# Epsilometer Uncertainties

Measurement uncertainty for the epsilometer may arise from a number of error sources. Systematic errors can be caused by computational modeling errors, fixture manufacturing variations, and VNA nonlinearities. The calibration procedure with a known specimen is designed to minimize these systematic uncertainties. Additional uncertainties may arise from VNA drift and noise, variation in electrode pressure and thickness uncertainty.

Figure 1 below shows a typical measurement variation analysis. In this example, a 2.3 mm Teflon specimen was measured nine separate times (inserting and removing the specimen each time). The estimated percent error in the real part of the permittivity is shown on the left and is calculated as two times the standard deviation of the multiple measurements. In this case the variation is generally less than 2% from 10 MHz up. For other cases, the measurement uncertainty may vary from 0.5% to 5% depending on thickness and permittivity.

Also shown on the right side of Figure 1 is the estimated uncertainty in imaginary permittivity for the 2.3 mm Teflon. This error is also calculated as twice the standard deviation and expressed in relative permittivity units. As the data show, imaginary permittivity uncertainty for low loss specimens is typically less than +/- 0.02, from 10 MHz up. In terms of loss tangent this is equivalent to +/- 0.01 over most of the frequency range (since Teflon has a permittivity of 2.00 and a loss tangent < 0.001 at room temperature).[1]
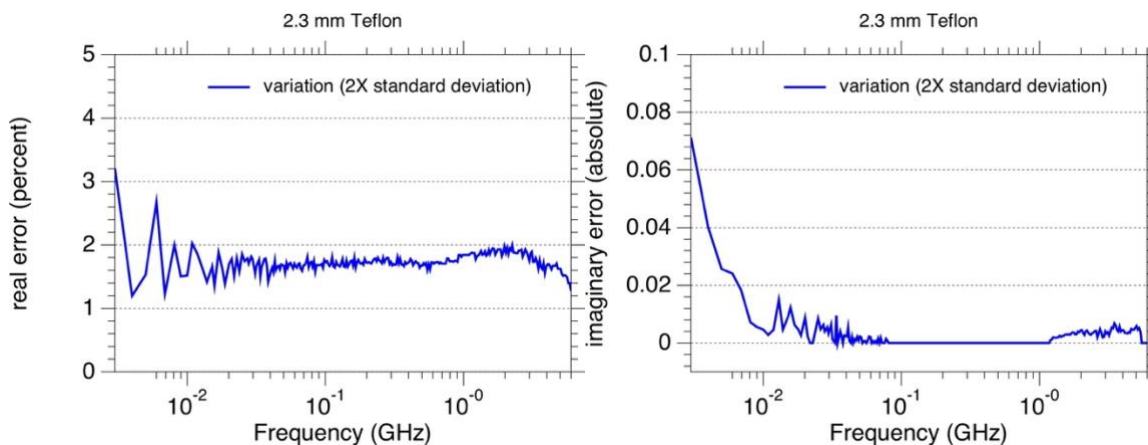


*Figure 1  Typical measurement variation of a 2.3 mm thick Teflon specimen*

Note the above uncertainty example does not account for thickness error. There may be additional uncertainty proportionate to the accuracy in which specimen thickness is known. A micrometer rather than calipers should be used to measure thickness to minimize this uncertainty. Another significant uncertainty can occur with hard ceramic specimens that are not exactly flat. Any air-gap between the specimen and the electrodes results in significant measurement error. In polymer materials, a non-flat specimen will yield to the electrodes so that lack of flatness is corrected. However, a hard ceramic specimen will not yield to the pressure of the electrodes and the residual air gap will effectively reduce the measured permittivity. This error is especially pronounced at higher permittivity.

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[1] P. Ehrlich, Journal of Research of the National Bureau of Standards, vol 51(4), October 1953