BIPM Capacity Building & Knowledge Transfer Programme

2022 BIPM - TÜBİTAK UME Project Placement

REPORT

Project Name	Realization of High-value capacitance (1μF to 1 mF range), low-value inductance standards (nH range) and design & fabrication of IVDs/Transformers for coaxial impedance bridges
Description	1.Realization of High value capacitance (1μF to 1 mF range) 2.Low-value inductance standards (nH range) 3.Design & fabrication of IVDs/Transformers for coaxial impedance bridges
Author, NMI	Sachin Kumar, CSIR-National Physical Laboratory, India
Mentor at TÜBİTAK UME	Mr. Enis Turhan, Impedance Laboratory, TUBITAK UME, Turkey
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Motivation& Introduction

The objectives of this project are to enhance the technical skills and measurement capabilities in the realization of high-value capacitance (1μF to 1 mF range), low-value inductance standards (nH range), and design & fabrication of IVDs (Inductive voltage dividers). During my stay at TUBITAK UME following tasks have been completed successfully.

Research:

Design & fabrication of IVDs /Transformers for coaxial impedance bridges:

I. **Inductive Voltage Dividers (IVDs):** Inductive voltage dividers are the accurate and stable a.c. voltage ratio standards. These IVDs use a two-stage construction in which separate core excitation and ratio windings are used.
The two-stage eight-decade IVD and 1/11 ratio IVDs have been fabricated under the BIPM-TUBITAK UME Project placement program.

Construction of IVD: In order to improve the accuracy of the voltage ratio, a two-stage construction is used with two magnetic cores. Two windings with the same number of turns are connected in parallel. One of these windings encloses one core only, while the other winding encloses both cores, figure 1. In such a connection, the major part of the excitation current is carried by the winding enclosing one core only (magnetizing winding). The parallel winding, which constitutes the ratio winding, carries very little current [1],[2].

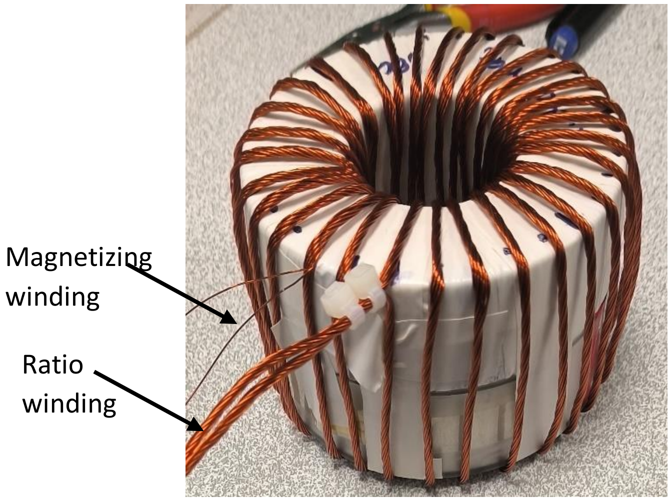

Fig.1. Two-stage construction of IVD

The first two decades of eight-decade IVD are constructed using two-stage technique and the subsequent decades are constructed using a single-stage technique. A twelve strands rope winding is used to construct the ratio winding of each decade on a high permeability toroidal core. Subdivision of voltage is achieved by interconnecting successive decades. The fabricated eight-decade IVD is shown in figure2.

Fig. 2. Eight-decade IVD

The eight-decade IVD is compared against a standard IVD, and the accuracy is <0.1 ppm for in-phase ratio at 1 kHz.

II. **1/11 ratio IVD:** This IVD is a two-stage guarded inductive voltage divider. Figure 3 shows the schematic diagram for the arrangement of cores, winding, and guarding of the IVD [3].

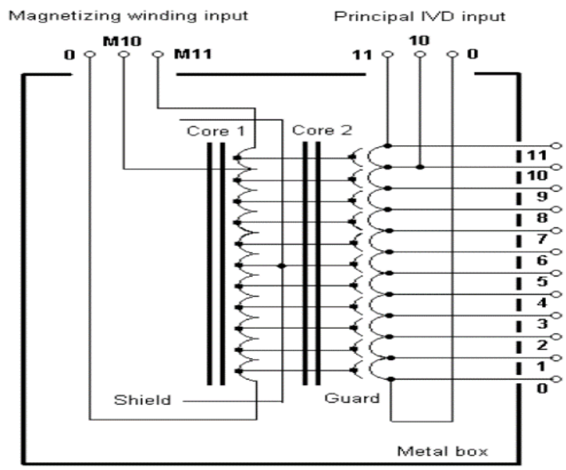

Fig. 3. Schematic diagram [3]showing the arrangement of cores, windings, and guarding

The first stage core comprises two high permeability toroidal cores placed one on top of the other. A uniform one-layer 220 turns magnetizing winding covers the entire first stage core. The guard source for the divider winding is obtained by tapping the magnetizing winding at appropriate points. The magnetizing winding is covered with Kapton tape and enclosed in a toroidal shield made of copper tape. The second stage core consists of two supermalloy toroidal cores. One core is placed on the top of the shielded magnetizing winding, and the other is below it (Fig. 4).

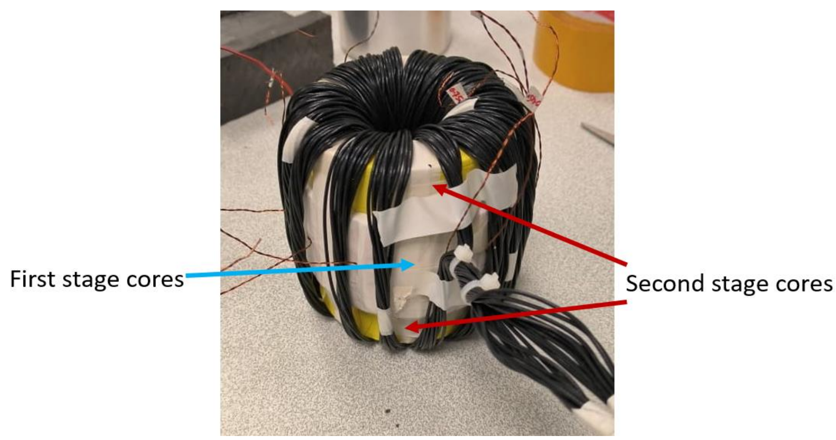

Fig.4. cores arrangements

This arrangement minimizes the leakage fields. The ratio winding consists of a 20-turn rope winding of 11 coaxial cables. The rope is wound around the core assembly, whose ends are connected in series to create a 220-turn winding. The tapped terminals 1,2…11 are brought out from the interconnections. The whole assembly is enclosed in a metal box, and the taps are brought out through the coaxial output sockets [3].

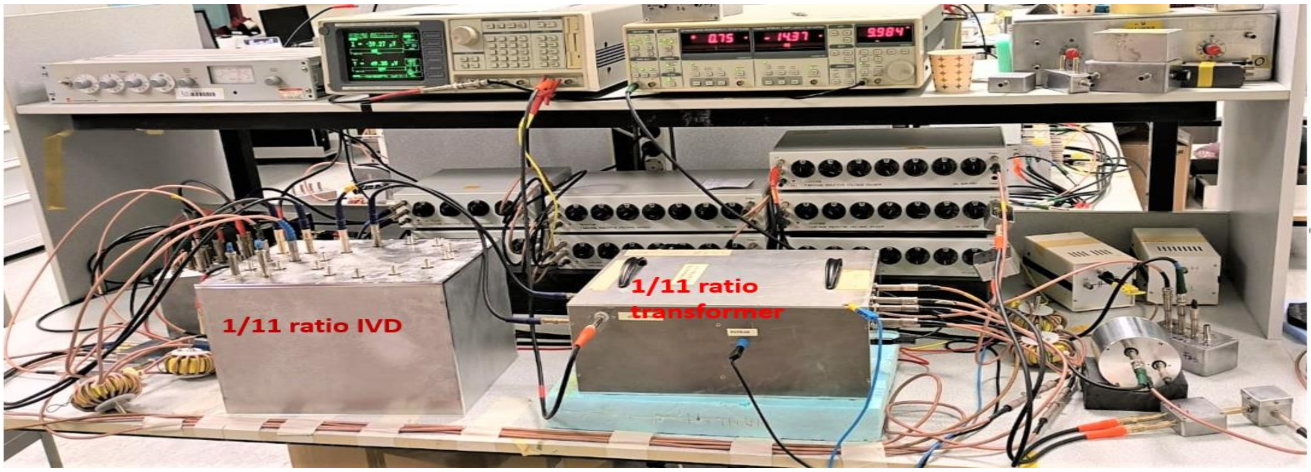

Fig. 5. Measurement setup for comparison of 1/11 ratio IVD [4]

Using the bootstrap method, this 1/11 ratio IVD is compared against a highly stable 1/11 ratio transformer [4]. The accuracy achieved is less than 0.5 ppm for the in-phase ratio. Figure 5 shows the measurement setup for 1/11 ratio IVD.

III. 100:1 Injection Transformer: An injection transformer is used to inject small voltages in various arms of the coaxial bridges. The primary winding of the transformer consists of 100 turns on a high permeability toroid core. The winding is then covered with Kapton tape, and after that a toroidal shield is made using copper foil. The single-turn secondary winding is also shielded with copper foil. The fabricated 100:1 injection transformer is shown in figure 6.

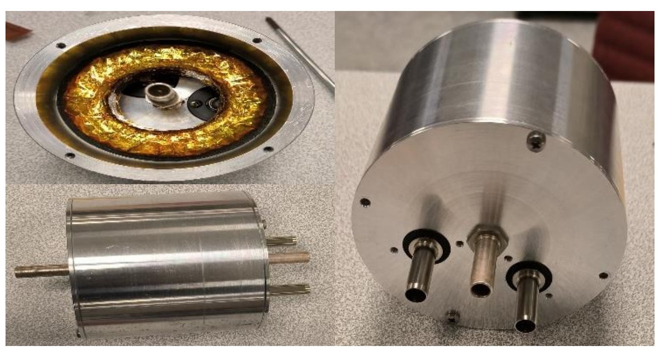

Fig. 6. 100:1 Injection transformer

IV. Isolation transformer: The isolation transformer is used to break the ground loops created by different ground points. This transformer has 100 turns in the primary and 200 in the secondary winding. In order to get 200 turns, two rope windings are used. The primary winding is covered with Kapton tape, and a toroidal shield, made of copper foil, is placed over the primary winding. To avoid the shorted turn overlap is prepared carefully. A second similar toroidal copper shield is placed over the first. The two copper shields with overlapping gaps surround the core in a special arrangement to decrease the capacitive currents that magnetize the core [5]. The second shield is also covered with Kapton tape.

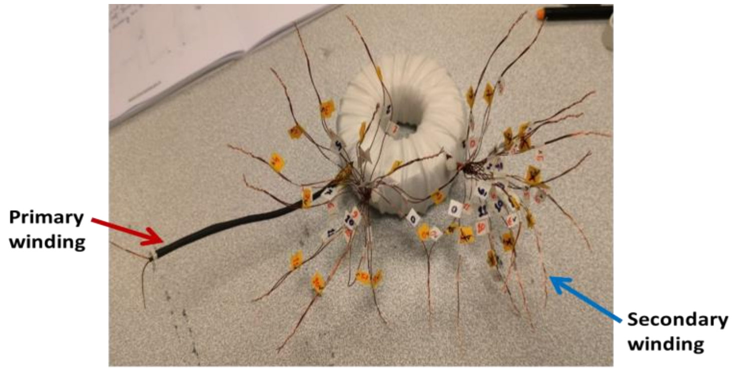

Fig. 7. Isolation transformer with primary and secondary windings

The secondary winding equipped with the following taps: -10U, -5U, -3U, -1U, 0, +1U, +3U, +5U and +10U (fig. 7). The output voltage at -10U and +10U taps will be two times of the input voltage.

Conclusions and Future Work

The Inductive voltage dividers are fabricated successfully. The accuracy of eight-decade and eleven-section IVDs are in the order of a few parts in 10^7 at 1 kHz. A 100:1 injection transformer is fabricated and tested on the coaxial bridge. The isolation transformer is also fabricated for impedance metrology applications.

The knowledge gained will be beneficial in fabricating new IVDs and transformers for coaxial impedance bridges and upgrading our calibration systems at CSIR-National Physical Laboratory.

Acknowledgements

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References:

1. T.A. Deacon and J. J. Hill, "Two-stage inductive voltage dividers." *PROC. IEE. Vol. 115, No. 6, June 1968, pp. 888-892.*

2. Saxena, Anil & Singh, Naib & R.N.Dhar, & S.L.Dahake, & K.Chandra, "Design and Development of precision 8 decade Inductive Voltage Divider". *Research and Industry." Vol. 32, March 1987, pp. 1- 4.*

3. Kyriazis, Gregory & Moreno, J & Melcher, J.. (2012). A Two-Stage, Guarded Inductive Voltage Divider with Small Ratio Errors for Coaxial Bridge Applications. *ACTA IMEKO. 1. 10.21014/acta_imeko.v1i1.20.*

4. Y. Gulmez, G. Gulmez, E. Turhan and T. Ozkan, "An inductive voltage calibration system based on bootstrapping method." *Conference Digest Conference on Precision Electromagnetic Measurements, 2002, pp. 350-351*.

5. Kyriazis, Gregory & Ogino, L & Afonso, E & Neves, J. "An isolation transformer for coaxial bridges used in the derivation of the capacitance unit from the Quantized Hall Resistance." *Proc. Satellite Meeting on Impedance Metrology, pp, 137 -144, NPL, New Delhi, India, Feb. 04, 2003.*