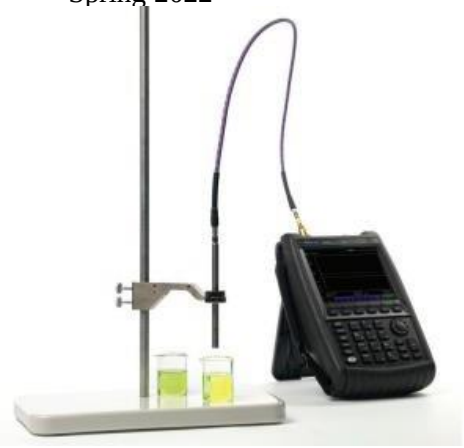

Figure 2. FieldFox Handheld Microwave Analyzer and dielectric probe method

3. Connect the PC and the FieldFox Handheld Microwave Analyzer with a network cable.

(1) At the PC side:

1) Open the "Network and Sharing Center"->Click "Change adapter configuration", as shown in Figure 3

Figure 3. Changing Adapter Configuration

2) Click "Local Connection"->"properties"->" Internet Protocol Version 4";

3) As shown in Figure 4, the automatic acquisition IP address is changed to a manual configuration and parameter settings are made.

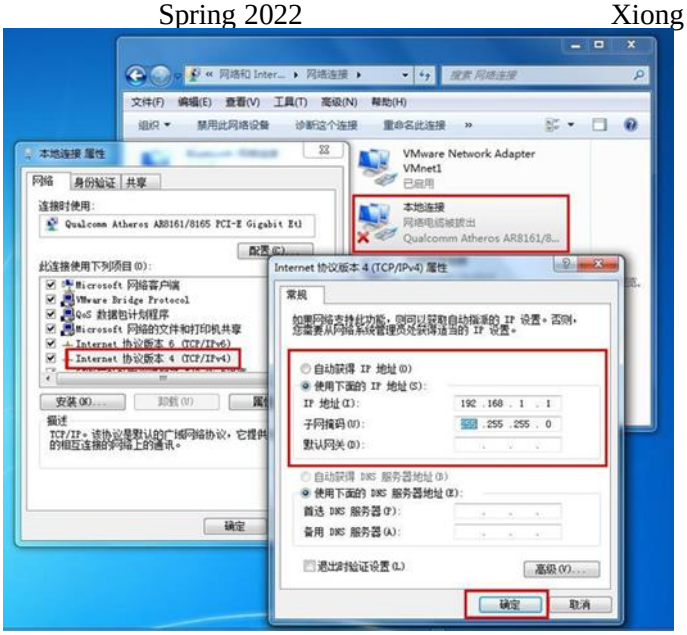

Figure 4. Manual configuration of PC IP

(2) At the handheld end:

1) Click on 【System】-> 【System Configuration】-> 【More】-> 【LAN】;

2) Set Static Subset Mask to a subnet mask segment with the PC, as shown in Figure 5, and set the parameters. (All modifications within the red wireframe are set to the same with the following image).

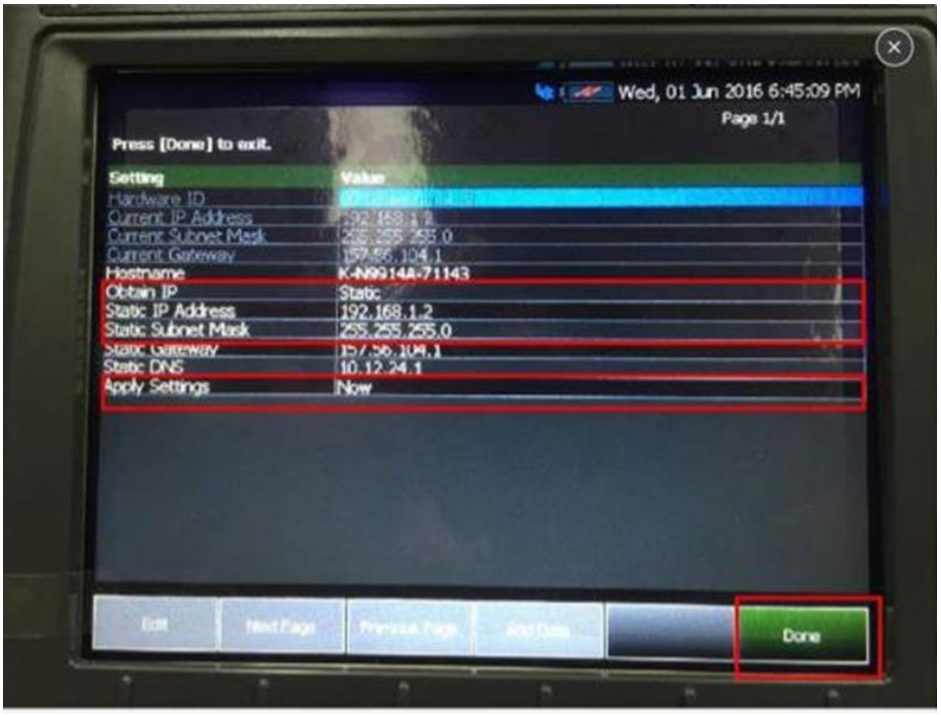

Figure 5. Configuring the FieldFox Handheld Microwave Analyzer

3) After the configuration is finished, set【Apply settings】 to【Now】,so that the above configuration takes effect.

4) Select【Done】.

(3) Back to the PC side:

1) As shown in Figure 6, open the connection software【Keysight Connection Export 】select【Manual Configuration】and 【LAN Insrument】;

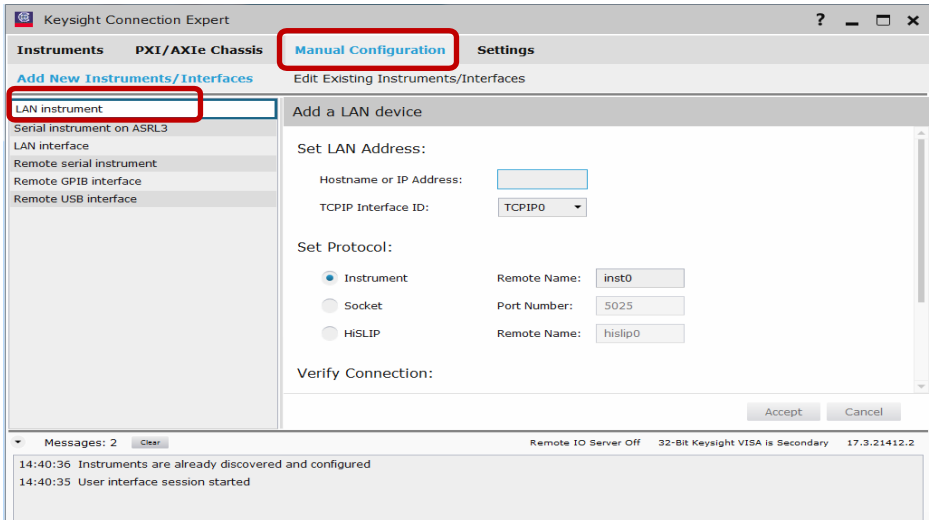

Figure 6

2) As shown in Figure 7, fill in 【Hostname or IP Address】and click【Test This VISA Address】

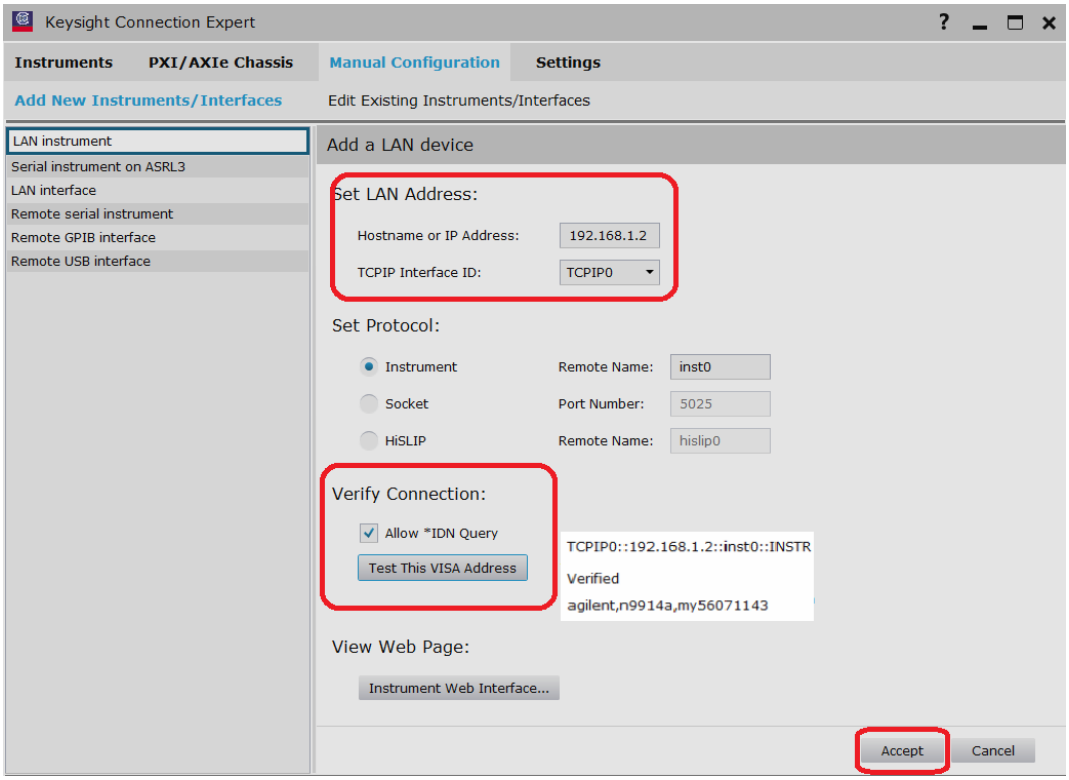

Figure 7.. Hostname or IP Address

3) Click”Accept”, the interface shown in Figure 8 appears.

Now,the connection between the PC side and the handheld table is configured. Note that after the connection is complete, the operation is PC-based, and there is no need to manipulate the FieldFox Handheld Microwave Analyzer.

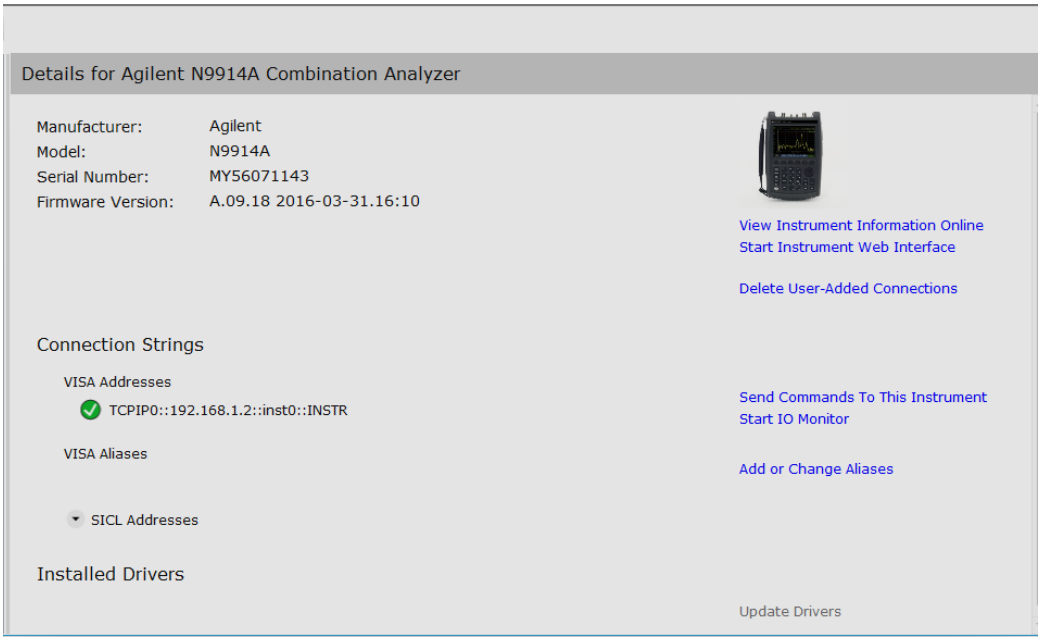

Figure 8. The connection configuration between PC and handheld meter is ok

4. Calibration

Before measuring, calibration at the tip of the probe must be performed.

A three-term calibration corrects for the directivity, tracking, and source match errors that can be present in a reflection measurement. In order to solve for these three error terms, three well-known standards are measured. The difference between the predicted and actual values is used to remove the systematic (repeatable) errors from the measurement. The three known standards are **air, a short circuit, and distillate and de-ionized water.** Even after calibrating the probe, there are additional sources of error that can affect the accuracy of a measurement. There are three main sources of errors:

• Cable stability
• Air Gaps
• Sample thickness

(1) On the PC side, open the software【Keysight Materials Measurement Suite 2016】, select【Coaxial Probe Method】, and click【Start】to enter the main interface;

(2) Calibration setup: as shown in Figure 9, select【Calibration】 -> 【Configure Calibration】to set the calibration type, probe type and water temperature (set to the actual temperature measured by mercury thermometer).

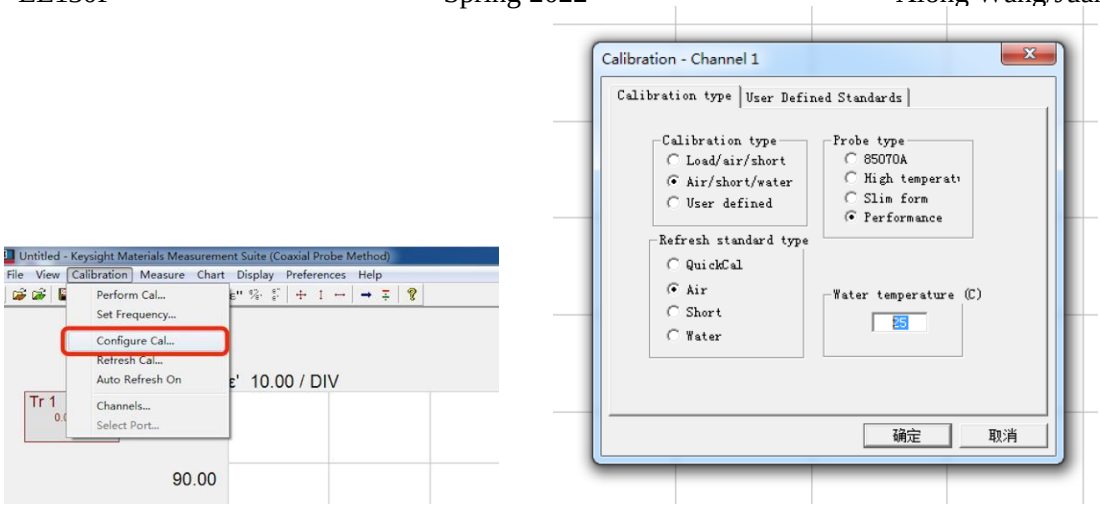

Figure 9. Calibration type settings

(3) As shown in Figure 10, select 【Calibration】 ->【Set Frequency】to set the start stop frequency, sampling points, power and IF bandwidth.The smaller the IF bandwidth,the less noise introduced, then the higher the measurement accuracy. The more the number of points, the longer the test time and the higher the measurement accuracy.

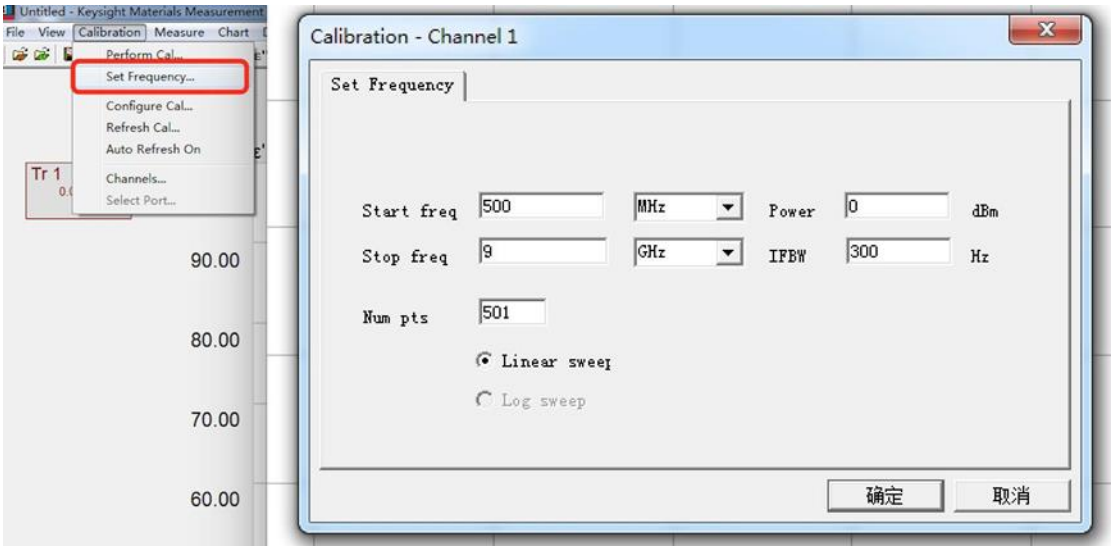

Figure 10. Calibration parameter settings

(4) After set up, select【Calibration】 ->【Perform Calibration 】as shown in Figure 11. Then calibrate with air, short-circuited devices, and deionized water according to the prompts given by the software.

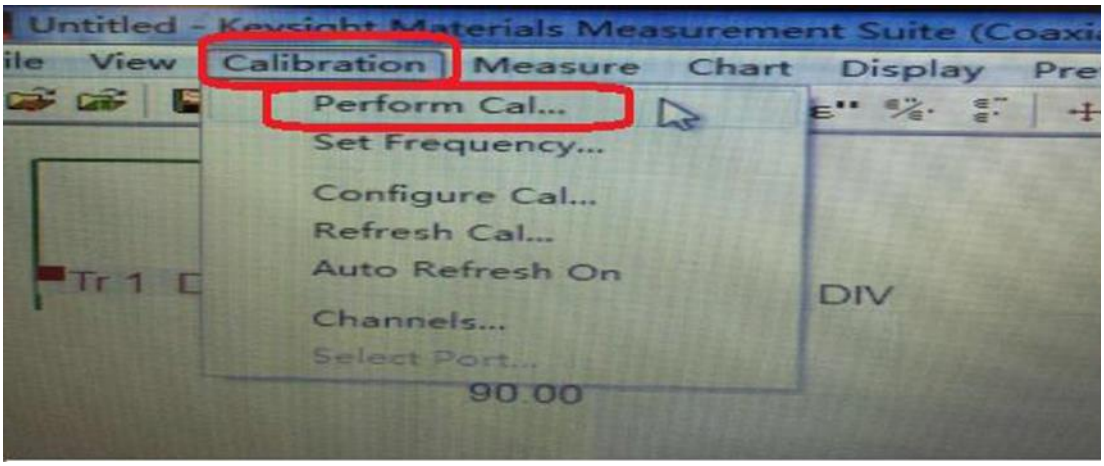

Figure 11. Calibration

1) Air: Expose the bottom of the probe to air, click【Measure】on the screen and wait a few seconds for the measurement to be completed ,then move on to the next step;
2) Short-circuit device: Connect the Performance probe short to the bottom of the Performance probe, tighten the calibration to ensure good contact. Please do be careful, too much force will damage the probe! The short-circuit calibration will done by the TA. Anyone who causes damage to the probe must pay compensation. Tap【Measure】on the screen ,wait a few seconds until the measurement is complete.

Figure 12 Performance probe and Performance probe short

3) Deionized water: Fill the beaker with about 80% full (400 ml) deionized water. Place the beech at the bottom of the probe and move it up slowly so that the roots of the probe are immersed in water of about 2 to 3 cm. During this process, please move the beaker slowly, and check the bottom of the probe to ensure no bubbles. If there are bubbles, lower the beech and shake slowly until the bubble disappears, and then immerse the probe in water.

Select【Measure】-> 【Trigger measurement】,wait a few seconds until the measurement is finished. Please note that the water should be always clean.

5. Measure: After calibration, a variety of liquids can be started to measure.

(1) After calibration, the parameters of deionized water can be measured directly.
Select【Measure】-> 【Trigger Measurement】 to measure the parameters of deionized water.When the measurement is finished, you can select on the screen to view the real and imaginary parts of the dielectric constant and the tangent of the loss angle, click "Save" to save the results as .csv format , and plot out in the experimental report;

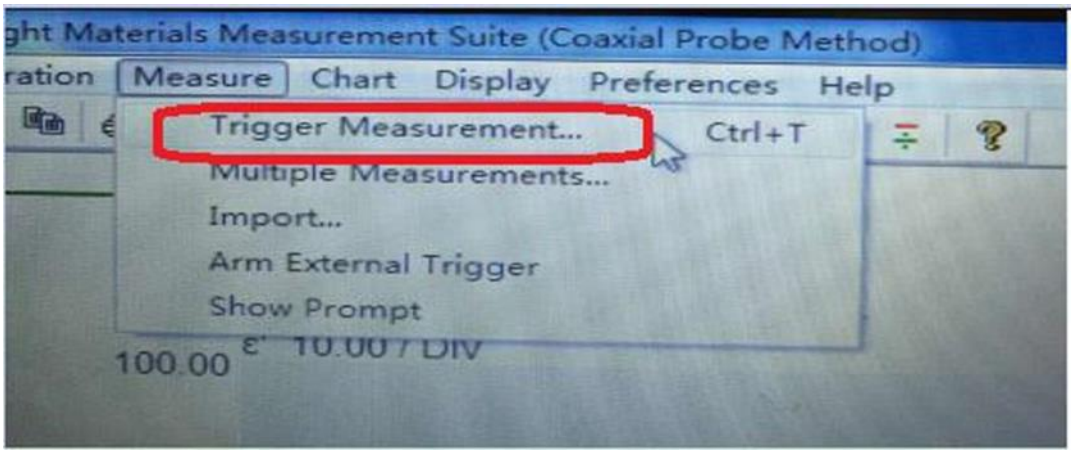

Figure 13. Measurement of dielectric constant

(2) Remove the beaker with deionized water, and wipe the bottom of the probe with a mirror paper carefully. Take a beaker with another liquid, and then immerse the bottom of the probe in the liquid to ensure that there are no bubbles. Select the 【Measure】->【Trigger Measurement】,wait a few seconds and save results.

(3) Replace the liquid and repeat the steps above. Please note that the bottom of the probe should be wiped carefully with mirror paper before measure a new liquid.

Report

1. Draw all the measured results of liquids in your report (photographic results are Not Acceptable). Note that the real part and imaginary part of the dielectric constant of each liquid are drawn in the same picture and distinguished by different colors or curve types.
2. Compare the measured results of deionized water and saline with the theoretical values, if the difference is large, please try to explain the possible reasons.
3. The measurement results of oil fluctuated more than those of water and alcohol, please try to explain the possible reasons.
4. After the calibration of high performance probe end, is there any error source in the test process? Why the liquid accounts for 80% of the full beaker, and the probe root should be immersed in the liquid for about 2 ~ 3 cm?