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2 TERMINAL DUAL SOURCE IMPEDANCE BRDIGE

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Abstract: Two terminal dual source low frequency impedance bridge was configured using commercial voltage calibrators. The bridge performance was evaluated by measuring 1 to 1 resistance ratio at 1 kHz using 1 kΩ and 10 kΩ resistors. The AC resistance ratio was also measured at frequencies from 100 Hz to 100 kHz. The same bridge was used for measuring ratios of other impedance combinations by adjusting the phase between the voltage sources. This simple two terminal dual source impedance bridge proved its reliable and versatile measurement capability.

Keywords: — Dual source bridge, LF impedance ratio.

1. INTRODUCTION

Conventional ratio transformer bridges employ inductive voltage divider (IVD) to divide the voltage of a single source according to the impedance ratio. Although these bridges are highly accurate and stable, they also tend to make the system heavy and complex. In an effort to overcome the shortcomings, another type of bridge, employing two voltage sources has been studied by several groups since early 1980's [1-4]. With the employment of two sources, one for each impedance, this type of bridge can compare any impedance combinations just by adjusting the phase between the sources, and the bridge parameters such as the frequency are flexible to changes.

In this study, we constructed two terminal dual source impedance bridge using the voltage calibrators and studied its measurement abilities by measuring impedance ratios at several frequencies.

2. EXPERIMENTAL

Schematic of the dual source impedance bridge system is illustrated in Fig. 1. For the voltage source, two Fluke 5720A calibrators were used. 1 V voltage range was chosen. At this range, the resolution is 10^{-6} V. The phase between the voltage signals were controlled to be synchronized at a certain phase. Then, two 1 kHz, 1 V sine waves of a given phase difference were generated and each applied to different impedances connected in series. To detect the balance (null) voltage between the impedances, General Radio 1238 detector was used.

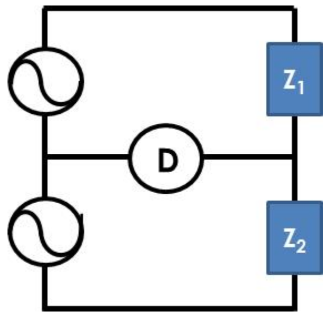

Fig. 1 Schematic of the dual source bridge.

The balance procedure is quite simple. First, the relative phase of the calibrator 1 is adjusted until the balance voltage at the detector is decreased to the minimum. Then, the voltage of the calibrator 1 is adjusted to further decrease the voltage at the detector. The balance could be achieved in less than a few minutes, and its stability was quite good. For 1 hour, the voltage ratio was not changed.

3. RESULTS AND DISCUSSIONS

1 kΩ and 10 kΩ resistors were used for the resistance to the resistance (R : R) ratio measurements. The resistors are Vishay resistors (VHA516-4 model) of high accuracy and stability. Each of them is placed inside a metal case. All the measurements were made under the controlled environment of (23.0 ± 1) °C. Having several 1 kΩ and 10 kΩ resistors, we measured the resistance ratios for various resistor combinations. The different measurement cases were numbered as (1) $R_a : R_b$ (1 kΩ : 1 kΩ), (2) $R_a : R_c$ (1 kΩ : 1 kΩ), (3) $R_b : R_c$ (1 kΩ : 1 kΩ), (4) $R_x : R_y$ (10 kΩ : 10 kΩ), and (5) $R_x : R_z$ (10 kΩ : 10 kΩ).

Since this bridge determines the impedance ratio from the voltage ratio, it would be important to construct the system symmetrically. The voltage ratio can be affected other than just by the impedance ratio if the electric line connection or length is asymmetric. Hence, in this system, electric lines of all similar lengths were used, and the connection between the detector and the calibrators or the impedances was made symmetric as can be seen in Fig. 1. Figure 2(a) depicts four different asymmetric connections. One of the four connection points between the detector and the calibrators or the impedances was intentionally connected asymmetrically. Connections A and C have the connection points near to calibrator 1 and impedance 1 and vice versa for connections B and D. As expected, the measurement value of resistance ratio was smaller for the connections A and C and larger for the connections B and D when compared to the symmetric connection (represented by the line in the middle) in Fig. 2(b). Therefore, careful considerations about the accurate voltage ratio measurements or the means of compensating the extra voltage drops are required.

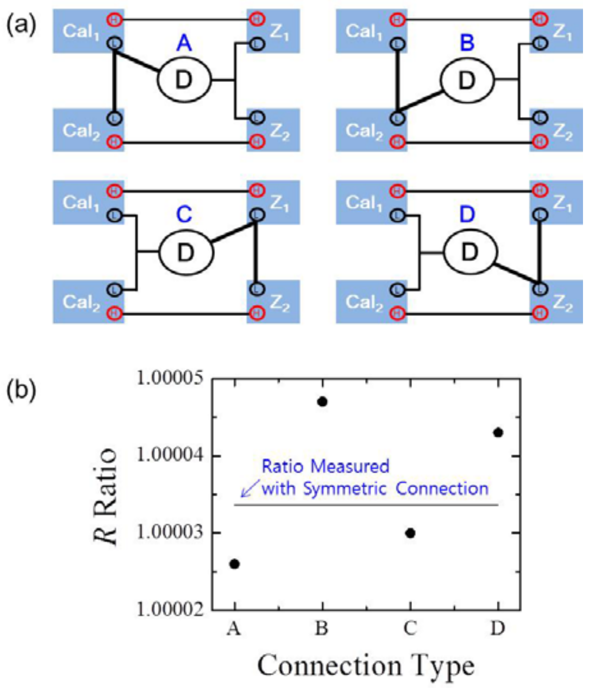

Fig. 2. (a) Four different asymmetric line connections between the detector and the source or the impedance. (b) Measurement values of the AC resistance ratio (R_a : R_b) at 1 kHz for the different asymmetric line connections.

The bridge system error, defined as $(r + r')/2 - 1$, was evaluated. r is the R_1 : R_2 ratio and r' is the R_2 : R_1 ratio ($1/r$). After R_1 to R_2 ratio was measured, the resistors were switched and R_2 to R_1 ratio was measured. If this bridge is ideally accurate, the bridge error calculated from the r and r' values should be zero. No such bridge would exist, and the bridge error was 0.49 x 10^{-6} on the average. Hereafter, the resistance ratio will be the mean value of the two measurements.

The AC resistance ratio at 1 kHz was measured for 1 kΩ and 10 kΩ resistors, and they were compared with the DC resistance ratio measurement values which were obtained using the digital multi-meter. The difference between the DC and the AC resistance ratio is an order of several parts in 10^{-6} on the average.

Table 1 presents the uncertainty analysis of the two terminal dual source impedance bridge. The uncertainty coming from the balance repeatability was between 0.5 and 1.5 x 10^{-6} for several different measurement cases. The uncertainty of the calibrator voltage is the calibration uncertainty from the calibration certificate. When the calibrator output voltage is measured by using a digital voltmeter, its measurement uncertainty (type A) is 0.36 x 10^{-6}. The former can be considered as the voltage accuracy and the latter can be seen as the voltage stability. Regarding the calibrator phase stability, it was found that the phase stability does not noticeably affect the voltage ratio stability. The uncertainty originated from the detector resolution was insignificant.

	Type	10^{-6}
Balance repeatability	A	0.28
Voltage of the calibrator (long term stability)	B	Calibrator 1 : 20.00 Calibrator 2 : 20.00
Phase between the calibrators	B	3.30
Total		28.48

Table 1. Uncertainty analysis of the two terminal dual source impedance bridge.

The measurement value of the AC resistance ratio (R_a : R_b) by the dual source bridge was compared with that obtained by the four terminal pair ratio transformer bridge. The difference between the measurement values by two bridges was 3 x 10^{-6}. Thus, this bridge proved its reliable measurement capability for the AC resistance ratio measurement.

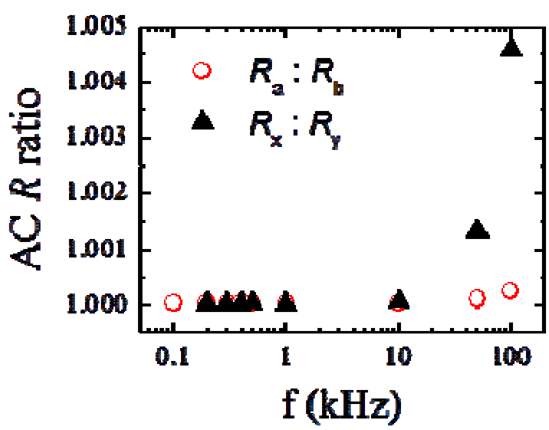

Fig. 3. AC resistance ratio measurements at frequencies between 100 Hz and 100 kHz.

Using the same bridge, C : C, R : C, R : L ratios were measured by controlling the phase between the voltage sources. The capacitance ratio measured by the dual source bridge and that measured by the commercial bridge

(AH2500A) agreed within 2 x 10^{-6} at the best. The AC resistance ratio could be obtained from the R : C ratio by multiplying the standard capacitance value.

4. SUMMARY

Two terminal dual source impedance bridge was configured using two calibrators as voltage sources. Just by controlling the phase between the two voltage sources, all the impedances of any combinations can be compared with each other. The bridge performance was evaluated by measuring R : R ratio at 1 kHz using 1 kΩ and 10 kΩ resistors. The bridge system error was about 0.49 x 10^{-6}. The measured AC resistance ratio was in a good agreement with that measured by using the four terminal pair ratio transformer bridge. In addition, the same bridge system was used to measure various impedance ratios by controlling the phase difference between the two voltage sources.

This simple two terminal dual source impedance bridge proved its reliable measurement capability. The two terminal measurement has the well known contact resistance and wire problems. Thus, with the four terminal pair configuration, the measurement accuracy will be further improved. Also, the resolution and the stability of the voltage and the phase can be increased further for more precise and versatile bridge.

5. REFERENCES

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