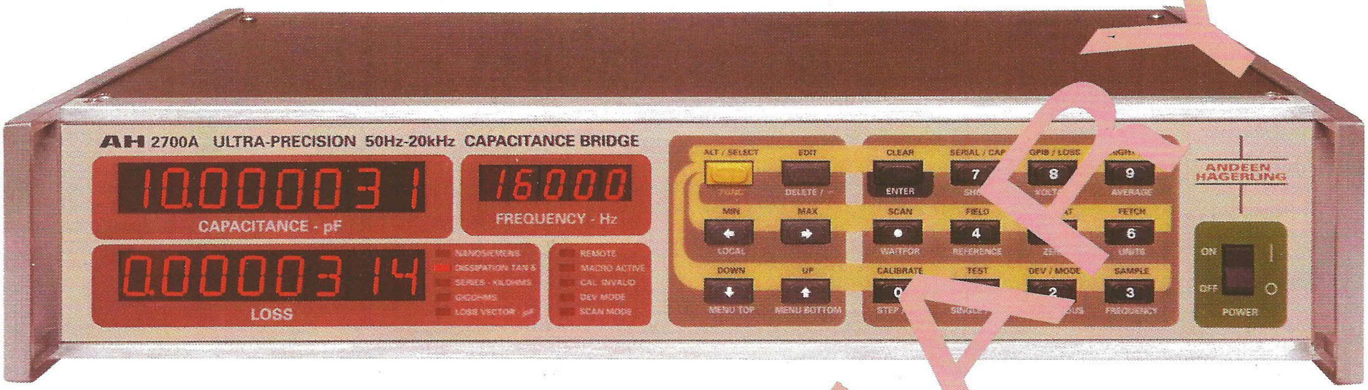
AH ANDEEN-HAGERLING

AH 2700A
Option-E
50 Hz-20 kHz Ultra-precision
Capacitance/Loss Bridge



Additional features of the Option-E version of the AH2700A 50Hz-20kHz bridge

The AH2700A Option-E is an enhanced precision version of the AH2700A 50 Hz-20kHz bridge. Much like the AH2500A Option-E, the AH2700A Option-E offers higher precision and significantly enhanced calibration and verification features over its base model.

Features in common with the AH2500A Option-E

- Quantitatively improved specifications:
  - Accuracy
  - Stability
  - Resolution
  - Temperature Coefficient (TCS)
- Automated ratio-transformer verification
- Full report of all internal and transformer calibration points
- Real-time temperature corrections
- Selected hardware for higher stability

Features New to the AH2700A Option-E

- Revised definitions for non-linearity and resolution
- New attenuator ratio specification
- Expanded cable correction commands
- DUT stray capacitance loading correction

Transformer Verification/Calibration

The three ratio transformers (main ratio transformer, quadrature transformer and attenuator transformer) used in the AH2700A are extremely linear and extremely stable. As a result, there is no provision to verify or calibrate these transformers in the non-Option-E version of the AH2700A.

However, the Option-E version of the AH2700A is factory calibrated to provide greater linearity between transformer taps. A procedure is provided to allow you to *verify* but not *calibrate* the linearity of the more critical taps of the main ratio transformer and attenuator transformer. The linearity is verified/calibrated by performing internal intercomparisons of transformer taps. No external reference transformer is used and no commercial ratio transformer has ever been made that is even close to being good enough for this purpose.

Verification/Calibration Reports

As part of the internal verification report, all versions of the AH2700A report the elapsed operating time and temperature difference between the conditions used to obtain the currently stored calibration values and the conditions used to obtain the new verification data. Non-Option-E bridges also report only the one internal calibration point that is furthest from its nominal value. Option-E bridges produce a more detailed report which includes the status of each of the internal calibration points in the bridge.

The transformer verification report is similar to the internal calibration report. It also reports the time difference and temperature differences between the new and stored verification data and the status of each of the transformer calibration points. The transformer calibration/verification reports are only available on Option-E bridges.

Real-time Temperature Corrections

An Option-E AH2700A contains additional internal calibration data in the form of temperature coefficients (T/C's) for all internal calibration points. This T/C data is generated when the bridge is manufactured and is considered to be permanent unless the main board or standard capacitor assembly is replaced. This T/C data is used to adjust the internal calibration data so that it is correct for the temperature at which the bridge is actually operating.

Revised Resolution and Non-linearity Specifications

The resolution and non-linearity uncertainty specifications as defined for the non-Option-E AH2700A bridge have been revised for the Option-E version. The non-Option-E non-linearity specification has been redefined as two new specifications:

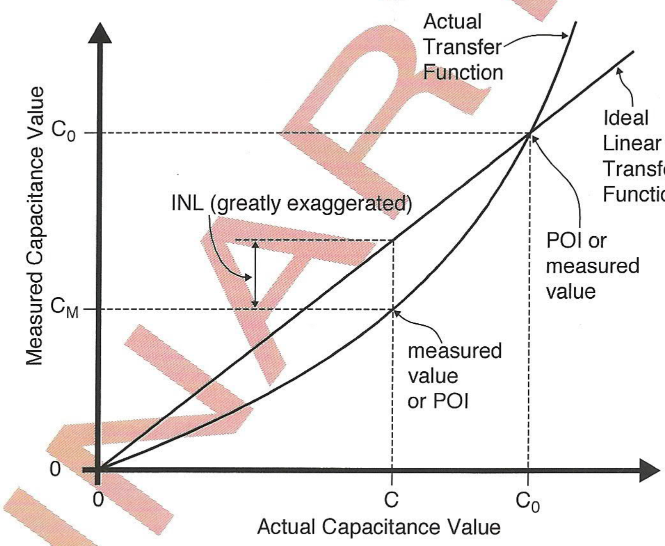
1. The first is a new Differential Non-Linearity (DNL) specification. This specification is intended to put an upper limit on the magnitude of tiny, local steps in the measurement results that occur as a function of capacitance and/or loss.

   In non-Option-E AH2700A and AH2550A bridges, this DNL uncertainty was (and still is) combined with the resolution specification. In the Option-E AH2700A bridge, the DNL and resolution uncertainties are separated into a DNL specification and a resolution specification. This makes the resolution specification for the Option-E AH2700A simpler than the one for the non-Option-E AH2700A. This new resolution specification puts an upper limit on the amount of random noise in the measurements while containing nothing about DNL.

2. The second new specification is a completely new Integral Non-Linearity (INL). This specification uses a commonly accepted method of defining an INL specification as a deviation from a straight line of the transfer curve of the measured value of capacitance (or loss) versus the actual value. An example is shown in the graph below. For this AH specification, the transfer curve and the straight line are both defined to pass through C=0. Another place on the straight line passes through a Point of Interest (POI) at C_{POI} chosen by the user. The measured capacitance (or loss) value, C_M, is where the INL uncertainty will be calculated. The INL uncertainty expression contains two input parameters: C and C_0, where C_0 must be greater than C. The values from C_{POI} and C_M are substituted into C and C_0. These values may have to be swapped so that C_0>C.

This method of computing INL shows that INL uncertainties are smaller when C_M and C_{POI} are closer together.

Integral Non-Linearity Variables



The Attenuator Pair Ratio Uncertainty Specification

Each AH2700A capacitance bridge contains ratio transformers having a set of eleven selectable attenuator taps that allow a variable voltage to be supplied to the H (High) terminal of the bridge. By selecting one of these taps at a time, this voltage can be very precisely set to cover a range of 15 volts thereby allowing the bridge to measure correspondingly larger capacitance values using eleven distinct ranges covering over 100 pF on the 15 V range to over 1.5 μF on the 0.001 V range. The 15 V range can be calibrated directly by measuring a traceable reference capacitor having a value compatible with this range such as 100 pF. Such direct calibration of the other ten ranges is not practical due to the limited stability of capacitors having larger values. Intercomparison of measurements made on adjacent ranges allows all the ranges to be calibrated relative to each other and especially of each to the 15 V range. At the same time, uncertainties can be determined for each pair of ranges (attenuator taps). These uncertainties are used to create the Attenuator Pair Ratio Uncertainty Specification (APR). The non-Option-E AH2700A bridge incorporates the APR uncertainties only into the accuracy specifications.

APR is fundamentally different from all the other uncertainties for AH bridges. The latter are always applicable only to a single measurement. The APR uncertainty only applies to a ***pair*** of measurements where it gives an uncertainty based on that pair's not having used the same attenuator tap for both measurements. If the same attenuator tap had been used for both members of the pair, then the APR uncertainty would be zero.

Application of APR

Suppose your lab has a very stable 100 pF reference capacitor with a high accuracy traceability certificate. Further suppose you have other capacitors having an array of capacitance values; you would like to calibrate these capacitors relative to your traceable 100 pF reference capacitor and you would like to provide a certificate of traceability with these capacitors. Using AH2700A bridges, there are three ways to do this:

1. You can use the AH capacitance calibration procedure described in the AH manual to calibrate your AH2700A non-Option-E bridge. This will allow that bridge to make traceable measurements throughout its range having uncertainties given mainly by the published accuracy specification for that AH2700A. A few other uncertainties such as described in NIST Special Publication 250-76 may also be desired. This is a safe way to make traceable measurements, but will not give the tightest possible uncertainties because the AH accuracy specification already allows for a large traceability uncertainty. This traceability uncertainty may be larger than necessary if your traceable 100 pF reference capacitor has a tighter certification.

2. You can apply the same procedure described above but using an AH2700A Option-E bridge. Since the published uncertainties for this bridge will be smaller, you will be able to produce tighter certificates of traceability than with paragraph 1 above.

3. You can use an AH2700A Option-E bridge to accurately measure your traceable 100 pF reference capacitor and record the results (without changing the calibration of your bridge). All subsequent capacitance measurements made with this bridge can then be corrected by the ratio between the earlier recorded results and the traceable certified value of your 100 pF reference capacitor. The uncertainty calculations for these measurements should not include the published accuracy specification for your AH2700A Option-E. Instead, the calculation should include the sum of the traceable uncertainty of the 100 pF reference and the resolution, DNL, INL and TCS for the measurement of the 100 pF reference. In addition, each subsequent capacitance measurement must add the sum of its own resolution, DNL, INL and TCS. A stability uncertainty is not needed unless enough time has passed to justify it. One more uncertainty must be added to this list. This is the new Attenuator Pair Ratio (APR) uncertainty. This is needed only for whichever subsequent measurements were made using a different attenuator tap than was used by the measurement of the 100 pF reference capacitor.

Expanded Cable Correction Commands

Correction Models

The cable correction model for the non-Option-E AH2700A allows the user to specify the electrical parameters of the dual coaxial cable that connects the bridge to the DUT. These include the capacitance per meter, inductance per meter, and resistance per meter, as well as the length of the cable. This model does not take into account any frequency dependent behavior of the cable. To make frequency-dependent corrections in this non-Option-E bridge, you must specify the cable parameters for each frequency at which a measurement is to be taken.

In contrast, each AH2700A Option-E bridge comes with an AH-DCOAX-TPG-1-BNC one meter cable. This cable has double-braided silver plated shields and gold plated BNC connectors. This construction allows the cable's electrical parameters and its frequency dependent behavior to be more accurately and stably defined.

The AH2700A Option-E bridge introduces a new ability to select *correction models* for specific cable types and DUT configurations. These models have a built-in knowledge of electrical parameters for specific cable and DUT types. This includes the frequency dependence of these parameters if it's significant.

One of these models is for use with the AH-DCOAX-TPG-1-BNC cable alone. Another is for use with that cable in conjunction with the AH-TTA1 two-terminal to three-terminal adapter. These correction models are selectable by default as an alternative to the ability to specify individual cable electrical parameters for cable correction.

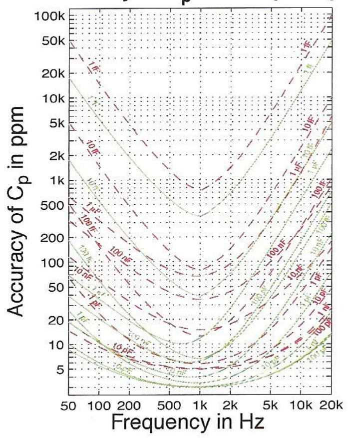
DUT Loading Corrections

Stray capacitance from high-to-ground (C_{HG}) and low-to-ground (C_{LG}) at the DUT causes the measured capacitance to be larger than it should by amounts that are proportional to C_{HG} and C_{LG}. The AH2700A Option-E allows the user to enter the values for C_{HG} and C_{LG} at the DUT when using any of the correction models associated with the AH-DCOAX-TPG-1-BNC cable. When using these models, the bridge will always automatically correct the measurement results for these stray capacitances. If C_{HG} and C_{LG} have never been entered, then default values will be used.

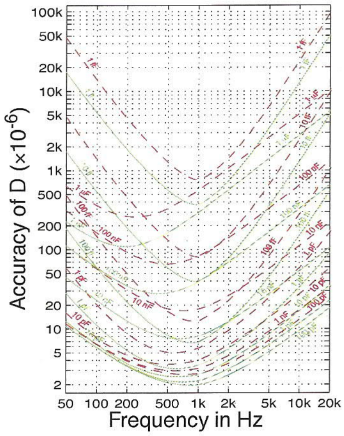
Performance Specifications

Selected specifications for the AH2700A and preliminary specifications for the AH2700A Option-E are shown in the graphs below. Specifications for the non-Option-E AH2700A are shown in red while specifications for the Option-E are shown in green.

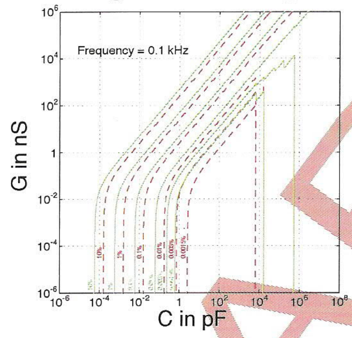
Accuracy of C_p vs. Frequency



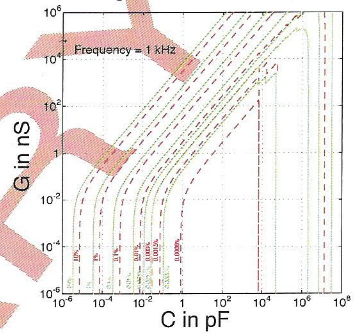
Accuracy of D vs. Frequency



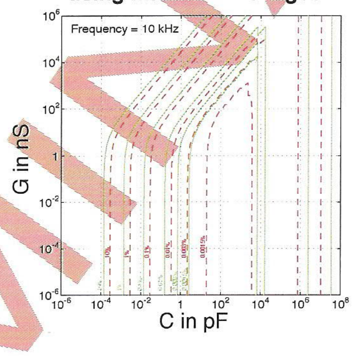
Accuracy of C_p vs. C_p and G using maximum voltages



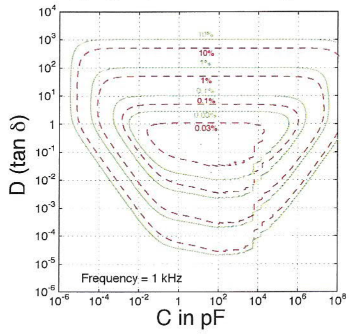
Accuracy of C_p vs. C_p and G using maximum voltages



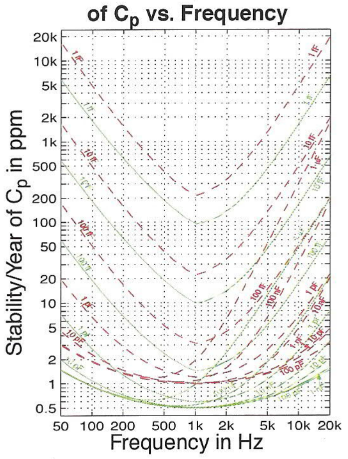
Accuracy of C_p vs. C_p and G using maximum voltages



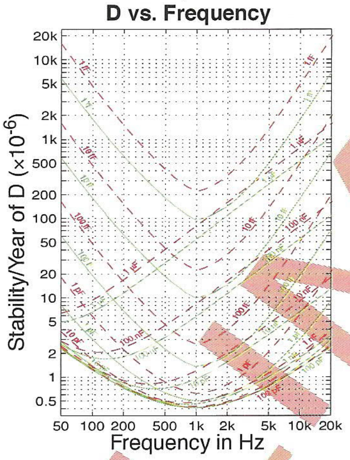
Accuracy of D vs. C_p and D using maximum voltages



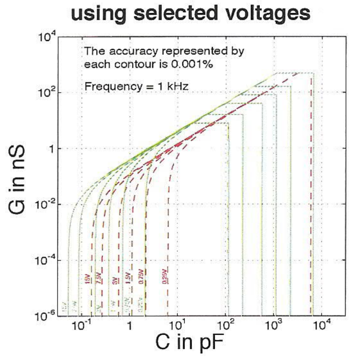
Stability/Year of C_p vs. Frequency



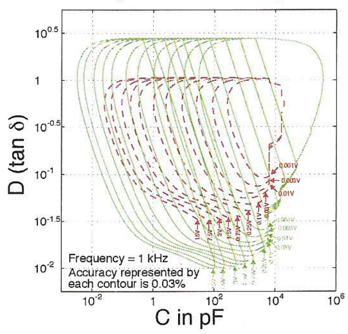
Stability/Year of D vs. Frequency



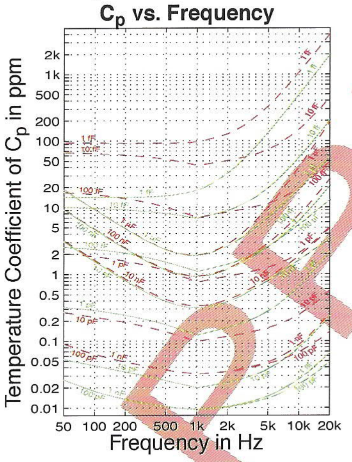
Accuracy of C_p vs. C_p and G using selected voltages



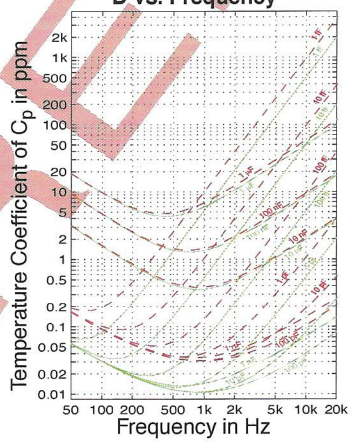
Accuracy of D vs. C_p and D using selected voltages



Temperature Coefficient of C_p vs. Frequency



Temperature Coefficient of D vs. Frequency



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