Evaluating and Expressing Uncertainty in High-frequency Electromagnetic Measurements – A Selective Review

Professor Nick Ridler *IEEE Fellow*

National Physical Laboratory, UK

Abstract

This talk examines the impact of the Guide to the expression of Uncertainty in Measurement (GUM) on selected types of electromagnetic measurement. The main focus is on high-frequency electrical measurements – i.e. measurements made at Radio Frequencies (RF) and above. These measurements impact sectors of industry such as communications, defence, security, healthcare and domestic electronics (computers, mobile phones, etc).

A distinguishing feature with these measurements is that, in general, the measurands have both a magnitude and phase component – i.e. the measurand is a complex-valued quantity, $y = a + jb$, where a and b are the real and imaginary components, respectively, of the complex-valued measurand, y, with $j^2 = -1$. The component representation – i.e. either magnitude and phase, or, real and imaginary – needs to be considered when the uncertainty in complex-valued measurands is evaluated and expressed. In addition, it is common for the measurands to be transformed to other representations, for the convenience of specific applications – e.g. impedance quantities (resistance, capacitance, etc) that are used in high-frequency electronics applications. Again, this impacts the evaluation and expression of the uncertainty in these measurands. It is also common for a measurement process to result in the simultaneous determination of multiple measurands – i.e. several complex-valued quantities evaluated at many different frequencies. This raises considerations concerning the correlation between the measurements of these multiple measurands and the use of a region of uncertainty to represent the overall uncertainty (rather than an interval of uncertainty that is used for a conventional scalar measurement quantity).

The GUM and its Supplements have made a major impact on all the above measurement issues. Hence, the GUM and its Supplements have become key enabling mechanisms for determining the overall quality and demonstrating the integrity of many electromagnetic measurements. This talk reviews the above issues and shows how the GUM and its Supplements have provided a firm basis for the metrology that underpins the industries that require reliable electromagnetic measurements. The talk concludes by considering how future industrial requirements for new forms of measurement will be driving the need for further development of uncertainty evaluation practises in the years to come.

This invited lecture was first given at a conferenced to celebrate the 20th anniversary of the publication of the ‘Guide to the Expression of Uncertainty in Measurement’, which took place at the National Physical Laboratory, Teddington, in November 2013.