

Recent Advancements in Impedance Metrology at CSIR-NPL

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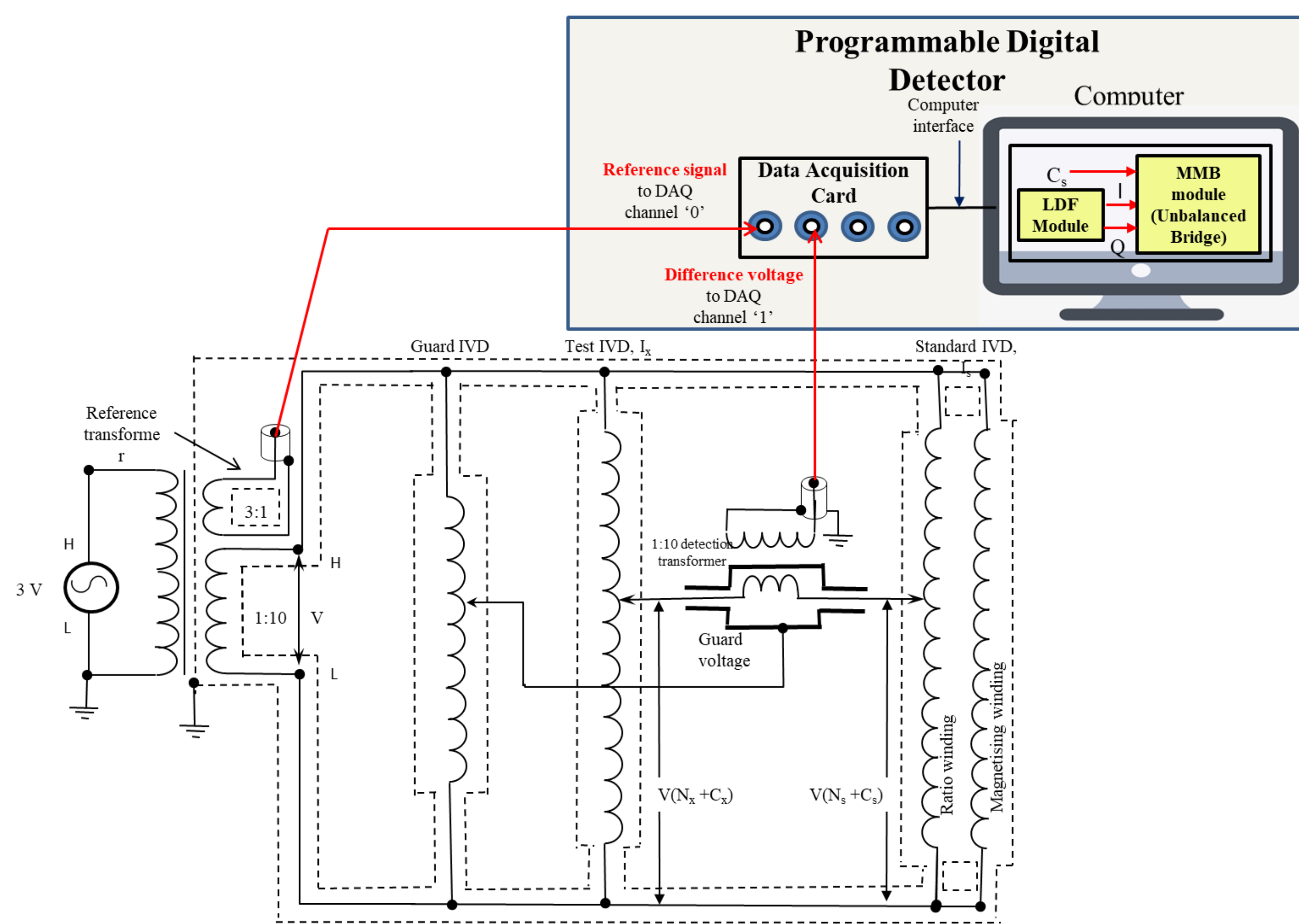


Introduction : This study presents the results of recently established measurement techniques for inductive voltage dividers (IVDs) and inductance calibration using digital instrumentation.

- A digitally assisted (DA) ratio comparison bridge for inductive voltage divider (IVD) calibration has been developed with uncertainties in the order of a few parts in 10^7 . A programmable digital detector (PDD) predict the bridge balance without actually balancing the bridge. It can be achieved with concise analysis of the bridge circuit, its equations at unbalance and high-resolution data acquisition card.
- To minimize the process of inductance traceability, a new methodology to realize inductance directly through capacitance is established. The inductive reactance X_L at frequency 'f' can be compared with a similar magnitude of capacitive reactance X_C . The precision LCR meter, with eliminating errors for reactance measurement can be conveniently used for relating X_L and X_C .

A digitally assisted IVD calibration bridge using Programmable Digital Detector

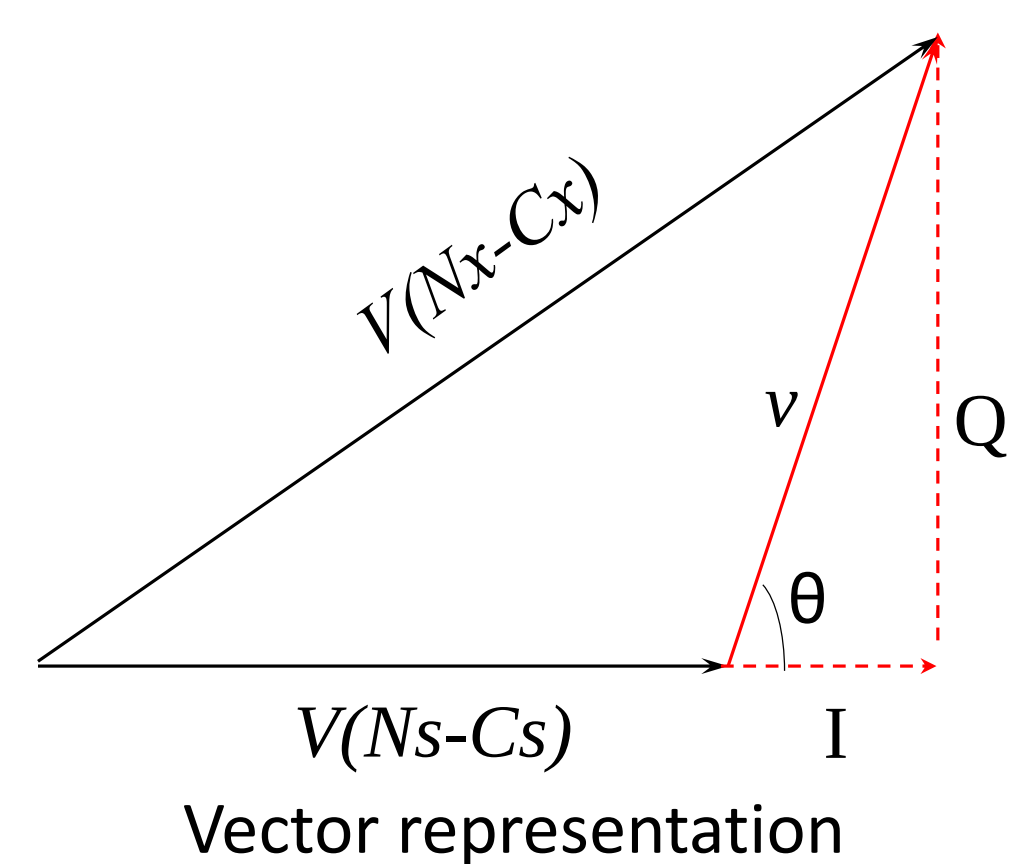
Measurement setup



Where,

- V Applied voltage to the bridge at 1 kHz
- N The nominal ratio for comparison
- N_x the n^{th} ratio of test IVD, nominal
- C_x Ratio correction of test IVD
- N_s the n^{th} ratio of standard IVD, nominal
- C_s Ratio correction of standard IVD
- v Difference-voltage for n^{th} ratio tapping of test and standard IVD
- θ Phase difference with respect to the reference voltage, Degree

Mathematical modeling of the Bridge



$$v = I + jQ \quad (1)$$

$$v = V(N_x + C_x) - V(N_s + C_s) \quad (2)$$

Ratio correction is determined for the same nominal ratio. It means

$$N_x = N_s = N, \text{ then (2) modifies as}$$

$$v = V(C_x - C_s) \quad (3)$$

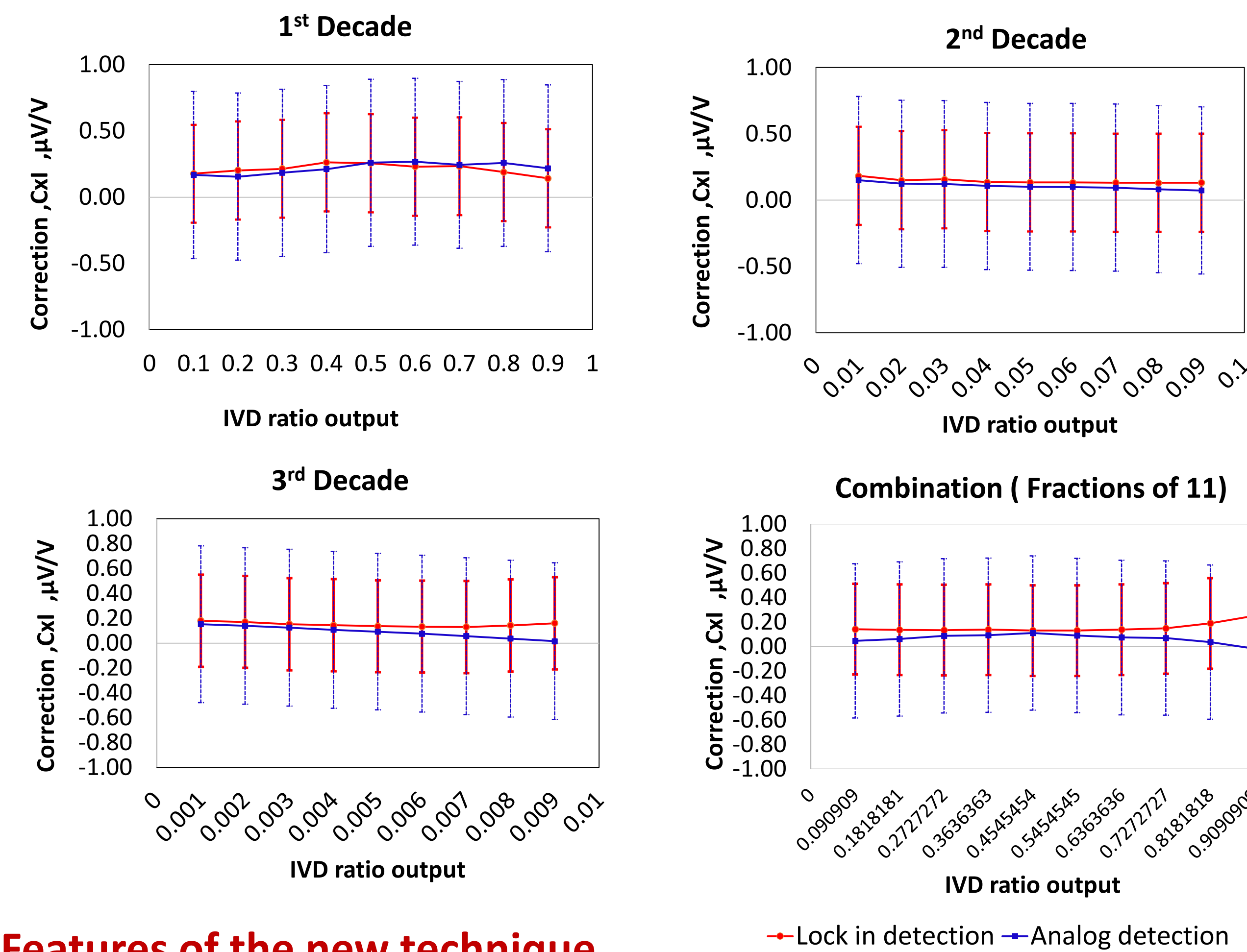
Substituting (1) into (3) gives the correction factor of the test IVD,

C_x in terms of C_s , I and Q . It is written as

$$I + jQ = V(C_x - C_s) \quad (4)$$

$$C_x = (C_s + I/V) + jQ/V \quad (5)$$

Results



Features of the new technique

- Based on difference voltage measurement.
- Programmable digital detector = NI PCI 4474 DAQ + LDF (Lock-in detection function) + MMB (Mathematical model of the bridge) module implemented in LabVIEW.
- LDF module Implemented for difference voltage measurement.
- MMB defined for unbalanced bridge equation.
- The corrections of test IVD ratio evaluated with Programmable digital detector.

Novelty of the work & conclusion

- Eliminates the bridge balancing mechanism.
- Programmable Digital Detector (PDD) developed with NI-PCI 4474 Data acquisition card and LabVIEW Software.
- Minimizes the bridge complexity.
- PDD can replaces the function of Commercial detectors / lock-in amplifiers, signal generators / synthesizers, R-C networks etc.
- Significantly reduce the measurement time from 120 min to 20 min for manual IVD calibration.

Uncertainty in Measurement

IVD Calibration	In-phase Uncertainty	Quadrature Uncertainty	Measurement time
PDD based bridge	± 0.55 ppm,	± 0.56 ppm	20 min
Manual bridge	± 0.63 ppm	± 1.5 ppm	120 min

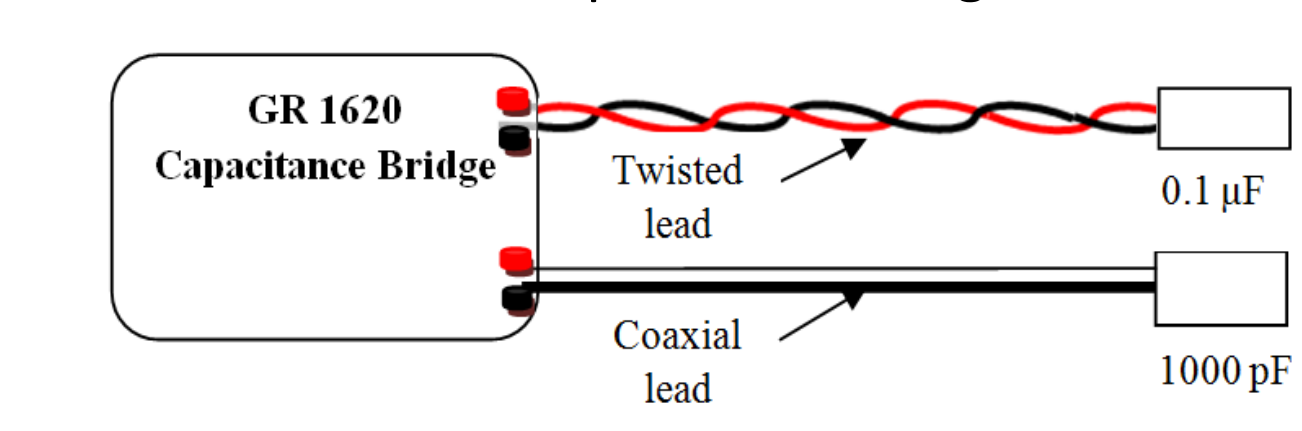
Acknowledgement

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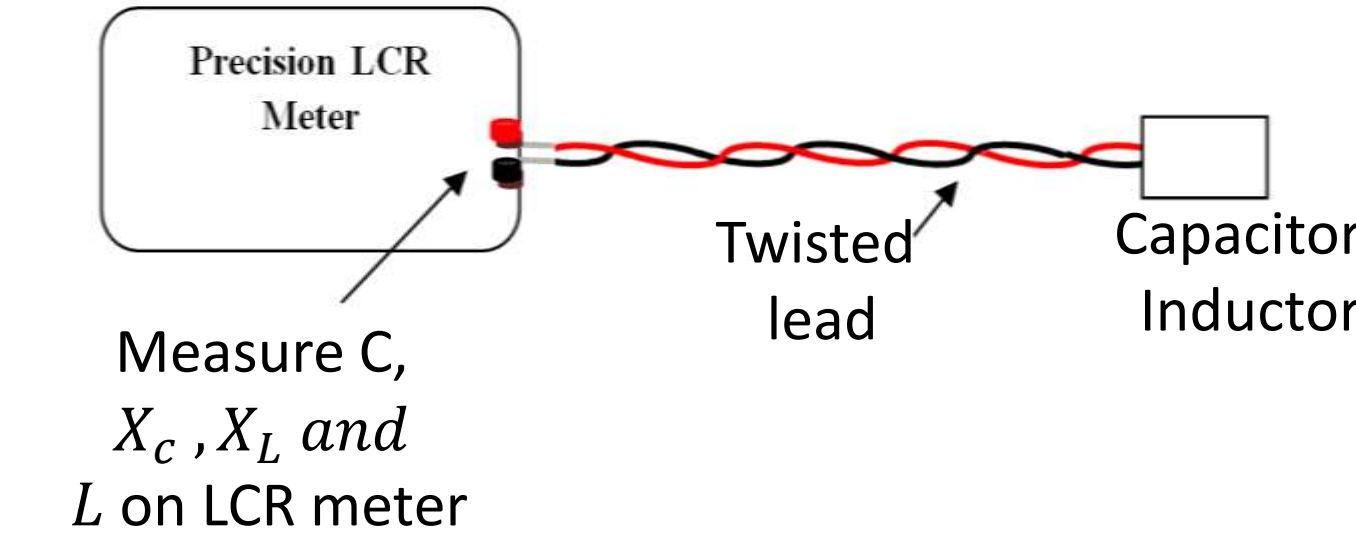
Determination of inductance through capacitance

Experimental Setup

Step 1- Measurement of capacitors on 1620 Capacitance Bridge



Step 2- Direct measurement of impedance parameters on LCR meter



Features of the new technique

- Based on reactance substitution using LCR meter.
- Capacitive reactance X_C of standard capacitance at frequency 'f' defines the error of LCR meter for reactance magnitude.
- Measured inductive reactance X_L of the inductance (DUC) with applied error correction defines the inductance 'L'.

Inductance Determination

Measurement of Capacitance standard on 1620 Capacitance bridge with connecting lead, Calculate X_C at frequency f

Define the error (Δ) of LCR meter in reactance (X_C) measurement at frequency (f)

Measure X_L at frequency (f)

Determine corrected reactance X_L' of inductor $X_L' = X_L - \Delta$

Derive L from equation, $X_L' = \omega L$

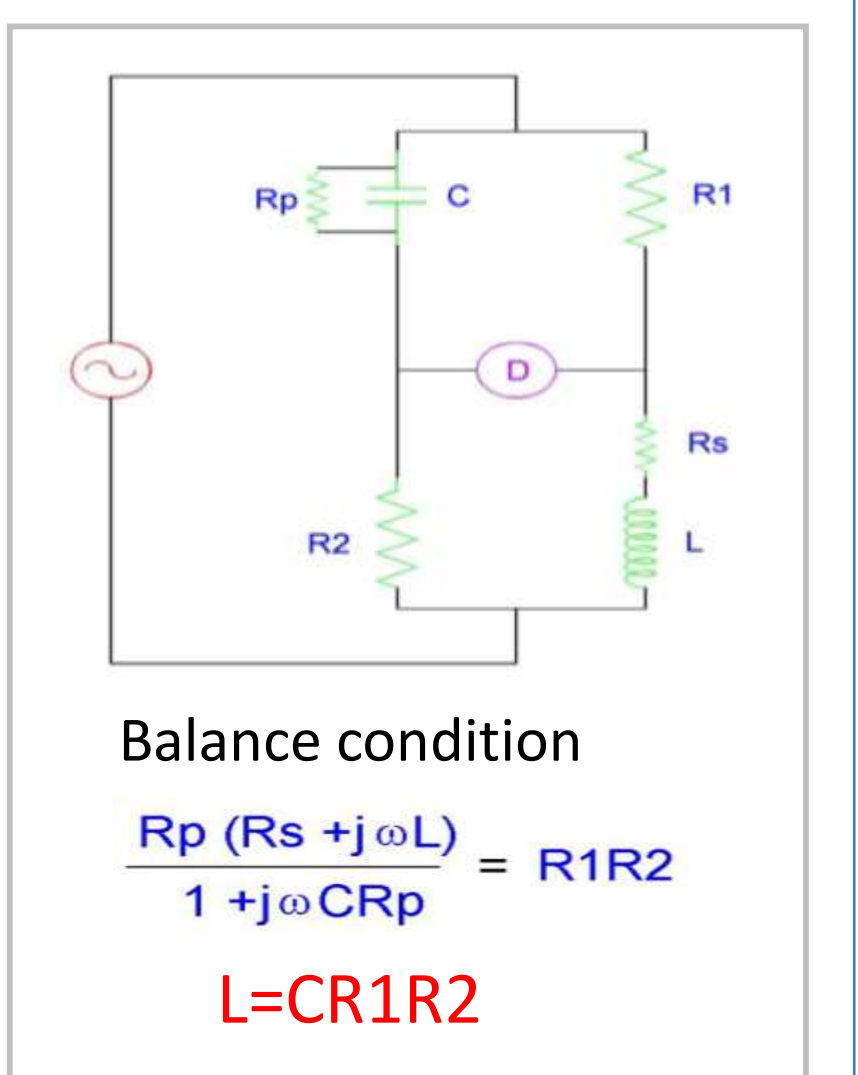
Subtract lead inductance from the calculated L

Inductance of DUC

Comparison with Maxwell Wien Bridge

Parameters	New Techniques	Maxwell Wien Bridge (MWB)
Methodology	Substitution method using LCR meter	Null balancing of MWB
Traceability	Establishes through standard capacitor.	Establishes through three standards, R1, R2 and C.
Uncertainty evaluated for 100 mH inductor	Few parts in 10^5	Few parts in 10^5

Maxwell Wien Bridge



Conclusions

- The presented work demonstrates the implementation of digital techniques precision impedance measurement without compromising the uncertainty.
- Digitally assisted bridges can be consciously designed to eliminate the need of bridge balancing and minimising the circuit complexity.
- Digital instruments are the effective tool to simplify the impedance calibration process.
- LCR meter can provide a wide scope to inter-relate the impedance parameters with SI traceability.
- Application of PDD in impedance measurement effectively reduce the measurement time and circuit complexity.