Special Inductive Voltage Divider with High Input Impedance at Ultrawide-Band Frequencies

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Abstract

In order to obtain a single-decade inductive voltage divider (IVD) with a high input impedance at ultrawide-band frequencies, a new winding method has been developed at Japan Electric Meters Inspection Corporation (JEMIC). This paper describes a new winding method for reducing the ratio errors caused by the interwinding capacitances as well as for obtaining a high input impedance at ultrawide-band frequencies.

1. Introduction

In calibration laboratories, IVDs are one of the important equipment in the field of alternating current (AC) measurements. IVDs are now widely used as a voltage ratio standard and as ratio arms of impedance bridges [1]. In particular, if an IVD is used for an impedance-to-voltage conversion circuit, it should have a high input impedance. On the other hand, a commercially available IVD can maintain a high input impedance only at the resonance frequency. Therefore, if an IVD with a high input impedance is required over a wide range of frequencies, we will have to prepare several IVDs. In this paper, a new winding method for a special IVD is presented. As a result, the special IVD maintains a high input impedance at frequencies up to 10 kHz using only one IVD. Furthermore, the voltage ratio errors of this IVD are within 1 ppm of the input for in-phase errors and within 5 ppm of the input for quadrature errors at frequencies from 50 Hz to 1 kHz. In this paper, the details of new winding method for maintaining a high input impedance and its performance are described.

2. New Winding Method for IVD

IVDs used for measurement purposes are generally wound as a uniform single layer of a cable of randomly stranded conductors onto a magnetic core with high permeability. In order to obtain an IVD that can be used over a wide range of frequencies, a winding method that does not increase the equivalent input capacitance is required [2]. Thus, the error in the frequency characteristic of the voltage ratio that occurs due to the effect of interwinding capacitance can be improved [3].

The arrangement of an IVD with eight sections is shown in Fig. 1 as an example. The maximum input voltage of this IVD is 2f (f in Hz). To arrange the winding area, a magnetic ring core is distributed to eight sections. In addition, each section is divided into ten divisions to compose a single decade.

Figure 2 shows the circuit diagram of this IVD. The details of the new winding method are as follows. First, the winding is wound toroidally around a magnetic core at the first division (1-1) of the first section (see Fig. 2). Next, the winding of the first division of each section is similarly wound to the eighth section (1-2~1-8). In addition, each winding is connected in series to compose the output tap of ratio 0.1. Similarly, the winding is wound at the second division of each section (2-1~2-8), and the output tap of ratio 0.2 is composed by connecting each winding in series. Subsequently, other windings are similarly connected, and a single-decade IVD is completed.

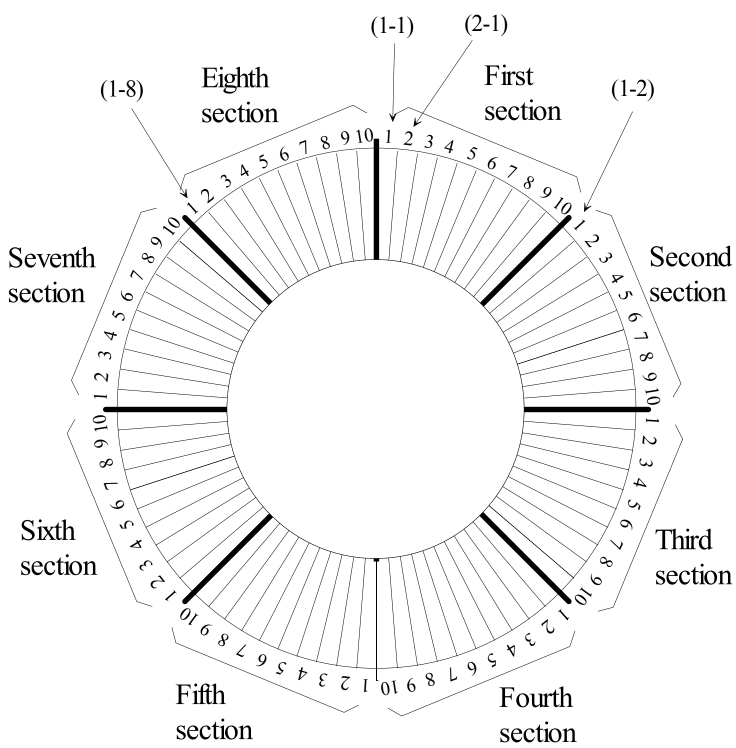

Figure 1. Structure of divided-winding IVD with eight sections

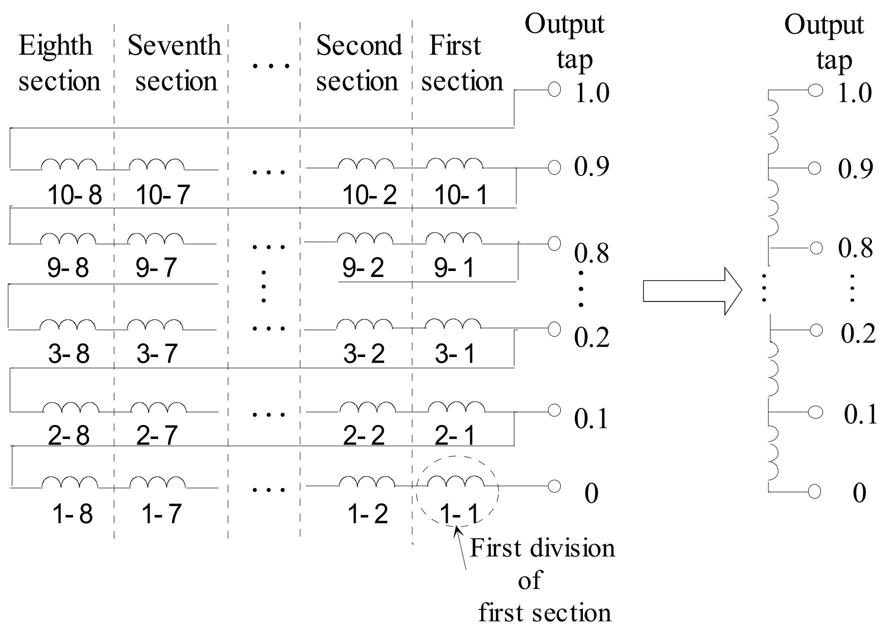

Figure 2. Circuit diagram of divided-winding IVD with eight sections

3. Measurement Results

Divided-winding IVDs of two types, namely, a 2f IVD with eight sections and a 6f IVD with four sections, were fabricated experimentally. Commercially available IVDs (2f IVD and 5f IVD) were also used to evaluate the performance of the divided-winding IVDs (2f IVD and 6f IVD).

3.1 Voltage Ratio Error

The comparison results of voltage ratio errors of the divided-winding IVD (2f IVD) and commercially available IVD (2f IVD) at frequencies from 60 Hz to 10 kHz are shown in Figs. 3 to 12, respectively.

The in-phase and quadrature errors of the divided-winding IVD (2f IVD) are slightly larger than those of the commercially available IVD (2f IVD) at lower frequencies (see Figs. 3 to 5). These errors occur due to the imbalance of the leakage inductance and the resistance at each division of the winding. However, these errors are almost the same in the divided-winding IVD (2f IVD) and commercially available IVD (2f IVD).

On the other hand, the in-phase and quadrature errors of the divided-winding IVD (2f IVD) are smaller than those of the commercially available IVD (2f IVD) at higher frequencies (see Figs. 7 to 12), because the interwinding capacitances of the divided-winding IVD (2f IVD) can be reduced by the new winding method.

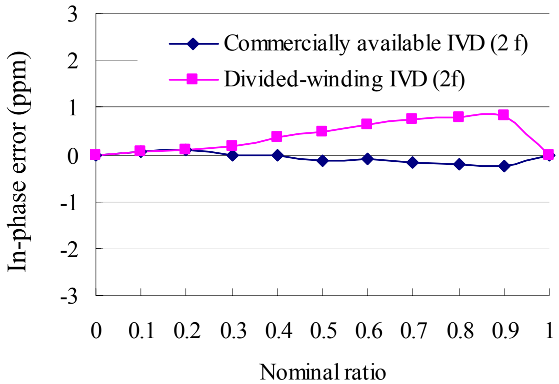

Figure 3. Comparison of in-phase errors (60 Hz)

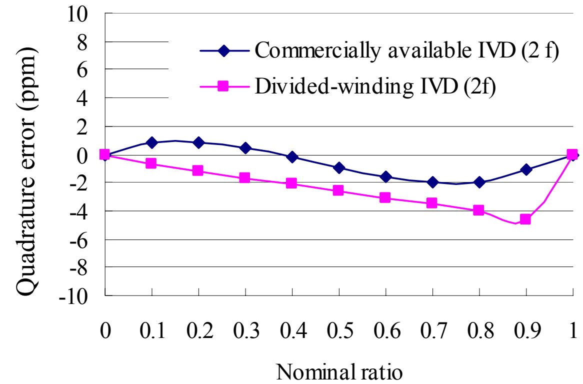

Figure 4. Comparison of quadrature errors (60 Hz)

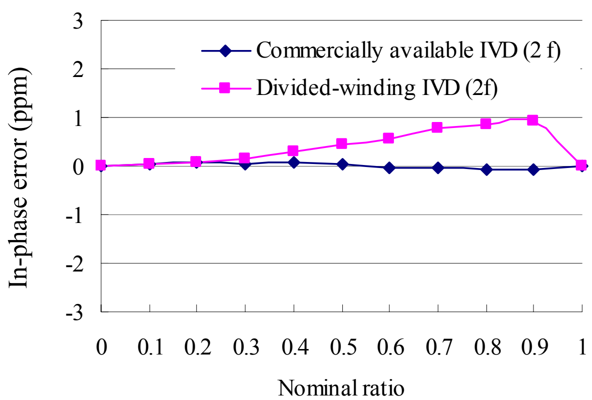

Figure 5. Comparison of in-phase errors (120 Hz)

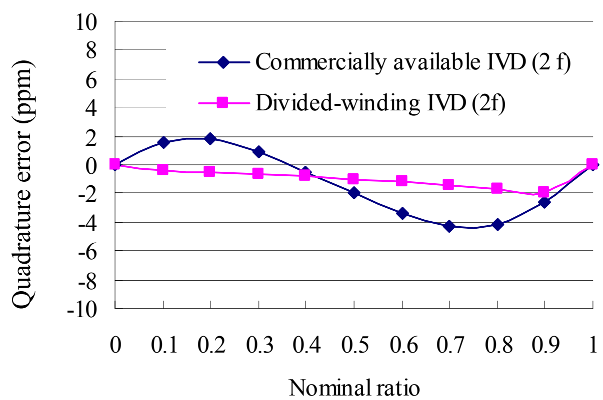

Figure 6. Comparison of quadrature errors (120 Hz)

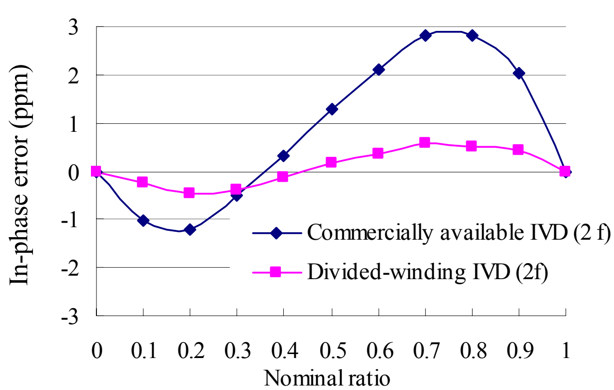

Figure 7. Comparison of in-phase errors (1 kHz)

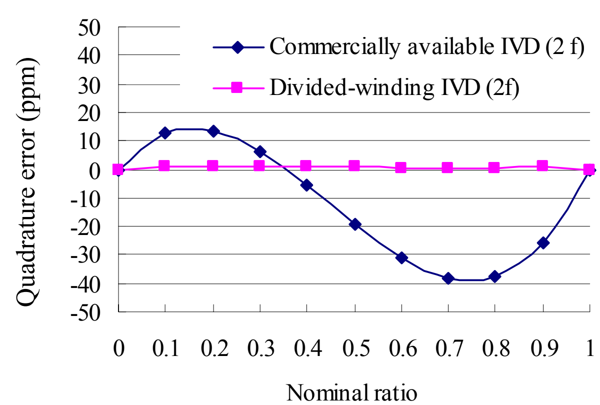

Figure 8. Comparison of quadrature errors (1 kHz)

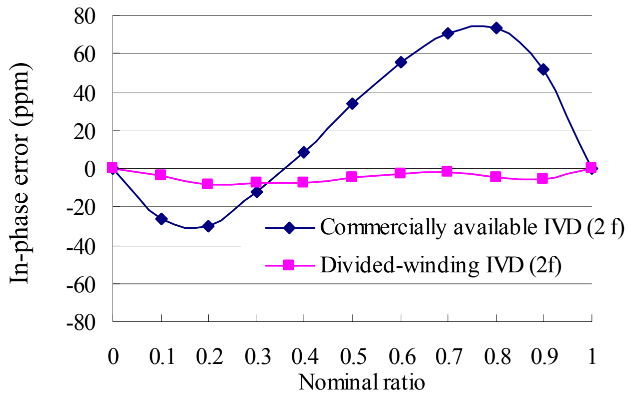

Figure 9. Comparison of in-phase errors (5 kHz)

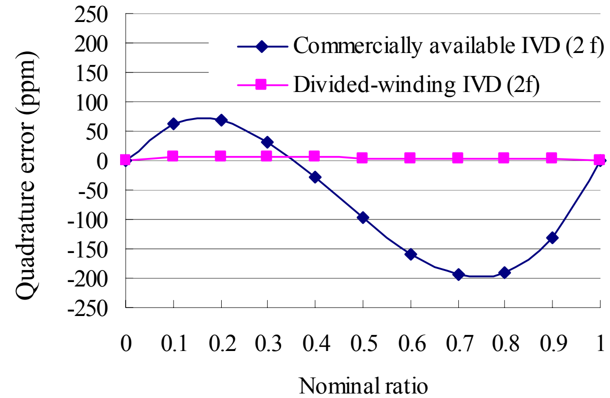

Figure 10. Comparison of quadrature errors (5 kHz)

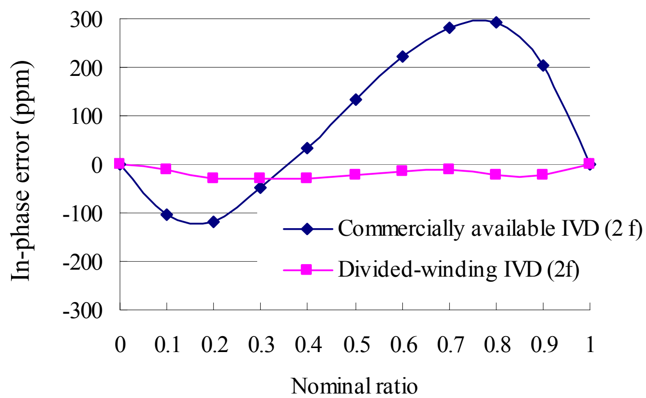

Figure 11. Comparison of in-phase errors (10 kHz)

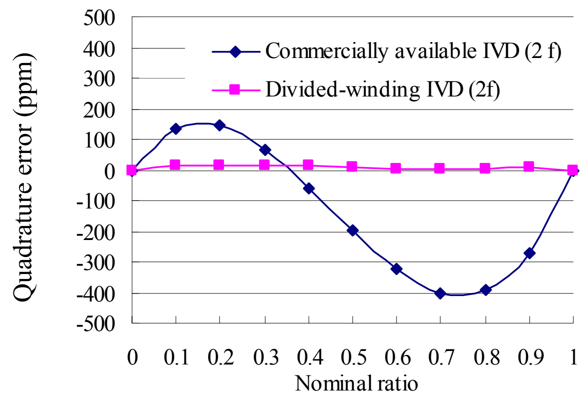

Figure 12. Comparison of quadrature errors (10 kHz)

3.2 Input Impedance

The comparison results of the input impedance of the divided-winding IVD (2f IVD and 6f IVD) and the commercially available IVD (2f and 5f IVD) are shown in Figs. 13 and 14, respectively. As shown in the figure, the input impedance is approximately 1 MΩ at frequencies from 1 kHz to 2 kHz (see Fig. 13). Furthermore, the divided-winding IVD (2f IVD and 6f IVD) can be maintained at approximately 100 kΩ at frequencies up to 10 kHz (see Fig. 14), because the equivalent input capacitance of the divided-winding IVD (2f IVD and 6f IVD) can be reduced more considerably than that of the commercially available IVD (2f IVD and 5f IVD).

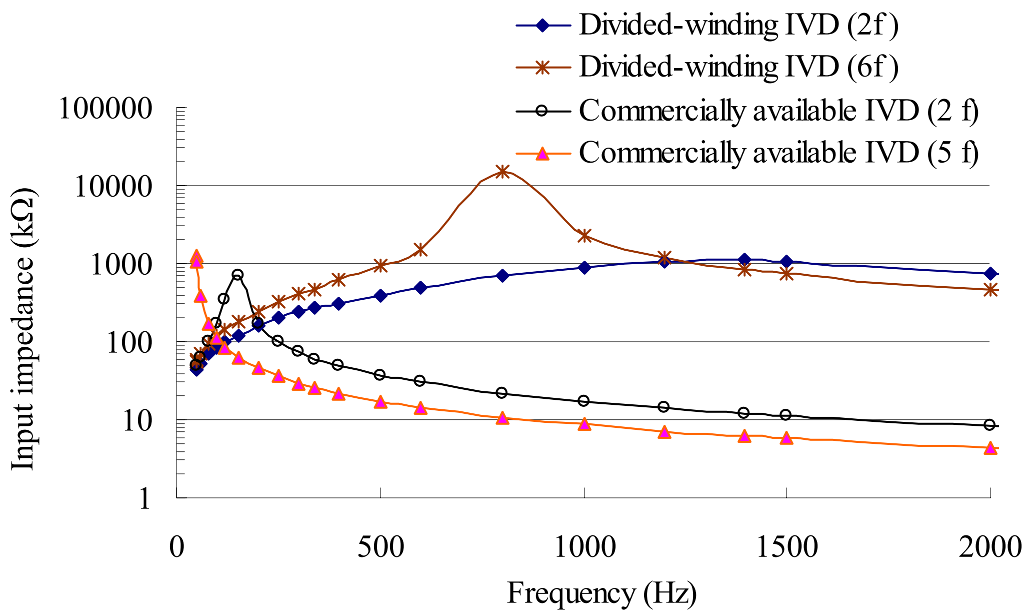

Figure 13. Comparison of input impedances

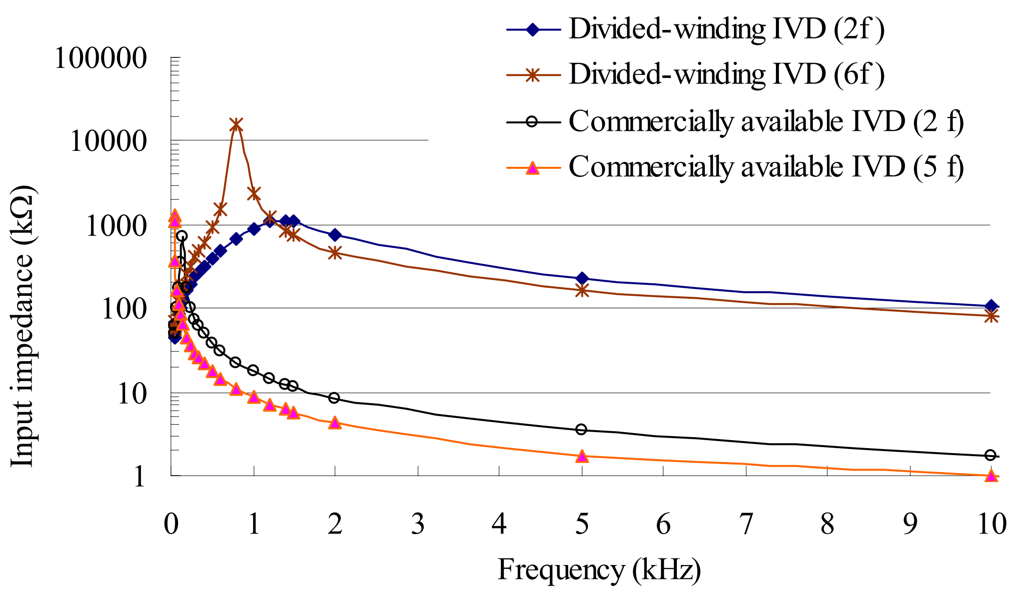

Figure 14. Comparison of input impedances

3.3 Leakage Inductance

The comparison results of the leakage inductances of the divided-winding IVD (2f IVD and 6f IVD) and commercially available IVD (2f and 5f IVD) are shown in Fig. 15. As shown in the figure, the leakage inductances of the divided-winding IVD (2f IVD and 6f IVD) are larger than those of the commercially available IVD (2f and 5f IVD), because the divided-winding IVD (2f IVD and 6f IVD) is not wound as a uniform single layer of a cable of randomly stranded conductors onto a magnetic core. Therefore, the coupling factor of each division of the divided-winding IVD (2f IVD and 6f IVD) is not better. As a result, the leakage inductances increase. However, because an IVD is generally used under an unloaded condition, these leakage inductances of the divided-winding IVD (2f IVD and 6f IVD) are not a major cause of voltage ratio errors. Moreover, as shown clearly in the figure, these leakage inductances of divided-winding IVD (2f IVD and 6f IVD) can be reduced by increasing the number of sections.

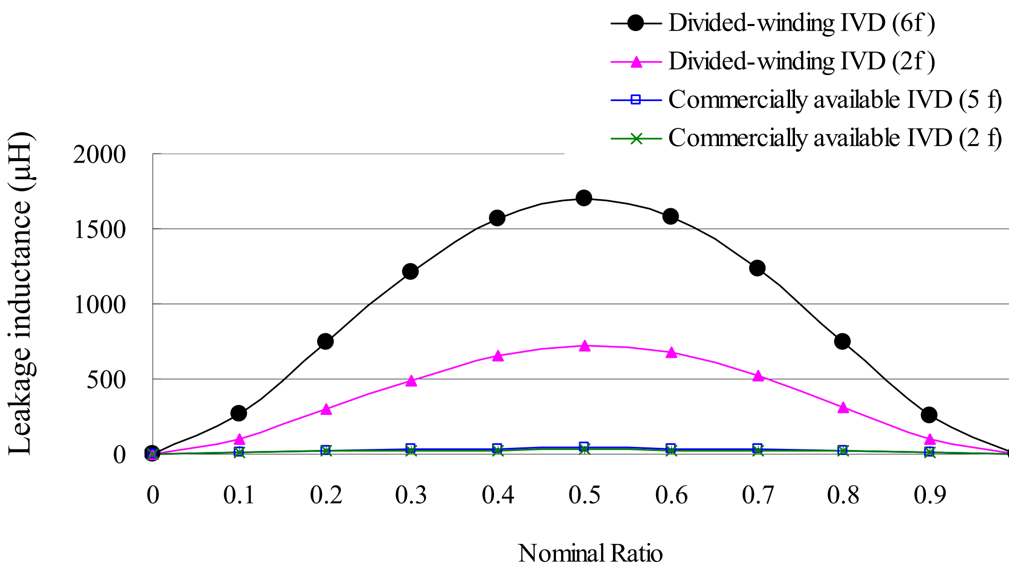

Figure 15. Comparison of leakage inductances

4. Conclusion

This paper reports on the measurement results of the input impedance of the divided-winding IVD. The major results are summarized as follows:

(1) A new winding method is proposed to maintain a high input impedance at ultrawide-band frequencies.

(2) The input impedance is approximately 100 kΩ at frequencies up to 10 kHz.

(3) The voltage ratio errors are within 1 ppm of the input for in-phase errors and within 5 ppm of the input for quadrature errors at frequencies from 50 Hz to 1 kHz.

References

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